IPCC Working Group I
Assessment of Physical Climate Change

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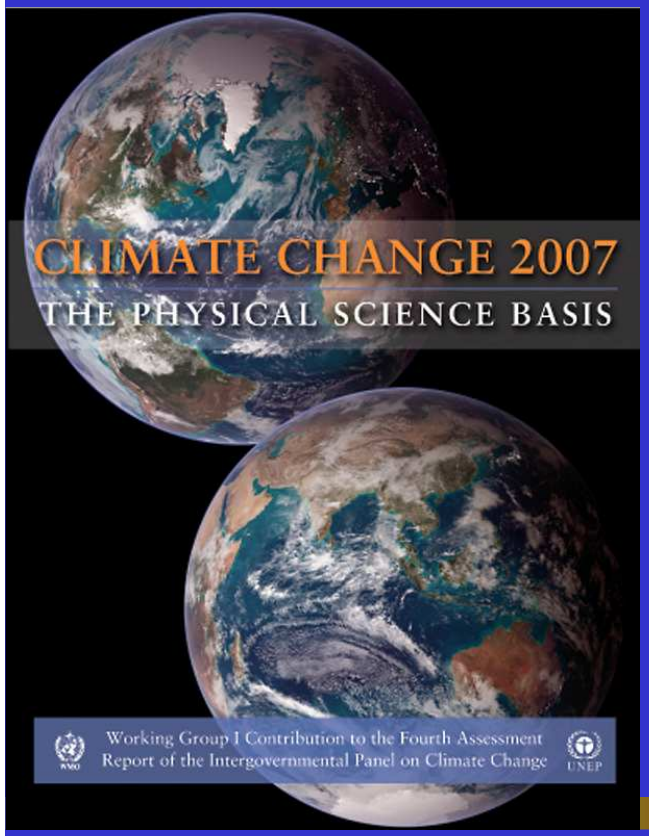


1. Observed climate change
2. Drivers of climate change
3. Projections
4. Sea Level
5. Extremes
6. Climate change & carbon cycle

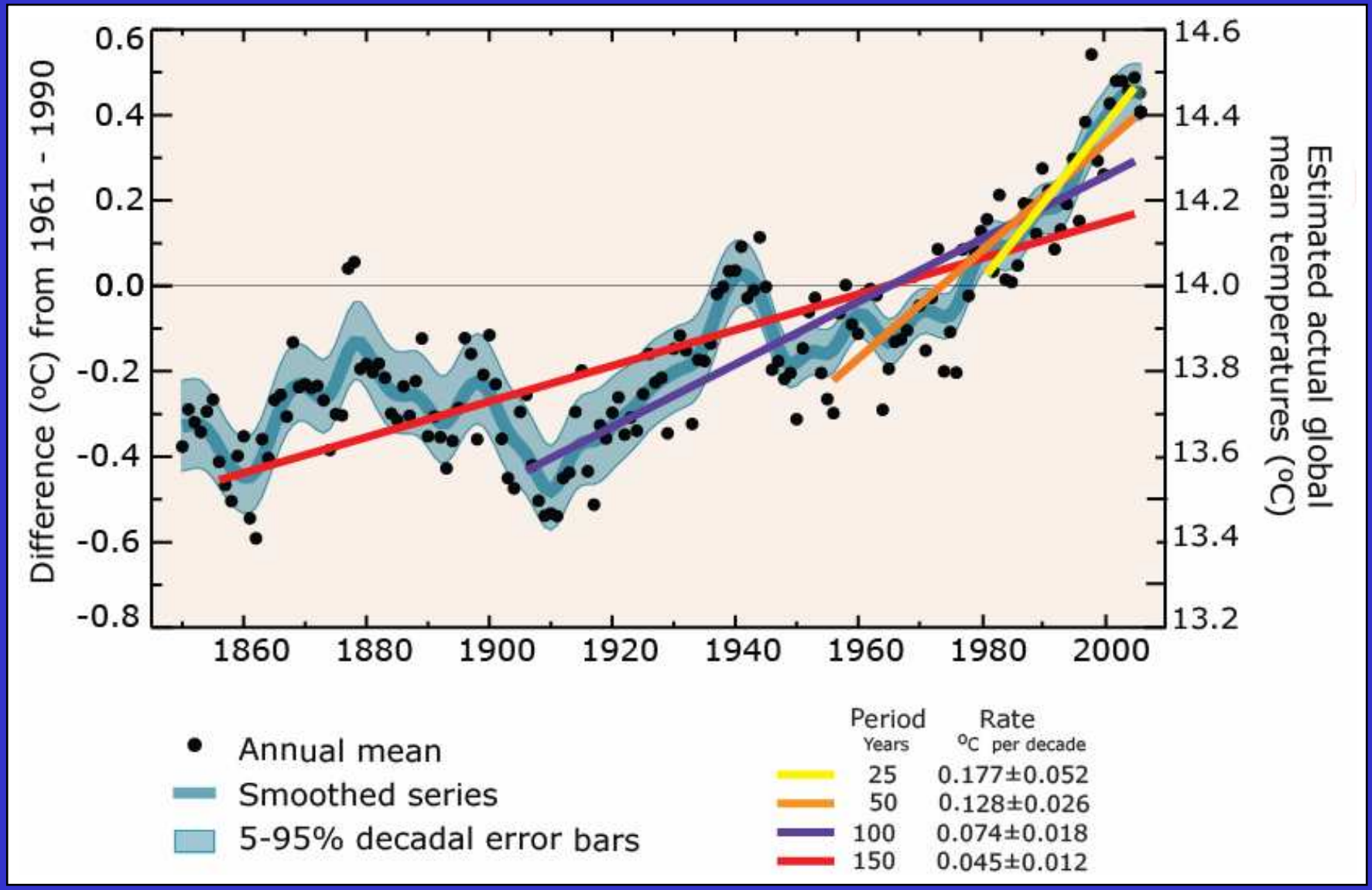
Observed Climate Change

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



Consistent pattern of warming

- Surface temperatures increasing
- Tropospheric temperatures increasing
- Atmospheric water vapour content increasing
- Ocean heat content increasing ….
- … now directly linked to sea level rise
- Greenland and Antarctic Ice Sheets losing mass
- Glaciers and snow cover increasing
- Arctic sea ice extent decreasing
- Area of seasonally frozen ground decreasing
- 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

