Institute for Governance & Sustainable Development

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

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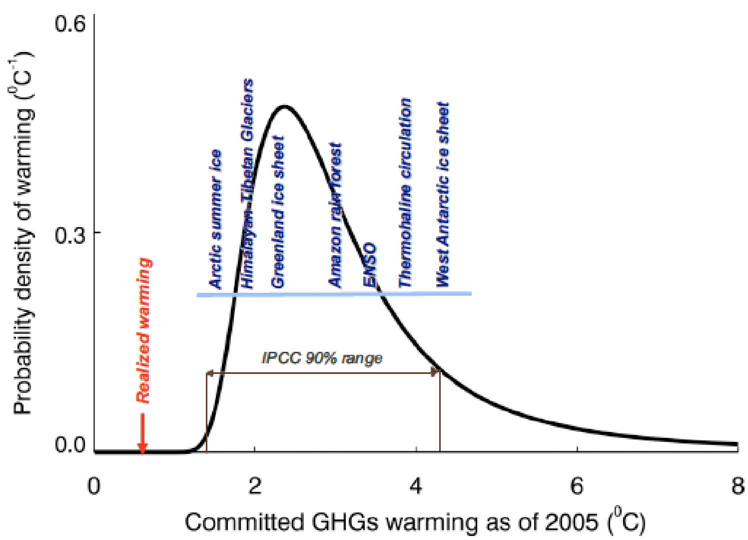
The paleoclimate records show that past climate changes have included both steady, linear changes as well as abrupt, non-linear changes, where small increases in global warming produced large and irreversible impacts once tipping points were passed. Climate scientists now warn that anthropogenic emissions are pushing the planet's climate system toward such tipping points sooner than previously expected, 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, megadroughts, and famine, and could lead to political instability and resource wars.[2] Other impacts include release of methane and other global warming gases 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] which is within the range of predicted tipping points. See Figure.



"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. …"[4]

The present observed temperature increase of 0.76˚C[5] 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.[6] As we continue to reduce the pollution creating these clouds, largely for health reasons, we are unmasking the 1˚C or greater temperature increase committed from current emissions.[7] An additional 0.6˚C warming is currently trapped by ocean thermal inertia.[8] Total committed warming is 2.4˚C, with more than 50% expected to occur within decades.[9]

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,"[10] including the Yellow, Yangtze, Red, Mekong, Irrawady, Ganges, and Indus.

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.[11] Between 1965 and 2005, Arctic temperatures increased at least twice as fast as global averages.[12] The Greenland Ice Sheet is warming 2.2 times faster than global averages.[13] 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.[14] Since the 1950's, warming in excess of 1˚C on the Tibetan side of the Himalayas has contributed to glacial retreat.[15] Melting Arctic sea ice produces positive feedbacks by reducing albedo, or reflectivity, leading to more absorption of heat by exposed Arctic waters.[16] Further darkening of polar surfaces is caused when black carbon, or soot, is released into the atmosphere and deposited on snow and ice.[17] Deposition of black carbon on snow and ice is also proposed as a major driver for the glacial retreat.[18]

Scientists estimate that tipping points for abrupt climate changes could be passed this century, or even this decade.[19] 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.[20] 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.[21] 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.[22]

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.[23] 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.[24] While the focus must continue on mid- and long-term mitigation strategies to reduce CO_2 emissions, we also must begin fast-track mitigation strategies that can produce immediate climate mitigation and help delay the onset of tipping points.

In his commentary 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."[25]

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.[26] Other near-term climate mitigation strategies include reducing other short-lived forcers such as methane and tropospheric ozone precursors,[27] as well as accelerating efforts under the Montreal Protocol to reduce ozone-depleting substances, which are powerful climate gases.[28] Other fast-track efforts include bio-sequestration in forests and soils. Biochar, for example, 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 and reducing the need for fossil fuel-based fertilizer.[29] Improving energy efficiency [30] and expanding renewables, especially wind, also can produce fast mitigation,[31] as can improving urban albedo.[32] 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

[*] Institute for Governance & Sustainable Development, www.igsd.org, and International Network for Environmental Compliance & Enforcement, www.inece.org.

