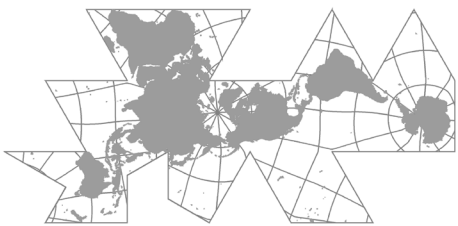
Paleoenvironment and Archaeology Provide Cautionary Tales for Climate Policymakers

*Brett Kaufman**
Institute of Cultural Heritage and History of Science & Technology, University of Science and Technology Beijing, 30 Xueyuan Road, Beijing, 100083, China (bkaufman@ucla.edu)
Department of the Classics, University of Illinois at Urbana-Champaign, 707 South Mathews Avenue, Urbana, IL, 61801, USA

Christopher S. Kelly
Science Department, Dwight-Englewood School, 315 East Palisade Avenue, Englewood, NJ , 07631, USA (kellyc@d-e.org)
Department of Earth, Environmental, and Planetary Sciences, Brown University, Box 1846, 324 Brook Street, Providence, RI, 02912, USA
Institute at Brown for Environment and Society, Brown University, Box 1951, 85 Waterman Street, Providence, RI, 02912, USA

Richard S. Vachula
Department of Earth, Environmental, and Planetary Sciences, Brown University, Box 1846, 324 Brook Street, Providence, RI, 02912, USA (richard_vachula@brown.edu)
Institute at Brown for Environment and Society, Brown University, Box 1951, 85 Waterman Street, Providence, RI, 02912, USA



ABSTRACT

Federal climate policy in the United States is still in its infancy and is in large part characterized by efforts to reach a consensus on the very existence and causality of climate change. This has stemmed from a sociopolitical rift within the country, with the objectivity and usefulness of science attacked by detractors. Scientists who are most qualified to defend their methods and provide information to policymakers rarely have an institutional incentive to share this knowledge, but should be encouraged to communicate their findings to the public, especially those who receive public funding. By not doing so, they are effectively 1) keeping data and their interpretations within the academy alone, despite their importance to the public welfare, 2) losing public support through inactivity, and 3) potentially harming the future availability of research support in what has rapidly become a politically polarized funding atmosphere. Archaeologists and geoscientists in particular, as repositories of past ecological knowledge established through one method (Western academic) of empirical examination, are well positioned to broadcast to the public a variety of societal responses to long-term environmental change as well as the repercussions of political reorganization in the wake of resource shortage-induced societal collapse. This paper summarizes a few promising public outreach engagements on environment and climate change, and suggests further venues for institutional change at the university level. As an example of how multi-causal socio-ecological processes can be concisely packaged for consumption by the public and policymakers without oversimplifying data, we present a synthesis of regional case studies from the New and Old Worlds. Case studies are connected through anthropological processes of cooperation versus exclusion, subsistence shifts, sociopolitical (re)organization and hierarchy, violence, and disease in a preliminary attempt a) to identify the emotional and anecdotal psychology of our own society when it comes to the chang-

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ing global environment, b) to discuss the issue of scalar differences between ancient and modern ecology, and c) to call on academics to introspectively alter our own attitudes and systems of incentives at the university level.

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INTRODUCTION

Polarizing bipartisan politics are not new to the United States of America, but the content of the polarities often shifts. Currently, one of the most divisive issues is that of science (Funk and Rainie 2015a, 2015b)[1,2]. In particular, scientific studies into climate change are at the center of this fight, with the interpretations and sometimes even results of research being called into question from fields including but not limited to geological, geochemical, atmospheric, oceanic, earth, and planetary sciences (Leiserowitz et al. 2013). At stake here is public trust, the societal belief that science can aspire to "facts" or "truths," and the social consequences if knowledge based on science is ignored for the sake of political agendas, and individual and corporate gains. Furthermore, disconnects between scientific findings and popular belief highlight a systemic issue; research science is transmitted to the public through biasing filters of political, cultural, economic, and religious ideologies (Schwadel and Johnson 2017; Stenport and Vachula 2016; Carr et al. 2012; McCright and Dunlap 2011; Brüggemann and Engesser 2014).

The historical antecedents to the popular discussion surrounding science, and climate science as a particular example, are complex and rooted in the deepest sociopolitical threads of successive generations; as such, they are beyond the scope of this entryway (readers are easily referred, e.g., to whole books synthesizing scholarship on this front: (Howe 2014; Weart 2008; Oreskes and Conway 2011; Fleming 2005; Hulme 2009)). But, to summarize the moment, public engagement with science is now an openly hostile reality, with protests, dramatic rhetoric, censorship, and outright conflict between different levels of government all common occurrences[3]. Concomitant with a change in party control, the White House has recently banned several government agencies and bureaucrats from communicating with the press or the public via social media, including the Environmental Protection Agency, the US Department of Agriculture, the Department of Health and Human Services, the Department of Transportation, and the National Park Service[4,5,6]. In response, some scientists and members of the public are increasing their activism through a variety of means including protests, policy engagements, and educational initiatives[7,8]. The full gravity of this shift in strategy and its consequences remain to be seen. Even the slightest politicization on the part of scientific statements or individuals is a disconcerting development to many other scientists, and it is as of yet unclear whether we are bearing witness to an actual paradigm change regarding the acceptance and style of public engagements within the academy and laboratory.

