Causes of past climate change and projections of future changes in climate

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1. The causes of observed climate change

2. Global and regional climate projections for the future

3. Observations and projections of sea level rise

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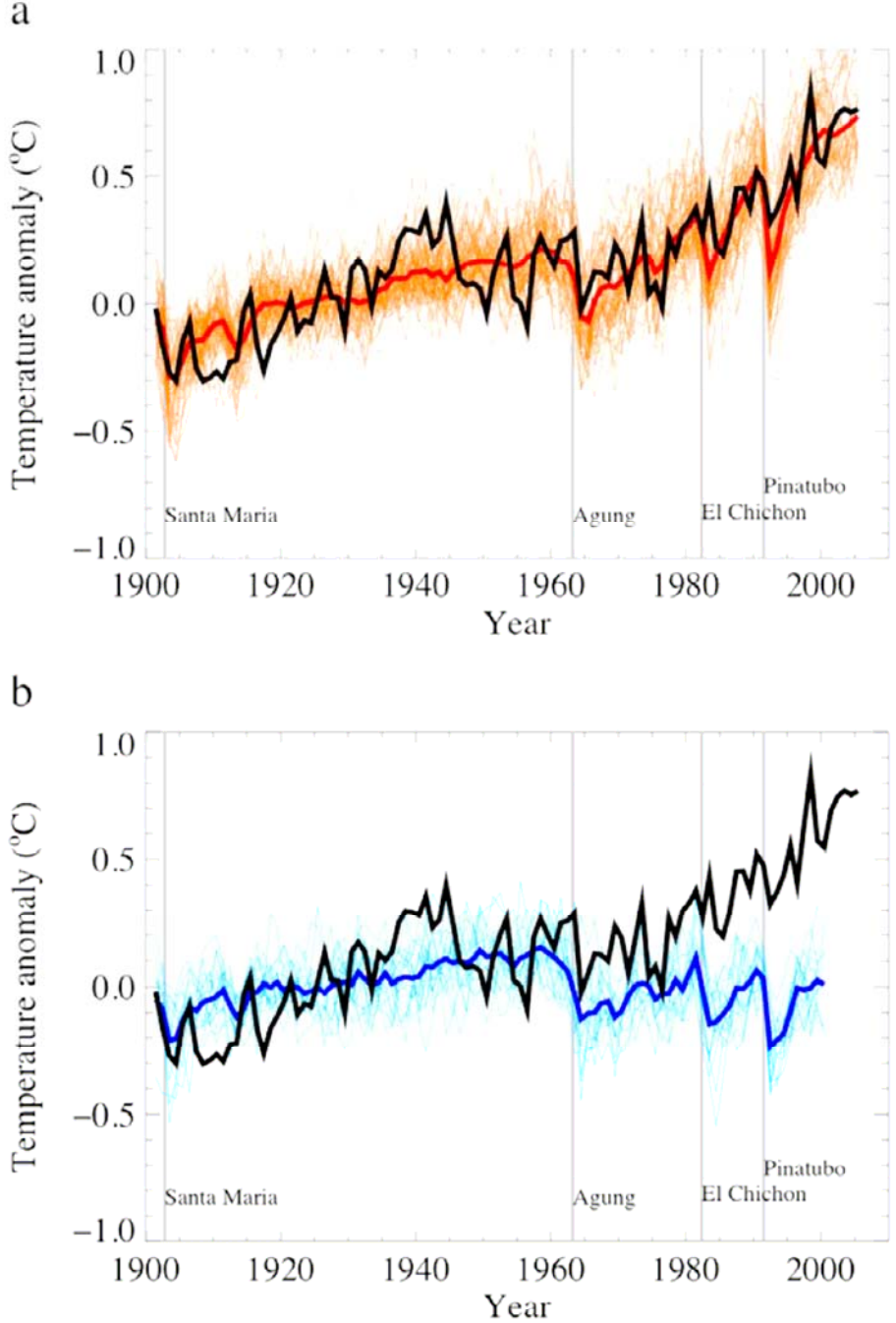
Attribution

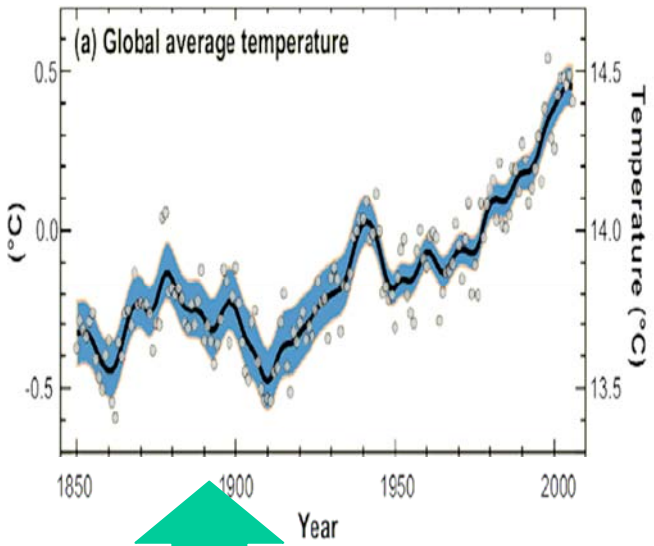
- Asks whether observed changes are consistent with

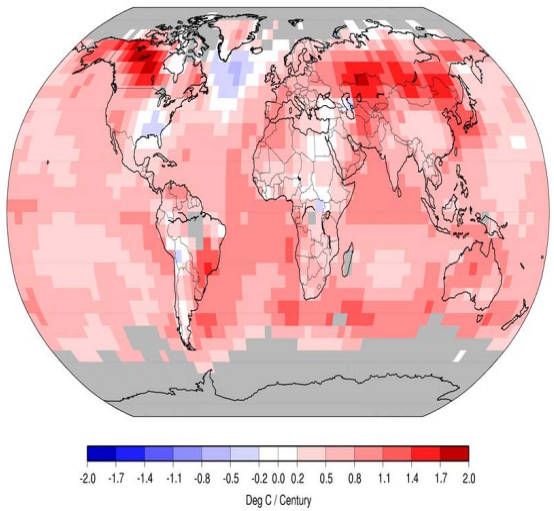
☑ expected responses to forcings

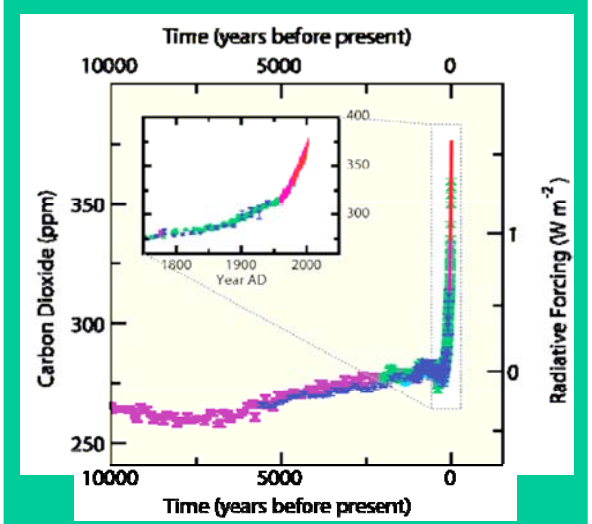
☒ inconsistent with alternative explanations



