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by

Stewart Smith

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EXECUTIVE SUMMARY

The major constituents of the atmosphere (oxygen and nitrogen) are essentially transparent to both the incoming solar radiation and the infrared radiation emitted upward from the earth's surface. A number of minor constituents, especially water vapour and carbon dioxide, are also largely transparent to the incoming solar radiation, but strongly absorb the infrared radiation emitted from the ground. The radiation absorbed by these gases is re-emitted in all directions, some back toward the surface leading to a net warming of the surface. These so-called greenhouse gases trap heat in the near surface layers of the atmosphere and thus cause the earth's surface to be considerably warmer than if there were no greenhouse effect. With no greenhouse gases, the earth would have an average temperature of –18 °C.

The global average surface temperature has increased by 0.6 +/- 0.2°C since the late 19th century. It is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861. Globally, 2005 was the second warmest year on record, and the hottest year on record for Australia.

Reconstructions of temperature over the last 1,000 years indicate that the temperature changes over the last hundred years are unlikely to be entirely natural in origin. The Intergovernmental Panel on Climate Change is recognised as the global authority on climate change. The IPCC concluded that most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations. The IPCC projects that global mean temperature will increase by 1.4 to 5.8 ˚C over the period 1990 to 2100. This projection has led many scientists to predict that if society pursues a 'business as usual' approach to greenhouse emissions, the collapse of society due to climate change is inevitable.

However, the 'consensus' science of the IPCC has been disputed. The majority of arguments put forward by greenhouse 'skeptics' can be categorised into three areas: recent warming of the earth's surface is not unusual in the context of climate history; general circulation models are not adequate representations of climate, and are unreliable to project future climate states; and projected global warming scenarios are exaggerated. In particular, the ability of global climate models to project future climate is disputed. For instance, the IPCC itself acknowledges that scientists do not know if clouds enhance or diminish the greenhouse effect.

'Contrarian' climate change scientists dispute the 'collapse of civilisation' predictions, with many believing that global warming will be at the lower end of the IPCC temperature range projections.

The challenge for governments is to assess this conflicting science to develop public policy.

PART ONE: THE GREENHOUSE CONSENSUS

1.0 INTRODUCTION

This paper reviews the science of climate change. After briefly explaining some of the fundamental forces driving world climate, the paper is divided into two sections. Section one presents the 'consensus' view on climate change – that human society and its greenhouse gas emissions are responsible for most of the observed warming of the planet over the last 50 years. Section two presents the contrarian view and provides a critique of climate change science.

1.1 The Fundamentals of World Climate

The major factors that determine the patterns of climate on earth include:

- The strength of the incident radiation from the sun, which determines the overall planetary temperature of the earth;
- the spherical shape of the earth and the orientation of its axis;
- the greenhouse effect of water vapour and other radiatively active trace gases;
- the various physical, chemical and biological processes that take place within the atmosphere - geosphere-biosphere climate system;
- the rotation of the earth, which substantially modifies the large-scale thermally-driven circulation patterns of the atmosphere and ocean; and
- the distribution of continents and oceans.

Energy from the sun is measured in watts per square metre (W/m^2). Earth receives an average solar influx of 1370 W/m^2. As the earth is spherical, each square metre receives about one fourth of this, or about 342 W/m^2. The majority of incoming solar radiation is absorbed in equatorial regions, whereas the polar regions emit considerable quantities of infrared radiation. This means that, averaged over the year, there is a net inflow of energy in the tropics and a net outflow of energy in high latitudes. To balance these differences, the atmosphere and oceans must transport energy towards the poles. This equator to pole or meridional radiation imbalance is the fundamental driving force of the climate system.[1]

The ocean covers 71% of the earth's surface to an average depth of 3800 m and plays a key role in redistributing heat around the globe. The relative heat capacity of the ocean compared to the atmosphere is huge - the heat capacity of the entire atmosphere is equivalent to that of only 3.2 m of ocean depth. Considerable amounts of thermal energy are stored in the ocean. The ocean is, however, not in equilibrium with the atmospheric and external climate system influences because of the long time-scales involved in many oceanic processes, such as the large-scale overturning of the deep ocean which takes thousands of years. Water carried from the surface to the deep ocean is isolated from atmospheric influence and hence may sequester heat for periods of a thousand years or more.[2]

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1 Burroughs,W. (Ed) *Climate Into the 21st Century.* World Meteorological Organisation, 2003.

2 Australian Bureau of Meteorology, *The Greenhouse Effect and Climate Change*, ND (post 2001), at 8.

1.2 The greenhouse effect

The major constituents of the atmosphere (oxygen and nitrogen) are essentially transparent to both the incoming solar (short wave) radiation and the infrared (long wave) radiation emitted upward from the earth's surface. A number of minor constituents, especially water vapour and carbon dioxide, are also largely transparent to the incoming solar radiation, but strongly absorb the infrared radiation emitted from the ground. The most significant is water vapour, which is not well mixed and may vary locally from less than 0.01% by volume to more than three per cent. The next most abundant is carbon dioxide, which has a long lifetime in the atmosphere and is well mixed around the globe. Other important trace gases include: methane; nitrous oxide; ozone; and anthropogenic halocarbon compounds, such as the ozone-depleting chlorofluorocarbons and hydrofluorocarbons.[3]

The radiation absorbed by these gases is re-emitted in all directions, some back toward the surface leading to a net warming of the surface. These so-called greenhouse gases trap heat in the near surface layers of the atmosphere and thus cause the earth's surface to be considerably warmer than if there were no greenhouse effect. With no greenhouse gases, the earth would have an average temperature of –18 °C. This is considerably lower than the observed average temperature of about 14 °C. Of the 32 °C difference in temperature due to the greenhouse effect, water vapour contributes 21 °C, carbon dioxide 7 °C and ozone 2 °C. Water vapour is thus the most important greenhouse gas.[4]

2.0 THE SCIENTIFIC BASIS OF CLIMATE CHANGE – THE IPPC THIRD ASSESSMENT REPORT

2.1 The Intergovernmental Panel on Climate Change

The Intergovernmental Panel on Climate Change (IPCC) was jointly established by the World Meteorological Organisation (WMO) and the United Nations Environment Program (UNEP) in 1988. The IPPC is open to all member countries of the WMO and UNEP.

The IPCC has three working groups and a Task Force on National Greenhouse Gas Inventories. The working groups are:

- Working Group I - assesses the scientific aspects of the climate system and of climate change;
- Working Group II - addresses the vulnerability of socio-economic and natural systems to climate change, the negative and positive consequences of climate change and options for adapting to them;
- Working Group III - assesses options for limiting greenhouse gas emissions and otherwise mitigating climate change.

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3 Australian Bureau of Meteorology, *The Greenhouse Effect and Climate Change*, ND (post 2001), at 2.

4 Burroughs,W. (Ed) *Climate Into the 21st Century.* World Meteorological Organisation, 2003.

Section one of this Background Paper is based on the work of Working Group 1 – the scientific basis of the greenhouse effect.

The IPCC's *First Assessment Report* was released in 1990. The *Second Assessment Report* was released in 1995 and the *Third Assessment Report*, on which this paper is based, in 2001. The *Fourth Assessment Report* is due in 2007.

IPCC reports are written by teams of authors nominated by governments and international organisations and selected for a specific task according to their expertise. Several hundred experts from all over the world are normally involved in drafting IPCC reports. In addition, several hundred experts participate in the review process. IPCC reports pass through a two-stage scientific and technical review process. For the first review, the drafts are circulated to specialists with significant expertise and publications in the field. Revised drafts are distributed for the second review to governments and to all authors and expert reviewers. After taking into account the expert and government comments, the final drafts are presented to plenary for acceptance of their content.

Summaries for Policymakers are prepared concurrently with the main reports and undergo a simultaneous expert and government review. They are approved in plenary session line-by-line, with the concurrence of the lead authors.[5]

Except where otherwise footnoted, this part of the paper is adapted from the Technical Summary of the IPCC Third Assessment Report.[6] This presents the consensus view of the greenhouse effect.

2.2 Observed Changes in Temperature

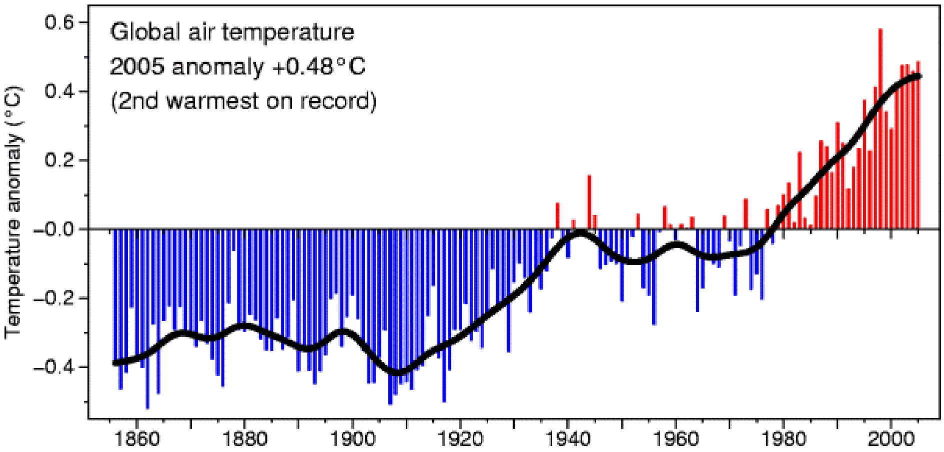
The global average surface temperature has increased by 0.6 +/- 0.2°C since the late 19th century. It is very likely that the 1990s was the warmest decade and 1998 the warmest year in the instrumental record since 1861. As shown in Figure 1, 1998 had a temperature anomaly of 0.58°C above the 1961-1990 mean (which is used as a reference period for temperature anomalies). 2005, with a temperature anomaly of +0.48 ˚C, is the second warmest year on record. Most of the increase in global temperature since the late 19th century has occurred in two distinct periods: 1910 to 1945 and since 1976. The rate of increase of temperature for both periods is about 0.15°C /decade. Nine of the ten warmest years have now occurred in the past ten years (1996-2005). The only year in the last ten not among the warmest ten is 1996 (replaced in the warm list by 1990).[7]

5 Intergovernmental Panel on Climate Change, *Introduction - The Intergovernmental Panel on Climate Change*. See IPCC website: http://www.ipcc.ch/about/about.htm, Accessed December 2005.

6 Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001.

7 World Meteorological Organisation, *Press Release – WMO Statement on the Status of the Global Climate in 2005*. See WMO website: http://www.wmo.ch/index-en.html, Accessed February 2006.

Figure 1: Global combined annual land surface and sea surface temperature anomalies 1861 to 2004.



Source: Climatic Research Unit, University of Anglia, United Kingdom. *Global Temperature Record*, See website http://www.cru.uea.ac.uk/cru/info/warming/, Accessed February 2006.

Whilst Figure 1 represents global averages, warming has not been uniform. In recent decades, the warming has been greatest over the continental northern hemisphere at latitudes between 40°N and 70°N. Generally, both day and night time temperatures have risen, although night time temperatures have generally warmed more than day time temperatures.[8]

The Third Assessment Report stated that an analysis of daily maximum and minimum land surface temperatures for 1950 – 1993 continue to show that the diurnal temperature range is decreasing very widely, although not everywhere. The global ocean heat content has increased significantly since the late 1950s. More than half of this warming has occurred in the upper 300 m of the ocean, equivalent to a rate of temperature increase in this layer of 0.04°C/decade.

2.3 Temperatures from satellite and weather balloon records

Surface temperature measurements from thermometers are available from 1860, whilst weather balloon measurements are available since 1958. Satellite temperature measurements of the troposphere[9] are available from 1979. The Third Assessment Report noted that balloon and satellite records show significantly less lower tropospheric warming than observed at the surface. Analysis of temperature trends since 1958 for the lowest 8km of the atmosphere and at the surface are in good agreement, with a warming of about 0.1°C/decade. However, since the beginning of the satellite record in 1979, the temperature data from both satellites and balloons show a warming of half this (0.05 +/-

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8 Australian Bureau of Meteorology, *The Greenhouse Effect and Climate Change*, ND (post 2001), at 26.

9 The troposphere is the lowermost portion of the atmosphere and the one in which most weather occurs. The troposphere starts at the earth's surface and extends to a height of 16-18 km over tropical regions, decreasing to less than 10 km over the poles. This layer contains approximately 80% of the atmosphere's total mass. The troposphere is directly below the stratosphere.

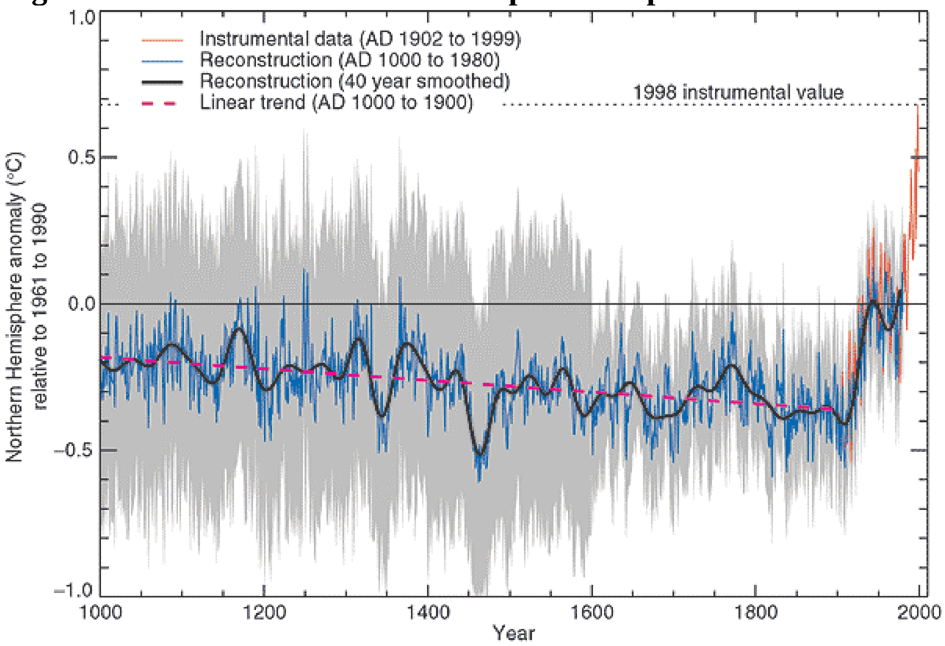
0.15°C/decade). The global average surface temperature has increased significantly by 0.15+/- 0.05°C/decade.

2.4 Surface temperatures during the pre-instrumental period from the proxy record.

It is likely that the rate and duration of the warming of the 20th century is larger than any other time during the last 1,000 years. The 1990s are likely to have been the warmest decade of the millennium in the Northern Hemisphere, and 1998 is likely to have been the warmest year.

Proxy records from tree rings, ice cores and corals can be used to reconstruct the historical temperature record. Figure 2 is a detailed temperature record of the Northern Hemisphere, adapted by the IPCC from the work of Mann, Bradley and Hughes from a 1999 publication. This analysis shows a relatively warm period associated with the 11th to 14th centuries and a relatively cool period associated with the 15th to 19th centuries in the Northern Hemisphere. Often referred to as the 'Medieval Warm Period' and the 'Little Ice Age' periods respectfully, the evidence does not support these events as being globally significant, but more of a Northern Hemisphere occurrence. As Figure 2 shows, the rate and duration of warming in the Northern Hemisphere in the 20th century appears to have been unprecedented during the millennium, and cannot simply be considered to be a recovery from the 'Little Ice Age' of the 15th to 19th centuries. The warmth of the recent decade is even warmer than the 95% confidence interval (shaded in grey in Figure 2) of temperature uncertainty, even during the warmest periods of the millennium.

Figure 2: Millennial Northern Hemisphere temperature reconstruction



Source: Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 29. Adapted from the work of Mann, Bradley and Hughes.

The work of Mann, Bradley and Hughes, as used extensively by the IPCC as in Figure 2 above, has resulted in what is referred to as the 'hockey stick' graph, because the curve looks like a hockey stick lying down. As will be discussed later, this graph is at the centre of much climate change debate.

The IPCC noted that because less data is available, less is known about annual average temperatures prior to about 1,000 years before present and for conditions prevailing in most of the Southern Hemisphere prior to 1861.

2.5 Observed changes in precipitation and atmospheric moisture

Since the Second Assessment Report (1995), annual land precipitation has continued to increase in the middle and high latitudes of the Northern Hemisphere, except over Eastern Asia. Over the sub-tropics, land surface rainfall has decreased on average, although this has shown signs of recovery in recent years. In contrast to the Northern Hemisphere, no comparable systematic changes in precipitation have been detected in broad latitudinal averages over the Southern Hemisphere.

It is likely that total atmospheric water vapour has increased several percent per decade in many regions of the Northern Hemisphere. Changes in total cloud amounts over Northern Hemisphere mid and high latitude regions indicate a likely increase in cloud cover of about two percent since the beginning of the 20th century, which has been positively correlated with decreases in the diurnal temperature range. Similar changes have been shown over Australia, the only Southern Hemisphere continent where such an analysis has been completed. Changes in total cloud amount are uncertain both over sub-tropical and tropical land areas, as well as over the oceans.

2.6 Observed changes in snow cover and land and sea ice extent

Decreasing snow cover and land ice extent continue to be positively correlated with increasing land surface temperatures. Satellite data show that there are very likely to have been decreases of about 10% in the extent of snow cover since the late 1960s. There is a highly significant correlation between increases in Northern Hemisphere land temperatures and the decreases. There is now ample evidence to support a major retreat of alpine and continental glaciers in response to 20th century warming. In a few maritime regions, increases in precipitation have overshadowed increases in temperature in the past two decades, and glaciers have re-advanced. Over the past 100 – 150 years, ground based observations show that there is very likely to have been a reduction of about two weeks in the annual duration of land and river ice in the mid to high latitudes of the Northern Hemisphere.

Arctic spring and summer sea ice has retreated 10 to 15% since the 1950s, consistent with an increase in spring temperatures and to a lesser extent, summer temperatures in the high latitudes. There is little indication of reduced Arctic sea ice extent during winter when temperatures have increased in the surrounding region. Similarly, Arctic sea ice thickness has likely decreased approximately 40% in late summer to early autumn between the period 1958 to 1976 (when submarines first began upward sonar profiling) to the mid 1990s. However, inter-annual variability and inter-decadal variability could be influencing these changes.

By contrast, no significant trends in Antarctic sea ice extent are apparent. There is no readily apparent relationship between decadal changes in Antarctic temperatures and sea ice extent since 1973. After an initial decrease in the mid 1970s, Antarctic sea ice extent has remained stable or even slightly increased. Although warming over Antarctica as a whole appears to have been perhaps half a degree in the last half century, the Antarctic Peninsula has warmed more rapidly, by more than 2˚C since the 1940s. This regional warming, the cause of which has yet to be fully discovered, has led to a southerly migration of the climatic limit of ice shelves, so that five ice sheets have retreated over the last century.[10]

2.7 Changes in sea level

Based on tide gauge data, the rate of global mean sea level rise during the 20th century is in the range 1.0 to 2.0 mm/yr, with a central value of 1.5 mm/yr. Based on the very few long term tide gauge records, the average rate of sea level rise has been larger during the 20th century than during the 19th century. No significant acceleration in the rate of sea level rise during the 20th century has been detected. This is not inconsistent with model results due to the possibility of compensating factors and the limited data.

Since the last glacial maximum about 20,000 years ago, the sea level has risen by over 120 metres as a result of the loss of mass from extensive ice sheets. Vertical land movements, both upward and downward, are still occurring in response to these large transfers of mass from ice sheets to oceans. The most rapid rise in global sea level was between 15,000 and 6,000 years ago, with an average rate of 10 mm/yr. Based on geological data, eustatic sea level (ie, corresponding to a change in ocean volume) may have risen at an average rate of 0.5 mm/yr over the past 6,000 years and at an average rate of 0.1 to 0.2 mm/yr over the last 3,000 years. This rate is about one tenth of that occurring during the 20th century.

2.8 Observed changes in atmospheric and oceanic circulation patterns

The behaviour of El-Nino / Southern Oscillation (ENSO) has been unusual since the mid 1970s compared with the previous 100 years, with warm phase ENSO episodes being relatively more frequent, persistent, and intense than the opposite cool phase. This recent behaviour of ENSO is reflected in variations in precipitation and temperature over much of the global tropics and sub-tropics. The overall effect is likely to have been a small contribution to the increase in global temperatures during the last few decades.

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10 Folland CK and Karl TR *et al*, Observed Climate Change and Variability, In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 126.

2.9 Observed changes in climate variability and extreme weather and climate events

In regions where total precipitation has increased, it is very likely that there have been even more pronounced increases in heavy and extreme precipitation events. The converse is also true. In some regions, heavy and extreme events have increased, despite the fact that total precipitation has decreased or remained constant. Overall, it is likely that for many mid and high latitude areas, primarily in the Northern Hemisphere, statistically significant increases have occurred in the proportion of total annual precipitation from heavy and extreme precipitation events. It is likely that there has been a 2 to 4% increase in the frequency of heavy precipitation events over the latter half of the 20th century.
There is no compelling evidence to indicate that the characteristics of tropical and extratropical storms have changed. Changes in tropical storm intensity and frequency are dominated by interdecadal to multidecadal variations, which may be substantial. In the Southern Hemisphere, analysis suggests a decrease in extra-tropical cyclone activity since the 1970s. In general, trends in severe weather events are difficult to detect because of their relatively rare occurrence and large spatial variability.

2.10 Conclusion to Evidence of a Warming World

The IPCC states that a suite of climate changes is now well documented, and taken together these trends illustrate a collective picture of a warming world. The IPCC summarises the trends as follows:

- Surface temperature measurements over the land and oceans have been measured and adjusted independently. All data sets show quite similar upward trends globally, with two major warming periods globally: 1910 to 1945 and since 1976. There is an emerging tendency for global land surface air temperatures to warm faster than the global ocean surface temperature;
- Weather balloon measurements show that lower tropospheric temperatures have been increasing since 1958, though only slightly since 1979. Since 1979, satellite data are available and show similar trends to balloon data;
- The decrease in the continental diurnal temperature range coincides with increases in cloud amount, precipitation, and increases in total water vapour;
- The nearly worldwide decrease in mountain glacier extent and ice mass is consistent with worldwide surface temperature increases. A few recent exceptions in coastal regions are consistent with atmospheric circulation variations and related precipitation increases;
- The decreases in snow cover and the shortening seasons of land and river ice relate well to increases in Northern Hemispheric land surface temperatures;
- The systematic decrease in spring and summer sea ice extent and thickness in the Arctic is consistent with increases in temperature over most of the adjacent land and ocean;
- Ocean heat content has increased, and global average sea level has risen;
- The increases in total tropospheric water vapour in the last 25 years are qualitatively consistent with increases in tropospheric temperatures and an enhanced hydrologic cycle, resulting in more extreme and heavier precipitation events in many areas with increasing precipitation.

