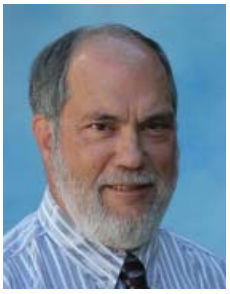

Thomas P. Ackerman

Response to Donald Morton

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Donald Morton wrote an article for *Perspectives on Science and Christian Faith*, to which I was asked to respond in a companion article.[1] Following the publication of these two articles, Morton responded with a shorter piece that included quite a few comments challenging the reality of human-induced climate change and the reliability of climate models.[2] As I struggled to find an appropriate response to Morton's comments, I began to feel that I had been assigned a new "labor of Hercules."

The crux of the matter is that, given a limited print space, it is far easier to raise issues and ask questions than to answer them, because adequate answers always take more words than the questions themselves. So, I find myself with a dilemma: I can write a short textbook on climate science or I can write a handful of very brief rebuttal statements. If I do the former, it will be too long to publish in this journal. If I do the latter, Morton (and perhaps other readers) will see my response as inadequate and perhaps even arrogant, because I must of necessity appeal to expert knowledge without providing detailed explanations of that knowledge. So what to do? Instead of responding to all of Morton's questions, I have tried to respond to a few of these, but focus on what I see is the core issue: Should we as Christians be actors in combating climate change or should we be passive watchers, or perhaps a spirited opposition?

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The Summary for Policy Makers (SPM) prepared by the International Panel on Climate Change (IPCC) in the most recent of their periodic reports (the Fifth Assessment Report or AR5) provides the following two conclusions.[3]

> SPM 1.2: Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century. (p. 4)
>
> SPM 2.2: Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise. (p. 10)

We climate scientists have tried to make these statements as clear and compelling as possible. Earth surface temperature has warmed significantly in the last one hundred years; greenhouse gas concentrations have increased during this same period to levels not seen in the last 800,000 years (the extent of our reliable ice core measurements); increasing greenhouse gas concentrations are due

to human activity; and the overwhelming consensus of our science community is that these greenhouse gases are "extremely likely to have been the dominant cause of the observed warming." Furthermore, our carefully considered conclusion is that warming will continue throughout the twenty-first century leading to climatic extremes in the atmosphere and ocean. This is as close as we can get to the "dependable estimate" that Morton requests. The statements are both scientifically accurate and unambiguous.

Our primary measure of climate change is an increase in the global surface air temperature over the last century, but many other impacts of climate change are well documented. These include the loss of Arctic sea ice, an acceleration in the rate of sea level rise, melting glaciers, heat trapping in the ocean, increased thawing of permafrost, and the poleward migration of species. These effects can only become more severe over the next few decades.

One of Morton's contentions is that conclusions cannot be safely drawn from climate models because their uncertainties are too large. Morton supports this statement by extracting from a very long document (over 1,500 pages) a few sentences that discuss uncertainties in climate models. Uncertainty is an integral part of all science. The IPCC author teams are fully aware of the uncertainties in the models. Nonetheless, these author teams came to the conclusions I quoted. How do we reconcile the conclusions with the uncertainties? Is the climate science community being deliberately deceitful and trying to hide these issues? Morton suggests that the authors might be unduly influenced by government or IPCC "sponsors."[4] Hardly so. The SPM is drawn directly from the detailed report that summarizes the current state of our understanding of climate and climate change. A look through the IPCC volume on the physical science basis will convince one that there is enormous breadth in peer-reviewed climate research and that uncertainties are taken seriously in those research papers and the IPCC report. The climate science community has in fact considered the very issues that Morton raises and has concluded that, while important, they do not stand in the way of the conclusion that *human activity has changed and is changing our climate in ways that will negatively impact our future and the future of our children and grandchildren*.

What can I say in answer to Morton's specific questions about climate models? Actually, I and my colleagues can say a great deal, as evidenced by the hundreds of articles cited in the IPCC report. The climate models that we use to study current and future climate are not perfect, but they are very good, particularly when we use them to study changes in the global climate and changes in climate on large regional scales such as the United States. This applies to current climate, changes in past climate, and projections of future climate. Many of the uncertain parts of climate science are about specific types of outcomes (for example, storm frequency and intensity) and projections of changes in smaller regional climate patterns (such as monsoon rainfall).

