Responses to Questions & Objections on Climate Change

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Introduction

This document is intended as a brief collection of responses to some of the most common questions and objections on climate change. It is not intended to be comprehensive and the interested reader is referred to the 'Useful Resources' section at the end for more comprehensive websites and other materials. Please send any comments or suggestions for improvements to: Brett.Parris@buseco.monash.edu.au

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

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.[1] 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.[2]

Temperatures have also increased rapidly in the past. In Greenland temperatures rose around 10°C within three years around 14,700 years ago.[3] 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.[4] 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.[5]

> 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.[6]

[1] Overpeck *et al.* (2006), p. 1747.
[2] Alley *et al.* (2005), p. 456 ; Pagani *et al.* (2005).
[3] Steffensen *et al.* (2008), pp. 680-681.
[4] National Research Council (2002), p. 27. See also: Pearce (2007), pp. 149-150; Alley (2000).
[5] National Research Council (2002), p. 153.
[6] Alley (2004), p. 64.

Sea-levels have also risen very 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.[7]

These are ***huge*** ranges of 'natural variability' for both sea levels, rates of sea-level rise, and temperature changes. There is no way existing human social systems and eco-systems could adapt to some of these changes, so the fact that some of the changes that we are now driving are of similar magnitude to those in the past is hardly a reason for inaction.

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

False. The overwhelming, broad consensus of the world's climate scientists is that we cannot explain observed climate changes without taking into account human influence.[8] 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."[9]

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."[10]

3. 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.[11] 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.[12] 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.[13] It is simply false to assert that species can always adapt – even under past conditions. The world experienced several mass extinctions in the past related to dramatic climate changes. 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

[7] Rohling *et al.* (2008), p. 38.
[8] IPCC (2007a) p. 11.
[9] Gillett *et al.* (2008), p. 750.
[10] Kerr (2007), p. 1859. See also Rosenzweig *et al.* (2008).
[11] Alley *et al.* (2005).
[12] IPCC (2007b), p. 17.
[13] Anthoff *et al.* (2006).

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.[14]

4. Climate models are unreliable 'voodoo science'.

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 Pinatubo in 1991.[15]

Skeptics frequently 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 paper on chaotic complex systems, Crutchfield *et al.* (1986, p. 41) 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!" This exponential amplification of initial measurement errors is due to the system's extreme sensitivity to initial conditions – a characteristic that defines chaotic systems.

Long-term modeling of complex systems focuses therefore, not on a precise '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.[16]

When skeptics disparage climate models because they have not 'predicted' the particular evolution of the temperature path in a 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.[17]

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[14] For more on the possibilities of mass extinctions, see: http://bravenewclimate.com/2008/08/14/will-global-warming-cause-a-mass-extinction-event/

[15] Schmidt (2007); IPCC FAQ 8.1: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-faqs.pdf

[16] See for example Auyang (1998), one of the best inter-disciplinary introductions to complex systems science.

[17] For more on this, see: http://www.realclimate.org/index.php/archives/2005/01/is-climate-modelling-science/

It should also be noted that it is not possible for anyone, climate skeptic or otherwise, to make assertions about the future relationship between greenhouse gases and global climate without some explicit or implicit reference to a model of how the world's climate works. So when skeptics assert 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 say that if they are basing the assertion on some sophisticated understanding of how the climate system works – in other words, a model.

Lastly, it is also striking that so often the same people who are so skeptical of the validity of climate models place so much faith in those economic models which suggest that mitigating climate change would be terrible for our economies – when most economic models in fact have far less claim to scientific accuracy than climate models do.[18]

5. 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*.[19] 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.

6. Global warming ended around 1998 anyway – there's been cooling since around the turn of the century.

False. The year 1998 saw a major temperature spike from the strong El Niño, so of course if you are going to take the end of that El Niño as a starting point, then the years immediately following it during the neutral and La Niña phases are going to be cooler. The atmospheric warming from climate change is not expected to be a relentless year-on-year increase in temperatures. Temperatures have zigzagged up and down and they will continue to do so, and temperature increases from human caused climate change will continue to be overlain by natural climatic variations such as El Niño and La Niña events. The 2005 global temperature was statistically indistinguishable from 1998 and the NASA GISS data which also takes into account Arctic temperatures put 2005 as slightly warmer than 1998 which tied with 2007.[20] It

[18] 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.
[19] Peterson *et al.* (2008).
[20] See: http://data.giss.nasa.gov/gistemp/

is also critical to emphasise that atmospheric temperatures are only part of the story – the overwhelming proportion of increased heat has gone into warming the oceans since the 1950s.[21]

So despite the year-to-year variations in atmospheric temperatures, the long-term trend is upwards. Australia's Garnaut Review investigated the assertion that warming had finished, using experts in the analysis of time series data, who 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."[22] From a scientific, statistical perspective, there is no justification for asserting that the warming trend witnessed in the 20th century has ended.[23]