However, some important aspects of climate appear not to have changed:

- A few areas of the globe have not warmed in recent decades, mainly some parts of the Southern Hemisphere oceans and parts of Antarctica;
- No significant trends in Antarctic sea ice extent are apparent over the period of systematic satellite measurements;
- Based on limited data, the observed variations in the intensity and frequency of tropical and extra-tropical cyclones and severe local storms show no clear trends in the last half of the 20[th] century, although multi-decadal fluctuations are sometimes apparent.

3.0 THE FORCING AGENTS THAT CAUSE CLIMATE CHANGE

Scientists have measured not only changes in climate, but also changes in the agents that can cause climate change. Most notable among these are increases in the atmospheric concentrations of greenhouse gases and aerosols (microscopic airborne particles or droplets) and variations in solar activity, both of which can alter the earth's radiation budget and hence climate. A change in the energy available to the global earth atmosphere system due to changes in these forcing agents is termed radiative forcing of the climate system. The radiative forcings of individual agents can be positive (ie, warms the earth) or negative (ie, cools the earth).

3.1 Observed changes in globally well mixed greenhouse gas concentrations and radiative forcing

Over the millennium before the industrial era, the atmospheric concentration of greenhouse gases remained relatively constant. Since then, the concentrations of many greenhouse gases have increased directly or indirectly because of human activities. Table 1 provides examples of several greenhouse gases and summarises their 1750 and 2003 concentrations, their change during the 1990s, and their atmospheric lifetimes. The latter, the atmospheric residence time of the greenhouse gas, is a highly relevant characteristic. Emissions of a greenhouse gas that has a long atmospheric residence time is a quasi-irreversible commitment to sustained radiative forcing over decades, centuries or millennia, before natural processes can remove the quantities emitted.

Table 1: Examples of greenhouse gases

	Carbon dioxide CO_2	Methane CH_4	Nitrous oxide N_20	Chlorofluoro-carbon –11 CFC-11	Hydrofluoro-carbon-23 HFC-23	Perfluoro-Methane CF_4
Pre-industrial concentration	About 280 ppm	About 700 ppb	About 270 ppb	Zero	Zero	40 ppt
Concentration in 1998 (in 2003)	365 ppm (375)	1745 ppb (1852/1730[a])	314 ppb (319/317[a])	268 ppt (256/253[a])	14 ppt (14)	80 ppt
Rate of concentration change	1.5 ppm/yr[b]	7.0 ppb/yr[b]	0.8 ppb/yr	-1.4 ppt/yr	0.55 ppt/yr	1 ppt/yr
Atmospheric lifetime	5 to 200	12	114	45	260	>50,000

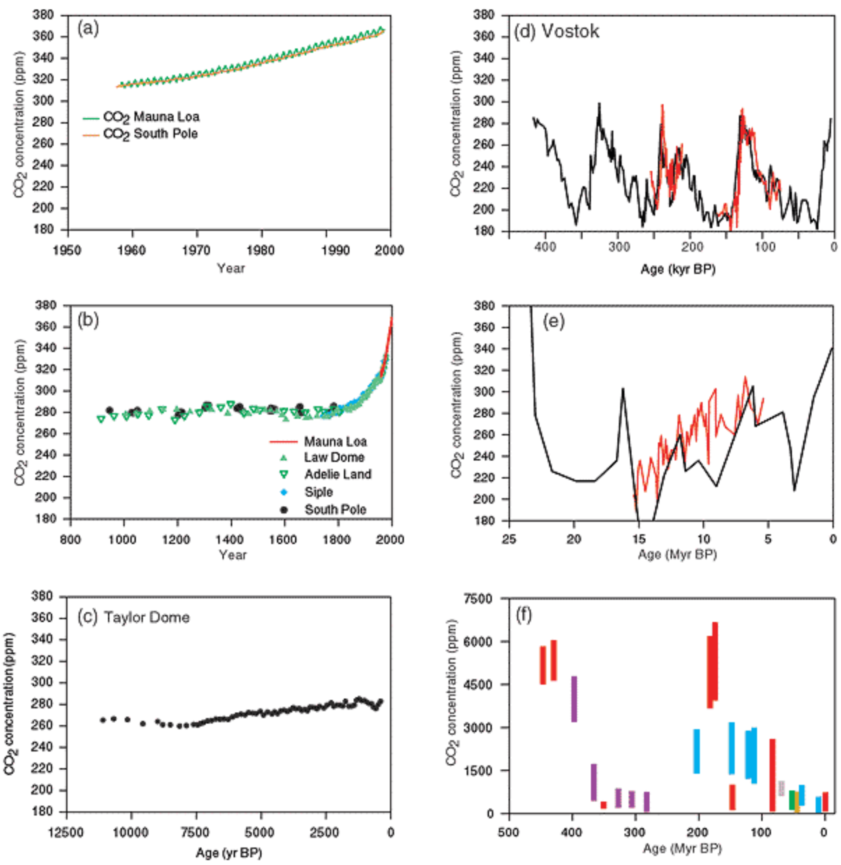
Notes:

[a]: The first value represents Mace Head, Ireland, a mid-latitude Northern-Hemisphere site, and the second value represents Cape Grim, Tasmania, a mid-latitude Southern-Hemisphere site.
[b]: Rate has fluctuated between 0.9 ppm/yr and 2.8 ppm/yr for CO_2 and 0 and 13 ppb/yr for CH_4 over the period 1990 – 1999.
ppm is parts per million; ppb is parts per billion; and ppt is parts per trillion.
Source: Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 38. Data from 2003 concentration of gases is from: Blasing, TJ and Jones S. *Current Greenhouse Gas Concentrations*, United States Department of Energy, Carbon Dioxide Information Analysis Centre, http://cdiac.esd.ornl.gov/pns/current_ghg.html, Accessed September 2005.

3.1.1 Carbon dioxide

The atmospheric concentration of carbon dioxide has increased from 280 ppm in 1750 to 375 ppm in 2003. Today's concentration of carbon dioxide has not been exceeded during the last 420,000 years, and likely not during the past 20 million years. The rate of increase over the past century is unprecedented, at least during the past 20,000 years. Most of the emissions during the last 20 years are due to fossil fuel burning, the rest (10-30%) is due to land use change, especially deforestation. Compared to the relatively stable concentration of carbon dioxide of the preceeding several thousand years, the increase in the Industrial Era is dramatic, as shown at a variety of different time scales in Figure 3.

Figure 3: Variations in atmospheric carbon dioxide concentrations on different time scales.



Notes:
(a): Direct measurements of atmospheric carbon dioxide, Mauna Loa, Hawaii;
(b): Carbon dioxide concentration in Antarctic ice cores for the past millennium. Recent measurements from Mauna Loa are shown for comparison;
(c): Carbon dioxide concentration in the Taylor Dome Antarctic ice core;
(d): Carbon dioxide concentration in the Vostok Antarctic ice core (different colours represent results from different studies);
(e) to (f): Geochemically inferred carbon dioxide concentrations (coloured bars and lines represent different published studies).
Source: Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 40.

The average rate of increase of carbon dioxide since 1980 is 0.4%/yr. Carbon dioxide is the dominant human influenced greenhouse gas, responsible for 60% of the total radiative forcing of all the globally mixed greenhouse gases. The next most important is methane, responsible for 20%, halocarbons 14% and nitrous oxide 6% of the proportional contribution to greenhouse warming.

3.1.2 Methane

Atmospheric methane concentrations have increased by about 150% since 1750. The present methane concentration has not been exceeded during the past 420,000 years. Methane is a greenhouse gas with both natural (eg wetlands) and human influenced sources (eg agriculture, natural gas activities and landfill). Slightly more than half of current methane emissions are anthropogenic.

The atmospheric abundance of methane continues to increase, from about 1,610 ppb in 1983 to 1,745 ppb in 1998, but the observed annual increase has declined during this period. The rate of increase in atmospheric methane is due to a small imbalance between poorly characterised sources and sinks, which makes the prediction of future concentrations problematic.

3.1.3 Halocarbons

The atmospheric concentrations of many of those gases that are both ozone depleting and greenhouse gases are either decreasing (CFC – 11, CFC – 113) or increasing more slowly (CFC – 12) in response to reduced emissions under the regulations of the Montreal Protocol. The combined tropospheric abundance of ozone depleting gases peaked in 1994 and is slowly declining. The atmospheric abundances of some of the major greenhouse halocarbons have peaked.

The observed atmospheric concentrations of the substitutes for CFCs are increasing, and some of these are greenhouse gases, although their contribution to radiative forcing is relatively small and future emissions are limited by the Montreal Protocol.

The perfluorcarbons have anthropogenic sources, extremely long atmospheric residence times, and are strong absorbers of infrared radiation. Therefore, these compounds, even with relatively small emissions, have the potential to influence climate far into the future.

3.1.4 Nitrous Oxide

The atmospheric concentration of nitrous oxide is now 16% larger than in 1750. The present concentration of nitrous oxide has not been exceeded during at least the past thousand years. The growth rate of atmospheric concentrations of nitrous oxide was 0.25%/yr from 1980 to 1998. However, significant interannual variations in the upward trend of nitrous oxide is observed. For instance, there was a 50% reduction in annual growth rate from 1991 to 1993. Since 1993, the growth rate has returned to rates closer to that of the 1980s.

3.1.5 Aerosols

Aerosols – very small airborne particles and droplets, are known to influence significantly the radiative budget of the earth/atmosphere. Aerosol radiative effects occur in two distinct ways:

- The direct effect, whereby aerosols themselves scatter and absorb solar and thermal infrared radiation; and
- The indirect effect, whereby aerosols modify the microphysical and hence the radiative properties and amount of clouds.

Aerosols are produced both naturally (eg dust storms and volcanic activity) and anthropogenically (including fossil fuel and biomass burning). Most aerosols are found in the lower troposphere, but the radiative effect of many aerosols is sensitive to vertical distribution. Aerosols undergo chemical and physical changes whilst in the atmosphere, notably within clouds, and are removed rapidly by precipitation – typically within a week. The radiative forcing of aerosols depends not only on their distribution, but also on the size, shape and chemical composition of the particles and the various aspects of the hydrological cycle. Hence obtaining accurate estimates of this forcing have been challenging. In terms of measuring the direct effect of aerosols, a negative forcing (ie cooling effect) is found for: sulphate; biomass burning; and fossil fuel organic carbon aerosols, and a positive forcing for fossil fuel black carbon aerosols. However, uncertainties remain relatively large. Estimates of the indirect radiative forcing by anthropogenic aerosols remain problematic, although observational evidence points to a negative aerosol induced indirect forcing in warm clouds.

3.2 Observed and modelled changes in solar and volcanic activity

The fundamental source of all energy in the earth's climate system is radiation from the sun. Therefore, variation in solar output is a radiative forcing agent. Radiative forcing of the climate system due to solar irradiance change is estimated to be 0.3 +/- 0.2 watts per square metre, and most of the change is estimated to have occurred in the first half of the 20^{th} century. Since the late 1970s, satellite instruments have observed small oscillations (of about 0.1%) due to the 11 year solar cycle. Other mechanisms for the amplification of solar effects on climate have been proposed, but do not have a rigorous theoretical or observational basis.

Enhanced stratospheric aerosol content due to volcanic eruptions, together with small solar irradiance variations, resulted in a net negative natural radiative forcing over the past two, and possibly even the past four, decades.

3.3 The Simulation of the Climate System and its Changes

A climate model is a simplified mathematical representation of the earth's climate system. The degree to which the model can simulate the responses of the climate system hinges to a very large degree on the level of understanding of the physical, geophysical, chemical and biological processes that govern the climate system. Since the Second Assessment Report, researchers have made substantial improvements in the simulation of the Earth's climate system with models.

Overall, the Third Assessment Report concluded that coupled models[11] have evolved and improved significantly since the second report. In general, they provide credible simulations of climate, at least down to sub-continental scales and over temporal scales from seasonal to decadal. Confidence in the ability of models to project future climates is increased by the ability of several models to reproduce warming trends in the 20th century surface air temperatures when driven by increased greenhouse gases and sulphate aerosols. Analysis and confidence in extreme events simulated within climate models are still emerging, particularly for storm tracks and storm frequency. The performance of coupled models in simulating ENSO has improved, however its variability is displaced westward and its strength is generally underestimated.

4.0 THE IDENTIFICATION OF A HUMAN INFLUENCE ON CLIMATE CHANGE

This section of the Third Assessment Report used the information from previous sections to examine the question of whether a human influence on climate change to date can be identified. Detection is defined as the process of demonstrating that an observed change is significantly different (in a statistical sense) to that which can be explained by natural variability. Attribution is the process of establishing cause and effect with some defined level of confidence.

The Third Assessment Report noted that three of the last five years (1995, 1997 and 1998) were the warmest globally in the instrumental record. Since the Report, published in 2001, the years 2001, 2002, 2003, 2004 and 2005 have each been warmer than 1995 or 1997 (but cooler than 1998). Reconstructions of temperature over the last 1,000 years indicate that the temperature changes over the last hundred years are unlikely to be entirely natural in origin. The warming over the past 100 years is very unlikely to be due to internal variability alone.

Assessments based on physical principles and model simulations indicate that natural forcing alone is unlikely to explain the recent observed global warming or the observed changes in vertical temperature structure of the atmosphere.

Most attribution studies find that, over the last 50 years, the estimated rate and magnitude

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11 The climate system can be represented by models of varying complexity. Coupled atmosphere/ocean/sea-ice General Circulation Models provide a comprehensive representation of the climate system.

of global warming due to increasing concentrations of greenhouse gases alone are comparable with or larger than the observed warming. Uncertainties in other forcings that have been included do not prevent identification of the effect of anthropogenic greenhouse gases over the last 50 years. It is very likely that the 20th century warming has contributed significantly to the observed sea level rise, through thermal expansion of sea water and widespread loss of sea ice.

Some progress has been made in reducing uncertainty, though many of the sources of uncertainty in the Second Assessment Report still exist. These include:

- Discrepancies between the vertical profile of temperature change in the troposphere seen in observations and models;
- Large uncertainties in estimates of internal climate variability from models and observations. Although these are unlikely (bordering on the very unlikely) to be large enough to nullify the claim that a detectable climate change has taken place;
- Considerable uncertainty in the reconstructions of solar and volcanic forcing which are based on proxy or limited observational data for all but the last two decades;
- Large uncertainties in anthropogenic forcing are associated with the effects of aerosols;
- Large differences in the response of different models to the same forcing. These differences, which are often greater than the difference in response to the same model with and without aerosol effects, highlight the need to quantify uncertainty and reduce it through better observational data sets and model improvement.

Conclusion
In the light of new evidence and taking into account the remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations.

5.0 THE PROJECTIONS OF THE EARTH'S FUTURE CLIMATE

Climate models are used with future scenarios of greenhouse emissions and other climate forcing agents such as aerosols to make a suite of projected future climate changes. Whilst the previous section of this paper described climate models, the next section describes future scenarios of greenhouse emissions.

5.1 The IPCC Special Report on Emission Scenarios

In 1992 the Intergovernmental Panel on Climate Change released emission scenarios to be used for driving global circulation models to develop climate change scenarios. The so-called IS92 scenarios were the first global scenarios to provide estimates for the full suite of greenhouse gases. In 1996 the IPCC decided to develop a new set of emission scenarios to provide input into the IPCC Third Assessment Report. The resultant IPCC Special Report on Emission Scenarios (often referred to as SRES) was approved on 15 March 2000.

Four different narrative story lines were developed to describe the relationships between the forces driving emissions and their evolution. The resulting set of 40 scenarios cover a wide range of the main demographic, economic and technological driving forces of future greenhouse gas and sulphur emissions. 35 of the scenarios developed contained the full range of gases required to force climate models. The four emission storylines were:

- A1 – very rapid economic growth, a global population that peaks in mid-century and declines thereafter, and rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1F1); non-fossil energy sources (A1T); or a balance across all energy sources (A1B).
- A2 – this storyline describes a very heterogenous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower than other storylines.
- B1 – this storyline describes a convergent world with the same population as the A1 storyline (peaks in mid-century and declines thereafter), but with rapid change in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives;
- B2 – this storyline describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B2 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

None of the scenarios developed included explicitly the implementation of the United Nations Framework Convention on Climate Change or the emission targets of the Kyoto Protocol. As the final scenarios were not approved until March 2000, this was too late for the modelling community to incorporate them into their models and have the results available in time for the Third Assessment Report. Instead, in 1998 one marker scenario was chosen from each of the four scenario groups. In addition, two scenarios from the A1 family (one non-fossil energy scenario and one balanced energy scenario) were chosen, as these scenarios explore alternative technology developments, holding the other driving forces constant. Hence six illustrative scenarios were selected, all of them considered equally plausible.

5.2 Projections of future changes in greenhouse gases and aerosols

Models indicate that the six illustrative SRES scenarios lead to very different carbon dioxide concentration trajectories. By 2100, models project atmospheric carbon dioxide concentrations of 540 ppm (scenario B1) to 970 ppm (scenario A1F1). This is 90 to 250% above the concentration of 280 ppm in 1750. Uncertainties, especially about the magnitude of the climate feedback from the terrestrial biosphere, cause a variation of –10 to +30% around each scenario. Hence the total range is 490 to 1260 ppm, 75 to 350% above the 1750 concentration.

5.3 Projections of Future Changes in Temperature

5.3.1 Atmosphere – Ocean Global Climatic Model

Climate sensitivity is the term used to describe the equilibrium response of global surface temperature to a doubling of equivalent carbon dioxide concentration. The Atmospheric – Ocean General Climatic Models (AOGCM) indicate that climate sensitivity is likely to be in the range of 1.5 to 4.5 ˚C. The range in estimates arises from uncertainties in the climate models and their internal feedbacks, particularly those related to clouds.

The Third Assessment Report also modelled what is called the Transient Climate Response. This is defined as the globally averaged surface air temperature change, at the time of doubling of carbon dioxide, when carbon dioxide is increased by 1% each year. The range of the Transient Climate Response for AOGCMs was 1.1 to 3.1 ˚C.

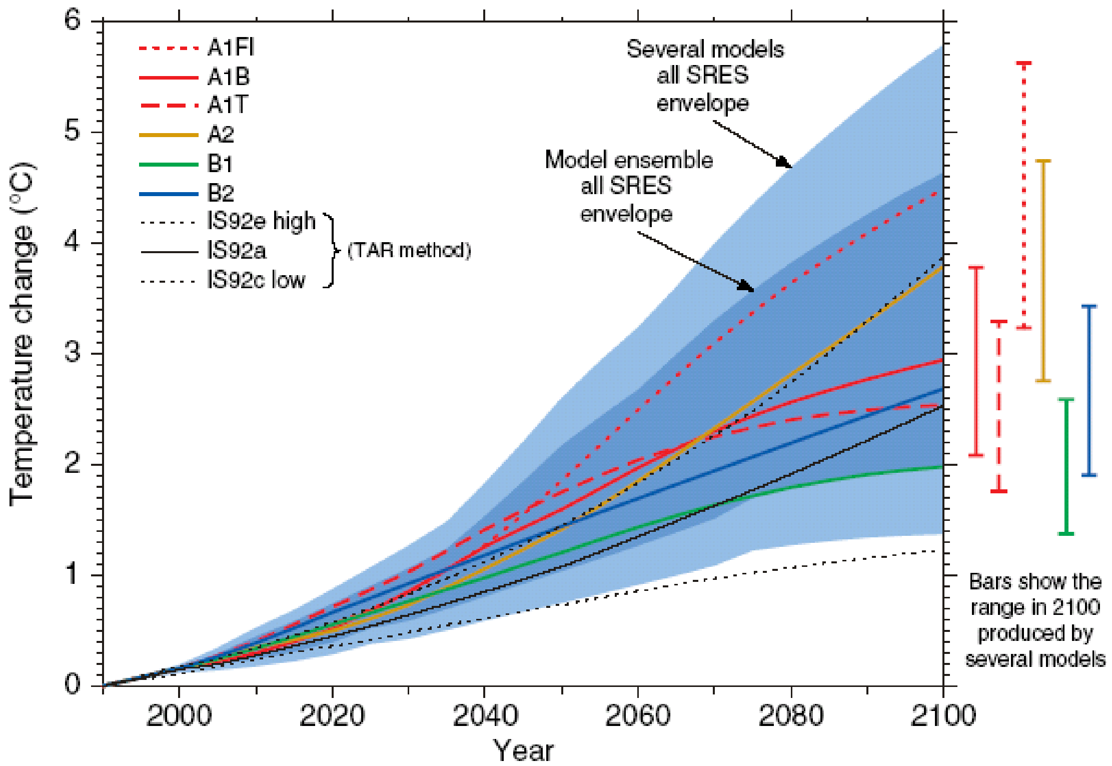
Using AOGCM results, for the end of the 21st century (2071 to 2100), the mean change in global average surface air temperature, relative to the period 1961 to 1990, was: 3.0 ˚C (with a range of 1.3 to 4.5 ˚C) for the A2 draft marker scenario; and 2.2 ˚C (range of 0.9 to 3.4 ˚C) for the B2 draft marker scenario.

5.3.2 Simple Climate Model Results

Due to computational expense, coupled Atmospheric Ocean General Circulation Models can only be run for a limited number of scenarios. A simple model can be calibrated to represent globally averaged coupled models and run for a much larger number of scenarios.

Using this approach, for the full range of 35 SRES scenarios, the globally averaged surface temperature is projected to increase by 1.4 to 5.8 ˚C over the period 1990 to 2100, as shown in figure 4 below.

Figure 4: Projected average surface temperature for the six illustrative SRES scenarios.



Notes: Global mean temperature change for the six illustrative SRES scenarios using a simple climate model tuned to seven AOGCMs (which ranged in their climate sensitivity from 1.7 to 4.2 ˚C). The lighter shading is the range of temperatures (1.4 to 5.8 ˚C) based on all seven models, using the full set of 35 SRES scenarios. The darker shading represents the range of the full set of 35 SRES scenarios using the average of the seven model results (mean climate sensitivity was 2.8 ˚C). The bars on the right hand side show, for each of the six illustrative SRES scenarios, the range of simple model results in 2100 for the seven AOGCM tunings.

Source: Source: Cubasch,U. and Meehl,G.A, *Projections of Future Climate Change*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 555.

