A report of Working Group I of the Intergovernmental Panel on Climate Change

Summary for Policymakers

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Introduction

The Working Group I contribution to the IPCC Fourth Assessment Report describes progress in understanding of the human and natural drivers of climate change,[1] observed climate change, climate processes and attribution, and estimates of projected future climate change. It builds upon past IPCC assessments and incorporates new findings from the past six years of research. Scientific progress since the Third Assessment Report (TAR) is based upon large amounts of new and more comprehensive data, more sophisticated analyses of data, improvements in understanding of processes and their simulation in models and more extensive exploration of uncertainty ranges.

The basis for substantive paragraphs in this Summary for Policymakers can be found in the chapter sections specified in curly brackets.

Human and Natural Drivers of Climate Change

Changes in the atmospheric abundance of greenhouse gases and aerosols, in solar radiation and in land surface properties alter the energy balance of the climate system. These changes are expressed in terms of radiative forcing,[2] which is used to compare how a range of human and natural factors drive warming or cooling influences on global climate. Since the TAR, new observations and related modelling of greenhouse gases, solar activity, land surface properties and some aspects of aerosols have led to improvements in the quantitative estimates of radiative forcing.

Global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (see Figure SPM.1). The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture. {2.3, 6.4, 7.3}

- Carbon dioxide is the most important anthropogenic greenhouse gas (see Figure SPM.2). The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm[3] in 2005. The atmospheric concentration of carbon dioxide in 2005 exceeds by far the natural range over the last 650,000 years (180 to 300 ppm) as determined from ice cores. The annual carbon dioxide concentration growth rate was larger during the last 10 years (1995–2005 average: 1.9 ppm per year), than it has been since the beginning of continuous direct atmospheric measurements (1960–2005 average: 1.4 ppm per year) although there is year-to-year variability in growth rates. {2.3, 7.3}

- The primary source of the increased atmospheric concentration of carbon dioxide since the pre-industrial period results from fossil fuel use, with land-use change providing another significant but smaller contribution. Annual fossil carbon dioxide emissions[4] increased from an average of 6.4 [6.0 to 6.8][5] GtC (23.5 [22.0 to 25.0] $GtCO_2$) per year in the 1990s to 7.2 [6.9 to 7.5] GtC (26.4 [25.3 to 27.5] $GtCO_2$) per year in 2000–2005 (2004 and 2005 data are interim estimates). Carbon dioxide emissions associated with land-use change

[1] *Climate change* in IPCC usage refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the United Nations Framework Convention on Climate Change, where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

[2] *Radiative forcing* is a measure of the influence that a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. Positive forcing tends to warm the surface while negative forcing tends to cool it. In this report, radiative forcing values are for 2005 relative to pre-industrial conditions defined at 1750 and are expressed in watts per square metre ($W\ m^{-2}$). See Glossary and Section 2.2 for further details.

[3] ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of greenhouse gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a greenhouse gas per million molecules of dry air.

[4] Fossil carbon dioxide emissions include those from the production, distribution and consumption of fossil fuels and as a by-product from cement production. An emission of 1 GtC corresponds to 3.67 $GtCO_2$.

[5] In general, uncertainty ranges for results given in this Summary for Policymakers are 90% uncertainty intervals unless stated otherwise, that is, there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Best estimates are given where available. Assessed uncertainty intervals are not always symmetric about the corresponding best estimate. Note that a number of uncertainty ranges in the Working Group I TAR corresponded to 2 standard deviations (95%), often using expert judgement.

Changes in Greenhouse Gases from Ice Core and Modern Data

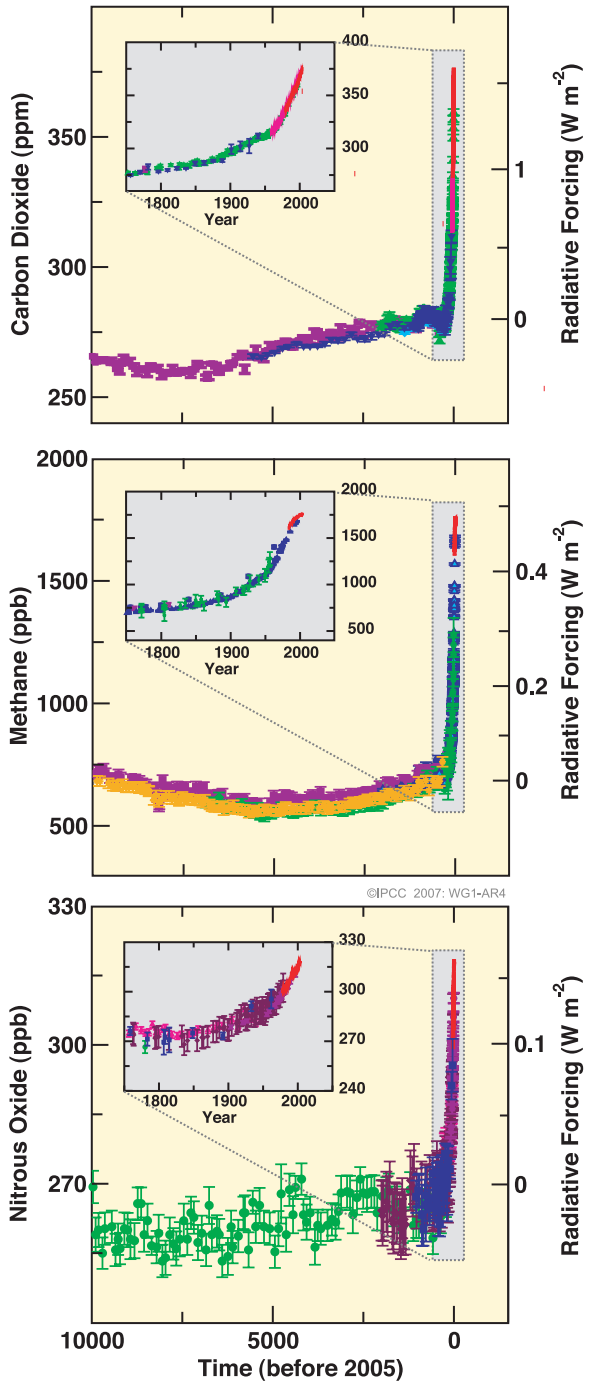

Figure SPM.1. *Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels) and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. {Figure 6.4}*

are estimated to be 1.6 [0.5 to 2.7] GtC (5.9 [1.8 to 9.9] $GtCO_2$) per year over the 1990s, although these estimates have a large uncertainty. {7.3}

- The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 ppb to 1732 ppb in the early 1990s, and was 1774 ppb in 2005. The atmospheric concentration of methane in 2005 exceeds by far the natural range of the last 650,000 years (320 to 790 ppb) as determined from ice cores. Growth rates have declined since the early 1990s, consistent with total emissions (sum of anthropogenic and natural sources) being nearly constant during this period. It is *very likely*[6] that the observed increase in methane concentration is due to anthropogenic activities, predominantly agriculture and fossil fuel use, but relative contributions from different source types are not well determined. {2.3, 7.4}

- The global atmospheric nitrous oxide concentration increased from a pre-industrial value of about 270 ppb to 319 ppb in 2005. The growth rate has been approximately constant since 1980. More than a third of all nitrous oxide emissions are anthropogenic and are primarily due to agriculture. {2.3, 7.4}

The understanding of anthropogenic warming and cooling influences on climate has improved since the TAR, leading to *very high confidence*[7] that the global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W m^{-2} (see Figure SPM.2). {2.3., 6.5, 2.9}

- The combined radiative forcing due to increases in carbon dioxide, methane, and nitrous oxide is +2.30 [+2.07 to +2.53] W m^{-2}, and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years (see Figures

[6] In this Summary for Policymakers, the following terms have been used to indicate the assessed likelihood, using expert judgement, of an outcome or a result: *Virtually certain* > 99% probability of occurrence, *Extremely likely* > 95%, *Very likely* > 90%, *Likely* > 66%, *More likely than not* > 50%, *Unlikely* < 33%, *Very unlikely* < 10%, *Extremely unlikely* < 5% (see Box TS.1 for more details).

[7] In this Summary for Policymakers the following levels of confidence have been used to express expert judgements on the correctness of the underlying science: *very high confidence* represents at least a 9 out of 10 chance of being correct; *high confidence* represents about an 8 out of 10 chance of being correct (see Box TS.1)

SPM.1 and SPM.2). The carbon dioxide radiative forcing increased by 20% from 1995 to 2005, the largest change for any decade in at least the last 200 years. {2.3, 6.4}

- Anthropogenic contributions to aerosols (primarily sulphate, organic carbon, black carbon, nitrate and dust) together produce a cooling effect, with a total direct radiative forcing of –0.5 [–0.9 to –0.1] W m^{-2} and an indirect cloud albedo forcing of –0.7 [–1.8 to –0.3] W m^{-2}. These forcings are now better understood than at the time of the TAR due to improved *in situ*, satellite and ground-based measurements and more comprehensive modelling, but remain the dominant uncertainty in radiative forcing. Aerosols also influence cloud lifetime and precipitation. {2.4, 2.9, 7.5}

- Significant anthropogenic contributions to radiative forcing come from several other sources. Tropospheric ozone changes due to emissions of ozone-forming chemicals (nitrogen oxides, carbon monoxide, and hydrocarbons) contribute +0.35 [+0.25 to +0.65] W m^{-2}. The direct radiative forcing due to changes in halocarbons[8] is +0.34 [+0.31 to +0.37] W m^{-2}. Changes in surface albedo, due to land cover changes and deposition of black carbon aerosols on snow, exert

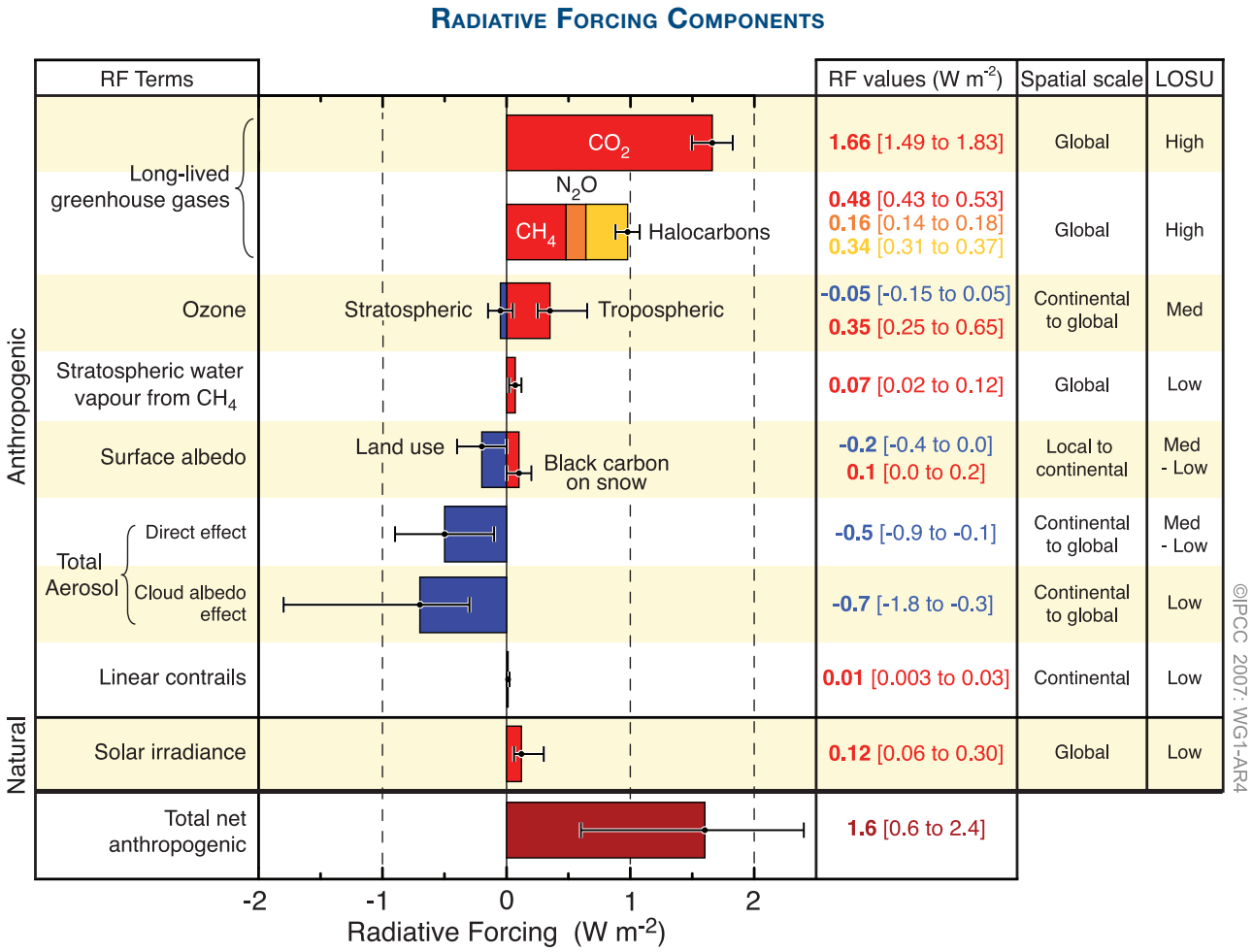

Figure SPM.2. *Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness. {2.9, Figure 2.20}*

[8] Halocarbon radiative forcing has been recently assessed in detail in *IPCC's Special Report on Safeguarding the Ozone Layer and the Global Climate System* (2005).

respective forcings of –0.2 [–0.4 to 0.0] and +0.1 [0.0 to +0.2] W m^{-2}. Additional terms smaller than ±0.1 W m^{-2} are shown in Figure SPM.2. {2.3, 2.5, 7.2}

- Changes in solar irradiance since 1750 are estimated to cause a radiative forcing of +0.12 [+0.06 to +0.30] W m^{-2}, which is less than half the estimate given in the TAR. {2.7}

Direct Observations of Recent Climate Change

Since the TAR, progress in understanding how climate is changing in space and in time has been gained through improvements and extensions of numerous datasets and data analyses, broader geographical coverage, better understanding of uncertainties, and a wider variety of measurements. Increasingly comprehensive observations are available for glaciers and snow cover since the 1960s, and for sea level and ice sheets since about the past decade. However, data coverage remains limited in some regions.

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level (see Figure SPM.3). {3.2, 4.2, 5.5}

- Eleven of the last twelve years (1995–2006) rank among the 12 warmest years in the instrumental record of global surface temperature[9] (since 1850). The updated 100-year linear trend (1906 to 2005) of 0.74°C [0.56°C to 0.92°C] is therefore larger than the corresponding trend for 1901 to 2000 given in the TAR of 0.6°C [0.4°C to 0.8°C]. The linear warming trend over the last 50 years (0.13°C [0.10°C to 0.16°C] per decade) is nearly twice that for the last 100 years. The total temperature increase from 1850–1899 to 2001–2005 is 0.76°C [0.57°C to 0.95°C]. Urban heat island effects are real but local, and have a negligible influence (less than 0.006°C per decade over land and zero over the oceans) on these values. {3.2}

- New analyses of balloon-borne and satellite measurements of lower- and mid-tropospheric temperature show warming rates that are similar to those of the surface temperature record and are consistent within their respective uncertainties, largely reconciling a discrepancy noted in the TAR. {3.2, 3.4}

- The average atmospheric water vapour content has increased since at least the 1980s over land and ocean as well as in the upper troposphere. The increase is broadly consistent with the extra water vapour that warmer air can hold. {3.4}

- Observations since 1961 show that the average temperature of the global ocean has increased to depths of at least 3000 m and that the ocean has been absorbing more than 80% of the heat added to the climate system. Such warming causes seawater to expand, contributing to sea level rise (see Table SPM.1). {5.2, 5.5}

- Mountain glaciers and snow cover have declined on average in both hemispheres. Widespread decreases in glaciers and ice caps have contributed to sea level rise (ice caps do not include contributions from the Greenland and Antarctic Ice Sheets). (See Table SPM.1.) {4.6, 4.7, 4.8, 5.5}

- New data since the TAR now show that losses from the ice sheets of Greenland and Antarctica have *very likely* contributed to sea level rise over 1993 to 2003 (see Table SPM.1). Flow speed has increased for some Greenland and Antarctic outlet glaciers, which drain ice from the interior of the ice sheets. The corresponding increased ice sheet mass loss has often followed thinning, reduction or loss of ice shelves or loss of floating glacier tongues. Such dynamical ice loss is sufficient to explain most of the Antarctic net mass loss and approximately half of the Greenland net mass loss. The remainder of the ice loss from Greenland has occurred because losses due to melting have exceeded accumulation due to snowfall. {4.6, 4.8, 5.5}

- Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm per year over 1961 to 2003. The rate was faster over 1993 to 2003: about 3.1 [2.4 to 3.8] mm per year. Whether the faster rate for 1993 to 2003 reflects decadal variability or an increase in the longer-term trend is unclear. There is *high confidence* that

[9] The average of near-surface air temperature over land and sea surface temperature.

Changes in Temperature, Sea Level and Northern Hemisphere Snow Cover

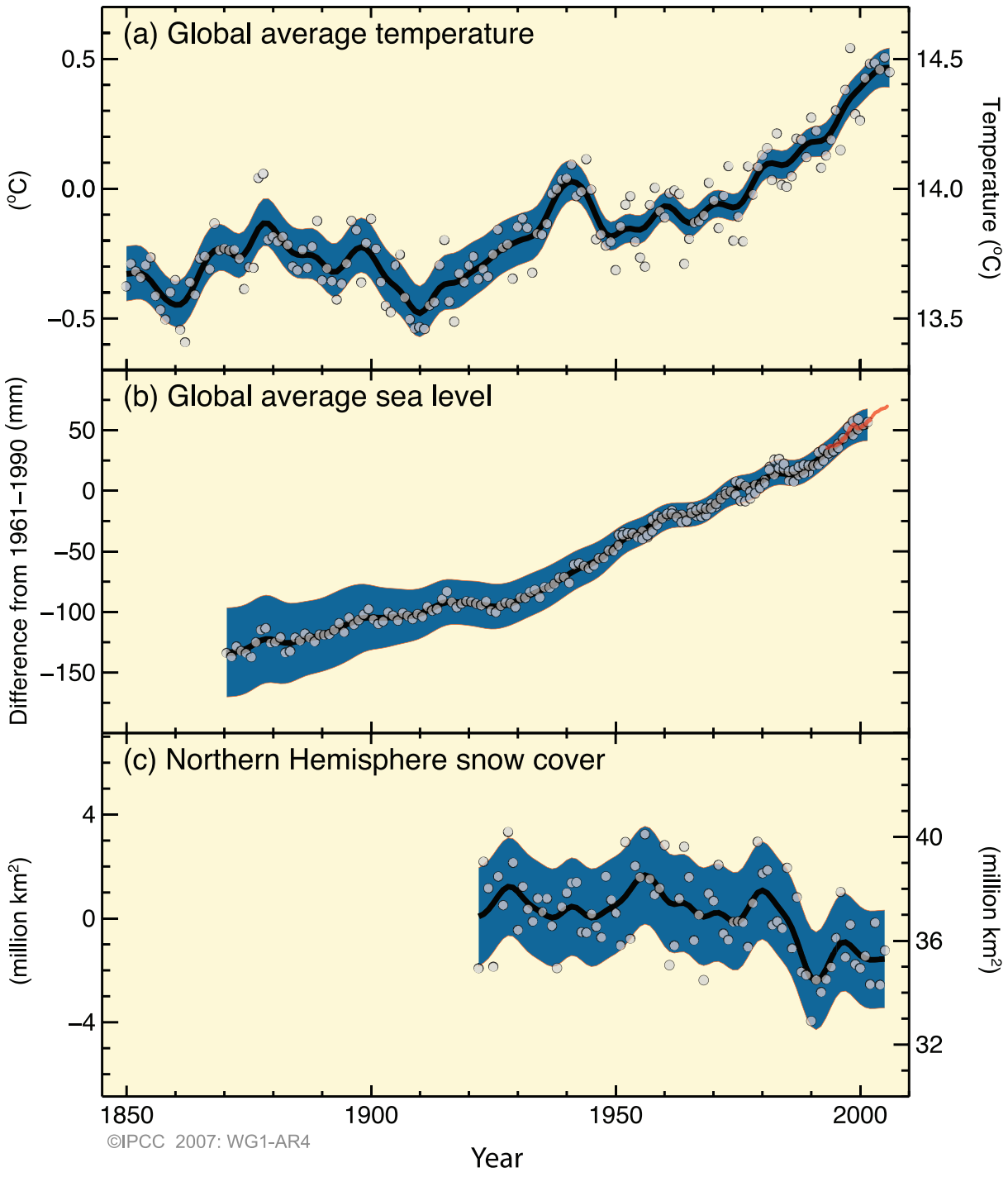

Figure SPM.3. *Observed changes in (a) global average surface temperature, (b) global average sea level from tide gauge (blue) and satellite (red) data and (c) Northern Hemisphere snow cover for March-April. All changes are relative to corresponding averages for the period 1961–1990. Smoothed curves represent decadal average values while circles show yearly values. The shaded areas are the uncertainty intervals estimated from a comprehensive analysis of known uncertainties (a and b) and from the time series (c). {FAQ 3.1, Figure 1, Figure 4.2, Figure 5.13}*

the rate of observed sea level rise increased from the 19th to the 20th century. The total 20th-century rise is estimated to be 0.17 [0.12 to 0.22] m. {5.5}

- For 1993 to 2003, the sum of the climate contributions is consistent within uncertainties with the total sea level rise that is directly observed (see Table SPM.1). These estimates are based on improved satellite and *in situ* data now available. For the period 1961 to 2003, the sum of climate contributions is estimated to be smaller than the observed sea level rise. The TAR reported a similar discrepancy for 1910 to 1990. {5.5}

At continental, regional and ocean basin scales, numerous long-term changes in climate have been observed. These include changes in arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones.[10] {3.2, 3.3, 3.4, 3.5, 3.6, 5.2}

- Average arctic temperatures increased at almost twice the global average rate in the past 100 years. Arctic temperatures have high decadal variability, and a warm period was also observed from 1925 to 1945. {3.2}

- Satellite data since 1978 show that annual average arctic sea ice extent has shrunk by 2.7 [2.1 to 3.3]% per decade, with larger decreases in summer of 7.4 [5.0 to 9.8]% per decade. These values are consistent with those reported in the TAR. {4.4}

- Temperatures at the top of the permafrost layer have generally increased since the 1980s in the Arctic (by up to 3°C). The maximum area covered by seasonally frozen ground has decreased by about 7% in the Northern Hemisphere since 1900, with a decrease in spring of up to 15%. {4.7}

- Long-term trends from 1900 to 2005 have been observed in precipitation amount over many large regions.[11] Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe and northern and central Asia. Drying has been observed in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Precipitation is highly variable spatially and temporally, and data are limited in some regions. Long-term trends have not been observed for the other large regions assessed.[11] {3.3, 3.9}

- Changes in precipitation and evaporation over the oceans are suggested by freshening of mid- and high-latitude waters together with increased salinity in low-latitude waters. {5.2}

Table SPM.1. *Observed rate of sea level rise and estimated contributions from different sources. {5.5, Table 5.3}*

Source of sea level rise	Rate of sea level rise (mm per year) 1961–2003	1993–2003
Thermal expansion	0.42 ± 0.12	1.6 ± 0.5
Glaciers and ice caps	0.50 ± 0.18	0.77 ± 0.22
Greenland Ice Sheet	0.05 ± 0.12	0.21 ± 0.07
Antarctic Ice Sheet	0.14 ± 0.41	0.21 ± 0.35
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	2.8 ± 0.7
Observed total sea level rise	1.8 ± 0.5[a]	3.1 ± 0.7[a]
Difference (Observed minus sum of estimated climate contributions)	0.7 ± 0.7	0.3 ± 1.0

Table note:
[a] Data prior to 1993 are from tide gauges and after 1993 are from satellite altimetry.

[10] Tropical cyclones include hurricanes and typhoons.

[11] The assessed regions are those considered in the regional projections chapter of the TAR and in Chapter 11 of this report.

- Mid-latitude westerly winds have strengthened in both hemispheres since the 1960s. {3.5}

- More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics. Increased drying linked with higher temperatures and decreased precipitation has contributed to changes in drought. Changes in sea surface temperatures, wind patterns and decreased snowpack and snow cover have also been linked to droughts. {3.3}

- The frequency of heavy precipitation events has increased over most land areas, consistent with warming and observed increases of atmospheric water vapour. {3.8, 3.9}

- Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent (see Table SPM.2). {3.8}

Table SPM.2. *Recent trends, assessment of human influence on the trend and projections for extreme weather events for which there is an observed late-20th century trend. {Tables 3.7, 3.8, 9.4; Sections 3.8, 5.5, 9.7, 11.2–11.9}*

Phenomenon[a] and direction of trend	Likelihood that trend occurred in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells/heat waves. Frequency increases over most land areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely* in many regions since 1970s	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely* in some regions since 1970	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[f,h]	*Likely*[i]

Table notes:

[a] See Table 3.7 for further details regarding definitions.

[b] See Table TS.4, Box TS.5 and Table 9.4.

[c] Decreased frequency of cold days and nights (coldest 10%).

[d] Warming of the most extreme days and nights each year.

[e] Increased frequency of hot days and nights (hottest 10%).

[f] Magnitude of anthropogenic contributions not assessed. Attribution for these phenomena based on expert judgement rather than formal attribution studies.

[g] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[h] Changes in observed extreme high sea level closely follow the changes in average sea level. {5.5} It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5}

[i] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period. {10.6} The effect of changes in regional weather systems on sea level extremes has not been assessed.

- There is observational evidence for an increase in intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures. There are also suggestions of increased intense tropical cyclone activity in some other regions where concerns over data quality are greater. Multi-decadal variability and the quality of the tropical cyclone records prior to routine satellite observations in about 1970 complicate the detection of long-term trends in tropical cyclone activity. There is no clear trend in the annual numbers of tropical cyclones. {3.8}

Some aspects of climate have not been observed to change. {3.2, 3.8, 4.4, 5.3}

- A decrease in diurnal temperature range (DTR) was reported in the TAR, but the data available then extended only from 1950 to 1993. Updated observations reveal that DTR has not changed from 1979 to 2004 as both day- and night-time temperature have risen at about the same rate. The trends are highly variable from one region to another. {3.2}

- Antarctic sea ice extent continues to show interannual variability and localised changes but no statistically significant average trends, consistent with the lack of warming reflected in atmospheric temperatures averaged across the region. {3.2, 4.4}

- There is insufficient evidence to determine whether trends exist in the meridional overturning circulation (MOC) of the global ocean or in small-scale phenomena such as tornadoes, hail, lightning and dust-storms. {3.8, 5.3}

A Palaeoclimatic Perspective

Palaeoclimatic studies use changes in climatically sensitive indicators to infer past changes in global climate on time scales ranging from decades to millions of years. Such proxy data (e.g., tree ring width) may be influenced by both local temperature and other factors such as precipitation, and are often representative of particular seasons rather than full years. Studies since the TAR draw increased confidence from additional data showing coherent behaviour across multiple indicators in different parts of the world. However, uncertainties generally increase with time into the past due to increasingly limited spatial coverage.

Palaeoclimatic information supports the interpretation that the warmth of the last half century is unusual in at least the previous 1,300 years. The last time the polar regions were significantly warmer than present for an extended period (about 125,000 years ago), reductions in polar ice volume led to 4 to 6 m of sea level rise. {6.4, 6.6}

- Average Northern Hemisphere temperatures during the second half of the 20th century were *very likely* higher than during any other 50-year period in the last 500 years and *likely* the highest in at least the past 1,300 years. Some recent studies indicate greater variability in Northern Hemisphere temperatures than suggested in the TAR, particularly finding that cooler periods existed in the 12th to 14th, 17th and 19th centuries. Warmer periods prior to the 20th century are within the uncertainty range given in the TAR. {6.6}

- Global average sea level in the last interglacial period (about 125,000 years ago) was *likely* 4 to 6 m higher than during the 20th century, mainly due to the retreat of polar ice. Ice core data indicate that average polar temperatures at that time were 3°C to 5°C higher than present, because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields *likely* contributed no more than 4 m of the observed sea level rise. There may also have been a contribution from Antarctica. {6.4}

Understanding and Attributing Climate Change

This assessment considers longer and improved records, an expanded range of observations and improvements in the simulation of many aspects of climate and its variability based on studies since the TAR. It also considers the results of new attribution studies that have evaluated whether observed changes are quantitatively consistent with the expected response to external forcings and inconsistent with alternative physically plausible explanations.

Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.[12] This is an advance since the TAR's conclusion that "most of the observed warming over the last 50 years is *likely* to have been due to the increase in greenhouse gas concentrations". Discernible human influences now extend to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns (see Figure SPM.4 and Table SPM.2). {9.4, 9.5}

- It is *likely* that increases in greenhouse gas concentrations alone would have caused more warming than observed because volcanic and anthropogenic aerosols have offset some warming that would otherwise have taken place. {2.9, 7.5, 9.4}

- The observed widespread warming of the atmosphere and ocean, together with ice mass loss, support the conclusion that it is *extremely unlikely* that global climate change of the past 50 years can be explained without external forcing, and *very likely* that it is not due to known natural causes alone. {4.8, 5.2, 9.4, 9.5, 9.7}

- Warming of the climate system has been detected in changes of surface and atmospheric temperatures in the upper several hundred metres of the ocean, and in contributions to sea level rise. Attribution studies have established anthropogenic contributions to all of these changes. The observed pattern of tropospheric warming and stratospheric cooling is *very likely* due to the combined influences of greenhouse gas increases and stratospheric ozone depletion. {3.2, 3.4, 9.4, 9.5}

- It is *likely* that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica (see Figure SPM.4). The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time, are only simulated by models that include anthropogenic forcing. The ability of coupled climate models to simulate the observed temperature evolution on each of six continents provides stronger evidence of human influence on climate than was available in the TAR. {3.2, 9.4}

- Difficulties remain in reliably simulating and attributing observed temperature changes at smaller scales. On these scales, natural climate variability is relatively larger, making it harder to distinguish changes expected due to external forcings. Uncertainties in local forcings and feedbacks also make it difficult to estimate the contribution of greenhouse gas increases to observed small-scale temperature changes. {8.3, 9.4}

- Anthropogenic forcing is *likely* to have contributed to changes in wind patterns,[13] affecting extra-tropical storm tracks and temperature patterns in both hemispheres. However, the observed changes in the Northern Hemisphere circulation are larger than simulated in response to 20th-century forcing change. {3.5, 3.6, 9.5, 10.3}

- Temperatures of the most extreme hot nights, cold nights and cold days are *likely* to have increased due to anthropogenic forcing. It is *more likely than not* that anthropogenic forcing has increased the risk of heat waves (see Table SPM.2). {9.4}

[12] Consideration of remaining uncertainty is based on current methodologies.

