Value Chain Bibliography with abstracts

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Contents

Purpose

The *information value chain* provides a useful framework for characterizing the production, communication, and use of high impact weather warnings in terms of their processes, inputs and outputs, relationships, contributions, and operational contexts of stakeholders. A 4-year multidisciplinary project on Value Chain Approaches to Evaluate the End-to-End Warning Chain[1] aims to

a) review value chain practices used to describe and understand weather, warning and climate services,

b) assess and provide guidance on how to effectively apply value chains in a weather warning context involving multiple users and partnerships, and

c) create a searchable warning chain database that researchers and practitioners can use to explore the organisation and performance of actual end-to-end warning chains for high impact events and assess their effectiveness using value chain approaches.

This **Value Chain Bibliography** has been created to assist the project with the first two aims. Relevant literature has been collected and tagged using Mendeley and is available to the project. The chapters in this bibliography contain references for groups of documents describing different concepts and components of the information value chain for warnings.

The bibliography will be updated periodically as new literature is added to the collection. A version of the bibliography that does not include abstracts is also available.

To contribute additional literature, provide feedback, or get involved with the project please contact Beth.Ebert@bom.gov.au or David.Hoffmann@bom.gov.au.

[1] The Value Chain project is a flagship project of the World Meteorological Organization's (WMO) World Weather Research Programme (WWRP) High Impact Weather (HIWeather) project and the Societal and Economic Research Applications (SERA) Working Group. More information can be found at the HIWeather website, http://hiweather.net/Lists/130.html.

Value Chain

Keywords: agricultural value chains, associated challenges in warning communication, bushfire impact assessment, citizen science, components, challenges, data-value chain, disaster management cycle, data-based value creation, effectiveness, effective disaster management, fire management, flow of information, forecasting challenges, gaps, GAR paper, high-impact weather project, HIWeather project overview, hydromet value chain, information value chain, knowledge value-chain, links, meteorological value chain, modelling the VC, overview, potential benefits, professional management, product development, good practice, steps, supply chain, value chain, value chain adaptation, VOICE, value chain in conservation, value chain overview, value tree, VC, warning chain, warning systems, weather service chain analysis, use of weather data, climate risk and early warning systems (CREWS)

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Alliance for Hydromet Development. (2021). *HYDROMET GAP REPORT 2021 Alliance for Hydromet Development*.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (Eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., Lazrus, H., & Hudson, R. (2016). A Mental Models

Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making*. *Weather, Climate, and Society*, *8*(2), 111–129. https://doi.org/10.1175/WCAS-D-15-0033.1
The study reported here explores how to enhance the public value of hurricane forecast and warning information by examining the entire warning process. A mental models research approach is applied to address three risk management tasks critical to warnings for extreme weather events: 1) understanding the risk decision and action context for hurricane warnings, 2) understanding the commonalities and conflicts in interpretations of that context and associated risks, and 3) exploring the practical implications of these insights for hurricane risk communication and management. To understand the risk decision and action context, the study develops a decision-focused model of the hurricane forecast and warning system on the basis of results from individual mental models interviews with forecasters from the National Hurricane Center (n = 4) and the Miami–South Florida Weather Forecast Office (n = 4), media broadcasters (n = 5), and public officials (n = 6), as well as a group decision-modeling session with a subset of the forecasters. Comparisons across professionals reveal numerous shared perceptions, as well as some critical differences. Implications for improving extreme weather event forecast and warning systems and risk communication are threefold: 1) promote thinking about forecast and warning decisions as a system, with informal as well as formal elements; 2) evaluate, coordinate, and consider controlling the proliferation of forecast and warning information products; and 3) further examine the interpretation and representation of uncertainty within the hurricane forecast and warning system as well as for users.

Carabine, E., & Simonet, C. (2018). *Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors.* 76 pp. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12286.pdf%0Ahttps://www.cabdirect.org/cabdirect/abstract/20183299617
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Climate Risk and Early Warning (CREWS), (IN-MHEWS), T. I. N. for M.-H. E. W. S., Climate Risk and Early Warning (CREWS), (IN-MHEWS), T. I. N. for M.-H. E. W. S., & Climate Risk and Early Warning (CREWS). (2017). *Draft Consultation Document On Measuring Early Warning Access and Effectiveness*. https://public.wmo.int/en/resources
the present consultation document aims to identify a set of metrics to provide guidance on how the effectiveness of, and access to, early warning systems can be measured, encompassing a conceptual framework of key elements, including sources of data and information and methodologies.

Coiera, E. (2019). Assessing Technology Success and Failure Using Information Value Chain Theory. *Studies in Health Technology and Informatics*, *263*, 35–48. https://doi.org/10.3233/SHTI190109
Information value chain theory provides a straightforward approach to information system evaluation and design. It first separates the different benefits and costs that might be associated with the use of a given information technology at different stages along a value chain stretching

from user interaction to real world outcome. Next, using classical decision theoretic measures such as probabilities and utilities, the resulting value chain can be used to create a profile for a particular technology or technology bundle. Value chain analysis helps focus on the reasons for system implementation success or failure. It also assists in making comparative assessments amongst different solutions, to understand which might be best suited for different clinical contexts.

Demuth, J. L., Morss, R. E., Morrow, B. H., & Lazo, J. K. (2012). Creation and communication of hurricane risk information. *Bulletin of the American Meteorological Society*, *93*(8), 1133–1145. https://doi.org/10.1175/BAMS-D-11-00150.1
Reducing loss of life and harm when a hurricane threatens depends on people receiving hurricane risk information that they can interpret and use in protective decisions. To understand and improve hurricane risk communication, this article examines how National Weather Service (NWS) forecasters at the National Hurricane Center and local weather forecast offices, local emergency managers, and local television and radio media create and convey hurricane risk information. Data from in-depth interviews and observational sessions with members of these groups from Greater Miami were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Together, these groups succeed in partnering with each other to make information about approaching hurricane threats widely available. Yet NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios. Thus, we recommend that warning system partners 1) build understanding of each other's needs and constraints; 2) ensure formalized, yet flexible mechanisms exist for exchanging critical information; 3) improve hurricane risk communication by integrating social science knowledge to design and test messages with intended audiences; and 4) evaluate, test, and improve the NWS hurricane-related product suite in collaboration with social scientists. ©2012 American Meteorological Society.

Garcia, C., & Fearnley, C. J. (2012). Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, *11*(2), 123–137. https://doi.org/10.1080/17477891.2011.609877
Early warning systems (EWSs) are extensive systems that integrate different components of disaster risk reduction for the provision of timely warnings to minimize loss of life and to reduce economic and social impact on vulnerable populations. Historically, empirical research has focused on the individual components or sub-systems of EWSs, such as hazard monitoring, risk assessment, forecasting tools and warning dissemination. However, analyses of natural hazard disasters indicate that, in most cases, the processes that link individual components of EWS fail, rather than the components themselves. This paper reviews several case studies conducted over the last 40 years to present common emerging factors that improve links between the different components of EWSs. The identified factors include: (1) establishing effective communication networks to integrate scientific research into practice; (2) developing effective decision-making processes that incorporate local contexts by defining accountability and responsibility; (3) acknowledging the importance of risk perception and trust for an effective reaction; and (4) consideration of the differences among technocratic and participatory approaches in EWSs when applied in diverse contexts. These factors show the importance of flexibility and the consideration of local context in making EWSs effective, whereas increasing levels of standardization within EWSs nationally and globally might challenge the ability to incorporate the required local expertise and circumstances.

Golding, B., Mittermaier, M., Ross, C., Ebert, B., Panchuk, S., Scolobig, A., & Johnston, D. (2019). A Value

Chain Approach to Optimising Early Warning Systems. *Global Assessment Report*, 1–30.
The impact of weather-related hazards continues to be a major cause of human and economic loss in the world. Reducing those losses requires a combination of policies that protect, avoid and facilitate recovery. Early warnings are a key contributor, especially in countries without the governance structures and resources to provide permanent protection or avoidance. Advances in weather modelling, earth observation from space, and hazard reporting by citizens, provide a solid baseline for hazard mapping; however, this needs to be matched by comparable mapping of the (time-dependent) exposure and vulnerability of people, buildings and infrastructure, and by the development of response capability especially in risk hot-spots.

Hämäläinen, D. prof. R. P. (n.d.). *Introduction to Value Tree Analysis*. Evatech seminar.

Haupt, S. E., Kosović, B., Jensen, T., Lazo, J. K., Lee, J. A., Jiménez, P. A., Cowie, J., Wiener, G., Mccandless, T. C., Rogers, M., Miller, S., Sengupta, M., Xie, Y., HinKeLman, L., KaLb, P., & Heiser, J. H. (2018). Building the SUN4CAST system. *Bulletin of the American Meteorological Society*, *99*(1), 121–135. https://doi.org/10.1175/BAMS-D-16-0221.1
The Sun4Cast System results from a research-to-operations project built on a value chain approach, benefiting electric utilities' customers, society, and the environment by improving state-of-the-science solar power forecasting capabilities.

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).
This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Kelman, I., Ahmed, B., Esraz-Ul-Zannat, M., Saroar, M. M., Fordham, M., & Shamsudduha, M. (2018). Warning systems as social processes for Bangladesh cyclones. *Disaster Prevention and Management: An International Journal*, *27*(4), 370–379. https://doi.org/10.1108/DPM-12-2017-0318
Purpose: The purpose of this paper is to connect the theoretical idea of warning systems as social processes with empirical data of people's perceptions of and actions for warning for cyclones in Bangladesh. Design/methodology/approach: A case study approach is used in two villages of Khulna district in southwest Bangladesh: Kalabogi and Kamarkhola. In total, 60 households in each village were surveyed with structured questionnaires regarding how they receive their cyclone warning information as well as their experiences of warnings for Cyclone Sidr in 2007 and Cyclone Aila in 2009. Findings: People in the two villages had a high rate of receiving cyclone warnings and accepted them as being credible. They also experienced high impacts from the cyclones. Yet evacuation rates to cyclone shelters were low. They did not believe that significant cyclone damage would affect them and they also highlighted the difficulty of getting to cyclone shelters due to poor roads, leading them to prefer other evacuation options which were implemented if needed. Originality/value: Theoretical constructs of warning systems, such as the First Mile and late warning, are rarely examined empirically according to people's perceptions of warnings. The case study villages have not before been researched with respect to warning systems. The findings provide empirical evidence for long-established principles of warning systems as social processes, usually involving but not relying on technical components.

Kim, M. O., Coiera, E., & Magrabi, F. (2017). Problems with health information technology and their effects on care delivery and patient outcomes: a systematic review. *Journal of the American Medical Informatics Association : JAMIA*, *24*(2), 246–250. https://doi.org/10.1093/jamia/ocw154

Objective: To systematically review studies reporting problems with information technology (IT) in health care and their effects on care delivery and patient outcomes. Materials and methods: We searched bibliographic databases including Scopus, PubMed, and Science Citation Index Expanded from January 2004 to December 2015 for studies reporting problems with IT and their effects. A framework called the information value chain, which connects technology use to final outcome, was used to assess how IT problems affect user interaction, information receipt, decision-making, care processes, and patient outcomes. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. Results: Of the 34 studies identified, the majority (n = 14, 41%) were analyses of incidents reported from 6 countries. There were 7 descriptive studies, 9 ethnographic studies, and 4 case reports. The types of IT problems were similar to those described in earlier classifications of safety problems associated with health IT. The frequency, scale, and severity of IT problems were not adequately captured within these studies. Use errors and poor user interfaces interfered with the receipt of information and led to errors of commission when making decisions. Clinical errors involving medications were well characterized. Issues with system functionality, including poor user interfaces and fragmented displays, delayed care delivery. Issues with system access, system configuration, and software updates also delayed care. In 18 studies (53%), IT problems were linked to patient harm and death. Near-miss events were reported in 10 studies (29%). Discussion and conclusion: The research evidence describing problems with health IT remains largely qualitative, and many opportunities remain to systematically study and quantify risks and benefits with regard to patient safety. The information value chain, when used in conjunction with existing classifications for health IT safety problems, can enhance measurement and should facilitate identification of the most significant risks to patient safety.

Landry, R., Amara, N., Pablos-Mendes, A., Shademani, R., & Gold, I. (2006). The knowledge-value chain: A conceptual framework for knowledge translation in health. *Bulletin of the World Health Organization*, *84*(8), 597–602. https://doi.org/10.2471/BLT.06.031724
This article briefly discusses knowledge translation and lists the problems associated with it. Then it uses knowledge-management literature to develop and propose a knowledge-value chain framework in order to provide an integrated conceptual model of knowledge management and application in public health organizations. The knowledge-value chain is a non-linear concept and is based on the management of five dyadic capabilities: mapping and acquisition, creation and destruction, integration and sharing/transfer, replication and protection, and performance and innovation.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York

City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., Adkins, J. E., & Jeffrey K. Lazo, Heather R. Hosterman, Jennifer M. Sprague-Hilderbrand, and J. E. A. (2020). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., & Mills, B. (2021). *Weather-Water-Climate Value Chain(s): Giving VOICE to the Characterization of the Economic Benefits of Hydro-Met Services and Products* (Vol. 3, Issue March). American Meteorological Society.
This study presents the concept of the Earth system observations, science, and services (ESOSS) information value chain. The value chain concept can be used to characterize the process of the creation, communication, and use of weather, water (fresh and salt), and climate information and knowledge from observations, research (basic and applied), modeling, forecasting, dissemination, decision support, and associated services through market transactions and the provision of nonmarket goods and services. The value chain—perhaps better conceived of as a process—involves a broad range of stakeholders with varying resources, objectives, and constraints that shape the nature and translation of the information as it moves from observations to end-user decisions. Understanding these processes, stakeholders, and decisions and outcomes is fundamental to identifying, measuring, and demonstrating the socioeconomic value of ESOSS. In this paper we present and discuss an initial approach to operationalize the value chain concept and how the broad set of social sciences—in addition to economics—can be used to study and improve the process. Focusing on information and socioeconomic value as one approach to discussing the information process, we propose a framework for elucidating value chains called the Value of Information Characterization and Evaluation or VOICE. The intent of this framework is to provide

an initial prototype that could be leveraged and further developed to encourage the use of the value chain concept in studies of ESOSS. We present several brief case studies to illustrate different ways the value chain concept can help us understand, communicate, and enhance societal benefits of ESOSS. This study is part of an ongoing AMS Policy Program project on valuation that is supported, primarily, by a grant from the National Oceanic and Atmospheric Administration (NA19NWS4620018). The project consists of studies (including this one) and related capacity-building efforts to enable improved understanding, communication, and enhancement of societal benefits of information and services in weather, water (fresh and salt), and climate. Dr. Paul Higgins' 2021 AMS Policy Program paper "Societal Benefits of Earth System Observations, Science, and Services: Understanding, communication, and enhancement for weather, water (fresh and salt) and climate" further explores the role of ESOSS in modern society, particularly as they relate to weather, water, and climate to 1) im…

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1

As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., SM, H., Jeanneret, T., & Nelson, R. (2016). *Adaptive value chain approaches. Understanding adaptation in food value chains* (Issue June).

The impacts of climate change are felt along the whole chain of actors that produce, handle, process and market agri-food products. This project aims to help agri-food companies to systematically identify, assess, prioritise and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach. A holistic and systematic evaluation of the risks that climate change poses, both direct and indirect, is crucial for adaptation planning. Understanding the complexity of interactions between biophysical, social and economic drivers in the context of climate change enables businesses within a value chain to have line of sight of indirect, but impactful, effects. It also enables businesses, from farming all the way to retailing, to begin to understand their 'tipping points'' better – where the impacts of multiple events along the value chain result to one or multiple stages of the chain unable to recover or remain competitive. There are three key outcomes from this study: 1. Our study has found that climate change, in itself, is not enough to encourage consumers to accept an adapted product, because there is a lack of understanding of how climate change can impact day-to-day life in general. At present, adaptation for agri-food businesses serves as a risk mitigation strategy, rather than a marketing opportunity. This however, may prove to be a competitive

advantage for those who are in touch with consumer sentiment on adaptation, as sentiments may change in the future. 2. Value chain adaptation needs to consider the impact of any action on the value created and received by the chain. Our study has found that approaching value chain adaptation using a future storylines approach allows agri-food businesses to consider not only the adaptation benefits of a strategy, but also benefits to GHG mitigation and competitiveness. The process we have developed here enables business to gauge the merits of an adaptation action against multiple, and potentially competing, priorities. 3. Based on the findings of this study, an adapted value chain is one that is able to sustain its competitive advantage in a changing climate. A non-adapted value chain can only continue to exist up to a certain point where climate and weather risk and threats, both direct and indirect, are insurmountable and hence the value chain can no longer be profitable on an ongoing basis. Non- adapted value chains also miss opportu…'

Lim, C., Kim, K. H., Kim, M. J., Heo, J. Y., Kim, K. J., & Maglio, P. P. (2018). From data to value: A nine-factor framework for data-based value creation in information-intensive services. *International Journal of Information Management*, *39*(December 2017), 121–135. https://doi.org/10.1016/j.ijinfomgt.2017.12.007
Service is a key context for the application of IT, as IT digitizes information interactions in service and facilitates value creation, thereby contributing to service innovation. The recent proliferation of big data provides numerous opportunities for information-intensive services (IISs), in which information interactions exert the greatest effect on value creation. In the modern data-rich economy, understanding mechanisms and related factors of data-based value creation in IISs is essential for using IT to improve such services. This study identified nine key factors that characterize this data-based value creation: (1) data source, (2) data collection, (3) data, (4) data analysis, (5) information on the data source, (6) information delivery, (7) customer (information user), (8) value in information use, and (9) provider network. These factors were identified and defined through six action research projects with industry and government that used specific datasets to design new IISs and by analyzing data usage in 149 IIS cases. This paper demonstrates the usefulness of these factors for describing, analyzing, and designing the entire value creation chain, from data collection to value creation, in IISs. The main contribution of this study is to provide a simple yet comprehensive and empirically tested basis for the use and management of data to facilitate service value creation.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain

analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Lukasiewicz, A., & Baldwin, C. (2020). *Natural hazards and disaster justice: Challenges for australia and its neighbours* (Issue February). https://doi.org/10.1007/978-981-15-0466-2
This book explores policy, legal, and practice implications regarding the emerging field of disaster justice, using case studies of floods, bushfires, heatwaves, and earthquakes in Australia and Southern and South-east Asia. It reveals geographic locational and social disadvantage and structural inequities that lead to increased risk and vulnerability to disaster, and which impact ability to recover post-disaster. Written by multidisciplinary disaster researchers, the book addresses all stages of the disaster management cycle, demonstrating or recommending just approaches to preparation, response and recovery. It notably reveals how procedural, distributional and interactional aspects of justice enhance resilience, and offers a cutting edge analysis of disaster justice for managers, policy makers, researchers in justice, climate change or emergency management. BoM Staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6028057

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F., Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704
Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

Mwongera, C., Nowak, A., Notenbaert, A. M. O., Grey, S., Osiemo, J., Kinyua, I., Lizarazo, M., & Girvetz, E. (2019). Climate-Smart Agricultural Value Chains: Risks and Perspectives. In *The Climate-Smart Agriculture Papers* (pp. 235–245). Springer International Publishing. https://doi.org/10.1007/978-3-319-92798-5_20
Extreme weather is causing significant problems for smallholder farmers and others who depend on agricultural value chains in developing countries. Although value-chain analysis can help untangle the complex relationships within agricultural systems, it often has failed to take into account the effects of climate change. Climate-change assessments, meanwhile, often focus on the production node while neglecting other components of the value chain. In response to these shortcomings, the International Center for Tropical Agriculture (CIAT), in collaboration with the Government of Kenya, developed the climate risk profiles (CRP) approach. Using a case study from Nyandarua County in Kenya, we illustrate how this approach (i) supports identification of major climate risks and their impacts on the value chain, (ii) identifies adaptation interventions, and (iii)

promotes the mainstreaming of climate-change considerations into development planning at the subnational level. Our results show that the magnitude of a climate risk varies across value chains. At the input and production stage, strategies for supporting climate-smart value chains include the following: improving access to input markets, supporting diversification and value addition, provision of climate-smart production technologies, dissemination of climate information services, and making financial and insurance services available. At the harvesting, processing and marketing stages, useful interventions would include strengthening farmer organization, investing in climate-proofed infrastructure including roads and facilities for storage, processing and improving access to output markets. Finally, climate-change adaptation along the value chain would be improved by strengthening existing institutions, exploring public-private partnerships and adopting coherent local policies.

Nations, U. (2006). *Capacities, gaps and opportunities of early warning systems (UN 2006)*.

Nurmi, P., Perrels, A., & Nurmi, V. (2013). Expected impacts and value of improvements in weather forecasting on the road transport sector. *Meteorological Applications*, *20*(2), 217–223. https://doi.org/10.1002/met.1399

Atmospheric predictability has improved by approximately 1day per decade during the last 20years based on verification results of ECMWF forecast output. In Finland, locally applied accuracy measures indicate marked improvements in the quality of forecasts for the general public since the late 1980s. It is assumed that similar trends will continue to the foreseeable future. Use of weather information will allow for better options in the decision-making of various stake holders in the transport sector, such as commuters or tourists, transport infrastructure owners and transport service and maintenance operators. This paper discusses the economic impacts and value of weather forecasts on different transport modes (road, rail, air) highlighting the effects of potential improvements in forecast quality in the expected future climates in Europe. It is not only the improved quality of available weather forecasts that will define the value of information. The way in which the information is communicated and how it is being utilized by decision-makers are highly relevant steps in a weather service value chain. Rather than applying the traditional Cost-Loss model, which would relate improved forecast accuracy to increased expected utility, an alternative approach is being applied. This “Weather Service Chain Analysis” (WSCA) accounts for imperfect features in the communication chain and in the use of weather information by analysing the decay of the total potential benefits via decomposing the information flow from original forecast generation to final benefit realization. Concrete estimates are provided for the road transport modes both in Finland and in Europe. © 2013 Royal Meteorological Society.

Parker, D. J., & Priest, S. J. (2012). The Fallibility of Flood Warning Chains: Can Europe’s Flood Warnings Be Effective? *Water Resources Management*, *26*(10), 2927–2950. https://doi.org/10.1007/s11269-012-0057-6

Taking a broad overview, this paper explores recent evidence on flood forecasting, warning communication and public warning response in Europe between 1995 and 2010. Key flood warning chain deficiencies are identified together with the effect these deficiencies have on flood warning effectiveness and loss reduction. Europe-wide data on flood forecasting and warning communication are examined alongside recent in-depth research evidence from various parts of Europe on flood warning receipt, warning response and warning effectiveness. Using the latest flood warning benefit assessment methodologies, the results of case studies of flood loss avoidance through warnings reveal the damage saving potential of flood warning. Although these savings are significant, currently they are inhibited by a series of shortcomings which transfer through the warning chain limiting warning impact. Flood forecasting, warning and warning response systems are inherently fallible and so it is doubtful that they will ever be consistently

effective. Sole reliance upon them to protect life and property carries inevitable risks and governments should not be surprised when flood warnings are only partially effective. Although Europe's flood forecasting and warnings have been improving, the scope for further improvement is large. Extending flood forecasting and warning coverage, extending warning lead times by combining meteorological and hydrological forecasts, building greater redundancy into warning communication, and crucially also building it into cooperative strategies designed to engage at risk communities in flood warning response, are all likely to be important. © 2012 Springer Science+Business Media B.V.

Pilli-Sihvola, K., Nurmi, V., Perrels, A., Harjanne, A., Bösch, P., & Ciari, F. (2016). Innovations in weather services as a crucial building block for climate change adaptation in road transport. *European Journal of Transport and Infrastructure Research*, *16*(1), 150–173. https://doi.org/10.18757/ejtir.2016.16.1.3119
The road transport sector is facing rising uncertainties in planning and operations due to climate change induced changes in weather variability and extreme events. However, because of the high level of uncertainty related to the future climate, adaptation measures should be robust so as to retain the option value of the portfolio of measures. As an example of such a measure, this paper evaluates how foreseen innovations in weather services could reduce weather sensitivity and, consequently reduce the negative effects of climate change in the sector. The study is based on a theoretical framework on climate change adaptation and valuation of weather and climate services using the Weather Service Chain Analysis. We apply these frameworks to the road transport sector with a special emphasis on drivers' decision making before and during a trip. We show that improved weather information, including more accurate weather forecasts, new applications and information dissemination channels can decrease the vulnerability of the mode to projected shifts in extreme weather patterns due to climate change.

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.'''''''

Sättele, M., Bründl, M., & Straub, D. (2016). Quantifying the effectiveness of early warning systems for natural hazards. *Natural Hazards and Earth System Sciences*, *16*(1), 149–166. https://doi.org/10.5194/nhess-16-149-2016
Early warning systems (EWSs) are increasingly applied as preventive measures within an integrated risk management approach for natural hazards. At present, common standards and detailed guidelines for the evaluation of their effectiveness are lacking. To support decision-makers in the identification of optimal risk mitigation measures, a three-step framework approach for the evaluation of EWSs is presented. The effectiveness is calculated in function of the technical and the inherent reliability of the EWS. The framework is applicable to automated and non-automated EWSs and combinations thereof. To address the specifics and needs of a wide variety of EWS designs, a classification of EWSs is provided, which focuses on the degree of automations encountered in varying EWSs. The framework and its implementation are illustrated through a series of example applications of EWS in an alpine environment.

Strahlendorff, M., Veijola, K., Gallo, J., Vitale, V., Savela, H., & Smirnov, A. (2019). *Value tree for physical atmosphere and ocean observations in the Arctic*. http://hdl.handle.net/10138/300768
This report describes the first instance to employ the international assessment framework for arctic observations developed by SAON and IDA STPI in 2017. Earth Observation (EO) inputs like SYNOP station measurements of physical atmosphere and in other stations ocean variables were linked to key products/outcomes/services like numerical weather prediction and through groups like in this case weather service connected to key objectives of the assessment framework. Representative yearly unit costs of EO inputs and modelling components were estimated by station experts or estimated based on European Union projects or Copernicus program tenders. The WMO OSCAR database for satellite and surface observation systems north of 60°N was used for numbers of the different station and mission categories in the Arctic. The total yearly value of this observation system including EO inputs and modeling is over 204 million €. Compared to the observing system estimated costs in the area 30°N to 60°N this is only about a fifth. The value tree can now follow and combine the value invested in these components as it flows towards services. The key objectives have been connected by SAON/AMAP project members in a workshop to the services to build the first full value tree for a certain kind of observations. These observations are mainly produced by national meteorological and marine institutes in an operational mode. The yearly value invested in the observation can now be distributed between the 12 Societal Benefit Areas and their sub areas identified in the assessment framework. The value tree is presented at a web page by FMI and Spatineo (2019) with a browser that can highlight single components to analyze which inputs and which SBA targets its being used for. This can help to more holistically support the whole observation system for optimal impact on societal benefit. The value tree tool will be available for further work to address the many more EO domains like atmospheric composition or biodiversity. All in all this report can hopefully start a continuous action to update and improve the value tree. EO inputs are not static, the network changes, the costs are fluctuating and as the Arctic is becoming more accessible, it would be important to extend the observation system accordingly. https://space.fmi.fi/2019/04/15/value-of-arctic-observations-estimated-in-new-report/

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

van Noordwijk, M., Matthews, R., Agus, F., Farmer, J., Verchot, L., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., Dewi, S., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., &

Dewi, S. (2014). Mud, muddle and models in the knowledge value-chain to action on tropical peatland conservation. *Mitigation and Adaptation Strategies for Global Change*, *19*(6), 887–905. https://doi.org/10.1007/s11027-014-9576-1
Tropical peatlands are known not only for their high, area-based, carbon emissions in response to land-use change but also as hot spots of debate about associated data uncertainties. Perspectives are still evolving on factors underlying the variability and uncertainty. Debate includes the ways of reducing emissions through rewetting, reforestation and agroforestry. A knowledge value-chain that is long and complex links (a) fundamental understanding of peat and peatland processes leading to sciencebased quantification and default values, (b) willingness and (c) ability to act towards emission reduction, and ultimately (d) to local, national and global actions that effectively provide rules, incentives and motivation to conserve peat and reduce emissions. We discuss this value chain, its stakeholders and issues that still remain partially unresolved. We conclude that, to shorten the denial and conspiracy-theory stages of debate that otherwise slow down steps B and C, networks of international and national scientists have to be involved at the early stage of identifying policysensitive environmental issues. Models span part of the knowledge value-chain but transition of analysis units requires specific attention, from soil volumes through area and commodity flows to opportunities for reductions. While drainage of peatlands triggers landscape-scale increases in emissions, factors beyond drainage depth, including nutrient supply, may have a major influence on decomposition rates. Attempts to disentangle the contributions of plant and peat-based respiration in surface flux measurements involve assumptions that cannot be easily verified in comparisons between land uses. With progress on A leading to new internationally accepted defaults and with resistance on step B reduced, the reality of C and lack of working solutions for D is currently constraining further progress. © 2014 The Author(s).

Waskow, D., Jacoby Jonathan, Ocharan, J., de Messieres, S., GLucksman, S., Fischer-Mackey, J., Jochnick, C., Slack, K., Shelley, B., & Woodward, S. (2013). *Value Chain Climate Resilience*. https://www.bsr.org/reports/PREP-Value-Chain-Climate-Resilience_copy.pdf
This guide discusses a value chain approach to building climate resilience, and provide cases studies of climate resilience in action.

Wu, W., Emerton, R., Duan, Q., Wood, A. W., Wetterhall, F., & Robertson, D. E. (2020). Ensemble flood forecasting: Current status and future opportunities. *WIREs Water*, *7*(3), 1–32. https://doi.org/10.1002/wat2.1432
Ensemble flood forecasting has gained significant momentum over the past decade due to the growth of ensemble numerical weather and climate prediction, expansion in high performance computing, growing interest in shifting from deterministic to risk-based decision-making that accounts for forecast uncertainty, and the efforts of communities such as the international Hydrologic Ensemble Prediction Experiment (HEPEX), which focuses on advancing relevant ensemble forecasting capabilities and fostering its adoption. With this shift, comes the need to understand the current state of ensemble flood forecasting, in order to provide insights into current capabilities and areas for improvement, thus identifying future research opportunities to allow for better allocation of research resources. In this article, we provide an overview of current research activities in ensemble flood forecasting and discuss knowledge gaps and future research opportunities, based on a review of 70 papers focusing on various aspects of ensemble flood forecasting around the globe. Future research directions include opportunities to improve technical aspects of ensemble flood forecasting, such as data assimilation techniques and methods to account for more sources of uncertainty, and developing ensemble forecasts for more variables, for example, flood inundation, by applying techniques such as machine learning. Further to this, we conclude that there is a need to not only improve technical aspects of flood forecasting, but also to

bridge the gap between scientific research and hydrometeorological model development, and real-world flood management using probabilistic ensemble forecasts, especially through effective communication. This article is categorized under: Engineering Water > Methods Science of Water > Water Extremes

Zhang, Q., Li, L., Ebert, B., Golding, B., Johnston, D., Mills, B., Panchuk, S., Potter, S., Riemer, M., Sun, J., Taylor, A., Jones, S., Ruti, P., & Keller, J. (2019). Increasing the value of weather-related warnings. *Science Bulletin*, *64*(10), 647–649. https://doi.org/10.1016/j.scib.2019.04.003
A successful warning relies on information produced by the meteorological and related physical sciences, thus its effectiveness of delivery depends on applications of social, behavioral and economic sciences. The workshop of WMO High Impact Weather Project was held in Beijing during 20–22 November of 2018, attracted a diverse and interdisciplinary group of over 70 scientists from 25 countries in the broad field of physical and social science, during which all elements of the warning chain were discussed critically. The aims of the workshop were to review progress to date, to refresh the aims and objectives of the HIWeather project, and to identify and plan new activities on how to increase the value of weather-related warnings. Five focal aspects of warning were described in the following sections: (1) what makes a successful warning? (2) Advances in physical processes. (3) Weather-related hazard and impact prediction. (4) Advances in understanding impacts, vulnerability and risk. (5) Measuring skill and value.[6]

Economics

Keywords: altruistic value, asymmetric loss function, avoided losses, benefit analysis, benefit cost ratios, benefit model, benefit-cost ratio, benefits of warning systems, benefits transfer, bequest value, cost of bad weather, cost/benefit ratio, cost/loss ratio, cost-benefit analysis, cost-loss approach, costs of disasters, costing environmental losses from natural disaster, economic, economic and social value, economic assessment, economic benefit, economic loss, economic measures, economic value, environmental losses, environmental value, estimating loss and benefit, EWS benefits, forecast value, funding, intangible value, investments, logic model, loss assessment, market observatory, merit good, monetary value, non-economic loss and damage, non-use values, financial hardship, potential economic value, SEB, social-economic benefit assessment, social benefit, societal benefits, socioeconomic value, user benefit, value, value added, value analysis, value assessment, value conversion, willingness to pay

Alberini, A., Rheinberger, C. M., Leiter, A., McCormick, C. A., & Mizrahi, A. (n.d.). *What is the value of hazardous weather forecasts: Evicence from a survey of backcountry skiers*.
What is the value of hazardous weather warnings? To answer this question, we focus on the avalanche bulletin for Switzerland issued by the WSL Institute for Snow and Avalanche Research (SLF). We take a survey-based, non-market valuation approach to estimating the value of hypothetical improvements in avalanche forecasting. We focus on backcountry skiers because (i) safety is arguably the most important type of benefit associated with the avalanche bulletin, (ii) they voluntarily undertake risks, and (iii) they perceive themselves and are generally perceived by others as skilled in avoiding risks. The respondents' willingness to pay (WTP) for the improved services ranges between CHF 42 to 46, implying a mean value of statistical life (VSL) of CHF 1.75 million. We find that WTP increases with income and is higher among Swiss nationals and those who rate the current bulletin "useful." Risk-tolerant individuals, persons who assessed their personal risk as lower than average, professional guides, and those who perceive themselves as proficient in using the existing bulletin report lower WTP figures. This suggests that the monetized

value that people place on the enhanced bulletin reflects how productive these individuals are (or think they are) in using information to avoid avalanche risks.

Allee, V. (2008). Value network analysis and value conversion of tangible and intangible assets. *Journal of Intellectual Capital*, *9*(1), 5–24. https://doi.org/10.1108/14691930810845777
Purpose The purpose of this paper is to provide examples and technical details for conducting a value network analysis that addresses the conversion and utilisation of intangible assets. Design/methodology/approach Value network analysis was first developed in 1993 and was adapted in 1997 for intangible asset management. It has been tested in applications from shop floor work groups to business webs and economic regions. It draws from a theory based in living systems, knowledge management, complexity theory, system dynamics, and intangible asset management. Findings The paper provides a high level of detail on the analysis method and insights from its practical application across a range of business issues. Tips are provided for how to integrate the methodology with other business analysis approaches. Research limitations/implications The paper does not provide a comparative analysis with other methods because most other value network models are process views, social network analysis or clustering techniques. Practical implications Sufficient detail is provided so researchers and practitioners will be able to apply the method in their own investigations. Further resources are noted, as well as access points to the global user community and open source tools. Originality/value This paper is the first detailed publication of the value network analysis method, which has been acclaimed by experts in intangibles, network analysis, knowledge management, and process analysis. It fills a gap between theory and practice for managers, executives, analysts, and researchers. © 2008, Emerald Group Publishing Limited

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Bahinipati, C. S. (2020). Assessing the costs of droughts in rural India: A comparison of economic and non-economic loss and damage. *Current Science*, *118*(11), 1832–1841. https://doi.org/10.18520/cs/v118/i11/1832-1841
Drought, recognized as one of the major disasters, negatively affects India's agrarian economy, and in turn, farmers' well-being. Households incur both economic and non-economic loss and damage. The latter is most often unnoticed and unaddressed although it is expected to be quite significant in developing nations. Understanding and assessing loss and damage are the prime objectives of the Warsaw International Mechanism. While numerous studies have emerged to estimate the impact on crop production, income, on-farm employment and financial status, there are only limited studies with respect to assessing loss and damage to intangible resources and the total cost of a drought in particular. By interviewing droughtaffected farmers in the Kutch district of Gujarat state, this study aims to understand the perception of farmers and to estimate total economic value and noneconomic loss and damage. A contingent valuation method was employed. In sum, two major findings emerged: (i) intensity of economic loss and damage is perceived as relatively high as compared to noneconomic loss and damage, although the reverse was expected, and (ii) the average total economic value of a drought was INR 8303, and the mean value of noneconomic loss and damage was INR 4831. This study reveals that households give lower value to intangible losses that occurs over a period than the immediate tangible loss and damage which directly affect their total wealth. Given this, community-level adaptations to minimize non-economic loss and damage are less likely to be formulated. From the policy perspective, this study strongly advocates

the evaluation of intangible costs, so that upcoming state action plans, disaster management plans and ex-post assessment reports could be tailored accordingly for minimizing these risks.

Biddle, N., Bryant, C., Gray, M., & Marasinghe, D. (2020). *Measuring the economic impact of early bushfire detection* (Issue March). https://csrm.cass.anu.edu.au/sites/default/files/docs/2020/9/Measuring_the_economic_impact_of_early_bushfire_detection.pdf
The fires that occurred over the 2019/20 Australian summer were unprecedented in scale and had a devastating impact on large parts of Australia. In this paper, we estimate the economic costs of bushfires between 2020 and 2049 and the potential reduction in these costs from investments in early fire detection systems. Under various plausible climate change related scenarios the costs of fires over the next 30 years will be considerable, up to $2.2billion per year, or $1.2billion per year in Net Present Value terms. Even with conservative estimates of the reduction in the number of economically damaging fires due to earlier fire detection, the reduction in the costs of fires over the next 30 years is considerable. Under plausible scenarios of change leading to a growth in large fires (which almost all scientists expect it will) and early detection leading a reduction in the probability of large fires, then we predict an economic benefit of around $14.4billion, or $8.2billion in Net Present Value terms.

Bringas, B., Bunyi, L. J., & Manapat, C. L. (2022). An Analysis on the Impact of Natural Disasters on the Economy of the Philippines. *Journal of Economics, Finance and Accounting Studies*, *4*(1), 163–183. https://doi.org/10.32996/jefas.2022.4.1.11
Over the past century, natural disasters have been terrorizing the economy by causing human fatalities and damaging infrastructure and production inputs. The Solow growth model suggests that natural disasters adversely affect gross domestic product (GDP) since these disrupt the production of inputs. On the contrary, the Schumpeterian growth theory provides an explanation behind the positive effect of natural disasters on economic growth. This study analyzed the relationship between natural disasters (i.e. earthquake, flood, and storm), economic activities (i.e. foreign aid and foreign direct investment) and GDP per capita income in the Philippines from 1990 to 2019. This study employed a multivariate analysis, time series regression, and autoregressive distributed lag (ARDL) approach. The results revealed a complex relationship between GDP per capita and the regressors. In the short run, the independent variables have a negative and significant relationship with the country's per capita income. On the contrary, only FDI has a significant long-run relationship with the economy of the Philippines. The results highlight the Philippines' need for comprehensive disaster plans and to lessen its dependence on foreign and external factors.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Cho, J. Y. N., & Kurdzo, J. M. (2019). Weather radar network benefit model for tornadoes. *Journal of Applied Meteorology and Climatology*, *58*(5), 971–987. https://doi.org/10.1175/JAMC-D-18-0205.1
A monetized tornado benefit model is developed for arbitrary weather radar network configurations. Geospatial regression analyses indicate that improvement of two key radar parameters-fraction of vertical space observed and cross-range horizontal resolution-leads to better tornado warning performance as characterized by tornado detection probability and false-alarm ratio. Previous experimental results showing faster volume scan rates yielding greater warning performance are also incorporated into the model. Enhanced tornado warning performance, in turn, reduces casualty rates. In addition, lower false-alarm ratios save costs by cutting down on work and personal time lost while taking shelter. The model is run on the existing contiguous U.S. weather radar network as well as hypothetical future configurations. Results show that the current radars provide a tornado-based benefit of;$490 million (M) yr-1. The remaining benefit pool is about $260M yr-1, split roughly evenly between coverage- and rapid-scanning-related gaps.

Emanuel, K., Fondriest, F., & Kossin, J. (2012). Potential economic value of seasonal hurricane forecasts. *Weather, Climate, and Society*, *4*(2), 110–117. https://doi.org/10.1175/WCAS-D-11-00017.1
This paper explores the potential utility of seasonal Atlantic hurricane forecasts to a hypothetical property insurance firm whose insured properties are broadly distributed along the U.S. Gulf and East Coasts. Using a recently developed hurricane synthesizer driven by large-scale meteorological variables derived from global reanalysis datasets, 1000 artificial 100-yr time series are generated containing both active and inactive hurricane seasons. The hurricanes thus produced damage to the property insurer's portfolio of insured property, according to an aggregate wind-damage function. The potential value of seasonal hurricane forecasts is assessed by comparing the overall probability density of the company's profits from a control experiment, in which the insurer purchases the same reinsurance coverage each year, to various test strategies in which the amount of risk retained by the primary insurer, and the corresponding premium paid to the reinsurer, varies according to whether the season is active or quiet, holding the risk of ruin constant. Under the highly idealized conditions of this experiment, there is a clear advantage to the hypothetical property insurance firm of using seasonal hurricane forecasts to adjust the amount of reinsurance it purchases each year. Under a strategy that optimizes the company's profits by holding the risk of ruin constant, the probability distribution of profit clearly separates from that of the control strategy after less than 10 yr when the seasonal forecasts are perfect. But when a more realistic seasonal forecast skill is assumed, the potential value of forecasts becomes significant only after more than a decade. © 2012 American Meteorological Society.

Fakhruddin, B. S. H. M. H. M., & Schick, L. (2019). Benefits of economic assessment of cyclone early warning systems - A case study on Cyclone Evan in Samoa. *Progress in Disaster Science*, *2*(2019), 100034. https://doi.org/10.1016/j.pdisas.2019.100034
Samoa is extremely exposed to natural hazards, particularly tropical cyclones and earthquake-generated tsunami. Some studies have put forth the position that adequate investment in early warning systems can contribute to the social and economic well-being of countries. However, in spite of these research findings there is still a lack of understanding on how to measure effectiveness that leads to limited investment. Cost-benefit analysis (CBA) is a tool used in this study to summarize the value for money in terms of investment to enhance an early warning system. This paper aims to summarize the benefits of adopting early warning systems and its effectiveness against the investment required and its value proposition. Data from the 'Samoa Post-Disaster Needs Assessment of the Cyclone Evan event in 2012' have been used to assess damage information, and stakeholders consultations and interviews were carried out for cost-

benefit analysis. We have conducted quantified CBA of early warning services for cyclone hazards and the results have shown that for every USD 1 invested, there is a return of USD 6 as benefit. This paper suggests that economic assessment of early warning services could help in quantifying pre-impact assessment to demonstrate to policy makers the economic benefit of disaster risk reduction (DRR).

Florec, V., Chalak, M., & Hailu, A. (2017). Integrating intangible values in economic analyses of flood mitigation: A case study of the Brown Hill and Keswick creeks catchment in Adelaide. *Australian Journal of Emergency Management*, *32*(4), 30–36.
This study undertakes an economic analysis of flood mitigation options for a high flood-risk catchment in Adelaide. To date, economic analyses have focused primarily on estimating the tangible (market) costs and benefits of mitigation strategies and have largely ignored the intangible (nonmarket) costs and benefits. This analysis improves upon previous studies by conducting a benefit-cost analysis that incorporates the intangible costs and benefits of mitigation. The benefit transfer method was used to include intangible values in the analysis. It was found that, for this particular case study, the inclusion of intangible values does not change the attractiveness of the mitigation options evaluated and the benefit-cost ratios remain below one.

Gill, D., Siddharth, P., O'Connor, D., Derek Gill, Siddharth, P., O'Connor, D., NZIER, O'Connor, D., NZIER, Gill, D., Siddharth, P., & O'Connor, D. (2018). *The value of MetService's public weather forecasts and weather warnings* (Issue February).
https://nzier.org.nz/static/media/filer_public/1b/6b/1b6b2288-9880-4f94-9494-97dec9099930/the_value_of_metservice_final_report_february_2018.pdf
The findings from our literature were mainly overseas studies that compared the costs and benefits of meteorological forecasting services. For studies of developed countries, the benefit to cost ratios (BCRs) mainly fell in the range 4:1 to 14:1. New Zealand based studies of weather events were rare (we identified ten studies in our literature scan). We used a benefit transfer approach based on studies of the Australian Bureau of Meteorology, but including New Zealand values and data on weather events. Taken at face value, the potential benefits to any one of the main user groups on their own could justify the continuation of the provision of public weather services under the Crown contract. In line with comparable studies, this study focuses on the benefits to land-based groups of users. It does not directly address the benefits of the weather forecast and warning services provided to maritime users under the Crown contract.

Golding, B., Mittermaier, M., Ross, C., Ebert, B., Panchuk, S., Scolobig, A., & Johnston, D. (2019). A Value Chain Approach to Optimising Early Warning Systems. *Global Assessment Report*, 1–30.
The impact of weather-related hazards continues to be a major cause of human and economic loss in the world. Reducing those losses requires a combination of policies that protect, avoid and facilitate recovery. Early warnings are a key contributor, especially in countries without the governance structures and resources to provide permanent protection or avoidance. Advances in weather modelling, earth observation from space, and hazard reporting by citizens, provide a solid baseline for hazard mapping; however, this needs to be matched by comparable mapping of the (time-dependent) exposure and vulnerability of people, buildings and infrastructure, and by the development of response capability especially in risk hot-spots.

Hallegatte, S. (2008). An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. *Risk Analysis*, *28*(3), 779–799. https://doi.org/10.1111/j.1539-6924.2008.01046.x
This article proposes a new modeling framework to investigate the consequences of natural disasters and the following reconstruction phase. Based on input-output tables, its originalities are

(1) the taking into account of sector production capacities and of both forward and backward propagations within the economic system; and (2) the introduction of adaptive behaviors. The model is used to simulate the response of the economy of Louisiana to the landfall of Katrina. The model is found consistent with available data, and provides two important insights. First, economic processes exacerbate direct losses, and total costs are estimated at $149 billion, for direct losses equal to $107 billion. When exploring the impacts of other possible disasters, it is found that total losses due to a disaster affecting Louisiana increase nonlinearly with respect to direct losses when the latter exceed $50 billion. When direct losses exceed $200 billion, for instance, total losses are twice as large as direct losses. For risk management, therefore, direct losses are insufficient measures of disaster consequences. Second, positive and negative backward propagation mechanisms are essential for the assessment of disaster consequences, and the taking into account of production capacities is necessary to avoid overestimating the positive effects of reconstruction. A systematic sensitivity analysis shows that, among all parameters, the overproduction capacity in the construction sector and the adaptation characteristic time are the most important. © 2008 Society for Risk Analysis.

Handmen, J., Ladds, M., & Magee, L. (2018). Updating the costs of disasters in Australia. *Australian Journal of Emergency Management*, *33*(4), 40–46. https://knowledge.aidr.org.au/resources/ajem-apr-2018-updating-the-costs-of-disasters-in-australia/
The Bureau of Transport Economics (BTE) 2001 report, Economic Costs of Natural Disasters in Australia (BTE 2001), has been the only comprehensive, national assessment of the economic impacts of disasters in Australia. Statistics and economic impact assessment methodology presented in the report have been widely used for research and policy analysis, particularly for assessing the costs and benefits of disaster risk reduction and mitigation. This is the case even though the data and analysis are over one and a half decades old. It has needed updating in terms of the approach to analysis and the dataset to include the many relevant disasters triggered by natural phenomena from 1999 to 2013. This paper sets out the approach used to update the 2001 report through a National Emergency Management Projects grant, documents the major issues faced, including the need for a new dataset and presents some results. The main differences between the BTE 2001 report and the update concern increase losses from bushfires, the inclusion of heatwaves, with heatwaves responsible for half of all deaths, and changes in the pattern of loss at the state level.[21]

Handmer, J., & Proudley, B. (n.d.). The Economics of Interface Wildfires. *Proceedings of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View*, *April 2004*, 19–22.
The new Australian Bushfire CRC (Cooperative Research Centre) is a major long-term effort intended to improve the safety of Australian communities by harnessing research for improving wildfire related policy and practice. One of the CRC's projects concerns the development of "Reliable Assessment Methods for the Total Costs of Bushfires and the Benefits of Mitigation". The initial part of this project is the subject of this presentation. Economic analysis for flood hazard management has a long history and is highly developed for urban areas. Drawing on this extensive material, as well as existing approaches to the economics of fire and the criminological literature on the economics of arson, we are working towards the development of a model for the comprehensive assessment of the economics of interface wildfires. Special attention is paid to the "exceptional" events that contribute most fire losses – and for which suppression is problematic. In addition, the extra costs imposed by arson will be incorporated into the approach. We will be identifying the primary drivers of costs and benefits, and the main opportunities for significant cost savings in the current and likely future Australian fire management environment. Future elements of the project will examine the economic implications of different approaches to fire and fire

management, and link the preferred economic model and its outputs with models of fire behaviour and suppression.

Higgins, P. A. (2021). Societal Benefits in Weather, Water, and Climate: Understanding, Communication, and Enhancement. *An AMS Policy Program Study.*, *April*.
The study highlights the societal benefits that result from Earth system OSS and help identify unmet and emerging user needs in OSS. The studies will also provide a strong and overarching emphasis on public–private partnerships; most notably, the studies will help to refresh aspects of the 2003 Fair Weather report by the National Academies of Science, which has been foundational to the weather enterprise over the past two decades

Johar, M., Johnston, D. W., Shields, M. A., Siminski, P., & Stavrunova, O. (2022). The economic impacts of direct natural disaster exposure. *Journal of Economic Behavior and Organization*, *196*, 26–39. https://doi.org/10.1016/j.jebo.2022.01.023
We estimate the economic impacts of having your home damaged or destroyed by a natural disaster. Regressions with individual, area and time fixed-effects, indicate that experiencing a natural disaster has no impact on employment and income, but substantial impacts on financial hardship and risk aversion. Impacts are particularly large for smaller isolated disasters, which attract little government support. Conversely, impacts of residing in a disaster zone without experiencing residential destruction are small. Using a Group Fixed Effects estimator, we find predictors of financial vulnerability to destruction include age, parenthood, illness, and social support. These results can help improve the allocation of government assistance after future disasters.

Johnson, L. A., Rabinovici, S., Kang, G. S., Mahin, S. A., Curry, C., Arba, R., Chief, B., Parkinson, S. I., Salinas, A. C., Strack, T., Knudson, H., Goodwin, R., Cooley, K., Hellweg, M. P., Johnson, T., & Valencia, S. (2016). California Earthquake Early Warning System Benefit Study. *CSSC Publication*, 4–16.
In a six-month investigation, researchers conducted 18 semi-structured interviews with 24 organizations representing 14 important sectors of the state's infrastructure and economy. The interviews focused on the perceived value of a statewide EEWS for each organization as well as specific types and settings for EEWS use that could benefit public and employee safety, business resiliency, and the protection of critical operations and assets that serve local communities and the economy. Information from the interviews was then consolidated and interpreted into this summary, which is primarily aimed at informing future study needed to quantitatively assess the costs and benefits of a statewide EEWS. More information about the organizations participating in the study and the study approach is provided in Section 2, as well as the appendices of the report.

Keating, A., & Handmer, J. (2011). The cost of disasters to Australia and Victoria – no straightforward answers. In *VCCCAR Project: Framing Adaptation in the Victorian Context - Working paper 3* (Issue April).
This paper looks at the current cost of extreme meteorological disasters to Australia and Victoria in an effort to provide a starting point for appreciating the types of costs that may be present and increasing under climate change. There exists a confounding variety and breadth of estimates relating to the cost of weather related disasters in Victoria and Australia. Comparative analysis shows that data source and methodology have profound impacts on the conclusions drawn from both aggregate analyses of disaster costs and analyses of individual events, in this case the 1983 Ash Wednesday bushfires. Disaster cost estimates in Australia are largely drawn from insurance data or insurance data with some augmentation; the estimates that utilise insurance data are a limited proxy for disaster cost. Insurance data only account for insured losses, and these represent

only a fraction of the total cost of a disaster. In particular they do not include many indirect costs, valuations for loss of life, nor intangibles such as ecosystem services which can have significant impacts on cost estimates. Analyses based on insurance data also draw conclusions influenced by which hazards and assets are or are not insured.

Kellogg, W. K. (2004). *Using Logic Models to Bring Together Planning, Evaluation, and Action - Logic Model Development Guide*.
In line with its core mission – To help people help themselves through the practical application of knowledge and resources to improve their quality of life and that of future generations – the W.K. Kellogg Foundation has made program evaluation a priority. As our staff and grantees work on a spectrum of social improve- ment programs, the need for shaping and contributing to the body of knowledge regarding evaluation becomes increasingly clear. Our first guide, the W.K. Kellogg Foundation Evaluation Handbook, was pub- lished in 1998, and has been made available to nearly 7,500 people.The Evaluation Handbook is a prac- tical, step-by-step manual for conducting evaluations.With the Handbook, we introduced the concept of the program logic model and the ways in which applying this concept has added value to our own work.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1
As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is

that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

May, T., Williams, M., Wiggins, R., & Bryman, A. (2021). *Special report: Update to the economic costs of natural disasters in Australia* (Issue 1996).
This report updates the previous estimates of the costs of natural disasters with new data and extends the analysis to consider how climate change will affect costs under three different climate change scenarios based on the United Nations' Intergovernmental Panel on Climate Change (IPCC).

Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Assessment of economic flood damage. *Natural Hazards and Earth System Science*, *10*(8), 1697–1724. https://doi.org/10.5194/nhess-10-1697-2010
Damage assessments of natural hazards supply crucial information to decision support and policy development in the fields of natural hazard management and adaptation planning to climate change. Specifically, the estimation of economic flood damage is gaining greater importance as flood risk management is becoming the dominant approach of flood control policies throughout Europe. This paper reviews the state-of-the-art and identifies research directions of economic flood damage assessment. Despite the fact that considerable research effort has been spent and progress has been made on damage data collection, data analysis and model development in recent years, there still seems to be a mismatch between the relevance of damage assessments and the quality of the available models and datasets. Often, simple approaches are used, mainly due to limitations in available data and knowledge on damage mechanisms. The results of damage assessments depend on many assumptions, e.g. the selection of spatial and temporal boundaries, and there are many pitfalls in economic evaluation, e.g. the choice between replacement costs or depreciated values. Much larger efforts are required for empirical and synthetic data collection and for providing consistent, reliable data to scientists and practitioners. A major shortcoming of damage modelling is that model validation is scarcely performed. Uncertainty analyses and thorough scrutiny of model inputs and assumptions should be mandatory for each damage model development and application, respectively. In our view, flood risk assessments are often not well balanced. Much more attention is given to the hazard assessment part, whereas damage assessment is treated as some kind of appendix within the risk analysis. Advances in flood damage assessment could trigger subsequent methodological improvements in other natural hazard areas with comparable time-space properties.

Meza, F. J., Hansen, J. W., & Osgood, D. (2008). Economic value of seasonal climate forecasts for agriculture: Review of ex-ante assessments and recommendations for future research. In *Journal of Applied Meteorology and Climatology* (Vol. 47, Issue 5, pp. 1269–1286). https://doi.org/10.1175/2007JAMC1540.1
Advanced information in the form of seasonal climate forecasts has the potential to improve farmers' decision making, leading to increases in farm profits. Interdisciplinary initiatives seeking to understand and exploit the potential benefits of seasonal forecasts for agriculture have produced a number of quantitative ex-ante assessments of the economic value of seasonal climate forecasts. The realism, robustness, and credibility of such assessments become increasingly important as efforts shift from basic research toward applied research and implementation. This paper surveys published evidence about the economic value of seasonal climate forecasts for agriculture, characterizing the agricultural systems, approaches followed, and scales of analysis. The climate

forecast valuation literature has contributed insights into the influence of forecast characteristics, risk attitudes, insurance, policy, and the scale of adoption on the value of forecasts. Key innovations in the more recent literature include explicit treatment of the uncertainty of forecast value estimates, incorporation of elicited management responses into bioeconomic modeling, and treatment of environmental impacts, in addition to financial outcomes of forecast response. It is argued that the picture of the value of seasonal forecasts for agriculture is still incomplete and often biased, in part because of significant gaps in published valuation research. Key gaps include sampling of a narrow range of farming systems and locations, incorporation of an overly restricted set of potential management responses, failure to consider forecast responses that could lead to "regime shifts," and failure to incorporate state-of-the-art developments in seasonal forecasting. This paper concludes with six recommendations to enhance the realism, robustness, and credibility of ex-ante valuation of seasonal climate forecasts. © 2008 American Meteorological Society.