Of the six illustrative scenarios, the bars on the right hand side of Figure 4 show that the scenarios A1F1 and B1 define the top and bottom of the range of projected temperature changes respectively. It is helpful to revisit what these scenarios are to relate them to projected temperature change:

- A1F1 – very rapid economic growth; global population peaking mid-century and declining thereafter; rapid introduction of new and more efficient technologies; convergence among regions, a substantial reduction in regional differences per capita income; fossil fuel intensive.
- B1 – same population story as A1F1, but with rapid change in economic structures toward a service and information economy; reductions in material intensity; the introduction of clean and resource efficient technologies; emphasis on global

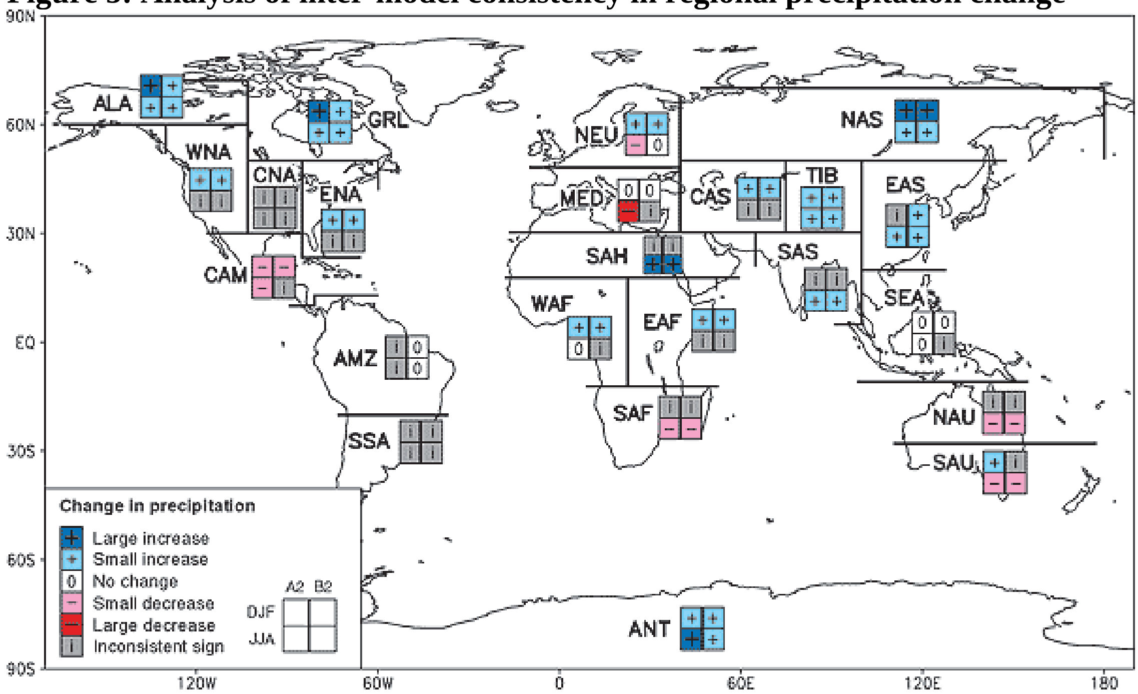
solutions to economic, social and environmental sustainability; no additional climate initiatives.

5.4 Projections of future changes to climate systems

5.4.1 Precipitation

- Globally averaged water vapour, evaporation and precipitation are projected to increase. At the regional scale, both increases and decreases in precipitation are seen. Results from AOGCM simulations forced with SRES A2 and B2 emissions (Figure 5) indicate that it is likely for precipitation to increase in both summer and winter over high-latitude regions. In winter, increases are also seen over northern mid-latitudes, tropical Africa and Antarctica, and in summer in southern and eastern Asia. Australia, central America, and southern Africa show consistent decrease in winter rainfall.

Figure 5: Analysis of inter-model consistency in regional precipitation change



Notes: For each region, information on regional precipitation change is shown in four boxes. The top layer of the box is for summer (December, January, February) for the scenarios A2 and B2, whilst the bottom layer is for winter (June, July, August) for the two scenarios.

Regions are classified as showing either agreement on increase with an average change of greater than 20% (‘Large increase’), agreement on increase with an average change between 5 and 20% (‘Small increase’), agreement on a change between −5 and +5% or agreement with an average change between −5 and 5% (‘No change’), agreement on decrease with an average change between −5 and −20% (‘Small decrease’), agreement on decrease with an average change of less than −20% (‘Large decrease’), or disagreement (‘Inconsistent sign’). A consistent result from at least seven of the nine models is deemed necessary for agreement.

Source: Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 71.

5.4.2 Projections of future changes in extreme events

- More hot days and heat waves are very likely over nearly all land areas;
- Increases in daily minimum temperatures are projected to occur over nearly all land areas;
- Frost days and cold waves are very likely to become fewer;
- Precipitation extremes are projected to increase more than the mean and the intensity of precipitation events are projected to increase;
- The frequency of extreme precipitation events is projected to increase almost everywhere;
- There is little consistent evidence that shows changes in the projected frequency of tropical cyclones and areas of formation.

5.4.3 Projections of future changes in thermohaline circulation

- Most models show weakening of the Northern Hemisphere thermohaline circulation, which contributes to a reduction of the surface warming in the northern North Atlantic;
- In experiments where atmospheric greenhouse gas concentration is stabilised at twice its present day value (ie, not double pre-industrial values), the North Atlantic thermohaline circulation is projected to recover from initial weakening within one to several centuries;
- The thermohaline circulation could collapse entirely in either hemisphere if the rate of change in radiative forcing is large enough and applied long enough. However, it is too early to say with confidence whether an irreversible collapse in the thermohaline circulation is likely or not, or at what threshold it might occur and what the climate implications could be;
- None of the current projections with coupled models exhibit a complete shut-down of the thermohaline circulation by 2100.

5.4.4 Projections of future changes in modes of natural variability

- Confidence in projections of changes in future frequency, amplitude, and spatial pattern of El Nino events in the tropical Pacific is tempered by some shortcomings in how well El Nino is simulated in complex models. Current projections show little change or a small increase in amplitude for El Nino events over the next 100 years. However, even with little or no change in El Nino amplitude, global warming is likely to lead to greater extremes of drying and heavy rainfall and increase the risk of droughts and floods that occur with El Nino events in many regions.

5.4.5 Projections of future changes in land ice (glaciers, ice caps and ice sheets), sea ice and snow cover

- Glaciers and ice caps will continue their widespread retreat during the 21st century and Northern Hemisphere snow cover and sea ice are projected to decrease further;
- The Antarctic ice sheet is likely to gain mass because of greater precipitation, while the Greenland ice sheet is likely to lose mass because the increase in runoff will exceed the precipitation increase.

5.4.6 Projections of future changes in sea level

- For the full set of SRES scenarios, a sea level rise of 0.09 to 0.88 metres is projected for 1990 to 2100, primarily from thermal expansion and loss of mass from glaciers and ice caps. The central value is 0.48 metres, which corresponds to an average rate of about two to four times the rate over the 20th century.
- More recent work from the CSIRO has identified an acceleration in sea level rise in the 20th century. If this acceleration remains constant, then the 1990 – 2100 rise would range from 280 to 340 mm[12] – less than the central value of the IPCC projections.

5.5 Projections of future changes in response to carbon dioxide concentration stabilisation profiles

- Carbon dioxide emission rates that arrive at stable carbon dioxide concentration levels from 450 to 1,000 ppm were studied. Stabilisation at 450, 650 or 1,000 ppm would require global anthropogenic emissions to drop below 1990 levels within a few decades, about a century, or about two centuries, respectively, and continue to steadily decrease thereafter. Even several centuries after emissions occurred, about a quarter of the increase in concentration caused by these emissions is still present in the atmosphere.
- Global mean temperatures continues to increase for hundreds of years at a rate of a a few tenths of a degree per century after concentrations of carbon dioxide have been stabilised, due to long time scales in the ocean;
- If greenhouse gas concentrations were stabilised (even at present levels), sea level would continue to rise for hundreds of years. After 500 years, sea level rise from thermal expansion may have reached only half its eventual level;
- Ice sheets will continue to react to climate change during the next several thousand years, even if the climate is stabilised;
- Models project that a local annual average warming of larger than 3 ˚C, sustained for millennia, would lead to virtually a complete melting of the Greenland ice sheet with a resulting sea level rise of about 7 metres;
- Current ice dynamic models project that the West Antarctic ice sheet will contribute no more than 3 mm/year to sea level rise over the next thousand years, even if significant changes were to occur in the ice shelves;
- For warmings of more than 10 ˚C, irreversible disintegration of the West Antarctic ice sheet would result. Disintegration would take at least a few millennia;
- Thresholds for total disintegration of the East Antarctic ice sheet involve warmings above 20 ˚C, a situation that has not occurred for at least 15 million years and which is far more than predicted by any scenario of climate change currently under consideration.[13]

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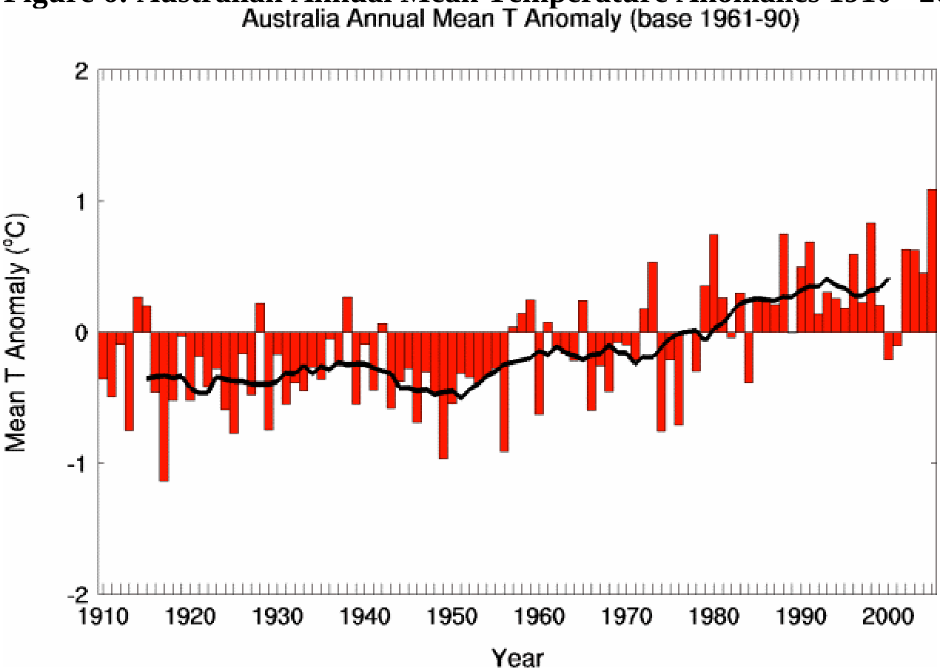
12 Church,J. and White, N. "A 20th century acceleration in global sea-level rise." In *Geophysical Research Letters*, Vol 33, LO1602, doi:10.1029/2005GL024826, January 2006.

13 Albritton DL and Meira Filho LG *et al*, *Technical Summary*: In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom

6.0 AUSTRALIAN CLIMATIC TRENDS

The Australian annual mean temperature anomaly is generally consistent with the global trend, and is shown in Figure 6. However, 2005 was Australia's warmest year on record, with the mean temperature anomaly 1.09 ˚C above the standard 1961-1990 average.[14] This surpasses the previous high of +0.83 ˚C recorded in 1998. The 11 year average mean, shown by the black line in Figure 6, crossed over zero and has been positive since approximately 1980, after having been negative since reliable temperature records began.

Figure 6: Australian Annual Mean Temperature Anomalies 1910 - 2005



Source: Australian Bureau of Meteorology, Time Series – Australian Climatic Variability and Change. See website: http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi, Accessed February 2006.

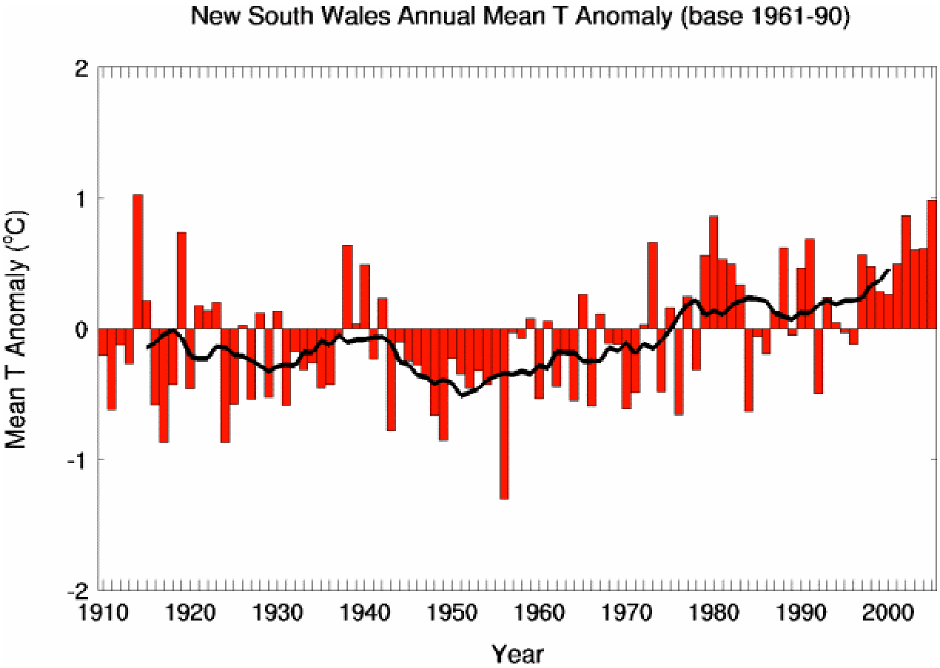
The time series of annual mean temperature anomalies for NSW is presented in Figure 7. For NSW, the hottest year on record was 1914, 1.02°C warmer than the mean, with the second hottest in 2005 (0.98˚C). The third hottest year was 2002 (0.865°C) closely followed by 1980 (0.86°C).[15]

and New York, 2001.

14 Australian Bureau of Meteorology, *Annual Australian Climate Summary 2005*. See website: http://www.bom.gov.au/announcements/media_releases/climate/change/20060104.shtml, accessed February 2006.

15 Australian Bureau of Meteorology, Time Series – Australian Climatic Variability and Change. See website: http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi, Accessed February 2006.

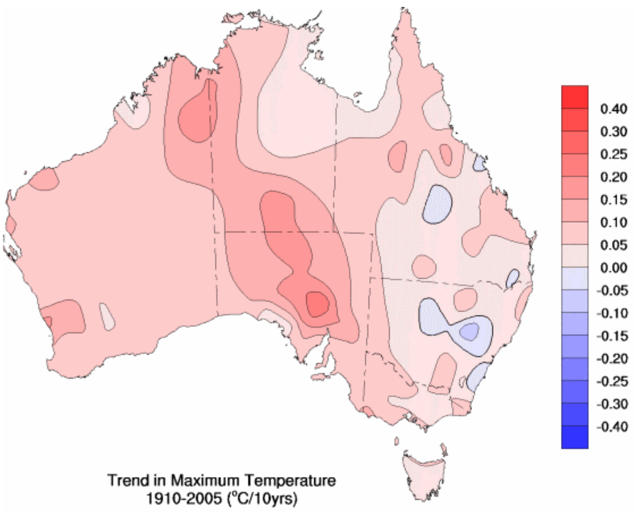
Figure 7: NSW Annual Mean Temperature Anomalies 1910 - 2005

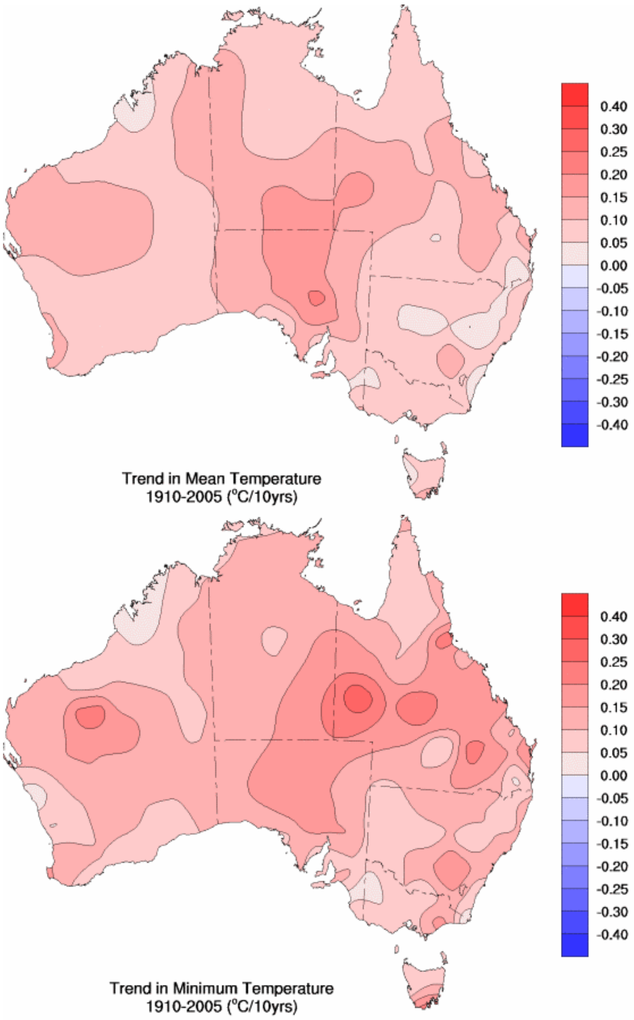


Source: Australian Bureau of Meteorology, Time Series – Australian Climatic Variability and Change. See website: http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi, Accessed February 2006.

The Australian Bureau of Meteorology notes that the warming trend is not uniform throughout the country, nor is it the same for maximum and minimum temperatures. The increase in mean minimum temperatures is greater than the increase in mean maxima. As shown in Figure 8, the areas showing the greatest increases in minimum temperatures, with trends of more than 2°C per century, are in inland Queensland.

Figure 8: Trends in annual maximum (top), mean (middle) and minimum (bottom) temperature over Australia 1910 – 2005.





Source: Australian Bureau of Meteorology, *Trend Maps*. *Australian Climate Variability and Change*. See Bureau of Meteorology website: http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi. Accessed February 2006.

For the nation as a whole, Australian average temperatures have risen by 0.7 ºC over the past century, with a commensurate increase in the frequency of very warm days and a decrease in the frequency of frosts and very cold days. Night-time temperatures have risen faster than daytime temperatures; hence the diurnal temperature range has decreased noticeably in most places.[16]

It has been reported that using both instrumental observations and climate model data, analysis shows that the warming trend over the last 50 years in Australia cannot be explained by natural climate variability alone and that most of this warming is likely due to the increase in greenhouse gases in the atmosphere. The actual trend in Australian temperatures since 1950 is now matching climate model simulations of how temperatures respond to increased greenhouse gases in the atmosphere.[17]

16 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

17 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*.

Trends in rainfall are less clear. Australian annual mean rainfall has increased by about 6% over the past century. From 1951 to 2002 there have been strong increases in the north-west, but decreases in the south-west of Western Australia and over much of the south-east and east coast.

The largest and most statistically significant change has been a decline in rainfall in the winter-rainfall-dominated region of the far southwest of Western Australia, where in the period 1910 to 1995, winter rainfall declined by 25%, mainly during the 1960s and 1970s. Several have noted this decrease and relate it to atmospheric circulation changes, notably an increase in surface pressure in the vicinity. These studies leave open how much of the change can be attributed to natural variability versus the enhanced greenhouse effect. A similar decline is projected by most climate models that include enhanced greenhouse gases and direct effects of aerosols, for the first half of the 21st century.[18] However, highlighting the difficulty of identifying attribution, in early 2005 three CSIRO researchers reported that the CSIRO Mark 3 climate model also produced multi-decadal long drying trends comparable to those observed in an experiment without climate change forcing (ie, adding enhanced greenhouse gas emissions into the climate model).[19]

It should also be noted that relatively abrupt shifts in rainfall have occurred several times in Australia since good records began in the 1890s, notably widespread decreases in large areas of New South Wales and Queensland in the 1890s, and increases in Victoria and New South Wales around 1945. The same analysis shows a sharp decrease in rainfall around 1967–72 in the south-west of Western Australia, and widely scattered increases further east. The reason for such abrupt changes is not yet understood, but is presumably largely natural.[20]
A good example demonstrating abrupt shifts in rainfall in Australia is from three volcanic crater lakes in western Victoria. The lakes are members of a suite of closed lakes that have exhibited a sustained fall in water level since the first written records, dating from 1841. Due to their high lake/catchment area, and relatively low groundwater inputs, the water budgets of these lakes are dominated by rainfall and evaporation at the water's surface. Following a period of relative stability lasting most of the previous thousand years, historical water levels have fallen by more than 15 metres at one lake and more than 20 metres at another.

A team of researchers from the CSIRO and the University of Melbourne investigated the relationship between lake levels and climate change and found the following:

Australian Greenhouse Office, 2003.

18 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003, at 48.

19 Cai,W. *et al*, "Multidecadal fluctuations of winter rainfall over southwest Western Australia simulated in the CSIRO Mark 3 coupled model." In *Geophysical Research Letters*, Vol 32, L12701, 2005.

20 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

- The maar lakes of Western Victoria are falling due to a climate change that occurred around 1840 and before 1863. This change involved a significant movement in precipitation/evaporation ratio from 0.94-0.96 to 0.79;
- The pre-European high lake levels were maintained by a climate that was almost certainly wetter, probably cloudier and perhaps cooler, when compared to the instrumental climate record;
- The lakes offer the first independent evidence of a climate change occurring prior to large-scale changes in land use;
- Climate change reflected in both the instrumental climate record and changing lake levels of the study lakes are representative of regional climate change.[21]

This study highlights the natural variability of climate – in this case an Australian regional climate is stable for around one thousand years, and then suddenly changes. The significance of this of course is that climate change occurring at around 1840 precedes the major growth in greenhouse gases so is likely to be natural.

The average rise in sea level in the Australia/ New Zealand region over the past 50 years is about 20 mm per decade, which is within the range of the current estimate of global sea level rise. There has been a weak warming trend in ocean temperatures to 100 m depth in the south-west Pacific (39°S to 49°S, 141°E to 179°E) of about 0.13 °C during the 34-year period 1955 to 1988, and there have been shorter period sea-surface temperature fluctuations associated with ENSO.[22]

7.0 CSIRO AUSTRALIAN CLIMATE CHANGE PROJECTIONS FOR THE 21ST CENTURY

CSIRO issued climate change projections in May 2001. Changes in future Australian temperature and rainfall were derived from simulations by nine different climate models, in which the level of greenhouse gas concentrations was enhanced. Each of these models was found, by comparison with observations, to have an acceptable simulation of Australia's climate under current conditions. Ranges of change were presented that incorporate quantifiable uncertainties associated with the IPCC range of future emission scenarios, the range of global responses of climate models, and model-to-model differences in the regional pattern of climate change.[23]

The ranges are based on:

- global warming projections which provide information on the magnitude of the global climate response over time;

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21 Jones,R.N., McMahon,T.A. and Bowler, J.M., "Modelling historical lake levels and recent climate change at three closed lakes, Western Victoria, Australia, (c.1840 – 1990)." In *Journal of Hydrology*, Vol 246, 2001.

22 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

23 This section is adapted from: Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

- the regional response in terms of local change (in °C for temperature and in percentage for rainfall) per °C of global warming. A range of local values is derived from the differing results of nine climate model simulations.

7.1 Temperature

By 2030, annual average temperatures are 0.4 to 2.0 °C higher over most of Australia, with slightly less warming in some coastal areas and Tasmania, and the potential for greater warming in the north-west. By 2070, annual average temperatures have increased by 1.0 to 6.0 °C over most of Australia with spatial variation similar to that for 2030. The range of warming is greatest in spring and least in winter. In the north-west, the greatest potential warming occurs in summer.

Model results indicate that future increases in daily maximum and minimum temperature will be similar to the changes in average temperature. This contrasts with the greater increase in minima than maxima observed over Australia in the 20th century.

