EVIDENCE OF ACCELERATED CLIMATE CHANGE

Prepared by the Climate Adaptation Science and Policy Initiative, The University of Melbourne for the Climate Institute.

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The IPCC Fourth Assessment Report (2007) provides the latest and most authoritative available review of the science of climate change. However, the IPCC report only uses material published up to mid-2006, and many new important observations have been published since. These suggest that the IPCC assessment is underestimating the risks of adverse impacts due to increased warming during this century and that impacts previously considered to be at the upper end of likelihood are now more probable.[1] Greenhouse emissions are rising faster than the worst case IPCC scenarios. There is also concern that the IPCC process, in its efforts to represent the full range of uncertainties in climate change projections has not concentrated on some of the low probability, high consequence events. In particular, these include those which are not well represented in climate models such as rapid collapse of ice sheets or climate-ecosystem feedbacks.

The Climate Institute (Australia) (TCI) commissioned Climate Adaptation Science and Policy Initiative (CAPSI) to produce an independent review of the climate science post 2006 and subsequent to IPCC considerations. This research has been peer-reviewed by Graeme Pearman.

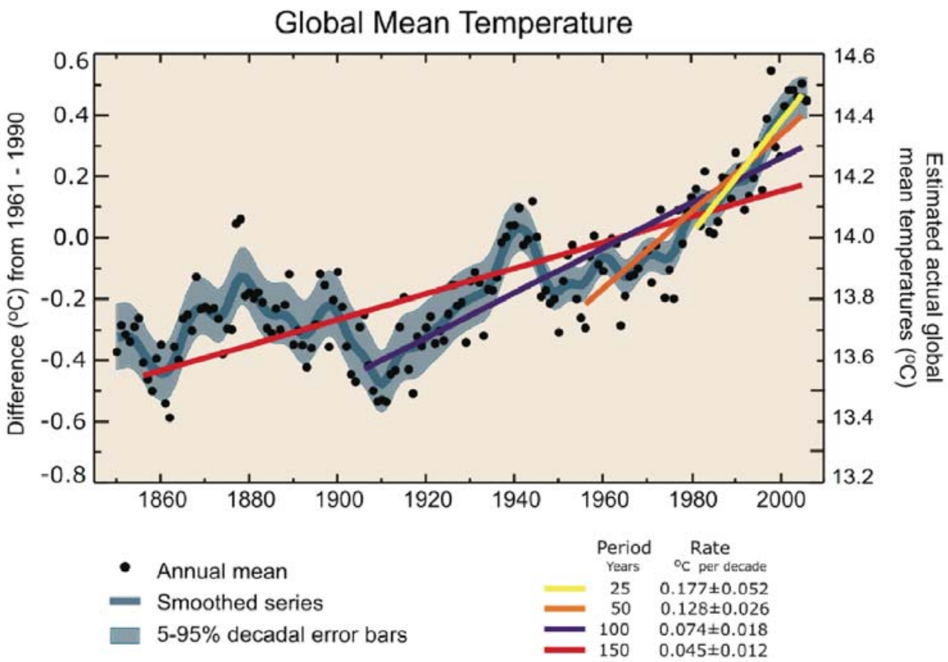
The Climate Adaptation Science and Policy Initiative (CASPI), is a cross-disciplinary initiative at the University of Melbourne that connects science and public policy to meet the local and global challenges of climate change. Prof Jim Falk is the convenor of CASPI and Mr Roger Bodman is the Research Officer.

Dr. Graeme Pearman was elected to Fellowship of the Australian Academy of Science in 1988 and has been a member and chair of many Australian and international meteorological/global change committees. Graeme was the former head of CSIRO Division of Atmospheric Research. He was also a recipient of a United Nation's Environment Program Global 500 Award in 1989 for his active involvement in a national awareness program on climate change and in 1999 he was awarded the Australian Medal of the Order of Australia for his services to atmospheric science and promotion of the science of climate change to the public.

Higher Temperatures

The average global warming is now 0.8°C over the past century, with recent warming growing at 0.2°C per decade.[2] If continued such a trend will lead to a temperature rise of approximately 3°C by the end of this century (relative to pre-industrial temperatures). Climate models also suggest that this 'business as usual' trend will produce global warming of around 3°C by the end of this century. This would be the highest global temperature rise recorded in recent palaeoclimate history. The global temperature warming trend is accelerating (see Figure 1).

FIGURE 1 – TRENDS IN GLOBAL TEMPERATURES.