In this context of prediction, Morton raises the very interesting subjects of the stochastic nature of the climate system and the role of chaos in climate science and projection. These issues are challenging to understand because of their complexity. But, they are receiving due attention from the climate science community and our collective understanding is included in the IPCC report. When Morton cites the IPCC report as stating, "There are fundamental limits to just how precisely annual temperatures can be projected, because of the chaotic nature of the climate system," he draws the unfounded conclusion that we have no understanding of the validity of the timescales of climate projections. No reputable climate scientist argues that climate models (or weather models) can be used to predict the global annual temperature precisely, because the randomness (stochastic nature) of internal variability in the climate system prevents us from doing so. Climate models are able to simulate temperature rise over the past century (albeit with certain caveats) but at the decadal (10-year) or longer timescale, which is what we expect. The statement quoted by Morton is not a concession by scientists of a flaw in climate models; it is an explanation of the model limits. In addition, the role of chaos in the climate system is much more nuanced than Morton suggests. While there appear to be attractors (relatively stable states) in the system, there are many of them and the transitions between states are relatively smooth.[5] The fact that we do not yet completely understand some of these complex issues does not detract from the conclusions of the IPCC report. In the opinion of the climate community, the report conclusions are not materially affected by the uncertainty remaining at this point.[6]

Morton spends considerable time criticizing the representation of clouds in climate models, particularly

the use of parameterizations. Climate scientists have invested an enormous amount of time and effort on this problem in the last twenty years. Despite Morton's assertion, clouds in climate models do not "enter simply as parameters." Climate-model clouds form, produce precipitation, and decay similarly to what occurs in the real world, based on mathematical expressions for the chemistry, physics, and thermodynamics of a wet atmosphere (one containing water vapor). These complex equations contain parameters, which are variables that need to be specified because they cannot be calculated within the model, generally because of a lack of computer time. One example of a parameter might be the average size of a cloud droplet or ice particle. The values of these parameters are determined by comparison with data from large atmospheric field programs, time series data from ground observing sites, and satellite data records. Most of these data have been acquired in the last 15–20 years by a constellation of complex instruments in space and on the ground. So, we might use global satellite measurements to say that the average droplet diameter in boundary layer clouds over the ocean is 15 micrometers, which is consistent with field observations (made from aircraft and ships) as well. Because clouds are highly reflective, we might find that droplets that are slightly smaller (say 13 micrometers) give better agreement with satellite measurements of top-of-atmosphere reflected solar radiation. Since a diameter of 13 micrometers is within the uncertainty of our measurements, we prefer to use 13 instead of 15. This is the extent of the "tuning" of models and is hardly the huge problem suggested by Morton. (Cloud properties and their effect on the earth energy budget is one of my ongoing scientific interests, so I am figuratively biting my tongue at this point, trying hard not to add another few pages!)

Detailed responses to Morton's assertions about clouds and parameterizations can be found in the IPCC report, volume 1 (particularly chapter 7 on clouds and chapter 9 on the evaluation of climate models) and in the references cited there as well. Uncertainties are discussed at length. Contrary to Morton's assertions, climate models are not "linear approximations" to past data, nor are parameters set to arbitrary values. There is no evidence for his statement that "the physics quickly is overwhelmed by the adjustment (tuning) of hundreds of parameters …" In fact, as I just discussed, such tuning does not occur in the manner that he suggests and these parameters are part of the physics, not some afterthought.

Our current climate models solve a set of coupled and fully nonlinear differential equations in both atmosphere and ocean. We simulate the future by forcing these equations with projections of increasing greenhouse gas concentrations. We also simulate the effects of possible changes in solar activity, volcanic activity, and human-generated air pollution. Finally, we continue to test our models against current observations and against past data. As we learn more about how climate science works, we continually improve our models to make them the best representation of climate that we can.

Now let's move on to what I see is the issue at the core of Morton's comments. If climate change science is correct and our current actions are creating a situation that threatens human lives and ecosystems around the world, then as Christians we must respond to that situation by altering our behavior and working to alter the behavior of our broader society. If one can argue, however, that climate science is terribly uncertain, then we do not have to do anything. Suppose that climate scientists are wrong in our estimates of anticipated climate change effects over this century. How wrong do we have to be before this issue no longer demands an ethical response? If what actually happens to climate over the next fifty to one hundred years is somewhat less than climate scientists are currently predicting, would that absolve us from taking action now? If what happens is only half as bad, would that absolve us? Do we then do nothing? Apparently Morton thinks so, because he claims that if 50% of the warming to date is anthropogenic, then we have nothing to worry about. As far as I know, this statement is completely unsupported by any evidence.