7. 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.[24] 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."[25] The emergence from the last ice age for example, was characterised by dramatic oscillations, or 'flickering' between cold and warm periods.[26]

The humanitarian, economic and security implications of unmitigated climate change would also be staggering.[27] In Africa 75-250 million people are expected to be suffering water stress by the 2020s and 350-600 million by the 2050s.[28] 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 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.[29] 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

[21] Barnett, *et al.* (2005); AchutaRao *et al.* (2007).
[22] Garnaut, (2008), p. 79.
[23] 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
[24] See: Pearce (2007); Alley (2004), Lenton *et al.* (2008).
[25] Hansen *et al.* (2007a), p. 1925.
[26] Taylor *et al.* (1993).
[27] On the security implications see: Dupont (2008), Chellaney (2007), Campbell *et al.* (2007) & Campbell (2008).
[28] Boko *et al.* (2007), p. 435.
[29] Qiu, (2008).

shrink from their 1995 extent of 500,000 km^2 to an expected 100,000 km^2 by 2035.[30] 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.[31]

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. It is particularly curious that those skeptics who place so much weight on the supposed economic dangers of reducing greenhouse gas emissions seem to give little or no weight to the dire economic, humanitarian and security implications of unmitigated climate change.

8. Science is not about consensus – the Wright brothers and Galileo were 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 periphery of every scientific field, for every true Galileo there are usually hundreds of people who would like to think of themselves as Galileo. Their odds are not good. It is perfectly rational for lay-people to take the agreement of the vast majority of qualified climate scientists as a strong signal that they are most probably right – particularly when evidence has been built up over many years and from many different fields, as in climate change. 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 the US, Canada, the UK, Germany, France, Italy, Japan, Russia, China, India, Mexico, South Africa and Brazil .[32] The skeptics' lack of confidence in their argument that the scientific consensus is irrelevant is reflected in their own attempts to garner signatures from professional scientists for statements asserting that humans are not one of the causes of climate change.

9. 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. This assertion relates to the well-known property that the warming effect of CO_2 in the atmosphere diminishes (logarithmically[33]) as its concentration increases, so that a doubling of CO_2 would lead to about **1.7ºC** of warming (not just 1ºC as is sometimes claimed) – but this applies only ***if*** we completely ignore the feedback effects on the climate system that flow from this increase in CO_2 or presume (on the basis of a climate model?) that the feedbacks cancel out.[34] Once those feedbacks are taken into account the temperature increase resulting from a doubling of pre-industrial CO_2 levels (referred to as the 'climate sensitivity') is "likely

[30] Cruz *et al.* 2007, p. 493, 481.
[31] IPCC, (2007b), p. 13.
[32] 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
[33] So each doubling of CO_2 adds a fixed amount of radiative forcing (Enting, 2007, p. 41-43) and hence temperature.
[34] Enting (2007), pp. 54-56.

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."[35]

The most recent assessment of climate sensitivity by James Hansen and his team, based on empirical geological evidence, is even more disturbing.[36] Hansen argues that the figure of 3°C for climate sensitivity 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.[37] 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.[38] What is the highest level of CO_2 the skeptics consider safe? Is there *any* level of CO_2 concentration they would agree is too high?

Note also that while some skeptics pour scorn on climate models as 'voodoo science', by asserting that the climate sensitivity to a doubling of CO_2 is just 1ºC, they are effectively adopting a climate model which either ignores *all* feedback effects, or which presumes that such effects cancel out. If we want to say something about the effects of greenhouse gases on climate there is no alternative but to use some kind of model – whether explicitly with equations, or implicitly with a conceptual model. Using any kind of model that arbitrarily assumes that feedback effects are zero, or just assuming that they all cancel out, is completely scientifically unjustifiable.

10. 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. The skeptics also tend to ignore the other greenhouse gases released by human activities, like CH_4 (methane), SF_6 (sulfur hexafluoride), N_2O (nitrous oxides), HFCs (hydrofluorocarbons), and PFCs (perfluorocarbons).

11. Any warming is the Sun's fault.

False. In 2002, solar physicist Sami Solanki wrote, "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

[35] 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.
[36] Hansen *et al.* (2008).
[37] Hansen *et al.* (2008), p. 226.
[38] The 1000 ppm figure is from Garnaut (2008), p. 246. It is equivalent to about 1600 ppm CO_2-e.

increase, with man-made greenhouse gases being the likely dominant alternative."[39] A recent study has further debunked the notion that variations in solar luminosity are responsible for the recent warming rather than greenhouse gases produced by humans, concluding: "Over 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."[40] It has also been shown that solar influences are not well correlated with past climatic changes, based on a 9000 year dataset.[41]

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

False. Some studies have reported 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. In discussing this argument, however 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.[42]

In somewhat more detail, the IPCC concluded that:

> [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 ...[43]

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'.[44]

