What Is “Dangerous” Climate Change?

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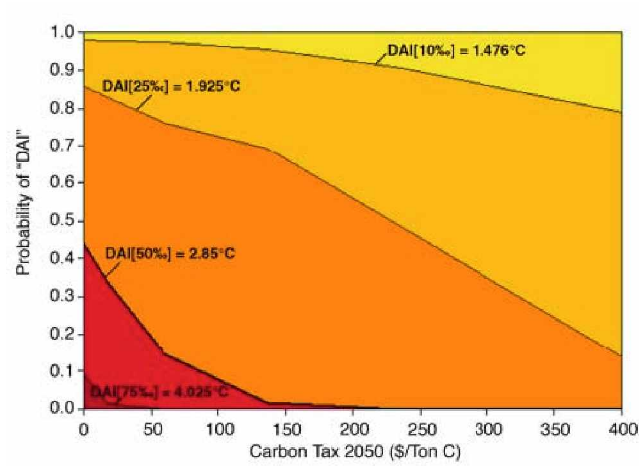
Sponsors: Partial support from the Winslow Foundation, the U.S. Department of Energy, and the National Science Foundation

Description: In 2001, the Intergovernmental Panel on Climate Change (IPCC) released its Third Assessment Report (TAR), which stated that the authors expected that the climate would warm between 1.4º to 5.8º C by 2100. Based on these temperature forecasts, the IPCC has produced a list of likely effects of climate change, some of which are positive (e.g., longer high-latitude growing seasons), but most of which are negative, including more frequent heat waves (and less frequent cold spells); more intense storms (hurricanes, tropical cyclones, etc.), and a surge in weather-related damage; increased intensity of floods and droughts; warmer surface temperatures, especially at higher latitudes; more rapid spread of disease; loss of farming productivity, mostly at lower latitudes; rising sea levels, which could inundate coastal areas and small island nations; and species extinction and loss of biodiversity. The IPCC also suggested that climate change could trigger “surprises”: rapid, non-linear responses of the climate system to anthropogenic forcing, thought to occur when environmental thresholds are crossed and new (and not always beneficial) equilibriums are reached. These surprises could include collapse of the “conveyor belt” circulation in the North Atlantic Ocean or rapid deglaciation of polar ice sheets and would likely qualify as what the 1992 United Nations Framework Convention on Climate Change (UNFCCC) called “dangerous anthropogenic interference with the climate system.”

Unfortunately, climate change assessments rarely consider low-probability, but high-consequence extreme events like surprises. Thus, decision-makers reading the “standard” literature will rarely appreciate the *full* range of possible climate change outcomes, and might be more willing to risk adapting to prospective changes rather than attempting to avoid them through abatement than they would be otherwise. We advocate an inclusion of abrupt events in scientific climate assessments, so that scientists can aid policymakers in defining “dangerous,” particularly by outlining the elements of risk, which is classically defined as probability x consequence, and suggesting policy measures that may be effective in reducing the chances of dangerous climate change occurring. Determining what constitutes “dangerous” climate change can be informed by scientific research, but it is ultimately a value-laden process, one that will undoubtedly lead to different assessments of danger for different stakeholders in different regions, who will apply different perceptions and values to the question. Although there are some impact categories for which thresholds exist beyond which there is a nonlinear response (e.g., ice sheet collapse), there are other categories for which different points along a rising continuum of impact intensity will be seen as “dangerous” by different people (e.g., sea level rise). Ultimately, what constitutes “dangerous” climate change must be decided by value judgments of policymakers, based on what risks they are willing to face and what risks must be avoided (hopefully, decisions based on sound scientific information).

