Appendix H

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A critical appraisal, with supporting references, of the Department of Climate Change's paper

Climate Change 2009:
Faster Change & More Serious Risks

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Extract[1] from the Due Diligence Report (2nd ed.) on Senator Wong's Replies to 3 Climate Questions

Review by:

Bob Carter, David Evans,
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[1] Full report available at: < http://joannenova.com.au/global-warming/the-wong-fielding-meeting-on-global-warming-documents/>

Appendix H – "Climate Change 2009: Faster Change & More Serious Risks"

Review of a commissioned report to the Department of Climate Change
by Professor Will Steffen, Australian National University

1. Professor Steffen's July 9 report carries an express disclaimer by the Department that it "*does not represent a statement of the policy of the Commonwealth of Australia*", and another by Steffen that "*The views expressed in this document are my own, and do not necessarily represent the views of the Australian Government Department of Climate Change*". Nevertheless, the report has been commissioned by the Department to reflect the views of the Australian scientific community, and it is therefore expected to be a major input to government policy.

   Some of the report's arguments were advanced also by Senator Wong in her discussions with Senator Fielding, and clearly have already been incorporated into government policy development.

2. In the Preface, Steffen indicates that his document "*reviews and synthesises the science of climate change since the publication of the IPCC's AR4, with an emphasis on rapidly changing areas of science of direct policy relevance*", and that it focuses especially "*on issues of importance to Australia*". Apart from this Australian customization, the report has significant commonalities with that of Richardson et al. (2009), which has been discussed in section F of the main text.

3. The credibility of the July 9 report is damaged at the outset by the inclusion in the Executive Summary of a version of the Mann et al. "hockey-stick" graph of northern hemisphere temperature for the last 1,000 years, complete with a shaded envelope of "natural variability" (which under-represents the magnitude of known recent climate variability), and vivid, red colouration applied to a "burning embers diagram" that is intended to convey alarm. For further comments on the inappropriateness of using this diagram, see paragraph E7.3 (main text).

   The value of the report is also compromised by its heavy dependence upon unvalidated modelling studies and "grey" literature, such as the Richardson et al. (2009) report, and its failure to consider recent research results that conflict with the IPCC's findings. A field as well funded as climate science is in a ferment of research, much of which is only available in pre-print or *in press* papers and in discussion on websites, which is where the breaking research-fronts lie. We use and cite such work when appropriate, because our concern is with the relevance, up-to-datedness and correctness of any science that we discuss: who performed the analyses, or where they might be available from, is irrelevant.

4. Therefore, as part of this review and its accompanying report, we have provided a selection of more than 130 recent references that contain evidence that contradicts the IPCC's assertions (i) that human-caused carbon dioxide emissions were the primary cause of the mild planetary warming observed in the 20th century, and (ii) that continuing human-caused emissions will cause dangerous future warming. The majority of these papers are published or *in press* in major peer-reviewed journals. In addition, tens of thousands of other high quality, refereed papers contain evidence that is consistent with the null hypothesis that the fluctuating 20th century temperatures were largely caused by natural processes.

   Recent research that throws doubt on the IPCC's central claims includes work that covers the validity of the concept of global temperature as a measure of climate change (Essex et al., 2007a), the inadequacy of deterministic climate modelling (Essex et al., 2007a; Green et al., 2009; Koutsoyiannis et al., 2008; Kucharski et al., 2009; Kukla & Gavin, 2004), negative feedback effects due to clouds (Cotton, 2009), ocean-land temperature relations, phase changes in annual temperature cycling, the influence of El Nino on global temperature and the impact of land-cover on temperature trends (Comp & Sardeshmukh, 2009; Fall et al., 2009; McLean et al., 2009; Pielke et al., 2007; Stine et al., 2009), falling ocean temperatures in southern Australia over the last several thousand years (Calvo et al., 2007) and globally over the last few years (Loehle, 2009), the residence time of carbon dioxide in the atmosphere (Essenhigh, 2009), and the low sensitivity of climate to increases in greenhouse gases (Lindzen & Choi, 2009; Soon, 2009; Spencer & Braswell, 2008).

   In presenting an updated account of the IPCC's central thesis of dangerous human-caused global warming, the Steffen July 9 report ignores these and other important recent papers, and its four main chapters present instead an account of climate change that is heavily dependent upon GCM computer modelling. We comment in more detail on each chapter of the report in turn, below.

5. ***Chapter 1.*** This chapter briefly summarizes the main conclusions of IPCC's Fourth Assessment Report, claims that some recent changes observed in ice sheets and natural carbon sinks are "*consistent with accelerating climate change*", and argues that incremental changes in temperature may cause deleterious climate "*tipping points*" to occur.

   In support of this, four graphs are provided of recent changes in carbon dioxide emissions, temperature change, sea-level change and Arctic ice extent to show that these claimed deleterious changes (warming, sea-level rise, ice shrinkage) are tracking in "*the upper range of the IPCC projections of climate change for this century*".

First, and as covered in more detail in Appendix D, the GCM computer projections that two of these graphs represent have no demonstrated forecast skill.

Second, even if the GCM-projected changes should eventuate, it is far from self-evident what the balance of environmental and socio-economic benefits and disbenefits will be.

