Climate Change: Beyond the Talking Points

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NWS/WRH/SSD


181 THINGS YOU NEED TO KNOW NOW
SUMMER DOUBLE ISSUE
Newsweek

Which of These Is Not Causing Global Warming Today?

A SPORT UTILITY VEHICLES

B RICE FIELDS

C INCREASED SOLAR OUTPUT

BY SHARON BEGLEY AND ANDREW MURR

WHEN 600 CLIMATE SCIENTISTS from 40 countries reported in February that there was, for the first time, "unequivocal" evidence that the world is warming and greater than 90 percent certainty that man-made greenhouse gases have caused most of the warming since 1950, at least one expert demurred. "We're going to see a big debate on it going forward," said Vice President Dick Cheney. By "it," he meant "the extent to which [the warming] is part of a normal cycle versus the extent to which it's caused by man."

There is no denying the intuitive appeal of the idea that climate change is natural. After all, lo[illegible] temperatures can rise or fall by 40 degrees from one day to the next; violent storms can barrel in over the course of only minutes. It's little surprise, then, that many laypeople look at much tinier and subtler changes—the 1 degree Fahrenheit increase in global mean temperature since the 1970s, say—and figure those, too, could well be natural. As for 11 of the 12 hottest years on record occurring in the last 12? Well, everyone has experienced a run of statistics-defying weather. Besides, some signs of climate change are undeniably the work of Mother Nature's whims and not man's "addiction" (as President Bush called it) to fossil fuels, at least in part. For instance, glaciers in East Africa, including Mount Kilimanjaro, began shrinking around 1880—well before the greenhouse effect ramped up. And the 1936 heat wave is still the worst many American cities ever experienced, never mind the (globally) record-setting 1990s. No wonder that, in the NEWSWEEK Poll, only 17 percent of those surveyed correctly absolved a hotter sun of responsibility for recent global warming.

That impression is at odds with the science, however. As the February report from the Intergovernmental Panel on Climate Change concluded, greenhouse gases have caused most of the recent warming. "Without greenhouse gases and other [man-made] forcings," says climatologist Gabriele Hegerl of Duke University, an author of the report, "we cannot really explain the observed climate changes."

[illegible]imatologists did not reach that conclusion lightly. They know full well that climate change can arise from any of three basic causes. One is what they call "internal, natural variability" (a fancy name for "s--t happens," climate-wise). Because there is as much randomness in climate as there is in a roulette wheel, droughts and heat waves and killer storms are to be expected, just like a run of evens or reds in Las Vegas. Around 1880, for instance, atmospheric circulation over the Indian Ocean strengthened in such a way that less rain and snow fell on East Africa, including Kilimanjaro, finds glaciologist Stefan Hastenrath of the University of Wisconsin. No one knows why the circulation changed. But the result of this natu-

GOING LIGHT ON GASOLINE

IF EVERYONE IN THE UNITED STATES STOPPED DRIVING FOR ONE DAY, WE COULD SAVE ABOUT 385 MILLION GALLONS OF GASOLINE. IF EVERYONE IN CHINA—THE MOST POPULOUS COUNTRY IN THE WORLD—DID THE SAME, 39.7 MILLION GALLONS WOULD BE SAVED.

The Future Of Flex-Fuel Lies in Brazil

Want to see the potential of ethanol-fueled transportation? Go to Brazil, where flex-fuel cars (those that run on either ethanol or regular gasoline) make up more than 80 percent of all new car sales. Just since January, Brazilians have bought nearly 700,000 flex-fuel cars, like the Obvio! (below), prompting manufacturers to double the number expected to be built in 2007 to 2.8 million. By 2013, half of Brazil's 30 million cars are expected to be flex-fuel. Brazil isn't the only place where flex-fuel cars are selling. More than a million are on the road in the U.S. The difference is Brazil has the infrastructure and cost incentive to support them. Ethanol is half the price of gas there, and most filling stations are ethanol-ready. It helps that Brazil is the world's leading producer of ethanol, which they make from sugar cane as opposed to corn-based U.S. ethanol. —MATTHEW PHILIPS

TOP TO BOTTOM, LEFT TO RIGHT: JOHN AMIS—AP, SCOTT OLSON—GETTY IMAGES, ZORIAH—WPN, ANUP SHAH—GETTY IMAGES, REUTERS—LANDOV

Outline

- Goals and Background
- The 4th IPCC
  - Changes in human and natural drivers of climate change
  - Observations of climate change
  - Attributing change
  - Projections for future climate change
- Discussion

Goals

- Develop understanding of climate change science
  - Much of NWS focus is on politics and talking points
  - NWS users want access to climate change science and its impact on them
- Survey existing IPCC materials for possible use in NWS climate program
- Add substance to help determine role for NWS in climate change

2500+ SCIENTIFIC EXPERT REVIEWERS
800+ CONTRIBUTING AUTHORS AND
450+ LEAD AUTHORS FROM
130+ COUNTRIES
6 YEARS WORK
1 REPORT

2007

The IPCC 4th Assessment Report is coming out
A picture of climate change
the current state of understanding

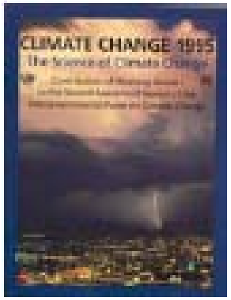
WMO

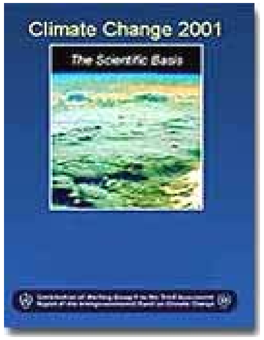
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

UNEP

IPCC Background

- IPCC (The Intergovernmental Panel on Climate Change) is a UN chartered group of leading scientists charged with assessing the state of climate change science and its impacts.
- The IPCC expresses the consensus of many leading scientists
- History:
  - Established in 1988
  - 1st Assessment Report (AR) - 1990
  - 2nd AR - 1995
  - 3rd AR - 2001
  - 4th AR – Released in 2007. This report well represents the state of the science and will be addressed here





Why IPCC?

- Scientific consensus
- User friendly figures
- Accounts for uncertainty
- Accounts for level of scientific understanding
- Assesses changes in scientific understanding
- Not perfect… recommend augmenting with supplemental material – particularly for regional scale issues

(Mis)understanding IPCC

- Real comments from NWS employees regarding 4th AR:
  - “IPCC doesn’t show uncertainty”
  - “It doesn’t use paleo data or put current trends in long term perspective”
  - “It doesn’t cover the spectrum of science available”
- An understanding of the state of climate change science is the critical foundation on which an NWS climate change program should rest
- Many uncertainties exist – particularly in regard to future predictions. But there is much we do know…

THE FLAT EARTH SOCIETY

IPCC WG1 AR4 Report

Please access the Summary for Policymakers (SPM), the Technical Summary (TS), chapters and other material from the following table of links. Links to the Supplementary Material pages are also provided.

Note: A dash in the Supplementary Material column indicates that there is no Supplementary Material for that chapter.

#	Section Title	Section (PDF)	Supplementary Material
	Front Matter	pdf (0.3 MB)	-
	------------------------	------------	--------
	Summary for Policymakers	pdf (2.9 MB)	-
	Technical Summary	pdf (14.8 MB)	-
	Frequently Asked Questions *(extracted from chapters below)*	pdf (10.9 MB)	-
	------------------------	------------	--------
1	Historical Overview of Climate Change Science	pdf (7.4 MB)	-
2	Changes in Atmospheric Constituents and in Radiative Forcing	pdf (8.6 MB)	-
3	Observations: Surface and Atmospheric Climate Change	pdf (22.9 MB)	webpage
4	Observations: Changes in Snow, Ice and Frozen Ground	pdf (6.5 MB)	-
5	Observations: Oceanic Climate Change and Sea Level	pdf (12.9 MB)	-
6	Palaeoclimate	pdf (7.9 MB)	webpage
7	Couplings Between Changes in the Climate System and Biogeochemistry	pdf (8.5 MB)	-
8	Climate Models and their Evaluation	pdf (6.4 MB)	webpage
9	Understanding and Attributing Climate Change	pdf (5.6 MB)	webpage
10	Global Climate Projections	pdf (18.3 MB)	webpage
11	Regional Climate Projections	pdf (11.5 MB)	webpage
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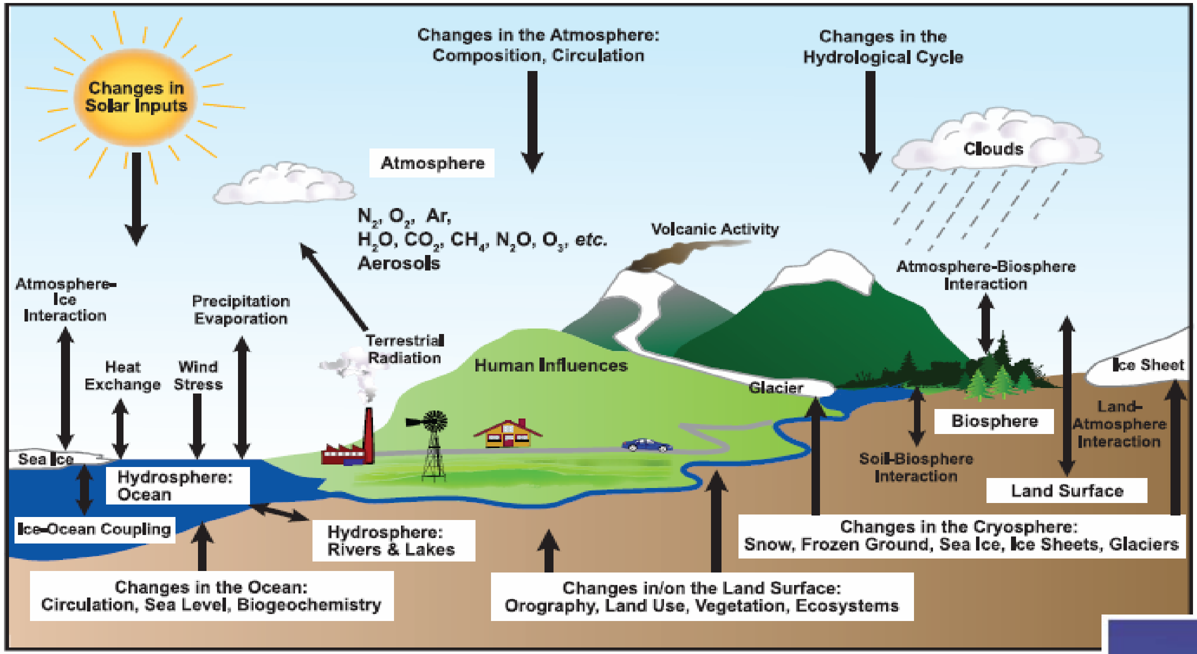
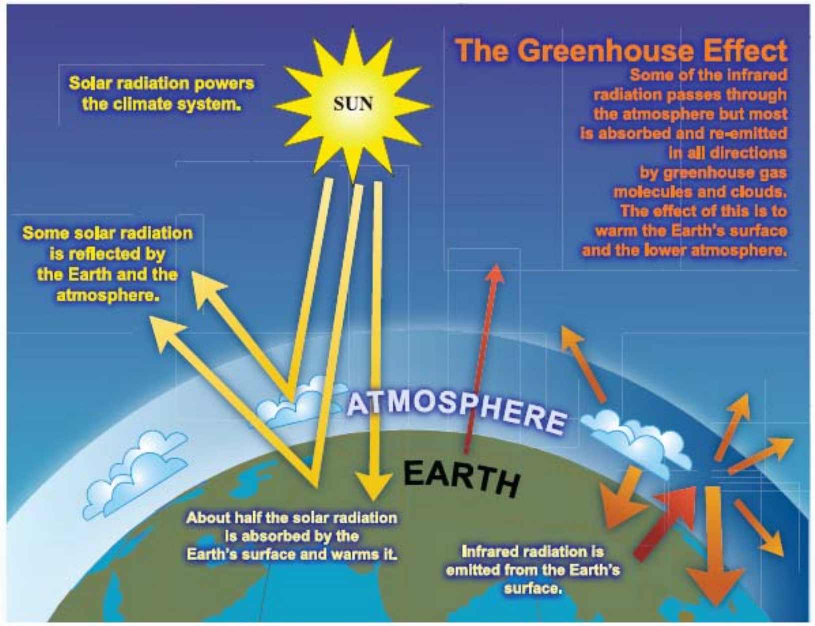
IPCC 4th AR WG1

