Responses to Questions & Objections on Climate Change

Dr Brett Parris

Chief Economist, World Vision Australia
&
Research Fellow, Monash University

18 September 2009

Contents

Introduction

This paper grew out of my work at both Monash University and at World Vision, where I focus on the current impacts and future projections of climate change in developing countries. Some may be interested to know why an international development agency like World Vision would be taking the science of climate change so seriously. The reason is that climate change is already impacting poor communities around the world and the projections of future impacts if we do not act to rein in emissions are nothing short of horrific – a word I do not use lightly.

For the poor and for today's children who will inherit our legacy, these are not abstract debates. They are not opportunities for political point scoring, or for fighting left-right culture wars. The science of climate change matters and it deserves to be taken seriously.

When the British economist John Maynard Keynes was derided for changing his position on economic policy he replied: "When the facts change, I change my position. What do you do, sir?" Keynes' response reflects the open-minded attitude of a genuine inquirer, a true skeptic, willing to change his mind when new information emerges, or when the weight of evidence, the balance of probabilities and the risks and consequences of being wrong become overwhelming.

Not everyone approaches the issue of climate change in this open-minded way. Some come to the science through the lenses of political ideologies or economic interests, maintaining positions dogmatically in the face of overwhelming evidence to the contrary, and endlessly recycling views that have been repeatedly debunked by scientists. We have seen this approach before with those who continue to deny the moon landings, the link between HIV and AIDS and the link between smoking and cancer.[1] Some continue to try to convince the public and governments that there is a raging debate among scientists about the main drivers of climate change. There isn't. As Nicholas Stern, author of *The Stern Review* on the climate change for the British Government[2], wrote recently:

> The argument for inaction, or for weak or delayed action, would make sense on the basis of reservations about the science only if one could assert that we know for certain that the risks are small. In the face of the evidence we now have, that is a complacent, ignorant and dangerous position to take. It is not healthy skepticism or an openness of mind; it is a denial of evidence and reason.[3]

This document discusses some of that evidence and responds to some of the most common objections. It is not intended to be comprehensive and the interested reader is referred to the reference list and the 'Useful Resources' section at the end for more comprehensive websites and other materials. Please send any constructive comments or suggestions for improvements to: Brett.Parris@buseco.monash.edu.au

[1] This is not an idle comparison. See for example the Union of Concerned Scientists' (2007) documentation of how one oil company's tactics were virtually identical to those of the tobacco lobby.
[2] Stern (2007).
[3] Stern (2009), p. 35.

1. The IPCC is a political body and its reports are scientifically unreliable.

False. There are many misconceptions about the Intergovernmental Panel on Climate Change (IPCC). Some people appear to believe the IPCC's reports are concocted by a small band of 'UN scientists' in collaboration with (presumably) left-wing governments intent on deceiving the world. Nothing could be further from the truth. The IPCC is a scientific intergovernmental body created in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP). It is the principal source of scientific advice for the United Nations Framework Convention on Climate Change (UNFCCC).[4]

The IPCC does not conduct its own research or climate monitoring. Instead it undertakes a comprehensive review and distillation of many thousands of published peer-reviewed papers and reports, representing the work of the overwhelming majority of the world's climate scientists and produces assessment reports publishing these findings. A good summary of the nature of the IPCC's work was given by Rik Leemans: "a scientific assessment applies the *judgment* of experts to *existing* knowledge to provide scientifically *credible* answers to *policy-relevant* questions."[5]

The three working groups of the *Fourth Assessment Report*, published in 2007, produced reports on *The Physical Science Basis*, *Impacts, Adaptation and Vulnerability* and *Mitigation of Climate Change*, as well as a *Synthesis Report*. Drafts of the chapters attracted more than 30,000 comments, which were taken into account in producing the final reports.[6] Each of the reports includes a *Summary for Policymakers*. Unlike the chapters making up the substance of the reports on which these summaries are based, the summaries are agreed line-by-line by government delegates, which includes all governments who are members of the WMO and UNEP. While tedious and sometimes controversial, this process has had the advantage of ensuring that all member governments sign off on the summaries of the reports, which, as Leemans notes, "has been instrumental in the broad acceptance of IPCC's conclusions by UNFCCC and policy makers."[7]

Some have interpreted the government approval of the summaries as proof that the IPCC reports are 'political' and therefore unreliable. Usually those making this charge are implying that the IPCC reports are unnecessarily 'alarmist' and are being driven by radical left-wing government agendas.

A moment's thought should show that this is nonsense: Sitting around the table approving the *Summaries for Policymakers* for the 2007 *Fourth Assessment Report* were: the conservative government of Australia, the world's largest coal exporter, under John Howard, the United States under the conservative administration of George W. Bush, the governments of Saudi Arabia, the other OPEC states and Russia, all major oil and gas producers, and the government of China, the fastest growing greenhouse gas emitter in the world. If anything the influence of some governments served to make the final summary texts more conservative than the scientists would have preferred.

---

[4] See: http://www.ipcc.ch/about/index.htm
[5] Leemans (2008), p. 12.
[6] Biello (2007).
[7] Leemans (2008), p. 13.

A couple of examples are useful here: For the *Summary for Policymakers* of Working Group II, the text that had been submitted to the final government review was:

> Roughly 20-30% of species are likely to be at high risk of irreversible extinction if global average temperature exceeds 1.5-2.5°C.[8]

The actual paper which formed one of the main bases for this statement had used the phrase "committed to extinction".[9] So during discussions the statement was modified to:

> Twenty to thirty percent of species will be committed to extinction if increases in global temperature exceed 1.5-2.5°C.[10]

The final text approved by the governments however watered down the notion that species were "committed to extinction", preferring the far more vague "likely to be at increased risk of extinction":

> Approximately 20-30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5-2.5°C.[11]

This phrasing is far more difficult to interpret than the original wording. "At increased risk …" – from what baseline? An "increased risk of extinction" from 0% to 5% would meet that criterion, which is far from the sense of the original idea of species being "committed to extinction".

David Biello cited another case where government intervention resulted in a more conservative stance than scientists would have preferred:

> For example, after objections by Saudi Arabia and China, the report dropped a sentence stating that the impact of human activity on the Earth's heat budget exceeds that of the sun by fivefold. "The difference is really a factor of 10," says lead author Piers Forster of the University of Leeds in England: compared with its historical output, the sun currently contributes an extra 0.12 watt of energy for each square meter of the earth's surface, whereas man-made sources trap an additional 1.6 watts per square meter.[12]

There are two other ways in which the IPCC reports tend to be conservative:

Firstly, because of the lengthy process of assessment, review, drafting and approval, the reports published in 2007 could really only assess papers published up to late 2005 to early 2006, often based on work undertaken a year or more previously because of the time it takes for findings to be published. This means that inevitably, the *Assessment Reports* are somewhat out of date when they are published and tend not to adequately represent some of the more worrying findings that were only just being discovered or had not had time to become widely accepted.

Secondly, some of the findings are presented in a way that inadvertently obscures some worrying implications. For example, Table 5.1 from the IPCC's *Synthesis Report* presents a

[8] Palutikof (2009).
[9] Thomas *et al.* (2004), p. 145.
[10] Palutikof (2009).
[11] IPCC (2007b), p. 11.
[12] Biello (2007).

range of possible CO_2 stabilization levels and likely associated temperature and sea-level rises.[13] Tucked away in the footnotes to the table are two critical pieces of information: the emissions reductions required to achieve particular CO_2 stabilization levels could be underestimated because many of the models do not include carbon-cycle feedbacks (natural processes reinforcing and exacerbating climate change) (note a) and the contributions to sea-level rise of melting ice sheets, glaciers and ice caps are ignored (note f).

Similarly, the *Summary for Policymakers* of Working Group I on the science of climate change presented a table (Table SPM.3, p. 13) which showed the estimated upper limit of likely sea-level rise from the worst climate change scenario by 2100 as 59 cm.[14] The column heading included the caveat "Model-based range excluding rapid dynamical changes in ice flow" and on the next page the report emphasised: "Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow. … Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise." Despite these caveats, many people only looked at the table and took 59 cm as the IPCC's upper-bound estimate, when it was actually simply the upper bound of what then-current models were capable of representing. Australia's *Garnaut Review*, for example estimated the costs of sea-level rise as 'low' on the basis of this 59 cm figure.[15] But once ice sheet dynamics are taken into account, sea-level rises are more likely to be at least 0.8 m and possibly even 2 metres by 2100.[16]

In summary, far from being unreliable, the IPCC reports represent the best assessment of the published peer-reviewed scientific consensus up to about a year before their publication. Any political influence during the process of government approval of the summaries tends to make the reports err on the side of conservatism rather than radicalism. Since 2006 when the reports were being written, scientists have become increasingly concerned by the pace and extent of climate change.[17]

2. Science is not about consensus – Galileo was ridiculed by the authorities and the scientific establishment.

True – but misleading. This argument is used to suggest that the agreement of the vast majority of qualified climate scientists is irrelevant. Not so. On the edge of every scientific field, for every true Galileo who was proven right, there are usually hundreds of people who would like to think of themselves as a Galileo. Their odds are not good.[18] It is perfectly sensible for lay-people to take the overwhelming agreement of the vast majority of qualified climate scientists as a strong indication that the scientists are probably right – particularly since the evidence has been painstakingly built up over many years from many different fields.

---

[13] IPCC (2007d), p. 67.
[14] IPCC (2007a), p. 13.
[15] Garnaut (2008), Table 11.2, p. 254.
[16] Rahmstorf (2007), Pfeffer *et al.* (2008)
[17] Kintisch (2009); Richardson *et al.* (2009). See also: http://climatecongress.ku.dk/
[18] One reason includes the so-called Kruger-Dunning effect in psychology, whereby less competent people often rate their abilities and understanding more highly than competent people do, since they are blind to the limitations of their own understanding. See: http://en.wikipedia.org/wiki/Dunning-Kruger_effect and Kruger & Dunning (1999).

‘Consensus’ does not mean that climate scientists agree on every single detail of climate change and its implications. Of course there is disagreement and uncertainty about a range of issues. But one of the most useful features of the presentation of the IPCC reports was the fact that the most important statements came with an indication of the level of confidence the scientists had in them. On the main features of climate change, and on the dangers posed by rising greenhouse gas emissions, there is very strong agreement.

It is important to emphasise that this is not simply an argument from authority. An argument from authority is weak because it asserts that we should believe something *simply* because an authority figure says it is true. That is not what is going on here. No-one is saying that we should believe the IPCC simply because of its status as an international institution. The reasons for confidence in the statements of the IPCC and the world’s leading scientific bodies do not rest not on their status as authoritative institutions but on the evidence for their statements. This evidence has already been through the wringer of peer-review publication and has survived post-publication scrutiny by the international scientific community.

So, far from being able to be dismissed simplistically as an argument from authority, giving due weight to the strong consensus among climate scientists is an entirely appropriate acknowledgement of the rigorous process of evidence gathering and sifting that the international community of climate scientists has undertaken over many decades.

3. There’s no consensus - 31,000 scientists signed a petition denying the link between greenhouse gas emissions and climate change

There is and they didn’t. Some of those who denied the link between greenhouse gases and climate change didn’t have much confidence themselves in the argument that the scientific consensus was irrelevant, so they tried to gather signatures from professional scientists for statements asserting that humans are not one of the main causes of climate change. As a result of these efforts, it is often claimed for example, that 31,000 or more scientists have signed a petition denying the link between greenhouse gas emissions and climate change. But it is well known that the great majority of people on these kinds of lists are not practising research scientists with PhDs, and of those who are, very few are climate scientists.[19] Science encompasses a broad range of fields, many of which are quite unrelated to climate science. When the views of climate scientists are considered, very few remain unconvinced that greenhouse gases emitted by human activities are contributing to climate change, and will continue to do so in the coming decades.

So is it true that the vast majority of qualified scientists agree that humans are significantly contributing to climate change? Yes it is. Aside from the work of the Intergovernmental Panel on Climate Change, strong statements affirming the reality of human contribution to climate change have been released by the National Academies of Science of many countries, including: Australia, Belgium, Brazil, Canada, the Caribbean, China, France, Germany, India, Indonesia, Ireland, Italy, Japan, Malaysia, Mexico, New Zealand, Russia, South Africa,

---

[19] For more see: The Great Petition Fraud: http://www.youtube.com/watch?v=5P8mlF8KT6I
http://www.realclimate.org/index.php/archives/2007/10/oregon-institute-of-science-and-malarkey/
http://scienceblogs.com/deltoid/2004/05/oregonpetition.php
http://www.desmogblog.com/oregon-petition
http://greenfyre.wordpress.com/2009/07/12/what-if-the-oregon-petition-names-were-real/

Sweden, the US and UK.[20] Reviews have also been undertaken of the scientific literature and again and again the finding is that the vast majority of qualified scientists with expertise in the relevant areas support the view that humans are influencing the climate.[21]

A large number of professional scientific bodies and associations have also affirmed the reality of human influence on the climate, including, in the United States, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, NASA's Goddard Institute of Space Studies, the American Geophysical Union, the American Institute of Physics, the National Center for Atmospheric Research, the American Meteorological Society, the American Association for the Advancement of Science, as well as the Royal Society of the UK, the Canadian Meteorological and Oceanographic Society, and Australia's CSIRO.

In a recent survey of Earth scientists, predominantly from the United States, participants were asked two questions:

1. When compared with pre-1800s levels, do you think that mean global temperatures have generally risen, fallen, or remained relatively constant?
2. Do you think human activity is a significant contributing factor in changing mean global temperatures?

Of the 10,257 invited to participate, 3146 individuals responded, 90% of whom answered 'Yes' to question 1 and 82% answered 'Yes' to question 2. Earth science of course takes in a broad range of fields, not all of which have a close familiarity with climate science. It is a common misperception among the public that just because someone has a PhD and is a scientist in one field, it somehow gives them a privileged insight into other fields. It may, if they have closely followed that field and have kept up with the scientific literature, but it does not necessarily. We should not imagine for example, that a researcher in electrical engineering would necessarily have a highly developed up-to-date understanding of developments in aeronautical engineering. Equally, just because someone is a qualified tradesman, like a plumber, that does not make them an expert on carpentry. It is therefore important to sift the respondents to see what those with particular expertise in climate science believe.

Of the respondents, 79 scientists had expertise in climate science and had published more than 50% of their recent peer-reviewed papers on the subject of climate change. Of these 79 scientists, 96.2% (76 out of 79) answered 'Yes' to question 1 and 97.4% (75 out of 77) answered 'Yes' to question 2.[22] The authors of the survey concluded:

> It seems that the debate on the authenticity of global warming and the role played by human activity is largely nonexistent among those who understand the nuances and scientific basis of long-term climate processes. The challenge, rather, appears to be how to effectively communicate this fact to policy makers and to a public that continues to mistakenly perceive debate among scientists.[23]

[20] See the links to the Joint Science Academies' statements (2001, 2005, 2007, 2008) and Union of Concerned Scientists (2008) in the Reference list and also: http://www.logicalscience.com/consensus/consensus.htm
[21] See for example Oreskes (2004, 2005), and responses to objections to this study at: http://www.skepticalscience.com/argument.php?a=24
[22] Doran & Zimmerman (2009).
[23] Doran & Zimmerman (2009), p. 23.

There is rarely total unanimity on anything very complex in the Earth sciences, so by any measure, the agreement of more than 96% of scientists with demonstrated expertise in the field, plus the backing of all of the world's major national academies of science and major professional scientific associations represents an extremely strong professional consensus on the core issue that the climate is warming and that humans are contributing to the problem through excessive greenhouse gas emissions.

4. We should wait until there is more evidence before reducing greenhouse gas emissions.

We've already done that and the evidence is in. The basic physics of the warming potential of the greenhouse gases was worked out more than a century ago through laboratory experiments by John Tyndall[24] and Svante Arrhenius, [25] and in 1938, G.S. Callendar solved a set of equations linking carbon dioxide to climate change.[26] In modern times, scientists became increasingly concerned about the possibility of climate change. In 1988 the Intergovernmental Panel on Climate Change (IPCC) was set up by the UN Environment Program and the World Meteorological Organization in response to growing scientific concern, exemplified by NASA scientist James Hanson's testimony before the US Congress that year that global warming was a reality.[27]

The IPCC produced its First Assessment Report in 1990 and the UN Framework Convention on Climate Change (UNFCCC) was produced in 1992. By 1995 the IPCC had concluded in its *Second Assessment Report*: "The balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate."[28] The Kyoto Protocol was adopted in 1997, the IPCC produced its *Third Assessment Report* in 2001 and its *Fourth Assessment Report* in 2007, concluding: "Warming of the climate system is unequivocal"[29] and "The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR [Third Assessment Report], leading to very high confidence [at least a 9 out of 10 chance of being correct] that the global average net effect of human activities since 1750 has been one of warming."[30] The first commitment period of the Kyoto Protocol will end in 2012. A new agreement is needed to govern the period after 2012 and is the subject of current negotiations to culminate in Copenhagen in December 2009.

In short, we now know enough to know that drastic reductions in emissions are needed. What's more, we also know that the climate system is a highly complex, nonlinear system with considerable momentum. We have already had about 0.76ºC of warming[31]; we have about another 0.6ºC above 1980-99 levels guaranteed by 2100 from past emissions[32], plus another 0.4ºC from emissions over the next couple of decades as we try to bring our emissions under control.[33] So we are guaranteed at least 1.8ºC warming above pre-industrial

[24] Tyndall (1861).
[25] Arrhenius (1896).
[26] Callendar (1938).
[27] For Hansen's reflections 20 years later, see: http://www.columbia.edu/~jeh1/2008/TwentyYearsLater_20080623.pdf
[28] See: http://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf p. 5.
[29] IPCC (2007a), p. 5.
[30] IPCC (2007a), p. 3.
[31] IPCC (2007a), p. 5
[32] IPCC (2007b), p. 19.
[33] IPCC (2007a), p. 12.

levels. Another recent study however, revealed that the warming we are committed to, due to past greenhouse gas emissions, could already be around 2.4°C, much higher than previously suspected, and that the effect of the greenhouse gases was being masked by aerosols – fine pollutant particles in the atmosphere which reflect the sun's heat:

> The observed increase in the concentration of greenhouse gases (GHGs) since the preindustrial era has most likely committed the world to a warming of 2.4°C (1.4°C to 4.3°C) above the preindustrial surface temperatures. The committed warming is inferred from the most recent Intergovernmental Panel on Climate Change (IPCC) estimates of the greenhouse forcing and climate sensitivity. The estimated warming of 2.4°C is the equilibrium warming above preindustrial temperatures that the world will observe even if GHG concentrations are held fixed at their 2005 concentration levels but without any other anthropogenic forcing such as the cooling effect of aerosols. The range of 1.4°C to 4.3°C in the committed warming overlaps and surpasses the currently perceived threshold range of 1°C to 3°C for dangerous anthropogenic interference with many of the climate-tipping elements such as the summer arctic sea ice, Himalayan–Tibetan glaciers, and the Greenland Ice Sheet. IPCC models suggest that ~25% (0.6°C) of the committed warming has been realized as of now. About 90% or more of the rest of the committed warming of 1.6°C will unfold during the 21st century, determined by the rate of the unmasking of the aerosol cooling effect by air pollution abatement laws and by the rate of release of the GHGs-forcing stored in the oceans.[34]

The climate system is like driving a fully-laden semi-trailer down a mountain road. We need to brake when we see the bend in the road coming. If we wait until we're heading into the bend before we brake, we're going over the cliff. In his Review conducted for the Australian Government, economist Ross Garnaut warned:

> [T]he science, and the realities of emissions growth in the absence of mitigation, show that we do not have time. The world is rapidly approaching points at which high risks of dangerous climate change are no longer avoidable. We would delude ourselves if we thought that scientific uncertainties were cause for delay. Such an approach would eliminate attractive lower-cost options, and diminish the chance of avoiding dangerous climate change.[35]

5. Climate change has been happening throughout geological and human history. What is happening now is not outside the bounds of natural climatic variability.

Mostly true – but irrelevant. Climate changes have certainly happened throughout history, but with differing degrees of severity and different rates: Between around 130,000 to 118,000 years ago for example, at the height of the last interglaciation (the period between ice ages) the sea levels were some four to seven metres higher than they are now.[36] This is around the same increase in level that would occur if the Greenland Ice Sheet were to melt. But more extreme levels have also occurred in the past. Sea levels were around 70 metres higher 45 million years ago when CO_2 levels were around 1000 to 1500 ppm and there was no permanent ice on the planet. More recently, they were around 130 metres lower during the Last Glacial Maximum 21,000 years ago when CO_2 levels were around 185 ppm.[37]

[34] Ramanathan & Feng (2008), p. 14245.
[35] Garnaut (2008), p. 287.
[36] Overpeck *et al.* (2006), p. 1747.
[37] Alley *et al.* (2005), p. 456 ; Pagani *et al.* (2005).

Local and regional temperatures have also increased rapidly in the past. In Greenland temperatures rose around 10°C within three years around 14,700 years ago.[38] This warming was interrupted by an abrupt cooling about 12,900 years ago known as the Younger Dryas, sending temperatures plummeting again in the Northern hemisphere. It ended suddenly around 11,700 years ago when temperatures in Greenland rose some 8°C within 10 years.[39] The abrupt climatic shifts of the Younger Dryas period are by no means unique, as two recent studies on the ancient climatic records have shown:

> Paleoclimatic records show that large, widespread, abrupt climate changes have affected much or all of the earth repeatedly over the last ice-age cycle as well as earlier – and these changes sometimes have occurred in periods as short as a few years. Perturbations in some regions were spectacularly large: some had temperature increases of up to 16°C and doubling of precipitation within decades, or even single years.[40]

> Intense, abrupt warming episodes appeared more than 20 times in the Greenland ice records. Within several hundreds or thousands of years after the start of a typical warm period, the climate reverted to slow cooling followed by quick cooling over as short a time as a century. Then the pattern began again with another warming that might take only a few years.[41]

Sea-levels have also risen rapidly in the past, with average rates of sea-level rise during the last interglacial period of around 1.6 m per century, and peak rates of up to 5 m per century.[42] Most of the strong climate changes of the past however, were either local or regional or, if global, took at least many thousands of years. As the IPCC emphasised:

> The largest temperature changes of the past million years are the glacial cycles, during which the global mean temperature changed by 4°C to 7°C between ice ages and warm interglacial periods (local changes were much larger, for example near the continental ice sheets). However, the data indicate that the global warming at the end of an ice age was a gradual process taking about 5,000 years … It is thus clear that the current rate of global climate change is much more rapid and very unusual in the context of past changes. The much-discussed abrupt climate shifts during glacial times … are not counter-examples, since they were probably due to changes in ocean heat transport, which would be unlikely to affect the global mean temperature. … although large climate changes have occurred in the past, there is no evidence that these took place at a faster rate than present warming. If projections of approximately 5°C warming in this century … are realised, then the Earth will have experienced about the same amount of global mean warming as it did at the end of the last ice age; there is no evidence that this rate of possible future global change was matched by any comparable global temperature increase of the last 50 million years.[43]

In summary, the past global ‘natural variability’ of sea levels, rates of sea-level rise, temperature changes and so on, cover an enormous range, and the extremes are outside the experience of human civilizations. There is also no evidence of a *global* temperature increase of 5°C (which would be accompanied by much larger regional increases) in a single century for the past 50 million years. Neither human social systems, nor many eco-systems, could

---

[38] Steffensen *et al.* (2008), pp. 680-681.
[39] National Research Council (2002), p. 27. See also: Pearce (2007), pp. 149-150; Alley (2000).
[40] National Research Council (2002), p. 153.
[41] Alley (2004), p. 64.
[42] Rohling *et al.* (2008), p. 38.
[43] Jansen *et al*. (2007), FAQ 6.2 *Is the Current Climate Change Unusual Compared to Earlier Changes in Earth’s History?* p. 465.

adapt to some of these changes, so the fact that some are of similar magnitude to those in the past is hardly comforting and does not provide a reason for inaction.

6. Because what is happening now is within the realms of natural variability, we can't say that humans are contributing to climate change.

False. It is sometimes asserted that if climates changed in the past from natural causes without any human influence, then any climate change occurring now must also be entirely due to natural causes. This is simply an error of logic. The fact that lightning strikes caused bushfires in the distant past, and continue to do so today, does not imply that arsonists never cause bushfires. The same event can have a number of different possible causes and no fire investigator in her right mind would rule out arson simply because the natural explanation of lightning strikes was adequate to explain the outbreak of bushfires in general. She is not interested in past bushfires in general – she is interested in how *particular* bushfires started. In the same way, the fact that past climate changes were entirely natural in no way rules out the possibility that humans are contributing to the current changes – particularly if, as we know, humans are now emitting gases on an epic scale which have strongly influenced the climate in the past. We are interested in the causes of this particular episode of climate change, not past climate changes in general.

The overwhelming, broad consensus of the world's climate scientists is that we cannot explain observed climate changes without taking into account human influence.[44]
A recent comprehensive study of the polar regions concluded for example,

> [T]he observed changes in Arctic and Antarctic temperatures are not consistent with internal climate variability or natural climate drivers alone, and are directly attributable to human influence. Our results demonstrate that human activities have already caused significant warming in both polar regions, with likely impacts on polar biology, indigenous communities, ice-sheet mass balance and global sea level."[45]

Substantial changes in the climate of the Western United States have also been observed that can only be explained by factoring in human influence:

> They found that the models could produce the observed trends in temperature, snowpack, and river flow of the past few decades only when they included the actual amounts of human-made greenhouse gases and pollutant hazes. Run without them, the models poked along, warming and cooling without a long-term trend. "There's no way we can make a natural-variability explanation for what we've seen" in the West, said Barnett. "I'd put the odds at between one in 100 and one in 1000 that we were fooled. Quite frankly, it's us."[46]

Similarly, the warming of the world's oceans cannot be explained without taking into account human influence:

> A warming signal has penetrated into the world's oceans over the past 40 years. The signal is complex, with a vertical structure that varies widely by ocean; it cannot be explained by natural internal climate variability or solar and volcanic forcing, but is well simulated by

---

[44] IPCC (2007a) p. 11.
[45] Gillett *et al.* (2008), p. 750. See also Post *et al.* (2009).
[46] Kerr (2007), p. 1859. See also Rosenzweig *et al.* (2008).

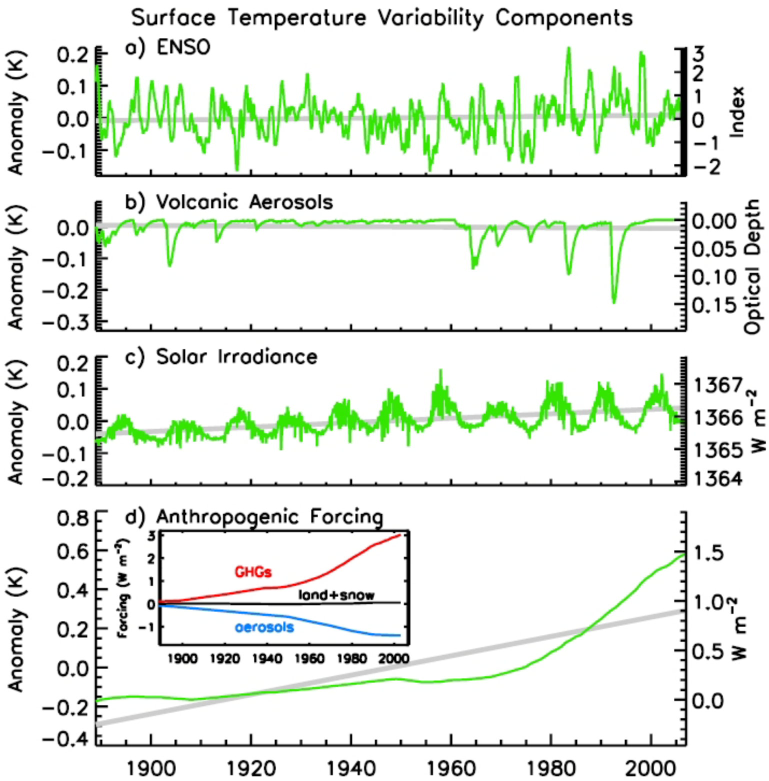
two anthropogenically forced climate models. We conclude that it is of human origin, a conclusion robust to observational sampling and model differences.[47]

In 2003 a heatwave in Europe with average temperatures 3.5°C above normal killed between 22 and 45,000 people.[48] Scientists who examined temperature records concluded that human influence had greatly increased the risk of such heatwaves:

> Using a threshold for mean summer temperature that was exceeded in 2003, but in no other year since the start of the instrumental record in 1851, we estimate it is very likely (confidence level >90%) that human influence has at least doubled the risk of a heatwave exceeding this threshold magnitude.[49]

Judith Lean and David Rind undertook a statistical regression analysis of the influences on temperature of both natural influences, such as solar variation, volcanoes and the El Niño Southern Oscillation (ENSO), and anthropogenic greenhouse gases. As can be seen from Figure 1, their results showed that anthropogenic influences were the dominant driver of climate change over the 20th century.

