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Editorial: Climate Science Advances to Address 21st Century Weather and Climate Extremes

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The Editorial on the Research Topic

Climate Science Advances to Address 21st Century Weather and Climate Extremes

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AN OVERVIEW OF THIS ISSUE

The science surrounding weather and climate extremes, and their relationship with climate change, is rapidly expanding, feeding into improved climate services. As co-editors of "*Climate Science Advances to Address 21st Century Weather and Climate Extremes*," we are proud to share with you these excellent articles that provide valuable advances to our discipline, and come from researchers all over the world. The papers led by Lindsay Johnson and Phuong-Loan Nguyen address, respectively, the development of adequate data resources needed to support drought early warning and the study of precipitation extremes. Johnson et al. *"explore the use of updated drought monitoring tools to analyze data and develop a more holistic drought climatology applicable for New Mexico."* Nguyen et al. *"use a new high-resolution validation dataset to assess the consistency of the representation of annual daily precipitation maxima over land in 13 observational datasets."* Focusing on four cities in Ethiopia, Dessu et al. describe how the rapid expansion of built-up areas and sharp declines in green-space may be increasing climatic risk. Harvey et al. examines ways in which climate information was mobilized for use under Future Climate for Africa, and their findings "*revealed the central role of co-production principles in engaging potential users of climate information, regardless of the knowledge mobilization approach being used.*" Finally, the study by Trainer et al., explored "*trends in nearshore domoic acid along the US west coast in recent years, including the recent establishment of a new seed bed of highly-toxic Pseudo-nitzschia*," and described "*how early warning systems are a useful tool to mitigate the human and environmental health and economic impacts associated with harmful algal blooms.*" All of these articles advance the science of climate services in a warming world, moving us toward a greater capacity to manage future climate risk.

As discussed in Sarah Harrison's excellent article in WIRED[1], studies like "*trends in nearshore domoic acid*" can help motivate and inform effective early warning systems, fostering unique partnerships between scientists and community members.

HOW CONCEPTUAL MODELS CAN INFORM CLIMATE SERVICES

Climate attribution and climate diagnostic studies highlight the mechanisms driving extreme events, and elucidate their potential to increase in intensity and frequency as the Earth warms. This research can, and should, inform the development of 21st century climate services. But while the nuts and bolts of climate science are essential, climate services are also fundamentally cultural; they support distributed non-local communities of practice that act, adapt, mitigate, plan, and respond in coherent ways that allow us to better cope with climate and weather risk. These important sub-cultures typically span many academic disciplines and sectors of society. Spanning these gaps is challenging, and it is therefore useful to consider our work from the lens of cultural anthropology.

Cultural anthropologists study how people who share a common cultural system organize and shape the physical and social world around them, and are in turn shaped by those ideas, behaviors, and physical environments. According to one seminal cultural anthropologist, Clifford Geertz, culture is "*a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate, and develop their knowledge about and attitudes toward life*" (The Interpretation of Cultures," Geertz, 1973). In Interpretation of Cultures Geertz introduces the idea that cultures behave coherently by effectively combining "models of the world" and "models for the world." Models "of" the world resemble our numerical models; they attempt to imitate or simulate the world-as-it-is. Models "for" the world, however, imply specific and coherent actions, actions informed by our models "of" the world. So, according to Geertz, the study of hydraulics might help us design a dam. Because human behavior is driven by extrinsic symbolic structures (not just our genes), that it is precisely the interaction of these two distinct types of models that makes human culture possible.

But what is exciting, and challenging, is that today we can no longer afford to rely on "*inherited conceptions*." In the face of climate change, more and more scientists are realizing that they need to actively participate in culture "fabrication." In addition to algorithms, numerical models, datasets and simulations, we can help co-create coherent systems for early action. But an important component such systems is clear thinking, the development of crisp conceptual models. To be truly successful climate services need to combine accurate and representative models "of" the world with appropriate and localized models "for" intervention. Stepping back from the science, this editorial briefly discusses the important aspect of how these pieces can fit together when disparate "communities of practice"—like the oceanographers, health experts and local tribal leaders discussed in Sarah's story (see text footnote 1), work together.

