Donald Trump, Global Warming, and Public Philosophy of Science

Volume 2, Number 1
Spring 2019
DOI: 10.25335/PPJ.2.1-5

James Marcum
Yunus Prasetya

Abstract

Global warming is at best a controversial contemporary scientific, economic, social, and political issue, at least from the perspective of public media and persona. In other words, it is a wicked problem, which requires public attention and response. Unfortunately, the public's perspective of the controversy is often (mis)informed through the media and its star persona.

1. Introduction

Global climate change, with respect to what it is and what is causing it, is a controversial contemporary scientific, economic, social, and political issue, to say the least—at least from the perspective of public media and celebrities.[1] It has been called a "wicked" problem,[2] which requires public attention and response. Unfortunately, our understanding of the controversy is often (mis)informed by the media and celebrities. For example, Donald Trump participated vigorously in climate change discussions prior to his presidency. In September 2014, he tweeted, "Great article on so-called climate change, formerly known as global warming."[3] The article he cites was published several days earlier in the *New York Post*. There, Tom Harris and Bob Carter claim, "There is essentially zero evidence that carbon dioxide from human activities is causing catastrophic climate change."[4] Later, in January 2015, Trump tweeted, "It's record cold all over the country and world—where the hell is global warming, we need some fast!"[5] Trump's tweets disclose a fundamental misunderstanding of the natural sciences and their practices, which has serious implications for shaping discussion of global climate change and for understanding climate science, as well as for how to proceed in terms of government policy.

In a review of the literature on global climate change, Philip Kitcher challenged philosophers to contribute to the climate change controversy—particularly in terms of addressing misconceptions concerning climate science and its practice.[6] Philosophers—especially philosophers of science—have an opportunity to clarify misconceptions of this science; unfortunately, few have, and when philosophers have contributed they have done so almost exclusively in the professional scientific and

1. See Paul N. Edwards, *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming* (Cambridge, MA: MIT Press, 2010); Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (London: Bloomsbury Publishing, 2011); Spencer R. Weart, *The Discovery of Global Warming* (Cambridge, MA: Harvard UP, 2008). For media coverage of the controversy, see, PBS's NOVA series on climate change and National Geographic's *Before the Flood*.

2. See Frank P. Incropera, *Climate Change: A Wicked Problem* (New York: Cambridge UP, 2016).

3. Global climate change includes not only global warming but also glacial retreat, rising sea levels, and various extreme climatic events; see Timothy Kusky, *Climate Change: Shifting Glaciers, Deserts, and Climate Belts* (New York: Facts on File, 2009). For Trump's tweets, see, Dylan Matthews, "Donald Trump Has Tweeted Climate Change Skepticism 115 Times. Here's All of It," *Vox*, Jun. 1, 2017, https://www.vox.com/policy-and-politics/2017/6/1/15726472/trump-tweets-global-warming-paris-climate-agreement.

4. Tom Harris and Bob Carter, "Leo vs. Science: Vanishing Evidence for Climate Change," *New York Post*, Sept. 14, 2014, https://nypost.com/2014/09/14/leo-v-science-vanishing-evidence-for-climate-change/.

5. See Dylan Matthews, "Donald Trump Has Tweeted Climate Change Skepticism 115 Times. Here's All of It," *Vox*, Jun. 1, 2017, https://www.vox.com/policy-and-politics/2017/6/1/15726472/trump-tweets-global-warming-paris-climate-agreement.

6. See Philip Kitcher, "The Climate Change Debates," *Science* 328, no. 5983 (2010): 1230-34.

philosophical literature.[7] Our goal is to respond to Kitcher's challenge by introducing a public philosophy of science that explores the power and limits of climate science and its practice. Specifically, we examine and evaluate the rhetoric associated with the global climate change controversy. To that end, we identify the assumptions surrounding this controversy, especially in terms of global climate modeling. For modeling is the means by which climate scientists not only predict what climate changes to expect in the future but also to ascertain what is causing them and how best to prevent harmful changes, especially through government policies.

As illustrated in Trump's 2014 tweet, the controversy often hinges on whether carbon dioxide emission from human activity is responsible for climate change, especially global warming. Our proposed public philosophy of science can help to clarify, for example, what scientists mean when they claim that evidence supports the statement that carbon dioxide and other greenhouse gases, which humans have spewed into the atmosphere during the second-half of the twentieth century, are responsible for current global climate change. Further, we seek to explain why global warming, along with other climate change, is occurring at its present alarming rate. As Trump's 2015 tweet illustrates, a public philosophy of science can also help to clarify why a temporary record cold spell does not necessarily refute the scientific community's consensus explanation for climate change as forecasted or predicted through global climate models and other observations, especially from previous geological periods. Both observations and models play a critical role in climate scientists' accounts of current global climate change. The models help them understand what climate observations mean with respect to global climate change. Our public philosophy of science describes what kind of observations are required to challenge the accuracy of current climate models and what climate skeptics have to do in order to contest the current consensus in climate science. Lastly, our philosophy serves the social, economic, and political good by addressing the misconceptions often infecting discussions of important social and political controversies like global warming.

In the following section, we define global climate change and how to model it, as well as clarify misconceptions about the assumptions and concepts of climate modeling. For these misconceptions often lead to distorted or biased understandings of climate change. In the third section, we explore how scientists know that global climate change is taking place and how they explain this change, especially through the construction of global climate models. In our conclusion, we discuss how society can exercise its right to insist that government officials enact policies to curb global climate changes like global warming. Finally, by way of introduction, the aim of our public philosophy of science is to incorporate the natural sciences as a social institution into a democratic society so that we can participate meaningfully and representatively in these sciences to address controversies over social, economic, and political issues such as global climate change. Otherwise, the current polarity and extremism over the wicked problem of global climate change could have a harmful impact not only on the environment but also on the flourishing of future generations.

2. What Is Global Climate Change and How is It Modeled?

Our definition of global climate change takes into consideration a variety of concepts, including scientific laws, theories, and hypotheses; models and their simulations or reproductions of natural events; assumptions and beliefs about what makes up the natural world and

7. For examples, see, Mark Charlesworth and Chukwumerije Okereke, "Policy Responses to Climate Change: An Epistemological Critique of Dominate Approaches," *Global Environmental Change* 20, no. 1 (2010): 121-29; Hélène Guillemot, "Connections between Simulations and Observation in Climate Computer Modeling. Scientist's Practices and 'Bottom-Up Epistemology' Lessons," *Studies in History and Philosophy of Science Part B* 41, no. 3 (2010): 242-52; Joel Katzav, "The Epistemology of Climate Models and Some of Its Implications for Climate Science and the Philosophy of Science," *Studies in History and Philosophy of Science Part B* 46 (2014): 228-38; Richard Lawson, "Climate Science and Falsifiability," *Philosophy Now* 104 (2014): 28-29; Arthur C. Petersen, "Philosophy of Climate Science," *Bulletin of the American Meteorological Society* 81, no. 2 (2000): 265-71; Gavin A. Schmidt and Steven Sherwood, "A Practical Philosophy of Complex Climate Modelling," *European Journal for Philosophy of Science* 5, no. 2 (2015): 149-69. Stephen Gardiner also complains that few ethicists have responded to the controversy in "Ethics and Global Climate Change," *Ethics* 114, no. 3 (2004): 555-600.