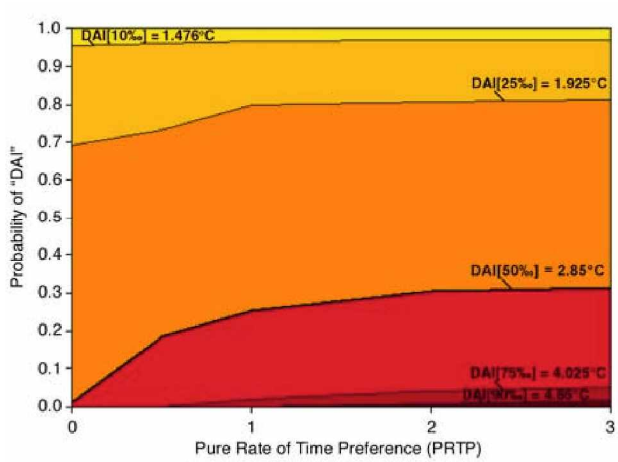
We have published two key papers in the last two years on this topic (Mastrandrea & Schneider, 2004 and Schneider and Mastrandrea, 2005 – listed in "Selected Publications") in which we present an analysis of plausible thresholds for "dangerous anthropogenic interference" (DAI) – that we suggest defining in terms of the accumulation of various impacts of climate change. In Mastrandrea and Schneider (2004), we presented a cumulative density function (CDF) of the threshold for DAI, based on the IPCC "Reasons for Concern about Climate Change." Each category represents a semi-independent "consensus estimate" of a metric for measuring "concern" about the climate system. One interpretation of these metrics is to see them as indicators of the level of global mean temperature change associated with DAI in the categories presented. Interpreted in this way, increasing temperatures will progressively exceed thresholds in each metric and cumulatively contribute to the likelihood that the climate change occurring will be perceived to be "dangerous" by an ever widening group of stakeholders and decision makers. This aggregation method acts to average the thresholds of each impact metric, producing a median, 50th percentile threshold of 2.85ºC above current temperatures, and a 90% confidence interval of [1.45°C, 4.65°C]. We intend this metric to represent the fact that, at some stage, there must be, implicitly or explicitly, an aggregation of stakeholder values in any internationally negotiated climate policy target based on preventing "dangerous" climate change. However, such an aggregation is likely to mean that "dangerous" change will not be avoided for some stakeholders. Thus, it is also important to consider individual stakeholder metrics, examples of which we present in Schneider and Mastrandrea (2005), based on individual "reasons for concern." We apply these DAI thresholds to the results of both optimizing integrated assessment models and climate models driven by specified emissions scenarios.

The figure below, from Mastrandrea and Schneider (2004), illustrates that whatever the threshold temperature for DAI, climate policy controls significantly reduce the probability of DAI occurring. For example, if DAI occurs at 1.925°C above current temperatures (DAI[25%]), then there is about an 85% chance that the threshold will be exceeded by 2100 in the absence of policy, and a less than 20% chance it will occur if the strongest policy (carbon tax of $400/ton) is implemented. If we inspect the median threshold for DAI (the thicker black line in the figure), we see that a carbon tax by 2050 of $150-$200/ton will reduce the probability of DAI by 2100 to nearly zero, from 45% without policy.



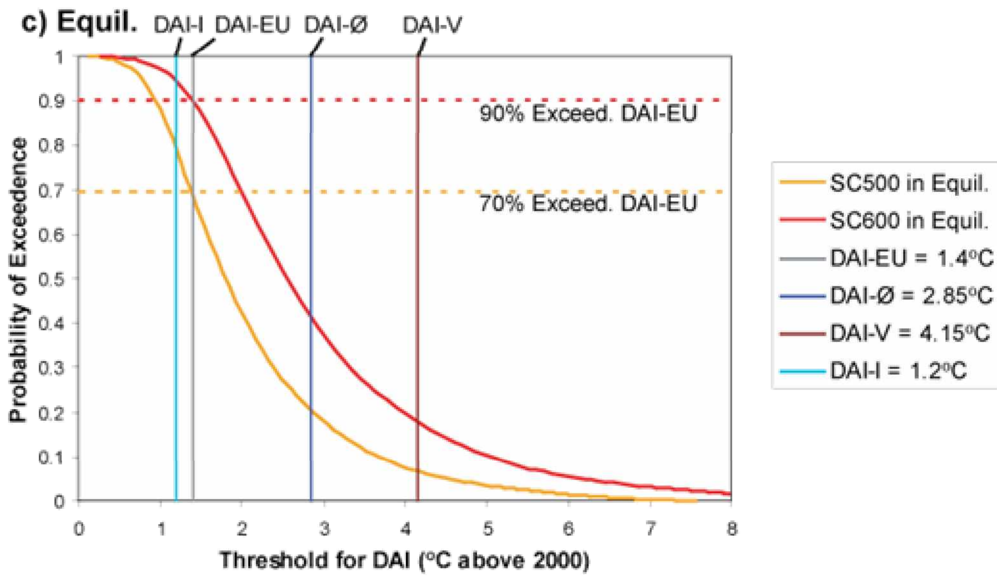
Our research indicates first, that abrupt changes are possible when certain thresholds are exceeded, and second, that including abrupt changes in integrated assessment models – common policy analysis tools which couple models of the climate system and the economic system and balance costs and benefits of climate change mitigation to determine an "optimal" policy – like the one discussed above, could significantly alter the definition of what is "optimal." Policy is also highly important in inducing more research into the development of "clean" (non-CO2-emitting) technologies. There is overwhelming evidence that energy policies are of *critical* importance to the development of alternative technologies and are more effective in spurring technological advancement than subsidies.

