# the big melt

## Lessons from the Arctic summer of 2007

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# The big melt: lessons from the Arctic summer of 2007

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**Note:** *Unless otherwise specified, temperature increases are from the 1750 _pre-industrial level. The increase was 0.7°C to 2000 and 0.8°C to 2006.*

## Executive summary

- Climate change impacts are happening at lower temperature increases and more quickly than projected.
- The Arctic's floating sea ice is headed towards rapid summer disintegration as early as 2013, a century ahead of the International Panel on Climate Change (IPCC) projections.
- The rapid loss of Arctic sea ice will speed up the disintegration of the Greenland ice sheet, and a rise in sea levels by even as much as 5 metres by the turn of this century is possible.
- The Antarctic ice shelf reacts far more sensitively to warming temperatures than previously believed.
- Long-term climate sensitivity (including "slow" feedbacks such as carbon cycle feedbacks which are starting to operate) may be double the IPCC standard.
- A doubling of climate sensitivity would mean we passed the widely accepted 2°C threshold of "dangerous anthropogenic interference" with the climate four decades ago, and would require us to find the means to engineer a rapid drawdown of current atmospheric greenhouse gas.
- Carbon dioxide (CO2) emissions are now growing more rapidly than "business-as-usual", the most pessimistic of the IPCC scenarios.
- Temperatures are now within ≈1°C of the maximum temperature of the past million years.
- We must choose targets and take actions that can actually solve the problem in a timely manner.
- The object of policy-relevant advice must be to avoid unacceptable outcomes and seemingly extreme or alarming possibilities, not to determine just the apparently most likely outcome.
- The 2°C warming cap is a political compromise; with the speed of change now in the climate system and the positive feedbacks that 2°C will trigger, it looms for perhaps billions of people and millions of species as a death sentence.
- To allow the reestablishment and long-term security of the Arctic summer sea ice it is likely to be necessary to bring global warming back to a level at or below 0.5°C (a long-term precautionary warming cap) and for the level of atmospheric greenhouse gases at equilibrium to be brought down to or below a long-term precautionary cap of 320 ppm CO2e.
- The IPCC suffers from a scientific reticence and in many key areas the IPCC process has been so deficient as to be an unreliable and dangerously misleading basis for policy-making.

**Cover:** Melt descending into a moulin,a vertical shaft carrying water to Greenland ice sheet base.
Photo: Roger Braithwaite, University of Manchester (UK)

# Emissions trajectory

Carbon dioxide (CO2) emissions are rising at an increasing rate: a May 2007 study found the annual growth in global CO2 emissions caused by human activity jumping from an average 1.1 per cent for 1990–1999 to more than 3 per cent for 2000–2004. The growth rate since 2000 is greater than for "business-as-usual", the most fossil-fuel intensive of the International Panel on Climate Change (IPCC) emissions scenarios, and "no region is decarbonizing its energy supply" (Raupach et al., 2007).

The study also found that while emissions of CO2 are accelerating worldwide, we are gaining fewer economic benefits from each tonne of fossil fuel burned. Lead author Michael Raupach, _co-chairman of the Global Carbon Project based at the CSIRO in Canberra, notes that "a major driver accelerating the growth rate in global emissions is that, globally, we're burning more carbon per dollar of wealth created. In the last few years, the global use of fossil fuels has actually become less efficient. This adds to pressures from increasing population and wealth" (Innovations Report, 2007). In assessing the same data for Australia, Raupach found Australia's carbon emissions have grown at about twice the global average over the past 25 years, and about double the rate of emissions growth in the United States and Japan. Raupach concludes that because "emissions are increasing faster than we thought… the impacts of climate change will also happen even sooner than expected" (Minchin, 2007).

The rising rate of CO2 emissions is reflected in a larger annual increase in the level of atmospheric CO2. The average increase of 1.5 parts per million (ppm) for 1970–2000 has jumped to 2.2 ppm since 2001 (Adam, 2007c). James Hansen estimates that "if we go another 10 years, by 2015, at the current rate of growth of CO2 emissions, which is about 2 per cent per year, the emissions in 2015 will be 35 per cent larger than they were in 2000," and this would take emissions scenarios to avoid dangerous climate change beyond reach (Connor, 2007a). Hansen, the Director of NASA's Goddard Institute for Space Science, and one of the world's most eminent climate scientists, says we must "begin to move our energy systems in a fundamentally different direction within about a decade, or we will have pushed the planet past a tipping point beyond which it will be impossible to avoid far-ranging undesirable consequences". Global warming of two to three degrees above the present temperature, he warns, would produce a planet without Arctic sea ice, a catastrophic sea level rise in the pipeline of around 25 metres, and a super-drought in the American west, southern Europe, the Middle East and parts of Africa. "Such a scenario threatens even greater calamity, because it could unleash positive feedbacks such as melting of frozen methane in the Arctic, as occurred 55 million years ago, when more than ninety per cent of species on Earth went extinct" (Hansen, 2006b).

Tony Blair and his Dutch counterpart, Jan Peter Balkenende, told European leaders in 2006 that "without further action, scientists now estimate we may be heading for temperature rises of at least three to four degrees above pre-industrial levels… We have a window of only 10 to 15 years to avoid crossing catastrophic tipping points. These would have serious consequences for our economic growth prospects, the safety of our people and the supply of resources, most notably energy" (Colebatch, 2006).

Atmospheric CO2 levels are now substantially higher than at any time in the last 800,000 years. Atmospheric CO2 rose 30 ppm in the last 17 years, yet ice cores drilled in Antarctica show that in the last million years, prior to recent times, the fastest increase of carbon dioxide was 30 ppm over a 1000-year period. The speed of heat imbalances is way outside planet's recent climate history: "We really are in the situation where we don't have an analogue in our records," says Dr Eric Wolff from the British Antarctic Survey (Amos, 2007). Wolf says that although opinions differ, it is generally accepted that at some stage a "step change" or "tipping point" is reached after which global warming accelerates exponentially and, according to the new evidence, "we could expect that tipping point to arrive in 10 years' time" (von-Radowitz, 2007). Recent observations from the Arctic, and its implications for the Greenland ice sheet and sea-level rises, suggests we may already be close to or have already passed that point.

In 2004, the International Energy Agency projected that CO2 emissions will increase by 63 per cent over 2002 levels by 2030 (IEA, 2004). "Business-as-usual" will see global energy use more than double by 2050, from 10 giga-tonne oil equivalent (Gtoe) to 22 Gtoe, with 70 per cent of the increase coming from fossil fuels, according to the European Union's 2007 World Energy Technology Outlook. The report assumes energy efficiency will almost double, to support an economy that is four times as large as today, but even so finds that the "resulting emission profile corresponds to a concentration of CO2 in the atmospheric between 900 to 1000 ppm in 2050. This value far exceeds what is considered today as an acceptable range for stabilisation of the concentration" (European Union, 2007: 12-13). The conclusion is that carbon emissions cuts will come too late to avert "runaway" climate change if current policy trends continue in Europe and across the world, and this would happen despite a "massive" growth in renewables after 2030, including rapid deployment of new technologies like offshore wind.

With emissions now tracking worse than "business-as-usual", the IPCC's projections may well be too conservative. The temperature rise from 1990 to 2005 – 0.33°C – was near the top end of the range of IPCC climate model predictions, and overall "the data available for the period since 1990 raise concerns that the climate system, in particular sea level, may be responding more quickly to climate change than our current generation of models indicates" (Rahmstorf, Cazenave et al., 2007). The IPCC's pessimistic "business-as-usual" scenario has a median predicted temperature increase of 4.7°C by 2100, but, for example, average summer temperatures in the eastern US could soar by 5.5°C (10°F) by 2080, if human emissions continue to grow at their current rate of 2 per cent a year, according to a new NASA model (Brahic, 2007b).