The provision of freely available climate services is a very exciting prospect, a force for good that can help counter two growing threats—climate change and increasing economic disparity. While climate services will not reverse inequality, they can help the communities most vulnerable to extremes. Enhanced early warning systems are one of the most cost-effective approaches[2] to increasing resilience. Climate information can leap across continents, improving decision-making, early warning systems, and outcomes almost anywhere. As these systems evolve, we will be better together, faster, and more effectively, if we pay attention to the conceptual models that undergird our shared activities.

Climate Services are unique, challenging, exciting, and empowering, precisely because they connect and span many intellectual domains (**Figure 1**). These connections can transform data into wise actions. While the origins of the Data-Information-Knowledge-Wisdom hierarchy is uncertain, it may have originated (Wallace, 2007) in T. S. Eliot's poem "Choruses from the Rock" (Eliot, 1934):

> *Where is the Life we have lost in living?*
> *Where is the wisdom we have lost in knowledge?*
> *Where is the knowledge we have lost in information?*

Effective climate services typically involve contributions from overlapping "communities of practice." These collaborations connect technical engineering and science efforts (on the left-hand-side of **Figure 1**) with on-the-ground actions and interventions on the right-hand-side. Going data to information to knowledge to wisdom, we also tend to transition from the general to the specific. On the left-hand-side, we might find an atmospheric model based on universal physical laws or "rocket scientists" who use highly generalized algorithms to translate satellite imagery into precipitation estimates (Kummerow et al., 2015; Skofronick-Jackson et al., 2017; Huffman, 2020). But, as one moves to the right-hand-side in **Figure 1**, we find tailored effective interventions guided by local expertise.

Connecting data providers and responders, we find the sequential contributions of "climate intermediaries." To be actionable, information typically needs to be transformed into impact assessments, answering questions like: "*how might the expected or observed weather or climate conditions affect our crops, water supply, or fire fuels.*" This translation can add great value. For example, a recent study of drought warning activities in Malawi, found that what farmers really wanted and needed was agricultural advice, not weather data (Calvel et al., 2020), i.e., knowledgeable actionable guidance, not just data or information.

Shared conceptual frameworks can facilitate effective collaboration and communication across these communities of practice, guiding the translation of data and information into knowledge and appropriate action. For example, the Famine Early Warning Systems Network (http://www.

[1] https://www.wired.com/story/a-unique-alliance-could-help-warn-us-of-toxic-algae/

[2] https://gca.org/reports/adapt-now-a-global-call-for-leadership-on-climate-resilience/

