Climate Change

Observation

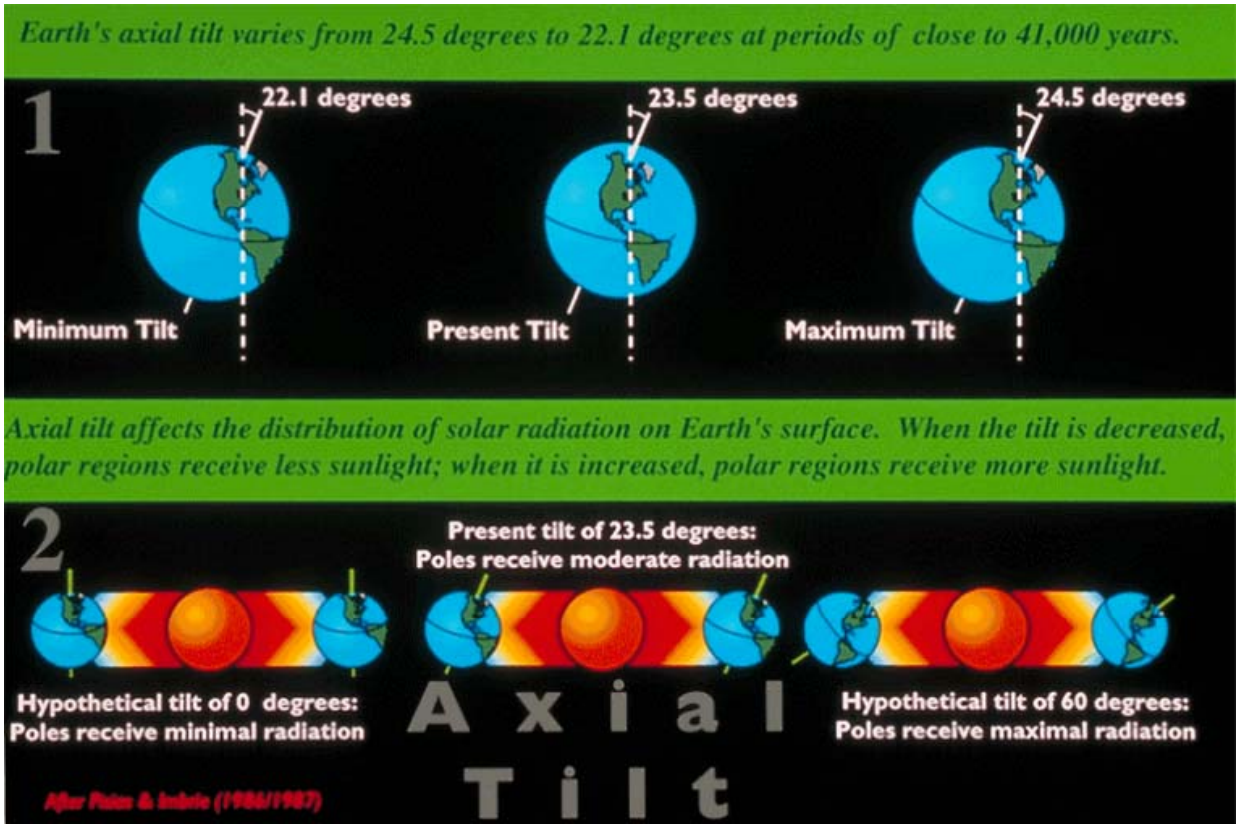
Climate Change

Broad definition:

- **IPCC:**
  Change in climate over time, whether due to natural variability or as a result of human activity.

- **More narrow definition:**
  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 variability

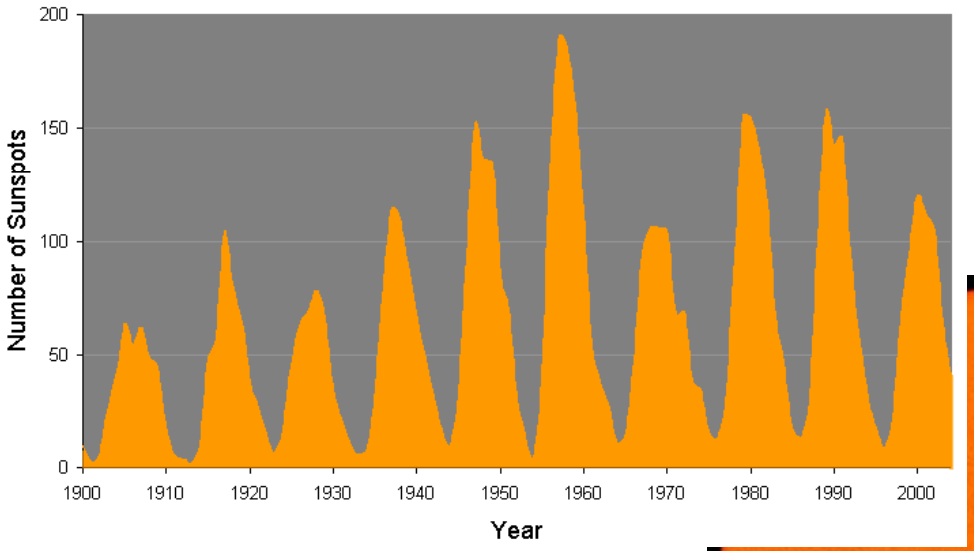
Non-anthropogenic climate change, Looong-run



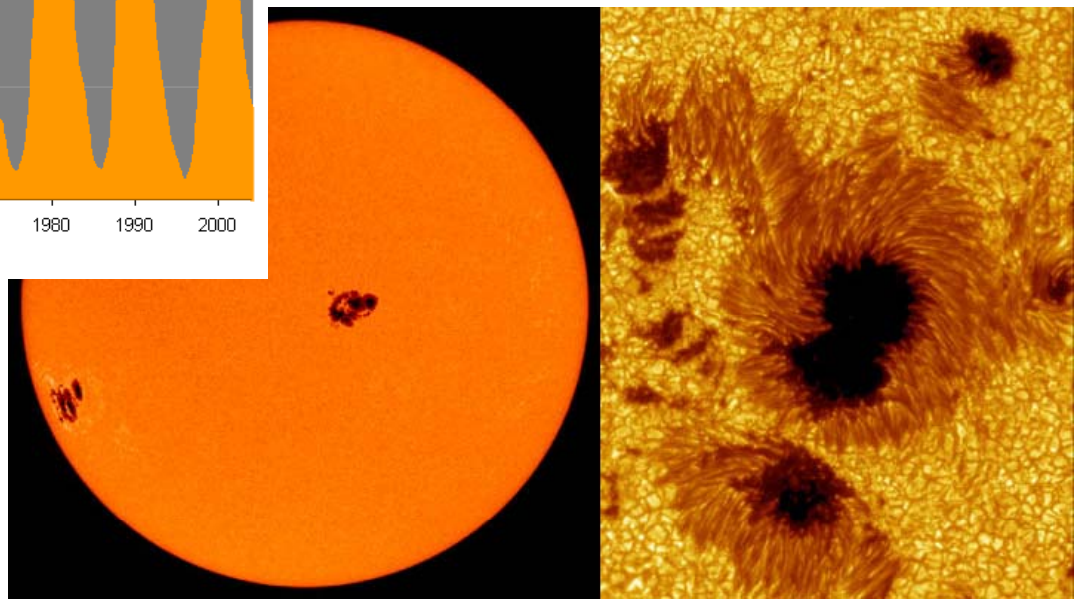
The Earth changes its position/tilt with respect to the sun periodically. The picture above explains changes in a 41 000 year period. Other changes takes place in a 100 000 year cycle and a 400 000 year cycle as well as shorter cycles. These cycles are called Milankovitch cycles.