[13] In particular, the Southern and Northern Annular Modes and related changes in the North Atlantic Oscillation. {3.6, 9.5, Box TS.2}

Global and Continental Temperature Change

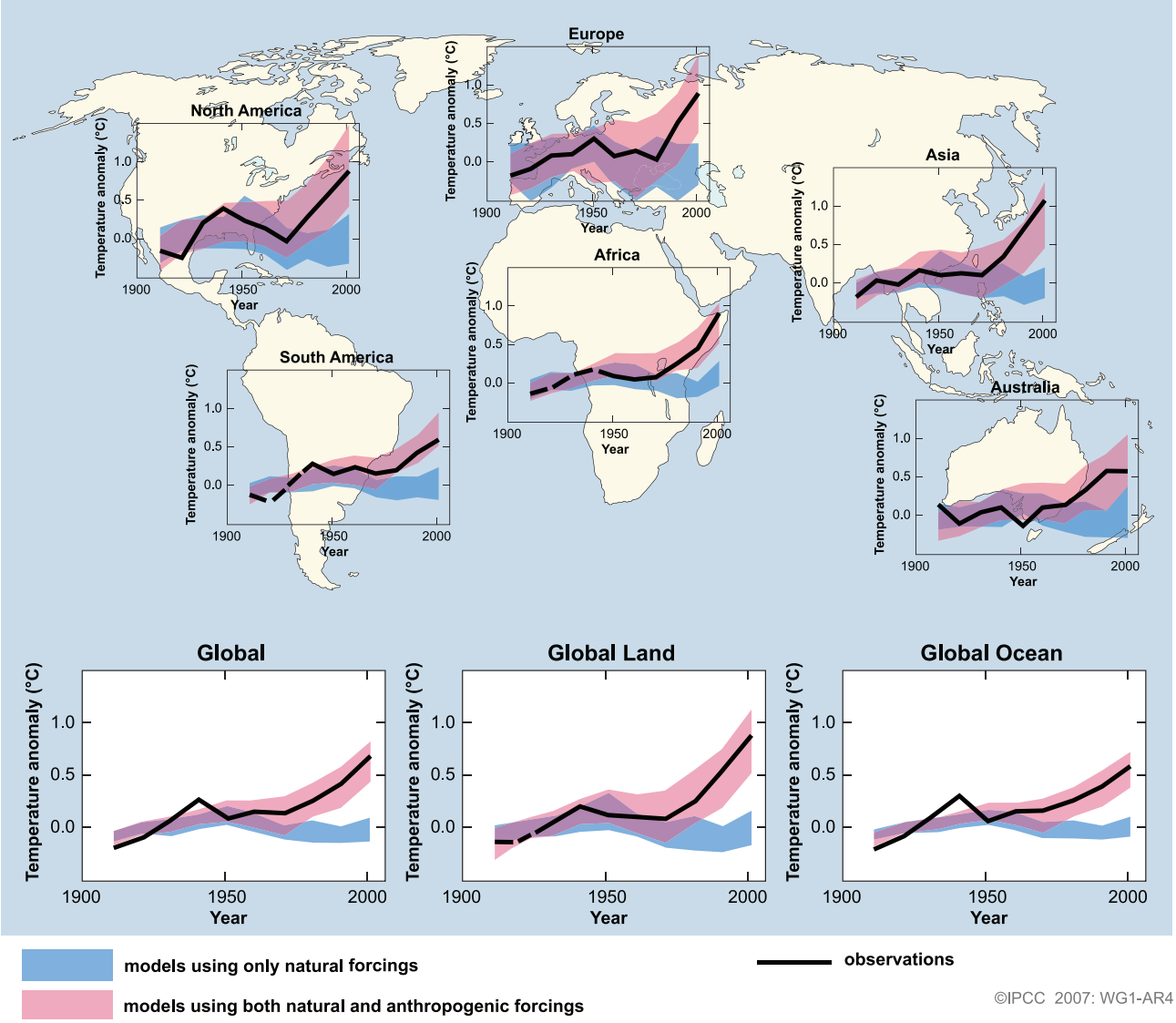

Figure SPM.4. *Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906 to 2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901–1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5–95% range for 19 simulations from five climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5–95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings. {FAQ 9.2, Figure 1}*

Analysis of climate models together with constraints from observations enables an assessed *likely* range to be given for climate sensitivity for the first time and provides increased confidence in the understanding of the climate system response to radiative forcing. {6.6, 8.6, 9.6, Box 10.2}

- The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing. It is not a projection but is defined as the global average surface warming following a doubling of carbon dioxide concentrations. It is *likely* to be in the range 2°C to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C. Values substantially higher than 4.5°C cannot be excluded, but agreement of models with observations is not as good for those values. Water vapour changes represent the largest feedback affecting climate sensitivity and are now better understood than in the TAR. Cloud feedbacks remain the largest source of uncertainty. {8.6, 9.6, Box 10.2}

- It is *very unlikely* that climate changes of at least the seven centuries prior to 1950 were due to variability generated within the climate system alone. A significant fraction of the reconstructed Northern Hemisphere inter-decadal temperature variability over those centuries is *very likely* attributable to volcanic eruptions and changes in solar irradiance, and it is *likely* that anthropogenic forcing contributed to the early 20th-century warming evident in these records. {2.7, 2.8, 6.6, 9.3}

Projections of Future Changes in Climate

A major advance of this assessment of climate change projections compared with the TAR is the large number of simulations available from a broader range of models. Taken together with additional information from observations, these provide a quantitative basis for estimating likelihoods for many aspects of future climate change. Model simulations cover a range of possible futures including idealised emission or concentration assumptions. These include SRES[14] illustrative marker scenarios for the 2000 to 2100 period and model experiments with greenhouse gases and aerosol concentrations held constant after year 2000 or 2100.

For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. {10.3, 10.7}

- Since IPCC's first report in 1990, assessed projections have suggested global average temperature increases between about 0.15°C and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade, strengthening confidence in near-term projections. {1.2, 3.2}

- Model experiments show that even if all radiative forcing agents were held constant at year 2000 levels, a further warming trend would occur in the next two decades at a rate of about 0.1°C per decade, due mainly to the slow response of the oceans. About twice as much warming (0.2°C per decade) would be expected if emissions are within the range of the SRES scenarios. Best-estimate projections from models indicate that decadal average warming over each inhabited continent by 2030 is insensitive to the choice among SRES scenarios and is *very likely* to be at least twice as large as the corresponding model-estimated natural variability during the 20th century. {9.4, 10.3, 10.5, 11.2–11.7, Figure TS-29}

[14] SRES refers to the *IPCC Special Report on Emission Scenarios* (2000). The SRES scenario families and illustrative cases, which did not include additional climate initiatives, are summarised in a box at the end of this Summary for Policymakers. Approximate carbon dioxide equivalent concentrations corresponding to the computed radiative forcing due to anthropogenic greenhouse gases and aerosols in 2100 (see p. 823 of the TAR) for the SRES B1, A1T, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1,550 ppm respectively. Scenarios B1, A1B and A2 have been the focus of model intercomparison studies and many of those results are assessed in this report.

Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century. {10.3}

- Advances in climate change modelling now enable best estimates and *likely* assessed uncertainty ranges to be given for projected warming for different emission scenarios. Results for different emission scenarios are provided explicitly in this report to avoid loss of this policy-relevant information. Projected global average surface warmings for the end of the 21st century (2090–2099) relative to 1980–1999 are shown in Table SPM.3. These illustrate the differences between lower and higher SRES emission scenarios, and the projected warming uncertainty associated with these scenarios. {10.5}

- Best estimates and *likely* ranges for global average surface air warming for six SRES emissions marker scenarios are given in this assessment and are shown in Table SPM.3. For example, the best estimate for the low scenario (B1) is 1.8°C (*likely* range is 1.1°C to 2.9°C), and the best estimate for the high scenario (A1FI) is 4.0°C (*likely* range is 2.4°C to 6.4°C). Although these projections are broadly consistent with the span quoted in the TAR (1.4°C to 5.8°C), they are not directly comparable (see Figure SPM.5). The Fourth Assessment Report is more advanced as it provides best estimates and an assessed likelihood range for each of the marker scenarios. The new assessment of the *likely* ranges now relies on a larger number of climate models of increasing complexity and realism, as well as new information regarding the nature of feedbacks from the carbon cycle and constraints on climate response from observations. {10.5}

- Warming tends to reduce land and ocean uptake of atmospheric carbon dioxide, increasing the fraction of anthropogenic emissions that remains in the atmosphere. For the A2 scenario, for example, the climate-carbon cycle feedback increases the corresponding global average warming at 2100 by more than 1°C. Assessed upper ranges for temperature projections are larger than in the TAR (see Table SPM.3) mainly because the broader range of models now available suggests stronger climate-carbon cycle feedbacks. {7.3, 10.5}

- Model-based projections of global average sea level rise at the end of the 21st century (2090–2099) are shown in Table SPM.3. For each scenario, the midpoint of the range in Table SPM.3 is within 10% of the

Table SPM.3. *Projected global average surface warming and sea level rise at the end of the 21st century. {10.5, 10.6, Table 10.7}*

	Temperature Change (°C at 2090-2099 relative to 1980-1999)[a]		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations[b]	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Table notes:
[a] These estimates are assessed from a hierarchy of models that encompass a simple climate model, several Earth System Models of Intermediate Complexity and a large number of Atmosphere-Ocean General Circulation Models (AOGCMs).
[b] Year 2000 constant composition is derived from AOGCMs only.

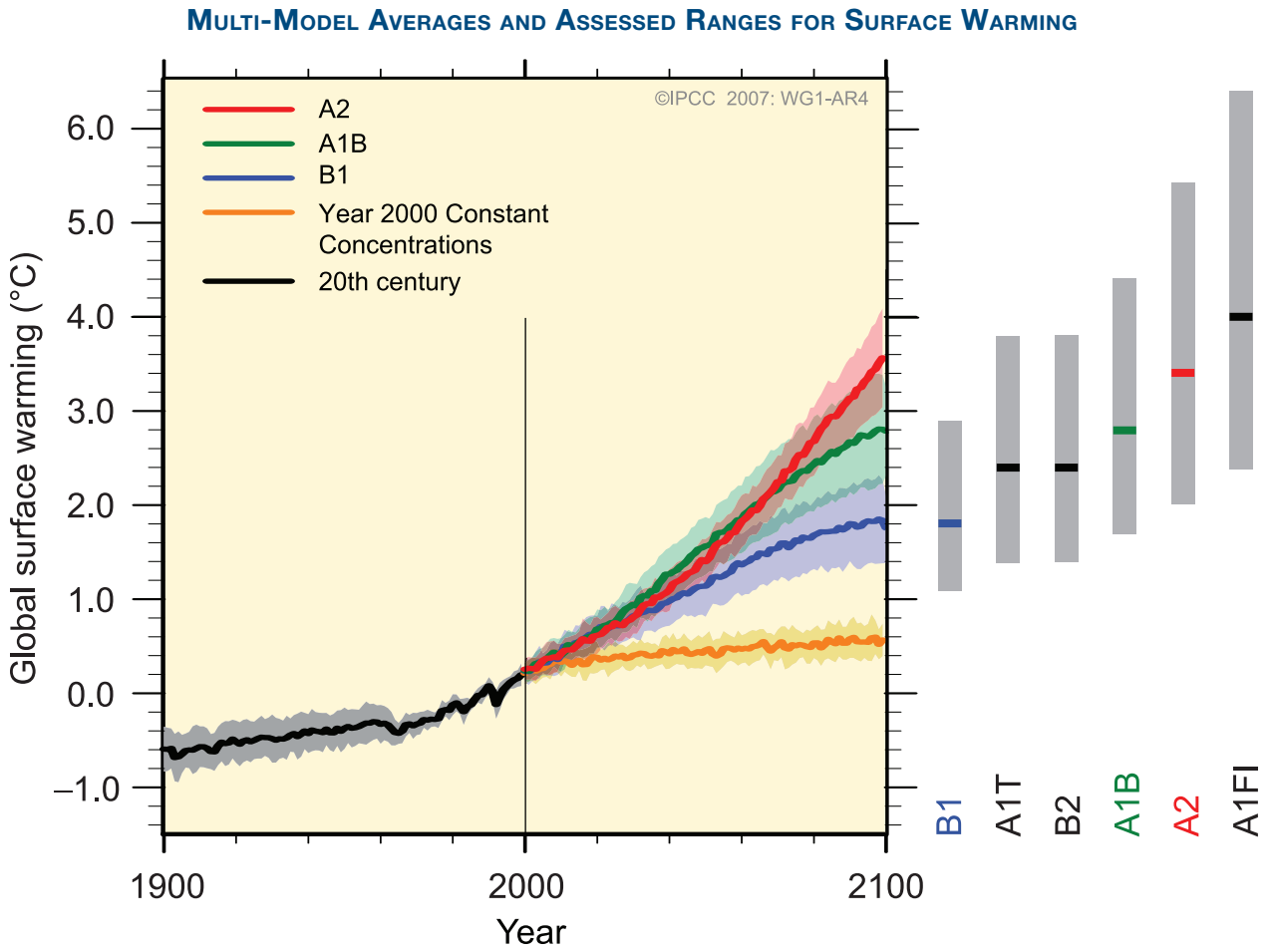

Figure SPM.5. *Solid lines are multi-model global averages of surface warming (relative to 1980–1999) for the scenarios A2, A1B and B1, shown as continuations of the 20th century simulations. Shading denotes the ±1 standard deviation range of individual model annual averages. The orange line is for the experiment where concentrations were held constant at year 2000 values. The grey bars at right indicate the best estimate (solid line within each bar) and the **likely** range assessed for the six SRES marker scenarios. The assessment of the best estimate and **likely** ranges in the grey bars includes the AOGCMs in the left part of the figure, as well as results from a hierarchy of independent models and observational constraints. {Figures 10.4 and 10.29}*

TAR model average for 2090–2099. The ranges are narrower than in the TAR mainly because of improved information about some uncertainties in the projected contributions.[15] {10.6}

- Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993 to 2003, but these flow rates could increase or decrease in the future. For example, if this contribution were to grow linearly with global average temperature change, the upper ranges of sea level rise for SRES scenarios shown in Table SPM.3 would increase by 0.1 to 0.2 m. Larger values cannot be excluded, but understanding of these effects is too limited to assess their likelihood or provide a best estimate or an upper bound for sea level rise. {10.6}

- Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections based on SRES scenarios give reductions in average global surface ocean pH[16] of between 0.14 and 0.35 units over the 21st century, adding to the present decrease of 0.1 units since pre-industrial times. {5.4, Box 7.3, 10.4}

[15] TAR projections were made for 2100, whereas projections in this report are for 2090–2099. The TAR would have had similar ranges to those in Table SPM.3 if it had treated the uncertainties in the same way.

[16] Decreases in pH correspond to increases in acidity of a solution. See Glossary for further details.

There is now higher confidence in projected patterns of warming and other regional-scale features, including changes in wind patterns, precipitation and some aspects of extremes and of ice. {8.2, 8.3, 8.4, 8.5, 9.4, 9.5, 10.3, 11.1}

- Projected warming in the 21st century shows scenario-independent geographical patterns similar to those observed over the past several decades. Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean (see Figure SPM.6). {10.3}

- Snow cover is projected to contract. Widespread increases in thaw depth are projected over most permafrost regions. {10.3, 10.6}

- Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES scenarios. In some projections, arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century. {10.3}

- It is *very likely* that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. {10.3}

- Based on a range of models, it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures. There is less confidence in projections of a global decrease in numbers of tropical cyclones. The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period. {9.5, 10.3, 3.8}

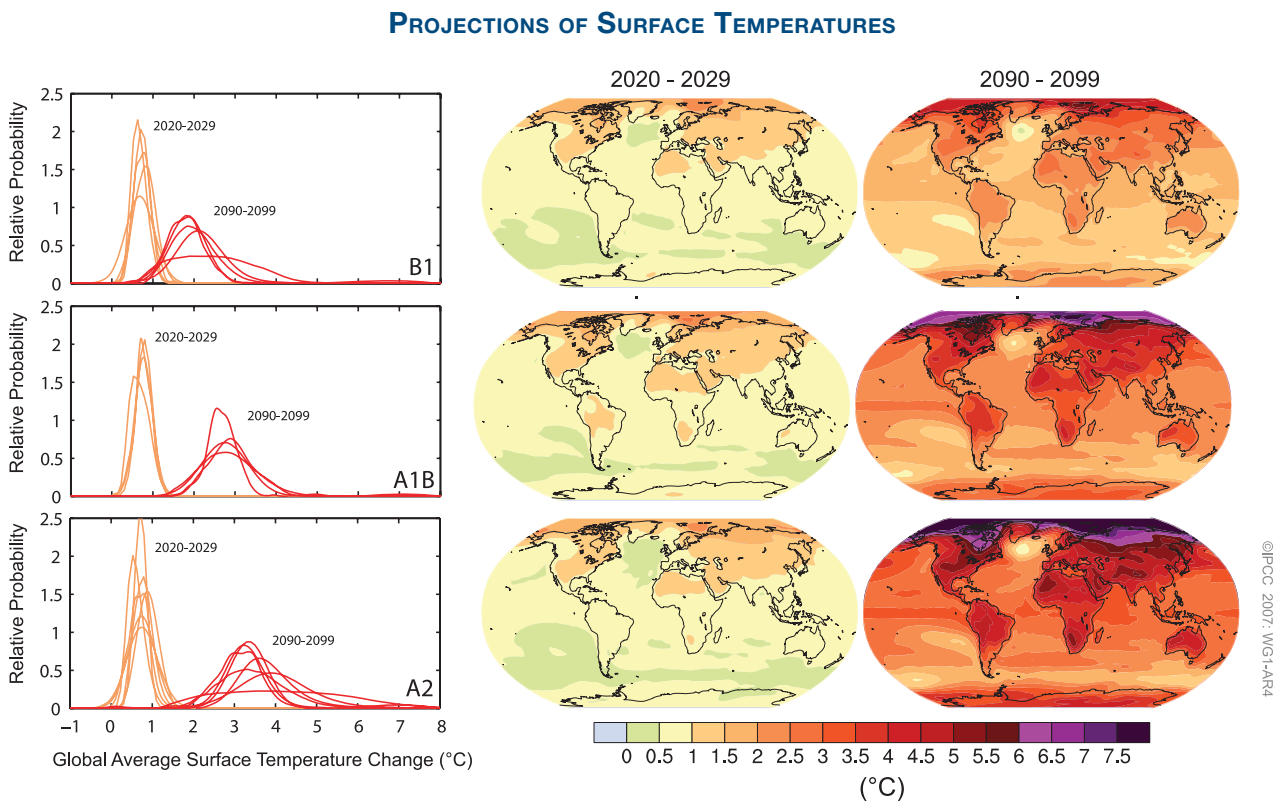

Figure SPM.6. *Projected surface temperature changes for the early and late 21st century relative to the period 1980–1999. The central and right panels show the AOGCM multi-model average projections for the B1 (top), A1B (middle) and A2 (bottom) SRES scenarios averaged over the decades 2020–2029 (centre) and 2090–2099 (right). The left panels show corresponding uncertainties as the relative probabilities of estimated global average warming from several different AOGCM and Earth System Model of Intermediate Complexity studies for the same periods. Some studies present results only for a subset of the SRES scenarios, or for various model versions. Therefore the difference in the number of curves shown in the left-hand panels is due only to differences in the availability of results. {Figures 10.8 and 10.28}*

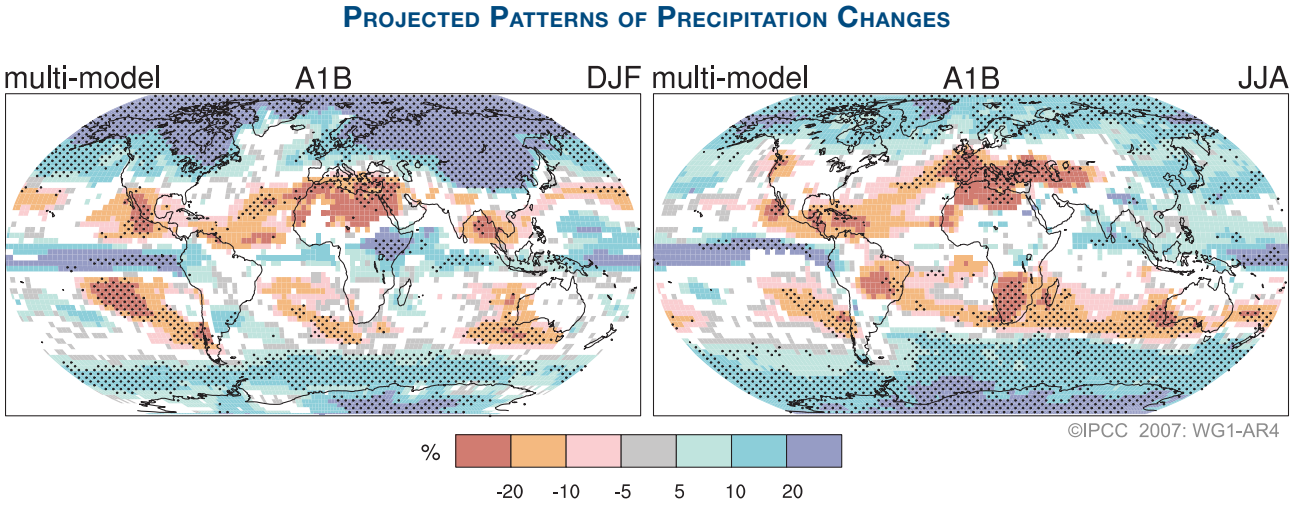

Figure SPM.7. *Relative changes in precipitation (in percent) for the period 2090–2099, relative to 1980–1999. Values are multi-model averages based on the SRES A1B scenario for December to February (left) and June to August (right). White areas are where less than 66% of the models agree in the sign of the change and stippled areas are where more than 90% of the models agree in the sign of the change. {Figure 10.9}*

- Extratropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns, continuing the broad pattern of observed trends over the last half-century. {3.6, 10.3}

- Since the TAR, there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high latitudes, while decreases are *likely* in most subtropical land regions (by as much as about 20% in the A1B scenario in 2100, see Figure SPM.7), continuing observed patterns in recent trends. {3.3, 8.3, 9.5, 10.3, 11.2 to 11.9}

- Based on current model simulations, it is *very likely* that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century. The multi-model average reduction by 2100 is 25% (range from zero to about 50%) for SRES emission scenario A1B. Temperatures in the Atlantic region are projected to increase despite such changes due to the much larger warming associated with projected increases in greenhouse gases. It is *very unlikely* that the MOC will undergo a large abrupt transition during the 21st century. Longer-term changes in the MOC cannot be assessed with confidence. {10.3, 10.7}

Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised. {10.4, 10.5, 10.7}

- Climate-carbon cycle coupling is expected to add carbon dioxide to the atmosphere as the climate system warms, but the magnitude of this feedback is uncertain. This increases the uncertainty in the trajectory of carbon dioxide emissions required to achieve a particular stabilisation level of atmospheric carbon dioxide concentration. Based on current understanding of climate-carbon cycle feedback, model studies suggest that to stabilise at 450 ppm carbon dioxide could require that cumulative emissions over the 21st century be reduced from an average of approximately 670 [630 to 710] GtC (2460 [2310 to 2600] $GtCO_2$) to approximately 490 [375 to 600] GtC (1800 [1370 to 2200] $GtCO_2$). Similarly, to stabilise at 1000 ppm, this feedback could require that cumulative emissions be reduced from a model average of approximately 1415 [1340 to 1490] GtC (5190 [4910 to 5460] $GtCO_2$) to approximately 1100 [980 to 1250] GtC (4030 [3590 to 4580] $GtCO_2$). {7.3, 10.4}

- If radiative forcing were to be stabilised in 2100 at B1 or A1B levels[14] a further increase in global average temperature of about 0.5°C would still be expected, mostly by 2200. {10.7}

- If radiative forcing were to be stabilised in 2100 at A1B levels[14], thermal expansion alone would lead to 0.3 to 0.8 m of sea level rise by 2300 (relative to 1980–1999). Thermal expansion would continue for many centuries, due to the time required to transport heat into the deep ocean. {10.7}

- Contraction of the Greenland Ice Sheet is projected to continue to contribute to sea level rise after 2100. Current models suggest that ice mass losses increase with temperature more rapidly than gains due to precipitation and that the surface mass balance becomes negative at a global average warming (relative to pre-industrial values) in excess of 1.9°C to 4.6°C. If a negative surface mass balance were sustained for millennia, that would lead to virtually complete elimination of the Greenland Ice Sheet and a resulting contribution to sea level rise of about 7 m. The corresponding future temperatures in Greenland are comparable to those inferred for the last interglacial period 125,000 years ago, when palaeoclimatic information suggests reductions of polar land ice extent and 4 to 6 m of sea level rise. {6.4, 10.7}

- Dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheets to warming, increasing future sea level rise. Understanding of these processes is limited and there is no consensus on their magnitude. {4.6, 10.7}

- Current global model studies project that the Antarctic Ice Sheet will remain too cold for widespread surface melting and is expected to gain in mass due to increased snowfall. However, net loss of ice mass could occur if dynamical ice discharge dominates the ice sheet mass balance. {10.7}

- Both past and future anthropogenic carbon dioxide emissions will continue to contribute to warming and sea level rise for more than a millennium, due to the time scales required for removal of this gas from the atmosphere. {7.3, 10.3}

The Emission Scenarios of the IPCC Special Report on Emission Scenarios (SRES)[17]

A1. The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the 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 (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B) (where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2. The A2 storyline and scenario family describes a very heterogeneous 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 more fragmented and slower than other storylines.

B1. The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward 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. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously 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 B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

An illustrative scenario was chosen for each of the six scenario groups A1B, A1FI, A1T, A2, B1 and B2. All should be considered equally sound.

The SRES scenarios do not include additional climate initiatives, which means that no scenarios are included that explicitly assume implementation of the United Nations Framework Convention on Climate Change or the emissions targets of the Kyoto Protocol.

[17] Emission scenarios are not assessed in this Working Group I Report of the IPCC. This box summarising the SRES scenarios is taken from the TAR and has been subject to prior line-by-line approval by the Panel.

Testimony of Roy W. Spencer before the
Senate Environment and Public Works Committee on 22 July 2008

I would like to thank Senator Boxer and members of the Committee for allowing me to discuss my experiences as a NASA employee engaged in global warming research, as well as to provide my current views on the state of the science of global warming and climate change.

I have a PhD in Meteorology from the University of Wisconsin-Madison, and have been involved in global warming research for close to twenty years. I have numerous peer reviewed scientific articles dealing with the measurement and interpretation of climate variability and climate change. I am also the U.S. Science Team Leader for the AMSR-E instrument flying on NASA's Aqua satellite.

1. White House Involvement in the Reporting of Agency Employees' Work

On the subject of the Administration's involvement in policy-relevant scientific work performed by government employees in the EPA, NASA, and other agencies, I can provide some perspective based upon my previous experiences as a NASA employee. For example, during the Clinton-Gore Administration I was told what I could and could not say during congressional testimony. Since it was well known that I am skeptical of the view that mankind's greenhouse gas emissions are mostly responsible for global warming, I assumed that this advice was to help protect Vice President Gore's agenda on the subject.

This did not particularly bother me, though, since I knew that as an employee of an Executive Branch agency my ultimate boss resided in the White House. To the extent that my work had policy relevance, it seemed entirely appropriate to me that the privilege of working for NASA included a responsibility to abide by direction given by my superiors.

But I eventually tired of the restrictions I had to abide by as a government employee, and in the fall of 2001 I resigned from NASA and accepted my current position as a Principal Research Scientist at the University of Alabama in Huntsville. Despite my resignation from NASA, I continue to serve as Team Leader on the AMSR-E instrument flying on the NASA Aqua satellite, and maintain a good working relationship with other government researchers.

2. Global Warming Science: The Latest Research

Regarding the currently popular theory that mankind is responsible for global warming, I am very pleased to deliver good news from the front lines of climate change research. Our latest research results, which I am about to describe, could have an enormous impact on policy decisions regarding greenhouse gas emissions.

Despite decades of persistent uncertainty over how sensitive the climate system is to increasing concentrations of carbon dioxide from the burning of fossil fuels, we now have new satellite evidence which strongly suggests that the climate system is much less sensitive than is claimed by the U.N.'s Intergovernmental Panel on Climate Change

(IPCC). Another way of saying this is that the real climate system appears to be dominated by "negative feedbacks" -- instead of the "positive feedbacks" which are displayed by all twenty computerized climate models utilized by the IPCC. (Feedback parameters larger than 3.3 Watts per square meter per degree Kelvin ($Wm^{-2}K^{-1}$) indicate negative feedback, while feedback parameters smaller than 3.3 indicate positive feedback.)

If true, an insensitive climate system would mean that we have little to worry about in the way of manmade global warming and associated climate change. And, as we will see, it would also mean that the warming we have experienced in the last 100 years is mostly natural. Of course, if climate change is mostly natural then it is largely out of our control, and is likely to end -- if it has not ended already, since satellite-measured global temperatures have not warmed for at least seven years now.

2.1 Theoretical evidence that climate sensitivity has been overestimated

The support for my claim of low climate sensitivity (net negative feedback) for our climate system is two-fold. First, we have a new research article[1] in-press in the *Journal of Climate* which uses a simple climate model to show that previous estimates of the sensitivity of the climate system from satellite data were biased toward the high side by the neglect of natural cloud variability. It turns out that the failure to account for natural, chaotic cloud variability generated internal to the climate system will always lead to the illusion of a climate system which appears more sensitive than it really is.

Significantly, prior to its acceptance for publication, this paper was reviewed by two leading IPCC climate model experts - Piers Forster and Isaac Held-- both of whom agreed that we have raised a legitimate issue. Piers Forster, an IPCC report lead author and a leading expert on the estimation of climate sensitivity, even admitted in his review of our paper that other climate modelers need to be made aware of this important issue.

To be fair, in a follow-up communication Piers Forster stated to me his belief that the net effect of the new understanding on climate sensitivity estimates would likely be small. But as we shall see, the latest evidence now suggests otherwise.

2.2 Observational evidence that climate sensitivity has been overestimated

The second line of evidence in support of an insensitive climate system comes from the satellite data themselves. While our work in-press established the existence of an observational bias in estimates of climate sensitivity, it did not address just how large that bias might be.

But in the last several weeks, we have stumbled upon clear and convincing observational evidence of particularly strong negative feedback (low climate sensitivity) from our latest and best satellite instruments. That evidence includes our development of two new methods for extracting the feedback signal from either observational or climate model data, a goal which has been called the "holy grail"[2] of climate research.