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

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:

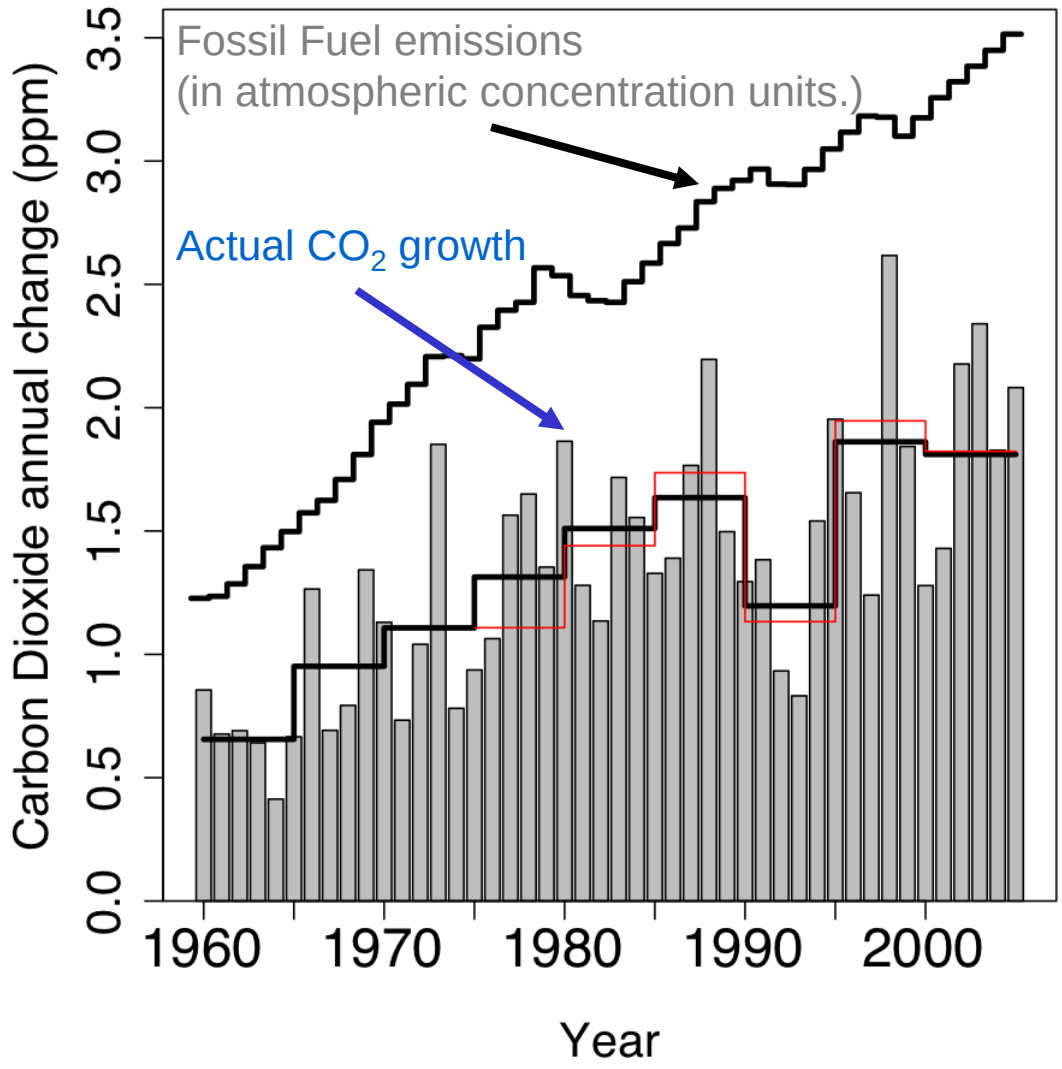
1980s: 5.1 $GtCO_2$ /yr

1990s: 5.9 $GtCO_2$ /yr

Atmospheric CO_2 growth rate:

