Global Warming and Uncertainty: – What is the appropriate response?

Address to Economic Society, 2 October 2009

Des Moore

Those who have knowledge, don't predict. Those who predict, don't have knowledge" – Lao Tzu, 6th Century BC Chinese Poet

I am grateful to members of the Society for agreeing to listen to what Nobel Prize winner Paul Krugman would doubtless characterise as "treason against the planet" ("Betraying the Planet", NY Times, 29 June 09). Of course, as our own true believing economist Professor Ross Garnaut accepts in his Final Report that "there are … large uncertainties in the science" (September 2008, page xvii), I assume even he would agree that Krugman is over the top. My own response to Krugman and his ilk would be to suggest that the main treasonable acts are by those advocating policies designed to lay waste to coal, which is this country's most valuable asset.

I would also refer any Krugmanites to famous American theoretical physicist and mathematician, Freeman Dyson, who accepts that warming causes problems but regards them as "grossly exaggerated". Dyson co-signed a letter to the UN strongly criticising the IPCC and deploring the open contempt shown by the majority of scientists to the minority who reject IPCC views. "In the history of science", he stated, "it has often happened that the majority was wrong and refused to listen to a minority that later turned out to be right."

Dyson is far from being the only sceptical scientist: around the world well over 30,000 scientists have expressed sceptical or dissenting views on global warming, including many Australians with expertise in climatology and one of our very own expert physicists Dr Tom Quirk with me here today who has constructed the circulated graphs. The astonishing claim by IPCC head, Pachauri, that "the number of sceptics is going down rapidly" (7.30 report, 29/9) is one of many examples of attempted factual deception by that body. Remember also that scientists are not gods: historically many have wrongly predicted disaster for the world unless governments intervene to control human activity. Christopher Booker and Richard North's recent book on *Scared to Death* reveals many examples over the past 30 years of governments acting on "expert" views of scientists whose analyses turned out to be totally wrong. Australia's professionally respected Productivity Commission has pointed out that "uncertainty continues to pervade the science and geopolitics and, notwithstanding the Stern Report, the economics". It adds that "independent action by Australia to substantially reduce GHG emissions, in itself, would deliver barely discernible climate benefits, but could be nationally very costly". It also describes the Stern report "as much an exercise in advocacy as it is an economic analysis of climate".

Although chief adviser to all Australian Governments, Garnaut has dodged any attempt to assess the science because, he claims, "the outsider to climate science has no rational choice but to accept that, on the balance of probabilities, the mainstream science is right in pointing to high risks from unmitigated climate change" (Final Report on Climate Change Review, September 2008). Based on this incorrect view he accepts that an externality exists requiring government intervention consistent with global action to stabilise CO2 concentrations at a level that would supposedly avoid further "dangerous" increases in temperatures. During a recent address I attended he also demonstrated a capacity for politicking by arguing that even if Australia went ahead without a binding global agreement there would be no significant adverse effects for us.

Let me just confirm here that I am not a scientist. But my nearly 50 years experience as an economic analyst both in Treasury and outside has provided me with a basis for assessing the credibility of much of the data used to justify the dangerous warming thesis and for examining alternative explanations by sceptical scientists. Contrary to Garnaut's claim, it is appropriate for outsiders involved in assessing policy options to pass judgement on science-based proposals.

My main conclusion, based on a national interest test, is that the uncertainties about mainstream science and the extent of dissent are so large that they rule out any application of the so-called precautionary principle. I also conclude that, even if it were accepted that temperatures will increase over time, the large uncertainties about the timing and extent of the alleged mitigating action said to be needed suggests that no case exists for governments to *start* a comprehensive program now to reduce greenhouse gas emissions. I discuss possible mitigatory timing and extent before considering the science.

Analysis of Economic Effects

Garnaut has acknowledged that a meaningful emissions reduction program would involve "a major change in the structure of our economy". However, like many other expert economic analysts here and overseas, he concludes that, over time, the net effect of mitigatory action will be beneficial. This conclusion is based on a view that, in addition to preventing damage from higher temperatures, Australian and other major economies have adaptive capacities that allow the transfer to low-emissions energy with only relatively small initial adverse economic effects. As that well known cynic, Ross Gittins, has observed, economists "think all we've got to do is switch to low-carbon energy sources … and the economy can go on growing as if nothing had happened" (The Age, 23 Sept).

The assumption that normal adaptive behaviour would readily make the necessary changes is seemingly reflected in the Treasury modelling of a "world without climate change" ("Climate change mitigation policy modelling, Summary of Assumptions and Data Sources", 3 Oct 2008). By contrast with some past Treasury analyses that have weighed up a range of possible influences on policy options, this modelling uses no error ranges and simply has an introductory note saying that "many of the assumptions used … are uncertain, especially over the long time horizons being examined". The outcome, which is described as "a function of assumptions used about labour supply and productivity" (p7), shows a sharp reduction in economic

growth after the current and next decades but, after 2030, growth then runs steadily on at about 2% pa per decade for the next 70 years. Treasury does not appear to model explicitly the outcome if there is no mitigatory action and it has published no economic analysis of the implications of a policy of Australia proceeding on its own (or with the EU only).

Garnaut's Final report identifies four types of costs of climate change that are potentially avoidable. However, only one type can apparently be modelled and there is an acknowledgement of resort to assumptions, including even "speculative" ones. Interestingly, the report also acknowledges that "the main costs … and therefore the main benefits of mitigation, accrue in the 22nd and 23rd centuries and beyond" (p249). And while accepting the possibility of large deadweight costs from "a distorted emissions trading scheme that diverts management effort from commercial activities into applying pressure for political preferment" (p252), no allowance is made in the modelling for any adverse effects from the extensive rent seeking already happening and likely to increase further.

The Garnaut modelling of the 550 ppm stabilisation objective by 2050 uses a temperature centred on a 5 degrees increase in the 21st century if no action is taken – that is, even higher than the IPCC range. However, "Australian material living standards are likely to grow strongly through the 21st century, with or without mitigation" (p565) and the modelling outcome finds "mitigation cutting the growth rate over the next half century, lifting it somewhat in the last decades" and a GDP at the end of the century "higher with 550 mitigation than without" (p 245). The graphical presentation of the mitigated outcome shows GDP about 5 per cent higher in 2100, without any error range (p 267). So, under a mitigatory policy the present generation would have lower growth for the next 40 or so years so that the next (and later) generations can (supposedly) benefit.

Looking at the matter another way, mitigatory action to reduce emissions apparently has the potential to "save" the slightly lower growth of GDP that the post 2050 generation would experience in the second half of the century, resulting in a "saving" for it of about 5% of GDP in 2100. However, the modelling also indicated that the "saving" would be from a GDP that at the end of the century would otherwise be 700 per cent larger in real terms than today even after supposed damage from higher temperatures.

What can we conclude from the modelling? My assessment is that it has the potential for substantive error given that normal adaptive behaviour is assumed despite the acknowledged major structural changes and that no allowance is made for possible "shock" effects. To quote just one other estimate, prominent climate economist Richard Tol (who was commissioned by Bjorn Lomborg) reportedly puts the cost of mitigatory action by 2100 at about 40 times greater than the benefits (see "Climate folly before failure" by Alan Wood, The Australian, 1 October). We are looking at a world of unknowables and no human modelling can tell us the answer. If there is mitigatory action between now and 2020 to lower emissions by 20 percent, there could be significantly greater adverse economic effects than suggested by the modelling. By definition countries would be shifting to productive systems based on less efficient capital and energy and there would also be a major increase in government intervention in economic decision-making with potential to inhibit

entrepreneurial activity outside the financial sector. In their pamphlet "Back to the 19th Century" some colleagues, including former Finance Minister Peter Walsh, have outlined the extensive potential for adverse influences.

This leads to three questions.

First, given that the Garnaut report effectively assumes that Australian living standards would increase progressively to ever higher levels even if there is also a large increase in temperatures, doesn't this suggest that a private sector that is getting wealthier and wealthier should be *directly* responsible for alleviating or suffering the main costs? This should mean a policy based mainly on adaptation rather than mitigatory action enforced by government.