Figure 1. Natural and anthropogenic contributions to temperature change
Source: Lean & Rind (2008), Figure 2, p. 2. Caption: "Reconstructions of the contributions to monthly mean global surface temperatures by individual natural and anthropogenic influences (at appropriate lags) are shown. The right hand ordinates give the native scales of each influence and the left hand ordinates give the corresponding temperature change determined from the multiple regression analysis. The grey lines are trends for the whole interval. The inset in Figure 2d shows the individual greenhouse gases, tropospheric aerosols and the land surface plus snow albedo components that combine to give the net anthropogenic forcing."



[47] Barnett *et al.* (2005), p. 284.
[48] Patz *et al.* (2005), p. 310.
[49] Stott *et al.* (2004), p. 610.

Overall both empirical and theoretical studies are in agreement that greenhouse gas emissions from human activities must be taken into account to explain the warming we have witnessed, as Lean and Rind concluded:

> Natural changes cannot account for the significant long-term warming in the historical global surface temperature anomalies. Linear trends in temperature attributed to ENSO, volcanic aerosols and solar irradiance over the past 118 years … are, respectively, 0.002, -0.001 and 0.007 K per decade. Only by associating the surface warming with anthropogenic forcing is it possible to reconstruct the observed temperature anomalies. The average anthropogenic-related warming is 0.05 K per decade from 1889 to 2006, which is in close agreement with that determined independently from *Allen et al.'s* [2006] synthesis of theoretical model studies.[50]

7. Because what is happening now is within the realms of natural variability, it is not something to worry about. Species have always adapted.

False. Sea levels have been more than 70 metres higher in the past.[51] Melting of the Greenland ice sheet would raise seas by 7 m and melting the West Antarctic ice sheet would raise sea levels by 5 metres.[52] Sea level rise of 1 metre would displace around 145 million people and take out some of the world's best farmland leading to enormous stress on human societies.[53] It is simply false to assert that species can always adapt – even under past conditions.

The world experienced several mass extinctions in the past where 50-90% of species became extinct with temperature changes of around 5°C.[54] The Permian-Triassic extinction around 251 million years ago, for example, is thought to have extinguished 95% of the world's species in existence at the time. Under today's circumstance with possible migration routes blocked by fences, human settlements and degraded habitats (such as isolated pockets of forest surrounded by cleared farmland), it is wishful thinking to imagine that species can simply migrate and adapt to any climate change.[55]

8. It was warmer during medieval times.

Probably false, but irrelevant anyway. Many of those who most strenuously deny any link between greenhouse gas emissions and climate change make a great deal of the period from roughly 800 to 1300 AD, when it is possible that temperatures may have been slightly warmer than at present – at least in northern Europe. The argument runs that if temperatures were warmer then, and CO_2 levels were lower, then (somehow) that is supposed to show that rising greenhouse gas levels are nothing to worry about because natural variability can lead to warming. There are a few problems with this logic.

---

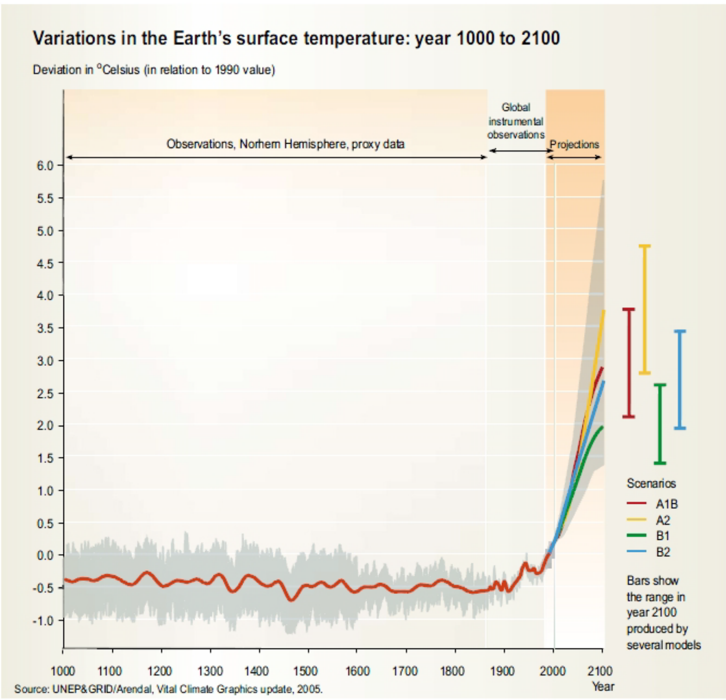
[50] Lean & Rind (2008), p. 5, referring to Allen *et al.* (2006). ENSO refers to the El Niño-Southern Oscillation, and 'K' refers to the Kelvin temperature scale, which has the same increments as the Celsius scale.
[51] Alley *et al.* (2005).
[52] IPCC (2007b), p. 17.
[53] Anthoff *et al.* (2006).
[54] Hansen *et al.* (2006), p. 14292.
[55] For more on the possibilities of mass extinctions, see: http://bravenewclimate.com/2008/08/14/will-global-warming-cause-a-mass-extinction-event/

Firstly, even if temperatures were slightly higher in medieval times, that is irrelevant to our current situation. No-one claims that rising greenhouse gas levels are the only factor that has ever led to higher temperatures. Changes in solar intensity, variations in ocean currents and a number of other factors can influence temperatures. In this case a persistent positive North Atlantic Oscillation from 1050 to 1400 seems to have played an important role.[56] The fact that temperatures appear to have been warm during medieval times in certain regions does not necessarily imply that the warming in our current era can be explained by similar factors. The main reason scientists are so concerned is because they cannot explain the changes over the past century without taking into account rising greenhouse gas levels.

Second, recent research suggests that the 'Medieval Climate Anomaly' as it now increasingly described by scientists, was warmer than the Little Ice Age, which lasted from around 1500 to 1850, but globally it was probably slightly cooler than the last 30 years. It was also most likely a regional, rather than a global phenomenon.[57]

Third, as David Archer has warned, "Beware the bait and switch!"[58] The projections for global climate change for the current century and beyond do not depict a fraction of a degree increase in temperatures that would usher in a benign era of more pleasant winters and balmy summer evenings. Instead, projections show that even 2ºC above pre-industrial temperatures would bring major adverse impacts. As Figure 2 shows, on current trajectories we could see average global temperature increases of 6ºC or more by 2100, which would lead to a humanitarian catastrophe and a dramatically different planet.

Figure 2: Past and projected future temperature variations
Source: UNEP (2009), p. 26.



[56] Jungclaus (2009), p. 469.
[57] Jungclaus (2009); Bradley *et al.* (2003); Mann & Jones (2003); Mann *et al.* (2008 & 2009); Brumfiel (2006). See also: http://www.realclimate.org/index.php/archives/2004/12/myths-vs-fact-regarding-the-hockey-stick/ http://www.realclimate.org/index.php/archives/2005/02/dummies-guide-to-the-latest-hockey-stick-controversy/
[58] Archer (2009), p. 62.

9. Climate models are unreliable.

False. No-one claims that climate models are perfect, but they are based on sound science and have been able to replicate past observations to a good degree of accuracy and have also anticipated effects such as the global cooling effects resulting from major volcanic eruptions such as Mt Agung in Bali in 1963[59] and Mt Pinatubo in the Philippines in 1991,[60] as well as the more recent partial offsetting of the effects of rising greenhouse gas levels by natural internal variability.[61]

Some commentators however, misunderstand or deliberately misrepresent the purpose of modeling complex systems such as the climate. For any chaotic or complex system it is not possible to construct a simulation that will precisely predict the future time path of the system, except under very strict conditions such as complete, accurate knowledge of all initial parameters and a short prediction horizon. That is why the weather is so hard to forecast over more than a few days. In an overview of chaotic complex systems, the authors asked their readers to imagine an idealised game of billiards where the balls move across a frictionless surface and collide with negligible loss of energy. They then asked us to guess for how long an expert player with perfect strike control could *precisely* predict the cue ball's trajectory. Their answer: "If the player ignored an effect even as miniscule as the gravitational attraction of an electron at the edge of the galaxy, the prediction would become wrong after one minute!"[62]

The future trajectories of complex nonlinear systems like the climate are extremely sensitive to initial conditions. Long-term modeling of complex systems therefore focuses, not on a precise single 'prediction' of a system's future time path, but on modeling suites of possible scenarios across a range of parameter values using hundreds or thousands of simulation runs. This process yields a set of scenarios within which the future path of the system is highly likely to lie. If the system is well understood, the set of likely scenarios will be relatively narrow and there will be high confidence that the evolution of the actual system's path will fall within that set of scenarios. All complex systems scientists understand this approach as it is common across a range of scientific disciplines.[63]

When people disparage climate models because they have not 'predicted' the evolution of the temperature path in one particular locality, they reveal that they do not understand climate modelling or complex systems modeling more generally. It is also extremely misleading to give people the impression that because models can't necessarily 'predict' the future temperature paths precisely, that the models are therefore useless as guides for policy. If, as is the case currently, a large number of model scenarios from a large number of different models all yield dire projections for future climate scenarios, then it strongly suggests we have a problem.[64]

It should also be noted that it is not possible for anyone, including those who deny the human influence on climate, to make assertions about the future relationship between greenhouse

---

[59] Hansen *et al.* (1978).
[60] Schmidt (2007); Randall *et al.* (2007), FAQ 8.1: *How Reliable Are the Models Used to Make Projections of Future Climate Change?*, pp. 600-601. For a good recent overview see also Reichler & Kim (2008).
[61] Smith *et al.* (2007).
[62] Crutchfield *et al.* (1986), p. 41.
[63] See for example Auyang (1998), one of the best inter-disciplinary introductions to complex systems science.
[64] For more on this, see: http://www.realclimate.org/index.php/archives/2005/01/is-climate-modelling-science/

gases and global climate without some explicit or implicit reference to a model of how the world's climate works. So when someone asserts definitively that greenhouse gases will have no effect on climate, or only a minor effect that is not worth worrying about, we are entitled to ask: How do they know? They can only make that assertion based on some more or less sophisticated understanding of how the climate system works – in other words, a model. But where are these climate models? Where are the models which show that human greenhouse emissions will have little or no effect on the world's climate?

Lastly, it is also worth mentioning how striking it is that so often the same people who deny the validity of climate models, place so much faith in the minority of economic models which suggest that mitigating climate change would be terrible for our economies. Most economic models in fact have far less claim to scientific validity than climate models.[65]

10. There was a consensus among climate scientists in the 1970s that we would soon be heading into another ice age.

False. This is one of those persistent assertions that is repeated endlessly, but which has little basis in fact. The implication of the statement is that if scientists were wrong in the 1970s, there's no reason to believe them now when they warn of climate change. But it is a complete myth that there was any kind of consensus among climate scientists in the 1970s that we were heading into a cool period – in fact there was far more concern about warming. The most thorough recent debunking of this myth was given in a 2008 paper in the *Bulletin of the American Meteorological Society*.[66] The authors undertook a review of climate science publications and found 7 papers "predicting, implying, or providing supporting evidence for future global cooling", 20 that were neutral and 44 supporting future warming. From their publication date to 1983, "The cooling papers received a total of 325 citations, neutral 424, and warming 2,043" (p. 1333). The authors concluded (p. 1326):

> A review of the climate science literature from 1965 to 1979 shows this myth to be false. The myth's basis lies in a selective misreading of the texts both by some members of the media at the time and by some observers today. In fact, emphasis on greenhouse warming dominated the scientific literature even then.

11 Global warming ended around 1998 anyway – it's been cooling since then.

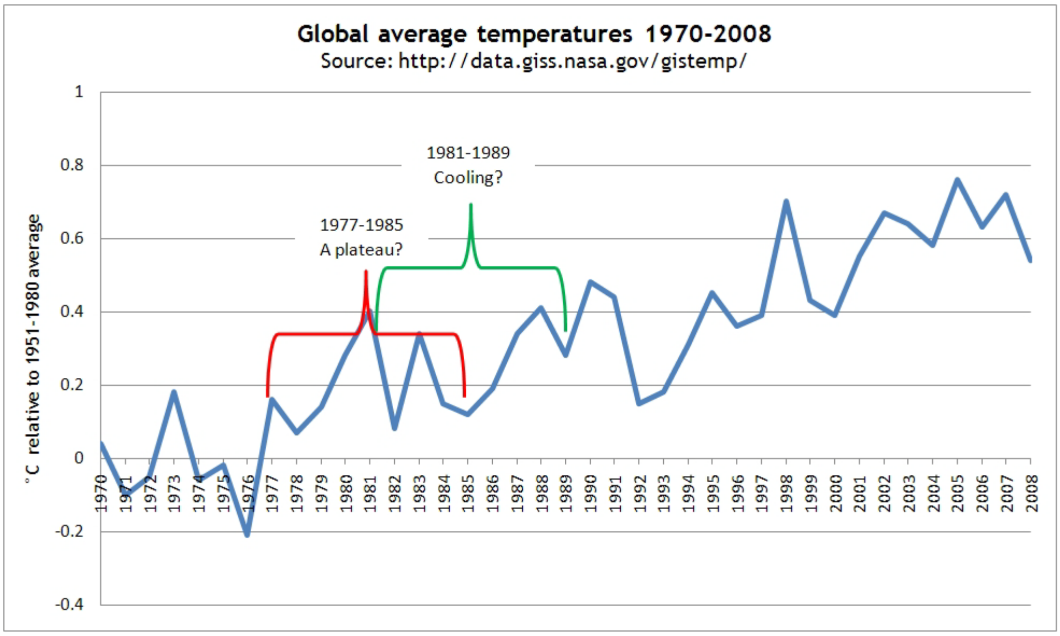
False. There are a couple of issues that need to be addressed here: the cherry-picking of data and the complex relationship between emissions and temperatures.

Firstly, the cherry-picking: Choosing particular years, like 1998, to derive 'trends' that are not representative of the data is called cherry-picking. The years 1997-1998 saw a major temperature spike from the strong El Niño in the Pacific, so if we take a big El Niño year like 1998 as a starting point, then of course the years immediately following it during the neutral and La Niña phases are going to be relatively cooler.

[65] I say this as an economist. For an outstanding overview of the limitations of current economic models see DeCanio (2003). Ackerman (2008) is also very good.
[66] Peterson *et al.* (2008).

To see why such cherry picking is so silly (or deliberately deceptive), consider the following: As Figure 3 shows, the 2005 global temperature was statistically indistinguishable from 1998 (they were both very warm years), and the NASA GISS data, which also takes into account Arctic temperatures, put 2005 as slightly warmer than 1998, which in the NASA data tied with 2007.[67] So if we took either 1997 or 1999 as our starting year rather than 1998, we'd be able to show a strong warming trend between those years and 2005. Even taking the period 1999 to 2008 would show a strong, statistically significant, warming trend.

Figure 3. 'Plateaus' and 'cooling' within the recent warming trend



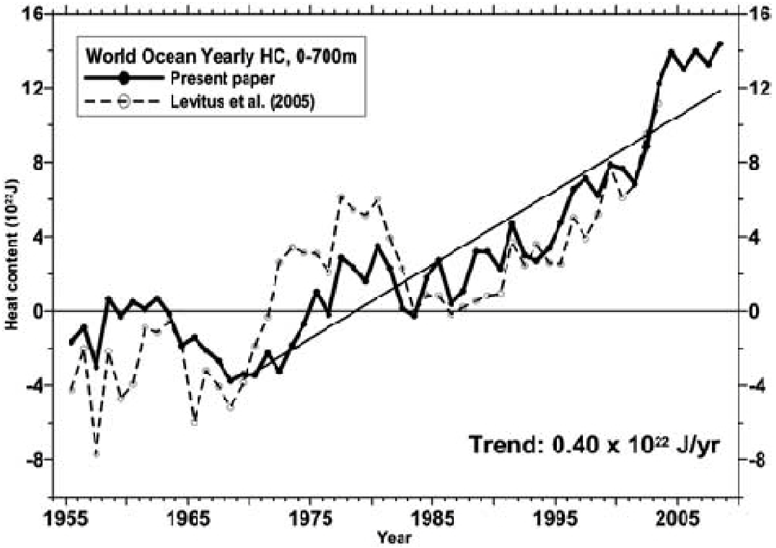
Scientists don't cherry pick data like that because it is meaningless to try to pick major long-term climate trends based on just a few years of data. If we look back through the 20th century and most recent years, or forwards through the simulations produced by climate models, we see a number of periods where temperatures were flat or even cooled for a period of a few years – but all within a long-term warming trend. For example, as Figure 3 also shows, if we took either of the periods 1977-1985 or 1981-1989 we would see no significant trend at all, even though both periods fall within the period 1975 to 2008 which showed a strong overall warming trend.[68]

Australia's *Garnaut Review*, commissioned by the Australian Government to examined the science and economics of climate change, investigated the assertion that warming had finished, using experts in the analysis of time series data. They concluded: "Viewed from the perspective of 30 or 50 years ago, the temperatures recorded in most of the last decade lie above the confidence band produced by any model that does not allow for a warming trend."[69] From a scientific, statistical perspective, there is no justification for asserting that the warming trend witnessed in the late-20th century has ended.[70]

[67] See: http://data.giss.nasa.gov/gistemp/
[68] Easterling & Wehner (2009), p. 1.
[69] Garnaut, (2008), p. 79.
[70] For more on this, see: http://www.realclimate.org/index.php/archives/2008/11/mind-the-gap/#more-611
http://bravenewclimate.com/2008/11/23/what-bob-carter-and-andrew-bolt-fail-to-grasp/
http://www.newscientist.com/article/dn14527-climate-myths-global-warming-stopped-in-1998.html?full=true

Second, the relationship between emissions and temperatures is complex. One of the most persistent misunderstandings among the general public, and one of the most willful misrepresentations by those who deny the human influence on climate, is that climate scientists are claiming that atmospheric temperatures will increase relentlessly, year after year, in lock-step with CO_2 levels. This is simply incorrect. For one thing, atmospheric temperatures are only part of the story – as Figure 4 shows, an enormous amount of energy has actually gone into warming the oceans since the 1950s.[71]

Figure 4. Heat content of the oceans, 1955-2008
Source: Levitus *et al.* (2009), Figure 1, p. 2. Caption: "Time series of yearly ocean heat content (10^{22}J) for the 0-700 m layer from this study (solid) and from Levitus et al. [2005] (dashed). Each yearly estimate is plotted at the midpoint of the year. Reference period is 1957-1990."



But leaving ocean temperatures aside, surface temperatures are not just governed by greenhouse gas levels. Variations in solar radiation over the 11-year solar cycle play a role, and declining solar activity in the waning of the previous solar cycle are thought to have countered much of the warming due to greenhouse gas emissions from 2002 to 2008.[72] Major volcanic eruptions, such as Mt Pinatubo in the Philippines in 1991, can reduce also temperatures for a year to two afterwards because of all the highly reflective sulfate aerosols they inject into the atmosphere. The climatic patterns or 'modes', which govern wind patterns and ocean currents, redistribute heat around the planet and also produce temperature variability. These modes include the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), the southern annular mode (SAM), the northern annular mode (NAM), the North Atlantic Oscillation (NAO), the Atlantic Multi-decadal Oscillation (AMO), the Pacific-North American (PNA) pattern, the Pacific-South American (PSA) pattern and the Indian Ocean Dipole (IOD).[73] Depending on their relative strengths and degrees of coupling and synchronization, these modes can raise or lower average surface temperatures above or below long-term trends for several years. One type of process by which these shifts can occur involves changes to the transparency of the atmosphere due to changes in cloud cover and the abundance and characteristics of aerosol particles. These

[71] AchutaRao *et al.* (2007); Barnett, *et al.* (2005); Levitus *et al.* (2009).
[72] Lean & Rind (2009), p. 1.
[73] Trenberth *et al.* (2007), pp. 286-295.

atmospheric changes can lead to more or less solar radiation reaching the surface, phases which are referred to as *brightening* and *dimming*.[74] Overall Lean and Rind concluded:

> Natural influences also alter surface temperatures, producing as much as 0.2ºC global warming during major ENSO events, near 0.3ºC cooling following large volcanic eruptions, and 0.1ºC warming from minima to maxima of recent solar cycles … On time scales of years to a decade, naturally induced surface temperature changes can dominate current anthropogenic warming of 0.2ºC per decade … especially in some locations, where regional changes can exceed the global response by an order of magnitude.[75]

The coupling and synchronization of modes in nonlinear systems gets complicated, to say the least.[76] There seems to be some evidence that major climate shifts from warming periods, such as those from around 1910-1940 and after about 1975, and temperature stabilizations or slight cooling periods, such as that from the 1940s to mid-1970s, are influenced by the degree of coupling and synchronization between major climatic modes.[77] Temperatures have been relatively stable so far this century and so while not enough years have yet passed to make a statistically significant judgement, it is not impossible that changes in these natural couplings have begun to temper the strong warming trend we have experienced since the 1970s. It may even be possible that we will see a cooling trend for some years before the resumption of warming. That would bring welcome relief, but we should not delude ourselves that these natural reorganizations of heat transfer within the global climate system somehow invalidate the well-established evidence for human influence on the long-term warming trend. It would be particularly unfortunate, scientifically irresponsible and counter-productive for global climate change mitigation efforts, if a possible series of cool years in the coming decade were seized on as evidence that the century-long warming trend has 'stopped' or 'gone into reverse' so that we can just carry on pumping out greenhouse gases as before. As Swanson and Tsonis emphasized in concluding their study on these effects:

> Finally, it is vital to note that there is no comfort to be gained by having a climate with a significant degree of internal variability, even if it results in a near-term cessation of global warming. It is straightforward to argue that a climate with significant internal variability is a climate that is very sensitive to applied anthropogenic radiative anomalies … If the role of internal variability in the climate system is as large as this analysis would seem to suggest, warming over the 21st century may well be larger than that predicted by the current generation of models, given the propensity of those models to underestimate climate internal variability.[78]

In summary, cherry-picking data is poor scientific practice, it cannot yet be concluded statistically that the warming trend since the late 1970s has ended, and greenhouse gas increases were never expected to lead to a relentless year-after-year increase in temperatures in any case. Temperatures have zigzagged up and down due to the complex natural internal variability of the climate system, and they will continue to do so. But despite these year-to-year variations, we have every reason to believe, based on the science of the climate system, that the long-term warming trend experienced since the early 20th century will continue, even if for certain periods temperatures stabilize or even cool for a while.

---

[74] See: Wild (2009); Wild *et al.* (2009).
[75] Lean & Rind (2009), p. 1.
[76] See for example, Pecora *et al.* (1997).
[77] Tsonis *et al.* (2007); Swanson & Tsonis (2009).
[78] Swanson & Tsonis (2009), p. 4.

12. Our best strategy is simply to adapt to climate change.

False. This approach greatly underestimates the risks from unmitigated climate change and also presumes that the climate will settle into a new stable state that we can adapt to. But the Earth's climate is a highly complex nonlinear system with the potential to cross thresholds or tipping points and lurch from one stable state to another.[79] We cannot simply assume that the world's climate will settle into a new state that is both stable and suitable enough to prevent catastrophic consequences for ecological and human systems. As one recent study put it: "Palaeoclimate data show that the Earth's climate is remarkably sensitive to global forcings. Positive feedbacks predominate. This allows the entire planet to be whipsawed between climate states."[80] The emergence from the last ice age for example, was characterised by dramatic oscillations, or 'flickering' between cold and warm periods.[81]

The humanitarian, economic and security implications of unmitigated climate change would also be staggering.[82] In Africa 75-250 million people are expected to be suffering water stress by the 2020s and 350-600 million by the 2050s.[83] In Asia, the projections are even worse. The glaciers of the Himalayas and Tibetan Plateau are the source for seven of Asia's most important rivers: the Ganges, which flows across northern India to join the Brahmaputra in Bangladesh; the Indus which flows through Indian-controlled Jammu and Kashmir before becoming the lifeblood of Pakistan's agriculture; the Salween which flows through China and Burma into Thailand; the Mekong which flows through half a dozen countries and is critical to food supplies in Vietnam, Cambodia and Laos; and two of China's great rivers, the Yangtze and the Huang (Yellow River). Temperatures on the Tibetan Plateau have risen three times faster than the global average for the last 50 years.[84] Increased glacier melt in the next 20-30 years is likely to increase flooding, including sudden and catastrophic glacier lake outburst floods. But by the late 2030s, river flows are likely to decrease dramatically as the glaciers shrink from their 1995 extent of 500,000 km^2 to an expected 100,000 km^2 by 2035.[85] By the 2050s more than a billion people in Central and South Asia could be suffering significant water shortages and crop yields could decrease by 30 per cent.[86]

The recommendation to just let climate change run its course and adapt to it seems to come only from those who either do not believe the climate is warming, or if it is, do not believe anything can be done. I am not aware of a single expert in humanitarian aid, geopolitics, economics or international security who believes human societies and economies could adapt smoothly or peacefully to unmitigated climate change. Those who place so much emphasis on the short-term economic costs of investing to reducing greenhouse gas emissions should consider the dire economic, humanitarian and security implications of unmitigated climate change.

---

[79] See: Pearce (2007); Alley (2004), Lenton *et al*. (2008).
[80] Hansen *et al.* (2007a), p. 1925.
[81] Taylor *et al.* (1993).
[82] On the security implications see: Dupont (2008), Chellaney (2007a,b), Campbell *et al.* (2007) & Campbell (2008).
[83] Boko *et al.* (2007), p. 435.
[84] Qiu, (2008).
[85] Cruz *et al.* 2007, p. 493, 481.
[86] IPCC, (2007b), p. 13.

13. CO_2 exists only in very low concentrations in the atmosphere, therefore it cannot have significant effects.

False. The concentration of CO_2 in the atmosphere has risen from around 280 ppm (parts per million) at the start of the industrial revolution in about 1750 to around 388 ppm today – a 39% increase. Nevertheless, 388 ppm constitutes just 0.0388% of the atmosphere by volume and it is sometimes asserted that the increase in concentration can't possibly have any significant effect – simply because it is such a low concentration. This assertion is simply an error of logic, since it presumes that, by definition, a small cause cannot have a large impact, which is demonstrably false. To take just one example, a drop of the nerve agent VX around the size of a grain of sand is enough to kill an adult.[87] It cannot be asserted that just because the concentration of a substance is low, it therefore cannot have major effects on the system it is interacting with. The potential impact of the substance on the system must be examined and understood before any comment can be made on the likely effects of different concentrations.