The first method separates the true signature of feedback, wherein radiative flux variations are highly correlated to the temperature changes which *cause* them, from internally-generated radiative forcings, which are uncorrelated to the temperature

variations which *result* from them. *It is the latter signal which has been ignored in all previous studies, the neglect of which biases feedback diagnoses in the direction of positive feedback (high climate sensitivity).*

Based upon global oceanic climate variations measured by a variety of NASA and NOAA satellites during the period 2000 through 2005 we have found a signature of climate sensitivity so low that it would reduce future global warming projections to below 1 deg. C by the year 2100. As can be seen in Fig. 1, that estimate from satellite data is much less sensitive (a larger diagnosed feedback) than even the least sensitive of the 20 climate models which the IPCC summarizes in its report. It is also consistent with our previously published analysis of feedbacks associated with tropical intraseasonal oscillations[3].

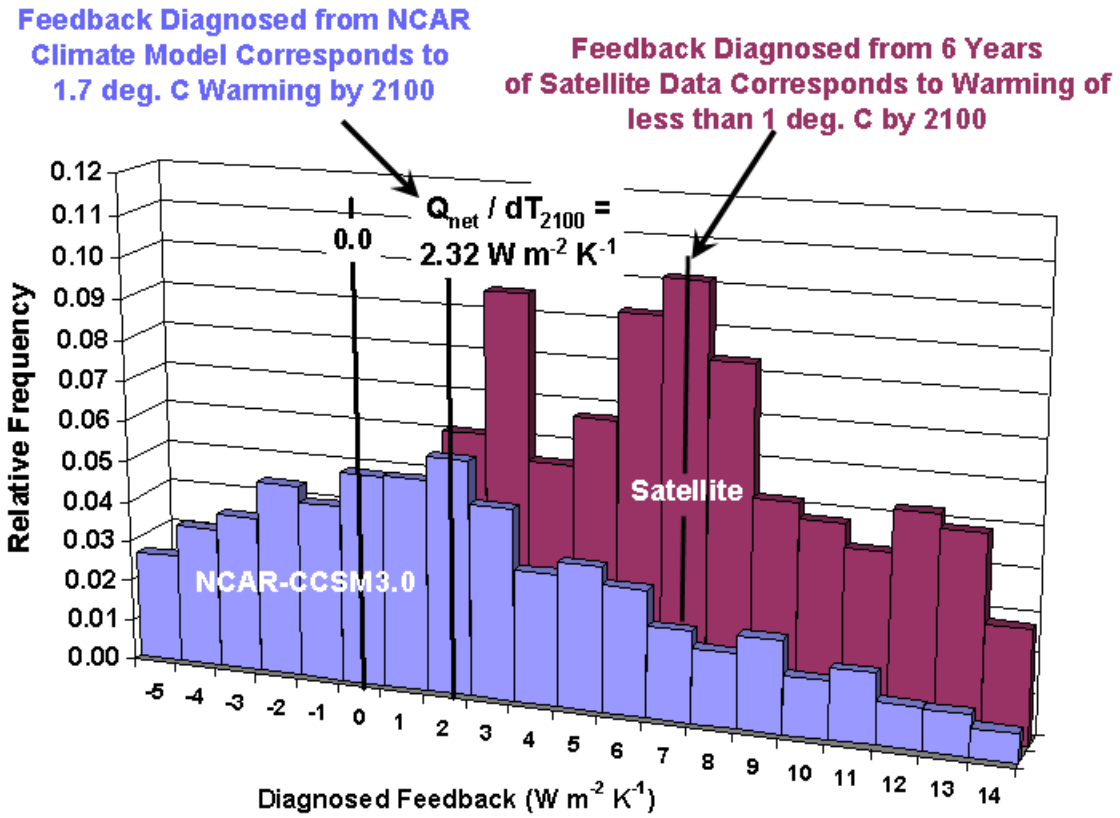

Fig. 1. Frequency distributions of feedback parameters (regression slopes) computed from three-month low-pass filtered time series of temperature (from channel 5 of the AMSU instrument flying on the NOAA-15 satellite) and top-of-atmosphere radiative flux variations for 6 years of global oceanic satellite data measured by the CERES instrument flying on NASA's Terra satellite; and from a 60 year integration of the NCAR-CCSM3.0 climate model forced by 1% per year CO2 increase. Peaks in the frequency distributions indicate the dominant feedback operating. This NCAR model is the least sensitive (greatest feedback parameter value) of all 20 IPCC models.

A second method for extracting the true feedback signal takes advantage of the fact that during natural climate variability, there are varying levels of internally-generated radiative forcings (which are uncorrelated to temperature), versus non-radiative forcings

(which are highly correlated to temperature). If the feedbacks estimated for different periods of time involve different levels of correlation, then the "true" feedback can be estimated by extrapolating those results to 100% correlation. This can be seen in Fig. 2, which shows that even previously published[4] estimates of positive feedback are, in reality, supportive of negative feedback (feedback parameters greater than 3.3 $Wm^{-2}K^{-1}$).

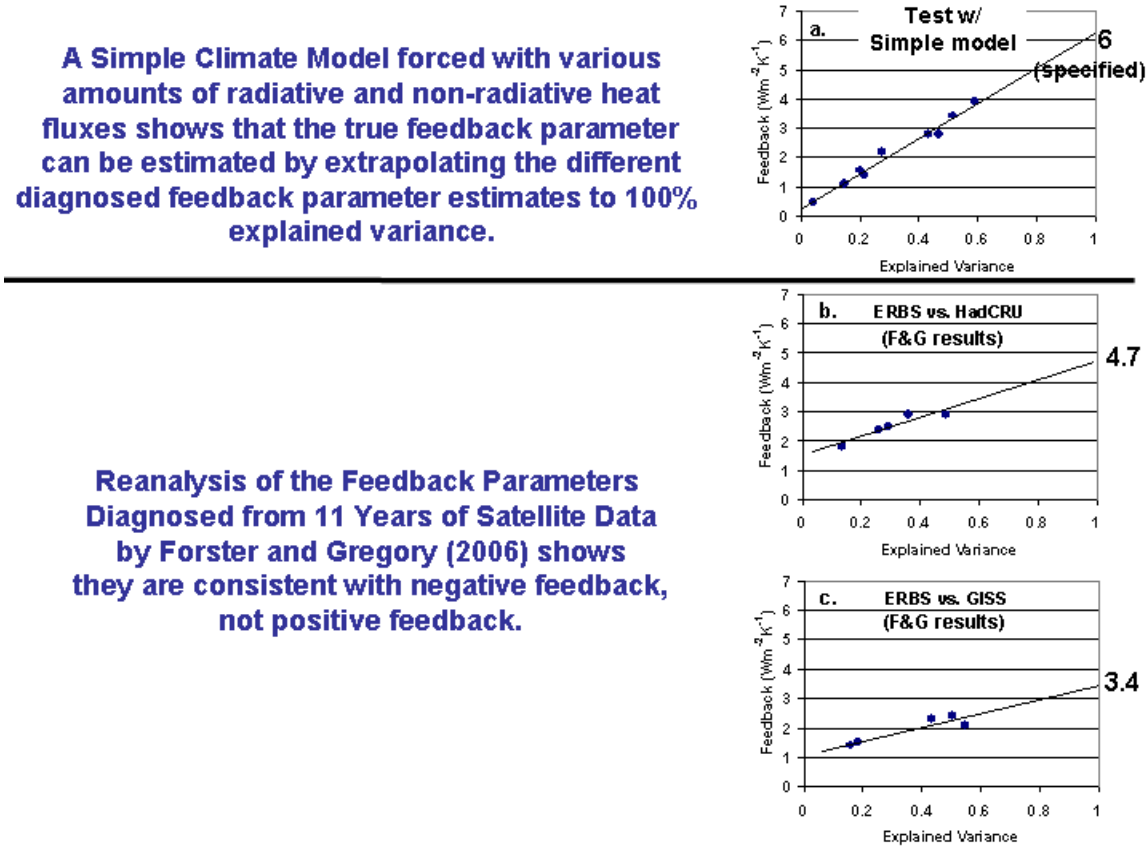

Fig. 2. Re-analysis of the satellite-based feedback parameter estimates of Forster and Gregory (2006) showing that they are consistent with negative feedback rather than positive feedback (low climate sensitivity rather than high climate sensitivity).

2.3 Why do climate models produce so much global warming?

The results just presented beg the following question: If the satellite data indicate an insensitive climate system, why do the climate models suggest just the opposite? I believe the answer is due to a misinterpretation of cloud behavior by climate modelers.

The cloud behaviors programmed into climate models (cloud "parameterizations") are based upon researchers' interpretation of cause and effect in the real climate system[5]. When cloud variations in the real climate system have been measured, it has been assumed that the cloud changes were the *result of* certain processes, which are ultimately tied to surface temperature changes. But since other, chaotic, internally generated mechanisms can also be the cause of cloud changes, the neglect of those processes leads to cloud parameterizations which are inherently biased toward high climate sensitivity.

The reason why the bias occurs only in the direction of high climate sensitivity is this: While surface warming could conceivably cause cloud changes which lead to either

positive or negative cloud feedback, causation in the opposite direction (cloud changes causing surface warming) can only work in one direction, which then "looks like" positive feedback. For example, decreasing low cloud cover can only produce warming, not cooling, and when that process is observed in the real climate system and assumed to be a feedback, it will always suggest a positive feedback.

2.4 So, what has caused global warming over the last century?

One necessary result of low climate sensitivity is that the radiative forcing from greenhouse gas emissions in the last century is not nearly enough to explain the upward trend of 0.7 deg. C in the last 100 years. This raises the question of whether there are natural processes at work which have caused most of that warming.

On this issue, it can be shown with a simple climate model that small cloud fluctuations assumed to occur with two modes of natural climate variability -- the El Nino/La Nina phenomenon (Southern Oscillation), and the Pacific Decadal Oscillation -- can explain 70% of the warming trend since 1900, as well as the nature of that trend: warming until the 1940s, no warming until the 1970s, and resumed warming since then. These results are shown in Fig. 3.

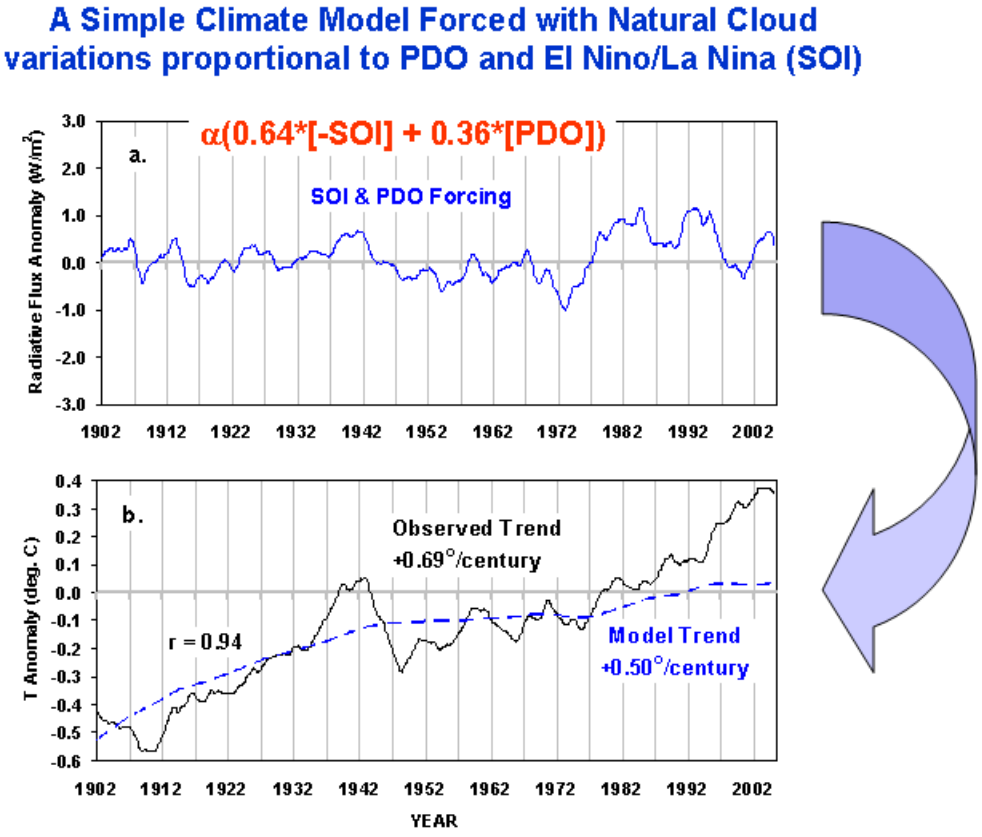

Fig. 3. A simple climate model forced with cloud cover variations assumed to be proportional to a linear combination of the Southern Oscillation Index (SOI) and Pacific Decadal Oscillation (PDO) index. The heat flux anomalies in (a), which then result in the modeled temperature response in (b), are assumed to be distributed over the top 27% of the global ocean (1,000 meters), and weak negative feedback has been assumed (4 W m^{-2} K^{-1}).

While this is not necessarily being presented as the only explanation for most of the warming in the last century, it does illustrate that there are potential explanations for recent warming other that just manmade greenhouse gas emissions. *Significantly, this is an issue on which the IPCC has remained almost entirely silent. There has been virtually no published work on the possible role of internal climate variations in the warming of the last century.*

3. Policy Implications

Obviously, what I am claiming today is of great importance to the global warming debate and related policy decisions, and it will surely be controversial. These results are not totally unprecedented, though, as other recently published research[6] has also led to the conclusion that the real climate system does not exhibit net positive feedback.

While it will take some time for the research community to digest this new information, it must be mentioned that new research contradicting the latest IPCC report is entirely consistent with the normal course of scientific progress. I predict that in the coming years, there will be a growing realization among the global warming research community that most of the climate change we have observed is natural, and that mankind's role is relatively minor.

While other researchers need to further explore and validate my claims, I am heartened by the fact that my recent presentation of these results to an audience of approximately 40 weather and climate researchers at the University of Colorado in Boulder last week (on July 17, 2008) led to no substantial objections to either the data I presented, nor to my interpretation of those data.

And, curiously, despite its importance to climate modeling activities, no one from Dr. Kevin Trenberth's facility, the National Center for Atmospheric Research (NCAR), bothered to drive four miles down the road to attend my seminar, even though it was advertised at NCAR.

I hope that the Committee realizes that, if true, these new results mean that humanity will be largely spared the negative consequences of human-induced climate change. This would be good news that should be celebrated -- not attacked and maligned.

And given that virtually no research into possible natural explanations for global warming has been performed, it is time for scientific objectivity and integrity to be restored to the field of global warming research. This Committee could, at a minimum, make a statement that encourages that goal.

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Climate Change

Statement of

William Happer

Cyrus Fogg Brackett Professor of Physics
Princeton University

Before the
U.S. Senate Environment & Public Works Committee
Senator Barbara Boxer, Chair

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Climate Change

William Happer testimony to Senate Energy Committee on February 25, 2009

Madam Chairman and members, thank you for the opportunity to appear before the Committee on Environment and Public Works to testify on Climate Change. My name is William Happer, and I am the Cyrus Fogg Bracket Professor of Physics at Princeton University. I am not a climatologist, but I don't think any of the other witnesses are either. I do work in the related field of atomic, molecular and optical physics. I have spent my professional life studying the interactions of visible and infrared radiation with gases – one of the main physical phenomena behind the greenhouse effect. I have published over 200 papers in peer reviewed scientific journals. I am a member of a number of professional organizations, including the American Physical Society and the National Academy of Sciences. I have done extensive consulting work for the US Government and Industry. I also served as the Director of Energy Research at the Department of Energy (DOE) from 1990 to 1993, where I supervised all of DOE's work on climate change. I have come here today as a concerned citizen to express my personal views, and those of many like me, about US climate-change policy. These are not official views of my main employer, Princeton University, nor of any other organization with which I am associated.

Let me state clearly where I probably agree with the other witnesses. We have been in a period of global warming over the past 200 years, but there have been several periods, like the last ten years, when the warming has ceased, and there have even been periods of substantial cooling, as from 1940 to 1970. Atmospheric concentrations of carbon dioxide (CO_2) have increased from about 280 to 380 parts per million over past 100 years. The combustion of fossil fuels, coal, oil and natural gas, has contributed to the increase of CO_2 in the atmosphere. And finally, increasing concentrations of CO_2 in the atmosphere will cause the earth's surface to warm. The key question is: will the net effect of the warming, and any other effects of the CO_2, be good or bad for humanity?

I believe that the increase of CO_2 is not a cause for alarm and will be good for mankind. I predict that future historians will look back on this period much as we now view the period just before the passage of the 18th Amendment to the US Constitution to prohibit "the manufacturing, sale or transportation of intoxicating liquors." At the time, the 18th amendment seemed to be exactly the right thing to do – who wanted to be in league with demon rum? It was the 1917 version of saving the planet. More than half the states enacted prohibition laws before the 18th amendment was ratified. Only one state, Rhode Island, voted against the 18th amendment. Two states, Illinois and Indiana, never got around to voting and all the rest voted for it. There were many thoughtful people, including a majority of Rhode Islanders, who thought that prohibition might do more harm than good. But they were completely outmatched by the temperance movement, whose motives and methods had much in common with the movement to stop climate change. Deeply sincere people thought they were saving humanity from the evils of alcohol, just as many people now sincerely think

I believe that the increase of CO_2 is not a cause for alarm and will be good for mankind.

they are saving humanity from the evils of CO2. Prohibition was a mistake, and our country has probably still not fully recovered from the damage it did. Institutions like organized crime got their start in that era. Drastic limitations on CO2 are likely to damage our country in analogous ways.

Let me turn now to the science and try to explain why I and many scientists like me are not alarmed by increasing levels of CO2.

But what about the frightening consequences of increasing levels of CO2 that we keep hearing about? In a word, they are wildly exaggerated, just as the purported benefits of prohibition were wildly exaggerated. Let me turn now to the science and try to explain why I and many scientists like me are not alarmed by increasing levels of CO2.

The earth's climate really is strongly affected by the greenhouse effect, although the physics is not the same as that which makes real, glassed-in greenhouses work. Without greenhouse warming, the earth would be much too cold to sustain its current abundance of life. However, at least 90% of greenhouse warming is due to water vapor and clouds. Carbon dioxide is a bit player. There is little argument in the scientific community that a direct effect of doubling the CO2 concentration will be a small increase of the earth's temperature -- on the order of one degree.[1] Additional increments of CO2 will cause relatively less direct warming because we already have so much CO2 in the atmosphere that it has blocked most of the infrared radiation that it can. It is like putting an additional ski hat on your head when you already have a nice warm one below it, but you are only wearing a windbreaker. To really get warmer, you need to add a warmer jacket. The IPCC thinks that this extra jacket is water vapor and clouds.

With each passing year, experimental observations further undermine the claim of a large positive feedback from water.

Since most of the greenhouse effect for the earth is due to water vapor and clouds, added CO2 must substantially increase water's contribution to lead to the frightening scenarios that are bandied about. The buzz word here is that there is "positive feedback." With each passing year, experimental observations further undermine the claim of a large positive feedback from water.

In fact, observations suggest that the feedback is close to zero and may even be negative. That is, water vapor and clouds may actually diminish the already small global warming expected from CO2, not amplify it. The evidence here comes from satellite measurements of infrared radiation escaping from the earth into outer space, from measurements of sunlight reflected from clouds and from measurements of the temperature the earth's surface or of the troposphere, the roughly 10 km thick layer of

[1] All footnotes in this paper added by SPPI.
See http://scienceandpublicpolicy.org/images/stories/papers/monckton/temperature_co2_change_scientific_briefing.pdf and http://scienceandpublicpolicy.org/monckton/climate_sensitivity_reconsidered.html.

the atmosphere above the earth's surface that is filled with churning air and clouds, heated from below at the earth's surface, and cooled at the top by radiation into space.

But the climate is warming and CO2 is increasing. Doesn't this prove that CO2 is causing global warming through the greenhouse effect? No, the current warming period began about 1800 at the end of the little ice age, long before there was an appreciable increase of CO2. There have been similar and even larger warmings several times in the 10,000 years since the end of the last ice age. These earlier warmings clearly had nothing to do with the combustion of fossil fuels. The current warming also seems to be due mostly to natural causes, not to increasing levels of carbon dioxide. Over the past ten years there has been no global warming, and in fact a slight cooling.[2] This is not at all what was predicted by the IPCC models.

The climate has changed many times in the past with no help by mankind. Recall that the Romans grew grapes in Britain around the year 100, and Viking settlers prospered on small farms in Greenland for several centuries during the Medieval Climate Optimum around 1100. People have had an urge to control the climate throughout history so I suppose it is no surprise that we are at it again today. For example, in June of 1644, the Bishop of Geneva led a flock of believers to the face of a glacier that was advancing "by over a musket shot" every day. The glacier would soon destroy a village. The Bishop and his flock prayed over the glacier, and it is said to have stopped. The poor Vikings had long since abandoned Greenland where the advancing glaciers and cooling climate proved much less susceptible to prayer. Sometimes the obsession for control of the climate got a bit out of hand, as in the Aztec state, where the local scientific/religious establishment of the year 1500 had long since announced that the debate was over and that at least 20,000 human sacrifices a year were needed to keep the sun moving, the rain falling, and to stop climate change. The widespread dissatisfaction of the people who were unfortunate enough to be the source of these sacrifices played an important part in the success of the Spanish conquest of Mexico.

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The existence of climate variability in the past has long been an embarrassment to those who claim that all climate change is due to man and that man can control it. When I was a schoolboy, my textbooks on earth science showed a prominent "medieval warm period" at the time the Vikings settled Greenland, followed by a vicious "little ice age" that drove them out. So I was very surprised when I first saw the celebrated "hockey stick curve," in the Third Assessment Report of the IPCC.[3] I could hardly believe my eyes. Both the little ice age and the Medieval Warm Period were gone, and the newly revised temperature of the world since the year 1000 had suddenly become absolutely flat until the last hundred years when it shot up like the blade on a hockey stick. This was far from an obscure detail, and the hockey stick was trumpeted around the world as evidence that the end was near.

[2] See http://scienceandpublicpolicy.org/monckton/global_warming_has_stopped.html.
[3] See http://scienceandpublicpolicy.org/monckton/what_hockey_stick.html.

The whole hockey-stick episode reminds me of the motto of Orwell's Ministry of Information in the novel "1984:" "He who controls the present, controls the past. He who controls the past, controls the future."

We now know that the hockey stick has nothing to do with reality but was the result of incorrect handling of proxy temperature records and incorrect statistical analysis. There really was a little ice age and there really was a medieval warm period that was as warm or warmer than today. I bring up the hockey stick as a particularly clear example that the IPCC summaries for policy makers are not dispassionate statements of the facts of climate change. It is a shame, because many of the IPCC chapters are quite good. The whole hockey-stick episode reminds me of the motto of Orwell's Ministry of Information in the novel "1984:" "He who controls the present, controls the past. He who controls the past, controls the future." The IPCC has made no serious attempt to model the natural variations of the earth's temperature in the past. Whatever caused these large past variations, it was not due to people burning coal and oil. If you can't model the past, where you know the answer pretty well, how can you model the future?

Many of us are aware that we are living in an ice age, where we have hundred-thousand-year intervals of big continental glaciers that cover much of the land area of the northern hemisphere, interspersed with relative short interglacial intervals like the one we are living in now. By looking at ice cores from the Greenland and Antarctic ice sheets, one can estimate past temperatures and atmospheric concentrations of CO_2. Al Gore likes to display graphs of temperature and CO_2 concentrations over the past million years or so[4], showing that when CO_2 rises, the temperature also rises. Doesn't this prove that the temperature is driven by CO_2? Absolutely not! If you look carefully at these records, you find that first the temperature goes up, and then the CO_2 concentration of the atmosphere goes up.

There is a delay between a temperature increase and a CO_2 increase of about 800 years. This casts serious doubt on CO_2 as a climate driver because of the fundamental concept of causality. A cause must precede its effect. For example, I hear my furnace go on in the morning about six o'clock, and by about 7 o'clock, I notice that my house is now so warm that I have too many covers on my bed. It is time to get up. It would never occur to me to assume that the furnace started burning gas at 6 o'clock because the house got warm at 7 o'clock. Sure, temperature and gas burning are correlated, just like temperature and atmospheric levels of CO_2. But the thing that changes first is the cause. In the case of the ice cores, the cause of increased CO_2 is almost certainly the warming of the oceans. The oceans release dissolved CO_2 when they warm up, just like a glass of beer rapidly goes flat in a

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[4] See http://scienceandpublicpolicy.org/monckton/goreerrors.html.

warm room. If not CO2, then what really causes the warming at the end of the cold periods of ice ages? A great question and one of the reasons I strongly support research in climate.

I keep hearing about the "pollutant CO2," or about "poisoning the atmosphere" with CO2, or about minimizing our "carbon footprint." This brings to mind another Orwellian pronouncement that is worth pondering: "But if thought corrupts language, language can also corrupt thought." CO2 is not a pollutant and it is not a poison and we should not corrupt the English language by depriving "pollutant" and "poison" of their original meaning. Our exhaled breath contains about 4% CO2. That is 40,000 parts per million, or about 100 times the current atmospheric concentration. CO2 is absolutely essential for life on earth.[5] Commercial greenhouse operators often use CO2 as a fertilizer to improve the health and growth rate of their plants. Plants, and our own primate ancestors evolved when the levels of atmospheric CO2 were about 1000 ppm, a level that we will probably not reach by burning fossil fuels, and far above our current level of about 380 ppm. We try to keep CO2 levels in our US Navy submarines no higher than 8,000 parts per million, about 20 time current atmospheric levels. Few adverse effects are observed at even higher levels.

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We are all aware that "the green revolution" has increased crop yields around the world. Part of this wonderful development is due to improved crop varieties, better use of mineral fertilizers, herbicides, etc. But no small part of the yield improvement has come from increased atmospheric levels of CO2. Plants photosynthesize more carbohydrates when they have more CO2. Plants are also more drought-tolerant[6] with more CO2, because they need not "inhale" as much air to get the CO2 needed for photosynthesis. At the same time, the plants need not "exhale" as much water vapor when they are using air enriched in CO2. Plants decrease the number of stomata or air pores on their leaf surfaces in response to increasing atmospheric levels of CO2. They are adapted to changing CO2 levels and they prefer higher levels than those we have at present. If we really were to decrease our current level of CO2 of around 400 ppm to the 270 ppm that prevailed a few hundred years ago, we would lose some of the benefits of the green revolution. Crop yields will continue to increase as CO2 levels go up, since we are far from the optimum levels for plant growth. Commercial greenhouse operators are advised to add enough CO2 to maintain about 1000 ppm around their plants. Indeed, economic studies like those of Dr. Robert Mendelsohn at Yale University project that

[5] See http://co2science.org/education/experiments/global.php and http://co2science.org/subject/c/summaries/carbondioxide.php.

[6] See http://co2science.org/subject/c/c4plantwue.php.

moderate warming is an overall benefit to mankind because of higher agricultural yields and many other reasons.

Enormous effort and imagination have gone into showing that increasing concentrations of CO2 will be catastrophic.

I remember being forced to read Voltaire's novel, Candide, when I was young. You recall that Dr. Pangloss repeatedly assured young Candide that he was living in "the best of all possible worlds," presumably also with the best of all CO2 concentrations. That we are (or were) living at the best of all CO2 concentrations seems to be a tacit assumption of the IPCC executive summaries for policy makers. Enormous effort and imagination have gone into showing that increasing concentrations of CO2 will be catastrophic[7], cities will be flooded by sea-level rises that are ten or more times bigger than even IPCC predicts, there will be mass extinctions of species, billions of people will die, tipping points will render the planet a desert. A few months ago I read that global warming will soon bring on a devastating epidemic of kidney stones. If you write down all the ills attributed to global warming you fill up a very thick book.[8]

Much is made about tropical diseases like malaria and yellow fever devastating the populations of temperate climates because of the burning of fossil fuels and the subsequent warming of the earth. Many people who actually work with tropical diseases, notably Dr. Paul Reiter,[9] a specialist on tropical diseases, have pointed out how silly all of this is. Perhaps I can add a few bits of history to illustrate this point. One of the first military expenditures of the Continental Congress in 1775 was $300 to purchase quinine for the Continental Army and to mitigate the effects of malaria. The Continental Congress moved from the then Capital of the United States , Philadelphia, to my home town of Princeton, New Jersey, in the summer of 1783 for two reasons. The first was that the Congress had not yet paid many soldiers of the Revolutionary War their promised wages, and disgruntled veterans were wandering up and down the streets of Philadelphia. Secondly, there were outbreaks of malaria in cities as far north as Boston. The Congress knew you were less likely to catch malaria in Princeton than in Philadelphia. In 1793 there was not only malaria, but a horrendous outbreak of yellow fever in Philadelphia. Many thousands of people died in a city with a population of about 50,000. And I should point out that Philadelphia was a bit cooler then than now, since the little ice age was just coming to an end. Controlling tropical diseases and many other diseases has little to do with temperature, and everything to do with curtailing the factors that cause the spread – notably mosquitoes in the case of malaria and yellow fever.

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[7] See http://scienceandpublicpolicy.org/images/stories/papers/originals/gore_testimony.pdf.

[8] For a list of ills attributed to global warming, see http://www.numberwatch.co.uk/warmlist.htm.

[9] See http://scienceandpublicpolicy.org/scarewatch/global_warming_spreads_malaria_.html, http://www.cdc.gov/ncidod/EID/vol6no1/reiter.htm, http://commerce.senate.gov/pdf/reiter-042606.pdf, and http://www.publications.parliament.uk/pa/ld200506/ldselect/ldeconaf/12/12we21.htm.

Many of the frightening scenarios about global warming come from large computer calculations, "general circulation models," that try to mimic the behavior of the earth's climate as more CO2 is added to the atmosphere. It is true that climate models use increasingly capable and increasingly expensive computers. But their predictions have not been very good. For example, none of them predicted the lack of warming that we have experienced during the past ten years. All the models assume the water feedback is positive, while satellite observations suggest that the feedback is zero or negative.[10]

All the models assume the water feedback is positive, while satellite observations suggest that the feedback is zero or negative.

Modelers have been wrong before. One of the most famous modeling disputes involved the physicist William Thompson, later Lord Kelvin, and the naturalist Charles Darwin. Lord Kelvin was a great believer in models and differential equations.

Charles Darwin was not particularly facile with mathematics, but he took observations very seriously. For evolution to produce the variety of living and fossil species that Darwin had observed, the earth needed to have spent hundreds of millions of years with conditions not very different from now. With his mathematical models, Kelvin rather pompously demonstrated that the earth must have been a hellish ball of molten rock only a few tens of millions of years ago, and that the sun could not have been shining for more than about 30 million years. Kelvin was actually modeling what he thought was global and solar cooling. I am sorry to say that a majority of his fellow physicists supported Kelvin. Poor Darwin removed any reference to the age of the earth in later editions of the "Origin of the Species." But Darwin was right the first time, and Kelvin was wrong. Kelvin thought he knew everything but he did not know about the atomic nucleus, radioactivity and nuclear reactions, all of which invalidated his elegant modeling calculations.