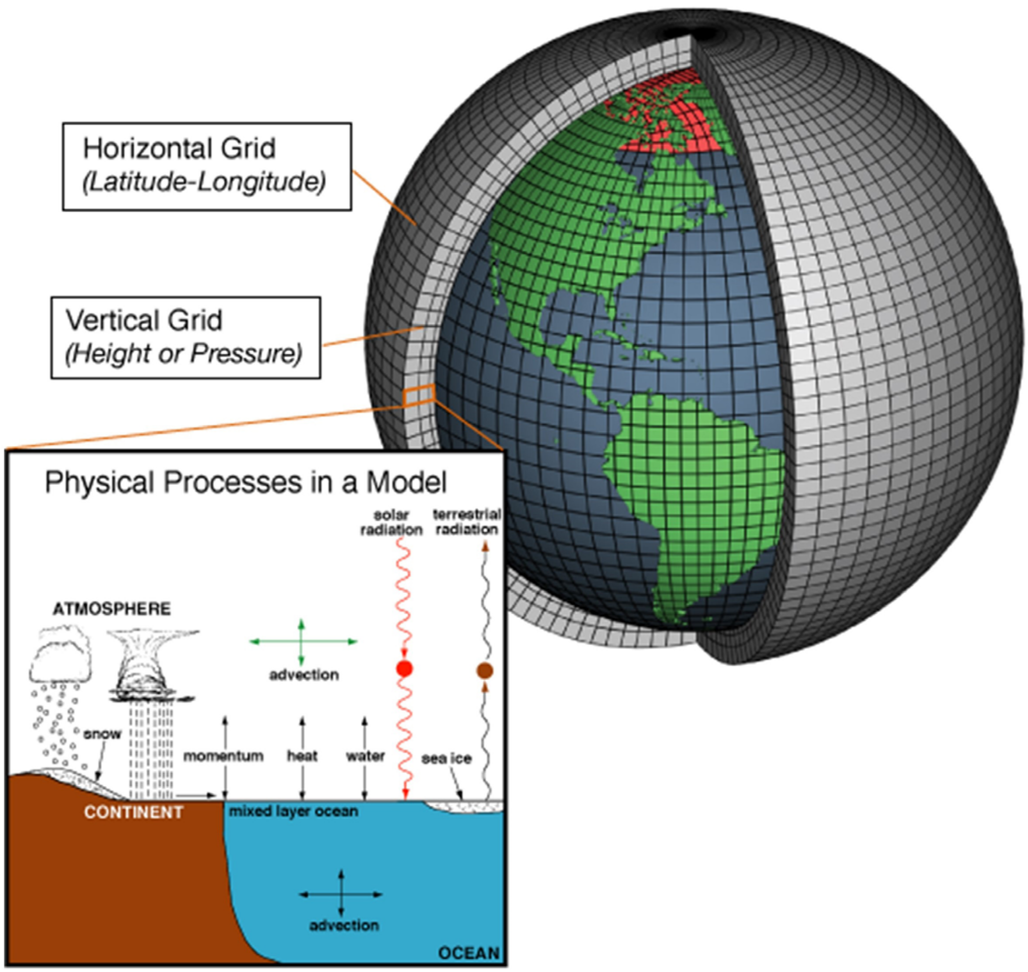

Figure 1. Schematic for Global Climate Model.
(From NOAA Climate.gov: https://www.climate.gov/maps-data/primer/climate-models).

how to investigate it; generalizations about natural events that are not limited by the concrete and particular; mathematical equations; and values about how the natural world ought to be investigated.[8] We define global climate change as disruptions or fluctuations in the normal patterns of global climate. These disruptions include not only global warming but also other events, such as the melting of the polar ice caps and glaciers with the consequent rising of ocean and sea levels, changes in precipitation patterns with some areas receiving more rain with associated flooding and other areas less rain with associated droughts and heat waves, lengthening of frost-free and growing seasons, and increase in frequency and strength of hurricanes and tornadoes. Climate scientists use modeling not only to predict these global climate changes but also how best to prevent them. In the remainder of this section, we explore what constitutes climate models, since a variety of models have been constructed not only to hindcast, or account for past global climate change, but also to forecast, or predict future change.

Global climate models are based on certain assumptions and concepts about the nature and measurement of geological, glaciological, and meteorological observations concerning climate change.[9] Although a variety of assumptions can be identified and examined,

8. See Edward J. Hall, *Philosophy of Science: Metaphysical and Epistemological Foundation* (Oxford: Wiley-Blackwell, 2009); Markus Schrenk, *Metaphysics of Science: A Systematic and Historical Introduction* (New York: Routledge, 2017).

9. For a narrative on the history of global climate modeling, see Paul N. Edwards, "History of Climate Modeling," *Wiley Interdisciplinary Reviews: Climate Change* 2, no. 1 (2011): 128-39.

such as assuming average or homogeneous temperature distribution within a given geographic area or cell (Figure 1), we discuss only the assumption of parsimony in terms of its impact upon modeling climate change, as well as upon global climate science and its practice. In addition, we explore various concepts, including uncertainty, complexity, and causation, that are crucial for understanding and addressing problems surrounding the controversy.

In general, a model is a representation of a target system.[10] In some contexts, however, representation is not an end in itself. Rather, a model, by representing its target system, can serve a variety of purposes. For this reason, a model must be evaluated primarily on the basis of whether it achieves the purposes for which it was designed. A model's ability to represent its target reliably is valuable only insofar as it helps to achieve the purposes for which the model is made. This applies, especially, to climate models, which are generally designed to inform government policy on anthropogenic (human-driven) climate change.[11] To this end, a climate model should be evaluated, primarily, on the basis of whether it can help to make informed decisions on what, if anything, should be done about anthropogenic climate change.

