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Viewpoint

From hubris to humility: Transcending original sin in managing hydroclimatic risk

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ABSTRACT

The characteristics of hydroclimatic risk in the 21st Century are rapidly changing. Increases in extreme weather events and population densities alter exposure to floods and droughts. Water infrastructure is unable to keep pace and deterministic models can mislead. Yet, predominant strategies for managing risk continue to follow historical precedent, striving to tame nature's outbursts and mitigate disasters through conventional engineering structures. In this Viewpoint article, scholars from three disciplines address underlying limitations in contemporary risk management, each of which is rooted in the concept of hubris. They argue that effective risk management must extend beyond hubris-thinking to an approach based on humility. Extending from the three types of limitations—described as Disconnect from Nature, Engineers of a Fixed Nature. and Modelers of Nature— a collective and synthetic consideration provides insights into potential pathways forward for both science and practice. More satisfactory strategies for managing hydroclimatic risk will require a shift from a hubris-based paradigm to a more humility-based approach.

1. Introduction

Society is not keeping pace with changing hydroclimatic risks. The human, social, ecological, and economic costs of water-related disasters, including droughts and floods, are increasing (Najibi and Devineni, 2018) and are projected to continue, in part, as a result of a changing climate (Alfieri et al., 2018). The societal role in mitigating hydroclimate risks is rooted in the title's reference to "Original Sin." The term conveys a vernacular understanding of human hubris, not only of an unjustified arrogance, but also a conceitedness manifested in pride, which attempts to transcend human limitations (Berry, 1987). Science has a pivotal role to play in mitigating hydroclimate risks. Yet, unless humans awaken to their hubris, in their various roles as, scientists, professionals, citizens, and decision-makers, well-intentioned efforts to manage risk may fall short.

Predominant approaches to managing risks from flooding adhere to a centuries-old model, grounded in controlling nature's outbursts and mitigating disasters with conventional engineering structures. These approaches in turn, are based on an understanding of the world in which humans are separate from, and able to control an often mercurial nature. But broad-scale, unprecedented changes in Earth systems and their ensuing risks require a fundamental re-orientation in the ways we comprehend and manage risk (Field et al., 2012). Extreme events of this generation include Typhoon Hagibis in Japan and Hurricane Harvey in Texas. They reveal the shortcomings of traditional approaches to flood management, expose social vulnerabilities, and draw attention to the linkages between extreme events, climate change, and human well-being. While we know that climatological changes contribute to increased risk, we also know that the magnitude and distribution of risk are co-created and shaped through the interactions of the material world with the social setting, through our behavior, technologies, politics, and economics (Adger, 2006).

In this Viewpoint article, colleagues from different disciplines (Anthropology, Engineering, and Atmospheric Sciences) analyze three interrelated domains in which human hubris undermines effective risk management: Disconnect from Nature; Engineers of a Fixed Nature; and Modelers of Nature. They argue that society must begin to rethink its approach to hydroclimate science, engineering, and the practice of hydroclimate risk management in order to effectively respond to current and future risks. Risk is a

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measure of exposure and adaptive capacity, which entails social, engineering, and modeling components. The analysis thus underscores the interdependence of these domains and emphasizes the need for humility across the board. Anything less will likely result in efforts that fall short of objectives due to social resistance, inappropriate technologies, or repetition of past mistakes. The domains were chosen specifically because, although based in different disciplines, they emerge from the same root cause of hubris. Additionally, if society is unable to move towards a humility-based model of risk management, all the potential technologies available will not suffice to justly and effectively respond to the current crises. Individually, each discipline acknowledges the limitations in each domain, but considered collectively, the domains provide insights into potential pathways forward for both science and practice.

2. Disconnect from Nature

> Can Nature be whole in half the world?
>
> (Jackson, 2011p. 40)

A Western worldview posits an underlying dichotomy that demarcates humans from nature (Latour, 1993), and conceptually extracts and separates humans from the world we perceive around us. Even as this perspective obscures the multiple ways in which humans relate and engage with nature, we simultaneously observe the ongoing interactions between ourselves and the material world around us. Scholars increasingly recognize the interdependent nature of ecological and social processes, and that current conditions are not the result of socially prescribed control of nature, but rather the result of historically based social-natural transformations (Swyngedouw, 1999). These transformations, which may be obfuscated by philosophical worldviews, nevertheless generate emergent material outcomes that are unpredictable, and yet central to our daily lives (Trosper, 2005). While we may envision a particular future, the world around us also has a say in what that future looks like.