Miller, A. (2022). *What's it worth? Four Perspectives on the Valuation of the Weather, Water, Climate Enterprise*. American Meteorological Society.
Earth system observations, science, and services (OSS) inform and guide the activities of virtually every economic sector and innumerable institutions underlying modern civilization. OSS are a fundamental component of efforts to meet basic human needs including food, shelter, energy, health and safety. At the same time, opportunities to enhance the societal benefits of OSS are vast and increasing. Better understanding of the weather, water, and climate (WWC) enterprise's value could: create new opportunities to apply OSS for societal benefit; help justify public investments in OSS; and guide future investments in OSS to help ensure that they confer the maximum possible benefit to society. As a result, there is great need for efforts to understand, assess, communicate, and advance the value of OSS. This study synthesizes the results of a multi-year project on the valuation of Earth system OSS. The conclusions are based on four studies relating to different aspects of the societal benefits of Earth system OSS: 1) Societal Benefits of Weather, Water, and Climate: Understanding, Communication, and Enhancement (bit.ly/sbwxc), 2) The Value Chain of Earth System Observations, Science, and Services (bit.ly/3uAHjXG), 3) Three Policies Shape Enterprise Value: Minor Adjustments Could Enhance the Societal Benefit (https://bit.ly/3Wxpolicies) and 4) Options for Enhancing the Value of the NOAA Weather-Ready Nation Ambassador Initiative (https://bit.ly/30qRnY1).

Moon, B., & Harrison, E. (2021). *Queensland's New Framework for Flood Risk Management Economic Assessments*. Copernicus GmbH. https://doi.org/10.5194/egusphere-egu21-1926
Flooding is one of Australia's more prevalent natural disasters, causing injury to people, damage to property and infrastructure, losses to business earnings, increases to the costs of providing government services, and intangible impacts such as environmental or social damages. Australia's National Strategy for Disaster Resilience (2011) and Queensland's Strategy for Disaster Resilience (2017) provide the overarching framework to build disaster resilient communities in Queensland and Australia. Within this, Government has the role of identifying and implementing strategies to manage the disaster risks. The National Strategy recognises that consistent information on the costs and benefits of risk management options, which considers the full impacts on the social, built, economic and natural environments, is required to support this. In Australia economic assessments for flood management projects have traditionally focused on the tangible damages of flooding, particularly to property. Other impacts of flooding, such as environmental or social impacts, are typically considered qualitatively or assessed through a multi-criteria assessment. The absence of state and/or national guidance on undertaking such assessments has also led to a wide variety of approaches, methodologies, data and results. This creates an unnecessary layer of complexity when seeking to compare and prioritise projects, within states and across Australia. It

can also lead to the underestimation of the return on investment resulting from flood risk management projects, due to the incomplete capture of benefits. The Brisbane River Strategic Floodplain Management Plan (SFMP) was publicly released in 2019 and includes 52 actions aimed to improve the resilience, safety and prosperity of the community and businesses in the Brisbane River floodplain, and Queensland more widely. The Queensland Reconstruction Authority (QRA) was allocated the lead to implement Action FM7 'Extend the economic framework established in the Strategic Plan and Technical Evidence Report to include community awareness and resilience, disaster management and land use planning.'' The Economic Assessment Framework for Flood Risk Management Projects is due for publication in early 2021. It was developed through a collaborative process with other state governments, universities, private practitioners, and key stakeholders to road test a number of approaches and develop the guideline to support a consistent methodology for eco…'

Mulder, O. J., Mulder, K. P., Kubiszewski, I., Anderson, S. J., Costanza, R., & Sutton, P. (2020). The value of coastal wetlands for storm protection in Australia. *Ecosystem Services*, *46*. https://doi.org/10.1016/j.ecoser.2020.101205

Cyclones cause significant damage, particularly to coastal areas. In the 50 years between 1967 and 2016, 54 cyclones struck Australia with total damages of approximately AUD 3 billion. Wetlands diminish cyclone impacts by absorbing storm surges and slowing winds. We examine the effects of wetlands on cyclone damage by creating a Bayesian regression model for storm damage as a function of wind speed, economic development in the storm swath, and the area of wetlands in the coastal plain in the storm swath using data from all 54 storms. Our results show that wind speed has a strong positive effect on cyclone damage and that wetland area has a strong negative effect. We estimate a total of AUD 29.6 billion of damage was averted during the 54 storms because of the presence of wetlands with a median of AUD 236 million per storm. This equates to an average of AUD 4203 per year per hectare of wetland, consistent with previous studies. Our results suggest that preserving wetlands is a cost-effective way to minimize cyclone damage while providing numerous other valuable ecosystem services. We estimate that maintaining at least 1.5% of coastal area as wetlands maximizes the averted damage.

Mwongera, C., Nowak, A., Notenbaert, A. M. O., Grey, S., Osiemo, J., Kinyua, I., Lizarazo, M., & Girvetz, E. (2019). Climate-Smart Agricultural Value Chains: Risks and Perspectives. In *The Climate-Smart Agriculture Papers* (pp. 235–245). Springer International Publishing. https://doi.org/10.1007/978-3-319-92798-5_20

Extreme weather is causing significant problems for smallholder farmers and others who depend on agricultural value chains in developing countries. Although value-chain analysis can help untangle the complex relationships within agricultural systems, it often has failed to take into account the effects of climate change. Climate-change assessments, meanwhile, often focus on the production node while neglecting other components of the value chain. In response to these shortcomings, the International Center for Tropical Agriculture (CIAT), in collaboration with the Government of Kenya, developed the climate risk profiles (CRP) approach. Using a case study from Nyandarua County in Kenya, we illustrate how this approach (i) supports identification of major climate risks and their impacts on the value chain, (ii) identifies adaptation interventions, and (iii) promotes the mainstreaming of climate-change considerations into development planning at the subnational level. Our results show that the magnitude of a climate risk varies across value chains. At the input and production stage, strategies for supporting climate-smart value chains include the following: improving access to input markets, supporting diversification and value addition, provision of climate-smart production technologies, dissemination of climate information services, and making financial and insurance services available. At the harvesting, processing and marketing

stages, useful interventions would include strengthening farmer organization, investing in climate-proofed infrastructure including roads and facilities for storage, processing and improving access to output markets. Finally, climate-change adaptation along the value chain would be improved by strengthening existing institutions, exploring public-private partnerships and adopting coherent local policies.

Nguyen, T. C., & Robinson, J. (2015). Analysing motives behind willingness to pay for improving early warning services for tropical cyclones in Vietnam. *Meteorological Applications*. https://doi.org/10.1002/met.1441
Pressure on government budgets has made it more important to quantify the value of public goods, e.g. tropical cyclone warning services, to society as a whole. Based on a stated preference survey, in which respondents could indicate the amount of their willingness to pay (WTP), this study elicited values for an improved cyclone warning service in Vietnam. To examine motives or reasons behind respondents' WTP, respondents were requested to allocate 10 points among different types of values, including self-interest motivated value (termed use value), and values with respect to the interests of others (altruistic value) and future generations (bequest value). The more influential the value, the higher the point is scored. Use value, which was scored the highest mean point of 4.1 out of 10, is the most important motive for valuing improvements in cyclone warning services. Altruistic and bequest values were given similar points, approximately 2.9 and 3.0, respectively. This study empirically demonstrates that respondents hold not only self-interest motivated value, but also altruistic and bequest values. Given the importance of non-use values, i.e. altruistic and bequest values, economic assessments focusing on only use value would underestimate the benefits of an improved cyclone warning service to society.

Nguyen, T. C., Robinson, J., Kaneko, S., & Komatsu, S. (2013). Estimating the value of economic benefits associated with adaptation to climate change in a developing country: A case study of improvements in tropical cyclone warning services. *Ecological Economics*, *86*, 117–128. https://doi.org/10.1016/j.ecolecon.2012.11.009
Linking tropical cyclone activity with anthropogenic climate change is subject to on-going debate. However, modelling studies consistently have projected that climate change is likely to increase the intensity of cyclones and the related rainfall rates in the future. A precautionary approach to this possibility is to adapt to the adverse effects of the changing climate by improving early warning services for cyclones as a "no or low-regrets" option. Given limited funding resources, assessments of economic efficiency will be necessary, and values for benefits are an essential input. This paper aims to estimate the benefits to households of an improved cyclone warning service in Vietnam. Choice experiment surveys with 1014 respondents were designed and conducted to inform this paper. The benefit estimates of the maximal improvements in a number of attributes of cyclone warning services (i.e. forecasting accuracy, frequency of update, and mobile phone based warnings) are approximately USD7.1-8.1 per household, which would be an upper bound estimate. Results from the marginal willingness to pay for the attributes suggest that investments should be dedicated to improvements in the accuracy of warning information and a warning service based on mobile phone short message.[37]

Nurmi, P., Perrels, A., & Nurmi, V. (2013). Expected impacts and value of improvements in weather forecasting on the road transport sector. *Meteorological Applications*, *20*(2), 217–223. https://doi.org/10.1002/met.1399
Atmospheric predictability has improved by approximately 1day per decade during the last 20years based on verification results of ECMWF forecast output. In Finland, locally applied accuracy measures indicate marked improvements in the quality of forecasts for the general public since the late 1980s. It is assumed that similar trends will continue to the foreseeable future. Use of weather

information will allow for better options in the decision-making of various stake holders in the transport sector, such as commuters or tourists, transport infrastructure owners and transport service and maintenance operators. This paper discusses the economic impacts and value of weather forecasts on different transport modes (road, rail, air) highlighting the effects of potential improvements in forecast quality in the expected future climates in Europe. It is not only the improved quality of available weather forecasts that will define the value of information. The way in which the information is communicated and how it is being utilized by decision-makers are highly relevant steps in a weather service value chain. Rather than applying the traditional Cost-Loss model, which would relate improved forecast accuracy to increased expected utility, an alternative approach is being applied. This "Weather Service Chain Analysis" (WSCA) accounts for imperfect features in the communication chain and in the use of weather information by analysing the decay of the total potential benefits via decomposing the information flow from original forecast generation to final benefit realization. Concrete estimates are provided for the road transport modes both in Finland and in Europe. © 2013 Royal Meteorological Society.

Pearl, J. (2010). The International Journal of Biostatistics An Introduction to Causal Inference An Introduction to Causal Inference ∗. *The International Journal of Biostatistics*, *6*(2), Article 7.
This paper summarizes recent advances in causal inference and underscores the paradigmatic shifts that must be undertaken in moving from traditional statistical analysis to causal analysis of multivariate data. Special emphasis is placed on the assumptions that underlie all causal inferences, the languages used in formulating those assumptions, the conditional nature of all causal and counterfactual claims, and the methods that have been developed for the assessment of such claims. These advances are illustrated using a general theory of causation based on the Structural Causal Model (SCM) described in Pearl (2000a), which subsumes and unifies other approaches to causation, and provides a coherent mathematical foundation for the analysis of causes and counterfactuals. In particular, the paper surveys the development of mathematical tools for inferring (from a combination of data and assumptions) answers to three types of causal queries: those about (1) the effects of potential interventions, (2) probabilities of counterfactuals, and (3) direct and indirect effects (also known as "mediation"). Finally, the paper defines the formal and conceptual relationships between the structural and potential-outcome frameworks and presents tools for a symbiotic analysis that uses the strong features of both. The tools are demonstrated in the analyses of mediation, causes of effects, and probabilities of causation.

Perrels, A. (2020). Quantifying the uptake of climate services at micro and macro level. *Climate Services*, *17*(January), 100152. https://doi.org/10.1016/j.cliser.2020.100152
Quantification and communication of the expected net benefits of climate services for particular types of users and society at large has been hitherto a rather weak element in the deployment of climate services. This article discusses the challenges of quantification and warns that there is no universal method for this. It provides a general structure to assess benefit-cost ratios of new climate services. From this framework proper valuation of climate services can be developed. It also underscores the significance of aptness for verification of the performance of a climate service, as well as contextual effects, such as market form, regulations, and pace of innovation. Only for subsets of seasonal climate services the so-called cost-loss approach and some other forecast accuracy-oriented approaches are applicable. For other types of climate services performance indicators need to be developed. Furthermore, for some types of effectiveness evaluations more user/use oriented indicators are necessary, even if forecast accuracy based approaches would be applicable as well, as these approaches do not guarantee that the highest utility for the user has been achieved using the climate services. The proposed framework emphasizes the inclusion of competitive conditions under which the CS users operate, the role of

information exclusiveness vs. sharing, the role of adequate quality assurance and communication, the effects learning and R&D for climate services.

Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, *10*(1), 65–70. https://doi.org/10.5194/asr-10-65-2013
Abstract. There is a rising interest around the world for a better understanding of the economic and social value added of weather services. National hydro-meteorological services and international cooperative bodies in meteorology have ever more to justify their use of public budgets. Furthermore, the development of hydrological and meteorological services is to a large extent steered by expectations regarding the eventual benefits of the envisaged new developments. This article provides a compact overview of the impediments for uptake of socio-economic benefit (SEB) studies, methods and results of SEB studies to date. It also discusses some pitfalls and crucial steps to enhance a broader uptake of SEB studies.

Perrels, A., Le, T. T., Cortekar, J., Hoa, E., & Stegmaier, P. (2020). How much unnoticed merit is there in climate services? *Climate Services*, *17*(June 2019), 100153. https://doi.org/10.1016/j.cliser.2020.100153
The European Union and a growing number of its Member States have become active in promoting and funding the development and to some extent deployment of climate services. Despite significant progress in the creation of large high-quality open access repositories of basic climate data and despite the growing number of pilot projects with more tailored co-designed climate services for various sectors, no real breakthrough in the uptake of climate services has been witnessed. Two projects EU-MACS and MARCO, funded from the EU H2020 programme, assessed what the obstacles to uptake were and how these could be alleviated. This article discusses main outcomes from these projects, with special attention for the need to better underpin the concept of climate services and the justification to promote their use, e.g. by means of the merit good concept. The projects also identified the need for a climate services market observatory. Other articles in the same special issue provide more in-depth insights regarding several subjects.

Rabonza, M. L., & Lallemant, D. (2022). *Shedding light on avoided disasters: Measuring the invisible benefits of disaster risk management using probabilistic counterfactual analysis*. Global Assessment Report on Disaster Risk Reduction

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2021.102344
Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP,

CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.'''''''

Rogers, D. P., & Tsirkunov, V. V. (2013). Weather and Climate Resilience. In *Weather and Climate Resilience* (Issue February 2015). https://doi.org/10.1596/978-1-4648-0026-9
The importance of weather, climate, and water information is rising because of the need to serve more elaborate societal needs, minimize growing economic losses, and help countries adapt to climate change. Weather, climate and water impacts societies and economies through extreme events, such as tropical cyclones, floods, high winds, storm surges and prolonged droughts, and through high impact weather and climate events that effect demand for electricity and production capacity, planting and harvesting dates, managing construction, transportation networks and inventories, and human health. The key players are the National Meteorological and Hydrological Services (NMHSs). By international agreement under the auspices of the World Meteorological Organization, they are the government's authoritative source of weather, climate, and water information, providing timely input to emergency managers, national and local administrations, the public, and critical economic sectors. NMHSs are a small but important public sector with budgets usually about 0.01-0.05 percent of national GDP, and total annual public funding of NMHSs globally exceeding $15 billion. The problem is that their capacity has become so degraded in many regions over the past 15-20 years - primarily owing to underfunding, low visibility,

economic reforms, and in some instances military conflict- that they are now inadequate. As a result, globally, NMHSs in over 100 countries, more than half of which are in Africa, need to be modernized. How much will this cost? A conservative estimate of high priority modernization investment needs in developing countries exceeds $1.5-2 billion. In addition, a minimum of $400-500 million per year will be needed to support operations of the modernized systems. These recurrent costs should be covered by national governments, but few are ready to do this. The book underscores the urgent need to strengthen NMHSs, especially in developing countries, and provides cost-benefit estimates of the return that countries can hope to achieve. It also offers a recommended approach that has been tested and implemented in Europe, Central and South Asia, and other countries. And it underscores the significance of international collaboration to access data, knowledge, and know-how of the large-scale atmospheric and oceanic conditions that drive the global weather patterns that affect individual countries. It has been conservatively estimated that upgrading all hydrometeorological i…

Sangha, K. K., Russell-Smith, J., Evans, J., & Edwards, A. (2020). Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction*, *49*. https://doi.org/10.1016/j.ijdrr.2020.101619
Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environmental when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank [1]; and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was estimated at AU$95-132million per year. Evaluating such costs for loss of Indigenous peoples' well-being who reside in remote parts of the NT, presents an estimate of AU$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Tatano, H., & Kajitani, Y. (2022). *Methodologies for estimating the economic impacts of natural disasters*. https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499
This book outlines methodologies to estimate the economic impacts of natural disasters based on business surveys conducted after large disasters in Japan. By including numerous observations on business activities in past disasters and the validations of both engineering and economic models based on these data sets, this book appeals to practitioners who estimate the regional economic impacts as well as to students and young professionals in various fields who conduct disaster impact studies. The book consists of 7 chapters and includes theories and practices, which help readers to interlink the estimation methods with real-world problems. The study primarily focuses on cases in Japan, but the methods employed can be generalized and applied in other countries. BoM staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-

/weather-and-climate-systems---africa.html

United Nations Office for Disaster Risk Reduction. (2016). *Climate early warning initiative focuses on most vulnerable*. Https://Www.Undrr.Org/News/Climate-Early-Warning-Initiative-Focuses-Most-Vulnerable.

Watkiss, P., & Cimato, F. (2021). *The Socio-Economic Benefits of the WISER Programme*. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/wiser/wiser-seb-results_final-web.pdf
The socio-economic benefits of eight WISER East Africa projects have been assessed. These include projects that have led to new or improved weather and seasonal forecasts, as well as early warning systems, at the national and regional level.

WMO. (2015). Valuing Weather and Climate : In *World Meteorological Organization* (Vol. 09, Issue 1153).
Since the 1950s, the interest in the economic valuation of hydrometeorological services has been growing in the hydrometeorological, climate and economics communities. As part of a process of improving the understanding of SEBs of hydrometeorological services, the World Meteorological Organization's (WMO) high-level international conference "Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate, and Water Services", held in Madrid in 2007, agreed on a Statement and Action Plan that sets out a comprehensive strategy for the enhancement, development and application of improved methodologies for evaluating the benefits from the operation of NMHSs. The present publication addresses the growing interest and need identified during this conference and in the years since it took place. It is directed at the hydrometeorological and socioeconomic research and service-provider communities, as well as officials from government and international development agencies; but the general public will also find an interest in understanding the role weather, climate and water information plays in their daily life. World Bank Group, with a current hydrometeorological investment portfolio of around US$ 500 million, estimates that globally improved weather, climate, and water observation and forecasting could lead to up to US$ 30 billion per year in increases in global productivity and up to US$ 2 billion per year in reduced asset losses.3 This scale of improved productivity could be crucial to lifting out of poverty the millions around the world whose livelihoods are at risk of climate shocks. The recognition of these benefits and their contribution to sustainable development, poverty reduction and shared prosperity is motivating the development community to invest more holistically in modernizing hydrometeorological services4 and ensuring that service providers are better connected with service users. The review of all past and current SEB analysis performed for this publication indicates that properly planned investments in hydrometeorological services provide significant benefits relative to their costs. While the publication attempts to capture the currently available wealth of experience and expertise across different contexts, it is not the end point for developing global knowledge on SEB analysis of hydrometeorological studies. Indeed, as we move to implement new global commitments on sustainable development goals, climate change adaptation an…

Wood, D. (2021). Australia's top five most expensive natural disasters revealed. *Insurance Business Magazine*, October 19, 2021. https://www.insurancebusinessmag.com/au/news/natural-catastrophe/australias-top-five-most-expensive-natural-disasters-revealed-313539.aspx
Insurance Business has put together a list of the top five most expensive natural disasters in Australia's recent history. Sydney's hailstorms in 1999 come in first place with the total losses from claims in today's dollar value amounting to $5.8 billion. The list represents the costliest catastrophes in terms of insurance claims from 1970 until the present day: Hailstorms, 1999,

Sydney. Claims costs today about $5.8 billion and total financial costs possibly much more. Black Summer, 2019/20 NSW, VIC, SA and QLD. Claims costs about $5.5 billion versus total financial costs of about $10 billion . Tropical Cyclone Tracy, 1974, Darwin. Claims costs today about $5.3 billion versus total financial costs of about $7 billion. Earthquake, 1989, Newcastle. Claims costs today about $4.4 billion versus total financial costs of about $8.7 billion Floods, 1974, Brisbane. Claims costs today about $3.3 billion versus total financial costs of about $8.2 billion.

Climate

Keywords: adaptation, climate change, climate change adaptation, climate change impacts, climate change risk, climate risk, climate risks, climate service, climate services

Allen, S., Gonzales Iwanciw, J., Rodríguez, L., Stoffel, M., Grünwaldt, A., Brusa, F., & Bocco, M. J. (2020). Building Transformative Institutional Adaptive Capacity: Assessing The Potential Contribution of PPCR to Build a Climate Resilient Water Governance Framework in The Plurinational State of Bolivia. *Building Transformative Institutional Adaptive Capacity: Assessing The Potential Contribution of PPCR to Build a Climate Resilient Water Governance Framework in The Plurinational State of Bolivia*. https://doi.org/10.18235/0002226

Altvater, S., de Block, D., Bouwma, I., Dworak, T., Frelih-Larsen, A., Gorlach, B., Hermeling, C., Klostermann, J., Konig, M., Leitner, M., Marinova, N., McCallum, S., Naumann, S., Osberghaus, D., Prutsch, A., Reif, C., van de Sandt, K., Swart, R., Troltzsch, J., … Troltzsch, J. (2014). Adaptation Measures in the EU: Policies, Costs, and Economic Assessment ("Climate Proofing" of Key EU Policies). *SSRN Electronic Journal*, *February*. https://doi.org/10.2139/ssrn.2460266
The aim of this report is to ascertain priority concerns for further climate proofing action through opposing current EU efforts to different threats, and suggest complementary options (cf. chapter 3) for the following four sectors: (1) Energy, (2) Transport infrastructure, (3) Urban areas, and (4) Agriculture. A final selection of measures to be assessed with a view to their costs and economic, social and environmental impacts was agreed at the first interim meeting with the Commission. Measures already part of EU wide assessment projects were not part of the assessment. In a first step (chapter 3) key policy areas have been screened to identify adaptation measures. A final selection of measures agreed with the Commission was further processed in terms of costing (chapter 4) and the assessment of impacts (chapter 5).

Bours, D., McGinn, C., & Pringle, P. (2014). *Guidance note 2 : Selecting indicators for climate change adaptation programming*. *January*, 10.
http://www.seachangecop.org/sites/default/files/documents/2014 01 SEA Change UKCIP GN2 Selecting indicators for CCA_0.pdf
This guidance note includes a brief review of approaches to climate change adaptation (CCA) programme design, monitoring, and evaluation and discusses how to identify appropriate indicators. It demonstrates that CCA does not necessarily call for a separate set of indicators; rather, the key is to select a medley that appropriately frames progress towards adaptation and resilience.

Bruno Soares, M., Alexander, M., & Dessai, S. (2018). Sectoral use of climate information in Europe: A synoptic overview. *Climate Services*, *9*, 5–20. https://doi.org/10.1016/j.cliser.2017.06.001
Society can benefit from usable climate information to better prepare and adapt to the risks and opportunities posed by climate variability and change. An adequate and effective provision of climate information – from historical observations through to seasonal forecasts, and multi-

decadal climate change projections – is critical to inform planning and decision-making in climate-sensitive sectors. Central to this are the end-users of climate information and a growing emphasis on tailored climate information and services shaped by user needs. However, knowledge about the use of climate information across European economic sectors is limited. This paper identifies the spectrum of sectoral information requirements across a number of sectors including agriculture, forestry, energy, water, tourism, insurance, health, emergency services and transport sectors, drawing from an online survey (n = 462) and interviews with (potential) users of climate information (n = 80). This analysis reveals shared opportunities across sectors including the potential application of decadal climate predictions. In addition, common barriers and enablers to the uptake of climate information were also noted including the format of the information provided, the need for compatibility with existing in-house systems, and the perceived credibility and trust of information providers. This analysis also points towards a perceived increasing fragmentation of available information and the desire amongst end-users for a European body able to centralise and coordinate climate data. We highlight some of the current factors that still need to be adequately addressed in order to enhance the uptake and application of climate information in decision-making across European economic sectors.

Carabine, E., & Simonet, C. (2018). *Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors.* 76 pp. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12286.pdf%0Ahttps://www.cabdirect.org/cabdirect/abstract/20183299617
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Center for Climate and Energy Solutions. (2015). *Weathering the Next Storm : a Closer Look At Business Resilience* (Issue September). http://www.c2es.org/publications/weathering-next-storm-closer-look-business-resilience
In 2013, C2ES released Weathering the Storm: Building Business Resilience to Climate Change (hereafter WTS 2013), which examined how companies listed in the Standard and Poor's (S&P) Global 100 Index were approaching climate risks. WTS 2013 provided a baseline perspective on how major companies were assessing their climate vulnerabilities and whether and how they were working to strengthen their climate resilience. This report provides an update and takes a closer look at how companies are preparing for climate change and what is keeping them from doing more. The report is based on several lines of research: • A comprehensive review of the perspectives and activities of S&P Global 100 companies, based on their reporting to CDP1 and their corporate sustainability reports and annual financial filings; • Interviews with company representatives to gather more detailed information on whether and how companies are assessing climate risks and what barriers are keeping them from doing more; and • Dialogues conducted with companies, federal and local government agencies, academics, and other stakeholders through several workshops and events focused on business resilience. These sources provide an in-depth look at the state of climate risk assessment and resilience planning within the business

community. While some companies have taken steps to assess risks and prepare their business for future climate changes, many companies face various internal and external challenges that hinder efforts toward greater climate resilience. This report identifies various approaches companies are using to address climate risks, examines challenges companies face in managing and reporting risks, and suggests strategies to overcome these challenges and strengthen climate risk management within the private sector.

Cortekar, J., Bender, S., Brune, M., & Groth, M. (2016). Why climate change adaptation in cities needs customised and flexible climate services. *Climate Services*, *4*, 42–51. https://doi.org/10.1016/j.cliser.2016.11.002
Cities are key players in climate change adaptation and mitigation due to a spatial concentration of assets, people and economic activities. They are thus contributing to and especially vulnerable to climate change. Identifying, planning, implementing and monitoring respective measures in cities is challenging and resource consuming. The paper outlines challenges for adaptation, discusses most common approaches and argues why implementation of theoretical methods has its shortcomings. Based on case studies, an innovative, practice-oriented approach has been tested to develop a climate service prototype product. It provides a general framework that allows a flexible and customised support for cities to adapt to expected impacts of a changing climate.

International Federation of Red Cross and Red Crescent Societies (IFRC). (2020). Tackling the humanitarian impacts of the climate crisis together. In *World Disaster Report 2020*.
The analysis presented in World Disasters Report 2020 shows that none of the 20 countries most vulnerable to climate change (according to ND-GAIN) and to climate- and weather-related disasters (according to INFORM) were among the 20 highest per person recipients of climate change adaptation funding. Somalia, the most vulnerable, ranks only 71st for per person funding disbursements. None of the countries with the five highest disbursements had high or very high vulnerability scores. At the other end of the spectrum, 38 high vulnerability countries (out of 60) and 5 very high vulnerability countries (out of 8) received less than $1 per person in climate adaptation funding, while two (Central African Republic and DPRK) received no disbursements at all. Notably, none of the largest five recipients are fragile contexts. An additional challenge is ensuring that funding reaches the most at-risk people within these countries. Many communities may be particularly vulnerable to climate-related risks, from people affected by conflict whose capacity to manage shocks is already strained, to migrants and displaced people who may struggle to access the services and assistance they need, to urban poor people and other marginalized communities. Support needs to reach these communities most vulnerable to climate-related risks as a priority. The issues are not only financial. The report argues it is time to shake off business as usual and turn words into action. Much of what needs to be done has been known for years – it is just overdue in implementation. But we also need to scale up some new lessons learned more recently from our changed environment. Fundamentally, we need to ensure that we are implementing the intertwined commitments in the Sustainable Development Goals (SDGs), the Paris Agreement and the Sendai Framework for Disaster Risk Reduction 2015–2030 in a joined-up way. And we must do a much better job of ensuring that all actors – including governments, donors, the humanitarian, development, climate and environmental sectors – prioritize support for the people, communities and countries most at risk. The World Disasters Report 2020 takes a deep dive into the disaster risks that climate change is driving, and analyses the action needed to address their human impacts.

Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., SM, H., Jeanneret, T., & Nelson, R. (2016). *Adaptive value chain approaches. Understanding adaptation in food value chains* (Issue June).

The impacts of climate change are felt along the whole chain of actors that produce, handle, process and market agri-food products. This project aims to help agri-food companies to systematically identify, assess, prioritise and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach. A holistic and systematic evaluation of the risks that climate change poses, both direct and indirect, is crucial for adaptation planning. Understanding the complexity of interactions between biophysical, social and economic drivers in the context of climate change enables businesses within a value chain to have line of sight of indirect, but impactful, effects. It also enables businesses, from farming all the way to retailing, to begin to understand their 'tipping points'' better – where the impacts of multiple events along the value chain result to one or multiple stages of the chain unable to recover or remain competitive. There are three key outcomes from this study: 1. Our study has found that climate change, in itself, is not enough to encourage consumers to accept an adapted product, because there is a lack of understanding of how climate change can impact day-to-day life in general. At present, adaptation for agri-food businesses serves as a risk mitigation strategy, rather than a marketing opportunity. This however, may prove to be a competitive advantage for those who are in touch with consumer sentiment on adaptation, as sentiments may change in the future. 2. Value chain adaptation needs to consider the impact of any action on the value created and received by the chain. Our study has found that approaching value chain adaptation using a future storylines approach allows agri-food businesses to consider not only the adaptation benefits of a strategy, but also benefits to GHG mitigation and competitiveness. The process we have developed here enables business to gauge the merits of an adaptation action against multiple, and potentially competing, priorities. 3. Based on the findings of this study, an adapted value chain is one that is able to sustain its competitive advantage in a changing climate. A non-adapted value chain can only continue to exist up to a certain point where climate and weather risk and threats, both direct and indirect, are insurmountable and hence the value chain can no longer be profitable on an ongoing basis. Non- adapted value chains also miss opportu…'

Máñez Costa, M., Oen, A. M. P., Neset, T.-S., Celliers, L., & Coauthors. (2021). *Co-production of Climate Services. A diversity of approaches and good practice from the ERA4CS projects (2017-2021)*. https://ris.utwente.nl/ws/portalfiles/portal/276843806/Manez_costa_2022_Co_production_of_climate_services_.pdf

This guide presents a joint effort of projects funded under the European Research Area for Climate Services (ERA4CS) (http://www.jpi-climate.eu/ERA4CS), a co- funded action initiated by JPI Climate with co-funding by the European Union (Grant 690462), 15 national public Research Funding Organisations (RFOs), and 30 Research Performing Organisations (RPOs) from 18 European countries. This guide sets out to increase the understanding of different pathways, methods, and approaches to improve knowledge co-production of climate services with users as a value-added activity of the ERA4CS Programme. Reflecting on the experiences of 16 of the 26 projects funded under ERA4CS, this guide aims to define and recommend good practices for transdisciplinary knowledge co-production of climate services to researchers, users, funding agencies, and private sector service providers. Drawing on responses from ERA4CS project teams to a questionnaire and interviews, this guide maps the diversity of methods for stakeholder identification, involvement, and engagement. It also conducts an analysis of methods, tools, and mechanisms for engagement as well as evaluation of co-production processes. This guide presents and discusses good practice examples based on the review of the ERA4CS projects, identifying enablers and barriers for key elements in climate service co-production processes. These were: namely (i) Forms of Engagement; (ii) Entry Points for Engagement; and, (iii) Intensity of Involvement. It further outlines key ingredients to enhance the quality of co-producing climate services with users and stakeholders. Based on the analysis of the lessons learned from ERA4CS projects, as well as a review of key

concepts in the recent literature on climate service co-production, we provide a set of recommendations for researchers, users, funders and private sector providers of climate services.

Skelton, M., Fischer, A. M., Liniger, M. A., & Bresch, D. N. (2019). Who is 'the user' of climate services? Unpacking the use of national climate scenarios in Switzerland beyond sectors, numeracy and the research–practice binary. *Climate Services*, *15*. https://doi.org/10.1016/j.cliser.2019.100113
By whom are national climate scenarios taken up, and which products are used? Despite numerous (national) climate scenarios being published by countries across the globe, studies of their actual uptake and application remain low. Analysing a survey and group interviews on the ways the Swiss climate scenarios CH2011 have been actually used by the Swiss adaptation community, we encoded the emerging differences in a new typology of observers, sailors, and divers. Taking an iceberg as a metaphor for climate scenarios, most respondents were sailors, accessing only key findings above the waterline (i.e., summary brochures). However, the vast majority of climate scenario data remains below the surface (i.e., downscaled climate model data), accessible only to the quarter of respondents labelled divers. Lastly, another quarter are observers, interested in the iceberg from afar, but without applying the climate information directly to their work. By describing three ways of using climate scenarios, we aim to clarify the often vague notion of 'user' circulating prominently in discussions around climate services and knowledge co-production. In addition, our results question the adequacy of simplifying climate scenario use by a user's easily observable characteristics – such as being a researcher or practitioner, by sector or by numeracy. Our typology thus highlights the diversity of use(r)s within sectors or academia, but is also able to characterise various similarities of use(r)s between sectors, researchers and practitioners. Our findings assist in more nuanced and informed discussions of how 'users' are imagined and characterised in future developments of usable climate services.

Tesfaye, A., Hansen Girma, J. W., Kassie, T., & Radeny, M. (n.d.). *Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach*. www.ccafs.cgiar.org

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Vogel, J., Letson, D., & Herrick, C. (2017). A framework for climate services evaluation and its application to the Caribbean Agrometeorological Initiative. *Climate Services*, *6*(July), 65–76. https://doi.org/10.1016/j.cliser.2017.07.003
Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the numerous and diverse investments international donor organizations, national governments, and regional institutions are making in climate services. This paper describes an elaborated logic model to structure the evaluation of a climate services program, which we demonstrate in a case study of the Caribbean Agrometeorological Initiative (CAMI). Moving beyond the "loading dock" model of scientific information application, this logic model helps evaluators to address all elements of the provision of climate services – including the quality of weather and climate forecasts and agronomic advisories, the distribution of that information, the uptake of that information, and actions taken by farmers (See Fig. 1). Our logic model links the provision of information on weather, climate, and agriculture with decision making, and ultimately with improved social and economic outcomes. While such a logic model necessarily simplifies the full context of any climate services program, it also makes project evaluation much more tractable and generalizable across contexts. Furthermore, this simple logic model can serve to deconstruct

conventional thinking about climate services by explicitly addressing the social and process dimensions of climate services that are sometimes neglected in project design, implementation, and evaluation. CAMI partner countries are developing climate outlook bulletins to communicate a three-month seasonal forecast. Despite these high quality seasonal forecasts, we note shortcomings regarding the dissemination of that information, its uptake by farmers, or the ability or willingness of farmers to act on that information.

Use cases

- Use case 1 – Design a new service
- Use case 2 – Understand an existing value chain
- Use case 3 – Evaluate service effectiveness
- Use case 4 – Assess the value of service improvements
- Use case 5 – Prioritise allocation of resources

Keywords (tags): co-design, co-design and co-production, existing VC structures, mapping value chains, service improvements, service design, UC 1, UC 2, UC 3, UC 4, UC 5

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (Eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts?

Weather and Climate Extremes, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., Lazrus, H., & Hudson, R. (2016). A Mental Models Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making*. *Weather, Climate, and Society*, *8*(2), 111–129. https://doi.org/10.1175/WCAS-D-15-0033.1
The study reported here explores how to enhance the public value of hurricane forecast and warning information by examining the entire warning process. A mental models research approach is applied to address three risk management tasks critical to warnings for extreme weather events: 1) understanding the risk decision and action context for hurricane warnings, 2) understanding the commonalities and conflicts in interpretations of that context and associated risks, and 3) exploring the practical implications of these insights for hurricane risk communication and management. To understand the risk decision and action context, the study develops a decision-focused model of the hurricane forecast and warning system on the basis of results from individual mental models interviews with forecasters from the National Hurricane Center (n = 4) and the Miami–South Florida Weather Forecast Office (n = 4), media broadcasters (n = 5), and public officials (n = 6), as well as a group decision-modeling session with a subset of the forecasters. Comparisons across professionals reveal numerous shared perceptions, as well as some critical differences. Implications for improving extreme weather event forecast and warning systems and risk communication are threefold: 1) promote thinking about forecast and warning decisions as a system, with informal as well as formal elements; 2) evaluate, coordinate, and consider controlling the proliferation of forecast and warning information products; and 3) further examine the interpretation and representation of uncertainty within the hurricane forecast and warning system as well as for users.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This

mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Cawood, M., Keys, C., & Wright, C. (2018). The total flood warning system: What have we learnt since 1990 and where are the gaps. *Australian Journal of Emergency Management*, *33*(2), 47–52.
April 1990 was a month of severe flooding in eastern Australia. Two months later, a national workshop was held in which a large number of flood management specialists sought to capture the lessons of the floods while they were still fresh. Many aspects of the management of the events were examined, with flood warning highlighted as a key function. A second meeting the following year resolved to produce a best-practice manual to help guide practitioners in the development of flood warning services. The term “Total Flood Warning System” (TFWS) was adopted to describe the need to integrate the many elements of effective warning. The need to help those in the path of a flood to understand the warnings they received and take effective action was recognised as central. The manual was published in 1995 and revised and updated in 1999 and 2009. This paper asks what has changed and improved in the flood warning field since 1990 and what is needed in TFWS terms to further help communities and individuals manage their flood risk.

Demuth, J. L., Morss, R. E., Morrow, B. H., & Lazo, J. K. (2012). Creation and communication of hurricane risk information. *Bulletin of the American Meteorological Society*, *93*(8), 1133–1145. https://doi.org/10.1175/BAMS-D-11-00150.1
Reducing loss of life and harm when a hurricane threatens depends on people receiving hurricane risk information that they can interpret and use in protective decisions. To understand and improve hurricane risk communication, this article examines how National Weather Service (NWS) forecasters at the National Hurricane Center and local weather forecast offices, local emergency managers, and local television and radio media create and convey hurricane risk information. Data from in-depth interviews and observational sessions with members of these groups from Greater Miami were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Together, these groups succeed in partnering with each other to make information about approaching hurricane threats widely available. Yet NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios. Thus, we recommend that warning system partners 1) build understanding of each other’s needs and constraints; 2) ensure formalized, yet flexible mechanisms exist for exchanging critical information; 3) improve hurricane risk communication by integrating social science knowledge to design and test messages with intended audiences; and 4) evaluate, test, and improve the NWS hurricane-related product suite in collaboration with social scientists. ©2012 American Meteorological Society.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., & Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response.

International Journal of Disaster Risk Reduction, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811
Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Golding, B., Mittermaier, M., Ross, C., Ebert, B., Panchuk, S., Scolobig, A., & Johnston, D. (2019). A Value Chain Approach to Optimising Early Warning Systems. *Global Assessment Report*, 1–30.
The impact of weather-related hazards continues to be a major cause of human and economic loss in the world. Reducing those losses requires a combination of policies that protect, avoid and facilitate recovery. Early warnings are a key contributor, especially in countries without the governance structures and resources to provide permanent protection or avoidance. Advances in weather modelling, earth observation from space, and hazard reporting by citizens, provide a solid baseline for hazard mapping; however, this needs to be matched by comparable mapping of the (time-dependent) exposure and vulnerability of people, buildings and infrastructure, and by the development of response capability especially in risk hot-spots.

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).
This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Jeuring, J., Knol-Kauffman, M., & Sivle, A. (2020). Toward valuable weather and sea-ice services for the marine Arctic: exploring user–producer interfaces of the Norwegian Meteorological Institute. *Polar Geography*, *43*(2–3), 139–159. https://doi.org/10.1080/1088937X.2019.1679270
Recognition is growing that valuable weather, water, ice and climate (WWIC) services for marine, Arctic environments can only be produced in close dialogue with its actual users. This denotes an acknowledgement that knowing how users incorporate WWIC information in their activities should be considered throughout the information value chain. Notions like co-production and user engagement are current terms to grapple with user needs, but little is known about how such concepts are operationalized in the practical context of tasks and responsibilities of National Meteorological and Hydrometeorological Services (NMHS). Based on a series of in-depth, qualitative interviews with a diversity of personnel from the Norwegian Meteorological Institute,

we describe the shifting dynamics of interactions between WWIC information providers and maritime stakeholders operating in Arctic environments. Three key challenges are discussed, pertaining to both day-to-day and strategic interactions: (1) the importance of knowing how information is used, (2) the increasing automation of meteorological practices and the growing need for user observations, and (3) the need for bridging research-to-operations gaps. We embed these findings in a discussion on how user–producer interfaces are shaped and transforming through an ongoing negotiation of expertise, changing the roles and responsibilities within particular constellations of co-producing WWIC information services.

Johar, M., Johnston, D. W., Shields, M. A., Siminski, P., & Stavrunova, O. (2022). The economic impacts of direct natural disaster exposure. *Journal of Economic Behavior and Organization*, *196*, 26–39. https://doi.org/10.1016/j.jebo.2022.01.023

We estimate the economic impacts of having your home damaged or destroyed by a natural disaster. Regressions with individual, area and time fixed-effects, indicate that experiencing a natural disaster has no impact on employment and income, but substantial impacts on financial hardship and risk aversion. Impacts are particularly large for smaller isolated disasters, which attract little government support. Conversely, impacts of residing in a disaster zone without experiencing residential destruction are small. Using a Group Fixed Effects estimator, we find predictors of financial vulnerability to destruction include age, parenthood, illness, and social support. These results can help improve the allocation of government assistance after future disasters.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1

As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm

surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Máñez Costa, M., Oen, A. M. P., Neset, T.-S., Celliers, L., & Coauthors. (2021). *Co-production of Climate Services. A diversity of approaches and good practice from the ERA4CS projects (2017-2021)*. https://ris.utwente.nl/ws/portalfiles/portal/276843806/Manez_costa_2022_Co_production_of_climate_services_.pdf
This guide presents a joint effort of projects funded under the European Research Area for Climate Services (ERA4CS) (http://www.jpi-climate.eu/ERA4CS), a co- funded action initiated by JPI Climate with co-funding by the European Union (Grant 690462), 15 national public Research Funding Organisations (RFOs), and 30 Research Performing Organisations (RPOs) from 18 European countries. This guide sets out to increase the understanding of different pathways, methods, and approaches to improve knowledge co-production of climate services with users as a value-added activity of the ERA4CS Programme. Reflecting on the experiences of 16 of the 26 projects funded under ERA4CS, this guide aims to define and recommend good practices for transdisciplinary knowledge co-production of climate services to researchers, users, funding agencies, and private sector service providers. Drawing on responses from ERA4CS project teams to a questionnaire and interviews, this guide maps the diversity of methods for stakeholder identification, involvement, and engagement. It also conducts an analysis of methods, tools, and mechanisms for engagement as well as evaluation of co-production processes. This guide presents and discusses good practice examples based on the review of the ERA4CS projects, identifying enablers and barriers for key

elements in climate service co-production processes. These were: namely (i) Forms of Engagement; (ii) Entry Points for Engagement; and, (iii) Intensity of Involvement. It further outlines key ingredients to enhance the quality of co-producing climate services with users and stakeholders. Based on the analysis of the lessons learned from ERA4CS projects, as well as a review of key concepts in the recent literature on climate service co-production, we provide a set of recommendations for researchers, users, funders and private sector providers of climate services.

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Nurmi, P., Perrels, A., & Nurmi, V. (2013). Expected impacts and value of improvements in weather forecasting on the road transport sector. *Meteorological Applications*, *20*(2), 217–223. https://doi.org/10.1002/met.1399
Atmospheric predictability has improved by approximately 1day per decade during the last 20years based on verification results of ECMWF forecast output. In Finland, locally applied accuracy measures indicate marked improvements in the quality of forecasts for the general public since the late 1980s. It is assumed that similar trends will continue to the foreseeable future. Use of weather information will allow for better options in the decision-making of various stake holders in the transport sector, such as commuters or tourists, transport infrastructure owners and transport service and maintenance operators. This paper discusses the economic impacts and value of weather forecasts on different transport modes (road, rail, air) highlighting the effects of potential improvements in forecast quality in the expected future climates in Europe. It is not only the improved quality of available weather forecasts that will define the value of information. The way in which the information is communicated and how it is being utilized by decision-makers are highly relevant steps in a weather service value chain. Rather than applying the traditional Cost-Loss model, which would relate improved forecast accuracy to increased expected utility, an alternative approach is being applied. This “Weather Service Chain Analysis” (WSCA) accounts for imperfect features in the communication chain and in the use of weather information by analysing the decay of the total potential benefits via decomposing the information flow from original forecast generation to final benefit realization. Concrete estimates are provided for the road transport modes both in Finland and in Europe. © 2013 Royal Meteorological Society.

Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, *10*(1), 65–70. https://doi.org/10.5194/asr-10-65-2013
Abstract. There is a rising interest around the world for a better understanding of the economic and social value added of weather services. National hydro-meteorological services and international cooperative bodies in meteorology have ever more to justify their use of public budgets. Furthermore, the development of hydrological and meteorological services is to a large extent steered by expectations regarding the eventual benefits of the envisaged new developments. This article provides a compact overview of the impediments for uptake of socio-economic benefit (SEB) studies, methods and results of SEB studies to date. It also discusses some pitfalls and crucial steps to enhance a broader uptake of SEB studies.

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk*

Reduction. https://doi.org/10.1016/j.ijdrr.2021.102344
Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP, CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Risbey, J. S., Squire, D. T., Black, A. S., DelSole, T., Lepore, C., Matear, R. J., Monselesan, D. P., Moore, T. S., Richardson, D., Schepen, A., Tippett, M. K., & Tozer, C. R. (2021). Standard assessments of climate forecast skill can be misleading. *Nature Communications*, *12*(1), 4346. https://doi.org/10.1038/s41467-021-23771-z
Assessments of climate forecast skill depend on choices made by the assessor. In this perspective, we use forecasts of the El Niño-Southern-Oscillation to outline the impact of bias-correction on skill. Many assessments of skill from hindcasts (past forecasts) are probably overestimates of attainable forecast skill because the hindcasts are informed by observations over the period assessed that would not be available to real forecasts. Differences between hindcast and forecast skill result from changes in model biases from the period used to form forecast anomalies to the period over which the forecast is made. The relative skill rankings of models can change between hindcast and forecast systems because different models have different changes in bias across periods.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be

used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.'"""""

Sangha, K. K., Russell-Smith, J., Evans, J., & Edwards, A. (2020). Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction*, *49*. https://doi.org/10.1016/j.ijdrr.2020.101619
Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environmental when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank [1]; and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was estimated at AU$95-132million per year. Evaluating such costs for loss of Indigenous peoples' well-being who reside in remote parts of the NT, presents an estimate of AU$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

van Noordwijk, M., Matthews, R., Agus, F., Farmer, J., Verchot, L., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., Dewi, S., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., & Dewi, S. (2014). Mud, muddle and models in the knowledge value-chain to action on tropical peatland conservation. *Mitigation and Adaptation Strategies for Global Change*, *19*(6), 887–905. https://doi.org/10.1007/s11027-014-9576-1
Tropical peatlands are known not only for their high, area-based, carbon emissions in response to land-use change but also as hot spots of debate about associated data uncertainties. Perspectives are still evolving on factors underlying the variability and uncertainty. Debate includes the ways of reducing emissions through rewetting, reforestation and agroforestry. A knowledge value-chain

that is long and complex links (a) fundamental understanding of peat and peatland processes leading to sciencebased quantification and default values, (b) willingness and (c) ability to act towards emission reduction, and ultimately (d) to local, national and global actions that effectively provide rules, incentives and motivation to conserve peat and reduce emissions. We discuss this value chain, its stakeholders and issues that still remain partially unresolved. We conclude that, to shorten the denial and conspiracy-theory stages of debate that otherwise slow down steps B and C, networks of international and national scientists have to be involved at the early stage of identifying policysensitive environmental issues. Models span part of the knowledge value-chain but transition of analysis units requires specific attention, from soil volumes through area and commodity flows to opportunities for reductions. While drainage of peatlands triggers landscape-scale increases in emissions, factors beyond drainage depth, including nutrient supply, may have a major influence on decomposition rates. Attempts to disentangle the contributions of plant and peat-based respiration in surface flux measurements involve assumptions that cannot be easily verified in comparisons between land uses. With progress on A leading to new internationally accepted defaults and with resistance on step B reduced, the reality of C and lack of working solutions for D is currently constraining further progress. © 2014 The Author(s).

Case studies

Keywords: Africa, Asian countries, Australia, Australia case study, agriculture, Arctic, case studies, case study, country profiles, country specific data, critical infrastructure, flood event case studies, most vulnerable countries, past efforts, solar energy, Sri Lanka, Tanzania, transport

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-

Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Amegnaglo, C. J., Anaman, K. A., Mensah-Bonsu, A., Onumah, E. E., & Amoussouga Gero, F. (2017). Contingent valuation study of the benefits of seasonal climate forecasts for maize farmers in the Republic of Benin, West Africa. *Climate Services*, *6*, 1–11. https://doi.org/10.1016/j.cliser.2017.06.007
This study aims to assess the economic benefits of seasonal climate forecasts in West Africa based on a random survey of 354 maize farmers and to use the contingent valuation method. Results indicate that farmers need accurate seasonal climate forecasts between 1 and 2 months before the onset of rains. The most desirable dissemination channels are radio, local elders, local farmer meetings and extension agents. The most likely used farming strategies are change of: planting date, crop acreage, crop variety, and production intensification. The vast majority of farmers are willing to pay for seasonal climate forecasts, and the average annual economic value of seasonal climate forecasts are about USD 5492 for the 354 sampled farmers and USD 66.5 million dollar at the national level. Furthermore, benefits of seasonal climate forecasts are likely to increase with better access to farmer based organisation, to extension services, to financial services, to modern communication tools, intensity of use of fertilizer and with larger farm sizes. Seasonal climate forecasts are a source of improvement of farmers' performance and the service should be integrated in extension programmes and in national agricultural development agenda.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Carabine, E., & Simonet, C. (2018). *Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors.* 76 pp. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12286.pdf%0Ahttps://www.cabdirect.org/cabdirect/abstract/20183299617
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage

reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Cawood, M., Keys, C., & Wright, C. (2018). The total flood warning system: What have we learnt since 1990 and where are the gaps. *Australian Journal of Emergency Management*, *33*(2), 47–52.
April 1990 was a month of severe flooding in eastern Australia. Two months later, a national workshop was held in which a large number of flood management specialists sought to capture the lessons of the floods while they were still fresh. Many aspects of the management of the events were examined, with flood warning highlighted as a key function. A second meeting the following year resolved to produce a best-practice manual to help guide practitioners in the development of flood warning services. The term "Total Flood Warning System" (TFWS) was adopted to describe the need to integrate the many elements of effective warning. The need to help those in the path of a flood to understand the warnings they received and take effective action was recognised as central. The manual was published in 1995 and revised and updated in 1999 and 2009. This paper asks what has changed and improved in the flood warning field since 1990 and what is needed in TFWS terms to further help communities and individuals manage their flood risk.

Everingham, Y. L., Muchow, R. C., Stone, R. C., Inman-Bamber, N. G., Singels, A., & Bezuidenhout, C. N. (2002). Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. *Agricultural Systems*, *74*(3), 459–477. https://doi.org/10.1016/S0308-521X(02)00050-1
Sugarcane industries worldwide are exposed to uncertainty associated with variable climate. This variability produces impacts across an integrated value chain comprising of the following industry sectors: cane growing, harvesting and transport, milling, and marketing. The purpose of this paper is to advocate a comprehensive systems approach for using seasonal climate forecast systems to improve risk management and decision-making capability across all sugarcane industry sectors. The application of this approach is outlined for decisions relating to yield forecasting, harvest management, and the use of irrigation. Key lessons learnt from this approach include the need for a participative R&D approach with stakeholders and the need to consider the whole industry value chain. Additionally, there is the need for climate forecast systems to target the varying needs of sugarcane industries. © 2002 Elsevier Science Ltd. All rights reserved.

Fakhruddin, B. S. H. M. H. M., & Schick, L. (2019). Benefits of economic assessment of cyclone early warning systems - A case study on Cyclone Evan in Samoa. *Progress in Disaster Science*, *2*(2019), 100034. https://doi.org/10.1016/j.pdisas.2019.100034
Samoa is extremely exposed to natural hazards, particularly tropical cyclones and earthquake-generated tsunami. Some studies have put forth the position that adequate investment in early warning systems can contribute to the social and economic well-being of countries. However, in spite of these research findings there is still a lack of understanding on how to measure effectiveness that leads to limited investment. Cost-benefit analysis (CBA) is a tool used in this study to summarize the value for money in terms of investment to enhance an early warning system. This paper aims to summarize the benefits of adopting early warning systems and its effectiveness against the investment required and its value proposition. Data from the 'Samoa Post-Disaster Needs Assessment of the Cyclone Evan event in 2012' have been used to assess damage information, and stakeholders consultations and interviews were carried out for cost-benefit analysis. We have conducted quantified CBA of early warning services for cyclone hazards and the results have shown that for every USD 1 invested, there is a return of USD 6 as benefit.

This paper suggests that economic assessment of early warning services could help in quantifying pre-impact assessment to demonstrate to policy makers the economic benefit of disaster risk reduction (DRR).

Fekete, A. (2019). Critical infrastructure and flood resilience: Cascading effects beyond water. *WIREs Water*, *6*(5), 1–13. https://doi.org/10.1002/wat2.1370
Abstract Critical infrastructure and cascading effects are analyzed in this article as cross-cutting topics in flood risk and resilience. A concept is developed for integrating aspects of disaster risk, hazard, vulnerability and resilience with critical infrastructure analytic components such as redundancy, rapidity or resourcefulness. These components are expressed for each phase of an unfolding flood event and cascading effects are indicated, too. This contribution discusses the implications of such a conceptual frame for the advancement of existing flood risk management concepts. Current international guiding strategies such as the United Nations Sendai Framework for Disaster Risk Reduction, the "Making Cities Resilient" campaigns in field of urban disaster resilience, Climate Change Adaptation processes such as the Paris Agreement of the IPCC process, or urban planning in the field of UN HABITAT are all interconnected to the topic of (critical) infrastructure. The article shows how flood risk management can connect to such wider international developments by the conceptual frame discussion presented. This article is categorized under: Engineering Water > Planning Water Science of Water > Water Extremes Human Water > Water Governance

Garcia, C., & Fearnley, C. J. (2012). Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, *11*(2), 123–137. https://doi.org/10.1080/17477891.2011.609877
Early warning systems (EWSs) are extensive systems that integrate different components of disaster risk reduction for the provision of timely warnings to minimize loss of life and to reduce economic and social impact on vulnerable populations. Historically, empirical research has focused on the individual components or sub-systems of EWSs, such as hazard monitoring, risk assessment, forecasting tools and warning dissemination. However, analyses of natural hazard disasters indicate that, in most cases, the processes that link individual components of EWS fail, rather than the components themselves. This paper reviews several case studies conducted over the last 40 years to present common emerging factors that improve links between the different components of EWSs. The identified factors include: (1) establishing effective communication networks to integrate scientific research into practice; (2) developing effective decision-making processes that incorporate local contexts by defining accountability and responsibility; (3) acknowledging the importance of risk perception and trust for an effective reaction; and (4) consideration of the differences among technocratic and participatory approaches in EWSs when applied in diverse contexts. These factors show the importance of flexibility and the consideration of local context in making EWSs effective, whereas increasing levels of standardization within EWSs nationally and globally might challenge the ability to incorporate the required local expertise and circumstances.

Haupt, S. E., Kosović, B., Jensen, T., Lazo, J. K., Lee, J. A., Jiménez, P. A., Cowie, J., Wiener, G., Mccandless, T. C., Rogers, M., Miller, S., Sengupta, M., Xie, Y., HinKeLman, L., KaLb, P., & Heiser, J. H. (2018). Building the SUN4CAST system. *Bulletin of the American Meteorological Society*, *99*(1), 121–135. https://doi.org/10.1175/BAMS-D-16-0221.1
The Sun4Cast System results from a research-to-operations project built on a value chain approach, benefiting electric utilities' customers, society, and the environment by improving state-of-the-science solar power forecasting capabilities.

Horita, F. E. A., de Albuquerque, J. P., & Marchezini, V. (2018). Understanding the decision-making process in disaster risk monitoring and early-warning: A case study within a control room in Brazil.

International Journal of Disaster Risk Reduction, *28*(September 2017), 22–31. https://doi.org/10.1016/j.ijdrr.2018.01.034
The tasks of disaster risk monitoring and early warning are an important means of improving the efficiency of disaster response and preparedness. However, although the current works in this area have sought to provide a more accurate and better technological infrastructure of systems to support these tasks, they have failed to examine key features that may affect the decision-making. In light of this, this paper aims to provide an understanding of the decision-making process in control rooms for disaster risk monitoring and early warning. This understanding is underpinned by a conceptual framework, which has been developed in this work and describes factors that influence the decision-making. For doing so, data were collected through a series of semi-structured interviews and participatory observations and later evaluated with members of the control room of the Brazilian Center for Monitoring and Early Warning of Natural Disasters (Cemaden). The study findings provided a solid basis for designing the conceptual framework of the essential factors required by the decision-makers. These factors are separated into two groups: 1) the "dimensions" of decision-making (i.e., the type of hazard, the phase of the disaster risk, the location, and area of expertise of the operators) and the "pillars" of decision-making (i.e., the tasks, their required information, useful data sources, and the decision rule). Finally, the contributions achieved in this study may help operators to understand and propose proactive measures that could improve their decision-making, overcome uncertainties, standardize the team's decision-making, and put less pressure on operators.

