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Climate Change: How Debates over Standards Shape the Biophysical, Social, Political and Economic Climate

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Abstract. In their understandable zeal to ward off the 'nay-sayers', for whom climate change is merely an illusion, rural sociologists have defended the modern constitution that separates the natural from the social. Yet, standards must be developed to identify the phenomena of concern to both climate scientists and the public. Standards must be identified to stabilize the phenomena of interest, making them into something that can be acted on. In addition, standards must point the way forward and measure progress toward the amelioration of the problem(s). In short, standards simultaneously perform, measure, and point toward the transformation of 'the climate.' Yet, even as standards are necessary, they may actually lead us astray. Drawing on Foucault and recent work in Science Studies, I argue that grappling with climate change will require changing the political and even epistemological climate, re-enacting the sciences as well as agriculture and food.

We live in an age of crises – the climate change crisis, the financial crisis, the health care crisis, the crisis of democratic governance, and the biodiversity crisis among others. These are usually posed as future (or current) situations to be avoided. At the same time, a variety of persons and groups have proposed desirable futures in which crises will be resolved, and other chronic problems will be ameliorated. These include the promises of nanotechnologies, genomics, renewable energy sources, geo-engineering, greater income equality, food for all, green chemistry, and so on. The proponents of such potential futures attempt to *perform* them by engaging in a variety of (usually) appropriate activities.[1] They lobby for and engage in scientific research. They protest in the streets. They propose new policies, laws, regulations, and standards.

Short-term crises are immediately apparent.[2] We can all see the fire that is consuming down town, the farm that is under water as the result of unexpected heavy rain, the volcano that erupts. In each of these cases, we can then take action. We may disagree about which actions to take, but the immediacy of the situation forces us to take action. The story of Nero, fiddling while Rome burned, is clearly the exception.

But the crises that face us today as well as their solutions are generally not immediately apparent. As Jared Diamond (2005) has made abundantly clear, there are many historical examples of societal collapse brought on by failure to recognize long

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term environmental degradation. Indeed, not only small simple societies, but even large complex ones, such as that of the Mayans, have apparently vanished in this manner. Of key importance in most instances was that the very gradual character of the change made it barely noticeable to most or even all members of the population.

In contrast to the members of these now extinct civilizations, we have two major advantages. First, given our much greater ability to manipulate the natural world, we can do damage on a much greater scale and thereby notice it far sooner – perhaps soon enough to make the necessary corrections. Second, over the last 150 years we have developed the means to detect – with more or less success – relatively small changes in our environment. Doing this has required sifting through ever more massive amounts of data and, perhaps most importantly, developing standards of all kinds.

Specifically, we have developed standards, in the form of metrics, indices, instruments, reference materials (i.e., standardized physical objects) and the like 1. to identify the phenomena of concern; 2. to stabilize the phenomena of interest, making them into something that can be acted on; and 3. to point the way forward and measure progress toward the amelioration of the problem. In short, standards simultaneously perform, measure, and point toward the transformation of the phenomena of interest (Busch, 2011). Yet, even as standards are necessary, they may actually lead us astray. But before addressing this issue, let me digress by examining briefly the 'official' sociological response to climate change.

The Elephant in the Room

Recently, sociologists and other social scientists have been called upon to embrace the 'human dimensions of climate change' (Nagel et al., 2009). To my mind, there is something fundamentally oxymoronic about this phrase. Climate change is clearly a human concern at its core; nature does not particularly care one way or the other. Were we to disappear from the planet tomorrow, the earth would still revolve around the sun. As humans, we appear to have: 1. created much of the current round of climate change; 2. identified it as a problem for us (as well as for the many other life forms on which we depend) through the use of a wide range of scientific instruments, methods, and models, most of which are *inaccessible to the general public*; and 3. proposed a number of (heatedly debated) policy changes designed to mitigate it. All of these activities are human in character even as all involve interaction with the (rest of the) natural world. As the now voluminous literature on science studies shows, the 'modern constitution' that neatly divides the social from the natural is fundamentally flawed (see e.g. Haraway, 1997; Latour, 1993, 2004; Henke, 2008; Law, 2008).