Non-anthropogenic climate change, short run

- Solar sun spots (disturbance of the solar magnetic field) increase irradiance (and the solar constant), period 11 years

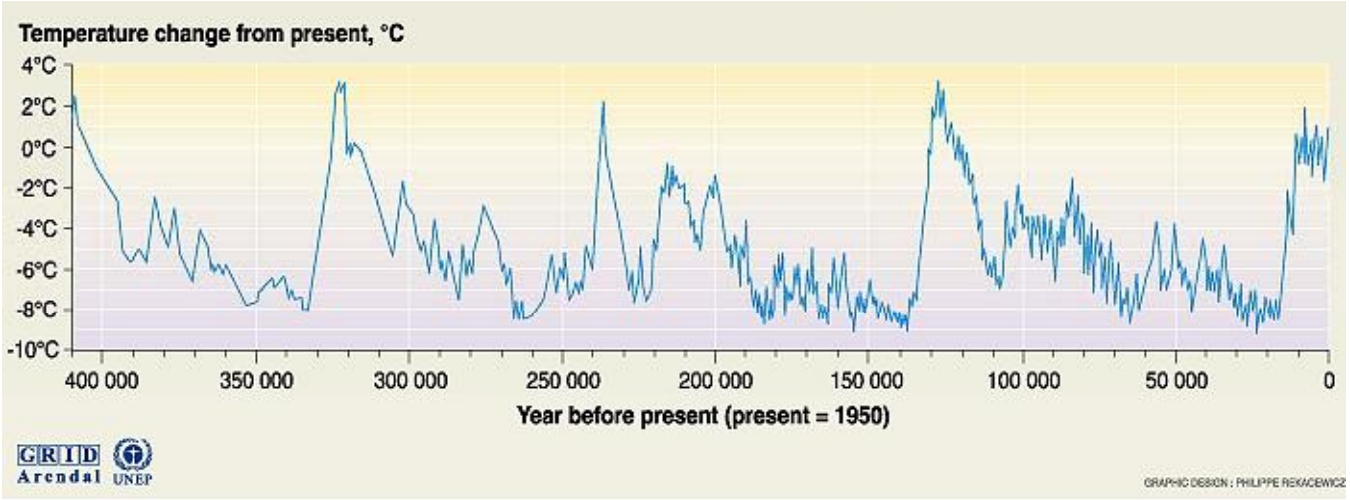


Solar constant varies ~ 1.3 W/m^2



Source: http://www.windows.ucar.edu/tour/link=/sun/atmosphere/sunspots.html

Temperature change observations, looong term



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

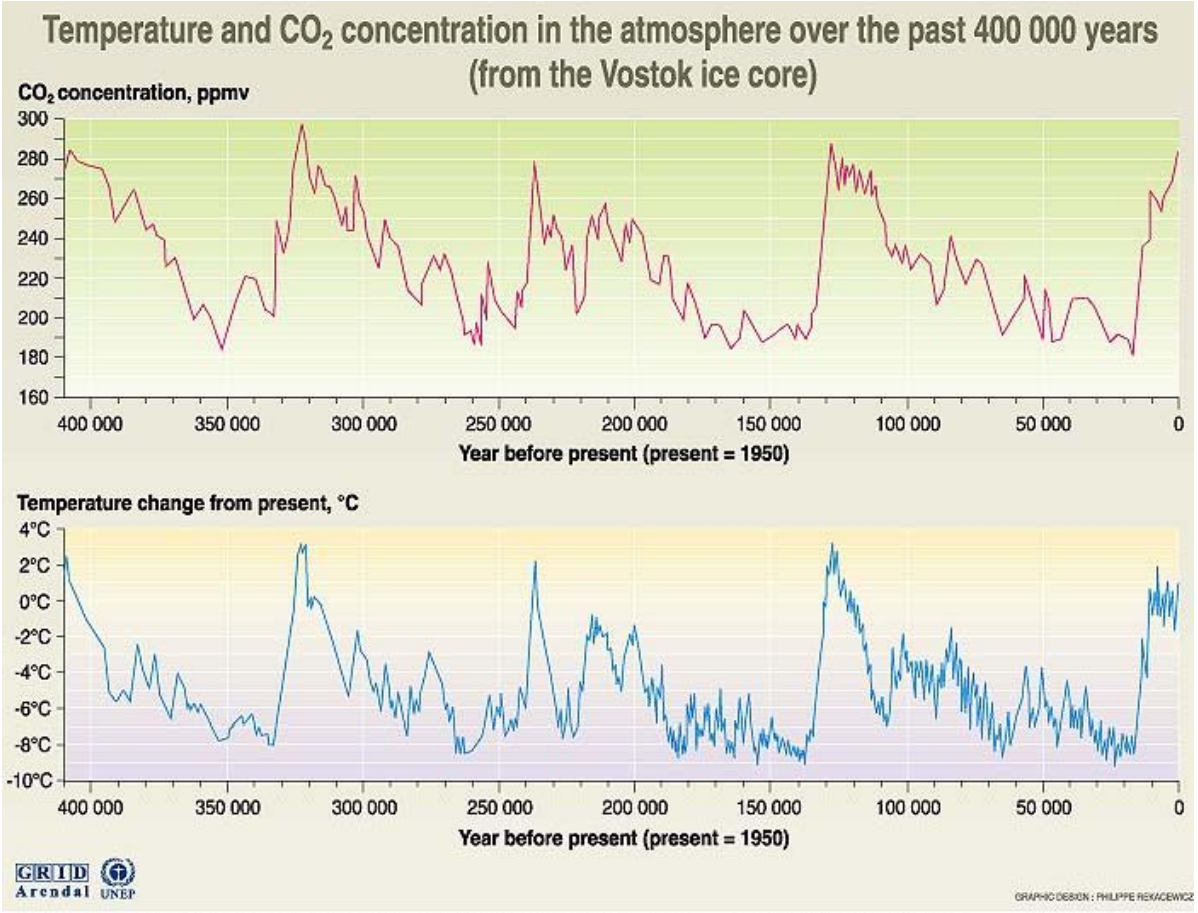
- Pattern related to above periodic changes of forcing (Milankovitch cycles)
- However, calculating the direct forcing implied by these cyclic effects alone is not enough to explain these temperature changes
- There would have to be feedback effects (this is an(!) 'ice age theory')

…before looking for possible indications of feedback…

- How do they actually get temperatures hundreds of thousands years back ?!

- Drilling deep, deep holes into glaciers and polar ice and analyzing tiny air bubbles for isotopes whose composition reflects the temperature as it prevailed on the surface when they were trapped
- And: These air bubbles also indicate the CO_2 concentration at that time!