So far temperatures have risen 0.8°C above pre-industrial levels. Due to "thermal inertia", or lags in system, there will be a further 0.6°C of warming as a result of the pollution we have already put in the air (Hansen, Nazarenko et al., 2006). Yet Hansen and his colleagues suggest that "comparison of measured sea surface temperatures in the Western Pacific with paleoclimate data suggests that this critical ocean region, and probably the planet as a whole, is approximately as warm now as at the Holocene maximum and within ≈1°C of the maximum temperature of the past million years. We conclude that global warming of more than ≈1°C, relative to 2000, will constitute 'dangerous' climate change as judged from likely effects on sea level and extermination of species" (Hansen, Sato et al., 2006).

With the rise over pre-industrial levels of 0.7°C up to 2000, the Hansen target is 1.7°C, yet today 1.4°C is already in the system and emissions are tracking at worse than the IPCC's most pessimistic scenario. The implications for policy are far beyond the current public discourse.

## The accelerating loss of the Arctic ice sheet

> "We are all used to talking about these impacts coming in the lifetimes of our children and grandchildren. Now we know that it's us." – Professor Martin Parry, co-chairman of the IPCC impacts working group (Adam, 2007b)

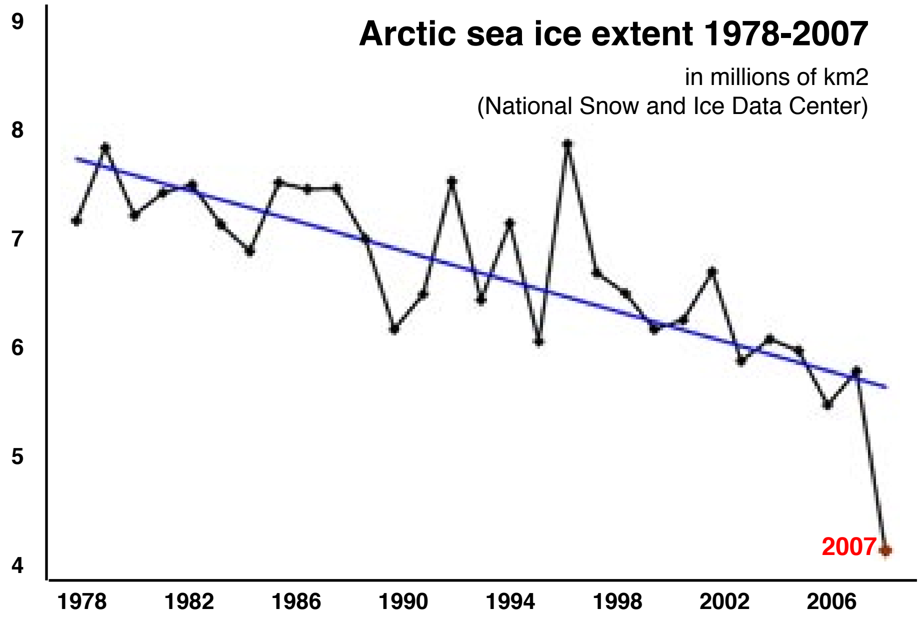
Events in the Arctic in the northern summer of 2007 have profound consequences for climate policy, the credibility of the IPCC, the assessment of projected sea-level rises and the question as to whether we may have already passed one or more of the critical "tipping points" for dangerous anthropogenic interference.

In its 2007 Fourth Assessment Report, the IPCC said that "Arctic sea ice is responding sensitively to global warming. While changes in winter sea ice cover are moderate, late summer sea ice is projected to disappear almost completely towards the end of the 21st century" (IPCC, 2007a: 776).

But even before they were drafted, the 2007 IPCC projections were well behind the physical reality in the environment. In late 2005, Tore Furevik of the Geophysical Institute in Bergen had graphically demonstrated that "the recent [Arctic] sea-ice retreat is larger than in any of the (19) IPCC models" (Furevik, 2005). In December 2006, data was presented to a American Geophysical Union conference suggesting that the Arctic may be free of all summer ice by as early as 2030 and likely by 2040 (Holland, Bitz et. al., 2006) – setting up "a positive feedback loop with dramatic implications for the entire Arctic region" (Amos, 2006).

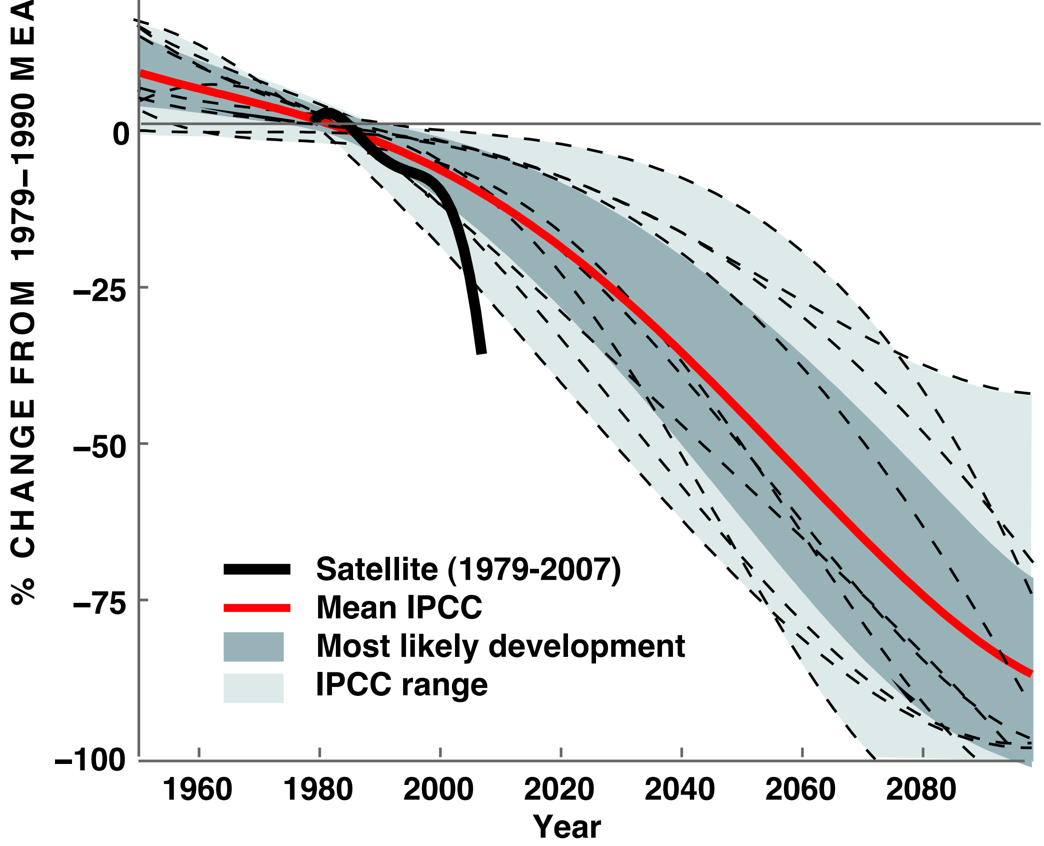
This was affirmed by studies published in March and May 2007 (Serreze, Holland et al., 2007; Stroeve, Holland, et al., 2007) which led Penn State climatologist Richard Alley to comment that the ice sheets appear to be shrinking "100 years ahead of schedule" (Spotts, 2006).