Changes in daily temperature extremes can be influenced by changes in daily variability and changes in average maximum or minimum temperature. CSIRO modelling results for Australia indicate that future changes in variability are relatively small and the increases in average maximum and minimum temperature mainly determine the change in extremes. Changes in extreme temperatures, assuming no change in variability, are given in Tables 2 and 3.

Table 2: The average number of summer days over 35˚C at capital cities for present conditions, 2030 and 2070

	Present	**2030**	**2070**
Hobart	1	1-2	1-4
Sydney	2	2-4	3-11
Brisbane	3	3-6	4-35
Canberra	4	6-10	6-30
Melbourne	8	9-12	10-20
Adelaide	10	11-16	13-28
Perth	15	16-22	18-39

Source: Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

Table 3: The average number of winter days below 0˚C at selected sites for present conditions, 2030 and 2070

	Present	**2030**	**2070**
Canberra (ACT)	44	31-42	6-38
Orange (NSW)	38	18-32	1-27
Launceston (TAS)	21	10-18	0-14
Tatural (VIC)	15	6-13	0-9
Wandering (WA)	14	5-11	0-9
Dalby (QLD)	10	3-7	0-6
Nuriootpa (SA)	9	2-7	0-5

Source: Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

7.2 Rainfall

Projected annual average ranges tend toward decrease in the south-west (-20% to +5% by 2030 and -60% to +10% by 2070, rounded to the nearest 5%), and in parts of south-east Australia and Queensland (-10% to +5% by 2030 and -35% to +10% by 2070). In some other areas, including much of eastern Australia, projected ranges are –10% to +10% by 2030 and -35% to +35% by 2070. The ranges for the tropical north (-5% to +5% by 2030 and -10% to +10% by 2070) represent little change from current conditions.

In summer and autumn, projected rainfall ranges for most locations are –10% to +10% by 2030 and –35% to +35% by 2070 or tend toward increase (–10% to +20% by 2030 and –35% to +60% by 2070). The latter occur mainly in parts of southern inland Australia in summer and inland areas in autumn. In some parts of northern and eastern Australia in summer, and inland Australia in autumn, the tendency for wetter conditions is -5% to +10% by 2030 and -10% to +35% by 2070. However, for the far south-east of the continent and Tasmania, projected rainfall tends to decrease in both seasons (-10% to +5% by 2030 and -35% to +10% by 2070).

In winter and spring most locations tend toward decreased rainfall (or are seasonally dry). Ranges are typically -10% to +5% by 2030 and -35% to +10% by 2070. Projected decreases are stronger in the south-west (-20% to +5% by 2030 and -60% to +10% by 2070) while Tasmania tends toward increases in winter (-5% to +20% by 2030 and -10% to +60% by 2070). Individual locations within a classification may show significantly narrower ranges of change.

Where average rainfall increases, there would be more extremely wet years, and where average rainfall decreases there would be more dry spells. Most models simulate an increase in extreme daily rainfall leading to more frequent heavy rainfall events. This can occur even where average rainfall decreases. Reductions in extreme rainfall occur where average rainfall declines significantly. Increases in extreme daily rainfall are likely to be associated with increased flooding.

7.3 Evaporation and moisture balance

Higher temperatures are likely to increase evaporation. CSIRO has calculated projections of change in potential evaporation (atmospheric water demand) from eight climate models. The results show that increases occur in all seasons and, annually averaged, range from 0 to 8% per °C of global warming over most of Australia, and up to 12% over the eastern highlands and Tasmania. The increases tend to be larger where there is a corresponding decrease in rainfall. The difference between potential evaporation and rainfall gives a net atmospheric water balance. In general, Australia has an annual net moisture balance deficit, and our environment is largely moisture-limited. When the simulated increases in potential evaporation are considered in combination with simulated rainfall change, the overall pattern shows decreases in moisture balance on a national basis.

Average decreases in annual water balance range from about 40 to 130 mm by 2030, which means greater moisture stress for Australia. This represents decreases of 15 to 160 mm by 2030 and 40 to 500 mm by 2070. The simulated changes show the greatest consistency between models in spring. Decreases in spring are greatest over eastern Australia.

7.4 El Niño-Southern Oscillation

The El Niño-Southern Oscillation has a strong influence on climate variability in many parts of Australia, and this will continue. However, it is likely that global warming will enhance the drying associated with El Niño events due to increased potential evaporation. Climate models do not give a consistent indication of future changes, although some simulations suggest more El Niño-like average conditions – this implies more drought like conditions.

7.5 Uncertainties and probabilistic scenarios

Uncertainties about future human behaviour and shortcomings in climate modelling limit our climate change projections to ranges of change for some variables, and qualified statements on possible changes for others. Greenhouse gas emissions are subject to uncertainties concerning population growth, technological change and social and political behaviour. Climate model responses are most uncertain in how they represent feedback effects, particularly those dealing with changes to cloud regimes, biological effects and ocean-atmosphere interactions. The coarse spatial resolution of climate models also remains a limitation on their ability to simulate the details of regional climate change. Future climate change will also be influenced by other, largely unpredictable, factors such as changes in solar radiation, volcanic eruptions and chaotic variations within the climate system itself.[24]

8.0 NSW CLIMATE PROJECTIONS

In a 2004 consultancy report for the NSW Government, CSIRO projected changes to climate in NSW under several warming scenarios. Using climate models, CSIRO found:

- NSW is likely to experience greatest warming west and north of the highlands, and least in southern and coastal areas;
- Most warming is expected to occur in spring and summer, and least in winter. By the year 2030, the SRES scenarios give an annual-average warming of 0.2 to 1.6 °C in coastal and southern regions, relative to 1990, 0.2 to 1.8 °C in the central-west, and 0.3 to 2.1 °C in the north;
- By 2070, the warming increases to 0.7 to 4.8 °C in coastal and southern regions, 0.7 to 5.6 °C in the central west, and 0.9 to 6.4 °C in the north;
- There is a general tendency for decreasing annual-average rainfall. This is mainly confined to winter and spring. In autumn, the direction of rainfall change is uncertain over most of the State, with a tendency for decreases in the north and

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24 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

increases in the far west. Summer rainfall changes are uncertain over much of southern and western NSW, with a tendency for increases along the coast and in the north-east, and a tendency for decreases in the north-west. The magnitude of rainfall change depends on the scenario;

- By the year 2030, the SRES scenarios give changes to precipitation of -13% to +7% in winter, in the north-west in summer and in the north in autumn, relative to 1990; -20% to +7% in spring; -7% to 13% along the coast and north-east in summer and in the far west in autumn. By 2070, these ranges of change triple, e.g. -13% to +7% becomes -40% to +20%.[25]

9.0 THE STABILISATION OF CLIMATE

The Framework Convention on Climate Change aims for the stabilisation of greenhouse gases at a level that would 'prevent dangerous anthropomorphic interference with the climate system'. The CSIRO notes that 'dangerous anthropomorphic interference' is not well defined, and put forward the work of two researchers who provided three examples of 'dangerous' environmental consequences. These were:

- Sustained global warming in excess of 1°C, which would cause coral bleaching to become an annual event in most oceans;
- Complete disintegration of the West Antarctic Ice Sheet could occur for a 2 ˚C warming – raising sea level by four to six metres;
- A warming in excess of 3°C could weaken or shut down the large-scale thermohaline circulation of the oceans, which regulates the distribution of heat and other properties over the global oceans.[26]

Australian scientist Tim Flannery, Director of the South Australian Museum and Chair of South Australia's State Science Council and Sustainability Roundtable wrote:

> We have seen that human health, water and food security are now under threat from the modest amount of climate change that has already occurred. If humans pursue a business-as-usual course for the first half of this century, I believe the collapse of civilisation due to climate change becomes inevitable.[27]

Flannery identified three main 'tipping points' for earth's climate. These were:

- A slowing or collapse of the Gulf Stream;
- The demise of the Amazon rainforests; and
- The release of methane gas hydrates from the sea floor.

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25 Hennessy, K. *et al*, *Climate Change in New South Wales. Part 1. Past climate variability and projected changes in average climate*. CSIRO Consultancy report for the New South Wales Greenhouse Office. July 2004.

26 Hennessy, K. *et al*, *Climate Change in New South Wales. Part 1. Past climate variability and projected changes in average climate*. CSIRO Consultancy report for the New South Wales Greenhouse Office. July 2004, at 29.

27 Flannery,T. *The Weather Makers. The History and Future Impact of Climate Change*. Text Publishing, 2005, at 209.

Flannery noted that: all three occur on occasion in global circulation models; there is some geological evidence that all three may have occurred in earth history; and that given the current rate and direction of climate change, "one, two or perhaps all three may take place this century."[28]

The Hadley Centre, which is the United Kingdom Government's centre for research into climate change, defined 'dangerous' climate change based on two scenarios – abrupt / irreversible climate change and when climate changes gradually. For the former, the Centre suggested these conditions:

- Changes to the Gulf Stream;
- Changes to ecosystems and carbon sinks;
- Melting of the Greenland ice sheet;
- Increasing natural methane emissions (methane hydrates).

The Centre defined 'dangerous' for gradual climate change as:

- Climate change from the IPCC stabilisation scenarios;
- Changes in Arctic sea ice;
- Changes in extremes.[29]

There is increasing international convergence on the idea that global warming should be limited to 2 °C above pre-industrial levels. For example, the European Council has adopted this figure, as did the International Climate Change Taskforce in January 2005.[30] The ramifications of this in terms of global emissions is as follows.

As noted earlier in this paper, the relationship between increased concentrations of greenhouse gases and global temperature is known as 'climate sensitivity' – defined as the warming occurred with a doubling of carbon dioxide concentrations. For the IPCC Third Assessment Report, climate sensitivity ranged from 2 °C to 5.1 °C. This uncertainty in climate sensitivity translates into an uncertainty in allowable greenhouse gas emissions to avoid dangerous climate change. For instance, the Hadley Centre calculates that if the temperature rise by 2150 was required to be kept to 2 °C, a climate sensitivity of 3 °C would mean stabilising carbon dioxide equivalent below 350ppm. If the climate sensitivity was at the bottom end of the range at 1.5 °C — stabilisation could be as high as about 700ppm and still allow temperature rise to be limited to 2 °C. On the other hand, if climate sensitivity was greater than 3 °C, stabilisation at concentrations well below those of today would be required.

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28 Flannery,T. *The Weather Makers. The History and Future Impact of Climate Change*. Text Publishing, 2005, at 190.

29 UK Department of Environment, Food and Rural Affairs, The Hadley Centre, *Stabilising climate to avoid dangerous climate change – a summary of relevant research at the Hadley Centre.* January 2005.

30 International Climate Change Taskforce, *Meeting the Climate Challenge. Recommendations of the International Climate Change Taskforce.* January 2005.

The Hadley Centre, using an initial 53 models demonstrated that the level of concentration at which carbon dioxide would need to be stabilised in order to limit global-mean temperature rise to 2 °C above present day, would be in the range of about 490ppm to 670ppm[31].

At the invitation of the British Prime Minister Tony Blair, the International Symposium on Stabilisation of Greenhouse Gas Concentrations – *Avoiding Dangerous Climate Change* – took place in February 2005. The Symposium noted that serious risk of large scale, irreversible system disruption, such as reversal of the land carbon sink and possible destabilisation of the Antarctic ice sheets is more likely above 3 ˚C. It concluded that limiting climate change to 2 ˚C above pre-industrial levels would suggest a stabilisation at 450 ppm CO_2, implying a medium likelihood (~50%) of staying below the 2 ˚C warming.[32]

The IPCC considered carbon dioxide stabilization at concentrations of 450, 550, 650, 750 and 1000 ppm sometime between the year 2090 and 2300. In all cases except the 1000 ppm scenario, stabilising carbon dioxide concentrations at a higher level than present (375 ppm) would require a reduction from the current level of 8 GtC (million tonnes of carbon) per year to around 3 GtC per year within the next 100 to 300 years, i.e. at least a 60% reduction in global emissions relative to present. For example, the path to stabilising at 550 ppm by 2150 would require emissions to peak at 40% above present (11.2 GtC) by the year 2025, then drop to 20% above present (9.5 GtC) by the year 2050, falling to 35% below present (5.2 GtC) by the year 2100.[33]
Hansen, of NASA, provides two scenarios. The first is to hold warming to 2 ˚C, and the second (termed alternative) scenario is to keep warming below 1 ˚C (compared to base year of 2000). He believes that avoiding dangerous anthropogenic interference with the climate means pursuing the alternative scenario.

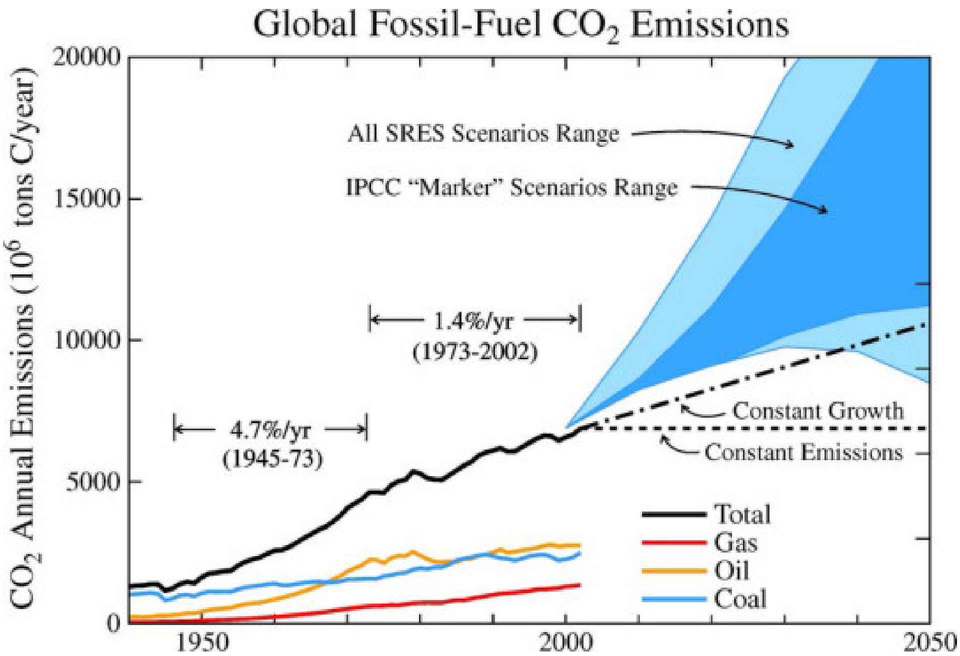
The alternative scenario has two components: a halt or reversal of growth in air pollutants, specifically soot, ozone, and methane; and maintenance of average fossil fuel carbon dioxide emissions over the next 50 years at about the same level as today. Referring to the graph on carbon dioxide emissions as shown in Figure 9, Hansen notes that the constant growth and constant emissions tracks are approximately what is needed to achieve the 2˚C and alternative climate scenarios. Hansen considers that keeping carbon dioxide emissions from exceeding the constant growth track for the next few decades may be comparatively easy. However, achieving the constant emissions path will requires a second sea change in fossil fuel use trends – comparable to the change in 1973 where carbon dioxide emissions reduced from annual growth of 4.7% per year to around 1.4%.

31 UK Department of Environment, Food and Rural Affairs, The Hadley Centre, *Stabilising climate to avoid dangerous climate change – a summary of relevant research at the Hadley Centre.* January 2005, at 14.

32 UK Department of Environment, Food and Rural Affairs, *Avoiding Dangerous Climate Change. Scientific Symposium on Stabilisation of Greenhouse Gases. February 1st to 3rd, 2005.* January 2006. See: www.defra.gov.auk. Accessed February 2006.

33 Hennessy, K. *et al*, *Climate Change in New South Wales. Part 1. Past climate variability and projected changes in average climate*. CSIRO Consultancy report for the New South Wales Greenhouse Office. July 2004, at 30.

Figure 9: Global fossil fuel carbon dioxide emissions



Source: Hansen,J. "Can we defuse the global warming time bomb?" in online journal *Natural Science*, http://naturalscience.com/ns/articles/01-16/ns_jeh6.html. Accessed November 2005.

To achieve stabilisation of atmospheric carbon dioxide, emissions for both scenarios must begin to decrease prior to mid-century. Long-term reduction in CO_2 emissions is a greater challenge, as energy use will continue to rise. Hansen notes that progress is needed across the board: continued efficiency improvements, more renewable energy, and new technologies. Next-generation nuclear power, if acceptable to the public, could be an important contributor. There may be new technologies before 2050 that we have not imagined. Hansen concludes that a fallback, should greater fossil fuel use be necessary, is the capture and sequestration of carbon dioxide.[34]

34 Hansen,J. "Can we defuse the global warming time bomb?" in online journal *Natural Science*, http://naturalscience.com/ns/articles/01-16/ns_jeh6.html. Accessed November 2005.

PART 2: THE SCIENTIFIC DEBATE

10.0 THE GREENHOUSE 'CONSENSUS'

A forceful argument for those supporting a reduced greenhouse gas emission future is that the scientific consensus is in support of the enhanced greenhouse effect. For instance, Professor Ian Lowe, President of the Australian Conservation Foundation, in his book *Living in the Hothouse*, whilst acknowledging uncertainties in climate science, states:

> While there is now consensus in the atmospheric science and climate science communities, it is important to emphasise that this represents a collective judgement about a complex and still uncertain subject…
>
> There are, of course, still a few scientists who don't accept this view, although the majority of those described by the media as 'greenhouse skeptics' are industrialists, economists, and statisticians rather than climate scientists….
>
> It is important to stress that there is a near-unanimous view among the experts that significant changes to the global climate are now inevitable.[35]

Greenpeace Australia Pacific states:

> Climate change is the warming of our planet, caused by human activity. It is the worst environmental and economic problem we face today. Most scientists and governments around the world now agree that climate change will damage or destroy many natural ecosystems and human communities….
>
> World renowned scientists on the Intergovernmental Panel on Climate Change (IPCC) have found new and stronger evidence that "most of the observed warming over the last 50 years is attributable to human activities."[36]

Dr Clive Hamilton, of the Australia Institute, comments:

> The media give an ear to the fossil fuel lobby and conservatives who are opposed to Kyoto and so promotes the views and gives credibility to a handful of skeptics without any scientific credibility. They have effectively created the impression that the scientists are divided, but they are not. There is the most extraordinary process through the IPCC which accommodates all credible views and pieces of analysis to reach a consensus view, ….[37]

Sir John Houghton, Chair of IPCC Working Group 1, which produced the scientific

35 Lowe, I. *Living in the Hothouse. How global warming affects Australia.* Scribe Publications, 2005, at 12.

36 Greenpeace Australia, *Understanding Climate Change*, See website: http://www.greenpeace.org.au/climate/overview/index.html, Accessed November 2005.

37 Dr Clive Hamilton, *Clean Air Forum 2004. Proceedings of the NSW Clean Air Forum2004*. Powerhouse Museum, Sydney 17 November 2004, at 25.

assessment as reported above, stated:

> I think there are very few scientists who'd disagree with the IPCC. And most of those who do disagree have not published much.[38]

In a review of the Kyoto Protocol process, Boehmer-Christiansen and Kellow note that Houghton's remarks are aimed at producing and bolstering, through the IPCC, a consensus in favour of a more certain and negative view of climate change than, in their view, is warranted by the evidence. The pair then identified some of the many scientists who have disputed the conclusions of the IPCC.[39] The argument of consensus is criticised by Crighton as follows:

> The work of science has nothing to do with consensus. Consensus is the business of politics. Science, on the contrary, requires only one investigator who happens to be right, which means that he or she has results that are verifiable by reference to the real world. In science, consensus is irrelevant. What is relevant is reproducible results. The greatest scientists in history are great precisely because they broke with the consensus.[40]

As Crighton shows in Figure 10, it was not all that long ago that society was confronting fears of the next ice age:

Figure 10: Fears of a coming ice age in the early 1970s

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38 "Human effect on climate change 'beyond doubt'" BBC News Online, 22 January 2001. As reported by Boehmer-Christiansem, S. and Kellow, A. *International Environmental Policy, Interests and the Failure of the Kyoto Process*. Edward Elgar Publishing, 2002, at 168.

39 Boehmer-Christiansem, S. and Kellow, A. *International Environmental Policy, Interests and the Failure of the Kyoto Process*. Edward Elgar Publishing, 2002, at 168.

40 Crighton, M. "The Impossibility of Prediction." Speech to the National Press Club, Washington ˚C, January 25 2005. See: http://www.crichton-official.com/speeches/, Accessed November 2005.

Source: Crighton, M. "The Impossibility of Prediction." Speech to the National Press Club, Washington ˚C, January 25 2005. See: http://www.crichton-official.com/speeches/, Accessed November 2005.

The second part of this paper looks at some of the criticisms of the science underlying the enhanced greenhouse effect. The majority of arguments put forward by greenhouse 'skeptics' can be categorised into three areas:

- Recent warming of the earth's surface is not usual in the context of climate history;
- General circulation models are not adequate representations of climate, and are unreliable to project future climate states; and
- Projected global warming scenarios are over exaggerated.

Each of these three arguments, and more, are explored further in this section.

11.0 RECENT WARMING IS NOT UNUSUAL IN THE CONTEXT OF CLIMATE HISTORY

Planet earth is some 4,600 million years old, and throughout geological history has changed continuously. Ian Plimer, Professor of Geology at the University of Melbourne, argues that whether humans make a small change to climate or not is irrelevant. Major natural climate cycles will continue to dominate the geological record and will swamp any projected human-induced climate change. When discussing climate change, Plimer emphasises the importance of time – and from a geological perspective the enormity of time. From that perspective, the planet's carbon dioxide content is currently very low. The earth's atmosphere probably came from de-gassing of the earth itself – and periods of massive volcanicity have exhaled huge amounts of carbon dioxide. This process continues today. However, the earth is currently in a very quiet period of volcanicity.[41]

The earth has had 26 known glacial events over the last four thousand million years – 17 of them major. Nevertheless, the climate on the planet has been essentially warm and moist. Studying one-fifth of geological time – the last five hundred and seventy million years – the earth has had four major warm periods and four major cold periods. We are currently in one of those cold periods. The bulk of time of the history of the planet has been in warm temperature conditions – not in the conditions we experience today.[42]

In terms of geological time and changes in sea level, Plimer says there have been hundreds of sea level rises (and falls). If there is a six metre sea level rise from the complete melting of the West Antarctic ice sheet, sea levels will be restored to the position they were at 123,000 years ago. Whilst this would disrupt coastal populations, the fossil record shows high sea levels drive greater biodiversity, especially in shallow water ecosystems. History also shows warmer wetter times have led to great renaissances in human history. If the past

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41 Plimer, I. *A short history of planet earth*. ABC Books, 2001, at 220.