Communication breakdown over environmental degradation may all sound quite unfamiliar and feel like a new challenge – but it is not. Another science that engages with the effects of climatic and environmental change is that of archaeology. How have people reacted in the past to natural disasters and famine-inducing changes? Do they isolate themselves from other groups, turn on each other, or turn to the gods? Depending on the cultural, ideological, and political economic systems in place, the answers are varied. This paper reports a host of societal responses to environmental changes to impel greater popular awareness and catalyze movement among policymakers to avoid repeating our most devastating mistakes of the past.

ARCHAEOLOGISTS AND HISTORICAL GEOSCIENTISTS AS STEWARDS OF THE SOCIO-ENVIRONMENTAL INTERFACE

This article is a fusion of science, politics, and public affairs – not technically a scientific report. For the political side, we advocate for the use of science in the public sphere, and attempt to be objective and moderate so as not to undercut potential future discussions through polemics. Concerned with how paleoenvironment modulated past sociopolitical trends and hierarchical relationships as a potential analog to such change today, we mix current events and scholarship to frame our present moment. Regarding the scientific content, although archaeology can be used as an applied science for modern public health or environmental remediation[9], these applications are not the focus of the current paper. Rather, we synthesize previously published research from climate- or environment-induced/aided societal collapse in order to present big picture case studies to policymakers and the public—to distill cogent takeaways without oversimplification of their complex processes.

In this way, we lie somewhere in between geographer Mike Hulme's critique of "positivist science [and] Western (neo-)liberalism" in global elite discussions of global warming and his welcome call to "treat [climate] unambiguously as a manifestation of both Nature and Culture, to assert that the idea of climate can only be understood when its physical dimensions are allowed to be interpreted by their cultural meanings" (Hulme 2008). Indeed, as scholars of paleoenvironmental science and archaeology, we admit readily our enculturation and potential biases, acknowledge differential cultural responses to modern and past climate change, and yet nevertheless advocate that, in spite of their biases, scholars of the past must humbly take their work in good faith to the public in narrative format.

Far from its infancy, archaeologists and scientists have drawn many inferences from fruitful collaboration with paleoecologists and paleoclimatologists over the last few decades (Van de Noort 2011). As but one example, exaggerated seasonal volatility can precede climate regime shifts, while the effects of environmental and climatic change take decades or centuries to reach their extremes (DeMenocal 2001). Unfortunately, many such warnings have a limited shelf life outside academic circles without the diligence of high-profile scientific journalists and pop culture advocates—both processes which add another filter of bias in interpretation. We contend this represents a crucial failure at some level, given the consensus that when environmental social scientists cede the popular or political stage, public ecological knowledge is "cut off at the knees", putting the health of underprivileged, and even privileged communities at greater risk (cf. the extensive and ongoing work surrounding this issue such as Crumley 1994; Fiske et al. 2014; Lane 2015; Nelson et al. 2016; Rockman 2012; Sandweiss and Kelley 2012; Van de Noort 2011). While this sort of popular dissemination is both altruistic and empirically generative, its significance is not, in our view, adequately prioritized by tenure boards, funding agencies, or institutions. With a great repository of paleoecological data and traditional ecological knowledge (TEK), archaeologists and geoscientists alike should take, and be incentivized to take, an active role in providing information to policymakers about the consequences societies have faced during times of severe environmental degradation. While past climatic changes have been on a much lesser scale, there are nevertheless lessons for today's world (Hansen et al. 2016), especially because modern technology can offset some of the potential damages to society and biology. We contend the technological changes being suggested to reduce greenhouse gas emissions and address the Environmental Protection Agency climate change indicators must be only the initial steps in a much longer process to mitigate our ecological influence and adapt to shifting environments[10]. Adverse effects

of climate change are experienced by human populations at the seasonal, annual, decadal, and centennial scales (Dearing et al. 2010; DeMenocal 2001; Patterson et al. 2010), and current plans to reduce anthropogenic degradation of the environment will only be successful if adaptive industrial and consumer practices are implemented over several generations. These types of slow, multi-generational cultural adaptations have been measured in the archaeological record across many different regions and societies, with some examples discussed below.