Despite the warnings, experts were "shocked" at the extent of Arctic ice-sheet loss during the 2007 northern summer; Mark Serreze, an Arctic specialist at the US National Snow and Ice Data Centre (NSIDC) at Colorado University in Denver, told the Guardian: "It's amazing. It's simply fallen off a www.carbonequity.info/PDFs/arctic.pdf



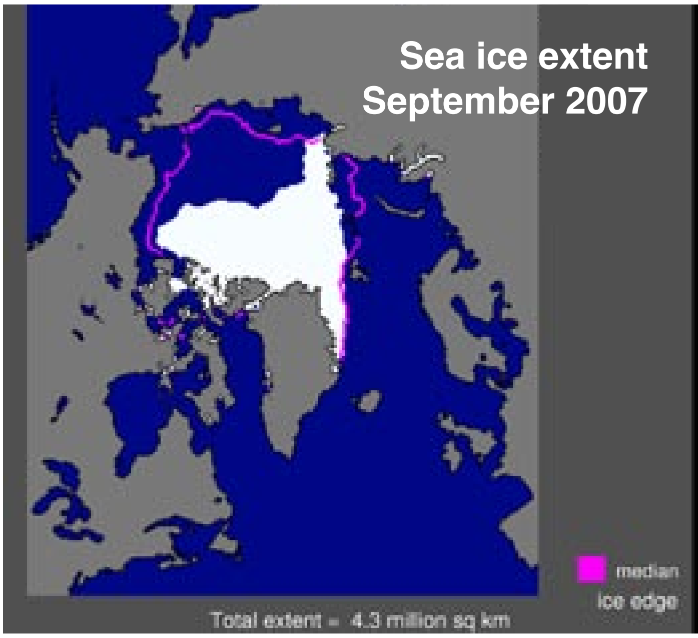
**Arctic sea ice extent 1978-2007**

in millions of km2
(National Snow and Ice Data Center)

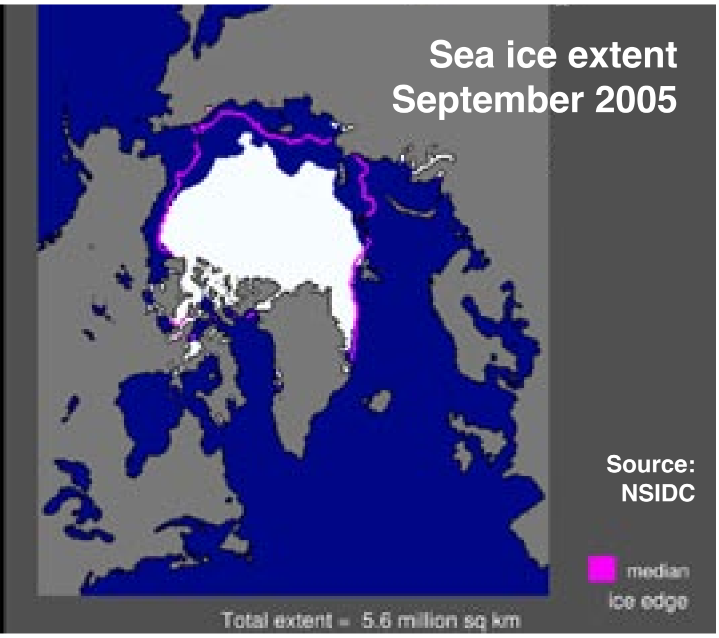


## Arctic sea ice summer extent loss compared to IPCC projections

Arctic ice extent loss to September 2007 compared to IPCC modelled changes using the SRES A2 CO2 scenario (IPCC high CO2 scenario). September loss data from satellite observations. Data smoothed with a 4th order polynomial to smooth out the year-to-year variability. Chart courtesy Dr Asgeir Sorteberg, Bjeknes Centre for Climate Research and University Center at Svalbard, Norway.



**Sea ice extent September 2007**



**Sea ice extent September 2005**

Source: NSIDC

cliff and we're still losing ice" (Adam, 2007a). The 2007 sea ice minimum on 16 September was 4.13 million square kilometers, compared to the previous record low of 5.32 million square kilometers in 2005, representing a precipitous decline of 22 per cent in two years: "The minimum for 2007 shatters the previous five-day minimum set on September 20–21, 2005, by 1.19 million square kilometers (460,000 square miles), roughly the size of Texas and California combined, or nearly five United Kingdoms" (NSIDC, 2007). This loss of ice extent of more than 20 per cent in two years compares to the decreasing trend in ice area of 7 per cent per decade between 1979 and 2005 (Alley, 2007). The ice retreat is likely to be even bigger next summer because this winter's freeze is starting from such a huge ice deficit (Revkin, 2007).

NSIDC research scientist Walt Meier said it was "the biggest drop from a previous record that we've ever had and it's really quite astounding… Certainly we've been on a downward trend for the last 30 years or so, but this is really accelerating the trend" (McCarthy, 2007). As well, large areas of the Arctic sea ice are now only one metre deep, which means the thickness of the ice has halved since 2001 (Bjornes, 2007) and down from a thickness of 3.5 metres in the early 1960s, and around about 2.5 metres in the late 1980s and early 1990s (Blakemore and Sandell, 2006). The decrease in both extent and thickness suggests that the summer sea ice has lost more than 80 per cent of its volume in 40 years. When the sea ice thins to around half a metre in thickness, it will be subject to even more rapid disintegration by wave and wind action.

Serreze says we may have already reached the tipping point when there is a rapid sea ice disintegration: "The big question is whether we are already there or whether the tipping point is still 10 or 20 years in the future… my guts are telling me we may well be there now" (Connor 2007b) and "an educated guess right now would be 2030" for the transition to an ice-free Arctic summer (McCarthy, 2007). His colleague at Colorado, Ted Scambos, agrees that "that 2030 is not unreasonable… I would not rule out 2020, given non-linearity and feedbacks" (Scambos, 2007). These views are supported by Ron Lindsay of the University of Washington: "Our hypothesis is that we've reached the tipping point. For sea ice, the positive feedback is that increased summer melt means decreased winter growth and then even more melting the next summer, and so on" (Connor and McCarthy, 2006). Australian-of-the-Year Tim Flannery suggests that "at the trajectory set by the new rate of melt, however, there will be no Arctic icecap in the next five to 15 years" (Flannery, 2006). Dr Wieslaw Maslowski of the Naval Postgraduate School in California, whose research focuses on modelling the processes of Arctic sea ice loss, projects a blue Arctic Ocean free of sea ice by the summer of 2013 (Revkin, 2007), the main reason being that the modeled thickness and volume appear to be decreasing at a much faster rate than the satellite derived ice extent (Maslowski, 2007). Maslowski's work suggests the sea ice is significantly being thinned by the effect of warming seas beneath, not just higher air temperatures.

"The reason so much (of the Arctic ice) went suddenly is that it is hitting a tipping point that we have been warning about for the past few years," says NASA's James Hansen; Germany's Potsdam Institute for Climate Impact Research says Arctic sea ice has "already tipped"; while Paal Prestrud of Oslo's Center for International Climate and Environmental Research says "I'd say we are reaching a tipping point or are past it for the ice. This is a strong indication that there is an amplifying mechanism here" (Doyle, 2007).