Furthermore, the call to greater sociological research on climate change suggests drawing on literatures of political economy, human ecology, status attainment, cultural and meaning systems, policy process research, and the social organization of science and science policy. While doubtless all of these approaches can provide relevant insights, it should be apparent from my argument above, that there is a rather large lacuna here: the failure to include science studies – that is, studies of the *practices* and *content* of the natural sciences of climate change. Indeed, the report calls for the training of more sociologists in natural science methods, even as it fails to ask sociological questions about those methods. In the 'official' document, only the papers by Dunlap (2009) and McCright (2009) raise questions about the nature of science, and then mainly in the context of distinguishing among 'mainstream' and 'skeptics' camps. Virtually all the other papers in the report as well as the introductory overview essentially presume that the science must inexorably lead to a particular set of policy recommendations (e.g. carbon emission reductions), which we fail to take up at our peril. They ignore 1. the dynamic character of climate change science, 2. its internal disputes and controversies, especially with respect to climate models (Demeritt, 2001), 3. the sharp divide between the social and natural sciences (e.g., Wainwright, 2010),[3] and 4. the assumptions behind the social imaginaries of the natural sciences. As such, they once again become handmaidens promoting a particular set of seemingly unquestionable policies and technologies as did the literature on the diffusion of agricultural innovations (e.g. Rogers, 1995), rather than critically examining those policies and technologies. Moreover, this is hardly a minor point: if the climate change scientists are even close to on target in their overall predictions, then we collectively can neither afford to adopt mistaken policies based on false assumptions about the future, nor can we afford to do nothing. Let me explain.

Making Crises Visible

Clearly one cannot directly perceive global warming. There are several very important reasons for this. First, as Anders Blok (2010, p. 897) notes, building on work of John Law, 'there is not "one global" but many "situated globalities"'. Climate change as experienced by a Ugandan farmer is quite different from that experienced by one in the US Midwest. Second, the changes we are talking about are subtle ones; changes of just a few degrees over a century are likely to cause considerable harm to (some) humans and other living creatures. Farmers may remember the terrible winter of 1977 or the drought of 1996, but they do not notice small changes in average temperature. Third, it appears that the variation in temperature is increasing. So when I experience a particularly warm winter, I cannot immediately attribute it to global warming. After all, temperatures always vary from one year to the next. Fourth, to know with complete confidence, I would need to experience warming everywhere all at once, playing what Donna Haraway (1997) calls the 'God Trick'. Even a second best solution, to cover the entire planet with thermometers, would require that I be everywhere at once, or have the means for acting at a distance in innumerable locations. Moreover, the cost of blanketing the planet with thermometers would vastly exceed the budgets of all the nations of the world. Fifth, I would have to gather and analyse data from all of these thermometers over time and to extrapolate from that what would happen in the future. This would require having begun the process many decades ago and arguably acquiring more computing power than we currently have from all computers combined.

However, several centuries ago the science of the state was invented. It was known as statistics (Porter, 1995). Statistics were initially little more than aggregated information about all sorts of characteristics of populations of humans – their wealth, their religious affiliation, their income, their demographics. As Michel Foucault (2007) has observed, much of this was caught up in what was called at the time, *Polizeiwissenschaft*, police knowledge, or knowledge that could be used by a ruler to police the population (cf. Scott, 1998). However, as time went on, statisticians began to develop the tools we know today. First, it became possible (with varying degrees of confidence) to make statistical inferences, to extrapolate from samples to populations, and from historical data to the future. Second, statistics began to be applied not solely to human populations and matters of state, but to virtually any subject, including climate change. Finally, the very notion of statistics lost its state-centeredness and became the anodyne notion of a branch of applied mathematics.

Consider the now famous hockey-stick figure (Figure 1), the chart providing deviations from the mean temperature for the last 1,000 years. Several things are immediately apparent from perusing it.

1. Constructing it required multiple measures from different instruments and materials.
2. The variances on nearly every measure are quite large.
3. Some of the measures are considerably at variance with others.
4. At least as displayed in the figure, all the sources are given equal weight.