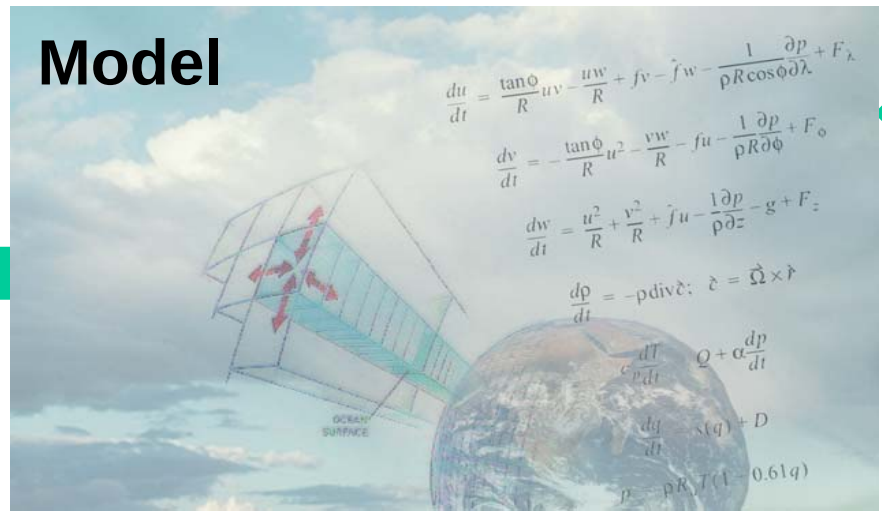
Attribution Process

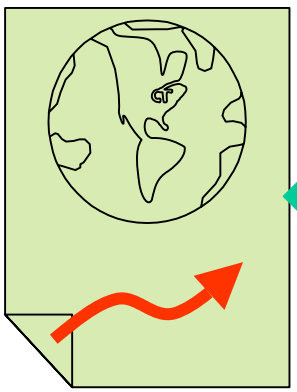






- other GHGs
- aerosols
- volcanic
- solar
- natural internal





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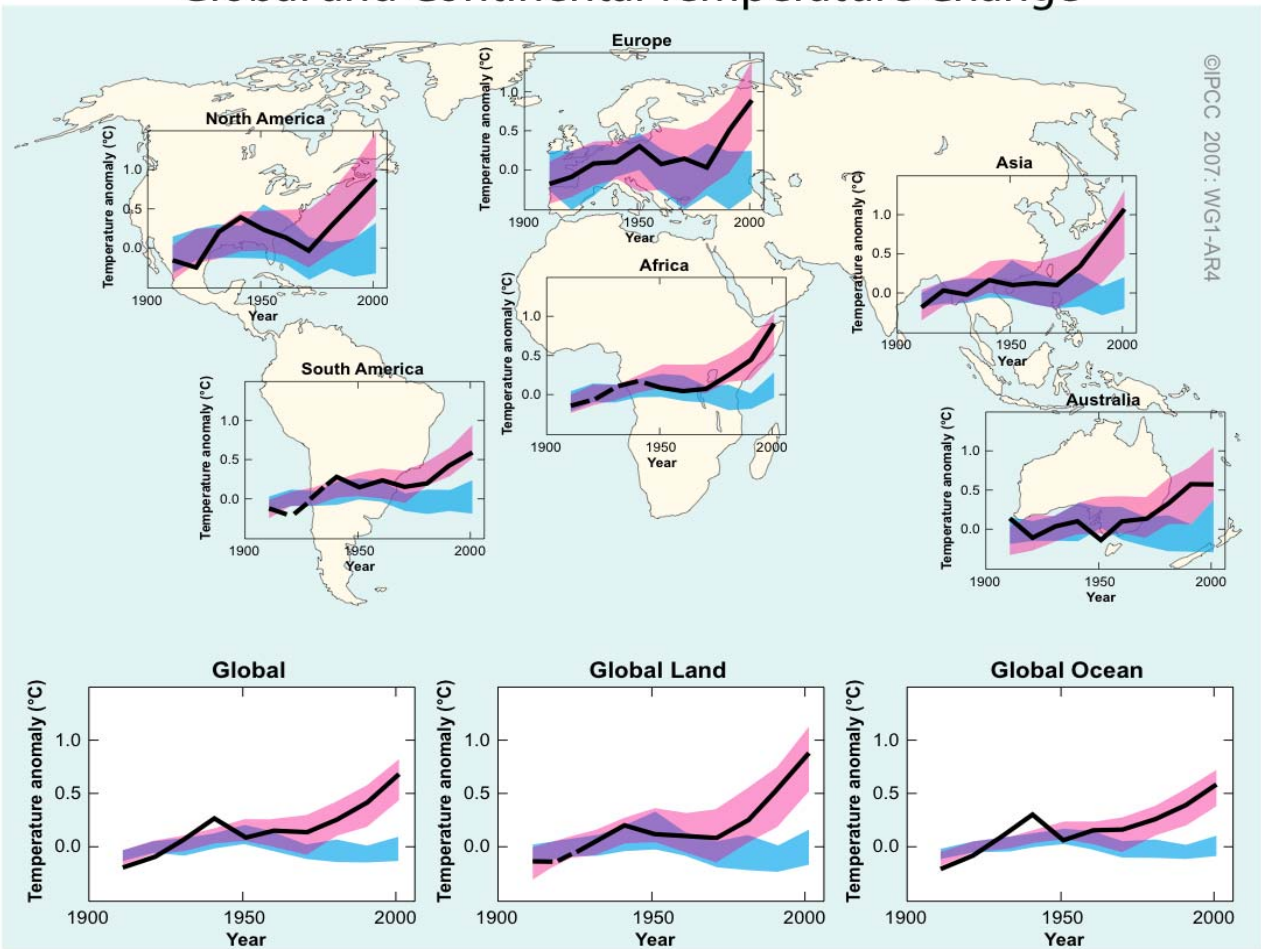
Climate Models

- Since the TAR there have been improvements in the simulation of many aspects of present mean climate and its variability on seasonal to inter-decadal time scales, although uncertainties remain.
- Models now employ more detailed representations of processes related to aerosols and other forcings.
- Simulations of 20th century climate change have used many more models and much more complete anthropogenic and natural forcings than were available for the TAR.

Global and Continental Temperature Change



- It is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica.

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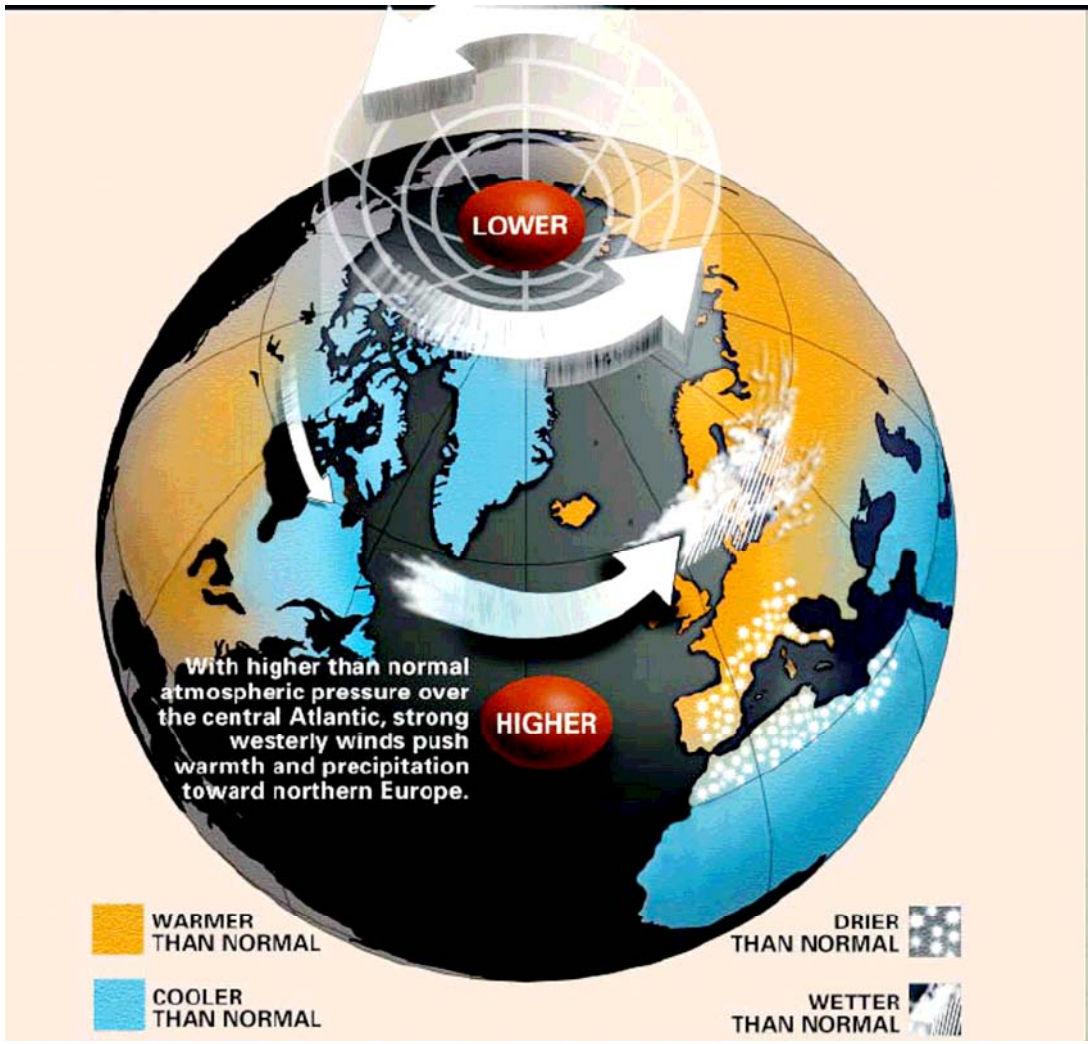
- The observed patterns of warming, including greater warming over land than over the ocean, and their changes over time are only simulated by models that include anthropogenic forcing.

