Tipping Points for Abrupt Climate Change
The Shadow that Haunts Climate Policy

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The paleoclimate records show that past climate changes have included both steady, linear changes as well as abrupt, non-linear changes, where small increases in global warming produced large and irreversible impacts once tipping points were passed. Climate scientists now warn that anthropogenic emissions are pushing the planet's climate system toward such tipping points and that impacts could be catastrophic.

Among potential impacts of passing climate tipping points are the disappearance of Arctic summer sea ice, disintegration of the Greenland Ice Sheet, collapse of the West Antarctic Ice Sheet, shutdown of the Atlantic Thermohaline Circulation, and dieback of Amazonian and boreal forests.[1] The catastrophic impacts from these events would include many meters of sea level rise, water shortages, mega-droughts, and famine, and could lead to political instability and wars.[2] Other impacts include release of methane from permafrost and ocean hydrates, which could set off runaway feedbacks.

In a recent study in the *Proceedings of the National Academy of Sciences*, V. Ramanathan and Y. Feng from Scripps Institution of Oceanography, University of California, San Diego, calculate that greenhouse gas [GHG] emissions as of 2005 have committed the planet to warming of "2.4˚C above the preindustrial surface temperatures,"[3] – in the range of predicted tipping points. See Figure 1. The present observed temperature increase of 0.76˚C[4] is misleading because warming of at least another 1˚C is presently being masked by "atmospheric brown clouds" containing cooling particulates released with greenhouse gas emissions and other pollution.[5] As we continue to reduce the pollution creating these clouds, largely for health reasons, we are unmasking the 1˚C temperature increase committed from current emissions.[6] An additional 0.6˚C warming is currently trapped by ocean thermal inertia.[7] Total committed warming is 2.4˚C, with more than 50% expected to occur within decades.[8]

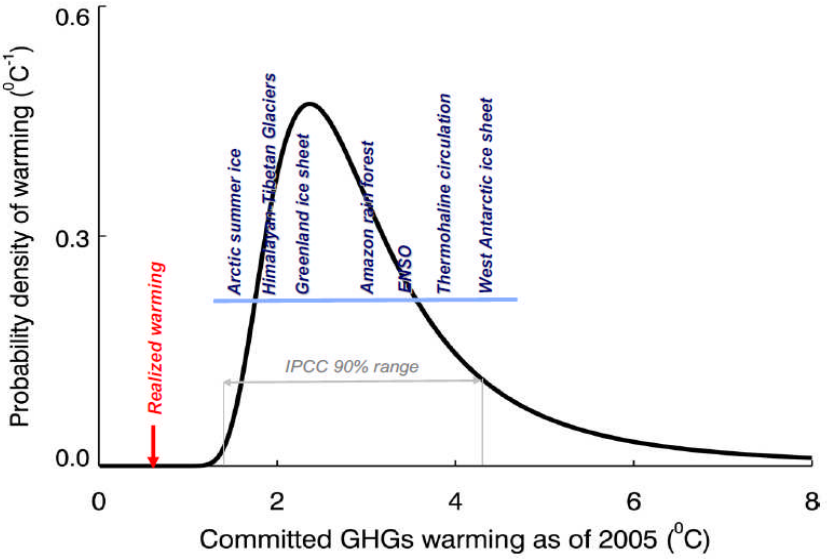

Fig. 1. Probability distribution for the committed warming by GHG between 1750 and 2005. … Shown are the tipping elements [large-scale components of the Earth's system] and the temperature threshold range that initiates the tipping. …[*]

[*] From V. Ramanathan and Y. Feng, *On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 38, 14245 (23 September 2008). [Request for permission pending.]