Why then do scientists believe that CO_2 and other greenhouse gases could be warming the planet? Isn't water vapour the most important greenhouse gas? Yes it is, by a long way. But direct human influence on the concentration of water vapour in the atmosphere is negligible – it is largely a feedback response to temperature changes, since warmer air can hold more moisture. The warm tropics therefore already experience a strong greenhouse effect, so adding more greenhouse gases impacts the drier polar regions more than the humid tropics. At the poles, the warmer air can hold significantly more water vapour than before, which acts to reinforce the warming due to the addition of other greenhouse gases such as CO_2.[88]

If water vapour is the main greenhouse gas, then what role does CO_2 play? To answer this question, a brief discussion of the basic physics of the greenhouse effect is needed. The sun emits most of its radiation, including the ultraviolet, visible light and near-infrared light, with wavelengths of around 0.2-4 μm. The longwave radiation that is reflected back from Earth as heat is emitted at wavelengths of 4-100 μm. [89] Our atmosphere consists overwhelmingly of simple gas molecules in the proportions: Nitrogen, N_2, (78.08%), Oxygen, O_2, (20.95%) and Argon, Ar, (0.93%). The greenhouse gases in the atmosphere – water vapour (H_2O), carbon-dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and others – absorb some of the radiation from the surface, emitting some of it back to the surface, which causes more warming, and emitting the rest back to space. If it were not for the greenhouse effect of these gases, the average temperature of the Earth would be around -18ºC, rather than 15ºC.[90]

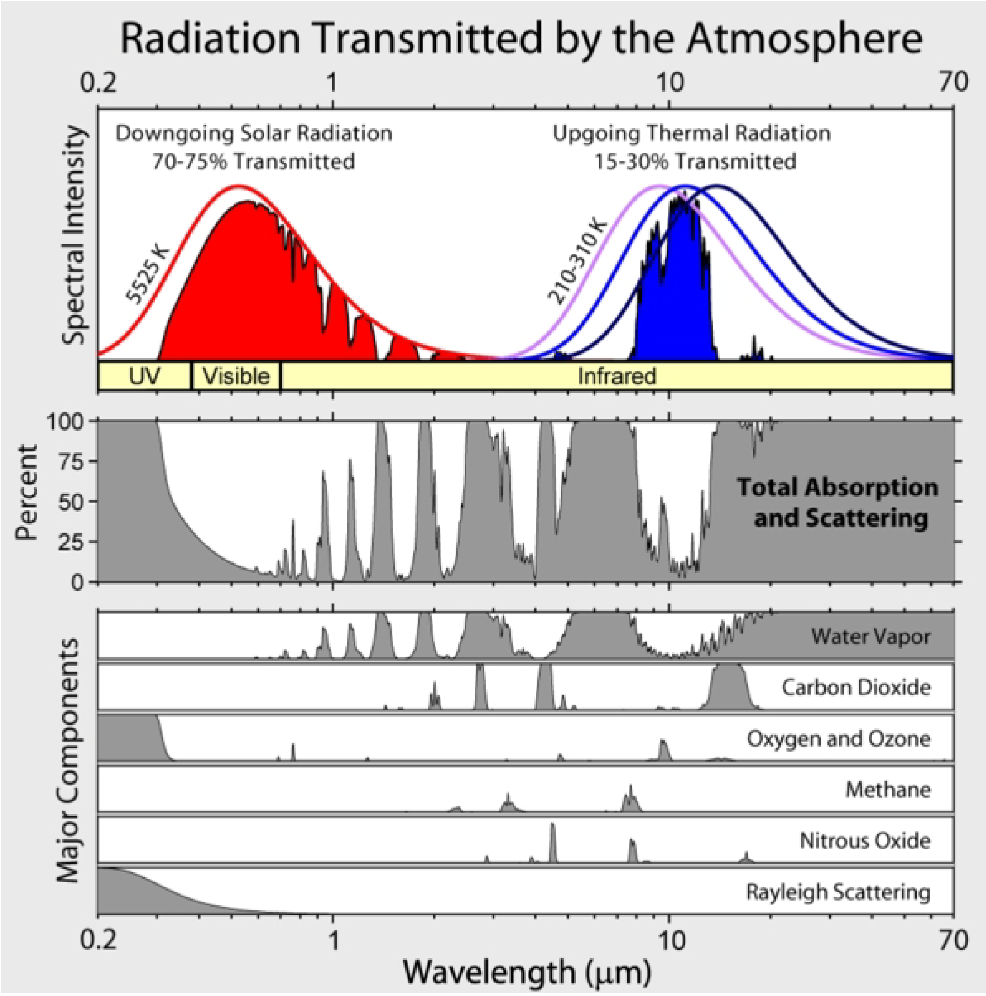
Adding more greenhouse gases to the atmosphere increases the altitude from which heat radiation escapes back into space. At the higher altitude, temperatures are cooler and so emission temperatures and rates of radiation emission to space will be lower than they would have been without the additional greenhouse gas. To restore thermal equilibrium, temperatures in the lower atmosphere (troposphere) and the Earth's surface increase until the incoming solar radiation is once again balanced with the outgoing heat radiation.[91]

---

[87] See: http://www.fas.org/programs/ssp/bio/chemweapons/cwagents.html
[88] See: Le Treut *et al.* (2007), FAQ 1.3 *What is the Greenhouse Effect?*, pp. 115-116.
[89] Mitchell (1989), p. 116. μm stands for 'micro-metres' and equals 10^{-6} metres, or 0.000001 metres.
[90] Mitchell (1989), p. 136.
[91] Mitchell (1989), p. 136.

The effectiveness of a greenhouse gas depends on a number of factors, including the wavelength at which the gas absorbs radiation, the gas concentration, the strength of the absorption per molecule and also whether other gases are already strongly absorbing at that particular wavelength. These factors are important because it means that different gases absorb radiation at different wavelengths, as Figure 5 shows.

Figure 5. Radiation transmitted by the atmosphere showing greenhouse gas absorption bands. Source: http://en.wikipedia.org/wiki/File:Atmospheric_Transmission.png



Water vapour for example, absorbs across a large number of bands, but particularly strongly near 6.3 μm and 2.7 μm due to changes in molecular vibrational energy, and also at wavelengths greater than 18 μm because of changes in rotational energy. CO_2 on the other hand, absorbs around 4.3 μm, only weakly between 8-12 μm and most strongly in the 13-17 μm zone, centred on 15 μm (but also with significant absorption at 13.9 μm and 16.2 μm), which is right near the peak of the longwave radiation spectrum and causes more than 90% of the warming due to CO_2.[92] From about 7.7 μm to 12 μm, the so called "atmospheric

[92] Mitchell (1989), p. 118; Dickinson & Cicerone (1986), p. 110; Clough & Iacono (1995), p. 16,523; Hansen *et al.* (1981), p. 958; Kiehl & Ramanathan (1983), Table 1, p. 5192; Kiehl (1985). Ellingson & Gille (1978) report close agreement between modelled and observed spectral radiance. Original empirical data can be found in McClatchey *et al.* (1973), Gryvnak *et al.* (1976), and most recently in the 2008 version of the HITRAN database, described in Rothman *et al.* (2009) and found at: http://www.cfa.harvard.edu/hitran/

window", absorption by water vapour and CO_2 is weak and other trace gases such as ozone (with a peak around 9.6 μm), methane (7.7 μm) and nitrous oxide (7.8 μm) absorb more strongly, despite their low concentrations.[93] Other greenhouse gases such as the chlorofluorocarbons are present only in low concentrations but they are very powerful greenhouse gases and they absorb strongly in the atmospheric window where water vapour and CO_2 are weak, at wavelengths such as 8.7 μm, 9.1 μm, 9.2 μm, 10.9 μm and 11.8 μm.[94]

It is important to emphasise that the atmospheric physics of the various greenhouse gases, including their effects on different wavelengths of outgoing longwave radiation, is well established both empirically and theoretically.[95] It is simply incorrect to assert that gases such as CO_2 must have little effect because of their low concentrations compared to the main atmospheric gases.

14. CO_2 is a weak greenhouse gas. Doubling of CO_2 from its pre-industrial levels of 280 ppm to 560 ppm would only bring warming of about 1ºC.

False - twice. The warming effect of CO_2 in the atmosphere diminishes logarithmically as its concentration increases, as Svante Arrhenius confirmed in 1896.[96] It has been claimed by some who accept this logarithmic relationship, that a doubling of CO_2 would only bring warming of around 1ºC and that since we have already experienced about 0.76°C of warming there is only a very small amount of benign warming still to come. But this claim is false in two different ways:

Firstly, basic radiation calculations show that for a doubling of CO_2, surface temperatures would warm by around 1.2ºC (not 1ºC) ***if,*** and only if, the structure of the atmosphere and all other factors remained fixed.[97] So the assertion that doubling CO_2 would bring warming of only 1ºC is already about 0.2 ºC wide of the mark in this purely theoretical calculation.

Far more serious is the second way in which this assertion is false, namely that in the real world, the structure of the atmosphere and a host of other factors are not fixed at all. There are a large number of feedbacks in the climate system which reinforce the warming.

Virtually everyone accepts the logarithmic relation between CO_2 concentration increases and temperature increases. In order to run the argument, "We have already experienced most of the warming from a doubling of CO_2 so there is not much left to worry about", then it must also be accepted that the 35% increase in CO_2 concentrations from 280 in pre-industrial times to 379 ppm up to 2005 led to the approximately 0.76°C warming we experienced over that

[93] Mitchell (1989), p. 119; Wang *et al.* (1976), pp. 687-688; Dickinson & Cicerone (1986), p. 110; Donner & Ramanathan (1980).
[94] Mitchell (1989), p. 119, Table 2. Wave numbers, ν, in units of cm^{-1} are converted to wavelengths, λ, in units of μm, by the following formula: $\lambda = (1/\nu) * 10{,}000$.
[95] For a good introduction see Petty (2006).
[96] Arrhenius (1896). This means that each doubling of CO_2 adds a fixed amount of radiative forcing and, to a first approximation, temperature increase (Enting, 2007, p. 41-43).
[97] The calculation is as follows: $\Delta T_e = T_e \Delta Q/(1-\alpha)S \approx 1.2°C$, where ΔT_e = change in equilibrium temperature; T_e = initial equilibrium temperature = 288 K; ΔQ = increase of radiative forcing from a doubling of $CO_2 \approx 4\ W\ m^{-2}$; α = planetary reflectivity or albedo = 0.3; S = solar constant = 1,370 W m^{-2}. Source: Lorius *et al.* (1990), p. 139.

period. In that case, it is easily shown that a doubling of CO_2 from pre-industrial levels would likely lead to at least about 1.74ºC of warming.[98]

This calculation however, presumes that we have already experienced the full effects of the increase in CO_2 concentrations to 379 ppm. We haven't. We have experienced some of the feedbacks from this increase, but by no means all. The climate system has momentum and delayed feedbacks, due to factors such as the immense volume of the oceans which take a long time to warm up. So there would have been a further 'committed warming' already guaranteed from the increase to 379 ppm even if all emissions had ceased in 2005. In other words, the 1.74ºC figure applies only if we ignore the committed warming we will get from past emissions and their feedbacks on the climate system – or if we presume (on the basis of a climate model?) that the feedbacks cancel out. Once those feedbacks are properly taken into account however, the temperature increase resulting from a doubling of pre-industrial CO_2 levels (referred to as the 'climate sensitivity') 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."[99]

The most recent assessment of climate sensitivity by James Hansen and his team, based on empirical geological evidence, is even more disturbing.[100] Hansen argues that the figure of 3°C for the sensitivity of the climate to a doubling of CO_2 used in most climate models only accounts for 'fast' feedback effects, such as cloud formation, water vapour, and sea ice. Once 'slow' feedback effects are accounted for (on timescales of centuries or less), such as ice sheet disintegration, vegetation changes, and CO_2 and methane releases from soils, tundra and ocean sediments, the climate sensitivity for a doubling of CO_2 above pre-industrial levels is likely to be more like 6°C. This higher climate sensitivity suggests that a 300-325 ppm CO_2 target is what we need for a safe climate with sea ice restored to its area of 25 years ago.[101] Since CO_2 levels are now approaching 390 ppm, this implies not only drastically reduced emissions but an extended period of actually removing CO_2 from the atmosphere.

Furthermore, even ignoring these feedback effects, emissions projections at current trajectories are likely to see CO_2 levels of 1000 ppm by 2100, leading in turn to temperatures well over 3°C.[102] What is the highest level of CO_2 that those who are opposed to strong emissions reductions would consider safe? Is there *any* level of CO_2 concentration they would agree is too high?

Let's allow for the moment the argument that human greenhouse gas emissions have not contributed much at all to warming so far, and that the warming we've seen (which is not in

---

[98] To see this, consider that the increase of CO_2 from 280 to 379 ppm by 2005 has already led to a best-estimate temperature increase of 0.76°C [0.57-0.95 °C is the 90% confidence range] (IPCC, 2007a, pp. 2 & 5). With a logarithmic relationship between CO_2 concentrations and radiative forcing (or temperature, roughly) the additional forcing factor for a doubling of CO_2 = ln(560/280) = ln(2) = 0.693147. (To get the actual change in radiative forcing in Watts per m^2, this forcing factor would need to be multiplied by a constant, such as 5.35. See Myhre *et al.* (1998), p. 2718). The additional forcing factor from the increase from 280 to 379 is ln(379/280) = 0.302747, which is 43.67% of the additional forcing from doubling CO_2 from 280 to 560 ppm. Since we gained around 0.76°C [0.57-0.95 °C] from increasing CO_2 from 280 to 379, the implied gain from 560 ppm would be 1.74°C [1.31-2.18 °C], since 100/43.67*0.76 = 1.74. Calculations and discussion are based on those in Enting (2007), pp. 54-56.

[99] IPCC, (2007a), p. 12; and see also Roe & Baker (2007) for a good discussion of why it is difficult to narrow the range of climate sensitivity further than 2 to 4.5°C.

[100] Hansen *et al.* (2008).

[101] Hansen *et al.* (2008), p. 226.

[102] The 1000 ppm figure is from Garnaut (2008), p. 246. It is equivalent to about 1600 ppm CO_2-e.

dispute) is mostly of natural origin: What then is the policy implication? Well, the evidence from both theoretical physics and empirical data collected over more than 100 years show that these gases do contribute to warming, so if we're already being subjected to natural warming, does that in any way lessen the case for reducing our emissions? Hardly. That argument only follows if, for sound theoretical reasons, we believe that the greenhouse gases we emit will have no significant impact on the climate. But such a judgement has no sound basis in science and could only be arrived at by use of a climate model, none of which show negligible impact from rising greenhouse gases.

It should be remembered then, that when critics spurn climate models as 'voodoo science', asserting that the sensitivity of the climate to a doubling of CO_2 is just 1ºC or less, they must be implicitly adopting a climate model which either ignores all feedback effects, or which presumes that the feedbacks cancel out. To say anything about the effects of greenhouse gases on climate, there is no alternative but to use some kind of model – and any model that arbitrarily assumes either that there are no feedback effects or that they all cancel out, is scientifically unjustifiable. As Reto Knutti from the Institute for Atmospheric and Climate Science in Zurich wrote recently in his evaluation of climate model projections,

> No credible model has been produced that questions the strong anthropogenic influence on climate in the past and future. I, therefore, argue that the large-scale model projections are very likely robust and accurate within the stated uncertainties.[103]

15. CO_2 is not a pollutant – it is completely natural and essential for life.

Misleading. In general, whether something is a pollutant or not depends not on whether it is natural, but whether its *concentration* has increased sufficiently to adversely affect an ecosystem or human or animal health. Manure is natural and highly beneficial as a fertilizer on fields – but only up to a certain point. Even at current concentrations CO_2 is already a pollutant, adversely affecting human and natural systems.

Those who make this argument often also imply that greenhouse gases in general aren't pollutants. In doing so, they ignore the other main greenhouse gases released by human activities like CH_4 (methane) and N_2O (nitrous oxide), plus around 60 other gases under the broad categories of CFCs (chlorofluorocarbons), HCFCs (hydrochlorofluorocarbons), HFCs (hydrofluorocarbons), PFCs (perfluorinated compounds) such as SF_6 (sulfur hexafluoride), fluorinated ethers, perfluoropolyethers, halocarbons and other various other compounds.[104] Many of these synthetic gases are extremely potent greenhouse gases and contribute significantly to the overall human influence on the climate.

16. Any warming is the Sun's fault.

False. No-one claims that increased greenhouse gas emissions are the *only* cause of climate change. Fluctuations in solar activity also influence the world's climate, but their effects are taken into account by climate scientists and they are not enough to explain the changes we are seeing.[105] A number of recent studies have debunked the notion that solar variations are

[103] Knutti (2008).
[104] Forster *et al.* (2007), pp. 141, 212-213.
[105] For good discussions of this topic see: http://cce.890m.com/solar-cosmic-rays/ and http://www.skepticalscience.com/solar-activity-sunspots-global-warming.htm

responsible for the recent warming rather than greenhouse gases produced by humans, concluding:

> After 1980 … the Earth's temperature exhibits a remarkably steep rise, while the Sun's irradiance displays at the most a weak secular trend. Hence the Sun cannot be the dominant source of this latest temperature increase, with man-made greenhouse gases being the likely dominant alternative.[106]

> Variations in the Sun's total energy output (luminosity) are caused by changing dark (sunspot) and bright structures on the solar disk during the 11-year sunspot cycle. The variations measured from spacecraft since 1978 are too small to have contributed appreciably to accelerated global warming over the past 30 years.[107]

> This comparison shows without requiring any recourse to modeling that since roughly 1970 the solar influence on climate (through the channels considered here) cannot have been dominant. In particular, the Sun cannot have contributed more than 30% to the steep temperature increase that has taken place since then, irrespective of which of the three considered channels is the dominant one determining Sun-climate interactions: tropospheric heating caused by changes in total solar irradiance, stratospheric chemistry influenced by changes in the solar UV spectrum, or cloud coverage affected by the cosmic ray flux.[108]

> [O]ver the past 20 years, all the trends in the Sun that could have had an influence on the Earth's climate have been in the opposite direction to that required to explain the observed rise in global mean temperatures.[109]

> [E]ven large solar irradiance change combined with realistic volcanic forcing over past centuries could not explain the late 20th century warming without inclusion of greenhouse gas forcing. Although solar and volcanic effects appear to dominate most of the slow climate variations within the past thousand years, the impacts of greenhouse gases have dominated since the second half of the last century.[110]

> [T]he energy content of the climate system increased between about 1955 and 1995 by about 2 x 1023 J, equivalent to an energy imbalance at the top of the atmosphere of 0.3 W/m2. Because incoming solar energy … has not changed, the imbalance must result from increased absorption of outgoing energy, such as by increased greenhouse gases.[111]

Lean and Rind concluded that there was no chance that variation in solar radiation was primarily responsible for the warming witnessed in the 20th century:

> For the ninety years from 1906 to 1996, the average slope of the anthropogenic–related temperature change … is 0.045 K per decade … Solar-induced warming is almost an order of magnitude smaller. It contributes 10%, not 65% … of surface warming in the past 100 years and, if anything, a very slight overall cooling in the past 25 years … not 20–30% of the warming.[112]

---

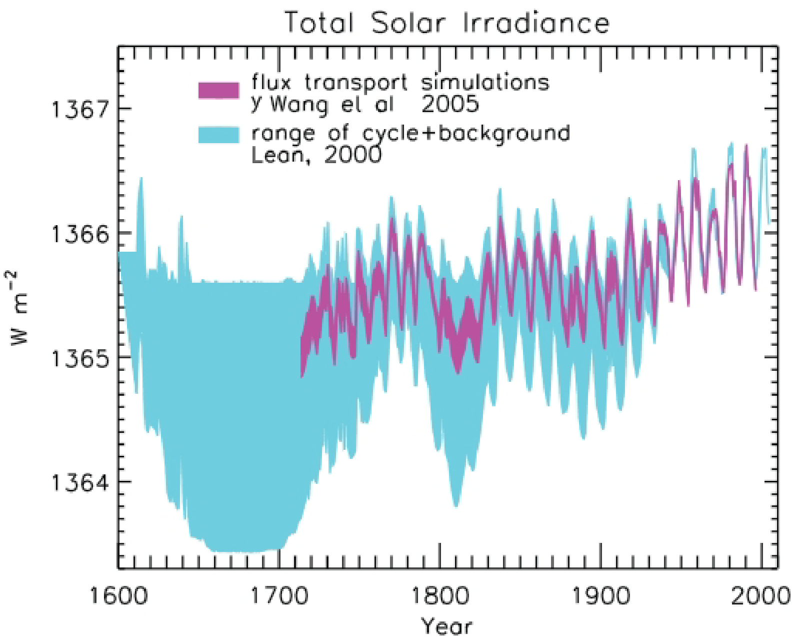
[106] Solanki (2002), p. 5.13.
[107] Foukal *et al.* (2006), p. 161.
[108] Solanki & Krivova (2003), p. 1
[109] Lockwood & Fröhlich (2007), p. 2447. See also Lockwood & Fröhlich (2008a & b).
[110] Ammann *et al.* (2007), p. 3713.
[111] Duffy *et al.* (2009), p. 48.
[112] Lean & Rind (2008), p. 5. See also Lean *et al.* (2005).

It has also been shown that solar influences are not well correlated with past climatic changes, based on a 9000 year dataset.[113]

As Figure 6 shows, there is no strong trend in solar activity that could explain recent warming, so the variation in radiative forcing (in Watts per square metre, W m^{-2}) within each 11 year solar cycle, is significantly greater than any trend change in average solar irradiance.

Figure 6. Total solar irradiance

Source: Forster *et al.* (2007), Fig. 2.17, p. 190. Caption: "Reconstructions of the total solar irradiance time series starting as early as 1600. The upper envelope of the shaded regions shows irradiance variations arising from the 11-year activity cycle. The lower envelope is the total irradiance reconstructed by Lean (2000), in which the long-term trend was inferred from brightness changes in Sun-like stars. In comparison, the recent reconstruction of Y. Wang et al. (2005) is based on solar considerations alone, using a flux transport model to simulate the long-term evolution of the closed flux that generates bright faculae."



17. Climate change is due to the effects of cosmic rays.

False. Cosmic rays are not really rays, but high-energy particles such as protons and helium nuclei (alpha particles) from the sun and other stars which enter the Earth's atmosphere. Some studies have purported to show a degree of correlation in some parts of the world between cosmic ray fluxes and increases in low-level cloud cover. From these correlations, some have concluded that cosmic rays are a primary cause of increased cloud cover, which would have a cooling effect due to their greater reflectivity (albedo). When the Sun is more active, its magnetic field deflects more of these fast-moving particles away from the Earth, and so it is postulated that the influence of solar activity has been significantly underestimated since a more active sun would lead to fewer particles, fewer clouds and more warming. Other studies however have shown no correlation between cosmic ray fluxes and cloud cover. For example, an analysis of US data from 1900-1987 found that while solar

[113] Turney *et al.* (2005).

irradiance variations were correlated with cloud cover changes, cosmic rays were not.[114] Similarly, a 2002 review of the issue concluded:

> No meaningful relationship is found between cosmic ray intensity and cloud cover over tropical and extratropical land areas back to the 1950s. The high cosmic ray-cloud cover correlation in the period 1983–1991 over the Atlantic Ocean, the only large ocean area over which the correlation is statistically significant, is greatly weakened when the extended satellite data set (1983–1993) is used. Cloud cover data from ship observations over the North Atlantic, where measurements are denser, did not show any relationship with solar activity over the period 1953–1995, though a large discrepancy exists between ISCCP D2 data and surface marine observations. Our analysis also suggests that there is not a solid relationship between cosmic ray flux and low cloudiness …[115]

In discussing this issue the Royal Society concluded:

> [O]bservations of clouds and galactic cosmic rays show that, at most, the possible link between cosmic rays and clouds only produces a small effect. Even if cosmic rays were shown to have a more substantial impact, the level of solar activity has changed so little over the last few decades the process could not explain the recent rises in temperature that we have seen.[116]

In somewhat more detail, the IPCC concluded:

> [T]he cosmic ray time series does not correspond to global total cloud cover after 1991 or to global low-level cloud cover after 1994 … without unproven de-trending … Furthermore, the correlation is significant with low-level cloud cover based only on infrared (not visible) detection. Nor do multi-decadal (1952 to 1997) time series of cloud cover from ship synoptic reports exhibit a relationship to cosmic ray flux. However, there appears to be a small but statistically significant positive correlation between cloud over the UK and galactic cosmic ray flux during 1951 to 2000 … Contrarily, cloud cover anomalies from 1900 to 1987 over the USA do have a signal at 11 years that is anti-phased with the galactic cosmic ray flux ...[117]

Moreover, in assessing the scientific evidence for various climate forcing agents, the IPCC ranked cosmic rays as having ‘insufficient evidence’, ‘insufficient consensus’ and a ‘very low’ level of scientific understanding and a ‘General lack/doubt regarding the physical mechanism; dependence on correlation studies’.[118]

More recently, the first calculations of the magnitude of the cosmic ray effect on clouds were published, with the authors concluding that the effect of cosmic rays was about 100 times too small to account for the observed changes in cloud properties: “Consequently we conclude that the hypothesized effect is too small to play a significant role in current climate change.”[119]

It is possible then that cosmic rays do have some minor effects on the climate. But some people give enormous weight to the supposed effects of cosmic rays, despite their speculative

114 Udelhofen & Cess (2001).
115 Sun & Bradley (2002), p. 1.
116 The Royal Society (2008), p. 9.
117 Forster *et al.* (2007), p. 193.
118 Forster *et al.* (2007), p. 202.
119 Pierce & Adams (2009), p. 1.

foundations, inadequate evidence and a general view among scientists that they are unlikely to be very important in determining recent and projected climate changes. This stands in stark contrast to the often emphatic rejection of the warming effects of long-lived greenhouse gases by the same people, despite the fact that these gases are given the highest grades possible in each category of the IPCC's assessment: 'strong evidence' for their warming impacts, a 'good deal of consensus' among the scientific community and a 'high' level of scientific understanding.[120] This 'uneven' approach to the scientific evidence on cosmic rays compared with greenhouse gases appears to betray a pre-determined conclusion in a search of support, rather than an honest and rigorous appraisal of the weight of the available scientific evidence.[121]

18. Lack of warming in the tropical troposphere (lower atmosphere) proves anthropogenic global warming is a myth.

False. For some years an apparent discrepancy existed between the predictions by climate models that the tropical troposphere would be warming, and certain satellite data which suggested it was not. When a paper by Douglass *et al.* (2008) was published online in 2007, it was hailed by some as a knock-out blow for climate models in general and even the whole phenomenon of anthropogenic (human-caused) climate change. But a more recent assessment of the issue found serious flaws in the Douglass paper including a failure to account for natural variability and a flawed statistical test. Santer *et al.* (2008) concluded that "There is no longer a serious and fundamental discrepancy between modelled and observed trends".[122]

19. Coming out of the ice ages, the changes in CO_2 happened after the warming began, so CO_2 doesn't affect atmospheric temperatures.

Half-true but a false conclusion. At the end of the ice ages, variations in the Earth's orbit and the angle of its axis warmed the planet again. Temperatures began to increase, followed 200 to 2000 years later by rising CO_2 concentrations. The fact that warming generally preceded the CO_2 increases has often been misrepresented as somehow proving that increases in CO_2 do not contribute to global warming. In fact it proves nothing of the sort. What it demonstrates is that CO_2 was not the forcing that drove the *initial* warming after periods of glaciation. The initial phase of warming however, is only a fraction of the total warming period. For example, during the so-called 'Termination III', some 240,000 years ago, the initial warming was only around 800 years out of a total warming period of some 5000 years. The rising CO_2 amplified the initial effects, making the warming periods longer and warmer than they would otherwise have been without the extra CO_2.

It is also not true that temperature increases *worldwide* always came before CO_2 increases. At least for Termination III, while the CO_2 increase in the Antarctic followed the initial warming by about 800 years, "the CO_2 increase clearly precedes the Northern Hemisphere deglaciation."[123]

[120] Forster *et al.* (2007), p. 201.
[121] For more on this issue see: http://cce.890m.com/solar-cosmic-rays/
[122] See Santer *et al.* (2008), pp. 1718-1719. See also their factsheet: http://www.realclimate.org/docs/santer_etal_IJoC_08_fact_sheet.pdf and: http://www.realclimate.org/index.php/archives/2008/10/tropical-tropopshere-iii/
[123] Caillon *et al.* (2003), p. 1730. See also Timmermann *et al.* (2009).

20. Antarctica is cooling, so that proves the global climate isn't warming.

False. While parts of Antarctica seem to be cooling, overall the continent is warming, and even the localised cooling and sea-ice expansion is consistent with climate change theory.