- 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.

- Attribution remains difficult at smaller scales.

Additional Evidence

- Warming is widespread
  - Surface, atmosphere, ocean, cryosphere
- Temperatures of the most extreme hot nights, cold nights and cold days are **likely** to have increased due to anthropogenic forcing
- Anthropogenic forcing has **likely** contributed to circulation change
  - storm tracks, winds and temperature patterns
- Human influence has **more likely than not** increased the risk of heatwaves
- External influence on rainfall, droughts, stream flow



TS, Box 3.1, Fig 1

- Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic greenhouse gas concentrations.

- 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 influence now extends to other aspects of climate, including ocean warming, continental-average temperatures, temperature extremes and wind patterns.

Very likely > 90% chance

Temperature of last 7 centuries

- ***Very unlikely*** unforced variability alone
- Influence of external forcing detected
- Independent temperature and forcing reconstructions

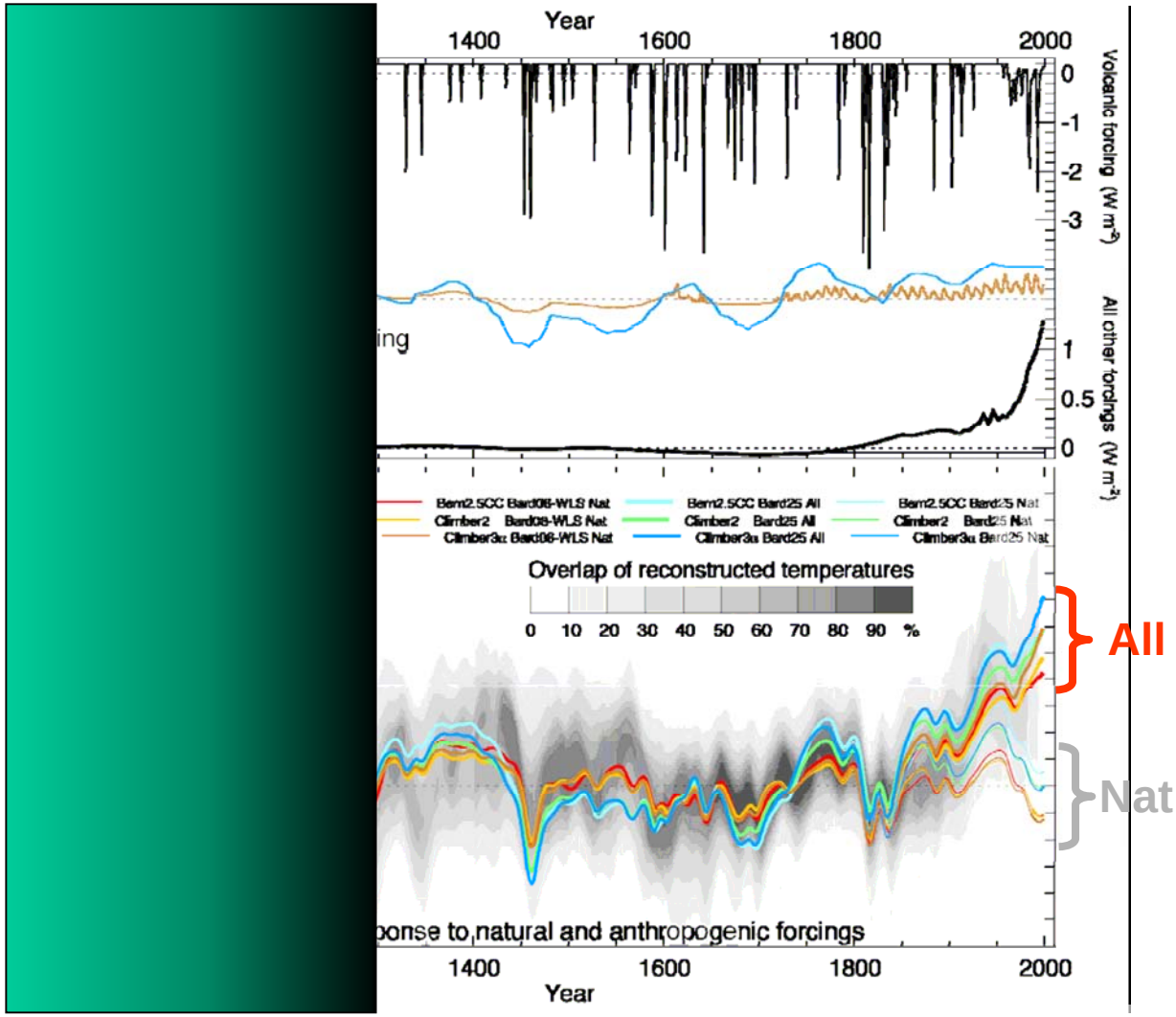


Fig. 6.14

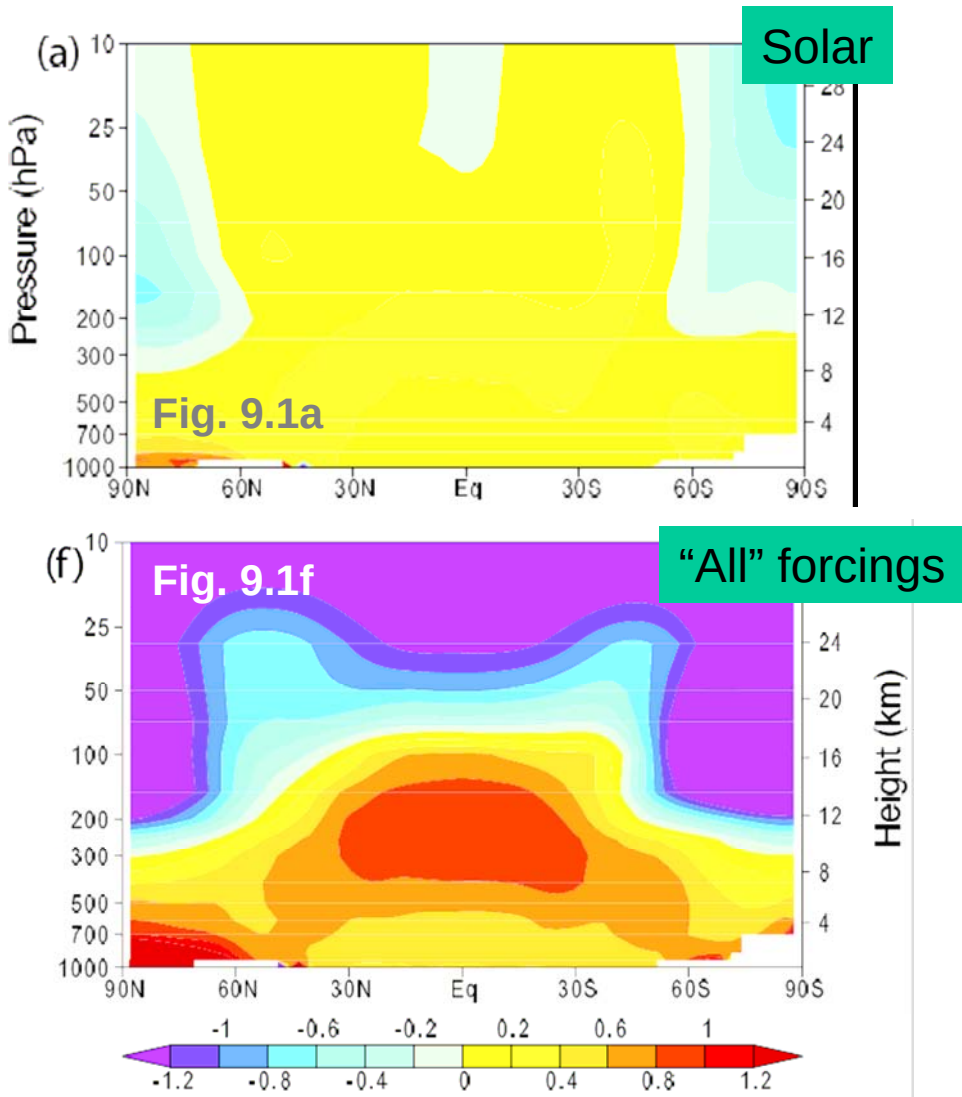
Solar forcing cannot explain observed change

- much smaller than greenhouse gas forcing

Attribution studies

- Separate time-space patterns of response
- allow for enhanced response to solar forcing
- find solar contribution to observed warming *very unlikely* greater than greenhouse gas contribution

Simulated – 1890-1999 (PCM)



Analysis of climate models together with constraints from observations enables an assessed range to be give for climate sensitivity for the first time and provides increased confidence in the understanding of the climate system response to radiative forcing.