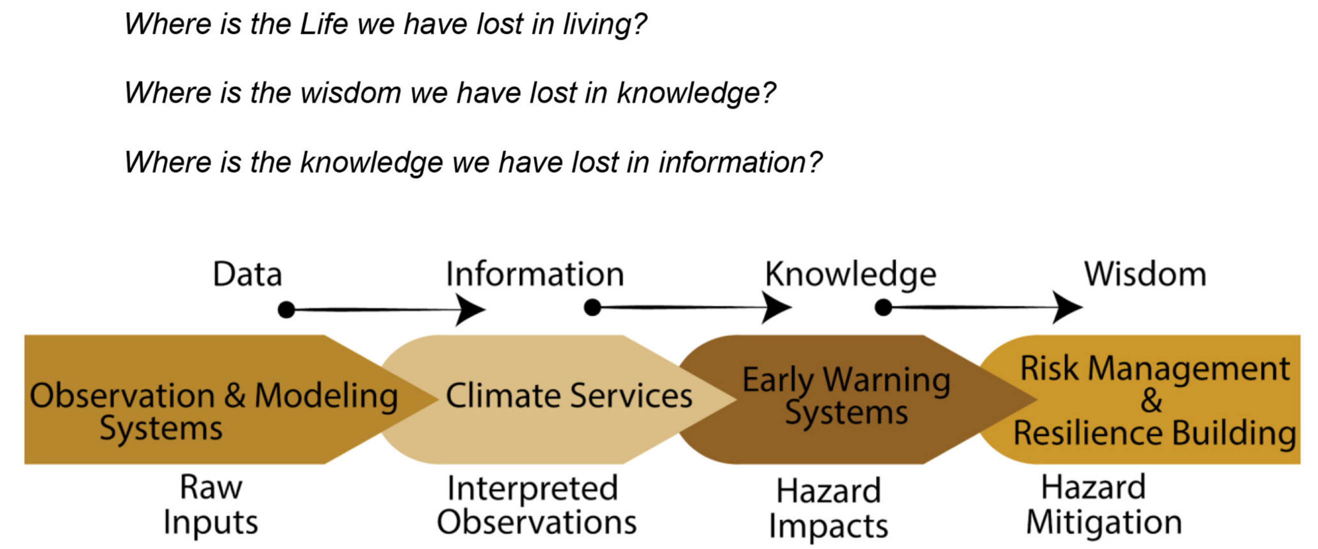

FIGURE 1 | A schematic diagram showing how multiple communities of practice can all contribute to effective hazard mitigation, risk management, and capacity-building.

fews.net/) identifies severely food insecure populations by developing scenarios[3] that analyze household level food economies, but these scenarios use a rigorous multi-agency "food security outlook[4]" process to translate climate information into likely impacts on incomes, food access and food availability.

Yes—we need to translate climate data into information that drives impact models that provide accessible outputs that can support effective actions, and each of those verbs typically manifests as thousands of lines of code and extensive computations, but no, computation alone does not suffice.

The transitions described in **Figure 1** describe a series of coherent social interactions, emergent collaborative complex behavior, and when thinking about such structures the climate services community can learn from experts who study how cultures evolve. Seen from this perspective, successful early warning communities are subcultures that evolve to address specific threats, such as drought or food insecurity, and their success depends on translating data into wise action (**Figure 1**) using shared models "for" reality supported by accurate models "of" reality. Hence, such systems spend considerable effort on describing how hazards are detected and defined (Pulwarty and Sivakumar, 2014; Wilhite and Pulwarty, 2017; Funk and Shukla, 2020). Crisp definitions of drought (Wilhite and Glantz, 1985; Svoboda and Fuchs, 2016), and food insecurity (FEWS NET, 2021), can form a shared basis for collaboration and coherent climate services development. But these definitions, and the associated impact assessments and risk management responses, will be highly location specific—thereby requiring local knowledge.

But climate change is accelerating the need for climate services, and demanding that we have the best possible models "for" early warning. Surveys of extreme events, such as the book "Drought Fire Flood" (Funk, 2021)[5] can help guide climate service development. Analyses focusing on the new science of climate change attribution evaluate how climate change may or may not contribute to extreme events. Such studies can also provide search patterns, or models "for" hazards that can guide prediction and monitoring (i.e., a, b, c, d, e). For example, many studies have suggested that climate change will produce more frequent extreme El Niño and La Niña events. For La Niñas, it turns out that numerical models "of" the climate can predict these conditions very early, in June[6], providing a very valuable opportunity for early warning, predicated on a conceptual model "for" climate change impacts built around the assumption that extreme sea surface temperatures will provide a solid foundation for forecasting. Given that ENSO is the leading component of seasonal forecasting skill, linking our successful model "of" the climate to models "for" early action can help us move effectively from data to information to wise interventions (**Figure 1**). But there are as many opportunities for effective climate services as there are categories of climate impacts. Our age offers us many exciting opportunities to contribute to the production of data, information, knowledge, and wise action.

[3]https://fews.net/our-work/our-work/scenario-development
[4]https://public.wmo.int/en/resources/bulletin/how-climate-forecasts-strengthen-food-security
[5]https://www.cambridge.org/core/books/drought-flood-fire/96E0EB1519F5175B68079D294D0B0E93
[6]https://blog.chc.ucsb.edu/?p=757

These contributions are helping us cope with an increasing hazardous world.

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