Much of the research into past social responses to paleoenvironment has been conducted using the guiding theoretical tenets of cultural ecology. Cultural ecology was pioneered by anthropologists who realized that temporally and spatially bounded datasets such as those recovered by archaeological methods are the ideal means to quantify diachronic patterns of resource availability and cultural adaptations to scarcity at both local and regional scales (cf. Steward 1955; Sutton and Anderson 2014; Vayda and Rappaport 1968; Vayda 2009; White 1959). With all these data in hand, archaeologists, geoscientists, and other scientists within the physical, natural, and social sciences are uniquely suited (and we argue have a social responsibility) to contribute to policy considerations on climate change, if not for advice on the specific industrial or financial steps needed to limit warming increases to under 2°C per year (Fawcett et al. 2015), then for heralding the inevitable repercussions that ignoring climate change and degraded ecosystems will bring. Anthropologists, archaeologists, and other social scientists should push beyond the traditional limitations of the academy—the lessons of cultural ecology can be applied to the sphere of policy and political ecology in an effort to activate research findings toward the public benefit (Crate 2011; Orlove 2005; Zimmerer 2006; d'Alpoim Guedes et al. 2016).

Humans have altered the earth in such drastic ways that many have called for the assignment of a new geological age, the Anthropocene[11](Crutzen 2002; Crutzen and Stoemer 2000; McNeill and Engelke 2016; Jacobs, Jonstone, and Kelly 2016). The possibility of such an arrival further challenges our most basic assumptions of disciplinarity and belief systems. As the eminent historian Dipesh Chakrabarty writes:

> Changing the climate, increasingly not only the average temperature of the planet but also the acidity and the level of the oceans, and destroying the food chain are actions that cannot be in the interest of our lives. These parametric conditions hold irrespective of our political choices. It is therefore impossible to understand global warming as a crisis without engaging the propositions put forward by [Earth system] scientists. At the same time, the story of capital, the contingent history of our falling into the Anthropocene, cannot be denied by recourse to the idea of species, for the Anthropocene would not have been possible, even as a theory, without the history of industrialization (Chakrabarty 2009, brackets ours).

We take this thesis seriously—that the specter of climate is hazily rendered without integrating knowledge of the earth system with critical social histories of capital and human economy. That being said, while today's markets are unprecedented in scale, the political economies of past cultures and their relationship with environmental degradation (and mitigation thereof) can help guide modern roadmaps toward economic transformation without the violence associated with conquest, revolution, and collapse. As such, it seems natural that the first step to making collective wise decisions is comprehension. We propose a need to demystify what we do understand about physical and social systems, and take that directly to the people, not in a "doom and gloom" manner, but as a practical discussion of where we have been, where we are, and where we might be headed.

Furthermore, whether or not past or future climate change or environmental degradation is actually *caused* by humans in a given region, it is human society that must respond and adapt to the change in a myriad of ways, or risk adverse effects. The climate policy debate must be infused with reports of the scales of human disaster and suffering that have occurred several times over the course of prehistory and history when cultures have failed to adapt to their surroundings, or been confronted with overwhelming disasters. Policymakers may see value (and may find pause in the extent to which this rate of warming seems unprecedented in recent geological history (Kump 2011)) in understanding the policies past leaderships have implemented that either succeeded or failed in preventing radical shifts in sociopolitical organization and/or subsistence strategies, if only to become more effective in communicating these threats to their constituencies. To highlight this point, several examples of societal consequences as synthesized through empirical archaeological, paleoclimatic, and paleoenvironmental research are briefly described below, painted in broad strokes.

CASE STUDY: SOCIETAL EXTINCTION

The stability of incumbent forms of sociopolitical organization is predicated on the success of particular subsistence strategies (e.g. agriculture, fishing, hunting, foraging). Other factors such as ideology, technology, and communication of information also determine the longevity of established hierarchies, including ideological flexibility in entertaining adaptive cultural mechanisms to weather environmental degradation while maintaining balance in the sociopolitical status quo. A classic example of failure to adopt sufficient cultural mechanisms to deal with climate change is that of the Viking Age Greenland Norse (Kintisch 2016). Greenland was settled by the Norse around 1000 CE, during a time of global warming that permitted increased maritime navigation due to a reduction in ice formations and increase in arable land in arctic or subarctic zones such as Greenland, Iceland, and Newfoundland (Dahl-Jensen et al. 1998; Patterson et al. 2010).

The indigenous Inuit whom the Norse encountered upon arrival in Greenland had already adapted to living in low temperatures through physiological mechanisms such as the maintenance of non-shivering thermogenesis into adulthood, and cultural adaptations such as social meat-sharing arrangements, architectural sustainability using local building materials, sustainable warm clothing, low-energy hunting techniques to harvest sea mammals, and conservation practices rooted in an animistic religion that discouraged the over-harvesting of sea mammals (McElory and Townsend 2015).

Obviously unable to develop physiological adaptations within a short time frame, the Norse were also slow to adopt Inuit cultural adaptations to the local environment. Rather, they brought with them European subsistence techniques through the maintenance of sheep and goat herds, barley and flax agriculture, clothing, and building materials (Dugmore et al. 2012, 3658). Religious leaders succeeded in engineering internal harmony as evidenced through their ability to marshal large-scale construction projects for the church, although economic inequality may have been exacerbated by the changing environment and resource shortages (McGovern 1991; Kintisch 2016, 701). Intermarriage with Inuit was discouraged, resulting in a reduced capacity to receive assistance from the Inuit in times of stress, while at the same time contact with Europe lessened. Although the earliest settlers switched decisively from fishing to seal harvesting, highly specialized Inuit sea ice hunting techniques were not used by the Norse which limited their overall bounty (Dugmore et al. 2012, 3659-3660).