This is a measure of the climate system response to a sustained radiative forcing and is not a projection.

	TAR	AR4
Equilibrium climate sensitivity	range 1.5 to 4.5°C	***likely* range: 2.0 to 4.5°C** ***very unlikely* <1.5°C** **best estimate about 3°C**
Transient climate response	range 1.1 to 3.1°C	***very unlikely* <1.0°C** ***very unlikely* >3.0°C**

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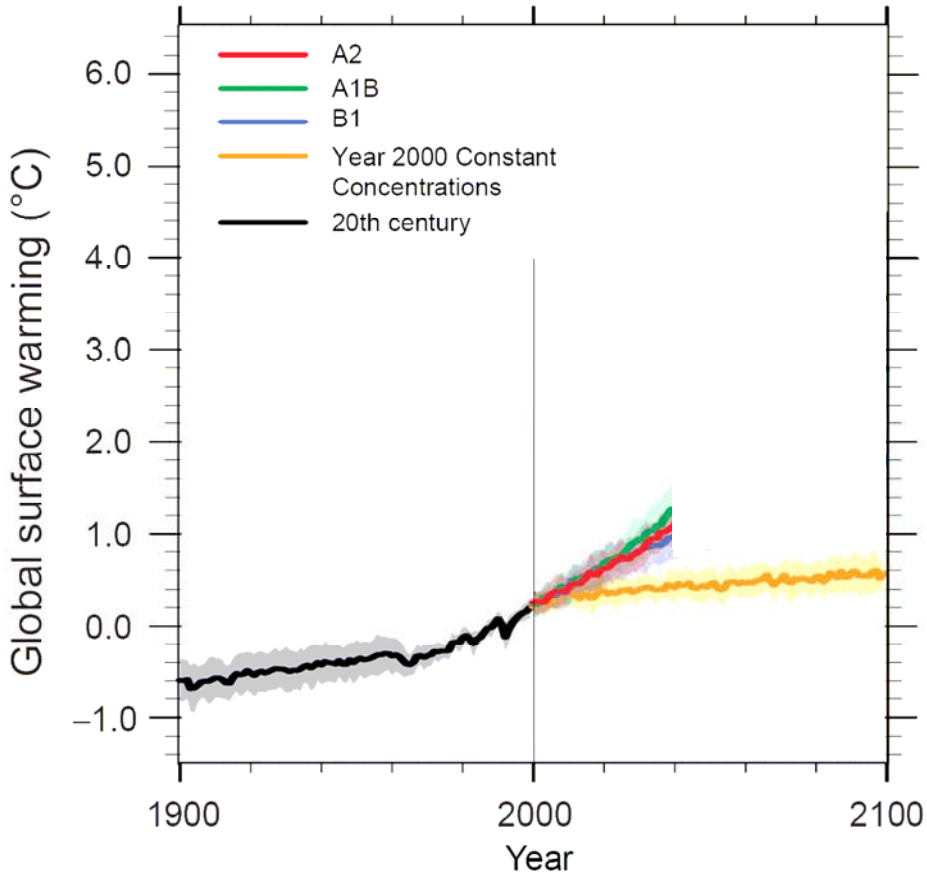
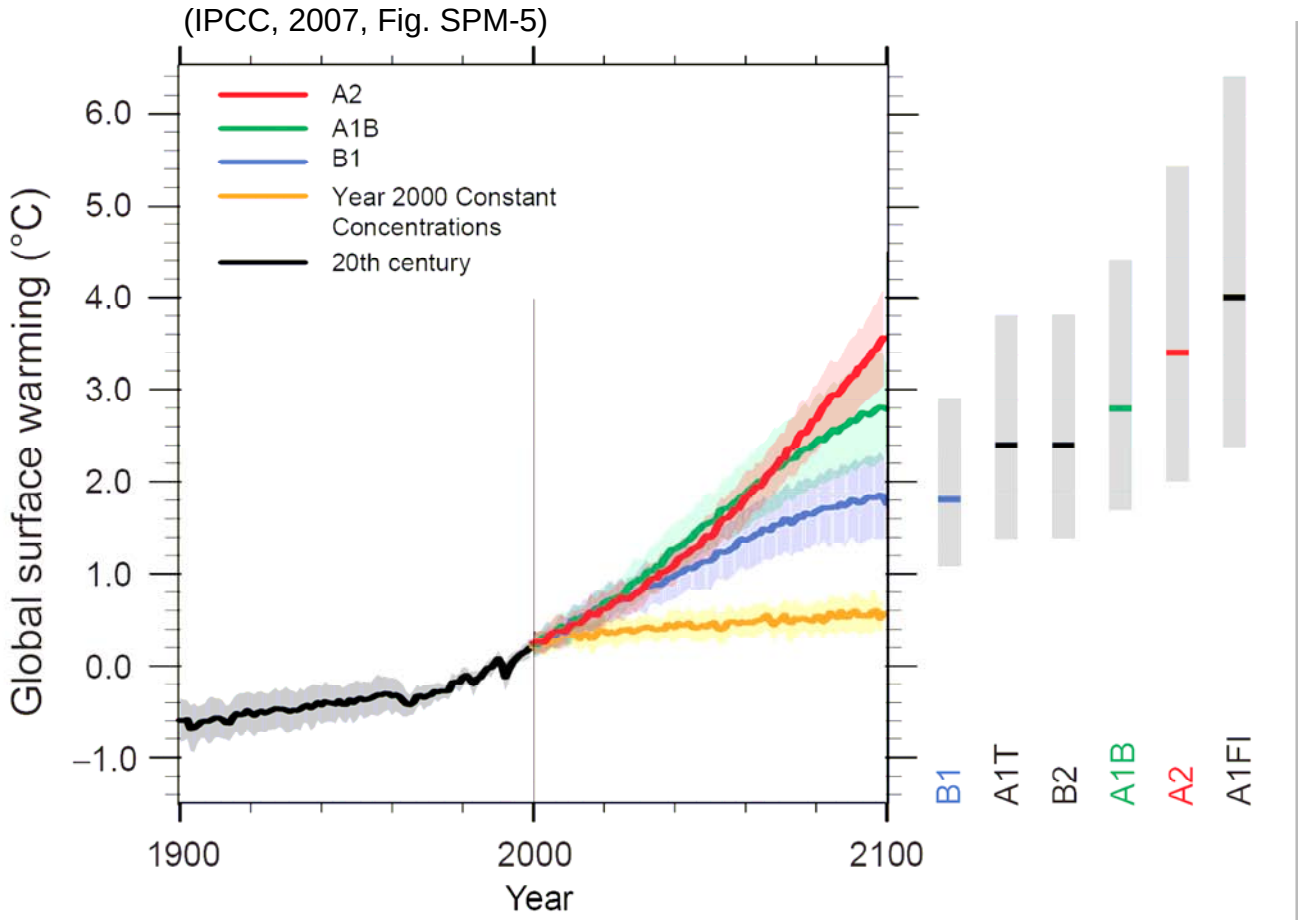
(IPCC, 2007, Fig. SPM-5)



