Title: Introduction to Special Theme Section "Accounting for Climate Change: Measurement, Management, Morality, and Myth"

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Abstract
This special section considers contemporary efforts to account for climate change through four frames: measurement, management, morality and myth. Our introduction briefly outlines these perspectives and the relevant literature, asking: 1) How have techniques of measurement and quantification emerged from and contributed to the particular politics of the "Anthropocene"?; 2) How have our efforts to measure socioclimatic systems facilitated new techniques of socio-environmental management and, at times, worked to reshape the very systems they describe?; 3) How have accounting practices worked to both elucidate and obscure questions of morality, value, responsibility and justice?; and 4) How we might address the critique that climate science is a myth and improve understanding with greater incorporation of historical and cross cultural knowledge from human ecology, human geography and anthropology.

Introduction

Despite a strong scientific consensus and growing international political sentiment that we, as a global society, must quickly reduce anthropogenic greenhouse gas (GHG) emissions (Cook *et al*. 2016), there is significant contention about whether and how to respond in the United States, where the issue has been highly politicized (McCright and Dunlap 2011). Economic interests, low levels of climate literacy, and political disagreements about governmental priorities have all delayed action. Adding to this, climate contrarians have exploited scientific uncertainties to create doubt about anthropogenic climate change (Oreskes and Conway 2010). It is certainly true that there are uncertainties about net climate forcing, carbon stocks, positive feedbacks, tipping points, and potential human responses, but these uncertainties reflect the difficulty of the scientific task rather than disagreement about anthropogenic climate change among professional climate scientists (Knutti and Sedláček 2013). As Edwards writes, "understanding and predicting the climate is very difficult. In fact, it's one of the hardest challenges science has ever tackled, because it involves many interlocking systems, including the atmosphere, the oceans, the cryosphere, land surfaces and the biosphere" (2010:xv). This difficulty is compounded when highly unpredictable and culturally variable human behaviors are also taken into consideration, complicating efforts to predict climate futures by several orders of magnitude. Despite these challenges, our attempts to model the human-climate system are necessary to improve our understanding and inform appropriate mitigation and adaptation solutions. Yet even as we recognize the importance of this work, we are reminded by climate contrarians' exploitation of scientific uncertainties that our efforts to measure, represent, account for and predict climatic changes are deeply political and require reflexivity, transparency, complication and refinement to ensure reliability, avoid unfair or manipulative critique, and inform appropriate solutions.

This special section of *Human Ecology* considers contemporary efforts to account for climate change through four frames: measurement, management, morality, and myth. This introduction briefly outlines these perspectives and the relevant literature: 1) how techniques of *measurement* and quantification have emerged from and contributed to the particular politics of the "Anthropocene" (Crutzen and Stoermer 2000; Haraway 2015; Latour 2014); 2) how our efforts to account for socio-climatic systems have facilitated new techniques of socio-environmental *management* and at times even worked to reshape the very systems they describe; 3) how accounting practices have worked to both elucidate and obscure *moral* questions of value, responsibility, and justice; and 4) how we might address the critique that climate science is a *myth* and improve understanding with greater incorporation of historical and cross cultural knowledge from human ecology, human geography and anthropology.

Together, the contributors to this special section demonstrate that while there are many pitfalls associated with contemporary attempts to account for climate change, the incorporation of insights from the environmental social sciences can help to improve our efforts to understand and account for climate change, and perhaps more importantly, to craft more equitable and legitimate policy responses with greater potential for human buy-in and long-term success.

Measurement

A significant body of interdisciplinary data—revealed in ice cores, lake sediment, pollen remains, tree rings, historical weather data, shell middens and the archaeological record—illustrates that humans have influenced the climate for thousands of years (Crumley 2014; Rosman *et al*. 1997; Ruddiman 2013). However, in the past century, humans have drastically accelerated climate impacts on a global scale due to land use changes and rapid, carbon-intensive development (Fiske *et al*. 2014; IPCC 2014). Indeed, the widespread—though not uncontroversial—use of the "Anthropocene" meme signals a strong and growing recognition that recent human impact on our global environment is unprecedented.