- Changes in human and natural drivers of climate change
- Observations of climate change
- Attributing change
- Projections for future climate change

TS.2 Changes in Human and Natural Drivers of Climate Change

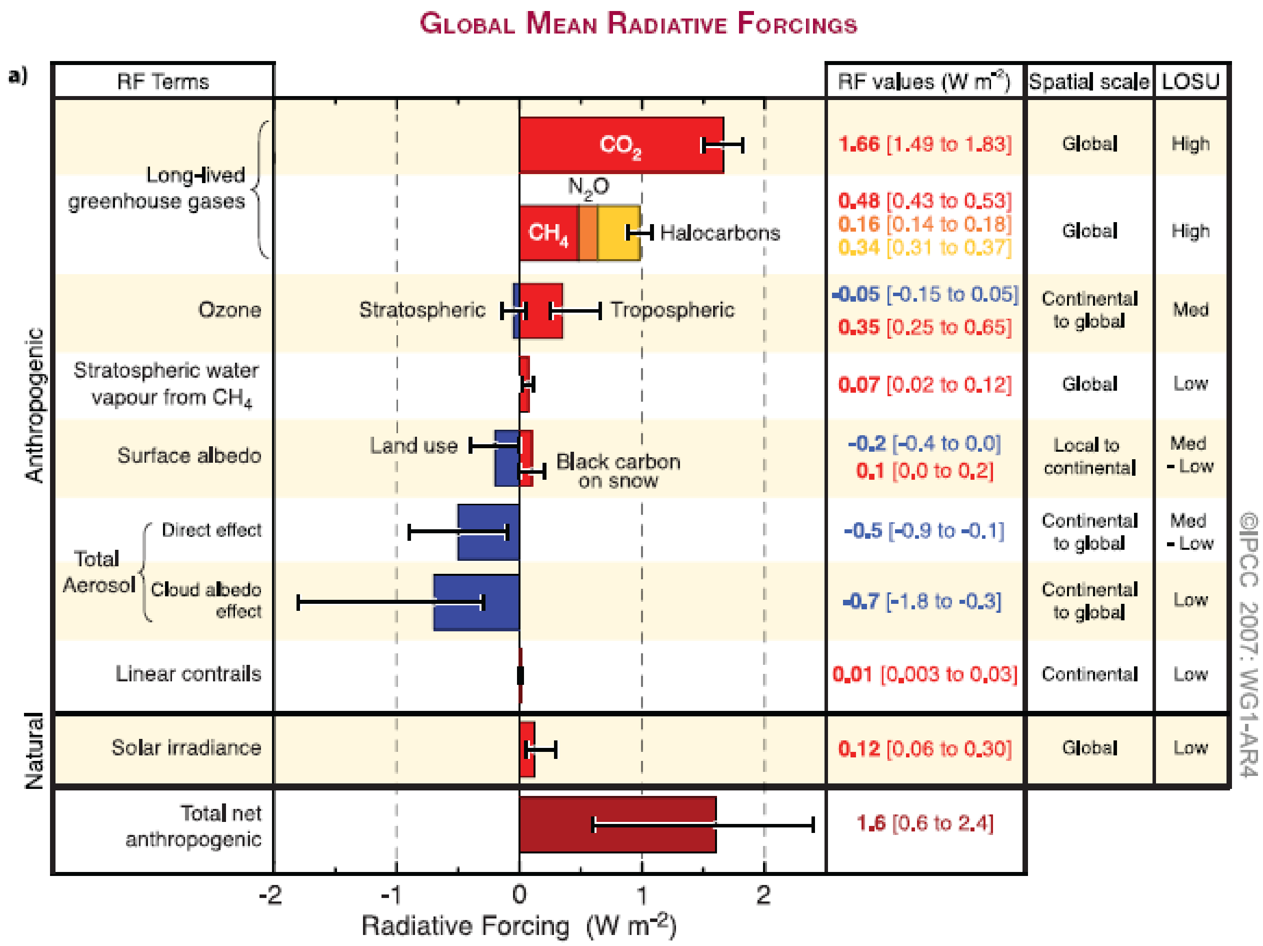




TS.2 Changes in Human and Natural Drivers of Climate Change

Drivers are measured according to their radiative forcing (W/m^2)

Positive changes indicate more net energy at Earth's suface



Greenhouse Gases

- Greenhouse gases – led by CO_2 - are leading contributers to climate change drivers
- Long lived gases – chemically stable and persist in atmosphere for decades to centuries:
  - Carbon Dioxide (+1.66 +/- 0.17 W/m^2)
  - Methane (+0.48 +/- 0.05 W/m^2)
  - Nitrous oxide (+0.16 +/- 0.02 W/m^2)
- Short lived gases – chemically reactive and removed by precipitation or natural oxidation for example.

Changes in Greenhouse Gases from Ice Core and Modern Data

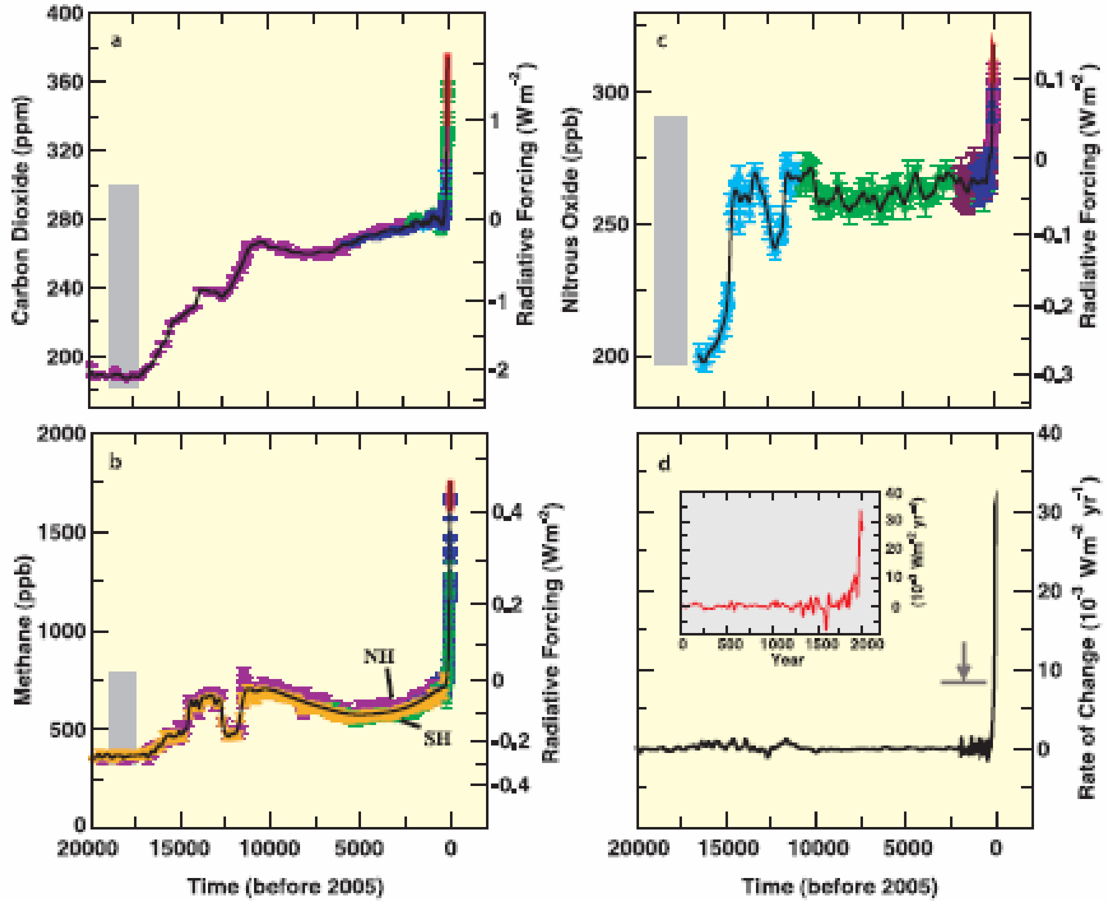
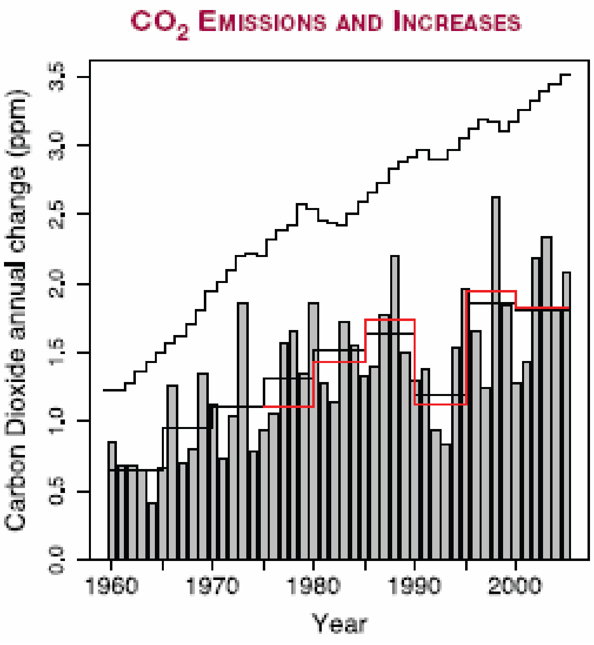


Figure TS.2. *The concentrations and radiative forcing by (a) carbon dioxide (CO_2), (b) methane (CH_4), (c) nitrous oxide (N_2O) and (d) the rate of change in their combined radiative forcing over the last 20,000 years reconstructed from antarctic and Greenland ice and firn data (symbols) and direct atmospheric measurements (panels a,b,c, red lines). The grey bars show the reconstructed ranges of natural variability for the past 650,000 years. The rate of change in radiative forcing (panel d, black line) has been computed from spline fits to the concentration data. The width of the age spread in the ice data varies from about 20 years for sites with a high accumulation of snow such as Law Dome, Antarctica, to about 200 years for low-accumulation sites such as Dome C, Antarctica. The arrow shows the peak in the rate of change in radiative forcing that would result if the anthropogenic signals of CO_2, CH_4, and N_2O had been smoothed corresponding to conditions at the low-accumulation Dome C site. The negative rate of change in forcing around 1600 shown in the higher-resolution inset in panel d results from a CO_2 decrease of about 10 ppm in the Law Dome record. (Figure 6.4)*

Carbon Dioxide

- Dominates radiative forcing agents – 20% increase in radiative forcing from 1995 to 2005 alone.
- Increased from pre-industrial 280 ppm to about 379 ppm in 2005
- “Multiple lines of evidence confirm that the post-industrial rise in these gases does not stem from natural mechanisms.”
- It is “very likely the rate of increase over the period since 1750 are unprecedented in more than 10,000 years.”
- Uptake by biosphere and oceans typically removes 30% of co2 within 30 years and another 30% over a few centuries.