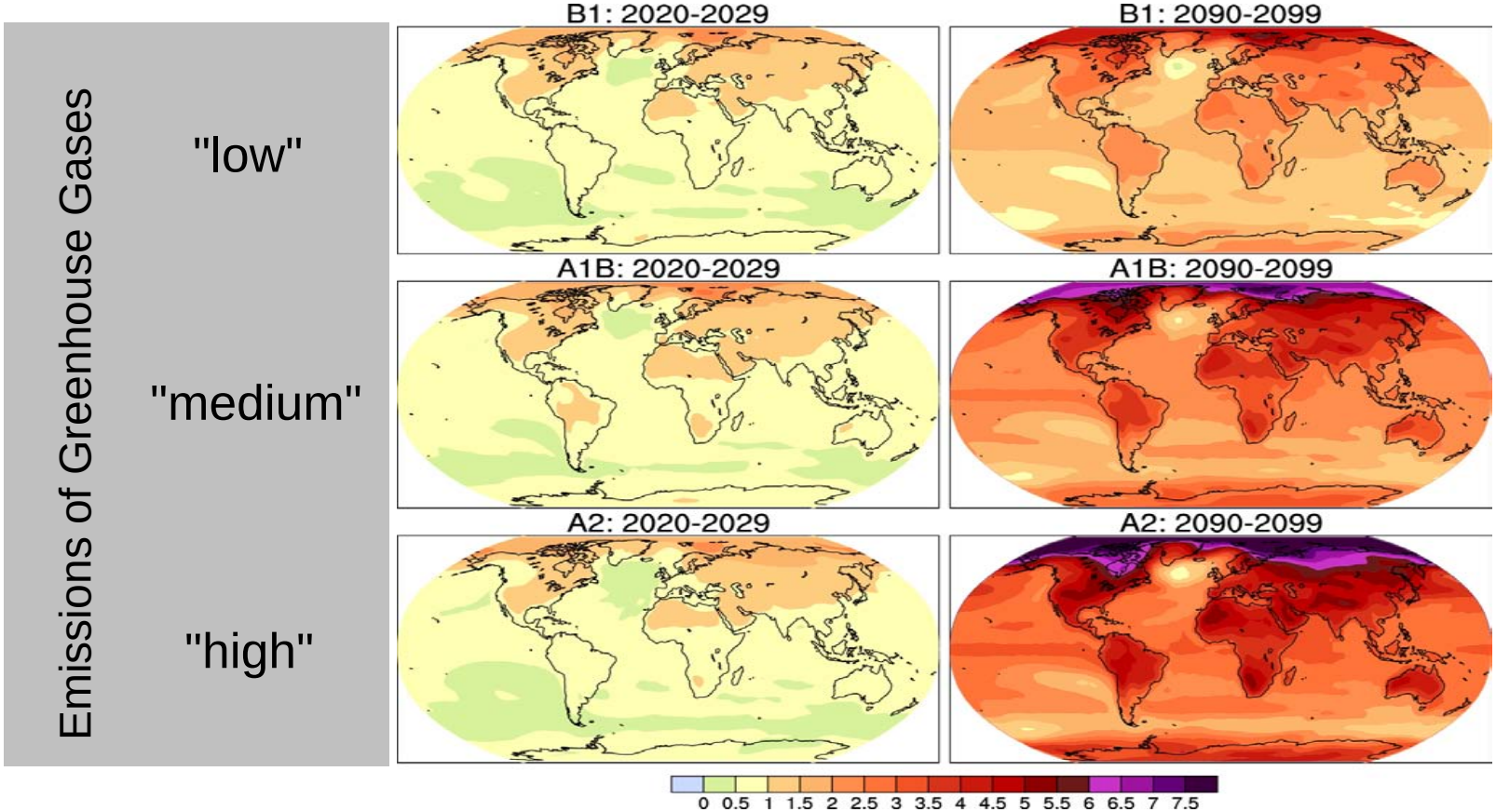
For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios. Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.

(IPCC, 2007, Fig. SPM-5)



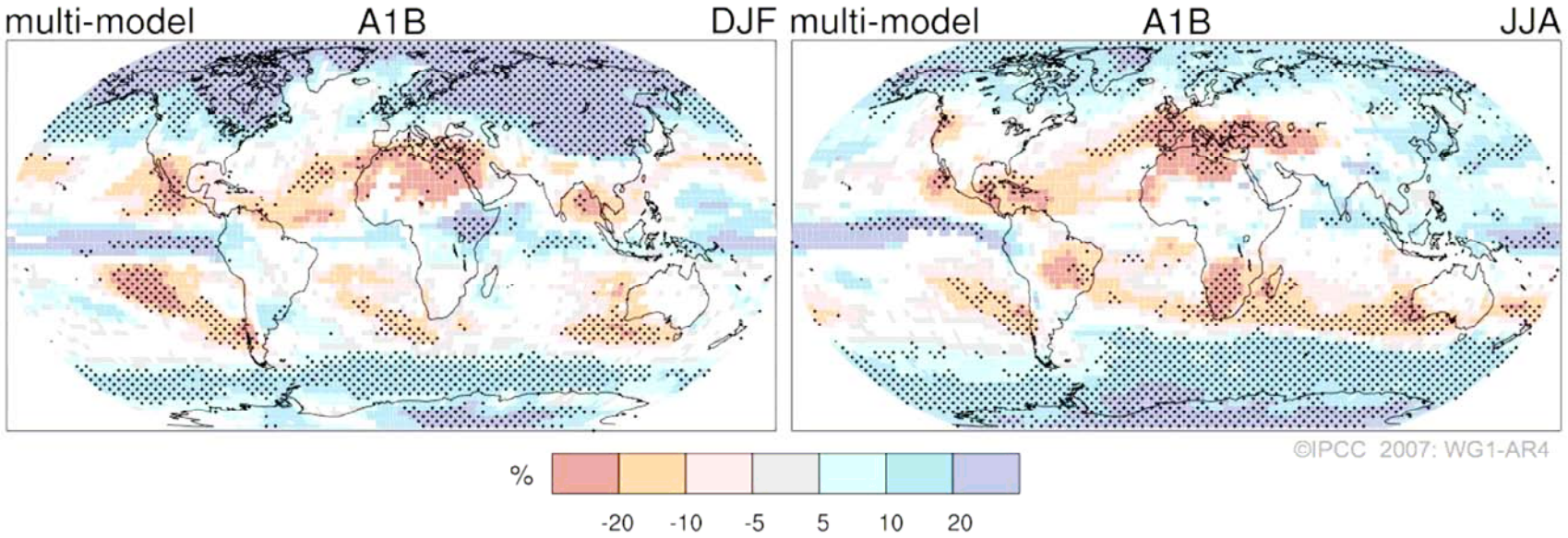
Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century. Warming tends to reduce land and ocean uptake of carbon dioxide, increasing the fraction of anthropognic emissions that remain in the atmosphere. This leads to greater climate change for a given emissions scenario.

There is now higher confidence in projected patterns of warming and other regional-scale features.



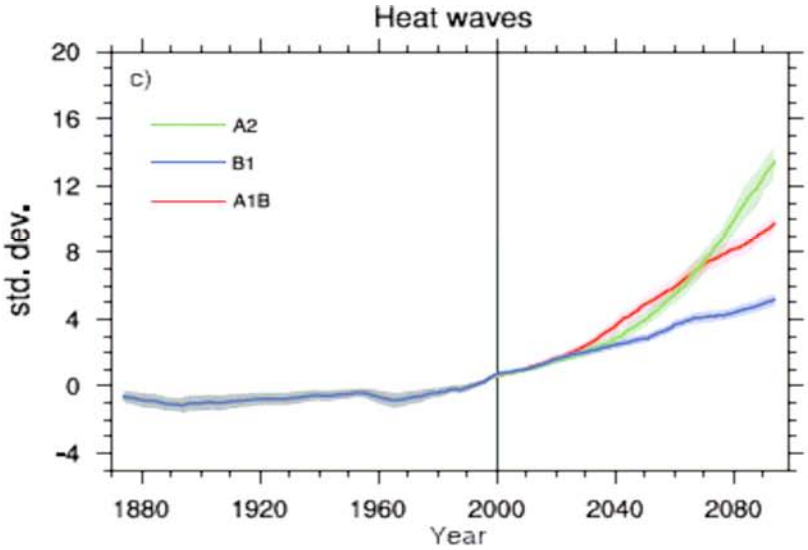
(IPCC, 2007, Fig. SPM-6, adapted)

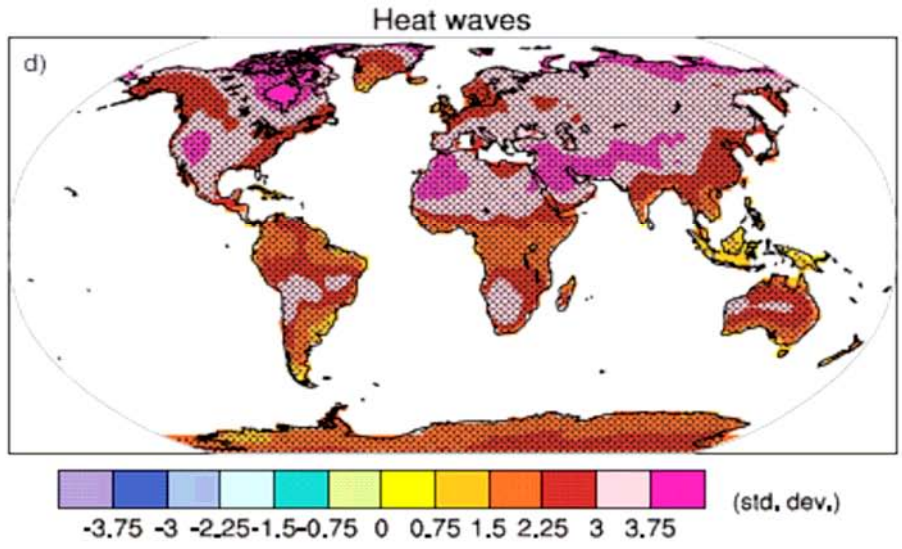
Projected warming in the 21st century shows scenario-independent patterns... Warming is expected to be greatest over land and at most high northern latitudes, and least over the Southern Ocean and parts of the North Atlantic Ocean.