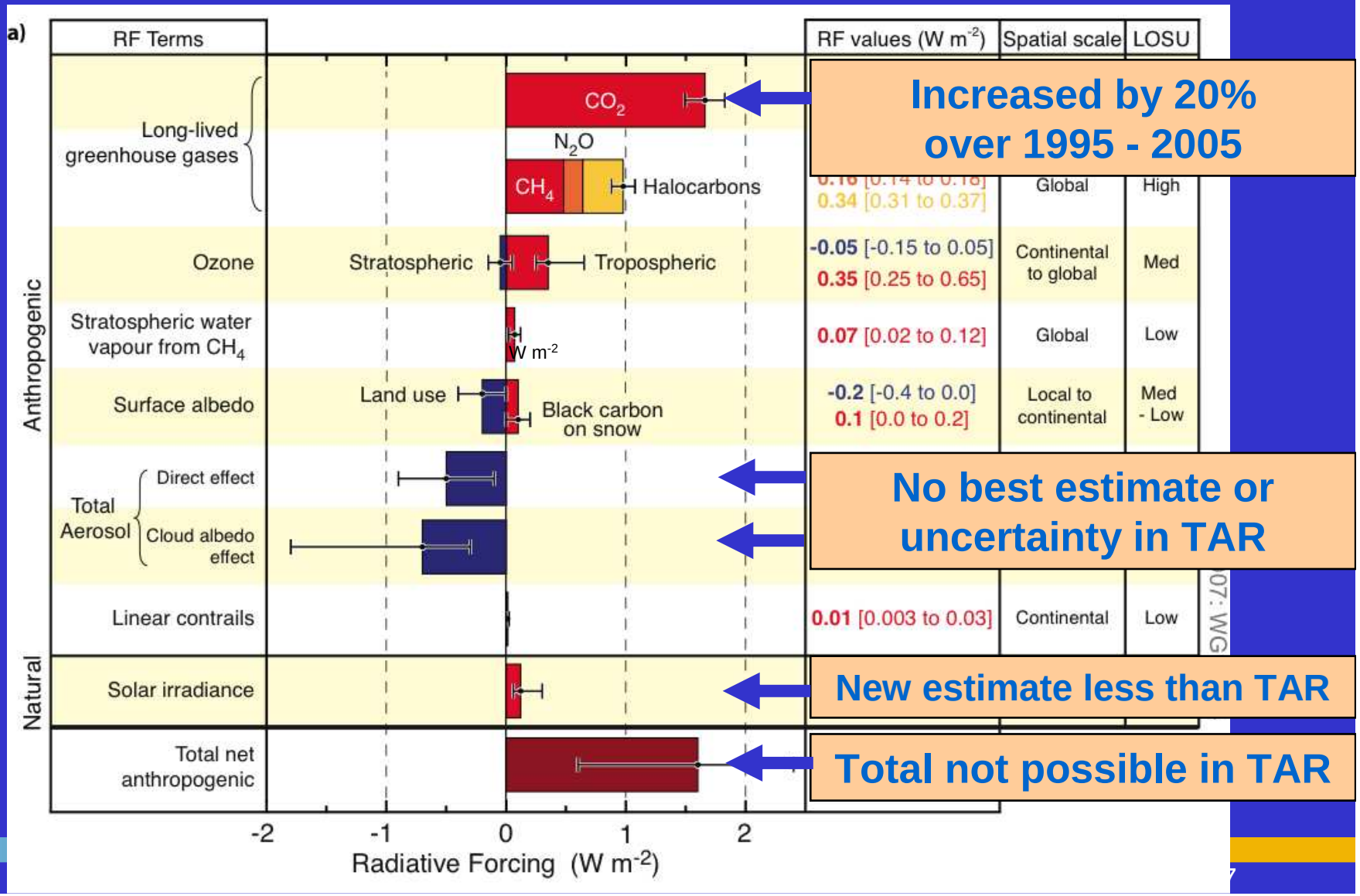
1960 – 2005: 1.4 ppm /yr

1995 – 2005: 1.9 ppm /yr



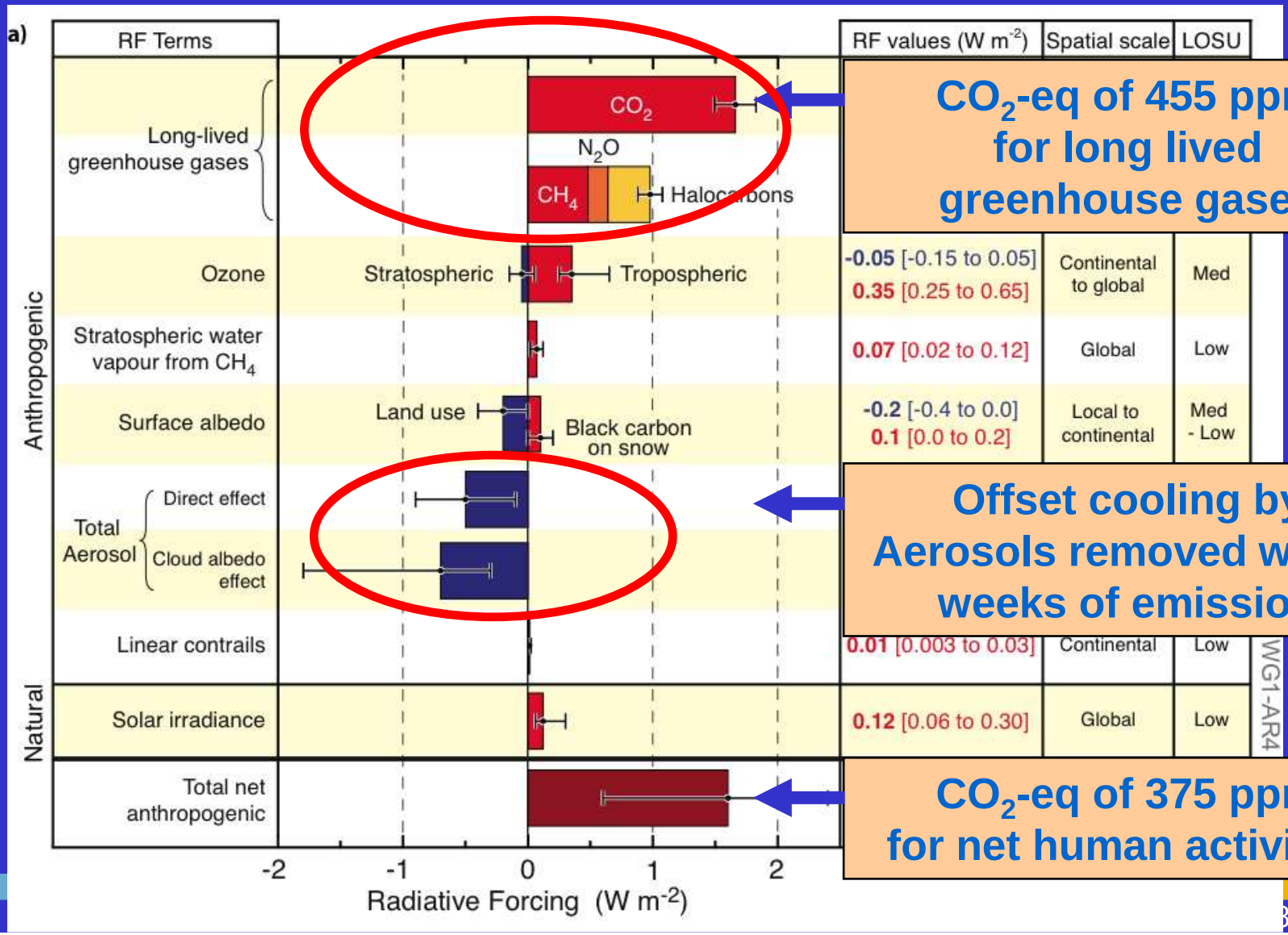
Radiative forcing: change in energy balance