Second, given the wide range already available of technological alternatives to fossil fuels, and having regard to the considerable research assistance already being provided by governments, is it not very likely that over the next 25 years one or more of those technologies will become economically viable? Indeed, even if this does not eventuate, is there any substantive reason why nuclear power could not start to be used in Australia, perhaps initially on a subsidised basis, and then extended progressively if temperatures do increase? (Even Garnaut states that "when the economic modelling includes a nuclear option for Australia, nuclear is adopted, supplying 27 per cent of total electricity demand by 2050 in the 550 scenario …" Final Report, p488). In sum, it is surely contrary to the national interest for the Government to start *now* to force reductions in CO2 emissions, let alone to mandate resort to alternatives to supply 20 per cent of electricity by 2020.

It is relevant that one parameter in the Treasury modelling is that "carbon capture and storage technology combined with coal and gas electricity generation is assumed to be available on a *commercial* scale from 2020 in both Australia and the world" (emphasis added). Did the Government accept this assumption and, if so, why is it proceeding with an emissions reduction policy?

Highly pertinent also is the reported analysis by the already mentioned German climate economist Richard Tol that "cutting emissions now is much more expensive because there are few inexpensive alternatives to fossil fuels" (See article by Bjorn Lomborg in The Australian in August). The most efficient emissions reduction strategy now would be one requiring only a very limited reduction, such as through a low carbon tax, to encourage alternatives.

Following on what I have just said, my third question is why is it necessary to "do a Stern" and look at what might happen beyond 2050 when temperatures are, or were, projected to reach an additional two degrees tipping point beyond which feedback will supposedly make it impossible to stop further increases? Existing alternative energy technologies will very likely develop to an economically usable level and, even if they don't history tells us that science would very likely produce a new, but now unknown viable solution sometime over the next 40 or so years. Think of all the scientific innovations over the last 40 years, such as in computerisation or even motor cars. It is simply childlike nonsense to argue for government intervention now to "save the planet" on the basis that no solution is *currently* available to the private sector on an economic basis.

My assessment of the published economic modelling, and the potential availability of alternative technology, leads me to conclude that there is no substantive basis for urgent action by Australia, let alone the world, to reduce greenhouse gas emissions. But, as Garnaut rightly says "Climate change policy must begin with the science" (Garnaut Climate Change Review Interim Report, February 2008, p8) and I turn now to consider the data used to justify the scientific basis.

Assessing the Science

I have already pointed out that there is no scientific consensus based on IPCC reports. The IPCC itself undertakes no scientific research and its head, Rajendra Pachauri, is not a scientist. Moreover, although its key public document ("Summary for Policy Makers") derives from submissions by scientists, there is evidence that the drafters of that public document have mainly been people sympathetic to the dangerous global warming view and that officials have refused to provide to outsiders data used to reach conclusions in IPCC reports. A considerable number of scientists who made submissions have subsequently rejected or qualified analyses in IPCC reports, the latest being German Professor Latif, a leading climate modeller who was a lead author to the last two reports that endorsed the thesis of continuing increases in temperatures in line with CO2 emissions. Professor Latif reportedly told the UN World Climate Conference in early September that, while he remains a believer, the absence of any warming for a decade and the probability that North Atlantic Oscillation cycles were probably "responsible for some of the strong global warming seen in the past three decades" makes it now likely that there will be "one or even two decades during which temperatures cool". He is not the first IPCC believer to acknowledge that there are periods when "natural" forces determine temperature levels and that there could now be a period of cooling or stasis. The increased acceptance of this makes it difficult to justify a need for urgent government action.

There are also now many scientific groups rejecting or questioning analyses in IPCC reports. The latest comprised more than 60 German scientists, including some who had made submissions to the IPCC, who on 26 July sent a letter to Chancellor Merkel asking for the convening of an impartial panel to review the latest climate science developments, stating that "humans have had no measurable role on global warming through CO2 emissions in temperature", and accusing the IPCC of completely ignoring facts of which it had to have been aware.

In the United States, a highly uncertain political situation exists following the securing of the passage of the ETS legislation by the House of Representatives by what amounted to bribery through the last minute use of special grants to Congressmen who otherwise would not have voted for the legislation. Public opinion polls in the United States have also changed over the past year or so from showing sceptics as a minority to having them as a slight majority of the population. Even the New York Times' environment journalist wrote on 4 August that as the IPCC gears up for its next climate review, "many specialists in climate science and policy, both inside and out of the network, are warning that it could quickly lose relevance unless it adjusts its methods and focus" (this suggestion appears to relate to, inter alia, a perceived need for the IPCC to assess the possible influence of melting ice sheets, which was expressly excluded from the 2007 report).

At the political level in Australia, apart from Senator Fielding's "outing" of himself and the notional acceptance by Climate Minister Wong that an alternative scientific view at least exists, there have been increasing public indications that considerable numbers of MP sceptics exist in the major political parties. A new political party – The Climate Sceptics – has also been formed to challenge the IPCC thesis (it also has other small government type policies) and stand candidates in next year's election. Last Saturday The Australian's editorial pointed out that "the science has been politicised".

The essence of the science is that the last 100 years of increasing global temperatures and concentrations of CO2 in the atmosphere will continue because increasing human activity involves the growing use of fossil fuels and hence increased emissions of carbon dioxide. Some emissions do not simply disappear into space but stay in the atmosphere in a concentrated form that reflects back to earth some of the heat radiated from the earth's surface. Hence (the story goes), as the concentrations also increase so too do temperatures. Assessing this story requires an examination of relevant data.

Temperatures and CO2 Concentrations

For the period since the mid 19th century the Hadley Centre's data shows very little change in temperatures until about 1920, then an upward trend until about 1940 followed by a downward trend until the late 1970s, then a clear increase until 1998 since when there has been a period of slight cooling (Figures 1 and 3 in graphs). There was a jump of about 0.6 of a degree in the late 1970s which coincided with an unexplained upwelling, resulting in slightly warmer surface temperatures across the tropical Pacific Ocean without any apparent connection with emissions of CO2.

These variations in temperatures have not been replicated in CO2 concentration levels, which except for a brief period in the 1940s have been on a continuous upward trend since the late 19th century, with the rate of growth increasing over the last 50 years. Looking at earlier history, which can be done through analyses of ice cores going back 130,000 years, this shows temperatures increased several hundred years *before* CO2 concentrations did (see Figure 6).

So, if temperatures vary but CO2 concentration levels do not how can a continuous increase in emissions be responsible for temperatures which vary? As mentioned, even some contributors to IPCC reports are recognising that *natural* influences, such as ocean upwellings or variations in the earth's orbit around the sun or in sunspot activity may cause variations in temperatures. But if natural influences cause such variations from time to time, how long are the fluctuations likely to last and doesn't this mean, at the very least, that there is much less urgency to start reducing emissions? We may well be in for a repetition of the 1940 to late 1970s experience of downward temperatures.

The fall-back position of the believers is that there is an underlying upward trend that will continue. The IPCC has claimed, for example, that global temperatures in the last 50 years are likely to have been the highest in at least the last 1300 years and both the CSIRO and the Government's Green paper assert that 12 of the last 13 years have been Australia's warmest.

But well-known features of history show that temperatures in periods when no official records were kept in the past, such as in the Medieval Warm Period (800-1,100 AD) and the Greco-Roman warm period (600 BC – 200 AD), have almost certainly been higher than recently. After the IPCC published in its 1990 report a graph showing temperatures for the Medieval period higher than for the 20th century, it did not repeat the publication in subsequent reports. It adopted the same tactic after the so-called hockey stick analysis it published, purporting to show rising temperatures only since industrialisation, was shown to be wrong in a report commissioned by the US Congress from an expert statistician. Presumably the IPCC strategy is, if we are wrong, we do not acknowledge the mistake but cease its publication. This scarcely gives confidence in the IPCC analyses.

I conclude that the IPCC analysis of what has caused (or not caused) global temperature levels in both the distant and recent pasts is seriously defective and does not form any basis for the projection of an increase in temperatures to 2100 ranging from 2-4 degrees. An alternative projection based what has happened over the last 50 years would imply an increase of only about one degree, well within the range in which humans already live comfortably. For example, Singaporeans live with an average temperature of about 27 degrees while Helsinki residents experience an average below 10.

Greenland, Antarctic and Arctic Ice Sheets

If large ice sheets and glaciers started to melt, sea levels rose and low-lying land became more susceptible to flooding that could be evidence of warming.