The central point is that Arctic is now irreversibly headed to total summer sea ice loss very quickly, way beyond the expectation of the IPCC whose Arctic scenarios are no longer credible [see figure], and of most scientists' views only two-to-three years ago. It is an instance of the non-linearity in climate systems that should reinforce the need for strict adherence to the precautionary principle in assessing what is likely to constitute dangerous human interference, and how we should respond in constructing emission scenarios and policies to avoid it.

## Stability of the Greenland ice sheet

Global warming so far has been greatest in the high latitudes of the northern hemisphere, particularly in the sub-Arctic boreal forests of Siberia and North America (ACIA 2005). Arctic temperatures will rise much more quickly than the global average: for a global warming of 2°C, the area-mean annual temperature increase over the Arctic (60-90°N) is likely to be between 3.2° and 6.6°C (0.45° to 0.75°C per decade, and possibly even as large as 1.55°C per decade) (New, 2006).

The view that a 2°C global temperature increase will be hard to avoid is widespread: from Nicholas Stern (Stern, 2006a: 4) to the co-chair of the IPCC's impacts working group, Martin Parry (Adam, 2007b). But well before two degrees average global warming, a high momentum melting of much of the Greenland ice sheet will be underway (Hansen, 2005). Greenland's critical melt threshold is a regional temperature rise of 2.7 degrees (Gregory, Huybrechts et al, 2004), but with its temperature increase at least 2.2 times the global average (Chylek and Lohmann, 2005), that point will have been triggered at just over a one degree global rise. [Nevertheless, the 2001 IPCC report thought that neither Greenland nor Antarctica would lose significant mass by 2100.]

The loss of the Arctic sea ice "100 years ahead of schedule" raises two questions of significance about the Greenland ice sheet: what will the effect on the timing of the Greenland tipping point be; and what will be effect on the rate of ice loss from Greenland (which if fully achieved would raise the global sea level by 5–7 metres)?

Rising Arctic regional temperatures resulting from sea ice loss and the albedo effect (white reflective ice replaced by dark, heat-absorbing sea) are already at "the threshold beyond which glaciologists think the (Greenland) ice sheet may be doomed"; this accelerated melting "is caused by meltwater penetrating crevasses and lubricating the glaciers' flow… The ice is in effect sliding into the ocean on rivers of water," an effect not included in models of the effect of global warming on the Arctic (New Scientist, 2006). A recent study found that the Greenland ice cap "may be melting three times faster than indicated by previous measurements" and that "the mass loss is increasing with time" (Young, 2006). Greenland experienced more days of melting snow in 2006 than the island had averaged over recent decades (Saupe, 2007), the edges of the ice-sheet are melting up to 10 times more rapidly than earlier research had indicated, and the ice sheet height is falling by up to 10 metres a year (Shukman, 2007). As well, the Greenland ice cap is melting so quickly that it is triggering earthquakes as pieces of ice several cubic kilometres in size break off, with "a massive acceleration of the speed with which these glaciers are moving into the sea" (Brown, 2007).

James Hansen notes that "Ice sheet disintegration starts slowly but multiple positive feedbacks can lead to rapid non-linear collapse" and than "equilibrium sea level rise for ~3°C warming _(25±10 m = 80 feet) implies the potential for us to lose control" because "we cannot tie a rope around a collapsing ice sheet" (Hansen 2006a, Hansen 2006b).

At this point there is a methodological problem: climate scientists have had difficulty modelling _ice-sheet streams and dynamics (Oppenheimer & Alley, 2004). Robert Corell, a US-based Arctic scientist and member of the IPCC says of Greenland: "Nobody knows now how quickly it will melt… This is all unprecedented in the science… Until recently we didn't believe it possible, for instance, for water to permeate a glacier all the way to the bottom. But that's what's happening. As the water pools, it opens more areas of ice to melting" (Hilton, 2007). With the uncertainty and lack of verifiable projections, at an official level little is said, or what is said is dangerously conservative. This is what the 2007 IPCC report did in regard to sea-level rises, where its projection of a 18-59 cm rise by 2100 was based on models which do not "include the potential for increasing contributions from rapid dynamic processes in the Greenland and West Antarctic ice sheets, which have already had a significant effect on sea level over the past 15 years and could eventually raise sea level by many meters. Lacking such processes, models cannot fully explain observations of recent sea level rise, and accordingly, projections based on such models may seriously understate potential future increases" (Oppenheimer, O'Neill et al., 2007).

But the lack of tested projections is not to say that large parts of Greenland may not have already passed their "tipping point", just because there are not strict, verifiable models to support the assertion. The same was true of the Arctic sea ice, which was why the conservatism of the scientific method meant that there was a failure to predict the events until they were all but upon us, at which point even those scientists who had speculated as to what was about to happen were "shocked" at the sea ice loss in the northern summer of 2007.

Thus James Hansen identifies a "scientific reticence" that "in at least some cases, hinders communication with the public about dangers of global warming... Scientific reticence may be a consequence of the scientific method. Success in science depends on objective skepticism. Caution, if not reticence, has its merits. However, in a case such as ice sheet instability and sea level rise, there is a danger in excessive caution. We may rue reticence, if it serves to lock in future disasters" (Hansen, 2007a).

But there are useful sources other than models for thinking about the likely future rate of loss of the Greenland ice sheet, including expert elicitations and paleoclimatology. In response to the deep concerns about the 2007 IPCC Working Group 1 Summary for Policymakers, it has been proposed that the base of inputs be broadened "to give observational, paleoclimatic, or theoretical evidence of poorly understood phenomena comparable weight with evidence from numerical modeling. In areas in which modeling evidence is sparse or lacking, IPCC sometimes provides no uncertainty estimate at all. In other areas, models are used that have quantitatively similar structures, leading to artificially high confidence in projections (e.g., in the sea-level, ocean circulation, and carbon-cycle examples above). One possible improvement would be for the IPCC to fully include judgments from expert elicitations" (Oppenheimer, O'Neill et. al., 2007).

One expert elicitation suggests: "Could the Greenland ice sheet survive if the Arctic were ice-free in summer and fall? It has been argued that not only is ice sheet survival unlikely, but its disintegration would be a wet process that can proceed rapidly. Thus an ice-free Arctic Ocean, because it may hasten melting of Greenland, may have implications for global sea level, as well as the regional environment, making Arctic climate change centrally relevant to definition of dangerous human interference" (Hansen & Sato, 2007). Off the record, Arctic climate researchers will say this is not an unreasonable view; on the record they will say there are no verifiable models which produce this result. These statements are not in contradiction.

So, for example, Eric Rignot, a lead author of a paper (Rignot & Kanagaratnam, 2006) showing a doubling of loss from the Greenland ice sheet over a decade, was moved to comment that "These results absolutely floored us… The glaciers are sending us a signal. Greenland is probably going to contribute more and faster to sea-level rise than predicted by current models" (New Scientist, 2006). Another informed opinion comes from Robert Correll of the Arctic Climate Impact Assessment, who reports, as mentioned above, that the Greenland ice cap is melting so quickly that it is triggering earthquakes as pieces of ice several cubic kilometres in size break off, such that "scientists monitoring events this summer say the acceleration could be catastrophic in terms of sea-level rise and make predictions this February by the Intergovernmental Panel on Climate Change far too low" (Brown, 2007).

As for paleoclimate record, global average temperatures are within 1°C of those that thawed much of Greenland's ice cap some 130,000 years ago, when the planet last enjoyed a balmy respite from continent-covering glaciers, and sea were 5–6 metres higher than today. Global warming appears to be pushing vast reservoirs of ice on Greenland and Antarctica toward a significant, long-term meltdown, and the world may have as little as a decade to take the steps to avoid this scenario (Spotts, 2006; Hansen, 2005; Hansen, Sato et al, 2006).