Some adaptations did aid the Norse and allowed the colony to survive for centuries. These included building out their TEK to include hunting seals, whales, walrus, fowl, and caribou, and gathering wild eggs, while

importing Medieval European game management strategies that resulted in sustained caribou populations for the settlers over the generations (Dugmore et al. 2012, 3658-3659). Maintaining relations with Norway shaped the Greenland settlements into a provider of luxury exotica, including live polar bears (Dugmore et al. 2012, 3660; Dugmore, Keller, and McGovern 2007). This economic status helped the Greenlanders acquire foreign goods, but also evidences a preference for long-distance, costly, and dangerous transatlantic trade with a culturally familiar community at the exclusion of what may have been a much more practical, subsistence-driven trade with local Inuit. As socioeconomic factors shifted within Europe following the Black Plague, demand for Greenlandic products dropped and left the settlers in a hazardous subsistence situation (Dugmore, Keller, and McGovern 2007, 18; Dugmore et al. 2012, 3660). Previous adaptations proved to be outdated as the climate worsened and the European lifeline disappeared.

The Norse settlements of Greenland survived for around 400-500 years until the Little Ice Age reduced the average temperature by around 2°C since the time of first settlement (Dahl-Jensen et al. 1998; Patterson et al. 2010). Clearly, it was a great feat for subsequent generations of Norse to survive for so long in an environment relatively inhospitable to what they were accustomed. The resilience and accumulated TEK of other North Atlantic Norse island communities enabled survival until today. Still, despite these prior adaptations and some willingness to mirror Inuit-style lifeways, having refused to adopt sustainable, local technology, and with an internally cohesive ideology that largely prohibited cultural exchange with the Inuit and eventually led to conflict, the Norse colony on Greenland went extinct sometime around the mid-15th century CE. Why did the community fail? Was it due to not enough adaptation; failure to recognize a worsening climate and change behaviors accordingly; or simply that the environment became too hostile for survival? Scholars may dispute the causes (Kintisch 2016), and it may never be possible to quantify exactly what components of the Norse failings on Greenland were due to maladaptive versus determinative climatic causes. Whatever the answer, the extinction of this particular community highlights the need for recognition of climate variability, active management of fluctuating resources, and constant socio-ecological flexibility including alliance building with foreign communities.

CASE STUDY: POLITICAL INSTABILITY AND SUBSISTENCE COLLAPSE

Absolute demographic eradications such as that of the Greenland Norse are rare. More commonly observed in the archaeological record is a severe reduction in population that undermines the sociopolitical hierarchy in control or forces a change in subsistence strategies because of starvation risks. Both of these types of dramatic changes occurred in the southern Levant during the Late Holocene Climate Episode beginning around 2300 BCE, one of the most intensively researched paleoecological events. The Late Holocene Climate Episode was the culmination of centuries of severe climatic and precipitation fluctuations during the Early Bronze Age I-III (~3500-2300 BCE) across the Ancient Near East and extending globally (Bar-Matthews and Ayalon 2011; Dalfes, Kukla, and Weiss 1997; Riehl 2009; Roberts et al. 2011). By 2200 BCE, there was a 30-50 % reduction in precipitation resulting in a megadrought that transformed societies across the Ancient Near East and Mediterranean. It is also within this time frame and region that some of the highest resolution archaeological activities have been carried out, providing unprecedented holistic interdisciplinary syntheses of paleoclimate and ancient civilization (Weiss 2016).

The period from around 2900-2300 BCE was witness to the earliest urban civilization, with cities founded in southern Mesopotamia

and radiating out across the Fertile Crescent. Nutritional needs were satisfied primarily by the cultivation of surplus cereal agriculture and state-controlled sheep and goat herds, while leaders exploited the growing labor pool to erect monumental buildings and temples (Algaze 2008). Throughout the Levant and Mesopotamia, climate cycles became erratic from around 2600-2400 BCE, alternately characterized by torrential rains, seasonal flooding, and drought (Weiss et al. 1993).

As aridity increased in the 24th century BCE, urban elites at the Mesopotamian site of Tell Leilan switched from religious to state control and erected a two meter thick defensive wall around the city center, storerooms, and administrative buildings. Despite their attempts to consolidate control, they were defeated by the Akkadians who were able to exploit the sociopolitical instability made worse by climate change, and who also defeated the Sumerians to become the world's first empire. Due to the ample water flow from the Tigris and Euphrates, the Mesopotamian sociopolitical organization of urban-based elites was not altered, nor was the subsistence base of cereal agriculture. Despite attempts to mitigate the effects of climate such as irrigation canal dredging, the Akkadian culture collapsed as well and by around 2200 BCE Tell Leilan lay deserted for 300 years (Courty and Weiss 1997; Weiss 2010; Weiss et al. 1993).