Hosterman, H. R., Lazo, J. K., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2019). Using the National Weather Service's impact-based decision support services to prepare for extreme winter storms. *Journal of Emergency Management (Weston, Mass.)*, *17*(6), 455–467. https://doi.org/10.5055/jem.2019.0439
In recent years, the National Weather Service (NWS) increased its focus on providing decision support services to the emergency management community and other core partners to help them understand its forecasts and take appropriate actions in the face of upcoming extreme events. In 2011, the Weather-Ready Nation Strategic Plan began to formalize the NWS approach to impact-based decision support services (IDSS). NWS recognizes IDSS as a primary service and is working to fully and more effectively provide it to federal, state, local, and tribal decision-makers. To do so, it is important that NWS understands how users are benefiting from existing IDSS, even as they look to improve it. This article aims to provide emergency managers (EMs) with an understanding of the efficacy of IDSS. The authors define IDSS and describe the IDSS products and services available during each stage of the emergency-management cycle: preparedness, mitigation, response, and recovery. To demonstrate the role of IDSS for the emergency management community, the authors use a case study analysis to compare two winter storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 winter storm (no formal IDSS) and the January 2016 winter storm (formal IDSS). In comparing the winter storm case studies, the authors find that formal IDSS provides EMs and other core partners with accurate, actionable, and consistent weather information and support that allows them to respond to winter storms in a way that reduces impacts to lives and livelihoods.

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).
This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Keating, A., & Handmer, J. (2011). The cost of disasters to Australia and Victoria – no straightforward

answers. In *VCCCAR Project: Framing Adaptation in the Victorian Context - Working paper 3* (Issue April).
This paper looks at the current cost of extreme meteorological disasters to Australia and Victoria in an effort to provide a starting point for appreciating the types of costs that may be present and increasing under climate change. There exists a confounding variety and breadth of estimates relating to the cost of weather related disasters in Victoria and Australia. Comparative analysis shows that data source and methodology have profound impacts on the conclusions drawn from both aggregate analyses of disaster costs and analyses of individual events, in this case the 1983 Ash Wednesday bushfires. Disaster cost estimates in Australia are largely drawn from insurance data or insurance data with some augmentation; the estimates that utilise insurance data are a limited proxy for disaster cost. Insurance data only account for insured losses, and these represent only a fraction of the total cost of a disaster. In particular they do not include many indirect costs, valuations for loss of life, nor intangibles such as ecosystem services which can have significant impacts on cost estimates. Analyses based on insurance data also draw conclusions influenced by which hazards and assets are or are not insured.

Kelman, I., Ahmed, B., Esraz-Ul-Zannat, M., Saroar, M. M., Fordham, M., & Shamsudduha, M. (2018). Warning systems as social processes for Bangladesh cyclones. *Disaster Prevention and Management: An International Journal*, *27*(4), 370–379. https://doi.org/10.1108/DPM-12-2017-0318
Purpose: The purpose of this paper is to connect the theoretical idea of warning systems as social processes with empirical data of people's perceptions of and actions for warning for cyclones in Bangladesh. Design/methodology/approach: A case study approach is used in two villages of Khulna district in southwest Bangladesh: Kalabogi and Kamarkhola. In total, 60 households in each village were surveyed with structured questionnaires regarding how they receive their cyclone warning information as well as their experiences of warnings for Cyclone Sidr in 2007 and Cyclone Aila in 2009. Findings: People in the two villages had a high rate of receiving cyclone warnings and accepted them as being credible. They also experienced high impacts from the cyclones. Yet evacuation rates to cyclone shelters were low. They did not believe that significant cyclone damage would affect them and they also highlighted the difficulty of getting to cyclone shelters due to poor roads, leading them to prefer other evacuation options which were implemented if needed. Originality/value: Theoretical constructs of warning systems, such as the First Mile and late warning, are rarely examined empirically according to people's perceptions of warnings. The case study villages have not before been researched with respect to warning systems. The findings provide empirical evidence for long-established principles of warning systems as social processes, usually involving but not relying on technical components.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that

formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., Adkins, J. E., & Jeffrey K. Lazo, Heather R. Hosterman, Jennifer M. Sprague-Hilderbrand, and J. E. A. (2020). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1
As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk

communication, expanding it into a comprehensive relational model of environmental cognition.

Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., SM, H., Jeanneret, T., & Nelson, R. (2016). *Adaptive value chain approaches. Understanding adaptation in food value chains* (Issue June).

The impacts of climate change are felt along the whole chain of actors that produce, handle, process and market agri-food products. This project aims to help agri-food companies to systematically identify, assess, prioritise and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach. A holistic and systematic evaluation of the risks that climate change poses, both direct and indirect, is crucial for adaptation planning. Understanding the complexity of interactions between biophysical, social and economic drivers in the context of climate change enables businesses within a value chain to have line of sight of indirect, but impactful, effects. It also enables businesses, from farming all the way to retailing, to begin to understand their 'tipping points'' better – where the impacts of multiple events along the value chain result to one or multiple stages of the chain unable to recover or remain competitive. There are three key outcomes from this study: 1. Our study has found that climate change, in itself, is not enough to encourage consumers to accept an adapted product, because there is a lack of understanding of how climate change can impact day-to-day life in general. At present, adaptation for agri-food businesses serves as a risk mitigation strategy, rather than a marketing opportunity. This however, may prove to be a competitive advantage for those who are in touch with consumer sentiment on adaptation, as sentiments may change in the future. 2. Value chain adaptation needs to consider the impact of any action on the value created and received by the chain. Our study has found that approaching value chain adaptation using a future storylines approach allows agri-food businesses to consider not only the adaptation benefits of a strategy, but also benefits to GHG mitigation and competitiveness. The process we have developed here enables business to gauge the merits of an adaptation action against multiple, and potentially competing, priorities. 3. Based on the findings of this study, an adapted value chain is one that is able to sustain its competitive advantage in a changing climate. A non-adapted value chain can only continue to exist up to a certain point where climate and weather risk and threats, both direct and indirect, are insurmountable and hence the value chain can no longer be profitable on an ongoing basis. Non- adapted value chains also miss opportu…'

Lin, H.-I., Liou, J.-L., & Hsu, S.-H. (2019). Economic Valuation of Public Meteorological Information Services—A Case Study of Agricultural Producers in Taiwan. *Atmosphere*, *10*(12), 753. https://doi.org/10.3390/atmos10120753

Most meteorological information services in Taiwan are currently provided by the Central Weather Bureau, Ministry of Transportation and Communications. As agricultural production activities are sensitive to weather and climate conditions, meteorological information services are more important for agricultural decision-makers than those in other sectors. This study uses the contingent valuation method to estimate the economic value of meteorological information services in Taiwan for agricultural producers. We assess the agricultural producers' willingness to pay (WTP) for the meteorological information services, conducting a national face-to-face survey of 400 registered farmers in 20 municipalities in Taiwan in 2013. The results show the adjusted WTP for every agricultural household each year with a 95% confidence interval which ranges from 56.06 US dollars to 90.92 US dollars. The inferred annual economic value of meteorological information services for agricultural producers in Taiwan is between 28.06 million US dollars and 45.51 million US dollars. Moreover, the agricultural producers' subjective assessment of weather forecast accuracy, farm size, and first bid price significantly affect the amount agricultural producers are willing to pay for meteorological information services.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Middelmann, M. H. (2007). *Natural hazards in Australia : identifying risk analysis requirements*. Australian Government/Geoscience Australia/Department of Transport and Regional Services/Bureau of Meteorology/CSIRO. https://d28rz98at9flks.cloudfront.net/65444/65444.pdf

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, *10*(1), 65–70. https://doi.org/10.5194/asr-10-65-2013
Abstract. There is a rising interest around the world for a better understanding of the economic

and social value added of weather services. National hydro-meteorological services and international cooperative bodies in meteorology have ever more to justify their use of public budgets. Furthermore, the development of hydrological and meteorological services is to a large extent steered by expectations regarding the eventual benefits of the envisaged new developments. This article provides a compact overview of the impediments for uptake of socio-economic benefit (SEB) studies, methods and results of SEB studies to date. It also discusses some pitfalls and crucial steps to enhance a broader uptake of SEB studies.

Pilli-Sihvola, K., Nurmi, V., Perrels, A., Harjanne, A., Bösch, P., & Ciari, F. (2016). Innovations in weather services as a crucial building block for climate change adaptation in road transport. *European Journal of Transport and Infrastructure Research*, *16*(1), 150–173. https://doi.org/10.18757/ejtir.2016.16.1.3119
The road transport sector is facing rising uncertainties in planning and operations due to climate change induced changes in weather variability and extreme events. However, because of the high level of uncertainty related to the future climate, adaptation measures should be robust so as to retain the option value of the portfolio of measures. As an example of such a measure, this paper evaluates how foreseen innovations in weather services could reduce weather sensitivity and, consequently reduce the negative effects of climate change in the sector. The study is based on a theoretical framework on climate change adaptation and valuation of weather and climate services using the Weather Service Chain Analysis. We apply these frameworks to the road transport sector with a special emphasis on drivers' decision making before and during a trip. We show that improved weather information, including more accurate weather forecasts, new applications and information dissemination channels can decrease the vulnerability of the mode to projected shifts in extreme weather patterns due to climate change.

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

Strahlendorff, M., Veijola, K., Gallo, J., Vitale, V., Savela, H., & Smirnov, A. (2019). *Value tree for physical atmosphere and ocean observations in the Arctic*. http://hdl.handle.net/10138/300768
This report describes the first instance to employ the international assessment framework for arctic observations developed by SAON and IDA STPI in 2017. Earth Observation (EO) inputs like SYNOP station measurements of physical atmosphere and in other stations ocean variables were linked to key products/outcomes/services like numerical weather prediction and through groups like in this case weather service connected to key objectives of the assessment framework. Representative yearly unit costs of EO inputs and modelling components were estimated by station experts or estimated based on European Union projects or Copernicus program tenders. The WMO OSCAR database for satellite and surface observation systems north of 60°N was used for numbers of the different station and mission categories in the Arctic. The total yearly value of this observation system including EO inputs and modeling is over 204 million €. Compared to the observing system estimated costs in the area 30°N to 60°N this is only about a fifth. The value tree can now follow and combine the value invested in these components as it flows towards services. The key objectives have been connected by SAON/AMAP project members in a workshop to the services to build the first full value tree for a certain kind of observations. These observations are mainly produced by national meteorological and marine institutes in an operational mode. The yearly value invested in the observation can now be distributed between the 12 Societal Benefit Areas and their sub areas identified in the assessment framework. The value tree is presented at a web page by FMI and Spatineo (2019) with a browser that can highlight single components to analyze which inputs and which SBA targets its being used for. This can help to more holistically

support the whole observation system for optimal impact on societal benefit. The value tree tool will be available for further work to address the many more EO domains like atmospheric composition or biodiversity. All in all this report can hopefully start a continuous action to update and improve the value tree. EO inputs are not static, the network changes, the costs are fluctuating and as the Arctic is becoming more accessible, it would be important to extend the observation system accordingly. https://space.fmi.fi/2019/04/15/value-of-arctic-observations-estimated-in-new-report/

Tall, A., Coulibaly, J. Y., & Diop, M. (2018). Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. In *Climate Services* (Vol. 11, pp. 1–12). Elsevier B.V. https://doi.org/10.1016/j.cliser.2018.06.001
This paper addresses the need for more rigorous evaluation of climate service projects and investments given the existence of little evidence on the actual value of climate services and the challenges that hamper current efforts to evaluate the impact of climate services for the agricultural community. Based on our in-depth review of existing literature from Africa and around the world, we find that rigorous methods for evaluating climate services span qualitative context-based and quantitative methodological approaches. The few studies that have been conducted so far to determine the value of climate services for farmers were for initiatives that incorporated in their design an evaluation framework. This highlights the importance of experimentally designing climate service programs for evaluation based on an impact pathway, rather than leaving evaluation as an after-thought. To strengthen the evidence base on the actual value of climate information services, complementary evaluation efforts will need to draw on a combination of qualitative and quantitative approaches, be sensitive to the heterogeneity of user groups, and go beyond the focus on agricultural production to include other dimensions of the agricultural system.

Tesfaye, A., Hansen Girma, J. W., Kassie, T., & Radeny, M. (n.d.). *Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach*. www.ccafs.cgiar.org

Thieken, A. H., Bubeck, P., Heidenreich, A., Keyserlingk, J. Von, Dillenardt, L., & Otto, A. (2022). *Performance of the flood warning system in Germany in July 2021 – insights from affected residents*. *June 2016*, 1–26.
In July 2021 intense rainfall caused devastating floods in Western Europe and 184 fatalities in the German federal states of North Rhine-Westphalia (NW) and Rhineland-Palatinate (RP) questioning their flood forecasting, warning and response system (FFWRS). Data from an online survey (n = 1315) reveal that 35% of the respondents from NW and 29% from RP did not receive any warning. Of those who were warned 85% did not expect a very severe flooding and 46% did not know what to do. Regression analysis reveals that this knowledge is influenced by gender and flood experience, but also by the contents and the source of the warning message. The results are complemented by analyses of media reports and official warnings that show shortcomings in providing adequate recommendations to people at risk. Dissemination of warnings communication of the expected flood magnitude and adequate responses are seen as entry points for improving the FFWRS in Germany.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Vogel, J., Letson, D., & Herrick, C. (2017). A framework for climate services evaluation and its application to the Caribbean Agrometeorological Initiative. *Climate Services*, *6*(July), 65–76. https://doi.org/10.1016/j.cliser.2017.07.003
Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the numerous and diverse investments international donor organizations, national governments, and regional institutions are making in climate services. This paper describes an elaborated logic model to structure the evaluation of a climate services program, which we demonstrate in a case study of the Caribbean Agrometeorological Initiative (CAMI). Moving beyond the "loading dock" model of scientific information application, this logic model helps evaluators to address all elements of the provision of climate services – including the quality of weather and climate forecasts and agronomic advisories, the distribution of that information, the uptake of that information, and actions taken by farmers (See Fig. 1). Our logic model links the provision of information on weather, climate, and agriculture with decision making, and ultimately with improved social and economic outcomes. While such a logic model necessarily simplifies the full context of any climate services program, it also makes project evaluation much more tractable and generalizable across contexts. Furthermore, this simple logic model can serve to deconstruct conventional thinking about climate services by explicitly addressing the social and process dimensions of climate services that are sometimes neglected in project design, implementation, and evaluation. CAMI partner countries are developing climate outlook bulletins to communicate a three-month seasonal forecast. Despite these high quality seasonal forecasts, we note shortcomings regarding the dissemination of that information, its uptake by farmers, or the ability or willingness of farmers to act on that information.

Wood, D. (2021). Australia's top five most expensive natural disasters revealed. *Insurance Business Magazine*, October 19, 2021. https://www.insurancebusinessmag.com/au/news/natural-catastrophe/australias-top-five-most-expensive-natural-disasters-revealed-313539.aspx
Insurance Business has put together a list of the top five most expensive natural disasters in Australia's recent history. Sydney's hailstorms in 1999 come in first place with the total losses from claims in today's dollar value amounting to $5.8 billion. The list represents the costliest catastrophes in terms of insurance claims from 1970 until the present day: Hailstorms, 1999, Sydney. Claims costs today about $5.8 billion and total financial costs possibly much more. Black Summer, 2019/20 NSW, VIC, SA and QLD. Claims costs about $5.5 billion versus total financial costs of about $10 billion . Tropical Cyclone Tracy, 1974, Darwin. Claims costs today about $5.3 billion versus total financial costs of about $7 billion. Earthquake, 1989, Newcastle. Claims costs today about $4.4 billion versus total financial costs of about $8.7 billion Floods, 1974, Brisbane. Claims costs today about $3.3 billion versus total financial costs of about $8.2 billion.

World Bank. (2022). *Strengthening Hydromet and Early Warning Systems and Services in Tunisia A roadmap*.
This roadmap uses a series of progress models to measure Tunisia's Meteorological and Hydrological Service Providers' capacities in several key areas: service delivery, observation and telecommunication, and modeling and forecasting. Tunisia is highly vulnerable to natural hazards. Hydrometeorological (Hydromet) hazards, such as various types of floods, droughts, heat extremes and heatwaves, and sea level rise pose a direct threat to lives; impact livelihoods; and retard development. Underlying processes, including climate change, population growth, land use changes, and urbanization, mean that growing numbers of Tunisians face hydrometeorological hazards, especially in coastal areas. National Meteorological and Hydrological Services (NMHSs) provide Hydromet and early warning services and tailor them to different users. Given current and predicted Hydromet-related hazards, and as in other countries of the Middle East and North Africa

(MENA) region, Tunisia needs Hydromet information to protect people, economies, and development gains. To contain growing economic losses from hydrometeorological hazards, adapt to climate change, and guide economic development across different sectors, Tunisia needs to invest in its multi-hazard early warning systems, and hydromet services.

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Amegnaglo, C. J., Anaman, K. A., Mensah-Bonsu, A., Onumah, E. E., & Amoussouga Gero, F. (2017). Contingent valuation study of the benefits of seasonal climate forecasts for maize farmers in the Republic of Benin, West Africa. *Climate Services*, *6*, 1–11. https://doi.org/10.1016/j.cliser.2017.06.007
This study aims to assess the economic benefits of seasonal climate forecasts in West Africa based on a random survey of 354 maize farmers and to use the contingent valuation method. Results indicate that farmers need accurate seasonal climate forecasts between 1 and 2 months before the onset of rains. The most desirable dissemination channels are radio, local elders, local farmer meetings and extension agents. The most likely used farming strategies are change of: planting date, crop acreage, crop variety, and production intensification. The vast majority of farmers are willing to pay for seasonal climate forecasts, and the average annual economic value of seasonal climate forecasts are about USD 5492 for the 354 sampled farmers and USD 66.5 million dollar at the national level. Furthermore, benefits of seasonal climate forecasts are likely to increase with better access to farmer based organisation, to extension services, to financial services, to modern communication tools, intensity of use of fertilizer and with larger farm sizes. Seasonal climate forecasts are a source of improvement of farmers' performance and the service should be integrated in extension programmes and in national agricultural development agenda.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Carabine, E., & Simonet, C. (2018). *Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors.* 76 pp. https://www.odi.org/sites/odi.org.uk/files/resource-documents/12286.pdf%0Ahttps://www.cabdirect.org/cabdirect/abstract/20183299617
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Cawood, M., Keys, C., & Wright, C. (2018). The total flood warning system: What have we learnt since 1990 and where are the gaps. *Australian Journal of Emergency Management*, *33*(2), 47–52.
April 1990 was a month of severe flooding in eastern Australia. Two months later, a national workshop was held in which a large number of flood management specialists sought to capture the lessons of the floods while they were still fresh. Many aspects of the management of the events were examined, with flood warning highlighted as a key function. A second meeting the following year resolved to produce a best-practice manual to help guide practitioners in the development of flood warning services. The term “Total Flood Warning System” (TFWS) was adopted to describe the need to integrate the many elements of effective warning. The need to help those in the path of a flood to understand the warnings they received and take effective action was recognised as central. The manual was published in 1995 and revised and updated in 1999 and 2009. This paper asks what has changed and improved in the flood warning field since 1990 and what is needed in TFWS terms to further help communities and individuals manage their flood risk.

Everingham, Y. L., Muchow, R. C., Stone, R. C., Inman-Bamber, N. G., Singels, A., & Bezuidenhout, C. N.

(2002). Enhanced risk management and decision-making capability across the sugarcane industry value chain based on seasonal climate forecasts. *Agricultural Systems*, *74*(3), 459–477. https://doi.org/10.1016/S0308-521X(02)00050-1
Sugarcane industries worldwide are exposed to uncertainty associated with variable climate. This variability produces impacts across an integrated value chain comprising of the following industry sectors: cane growing, harvesting and transport, milling, and marketing. The purpose of this paper is to advocate a comprehensive systems approach for using seasonal climate forecast systems to improve risk management and decision-making capability across all sugarcane industry sectors. The application of this approach is outlined for decisions relating to yield forecasting, harvest management, and the use of irrigation. Key lessons learnt from this approach include the need for a participative R&D approach with stakeholders and the need to consider the whole industry value chain. Additionally, there is the need for climate forecast systems to target the varying needs of sugarcane industries. © 2002 Elsevier Science Ltd. All rights reserved.

Fakhruddin, B. S. H. M. H. M., & Schick, L. (2019). Benefits of economic assessment of cyclone early warning systems - A case study on Cyclone Evan in Samoa. *Progress in Disaster Science*, *2*(2019), 100034. https://doi.org/10.1016/j.pdisas.2019.100034
Samoa is extremely exposed to natural hazards, particularly tropical cyclones and earthquake-generated tsunami. Some studies have put forth the position that adequate investment in early warning systems can contribute to the social and economic well-being of countries. However, in spite of these research findings there is still a lack of understanding on how to measure effectiveness that leads to limited investment. Cost-benefit analysis (CBA) is a tool used in this study to summarize the value for money in terms of investment to enhance an early warning system. This paper aims to summarize the benefits of adopting early warning systems and its effectiveness against the investment required and its value proposition. Data from the 'Samoa Post-Disaster Needs Assessment of the Cyclone Evan event in 2012' have been used to assess damage information, and stakeholders consultations and interviews were carried out for cost-benefit analysis. We have conducted quantified CBA of early warning services for cyclone hazards and the results have shown that for every USD 1 invested, there is a return of USD 6 as benefit. This paper suggests that economic assessment of early warning services could help in quantifying pre-impact assessment to demonstrate to policy makers the economic benefit of disaster risk reduction (DRR).

Fekete, A. (2019). Critical infrastructure and flood resilience: Cascading effects beyond water. *WIREs Water*, *6*(5), 1–13. https://doi.org/10.1002/wat2.1370
Abstract Critical infrastructure and cascading effects are analyzed in this article as cross-cutting topics in flood risk and resilience. A concept is developed for integrating aspects of disaster risk, hazard, vulnerability and resilience with critical infrastructure analytic components such as redundancy, rapidity or resourcefulness. These components are expressed for each phase of an unfolding flood event and cascading effects are indicated, too. This contribution discusses the implications of such a conceptual frame for the advancement of existing flood risk management concepts. Current international guiding strategies such as the United Nations Sendai Framework for Disaster Risk Reduction, the "Making Cities Resilient" campaigns in field of urban disaster resilience, Climate Change Adaptation processes such as the Paris Agreement of the IPCC process, or urban planning in the field of UN HABITAT are all interconnected to the topic of (critical) infrastructure. The article shows how flood risk management can connect to such wider international developments by the conceptual frame discussion presented. This article is categorized under: Engineering Water > Planning Water Science of Water > Water Extremes Human Water > Water Governance

Garcia, C., & Fearnley, C. J. (2012). Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, *11*(2), 123–137. https://doi.org/10.1080/17477891.2011.609877
Early warning systems (EWSs) are extensive systems that integrate different components of disaster risk reduction for the provision of timely warnings to minimize loss of life and to reduce economic and social impact on vulnerable populations. Historically, empirical research has focused on the individual components or sub-systems of EWSs, such as hazard monitoring, risk assessment, forecasting tools and warning dissemination. However, analyses of natural hazard disasters indicate that, in most cases, the processes that link individual components of EWS fail, rather than the components themselves. This paper reviews several case studies conducted over the last 40 years to present common emerging factors that improve links between the different components of EWSs. The identified factors include: (1) establishing effective communication networks to integrate scientific research into practice; (2) developing effective decision-making processes that incorporate local contexts by defining accountability and responsibility; (3) acknowledging the importance of risk perception and trust for an effective reaction; and (4) consideration of the differences among technocratic and participatory approaches in EWSs when applied in diverse contexts. These factors show the importance of flexibility and the consideration of local context in making EWSs effective, whereas increasing levels of standardization within EWSs nationally and globally might challenge the ability to incorporate the required local expertise and circumstances.

Haupt, S. E., Kosović, B., Jensen, T., Lazo, J. K., Lee, J. A., Jiménez, P. A., Cowie, J., Wiener, G., Mccandless, T. C., Rogers, M., Miller, S., Sengupta, M., Xie, Y., HinKeLman, L., KaLb, P., & Heiser, J. H. (2018). Building the SUN4CAST system. *Bulletin of the American Meteorological Society*, *99*(1), 121–135. https://doi.org/10.1175/BAMS-D-16-0221.1
The Sun4Cast System results from a research-to-operations project built on a value chain approach, benefiting electric utilities' customers, society, and the environment by improving state-of-the-science solar power forecasting capabilities.

Horita, F. E. A., de Albuquerque, J. P., & Marchezini, V. (2018). Understanding the decision-making process in disaster risk monitoring and early-warning: A case study within a control room in Brazil. *International Journal of Disaster Risk Reduction*, *28*(September 2017), 22–31. https://doi.org/10.1016/j.ijdrr.2018.01.034
The tasks of disaster risk monitoring and early warning are an important means of improving the efficiency of disaster response and preparedness. However, although the current works in this area have sought to provide a more accurate and better technological infrastructure of systems to support these tasks, they have failed to examine key features that may affect the decision-making. In light of this, this paper aims to provide an understanding of the decision-making process in control rooms for disaster risk monitoring and early warning. This understanding is underpinned by a conceptual framework, which has been developed in this work and describes factors that influence the decision-making. For doing so, data were collected through a series of semi-structured interviews and participatory observations and later evaluated with members of the control room of the Brazilian Center for Monitoring and Early Warning of Natural Disasters (Cemaden). The study findings provided a solid basis for designing the conceptual framework of the essential factors required by the decision-makers. These factors are separated into two groups: 1) the "dimensions" of decision-making (i.e., the type of hazard, the phase of the disaster risk, the location, and area of expertise of the operators) and the "pillars" of decision-making (i.e., the tasks, their required information, useful data sources, and the decision rule). Finally, the contributions achieved in this study may help operators to understand and propose proactive measures that could improve their decision-making, overcome uncertainties, standardize the team's decision-making, and put less pressure on operators.

Hosterman, H. R., Lazo, J. K., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2019). Using the National Weather Service's impact-based decision support services to prepare for extreme winter storms. *Journal of Emergency Management (Weston, Mass.)*, *17*(6), 455–467. https://doi.org/10.5055/jem.2019.0439

In recent years, the National Weather Service (NWS) increased its focus on providing decision support services to the emergency management community and other core partners to help them understand its forecasts and take appropriate actions in the face of upcoming extreme events. In 2011, the Weather-Ready Nation Strategic Plan began to formalize the NWS approach to impact-based decision support services (IDSS). NWS recognizes IDSS as a primary service and is working to fully and more effectively provide it to federal, state, local, and tribal decision-makers. To do so, it is important that NWS understands how users are benefiting from existing IDSS, even as they look to improve it. This article aims to provide emergency managers (EMs) with an understanding of the efficacy of IDSS. The authors define IDSS and describe the IDSS products and services available during each stage of the emergency-management cycle: preparedness, mitigation, response, and recovery. To demonstrate the role of IDSS for the emergency management community, the authors use a case study analysis to compare two winter storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 winter storm (no formal IDSS) and the January 2016 winter storm (formal IDSS). In comparing the winter storm case studies, the authors find that formal IDSS provides EMs and other core partners with accurate, actionable, and consistent weather information and support that allows them to respond to winter storms in a way that reduces impacts to lives and livelihoods.

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).

This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Keating, A., & Handmer, J. (2011). The cost of disasters to Australia and Victoria – no straightforward answers. In *VCCCAR Project: Framing Adaptation in the Victorian Context - Working paper 3* (Issue April).

This paper looks at the current cost of extreme meteorological disasters to Australia and Victoria in an effort to provide a starting point for appreciating the types of costs that may be present and increasing under climate change. There exists a confounding variety and breadth of estimates relating to the cost of weather related disasters in Victoria and Australia. Comparative analysis shows that data source and methodology have profound impacts on the conclusions drawn from both aggregate analyses of disaster costs and analyses of individual events, in this case the 1983 Ash Wednesday bushfires. Disaster cost estimates in Australia are largely drawn from insurance data or insurance data with some augmentation; the estimates that utilise insurance data are a limited proxy for disaster cost. Insurance data only account for insured losses, and these represent only a fraction of the total cost of a disaster. In particular they do not include many indirect costs, valuations for loss of life, nor intangibles such as ecosystem services which can have significant impacts on cost estimates. Analyses based on insurance data also draw conclusions influenced by which hazards and assets are or are not insured.

Kelman, I., Ahmed, B., Esraz-Ul-Zannat, M., Saroar, M. M., Fordham, M., & Shamsudduha, M. (2018). Warning systems as social processes for Bangladesh cyclones. *Disaster Prevention and Management: An International Journal*, *27*(4), 370–379. https://doi.org/10.1108/DPM-12-2017-0318

Purpose: The purpose of this paper is to connect the theoretical idea of warning systems as social

processes with empirical data of people's perceptions of and actions for warning for cyclones in Bangladesh. Design/methodology/approach: A case study approach is used in two villages of Khulna district in southwest Bangladesh: Kalabogi and Kamarkhola. In total, 60 households in each village were surveyed with structured questionnaires regarding how they receive their cyclone warning information as well as their experiences of warnings for Cyclone Sidr in 2007 and Cyclone Aila in 2009. Findings: People in the two villages had a high rate of receiving cyclone warnings and accepted them as being credible. They also experienced high impacts from the cyclones. Yet evacuation rates to cyclone shelters were low. They did not believe that significant cyclone damage would affect them and they also highlighted the difficulty of getting to cyclone shelters due to poor roads, leading them to prefer other evacuation options which were implemented if needed. Originality/value: Theoretical constructs of warning systems, such as the First Mile and late warning, are rarely examined empirically according to people's perceptions of warnings. The case study villages have not before been researched with respect to warning systems. The findings provide empirical evidence for long-established principles of warning systems as social processes, usually involving but not relying on technical components.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., Adkins, J. E., & Jeffrey K. Lazo, Heather R. Hosterman, Jennifer M. Sprague-Hilderbrand, and J. E. A. (2020). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are

more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1

As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., SM, H., Jeanneret, T., & Nelson, R. (2016). *Adaptive value chain approaches. Understanding adaptation in food value chains* (Issue June).

The impacts of climate change are felt along the whole chain of actors that produce, handle, process and market agri-food products. This project aims to help agri-food companies to systematically identify, assess, prioritise and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach. A holistic and systematic evaluation of the risks that climate change poses, both direct and indirect, is crucial for adaptation planning. Understanding the complexity of interactions between biophysical, social and economic drivers in the context of climate change enables businesses within a value chain to have line of sight of indirect, but impactful, effects. It also enables businesses, from farming all the way to retailing, to begin to understand their 'tipping points'' better – where the impacts of multiple events along the value chain result to one or multiple stages of the chain unable to recover or remain competitive. There are three key outcomes from this study: 1. Our study has found that climate change, in itself, is not enough to encourage consumers to accept an adapted product, because there is a lack of understanding of how climate change can impact day-to-day life in general. At present, adaptation for agri-food businesses serves as a risk mitigation strategy, rather than a marketing opportunity. This however, may prove to be a competitive advantage for those who are in touch with consumer sentiment on adaptation, as sentiments may

change in the future. 2. Value chain adaptation needs to consider the impact of any action on the value created and received by the chain. Our study has found that approaching value chain adaptation using a future storylines approach allows agri-food businesses to consider not only the adaptation benefits of a strategy, but also benefits to GHG mitigation and competitiveness. The process we have developed here enables business to gauge the merits of an adaptation action against multiple, and potentially competing, priorities. 3. Based on the findings of this study, an adapted value chain is one that is able to sustain its competitive advantage in a changing climate. A non-adapted value chain can only continue to exist up to a certain point where climate and weather risk and threats, both direct and indirect, are insurmountable and hence the value chain can no longer be profitable on an ongoing basis. Non- adapted value chains also miss opportu…'

Lin, H.-I., Liou, J.-L., & Hsu, S.-H. (2019). Economic Valuation of Public Meteorological Information Services—A Case Study of Agricultural Producers in Taiwan. *Atmosphere*, *10*(12), 753. https://doi.org/10.3390/atmos10120753
Most meteorological information services in Taiwan are currently provided by the Central Weather Bureau, Ministry of Transportation and Communications. As agricultural production activities are sensitive to weather and climate conditions, meteorological information services are more important for agricultural decision-makers than those in other sectors. This study uses the contingent valuation method to estimate the economic value of meteorological information services in Taiwan for agricultural producers. We assess the agricultural producers' willingness to pay (WTP) for the meteorological information services, conducting a national face-to-face survey of 400 registered farmers in 20 municipalities in Taiwan in 2013. The results show the adjusted WTP for every agricultural household each year with a 95% confidence interval which ranges from 56.06 US dollars to 90.92 US dollars. The inferred annual economic value of meteorological information services for agricultural producers in Taiwan is between 28.06 million US dollars and 45.51 million US dollars. Moreover, the agricultural producers' subjective assessment of weather forecast accuracy, farm size, and first bid price significantly affect the amount agricultural producers are willing to pay for meteorological information services.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Middelmann, M. H. (2007). *Natural hazards in Australia : identifying risk analysis requirements*. Australian Government/Geoscience Australia/Department of Transport and Regional

Services/Bureau of Meteorology/CSIRO. https://d28rz98at9flks.cloudfront.net/65444/65444.pdf

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, *10*(1), 65–70. https://doi.org/10.5194/asr-10-65-2013
Abstract. There is a rising interest around the world for a better understanding of the economic and social value added of weather services. National hydro-meteorological services and international cooperative bodies in meteorology have ever more to justify their use of public budgets. Furthermore, the development of hydrological and meteorological services is to a large extent steered by expectations regarding the eventual benefits of the envisaged new developments. This article provides a compact overview of the impediments for uptake of socio-economic benefit (SEB) studies, methods and results of SEB studies to date. It also discusses some pitfalls and crucial steps to enhance a broader uptake of SEB studies.

Pilli-Sihvola, K., Nurmi, V., Perrels, A., Harjanne, A., Bösch, P., & Ciari, F. (2016). Innovations in weather services as a crucial building block for climate change adaptation in road transport. *European Journal of Transport and Infrastructure Research*, *16*(1), 150–173. https://doi.org/10.18757/ejtir.2016.16.1.3119
The road transport sector is facing rising uncertainties in planning and operations due to climate change induced changes in weather variability and extreme events. However, because of the high level of uncertainty related to the future climate, adaptation measures should be robust so as to retain the option value of the portfolio of measures. As an example of such a measure, this paper evaluates how foreseen innovations in weather services could reduce weather sensitivity and, consequently reduce the negative effects of climate change in the sector. The study is based on a theoretical framework on climate change adaptation and valuation of weather and climate services using the Weather Service Chain Analysis. We apply these frameworks to the road transport sector with a special emphasis on drivers' decision making before and during a trip. We show that

improved weather information, including more accurate weather forecasts, new applications and information dissemination channels can decrease the vulnerability of the mode to projected shifts in extreme weather patterns due to climate change.

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

Strahlendorff, M., Veijola, K., Gallo, J., Vitale, V., Savela, H., & Smirnov, A. (2019). *Value tree for physical atmosphere and ocean observations in the Arctic*. http://hdl.handle.net/10138/300768
This report describes the first instance to employ the international assessment framework for arctic observations developed by SAON and IDA STPI in 2017. Earth Observation (EO) inputs like SYNOP station measurements of physical atmosphere and in other stations ocean variables were linked to key products/outcomes/services like numerical weather prediction and through groups like in this case weather service connected to key objectives of the assessment framework. Representative yearly unit costs of EO inputs and modelling components were estimated by station experts or estimated based on European Union projects or Copernicus program tenders. The WMO OSCAR database for satellite and surface observation systems north of 60°N was used for numbers of the different station and mission categories in the Arctic. The total yearly value of this observation system including EO inputs and modeling is over 204 million €. Compared to the observing system estimated costs in the area 30°N to 60°N this is only about a fifth. The value tree can now follow and combine the value invested in these components as it flows towards services. The key objectives have been connected by SAON/AMAP project members in a workshop to the services to build the first full value tree for a certain kind of observations. These observations are mainly produced by national meteorological and marine institutes in an operational mode. The yearly value invested in the observation can now be distributed between the 12 Societal Benefit Areas and their sub areas identified in the assessment framework. The value tree is presented at a web page by FMI and Spatineo (2019) with a browser that can highlight single components to analyze which inputs and which SBA targets its being used for. This can help to more holistically support the whole observation system for optimal impact on societal benefit. The value tree tool will be available for further work to address the many more EO domains like atmospheric composition or biodiversity. All in all this report can hopefully start a continuous action to update and improve the value tree. EO inputs are not static, the network changes, the costs are fluctuating and as the Arctic is becoming more accessible, it would be important to extend the observation system accordingly. https://space.fmi.fi/2019/04/15/value-of-arctic-observations-estimated-in-new-report/

Tall, A., Coulibaly, J. Y., & Diop, M. (2018). Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. In *Climate Services* (Vol. 11, pp. 1–12). Elsevier B.V. https://doi.org/10.1016/j.cliser.2018.06.001
This paper addresses the need for more rigorous evaluation of climate service projects and investments given the existence of little evidence on the actual value of climate services and the challenges that hamper current efforts to evaluate the impact of climate services for the agricultural community. Based on our in-depth review of existing literature from Africa and around the world, we find that rigorous methods for evaluating climate services span qualitative context-based and quantitative methodological approaches. The few studies that have been conducted so far to determine the value of climate services for farmers were for initiatives that incorporated in their design an evaluation framework. This highlights the importance of experimentally designing climate service programs for evaluation based on an impact pathway, rather than leaving

evaluation as an after-thought. To strengthen the evidence base on the actual value of climate information services, complementary evaluation efforts will need to draw on a combination of qualitative and quantitative approaches, be sensitive to the heterogeneity of user groups, and go beyond the focus on agricultural production to include other dimensions of the agricultural system.

Tesfaye, A., Hansen Girma, J. W., Kassie, T., & Radeny, M. (n.d.). *Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach*. www.ccafs.cgiar.org

Thieken, A. H., Bubeck, P., Heidenreich, A., Keyserlingk, J. Von, Dillenardt, L., & Otto, A. (2022). *Performance of the flood warning system in Germany in July 2021 – insights from affected residents*. *June 2016*, 1–26.
In July 2021 intense rainfall caused devastating floods in Western Europe and 184 fatalities in the German federal states of North Rhine-Westphalia (NW) and Rhineland-Palatinate (RP) questioning their flood forecasting, warning and response system (FFWRS). Data from an online survey (n = 1315) reveal that 35% of the respondents from NW and 29% from RP did not receive any warning. Of those who were warned 85% did not expect a very severe flooding and 46% did not know what to do. Regression analysis reveals that this knowledge is influenced by gender and flood experience, but also by the contents and the source of the warning message. The results are complemented by analyses of media reports and official warnings that show shortcomings in providing adequate recommendations to people at risk. Dissemination of warnings communication of the expected flood magnitude and adequate responses are seen as entry points for improving the FFWRS in Germany.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Vogel, J., Letson, D., & Herrick, C. (2017). A framework for climate services evaluation and its application to the Caribbean Agrometeorological Initiative. *Climate Services*, *6*(July), 65–76. https://doi.org/10.1016/j.cliser.2017.07.003
Novel approaches to project evaluations are needed to document the outcomes and lessons to be learned from the numerous and diverse investments international donor organizations, national governments, and regional institutions are making in climate services. This paper describes an elaborated logic model to structure the evaluation of a climate services program, which we demonstrate in a case study of the Caribbean Agrometeorological Initiative (CAMI). Moving beyond the "loading dock" model of scientific information application, this logic model helps evaluators to address all elements of the provision of climate services – including the quality of weather and climate forecasts and agronomic advisories, the distribution of that information, the uptake of that information, and actions taken by farmers (See Fig. 1). Our logic model links the provision of information on weather, climate, and agriculture with decision making, and ultimately with improved social and economic outcomes. While such a logic model necessarily simplifies the full context of any climate services program, it also makes project evaluation much more tractable and generalizable across contexts. Furthermore, this simple logic model can serve to deconstruct conventional thinking about climate services by explicitly addressing the social and process dimensions of climate services that are sometimes neglected in project design, implementation, and evaluation. CAMI partner countries are developing climate outlook bulletins to communicate a three-month seasonal forecast. Despite these high quality seasonal forecasts, we note shortcomings regarding the dissemination of that information, its uptake by farmers, or the ability

or willingness of farmers to act on that information.

Wood, D. (2021). Australia's top five most expensive natural disasters revealed. *Insurance Business Magazine*, October 19, 2021. https://www.insurancebusinessmag.com/au/news/natural-catastrophe/australias-top-five-most-expensive-natural-disasters-revealed-313539.aspx
Insurance Business has put together a list of the top five most expensive natural disasters in Australia's recent history. Sydney's hailstorms in 1999 come in first place with the total losses from claims in today's dollar value amounting to $5.8 billion. The list represents the costliest catastrophes in terms of insurance claims from 1970 until the present day: Hailstorms, 1999, Sydney. Claims costs today about $5.8 billion and total financial costs possibly much more. Black Summer, 2019/20 NSW, VIC, SA and QLD. Claims costs about $5.5 billion versus total financial costs of about $10 billion . Tropical Cyclone Tracy, 1974, Darwin. Claims costs today about $5.3 billion versus total financial costs of about $7 billion. Earthquake, 1989, Newcastle. Claims costs today about $4.4 billion versus total financial costs of about $8.7 billion Floods, 1974, Brisbane. Claims costs today about $3.3 billion versus total financial costs of about $8.2 billion.

World Bank. (2022). *Strengthening Hydromet and Early Warning Systems and Services in Tunisia A roadmap*.
This roadmap uses a series of progress models to measure Tunisia's Meteorological and Hydrological Service Providers' capacities in several key areas: service delivery, observation and telecommunication, and modeling and forecasting. Tunisia is highly vulnerable to natural hazards. Hydrometeorological (Hydromet) hazards, such as various types of floods, droughts, heat extremes and heatwaves, and sea level rise pose a direct threat to lives; impact livelihoods; and retard development. Underlying processes, including climate change, population growth, land use changes, and urbanization, mean that growing numbers of Tunisians face hydrometeorological hazards, especially in coastal areas. National Meteorological and Hydrological Services (NMHSs) provide Hydromet and early warning services and tailor them to different users. Given current and predicted Hydromet-related hazards, and as in other countries of the Middle East and North Africa (MENA) region, Tunisia needs Hydromet information to protect people, economies, and development gains. To contain growing economic losses from hydrometeorological hazards, adapt to climate change, and guide economic development across different sectors, Tunisia needs to invest in its multi-hazard early warning systems, and hydromet services.

Actors

Keywords: authorities and agencies, coordinating bodies, boundary organizations, decision making, decision, evacuation decision making, forecast users, forecaster decision making, gender, identifying key stakeholders, identifying user needs, hydromet services, human resources, interdisciplinary collaborations, key requirements, knowledge coproduction, local communities, national meteorological and hydrological services, NMHS, NMHSs, partnerships, public-private partnerships, stakeholder, stakeholders, tropical cyclone warning services, trust, user groups, users in product development, time requirements

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the

impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S., Sivle, A. D., Agersten, S., Schmid, F., & Simon, A. (2016). Use and perception of weather forecast information across Europe Journal: *Meteorological Applications*, *4*(434), 1–2. https://doi.org/10.1002/met.2053
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Arain, F. (2015). Knowledge-based Approach for Sustainable Disaster Management: Empowering Emergency Response Management Team. *Procedia Engineering*, *118*, 232–239. https://doi.org/10.1016/j.proeng.2015.08.422
Over the past two decades, the impact of disasters has been devastating, affecting 4.4 billion people, resulted in 1.3 million causalities and $2 trillion in economic losses. Post-disaster

reconstruction and rehabilitation is a complex process with several dimensions. Government, nongovernmental, and international organizations have their own stakes in disaster recovery programs, and links must be established among them as well as with the community. Concerning post-disaster reconstruction scenario, the most significant factor is prompt decision making based on best possible information available. Effective sustainable post-disaster response is crucial and lies at the heart of disaster management agencies in almost every cautious country around the globe. Development is a dynamic process and disasters provide the opportunities to vitalize and/or revitalize this process, especially to generate local economies, and to upgrade livelihood and living condition. The success of the reconstruction phases, i.e., rescue, relief, and rehabilitation, is mainly dependent on the availability of efficient project teams and timely information to make informed decision. By having the knowledge-based system to make well-informed decisions, combined with the efficiency of a project team and strong coordination, project success should increase. This paper presents a theoretical framework of a knowledge-based approach for enhancing prompt and effective sustainable disaster management. The conceptual model consists of two main IT based components of knowledge- based system, i.e., a knowledge-base and a decision support shell for making more informed decisions for effective, timely and sustainable response in post-disaster reconstruction scenarios. The system is expected to assist in improving reconstruction project processes, coordination, and team building process because the most likely areas on which to focus can be identified during the early stage of the post-disaster scenario. Tapping into the past experiences of post-disaster scenarios, the knowledge-based system provides a wealth of pertinent and useful information for decision makers and will eventually enhance collaborative ventures for sustainable disaster management. The system would be helpful for emergency response management teams to take proactive measures by learning from past similar experiences, making informed decisions related to team building and project coordination processes undertaken by disaster man…

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., Lazrus, H., & Hudson, R. (2016). A Mental Models Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making*. *Weather, Climate, and Society*, *8*(2), 111–129. https://doi.org/10.1175/WCAS-D-15-0033.1
The study reported here explores how to enhance the public value of hurricane forecast and warning information by examining the entire warning process. A mental models research approach is applied to address three risk management tasks critical to warnings for extreme weather events: 1) understanding the risk decision and action context for hurricane warnings, 2) understanding the commonalities and conflicts in interpretations of that context and associated risks, and 3) exploring the practical implications of these insights for hurricane risk communication and management. To understand the risk decision and action context, the study develops a decision-focused model of the hurricane forecast and warning system on the basis of results from individual mental models interviews with forecasters from the National Hurricane Center (n = 4) and the Miami–South Florida Weather Forecast Office (n = 4), media broadcasters (n = 5), and public officials (n = 6), as well as a group decision-modeling session with a subset of the forecasters. Comparisons across professionals reveal numerous shared perceptions, as well as some critical differences. Implications for improving extreme weather event forecast and warning systems and risk communication are threefold: 1) promote thinking about forecast and warning decisions as a system, with informal as well as formal elements; 2) evaluate, coordinate, and consider controlling the proliferation of forecast and warning information products; and 3) further examine the interpretation and representation of uncertainty within the hurricane forecast and warning system as well as for users.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System.

Natural Hazards Review, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Colavito, M. M., Trainor, S. F., Kettle, N. P., & York, A. (2019). Making the transition from science delivery to knowledge coproduction in boundary spanning: A case study of the Alaska fire science consortium. *Weather, Climate, and Society*, *11*(4), 917–934. https://doi.org/10.1175/WCAS-D-19-0009.1
Boundary organizations facilitate two-way, sustained interaction and communication between research and practitioner spheres, deliver existing science, and develop new, actionable scientific information to address emerging social–ecological questions applicable to decision-making. There is an increasing emphasis on the role of boundary organizations in facilitating knowledge coproduction, which is collaborative research with end users to develop actionable scientific information for decision-making. However, a deeper understanding of how boundary organizations and knowledge coproduction work in practice is needed. This paper examines the Alaska Fire Science Consortium (AFSC), a boundary organization focused on fire science and management in Alaska that is working to address climate impacts on wildfire. A case study approach was used to assess AFSC activities over time. AFSC's boundary spanning involves a continuum of outputs and activities, but their overall trajectory has involved a deliberate transition from an emphasis on science delivery to knowledge coproduction. Key factors that facilitated this transition included a receptive and engaged audience, built-in evaluation and learning, subject matter expertise and complementarity, and embeddedness in the target audience communities. Recommendations for boundary organizations wishing to develop knowledge coproduction capacity include knowing your audience, employing trusted experts in boundary spanning, and engaging in frequent self-evaluation to inform change over time.

Demuth, J. L., Morss, R. E., Morrow, B. H., & Lazo, J. K. (2012). Creation and communication of hurricane risk information. *Bulletin of the American Meteorological Society*, *93*(8), 1133–1145. https://doi.org/10.1175/BAMS-D-11-00150.1
Reducing loss of life and harm when a hurricane threatens depends on people receiving hurricane risk information that they can interpret and use in protective decisions. To understand and improve hurricane risk communication, this article examines how National Weather Service (NWS) forecasters at the National Hurricane Center and local weather forecast offices, local emergency managers, and local television and radio media create and convey hurricane risk information. Data from in-depth interviews and observational sessions with members of these groups from Greater Miami were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Together, these groups succeed in partnering with each other to make information about approaching hurricane threats widely available. Yet NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency

managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios. Thus, we recommend that warning system partners 1) build understanding of each other's needs and constraints; 2) ensure formalized, yet flexible mechanisms exist for exchanging critical information; 3) improve hurricane risk communication by integrating social science knowledge to design and test messages with intended audiences; and 4) evaluate, test, and improve the NWS hurricane-related product suite in collaboration with social scientists. ©2012 American Meteorological Society.

Grunert, K. G., Trondsen, T., & Young, J. A. (2010). Market orientation in the mental models of decision makers: Two cross-border value chains. *International Marketing Review*, *27*(1), 7–27. https://doi.org/10.1108/02651331011020384

Purpose – The purpose of this paper is to determine whether predictions about different degrees of market orientation in two cross-border value chains also appear in the mental models of decision makers at two levels of these value chains. Design/methodology/approach – The laddering method elicits mental models of actors in two value chains: Norwegian salmon exported to Japan and Danish pork exported to Japan. The analysis of the mental models centers on potential overlap and linkages between actors in the value chain, including elements in the mental models that may relate to the actors' market orientation. Findings – In both value chains, decision makers exhibit overlap in their views of what drives their business. The pork chain appears dominated by a focus on efficiency, technology, and quality control, though it also acknowledges communication as important. The salmon chain places more emphasis on new product development and good relations between chain partners. Research limitations/implications – While confirming prior results regarding the role of competitive pressure, end-user heterogeneity/dynamism, regulations, and trade associations, the results also generate new insights into the possible role of relational governance in promoting the market orientation of value chains. Originality/value – This paper offers three novel ideas: using the concept of mental models as a possible mediator between factors that influence the degree of market orientation and market-oriented activity; using a laddering method to elicit mental models; and considering concepts shared among actors in a value chain as possible indicators of the degree of market orientation. © 2010, Emerald Group Publishing Limited

Higgins, P. A. (2021). Societal Benefits in Weather, Water, and Climate: Understanding, Communication, and Enhancement. *An AMS Policy Program Study.*, *April*.

The study highlights the societal benefits that result from Earth system OSS and help identify unmet and emerging user needs in OSS. The studies will also provide a strong and overarching emphasis on public–private partnerships; most notably, the studies will help to refresh aspects of the 2003 Fair Weather report by the National Academies of Science, which has been foundational to the weather enterprise over the past two decades

Horita, F. E. A., de Albuquerque, J. P., & Marchezini, V. (2018). Understanding the decision-making process in disaster risk monitoring and early-warning: A case study within a control room in Brazil. *International Journal of Disaster Risk Reduction*, *28*(September 2017), 22–31. https://doi.org/10.1016/j.ijdrr.2018.01.034

The tasks of disaster risk monitoring and early warning are an important means of improving the efficiency of disaster response and preparedness. However, although the current works in this area have sought to provide a more accurate and better technological infrastructure of systems to support these tasks, they have failed to examine key features that may affect the decision-making. In light of this, this paper aims to provide an understanding of the decision-making process in control rooms for disaster risk monitoring and early warning. This understanding is underpinned by

a conceptual framework, which has been developed in this work and describes factors that influence the decision-making. For doing so, data were collected through a series of semi-structured interviews and participatory observations and later evaluated with members of the control room of the Brazilian Center for Monitoring and Early Warning of Natural Disasters (Cemaden). The study findings provided a solid basis for designing the conceptual framework of the essential factors required by the decision-makers. These factors are separated into two groups: 1) the "dimensions" of decision-making (i.e., the type of hazard, the phase of the disaster risk, the location, and area of expertise of the operators) and the "pillars" of decision-making (i.e., the tasks, their required information, useful data sources, and the decision rule). Finally, the contributions achieved in this study may help operators to understand and propose proactive measures that could improve their decision-making, overcome uncertainties, standardize the team's decision-making, and put less pressure on operators.

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).
This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Jayawardene, V., Huggins, T. J., Prasanna, R., & Fakhruddin, B. (2021). The role of data and information quality during disaster response decision-making. *Progress in Disaster Science*, *12*, 100202. https://doi.org/10.1016/j.pdisas.2021.100202
Massive amounts of data and information are exchanged during the response phase of disaster management. A large body of contemporary research has indicated that most of these data and information have severe quality related concerns, meaning that they may not be suitable for critical decision-making. The current paper addresses these issues by identifying how certain features of data and information quality function, to support specific, naturalistic decision-making processes during disaster response. These functions are used to revise and consolidate pre-existing definitions of data and information quality, for use in further disaster response research.

Jeuring, J., Knol-Kauffman, M., & Sivle, A. (2020). Toward valuable weather and sea-ice services for the marine Arctic: exploring user–producer interfaces of the Norwegian Meteorological Institute. *Polar Geography*, *43*(2–3), 139–159. https://doi.org/10.1080/1088937X.2019.1679270
Recognition is growing that valuable weather, water, ice and climate (WWIC) services for marine, Arctic environments can only be produced in close dialogue with its actual users. This denotes an acknowledgement that knowing how users incorporate WWIC information in their activities should be considered throughout the information value chain. Notions like co-production and user engagement are current terms to grapple with user needs, but little is known about how such concepts are operationalized in the practical context of tasks and responsibilities of National Meteorological and Hydrometeorological Services (NMHS). Based on a series of in-depth, qualitative interviews with a diversity of personnel from the Norwegian Meteorological Institute, we describe the shifting dynamics of interactions between WWIC information providers and maritime stakeholders operating in Arctic environments. Three key challenges are discussed, pertaining to both day-to-day and strategic interactions: (1) the importance of knowing how information is used, (2) the increasing automation of meteorological practices and the growing need for user observations, and (3) the need for bridging research-to-operations gaps. We embed these findings in a discussion on how user–producer interfaces are shaped and transforming through an ongoing negotiation of expertise, changing the roles and responsibilities within particular constellations of co-producing WWIC information services.

Kaltenberger, R., Schaffhauser, A., & Staudinger, M. (2020). What the weather will do-results of a survey on impact-oriented and impact-based warnings in European NMHSs. *Advances in Science and Research*, *17*, 29–38. https://doi.org/10.5194/asr-17-29-2020
European NMHSs are progressing from warnings based on fixed thresholds or climatology-based thresholds to impact-oriented and impact-based warnings. This publication gives an overview of warning implementation as surveyed at 32 of the 37 NMHSs participating in the EUMETNET Meteoalarm project. The report addresses these topics: warning format, legislation and production process of warnings, dissemination and verification of warnings, impact databases, warning strategy and cooperation, legal obstacles and cross-border collaboration. Potential obstacles are identified and possible trends are discussed.

Kox, T., & Lüder, C. (2021). Impacts as Triggers for Weather-Related Decision Making: Observations at the Berlin Fire Brigade Control and Dispatch Center. *International Journal of Disaster Risk Science*, *12*(4), 610–615. https://doi.org/10.1007/s13753-021-00356-4
This article presents the results of a series of ethnographic observations at the Berlin fire brigade control and dispatch center during routine and severe weather situations. The weather-related challenges of a fire brigade lie between the anticipation of events and their potential consequences, and the ad hoc reactions to actual impacts of weather. The results show that decisions and actions related to high impact weather are not necessarily motivated by weather warnings alone. Instead, they are reactions to the experience of impacts, for example, an increased number of missions or emergency calls. Impacts are the main trigger for the decision making. Weather is one additional external factor that influences the operational capability of a fire brigade. While commanding officers in a fire brigade control and dispatch center experience weather primarily through technical equipment, verified by ground truth, observations showed that direct personal contact with the regional weather service and colleagues on the ground takes on a greater role in actual severe weather situations. The observations point to the need for increased interagency communication between the emergency services, the weather service, and other organizations to integrate weather information, impacts, and non-weather-related tasks into coherent weather-related decision making.