Third, the illustrative graphs provided have been chosen or prepared in a selective way. For example, the Arctic sea-ice record chosen for display (Fig. 2a) fails to record the known earlier examples of Arctic ice-melt, such as the report in the Monthly Weather Review (Nov 1922) that warmer conditions in Arctic Norway had commenced in 1918, that by 1922 the waters around Spitzbergen no longer froze in winter, and that land ice had receded to be replaced by moraines as glaciers that had extended into the sea had disappeared; similarly Time (13/9/1937) reported the discovery of a new shorter navigable northwest passage, noting also that the northeast passage to China was first navigated in 1879 and that in 1937 Russia was operating a fleet of 160 freighters through the northeast Passage on summer schedules. In another example of selectivity, by terminating the ice record around 2006, Steffen's Fig. 2a also fails to record the rebound of sea-ice that has occurred in the last two years, with the result that the area of sea-ice is now similar to that in 1979 (cf. paragraph E4.4 and figure, main text).

6. Even more importantly, the projected global average temperature (Fig. 1b) and sea-level (Fig. 1c) projections cited as evidence that "*the climate system appears to be changing faster than earlier thought likely*" originate from Rahmstorf et al. (2007) and Rahmstorf (2009), and have been shown to be invalid by discussions amongst a number of different, independent scientists (e.g., Liljegren 2009; McIntyre 2009; Stockwell 2009a, 2009b).

   Rahmstorf (2009) used smoothing techniques that cause spurious correlations which affect significance testings and exaggerate the warming temperature and rising sea level trends, as follows:

   - the size of the smoothing filter was enlarged from previous smaller filter size used in original Rahmstorf et al. (2007), in order to display a continuing rising trend;
   - excessive data "smoothing" was undertaken, with 5 different types of smoothing method (Stockwell 2009b) and non-objective data padding procedures (Liljegren 2009; McIntyre 2009);

- superceded confidence intervals were taken from the 2001 IPCC report rather than the latest 2007 report (Liljegren 2009).

Figs. 1a and 1b must therefore be rejected, yet they are pivotal to the argument that current "evidence" is "*consistent with accelerating climate change".* A more objective, transparent and empirically-based discussion of the available scientific data must be insisted upon.

7. The second argument presented in Chapter 1 is that accelerated climate change will lead to the transgression of dangerous tipping points. Notwithstanding that no accelerated change has been demonstrated (4, above), we agree with Steffen's overall comment, which is that "*much more needs to be understood about these phenomena to assess the degree of risk they pose*", and "*much uncertainty surrounds the location of such tipping points and the probability that they will be crossed*". Indeed, we would go further to say that 'tipping points' are an emotive proposition with no basis in science. As Priestley (1966) has noted, surface temperatures are constrained by evaporation and 70 percent of the Earth's surface is comprised of freely evaporating oceans.

   It is established that sudden natural climate events are a real and present danger, and more research is certainly needed into the topic; but at present no evidence exists, nor is there good reason offered, that human activity is significantly increasing the likelihood of occurrence of dangerous natural climate events. In this regard, more research is necessary in particular into the causes and varying regional magnitudes of the historical multi-decadal to centennial events epitomised by the Greco-Roman Warm Period, the Dark Ages of the first millennium, the Medieval Warm Period, the Little Ice Age, and the current period of comparative warmth.

8. ***Chapter 2.***This chapter develops the themes raised in Chapter 1 by discussing in more detail several of the natural processes of climate change that are claimed to be operating at "*rates at or near the upper level of IPCC projections*". No reasons are given as to why this should necessarily be a problem, even were it to be true, and in no case is the hypothetical human climate signal that is claimed able to be identified as measurable, i.e. as discrete from natural rates of change.

   The processes discussed are melting ice and rising global sea-level, changes in the hydrological cycle in Australia, ocean acidification, and changes in storms and other extreme events. We have already dealt with some in these issues in the main text of this report. Space precludes our giving a detailed treatment here, but we provide a brief summary of the main topics in the next few paragraphs.

9. ***Melting ice and rising sea level (2.1).*** The IPCC approach to sea-level study, which Steffen summarizes, is heavily theoretical, is based upon deterministic

computer modelling and is concerned solely with eustatic (i.e., global) sea-level as opposed to the site-specific local relative sea-level knowledge that is required for meaningful coastal management around the world. Calculation of theoretical eustatic sea-level requires an accurate knowledge of the cryosphere and its processes that does not yet exist, as is indeed acknowledged in Steffen's comment (p. 7) that "*estimates of the contributions [to sea level rise] from polar ice sheet dynamics …. cannot yet be modelled quantitatively with confidence*".

10. Steffen's Fig. 5 requires special comment because in the context of Greenland and Antarctic ice masses the explanation provided is misleading, and particularly alarmist.

    The cartoon suggests that surface meltwater finds its way from the surface through cracks and crevices of the ice sheet to bedrock, and contributes to ice sheet instability by lubricating the ice-bedrock interface. But such a process is confined to the lower elevations of the ice sheet periphery, where solar radiation is absorbed at the ice surface and causes melting. This meltwater may then be subject to re-freezing, as energy is lost to colder near-surface air and surrounding ice at sub-zero temperatures. In general, however, interior snow accumulation and ice sheet peripheral melting are co-existing processes in a stable ice sheet, and changes in the precise position of the ice front occur constantly through time in line with regional variations in precipitation and temperature.