Temperature - CO2 relation over last 400 000 years



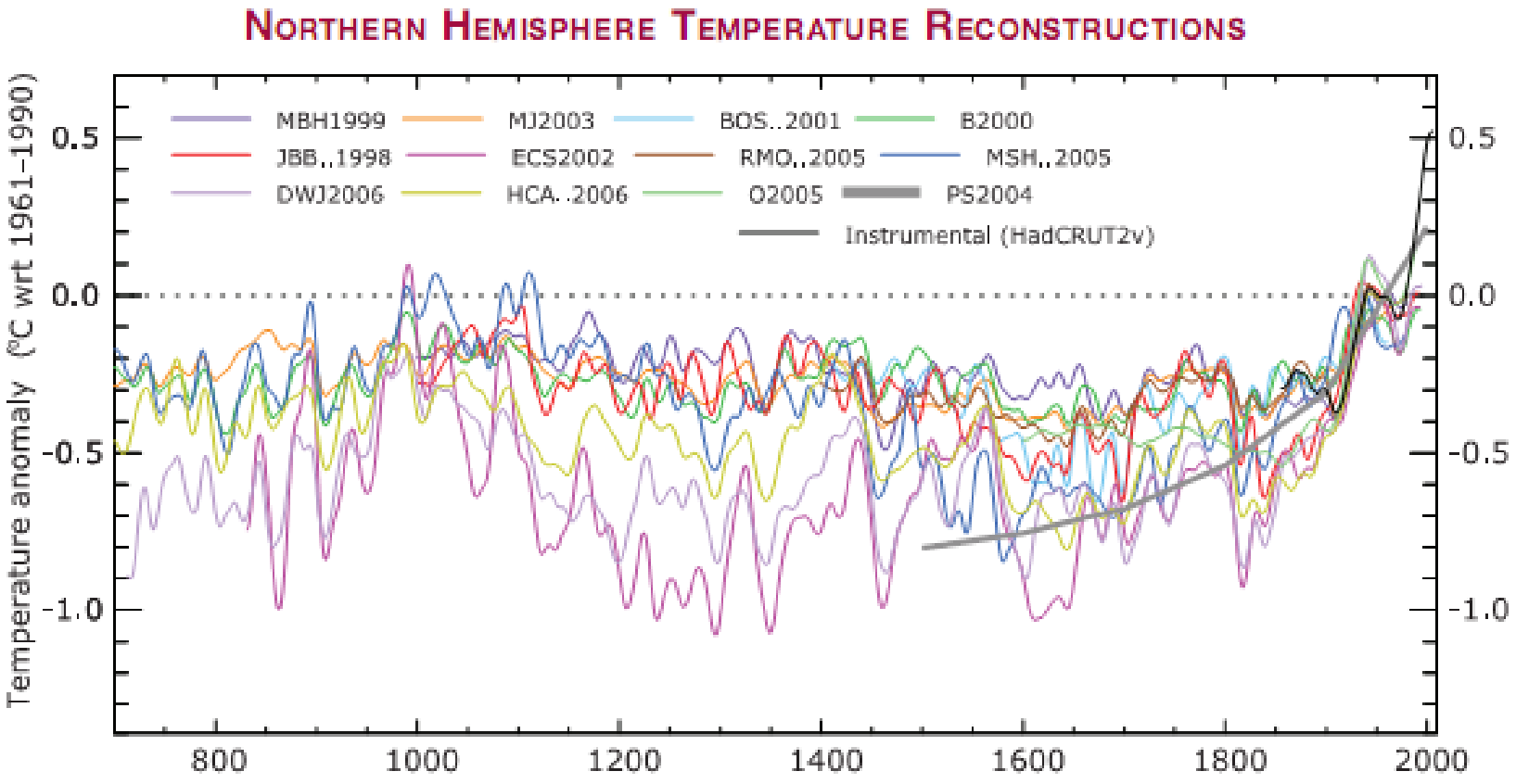
Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.

We do observe that warmer climate was usually associated with higher atmospheric concentrations of greenhouse gases

(Methane has similar pattern,

Snow and ice part of the game, probably also other parts of climate system like ocean currents)

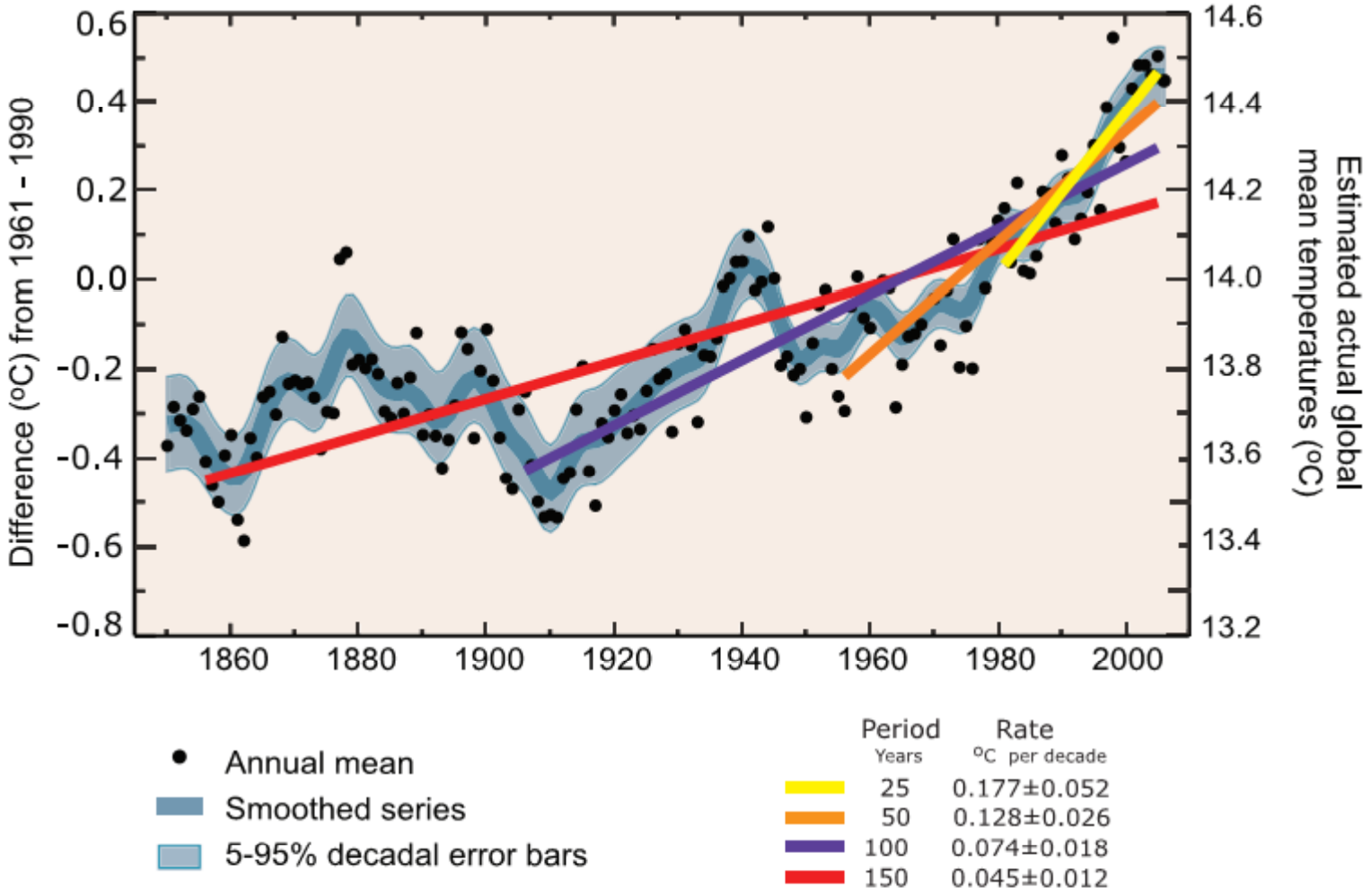
Temperature change observations, shorter run



Source: IPCC (2007) WG 1.