Annual global mean surface temperatures (black dots) with linear fits to the data. The left hand axis shows temperature anomalies relative to the 1961 to 1990 average and the right hand axis shows estimated actual temperatures, both in °C. Linear trends are shown for the last 25 (yellow), 50 (orange), 100 (magenta) and 150 years (red). The smooth blue curve shows decadal variations, with the decadal 90% error range shown as a pale blue band about that line.[3]

Greenhouse Gas Concentration

Carbon dioxide emissions growth is accelerating. The growth rate is increasing from 1.1% per year for 1990-1999 to over 3% per year for 2000-2004. This recent high growth rate exceeds that in the most fossil fuel intensive emissions scenarios used by the IPCC.[4] In the face of limited efforts to curtail the production of carbon dioxide and other greenhouse gases, the concentration of these gases is continuing to increase (see Figure 2). The IPCC reports that the concentration of carbon dioxide per se (i.e., not CO_2 equivalent but pure CO_2) has increased from a pre-industrial value of 280 ppm to 379 ppm in 2005, with the recent ten year average growth rate rising to 1.9 ppm/year (1995-2005) compared to the 1.4 ppm/year average over 1960 to 2005.[5] The most recent data show that present day carbon dioxide concentration is now over 382 ppm.[6]

A major concern with this increasing concentration of greenhouse gases is how it translates into 'dangerous climate change'. The IPCC (2007) assessment suggest that this must be at or below 450 ppm CO_2-equivalent (CO_2-eq),[7] since this will lead to a 2^0C (median value) increase in global average surface temperatures above pre-industrial times. This level of change is accepted by the European Union as the limit beyond which there will be sufficient adverse impacts on the Earth's biogeophysical systems, animals and plants to constitute 'dangerous' change.[8]

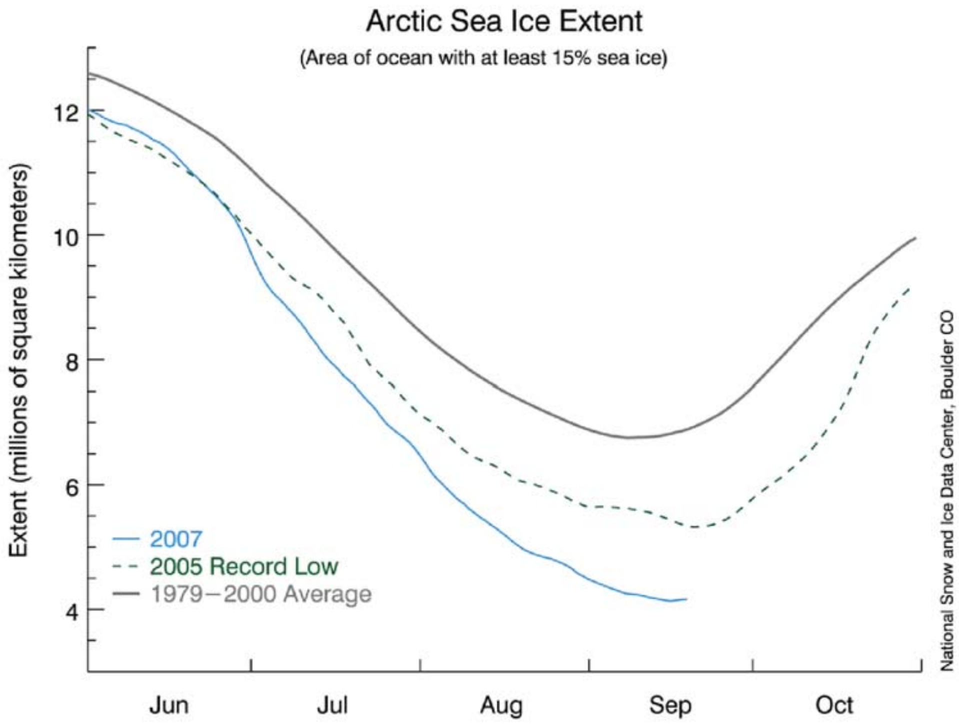
We are already at this 450 ppm CO_2-eq level. The IPCC reports that the total carbon dioxide equivalent concentration (CO_2-eq) of all long-lived greenhouse gases is now about 455 ppm CO_2-eq (range: 433-477 ppm CO_2-eq).[9] However, the immediate warming effect is reduced by atmospheric aerosols and other air pollutants, which result in an effective 311-435 ppm CO_2-eq concentration. But as the cooling effect of the aerosols declines, due to measures to avoid urban air pollution and acid rain, the warming effect remains. And there are no signs so far of any reduction in the growth of emissions in the long-lived greenhouse gases.

