Climate Change 2007: Observations and Drivers of Climate Change

Martin Manning
Director, IPCC Working Group I Support Unit

1. Observed climate change
2. Paleoclimatic perspective
3. Drivers of climate change

Acknowledgements

WG I Co-chairs, Drs Susan Solomon and Dahe Qin

152 Lead Authors

WG I Bureau

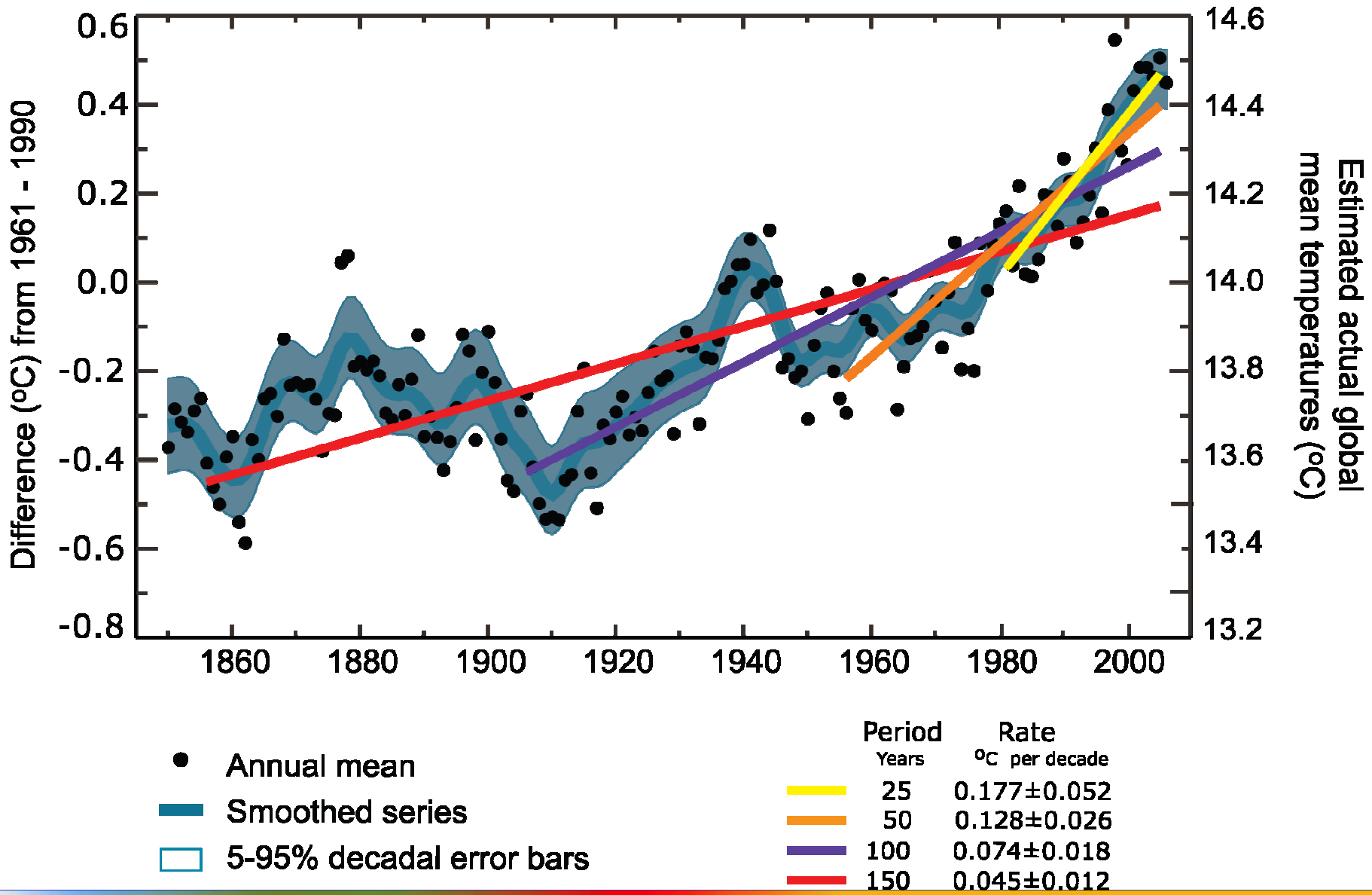
Observed Climate Change

Warming of the climate system is unequivocal

Numerous long-term changes in climate observed at continental, regional and ocean basin scales

Some aspects of climate have not been observed to change

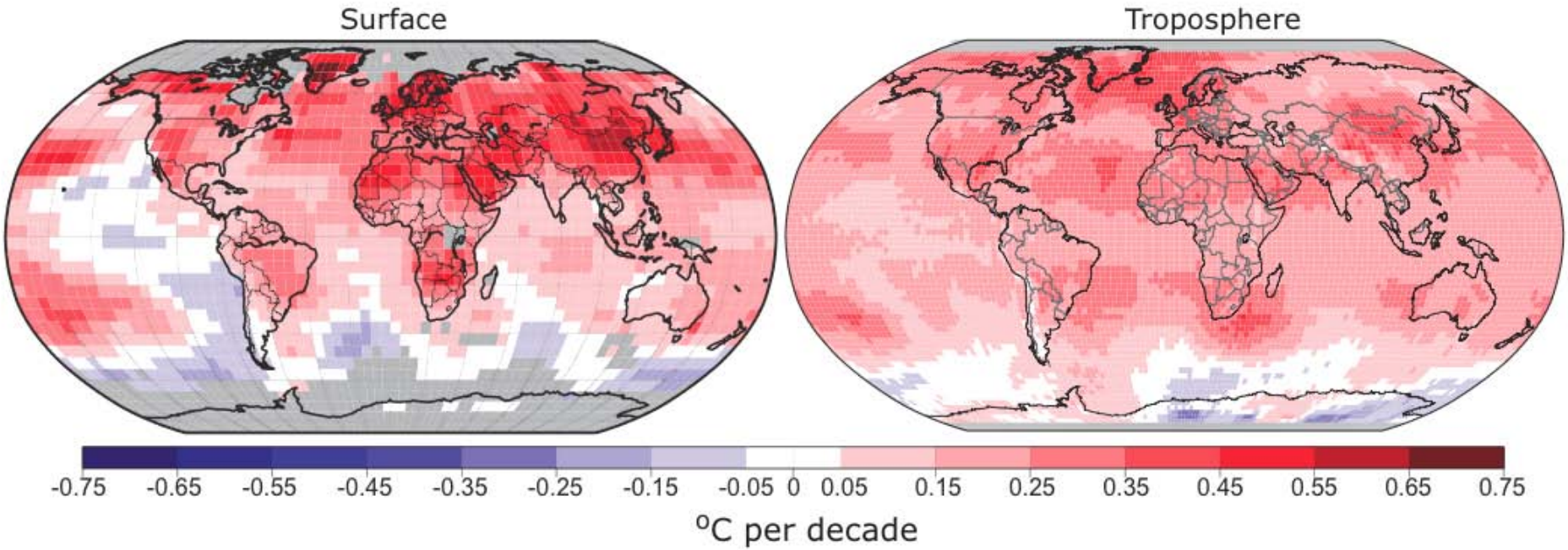
Global average temperature



Warming is truly global

Warming trends since 1979 (when satellite measurements started) show:

- Warming everywhere at surface except in eastern Pacific, Southern Ocean and parts of Antarctica;
- Land warming significantly faster than ocean over last 20 years;
- Mid-troposphere warming consistent with that at surface.