In regard to sea levels the latest IPCC report estimated for the relatively warm period from 1961 to 2003 an increase in average levels of 7 centimetres (about 3 inches), which is a lower rate of increase than had previously occurred since the end of the last Ice Age in the early 19th century. Looking ahead, the initial IPCC prediction to 2100 was for an increase ranging between 18 and 59 cms (about 2 feet). However, a dispute amongst "experts" led the IPCC to announce it was not making *any* prediction, another indication of doubts about the analytical capacity of the supposed experts.

Satellite measurements of sea levels from 1994 show an average rate of increase close to the lower end of the IPCC's initial predicted range, *but* with little or no increase in the last 5 years (See figure 11). Potential sea level problems are normal for the Dutch whose Meteorological Institute stated late last year that sea levels have risen 20 centimetres (about 8 inches) in the past century and there is "no evidence for accelerated sea-level rise".

As to the Arctic, while meltings did sharply reduce the extent of sea ice in 2007, that occurred when global temperatures were falling and during a prolonged period of cloudlessness in the area. Since then the sea ice has increased to levels in earlier years, although a downward trend remains (See Figure 12). However, more extensive meltings in the Arctic have occurred in the past when CO2 emissions were very much lower and such meltings have no effect on sea levels because the ice is already in the sea.

As to the Antarctic, the total ice area has been increasing and recently reached record levels (see Figure 12). Break offs of sections of the Antarctic ice sheet do occur but are normal and recent claims of a small increase in temperatures (from 50 degrees *below*) were largely based on estimates because there are no weather stations in large areas.

Droughts and Rainfall

Although the Green paper acknowledges that since the 1950s the north-east of Australia has become wetter (it actually appears to be more in the NW), much attention has been given by politicians of both sides to the below average rainfalls in other areas, particularly in the Murray-Darling Basin since 2000. Droughts are portrayed as reflecting in some way Australia's above average temperatures over that period (see Figure 9). Indeed, drawing on advice from the CSIRO and the BOM, Garnaut's modelling assumes that the projected higher temperatures will be accompanied by lower rainfall and, in the case of the MDB, "by mid-century it would lose half of its annual irrigated agricultural output … and by the end of the century … would no longer be a home to agriculture" (Final Report, p258).

There is no scientific basis for assuming such a threat to the MDB, whose variations in annual rainfall clearly show no connection with levels or variations in Australia's average temperature. Indeed, there was no statistically significant change in MDB rainfall over the whole period since 1900 and the above average temperatures in the 1980-2000 period were accompanied by *above average* rainfall (see Figures 9 & 10 and accompanying note).

Garnaut should revise his assessment and advise the Government that, as past Australian droughts occurred when global temperatures were lower than now and wetter years occurred when such temperatures were rising, there is no reason to expect that to change.

The Science of Emission Concentrations

The IPCC's 2001 report acknowledged that the climate is a "complex, non-linear, chaotic object" and that long-term prediction of climate states is "impossible". All such analytical qualifications have since disappeared seemingly because climate science has become politicised.

This has occurred despite the acceptance in IPCC reports of research that shows a progressive diminution in the temperature-increase effects from increases in CO2 concentration levels (see Figures 4 and 5). This research shows a greenhouse effect coming from the radiation back to earth from CO2 concentrations in the atmosphere. But it also shows this initial warming does not increase in line with the increase in CO2 concentration levels.

Calculations based on the research show that, even if CO2 concentrations doubled between now and 2100, temperatures would increase by no more than 0.5 of a degree. Expert meteorologist Professor Richard Lindzen of MIT has suggested the amount of carbon dioxide in the atmosphere may already have reached a level at which it is ceasing to have any significant warming effect. The IPCC's failure to recognise in its

conclusions that there is no linear relationship between temperatures and CO2 concentrations is yet another confirmation of its politicisation.

There is also very considerable doubt about the accuracy of the modelling used by the IPCC to project temperature increases. These models incorporate the positive feedbacks from water vapour that *increase* the radiation effects back to earth from increased CO2 concentrations (and hence cause some initial rise in temperatures). However, the models fail to take full account of the temperature *reducing* effects from the negative feedback coming from the strong increase in surface evaporation that also occurs as surface temperatures rise. This means that the IPCC models significantly *understate* the temperature reducing effects and the modelled outcome of larger CO2 concentrations is a much larger increase in surface temperature than would actually occur.

Conclusion

In conclusion, I submit that a policy based on adaptation by the private sector is the appropriate response to alarmist analyses proposing mitigatory action to prevent supposed dangerous global warming. My view is that there are fundamental faults in the science used to justify mitigatory action by governments; that claims of a consensus on the IPCC science have no credibility and that account is not taken of the long history of faulty analyses by scientists; that examination of the temperature and CO2 concentrations data indicates little or no causal connection between changes in the two; that there is no substantive evidence of threats from rising sea levels or meltings of sea ice in the Arctic or Antarctic; and that there is no evidence that droughts occur when temperatures increase.

Whatever the origins of the argument for extensive government intervention to reduce emissions of CO2, it has now become a political objective for those who want to increase the role of government in society. Vote ETS for bigger government.

170 YEARS OF ATMOSPHERIC MEASUREMENTS – 1840 TO 2010

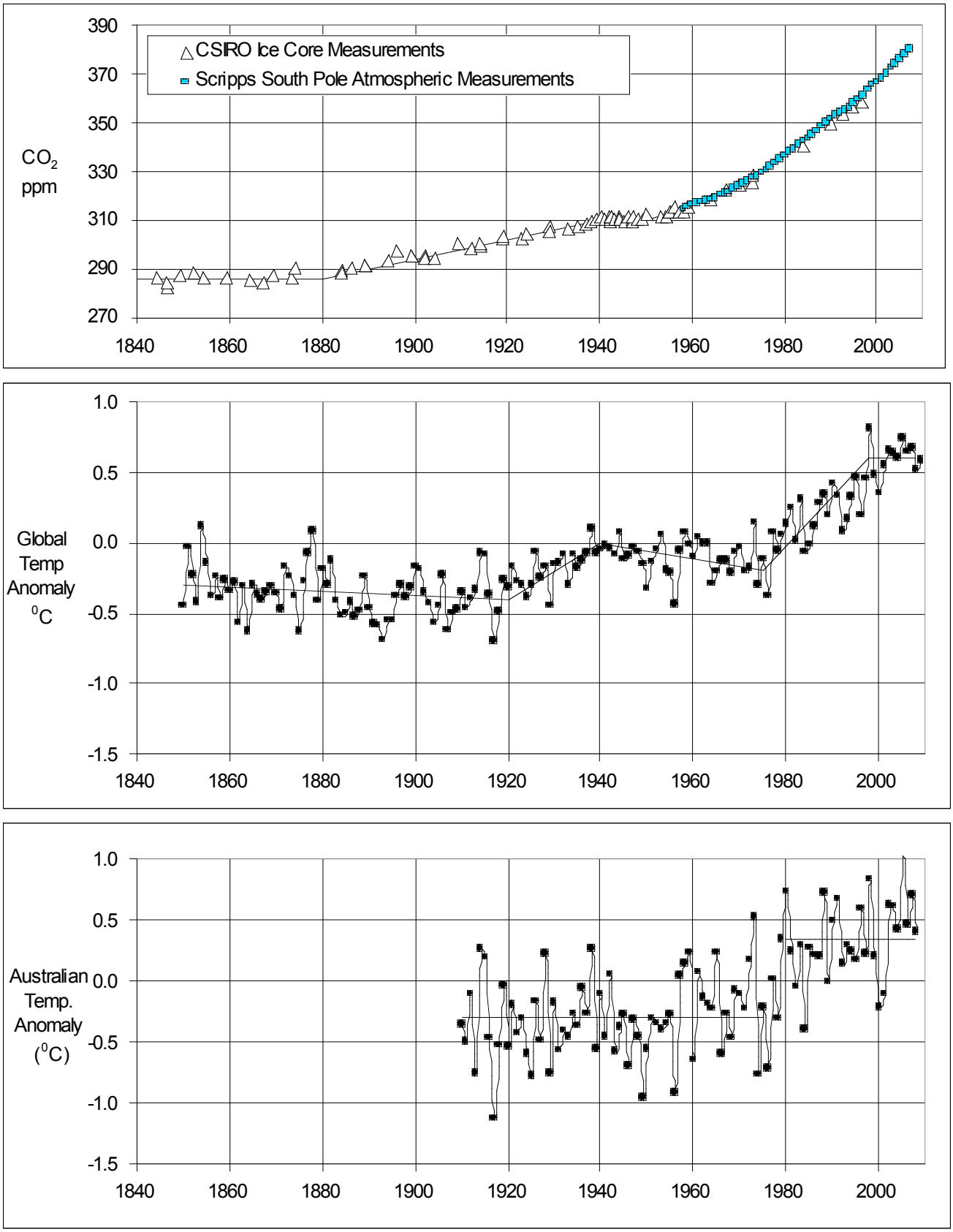


Figure 1: Top – *Ice core and atmospheric measurements of CO_2 concentration levels in Antarctica and at the South Pole. In the 1940s and early 1950s there was no increase in CO_2,* ***Middle –*** *Global temperatures estimated by the Hadley Centre of the UK Met Office. Solid lines indicate warming and cooling periods* ***and Bottom –*** *Australian temperature estimated by the Bureau of Meteorology. Note for the solid lines the 0.6^0C step is at the time of the Great Pacific Climate Shift in 1976.*