To achieve the end of aiding in policy-formation, climate scientists use models to investigate the conditions that might be responsible for changes in global climate.[12] For this reason, climate models are generally designed to be manipulable representations of climate conditions. A good illustration of these types of models are earth system models.[13] One of the earlier models was based on "dish-pan" experiments, conducted by David Fultz and colleagues at the University of Chicago, in which a pan was filled with water and rotated. By heating the pan's edge and cooling its center, Fultz and colleagues could mimic global atmospheric and oceanic circulation. However, the dish-pan model was simply too crude or simple, especially in terms of its size or scale, to mimic atmospheric and oceanic circulation realistically. Given the limitations of many physical models, as illustrated by earth system models, global climate models are hypothetical, and to some extent fictional, in that natural events cannot be represented with absolute accuracy and perfect precision either physically or mathematically.[14] What is important, however, is that these models can explain and predict global climate, as well as simulate what-if scenarios. They can predict, for example, what would happen to our climate if we do not limit our production of greenhouse gasses. In other words, climate scientists construct models to investigate and understand events like global climate change, but these events represent an open system in which elements of that system often interact on a chance or probabilistic basis.

Although global climate models are limited, they continue to play a pivotal role, especially as computer simulations or representations, in climate science and in the global climate change controversy.[15] As shown in Figure 1, global climate models exhibit a three-dimensional spatial structure consisting of specific geographic areas, or cells, with one of the dimensions representing atmosphere and the others representing land and water. The model's spatial resolving power, or smallest unit of measurement, is an outcome of the

10. See Sidney Yip and Tomas Diaz Rubia, *Scientific Modeling and Simulations* (New York: Springer, 2009).
11. See Judith Curry, *Climate Models for the Layman* (London: The Global Warming Policy Foundation, 2017).
12. See Daniela Bailer-Jones, *Scientific Models in Philosophy of Science* (Pittsburgh: U of Pittsburgh P, 2009); Roman Frigg and Stephan Hartmann, "Models in Science," *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, 2018, https://plato.stanford.edu/entries/models-science; Lorenzo Magnani and Tommaso Bertolotti, eds., *Handbook of Model-Based Science* (New York: Springer, 2017).
13. See Gregory M. Flato, "Earth System Models: An Overview," *Wiley Interdisciplinary Reviews: Climate Change* 2, no. 6 (2011): 783-800.
14. See Nancy Cartwright, *How the Laws of Physics Lie* (New York: Oxford UP, 1983); Naomi Oreskes et al, "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences," *Science* 263, no. 5147 (1994): 641-46.
15. See Judith Curry, *Climate Models for the Layman* (London: The Global Warming Policy Foundation, 2017); Andrew Gettelman and Richard B. Rood, *Demystifying Climate Models: A Users Guide to Earth Systems Models* (New York: Springer, 2016); David J. Neelin, *Climate Change and Climate Modeling* (Cambridge: Cambridge UP, 2011); David A. Randall et al., "Climate Models and Their Evaluation." In *Climate Change 2007: The Physical Science Basis*, ed. S. Solomon et al., 589-662 (New York: Cambridge UP, 2007). There are many different climate models, most of which can be categorized either as atmosphere-oceanic general circulation or global climate models or as regional or local circulation models. The former models simulate larger areas of climate change and have low resolving power, while the latter simulate smaller areas of climate change and have higher resolving power. The challenge is how to integrate these two types of models.

cell's size—the smaller the cell, the greater the model's resolving power. The problem with increasing the resolving power, unfortunately, is that to double it requires an order of magnitude or tenfold increase in computing time. Besides the model's spatial resolving power, there is also its temporal resolving power, which refers to the duration of time or time-step intervals over which data are collected in the field. A model's temporal resolving power is the outcome of the duration of these time-steps. So, the more frequent, or shorter the time-steps, the greater the resolving power. As true for higher spatial resolving power, greater temporal resolving power also requires longer computing times.

Climate models consist of various mathematical equations based on fundamental physical principles and laws, such as the conservation of mass, energy, and momentum.[16] These equations are used to calculate the relationship between different factors that affect climate, such as temperature, pressure, wind, and humidity—to name a few. Data for each of these factors must be collected from different geographic areas, or cells, if the model is to simulate or represent reliably the climate within those areas. The designing and building of a climate model does not involve simply collecting data on the average temperature and greenhouse gas concentrations, as well as other factors, over a specific time period and then projecting future climate change based on the observed data.[17] Rather, the model's design and construction starts with fundamental physical principles and laws, and it is only when the model reliably represents observed climate data that it is used to forecast or predict climate change, such as global warming. In other words, the reliability of these models is based on known physical processes and laws and not simply on climate observations and extrapolations of large-scale correlations.

Although models for global climate change make a number of assumptions in terms of forecasting or predicting trends in climate change, probably the most important assumption is parsimony.[18] Parsimony refers to the practice of not multiplying or increasing the number of entities or factors involved in understanding something of interest.[19] Specifically, it pertains to reducing the number of entities or factors to a minimum in order to understand and explain something, especially in cause and effect terms. Moreover, parsimony can prevent overfitting a model—that is, when too many factors are used to tune or tweak the model to make it account for observed data.[20] Overfitting a model can reduce its predictive ability. For global climate models, parsimony insists that only factors having an impact on predicting trends in climate change be used. To multiply these factors unnecessarily would hinder the construction of functional models. By assuming parsimony, then, global climate models can be constructed to simulate or represent reliably global climate change.

One of the chief problems facing climate models is that to account for past climate data often requires introducing fudge factors.[21] For example, Richard Kerr claims that "climate modellers have gotten into the habit of fiddling with fudge factors, so called 'flux adjusters', until the model gets it right."[22] Obviously, we cannot apply fudge factors in forecasting future climate. So to the extent that climate models need fudge factors to hindcast past climate patterns accurately, their ability to

16. See Jouni Räisänen, "How Reliable Are Climate Models?" *Tellus A* 59, no. 1 (2007): 2-29.

17. See Wendy S. Parker, "Climate Science." *The Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta, 2018, https://plato.stanford.edu/archives/sum2018/entries/climate-science/.

18. See Simon Shackley et al., "Uncertainty, Complexity and Concepts of Good Science in Climate Change Modelling: Are GCMs the Best Tools?" *Climatic Change* 38, no. 2 (1998): 159-205.

19. See Daniel Nolan, "Quantitative Parsimony." *The British Journal for the Philosophy of Science* 48, no. 3 (1997): 329-43; Elliott Sober, "The Principle of Parsimony," *The British Journal for the Philosophy of Science* 32, no. 2 (1981): 145-56.

20. See Ratnadip Adhikari and Ramesh K. Agrawal, *An Introductory Study on Time Series Modeling and Forecasting* (Saarbrücken, Germany: Lambert Academic Publishing, 2013); Frédéric Hourdin et al., "The Art and Science of Climate Model Tuning," *Bulletin of the American Meteorological Society* 98, no. 3 (2017): 589-602.

21. See Neil A. Hutton, *Climate Change* (Calgary, Alberta: Canadian Society of Petroleum Geologists, 2009); Anthony Lupo and William Kinimonth, "Global Climate Models and Their Limitations." In *Climate Change Reconsidered II: Physical Science*, 7-148. Nongovernmental International Panel on Climate Change, 2013. https://www.heartland.org/_template-assets/documents/CCR/CCR-II/Chapter-1-Models.pdf; Doug M. Smith et al., "Real-Time Multi-Model Decadal Climate Predictions." *Climate Dynamics* 41, no. 11-12 (2013): 2875-88.