(IPCC, 2007, Fig. SPM-7)

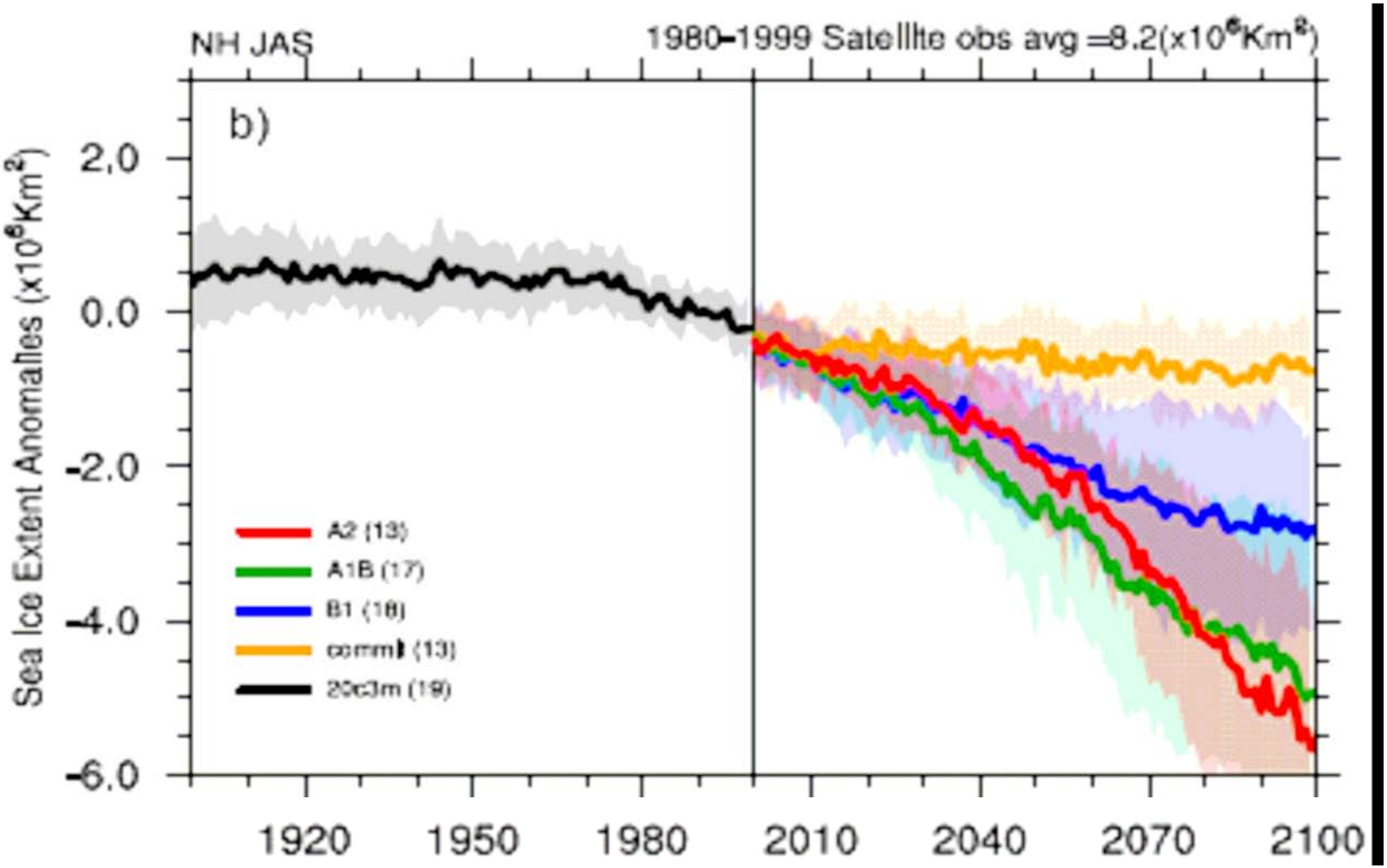
Since the TAR there is an improving understanding of projected patterns of precipitation. Increases in the amount of precipitation are *very likely* in high-latitudes, while decreases are *likely* in most subtropical land regions ... continuing observed patterns in recent trends.





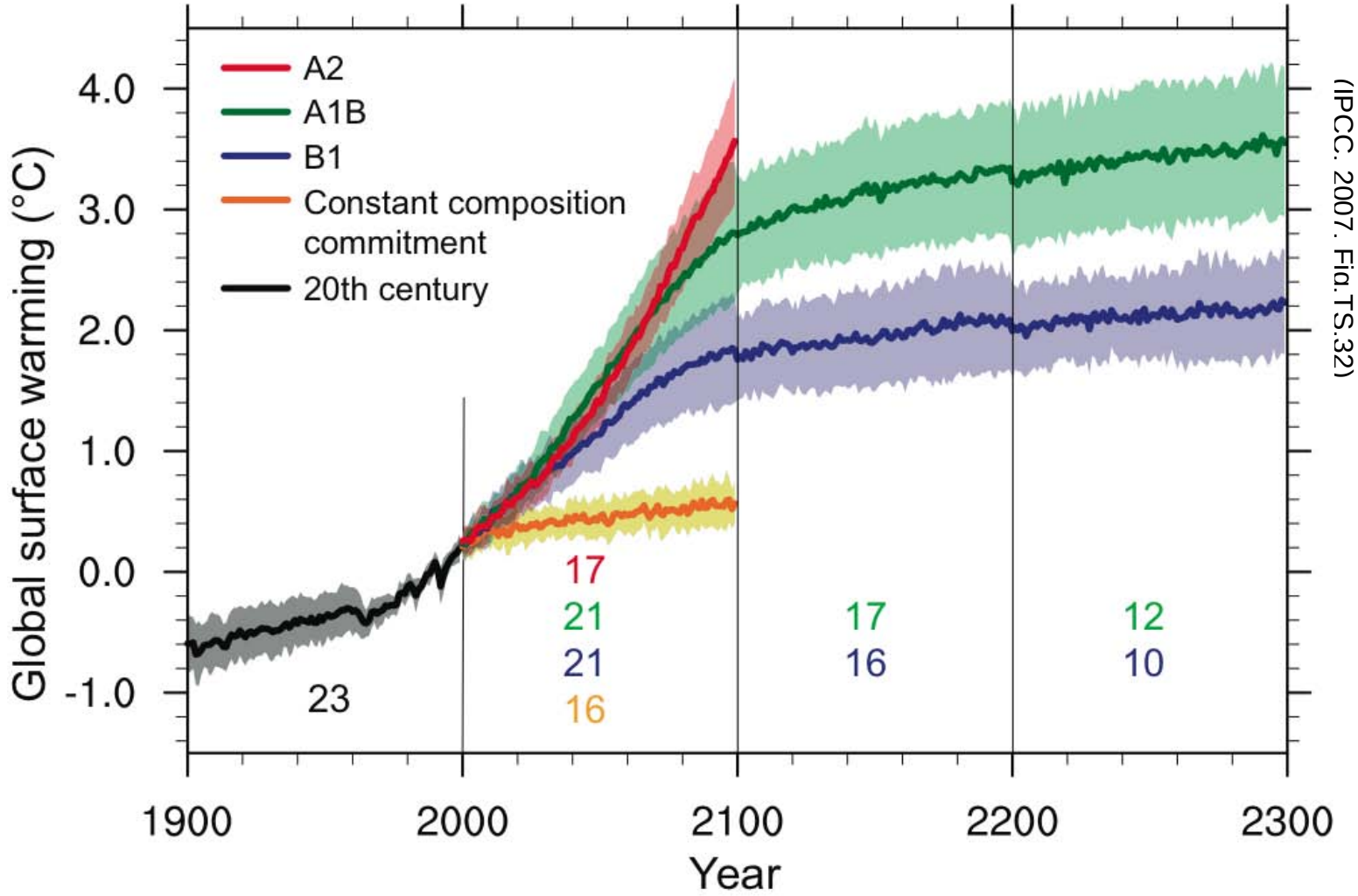
(IPCC, 2007, Fig. 10.19)

- Warming of day and night extreme temperatures is virtually certain.
- It is *very likely* that .. heat waves and heavy precipitation events will continue to become more frequent.
- Based on a range of models, it is *likely* that future tropical cyclones (typhoons, hurricanes) will become more intense ...