42 Plimer, I. "The Geology of Greenhouse." *1995 Annual Oration*, Australian Academy of Technological Sciences and Engineering. See http://www.atse.org.au. Accessed August 2005.

is a key to the present, a sea level rise by ice melting or expansion of the oceans will initially put pressure on humans before a period of great prosperity and expansion.[43]

Climate change is well recorded. Cave paintings in the Sahara show animals from wetter climates – from six thousand years ago, three and half thousand years ago, and one thousand years ago. The thousand year old paintings coincide with a period of global warming – known as the Medieval Optimum. It was a period when Vikings could sail around the northern part of Greenland – named as such because it was covered with grass. Grapes could be grown in the north of England. The earth had a period of global warming – certainly not due to human activity. From 1450 to 1850 we had a little Ice Age. From 1861 to the present temperature has shown great fluctuations. Plimer says that climate change is normal.[44]

Plimer also warns that the history of recent climate change suggests Earth will soon lurch into another glaciation, possibly in only 300 to 400 years time but certainly before 2800. He notes that past ice ages have led to famine, disease, population reduction and warfare. Urban communities will drift into subsistence agriculture and cities will be vacated. If the next glaciation is as intense as the last, the area now inhabited by 60% of the planet's population will be covered by ice. Sea level will drop, forests will retreat, and there will be massive migration and competition for resources.[45]

Plimer concludes:

> Planet earth has a past, present and future. If we ignore the past, then we do so at our peril. … What we see and measure as changes to the Earth in our own lifetime constitute just one frame in the movie of the history of Earth. If we try to understand the whole movie by looking at just one frame, conclusions are meaningless. Yet, this view of the planet pervades in the modern world.[46]

11.1 The Hockey Stick Debate

Two Canadian researchers / academics, Ross McKitrick and Stephen McIntryre, argue that the 'hockey stick' as presented in the IPCC Third Assessment Report, is flawed.

As discussed earlier in this paper, the hockey stick graph shows that the earth's climate was very stable from AD1000 to 1900, then suddenly began to change, with temperatures in the Northern Hemisphere rising dramatically. McKitrick and McIntyre argue that the hockey stick was central to the 2001 Third Assessment Report. It appears as Figure 1b in the Working Group Summary for Policymakers, Figure 5 in Technical Summary, twice in

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43 Plimer, I. *A short history of planet earth*. ABC Books, 2001, at 217.

44 Plimer, I. "The Geology of Greenhouse." *1995 Annual Oration*, Australian Academy of Technological Sciences and Engineering. See http://www.atse.org.au. Accessed August 2005.

45 Plimer, I. *A short history of planet earth*. ABC Books, 2001, at 218.

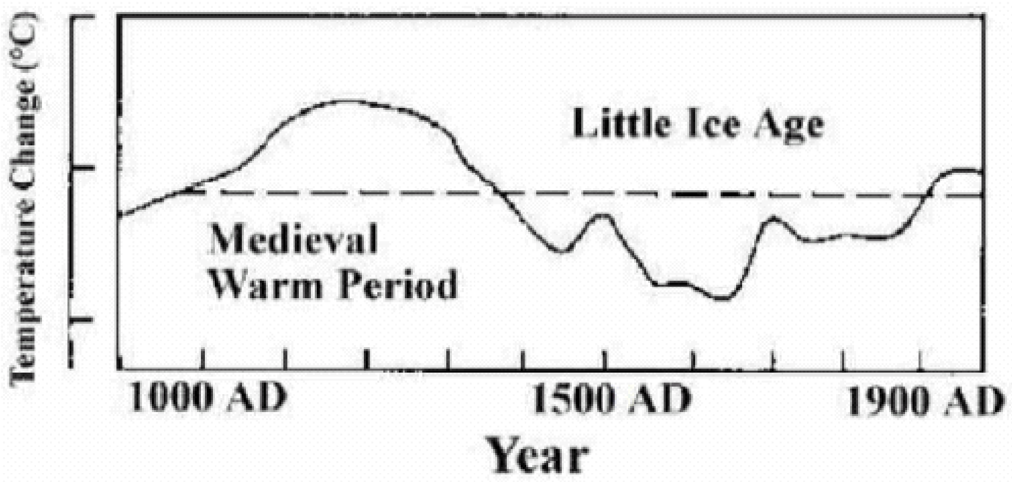
46 Plimer, I. *A short history of planet earth*. ABC Books, 2001, at 226.

Chapter 2 of the main report, and Figures 2-3 and 9-1B in the Synthesis Report. Referring to this figure, the IPCC Summary for Policymakers (and Technical Summary) claimed it is likely "that the 1990s has been the warmest decade and 1998 the warmest year of the millennium" for the Northern Hemisphere.

The Canadian researchers noted that the Canadian government subsequently included the hockey stick in material sent to schools across the country. The now famous conclusion about the 1990s being the warmest decade of the millennium was the opening line of a pamphlet sent to every household in Canada to promote the Kyoto Protocol. Worldwide it is provided as primary evidence for global warming.

The Medieval Warm Period is a period of time from approximately AD1000 to AD1300 during which many places around the world exhibited conditions that seem warm compared to today. In the 1990 First Assessment Report of the IPCC, there was no hockey stick. Instead the millennial climate history contained a Medieval Warm Period and a subsequent Little Ice Age – as shown in Figure 11. Looked at in this context, the warming of the late 20th century appears to be completely 'normal'. McKitrick writes: "It is easy to see why this graph was a problem for those pushing the global warming alarm. If the world could warm so much on such a short time scale as a result of natural causes, surely the 20th century climate change could simply be a natural effect as well. And the present climate change could hardly be considered unusually hazardous if even larger climate changes happened in the recent past…"[47]

Figure 11: Millenial climate history from the 1990 IPCC First Assessment Report

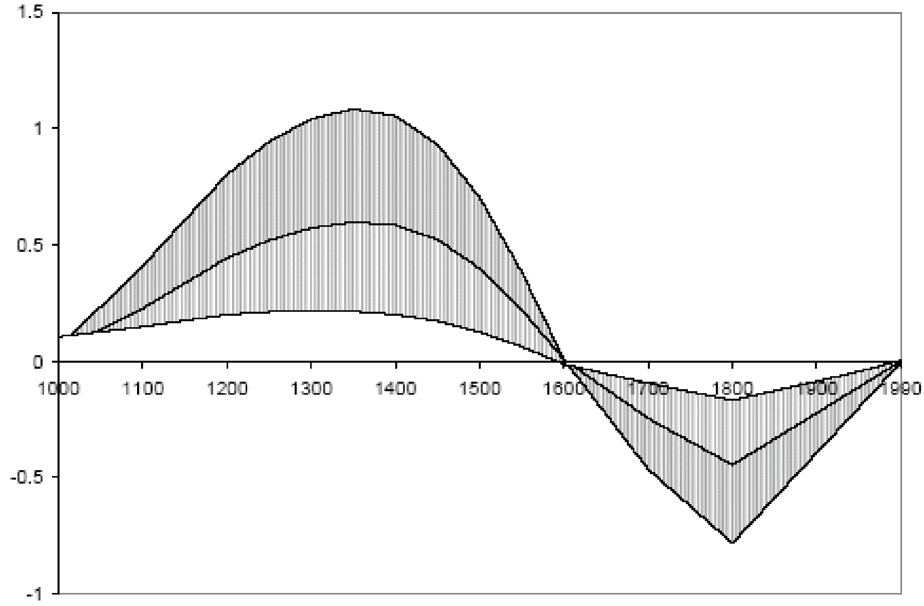


Source: McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, at 5.
See http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

[47] McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, at 5. See http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

McKitrick notes the work of Huang *et al* of the University of Michigan who completed an analysis of 6,000 borehole records from every continent around the world. The analysis of boreholes is another proxy measurement for temperature. Whilst Huang *et al* 's study went back 20,000 years, the portion covering the last millennium is shown in Figure 12.

Figure 12: World climate history after AD1,000 according to ground borehole evidence



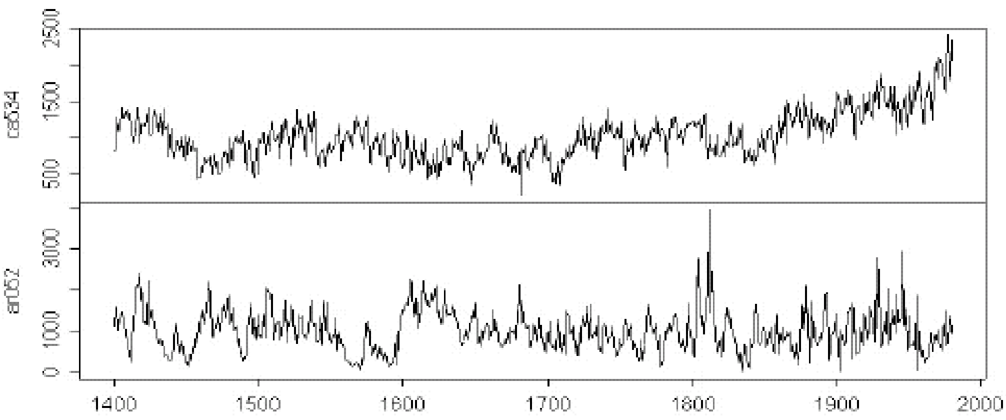
Source: McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, at 6.
See: http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

The similarity to the IPCC's graph in 1990 is evident – the world experienced a 'warm' interval in the medieval era that dwarfs 20th century changes. Huang *et al* published their findings in the journal *Geophysical Research Letters* in 1997. The next year, *Nature* published the first Mann hockey stick paper. Mann *et al* followed up in 1999 with a paper in the journal *Geophysical Research Letters*. In early 2000 the IPCC released the first draft of the Third Assessment Report. The hockey stick was the only paleoclimate reconstruction shown in the Summary, and was the only one in the whole report to be singled out for repeated presentation.

McKitrick notes that as soon as the IPCC Third Assessment Report came out, the hockey stick version of climate history became canonical, and suddenly it was the 'consensus' view.

McIntryre and McKitrick attempted to replicate the work of Mann *et al*, and found that they couldn't. Instead, they argue that they have found a fundamental flaw in the computer program that was used to produce Mann's work and the hockey stick shape. Mann used the statistical procedure of principal component analysis to find the dominant features in a set of more than 70 different climate records. According to McIntyre and McKitrick, the algorithm used by Mann in the principal component analysis process would look through a data set and identify series with a 20th century trend, then load all the weight (ie, importance) on them. For instance, Figure 13 shows two tree ring chronologies from the Mann data set – one from California and the other from Arizona. In the bottom panel, the mean over the last 80 years is roughly equal to the mean for the previous 500 years, but in the top panel the post-1900 mean is above that for the pre-1900 portion. Mann's algorithm gives 390 times as much weight to the top series as to the bottom series in his principal component analysis.

Figure 13: Two tree ring chronologies from the Mann et al 1998 data set



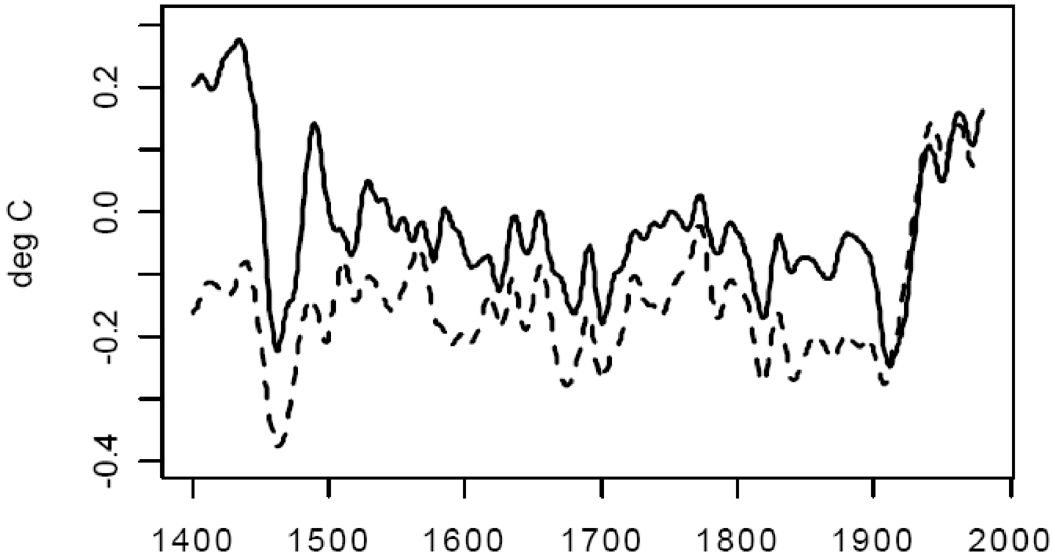
Source: McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, at 9.
See http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

To test the power of Mann's algorithm McIntyre and McKitrick developed sequences of random numbers – called 'red noise', which was trendless random noise that simulated the data you would get from trees in a climate that is only subject to random fluctuations with no warming trend. In 10,000 repetitions on groups of red noise, the pair found that a conventional principal component analysis algorithm almost never yielded a hockey stick shape, but the Mann algorithm yielded a pronounced hockey stick shape over 99% of the time.

McIntryre and McKitrick extended their study to demonstrate that Mann's algorithm also highlighted an unusual group of bristlecone pine chronologies, which were described in a 1993 publication. These trees exhibited a 20th century growth spurt that has not been fully explained, but is likely to at least part due to carbon dioxide fertilisation. It is known not to be a temperature signal since they do not match nearby temperature records, and the original authors stressed that they are not proper climate proxies. McIntyre and McKitrick ran Mann's algorithm after removing the above bristlecone series – and the result was just like that from a conventional algorithm – with no hockey shape and a pronounced peak in the 15th century.

After McIntyre and McKitrick 'corrected' the methodology and proxy data, they provided their version of the hockey stick chart – Figure 14. The McIntyre and McKitrick version shows the 20th century climate to be unexceptional compared to earlier centuries.[48]

Figure 14: Temperature index reconstruction.



NB: Solid line is the McIntyre / McKitrick reconstruction, the dashed line is the Mann *et al* work.
Source: McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, at 14.
See http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

The work of McIntyre and McKitrick has created significant controversy in the climate change community. Mann *et al* have vigorously defended their work, and both 'sides' have created weblogs to support their claims and critique the work, methodology and in some cases, the credentials of those opposing their views. For instance, the weblog 'realclimate.org', supporting the work of Mann *et al* and others, under the heading "Myth vs Fact Regarding the "Hockey Stick", identified at least four 'myths' and outlined why, in their opinion, they were factually wrong. The weblog stated:

> The claims of McIntyre and McKitrick, … are readily seen to be false , …
>
> The claims of McIntyre and McKitrick have now been further discredited in the peer-reviewed scientific literature, …[49]

A good example demonstrating the state of the debate over the extent of warming in recent

[48] McKitrick,R. "What is the 'Hockey Stick' Debate About?" in APEC Study Group, Presentation to the Conference "Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future". April 2005, http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf

[49] "Myth vs Fact Regarding the 'Hockey Stick'" at Realclimate weblog, http://www.realclimate.org/index.php?p=11. Accessed November 2005.

climate history is the reaction to an article by Moberg *et al*, published in *Nature* early in 2005. Moberg, in a reconstruction of temperature in the Northern Hemisphere over the last 2000 years, using a new technique, found greater temperature variability than previous reconstructions. The relevant parts of the abstract are below:

> A number of reconstructions of millennial-scale climate variability have been carried out in order to understand patterns of natural climate variability, on decade to century timescales, and the role of anthropogenic forcing. ….. Here we reconstruct Northern Hemisphere temperatures for the past 2,000 years by combining low-resolution proxies with tree-ring data, using a wavelet transform technique to achieve timescale-dependent processing of the data. Our reconstruction shows larger multicentennial variability than most previous multi-proxy reconstructions, but agrees well with temperatures reconstructed from borehole measurements and with temperatures obtained with a general circulation model. According to our reconstruction, high temperatures—similar to those observed in the twentieth century before 1990—occurred around ad 1000 to 1100, and minimum temperatures that are about 0.7 K below the average of 1961–90 occurred around ad 1600. This large natural variability in the past suggests an important role of natural multicentennial variability that is likely to continue.[50]

The reaction to the Moberg paper is presented as follows. For the greenhouse 'skeptics', Patrick Michaels wrote in his weblog:

> … it's all over for the hockey stick. … Moberg's reconstruction contains strong MWP [Medieval Warm Period] and LIA [Little Ice Age] signals. The natural variation of temperatures in the Moberg reconstruction is two to three times that of the Mann *et al*. "hockey stick." Again, the handle of the "hockey stick" was found to be too flat.
>
> Had the original reconstruction by Mann and colleagues looked like the latest reconstruction by Moberg *et al*., no one would have paid it much attention, because it would have fit nicely with the expectations given all of the prior research on the climate history of the past millennium. It would have been nothing remarkable.
>
> But, the "hockey stick" was remarkable. And as such, it will be remembered as a remarkable lesson in how fanaticism can temporarily blind a large part of the scientific community and allow unproven results to become mainstream thought overnight. The embarrassment that it caused to many scientists working in the field of climatology will not be soon forgotten. Hopefully, new findings to come, as remarkable and enticing as they may first appear, will be greeted with a bit more caution and thorough investigation before they are widely accepted as representing the scientific consensus.[51]

In contrast, the 'realclimate' weblog, with contributing writers including those who

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50 Moberg, A., *et al*. Highly variable Northern Hemisphere temperatures reconstructed from low- and high-resolution proxy data. *Nature*, **433**, 613-617. 10 February 2005.

51 Michaels, P. "Hockey Stick, 1998-2005. RIP." 3 March2005. See http://www.worldclimatereport.com/index.php/2005/03/03/hockey-stick-1998-2005-rip/, Accessed November 2005.

produced the original ‘hockey stick’, wrote:

> A key result is a reconstruction showing more century-scale variability in mean Northern Hemisphere temperatures than is shown in previous reconstructions. This result will undoubtedly lead to much discussion and further debate over the validity of previous work. The result, though, does not fundamentally change one of the most discussed aspected of that previous work: temperatures since 1990 still appear to be the warmest in the last 2000 years.
> Moberg et al. end up with two "warm peaks" in the smoothed record around 1000 and 1100 A.D., at 0 ºC on their anomaly scale. A few individual years within these intervals are almost +0.4 ºC warmer than the average. In comparison, the most recent data from the instrumental record post 1990 peak at +0.6 or a bit more, on the same scale. The coldest years of the so called "Little Ice age" occur around 1600 and are about -0.7 colder than average, with individual years down to -1.2 ºC.
>
> We hope that press reports about this paper that mention the increased variability will also emphasize the other key result: that there is "no evidence for any earlier periods in the last millennium with warmer conditions than the post-1990 period - in agreement with previous similar studies."
>
> It is worth noting that, in any case, the results of Moberg *et al*., if they prove correct, would not require any change in the IPCC TAR [Third Assessment Report] summary for policymakers, which says "the increase in temperature in the 20th century is likely to have been the largest of any century during the past 1,000 years. It is also likely that, in the Northern Hemisphere, the 1990s was the warmest decade and 1998 the warmest year.”[52]

The fact that the ‘hockey stick’ debate has been on-going for at least two years indicates that there is considerable disagreement within the climate change community. McKitrick writes that he and McIntyre have ‘enjoyed the satisfaction of knowing we are winning over the expert community, one at a time’, and included several comments from climatologists from around the world supporting their work.[53] In Australia, the ‘hockey stick’ debate has attracted little interest. In contrast, the United States House of Representatives Committee on Energy and Commerce has opened a Congressional investigation. The Committee has written to the Chairman of the IPCC seeking details on the work of Mann *et al* and the IPCC review process (Mann was both the lead author of the ‘hockey stick’ study, as well as a lead author of the IPCC chapter that assessed and reported the same work).[54] The letter is reproduced in Appendix One.

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52 RealClimate weblog, “Moberg *et al*: Highly variable Northern Hemisphere temperatures?” 15 Feb 2005. see: http://www.realclimate.org/index.php?p=122#more-122, Accessed November 2005.

53 McKitrick,R. “What is the ‘Hockey Stick’ Debate About?” in APEC Study Group, Presentation to the Conference “Managing Climate Change – Practicalities and Realities in a Post-Kyoto Future”. April 2005, http://www.climatechangeissues.com/files/PDF/conf05mckitrick.pdf, at 14.

54 Unites States House of Representatives, Committee on Energy and Commerce, http://energycommerce.house.gov/108/Letters/06232005_1570.htm, Accessed November 2005.

12.0 THE EXTENT OF GLOBAL WARMING

Climatologist Patrick Michaels is Research Professor of Environmental Sciences at the University of Virginia. He is a past president of the American Association of State Climatologists. Michaels notes that the correlation of sunspots and proxy temperature measurements is quite good until around 1970, when suddenly the thermometric data warms and diverges above the solar record.[55]

Michaels studied the question of whether the warming that began around 1970 is largely the result of greenhouse changes. He describes this question as a testable hypothesis, and one he and three colleagues tested with experiments, and published in the journal *Climate Research*. The response of temperature to carbon dioxide is a logarithmic response – meaning that warming begins to damp off as carbon dioxide increases. Another greenhouse gas – water vapour, absorbs much of the same type of radiation and therefore acts much the same. The similarity has an important distinction.

If on earth there was a place in which there is very little water vapour and there was very little carbon dioxide (before humans burned much fossil fuel), then adding carbon dioxide to the atmosphere should produce a rapid warming as the temperature response is on the rapidly ascending part of the greenhouse response logarithm.

Siberia, in the middle of winter, is an ideal test case. January temperatures are around minus 40˚C and as a result there is virtually no water vapour. It turns out that by far the largest warmings on earth are occurring in Siberian winter – just as greenhouse theory predicts. Michaels and his colleagues showed that the colder and dryer the air was, the more it warmed. If the air was moist and cold, there was little if any warming. The experiment was also conducted for summer, where the same theory would predict maximum warming in the driest places. Indeed, where adequate data exist, the largest warmings were in or near the Sahara Desert.

Michaels concludes that that is the signature of greenhouse warming: a disproportionate warming of dry air. That signature appears to have begun in the early 1970s – when the divergence from the solar (sun spot) temperature begins, and the differential warm-up of dry air, mainly in Siberia, begins. So how to use this information to predict future temperatures?

Michaels notes that computer climate models, known as general circulation models, are only as good as our understanding of the dynamic processes that they simulate. For example, we don't really have a very good understanding of the basic flow of carbon dioxide through the atmosphere. After a molecule of fossil carbon is burned, how long does it take before it is ultimately sequestered back in the earth? That depends on the assumptions about the rate of uptake by plants, which means their response to weather and climate. It also depends on the rate of decay of dead plant matter on the world's forest

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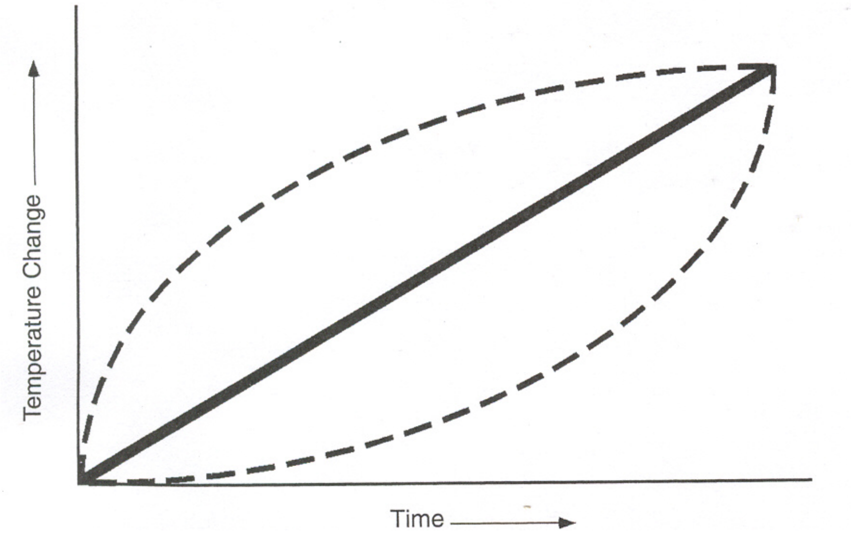
55 This section of the paper is adapted from: Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004.

floors. For all those processes, rate estimates vary widely. As a result, the estimates for the 'atmospheric lifetime' of a newly released molecule of carbon dioxide vary from 25 to 150 years.