22. See Richard Kerr, "Climate Change: Model Gets It Right—Without Fudge Factors," *Science* 276, no. 5315 (1997): 1041-42, p. 1041.

forecast future climate is jeopardized. Assuming parsimony prevents forcing the model to fit past climate data, although it does not guarantee the ability of the model to predict future climate change. For the environmental conditions, such as greenhouse gas emissions responsible for past climate change, may be different from future conditions and the model may not be able to account for that change.[23]

There are several conceptual issues with the construction of global climate models, especially for predicting trends in global climate change. The first is that uncertainty involved in predicting global climate trends—due to the technical challenges involved in collecting and analyzing climate data—has an impact on the level of confidence in forecasting such trends.[24] Such uncertainty is common not only in global climate science but also in most natural sciences. Part of this uncertainty results from the complexity of the factors responsible for climate change.[25] Given this complexity, climate models cannot precisely or completely predict the degree of global climate change but can only provide a range of possible change. Unfortunately, uncertainty often compounds or adds to itself in terms of a "cascade of uncertainties."[26] So, uncertainty surrounding the measurement and reporting of carbon emissions, for example, can lead to uncertainty in modeling their impact on global climate, which can lead to uncertainty as to how to proceed in terms of climate policy formation.[27]

Members of Trump's administration continue to deny global climate change and to muddle issues surrounding it. As Sidney Fussell reports in *Climate Change*, "When Bernie Sanders asked [Scott Pruitt] what caused global warming, Pruitt said CO_2 from human activity 'impacted,' rather than 'caused' climate change."[28] Pruitt's distinction between impact and cause is conceptually incorrect. In fact, the most controversial issue surrounding causation and global climate change has to do with whether global warming is caused by human activity (anthropogenic) or simply the result of natural cycles. If global climate change is just the result of natural cycles, then humans are not responsible for it and probably can do little to reduce it. Although global temperature is presently increasing, it may eventually return to lower temperatures as part of a natural cycle. If, on the other hand, global climate change is caused by human activity, then that activity must be altered so as to reverse or reduce climate change. In other words, if human activity is causing an increase in global temperature, then this activity must be curtailed or decreased to minimize its potential damage on the environment.

Moreover, it is a false dichotomy, or an at best questionable argument, to claim that global climate change is *either* caused by natural cycles *or* by human activity. In fact, scientific evidence suggests that *both* human activity and natural cycles significantly contribute to climate change.[29] The two forces sometimes lead to the same effect, as when both natural cycles and human activity are increasing global

23. It is important to note that climate models continue to evolve and that the use fudge factors are not as prevalent today as they were several decades ago. But, as Gerald North and Kwang-Yul Kim recently advised fellow climate modelers in *Energy Balance Climate Models* (Weinheim, Germany: Wiley-VCH, 2017), "we must be 'parsimonious' with our fudge factors" (28).

24. See Wendy S. Parker, "Values and Uncertainties in Climate Prediction, Revisited." *Studies in History and Philosophy of Science Part A* 46 (2014): 24-30; Arthur C. Petersen, "Philosophy of Climate Science." *Bulletin of the American Meteorological Society* 81, no. 2 (2000): 265-71; Eric Winsberg, "Values and Uncertainties in the Predictions of Global Climate Models." *Kennedy Institute of Ethics Journal* 22, no. 2 (2012): 111-37.

25. See David Rind, "Complexity and Climate," *Science* 284, no. 5411 (1999): 105-07.

26. See Stephen H. Schneider, "What is 'Dangerous' Climate Change?" *Nature* 411, no. 6833 (2001): 17-19.

27. See Alice E. Milne et al., "Communicating the Uncertainty in Estimated Greenhouse Gas Emissions from Agriculture," *Journal of Environmental Management* 160 (2015): 139-53. This, of course, leads to the question of when does the level of uncertainty become unacceptable. Under what conditions should we judge that climate models are too imprecise to guide policy formation? Answering such a question requires both an evaluation of the probability of error and a cost-benefit analysis of the risks involved in climate change. Ultimately, how much uncertainty is tolerable depends on what we, as a society, are willing to risk in terms of climate change. If we decide that the potential costs of climate change are too catastrophic, then we may have a high threshold for the level of uncertainty in climate models. If, on the other hand, we are willing to accept the risk of climate change for the potential economic benefits of weakening environmental policies, then we may have a lower threshold for uncertainty in climate models.

28. See Sidney Fussell, "Trump's New EPA Head Wants to Debate Global Warming as the World Burns." *Climate Change*, Mar. 9, 2017. https://gizmodo.com/epa-head-scott-pruitt-still-not-sure-about-this-carbon-1793122171.

29. See Naomi Oreskes et al., *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (London: Bloomsbury Publishing, 2011).

temperature, and other times pull global temperature in opposite directions, as when natural cycles cause cooling while humans cause warming. In either case, models must take into account both natural and anthropogenic factors if they are to represent global climate reliably.

A couple of examples may help to illustrate the importance of both natural and human factors in modeling global climate. In the first example, a climate model simulating the trend of increasing average surface atmospheric temperature shows that the climate change in the first half of the twentieth century was attributable to natural factors, such as solar and volcanic activity.[30] However, the model could not account for the warming trend in the second half of the century without including human production of greenhouse gases. Only after taking this anthropogenic factor into account, along with natural factors, was the model able to simulate the warming trend in the second half of the century. This is strong evidence that anthropogenic factors do significantly contribute to the earth's climate. Another example involves modeling the cooling trend during the latter 2000s in which both natural cooling and anthropogenic warming processes had an impact on overall temperature patterns.[31] These models and others like them confirm that both natural cycles and human activity contribute to change in climate. However, the issue is determining the relative contribution of natural and human factors to global climate change.

It is worth noting that although both natural cycles and human activity may be involved in global climate change, they are different in one important respect.[32] On the one hand, natural cycles can be responsible for trends towards cooling and warming. On the other hand, human activity, thus far, has only been to drive global climate towards warming and not towards cooling. There are, to be sure, certain human activities that are responsible for some level of cooling (for example, planting trees), but such activities pale in comparison to the impact of anthropogenic warming, especially greenhouse gas emissions.

Finally, assuming parsimony has an impact on climate models in terms of their precision. By intentionally ignoring factors that are not highly significant contributors to climate, a climate model misrepresents its target system. As a consequence, a certain degree of precision in model predictions is sacrificed by assuming parsimony. This results in a dilemma for climate scientists. A climate model that is too parsimonious sacrifices too much in terms of precision, and it ceases to be useful in that regard. On the other hand, a model that is too precise may be too complex to manipulate easily, and it may require too much computing resources. Thus, it ceases to be useful in that regard. The challenge is to find a model that provides a balance between parsimony and precision and that is well-equipped to serve the purposes it was designed to achieve—to help decide what ought to be done regarding human effect on climate.