Lazo, J. K., Waldman, D. M., Morrow, B. H., & Thacher, J. A. (2010). Household Evacuation Decision Making and the Benefits of Improved Hurricane Forecasting: Developing a Framework for Assessment. *Weather and Forecasting*, *25*(1), 207–219. https://doi.org/10.1175/2009WAF2222310.1
Hurricane warnings are the primary sources of information that enable the public to assess the risk and develop responses to threats from hurricanes. These warnings have significantly reduced the number of hurricane-related fatalities in the last several decades. Further investment in the science and implementation of the warning system is a primary mission of the National Weather Service and its partners. It is important that the weather community understand the public's preferences and values for such investments; yet, there is little empirical information on the use of forecasts in evacuation decision making, the economic value of current forecasts, or the potential use or value for improvements in hurricane forecasts. Such information is needed to evaluate whether improved forecast provision and dissemination offer more benefit to society than alternative public investments.

Morss, R. E., Vickery, J., Lazrus, H., Demuth, J., & Bostrom, A. (2022). Improving Tropical Cyclone Forecast Communication by Understanding NWS Partners' Decision Timelines and Forecast Information Needs. *Weather, Climate, and Society*, 783–800. https://doi.org/10.1175/wcas-d-21-0170.1
As tropical cyclone threats evolve, broadcast meteorologists and emergency managers rely on

timely forecast information to help them communicate risk with the public and protect public safety. This study aims to improve the usability and applicability of NWS forecast information in the context of these NWS core partners' decisions during tropical cyclone threats. The research collected and analyzed data from in-depth interviews with broadcast meteorologists and emergency managers in 3 coastal U.S. states. These data were used to analyze broadcast meteorologists' and emergency managers' tropical cyclone decision and action timelines, their use of tropical cyclone information during different phases of threats, and gaps in forecast information for decision making. Based on these findings, several opportunities for improving tropical cyclone risk communication were identified. Recommendations to address gaps in the NWS tropical cyclone product suite include designing improved ways to communicate storm-specific storm surge risk at greater than 48 hours lead time, expanding the use of concise highlights that help people quickly extract and understand key information, and improving product understandability and usability by more comprehensively integrating users' perspectives into product research and development. Broader strategic recommendations include developing new approaches for informing broadcast meteorologists about major forecast updates, presenting forecast information in ways that enable locally relevant interpretation, and supporting human forecasters' contributions to the effectiveness of NWS products and services. These findings and recommendations can help NOAA prioritize ways to modernize the current NWS tropical cyclone product suite as well as motivate research to enable longer-term high-priority improvements.

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Nguyen, T. C., & Robinson, J. (2015). Analysing motives behind willingness to pay for improving early warning services for tropical cyclones in Vietnam. *Meteorological Applications*. https://doi.org/10.1002/met.1441

Pressure on government budgets has made it more important to quantify the value of public goods, e.g. tropical cyclone warning services, to society as a whole. Based on a stated preference survey, in which respondents could indicate the amount of their willingness to pay (WTP), this study elicited values for an improved cyclone warning service in Vietnam. To examine motives or reasons behind respondents' WTP, respondents were requested to allocate 10 points among different types of values, including self-interest motivated value (termed use value), and values with respect to the interests of others (altruistic value) and future generations (bequest value). The more influential the value, the higher the point is scored. Use value, which was scored the highest mean point of 4.1 out of 10, is the most important motive for valuing improvements in cyclone warning services. Altruistic and bequest values were given similar points, approximately 2.9 and 3.0, respectively. This study empirically demonstrates that respondents hold not only self-interest motivated value, but also altruistic and bequest values. Given the importance of non-use values, i.e. altruistic and bequest values, economic assessments focusing on only use value would underestimate the benefits of an improved cyclone warning service to society.

Nguyen, T. C., Robinson, J., Kaneko, S., & Komatsu, S. (2013). Estimating the value of economic benefits associated with adaptation to climate change in a developing country: A case study of improvements in tropical cyclone warning services. *Ecological Economics*, *86*, 117–128. https://doi.org/10.1016/j.ecolecon.2012.11.009
Linking tropical cyclone activity with anthropogenic climate change is subject to on-going debate. However, modelling studies consistently have projected that climate change is likely to increase the intensity of cyclones and the related rainfall rates in the future. A precautionary approach to this possibility is to adapt to the adverse effects of the changing climate by improving early warning services for cyclones as a "no or low-regrets" option. Given limited funding resources, assessments of economic efficiency will be necessary, and values for benefits are an essential input. This paper aims to estimate the benefits to households of an improved cyclone warning service in Vietnam. Choice experiment surveys with 1014 respondents were designed and conducted to inform this paper. The benefit estimates of the maximal improvements in a number of attributes of cyclone warning services (i.e. forecasting accuracy, frequency of update, and mobile phone based warnings) are approximately USD7.1-8.1 per household, which would be an upper bound estimate. Results from the marginal willingness to pay for the attributes suggest that investments should be dedicated to improvements in the accuracy of warning information and a warning service based on mobile phone short message.[37]

Perrels, A., Frei, T., Espejo, F., Jamin, L., & Thomalla, A. (2013). Socio-economic benefits of weather and climate services in Europe. *Advances in Science and Research*, *10*(1), 65–70. https://doi.org/10.5194/asr-10-65-2013
Abstract. There is a rising interest around the world for a better understanding of the economic and social value added of weather services. National hydro-meteorological services and international cooperative bodies in meteorology have ever more to justify their use of public budgets. Furthermore, the development of hydrological and meteorological services is to a large extent steered by expectations regarding the eventual benefits of the envisaged new developments. This article provides a compact overview of the impediments for uptake of socio-economic benefit (SEB) studies, methods and results of SEB studies to date. It also discusses some pitfalls and crucial steps to enhance a broader uptake of SEB studies.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what

IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.'"'"'"'"'

Seebauer, S., & Babcicky, P. (2018). Trust and the communication of flood risks: comparing the roles of local governments, volunteers in emergency services, and neighbours. *Journal of Flood Risk Management*, *11*(3), 305–316. https://doi.org/10.1111/jfr3.12313

Sorensen, J. H., Lindell, M. K., Baker, E. J., & Lehman, W. P. (2020). Community response to hurricane threat: Estimates of warning issuance time distributions. *Weather, Climate, and Society*, *12*(4), 837–846. https://doi.org/10.1175/WCAS-D-20-0031.1
Hurricane evacuation warnings from local officials are one of the most significant determinants of households' evacuation departure times. Consequently, it is important to know how long after the National Hurricane Center (NHC) issues a hurricane watch or warning that local officials wait to issue evacuation warnings. The distribution of local evacuation warning issuance delays determined from poststorm assessment data shows a wide range of warning issuance delay times over an 85-h time span, although the vast majority of times fall within a 40-h window. Nearly 30% of the jurisdictions issued evacuation warnings before an NHC hurricane warning. Only 5% delayed the decision for more than 25 h after the NHC hurricane warning. The curves for warning issuance delays, using both the NHC watch and NHC warning issuance times as reference points, are very different from the warning issuance curves observed for the rapid-onset events. The hurricane data exhibit much more of an '"S shape"' than the exponential shape that is seen for rapid-onset data. Instead, curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension, follow three noticeably different logistic distributions. The data also indicate that warnings were issued significantly earlier for coastal counties than for inland counties. These results have direct practical value to analysts that are calculating evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions

for future research on the reasons for the timing of local officials' hurricane evacuation decisions. SIGNIFICANCE STATEMENT: Local officials rely on National Hurricane Center (NHC) hurricane watches and warnings to guide them in issuing evacuation warnings but do not automatically issue evacuation warnings as soon as the NHC issues a watch or warning. Thus, this study constructed a database that contains the timing of NHC hurricane watches and warnings, as well as local evacuation warnings, for 20 hurricanes that threatened 290 U.S. jurisdictions from 1979 to 2008. The data reveal distinct curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension. These results are of direct practical value to analysts who calculate evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions for future research on the reasons for the timing of local officials' hu…

Speight, L. J., Cranston, M. D., White, C. J., & Kelly, L. (2021). Operational and emerging capabilities for surface water flood forecasting. *Wiley Interdisciplinary Reviews: Water*, *8*(3), 1–24. https://doi.org/10.1002/wat2.1517
Surface water (or pluvial) flooding is caused by intense rainfall before it enters rivers or drainage systems. As the climate changes and urban populations grow, the number of people around the world at risk of surface water flooding is increasing. Although it may not be possible to prevent such flooding, reliable and timely flood forecasts can help improve preparedness and recovery. Unlike riverine and coastal flooding where forecasting methods are well established, surface water flood forecasting presents a unique challenge due to the high uncertainties around predicting the location, timing, and impact of what are typically localized events. Over the past 5 years, there has been rapid development of convection-permitting numerical weather prediction models, ensemble forecasting, and computational ability. It is now theoretically feasible to develop operational surface water forecasting systems. This paper identifies three approaches to surface water forecasting utilizing state-of-the-art meteorological forecasts: empirical-based scenarios, hydrological forecasts linked to presimulated impact scenarios, and real-time hydrodynamic simulation. Reviewing operational examples of each approach provides an opportunity to learn from international best practice to develop targeted, impact-based, surface water forecasts to support informed decision-making. Although the emergence of new meteorological and hydrological forecasting capabilities is promising, there remains a scientific limit to the predictability of convective rainfall. To overcome this challenge, we suggest that a rethink of the established role of flood forecasting is needed, alongside the development of interdisciplinary solutions for communicating uncertainty and making the best use of all available data to increase preparedness. This article is categorized under: Engineering Water > Engineering Water.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

United Nations Office for Disaster Risk Reduction. (2016). *Climate early warning initiative focuses on most vulnerable*. Https://Www.Undrr.Org/News/Climate-Early-Warning-Initiative-Focuses-Most-Vulnerable.

van Noordwijk, M., Matthews, R., Agus, F., Farmer, J., Verchot, L., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., Dewi, S., Hergoualc'h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., & Dewi, S. (2014). Mud, muddle and models in the knowledge value-chain to action on tropical peatland conservation. *Mitigation and Adaptation Strategies for Global Change*, *19*(6), 887–905. https://doi.org/10.1007/s11027-014-9576-1

Tropical peatlands are known not only for their high, area-based, carbon emissions in response to land-use change but also as hot spots of debate about associated data uncertainties. Perspectives are still evolving on factors underlying the variability and uncertainty. Debate includes the ways of reducing emissions through rewetting, reforestation and agroforestry. A knowledge value-chain that is long and complex links (a) fundamental understanding of peat and peatland processes leading to sciencebased quantification and default values, (b) willingness and (c) ability to act towards emission reduction, and ultimately (d) to local, national and global actions that effectively provide rules, incentives and motivation to conserve peat and reduce emissions. We discuss this value chain, its stakeholders and issues that still remain partially unresolved. We conclude that, to shorten the denial and conspiracy-theory stages of debate that otherwise slow down steps B and C, networks of international and national scientists have to be involved at the early stage of identifying policysensitive environmental issues. Models span part of the knowledge value-chain but transition of analysis units requires specific attention, from soil volumes through area and commodity flows to opportunities for reductions. While drainage of peatlands triggers landscape-scale increases in emissions, factors beyond drainage depth, including nutrient supply, may have a major influence on decomposition rates. Attempts to disentangle the contributions of plant and peat-based respiration in surface flux measurements involve assumptions that cannot be easily verified in comparisons between land uses. With progress on A leading to new internationally accepted defaults and with resistance on step B reduced, the reality of C and lack of working solutions for D is currently constraining further progress. © 2014 The Author(s).

Wall, T. U., Brown, T. J., & Nauslar, N. J. (2017). Spot weather forecasts: Improving utilization, communication, and perceptions of accuracy in sophisticated user groups. *Weather, Climate, and Society*, *9*(2), 215–226. https://doi.org/10.1175/WCAS-D-15-0055.1
Spot weather forecasts (SWFs) are issued by Weather Service offices throughout the United States and are primarily for use by wildfire and prescribed fire practitioners for monitoring local-scale weather conditions. This paper focuses on use of SWFs by prescribed fire practitioners. Based on qualitative, in-depth interviews with fire practitioners and National Weather Service forecasters, this paper examines factors that influence perceptions of accuracy and utilization of SWFs. Results indicate that, while several well-understood climatological, topographical, and data-driven factors influence forecast accuracy, social factors likely have the greater impact on perceptions of accuracy, quantitative accuracy, and utilization. These include challenges with building and maintaining relationships between forecasters and fire managers, communication issues around updating SWFs, and communicating forecast confidence and uncertainty. Operationally, improved quantitative skill in a forecast is always desirable, but key opportunities for improving accuracy and utilization of these forecasts lie in 1) enhancing the processes and mechanisms for communication between a Weather Forecast Office and fire practitioners—before, during, and after an SWFs is issued—and 2) working with the wildland fire community to experiment with forecast uncertainty and confidence information in SWFs and evaluate impacts of these approaches.

Wang, Y., Yin, Y., & Song, L. (2022). Risk Assessment of Typhoon Disaster Chains in the Guangdong–Hong Kong–Macau Greater Bay Area, China. *Frontiers in Earth Science*, *10*(March), 1–17. https://doi.org/10.3389/feart.2022.839733
The typhoon disaster chain is one of the leading climate risks in constructing the Guangdong–Hong Kong–Macau Greater Bay Area (GBA). In this study, the risks of the typhoon disaster chains including typhoon-induced gales, rainstorms, and storm surges in the GBA, as well as the comprehensive risk of typhoon disaster, are investigated at county level by comprehensively analyzing the hazard, exposure, and vulnerability. The results show that the high- and very-high-risk areas of typhoon–gale disaster chain are located in Zhuhai, Zhongshan, Foshan, Dongguan,

central-southern Jiangmen, southern Shenzhen, and parts of Huizhou. The high- and very high-risk areas of typhoon–rainstorm disaster chain include Zhuhai, Zhongshan, Shenzhen, central-southern Foshan, northern Dongguan, central Jiangmen, and central Huizhou. Regarding the typhoon–storm surge disaster chain, the areas at high and very high risk are located in Zhuhai, eastern Zhongshan, and the coastal areas of the Pearl River Estuary. In addition, the comprehensive risk of typhoon disaster is very high in Zhuhai and high in Zhongshan, Jiangmen, Dongguan, and Shenzhen. By verifying the spatial correlation between typhoon disaster risk indexes and actual losses, it is found that the comprehensive risk index of typhoon disaster constructed in this study can better reflect the actual losses. Overall, the findings of this study can provide a scientific basis for typhoon disaster prevention and mitigation in the GBA, and it can also serve as a reference for typhoon disaster risk research in other areas.

Zommers, Z., & Singh, A. (2014). Reducing disaster: Early warning systems for climate change. *Reducing Disaster: Early Warning Systems for Climate Change*, *9789401785*, 1–387. https://doi.org/10.1007/978-94-017-8598-3
Around the world, extreme weather events are becoming increasingly “the new normal” and are expected to increase in the 21st century as a result of climate change. Extreme weather events have devastating impacts on human lives and national economies. This book examines ways to protect people from hazards using early warning systems, and includes contributions from experts from four different continents representing 14 different universities, 8 government agencies and two UN agencies. Chapters detail critical components of early warning systems, ways to identify vulnerable communities, predict hazards and deliver information. Unique satellite images illustrate the transnational impact of disasters, while case studies provide detailed examples of warning systems. With contributors from the fields of economics, ethics, meteorology, geography and biology, this book is essential reading for anyone interested in disaster risk reduction or climate change.

Social

Keywords: behavioural recommendations, educational needs, evacuation behaviour, health care, intervention, counterfactual studies, mental health, perception of forecasts, public and private engagement, psychometric paradigm, qualitative benefits of services provided by NHMSs, risk perception, risk aversion, causal inference, socioeconomic vulnerability, social characteristics, social inequity, social measure, social process, social science, two-way interaction, understanding of risk, user decision, user feedback, user judgment, user needs, user preference, user psychological factors, user uptake, vulnerability

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S., Sivle, A. D., Agersten, S., Schmid, F., & Simon, A. (2016). Use and perception of weather forecast information across Europe Journal:

Meteorological Applications, *4*(434), 1–2. https://doi.org/10.1002/met.2053
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., Lazrus, H., & Hudson, R. (2016). A Mental Models Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making*. *Weather, Climate, and Society*, *8*(2), 111–129. https://doi.org/10.1175/WCAS-D-15-0033.1
The study reported here explores how to enhance the public value of hurricane forecast and warning information by examining the entire warning process. A mental models research approach

is applied to address three risk management tasks critical to warnings for extreme weather events: 1) understanding the risk decision and action context for hurricane warnings, 2) understanding the commonalities and conflicts in interpretations of that context and associated risks, and 3) exploring the practical implications of these insights for hurricane risk communication and management. To understand the risk decision and action context, the study develops a decision-focused model of the hurricane forecast and warning system on the basis of results from individual mental models interviews with forecasters from the National Hurricane Center (n = 4) and the Miami–South Florida Weather Forecast Office (n = 4), media broadcasters (n = 5), and public officials (n = 6), as well as a group decision-modeling session with a subset of the forecasters. Comparisons across professionals reveal numerous shared perceptions, as well as some critical differences. Implications for improving extreme weather event forecast and warning systems and risk communication are threefold: 1) promote thinking about forecast and warning decisions as a system, with informal as well as formal elements; 2) evaluate, coordinate, and consider controlling the proliferation of forecast and warning information products; and 3) further examine the interpretation and representation of uncertainty within the hurricane forecast and warning system as well as for users.

Colavito, M. M., Trainor, S. F., Kettle, N. P., & York, A. (2019). Making the transition from science delivery to knowledge coproduction in boundary spanning: A case study of the Alaska fire science consortium. *Weather, Climate, and Society*, *11*(4), 917–934. https://doi.org/10.1175/WCAS-D-19-0009.1

Boundary organizations facilitate two-way, sustained interaction and communication between research and practitioner spheres, deliver existing science, and develop new, actionable scientific information to address emerging social–ecological questions applicable to decision-making. There is an increasing emphasis on the role of boundary organizations in facilitating knowledge coproduction, which is collaborative research with end users to develop actionable scientific information for decision-making. However, a deeper understanding of how boundary organizations and knowledge coproduction work in practice is needed. This paper examines the Alaska Fire Science Consortium (AFSC), a boundary organization focused on fire science and management in Alaska that is working to address climate impacts on wildfire. A case study approach was used to assess AFSC activities over time. AFSC's boundary spanning involves a continuum of outputs and activities, but their overall trajectory has involved a deliberate transition from an emphasis on science delivery to knowledge coproduction. Key factors that facilitated this transition included a receptive and engaged audience, built-in evaluation and learning, subject matter expertise and complementarity, and embeddedness in the target audience communities. Recommendations for boundary organizations wishing to develop knowledge coproduction capacity include knowing your audience, employing trusted experts in boundary spanning, and engaging in frequent self-evaluation to inform change over time.

Demuth, J. L., Lazo, J. K., & Morss, R. E. (2011). Exploring variations in people's sources, uses, and perceptions of weather forecasts. *Weather, Climate, and Society*, *3*(3), 177–192. https://doi.org/10.1175/2011WCAS1061.1

Past research has shown that individuals vary in their attitudes and behaviors regarding weather forecast information. To deepen knowledge about these variations, this article explores 1) patterns in people's sources, uses, and perceptions of everyday weather forecasts; and 2) relationships among people's sources, uses, and perceptions of forecasts, their personal characteristics, and their experiences with weather and weather forecasts. It does so by performing factor and regression analysis on data from a nationwide survey of the U.S. public, combined with other data. Forecast uses factored into planning for leisure activities and for work/school-related activities,

while knowing what the weather will be like and planning how to dress remained separate. Forecast parameters factored into importance of precipitation parameters and of temperaturerelated parameters, suggesting that these represent conceptually different constructs. Regression analysis showed that the primary drivers for how often people obtain forecasts are what they use forecasts for and their perceived importance of and confidence in forecast information. People's forecast uses are explained in large part by their frequency of obtaining forecasts and their perceived importance of temperature-related and precipitation forecast information. This suggests that that individuals' frequency of obtaining forecasts, forecast use, and importance of forecast parameters are closely interrelated. Sociodemographic characteristics and, to a lesser extent, weather-related experience also influence some aspects of people's forecast sources, uses, and perceptions. These findings continue to build understanding of variations among weather forecast users, which can help weather information providers improve communication of forecasts to better meet users' needs. © 2011 American Meteorological Society.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., & Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811

Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Hahlin, J. (2019). Evacuation behaviour intentions based on the summer 2018 Swedish forest fire season. *Lutvdg/Tvbb*. https://lup.lub.lu.se/student-papers/record/8998490

…The corresponding numbers for the personnel group are 100 %. The main conclusion of this study is survey respondents indicate the need for further improve evacuation planning and communication during large forest fire scenarios …

Higgins, P. A. (2021). Societal Benefits in Weather, Water, and Climate: Understanding, Communication, and Enhancement. *An AMS Policy Program Study.*, *April*.

The study highlights the societal benefits that result from Earth system OSS and help identify unmet and emerging user needs in OSS. The studies will also provide a strong and overarching

emphasis on public–private partnerships; most notably, the studies will help to refresh aspects of the 2003 Fair Weather report by the National Academies of Science, which has been foundational to the weather enterprise over the past two decades

Houmann, L. D. (2016). The Power of Partnership. *Healthcare Executive*, *31*(2).
This report provides guidance to regulators, hydromet service providers, and private actors as well as development practitioners to achieve successful public-private-academic engagements. It is based on a systematic analysis of the various forms taken by private-public engagements in hydromet services in different countries.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Che Mamat, C. S. N. B., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J. L. J. L., Wandala, A., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Mamat, C. S. N. B. C., Moron, L. A., Cecilia A Monteverde, M., Cayanan, E. O., … Harris, A. J. L. J. L. (2022). Impact-based forecasting in South East Asia – What underlies impact perceptions? *International Journal of Disaster Risk Reduction*, *76*(March), 102943. https://doi.org/10.1016/j.ijdrr.2022.102943
The move towards impact-based forecasting presents a challenge for forecasters, who must combine information not just on what the weather might be, but also on what the weather might do. Yet different hazards and impacts are qualitatively distinct, meaning such information cannot be easily or straightforwardly integrated. The present study aimed to provide a way of characterising seemingly disparate impacts. In a collaboration between UK psychologists and partners from three meteorological organisations in Indonesia, Malaysia and the Philippines, the psychometric paradigm was employed to investigate how forecasters and stakeholders perceive weather-related impacts. Participants provided ratings of nine categories of impacts on a total of 10 characteristics, as well as providing an overall impact severity rating. Principal components analysis revealed differing component solutions across countries, which explained around 75% of the variance in perceptions. There were some similarities across all countries, with the characteristics 'worry'' and "destructiveness'' loading positively together, as well as 'likelihood of harm'' and "seriousness of harm''. We did not find strong evidence to indicate that forecasters and stakeholders perceive impacts in different ways. Our results highlight the complex nature of impact perceptions, which are characterised not just by objective factors such as impact scope and duration, but also subjective factors, such as worry and perceived severity."'"'

Johar, M., Johnston, D. W., Shields, M. A., Siminski, P., & Stavrunova, O. (2022). The economic impacts of direct natural disaster exposure. *Journal of Economic Behavior and Organization*, *196*, 26–39. https://doi.org/10.1016/j.jebo.2022.01.023
We estimate the economic impacts of having your home damaged or destroyed by a natural disaster. Regressions with individual, area and time fixed-effects, indicate that experiencing a natural disaster has no impact on employment and income, but substantial impacts on financial hardship and risk aversion. Impacts are particularly large for smaller isolated disasters, which attract little government support. Conversely, impacts of residing in a disaster zone without experiencing residential destruction are small. Using a Group Fixed Effects estimator, we find predictors of financial vulnerability to destruction include age, parenthood, illness, and social support. These results can help improve the allocation of government assistance after future disasters.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., Adkins, J. E., & Jeffrey K. Lazo, Heather R. Hosterman, Jennifer M. Sprague-Hilderbrand, and J. E. A. (2020). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Leach, M., & Scoones, I. (2006). The Slow Race: Making Technology Work For The Poor. *Demos*, 7–73. Citizen engagement is vital to ensure that science and technology respond to the challenges of international development ..

Martinez, A. B. (2020). Forecast accuracy matters for hurricane damage. *Econometrics*, *8*(2). https://doi.org/10.3390/econometrics8020018
I analyze damage from hurricane strikes on the United States since 1955. Using machine learning methods to select the most important drivers for damage, I show that large errors in a hurricane's predicted landfall location result in higher damage. This relationship holds across a wide range of model specifications and when controlling for ex-ante uncertainty and potential endogeneity. Using a counterfactual exercise I find that the cumulative reduction in damage from forecast improvements since 1970 is about $82 billion, which exceeds the U.S. government's spending on the forecasts and private willingness to pay for them.

Mason, K., Lindberg, K., Haenfling, C., Schori, A., Marsters, H., Read, D., & Borman, B. (2021). Social vulnerability indicators for flooding in aotearoa New Zealand. *International Journal of Environmental Research and Public Health*, *18*(8). https://doi.org/10.3390/ijerph18083952
Social vulnerability indicators are a valuable tool for understanding which population groups are more vulnerable to experiencing negative impacts from disasters, and where these groups live, to inform disaster risk management activities. While many approaches have been used to measure social vulnerability to natural hazards, there is no single method or universally agreed approach. This paper proposes a novel approach to developing social vulnerability indicators, using the example of flooding in Aotearoa New Zealand. A conceptual framework was developed to guide selection of the social vulnerability indicators, based on previous frameworks (including the MOVE framework), consideration of climate change, and a holistic view of health and wellbeing. Using this framework, ten dimensions relating to social vulnerability were identified: exposure; children; older adults; health and disability status; money to cope with crises/losses; social connectedness; knowledge, skills and awareness of natural hazards; safe, secure and healthy housing; food and water to cope with shortage; and decision making and participation. For each dimension, key indicators were identified and implemented, mostly using national Census population data. After development, the indicators were assessed by end users using a case study of Porirua City, New

Zealand, then implemented for the whole of New Zealand. These indicators will provide useful data about social vulnerability to floods in New Zealand, and these methods could potentially be adapted for other jurisdictions and other natural hazards, including those relating to climate change.

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

Morrow, B. H., Lazo, J. K., Rhome, J., & Feyen, J. (2015). Improving storm surge risk communication: Stakeholder perspectives. *Bulletin of the American Meteorological Society*, *96*(1), 35–48. https://doi.org/10.1175/BAMS-D-13-00197.1
Storm surge associated with tropical and extratropical cyclones has a long history of causing death and destruction along our coastlines. With more than 123 million people living in coastal shoreline areas and much of the densely populated Atlantic and Gulf coastal areas less than 10 ft (∼3 m) above mean sea level, the threat has never been greater. In this article, we summarize and integrate the most intensive series of studies completed to date on communication of storm surge risk. These were primarily geographically focused stakeholder surveys for evaluating the storm surge communication perceptions and preferences of forecasters, broadcast meteorologists, public officials, and members of the public - each a primary user group for storm surge forecasts. According to findings from seven surveys, each group strongly supports the National Weather Service (NWS) issuing watches and warnings for storm surge, whether associated with tropical cyclones (TC) or extratropical (ET) cyclones. We discuss results on public understanding of storm surge vulnerability, respondents' preferences for separate storm surge information products, and initial assessments of potential storm surge warning text and graphics. Findings from the research reported here are being used to support relevant NWS decisions, including a storm surge watch and warning product that has been approved for use on an experimental basis in 2015 and the National Hurricane Center (NHC) issuance of local surge inundations maps on an experimental basis in 2014.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Pearl, J. (2010). The International Journal of Biostatistics An Introduction to Causal Inference An Introduction to Causal Inference ∗. *The International Journal of Biostatistics*, *6*(2), Article 7.
This paper summarizes recent advances in causal inference and underscores the paradigmatic shifts that must be undertaken in moving from traditional statistical analysis to causal analysis of multivariate data. Special emphasis is placed on the assumptions that underlie all causal inferences, the languages used in formulating those assumptions, the conditional nature of all causal and counterfactual claims, and the methods that have been developed for the assessment of such claims. These advances are illustrated using a general theory of causation based on the Structural Causal Model (SCM) described in Pearl (2000a), which subsumes and unifies other approaches to causation, and provides a coherent mathematical foundation for the analysis of causes and counterfactuals. In particular, the paper surveys the development of mathematical tools for inferring (from a combination of data and assumptions) answers to three types of causal queries: those about (1) the effects of potential interventions, (2) probabilities of counterfactuals, and (3) direct and indirect effects (also known as "mediation"). Finally, the paper defines the formal and conceptual relationships between the structural and potential-outcome frameworks and presents tools for a symbiotic analysis that uses the strong features of both. The tools are demonstrated in the analyses of mediation, causes of effects, and probabilities of causation.

Rabonza, M. L., & Lallemant, D. (2022). *Shedding light on avoided disasters: Measuring the invisible benefits of disaster risk management using probabilistic counterfactual analysis*. Global Assessment Report on Disaster Risk Reduction

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2021.102344
Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP, CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-

negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.’”””””’

Tart, S., Groth, M., & Seipold, P. (2020). Market demand for climate services: An assessment of users’ needs. *Climate Services*, *17*. https://doi.org/10.1016/j.cliser.2019.100109
As organisations start to make combatting climate change a more prominent part of their sustainability plans, climate services are emerging among a broad range of industries and for multiple purposes. The analysis provided in this paper depicts how such changes are unfolding among both traditional and non-traditional climate service sectors. In addition to desktop research, data has been collected via an online survey conducted among climate service users around the world (n = 248), and from interviews with both users and non-users of climate services (n = 36) across three economic sectors in Europe: food and drink; manufacturing; and pharmaceuticals and healthcare. These sectors were chosen for this paper due to their potential links to climate services, and the fact that they provide a glimpse into how climate services can be used in conjunction with the private sector. Analysis shows that users have a greater need for either past climate data or data analysis that falls within the next year, meaning they are less interested in long-term data with higher uncertainties. Moreover, while climate services hold great potential and offer huge societal benefits, their presence is not always easy to find outside of research purposes. Policies and regulations can fill this gap and be a strong purchase driver for climate services, as can the development of climate services that help companies achieve their corporate social responsibility and sustainability goals.

Terti, G., Ruin, I., Anquetin, S., & Gourley, J. J. (2015). Dynamic vulnerability factors for impact-based flash flood prediction. *Natural Hazards*, *79*(3), 1481–1497. https://doi.org/10.1007/s11069-015-1910-8
Social vulnerability explains the sociological and human-dependent circumstances that translate a natural event into a deadly disaster. But, what are the space–time characteristics of vulnerability (i.e., dynamic vulnerability) that influence how people are impacted by a specific natural hazard? This paper performs a critical analysis of previous flood-related human impact and vulnerability studies to better understand and summarize the human-related factors that determine the impacts from flash flood events. The paper is motivated by the hypothesis that the intersection of the spatiotemporal context of the hazard with the distribution of people and their characteristics across space and time reveals different paths of vulnerability and defines the most probable space of an exposed area in terms of deadly impacts. Based on this idea, a conceptual model for assessing vulnerability to flash flooding is developed and presented herein. The most important advance of the current research in comparison with previous efforts in vulnerability assessment is the introduction of the concept of the spatial and temporal variability of vulnerability. This means that the proposed conceptual model does not consider vulnerability as a static synopsis that can be described by a single map, but as an ever-evolving process derived from the interaction of social and physical dynamics. The dynamic perspective of vulnerability is key for the identification of pertinent vulnerability variables to be used for flash flood vulnerability assessment and dynamic mapping, and prediction.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Wall, T. U., Brown, T. J., & Nauslar, N. J. (2017). Spot weather forecasts: Improving utilization,

communication, and perceptions of accuracy in sophisticated user groups. *Weather, Climate, and Society*, *9*(2), 215–226. https://doi.org/10.1175/WCAS-D-15-0055.1
Spot weather forecasts (SWFs) are issued by Weather Service offices throughout the United States and are primarily for use by wildfire and prescribed fire practitioners for monitoring local-scale weather conditions. This paper focuses on use of SWFs by prescribed fire practitioners. Based on qualitative, in-depth interviews with fire practitioners and National Weather Service forecasters, this paper examines factors that influence perceptions of accuracy and utilization of SWFs. Results indicate that, while several well-understood climatological, topographical, and data-driven factors influence forecast accuracy, social factors likely have the greater impact on perceptions of accuracy, quantitative accuracy, and utilization. These include challenges with building and maintaining relationships between forecasters and fire managers, communication issues around updating SWFs, and communicating forecast confidence and uncertainty. Operationally, improved quantitative skill in a forecast is always desirable, but key opportunities for improving accuracy and utilization of these forecasts lie in 1) enhancing the processes and mechanisms for communication between a Weather Forecast Office and fire practitioners—before, during, and after an SWFs is issued—and 2) working with the wildland fire community to experiment with forecast uncertainty and confidence information in SWFs and evaluate impacts of these approaches.

Waskow, D., Jacoby Jonathan, Ocharan, J., de Messieres, S., GLucksman, S., Fischer-Mackey, J., Jochnick, C., Slack, K., Shelley, B., & Woodward, S. (2013). *Value Chain Climate Resilience*. https://www.bsr.org/reports/PREP-Value-Chain-Climate-Resilience_copy.pdf
This guide discusses a value chain approach to building climate resilience, and provide cases studies of climate resilience in action.

Watkiss, P., & Cimato, F. (2021). *The Socio-Economic Benefits of the WISER Programme*. https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/business/international/wiser/wiser-seb-results_final-web.pdf
The socio-economic benefits of eight WISER East Africa projects have been assessed. These include projects that have led to new or improved weather and seasonal forecasts, as well as early warning systems, at the national and regional level.

Weyrich, P., Scolobig, A., Bresch, D. N., & Patt, A. (2018). Effects of Impact-Based Warnings and Behavioral Recommendations for Extreme Weather Events. *Weather, Climate, and Society*, *10*(4), 781–796. https://doi.org/10.1175/WCAS-D-18-0038.1
Bad weather continues not only to inflict damage on property but also to kill and injure people, despite significant advances in the predictive power of meteorological warnings. There is evidence that people tend to underreact to weather warning information, to a large extent because of insufficient understanding of the impacts that severe weather events can have, as well as to demonstrate the appropriate response behavior. A growing number of experts are suggesting that standard warning information should be augmented with additional information about these factors, but this has so far largely failed to take place. Past research studies have shown possible advantages of including impact-based warnings (IBWs) and behavioral recommendations (BRs) into the warning information, but the results are in part ambiguous, due to a failure to have tested for effects of the two kinds of information separately and in combination. Based on quantitative results from a survey experiment in Switzerland, this knowledge gap is addressed. Results of the research reported here indicate significant benefits from providing both sets of information together, in terms of improving both perception and understanding of warning and intended behavioral responses. When only one piece of information is given, BRs have a significant effect on both perception and intended response, whereas IBWs have a significant effect only on intended response. These findings offer empirical justification for the added expense and time associated

with the more detailed hazard warnings.

Wilkins, E. J., Miller, H. M., Tilak, E., & Schuster, R. M. (2018). Communicating information on nature-related topics: Preferred information channels and trust in sources. *PLOS ONE*, *13*(12), e0209013. https://doi.org/10.1371/journal.pone.0209013

Evaluation and verification

Keywords: evaluation, evaluation and monitoring methods, evaluation of forecast skill, evaluation of risk, evaluation of simulation performance, accuracy, EWS limitations, FAR, hazard analysis, impact assessment, assessment, assessment of emergency preparedness, assessment of emergency preparedness/response/coordination, assessment of hindcasts, assessment of responsibilities, assessment of warning accuracy, improvements, improvements in communication, level of threat, methods, monitoring and evaluation, obstacles to uptake, performance assessment, POD, probabilistic counterfactual analysis, reliability, risk assessment, measuring producer skill, probabilistic lives saved, risk reduction, technological needs, uncertainty, valuation, value of forecasts, value of information, value of service, value of weather and climate information, value proposition, value network analysis, value chain analysis, warning communication methods

Abimbola, S., Keelan, S., Everett, M., Casburn, K., Mitchell, M., Burchfield, K., & Martiniuk, A. (2019). The medium, the message and the measure: A theory-driven review on the value of telehealth as a patient-facing digital health innovation. *Health Economics Review*, *9*(1). https://doi.org/10.1186/s13561-019-0239-5

By what measure should a policy maker choose between two mediums that deliver the same or similar message or service? Between, say, video consultation or a remote patient monitoring application (i.e. patient-facing digital health innovations) and in-person consultation? To answer this question, we sought to identify measures which are used in randomised controlled trials. But first we used two theories to frame the effects of patient-facing digital health innovations on - 1) transaction costs (i.e. the effort, time and costs required to complete a clinical interaction); and 2) process outcomes and clinical outcomes along the care cascade or information value chain, such that the "value of information" (VoI) is different at each point in the care cascade or value chain. From the trials, we identified three categories of measures: outcome (process or clinical), satisfaction, and cost. We found that although patient-facing digital health innovations tend to confer much of their value by altering process outcomes, satisfaction, and transaction costs, these measures are inconsistently assessed. Efforts to determine the relative value of and choose between mediums of service delivery should adopt a metric (i.e. mathematical combination of measures) that capture all dimensions of value. We argue that "value of information" (VoI) is such a metric - it is calculated as the difference between the "expected utility" (EU) of alternative options. But for patient-facing digital health innovations, "expected utility" (EU) should incorporate the probability of achieving not only a clinical outcome, but also process outcomes (depending on the innovation under consideration); and the measures of utility should include satisfaction and transaction costs; and also changes in population access to services, and health system capacity to deliver more services, which may result from reduction in transaction costs.

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749

Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Alfieri, L., Burek, P., Dutra, E., Krzeminski, B., Muraro, D., Thielen, J., & Pappenberger, F. (2013). GloFAS – global ensemble streamflow forecasting and flood early warning. *Hydrology and Earth System Sciences*, *17*(3), 1161–1175. https://doi.org/10.5194/hess-17-1161-2013
Abstract. Anticipation and preparedness for large-scale flood events have a key role in mitigating their impact and optimizing the strategic planning of water resources. Although several developed countries have well-established systems for river monitoring and flood early warning, figures of populations affected every year by floods in developing countries are unsettling. This paper presents the Global Flood Awareness System (GloFAS), which has been set up to provide an overview on upcoming floods in large world river basins. GloFAS is based on distributed hydrological simulation of numerical ensemble weather predictions with global coverage. Streamflow forecasts are compared statistically to climatological simulations to detect probabilistic exceedance of warning thresholds. In this article, the system setup is described, together with an evaluation of its performance over a two-year test period and a qualitative analysis of a case study for the Pakistan flood, in summer 2010. It is shown that hazardous events in large river basins can be skilfully detected with a forecast horizon of up to 1 month. In addition, results suggest that an accurate simulation of initial model conditions and an improved parameterization of the hydrological model are key components to reproduce accurately the streamflow variability in the many different runoff regimes of the earth.

Allee, V. (2008). Value network analysis and value conversion of tangible and intangible assets. *Journal of Intellectual Capital*, *9*(1), 5–24. https://doi.org/10.1108/14691930810845777
Purpose The purpose of this paper is to provide examples and technical details for conducting a value network analysis that addresses the conversion and utilisation of intangible assets. Design/methodology/approach Value network analysis was first developed in 1993 and was adapted in 1997 for intangible asset management. It has been tested in applications from shop floor work groups to business webs and economic regions. It draws from a theory based in living systems, knowledge management, complexity theory, system dynamics, and intangible asset management. Findings The paper provides a high level of detail on the analysis method and insights from its practical application across a range of business issues. Tips are provided for how to integrate the methodology with other business analysis approaches. Research limitations/implications The paper does not provide a comparative analysis with other methods because most other value network models are process views, social network analysis or clustering techniques. Practical implications Sufficient detail is provided so researchers and practitioners will be able to apply the method in their own investigations. Further resources are noted, as well as

access points to the global user community and open source tools. Originality/value This paper is the first detailed publication of the value network analysis method, which has been acclaimed by experts in intangibles, network analysis, knowledge management, and process analysis. It fills a gap between theory and practice for managers, executives, analysts, and researchers. © 2008, Emerald Group Publishing Limited

Alliance for Hydromet Development. (2021). *HYDROMET GAP REPORT 2021 Alliance for Hydromet Development*.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Bostrom, A., Morss, R. E., Lazo, J. K., Demuth, J. L., Lazrus, H., & Hudson, R. (2016). A Mental Models Study of Hurricane Forecast and Warning Production, Communication, and Decision-Making*. *Weather, Climate, and Society*, *8*(2), 111–129. https://doi.org/10.1175/WCAS-D-15-0033.1
The study reported here explores how to enhance the public value of hurricane forecast and warning information by examining the entire warning process. A mental models research approach is applied to address three risk management tasks critical to warnings for extreme weather events: 1) understanding the risk decision and action context for hurricane warnings, 2) understanding the commonalities and conflicts in interpretations of that context and associated risks, and 3) exploring the practical implications of these insights for hurricane risk communication and management. To understand the risk decision and action context, the study develops a decision-focused model of the hurricane forecast and warning system on the basis of results from individual mental models interviews with forecasters from the National Hurricane Center (n = 4) and the Miami–South Florida Weather Forecast Office (n = 4), media broadcasters (n = 5), and public officials (n = 6), as

well as a group decision-modeling session with a subset of the forecasters. Comparisons across professionals reveal numerous shared perceptions, as well as some critical differences. Implications for improving extreme weather event forecast and warning systems and risk communication are threefold: 1) promote thinking about forecast and warning decisions as a system, with informal as well as formal elements; 2) evaluate, coordinate, and consider controlling the proliferation of forecast and warning information products; and 3) further examine the interpretation and representation of uncertainty within the hurricane forecast and warning system as well as for users.

Center for Climate and Energy Solutions. (2015). *Weathering the Next Storm : a Closer Look At Business Resilience* (Issue September). http://www.c2es.org/publications/weathering-next-storm-closer-look-business-resilience
In 2013, C2ES released Weathering the Storm: Building Business Resilience to Climate Change (hereafter WTS 2013), which examined how companies listed in the Standard and Poor's (S&P) Global 100 Index were approaching climate risks. WTS 2013 provided a baseline perspective on how major companies were assessing their climate vulnerabilities and whether and how they were working to strengthen their climate resilience. This report provides an update and takes a closer look at how companies are preparing for climate change and what is keeping them from doing more. The report is based on several lines of research: • A comprehensive review of the perspectives and activities of S&P Global 100 companies, based on their reporting to CDP1 and their corporate sustainability reports and annual financial filings; • Interviews with company representatives to gather more detailed information on whether and how companies are assessing climate risks and what barriers are keeping them from doing more; and • Dialogues conducted with companies, federal and local government agencies, academics, and other stakeholders through several workshops and events focused on business resilience. These sources provide an in-depth look at the state of climate risk assessment and resilience planning within the business community. While some companies have taken steps to assess risks and prepare their business for future climate changes, many companies face various internal and external challenges that hinder efforts toward greater climate resilience. This report identifies various approaches companies are using to address climate risks, examines challenges companies face in managing and reporting risks, and suggests strategies to overcome these challenges and strengthen climate risk management within the private sector.

Climate Risk and Early Warning (CREWS). (2017). *Draft Consultation Document On Measuring Early Warning Access and Effectiveness*. https://public.wmo.int/en/resources
the present consultation document aims to identify a set of metrics to provide guidance on how the effectiveness of, and access to, early warning systems can be measured, encompassing a conceptual framework of key elements, including sources of data and information and methodologies.

Coiera, E. (2019). Assessing Technology Success and Failure Using Information Value Chain Theory. *Studies in Health Technology and Informatics*, *263*, 35–48. https://doi.org/10.3233/SHTI190109
Information value chain theory provides a straightforward approach to information system evaluation and design. It first separates the different benefits and costs that might be associated with the use of a given information technology at different stages along a value chain stretching from user interaction to real world outcome. Next, using classical decision theoretic measures such as probabilities and utilities, the resulting value chain can be used to create a profile for a particular technology or technology bundle. Value chain analysis helps focus on the reasons for system implementation success or failure. It also assists in making comparative assessments amongst different solutions, to understand which might be best suited for different clinical

contexts.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., & Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811
Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Fenwick, E., Steuten, L., Knies, S., Ghabri, S., Basu, A., Murray, J. F., Koffijberg, H. (Erik), Strong, M., Sanders Schmidler, G. D., & Rothery, C. (2020). Value of Information Analysis for Research Decisions—An Introduction: Report 1 of the ISPOR Value of Information Analysis Emerging Good Practices Task Force. *Value in Health*, *23*(2), 139–150. https://doi.org/10.1016/j.jval.2020.01.001
Healthcare resource allocation decisions made under conditions of uncertainty may turn out to be suboptimal. In a resource constrained system in which there is a fixed budget, these suboptimal decisions will result in health loss. Consequently, there may be value in reducing uncertainty, through the collection of new evidence, to make better resource allocation decisions. This value can be quantified using a value of information (VOI) analysis. This report, from the ISPOR VOI Task Force, introduces VOI analysis, defines key concepts and terminology, and outlines the role of VOI for supporting decision making, including the steps involved in undertaking and interpreting VOI analyses. The report is specifically aimed at those tasked with making decisions about the adoption of healthcare or the funding of healthcare research. The report provides a number of recommendations for good practice when planning, undertaking, or reviewing the results of VOI analyses.

Gill, D., Siddharth, P., O'Connor, D., Derek Gill, Siddharth, P., O'Connor, D., NZIER, O'Connor, D., NZIER, Gill, D., Siddharth, P., & O'Connor, D. (2018). *The value of MetService's public weather forecasts and weather warnings* (Issue February). https://nzier.org.nz/static/media/filer_public/1b/6b/1b6b2288-9880-4f94-9494-97dec9099930/the_value_of_metservice_final_report_february_2018.pdf
The findings from our literature were mainly overseas studies that compared the costs and

benefits of meteorological forecasting services. For studies of developed countries, the benefit to cost ratios (BCRs) mainly fell in the range 4:1 to 14:1. New Zealand based studies of weather events were rare (we identified ten studies in our literature scan). We used a benefit transfer approach based on studies of the Australian Bureau of Meteorology, but including New Zealand values and data on weather events. Taken at face value, the potential benefits to any one of the main user groups on their own could justify the continuation of the provision of public weather services under the Crown contract. In line with comparable studies, this study focuses on the benefits to land-based groups of users. It does not directly address the benefits of the weather forecast and warning services provided to maritime users under the Crown contract.

Golding, B., Mittermaier, M., Ross, C., Ebert, B., Panchuk, S., Scolobig, A., & Johnston, D. (2019). A Value Chain Approach to Optimising Early Warning Systems. *Global Assessment Report*, 1–30.
The impact of weather-related hazards continues to be a major cause of human and economic loss in the world. Reducing those losses requires a combination of policies that protect, avoid and facilitate recovery. Early warnings are a key contributor, especially in countries without the governance structures and resources to provide permanent protection or avoidance. Advances in weather modelling, earth observation from space, and hazard reporting by citizens, provide a solid baseline for hazard mapping; however, this needs to be matched by comparable mapping of the (time-dependent) exposure and vulnerability of people, buildings and infrastructure, and by the development of response capability especially in risk hot-spots.

Gordon, N., & Shaykewich, J. (2000). Guidelines on Performance Assessment of Public Weather Services. *Technical Document*, *1023*.

Gray, M. (2015). *Public Weather Service Value for Money Review*. *March*, 0–25.
http://www.metoffice.gov.uk/binaries/content/assets/mohippo/pdf/c/a/pws_value_for_money_review_-_march_20151.pdf
The study has reviewed available literature and studies which have looked at the economic benefits from weather services to the following sectors: ? The Public ? Aviation ? Civil Contingencies ? Land Transport ? Flood Damage Avoidance ? Storm Damage Avoidance ? Added Value to the Economy The study has also considered other benefits arising from the UK hosting ECMWF and being a member of EUMETSAT. Different methodologies have been used within different sectors which means care must be taken when combining these figures to generate an overall benefit from the PWS to the UK economy.

Harding, J. (2020). *How can we measure the effectiveness of our investments in early warning systems ? Can we measure early warning access / effectiveness ?* (Issue February).
https://www.unescap.org/sites/default/files/12_John
Presentation on early warning metrics.

Harrison, S., Silver, A., & Doberstein, B. (2015). Post-storm damage surveys of tornado hazards in Canada: Implications for mitigation and policy. *International Journal of Disaster Risk Reduction*, *13*, 427–440. https://doi.org/10.1016/j.ijdrr.2015.08.005
Tornadoes have the potential to cause significant destruction and loss of life in many regions across Canada. Accordingly, these hazards are essential to consider for a comprehensive emergency management plan. Following a suspected tornadic event, damage surveys are conducted by Environment Canada to determine the extent and severity of damage in order to assign an Enhanced Fujita scale rating. The purpose of this paper is to investigate the process involved in conducting storm damage surveys, and to assess how information gathered during these surveys is used. Primary research for this study involved conducting semi-structured

interviews with Environment Canada damage surveyors from various provinces (n=10) and wind engineering researchers from a large public university in Canada (n=2), as well as an onsite observation of a damage survey conducted in Angus, Ontario after a tornado struck on 17 June 2014. The results of this study underscored the subtle but important differences between storm damage surveys conducted in the United States and Canada. It was also found that the majority of damage surveys are now conducted remotely through photos, videos, and telephone interviews with key witnesses. Finally, damage surveys were found to be a critical component of the disaster management cycle by contributing to both risk reduction and preparedness. Introducing sophisticated technologies such as mobile devices and applications, as well as using volunteered geographic information to display damage reports on a web-map, could further improve the damage surveying process in both Canada and abroad.

Horita, F. E. A., de Albuquerque, J. P., & Marchezini, V. (2018). Understanding the decision-making process in disaster risk monitoring and early-warning: A case study within a control room in Brazil. *International Journal of Disaster Risk Reduction*, *28*(September 2017), 22–31. https://doi.org/10.1016/j.ijdrr.2018.01.034

The tasks of disaster risk monitoring and early warning are an important means of improving the efficiency of disaster response and preparedness. However, although the current works in this area have sought to provide a more accurate and better technological infrastructure of systems to support these tasks, they have failed to examine key features that may affect the decision-making. In light of this, this paper aims to provide an understanding of the decision-making process in control rooms for disaster risk monitoring and early warning. This understanding is underpinned by a conceptual framework, which has been developed in this work and describes factors that influence the decision-making. For doing so, data were collected through a series of semi-structured interviews and participatory observations and later evaluated with members of the control room of the Brazilian Center for Monitoring and Early Warning of Natural Disasters (Cemaden). The study findings provided a solid basis for designing the conceptual framework of the essential factors required by the decision-makers. These factors are separated into two groups: 1) the “dimensions” of decision-making (i.e., the type of hazard, the phase of the disaster risk, the location, and area of expertise of the operators) and the “pillars” of decision-making (i.e., the tasks, their required information, useful data sources, and the decision rule). Finally, the contributions achieved in this study may help operators to understand and propose proactive measures that could improve their decision-making, overcome uncertainties, standardize the team’s decision-making, and put less pressure on operators.

Jaligot, R., Wilson, D. C., Cheeseman, C. R., Shaker, B., & Stretz, J. (2016). Applying value chain analysis to informal sector recycling: A case study of the Zabaleen. *Resources, Conservation and Recycling*, *114*, 80–91. https://doi.org/10.1016/j.resconrec.2016.07.006

A methodology has been developed to apply value chain analysis (VCA) to the informal recycling sector, and demonstrated using the Zabaleen in Cairo, Egypt as a case study. The VCA methodology provides a ‘toolkit’ comprising four stages. The first involves mapping the value chain and has been demonstrated using the recycling of polyethylene terephthalate (PET) bottles as the particular example. Stage 2 tabulates the value added at each step in the value chain; this has been demonstrated for different types of plastics as well as other recycled fractions. Stage 3 identifies and then applies a set of indicators for the development of the informal sector recycling value chain in order to address technical and socio-economic challenges. The indicators proposed are in three categories: connections in the value chain, waste valorisation and the enabling environment. Stage 4 involves developing a system dynamic map that shows connections between the indicators, and the stocks and flow variables in the value chain. In particular, it identifies the most

highly connected indicators on which to focus interventions, as these are likely to have the greatest impact on the overall system. For the Zabaleen, these are improving the quality of waste inputs into the value chain through source segregation, optimising access to waste and upgrading recycling activities through access to finance and technical knowledge.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Kelman, I., Ahmed, B., Esraz-Ul-Zannat, M., Saroar, M. M., Fordham, M., & Shamsudduha, M. (2018). Warning systems as social processes for Bangladesh cyclones. *Disaster Prevention and Management: An International Journal*, *27*(4), 370–379. https://doi.org/10.1108/DPM-12-2017-0318
Purpose: The purpose of this paper is to connect the theoretical idea of warning systems as social processes with empirical data of people's perceptions of and actions for warning for cyclones in Bangladesh. Design/methodology/approach: A case study approach is used in two villages of Khulna district in southwest Bangladesh: Kalabogi and Kamarkhola. In total, 60 households in each village were surveyed with structured questionnaires regarding how they receive their cyclone warning information as well as their experiences of warnings for Cyclone Sidr in 2007 and Cyclone Aila in 2009. Findings: People in the two villages had a high rate of receiving cyclone warnings and accepted them as being credible. They also experienced high impacts from the cyclones. Yet evacuation rates to cyclone shelters were low. They did not believe that significant cyclone damage would affect them and they also highlighted the difficulty of getting to cyclone shelters due to poor roads, leading them to prefer other evacuation options which were implemented if needed. Originality/value: Theoretical constructs of warning systems, such as the First Mile and late warning, are rarely examined empirically according to people's perceptions of warnings. The case study villages have not before been researched with respect to warning systems. The findings provide empirical evidence for long-established principles of warning systems as social processes, usually involving but not relying on technical components.

Kumar, D., & Rajeev, P. V. (2016). Value Chain: a Conceptual Framework. *International Journal of Information Engineering and Management Sciences*, *7*(1), 74–77.
The prime objective of this article is to deepen the understanding of the value concept as well as to enlighten the role of value to create a chain which provides a basic framework for the development of goods or services. Any value adding activities or strategy which enlighten the customer satisfaction. The value chain is one of the recent and most popular trends to days. The

concept of value in value chain is multifaceted and complicated. This article focusing on efforts and commitment to understand really what it means to provides value to customers, how added value which actually customers' needs and provides wealth to all stakeholders who involved. There is no any specific ways to add value in goods or services but it emphasized the ways which minimize cost and time without compromise the quality of the products in an effective and efficient ways. It tried to summarize few available literatures which gave a little glimpse of value chain and its necessity for survival of the company and how to fulfill the actual needs and demands of the customers in present era.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020a). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020b). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground

transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., & Mills, B. (2021). *Weather-Water-Climate Value Chain(s): Giving VOICE to the Characterization of the Economic Benefits of Hydro-Met Services and Products* (Vol. 3, Issue March). American Meteorological Society.
This study presents the concept of the Earth system observations, science, and services (ESOSS) information value chain. The value chain concept can be used to characterize the process of the creation, communication, and use of weather, water (fresh and salt), and climate information and knowledge from observations, research (basic and applied), modeling, forecasting, dissemination, decision support, and associated services through market transactions and the provision of nonmarket goods and services. The value chain—perhaps better conceived of as a process—involves a broad range of stakeholders with varying resources, objectives, and constraints that shape the nature and translation of the information as it moves from observations to end-user decisions. Understanding these processes, stakeholders, and decisions and outcomes is fundamental to identifying, measuring, and demonstrating the socioeconomic value of ESOSS. In this paper we present and discuss an initial approach to operationalize the value chain concept and how the broad set of social sciences—in addition to economics—can be used to study and improve the process. Focusing on information and socioeconomic value as one approach to discussing the information process, we propose a framework for elucidating value chains called the Value of Information Characterization and Evaluation or VOICE. The intent of this framework is to provide an initial prototype that could be leveraged and further developed to encourage the use of the value chain concept in studies of ESOSS. We present several brief case studies to illustrate different ways the value chain concept can help us understand, communicate, and enhance societal benefits of ESOSS. This study is part of an ongoing AMS Policy Program project on valuation that is supported, primarily, by a grant from the National Oceanic and Atmospheric Administration (NA19NWS4620018). The project consists of studies (including this one) and related capacity-building efforts to enable improved understanding, communication, and enhancement of societal benefits of information and services in weather, water (fresh and salt), and climate. Dr. Paul Higgins' 2021 AMS Policy Program paper "Societal Benefits of Earth System Observations, Science, and Services: Understanding, communication, and enhancement for weather, water (fresh and salt) and climate" further explores the role of ESOSS in modern society, particularly as they relate to weather, water, and climate to 1) im…

Leach, M., & Scoones, I. (2006). The Slow Race: Making Technology Work For The Poor. *Demos*, 7–73.
Citizen engagement is vital to ensure that science and technology respond to the challenges of international development ..