In Mesopotamia, political power changed hands but agricultural society did not collapse. The Levant witnessed a different type of devastating transformation marked by an extreme spectrum shift in both sociopolitical organization and subsistence strategy. During the severe flooding and drought events leading up to 2300 BCE, leaders in the southern Levant invested their resources in the erection of temples (Rosen 1995). Outwardly this can be seen as an attempt to appeal to the gods for help, but from a resource redistribution perspective it served as a last attempt to distract the common people and keep them committed to the incumbent hierarchy. No attempts to improve agricultural yield have been recovered in the material or paleoenvironmental records, and in the 23rd century BCE nearly all cities in the southern Levant were completely abandoned, with an estimated 90% population reduction (Broshi and Gophna 1984; Gophna 1992, 156). Agricultural activity was severely reduced, deforestation and erosion rates were the highest on record (Baruch 1986; Horowitz 1974, 1979; Rosen 1986), and the people adapted by giving up agriculture and settled urban life, instead opting for the survival strategy of transhumant tending of sheep and goat herds. It is unclear how much of the plunge in recorded population is due to starvation, plague, or people switching to the (difficult to detect archaeologically) practice of semi-nomadic pastoralism. It is only following urban societal collapse that adaptive mechanisms are recorded in the archaeological record, and after some 300 years Levantine urban society regenerated.

CASE STUDY: VIOLENCE AND DISEASE

Societies in Mesoamerica also faced several rounds of climatic and environmental stressors that disrupted and eventually helped undermine their sociopolitical organization. The pattern of independent urban-based powers during the Classic Maya period (150-900 CE) originated in the previous two millennia as hierarchies formed across the region, with large-scale forest burning activities to create agricultural zones needed to feed the burgeoning population (Kennett and Beach 2013). This urban civilization was characterized by a fluorescence in long-distance trade, mining activities, population growth leading to increased deforestation, and hereditary divine kingship with an ideology that legitimized violent acquisition of natural and human resources. Severe drought during the Late and Terminal Classic in the Maya regions was comprised of fluctuations between moist and arid conditions that exceeded the resilience of the ecological system, as opposed

to one protracted drought episode. These oscillating drought episodes taxed maize agriculture and are contemporary with increased competition, the balkanization of polities, and severe internecine violence (Kennett et al. 2012). Maya kings had traditionally derived power and capital from the control of water resources, and prolonged drought undermined their legitimacy (Lucero 2002, 2007). The collapse of the Classic Maya is taken to be one of the major examples of environmental impact on a culture, but even then the downward plunge into warfare and famine was protracted over two or three generations (Dunning, Beach, and Luzzadder-Beach 2012; Beach et al. 2016).

A few hundred years passed before the disrupted imperial sociopolitical organization of Mesoamerica was reinstated with the advent of the Aztec Empire. This interregnal period can be compared to the Near Eastern Late Holocene Climate Episode, with the rise of the Third Dynasty of Ur marking a period of urban renaissance. The difference between these situations is that another type of socioecological disaster put a final end to indigenous empire formation in the New World: that of widespread disease brought by Europeans throughout and beyond the 16th century CE.

There are yet other examples of cultures that achieved long-term sustainability without any evidence for endogenous collapse, such as the Native Americans of the Pacific Northwest. They developed complex society based on conservative exploitation of natural resources, primarily salmon but with a wide range of other hunted, gathered, and prepared goods (Ames and Maschner 1999; Lepofsky et al. 2015; Cannon and Yang 2006). Like the Aztec and Inca, the collapse of traditional society in the Pacific Northwest was caused ultimately by invasion and plague brought about by the external factor of European colonization. The most powerful civilization of South America, the Inca, lost some 80% of their population to disease (Baied and Wheeler 1993). Sudden plague episodes may not be easily traceable in the prehistoric record, especially when burial sites are unknown and bioarchaeological methods cannot be employed. Plague may have been a more common causal factor inducing sociopolitical reorganization than the material record indicates. Diseases such as those of the Columbian Exchange and Black Death are relatively well-documented and may serve as templates for possible scales of epidemiological devastation and subsequent liquidation of incumbent hierarchies.

For today's society, plague by conquest is not a likely scenario for the transmission of disease, but the threat of pandemics is linked to modern climate change. The consequences of modern anthropogenic deforestation and climate change, combined with global interconnectivity through travel and trade, are that infectious tropical diseases are able to extend their range beyond their equatorial bases—a phenomenon known as the third epidemiological transition (McElroy and Townsend 2015). Additionally, should climate change render conflict more likely in a water-scarce, high-population world, infectious disease would almost certainly accompany the hatchet (e.g. Alland Jr. 1968; Smallman-Raynor and Cliff 2004; Garfield, Frieden, and Vermund 1987). Despite the fact that severe outbreaks have not threatened the Global North in recent times, widespread pandemics are a likely outcome of environmental change and any sense of security based on past immunity is false.