CO_2 IN THE ATMOSPHERE 1980 - 2008

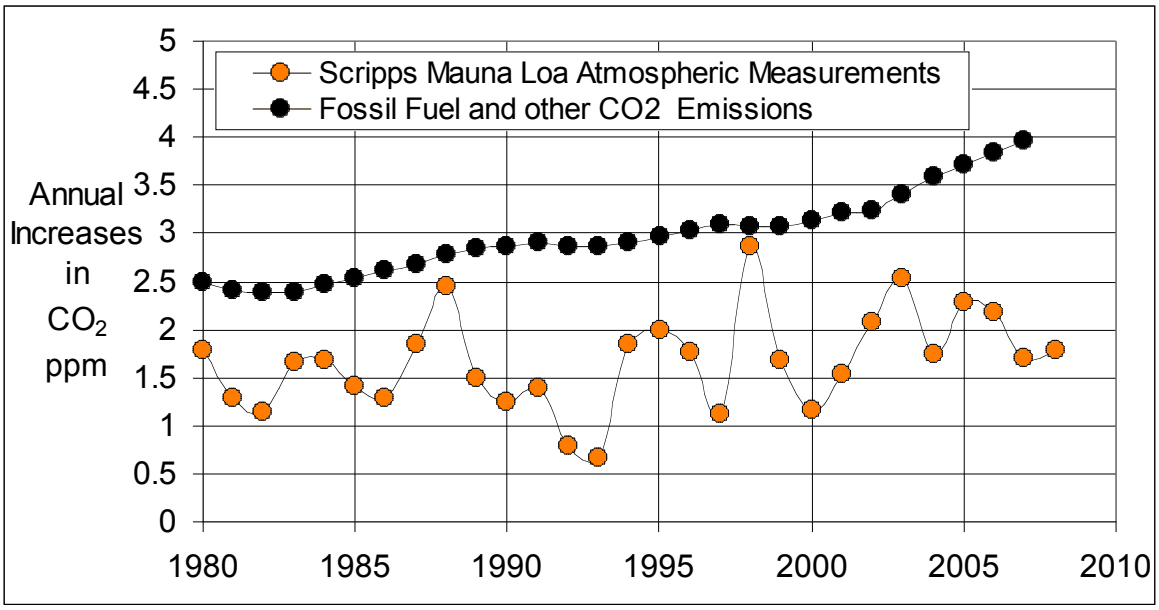


Figure 2: *Annual increases in atmospheric CO_2 concentrations measured at Mauna Loa, Hawaii (Scripps) and estimated annual emissions of CO_2 from human activity (Carbon Dioxide Information Analysis Center).*

ANNUAL GLOBAL TEMPERATURE ANOMALY 1980 TO 2009

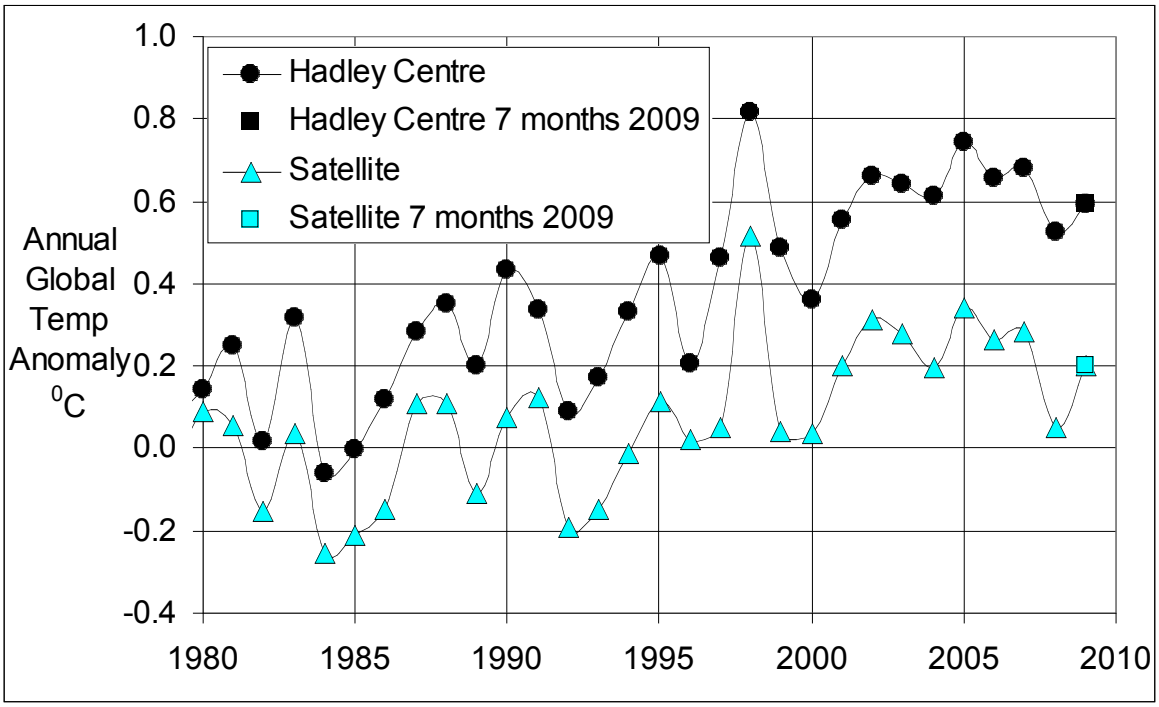


Figure 3 *Annual global temperature anomaly calculated from surface measurements (Hadley Centre of the UK Met Office) compared to the average for 1961 to 1990 and from satellite measurements (University of Alabama at Huntsville) compared to the satellite average for 1979 to 1998. Note that the year on year variations are in good agreement although the Hadley anomaly shows an increase of 0.1^{0}C per decade compared to the satellite values.*

The 1998 to 2008 data are compatible with no temperature change: Hadley +0.05 +/- 0.13 ^{0}C per decade and satellite (UAH) -0.05 +/- 0.15 ^{0}C per decade.