Climate models do have some 'core beliefs'. One, as discussed above, is that the response of temperature to increments of carbon dioxide is logarithmic – meaning that it begins to damp off as concentrations increase. That means that the first increments of carbon dioxide create the greatest warming. All climate models also assume that the growth rate of carbon dioxide in the atmosphere is exponential, at 1% per year, meaning that it is going into the atmosphere at ever-increasing rates. The climate models hold that the carbon dioxide itself will not damp off, but will continually rise in concentration. These two factors are important, because the interaction of a logarithmic response of temperature to carbon dioxide, coupled to an exponential increase, as shown in Figure 15, can easily combine to a straight line. Climate models converge on this solution.

Figure 15: The combination of an exponential increase of carbon dioxide coupled to a logarithmic response



Source: Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004, at 16.

Climate models must be calibrated and compared to the greenhouse warming observed since the 1970s. Michaels notes that we can take the observed warming, which itself has been highly linear, and project it onto other climate forecasts. It then becomes very clear that, unless the central tendency for linearity is very wrong, that we already know the warming rate to a very small error.

As a result, Michaels states that scientists know quite precisely how much the climate will warm in the policy foreseeable future of 50 years – what he describes as a modest ¾ ˚C. Michaels quotes NASA scientist James Hansen, (Hansen is best known for his testimony on climate change to United States congressional committees in the 1980s that helped raise broad awareness of the global warming issue):

> Future global warming can be predicted much more accurately that is generally realized…we predict additional warming in the next 50 years of ¾ degrees C, a warming rate of 0.15 degree C +/- 0.05 degree C per decade.
>
> It is now impossible to avoid global warming this century. However, the actions outlined here can slow the warming, while having other benefits that justify the actions. If CO_2 emissions are kept level, and if technology is developed to reduce or capture emissions in the second quartile of the century, it should be possible to limit midcentury warming to 0.5°C and stabilize atmospheric composition later in the century.[56]

Michaels notes that this warming rate is about four times less than the top figure widely reported by the IPCC, and asked why it wasn't front page news that the scientist who was responsible for much of the global warming 'furor' was now predicting, with high confidence, only a modest warming? Michaels again quotes Hansen from the online journal *Natural Science*:

> Emphasis on extreme scenarios may have been appropriate at one time, when the public and decision makers were relatively unaware of the global warming issue. Now, however, the need is for demonstrably objective science… scenarios consistent with what is realistic under current conditions.[57]

13.0 THE IPCC SPECIAL REPORT ON EMISSION SCENARIOS

13.1 The Plausibility of the IPCC Emission Scenarios Debate

Michaels notes that the IPCC, using a combination of scenarios (the SRES scenarios as described previously) and climate models, provided 245 different future temperature projections of warming of between 1.4 ˚C and 5.8 ˚C. Michaels asks whether all projections are equally likely – noting that a warming of 5.8 ˚C would result in severe consequences. The IPCC provided no judgement as the preference of occurrence of any of the scenarios, and the Summary for Policy Makers states "All [scenarios] should be considered equally sound".

With this approach, Michaels observes that nobody is able to assess whether a prediction of 5.8 ˚C is a single 'outlier', or is accompanied by other forecasts that are nearly as high. Readers are then forced to assume that the 245 forecasts fall into a 'normal distribution' – ie, with a bell shaped curve, with an average value of 3.6 ˚C midway between the top and bottom values. However, an analysis by Stephen Schneider, who plotted the actual distribution of warming forecasts, showed that they are skewed toward the low end.

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56 Hansen,JE and Sato, M. "Trends of measured climate forcing agents." In *Proceedings of the National Academy of Sciences*, vol 98: 14778-83, 2001. See: http://www.pnas.org/cgi/content/full/98/26/14778, Accessed November 2005.

57 Hansen,J. "Can we defuse the global warming time bomb?" in online journal *Natural Science*, http://naturalscience.com/ns/articles/01-16/ns_jeh6.html. Accessed November 2005.

Instead of half the forecasts predicting temperatures higher than 3.6 ˚C, only about a quarter do. Just under 50% forecast warming less than 2.5 ˚C. Michaels concludes that without any comment from the IPCC on probability, it is much more likely that future global warming would fall nearer the low end of the IPCC range, 1.4 ˚C, rather than the high end. Michaels states: "The IPCC has known that all along, yet they've let a hysterical environmental and popular press run with apocalyptic scenarios touting the huge 5.8 ˚C warming."[58]

In July this year the United Kingdom House of Lords, Select Committee on Economic Affairs, published a comprehensive report on the economics of climate change. The Committee investigated the plausibility of the SRES scenarios and concluded:

> Whatever the intent of the IPCC, the public perception of the scenario exercise is often that each scenario is equally plausible: by not assigning levels of significance—quantitative or qualitative—to the scenarios, the impression given is that each has the same probability of occurrence. One of the salient features of the Henderson-Castles critique was that the high- emission scenarios rest on assumptions that are not credible. We were therefore concerned to hear from Dr Nakicenovic that IPCC had no intention of undertaking any significant reappraisal of the SRES for the IPCC Fourth Assessment exercise (AR4) for 2007. It seems to us that there is an urgent need for a wholesale reappraisal of the emissions scenario exercise.
>
> … We received a significant amount of evidence on the realism of the IPCC emissions scenarios, and doubts were raised, particularly about the high emissions scenarios. The balance of this evidence suggests to us that the high emissions scenarios contained some questionable assumptions and outcomes. [59]

13.2 The Market Exchange / Purchasing Power Debate

The IPCC Scenarios have attracted considerable criticism, especially with their underlying economic analyses. Two economists in particular, Ian Castles and David Henderson, have raised issues that have attracted worldwide interest. Castles was head of the Australian Department of Finance from 1979 to 1986 and the Australian Statistician from 1986 to 1994. Henderson was formerly the chief economist for the Organisation for Economic Cooperation and Development. The issue involves the mechanism for comparing the economy of one country compared to another – for which there are two main methods.

The first method is to convert the gross domestic product of each country into a universal standard (US$) based on the going market exchange (MEX) rate. This is the method the IPCC uses. The alternative is the purchasing power parity method, which compares the cost of the same basket of goods in two different countries. Castles and Henderson state that the IPCC should have used the purchasing power method.

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58 Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004, at 26.

59 United Kingdom House of Lords, Select Committee on Economic Affairs, *The Economics of Climate Change.* Volume I: Report. 6th July 2005, at 34. See: http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12i.pdf

The reason it matters is that the SRES assumes there will be a substantial degree of convergence of real per capita incomes between rich and poor countries by about 2100. Hence economic growth rates in developing countries are assumed to be higher than in rich countries. Using the market exchange rate method underestimates the current purchasing power of developing countries and therefore leads to unrealistic future growth rates to make up for that initial inequality. Using the purchasing power method, the growth rates of lesser developed countries will be lower (compared to what would happen with the market exchange methodology) and hence emissions growth will be lower, other things being equal. If the IPCC storylines are adjusted, climate models show a reduction in projected temperature in 2100 of about 0.5˚C – a reduction of about 15% with slight variation among the scenarios.[60]

In response to the work of Castles and Henderson the IPCC issued this media release:

> In recent months some disinformation has been spread questioning the scenarios used by the IPCC as developed in its Special Report on Emissions Scenarios 2000 (SRES). Like all reports published by the IPCC, this publication was based on an assessment of peer reviewed literature available at the time of the preparation of the report and subject to the review and acceptance procedures followed by the IPCC. As the work of the IPCC proceeds further any new literature that becomes available in this field will be assessed.
>
> Criticism of IPCC's work has been mounted by so called "two independent commentators" Ian Castles and David Henderson (referred to in subsequent paragraphs as C&H). Arguments of C&H allege that scenarios used by the IPCC are based on a method of income-gap closure, using Market Exchange Rates (MEX) rather than purchasing power parity (PPP), leading to unrealistically high economic growth rate assumptions for developing countries This is factually incorrect. Economic growth rate assumptions were carefully chosen in line with historic data.
>
> …Recently, in the wake of C&H's unfounded criticism, some further detailed model runs have been carried out by Alan Manne of Stanford University and R. Richels of the Electric Power Research Institute. Their results show very minor differences with PPP in comparison with the use of MEX. The claim of C&H, therefore, that there is an upward bias in the SRES scenarios is totally unfounded.[61]

The United Kingdom House of Lords Select Committee on Economic Affairs inquired into the economics of climate change, and published their findings in July 2005. The Committee heard considerable evidence on the purchasing parity power / market exchange rate (MER) debate. The Committee concluded:

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60 Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004, at 31.

61 Intergovernmental Panel on Climate Change, *IPCC Press Information on AR4 and emission scenarios*. 8 December 2003. See IPCC website: http://www.ipcc.ch/press/pr08122003.htm, Accessed November 2005.

> We found no support for the use of MER in such exercises, other than from Dr Nakicenovic of the IPCC. We consider that Professor Henderson and Mr Castles were right to raise the issue. In so doing, they have helped to generate a valuable literature that calls into question a whole series of issues relating to the IPCC SRES, not just the issue of MER versus PPP. …It seems unlikely that the debate over the emissions scenarios would have occurred at all had Professor Henderson and Mr Castles not persisted in their views. We consider that they have performed a public service. [62]

13.3 Carbon Dioxide Emission Rates

As noted, climate models assume carbon dioxide emissions to rise exponentially. The House of Lords Select Committee on Economic Affairs found that whilst emissions of carbon dioxide are increasing, the rate of global increase has fallen steadily since 1960. Similarly, per capita emissions are falling, not rising, and "carbon intensity"—carbon emissions divided by GDP—is also falling at a fairly constant rate. These changes in the past 30 years or so can be compared with the IPCC emissions scenario projections for 1990-2020. Table 4 shows that even the low emissions scenario (B1) has rates of growth of carbon emissions higher than the recent historical rates of change. The Select Committee concluded that this suggests that the IPCC scenarios are not capturing recent experience in their short term projections.

Table 4: World carbon dioxide emission trends and the IPCC scenario trends

	Average annual growth in CO2 emissions (excluding land-use change) % p.a.	Average annual growth in CO2 emissions per capita % p.a.	Average annual growth
1960-2000	2.3	+0.2	- 1.3
1970-2000	1.6	- 0.1	- 1.5
1980-2000	1.3	- 0.3	- 1.6
1990-2000	1.2	- 0.2	- 1.4
IPCC projections 1990 – 2020	A1F1 2.1 AIB 2.4 A1T 1.7 A2 2.0 B1 1.7 B2 1.4		

Source: United Kingdom House of Lords, Select Committee on Economic Affairs, *The Economics of Climate Change.* Volume I: Report. 6th July 2005, http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12i.pdf, at 40.

62 United Kingdom House of Lords, Select Committee on Economic Affairs, *The Economics of Climate Change.* Volume 1: Report. 6 July 2005, at 34. See: http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12i.pdf

The Select Committee also received evidence from Professor Ross McKitrick and Dr Mark Strazicich. Their analysis showed per capita emissions as a stationary constant at around 1.1 tonnes carbon per person on a global basis. They computed the implied per capita emission levels in the 40 IPCC scenarios and found that only seven of these scenarios remain in 2050 within even a wide margin of error relative to the current average emission level. The Committee noted that assumptions about very rapid growth in emissions in developing economies could change, i.e. scenarios could be constructed that assume a break between the time series for the past decades and the coming 100 years. However, the Committee concluded: "But what cannot be justified is an assumption whereby most of the scenarios assume that break will happen. The work of McKitrick and his colleague Dr Mark Strazicich seems to us to point, once again, to the failure of the IPCC scenarios to be rooted in historical precedent."[63]

Michaels also reviewed the evidence and noted that the emission of carbon dioxide per capita has stabilised since the early 1980s. If the combined trends of a progressive lowering of future population estimates and a decreased per capita carbon dioxide use continue, then the increase in atmospheric carbon dioxide is likely to be in a transition from exponential (constantly increasing growth rates) to a linear (constant) growth rate. In fact, Michaels demonstrated that this transition has already began, and that that the basic assumption used for future behaviour by every climate model – ie, an exponential growth of carbon dioxide emissions of one percent per year, hasn't been correct for the last three decades. Michaels concludes: "The observed behaviour of per capita carbon dioxide vs reality is a stark example of the exaggeration of global warming, in which the climatological modelling community and the UN's IPCC continues to assume something that is obviously wrong."[64]

According to Michaels, the implications of this erroneous assumption are staggering. As noted, a constant greenhouse warming trend actually requires an exponential change in atmospheric carbon dioxide - yet this exponential growth behaviour appears to have ceased nearly 30 years ago. Will global warming therefore slow down in coming decades? Michaels notes that the answer may lie in the behaviour of the oceans. There is a difference in the temperature of the oceanic surface and the ocean deep (10,000 feet depths). The time lag between the two parts of the ocean mixing is roughly 35 to 40 years. This indicates how long it will take for the rate of temperature increase to respond to a damping of the carbon dioxide increase from exponential to linear – which began about 30 years ago. The peak in the lag correlation at about 35 – 40 years is strongly suggestive that the modest rate of surface warming may begin to decline in a decade or so. Michaels notes that if it occurs, the decline in rate will be slight and will take a decade or two to be noticed, but that is the result of these observations.[65]

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63 United Kingdom House of Lords, Select Committee on Economic Affairs, *The Economics of Climate Change.* Volume I: Report. 6th July 2005, at 40. See: http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12i.pdf

64 Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004, at 28.

65 Michaels, P. *Meltdown. The Predictable Distortion of Global Warming by Scientists, Politicians, and the Media*. CATO Institute, 2004, at 29.

13.4 Criticisms of the IPCC as an institution

In a review of the IPCC and the Kyoto process, Boehmer-Christiansen and Kellow have been sceptical of greenhouse science as it has been funded and used for policy purposes. They consider that climate change science is riddled with interests to the extent that it has much less power as a force for consensus than was the case for ozone depletion. For instance, the originators of research for IPCC Working Group 1 (the scientific basis), were either government employees or working in government funded centres frequently associated with meteorological offices and institutes that had an interest in there being a climate problem which would justify further research. Few university scientists contributed to the IPCC process because they lacked the travel funds, access to the largest computers and the ability to attend meetings regularly due to teaching commitments. The IPCC process has therefore been dominated by scientists whose livelihoods depend upon direct government allocations for climate research.[66]

Boehmer-Christiansen and Kellow also compared the IPCC review process with that of normal scientific journals. They concluded the IPCC process fell short of the 'accepted' procedure in five ways:

- The review process is conducted by the authors of a draft chapter of the IPCC report, the report having developed from a list of chapter headings laid down by a small group of researchers who then invite submissions from their colleagues;
- The authors are themselves active researchers in the field, rather than being disinterested as are the editors of scientific journals;
- The lead authors choose the reviewers they will send their drafts to;
- The lead authors choose whether to accept or reject the criticisms offered; and
- There is no possibility that the draft chapter will not be published.

In terms of the IPCC consensus, the authors concluded:

> The very notion of establishing an institution to produce a scientific consensus suggests that a certain kind of consensus was likely to emerge, because the only reason for producing a consensus lay in the belief that an international convention would not be developed unless there was such an ingredient. If one is not convinced of a need for a convention, there would be no need for consensus on the knowledge base because the existence of normal scientific controversy would be of no consequence. The very establishment of an institution to produce consensus can thus be seen as exerting a corrupting influence on the conduct of climate change research.[67]

Henderson, who provided evidence to the House of Lords Select Committee as discussed above, has noted that the IPCC has established itself, in the eyes of its member governments, as their sole authoritative source of information, evidence, analysis, interpretation and advice on the whole range of issues relating to climate change. It has in

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66 Boehmer-Christiansem, S. and Kellow, A. *International Environmental Policy, Interests and the Failure of the Kyoto Process*. Edward Elgar Publishing, 2002, at 140.

67 Boehmer-Christiansem, S. and Kellow, A. *International Environmental Policy, Interests and the Failure of the Kyoto Process*. Edward Elgar Publishing, 2002, at 146.

effect acquired a monopoly position. However, he considers that there are good reasons to query the claims to authority and representative status that are made by and on behalf of the IPCC.

Henderson states that the IPCC process is far from being a model of rigour, inclusiveness and objectivity. In particular:

- Aspects of the Panel's work have been shown to be dubious or at fault. These include, but are not confined to, its treatment of economic issues;
- The response of the Panel's directing circle and milieu to informed criticism has typically been inadequate or dismissive;
- Despite the numbers involved, the IPCC milieu is not professionally representative;
- Both the directing circle and the milieu more generally are characterised by an endemic bias, towards alarmist assessments and radical 'solutions'. This bias goes back to the earliest days of the IPCC - it reflects the views and presumptions of the Panel's sponsoring departments and agencies.

Henderson notes the House of Lords Committee criticisms of the IPCC, and stated:

> For the first time since the IPCC came into being, searching criticisms of it have come from a source which cannot easily be disregarded or set aside by its directing circle or by governments. A group of eminent, experienced and responsible persons, drawn from a famous national legislative body and spanning the political spectrum, after taking and weighing expert evidence, has published a carefully considered and unanimous report in which, among other things, the work and role of the Panel are put in question.[68]

Henderson considers that two main actions are needed: make the IPCC process more professionally representative and watertight, especially, though not only, on the economic side; and to ensure that work undertaken on issues relating to climate change is made subject to more effective scrutiny than is now the case.[69]

Dr John Zillman, President of the Australian Academy of Technological Sciences and Engineering and former Principal Delegate of Australia (1994 – 2004) to the IPCC, argues that in relation to the IPCC assessment process, there is no mechanism yet in existence for providing a more reliable assessment of the state of knowledge of climate change. However, Zillman identified the following pressures on the integrity / reliability of the 1996 Second Assessment Report:

- Confusion on the definition of climate change;
- The inherent tension of being both scientific and intergovernmental;

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68 Henderson, D. "Challenging the IPCC Monopoly: The Way Ahead." 30 October 2005. See websitehttp://www.staff.livjm.ac.uk/spsbpeis/CHALLENGING%20THE%20IPCC%20MONOPOLY.htm. Accessed December 2005.

69 Henderson, D. "Challenging the IPCC Monopoly: The Way Ahead." 30 October 2005. See websitehttp://www.staff.livjm.ac.uk/spsbpeis/CHALLENGING%20THE%20IPCC%20MONOPOLY.htm. Accessed December 2005.

- The influence of lobby group pressures;
- The pressure for consensus;
- The tension between concurrent and sequential review;
- The time demands on Lead Authors and Reviewers;
- The time frame of the review process;
- The risk of disproportionate influence of dominant personalities;
- The location of authority for final decision with Lead Authors; and
- Who decides what constitutes dangerous anthropogenic interference with the climate system.

Additional pressures on the integrity of the Third Assessment Report were identified by Zillman as:

- Intimidation of Lead Authors;
- Political agendas disguised as scientific argument;
- Lead author and reviewer fatigue;
- Some indications of political agendas within;
- Critical mass of expertise at key stages.

Asking how reliable are model projections of climate change, Zillman responds:

- The IPCC assessments, in their approved formulation, are the most reliable there is;
- The distinction between scenarios, projections and prediction is fundamental;
- The spread of model sensitivity is a good indicator of the current level of reliability of projections of global warming;
- Little reliance should be placed on regional projections of climate change.[70]

The noteworthy point about Zillman's final comment about regional projections is that it is at the regional scale that government's are most likely to need information on the impacts of climate change. For instance, as reported in the first part of this paper, the NSW Government commissioned CSIRO to produce climate change projections for the State. The CSIRO did a similar exercise for Kiama Municipal Council.[71] Whilst regional governments are preparing policy responses to these projections, Australia's lead delegate to the IPCC is stating that little reliance should be placed on them.

Zillman also notes the fundamental difference between climate projections and predictions. Michaels has noted that groups promoting a carbon constrained future often use the IPCC projections as 'proof' or prediction of global warming. The IPCC defines a climate projection as follows:

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70 Zillman, J. "The IPCC assessment process and the reliability of model projections of climate change." Presentation to Australian APEC Study Centre Conference, *Managing Climate Change: Practicalities and Realities in a post – Kyoto future*. April 4 2005. Dr Zillman is the President of the Australia Academy of Technological Sciences and Engineering and former Principal Delegate of Australia (1994 – 2004) to the IPCC.

71 CSIRO, *Potential Impacts of Climate Change on the Kiama Local Government Area. Report prepared by CSIRO for Kiama Municipal Council*. March 2005.

> A projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models. Climate projections are distinguished from climate predictions in order to emphasise that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions, concerning, eg, future socio-economic and technological developments, that may or may not be realised, and are **therefore subject to substantial uncertainty** [emphasis added].[72]

In contrast, a climate prediction is defined by the IPCC as: "the result of an attempt to produce a most likely description or estimate of the actual evolution of the climate in the future." The IPCC has released temperature projections.

14.0 CLIMATE MODEL CRITICISMS

Garth Paltridge, former Chief Research Scientist of the CSIRO Division of Atmospheric Research, in a critique of climate models, notes that it is fairly easy to calculate the likely rise of global average temperature for the purely theoretical situation where atmospheric carbon dioxide is doubled but nothing else about the atmosphere is allowed to change. The increase is about 1.2 °C, and it would take a couple of hundred years to complete the change. However, in the real world, all sorts of other atmospheric and oceanic processes that depend on surface temperature are happening. These are called feedback processes, and many of them amplify or reduce the original change of 1.2 degrees caused directly by the carbon dioxide. Their effects need to be added up to give an overall value for the total 'feedback factor' (F) to calculate the predicted change in temperature. Thus the calculated temperature change may be greater or less than 1.2 degrees – this depending entirely on the value of F and on whether it is positive or negative.

Paltridge notes that considering all the fairly respectable climate models of the last twenty years or so, their total value for feedback ranges from F = -0.3 to F = +0.95. However, the particular models selected by the IPCC in its 2001 Third Assessment Report, the value of F ranges between (roughly) 0.4 and 0.8, and to a corresponding rise of temperature between (roughly) 2 and 4 degrees.