With growing recognition of anthropogenic climate change and the urgent need to mitigate and adapt, climate scientists have sought to gather key insights from hard won understandings of the climatic system in the past and present, including the quantification of stores, flows, forcing mechanisms, and human responses. Three-dimensional climate systems models and various accounting techniques extend these insights into the future to help us understand how the climate and human societies might react to a wide array of plausible future scenarios. Without empirical data about the future, or the ability to run scientific experiments, computer-based models have become a cornerstone of the climate sciences (Edwards 2010). These methodologies, Lahsen writes, "are part of a broader trend in science toward simulation technology that allows scientific investigation of, and experimentation with, complex systems without some of the time and access constraints of traditional experimentation" (2005:897).

It is in this context, of the anthropocene, that techniques designed to help us to model and account for climate change—such as general circulation models (GCMs), carbon stock assessments, national emissions inventories (NEIs), vulnerability assessments, and integrated assessment models (IAMs)—have proliferated. In short, these models and a wide array of accounting techniques designed to quantify complex interactions allow us to approximate and conceptualize various futures for our planet, which can enable anticipatory decision-making on a planetary scale. These efforts are valuable and arguably necessary to make the relationships between humans and ecosystems clear for national and international decision-makers (Fisher *et al.* 2009; Jassanoff 2004; Norgaard 2010).

Management

Our efforts to account for climate change are also fundamentally concerned with aiding rational decision making (Maurer 2002) and can thus move from the realm of pure science into that of accounting intended for management (O'Reilly 2015). While this is, of course, an important function of science, climate models do bring risks of oversimplification when numbers, stripped of their complex social and ecological context, come to be the primary—or the only—indicators that figure into policy and decision-making. Framed in an, all too often, opaque language of quantitative objectivism and rationality, "the numbers" help guide decisions and to provide tools for subjecting climate and human behavior to management and policy, though, as some of our contributions suggest, numerical anchoring can occur at the cost of ignoring other, less easily quantifiable variables.

"Governing by the numbers" is certainly nothing new (Scott 1999; Shore and Wright 2015; Weber 2013) but we should also recognize that many of our efforts - to quantify carbon stocks, sequestration potential, or efficiency gains – can also be seen as symbols of market-based environmental governance. Simmel observed that modern life is full of "unrelenting calculations," which he considered a product of a monetary economy. In this world, problems are envisioned as a series of mathematical equations to be solved, daily life is filled "with weighing, calculating, and enumerating," and qualitative values are reduced to quantitative formulas and economic parameters (Simmel and Wolff 1950:411). While quantification has long been recognized as a technology of state power (Burchell *et al.* 1991; Scott 1999), new forms of governance, seemingly separated from the state, have emerged and intensified the trend toward measurement, indicators, rankings, and audits over the last several decades (Merry 2011).

Indeed, scientists and scholars from multiple disciplines have observed a relationship between this shift toward efforts to quantify, account, and enumerate—what some have referred to as a new "audit culture" —and the growing dominance of free market mentalities and neoliberal forms of governance (Büscher 2010; Carrier and West 2009; Fletcher 2010). In this era, "market processes of commodification and trade penetrate proposed solutions to environmental problems, essentially reregulating nature through quantification and commodification" (Peterson and Isenhour 2014; see also Igoe and Brockington 2007). Indeed many market-based solutions require the simplification and quantification of complex phenomena, spawning efforts to standardize and translate values into commensurable units in order to "make things the same" (MacKenzie 2009) and allow markets to work (Callon *et al.* 1986). These techniques require highly complex and contingent variables such as carbon sequestration potential, human awareness, and technological improvement to be reduced to single (albeit empirically informed) numbers and plugged into mathematical models.