Antarctica is a large and complex continent about 1.3 times the size of Europe, comprising two main zones, separated by the Transantarctic Mountains: East Antarctica, which is covered by the East Antarctic Ice Sheet (EAIS), and the much smaller West Antarctica, covered by the West Antarctic Ice Sheet (WAIS). The Antarctic Peninsula is a third important zone which extends north towards the southern tip of South America from West Antarctica. The continent is completely encircled by the Southern Ocean's Antarctic Circumpolar Current, which drives water and winds from west to east around the continent. The climate in Antarctica is responding in different ways across its vast area, just as it does on the other continents. Overall though there is a positive overall warming trend for Antarctica:

> Here we show that significant warming extends well beyond the Antarctic Peninsula to cover most of West Antarctica, an area of warming much larger than previously reported. West Antarctic warming exceeds 0.1ºC per decade over the past 50 years, and is strongest in winter and spring. Although this is partly offset by autumn cooling in East Antarctica, the continent-wide average near-surface temperature trend is positive.[124]

The Antarctic Peninsula has experienced some of the most rapid warming on Earth over the past 50 years, already warming by approximately 2ºC since the 1950s.[125] This rapid warming has led to greater summer snowmelt, the loss of ice shelves and the retreat of 87% of marine and tidewater glacier fronts. Measurements of 300 glaciers between 1992 and 2005 covering 95,000 km^2, showed flow rates increasing by an average of 12% over the period. Mass loss from the Antarctic Peninsula glaciers and from West Antarctica "is probably large enough to outweigh mass gains in East Antarctica and to make the total Antarctic sea level contribution positive." [126]

Another team used satellite observations from 1992 to 2006 covering 86% of Antarctica's coastline to estimate how much mass was being lost in different regions. They found large variations:

> In East Antarctica, small glacier losses in Wilkes Land and glacier gains at the mouths of the Filchner and Ross ice shelves combine to a near-zero loss of 4±61 Gt yr^{-1}. In West Antarctica, widespread losses along the Bellingshausen and Amundsen seas increased the ice sheet loss by 59% in 10 years to reach 132±60 Gt yr^{-1} in 2006. In the Peninsula, losses increased by 140% to reach 60±46 Gt yr^{-1} in 2006. Losses are concentrated along narrow channels occupied by outlet glaciers and are caused by ongoing and past glacier acceleration. Changes in glacier flow therefore have a significant, if not dominant impact on ice sheet mass balance.[127]

One of the authors of this study, Eric Rignot, emphasised that, "Without doubt, Antarctica as a whole is now losing ice yearly, and each year it's losing more."[128]

---

[124] Steig *et al.* (2009), p. 459.
[125] Cook *et al.* (2005), p. 541.
[126] Pritchard & Vaughan (2007), p. 1.
[127] Rignot *et al.* (2008). Gt yr^{-1} means 'billion tonnes per year'.
[128] Kaufman (2008).

Another recent study found that mountain glaciers and ice caps in Antarctica were estimated to be contributing around 28% of global contributions to sea level rise from mountain glaciers and ice caps, "due to exceptional warming around the Antarctic Peninsula and high sensitivities to temperature similar to those we find in Iceland, Patagonia and Alaska."[129]

One apparent paradox that is that Antarctic sea ice cover *increased* since the late 1970s, particularly during autumn, despite warming in both the atmosphere and ocean. The increase has not been uniform. Increases in the Weddell Sea, Pacific Ocean and Ross Sea have been offset by declines in the Indian Ocean and Amundsen-Bellinghausen Sea.[130] The paradox is only apparent however, and in no way lends support to those denying that greenhouse gases are warming the global climate. The reasons why Antarctic sea ice has increased despite warming temperatures, seem likely to involve two main processes. The first is a strengthening of the autumn wind speeds around the continent due to stratospheric ozone depletion.[131] The second is somewhat more complex, involving the melting due to warmer temperatures being more than offset by reduced upwelling of warmer waters:

> The model shows that an increase in surface air temperature and downward longwave radiation results in an increase in the upper-ocean temperature and a decrease in sea ice growth, leading to a decrease in salt rejection from ice, in the upper-ocean salinity, and in the upper-ocean density. The reduced salt rejection and upper-ocean density and the enhanced thermohaline stratification tend to suppress convective overturning, leading to a decrease in the upward ocean heat transport and the ocean heat flux available to melt sea ice. The ice melting from ocean heat flux decreases faster than the ice growth does in the weakly stratified Southern Ocean, leading to an increase in the net ice production and hence an increase in ice mass. This mechanism is the main reason why the Antarctic sea ice has increased in spite of warming conditions both above and below during the period 1979–2004 and the extended period 1948–2004.[132]

In other words, two opposing factors seem to be at work: The first factor is that warmer temperatures tend to reduce sea-ice growth. The second factor is that the reduction in sea-ice growth reduces salt rejection from the ice, which in turn reduces the salinity (and therefore the density) of the upper-ocean. The less dense upper-ocean water then impedes the upwelling of warmer waters to melt the ice from below. This second factor, impeding the upwelling heat available to melt the sea ice, has been stronger than the first factor, the warmer temperatures impeding ice growth. As a result, there has been a net increase in ice mass.

21. Action on climate change would ruin our economies.

False. Quite the opposite in fact, for five main reasons:

21.1 The conventional economic estimates of the 'costs' of addressing climate change are small

The IPCC noted that "In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO_2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline", and

[129] Hock *et al.* (2009), p. 1.
[130] Turner *et al.* (2009), p. 1.
[131] Turner *et al.* (2009), p. 1.
[132] Zhang (2007), p. 2515.

that even a 3% decrease compared to the (growing) baseline translated to less than 0.12 percentage points off the economic growth rates that would be expected in the absence of action to rein in climate change.[133]

The Australian Treasury found similar figures for Australia. Modelling for an emissions reduction target of 25% below 2000 levels by 2020, Treasury concluded that it would shave approximately 0.1 percentage points each year off real per capita economic growth (taking into account both population increase and price inflation). So annual GNP per capita growth would be around 1.1% rather than 1.2%, implying that Australians would have to wait until 2054 to be as rich as we would have been in 2050. Note that this 'reduction' is a reduction below baseline projections in the context of continued strong growth and rising living standards – it is not a reduction from current income levels. Australia's average GNP per capita was $50,400 in 2008 and under the 25% target, Treasury's modelling suggested it would rise to $78,000, by 2050, leaving the average Australian $27,600 (or 55%) richer.[134]

Elsewhere, for 2020, the Australian Government's *White Paper* states:

> GNP is 1.3 per cent to 1.7 per cent below the reference case in 2020 in the CPRS [Carbon Poverty Reduction Scheme] scenarios, and up to 2.0 per cent below the reference case in the Garnaut Final Report scenarios. *These impacts are equivalent to about four months of economic growth*, implying that the level of economic activity achieved in January 2020 in the reference case would be achieved in April 2020 in the CPRS scenarios.[135]

So the Australian Government's modelling concluded that even reaching a target of 25% emissions reductions below 2000 levels by 2020 (which translates to 24% below 1990 levels – the usual baseline used in international negotiations) the net economic impact would be likely to be only 0.1 percentage points foregone from real per capita GNP growth. To put that figure into some context, by 1942-43 Australia was spending the equivalent of 40% of its national income fighting the Second World War.[136]

If we accept the IPCC's and Treasury's modelling then, there are no serious economic impediments to strong action on climate change. But are there reasons to doubt this type of modelling? Yes – but these doubt only make the case for action even more compelling.

21.2 The conventional economic estimates of the 'costs' of addressing climate change are not the 'net costs' – i.e. costs vs. benefits

The key to the IPCC's and Treasury's framework is the 'baseline' projections for GNP growth that are used to provide a benchmark against which to compare the 'costs' of mitigating climate change. Regrettably, these baselines generally do not take into account the economic costs of letting climate change run its course. The computable-general equilibrium (CGE) models used for this analysis are rarely well-integrated with dynamic climate models.[137]

---

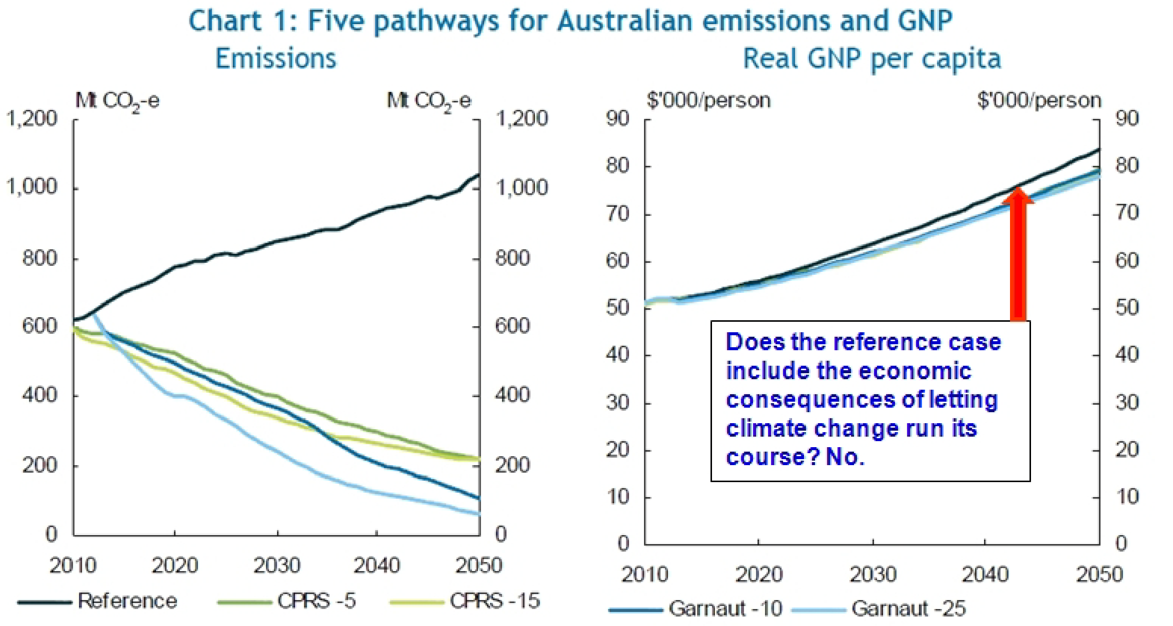
[133] IPCC (2007c), pp. 11-12.
[134] Australian Government (2008a), p. xii.
[135] Australian Government (2008b), p. 4-12. Emphasis added.
[136] Long, (1973), pp. 5 & 474.
[137] See Hall & Behl (2006).

For example, in the *OECD Environmental Outlook to 2030*, some of the most important sentences in the whole report for understanding the implications of the economic models are tucked away in an appendix:

> The *OECD Environmental Outlook* … shows the impact of the global economy's development on the physical world; i.e. the environment. It does not, however, reflect the environmental impact back on the economy. Failing to provide this fully integrated picture has two implications. First, the Baseline fails to reflect GDP loss from environmental damage, so GDP projections may be higher than are justified. Second, since without that feedback environmental policy will always show a loss of GDP, there is a misleading implication that environmental policy always decreases welfare.[138]

The 'Baseline' projection then, with which all policy responses are compared, does *not* take into account the likely effects of climate change on the global economy. In Australia, the *Garnaut Review* and Treasury analysis in *Australia's Low Pollution Future*, both used a 'Garnaut-Treasury Reference Case' in which emissions and GNP growth were projected as far as 2100.[139] Critically, as Figure 7 shows, the likely impacts of unmitigated climate change on the economy are again *not* taken into account in the reference case.

Figure 7. Chart 1 from the Australian Treasury's analysis
Source: Australian Government (2008a), pp. xii. Box and arrow added.



Note: Units are in Australian dollars, 2005 prices. The reference scenario shows modelled emissions, while the policy scenarios show allocations (policy targets). Actual emissions differ from allocations due to banking of permits and international permit trade.
Source: Treasury estimates from MMRF.

[138] OECD (2008), p. 513.
[139] Garnaut (2008), p. 59-62; Australian Government (2008a), Chapter 3.

For example, Treasury says,

> The modelling does not include the economic impacts of climate change itself, so does not assess the benefits of reducing climate change risks through mitigation.[140]
>
> The reference scenario … presents a plausible future path for economic growth, population levels, energy consumption and greenhouse gas emissions in a world without climate change. The reference scenario is not a prediction and does not include risks arising from climate change itself.[141]

Nor apparently, are the constraints of natural resources or sinks considered, since global output in the reference case is projected to be 17 times current levels by 2100.[142] The Garnaut Review further noted that, "By the end of the century, the concentration of long-lived greenhouse gases is 1565 ppm CO_2-e, and carbon dioxide concentrations are over 1000 ppm – more than 3.5 times higher than pre-industrial concentrations."[143] The consequences of such a drastic rise in emissions have no impact on economic growth in the reference case.

While it is useful to conduct such a modelling exercise to get a sense of where global economic and emissions trends are leading us, it is quite another matter to suggest that comparison with such a 'reference case' constitutes a useful basis for estimating the 'costs' of mitigating climate change. The *Garnaut Review*, to its credit, acknowledged this problem and tried to estimate the costs of climate change on the economy, distinguishing four types of costs, only the first of which could be estimated with any confidence.[144] The Treasury analysis did not do this, instead presenting results as "Overall mitigation cost, 2010-2050" (p. xii) for the various scenarios, with the 'costs' of mitigation presented as being around 0.1 percentage points of annual GNP per capita growth. It also asserts:

> All scenarios show Australia, at the-whole-of-economy level, can achieve substantial emission reductions with relatively small *reductions* in economic growth.[145]
>
> The introduction of emission pricing will *reduce* Australia's GNP per capita compared with the reference scenario, but GNP per capita continues to grow across all the mitigation scenarios.[146]

These statements however, are quite misleading presentations of the results. While it is true that in the context of the model, emissions pricing reduces GNP relative to the reference scenario, this result cannot be transferred to the real world with any great relevance beyond the first few years. It cannot be asserted for example, on the basis of this modelling exercise, that Australia's GNP would be *lower* in 2050 with mitigation efforts (as part of a global effort) than it would have been without them. By 2050, the *Garnaut Review* noted that in the Murray-Darling basin, Australia's breadbasket, we could expect to lose half the irrigated agriculture, and possibly as much as 72%, due to unmitigated climate change, and that "fundamental restructuring of the irrigated agriculture industry" would be required.[147]

---

140 Australian Government (2008a), p. xi.
141 Australian Government (2008a), p. 27.
142 Garnaut (2008), p. 69.
143 Garnaut (2008), p. 86.
144 Garnaut (2008), pp. 247-249.
145 Australian Government (2008a), p. 137. Emphasis added.
146 Australian Government (2008a), p. 144. Emphasis added.
147 Garnaut (2008), p. 130.

The methodology used in the Treasury analysis guarantees *by assumption* that any serious mitigation efforts will look like a net cost because they are being compared with an imaginary economic growth trajectory in which climate change does not exist. In fact, the modelling approach used does not allow us to say anything about the real world net costs of mitigation since the exercise must be viewed over a multi-decade time frame, during which unchecked climate change would certainly lead to major economic impacts. The baseline ‘reference case’ cannot occur because it ignores the impacts of climate change on the economy. A model that fully integrated the global economic and climate systems would be far more likely to show that strong mitigation action is the only way to prevent catastrophic climate change and so ensure that we retain a living standard even comparable to today, let alone global output being 17 times greater than today and Australian incomes per capita being US$137,000 in 2100 compared with US$36,000 in 2005 as the *Garnaut Review* envisages.[148]

In summary, projecting a reference case for economic growth out to 2050 or 2100 based on past experience and ‘business as usual projections’, as if climate change was not happening, does not constitute an adequate basis for comparing the costs and benefits of mitigation measures. It is like deciding whether or not to hose a house down based purely on the cost of the water, ignoring the fact that the house is on fire.

21.3 Much economic analysis tends to grossly underestimate the likely costs of unmitigated climate change.

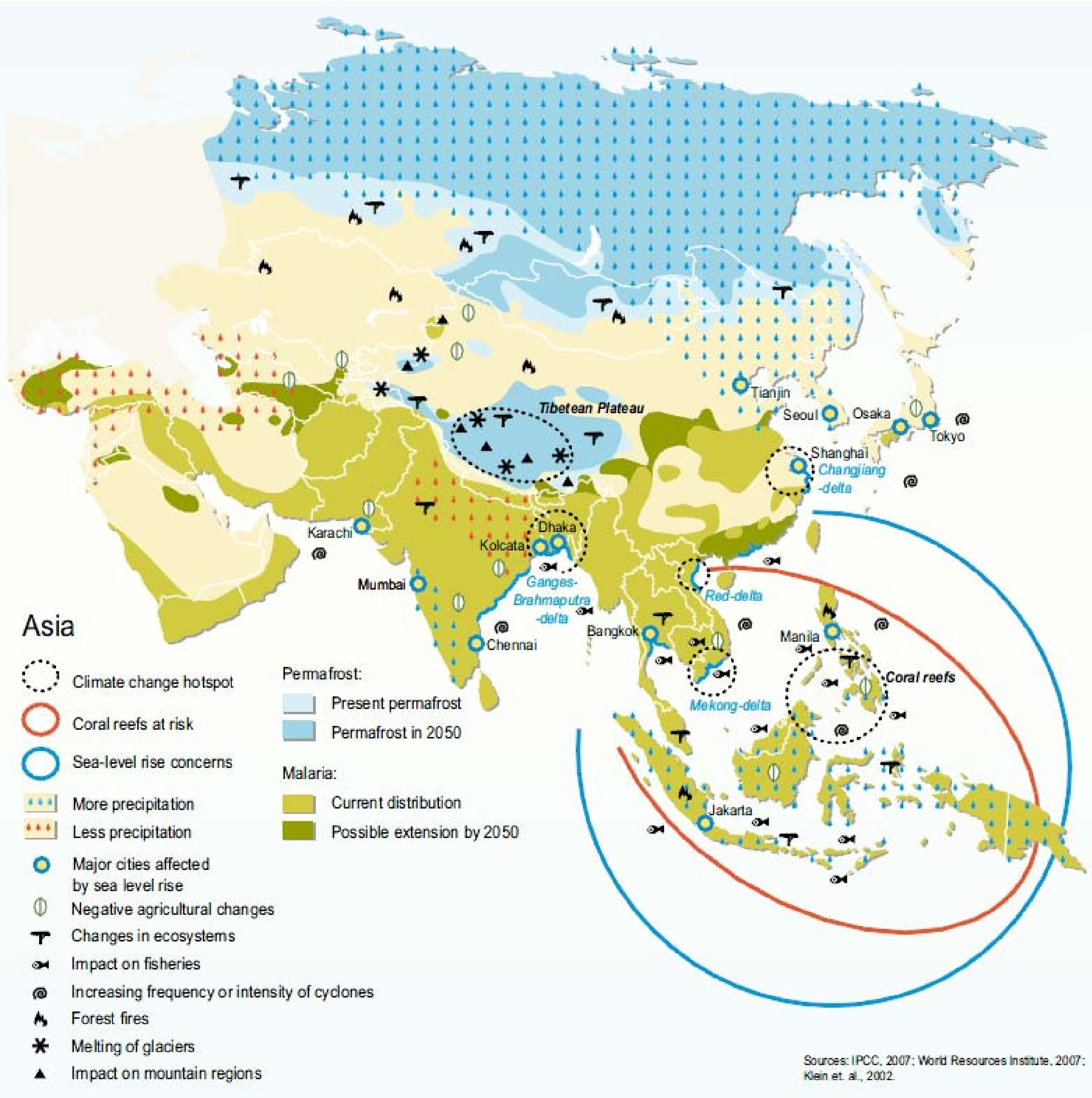
Most economic analysis of climate change simply presumes that economic growth will continue onward and upward, regardless of any impacts climate change might have on economies and societies. Most economic models are not well integrated with biophysical, political or financial models. So they cannot, for example, examine the effects of famines and mass migrations on the stability of governments, the likelihood of conflict and the impacts on investment decisions and financial markets. Neither can they account for the impacts of sea-level rise on coastal property values, financial markets and insurance markets.

For example, once ice sheet dynamics are taken into account, sea-levels are likely to rise at least 0.8 m and possibly even 2 metres by 2100.[149] Even a one metre sea-level rise would impact around 105 million people in Asia and 145 million worldwide.[150] As Figure 8 shows, many of Asia’s major coastal cities are vulnerable to sea-level rise. The *Garnaut Review* further noted that:

> Most of Asia’s densest aggregations of people and productive lands are on coastal deltas, including the cities of Shanghai, Tianjin, Guanzhou, Tokyo, Jakarta, Manila, Bangkok, Ningbo, Mumbai, Kolkata and Dhaka. Much of Hong Kong and Singapore are on low-lying land, much of it recently reclaimed from the sea. The areas under greatest threat are the Yellow and Yangtze river deltas in China; Manila Bay in the Philippines; the low-lying coastal fringes of Sumatra, Kalimantan and Java in Indonesia; the Mekong (Vietnam), Chao Phraya (Thailand) and Irrawaddy (Myanmar) deltas … and the delta cities of south Asia.[151]

[148] Garnaut (2008), p. 69.
[149] Rahmstorf (2007); Pfeffer *et al.* (2008).
[150] Anthoff *et al.* (2006).
[151] Garnaut (2008), p. 148.

Figure 8. Likely climate impacts in Asia including cities and river deltas vulnerable to sea-level rise. Source: UNEP (2009), p. 34.



The sea-level issue is particularly important since it is often assumed that sea-level rise represents a slow, progressive inundation that is relatively straightforward to manage. But one of the greatest dangers from higher seas are the storm surges which accompany tropical storms and which can often be 5-7 metres high. The storm surge accompanying cyclone Nargis in Myanmar on 2-3 May 2008 peaked at over 5 m on the coast, with storm waves of around 2 m superimposed on top of the 5 m surge in most areas. The storm surge travelled up to 50 km inland, killing around 140,000 people and flooding around 14,400 km^2, an area a third the size of Switzerland. Fatalities exceeded 80% in the hardest-hit villages.[152] The storm surge from Hurricane Katrina that struck the US Gulf Coast from 23-30 August 2005, reached 10 m on parts of the Mississippi coastline.[153] Periodic inundations by storm surges have also been shown to be of the order of 9-28 times more expensive than permanent

[152] Fritz *et al.* (2008a, 2009); Luetz (2008), p. 12.
[153] Fritz *et al.* (2008b).

inundation because of factors such as repeated rebuilding and repair costs and higher insurance costs.[154]

As the science relating to sea-level rise continues to consolidate over the next decade, the potential for future sea level rises and associated shoreline erosion and storm surges are likely to have very serious implications for coastal property values and insurance premiums around the world. A critical point is that the sea-level rises do not have to have taken place yet for projected rises to have immediate economic effects. Properties used for loan collateral may be devalued by lenders and land taxes may become delinked from falling property values. Over time insurance premiums may also climb across entire economies if losses in coastal areas and from extreme weather events are cross-subsidised by insurance companies from elsewhere. These climate system-financial market links do not appear to be captured by current modeling.

Questions are already being raised in Australia about the legal liability of local councils and government planning bodies for the effects of coastal planning regulations on property values in the context of likely sea-level rise.[155] Indeed, one issue that is likely to be exercising the minds of lawyers in the coming decades is that of the legal liability of decision makers who knew, or had the responsibility to know, beyond reasonable doubt, the grave risks of allowing certain developments or policies to proceed, and allowed them anyway.

Other major international impacts noted by Australia's *Garnaut Review* with potentially large economic repercussions include the following:

> Key Australian export markets are projected to have significantly lower economic activity as a result of climate change. This is likely to feed back into significantly lower Australian export prices and terms of trade.[156]
>
> Weather extremes and large fluctuations in rainfall and temperatures have the capacity to refashion Asia's productive landscape and exacerbate food, water and energy scarcities in Asia and the south-west Pacific. Australia's immediate neighbours are vulnerable developing countries with limited capacity to adapt to climate change. Climate change outcomes such as displacement of human settlements by sea-level rise, reduced food production, water scarcity and increased disease, while immensely important in themselves, also have the potential for destabilisation of domestic and international political systems in parts of Asia and the south-west Pacific.[157]
>
> Climate change can generate security risks through infectious disease. … A study by the World Health Organization (2002) estimated that 154 000 deaths annually were already attributable to the ancillary effects of climate change due mainly to malaria and malnutrition. The study suggests that this number could nearly double by 2020.[158]
>
> In the future … climate refugees could constitute the fastest-growing proportion of refugees globally, with serious consequences for international security.[159]

[154] Michael (2007).
[155] Millar (2008).
[156] Garnaut (2008), p. 125.
[157] Garnaut (2008), p. 145.
[158] Garnaut (2008), 147.
[159] Garnaut (2008), p. 149.

The geopolitical implications of water projections in Asia are extremely serious.[160] The glaciers of the Himalayas and Tibetan Plateau are the source for seven of Asia's most important rivers: the Ganges, which flows across northern India to join the Brahmaputra in Bangladesh; the Indus which flows through Indian-controlled Jammu and Kashmir before becoming the lifeblood of Pakistan's agriculture; the Salween which flows through China and Burma into Thailand; the Mekong which flows though half a dozen countries and is critical to food supplies in Vietnam, Cambodia and Laos; and two of China's great rivers, the Yangtze and the Huang (Yellow River). Temperatures on the Tibetan Plateau have risen three times faster than the global average for the last 50 years.[161] Increased glacier melt in the next 20-30 years is likely to increase flooding, including sudden and catastrophic glacier lake outburst floods. But by the late 2030s, river flows are likely to decrease dramatically as the glaciers shrink from their 1995 extent of 500,000 km^2 to an expected 100,000 km^2 by 2035.[162]

By the 2050s more than a billion people in Central and South Asia could be suffering significant water shortages and crop yields could decrease by 30 per cent.[163] The *Garnaut Review* also warned that food production in Asia was likely to drop:

> The Consultative Group on International Agricultural Research (2002) has predicted that food production in Asia will decrease by as much as 20 per cent due to climate change. These forecasts are in line with IPCC projections showing significant reductions in crop yield (5-30 per cent compared with 1990) affecting more than one billion people in Asia by 2050.[164]

In 2008 there were food riots in more than 30 countries as the price of food staples skyrocketed due to several factors that included reduced harvests due to drought and diversion of land to first-generation biofuels. Food prices are closely tied to economic and political stability and so can have major economic impacts beyond their first-round effects.

The IPCC also noted that India is likely to face severe water stress:

> The gross per capita water availability in India will decline from about 1,820 m^3/yr in 2001 to as low as about 1,140 m^3/yr in 2050 … India will reach a state of water stress before 2025 when the availability falls below 1000 m^3 per capita.[165]

There is substantial potential for tension between India and Pakistan over water since the Indus and several of its main tributaries, such as the Chenab, Ravi, Jhelum and Sutlej, pass through India before reaching Pakistan.[166] The Middle East and Mediterranean basin are also expected to be afflicted by severe water shortages.[167] The *Garnaut Review* highlighted the dangers posed by some of these likely sources of tension:

> China's efforts to rectify its own emerging water and energy problems indirectly threaten the livelihoods of millions of people in downstream, riparian states. Chinese dams on the Mekong are already reducing flows to Myanmar, Thailand, Laos, Cambodia and Vietnam.

[160] As the *Review* discusses in Garnaut (2008), Box 6.5, p. 147.
[161] Qiu (2008).
[162] Cruz *et al.* (2007), p. 493.
[163] IPCC (2007b), p. 13.
[164] Garnaut (2008), p. 146.
[165] Cruz *et al.* (2007), p. 484.
[166] Klare (2001), pp. 182-189. See also Pai (2008).
[167] IPCC (2007c), Fig 3.5, p. 49.

> India is concerned about Chinese plans to channel the waters of the Brahmaputra to the over-used Yellow River. Should China go ahead with this ambitious plan, tensions with India and Bangladesh would almost certainly increase … Any disruption of flows in the Indus would be highly disruptive to Punjabi agriculture on both sides of the India–Pakistan border. It would raise difficult issues in India–Pakistan relations. Any consequent conflicts between China and India, or India and Pakistan, or between other water-deficient regional states, could have serious implications for Australia, disrupting trade and people flows and increasing strategic competition in Asia.[168]

There are enormous humanitarian and security implications of probable widespread water shortages across Turkey, Israel, Lebanon, Syria, Iraq, Iran, the Caucasus, Pakistan, Afghanistan, India and parts of China.[169] Water shortages and declining crop yields in the face of rising populations would lead to widespread food shortages, which would be likely to trigger large movements of people and potentially, if history is any guide, major armed conflicts with staggering humanitarian and economic costs. Four of these states already possess nuclear weapons. Iran seems to want them and Iraq may still have them by proxy with strong US security ties. The last thing the region needs is a series of 'threat multipliers' due to food and water shortages brought on by climate change.