Used to compare different drivers of climate change



Radiative forcing: CO_2 equivalents

Used to compare different drivers of climate change



CO_2-eq of 455 ppm for long lived greenhouse gases

Offset cooling by Aerosols removed within weeks of emission

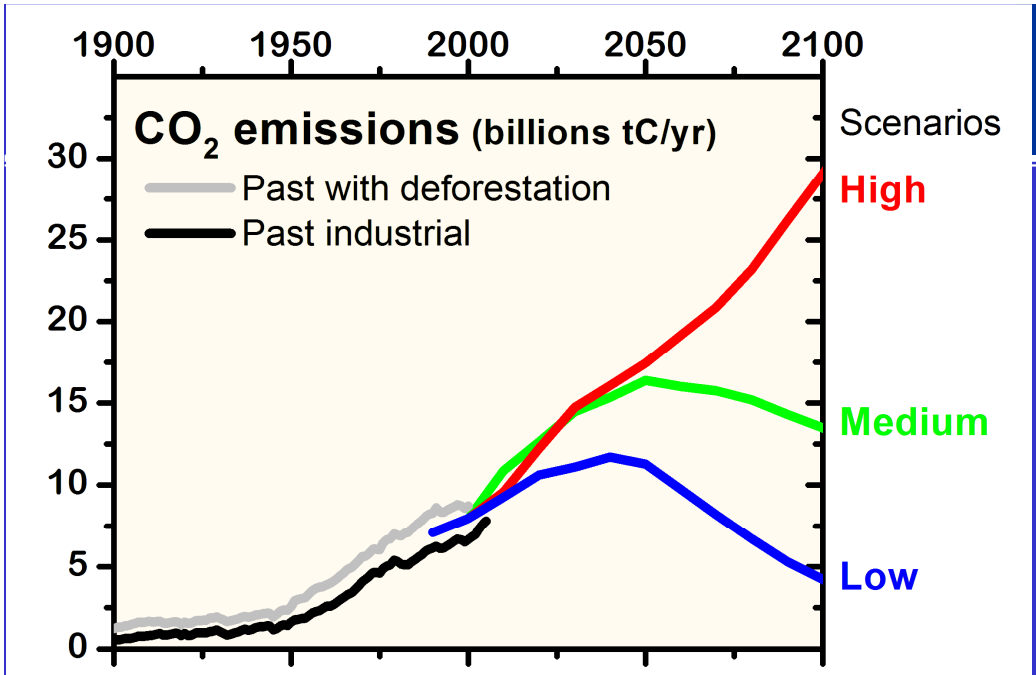
CO_2-eq of 375 ppm for net human activities

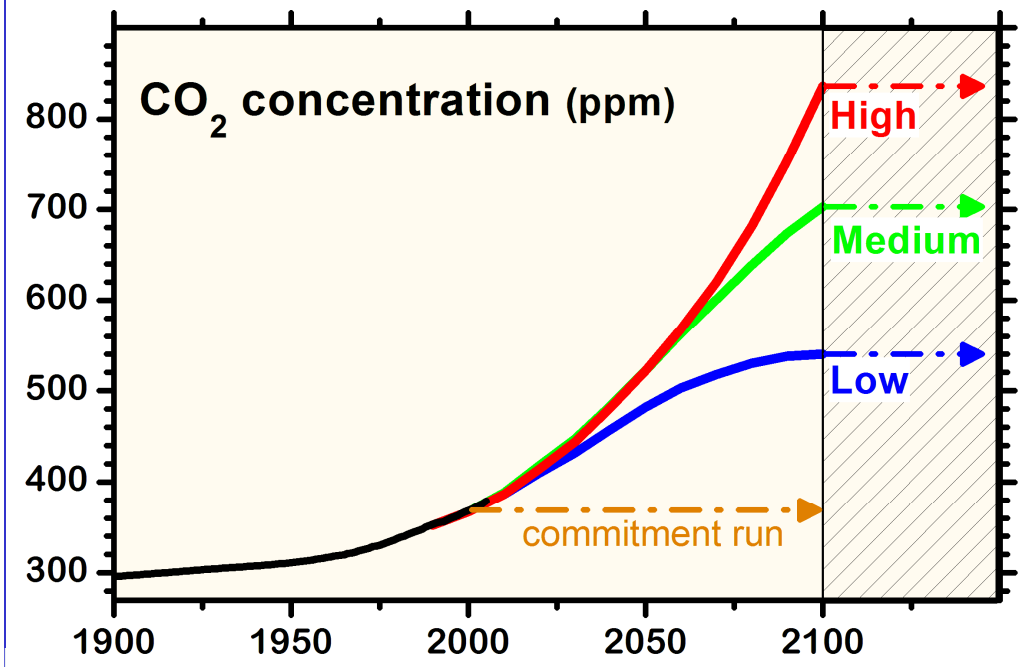
Projections of future climate

For the next two decades, a warming of about 0.2℃ per decade is projected for a range of SRES emission scenarios.

Subsequent warming depends on how much greenhouse gases are emitted to the atmosphere.

Scenarios used





Based on pre-2000 literature

No additional climate change policy (no mitigation)

Low, Medium, and High emission scenarios.