The creation of flood insurance maps, life cycle analyses, and attempts to quantify ecosystem services, for example, render complex relationships and problems into economic values to which a price can be assigned (see Crane, this issue). The implicit assumption is that through conversion into market values, free market actors and policy makers alike can be steered by their own economic rationality. A generation of scholars inspired by Foucault (Burchell *et al.* 1991) and social studies of science (Callon *et al*. 1986; Latour 1988) have demonstrated how techniques of calculation—statistics, rankings and indicators—can discipline human behavior and yet because of the widespread perception of numerical objectivity and neutrality, are seemingly independent of political and moral realms. But models and accountancy techniques exist in a grey area between science and policy (Jasanoff 2004) in that they not only seek to describe and represent reality, but are also based on, and carry within them, assumptions about how the world ought to look (Shore and Wright 2015). As such, there is significant evidence to suggest that these calculative technologies, models, and formulas not only seek to portray reality, but are also powerful agents that can both reproduce and reconfigure the very socio-ecological relations they seek to represent – making it even more important that we get them right and that we recognize both complexity and uncertainty (Callon *et al*. 2007; Carrier and West 2009). We certainly do not dispute the utility of abstraction but suggest that a singular, dominant focus on quantifiable data, often derived for market purposes, can result in bad science and overly simplistic policy prescriptives and is likely to fail.

Morality

The quantification of complex social and physical interactions requires myriad decisions and assumptions, particularly under conditions of uncertainty. It is imperative that scientists are clear and transparent about these assumptions and associated uncertainties because, once translated into a number, equation, or model, these assumptions appear objective and politically neutral. Without seeming to exist in the moral or political realm, and without intention or malice, techniques of calculation and accountancy can prioritize the perspectives and interests of those in power, reproducing inequality and maintaining silences and blind spots. Because our efforts to account for climate change involve analyses of subjectivity, the outcomes will reflect the producers' knowledge of climate-society dynamics, cultural understandings of the relationship between humans and nature, and differences among political philosophies regarding the best possible paths for moving forward. Yocum (this issue) illustrates this point through her ethnographic analysis of REDD+ project developers. Indeed, we find that contemporary efforts to account for climate change often preference the perspectives of the Western-educated, urban, and affluent technocrats that contribute to their creation. Yet, as Lahsen writes, "through acts of abstraction and avoidance, climate science continues to commonly appear to be independent of the culturally laden specificities of human experience in its production and reception" (2015:225). The articles in this special section illustrate the cultural determinants of climate science, not to practice revelatory politics often employed by climate contrarians, but to leverage understandings in the social sciences to produce more accurate and representative knowledge about climate change and people's experiences with it.

Take for example something as seemingly simple as the protocols for national emissions inventories utilized by the United Nations Framework Convention on Climate Change (UNFCCC). Signatories are required to account for all the emissions released within their borders and territories. The UN reports that the countries with targets under the initial Kyoto period collectively achieved a 22 % reduction in emissions between 1990 and 2012. This laudable achievement is important, but territorial calculation of emissions miss a very important part of the picture, the emissions embodied in international trade (Barrett *et al*. 2013; Isenhour and Feng 2016). Affluent nations continue to drive significant demand for global production and benefit from imported products that contribute to net global emissions growth, but production-based emissions accounting methods assign responsibility for mitigating the associated emissions to producer nations. Thus the current method of accounting for climate responsibility preferences already-developed nations and reproduces global inequality, reminding us that processes of accounting involve comprehension in the numerical sense, as well as accountability in a moral sense (Isenhour 2012; O'Reilly 2015).

Moral and ethical arguments about climate mitigation found a broader public audience with the publication of Pope Francis' *Laudato Si,* the Papal encyclical that draws a strong moral connection between the alleviation of global poverty and anthropogenic climate change—both consequences of late, global capitalism (Beck 2008; Francesco 2015). In it, Pope Francis does not have to be conservative about findings or reticent to make connections between sociocultural choices and scientific observations, which are dispositions scientists are trained to enact (Brysse *et al*. 2013). The fact that these sorts of connections are being made—and in novel ways, by new climate interlocutors—contributes to public and scholarly imaginations about our global climate future.