Like most economic analyses which are unable to incorporate the nonlinear effects of major conflicts into their economic models, the *Garnaut Review* noted these concerns, but downplayed their likely economic impacts:

> Climate change may lead to geopolitical instability, which will require an increase in the capability and requirements of Australia's defence force and an increase in the level of Australia's spending on emergency and humanitarian aid abroad. Previous Australian interventions in small neighbouring nations provide some indication of the potential size of future defence costs that may arise from climate change. The combined aid and defence budget for the five-year intervention in Timor-Leste has exceeded $700 million per year. Australia's intervention in Solomon Islands is estimated to cost around $200 million per year (Wainwright 2005). This level of intervention is likely to continue until at least 2013. Climate change could lead to the involvement of larger countries through geopolitical pressures, and thus may lead to much higher spending than would be indicated by recent history. A 10 per cent increase in defence spending would be a cost of 0.2 per cent of GDP. Although extra defence spending does not automatically lead to reduced GDP, the Review treats it as a cost since it represents resources that would otherwise have been available for productive use elsewhere.[170]

It is of course extremely difficult to envisage the economic and social consequences of geopolitical instability, but the outlook is sobering. Island states of the Pacific face increasing pressures, and in Asia and Africa, combinations of water and food shortages and climate refugees are likely to exacerbate existing tensions. Even if actual conflicts are avoided, it is highly likely that a deteriorating strategic outlook and an increasing need for military and disaster assistance will increase pressures for defence spending, part of which must also be counted as a cost of climate change.

On balance it is likely that the total economic costs of future geopolitical tensions in Africa and the Asia-Pacific due to the effects of climate change will dwarf the costs of recent UN-

[168] Garnaut (2008), Box 6.5, p. 147.
[169] See: Dyer (2008), Schubert *et al.* (2008), Campbell *et al.* (2007); Campbell (2008); Chellaney (2007a,b).
[170] Garnaut (2008), p. 260.

backed interventions in places such as Rwanda, the Solomon Islands and Timor-Leste. The costs of major regional conflicts would of course be far greater.

21.4 Industries tend to overestimate the costs of adjustment to emissions reduction policies

Another reason much of the discussion about the economic costs of addressing climate change are likely to be overestimated is because the industries lobbying against the changes have every incentive to overestimate the impacts in order to persuade governments to be less stringent with regulations and more generous with assistance packages. Around the world as governments have prepared to introduce emissions trading schemes or carbon taxes, industries have lined up to explain why such measures would ruin them. It is instructive to analyse what actually happened to industries in the past when such measures were introduced.

In California for example, motor vehicle manufacturers overestimated their compliance costs with new efficiency regulations by a factor of between two and ten times. Regulators also overestimated compliance costs, but only by a factor of around one to two times. The main reason for these overestimates was unanticipated technological innovation which lowered compliance costs.[171]

While fighting the introduction of a new law, companies have every inventive to overstate the compliance costs. Once a new law is introduced resources are at least partially switched to innovating to minimize compliance costs.

21.5 Current markets and industrial structures are distorted by two centuries of misleading price signals

Some policymakers and elected officials are concerned that measures to address climate change could be ‘market distorting’ and therefore ‘inefficient’. This perspective needs to be challenged because it rests on an unspoken assumption that the current market environment is efficient. In fact, the entire problem of anthropogenic climate change has been caused by the most colossal market failure in history – the failure of prices to reflect the true costs of emissions for the last 200 years. Our markets and our entire industrial structure are currently distorted by this long-term market failure and also by explicit subsidies to emission-intensive fuels and industries.[172]

Markets do not exist in a vacuum. They rest on complex legal foundations that include standards, regulations, contract and employment law, human rights law, dispute resolution mechanisms and so on.[173] Real-world markets are also characterized by imperfect information and information asymmetries, principal-agent problems (eg. lack of incentives for landlords to improve energy efficiency for tenants), imperfect credit and risk markets, coordination failures, rent-seeking by firms, rapidly evolving technologies, and natural monopolies (such as rail or fibre-optic network infrastructure).

Today, new low-carbon industries are trying to establish themselves and compete with established emissions-intensive industries on a playing field that is severely distorted in favour of heavy emitters. It is entirely appropriate that a raft of policy measures be used to

[171] Hwang & Peak (2006).
[172] Riedy & Diesendorf (2003).
[173] For an early discussion see Commons (1924).

correct this distortion. Such measures should include market measures such as emissions trading, but in the context of a highly distorted market, policymakers should not assume that others measures are ‘market distorting’ or ‘sub-market’.

Measures such as higher efficiency standards, subsidies for low-emissions renewable technologies, public investment in network infrastructure and so on would, in fact, make the market more efficient by enabling the price signals it sends to better reflect the true costs of emissions.

Current markets and industrial structures are highly distorted by the pervasive externality of the historic failure of prices to reflect the true costs of emissions. Correction of these distortions through a combination of market-measures, regulations, subsidies and standards should not be viewed as ‘market-distorting’ but ‘market correcting’, ensuring that prices better reflect the true costs of emissions.

As the true costs of greenhouse gas emissions come to be better reflected in prices, and as energy efficiency standards are tightened we see the emergence of a clean industrial revolution with thousands of new jobs being created. Many of these are labour-intensive, blue collar jobs – both in rural and urban areas: building new distributed renewable energy systems and smart power grids, retrofitting buildings and homes, building new mass transit infrastructure, installing renewable energy systems at large and small scales, and so on.[174]

Conclusions

In June 2009 the US Government released a comprehensive assessment of the impacts of climate change on the United States.[175] The report was commissioned by the Bush administration and was produced by a consortium of 13 federal agencies, as well as experts from several universities and research institutes. In launching the report, one of the lead authors, Dr Jerry Melillo, warned:

> It is clear that climate change is happening now. The observed climate changes we report are not opinions to be debated. They are facts to be dealt with.[176]

Many who describe themselves as ‘skeptics’ however, continue to distort the public debate on climate change, portraying themselves as a courageous band of level-headed rebels struggling against a vast global conspiracy to deceive the world and take away our freedom. If only it were true. If any one of them had been able to offer convincing evidence that anthropogenic greenhouse emissions were not contributing to climate change they would have received the Nobel Prize instead of the IPCC, along with the thanks of a grateful world.

Instead, those who contest the link between anthropogenic emissions and climate change tend to concentrate on CO_2, ignoring the other very potent greenhouse gases human beings have released. They also, bizarrely, frequently attribute this fixation to climate scientists, accusing

[174] For more on the clean industrial revolution strong jobs growth that action on climate change could induce, see: ACTU & ACF (2008); UNEP (2009); UNEP *et al.* (2008); Friedman (2008), pp. 211-291; Jones (2008); Teske & Vincent (2008); McKinsey & Company (2008, 2009); McNeil (2009) and The Pew Charitable Trusts, (2009).
[175] See: Karl *et al.* (2009) and: http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts
[176] Quoted at http://www.abc.net.au/news/stories/2009/06/17/2600335.htm

them of focusing solely on CO_2 and ignoring factors such as water vapour. Even a cursory examination of the IPCC's *Fourth Assessment Report* shows this to be nonsense. They also tend to make a great deal of minor discrepancies in atmospheric temperature data and year-to-year fluctuations, largely ignoring the huge body of other evidence for climate change and its impacts such as:

- The widespread melting of glaciers[177]
- The accelerated melting of the Greenland ice sheet[178]
- Unexpectedly rapid sea-level rise[179]
- Tens of thousands of observed changes in species ranges and timing of annual ecosystem events[180]
- Rapid Arctic ice melting, well ahead of expectations[181]
- The warming of the oceans[182]
- The acidification of the oceans due to CO_2 absorption[183]
- The spread of oxygen-starved dead zones in the oceans[184]
- Changing hydrological and rainfall patterns with more extreme rainfall events[185]
- Changes in the height of the tropopause, the boundary between the troposphere and stratosphere[186]
- The cooling of the stratosphere due to more heat being trapped in the troposphere below[187]
- The expansion of the Earth's tropical belt, and consequent movement of the subtropical dry zones and jet-streams towards the poles[188]
- The greater intensity of cyclones[189]
- Influence of CO_2 levels on past climate changes[190]

---

[177] Cook *et al.* (2005); Ding *et al.* (2006); Hock *et al.* (2009); Holland *et al.* (2008); Howat *et al.* (2008); Kehrwald et al. (2008); Meier *et al.* (2007) ; Soruco et al. (2009); Pritchard & Vaughan (2007); Thompson *et al.* (2006); UNEP & WGMS (2008); WWF Nepal Program (2005); Yao *et al.* (2007a); Yao *et al.* (2007b).
[178] Chen *et al.* (2006); Zwally *et al.* (2002).
[179] Rahmstorf *et al.* (2007); Church & White (2006); Church *et al.* (2008).
[180] Rosenzweig *et al.* (2008); Menzel *et al.* (2006); Parmesan & Yohe (2003).
[181] Stroeve *et al.* (2007); Wang & Overland (2009).
[182] Barnett *et al.* (2005b); Domingues *et al.* (2008); Levitus *et al.* (2005); Levitus *et al.* (2009).
[183] Hoegh-Guldberg *et al.* (2007); Hofmann & Schellnhuber (2009) ; McNeil & Matear (2008) ; Orr *et al.* (2005); Riebesell (2008); Silverman *et al.* (2009); Zeebe *et al.* (2008).
[184] Diaz & Rosenberg (2008); Hofmann & Schellnhuber (2009); Huey & Ward (2005); Kiehl & Shields (2005); Meyer & Kump (2008). Shaffer et al. (2009)
[185] Barnett *et al.* (2008); Quetelard *et al.* (2009) ; Rajeevan *et al.* (2008); Zhang *et al.* (2007).
[186] Santer *et al.* (2003).
[187] Ramaswamy *et al.* (2006)
[188] Seidel *et al.* (2008); Johansen & Fu (2009).
[189] Elsner *et al.* (2008); Emanuel (2005a,b); Lin *et al.* (2009); Webster *et al.* (2005); Yu & Wang (2009).
[190] Came *et al.* (2007); DeConto & Pollard (2003); Fletcher *et al.* (2008); Glickson (2008); Lunt (2008); Royer (2006); Royer *et al.* (2004); Royer *et al.* (2007).

Those opposed to strong emissions reductions also seem remarkably cavalier about the possibilities of long-term consequences, many of which are irreversible, including:

- Sudden shifts in the climate system[191]
- Dramatic oscillations in the climate system[192]
- A decline in the effectiveness of natural CO_2 sinks, accelerating atmospheric CO_2 accumulation[193]
- A reinforcement of human-induced emissions by carbon-cycle feedbacks[194]
- The potential for large releases of CO_2 and methane from melting permafrost and marine deposits[195]
- Multi-metre sea-level rises as warming continues after 2100[196]
- The high probability that warming induced by our emissions would last for many thousands of years[197]
- The likelihood of significantly greater insect predation on forests and food supplies[198]
- The likely expansion of the world's deserts[199]
- Threats to global food security[200]
- Threats to global freshwater supplies[201]
- Threats to human health[202]
- Species extinctions and threats to biodiversity[203]

---

[191] Alley *et al.* (2003); Alley (2004); Bamber *et al.* (2007); Kobashi *et al*. (2008); Lenton *et al*. (2008); MacCracken *et al.* (2008); Narisma *et al.* (2007); Pearce (2007); Steffensen *et al.* (2008); Thompson *et al.* (2006).
[192] Meissner *et al.* (2008); Taylor *et al.* (1993).
[193] Arnone *et al.* (2008); Baker (2007); Baldocchi (2005); Ciais et al. (2005); Le Quéré *et al.* (2007, 2008); Canadell *et al.* (2007a); Canadell *et al.* (2007b); Frieldlingstein *et al.* (2006); Lenton *et al.* (2009); Sitch *et al.* (2008).
[194] Cox *et al.* (2000); Friedlingstein *et al.* (2006); Jones *et al.* (2003); Matthews & Keith (2007); O'ishi *et al.* (2009); Torn & Harte (2006).
[195] Archer (2007, 2009), Archer *et al.* (2008); Khvorostyanov *et al*. (2008); Reagan & Moridis (2007); Schuur *et al.* (2008); Schuur *et al.* (2009); Solomon *et al.* (2009) ; Tarnocai *et al.* (2009); Walter *et al.* (2006); Walter *et al.* (2007a); Walter *et al.* (2007b) ; Westbrook *et al.* (2009).
[196] Bamber *et al.* (2007); Bamber *et al.* (2009); Charbit *et al.* (2008); Pollard & DeConto (2009); Rignot & Jacobs (2002); Rohling *et al.* (2008); Rohling *et al.* (2009).
[197] Archer *et al.* (2008); Archer & Brovkin (2008); Doney & Schimel (2007); Eby *et al.* (2009); Lowe *et al.* (2009); Montenegro *et al.* (2007); Plattner (2009); Solomon *et al.* (2009).
[198] Kurz *et al.* (2008), Currano *et al.* (2008); DeLucia *et al.* (2008).
[199] Zeng & Yoon (2009).
[200] Battisti & Naylor (2009); Brown & Funk (2008); Challinor *et al.* (2007); Funk *et al.* (2008); Lobell & Field (2007); Parris (2008); Parry *et al.* (2004); Schlenker & Roberts (2009); Schmidhuber & Tubiello (2007).
[201] Barnett *et al.* (2005a) ; Barnett *et al.* (2008); Kehrwald et al. (2008); Levi (2008); Overpeck & Cole (2007); Qiu (2008); Rosenzweig *et al.* (2004); Singh & Bengtsson (2004).
[202] Alsop (2007); Bunyavanich *et al.* (2003); Costello *et al.* (2009); Epstein & Miles (2005); Haines *et al.* (2006); Luber & McGeehin (2008); McMichael *et al.* (2004); McMichael *et al.* (2006); Patz *et al.* (2005); Patz *et al.* (2007); VicHealth (2009).
[203] Chivian & Bernstein (2008); Colwell *et al.* (2008); Huey & Ward (2005); Kiehl & Shields (2005); Lovejoy (2009); Meyer & Kump (2008); Møller *et al.* (2008); Pennisi (2008); Thomas *et al.* (2004); Vaquer-Sunyer & Duarte (2008).

- The commitment of ecosystems to further deterioration, such as the dieback of the Amazon, for decades after temperatures are stabilised[204]
- A significant, potentially permanent, deterioration in international security and the emergence of major conflicts[205]
- A legacy that could amount to the greatest wholesale violation of the rights of children in human history.[206]

In their book *Poles Apart: Beyond the Shouting, Who's Right About Climate Change*, authors Gareth Morgan and John McCrystal set out to weigh the evidence on human contributions to climate change. Trying to be as fair as possible to different views, they engaged two separate panels of expert advisers, one representing mainstream climate scientists, and the other the skeptics, to guide them through the best evidence on both sides. Their conclusion, though polite, was damning:

> The Alarmists were right, and we shouldn't call them alarmists any more – or at least not all of them! And further, it has to be said that only a few of the Sceptics are actually sceptics: too many are mere gadflies and deniers.[207]

Perhaps the most forceful recent condemnation of those who continue to deny that greenhouse gas emissions from human activities are contributing to climate change came from the winner of the 2008 Nobel Prize in economics, Professor Paul Krugman. Writing after the vote on the Waxman-Markey climate change bill in the US Congress, Krugman considered the implications of unmitigated climate change for the US economy and for future generations. He concluded that continued denial of the link between anthropogenic greenhouse gases and climate change, with the aim of thwarting action to reduce emissions, was a form of treason:

> So the House passed the Waxman-Markey climate-change bill. In political terms, it was a remarkable achievement. But 212 representatives voted no. A handful of these no votes came from representatives who considered the bill too weak, but most rejected the bill because they rejected the whole notion that we have to do something about greenhouse gases. And as I watched the deniers make their arguments, I couldn't help thinking that I was watching a form of treason – treason against the planet. To fully appreciate the irresponsibility and immorality of climate-change denial, you need to know about the grim turn taken by the latest climate research. The fact is that the planet is changing faster than even pessimists expected: ice caps are shrinking, arid zones spreading, at a terrifying rate. And according to a number of recent studies, catastrophe – a rise in temperature so large as to be almost unthinkable – can no longer be considered a mere possibility. It is, instead, the most likely outcome if we continue along our present course. …
>
> … if you watched the debate on Friday, you didn't see people who've thought hard about a crucial issue, and are trying to do the right thing. What you saw, instead, were people who show no sign of being interested in the truth. They don't like the political and policy implications of climate change, so they've decided not to believe in it – and they'll grab any argument, no matter how disreputable, that feeds their denial. …

[204] Jones *et al.* (2009).
[205] Busby (2007); Campbell *et al.* (2007); Campbell (2008); Chellaney (2007a, b); Dupont (2008); Pai (2008); Reuveny (2007); Schubert *et al.* (2008); Wallace (2009).
[206] Save the Children (2007, 2008); UNICEF (2007, 2008), UNICEF UK (2008).
[207] Morgan & McCrystal (2009), p. 248.

> … Still, is it fair to call climate denial a form of treason? Isn't it politics as usual? Yes, it is – and that's why it's unforgivable. … the existential threat from climate change is all too real. Yet the deniers are choosing, willfully, to ignore that threat, placing future generations of Americans in grave danger, simply because it's in their political interest to pretend that there's nothing to worry about. If that's not betrayal, I don't know what is.[208]

Strong language indeed. But when we consider, as Krugman does, the fact that the most recent scientific projections are considerably more dire than even a few years ago, strong language is justified. The team at the Massachusetts Institute of Technology for example, recently undertook a comprehensive reassessment of the likely outcomes if we do not act decisively to rein in emissions. In 2003 they had concluded that the median likely outcome (with 50% of projections above and below the median) was 2.4°C of warming above 1990 levels, or 2.9°C above pre-industrial levels.[209] In their recent reassessment, based on a significantly improved model and improved input parameters, they increased this median projection to 5.2°C, with a 90% probability range of 3.5°C to 7.4°C above 1990 levels, or equivalently a 5.7°C median with a 90% range of 4.0°C to 7.9°C above pre-industrial levels.[210] The word 'disaster' hardly begins to capture the consequences of warming anywhere close to 5.7°C above pre-industrial levels, let alone 7.9°C.

Science is driven by genuine inquiry and genuine skepticism. But continued denial of overwhelming evidence from multiple sources is not genuine skepticism. Denial is understandable from a psychological point of view – no-one wants the projections of severe climate change to be true. But dressing up denial in scientific obfuscation does not contribute constructively to the public policy debate. Like those who continued to deny the links between smoking and cancer and between HIV and AIDS long after the evidence was in, those continuing to deny the links between greenhouse gas emissions and climate change are using specious arguments that have been repeatedly shown to be false, weak or irrelevant in the peer-reviewed scientific literature in order to try to thwart action. Those earlier cases of denial were serious enough. But when we consider what now is at stake for our societies, for the poor, for our children, for the other species on our planet, and for future generations, strong language is not inappropriate. It is time to listen to the warnings of the scientists and to pull together to prevent a catastrophe unparalleled in human history.

[208] Krugman (2009).
[209] Webster *et al.* (2003).
[210] Sokolov *et al.* (2009). For a report on the study, see Chandler (2009).

Acknowledgments

I am grateful to Roger Jones, John Finnigan, Christian Jakob, Neville Nichols, Kamal Siddiqui, Brett Inder, Will Steffen, Jeff McLean, Ed Lockhart, Simon Angus, Behrooz Hassani-M., Dave Batten, Simon Angus, Roger Bradbury, Anne-Marie Grisogono, Rachel Coghlan, Gerard Finnigan, Bill Pheasant, Melanie Gow, Paul Ronalds, Tim Costello and David Lansley for useful discussions and particularly to Barry Brook, Andrew Glickson, Dave Griggs, Greame Pearman, Tony Kevin, Mike Raupach, Beth Fulton, Michael Ashley, Chris Shore and Julie Tanaka for comments on an earlier draft. None are responsible for the opinions expressed here, or for any remaining errors.

Author Note

Dr Brett Parris is the Chief Economist for World Vision Australia where he also co-manages World Vision's Economics, Climate and Natural Resources team. He is also a Research Fellow at Monash University in the Department of Econometrics and Business Statistics. He has a BSc in geology and chemistry, an MA in development studies and a PhD in economics. His PhD focused on the application of complex systems science perspectives to economics, and the evaluation of different approaches to modeling economic development policy. His work currently focuses on the interactions between economic development, poverty, climate change, energy and conflict. For more information see:
http://www-personal.buseco.monash.edu.au/~BParris/

References

AchutaRao, K.M., Ishii, N., Santer, B.D., Gleckler, P.J., Taylor, A.M., Barnett, T.P., Pierce, D.W., Stouffer, R.J. and Wigley, T.M.L., (2007) "Simulated and Observed Variability in Ocean Temperature and Heat Content", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 104, No. 26, 26 June, pp. 10768-10773. http://www.pnas.org/content/104/26/10768.full.pdf+html

Ackerman, F., (2008) *Can We Afford the Future? The Economics of a Warming World*, The New Economics Series; Zed Books, London & New York, viii +151 pp.

ACTU and ACF, (2008) "Green Gold Rush: How Ambitious Environmental Policy Can Make Australia a Leader in the Global Race for Green Jobs", Melbourne, Australian Council of Trade Unions and Australian Conservation Foundation, October, 36 pp.
http://www.actu.asn.au/Media/Mediareleases/GreenGoldRushreportalmostamilliongreenjobsforAustraliaby2030.aspx

Allen, M.R., Gillett, N.P., Kettleborough, J.A., Hegerl, G., Schnur, R., Stott, P.A., Boer, G., Covey, C., Delworth, T.L., Jones, G.S., Mitchell, J.F.B. and Barnett, T.P., (2006) "Quantifying Anthropogenic Influence on Recent Near-Surface Temperature Change", *Surveys in Geophysics*, Vol. 27, No. 5, September, pp. 491-544. http://www.cccma.ec.gc.ca/papers/gboer/PDF/Allen_etal.pdf

Alley, R.B., (2000) "The Younger Dryas Cold Interval as Viewed from Central Greenland", *Quaternary Science Reviews*, Vol. 19, No. 1-5, January, pp. 213-226.

Alley, R.B., (2004) "Abrupt Climate Change", *Scientific American*, Vol. 291, No. 5, November, pp. 62-69. http://www.chicagocleanpower.org/alley.pdf

Alley, R.B., Clark, P.U., Huybrechts, P. and Joughin, I., (2005) "Ice-Sheet and Sea-Level Changes", *Science*, Vol. 310, No. 5747, 21 October, pp. 456–460.

Alley, R.B., Marotzke, J., Nordhaus, W.D., Overpeck, J.T., Peteet, D.M., Pielke, R.A., Jr. , Pierrehumbert, R.T., Rhines, P.B., Stocker, T.F., Talley, L.D. and Wallace, J.M., (2003) "Abrupt Climate Change", *Science*, Vol. 299, No. 5615, 28 March, pp. 2005-2010.

Alsop, Z., (2007) "Malaria Returns to Kenya's Highlands as Temperatures Rise", *The Lancet*, Vol. 370, No. 9591, 15 September, pp. 925-926.

Ammann, C.C., Joos, F., Schimel, D.S., Otto-Bliesner, B.L. and Tomas, R.A., (2007) "Solar Influence on Climate During the Past Millennium: Results from Transient Simulations with the NCAR Climate System Model", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 104, No. 10, 6 March, pp. 3713-3718. http://www.pnas.org/content/104/10/3713.abstract

Anthoff, D., Nicholls, R.J., Tol, R.S.J. and Vafeidis, A.T., (2006) "Global and Regional Exposure to Large Rises in Sea-Level: A Sensitivity Analysis", Working Paper 96, Norwich, Tyndall Centre for Climate Change Research, October, 29 pp. http://www.tyndall.ac.uk/publications/working_papers/twp96.pdf

Archer, D., (2007) "Methane Hydrate Stability and Anthropogenic Climate Change", *Biogeoscience*, Vol. 4, No. 4, 25 July, pp. 521-544. www.biogeosciences.net/4/521/2007/

Archer, D., (2009) *The Long Thaw: How Humans are Changing the Next 100,000 Years of Earth's Climate,* Princeton University Press, Princeton, NJ & Oxford, xi + 180 pp.

Archer, D. and Brovkin, V., (2008) "The Millennial Atmospheric Lifetime of Anthropogenic CO2", Climatic Change, Vol. 90, No. 3, October, pp. 283-297.

Archer, D., Buffett, B. and Brovkin, V., (2008) "Ocean Methane Hydrates as a Slow Tipping Point in the Global Carbon Cycle", *Proceedings of the National Academy of Sciences of the United States of America*, online before print 18 November, 6 pp.

Archer, D., Eby, M., Brovkin, V., Ridgwell, A., Cao, L., Mikolajewicz, U., Caldeira, K., Matsumoto, K., Munhoven, G., Montenegro, A. and Tokos, K., (2009) "Atmospheric Lifetime of Fossil Fuel Carbon Dioxide", *Annual Review of Earth and Planetary Sciences,* Vol. 37, May, pp. 117-134.

Arnone, J.A., III, Verburg, P.S.J., Johnson, D.W., Larsen, J.D., Jasoni, R.L., Lucchesi, A.J., Batts, C.M., von Nagy, C., Coulombe, W.G., Schorran, D.E., Buck, P.E., Braswell, B.H., Coleman, J.S., Sherry, R.A., Wallace, L.L., Luo, Y. and Schimel, D.S., (2008) "Prolonged Suppression of Ecosystem Carbon Dioxide Uptake after an Anomalously Warm Year", *Nature,* Vol. 455, No. 7211, 18 September, pp. 383-386.

Arrhenius, S., (1896) "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground", *Philosophical Magazine and Journal of Science, Series 5,* Vol. 41, No. 251, April, pp. 237-276.

Australian Government, (2008a) "Australia's Low Pollution Future: The Economics of Climate Change Mitigation", Canberra, Australian Government, October, xvi + 276 pp. http://www.treasury.gov.au/lowpollutionfuture/

Australian Government, (2008b) "Carbon Pollution Reduction Scheme: Australia's Low Pollution Future", White Paper, 2 vols; Canberra, Australian Government, December. http://www.climatechange.gov.au/whitepaper/index.html

Auyang, S.Y., (1998) *Foundations of Complex System Theories: In Economics, Evolutionary Biology and Statistical Physics,* Cambridge University Press, Cambridge, New York, Melbourne & Madrid, xii + 404 pp.

Baker, D.F., (2007) "Reassessing Carbon Sinks", *Science,* Vol. 316, No. 5832, 22 June, pp. 1708-1709.

Baldocchi, D., (2005) "The Carbon Cycle Under Stress", *Nature,* Vol. 437, No. 7058, 22 September, pp. 483-484.

Bamber, J.L., Alley, R.B. and Joughin, I., (2007) "Rapid Response of Modern Day Ice Sheets to External Forcing", *Earth and Planetary Science Letters,* Vol. 257, No. 1-2, 15 May, pp. 1-13.

Bamber, J.L., Riva, R.E.M., Vermeersen, B.L.A. and LeBrocq, A.M., (2009) "Reassessment of the Potential Sea-Level Rise from a Collapse of the West Antarctic Ice Sheet", *Science*, Vol. 324, No. 5929, 15 May, pp. 901-903.

Barnett, T.P., Adam, J.C. and Lettenmaier, D.P., (2005a) "Potential Impacts of a Warming Climate on Water Availability in Snow-Dominated Regions", *Nature*, Vol. 438, No. 7066, 17 November, pp. 303-309.

Barnett, T.P., Pierce, D.W., AchutaRao, K.M., Gleckler, P.J., Santer, B.D., Gregory, J.M. and Washington, W.M., (2005b) "Penetration of Human-Induced Warming into the World's Oceans", *Science*, Vol. 309, No. 5732, 8 July, pp. 284-287.