Levi¨akangas, P. (2009). Valuing meteorological information. *Meteorological Applications*, *101*(February), 91–101. https://doi.org/10.1002/met
This paper approaches the value of meteorological information from the perspectives of value engineering, pricing or valuation techniques and information economics. The value of information can be looked at from at least two angles: the value of information to the decision maker and the value of information realized through the impact occurring as a result actions and decisions based on information. The value of information is not a singular, uniform concept. It consists of multiple attributes weighed in different ways by different actors who evaluate information according to their own particular preferences. When designing information value chains the value build-up and relative importance of different attributes in different sections of the chain cannot be neglected. There are multiple methods and techniques for measuring the value, but these must be applied

with care, being aware of the relevant attributes and in which part of the information value chain the measurement takes place. With the valuation tools described in this paper, the valuation problem can be clarified and appropriate methods selected.

Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., SM, H., Jeanneret, T., & Nelson, R. (2016). *Adaptive value chain approaches. Understanding adaptation in food value chains* (Issue June).

The impacts of climate change are felt along the whole chain of actors that produce, handle, process and market agri-food products. This project aims to help agri-food companies to systematically identify, assess, prioritise and act against risks and to seize opportunities that extreme weather and a changing climate might offer to their chains using a value chain approach. A holistic and systematic evaluation of the risks that climate change poses, both direct and indirect, is crucial for adaptation planning. Understanding the complexity of interactions between biophysical, social and economic drivers in the context of climate change enables businesses within a value chain to have line of sight of indirect, but impactful, effects. It also enables businesses, from farming all the way to retailing, to begin to understand their 'tipping points'' better – where the impacts of multiple events along the value chain result to one or multiple stages of the chain unable to recover or remain competitive. There are three key outcomes from this study: 1. Our study has found that climate change, in itself, is not enough to encourage consumers to accept an adapted product, because there is a lack of understanding of how climate change can impact day-to-day life in general. At present, adaptation for agri-food businesses serves as a risk mitigation strategy, rather than a marketing opportunity. This however, may prove to be a competitive advantage for those who are in touch with consumer sentiment on adaptation, as sentiments may change in the future. 2. Value chain adaptation needs to consider the impact of any action on the value created and received by the chain. Our study has found that approaching value chain adaptation using a future storylines approach allows agri-food businesses to consider not only the adaptation benefits of a strategy, but also benefits to GHG mitigation and competitiveness. The process we have developed here enables business to gauge the merits of an adaptation action against multiple, and potentially competing, priorities. 3. Based on the findings of this study, an adapted value chain is one that is able to sustain its competitive advantage in a changing climate. A non-adapted value chain can only continue to exist up to a certain point where climate and weather risk and threats, both direct and indirect, are insurmountable and hence the value chain can no longer be profitable on an ongoing basis. Non- adapted value chains also miss opportu…'

Lin, H.-I., Liou, J.-L., & Hsu, S.-H. (2019). Economic Valuation of Public Meteorological Information Services—A Case Study of Agricultural Producers in Taiwan. *Atmosphere*, *10*(12), 753. https://doi.org/10.3390/atmos10120753

Most meteorological information services in Taiwan are currently provided by the Central Weather Bureau, Ministry of Transportation and Communications. As agricultural production activities are sensitive to weather and climate conditions, meteorological information services are more important for agricultural decision-makers than those in other sectors. This study uses the contingent valuation method to estimate the economic value of meteorological information services in Taiwan for agricultural producers. We assess the agricultural producers' willingness to pay (WTP) for the meteorological information services, conducting a national face-to-face survey of 400 registered farmers in 20 municipalities in Taiwan in 2013. The results show the adjusted WTP for every agricultural household each year with a 95% confidence interval which ranges from 56.06 US dollars to 90.92 US dollars. The inferred annual economic value of meteorological information services for agricultural producers in Taiwan is between 28.06 million US dollars and 45.51 million US dollars. Moreover, the agricultural producers' subjective assessment of weather forecast

accuracy, farm size, and first bid price significantly affect the amount agricultural producers are willing to pay for meteorological information services.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Lopez, A., Coughlan de Perez, E., Bazo, J., Suarez, P., van den Hurk, B., & van Aalst, M. (2020). Bridging forecast verification and humanitarian decisions: A valuation approach for setting up action-oriented early warnings. *Weather and Climate Extremes*.
https://doi.org/10.1016/j.wace.2018.03.006
Empirical evidence shows that acting on early warnings can help humanitarian organizations reduce losses, damages and suffering while reducing costs. Available forecasts of extreme events can provide the information required to automatically trigger preparedness measures, while 'value of information'' approaches can, in principle, guide the selection of forecast thresholds that make early action preferable to inaction. We acknowledge here that, for real-world humanitarian situations, the value of information approach accurately estimates the value of forecasts only if key factors relevant for the humanitarian sector are taken into account. First, the negative consequences of acting in vain are significant and must be factored in. Secondly, the "most valuable" forecast thresholds depend on criteria beyond expenses reduction, and this choice must be explicitly considered in funding mechanisms for early warning products and services. Two options to guide this selection are examined: a maximizing criterion for cost effectiveness, and a satisficing criterion for loss avoidance. Third, decision-makers must be able to confidently assess whether the forecast threshold they are selecting is robust to all possible cost/loss structures for the action in question. Based on these considerations, we explore the application of the valuation approach to select which forecasts (magnitude, probability and lead time) should trigger humanitarian actions. Using a basic example of ensemble precipitation forecast to prepare for potential floods, we discuss how the valuation approach can be used to select probability thresholds that trigger early action, and some of the generalisations required to make this applicable to a wider range of humanitarian situations.'

Martinez, A. B. (2020). Forecast accuracy matters for hurricane damage. *Econometrics*, *8*(2).
https://doi.org/10.3390/econometrics8020018
I analyze damage from hurricane strikes on the United States since 1955. Using machine learning methods to select the most important drivers for damage, I show that large errors in a hurricane's

predicted landfall location result in higher damage. This relationship holds across a wide range of model specifications and when controlling for ex-ante uncertainty and potential endogeneity. Using a counterfactual exercise I find that the cumulative reduction in damage from forecast improvements since 1970 is about $82 billion, which exceeds the U.S. government's spending on the forecasts and private willingness to pay for them.

Matte, S., Boucher, M.-A., Boucher, V., & Fortier Filion, T.-C. (2017). Moving beyond the cost–loss ratio: economic assessment of streamflow forecasts for a risk-averse decision maker. *Hydrology and Earth System Sciences*, *21*(6), 2967–2986. https://doi.org/10.5194/hess-21-2967-2017
<p>Abstract. A large effort has been made over the past 10 years to promote the operational use of probabilistic or ensemble streamflow forecasts. Numerous studies have shown that ensemble forecasts are of higher quality than deterministic ones. Many studies also conclude that decisions based on ensemble rather than deterministic forecasts lead to better decisions in the context of flood mitigation. Hence, it is believed that ensemble forecasts possess a greater economic and social value for both decision makers and the general population. However, the vast majority of, if not all, existing hydro-economic studies rely on a cost–loss ratio framework that assumes a risk-neutral decision maker. To overcome this important flaw, this study borrows from economics and evaluates the economic value of early warning flood systems using the well-known Constant Absolute Risk Aversion (CARA) utility function, which explicitly accounts for the level of risk aversion of the decision maker. This new framework allows for the full exploitation of the information related to a forecasts' uncertainty, making it especially suited for the economic assessment of ensemble or probabilistic forecasts. Rather than comparing deterministic and ensemble forecasts, this study focuses on comparing different types of ensemble forecasts. There are multiple ways of assessing and representing forecast uncertainty. Consequently, there exist many different means of building an ensemble forecasting system for future streamflow. One such possibility is to dress deterministic forecasts using the statistics of past error forecasts. Such dressing methods are popular among operational agencies because of their simplicity and intuitiveness. Another approach is the use of ensemble meteorological forecasts for precipitation and temperature, which are then provided as inputs to one or many hydrological model(s). In this study, three concurrent ensemble streamflow forecasting systems are compared: simple statistically dressed deterministic forecasts, forecasts based on meteorological ensembles, and a variant of the latter that also includes an estimation of state variable uncertainty. This comparison takes place for the Montmorency River, a small flood-prone watershed in southern central Quebec, Canada. The assessment of forecasts is performed for lead times of 1 to 5 days, both in terms of forecasts' quality (relative to the corresponding record of observations) and in terms of economic value, using t…

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F., Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704
Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common

target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Miller, A. (2022). *What's it worth? Four Perspectives on the Valuation of the Weather, Water, Climate Enterprise*. American Meteorological Society.
Earth system observations, science, and services (OSS) inform and guide the activities of virtually every economic sector and innumerable institutions underlying modern civilization. OSS are a fundamental component of efforts to meet basic human needs including food, shelter, energy, health and safety. At the same time, opportunities to enhance the societal benefits of OSS are vast and increasing. Better understanding of the weather, water, and climate (WWC) enterprise's value could: create new opportunities to apply OSS for societal benefit; help justify public investments in OSS; and guide future investments in OSS to help ensure that they confer the maximum possible benefit to society. As a result, there is great need for efforts to understand, assess, communicate, and advance the value of OSS. This study synthesizes the results of a multi-year project on the valuation of Earth system OSS. The conclusions are based on four studies relating to different aspects of the societal benefits of Earth system OSS: 1) Societal Benefits of Weather, Water, and Climate: Understanding, Communication, and Enhancement (bit.ly/sbwxc), 2) The Value Chain of Earth System Observations, Science, and Services (bit.ly/3uAHjXG), 3) Three Policies Shape Enterprise Value: Minor Adjustments Could Enhance the Societal Benefit (https://bit.ly/3Wxpolicies) and 4) Options for Enhancing the Value of the NOAA Weather-Ready Nation Ambassador Initiative (https://bit.ly/30qRnY1).

Millner, A. (2009). What is the true value of forecasts? *Weather, Climate, and Society*, *1*(1), 22–37. https://doi.org/10.1175/2009WCAS1001.1
Understanding the economic value of weather and climate forecasts is of tremendous practical importance. Traditional models that have attempted to gauge forecast value have focused on a best-case scenario, in which forecast users are assumed to be statistically sophisticated, hyperrational decision makers with perfect knowledge and understanding of forecast performance. These models provide a normative benchmark for assessing forecast value, but say nothing about the value that actual forecast users realize. Real forecast users are subject to a variety of behavioral effects and informational constraints that violate the assumptions of normative models. In this paper, one of the normative assumptions about user behavior is relaxed - users are no longer assumed to be in possession of a perfect statistical understanding of forecast performance. In the case of a cost-loss decision, it is shown that a model of users' forecast use choices based on the psychological theory of reinforcement learning leads to a behavioral adjustment factor that lowers the relative value score that the user achieves. The dependence of this factor on the user's decision parameters (the ratio of costs to losses) and the forecast skill is deduced. Differences between the losses predicted by the behavioral and normative models are greatest for users with intermediate cost-loss ratios, and when forecasts have intermediate skill. The relevance of the model as a tool for directing user education initiatives is briefly discussed, and a direction for future research is proposed.

Moon, B., & Harrison, E. (2021). *Queensland's New Framework for Flood Risk Management Economic Assessments*. Copernicus GmbH. https://doi.org/10.5194/egusphere-egu21-1926
Flooding is one of Australia's more prevalent natural disasters, causing injury to people, damage to property and infrastructure, losses to business earnings, increases to the costs of providing government services, and intangible impacts such as environmental or social damages. Australia's

National Strategy for Disaster Resilience (2011) and Queensland's Strategy for Disaster Resilience (2017) provide the overarching framework to build disaster resilient communities in Queensland and Australia. Within this, Government has the role of identifying and implementing strategies to manage the disaster risks. The National Strategy recognises that consistent information on the costs and benefits of risk management options, which considers the full impacts on the social, built, economic and natural environments, is required to support this. In Australia economic assessments for flood management projects have traditionally focused on the tangible damages of flooding, particularly to property. Other impacts of flooding, such as environmental or social impacts, are typically considered qualitatively or assessed through a multi-criteria assessment. The absence of state and/or national guidance on undertaking such assessments has also led to a wide variety of approaches, methodologies, data and results. This creates an unnecessary layer of complexity when seeking to compare and prioritise projects, within states and across Australia. It can also lead to the underestimation of the return on investment resulting from flood risk management projects, due to the incomplete capture of benefits. The Brisbane River Strategic Floodplain Management Plan (SFMP) was publicly released in 2019 and includes 52 actions aimed to improve the resilience, safety and prosperity of the community and businesses in the Brisbane River floodplain, and Queensland more widely. The Queensland Reconstruction Authority (QRA) was allocated the lead to implement Action FM7 'Extend the economic framework established in the Strategic Plan and Technical Evidence Report to include community awareness and resilience, disaster management and land use planning.'' The Economic Assessment Framework for Flood Risk Management Projects is due for publication in early 2021. It was developed through a collaborative process with other state governments, universities, private practitioners, and key stakeholders to road test a number of approaches and develop the guideline to support a consistent methodology for eco…'

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1 This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating*

Uncertainty for Better Decisions Using Weather and Climate Forecasts. National Academies Press. https://doi.org/10.17226/11699

Parsons, M., & Foster, H. (2020). *Reimagining program monitoring and evaluation for disaster resilience outcomes*.
Emergency service and emergency management agencies have undertaken to better understand and support disaster resilient communities. These agencies have developed resilience- based doctrine, policy, programs and projects to strengthen and support communities before, during and after emergencies. Community disaster resilience is a goal of many community engagement programs, but the contributions of these programs to disaster resilience can be difficult to quantify and assess. The gap in the sector is to monitor and evaluate the impact that policies and programs are having collectively in building community disaster resilience. This project was proposed by Emergency Management Victoria through the Tactical Research Fund of the Bushfire and Natural Hazards CRC, and supported by AFAC. It examines new approaches to monitoring and evaluating the contributions of agency programs to community disaster resilience.

Perera, D., Seidou, O., Agnihotri, J., Rasmy, M., Smakhtin, V., Coulibaly, P., & Mehmood, H. (2019). *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects 08. UNU-INWEH Report Series, Issue 08* (Issue August). https://doi.org/10.13140/RG.2.2.28339.78880
Floods are major water-related disasters that affect millions of people resulting in thousands of mortalities and billiondollar losses globally every year. Flood Early Warning Systems (FEWS) - one of the floods risk management measures - are currently operational in many countries. The UN Office for Disaster Risk Reduction recognises their importance and strongly advocates for an increase in their availability under the targets of the Sendai Framework for Disaster Risk Reduction, and Sustainable Development Goals (SDGs). However, despite widespread recognition of the importance of FEWS for disaster risk reduction (DRR), there's a lack of information on their availability and status around the world, their benefits and costs, challenges and trends associated with their development. This report contributes to bridging these gaps by analyzing the responses to a comprehensive online survey with over 80 questions on various components of FEWS (risk knowledge, monitoring and forecasting, warning dissemination and communication, and response capabilities), investments into FEWS, their operational effectiveness, benefits, and challenges. FEWS were classified as technologically "basic", "intermediate" and "advanced" depending on the existence and sophistication of FEWS` components such as hydrological data collection systems, data transfer systems, flood forecasting methods, and early warning communication methods. The survey questionnaire was distributed to flood forecasting and warning centers around the globe; the primary focus was developing and least-developed countries (LDCs). The questionnaire is available here: https://inweh.unu.edu/questionnaireevaluation-of-flood-early-warning-systems/ and can be useful in its own right for similar studies at national or regional scales, in its current form or with case-specific modifications.

Perrels, A. (2020). Quantifying the uptake of climate services at micro and macro level. *Climate Services*, *17*(January), 100152. https://doi.org/10.1016/j.cliser.2020.100152
Quantification and communication of the expected net benefits of climate services for particular types of users and society at large has been hitherto a rather weak element in the deployment of climate services. This article discusses the challenges of quantification and warns that there is no universal method for this. It provides a general structure to assess benefit-cost ratios of new climate services. From this framework proper valuation of climate services can be developed. It also underscores the significance of aptness for verification of the performance of a climate service, as well as contextual effects, such as market form, regulations, and pace of innovation. Only for subsets of seasonal climate services the so-called cost-loss approach and some other

forecast accuracy-oriented approaches are applicable. For other types of climate services performance indicators need to be developed. Furthermore, for some types of effectiveness evaluations more user/use oriented indicators are necessary, even if forecast accuracy based approaches would be applicable as well, as these approaches do not guarantee that the highest utility for the user has been achieved using the climate services. The proposed framework emphasizes the inclusion of competitive conditions under which the CS users operate, the role of information exclusiveness vs. sharing, the role of adequate quality assurance and communication, the effects learning and R&D for climate services.

Perrels, A., Le, T. T., Cortekar, J., Hoa, E., & Stegmaier, P. (2020). How much unnoticed merit is there in climate services? *Climate Services*, *17*(June 2019), 100153. https://doi.org/10.1016/j.cliser.2020.100153
The European Union and a growing number of its Member States have become active in promoting and funding the development and to some extent deployment of climate services. Despite significant progress in the creation of large high-quality open access repositories of basic climate data and despite the growing number of pilot projects with more tailored co-designed climate services for various sectors, no real breakthrough in the uptake of climate services has been witnessed. Two projects EU-MACS and MARCO, funded from the EU H2020 programme, assessed what the obstacles to uptake were and how these could be alleviated. This article discusses main outcomes from these projects, with special attention for the need to better underpin the concept of climate services and the justification to promote their use, e.g. by means of the merit good concept. The projects also identified the need for a climate services market observatory. Other articles in the same special issue provide more in-depth insights regarding several subjects.

Rabonza, M. L., & Lallemant, D. (2022). *Shedding light on avoided disasters: Measuring the invisible benefits of disaster risk management using probabilistic counterfactual analysis*. Global Assessment Report on Disaster Risk Reduction

Risbey, J. S., Squire, D. T., Black, A. S., DelSole, T., Lepore, C., Matear, R. J., Monselesan, D. P., Moore, T. S., Richardson, D., Schepen, A., Tippett, M. K., & Tozer, C. R. (2021). Standard assessments of climate forecast skill can be misleading. *Nature Communications*, *12*(1), 4346. https://doi.org/10.1038/s41467-021-23771-z
Assessments of climate forecast skill depend on choices made by the assessor. In this perspective, we use forecasts of the El Niño-Southern-Oscillation to outline the impact of bias-correction on skill. Many assessments of skill from hindcasts (past forecasts) are probably overestimates of attainable forecast skill because the hindcasts are informed by observations over the period assessed that would not be available to real forecasts. Differences between hindcast and forecast skill result from changes in model biases from the period used to form forecast anomalies to the period over which the forecast is made. The relative skill rankings of models can change between hindcast and forecast systems because different models have different changes in bias across periods.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these

could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to calculate a "User Brier Score'' (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the 'regret'' of serious injury and the "pain'' of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from 'complete misses'' – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.'''''''''

Rothery, C., Strong, M., Koffijberg, H. (Erik), Basu, A., Ghabri, S., Knies, S., Murray, J. F., Sanders Schmidler, G. D., Steuten, L., & Fenwick, E. (2020). Value of Information Analytical Methods: Report 2 of the ISPOR Value of Information Analysis Emerging Good Practices Task Force. *Value in Health*, *23*(3), 277–286. https://doi.org/10.1016/j.jval.2020.01.004
The allocation of healthcare resources among competing priorities requires an assessment of the expected costs and health effects of investing resources in the activities and of the opportunity cost of the expenditure. To date, much effort has been devoted to assessing the expected costs and health effects, but there remains an important need to also reflect the consequences of uncertainty in resource allocation decisions and the value of further research to reduce uncertainty. Decision making with uncertainty may turn out to be suboptimal, resulting in health loss. Consequently, there may be value in reducing uncertainty, through the collection of new evidence, to better inform resource decisions. This value can be quantified using value of information (VOI) analysis. This report from the ISPOR VOI Task Force describes methods for computing 4 VOI measures: the expected value of perfect information, expected value of partial perfect information (EVPPI), expected value of sample information (EVSI), and expected net benefit of sampling (ENBS). Several methods exist for computing EVPPI and EVSI, and this report provides guidance on selecting the most appropriate method based on the features of the decision problem. The report provides a number of recommendations for good practice when planning, undertaking, or reviewing VOI analyses. The software needed to compute VOI is discussed, and areas for future research are highlighted.

Sangha, K. K., Evans, J., Edwards, A., & Russell-Smith, J. (2019). Measuring environmental losses from natural disasters: A case study of costing bushfires in the Northern Territory. *Australian Journal of Emergency Management*, *34*(4), 31–39.
Natural hazards cause sustained loss to the environment, yet the economic costs are largely not accounted for due to a lack of market measures. This research applies methods of global and

national costing and proposes an integrated framework that incorporates marketable and non-marketable losses including those to the environment. These methods are applied to bushfires in the Northern Territory for estimating the cost of loss of ecosystem services as a surrogate. These fire events affect 20 per cent of the total land area annually (based on 18 years average from 2000-2018) and cost $~$150 million per annum. Losses were greatest on the Indigenous lands, followed by pastoral and conservation areas. It is calculated that the effect of bushfires on "loss of wellbeing" for the remote Indigenous population is, conservatively, $272 million per year. An understanding of the costs of loss of environment is essential to develop emergency management policies that are effective in enhancing the resilience of communities.

Sangha, K. K., Russell-Smith, J., Evans, J., & Edwards, A. (2020). Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction*, *49*. https://doi.org/10.1016/j.ijdrr.2020.101619
Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environmental when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank [1]; and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was estimated at AU$95-132million per year. Evaluating such costs for loss of Indigenous peoples' well-being who reside in remote parts of the NT, presents an estimate of AU$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Sättele, M., Bründl, M., & Straub, D. (2016). Quantifying the effectiveness of early warning systems for natural hazards. *Natural Hazards and Earth System Sciences*, *16*(1), 149–166. https://doi.org/10.5194/nhess-16-149-2016
Early warning systems (EWSs) are increasingly applied as preventive measures within an integrated risk management approach for natural hazards. At present, common standards and detailed guidelines for the evaluation of their effectiveness are lacking. To support decision-makers in the identification of optimal risk mitigation measures, a three-step framework approach for the evaluation of EWSs is presented. The effectiveness is calculated in function of the technical and the inherent reliability of the EWS. The framework is applicable to automated and non-automated EWSs and combinations thereof. To address the specifics and needs of a wide variety of EWS designs, a classification of EWSs is provided, which focuses on the degree of automations encountered in varying EWSs. The framework and its implementation are illustrated through a series of example applications of EWS in an alpine environment.

Tall, A., Coulibaly, J. Y., & Diop, M. (2018). Do climate services make a difference? A review of evaluation methodologies and practices to assess the value of climate information services for farmers: Implications for Africa. In *Climate Services* (Vol. 11, pp. 1–12). Elsevier B.V. https://doi.org/10.1016/j.cliser.2018.06.001
This paper addresses the need for more rigorous evaluation of climate service projects and investments given the existence of little evidence on the actual value of climate services and the

challenges that hamper current efforts to evaluate the impact of climate services for the agricultural community. Based on our in-depth review of existing literature from Africa and around the world, we find that rigorous methods for evaluating climate services span qualitative context-based and quantitative methodological approaches. The few studies that have been conducted so far to determine the value of climate services for farmers were for initiatives that incorporated in their design an evaluation framework. This highlights the importance of experimentally designing climate service programs for evaluation based on an impact pathway, rather than leaving evaluation as an after-thought. To strengthen the evidence base on the actual value of climate information services, complementary evaluation efforts will need to draw on a combination of qualitative and quantitative approaches, be sensitive to the heterogeneity of user groups, and go beyond the focus on agricultural production to include other dimensions of the agricultural system.

Tatano, H., & Kajitani, Y. (2022). *Methodologies for estimating the economic impacts of natural disasters*. https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499
This book outlines methodologies to estimate the economic impacts of natural disasters based on business surveys conducted after large disasters in Japan. By including numerous observations on business activities in past disasters and the validations of both engineering and economic models based on these data sets, this book appeals to practitioners who estimate the regional economic impacts as well as to students and young professionals in various fields who conduct disaster impact studies. The book consists of 7 chapters and includes theories and practices, which help readers to interlink the estimation methods with real-world problems. The study primarily focuses on cases in Japan, but the methods employed can be generalized and applied in other countries. BoM staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499

Tesfaye, A., Hansen Girma, J. W., Kassie, T., & Radeny, M. (n.d.). *Estimating the economic value of climate services for strengthening resilience of smallholder farmers to climate risks in Ethiopia: A choice experiment approach*. www.ccafs.cgiar.org

Thiboult, A., Anctil, F., & Ramos, M. H. (2017). How does the quantification of uncertainties affect the quality and value of flood early warning systems? *Journal of Hydrology*, *551*, 365–373. https://doi.org/10.1016/j.jhydrol.2017.05.014
In an operational context, efficient decision-making is usually the ultimate objective of hydrometeorological forecasts. Because of the uncertainties that lay within the forecasting process, decisions are subject to uncertainty. A better quantification of uncertainties should provide better decisions, which often translate into optimal use and economic value of the forecasts. Six Early Warning Systems (EWS) based on contrasted forecasting systems are constructed to investigate how the quantification of uncertainties affects the quality of a decision. These systems differ by the location of the sources of uncertainty, and the total amount of uncertainty they take into account in the forecasting process. They are assessed with the Relative Economic Value (REV), which is a flexible measure to quantify the potential economic benefits of an EWS. The results show that all systems provide a gain over the case where no EWS is used. The most complex systems, i.e. those that consider more sources of uncertainty in the forecasting process, are those that showed the most reduced expected damages. Systems with better accuracy and reliability are generally the ones with higher REV, even though our analysis did not show a clear-cut relationship between overall forecast quality and REV in the context investigated.

Toolkit for value chain analysis and market development integrating climate resilience and gender responsiveness (Issue November). (2020).
Integrating agriculture in National Adaptation Plans (NAP-Ag) Programme

Wilson, E. C. F. (2015). A Practical Guide to Value of Information Analysis. *PharmacoEconomics*, *33*(2), 105–121. https://doi.org/10.1007/s40273-014-0219-x
Value of information analysis is a quantitative method to estimate the return on investment in proposed research projects. It can be used in a number of ways. Funders of research may find it useful to rank projects in terms of the expected return on investment from a variety of competing projects. Alternatively, trialists can use the principles to identify the efficient sample size of a proposed study as an alternative to traditional power calculations, and finally, a value of information analysis can be conducted alongside an economic evaluation as a quantitative adjunct to the 'future research' or 'next steps' section of a study write up. The purpose of this paper is to present a brief introduction to the methods, a step-by-step guide to calculation and a discussion of issues that arise in their application to healthcare decision making. Worked examples are provided in the accompanying online appendices as Microsoft Excel spreadsheets.

WMO. (2015). Valuing Weather and Climate : In *World Meteorological Organization* (Vol. 09, Issue 1153).
Since the 1950s, the interest in the economic valuation of hydrometeorological services has been growing in the hydrometeorological, climate and economics communities. As part of a process of improving the understanding of SEBs of hydrometeorological services, the World Meteorological Organization's (WMO) high-level international conference "Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate, and Water Services", held in Madrid in 2007, agreed on a Statement and Action Plan that sets out a comprehensive strategy for the enhancement, development and application of improved methodologies for evaluating the benefits from the operation of NMHSs. The present publication addresses the growing interest and need identified during this conference and in the years since it took place. It is directed at the hydrometeorological and socioeconomic research and service-provider communities, as well as officials from government and international development agencies; but the general public will also find an interest in understanding the role weather, climate and water information plays in their daily life. World Bank Group, with a current hydrometeorological investment portfolio of around US$ 500 million, estimates that globally improved weather, climate, and water observation and forecasting could lead to up to US$ 30 billion per year in increases in global productivity and up to US$ 2 billion per year in reduced asset losses.3 This scale of improved productivity could be crucial to lifting out of poverty the millions around the world whose livelihoods are at risk of climate shocks. The recognition of these benefits and their contribution to sustainable development, poverty reduction and shared prosperity is motivating the development community to invest more holistically in modernizing hydrometeorological services4 and ensuring that service providers are better connected with service users. The review of all past and current SEB analysis performed for this publication indicates that properly planned investments in hydrometeorological services provide significant benefits relative to their costs. While the publication attempts to capture the currently available wealth of experience and expertise across different contexts, it is not the end point for developing global knowledge on SEB analysis of hydrometeorological studies. Indeed, as we move to implement new global commitments on sustainable development goals, climate change adaptation an…

World Bank. (2022). *Strengthening Hydromet and Early Warning Systems and Services in Tunisia A roadmap*.
This roadmap uses a series of progress models to measure Tunisia's Meteorological and Hydrological Service Providers' capacities in several key areas: service delivery, observation and telecommunication, and modeling and forecasting. Tunisia is highly vulnerable to natural hazards. Hydrometeorological (Hydromet) hazards, such as various types of floods, droughts, heat extremes

and heatwaves, and sea level rise pose a direct threat to lives; impact livelihoods; and retard development. Underlying processes, including climate change, population growth, land use changes, and urbanization, mean that growing numbers of Tunisians face hydrometeorological hazards, especially in coastal areas. National Meteorological and Hydrological Services (NMHSs) provide Hydromet and early warning services and tailor them to different users. Given current and predicted Hydromet-related hazards, and as in other countries of the Middle East and North Africa (MENA) region, Tunisia needs Hydromet information to protect people, economies, and development gains. To contain growing economic losses from hydrometeorological hazards, adapt to climate change, and guide economic development across different sectors, Tunisia needs to invest in its multi-hazard early warning systems, and hydromet services.

World Meteorological Organization. (2008). Guidelines on communicating forecast uncertainty. *Wmo Td-1722*, *PWS-18*, 25 pages.
These Guidelines address the issue of communicating forecast uncertainty. Although they include a discussion on the sources of uncertainty, and touch on the related science (e.g. probabilistic forecasting, the use of Numerical Weather Prediction (NWP) ensembles), this is not their focus. Rather, the emphasis is on how National Meteorological and Hydrological Services (NMHSs) can incorporate uncertainty information in their hydrometeorological forecast services, including the best ways to communicate this information to the benefit of users.

Yasitli, A. N. (2021). *Assessing the effectiveness of flood management : a comparative study between Turkey and the UK* (Issue June).
https://pure.port.ac.uk/ws/portalfiles/portal/43263956/Ali_Nedim_Yasitli_PhD_Thesis.pdf
The findings of the research revealed that in Turkey, the government adopts a predominantly reactive approach, while the UK has put in place policies and legislation for proactive flood management. Key legislation in the UK is the Flood and Water Management Act 2010, which advocates for the cooperation and sharing of information among all stakeholder entities within flood management, extending down to local community level. The reactive approaches in Turkey are characterised by non-definite laws that have caused ineffective planning, poor warning systems, and unorganised stakeholders within the flood management system. Additionally, flood management is lacking at the local community level in Turkey. Although the two countries have not achieved impeccable flood management in terms of preparedness, response, and recovery, this research indicates that the UK system is more effective than the Turkish system. The study makes some recommendations for improving flood management in the two countries, notably that Turkey should improve its flood planning initiatives and early warning system. Also, Turkey should improve the level of institutional learning and integrate more flood management stakeholders. In the context of the UK, the study recommends that flood management should be improved, and that the early warnings should be implemented effectively during actual flooding events. Finally, there is a need to provide more frequent training and proper institutional learning for flood managers in both countries.

Yigitcanlar, T., Regona, M., Kankanamge, N., Mehmood, R., D'costa, J., Lindsay, S., Nelson, S., & Brhane, A. (2022). Detecting Natural Hazard-Related Disaster Impacts with Social Media Analytics: The Case of Australian States and Territories. *Sustainability (Switzerland)*, *14*(2).
https://doi.org/10.3390/su14020810
Natural hazard-related disasters are disruptive events with significant impact on people, communities, buildings, infrastructure, animals, agriculture, and environmental assets. The exponentially increasing anthropogenic activities on the planet have aggregated the climate change and consequently increased the frequency and severity of these natural hazard-related disasters, and consequential damages in cities. The digital technological advancements, such as monitoring

systems based on fusion of sensors and machine learning, in early detection, warning and disaster response systems are being implemented as part of the disaster management practice in many countries and presented useful results. Along with these promising technologies, crowdsourced social media disaster big data analytics has also started to be utilized. This study aims to form an understanding of how social media analytics can be utilized to assist government authorities in estimating the damages linked to natural hazard-related disaster impacts on urban centers in the age of climate change. To this end, this study analyzes crowdsourced disaster big data from Twitter users in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method and conducts sentiment and content analyses of location-based Twitter messages (n = 131,673) from Australia. The study informs authorities on an innovative way to analyze the geographic distribution, occurrence frequency of various disasters and their damages based on the geo-tweets analysis.

Zommers, Z., & Singh, A. (2014). Reducing disaster: Early warning systems for climate change. *Reducing Disaster: Early Warning Systems for Climate Change*, *9789401785*, 1–387. https://doi.org/10.1007/978-94-017-8598-3
Around the world, extreme weather events are becoming increasingly “the new normal” and are expected to increase in the 21st century as a result of climate change. Extreme weather events have devastating impacts on human lives and national economies. This book examines ways to protect people from hazards using early warning systems, and includes contributions from experts from four different continents representing 14 different universities, 8 government agencies and two UN agencies. Chapters detail critical components of early warning systems, ways to identify vulnerable communities, predict hazards and deliver information. Unique satellite images illustrate the transnational impact of disasters, while case studies provide detailed examples of warning systems. With contributors from the fields of economics, ethics, meteorology, geography and biology, this book is essential reading for anyone interested in disaster risk reduction or climate change.

Tools

Keywords: digital technology, decision thresholds, decision making probabilities, detection, disaster classification, economic framework, country hydromet diagnostics, flood modelling framework, framework, guide, expert elicitation, impact-based decision support, indicators, manual, policy, questionnaire, Sendai framework, Sendai framework for disaster risk reduction, strategies to solve solutions, survey, survey and observation strategies, surveys

Alliance for Hydromet Development. (2021). *HYDROMET GAP REPORT 2021 Alliance for Hydromet Development*.

Altvater, S., de Block, D., Bouwma, I., Dworak, T., Frelih-Larsen, A., Gorlach, B., Hermeling, C., Klostermann, J., Konig, M., Leitner, M., Marinova, N., McCallum, S., Naumann, S., Osberghaus, D., Prutsch, A., Reif, C., van de Sandt, K., Swart, R., Troltzsch, J., … Troltzsch, J. (2014). Adaptation Measures in the EU: Policies, Costs, and Economic Assessment (“Climate Proofing” of Key EU Policies). *SSRN Electronic Journal*, *February*. https://doi.org/10.2139/ssrn.2460266
The aim of this report is to ascertain priority concerns for further climate proofing action through opposing current EU efforts to different threats, and suggest complementary options (cf. chapter 3) for the following four sectors: (1) Energy, (2) Transport infrastructure, (3) Urban areas, and (4) Agriculture. A final selection of measures to be assessed with a view to their costs and economic,

social and environmental impacts was agreed at the first interim meeting with the Commission. Measures already part of EU wide assessment projects were not part of the assessment. In a first step (chapter 3) key policy areas have been screened to identify adaptation measures. A final selection of measures agreed with the Commission was further processed in terms of costing (chapter 4) and the assessment of impacts (chapter 5).

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S. (2016). *Use and perception of weather forecast information across Europe Journal: 4*(434), 1–2.
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Borga, M., Comiti, F., Ruin, I., & Marra, F. (2019). Forensic analysis of flash flood response. *WIREs Water*, *6*(2). https://doi.org/10.1002/wat2.1338
The last decade has witnessed the development of methodologies for the post-flood documentation of both hydrogeomorphological and social response to extreme precipitation. These investigations are particularly interesting for the case of flash floods, whose space–time scales make their observations by conventional hydrometeorological monitoring networks particularly challenging. Effective flash flood documentation requires post-flood survey strategies encompassing accurate radar estimation of rainfall, field and remote-sensing observations of the geomorphic processes, indirect reconstruction of peak discharges—as well eyewitness interviews. These latter can give valuable information on both flood dynamics and the related individual and collective responses. This study describes methods for post-flood surveys based on interdisciplinary collaborations between natural and social scientists. These surveys may help to better understand the links between hydrometeorological dynamics and geomorphic processes as well as the relationship between flood dynamics and behavioral response in the context of fast

space–time changes of flooding conditions.

CREWS. (2017). *Draft Consultation Document On Measuring Early Warning Access and Effectiveness*. the present consultation document aims to identify a set of metrics to provide guidance on how the effectiveness of, and access to, early warning systems can be measured, encompassing a conceptual framework of key elements, including sources of data and information and methodologies.

Cuthbertson, J., Archer, F., Robertson, A., & Rodriguez-Llanes, J. M. (2021). Improving disaster data systems to inform disaster risk reduction and resilience building in Australia: A comparison of databases. *Prehospital and Disaster Medicine*, *36*(5), 511–518. https://doi.org/10.1017/S1049023X2100073X
Objective: Disaster impact databases are important resources for informing research, policy, and decision making. Therefore, understanding the underpinning methodology of data collection used by the databases, how they differ, and quality indicators of the data recorded is essential in ensuring that their use as reference points is valid. Methods: The Australian Disaster Resilience Knowledge Hub (AIDRKH) is an open-source platform supported by government to inform disaster management practice. A comparative descriptive review of the Disaster Mapper (hosted at AIDRKH) and the international Emergency Events Database (EM-DAT) was undertaken to identify differences in how Australian disasters are captured and measured. Results: The results show substantial variation in identification and classification of disasters across hazard impacts and hazard types and a lack of data structure for the systematic reporting of contextual and impact variables. Conclusions: These differences may have implications for reporting, academic analysis, and thus knowledge management informing disaster prevention and response policy or plans. Consistency in reporting methods based on international classification standards is recommended to improve the validity and usefulness of this Australian database.

Dottori, F., Salamon, P., Bianchi, A., Alfieri, L., Hirpa, F. A., & Feyen, L. (2016). Development and evaluation of a framework for global flood hazard mapping. *Advances in Water Resources*, *94*, 87–102. https://doi.org/10.1016/j.advwatres.2016.05.002
Nowadays, the development of high-resolution flood hazard models have become feasible at continental and global scale, and their application in developing countries and data-scarce regions can be extremely helpful to increase preparedness of population and reduce catastrophic impacts.The present work describes the development of a novel procedure for global flood hazard mapping, based on the most recent advances in large scale flood modelling. We derive a long-term dataset of daily river discharges from the hydrological simulations of the Global Flood Awareness System (GloFAS). Streamflow data is downscaled on a high resolution river network and processed to provide the input for local flood inundation simulations, performed with a two-dimensional hydrodynamic model. All flood-prone areas identified along the river network are then merged to create continental flood hazard maps for different return periods at 30'' resolution. We evaluate the performance of our methodology in several river basins across the globe by comparing simulated flood maps with both official hazard maps and a mosaic of flooded areas detected from satellite images. The evaluation procedure also includes comparisons with the results of other large scale flood models. We further investigate the sensitivity of the flood modelling framework to several parameters and modelling approaches and identify strengths, limitations and possible improvements of the methodology.

Giraldo-Mendez, D., Martínez-Barón D Loboguerrero, A., & Co-authors. (n.d.). *Technical Agroclimatic Committees (MTA)*.
MTA is a dialogue process among a diversity of local actors including scientists, technicians,

representatives from the public and private sectors, and farmers, which seeks to understand the climate's possible behavior in a locality, and to generate recommendations to reduce risks associated with expected climate variability (Loboguerrero et al. 2018). This dialogue is then used to create an agroclimatic bulletin that contains the region's climate prediction, it is possible impact on crops for specific conditions in time and space, as well as recommendations around decision-making for each productive sector. The climatic predictions are generated in consensus among each country's meteorological service and the agro-meteorology groups from the institutions in order to identify climate-smart practices to climatic phenomena, which are then shared with local technicians and producers by way of the Local Agroclimatic Bulletin. This manual provides step-by-step instructions for implementing the MTA approach. It is directed mainly towards the leading institutions in the agricultural sector that might have an interest in implementing a discussion space in their region. The approach consists of eight steps, which are carried out with the participating institutions. Given the specific nature of each location, there is a series of preparation activities that need to be done before each meeting.

Grainger, S., Dessai, S., Daron, J., Taylor, A., & Siu, Y. L. (2022). Using expert elicitation to strengthen future regional climate information for climate services. *Climate Services*, *26*(December 2021), 100278. https://doi.org/10.1016/j.cliser.2021.100278
Climate change knowledge can inform regional and local adaptation decisions. However, estimates of future climate are uncertain and methods for assessing uncertainties typically rely on the results of climate model simulations, which are constrained by the quality of assumptions used in model experiments and the limitations of available models. To strengthen scientific knowledge for climate services and climate change adaptation decisions, we explore the use of structured expert elicitation to assess future regional climate change. Using the Lower Yangtze region in China as a case study, we elicit judgements from six experts on future changes in temperature and precipitation as well as uncertainty sources, and compare it with climate model outputs from the Couple Model Intercomparison Project phase 5 (CMIP5). We find high consensus amongst experts that the Lower Yangtze region will be warmer in the coming decades, albeit with differences in the magnitude of change. There is less consensus about the direction and magnitude of future precipitation change. Compared with CMIP5 climate model outputs, experts provide similar or narrower uncertainty ranges for temperature change and very different uncertainty ranges for precipitation. Experts considered additional factors (e.g. model credibility, observations, theory and paleo-climatic evidence) and uncertainties not usually represented in conventional modelling approaches. We argue that, in context of regional climate information provision, expert-elicited judgements can characterise less predictable, or less explored, elements of the climate system and expert-elicited reasoning provides additional information and knowledge that is absent from modelling approaches. We discuss the value in bringing together multiple lines of evidence, arguing that expert elicited information can complement model information to strengthen regional climate change knowledge and help in building dialogue between climate experts and regional stakeholders, as part of a more complete climate service.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., & Harris, A. J. (2022). Investigating the decision thresholds for impact-based warnings in South East Asia. *International Journal of Disaster Risk Reduction*, *76*, 103021. https://doi.org/10.1016/j.ijdrr.2022.103021

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key

sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Kellogg, W. K. (2004). *Using Logic Models to Bring Together Planning, Evaluation, and Action - Logic Model Development Guide*.
In line with its core mission – To help people help themselves through the practical application of knowledge and resources to improve their quality of life and that of future generations – the W.K. Kellogg Foundation has made program evaluation a priority. As our staff and grantees work on a spectrum of social improve- ment programs, the need for shaping and contributing to the body of knowledge regarding evaluation becomes increasingly clear. Our first guide, the W.K. Kellogg Foundation Evaluation Handbook, was pub- lished in 1998, and has been made available to nearly 7,500 people.The Evaluation Handbook is a prac- tical, step-by-step manual for conducting evaluations.With the Handbook, we introduced the concept of the program logic model and the ways in which applying this concept has added value to our own work.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). The Value of Impact-Based Decision Support Services: Case Studies with Winter Storms. *Bulletin of the American Meteorological Society*, *101*(11), 975–980. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Mason, K., Lindberg, K., Haenfling, C., Schori, A., Marsters, H., Read, D., & Borman, B. (2021). Social vulnerability indicators for flooding in aotearoa New Zealand. *International Journal of*

Environmental Research and Public Health, *18*(8). https://doi.org/10.3390/ijerph18083952
Social vulnerability indicators are a valuable tool for understanding which population groups are more vulnerable to experiencing negative impacts from disasters, and where these groups live, to inform disaster risk management activities. While many approaches have been used to measure social vulnerability to natural hazards, there is no single method or universally agreed approach. This paper proposes a novel approach to developing social vulnerability indicators, using the example of flooding in Aotearoa New Zealand. A conceptual framework was developed to guide selection of the social vulnerability indicators, based on previous frameworks (including the MOVE framework), consideration of climate change, and a holistic view of health and wellbeing. Using this framework, ten dimensions relating to social vulnerability were identified: exposure; children; older adults; health and disability status; money to cope with crises/losses; social connectedness; knowledge, skills and awareness of natural hazards; safe, secure and healthy housing; food and water to cope with shortage; and decision making and participation. For each dimension, key indicators were identified and implemented, mostly using national Census population data. After development, the indicators were assessed by end users using a case study of Porirua City, New Zealand, then implemented for the whole of New Zealand. These indicators will provide useful data about social vulnerability to floods in New Zealand, and these methods could potentially be adapted for other jurisdictions and other natural hazards, including those relating to climate change.

Moon, B., & Harrison, E. (2021). *Queensland's New Framework for Flood Risk Management Economic Assessments*. Copernicus GmbH. https://doi.org/10.5194/egusphere-egu21-1926
Flooding is one of Australia's more prevalent natural disasters, causing injury to people, damage to property and infrastructure, losses to business earnings, increases to the costs of providing government services, and intangible impacts such as environmental or social damages. Australia's National Strategy for Disaster Resilience (2011) and Queensland's Strategy for Disaster Resilience (2017) provide the overarching framework to build disaster resilient communities in Queensland and Australia. Within this, Government has the role of identifying and implementing strategies to manage the disaster risks. The National Strategy recognises that consistent information on the costs and benefits of risk management options, which considers the full impacts on the social, built, economic and natural environments, is required to support this. In Australia economic assessments for flood management projects have traditionally focused on the tangible damages of flooding, particularly to property. Other impacts of flooding, such as environmental or social impacts, are typically considered qualitatively or assessed through a multi-criteria assessment. The absence of state and/or national guidance on undertaking such assessments has also led to a wide variety of approaches, methodologies, data and results. This creates an unnecessary layer of complexity when seeking to compare and prioritise projects, within states and across Australia. It can also lead to the underestimation of the return on investment resulting from flood risk management projects, due to the incomplete capture of benefits. The Brisbane River Strategic Floodplain Management Plan (SFMP) was publicly released in 2019 and includes 52 actions aimed to improve the resilience, safety and prosperity of the community and businesses in the Brisbane River floodplain, and Queensland more widely. The Queensland Reconstruction Authority (QRA) was allocated the lead to implement Action FM7 'Extend the economic framework established in the Strategic Plan and Technical Evidence Report to include community awareness and resilience, disaster management and land use planning.'' The Economic Assessment Framework for Flood Risk Management Projects is due for publication in early 2021. It was developed through a collaborative process with other state governments, universities, private practitioners, and key stakeholders to road test a number of approaches and develop the guideline to support a consistent methodology for eco…'

Moriyama, K., Sasaki, D., & Ono, Y. (2018). Comparison of Global Databases for Disaster Loss and Damage Data. *Journal of Disaster Research*, *13*(6), 1007–1014. https://doi.org/10.20965/jdr.2018.p1007
After the Sendai Framework for Disaster Risk Reduction is adopted, a global database as a tool to monitor disaster loss and damage databases is required. Several disaster loss and damage databases are in use globally. This paper aims to explore how the existing databases vary in three aspects of threshold, spatial resolution, and data quality control, as well as the limitations of the existing databases. We review previous studies comparing the existing global databases and extract the differences and limitations. The threshold of EM-DAT is clear, but its threshold results in ignoring small-scale disasters that DesInventar captures. The differences in disaster threshold create different pictures of disaster losses and/or risks. Regarding spatial resolution, only DesInventar provides disaster impact data at a municipal level, while others provide information at a country level. The limitations of the existing global database are categorized into four aspects, as follows: lack of disaggregated data, limited spatial coverage and resolution, insufficiency of completeness and reliability of data, and insufficient information on indirect loss. The implication from our findings is that, in order to complement the limitations of the existing disaster loss databases to use for decision making on disaster risk reduction, the following are required: cross-checking of data across different databases; complementary disaster loss data; and collection of an exhaustive and firsthand dataset with a transparent and internationally consistent methodology by policy makers.

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

Perera, D., Seidou, O., Agnihotri, J., Rasmy, M., Smakhtin, V., Coulibaly, P., & Mehmood, H. (2019). *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects 08. UNU-INWEH Report Series, Issue 08* (Issue August). https://doi.org/10.13140/RG.2.2.28339.78880
Floods are major water-related disasters that affect millions of people resulting in thousands of mortalities and billiondollar losses globally every year. Flood Early Warning Systems (FEWS) - one

of the floods risk management measures - are currently operational in many countries. The UN Office for Disaster Risk Reduction recognises their importance and strongly advocates for an increase in their availability under the targets of the Sendai Framework for Disaster Risk Reduction, and Sustainable Development Goals (SDGs). However, despite widespread recognition of the importance of FEWS for disaster risk reduction (DRR), there's a lack of information on their availability and status around the world, their benefits and costs, challenges and trends associated with their development. This report contributes to bridging these gaps by analyzing the responses to a comprehensive online survey with over 80 questions on various components of FEWS (risk knowledge, monitoring and forecasting, warning dissemination and communication, and response capabilities), investments into FEWS, their operational effectiveness, benefits, and challenges. FEWS were classified as technologically "basic", "intermediate" and "advanced" depending on the existence and sophistication of FEWS` components such as hydrological data collection systems, data transfer systems, flood forecasting methods, and early warning communication methods. The survey questionnaire was distributed to flood forecasting and warning centers around the globe; the primary focus was developing and least-developed countries (LDCs). The questionnaire is available here: https://inweh.unu.edu/questionnaireevaluation-of-flood-early-warning-systems/ and can be useful in its own right for similar studies at national or regional scales, in its current form or with case-specific modifications.

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2021.102344
Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP, CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Rodwell, M. J., Hammond, J., Thornton, S., & Richardson, D. S. (2020). User decisions, and how these could guide developments in probabilistic forecasting. *Quarterly Journal of the Royal Meteorological Society*, *146*(732), 3266–3284. https://doi.org/10.1002/qj.3845
We investigate how users combine objective probabilities with their own subjective feelings when deciding how to act on weather forecast information. Results are based on two scenarios investigated at a Live Science event held by the Royal Meteorological Society. When deciding whether to go to the beach with the possibility of warm, dry weather, we find that users attempt to identify their 'Bayes Action'': the one which minimises their expected negative feeling or utility. Key factors are the "thrill'' of a nice day at the beach and the 'pain'' of coping with, for example, children in wet weather, and the costs of travel. The users' threshold probabilities for deciding to go to the beach thus approximately define their distribution of cost/loss ratios. This is used to

calculate a “User Brier Score’’ (UBS): a measure of the overall utility to society, and which could be used to guide forecast system development. When applied to operational ensemble forecasts issued by the European Centre for Medium-Range Weather Forecasts (ECMWF) over the period 1995–2018, the UBS tends to be higher (i.e., worse) than the Brier Score, largely because users tended not to exhibit high cost/loss ratios. When deciding whether to leave a campsite in the face of potentially dangerous gales, users try to find a balance between the ‘regret’’ of serious injury and the “pain’’ of spoiling an enjoyable holiday. Some users decide to stay even at high probabilities of serious consequences – partly due to a lack of experience. On the other hand, forecasts suffer from ‘complete misses’’ – where probabilities of zero are accompanied by non-negligible outcome frequencies. These dominate the overall Brier Score. The frequency of complete misses halved over the period 1995–2018: a welcome improvement for users who do wish to avoid danger at low probabilities.’”’”’”’

Sangha, K. K., Russell-Smith, J., Evans, J., & Edwards, A. (2020). Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction*, *49*. https://doi.org/10.1016/j.ijdrr.2020.101619
Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environmental when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank [1]; and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was estimated at AU$95-132million per year. Evaluating such costs for loss of Indigenous peoples’ well-being who reside in remote parts of the NT, presents an estimate of AU$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

van Noordwijk, M., Matthews, R., Agus, F., Farmer, J., Verchot, L., Hergoualc’h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., Dewi, S., Hergoualc’h, K., Persch, S., Tata, H. L., Lusiana, B., Widayati, A., & Dewi, S. (2014). Mud, muddle and models in the knowledge value-chain to action on tropical peatland conservation. *Mitigation and Adaptation Strategies for Global Change*, *19*(6), 887–905. https://doi.org/10.1007/s11027-014-9576-1
Tropical peatlands are known not only for their high, area-based, carbon emissions in response to land-use change but also as hot spots of debate about associated data uncertainties. Perspectives are still evolving on factors underlying the variability and uncertainty. Debate includes the ways of reducing emissions through rewetting, reforestation and agroforestry. A knowledge value-chain that is long and complex links (a) fundamental understanding of peat and peatland processes leading to sciencebased quantification and default values, (b) willingness and (c) ability to act towards emission reduction, and ultimately (d) to local, national and global actions that effectively provide rules, incentives and motivation to conserve peat and reduce emissions. We discuss this

value chain, its stakeholders and issues that still remain partially unresolved. We conclude that, to shorten the denial and conspiracy-theory stages of debate that otherwise slow down steps B and C, networks of international and national scientists have to be involved at the early stage of identifying policysensitive environmental issues. Models span part of the knowledge value-chain but transition of analysis units requires specific attention, from soil volumes through area and commodity flows to opportunities for reductions. While drainage of peatlands triggers landscape-scale increases in emissions, factors beyond drainage depth, including nutrient supply, may have a major influence on decomposition rates. Attempts to disentangle the contributions of plant and peat-based respiration in surface flux measurements involve assumptions that cannot be easily verified in comparisons between land uses. With progress on A leading to new internationally accepted defaults and with resistance on step B reduced, the reality of C and lack of working solutions for D is currently constraining further progress. © 2014 The Author(s).

Wilkins, A., Pennaz, A., Dix, M., Smith, A., Vawter, J., Karlson, D., Tokar, S., & Brooks, E. (2021). Challenges and opportunities for Sendai framework disaster loss reporting in the United States. *Progress in Disaster Science*, *10*, 100167. https://doi.org/10.1016/J.PDISAS.2021.100167
The Sendai Framework for Disaster Risk Reduction provides quantitative indicators for nations to measure progress in the reduction of disaster losses. The collection and analysis of disaster loss data under the Sendai Framework improves our understanding of the effectiveness of national disaster risk reduction strategies and interventions. The Sendai Framework has enhanced cooperation among Federal agencies to collect and track disaster loss data in the U.S., yet challenges remain for reporting disaster losses. Based on our experiences collecting and reporting U.S. data to the Sendai Monitor, we identify opportunities to improve disaster loss reporting in the U.S.

WMO. (2015). *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services* (Issue 1150).
The spherical tokamak (ST) is a leading candidate for a Fusion Nuclear Science Facility (FNSF) due to its compact size and modular configuration. The National Spherical Torus eXperiment (NSTX) is a MA-class ST facility in the US actively developing the physics basis for an ST-based FNSF. In plasma transport research, ST experiments exhibit a strong (nearly inverse) scaling of normalized confinement with collisionality, and if this trend holds at low collisionality, high fusion neutron fluences could be achievable in very compact ST devices. A major motivation for the NSTX Upgrade (NSTX-U) is to span the next factor of 3–6 reduction in collisionality. To achieve this collisionality reduction with equilibrated profiles, NSTX-U will double the toroidal field, plasma current, and NBI heating power and increase the pulse length from 1–1.5 s to 5–8 s. In the area of stability and advanced scenarios, plasmas with higher aspect ratio and elongation, high βN, and broad current profiles approaching those of an ST-based FNSF have been produced in NSTX using active control of the plasma β and advanced resistive wall mode control. High non-inductive current fractions of 70% have been sustained for many current diffusion times, and the more tangential injection of the 2nd NBI of the Upgrade is projected to increase the NBI current drive by up to a factor of 2 and support 100% non-inductive operation. More tangential NBI injection is also projected to provide non-solenoidal current ramp-up as needed for an ST-based FNSF. In boundary physics, NSTX measures an inverse relationship between the scrape-off layer heat-flux width and plasma current that could unfavourably impact next-step devices. Recently, NSTX has successfully demonstrated substantial heat-flux reduction using a snowflake divertor configuration, and this type of divertor is incorporated in the NSTX-U design. The physics and engineering design supporting NSTX Upgrade is described.

World Meteorological Organization. (2008). Guidelines on communicating forecast uncertainty. *Wmo*

Td-1722, *PWS-18*, 25 pages.
These Guidelines address the issue of communicating forecast uncertainty. Although they include a discussion on the sources of uncertainty, and touch on the related science (e.g. probabilistic forecasting, the use of Numerical Weather Prediction (NWP) ensembles), this is not their focus. Rather, the emphasis is on how National Meteorological and Hydrological Services (NMHSs) can incorporate uncertainty information in their hydrometeorological forecast services, including the best ways to communicate this information to the benefit of users.

World Meteorological Organization. (2021). *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services (WMO-No. 1150), Part II: Putting Multi-Hazard IBFWS into Practice* (Issue 1150).

Yigitcanlar, T., Regona, M., Kankanamge, N., Mehmood, R., D'costa, J., Lindsay, S., Nelson, S., & Brhane, A. (2022). Detecting Natural Hazard-Related Disaster Impacts with Social Media Analytics: The Case of Australian States and Territories. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020810
Natural hazard-related disasters are disruptive events with significant impact on people, communities, buildings, infrastructure, animals, agriculture, and environmental assets. The exponentially increasing anthropogenic activities on the planet have aggregated the climate change and consequently increased the frequency and severity of these natural hazard-related disasters, and consequential damages in cities. The digital technological advancements, such as monitoring systems based on fusion of sensors and machine learning, in early detection, warning and disaster response systems are being implemented as part of the disaster management practice in many countries and presented useful results. Along with these promising technologies, crowdsourced social media disaster big data analytics has also started to be utilized. This study aims to form an understanding of how social media analytics can be utilized to assist government authorities in estimating the damages linked to natural hazard-related disaster impacts on urban centers in the age of climate change. To this end, this study analyzes crowdsourced disaster big data from Twitter users in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method and conducts sentiment and content analyses of location-based Twitter messages (n = 131,673) from Australia. The study informs authorities on an innovative way to analyze the geographic distribution, occurrence frequency of various disasters and their damages based on the geo-tweets analysis.