Other Greenhouse Gases

- Methane
  - At 1774 ppb (2005) is more than double pre-industrial value
  - Growth rates are decreasing since 1993 (concentration still increasing though) suggesting atmosphere is approaching steady state with anthropogenic emissions
  - Atmospheric methane is mostly antropogenic from rice agriculture, biomass burning, etc.
- Nitrous Oxide
  - 18% higher than pre-industrial levels

Halocarbons & Ozone

- CPCs and hydrochlorofluorocarbons (HCFCs) emissions decreasing under Montreal Protocol. CFC-11 and CFC-113 concentrations now decreasing
- +0.32 +/- 0.03 W/m2
- Stratospheric ozone still 4% below pre 1980 values – not clear if recovery has begun due to Montreal Protocols
- Tropospheric ozone
  - Radiative forcing +0.35 (+0.25 - +0.65) W/m2
  - Short lived gas formed from carbon monoxide and nitrogen oxides
- Direct anthropogenic water vapor emissions of negligible impact

Aerosols

- Total direct aerosol radiative forcing is -0.5 +/- 0.4 W/m2
  - Major advance since previous IPCC
  - Sulphate (-0.4 - +0.2)
  - Fossil Fuel organic carbon
- Indirect RF due to cloud albedo effect is -0.7 (-0.3 - -1.8) W/m2
  - First estimate and most uncertain RF term
- Medium-low level of scientific understanding

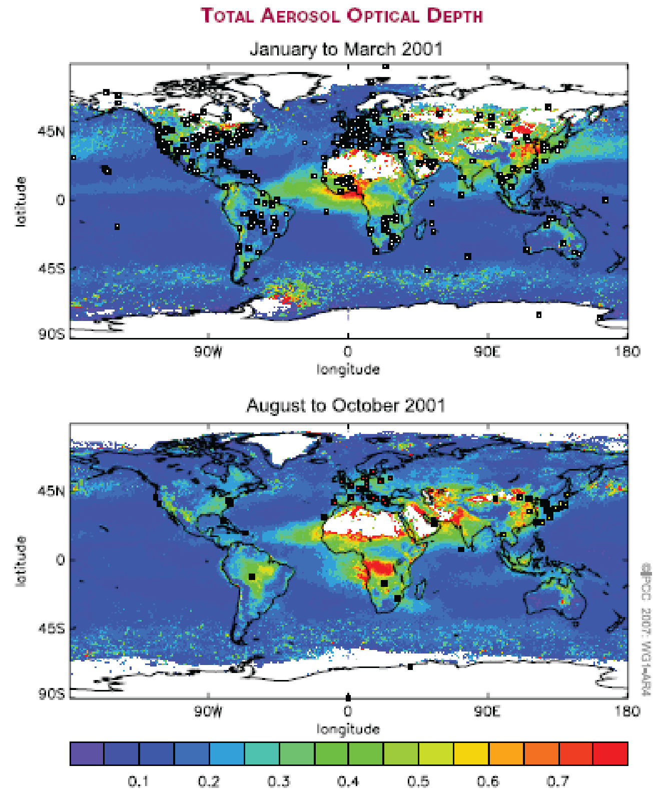


Figure TS.4. *(Top) The total aerosol optical depth (due to natural plus anthropogenic aerosols) at a mid-visible wavelength determined by satellite measurements for January to March 2001 and (bottom) August to October 2001, illustrating seasonal changes in industrial and biomass-burning aerosols. Data are from satellite measurements, complemented by two different kinds of ground-based measurements at locations shown in the two panels (see Section 2.4.2 for details). (Figure 2.11)*

Contrails and Land Use

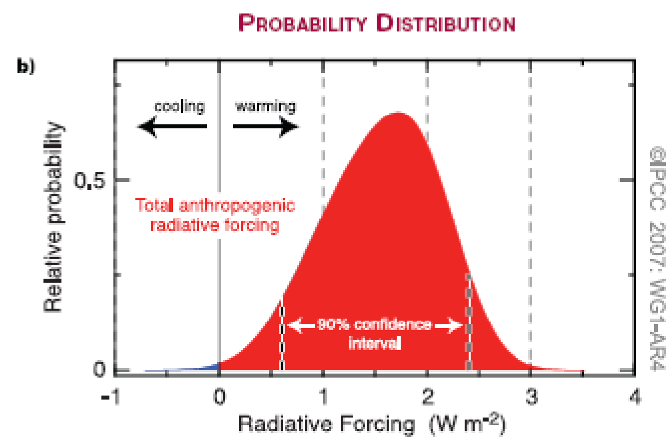
- Contrails from global aviation are not well understood but likely insignificant (< 0.03 W/m2)
- Human induced changes in land cover have increased global surface albedo
  - RF is -0.2 +/- 0.2 W/m2
- Land use change is locally significant but small at global scale in comparison with greenhouse gas warming
- Heat from anthropogenic energy production may be significant in urban areas; insignificant globally

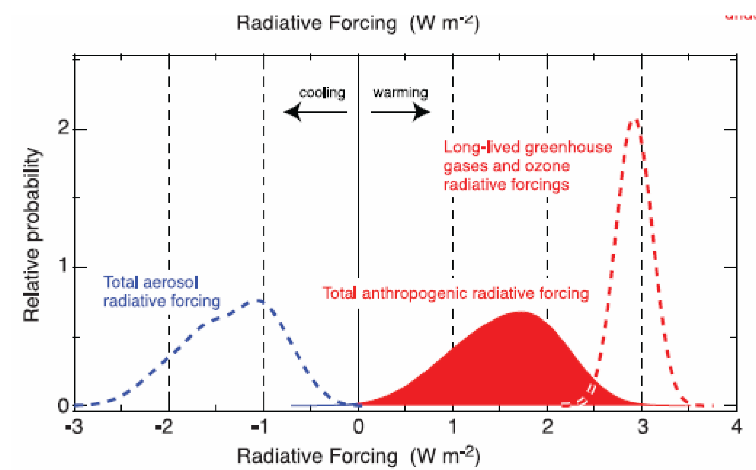
Solar and Volcanic Activity

- 11 year cycle in solar irradiance well documented
  - 0.08% variation in solar input
- Change in solar output since 1750 is +0.12 W/m2.
- Volcanoes can strongly increase stratospheric sulphate and cool global mean climate for a few years
  - Last major eruption was Pinatubo in 1991
  - (side comment: Volcanoes remain largely unpredictable)

Net global radiative forcing

- **MAJOR POINT: Very high confidence that the effect of human activities since 1750 has been a net forcing of +1.6 (+0.6 - +2.4) W/m2**
  - Improved scientific understanding since previous IPCC makes this estimate possible for the first time





TS.3 Observations of Changes in Climate

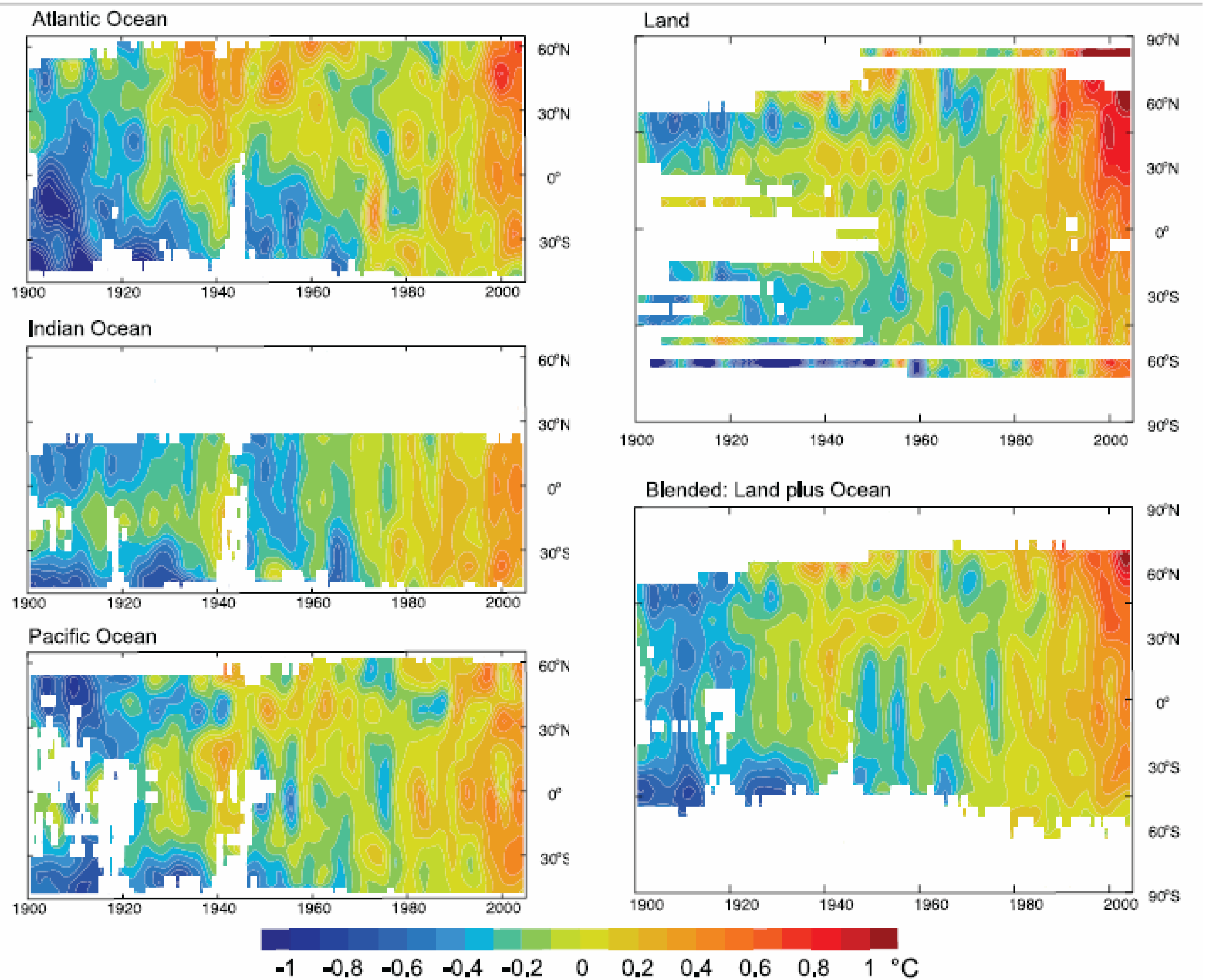


Figure 3.5. *Latitude-time sections of zonal mean temperature anomalies (°C) from 1900 to 2005, relative to the 1961 to 1990 mean. Left panels: SST annual anomalies across each ocean from HadSST2 (Rayner et al., 2006). Right panels: Surface temperature annual anomalies for land (top, CRUTEM3) and land plus ocean (bottom, HadCRUT3). Values are smoothed with the 5-point filter to remove fluctuations of less than about six years (see Appendix 3.A);* ***and white areas indicate missing data.***