Temperature reconstruction using various sources (tree rings, boreholes, ice cores, instrumental record)

Temperature change observations, even shorter run & trends



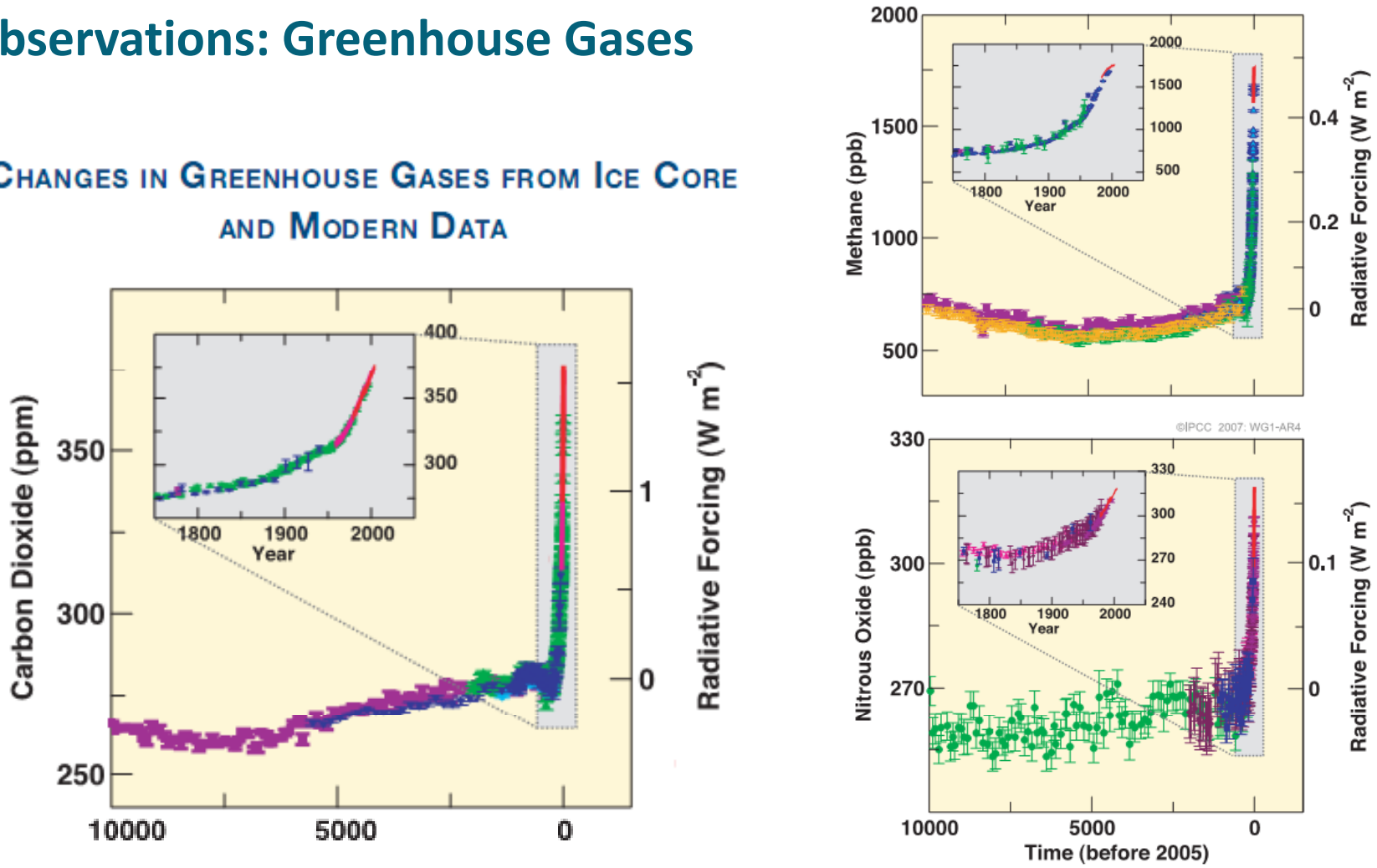
Detection vs Attribution

- **Detection** of climate change is the process of demonstrating that an observed change is significantly different (in a statistical sense) from what can be explained by natural variability.

The detection of a change, however, does not necessarily imply that its causes are understood.

- **Attribution** of climate change to anthropogenic causes involves statistical analysis and the assessment of multiple lines of evidence to demonstrate the observed changes are
  - unlikely to be due entirely to natural internal climate variability
  - consistent with estimated or modelled responses to the given combination of anthropogenic and natural forcing
  - And not consistent with alternative, plausible explanations

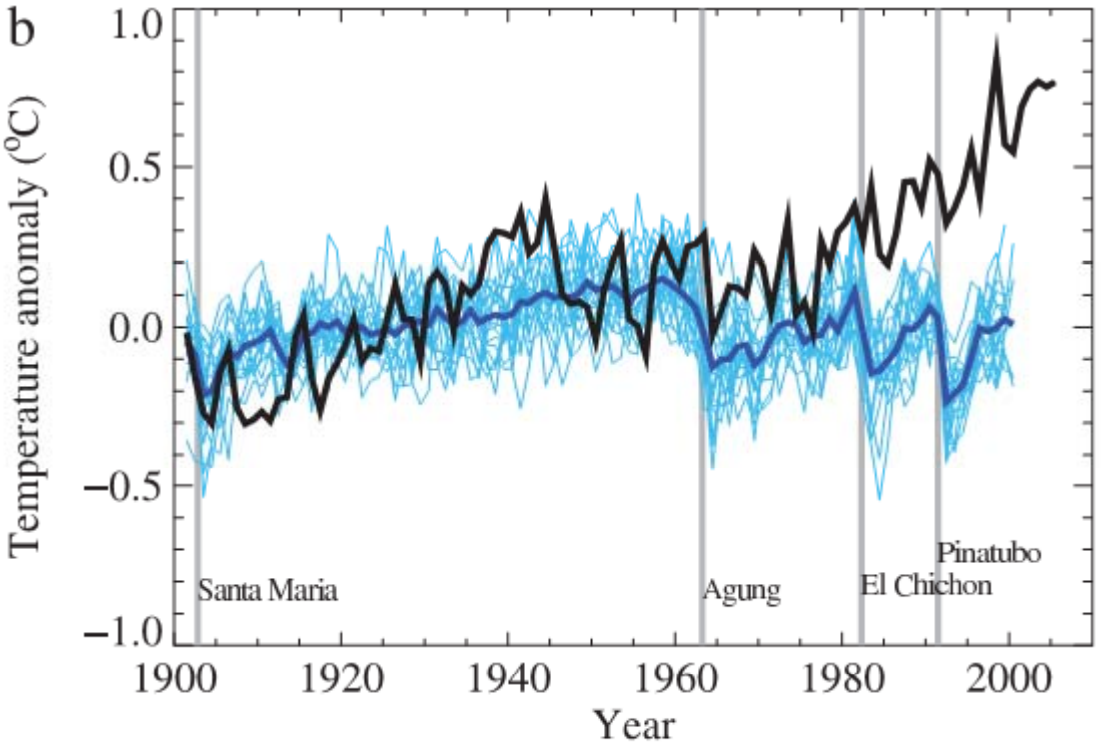
Observations: Greenhouse Gases



Source: IPCC (2007) SPM 1. Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years and since 1750 .