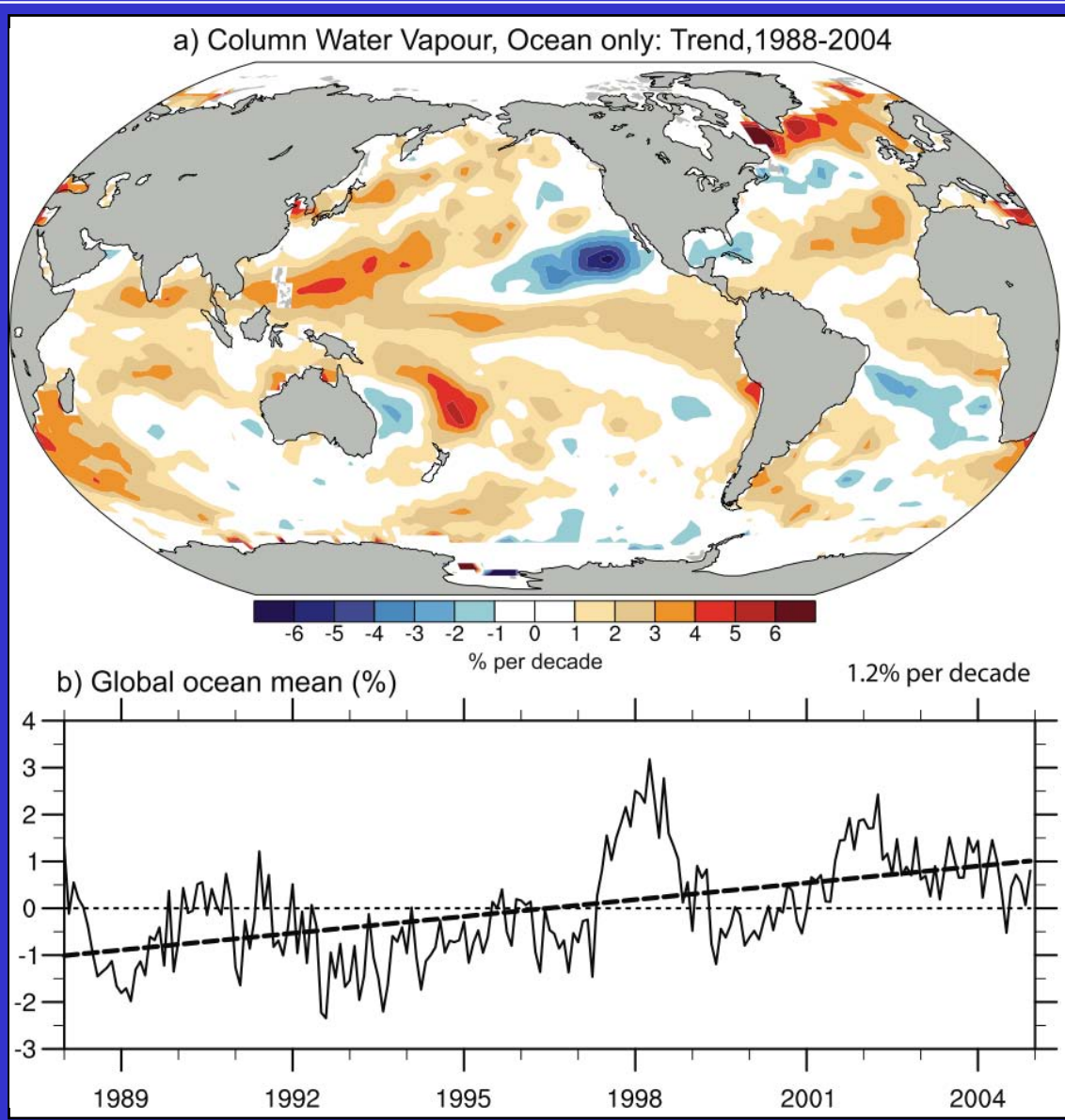


Water vapour increases

Precipitable water vapour over the ocean: Trends for 1988 – 2004 are near zero or positive in most places.

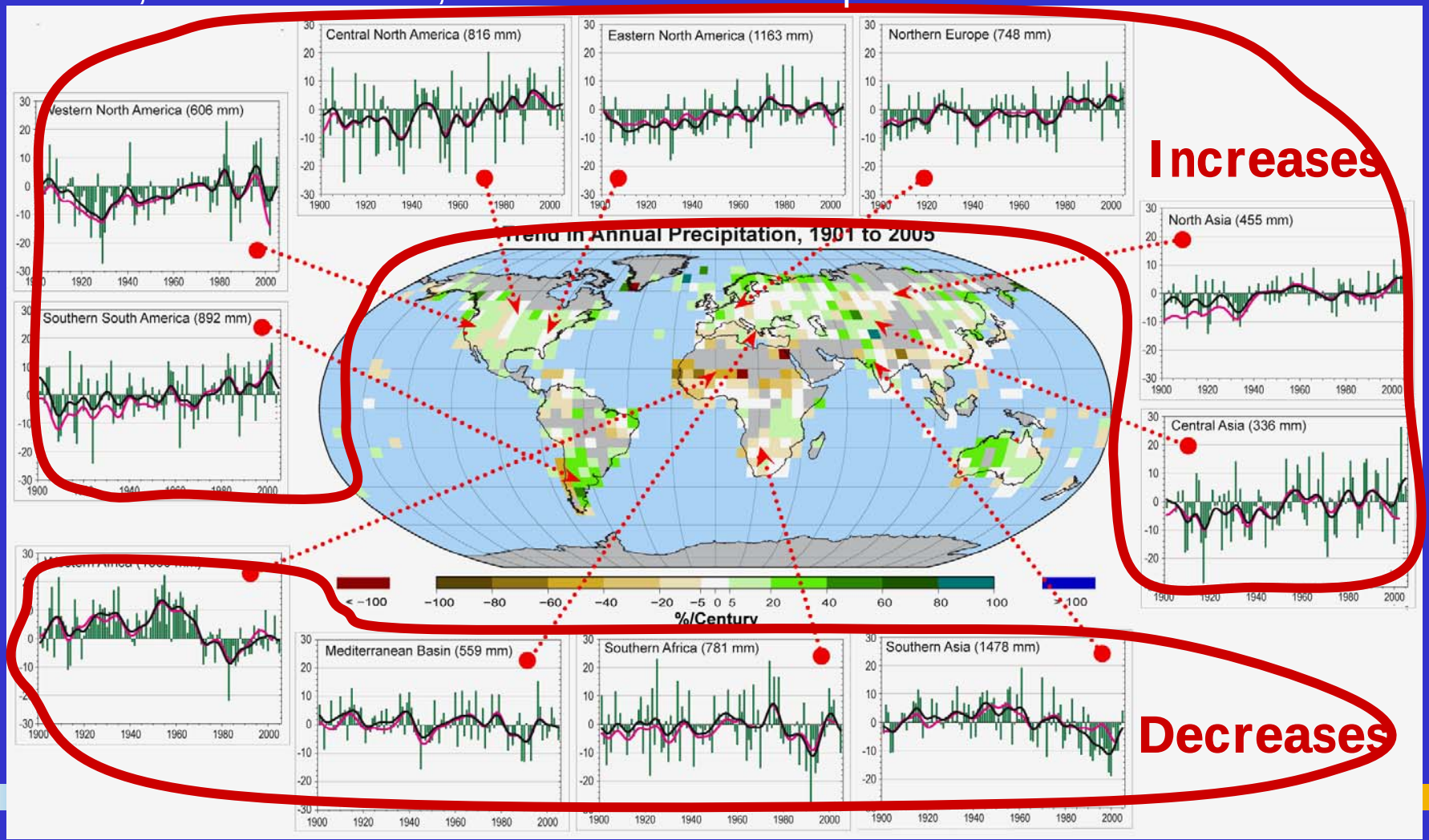
Global mean trend is +1.2 % per decade.

Consistent with a warming atmosphere.



Precipitation (rain & snow) is variable – but there is evidence for systematic change

Precipitation has increased in eastern parts of North and South America, northern Europe and northern and central Asia – and decreased in the Sahel, Mediterranean, southern Africa and parts of southern Asia.