INTROSPECTION AND A COLLABORATIVE WAY FORWARD

Many members of the public inform themselves about climate change, and seek anecdotal evidence for its effects and possible fixes in their own day to day life. Archaeology and other environmentally related social sciences can increase scientific awareness in the public by tapping into these sentiments and providing guidance on the ways past and present cultures have coped with similar problems.

We might take several lessons from the above case studies with critical consideration;

but, first one must ask to what degree are ancient environmental management strategies relevant to the modern climate change debate? This is an essential question to keep in mind in order to avoid reductionist applications of scientific data or mono-causal reasoning. Moreover, posing this question is a good first step for scholars to engage in discussion with climate or more general science skeptics, since the mere existence of social sciences and humanities is often sadly considered disruptive to practical forms of higher education[12], and the relevance of paleoecological fields to modern questions must be demonstrated. To begin to formulate an answer, we paraphrase a passage that the archaeologist Laurent Olivier recently delivered:

> "We are in a time of great change. If civilization collapses in the coming centuries, will we become a more rural, decentralized agrarian society like what happened in the Middle Ages after the fall of the Roman Empire? Or is the urban society we have built durable and practically eternal, like agriculture following the Neolithic Revolution? This is an archaeological question" (Olivier 2016).

Clearly, past industrial practices, resource types, medical innovations, and scales of production and demography are completely different in absolute terms when compared to today. But the types of behavioral decision-making processes, emotional reactions, and cognitive mechanisms of how to combat resource scarcity and societal instability have been the same since the Middle to Upper Paleolithic—a fact which should both humble and guide us (Wilson 2012). Temperature or precipitation oscillations amalgamated over years, decades, or centuries have been harbingers of severe climate change in the past; or in other words, both unseasonably warm and cold winters could be interpreted by the public as parts of a series of troubling oscillations leading to an unforgiving climate event (Kennett et al. 2012; Wilkinson 1997; Rosen 1986). Publicity stunts like bringing a snowball to Congress to "prove" that global warming is a "hoax" do nothing but endanger the public through rejection of scientific facts and the cessation of dialog through mockery[13]. Unfortunately, this deliberate strategy has proved all too effective in manufacturing bedlam and confusion in the public climate discourse (Oreskes and Conway 2011).

As students of our ecological past seeking to spread scientific awareness, we can conceive of possible future actions in a multi-pronged approach:

1) ***Scholars*** within archaeology, geoscience, and other social sciences who are well-versed in societal reactions to paleoenvironment can inform policy-makers to the havoc that long-term climate change has wreaked on societies of the past. Researchers are often publicly funded and have as much a responsibility as politicians to engage in this debate, not just to be repositories of long-term local ecological or cultural knowledge communicated only within the academic community, but to communicate this knowledge as widely as possible. Archaeologists, who thrive at the natural crossroads between environment, culture, and politics in the past, should exploit the public fascination for their field to emerge as such moderators today, and policymakers should too. There is no doubt that archaeologists and others have attempted to address this issue, but public awareness of paleoecological lessons is still essentially non-existent. So, despite notable efforts of organizations and initiatives such as the American Anthropological Association Global Climate Change Task Force (AAA GCCTF), the Climate History Network (CHN), HistoricalClimatology.com, the American Association of Geographers (AAG) Climate Specialty Group, and the Integrated History and Future of People on Earth (IHOPE), why hasn't the academy made more widespread outreach efforts? At least one obvious answer is that no institutions require it. As scholars we have

the most power to change our own sphere: the academy.

Universities should mandate and incentivize social scientists and scientists alike to commit to such outreach and be active in pursuing public engagement and moderated dialogue. University administrators should be petitioned to make these changes. Peer-reviewed articles and other traditional benchmarks toward tenure must be encouraged, but we believe public outreach activities should also be quantified in standard, explicit ways to contribute to career advancement. Some universities do count service; some do not, but all could increase this component if public awareness is truly a priority, with specific emphasis on environmental outreach and/or communication. Only this type of institutionalized incentive will inspire widespread public outreach by academics, as opposed to paying it lip service. Tenure or career advancement equivalencies could involve *x* educational outreach engagements, *y* media appearances, *z* consultations with policymakers to equal a fraction or whole of a peer-reviewed article. While a first order criticism may suggest that dedication to outreach will be at the expense of research quality and impact by traditional standards, the potential impact of such measures on public prestige and image remains an unexplored, untested possibility.

It can be argued that even tenured professors do not have the power to change university policy, and that these incentives must be changed at the dean, chancellor, vice president, or president level. As stated above, without public support for scientific endeavors, university funding will be threatened, and executive administrators should be concerned. The battle for public opinion as it relates to science and climate change is not lost, and marketing campaigns such as inviting local community members to visit science departments could be an effective activity.