This brings up the frequent assertion that there is a consensus behind the idea that there is an impending disaster from climate change, and that it may already be too late to avert this catastrophe, even if we stop burning fossil fuels now. We are told that only a few flat-earthers still have any doubt about the calamitous effects of continued CO2 emissions. There are a number of answers to this assertion.

What is correct in science is not determined by consensus but by experiment and observations.

First, what is correct in science is not determined by consensus but by experiment and observations. Historically, the consensus is often wrong, and I just mentioned the incorrect consensus of modelers about the age of the earth and the sun. During the yellow fever epidemic of 1793 in Philadelphia the medical consensus was that you could cure almost anything by bleeding the patient. Benjamin Rush, George Washington's Surgeon General during the War of Independence, and a brave man,

[10] See http://scienceandpublicpolicy.org/reprint/cloud_changes_response_to_pdo.html.

stayed in Philadelphia throughout the yellow fever epidemic. He worked tirelessly to save the stricken by bleeding them, the consensus treatment of the day. A few cautious observers noticed that you were more likely to survive the yellow fever without the services of the great man. But Dr. Rush had plenty of high level-friends and he was backed up by the self-evident consensus, so he went ahead with his ministrations. In summary, a consensus is often wrong.

I personally certainly don't believe we are facing a crisis unless we create one for ourselves.

Secondly, I do not think there is a consensus about an impending climate crisis. I personally certainly don't believe we are facing a crisis unless we create one for ourselves, as Benjamin Rush did by bleeding his patients. Many others, wiser than I am, share my view. The number of those with the courage to speak out is growing. There may be an illusion of consensus. Like the temperance movement one hundred years ago the climate-catastrophe movement has enlisted the mass media, the leadership of scientific societies, the trustees of charitable foundations, and many other influential people to their cause. Just as editorials used to fulminate about the slippery path to hell behind the tavern door, hysterical op-ed's lecture us today about the impending end of the planet and the need to stop climate change with bold political action. Many distinguished scientific journals now have editors who further the agenda of climate-change alarmism. Research papers with scientific findings contrary to the dogma of climate calamity are rejected by reviewers, many of whom fear that their research funding will be cut if any doubt is cast on the coming climate catastrophe.

If you have the power to stifle dissent, you can indeed create the illusion of peace or consensus.

Speaking of the Romans, then invading Scotland in the year 83, the great Scottish chieftain Calgacus is quoted as saying "They make a desert and call it peace." If you have the power to stifle dissent, you can indeed create the illusion of peace or consensus. The Romans have made impressive inroads into climate science. Certainly, it is a bit unnerving to read statements of Dr. James Hansen in the Congressional Record that climate skeptics are guilty of "high crimes against humanity and nature."

Even elementary school teachers and writers of children's books[11] are enlisted to terrify our children and to promote the idea of impending climate doom. Having observed the education of many children, including my own, I am not sure how effective the effort will be. Many children seem to do just the opposite of what they are taught. Nevertheless, children should not be force-fed propaganda, masquerading as science. Many of you may know that in 2007 a British Court ruled[12] that if Al Gore's book, "An

[11] See http://scienceandpublicpolicy.org/sppi_ewire_10_26_2007/should_laurie_david_s_new_kids_book_be_renamed_an_inconvenient_error_.html and http://scienceandpublicpolicy.org/other/childrensbookerror.html.

[12] See http://scienceandpublicpolicy.org/reprint/ukcourthearing.html and http://scienceandpublicpolicy.org/monckton/goreerrors.html.

Inconvenient Truth," was used in public schools, the children had to be told of eleven particularly troubling inaccuracies. You can easily find a list of the inaccuracies on the internet, but I will mention one. The court ruled that it was not possible to attribute hurricane Katrina to CO2. Indeed, had we taken a few of the many billions of dollars we have been spending on climate change research and propaganda and fixed the dykes and pumps around the New Orleans, most of the damage from Hurricane Katrina could have been avoided.

To think that limiting CO2 emissions will stop sea level rise is a dangerous illusion.

The sea level is indeed rising, just as it has for the past 20,000 years since the end of the last ice age.[13] Fairly accurate measurements of sea level have been available since about 1800. These measurements show no sign of any acceleration. The rising sea level can be a serious local problem for heavily-populated, low-lying areas like New Orleans, where land subsidence compounds the problem. But to think that limiting CO2 emissions will stop sea level rise is a dangerous illusion. It is also possible that the warming seas around Antarctica will cause more snowfall over the continent and will counteract the sea-level rise. In any case, the rising sea level is a problem that needs quick local action for locations like New Orleans rather than slow action globally.

In closing, let me say again that we should provide adequate support to the many brilliant scientists, some at my own institution of Princeton University, who are trying to better understand the earth's climate, now, in the past, and what it may be in the future. I regret that the climate-change issue has become confused with serious problems like secure energy supplies[14], protecting our environment, and figuring out where future generations will get energy supplies after we have burned all the fossil fuel we can find. We should not confuse these laudable goals with hysterics about carbon footprints.

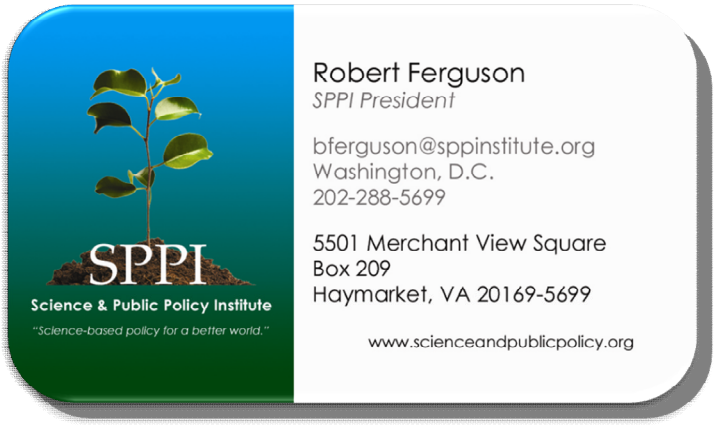
I regret that the climate-change issue has become confused with serious problems like secure energy supplies, protecting our environment, and figuring out where future generations will get energy supplies after we have burned all the fossil fuel we can find.

For example, when weighing pluses and minuses of the continued or increased use of coal, the negative issue should not be increased atmospheric CO2, which is probably good for mankind. We should focus on real issues like damage to the land and waterways by strip mining, inadequate remediation, hazards to miners, the release of real pollutants and poisons like mercury, other heavy metals, organic carcinogens, etc. Life is about making decisions and decisions are about trade-offs. The Congress can

[13] See http://scienceandpublicpolicy.org/other/increasedco2effects.html.

[14] See http://scienceandpublicpolicy.org/monckton/cost_and_futility_of_trading_hot_air.html and http://scienceandpublicpolicy.org/originals/climate_action_plans_fail_to_deliver.html.

choose to promote investment in technology that addresses real problems and scientific research that will let us cope with real problems more efficiently. Or they can act on unreasonable fears and suppress energy use, economic growth and the benefits that come from the creation of national wealth.



The Missing Hotspot

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Summary

Each cause of global warming heats up the atmosphere in a distinctive pattern—its "signature". According to IPPC climate theory, the signature of carbon emissions and the signature of warming due to all causes during the recent global warming both include a prominent "hotspot" at about 10 – 12 km in the air over the tropics. But the observed warming pattern during the recent global warming contains no trace of any such hotspot. Therefore:

1. IPCC climate theory is fundamentally wrong.
2. To the extent that IPCC climate theory is correct in predicting a hotspot due to extra carbon dioxide, we know that carbon emissions did not cause the recent global warming.

The hotspot is not incidental to IPCC climate theory—it lies at its heart, because the same water vapor feedback that produces the hotspot in IPCC climate theory also doubles or triples the temperature increases predicted by the IPCC climate models. If the IPCC climate modellers just turn down the water vapor feedback in their models enough so their theoretical signatures match the observed warming patterns, then the predicted temperature increases due to projected carbon emissions are greatly reduced and are no longer of much concern.

Causes Leave Signatures

Each cause of global warming heats up the atmosphere in a distinctive pattern. The pattern of areas that heat up fastest during a warming is the "signature" of the cause.

The situation is analogous to a house fire. If the initial warming is in the living room in front of the fireplace, then this would point to a burning log rolling out of the fireplace. Initial heating in the kitchen is the signature of a fire on the stove. The signature of a cigarette left burning in a bed would be initial heating in a bedroom. Fire investigators use the pattern of initial heating and the spread of the fire to narrow down the cause of the fire.

Signatures are like fingerprints: telltale marks that tell you something about who done it.

Unfortunately we cannot use signatures to prove that a particular cause ***was*** the main cause of global warming, because the signatures of some leading suspects are

unknown. But we can use signatures to rule out those causes whose signatures were definitely not observed.

Signatures are Important

Signatures are second only to the temperatures themselves in the debate about the causes of global warming, because they can immediately and definitively:

1. Confirm or falsify the IPCC climate theory models.
2. Rule out some causes of global warming.

Temperatures are of course the other observations that can prove that the IPCC climate theory is false, but they will take decades to play out. It will take at least another decade or two of non-rising temperatures to convince the IPCC climate theorists they are wrong: as of March 2009, some alarmist scientists were acknowledging that the planet is in a cooling phase that could last another thirty years.

Most global warming debating points do not matter much. For example, some say the receding snowline on Mt Kilimanjaro is due to global warming, while others say it is due to local deforestation reducing the snowfall. But this debate has never converted anyone between alarmism and skepticism, and has no bearing on the causes of global warming or whether we should have a carbon tax. On the other hand, signatures can confirm or disprove the IPCC climate theory, and thereby indicate whether or not we should reduce carbon emissions.

Evidence about the causes of global warming is fairly rare. There is lots of evidence that global warming has been taking place, and the media are eager to report it. However this is not evidence about what ***causes*** global warming—because it says nothing about whether, say, the earth is heating because of rising carbon dioxide levels, the sun is getting hotter, or aliens are warming the planet with ray guns. Unfortunately this logical difference is often overlooked in the media's fear and alarmism. In the public's mind, the evidence that global warming is happening has been conflated with evidence that it is due to carbon emissions.

No One Knows About Signatures

Alarmists keep very quiet about signatures. Hardly anyone in the public or government realises the observed warming data exists or its significance. The "news" services aren't exactly falling over themselves to tell you about it. There has been near complete official silence on the topic: ever notice that, outside highly technical circles, the IPCC or alarmists never mention the idea that warming patterns are evidence of causes, or talk about signatures or hotspots?

Definitive data on the last warming period was collected by 1999 (thereby including the big El Nino warming peak of 1998), but the earliest technical publications did not appear until 2003 and the first public outing of signatures did not occur until 2007 (as far as I am aware). The observed warming pattern and the comparisons with signatures

below in this document have never appeared anywhere in the mainstream media as of March 2009 (again, as far as I know).

Unless you are a climate scientist or closely involved with the global warming debate, you almost certainly did not hear of the idea that atmospheric warming patterns contain telltale clues of their causes before 2008. And almost no one outside a small group knew of the observed warming pattern data until skeptics tried to draw attention to it, in plain language, starting in 2007.

Of course, if the signature of increased greenhouse warming truly had been observed then we would have heard ALL about it. Every two-bit science reporter would be an expert on signatures, and the media would be screaming from the rooftops that signatures were vital evidence that confirmed the IPCC climate theory.

The Observed Warming Pattern

To observe the warming pattern we need to measure the temperature at each height and latitude around the world during a warming. (The longitude does not matter much, because the climate is pretty much the same all around the world at a given latitude.)

Satellites cannot measure temperatures at specific heights in the atmosphere, so we need to use radiosondes—lighter-than-air balloons that ascend through the atmosphere with a thermometer, radioing the temperatures back to a ground station. Fortunately people have been using radiosondes to observe atmospheric temperatures since the 1960s, so we have a reasonably good picture of the pattern of variations in atmospheric temperatures during the recent period of global warming from 1977 to 2001.

Despite the importance of the observed warming pattern, it was a long while before it was published in any document accessible to the public. Finally in 2006 the US Climate Change Science Program (CCSP) published it in a small diagram buried near the back of a report in among some theoretical diagrams: part E of Figure 5.7 in section 5.5 on page 116:

http://www.climatescience.gov/Library/sap/sap1-1/finalreport/sap1-1-final-chap5.pdf.

It is reproduced here:

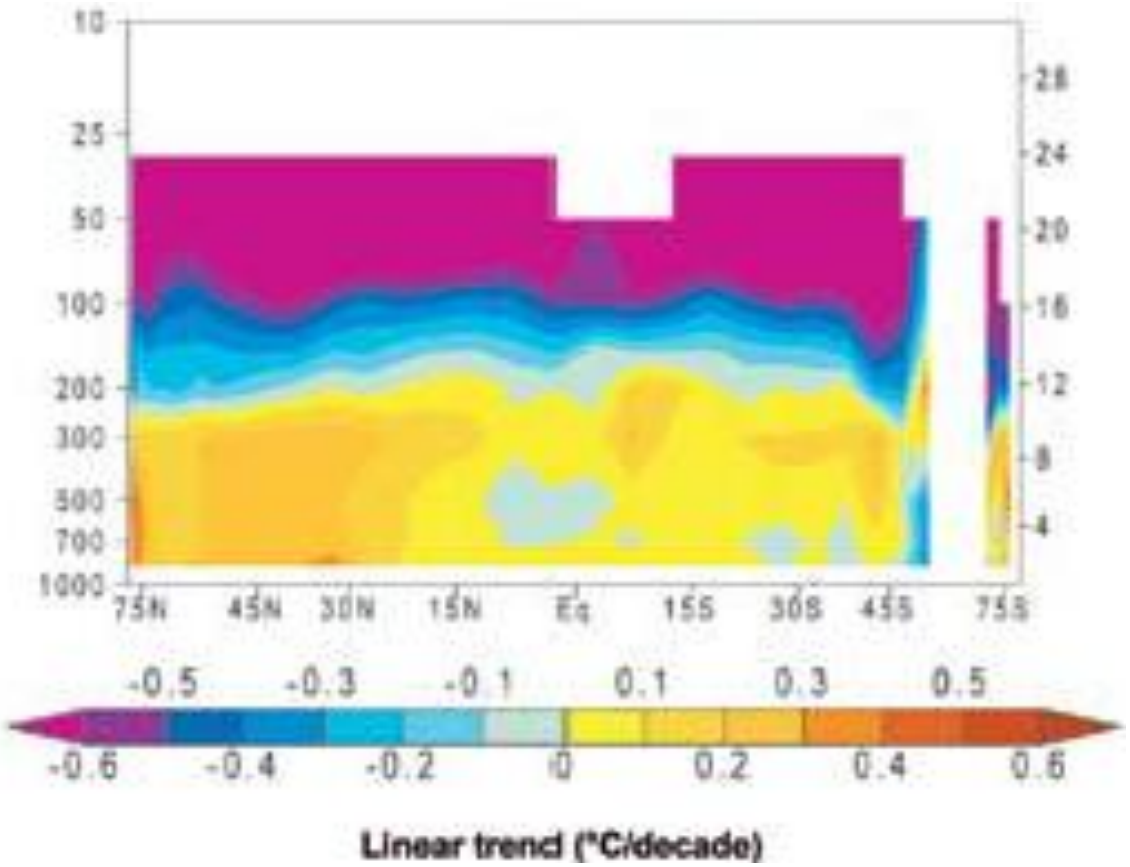


Figure 1: The observed pattern of atmospheric warming, 1979 – 1999, as per the US CCSP part E of Figure 5.7 in section 5.5 on page 116.

This is the pattern of atmospheric warming for the period 1979 to 1999, which covers nearly all the recent period of global warming. All the radiosonde data in that period is combined into a single picture, showing temperature variation over the 20 year period by latitude and by height in the atmosphere (for each latitude and height, the results at different longitudes are averaged into a single number or point in the diagram).

The horizontal axis is the latitude, from 75 degrees north through the equator in the middle to 75 degrees south. There is no data around 60 degrees south because there is little data from that region (there is no inhabited land around that latitude). The vertical axis is the height in the atmosphere, marked on the right hand side as 0 – 28 km (and on the left hand side as the corresponding air pressures in hPa). The colors in the diagram shows the temperature changes on a per-decade basis.

What warming pattern do we see? There was broad stratospheric cooling and broad tropospheric warming, and a little more warming in the northern hemisphere than the south.

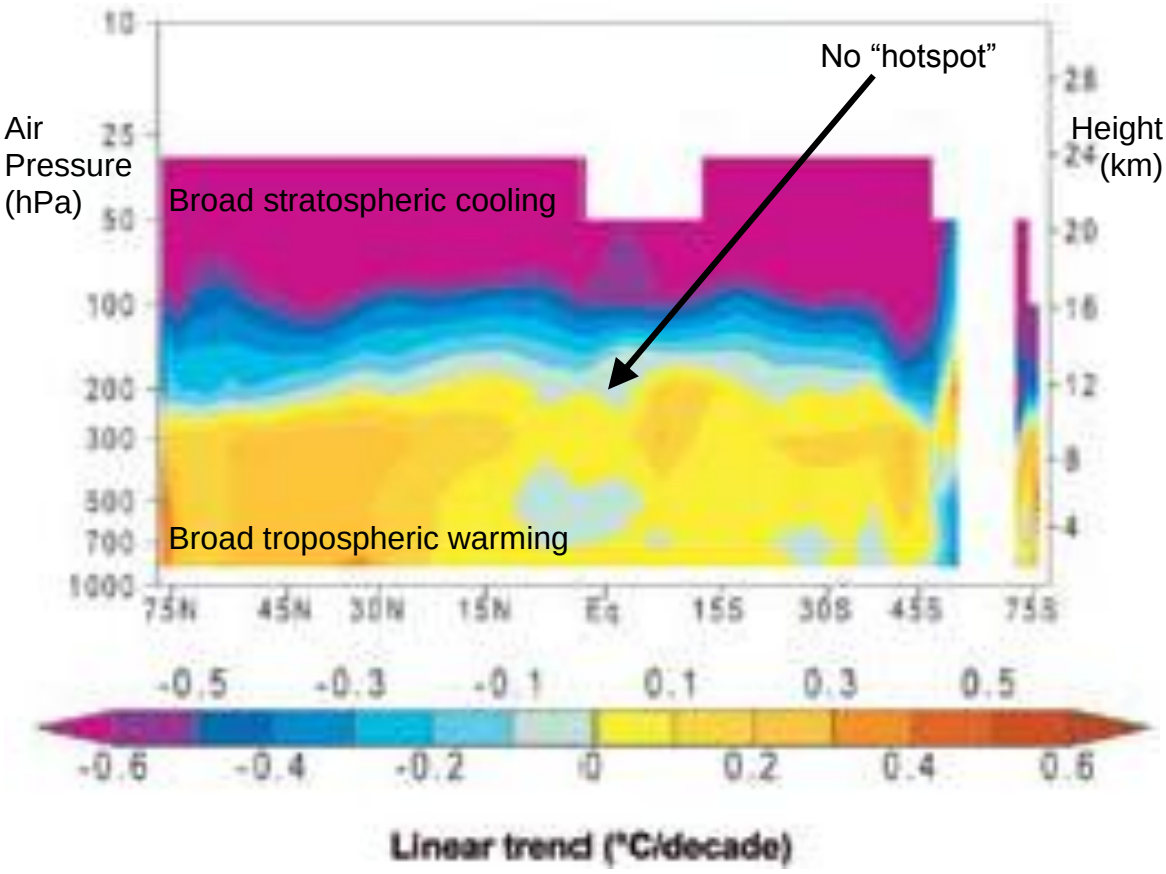


Figure 2: The observed pattern of atmospheric warming, 1979 – 1999, annotated.

What we ***don't*** see is a hotspot at the top of the tropical troposphere. There is no hotspot at all at 10 − 12 km up, from 23°N to 23°S: indeed, much or most of the troposphere warmed by more than the region where the hotspot would be.

This is all the data we will ever have about that warming period, because we cannot go back in time and take more or better measurements. Furthermore, the world has not been warming since 2001, so we haven't been able to take more measurements since then (we are only interested in the atmospheric pattern when there is warming). This particular view of the data is known as the "HadAT2 temperature data". The raw data from the radiosondes can be processed in slightly different ways, so there are some small variations on this picture, but basically this is it.

Radiosondes reliably detect temperature differences of 0.1°C when correctly calibrated and operated. There were variations in equipment and procedures over those 20 years, not all operators were equally skilful, and some radiosonde data was contaminated by radiosondes passing through cold clouds and getting iced up (the data from these radiosondes was discarded). Nonetheless, most of the radiosondes were definitely sensitive enough to notice temperature variations of a small fraction of a degree.

Signatures From the IPCC, for 1958 − 1999

The published theoretical signatures produced by the IPCC climate theory that best matches the period of the observed warming pattern (1979 – 1999) appeared in the US Climate Change Science Program, 2006, Chapter 1,

http://www.climatescience.gov/Library/sap/sap1-1/finalreport/sap1-1-final-chap1.pdf.

It shows six signature diagrams in Figure 1.3, in Section 1.5 on page 25, for the period 1958 − 1999, which are reproduced here:

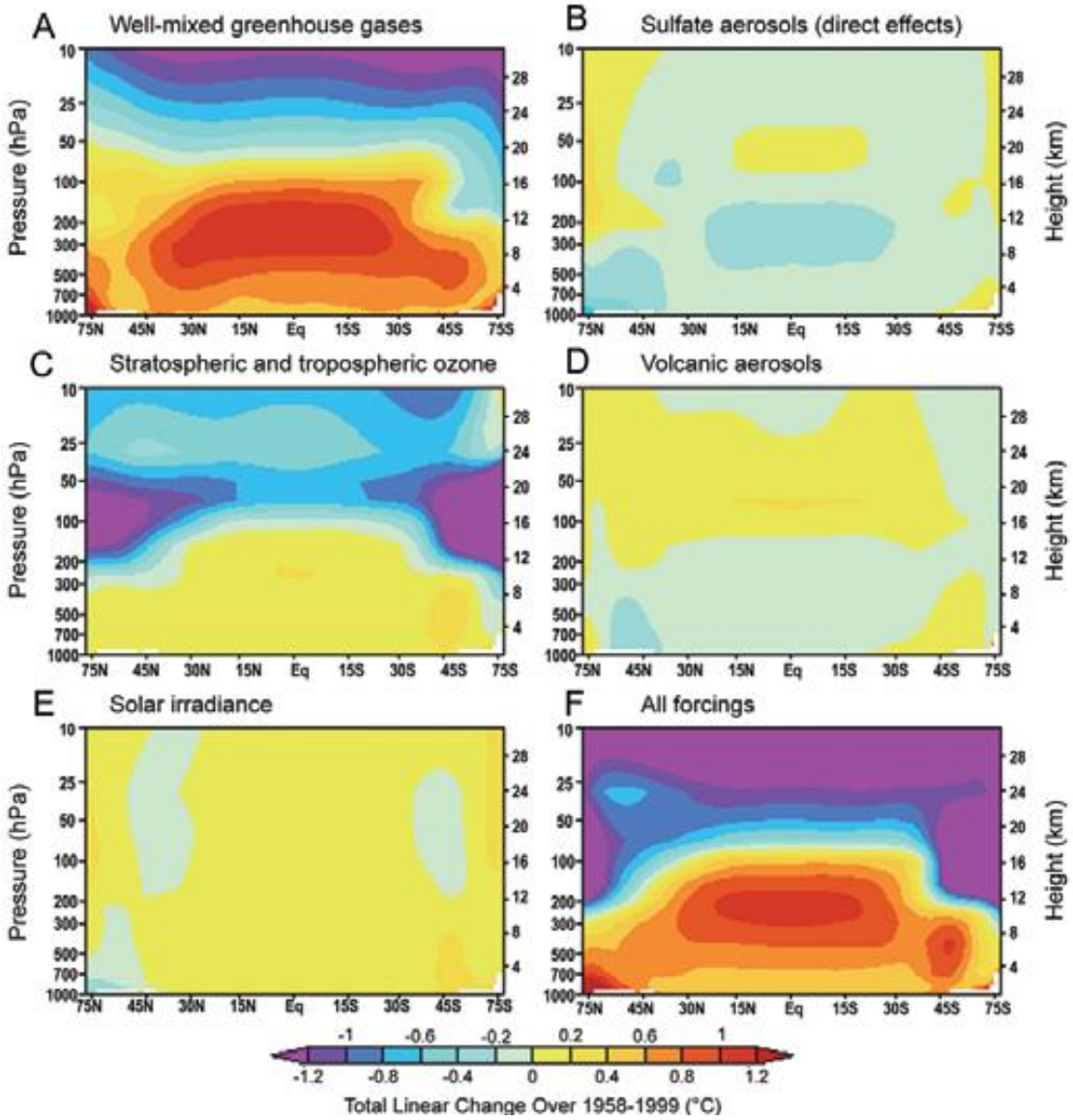


Figure 3: The theoretical warming patterns calculated by the IPCC climate models for 1958 to 1999, in °C per 42 years.

These diagrams show what the IPCC say occurred, according to their climate models. In particular, diagram A is the signature of warming due to an increase in greenhouse gases other than water vapor, that is, from carbon emissions. And diagram F is the warming pattern expected from the sum of all the five signatures A – E in the proportions the IPCC believe those causes contributed to global temperature changes;

it is dominated by signature A because the IPCC's theory is that the warming was mainly due to carbon emissions.

These signatures are for 1958 – 1999. But since there was little warming or cooling from 1958 to 1978, they are fairly directly comparable to the observed warming pattern for 1979 − 1999.

Notice that the signature A for increased greenhouse warming has two main features:

1. A hotspot over the tropics at about 10 – 12 kms.
2. Broad stratospheric cooling and broad tropospheric warming.

That second feature is also present in signature C for ozone depletion.

Signatures From the IPCC, for 1890 − 1999

The most authoritative source of signatures based on the IPCC theory is the latest assessment report from the IPCC itself. The IPCC Assessment Report 4 (AR4), 2007, Chapter 9,

http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch09.pdf

shows six signature diagrams in Figure 9.1, in Section 9.2.2.1 on page 675, which are reproduced here:

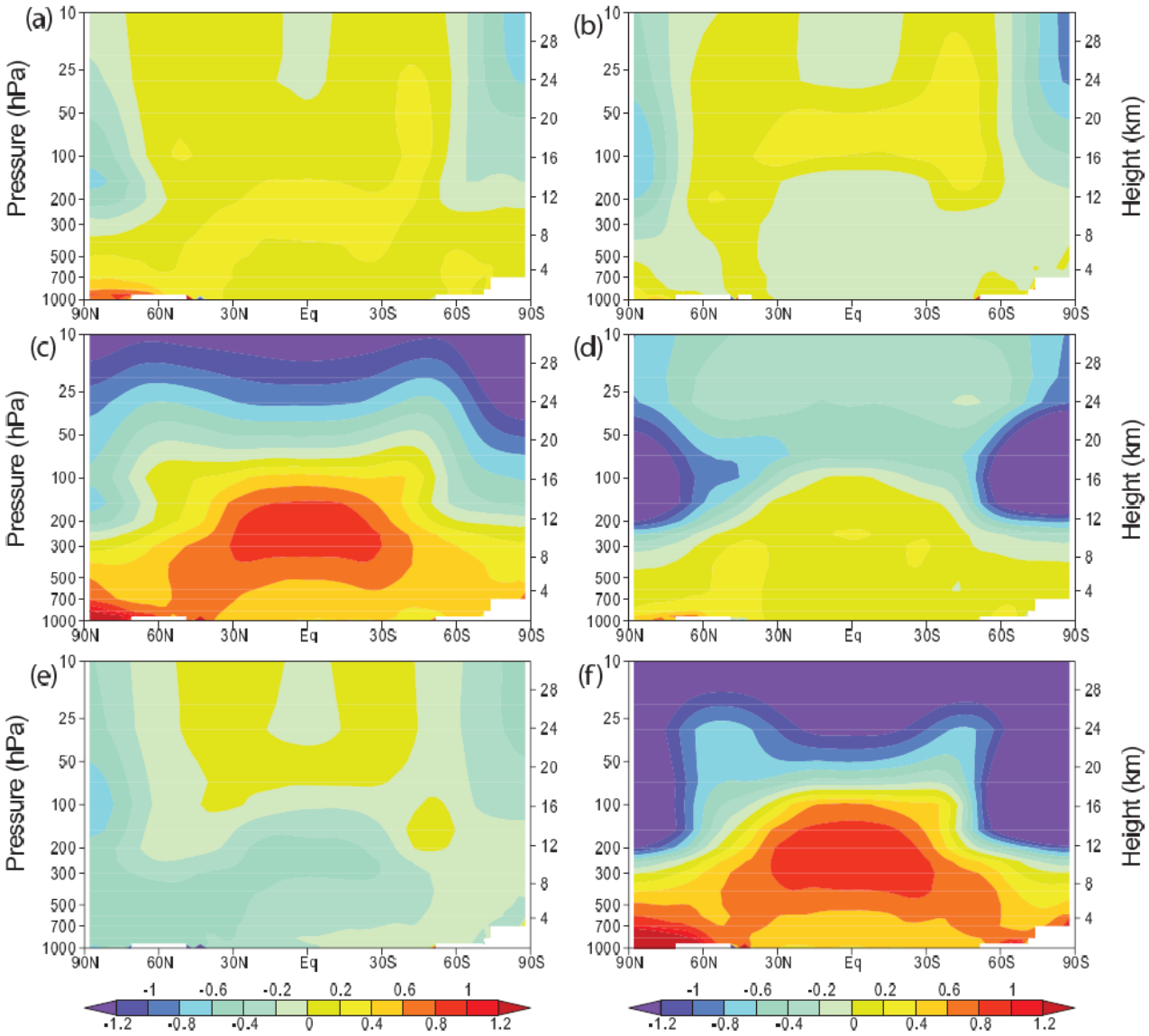


Figure 4: The theoretical warming patterns calculated by the IPCC climate models for 1890 to 1999, in °C per century. They show the theoretical warming signatures from (a) the sun getting hotter, (b) volcanoes, (c) an increase in non-water-vapor greenhouse gases, (d) ozone depletion, (e) aerosol emissions, and (f) the sum of all these five factors in the proportions the IPCC believe those causes contributed to global temperature changes.

These signatures are for a time period that includes global cooling from 1890 to 1910, then warming to 1944, then cooling to 1977, then warming again to 1999. However there was net warming over the entire period and the IPCC climate theory is that the overall warming was for the same reasons as the 1979 − 1999 warming. As a result the signatures have very similar features (though different magnitudes of temperature changes) to the ones for 1958 − 1999, and are thus also directly comparable to the observed warming pattern of 1979 − 1999.