Forecasts

Keywords: ensemble forecast comparison, accurate data simulation, data assimilation, data modelling, development of impact-based forecasting, flood forecasting, forecast uncertainty, forecasting, forecasting models, hazard forecast, hazard modelling, IBF implementation, impact-based forecasting, multiscale hazard forecasting theme, risk modelling, use of seasonal climate forecasts, weather, weather modelling, weather predictions

Alfieri, L., Burek, P., Dutra, E., Krzeminski, B., Muraro, D., Thielen, J., & Pappenberger, F. (2013). GloFAS – global ensemble streamflow forecasting and flood early warning. *Hydrology and Earth System Sciences*, *17*(3), 1161–1175. https://doi.org/10.5194/hess-17-1161-2013
<p>Abstract. Anticipation and preparedness for large-scale flood events have a key role in mitigating their impact and optimizing the strategic planning of water resources. Although several developed countries have well-established systems for river monitoring and flood early warning,

figures of populations affected every year by floods in developing countries are unsettling. This paper presents the Global Flood Awareness System (GloFAS), which has been set up to provide an overview on upcoming floods in large world river basins. GloFAS is based on distributed hydrological simulation of numerical ensemble weather predictions with global coverage. Streamflow forecasts are compared statistically to climatological simulations to detect probabilistic exceedance of warning thresholds. In this article, the system setup is described, together with an evaluation of its performance over a two-year test period and a qualitative analysis of a case study for the Pakistan flood, in summer 2010. It is shown that hazardous events in large river basins can be skilfully detected with a forecast horizon of up to 1 month. In addition, results suggest that an accurate simulation of initial model conditions and an improved parameterization of the hydrological model are key components to reproduce accurately the streamflow variability in the many different runoff regimes of the earth.</p>

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S. (2016). *Use and perception of weather forecast information across Europe Journal: 4*(434), 1–2.
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It

also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Borga, M., Comiti, F., Ruin, I., & Marra, F. (2019). Forensic analysis of flash flood response. *WIREs Water*, *6*(2). https://doi.org/10.1002/wat2.1338
The last decade has witnessed the development of methodologies for the post-flood documentation of both hydrogeomorphological and social response to extreme precipitation. These investigations are particularly interesting for the case of flash floods, whose space–time scales make their observations by conventional hydrometeorological monitoring networks particularly challenging. Effective flash flood documentation requires post-flood survey strategies encompassing accurate radar estimation of rainfall, field and remote-sensing observations of the geomorphic processes, indirect reconstruction of peak discharges—as well eyewitness interviews. These latter can give valuable information on both flood dynamics and the related individual and collective responses. This study describes methods for post-flood surveys based on interdisciplinary collaborations between natural and social scientists. These surveys may help to better understand the links between hydrometeorological dynamics and geomorphic processes as well as the relationship between flood dynamics and behavioral response in the context of fast space–time changes of flooding conditions.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Cawood, M., Keys, C., & Wright, C. (2018). The total flood warning system: What have we learnt since 1990 and where are the gaps. *Australian Journal of Emergency Management*, *33*(2), 47–52.
April 1990 was a month of severe flooding in eastern Australia. Two months later, a national workshop was held in which a large number of flood management specialists sought to capture the lessons of the floods while they were still fresh. Many aspects of the management of the events were examined, with flood warning highlighted as a key function. A second meeting the following year resolved to produce a best-practice manual to help guide practitioners in the development of flood warning services. The term “Total Flood Warning System” (TFWS) was adopted to describe the need to integrate the many elements of effective warning. The need to help those in the path of a flood to understand the warnings they received and take effective action was recognised as central. The manual was published in 1995 and revised and updated in 1999 and 2009. This paper asks what has changed and improved in the flood warning field since 1990 and what is needed in TFWS terms to further help communities and individuals manage their flood risk.

Demuth, J. L., Lazo, J. K., & Morss, R. E. (2011). Exploring variations in people’s sources, uses, and perceptions of weather forecasts. *Weather, Climate, and Society*, *3*(3), 177–192.

https://doi.org/10.1175/2011WCAS1061.1
Past research has shown that individuals vary in their attitudes and behaviors regarding weather forecast information. To deepen knowledge about these variations, this article explores 1) patterns in people's sources, uses, and perceptions of everyday weather forecasts; and 2) relationships among people's sources, uses, and perceptions of forecasts, their personal characteristics, and their experiences with weather and weather forecasts. It does so by performing factor and regression analysis on data from a nationwide survey of the U.S. public, combined with other data. Forecast uses factored into planning for leisure activities and for work/school-related activities, while knowing what the weather will be like and planning how to dress remained separate. Forecast parameters factored into importance of precipitation parameters and of temperaturerelated parameters, suggesting that these represent conceptually different constructs. Regression analysis showed that the primary drivers for how often people obtain forecasts are what they use forecasts for and their perceived importance of and confidence in forecast information. People's forecast uses are explained in large part by their frequency of obtaining forecasts and their perceived importance of temperature-related and precipitation forecast information. This suggests that that individuals' frequency of obtaining forecasts, forecast use, and importance of forecast parameters are closely interrelated. Sociodemographic characteristics and, to a lesser extent, weather-related experience also influence some aspects of people's forecast sources, uses, and perceptions. These findings continue to build understanding of variations among weather forecast users, which can help weather information providers improve communication of forecasts to better meet users' needs. © 2011 American Meteorological Society.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Che Mamat, C. S. N. B., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J. L. J. L., Wandala, A., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Mamat, C. S. N. B. C., Moron, L. A., Cecilia A Monteverde, M., Cayanan, E. O., … Harris, A. J. L. J. L. (2022). Impact-based forecasting in South East Asia – What underlies impact perceptions? *International Journal of Disaster Risk Reduction*, *76*(March), 102943. https://doi.org/10.1016/j.ijdrr.2022.102943
The move towards impact-based forecasting presents a challenge for forecasters, who must combine information not just on what the weather might be, but also on what the weather might do. Yet different hazards and impacts are qualitatively distinct, meaning such information cannot be easily or straightforwardly integrated. The present study aimed to provide a way of characterising seemingly disparate impacts. In a collaboration between UK psychologists and partners from three meteorological organisations in Indonesia, Malaysia and the Philippines, the psychometric paradigm was employed to investigate how forecasters and stakeholders perceive weather-related impacts. Participants provided ratings of nine categories of impacts on a total of 10 characteristics, as well as providing an overall impact severity rating. Principal components analysis revealed differing component solutions across countries, which explained around 75% of the variance in perceptions. There were some similarities across all countries, with the characteristics 'worry'' and "destructiveness'' loading positively together, as well as 'likelihood of harm'' and "seriousness of harm''. We did not find strong evidence to indicate that forecasters and stakeholders perceive impacts in different ways. Our results highlight the complex nature of impact perceptions, which are characterised not just by objective factors such as impact scope and duration, but also subjective factors, such as worry and perceived severity."""'

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., & Harris, A. J. (2022). Investigating the decision thresholds for impact-based warnings in South East Asia. *International Journal of Disaster Risk Reduction*, *76*, 103021. https://doi.org/10.1016/j.ijdrr.2022.103021

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Klafft, M., & Meissen, U. (2011). Assessing the Economic Value of Early Warning Systems. *Proceedings of the 8th International ISCRAM Conference – Lisbon, Portugal, May 2011*.
As of today, investments into early warning systems are, to a large extent, politically motivated and "disaster-driven." This means that investments tend to increase significantly if a disaster strikes, but are often quickly reduced in the following disaster-free years. Such investment patterns make the continuous operation, maintenance and development of the early warning infrastructure a challenging task and may lead to sub-optimal investment decisions. The paper presented here proposes an economic assessment model for the tangible economic impact of early warning systems. The model places a focus on the false alert problematic and goes beyond previous approaches by incorporating some socio-cultural factors (qualitatively estimated as of now). By doing so, it supports policymakers (but also private investors) in their investment decisions related to early warning applications.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Majumdar, S. J., Sun, J., Golding, B., Joe, P., Dudhia, J., Caumont, O., Chandra Gouda, K., Steinle, P., Vincendon, B., Wang, J., & Yussouf, N. (2021). Multiscale Forecasting of High-Impact Weather: Current Status and Future Challenges. *Bulletin of the American Meteorological Society*, *102*(3), E635–E659. https://doi.org/10.1175/BAMS-D-20-0111.1
Improving the forecasting and communication of weather hazards such as urban floods and extreme winds has been recognized by the World Meteorological Organization (WMO) as a priority for international weather research. The WMO has established a 10-yr High-Impact Weather Project (HIWeather) to address global challenges and accelerate progress on scientific and social solutions. In this review, key challenges in hazard forecasting are first illustrated and summarized via four examples of high-impact weather events. Following this, a synthesis of the requirements, current status, and future research in observations, multiscale data assimilation, multiscale ensemble forecasting, and multiscale coupled hazard modeling is provided.

Matte, S., Boucher, M.-A., Boucher, V., & Fortier Filion, T.-C. (2017). Moving beyond the cost–loss ratio: economic assessment of streamflow forecasts for a risk-averse decision maker. *Hydrology and Earth System Sciences*, *21*(6), 2967–2986. https://doi.org/10.5194/hess-21-2967-2017
<p>Abstract. A large effort has been made over the past 10 years to promote the operational use of probabilistic or ensemble streamflow forecasts. Numerous studies have shown that ensemble forecasts are of higher quality than deterministic ones. Many studies also conclude that decisions based on ensemble rather than deterministic forecasts lead to better decisions in the context of flood mitigation. Hence, it is believed that ensemble forecasts possess a greater economic and social value for both decision makers and the general population. However, the vast majority of, if not all, existing hydro-economic studies rely on a cost–loss ratio framework that assumes a risk-neutral decision maker. To overcome this important flaw, this study borrows from economics and evaluates the economic value of early warning flood systems using the well-known Constant Absolute Risk Aversion (CARA) utility function, which explicitly accounts for the level of risk aversion of the decision maker. This new framework allows for the full exploitation of the information related to a forecasts' uncertainty, making it especially suited for the economic assessment of ensemble or probabilistic forecasts. Rather than comparing deterministic and ensemble forecasts, this study focuses on comparing different types of ensemble forecasts. There are multiple ways of assessing and representing forecast uncertainty. Consequently, there exist many different means of building an ensemble forecasting system for future streamflow. One such possibility is to dress deterministic forecasts using the statistics of past error forecasts. Such dressing methods are popular among operational agencies because of their simplicity and intuitiveness. Another approach is the use of ensemble meteorological forecasts for precipitation and temperature, which are then provided as inputs to one or many hydrological model(s). In this study, three concurrent ensemble streamflow forecasting systems are compared: simple statistically dressed deterministic forecasts, forecasts based on meteorological ensembles, and a variant of the latter that also includes an estimation of state variable uncertainty. This comparison takes place for the Montmorency River, a small flood-prone watershed in southern central Quebec, Canada. The assessment of forecasts is performed for lead times of 1 to 5 days, both in terms of forecasts' quality (relative to the corresponding record of observations) and in terms of economic value, using t…

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F., Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704

Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Morss, R. E., Demuth, J. L., Lazrus, H., Palen, L., Barton, C. M., Davis, C. A., Snyder, C., Wilhelmi, O. V., Anderson, K. M., Ahijevych, D. A., Anderson, J., Bica, M., Fossell, K. R., Henderson, J., Kogan, M., Stowe, K., & Watts, J. (2017). Hazardous weather prediction and communication in the modern information environment. *Bulletin of the American Meteorological Society*, *98*(12), 2653–2674. https://doi.org/10.1175/BAMS-D-16-0058.1
Understanding the dynamic, interconnected processes that characterize the modern hazard information system can transform the creation, communication, and use of weather and climate information.

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Risbey, J. S., Squire, D. T., Black, A. S., DelSole, T., Lepore, C., Matear, R. J., Monselesan, D. P., Moore, T.

S., Richardson, D., Schepen, A., Tippett, M. K., & Tozer, C. R. (2021). Standard assessments of climate forecast skill can be misleading. *Nature Communications*, *12*(1), 4346. https://doi.org/10.1038/s41467-021-23771-z
Assessments of climate forecast skill depend on choices made by the assessor. In this perspective, we use forecasts of the El Niño-Southern-Oscillation to outline the impact of bias-correction on skill. Many assessments of skill from hindcasts (past forecasts) are probably overestimates of attainable forecast skill because the hindcasts are informed by observations over the period assessed that would not be available to real forecasts. Differences between hindcast and forecast skill result from changes in model biases from the period used to form forecast anomalies to the period over which the forecast is made. The relative skill rankings of models can change between hindcast and forecast systems because different models have different changes in bias across periods.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Wang, Y., Yin, Y., & Song, L. (2022). Risk Assessment of Typhoon Disaster Chains in the Guangdong–Hong Kong–Macau Greater Bay Area, China. *Frontiers in Earth Science*, *10*(March), 1–17. https://doi.org/10.3389/feart.2022.839733
The typhoon disaster chain is one of the leading climate risks in constructing the Guangdong–Hong Kong–Macau Greater Bay Area (GBA). In this study, the risks of the typhoon disaster chains including typhoon-induced gales, rainstorms, and storm surges in the GBA, as well as the comprehensive risk of typhoon disaster, are investigated at county level by comprehensively analyzing the hazard, exposure, and vulnerability. The results show that the high- and very-high-risk areas of typhoon–gale disaster chain are located in Zhuhai, Zhongshan, Foshan, Dongguan, central-southern Jiangmen, southern Shenzhen, and parts of Huizhou. The high- and very high-risk areas of typhoon–rainstorm disaster chain include Zhuhai, Zhongshan, Shenzhen, central-southern Foshan, northern Dongguan, central Jiangmen, and central Huizhou. Regarding the typhoon–storm surge disaster chain, the areas at high and very high risk are located in Zhuhai, eastern Zhongshan, and the coastal areas of the Pearl River Estuary. In addition, the comprehensive risk of typhoon disaster is very high in Zhuhai and high in Zhongshan, Jiangmen, Dongguan, and Shenzhen. By verifying the spatial correlation between typhoon disaster risk indexes and actual losses, it is found that the comprehensive risk index of typhoon disaster constructed in this study can better reflect the actual losses. Overall, the findings of this study can provide a scientific basis for typhoon disaster prevention and mitigation in the GBA, and it can also serve as a reference for typhoon disaster risk research in other areas.

Zhang, Q., Li, L., Ebert, B., Golding, B., Johnston, D., Mills, B., Panchuk, S., Potter, S., Riemer, M., Sun, J., Taylor, A., Jones, S., Ruti, P., & Keller, J. (2019). Increasing the value of weather-related warnings. *Science Bulletin*, *64*(10), 647–649. https://doi.org/10.1016/j.scib.2019.04.003
A successful warning relies on information produced by the meteorological and related physical sciences, thus its effectiveness of delivery depends on applications of social, behavioral and economic sciences. The workshop of WMO High Impact Weather Project was held in Beijing during 20–22 November of 2018, attracted a diverse and interdisciplinary group of over 70 scientists from 25 countries in the broad field of physical and social science, during which all elements of the warning chain were discussed critically. The aims of the workshop were to review progress to date,

to refresh the aims and objectives of the HIWeather project, and to identify and plan new activities on how to increase the value of weather-related warnings. Five focal aspects of warning were described in the following sections: (1) what makes a successful warning? (2) Advances in physical processes. (3) Weather-related hazard and impact prediction. (4) Advances in understanding impacts, vulnerability and risk. (5) Measuring skill and value.[6]

Hazard

Keywords: drought, earthquake, fire, flood, bushfires, heatwaves, hurricane, hazard characteristics, natural disaster, natural disasters, natural hazard-related disaster, natural hazards, storm surge, tornadoes, tsunami, typhoon, volcano

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Bahinipati, C. S. (2020). Assessing the costs of droughts in rural India: A comparison of economic and non-economic loss and damage. *Current Science*, *118*(11), 1832–1841. https://doi.org/10.18520/cs/v118/i11/1832-1841
Drought, recognized as one of the major disasters, negatively affects India's agrarian economy, and in turn, farmers' well-being. Households incur both economic and non-economic loss and damage. The latter is most often unnoticed and unaddressed although it is expected to be quite significant in developing nations. Understanding and assessing loss and damage are the prime objectives of the Warsaw International Mechanism. While numerous studies have emerged to estimate the impact on crop production, income, on-farm employment and financial status, there are only limited studies with respect to assessing loss and damage to intangible resources and the total cost of a drought in particular. By interviewing droughtaffected farmers in the Kutch district of Gujarat state, this study aims to understand the perception of farmers and to estimate total economic value and noneconomic loss and damage. A contingent valuation method was employed. In sum, two major findings emerged: (i) intensity of economic loss and damage is perceived as relatively high as compared to noneconomic loss and damage, although the reverse was expected, and (ii) the average total economic value of a drought was INR 8303, and the mean value of noneconomic loss and damage was INR 4831. This study reveals that households give lower value to intangible

losses that occurs over a period than the immediate tangible loss and damage which directly affect their total wealth. Given this, community-level adaptations to minimize non-economic loss and damage are less likely to be formulated. From the policy perspective, this study strongly advocates the evaluation of intangible costs, so that upcoming state action plans, disaster management plans and ex-post assessment reports could be tailored accordingly for minimizing these risks.

Cho, J. Y. N., & Kurdzo, J. M. (2019). Weather radar network benefit model for tornadoes. *Journal of Applied Meteorology and Climatology*, *58*(5), 971–987. https://doi.org/10.1175/JAMC-D-18-0205.1
A monetized tornado benefit model is developed for arbitrary weather radar network configurations. Geospatial regression analyses indicate that improvement of two key radar parameters-fraction of vertical space observed and cross-range horizontal resolution-leads to better tornado warning performance as characterized by tornado detection probability and false-alarm ratio. Previous experimental results showing faster volume scan rates yielding greater warning performance are also incorporated into the model. Enhanced tornado warning performance, in turn, reduces casualty rates. In addition, lower false-alarm ratios save costs by cutting down on work and personal time lost while taking shelter. The model is run on the existing contiguous U.S. weather radar network as well as hypothetical future configurations. Results show that the current radars provide a tornado-based benefit of;$490 million (M) yr-1. The remaining benefit pool is about $260M yr-1, split roughly evenly between coverage- and rapid-scanning-related gaps.

Emanuel, K., Fondriest, F., & Kossin, J. (2012). Potential economic value of seasonal hurricane forecasts. *Weather, Climate, and Society*, *4*(2), 110–117. https://doi.org/10.1175/WCAS-D-11-00017.1
This paper explores the potential utility of seasonal Atlantic hurricane forecasts to a hypothetical property insurance firm whose insured properties are broadly distributed along the U.S. Gulf and East Coasts. Using a recently developed hurricane synthesizer driven by large-scale meteorological variables derived from global reanalysis datasets, 1000 artificial 100-yr time series are generated containing both active and inactive hurricane seasons. The hurricanes thus produced damage to the property insurer's portfolio of insured property, according to an aggregate wind-damage function. The potential value of seasonal hurricane forecasts is assessed by comparing the overall probability density of the company's profits from a control experiment, in which the insurer purchases the same reinsurance coverage each year, to various test strategies in which the amount of risk retained by the primary insurer, and the corresponding premium paid to the reinsurer, varies according to whether the season is active or quiet, holding the risk of ruin constant. Under the highly idealized conditions of this experiment, there is a clear advantage to the hypothetical property insurance firm of using seasonal hurricane forecasts to adjust the amount of reinsurance it purchases each year. Under a strategy that optimizes the company's profits by holding the risk of ruin constant, the probability distribution of profit clearly separates from that of the control strategy after less than 10 yr when the seasonal forecasts are perfect. But when a more realistic seasonal forecast skill is assumed, the potential value of forecasts becomes significant only after more than a decade. © 2012 American Meteorological Society.

Fekete, A. (2019). Critical infrastructure and flood resilience: Cascading effects beyond water. *WIREs Water*, *6*(5), 1–13. https://doi.org/10.1002/wat2.1370
Abstract Critical infrastructure and cascading effects are analyzed in this article as cross-cutting topics in flood risk and resilience. A concept is developed for integrating aspects of disaster risk, hazard, vulnerability and resilience with critical infrastructure analytic components such as redundancy, rapidity or resourcefulness. These components are expressed for each phase of an unfolding flood event and cascading effects are indicated, too. This contribution discusses the implications of such a conceptual frame for the advancement of existing flood risk management concepts. Current international guiding strategies such as the United Nations Sendai Framework

for Disaster Risk Reduction, the “Making Cities Resilient” campaigns in field of urban disaster resilience, Climate Change Adaptation processes such as the Paris Agreement of the IPCC process, or urban planning in the field of UN HABITAT are all interconnected to the topic of (critical) infrastructure. The article shows how flood risk management can connect to such wider international developments by the conceptual frame discussion presented. This article is categorized under: Engineering Water > Planning Water Science of Water > Water Extremes Human Water > Water Governance

Hallegatte, S. (2008). An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. *Risk Analysis*, *28*(3), 779–799. https://doi.org/10.1111/j.1539-6924.2008.01046.x

This article proposes a new modeling framework to investigate the consequences of natural disasters and the following reconstruction phase. Based on input-output tables, its originalities are (1) the taking into account of sector production capacities and of both forward and backward propagations within the economic system; and (2) the introduction of adaptive behaviors. The model is used to simulate the response of the economy of Louisiana to the landfall of Katrina. The model is found consistent with available data, and provides two important insights. First, economic processes exacerbate direct losses, and total costs are estimated at $149 billion, for direct losses equal to $107 billion. When exploring the impacts of other possible disasters, it is found that total losses due to a disaster affecting Louisiana increase nonlinearly with respect to direct losses when the latter exceed $50 billion. When direct losses exceed $200 billion, for instance, total losses are twice as large as direct losses. For risk management, therefore, direct losses are insufficient measures of disaster consequences. Second, positive and negative backward propagation mechanisms are essential for the assessment of disaster consequences, and the taking into account of production capacities is necessary to avoid overestimating the positive effects of reconstruction. A systematic sensitivity analysis shows that, among all parameters, the overproduction capacity in the construction sector and the adaptation characteristic time are the most important. © 2008 Society for Risk Analysis.

Handmer, J., & Proudley, B. (n.d.). The Economics of Interface Wildfires. *Proceedings of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View*, *April 2004*, 19–22.

The new Australian Bushfire CRC (Cooperative Research Centre) is a major long-term effort intended to improve the safety of Australian communities by harnessing research for improving wildfire related policy and practice. One of the CRC’s projects concerns the development of “Reliable Assessment Methods for the Total Costs of Bushfires and the Benefits of Mitigation”. The initial part of this project is the subject of this presentation. Economic analysis for flood hazard management has a long history and is highly developed for urban areas. Drawing on this extensive material, as well as existing approaches to the economics of fire and the criminological literature on the economics of arson, we are working towards the development of a model for the comprehensive assessment of the economics of interface wildfires. Special attention is paid to the “exceptional” events that contribute most fire losses – and for which suppression is problematic. In addition, the extra costs imposed by arson will be incorporated into the approach. We will be identifying the primary drivers of costs and benefits, and the main opportunities for significant cost savings in the current and likely future Australian fire management environment. Future elements of the project will examine the economic implications of different approaches to fire and fire management, and link the preferred economic model and its outputs with models of fire behaviour and suppression.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Che Mamat, C. S. N. B., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J. L. J. L., Wandala, A., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Mamat, C. S. N. B. C., Moron, L. A., Cecilia A

Monteverde, M., Cayanan, E. O., … Harris, A. J. L. J. L. (2022). Impact-based forecasting in South East Asia – What underlies impact perceptions? *International Journal of Disaster Risk Reduction*, *76*(March), 102943. https://doi.org/10.1016/j.ijdrr.2022.102943

The move towards impact-based forecasting presents a challenge for forecasters, who must combine information not just on what the weather might be, but also on what the weather might do. Yet different hazards and impacts are qualitatively distinct, meaning such information cannot be easily or straightforwardly integrated. The present study aimed to provide a way of characterising seemingly disparate impacts. In a collaboration between UK psychologists and partners from three meteorological organisations in Indonesia, Malaysia and the Philippines, the psychometric paradigm was employed to investigate how forecasters and stakeholders perceive weather-related impacts. Participants provided ratings of nine categories of impacts on a total of 10 characteristics, as well as providing an overall impact severity rating. Principal components analysis revealed differing component solutions across countries, which explained around 75% of the variance in perceptions. There were some similarities across all countries, with the characteristics 'worry'' and "destructiveness'' loading positively together, as well as 'likelihood of harm'' and "seriousness of harm''. We did not find strong evidence to indicate that forecasters and stakeholders perceive impacts in different ways. Our results highlight the complex nature of impact perceptions, which are characterised not just by objective factors such as impact scope and duration, but also subjective factors, such as worry and perceived severity."'''

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1

Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Johar, M., Johnston, D. W., Shields, M. A., Siminski, P., & Stavrunova, O. (2022). The economic impacts of direct natural disaster exposure. *Journal of Economic Behavior and Organization*, *196*, 26–39. https://doi.org/10.1016/j.jebo.2022.01.023

We estimate the economic impacts of having your home damaged or destroyed by a natural disaster. Regressions with individual, area and time fixed-effects, indicate that experiencing a natural disaster has no impact on employment and income, but substantial impacts on financial hardship and risk aversion. Impacts are particularly large for smaller isolated disasters, which attract little government support. Conversely, impacts of residing in a disaster zone without experiencing residential destruction are small. Using a Group Fixed Effects estimator, we find predictors of financial vulnerability to destruction include age, parenthood, illness, and social support. These results can help improve the allocation of government assistance after future disasters.

Johnson, L. A., Rabinovici, S., Kang, G. S., Mahin, S. A., Curry, C., Arba, R., Chief, B., Parkinson, S. I., Salinas, A. C., Strack, T., Knudson, H., Goodwin, R., Cooley, K., Hellweg, M. P., Johnson, T., & Valencia, S. (2016). California Earthquake Early Warning System Benefit Study. *CSSC Publication*, 4–16.

In a six-month investigation, researchers conducted 18 semi-structured interviews with 24 organizations representing 14 important sectors of the state's infrastructure and economy. The interviews focused on the perceived value of a statewide EEWS for each organization as well as specific types and settings for EEWS use that could benefit public and employee safety, business resiliency, and the protection of critical operations and assets that serve local communities and the economy. Information from the interviews was then consolidated and interpreted into this summary, which is primarily aimed at informing future study needed to quantitatively assess the costs and benefits of a statewide EEWS. More information about the organizations participating in the study and the study approach is provided in Section 2, as well as the appendices of the report.

Kelman, I. (2006). Warning for the 26 December 2004 tsunamis. *Disaster Prevention and Management: An International Journal*, *15*(1), 178–189. https://doi.org/10.1108/09653560610654329

Purpose - To investigate whether or not people at risk from the 26 December 2004 tsunamis could have had better warning of the event. Design/methodology/ approach - This paper examines short-term actions related to warning following the earthquake and long-term actions related to setting up an Indian Ocean tsunami warning system prior to the disaster. The evidence is presented in the context of the long-term processes needed to create and maintain successful warning systems. Findings - The evidence shows that, based on the knowledge and procedures existing at the time, any expectation of effective warning prior to the tsunamis was unreasonable. On 26 December 2004, as much action was taken as feasible. Prior to the catastrophe, the Indian Ocean tsunami risks were acknowledged but no warning systems were implemented because other priorities were deemed to be higher. Research limitations/implications - This paper presents a snapshot of the complex issue of warning system development and implementation. Each national and regional case study deserves detailed attention. Further work would add to a more complete understanding of conditions before 26 December 2004. Practical implications - This case study provides a reminder that planning for warnings must be done before extreme events, not following them. Successful warning systems require investment in a long-term, ongoing process involving pre-event planning, education, and awareness. Originality/value - This paper provides an initial attempt at evaluating Indian Ocean tsunami warnings on 26 December 2004. © Emerald Group Publishing Limited.

Kuller, M., Schoenholzer, K., & Lienert, J. (2021). Creating effective flood warnings: A framework from a critical review. *Journal of Hydrology*, *602*(March), 126708. https://doi.org/10.1016/j.jhydrol.2021.126708

As climate change is intensifying the frequency and severity of floods around the globe, adaptation is increasingly vital. Besides structural measures to mitigate flood risk, non-structural measures are known to be highly effective and low-cost. Such non-structural measures include Flood Early Warning Systems (FEWS). Effective warning creation and dissemination are crucial to successful FEWS. Despite extensive bodies of research that cross the boundaries between disciplines and application domains, systematic understanding of the detailed aspects contributing to the effectiveness of flood warnings is lacking. We systematically review the state-of-the-art in risk perception and warning communication present in academic (and grey) literature for FEWS. We focus on the elements of risk warnings specifically, rather than reviewing the topic of risk communication in general. We start with exploring how personal attributes affect individual risk perception related to flood warnings. We then deconstruct flood warnings into three basic components: content, format and dissemination channel. Most importantly, we found 21

individual elements (options) for these components, each associated with varying levels of support for their effectiveness in literature. Important caveats were identified, such as a lack of research into the speech format and SMS channel. We then describe and visualise the warning creation process, providing a framework for guidance. Accelerating technological advancement necessitates continued research into the effectiveness of novel formats and channels, rendering the currently most widely supported and researched elements increasingly obsolete. Further research is needed to explore the complex interplay between elements, i.e., how do different combinations impact effectiveness? Finally, little is known about the transferability of our findings to Africa, Asia and South America, as industrialised countries dominate the research. We hope our findings will contribute to improved understanding, and support the practice of creating effective flood warnings.

Ladds, M., Keating, A., Handmer, J., & Magee, L. (2017). How much do disasters cost? A comparison of disaster cost estimates in Australia. *International Journal of Disaster Risk Reduction*, *21*, 419–429. https://doi.org/10.1016/J.IJDRR.2017.01.004

Extreme weather events in Australia are common and a large proportion of the population are exposed to such events. Therefore, there is great interest as to how these events impact Australia's society and economy, which requires understanding the current and historical impact of disasters. Despite global efforts to record and cost disaster impacts, no standardised method of collecting and recording data retrospectively yet exists. The lack of standardisation in turn results in a range of different estimates of economic impacts. This paper examines five examples of aggregate disaster loss and impacts of natural disasters in Australia, and comparisons between them reveal significant data shortcomings. The reliability of data sources, and the methodology employed to analyse them can have significant impacts on conclusions regarding the overall cost of disasters, the relative costs of different hazards (disaster types), and the distribution of losses across Australian states. We highlight difficulties with time series comparisons, further complicated by the interdependencies of the databases. We reiterate the need for consistent and comparable data collection and analysis, to respond to the increasing frequency and severity of disasters in Australia.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1

As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Lukasiewicz, A., & Baldwin, C. (2020). *Natural hazards and disaster justice: Challenges for australia and its neighbours* (Issue February). https://doi.org/10.1007/978-981-15-0466-2

This book explores policy, legal, and practice implications regarding the emerging field of disaster

justice, using case studies of floods, bushfires, heatwaves, and earthquakes in Australia and Southern and South-east Asia. It reveals geographic locational and social disadvantage and structural inequities that lead to increased risk and vulnerability to disaster, and which impact ability to recover post-disaster. Written by multidisciplinary disaster researchers, the book addresses all stages of the disaster management cycle, demonstrating or recommending just approaches to preparation, response and recovery. It notably reveals how procedural, distributional and interactional aspects of justice enhance resilience, and offers a cutting edge analysis of disaster justice for managers, policy makers, researchers in justice, climate change or emergency management. BoM Staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6028057

Martinez, A. B. (2020). Forecast accuracy matters for hurricane damage. *Econometrics*, *8*(2). https://doi.org/10.3390/econometrics8020018
I analyze damage from hurricane strikes on the United States since 1955. Using machine learning methods to select the most important drivers for damage, I show that large errors in a hurricane's predicted landfall location result in higher damage. This relationship holds across a wide range of model specifications and when controlling for ex-ante uncertainty and potential endogeneity. Using a counterfactual exercise I find that the cumulative reduction in damage from forecast improvements since 1970 is about $82 billion, which exceeds the U.S. government's spending on the forecasts and private willingness to pay for them.

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F., Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704
Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Moon, B., & Harrison, E. (2021). *Queensland's New Framework for Flood Risk Management Economic Assessments*. Copernicus GmbH. https://doi.org/10.5194/egusphere-egu21-1926
Flooding is one of Australia's more prevalent natural disasters, causing injury to people, damage to property and infrastructure, losses to business earnings, increases to the costs of providing government services, and intangible impacts such as environmental or social damages. Australia's National Strategy for Disaster Resilience (2011) and Queensland's Strategy for Disaster Resilience (2017) provide the overarching framework to build disaster resilient communities in Queensland and Australia. Within this, Government has the role of identifying and implementing strategies to manage the disaster risks. The National Strategy recognises that consistent information on the costs and benefits of risk management options, which considers the full impacts on the social, built, economic and natural environments, is required to support this. In Australia economic assessments for flood management projects have traditionally focused on the tangible damages of

flooding, particularly to property. Other impacts of flooding, such as environmental or social impacts, are typically considered qualitatively or assessed through a multi-criteria assessment. The absence of state and/or national guidance on undertaking such assessments has also led to a wide variety of approaches, methodologies, data and results. This creates an unnecessary layer of complexity when seeking to compare and prioritise projects, within states and across Australia. It can also lead to the underestimation of the return on investment resulting from flood risk management projects, due to the incomplete capture of benefits. The Brisbane River Strategic Floodplain Management Plan (SFMP) was publicly released in 2019 and includes 52 actions aimed to improve the resilience, safety and prosperity of the community and businesses in the Brisbane River floodplain, and Queensland more widely. The Queensland Reconstruction Authority (QRA) was allocated the lead to implement Action FM7 'Extend the economic framework established in the Strategic Plan and Technical Evidence Report to include community awareness and resilience, disaster management and land use planning.'' The Economic Assessment Framework for Flood Risk Management Projects is due for publication in early 2021. It was developed through a collaborative process with other state governments, universities, private practitioners, and key stakeholders to road test a number of approaches and develop the guideline to support a consistent methodology for eco…'

Morss, R. E., Vickery, J., Lazrus, H., Demuth, J., & Bostrom, A. (2022). Improving Tropical Cyclone Forecast Communication by Understanding NWS Partners' Decision Timelines and Forecast Information Needs. *Weather, Climate, and Society*, 783–800. https://doi.org/10.1175/wcas-d-21-0170.1

As tropical cyclone threats evolve, broadcast meteorologists and emergency managers rely on timely forecast information to help them communicate risk with the public and protect public safety. This study aims to improve the usability and applicability of NWS forecast information in the context of these NWS core partners' decisions during tropical cyclone threats. The research collected and analyzed data from in-depth interviews with broadcast meteorologists and emergency managers in 3 coastal U.S. states. These data were used to analyze broadcast meteorologists' and emergency managers' tropical cyclone decision and action timelines, their use of tropical cyclone information during different phases of threats, and gaps in forecast information for decision making. Based on these findings, several opportunities for improving tropical cyclone risk communication were identified. Recommendations to address gaps in the NWS tropical cyclone product suite include designing improved ways to communicate storm-specific storm surge risk at greater than 48 hours lead time, expanding the use of concise highlights that help people quickly extract and understand key information, and improving product understandability and usability by more comprehensively integrating users' perspectives into product research and development. Broader strategic recommendations include developing new approaches for informing broadcast meteorologists about major forecast updates, presenting forecast information in ways that enable locally relevant interpretation, and supporting human forecasters' contributions to the effectiveness of NWS products and services. These findings and recommendations can help NOAA prioritize ways to modernize the current NWS tropical cyclone product suite as well as motivate research to enable longer-term high-priority improvements.

Munroe, R., Montz, B., & Curtis, S. (2018). Getting more out of storm surge forecasts: Emergency support personnel needs in North Carolina. *Weather, Climate, and Society*, *10*(4), 813–820. https://doi.org/10.1175/WCAS-D-17-0074.1

Storm surge has been identified as a dangerous and damaging coastal hazard that is expected to be exacerbated by rising sea levels. However, storm surge research and applications are relatively new and poorly understood compared to other storm-related hazards. This survey-based research of emergency support personnel across eastern North Carolina aims to connect ongoing research

with the needs of storm surge users. Results indicate that emergency managers and other emergency support functions depend on storm surge information to assess and communicate risk, to educate the public, to evacuate the public, or for long-term resilience and recovery planning. They were generally satisfied with the type and timing of currently available surge information, but desired additional types of surge information (i.e., timing) and longer lead times.

Parker, D. J., & Priest, S. J. (2012). The Fallibility of Flood Warning Chains: Can Europe's Flood Warnings Be Effective? *Water Resources Management*, *26*(10), 2927–2950. https://doi.org/10.1007/s11269-012-0057-6

Taking a broad overview, this paper explores recent evidence on flood forecasting, warning communication and public warning response in Europe between 1995 and 2010. Key flood warning chain deficiencies are identified together with the effect these deficiencies have on flood warning effectiveness and loss reduction. Europe-wide data on flood forecasting and warning communication are examined alongside recent in-depth research evidence from various parts of Europe on flood warning receipt, warning response and warning effectiveness. Using the latest flood warning benefit assessment methodologies, the results of case studies of flood loss avoidance through warnings reveal the damage saving potential of flood warning. Although these savings are significant, currently they are inhibited by a series of shortcomings which transfer through the warning chain limiting warning impact. Flood forecasting, warning and warning response systems are inherently fallible and so it is doubtful that they will ever be consistently effective. Sole reliance upon them to protect life and property carries inevitable risks and governments should not be surprised when flood warnings are only partially effective. Although Europe's flood forecasting and warnings have been improving, the scope for further improvement is large. Extending flood forecasting and warning coverage, extending warning lead times by combining meteorological and hydrological forecasts, building greater redundancy into warning communication, and crucially also building it into cooperative strategies designed to engage at risk communities in flood warning response, are all likely to be important. © 2012 Springer Science+Business Media B.V.

Perera, D., Seidou, O., Agnihotri, J., Rasmy, M., Smakhtin, V., Coulibaly, P., & Mehmood, H. (2019). *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects 08. UNU-INWEH Report Series, Issue 08* (Issue August). https://doi.org/10.13140/RG.2.2.28339.78880

Floods are major water-related disasters that affect millions of people resulting in thousands of mortalities and billiondollar losses globally every year. Flood Early Warning Systems (FEWS) - one of the floods risk management measures - are currently operational in many countries. The UN Office for Disaster Risk Reduction recognises their importance and strongly advocates for an increase in their availability under the targets of the Sendai Framework for Disaster Risk Reduction, and Sustainable Development Goals (SDGs). However, despite widespread recognition of the importance of FEWS for disaster risk reduction (DRR), there's a lack of information on their availability and status around the world, their benefits and costs, challenges and trends associated with their development. This report contributes to bridging these gaps by analyzing the responses to a comprehensive online survey with over 80 questions on various components of FEWS (risk knowledge, monitoring and forecasting, warning dissemination and communication, and response capabilities), investments into FEWS, their operational effectiveness, benefits, and challenges. FEWS were classified as technologically "basic", "intermediate" and "advanced" depending on the existence and sophistication of FEWS` components such as hydrological data collection systems, data transfer systems, flood forecasting methods, and early warning communication methods. The survey questionnaire was distributed to flood forecasting and warning centers around the globe; the primary focus was developing and least-developed countries (LDCs). The questionnaire is available here: https://inweh.unu.edu/questionnaireevaluation-of-flood-early-warning-systems/

and can be useful in its own right for similar studies at national or regional scales, in its current form or with case-specific modifications.

Sangha, K. K., Russell-Smith, J., Evans, J., & Edwards, A. (2020). Methodological approaches and challenges to assess the environmental losses from natural disasters. *International Journal of Disaster Risk Reduction*, *49*. https://doi.org/10.1016/j.ijdrr.2020.101619

Disasters cause enormous damages to the natural environment which underpins human survival, yet we largely fail to account for the loss of services from the damaged environmental when it comes to accounting for disaster-related costs. This is mainly due to lack of conventional market price-tag for the services that are readily obtained from the natural environment. This study presents a costing framework, following the World Bank [1]; and a set of methodologies for how to measure such losses. A key focus of proposed methodologies is to assess these losses in terms of their impacts on human well-being, applying both the monetary and non-monetary measures. This paper further demonstrates the application of the proposed framework and methodologies for assessing the loss of ecosystem services from bushfires in the Northern Territory (NT), Australia, where wildfires are frequent, extensive, and often destructive. The total bushfires-related loss was estimated at AU$95-132million per year. Evaluating such costs for loss of Indigenous peoples' well-being who reside in remote parts of the NT, presents an estimate of AU$272 million/yr. It discusses the key challenges to evaluate environmental losses, particularly the importance of applying local values, and understanding the local context and intricacies between social and economic systems. The framework and methodologies presented here to evaluate environmental losses can be useful to inform policy planning in natural disaster management.

Sorensen, J. H., Lindell, M. K., Baker, E. J., & Lehman, W. P. (2020). Community response to hurricane threat: Estimates of warning issuance time distributions. *Weather, Climate, and Society*, *12*(4), 837–846. https://doi.org/10.1175/WCAS-D-20-0031.1

Hurricane evacuation warnings from local officials are one of the most significant determinants of households' evacuation departure times. Consequently, it is important to know how long after the National Hurricane Center (NHC) issues a hurricane watch or warning that local officials wait to issue evacuation warnings. The distribution of local evacuation warning issuance delays determined from poststorm assessment data shows a wide range of warning issuance delay times over an 85-h time span, although the vast majority of times fall within a 40-h window. Nearly 30% of the jurisdictions issued evacuation warnings before an NHC hurricane warning. Only 5% delayed the decision for more than 25 h after the NHC hurricane warning. The curves for warning issuance delays, using both the NHC watch and NHC warning issuance times as reference points, are very different from the warning issuance curves observed for the rapid-onset events. The hurricane data exhibit much more of an '"S shape"' than the exponential shape that is seen for rapid-onset data. Instead, curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension, follow three noticeably different logistic distributions. The data also indicate that warnings were issued significantly earlier for coastal counties than for inland counties. These results have direct practical value to analysts that are calculating evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions for future research on the reasons for the timing of local officials' hurricane evacuation decisions. SIGNIFICANCE STATEMENT: Local officials rely on National Hurricane Center (NHC) hurricane watches and warnings to guide them in issuing evacuation warnings but do not automatically issue evacuation warnings as soon as the NHC issues a watch or warning. Thus, this study constructed a database that contains the timing of NHC hurricane watches and warnings, as well as local evacuation warnings, for 20 hurricanes that threatened 290 U.S. jurisdictions from 1979 to 2008. The data reveal distinct curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension. These results are of direct

practical value to analysts who calculate evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions for future research on the reasons for the timing of local officials' hu…

Speight, L. J., Cranston, M. D., White, C. J., & Kelly, L. (2021). Operational and emerging capabilities for surface water flood forecasting. *Wiley Interdisciplinary Reviews: Water*, *8*(3), 1–24. https://doi.org/10.1002/wat2.1517

Surface water (or pluvial) flooding is caused by intense rainfall before it enters rivers or drainage systems. As the climate changes and urban populations grow, the number of people around the world at risk of surface water flooding is increasing. Although it may not be possible to prevent such flooding, reliable and timely flood forecasts can help improve preparedness and recovery. Unlike riverine and coastal flooding where forecasting methods are well established, surface water flood forecasting presents a unique challenge due to the high uncertainties around predicting the location, timing, and impact of what are typically localized events. Over the past 5 years, there has been rapid development of convection-permitting numerical weather prediction models, ensemble forecasting, and computational ability. It is now theoretically feasible to develop operational surface water forecasting systems. This paper identifies three approaches to surface water forecasting utilizing state-of-the-art meteorological forecasts: empirical-based scenarios, hydrological forecasts linked to presimulated impact scenarios, and real-time hydrodynamic simulation. Reviewing operational examples of each approach provides an opportunity to learn from international best practice to develop targeted, impact-based, surface water forecasts to support informed decision-making. Although the emergence of new meteorological and hydrological forecasting capabilities is promising, there remains a scientific limit to the predictability of convective rainfall. To overcome this challenge, we suggest that a rethink of the established role of flood forecasting is needed, alongside the development of interdisciplinary solutions for communicating uncertainty and making the best use of all available data to increase preparedness. This article is categorized under: Engineering Water > Engineering Water.

Sutter, D., & Erickson, S. (2010). The time cost of tornado warnings and the savings with storm-based warnings. *Weather, Climate, and Society*, *2*(2), 103–112. https://doi.org/10.1175/2009WCAS1011.1

The authors examine the cost of time spent under tornado warnings issued annually by the National Weather Service (NWS). County-based tornado warnings imposed substantial costs on the nation: an average of 234 million person-hours spent under warnings annually between 1996 and 2004, with a value of $2.7 billion (U.S. dollars) per year. Counties are large relative to tornado damage areas; therefore, county-based warnings overwarned for tornadoes, warning many persons a safe distance from the storm and not in immediate danger. In October 2007 the NWS introduced storm-based warnings (SBW) for tornadoes, which are expected to reduce the area warned by 70%-75%. SBW consequently will reduce the time spent under warnings by over 160 million person-hours per year, with a value of $1.9 billion. The time spent under warnings does not measure the full cost to society because many people do not respond to the warnings. Adjusting for warning response, this study estimates that SBW might save 66 million person-hours actually spent sheltering a year with a value of $750 million. Sensitivity analysis indicates that the value of time spent sheltering saved by SBW exceeds $100 million per year with a probability of 0.95. © 2010 American Meteorological Society.

Sutton, J., & Fischer, L. M. (2020). Understanding Visual Risk Communication Messages: An Analysis of Visual Attention Allocation and Think-Aloud Responses to Tornado Graphics. *Weather, Climate, and Society*, *13*(1), 173–188. https://doi.org/10.1175/wcas-d-20-0042.1

Online channels for communicating risk frequently include features and technological capabilities to support sharing images of risk. In particular, the affordances found in social media, such as

Twitter, include the ability to attach maps, photographs, videos, and other graphical information. The inclusion of visual cues such as colors and shapes and their different sizes are important for making sense of approaching threats, populations at risk, the potential impacts, and ranges of associated uncertainty. The reception of and attention to these visual cues in messages about a potential threat is the necessary first stage to making a decision about protective actions. Understanding what visual features capture individual attention and how attention is directed to visual images of risk on social media has the potential to affect the design of risk communication messages and the protective actions that follow. In this paper we use eye-tracking methods to identify where people allocate attention to a series of tweets and qualitative "think alouds" to determine what features of the tweets people attend to in their visual field are salient to message receivers. We investigate visual attention to a series of tweets that depict an emerging tornado threat to identify areas of visual interest and the properties of those visual cues that elicit attention. We find the use of color, properties of text presentation, and contents of messages affect attention allocation. These findings could help practitioners as they design and disseminate their weather messages to inform the public of emerging threats.

Wall, T. U., Brown, T. J., & Nauslar, N. J. (2017). Spot weather forecasts: Improving utilization, communication, and perceptions of accuracy in sophisticated user groups. *Weather, Climate, and Society*, *9*(2), 215–226. https://doi.org/10.1175/WCAS-D-15-0055.1

Spot weather forecasts (SWFs) are issued by Weather Service offices throughout the United States and are primarily for use by wildfire and prescribed fire practitioners for monitoring local-scale weather conditions. This paper focuses on use of SWFs by prescribed fire practitioners. Based on qualitative, in-depth interviews with fire practitioners and National Weather Service forecasters, this paper examines factors that influence perceptions of accuracy and utilization of SWFs. Results indicate that, while several well-understood climatological, topographical, and data-driven factors influence forecast accuracy, social factors likely have the greater impact on perceptions of accuracy, quantitative accuracy, and utilization. These include challenges with building and maintaining relationships between forecasters and fire managers, communication issues around updating SWFs, and communicating forecast confidence and uncertainty. Operationally, improved quantitative skill in a forecast is always desirable, but key opportunities for improving accuracy and utilization of these forecasts lie in 1) enhancing the processes and mechanisms for communication between a Weather Forecast Office and fire practitioners—before, during, and after an SWFs is issued—and 2) working with the wildland fire community to experiment with forecast uncertainty and confidence information in SWFs and evaluate impacts of these approaches.

Wang, Y., Yin, Y., & Song, L. (2022). Risk Assessment of Typhoon Disaster Chains in the Guangdong–Hong Kong–Macau Greater Bay Area, China. *Frontiers in Earth Science*, *10*(March), 1–17. https://doi.org/10.3389/feart.2022.839733

The typhoon disaster chain is one of the leading climate risks in constructing the Guangdong–Hong Kong–Macau Greater Bay Area (GBA). In this study, the risks of the typhoon disaster chains including typhoon-induced gales, rainstorms, and storm surges in the GBA, as well as the comprehensive risk of typhoon disaster, are investigated at county level by comprehensively analyzing the hazard, exposure, and vulnerability. The results show that the high- and very-high-risk areas of typhoon–gale disaster chain are located in Zhuhai, Zhongshan, Foshan, Dongguan, central-southern Jiangmen, southern Shenzhen, and parts of Huizhou. The high- and very high-risk areas of typhoon–rainstorm disaster chain include Zhuhai, Zhongshan, Shenzhen, central-southern Foshan, northern Dongguan, central Jiangmen, and central Huizhou. Regarding the typhoon–storm surge disaster chain, the areas at high and very high risk are located in Zhuhai, eastern Zhongshan, and the coastal areas of the Pearl River Estuary. In addition, the comprehensive risk of typhoon disaster is very high in Zhuhai and high in Zhongshan, Jiangmen, Dongguan, and Shenzhen. By

verifying the spatial correlation between typhoon disaster risk indexes and actual losses, it is found that the comprehensive risk index of typhoon disaster constructed in this study can better reflect the actual losses. Overall, the findings of this study can provide a scientific basis for typhoon disaster prevention and mitigation in the GBA, and it can also serve as a reference for typhoon disaster risk research in other areas.

Wu, W., Emerton, R., Duan, Q., Wood, A. W., Wetterhall, F., & Robertson, D. E. (2020). Ensemble flood forecasting: Current status and future opportunities. *WIREs Water*, *7*(3), 1–32. https://doi.org/10.1002/wat2.1432

Ensemble flood forecasting has gained significant momentum over the past decade due to the growth of ensemble numerical weather and climate prediction, expansion in high performance computing, growing interest in shifting from deterministic to risk-based decision-making that accounts for forecast uncertainty, and the efforts of communities such as the international Hydrologic Ensemble Prediction Experiment (HEPEX), which focuses on advancing relevant ensemble forecasting capabilities and fostering its adoption. With this shift, comes the need to understand the current state of ensemble flood forecasting, in order to provide insights into current capabilities and areas for improvement, thus identifying future research opportunities to allow for better allocation of research resources. In this article, we provide an overview of current research activities in ensemble flood forecasting and discuss knowledge gaps and future research opportunities, based on a review of 70 papers focusing on various aspects of ensemble flood forecasting around the globe. Future research directions include opportunities to improve technical aspects of ensemble flood forecasting, such as data assimilation techniques and methods to account for more sources of uncertainty, and developing ensemble forecasts for more variables, for example, flood inundation, by applying techniques such as machine learning. Further to this, we conclude that there is a need to not only improve technical aspects of flood forecasting, but also to bridge the gap between scientific research and hydrometeorological model development, and real-world flood management using probabilistic ensemble forecasts, especially through effective communication. This article is categorized under: Engineering Water > Methods Science of Water > Water Extremes

Yasitli, A. N. (2021). *Assessing the effectiveness of flood management : a comparative study between Turkey and the UK* (Issue June). https://pure.port.ac.uk/ws/portalfiles/portal/43263956/Ali_Nedim_Yasitli_PhD_Thesis.pdf

The findings of the research revealed that in Turkey, the government adopts a predominantly reactive approach, while the UK has put in place policies and legislation for proactive flood management. Key legislation in the UK is the Flood and Water Management Act 2010, which advocates for the cooperation and sharing of information among all stakeholder entities within flood management, extending down to local community level. The reactive approaches in Turkey are characterised by non-definite laws that have caused ineffective planning, poor warning systems, and unorganised stakeholders within the flood management system. Additionally, flood management is lacking at the local community level in Turkey. Although the two countries have not achieved impeccable flood management in terms of preparedness, response, and recovery, this research indicates that the UK system is more effective than the Turkish system. The study makes some recommendations for improving flood management in the two countries, notably that Turkey should improve its flood planning initiatives and early warning system. Also, Turkey should improve the level of institutional learning and integrate more flood management stakeholders. In the context of the UK, the study recommends that flood management should be improved, and that the early warnings should be implemented effectively during actual flooding events. Finally, there is a need to provide more frequent training and proper institutional learning for flood managers in both countries.

Yigitcanlar, T., Regona, M., Kankanamge, N., Mehmood, R., D'costa, J., Lindsay, S., Nelson, S., & Brhane, A. (2022). Detecting Natural Hazard-Related Disaster Impacts with Social Media Analytics: The Case of Australian States and Territories. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020810

Natural hazard-related disasters are disruptive events with significant impact on people, communities, buildings, infrastructure, animals, agriculture, and environmental assets. The exponentially increasing anthropogenic activities on the planet have aggregated the climate change and consequently increased the frequency and severity of these natural hazard-related disasters, and consequential damages in cities. The digital technological advancements, such as monitoring systems based on fusion of sensors and machine learning, in early detection, warning and disaster response systems are being implemented as part of the disaster management practice in many countries and presented useful results. Along with these promising technologies, crowdsourced social media disaster big data analytics has also started to be utilized. This study aims to form an understanding of how social media analytics can be utilized to assist government authorities in estimating the damages linked to natural hazard-related disaster impacts on urban centers in the age of climate change. To this end, this study analyzes crowdsourced disaster big data from Twitter users in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method and conducts sentiment and content analyses of location-based Twitter messages (n = 131,673) from Australia. The study informs authorities on an innovative way to analyze the geographic distribution, occurrence frequency of various disasters and their damages based on the geo-tweets analysis.

Zachry, B. C., Booth, W. J., Rhome, J. R., & Sharon, T. M. (2015). A national view of storm surge risk and inundation. *Weather, Climate, and Society*, *7*(2), 109–117. https://doi.org/10.1175/WCAS-D-14-00049.1

The National Oceanic and Atmospheric Administration (NOAA), specifically the National Weather Service's (NWS) National Hurricane Center (NHC), utilizes the hydrodynamic Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model to simulate storm surge in 27 basins along the U.S East and Gulf Coasts. This information is provided to federal, state, and local partners to assist in a range of planning processes, risk assessment studies, and decision making. Based on climatology, tens of thousands of hypothetical hurricanes are simulated in each basin, and the potential storm surges are calculated. Storm surge composites - maximum envelopes of water (MEOWs) and maximum of maximums (MOMs) - are created to assess and visualize storm surge risk under varying conditions. While MEOWs and MOMs provide a local assessment of storm surge risk, they do not provide a national perspective owing to the 27 discrete grids. National assessments must therefore merge the grids together, which is a laborious task requiring considerable SLOSH and hydrodynamic modeling expertise. This paper describes the technique used to create national inundation maps for category 1-5 hurricanes using the SLOSH MOM product, and it provides a simple quantitative assessment of the potential societal impacts. Approximately 22 million people along the U.S East and Gulf Coasts are vulnerable to storm surge. For all hurricane categories, a substantial portion of the coastal population and housing units are at risk, and many evacuation routes become inundated. Florida is the most vulnerable state with 40% of its population at risk. These maps and analyses provide a new way to view, analyze, and communicate national storm surge risk and inundation.

Communication

Keywords: communication channels, communication effectiveness, communication of information, communication of risk, communication pathways, communication roles, media communication, risk

communication, social media, social media (Twitter), telecommunications and public-private partnerships, Twitter, warning communication

(IN-MHEWS), T. I. N. for M.-H. E. W. S., & Climate Risk and Early Warning (CREWS). (2017). *Draft Consultation Document On Measuring Early Warning Access and Effectiveness*. https://public.wmo.int/en/resources
the present consultation document aims to identify a set of metrics to provide guidance on how the effectiveness of, and access to, early warning systems can be measured, encompassing a conceptual framework of key elements, including sources of data and information and methodologies.