In addition, a few moments reflection reveals several other characteristics:

5. Each measure is dependent on measurements taken at spatially and physically different sampling sites. Put differently, the ice cores of the polar ice-caps provide, for example, a different set of samples from an examination of tree-rings. These, in turn, provide different data than do sedimentary samples or soil profiles.
6. Each data point conceals variable confidence intervals. In other words, ambient temperature data from thermometers taken yesterday likely have a much narrower confidence interval than those inferred from ice cores as evidence of temperature 1,000 years ago. Similarly, ice core samples will likely have a different confidence interval than those of tree-rings.
7. The entire exercise conceptualizes climate change as a *global* problem. Yet, its effects will be felt locally. In some places, the climate may hardly change at all. Food production may actually increase in some locales, even as it decreases elsewhere. Put differently, the global is a construct; there is no such place. Yet, while local variability has been noted, the studies that carry prestige and funding tend to be those that emphasize the global, i.e. abstract and generalized, effects.

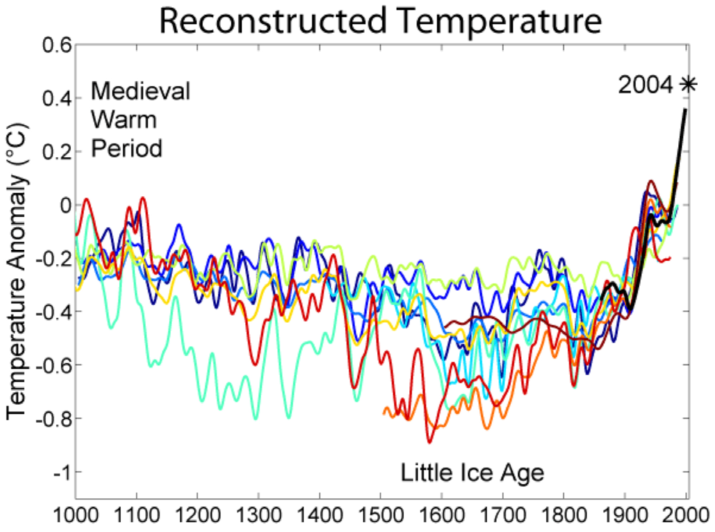

Figure 1. Reconstructed Temperature, 1000-2004.
Source: Image created by Robert A. Rohde/Global Warming Art; reprinted by permission. Figure illustrates 10 different estimations of the last millennium of temperature change, based on different procedures. For more details, see Rohde, 2009.

Actor-network Theory (ANT) (e.g. Latour, 1987, 2005; Law, 2008; Callon et al., 2009) provides a useful way of making sense of just what is going on here. Although space prohibits a detailed discussion of ANT here, a few words are in order for those unfamiliar with it. Proponents of ANT argue that rather than taking the major antinomies of contemporary life for granted, we must ask how the practices of scientists and others include sorting phenomena along various divides: culture/nature, human/non-human, true knowledge/false knowledge, local/global, social science/natural science, etc. Similarly, rather than taking class, race, gender or ethnicity as explanatory variables, ANT turns the questions around and asks how these phenomena are (re)constructed by a range of social practices. Moreover, ANT proponents assert that we all live in a world that includes not only other human actors, but a wide range of non-human actants that influence human actions by virtue of their resistance. For example, the most respected climate scientist would have little to say were the tools of the profession (e.g. climate models, professional associations, scientific instruments, tree-rings, ice cores) unavailable to them. Similarly, the most productive farmer would suddenly become rather unproductive were the tools of the trade (e.g. plows, tractors, fertilizers, soil) to become unavailable.

Moreover, to pursue this proponents of ANT employ a particular set of methods. This includes following the actors/actants through controversies (e.g. global climate change), observing how 1. they construct networks, 2. they attempt to create obligatory passage points where all practitioners must pass (e.g. mathematical climate models), and 3. they create immutable mobiles (objects that can be transported from site to site while remaining relatively stable, e.g. thermometers). In short, ANT forces us to ask a different set of questions about climate change, as illustrated below.