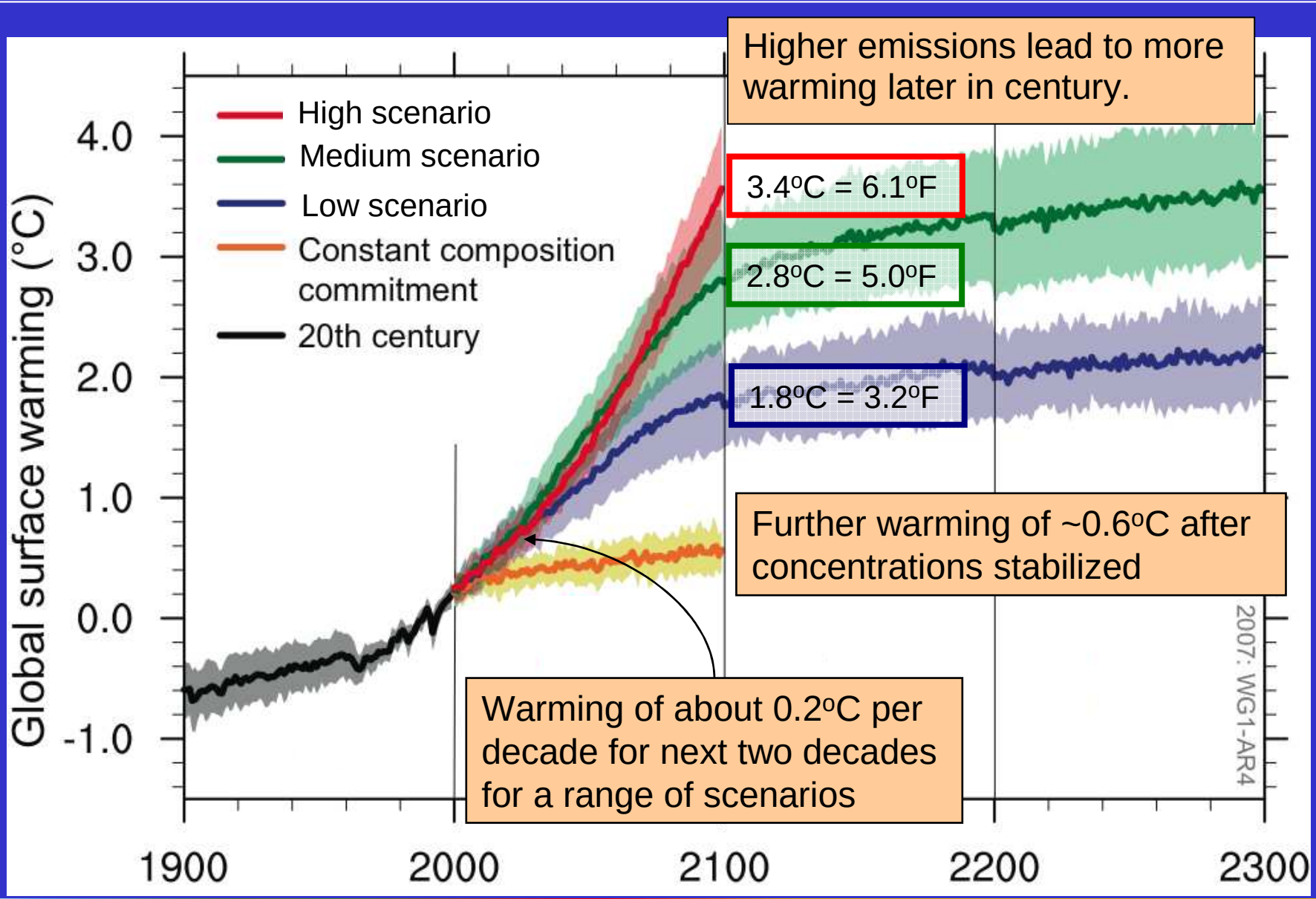
"Physics tests" kept atmospheric composition constant.

Compare doing so in 2100 vs doing so in 2000.