To recap, it is reasonable to expect the very rapid loss of the Arctic sea ice, with a significant impact on regional temperatures due to the albedo effect. It is also reasonable to expect, as a consequence, an acceleration of the rate of loss of the Greenland ice sheet, which may already be at or near its disintegration tipping point for a large part of the ice sheet, a situation that was previously not expected for a long time. The precautionary principle suggests that we fully take into account the possibility of these outcomes, especially for their wider impact on the climate system (NASA, 2007), and on the sea-level rise the loss of the Greenlad ice sheet will produce, perhaps in as little as a century or so.

## Projected sea-rise levels to 2100

The 2007 IPPC report's suggestion of a sea-level rise by 2100 of 0.18–0.59 m (IPCC, 2007: 820) was greeted with dismay be many climate scientists. Before the report was released, satellite data showed that sea levels had risen by an average of 3.3 mm per year between 1993 and 2006, whereas the 2001 IPCC report, in contrast, projected a best-estimate rise of less than 2 mm per year (Brahic, 2007a). In late 2006, research concluded that previous estimates of how much the world's sea level will rise as a result of global warming may have seriously underestimated the problem (Ramsdorf et. al, 2007). Lead researcher Steve Rahmstorf said the data now available "raise concerns that the climate system, in particular sea level, may be responding more quickly than climate models indicate" (Chandler, 2006).

So how much will sea levels rise this century, and in particular, at what rate will the Greenland and

West Antarctic ice sheets disintegrate, and what influence will the "premature" loss of the Artic sea ice have on Greenland's rate of loss? This question has caused turmoil in scientific circles, because there is a general acknowledgement that it will be a good deal higher than the IPCC suggests, but there are no reliable ice-sheet disintegration models. However, this topic is now the subject of urgent collaborative work between a number of US agencies and research centres.

The lead in this discussion has been taken by James Hansen and his collaborators in a number of recent, peer-reviewed papers (Hansen, 2005; Hansen & Sato, 2007a; Hansen, 2007a; Hansen, Sato, et. al., 2007), in which their essential argument, based on the paleoclimate record, is that the sea-rise level is likely to be about 5 metres this century if emissions continue down the "business-as-usual" trajectory. Here is the core of Hansen's expert elicitation [all warmings in this quoted material are relative to the temperature in 2000]:

> I find it almost inconceivable that "business as usual" climate change will not result in a rise in sea level measured in metres within a century... Because while the growth of great ice sheets takes millennia, the disintegration of ice sheets is a wet process that can proceed rapidly.
>
> ... the primary issue is whether global warming will reach a level such that ice sheets begin to disintegrate in a rapid, non-linear fashion on West Antarctica, Greenland or both. Once well under way, such a collapse might be impossible to stop, because there are multiple positive feedbacks. _In that event, a sea level rise of several metres at least would be expected.
>
> As an example, let us say that ice sheet melting adds 1 centimetre to sea level for the decade 2005 to 2015 [this is less than the current rate - DS], and that this doubles each decade until the West Antarctic ice sheet is largely depleted. This would yield a rise in sea level of more than 5 metres by 2095.
>
> Of course, I cannot prove that my choice of a 10-year doubling time is accurate but I'd bet $1000 to a doughnut that it provides a far better estimate of the ice sheet's contribution to sea level rise than a linear response. In my opinion, if the world warms by 2 °C to 3 °C, such massive sea level rise is inevitable, and a substantial fraction of the rise would occur within a century. Business-as-usual global warming would almost surely send the planet beyond a tipping point, guaranteeing a disastrous degree of sea level rise.
>
> Although some ice sheet experts believe that the ice sheets are more stable, I believe that their view is partly based on the faulty assumption that the Earth has been as much as 2 °C warmer in previous interglacial periods, when the sea level was at most a few metres higher than at present. There is strong evidence that the Earth now is within 1 °C of its highest temperature in the past million years. Oxygen isotopes in the deep-ocean fossil plankton known as foraminifera reveal that the Earth was last 2°C to 3°C warmer around 3 million years ago, with carbon dioxide levels of perhaps 350 to 450 parts per million. It was a dramatically different planet then, with no Arctic sea ice in the warm seasons and sea level about 25 metres higher, give or take 10 metres.
>
> There is not a sufficiently widespread appreciation of the implications of putting back into the air a large fraction of the carbon stored in the ground over epochs of geologic time. The climate forcing caused by these greenhouse gases would dwarf the climate forcing for any time in the past several hundred thousand years - the period for which accurate records of atmospheric composition are available from ice cores.
>
> Models based on the business-as-usual scenarios of the Intergovernmental Panel on Climate Change (IPCC) predict a global warming of at least 3 °C by the end of this century. What many people do not realise is that these models generally include only fast feedback processes: changes in sea ice, clouds, water vapour and aerosols. Actual global warming would be greater as slow feedbacks come into play: increased vegetation at high latitudes, ice sheet shrinkage and further greenhouse gas emissions from the land and sea in response to global warming.
>
> The IPCC's latest projection for sea level rise this century is 18 to 59 centimetres. Though it explicitly notes that it was unable to include possible dynamical responses of the ice sheets in its calculations, the provision of such specific numbers encourages a predictable public belief that the projected sea level change is moderate, and indeed smaller than in the previous IPCC report. There have been numerous media reports of "reduced" predictions of sea level rise, and commentators have denigrated suggestions that business-as-usual emissions may cause a sea level rise measured in metres. However, if these IPCC numbers are taken as predictions of actual sea level rise, as they have been by the public, they imply that the ice sheets can miraculously survive a business-as-usual climate forcing assault for a millennium or longer.
>
> There are glaciologists who anticipate such long response times, because their ice sheet models have been designed to match past climate changes. However, work by my group shows that the typical 6000-year timescale for ice sheet disintegration in the past reflects the gradual changes in Earth's orbit that drove climate changes at the time, rather than any inherent limit for how long it takes ice sheets to disintegrate.
>
> Indeed, the palaeoclimate record contains numerous examples of ice sheets yielding sea level rises of

> several metres per century when forcings were smaller than that of the business-as-usual scenario. For example, about 14,000 years ago, sea level rose approximately 20 metres in 400 years, or about 1 metre every 20 years.
>
> There is growing evidence that the global warming already under way could bring a comparably rapid rise in sea level. The process begins with human-made greenhouse gases, which cause the atmosphere to be more opaque to infrared radiation, thus decreasing radiation of heat to space. As a result, the Earth is gaining more heat than it is losing: currently 0.5 to 1 watts per square metre. This planetary energy imbalance is sufficient to melt ice corresponding to 1 metre of sea level rise per decade, if the extra energy were used entirely for that purpose - and the energy imbalance could double if emissions keep growing.
>
> So where is the extra energy going? A small part of it is warming the atmosphere and thus contributing to one key feedback on the ice sheets: the "albedo flip" that occurs when snow and ice begin to melt. Snow-covered ice reflects back to space most of the sunlight striking it, but as warming air causes melting on the surface, the darker ice absorbs much more solar energy. This increases the planetary energy imbalance and can lead to more melting. Most of the resulting meltwater burrows through the ice sheet, lubricating its base and speeding up the discharge of icebergs to the ocean.
>
> The area with summer melt on Greenland has increased from around 450,000 square kilometres when satellite observations began in 1979 to more than 600,000 square kilometres in 2002. Seismometers around the world have detected an increasing number of earthquakes on Greenland near the outlets of major ice streams. The earthquakes are an indication that large pieces of the ice sheet lurch forward and then grind to a halt because of friction with the ground. The number of these "ice quakes" doubled between 1993 and the late 1990s, and it has since doubled again. It is not yet clear whether the quake number is proportional to ice loss, but the rapid increase is cause for concern about the long-term stability of the ice sheet.
>
> Additional global warming of 2 °C to 3 °C is expected to cause local warming of about 5 °C over Greenland. This would spread summer melt over practically the entire ice sheet and considerably lengthen the melt season. In my opinion it is inconceivable that the ice sheet could withstand such increased meltwater for long before starting to disintegrate rapidly, but it is very difficult to predict when such a period of large, rapid change would begin.
>
> Summer melt on West Antarctica has received less attention than on Greenland, but it is more important. The West Antarctic ice sheet, which rests on bedrock far below sea level, is more vulnerable as it is being attacked from below by warming ocean water, as well as from above by a warming atmosphere. Satellite observations reveal increasing areas of summer melt on the West Antarctic ice sheet, and also a longer melt season. (Hansen, 2007c)

