Projections of climate and sea level change

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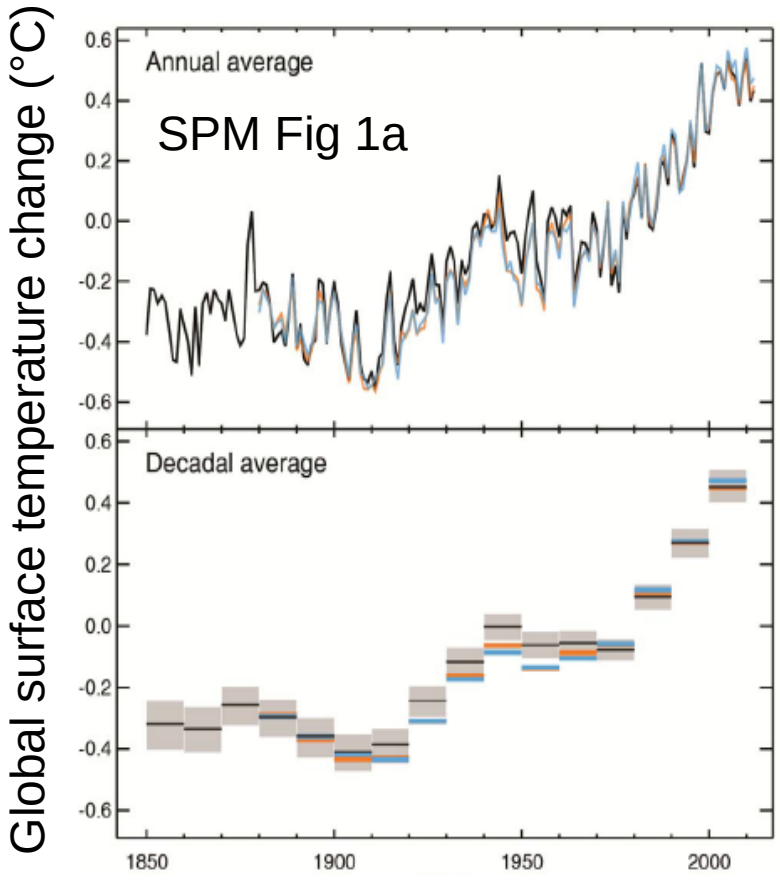
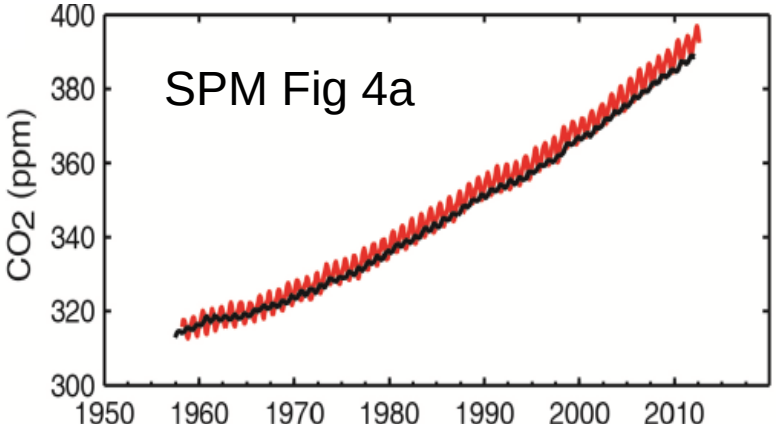
Warming of the climate system is unequivocal

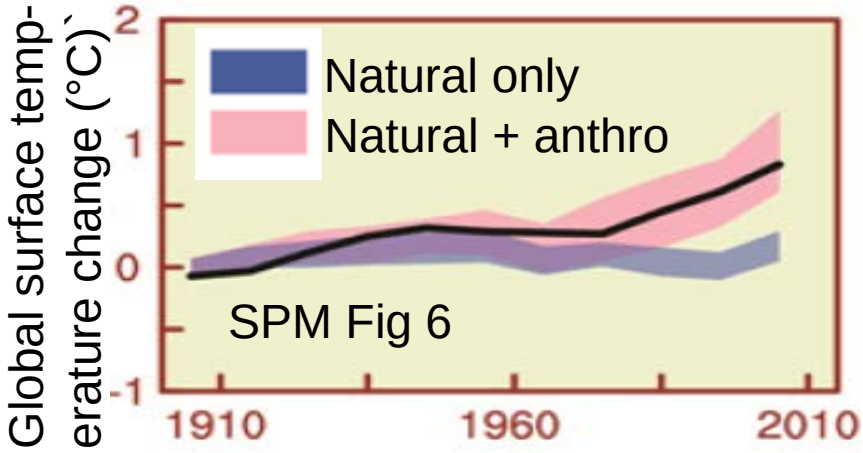


Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.

Increasing CO_2 concentration makes the largest contribution to radiative forcing



It is *extremely likely* that human influence has been the dominant cause of the observed warming since the mid-20th century



Causes of global mean sea level rise (GMSLR)

Global mean sea level change is caused by

- change in the volume of the ocean basin (on geological timescales)
- change in the volume of the ocean water, which is caused by
  - change in the density of the ocean water (steric), which is nearly entirely thermal expansion (thermosteric)
  - change in the mass of the ocean (barystatic), due to change in mass of ice and water on land.

The TAR, AR4 and AR5 recommend that the word ~~eustatic~~ should not be used.