11. In addition to acknowledging inadequacies in modelling skill, Steffen also quotes papers that, contrary to many other studies, report empirical data in support of a recently enhanced rate of sea-level rise (Church & White, 2006; Domingues et al., 2006) and a warming of Antarctica (Steig et al., 2009). In reality, these papers are underpinned by complex data manipulations and computer modelling, and the outlier results that they produce contradict other similarly detailed studies that show a steady rate of long term sea level rise (albeit with decadal modulations which include the start of a recent fall; Jevrejeva et al. 2008; Cazenave et al. 2009; Woodworth et al. 2009) and a cooling Antarctic ice cap - which, like Greenland, appears to be close to mass-balance (Stenni et al. 2002; Goodwin et al. 2004; Masson-Delmotte et al. 2004; Schneider, et al. 2006; Monaghan, et al. 2008; Schneider & Steig, 2008; Chapman, 2009).

12. In summary, and as discussed in the main text (E4), no empirical evidence exists that a substantial global melting of ice is underway, and most sea-level studies show that a long-term natural rate of rise of ~1.6 mm/yr has characterised the last 200 years and remains unchanged.

13. ***Changes in the Australian hydrological cycle (2.2).*** This section of the report is concerned primarily with detailed analysis of various aspects of the Australian

hydrological cycle, with especial reference to drought and the Murray-Darling Basin.

We do not wish to discount the vital importance for Australia of the issues raised here. But all of them concern local, or at their widest regional, climatic patterning. As such, they are neither amenable to deterministic modelling and nor do they bear any necessary relationship to hypothetical human-caused global warming. We discuss several of issues more fully in Section D of the main text, where we conclude that no empirical evidence exists that human carbon dioxide emissions are affecting Murray-Darling Basin rainfall patterns or regional Australian droughts.

The only meaningful graphic of the sequence in Fig. 10 is the first distribution chart (a). This shows the trend in annual total rainfall for the period 1900-2005 where, for most of Australia, the trend is positive. This is consistent with slightly warming sea surface temperatures, increasing ocean evaporation, and consequently increasing rainfall.

14. ***Changing alkalinity of the ocean (2.3).*** It is no coincidence that section 2.3 of Chapter 2 is entitled "*Ocean acidification*", for control of language is a powerful tool deployed by those who wish to convert others to a cause. Thus we hear about "carbon" when "carbon dioxide" is meant, "climate change" when "dangerous human-caused global warming" is meant, and now "ocean acidification" when "changing alkalinity of the ocean" is meant, because the oceans are consistently alkaline despite rainfall with its dissolved carbon dioxide being acidic.

15. The oceans have been alkaline since the late Precambrian, about 750 My ago, when the amount of carbon dioxide in the atmosphere was up to 20 times higher than now (e.g., Kump et al., 2000). Today, we live on a carbon dioxide starved planet as judged against geological history. In between, carbon dioxide was progressively removed from the atmosphere via inorganic and organic carbonate sediment deposition, some of which later became sequestered as onland limestone by tectonic processes of accretion of sea-floor to the continental margins.

    These geochemical, geological and biological processes continue today, in an ocean that is now heavily buffered by water-rock and water-sediment reactions (e.g., Walker et al. 1981), which means that it is difficult to permanently change the pH by adding acids (including dissolved carbon dioxide as $H_2CO_3^-$) or bases. At least as long ago as the Eocene, ~45 Ma, the pH range in shallow ocean water is estimated to have been similar to today, at 8.33-7.91 (Pearson & Palmer, 1999).

16. Ocean bio- and geochemical processes that involve carbon dioxide are controlled by the saturation level, which is the maximum amount of gas that can be dissolved in a given volume of sea water. The saturation level varies with temperature, pressure and the concentration of other dissolved materials; pH is consequential and of lesser importance. The carbon dioxide saturation level decreases with increasing temperature, and increases with increasing pressure. Saturation at the ocean surface is therefore controlled mainly by temperature, and at ocean depths near and below 3-4 km (at a level termed the lysocline, below which calcium carbonate dissolves) by pressure.

    Warm and shallow tropical ocean waters occasionally become supersaturated with carbon dioxide, causing the direct precipitation of inorganic calcium carbonate. More generally, and as a result of the biological processes of photosynthesis, respiration and decomposition, the oceans at large are undersaturated. Nonetheless, and despite the strong buffering, local, regional and depth variations in pH all exist; near the surface these are related to temperature changes and biological activity, and at depth to pressure and water-mass transport. The result is that seawater average pH is widely variable, typically from 7.5 at depth to around 8.5 in surface waters. Finally, pH varies not only with depth and geography, but also with time as a result of diurnal variations in temperature and biological activity. For example, Revelle & Fairbridge (1957) recorded a pH of 9.4 in isolated coral reef pools during the warmth of the day and 7.5 at night, the reduction being attributable to a lack of photosynthetic uptake but continued respiration; meanwhile, adjacent reef waters remained more or less steady at pH 8.2.