Natural resource approaches such as adaptive management and ecological restoration recognize the co-constitution of humans/nature (Asplen, 2008). These approaches are indicative of a shift away from a "command and control" model and a dualistic interpretation of the world. At the project level for natural resources management, adaptive management recognizes uncertainty in the ability to meet objectives and the need to adapt to changing conditions by creating space to test, evaluate, and respond to new circumstances (Allen et al., 2011). Similarly, unforeseen and emergent outcomes are observable at the societal level. McPhee, (1989 cited in, Pickering, 2010), tells the story of how New Orleans became a city ringed by 20 foot high levees, and where, relative to street level, boats pass by overhead. This contemporary scenario was not envisioned by the original city planners, but rather emerged from New Orleans's ongoing struggle against the shifting course of the Mississippi River. Within this narrative, one can only fully understand human action in relation to the actions of the river. Far from a one-way controlling of the river, the relationship is best considered as a continual negotiation with the river (Pickering, 2010). Related processes continually unfold in other places around the world—fire regimes in the American West (Trosper, 2005) and elsewhere, and the ecological regimes shifts in the Everglades (Folke et al. 2004), to name but two examples. Natural resource managers, farmers, fishers, city planners, and legislative bodies all respond to nature through iterative negotiations (whether recognized as such or not) in which the outcomes are not predicted, though they can be encouraged. The human responses and negotiations with the material are not foreordained, but rather reflect cultural norms, values and objectives and are shaped by political and social structures (Linton and Budds, 2014).

Ultimately, the continued pursuit of the human/nature dichotomy hampers science and, in turn, the effective management of hydroclimatic risk (Head, 2008). The dichotomy contributes to cognitive heuristics that underlie risk models that assume inordinate control and discount the fat-tail probability distributions (cf. Wagner and Weitzman, 2015), which may be critical as climate continues to undergo rapid change (Anderies, 2015). Failure to appreciate the intimate interrelationships between humans and the broader world constrains our appreciation of the iterative and reciprocal relationships between humans and the environment and the emergent outcomes of management and policy decisions that create externalities and unequal distributions of risk. In response, some researchers have argued (O'Connell and O'Donnell, 2014) that our increasing appreciation of the interdependence of humans and nature requires better engineering of these systems through a balance of social, economic, and environmental considerations. This mode of thinking leads directly to our second domain.

3. Humans as Engineers of a Fixed Nature

Engineering efforts to "control" hydroclimatic extremes with levees, dams, seawalls, river "training" and straightening, and other tactics have accelerated dramatically over the past two centuries. Infrastructure for managing floods and engineered river corridors are now commonplace throughout much of the world. The United States has roughly 160,000 km of levees, for example, and approximately 43 percent of the U.S. population lives in counties with levees, according to FEMA (2019). But despite the prevalence of engineered flood control features and investments in hard infrastructure, faith in these approaches is starting to erode if the face of increasing risks and disasters.

As the public and decision-makers face mounting evidence of a changing operating environment, in which no absolute protection is possible from flooding and other hydroclimate events, the wisdom of the conventional risk management paradigm is increasingly subject to scrutiny. Flood damages in the U.S. continue to rise despite massive investments in flood management infrastructure over the last several decades (e.g. Cartwright, 2005; Munoz et al., 2018). Further, hard structural approaches to controlling floods can instill a false sense of security in the public that contributes to floodplain encroachment and development behind levees and in other hazardous locations (White, 1945; Montz and Tobin, 2008).

Numerous critics have characterized the dominant engineering approach to flood risk management as a manifestation of a larger pattern of humans' misguided efforts to control and subdue nature (e.g. McPhee, 1989; Leopold, 1992; Mount, 1998). We suggest that important signs point to a new emerging flood management paradigm. One of the most significant indications of such a shift is the profound reframing of natural systems as being, in part, infrastructure (e.g. Browder et al., 2019). This reframing has led the engineering community to begin recognizing floodplains, forests, wetlands, and other natural and nature-based features as essential components of flood infrastructure systems (e.g. Lane, 2017). This awareness is reorienting the longstanding tendency to *replace* natural infrastructure – vegetation, soils, floodplains, and wetlands that store precipitation and runoff – solely with hard "gray" infrastructure.