Furthermore, uncertainty is a two-edged sword. What if what happens is actually worse than what we are predicting (an equally plausible outcome)? It is possible that global warming may alter the climate much more than we currently expect. How should we behave when that outcome is a risk? The best science on the problem of climate change says that we are driving our planet toward a very uncertain future and that future is most problematic for the poor, the generations yet to be born, and the ecosystems on which we depend. You can see these arguments and evidences fleshed out in the second

volume of the IPCC report on *Impacts, Adaptation and Vulnerability*. The National Academy of Sciences has also produced numerous reports on climate change, the science, uncertainties and likely outcomes (for example, the multi-volume work *America's Climate Choices*).[7] Reports arriving at similar conclusions have been written by learned societies in other countries.

Morton ends his commentary with three things that we should do. The first is that "we should state the whole truth about the uncertainties in the climate models including the fraction of warming actually due to human activity." I (and my scientific colleagues) absolutely agree. That is why the IPCC report runs to 1,500 pages. Because these models are complex, stating the whole that is known about their uncertainties requires hundreds of pages. However, we can summarize what we know in shorter format. The most recent and currently best summary on climate change and its uncertainties, as well as the relative contributions of natural variability and human activity to that change, can be found in the IPCC report, volume 1, "Summary for Policy Makers" (p. 14). Morton's insistence on knowing the precise fraction due to human activity is a "red herring," distracting us from the essential point that human activity is causing, and will continue to cause, global warming, unless we reduce human emissions of greenhouse gases.

I certainly agree with Morton's point about not wasting energy. I am a strong advocate of using renewable energy resources, in part because that allows us to conserve fossil fuels for other uses than simply burning them and avoids a whole range of associated environmental problems. While I can and do practice energy conservation in my daily life, there are many actions that can be taken only at the societal level. I look forward to the Christian community taking an active lead in promoting energy conservation and the use of renewable energy in North America.

My position is that we need to take action now, because every day that we delay makes the problem worse, given the very long lifetime (hundreds of years at least) of carbon dioxide in our atmosphere. In 2013 a team of 31 international researchers who modeled a number of emissions projections concluded that, even if we could reach zero carbon emissions within fifty years (a very difficult task), it would take centuries to return ocean and surface temperatures to current conditions. This effect is called the "climate commitment." The actions we take today will play out over long periods of time.[8]

While neither Morton nor I are economists, analyses of the economic and social risks associated with climate change have been carried out. They show that the potential costs of waiting to change are high and that these costs can be reduced by acting now. Many economists disagree with the conclusions Morton raises, even in the face of scientific uncertainty. Some researchers have argued that "effective mitigation action must be started decades before the climate changes of concern are actually observed,"[9] and that "in general, uncertainty about a problem may indicate the need for more, or less, action to address it, depending on the nature of the unknowns."[10]

Certainly, there are costs to changing our reliance on fossil fuels. There are also costs to not doing so, and conversely, benefits from making such changes. The US government and many parts of the private sector recognize the costs of inaction. For example, FEMA is requiring states to have climate change action plans before they receive disaster aid in the future, because of potential costs from sea-level rise and other problems. The Department of Defense also disagrees strongly with Morton's position, in part because they see climate change as a national security issue.[11] The insurance industry has come down on the side of climate change mitigation because the costs of climate change to industries and municipalities are significant. On the other hand, the costs of making changes in order to lower greenhouse gas emissions can provide co-benefits. Cleaning up the large atmospheric brown clouds that harm human health and crop growth over much of Asia would save human lives as well as slow greenhouse gas emissions. Promoting urban vegetation would absorb greenhouse gases but would also absorb dangerous particulates and lower local temperatures, two outcomes that would significantly improve human health in cities. Actions such as lowering food waste, something the U.N. has called for, would both help provide food for growing numbers of people, and lower carbon emissions.

Joel Pett of the *Lexington Herald-Leader* drew an often-reproduced cartoon that shows people at a climate summit conference listening to a speaker providing a list of benefits obtained by moving away from reliance on carbon-based fuels. These benefits include cleaner air and water, healthier children, sustainability, renewable energy, and so forth. A grumpy

individual in the audience then opines: "What if it's all a big hoax and we create a better world for nothing?" To some extent, this is my reply to Morton. Global warming is not a hoax. But, it is a major component of the multiple human impacts on the environment that are working together to damage our atmosphere, ocean, and land, as well as human health and agricultural productivity.