Paltridge concludes that the apparent convergence of the predictions of the IPCC models into a narrower range of possible temperature rise has to be taken with 'a considerable grain of salt'. It is not necessarily an indication of getting better at forecasting the future. Because modern climate models are so complex, it is very rare that a group of researchers develops a new model from scratch. They take some or all of the code from an existing model of another group, and slightly modify those bits of it that are relevant to their particular interest and expertise. The modified model is usually given a new name. The overall process ensures that there can be a gradual, and largely unconscious, development of a situation where all the supposedly independent models have common physics and common values for their tune-able parameters. They will quite naturally – but for no good

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72 Baede, A. *Glossary* in *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001.

physical reason - begin to tell the same story. With this situation comes the danger that the narrowing range of answers given by the various models will be interpreted by scientists as an indication that the accuracy of their forecasts is improving.[73]

In Paltridge's opinion, the real problem is that the climate models are now so complex that no scientist outside the closed shop of the numerical modelling community can ever really hope to assess whether or not the physical representations within them are acceptable. The normal and necessary process of scientific criticism cannot take place. He considers that the very least that needs to be done if the IPCC is to maintain its credibility is to insist that all models used in IPCC assessments must calculate and publish the implicit feedback factors built into their calculations.[74]

15.0 PAN EVAPORATION

One area of research of increasing interest, but to date rarely (if at all) reported in the media, is the issue of pan evaporation. It is of increasing interest because some of the observations are at odds to what global climate models are predicting. In November 2004 the Australian Academy of Science and the Australian Greenhouse Office supported a workshop to discuss the conflict of scientific opinion as to whether the evaporative demand of the atmosphere necessarily increases with global warming. Resolution of this conflict is important to validating global climate models and attributing observed climatic changes to causes.[75] This section draws from the published proceedings of that workshop.

Central to the theoretical and observational development of the greenhouse warming concept is the positive feedback onto air temperature caused by the water cycle. The positive feedback is because warming increases the concentration of water vapour in the atmosphere and water vapor is itself a powerful greenhouse gas. This notion is expressed in all the global climate models that predict human induced greenhouse warming. Accordingly, comparison of global climate model-outputs with observations on various components of the global hydrologic cycle should be very important for validating the models. Rainfall and humidity are obvious aspects of the hydrologic cycle and daily

73 Paltridge, G. "Some 'Ifs and Buts' of Climate Models, and Why Should We Care Anyway?" Presentation to Australian APEC Study Centre Conference, *Managing Climate Change: Practicalities and Realities in a post – Kyoto future*. April 4 2005. See: http://www.climatechangeissues.com/files/PDF/conf05paltridge.pdf, Accessed November 2005.

74 Paltridge, G. "Some 'Ifs and Buts' of Climate Models, and Why Should We Care Anyway?" Presentation to Australian APEC Study Centre Conference, *Managing Climate Change: Practicalities and Realities in a post – Kyoto future*. April 4 2005. See: http://www.climatechangeissues.com/files/PDF/conf05paltridge.pdf, Accessed November 2005.

75 Gifford,R. *et al*, *Preface*, in *Pan evaporation: an example of the detection and attribution of trends in climate variables*. Australian Academy of Science National Committee for Earth System Science, Proceedings of a workshop held at Shine Dome, Australian Academy of Science, Canberra November 22-23, 2004. April 2005. See: http://www.greenhouse.crc.org.au/crc/ecarbon/publications/panevap_proceedings_050426.pdf, Accessed November 2005.

measurements of these are routinely collected across the globe. Another, less obvious, aspect of the hydrologic cycle is the evaporative demand of the atmosphere. Since the 1960s the Class A Pan Evaporimeter has been used by meteorologists to determine the evaporative demand of the atmosphere on a daily basis. Daily data from these devices have been collected at many meteorological stations for decades especially in rural areas where the information can be used for irrigation scheduling. However, it was not until the mid-1990s that those records were compiled for large areas. The results of such examinations of pan evaporimeter records averaged across continental scales over the decades of recent global warming have produced 'a torrent of argument'.[76]

Class A pans are large standardized pans of water open to the atmosphere to estimate the evaporative demand of the atmosphere (potential evaporation) primarily for irrigation scheduling purposes. Such pan evaporation rates averaged over large areas and long time-periods have been reported to be declining on average by about 3 mm/year per year everywhere it has been examined globally since the 1970s.

The annual rate of evaporation from open pans averaged over Australia between 1970 and 2004 shows variability around a long term downward trend. The variability around the downward trend involves a decrease in the early 1970s, followed by increase up to the early 1980s, then decrease over the next two decades before increasing from 2001. The overall downward trend averaged 2.8mm per year per year for the 30 years since 1975 when widespread reliable data came available to 2004. That is a 3% decrease of the annual pan evaporation rate over 30 years. The trend in Australia has been of similar magnitude to the trend in the northern hemisphere.

The physics of evaporation are well understood. Changing evaporative demand can only be caused by three factors:

- Changing water vapour pressure deficit of the air;
- Changing wind speed; and
- Changing net radiation impinging on the evaporative surface.

Analysis has shown that a single cause cannot account for the declines in pan evaporation observed in diverse places around the world. All three factors have played a role to differing degrees in different places.

Air temperature *per se* does not influence pan evaporation over time scales of greater than about a week or so. It can influence evaporation indirectly via two mechanisms. One is by influencing the vapour pressure deficit of the air. Due to the hydrological physics involved, for global atmospheric warming to increase the vapour pressure deficit, the air would have to be warming faster during the day than the night. However, the opposite trends have both been widely observed. For example, on average for Australia and elsewhere, mean daily

76 Gifford,R. *et al*, *Preface*, in *Pan evaporation: an example of the detection and attribution of trends in climate variables*. Australian Academy of Science National Committee for Earth System Science Proceedings of a workshop held at Shine Dome, Australian Academy of Science, Canberra November 22-23, 2004. April 2005. See: http://www.greenhouse.crc.org.au/crc/ecarbon/publications/panevap_proceedings_050426.pdf, Accessed November 2005.

temperature minima increased almost twice as fast as mean daily maxima during the twentieth century producing an approximately 0.2°C decline trend in daily temperature range between 1960 and 1990. This decrease in daily temperature range, leads to an approximately conserved vapour pressure deficit, implying that changes in vapour pressure deficit should generally be small, and have, on average, little impact on pan evaporation.

Complex changes in surface wind speeds are expected as part of the greenhouse effect on general atmospheric circulation. Any reductions in wind speed could contribute to the observed declines in pan evaporation. Wind-run fields in Australia are not as well documented as are other climate variables. Therefore wind remains a potential cause that is difficult to evaluate. Indications are that decreases in wind speed have occurred in parts of eastern and southern Australia. However, other studies have demonstrated that it takes large changes in wind speed to cause a small change in pan evaporation.

On average worldwide, solar irradiance has declined 4-5% in the 30 years to 1990. Results on changes in global solar radiation over the last 10 years are equivocal. Direct pyranometer networks indicate that a re-brightening has been occurring widely since 1990 but not everywhere. Continued solar dimming has been reported for India and the European Alps. Indirect evidence, derived from earthshine reflected off the moon, that a period of brightening at the earth's surface in the 1990s has given way to re-dimming since 2000 is intensely debated. For Australia there is only a small integrated network of 8 instruments since 1990. What evidence there is does not show any systematic trend in incident solar radiation.

Scientists do not know exactly what has been causing the observed variations in solar irradiance at the surface in many places around the world especially in the northern hemisphere. Two factors may be involved:

- One is changes in the atmospheric loading of human-induced aerosols that directly absorb solar radiation and also indirectly change cloud properties;
- The second is a potential negative feedback within the climate system in which greenhouse warming may cause changes in cloud amount or properties leading to more solar radiation absorption or reflection by cloud.

The conclusions of the Academy of Science workshop are significant in their implications:

> The widespread failure of potential evaporation to increase on land, with several reports of widespread declines, as the world warmed, and unexplained decreases in solar radiation, indicate considerable gaps in our climatic understanding. For reliable climate prediction we do not know enough of the fundamentals of how greenhouse gases and aerosol accumulation influences atmospheric humidity, cloud formation and cloud properties, solar radiation, whether greenhouse warming involves an intensification or a dampening of the hydrologic cycle, and how ocean evaporation responds to greenhouse warming.
>
> A deficiency of the [climate] models is the poor level of understanding and treatment of ocean evaporation, and of clouds and their effects on short-wave as well as long-wave radiation at ground level as influenced by greenhouse gases and aerosols. The observations strengthen the need for more careful theoretical assessments of (i)

> whether or not Australia (and other places) will get drier as temperature increases, and (ii) whether cloud feedback will strengthen or diminish global warming.
>
> It is affirmed that global atmospheric warming does not necessarily mean a more drying atmosphere or a drier land surface.[77]

What is different in this case is that to date, those outside the greenhouse warming 'consensus' fraternity have outlined the limitations of climate models, but have been widely criticised by the 'consensus' scientists. Those not agreeing with the 'consensus' are labeled as skeptics, or given more derogatory terms. In this case, respected scientists 'in the loop' of studying global warming are making these cautionary statements. It could be argued that not knowing the basic physics of whether clouds increase or decrease global warming makes it impossible for a climate model to accurately project the future. It is appropriate to recount some Australian climate projections, for example, *Climate Change: An Australian Guide to the Science and Potential Impacts* stated:

> **Evaporation and moisture balance**
> Higher temperatures are likely to increase evaporation. CSIRO has calculated projections of change in potential evaporation (atmospheric water demand) from eight climate models. The results show that increases occur in all seasons and, annually averaged, range from 0 to 8% per °C of global warming over most of Australia, and up to 12% over the eastern highlands and Tasmania. … In general, Australia has an annual net moisture balance deficit, and our environment is largely moisture-limited. When the simulated increases in potential evaporation are considered in combination with simulated rainfall change, the overall pattern shows decreases in moisture balance on a national basis…..This would lead to a greater incidence of drought, as has been projected by several modeling studies.[78]

The fundamental basis of the *Australian Guide* as above is taken from the IPCC Third Assessment Report. The Third Assessment Report stated:

> With increasing temperature, the surface energy budget tends to become increasingly dominated by evaporation…The increase in evaporation is not strictly inevitable, but it occurs in all general circulation models, though with varying strength…. Naturally occurring droughts are likely to be exacerbated by enhanced potential evapotranspiration, which quickly robs soil of its moisture.[79]

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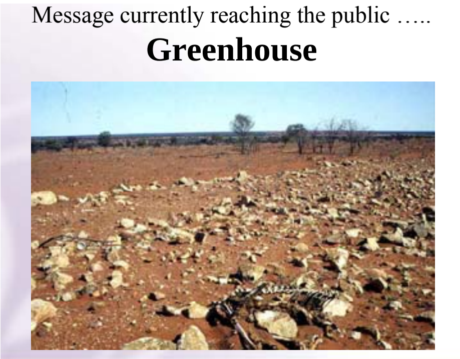
77 Gifford,R. *et al*, *Preface*, in *Pan evaporation: an example of the detection and attribution of trends in climate variables*. Australian Academy of Science National Committee for Earth System Science Proceedings of a workshop held at Shine Dome, Australian Academy of Science, Canberra November 22-23, 2004. April 2005. See: http://www.greenhouse.crc.org.au/crc/ecarbon/publications/panevap_proceedings_050426.pdf, Accessed November 2005.

78 Pittock,B. (Ed) *Climate Change: An Australian Guide to the Science and Potential Impacts*. Australian Greenhouse Office, 2003.

79 Stocker,TF *et al*, Physical Climate Processes and Feedbacks. In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 432.

> [In relation to the effect of clouds on future projections of climate]
>
> The physical basis of the cloud parametrizations included into the models has also been greatly improved. However, this increased physical veracity has not reduced the uncertainty attached to cloud feedbacks: **even the sign [ie, positive or negative]of this feedback remains unknown** (emphasis added).[80]

Reporting the outcomes of the Academy of Science workshop on pan evaporation at the Greenhouse 2005 conference, the researchers noted that the message currently reaching the public is that 'greenhouse' is associated with a 'brownhouse' – ie drought. In contrast, intuition suggests that a 'greenhouse' should be 'green' – as per the two figures below.



Source: Roderick,M *et al*, Climate Change: Wetter or Drier? In *Greenhouse 2005 – Action on Climate Change Conference*, Melbourne, 13-17 November 2005. See http://www.greenhouse2005.com/Program.html, Accessed November 2005

They conclude that globally averaged trends to date, of more rainfall and less evaporative demand, will result in a 'greenhouse'.

The pan evaporation observations indicate that increasing temperature does not necessarily lead to a drier atmosphere. The results of the workshop reinforce what many critics of climate models claim – that we simply do not know enough about the fundamental physics of many components of the hydrological cycle to make reliable modeled climate projections.

16.0 THE ARGUMENT THAT GREENHOUSE CLAIMS ARE EXAGGERATED

16.1 Is Global Warming Responsible for Recent Rainfall Declines?

The Australian Climate Group was convened in late 2003 by World Wildlife Fund Australia and the Insurance Australia Group. The Group is composed of nine high profile individuals from academia, ex-CSIRO, business and conservation groups. The Group has called for Australian greenhouse emissions to be cut by 60% to lower the risk that climate

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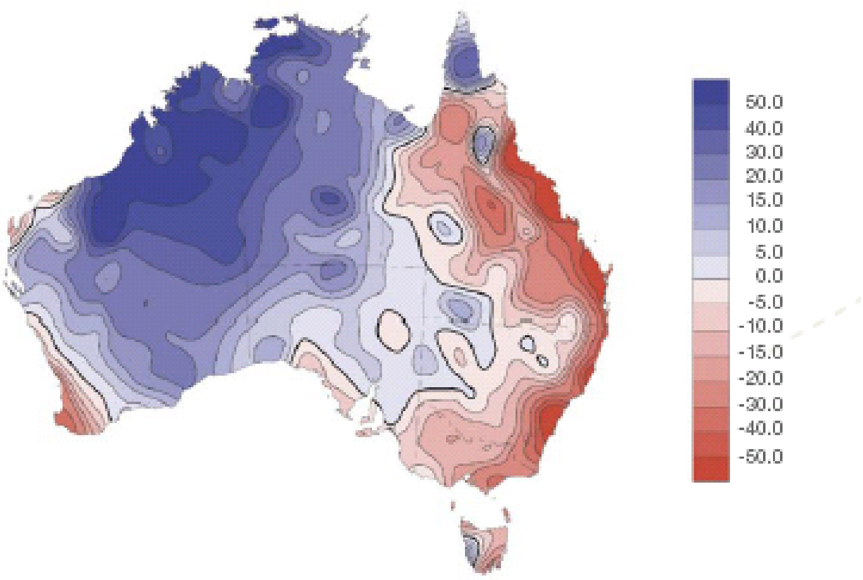
80 Stocker,TF *et al*, Physical Climate Processes and Feedbacks. In *Climate Change 2001: The Scientific Basis.* Contribution of Working Group 1 to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, United Kingdom and New York, 2001, at 419.

change will reach a dangerous level. Outlining the expected impacts of a warming climate on Australia, under the heading *Very small changes in the global temperature have very large impacts*, the Group states:

> This group believes that the recent downward trends in rainfall in parts of Australia are closely linked to global warming….
>
> Much of Australia's rainfall is affected by irregular changes in Southern Hemisphere circulation of the atmosphere and oceans such as the El Nino-Southern Oscillation and the major Pacific and Indian Ocean currents. As a result, Australia's rainfall is fickle, with high variability from year to year. There is a risk that our rainfall is particularly sensitive to changes in the global climate.
>
> A number of regions that are important for agriculture have seen a substantial decline in rainfall over the past few decades. In southwest Australia, rainfall declined sharply during the 1970s by 15-20%….
>
> Climate change will cause different changes in rainfall in different parts of the country – the map shows changing rainfall trends over Australia from 1950-2002. It shows significant decreases in rain in the southwest and southeast, while there have been increases in rain intensity in the northwest.

Trend in annual total rainfall 1950 – 2003 (mm/10 yrs)
Source: Bureau of Meteorology, 2004

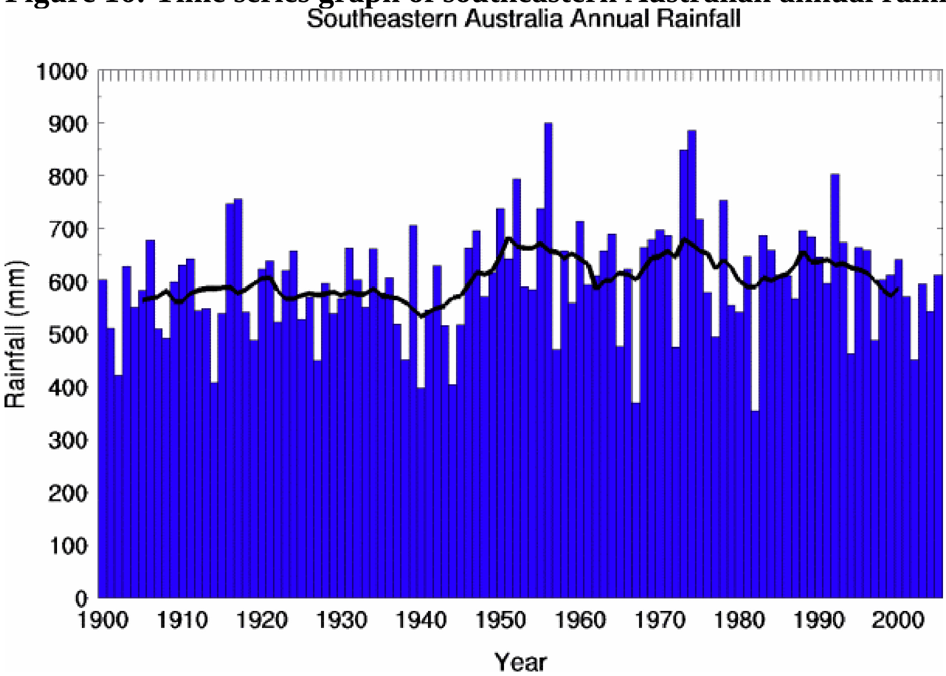


> Changes in rainfall and evaporation are serious. Our major cities – Sydney, Melbourne, Perth, Canberra, the Gold Coast and Adelaide – all need more water.[81]

81 The Australian Climate Group, *Climate Change. Solutions for Australia*, WWF Australia, June 2004 at 23. See http://www.iag.com.au/pub/iag/sustainability/publications/climate/intro.shtml, accessed November 2005.

The trend map above does indeed show quite a severe downward trend in rainfall over the east coast and southwest corner of Australia. The Group's statement notes that Australian rainfall is fickle, so it is interesting to see the trend over a longer time period – since records reliable enough for analysis began in 1900. Figure 16, from the Bureau of Meteorology, is a time series graph of southeastern Australian annual rainfall since 1900.

Figure 16: Time series graph of southeastern Australian annual rainfall since 1900



Source: Australian Bureau of Meteorology, *Time series – Australian Climate Variability and Change*. See http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/timeseries.cgi. Black line is 11 year rolling average. Average value 1961 – 1990 was 625.22 mm. Accessed February 2006.

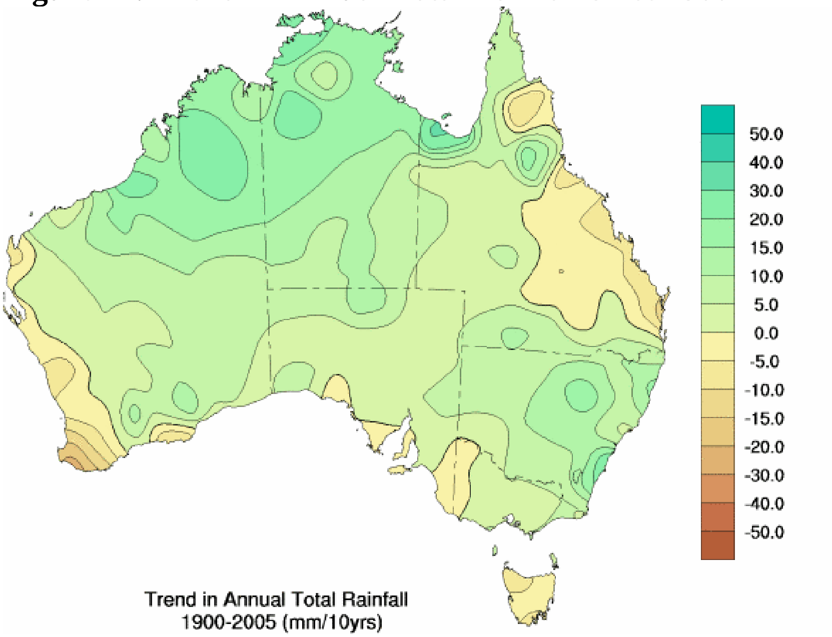
It can be seen that over the 104 year period shown, the wettest decades were that of the 1950s and 1970s. Any rainfall trend map that begins its analysis from 1950 onwards is going to demonstrate a drying trend – as per the map in the Climate Group of Australia publication. The 11 year rainfall rolling average for the first half of the century – 1900 – 1950, was stable and relatively dry – clearly below the average of 625 mm from the 1961 – 1990 reference period. The 11 yr average at the end of the century is only just approaching that of the beginning of the century, and the recent decline in rainfall appears to be completely in context when compared to the total rainfall record.

So a rainfall trend map for all of Australia, from 1900 to 2004, as shown in Figure 17, looks very different from the one put forward as evidence of climate change by the Australian Climate Group. The drying of the south west of the continent is still very pronounced, but the southeastern part of the mainland is showing a positive total rainfall trend over a hundred year period. It is worth reviewing the comments in Chapter 6 – Australian Climatic Trends – which concluded that studies had left open how much of the change in rainfall can be attributed to natural variability versus the enhanced greenhouse effect. Reviewing the evidence of climate change in the Southern Hemisphere, Karoly concludes:

The observed rainfall trends in southwest Western Australia are much greater than expected from most climate model simulations with increasing greenhouse gases. Furthermore, they occur in a season when there is likely to be little influence from stratospheric ozone depletion. Hence, natural decadal climate variations are likely to be an important factor in these rainfall decreases.