Impacts from this warming, Ramanathan and Feng observe, could include "widespread loss of biodiversity, widespread deglaciation of the Greenland Ice Sheet, and a major reduction of area and volume of Hindu-Kush-Himalaya-Tibetan (HKHT) glaciers, which provide the head-waters for most major river systems of Asia."[9]

At both high latitudes and high altitudes, temperatures are rising faster than the global average. The Arctic, Greenland, and the Tibetan Plateau are at particular risk.[10] Between 1965 and 2005, Arctic temperatures increased at least twice as fast as global averages.[11] The Greenland Ice Sheet is warming 2.2 times faster than global averages.[12] Meanwhile, on the Tibetan Plateau temperature increases of up to 0.3˚C per decade, about three times the global average, have been measured for the past half-century.[13] Melting Arctic sea ice produces positive feedbacks by reducing albedo, or reflectivity, leading to more absorption of heat by exposed Arctic waters.[14] Further darkening of polar surfaces is caused when black carbon, or soot, is released into the atmosphere and deposited on snow and ice.[15] Deposition of black carbon on snow and ice is also proposed as a major driver for the glacial retreat.[16]

Scientists estimate that tipping points for abrupt climate changes could be passed this century, or even this decade.[17] Under a "business-as-usual" scenario, where atmospheric CO_2 concentrations are increasing 2-3 ppm/year, the question is not whether abrupt climate change will occur, but rather how soon.[18] Dr. James Hansen agrees with Ramanathan and Feng that we have already passed the threshold for "dangerous anthropogenic interference" with the natural climate system. Hansen calculates that CO_2 concentrations must be reduced from their current 385 ppm to 350 ppm maximum if we want to preserve planetary conditions similar to those where civilization developed and humanity is adapted.[19] Current projections are that CO_2 concentrations will approach 441 ppm with a corresponding temperature of 3.1˚C by 2030 in the absence of strong countervailing mitigation.[20]

Despite the certainty that abrupt changes have occurred in the past and could be triggered again in the near future, current climate change policy does not account for abrupt climate change.[21] In particular, abrupt climate change is not incorporated into the projections of the Intergovernmental Panel on Climate Change (IPCC), which is regarded as the most authoritative, if often conservative, source of information on climate issues.[22] While the focus must continue on mid- and long-term mitigation strategies to reduce CO_2 emissions, we also must begin fast-action mitigation strategies that can produce immediate climate mitigation and help delay the onset of tipping points.

In his response to the Ramanathan and Feng study, Professor Hans Joachim Schellnhuber from the Potsdam Institute for Climate Impact Research concludes that "we are still left with a fair chance to hold the 2˚C line, yet the race between climate dynamics and climate policy will be a close one. The odds… may be improved by aerosol management… (taking the warming components such as black carbon out first), and even techniques for extracting atmospheric CO_2 (like bio-sequestration)… However, the quintessential challenges remain, namely bending down the global [climate emissions]… in the 2015-2020 window… and phasing out carbon dioxide emissions completely by 2100. This requires an industrial revolution for sustainability starting now."[23]

Black carbon, or soot, may be the second largest contributor to climate warming, and because its atmospheric lifetime is days to weeks, reducing it may offer the fastest mitigation.[24] Other near-term climate mitigation strategies include reducing other short-lived forcers such as methane and tropospheric ozone precursors,[25] as well as accelerating efforts under the Montreal Protocol to reduce ozone-depleting substances, which are powerful climate gases.[26] Other fast-track efforts include bio-sequestration in forests and soils. Biochar removes carbon from the carbon cycle by drawing down atmospheric concentrations of CO_2 in a carbon-negative process, and provides permanent carbon

storage while also improving soil productivity.[27] Improving energy efficiency and expanding renewables, especially wind, also can produce fast mitigation. Most of these near-term strategies have strong co-benefits, such as public health benefits from black carbon reductions, soil enhancement from biochar, and increased energy security from efficiency and renewables, providing further incentives to act now to forestall tipping points visible on the horizon.