Creating a better world means first acknowledging that our actions are changing global climate, and then taking responsibility for those actions. It means leading our society toward a solution to the problem of climate change and toward a sustainable future. To do so, we must lower carbon emissions, and we need to start now. To be blunt, we should have started years ago. The few actions taken by the governments of the USA and Canada over the past two decades have had a largely negligible impact on CO_2 emissions and global warming. This is not because we cannot do anything, but because we will not. I agree with Morton that we need to think carefully about the costs and benefits of various actions, such as the use of biofuels to lower emissions, and that we should "terminate bad policies," but we cannot use "thinking" as an excuse to do nothing. Christians profess God's love for the world and for all God's children. We must show this love through our actions. We must be leaders, not reluctant followers, in the struggle to reduce carbon emissions and stabilize climate, not only for the sake of our generation, but for the sake of our children and our children's children. ◈

Notes

[1]D. C. Morton, "Climate Science and the Dilemma for Christians," *Perspectives on Science and Christian Faith* 66, no. 4 (2014): 236–41; and T. P. Ackerman, "Christian Action in the Face of Climate Change," ibid., 242–47.

[2]D. C. Morton, "Climate Science Continued," *Perspectives on Science and Christian Faith* 67, no. 2 (2015): 135–37.

[3]The IPCC "Summary for Policy Makers" is a condensation of each of the IPCC reports from three working groups: *I. The Physical Science Basis*; *II. Impacts, Adaptation and Vulnerability*; and *III. Mitigation of Climate Change*. These volumes, along with a "Synthesis Report" were prepared as part of the Fifth Assessment Report published during 2013–2014 (found at http://www.ipcc.ch/). These reports are the result of an exhaustive process of summarizing the existing scientific literature, reaching consensus on the conclusions of the literature, and thoroughly vetting those conclusions throughout the scientific community before publication. I strongly encourage those interested in this subject to read the "Summary for Policy Makers" (SPM). In his comments, Morton quotes from the IPCC report, *Climate Change 2013, The Physical Science Basis*, which provides the foundation for the SPM. The "Technical Summary" of this document is an excellent resource for the scientifically and technically inclined reader.

[4]This comment reflects a severe misunderstanding of the IPCC process. The IPCC was created by the United Nations Environmental Programme and the World Meteorological Organization to provide assessment reports. It does not fund the time of scientists involved in the assessments or provide research money, although it does fund travel expenses to IPCC meetings. The US government, as well as most countries, does not provide funding for IPCC assessment activities either. The result is that IPCC assessments require a substantial commitment of scientists' time with no remuneration of any kind. As a participant in WMO activities over the years, I can assure the readers that these activities have been a drain on my personal time and resources that has not been reimbursed in any way. Scientists such as I agree to do these activities because they are a public good, not because they provide personal rewards.

[5]Research published by our group at the University of Washington uses cluster analysis to show that atmospheric weather patterns can be sorted into similar states or clusters. The weather system moves smoothly and, in some cases, predictably from one clustered state to another. The number of clusters is not unique but depends on the amount of data available and the mathematical analysis being employed. See, for example, S. Evans, R. T. Marchand, and T. P. Ackerman, "Variability of the Australian Monsoon and Precipitation Trends at Darwin," *Journal of Climate* 27 (2014): 8487–8500. doi: http://dx.doi.org/10.1175/JCLI-D-13-00422.1.

[6]It is interesting to note that the word "chaos" does not even appear in volume 1 of the most recent IPCC report. There are, however, extensive discussions of natural climate variability, which is the expression of chaos in the climate system, and of climate-model ensembles (groups of identical model simulations starting with different initial conditions), which is one of the effective ways to study the effects of chaos. One might conclude from my first statement that climate scientists are ignoring chaos, but that is far from the truth. Our study of scientific chaos theory has led us to a deeper understanding of the climate system and how to simulate that behavior.

[7]National Research Council of the National Academy of Sciences, *America's Climate Choices* (Washington, DC: National Academies Press, 2011).

[8]K. Zickfeld et al., "Long-Term Climate Change Commitment and Reversibility: An EMIC Intercomparison," *Journal of Climate* 26 (2013): 5782–809.

[9]M. Webster et al., "Uncertainty Analysis of Climate Change and Policy Response," *Climatic Change* 61 (2003): 295–320.

[10]Congressional Budget Office (CBO), *The Economics of Climate Change: A Primer* (Washington, DC: Congress of the US CBO, 2003), 32.

[11]The Department of Defense (DoD) reports such as the "2014 Climate Change Adaptation Roadmap," http://www.scribd.com/doc/242845848/Read-DoD-report-2014Climate-Change-Adaptation-Roadmap; and the "FY 2012 Strategic Sustainability Performance Plan," http://www.acq.osd.mil/ie/download/green_energy/dod_sustainability/2012/DoD%20SSPP%20FY12-FINAL.PDF, provide insight into DoD thinking on climate change.