In the end, climate scientists need to construct models that can account for and simulate climate change accurately so as to provide the necessary guidance for pragmatic action, especially through policy formation.[33] For this reason, it is usually acceptable to sacrifice a certain level of precision for the sake of parsimony. Another, promising way out of the dilemma is a pluralistic approach to climate modeling in which various models that simulate different dimensions of climate change can be integrated with one another to provide a more comprehensive picture or representation of that change, such as the Intergovernmental Panel on Climate Change's "multi-model ensembles" approach.[34]

30. See Peter A. Stott, "External Control of 20th Century Temperature by Natural and Anthropogenic Forcings," *Science* 290, no. 5499 (2000): 2133-37.

31. See Judith Perlwitz et al., "A Strong Bout of Natural Cooling in 2008," *Geophysical Research Letters* 36, no. 23 (2009): L23706.

32. See Peter A. Stott, "Attribution of Twentieth Century Temperature Change to Natural and Anthropogenic Causes," *Climate Dynamics* 17, no. 1 (2001): 1-21.

33. See Judith Curry, *Climate Models for the Layman* (London: The Global Warming Policy Foundation, 2017).

34. See Richard B. Norgaard and Paul Baer, "Collectively Seeing Climate Change: The Limits of Formal Models," *BioScience* 55, no. 11 (2005): 961-66; Fulvio Mazzocchi and Antonello Pasini, "Climate Model Pluralism beyond Dynamical Ensembles," *Wiley Interdisciplinary Reviews: Climate Change* 8, no. 6 (2017): e477; Wendy S. Parker, "Understanding Pluralism in Climate Modeling," *Foundations of Science* 11, no. 4 (2006): 349-68; Thomas F. Stocker et al., eds., *Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (New York: Cambridge UP, 2014).

3. How Do We Know Global Climate is Changing?

We examined in the previous section the nature of global climate models: what they aim to represent, the ends for which they are made, and, roughly, how they achieve those ends.[35] In this section, we explore what we can know and learn from these climate models. What do they reveal about the relationship between different factors affecting climate change? Also, what do they not tell us? What are their limitations? Most importantly, we discuss whether Trump's tweets constitute a serious challenge or objection to anthropogenic climate change.

As mentioned above, the earth's climate is a complex system that entails multiple factors.[36] Although climate models are significantly simpler than the natural events and processes they aim to represent, their simplicity makes them easy to use and provides valuable insights regarding how the earth's climate works. However, simplicity comes with a cost. Current climate models can only predict general changes in climate patterns. But, this level of precision does suffice for formulating government policies to control anthropogenic climate change, since it is general long-term patterns that such policies should address. Admittedly, the models cannot be used to predict a week-long cold-spell in the Midwest during January of 2050. But, this is not a problem because climate models need not be that precise in order to help make informed decisions on environmental policy concerning global climate change.

If we are to evaluate the reliability of climate models, we need the right kind of test.[37] That is, we need to test it against the phenomena that it is meant to represent. Thus, we cannot test a climate model against observed short-term weather events. The proper test for such a climate model's reliability involves comparing its predictions to observed, long-term climate patterns. If a model does not produce reliable predictions on long-term climate patterns, then it cannot help in making good, informed decisions on global climate change policy. Based on climate observations over the past seventy years, many climate models that take human production of greenhouse gases into consideration are reliable.[38]

Once a global climate model has been confirmed as reliable,[39] it can serve a variety of purposes. One important purpose is explanatory. It may provide the scientific framework needed to explain variations in climate—particularly in terms of global warming and why it is occurring. For example, sufficient evidence supports the claim that the rise in average global temperature is correlated with an increase in greenhouse gases.[40] Climate models use the greenhouse effect to explain the link between greenhouse gases and global temperature.[41]

As an extension of the explanatory purpose, reliable climate models can also serve predictive purposes. For example, these models can forecast what is likely to happen if greenhouse gasses are produced at the current rate from using fossils fuels.[42] The fundamental physical principles incorporated in the models are invariant. So, to the extent that the models are able to hindcast past climate changes, such as global warming, they can be used to forecast future climate changes as well. Again, the climate models do not predict short-term weather events but long-term climate trends. The models predict such things as the mean

35. See Edward J. Hall, *Philosophy of Science: Metaphysical and Epistemological Foundations* (Oxford: Wiley-Blackwell, 2009); Samir Okasha, *Philosophy of Science: Very Short Introduction* (New York: Oxford UP, 2016).
36. See Antonello, "Climate Models," *Rendiconti Lincei* 25 (2014): 49–58; David A. Randall et al., "Climate Models and Their Evaluation," in *Climate Change 2007: The Physical Science* Basis, ed. S. Solomon et al., 589-662 (New York: Cambridge UP, 2007).
37. See David C. Bader et al., *Climate Models: An Assessment of Strengths and Limitations* (Washington, DC: US Department of Energy Publications, 2008); Jouni Räisänen, "How Reliable Are Climate Models?" *Tellus A* 59, no. 1 (2007): 2-29.
38. See William James Burroughs, *Climate Change: A Multidisciplinary Approach* (Cambridge: Cambridge UP, 2007); Peter A. Stott et al., "External Control of 20th Century Temperature by Natural and Anthropogenic Forcings," *Science* 290, no. 5499 (2000): 2133-37.
39. See Naomi Oreskes et al., "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences," *Science* 263, no. 5147 (1994): 641-46.
40. See Jouni Räisänen, "How Reliable Are Climate Models?" *Tellus A* 59, no. 1 (2007): 2-29.
41. See Adolf Stips et al., "On the Causal Structure between CO2 and Global Temperature," *Scientific Reports* 6 (2016): 21691; Charles F. Keller, "Global Warming: The Balance of Evidence and Its Policy Implications. A Review of the Current State of the Controversy," *The Scientific World* 3 (2003): 357-411.
42. See Antonello Provenzale, "Climate Models," *Rendiconti Lincei* 25 (2014): 49–58.

temperature of a particular season, the mean precipitation, the likelihood of extreme weather, and so on. They do not predict the temperature of a particular geographical area over a particular weekend. Hence, Trump's 2015 tweet about a short-term cold spell cannot challenge the reliability of climate models, even if it certainly served rhetorical purposes politically.

So, what can challenge the reliability of global climate models? What does it take to make a strong scientific case for rejecting one of them? These questions raise the issue of what makes for a strong case against the current consensus among climate scientists about global climate change.[43] If climate skeptics are to provide a strong case against anthropogenic climate change, they must accomplish two things. First, they must show that current climate models cannot make reliable predictions of long-term patterns in climate based on observed data. That is, they must show that current climate models are unreliable, using the right kind of test.