Hansen's argument has been put at length here because he is one of the world's most eminent climate scientists; he has provided a compelling critique of the limitations of the IPCC models; he has opened a new understanding of the mechanics of rapid, wet-sheet disintegration; his views are based on paleoclimate evidence; his views are currently forcing a major rethink of sea-level rises amongst his fellow climate scientists; and there has been little rebuttal of this work. Perhaps most significantly, Hansen, a humble man who has twice testified before Congress on climate change (and endured the Bush administration slashing funding for the NASA Goddard Institute of Space Science because he refused to stop his public advocacy), has staked his formidable professional reputation on this issue. His preparedness to bet "$1000 to a doughnut" that his view is closer to the mark than the IPCC should not be underestimated as a signifier of his scientific confidence.

## Beyond the Arctic

The loss of the West Antarctic ice sheet would raise sea levels by a similar amount to the total loss of the Greenland ice sheet. While it is anticipated that the West Antarctic sheet is more stable at a 1–2°C rise, recent research demonstrates that the southern ice shelf reacts far more sensitively to warming temperatures than scientists had previously believed, based on ice-core data showing that "massive melting" must have occurred in the Antarctic during the Miocene-Pliocene warming 3 million years ago, when the average global temperature in the oceans increased by only 2–3°C (Schmitt, 2007). Much of the West Antarctic ice sheet sits on bedrock below sea-level, so if the ice shelves that buttress the ice sheet disintegrate, sea water breeching the base of the ice sheet may will hasten the rate of disintegration: "We foresee the gravest threat from the possibility of surface melt on West Antarctica, and interaction among positive feedbacks leading to catastrophic ice loss. Warming in West Antarctica in recent decades has been limited by effects of stratospheric ozone depletion. However, climate projections find warming of nearby ocean at depths that may attack buttressing ice shelves as well as surface warming in the region of West Antarctica. Loss of ice shelves allows more rapid discharge from ice streams, in turn a lowering and warming of the ice sheet surface, and increased surface melt. Rising sea level helps unhinge the ice from pinning points. With GHGs [greenhouse gases] continuing to increase, the planetary energy imbalance provides ample energy to melt ice corresponding to several meters of sea level per century..." (Hansen, Sato et. al, 2007)

But long before the Greenland or West Antarctic ice sheets fully disintegrate, even the loss of 20 per cent of Greenland's ice volume would be catastrophic. Nicholas Stern reported that "currently, more than 200 million people live in coastal floodplains around the world, with 2 million square kilometres of land and $1 trillion worth of assets less than 1 metre elevation above current sea level. One-quarter of Bangladesh’s population (~35 million people) lives within the coastal floodplain. Many of the world’s major cities (22 of the top 50) are at risk of flooding from coastal surges, including Tokyo, Shanghai, Hong Kong, Mumbai, Calcutta, Karachi, Buenos Aires, St Petersburg, New York, Miami and London. In almost every case, the city relies on costly flood defences for protection. Even if protected, these cities would lie below sea level with a residual risk of flooding like New Orleans today. The homes of tens of millions more people are likely to be affected by flooding from coastal storm surges with rising sea levels. People in South and East Asia will be most vulnerable, along with those living on the coast of Africa and on small islands" (Stern, 2006b). A rise of 5 metres would affect 669 million people and 2 million square kilometres of land of land would be lost (Kahn, 2007).

Underground water is the largest reserve of fresh water on the planet, and more than 2 billion people depend on it. Long before the rising seas inundate the land, acquifers will be contaminated. The 2006 Conference of the International Association of Hydrogeologists heard that rising sea levels will also lead to the inundation by salt water of the aquifers used by cities such as Shanghai, Manila, Jakarta, Bangkok, Kolkata, Mumbai, Karachi, Lagos, Buenos Aires and Lima. "The water supplies of dozens of major cities around the world are at risk from a previously ignored aspect of global warming. Within the next few decades rising sea levels will pollute underground water reserves with salt… Long before the rising tides flood coastal cities, salt water will invade the porous rocks that hold fresh water… The problem will be compounded by sinking water tables due to low rainfall, also caused by climate change, and rising water usage by the world's growing and increasingly urbanised population" (Pearce, 2006a).

Whilst big figures about large sea-level rises may seem abstract, a rise of one metre will have a devastating impact on the densely-population river deltas in the developing world as homes and agricultural land is lost and damaged by storm surges. In industrialised regions, there will be severe impacts on coastal infrastructure from small rises: loss of beaches, ports and shipping infrastructure, flooding of access and connecting transport links, and the inundation of underground civil services, including sewers, water, electricity transmission and communications, as well as the loss of industrial and domestic buildings.

Half an hour using Google earth with a sea-rise level overlay (for example, http://flood.firetree.net/) suggests that the lesson from the Arctic summer of 2007 is that we recognise that we now face a global warming emergency, requiring an emergency plan beyond politics-as-usual and business-as-usual.

## Climate sensitivity and the missing feedbacks

> "Climate change is... happening faster than the models predicted it would." _– Barrie Pittock, senior CSIRO climate scientist (Peddie, 2007).

Climate sensitivity refers to the expected increase in global temperature associated with a doubling in the atmospheric concentration of greenhouse gases (from the pre-industrial level of 280 ppm to 560 ppm CO2/e). Climate sensitivity research has produced quite divergent results, particularly earlier on, but is now widely viewed as being around 3°C, known as the "Charney 3°C" after its first proponent, thirty years ago. The IPCC report uses Equilibrium Climate Sensitivity (ECS) models to conclude that it is "likely to be in the range 2 to 4.5°C with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded (emphasis added), but agreement of models with observations is not as good for those values" (IPCC, 2007b: 12).

Nevertheless, researchers have found larger possible ranges, for example of 1–10°C and _1.4–7.7°C, and it has been suggested there is a 54 per cent likelihood that climate sensitivity lies outside the IPCC range (Andronova and Schlesinger, 2001). More recently two researchers found they could not "assign a significant probability to climate sensitivity exceeding 6°C" (Annan and Hargreaves, 2006) which is now widely seen as the likely upper limit.

But a climate sensitivity of 6°C if established would turn climate change policy upside down. The higher the sensitivity, the lower the permissible total emissions to meet a temperature target. At _3°C sensitivity, atmospheric greenhouse gas levels need to stabilise around 450 ppm CO2e to have a 50:50 chance of not exceeding 2°C; if sensitivity were established at 6°C, the stabilisation level would be around 350 ppm CO2e to meet the same target, implying that we have long since passed the threshold of dangerous anthropogenic interference with the climate.