High confidence in projections of thermal expansion

Good observational estimates

Consistency of historical simulations with observations

Better understanding of the Earth energy budget

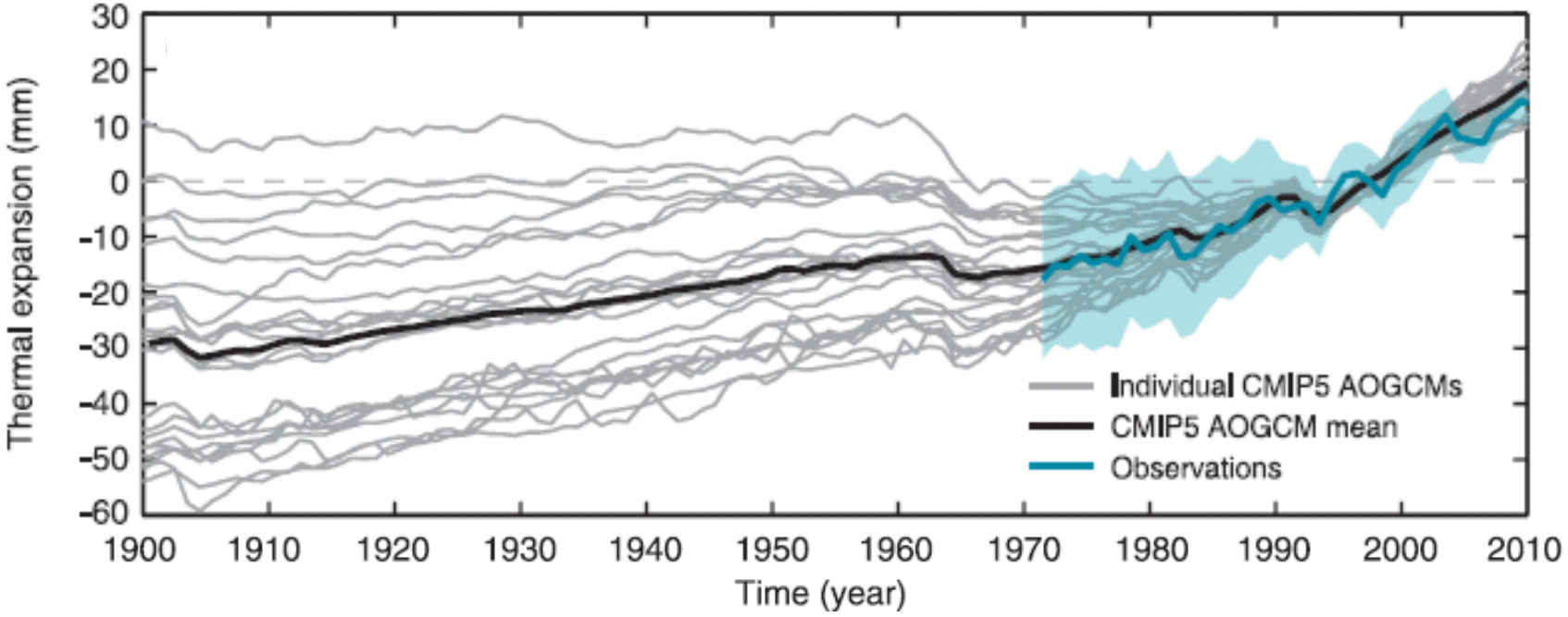
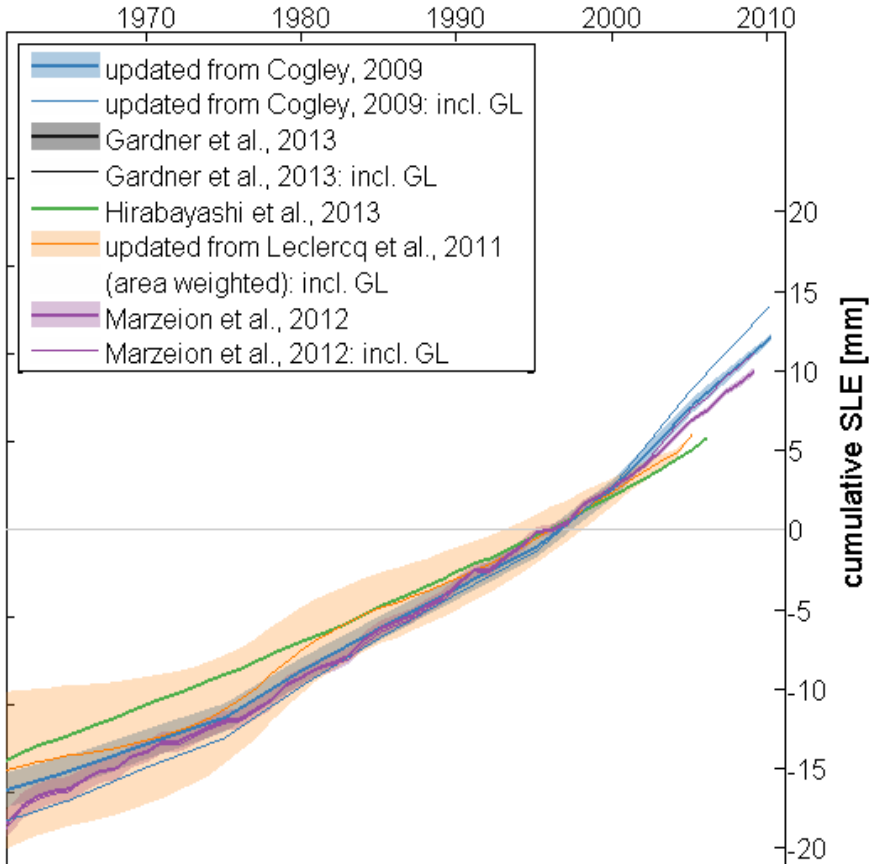


Fig 13.4a, change relative to 1986-2005

Medium confidence in projections of glacier mass loss



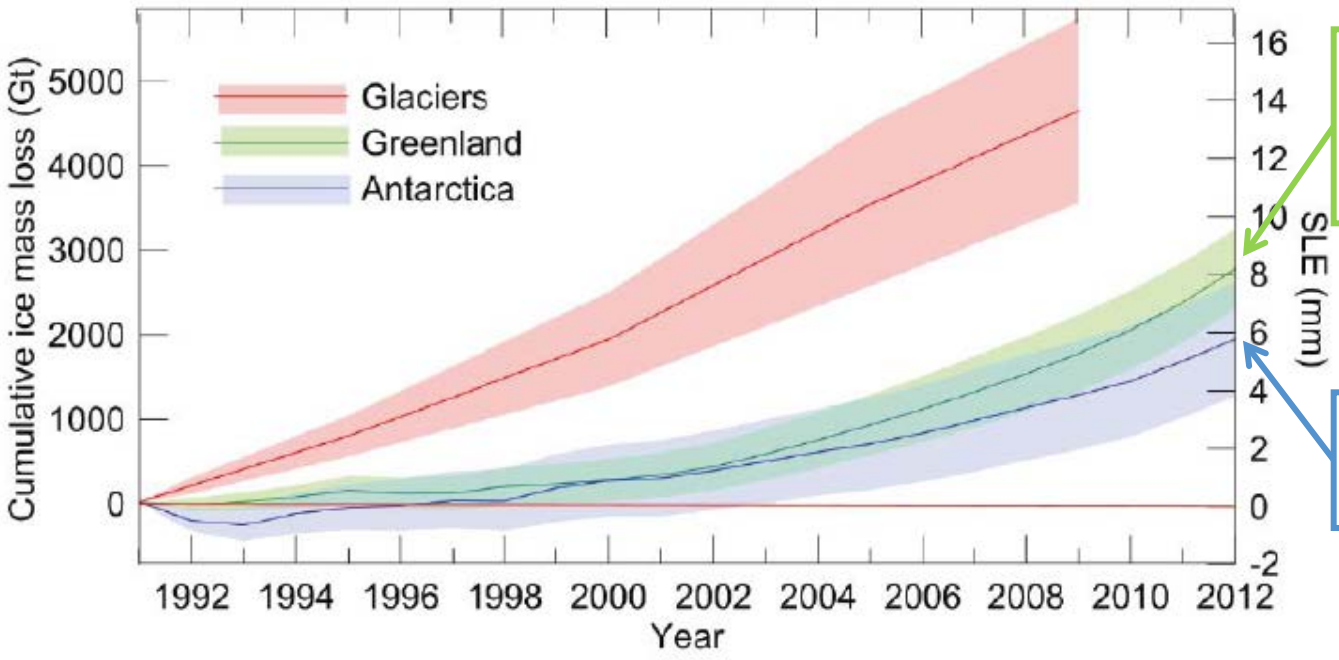
Observationally based estimates of past glacier mass loss, Figure 4.12b