Observation meets Model: Attribution

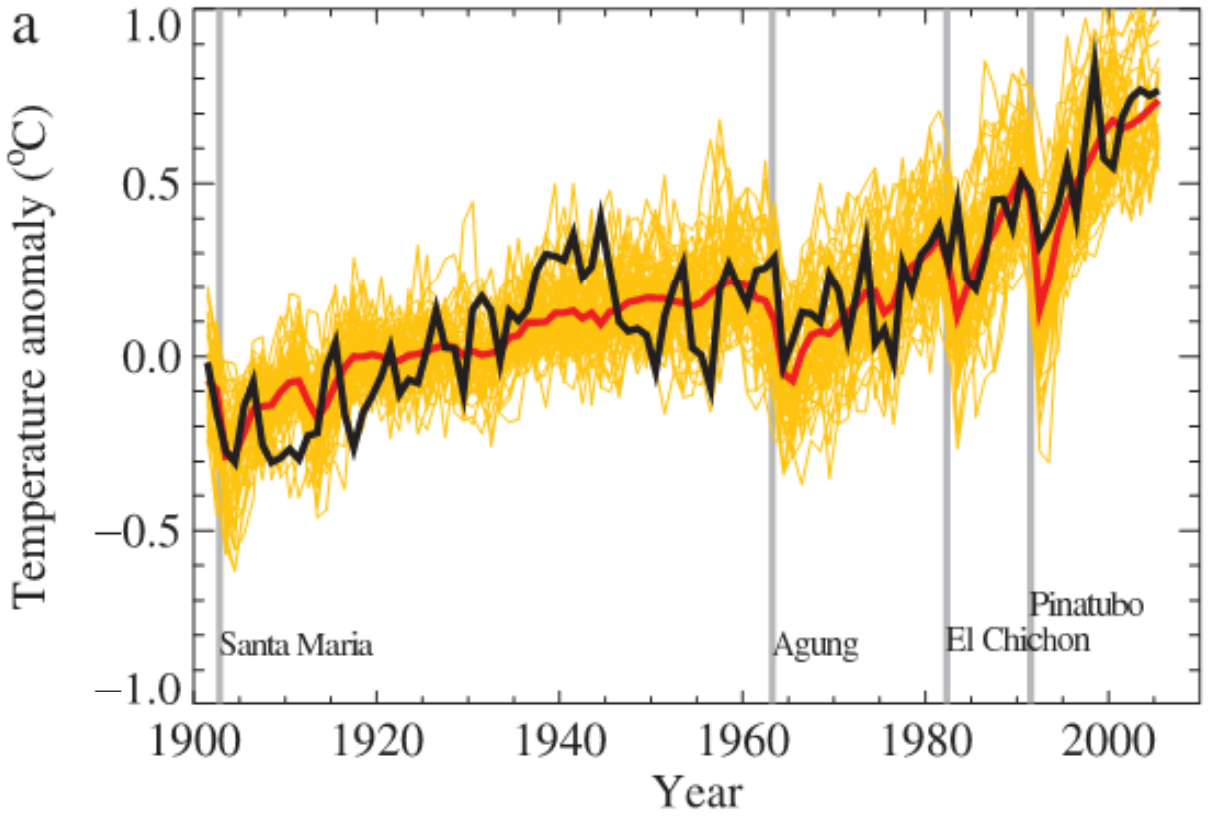
Natural forcing only, i.e. solar and volcanic:



Thick blue line: Multimodel-multirun average
Thick black line: Observation

Attribution

Natural forcing + anthropogenic forcing:



Thick red line: Multimodel-multirun average
Thick black line: Observation

Temperatures at the time of the 4 IPCC reports

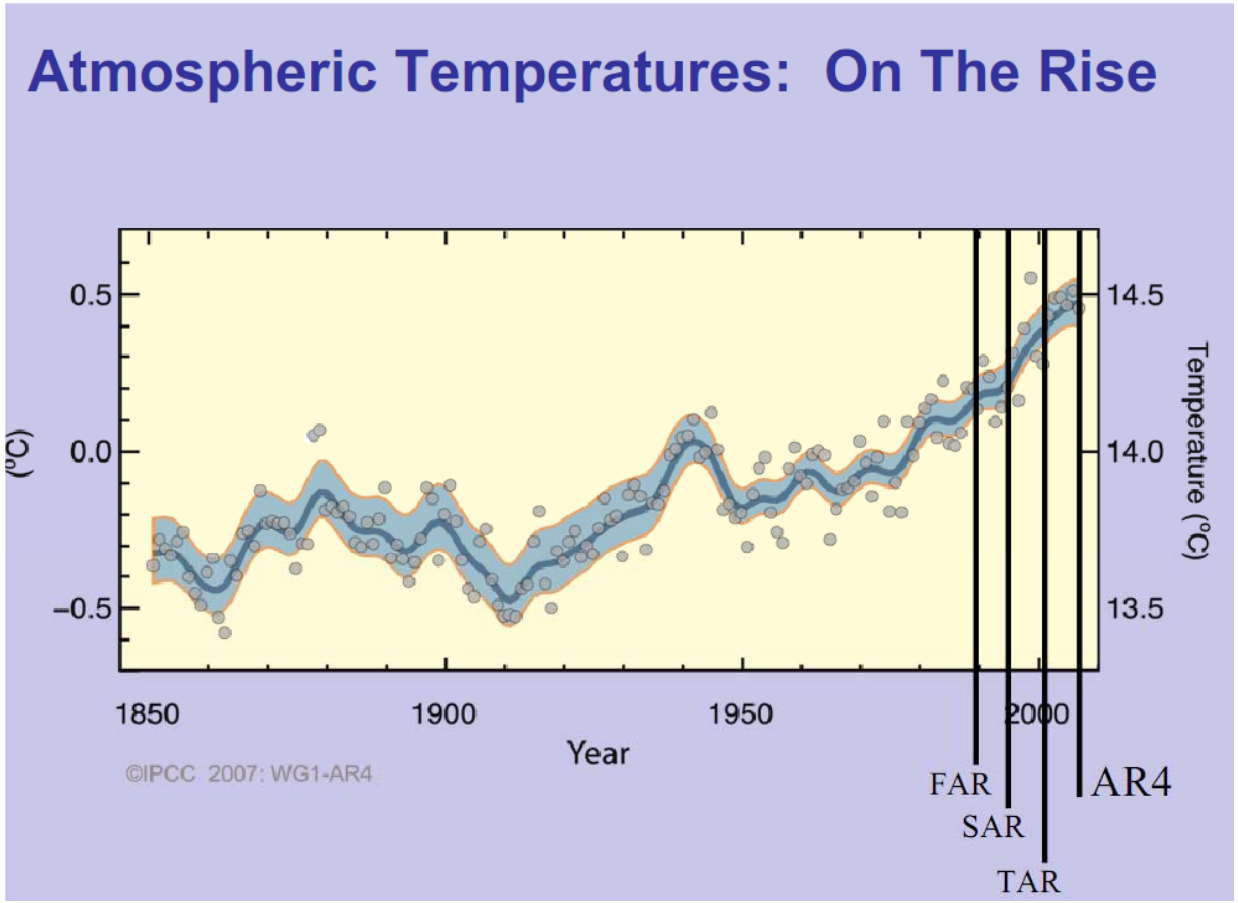
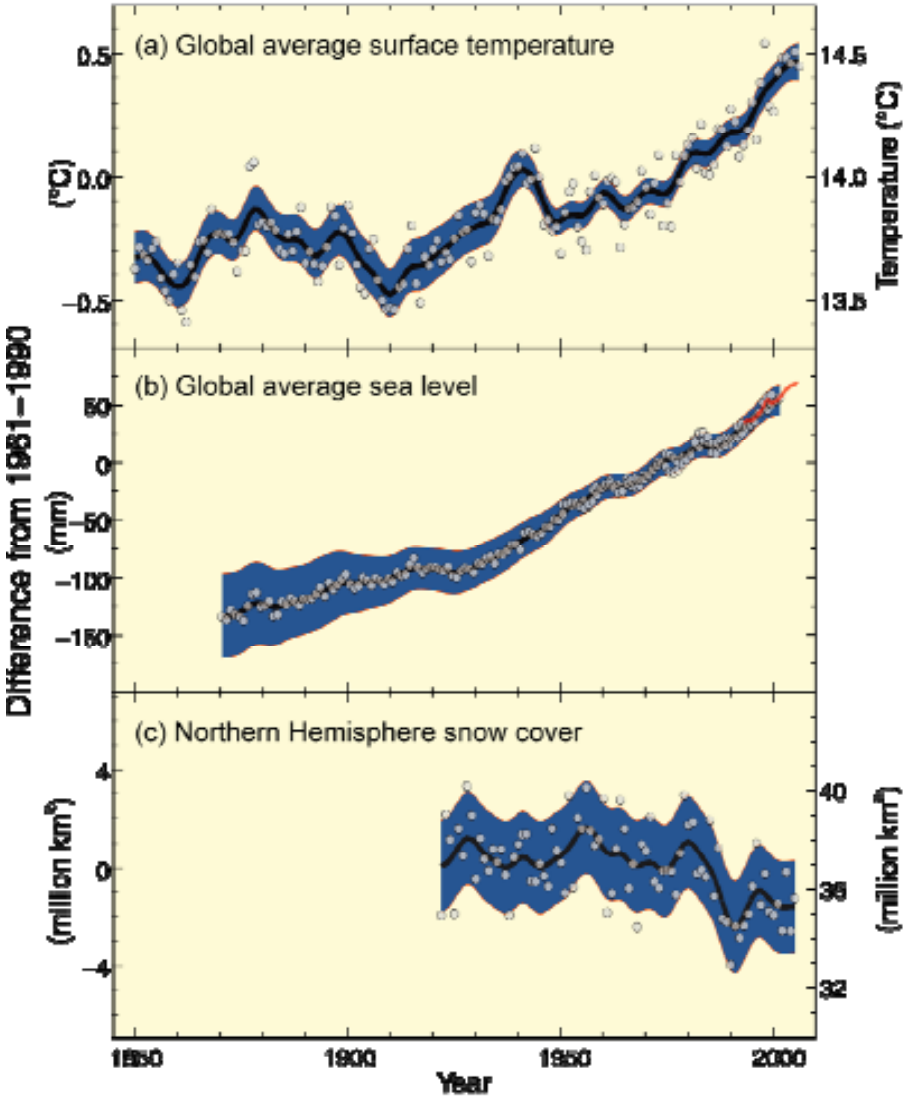


Figure taken from Presentation '20 years IPCC WG I' available at http://www.ipcc.ch/



IPCC 2007:
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 1300 years.

"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" (page 1)

Source: IPCC (2007), "Climate Change 2007: Synthesis Report"

