One Two Three More: Challenges to Describing a Warmer World

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Abstract

Our visions of warmer worlds are formed by a mix of firm century-old science and evolving state-of-the-art model output. The clarity of this vision when restricted to numerical models is limited, even for a zero degree warmer world. Various reasons for this are well known within the modelling community; these reasons are each sufficient to cloud our view, and we are unlikely to resolve all of them on the timescale on which critical policy decisions will be made. The implications for our determining the implications of a global climate change of 4+ degrees for people, ecosystems, and the Earth-system itself will be discussed and illustrated. Our inability to see details of a 4+ degree warmer Earth would in no way decrease the extreme impacts that such a change would bring us and the Earth-system. When interpreting model output in a naive-realism mode, the strongest rational arguments available to us suggest that our models reflect planets "similar to the Earth" but not the details of our Earth. Nevertheless our models provide robust results we expect to be shared by any planet roughly like ours, even one, say, with no long, high north-south mountain ridges. Our insights lie within this collection of "similar Earths" where the details of sub-gridscale parameterisations are not critical to the big picture: and that big picture defines and limits the results models can support as being robust. Once the details of the implementation matter (that is, the details of how some phenomenon or object is represented within a model), then we know we do not know; the insight provided by our models is not just uncertain, but unreliable, and we are dealing not with probability due to model uncertainty but ambiguity due to model inadequacy. To a large extent, today's robust results are supported by the models and, semi-independently, by climate science itself. We have high confidence that doubling CO2 will significantly warm the Earth, as it would any planet similar to our Earth. It would be of great value if climate scientists would clearly communicate explicit limits (in spatial resolution and in temporal resolution, as a function of lead time) of where current model output is believed to be robust. Where does insight fade? Where does model noise dominate? Where are we in an uncertain transition? Such limits would be of value not only to policy makers, but also to other specialist scientists considering impacts and adaptation. Alternative, softer, methods of communicating the limitations of our insight (such as including a lower-bound on structural model error in a pie chart, or presenting temperature anomalies as if they were temperatures) overstate our confidence, are likely to degrade decision making due to over-confidence, and threaten the credibility of the science in the longer term. Such limits to robustness will also, of course, be a function of the particular evolution a particular model run follows (that is, its trajectory in time), not just a function of space and time and lead-time. How do we best interpret models of warmer and warmer worlds as realistic visions of what a warmer Earth would look like, knowing that each trajectory carries a greater chance of a "Big Surprise" as the model moves farther and farther from our observations and insights of this Earth. Quantifying this chance, using the science to evaluate 145 the likelihood that today's model-visions of a warmer planet seriously misinform us, would be a significant value in decision support and policy making. Quantifying the probability of a “Big Surprise” is always an aid to model-based decision support, regardless of the application. In the case of climate policy, it might prove of more value than a detailed description of warmer model-worlds, if our aim is to inform rather than to motivate. A scientific presentation of a potential future is incomplete without some estimate of the probability that it is significantly misleading. This presentation offers an appeal for such calculations, it does not present them. Climate science argues on physical grounds

that some models are not expected to yield realistic results (defined, say, as "decision relevant" results), when they reach temperatures significantly greater than that model's "current" global mean value, a value which itself often differs significantly from that of the Earth. Current state-of-the-art model-worlds have global mean temperatures that fall within a range of about 3 degrees K. By construction, every model has an anomaly temperature of zero over the period used to define the anomaly, and that period varies depending on the results presented; often the anomaly is defined over 1900-1950 when discussing the last century, while when extrapolating into the future the period is often 1960-1990. Plotting anomalies clarifies agreement in "changes", both local and global, and gives the impression that the models agree. At the same time, local feedbacks (crops dying, ice melting, and so on) respond to the actual model-temperature, not the anomaly, and in this way agreement in anomalies might convey over-confidence in likely local effects and will not reflect the response of physics-based feedbacks in the model. Planets similar our Earth, but where Iceland or Britain, Indonesia or Mallorca do not exist, or where the Andes are a kilometre shorter, are expected to have similar global responses to a similar increase in levels of greenhouse gases, at least for small increases. For a civil servant or decision maker to view model output as suggestive of what our Earth would look like at 4+ degrees, what it would look like locally in OX1 1DW, in England, or across Europe based upon today's climate models, today's scientists must have some rational expectation that the global models provide high fidelity at that resolution and those global temperatures. The alternative is to accept that we know we do not know the details; few would recommend over-interpreting model noise. At longer lead times, feedbacks from differences in the eastern South America due to a low Andes range, for example, would be expected to have significant impact elsewhere in the world. Downscaling adds relevant details only under the assumption of fidelity on the large scales. At 4+ degrees, when might we expect "small scale" feedbacks to remain unimportant? With the caveats above, and those below, we can examine the variability among modelworlds which share the same global mean temperature. It will be seen that the available ensembles of model-worlds show wide variety in regional changes for the same global mean temperature, regions the size of the Central United States or Europe for example. Further, there is significant overlap in local changes in the same region in a +3 degree model-world and in a +5 degree model world. The take-home message for policy makers is that for regions as small as most countries, knowing the global mean temperature leaves significant uncertainty in the local response. And in politics, arguably, all climate is local. For informed decision making, our current climate models have limited skill at the resolution of most countries even under current conditions, our knowledge of vulnerability to natural variability comes more from observations and science than from modelling. Noting that this is the case for a zero degree warmer world, and accepting that the "climate signal" for large 146 scale average changes will soon come out of the noise (if it has not already), we can embrace the fact that our models are not very informative regarding what will actually be observed on the length scales of countries for even 2 or 3 degree warmer worlds. Decision relevant information on local impacts need never come "out of the noise" regardless of how clearly the "climate signal" does. The fact that 4+ degree warmer worlds would almost certainly initiate both known and unexpected feedbacks, feedbacks that are known not to be in today's models, sits uncomfortably with knowledge that most of the feedbacks discussed are positive and would lead to more warming globally-on-average. The policy question is whether or not we wish to explore these 4+ degree worlds empirically, given our limited vision of just how dangerous they might prove to be. Can we improve our vision of 4+ degree worlds short of driving our Earth to these temperatures? The fact that details of the trajectory determine its reliability means that interpreting ensembles as a probability distribution (in any Monte Carlo fashion, whether Bayesian or other) is fundamentally misguided. The diversity of our models simply fails to reflect the uncertainty in our future, even when a specific emissions scenario and other future non-climate drivers are fully specified. Determining global temperature at which a model should disqualify itself (becoming a "more" with no further quantitative information on even global mean temperature) is an open question for climate science. As the title of this presentation suggests, that number might be uncomfortably low, requiring decisions to be made under deep uncertainty.