Consistency of historical simulations with observations

Process-based understanding

But the set of well-observed glaciers is a very small fraction of the total.

Recent and projected mass loss from the ice sheets



About half due to increased surface melting

Due to increased ice outflow

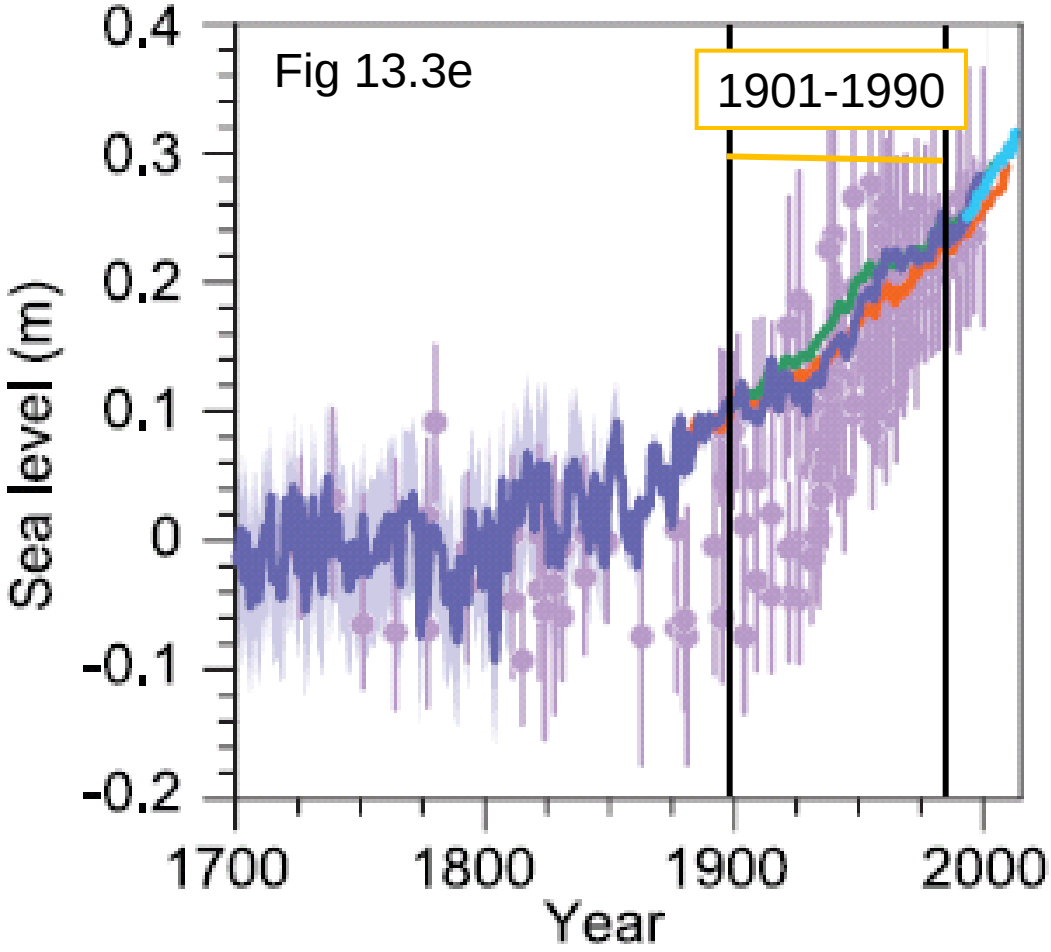
High confidence in projections of increasing Greenland surface mass loss.

Medium confidence in projections of increasing Antarctic snow accumulation.

Likely range (*medium confidence*) for the projected contributions from ice-sheet rapid dynamical change, estimated from a combination of process-based modelling, statistical extrapolation of recent trends, and informed judgement.

Rate of GMSLR has been greater since the mid-19th century

Rate of GMSLR during the last two millennia was of order a few tenths of mm yr^{-1}.