Similarly, a shift is evident from fail-safe to "graceful failure" or "safe-to-fail" designs that are robust across a range of plausible but unknowable futures (Stakhiv, 2011). Such designs tolerate various levels of failure, rather than existing solely in binary states of failure versus non-failure. This perspective reinforces the need to design non-structural and structural, as well as “gray” and natural, flood solutions conjunctively (François et al., 2019). Engineering thought leaders are also stepping forward to argue that multiple lines of natural and gray defenses, i.e. “redundancies,” are actually cost-effective if our thinking and accounting expands to encompass the full range of social, environmental, and economic benefits (Bridges et al., 2015; Vallejo and Mullan, 2017; Hallegatte et al., 2019). Nonetheless, modeling approaches that provide a sense of false security and scope of human capacity to respond still undergird reluctance to reframe flood management approaches (Fig. 1).

4. Modelers of Nature

Floods and other hydroclimatic extreme events often behave in capricious and unforeseen ways. Heavy rainfall may become most intense after the ground is saturated or frozen. Storm surge, river flooding, and high tides may synchronize. City streets become vast unplanned channel networks in which drainage infrastructure is clogged, overwhelmed, and bypassed. Predicting such behavior is fraught with complexity, interactions, surprises, and apparent randomness. But we never know if a “random” event is truly random, or a limit of our perception (Berry, 1987).

Modeling nature is an ongoing balancing act—a balance between 1) the risk of oversimplifying and misrepresenting the system of interest, versus 2) the risk of being paralyzed by uncertainty, equifinality, input demands, and large investments of resources required by highly complex models. The authors are concerned about the attitude that "if we get the mechanisms right" (which in its extreme is absurd, given the complexity of nature), then the model must be good. To be sure, complex models have their place as hypotheses and a means of probing the depths of understanding. Prediction error, not perception of mechanistic correctness, however, should be the most important criterion reflecting the usefulness of a model. Another concern is that, unless modelers adequately and transparently estimate the errors of prediction and present that estimate of error to the users of model results (Pappenberger and Beven, 2006), the risk of damaging the credibility of our science increases, making ourselves irrelevant.

Decision-making related to hydroclimate risks must be rooted in models that are specifically designed to address management questions and actions. In this context, emphasis on mechanistic detail and description is misplaced unless it relates to a decision-based model criterion. For example, recently released flood insurance rate maps for the coast of Georgia (USA)—based on updated storm surge models touted for their increased mechanistic detail—depict reduced risks of flooding for many homeowners compared to past maps (Parker, 2018). These models do not account for near-term sea-level rise, however, nor some recent and extreme historical storms. Similarly, naively optimistic and politicized maps that depict flood hazard zones with clear, deterministic boundaries (when these boundaries are in fact highly uncertain), can mask risks and thereby enable development in hazardous locations (Bell and Tobin, 2007; Stephens and Bledsoe, 2019). Most standard practice models used to delineate flood hazard zones inadequately account for uncertainty in key inputs and parameters. These models include future rainfall and flood magnitudes, highly influential parameters representing hydraulic resistance, and the changing geometry and capacity of channels and other geomorphic features. The inherent fuzziness and uncertainty in these models and maps may become a fixed reality in the minds of the individuals who gladly accept a reduction in their flood insurance premiums.

Predictive modeling of flood hazards embodies substantial uncertainties in terms of both the forcing processes and the response of the human systems. Hubris can lead us to embrace deterministic representations of processes and responses that mask uncertainties and can mislead unless the models explicitly quantify uncertainty in prediction. The predictive models that hold the most promise in flood management may be best thought of as probabilistic predictive assessments—that is, flexible, changeable mixes of mechanistic models, statistical analyses, and expert scientific judgment. Pragmatic approaches to managing hydroclimate risks and water resources under nonstationarity and deep climate uncertainty are beginning to permeate the mainstream of

Fig. 1. Christmas Flood of 1964, the Walla Walla River bursting levees and reverting to meanders. (Waananen et al., 1971).

the engineering community (Stakhiv, 2011; Mendoza et al., 2018; ASCE (2020). Ultimately, objectives associated with reducing risks and vulnerabilities should be the primary focus of science in support of decision-making, rather than building more-detailed models with the hope that they will provide clear cut answers.