"Optimal" policies will rely not only on climate sensitivity and the degree of climate damages, but on the discount rate. Discounting is a method of aggregating costs and benefits over a long time horizon by summing net costs (or benefits), which have been multiplied by a discount rate typically greater than zero, across future time periods. If the discount rate equals zero, then each time period is valued equally (case of infinite patience). If the discount rate is infinite, then only the current period is valued (case of extreme myopia). The discount rate chosen in assessment models is critical, since abatement costs will be typically incurred in the relatively near term, but the brunt of climate damages will be realized primarily in the long term. Thus, if the future is sufficiently discounted, present abatement costs, by construction, will outweigh discounted future climate damages. In our recent research, we have found that incorporating large, non-linear damages (like "surprises") into our modeling considerably increases present "optimal" carbon taxes, using conventional discounting with pure rate of time preferences (a factor proportional to the discount rate) of 1.5% to 3.0%. In the figure below, also from Mastrandrea & Schneider (2004), we show how the probability of DAI changes with the pure rate of time preference. As shown for the median threshold case, the probability of DAI rises from near zero with a 0% PRTP (implying high carbon taxes) to 30% with a 3% PRTP (implying low carbon taxes).



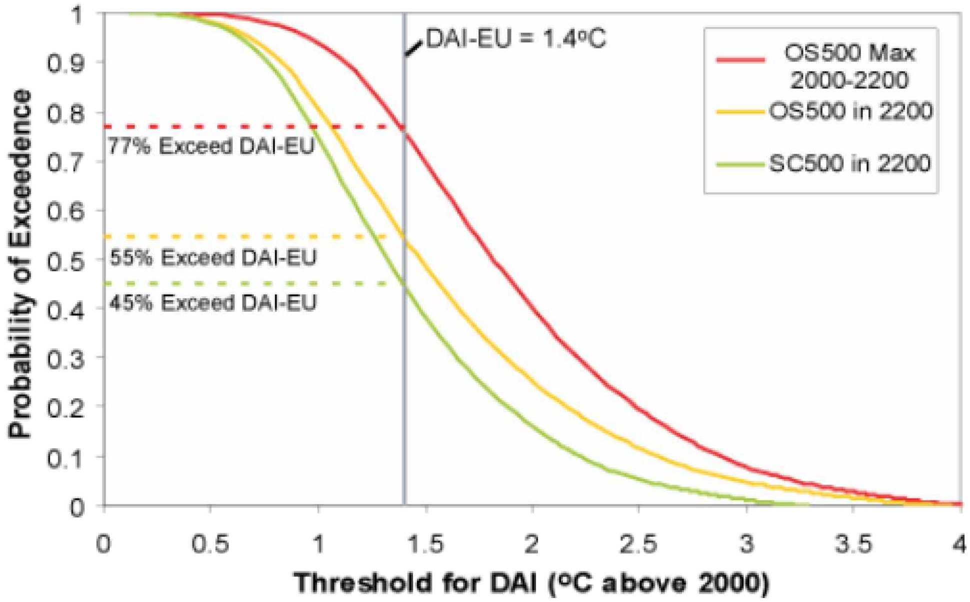
Article 2 of the UNFCCC mandates, "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" Our more recent research has focused on the implications of the uncertainty in the climate system for choosing stabilization levels, and probabilistic analysis of the relationship between concentration stabilization levels, temperature increase, and "dangerous" climate impacts.