17. Against this long background history of ocean buffering and natural variability in carbon dioxide saturation, and the additional, self-evident fact that modern marine organisms thrive across a wide alkalinity range, it is asserted or implied, using deterministic computer modelling, that (i) a meaningful ocean average pH exists at which all, or most, marine organisms thrive; (ii) this average pH has become less alkaline by 0.1 pH units since pre-industrial time; and (iii) a doubling of atmospheric carbon dioxide will cause a dangerous further change in ocean alkalinity that is beyond the range of adaptive response of many marine organisms (e.g., Guinotte et al., 2003).

18. The persistent, and determinedly alarmist model projections of "acidification" of the oceans suffer, from many inadequacies. These include:

    - inadequate density of historical and geographical data coverage;

- uncertain accuracy of some historical pH measurements, including inadequate correction for the temperature-dependency of pH;

- a failure to take into account Henry's Law, whereby any warming of the oceans results in the outgassing of carbon dioxide, concomitantly reducing the amount of dissolved gas and increasing the alkalinity;

- the ignoring of experimental data which show that adding carbon dioxide or iron to the ocean can cause more photosynthesis (fertiliser effect) rather than pH change (Nielsdottir, M.C. et al., 2009) , a result consistent with the SeaWIFS satellite that has recorded an increase in oceanic chlorophyll-a levels over the last 15 years; new experimental results show that the common phytoplankton of the North Atlantic grow in size and volume with increasing carbon dioxide, in contradiction of earlier experiments that incorrectly reduced the pH of the ocean water used by the direct addition of hydrochloric acid instead of letting carbon dioxide bubble through the water;

- the effect of weathering resulting from enhanced atmospheric carbon dioxide, which would slightly accentuate the acidity of rain, cause an acceleration in weathering and drive more calcium down the rivers to encourage the eventual formation of more oceanic limestone;

- the assumption that any decline in pH should be attributed to increased atmospheric carbon dioxide, whereas some such changes are certain to be related to natural multidecadal cycling (e.g., the Pacific Decadal Oscillation) which is known to change oceanic temperature and biological productivity;

- a lack of allowance for the proven adaptability of marine organisms; for example, ancient coral reefs first evolved at a time when the atmosphere contained many times the present concentration of carbon dioxide, in addition to which modern coral reefs thrive in carbon dioxide-rich environments; and

- a failure to consider that the small changes in equilibrium ocean pH calculated by chemical modelling lie well within the current natural range of pH variability to which many marine organisms are already comfortably adapted.

19. Steffen also reports the recent claim that carbon dioxide-linked changes in temperature and alkalinity have caused a recent 14% decline in the rate of calcification in the coral *Porites* from the Great Barrier Reef (De'eath et al., 2009).

    Though De'eath et al.'s (2009) paper has been widely quoted as demonstrating a recent collapse of GBR coral growth rates, that conclusion conflicts with earlier research that showed a statistically significant increase of 4% in growth rates during the warmings of the 20th century (Lough & Barnes, 2000).

    Stimulated to enquire into this, Ridd et al. (2009) have attempted to replicate the results of De'eath et al., and concluded that their inference of slowed coral growth rate "*depended unduly on questionable end-of-time-series data from cores that ended in the years 2004/2005".* In addition, their analysis *"did not allow for the naturally occurring ontogenetic reduction in calcification rate that is evident in the data set* ". Thus it is evident that the dataset analysed by De'eath et al. does not support the hypothesis that coral calcification has slowed recently on the GBR, whether due to acidification of the ocean or for any other environmental reason.

20. *Conclusions regarding Section 2.3.* The concept of "ocean acidification" is based on computer modelling of the reaction of adding carbon dioxide to water, and projecting that a large increase in atmospheric carbon dioxide will cause a small reduction in ocean pH. In effect, the pH of surface water is expected to become slightly less alkaline, and move closer to the mean pH of the oceans, but at the same time it will remain well within the range of tolerance of most marine organisms. True "acidification" of the ocean would require average pH to be reduced to below 7, which is impossible given the ocean's effectively limitless buffering capacity.

    Carbon dioxide levels in the atmosphere are controlled partly by outgassing from the oceans, and in turn the alkalinity of the surface ocean is generally consistent with the carbon dioxide content of the atmosphere. But both the oceans and the atmosphere are in constant turbulent motion, with consequent variability in gas interchange at different locations, and modulated also by differing time constants up to millennia long. Ocean pH is therefore not just a function of atmospheric carbon dioxide alone, but rather depends just as much on complex biogeochemical processes and physical changes in temperature, salinity and nutrients – a major consequence of which is that ocean surface pH varies widely from one location to another, from about 7.9 in regions of upwelling deep water to about 8.2 in areas of surface sinking.

    The idea that a small shift in ocean average pH, should it occur, will cause catastrophic environmental damage is fundamentally implausible; and the more so because the alarm is yet again centred around the projections of unvalidated computer models rather than empirical evidence.

21. ***Changes in storms and extreme events (2.4).*** Steffen notes at the outset (p. 25) that *"it is difficult to determine whether, in fact, extreme events have been increasing over the past several decades, primarily due to the quality and length of the data sets needed to detect significant changes in infrequent events".* This leads, yet again, to the inevitability that his discussion of extreme events is mostly predicated upon the projections of regional and global climate models, despite their established lack of statistical skill (cf. Appendix D).