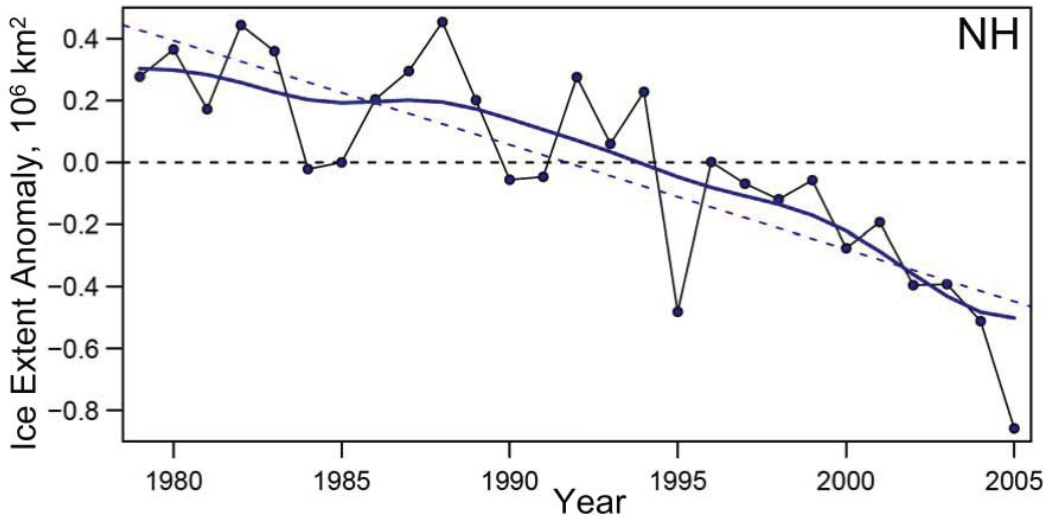


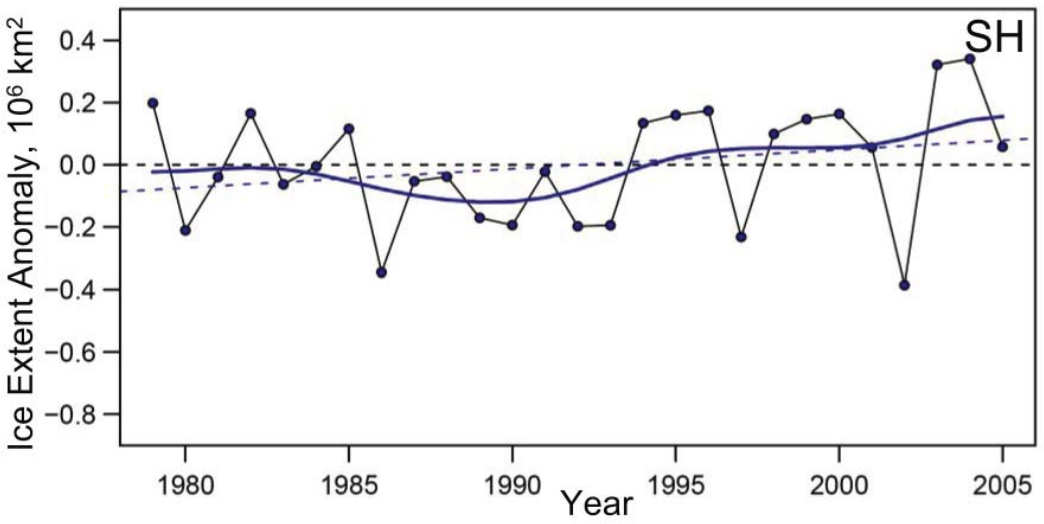
Sea ice extent changes

Arctic sea ice extent: 1980 – 2005 trend -2.7% per decade.

Summer minimum Arctic sea ice extent trend (not shown) -7.4% per decade.

Antarctic sea ice extent: no statistically significant trend

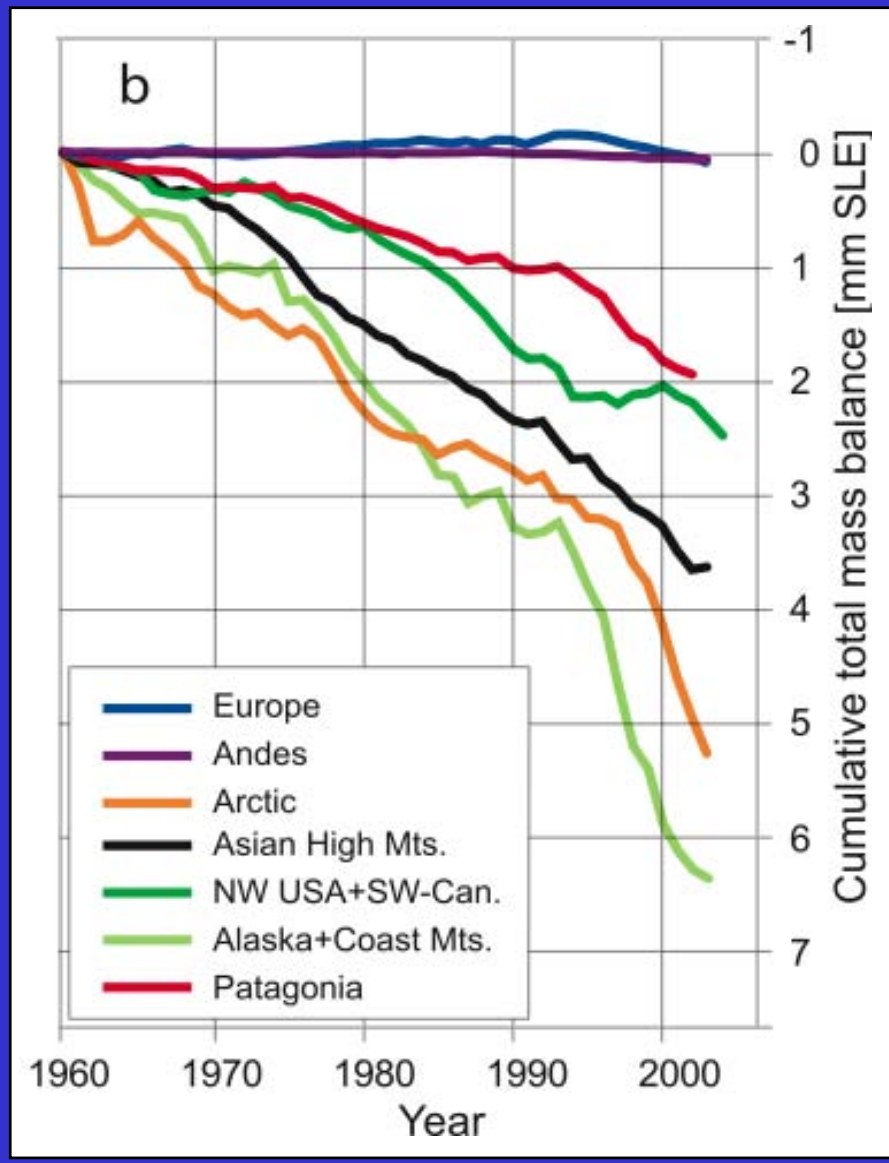




Glacier mass balance

Cumulative loss of glacier mass in many regions

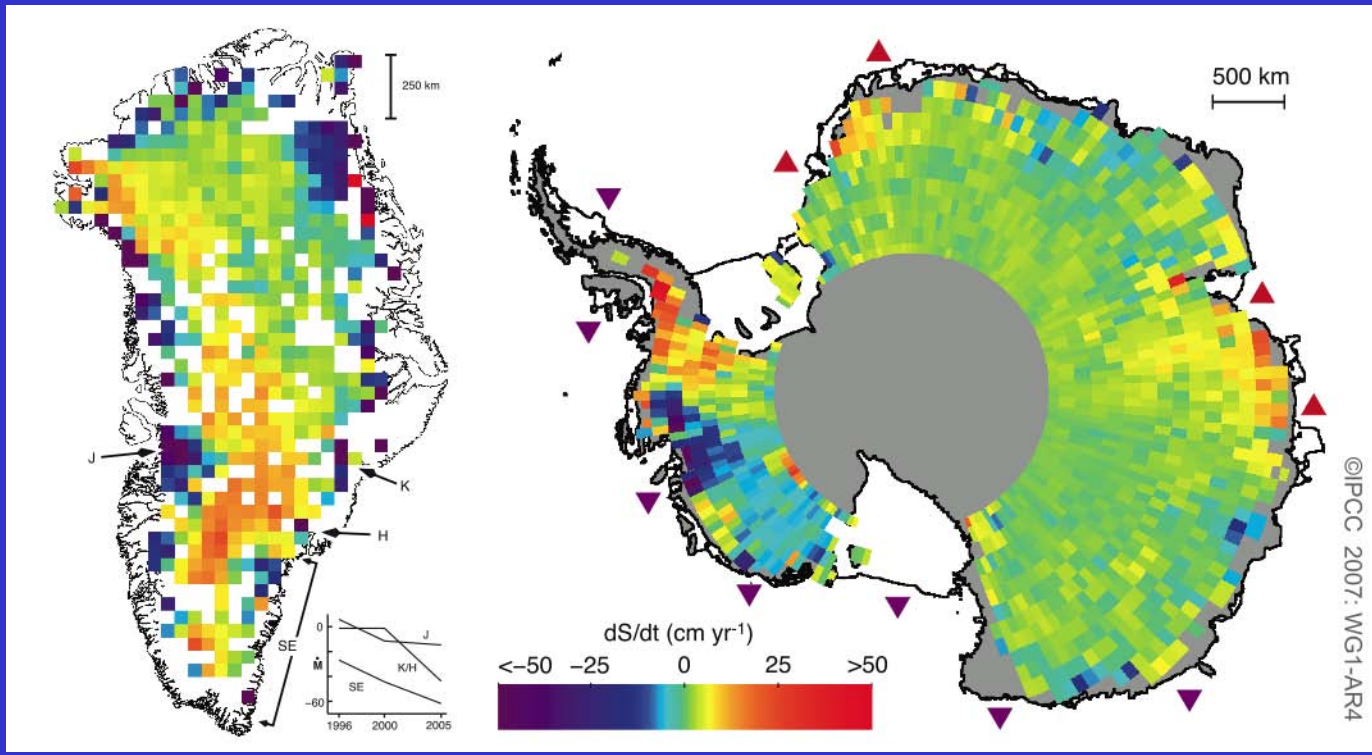
During the 20th century, glaciers and ice caps have experienced widespread mass losses and have contributed to sea level rise.



Changes in ice sheets

Surface elevation changes shown as red hues where rising and blue where falling.

Evidence for rapid changes in ice flow in some regions.