Results from

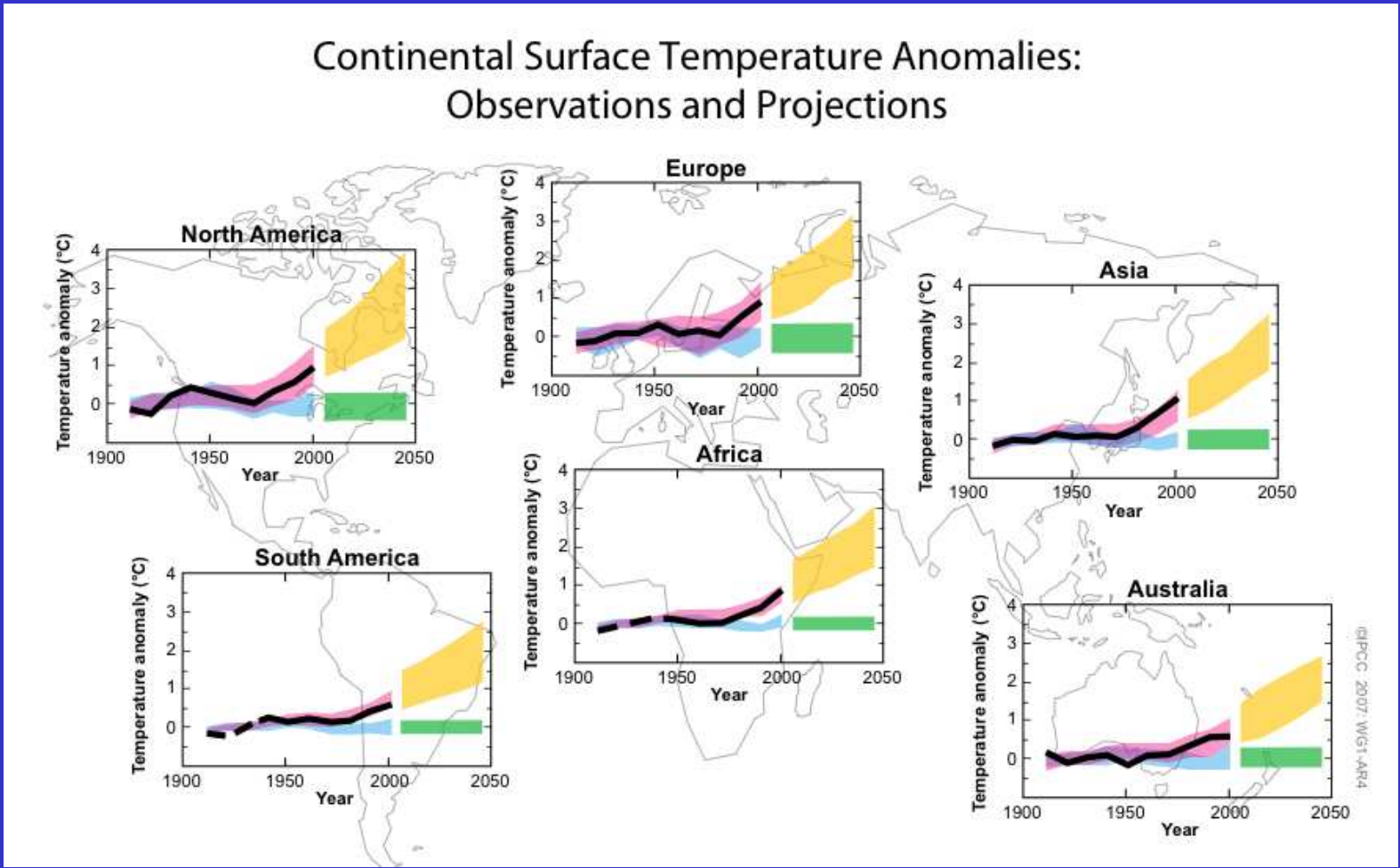
- 14 modelling groups
- 23 models

Projected global average warming



Near term climate change

For SRES scenarios average warming in all continents will exceed range of natural variability in next few decades.



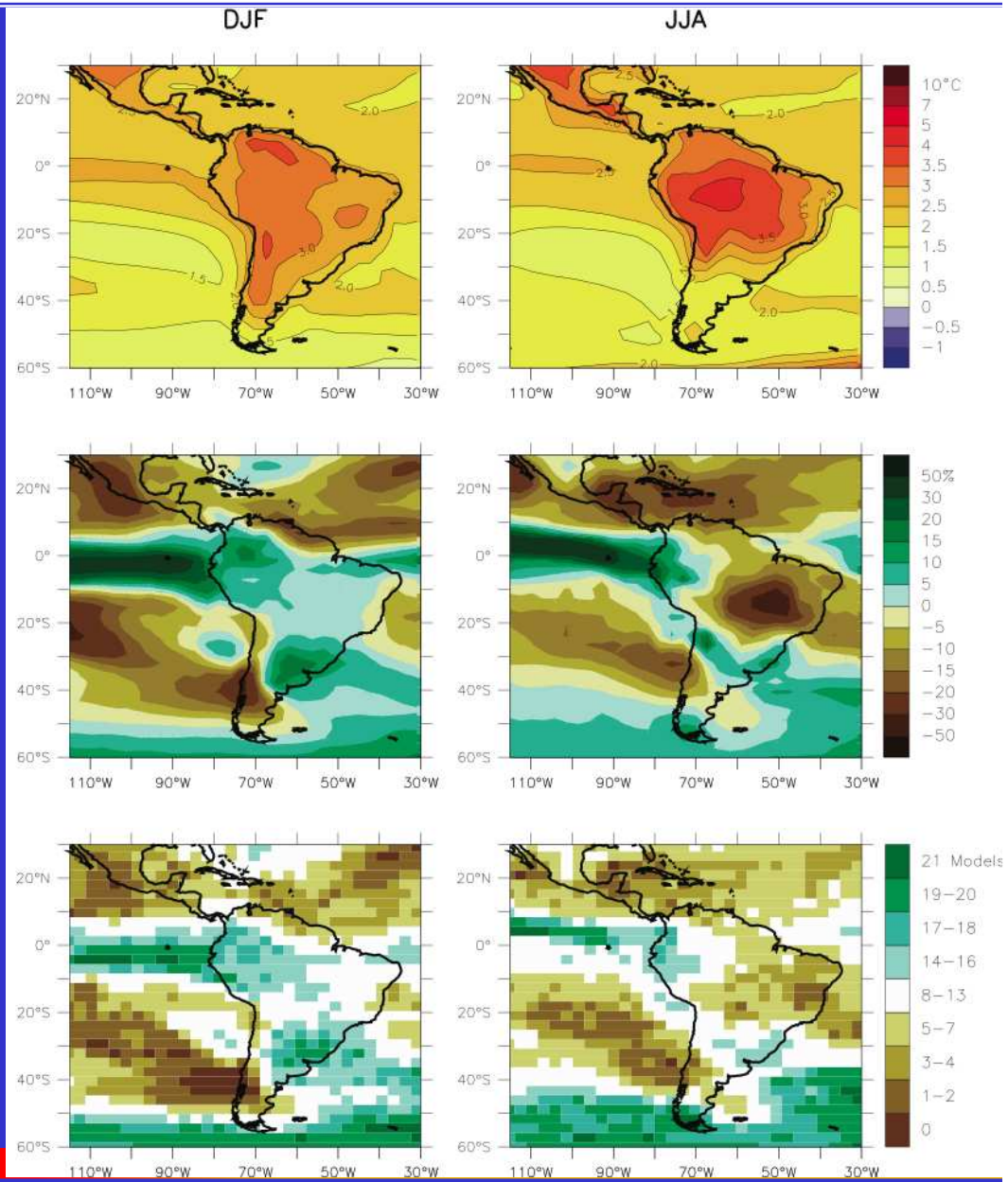
See Chapter 11 for regional detail

Medium (A1B) scenario
2080-2099 relative to 1980-1999

Multi-model mean warming °C

Multi-model mean relative change in precipitation %

Number of models that project increases in precipitation



(Modelled) Sea level rise

Sea level rise has 3 main components:

Thermal expansion	new estimates use much more detailed models and give results slightly less than in TAR. Causes 70 – 75% of projected sea level rise
Glaciers and small ice caps	uncertainties reduced using new data
Ice Sheets	processes that are simulated in ice dynamics models with confidence remain much as in TAR
(Total)	New projections are within 10% of those in the TAR but have smaller uncertainties.