Methane has the second largest warming effect after CO_2, with about half the effect, taking into account its indirect influence on tropospheric ozone and stratospheric water, associated with atmospheric chemical reactions. At present, the growth rate of methane emissions has slowed, the cause of which is not well understood.[10] However growth may increase in a warmer and wetter climate regime,[11] and could increase significantly as a result of permafrost thawing.

Melting Sea Ice

The recent rapid decreases in Arctic sea ice are occurring much faster than any of the climate model projections suggest. A new summer minimum has been set in 2007.[12] Models show declining Arctic ice cover, but very few model simulations show trends as large as are observed. The current summer minima are approximately 30 years ahead of a range of simulation model forecasts. Models suggest that in a 'business-as-usual' scenario, an ice free Arctic Ocean might be achieved from 2050 to 2100 or beyond. But observation, if extrapolated on the basis of current trends, suggests a much earlier ice free Arctic. This suggests that whilst this region has been expected to be sensitive to greenhouse warming and feedback effects, this sensitivity may be greater than many current models suggest.[13]

FIGURE 2 – NEW RECORD LOW ARCTIC SEA ICE EXTENT IN SEPTEMBER 2007 COMPARED WITH PREVIOUS RECORD LOW IN 2005 AND 1979-2000 AVERAGE*.

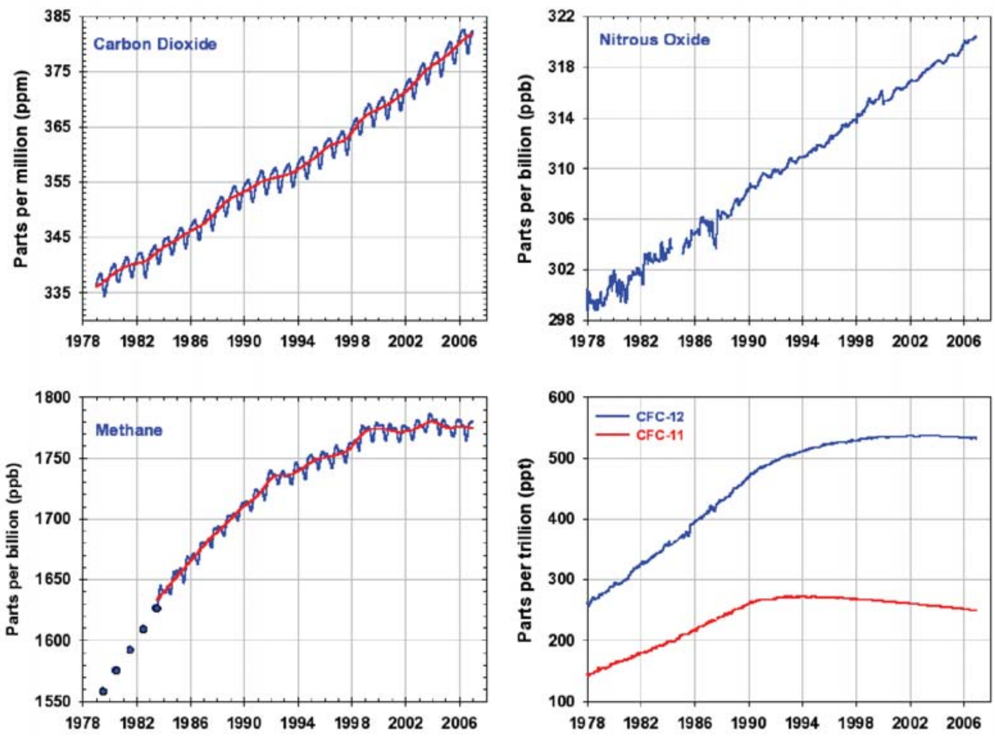


Collapsing Ice Shelves

The Antarctic Peninsula is one of the most rapidly warming regions of the planet.[14] The collapse of the Larsen B ice shelf in 2002 was the largest single event in a series of retreats by ice shelves in the Peninsula during the last 30 years. These retreats are attributed to strong climate warming in the region. The rate of warming in this region is approximately 0.5^0C per decade, compared to the global rate of about 0.2^0C per decade. This trend has existed since at least the late 1940s.[15] There has been increased summer snowmelt, loss of ice shelves and retreat of marine and tidewater glacial fronts. Flow rate measurements for Antarctic Peninsula glaciers indicate accelerating trends.