SURFACE ENERGY CHANGES FROM CO_2 IN THE ATMOSPHERE

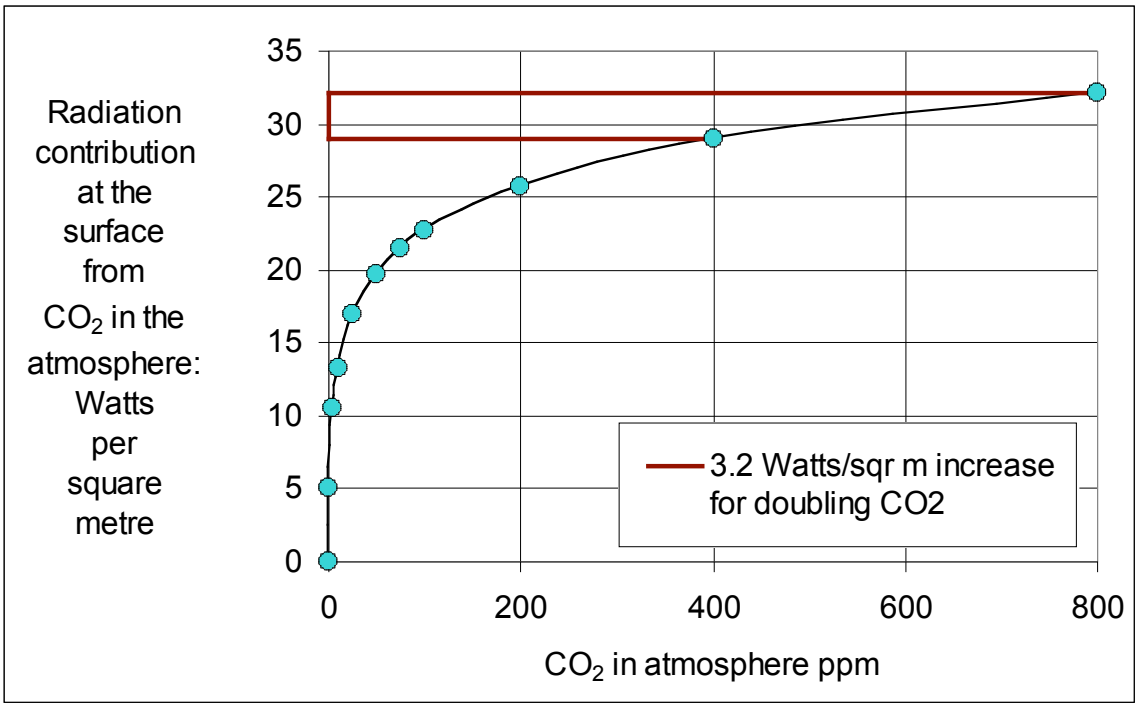


Figure 4 *As the concentration of CO_2 increases, there is increased radiation back to the surface of the earth (the greenhouse effect). This is measured in Watts per square metre (left axis). However the relationship is not linear. In fact doubling the concentration of CO_2 from 400 ppm to 800 ppm only increases the radiation from CO_2 at the surface by some 10% or 3.2 Watts per square metre. (Results derived for US standard atmosphere and cloudless sky from MODTRANS, a University of Chicago on-line calculator of energy in the atmosphere. MODTRANS is an international and IPCC accepted standard for atmospheric calculations).*

TEMPERATURE CHANGES AT THE SURFACE FROM CHANGES IN CO_2 CONCENTRATIONS

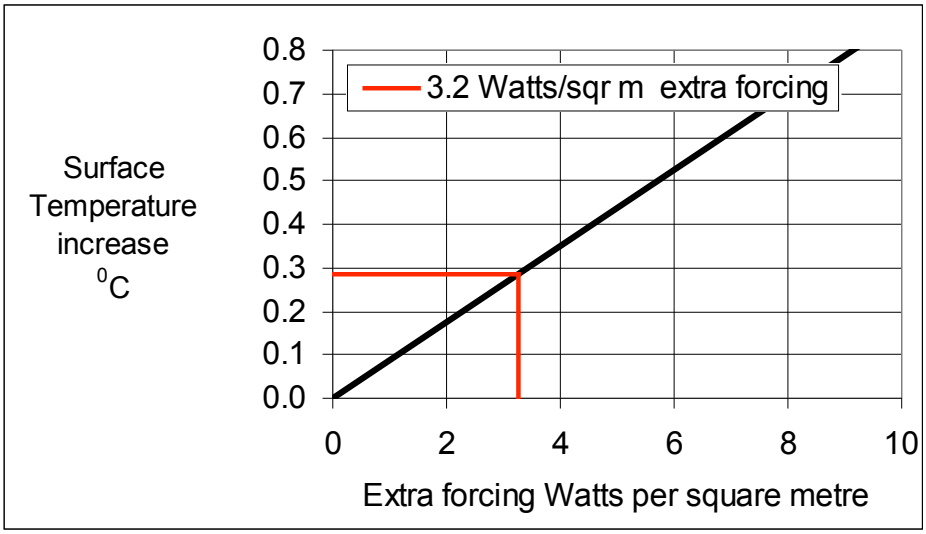


Figure 5 *Increased radiation forcing results in an increased surface temperature. However with 70% of the earth's surface as ocean, evaporation reduces the temperature increase by approximately a factor of two. Doubling the CO_2 concentration to 800 ppm with a 3.2 Watts per square metre radiation increase, gives a surface temperature increase of 0.3 ^{0}C. IPCC modelling suggests that this level of CO_2 will be reached in 2100 with their "business-as-usual" projection.*

TEMPERATURES RISE BEFORE CO_2 CONCENTRATIONS AT THE END OF ICE AGES

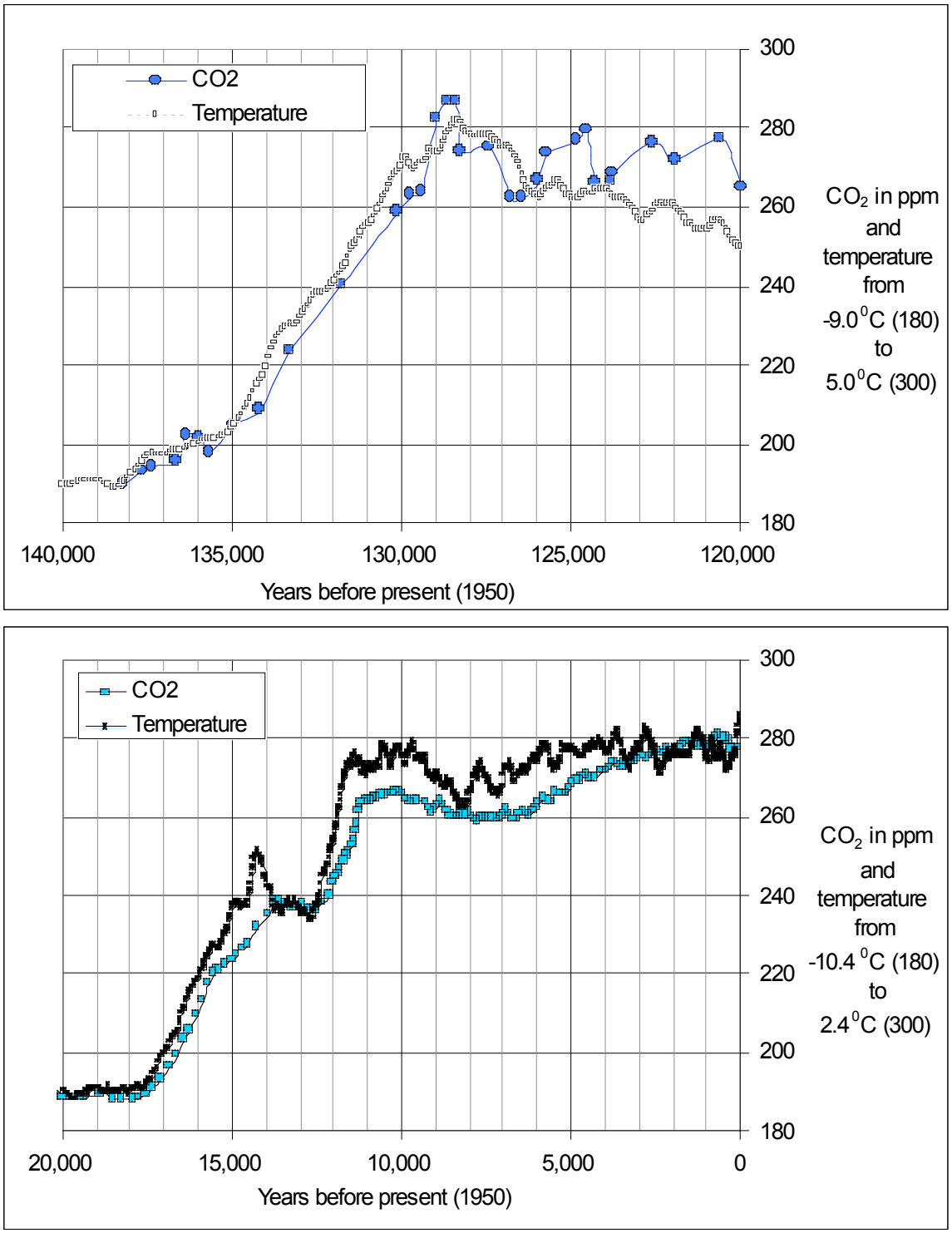


Figure 6 *Ice Core measurements at Vostok and EPICA in Antarctica. CO_2 measurements from air bubbles trapped in the ice. Temperatures estimated from changes in the oxygen and hydrogen isotope composition of the ice. Temperature rises lead CO_2 increases by several hundred years.* ***Top:*** *- End of the ice age 130,000 years before the present. Temperature increases by 6^0C. Note that temperature and CO_2 do not follow the same track after the end of the ice age. Temperature is likely to vary more with local conditions than CO_2. CO_2 levels come from a general sampling of the atmosphere. (Vostok measurements)* ***Bottom:*** *- End of the last ice age around 15,000 years before the present. Temperature increases by 8.5^0C. (EPICA measurements)*