An Actor Network Approach to Climate Change

From an ANT perspective, first, we never have data on temperatures everywhere; we have *networks* of points that can be brought together to tell multiple stories. Indeed, as Hulme et al. (2009, p. 201) note, ‘different formulations of the baseline period can result in quite radically different (statistical) portrayals of past and future climate change’. Moreover, these stories are based on both scientific data and cultural expectations about climate. In short, shifting temporal, spatial, and cultural constructs of climate allow us to tell rather different stories. Second, we have scientific networks – what Diana Crane (1972) once called invisible colleges – that permit the assembling of these data into intelligible form through the endless empirically grounded debate that constitutes science. Third, we have to *extrapolate* from the data in order to make the claim for global warming; as is always the case, the data do not speak for themselves. Indeed, the extrapolation process is actually quite complex. At the very least it involves five extrapolations: a. from the data points to the rest of the planet; b. into the future based on past data; c. from the rather messy data to tell a much clearer and more remarkable story: that climate change is happening; d. from average changes to changes in particular locations; and, finally, e. from these data to policy recommendations.

At any of these ‘moments’ it is possible that things could go awry. The instruments used to collect data might give false readings. The models used to do the calculations might be significantly flawed.[4] One or more of the various extrapolations might later prove to be erroneous. The policy recommendations, especially if based on global aggregations of data rather than much smaller units, might make the situation worse. Given this, is it any wonder that the international scientific community took several decades to reach its conclusions?

Please do not misunderstand. This is not an argument that climate change is not happening. Nor is it an argument that we are not contributing to it by virtue of the changes that we have made in the world. However, it is an argument that emphasizes the necessarily tentative character of such complex extrapolations. This becomes all the more problematic when it comes to measuring remediation, as I shall attempt to show below. But first let us look at the question of causes.

Identifying the Causes

Figure 2 shows the attributions of climate change to various major suspected or confirmed causes from 1900 to 1990. It also compares the modeled change to the ‘observed’ change over that time. Note that this figure is considerably more complex than that in the previous figure since it implies a *relationship* between measured temperature change over the century as well as estimated emissions that might account for positive or negative temperature variations. Here again, implicit is that each source of temperature change must be measured in a different way. Measuring sulfate emissions is different from measuring greenhouse gases, which is different in turn from measuring solar energy or volcanic eruptions. Each of these measures is also likely to have a different statistical error rate, since some measuring instruments are more accurate and precise than others. Indeed, some are based on known physical relationships, others on previous experimental data, and still others on the tacit knowledge obtained through years of modeling (Polanyi, 1958). Furthermore, all must be converted to a single metric in order to be displayed in the figure.

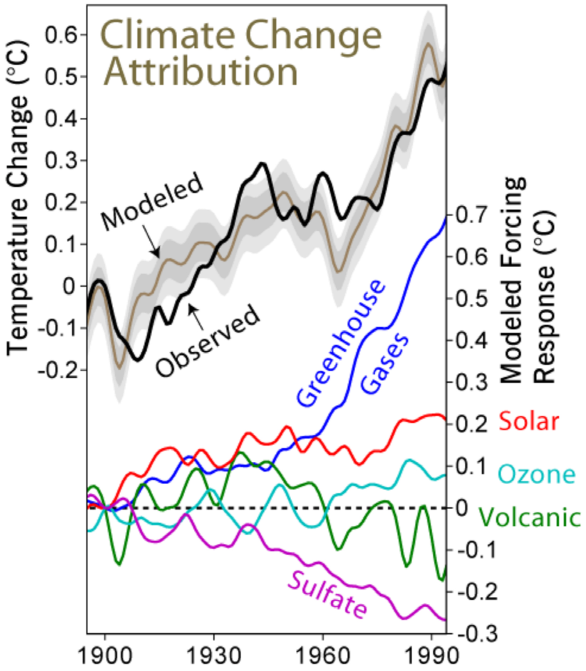

Figure 2. Climate Change Attribution, 1900–1994.

Source: Image created by Robert A. Rohde / Global Warming Art; reprinted by permission. Figure illustrates five year moving average of temperature measurements from various sources, results estimated by using a model, estimated contribution of each predetermined factor independently of running the model.

Of course, we could (and doubtless climate specialists have) employed a wide range of statistical procedures to analyse these data. But, despite this, all that the statistical analysis can tell us is that the variables in question co-vary to a certain degree. Even if we were to ‘explain’ 95% of the variance (highly unlikely given the variable quality of the data), we would simply have significant evidence in favour of the hypothesis that greenhouse gases, largely created by human endeavours, contribute to climate change. Since the data are not experimental, they cannot tell us whether any given set of variables *causes* temperatures to rise. We will only be able to determine that *ex post facto*, by implementing changes to reduce greenhouse gas emissions.