One consequence of this is to increase the annual sea-level contribution from this region, with an implied combined contribution of 0.16 ± 0.06mm/year. This amount is probably sufficient to make the total Antarctic contribution to sea-level positive, offsetting any mass gains in East Antarctica.[16] Surface and ocean warming may trigger accelerated ice discharge and, over the course of this century, counteract snowfall gains predicted by current climate models.[17] The predicted snowfall gains in Antarctica have not been observed.[18]

FIGURE 3 – GLOBAL AVERAGES OF THE CONCENTRATIONS OF CARBON DIOXIDE, METHANE, NITROUS OXIDE, CFC-12 AND CFC-11, FROM 1978 TO 2006.



Global averages of the concentrations of the major, well-mixed, long-lived greenhouse gases – carbon dioxide, methane, nitrous oxide, CFC-12 and CFC-11, from 1978 to 2006. These gases account for about 97% of the direct warming effect of the long-lived greenhouse gases since 1750. The remaining 3% is contributed by an assortment of 10 minor halogen gases. (Source NOAA, Annual Greenhouse Gas Index, http://www.esrl.noaa.gov/gmd/aggi/].

Sea Level Rise

A recent review of climate observations compared to projections suggests that the IPCC projections may have underestimated sea level rise. The observed sea level rise for 1993 to 2006 shows a linear trend of 3.3 +/- 0.4 mm/year, which is higher than the IPCC projected best estimate of 2mm/year.[19] Rahmstorf estimates a sea level rise of 0.5 to 1.4 meters by 2100,[20] which is much higher than the range of projections in the IPCC Fourth Assessment Report. In its 2007 assessment, the IPCC assumed a negligible contribution to 2100 sea level change from the loss of Greenland and West Antarctic ice. More recent work suggests that this conclusion is likely to be incorrect. Projected warming of 2-3^{o}C would result in increased melt-water during lengthened melt seasons. Multiple positive feedbacks would have a significant impact on accelerated loss of ice sheets. The consequences "could yield sea level rise of several metres per century with eventual rise of tens of meters, enough to transform global coastlines."[21]

Declining Sinks and Growing Sources

Recent work suggests that the capacity for the land and oceans to absorb carbon dioxide emissions is declining. IPCC science expected this decrease but the observed changes are larger than estimated suggesting that the carbon cycle is resulting in stronger and earlier warming effects than anticipated.[22] These sinks are important since roughly half of the anthropogenic carbon dioxide emissions are absorbed by land and oceans.

Increased atmospheric carbon dioxide concentration is expected to cause a decline in the oceans' capacity to absorb CO_2 as they become saturated. As a result, the marine biosphere becomes less effective in absorbing CO_2 emissions, and therefore atmospheric CO_2 concentrations rise more rapidly.[23] Further, as reported in a recent study of the Southern Ocean, there are signs that there has been an additional relative weakening of oceanic sinks as a result of changes in other atmospheric factors (wind, surface air temperatures and water fluxes).[24]

The terrestrial uptake of $CO_{2,}$ is expected to be reduced in the future, resulting in an additional increase in the atmospheric concentration of CO_2 and therefore further global warming.[25] As terrestrial ecosystems respond to anthropogenic climate change, including warming everywhere and drying in some regions, it is likely that some regions that have been sinks of atmospheric carbon will become sources, through decreases in net primary production, increased occurrence of wild fires, and changes in ecosystem composition.

Additional sources of methane may eventuate with increased temperatures, with releases from oceanic and terrestrial storages. With global warming over 1^{o}C there is an increased possibility of positive feedback from methane hydrates.[26] There is considerable uncertainty over the amount of methane hydrates, as well as the mechanisms and timeframes over which methane from hydrates might be released. There is a theoretical possibility of catastrophic release of a large proportion of the thousands of gigatonnes of carbon in the ocean hydrate reservoir, due to subsurface warming of the sediments in areas of rapid penetration of warmer water from the ocean surface.