Because of uncertainty in the climate sensitivity in response to increased atmospheric greenhouse gas concentrations, a given stabilization level (500 ppm or 600 ppm CO2-equivalent, in the figure below from Schneider and Mastrandrea, 2005) can induce a wide range of equilibrium temperature increase. This range of possibilities indicates that low long-term stabilization levels must be chosen to have a high probability of avoiding thresholds for DAI. For example, neither stabilization level implies a high probability of avoiding exceedence of the European Union threshold (DAI-EU) of 2ºC above preindustrial temperature (1.4ºC above current temperatures), as pictured here.



It is increasingly likely that approach to a future stabilization goal, should one be set, will follow an overshoot pathway, by which atmospheric concentrations exceed the desired goal temporarily before stabilizing. While overshoot profiles may reduce the mitigation costs of reaching a given stabilization level, they may also increase the climate impacts associated with a given stabilization goal. Further, the additional transient warming induced by overshoot stabilization profiles may exceed temperature thresholds for irreversible, abrupt nonlinear climate changes or impacts (like species extinctions), which will persist long after the temporary threshold exceedence. The higher and more rapid rise of temperatures will increase the probability of DAI exceedence for overshoot profiles, compared to monotonically increasing profiles reaching the same stabilization level. While overshoot profiles may ensure long-term stabilization below the desired temperature target, such profiles significantly increase the probability of temporary exceedence.

The figure below, from Schneider and Mastrandrea (2005), demonstrates this phenomenon by comparing the probability of exceedence of the 2ºC above pre-industrial temperatures (~1.4ºC above current temperatures) for an overshoot (OS500) and a non-overshoot profile (SC500) stabilizing at 500 ppm CO2-equivalent. The green and yellow curves display probabilities of exceedence for transient temperature increase in 2200, while the red curve displays probabilities of exceedence for the maximum temperature reached sometime between 2000 and 2200 for the overshoot (OS500) concentration profile. While there is only a modest increase in the probability of exceedence of the 2ºC threshold in 2200 between the two profiles, there is a significant increase in the probability of at least a temporary exceedence of the 2ºC threshold prior to 2200.



Other recent research has centered on equity issues in climate change (and especially abrupt climate change), particularly on the uneven distribution of effects climate change promises to bring and the injustice inherent in the policymaking process itself. We have also spent considerable time on our climate change website, where we present facts on climate science, impacts, and policy; maintain an up-to-date climate news section; and discuss various problems related to and solutions for getting messages on climate change out to policymakers and the public (including a very tongue-in-cheek section called “Mediarology”).

In summary, my group’s work has focused on climate science and impacts (including equity impacts), climate policy, and the crossroads between them. We attempt to express uncertainties in climate science and impacts estimation quantitatively as probability functions, though we do not assign high confidence to such probability distributions; much more research is needed in this area. We believe approaching climate change probabilistically gives the best chances of assuring that scientists’ and decision-makers’ respective areas of expertise are applied credibly to the policy process.

Status: A multitude of projects continue in the areas of subjective probabilities, “dangerous” climate change, surprises, evidence of anthropogenic climate change affecting plant and animal communities (known as fingerprinting studies), using integrated assessment models to find “optimal” abatement (and other) policy solutions, and other topics.

Selected Publications:

Mastrandrea, M.D. and S.H. Schneider, 2004: “Probabilistic Integrated Assessment of ‘Dangerous’ Climate Change,” Science 304: 571-573.

Root, T.L., J.T. Price, K.R. Hall, S.H. Schneider, C. Rosenzweig, and J. A. Pounds, 2003:

“'Fingerprints of Global Warming on Animals and Plants,” Nature 421: 57-60.

Schneider, S.H., 2003: “Imaginable Surprise", Chapter 54 in Potter, T.D. (ed.), Handbook of Weather, Climate, and Water (Hoboken, NJ: John Wiley and Sons), 947-954.

Schneider, S.H., 2004: “Abrupt Non-Linear Climate Change, Irreversibility and Surprise,” Journal of Global Environmental Change: Human and Policy Dimensions 14: 245-258.

Schneider, S.H. and J. Lane, 2005: Dangers and Thresholds in Climate Change and the Implications for Justice, Chapter 2 in Adger, N. et al. (eds.), Justice in Adaptation to Climate Change (Cambridge, MA: MIT Press).

Schneider, S. H. and Mastrandrea, M. D. 2005: “Probabilistic Assessment of ‘Dangerous’ Climate Change and Emissions Pathways,” Proceedings of the National Academy of Sciences 102: 15728-15735.

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