For the parts of sea level rise explained by models, projections for 2100 range from 0.28 to 0.43 m (9 to 16 in)

Sea level rise – limits to knowledge

Accelerated ice sheet discharge observed in recent years implies ice processes that are not in current models.

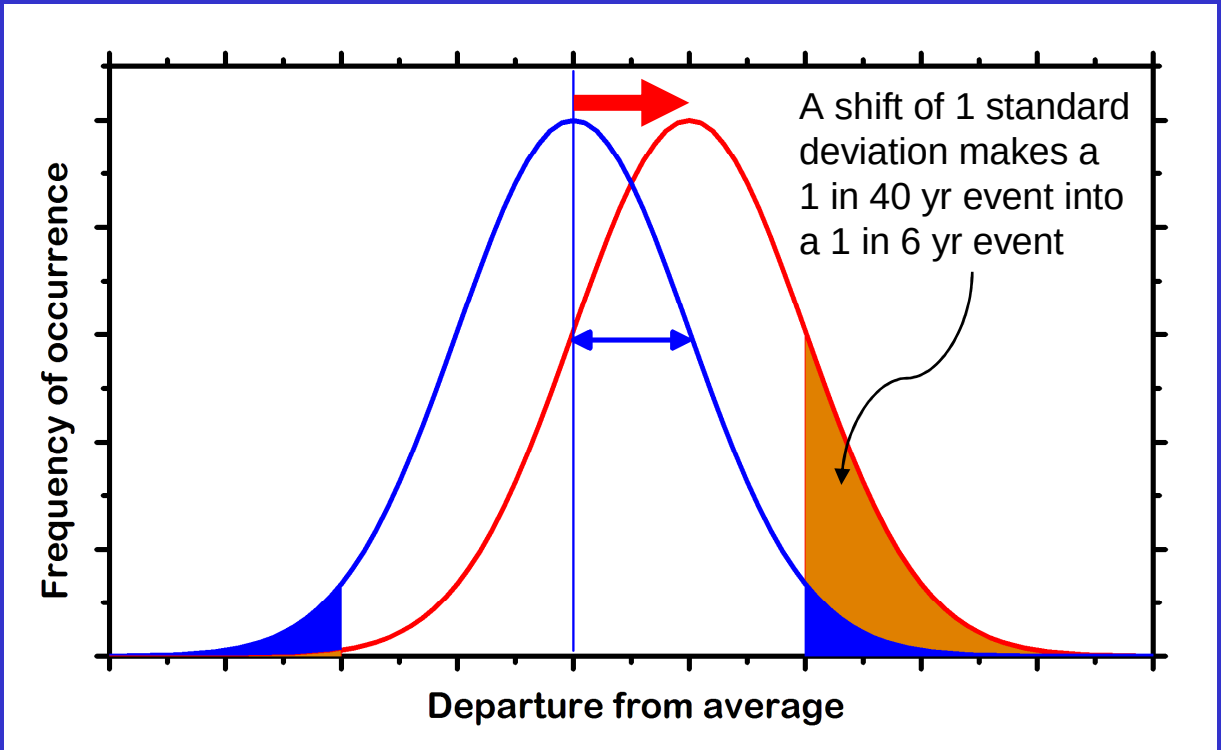
We can not provide a best estimate or upper bound for sea level rise by 2100

Surface melt on Greenland ice sheet descending into moulin, a vertical shaft carrying the water to base of ice sheet. Photo credit: Roger Braithwaite

Calculus of extremes

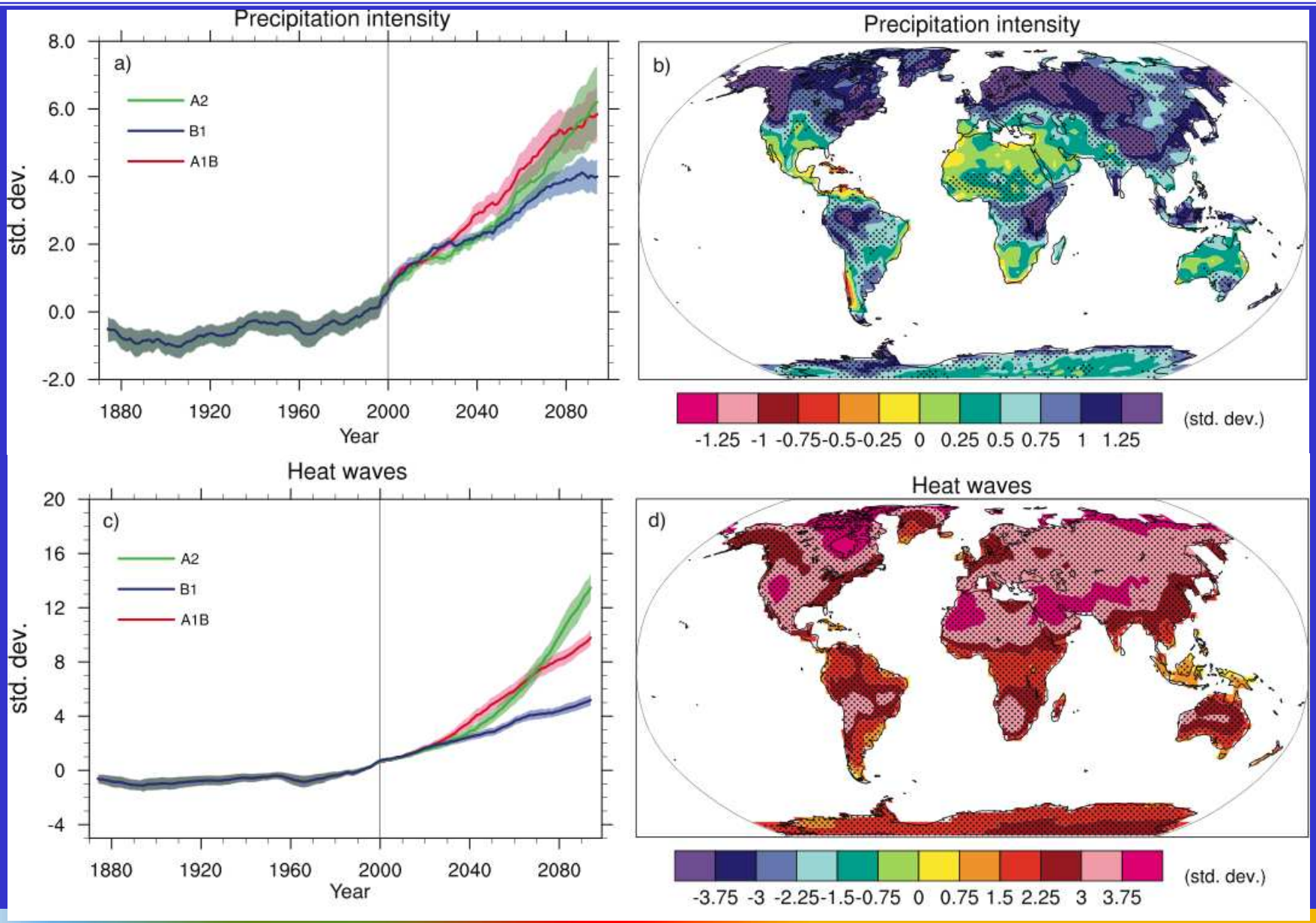
The distribution of weather events around the climatic average follows a ‘bell-shaped’ curve.