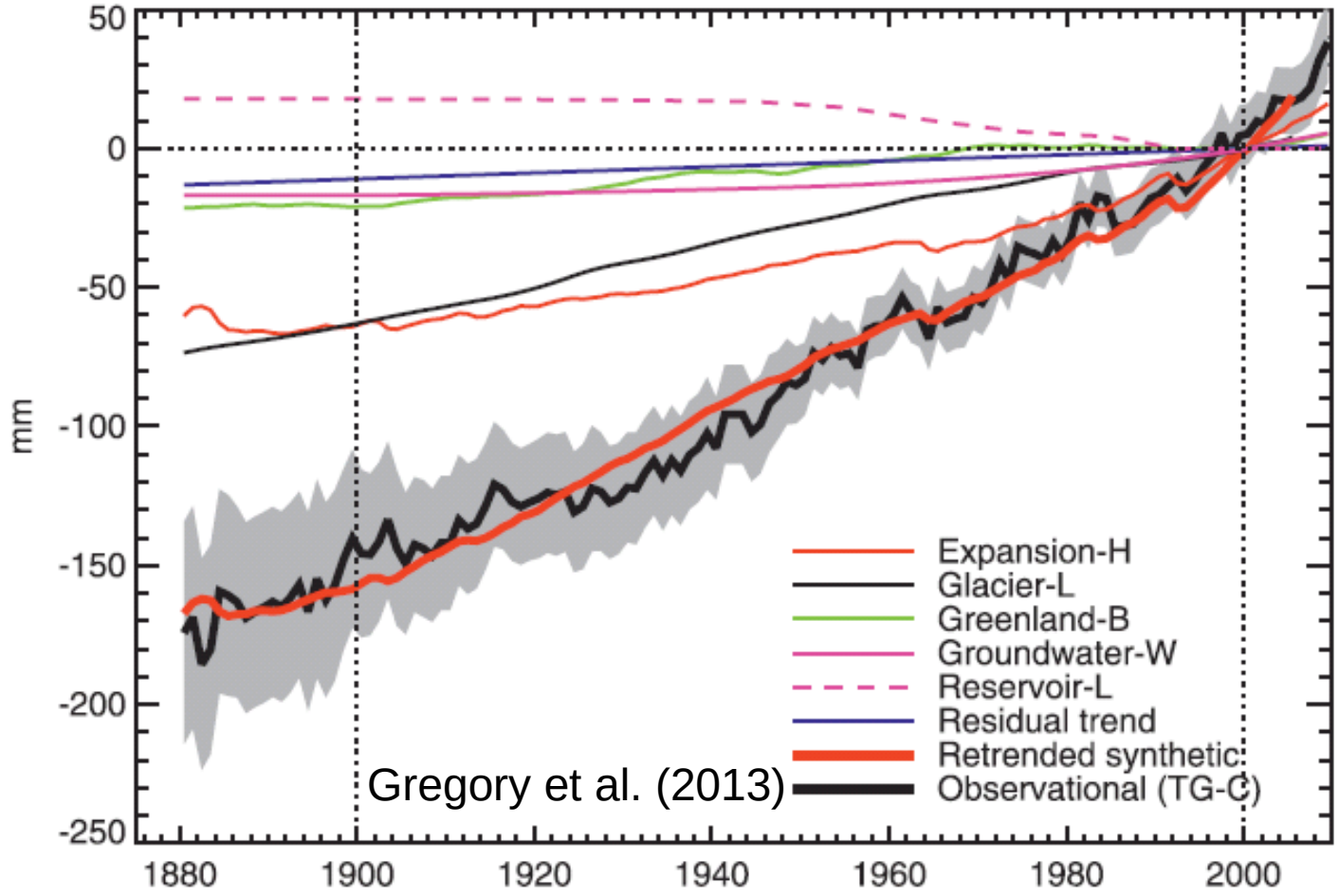
Rate during 1901-1990 was 1.5 [1.3 to 1.7] mm yr^{-1}.

Twentieth-century sea-level: an enigma

Walter Munk (PNAS, 2002)

“The historic rise started too early, has too linear a trend, and is too large.”

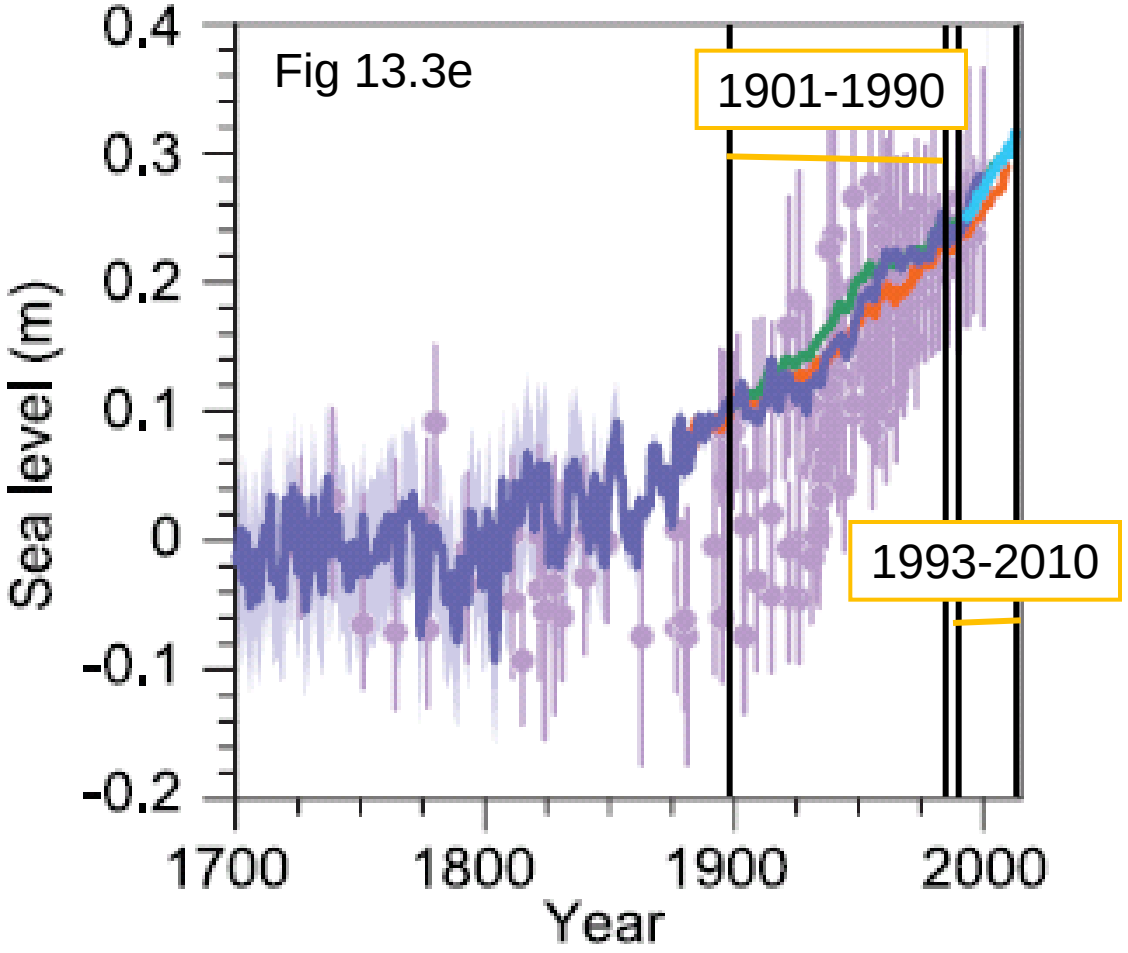
Expansion + glaciers explain most of GMSLR 1901-1990



The remainder could be explained by mass loss from the Greenland ice sheet (especially during the early 20th century) and the Antarctic ice sheet (long-term). Land water storage change has made a small net contribution.

Rate of GMSLR has been greater since the mid-19th century

Rate of GMSLR during the last two millennia was of order a few tenths of mm yr^{-1}.