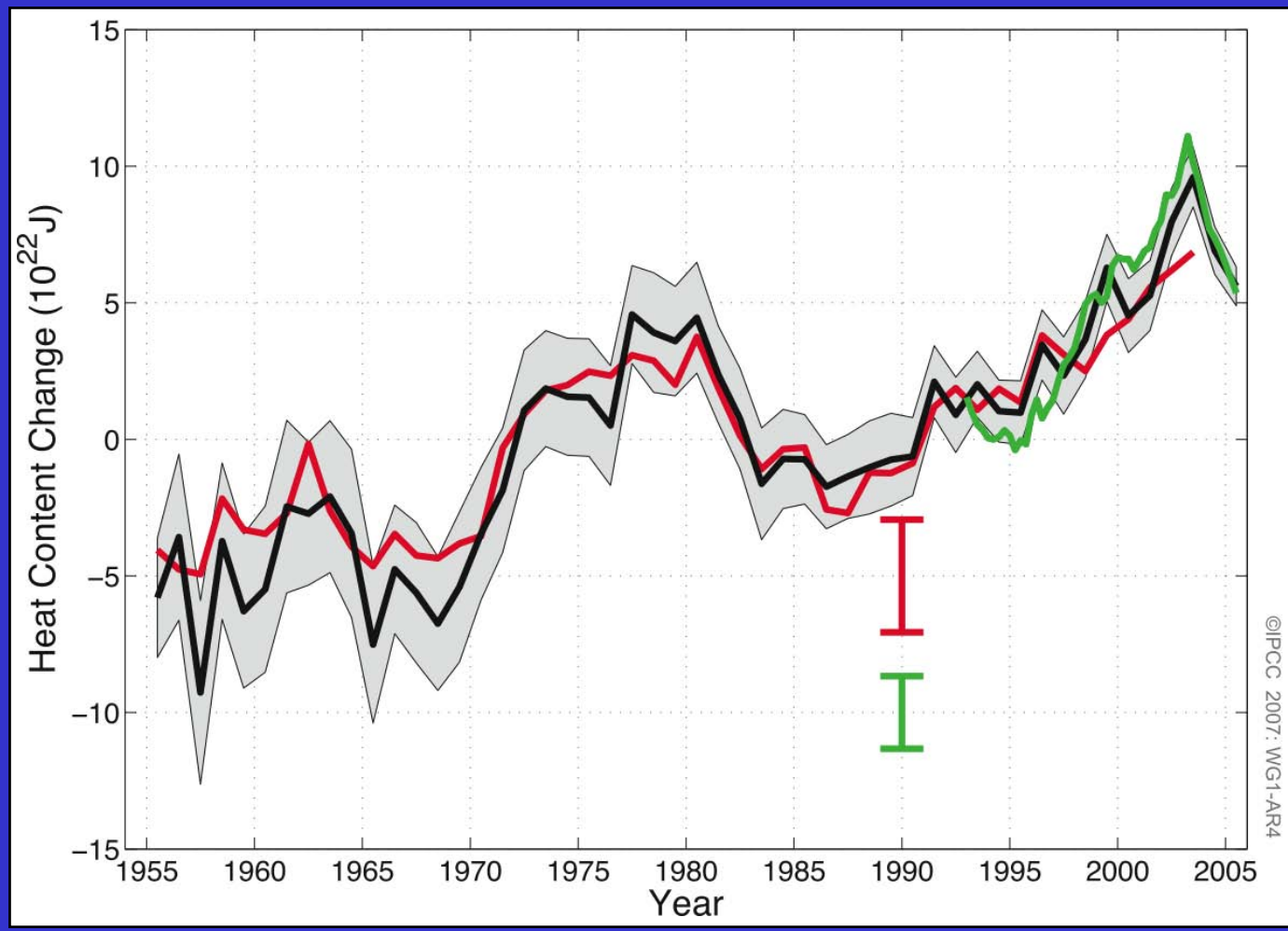
Very likely that Greenland Ice Sheet shrunk from 1993 to 2003. Thickening in central regions more than offset by increased melting in coastal regions.

Antarctic ice sheet also estimated to have lost mass, but uncertainties are larger.

Ocean heat content increasing

Ocean temperatures have increased to depths of at least 3000 m.

Estimates of total heat content from independent analyses show inter-annual variability but a positive trend since 1961.