Endnotes

[1] Timothy Lenton, Hermann Held, Elmar Kriegler, Jim Hall, Wolfgang Lucht, Stefan Rahmstorf, and Hans Joachim Schellnhuber, *Tipping elements in the Earth's climate system*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 6, 1786 (12 February 2008). *See generally*, CLIMATE BRIEFING NOTE ON TIPPING POINTS & ABRUPT CLIMATE CHANGES (IGSD, forthcoming October 2008), at _____.

[2] Lenton, *et al.*, *supra*, at 1788; Peter Schwartz and Doug Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security*, October 2003.

[3] V. Ramanathan and Y. Feng, *On avoiding dangerous anthropogenic interference with the climate system: Formidable challenges ahead*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 38, 14245 (23 September 2008).

[4] *Id.*, at 14247. Other authors describe observed warming as 0.8˚C instead of 0.76˚C. *See e.g.* James Hansen, Makiko Sato, Reto Ruedy, Ken Lo, David W. Lea, and Martin Medina-Elizade, *Global temperature change*, 103 PROC. OF THE NAT'L ACAD. OF SCI. 39, 14288 (26 September 2006) ("Global warming is now 0.6°C in the past three decades and 0.8°C in the past century.")

[5] *Id.*, at 14246-47.

[6] *Id*., at 14245-46.

[7] James Hansen, Makiko Sato, Pushker Kharecha, David Beerling, Valeris Masson-Delmotte, Mark Pagani, Maureen Raymo, Dana L. Royer, and James C. Zachos, *Target Atmospheric CO_2: Where Should Humanity Aim?* [hereinafter *Target Atmospheric CO_2*], 5.

[8] Ramanathan and Feng, *supra*, at 14247.

[9] *Id.*, at 14245.

[10] Lenton, *et al*, *supra*, at 1788 ("Transient warming is generally greater toward the poles and greater on the land than in the ocean."); *see also* Jane Qui, *The Third Pole*, NATURE, Vol 454, 393 (24 July 2008).

[11] Lemke, P., J. Ren, R.B. Alley, I. Allison, J. Carrasco, G. Flato, Y. Fujii, G. Kaser, P. Mote, R.H. Thomas and T. Zhang, 2007: Observations: Changes in Snow, Ice and Frozen Ground. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 339 ("Recent decreases in ice mass are correlated with rising surface air temperatures. This is especially true for the region north of 65°N, where temperatures have increased by about twice the global average from 1965 to 2005.")

[12] Petr Cheylik and Ulrike Lohmann, *Ratio of the Greenland to global temperature change: Comparison of observations and climate modeling results* GEOPHYSICAL RESEARCH LETTERS, Vol. 32, L14705 (21 July 2005).

[13] Qui, *supra*, at 393.

[14] Lenton, *et al*, *supra*, at 1788.

[15] V. Ramanathan and G. Carmichael, *Global and regional climate changes due to black carbon*, NATURE GEOSCIENCE, Vol. 1, 222 (23 March 2008).

[16] *Id*., at 224.

[17] Lenton, *et al*, *supra*, at 1786; Committee on Abrupt Climate Change, *Abrupt Climate Change: Inevitable Surprises*, National Academies Press, Washington, D.C., 2003, 107-8.

[18] James Hansen, *Climate Catastrophe*, NEW SCIENTIST, 28 July 2007.

[19] *Target Atmospheric CO_2*, *supra*, at 1.

[20] Ramanathan and Feng, *supra*, at 14247-14249.