Myth

We can consider the mythic dimensions of our efforts to account for climate change from two perspectives. First, *in common usage,* myth is viewed as an antonym for reality. Indeed many scholars recognize that, while often extremely useful and important, the outputs of models, formulas, and other techniques of accounting are only as good as the data and assumptions that feed them: "garbage in, garbage out" (Fiske *et al*. 2014; Rudman 1997). To avoid critiques, it is therefore imperative that scientists utilize the most reliable data and are explicit about assumptions and the limitations of their calculations. Likewise it is also essential for data consumers to practice critical literacy. Climate models are based on empirical observation and documented reality (Edwards 2010) but uncertainties remain and emergent methods of modelling and calculation (for example the estimation of carbon stores, the auditing practices necessary to track carbon offsets, or poorly understood ice sheet dynamics) often require that project teams move forward with assumptions and best guesses. Several scholars have documented how "casual numbers", "back of envelope calculations" (O'Reilly *et al.* 2012), and pure guesswork "become scientific" once translated into statistics (Yocum 2013). The process erases, as Yocum argues, the "contingent and emergent nature of these numbers" (this issue).

In accounting for climate change, assumptions are necessary not only to create baseline scenarios (what would the future look like if things stayed exactly the same; "business as usual") but also to estimate avoided emissions and adaptation activities associated with alternative futures, what Yocum refers to as second order abstraction (this issue). In the calculation of baseline scenarios, critics point to examples such as Integrated Assessment Models (IAMs) that attempt to calculate the costs of climate change (Ackerman *et al*. 2009; Scrieciu *et al*. 2013). These efforts require speculation about what the future economy would look like without climate change mitigation efforts (holding all else constant). Yet with so many variables affecting our economy, the future could look extremely different than we might expect, regardless of climate change. Barker and colleagues (2006) conducted a meta-analysis of the baseline scenarios utilized by IAMs designed to calculate the costs of mitigation up to the year 2100. The authors found that the models made notably different assumptions about growth and technology resulting in baseline differences of as much as 30 gigatons of CO_2 by 2100. This variability reflects the degree of guesswork and estimation necessary to produce these counterfactual estimates of social and climate futures.

Our efforts to represent and account for climate change would be more realistic with incorporation of greater complexity. While modelers often subscribe to the idea that the best models are the simplest, it may be that climate change necessitates more complex models that can accommodate and represent complex planetary and human systems with unforeseen emergent properties. Nonlinear changes associated with feedback mechanisms, tipping points, and potentially "abrupt" climatic changes, like rapid glacial disintegration or arctic methane release are difficult to model due to high levels of uncertainty and the complex nature of interacting systemic variables (Lenton *et al*. 2008; Lenton 2011). This is also true, and perhaps even more so, for relationships related to human behavior. Take for example future emissions scenarios. The International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) have both utilized methodologies that assume a direct and linear relationship between increased energy efficiency and reduced emissions. This assumption is intuitively sound, yet a significant body of empirical research has demonstrated that energy efficiency can lead to significant "rebound effects" when the savings associated with efficiency gains are reinvested in the economic system and drive further economic growth and associated emissions, often partially or wholly offsetting gains (Jenkins *et al.* 2011). Thus some of the equations used to create future emissions scenarios may, indeed, be more akin to myth than reality.

Myth can also be viewed from second, perhaps more interesting perspective, rooted in anthropological understandings. During the course of the late nineteenth century, it became common to equate myth with fiction, but subject experts understand myth as much more complex than truth or fiction. Myth, in this *anthropological frame*, can be seen as a uniting symbolic narrative connected to shared histories and cultural beliefs, capable of directing human behavior and cultural reproduction. Using this definition, the contemporary power of numbers and quantitative communication can arguably be considered mythic. Anthropologist Laura Nader famously described her experience working with physical scientists and mathematicians as they worked together to model energy futures, "they were all tripping over their methods and coming out with fancy computer statements that had little credibility. Shamans would evoke more confidence. As an anthropologist I find this wedding to numbers fascinating. The belief is so strong, it's like numerology, the belief that numbers in themselves are useful… that numbers in and of themselves add strength to an analysis of the future" (Nader 1981:100).