Rate during 1901-1990 was 1.5 [1.3 to 1.7] mm yr^{-1}.

Rate during 1993-2010 was 3.2 [2.8 to 3.6] mm yr^{-1}.

Model-based estimates of ocean thermal expansion and glacier contributions indicate that the greater rate of rise since 1990 is a response to radiative forcing and increased loss of ice-sheet mass (*medium confidence*).

RCPs for anthropogenic radiative forcing

RCP stands for *representative concentration pathway*

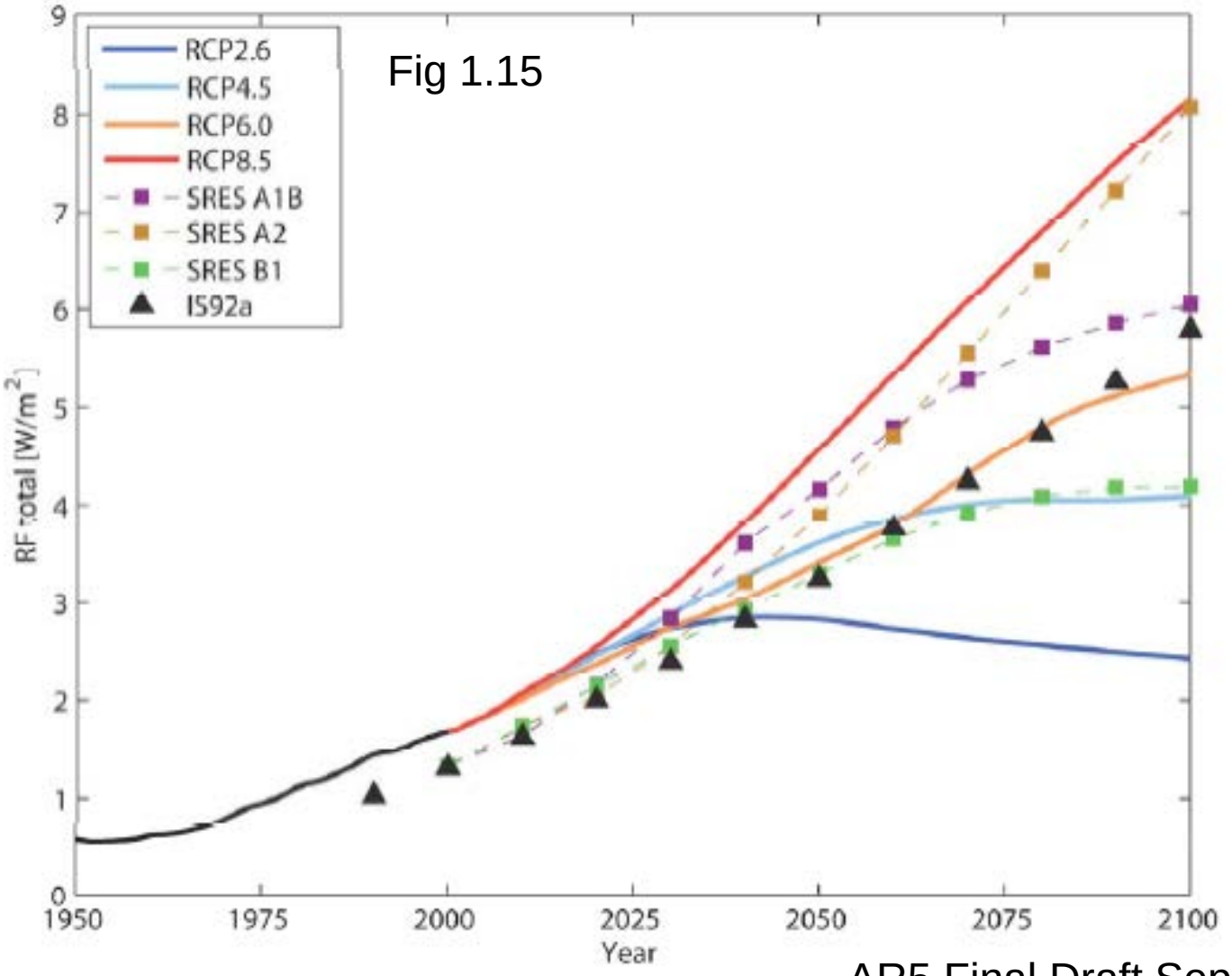


Fig 1.15

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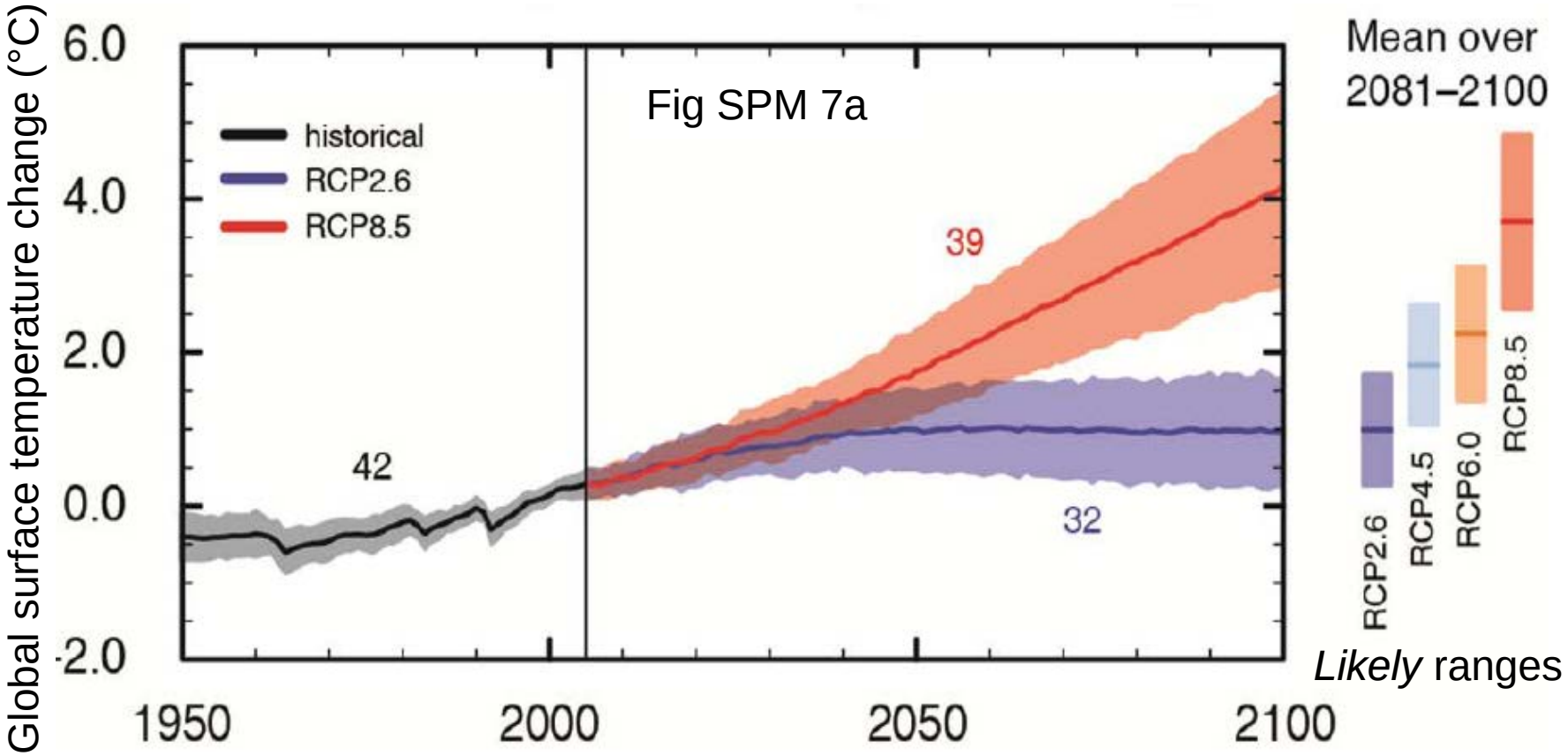
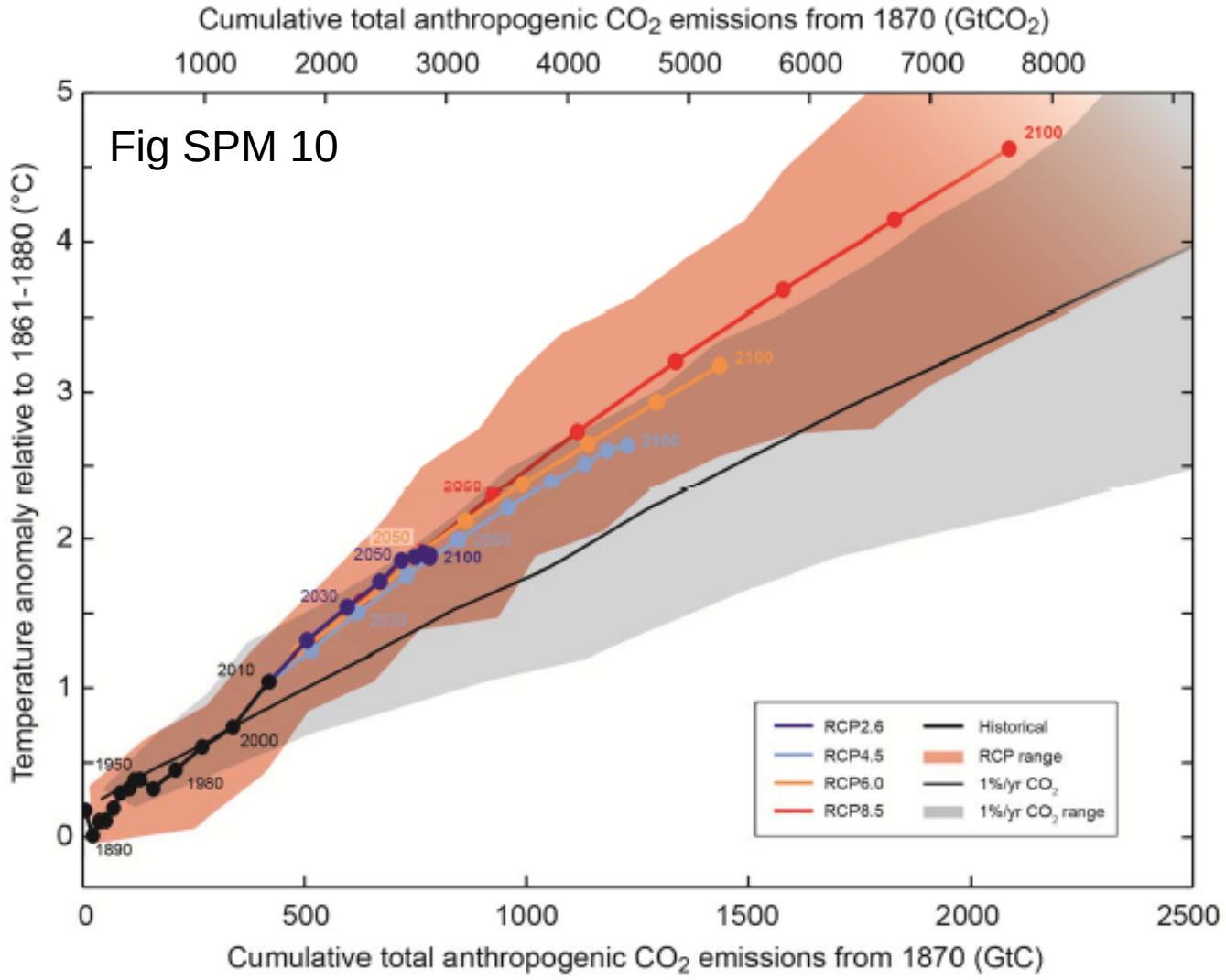
Continued emissions of greenhouse gases will cause further warming and changes in all components of the climate system