(IPCC, 2007, Fig.10-13b)

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.



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.

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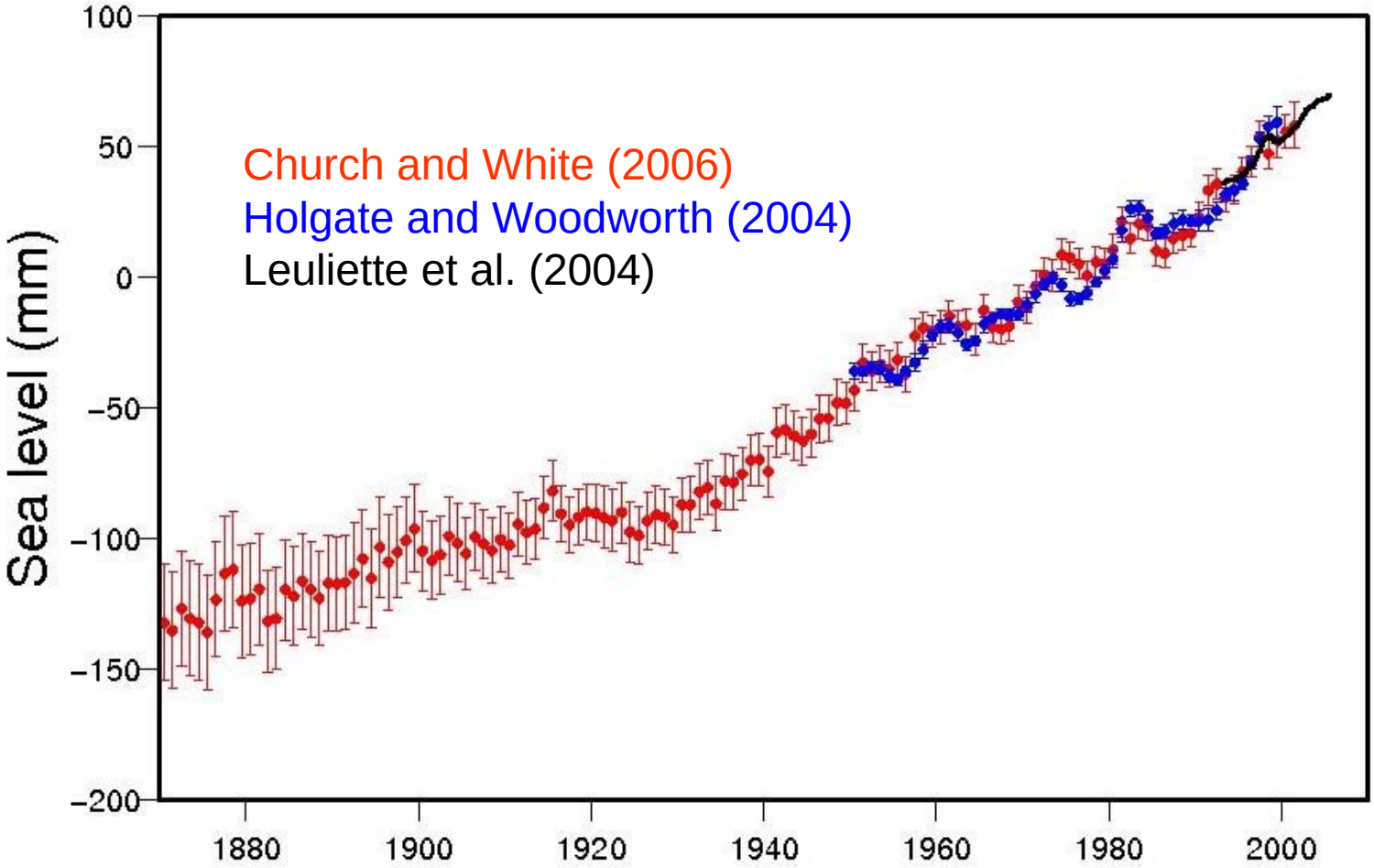
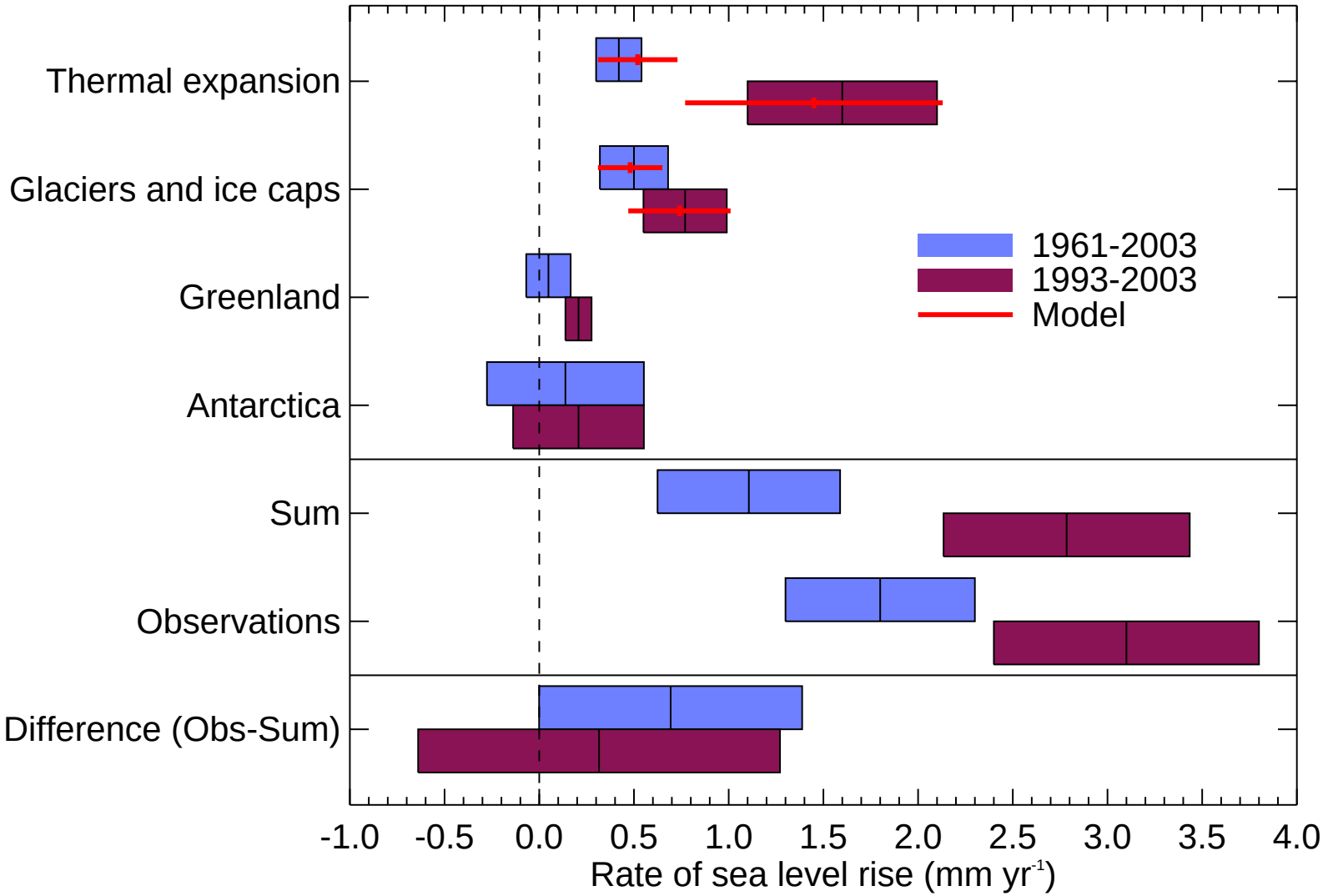
Observed global mean sea level rise