Conclusion 1: IPCC Climate theory is wrong

Compare the observed warming for 1979 − 1999 in Figure 1 to what the IPCC climate models say happened for 1958 – 1999 in Figure 3F:

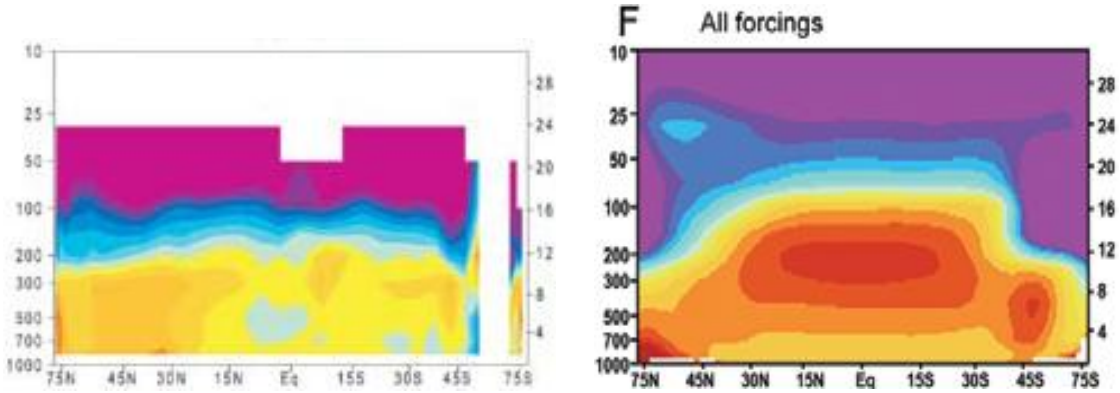


Figure 5: Observed warming (left) versus IPCC theory (right).

- The IPCC climate theory predicts a hotspot.
- There was no hotspot.

=> IPCC climate theory is wrong.

Below we examine the role of water vapor feedback in IPCC climate theory. That feedback both creates the hotspot and is responsible for a half to two-thirds of the temperature rises predicted by the IPCC climate models. So the hotspot is not an incidental or optional part of the IPCC's climate theory—it is an integral part. Thus the missing hotspot shows that IPCC climate theory is ***fundamentally*** wrong.

Conclusion 2: CO_2 is Innocent

Compare the observed warming for 1979 − 1999 in Figure 1 to the IPCC's signature for warming due to increased (non-water-vapor) greenhouse gases for 1958 − 1999 in Figure 3A:

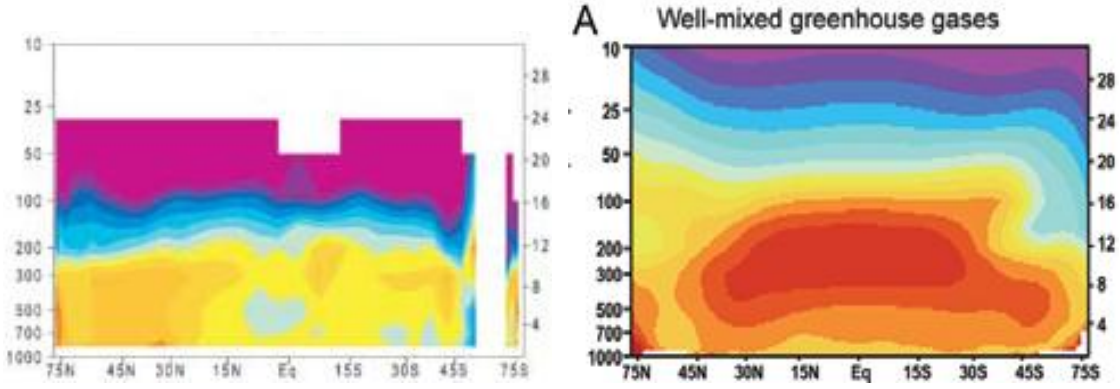


Figure 6: Observed warming (left) versus the IPCC's signature due to increased (non-water vapor) greenhouse gases (right).

- The IPCC's signature for warming due to an increase in (non-water-vapor) greenhouse gases includes a hotspot.

- There was no hotspot.

=> To the extent that IPCC's greenhouse signature is correct, we know that carbon emissions did not cause the recent global warming.

It comes down to ***how*** correct the IPCC's climate theory is. Their theory might be so broken that the real signature of increased non-water vapor greenhouse gases does not have a hotspot, in which case:

- We cannot draw the conclusion that CO2 is innocent (though it may well be).
- The predicted temperature increases due to rising carbon levels must be a lot smaller (so they cannot be much of a problem). We will examine this issue below, when looking at the water vapor feedback.

IPPC Attacks the Observations

The missing hotspot is an enormous problem for the IPCC, because it:

1. Proves that IPCC climate theory is false.
2. Undermines the theory that carbon emissions cause global warming.

The usual practice when observations and theory disagree is that the theory must yield to the observations. However in this case the IPCC choose instead to attack the observations, and to preserve their theory and models without modification.

Next we look at their two objections and conclude that they are obviously feeble. Perhaps there was too much power and money and too many good science jobs at stake to admit any problems in the IPCC climate theory.

Santer's Objection

Ben Santer, the IPCC's foremost expert on the observed warming pattern, emphasized the uncertainties in the data from the radiosonde thermometers—he stretched the error bars. On the basis of a complex statistical argument he argued that it was possible that the hotspot might be present and yet went undetected:

https://publicaffairs.llnl.gov/news/news_releases/2008/NR-08-10-05-article.pdf

But while the uncertainties in temperature measurements from a radiosonde are indeed large enough for a single radiosonde to maybe miss the hotspot, hundreds of radiosondes have given the same answers—so statistically it is extremely unlikely that they collectively failed to notice the hotspot. Statistical counter arguments to Santer's analysis are aired at

http://www.climateaudit.org/?p=4101

Radiosondes are calibrated to detect temperature differences of 0.1°C, and Figure 3 shows that the hotspot should be at least 0.6°C and probably around 1°C. Simple scrutiny of the observed data in Figure 1 shows how hard it is to credibly claim that the hotspot might be there. Santer is essentially claiming that the hotspot could be present in Figure 1, but we just cannot see it due to the noise.

Santer tortured the radiosonde data looking for a hotspot for years, from 2000 to 2008, but the best he came up with was a tendentious claim that the hotspot could possibly be there but went undetected.

Sherwood's Objection

Steven Sherwood, another leading IPCC scientist, thinks we should throw away the data from the thermometers in the radiosondes and use wind data from the radiosondes instead! When combined with a theory about wind shear, he estimated the temperatures on his computer—and says that the results show that we cannot rule out the presence of a hotspot:

http://lubos.motl.googlepages.com/sherwood-allen-ngeo-2008.pdf

Thermometers are designed to measure temperature, so it's a bit of a stretch to claim that wind gauges are accidentally better at it.

Objections Are Plainly Weak

It is important to note that the IPCC scientists never claimed to have found the hotspot, only that we might have missed it. This is an important distinction. They wrote several densely worded papers that suggested, to a casual reader, that the hotspot had indeed been found. But on careful scrutiny those papers always stop just short of claiming to have found the hotspot.

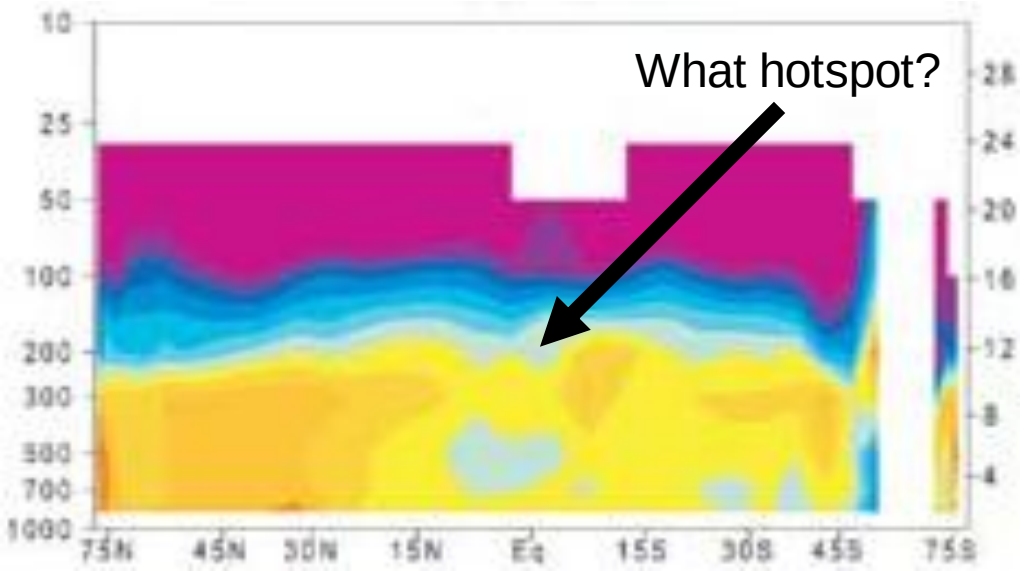


Figure 7: The observed warming pattern. If the hotspot is there, where is it?

The objections by the IPCC scientists are fair enough, because we need to see the best possible arguments from both sides. But their attempts to say the hotspot might not be missing are plainly weak.

Water Vapor Feedback

According to IPCC climate theory, a hotspot is present to some degree in the signature of any cause of global warming that heats the earth's surface due to the water vapor feedback. This is the heart of IPCC climate theory and where it went wrong.

A little background on the atmosphere: The part of the atmosphere that contains water vapor is called the *troposphere*. Water vapor is a greenhouse gas, each molecule absorbing radiation and later reradiating it in a random direction at a water vapor absorption frequency. Thus the troposphere is effectively a blanket at the water vapor absorption frequencies. The troposphere is partitioned into the *lower* and *upper* troposphere by the *characteristic emissions level* (CEL), which is one optical depth below the top of the troposphere. Above the CEL radiation at the water vapor absorption frequencies effectively radiate straight into space, but below the CEL it effectively does not. Thus the lower troposphere is "in" the warming blanket and is warmer, while the upper troposphere is increasingly "out" of the blanket and gets colder as you go higher. The CEL tends to be at a constant temperature fixed by the radiation balance to and from space.

Theoretically, according to IPCC climate theory:

- Any increase in surface temperature increases ocean evaporation, which increases water vapor in the atmosphere.
- The extra water vapor adds to the existing water vapor, thereby enlarging the lower troposphere (and pushing the CEL higher).
- This extends the warmer lower troposphere into volume previously occupied by the colder upper troposphere. That volume was previously partly outside the water vapor warming blanket and above the CEL, but is now inside the warming blanket and below the CEL—so that volume is now warmer, and it constitutes the hotspot.
- This occurs mainly in the tropics, which are much moister than the temperate and polar areas. So a hotspot develops at the top of the tropical lower troposphere.
- Water vapor is a greenhouse gas that traps heat. Enlarging the lower troposphere traps more heat and thus causes the world to warm further. This temperature rise is in addition to the initial temperature rise that caused the extra water vapor in the first place.

More details:

- The increased water vapor decreases the moist-adiabatic lapse rate of the lower troposphere—that is, there is a drop in the rate of temperature at which decreases with height between the ground and the top of the lower troposphere.
- So if the lapse rate drops then the top of the lower troposphere must rise to compensate. This rise creates the hotspot.

The extra water vapor is the result of the initial temperature rise, and feeds back into a further rise in temperature. This is why the effect is called the "water vapor feedback". The water vapor feedback amplifies any temperature rise *and* creates a hotspot. The

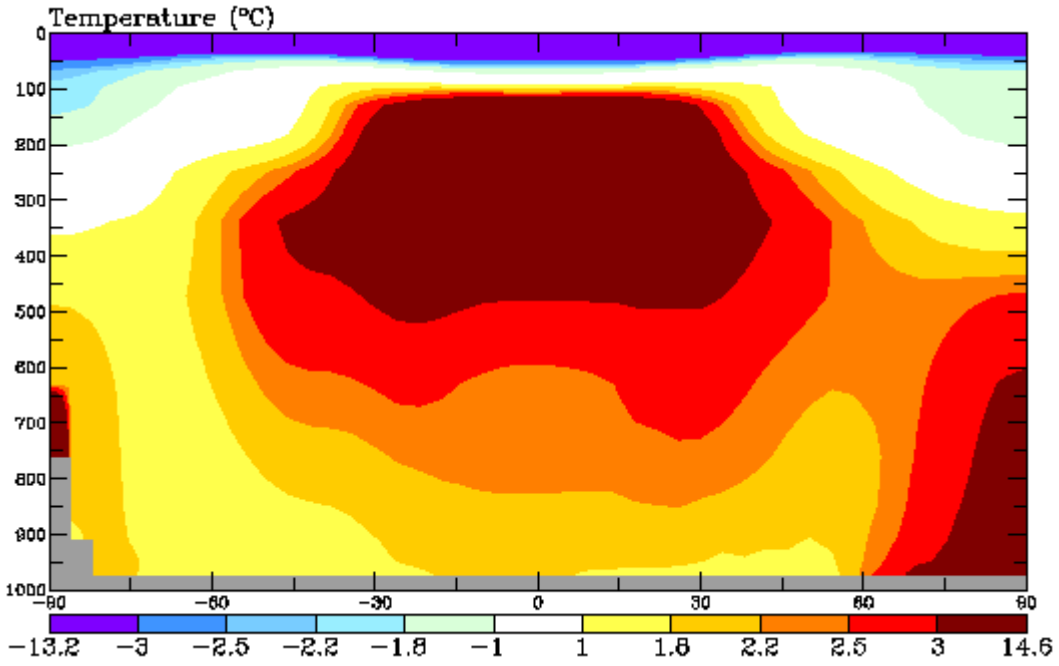
hotspot is an intrinsic part of the process: you cannot get the temperature amplification without also getting the hotspot.

We stress that the preceding description of the water vapor feedback in this section is purely theoretical, and comes from IPCC climate theory. In fact it is wrong, as demonstrated by the lack of a hotspot during the last warming period 1979 −1999. In reality any extra water vapor due to that warming did ***not*** form a hotspot, and presumably therefore did not amplify the initial temperature increase and will not amplify any future temperature increases due to rising carbon dioxide levels—so the IPCC's temperature predictions are much too high.

To illustrate that a hotspot forms due to any surface heating in IPCC climate theory, consider these two theoretical signatures published by the *Real Climate* website at

http://www.realclimate.org/index.php/archives/2007/12/tropical-troposphere-trends

Both are dominated by a hotspot, yet they are due to quite different causes.



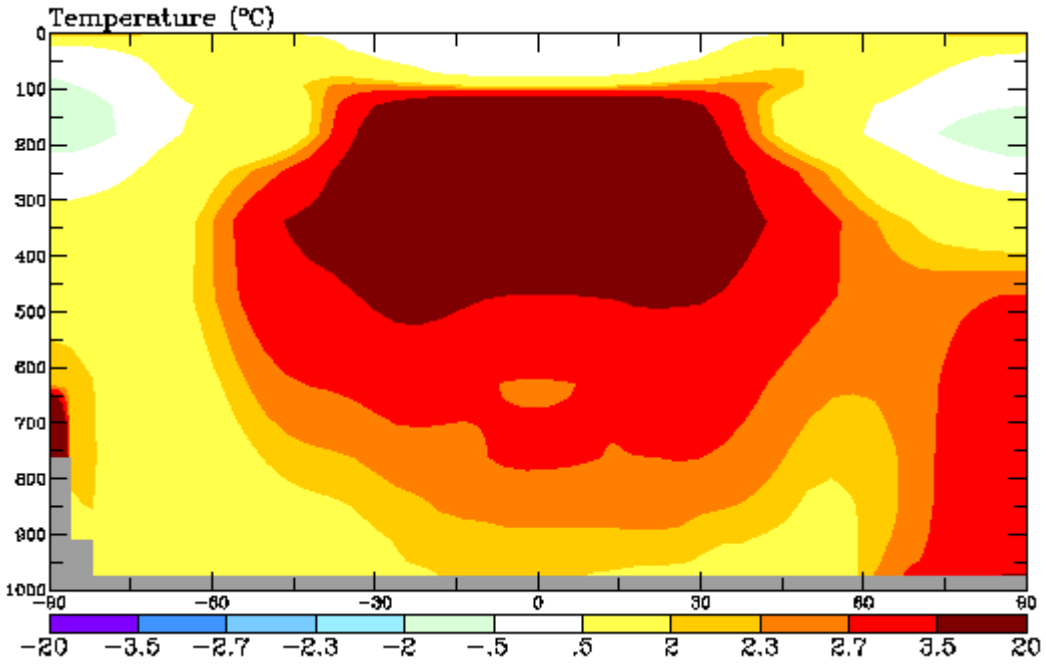


Figure 8: Signatures of a doubling of CO_2 (top) and a 2% increase in radiation from the sun (bottom), according to the GISS model. Each is dominated by a hotspot.

The Water Vapor Feedback is Wrongly Responsible For Most of the Temperature Rise Predicted By the IPCC Climate Models

We will now quantify the effect of the theoretical water vapor feedback in the IPCC's climate models, to show how important it is to their predictions. We will show that turning down the water vapor feedback in IPCC models to a level consistent with the observation of a missing or faint hotspot, and making no other changes, reduces their predicted temperature rises by over a half.

The IPCC does not explicitly understand the atmosphere is terms of system diagrams with feedbacks, because it relies primarily on its climate models. However it does provide enough data in its assessment reports to show how it thinks the climate system works in terms of systems and feedbacks. Which is fortunate for us because it means we do not need a supercomputer running their climate models to calculate what happens if we turn down their theoretical water vapor feedback—just the system diagram and a small calculation.

Christopher Monckton, a journalist who has delved deeply into the IPCC claims, has pieced together the most recent opinions of the IPCC into a single feedback diagram, which he presents in Figure 3 at

http://www.aps.org/units/fps/newsletters/200807/monckton.cfm

That diagram is reproduced here:

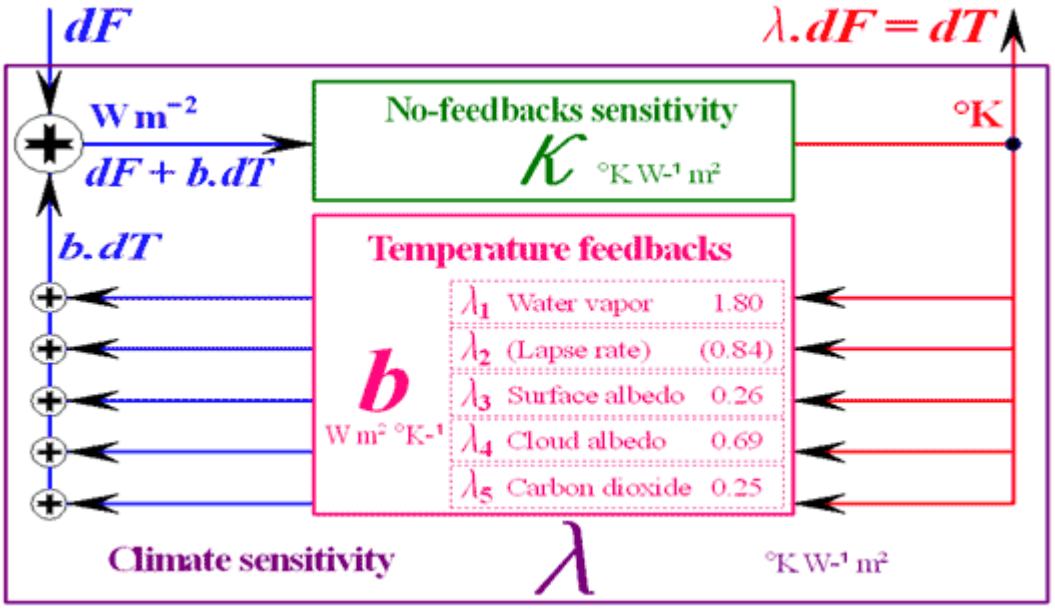


Figure 9: A perturbation *dF* in the incoming solar radiation (or "forcing") is input to the earth's climate system (purple box). It is multiplied by κ by the no-feedbacks climate system (green box), to produce an initial temperature perturbation *dT*. But *dT* also causes temperature feedbacks (red box) which add a further *b dT* to the input of the no-feedbacks climate system! After sorting out the simultaneous effects, the final temperature perturbation due to *dF* is $dT = \kappa\, dF / (1 - b\kappa)$.

The system diagram in Figure 9 is a bit rough and ready because the feedbacks aren't really independent of one another, and the subsystems aren't really linear and passive, and transients are ignored. However it has sufficient explanatory power for an approximate quantitative understanding of the IPCC climate models.

According to the IPCC, the total temperature feedback is b = 1.80 - 0.84 + 0.26 + 0.69 +0 .25= 2.16 $Wm^{-2}K^{-1}$ and the no-feedbacks sensitivity is κ = 0.313 $W^{-1}m^2K$.

The IPCC reckons that a doubling of CO_2 levels from pre-industrial times (due around 2070 on current trends) is equivalent to a forcing perturbation of dF = 3.4 Wm^{-2}. Their predicted temperature increase for a doubling of CO_2 is thus

$$dT = \kappa\, \mathrm{dF} / (1 - b\kappa) = 0.313 * 3.4 / (1 - 2.16 * 0.313) = 3.3\ °C,$$

which agrees with the published predictions from the IPCC's climate models. This gives us confidence that the system model above mimics the IPCC climate models.

According to the IPCC, the water vapor feedback is 1.80 $Wm^{-2}K^{-1}$. This is a quantification of the IPCC's theoretical hotspot-creating water vapor feedback mechanism that we described above: for every temperature rise of 1°C, the consequent extra water vapor heats the earth by an amount equivalent to an increase in solar radiation of 1.80 Watts per square meter. (By way of comparison, the current incoming solar radiation is about 1,367 Wm^{-2}.)

But we know from the observed warming pattern in Figure 1 that during the recent warming of 1979–1999 there was in fact no hotspot (or at most, a faint one). This

suggests that in reality there was no water vapor feedback, for whatever reason. So what is the impact of removing the water vapor feedback on the IPCC temperature predictions?

If the water vapor feedback is zero and the other feedbacks remain the same then b = 0 - 0.84 + 0.26 + 0.69 +0 .25= 0.36 $Wm^{-2}K^{-1}$ and the temperature increase for a doubling of CO_2 is

$$dT = \kappa \, dF / (1 - b\kappa) = 0.313 * 3.4 / (1 - 0.36 * 0.313) = 1.2 \, °C.$$

More generously: the hotspot might merely be faint, so there was still some water vapor feedback, and the magnitude of the lapse rate feedback would be smaller if the water vapor feedback was smaller. So let's have a small positive water vapor feedback of 0.20 $Wm^{-2}K^{-1}$ and halve the lapse rate feedback to -0.42 $Wm^{-2}K^{-1}$, for a total feedback of b = 0.20 - 0.42 + 0.26 + 0.69 +0 .25= 0.98 $Wm^{-2}K^{-1}$. The temperature increase for a doubling of CO_2 is then

$$dT = \kappa \, dF / (1 - b\kappa) = 0.313 * 3.4 / (1 - 0.98 * 0.313) = 1.5 \, °C.$$

Perhaps more realistically: some observers of clouds outside the IPCC camp reckon that the water vapor feedback is in fact negative. A small negative water vapor feedback of -0.20 $Wm^{-2}K^{-1}$ and a halved lapse rate feedback of -0.42 $Wm^{-2}K^{-1}$ give a total feedback of b = -0.20 - 0.42 + 0.26 + 0.69 +0 .25= 0.58 $Wm^{-2}K^{-1}$. The temperature increase for a doubling of CO_2 is then

$$dT = \kappa \, dF / (1 - b\kappa) = 0.313 * 3.4 / (1 - 0.58 * 0.313) = 1.3 \, °C.$$

Conclusion: Between a half and two thirds of the temperature increases predicted by the IPCC are due to their assumed theoretical water vapor feedback, which is also responsible for the hotspot. Reducing the water vapor feedback in the climate models in line with the faint or absent hotspot in the observed warming pattern, while leaving the rest of their climate model unchanged, cuts the temperature increases projected by the IPCC by more than half.

The Water Vapor Feedback is Wrongly Responsible For the Climate Instability Implied by the IPCC Climate Models

The climate system shown in Figure 9 becomes unstable and goes into runaway warming if the *loop gain*, the total amplification in going once around the loop through the "no-feedbacks" climate system (green box, κ) then the temperature feedbacks (red box, b), exceeds one. The loop gain is the amplification a forcing or temperature perturbation receives in going once around the feedback loop and back to where it started. So if the loop gain, which is equal to $b\kappa$, exceeds one then the perturbation gets bigger each time it goes around the loop—and so it "runs away to infinity". In climate terms, this means runaway warming—the world would get much hotter (until something about the system changed to bring the loop gain back below one).

Electrical and electronic engineers have used feedback systems very extensively for decades, and nearly every electrical and electronic device you encounter deliberately has some feedback built into it. A large body of knowledge about such systems has grown up, called *control theory*.

The values of the various factors in the climate system in Figure 9 are always evolving and changing by small amounts. For example, human emissions of carbon dioxide are increasing the "no-feedbacks" amplification factor κ, though it is not known by how much. Also, there are a myriad of small factors of the real climate not portrayed in the diagram. And finally, the climate system cannot truly be analysed in terms of independent linear systems, so the diagram is only an approximation of the climate system. As a result of these factors, engineers know that this system would be prone to instability if the loop gain is anywhere near one in a logarithmic sense. Technically the tipping point would be if the loop gain $b\kappa$ exceeds one, but more realistically the system might be prone to occasional instability if the loop gain exceeded 0.1, or maybe even a lower amount.

According to the IPCC, the total temperature feedback is $b = 2.16\ \mathrm{Wm^{-2}K^{-1}}$ and the no-feedbacks sensitivity is $\kappa = 0.313\ \mathrm{W^{-1}m^2K}$, for a loop gain of $b\kappa = 0.68$. This suggests a climate system that is very prone to instability. It also suggests that the IPCC has tuned their climate models to be as close as possible to instability (and the dreaded tipping point!) without already being too obviously unstable.

But, unlike Venus, the earth has never gone into runaway greenhouse warming—despite asteroid strikes, carbon dioxide levels up to twenty times today's level, continents drifting around, volcanoes, and so on. The earth's climate system has in practice been quite stable, surviving some large perturbations and billions of years of evolving parameters in the system diagram. This historical stability is a solid clue that the IPCC climate models are wrongly set way too close to the tipping point, and that the loop gain $b\kappa$ is in reality a lot lower.

Simply turning down the water vapor feedback to say zero (it might even be negative) in line with the observations of a missing or faint hotspot, and halving the magnitude of the lapse rate feedback, reduces the total feedback to $b = 0 - 0.42 + 0.26 + 0.69 + 0.25 = 0.78\ \mathrm{Wm^{-2}K^{-1}}$ and the loop gain to $b\kappa = 0.24$. This is much more stable, though still unrealistically high.

Conclusion: The IPCC climate models are currently set unrealistically close to the tipping point of runaway warming. Reducing the water vapor feedback in the climate models in line with the faint or absent hotspot in the observed warming pattern, while leaving the rest of their climate model unchanged, makes the climate models much more stable—and more consistent with the earth's historic climate stability.

Unknown Signatures

Signatures are always theoretical. To be empirically derived, a signature would have to be observed during a period of global warming that was somehow known to be due solely to one cause, and that has never occurred.

There are many possible causes of global warming whose signatures are unknown (as far as I know), including the signatures of:

1. The Pacific Decadal Oscillation. Global temperature changes for the last century can be largely explained by a long-term fluctuations of the Pacific Ocean. See www.drroyspencer.com/research-articles/global-warming-as-a-natural-response.
2. Cosmic rays. This theory, championed by Henrik Svensmark in his book *The Chilling Stars: The New Theory of Climate Change*, notes that cosmic rays impacting on the earth cause showers of particles that provide the nuclei for water droplets to form clouds from water vapor. The sun's magnetic field (but not the earth's, because it is too weak) shields us from cosmic rays, so when the sun is more active we get fewer cosmic rays, fewer low clouds, and the earth heats up. The sun has been unusually active for the last century and especially the last couple of decades. The correlations of global temperatures with cosmic rays on all time scales, from decades to millions of years, are very good—far better than the correlations with carbon dioxide levels.

These possible causes are not necessarily mutually exclusive—they may influence each other.

The main reason more signatures aren't known is because the IPCC scientists produce most of the signatures, but the IPCC's mandate is to investigate the effect of ***human emissions*** on global temperature—and they vigorously ignore other possible causes.

Logically, because some likely causes have unknown signatures, the observed pattern cannot definitely prove what caused global warming, because it might be wholly or partly due to the causes whose signatures are unknown. The observed warming pattern can only rule causes out.

Can the Observed Pattern of Warming Tell Us What *Did* Cause Global Warming?

If we definitely knew all the signatures of all the possible causes, and they were all sufficiently distinct, then we could probably figure out from the observed warming pattern in Figure 1 what caused the recent global warming.

But we don't know the signatures of some leading candidates. We don't even reliably know the signatures of increased CO_2 or increased solar radiation, because their theoretical signatures as published by the IPCC have large hotspots due to the water vapor feedback assumed by the IPCC—and the absence of a hotspot in the last warming period tells us that the IPCC's theory of water vapor feedback is wrong. Perhaps the signatures of increased CO_2 or increased solar radiation are as per Figures 3 and 4, but without the hotspot. Who knows?

So we cannot tell much about what ***did*** cause the global warming. We can however note the broad similarities between Figures 1 and Figures 3C and 4 (d), from which we can conclude that maybe ozone depletion was a significant cause of warming from 1979 to 1999.

To the extent that the signature of increased greenhouse warming includes a hotspot, then carbon emissions were not a significant cause of the warming. However, if the IPCC's climate theory is so broken that the true signature of increased non-water-vapor greenhouse gases does not include a hotspot, then carbon emissions might have had a significant role in the recent global warming—but if so then the IPCC's theoretical water vapor feedback is wrong and the IPCC's predictions for future temperatures due to rising CO2 levels should be reduced by at least a half.

Further Discussion

To go deeper into the missing hotspot issue, perhaps look at these articles and comments on the leading alarmist and skeptical websites:

http://www.climateaudit.org/?p=3161

http://www.climateaudit.org/?p=4101

http://www.realclimate.org/index.php/archives/2007/12/tropical-troposphere-trends

http://global-warming.accuweather.com/2008/05/climate_models_get_a_boost_fro_1.html

http://joannenova.com.au/2008/10/30/not-found-the-hot-spot

http://clubtroppo.com.au/2008/12/19/david-evans-greenhouse-sceptic-debates-his-views-on-troppo/#more-6780

Some Political Observations

What Else Can They Say?

The IPCC scientists do not claim that the hotspot was found, only that we might have missed it. Consider the alternatives for the IPCC scientists—what else can they say?

Suppose the IPCC agreed that the hotspot was not present in the observed data at a strength consistent with an increased greenhouse effect as a significant cause of the recent warming. Then the IPCC much less reason to exist and would lose much of its status and influence. Santer and his colleagues would get less funding and some would lose their jobs, while future carbon emission trading profits would disappear. See any vested interests there? Of course Santer and co. are going to put forward the strongest case that the hotspot is there—but the striking thing is how weak their case is.