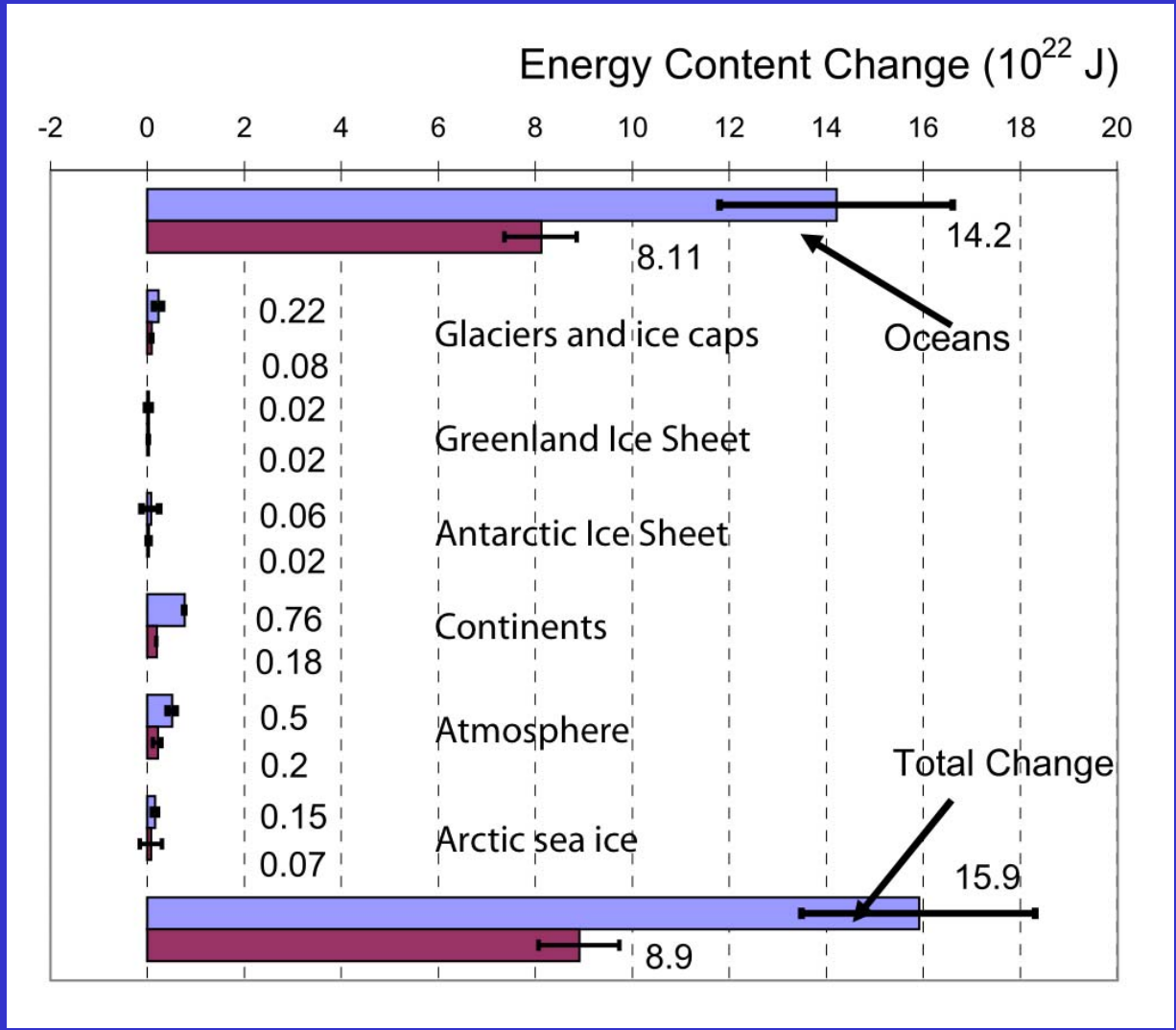


Heat content changes in climate system

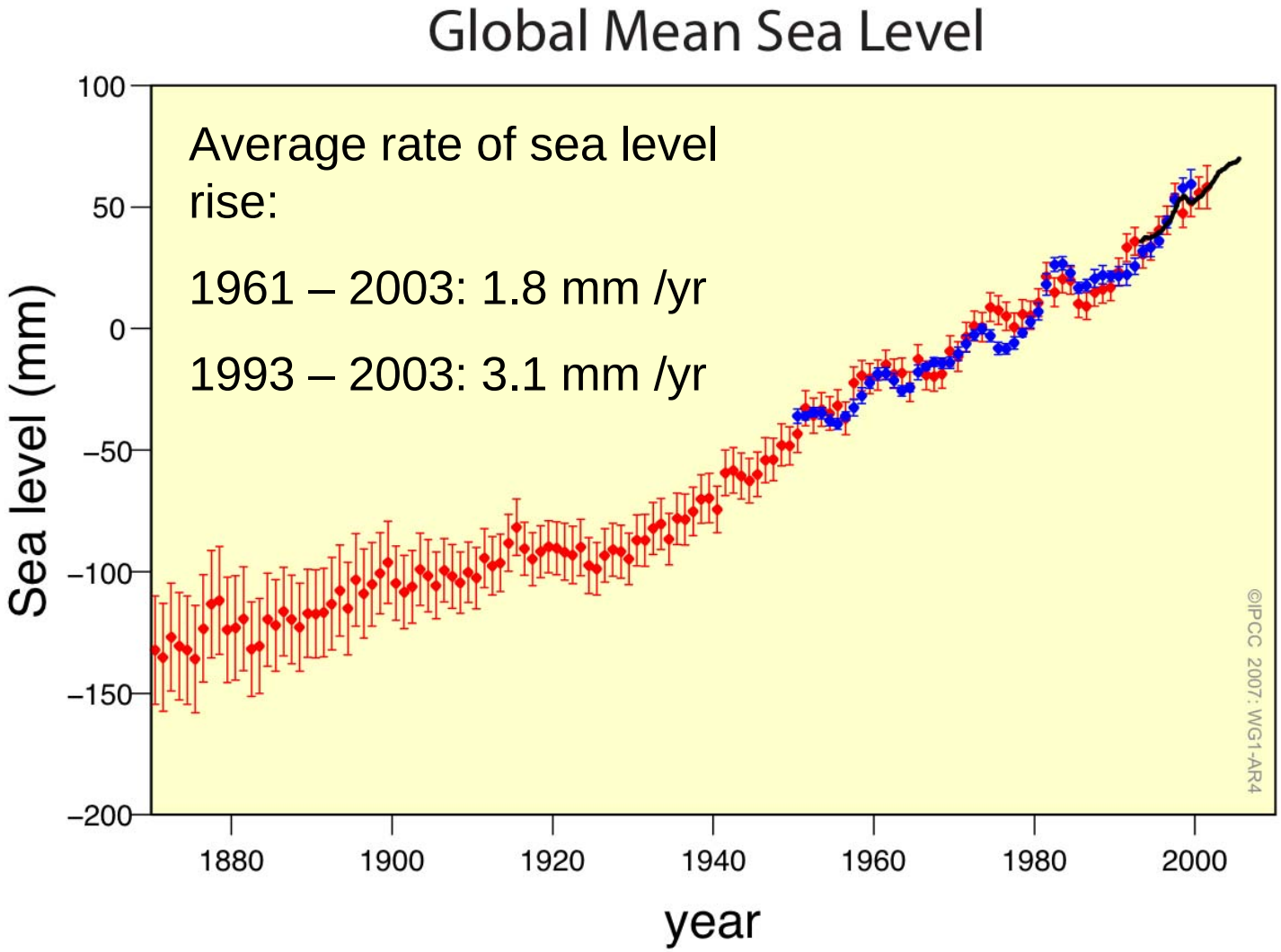
Oceans have been absorbing more than 80% of heat added to the climate system.

Blue bars show heat content change for 1961 – 2003;

burgundy bars for 1993 – 2003.



Tide gauge and satellite data on sea level

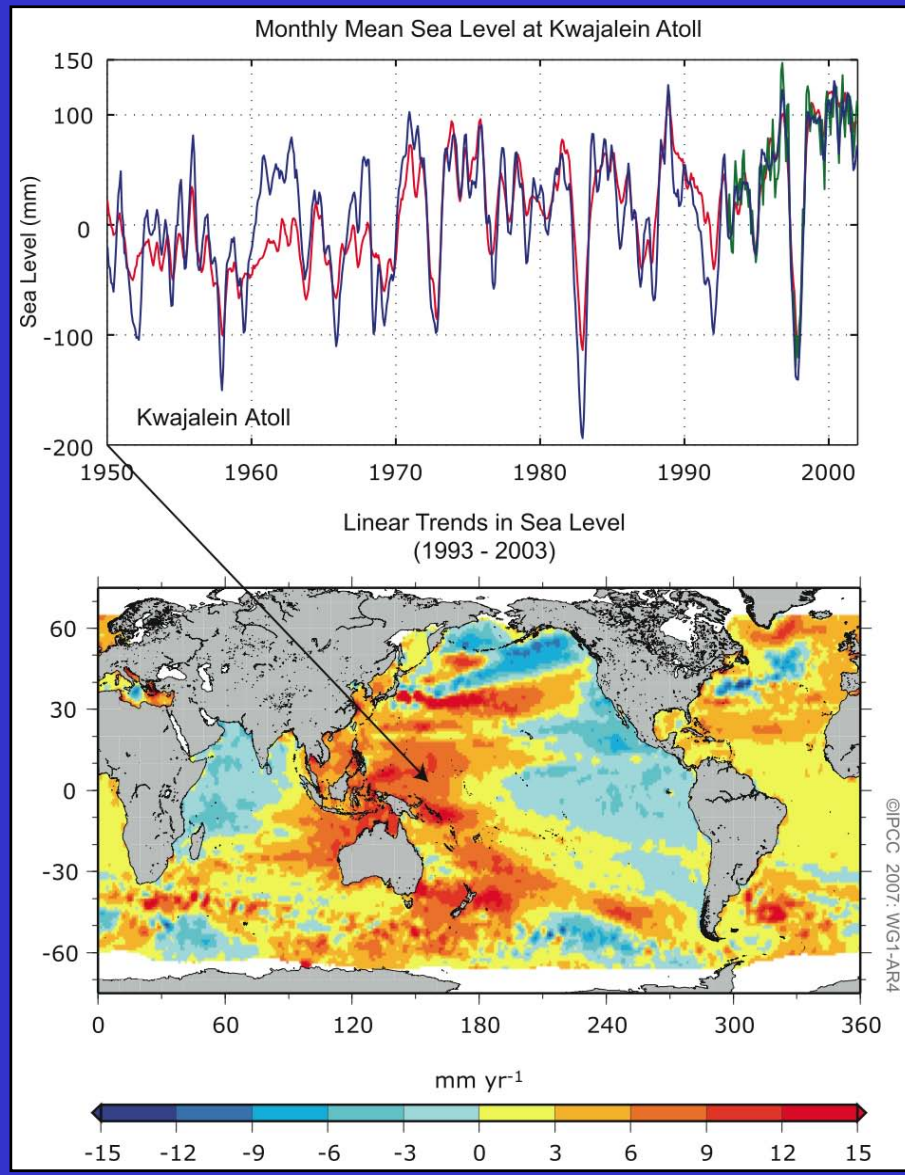


Sea level trends – satellite altimetry

Since 1993 satellite techniques have provided a much more detailed picture of sea level changes.

Over 1993 – 2003 trends vary significantly from place to place.

The pattern of sea level trends is very similar to that of the underlying change in ocean heat content.



Consistent pattern of warming

- Surface temperatures increasing
- Tropospheric temperatures increasing
- Atmospheric water vapour content increasing
- Ocean heat co
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- Mid-latitude wind patterns/ storm tracks shifting poleward
- More intense and longer droughts
- Frequency of heavy precipitation events increasing
- Extreme temperatures increasing
- Tropical cyclone intensity increasing