Barnett, T.P., Pierce, D.W., Hidalgo, H.G., Bonfils, C., Santer, B.D., Das, T., Bala, G., Wood, A.W., Nozawa, T., Mirin, A.A., Cayan, D.R. and Dettinger, M.D., (2008) "Human-Induced Changes in the Hydrology of the Western United States", *Science*, Vol. 319, No. 5866, 22 February, pp. 1080-1083. http://tenaya.ucsd.edu/~dettinge/barnett08.pdf

Battisti, D.S. and Naylor, R.L., (2009) "Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat", *Science*, Vol. 323, No. 5911, 9 January, pp. 240-244. http://iis-db.stanford.edu/pubs/22374/battisti_naylor_2009.pdf

Biello, D., (2007) "Conservative Climate", *Scientific American*, Vol. 296, No. 4, April, pp. 16-19. http://www.scientificamerican.com/article.cfm?id=conservative-climate

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. and Yanda, P., (2007) "Africa", In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.; Cambridge University Press, Cambridge & New York, pp. 433-467. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter9.pdf

Bradley, R.S., Hughes, M.K. and Diaz, H.F., (2003) "Climate in Medieval Time", *Science*, Vol. 302, No. 5644, 17 October, pp. 404-405. http://www.geo.umass.edu/faculty/bradley/bradley2003d.pdf

Brown, M.E. and Funk, C.C., (2008) "Food Security Under Climate Change", *Science*, Vol. 319, No. 5863, 1 February, pp. 580-581. http://www.verticalfarm.com/PDF/Science08Mar10.pdf

Brumfiel, G., (2006) "Academy Affirms Hockey-Stick Graph", *Nature*, Vol. 441, No. 7097, 29 June, pp. 1032-1033.

Bunyavanich, S., Landrigan, C.P., McMichael, A.J. and Epstein, P.R., (2003) "The Impact of Climate Change on Child Health", *Ambulatory Pediatrics*, Vol. 3, No. 1, January-February, pp. 44-52. http://chge.med.harvard.edu/publications/journals/documents/buny.pdf

Busby, J.W., (2007) "Climate Change and National Security: An Agenda for Action", Washington DC, Council on Foreign Relations, November, vii + 32 pp. http://www.ciaonet.org/pbei/cfr/0002812/index.html

Caillon, N., Severinghaus, J.P., Jouzel, J., Barnola, J.-M., Kang, J. and Lipenkov, V.Y., (2003) "Timing of Atmospheric CO_2 and Antarctic Temperature Changes Across Termination III", *Science*, Vol. 299, No. 5613, 14 March, pp. 1728-1731. http://icebubbles.ucsd.edu/Publications/CaillonTermIII.pdf

Callendar, G.S., (1938) "The Artificial Production of Carbon Dioxide and Its Influence on Temperature", *Quarterly Journal of the Royal Meteorological Society*, Vol. 64, No. 275, April, pp. 223-240. http://www.rmets.org/pdf/qjcallender38.pdf

Came, R.E., Eiler, J.M., Veizer, J., Azmy, K., Brand, U. and Weidman, C.R., (2007) "Coupling of Surface Temperatures and Atmospheric CO2 Concentrations During the Palaeozoic Era", *Nature*, Vol. 449, No. 7159, 13 September, pp. 198-201.

Campbell, K.M., Gulledge, J., McNeill, J.R., Podesta, J., Ogden, P., Fuerth, L., Woolsey, R.J., Lennon, A.T.J., Smith, J., Weitz, R. and Mix, D., (2007) *The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change*, Washington DC, Center for Strategic and International Studies &

Center for a New American Century, November, 119 pp.
http://www.csis.org/component/option,com_csis_pubs/task,view/id,4154/type,1/

Campbell, K.M. (Ed.) (2008) *Climatic Cataclysm: The Foreign Policy and National Security Implications of Climate Change*, Brookings Institution Press, Washington DC, viii + 237 pp.

Canadell, J.G., Le Quéré, C., Raupach, M.R., Field, C.B., Buitenhuis, E.T., Ciais, P., Conway, T.J., Gillett, N.P., Houghton, R.A. and Marland, G., (2007) "Contributions to Accelerating Atmospheric CO2 Growth from Economic Activity, Carbon Intensity, and Efficiency of Natural Sinks", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 104, No. 47, 20 November, pp. 18866-18870.
http://www.pnas.org/content/104/47/18866.abstract

Canadell, J.G., Pataki, D.E., Gifford, R., Houghton, R.A., Luo, Y., Raupach, M.R., Smith, P. and Steffen, W., (2007) "Saturation of the Terrestrial Carbon Sink", In *Terrestrial Ecosystems in a Changing World* ed. Canadell, J.G., Pataki, D.E. and Pitelka, L.; The IGBP Series; Springer-Verlag, Berlin & Heidelberg, pp. 59-78.
http://www.globalcarbonproject.org/global/pdf/Canadell.2007.SinkSaturation.Springer.pdf

Challinor, A., Wheeler, T., Garforth, C., Craufurd, P. and Kassam, A., (2007) "Assessing the Vulnerability of Food Crop Systems in Africa to Climate Change", *Climatic Change*, Vol. 83, No. 3, August, pp. 381-399.

Chandler, D., (2009) "Revised MIT Climate Model Sounds Alarm", *MIT Tech Talk*, Vol. 53, No. 26, 20 May, pp. 1 & 5. http://web.mit.edu/newsoffice/2009/techtalk53-26.pdf

Charbit, S., Paillard, D. and Ramstein, G., (2008) "Amount of CO_2 Emissions Irreversibly Leading to the Total Melting of Greenland", *Geophysical Research Letters*, Vol. 35, L12503, 26 June, 5 pp.

Chellaney, B., (2007a) "Climate Change: A New Factor in International Security?" Global Forces 2007, Proceedings of the ASPI Conference, Day 1, Australian Strategic Policy Institute, December, 20-36 pp.

Chellaney, B., (2007b) "Climate Change and Security in Southern Asia: Understanding the National Security Implications", *RUSI Journal*, Vol. 152, No. 2, April, pp. 62-69.

Chen, J.L., Wilson, C.R. and Tapley, B.D., (2006) "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet", *Science*, Vol. 313, No. 5795, 29 September, pp. 1958-1960.

Chivian, E. and Bernstein, A. (Eds.), (2008) *Sustaining Life: How Human Health Depends on Biodiversity*, Oxford University Press, Oxford & New York, 566 pp.

Church, J.A. and White, N.J., (2006) "A 20th Century Acceleration in Global Sea-Level Rise", *Geophysical Research Letters*, Vol. 33, L01602, 6 January, 4 pp.

Church, J.A., White, N.J., Aarup, T., Stanley Wilson, W., Woodworth, P.L., Domingues, C.M., Hunter, J.R. and Lambeck, K., (2008) "Understanding Global Sea Levels: Past, Present and Future", *Sustainability Science*, Vol. 3, No. 1, April, pp. 9-22.

Ciais, P., Reichstein, M., Viovy, N., Granier, A., Ogee, J., Allard, V., Aubinet, M., Buchmann, N., Bernhofer, C., Carrara, A., Chevallier, F., De Noblet, N., Friend, A.D., Friedlingstein, P., Grunwald, T., Heinesch, B., Keronen, P., Knohl, A., Krinner, G., Loustau, D., Manca, G., Matteucci, G., Miglietta, F., Ourcival, J.M., Papale, D., Pilegaard, K., Rambal, S., Seufert, G., Soussana, J.F., Sanz, M.J., Schulze, E.D., Vesala, T. and Valentini, R., (2005) "Europe-Wide Reduction in Primary Productivity Caused by the Heat and Drought in 2003", *Nature*, Vol. 437, No. 7058, 22 September, pp. 529-533.

Clough, S.A. and Iacono, M.J., (1995) "Line-by-line Calculation of Atmospheric Fluxes and Cooling Rates 2: Application to Carbon Dioxide, Ozone, Methane, Nitrous Oxide and the Halocarbons", *Journal of Geophysical Research*, Vol. 100, No. D8, pp. 16,519-16,535.

Colwell, R.K., Brehm, G., Cardelús, C.L., Gilman, A.C. and Longino, J.T., (2008) "Global Warming, Elevational Range Shifts, and Lowland Biotic Attrition in the Wet Tropics", *Science*, Vol. 322, No. 5899, 10 October, pp. 258-261.

Commons, J.R., (1924) *Legal Foundations of Capitalism,* Transaction Publishers reprint, 1995, New Brunswick, NJ; Originally published by Macmillan, xxxvi+394 pp.

Cook, A.J., Fox, A.J., Vaughan, D.G. and Ferrigno, J.G., (2005) "Retreating Glacier Fronts on the Antarctic Peninsula over the Past Half-Century", *Science,* Vol. 308, No. 5721, 22 April, pp. 541-544.

Costello, A., Abbas, M., Allen, A., Ball, S., Bell, S., Bellamy, R., Friel, S., Groce, N., Johnson, A., Kett, M., Lee, M., Levy, C., Maslin, M., McCoy, D., McGuire, B., Montgomery, H., Napier, D., Pagel, C., Patel, J., de Oliveira, J.A.P., Redclift, N., Rees, H., Rogger, D., Scott, J., Stephenson, J., Twigg, J., Wolff, J. and Patterson, C., (2009) "Managing the Health Effects of Climate Change: Lancet and University College London Institute for Global Health Commission", *The Lancet*, Vol. 373, No. 9676, 16 May, pp. 1693-1733.
http://www.ucl.ac.uk/global-health/ucl-lancet-climate-change.pdf

Cox, P.M., Betts, R.A., Jones, C.D., Spall, S.A. and Totterdell, I.J., (2000) "Acceleration of Global Warming Due to Carbon-Cycle Feedbacks in a Coupled Climate Model", *Nature,* Vol. 408, No. 6809, 9 November, pp. 184-187.

Crutchfield, J.P., Farmer, J.D., Packard, N.H. and Shaw, R.S., (1986) "Chaos", *Scientific American,* Vol. 255, No. 6, December, pp. 38-49.

Cruz, R.V., Harasawa, H., Lal, M., Wu, S., Anokhin, Y., Punsalmaa, B., Honda, Y., Jafari, M., Li, C. and Huu Ninh, N., (2007) "Asia", In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.; Cambridge University Press, Cambridge & New York, pp. 469-506.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-chapter10.pdf

Currano, E.D., Wilf, P., Wing, S.L., Labandeira, C.C., Lovelock, E.C. and Royer, D.L., (2008) "Sharply Increased Insect Herbivory During the Paleocene–Eocene Thermal Maximum", *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 105, No. 6, 12 February, pp. 1960-1964.

DeCanio, S.J., (2003) *Economic Models of Climate Change: A Critique,* Palgrave Macmillan, New York & Houndmills, Basingstoke, UK, xiii + 203 pp.

DeConto, R.M. and Pollard, D., (2003) "Rapid Cenozoic Glaciation of Antarctica Induced by Declining Atmospheric CO_2", *Nature,* Vol. 421, No. 6920, 16 January, pp. 245-249.

DeLucia, E.H., Casteel, C.L., Nabity, P.D. and O'Neill, B.F., (2008) "Insects Take a Bigger Bite out of Plants in a Warmer, Higher Carbon Dioxide World", *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 105, No. 6, 12 February, pp. 1781-1782.

Diaz, R.J. and Rosenberg, R., (2008) "Spreading Dead Zones and Consequences for Marine Ecosystems", *Science,* Vol. 321, No. 5891, 15 August, pp. 926-929.
http://www.precaution.org/lib/marine_dead_zones_growing.080815.pdf

Dickinson, R.E. and Cicerone, R.J., (1986) "Future Global Warming from Atmospheric Trace Gases", *Nature,* Vol. 319, No. 6049, 9 January, pp. 109-115.

Ding, Y., Liu, S., Li, J. and Shangguan, D., (2006) "The Retreat of Glaciers in Response to Recent Climate Warming in Western China", *Annals of Glaciology,* Vol. 43, No. 1, September, pp. 97-105.

Domingues, C.M., Church, J.A., White, N.J., Gleckler, P.J., Wijffels, S.E., Barker, P.M. and Dunn, J.R., (2008) "Improved Estimates of Upper-Ocean Warming and Multi-Decadal Sea-Level Rise", *Nature,* Vol. 453, No. 7198, 19 June, pp. 1090-1093.

Doney, S.C. and Schimel, D.S., (2007) "Carbon and Climate System Coupling on Timescales from the Precambrian to the Anthropocene", *Annual Review of Environment and Resources*, Vol. 32, November, pp. 31-66. https://darchive.mblwhoilibrary.org/bitstream/1912/1942/1/doney_schimel_arer_revised_final.pdf

Donner, L. and Ramanathan, V., (1980) "Methane and Nitrous Oxide: Their Effects on the Terrestrial Climate", *Journal of the Atmospheric Sciences*, Vol. 37, No. 1, January, pp. 119-124.

Doran, P.T. and Zimmerman, M.K., (2009) "Examining the Scientific Consensus on Climate Change", *EOS: Transactions of the American Geophysical Union*, Vol. 90, No. 3, 20 January, pp. 22-23. http://tigger.uic.edu/~pdoran/012009_Doran_final.pdf

Douglass, D.H., Christy, J.R., Pearson, B.D. and Singer, S.F., (2007) "A Comparison of Tropical Temperature Trends with Model Predictions", *International Journal of Climatology*, Vol. 28, No. 13, 15 November, pp. 1693-1701.

Duffy, P.B., Santer, B.D. and Wigley, T.M.L., (2009) "Solar Variability Does Not Explain Late-Twentieth-Century Warming", *Physics Today*, Vol. 62, No. 1, January, pp. 48-49. http://www.clas.ufl.edu/users/prwaylen/GEO2200ARTICLES/Part1/Solar%20variability%20in%20late%2020th%20century.pdf

Dupont, A., (2008) "The Strategic Implications of Climate Change", *Survival*, Vol. 50, No. 3, June - July, pp. 29-54.

Dyer, G., (2008) *Climate Wars*, Scribe, Melbourne, xiv + 256 pp.

Easterling, D.R. and Wehner, M.F., (2009) "Is the Climate Warming or Cooling?" *Geophysical Research Letters*, Vol. 36, No. 8, L08706, 25 April, 3 pp.

Eby, M., Zickfeld, K., Montenegro, A., Archer, D., Meissner, K.J. and Weaver, A.J., (2009) "Lifetime of Anthropogenic Climate Change: Millennial Time Scales of Potential CO_2 and Surface Temperature Perturbations", *Journal of Climate*, Vol. 22, No. 10, May, pp. 2501-2511.

Ellingson, R.G. and Gille, J.C., (1978) "An Infrared Radiative Transfer Model. Part 1: Model Description and Comparison of Observations with Calculations", *Journal of the Atmospheric Sciences*, Vol. 35, No. 3, March, pp. 523-545.

Elsner, J.B., Kossin, J.P. and Jagger, T.H., (2008) "The Increasing Intensity of the Strongest Tropical Cyclones", *Nature*, Vol. 455, No. 7209, 4 September, pp. 92-95.

Emanuel, K., (2005a) "Increasing Destructiveness of Tropical Cyclones over the Past 30 Years", *Nature*, Vol. 436, No. 7051, 4 August, pp. 686-688.

Emanuel, K., (2005b) "Emanuel Replies", *Nature*, Vol. 438, No. 7071, 22 December, pp. E13.

Enting, I.G., (2007) *Twisted: The Distorted Mathematics of Greenhouse Denial*, Australian Mathematical Sciences Institute, Melbourne, iv + 152 pp.

Epstein, P.R. and Mills, E., (2005) *Climate Change Futures: Health, Ecological and Economic Dimensions*, Center for Health and the Global Environment & Harvard Medical School, Boston, MA, 138 pp. http://www.climatechangefutures.org/report/index.html

Fletcher, B.J., Brentnall, S.J., Anderson, C.W., Berner, R.A. and Beerling, D.J., (2008) "Atmospheric Carbon Dioxide Linked with Mesozoic and Early Cenozoic Climate Change", *Nature Geoscience*, Vol. 1, No. 1, January, pp. 43-48.

Forster, P., Ramaswamy, V., Artaxo, P., Berntsen, T., Betts, R., Fahey, D.W., Haywood, J., Lean, J., Lowe, D.C., Myhre, G., Nganga, J., Prinn, R., Raga, G., Schulz, M. and Van Dorland, R., (2007) "Changes in Atmospheric Constituents and in Radiative Forcing", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 129-234. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf

Foukal, P., Fröhlich, C., Spruit, H. and Wigley, T.M.L., (2006) "Variations in Solar Luminosity and their Effect on the Earth's Climate", *Nature*, Vol. 443, No. 7108, 14 September, pp. 161-166.

Friedlingstein, P., Cox, P., Betts, R., Bopp, L., von Bloh, W., Brovkin, V., Cadule, P., Doney, S., Eby, M., Fung, I., Bala, G., John, J., Jones, C., Joos, F., Kato, T., Kawamiya, M., Knorr, W., Lindsay, K., Matthews, H.D., Raddatz, T., Rayner, P., Reick, C., Roeckner, E., Schnitzler, K.-G., Schnur, R., Strassmann, K., Weaver, A.J., Yoshikawa, C. and Zeng, N., (2006) "Climate-Carbon Cycle Feedback Analysis: Results from the C4MIP Model Intercomparison", *Journal of Climate*, Vol. 19, No. 14, July, pp. 3337-3353.

Friedman, T.L., (2008) *Hot, Flat, and Crowded: Why the World Needs a Green Revolution - and How We Can Renew our Global Future*, Allen Lane - Penguin Group, New York, London & Melbourne, 438 pp.
Fritz, H.M., Blount, C., Thwin, S., Thu, M. and Chan, N., (2008a) "Cyclone Nargis Surge in Myanmar Compared with Hurricane Katrina", Presentation at Pointe-a-Pitre, Guadeloupe, 10 December 2008, pp. http://lpat-geol.univ-ag.fr/serveur/tsunami/Carib_Waves_2008/Presentations/Guadeloupe_Nargis_Fritz.pdf

Fritz, H.M., Blount, C., Sokoloski, R., Singleton, J., Fuggle, A., McAdoo, B.G., Moore, A., Grass, C. and Tate, B., (2008b) "Hurricane Katrina Storm Surge Reconnaissance", *Journal of Geotechnical and Geoenvironmental Engineering*, Vol. 134, No. 5, May, pp. 644-656.
http://www.gtsav.gatech.edu/cee/groups/katrina/publications/2008_katrina.pdf

Fritz, H.M., Blount, C.D., Thwin, S., Thu, M.K. and Chan, N., (2009) "Cyclone Nargis Storm Surge in Myanmar", *Nature Geoscience*, Vol. 2, No. 7, July, pp. 448-449.

Funk, C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M. and Hoell, A., (2008) "Warming of the Indian Ocean Threatens Eastern and Southern African Food Security but Could be Mitigated by Agricultural Development", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 32, 12 August, pp. 11081-11086.

Garnaut, R., (2008) *The Garnaut Climate Change Review: Final Report*, Cambridge University Press, Melbourne, xlv + 616 pp. http://www.garnautreview.org.au/

Gillett, N.P., Stone, D.A., Stott, P.A., Nozawa, T., Karpechko, A.Y., Hegerl, G.C., Wehner, M.F. and Jones, P.D., (2008) "Attribution of Polar Warming to Human Influence", *Nature Geoscience*, Vol. 1, No. 11, November, pp. 750-754.

Glickson, A.Y., (2008) "Milestones in the Evolution of the Atmosphere with Reference to Climate Change", *Australian Journal of Earth Sciences*, Vol. 55, No. 2, pp. 125-139.

Gryvnak, D.A., Burch, D.E., Alt, R.L. and Zgonc, D.K., (1976) *Infrared Absorption by CH_4, H_2O, and CO_2*, AFGL-TR-76-0246, Air Force Geophysics Laboratory, Hanscom Air Force Base, Bedford, MA, December, 84 pp. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA039380&Location=U2&doc=GetTRDoc.pdf

Haines, A., Kovats, R.S., Campbell-Lendrum, D. and Corvalan, C., (2006) "Climate Change and Human Health: Impacts, Vulnerability, and Mitigation", *The Lancet*, Vol. 367, No. 9528, 24 June, pp. 2101-2109.

Hall, D.C. and Behl, R.J., (2006) "Integrating Economic Analysis and the Science of Climate Instability", *Ecological Economics*, Vol. 57, No. 3, 25 May, pp. 442-465.
http://www.csulb.edu/~dhall/Hall%20and%20Behl,%20Integrating%20economic%20analysis%20and%20the%20science%20of%20climate%20instability,%20Ecol%20Econ.pdf

Hansen, J.E., Johnson, D., Lacis, A., Lebedeff, S., Lee, P., Rind, D. and Russell, G., (1981) "Climate Impact of Increasing Atmospheric Carbon Dioxide", *Science*, Vol. 213, No. 4511, 28 August, pp. 957-966.
http://www.atmos.washington.edu/~davidc/ATMS211/articles_optional/Hansen81_CO2_Impact.pdf

Hansen, J.E., Sato, M., Kharecha, P., Russell, G., Lea, D.W. and Siddall, M., (2007) "Climate Change and Trace Gases", *Philosophical Transactions of the Royal Society A*, Vol. 365, No. 1865, 15 July, pp. 1925-1954.

Hansen, J.E., Sato, M., Kharecha, P., Beerling, D., Berner, R., Masson-Delmotte, V., Pagani, M., Raymo, M., Royer, D.L. and Zachos, J.C., (2008) "Target Atmospheric CO_2: Where Should Humanity Aim?" *Open Atmospheric Science Journal*, Vol. 2, pp. 217-231. http://www.bentham.org/open/toascj/openaccess2.htm

Hansen, J.E., Sato, M., Ruedy, R., Lo, K., Lea, D.W. and Medina-Elizade, M., (2006) "Global Temperature Change", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 103, No. 39, 26 September, pp. 14288-14293. http://www.pnas.org/content/103/39/14288.full

Hansen, J.E., Wang, W.-C. and Lacis, A.A., (1978) "Mount Agung Eruption Provides Test of a Global Climatic Perturbation", *Science*, Vol. 199, No. 4333, 10 March, pp. 1065-1068.

Hock, R., de Woul, M., Radic, V. and Dyurgerov, M., (2009) "Mountain Glaciers and Ice Caps around Antarctica make a Large Sea-Level Rise Contribution", *Geophysical Research Letters*, Vol. 36, No. 7, L07501, 2 April, 5 pp. http://www.agu.org/pubs/crossref/2009/2008GL037020.shtml

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A. and Hatziolos, M.E., (2007) "Coral Reefs Under Rapid Climate Change and Ocean Acidification", *Science*, Vol. 318, No. 5857, 14 December, pp. 1737-1742.

Hofmann, M. and Schellnhuber, H.-J., (2009) "Oceanic Acidification Affects Marine Carbon Pump and Triggers Extended Marine Oxygen Holes", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 106, No. 9, 3 March, pp. 3017-3022.

Holland, D.M., Thomas, R.H., de Young, B., Ribergaard, M.H. and Lyberth, B., (2008) "Acceleration of Jakobshavn Isbrae Triggered by Warm Subsurface Ocean Waters", *Nature Geoscience*, Vol. 1, No. 10, October, pp. 659-664.

Howat, I.M., Smith, B.E., Joughin, I. and Scambos, T.A., (2008) "Rates of Southeast Greenland Ice Volume Loss from Combined ICESat and ASTER Observations", *Geophysical Research Letters*, Vol. 35, L17505, 9 September, 5 pp.

Huey, R.B. and Ward, P.D., (2005) "Hypoxia, Global Warming, and Terrestrial Late Permian Extinctions", *Science*, Vol. 308, No. 5720, 15 April, pp. 398-401.

Hwang, R. and Peak, M., (2006) "Innovation and Regulation in the Automobile Sector: Lessons Learned and Implications for California's CO_2 Standards", April, 17 pp. http://docs.nrdc.org/air/files/air_08030301A.pdf

IPCC, (2007a) "Summary for Policymakers", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 1-17. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf

IPCC, (2007b) "Summary for Policymakers", In *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E.; Cambridge University Press, Cambridge & New York, pp. 7-22. http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4-wg2-spm.pdf

IPCC, (2007c) "Summary for Policymakers", In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A.; Cambridge University Press, Cambridge & New York, pp. 1-23. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-spm.pdf

IPCC, (2007d) *Climate Change 2007: Synthesis Report: Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.); IPCC, Geneva, 104 pp. http://www.ipcc.ch/ipccreports/ar4-syr.htm

Jansen, E., Overpeck, J., Briffa, K.R., Duplessy, J.-C., Joos, F., Masson-Delmotte, V., Olago, D., Otto-Bliesner, B., Peltier, W.R., Rahmstorf, S., Ramesh, R., Raynaud, D., Rind, D., Solomina, O., Villalba, R. and Zhang, D.e., (2007) "Paleoclimate", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 433-497. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter6.pdf

Johanson, C.M. and Fu, Q., (2009) "Hadley Cell Widening: Model Simulations versus Observations", *Journal of Climate*, Vol. 22, No. 10, 15 May, pp. 2713-2725. http://www.atmos.washington.edu/~qfu/Publications/jc.johanson.2009.pdf

Joint Science Academies, (2001) "The Science of Climate Change", A joint statement issued by the Australian Academy of Sciences, Royal Flemish Academy of Belgium for Sciences and the Arts, Brazilian Academy of Sciences, Royal Society of Canada, Caribbean Academy of Sciences, Chinese Academy of Sciences, French Academy of Sciences, German Academy of Natural Scientists Leopoldina, Indian National Science Academy, Indonesian Academy of Sciences, Royal Irish Academy, Accademia Nazionale dei Lincei (Italy), Academy of Sciences Malaysia, Academy Council of the Royal Society of New Zealand, Royal Swedish Academy of Sciences, and Royal Society (UK), 17 May, 2 pp. http://royalsociety.org/displaypagedoc.asp?id=13619

Joint Science Academies, (2005) "Joint Science Academies' Statement: Global Response to Climate Change", Joint statement released by the National Academies of Science of the G8 Countries plus China, India and Brazil, 7 June, 2 pp. http://www.royalsoc.ac.uk/document.asp?latest=1&id=3222

Joint Science Academies, (2007) "Joint Science Academies' Statement on Growth and Responsibility: Sustainability, Energy Efficiency and Climate Protection", Joint statement released by the National Academies of Science of the G8 Countries plus Brazil, China, India, Mexico and South Africa, 2 pp. http://www.nationalacademies.org/includes/G8Statement_Energy_07_May.pdf

Joint Science Academies, (2008) "Joint Science Academies' Statement: Climate Change Adaptation and the Transition to a Low Carbon Society", Joint statement released by the National Academies of Science of the G8 Countries plus Brazil, China, India, Mexico and South Africa, 2 pp. http://royalsociety.org/document.asp?tip=0&id=7821

Jones, C.D., Cox, P.M., Essery, R.L.H., Roberts, D.L. and Woodage, M.J., (2003) "Strong Carbon Cycle Feedbacks in a Climate Model with Interactive CO_2 and Sulphate Aerosols", *Geophysical Research Letters*, Vol. 30, No. 9, 1479, 9 May, 4 pp.

Jones, C., Lowe, J., Liddicoat, S. and Betts, R., (2009) "Committed Terrestrial Ecosystem Changes due to Climate Change", *Nature Geoscience*, Vol. 2, No. 7, July, pp. 484-487.

Jones, V., (2008) *The Green Collar Economy: How One Solution Can Fix Our Two Biggest Problems*, HarperOne, New York, 256 pp.

Jungclaus, J.H., (2009) "Lessons from the Past Millennium", *Nature Geoscience*, Vol. 2, No. 7, July, pp. 468-470. http://www.nature.com/ngeo/journal/v2/n7/abs/ngeo559.html

Karl, T.R., Melillo, J.M. and Peterson, T.C. (Eds.), (2009) *Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program*, Cambridge University Press, Cambridge & New York, 188 pp. http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts

Kaufman, M., (2008) "Escalating Ice Loss Found in Antarctica", *Washington Post*, Washington DC, 14 January, p. A01. http://www.washingtonpost.com/wp-dyn/content/article/2008/01/13/AR2008011302753.html

Kehrwald, N.M., Thompson, L.G., Tandong, Y., Mosley-Thompson, E., Schotterer, U., Alfimov, V., Beer, J., Eikenberg, J. and Davis, M.E., (2008) "Mass Loss on Himalayan Glacier Endangers Water Resources", *Geophysical Research Letters*, Vol. 35, L22503, 22 November, 6 pp.