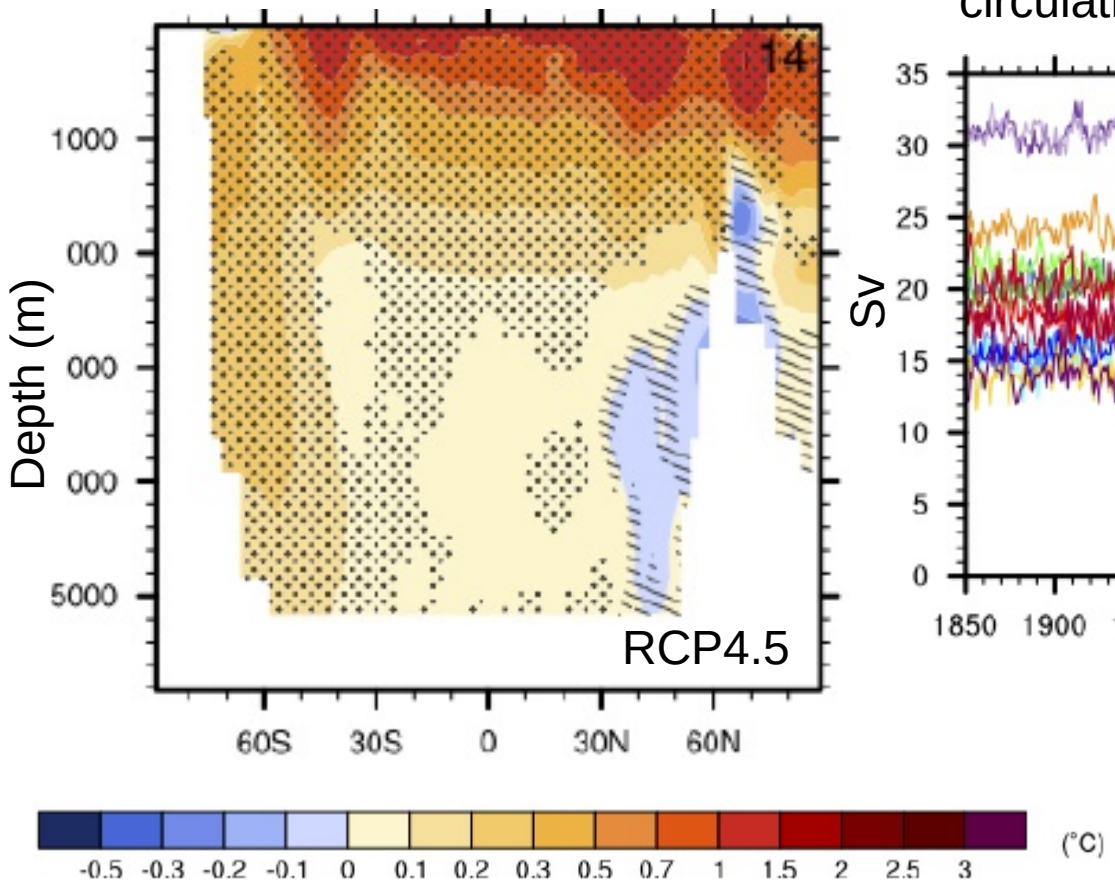
Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions. Global surface temperature change for the end of the 21st century is *likely* to exceed 2.0°C relative to 1850 to 1900 for RCP6.0 and RCP8.5.

Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond

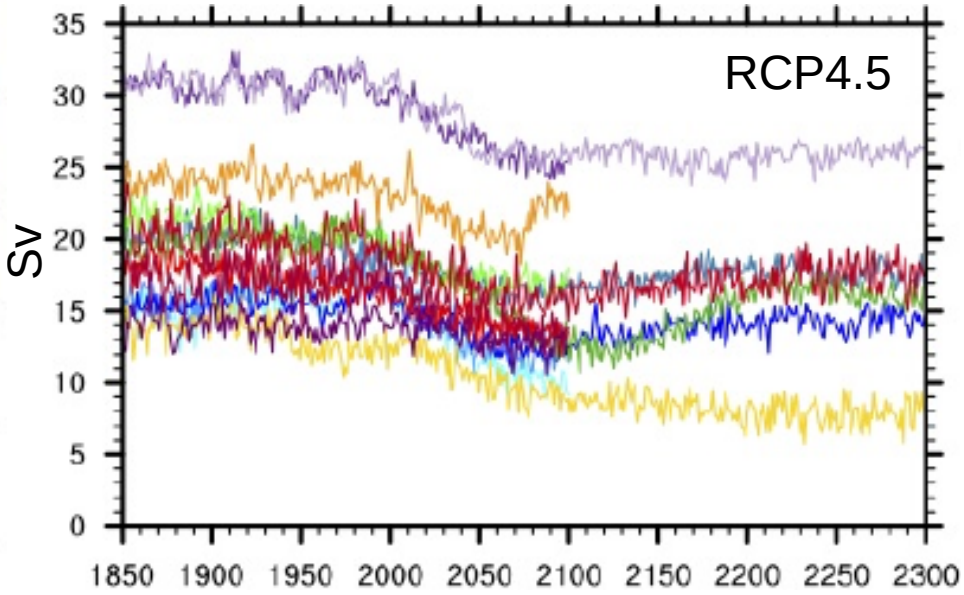


The global ocean will continue to warm. Heat will penetrate from the surface to the deep ocean and affect ocean circulation.