Ice level changes

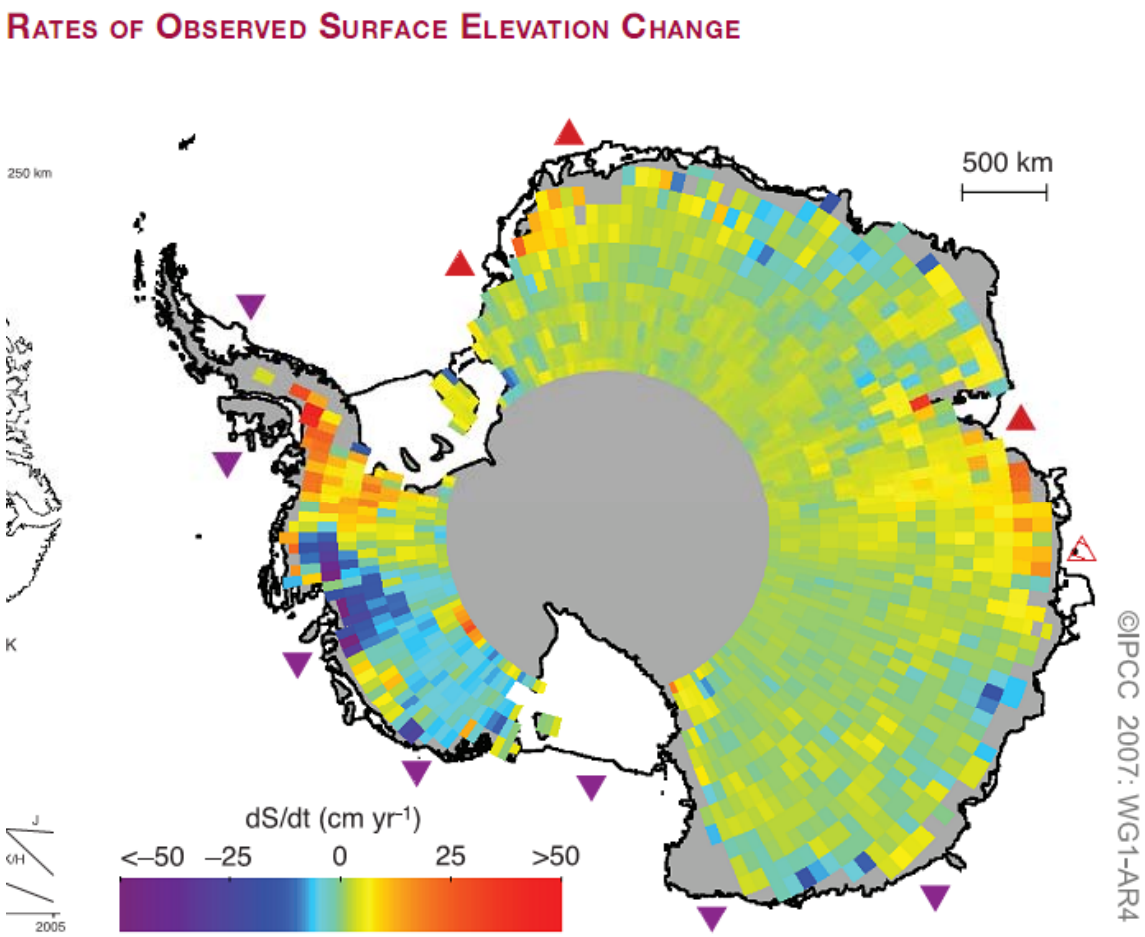


Figure TS.14. Rates of observed recent surface elevation change for Antarctica (1992–2005). Red hues indicate a rising surface and blue hues a falling surface, which typically indicate an increase or loss in ice mass at a site, although changes over time in bedrock elevation and in near-surface density can be important. For Antarctica, ice shelves estimated to be thickening or thinning by more than 30 cm/yr are shown by point-down purple triangles (thinning) and point-up red triangles (thickening) plotted just seaward of the relevant ice shelves.

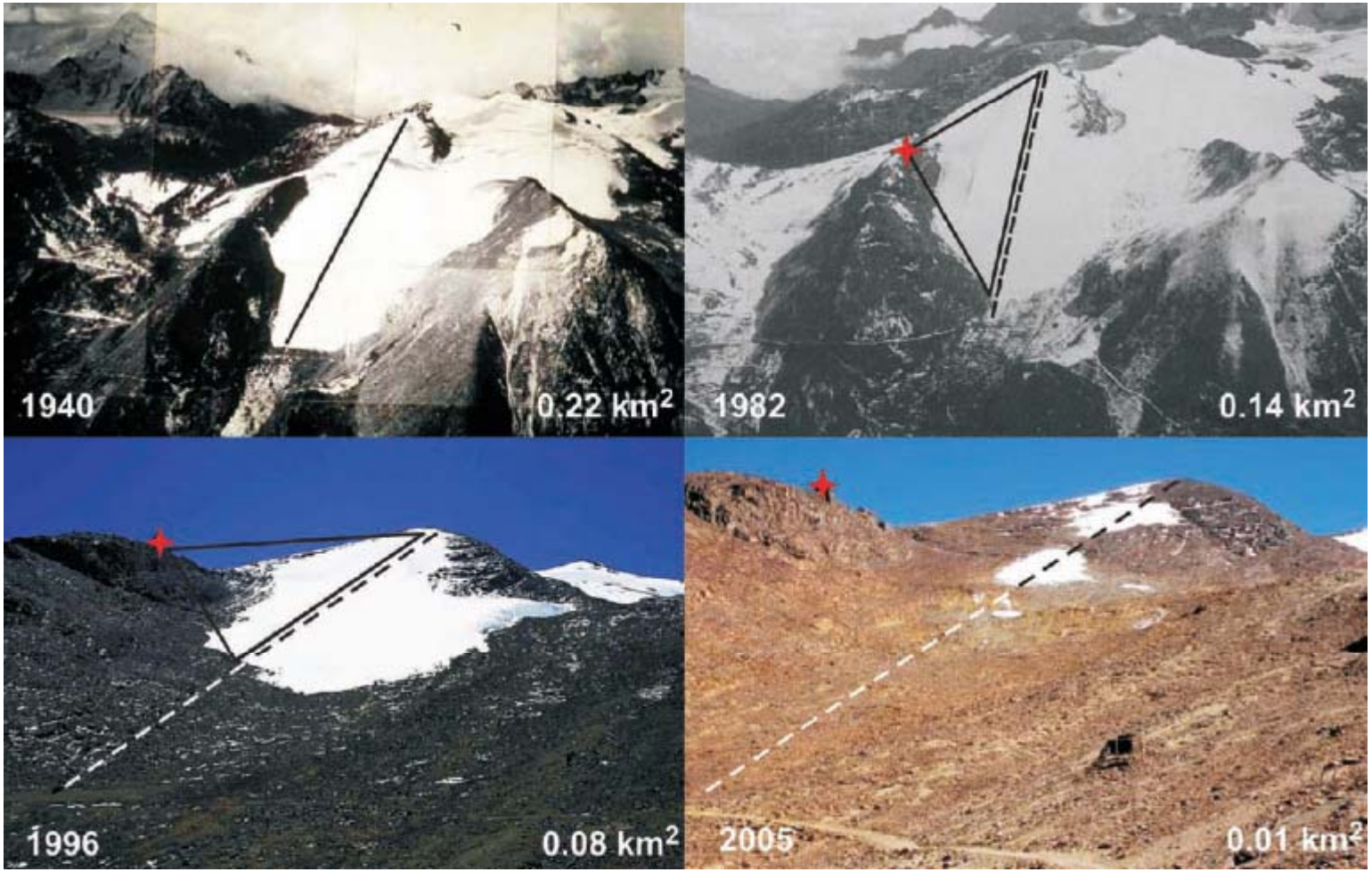
[Figure adapted by cutting out Greenland]

Glacier Bay (1941)

Glacier Bay (2004)

Kilimanjaro Ice Sheet (1993)

Kilimanjaro Ice Sheet (2000)



Areal extent of Chacaltaya Glacier, Bolivia, from 1940 to 2005, Source: IPCC (2007) WG2