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

[39] Solanki (2002), p. 5.13.
[40] Lockwood & Ehrlich (2007, 2008a &b). See also the similar conclusions of Foukal *et al.* (2006) following their comprehensive review of the literature.
[41] Turney *et al.* (2005).
[42] The Royal Society (2008), p. 9.
[43] Forster *et al.* (2007), p. 193.
[44] Forster *et al.* (2007), p. 202.

foundations, inadequate evidence and substantial disagreement among scientists as to their importance. This stands in stark contrast to their emphatic rejection of the warming effects of long-lived greenhouse gases, 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.[45] This 'uneven' approach to the scientific evidence on cosmic rays compared with greenhouse gases would seem to betray a pre-determined conclusion in a search of support, rather than an honest and rigorous appraisal of the weight of available scientific evidence.[46]

13. Lack of warming in the 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 skeptics 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".[47]

14. 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 the Earth's axis brought the Earth closer to the sun, warming the planet again. So for example, temperatures began to increase again, followed by the CO_2, with lags ranging from 200 to 2000 years. Climate change sceptics have often interpreted the fact that temperatures generally led the CO_2 increases as 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 amplifies 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 *always* came before CO_2 increases. We also know that, at least for termination III, "the CO_2 increase clearly precedes the Northern Hemisphere deglaciation."[48]

[45] Forster *et al.* (2007), p. 201.
[46] For more on this issue see: http://cce.890m.com/solar-cosmic-rays/
[47] 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/
[48] Caillon *et al.* (2003), p. 1730.

15. We should wait until there is more evidence before substantially 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 by John Tyndall[49] and Svante Arrhenius.[50] In modern times, scientists became increasingly concerned about the possibility of climate change several decades ago. 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.[51] 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."[52] 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"[53] 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."[54] 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[55]; we have about another 0.6ºC above 1980-99 levels guaranteed by 2100 from past emissions[56], plus another 0.4ºC from emissions over the next couple of decades as we try to bring our emissions under control.[57] So we are guaranteed at least 1.8ºC warming above pre-industrial 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

[49] Tyndall (1861).
[50] Arrhenius (1896).
[51] For Hansen's reflections 20 years later, see: http://www.columbia.edu/~jeh1/2008/TwentyYearsLater_20080623.pdf
[52] See: http://www.ipcc.ch/pdf/climate-changes-1995/ipcc-2nd-assessment/2nd-assessment-en.pdf p. 5.
[53] IPCC (2007a), p. 5.
[54] IPCC (2007a), p. 3.
[55] IPCC (2007a), p. 5
[56] IPCC (2007b), p. 19.
[57] IPCC (2007a), p. 12.

> 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.[58]

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.[59]

General remarks

- The 'skeptics' tend to concentrate on CO_2, ignoring other greenhouse gases.

- They tend to make a great deal of minor discrepancies in atmospheric temperature data, largely ignoring the huge body of other evidence for climate change such as:
    - The global melting of glaciers[60]
    - The accelerated melting of the Greenland ice sheet[61]
    - Unexpectedly rapid sea-level rise[62]
    - Tens of thousands of observed changes in species ranges and timing of annual ecosystem events[63]
    - Rapid Arctic ice melting[64],
    - The warming of the oceans[65]
    - The acidification of the oceans due to CO_2 absorption[66]
    - Changing hydrological and rainfall patterns with more extreme rainfall events.[67]

[58] Ramanathan & Feng (2008), p. 14245.
[59] Garnaut (2008), p. 287.
[60] WWF Nepal Program (2005); Meier *et al.* (2007).
[61] Chen *et al.* (2006); Zwally *et al.* (2002).
[62] Rahmstorf *et al.* (2007). ; Church & White (2006) ; Church *et al.* (2008).
[63] Rosenzweig *et al.* (2008); Menzel *et al.* (2006); Parmesan & Yohe (2003).
[64] Stroeve *et al.* (2007) ; Wang & Overland (2009).
[65] Barnett *et al.* (2005) ; Levitus *et al.* (2005).
[66] Hoegh-Guldberg *et al.* (2007); Orr *et al.* (2005); Riebesell (2008) ; Zeebe *et al.* (2008).
[67] Barnett *et al.* (2008); Zhang *et al.* (2007); Rajeevan *et al.* (2008).

- They usually admit climate is changing, but deny that CO_2 is one of the main causes, again ignoring the feedback effects of CO_2 on the climate system and ignoring the other very potent greenhouse gases human beings have released.

- Let's allow for the moment the argument that human greenhouse gas emissions have not contributed to warming so far, and that the warming we've seen (which is not in dispute) is entirely of natural origin: What is the policy implication? Well, we know 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 *theoretical* reasons, the skeptics believe that the greenhouse gases we emit will have *no impact* of any substance on the climate. Such a judgement has no sound basis in science and could only be arrived at by use of a climate model, which of course the skeptics disparage.

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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"
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