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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Dangerous human-made interference with climate: a GISS modelE study" *by* J. Hansen et al.

J. Hansen et al.

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We thank both referees for thoughtful reviews, which were very helpful for improving our paper.

Response to Referee #1

1. The referee expressed mild concern about terms such as "dangerous anthropogenic interference", "disruptive climate effects", and "tipping points". We appreciate his/her assessment that use of such terms depends on personal preference and that our use of the terms has been cautious.

Our conscious decision to use these terms is consistent with documented conclusions of the paper. One of our principal conclusions is that the "dangerous" level of global warming is probably much lower (nearer) than has commonly been assumed. Because

of the relevance of this conclusion to the public and policy-makers, we believe that it is important to include terminology that can aid communication with that audience.

"Tipping point", although objectionable to some scientists, conveys aspects of climate change that have been an impediment to public appreciation of the urgency of addressing human-caused global warming. It is a valid concept: as climate forcing and global warming increase, a point can be reached beyond which part of the climate system changes substantially with only small additional forcing. Examples include loss of Arctic sea ice and ice sheet disintegration.

The practical importance of these intervals of high sensitivity, paradoxically, is amplified by climate system inertia, especially the inertia of oceans and ice sheets. One effect of inertia, in the real-world case with continually increasing climate forcing, is that the system is out of equilibrium. The extent of disequilibrium (measured, e.g., by the planetary energy imbalance) may be enough, as an interval of high sensitivity is reached, to carry the system through a change (loss of all Arctic sea ice or disintegration of an ice sheet) with little or no additional forcing.

This phenomenon is made doubly important by the fact that it is difficult to move the public and policy-makers to action to address global warming until deleterious effects become obvious. Thus "tipping points" are central to determination of "dangerous" climate change and a legitimate topic for scientific discussion.

We use the phrase "tipping point" only twice: once with regard to Arctic sea ice, where we refer to another paper in which the phrase is used extensively (even in the paper's title), and once in the discussion section regarding the overall concept of "dangerous". We have clarified what we mean by this phrase and we believe that it conveys well this meaning, so it is our preference to retain use of the phrase in these two cases.

2. and 3. The referee points out the need to clarify the model's ability to simulate water cycle changes. He notes that we emphasize temperature change, asks whether we can relate temperature change to changes of the water cycle and weather extremes (factors

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important to ecosystems, wildlife and humans, thus to determination of "dangerous"), and recommends a brief discussion of these matters to motivate our emphasis on temperature.

The most important changes of the water cycle with global warming are intensification of the pattern of precipitation minus evaporation and its temporal variance, as discussed, e.g., by Held and Soden (2006) and Lu et al. (2007). The GISS model captures these effects. There is general agreement among a large number of models (shown, e.g., in the papers just noted) about the nature of these hydrologic changes with projected global warming in the 21st century. There is also some paleoclimate evidence in support of the nature of these changes. Following the referee's recommendation, we have added two paragraphs (second paragraph in section 4 and third paragraph in section 6.1.2) making these points.

4. We agree with both suggestions, and have changed the title of subsection 4.2.2 to Tropical Atlantic climate change and included reference to Trenberth and Shea (2006).

5. We agree that it is useful to make transparent the subdivision of scientific conclusions and personal inferences. We have done as suggested: (1) adding a sentence to the introduction informing the reader of our intent to make note of policy implications and stimulate discussion about the role of scientists in the climate debate, and (2) starting section 6.2 with a statement that policy consequences and recommendations are being formulated.

6. The referee is correct. Somehow, despite extensive calculations and discussion about what constitutes dangerous change, we did not summarize our conclusions on that central issue. We have followed his suggestion, adding a brief statement at the beginning of section 6.2 and a sentence in the abstract.

7. We agree that it is appropriate to clearly separate our comments about the role of scientists in communicating the dangers of climate change to the public. Thus, as suggested, we have made those comments a separate subsection 6.2.2.

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Response to Referee #2

A. The referee notes that our examination of Arctic climate change uses simulations for the past (1880-2003) rather than the future. He suggests addition of some comparison to simulated future climate change, e.g., the change by 2050.

We have used this suggestion effectively, while not losing the merit of comparison with 1880-2003 simulations, which have the advantage of (1) comparison with observations, thus testing the model, and (2) breakdown of warming into components caused by CO2 and non-CO2 pollutants (our simulations for the future were made only for the sum of all long-lived GHG forcings, not for individual forcings). We have added to Figure 5 the 50-year (to 2050) GHG warmings for the IPCC BAU and the alternative scenarios. The result shows that additional 50-year warming in the alternative GHG scenario is similar to prior warming by non-CO2 pollutants. Thus reduction of these latter forcings could substantially reduce net future warming, provided that the future GHG forcing is small, as in the alternative scenario.

Addition of the 2000-2050 results to Figure 5 makes it a 2-column figure, thus providing opportunity to compare results for a polar projection, as suggested, without further increasing the space. For consistency with other figures, we have not changed the shape of existing figures.

B. We have not added to the figure for the tropical Atlantic, because of the large number of papers on this topic published in the past year. When we first submitted this paper (to another journal) in December 2005 the results were original. Tropical storms are relevant to determination of "dangerous" climate change, so we have kept our limited discussion, modifying the concluding statement to address dangerous change specifically.

C. We agree that (prior) Figure 9 (now Figure 10, as we exchanged their order) could be made more original and informative. We have followed the referee's suggestion of graphing cumulative emissions, which provides an informative result. Also we have

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clarified that the figure is restricted to fossil fuels, because fossil fuel emissions are known much more accurately than net deforestation/reforestation, and fossil fuel emissions are presumed to be dominant on the long run. We have modified the pie charts (still strictly fossil fuel), making their definition and significance clearer.

D. Figure 9b (current numbering) is the original amount of CO2 in the different fossil fuel reservoirs, with indication of how much of each reservoir has been used already. To obtain the amount of fossil fuel CO2 still in the air at any time, the amount emitted in each previous year must be multiplied by the decay function (Fig. 9a) for the appropriate time interval, and integration performed over emissions from all preceding years. We have clarified the description of these figures.

Interactive comment on Atmos. Chem. Phys. Discuss., 6, 12549, 2006.