    A second problem with the Chapter 2 analysis of extreme events is the constant confusion of correlation and causation. To argue for environmental intervention to prevent or correct a human-induced change requires, first, demonstration of a change; second, demonstration that the change is on balance deleterious; and, third, demonstration that increasing human carbon dioxide emissions have caused the change, rather than happen to coincide with it. To our knowledge, these three conditions have not yet been met for any of the environmental issues that are commonly discussed in the global warming context, including those raised in Chapter 2.

    Our preference is to utilise empirical data in any search to identify changes in the power or frequency of occurrence of damaging natural events. Extreme events are a major hazard for which preparation is required, for communities have to manage them irrespective of whether they are related to climate change or simply represent the variability of the natural system.

22. One of the few certainties in a warming world is the rapid increase in surface evaporation from the warmer temperatures of the ocean surface. Archaeological and geological evidence points to a wetter Earth during the Holocene Climatic Optimum 4,000-8,000 years ago. The great inland sand dunes of Australia formed during cold, arid glacial periods and not during the warmer interglacials. Although Australia is subject to periods of drought, these events are linked to changes in ocean surface temperature patterns rather than the absolute value of ocean temperature. Current GCMs are unable to resolve the causes of these changing patterns of ocean surface temperature, and it is only for the last few years that subsurface temperature data have been available as a resource to validate the ocean component of the GCM.

    Storms and extreme events are manifestations of the thermodynamics and hydrodynamics of the atmosphere's circulation. Steffen does not demonstrate any theoretical way in which the intensity and frequency of storms and extreme events might be linked to temperature. For example, wind strength is related to pressure gradient, which can be linked to the vertically integrated horizontal temperature gradient. Measurements suggest that as global temperature rises the equator to pole temperature difference actually decreases, potentially leading to reduced rather than increased storm intensity. Other empirical evidence (Chen et al, 2006) also suggests that warming leads to increased meridional overturning in the tropics and stronger vertical wind shear, a known inhibitor of tropical cyclone formation and intensification.

23. Notwithstanding these theoretical and empirical expectations, Steffen refers to papers whose authors use recent historical data to claim an increase in the intensity or number of tropical cyclones. The topic is one of complex debate, but nevertheless the most recent studies indicate:

- that over the short term, 2009 represents a last-35 years lowpoint in the global energy index of tropical storm power (Maue, 2009 a, b);
- that over the longer term (6,000 years), the incidence of cyclones during the 20th century in tropical Queensland was less than the long term average rate of occurrence (Nott et al., 2009);
- that more landfalling cyclones occurred in tropical Queensland during the 15th, 17th and 19th centuries (Little Ice Age) than during the warmer 20th century (Nott et al., 2007); and
- that greater tropical decadal climate variability occurred in the 19th than in the warmer 20th century (Fig. 1) (Ault et al., 2009).

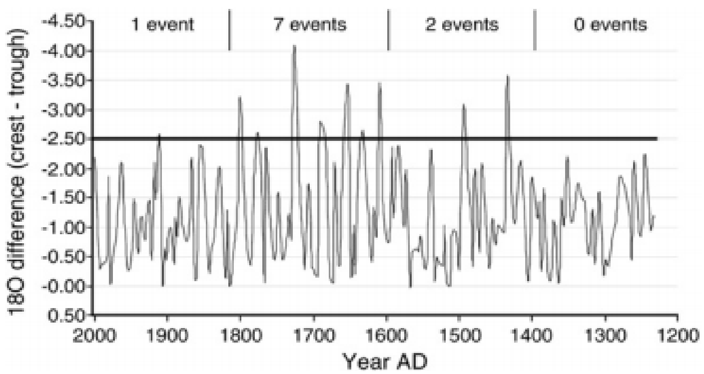


Fig. 1. Tropical storm history for the Chillagoe speleothem, North Queensland. Detrended $\delta^{18}O$‰ values in excess of –2.50‰ indicate landfalling severe cyclones. Note 7 events between AD 1600–1801 ("Little Ice Age") and only 1 event since AD 1801 (including late 19th and 20th century warming (after Nott et al, 2007).

24. ***Chapter 3.*** This chapter claims that the most important recent advances in climate science have stemmed from systems-level studies, illustrating that idea by presenting examples relevant to climate sensitivity, aerosol masking, carbon cycle feedbacks and palaeoclimate.

What is conveniently ignored are the known examples that show GCMs to exaggerate the human perturbation of the climate system. For example, Wentz et al. (2007) identify that GCMs used in the 2007 IPCC fourth assessment underestimate the rate of increase of global evaporation with temperature by a factor of three or more. Consequently the models underestimate the increased global precipitation that global warming will bring. Similarly, Held & Soden (2006) identify that the Hadley Cell circulation of the same GCMs decreases in intensity with warming, contrary to empirical evidence over the past few decades of exactly the opposite response.

25. ***Climate sensitivity (3.1).*** "*Climate sensitivity is often defined today as the long-term temperature increase that would result from a doubling of atmospheric CO_2 concentration from pre-industrial, that is, to about 560 ppm*" (Steffen, p. 32).

It is relatively uncontroversial that a doubling carbon dioxide will in the first instance produce a warming of no more than 1^0 C (e.g., Lindzen, 1997). In nature, this figure will then be moderated up and down by various feedback loops, especially those involving evaporation, water vapour and low clouds.