Unequivocal

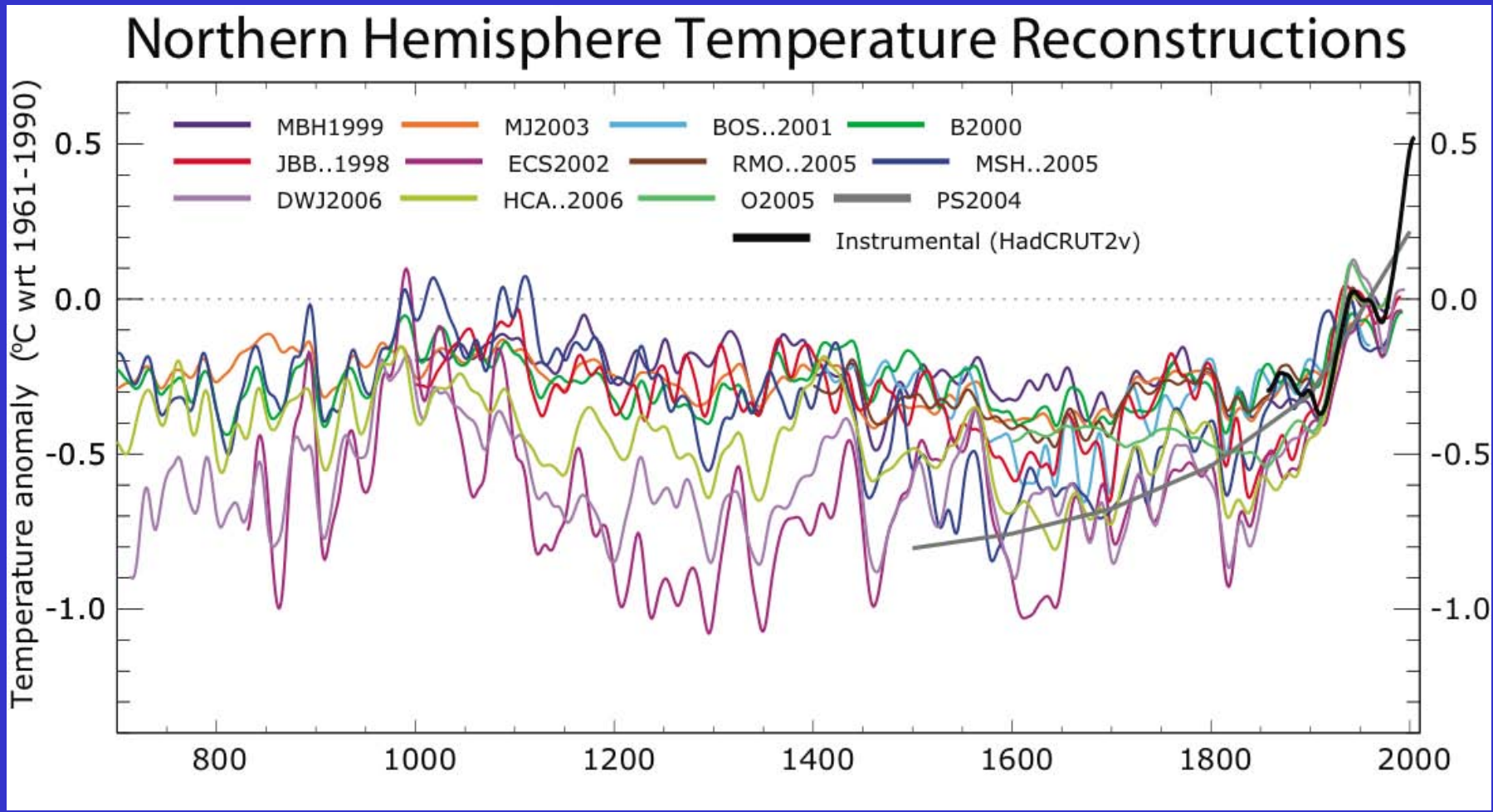
Paleoclimatic perspective

Warmth of the last half century is unusual in at least the previous 1,300 years

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.

A longer term perspective

Warmth of the last half century is unusual
in at least the previous 1300 years.



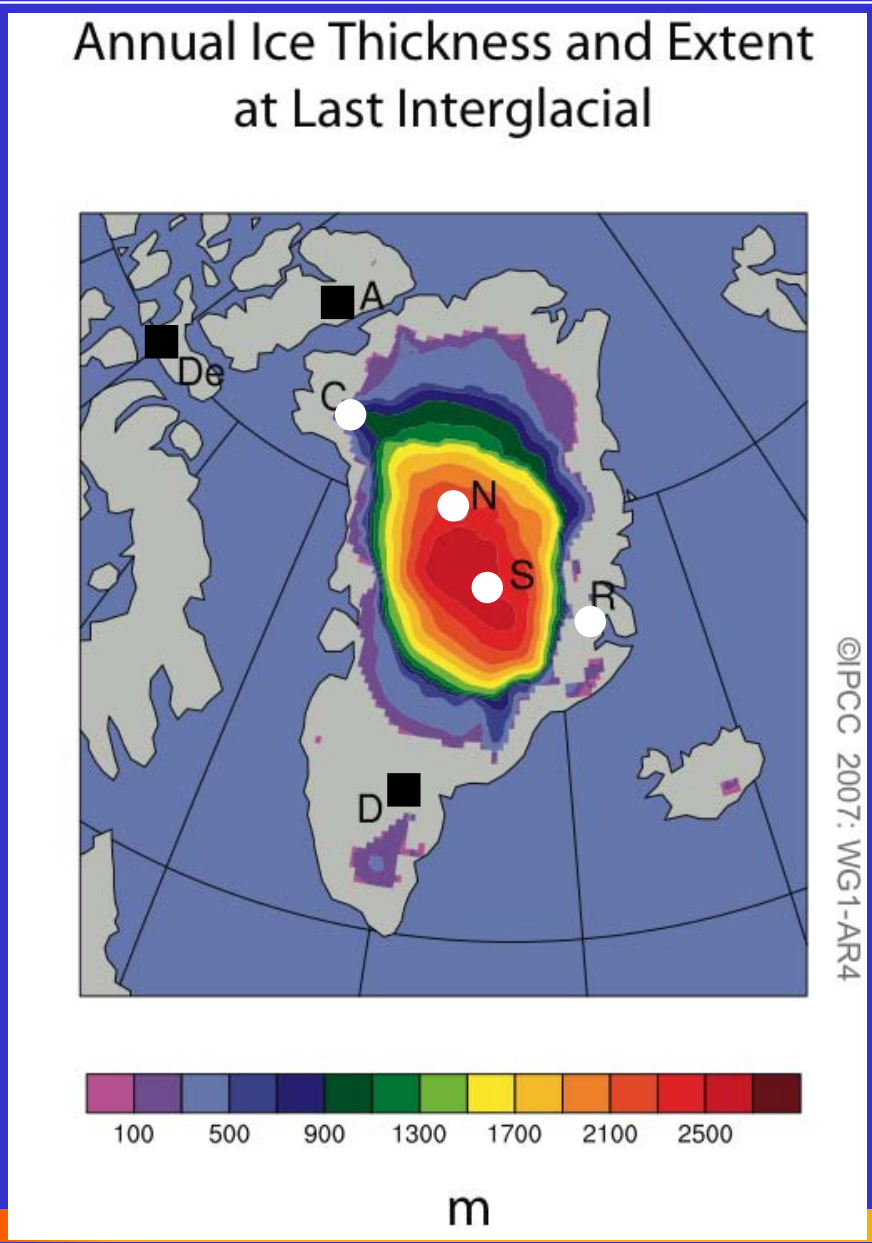
Greenland ice sheet 125,000 years ago

Contours are from average of 3 ice sheet models.

White dots show drill sites that had ice.

Black squares show sites that did not have ice.

The last time 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.



Drivers of Climate Change

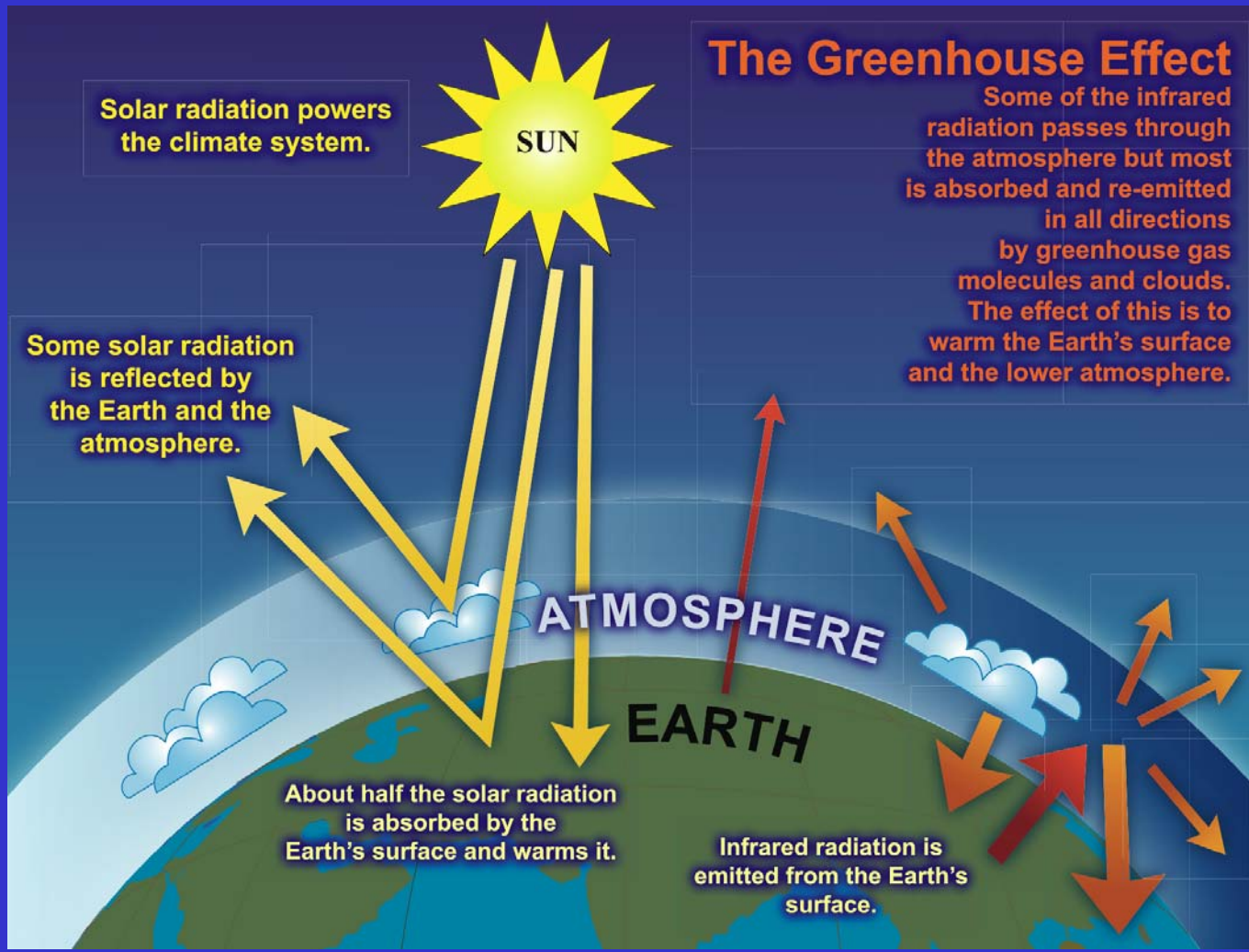
Concentrations of CO_2, methane and nitrous oxide have increased markedly as a result of human activities and now far exceed pre-industrial values