[1] Timothy Lenton, Hermann Held, Elmar Kriegler, Jim Hall, Wolfgang Lucht, Stefan Rahmstorf & Hans Joachim Schellnhuber, *Tipping elements in the Earth's climate system*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 1786, 1786 (12 February 2008); *see also* WORLD WILDLIFE FUND, CLIMATE CHANGE: FASTER, STRONGER, SOONER (2008) ("It is currently forecast that [Arctic] summer sea ice could completely disappear somewhere between 2013 and 2040 – a state not seen on planet Earth for more than a million years."). *See generally*, CLIMATE BRIEFING NOTE ON TIPPING POINTS & ABRUPT CLIMATE CHANGES (IGSD, forthcoming October 2008).

[2] Lenton et al., *supra* note 1, at 1788; Peter Schwartz & Doug Randall, *An Abrupt Climate Change Scenario and Its Implications for United States National Security* (October 2003), http://handle.dtic.mil/100.2/ADA469325.

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

[4] *Id*.

[5] *Id.* at 14247. *See also* James Hansen, Makiko Sato, Reto Ruedy, Ken Lo, David W. Lea & Martin Medina-Elizade, *Global temperature change,* 103 PROC. OF THE NAT'L ACAD. OF SCI. 14288, 14288 (26 September 2006) ("Global warming is now 0.6˚C in the past three decades and 0.8˚C in the past century.").

[6] Ramanathan & Feng, *supra* note 3, at 14246-47.

[7] *Id*. at 14245-46.

[8] James Hansen, Makiko Sato, Pushker Kharecha, David Beerling, Valeris Masson-Delmotte, Mark Pagani, Maureen Raymo, Dana L. Royer & James C. Zachos, *Target Atmospheric CO_2: Where Should Humanity Aim?* 3 OPEN ATMOSPHERIC SCIENCE JOURNAL (forthcoming 2009) [hereinafter *Target Atmospheric CO_2*].

[9] Ramanathan & Feng, *supra* note 3, at 14247.

[10] *Id.* at 14245.

[11] Lenton et al., *supra* note 1, at 1788 ("Transient warming is generally greater toward the poles and greater on the land than in the ocean."); *see also* Jane Qiu, *The Third Pole*, 454 NATURE 393 (24 July 2008).
[12] P. LEMKE ET AL., INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Observations: Changes in Snow, Ice and Frozen Ground*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 339 (S. Solomon et al. eds., 2007) ("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.").
[13] Petr Cheylik & Ulrike Lohmann, *Ratio of the Greenland to global temperature change: Comparison of observations and climate modeling results*, 32 GEOPHYSICAL RESEARCH LETTERS L14705 (21 July 2005).
[14] Qiu, *supra* note 11, at 393.
[15] V. Ramanathan & G. Carmichael, *Global and regional climate changes due to black carbon*, 1 NATURE GEOSCIENCE 224 (23 March 2008). *See* Qiu, *supra* note 11, at 393 ("The Tibetan plateau gets a lot less attention than the Arctic or Antarctic, but after them it is Earth's largest store of ice. And the store is melting fast. In the past half-century, 82% of the plateau's glaciers have retreated. In the past decade, 10% of its permafrost has degraded. As the changes continue, or even accelerate, their effects will resonate far beyond the isolated plateau, changing the water supply for billions of people and altering the atmospheric circulation over half the planet…. The melting seasons on the plateau now begin earlier and last longer.... If current trends hold, two thirds of the plateau glaciers could be gone by 2050.") In the nearby Tibetan Plateau Steppe, where the headwaters of the Yangtze, Mekong, and Indus are located, there is concern both for short-term flood and long-term reductions in water supplies. *See*, *e.g.*, Qiu, *supra* note 11, at 395 ("The risk of floods, though, is but a short-term danger far exceeded by long-term issues with water supplies atop the [Tibetan plateau].")
[16] Lenton et al., *supra* note 1, at 1788.
[17] Ramanathan & Carmichael, *supra* note 15. *See also* Flanner, M.G., C.S. Zender, J.T. Randerson & P.J. Rasch, *Present-day climate forcing and response from black carbon in snow,* 112 J. GEOPHYS. RES. D11202 (2007) (noting that "the 'efficacy' of BC/snow forcing is more than three times greater than forcing by CO_2").
[18] *Id*. at 224.
[19] Lenton et al., *supra* note 1, at 1786; COMMITTEE ON ABRUPT CLIMATE CHANGE & NATIONAL RESEARCH COUNCIL, ABRUPT CLIMATE CHANGE: INEVITABLE SURPRISES 107-08 (2003).
[20] James Hansen, *Climate Catastrophe*, NEW SCIENTIST (28 July 2007).
[21] *Target Atmospheric CO_2, supra* note 8.
[22] Ramanathan & Feng, *supra* note 3, at 14247-49.
[23] Peter Read & Jonathan Lermit, *Bio-Energy with Carbon Storage (BECS): a Sequential Decision Approach to the threat of Abrupt Climate Change*, 30 ENERGY 2654, 2654 (November 2005) ("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 risky 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 (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.).
[24] *See*, *e.g.*, James Hansen, *Scientific reticence and sea level rise*, ENVIRON. RES. LETT. 2, 5 (2007).
[25] Hans Joachim Schellnhuber, *Global Warming: Stop worrying, start panicking?*, 105 PROC. OF THE NAT'L ACAD. OF SCI. 14239, 14239-40 (23 September 2008).
[26] Ramanathan & Carmichael, *supra* note 15, 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."); *see also* 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); and Qiu, *supra* note 11, at 396 ("Reducing emissions of greenhouse gases and black carbon should be the top priority," according to Xu Baiqing of the Institute of Tibetan Plateau Research.)
[27] *Role of Black Carbon on Global and Regional Climate Change: Hearing on the role of black carbon as a factor in climate change Before H. Comm. on Oversight and Gov't Reform*, 110th Cong. 4 (2007) (testimony of V. Ramanathan).