The climate models used in the IPCC's 3rd and 4th Assessment Reports favour positive feedback loops due to water vapour and clouds, resulting in an estimated range of possible sensitivities between about 2.8 and 5.8^0 C for a doubling of atmospheric carbon dioxide. Steffen argues (p.34-35) that the IPCC models omit important slow feedback processes such as release of carbon dioxide from the deep ocean, and that when these are taken into account "*the eventual temperature rise in response to a doubling of CO_2 is at least 3°C and likely up to 6°C*". Such conjecture ignores the approximately 1,000 year overturning period of the thermohaline circulation, and the slow modification of carbon dioxide concentrations at the source regions (the polar seas) as the water mass slowly cycles through the deep oceans.

In contrast, independent scientists have argued that the IPCC's feedback calculations are overestimates, that clouds and water vapour exert negative feedback effects, and that a more likely climate sensitivity is between 0.3 and 1.5^0C (Idso, 2001; Schwartz, 2007; Idso & Singer, 2009, p.27; Spencer & Braswell, 2006; Spencer, 2009). Strong negative cloud feedbacks were demonstrated by Wyant et al. (2006), using superparameterization modelling techniques, and more recently, Lindzen & Choi (2009) have used empirical tests to show that the feedback from water vapour is negative, rather than positive as presumed by the IPCC.

It is clearly premature to raise global warming alarm with policymakers on the basis of presumed high climate sensitivities incorporated in climate computer models, the unvalidated projections of which are contradicted both by other modellings and above all by empirical evidence.

26. ***Aerosols (3.2).*** The tenor of Steffen's discussion underscores the many uncertainties surrounding our knowledge of aerosols on global climate. Empirical evidence clearly shows that aerosols injected into the stratosphere, for example by major volcanic eruptions, result in global cooling. The typical pattern is one of increased cooling as the volcanic aerosols disperse around the globe, followed by a return to the pre-volcanic trend as the aerosols sink to the troposphere under gravity and are washed out in rainfall. Even a major event becomes undetectable after a couple of years.

    The lower troposphere constantly receives aerosols injected into it by way of natural processes. Common sources include dust blowing over arid regions, smoke and ash from seasonal forest and grass fires, and salt and dimethyl sulfide from ocean evaporation. No accurate measurements are available regarding the relative contributions of human-caused and natural aerosol sources. To add to the uncertainty, the radiation absorbtion characteristics of atmospheric aerosols are poorly known, and even less is known about the quantification of their seasonal and regional distributions.

    Finally, a recent paper by Myhre (2009) uses satellite data to show that the assumed cooling effect of aerosols in the atmosphere is up to 40% less than that used by the IPCC in their climate models, i.e. the climate sensitivity set in the models is too high. As a result, the amount of warming credited to carbon dioxide by the models is overestimated

    It is therefore heroic, at best, for Steffen to claim that "*The direct cooling effect of most aerosols in the atmosphere is becoming better understood, and their quantitative effect on radiative forcing are included in the IPCC AR4 (2007)*". Rather, his frequent use of the word 'estimates' in his discussion is a reflection that no valid quantification yet exists for the impact of aerosols. Therefore, the suggestion that removal of the aerosols would lead to the elimination of Arctic sea ice and Himalayan-Tibetan glaciers is untrammelled speculation.

27. ***Carbon cycle feedbacks (3.3).*** In section 3.3, Steffen provides a brief description of some aspects of the global carbon cycle, including comments on sources and sinks and the conclusion (p. 35) that global warming may cause a "*weakening in the efficiency of natural sinks*" within which to absorb human emissions.

    In reality, the effect of human emissions on global levels of carbon dioxide and methane in the atmosphere is not well understood. No one, including the IPCC, can satisfactorily account for the observed levels, even approximately. What we do know is that:

- Humans currently add about 8 Gt of carbon per year to the atmosphere;
- The atmosphere contains about 780 Gt., of which each year it exchanges ~90 Gt with the oceans and another ~100 Gt with plants;
- Thus about 25% of the atmospheric carbon is turned over each year, and the observed decrease in carbon-14 after the cessation of atmospheric nuclear bomb tests in 1963 confirms that the half-life of carbon dioxide in the atmosphere is less than 10 years (Robinson et al., 2007);
- The ocean has about 38,000 Gt of carbon dissolved in it, some of which is lost each year in the formation of limestone. The vapor pressure of CO_2 above the ocean rises with ocean temperature; the oceans eventually absorb any CO_2 above that vapor pressure;
- The residence time of carbon dioxide in the atmosphere, at around 5 years, is much shorter than assumed by the IPCC, which suggests that only about 5% of the rise in carbon dioxide in the last hundred years is derived from human sources, the remainder being natural (Segalstad, 1998; Essenhigh, 2009).

In light of these numbers and rates of carbon turnover, the small observed trends inabsorption of carbon dioxide attributed to humans are not significant. In the long run, when equilibrium is achieved, human emissions will have an insignificant effect on the amounts of carbon dioxide and methane in the atmosphere and oceans. Though we know little about the transient effects of human emissions, there is little reason to suspect that they are dangerous; indeed, the effect of enhanced carbon dioxide on plant life is clearly beneficial.