Global Temperature

- 2005 and 1998 are warmest two years on record since 1850
- 11 of last 12 years rank in the 12 warmest years on record since 1850
- Effects of urbanization and land use is negligible on global temperatures
- New satellite and radiosonde measurements show consistent warming with each other and surface temperature record - previously there were unaccounted for discrepencies

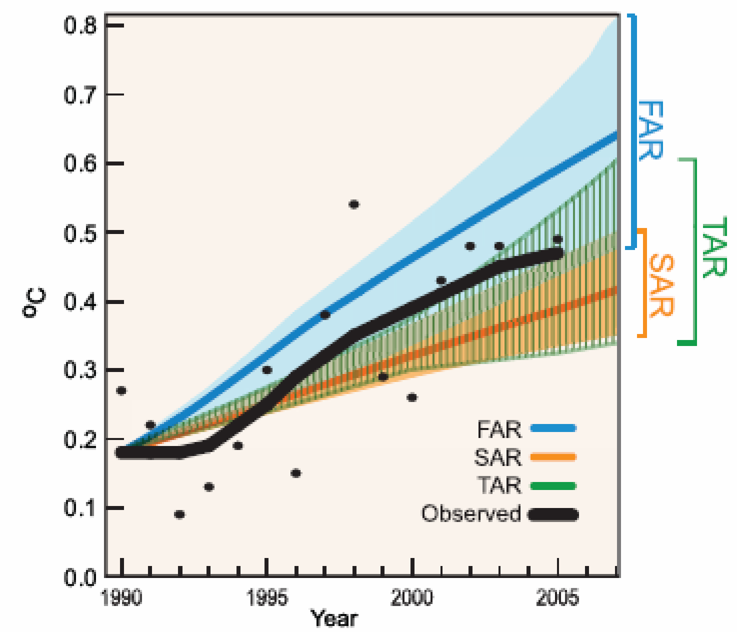


Figure 1.1. *Yearly global average surface temperature (Brohan et al., 2006), relative to the mean 1961 to 1990 values, and as projected in the FAR (IPCC, 1990), SAR (IPCC, 1996) and TAR (IPCC, 2001a). The 'best estimate' model projections from the FAR and SAR are in solid lines with their range of estimated projections shown by the shaded areas. The TAR did not have 'best estimate' model projections but rather a range of projections. Annual mean observations (Section 3.2) are depicted by black circles and the thick black line shows decadal variations obtained by smoothing the time series using a 13-point filter.*

Global Temperature Trends

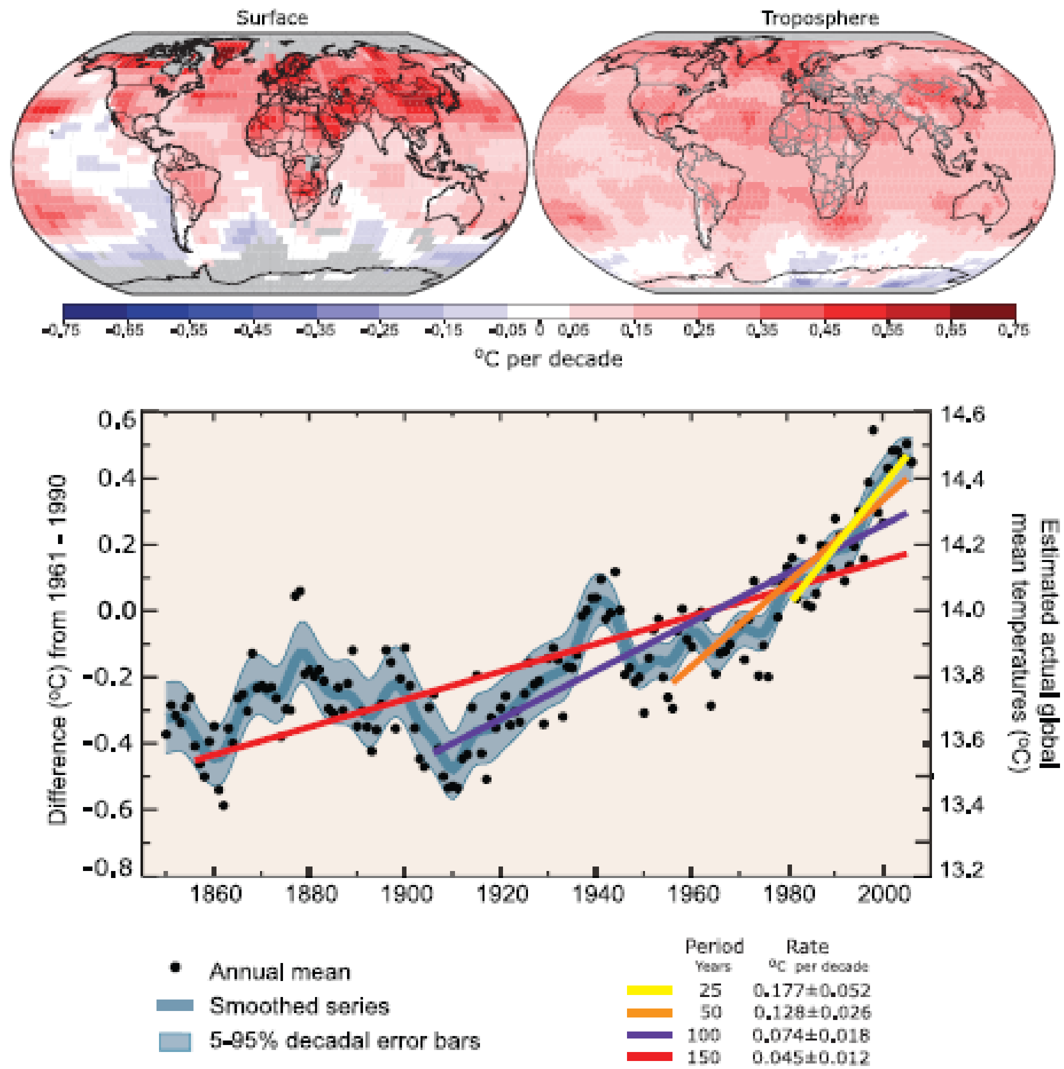


Figure TS.6. *(Top) Patterns of linear global temperature trends over the period 1979 to 2005 estimated at the surface (left), and for the troposphere from satellite records (right). Grey indicates areas with incomplete data. (Bottom) Annual global mean temperatures (black dots) with linear fits to the data. The left hand axis shows temperature anomalies relative to the 1961 to 1990 average and the right hand axis shows estimated actual temperatures, both in °C. Linear trends are shown for the last 25 (yellow), 50 (orange), 100 (magenta) and 150 years (red). The smooth blue curve shows decadal variations (see Appendix 3.A), with the decadal 90% error range shown as a pale blue band about that line. The total temperature increase from the period 1850 to 1899 to the period 2001 to 2005 is 0.76°C ± 0.19°C.*

Spatial distribution

- Land warming faster than ocean over past two decades (0.27 C vs 0.13 C)
- Warming is widespread and greatest in higher northern latitutes
- Poleward shift and strengthing of westerly winds supported by some studies
- Climate variability strong player for regional climate changes
- Changes in extreme temperature (e.g. tails of monthly and daily distributions) consistent with warming
- Heat waves have increased?
- Insufficient evidence to determining trends in tornadoes, hail, lightning, and dust storms

Changes in water cycle

- Long term trends in precipitation amounts from 1900 to 2005
- Substantial increases in heavy precipitation events have been observed – likely but not definite
- Tropical cyclones – reference page 41

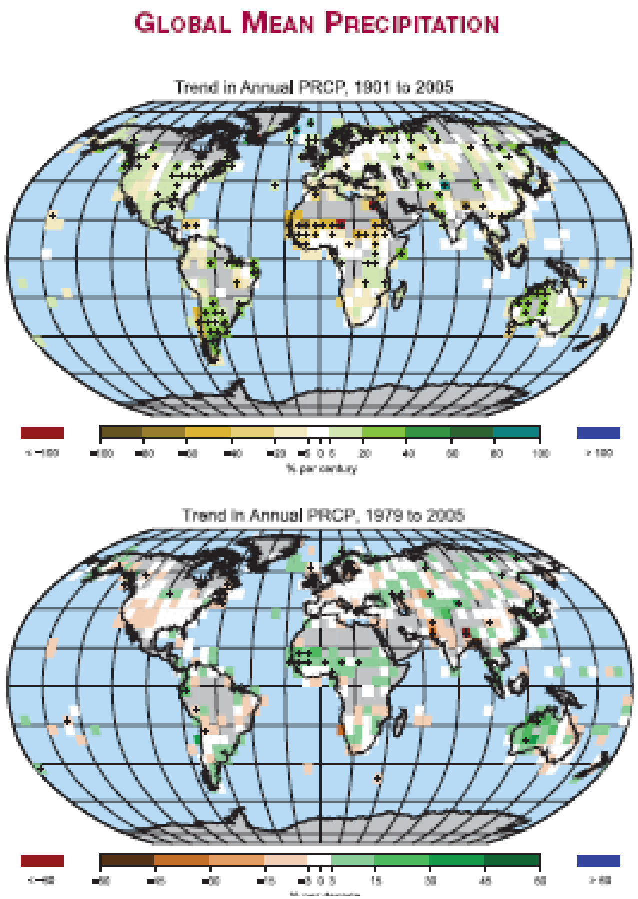
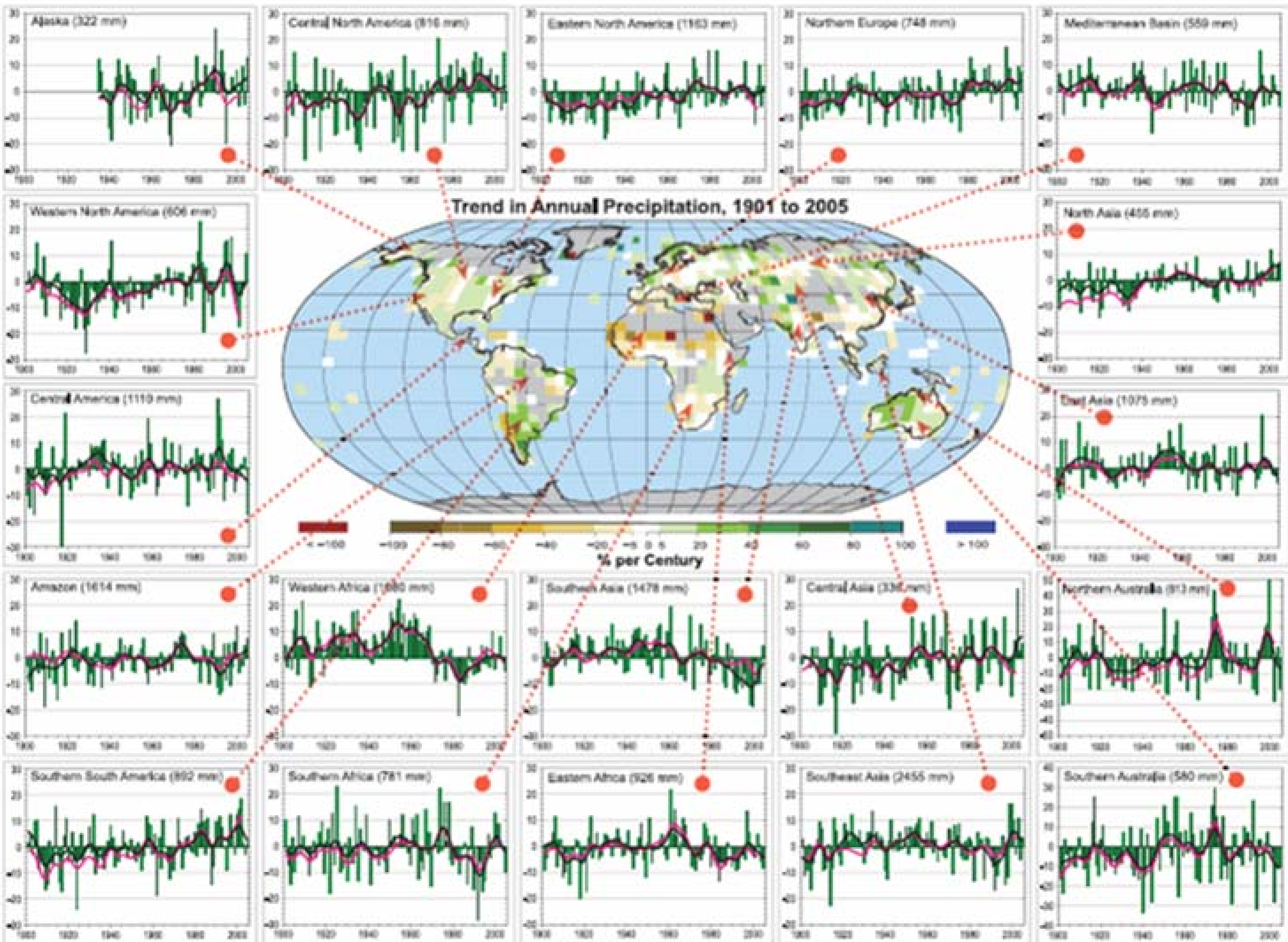


