MIT Joint Program on the Science and Policy of Global Change

Uncertainty Analysis of Global Climate Change Projections

Mort D. Webster, Chris E. Forest, John M. Reilly, Andrei P. Sokolov, Peter H. Stone, Henry D. Jacoby and Ronald G. Prinn

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The MIT Joint Program on the Science and Policy of Global Change is an organization for research, independent policy analysis, and public education in global environmental change. It seeks to provide leadership in understanding scientific, economic, and ecological aspects of this difficult issue, and combining them into policy assessments that serve the needs of ongoing national and international discussions. To this end, the Program brings together an interdisciplinary group from two established research centers at MIT: the Center for Global Change Science (CGCS) and the Center for Energy and Environmental Policy Research (CEEPR). These two centers bridge many key areas of the needed intellectual work, and additional essential areas are covered by other MIT departments, by collaboration with the Ecosystems Center of the Marine Biology Laboratory (MBL) at Woods Hole, and by short- and long-term visitors to the Program. The Program involves sponsorship and active participation by industry, government, and non-profit organizations.

To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

Henry D. Jacoby and Ronald G. Prinn,
Program Co-Directors

For more information, please contact the Joint Program Office

Postal Address: Joint Program on the Science and Policy of Global Change
77 Massachusetts Avenue
MIT E40-271
Cambridge MA 02139-4307 (USA)

Location: One Amherst Street, Cambridge
Building E40, Room 271
Massachusetts Institute of Technology

Access: Phone: (617) 253-7492
Fax: (617) 253-9845
E-mail: globalchange@mit.edu
Web site: http://MIT.EDU/globalchange/

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Peter H. Stone, Henry D. Jacoby and Ronald G. Prinn

Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology
77 Massachusetts Avenue, Building E40, Cambridge, MA 02139, USA

Communicating uncertainty in climate projections provides essential information to decision makers, allowing them to evaluate how policies might reduce the risk of climate impacts. In ongoing work, we use quantitative uncertainty techniques to develop this information. As an illustration of the approach we find that, absent mitigation policies, our median projection shows a global mean surface temperature rise from 1990 to 2100 of 2.3°C, with a 95% confidence interval of 0.9°C to 5.3°C (see figure). The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) reports a range for the global mean surface temperature rise by 2100 of 1.4 to 5.8°C[1] but does not provide likelihood estimates for this key finding although it does for others.

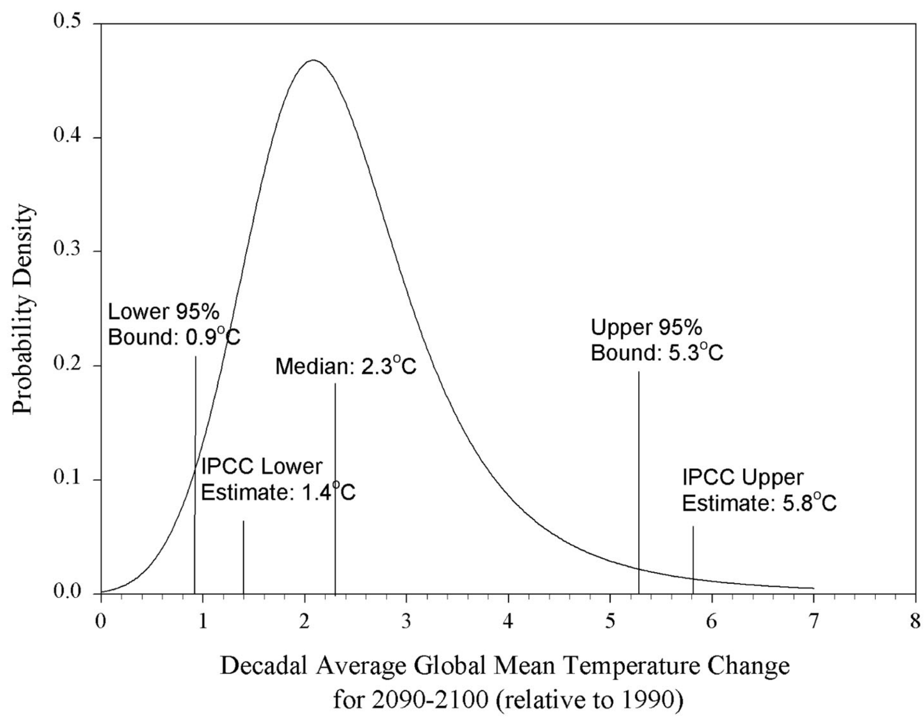
Our assessment applies an integrated earth systems model.[2,3] The climate model component is a two-dimensional (zonally averaged) model that reproduces the behavior of coupled atmosphere-ocean general circulation models (AOGCMs).[4] This flexibility allows us to analyze the effect of structural uncertainties present in existing AOGCMs.[5] We capture cascading uncertainties in natural and anthropogenic emissions of all climatically important substances, both gases and aerosols,[6] in the critical atmospheric, oceanic, and geochemical interactions, and in the carbon-cycle feedbacks from terrestrial ecosystems and the ocean. Our estimates of key climate model uncertainties are constrained by observations of the climate system for the period 1906-1995,[7] and uncertainty in emissions reflect errors in measurement of current emissions and expert judgment about variables that influence key economic projections.

Our estimated mean global surface temperature increase by 2100 is 2.5 °C, reflecting the fact that the distribution is skewed toward high temperature increases. In contrast to our analysis the IPCC does not indicate whether there is a 1 in 5 or 1 in 10,000 chance of exceeding its upper estimate of 5.8 °C. Our illustrative results suggest that there is about a 1 in 100 chance of a global mean surface temperature increase by 2100 as large as 5.8 °C. A caveat is that unknown and unmodeled processes (surprises) cannot be easily included in our analysis.

For decision-making we are often interested in low probability-high consequence events but it is critical to give some impression of their likelihood. Emissions reductions will lower the chance of exceeding an extreme climate outcome but not eliminate the risk entirely, and analysis of the reduction in probability is an important policy consideration. Our method allows us to calculate a very extreme warming scenario. For example, choosing all the 95% high warming input values, which has a joint probability of 1 in 2.5 million, will lead to a temperature increase of 8.1° C in 2100. Thus, quantifying uncertainty is essential for assessments intended to provide policy guidance.

Our research is not the last word on the likelihood of future climate change. Analysis is hampered by data gaps, inadequate understanding of key earth processes, and inadequate computation power. Still, future reports by the IPCC, and others presenting similar work, would better serve the policy process by including formal analysis of uncertainty for key projections, with an explicit description of the methods used.

A more complete report on this analysis is in preparation.



Probability density function for the change in global-mean surface temperature from 1990 to 2100, estimated as a best-fit of a beta distribution to 100 simulations using Latin Hypercube sampling from input distributions. The IPCC upper estimate is beyond our 95% confidence limit. Based on this distribution, there is a 12% chance that the temperature change in 2100 would be less than the IPCC lower estimate.

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