Archaeology can be conceived of as having two societal functions: 1) preserving knowledge for future generations including protection of heritage (culture history), and generating models for understanding human behavior which can operate as useful systems of knowledge for modern situational analogs (anthropology), and 2) inspiring modern communities through lessons from the past, including through entertainment, programs, and generating identities. In the case of environmental awareness, although the first function provides the knowledge, it is the second that is crucial for societal impact. Open houses for children and adults, field trips to natural or archaeological sites led by professors, film screenings of documentaries or feature films relating to topical content at museums or university grounds followed by a lecture and questions, production of film and documentary programs – these are all methods to meet the public on their own terms and get more people and families excited about science. In fact, the omission of funding and time dedicated to this outreach, or ostracizing colleagues who invest in such outreach, is ceding ground to those who advocate that science is a waste of time and money. Clearly, there is a middle ground in this endeavor between outright fictionalized entertainment and a scientific paper. Still, in our opinion, not every detail may matter to the public, and if we approach public engagement with the same attention to detail or terminology that we use to convince article referees, many members of the public will be confused or bored, simply because the scientific jargon is not familiar to them. If communication is the goal, we as scientists need to change the way we talk depending on the context.

The scientist reluctant to become science communicator fortunately finds her or himself with a number of resources to get started; we argue that strong communication to the public is not exclusively a gift, but also a skill, which can be developed as any other academic task (Kirkwood 1983). For example, the American Association for the Advancement of Science (AAAS) offers an online series of articles detailing strategies with which one might engage the public sphere, news outlets, and more[14]. Additionally, other books and

guides are available—we found *Am I Making Myself Clear: A Scientist's Guide to Talking to the Public* to be especially comprehensive in addressing topics so diverse as understanding the journalism world, managing public relations, speaking to reporters, contributing to opinion editorial pieces, and more (Dean 2009).

2) ***Policymakers*** may find expedience through consulting with geoscientists and archaeologists about the ecological past. Politicians equipped with this knowledge can responsibly alarm their voters to the dangers they face, couched in historical allegories, thereby encouraging environmental awareness and harnessing it during election cycles. A non-partisan group of researchers dedicated to such outreach could make itself available in a *pro bono* format but with professional incentives provided by home institutions as discussed in the previous section. A model could be found in the work of the National Council for Science and the Environment, but geared specifically toward paleoecologists. A remedy could be prescribed through the establishment of a new independent organization specifically for this purpose, not for research but strictly for dissemination, not bound by the restrictions of larger governmental or professional organizations. Similarly, bureaucrats, politicians, and scientists ought to streamline the communication of results of projects of common interest. A productive example can be found in the federal funding of fire science. The Joint Fire Science Program specifically aims to "provide credible research tailored to the needs of fire and fuel managers…[and] focus on science delivery when research is completed with a suite of communication tools to ensure that managers are aware of, understand, and can use the information to make sound decisions and implement projects."[15] While such a federal funding program could conceivably be politicized, the model serves as an example for other systems of policy-minded research. Furthermore, fire research conducted on federal lands is of interest to the general public as well as land managers; fire science is a fundamental component of the scientific outreach programming of many National Parks of the western U.S. As such, fire science serves as a model of unified scientific and governmental public outreach from which other disciplines could learn.

Fire-focused paleoenvironmental science and archaeology has been productive in assessing the relative role of human and natural influences upon the environment, subsequently informing policy surrounding fire-related issues and land management. As such, these fields serve as great models for future outreach-minded steps in other subfields. While, for example, a paleoclimatologist studying the spatiotemporal variability of the El Niño Southern Oscillation may not be equipped to directly translate their results to policymakers or to distinguish the human influences on this climatic mode, they ought to seek guidance from the body of literature that has isolated the role of humans in global fire activity of the past and present (Roos et al. 2014; Bowman et al. 2011). In this way, researchers should not be limited to the literatures of their narrow disciplines for policymaker outreach inspiration. Rather, they should draw from successful case studies in other disciplines to better communicate and frame their research for policymakers.

3) ***Bureaucrats*** who have had their freedom of speech curtailed as it relates to communicating scientific findings to the public should continue to speak out and disobey illegal injunctions. But, of course, their jobs are at stake. Therefore, academic and industrial researchers ought to take up the microphone during times of governmental gagging as they did in the spring of 2017[16]. While state-owned universities and their researchers might be subjected to similar political pressures, private institution researchers ought to use their privilege as a platform for condemnation of discourse-gagging and avocation of academic freedom. Administrators of such institutions ought to encourage such actions, as empowerment from senior leadership has unmeasurable influence.

4) ***Members of the public*** who have begun to rally for science must continue to do so, and actively protect government scientists. Watchdog groups and lawyers must support government bureaucrats, and continue to stage demonstrations to support science. While we will be the first to acknowledge that public engagement is dependent upon researchers, politically immune researchers ought to acknowledge their unique standing and be especially proactive during periods of politically silenced researchers. As distinguishing "good science" from "pseudo-science" is not always straightforward and even mainstream news coverage can be faulty, interested but skeptical readers are directed to such resources such as the infographic from *Real Clear Science* concerning the most trustworthy scientific journalism source[17]. For those who desire a more sweeping discussion of science and sources in which to put belief, we appreciated *New York Times* science writer and former science editor Cornelia Dean's new book *Making Sense of Science: Separating Substance from Spin* (Dean 2017).