Aguirre-Ayerbe, I., Merino, M., Aye, S. L., Dissanayake, R., Shadiya, F., & Lopez, C. M. (2020). An evaluation of availability and adequacy of Multi-Hazard Early Warning Systems in Asian countries: A baseline study. *International Journal of Disaster Risk Reduction*, *49*, 101749. https://doi.org/10.1016/j.ijdrr.2020.101749
Early warning systems are widely considered as one of the more important aspects to reduce the impacts and consequences that hazardous natural events pose to societies. Similar to the other terms related to disaster risk reduction, this concept has evolved over time to eventually result in a comprehensive framework, that includes features from the upstream phase, such as detection and forecasting tools and models, to the downstream phase that considers a people-centred approach. Based on this holistic conceptual framework, this paper attempts to assess the degree of adequacy and integration of early warning systems with reference to international standards using a multi-hazard perspective. The study is focused on the following Asian countries: the Maldives, Sri Lanka, Myanmar and the Philippines. Results: obtained provide an inventory of existing approaches and systems, showing common backgrounds and consistencies in their conceptualisation. In addition, the findings of this study highlight the strengths and weaknesses of Multi-Hazard Early Warning Systems in each country considering their technical, legal, and socio-economic complexities. These findings are intended to support target countries to improve the availability and effectiveness of their warning systems.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S., Sivle, A. D., Agersten, S., Schmid, F., & Simon, A. (2016). Use and perception of weather forecast information across Europe Journal: *Meteorological Applications*, *4*(434), 1–2. https://doi.org/10.1002/met.2053
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one

survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Cawood, M., Keys, C., & Wright, C. (2018). The total flood warning system: What have we learnt since 1990 and where are the gaps. *Australian Journal of Emergency Management*, *33*(2), 47–52.
April 1990 was a month of severe flooding in eastern Australia. Two months later, a national workshop was held in which a large number of flood management specialists sought to capture the lessons of the floods while they were still fresh. Many aspects of the management of the events were examined, with flood warning highlighted as a key function. A second meeting the following year resolved to produce a best-practice manual to help guide practitioners in the development of flood warning services. The term "Total Flood Warning System" (TFWS) was adopted to describe the need to integrate the many elements of effective warning. The need to help those in the path of a flood to understand the warnings they received and take effective action was recognised as central. The manual was published in 1995 and revised and updated in 1999 and 2009. This paper asks what has changed and improved in the flood warning field since 1990 and what is needed in TFWS terms to further help communities and individuals manage their flood risk.

Demuth, J. L., Morss, R. E., Morrow, B. H., & Lazo, J. K. (2012). Creation and communication of hurricane risk information. *Bulletin of the American Meteorological Society*, *93*(8), 1133–1145. https://doi.org/10.1175/BAMS-D-11-00150.1
Reducing loss of life and harm when a hurricane threatens depends on people receiving hurricane risk information that they can interpret and use in protective decisions. To understand and improve hurricane risk communication, this article examines how National Weather Service (NWS) forecasters at the National Hurricane Center and local weather forecast offices, local emergency managers, and local television and radio media create and convey hurricane risk information. Data from in-depth interviews and observational sessions with members of these groups from Greater Miami were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Together, these groups succeed in partnering with each other to make information about approaching hurricane threats widely available. Yet NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios. Thus, we recommend that warning system partners 1) build understanding of each other's needs and constraints; 2) ensure formalized, yet flexible mechanisms exist for exchanging critical information; 3) improve hurricane risk communication by integrating social science knowledge to design and test messages with intended audiences; and 4) evaluate, test, and improve the NWS hurricane-related product suite in collaboration with social scientists. ©2012 American Meteorological Society.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., &

Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811
Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Jayasekara, R. U., Jayathilaka, G. S., Siriwardana, C., Amaratunga, D., Haigh, R., Bandara, C., & Dissanayake, R. (2021). Identifying gaps in early warning mechanisms and evacuation procedures for tsunamis in Sri Lanka, with a special focus on the use of social media. *International Journal of Disaster Resilience in the Built Environment*. https://doi.org/10.1108/IJDRBE-02-2021-0012
Purpose: The current National Early Warning System for Sri Lanka (NEWS: SL) was established after the devastations of the Indian Ocean Tsunami in 2004. Although early warning (EW) systems and evacuation procedures are in place, several areas which need improvements have been emphasized in recent studies carried out in the country. Therefore, this paper aims to outline the gaps in existing EW and EP related to tsunami and other coastal hazards with a special focus on the use of social media for disaster communication based on age groups.
Design/methodology/approach: This study has drawn on a review of past studies carried out by the same research team to identify the scope of the study. In addition to that, a conceptual framework was developed for the use of social media in the event of a disaster. Based on this conceptual framework, an online questionnaire was administered to identify the current status of the use of social media in Sri Lanka during a disaster situation. In total, 408 responses were collected and analyzed using the binary logistic regression method to evaluate the variation of different predictors associated with the use of social media for disaster communication. Findings: Findings of the study revealed that the use of social media for disaster communication depends on the previous experience of users and their age. The gender of users does not affect the use of social media for disaster communication. Therefore, the accuracy and timeliness of disaster information distributed via social media should be improved further to enhance the use of social media for disaster communication. Moreover, the findings have highlighted unaddressed issues in areas such as governance; communication of technical agencies; evacuation and shelters; and response of the community. Originality/value: This paper has identified key areas that need attention in the process of enhancing the use of social media for disaster communication. More use of

technological platforms such as social media for receiving disaster-related information can address issues such as bottlenecks in communication, poor awareness and lack of last-mile dissemination. Furthermore, this paper has proposed recommendations for addressing the identified gaps in the overall EW mechanisms and EP pertaining to tsunamis and other coastal hazards to enhance the coastal disaster resilience in Sri Lanka.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., & Harris, A. J. (2022). Investigating the decision thresholds for impact-based warnings in South East Asia. *International Journal of Disaster Risk Reduction*, *76*, 103021. https://doi.org/10.1016/j.ijdrr.2022.103021

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1
As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

Morrow, B. H., Lazo, J. K., Rhome, J., & Feyen, J. (2015). Improving storm surge risk communication: Stakeholder perspectives. *Bulletin of the American Meteorological Society*, *96*(1), 35–48. https://doi.org/10.1175/BAMS-D-13-00197.1
Storm surge associated with tropical and extratropical cyclones has a long history of causing death and destruction along our coastlines. With more than 123 million people living in coastal shoreline areas and much of the densely populated Atlantic and Gulf coastal areas less than 10 ft (~3 m) above mean sea level, the threat has never been greater. In this article, we summarize and integrate the most intensive series of studies completed to date on communication of storm surge risk. These were primarily geographically focused stakeholder surveys for evaluating the storm surge communication perceptions and preferences of forecasters, broadcast meteorologists, public officials, and members of the public - each a primary user group for storm surge forecasts. According to findings from seven surveys, each group strongly supports the National Weather Service (NWS) issuing watches and warnings for storm surge, whether associated with tropical cyclones (TC) or extratropical (ET) cyclones. We discuss results on public understanding of storm surge vulnerability, respondents' preferences for separate storm surge information products, and initial assessments of potential storm surge warning text and graphics. Findings from the research reported here are being used to support relevant NWS decisions, including a storm surge watch and warning product that has been approved for use on an experimental basis in 2015 and the National Hurricane Center (NHC) issuance of local surge inundations maps on an experimental basis in 2014.

Morss, R. E., Demuth, J. L., Lazrus, H., Palen, L., Barton, C. M., Davis, C. A., Snyder, C., Wilhelmi, O. V., Anderson, K. M., Ahijevych, D. A., Anderson, J., Bica, M., Fossell, K. R., Henderson, J., Kogan, M., Stowe, K., & Watts, J. (2017). Hazardous weather prediction and communication in the modern information environment. *Bulletin of the American Meteorological Society*, *98*(12), 2653–2674. https://doi.org/10.1175/BAMS-D-16-0058.1
Understanding the dynamic, interconnected processes that characterize the modern hazard information system can transform the creation, communication, and use of weather and climate information.

Morss, R. E., Mulder, K. J., Lazo, J. K., & Demuth, J. L. (2016). How do people perceive, understand, and anticipate responding to flash flood risks and warnings? Results from a public survey in Boulder, Colorado, USA. *Journal of Hydrology*, *541*, 649–664. https://doi.org/10.1016/j.jhydrol.2015.11.047
This study investigates flash flood forecast and warning communication, interpretation, and decision making, using data from a survey of 418 members of the public in Boulder, Colorado, USA. Respondents to the public survey varied in their perceptions and understandings of flash flood risks in Boulder, and some had misconceptions about flash flood risks, such as the safety of crossing fast-flowing water. About 6% of respondents indicated consistent reversals of US watch-warning alert terminology. However, more in-depth analysis illustrates the multi-dimensional, situationally dependent meanings of flash flood alerts, as well as the importance of evaluating interpretation and use of warning information along with alert terminology. Some public respondents estimated low likelihoods of flash flooding given a flash flood warning; these were associated with lower anticipated likelihood of taking protective action given a warning. Protective action intentions were also lower among respondents who had less trust in flash flood warnings, those who had not made prior preparations for flash flooding, and those who believed themselves to be safer from flash flooding. Additional analysis, using open-ended survey questions about responses to warnings, elucidates the complex, contextual nature of protective decision making during flash flood threats. These findings suggest that warnings can play an important role not only by notifying people that there is a threat and helping motivate people to take protective action, but also by helping people

evaluate what actions to take given their situation.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2021.102344
Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP, CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Seebauer, S., & Babcicky, P. (2018). Trust and the communication of flood risks: comparing the roles of local governments, volunteers in emergency services, and neighbours. *Journal of Flood Risk Management*, *11*(3), 305–316. https://doi.org/10.1111/jfr3.12313

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

Sorensen, J. H., Lindell, M. K., Baker, E. J., & Lehman, W. P. (2020). Community response to hurricane threat: Estimates of warning issuance time distributions. *Weather, Climate, and Society*, *12*(4), 837–846. https://doi.org/10.1175/WCAS-D-20-0031.1
Hurricane evacuation warnings from local officials are one of the most significant determinants of households' evacuation departure times. Consequently, it is important to know how long after the National Hurricane Center (NHC) issues a hurricane watch or warning that local officials wait to issue evacuation warnings. The distribution of local evacuation warning issuance delays determined from poststorm assessment data shows a wide range of warning issuance delay times over an 85-h time span, although the vast majority of times fall within a 40-h window. Nearly 30% of the jurisdictions issued evacuation warnings before an NHC hurricane warning. Only 5% delayed the decision for more than 25 h after the NHC hurricane warning. The curves for warning issuance delays, using both the NHC watch and NHC warning issuance times as reference points, are very different from the warning issuance curves observed for the rapid-onset events. The hurricane data exhibit much more of an '"S shape"' than the exponential shape that is seen for rapid-onset data. Instead, curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension, follow three noticeably different logistic distributions. The data also indicate that warnings were issued significantly earlier for coastal

counties than for inland counties. These results have direct practical value to analysts that are calculating evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions for future research on the reasons for the timing of local officials' hurricane evacuation decisions. SIGNIFICANCE STATEMENT: Local officials rely on National Hurricane Center (NHC) hurricane watches and warnings to guide them in issuing evacuation warnings but do not automatically issue evacuation warnings as soon as the NHC issues a watch or warning. Thus, this study constructed a database that contains the timing of NHC hurricane watches and warnings, as well as local evacuation warnings, for 20 hurricanes that threatened 290 U.S. jurisdictions from 1979 to 2008. The data reveal distinct curves for three different types of storm tracks, defined by a perpendicular/parallel dimension and a straight/meandering dimension. These results are of direct practical value to analysts who calculate evacuation time estimates for coastal jurisdictions. Moreover, they suggest directions for future research on the reasons for the timing of local officials' hu…

Sutton, J., & Fischer, L. M. (2020). Understanding Visual Risk Communication Messages: An Analysis of Visual Attention Allocation and Think-Aloud Responses to Tornado Graphics. *Weather, Climate, and Society*, *13*(1), 173–188. https://doi.org/10.1175/wcas-d-20-0042.1
Online channels for communicating risk frequently include features and technological capabilities to support sharing images of risk. In particular, the affordances found in social media, such as Twitter, include the ability to attach maps, photographs, videos, and other graphical information. The inclusion of visual cues such as colors and shapes and their different sizes are important for making sense of approaching threats, populations at risk, the potential impacts, and ranges of associated uncertainty. The reception of and attention to these visual cues in messages about a potential threat is the necessary first stage to making a decision about protective actions. Understanding what visual features capture individual attention and how attention is directed to visual images of risk on social media has the potential to affect the design of risk communication messages and the protective actions that follow. In this paper we use eye-tracking methods to identify where people allocate attention to a series of tweets and qualitative "think alouds" to determine what features of the tweets people attend to in their visual field are salient to message receivers. We investigate visual attention to a series of tweets that depict an emerging tornado threat to identify areas of visual interest and the properties of those visual cues that elicit attention. We find the use of color, properties of text presentation, and contents of messages affect attention allocation. These findings could help practitioners as they design and disseminate their weather messages to inform the public of emerging threats.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Wall, T. U., Brown, T. J., & Nauslar, N. J. (2017). Spot weather forecasts: Improving utilization, communication, and perceptions of accuracy in sophisticated user groups. *Weather, Climate, and Society*, *9*(2), 215–226. https://doi.org/10.1175/WCAS-D-15-0055.1
Spot weather forecasts (SWFs) are issued by Weather Service offices throughout the United States and are primarily for use by wildfire and prescribed fire practitioners for monitoring local-scale weather conditions. This paper focuses on use of SWFs by prescribed fire practitioners. Based on qualitative, in-depth interviews with fire practitioners and National Weather Service forecasters, this paper examines factors that influence perceptions of accuracy and utilization of SWFs. Results indicate that, while several well-understood climatological, topographical, and data-driven factors influence forecast accuracy, social factors likely have the greater impact on perceptions of

accuracy, quantitative accuracy, and utilization. These include challenges with building and maintaining relationships between forecasters and fire managers, communication issues around updating SWFs, and communicating forecast confidence and uncertainty. Operationally, improved quantitative skill in a forecast is always desirable, but key opportunities for improving accuracy and utilization of these forecasts lie in 1) enhancing the processes and mechanisms for communication between a Weather Forecast Office and fire practitioners—before, during, and after an SWFs is issued—and 2) working with the wildland fire community to experiment with forecast uncertainty and confidence information in SWFs and evaluate impacts of these approaches.

Wilkins, E. J., Miller, H. M., Tilak, E., & Schuster, R. M. (2018). Communicating information on nature-related topics: Preferred information channels and trust in sources. *PLOS ONE*, *13*(12), e0209013. https://doi.org/10.1371/journal.pone.0209013

World Meteorological Organization. (2008). Guidelines on communicating forecast uncertainty. *Wmo Td-1722*, *PWS-18*, 25 pages.
These Guidelines address the issue of communicating forecast uncertainty. Although they include a discussion on the sources of uncertainty, and touch on the related science (e.g. probabilistic forecasting, the use of Numerical Weather Prediction (NWP) ensembles), this is not their focus. Rather, the emphasis is on how National Meteorological and Hydrological Services (NMHSs) can incorporate uncertainty information in their hydrometeorological forecast services, including the best ways to communicate this information to the benefit of users.

Yigitcanlar, T., Regona, M., Kankanamge, N., Mehmood, R., D'costa, J., Lindsay, S., Nelson, S., & Brhane, A. (2022). Detecting Natural Hazard-Related Disaster Impacts with Social Media Analytics: The Case of Australian States and Territories. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020810
Natural hazard-related disasters are disruptive events with significant impact on people, communities, buildings, infrastructure, animals, agriculture, and environmental assets. The exponentially increasing anthropogenic activities on the planet have aggregated the climate change and consequently increased the frequency and severity of these natural hazard-related disasters, and consequential damages in cities. The digital technological advancements, such as monitoring systems based on fusion of sensors and machine learning, in early detection, warning and disaster response systems are being implemented as part of the disaster management practice in many countries and presented useful results. Along with these promising technologies, crowdsourced social media disaster big data analytics has also started to be utilized. This study aims to form an understanding of how social media analytics can be utilized to assist government authorities in estimating the damages linked to natural hazard-related disaster impacts on urban centers in the age of climate change. To this end, this study analyzes crowdsourced disaster big data from Twitter users in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method and conducts sentiment and content analyses of location-based Twitter messages (n = 131,673) from Australia. The study informs authorities on an innovative way to analyze the geographic distribution, occurrence frequency of various disasters and their damages based on the geo-tweets analysis.

Data and information

Keywords: big data, crowdsource data, crowd-sourced and anecdotal data, crowd-sourced data, data analytics, data collection, agroclimatic bulletin, books, disaster loss and damage data, disaster

databases, disaster damage, emergency flood bulletin creation, exposure data, disaster impact, flood damage, global database, hurricane risk information, impact data, humanitarian impacts, information availability, information sharing, information systems, information technology, lack of information, information-intensive service, information lead time, modelling data, observations, observing systems, probabilistic information, Twitter data, uncertainty information, volunteered geographic information, vulnerability data

Alliance for Hydromet Development. (2021). *HYDROMET GAP REPORT 2021 Alliance for Hydromet Development*.

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (Eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S., Sivle, A. D., Agersten, S., Schmid, F., & Simon, A. (2016). Use and perception of weather forecast information across Europe Journal: *Meteorological Applications*, *4*(434), 1–2. https://doi.org/10.1002/met.2053
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Borga, M., Comiti, F., Ruin, I., & Marra, F. (2019). Forensic analysis of flash flood response. *WIREs Water*, *6*(2). https://doi.org/10.1002/wat2.1338
The last decade has witnessed the development of methodologies for the post-flood documentation of both hydrogeomorphological and social response to extreme precipitation. These investigations are particularly interesting for the case of flash floods, whose space–time scales make their observations by conventional hydrometeorological monitoring networks particularly challenging. Effective flash flood documentation requires post-flood survey strategies encompassing accurate radar estimation of rainfall, field and remote-sensing observations of the geomorphic processes, indirect reconstruction of peak discharges—as well eyewitness interviews.

These latter can give valuable information on both flood dynamics and the related individual and collective responses. This study describes methods for post-flood surveys based on interdisciplinary collaborations between natural and social scientists. These surveys may help to better understand the links between hydrometeorological dynamics and geomorphic processes as well as the relationship between flood dynamics and behavioral response in the context of fast space–time changes of flooding conditions.

Botzen, W. J. W., Deschenes, O., & Sanders, M. (2019). The economic impacts of natural disasters: A review of models and empirical studies. *Review of Environmental Economics and Policy*, *13*(2), 167–188. https://doi.org/10.1093/reep/rez004

Chichilniskyk, G., & Rezai, A. (2020). *Handbook on the Economics of Climate Change*. https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6237708
This timely Handbook recognizes the emergence of climate change as the defining topic of our time. With public climate discourse growing more urgent every year, this Handbook brings together international experts from different economic disciplines to answer critical climate policy questions. Chapters present key ideas and policies to support and accelerate advances in three key areas: the political economy of climate change and climate policy, integrated assessment modelling, and economic and resource sustainability. Contributors discuss the distributional implications of climate change and how policymakers may respond in order to contribute to economic transformation in the midst of a global crisis. With reference to both theoretical and applied economics, this Handbook is critical reading for economists working in the field of climate policy and climate change. It will also appeal to a broader group of environmental scientists and scholars. BoM staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6237708

Cuthbertson, J., Archer, F., Robertson, A., & Rodriguez-Llanes, J. M. (2021). Improving disaster data systems to inform disaster risk reduction and resilience building in Australia: A comparison of databases. *Prehospital and Disaster Medicine*, *36*(5), 511–518. https://doi.org/10.1017/S1049023X2100073X
Objective: Disaster impact databases are important resources for informing research, policy, and decision making. Therefore, understanding the underpinning methodology of data collection used by the databases, how they differ, and quality indicators of the data recorded is essential in ensuring that their use as reference points is valid. Methods: The Australian Disaster Resilience Knowledge Hub (AIDRKH) is an open-source platform supported by government to inform disaster management practice. A comparative descriptive review of the Disaster Mapper (hosted at AIDRKH) and the international Emergency Events Database (EM-DAT) was undertaken to identify differences in how Australian disasters are captured and measured. Results: The results show substantial variation in identification and classification of disasters across hazard impacts and hazard types and a lack of data structure for the systematic reporting of contextual and impact variables. Conclusions: These differences may have implications for reporting, academic analysis, and thus knowledge management informing disaster prevention and response policy or plans. Consistency in reporting methods based on international classification standards is recommended to improve the validity and usefulness of this Australian database.

Demuth, J. L., Morss, R. E., Morrow, B. H., & Lazo, J. K. (2012). Creation and communication of hurricane risk information. *Bulletin of the American Meteorological Society*, *93*(8), 1133–1145. https://doi.org/10.1175/BAMS-D-11-00150.1
Reducing loss of life and harm when a hurricane threatens depends on people receiving hurricane risk information that they can interpret and use in protective decisions. To understand and

improve hurricane risk communication, this article examines how National Weather Service (NWS) forecasters at the National Hurricane Center and local weather forecast offices, local emergency managers, and local television and radio media create and convey hurricane risk information. Data from in-depth interviews and observational sessions with members of these groups from Greater Miami were analyzed to examine their roles, goals, and interactions, and to identify strengths and challenges in how they communicate with each other and with the public. Together, these groups succeed in partnering with each other to make information about approaching hurricane threats widely available. Yet NWS forecasters sometimes find that the information they provide is not used as they intended; media personnel want streamlined information from NWS and emergency managers that emphasizes the timing of hazards and the recommended response and protective actions; and emergency managers need forecast uncertainty information that can help them plan for different scenarios. Thus, we recommend that warning system partners 1) build understanding of each other's needs and constraints; 2) ensure formalized, yet flexible mechanisms exist for exchanging critical information; 3) improve hurricane risk communication by integrating social science knowledge to design and test messages with intended audiences; and 4) evaluate, test, and improve the NWS hurricane-related product suite in collaboration with social scientists. ©2012 American Meteorological Society.

Department of Home Affairs. (2018). *National Disaster Risk Reduction Framework*. https://www.homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf
The National Disaster Risk Reduction Framework ('the framework') guides national, whole-of-society efforts to proactively reduce disaster risk in order to minimise the loss and suffering caused by disasters. This framework is designed to guide Australia's efforts to reduce disaster risk associated with natural hazards. It translates the first three Sendai Framework priorities into action for the Australian context; though the strategies outlined in this framework are applicable to disaster preparedness and recovery efforts, the fourth priority of the Sendai Framework is largely progressed through other national strategies, primarily the Australian Disaster Preparedness Framework. The framework establishes a 2030 vision, goals and priorities broadly aligned to the Sendai Framework and the 2030 Sustainable Development Goals, and outlines foundational strategies for action to meet these across the five years from 2019 – 2023. The framework will be reviewed and updated at the end of this five-year period to ensure its relevance and accuracy across the remaining years to 2030. It is not exhaustive nor prescriptive, and should be holistically applied across and between four key environments: built, social, natural, and economic.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., & Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811
Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The

research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Giraldo-Mendez, D., Martínez-Barón D Loboguerrero, A., & Co-authors. (n.d.). *Technical Agroclimatic Committees (MTA)*.
MTA is a dialogue process among a diversity of local actors including scientists, technicians, representatives from the public and private sectors, and farmers, which seeks to understand the climate's possible behavior in a locality, and to generate recommendations to reduce risks associated with expected climate variability (Loboguerrero et al. 2018). This dialogue is then used to create an agroclimatic bulletin that contains the region's climate prediction, it is possible impact on crops for specific conditions in time and space, as well as recommendations around decision-making for each productive sector. The climatic predictions are generated in consensus among each country's meteorological service and the agro-meteorology groups from the institutions in order to identify climate-smart practices to climatic phenomena, which are then shared with local technicians and producers by way of the Local Agroclimatic Bulletin. This manual provides step-by-step instructions for implementing the MTA approach. It is directed mainly towards the leading institutions in the agricultural sector that might have an interest in implementing a discussion space in their region. The approach consists of eight steps, which are carried out with the participating institutions. Given the specific nature of each location, there is a series of preparation activities that need to be done before each meeting.

Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., & Johnston, D. (2021). 'Where oh where is the data?': Identifying data sources for hydrometeorological impact forecasts and warnings in Aotearoa New Zealand. *International Journal of Disaster Risk Reduction*, *66*, 102619. https://doi.org/10.1016/j.ijdrr.2021.102619
Early Warning Systems are a key component to building preparedness and response capacities to hydrometeorological hazards that continue to affect people worldwide. Notable historic events have revealed gaps in current hazard-based warning systems. Impact Forecasts and Warnings (IFWs) have been proposed to fill these communication gaps by re-centring the warning thresholds and language around the consequences, or impacts, of the hazard(s), rather than just the physical characteristics. However, research has shown that implementing IFWs requires not just hazard data, but also data on impacts, vulnerability, and exposure to understand the risk of impacts. Using Grounded Theory Methodology, we conducted a series of interviews with users and creators of hazard, impact, vulnerability, and exposure (HIVE) data to identify data sources and understand how these data are collected and created to support the implementation of IFWs. We focus the study on the New Zealand context to support the country's efforts towards implementing IFWs. Our findings indicate that many sources for HIVE data exist that are collected for other uses (such as for disaster/emergency response efforts, and for research) and have relevant applications for IFWs. Our findings further suggest that priorities, motivation, and interest within organisations influence how well data is collected. Moreover, agencies tend to prefer official data, but official data has limitations that unofficial data may address, such as timeliness. To that end, a tension

exists between the timeliness and trustworthiness of data needed for emergency response and warnings.

Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., & Johnston, D. (2022a). Identifying the Impact-Related Data Uses and Gaps for Hydrometeorological Impact Forecasts and Warnings. *Weather, Climate, and Society*, *14*(1), 155–176. https://doi.org/10.1175/WCAS-D-21-0093.1
Impact forecasts and warnings (IFW) are key to resilience for hydrometeorological hazards. Communicating the potential social, economic, and environmental hazard impacts allows individuals and communities to adjust their plans and better prepare for the consequences of the hazard. IFW systems require additional knowledge about impacts and underlying vulnerability and exposure. Lack of data or knowledge about impacts, vulnerability, and exposure has been identified as a challenge for IFW implementation. In this study, we begin to address this challenge by developing an understanding of the data needs and uses for IFWs. Using the grounded theory method, we conducted a series of interviews with users and creators of hazard, impact, vulnerability, and exposure data (e.g., warning services, forecasters, meteorologists, hydrologists, emergency managers, data specialists, risk modelers) to understand where these data are needed and used in the warning value chain, a concept used to represent and understand the flow of information among actors in the warning chain. In support of existing research, we found a growing need for creating, gathering, and using impact, vulnerability, and exposure data for IFWs. Furthermore, we identified different approaches for impact forecasting and defining impact thresholds using objective models and subjective impact-oriented discussions depending on the data available. We also provided new insight into a growing need to identify, model, and warn for social and health impacts, which have typically taken a back seat to modeling and forecasting physical and infrastructure impacts. Our findings on the data needs and uses within IFW systems will help guide their development and provide a pathway for identifying specific relevant data sources.

Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., & Johnston, D. (2022b). 'Sharing is caring'': A socio-technical analysis of the sharing and governing of hydrometeorological hazard, impact, vulnerability, and exposure data in Aotearoa New Zealand.' *Progress in Disaster Science*, *13*, 100213. https://doi.org/10.1016/j.pdisas.2021.100213
There has been a growing recognition of the need to collect disaster and risk data over the last two decades. Accordingly, better collection and management of disaster data was identified as a priority of the Sendai Framework for Disaster Risk Reduction. The introduction and implementation of Impact Forecasts and Warnings (IFWs) have further highlighted this need to collect and access hazard, impact, vulnerability, and exposure (HIVE) data. However, challenges have been met with reporting and using disaster data, which have resulted in an identified need to establish principles for data collection, recording, reporting, exchange/sharing, and comparability. This introduces the concept of data governance and management for disaster data, particularly with regards to data custodianship, stewardship, and sharing. Using Grounded Theory, a series of interviews were conducted with users and creators of HIVE data to develop further understanding around managing and accessing it for severe weather hazards in New Zealand. A socio-technical lens guided the analysis to identify the organisational and technical intervening conditions and action/interaction strategies for accessing and sharing HIVE data in NZ. Findings indicated that there is a need to establish data governance principles for HIVE data in New Zealand. An additional need was identified for nurturing partnerships to continue building trust between stakeholders for sharing data. Furthermore, integration challenges continue to interfere with the use of various sources of HIVE data for effective risk and impact assessments for IFWs and beyond. Systematic and standardised data collection approaches using GIS-based tools can support integration.

Harrison, S., Potter, S., Prasanna, R., Doyle, E. E. H., & Johnston, D. (2020). Volunteered Geographic Information for people-centred severe weather early warning: A literature review. *Australasian Journal of Disaster and Trauma Studies*, *24*(1), 3–21.
Early warning systems (EWSs) can prevent loss of life and reduce the impacts of hazards. Yet, recent severe weather events indicate that many EWSs continue to fail at adequately communicating the risk of the hazard, resulting in significant life and property loss. Given these shortcomings, there has been a shift towards people-centred EWSs to engage with audiences of warnings to understand their needs and capabilities. One example of engaging with warning audiences is through the collection and co-creation of volunteered geographic information (VGI). Much of the research in the past has primarily focused on using VGI in disaster response, with less exploration of the role of VGI for EWSs. This review uses a scoping methodology to identify and analyse 29 research papers on EWSs for severe weather hazards. Results show that VGI is useful in all components of an EWS, but some platforms are more useful for specific components than are others. Furthermore, the different types of VGI have implications for supporting people-centred EWSs. Future research should explore the characteristics of the VGI produced for these EWS components and determine how VGI can support a new EWS model for which the World Meteorological Organization is advocating: that of impact-based forecasting and warning systems.

Insurance Council of Australia. (2022). *Historical Catastrophe Data List June 2022*.

International Federation of Red Cross and Red Crescent Societies (IFRC). (2020). Tackling the humanitarian impacts of the climate crisis together. In *World Disaster Report 2020*.
The analysis presented in World Disasters Report 2020 shows that none of the 20 countries most vulnerable to climate change (according to ND-GAIN) and to climate- and weather-related disasters (according to INFORM) were among the 20 highest per person recipients of climate change adaptation funding. Somalia, the most vulnerable, ranks only 71st for per person funding disbursements. None of the countries with the five highest disbursements had high or very high vulnerability scores. At the other end of the spectrum, 38 high vulnerability countries (out of 60) and 5 very high vulnerability countries (out of 8) received less than $1 per person in climate adaptation funding, while two (Central African Republic and DPRK) received no disbursements at all. Notably, none of the largest five recipients are fragile contexts. An additional challenge is ensuring that funding reaches the most at-risk people within these countries. Many communities may be particularly vulnerable to climate-related risks, from people affected by conflict whose capacity to manage shocks is already strained, to migrants and displaced people who may struggle to access the services and assistance they need, to urban poor people and other marginalized communities. Support needs to reach these communities most vulnerable to climate-related risks as a priority. The issues are not only financial. The report argues it is time to shake off business as usual and turn words into action. Much of what needs to be done has been known for years – it is just overdue in implementation. But we also need to scale up some new lessons learned more recently from our changed environment. Fundamentally, we need to ensure that we are implementing the intertwined commitments in the Sustainable Development Goals (SDGs), the Paris Agreement and the Sendai Framework for Disaster Risk Reduction 2015–2030 in a joined-up way. And we must do a much better job of ensuring that all actors – including governments, donors, the humanitarian, development, climate and environmental sectors – prioritize support for the people, communities and countries most at risk. The World Disasters Report 2020 takes a deep dive into the disaster risks that climate change is driving, and analyses the action needed to address their human impacts.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M.,

Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Jeuland, M., Hansen, K., Doherty, H., Eastman, L. B., & Tchamkina, M. (2019). The economic impacts of water information systems: A systematic review. *Water Resources and Economics*, *26*, 100128. https://doi.org/10.1016/j.wre.2018.09.001
Information systems can yield economic value by providing data and analyses that are useful for improving water operations and planning. Working from a simple typology of water management domains that acknowledges the coupling of supply and demand, we characterize the nature of peer-reviewed and practitioner research that considers or makes reference to the costs and benefits of water-related information. The coverage of the reviewed studies is heterogeneous across domains, sectors, analytical methods, type of information considered, and geographic regions. Studies that discuss costs and benefits of additional information relative to a counter-factual represent a minority (39%) of those reviewed. Most of these counterfactual studies use a model prediction (60%) and/or extrapolate from previous studies (34%); far fewer rely on em-pirical evidence (24%). Furthermore, measurement of and justification for the proposed benefits and costs – whether monetized or only quantified – remains limited. We also comment on several of the more prominent methodologies for analyzing the costs and benefits of investments in improved water information. This leads to reflections on a research agenda that would enrich what is known about the economic value of water resources information, and thereby perhaps improve decision-makers' ability to make fruitful investments in information systems. In the absence of more rigorous evidence on the contribution that specific systems make to societal well-being, decision-makers will likely remain tentative about further information investments

Joslyn, S., Nemec, L., & Savelli, S. (2013). The benefits and challenges of predictive interval forecasts and verification graphics for end users. *Weather, Climate, and Society*, *5*(2), 133–147. https://doi.org/10.1175/WCAS-D-12-00007.1
Two behavioral experiments tested the use of predictive interval forecasts and verification graphics by nonexpert end users. Most participants were able to use a simple key to understand a predictive interval graphic, showing a bracket to indicate the upper and lower boundary values of the 80% predictive interval for temperature. In the context of a freeze warning task, the predictive interval forecast narrowed user expectations and alerted participants to the possibility of colder temperatures. As a result, participants using predictive intervals took precautionary action more often than did a control group using deterministic forecasts. Moreover, participants easily understood both deterministic and predictive interval verification graphics, based on simple keys, employing them to correctly identify better performing forecast periods. Importantly, participants

with the predictive interval were more likely than those with the deterministic forecast to say they would use that forecast type in the future, demonstrating increased trust. Verification graphics also increased trust in both predictive interval and deterministic forecasts when the effects were isolated from familiarity in the second study. These results suggest that forecasts that include an uncertainty estimate might maintain user trust even when the single-value forecast fails to verify, an effect that may be enhanced by explicit verification data. © 2013 American Meteorological Society.

Kaltenberger, R., Schaffhauser, A., & Staudinger, M. (2020). What the weather will do-results of a survey on impact-oriented and impact-based warnings in European NMHSs. *Advances in Science and Research*, *17*, 29–38. https://doi.org/10.5194/asr-17-29-2020
European NMHSs are progressing from warnings based on fixed thresholds or climatology-based thresholds to impact-oriented and impact-based warnings. This publication gives an overview of warning implementation as surveyed at 32 of the 37 NMHSs participating in the EUMETNET Meteoalarm project. The report addresses these topics: warning format, legislation and production process of warnings, dissemination and verification of warnings, impact databases, warning strategy and cooperation, legal obstacles and cross-border collaboration. Potential obstacles are identified and possible trends are discussed.

Keating, A., & Handmer, J. (2011). The cost of disasters to Australia and Victoria – no straightforward answers. In *VCCCAR Project: Framing Adaptation in the Victorian Context - Working paper 3* (Issue April).
This paper looks at the current cost of extreme meteorological disasters to Australia and Victoria in an effort to provide a starting point for appreciating the types of costs that may be present and increasing under climate change. There exists a confounding variety and breadth of estimates relating to the cost of weather related disasters in Victoria and Australia. Comparative analysis shows that data source and methodology have profound impacts on the conclusions drawn from both aggregate analyses of disaster costs and analyses of individual events, in this case the 1983 Ash Wednesday bushfires. Disaster cost estimates in Australia are largely drawn from insurance data or insurance data with some augmentation; the estimates that utilise insurance data are a limited proxy for disaster cost. Insurance data only account for insured losses, and these represent only a fraction of the total cost of a disaster. In particular they do not include many indirect costs, valuations for loss of life, nor intangibles such as ecosystem services which can have significant impacts on cost estimates. Analyses based on insurance data also draw conclusions influenced by which hazards and assets are or are not insured.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York

City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lejano, R. P., Tan, J. M., Meriwether, A., & Wilson, W. (2016). A textual processing model of risk communication: Lessons from Typhoon Haiyan. *Weather, Climate, and Society*, *8*(4), 447–463. https://doi.org/10.1175/WCAS-D-16-0023.1
As the world's urban poor increase in numbers, they become acutely vulnerable to hazards from extreme weather events. On 8 November 2013, Typhoon Haiyan struck the province of Leyte, Philippines, with casualties numbering in the thousands, largely because of the ensuing storm surge that swept the coastal communities. This study investigates the role and dynamics of risk communication in these events, specifically examining the organizational processing of text within a complex institutional milieu. The authors show how the risk communication process failed to convey meaningful information about the predicted storm surge, transmitting and retransmitting the same routine text instead of communicating authentic messages in earnest. The key insight is that, rather than focus solely on the verbatim transmission of a scripted text, risk communication needs to employ various modes of translation and feedback signals across organizational and institutional boundaries. Adaptation will require overcoming organizational rigidities in order to craft proportionate responses to extreme weather events that may lie outside personal and institutional memory. Future work should build upon the textual processing approach to risk communication, expanding it into a comprehensive relational model of environmental cognition.

Lim, C., Kim, K. H., Kim, M. J., Heo, J. Y., Kim, K. J., & Maglio, P. P. (2018). From data to value: A nine-factor framework for data-based value creation in information-intensive services. *International Journal of Information Management*, *39*(December 2017), 121–135. https://doi.org/10.1016/j.ijinfomgt.2017.12.007
Service is a key context for the application of IT, as IT digitizes information interactions in service and facilitates value creation, thereby contributing to service innovation. The recent proliferation of big data provides numerous opportunities for information-intensive services (IISs), in which information interactions exert the greatest effect on value creation. In the modern data-rich economy, understanding mechanisms and related factors of data-based value creation in IISs is essential for using IT to improve such services. This study identified nine key factors that characterize this data-based value creation: (1) data source, (2) data collection, (3) data, (4) data analysis, (5) information on the data source, (6) information delivery, (7) customer (information user), (8) value in information use, and (9) provider network. These factors were identified and defined through six action research projects with industry and government that used specific datasets to design new IISs and by analyzing data usage in 149 IIS cases. This paper demonstrates the usefulness of these factors for describing, analyzing, and designing the entire value creation chain, from data collection to value creation, in IISs. The main contribution of this study is to provide a simple yet comprehensive and empirically tested basis for the use and management of data to facilitate service value creation.

Lukasiewicz, A., & Baldwin, C. (2020). *Natural hazards and disaster justice: Challenges for australia and its neighbours* (Issue February). https://doi.org/10.1007/978-981-15-0466-2
This book explores policy, legal, and practice implications regarding the emerging field of disaster justice, using case studies of floods, bushfires, heatwaves, and earthquakes in Australia and

Southern and South-east Asia. It reveals geographic locational and social disadvantage and structural inequities that lead to increased risk and vulnerability to disaster, and which impact ability to recover post-disaster. Written by multidisciplinary disaster researchers, the book addresses all stages of the disaster management cycle, demonstrating or recommending just approaches to preparation, response and recovery. It notably reveals how procedural, distributional and interactional aspects of justice enhance resilience, and offers a cutting edge analysis of disaster justice for managers, policy makers, researchers in justice, climate change or emergency management. BoM Staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6028057

Merz, B., Kreibich, H., Schwarze, R., & Thieken, A. (2010). Assessment of economic flood damage. *Natural Hazards and Earth System Science*, *10*(8), 1697–1724. https://doi.org/10.5194/nhess-10-1697-2010
Damage assessments of natural hazards supply crucial information to decision support and policy development in the fields of natural hazard management and adaptation planning to climate change. Specifically, the estimation of economic flood damage is gaining greater importance as flood risk management is becoming the dominant approach of flood control policies throughout Europe. This paper reviews the state-of-the-art and identifies research directions of economic flood damage assessment. Despite the fact that considerable research effort has been spent and progress has been made on damage data collection, data analysis and model development in recent years, there still seems to be a mismatch between the relevance of damage assessments and the quality of the available models and datasets. Often, simple approaches are used, mainly due to limitations in available data and knowledge on damage mechanisms. The results of damage assessments depend on many assumptions, e.g. the selection of spatial and temporal boundaries, and there are many pitfalls in economic evaluation, e.g. the choice between replacement costs or depreciated values. Much larger efforts are required for empirical and synthetic data collection and for providing consistent, reliable data to scientists and practitioners. A major shortcoming of damage modelling is that model validation is scarcely performed. Uncertainty analyses and thorough scrutiny of model inputs and assumptions should be mandatory for each damage model development and application, respectively. In our view, flood risk assessments are often not well balanced. Much more attention is given to the hazard assessment part, whereas damage assessment is treated as some kind of appendix within the risk analysis. Advances in flood damage assessment could trigger subsequent methodological improvements in other natural hazard areas with comparable time-space properties.

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F., Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704
Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in

impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Middelmann, M. H. (2007). *Natural hazards in Australia : identifying risk analysis requirements*. Australian Government/Geoscience Australia/Department of Transport and Regional Services/Bureau of Meteorology/CSIRO. https://d28rz98at9flks.cloudfront.net/65444/65444.pdf

Moriyama, K., Sasaki, D., & Ono, Y. (2018). Comparison of Global Databases for Disaster Loss and Damage Data. *Journal of Disaster Research*, *13*(6), 1007–1014. https://doi.org/10.20965/jdr.2018.p1007
After the Sendai Framework for Disaster Risk Reduction is adopted, a global database as a tool to monitor disaster loss and damage databases is required. Several disaster loss and damage databases are in use globally. This paper aims to explore how the existing databases vary in three aspects of threshold, spatial resolution, and data quality control, as well as the limitations of the existing databases. We review previous studies comparing the existing global databases and extract the differences and limitations. The threshold of EM-DAT is clear, but its threshold results in ignoring small-scale disasters that DesInventar captures. The differences in disaster threshold create different pictures of disaster losses and/or risks. Regarding spatial resolution, only DesInventar provides disaster impact data at a municipal level, while others provide information at a country level. The limitations of the existing global database are categorized into four aspects, as follows: lack of disaggregated data, limited spatial coverage and resolution, insufficiency of completeness and reliability of data, and insufficient information on indirect loss. The implication from our findings is that, in order to complement the limitations of the existing disaster loss databases to use for decision making on disaster risk reduction, the following are required: cross-checking of data across different databases; complementary disaster loss data; and collection of an exhaustive and firsthand dataset with a transparent and internationally consistent methodology by policy makers.

Morss, R. E., Demuth, J. L., Lazrus, H., Palen, L., Barton, C. M., Davis, C. A., Snyder, C., Wilhelmi, O. V., Anderson, K. M., Ahijevych, D. A., Anderson, J., Bica, M., Fossell, K. R., Henderson, J., Kogan, M., Stowe, K., & Watts, J. (2017). Hazardous weather prediction and communication in the modern information environment. *Bulletin of the American Meteorological Society*, *98*(12), 2653–2674. https://doi.org/10.1175/BAMS-D-16-0058.1
Understanding the dynamic, interconnected processes that characterize the modern hazard information system can transform the creation, communication, and use of weather and climate information.

NASA. (2012). Measuring Socioeconomic Impacts of Earth Observations. *NASA Report NP-2012-04-856-HQ*.

National Research Council. (2006). *Completing the Forecast: Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts*. National Academies Press. https://doi.org/10.17226/11699

Park, M. S., Park, S. H., Chae, J. H., Choi, M. H., Song, Y., Kang, M., & Roh, J. W. (2017). High-resolution urban observation network for user-specific meteorological information service in the Seoul Metropolitan Area, South Korea. *Atmospheric Measurement Techniques*, *10*(4), 1575–1594. https://doi.org/10.5194/amt-10-1575-2017
To improve our knowledge of urban meteorology, including those processes applicable to high-resolution meteorological models in the Seoul Metropolitan Area (SMA), the Weather Information

Service Engine (WISE) Urban Meteorological Observation System (UMS-Seoul) has been designed and installed. The UMS-Seoul incorporates 14 surface energy balance (EB) systems, 7 surface-based three-dimensional (3-D) meteorological observation systems and applied meteorological (AP) observation systems, and the existing surface-based meteorological observation network. The EB system consists of a radiation balance system, sonic anemometers, infrared CO2/H2O gas analyzers, and many sensors measuring the wind speed and direction, temperature and humidity, precipitation, and air pressure. The EB-produced radiation, meteorological, and turbulence data will be used to quantify the surface EB according to land use and to improve the boundary-layer and surface processes in meteorological models. The 3-D system, composed of a wind lidar, microwave radiometer, aerosol lidar, or ceilometer, produces the cloud height, vertical profiles of backscatter by aerosols, wind speed and direction, temperature, humidity, and liquid water content. It will be used for high-resolution reanalysis data based on observations and for the improvement of the boundary-layer, radiation, and microphysics processes in meteorological models. The AP system includes road weather information, mosquito activity, water quality, and agrometeorological observation instruments. The standardized metadata for networks and stations are documented and renewed periodically to provide a detailed observation environment. The UMS-Seoul data are designed to support real-Time acquisition and display and automatically quality check within 10ĝ€min from observation. After the quality check, data can be distributed to relevant potential users such as researchers and policy makers. Finally, two case studies demonstrate that the observed data have a great potential to help to understand the boundary-layer structures more deeply, improve the performance of high-resolution meteorological models, and provide useful information customized based on the user demands in the SMA.

Perrels, A. (2020). Quantifying the uptake of climate services at micro and macro level. *Climate Services*, *17*(January), 100152. https://doi.org/10.1016/j.cliser.2020.100152
Quantification and communication of the expected net benefits of climate services for particular types of users and society at large has been hitherto a rather weak element in the deployment of climate services. This article discusses the challenges of quantification and warns that there is no universal method for this. It provides a general structure to assess benefit-cost ratios of new climate services. From this framework proper valuation of climate services can be developed. It also underscores the significance of aptness for verification of the performance of a climate service, as well as contextual effects, such as market form, regulations, and pace of innovation. Only for subsets of seasonal climate services the so-called cost-loss approach and some other forecast accuracy-oriented approaches are applicable. For other types of climate services performance indicators need to be developed. Furthermore, for some types of effectiveness evaluations more user/use oriented indicators are necessary, even if forecast accuracy based approaches would be applicable as well, as these approaches do not guarantee that the highest utility for the user has been achieved using the climate services. The proposed framework emphasizes the inclusion of competitive conditions under which the CS users operate, the role of information exclusiveness vs. sharing, the role of adequate quality assurance and communication, the effects learning and R&D for climate services.

Robbins, J. C., & Titley, H. A. (2018). Evaluating high-impact precipitation forecasts from the Met Office Global Hazard Map (GHM) using a global impact database. *Meteorological Applications*, *25*(4), 548–560. https://doi.org/10.1002/met.1720
The Met Office Global Hazard Map (GHM) summarizes the risk of high-impact weather across the globe over the coming week using global ensemble forecast data. In addition to gridded daily probability forecasts, a symbol and polygon-based summary layer gives an at-a-glance view of likely high-impact weather for the week ahead. To evaluate the performance of the GHM, two

complementary approaches were used. The first is an objective precipitation verification approach comparing the daily gridded precipitation forecasts with global precipitation observations. The second, and the main focus of this paper is a new, semi-automated evaluation approach that assesses the ability of the multi-model ensemble precipitation summary layer to highlight events that cause community impacts, as recorded in an impact database. The verification against observed precipitation confirms there is good skill in the precipitation forecasts and that the multi-model ensemble provides the best guidance to take forward into the summary layer. The verification against impacts indicates there is a good spatial relationship between the GHM precipitation forecasts and heavy rainfall impacts across the globe. Hit rates for all impact severities range from 40 to 60% for days 1–3 and taper off to lower hit rates at the longer lead times (10–20% for days 6–7). High-impact events are captured marginally less well than the low-, medium- and disastrous-impact event categories and this paper illustrates a number of approaches that could positively alter the profile of the hit-rate curve.

Smith, L., Liang, Q., James, P., & Lin, W. (2017). Assessing the utility of social media as a data source for flood risk management using a real-time modelling framework. *Journal of Flood Risk Management*, *10*(3), 370–380. https://doi.org/10.1111/jfr3.12154

Strahlendorff, M., Veijola, K., Gallo, J., Vitale, V., Savela, H., & Smirnov, A. (2019). *Value tree for physical atmosphere and ocean observations in the Arctic*. http://hdl.handle.net/10138/300768
This report describes the first instance to employ the international assessment framework for arctic observations developed by SAON and IDA STPI in 2017. Earth Observation (EO) inputs like SYNOP station measurements of physical atmosphere and in other stations ocean variables were linked to key products/outcomes/services like numerical weather prediction and through groups like in this case weather service connected to key objectives of the assessment framework. Representative yearly unit costs of EO inputs and modelling components were estimated by station experts or estimated based on European Union projects or Copernicus program tenders. The WMO OSCAR database for satellite and surface observation systems north of 60°N was used for numbers of the different station and mission categories in the Arctic. The total yearly value of this observation system including EO inputs and modeling is over 204 million €. Compared to the observing system estimated costs in the area 30°N to 60°N this is only about a fifth. The value tree can now follow and combine the value invested in these components as it flows towards services. The key objectives have been connected by SAON/AMAP project members in a workshop to the services to build the first full value tree for a certain kind of observations. These observations are mainly produced by national meteorological and marine institutes in an operational mode. The yearly value invested in the observation can now be distributed between the 12 Societal Benefit Areas and their sub areas identified in the assessment framework. The value tree is presented at a web page by FMI and Spatineo (2019) with a browser that can highlight single components to analyze which inputs and which SBA targets its being used for. This can help to more holistically support the whole observation system for optimal impact on societal benefit. The value tree tool will be available for further work to address the many more EO domains like atmospheric composition or biodiversity. All in all this report can hopefully start a continuous action to update and improve the value tree. EO inputs are not static, the network changes, the costs are fluctuating and as the Arctic is becoming more accessible, it would be important to extend the observation system accordingly. https://space.fmi.fi/2019/04/15/value-of-arctic-observations-estimated-in-new-report/

Tatano, H., & Kajitani, Y. (2022). *Methodologies for estimating the economic impacts of natural disasters*. https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499
This book outlines methodologies to estimate the economic impacts of natural disasters based on

business surveys conducted after large disasters in Japan. By including numerous observations on business activities in past disasters and the validations of both engineering and economic models based on these data sets, this book appeals to practitioners who estimate the regional economic impacts as well as to students and young professionals in various fields who conduct disaster impact studies. The book consists of 7 chapters and includes theories and practices, which help readers to interlink the estimation methods with real-world problems. The study primarily focuses on cases in Japan, but the methods employed can be generalized and applied in other countries. BoM staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6745499

Toolkit for value chain analysis and market development integrating climate resilience and gender responsiveness (Issue November). (2020).
Integrating agriculture in National Adaptation Plans (NAP-Ag) Programme

Tschoegl, L., Below, R., & Guha-Sapir, D. (2006). An analytical review of selected data sets on natural disasters and impacts. In *Proceedings of the UNDP/CRED Workshop on Improving Compilation of Reliable Data on Disaster Occurence and Impact, Bangkok, April 2006*.
This paper aims to summarize the content, presentation, and accessibility of a select group of international, national, regional, and event-specific disaster loss databases. The objective is to provide as comprehensive a view as possible of the current disaster database landscape to better identify gaps in information and strengths in our individual interpretations.

United Nations. (2022). Preventionweb.net. In *Disaster Risk and Resilience*.
This knoweldge base provides latest Disaster risk and resilience publications.

Wilkins, A., Pennaz, A., Dix, M., Smith, A., Vawter, J., Karlson, D., Tokar, S., & Brooks, E. (2021). Challenges and opportunities for Sendai framework disaster loss reporting in the United States. *Progress in Disaster Science*, *10*, 100167. https://doi.org/10.1016/J.PDISAS.2021.100167
The Sendai Framework for Disaster Risk Reduction provides quantitative indicators for nations to measure progress in the reduction of disaster losses. The collection and analysis of disaster loss data under the Sendai Framework improves our understanding of the effectiveness of national disaster risk reduction strategies and interventions. The Sendai Framework has enhanced cooperation among Federal agencies to collect and track disaster loss data in the U.S., yet challenges remain for reporting disaster losses. Based on our experiences collecting and reporting U.S. data to the Sendai Monitor, we identify opportunities to improve disaster loss reporting in the U.S.

Yigitcanlar, T., Regona, M., Kankanamge, N., Mehmood, R., D'costa, J., Lindsay, S., Nelson, S., & Brhane, A. (2022). Detecting Natural Hazard-Related Disaster Impacts with Social Media Analytics: The Case of Australian States and Territories. *Sustainability (Switzerland)*, *14*(2). https://doi.org/10.3390/su14020810
Natural hazard-related disasters are disruptive events with significant impact on people, communities, buildings, infrastructure, animals, agriculture, and environmental assets. The exponentially increasing anthropogenic activities on the planet have aggregated the climate change and consequently increased the frequency and severity of these natural hazard-related disasters, and consequential damages in cities. The digital technological advancements, such as monitoring systems based on fusion of sensors and machine learning, in early detection, warning and disaster response systems are being implemented as part of the disaster management practice in many countries and presented useful results. Along with these promising technologies, crowdsourced social media disaster big data analytics has also started to be utilized. This study aims to form an

understanding of how social media analytics can be utilized to assist government authorities in estimating the damages linked to natural hazard-related disaster impacts on urban centers in the age of climate change. To this end, this study analyzes crowdsourced disaster big data from Twitter users in the testbed case study of Australian states and territories. The methodological approach of this study employs the social media analytics method and conducts sentiment and content analyses of location-based Twitter messages (n = 131,673) from Australia. The study informs authorities on an innovative way to analyze the geographic distribution, occurrence frequency of various disasters and their damages based on the geo-tweets analysis.

Zhang, Q., Li, L., Ebert, B., Golding, B., Johnston, D., Mills, B., Panchuk, S., Potter, S., Riemer, M., Sun, J., Taylor, A., Jones, S., Ruti, P., & Keller, J. (2019). Increasing the value of weather-related warnings. *Science Bulletin*, *64*(10), 647–649. https://doi.org/10.1016/j.scib.2019.04.003
A successful warning relies on information produced by the meteorological and related physical sciences, thus its effectiveness of delivery depends on applications of social, behavioral and economic sciences. The workshop of WMO High Impact Weather Project was held in Beijing during 20–22 November of 2018, attracted a diverse and interdisciplinary group of over 70 scientists from 25 countries in the broad field of physical and social science, during which all elements of the warning chain were discussed critically. The aims of the workshop were to review progress to date, to refresh the aims and objectives of the HIWeather project, and to identify and plan new activities on how to increase the value of weather-related warnings. Five focal aspects of warning were described in the following sections: (1) what makes a successful warning? (2) Advances in physical processes. (3) Weather-related hazard and impact prediction. (4) Advances in understanding impacts, vulnerability and risk. (5) Measuring skill and value.[6]

Warning

Keywords: cyclone warning, drought early warning, early warning, early warning services, early warning system, early warning system implementation, early warning system overview, early warning systems, early warnings, effective warning systems, enhancing warnings, EWS, EWS overview, flood early warning systems, flood warning system, impact-based forecasts and warnings, impact-based warnings, local EWS, mobile phone-based warning, tornado warning, warning, warning thresholds, warning time, warnings, warning nature and characteristics

Alfieri, L., Burek, P., Dutra, E., Krzeminski, B., Muraro, D., Thielen, J., & Pappenberger, F. (2013). GloFAS – global ensemble streamflow forecasting and flood early warning. *Hydrology and Earth System Sciences*, *17*(3), 1161–1175. https://doi.org/10.5194/hess-17-1161-2013
<p>Abstract. Anticipation and preparedness for large-scale flood events have a key role in mitigating their impact and optimizing the strategic planning of water resources. Although several developed countries have well-established systems for river monitoring and flood early warning, figures of populations affected every year by floods in developing countries are unsettling. This paper presents the Global Flood Awareness System (GloFAS), which has been set up to provide an overview on upcoming floods in large world river basins. GloFAS is based on distributed hydrological simulation of numerical ensemble weather predictions with global coverage. Streamflow forecasts are compared statistically to climatological simulations to detect probabilistic exceedance of warning thresholds. In this article, the system setup is described, together with an evaluation of its performance over a two-year test period and a qualitative analysis of a case study for the Pakistan flood, in summer 2010. It is shown that hazardous events in large river basins can be skilfully detected with a forecast horizon of up to 1 month. In addition, results suggest that an

accurate simulation of initial model conditions and an improved parameterization of the hydrological model are key components to reproduce accurately the streamflow variability in the many different runoff regimes of the earth.</p>

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S., Sivle, A. D., Agersten, S., Schmid, F., & Simon, A. (2016). Use and perception of weather forecast information across Europe Journal: *Meteorological Applications*, *4*(434), 1–2. https://doi.org/10.1002/met.2053
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It

also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Borga, M., Comiti, F., Ruin, I., & Marra, F. (2019). Forensic analysis of flash flood response. *WIREs Water*, *6*(2). https://doi.org/10.1002/wat2.1338
The last decade has witnessed the development of methodologies for the post-flood documentation of both hydrogeomorphological and social response to extreme precipitation. These investigations are particularly interesting for the case of flash floods, whose space–time scales make their observations by conventional hydrometeorological monitoring networks particularly challenging. Effective flash flood documentation requires post-flood survey strategies encompassing accurate radar estimation of rainfall, field and remote-sensing observations of the geomorphic processes, indirect reconstruction of peak discharges—as well eyewitness interviews. These latter can give valuable information on both flood dynamics and the related individual and collective responses. This study describes methods for post-flood surveys based on interdisciplinary collaborations between natural and social scientists. These surveys may help to better understand the links between hydrometeorological dynamics and geomorphic processes as well as the relationship between flood dynamics and behavioral response in the context of fast space–time changes of flooding conditions.