Recent research and data indicate that 3°C may be too low a figure. The senior CSIRO climate scientist Barrie Pittock suggested in 2006 that the "dated IPCC view might underestimate the upper end of the range of possibilities" and there is "a much higher probability of warmings by 2100 exceeding the midlevel (climate sensitivity) estimate of 3ºC". He surveyed recent data which "suggest that critical levels of global warming may occur at even lower greenhouse gas concentrations and/or anthropogenic emissions than was considered justified in the IPCC [2001] report". He elaborates on "at least eight recent developments, largely based on observed changes, [that] point to a higher probability of more serious impacts", including the lessening of global dimming, permafrost melting, biomass feedbacks, Arctic sea-ice retreat, circulation change in mid to high lattitudes, rapid changes in Greenland and Antarctica, increasing intensity of tropical cyclones, and a slowing of the Gulf Steam (Pittock, 2006).

The issue with the established climate sensitivity range is that it only takes into account "fast" feedbacks: "Climate sensitivity is the response to a specified forcing, after climate has had time to reach a new equilibrium, including effects of fast feedbacks" which "come into play quickly as temperature changes. For example, the air holds more water vapor as temperature rises, which is a positive feedback magnifying the climate response, because water vapor is a greenhouse gas. Other fast feedbacks include changes of clouds, snow cover, and sea ice" (Hansen, 2003).

The problem is that the ECS models omit "slow" feedbacks, such as ice sheet growth and decay, permafrost melting and methane release, and carbon cycle feedbacks that amplify climate changes on time scales of decades to centuries. Paleoclimate data identifies the impact of these missing slow feedbacks in pushing temperatures higher that expected: in the Arctic 55 million years ago temperatures were 11°C warmer that the ECS models would predict, suggesting "other feedback mechanisms" at work (Sluijs, Schouten et al, 2006); a 2006 study of Middle Ages climate found that the effect of amplifying feedbacks in the climate system "will promote warming by an extra 15 percent to 78 percent on a century-scale" compared to typical estimates by the IPCC model (Scheffer, Brovkin, et al., 2006).

The failure of the IPCC models to include slow feedbacks in climate sensitivity is explained by Hansen and Sato (2007b), who argue that the "Charney 3°C" is reasonable in the short run, but that there is also a "long-term" climate sensitivity "if these slow feedbacks are allowed to operate" which Hansen and Sato estimate from the paleoclimate data to be "about 6°C for doubled CO2". They then pose the question: "Which climate sensitivity is more relevant to humanity: the Charney 3°C for doubled CO2 or the 'long-term' 6°C for doubled CO2?" and answer "both." On the time scale of the last three decades, "the Charney sensitivity is a good approximation, as little contribution from slow feedbacks would be expected. Thus climate models with 3°C sensitivity for doubled CO2, incorporating only the fast feedbacks, are able to achieve good agreement with observed warming of the past century. We suggest, however, that these models provide only a lower limit on the expected warming on century time scales due to the assumed forcings. The real world will be aiming in the longer run at a warming corresponding to the higher climate sensitivity [of 6°C]". And they conclude that "Elsewhere we have described evidence that slower feedbacks, such as poleward expansion of forests, darkening and shrinking of ice sheets, and release of methane from melting tundra, are likely to be significant on decade-century time scales. This realization increases the urgency of estimating the level of climate change that would have dangerous consequences for humanity and other creatures on the planet, and the urgency of defining a realistic path that could avoid these dangerous consequences" (Hansen and Sato, 2007b).

This finding has enormous implications: as noted above, a long-term climate sensitivity of 6°C means we have passed the widely accepted 2°C threshold of dangerous anthropogenic interference with the climate (around 350 ppm CO2e) about four decades ago, and it therefore requires us to find the means to engineer a rapid drawdown of current atmospheric greenhouse gas.

A key question is whether the slow feedbacks have started to operate. In the case of the Greenland and Antarctic ice-sheets, the data is already disturbing. Others slow feedbacks to be considered include the reversal of the carbon cycle as the oceans and soils take up less CO2, and significant permafrost methane release.

**Carbon cycle feedback:** It is expected there will be deceased capacity of the earth's carbon sinks due to both human activity and as a consequence of higher temperatures (Jones 2003). The fraction of total anthropogenic CO2 emissions remaining in the atmosphere has increased slowly with time, implying a slight weakening of sinks relative to emissions (Raupach, Marland et al., 2007). A landmark study in 2000 found that about half of the current emissions are being absorbed by the ocean and by land ecosystems, but this absorption is sensitive to climate, as well as to atmospheric CO2 concentrations, which are creating a feedback loop, such that under a "business-as-usual" scenario the terrestrial biosphere acts as an overall carbon sink until about 2050, then turns into a source thereafter as the sinks fail. This is a "slow" feedback that will increase temperatures by another 1.5°C by 2100 (Cox et al., 2000).

**Ocean carbon cycle feedback:** There is new evidence of the saturation of the Southern Ocean CO2 sink due to recent climate change (Le Quéré, Rodenbeck et al, 2007). Lead author Dr Corinne Le Quéré says: "This is the first time that we've been able to say that climate change itself is responsible for the saturation of the Southern Ocean sink. This is serious. All climate models predict that this kind of 'feedback' will continue and intensify during this century. The Earth's carbon sinks – of which the Southern Ocean accounts for 15 per cent – absorb about half of all human carbon emissions. With the Southern Ocean reaching its saturation point more CO2 will stay in our atmosphere" (NIWA, 2007). As well, satellite data gathered over the past 10 years shows that the growth of marine phytoplankton, the basis of the entire ocean food chain, is being adversely affected by rising sea temperatures (Behrenfeld, Worthington, et al., 2007). Phytoplankton, the microscopic plants that permeate the oceans, underlie the entire marine food chain, removing up to 50 billion tons of carbon dioxide per year from Earth's atmosphere, as much as all plant life on the planet's surface. Marine life will also be further weakened by ocean acidification. If emissions continue "business-as-usual", CO2 levels in the oceans will rise to a point where, by 2050, ocean acidification will reach a level considered to be industrial waste by the US's own water quality standards (Caldeira, Archer et al, 2007) and, if unabated "has the potential to cause extinction of many marine species… What we're doing in the next decade will affect our oceans for millions of years… CO2 levels are going up extremely rapidly, and it's overwhelming our marine systems" (Eilperin, 2006; NASA, 2006c).

**Soil carbon cycle feedback:** Soils and the oceans have historically contributed equally to absorbing atmospheric carbon dioxide. The soil also releases carbon as plant and organic matter decompose. Professor Guy Kirk of the National Soil Resources Institute at Cranfield University has calculated that the increase in carbon lost by UK soil each year since 1978 of 13 million tons of carbon dioxide a year is more than the 12.7 million tons a year Britain saved by cleaning up its industrial emissions as part of its commitment to Kyoto. The loss is likely to be due to plant matter and organic material decomposing at a faster rate as temperatures rise. Soil sinks are predicted to release their carbon at an even faster rate as temperatures increase: "It's a feedback loop," says Kirk, "the warmer it gets, the faster it is happening" (Pickrell, 2005; Connor and McCarthy, 2006). It is thought that at 2–3°C, the conversion will begin of the terestrial carbon sink to a carbon source due to temperature-enhanced soil and plant respiration overcoming CO2-enhanced photosynthesis, resulting in widespread desertification and enhanced feedback (Sarmiento and Gruber 2003). Bristol University researchers argue that a previously unexplained surge of carbon dioxide levels in the atmosphere in recent years is due to more greenhouse gas escaping from trees, plants and soils. Global warming was making vegetation less able to absorb the carbon pollution pumped out by human activity (Knorr, 2007). Korr believes "We could be seeing the carbon cycle feedback kicking in, which is good news for scientists because it shows our models are correct. But it's bad news for everybody else."