Making Policy Choices

Based on the data shown in Figure 2, and many other studies as well, climate modelers have concluded that greenhouse gases, largely of human origin, are the major contributor to climate change. Based on their analysis, one obvious policy recommendation that flows from this conclusion is that it would be prudent to reduce those emissions.[5] Furthermore, since most of the emissions come from motor vehicles in the form of carbon, considerable effort has been expended in many nations to reduce carbon emissions by motor vehicles. Moreover, many nations have agreed that carbon reductions should be brought about by commodification of carbon and the introduction of carbon emissions trading. ‘In sum, under climate management regimes like the Kyoto Protocol, the world comes to be revealed as an undifferentiated grid of planetary carbon-ordering’ (Lansing, 2010, p. 720). Yet, clearly, nothing in the science of climate change leads inexorably to this particular means for reducing greenhouse gas emissions (Hulme, 2009).

However, let us proceed here on the assumption that reduced carbon emissions from motor vehicles is the strategy undertaken. There are at least two ways in which this might be accomplished: First, we could reduce or eliminate the use of motor vehicles. However, doing so would be quite disruptive and would likely prove infeasible except in the very long run. Second, we could reduce or eliminate the *emissions* produced by motor vehicles. This is the route already taken to varying degrees by several nations. Furthermore, most of these nations have chosen to focus on carbon emissions, although many other greenhouses gases are implicated in auto emissions.[6]

But these decisions are both unevenly distributed and nested. Quite obviously, regardless of the approach taken, wealthier vehicle owners (and, more generally, nations that are wealthier) will find it less life-changing to reduce or eliminate emissions than poor vehicle owners and poorer nations. Furthermore, once one has decided that reducing emissions while maintaining most (if not all) of the motor vehicle fleet is the approach to follow, then there are only four possible alternative approaches remaining: First, one can change the fuel one burns; this is one of the reasons for shifting to ethanol production, which itself transforms the agricultural landscape. Second, one can change the means of locomotion; this is the approach of hybrid as well as electric vehicles. Third, one can increase the fuel efficiency of conventional engines, i.e. reducing the number of calories required to propel a given mass a given distance; this is the rationale behind laws mandating greater fuel efficiency. Finally, one could do all of these, either in the form of a combination, or as alternatives used in different vehicles.

Before continuing, note that we have now whittled the complex and vexing – indeed, the wicked (Rittel, 1972; Rittel and Webber, 1973; Batie, 2008) – problem of climate change down to one focus: greenhouse gas emissions of motor vehicles. Furthermore, since carbon emissions make up the lion's share of total motor vehicle emissions, we may measure the emissions in terms of the carbon footprint of a given vehicle. This makes the problem far more tractable, but at the expense of ignoring many of the complexities surrounding it.[7]

In the US and the EU, we have seen several efforts to reduce carbon emissions, including: 1. increasing fuel efficiency in automobiles; 2. developing hybrid and electric vehicles; and 3. replacing some of the (petroleum-derived) gasoline with ethanol from edible plants, thereby indirectly raising the price of food. The first of these alternatives is arguably the least problematic, since conservation is the most effective means of reducing emissions (see e.g. Roberts, 2004) as well as the one with the fewest likely unexpected consequences. But let us examine the other two alternatives.

Electric vehicles clearly reduce emissions at the point of use, but it is not clear that they reduce overall emissions if the electricity they employ comes from burning coal. Hence, electric vehicle emissions standards must take into account the source(s) of electricity and what emissions they produce. Indeed, depending on the quality of the coal they burn and the efficiency of electricity generation and transmission, electric vehicles could *increase* greenhouse gas emissions. Hybrid vehicles are perhaps less problematic since they do not require recharging on a grid, but gain their electrical power from braking and capturing energy that would otherwise be wasted.

