COMMENTARY

# Defining dangerous anthropogenic interference

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Few would dispute that the nations of the world should collectively do what must be done to avert elevating atmospheric greenhouse gas concentrations to the point of "dangerous anthropogenic interference" (DAI) with our climate. However, the devil, as they say, is in the details, details most recently explored by Smith et al. (1) in this issue of PNAS.

### Dangerous Anthropogenic Interference

The United Nations Framework Convention on Climate Change (UNFCCC) commits signatory nations (which includes all major nations including the United States) to stabilizing greenhouse gas concentrations at levels short of DAI. To properly define DAI, one must take into account issues that are not only scientific, but, as I have argued elsewhere (2), economic, political, and even ethical in nature. Defining DAI begs the question, for example, "*Dangerous* to whom?" It amounts to the tacit adoption of some level of risk, risk that will not be shared equally among all nations and people.

The Intergovernmental Panel on Climate Change (IPCC) is charged by the United Nations Environment Program (UNEP) to assess climate change risks in a way that *informs*, but, importantly, does not *prescribe* the government policies necessary to avoid DAI. It is therefore not surprising that the IPCC stops short of defining what DAI actually is, let alone advocating policies designed to avoid it.

The determination of climate change risk involves the process of "integrated assessment" (3), that is, taking theoretical climate model-based projections of future climate change, using appropriate approaches to assess the likely environmental, societal, and economic impacts, then attributing a level of risk to society and/or our environment presented by these potential impacts. Uncertainties exist at each step, and propagate through this process. Despite claims often heard to the contrary, however, uncertainty is hardly an excuse for inaction. Indeed, careful economic analyses indicate that the current uncertainties surrounding climate change render sizeable near-term investments to mitigate greenhouse gas emissions a sound economic strategy, due to the possibility of low-probability, high-impact events that cannot be ruled out (4–7).

In the IPCC third assessment report, Smith et al. (8) first presented the now famous "burning embers diagram," a graphic, easily digested representation of the level of threat or risk associated with future projected anthropogenic climate change with respect to five different categories or "reasons for concern" (RFCs) which include: (*i*) risk to unique or threatened systems (e.g., the loss of endangered species, unique ecosystems, indigenous communities, and island nations), (*ii*) risk of extreme weather (e.g., more extreme heat waves, floods, and droughts, and more intense tropical cyclones), (*iii*) distribution of impacts (i.e., the degree to which impacts are differentially harmful to different nations, regions, and populations), (*iv*) aggregate damages (a set of climate change impact metrics measuring economic costs, lives affected or lost, etc.), and (*v*) risk of large-scale discontinuities (e.g., "tipping point" phenomena, which could include the sudden loss or partial loss of the continental ice sheets, and abrupt changes in the modes of behavior of the ocean–atmosphere system impacting, e.g., water resource availability, among other possibilities).

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The burning embers diagram characterizes the extent to which each of these RFCs increase with increasing global mean temperature (GMT). In the absence of any way to quantify the precise levels of risk associated with uncertain climate change impacts, Smith et al. relied on "expert judgment" for this assessment. That is to say, the team of experts in diverse areas of climate change impact assessment ascertained, as best they could, the qualitative levels of risk with respect to each of these RFCs.

### Embers Burn Brighter

Smith et al. have now updated this important diagram based on the most up-to-date impact assessments described in the more recent, 4th assessment report (AR4) of the IPCC (9). The picture that emerges from their analysis suggests a view (see figure 1 of ref. 1) more dire than that the original version of the figure, reflecting the greater apparent risk that climate change is now seen to present across the 5 RFCs considered. Smith et al. attribute the increased apparent risk to the observation that hypothesized impacts are now actually beginning to be observed, to a better and more detailed understanding of the broad array of climate change impacts, and to evidence that even moderate additional warming could generate more substantial environmental and societal impacts than previously thought.

Indeed, findings that have emerged even in the time since Smith et al. (1) provided their latest assessment suggest the possibility that even their reassessment of climate change risk might be conservative in some respects. This is particularly true with respect to the potential destabilization of the West Antarctic ice sheet and concomitant future sea level rise. A larger part of Antarctica appears to be warming than was apparent at the time of the AR4 report (10) and, while not necessarily indicative of destabilization of grounded ice, the Wilkins ice shelf now appears ready to collapse in entirety (11). Meanwhile, more detailed analyses of the sea level rise footprint of West Antarctic ice sheet collapse indicate the likelihood of even greater (by ≈1 m) sea level rise in key regions such as the U.S. East Coast (12).