**Permafrost:** As the Arctic warms, permafrost in the boreal forests and further north in the Arctic tundra is now starting to melt, triggering the release of methane, a greenhouse gas twenty-five times more powerful than CO2, from thick layers of thawing peat. With less than one degree of warming, Arctic ground frozen by permafrost for 3000 years is melting, producing thermokarst (land surface that forms as ice-rich permafrost melts) that potentially can affect 10–30% of arctic lowland landscapes and severely alter tundra ecosystems even under scenarios of modest climate warming (Jorgenson, Shur et al., 2006). As the permafrost thaws and lakes form, microbes convert the soil's organic matter into methane, which bubbles through the surface water into the atmosphere; where permafrost decay is a dry process, CO2 is released. A recent study found that Siberia's thawing wetlands are a significant, underestimated source of atmospheric methane. With lakes in the region growing in number and size and emission rates appearing to be five times higher than previously estimated, permafrost melting is now another positive, "slow" feedback to climate warming (Walter, Zimov et al, 2006).

This data suggests that "slow" feedbacks are now affecting the climate system, with profound implications for climate sensitivity and "safe" targets.

## Speed of impact and uncertainty

> "Governments don't like numbers, so some numbers were brushed out of it" _– Professor Martin Parry on the IPCC's Working Group 2's Summary for Policymakers (Adam, 2007b)

The data discussed above suggests that climate change impacts are happening at lower temperature increases and more quickly and than previously thought.

Speaking at the launch of the full 2007 IPCC report on the impacts of global warming, the co-chair of Working Group 2, Professor Martin Parry, told his audience that: "We are all used to talking about these impacts coming in the lifetimes of our children and grandchildren. Now we know that it's us." He said destructive changes in temperature, rainfall and agriculture were now forecast to occur several decades earlier than thought (Adam, 2007b).

The speed of change can in itself worsen impacts. Leemans and Eickhout (2004) found that species' adaptive capacity decreases rapidly with an increasing rate of climate change: five percent of all ecosystems cannot adapt more quickly than 0.1°C per decade over time. Forests will be among the ecosystems to experience problems first because their ability to migrate to stay within the climate zone they are adapted to is limited. If the rate is 0.3°C per decade, 15 percent of ecosystems will not be able to adapt. If the rate should exceed 0.4°C per decade, all ecosystems will be quickly destroyed, opportunistic species will dominate, and the breakdown of biological material will lead to even greater emissions of CO2. This will in turn increase the rate of warming (Kallbekken and Fuglestvedt, 2007). Temperatures are now increasing at a rate of more 0.2°C per decade with some IPCC scenarios showing the speed rising to 0.4°C per decade by mid-century, to which few species will be able to adapt. Another study of the IPPC report's low- and high-emission scenarios found 12-39% and 10-48% of the Earth's terrestrial surface may respectively experience novel and disappearing climates by 2100 AD (Williams, Jackson et al, 2007).

Speed of change and uncertainty impel us to consider the worse-case outcomes, not just the scenarios considered to be the most likely currently. Pittock (2006) argues persuasively that "Uncertainties in climate change science are inevitably large, due both to inadequate scientific understanding and to uncertainties in human agency or behavior. Policies therefore must be based on risk management, that is, on consideration of the probability times the magnitude of any deleterious outcomes for different scenarios of human behavior. A responsible risk management approach demands that scientists describe and warn about seemingly extreme or alarming possibilities, for any given scenario of human behavior (such as greenhouse gas emissions), even if they appear to have a small probability of occurring. This is recognized in military planning and is commonplace in insurance. The object of policy-relevant advice must be to avoid unacceptable outcomes, not to determine (just) the (apparently) most likely outcome."

It is something that has not always been done, leaving the science in crucial areas looking flat-footed and behind-the-times. Hansen sets the stage: "For the last decade or longer, as it appeared that climate change may be underway in the Arctic, the question was repeatedly asked: 'is the change in the Arctic a result of human-made climate forcings?' The scientific response was, if we might paraphrase, 'we are not sure, we are not sure, we are not sure…yup, there is climate change due to humans, and it is too late to prevent loss of all sea ice.' If this is the best that we can do as a scientific community, perhaps we should be farming or doing something else" (Hansen and Sato, 2007b).

Pittock (2007) has well-described the limitations of the IPCC process: "Vested interests harboured by countries heavily reliant on fossil fuels for industry and development, or for export, lead to pressure to remove worst case estimates; scientists… tend to focus on “best estimates”, which they consider most likely, rather than worst cases that may be serious but which have only a small probability of occurrence; many scientists prefer to focus on numerical results from models, and are uncomfortable with estimates based on known but presently unquantified mechanisms; and due to the long (four-year) process of several rounds of drafting and peer and government review, an early cut-off date is set for cited publications" (often a year before the reports appear).

# Conclusion

The data surveyed suggests strongly that in many key areas the IPCC process has been so deficient as to be an unreliable and indeed a misleading basis for policy-making. An independent and authorative review can establish a more up-to-date and relevant scientific base that integrates recent data and findings, expert elicitations and the need in moments of uncertainty to fully account for the most unacceptable but scientifically conceivable outcomes. On that basis we can build strategies that would at least give us a real chance to avoid the great dangers manifesting in the climate system, of which we humans have become both the masters and precariously also its likely victims.

The primary assumptions on which climate policy is based need to be re-interrogated. Take just one example: the most fundamental and widely supported tenet — that 2°C represents a reasonable maximum target if we are to avoid dangerous climate change — can no longer be defended. Today at less than a 1°C rise the Arctic sea ice is headed for very rapid disintegration, in all likelihood triggering the irreversible loss of the Greenland ice sheet and catastrophic sea level increases. Many species are on the precipice, climate-change-induced drought or changing monsoon patterns are sweeping every continent, the carbon sinks are losing capacity and the seas are acidifying.

If we could start all over again, surely we would say we must stabilise the climate at an equilibrium temperature that would ensure the stable continuity of the Arctic sea ice? Given that this safe level has long since been passed, as soon as we knew there was a problem with the climate we should have aimed for a level of atmospheric CO2 that would allow the restoration and then maintenance of the Arctic ice cap, with a safe margin for uncertainty and error. The Arctic began to lose volume at least 20 years ago when the global temperature was about 0.5°C over the pre-industrial level. So we can now see that to protect the Arctic the average global temperature rise should be under 0.5°C.

The 2°C warming cap was always a political compromise, but with the speed of change now in the climate system and the positive feedbacks that 2°C will trigger, it looms for perhaps billions of people and millions of species as a death sentence.

If, for example, instead we were to apply a 0.5°C (or lower) precautionary warming cap, it would be necessary for the level of target atmospheric greenhouse gases at equilibrium not exceed about 320 ppm CO2e, a point we passed more than half a century ago.

The simple imperative is for us to very rapidly decarbonise the world economy and to put in place the means to draw down the existing excess CO2 levels. We must choose targets and take actions that can actually solve the problem in a timely way. It is too late not to be honest with ourselves and our fellow citizens.

6 October 2007

www.carbonequity.info/PDFs/arctic.pdf

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