Employing ethanol as a partial substitute for gasoline poses yet another set of problems for standards development. As with electricity, the source of the ethanol is an important question since considerable energy must be expended to produce the ethanol. In the case of ethanol from maize, there appear to be two major problems for standards. First, there is considerable dispute as to the energy consumed over the entire length of the supply chain (see e.g. Pimentel and Patzek, 2005; Hill et al., 2006). Ethanol is more flammable than oil and must be hauled to distillation plants and to distribution points by truck, while much oil and gasoline is moved in pipelines much more efficiently. More important for the argument that I wish to make here is that even as carbon emissions from ethanol appear lower than those from gasoline, maize ethanol produces considerable amounts of nitrous oxide (N_2O). Apparently, 'for an equivalent mass, it is almost *300-fold greater* in its ability to warm the planet, and it is currently the third most important gas in causing global warming, after carbon dioxide and methane' (Howarth et al., 2009, p. 3, emphasis added). Quite obviously, standards for carbon footprints do not include N_2O emissions. Moreover, maize ethanol production has rapidly increased in the US – from 175 million gallons in 1980 to 9 billion gallons in 2008 (Renewable Fuels Association, 2009) – largely as a result of government subsidies, and now accounts for about half the global total. Finally, ethanol production from maize quite obviously competes with food uses of that cereal, helping to raise food prices and perhaps contributing to hunger in parts of the world.

The situation for ethanol from sugar cane, the common approach used in Brazil and eagerly purchased by Europeans wishing to reduce emissions, is not much better. Again, the carbon footprint is lowered. And while sugar ethanol produces less in the way of N_2O emissions, demand for it is leading to considerable and rapid destruction of the Amazon rain forest, thereby reducing the size of the world's largest carbon sink (Howarth et al., 2009).[8]

Again, none of this analysis is meant to suggest that we should abandon attempts to develop standards that will allow us to measure the impacts of policy changes designed to reduce the impact of global climate change. It is meant to suggest that the kind of (Cartesian) science we have been doing for the last 300 years may finally have reached its limits.

Science for Wicked Problems

In his now nearly iconic volume, *The Structure of Scientific Revolutions*, Thomas Kuhn (1970) argued that most science was 'normal science.' Under conditions of normal science, practitioners know what experiments to perform and what results to expect. There are anomalies, but it is widely believed that pursuit of normal science methods and procedures will eventually lead to their disappearance. Probably no better case for normal science could have been made than cosmologists' belief just a few years ago that they were close to the development of a Theory of Everything. Indeed, one cosmologist recently frankly noted that '[f]or the past two decades, most of my colleagues and I have been working under the assumption that we can know everything about the universe' (Ferreira, 2009, p. 43). Then, just as Truth was at hand, it evaporated.

Kuhn also noted that every so often the anomalies of a given normal science became overwhelming, leading to a scientific revolution. At this time, scientists jump ship; they gradually reject the old order and embrace the promise of a new paradigm that would, if successful, become the new normal science. Yet, even as Kuhn distinguished normal from revolutionary science, he implied that 1. his metaparadigm was permanent and eternal (it was *the* structure), and 2. there was no other way to engage in science.

In contrast, in a few short articles, Rittel (1972) and Rittel and Webber (1973) introduced the concept of a wicked problem. They argued that many of the most serious problems currently facing the world cannot be adequately addressed by either conventional reductionist science or by various systems approaches grouped under Operations Research or General Systems Theory. They argued that those approaches worked reasonably well for 'tame' problems in which relatively clear solutions were at hand, but were rather unsuitable for grappling with 'wicked' problems – problems that are difficult to describe, the subject of considerable political debate, and for which no optimal solution is likely to be found. These problems involve situations that might be amenable to improvement, but their very messiness requires that one go beyond more formalized methods and, equally important, that one abandon the idea that a solution as such might be found. Clearly, climate change is one of those wicked problems.

Improvements of the situations characterized by wicked problems appear to require not merely a new paradigm, but a reinvention of science itself. In recent years a number of approaches have been proposed for reinventing science. Proponents of post-normal science (Funtowicz and Ravetz, 1993) argue that it 'reminds us that there are hosts of urgent policy problems involving science, for which routine expertise is totally inadequate, and for which even the best professional knowledge and judgment are insufficient' (Ravetz, 2005, p. 73). Others argue that Global Climate Models (GCMs) are problematic to the extent that they tend to obfuscate complexities, thereby providing policy-makers with neat – but perhaps inadequate – answers to complex problems. As Shackley et al. (1998, p. 198) put it,

> 'GCMs… lend much credibility to the prospect and legitimacy of uniting and globalising diverse activities, including national and regional policy making. They achieve this through the application of standardised techniques, inputs and assumptions, as well as through promoting and legitimising the development, in other related domains, of such standard methods and techniques. So, for example, GCMs provide justification for the creation of greenhouse gas emission inventories, as well as for changing social practices in a way which reduces such emissions… If they are believed, deterministic models such as GCMs and their applications could become enormously powerful, both in technical and social terms.'