Second, climate skeptics must present alternative models that are able to predict long-term patterns in climate without taking human activity into account. Climate skeptics claim that "there is essentially zero evidence that carbon dioxide from human activities is causing catastrophic climate change."[44] This is a bold claim. Current climate models are constructed by applying fundamental physical principles. So, to claim that they are basically misguided is to challenge these physical principles or how they are used in current climate models. To substantiate such a claim, climate skeptics must specify exactly how and why current climate science is mistaken about the basic principles of science. That is, they need to pinpoint the purported error that has led to the unacceptably inaccurate models climate scientists currently accept. One way that climate skeptics may do this is to build alternative models that can predict the observed climate patterns without including anthropogenic factors. This would allow them to show where they think the error lies in current climate models.

To the extent that climate skeptics fail to provide competing climate models, they are not engaging science properly, and they are certainly not making significant contributions to scientific inquiry and the global climate change controversy. As an analogy, civil engineering does not improve significantly if all that civil engineers do are to note imperfections in current infrastructure. Significant progress is made only when civil engineers design better infrastructure. Similarly, the impressive progress we have made in science is not merely based on the rejection of imperfect scientific theories and models. Rather, scientific progress is driven by the construction of better theories and models. Thus, climate skeptics need to engage in the constructive part of climate science, in the search for better climate models, rather than simply expressing dissatisfactions regarding the current state of climate science.

Trump and other climate skeptics fail to meet either of these requirements. As for the first, they do not provide the long-term patterns of climate change to rebut global climate models; rather they point to short-term weather fluctuations, which cannot disconfirm these models. As for the second requirement, they have not provided competing climate models that can reliably represent long-term patterns in climate, without factoring in human activity. Without alternative models, the current models, which make reliable predictions only when they take human activity into account, remain the best models available. Without alternative models, then, climate skeptics do not have a strong case against anthropogenic climate change.

In sum, current global climate models are not only reliable in terms of predicting global climate change but they are also reliable with respect to explaining why such change is occurring at its present rate. Climate change skeptics, like Trump and his administration, might be able to question these models but the data they use is unable to disconfirm these models and they propose no other models to

43. See Naomi Oreskes, "The Scientific Consensus on Climate Change: How Do We Know We're Not Wrong?" in *Climate Modelling: Philosophical and Conceptual Issues*, ed. Elizabeth A. Lloyd and Eric Winsberg, 31-64 (Cham, Switzerland: Palgrave Macmillan, 2018); Arthur C. Petersen, "Philosophy of Climate Science," *Bulletin of the American Meteorological Society* 81, no. 2 (2000): 265-71.

44. See Tom Harris and Bob Carter, "Leo vs. Science: Vanishing Evidence for Climate Change," *New York Post*, Sept 14, 2014, https://nypost.com/2014/09/14/leo-v-science-vanishing-evidence-for-climate-change/.

account for global climate change. Finally, besides not meeting these requirements, Trump and his administration also fail to respect the rational and empirical basis upon which the natural sciences, like climate science, function.

4. Conclusion

Trump and his administration continue to ignore the wicked problem of global climate change, especially with respect to national security.[45] In the Trump administration's 2018 National Defense Strategy and 2017 National Security Strategy reports, for example, the threat of climate change was not acknowledged or even mentioned, which broke with previous reports that included climate change as a serious threat to national security. Trump's and his administration's omission of climate change represents a failure in fiduciary responsibility or moral obligation to make this threat known. To address Trump's and his administration's failure, we have introduced a public philosophy of science to clarify the scientific and philosophical issues surrounding the global climate change controversy. In this final section, that philosophy is implemented in terms of incorporating the natural sciences, particularly global climate science, into the democratic process of deliberation so that we can participate thoughtfully and effectively in the controversy.[46] Kitcher's notion of a "well-ordered science" and the values that inspire it are utilized to achieve this end.

Kitcher introduces the notion of a well-ordered science to incorporate the natural sciences into the democratic process of addressing social issues.[47] According to Kitcher, "science is well ordered when its specification of the problems pursued would be endorsed by an ideal conversation, embodying all human points of view, under conditions of mutual engagement."[48] In other words, as members of a society, we are actively invested in engaging and even guiding science as it practices its trade of investigating natural events that have an impact on society. Thus, we are involved in the process by which scientists identify the problems that they investigate, the investment of resources to solve those problems, and the best social means by which to implement those solutions. Our role in well-ordered science, according to Kitcher, is not technical in terms of the science itself but rather it pertains to determining what values are important in motivating science. Moreover, he is quick to point out that this is an ideal process but an ideal worthy of pursuit. We agree with Kitcher, especially as it involves addressing the wicked problem of global climate change.

So how do we enter into an "ideal conversation" of "mutual engagement" with one another, in terms of the global climate change controversy? As Kitcher advises, the route to our participation in this conversation is through identifying values that inspire a well-ordered climate science. What, then, are the values upon which this science can be ordered to provide workable solutions and policies to global climate change? What kind of world do we want to live in with respect not only to ourselves but also to the rest of the natural world? Although there are a number of values that can inspire climate science towards investigating problems facing human flourishing, we contend that probably the most important value is sustainability. Global climate change is not just a threat to national security and defense but also to living in a renewable world in which its living and nonliving components can flourish not just in the short run but also in the long run. Unless climate change is addressed both through national and international policy, then even the sustainability of human life may be in jeopardy.

The natural sciences do not have a monopoly on authority to participate in the controversy surrounding global climate change. At best, they might settle from a technical perspective the controversy of whether human activity is, in fact, causing global climate change. So, a public philosophy of science can, at least, help to clarify what the controversy is regarding the science of climate change, as we have done in this paper. It does not, however, address the controversy regarding the moral, econom-

45. See Dan Drollette, Jr., "US Intelligence Chiefs Break with Trump on Climate Threat," *Bulletin of the Atomic Scientists*, Feb. 14, 2018, https://thebulletin.org/us-intelligence-chiefs-break-trump-climate-threat11514.

46. See Christopher Long, ""Practicing Public Scholarship," *Public Philosophy Journal* 1, no. 1 (2018), http://kora.matrix.msu.edu/files/118/700/76-2BC-9F-19-76-2BC-9F-19-PracticingPublicScholarship.pdf.

47. See Philip Kitcher, *Science in a Democratic Society* (Amherst, NY: Prometheus Books, 2011) and *Science, Truth, and Democracy* (New York: Oxford UP, 2001).