GLOBAL MEAN RADIATIVE FORCING

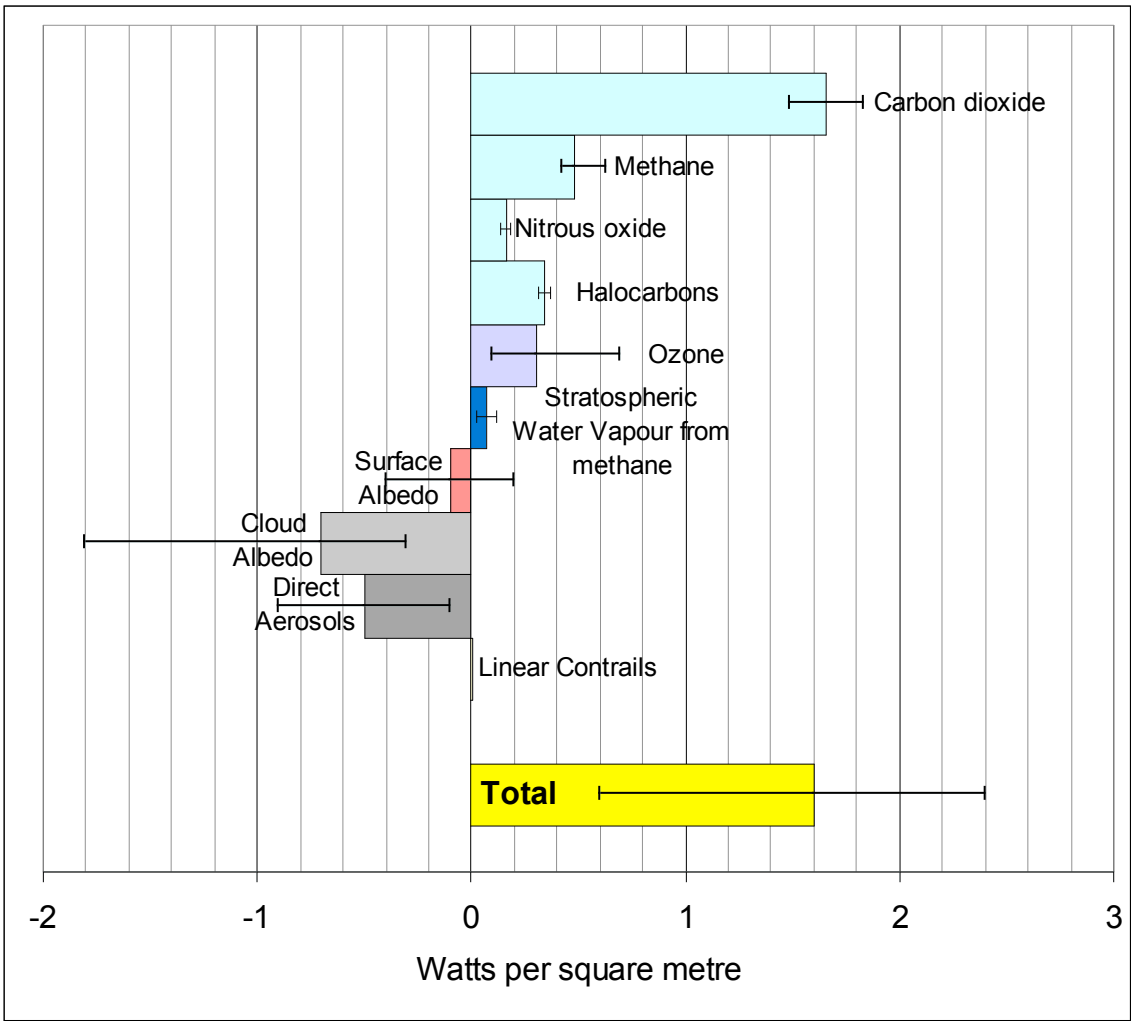


Figure 7: *Radiative forcings from various anthropogenic sources. This is the IPCC summary of the contributions from components of the atmosphere " the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2} (see Figure SPM.2)". [IPCC-AR4 2007 WG1 Fig SPM.2]. Note the large uncertainties for aerosol and albedo forcing, exceeding the values of greenhouse gas forcing. Some components have over 100% uncertainty and are most likely from expert opinion rather than measurements of uncertainty.*

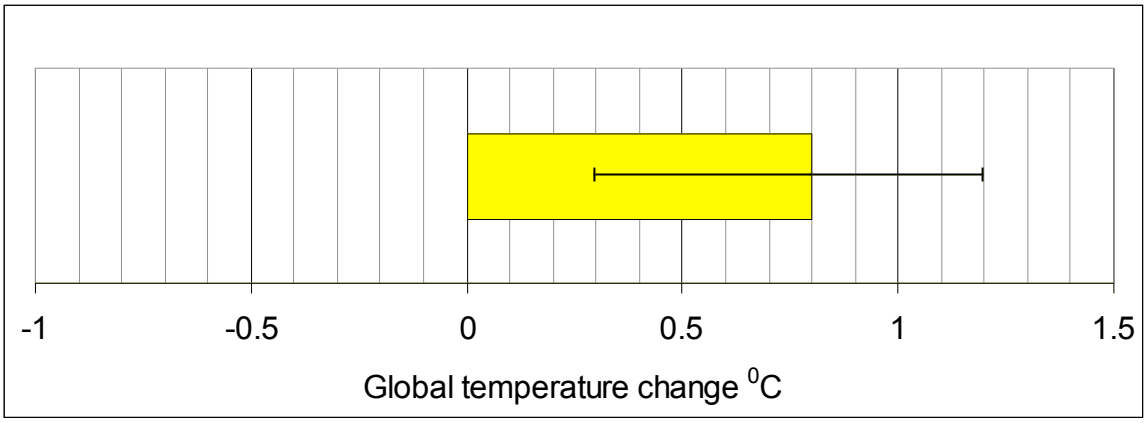


Figure 8: *IPCC inferred temperature increase of 0.8^{0}C since 1750. The temperature increase is the result of the 1.6 Watts per square metre estimated warming. Note the error bars that reflect the uncertainty in the temperature estimate are the compounded uncertainties of the radiation forcing where some components have over 100% uncertainty and are most likely from expert opinion rather than measurements of uncertainty.*