Consistent with the charge of the IPCC, which produced the original burning embers diagram, Smith et al. (1) stop short of attempting to define DAI, let alone suggesting policies to avert it. Their analysis nonetheless provides a useful framework for doing so. Reasonable people viewing the burning embers diagram could differ honestly in how they choose to infer from it an appropriate definition of DAI (5). However, the wiggle room seems somewhat limited. Given that risks to threatened systems, and risks associated with extreme weather enter into the "red zone," and the distribution of impacts begins to weigh heavily toward being adverse across diverse regions at ≈1 °C

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additional global mean warming (defined relative to a 1990 baseline), it would seem difficult for the risk averse among us to accept anything much above that as the standard for DAI. At 2 °C warming, we find that aggregate impacts begin to weigh toward the negative in most metrics, and the risk of large-scale discontinuities becomes nontrivial. Even those who "feel lucky" would thus find it hard to abide a definition of DAI much >2 °C.

So let us consider what actions would be necessary to avert DAI if it indeed lies within the range of 1–2 °C warming. We are already locked into anywhere from 0.3 to 0.7 °C additional "committed warming" relative to late 20th century levels due to the eventual impact of past historical emissions alone, with the precise level depending on the somewhat uncertain "sensitivity" of the climate to greenhouse gas forcing (12). (The sensitivity measures how much the globe will likely warm in response to a given increase in radiative forcing such as produced by an increase in greenhouse gas concentrations.) If the lower-end or even midsensitivity models are correct, we would (13) avoid 1 °C additional warming by stabilizing greenhouse gas concentrations at <450 ppm "$CO_2$ equivalent" (henceforth, "$CO_2$eq"—this represents the concentration of $CO_2$ that would give an equivalent radiative forcing to that provided by some basket of anthropogenic greenhouse gases). However, if the upper-range sensitivity models are correct, stabilization at 450 ppm $CO_2$eq would barely keep the future warming <2 °C (12). So regardless of one's precise definition of DAI, stabilizing greenhouse gas concentrations much above 450 ppm $CO_2$eq would be a terribly risky prospect. Accomplishing 450 ppm $CO_2$eq stabilization will require bringing global emissions to a peak within the next decade, and to ≈50% of the their 2000 levels by mid-century (12). As the industrializing world struggles to meet its end of the bargain, industrialized nations such as the United States will arguably need to make even more immediate cuts. A compelling argument has thus been made (14) that we bring our own emissions to a peak within the next few years, reducing our emissions to 80% <2000 levels by mid-century.

The risk is even greater than might be apparent from the foregoing discussion. First, it is quite possible that we will peak at greenhouse gas levels higher than the stabilization targets, in which case we will be exposed to the risk of even higher greenhouse gas concentrations for some period. Second, the precise magnitude of positive carbon cycle feedback is not known, and surprises could be in store. Finally, there is the so-called "Faustian Bargain" (15) that we have already entered into with respect to the offsetting impact of anthropogenic aerosols. If one considers the collective impact of anthropogenic greenhouse gases alone, we have already reached 450 ppm $CO_2$eq. It is only when the cooling due to anthropogenic aerosol production (e.g., sulfate) is taken into account (equivalent to ≈ −80 ppm $CO_2$eq) that we appear to be safely below the 450-ppm number, at an effective ≈375 ppm $CO_2$eq [this number is uncertain, due to the substantial uncertainty in estimates of the net impact of anthropogenic aerosols (13)]. If we were to suddenly halt the various dirty industrial and agricultural processes responsible for anthropogenic sulfate, nitrate, and other aerosols, we would suddenly find ourselves with 450 ppm $CO_2$eq on our hands. Although cleaning our atmosphere is indisputably a desirable goal, doing so would ironically make the goal of 450 ppm $CO_2$eq even more challenging, motivating the view that we must arguably strive to stabilize actual greenhouse gas concentrations <450 ppm $CO_2$eq (16).

The Smith et al. (1) analysis drives home the fact that there are indeed reasons for concern if we do not take relatively immediate and dramatic actions to curb fossil fuel emissions, and other activities, such as large-scale deforestation, contributing to elevated atmospheric greenhouse gas concentrations.


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