Climate change can involve change in the average, or the spread around the average (standard deviation), or both.



A shift in the distribution of temperatures has a much larger relative effect at the extremes than near the mean.

Projected changes in extremes



Extremes will increase

- Projected increases in heavy precipitation and drought are linked to physical processes – principally increased absolute humidity and patterns of convergence and divergence in atmospheric transport.
- Precipitation intensity increases - even where total precipitation decreases.
- Risk of 2003 type heat wave doubled in Europe due to current level of greenhouse gases (single study).
- Extreme summer temperatures become at least 20 times more frequent by end of century (average for 3 scenarios and for multiple models).

Climate – carbon cycle feedback

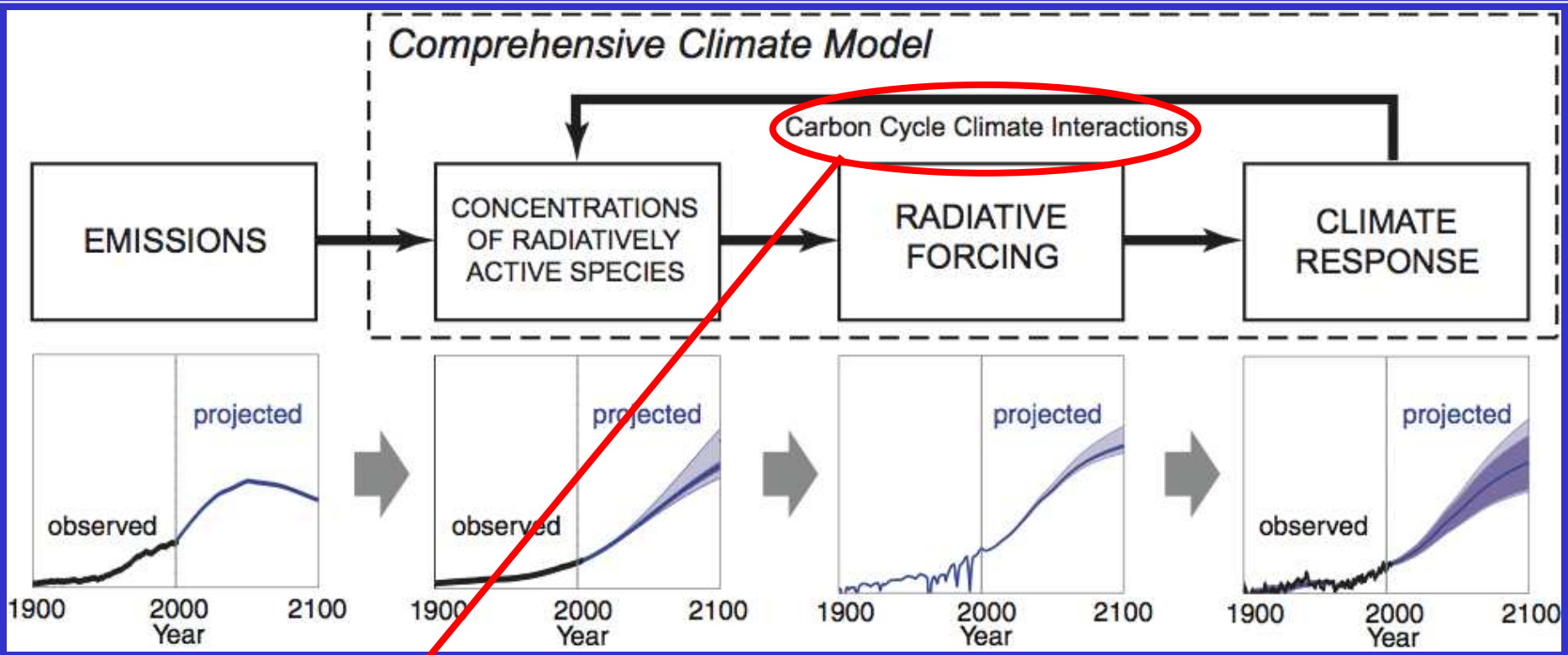
Global warming reduces carbon uptake on land and ocean.

For a high emissions scenario, model estimates of CO_2 growth by 2100 increase by 4% to 44% due to this positive feedback.

Will be affected by:

- extent of managed (agriculture, biofuels) vs unmanaged ecosystems
- changing incidence of fires
- ability of vegetation to adapt

Science uncertainties affecting policy



Carbon cycle

Positive, magnitude uncertain

Climate sensitivity

Best estimate 3°C, likely in range 2°C to 4.5°C

Summary

Confidence in climate change science has increased significantly.

Evidence for warming of the climate system is unequivocal.

We are changing the geography of the planet.

Reducing greenhouse gas emissions can reduce the magnitude of change in the longer term