48. See Philip Kitcher, *Science in a Democratic Society* (Amherst, NY: Prometheus Books, 2011), p. 105.

ic, social, or political implications of climate change. It is insufficient by itself to address what ought to be done in light of the scientific evidence that points the finger at human activity as a significant factor responsible for climate change. To address sufficiently the moral, economic, social, or political issues surrounding climate change also requires a public moral philosophy, a public economic philosophy, a public social philosophy, and a public political philosophy. Philosophers of science can and must work cooperatively with these public philosophies to address the controversy surrounding the wicked problem of climate change.

Finally, as Christopher Long argues, we must be informed of the goals, consequences, competing values, and necessary sacrifices surrounding issues facing society in order to make effective decisions to resolve them.[49] To nurture a comprehensive understanding of the controversy surrounding climate change, we contend that all aspects of the controversy, including the moral, economic, social, and political, must eventually be addressed. Only then can we be informed sufficiently to make knowledgeable and effective decisions on how to address global climate change—decisions that lead to a sustainable environment and are conducive to human and global flourishing.

ACKNOWLEDGMENTS

We thank Dean Christopher Long at Michigan State University for the opportunity to participate in the fourth annual *Public Philosophy Journal* Collaborative Writing Workshop. We also thank Andrea Walsh for serving as editor of the manuscript and the reviewers, Alison Singer and Joseph White, for their insightful comments on earlier versions of it, as well as Kurt Milberger for editing its final version. Finally, we thank Dean Lee Nordt at Baylor University for his support of our project.

BIBLIOGRAPHY

Adhikari, Ratnadip, and Ramesh K. Agrawal. *An Introductory Study on Time Series Modeling and Forecasting*. Saarbrücken, Germany: Lambert Academic Publishing, 2013.

Bader, David C., Curt Covey, William Gutowski, et al. *Climate Models: An Assessment of Strengths and Limitations*. Washington, DC: US Department of Energy Publications, 2008.

Bailer-Jones, Daniela M. *Scientific Models in Philosophy of Science*. Pittsburgh: U of Pittsburgh P, 2009.

Burroughs, William James. *Climate Change: A Multidisciplinary Approach*. Cambridge: Cambridge UP, 2007.

Cartwright, Nancy. *How the Laws of Physics Lie*. New York: Oxford UP, 1983.

Charlesworth, Mark, and Chukwumerije Okereke. “Policy Responses to Rapid Climate Change: An Epistemological Critique of Dominant Approaches.” *Global Environmental Change* 20, no. 1 (2010): 121-29.

Curry, Judith. *Climate Models for the Layman*. London: The Global Warming Policy Foundation, 2017.

Drollette, Jr., Dan. “US Intelligence Chiefs Break with Trump on Climate Threat.” *Bulletin of the Atomic Scientists*, Feb. 14, 2018. https://thebulletin.org/us-intelligence-chiefs-break-trump-climate-threat11514.

Edwards, Paul N. “History of Climate Modeling.” *Wiley Interdisciplinary Reviews: Climate Change* 2, no. 1 (2011): 128-39.

———. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. Cambridge, MA: MIT Press, 2010.

Flato, Gregory M. “Earth System Models: An Overview.” *Wiley Interdisciplinary Reviews: Climate Change* 2, no. 6 (2011): 783-800.

Frigg, Roman, and Stephan Hartmann. “Models in Science.” *The Stanford Encyclopedia of Philosophy, ed. Edward N. Zalta, 2018.* https://plato.stanford.edu/entries/models-science.

Fussell, Sidney. “Trump’s New EPA Head Wants to Debate Global Warming as the World

49. Christopher Long, “Practicing Public Scholarship,” *Public Philosophy Journal* 1, no. 1 (2018), http://kora.matrix.msu.edu/files/118/700/76-2BC-9F-19-76-2BC-9F-19-Practicing-PublicScholarship.pdf.

Burns." *Climate Change*, Mar. 9, 2017. https://gizmodo.com/epa-head-scott-pruitt-still-not-sure-about-this-carbon-1793122171.

Gardiner, Stephen M. "Ethics and Global Climate Change." *Ethics* 114, no. 3 (2004): 555-600.

Gettelman, Andrew, and Richard B. Rood. *Demystifying Climate Models: A Users Guide to Earth Systems Models*. New York: Springer, 2016.

Guillemot, Hélène. "Connections between Simulations and Observation in Climate Computer Modeling. Scientist's Practices and 'Bottom-up Epistemology' Lessons." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 41, no. 3 (2010): 242-52.

Hall, Edward J. *Philosophy of Science: Metaphysical and Epistemological Foundations*. Oxford: Wiley-Blackwell, 2009.

Harris, Tom, and Bob Carter. "Leo vs. Science: Vanishing Evidence for Climate Change." *New York Post*, Sept 14, 2014. https://nypost.com/2014/09/14/leo-v-science-vanishing-evidence-for-climate-change/.

Hourdin, Frédéric, Thorsten Mauritsen, Andrew Gettelman, et al. "The Art and Science of Climate Model Tuning." *Bulletin of the American Meteorological Society* 98, no. 3 (2017): 589-602.

Hutton, A. Neil. *Climate Change*. Calgary, Alberta: Canadian Society of Petroleum Geologists, 2009.

Incropera, Frank P. *Climate Change: A Wicked Problem*. New York: Cambridge UP, 2016.

Katzav, Joel. "The Epistemology of Climate Models and Some of Its Implications for Climate Science and the Philosophy of Science." *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics* 46 (2014): 228-38.

Keller, Charles F. "Global Warming: The Balance of Evidence and Its Policy Implications. A Review of the Current State of the Controversy." *The Scientific World* 3 (2003): 357-411.

Kerr, Richard. "Climate Change: Model Gets it Right—Without Fudge Factors." *Science* 276, no. 5315 (1997): 1041-42.

Kitcher, Philip. "The Climate Change Debates." *Science* 328, no. 5983 (2010): 1230-34.

———. *Science in a Democratic Society*. Amherst, NY: Prometheus Books, 2011.

———. *Science, Truth, and Democracy*. New York: Oxford UP, 2001.

Kusky, Timothy M. *Climate Change: Shifting Glaciers, Deserts, and Climate Belts*. New York: Facts on File, 2009.

Lawson, Richard. "Climate Science and Falsifiability." *Philosophy Now* 104 (2014): 28-29.

Long, Christopher P. "Practicing Public Scholarship." *Public Philosophy Journal* 1, no. 1 (2018): http://kora.matrix.msu.edu/files/118/700/76-2BC-9F-19-76-2BC-9F-19-PracticingPublicScholarship.pdf.

Lupo, Anthony, and William Kininmonth. "Global Climate Models and Their Limitations." In *Climate Change Reconsidered II: Physical Science*, 7-148. Nongovernmental International Panel on Climate Change, 2013. https://www.heartland.org/_template-assets/documents/CCR/CCR-II/Chapter-1-Models.pdf.

Magnani, Lorenzo, and Tommaso Bertolotti, eds. *Handbook of Model-Based Science*. New York: Springer, 2017.