[21] Peter Read and Jonathan Lermit, *Bio-Energy with Carbon Storage (BECS): a Sequential Decision Approach to the threat of Abrupt Climate Change*, 1 ("Abrupt Climate Change is an issue that 'haunts the climate change problem'(IPCC, 2001) but has been neglected by policy makers up to now, maybe for want of practicable measures for effective response, save for risk geo-engineering."); *see also* Lenton, *et al*, *supra* note 1, at 1792 ("Society may be lulled into a false sense of security by smooth projections of global change. Our synthesis of present knowledge suggests that a variety of tipping elements could reach their critical point within this century under anthropogenic climate change.") This may be changing, however, as the U.S. Department of Energy's Office of Biological and Environmental Research (OBER) recently launched IMPACTS – Investigation of the Magnitudes and Probabilities of Abrupt Climate Transitions – an effort by six national laboratories to address abrupt climate changes. *See Science Daily*, *Abrupt Climate Change Focus Of U.S. National*

Laboratories, Science Daily (23 September 2008) http://www.sciencedaily.com/releases/2008/09/080918192943.htm **(**The initial focus is on four types of ACC: instability among marine ice sheets, particularly the West Antarctic ice sheet; positive feedback mechanisms in subarctic forests and arctic ecosystems, leading to rapid methane release or large-scale changes in the surface energy balance; destabilization of methane hydrates (vast deposits of methane gas caged in water ice), particularly in the Arctic Ocean; and feedback between biosphere and atmosphere that could lead to megadroughts in North America.).

[22] *See e.g.* James Hansen, *Scientific reticence and sea level rise*, ENVIRON. RES. LETT. 2, 5 (2007).

[23] Hans Joachim Schellnhuber, *Global Warming: Stop worrying, start panicking?*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 38, 14239-40 (23 September 2008).

[24] V. Ramanathan and G. Carmichael, *supra*, at 222 ("The BC forcing of 0.9 W m–2 (with a range of 0.4 to 1.2 W m–2) … is as much as 55% of the CO_2 forcing and is larger than the forcing due to the other GHGs such as CH_4, CFCs, N_2O or tropospheric ozone."); and Mark Jacobson, *Control of Fossil-Fuel Particulate Black Carbon and Organic Matter, Possibly the Most Effective Method of Slowing Global Warming*, 107 J. GEOPHYS. RES. D19 (2002).

[25] V. Ramanathan, Testimony for the Hearing on Black Carbon and Climate Change, U.S. House Committee on Oversight and Government Reform 4 (18 October 2007).

[26] *See* Velders, *et al*., *The importance of the Montreal Protocol in protecting climate*, 104 PROC. NAT'L. ACAD. SCI. 4814-19, (20 March 2007), http://www.pnas.org/cgi/content/abstract/104/12/4814. (From 1990 to 2010, the Montreal Protocol will have reduced climate emissions by a net of 135 billion tonnes of CO_2-eq., delaying climate forcing by up to 12 years. This is ~ 13% of forcing due to accumulated anthropogenic emissions of CO_2, and several times the reductions sought under first phase of Kyoto Protocol.) In 2007, the Montreal Protocol was further strengthened to accelerate the phase-out of HCFCs; that adjustment has the potential to produce mitigation up to 16 billion tones of CO_2-eq. *See* US EPA 2008 Climate Award Winners, Team Award Winners, http://www.epa.gov/cppd/awards/2008winners.html ("The U.S. EPA estimates that, through 2040, the HCFC agreement could reduce emissions by up to 16 billion metric tonnes of carbon dioxide-equivalent. This is equal to the greenhouse gas emissions from the electricity use of more than 70 million U.S. households over the next 30 years."); TEAP, *Response to Decision XVIII/12, Report of the Task Force on HCFC Issues (with Particular Focus on the Impact of the Clean Development Mechanism) and Emissions Reductions Benefits Arising from Earlier HCFC Phase-Out and Other Practical Measures*, at 8, (August 2007), *available at* http://ozone.unep.org/teap/Reports/TEAP_Reports/TEAP-TaskForce-HCFC-Aug2007.pdf)

[27] Lehmann, Johannes, John Gaunt, and Marco Rondon, *Bio-char Sequestration In Terrestrial Ecosystems – A Review*, 11 MITIGATION AND ADAPTATION STRATEGIES FOR GLOBAL CHANGE 403, 404 (2006).