MURRAY-DARLING BASIN YEARLY RAINFALL 1900 TO 2008

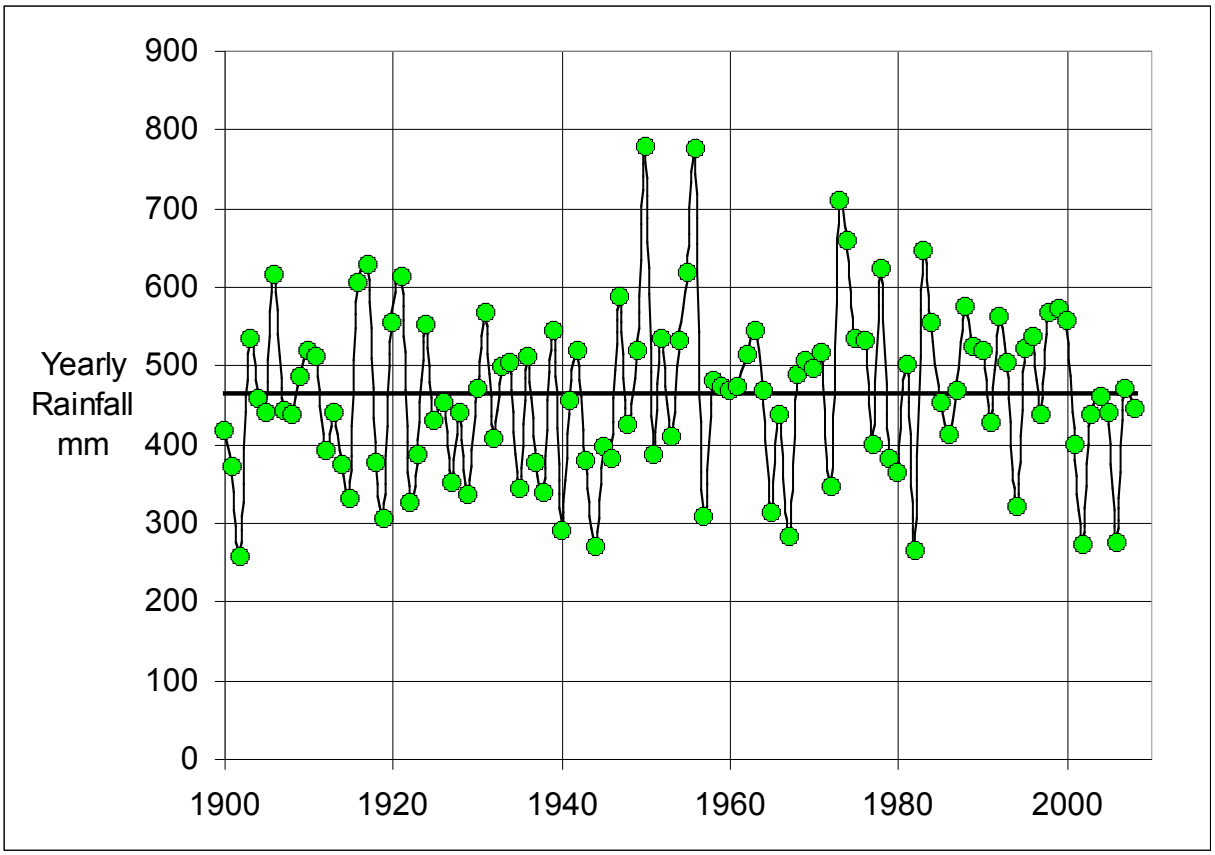


Figure 9: *Yearly rainfall in the Murray-Darling Basin. Mean value of 465 mm (solid line) and median 468 mm. There is no significant trend in rainfall through this period but with large variability- standard deviation of 106 mm with rainfall extremes of a minimum 257 mm and a maximum of 777 mm. It is therefore difficult to relate this to any temperature changes as shown in Figure 10.*

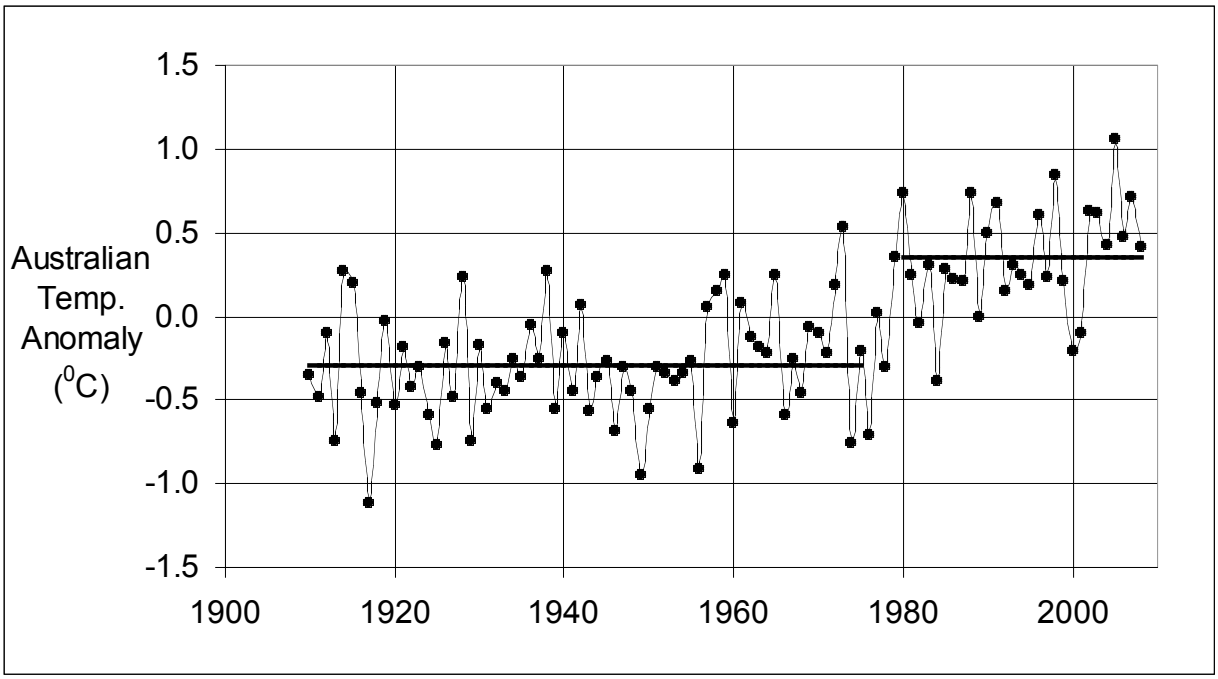


Figure 10– *Australian temperature anomaly estimated by the Bureau of Meteorology. The gap in the solid lines, a 0.6^{0}C step, is at the time of the Great Pacific Climate Shift of 1976.*