Indeed, an "aura has come to surround numbers" (Strathern 2000:8) and the trust we place in their objectivity often defies rationality. As Porter (1996) observes, numbers are symbols that portray a seemingly natural truth that text cannot match. Studying the IPCC, for example, O'Reilly (2015) observed that the quantitative data, often presented in charts and graphs, was prioritized in summaries for policy makers under the widely held assumption that such representations of quantification are particularly convincing and reputable. Numbers certainly do represent a shared mode of international communication, a uniting symbolic system designed to direct behavior and reproduce society. Yet at the same time, single numbers, formulas and full models compound and aggregate uncertainties while effectively masking underlying complexities and the nuanced, lived realities of the people who affect and are affected by the programs such representations inspire.

Accounting for the Human Dimensions of Climate Change

Efforts to calculate the emissions reductions associated with technological improvement, avoided deforestation or carbon taxation requires significant incorporation of knowledge generated in the social and behavioral sciences. Yet as many observers have lamented, many contemporary efforts to account for climate change fail to include adequate consideration of the "human dimensions" (e.g., Castree *et al.* 2014; Moore *et al.* 2015) leading to climate assessments that tend to be overly conservative (Brysse *et al*. 2013; Freudenburg and Muselli 2013). When assessments do incorporate the social sciences the perspectives included are typically limited to or disproportionately influenced by the discipline of economics (Demeritt 2009; Roscoe 2014). Yet economic models of human behavior can be highly reductionist and based on a well-documented Western bias which assumes that humans are inherently self-interested and rational economic maximizers (e.g., Henrich *et al*. 2001; Thaler 2000).

The non-economic social sciences have amassed a considerable and impressive body of research on the cultural, social, economic, political, and ideological influences on anthropogenic emissions (Adger *et al*. 2012; Rosa and Dietz 2012). As Roscoe (this issue) astutely observes, "it is hardly the case… that the non-economic social sciences are so little developed that their modeling potential can simply be written off. While they currently lack the mathematical precision of economics… they offer substantial bodies of climate-relevant knowledge with the potential to narrow down uncertainties in how humans drive GGEs and offer insights on the development of mitigation and adaptation policy" (this issue). Roscoe not only argues that sociocultural dynamics can be represented, but puts forward specific suggestions for modelling them, using cosmological systems as cultural proxies.

Certainly understanding the diverse cultural dimensions of climate change is necessary for crafting appropriate policy responses (Hulme 2008, 2009). In the end, climate change is essentially a social problem (Nader 1981) that will require incorporation of social responses. As Moore and colleagues note (2015), many climatologists and earth scientists have recognized the limits of knowledge generated solely in the physical sciences. Indeed, the traditional science-policy interface, exclusive of social science input, has not proven particularly successful in the case of climate change.

The contributors included in this special section of *Human Ecology* offer several key insights from the social sciences that can help to improve our attempts to account for climate change and provide important insights into the processes that influence popular support and policy momentum. Our unique contribution is our approach—with breadth and depth of time, geography, and culture—to analyze the promises and perils of attempts to "account for climate change" in a variety of specific contexts. Together they investigate the societal factors included in and excluded from attempts to model climate change; the uncertainties associated with human response; the calculation of carbon stores and efficiency gains for the purposes of carbon trading; and the moral and policy-based implications of these models as various actors attempt to "account" for climate responsibility.

The articles included here offer three key correctives from the environmental social sciences intended to improve our ability to account for climate change: 1) consideration of history; 2) recognition of the politics surrounding climate science and policy; and 3) the importance of accounting for cultural diversity.