Kerr, R.A., (2007) "Global Warming Coming Home to Roost in the American West", *Science*, Vol. 318, No. 5858, 21 December, p. 1859.

Kiehl, J.T., (1985) "Searching for the Radiative Signal of Increasing Carbon Dioxide and Other Trace Gases", In *Detecting the Climatic Effects of Increasing Carbon Dioxide* ed. MacCracken, M.C. and Luther, F.M.;

DOE/ER-0235, United States Department of Energy, Office of Energy Research, Office of Basic Energy Sciences, Carbon Dioxide Research Division, Washington DC, pp. 13-28.

Kiehl, J.T. and Ramanathan, V., (1983) "CO_2 Radiative Parameterization Used in Climate Models: Comparison With Narrow Band Models and With Laboratory Data", *Journal of Geophysical Research,* Vol. 88, No. C9, 20 June, pp. 5191-5202.

Kiehl, J.T. and Shields, C.A., (2005) "Climate Simulation of the Latest Permian: Implications for Mass Extinction", *Geology,* Vol. 33, No. 9, September, pp. 757-760.
http://www.cgd.ucar.edu/ccr/aboutus/staff/kiehl/Kiehl-Shields.pdf

Kintisch, E., (2009) "Projections of Climate Change Go From Bad to Worse, Scientists Report", *Science,* Vol. 323, No. 5921, 20 March, pp. 1546-1547.

Klare, M.T., (2001) *Resource Wars: The New Landscape of Global Conflict,* Henry Holt, New York, xiii + 289 pp.

Knutti, R., (2008) "Should We Believe Model Predictions of Future Climate Change?" *Philosophical Transactions of the Royal Society A,* Vol. 366, No. 1885, 28 December, pp. 4647-4664.

Kobashi, T., Severinghaus, J.P. and Barnola, J.-M., (2008) "4 ± 1.5 °C Abrupt Warming 11,270 Yr Ago Identified from Trapped Air in Greenland Ice", *Earth and Planetary Science Letters,* Vol. 268, No. 3-4, 30 April, pp. 397-407. http://icebubbles.ucsd.edu/Publications/Preboreal_EPSL_2008.pdf

Kruger, J. and Dunning, D., (1999) "Unskilled and Unaware of It: How Difficulties in Recognizing One's Own Incompetence Lead to Inflated Self-Assessments", *Journal of Personality and Social Psychology,* Vol. 77, No. 6, pp. 1121–1134. http://www.apa.org/journals/features/psp7761121.pdf

Kurz, W.A., Dymond, C.C., Stinson, G., Rampley, G.J., Neilson, E.T., Carroll, A.L., Ebata, T. and Safranyik, L., (2008) "Mountain Pine Beetle and Forest Carbon Feedback to Climate Change", *Nature,* Vol. 452, No. 7190, 24 April, pp. 987-990.

Khvorostyanov, D.V., Ciais, P., Krinner, G. and Zimov, S.A., (2008) "Vulnerability of East Siberia's Frozen Carbon Stores to Future Warming", *Geophysical Research Letters,* Vol. 35, L10703, 20 May, 5 pp.

Krugman, P.R., (2009) "Betraying the Planet", *New York Times,* New York, 29 June,
http://www.nytimes.com/2009/06/29/opinion/29krugman.html

Lean, J.L., (2000) "Evolution of the Sun's Spectral Irradiance Since the Maunder Minimum", *Geophysical Research Letters,* Vol. 27, No. 16, 15 August, pp. 2425-2428.
http://www.geo.fu-berlin.de/en/met/ag/strat/forschung/SOLARIS/Input_data/Lean2001.pdf

Lean, J.L. and Rind, D.H., (2008) "How Natural and Anthropogenic Influences Alter Global and Regional Surface Temperatures: 1889 to 2006", *Geophysical Research Letters,* Vol. 35, L18701, 16 September, 6 pp.

Lean, J.L. and Rind, D.H., (2009) "How will Earth's Surface Temperature Change in Future Decades?" *Geophysical Research Letters,* Vol. 36, No. 15, L15708, 15 August, 5 pp.

Lean, J., Rottman, G., Harder, J. and Kopp, G., (2005) "SORCE Contributions to New Understanding of Global Change and Solar Variability", *Solar Physics,* Vol. 230, No. 1-2, August, pp. 27-53.

Leemans, R., (2008) "Personal Experiences with the Governance of the Policy-Relevant IPCC and Millennium Ecosystem Assessments", *Global Environmental Change,* Vol. 18, No. 1, February, pp. 12-17.

Le Quéré, C., Rödenbeck, C., Buitenhuis, E.T., Conway, T.J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, N., Gillett, N. and Heimann, M., (2007) "Saturation of the Southern Ocean CO2 Sink Due to Recent Climate Change", *Science,* Vol. 316, No. 5832, 22 June, pp. 1735-1738.

Le Quéré, C., Rödenbeck, C., Buitenhuis, E.T., Conway, T.J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, N., Gillett, N.P. and Heimann, M., (2008) "Response to Comments on

"Saturation of the Southern Ocean CO2 Sink Due to Recent Climate Change"", *Science*, Vol. 319, No. 5863, 1 February, pp. 570.

Lenton, T.M., Held, H., Kriegler, E., Hall, J.W., Lucht, W., Rahmstorf, S. and Schellnhuber, H.J., (2008) "Tipping Elements in the Earth's Climate System", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 6, 12 February, pp. 1786-1793.
http://www.pnas.org/content/105/6/1786.full.pdf

Lenton, A., Codron, F., Bopp, L., Metzl, N., Cadule, P., Tagliabue, A. and Le Sommer, J., (2009) "Stratospheric Ozone Depletion Reduces Ocean Carbon Uptake and Enhances Ocean Acidification", *Geophysical Research Letters*, Vol. 36, L12606, 20 June, 5 pp.

Le Treut, H., Somerville, R., Cubasch, U., Ding, Y., Mauritzen, C., Mokssit, A., Peterson, T. and Prather, M., (2007) "Historical Overview of Climate Change Science", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 93-127.
http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter1.pdf

Levi, B.G., (2008) "Trends in the Hydrology of the Western US Bear the Imprint of Manmade Climate Change", Physics Today, Vol. 61, No. 4, April, pp. 16-18.
http://www.pima.gov/wisps2/Meetings/9.10.08/readings/Hydrology%20Trends%20West%20Physics%20Today.pdf

Levitus, S., Antonov, J.I. and Boyer, T.P., (2005) "Warming of the World Ocean, 1955-2003", *Geophysical Research Letters*, Vol. 32, L02604, 22 January, 4 pp.

Levitus, S., Antonov, J.I., Boyer, T.P., Locarnini, R.A., Garcia, H.E. and Mishonov, A.V., (2009) "Global Ocean Heat Content 1955–2008 in Light of Recently Revealed Instrumentation Problems", *Geophysical Research Letters*, Vol. 36, L07608, 11 April, 5 pp.

Lin, I.-I., Chen, C.-H., Pun, I.-F., Liu, W.T. and Wu, C.-C., (2009) "Warm Ocean Anomaly, Air Sea Fluxes, and the Rapid Intensification of Tropical Cyclone Nargis", *Geophysical Research Letters*, Vol. 36, L03817, 11 February, 5 pp.

Lobell, D.B. and Field , C.B., (2007) "Global Scale Climate Crop-Yield Relationships and the Impacts of Recent Warming", *Environmental Research Letters*, Vol. 2, 014002, 16 March, pp. 1-7.

Lockwood, M. and Fröhlich, C., (2007) "Recent Oppositely Directed Trends in Solar Climate Forcings and the Global Mean Surface Air Temperature", *Proceedings of the Royal Society A*, Vol. 463, No. 2086, October, pp. 2447–2460.

Lockwood, M. and Fröhlich, C., (2008a) "Recent Oppositely Directed Trends in Solar Climate Forcings and the Global Mean Surface Air Temperature II: Different Reconstructions of the Total Solar Irradiance Variation and Dependence on Response Time Scale", *Proceedings of the Royal Society A*, Vol. 464, No. 2094, 8 June, pp. 1367-1385.

Lockwood, M. and Fröhlich, C., (2008b) "Recent Oppositely Directed Trends in Solar Climate Forcings and the Global Mean Surface Air Temperature III: Analysis of Contributions to Global Mean Air Surface Temperature Rise", *Proceedings of the Royal Society A*, Vol. 464, No. 2094, 8 June, pp. 1387-1404.
Lorius, C., Jouzel, J., Raynaud, D., Hansen, J. and Le Treut, H., (1990) "The Ice-Core Record: Climate Sensitivity and Future Greenhouse Warming", *Nature*, Vol. 347, No. 6289, 13 September, pp. 139-145.

Lovejoy, T., (2009) "Climate Change's Pressures on Biodiversity", In *State of the World 2009: Into a Warming World*, Worldwatch Institute; W. W. Norton, New York & London, pp. 67-70.

Lowe, J.A., Huntingford, C., Raper, S.C.B., Jones, C.D., Liddicoat, S.K. and Gohar, L.K., (2009) "How Difficult is it to Recover from Dangerous Levels of Global Warming?" *Environmental Research Letters*, Vol. 4, No. 1, 014012, 11 March, 9 pp.

Luber, G. and McGeehin, M., (2008) "Climate Change and Extreme Heat Events", *American Journal of Preventative Medicine*, Vol. 35, No. 5, November, pp. 429-435.

Luetz, J., (2008) *Planet Prepare: Preparing Coastal Communities in Asia for Future Catastrophes,* World Vision International, Asia-Pacific Regional Office, Bangkok, 123 pp. http://wvasiapacific.org/media-releases/billions-must-be-spent-to-protect-coastal-poor.html

Lunt, D.J., Foster, G.L., Haywood, A.M. and Stone, E.J., (2008) "Late Pliocene Greenland Glaciation Controlled by a Decline in Atmospheric CO2 Levels", *Nature*, Vol. 454, No. 7208, 28 August, pp. 1102-1105.

MacCracken, M.C., Moore, F. and Topping, J.C., Jr. (Eds.), (2008) *Sudden and Disruptive Climate Change: Exploring the Real Risks and How We Can Avoid Them,* Earthscan, London & Sterling VA, xvii + 326 pp.

Mann, M.E. and Jones, P.D., (2003) "Global Surface Temperatures Over the Past Two Millennia", *Geophysical Research Letters*, Vol. 30, No. 15, 1820, 14 August, pp. 4.

Mann, M.E., Zhang, Z., Hughes, M.K., Bradley, R.S., Miller, S.K., Rutherford, S. and Ni, F., (2008) "Proxy-based Reconstructions of Hemispheric and Global Surface Temperature Variations over the Past Two Millennia", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 36, 9 September, pp. 13252-13257. http://www.pnas.org/content/early/2008/09/02/0805721105.abstract

Mann, M.E., Bradley, R.S. and Hughes, M.K., (2009) "Reply to McIntyre and McKitrick: Proxy-based Temperature Reconstructions are Robust", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 106, No. 6, 10 February, pp. E11. http://landshape.org/enm/wp-content/uploads/2009/04/pnas-2009-mann-0812936106.pdf

Matthews, H.D. and Keith, D.W., (2007) "Carbon-Cycle Feedbacks Increase the Likelihood of a Warmer Future", *Geophysical Research Letters*, Vol. 34, L09702, 4 May, 5 pp. http://www.ucalgary.ca/~keith/papers/83.Matthews.CarbonFeedback.f.pdf

McClatchey, R.A., Benedict, W.S., Clough, S.A., Burch, D.E., Calfee, R.F., Fox, K., Rothman, L.S. and Garing, J.S., (1973) *AFCRL Atmospheric Absorption Line Parameters Compilation*, AFCRL-TR-73-0096, Environmental Research Papers No. 434, Air Force Cambridge Research Laboratories, L. G. Hanscom Field, Bedford, MA, 26 January, 78 pp. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=AD762904&Location=U2&doc=GetTRDoc.pdf

McKinsey & Company, (2008) *An Australian Cost Curve for Greenhouse Gas Reduction*, McKinsey Australia Climate Change Initiative, February, 25 pp. http://www.mckinsey.com/clientservice/ccsi/pdf/Australian_Cost_Curve_for_GHG_Reduction.pdf

McKinsey & Company, (2009) *Pathways to a Low Carbon Economy - Version 2 of the Global Greenhouse Gas Abatement Cost Curve*, San Francisco, McKinsey Global Institute, 190 pp. http://www.mckinsey.com/clientservice/ccsi/pathways_low_carbon_economy.asp

McMichael, A.J., Campbell-Lendrum, D., Kovats, S., Edwards, S., Wilkinson, P., Wilson, T., Nicholls, R., Hales, S., Tanser, F., Le Sueur, D., Schlesinger, M. and Andronova, N., (2004) "Global Climate Change", In *Comparative Quantification of Health Risks: Global and Regional Burden of Disease Attributable to Selected Major Risk Factors* ed. Ezzati, M., Lopez, A.D., Rodgers, A. and Murray, C.J.L.; World Health Organization, Geneva, Vol. 2 pp. 1543-1649.

McMichael, A.J., Woodruff, R.E. and Hales, S., (2006) "Climate Change and Human Health: Present and Future Risks", *The Lancet*, Vol. 367, No. 9513, 11 March, pp. 859-869. http://nceph.anu.edu.au/Staff_Students/Staff_pdf_papers/Rosalie_Woodruff/Lancet_2006.pdf

McNeil, B., (2009) *The Clean Industrial Revolution: Growing Australian Prosperity in a Greenhouse Age*, Allen & Unwin, Sydney, 266 pp.

McNeil, B.I. and Matear, R.J., (2008) "Southern Ocean Acidification: A Tipping Point at 450-ppm Atmospheric CO_2", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 48, 2 December, pp. 18860-18864.

Meier, M.F., Dyurgerov, M.B., Rick, U.K., O'Neel, S., Pfeffer, W.T., Anderson, R.S., Anderson, S.P. and Glazovsky, A.F., (2007) "Glaciers Dominate Eustatic Sea-Level Rise in the 21st Century", *Science*, Vol. 317, No. 5841, 24 August, pp. 1064-1067.

Meissner, K., Eby, M., Weaver, A. and Saenko, O., (2008) "CO_2 Threshold for Millennial-Scale Oscillations in the Climate System: Implications for Global Warming Scenarios", *Climate Dynamics*, Vol. 30, No. 2, February, pp. 161-174.

Menzel, A., Sparks, T.H., Estrella, N., Koch, E., Aasa, A., Ahas, R., Alm-Kübler, K., Bissolli, P., Braslavská, O., Briede, A., Chmielewski, F.M., Crepinsek, Z., Curnel, Y., Dahl, Å., Defila, C., Donnelly, A., Filella, Y., Jatczak, K., Måge, F., Mestre, A., Nordli, Ø., Peñuelas, J., Pirinen, P., Remišová, V., Scheifinger, H., Striz, M., Susnik, A., van Vliet, A.J.H., Wielgolaski, F.-E., Zach, S. and Zust, A., (2006) "European Phenological Response to Climate Change Matches the Warming Pattern", *Global Change Biology*, Vol. 12, No. 10, October, pp. 1969-1976.

Meyer, K.M. and Kump, L.R., (2008) "Oceanic Euxinia in Earth History: Causes and Consequences", *Annual Review of Earth and Planetary Sciences*, Vol. 36, May, pp. 251-288.

Michael, J.A., (2007) "Episodic Flooding and the Cost of Sea-level Rise", *Ecological Economics*, Vol. 63, No. 1, 15 June, pp. 149-159.

Millar, R., (2008) "Coastal strategy all at sea as fears rise over compo claims", *The Age*, Melbourne, Saturday 13 September, p. 8.

Mitchell, J.F.B., (1989) "The "Greenhouse" Effect and Climate Change", *Reviews of Geophysics*, Vol. 27, No. 1, February, pp. 115-139.

Møller, A.P., Rubolini, D. and Lehikoinen, E., (2008) "Populations of Migratory Bird Species that Did Not Show a Phenological Response to Climate Change are Declining", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 42, 21 October, pp. 16195-16200.

Montenegro, A., Victor, B., Eby, M., Archer, D. and Weaver, A.J., (2007) "Long Term Fate of Anthropogenic Carbon", *Geophysical Research Letters*, Vol. 34, L19707, 10 October, pp. 5. http://climate.uvic.ca/people/alvaro/LTC_sci.pdf

Morgan, G. and McCrystal, J., (2009) *Poles Apart: Beyond the Shouting, Who's Right About Climate Change?*, Scribe, Melbourne, 287 pp.

Myhre, G., Highwood, E.J., Shine, K.P. and Stordal, F., (1998) "New Estimates of Radiative Forcing Due to Well Mixed Greenhouse Gases", *Geophysical Research Letters*, Vol. 25, No. 14, pp. 2715-2718.

Narisma, G.T., Foley, J.A., Licker, R. and Ramankutty, N., (2007) "Abrupt Changes in Rainfall During the Twentieth Century", *Geophysical Research Letters*, Vol. 34, L06710, 30 March, 5 pp.

National Research Council, (2002) *Abrupt Climate Change: Inevitable Surprises*, by the Committee on Abrupt Climate Change, Ocean Studies Board, Polar Research Board, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, National Research Council, Chaired by Richard B. Alley; National Academy Press, Washington DC, xii + 230 pp.

OECD, (2008) *OECD Environmental Outlook to 2030*, OECD, Paris, 517 pp. http://www.oecd.org/environment/outlookto2030

O'ishi, R., Abe-Ouchi, A., Prentice, I.C. and Sitch, S., (2009) "Vegetation Dynamics and Plant CO_2 Responses as Positive Feedbacks in a Greenhouse World", *Geophysical Research Letters*, Vol. 36, L11706, 6 June, 5 pp.

Oreskes, N., (2004) "The Scientific Consensus on Climate Change", *Science*, Vol. 306, No. 5702, 3 December, pp. 1686. http://historyweb.ucsd.edu/oreskes/Papers/ScientificConsensusonclimate.pdf

Oreskes, N., (2005) "Consensus about Climate Change? Response", *Science*, Vol. 308, No. 5724, 13 May, pp. 953-954.

Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R.M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R.G., Plattner, G.-K., Rodgers, K.B., Sabine, C.L., Sarmiento, J.L., Schlitzer, R., Slater, R.D., Totterdell, I.J., Weirig, M.-F., Yamanaka, Y. and Yool, A., (2005) "Anthropogenic Ocean Acidification over the Twenty-first Century and its Impact on Calcifying Organisms", *Nature*, Vol. 437, No. 7059, 29 September, pp. 681-686.

Overpeck, J.T. and Cole, J.E., (2007) "Lessons from a Distant Monsoon", *Nature*, Vol. 445, No. 7125, 18 January, pp. 270-271.

Overpeck, J.T., Otto-Bliesner, B.L., Miller, G.H., Muhs, D.R., Alley, R.B. and Kiehl, J.T., (2006) "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise", *Science*, Vol. 311, No. 5768, 24 March, pp. 1747-1750.

Pagani, M., Zachos, J.C., Freeman, K.H., Tipple, B. and Bohaty, S., (2005) "Marked Decline in Atmospheric Carbon Dioxide Concentrations During the Paleogene", *Science*, Vol. 309, No. 5734, 22 July, pp. 600-603.

Pai, N., (2008) "Climate Change and National Security: Preparing India for New Conflict Scenarios", *The Indian National Interest Policy Brief*, No. 1, April. http://nationalinterest.in/wp-content/uploads/2008/04/inipolicybrief-no1-climatechangeandnationalsecurity-nitinpai-april2008.pdf

Palutikof, J., (2009) "Climate Change: Impacts and Adaptation from an International Perspective", Presentation at *Greenhouse 2009: Climate Change and Resources*, Perth, 23-26 March, pp. http://www.greenhouse2009.com/downloads/Keynote_090323_1230_Palutikof.ppt.pdf

Parmesan, C. and Yohe, G., (2003) "A Globally Coherent Fingerprint of Climate Change Impacts Across Natural Systems", *Nature*, Vol. 421, No. 6918, 2 January, pp. 37-42.

Parris, B.W., (2008) "The Climate Change Threat to Food Security", *Global Future*, No. 3, World Vision International, pp. 16-17. http://tinyurl.com/BPCCFood

Parry, M.L., Rosenzweig, C., Iglesias, A., Livermore, M. and Fischer, G., (2004) "Effects of Climate Change on Global Food Production under SRES Emissions and Socio-economic Scenarios", *Global Environmental Change*, Vol. 14, No. 1, April, pp. 53-67. http://www.elsevier.com/framework_aboutus/pdfs/2-Effects_of_climate_change.pdf

Patz, J.A., Campbell-Lendrum, D., Holloway, T. and Foley, J.A., (2005) "Impact of Regional Climate Change on Human Health", *Nature*, Vol. 438, No. 7066, 17 November, pp. 310-317.

Patz, J., Gibbs, H., Foley, J., Rogers, J. and Smith, K., (2007) "Climate Change and Global Health: Quantifying a Growing Ethical Crisis", EcoHealth, Vol. 4, No. 4, December, pp. 397-405. http://www.springerlink.com/index/212LW8M6466N645P.pdf

Pearce, F., (2007) *With Speed and Violence: Why Scientists Fear Tipping Points in Climate Change*, Beacon Press, Boston, xxvi + 278 pp.

Pecora, L.M., Carroll, T.L., Johnson, G.A., Mar, D.J. and Heagy, J.F., (1997) "Fundamentals of Synchronization in Chaotic Systems, Concepts, and Applications", *Chaos*, Vol. 7, No. 4, December, pp. 520-543.

Pennisi, E., (2008) "Where Have All Thoreau's Flowers Gone?" Science, Vol. 321, No. 5885, 4 July, pp. 24-25.

Peterson, T.C., Connolley, W.M. and Fleck, J., (2008) "The Myth of the 1970s Global Cooling Scientific Consensus", *Bulletin of the American Meteorological Society*, Vol. 89, No. 9, September, pp. 1325-1337.

Petty, G.W., (2006) *A First Course in Atmospheric Radiation*, 2nd Edition; Sundog Publishing, Madison, WI, 459 pp.

Pfeffer, W.T., Harper, J.T. and O'Neel, S., (2008) "Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise", *Science,* Vol. 321, No. 5894, 5 September, pp. 1340-1343.

Pierce, J.R. and Adams, P.J., (2009) "Can Cosmic Rays Affect Cloud Condensation Nuclei by Altering New Particle Formation Rates?" *Geophysical Research Letters*, Vol. 36, L09820, 13 May, 6 pp.

Plattner, G.-K., (2009) "Long-Term Commitment of CO_2 Emissions on the Global Carbon Cycle and Climate", *IOP Conference Series: Earth and Environmental Sciences,* Vol. 6: 042008. http://www.iop.org/EJ/toc/1755-1315/6/4

Pollard, D. and DeConto, R.M., (2009) "Modelling West Antarctic Ice Sheet Growth and Collapse through the Past Five Million Years", *Nature*, Vol. 458, No. 7236, 19 March, pp. 329-332.

Post, E., Forchhammer, M.C., Bret-Harte, M.S., Callaghan, T.V., Christensen, T.R., Elberling, B., Fox, A.D., Gilg, O., Hik, D.S., Hoye, T.T., Ims, R.A., Jeppesen, E., Klein, D.R., Madsen, J., McGuire, A.D., Rysgaard, S., Schindler, D.E., Stirling, I., Tamstorf, M.P., Tyler, N.J.C., van der Wal, R., Welker, J., Wookey, P.A., Schmidt, N.M. and Aastrup, P., (2009) "Ecological Dynamics Across the Arctic Associated with Recent Climate Change", *Science,* Vol. 325, No. 5946, 11 September, pp. 1355-1358. http://www.sciencemag.org/cgi/content/abstract/325/5946/1355

Pritchard, H.D. and Vaughan, D.G., (2007) "Widespread Acceleration of Tidewater Glaciers on the Antarctic Peninsula", *Journal of Geophysical Research,* Vol. 112, F03S29, 6 June, 10 pp.

Qiu, J., (2008) "The Third Pole", *Nature,* Vol. 454, No. 7203, 24 July, pp. 393-396.

Quetelard, H., Bessemoulin, P., Cerveny, R.S., Peterson, T.C., Burton, A. and Boodhoo, Y., (2009) "Extreme Weather: World-Record Rainfalls During Tropical Cyclone Gamede", *Bulletin of the American Meteorological Society,* Vol. 90, No. 5, May, pp. 603-608.

Rahmstorf, S., (2007) "A Semi-Empirical Approach to Projecting Future Sea-Level Rise", *Science,* Vol. 315, No. 5810, 19 January, pp. 368-370.

Rahmstorf, S., Cazenave, A., Church, J.A., Hansen, J.E., Keeling, R.F., Parker, D.E. and Somerville, R.C.J., (2007) "Recent Climate Observations Compared to Projections", *Science,* Vol. 316, No. 5825, 4 May, p. 709.

Rajeevan, M., Bhate, J. and Jaswal, A.K., (2008) "Analysis of Variability and Trends of Extreme Rainfall Events over India Using 104 Years of Gridded Daily Rainfall Data", *Geophysical Research Letters,* Vol. 35, L18707, 20 September, 6 pp.

Ramanathan, V. and Feng, Y., (2008) "On Avoiding Dangerous Anthropogenic Interference with the Climate System: Formidable Challenges Ahead", *Proceedings of the National Academy of Sciences of the United States of America,* Vol. 105, No. 38, 23 September, pp. 14245-14250.

Ramaswamy, V., Schwarzkopf, M.D., Randel, W.J., Santer, B.D., Soden, B.J. and Stenchikov, G.L., (2006) "Anthropogenic and Natural Influences in the Evolution of Lower Stratospheric Cooling", *Science,* Vol. 311, No. 5764, 24 February, pp. 1138-1141.

Randall, D.A., Wood, R.A., Bony, S., Colman, R., Fichefet, T., Fyfe, J., Kattsov, V., Pitman, A., Shukla, J., Srinivasan, J., Stouffer, R.J., Sumi, A. and Taylor, K.E., (2007) "Climate Models and Their Evaluation", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 589-662. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter8.pdf

Reagan, M.T. and Moridis, G.J., (2007) "Oceanic Gas Hydrate Instability and Dissociation under Climate Change Scenarios", *Geophysical Research Letters,* Vol. 34, L22709, 27 November, 5 pp.

Reichler, T. and Kim, J., (2008) "How Well Do Coupled Models Simulate Today's Climate?" *Bulletin of the American Meteorological Society,* Vol. 89, No. 3, March, pp. 303–311.

Reuveny, R., (2007) "Climate Change-Induced Migration and Violent Conflict", *Political Geography*, Vol. 26, No. 6, August, pp. 656-673.

Riebesell, U., (2008) "Acid Test for Marine Biodiversity", *Nature*, Vol. 454, No. 7200, 3 July, pp. 46-47.

Riedy, C. and Diesendorf, M., (2003) "Financial Subsidies to the Australian Fossil Fuel Industry", *Energy Policy*, Vol. 31, No. 2, January, pp. 125-137.

Rignot, E., Bamber, J.L., van den Broeke, M.R., Davis, C., Li, Y., van de Berg, W.J. and van Meijgaard, E., (2008) "Recent Antarctic Ice Mass Loss from Radar Interferometry and Regional Climate Modelling", *Nature Geoscience*, Vol. 1, No. 2, February, pp. 106-110. http://www.phys.uu.nl/~broeke/home_files/MB_pubs_pdf/2008_Rignot_NatGeo.pdf

Rignot, E. and Jacobs, S.S., (2002) "Rapid Bottom Melting Widespread near Antarctic Ice Sheet Grounding Lines", *Science*, Vol. 296, No. 5575, 14 June, pp. 2020-2023.

Roe, G.H. and Baker, M.B., (2007) "Why Is Climate Sensitivity So Unpredictable?" *Science*, Vol. 318, No. 5850, 26 October, pp. 629-632.

Rohling, E.J., Grant, K., Hemleben, C., Siddall, M., Hoogakker, B.A.A., Bolshaw, M. and Kucera, M., (2008) "High Rates of Sea-Level Rise During the Last Interglacial Period", *Nature Geoscience*, Vol. 1, No. 1, January, pp. 38-42.