28. Steffen also canvasses the dangers of a surge from melting permafrost should Arctic warming resume, yet historical and geological evidence clearly discounts this as a problem. In the medieval warm period, when global temperatures were a little higher than currently, people were buried in graves in what is now permafrost—so there were areas not permafrost then that are permafrost now. It is clear, therefore, that the warming associated with the Mediaeval Warm Period must have caused melting of permafrost, and release of methane, that did not lead to runaway warming.

29. ***Palaeoclimate studies (3.4).*** An essential part of understanding climate change is the study of the patterns of past, ancient climate change. The context for making adequate judgements about contemporary change is provided by the study of climate records that extend back for at least hundreds of thousands of

years. Such records shows that there is nothing unusual at all about either the rate or magnitude of warming that occurred during the late 20th century (e.g., Carter, 2008).

30. Steffen commences his section on past climates unpropitiously by referring, first, to the results of a modelling study (Otto-Bleisner et al., 2009), followed by a commendation of the discredited Mann et al. (1999) "hockey stick" depiction of northern hemisphere temperatures (see main text, section E7) and a call for the development of a Southern Hemisphere equivalent. Steffen also uses information from the extended ENSO index record back to 1550 of Braganza et al. (2009), and a study of climate patterning in coral records from the eastern Indian Ocean since the mid-Holocene (6,500 ybp; Abram et al., 2007), to infer that "*the drought in south-east Australia is probably linked, at least partly, to climate change* ....".

Whilst the studies cited provide important information on the variability of ENSO and Indian Ocean Dipole activity over the more recent past, on their own they are inadequate as a context for Holocene (last 10,000 years) climate change, and they certainly do not sustain the conclusion that the current Australian drought is a result of human-caused global warming (cf. Lockart et al., 2009).

31. In many places around the world, the early Holocene, termed the "climatic optimum", was 1-2^0 C warmer than today, one major environmental consequence of which was the melting of the sea ice in the Arctic Ocean (Fisher et al., 2006). A recent study by Moros et al. (2009) shows that the southern Australian margin experienced reduced ENSO conditions at this time, as a result of a northward shift in oceanic frontal systems (Fig. 1). In addition, Moros et al.'s study shows the presence of a regular 1500 year climatic

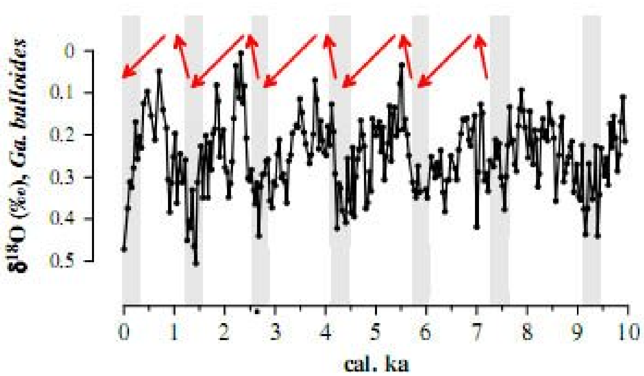
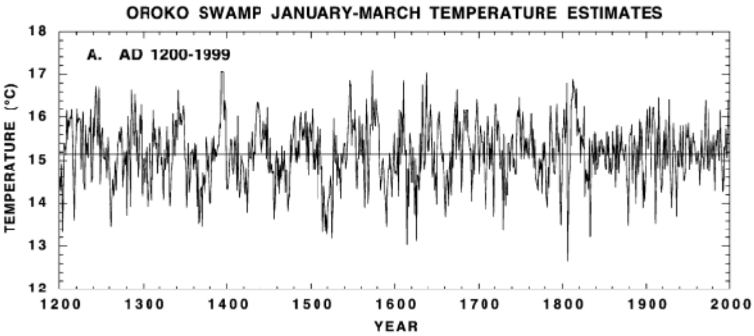


Fig. 2. Holocene climatic history represented by oxygen isotope analysis (a temperature proxy) of a marine core from Murray Canyon, southern Australia. Note the subdued record in the early Holocene, which relates to reduced ENSO variability, followed later by a marked ~1,550 yr cyclicity of climatic warming and cooling of possible solar origin (after Moros et al., 2009).

cycle of possible solar origin (cf. Singer & Avery, 2008) within which the warming at the end of the 20th century (not captured by the core) represents a regular sinusoidal warm peak, and is therefore entirely unfearsome. That unusual Southern Hemisphere warming did not occur at the end of the 20th century is also confirmed by the best extended tree-ring series available, three from Tasmania and South America (Cook et al., 1996) and one from western *Fig.*



3.800-year long tree ring reconstruction of summer temperatures for western South Island, New Zealand, using living and fossil specimens of silver pine. Note lack of unusual warming in the 20th century (after Cook et al., 2002).

South Island, New Zealand (Cook et al., 2002) (Fig. 3).

Clearly, knowledge of such mid-range climatic cyclicities is vital for the correct interpretation of late 20th century warming, yet neither Steffen's July 9 report nor the IPCC's climate models take serious account of them.

32. Polar regions are sensitive indicators of climate change, and their ice-core records provide particularly important, extended proxy records of geologically recent climate change that are superior to tree-ring records.