In short, GCMs may lead policy-makers and the general public to believe that climate change is a difficult and costly, but fully tractable problem; all we need do is to implement a few costly but straightforward policies and we will be able to put this all behind us. But, as noted above, this is an experiment never before attempted. Moreover, what we do now will likely affect the situation in which our great-grandchildren will find themselves.

Still others note that science and society are co-constructed (Jasanoff and Wynne, 1998; Hulme et al., 2009). The standards, laws and regulations that we put into place are not mere extrapolations from the brute data of science; they are negotiated socio-technical accomplishments that include both observations about the natural world and value commitments of scientists, politicians, and others. Indeed, at least one prominent meteorologist argues that 'the separation of the cultural from the physical that is implicit in the dominant understanding of the idea of climate is a peculiarly Western separation' (Hulme, 2009, p. 15).

Co-construction applies not only to, for example, the legal frameworks defined for accounting for carbon emissions, but to the choice of research problems and methods, as well as to the myriad scientific instruments, measurements and standards that are an essential part of doing science. Hence, chromatographs, thermometers, spectrometers and the entire array of scientific instruments each conceal (temporary) agreements about what is sufficient accuracy and precision, as well as what is feasible, necessary and affordable at a given place and time (Busch, 2000). If that is the case, then we cannot merely leave the science to the scientists, since the very process of doing science is essentially social.

Conclusions: Some Lessons of Climate Change Standards

As the Chinese word for crisis suggests, the climate change crisis offers both dangers and opportunities. On the one hand, our very quest to develop neat, well-defined, global standards with which to measure climate change may lead us astray. On the other hand, without standards we have no way of knowing what is happening or if our efforts are having even a modicum of success. Put differently, we need standards if we are to identify the phenomena we summarize as climate change, to develop policies to mitigate it, and to measure its mitigation or persistence. But at the same time, those standards will always be inadequate to the tasks at hand, precisely because climate change is a wicked problem. So what can we do?

1. As limited beings (Wimsatt, 2007) we need to abandon the search for Truth with a capital T. But we need not fall into despair or some form of relativism. Nor need we concede the territory to the reactionary critics who deny the realities of climate change. To admit that uncertainty exists is quite different than denial. Yet, by demanding that scientific Truth stand up to ideologically motivated nay-sayers, we merely perpetuate one of the great conceits of our age. Indeed, climate change may provide precisely the moment required to break the bounds and bonds of Cartesian science once and for all.
2. More positively, we need all the help we can get. We cannot maintain the fiction that science provides us with Truths which the rest of us must merely passively accept. We need to come to grips with the fact that scientific experiments a. are means by which we open new options for social development (Dewey, 1927), and b. are only fully tested when worked out in general use.[9] Laboratory testing (or its equivalent) is merely a first step down a rather long path. We also need to consider that science is but one source of knowledge about the world; other forms of knowledge always precede and inform it. For example, farmers' knowledge is essential to understanding the (always) local effects of climate change on food production.
3. Perhaps most controversially, we must admit that reductionism has been a very fruitful approach to resolving scientific problems. But for precisely this reason, its use is quite limited with respect to wicked problems. In these instances we need both the broader participation called for by Funtowicz and Ravetz (1993) and Callon et al. (2009), but also counter-reductions. In practical terms that means that even as we support climate change modeling, we need to challenge the sometimes tacit and often concealed technical and political assumptions behind such models (including the prestige currently associated with modeling itself). Even as we develop standards for carbon emissions, we need to support counter-reductionists who develop standards for methane, nitrous oxide, and (many) other emissions. Even as we agree that greenhouse gases are the major human-induced element in climate change, we need to support scientists' explorations into other causes and the development of standards that permit measurement of those 'natural' causes of climate change. Put more succinctly, we need *reflexive standardization*!
4. We cannot grapple with climate change as if it were a neatly bounded problem. As the widespread growth in the use of bio-fuels already illustrates, climate change issues are also intimately bound up with (among many other things) issues of food production and prices. Hence, at the very least, standards for measuring climate change must also come to grips with the (positive and negative) impact that it has on our food supply. Moreover, this impact will likely not be felt evenly across the globe, but will have different consequences in different locales. For example, farmers benefit from higher food prices at the proverbial farm gate, even as urban dwellers are forced to pay.