Figure 3.14. *Precipitation for 1900 to 2005. The central map shows the annual mean trends (% per century). Areas in grey have insufficient data to produce reliable trends. The surrounding time series of annual precipitation displayed (% of mean, with the mean given at top for 1961 to 1990) are for the named regions as indicated by the red arrows. The GHCN precipitation from NCDC was used for the annual green bars and black for decadal variations (see Appendix 3.A), and for comparison the CRU decadal variations are in magenta. The range is +30 to –30% except for the two Australian panels. The regions are a subset of those defined in Table 11.1 (Section 11.1) and include: Central North America, Western North America, Alaska, Central America, Eastern North America, Mediterranean, Northern Europe, North Asia, East Asia, Central Asia, Southeast Asia, Southern Asia, Northern Australia, Southern Australia, Eastern Africa, Western Africa, Southern Africa, Southern South America, and the Amazon.*



Con't

- More intense and longer droughts have been observed over wider areas, particularly in the tropics and subtropics since the 1970s

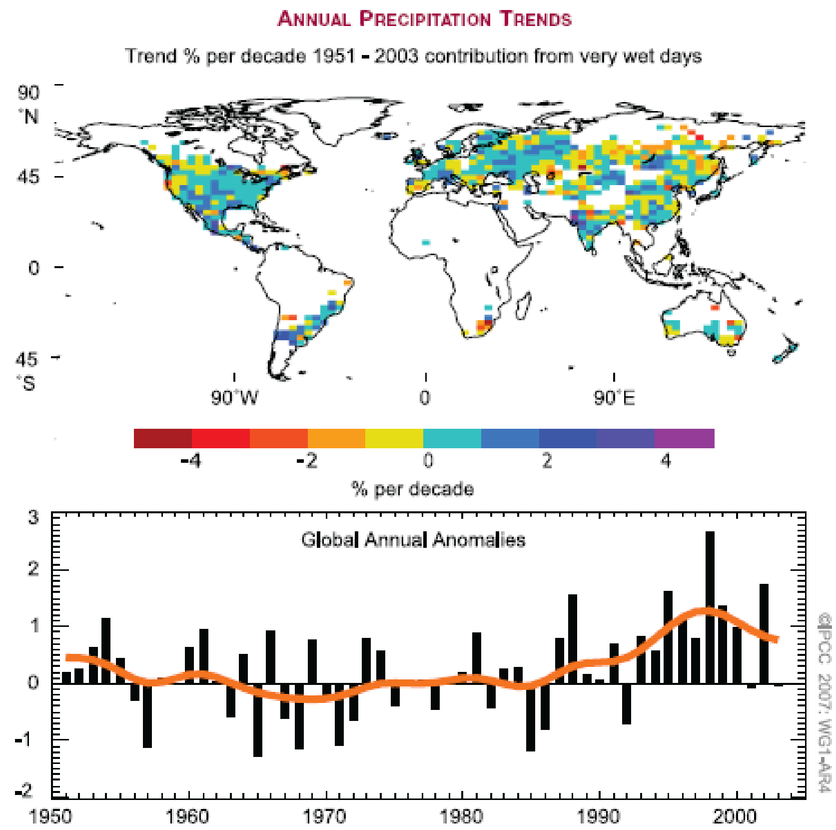
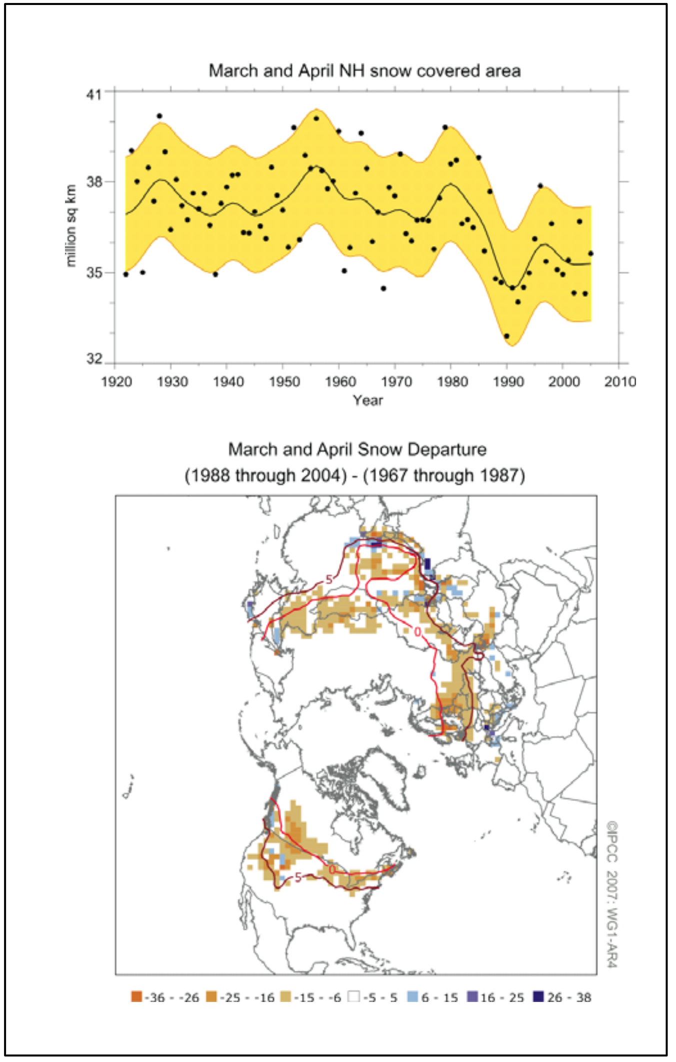


Figure TS.10. *(Top) Observed trends (% per decade) over the period 1951 to 2003 in the contribution to total annual precipitation from very wet days (i.e., corresponding to the 95th percentile and above). White land areas have insufficient data for trend determination. (Bottom) Anomalies (%) of the global (regions with data shown in top panel) annual time series of very wet days (with respect to 1961–1990) defined as the percentage change from the base period average (22.5%). The smooth orange curve shows decadal variations (see Appendix 3.A). (Figure 3.39)*

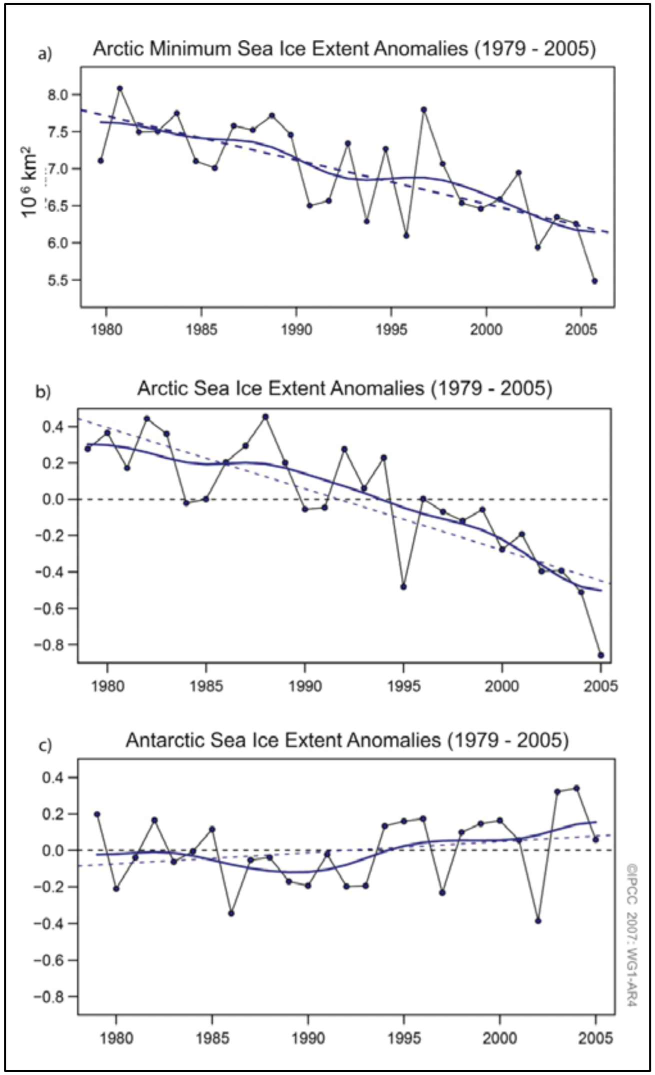
Cyrosphere

- NH Snow cover mostly decreasing – particularly in spring
- NH Mountain snow pack at marginal elevations can be particularly sensitive to small temperature changes
- NH Break-up becoming earlier at 6.5 +/- 1.4 days per century; freeze-up later at 5.8 +/- 1.9 days per century