Matthews, Dylan. "Donald Trump Has Tweeted Climate Change Skepticism 115 Times. Here's All of It." *Vox*, Jun. 1, 2017. https://www.vox.com/policy-and-politics/2017/6/1/15726472/trump-tweets-global-warming-paris-climate-agreement.

Mazzocchi, Fulvio, and Antonello Pasini. "Climate Model Pluralism beyond Dynamical Ensembles." *Wiley Interdisciplinary Reviews: Climate Change* 8, no. 6 (2017): e477.

Milne, Alice E., Margaret J. Glendining, R. Murray Lark, et al. "Communicating the Uncertainty in Estimated Greenhouse Gas Emissions from Agriculture." *Journal of Environmental Management* 160 (2015): 139-53.

National Geographic. *Before the Flood*. Oct. 30, 2016. https://archive.org/details/youtube-90CkXVF-Q8M.

Neelin, J. David. *Climate Change and Climate Modeling*. Cambridge: Cambridge UP, 2011.

Nolan, Daniel. "Quantitative Parsimony." *The British Journal for the Philosophy of Science* 48, no. 3 (1997): 329-43.

Norgaard, Richard B., and Paul Baer. "Collectively Seeing Climate Change: The Limits of Formal Models." *BioScience* 55, no. 11 (2005): 961-66.

North, Gerald R., and Kwang-Yul Kim. *Energy Balance Climate Models*. Weinheim, Germany: Wiley-VCH, 2017.

NOVA. *Decoding the Weather Machine*. PBS, Apr. 18, 2018. https://www.pbs.org/wgbh/nova/video/decoding-the-weather-machine.

Okasha, Samir. *Philosophy of Science: Very Short Introduction*. New York: Oxford UP, 2016.

Oreskes, Naomi. "The Scientific Consensus on Climate Change: How Do We Know We're Not Wrong?" In *Climate Modelling: Philosophical and Conceptual Issues*, ed. Elizabeth A. Lloyd and Eric Winsberg, 31-64. Cham, Switzerland: Palgrave Macmillan, 2018.

Oreskes, Naomi, and Erik M. Conway. *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*. London: Bloomsbury Publishing, 2011.

Oreskes, Naomi, Kristin, Shrader-Frechette, and Kenneth Belitz. "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences." *Science* 263, no. 5147 (1994): 641-46.

Parker, Wendy S. "Climate Science." *The Stanford Encyclopedia of Philosophy, ed. Edward N. Zalta, 2018*. https://plato.stanford.edu/archives/sum2018/entries/climate-science/.

———. "Understanding Pluralism in Climate Modeling." *Foundations of Science* 11, no. 4 (2006): 349-68.

———. "Values and Uncertainties in Climate Prediction, Revisited." *Studies in History and Philosophy of Science Part A* 46 (2014): 24-30.

Perlwitz, Judith, Martin Hoerling, Jon Eischeid, et al. "A Strong Bout of Natural Cooling in 2008." *Geophysical Research Letters* 36, no. 23 (2009): L23706.

Petersen, Arthur C. "Philosophy of Climate Science." *Bulletin of the American Meteorological Society* 81, no. 2 (2000): 265-71.

Provenzale, Antonello. "Climate Models." *Rendiconti Lincei* 25 (2014): 49–58.

Räisänen, Jouni. "How Reliable Are Climate Models?" *Tellus A* 59, no. 1 (2007): 2-29.

Randall, David A., Richard A. Wood, Sandrine Bony, et al. "Climate Models and Their Evaluation." In *Climate Change 2007: The Physical Science* Basis, ed. S. Solomon et al., 589-662. New York: Cambridge UP, 2007.

Rind, David. "Complexity and Climate." *Science* 284, no. 5411 (1999): 105-07.

Schmidt, Gavin A., and Steven Sherwood. "A Practical Philosophy of Complex Climate Modelling." *European Journal for Philosophy of Science* 5, no. 2 (2015): 149-69.

Schneider, Stephen H. "What is 'Dangerous' Climate Change?" *Nature* 411, no. 6833 (2001): 17-19.

Schrenk, Markus. *Metaphysics of Science: A Systematic and Historical Introduction*. New York: Routledge, 2017.

Shackley, Simon, Peter Young, Stuart Parkinson, et al. "Uncertainty, Complexity and Concepts of Good Science in Climate Change Modelling: Are GCMs the Best Tools?" *Climatic Change* 38, no. 2 (1998): 159-205.

Smith, Doug M., Adam A. Scaife, George J. Boer, et al. "Real-Time Multi-Model Decadal Climate Predictions." *Climate Dynamics* 41, no. 11-12 (2013): 2875-88.

Sober, Elliott. "The Principle of Parsimony." *The British Journal for the Philosophy of Science* 32, no. 2 (1981): 145-56.

Stips, Adolf, Diego Macias, Clare Coughlan, et al. "On the Causal Structure between CO2 and Global Temperature." *Scientific Reports* 6 (2016): 21691.

Stocker, Thomas F., Dahe Qin, Gian-Kasper Plattner, et al, eds. *Climate Change 2013: The Physical Science Basis: Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. New York: Cambridge UP, 2014.

Stott, Peter A., Simon F.B. Tett, Gareth S. Jones, et al. "Attribution of Twentieth Century Temperature Change to Natural and Anthropogenic Causes." *Climate Dynamics* 17, no. 1 (2001): 1-21.

Stott, Peter A., Simon F.B. Tett, Gareth S. Jones, et al. "External Control of 20th Century Temperature by Natural and Anthropogenic Forcings." *Science* 290, no. 5499 (2000): 2133-37.

Weart, Spencer R. *The Discovery of Global Warming*. Cambridge, MA: Harvard UP, 2008.

Winsberg, Eric. "Values and Uncertainties in the Predictions of Global Climate Models." *Kennedy Institute of Ethics Journal* 22, no. 2 (2012): 111-37.

Yip, Sidney, and Tomas Diaz Rubia. *Scientific Modeling and Simulations*. New York: Springer, 2009.

CONTRIBUTOR INFORMATION

James Marcum is professor of philosophy at Baylor University. He earned doctorates in philosophy from Boston College and in physiology from the University of Cincinnati Medical College. He was a faculty member at Harvard Medical School for over a decade before joining Baylor's philosophy department. He has authored or edited seven books and published several hundred articles appearing in journals such as *American Journal of Physiology*, *Biochemistry*, *Journal of Biological Chemistry*, *Journal of Cell Biology*, *Journal of Clinical Investigations*, *Journal of the History of Medicine and Allied Sciences*, *Perspectives in Biology and Medicine*, *Synthese*, and *Theoretical Medicine and Bioethics*.

Yunus Prasetya is a Ph.D. student in philosophy, studying at Baylor University. He is writing his dissertation on the topic of explanation in philosophy of science.