Fortunately for them, Santer and his colleagues only have to convince politicians and sympathetic journalists. A couple of impressive-looking papers from authority figures with dense language usually does the trick!

What If the Hotspot Had Been Found

Consider what would have happened if the hotspot was present in the observed warming pattern. The IPCC would have triumphantly told the world that they had finally found evidence that carbon emissions were causing global warming—and they would have been entitled to. They obviously really want to claim they have found the hotspot, but they always stop just short of making that claim.

Theory Versus Evidence

The missing hotspot is a case where the evidence does not support the theory. We skeptics demand theory yield to evidence. That's the usual practice. But so far the IPCC is still demanding that the evidence yield to its theory. The IPCC has had a few years to torture the radiosonde data, but it hasn't admitted to a hotspot—so exonerate carbon! Or at least admit that the IPCC predictions of temperature rises are way too high because they have the water vapor feedback all wrong!

What is Really Going On

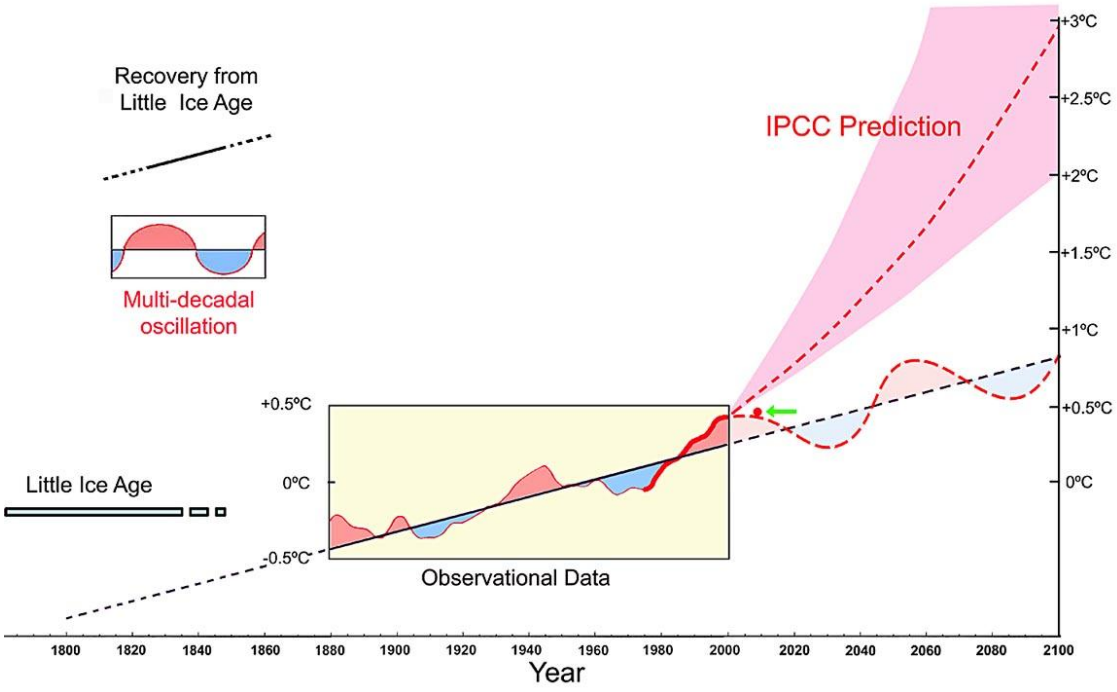


Figure 10: The big temperature picture. Excellent graph and insight from Dr Syun Akasofu (2009 International Conference on Climate Change, New York, March 2009).

The global temperature has been rising at a steady trend rate of 0.5°C per century since the end of the little ice age in the 1700s (when the Thames River would freeze over every winter). On top of the trend are oscillations that last about thirty years in each direction:

1882 – 1910	Cooling
1910 – 1944	Warming
1944 – 1975	Cooling
1975 – 2001	Warming

In 2009 we are where the green arrow points, with temperature levelling off. The pattern suggests that the world has entered a period of slight cooling until about 2030.

There was a cooling scare in the early 1970s at the end of the last cooling phase. The current global warming alarm is based on the last warming oscillation, from 1975 to 2001. The IPCC predictions simply extrapolated the last warming as if it would last forever, a textbook case of alarmism. However the last warming period ended after the usual thirty years or so, and the global temperature is now definitely tracking below the IPCC predictions.

The IPCC blames human emissions of carbon dioxide for the last warming. But by general consensus human emissions of carbon dioxide have only been large enough to be significant since 1940—yet the warming trend was in place for well over a century before that. And there was a cooling period from 1940 to 1975, despite human emissions of carbon dioxide. And there has been no warming since 2001, despite record human emissions of carbon dioxide.

There is no actual evidence that carbon dioxide emissions are causing global warming. Note that are just concatenations of calculations you could do on a hand-held calculator, so they are theoretical and cannot be part of any evidence. Although the models contain some well-established science, they also contain a myriad of implicit and explicit assumptions, guesses, and gross approximations (such as the assumption of water vapor feedback), and mistakes in any of them can invalidate the model outputs.

No one knows for sure what caused the little ice age or for how many more centuries the slow warming trend will continue. It has been warmer than the present for much of the 10 thousand years since the last big ice age: it was a little warmer for a few centuries in the medieval warm period around 1100 (when Greenland was settled for grazing) and also during the Roman-Climate Optimum at the time of the Roman Empire (when grapes grew in Scotland), and at least 1°C warmer for much of the Holocene Climate Optimum (4 to 8 thousand years ago).

(By the way: Measuring the global temperature is only reliably done by satellites, which circle the world 24/7 measuring the temperature over large swathes of land and ocean. But satellite temperature records only go back to 1979. Before that, the further back you go the more unreliable the temperature record gets. We have decent land thermometer records back to 1880, and some thermometer records back to the middle of the 1700s. Prior to that we rely on *temperature proxies*, such as ice cores, tree rings, ocean sediments, or snow lines.)

What Next?

Probably nothing.

The IPCC have known that the missing hotspot has been a problem since the mid 1990s, and said so publicly on occasion. Positions have hardened in the last few years, and now they are quiet about it. A couple of IPCC scientists, Santer and Sherwood, have quite properly tried to explain the missing hotspot—the only time the IPCC mentions the missing hotspot is each time it is explained away!

However there is plainly a problem and the IPCC knows it: the hotspot should have been detectable by the radiosondes if the IPCC climate theory was correct. Still, the IPCC scientists live in a world of few close critics and of well paid science jobs whose existence depends on government belief in the carbon dioxide scare.

Why should the IPCC just give up? Maybe they will find a hotspot next time there is a warming period, using better technology. They cannot just announce their climate theory is wrong and give up their jobs and funding: "Sorry folks, looks like we might have been wrong, no problem after all. Emit all the carbon you like." However they should at least now level with the public and say that maybe their climate theory isn't right: they should start turning down the water vapor feedback in their models, and lower their temperature predictions. Remember, even the IPCC in its 2007 Assessment Report only said it was 90% sure that carbon emissions caused global warming, so they have left themselves wiggle room for a backdown.

Some climate scientists such as Fred Singer have been talking about the missing signature since 1995. No one much has listened: there is too much bureaucratic momentum, government money, and carbon trading money behind AGW for anything to stop it now except a plunge in temperatures so sharp or so long that the public simply disbelieves all the hype that carbon emissions are causing the world to heat up. In the climate science world, that the hotspot is missing or too faint is neither new nor a secret. But in the wider world no one knows or cares.

The missing hotspot is a difficult topic to make accessible to the public. Alarmists can confuse the issue with talk about other signatures. Or they simply claim the hotspot has been found—very few people know to contradict them, and Santer and Sherwood give them some cover by providing authoritative and dense papers that give the impression that the hotspot has been found, while not actually claiming it has been found.

The Money Connection

So what is going on here? In time-honored journalistic fashion, just follow the money:

- The anti-AGW spend is around US$2 million per year. It comes primarily from big-oil and skeptic organizations such as Heartland.
- The pro-AGW spend is about US$3 billion per year, about 1,000 times larger. It mainly comes from big government spending on pro-AGW climate research and on promoting the AGW message, and from the Greens.
- Emissions trading by the finance industry was US$120 billion in 2008. This will grow to over US$1 trillion by 2012, and carbon emission permit trading will be the largest "commodity" market in the world—larger than oil, steel, rice, wheat etc. Typically the finance industry might pocket 1% – 5% of the turnover, so ***even now their financial interest matches the pro-AGW spend and soon it will vastly exceed it.***

Presumably therefore it is the finance industry that is driving the carbon emission permits agenda. It is not that the "science is settled" (a fine piece of anti-science propaganda!), but that the science is simply irrelevant now because big money interests are in control.

Who benefits? Emission permits are created by government fiat, out of thin air, yet have value. Trading favors the well-informed and those who can move the market, so big financial firms will routinely plunder the pockets of smaller market participants. The rest of us, one way or another, will pay for both the government-issued emission permits and the trading profits of the finance industry.

A former Chief IMF economist explains that the finance industry is now so powerful that it can sweep aside objections to its profit-making activities, no matter how ruinous they will be in the long term. From http://www.theatlantic.com/doc/print/200905/imf-advice:

> "*But these various policies—lightweight regulation, cheap money, the unwritten Chinese-American economic alliance, the promotion of homeownership—had something in common. Even though some are traditionally associated with Democrats and some with Republicans, they all benefited the financial sector. Policy changes that might have forestalled the crisis but would have limited the financial sector's profits—such as Brooksley Born's now-famous attempts to regulate credit-default swaps at the Commodity Futures Trading Commission, in 1998—were ignored or swept aside*."

I have met carbon emissions traders who say that they are well aware that carbon emissions almost certainly do not cause global warming. But that they are riding the trading for all it worth while it lasts, because it is good business. They told me that that view is widespread among carbon traders.

All of which suggests that the Greens and the politically-correct are acting in the interests of big money. Laughably, they are not even acting in their own professed interests:

- Carbon emission restrictions will make energy more expensive. Much of the third world can barely afford energy now, even without restrictions on cheap energy from hydrocarbons. So carbon emission restrictions will cause widespread poverty and death in the third world.
- As the missing hotspot shows, carbon emissions restrictions will make little or no difference to the world's temperature.

This is not the first time that uninformed leftists have unwittingly supported big money interests against their own professed ideals. For example, the creation of the fourth central bank in the United States in 1913 was by a leftist university professor plucked out of obscurity and propelled into the presidency, Woodrow Wilson. He later bitterly regretted what he had done.

Leftists in particular think they are saving the planet. But in reality science now damns their case, they are striving to make life harder or impossible for most of the world's population, and they are the unwitting tools of big money. Wake up!

The World Needs a Science Debate

In a courtroom trial, two sides argue their best cases and out of that argument some sort of truth emerges. The same happens in science, when it is healthy.

However in the global warming debate, one side has vastly more resources than the other—so only one side of the argument is heard. How did this come about? Since World War II, government has funded most science research. So if one paradigm captures government science funding, only that paradigm will get government funding. In climate science there is almost no industry research, so climate science research spending comes entirely from government. All western governments were long since captured by AGW forces, and no funding goes to competing ideas. (On the non-western side the alignments are often very different. For example the Russian government has always said that AGW is rubbish, while the Indian and Chinese governments have never supported AGW.) The solution might be for science funding bodies to cultivate diversity, to routinely and deliberately fund opposing paradigms in order to prevent the bad policy that results from unfair contests where only one voice is adequately resourced and heard.

Ever noticed that there have been no debates on the science in global warming? Formal televised debates where scientists outlay their cases and rebut each other? We skeptics constantly ask for debates, but are swept aside and ignored by the pro-AGW forces because their position could not get any better.

- A trial without a defence is a *sham*.
- Business without competition is a *monopoly*.
- Science without debate is *propaganda*.

Alarmist Propaganda

Until now this document has dealt with reasonable arguments made by honourable scientists in the debate. Now we will deal with some of the unreasonable claims and arguments made by less scrupulous alarmists. Alarmists are fighting a rearguard action of media blackout, misinformation, confusion, and outright lies on the signature issue.

Claim: The Signature of Increased Greenhouse Warming Has Been Found

This claim is sometimes made because part of the signature of increased greenhouse warming, the combination of broad stratospheric cooling and broad tropospheric warming, is indeed present in the observed warming pattern. But the other feature of that signature, the hotspot at the top of the tropical troposphere, is missing from the only data we have (Figures 1, 2, and 7). Therefore the signature of increased greenhouse warming has not been found.

It could be argued by alarmists (but never is) that the missing hotspot merely shows that the climate models are wrong about the hotspot, so the signature of increased greenhouse warming might just be the combination of broad stratospheric cooling and broad tropospheric warming without the hotspot. But if this were the case, then the water vapor feedback predicted by climate theory cannot be present (because there is no hotspot), so the predictions of future warming due to rising CO_2 levels must be reduced by at least half. Also, that combination of broad stratospheric cooling and broad tropospheric warming is at least partially due to ozone depletion, whose signature also has that feature and is known to have occurred during 1979–1999.

Finally, there is still no proof that the observed warming pattern isn't due to causes whose signatures are unknown, such as cosmic rays.

The less sophisticated argument is simply to claim that the climate models are correct ***and*** that the signature of increased greenhouse warming was found. This is obviously nonsense, as the comparisons above show. Even if Santer or Sherwood turn out to be correct that the hotspot might be present in Figure 1 but we just cannot see it, the claim that the signature of increased greenhouse warming was found is still wrong—because Santer and Sherwood only claim that the hotspot could be present in the observed data, not that it definitely is present. It is, at most, faint.

Finally there are even less sophisticated claims, which can be challenged with:

- Is there some other data? If so, climate scientists would be very interested in it.
- You can see the signature of an increased greenhouse effect, and thus the hotspot at 10 – 12 kms in the tropics, in the data in Figure 2? Where?
- How do you distinguish the signature of an increased greenhouse effect from the signature of ozone depletion, which we know ***was*** occurring?
- Do you acknowledge that the signature of an increased greenhouse effect includes a hotspot at the top of the tropical troposphere? If not, do you acknowledge that the water vapor feedback must therefore be much diminished—so the IPCC model's predictions of temperature rises due to rising CO_2 must also be much reduced?

Argument: More than One Possible Cause of Global Warming Has a Hotspot, So the Signature of Increased Greenhouse Warming Does Not Include the Hotspot

This argument is made whilst also claiming that IPCC climate theory is correct. Obviously the signature of an increased greenhouse effect does include a hotspot at 10 − 12 kms in the tropics (Figures 3 or 4). This argument is illogical and silly, but it was made prominently and seriously at

http://scienceblogs.com/deltoid/2008/07/the_australians_war_on_science_16.php

and no alarmists seems to have bothered to inform Tim that it doesn't make sense.

Multi-scale analysis of global temperature changes and trend of a drop in temperature in the next 20 years

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Summary A novel multi-timescale analysis method, Empirical Mode Decomposition (EMD), is used to diagnose the variation of the annual mean temperature data of the global, Northern Hemisphere (NH) and China from 1881 to 2002. The results show that: (1) Temperature can be completely decomposed into four timescales quasi-periodic oscillations including an ENSO-like mode, a 6–8-year signal, a 20-year signal and a 60-year signal, as well as a trend. With each contributing ration of the quasi-periodicity discussed, the trend and the 60-year timescale oscillation of temperature variation are the most prominent. (2) It has been noticed that whether on century-scale or 60-year scales, the global temperature tends to descend in the coming 20 years. (3) On quasi 60-year timescale, temperature abrupt changes in China precede those in the global and NH, which provides a denotation for global climate changes. Signs also show a drop in temperature in China on century scale in the next 20 years. (4) The dominant contribution of CO_2 concentration to global temperature variation is the trend. However, its influence weight on global temperature variation accounts for no more than 40.19%, smaller than those of the natural climate changes on the rest four timescales. Despite the increasing trend in atmospheric CO_2 concentration, the patterns of 20-year and 60-year oscillation of global temperature are all in falling. Therefore, if CO_2 concentration remains constant at present, the CO_2 greenhouse effect will be deficient in counterchecking the natural cooling of global climate in the following 20 years. Even though the CO_2 greenhouse effect on global climate change is unsuspicious, it could have been excessively exaggerated. It is high time to re-consider the trend of global climate changes.

Global Warming is *not* happening

by

Christopher Monckton

February 21, 2009

Science & Public Policy Institute

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GLOBAL WARMING IS *NOT* HAPPENING

by Christopher Monckton ~ February 21, 2009

The "global warming apocalypse" scare has the potential greatly to enrich scientists, academics, industrialists, and politicians willing to take unscrupulous advantage of it. However, we should do some due diligence before we join in reaping the considerable but short-lived rewards available to those who parrot the scientifically-baseless orthodoxy.

We begin with two graphs from the *Monthly CO2 Report*[1] (SPPI, 2009). First, on all measures, global temperatures for the past seven years have been falling (though the fall was largely unreported) at a rate equivalent to >2 Celsius degrees/century.

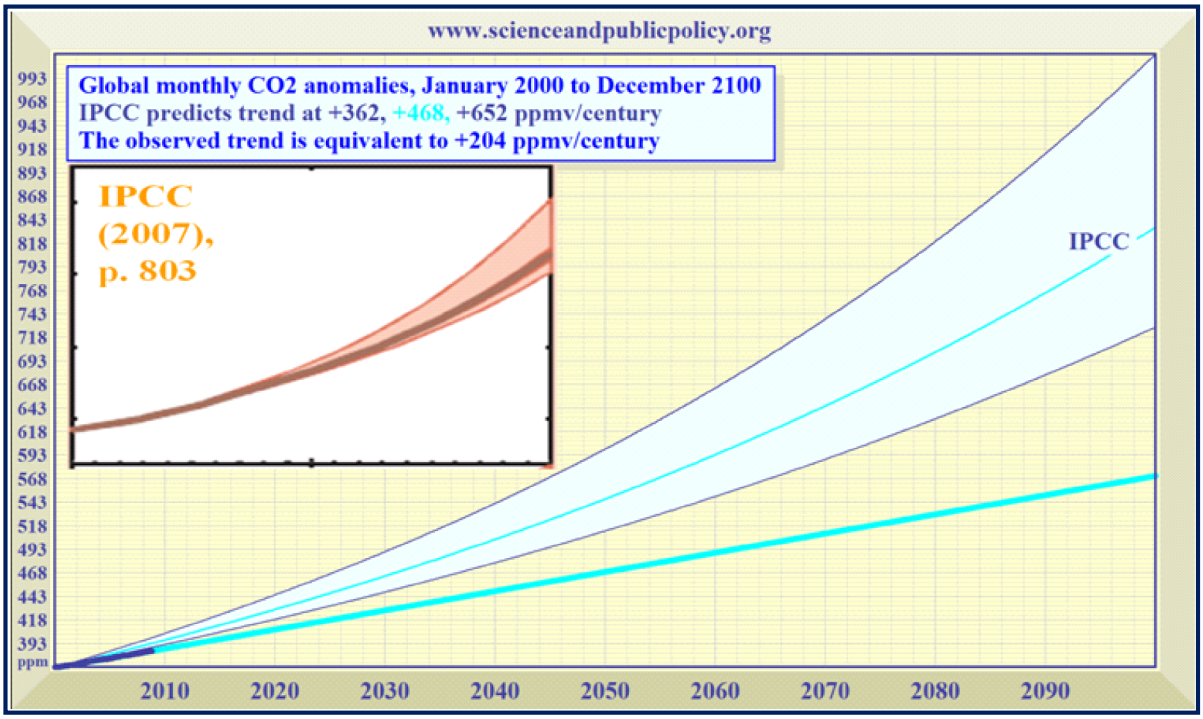
Seven years' global cooling: *The arithmetic mean of the Hadley and NCDC monthly terrestrial global-temperature datasets and the RSS and UAH satellite lower-troposphere datasets shows a (largely-unreported) cooling for seven years at a rate equivalent to 2.1 C°/century. The pink region shows the IPCC's projected range of warming rates: the pale pink region is 1 standard deviation either side of the IPCC's central estimate that global temperature will rise 3.9 C° to 2100.*

This seven-year decline in global temperatures is of great significance, for the IPCC's current methodology cannot explain it. Throughout the period, CO2 concentration has risen, and the IPCC quantifies the contribution of natural forcings such as that from the sun as being minuscule. Warming should have resulted.

Our second graph shows that the observed increase in atmospheric CO2 concentration is well below the IPCC's predicted range of increases.

[1] http://scienceandpublicpolicy.org/monthly_report/jan_co2_report.html

It is important to draw the distinction between the increase in CO2 *emission,* which has been at the high end of the IPCC's projections, and the corresponding increase in CO2 *concentration,* which has recently been very near linear, and is running well below the least of the exponential rates of increase projected by the IPCC.



Observed and predicted CO2 concentration, 2000-2100: *The pale-blue region, bounded by exponential curves, is the IPCC's predicted path for CO2 concentration. The observed, deseasonalized data from January 2000 to November 2008 (dark blue) is near-coincident with the least-squares linear-regression trend, (solid, light-blue line). The predictive region emulates the IPCC's graph for scenario A2 [inset].* ***Sources:*** *NOAA; [inset] IPCC (2007), p.803, after aspect-ratio adjustment.*

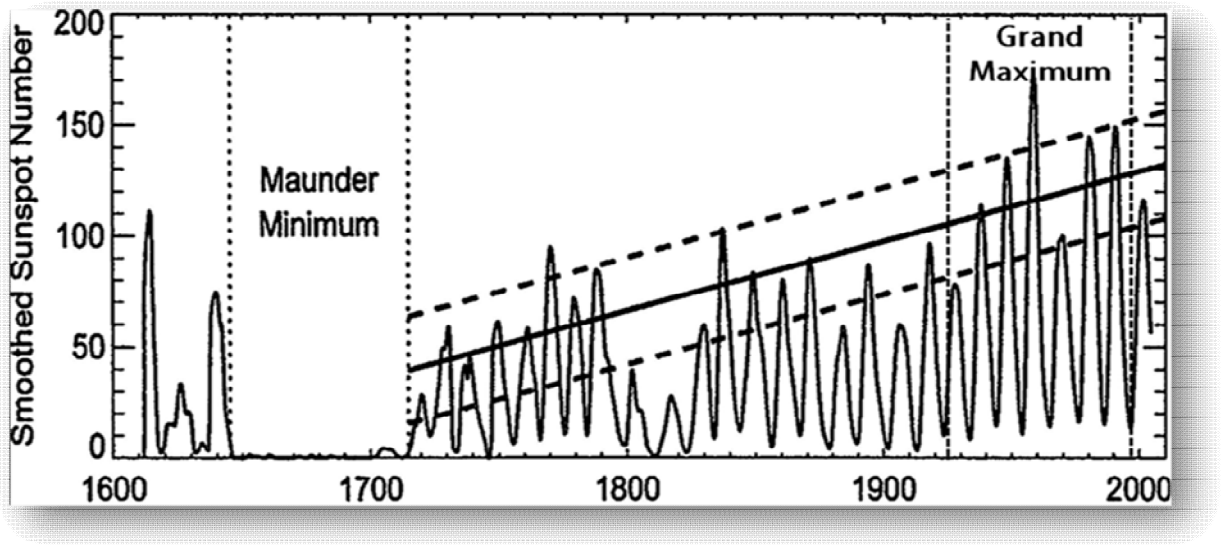
On the current, linear observed trend, CO2 concentration in 2100 will be just 575 ppmv (IPCC central estimate 836 ppmv), requiring the IPCC's central projection of temperature increase to 2100 to be halved from 3.9 to a harmless 1.9 C°.

The IPCC's prediction of Co2 increase is greatly exaggerated, chiefly because the IPCC cannot add up the global "carbon budget" to within a factor of two. According to its metric, CO2 emissions at their current record levels ought to be adding some 4.1 ppmv/year to the atmosphere, yet the actual increase is only 2 ppmv/year. Ever since CO2 concentration has been measured by modern methods, the increase in concentration has run below half the expected rate.

Nevertheless, the IPCC tries implausibly to claim 90% certainty that more than half of the warming of the past half-century is anthropogenic. It was the political representatives, not the scientists, who reached this conclusion by show of hands – an intriguing instance of the *argumentum ad populum,* an Aristotelian fallacy that has no place in serious thought. Science is not a democracy.

There is compelling evidence that much of the warming of the past half-century was caused by an exceptional increase in solar activity. During the 70 years 1645-1715, the Maunder Minimum, the Sun was less active than in 10,000 years. Then solar activity inexorably increased for almost 300 years until, during the 70 years 1925-1995,

peaking in 1960, the Solar Grand Maximum, the Sun was at least as active as at any time in the previous 11,400 years (Solanki *et al.,* 2005). Hathaway *et al.* (2004) illustrate this solar increase by reference to the 11-year cycles of sunspot numbers –



300 years' growth in solar activity: *Smoothed sunspot numbers, showing the Sun's 11-year cycles, reveal the increase in solar activity between the Maunder Minimum and the recent (though largely unreported) solar Grand Maximum.* ***Source:*** *Hathaway et al. (2004) (indication of Grand Maximum added by the author).*

This exceptional increase in solar activity from Maunder Minimum to Grand Maximum has led solar physicists to accord a far greater role to the Sun than the IPCC finds it expedient to allow.

The 2004 Symposium of the International Astronomical Union concluded that the Sun had been responsible for the warming of the past 250 years; that solar activity was now likely to decline; and that global cooling, not warming, was likely.

In the four years since then:

- Solar activity has declined sharply;
- Magnetic convection currents beneath the surface of both solar hemispheres have slowed to a rate never before observed;
- 266 days without sunspots occurred in 2008, the second-least solar activity in more than a century; and
- Global temperatures have duly fallen at a rate equivalent to 6 C°/century.

If that cooling were to persist, there would be an Ice Age by 2100. Scafetta & West (2008) conclude that the Sun caused 69% of the global warming that ceased in 1998.

The central question – on which there is no consensus – is how much warming a given proportionate increase in CO2 concentration will cause. Arrhenius (1896) estimated 5 C° at CO2 doubling; Hansen (1988) 4.2 C°; IPCC (1995) 3.8 C°; IPCC (2001) 3.5 C°; and IPCC (2007) 3.26 ± 0.69 C°.

At its very simplest, climate sensitivity to atmospheric enrichment with CO2 is a logarithmic function of the proportionate increase in CO2 concentration. The IPCC's current evaluation of this crucial climatic parameter is childishly *simpliste:* though 3.26 ± 0.69 C° sounds commendably precise, this value may be attained by the following startlingly naive method:

$$\begin{aligned} \Delta T_{S,2x} &= c \ln(C/C_0) \\ &= (4.7 \pm 1) \ln 2 \\ &= 3.26 \pm 0.69 \text{ C}^\circ. \end{aligned} \qquad \{1\}$$

This result is said to be derived from a "multi-model mean": however, it is – to say the least – suspicious that one obtains exactly one standard deviation above or below the central estimate simply by taking the coefficient $c = 4.7$ and adding or subtracting exactly unity. Plainly, further scrutiny is needed.

In the methodology of the IPCC, climate sensitivity – temperature response ΔT_S to an external perturbation such as anthropogenic greenhouse-gas enrichment – is the product of:

- Direct radiative forcings ΔF;
- The zero-feedback climate-sensitivity parameter κ; and
- Temperature feedbacks encompassed in the feedback multiplier *f,* such that:

$$f = (1 - b\kappa)^{-1}, \qquad \{2\}$$

where b is the sum of all positive and negative temperature feedbacks, which are then mutually amplified via Eq. {2}, the Bode linear feedback-amplification equation.

Thus the climate-sensitivity equation is:

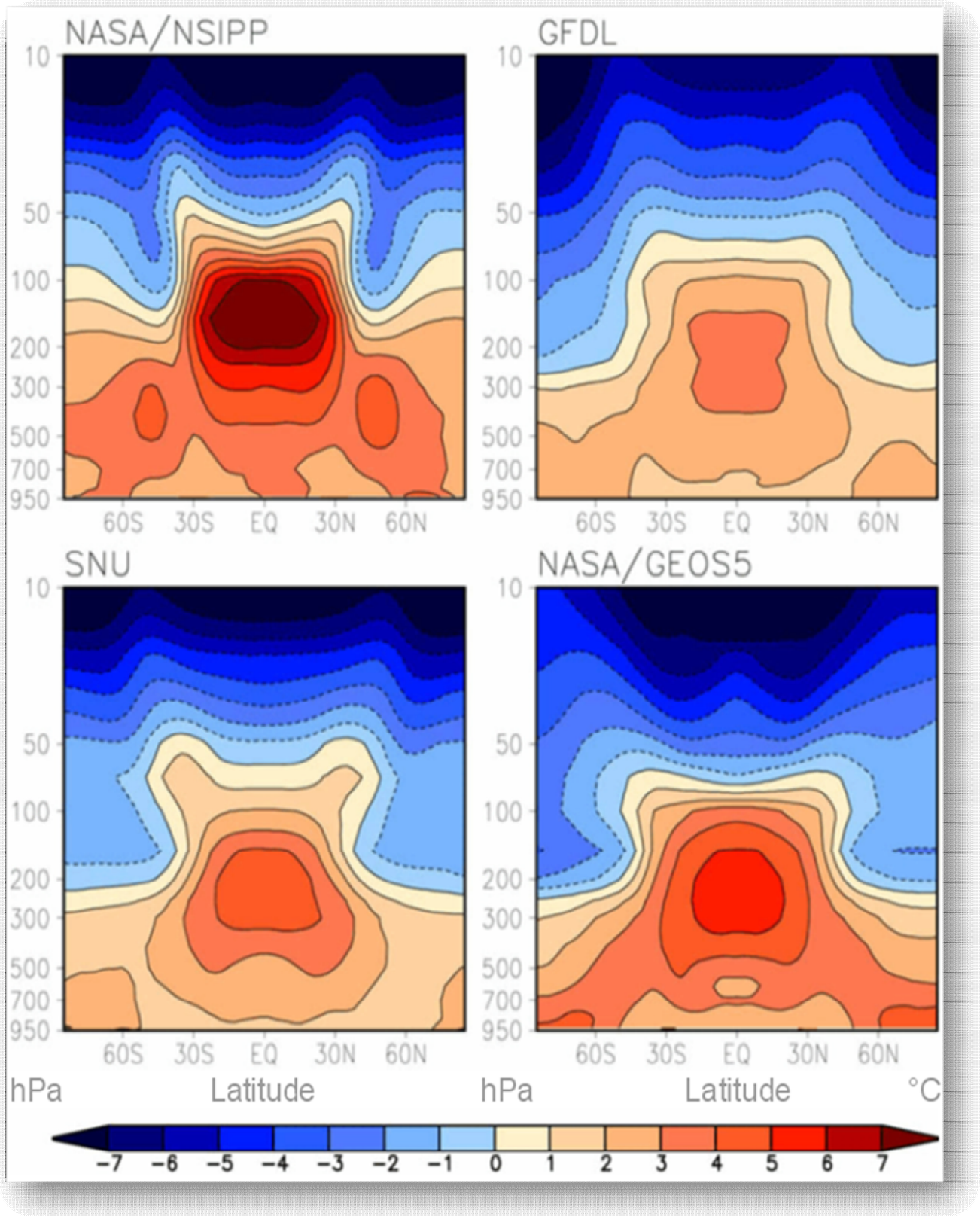
$$\Delta T_S = \Delta F \kappa f = \Delta F \kappa (1 - b\kappa)^{-1}. \qquad \{3\}$$

None of the three key parameters ΔF, κ, f can be definitively evaluated by theoretical demonstration, directly measured by instrumentation, or reliably inferred by experimentation (Monckton, 2008).