Rohling, E.J., Grant, K., Bolshaw, M., Roberts, A.P., Siddall, M., Hemleben, C. and Kucera, M., (2009) "Antarctic Temperature and Global Sea Level Closely Coupled over the Past Five Glacial Cycles", *Nature Geoscience*, Vol. 2, No. 7, July, pp. 500-504.

Rosenzweig, C., Strzepek, K.M., Major, D.C., Iglesias, A., Yates, D.N., McCluskey, A. and Hillel, D., (2004) "Water Resources for Agriculture in a Changing Climate: International Case Studies", *Global Environmental Change*, Vol. 14, No. 4, December, pp. 345-360.

Rosenzweig, C., Karoly, D., Vicarelli, M., Neofotis, P., Wu, Q., Casassa, G., Menzel, A., Root, T.L., Estrella, N., Seguin, B., Tryjanowski, P., Liu, C., Rawlins, S. and Imeson, A., (2008) "Attributing Physical and Biological Impacts to Anthropogenic Climate Change", *Nature*, Vol. 453, No. 7193, 15 May, pp. 353-357.

Rothman, L.S., Gordon, I.E., Barbe, A., Benner, D.C., Bernath, P.F., Birk, M., Boudon, V., Brown, L.R., Campargue, A., Champion, J.-P., Chance, K., Coudert, L.H., Dana, V., Devi, V.M., Fally, S., Flaud, J.-M., Gamache, R.R., Goldman, A., Jacquemart, D., Kleiner, I., Lacome, N., Lafferty, W.J., Mandin, J.-Y., Massie, S.T., Mikhailenko, S.N., Miller, C.E., Moazzen-Ahmadi, N., Naumenko, O.V., Nikitin, A.V., Orphal, J., Perevalov, V.I., Perrin, A., Predoi-Cross, A., Rinsland, C.P., Rotger, M., Simecková, M., Smith, M.A.H., Sung, K., Tashkun, S.A., Tennyson, J., Toth, R.A., Vandaele, A.C. and Vander Auwera, J., (2009) "The HITRAN 2008 Molecular Spectroscopic Database", *Journal of Quantitative Spectroscopy and Radiative Transfer*, Vol. 110, No. 9-10, June-July, pp. 533-572. http://www.cfa.harvard.edu/hitran/Download/HITRAN2008.pdf

Royer, D.L., (2006) "CO_2-forced Climate Thresholds During the Phanerozoic", *Geochimica et Cosmochimica Acta*, Vol. 70, No. 23, 1 December, pp. 5665-5675. https://wesfiles.wesleyan.edu/home/droyer/web/PhanCO2(GCA).pdf

Royer, D.L., Berner, R.A., Montañez, I.P., Tabor, N.J. and Beerling, D.J., (2004) "CO_2 as a Primary Driver of Phanerozoic Climate", *GSA Today*, Vol. 14, No. 3, March, pp. 4-10. http://www.soest.hawaii.edu/GG/FACULTY/POPP/Royer%20et%20al.%202004%20GSA%20Today.pdf

Royer, D.L., Berner, R.A. and Park, J., (2007) "Climate Sensitivity Constrained by CO_2 Concentrations over the Past 420 Million Years", *Nature*, Vol. 446, No. 7135, 29 March, pp. 530-532.

Santer, B.D., Wehner, M.F., Wigley, T.M.L., Sausen, R., Meehl, G.A., Taylor, K.E., Ammann, C., Arblaster, J., Washington, W.M., Boyle, J.S. and Bruggemann, W., (2003) "Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes", *Science*, Vol. 301, No. 5632, 25 July, pp. 479-483.

Santer, B.D., Thorne, P.W., Haimberger, L., Taylor, K.E., Wigley, T.M.L., Lanzante, J.R., Solomon, S., Free, M., Gleckler, P.J., Jones, P.D., Karl, T.R., Klein, S.A., Mears, C., Nychka, D., Schmidt, G.A., Sherwood, S.C. and Wentz, F.J., (2008) "Consistency of Modelled and Observed Temperature Trends in the Tropical Troposphere", *International Journal of Climatology*, Vol. 28, No. 13, 15 November, pp. 1703-1722.

Save the Children, (2007) *Legacy of Disasters: The Impact of Climate Change on Children*, London, Save the Children UK, April, 16 pp. http://www.savethechildren.org.uk/en/6180_499.htm

Save the Children, (2008) *In the Face of Disaster: Children and Climate Change*, London, Save the Children UK, June, 20 pp. http://www.savethechildren.org.uk/en/54_6057.htm

Schlenker, W. and Roberts, M.J., (2009) "Nonlinear Temperature Effects Indicate Severe Damages to U.S. Crop Yields Under Climate Change", *Proceedings of the National Academy of Sciences of the United States of America*, published online 28 August, 5 pp. http://www.pnas.org/content/early/2009/08/25/0906865106.abstract

Schmidhuber, J. and Tubiello, F.N., (2007) "Global Food Security Under Climate Change", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 104, No. 50, 11 December, pp. 19703-19708. http://www.pnas.org/content/104/50/19703.full.pdf

Schmidt, G.A., (2007) "The Physics of Climate Modeling", *Physics Today*, Vol. 60, No. 1, January, pp. 72-73. http://ptonline.aip.org/dbt/dbt.jsp?KEY=PHTOAD&Volume=60&Issue=1&usertype=indiv

Schubert, R., Schellnhuber, H.J., Buchmann, N., Epiney, A., Grießhammer, A., Kulessa, M., Messner, D., Rahmstorf, S. and Schmid, J., (2008) *Climate Change as a Security Risk*, London, Earthscan for the German Advisory Council on Global Change, xix + 248 pp. http://www.wbgu.de/wbgu_jg2007_engl.html

Schuur, E.A.G., Bockheim, J., Canadell, J.G., Euskirchen, E., Field, C.B., Goryachkin, S.V., Hagemann, S., Kuhry, P., Lafleur, P.M., Lee, H., Mazhitova, G., Nelson, F.E., Rinke, A., Romanovsky, V.E., Shiklomanov, N., Tarnocai, C., Venevsky, S., Vogel, J.G. and Zimov, S.A., (2008) "Vulnerability of Permafrost Carbon to Climate Change: Implications for the Global Carbon Cycle", *BioScience*, Vol. 58, No. 8, September, pp. 701-714. http://www.aibs.org/bioscience-press-releases/resources/Schuur.pdf

Schuur, E.A.G., Vogel, J.G., Crummer, K.G., Lee, H., Sickman, J.O. and Osterkamp, T.E., (2009) "The Effect of Permafrost Thaw on Old Carbon Release and Net Carbon Exchange from Tundra", *Nature*, Vol. 459, No. 7246, 28 May, pp. 556-559.

Seidel, D.J., Fu, Q., Randel, W.J. and Reichler, T.J., (2008) "Widening of the Tropical Belt in a Changing Climate", *Nature Geoscience*, Vol. 1, No. 1, January, pp. 21-24.

Shaffer, G., Olsen, S.M. and Pedersen, J.O.P., (2009) "Long-Term Ocean Oxygen Depletion in Response to Carbon Dioxide Emissions from Fossil Fuels", *Nature Geoscience*, Vol. 2, No. 2, February, pp. 105-109.

Silverman, J., Lazar, B., Cao, L., Caldeira, K. and Erez, J., (2009) "Coral Reefs May Start Dissolving when Atmospheric CO_2 Doubles", *Geophysical Research Letters*, Vol. 36, L05606, 13 March, 5 pp.

Singh, P. and Bengtsson, L., (2004) "Hydrological Sensitivity of a Large Himalayan Basin to Climate Change", *Hydrological Processes*, Vol. 18, No. 13, September, pp. 2363-2385.

Sitch, S., Huntingford, C., Gedney, N., Levy, P.E., Lomas, M., Piao, S.L., Betts, R., Ciais, P., Cox, P., Friedlingstein, P., Jones, C.D., Prentice, I.C. and Woodward, F.I., (2008) "Evaluation of the Terrestrial Carbon Cycle, Future Plant Geography and Climate-Carbon Cycle Feedbacks Using Five Dynamic Global Vegetation Models (DGVMs)", *Global Change Biology*, Vol. 14, No. 9, September, pp. 2015-2039.

Smith, D.M., Cusack, S., Colman, A.W., Folland, C.K., Harris, G.R. and Murphy, J.M., (2007) "Improved Surface Temperature Prediction for the Coming Decade from a Global Climate Model", *Science*, Vol. 317, No. 5839, 10 August, pp. 796-799.

Sokolov, A.P., Stone, P.H., Forest, C.E., Prinn, R.G., Sarofim, M.C., Webster, M., Paltsev, S., Schlosser, C.A., Kicklighter, D., Dutkiewicz, S., Reilly, J., Wang, C., Felzer, B. and Jacoby, H.D., (2009) "Probabilistic Forecast for 21st Century Climate Based on Uncertainties in Emissions (without Policy) and Climate Parameters", *Journal of Climate*, Early online release posted May 2009.

Solanki, S.K., (2002) "Solar Variability and Climate Change: Is there a Link?" *Astronomy & Geophysics*, Vol. 43, No. 5, October, pp. 5.9-5.13. http://noorderlicht.vpro.nl/attachment.db/18258097/Solanki.pdf

Solanki, S.K. and Krivova, N.A., (2003) "Can Solar Variability Explain Global Warming Since 1970?" *Journal of Geophysical Research*, Vol. 108 (A5), 21 May, 7 pp.

Solomon, E.A., Kastner, M., MacDonald, I.R. and Leifer, I., (2009) "Considerable Methane Fluxes to the Atmosphere from Hydrocarbon Seeps in the Gulf of Mexico", *Nature Geoscience*, Vol. 2, No. 8, August, pp. 561-565.

Solomon, S., Plattner, G.-K., Knutti, R. and Friedlingstein, P., (2009) "Irreversible Climate Change Due to Carbon Dioxide Emissions", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 106, No. 6, 10 February, pp. 1704-1709. http://www.pnas.org/content/106/6/1704.abstract?etoc

Soruco, A., Vincent, C., Francou, B. and Gonzalez, J.F., (2009) "Glacier Decline between 1963 and 2006 in the Cordillera Real, Bolivia", *Geophysical Research Letters*, Vol. 36, L03502, 11 February, 6 pp.

Steffensen, J.P., Andersen, K.K., Bigler, M., Clausen, H.B., Dahl-Jensen, D., Fischer, H., Goto-Azuma, K., Hansson, M., Johnsen, S.J., Jouzel, J., Masson-Delmotte, V., Popp, T., Rasmussen, S.O., Rothlisberger, R., Ruth, U., Stauffer, B., Siggaard-Andersen, M.-L., Sveinbjörnsdóttir, Á.E., Svensson, A. and White, J.W.C., (2008) "High-Resolution Greenland Ice Core Data Show Abrupt Climate Change Happens in Few Years", *Science*, Vol. 321, No. 5889, 1 August, pp. 680-684.

Steig, E.J., Schneider, D.P., Rutherford, S.D., Mann, M.E., Comiso, J.C. and Shindell, D.T., (2009) "Warming of the Antarctic Ice-Sheet Surface Since the 1957 International Geophysical Year", *Nature*, Vol. 457, No. 7228, 22 January, pp. 459-463. http://holocene.meteo.psu.edu/shared/articles/SteigetalNature09.pdf

Stern, N., (2009) *A Blueprint for a Safer Planet: How to Manage Climate Change and Create a New Era of Progress and Prosperity*, The Bodley Head, London, x + 246 pp.

Stott, P.A., Stone, D.A. and Allen, M.R., (2004) "Human Contribution to the European Heatwave of 2003", *Nature*, Vol. 432, No. 7017, 2 December, pp. 610-614.

Stroeve, J., Holland, M.M., Meier, W., Scambos, T. and Serreze, M., (2007) "Arctic Sea Ice Decline: Faster than Forecast", *Geophysical Research Letters*, Vol. 34, No. 9, 1 May, L09501, 5 pp.

Sun, B. and Bradley, R.S., (2002) "Solar Influences on Cosmic Rays and Cloud Formation: A Reassessment", *Journal of Geophysical Research*, Vol. 107, No. D14, 27 July, 13 pp.

Swanson, K.L. and Tsonis, A.A., (2009) "Has the Climate Recently Shifted?" *Geophysical Research Letters*, Vol. 36, No. 6, L06711, 31 March, 4 pp.

Tarnocai, C., Canadell, J.G., Schuur, E.A.G., Kuhry, P., Mazhitova, G. and Zimov, S., (2009) "Soil Organic Carbon Pools in the Northern Circumpolar Permafrost Region", *Global Biogeochemical Cycles*, Vol. 23, No. 2, GB2023, 27 June, 11 pp. http://www.globalcarbonproject.org/news/SoilOrganicPoolsinPermafrost.html

Taylor, K.C., Lamorey, G.W., Doyle, G.A., Alley, R.B., Grootes, P.M., Mayewski, P.A., White, J.W.C. and Barlow, L.K., (1993) "The 'Flickering Switch' of Late Pleistocene Climate Change", *Nature*, Vol. 361, No. 6411, 4 February, pp. 432-436.

Teske, S. and Vincent, J., (2008) "Energy [R]evolution: A Sustainable Australia Energy Outlook", Sydney & Brussels, Greenpeace Australia Pacific & European Renewable Energy Council, June, 47 pp. http://www.greenpeace.org/australia/news-and-events/news/Climate-change/blueprint-energy-rev

The Pew Charitable Trusts, (2009) *The Clean Energy Economy: Repowering Jobs, Businesses and Investments Across America*, Washington DC, 59 pp. http://www.pewcenteronthestates.org/uploadedFiles/Clean_Economy_Report_Web.pdf

The Royal Society, (2007) "Climate Change Controversies: A Simple Guide", London, 11 pp. http://royalsociety.org/page.asp?id=6229

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C., Erasmus, B.F.N., de Siqueira, M.F., Grainger, A., Hannah, L., Hughes, L., Huntley, B., van Jaarsveld, A.S., Midgley, G.F., Miles, L., Ortega-Huerta, M.A., Peterson, A.T., Phillips, O.L. and Williams, S.E., (2004) "Extinction Risk from Climate Change", *Nature*, Vol. 427, No. 6970, 8 January, pp. 145-148. http://www.fishclimate.ca/pdf/Extinction_risk_from_climate_change_Nature_2004.pdf

Thompson, L.G., Mosley-Thompson, E., Brecher, H., Davis, M., León, B., Les, D., Lin, P.-N., Mashiotta, T. and Mountain, K., (2006) "Abrupt Tropical Climate Change: Past and Present", *Proceedings of the National Academy of Science of the United States of America*, Vol. 103, No. 28, 11 July, pp. 10536-10543. http://bprc.osu.edu/Icecore/thompson_pnas_2006.pdf

Timmermann, A., Timm, O., Stott, L. and Menviel, L., (2009) "The Roles of CO_2 and Orbital Forcing in Driving Southern Hemispheric Temperature Variations during the Last 21 000 Yr", *Journal of Climate*, Vol. 22, No. 7, April, pp. 1626-1640.

Torn, M.S. and Harte, J., (2006) "Missing Feedbacks, Asymmetric Uncertainties, and the Underestimation of Future Warming", *Geophysical Research Letters*, Vol. 33, L10703, 26 May, 5 pp.

Trenberth, K.E., Jones, P.D., Ambenje, P., Bojariu, R., Easterling, D., Tank, A.K., Parker, D., Rahimzadeh, F., Renwick, J.A., Rusticucci, M., Soden, B. and Zhai, P., (2007) "Observations: Surface and Atmospheric Climate Change", In *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* ed. Solomon, S., Qin , D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M. and Miller, H.L.; Cambridge University Press, Cambridge & New York, pp. 235-336. http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter3.pdf

Tsonis, A.A., Swanson, K. and Kravtsov, S., (2007) "A New Dynamical Mechanism for Major Climate Shifts", *Geophysical Research Letters*, Vol. 34, L13705, 12 July, 5 pp.

Turner, J., Comiso, J.C., Marshall, G.J., Lachlan-Cope, T.A., Bracegirdle, T., Maksym, T., Meredith, M.P., Wang, Z. and Orr, A., (2009) "Non-Annular Atmospheric Circulation Change Induced by Stratospheric Ozone Depletion and its Role in the Recent Increase of Antarctic Sea Ice Extent", *Geophysical Research Letters*, Vol. 36, L08502, 23 April, 5 pp.

Turney, C., Baillie, M., Clemens, S., Brown, D., Palmer, J., Pilcher, J., Reimer, P. and Leuschner, H.H., (2005) "Testing Solar Forcing of Pervasive Holocene Climate Cycles", *Journal of Quaternary Science*, Vol. 20, No. 6, September, pp. 511-518.

Tyndall, J., (1861) "The Bakerian Lecture: On the Absorption and Radiation of Heat by Gases and Vapours, and on the Physical Connexion of Radiation, Absorption, and Conduction", *Philosophical Transactions of the Royal Society of London*, Vol. 151, pp. 1-36.

Udelhofen, P. and Cess, R., (2001) "Cloud Cover Variations Over the United States: An Influence of Cosmic Rays or Solar Variability?" *Geophysical Research Letters*, Vol. 28, No. 13, pp. 2617-2620.

UNEP, (2009) *Global Green New Deal: Policy Brief*, Nairobi, United Nations Environment Programme, March, 29 pp. http://www.unep.org/pdf/A_Global_Green_New_Deal_Policy_Brief.pdf

UNEP, ILO, IOE and ITUC, (2008) *Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World*, Worldwatch Institute, Washington DC for the United Nations Development Programme, Nairobi, September, xx + 352 pp. http://www.unep.org/labour_environment/PDFs/Greenjobs/UNEP-Green-Jobs-Report.pdf

UNEP & WGMS, (2008) "Global Glacier Changes: Facts and Figures", Geneva, Zurich & Nairobi, United Nations Environment Programme & World Glacier Monitoring Service, 88 pp. http://www.grid.unep.ch/glaciers/

UNICEF, (2007) *Climate Change and Children*, New York, United National Children's Fund, December, 20 pp. http://www.unicef.org/publications/index_42166.html

UNICEF, (2008) *Climate Change and Children: A Human Security Challenge*, Policy Review Paper, Florence, UNICEF Innocenti Research Centre, November, x + 51 pp. http://www.unicef-irc.org/cgi-bin/unicef/Lunga.sql?ProductID=509

UNICEF UK, (2008) *Climate Change: Our Climate, Our Children, Our Responsibility - The Implications of Climate Change for the World's Children*, London, UNICEF UK, 36 pp. http://www.unicef.org.uk/campaigns/campaign_sub_pages.asp?page=91

Union of Concerned Scientists, (2007) "Smoke, Mirrors & Hot Air: How ExxonMobil Uses Big Tobacco's Tactics to Manufacture Uncertainty on Climate Science", Cambridge, MA, Union of Concerned Scientists, January, 63 pp. http://www.ucsusa.org/assets/documents/global_warming/exxon_report.pdf

Union of Concerned Scientists, (2008) "U.S. Scientists and Economists' Call for Swift and Deep Cuts in Greenhouse Gas Emissions", Cambridge, MA, Union of Concerned Scientists, May, 67 pp. http://www.ucsusa.org/assets/documents/global_warming/Scientist_Economists_Call_to_Action_fnl.pdf

Vaquer-Sunyer, R. and Duarte, C.M., (2008) "Thresholds of Hypoxia for Marine Biodiversity", *Proceedings of the National Academy of Sciences of the United States of America*, Vol. 105, No. 40, 7 October, pp. 15452-15457.

VicHealth, (2009) *January 2009 Heatwave in Victoria: An Assessment of Health Impacts*, Melbourne, Victorian Government Department of Human Services, 20 pp. http://www.health.vic.gov.au/chiefhealthofficer/publications/heatwave.htm

Wallace, J., (2009) "The Security Dimensions of Climate Change", In *State of the World 2009: Into a Warming World*, Worldwatch Institute; W. W. Norton, New York & London, pp. 63-66.

Walter, K.M., Edwards, M.E., Grosse, G., Zimov, S.A. and Chapin, F.S., III, (2007) "Thermokarst Lakes as a Source of Atmospheric CH_4 During the Last Deglaciation", *Science,* Vol. 318, No. 5850, 26 October, pp. 633-636.

Walter, K.M., Smith, L.C. and Chapin, F.S., III, (2007) "Methane Bubbling from Northern Lakes: Present and Future Contributions to the Global Methane Budget", *Philosophical Transactions of the Royal Society A,* Vol. 365, No. 1856, 15 July, pp. 1657-1676. http://www.sscnet.ucla.edu/geog/downloads/297/299.pdf

Walter, K.M., Zimov, S.A., Chanton, J.P., Verbyla, D. and Chapin, F.S., III, (2006) "Methane Bubbling from Siberian Thaw Lakes as a Positive Feedback to Climate Warming", *Nature,* Vol. 443, No. 7107, 7 September, pp. 71-75.

Wang, M. and Overland, J.E., (2009) "A Sea Ice Free Summer Arctic Within 30 Years?" *Geophysical Research Letters,* Vol. 36, No. 7, L07502, 3 April, 5 pp.

Wang, W.C., Yung, Y.L., Lacis, A.A., Mo, T. and Hansen, J.E., (1976) "Greenhouse Effects Due to Man-Made Perturbations of Trace Gases", *Science,* Vol. 194, No. 4266, 12 November, pp. 685-690.

Wang, Y.M., Lean, J.L. and Sheeley, N.R., (2005) "Modeling the Sun's Magnetic Field and Irradiance Since 1713", *Astrophysical Journal,* Vol. 625, No. 1, 20 May, pp. 522-538. http://www.iop.org/EJ/article/0004-637X/625/1/522/61797.web.pdf

Webster, M., Forest, C., Reilly, J., Babiker, M., Kicklighter, D., Mayer, M., Prinn, R., Sarofim, M., Sokolov, A., Stone, P. and Wang, C., (2003) "Uncertainty Analysis of Climate Change and Policy Response", *Climatic Change,* Vol. 61, No. 3, December, pp. 295-320.

Webster, P.J., Holland, G.J., Curry, J.A. and Chang, H.-R., (2005) "Changes in Tropical Cyclone Number, Duration, and Intensity in a Warming Environment", *Science,* Vol. 309, No. 5742, 16 September, pp. 1844-1846.

Westbrook, G.K., Thatcher, K.E., Rohling, E.J., Piotrowski, A.M., Pälike, H., Osborne, A.H., Nisbet, E.G., Minshull, T.A., Lanoisellé, M., James, R.H., Hühnerbach, V., Green, D., Fisher, R.E., Crocker, A.J., Chabert, A., Bolton, C., Beszczynska-Möller, A., Berndt, C. and Aquilina, A., (2009) "Escape of Methane Gas from the Seabed along the West Spitsbergen Continental Margin", *Geophysical Research Letters*, Vol. 36, L15608, 6 August, 5 pp.

Wild, M., (2009) "Global Dimming and Brightening: A Review", *Journal of Geophysical Research*, Vol. 114, D00D16, 27 June, 31 pp.

Wild, M., Trüssel, B., Ohmura, A., Long, C.N., König-Langlo, G., Dutton, E.G. and Tsvetkov, A., (2009) "Global Dimming and Brightening: An Update beyond 2000", *Journal of Geophysical Research*, Vol. 114, D00D13, 16 May, 14 pp.

WWF Nepal Program, (2005) "An Overview of Glaciers, Glacier Retreat, and Subsequent Impacts in Nepal, India and China", March, 70 pp. http://assets.panda.org/downloads/himalayaglaciersreport2005.pdf

Yao, T.-D., Pu, J.-C., Lu, A., Wang, Y. and Yu, W., (2007a) "Recent Glacial Retreat and its Impact on Hydrological Processes on the Tibetan Plateau, China, and Surrounding Regions", *Arctic, Antarctic, and Alpine Research*, Vol. 39, No. 4, November, pp. 642-650.

Yao, T.-D., Pu, J.-C., Tian, L.-D., Yang, W., Duan, K.-Q., Ye, Q.-H. and Thompson, L.G., (2007b) "Recent Rapid Retreat of the Naimona'nyi Glacier in Southwestern Tibetan Plateau", *Journal of Glaciology and Geocryology*, Vol. 29, No. 4, pp. 503-508. [*In Chinese with English abstract*]

Yu, J. and Wang, Y., (2009) "Response of Tropical Cyclone Potential Intensity over the North Indian Ocean to Global Warming", *Geophysical Research Letters*, Vol. 36, L03709, 14 February, 5 pp.

Zeebe, R.E., Zachos, J.C., Caldeira, K. and Tyrrell, T., (2008) "Carbon Emissions and Acidification", *Science*, Vol. 321, No. 5885, 4 July, pp. 51-52.

Zhang, J., (2007) "Increasing Antarctic Sea Ice under Warming Atmospheric and Oceanic Conditions", *Journal of Climate*, Vol. 20, No. 11, June, pp. 2515-2529.
http://psc.apl.washington.edu/zhang/Pubs/Zhang_Antarctic_20-11-2515.pdf

Zhang, X., Zwiers, F.W., Hegerl, G.C., Lambert, F.H., Gillett, N.P., Solomon, S., Stott, P.A. and Nozawa, T., (2007) "Detection of Human Influence on Twentieth-Century Precipitation Trends", *Nature*, Vol. 448, No. 7152, 26 July, pp. 461-466.

Zwally, H.J., Abdalati, W., Herring, T., Larson, K., Saba, J. and Steffen, K., (2002) "Surface Melt-Induced Acceleration of Greenland Ice-Sheet Flow", *Science*, Vol. 297, No. 5579, 12 July, pp. 218-222.

Useful Resources

The IPCC's *Fourth Assessment Report* – particularly 'Frequently Asked Questions'
www.ipcc.ch http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf

RealClimate blog – particularly 'Responses to Common Contrarian Arguments'
www.realclimate.org http://www.realclimate.org/index.php/archives/2004/12/index/#Responses

RealClimate wiki
http://www.realclimate.org/wiki/index.php?title=RC_Wiki

BraveNewClimate blog – Prof. Barry Brook
http://bravenewclimate.com/

Research Institute for Climate Change and Sustainability – University of Adelaide
http://www.adelaide.edu.au/climatechange/seminars/climateqanda/

The Global Warming Debate http://cce.890m.com/

Skeptical Science: Explaining the Science of Global Warming Skepticism – John Cross
http://www.skepticalscience.com/

"How to talk to a climate change skeptic"
http://gristmill.grist.org/skeptics?source=most_popular

Climate Change Denial - George Marshall on the psychology of climate change denial
http://climatedenial.org/

New Scientist: Climate Change – A Guide for the Perplexed, Michael Le Page
http://www.newscientist.com/article/dn11462

YouTube Videos addressing skeptic concerns
http://www.youtube.com/profile?user=greenman3610&view=videos

UK Met Office – Climate Change: The Big Picture
http://www.metoffice.gov.uk/corporate/pressoffice/myths/bigpicture.pdf

Brian Angliss - Anti-Global Heating Claims: A Reasonably Thorough Debunking
http://scholarsandrogues.wordpress.com/2007/07/23/anti-global-heating-claims-a-reasonably-thorough-debunking/#index

NASA temperature data
http://data.giss.nasa.gov/gistemp/graphs/

Natural Environment Research Council (UK) – Climate Change Challenge
http://www.nerc.ac.uk/about/consult/debate/climatechange/summary.asp#newiceage

The Royal Society, (2007) "Climate Change Controversies: A Simple Guide", London, 11 pp.
http://royalsociety.org/page.asp?id=6229

The National Academies, (2008) "Understanding and Responding to Climate Change: Highlights of National Academies Reports", Washington DC, The National Academies of the United States: National Academy of Sciences, National Academy of Engineering, Institute of Medicine & National Research Council, 23 pp. http://dels.nas.edu/basc/climate-change/

CSIRO and the Australian Bureau of Meteorology, (2007) "Climate Change in Australia: Technical Report", Canberra, CSIRO and the Australian Bureau of Meteorology, 148 pp. http://www.climatechangeinaustralia.gov.au/

Jones, D., Watkins, A., Braganza, K. and Coughlan, M., (2007) "“The Great Global Warming Swindle”: A Critique", *Bulletin of the Australian Meteorological and Oceanographic Society*, Vol. 20, No. 3, pp. 63-72. http://www.amos.org.au/documents/item/27

Climate Change page – Brett Parris
http://www-personal.buseco.monash.edu.au/~BParris/BPClimateChange.html