First, contributor Paul Roscoe reminds us of the wealth of knowledge generated in archaeology, anthropology, human ecology, and historical ecology that provides key insights into historical interactions between climate and society. Taking a diachronic approach, Roscoe argues, can offer a "broader comparative framework" for understanding the relationship between social and environmental factors in human history (this issue; see also Dove and Carpenter 2007).

Second, in their contribution Crane and his colleagues remind us of the influence of politics in even seemingly neutral efforts to represent and account for climate change. They examine the "hidden politics" embedded in the construction of life cycle analyses, attempts to quantify ecosystem services and the conduct of vulnerability assessments. All too often these techniques attempt to isolate and quantify the effects of climate change to ensure climate mitigation and adaptation programs meet the “additionality” requirements of project funders—that is, researchers try to ensure that they are certain that their results are attributable to climate change, not other, seemingly extraneous factors. Yet in doing so these techniques fail to consider broader issues related to inequality and historical conditions of political marginalization (Moore *et al*. 2015). As Roscoe (this issue) points out, the history of colonialism has severely compromised many societies’ ability to respond to climate change. But by attempting to isolate the effects of climate change, we significantly constrain the set of possible solutions (Blaikie 2016). Moore and colleagues have noted that, “this process makes complex, highly politicized social problems appear amenable to technical and purportedly apolitical interventions” and go on to suggest that, “analyses that quantify and isolate the effects of climate change lend this project scientific legitimacy by implying that those made hungry or destitute because of climate are somehow qualitatively and identifiably distinct from those harmed by ongoing social processes” (2015:xx).

Finally, the contributors to this special section remind us of the importance of understanding cultural diversity and variability in our efforts to both account for and address climate change. Yocum documents how the production of carbon credits for the market requires “stripping away the specificities of social and ecological life.” These efforts essentially make all forests and community activities the same despite ecological and social differences, attributing economic value to forests and community actions in ways that reflect programmatic priorities and market dictates. These efforts to enumerate forests and target communities make sense for global trading but lose coherence at the scale of implementation. A long history of empirical observation in development studies has illustrated that top-down culturally inappropriate programs that disadvantage target communities rarely take hold or achieve forecasted outcomes. The shortcomings of contemporary attempts to account for climate change are not politically inconsequential. The transformation of vulnerability into a number, of qualities into quantities, of complexity into linear equations—these are, in the end, highly political endeavors capable of obscuring significant diversity, alternative meanings, and systems of valuation in human-environment interactions. When these complexities are quantified, they become the subject of technical and physical problem solving, and when the economic value of carbon stores and opportunity costs are calculated, the emotional, psychological, or non-utilitarian values of forest communities are effectively erased. This diversity seems to go largely unrecognized by the dominant players in climate adaptation and mitigation who, if proposed solutions are any indication, certainly seem to assume that status quo can be made more efficient with technological improvement or that behavior can be steered toward more rational decisions with economic incentives.

Conclusion

Efforts to account for climate change are both important and necessary: they provide necessary tools to understand particular dynamics of incredibly complex social-environmental systems. However, the dominant focus on quantitative data underlies a particular, socio-technical view of the complex problem of climate change. While we know that quantification can communicate knowledge effectively and powerfully, we encourage critical analysis of how these numbers come to be, along with the potential gaps and assumptions they might contain. This can be addressed through interdisciplinary collaboration designed to inform quantification with qualitative and empirical social science understandings. We must endeavor to understand past, contemporary, and potential future human-climate interactions since mitigation depends on our ability to understand geophysical processes that are often difficult to detect on a human and local scale. Indeed while the science of prediction is imperfect, it is also certainly necessary if we are to fully account for climate change and respond effectively. As researchers who value climate science, we understand one must walk a fine line to communicate the value of science and the necessity of calculation even while questioning its current state. Despite inherent critique of an imperfect process, the papers included here ultimately aim to inform and improve scientific efforts to understand and represent socio-ecological systems—and thus contribute to improved climate mitigation and adaption programs.

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