Official predictions of climate sensitivity, therefore, being reliant near-exclusively on numerical modeling, cannot be Popper-falsified. To this extent, the anthropogenic-warming contention is untestable, does not qualify as a hypothesis and, *stricto sensu,* is not of interest to science.

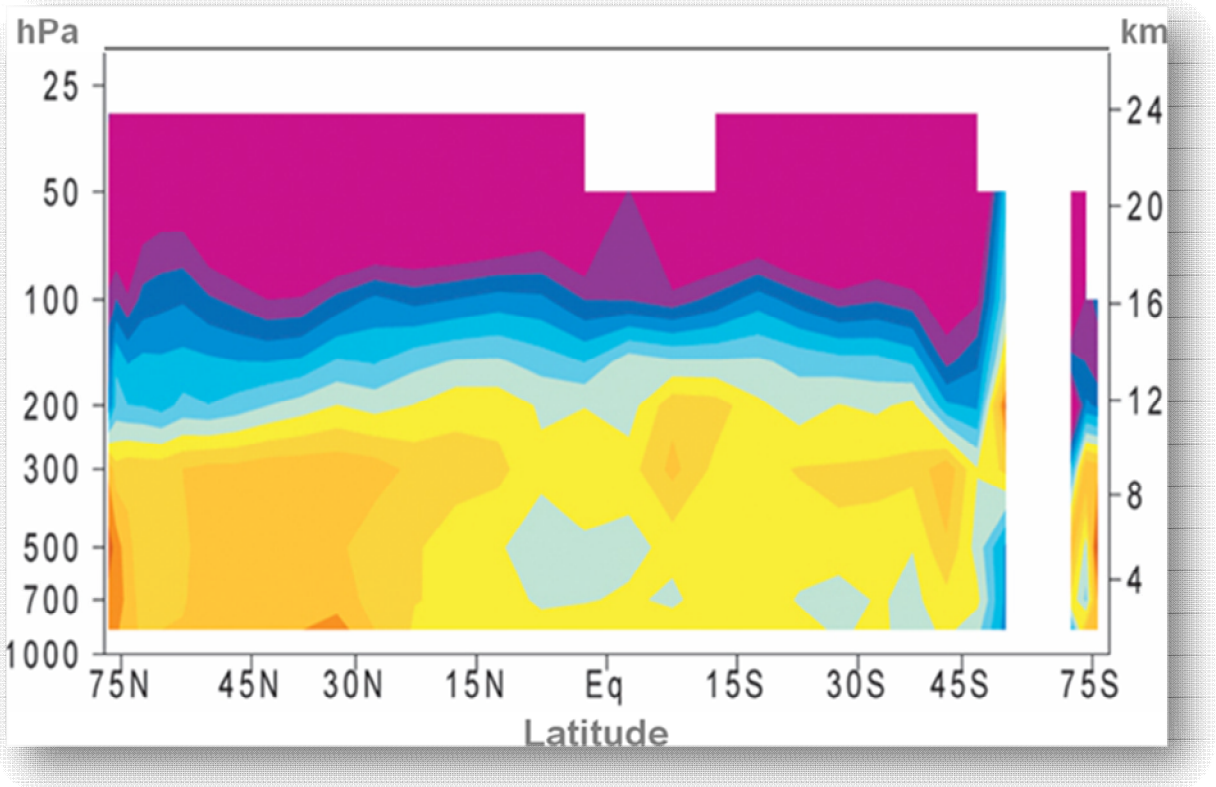
However, we may enquire into the reasonableness of the IPCC's values for the three key parameters ΔF, κ, f, whose product is final climate sensitivity ΔT_S.

First, all of the models on which the IPCC relies predict that most of the atmospheric warming that arises from anthropogenic greenhouse-gas enrichment will occur in the tropical upper troposphere, where the warming rate will be 2-3 times that observed at the surface:



Predicted "hot-spot": *Zonal mean equilibrium temperature change (°C) at CO_2 doubling (2x CO_2 – control), as a function of latitude and pressure (hPa) for 4 general-circulation models. All show the projected fingerprint of anthropogenic greenhouse-gas warming: the tropical mid-troposphere "hot-spot" is projected to warm at 2-3 times the surface rate.* ***Source:*** *Lee et al. (2007).*

However, the tropical mid-troposphere "hot-spot" that is so confidently predicted by all of the models is not observed in reality:



No "hot-spot": *Altitude-vs.-latitude plot of observed relative warming rates in the satellite era. The greater rate of warming in the tropical mid-troposphere that is projected by general-circulation models is clearly absent in this and all other observational datasets, whether satellite or radiosonde.* ***Source:*** *Hadley Centre for Forecasting (HadAT, 2006).*

Dr. Richard Lindzen, Alfred P. Sloan Professor of Meteorology at the Massachusetts Institute of Technology, the world's ranking expert on the behaviour of the atmosphere, has concluded from the absence of the "hot-spot" that:

> "... A doubling of CO2 leads to surface warming of from about 1.5-3.5 K. By contrast, the observed warming over the past century or so amounts to only about 0.6-0.8 K (not all of which need be due to increased greenhouse gases). ... Using basic theory, modeling results and observations, we can reasonably bound the anthropogenic contributions to surface warming since 1979 to a third of the observed warming, leading to a climate sensitivity too small to offer any significant measure of alarm ...".

This result is very much in line with that of Scafetta & West (2008. *op. cit.*). It requires that we divide the IPCC's imagined climate sensitivity to CO2 by *at least* 3.

Furthermore, the IPCC also overstates the zero-feedback climate sensitivity parameter (the "Planck parameter"), whose value cannot exceed 0.27 K W^{-1} m^2, taking 0.313 instead. This value is above any in the mainstream literature. It repeals the fundamental equation of radiative transfer, by taking temperature and radiant energy from different radiating surfaces.

Also, the IPCC underestimates the cooling effect of evaporation in calculating the water-vapor feedback (Wentz *et al.,* 2007), and regards the cloud feedback as strongly positive when it should be net-negative (Spencer, 2007), consequently – and substantially – overvaluing the feedback multiplier.

Correcting for each of these exaggerations reduces climate sensitivity to <0.6 C° at CO2 doubling (Monckton, 2008; *cf.* Lindzen, 2008; Spencer *et al.,* 2007; Schwartz, 2007).

Low climate sensitivity is to be expected, for CO2 is no more than a trace gas, occupying only 1 part in 10,000 more of the atmosphere than 250 years ago. Its effect on temperature is logarithmic: each additional molecule causes less warming than its predecessors. Indeed, the IPCC's formula for evaluating the radiative forcing from CO2 ceases to apply once concentration reaches 915 ppmv, above which adding CO2 has very little effect on temperature. Half a billion years ago, there was 25 times as much CO2 in the atmosphere as today. The planet did not fry.

It is often said that the effect of the warming we are causing will be observed for millennia to come. This is not so. The IPCC's central estimate of the *equilibrium* increase in global temperature from 2000-2100 (on its "business-as-usual" Scenario A2) is:

$$\Delta T_{S,2x} = 4.7 \ln (836/368) = 3.9\ C^{\circ}. \quad \{5\}$$

Yet the IPCC's stated estimate of *transient* climate sensitivity by 2100, in Table SPM.3, is 3.4 C°. Accordingly, if CO2 concentration were to be stabilized by 2100, temperature would rise thereafter by no more than 0.5 C° – and only by that much on the probably-incorrect assumption that the IPCC's estimates of climate sensitivity to atmospheric CO2 enrichment have not been absurdly exaggerated.

There are two obvious and fatal omissions in the IPCC's analysis, without which its climate-sensitivity values cannot be seriously taken at face value. First, in 1600 pages the IPCC neglects to mention any of the laboratory experiments on the basis of which it wishes us to believe that CO2 will in future have an effect on temperature far larger than that which it is visibly exerting today, still less how such experiments can be reliably translated from the lab to the atmospheric column.

Secondly, the IPCC does not mention whether the outgoing longwave radiation from the Earth's surface, as measured by satellites, has declined as fast as its models have predicted. As Professor Lindzen has pointed out, it was established in several papers published decades ago that the observed decline in outgoing longwave radiation has been far less than predicted, confirming empirically that climate sensitivity to further CO2 enrichment is small, and that the models – programmed to assume an excessive climate sensitivity – are indeed overegging the pudding.

Finally, what are the consequences of 300 years' planetary warming, during all but the last 30 of which we cannot have been to blame for the warming?

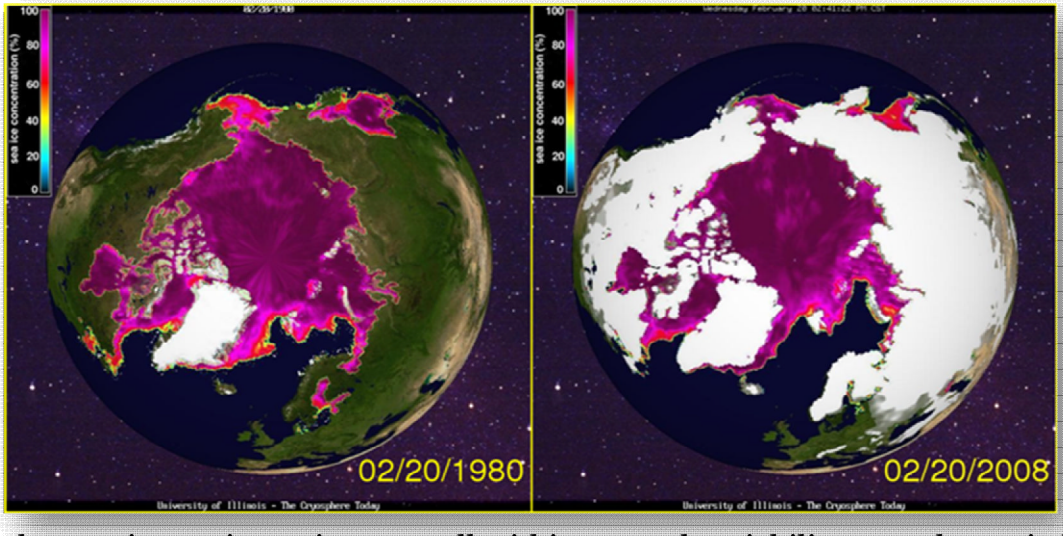
First, as expected, there are more warm years at the end of the period than at the beginning. This is often cited as a reason to believe that anthropogenic "global warming" is occurring: however, it is merely a reason to believe that warming (of whatever origin) has been occurring.

Secondly, sea level is rising at ~1 ft/century, compared with a mean centennial rate of rise of 4ft/century over the past 10,000 years. There is little sign of acceleration in this rate, and no evidence that sea level will imminently rise by 20 ft, as imagined by

Al Gore. The UK High Court has bluntly commented: "The Armageddon scenario that he depicts is not based on any scientific view" (Dimmock v. S of S Educ., 2007). *A fortiori,* a recent statement by a NASA researcher that sea level will rise by almost 250 feet is mere rodomontade. The oceans have been cooling since 2003, when 3175 automated bathythermographs were deployed to provide the first reliable measurements of ocean temperature.

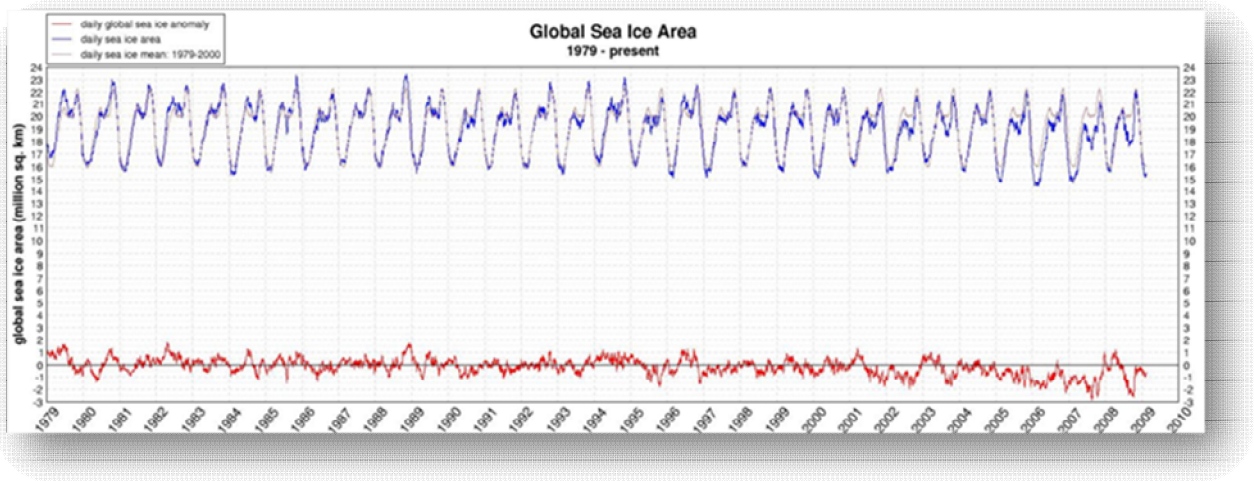
Thirdly, landfalling Atlantic hurricanes show no trend in 100 years, and severe typhoons and tropical storms have been in decline for 30 years. Losses from hurricane damage, adjusted for inflation, population changes and changes in the built environment in harm's way, have declined. Extra-tropical storms, expected to decrease in both frequency and intensity as warmer weather reduces temperature extremes, have indeed decreased.

Sea ice in the Arctic has been melting a little, particularly in the summer, but its winter extent (purple in the chart below) is much as it was 30 years ago when the satellites first looked. Note that more recent data are not available because the sensor has degraded:



The changes in Arctic sea ice are well within natural variability over the period. The Arctic was in fact warmer in the late 1930s and early 1940s than it is at present.

Sea ice in the Antarctic reached a record high (but largely-unreported) extent in October 2007. Globally, sea-ice extent shows little trend in 30 years:



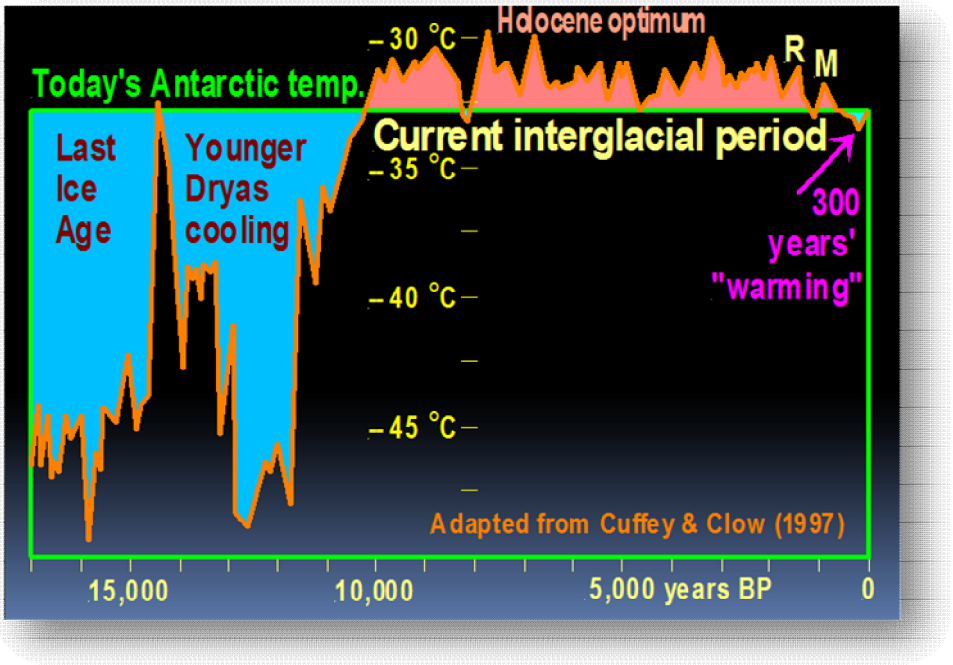
Land ice in Antarctica (90% of the world's total) and in Greenland (5%) has been accumulating throughout the period (Doran *et al.*, 2002; Johannesen *et al.*, 2005). Mountain glaciers had begun to decline in 1820-1800: there has been no increase in the rate of decline during the past 30 years, when we might have had some influence. Kilimanjaro's glacier has ablated owing to regional cooling and consequent desiccation of the atmosphere: the temperature at the summit has never risen above –1.6 degrees Celsius in 30 years of satellite observation, and the mean is –7 Celsius.

Northern-hemisphere snow cover, on which 40% of the world's population depends for its water supply, reached a record high extent in 2007/8 and shows no trend in 30 years.

Patterns of heatwave, cold snap, drought, and flood continue to change, as they always have. There is no evidence for worsening extremes: the drought of the early 20th century in the American Great Plains, for instance, was far worse than anything seen since, and the incidence of major flooding in the UK from mediaeval times (when the whole of the city of Derby was flooded) via the 18th century (when the entire county of Norfolk was underwater for six months) to the present shows no trend.

Though some extravagant claims for widespread species loss have been made, most of the world's life-forms thrive in the tropics, not at the Poles. Warmer weather will lead to speciation, not extinction. The warming of the 20th century, like that of the 19th and 18th centuries, was around 0.75 C°: not enough to cause harm. In Central England, in just one-third of a century between 1700 and 1735, temperatures rose by 2.2 Celsius degrees, equivalent to a centennial rate nearly nine times that which was observed globally in the 20th century. There is little reason to suppose that the warming of the present century (if and when it begins) will be any more severe than that of the 20th century.

Putting today's "global warming" in perspective, global temperatures were 7 C° warmer than the present throughout most of the past half-billion years; 5 C° warmer in each of the past four interglacial periods; 2-3 C° warmer throughout most of the past 10,000 years; and, notwithstanding a clumsy and now-discredited attempt by the IPCC to abolish it, 1-3 C° warmer during the medieval (M) warm period:



We conclude that catastrophic "global warming" is a fantasy; and that the warming from CO2 enrichment will be small, harmless, and beneficial.

Even if temperature had risen above natural variability, the recent solar Grand Maximum may have been chiefly responsible. Even if the sun were not chiefly to blame for the past half-century's warming, the IPCC has not demonstrated that CO2 has contributed more than a small fraction of the warming.

Even if CO2 were chiefly responsible for the warming that ceased in 1998 and may not resume until 2015 (Keenlyside *et al.,* 2008), the distinctive, projected fingerprint of anthropogenic "greenhouse-gas" warming is entirely absent from the observed record.

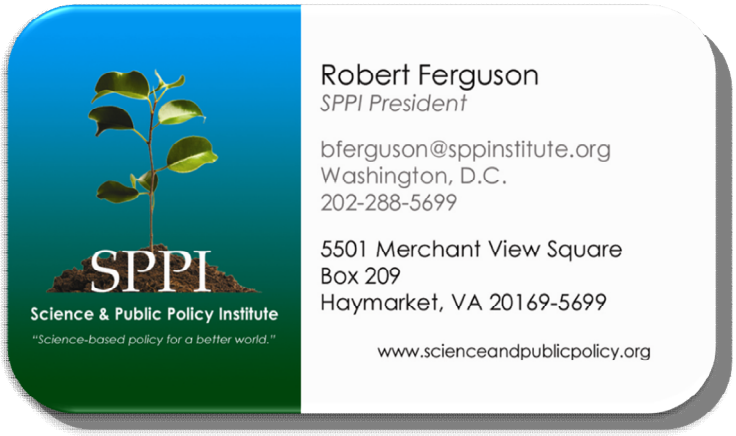
Even if the fingerprint were present, computer models are long proven (Lorenz, 1963) to be inherently incapable of providing projections of the future state of the climate that are sound enough for policymaking. Even if *per impossibile* the models could ever become reliable, it is evident that the world will not – indeed, cannot – warm as much as the IPCC imagines as a result of atmospheric greenhouse-gas enrichment.

Even if the world were to warm that much, the overwhelming majority of the scientific, peer-reviewed literature does not predict that catastrophe would ensue (Schulte, 2008). Even if catastrophe might ensue, proposals to mitigate future climate change by reducing emissions of carbon dioxide would make very little difference to the climate.

Even if mitigation were likely to be effective, it would do more harm than good: already millions face starvation as the environmentally-disastrous dash for biofuels takes agricultural land out of essential food production, a warning that taking precautions, "just in case", can do untold harm unless there is a sound, scientific basis for them.

Finally, even if mitigation might do more good than harm, adaptation when (and if) necessary would be far more cost-effective and far less likely to be harmful.

There is no case for spending a single penny more of taxpayers' money on "global warming" unless and until mean global surface temperatures shall have risen by at least 1 C° above the year 2000. On current evidence and trends, that will not happen for at least a century, if then. This is a scare that has been oversold for political reasons. It is time for a calmer, more science-based approach.



180 Years accurate CO_2 - Gasanalysis of Air by Chemical Methods (Short version)

Dipl. Biol. Ernst-Georg Beck, Merian-Schule Freiburg, 8/2006

1. Short summary on the knowledge about the CO_2 air gas analysis (2006)

The context of carbon dioxide as the base of all organic matter on earth with fundamental importance for metabolism of organisms is taught in each school and all universities of the world.
The background for these realizations were investigated among other things for approx. 200 years by scientists such as Pettenkofer, Benedict, Krogh (Nobel prize), Lundegardh and Warburg (Nobel prize).
In IPCCs Climate Change 2001: Working Group I: The Scientific Basis **you will find the following in chapter 3: "The Carbon Cycle…":3.1: "**
"The concentration of CO_2 in the atmosphere has risen from close to 280 parts per million (ppm) in 1800, at first slowly and then progressively faster to a value of 367 ppm in 1999, echoing the increasing pace of global agricultural and industrial development. This is known from numerous, well-replicated measurements of the composition of air bubbles trapped in Antarctic ice. Atmospheric CO_2 concentrations have been measured directly with high precision since 1957; these measurements agree with ice-core measurements, and show a continuation of the increasing trend up to the present."
Responsible for the relative measurements since 1958 is C.D. Keeling, University of California at San Diego, USA. He used cryogenic condensation of the samples and NDIR spectroscopy against a reference gas with manometric calibration. Today all measurements are done by this technique as a standard (WMO). Keeling's laboratory delivers the reference gases worldwide and have the calibration monopoly. .(38, 39, 40,41, 42, 43, 44, 45)
Measurement stations spreading over the world are mainly in oceanic areas to get air without contamination from vegetation, organisms and civilisation, the so called background level of CO_2.
So his initial work mainly on the active volcano Mauna Loa (Hawaii) is todays reference for determination of carbon dioxide with an accuracy of down to 0.1 ppm. (20, 21, 22, 24)
Accuracy from 1959 was much more in error and approx. 4 ppm between 1964 –1968 max. 1 ppm. (130)
A thorough review of existing literature (175 in this study) revealed in contrast to the published opinion based on the founders of modern greenhouse theory, Callendar and Keeling, that there exists some 90, 000 accurate measurements by chemical methods before 1957 back to 1857 with an accuracy better than 3%.
Accurate measurements had been done amongst others by de Saussure 1826, Pettenkofer/v.Gilm 1857, Schulze 1864/71, Farsky 1874, Uffelmann 1886, Letts und Blake 1897, Krogh and Haldane 1904, Benedict 1912, Lundegardh 1920, van Slyke 1929, Dürst and Kreutz 1934 alternatively 1940, Misra 1942 or Scholander 1946 with measuring instruments through which from 1857 (Pettenkofer) an accuracy of +/-0,0006 Vol% to under +/-0,0003 Vol% =~3 ppm (Lundegardh 1926) was achieved.
They show precise seasonal and some diurnal variation.
These pioneers of chemistry, biology, botany, medicine and physiology laid foundations for todays knowledge of metabolism, nutrition science, biochemistry and ecology. Modern climatology ignored their work till today even though it is the basis of all textbooks of the mentioned faculties and was honoured with several Nobel prizes.

2. Results of the literature review of this study:

To reconstruct historic fluctuation of carbon dioxide 137 yearly averages were used out of 175 technical papers within 1812 until 1961, the end of using chemical technique. Nearly all selected data had been received in rural areas or periphery of towns under comparable conditions with a measuring hight of approx. 2 m above ground and without large contamination of industry. Evaluation of chemical methods revealed a systematic accuracy of maximum 3% down to 1% in best cases by Henrik Lundegard 1920, a pionieer of plant physiology and ecology.

11 often used measuring techniques (gravimetric, titrimetric, volumetric and manometric) had been evolved from 1812 to modern times, from which the so called Pettenkofer method (titrimetric) was easy, fast and well understood and the optimized standard from 1857 for 100 years. Mentioned authors had calibrated their methods against each other and samples with known content. All measuring parameters, local modalities and measuring errors can be extracted out of available literature.

The available data used in this study can be researched in several comprehensive bibliographies:

Year	Autors	Cited autors and papers with data			Notes
		Gesamt	**19. Jh**	**20. Jh**	
1900	Letts and Blake (53)	252	252	-	only 19th century
1912	Benedict (51)	137	137	-	only 19th century; focus on O2-determination
1940	**Callendar (113)**	**13**	**7**	**6**	**cited Letts&Blake and Benedict**
1951	Effenberger (54)	56	32	24	cited Duerst, Misra und Kreutz
1952	Stepanova (118)				
1956	Slocum (128)	33	22	11	
1958	**Callendar (119)**	**30**	**18**	**12**	**No citing of Duerst, Kreutz and Misra**
1958	Bray (129)	49	20	19	
1986	Fraser (149)	6	6	-	
1986	**Keeling (147)**	**18**	**18**	**-**	**Only 19th century same as Callendar;**
2006	Beck (this study)	152	82	73	Only chemical determination until 1961

Table 1 Bibliographies and citation of papers.

It could be shown that between 1800 to 1961 more than 320 technical papers exist on the subject of air gas analysis containing verified data on atmospheric CO_2 concentrations.

Callendar(engineer), Keeling (chemist) and IPCC do not evaluate these chemical methods though being standard in analytical chemistry, discredited these techniques and data and rejected most as faulty and highly inaccurate because not helpful proving their hypothesis of fuel burning induced rise of carbon dioxide in the atmosphere. In using their concept of unpolluted background level they had examined about 10% of available literature and considered <1% (Müntz, Reiset, Buch) as accurate. (see references)

But history of air gas analysis was not like this (see references).

From 1857 with Pettenkofer process as a standard accuracy of 3% was enough to develop all modern knowledge of medicine, biology and physiology (photosynthesis, respiration end energy metabolism) which are taught today worldwide as a content of all text books of the mentioned faculties

Several Nobel (Krogh 1923, Warburg 1933, nominated Benedict 1923) and other awards (Schuftan Memorial Prize in Process Design in Chemical Engineering (UK) and Pettenkofer award (medicine, D) honoured these pioneering findings of modern natural science (58, 59, 60, 61, 64).

Others as Lundegardh induced a revolution of our knowlodge on ecology and plant physiology inventing modern techniques and revealed today well known facts (flame-photometer 1929, cytochrome 1950, (100))

And without the exact determination of blood gas levels with the aid of the apparatus of van Slyke hundred thousands of patients would have died in the 20th century.
Modern climate scientists based on the tasks of Keeling, Callendar and IPCC ignore their work.
In every decade from 1857 we will find several measuring series with hundreds of precise continous data.
The highest data density is achieved by W. Kreutz in the state-of-the-art meteorologic station of that time at Gießen (Germany) using the best available equipment (closed, volumetric, automatic system) designed by Paul Schuftan, the father of modern gas chromatography. He´d done more than 65 000 single measurements in 18 month from 1929 –1941 with 120 determinations a day every 90 minutes.
The longest series had been done in Paris at Montsouris laboratory with 12000 Determinations in 30 years from 1876 until 1910.
Presented data in this study are initially not modified, selected for a measuring hight of approx. 2 m above ground, extend mainly in northern hemisphere from Alaska over Europe to Pune (India).
Table 2 shows series of measurements since 1860 more than a year using the titrimetric Pettenkofer process. The Pettenkofer process and all its variants included the absorption of a known volume of air in alkaline solution ($Ba(OH)_2$, KOH, NaOH) and titration with acid(oxalic, sulphuric acid) of the produced carbonate. Basic accuracy is +-0,0003 volume% (70) optimized to 1% by Lundegardh and it can be found several comparative measurements with the other techniques.

Table 2 Series of measurements since 1860 more than a year using the titrimetric Pettenkofer process

	year	**author**	**locality**	**Amount of determinations**
1.	from 1855	v. Pettenkofer	München	many
2.	1856 (6 month)[1]	v. Gilm[1]	Innsbruck[1]	19
3.	1863 -1864	Schulze	Rostock, (D)	426
4.	1864/65	Smith	London, Manchester Scotland	246
5.	1868 - 1871	Schulze *	Rostock, (D)	1600
6.	1872 – 1873	Reiset	Dieppe, France (Northsea) (F)	92
7.	1873	Truchot	Clermont Ferrand	60
8.	1874 –1875	Farsky *	Tabor, Böhmen, (Cz)	295
9.	1874 -1875	Hässelbarth*	Dahme (D)	347
10.	1879 - 1880	Reiset	Dieppe (F)	118
11.	1883	Spring	Lüttich	266
12.	1886 - 1887	Uffelmann	Rostock	420
13.	1889 - 1891	Petermann	Gembloux (B)	525
14.	1897 - 1898	Letts&Blake	Nähe Belfast (I)	64
15.	1898 - 1901	Brown& Escombe	Kew Garden England (GB)	92
16.	1917 -1918	A. Krogh	Kopenhagen (DK)	viele
17.	1920-1926	Lundegardh	in southern Sweden (Kattegat) (S)	>3000
18.	1928	Krogh/Rehberg	Kopenhagen	
19.	1932 -1935	Buch	Northern atlantic ocean/Finland (FIN)	176
20.	1936 - 1939	Duerst	bei Bern (Schweiz) (CH)	>1000
21.	1941 -1943	Misra	Poona, India (IND)	> 250
22.	1950	Effenberger	Hamburg (D)	>40
23.	1954	Chapman et al.	Ames (IOWA, USA)	>100
24.	1957	Steinhauser	Vienna (AUS)	>500
25.	1955-1960	Fonselius et al. Bischof	Skandinavia	>3400

[1]v. Gilm: similar process as Pettenkofer, first calibrated
very similar to Pettenkofer process, sampling by tube through opening in window

Table 3 volumetric and manometric measurements

1	1875 (März)	Tissander	Paris, Ballonfahrt (volumetrisch)	<10
2	1880 - 1882	Müntz & Aubin	Bei Paris, Pyrenäen, Karibik usw. /F) volumetrisch	81+
3	1910 - 1912	Benedict	Washington (USA), volumetrisch	>264
4	1912 -1936	Haldane	volumetrisch	1500
5	**1939-1941**	**Kreutz**	**volumetrisch**	**64 000**
6	1946	Scholander	volumetrisch	>1000

The volumetric equipment before Haldane **(84)** and Benedict/Sonden/Petterson (e.g.. 1900, **51,82,83)** used by Regnault, Müntz, Tissander were **open systems** without efficient control of reacting temperature (see Schuftan 1933 (72)) So their data are partly erroneous.
Especially Müntz was highly praised by Keeling and IPCC as a source of best available data for that time.