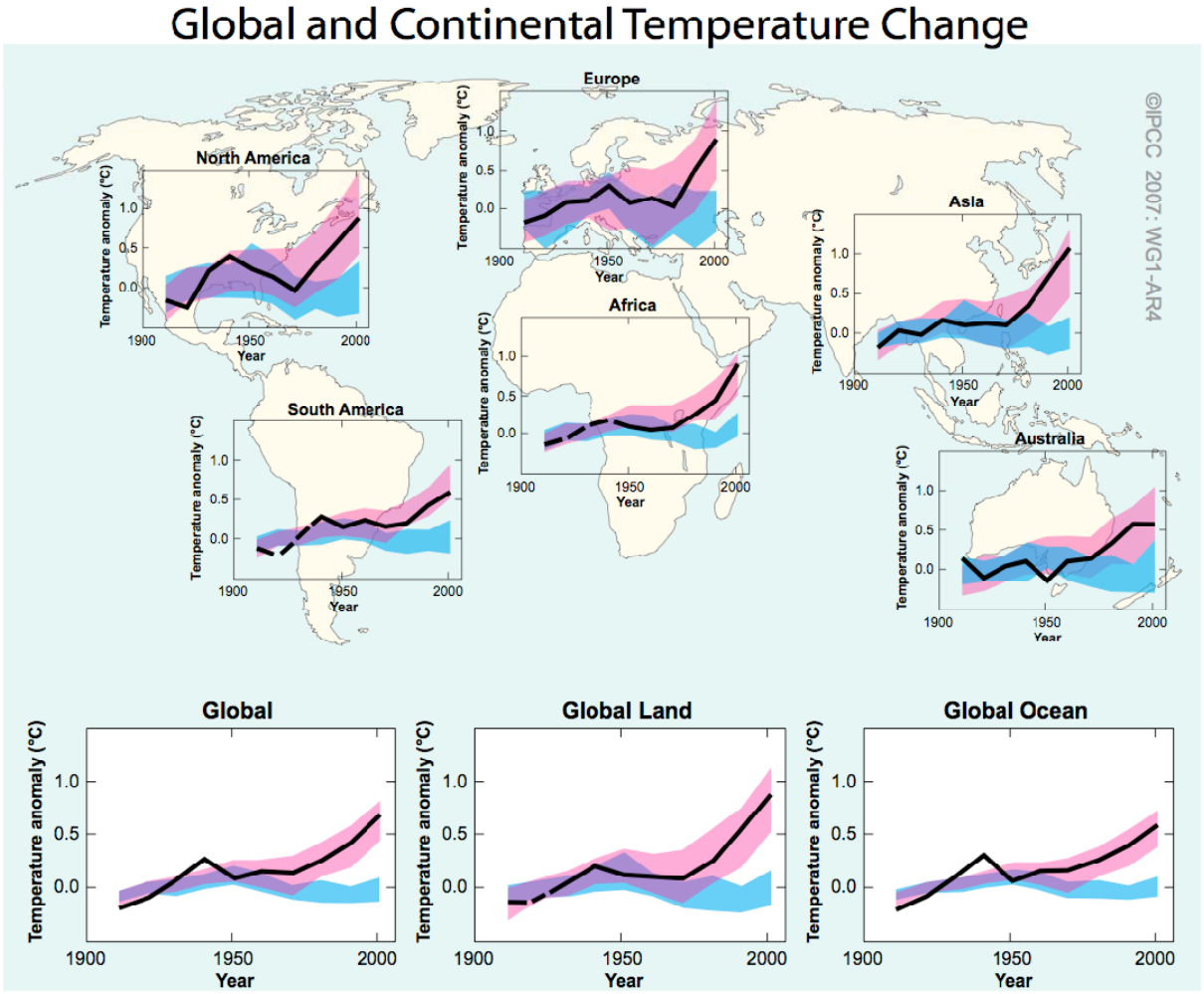
Findings: Sea Level Changes

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.

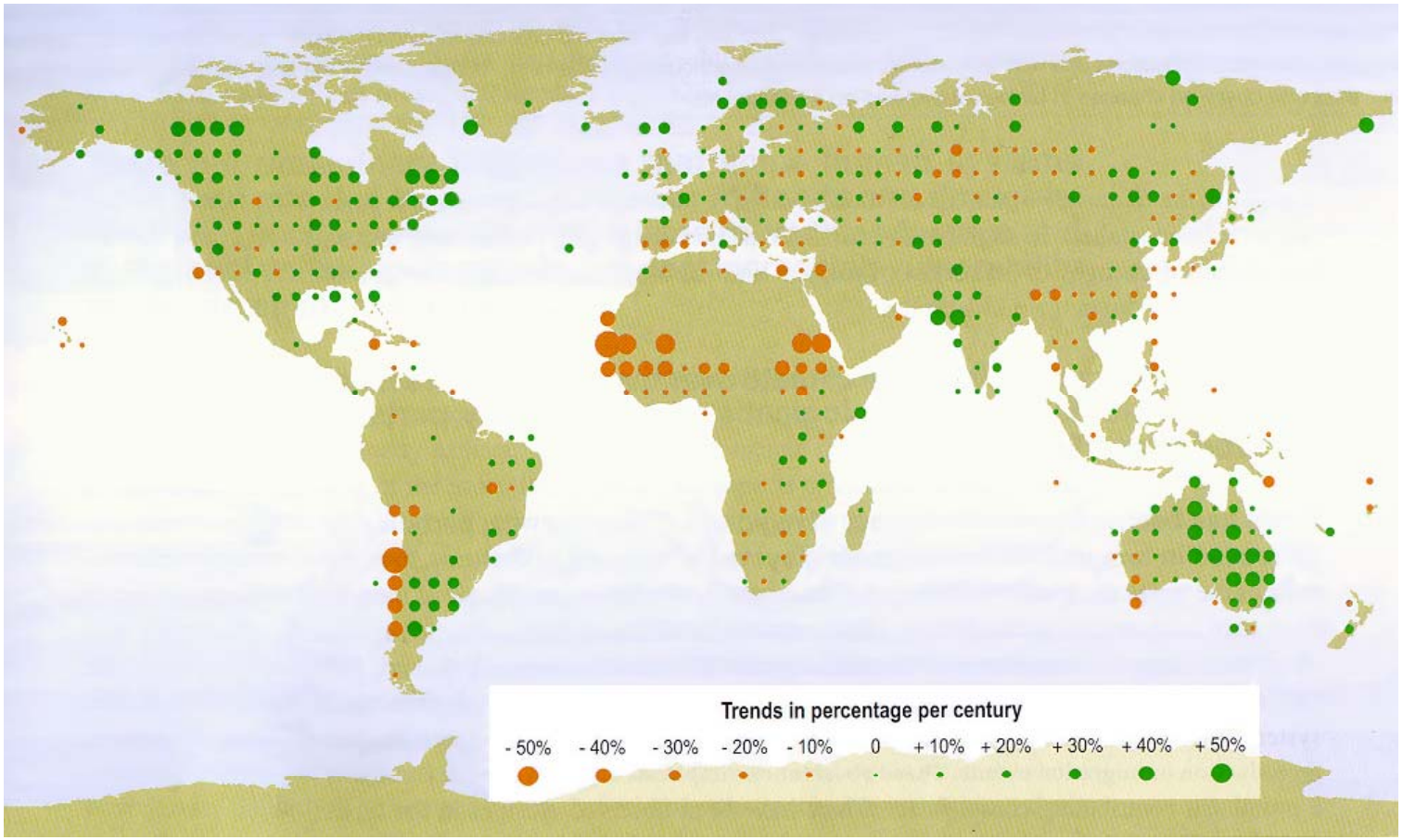
Regional Patterns



Source: IPCC (2007), WGI.

Change of precipitation pattern

- Precipitation has increased in some parts of the world and decreased in others
- Trends (%/century) in annual precipitation for 1900-2000



Source: IPCC (2001) WG 1.

Other observed Changes

- Shoreline Erosion
- Wetland Changes
- Changes of growing seasons
- Range expansion of terrestrial species
- Spread of vector born diseases
- Change in runoffs, floods and droughts)
- shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans
- Spread of kelp forests/macroalgae in warmer waters
- Coral bleaching

Evidence for changes in the climate, final statement:

IPCC Synthesis Report (2007), section 1.1:

- 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
- 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.
- From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern and central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has likely increased since the 1970s.
- There is observational evidence of an increase in intense tropical cyclone activity in the North Atlantic since about 1970, with limited evidence of increases elsewhere. There is no clear trend in the annual numbers of tropical cyclones.