GLOBAL SEA LEVEL CHANGES

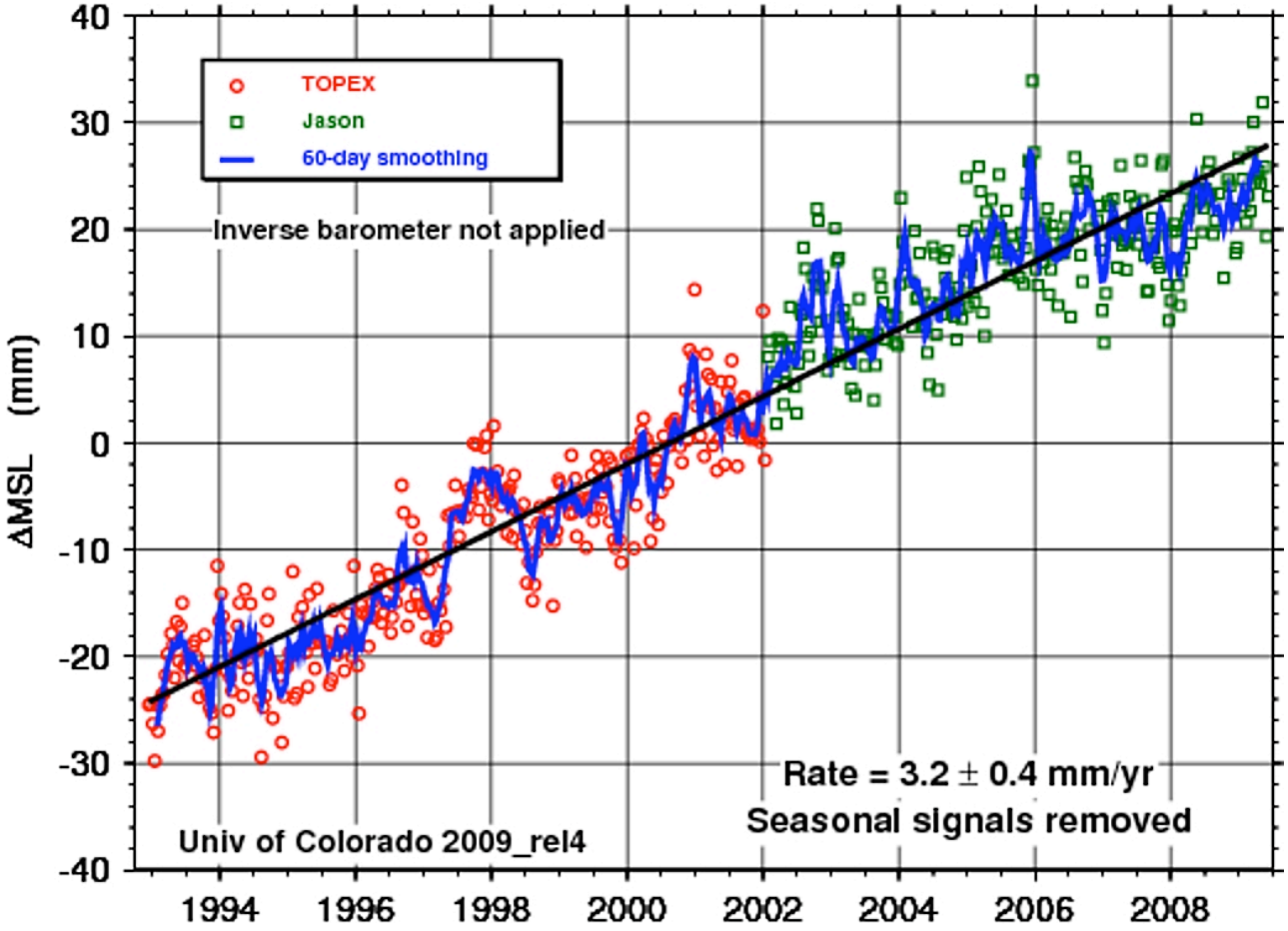
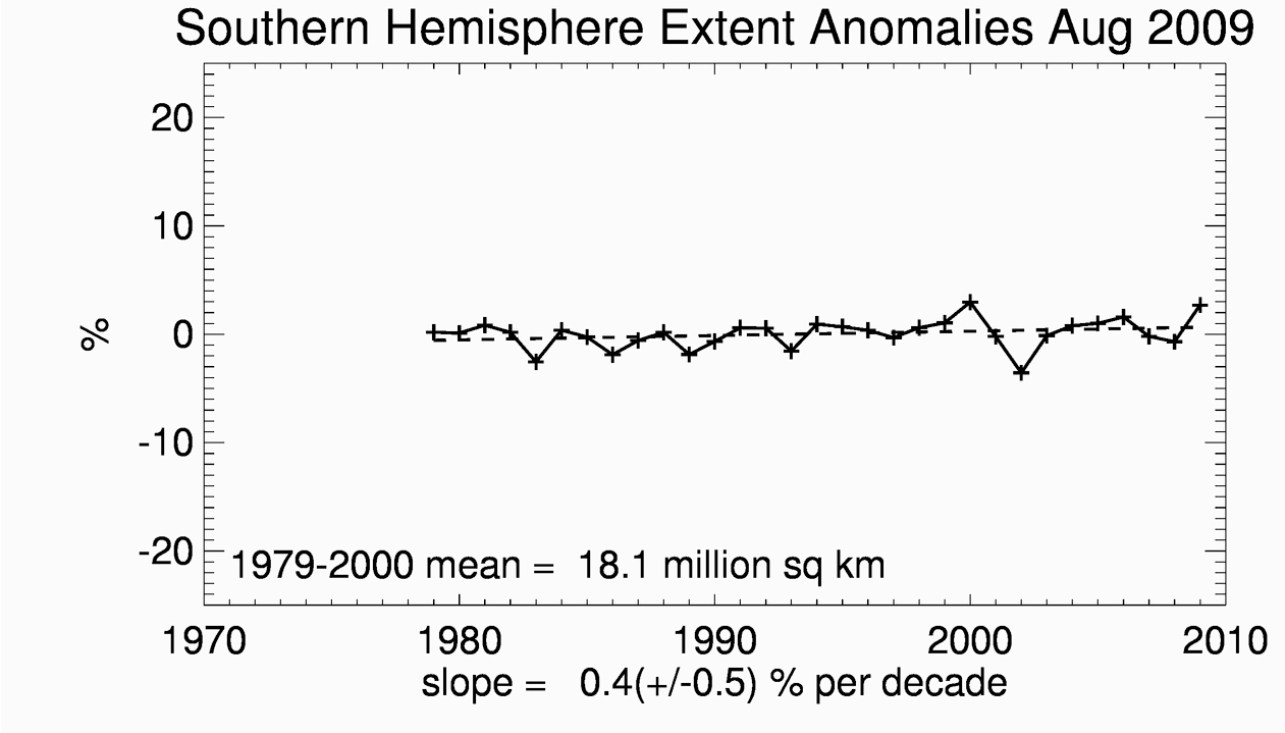


Figure 11 *The global mean sea level graph was made using satellite altimetry and processed by the University of Colorado at Boulder. Note that the rate of increase is 3.2 +/- 0.4 mm/year for1992 to 2009 but falls to 2.0+/- 0.4 mm/year for 2002-2009. These values are compatible with IPCC predictions to 2100.*

Long-term mean sea level change is a variable of considerable interest in the studies of global climate change. The measurement of long-term changes in global mean sea level can provide an important corroboration of predictions by climate models of global warming. Long term sea level variations are primarily determined with two different methods. Over the last century, global sea level change has typically been estimated from tide gauge measurements by long-term averaging. Alternatively, satellite altimeter measurements can be combined with precisely known spacecraft orbits to provide an improved measurement of global sea level change.

Since August 1992 the satellite altimeters have been measuring sea level on a global basis with unprecedented accuracy. The TOPEX/POSEIDON (T/P) satellite mission provided observations of sea level change from 1992 until 2005. Jason-1, launched in late 2001 as the successor to T/P, continues this record by providing an estimate of global mean sea level every 10 days with an uncertainty of 3-4 mm. The latest mean sea level time series and maps of regional sea level change can be found on this site. Concurrent tide gauge calibrations are used to estimate altimeter drift. Sea level measurements for specific locations can be obtained from our Interactive Wizard. Details on how these results are computed can be found in the documentation and the bibliography. Please contact us for further information



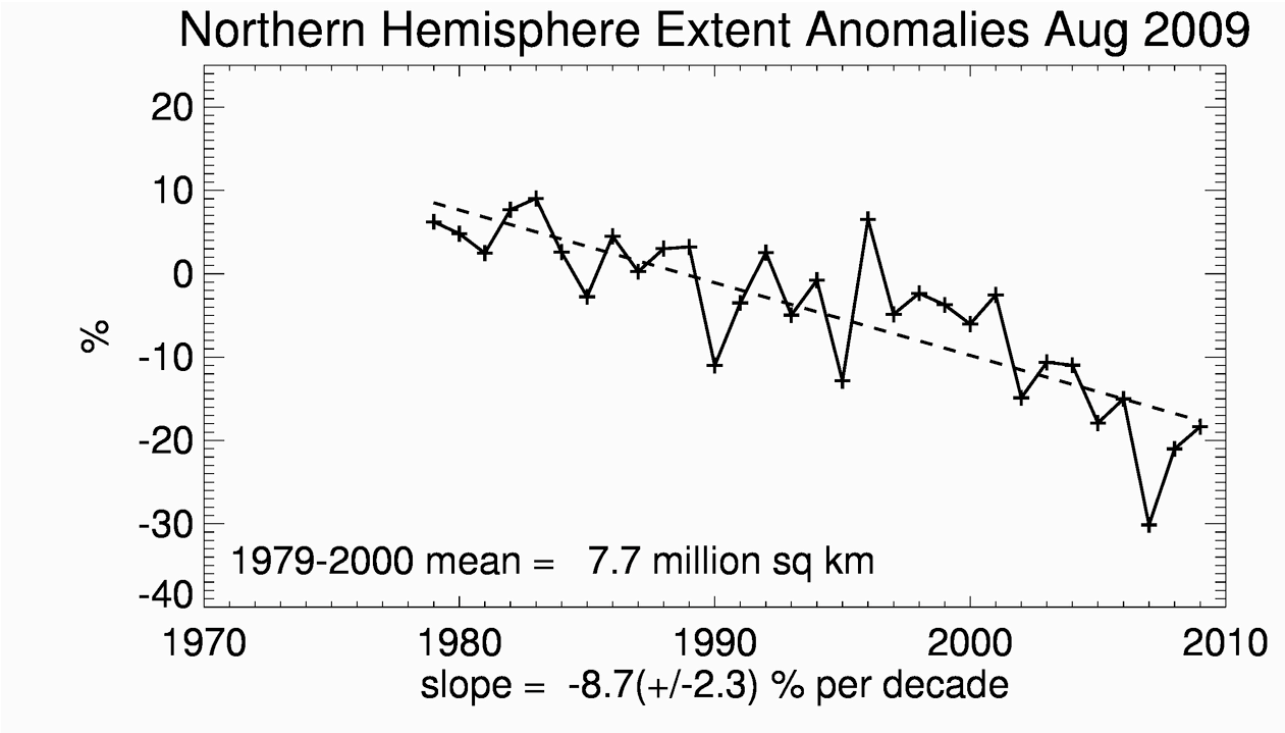


Figure 12 *Arctic and Antarctica ice extent. Note that the slopes for the fitted straight lines give the change per decade.*

Data from National Snow and Ice Data Center: http://nsidc.org/data/seaice_index/