Recent climate changes in the Southern Hemisphere are likely to result from a complex combination of natural climate processes (associated with interactions between the atmosphere, oceans, and sea ice) and human influences (including decreases in stratospheric ozone and increases in atmospheric greenhouse gases and aerosols).[82]

Figure 17: Trend in Annual Total Rainfall since 1900



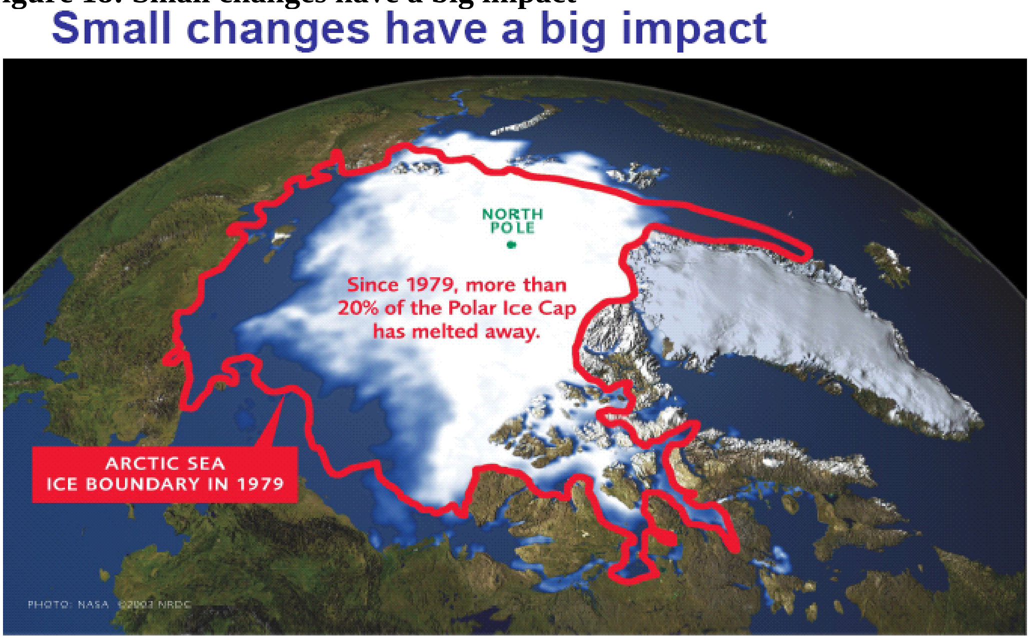
Source: Australian Bureau of Meteorology, *Trend* Maps - *Australian Climate Variability and Change*. See http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi, accessed February 2006.

16.2 Are Carbon Dioxide Emissions Responsible for Melting The Cryosphere?

One of the features of the debate about the advanced greenhouse effect is the melting of the cryosphere – that portion of earth covered at some point in time with ice and snow. For instance, Graeme Pearman, former chief of the CSIRO Division of Atmospheric Research, produced the following graphic indicating that small changes (ie, a small increase in temperature in the Arctic) are having a big impact.

82 Karoly,DJ. "Ozone and Climate Change." In *Science*, Vol 302, 10 October 2003, at 237. Professor Karoly is also a member of the Australian Climate Group.

Figure 18: Small changes have a big impact



Source: Pearman, G. "How dependable are predictions of temperature increases?" in Australian APEC Study Centre Conference, *Managing Climate Change: Practicalities and Realities in a post – Kyoto future*. April 4 2005. Dr Pearman is the former chief of the CSIRO Division of Atmospheric Research.

Similarly, the *Sydney Morning Herald* recently reported:

> Global warming in the Artic might be accelerating out of control, scientists have warned, as new data revealed the floating cap of sea ice has shrunk to probably its smallest in at least a century.[83]

The *Herald* was reporting the results of a survey of Arctic sea ice by the National Snow and Ice Data Center in Colorado. The Center reported:

> For the fourth consecutive year, National Snow and Ice Data Center and NASA scientists using satellite data have tracked a stunning reduction in sea ice at the end of the northern summer. The persistence of near-record low extents leads the group to conclude that Arctic sea ice is likely on an accelerating, long-term decline….
>
> If current rates of decline in sea ice continue, the summertime Arctic could be completely ice-free well before the end of this century….
>
> In addition, Arctic temperatures have increased in recent decades. Compared to the past 50 years, average surface air temperatures from January through August, 2005, were 2 to 3 ˚C warmer than average across most of the Arctic Ocean.
>
> "The year 2005 puts an exclamation point on the pattern of Arctic warming we've seen in recent years," said Mark Serreze of the NSIDC. "The sea ice cover seems to

83 "Artic meltdown just decades away, scientists warn" – *Sydney Morning Herald*, 30 September 2005.

> be rapidly changing and the best explanation for this is rising temperatures."[84]

However, these stories often only report what has been happening to Arctic temperatures since satellites began measuring it in the late 1970s. For instance, Chylek *et al* report that in the 1920s, average annual Greenland coastal temperatures rose between 2 ˚C and 4 ˚C, and up to 6 ˚C, over a ten year period. Since the 1940s, Greenland coastal temperatures have undergone predominantly a cooling trend. The abstract of the Chylek paper is reproduced below:

> The Greenland coastal temperatures have followed the early 20th century global warming trend. Since 1940, however, the Greenland coastal stations data have undergone predominantly a cooling trend. At the summit of the Greenland ice sheet the summer average temperature has decreased at the rate of 2.2 °C per decade since the beginning of the measurements in 1987. This suggests that the Greenland ice sheet and coastal regions are not following the current global warming trend. A considerable and rapid warming over all of coastal Greenland occurred in the 1920s when the average annual surface air temperature rose between 2 and 4 °C in less than ten years (at some stations the increase in winter temperature was as high as 6 °C). This rapid warming, at a time when the change in anthropogenic production of greenhouse gases was well below the current level, suggests a high natural variability in the regional climate. High anticorrelations (r = –0.84 to–0.93) between the NAO (North Atlantic Oscillation) index and Greenland temperature time series suggest a physical connection between these processes. Therefore, the future changes in the NAO and Northern Annular Mode may be of critical consequence to the future temperature forcing of the Greenland ice sheet melt rates.[85]

Similarly, researchers from the Norwegian Meteorological Institute, in a 2003 review of past and future climate variations in the Norwegian arctic, concluded:

> Annual temperatures in the Longyearbyen/Svalbard Airport area have increased by more than 1 ˚C since 1910, but because of large interannual and decadal variations this trend is not statistically significant. Although the temperature has increased significantly since the cold 1960s, the present temperature level is still lower than in the 1930s at all stations in the Norwegian Arctic.[86]

In terms of the graphic provided by Pearman above, showing the extent of retreat of the arctic sea ice decline since 1979, Shapiro *et al* from the International Arctic Research Center mapped the April sea ice extent in the Barents Sea (a region of the Arctic Ocean) from 1850 to 2001. The researchers identified April ice edges over three study sub-periods: 1850 – 1899; 1900 – 1949; and 1950 – 2001. It was found that over the 152 year

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84 National Snow and Ice Data Center, "Media Release: Sea Ice Decline Intensifies." 28 September 2005. See http://www.nsidc.org/news/press/20050928_trendscontinue.html, Accessed November 2005.

85 Chylek, P., J.E. Box, and G. Lesins, "Global Warming and the Greenland Ice Sheet." *Climatic Change*, **63**, 2004, at 201.

86 Forland, E.J. & Hanssen-Bauer, I. "Past and future climate variations in the Norwegian Arctic: overview and novel analyses." In *Polar Research*, 22 (2) 2003 at 123.

period the mean ice edge had retreated. However, the greatest retreat was during the 1850 – 1899 sub-period, followed by the 1900 – 1949 sub-period. Over the study years, ice retreated the least during the 1950 - 2001 sub-period.[87] In this area of the Arctic Ocean, sea ice retreated the most (1850 – 1899) when anthropomorphic greenhouse gas emissions were minimal.

Also of concern has been the state of the Greenland ice sheet – the perimeter of which is thinning. An article on recent ice-sheet growth in the interior of Greenland in the 11 November 2005 edition of *Science* reports:

> [From 1992 to 2003] An increase of 6.4 +/- 0.2 centimetres per year is found in the vast interior areas above 1500 metres, in contrast to previous reports of high elevation balance. Below 1500 metres, the elevation change is –2.0 +/- 0.9 cm/year, in qualitative agreement with reported thinning in the ice-sheet margins. Averaged over the study area, the increase is 5.4 +/- 0.2 cm/year or approx 60 cm over 11 years, or approx 54 cm when corrected for isostatic uplift. Winter elevation changes are shown to be linked to the North Atlantic Oscillation.[88]

Researchers Koch and Hansen report that black carbon (soot) may have an impact on the Arctic climate.[89] Black carbon warms the Arctic in two primary ways. When it is suspended in the atmosphere, it absorbs incoming solar radiation and warms the atmosphere while possibly decreasing cloudiness. On the ground, it blackens the snow and ice, making it less reflective so that it absorbs more warming radiation.

The researchers found that, in the atmosphere over the Arctic, about: one-third of the soot comes from South Asia; one-third from burning biomass or vegetation around the world; and the remainder from Russia, Europe and North America. South Asia is estimated to have the largest industrial soot emissions in the world, and the meteorology in that region readily sweeps pollution into the upper atmosphere where it is easily transported to the North Pole. The pollution from Europe and Russia travels closer to the surface. During the early 1980s the main sources of Arctic pollution are believed to have been from Russia and Europe. Both of those areas have decreased their tiny particles of pollution in the last 20 years, but the pollution from South Asia has increased. Koch and Hansen suggest that Southern Asia also makes the greatest contribution to soot deposited on Greenland.[90]

In their paper, Koch and Hansen argue that the temporal and spatial patterns of temperature

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87 Shapiro,I., Colony,R. & Vinje, T. "April sea ice extent in the Barents Sea, 1850 – 2001." In *Polar Research*, 22 (1), 2003 at 9.

88 Johannessen, O. M. *et al*,"Recent Ice-sheet Growth in the Interior of Greenland." *Science*, 11 November 2005, Vol 310, No 5750, at 1013.

89 Koch, D., and J. Hansen 2005. Distant origins of Arctic black carbon: A Goddard Institute for Space Studies ModelE experiment. *J. Geophys. Res.* **110**, D04204, doi:10.1029/2004JD005296.

90 "*Research News*: Black and White: Soot on Ice" March 23, 2005. Goddard Institute for Space Studies, New York. See: http://www.giss.nasa.gov/research/news/20050323/, Accessed November 2005.

changes and sea ice declines bear a greater resemblance to patterns of historical soot emissions than to carbon dioxide emissions. The authors stated:

> According to the 2002 AMAP [Arctic Monitoring and Assessment Program] Assessment … the past three decades show significant decreases in sea ice thickness and extent. This recent decrease is greatest in spring and fall and occurs in the western Arctic (western North America and Siberia). These observations defy recent modelling efforts, which show the largest impact of increased CO_2 on the Arctic winter rather than summer … The pattern of sea ice loss is believed to be linked to the phase of the AO [Arctic Oscillation] ... However it is interesting that these decades correspond to the increases in BC [black carbon, soot] from south Asia, and that this BC is transported over the Pacific and into the western Arctic, during summer as well as spring. Prior to this, sea ice also decreased during the 1930s–1940s. However this occurred during winter in the eastern part of the Arctic. Again it is interesting to note that during this earlier period, pollution from coal burning in the United States, Europe and Russia … would have been transported to the Arctic during winter-spring, and the Eurasian sources would deposit heavily in the eastern Arctic.[91]

It seems from the above that solely blaming carbon dioxide emissions and the enhanced greenhouse effect for the melting of the Arctic ice cap may be misleading.

Similar comments could be applied to the melting of Antarctica. For instance, WWF (formerly known as World Wildlife Fund) identified four key threats facing Antarctica and the South Ocean. The fourth threat was climate change. WWF stated:

> **Meltdown in Antarctica: An Unfolding Global Catastrophe**
> **The Four Key Threats…**
>
> 4/ Climate Change
> Climate change is the greatest long term threat to the region. With the ice-shelf melting and glaciers shrinking, there can be no longer any doubt that the Antarctic is getting warmer.
>
> If the climate continues to hot up, scientists predict that krill populations could be devastated – undermining the entire Southern Polar food chain.[92]

However, scientists have recorded a net cooling of Antarctica. Doran *et al* in a meteorological study show a net cooling of the Antarctic continent between 1966 and 2000.[93] Virtually the only part of the Antarctic continent which is warming is a region called the Antarctic Peninsula – which is the landmass that extends out towards South

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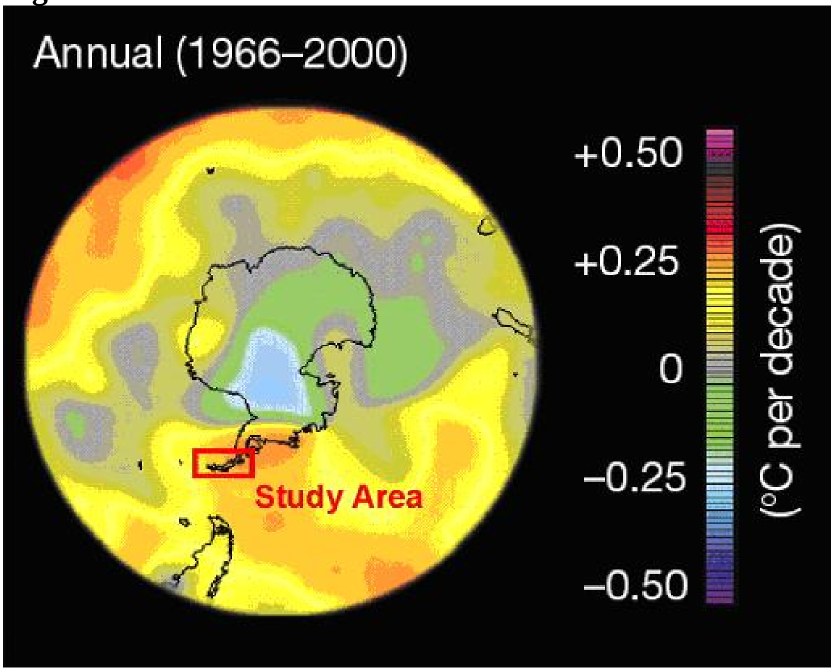
91 Koch, D., and J. Hansen 2005. Distant origins of Arctic black carbon: A Goddard Institute for Space Studies ModelE experiment. *J. Geophys. Res.* **110**, D04204, doi:10.1029/2004JD005296.

92 WWF, *Antarctica and the Southern Ocean under attack*. 23 November 2005. See WWF website: http://www.panda.org//news_facts/publications/index.cfm?uNewsID=51460. Accessed December 2005.

93 Doran, PT, *et al*, "Antarctic climate cooling and terrestrial ecosystem response." *Nature* 415.6871 (Jan 31, 2002): 517(3).

America. In this region, 87% of the 244 marine glacier fronts have retreated over the past 61 years.[94] Many of the greenhouse 'scare' stories about Antarctica melting are based around the recent warming of the Antarctic Peninsula. Figure 19 below is adapted from the Doran *et al* study, and shows trends in annual temperature in Antarctica. The Antarctic Peninsula, with the study of the melting glaciers, is labelled. It is evident that the majority of the Antarctic continent has been cooling from 1966 to 2000. The warming around the Antarctic Peninsula seems to be a regional event, the causes of which have still not been established.

Figure 19: Trend in annual temperature in Antarctica with the glacier study region outlined.



Source: Adapted from Doran *et al* in Michaels,P. *The Tip of the Iceberg: Yet another Predictable Distortion*, April 22, 2005. See website: http://www.worldclimatereport.com/index.php/2005/04/22/the-tip-of-the-iceberg-yet-another-predictable-distortion/. Accessed December 2005.

Michaels writes:

> The general cooling of Antarctica is highly scientifically significant because climate models run under increasing levels of greenhouse gases predict that the Antarctic continent as a whole, not just the Peninsula, should be rapidly warming. This is clearly a model failure ...[95]

Researchers from the British Antarctic Survey concluded about the warming on the

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94 Cook A.J. *et al*, "Retreating glacier Fronts on the Antarctic Peninsula over the Past Half-Century." In *Science* Vol 308, 22 April 2005, at 541.

95 Michaels,P. *The Tip of the Iceberg: Yet another Predictable Distortion*, April 22, 2005. See website: http://www.worldclimatereport.com/index.php/2005/04/22/the-tip-of-the-iceberg-yet-another-predictable-distortion/. Accessed December 2005.

Antarctic Peninsula:

> … we cannot yet distinguish cause and effect. Thus for the present we cannot determine which process is the probable cause of RRR [recent rapid regional] warming on the Antarctic Peninsula and until the mechanism initiating and sustaining the RRR is understood, and is convincingly reproduced in climate models, we lack a sound basis for predicting climate change in this region over the coming century.[96]

17.0 CONCLUSION

In October 2005 the Federal Minister for the Environment stated that the debate on climate change is over: "There is a very small handful of what we call skeptics who, in the face of seeing all of the evidence about carbon increases and all of the evidence about impacts on the climate, would still say that it's only natural variability that is causing it. … I think the Australian Government owes it to the public to tell it like it is – it is a very serious threat to Australia."[97]

In NSW, Premier Iemma, in a November 2005 speech announcing a new environmental agenda, stated:

> 2005 is the year that climate change hit home. Australia had its warmest year on record. Brazil had its first ever hurricane. Siberia's permafrost showed signs of melting. America had a record hurricane season that devastated an entire city. For NSW, global warming means longer and more destructive bushfire seasons, prolonged drought and harsher storm seasons. These trends threaten not only our environment but also our tourism and farming industries. While John Howard continues to hold out against Kyoto, NSW is getting on with the task of cutting greenhouse gas emissions. In fact, we were the first government in Australia to set greenhouse targets. We've pledged to cut carbon dioxide emissions by 60 percent by 2050. And to cut emissions to year 2000 levels within the next two decades.[98]

This paper has presented the 'consensus' science about climate change, as well as the evidence and comments of those who are more skeptical, or cautious. It is apparent that whilst those who believe in the 'consensus' science reject the ideas of the skeptics, the science is not as 'black and white' as they would have us believe. Some argue that while the greenhouse effect cannot be ignored, the impact is not as apocalyptic as has been claimed. The difficulty for governments of course, is to use this conflicting science to develop public policy.

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96 Vaughan,DG *et al*, Recent Rapid Regional Climate Warming on the Antarctic Peninsula", in *Climate Change*, Vol 60, No 3, October 2003, at 243.

97 "Debate over, it's time to save planet." in *The Australian*, 27 October 2005.

98 Speech by Premier Morris Iemma, *Towards 2010: A New Agenda For the Environment.* Tuesday November 29, 2005.

APPENDIX ONE

United States House of Representatives, Committee On Energy and Commerce
Letter to IPCC Chairman Rajendra Pachauri,
From Joe Barton Ed Whitfield, Chairman of Subcommittee on Oversight and Investigations

Dear Chairman Pachauri:
Questions have been raised, according to a February 14, 2005 article in *The Wall Street Journal*, about the significance of methodological flaws and data errors in studies by Dr. Michael Mann and co-authors of the historical record of temperatures and climate change. We understand that these studies of temperature proxies (tree rings, ice cores, corals, etc.) formed the basis for a new finding in the 2001 United Nation's Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (TAR). This finding – that the increase in 20th century northern hemisphere temperatures is "likely to have been the largest of any century during the past 1,000 years" and that the "1990s was the warmest decade and 1998 the warmest year" – has since been referenced widely and has become a prominent feature of the public debate surrounding climate change policy.

However, in recent peer-reviewed articles in *Science*, *Geophysical Research Letters*, *Energy & Environment,* among others, researchers question the results of this work. As these researchers find, based on the available information, the conclusions concerning temperature histories – and hence whether warming in the 20th century is actually unprecedented – cannot be supported by the Mann *et. al.* studies. In addition, we understand from the February 14 *Journal* and these other reports that researchers have failed to replicate the findings of these studies, in part because of problems with the underlying data and the calculations used to reach the conclusions. Questions have also been raised concerning the sharing and dissemination of the data and methods used to perform the studies. For example, according to the January 2005 *Energy & Environment*, the information necessary to replicate the analyses in the studies has not been made fully available to researchers upon request.

The concerns surrounding these studies reflect upon the quality and transparency of federally funded research and of the IPCC review process – two matters of particular interest to the Committee. For example, one concern relates to whether IPCC review has been sufficiently robust and independent. We understand that Dr. Michael Mann, the lead author of the studies in question,was also a lead author of the IPCC chapter that assessed and reported this very same work, and that two co-authors of the studies were also contributing authors to the same chapter. Given the prominence these studies were accorded in the IPCC TAR, we seek to learn more about the facts and circumstances that led to acceptance and prominent use of this work in the IPCC TAR and to understand what this controversy indicates about the data quality of key IPCC studies.

In light of the Committee's jurisdiction over energy policy and certain environmental issues in the U.S. House of Representatives, the Committee must have full and accurate information when considering matters relating to climate change policy. We open this review because the dispute surrounding these studies bears directly on important questions about the federally funded work upon which climate studies rely and the quality and transparency of analyses used to support the IPCC assessment process. With the IPCC currently working to produce a fourth assessment report, addressing questions of quality and transparency in the underlying analyses supporting that assessment, both scientific and economic, are of utmost importance if Congress is eventually going to make policy decisions drawing from this work.

To assist us as we begin this review, and pursuant to Rules X and XI of the U.S. House of Representatives, please provide the following information requested below on or before July 11, 2005:

1. Explain the IPCC process for preparing and writing its assessment reports, including, but not limited to: (a) how referenced studies are reviewed and assessed by the relevant Working Group; (b) the steps taken by lead authors, reviewers, and others to ensure the data underlying the studies forming the basis for key findings – particularly proxy and temperature data – are accurate and up to date; and (c) the IPCC requirements governing the quality of data used in reports.

2. What specifically did IPCC do to check the quality of the Mann et. al. studies and underlying data, cited in the TAR? Did IPCC seek to ensure the studies could be replicated?

3. What is your position with regard to: (a) the recent challenges to the quality of the Mann et. al. data, (b) related questions surrounding the sharing of methods and research for others to test the validity of these studies, and (c) what this controversy indicates about the data quality of key IPCC studies?

4. What did IPCC do to ensure the quality of data for other prominent historical temperature or proxy studies cited in the IPCC, including the Folland et. al. and Jones et. al. studies that were sources for the graphic accompanying the Mann et. al. graphic in the Summary for Policy Makers? Are the data and methodologies for such works complete and available for other researchers to test and replicate?

5. Explain (a) the facts and circumstances by which Dr. Michael Mann served as a lead author of the very chapter that prominently featured his work and (b) by which his work became a finding and graphical feature of the TAR Summary for Policymakers.

6. Explain (a) how IPCC ensures objectivity and independence among section contributors and reviewers, (b) how they are chosen, and (c) how the chapters, summaries, and the full report are approved and what any such approval signifies about the quality and acceptance of particular research therein.

7. Identify the people who wrote and reviewed the historical temperature-record portions of the TAR, particularly Section 2.3, "Is the Recent Warming Unusual?" and explain all their roles in the preparation of the TAR, including, but not limited to, the specific roles in the writing and review process.

8. Given the questions about Mann et. al. data, has the Working Group I or the IPCC made any changes to specific procedures or policies, including policies for checking the quality of data, for the forthcoming Fourth Assessment Report? If so, explain in detail any such changes, and why they were made.

9. Does the IPCC or Working Group I have policies or procedures regarding the disclosure and dissemination of scientific data referenced in the reports? If so, explain in detail any such policies and what happens when they are violated.

Thank you for your assistance. If you have any questions, please contact Peter Spencer of the Majority Committee staff at (202) 226-2424.

Sincerely,
Joe Barton Ed Whitfield
Chairman Chairman
Subcommittee on Oversight
and Investigations
cc: The Honorable John Dingell, Ranking Member
The Honorable Bart Stupak, Ranking Member,
Subcommittee on Oversight and Investigations[99]

[99] Unites States House of Representatives, Committee on Energy and Commerce, http://energycommerce.house.gov/108/Letters/06232005_1570.htm, Accessed November 2005.

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