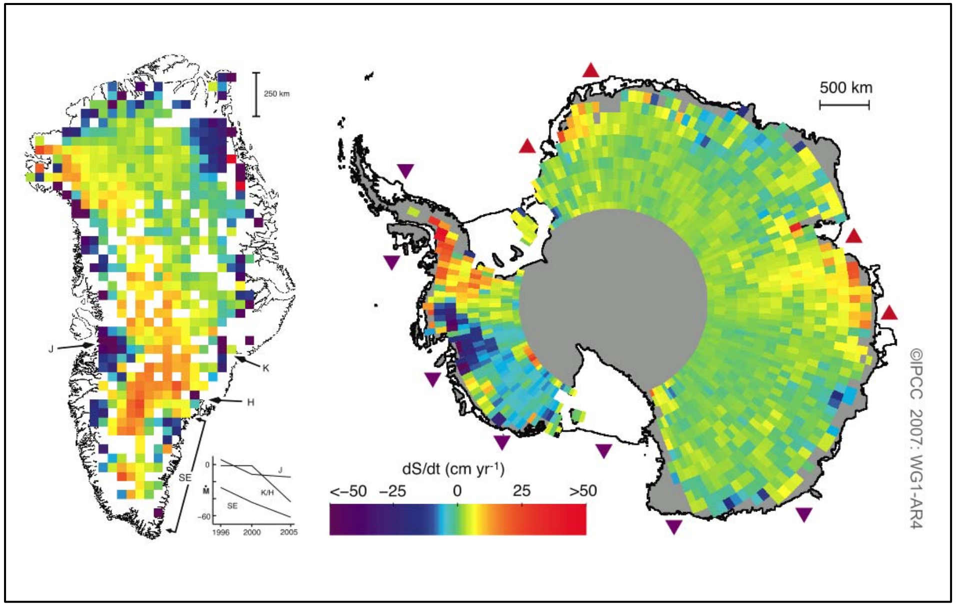
Cryosphere (con't)

- Sea Ice - Arctic sea ice extent shrinking by 2.7 +/- 0.6% per decade (no significant change in Antarctic extent)
- Glaciers – Mass loss of glaciers and ice caps likely has been a response to post-1970 warming



Cryosphere (con’t)

- Ice sheets – Very likely Greenland ice sheet shrunk from 1993-2003. Pre 1993 changes in ice sheets are not well established
  - Greenland shrinkage at -50 to -100 Gt per year
  - Antarctic change at +100 Gt per year to -200 Gt per year



Cryosphere Summary

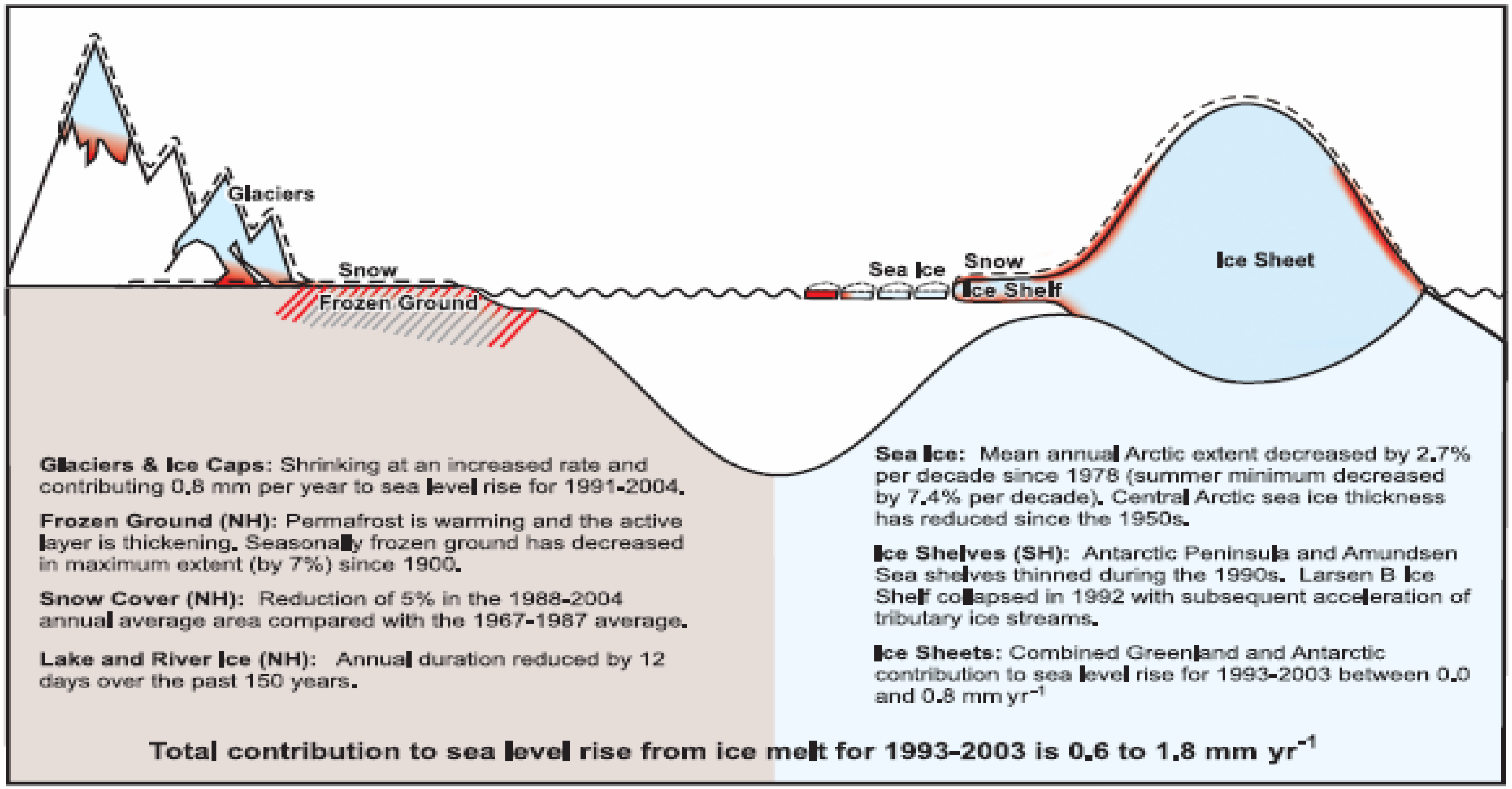


Figure 4.23. *Summary of observed variations in the cryosphere.*

Ocean

- World ocean has warmed since 1955, accounting for > 80% of the changes in the energy content of the Earth's system
- Ocean becoming more acidic – average decrease in pH of 0.1
- Salinity changing

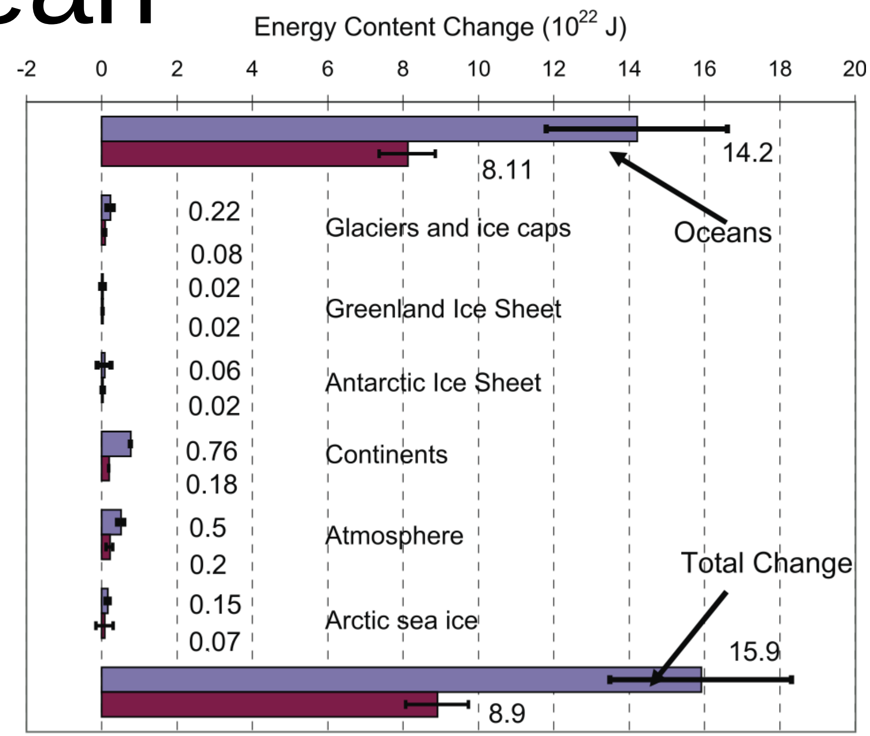


Figure TS.15. *Energy content changes in different components of the Earth system for two periods (1961–2003 and 1993–2003). Blue bars are for 1961 to 2003; burgundy bars are for 1993 to 2003. Positive energy content change means an increase in stored energy (i.e., heat content in oceans, latent heat from reduced ice or sea ice volumes, heat content in the continents excluding latent heat from permafrost changes, and latent and sensible heat and potential and kinetic energy in the atmosphere). All error estimates are 90% confidence intervals. No estimate of confidence is available for the continental heat gain. Some of the results have been scaled from published results for the two respective periods. {Figure 5.4}*

Ocean

- Average sea level rise in 1961-2003 is 1.8 +/- 0.5 mm/yr
  - Thermal expansion – 0.42 +/- 0.12 mm/yr
  - Ice melt – 0.7 +/- 0.5 mm/yr
  - Note discrepancy
- 1993-2003 rise is 3.1 +/- 0.7 mm/yr
  - High confidence sea level rise is accelerating

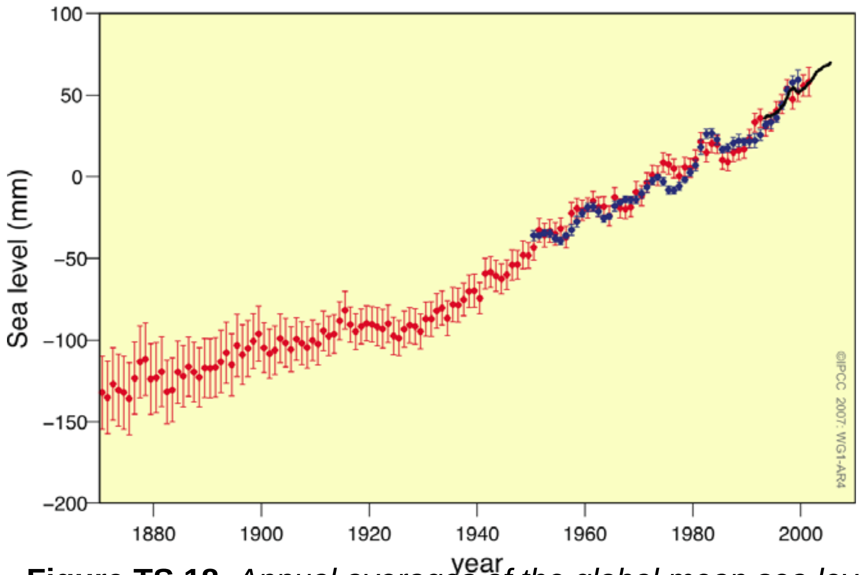


Figure TS.18. *Annual averages of the global mean sea level based on reconstructed sea level fields since 1870 (red), tide gauge measurements since 1950 (blue) and satellite altimetry since 1992 (black). Units are in mm relative to the average for 1961 to 1990. Error bars are 90% confidence intervals. {Figure 5.13}*