[28] *See* Guus J. M. Velders, Stephen O. Andersen, John S. Daniel, David W. Fahey & Mack McFarland, *The importance of the Montreal Protocol in protecting climate*, 104 PROC. NAT'L. ACAD. SCI. 4814, 4814-19 (20 March 2007), *available at* 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* U.S. 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."); TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL, UNITED NATIONS ENVIRONMENT PROGRAMME, 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 8 (August 2007), *available at* http://ozone.unep.org/teap/Reports/TEAP_Reports/TEAP-TaskForce-HCFC-Aug2007.pdf.

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

[30] Group of Eight Summit, Heiligendamm, Ger., June 6-8, 2007, *Growth and Responsibility in the World Economy: Summit Declaration*, ¶ 46 (June 7, 2007) ("Improving energy efficiency worldwide is the fastest, the most sustainable and the cheapest way to reduce greenhouse gas emissions and enhance energy security.").

[31] The IPCC has predicted that renewable energy sources, which have "a positive effect on energy security, employment and on air quality," will be able to provide 30-35% of the world's electricity by 2030. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Summary for Policymakers*, *in* CLIMATE CHANGE 2007: MITIGATION 13 (B. Metz et al. eds., 2007). The IPCC has also found that "wind is the fastest growing energy supply sector." INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, IPCC SCOPING MEETING ON RENEWABLE ENERGY SOURCES 4 (Olav Hohmeyer & Tom Trittin eds., 2008); *see also* GREENPEACE & GLOBAL WIND ENERGY COUNCIL, GLOBAL WIND ENERGY OUTLOOK 2006, at 38 (2006) ("Under the Advanced wind energy growth projection, coupled with ambitious energy saving, wind power could be supplying 29.1% of the world's electricity by 2030 and 34.2% by 2050.").

[32] *See* Hashem Akbari, Surabi Menon & Arthur Rosenfeld, *Global Cooling: Increasing Worldwide Urban Albedos to Offset CO_2*, CLIMATIC CHANGE[0] (forthcoming 2008) (If 100 large urban areas switched their roofs and pavement to highly reflective materials, the authors calculate this would "induce a negative radiative forcing of $4.4x10^{-2}$ Wm^{-2} equivalent to offsetting 44 Gt of emitted CO_2. A 44 Gt of emitted CO_2 offset resulting from changing the albedo of roofs and paved surfaces is worth about $1100 billion. Assuming a plausible growth rate of 1.5% in the world's CO_2-equivalent emission rate, we estimate that the 44 Gt CO_2-equivalent offset potential for cool roofs and cool pavements would counteract the effect of the growth in CO_2-equivalent emission rates for 11 years."); *see also* Hashem Akbari, *Global Cooling: Increasing World-wide Urban Albedos to Offset CO_2*, at the Fifth Annual California Climate Change Conference, Sacramento, CA (9 Sept. 2008), *available at* http://www.climatechange.ca.gov/events/2008_conference/presentations/2008-09-09/Hashem_Akbari.pdf. In California, which sets strict energy budgets for new construction, residential and some non-residential buildings can receive energy credits toward their energy budgets for installing "cool roofs." Cool roofs can lower roof temperatures up to 100 degrees Fahrenheit, reducing energy use for air conditioning and associated urban heat islands and smog. CAL. CODE REGS. tit. 24 § 118 (2007).