Another potential source of methane is from melting permafrost. Such melting is occurring in boreal forests of the Northern circumpolar region, with evidence that temperatures of discontinuous permafrost have warmed in recent years sufficiently to approach or pass the melting point in some areas.[27] The likelihood and extent of methane releases is largely unknown, with a recent study suggesting that scenarios that point towards massive releases from degrading permafrost are questionable.[28]

Summary

Managing the risk of climate change requires consideration of those consequences that we understand and those where there is the potential (particularly if it is large) for impacts, even though at this stage the probability of the occurrence is unknown. This paper suggests that there exists evidence that the IPCC process may have led to an underestimation of the risk of greater warming and that the impacts of climate change are occurring more rapidly then previously projected. In part this may reflect the rapidly unfolding observations and theoretical understanding of climate change. This range of issues will require close monitoring and further research, and inclusion into the risk management process preceding policy development. To the extent that the impacts of climate change may be in the more severe range of those outlined in the IPCC Fourth Assessment Report, the case for a policy of risk management and more urgent intervention is strengthened.

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FOOTNOTES

[1] See, for example, B. Pittock, "Are Scientists Underestimating Climate Change?," EOS, Transactions American Geophysical Union 87, no. 34 (2006).

[2] J. Hansen and others, "Global Temperature Change," Proceedings of the National Academy of Science 103, no. 39 (2006).

[3] IPCC, Climate Change 2007: The Physical Science Basis of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. S. Solomon et al. (Cambridge, UK and New York, NY, USA: Cambridge University Press, 2007), WGI FAQ 3.1, Figure 1.

[4] M.R. Raupach and others, "Global and Regional Drivers of Accelerating Co2 Emissions," PNAS, no. 0700609104 (2007).

[5] IPCC, Summary for Policy Makers p2.

[6] Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends) The latest year of data is still preliminary, pending recalibrations of reference gases and other quality control checks.

[7] The amount of carbon dioxide emission that would cause the same amount of warming, over a given time horizon, as an emitted amount of a well mixed greenhouse gas or a mixture of such gases

[8] 'dangerous' refers to the use of the words 'dangerous anthropogenic interference' used in Article 2 of the United Nations Framework Convention on Climate Change. http://unfccc.int/essential_background/convention/background/items/1353.php

[9] IPCC, Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ed. B. Metz et al. (Cambridge, UK and New York, NY, USA: Cambridge University Press, 2007), Chapter 1, p102.

[10] IPCC, Climate Change 2007: The Physical Science Basis of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, WGI TS.6.1, (7.4).

[11] Ibid., AR4 WGI Chapter 7 p502.

[12] National Snow and Ice Data Center (NSIDC). Press Release 20 Sept 2007. http://nsidc.org/news/press/2007_seaiceminimum/20070810_index.html

[13] J. Stroeve and others, "Arctic Sea Ice Decline: Faster Than Forecast," Geophysical Research Letters 34, no. L09501 (2007).

[14] H.D. Pritchard and D.G. Vaughan, "Widespread Acceleration of Tidewater Glaciers on the Antarctic Peninsula," Journal of Geophysical Research 112, no. F03S29 (2007).

[15] NSIDC: http://nsidc.org/iceshelves/larsenb2002/

[16] Pritchard and Vaughan.

[17] A. Shepherd and D. Wingham, "Recent Sea-Level Contributions of the Antarctic and Greenland Ice Sheets," Science 315 (2007).

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[19] S. Rahmstorf and others, "Recent Climate Observations Compared to Projections," Science 316 (2007).

[20] S. Rahmstorf, "A Semi-Empirical Approach to Projecting Future Sea-Level Rise," Science 315 (2007).

[21] Hansen and others.

[22] J.G. Canadell and others, "Contributions to Accelerating Atmospheric CO2 Growth from Economic Activity, Carbon Intensity, and Efficiency of Natural Sinks.," PNAS, no. 0702737104 (2007).

[23] J. Hansen and others, "Climate Change and Trace Gases," Philosophical Transactions of the Royal Society A 365 (2007).

[24] C. Le Quere and others, "Saturation of the Southern Ocean CO2 Sink Due to Recent Climate Change," Science 316 (2007).

[25] IPCC, Climate Change 2007: The Physical Science Basis of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, WGI Chapter 7.6 p566.

[26] Hansen and others, "Climate Change and Trace Gases." Methane hydrates are a solid form of water that contains a large amount of methane within its crystal structure. Extremely large deposits of methane hydrates have been found under sediments on the ocean floors of Earth. They are produced by decaying organic matter falling to the sea floor, but in temperature and pressure conditions that result in their formation.

[27] K.P. Wickland and others, "Effects of Permafrost Melting on CO_2 and CH_4 Exchange of Poorly Drained Black Spruce Lowland.," Journal of Geophysical Research 111, no. G02011 (2006).

[28] G. Delisle, "Near-Surface Permafrost Degradation: How Sever During the 21st Century?," Geophysical Research Letters 34, no. L09503 (2007).

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