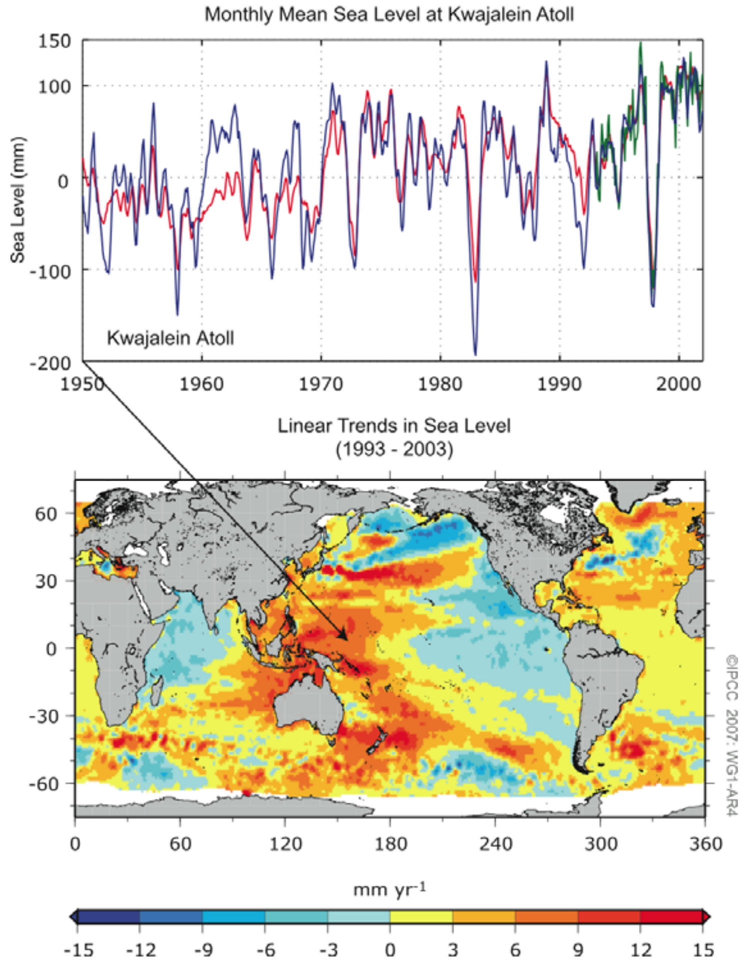
Ocean

	Sea Level Rise ($mm\ yr^{-1}$)			
	1961–2003		1993–2003	
Sources of Sea Level Rise	Observed	Modelled	Observed	Modelled
Thermal expansion	0.42 ± 0.12	0.5 ± 0.2	1.6 ± 0.5	1.5 ± 0.7
Glaciers and ice caps	0.50 ± 0.18	0.5 ± 0.2	0.77 ± 0.22	0.7 ± 0.3
Greenland Ice Sheet	0.05 ± 0.12[a]		0.21 ± 0.07[a]	
Antarctic Ice Sheet	0.14 ± 0.41[a]		0.21 ± 0.35[a]	
Sum of individual climate contributions to sea level rise	1.1 ± 0.5	1.2 ± 0.5	2.8 ± 0.7	2.6 ± 0.8
Observed total sea level rise	1.8 ± 0.5 (tide gauges)		3.1 ± 0.7 (satellite altimeter)	
Difference (Observed total minus the sum of observed climate contributions)	0.7 ± 0.7		0.3 ± 1.0	

Notes:

Ocean

- Satellite observations show spatial distribution of sea level changes
- Observations suggest extreme high water events have increased since 1975
- Box TS.4 Sea Level
  - Sea level 100m lower during last ice age
  - Warmer climates may produce more snow over Greenland and Antarctica which could partially offset increased melt. This is not well understood



Consistency among observations

- “Changes in the atmosphere, cyrosphere, and ocean show unequivocally that the world is warming.”
- “The warming of the climate is consistent with observed increases in the number of daily warm extremes, reductions in the number of daily cold extremes and reductions in the number of frost days at mid-latitudes.”

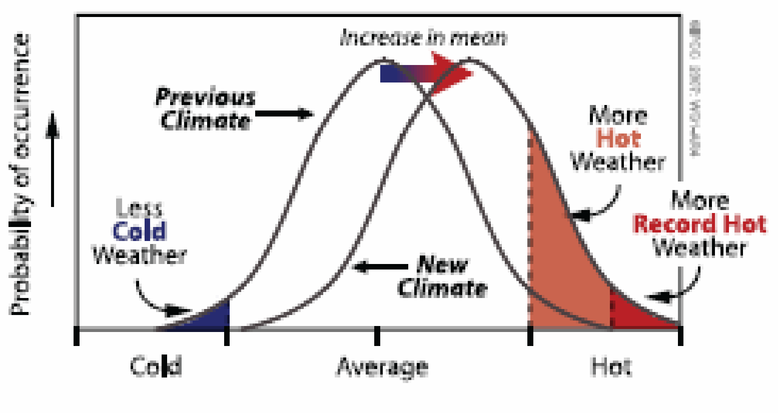


Table TS.4. *Recent trends, assessment of human influence on trends, and projections of extreme weather and climate events for which there is evidence of an observed late 20th-century trend. An asterisk in the column headed 'D' indicates that formal detection and attribution studies were used, along with expert judgement, to assess the likelihood of a discernible human influence. Where this is not available, assessments of likelihood of human influence are based on attribution results for changes in the mean of a variable or changes in physically related variables and/or on the qualitative similarity of observed and simulated changes, combined with expert judgement. {3.8, 5.5, 9.7, 11.2–11.9; Tables 3.7, 3.8, 9.4}*

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	D	Likelihood of future trend based on projections for 21st century using SRES[b] scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[e]	*	*Virtually certain*[e]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[d]	*Likely* (nights)[e]	*	*Virtually certain*[e]
Warm spells / heat waves: Frequency increases over most land areas	*Likely*	*More likely than not*		*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*		*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*		*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[f]	*Likely*	*More likely than not*[g]		*Likely*[h]

Notes:

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

[b] SRES refers to the IPCC Special Report on Emission Scenarios. The SRES scenario families and illustrative cases are summarised in a box at the end of the Summary for Policymakers.

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

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

[e] Warming of the most extreme days/nights each year

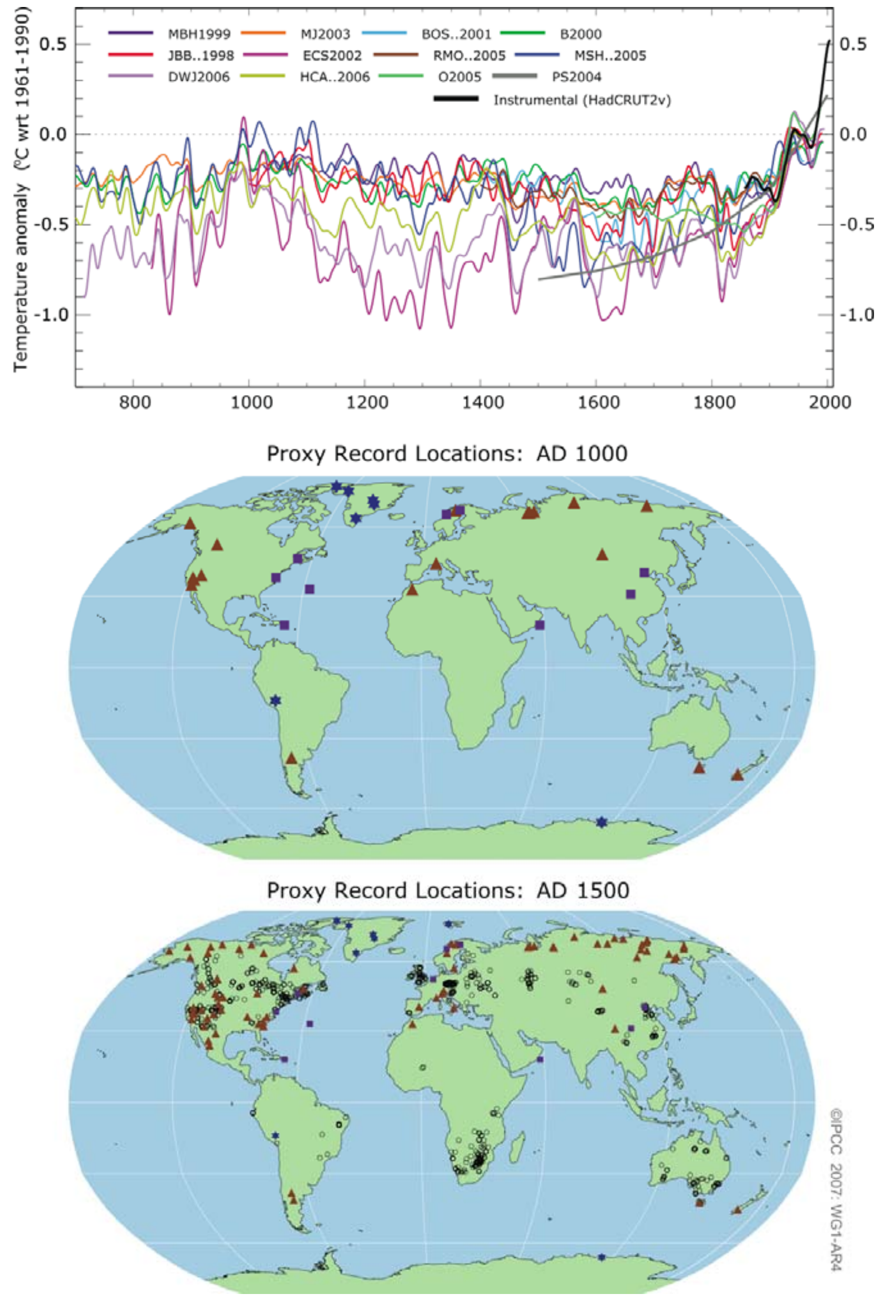
[f] Extreme high sea level depends on average sea level and on regional weather systems. It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.

[g] Changes in observed extreme high sea level closely follow the changes in average sea level {5.5.2.6}. It is *very likely* that anthropogenic activity contributed to a rise in average sea level. {9.5.2}

[h] 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.

Paleoclimatic Perspective

- Very likely that the average 1950-2000 NH temperatures were warmer than any other 50 year period since 1500 and likely warmest since 700AD.
- Orbital forcings and their relationship to ice ages are well understood (box TS.6)
  - Current climate models adequately simulate the last ice age (21000 years ago)
  - Models can separate this natural variability from the more recent warming



Frequently Asked Question 6.2

Is the Current Climate Change Unusual Compared to Earlier Changes in Earth's History?

Climate has changed on all time scales throughout Earth's history. Some aspects of the current climate change are not unusual, but others are. The concentration of CO_2 in the atmosphere has reached a record high relative to more than the past half-million years, and has done so at an exceptionally fast rate. Current global temperatures are warmer than they have ever been during at least the past five centuries, probably even for more than a millennium. If warming continues unabated, the resulting climate change within this century would be extremely unusual in geological terms. Another unusual aspect of recent climate change is its cause: past climate changes were natural in origin (see FAQ 6.1), whereas most of the warming of the past 50 years is attributable to human activities.

When comparing the current climate change to earlier, natural ones, three distinctions must be made. First, it must be clear which variable is being compared: is it greenhouse gas concentration or temperature (or some other climate parameter), and is it their absolute value or their rate of change? Second, local changes must not be confused with global changes. Local climate changes are often much larger than global ones, since local factors (e.g., changes in oceanic or atmospheric circulation) can shift the delivery of heat or moisture from one place to another and local feedbacks operate (e.g., sea ice feedback). Large changes in global mean temperature, in contrast, require some global forcing (such as a change in greenhouse gas concentration or solar activity). Third, it is necessary to distinguish between time scales. Climate changes over millions of years can be much larger and have different causes (e.g., continental drift) compared to climate changes on a centennial time scale.