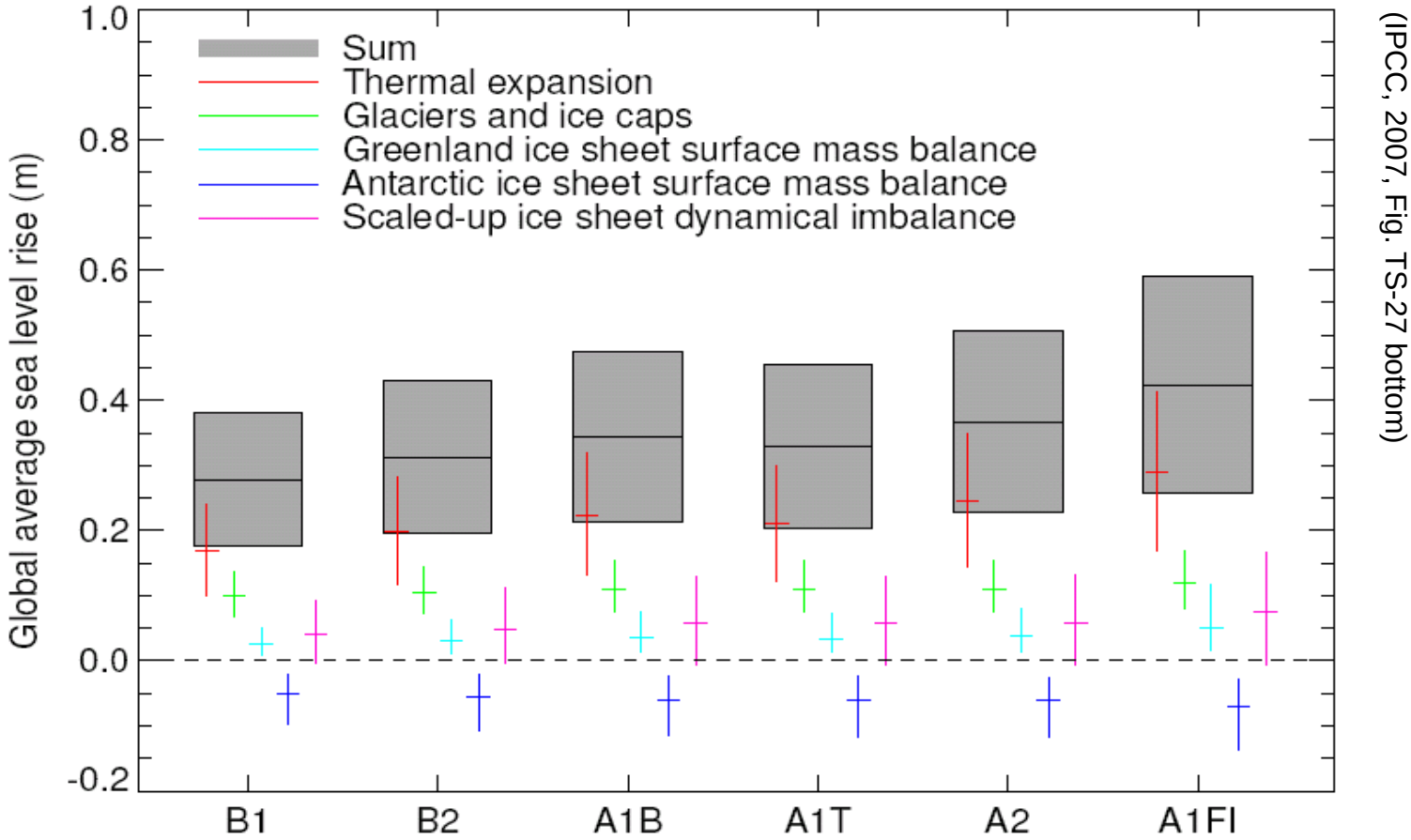


Global average sea level rose at an average rate of 1.8 [1.3 to 2.3] mm yr^{-1} over 1961 to 2003. The 20th century rise is estimated to be 0.17 [0.12 to 0.22] m. There is *high confidence* that the rate of observed sea level rise increased from the 19th to the 20th century.

Accounting for observed sea level rise

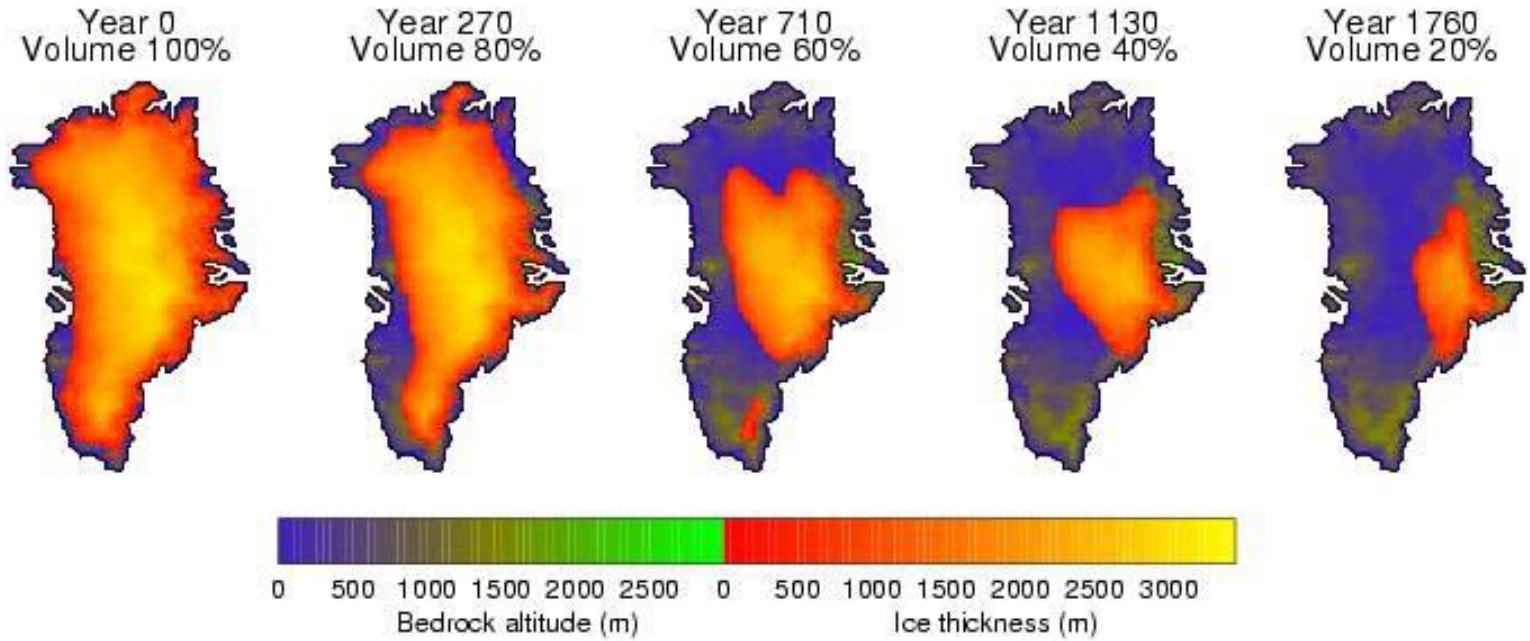


Budget is closed better for 1993-2003 than for 1961-2003.



(IPCC, 2007, Fig. TS-27 bottom)

Model-based projections of global average sea level rise at the end of the 21st century (2090-2099). For each scenario, the midpoint of the range ... is within 10% of the TAR ... The ranges are narrower than in the TAR ... The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003, but these flow rates could increase or decrease in the future.



(IPCC, 2007, Fig. 10-38)

Current models suggest … that the surface mass balance [of the Greenland ice sheet] becomes negative at a global average warming (relative to pre-industrial values) in excess of 1.9 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.

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. Understanding of these [dynamical] processes is limited and there is no consensus on their magnitude.

- Warming of the climate system is unequivocal.
- Most of the observed increase in global average temperatures is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.
- For the next two decades, a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios.
- 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.
- Anthropogenic warming and sea level rise would continue for centuries due to the timescales associated with climate processes and feedbacks, even if greenhouse gas concentrations were to be stabilised.