(Further comments and detailed analysis of methods and data see full version.)
According to Callendar, Keeling and IPCC allowed variations of atmospheric CO_2 are the diurnal, the seasonal and ice age/ interglacial fluctuations. Natural concentrations are in equilibrium, mankind disturbed this natural situation.
So let´s look at the data within 160 years air gas analysis by chemical means, at first the raw data out of 138 papers:

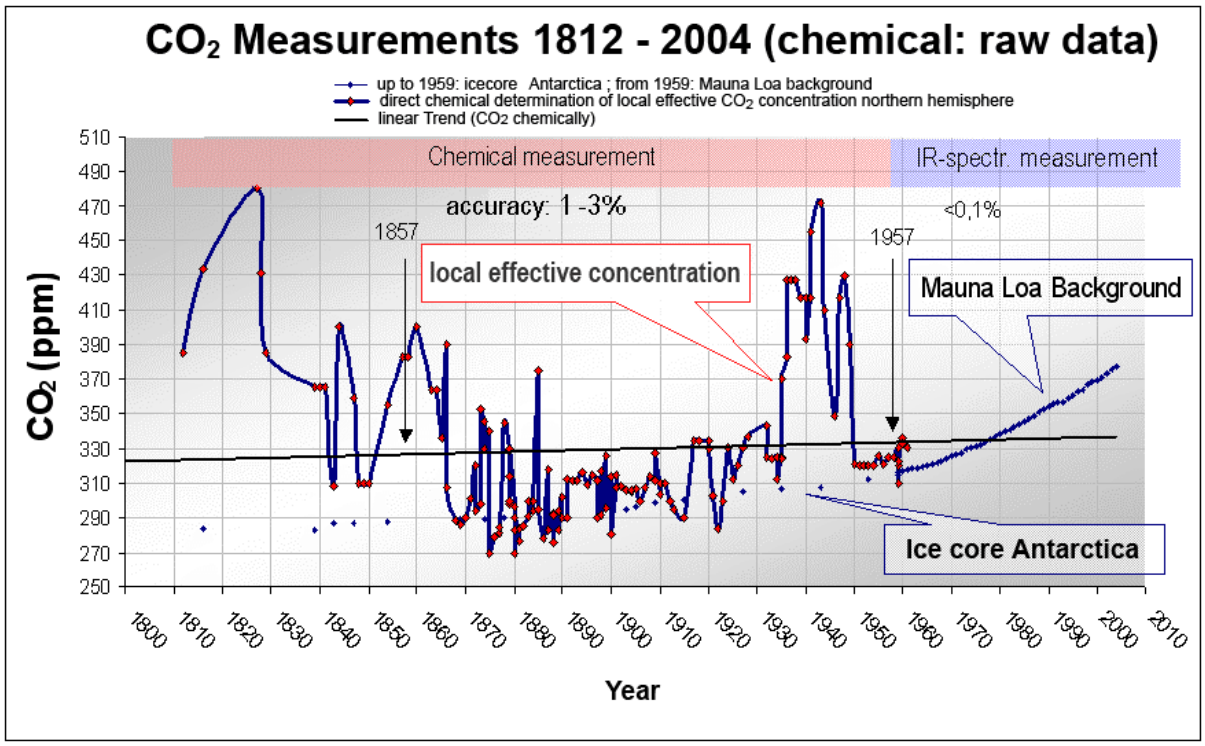


Fig. 1 138 yearly average from 1812 up to 1961 chemical determination (raw data)
And now the same data with 5 years average smoothing:

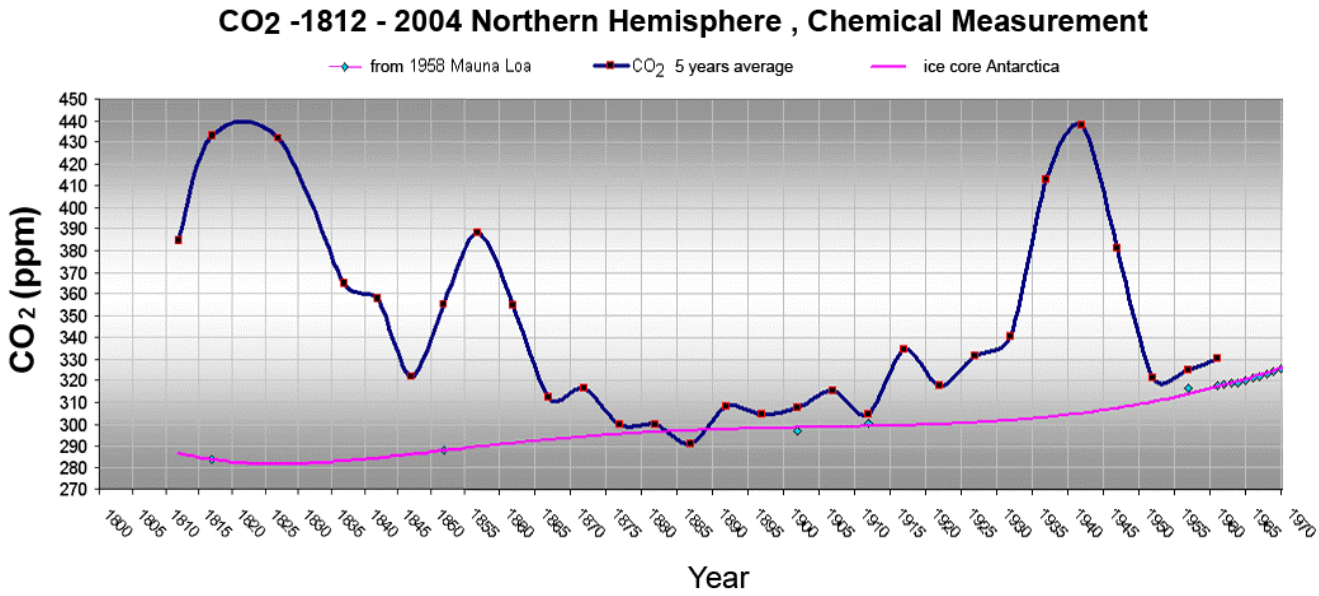


Fig. 2 138 yearly averages of local effective atmospheric CO_2 concentration from 1812 up to 1961 by chemical determination, smoothed as 5 years average (raw data); icecore reconstruction (Neftel et al. (13,14,15)) and Keeling measurements from Mauna Loa included.

It is easily seen that

1. atmospheric carbon dioxide fluctuates through 19th and 20th century contradicting the icecore reconstructions.
2. In 20th century we notice one big maximum around 1942 with more than 420 ppm and several little maxima in 1915 and 1905; in 19th century a big maximum occurred before 1870 and perhaps a big maximum in 1820 out of precise measurement area. Little maxima appeared around 1876, 1880 and 1890.
3. CO_2 concentrations rises from approx. 1880 to 1930 by some 20 ppm as Callendar speculated in 1938.
4. Big maximas with an amplitude of 100 ppm like the one in the 40s should be easily reproduced with chemical methods (3%). This is not mentioned in modern literature.

See full version for detailed analysis.

As an example for the quality of chemical measurements and real existing CO_2-maxima let´s take a closer look to the big CO_2 maximum 1942 in Fig. 3.

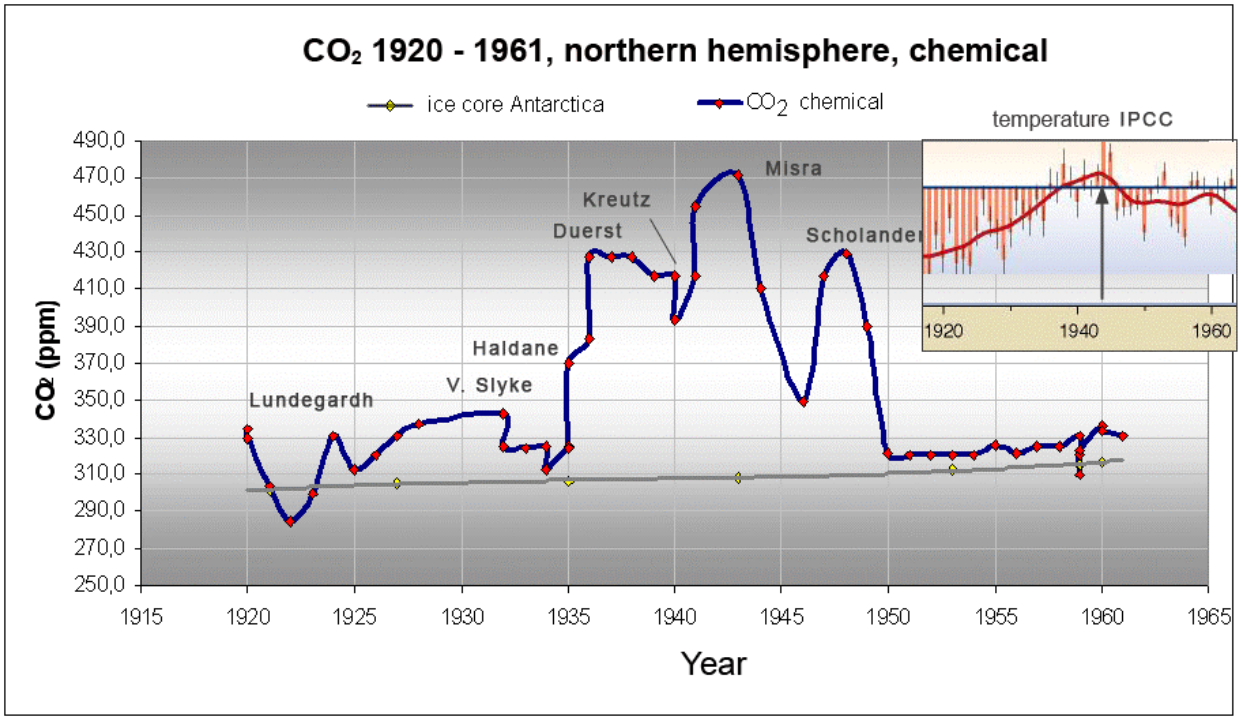


Fig. 3 The big CO2 maximum around 1942 in northrrn hemisphere detected with chemical analysis.

There are a lot of indications for this big variation:

- **High density of data** with broad geographic coverage:
- **41 series** includes approx. 70 000 single data with highest density in peak area 1939-1942,
- **Measuring stations are spread** throughout middle- and northern Europe, USA, Atlantic ocean Alaska, India and Antarctica. Continous rise since. 1925.
- **Application of different accurate standard measuring systems** with high accuracy of 2-3% designed by Krogh, Schuftan, van Slyke, Haldane, Scholander.
- **Measured by different, competent experts**: Buch, Duerst, Kreutz, Scholander, Lockhart
- Verified conditions of measuring stations, no exceptional contamination by local CO_2 sources e.g. civilisation, war, soil degassing, volcanic emissions.

The second world war cannot be responsible for high values because there is a continous rise from 1925 culminating still 1939 and second part of maximum was measured at places with no war activities. (Alaska, India)

To show quality of data and methods see results of W. Kreutz (Germany 1939 –1941):

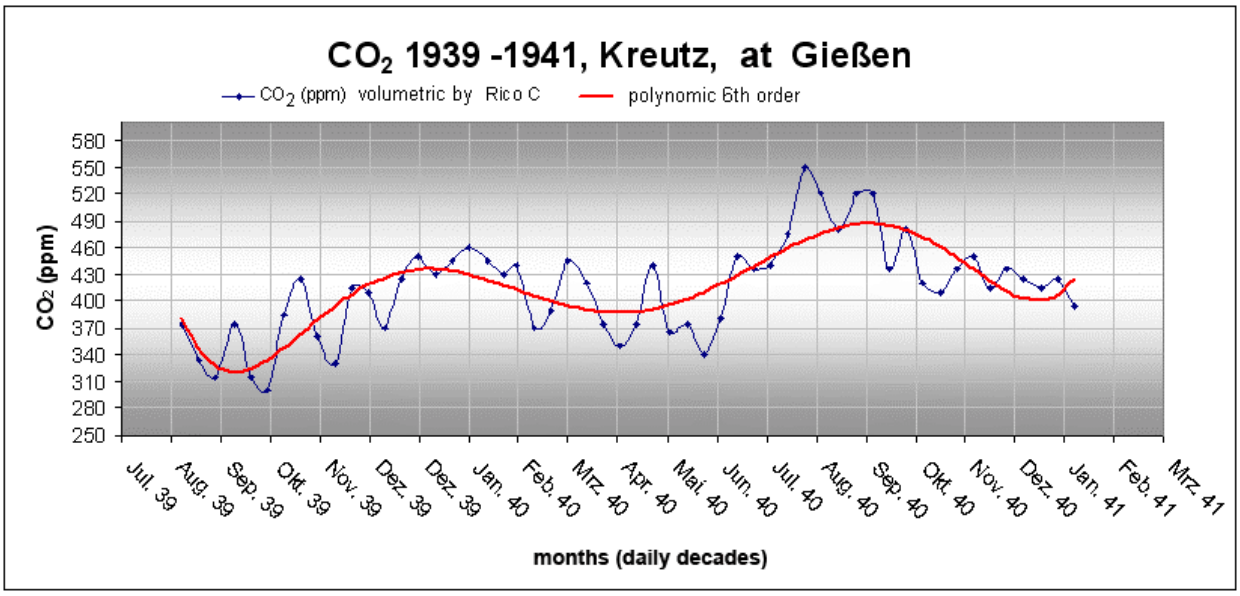


Fig. 4 CO_2 concentration at meteorological station in periphery of Gießen (Germany) 1939/40 smoothed by decade average

Climate science ignores the work of Kreutz, IPCC and Keeling have not cited him, Callendar excluded his data because it was considered out of allowed range. (119), others Slocum (128), Effenberger (54) and Bray (130) gave faulty citation of details. (see more facts in full version)

The same overall precision and accurate measurement of seasonal and diurnal variation one can see in a lot of determinations by 19th century scientist as F. Schultze (Rostock) at the Baltic sea.

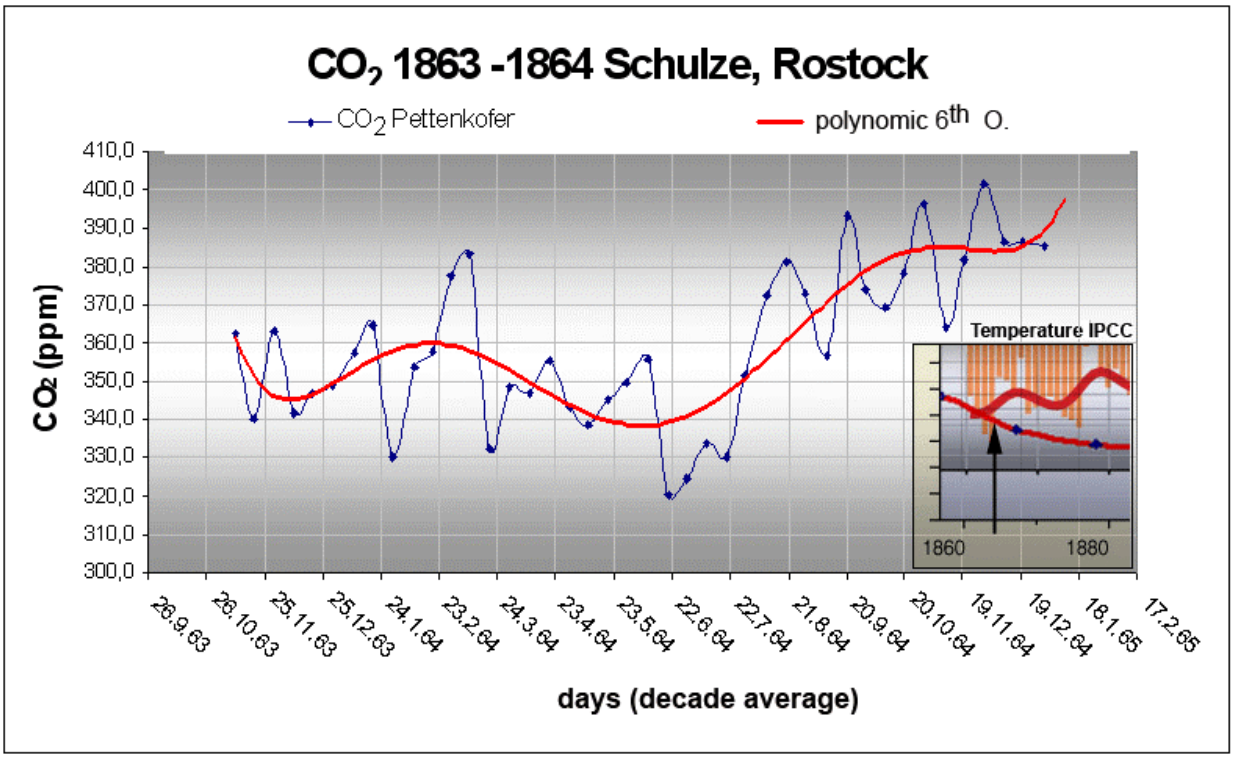


Fig. 5 CO_2 concentration at meteorological station near Rostock, Baltic sea (Germany) 1863/64 smoothed by decade average
(see much more in full version)

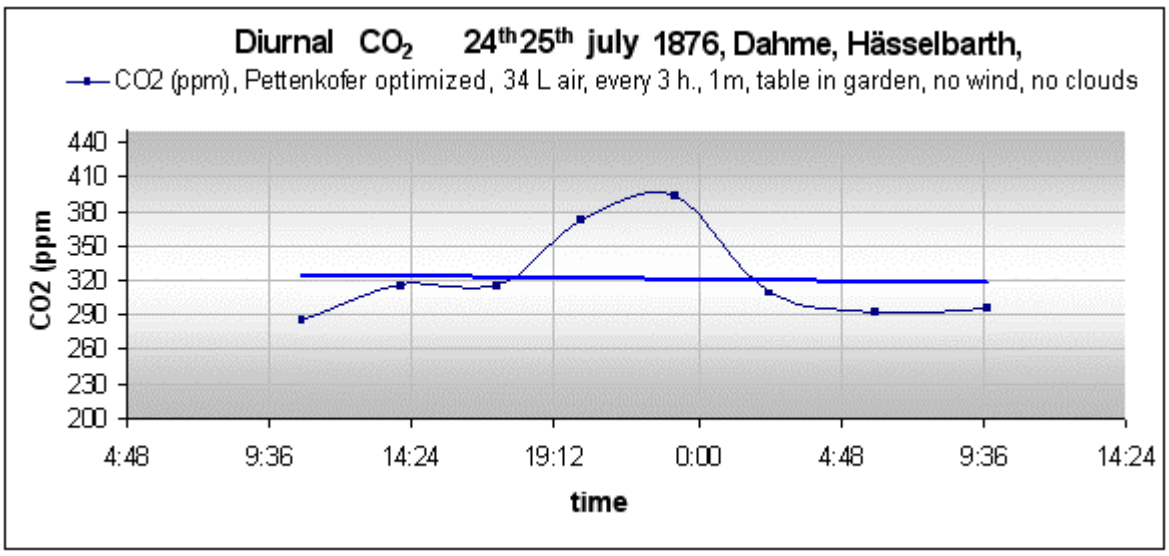


Fig. 6 Diurnal variation of CO_2 in $24^{th}/25^{th}$ of July 1876 in Dame (Prussia, Germany) by Hässelbarth

A smoothing of 138 yearly averages of CO_2 by 11 years of sunspot cycle maxima/minima leads to:

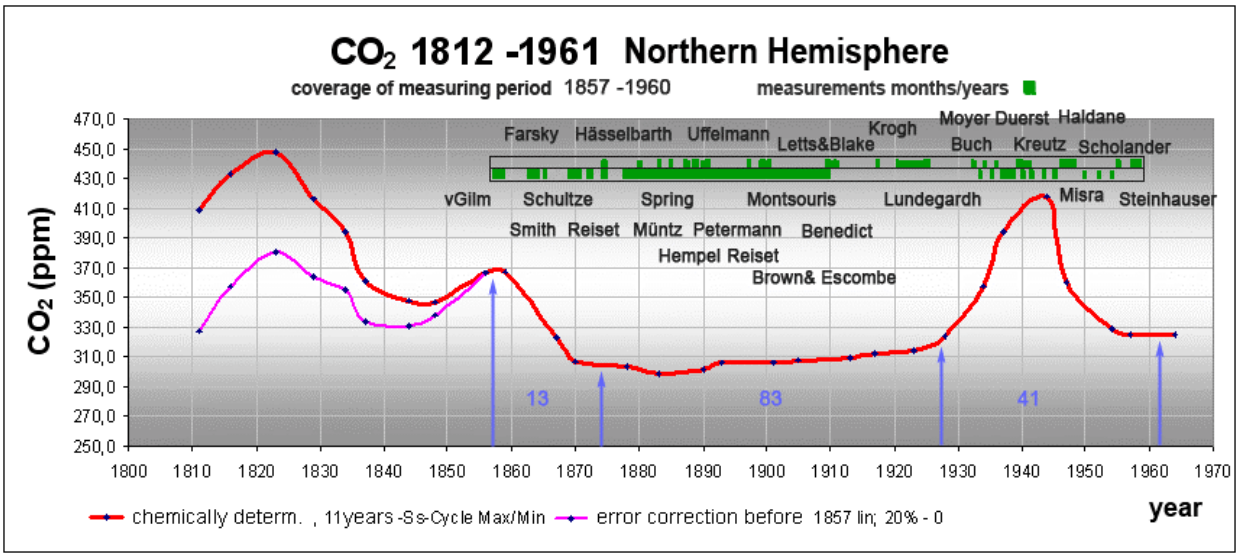


Fig. 7 Effective local CO_2 concentration chemically determined between 1812 - 1861 of northern hemisphere Nordhemisphäre (11 year averages with sunspot cycle maxima/minima) including data coverage, number of data and important scientists.

Fig. 7 shows also guessed linear error correction below accurate measuring 1857 The little maximas cannot reproduced by this smoothed curve. Result are 3 big maxima with one 1820 not exactly valuable because of missing comparative informations.
All needed details for evaluation can be found in full version.
Especially interesting is a comparison of measured atmospheric CO_2 to measured temperature.

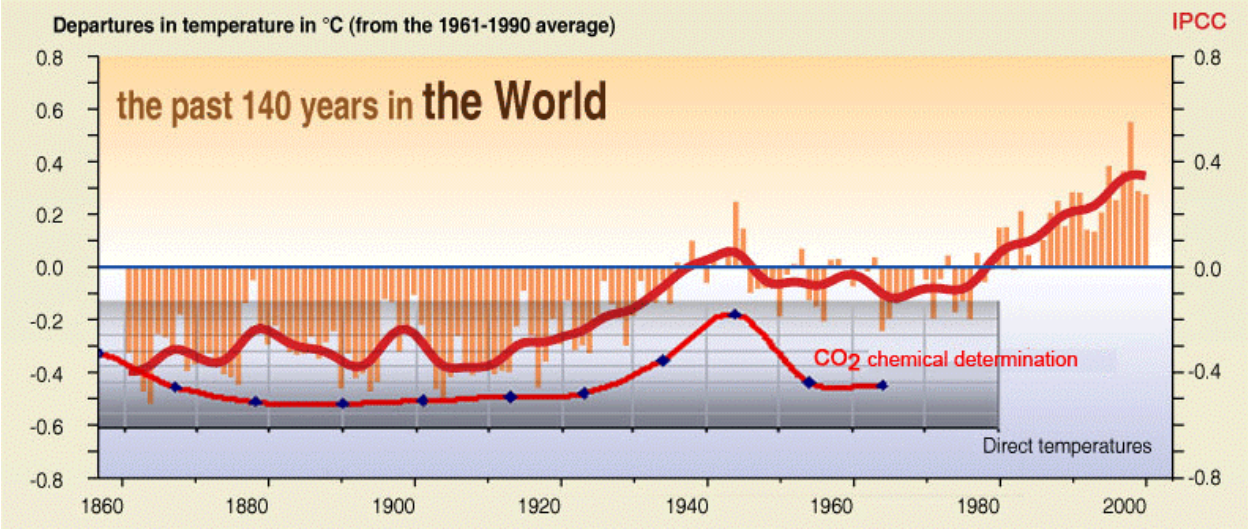


Fig. 8 Global temperature (stations, IPCC 2001) from 1860 and atmospheric CO_2 by chemical analysis The carbon dioxide maximum of 1942 perfectly fits to the measured temperatur maximum at that time. Smaller maxima cannot be seen because of 11 year smoothing.

Using the 5 year average all 8 temperature maximas within 100 years correspond accurate to CO_2-maximas. Temperature data, northern hemisphere, land from GHCN (170), Jones (171), Hansen (172).

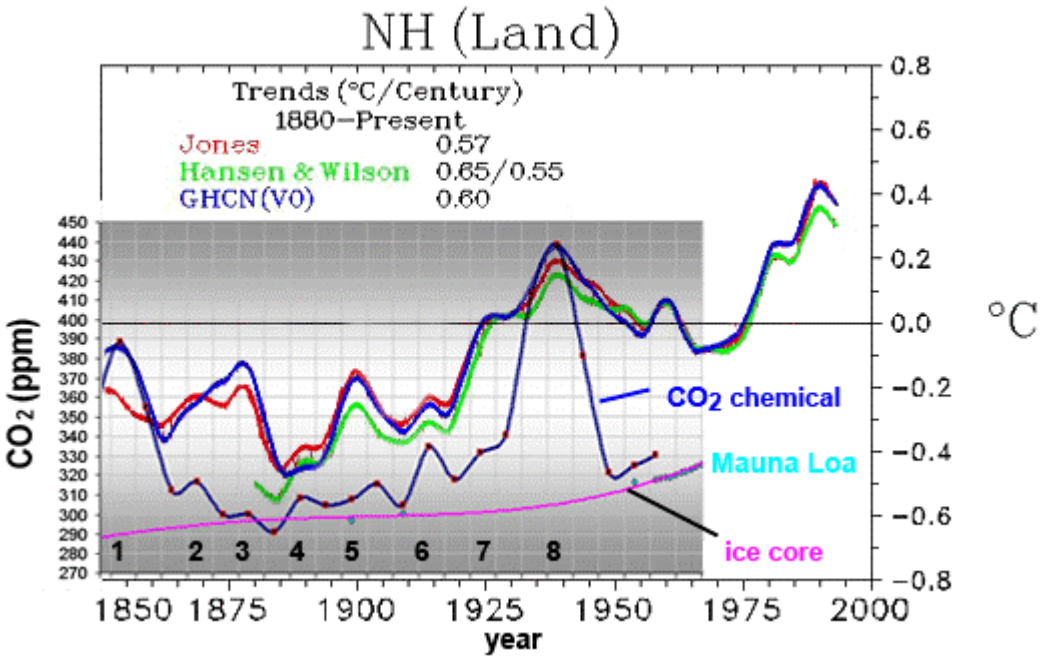


Fig. 9 Comparing measured temperature in northern hemisphere (land) from 1850 (Jones (171), Hansen (172), GHCN(170)) with CO_2 fluctuation. (5 years difference by averaging corrected) The temperature maximum around 1940 is not a result of exponential rise of CO_2. It´s the reverse, high temperature around 1940 had induced CO_2 maximum.

Summary

Accurate chemical CO_2 gas analyses of air over 180 years show a different trend compared to the literature of IPCC climate change actually published. From 1829 the concentration of carbon dioxide of air in the northern hemisphere fell down from a value of e.g. 400 ppm up to 1900 to less than 300 ppm rising till 1942 to more than 400 ppm. After that maximum it fell down to e.g. 350 ppm and rose again till today, 2006 to 380 ppm. Accurate measurements had been done amongst others by de Saussure 1826, Pettenkofer/v.Gilm 1857, Schulze 1864/71, Farsky 1874, Uffelmann 1886, Letts und Blake 1897, Krogh and Haldane 1904, Benedict 1912, Lundegardh 1920, van Slyke 1929, Dürst and Kreutz 1934 alternatively 1940, Misra 1942 or Scholander 1946 with measuring instruments through which from 1857 (Pettenkofer) an accuracy of +/-0,0006 Vol% to under +/-0,0003 Vol% =~3 ppm (Lundegardh 1926) was achieved. These pioneers of chemistry, biology, botany, medicine and physiology constituted the modern knowledge of metabolism, nutrition science, biochemistry and ecology. Modern climatology ignored their work till today even though it is the basis of all textbooks of the mentioned faculties and was honoured with several Nobel prizes. In total over 90 000 measurements within nearly every year since 180 year gave the following results:

1. There is no constant exponential rising CO_2-concentration since preindustrial times but a variing CO2-content of air following the climate. E.G. around 1940 there was a maximum of CO_2 of at least 420 ppm, before 1875 there was also a maximum.
2. Historical air analysis by chemical means **do not prove** a preindustrial CO_2-concentration of 285 ppm (IPCC),as modern climatology postulates. In contrast the average in the 19th century in northern hemisphere is 321 ppm and in the 20th century 338 ppm.
3. Todays CO_2 value of. 380 ppm, which is considered as threatening has been known several times in the last 200 years, in the 20 th century around 1942 and before 1870 in the 19th century. The maximum CO_2-concentration in the 20th century roses to over 420 pmm in 1942.
4. Accurate measurements of CO_2 air gas contents had been done from 1857 by chemical methods with a systematical error of maximal 3%. These results were ignored reconstructing the CO_2 concentration of air in modern warm period.
5. **Callendar** and **Keeling** were the most important founders of the modern greenhouse theory (IPCC) beside **Arrhenius.** Literature research confirmed that they ignored a big part of available technical papars and selected only a few values to get a validation of their hypothesis of fuel burning induced rise of CO_2 in air. Furthermore these authors discussed and reproduced the few selected historic results by chemical methods in a faulty way and propagated an unfounded view of the quality of these methods, without having dealt with its chemical basis.
6. To reconstruct the modern CO_2 concentration of air icecores from Antarctica had been used. The presented reconstructions are obviously not accurate enough to show the several variations of carbon dioxide in northern hemisphere.