5. Finally, we must reject the idea that the natural sciences alone can guide us. The future is constructed, performed, and enacted by our collective actions. When scientists envision a world of, for example, reduced carbon emissions, they draw on images of the future that extend far beyond climate science, and that include images of what 'the public' believes and accepts, as well as what policy-makers are likely to find acceptable. Such images are part of a much larger (and often more contentious) body of knowledge obtained through everyday practices and expectations by both scientists and the rest of us. As Wynne (2005, p. 68) puts it, 'imaginations of the public world, however that is construed, can be taken as integral to scientific knowledge-generation, not simply as afterthoughts'. We need to develop better means by which to ask collectively what kind of future we want and how we might get there, rather than assuming that there is merely one future and one road to it.[10] To do that we need all the good science we can get, but, as Dewey (1927, p. 208) reminded us many years ago, '[t]he essential need… is the improvement of the methods and conditions of debate, discussion and persuasion'.

In sum, the standards we employ to detect, measure, monitor and remediate climate change will have a profound effect on the political, social and economic climate. They may have an effect on the biophysical climate as well. But unless we challenge the assumptions upon which these standards are based, unless we engage in reflexive standardization, we may be led, lemming-like, into the abyss. If social scientists are to become engaged in action about climate change, we cannot be content with merely grafting our knowledge about society onto the models of climate change scientists.

Notes

1. For examples of performative approaches, see Callon, 1998; Hilgartner, 2000; MacKenzie et al., 2007.
2. To argue that they are immediately apparent is not to say that these phenomena are always interpreted in the same way. There is widespread agreement that hurricane Katrina demolished a large portion of New Orleans. However, some persons saw it as proof that the second coming was near, others that God was punishing sinners, and others that people built homes in places that should have been left in their 'natural' state.
3. Wainwright (2010, p. 986) asks: 'Do we in fact know which are the "fundamental questions" underlying global warming? If so, how? Is this a question that can be ascertained scientifically?'
4. The case of the recent financial collapse should make us pause; it was based on complex assumptions built into mathematical models – assumptions that later proved inadequate to the maintenance of the financial system. While these models are quite different from those used in climate change research, both sorts must include assumptions that are either unrecognized or ignored as unlikely or both. See Derman and Wilmott, 2008.
5. At least a few scientists see the solution in the more drastic step of geo-engineering; see e.g. Wood, 2009.
6. According to the EPA (n.d.), auto emissions include hydrocarbons (including those from incomplete burning as well as evaporation of fuel), nitrogen oxides, carbon monoxide, and carbon dioxide.
7. That said, merely measuring carbon emissions involves a set of complex calculations, and opens new possibilities for fraud. See e.g. BBC, 2007; Green and Capell, 2008.
8. For a highly critical view of sugar-ethanol production and its impact on the Brazilian rain forest as well as on small-holders, see Grain, 2009.
9. Computer scientists have been aware of this problem for some time; only after considerable use do many software problems become apparent (see Parnas et al., 1990). It is also recognized in pharmaceutical research as post-market surveillance of new drugs. When Vioxx (rofecoxib) was withdrawn from the market due to increased risk of heart attack, it was withdrawn because widespread use in a large population revealed problems not noticed in clinical trials. Most agricultural scientists and farmers have been less comfortable with this approach, only accepting that some pesticides were toxic many years after the problem had been noted.
10. We also need to ask whether the current form of capitalism, which excludes the interests of future generations from its calculus (e.g. Wainwright, 2010), and the current form of democracy, which excludes the representation of things (e.g. Latour, 2004) are adequate to the tasks at hand.

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