Carsell, K. M., Pingel, N. D., & Ford, D. T. (2004). Quantifying the Benefit of a Flood Warning System. *Natural Hazards Review*, *5*(3), 131–140. https://doi.org/10.1061/(asce)1527-6988(2004)5:3(131)
A flood warning system yields direct and indirect, tangible and intangible benefits. To achieve this, the system includes hardware, software, plans and procedures, and personnel that work in an integrated manner to increase the mitigation time available prior to the onset of flooding. This mitigation time increase is a consequence of a reduction in the time required to collect data, to evaluate and identify the flood threat, to notify emergency personnel and the public, and to make decisions about the appropriate response. The direct tangible benefit—the inundation damage reduction—can be computed with standard expected damage computation procedures, using modified depth-damage functions that include mitigation time as an independent variable and accounting for improvements to the efficiency of response due to the implementation of the flood warning system. This proposed method is applicable for benefit evaluation for any flood warning system; it is illustrated here with an example from the Sacramento River basin of central California.

Climate Risk and Early Warning (CREWS). (2017). *Draft Consultation Document On Measuring Early Warning Access and Effectiveness*. https://public.wmo.int/en/resources
the present consultation document aims to identify a set of metrics to provide guidance on how the effectiveness of, and access to, early warning systems can be measured, encompassing a conceptual framework of key elements, including sources of data and information and methodologies.

Fakhruddin, B. S. H. M. H. M., & Schick, L. (2019). Benefits of economic assessment of cyclone early warning systems - A case study on Cyclone Evan in Samoa. *Progress in Disaster Science*, *2*(2019), 100034. https://doi.org/10.1016/j.pdisas.2019.100034

Samoa is extremely exposed to natural hazards, particularly tropical cyclones and earthquake-generated tsunami. Some studies have put forth the position that adequate investment in early warning systems can contribute to the social and economic well-being of countries. However, in spite of these research findings there is still a lack of understanding on how to measure effectiveness that leads to limited investment. Cost-benefit analysis (CBA) is a tool used in this study to summarize the value for money in terms of investment to enhance an early warning system. This paper aims to summarize the benefits of adopting early warning systems and its effectiveness against the investment required and its value proposition. Data from the 'Samoa Post-Disaster Needs Assessment of the Cyclone Evan event in 2012' have been used to assess damage information, and stakeholders consultations and interviews were carried out for cost-benefit analysis. We have conducted quantified CBA of early warning services for cyclone hazards and the results have shown that for every USD 1 invested, there is a return of USD 6 as benefit. This paper suggests that economic assessment of early warning services could help in quantifying pre-impact assessment to demonstrate to policy makers the economic benefit of disaster risk reduction (DRR).

Fearnley, C., & Kelman, I. (2021). *Enhancing Warnings* (Issue December). National Preparedness Commission.
Background Warnings are part of our everyday life, whether traffic lights, food health warnings, the weather, advice from colleagues, or moralistic stories. Warnings serve to provide cautionary advice, give advance notice of something, and generate awareness to trigger consequent decisions and actions. Warnings are seldom considered beyond the issuance of a warning, yet warnings are far more complex, requiring a comprehensive tool and system to help implement preventative, mitigative, and disaster risk-reductive actions. This report offers insights into what warnings are and how they can better support actions for effective behavioural preparedness and responses across a wide range of hazards, stakeholders, and sectors. Warnings are not just a siren or phone alert but should be a long-term social process that is a carefully crafted, integrated system of preparedness involving vulnerability analysis and reduction, hazard monitoring and forecasting, disaster risk assessment, and communication. Together, these activities enable a wide range of leaders and others – such as individuals, local groups, governments, and businesses – to take timely and effective action to reduce disaster risks in advance of hazards. Warnings are represented via different iconographies and communicated via different mediums that usually express some form of threshold or tipping point. These vary enormously contingent on the hazard, and social, political, and economic context of the warning. Warnings should provide actionable guidance that is integrated into everyday life and behaviour, providing transparency and credibility to help manage risk in emerging and ongoing situations. Warnings must operate beyond the silos frequently seen in institutions, for different vulnerabilities, different hazards, and different stakeholders to become a long-term social process that can serve to bring together these diverse issues. This report examines how this can be implemented providing key case-study examples of lessons learnt and guidance on how to build effective warning systems. To enhance a warning requires placing it as part of a warning system, a long-term social process that embodies the 3 I's and 3 E's: 3 I's: Imagination, Initiative, Integration. 3 E's: Education, Exhange, Engagement.

Garcia, C., & Fearnley, C. J. (2012). Evaluating critical links in early warning systems for natural hazards. *Environmental Hazards*, *11*(2), 123–137. https://doi.org/10.1080/17477891.2011.609877
Early warning systems (EWSs) are extensive systems that integrate different components of disaster risk reduction for the provision of timely warnings to minimize loss of life and to reduce economic and social impact on vulnerable populations. Historically, empirical research has focused on the individual components or sub-systems of EWSs, such as hazard monitoring, risk assessment,

forecasting tools and warning dissemination. However, analyses of natural hazard disasters indicate that, in most cases, the processes that link individual components of EWS fail, rather than the components themselves. This paper reviews several case studies conducted over the last 40 years to present common emerging factors that improve links between the different components of EWSs. The identified factors include: (1) establishing effective communication networks to integrate scientific research into practice; (2) developing effective decision-making processes that incorporate local contexts by defining accountability and responsibility; (3) acknowledging the importance of risk perception and trust for an effective reaction; and (4) consideration of the differences among technocratic and participatory approaches in EWSs when applied in diverse contexts. These factors show the importance of flexibility and the consideration of local context in making EWSs effective, whereas increasing levels of standardization within EWSs nationally and globally might challenge the ability to incorporate the required local expertise and circumstances.

Golding, B. (2022). Towards the “Perfect” Weather Warning. In *Towards the “Perfect” Weather Warning*. Springer. https://doi.org/10.1007/978-3-030-98989-7

Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., & Johnston, D. (2022). Identifying the Impact-Related Data Uses and Gaps for Hydrometeorological Impact Forecasts and Warnings. *Weather, Climate, and Society*, *14*(1), 155–176. https://doi.org/10.1175/WCAS-D-21-0093.1
Impact forecasts and warnings (IFW) are key to resilience for hydrometeorological hazards. Communicating the potential social, economic, and environmental hazard impacts allows individuals and communities to adjust their plans and better prepare for the consequences of the hazard. IFW systems require additional knowledge about impacts and underlying vulnerability and exposure. Lack of data or knowledge about impacts, vulnerability, and exposure has been identified as a challenge for IFW implementation. In this study, we begin to address this challenge by developing an understanding of the data needs and uses for IFWs. Using the grounded theory method, we conducted a series of interviews with users and creators of hazard, impact, vulnerability, and exposure data (e.g., warning services, forecasters, meteorologists, hydrologists, emergency managers, data specialists, risk modelers) to understand where these data are needed and used in the warning value chain, a concept used to represent and understand the flow of information among actors in the warning chain. In support of existing research, we found a growing need for creating, gathering, and using impact, vulnerability, and exposure data for IFWs. Furthermore, we identified different approaches for impact forecasting and defining impact thresholds using objective models and subjective impact-oriented discussions depending on the data available. We also provided new insight into a growing need to identify, model, and warn for social and health impacts, which have typically taken a back seat to modeling and forecasting physical and infrastructure impacts. Our findings on the data needs and uses within IFW systems will help guide their development and provide a pathway for identifying specific relevant data sources.

Holzbecher, E., Hadidi, A., Volp, N., de Koning, J., Al Badi, H., Al Khatri, A., & Al Barwani, A. (2022). Advanced Tools for Flood Management: An Early Warning System for Arid and Semiarid Regions. In *Wadi Flash Floods* (pp. 209–223). Springer Singapore. https://doi.org/10.1007/978-981-16-2904-4_7
Abstract: Technologies concerning integrated water resources management, in general, and flood management, in particular, have recently undergone rapid developments. New smart technologies have been implemented in every relevant sector and include hydrological sensors, remote sensing, sensor networks, data integration, hydrodynamic simulation and visualization, decision support and early warning systems as well as the dissemination of information to decision-makers and the public. After providing a rough review of current developments, we demonstrate the operation of

an advanced system with a special focus on an early warning system. Two case studies are covered in this chapter: one specific urban case located in the city of Parrametta in Australia in an area that shows similar flood characteristics to those found in arid or semiarid regions and one case regarding the countrywide Flash Flood Guidance System in Oman (OmanFFGS).

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., & Harris, A. J. (2022). Investigating the decision thresholds for impact-based warnings in South East Asia. *International Journal of Disaster Risk Reduction*, *76*, 103021. https://doi.org/10.1016/j.ijdrr.2022.103021

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1
Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Kaltenberger, R., Schaffhauser, A., & Staudinger, M. (2020). What the weather will do-results of a survey on impact-oriented and impact-based warnings in European NMHSs. *Advances in Science and Research*, *17*, 29–38. https://doi.org/10.5194/asr-17-29-2020
European NMHSs are progressing from warnings based on fixed thresholds or climatology-based thresholds to impact-oriented and impact-based warnings. This publication gives an overview of warning implementation as surveyed at 32 of the 37 NMHSs participating in the EUMETNET Meteoalarm project. The report addresses these topics: warning format, legislation and production process of warnings, dissemination and verification of warnings, impact databases, warning strategy and cooperation, legal obstacles and cross-border collaboration. Potential obstacles are identified and possible trends are discussed.

Klafft, M., & Meissen, U. (2011). Assessing the Economic Value of Early Warning Systems. *Proceedings of the 8th International ISCRAM Conference – Lisbon, Portugal, May 2011*.
As of today, investments into early warning systems are, to a large extent, politically motivated and "disaster-driven." This means that investments tend to increase significantly if a disaster strikes, but are often quickly reduced in the following disaster-free years. Such investment patterns make the continuous operation, maintenance and development of the early warning infrastructure a challenging task and may lead to sub-optimal investment decisions. The paper presented here proposes an economic assessment model for the tangible economic impact of early warning systems. The model places a focus on the false alert problematic and goes beyond previous approaches by incorporating some socio-cultural factors (qualitatively estimated as of now). By doing so, it supports policymakers (but also private investors) in their investment decisions related

to early warning applications.

Kuller, M., Schoenholzer, K., & Lienert, J. (2021). Creating effective flood warnings: A framework from a critical review. *Journal of Hydrology*, *602*(March), 126708. https://doi.org/10.1016/j.jhydrol.2021.126708
As climate change is intensifying the frequency and severity of floods around the globe, adaptation is increasingly vital. Besides structural measures to mitigate flood risk, non-structural measures are known to be highly effective and low-cost. Such non-structural measures include Flood Early Warning Systems (FEWS). Effective warning creation and dissemination are crucial to successful FEWS. Despite extensive bodies of research that cross the boundaries between disciplines and application domains, systematic understanding of the detailed aspects contributing to the effectiveness of flood warnings is lacking. We systematically review the state-of-the-art in risk perception and warning communication present in academic (and grey) literature for FEWS. We focus on the elements of risk warnings specifically, rather than reviewing the topic of risk communication in general. We start with exploring how personal attributes affect individual risk perception related to flood warnings. We then deconstruct flood warnings into three basic components: content, format and dissemination channel. Most importantly, we found 21 individual elements (options) for these components, each associated with varying levels of support for their effectiveness in literature. Important caveats were identified, such as a lack of research into the speech format and SMS channel. We then describe and visualise the warning creation process, providing a framework for guidance. Accelerating technological advancement necessitates continued research into the effectiveness of novel formats and channels, rendering the currently most widely supported and researched elements increasingly obsolete. Further research is needed to explore the complex interplay between elements, i.e., how do different combinations impact effectiveness? Finally, little is known about the transferability of our findings to Africa, Asia and South America, as industrialised countries dominate the research. We hope our findings will contribute to improved understanding, and support the practice of creating effective flood warnings.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1
As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a

range of weather events as well as other methodological approaches to assessing benefits.

Lellyett, S., Truelove, R., & Huda, A. (2022). Improving Early Warning of Drought in Australia. *Climate*, *10*(7), 91. https://doi.org/10.3390/cli10070091
This invited review outlines a selection of recent technical and communication advances, in certain areas of climate and weather science that could improve the capability and utility of drought early warning systems in Australia. First, a selection of current operational outputs and their significance for drought early warning is reviewed, then a selection of advancements in the Research and Development (R&D) pipeline are considered, which have potential to help enable better decision-making by stakeholders subject to drought risk. The next generation of drought early warning systems should have a focus on index- and impact-based prediction models that go beyond basic weather and climate parameters, at seasonal through to multi-year timescales. Convergence and integration of emerging research, science and technology is called for across the fields of climate, agronomy, environment, economics and social science, to improve early warning information. The enablement of more predictively based drought policy, should facilitate more proactive responses by stakeholders throughout the agricultural value chain, and should make stakeholders more drought resilient.

Matte, S., Boucher, M.-A., Boucher, V., & Fortier Filion, T.-C. (2017). Moving beyond the cost–loss ratio: economic assessment of streamflow forecasts for a risk-averse decision maker. *Hydrology and Earth System Sciences*, *21*(6), 2967–2986. https://doi.org/10.5194/hess-21-2967-2017
<p>Abstract. A large effort has been made over the past 10 years to promote the operational use of probabilistic or ensemble streamflow forecasts. Numerous studies have shown that ensemble forecasts are of higher quality than deterministic ones. Many studies also conclude that decisions based on ensemble rather than deterministic forecasts lead to better decisions in the context of flood mitigation. Hence, it is believed that ensemble forecasts possess a greater economic and social value for both decision makers and the general population. However, the vast majority of, if not all, existing hydro-economic studies rely on a cost–loss ratio framework that assumes a risk-neutral decision maker. To overcome this important flaw, this study borrows from economics and evaluates the economic value of early warning flood systems using the well-known Constant Absolute Risk Aversion (CARA) utility function, which explicitly accounts for the level of risk aversion of the decision maker. This new framework allows for the full exploitation of the information related to a forecasts' uncertainty, making it especially suited for the economic assessment of ensemble or probabilistic forecasts. Rather than comparing deterministic and ensemble forecasts, this study focuses on comparing different types of ensemble forecasts. There are multiple ways of assessing and representing forecast uncertainty. Consequently, there exist many different means of building an ensemble forecasting system for future streamflow. One such possibility is to dress deterministic forecasts using the statistics of past error forecasts. Such dressing methods are popular among operational agencies because of their simplicity and intuitiveness. Another approach is the use of ensemble meteorological forecasts for precipitation and temperature, which are then provided as inputs to one or many hydrological model(s). In this study, three concurrent ensemble streamflow forecasting systems are compared: simple statistically dressed deterministic forecasts, forecasts based on meteorological ensembles, and a variant of the latter that also includes an estimation of state variable uncertainty. This comparison takes place for the Montmorency River, a small flood-prone watershed in southern central Quebec, Canada. The assessment of forecasts is performed for lead times of 1 to 5 days, both in terms of forecasts' quality (relative to the corresponding record of observations) and in terms of economic value, using t…

Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., Domeisen, D. I. V, Feser, F.,

Koszalka, I., Kreibich, H., Pantillon, F., Parolai, S., Pinto, J. G., Punge, H. J., Rivalta, E., Schröter, K., Strehlow, K., Weisse, R., & Wurpts, A. (2020). Impact Forecasting to Support Emergency Management of Natural Hazards. *Reviews of Geophysics*, *58*(4), 1–52. https://doi.org/10.1029/2020RG000704
Forecasting and early warning systems are important investments to protect lives, properties, and livelihood. While early warning systems are frequently used to predict the magnitude, location, and timing of potentially damaging events, these systems rarely provide impact estimates, such as the expected amount and distribution of physical damage, human consequences, disruption of services, or financial loss. Complementing early warning systems with impact forecasts has a twofold advantage: It would provide decision makers with richer information to take informed decisions about emergency measures and focus the attention of different disciplines on a common target. This would allow capitalizing on synergies between different disciplines and boosting the development of multihazard early warning systems. This review discusses the state of the art in impact forecasting for a wide range of natural hazards. We outline the added value of impact-based warnings compared to hazard forecasting for the emergency phase, indicate challenges and pitfalls, and synthesize the review results across hazard types most relevant for Europe.

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

Morrow, B. H., Lazo, J. K., Rhome, J., & Feyen, J. (2015). Improving storm surge risk communication: Stakeholder perspectives. *Bulletin of the American Meteorological Society*, *96*(1), 35–48. https://doi.org/10.1175/BAMS-D-13-00197.1
Storm surge associated with tropical and extratropical cyclones has a long history of causing death and destruction along our coastlines. With more than 123 million people living in coastal shoreline areas and much of the densely populated Atlantic and Gulf coastal areas less than 10 ft (~3 m) above mean sea level, the threat has never been greater. In this article, we summarize and integrate the most intensive series of studies completed to date on communication of storm surge risk. These were primarily geographically focused stakeholder surveys for evaluating the storm surge communication perceptions and preferences of forecasters, broadcast meteorologists, public officials, and members of the public - each a primary user group for storm surge forecasts. According to findings from seven surveys, each group strongly supports the National Weather Service (NWS) issuing watches and warnings for storm surge, whether associated with tropical cyclones (TC) or extratropical (ET) cyclones. We discuss results on public understanding of storm surge vulnerability, respondents' preferences for separate storm surge information products, and initial assessments of potential storm surge warning text and graphics. Findings from the research reported here are being used to support relevant NWS decisions, including a storm surge watch and warning product that has been approved for use on an experimental basis in 2015 and the National Hurricane Center (NHC) issuance of local surge inundations maps on an experimental basis in 2014.

Perera, D., Seidou, O., Agnihotri, J., Rasmy, M., Smakhtin, V., Coulibaly, P., & Mehmood, H. (2019). *Flood Early Warning Systems: A Review Of Benefits, Challenges And Prospects 08. UNU-INWEH Report Series, Issue 08* (Issue August). https://doi.org/10.13140/RG.2.2.28339.78880
Floods are major water-related disasters that affect millions of people resulting in thousands of mortalities and billiondollar losses globally every year. Flood Early Warning Systems (FEWS) - one of the floods risk management measures - are currently operational in many countries. The UN Office for Disaster Risk Reduction recognises their importance and strongly advocates for an increase in their availability under the targets of the Sendai Framework for Disaster Risk Reduction, and Sustainable Development Goals (SDGs). However, despite widespread recognition of the

importance of FEWS for disaster risk reduction (DRR), there's a lack of information on their availability and status around the world, their benefits and costs, challenges and trends associated with their development. This report contributes to bridging these gaps by analyzing the responses to a comprehensive online survey with over 80 questions on various components of FEWS (risk knowledge, monitoring and forecasting, warning dissemination and communication, and response capabilities), investments into FEWS, their operational effectiveness, benefits, and challenges. FEWS were classified as technologically "basic", "intermediate" and "advanced" depending on the existence and sophistication of FEWS` components such as hydrological data collection systems, data transfer systems, flood forecasting methods, and early warning communication methods. The survey questionnaire was distributed to flood forecasting and warning centers around the globe; the primary focus was developing and least-developed countries (LDCs). The questionnaire is available here: https://inweh.unu.edu/questionnaireevaluation-of-flood-early-warning-systems/ and can be useful in its own right for similar studies at national or regional scales, in its current form or with case-specific modifications.

Potter, S., Harrison, S., & Kreft, P. (2021). The Benefits and Challenges of Implementing Impact-Based Severe Weather Warning Systems: Perspectives of Weather, Flood, and Emergency Management Personnel. *Weather, Climate, and Society*, *13*(2), 303–314. https://doi.org/10.1175/wcas-d-20-0110.1

Warnings about impending hazards help to minimize the impacts and reduce the risk of the hazard through encouraging an appropriate and timely behavioral response. Many hydrometeorological agencies are moving toward impact-based forecast and warning (IBFW) systems, as encouraged by the World Meteorological Organization. Yet little research has been conducted on such systems from the perspectives of agencies who are or would be involved in their implementation. We investigated the challenges and benefits of IBFW systems as perceived by participants from agencies internationally and within New Zealand. Interviews and workshops were held with meteorologists and weather forecasters, flood forecasters and hydrologists, and emergency managers. We found that the benefits of implementing IBFW systems included a perceived increase in the understanding of the potential impacts by the public, added awareness of antecedent conditions by forecasters, a possible reduction in "false alarms," and increased interagency communication. Challenges identified by the participants included whether the system should be designed for individuals or society, a lack of impact data, verification of warnings based on impacts, a conflict with roles and responsibilities, the potential for conflicting messages, and the increased burden on agencies providing information to forecasters with a perception of little benefit in return. We argue that IBFWs could be designed for individual members of the public, with an increased focus on understanding vulnerability and capacities, and that more impact data need to be collected and stored to inform future warnings. Increased interagency coordination would assist with rapid decision-making and the success of IBFWs.

Rahaman, M. M., & Iqbal, M. H. (2021). Willingness-to-pay for improved cyclone early warning services across coastal Bangladesh: Application of choice experiment. *International Journal of Disaster Risk Reduction*. https://doi.org/10.1016/j.ijdrr.2021.102344

Effective early warning services are a prerequisite for significantly minimizing the personal injury, losses of lives and properties from devastating natural hazards like cyclones and storm surges across coastal Bangladesh. This study fills a gap in the literature regarding the value associated with cyclone early warning services. We measure willingness-to-pay (WTP), consumer surplus (CS) and revenue stream in response to the policy change of cyclone early warning services (EWS) on a sample (n = 219) observations. Following stratified sampling method, the survey and choice experiment (CE) were conducted in a few coastal villages of four coastal districts of Bangladesh for

eliciting stated preference (SP) data. Every participant in the survey faced three options in each card-two hypothetical alternatives and one status quo option. Our proposed attributes for EWS such as accuracy of mean track error, advance update information, and cyclone warning through mobile phone-based short message warning and annual payment for the warning services are considered to construct choice cards. Estimated results ensure that age, family size, years of schooling are the dominating contributors to choose the attributes of EWS. Results of MWTP, WTP, CS, and revenue stream for improved cyclone EWS make a guarantee that coastal households and investors get more benefits and return from improved EWS programs.

Sättele, M., Bründl, M., & Straub, D. (2016). Quantifying the effectiveness of early warning systems for natural hazards. *Natural Hazards and Earth System Sciences*, *16*(1), 149–166. https://doi.org/10.5194/nhess-16-149-2016
Early warning systems (EWSs) are increasingly applied as preventive measures within an integrated risk management approach for natural hazards. At present, common standards and detailed guidelines for the evaluation of their effectiveness are lacking. To support decision-makers in the identification of optimal risk mitigation measures, a three-step framework approach for the evaluation of EWSs is presented. The effectiveness is calculated in function of the technical and the inherent reliability of the EWS. The framework is applicable to automated and non-automated EWSs and combinations thereof. To address the specifics and needs of a wide variety of EWS designs, a classification of EWSs is provided, which focuses on the degree of automations encountered in varying EWSs. The framework and its implementation are illustrated through a series of example applications of EWS in an alpine environment.

Seebauer, S., & Babcicky, P. (2018). Trust and the communication of flood risks: comparing the roles of local governments, volunteers in emergency services, and neighbours. *Journal of Flood Risk Management*, *11*(3), 305–316. https://doi.org/10.1111/jfr3.12313

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Weyrich, P., Scolobig, A., Bresch, D. N., & Patt, A. (2018). Effects of Impact-Based Warnings and Behavioral Recommendations for Extreme Weather Events. *Weather, Climate, and Society*, *10*(4), 781–796. https://doi.org/10.1175/WCAS-D-18-0038.1
Bad weather continues not only to inflict damage on property but also to kill and injure people, despite significant advances in the predictive power of meteorological warnings. There is evidence that people tend to underreact to weather warning information, to a large extent because of insufficient understanding of the impacts that severe weather events can have, as well as to demonstrate the appropriate response behavior. A growing number of experts are suggesting that standard warning information should be augmented with additional information about these factors, but this has so far largely failed to take place. Past research studies have shown possible advantages of including impact-based warnings (IBWs) and behavioral recommendations (BRs) into the warning information, but the results are in part ambiguous, due to a failure to have tested for effects of the two kinds of information separately and in combination. Based on quantitative results from a survey experiment in Switzerland, this knowledge gap is addressed. Results of the research reported here indicate significant benefits from providing both sets of information together, in terms of improving both perception and understanding of warning and intended behavioral responses. When only one piece of information is given, BRs have a significant effect on both perception and intended response, whereas IBWs have a significant effect only on intended

response. These findings offer empirical justification for the added expense and time associated with the more detailed hazard warnings.

WMO. (2015). *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services* (Issue 1150).
The spherical tokamak (ST) is a leading candidate for a Fusion Nuclear Science Facility (FNSF) due to its compact size and modular configuration. The National Spherical Torus eXperiment (NSTX) is a MA-class ST facility in the US actively developing the physics basis for an ST-based FNSF. In plasma transport research, ST experiments exhibit a strong (nearly inverse) scaling of normalized confinement with collisionality, and if this trend holds at low collisionality, high fusion neutron fluences could be achievable in very compact ST devices. A major motivation for the NSTX Upgrade (NSTX-U) is to span the next factor of 3–6 reduction in collisionality. To achieve this collisionality reduction with equilibrated profiles, NSTX-U will double the toroidal field, plasma current, and NBI heating power and increase the pulse length from 1–1.5 s to 5–8 s. In the area of stability and advanced scenarios, plasmas with higher aspect ratio and elongation, high βN, and broad current profiles approaching those of an ST-based FNSF have been produced in NSTX using active control of the plasma β and advanced resistive wall mode control. High non-inductive current fractions of 70% have been sustained for many current diffusion times, and the more tangential injection of the 2nd NBI of the Upgrade is projected to increase the NBI current drive by up to a factor of 2 and support 100% non-inductive operation. More tangential NBI injection is also projected to provide non-solenoidal current ramp-up as needed for an ST-based FNSF. In boundary physics, NSTX measures an inverse relationship between the scrape-off layer heat-flux width and plasma current that could unfavourably impact next-step devices. Recently, NSTX has successfully demonstrated substantial heat-flux reduction using a snowflake divertor configuration, and this type of divertor is incorporated in the NSTX-U design. The physics and engineering design supporting NSTX Upgrade is described.

World Meteorological Organization. (2021). *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services (WMO-No. 1150), Part II: Putting Multi-Hazard IBFWS into Practice* (Issue 1150).

Zommers, Z., & Singh, A. (2014). Reducing disaster: Early warning systems for climate change. *Reducing Disaster: Early Warning Systems for Climate Change*, *9789401785*, 1–387. https://doi.org/10.1007/978-94-017-8598-3
Around the world, extreme weather events are becoming increasingly “the new normal” and are expected to increase in the 21st century as a result of climate change. Extreme weather events have devastating impacts on human lives and national economies. This book examines ways to protect people from hazards using early warning systems, and includes contributions from experts from four different continents representing 14 different universities, 8 government agencies and two UN agencies. Chapters detail critical components of early warning systems, ways to identify vulnerable communities, predict hazards and deliver information. Unique satellite images illustrate the transnational impact of disasters, while case studies provide detailed examples of warning systems. With contributors from the fields of economics, ethics, meteorology, geography and biology, this book is essential reading for anyone interested in disaster risk reduction or climate change.

Response

Keywords: business resilience, disaster resilience, disaster response operations, disaster risk reduction, emergency response, emergency coordination, emergency preparedness, human and community response, likelihood of evacuation, preparedness activities, public response, resilience, response, social response, user response

Amaratunga, D., Haigh, R., & Dias, N. (2021). *Multi-Hazard Early Warning and Disaster Risks* (D. Amaratunga, R. Haigh, & N. Dias (eds.)). Springer International Publishing. https://doi.org/10.1007/978-3-030-73003-1
Full text at https://www.researchgate.net/profile/Sunethra-Gunatilake-2/publication/354837896_Co-Management_Initiatives_in_Bush_Fire_Management-A_Case_of_Belihuloya_Mountain_Range_Sri_Lanka/links/614f1021154b3227a8a92bf8/Co-Management-Initiatives-in-Bush-Fire-Management-A-Case-of-Belihuloya-Mountain-Range-Sri-Lanka.pdf#page=658

Anders Doksæter Sivle*, Solfrid Agersten, Franziska Schmid, A. S. (2016). *Use and perception of weather forecast information across Europe Journal: 4*(434), 1–2.
Although European studies have become more common in recent years, published research on perception and use of weather information has been dominated by studies from the USA with some scattered contributions across Europe. The present study gives a broad European context, by providing perspectives from 18 countries and several user professions as well as from 14 National Meteorological and Hydrological Services (NMHSs), and by combining new insights from probabilistic forecasting, warning and interaction between NMHSs and their users. These new insights are based on two surveys undertaken in the frame of EUMETNET Nowcasting (E-NWC) Programme, where EUMETNET represents the European Meteorological Services' Network: one survey for the participating NMHSs in the E-NWC Programme, and the other one for their respective users. Both surveys were distributed in autumn 2019, and open for responses until spring 2020. Several findings from the surveys support conclusions of previous research, for example concerning the perception of probabilities or taking measures in case of severe weather (many users would start their preliminary measures at a probability level of 60%). Although most of the NMHSs and their users are in regular contact, there is room for increasing the frequency of face-to-face meetings between them. Nearly one third of NMHSs never meet face-to-face with users from the public. The two surveys indicate that there might be benefits of increased collaboration and sharing of data between European NMHSs to be able to offer their users more training, and to learn from each other in areas where insight already exists.

Andersson, L., Wilk, J., Graham, L. P., Wikner, J., Mokwatlo, S., & Petja, B. (2020). Local early warning systems for drought – Could they add value to nationally disseminated seasonal climate forecasts? *Weather and Climate Extremes*, *28*, 100241. https://doi.org/10.1016/j.wace.2019.100241
Limited application and use of forecast information restrict smallholder farmers' ability to deal with drought in proactive ways. This paper explores the barriers that impede use and uptake of seasonal climate forecasts (SCF) in two pilot communities in Limpopo Province. Current interpretation, translation and mediation of national SCF to the local context is weak. A local early warning system (EWS) was developed that incorporated hydrological modelled information based on national SCF, locally monitored rainfall and soil moisture by a wireless sensor network, and signs from indigenous climate indicators. We assessed to what degree this local EWS could improve interpretation of SCF and increase understanding and uptake by farmers. Local extension staff and champion farmers were found to play important knowledge brokering roles that could be strengthened to increase trust of SCF. The local EWS provided added value to national SCF by

involving community members in local monitoring, enacting knowledge interplay with indigenous knowledge and simplifying and tailoring SCF and hydrological information to the local context. It also helped farmers mentally prepare for upcoming conditions even if many do not currently have the adaptive mindsets, economic resources or pre-conditions to positively respond to SCF information.

Aparicio-Effen, M., Arana-Pardo, I., Aparicio, J., Ocampo, M., Roque, S., & Nagy, G. J. (2018). *A Successful Early Warning System for Hydroclimatic Extreme Events: The Case of La Paz City Mega Landslide* (pp. 241–264). https://doi.org/10.1007/978-3-319-56946-8_15
In this section the authors present the state of biodiversity conservation in the land-slide basin, land coverage and use of urban soil, water and sanitation in the area of the mega-landslide.

Borga, M., Comiti, F., Ruin, I., & Marra, F. (2019). Forensic analysis of flash flood response. *WIREs Water*, *6*(2). https://doi.org/10.1002/wat2.1338
The last decade has witnessed the development of methodologies for the post-flood documentation of both hydrogeomorphological and social response to extreme precipitation. These investigations are particularly interesting for the case of flash floods, whose space–time scales make their observations by conventional hydrometeorological monitoring networks particularly challenging. Effective flash flood documentation requires post-flood survey strategies encompassing accurate radar estimation of rainfall, field and remote-sensing observations of the geomorphic processes, indirect reconstruction of peak discharges—as well eyewitness interviews. These latter can give valuable information on both flood dynamics and the related individual and collective responses. This study describes methods for post-flood surveys based on interdisciplinary collaborations between natural and social scientists. These surveys may help to better understand the links between hydrometeorological dynamics and geomorphic processes as well as the relationship between flood dynamics and behavioral response in the context of fast space–time changes of flooding conditions.

Center for Climate and Energy Solutions. (2015). *Weathering the Next Storm : a Closer Look At Business Resilience* (Issue September).
see “Cost Examples Related to Extreme Weather” {1} “Global Weather-Related Losses (1980–2014)” {3} “Tools used by Companies for Assessing Climate Risks” {25}

Department of Home Affairs. (2018). *National Disaster Risk Reduction Framework*. https://www.homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf
The National Disaster Risk Reduction Framework (‘the framework’) guides national, whole-of-society efforts to proactively reduce disaster risk in order to minimise the loss and suffering caused by disasters. This framework is designed to guide Australia’s efforts to reduce disaster risk associated with natural hazards. It translates the first three Sendai Framework priorities into action for the Australian context; though the strategies outlined in this framework are applicable to disaster preparedness and recovery efforts, the fourth priority of the Sendai Framework is largely progressed through other national strategies, primarily the Australian Disaster Preparedness Framework. The framework establishes a 2030 vision, goals and priorities broadly aligned to the Sendai Framework and the 2030 Sustainable Development Goals, and outlines foundational strategies for action to meet these across the five years from 2019 – 2023. The framework will be reviewed and updated at the end of this five-year period to ensure its relevance and accuracy across the remaining years to 2030. It is not exhaustive nor prescriptive, and should be holistically applied across and between four key environments: built, social, natural, and economic.

Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R.,

Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N., & Stephens, E. (2020). Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response. *International Journal of Disaster Risk Reduction*, *50*(March), 101811. https://doi.org/10.1016/j.ijdrr.2020.101811
Humanitarian disasters such as Typhoon Haiyan (SE Asia, 2013) and the Horn of Africa drought (2011–2012) are examples of natural hazards that were predicted, but where forecasts were not sufficiently acted upon, leading to considerable loss of life. These events, alongside international adoption of the Sendai Framework for Disaster Risk Reduction, have motivated efforts to enable early action from early warnings. Through initiatives such as Forecast-based Financing (FbF) and the Science for Humanitarian Emergencies and Resilience (SHEAR) programme, progress is being made towards the use of science and forecasts to support international humanitarian organisations and governments in taking early action and improving disaster resilience. However, many challenges remain in using forecasts systematically for preparedness and response. The research community in place through SHEAR enabled the UK government's Department for International Development to task a collaborative group of scientists to produce probabilistic real-time flood forecast and risk bulletins, aimed at humanitarian decision-makers, for Cyclones Idai and Kenneth, which impacted Mozambique in 2019. The process of bulletin creation during Idai and Kenneth is reviewed and critically evaluated, including evaluation of the forecast information alongside evidence for how useful the bulletins were. In this context, this work seeks to navigate the "murky landscape" of national and international mandates, capacities, and collaborations for forecasting, early warning and anticipatory action, with the ultimate aim of finding out what can be done better in the future. Lessons learnt and future recommendations are discussed to enable better collaboration between producers and users of forecast information.

Ewbank, R., Perez, C., Cornish, H., Worku, M., & Woldetsadik, S. (2019). Building resilience to El Niño-related drought: experiences in early warning and early action from Nicaragua and Ethiopia. *Disasters*. https://doi.org/10.1111/disa.12340
Forecast-based drought early warning/early action has been hampered by both inadequate decision-making frameworks and a lack of appropriate funding mechanisms. Rural communities in Nicaragua and Ethiopia that have participated in resilience-building interventions of varying durations demonstrate the value of community-based actions informed by early warning, forecasts and drought management advice, both before and during the agricultural season. While drought affected all crops negatively, participants were better able to mitigate impacts, were more organised in accessing relief and recovered more effectively. These results are consistent with other research on the cost/benefit of anticipatory actions, use of climate services and appropriate drought management advice. They also confirm the importance of embedding short-term early action in long-term resilience-building. Despite this, formal systems, national and local, remain essentially unimplemented. Systems being developed at global level now need to be operationalised and translated into effective local drought management standard operating procedures for the most vulnerable.

Hahlin, J. (2019). Evacuation behaviour intentions based on the summer 2018 Swedish forest fire season. *Lutvdg/Tvbb*. https://lup.lub.lu.se/student-papers/record/8998490
…The corresponding numbers for the personnel group are 100 %. The main conclusion of this study is survey respondents indicate the need for further improve evacuation planning and communication during large forest fire scenarios …

Jayasekara, R. U., Jayathilaka, G. S., Siriwardana, C., Amaratunga, D., Haigh, R., Bandara, C., & Dissanayake, R. (2021). Identifying gaps in early warning mechanisms and evacuation procedures

for tsunamis in Sri Lanka, with a special focus on the use of social media. *International Journal of Disaster Resilience in the Built Environment*. https://doi.org/10.1108/IJDRBE-02-2021-0012
Purpose: The current National Early Warning System for Sri Lanka (NEWS: SL) was established after the devastations of the Indian Ocean Tsunami in 2004. Although early warning (EW) systems and evacuation procedures are in place, several areas which need improvements have been emphasized in recent studies carried out in the country. Therefore, this paper aims to outline the gaps in existing EW and EP related to tsunami and other coastal hazards with a special focus on the use of social media for disaster communication based on age groups.
Design/methodology/approach: This study has drawn on a review of past studies carried out by the same research team to identify the scope of the study. In addition to that, a conceptual framework was developed for the use of social media in the event of a disaster. Based on this conceptual framework, an online questionnaire was administered to identify the current status of the use of social media in Sri Lanka during a disaster situation. In total, 408 responses were collected and analyzed using the binary logistic regression method to evaluate the variation of different predictors associated with the use of social media for disaster communication. Findings: Findings of the study revealed that the use of social media for disaster communication depends on the previous experience of users and their age. The gender of users does not affect the use of social media for disaster communication. Therefore, the accuracy and timeliness of disaster information distributed via social media should be improved further to enhance the use of social media for disaster communication. Moreover, the findings have highlighted unaddressed issues in areas such as governance; communication of technical agencies; evacuation and shelters; and response of the community. Originality/value: This paper has identified key areas that need attention in the process of enhancing the use of social media for disaster communication. More use of technological platforms such as social media for receiving disaster-related information can address issues such as bottlenecks in communication, poor awareness and lack of last-mile dissemination. Furthermore, this paper has proposed recommendations for addressing the identified gaps in the overall EW mechanisms and EP pertaining to tsunamis and other coastal hazards to enhance the coastal disaster resilience in Sri Lanka.

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Che Mamat, C. S. N. B., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J. L. J. L., Wandala, A., Ayuliana, S., Novikarany, R., Khalid, N. B. M. B. M., Mamat, C. S. N. B. C., Moron, L. A., Cecilia A Monteverde, M., Cayanan, E. O., … Harris, A. J. L. J. L. (2022). Impact-based forecasting in South East Asia – What underlies impact perceptions? *International Journal of Disaster Risk Reduction*, *76*(March), 102943. https://doi.org/10.1016/j.ijdrr.2022.102943
The move towards impact-based forecasting presents a challenge for forecasters, who must combine information not just on what the weather might be, but also on what the weather might do. Yet different hazards and impacts are qualitatively distinct, meaning such information cannot be easily or straightforwardly integrated. The present study aimed to provide a way of characterising seemingly disparate impacts. In a collaboration between UK psychologists and partners from three meteorological organisations in Indonesia, Malaysia and the Philippines, the psychometric paradigm was employed to investigate how forecasters and stakeholders perceive weather-related impacts. Participants provided ratings of nine categories of impacts on a total of 10 characteristics, as well as providing an overall impact severity rating. Principal components analysis revealed differing component solutions across countries, which explained around 75% of the variance in perceptions. There were some similarities across all countries, with the characteristics 'worry'' and "destructiveness'' loading positively together, as well as 'likelihood of harm'' and "seriousness of harm''. We did not find strong evidence to indicate that forecasters and stakeholders perceive impacts in different ways. Our results highlight the complex nature of impact

perceptions, which are characterised not just by objective factors such as impact scope and duration, but also subjective factors, such as worry and perceived severity."'''

Jenkins, S. C., Putra, A. W., Ayuliana, S., Novikarany, R., Khalid, N. M., Che Mamat, C. S. N., Moron, L. A., Monteverde, M. C. A., Cayanan, E. O., Beckett, R., Harris, A. J., Biddle, N., Bryant, C., Gray, M. M., Marasinghe, D., Harrison, S. E., Potter, S. H., Prasanna, R., Doyle, E. E. H., … Wood, D. (2018). Value chain analysis for resilience in drylands (VC-ARID): identification of adaptation options in key sectors. *International Journal of Disaster Risk Reduction*, *13*(February), 76 pp. https://doi.org/10.1175/wcas-d-20-0110.1

Pathways to Resilience in Semi-arid Economies (PRISE) Project 3 identifies opportunities for economic transformation and diversification in the semi-arid lands of PRISE countries, by integrating sectors rooted in semi-arid lands into national economies. Taking a three-step, innovative, common methodology (Value Chain Analysis for Resilience in Drylands (VC-ARID)), the project aims to identify climate risk, adaptation options and opportunities for private sector development in Kenya, Senegal, Burkina Faso, Pakistan, Tajikistan and Ethiopia, specifically for the livestock and cotton sectors. The VC-ARID approach is innovative in that it considers the specific characteristics of semi-arid systems. This synthesis report focuses on the first of the three steps within the methodology: mapping the value chain. Seven value chains have been mapped. This step includes a literature review and the results of key informant interviews and focus group discussions. This report explains the results of Step 1.

Johar, M., Johnston, D. W., Shields, M. A., Siminski, P., & Stavrunova, O. (2022). The economic impacts of direct natural disaster exposure. *Journal of Economic Behavior and Organization*, *196*, 26–39. https://doi.org/10.1016/j.jebo.2022.01.023

We estimate the economic impacts of having your home damaged or destroyed by a natural disaster. Regressions with individual, area and time fixed-effects, indicate that experiencing a natural disaster has no impact on employment and income, but substantial impacts on financial hardship and risk aversion. Impacts are particularly large for smaller isolated disasters, which attract little government support. Conversely, impacts of residing in a disaster zone without experiencing residential destruction are small. Using a Group Fixed Effects estimator, we find predictors of financial vulnerability to destruction include age, parenthood, illness, and social support. These results can help improve the allocation of government assistance after future disasters.

Lazo, J. K., Hosterman, H. R., Sprague-Hilderbrand, J. M., & Adkins, J. E. (2020). Impact-Based Decision Support Services and the Socioeconomic Impacts of Winter Storms. *BAMS*, *101*(5), E626–E639. https://doi.org/10.1175/BAMS-D-18-0153.1

As part of its strategic plan for Building a Weather-Ready Nation, the U.S. National Weather Service (NWS) has increased their efforts to provide decision support services connecting forecasts and warnings to decision-making for core partners responsible for public safety. In 2011, the NWS formalized their approach to provide impact-based decision support services (IDSS) to help core partners better understand and utilize NWS forecasts and warnings in the face of upcoming extreme events. IDSS encourages weather forecasters to better consider societal impacts from weather events. This shift in emphasis toward impacts ensures NWS information and services are more relevant to decision-makers, which will allow those decision-makers to use NWS information and services to take proactive mitigating actions to protect life and property. This study posits that formal IDSS provides core partners with better information and supports decisions that reduce socioeconomic impacts during extreme winter storms. We compare two storms in the New York City area with similar characteristics but differing in their implementation of IDSS: the December 2010 storm occurred before the implementation of formal IDSS, whereas the January 2016 storm

occurred after the implementation of formal IDSS. The comparison of the storm events indicates that IDSS and mitigating actions reduce flight cancellations, improve recovery time in the ground transportation sector, and reduce the duration and number of customers affected by power outages. We recommend that future studies of the value of IDSS consider using case studies for a range of weather events as well as other methodological approaches to assessing benefits.

Lazo, J. K., Waldman, D. M., Morrow, B. H., & Thacher, J. A. (2010). Household Evacuation Decision Making and the Benefits of Improved Hurricane Forecasting: Developing a Framework for Assessment. *Weather and Forecasting*, *25*(1), 207–219. https://doi.org/10.1175/2009WAF2222310.1
Hurricane warnings are the primary sources of information that enable the public to assess the risk and develop responses to threats from hurricanes. These warnings have significantly reduced the number of hurricane-related fatalities in the last several decades. Further investment in the science and implementation of the warning system is a primary mission of the National Weather Service and its partners. It is important that the weather community understand the public's preferences and values for such investments; yet, there is little empirical information on the use of forecasts in evacuation decision making, the economic value of current forecasts, or the potential use or value for improvements in hurricane forecasts. Such information is needed to evaluate whether improved forecast provision and dissemination offer more benefit to society than alternative public investments.

Linkov, I., Carluccio, S., Pritchard, O., Bhreasail, Á. N., Galaitsi, S., & Keisler, J. M. (2020). The case for value chain resilience. *Management Research Review*.
PURPOSE Value chain analyses that help businesses build competitive advantage must include considerations of unpredictable shocks and stressors that can create costly business disruptions. Enriching value chain analysis with considerations of system resilience, meaning the ability to recover and adapt after adverse events, can reduce the imposed costs of such disruptions. DESIGN/METHODOLOGY/APPROACH The paper provides a perspective on resilience as both an expansion and complement of risk analysis. It examines applications of both concepts within current value chain literature and within supply chain literature that may inform potential directions or pitfalls for future value chain investigations. Established frameworks from the broader field of resilience research are proposed for value chain resilience analysis and practice. FINDINGS The synthesis reveals a need to expand value chain resilience analysis to incorporate phases of system disruption. Current explorations in the literature lack an explicit acknowledgement and understanding of system-level effects related to interconnectedness. The quantification methods proposed for value chain resilience analysis address these gaps. ORIGINALIT Y/ VALUE Using broader resilience conceptualizations, this paper introduces the resilience matrix and three-tiered resilience assessment that can be applied within value chain analyses to better safeguard long-term business feasibility despite a context of increasing threats.

Lukasiewicz, A., & Baldwin, C. (2020). *Natural hazards and disaster justice: Challenges for australia and its neighbours* (Issue February). https://doi.org/10.1007/978-981-15-0466-2
This book explores policy, legal, and practice implications regarding the emerging field of disaster justice, using case studies of floods, bushfires, heatwaves, and earthquakes in Australia and Southern and South-east Asia. It reveals geographic locational and social disadvantage and structural inequities that lead to increased risk and vulnerability to disaster, and which impact ability to recover post-disaster. Written by multidisciplinary disaster researchers, the book addresses all stages of the disaster management cycle, demonstrating or recommending just approaches to preparation, response and recovery. It notably reveals how procedural, distributional and interactional aspects of justice enhance resilience, and offers a cutting edge

analysis of disaster justice for managers, policy makers, researchers in justice, climate change or emergency management. BoM Staff access via VPN https://ebookcentral.proquest.com/lib/boma-ebooks/detail.action?docID=6028057

Mileti, D. S., & Sorensen, J. H. (1990). *Communication of emergency public warnings: A social science perspective and state-of-the-art assessment*. https://doi.org/10.2172/6137387

Msemo, H. E., Taylor, A. L., Birch, C. E., Dougill, A. J., & Hartley, A. (2021). The value of weather and climate information to the tanzanian disaster risk reduction sector using nonmonetary approaches. *Weather, Climate, and Society*, *13*(4), 1055–1068. https://doi.org/10.1175/WCAS-D-21-0005.1
This paper investigates the value of weather and climate information at different time scales for decisionmaking in the Tanzanian disaster risk reduction sector using nonmonetary approaches. Interviews and surveys were conducted with institutions responsible for disaster management at national, regional, and district levels. Arange of values were identified, including 1) making informed decisions for disaster-preparedness-, response-, recovery-, and restoration-related activities; 2) tailoring of directives and actions based on sectoral impacts; and 3) identification of hot-spot areas for diseases outbreaks and surplus food production. However, while a number of guidelines, policies, acts, and regulations for disaster risk reduction exist, it is not clear how well they promote the use of weather and climate information across climate-sensitive sectors. Nonetheless, we find that well-structured disaster risk reduction coordination across sectors and institutions from the national to the district level exists, although there is a need for further development of integrated early warning systems and a common platform to evaluate effectiveness and usefulness of weather warnings and advisories. Key challenges to address in increasing the uptake of weather warnings and advisories include language barriers, limited dissemination to rural areas, and limited awareness of forecasts. From the findings of this study, we recommend further quantitative evaluation of the skill of the severe weather warnings issued by the Tanzania Meteorological Authority and an assessment of how decisions and actions are made by recipients of the warnings in the disaster risk reduction sector at different stages in the warning, response, and recovery process.

Nguyen, T. C., & Robinson, J. (2015). Analysing motives behind willingness to pay for improving early warning services for tropical cyclones in Vietnam. *Meteorological Applications*. https://doi.org/10.1002/met.1441
Pressure on government budgets has made it more important to quantify the value of public goods, e.g. tropical cyclone warning services, to society as a whole. Based on a stated preference survey, in which respondents could indicate the amount of their willingness to pay (WTP), this study elicited values for an improved cyclone warning service in Vietnam. To examine motives or reasons behind respondents' WTP, respondents were requested to allocate 10 points among different types of values, including self-interest motivated value (termed use value), and values with respect to the interests of others (altruistic value) and future generations (bequest value). The more influential the value, the higher the point is scored. Use value, which was scored the highest mean point of 4.1 out of 10, is the most important motive for valuing improvements in cyclone warning services. Altruistic and bequest values were given similar points, approximately 2.9 and 3.0, respectively. This study empirically demonstrates that respondents hold not only self-interest motivated value, but also altruistic and bequest values. Given the importance of non-use values, i.e. altruistic and bequest values, economic assessments focusing on only use value would underestimate the benefits of an improved cyclone warning service to society.

O'Brien, A., Read, G. J. M., & Salmon, P. M. (2020). Situation Awareness in multi-agency emergency response: Models, methods and applications. *International Journal of Disaster Risk Reduction*, *48*,

101634. https://doi.org/10.1016/j.ijdrr.2020.101634
Effective emergency response to any disaster is predicated on successful multi-agency coordination, which in turn relies on agencies to understand 'what is going on'', generally known as Situation Awareness (SA). SA can be viewed from an individual, team or a systems perspective. Research in other safety critical environments and multi-team systems that have adopted a systems thinking perspective indicates that Distributed Situation Awareness (DSA) may be a suitable theoretical framework to use when attempting to understand and optimise multi-agency emergency response (ER) systems. Despite its popularity in other domains, it is unclear the extent to which the DSA perspective has been applied in the ER context. The aim of this review is to provide an overview of the current literature in the area of SA in multi-agency disaster response, and to establish the extent to which the theory of DSA has been examined in this context. A structured search of the literature identified only one study that applied the established DSA methodology to their research. Findings from this review reveal a knowledge gap exists in investigating SA from a systems perspective in ER and therefore future research utilising the theory of DSA in this domain is warranted.'

Parsons, M., & Foster, H. (2020). *Reimagining program monitoring and evaluation for disaster resilience outcomes*.
Emergency service and emergency management agencies have undertaken to better understand and support disaster resilient communities. These agencies have developed resilience- based doctrine, policy, programs and projects to strengthen and support communities before, during and after emergencies. Community disaster resilience is a goal of many community engagement programs, but the contributions of these programs to disaster resilience can be difficult to quantify and assess. The gap in the sector is to monitor and evaluate the impact that policies and programs are having collectively in building community disaster resilience. This project was proposed by Emergency Management Victoria through the Tactical Research Fund of the Bushfire and Natural Hazards CRC, and supported by AFAC. It examines new approaches to monitoring and evaluating the contributions of agency programs to community disaster resilience.

Potter, S., Harrison, S., & Kreft, P. (2021). The Benefits and Challenges of Implementing Impact-Based Severe Weather Warning Systems: Perspectives of Weather, Flood, and Emergency Management Personnel. *Weather, Climate, and Society*, *13*(2), 303–314. https://doi.org/10.1175/wcas-d-20-0110.1
Warnings about impending hazards help to minimize the impacts and reduce the risk of the hazard through encouraging an appropriate and timely behavioral response. Many hydrometeorological agencies are moving toward impact-based forecast and warning (IBFW) systems, as encouraged by the World Meteorological Organization. Yet little research has been conducted on such systems from the perspectives of agencies who are or would be involved in their implementation. We investigated the challenges and benefits of IBFW systems as perceived by participants from agencies internationally and within New Zealand. Interviews and workshops were held with meteorologists and weather forecasters, flood forecasters and hydrologists, and emergency managers. We found that the benefits of implementing IBFW systems included a perceived increase in the understanding of the potential impacts by the public, added awareness of antecedent conditions by forecasters, a possible reduction in "false alarms," and increased interagency communication. Challenges identified by the participants included whether the system should be designed for individuals or society, a lack of impact data, verification of warnings based on impacts, a conflict with roles and responsibilities, the potential for conflicting messages, and the increased burden on agencies providing information to forecasters with a perception of little benefit in return. We argue that IBFWs could be designed for individual members of the public,

with an increased focus on understanding vulnerability and capacities, and that more impact data need to be collected and stored to inform future warnings. Increased interagency coordination would assist with rapid decision-making and the success of IBFWs.

Robbins, J., Bee, E., Sneddon, A., Brown, S., Stephens, E., & Amuron, I. (2022). *Gaining user insights into the elements of Impact-based Forecasting (IbF) from within the SHEAR programme Summary of Findings* (Issue June 2022). https://nora.nerc.ac.uk/id/eprint/532837/1/IBF
this research aims to answer the following questions: (1) Is there a shared understanding of what IbF is across individuals involved in its development? (2) Is there a shared perception of the challenges, barriers and opportunities associated with implementing IbF operationally?

Seebauer, S., & Babcicky, P. (2018). Trust and the communication of flood risks: comparing the roles of local governments, volunteers in emergency services, and neighbours. *Journal of Flood Risk Management*, *11*(3), 305–316. https://doi.org/10.1111/jfr3.12313

Sushchenko, O., & Schwarze, R. (2020). *Economics and finance of disaster risk reduction and climate change adaptation* (Issue January).
In brief, the report investigates the most important finance and economic gaps3 that currently hinder production, integration and practical implementation of knowledge by DRR and CCA stakeholder groups. Those gaps provide also specific opportunities for a better alignment between both fields if addressed properly by appropriate stakeholders capable of introducing required changes. The alignment opportunity results from the fact that finance, insurance as well as risk transfer remain main driving forces for climate adaptation and disaster risk management leading to long-term sustainability. Consequently, the identified opportunities can be also used to improve the EU Green Deal and assure higher efficiency of the implemented measures. PLACARD as a platform for DRR and CCA community actively supports and contributes to that alignment process and a better integration of CCA and DRR into European Green Deal.

United Nations Development Programme. (2017). *A New Vision for Weather and Climate Services in Africa*.
http://www.undp.org/content/undp/en/home/librarypage/climate-and-disaster-resilience-/weather-and-climate-systems---africa.html

Waskow, D., Jacoby Jonathan, Ocharan, J., de Messieres, S., GLucksman, S., Fischer-Mackey, J., Jochnick, C., Slack, K., Shelley, B., & Woodward, S. (2013). *Value Chain Climate Resilience*.
https://www.bsr.org/reports/PREP-Value-Chain-Climate-Resilience_copy.pdf
This guide discusses a value chain approach to building climate resilience, and provide cases studies of climate resilience in action.

Weyrich, P., Scolobig, A., Bresch, D. N., & Patt, A. (2018). Effects of Impact-Based Warnings and Behavioral Recommendations for Extreme Weather Events. *Weather, Climate, and Society*, *10*(4), 781–796. https://doi.org/10.1175/WCAS-D-18-0038.1
Bad weather continues not only to inflict damage on property but also to kill and injure people, despite significant advances in the predictive power of meteorological warnings. There is evidence that people tend to underreact to weather warning information, to a large extent because of insufficient understanding of the impacts that severe weather events can have, as well as to demonstrate the appropriate response behavior. A growing number of experts are suggesting that standard warning information should be augmented with additional information about these factors, but this has so far largely failed to take place. Past research studies have shown possible advantages of including impact-based warnings (IBWs) and behavioral recommendations (BRs) into the warning information, but the results are in part ambiguous, due to a failure to have tested for

effects of the two kinds of information separately and in combination. Based on quantitative results from a survey experiment in Switzerland, this knowledge gap is addressed. Results of the research reported here indicate significant benefits from providing both sets of information together, in terms of improving both perception and understanding of warning and intended behavioral responses. When only one piece of information is given, BRs have a significant effect on both perception and intended response, whereas IBWs have a significant effect only on intended response. These findings offer empirical justification for the added expense and time associated with the more detailed hazard warnings.

Version history

Version	Date	Contact
1.0	9 December 2022	Beth.Ebert@bom.gov.au, David.Hoffmann@bom.gov.au