The main reason for the current concern about climate change is the rise in atmospheric carbon dioxide (CO_2) concentration (and some other greenhouse gases), which is very unusual for the Quaternary (about the last two million years). The concentration of CO_2 is now known accurately for the past 650,000 years from antarctic ice cores. During this time, CO_2 concentration varied between a low of 180 ppm during cold glacial times and a high of 300 ppm during warm interglacials. Over the past century, it rapidly increased well out of this range, and is now 379 ppm (see Chapter 2). For comparison, the approximately 80-ppm rise in CO_2 concentration at the end of the past ice ages generally took over 5,000 years. Higher values than at present have only occurred many millions of years ago (see FAQ 6.1).

Temperature is a more difficult variable to reconstruct than CO_2 (a globally well-mixed gas), as it does not have the same value all over the globe, so that a single record (e.g., an ice core) is only of limited value. Local temperature fluctuations, even those over just a few decades, can be several degrees celsius, which is larger than the global warming signal of the past century of about 0.7°C.

More meaningful for global changes is an analysis of large-scale (global or hemispheric) averages, where much of the local variation averages out and variability is smaller. Sufficient coverage of instrumental records goes back only about 150 years. Further back in time, compilations of proxy data from tree rings, ice cores, etc., go back more than a thousand years with decreasing spatial coverage for earlier periods (see Section 6.5). While there are differences among those reconstructions and significant uncertainties remain, all published reconstructions find that temperatures were warm during medieval times, cooled to low values in the 17th, 18th and 19th centuries, and warmed rapidly after that. The medieval level of warmth is uncertain, but may have been reached again in the mid-20th century, only to have likely been exceeded since then. These conclusions are supported by climate modelling as well. Before 2,000 years ago, temperature variations have not been systematically compiled into large-scale averages, but they do not provide evidence for warmer-than-present global annual mean temperatures going back through the Holocene (the last 11,600 years; see Section 6.4). There are strong indications that a warmer climate, with greatly reduced global ice cover and higher sea level, prevailed until around 3 million years ago. Hence, current warmth appears unusual in the context of the past millennia, but not unusual on longer time scales for which changes in tectonic activity (which can drive natural, slow variations in greenhouse gas concentration) become relevant (see Box 6.1).

A different matter is the current rate of warming. Are more rapid global climate changes recorded in proxy data? The largest temperature changes of the past million years are the glacial cycles, during which the global mean temperature changed by 4°C to 7°C between ice ages and warm interglacial periods (local changes were much larger, for example near the continental ice sheets). However, the data indicate that the global warming at the end of an ice age was a gradual process taking about 5,000 years (see Section 6.3). It is thus clear that the current rate of global climate change is much more rapid and very unusual in the context of past changes. The much-discussed abrupt climate shifts during glacial times (see Section 6.3) are not counter-examples, since they were probably due to changes in ocean heat transport, which would be unlikely to affect the global mean temperature.

Further back in time, beyond ice core data, the time resolution of sediment cores and other archives does not resolve changes as rapid as the present warming. Hence, although large climate changes have occurred in the past, there is no evidence that these took place at a faster rate than present warming. If projections of approximately 5°C warming in this century (the upper end of the range) are realised, then the Earth will have experienced about the same amount of global mean warming as it did at the end of the last ice age; there is no evidence that this rate of possible future global change was matched by any comparable global temperature increase of the last 50 million years.

Next up…

- TS.4 – Understanding and attributing climate change
- TS.5 – Projections of future changes in climate
- Dates TBA

A Teaser
Models are getting better…

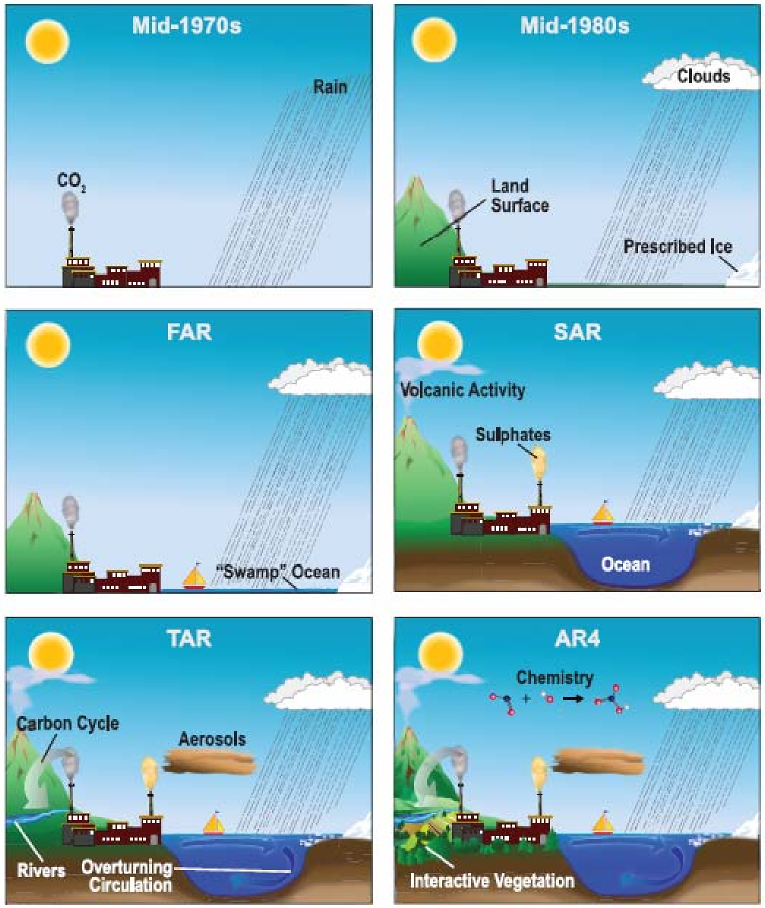


Figure 1.2. *The complexity of climate models has increased over the last few decades. The additional physics incorporated in the models are shown pictorially by the different features of the modelled world.*

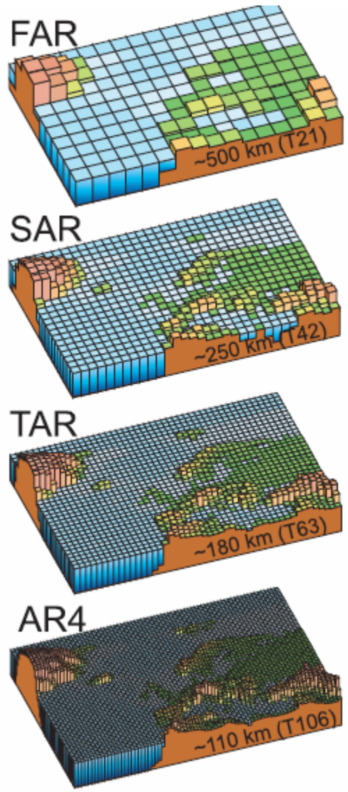
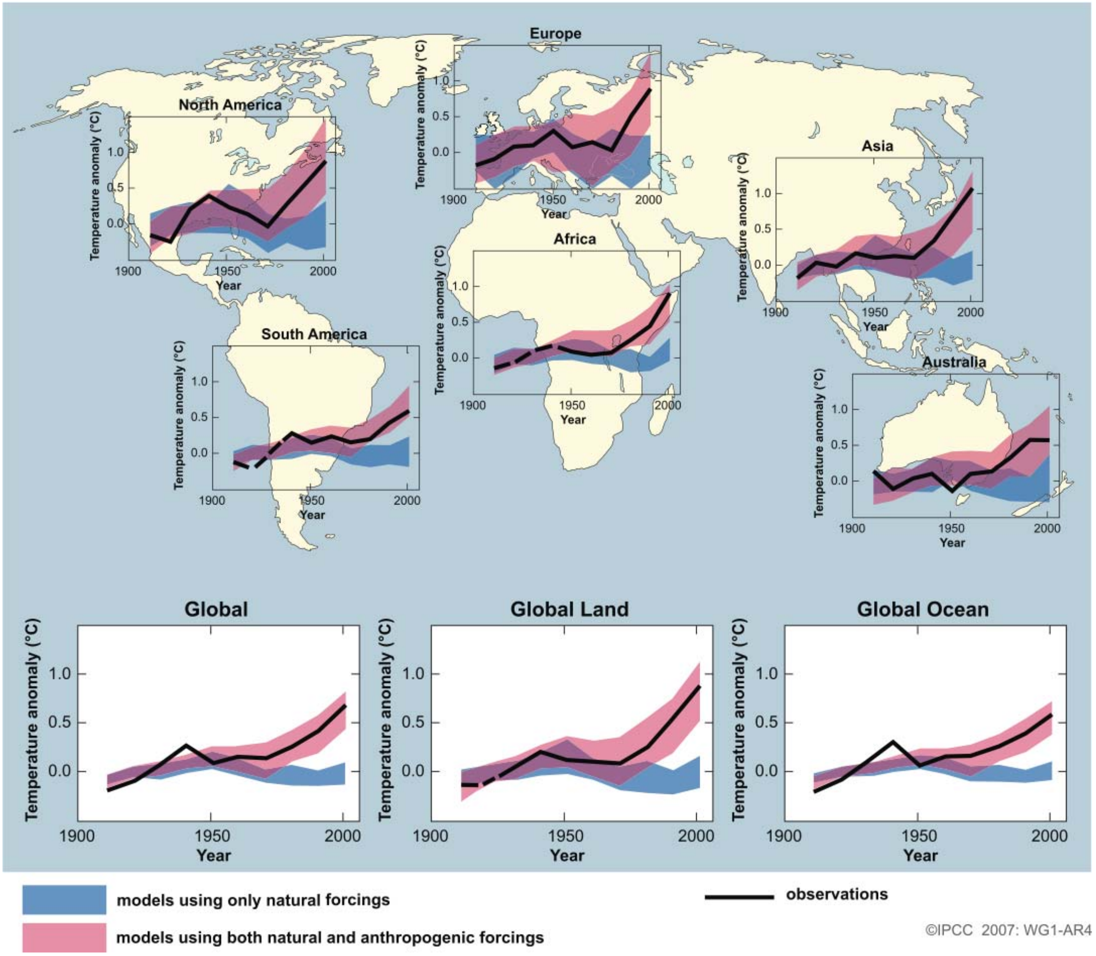


Figure 1.4. *Geographic resolution characteristic of the generations of climate models used in the IPCC Assessment Reports: FAR (IPCC, 1990), SAR (IPCC, 1996), TAR (IPCC, 2001a), and AR4 (2007). The figures above show how successive generations of these global models increasingly resolved northern Europe. These illustrations are representative of the most detailed horizontal resolution used for short-term climate simulations. The century-long simulations cited in IPCC Assessment Reports after the FAR were typically run with the previous generation's resolution. Vertical resolution in both atmosphere and ocean models is not shown, but it has increased comparably with the horizontal resolution, beginning typically with a single-layer slab ocean and ten atmospheric layers in the FAR and progressing to about thirty levels in both atmosphere and ocean.*

And it shows…


Europe
North America
Asia
Africa
South America
Australia
Global
Global Land
Global Ocean
Temperature anomaly (°C)
Year
1900
1950
2000
0.0
0.5
1.0
models using only natural forcings
models using both natural and anthropogenic forcings
observations
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