5) ***Communication and common ground***: Perhaps most important – all parties must develop routes of dialog and communication with people who oppose their viewpoints. Politics are polarized now on all "sides"; Democrats, Republicans, Liberals, Conservatives, Left- and Right-Wings, etc. It is tempting to be polemical and to insist that the terms of a conversation are so different, that the "other side" is so implacable, that discussion is impossible. Humans are at their peak when they communicate, transmit knowledge and experiences to each other, and focus on pro-social behaviors. The only guarantee for a disastrous societal rift (such as in the Greenland case study) is when communication breaks down.

This splits both ways. Those who advocate environmental protection must also be willing to consider the interests of corporations, especially those with business models that have been adapted to fight climate change and environmental degradation. For example, supporters of protecting the environment often demonize profitable business and the very concept of profit. This is misguided for the sake of dialog with corporations (the very entities that have real power to enact climate amelioration) and misinformed regarding the potential for environmental protection. Many industries and corporations do not see climate change policies as impediments, but rather as opportunities to gain support and market share from a growing base of environmentally conscientious consumers. Some corporations are researching ways to make money on ecologically responsible practices like developing emissions abatement technology, carbon capture use and storage, recycling and green waste disposal, and clean water protection[18, 19, 20](Sullivan and Gouldson 2013). Corporations will change their business strategy to accommodate public opinion even before policy is imposed on them, but find no incentive to do so if the very existence of their right to make money is rejected. As long as environmentalists shut corporations and profit-making out of the equation and rally their public supporters against them without differentiating between good- and bad-actor multinational companies, then corporate lobbies, bad-actor corporations, and anti-science politicians will close ranks and see little incentive in embracing even the most modest climate amelioration policies. In tandem with actual science and engineering solutions, dialog is one of the best tools for adaptation.

6) ***Encourage student engagement and outreach***: While we previously acknowledge the institutional inertia working against our suggested reforms within the academy, student programs of study and research are more readily adaptable. Undergraduate and graduate programs that fuse law, policy, geosciences, and social sciences may better prepare citizen students to engage in the sociopolitical climate debates, if not become policymakers themselve[21]. Furthermore, student research interests may be more exploratory, thereby allowing for student projects focusing upon our previously described objectives. As such, advisors and committees

ought to strive to encourage student interests in public outreach and engagement. In this way, we can empower the next generation of paleoenvironmental researchers to tackle the problems that we have described.

Every group has its own moral codes of norms and taboos that bracket the ways to conceive and discuss controversial topics. To those who reject climate change as a scientific fact but are still concerned about resource scarcity and the corollary, real risk of social upheaval and irreparable destabilization of the incumbent societal hierarchy, archaeological lessons can serve as a template for some of the consequences that were faced by like-minded ancient leaders. As academic social scientists, where are our brackets? We must still attempt to dialog with skeptics and communicate with the public on its own terms, shedding traditional aversions to media and other types of mass dissemination. If we avoid these engagements, we will be perceived as equally dogmatic as the anti-science community, become more disconnected from the public, and suffer from a lack of open communication and intellectual and political diversity that are so essential to societal adaptation. Modern society has undergone transformative change in the speed of information, transit, and technology, and the data indicate that we are also in a transitory stage regarding catastrophic climate change and the fallout from global pollution. Resource disruptions have not yet occurred to a devastating degree, but they probably will, and our ability to communicate will mitigate the level of disaster.

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Brett Kaufman is an assistant professor at the Institute of Cultural Heritage and History of Science & Technology at the University of Science and Technology Beijing. His research interests include the paleoecology of industry, specifically the technology surrounding ancient and historical metallurgy and mining and the long-term environmental, sociopolitical, and economic effects of deforestation and pollution resultant from such activities. He views the modern reception of archaeology as both a potential tool to foster shared heritage between peoples and to develop insights into environmental management. His work has been supported by the National Science Foundation and National Geographic Society.

Christopher S. Kelly is a progressive science educator at Dwight-Englewood School (Englewood, NJ, USA) and a 2013 U.S. Fulbright alumnus to Durban, South Africa. Currently, he teaches integrated biology/chemistry, environmental science, and climate change topics. Chris obtained his MSc in paleoclimate studies from Brown University in 2016 and maintains part-time research cooperation. At Brown, he reconstructed changes in sea surface temperature via ocean sediment archives over the last two millennia from a site off Baja California (Mexico) to illuminate changes in natural climate variability. He is a keen advocate for rigorous environmental science and awareness of social/environmental injustices.

Richard S. Vachula is a Ph.D. candidate at Brown University and has research interests bridging the environmental sciences and the humanities. These interests stem from his undergraduate degrees in Geology and French Studies. At Brown, he uses paleoecological and organic geochemical techniques to reconstruct terrestrial environmental histories

(including climate, ecology, and anthropology) from lake sediment archives. His past research has focused upon topics including the interplay between cultural perceptions of climate change and the Arctic, the Holocene climatic history of Alaska's North Slope, and computational modelling of lake sediment-based fire history proxies.