5. Conclusions

"All streams flow to the sea because it lies below them. Humility gives it its power"

Tao Te Ching Ch.66

Mitigating negative consequences of hydroclimatic extremes for a given population and engineered landscape will require a contextual balance and resilience, in which communities can absorb recurrent hydroclimate disturbances (Adger et al., 2005). A first step towards redemption requires re-imagining our fundamental relationships across all three of the domains described here (Fig. 2a). A fundamental precept is congruency across physical landscapes, worldviews, and policies. If they are not congruent, then a key element of sustainable risk management will not function as it should. This problem becomes evident when thinking through the consequences of change in only one or two of the domains (Fig. 2b). For example, a shift from an

a

Humility approach	Risk management shortcomings in the absence of each humility approach
Humans as part of nature	• Overwhelming resistance to a move away from isolated gray infrastructure • Management motivated by fear and desire for control • Disharmony among policy, design, and behavioral norms
Engineering a dynamic nature	• Decisions and designs lack robustness in dynamic environments • Infrastructure not adaptive, regenerative, and satisficing
Acknowledging complexity	• Myopic and oversimplified tactics result in unforeseen negative and cascading consequences • Repeat past mistakes, systems inflexible and unsafe to fail

b

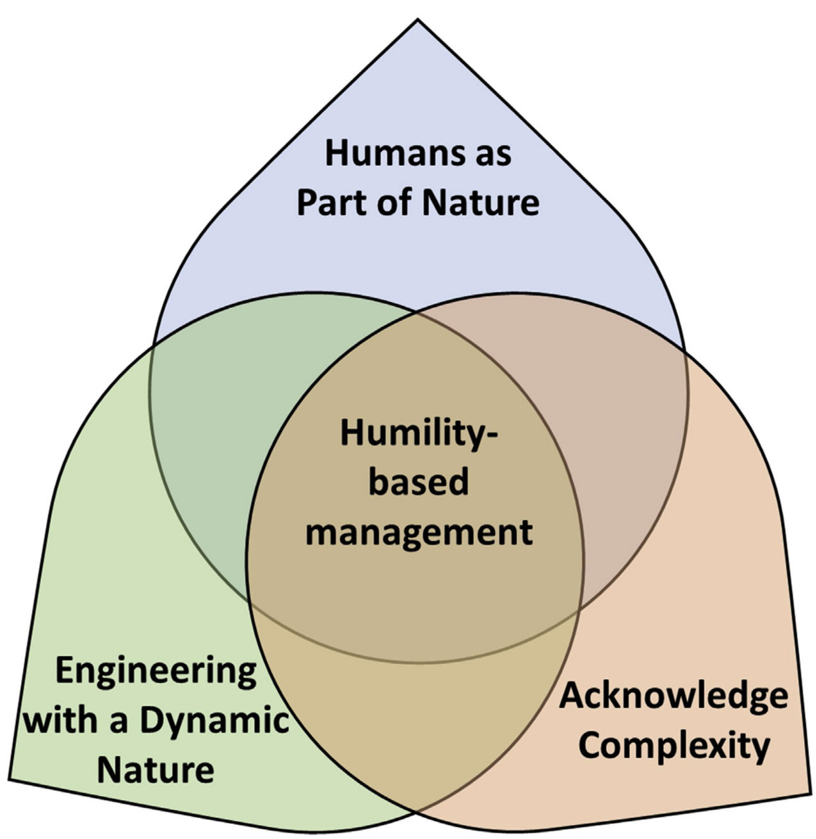

Fig. 2. a. Potential risk management implications given an absence of a humility shift in each domain. b. The interdependence of the three domains of humility.

Engineering a Fixed Nature to *Engineering a Dynamic Nature* would receive overwhelming resistance and pushback from the public, if a corresponding change in worldviews is not present that acknowledges *Humans as a Part of Nature*. Similarly, not *Acknowledging Complexity* leads to myopic and oversimplified tactics, which typically result in unforeseen negative and sometimes cascading consequences. A move to *Acknowledging Complexity* or *Humans as Part of Nature* in isolation will not translate into behavioral changes regarding infrastructure and repeating the same mistakes will continue. A logical question is which domain must change first. In practice, the integrated nature of these domains means that they will need to change together, with small gains in each which are linked through social, political, and scientific feedbacks.

People's current relationships with nature, characterized by human hubris, become material through our behaviors such as land-use, and through our decisions such as the discounting of low-probability, high-risk scenarios or subsidizing vulnerable infrastructure in floodplains. In hydrological systems, these material legacies of past hubris generate path-dependent trajectories (Manuel-Navarrete et al., 2019) that both create and mitigate risks across time and space, in non-random fashion. These trajectories are physical, but they are the outcome of our limited thinking and are exacerbated by disciplinary blinders. The rate and magnitude of contemporary climate and environmental change require a reorientation of hydroclimate science that incorporate aspects of humility across the three domains discussed. Scientific inquiry is at its best humble and self-correcting. It is based on being wrong and learning from it. But, the authors argue that to address hydroclimatic challenges, extending humility beyond the scientific process is necessary. Three critical arenas follow.