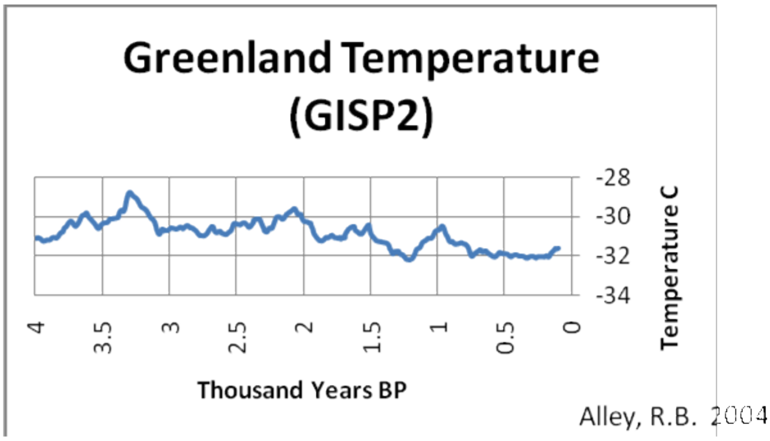


Fig. 4. Greenland temperature for the last 4,000 years, reconstructed from the GISP2 ice core. A millennial rhythm is apparent, with warmer temperature peaks at 3,700, 1,900 and 1,000 years ago.

More infrared radiation is emitted to space over polar regions than the local absorption of solar radiation. The local energy balance is maintained because the atmospheric circulation is continually transporting energy from the tropics to the polar regions. As a consequence, the temperatures over polar regions are warmer than they would be under purely local radiation balance. Therefore, variations in the intensity of the atmospheric circulation will lead to variations in temperature over polar regions: as the circulation increases and there is more rapid transport of energy then polar temperatures rise; if the atmospheric circulation diminishes there is a slowing of transport and polar temperatures cool.

The response of polar temperatures to atmospheric circulation helps explain why polar temperatures are much more variable than those of the tropics and middle latitudes. For example the magnitude of polar temperature variation over the glacial cycle is about 15^0C, whereas for the tropical oceans it is only about 3^0C. Other important conclusions from ice core data are discussed in section E6 of the main text.

33. ***Chapter 4.*** This chapter stresses the importance of studying climate change within the context of Earth Systems Science, including the effects of human activity. In this context, Steffen recommends that detailed attention be paid to developing a "*seamless prediction from weather to climate*", to studying the "*tipping points*" of the climate system, and stresses the importance of including human impacts in earth system models.

34. In discussing the first of these issues, Steffen claims (p. 41) that "*Global climate models can predict the state of the climate system a century into the future, given external forcing factors*", and that "*the missing scale in current modelling expertise is from a few years to a few decades*".

    It may be that writing "predict" rather than "project" represents an unconscious slip, but even with that word corrected the general tenor of these remarks is disturbing because it suggests that Steffen believes that GCMs are able to make valid climate predictions. This impression is reinforced by his independent statement on p. 34 that "*over shorter timeframes of less than a century or two, they* [global climate models] *are very reliable for projecting changes in global mean temperature*".

    On the contrary, Steffen's belief conflicts head-on with the realities of modern weather forecasting and climate modelling practice. A seamless prediction from weather to climate comes to an abrupt halt after a few days only, and "predictions" a week in advance are currently considered to be no better than early warnings. This is because computational rounding errors propagate rapidly through the simulation, and render predictions worthless. In addition, no ability currently exists to simulate the processes of internal climate variability such as ENSO, and a precise knowledge of the external forcing processes on climate remains lacking.

    The point cannot be overstressed that whilst weather forecast models are validated predictive tools on a scale of a few days, GCMs, for all their fine heuristic value, are not. This was the precisely the reason that we concluded in paragraph E11.4 (main text) that GCM outputs "*are highly misleading scenarios to provide to policymakers*", a point we now repeat.

35. This important matter apart, we agree with Steffen that the topics discussed in Chapter 4 are relevant to understanding climate change, and that the integrated systems approach is an important one. But, in studying matters at the system

level, sight must not be lost of the importance of rigorous disciplinary studies of the component parts of the system.35. Finally, we should always remember the IPCC's adjuration (3rd Assessment Report, Section 14.2.2.2, p. 774) that "*In climate research and modelling, we should recognize that we are dealing with a coupled non-linear chaotic system, and therefore that long-term prediction of future climate states is not possible*".

The solution to global environmental problems, therefore, is never going to be provided by the construction of ever more complex deterministic computer models (cf. Appendix D, last paragraph), however well integrated they might be, but by careful observational, statistical and theoretical studies using the time-honoured and sound techniques of empirical scientific investigation.

36. ***OVERALL CONCLUSION.*** The July 9 report by Professor Steffen draws on many of the same arguments for dangerous human-caused global warming that were advanced by Richardson et al. (2009) in their report from the *ad hoc* climate meeting in Copenhagen in March. These arguments are uncompelling.

In essence, the July 9 report reveals:

- an over-reliance on unvalidated computer model projections;
- a failure to take full account of natural climate variability, and known short to mid-length climatic rhythms, to explain 20th century temperature changes;
- an absence of any new empirical data in support of the concept of dangerous global warming caused by human carbon dioxide emissions; and
- a failure to consider many recent papers and discussions containing evidence that conflicts with warming alarmism.

In consequence, many of the conclusions of ***Climate Change 2009: Faster Change & More Serious Risks*** are misleading; and they are unsuitable, if not actually dangerous, as a basis for the development of public climate policy.

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