Net effect of human activities since 1750 has been one of warming

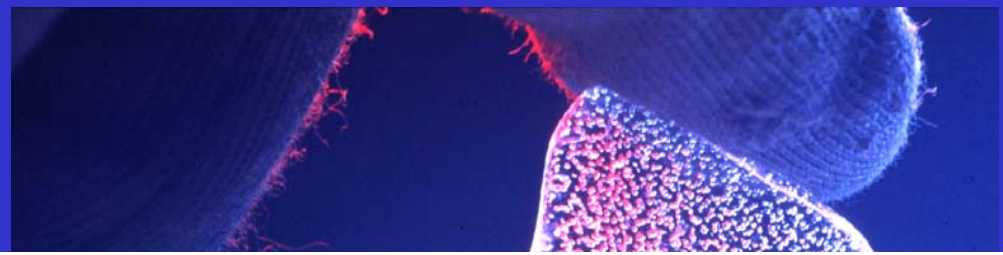
The greenhouse effect

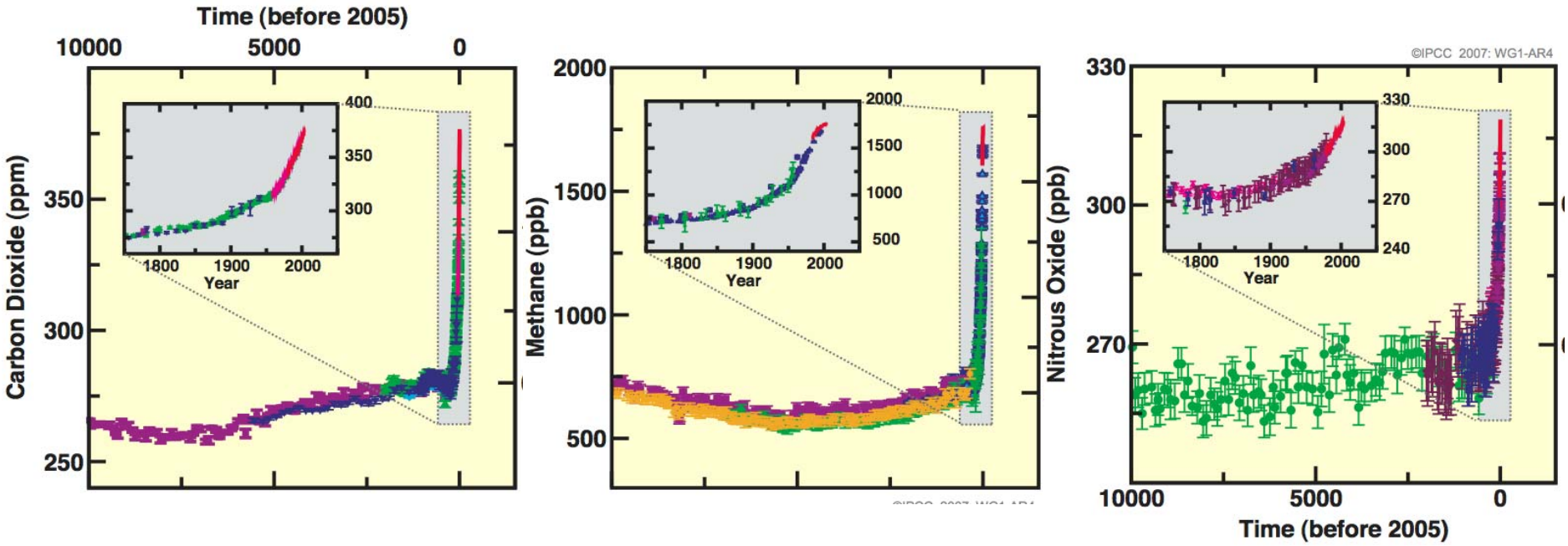
The natural greenhouse effect increases surface temperatures by about 30°C.

Increasing greenhouse gas concentrations tends to increase surface temperatures.



Industrial revolution and the atmosphere





The current concentrations of greenhouse gases and their rates of change are unprecedented.

Carbon Dioxide

Fossil fuel emissions:

1980s: 19.8 $GtCO_2$ /yr

1990s: 23.5 $GtCO_2$ /yr

2000-2005: 26.4 $GtCO_2$ /yr

Land Use Change flux:

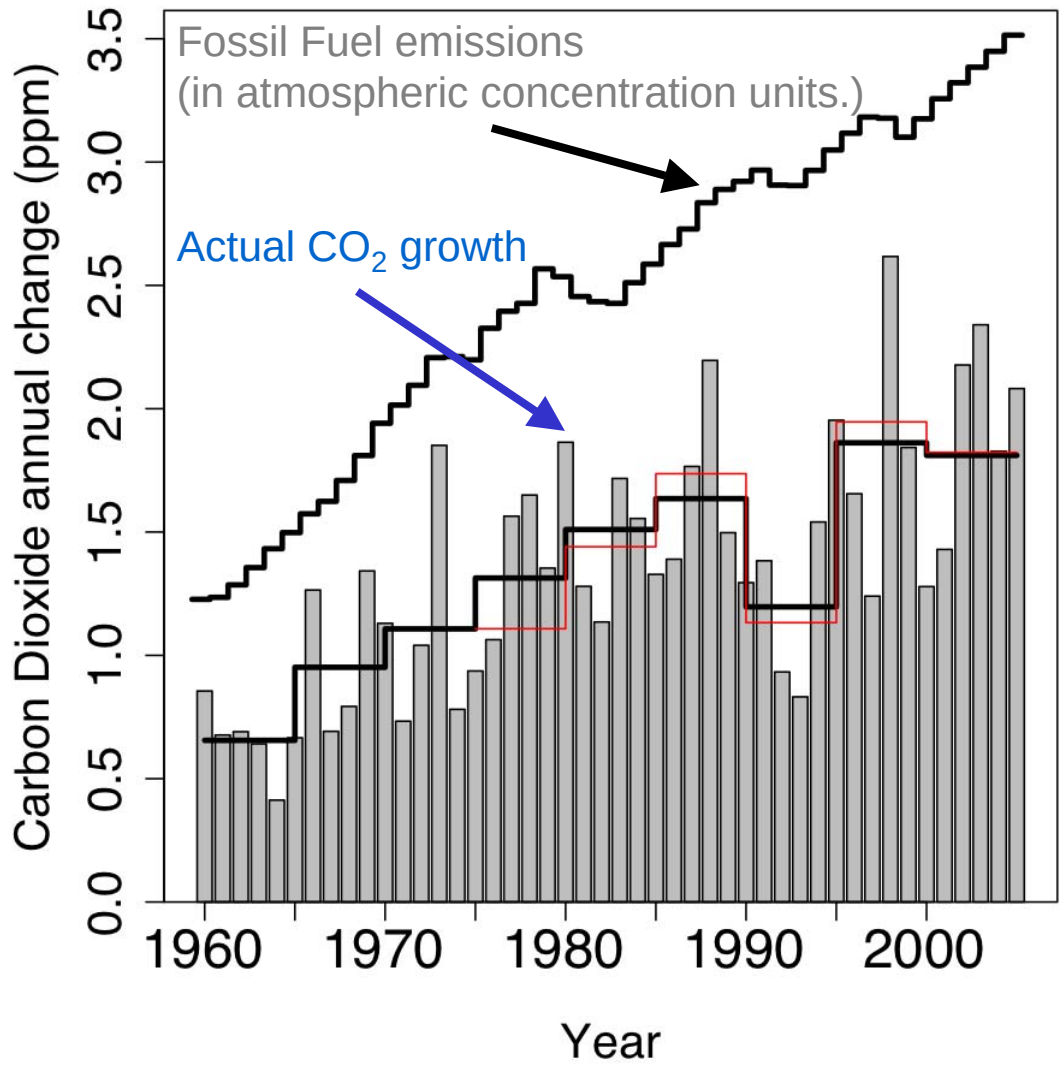
1980s: 5.1 $GtCO_2$ /yr

1990s: 5.9 $GtCO_2$ /yr

Atmospheric CO_2 growth rate:

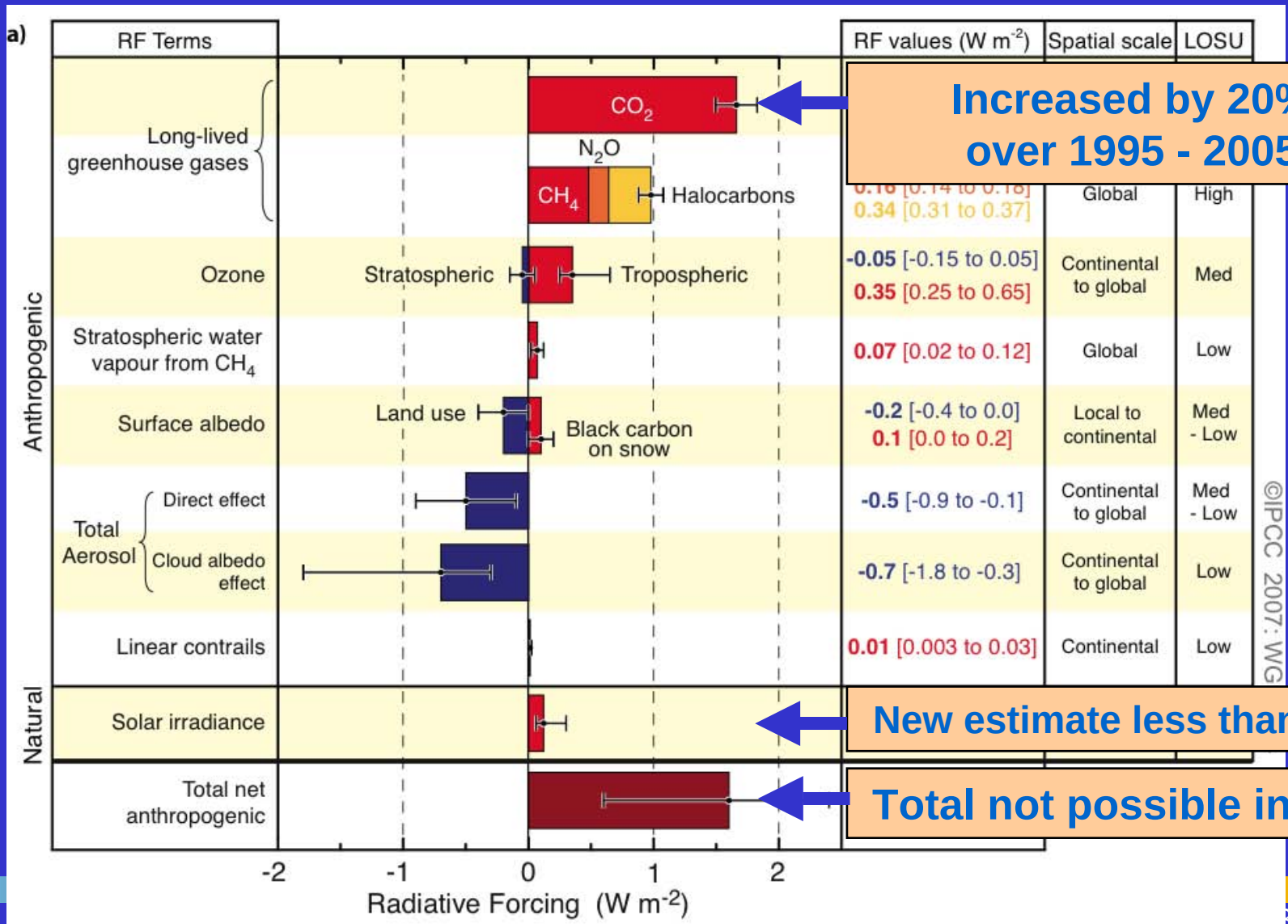
1960 – 2005: 1.4 ppm /yr

1995 – 2005: 1.9 ppm /yr



Radiative forcing: change in energy balance

Used to compare different drivers of climate change



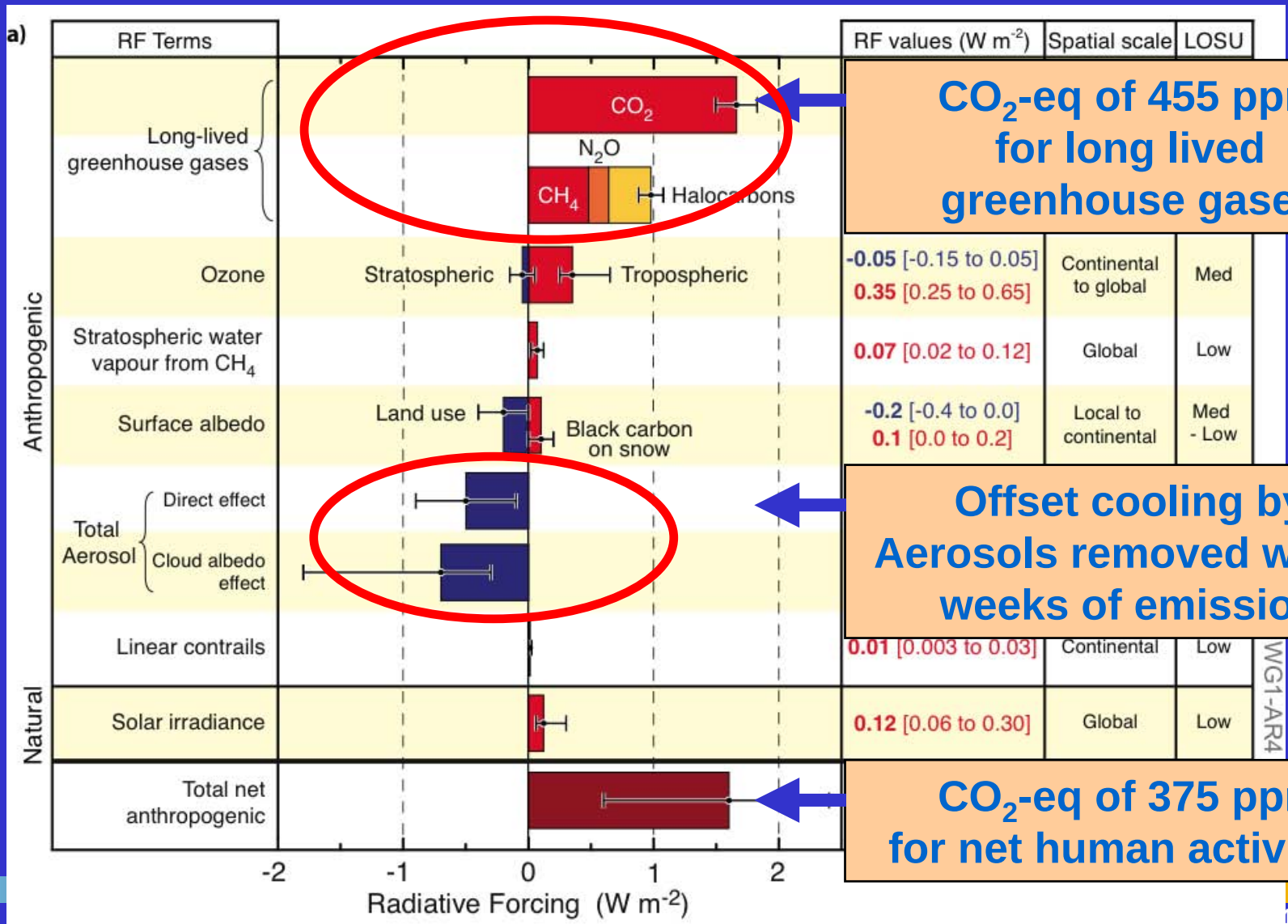
Increased by 20% over 1995 - 2005

New estimate less than TAR

Total not possible in TAR

Radiative forcing: CO_2 equivalents

Used to compare different drivers of climate change



Summary

Evidence for warming of the climate system is unequivocal.

We are seeing coherent changes in many aspects of the climate system other than temperature.

The role of greenhouse gases is well understood and their increases are clearly identified.

The net effect of human activities is now quantified and known to cause a warming at the Earth's surface.