1 **Acknowledging limits**: Value is inherent in scientific expertise that is enhanced through recognition of limits, which can provide a realistic assessment of possibilities. As outlined in this paper, limits to managing hydroclimate risk stem from at least three related areas: the capacity to influence emergent outcomes, capabilities to shape the physical world, and our incomplete knowledge of integrated dynamics. Within acknowledged limits societies have space to maneuver, recognizing the importance of flexibility and adaptability. While it is not possible to enforce particular desired outcomes, they can be influenced and encouraged. However, risk management does not reduce all risk equally across places and throughout society. This key limitation must be addressed through the following changes.
2 **Reattuned thinking**: To adequately address hydroclimatic risk, we must recognize what are often unquestioned and accepted paradigms. As humans, we are frequently blind to our own shortcomings. And while the shortcomings discussed in this paper are each recognized within specific disciplinary approaches, it is only by collective and simultaneous consideration of these limits that society creates the possibilities to respond meaningfully. In doing so, it opens space for innovative, creative, and productive problem-oriented work. "Reattuned thinking" requires scholars and practitioners to engage freely and openly - and with personal and disciplinary humility.
3 **Communication**: First, this arena requires moving away from providing a false sense of security to the public and decision makers. It entails a much greater emphasis on the inherently uncomfortable work of transparently acknowledging uncertainty and communicating potential risk and consequences of decisions. Full transparency involves rigorously examining potential interactions among pluvial, fluvial, and coastal flooding mechanisms, as well as addressing head on the compounding effects of climate, land use, and social drivers of flood risks and the ways in which these are distributed within society. Second is the need to move away from the push model of communicating science, and engendering humility in the way we interact with stakeholders and present science, so that there is a shared understanding of information needs and modalities. Finally, successful communication is predicated on openness to

Table 1
Contrast of Hubris- and Humility-based Flood Management Characteristics.

Hubris-based	Humility-based
· Control nature	· Work with nature
· River "training" and straightening	· Room for the river
· Overconfidence, illusion of certainty bias	· Embrace uncertainty, recognize complexity and that surprises are likely
· Impose indecipherable, black box models and decision processes on the public	· Transparent models and decision processes – collaborative, reflect local knowledge
· Impenetrable communication to layperson	· Effective communication through stories, case studies, virtual reality
· Replace natural infrastructure with gray	· Blend green and gray – natural infrastructure is an integral part of solution, not just an add on
· Fail safe, hard failure, set up catastrophic failures	· Graceful / soft failure / degradation, safe to fail, multiple lines of defense
· Redundancy and resilience deemed not cost-effective	· Redundancy and flexibility are prudent and cost-effective
· Deterministic model outputs, no sensitivity or uncertainty analysis, even when uncertainty is deep and potential consequences are grave	· Perform sensitivity and uncertainty analyses and clearly communicate prediction accuracy to laypersons
· Assume unchanging operating environment	· Design for satisficing, robustness across many plausible futures.
· Deny complexity, surprises, look to the past to optimize a design	· Design for nonstationarity and compounding effects
· React when crisis happens	· Prepared for windows of opportunity
· Natural hazards are root cause of risk	· Systems thinking – integration of people with nature
· Do not recognize possibilities for mistakes	· Recognize errors and learn from them

the role of science in risk management and communicating knowledge in ways that are accessible to people across the range of education levels.

The antidote to hubris is humility. Whether these recent, disciplinary shifts in perspective will ultimately replace the prevailing hubris-based flood management paradigm with a more humility-based approach remains to be seen. Clearly, it will take time to catalyze these new perspectives (Table 1). Some flood management projects and conceptual models demonstrate small shifts toward a humility-based approach and are making considerable progress in risk management (e.g., Rijke, van Herk et al. 2012; Forbes, Ball et al. 2015; Mendoza, Jeuken et al. 2018; Browder, Ozment et al. 2019; Wingfield, Macdonald et al. 2019), though none incorporate all three domains. Given the extent of people's original sin, damages will continue, even when well-designed, robust flood management systems perform effectively. Thus, compelling evidence derived from project-based experience and careful accumulation of empirical evidence must counter the "when in doubt, build it stout" mentality that rejects non-structural and nature-based solutions. The interdisciplinary community has an opportunity to provide much-needed vision and leadership in the transition to a humility-based approach that fuses social, mechanical and ecological wisdom. This transition will require a willingness to acknowledge the limitations of past approaches among practitioners who are trained to optimize designs for a single future. A humility-based approach also acknowledges and shares these limitations among a broader society, which expects protection from hydroclimate extremes behind the familiarity of hard infrastructure.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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