Ocean temperature change, Fig 12.12



Atlantic meridional overturning circulation strength at 30°N, Fig 12.35



Warming and precipitation change will not be uniform

Fig SPM 8a

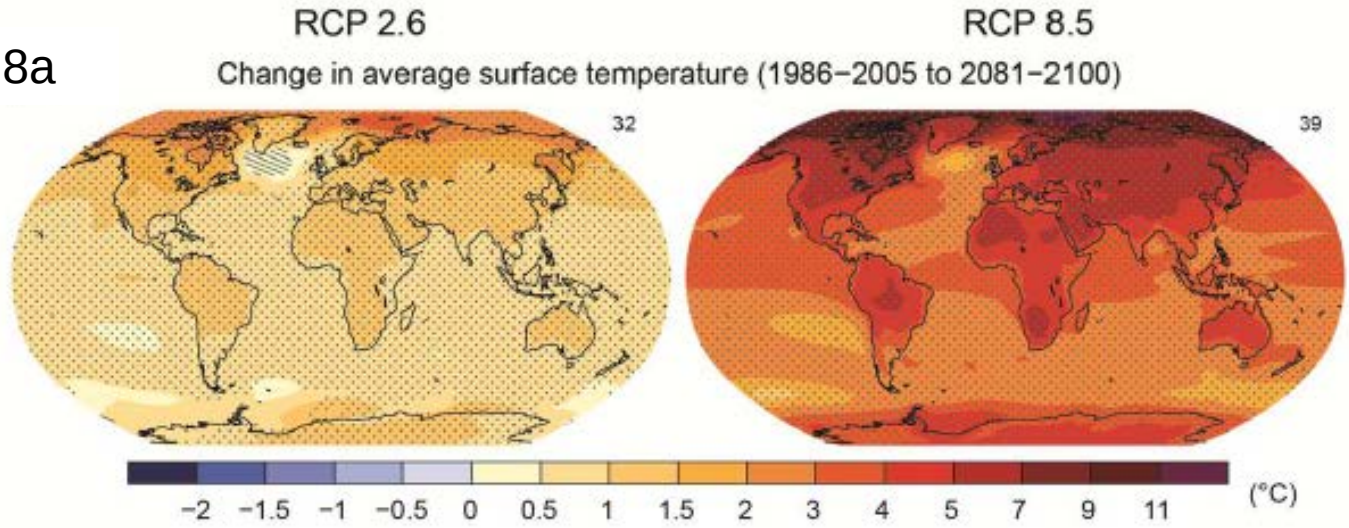
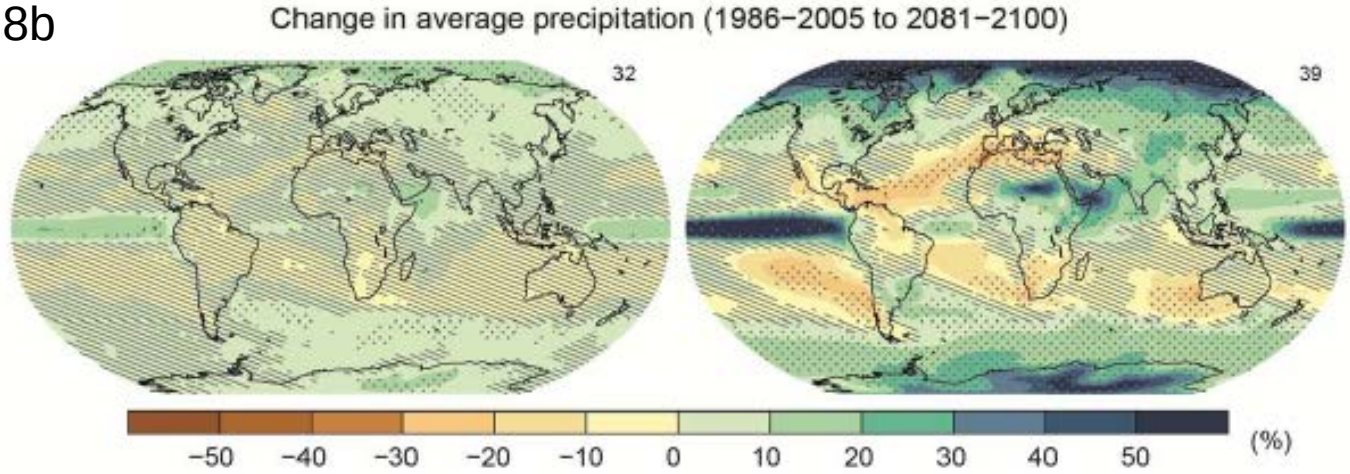
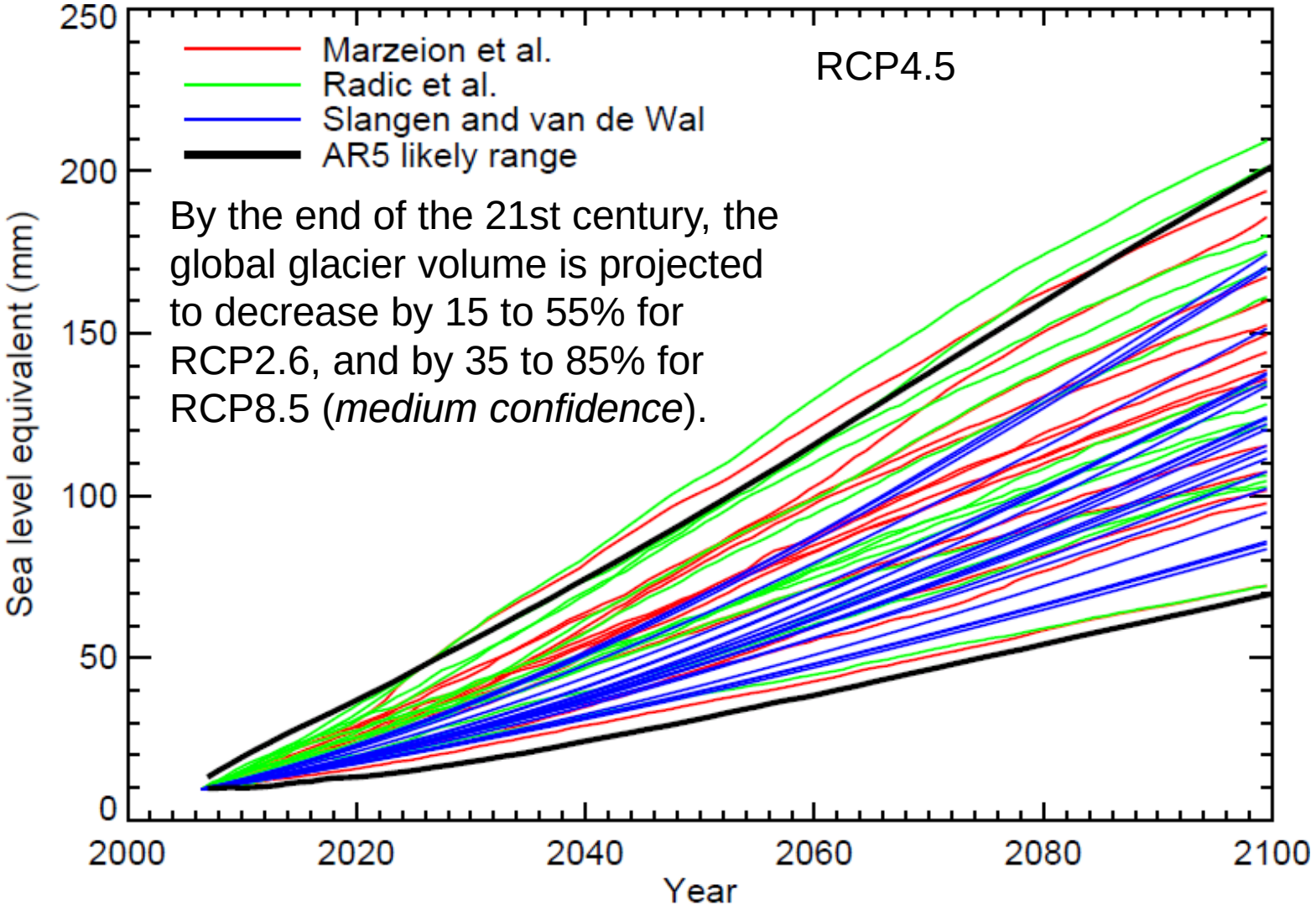


Fig SPM 8b



A nearly ice-free Arctic Ocean in September before mid-century is likely for RCP8.5 (*medium confidence*).

Global glacier volume will further decrease



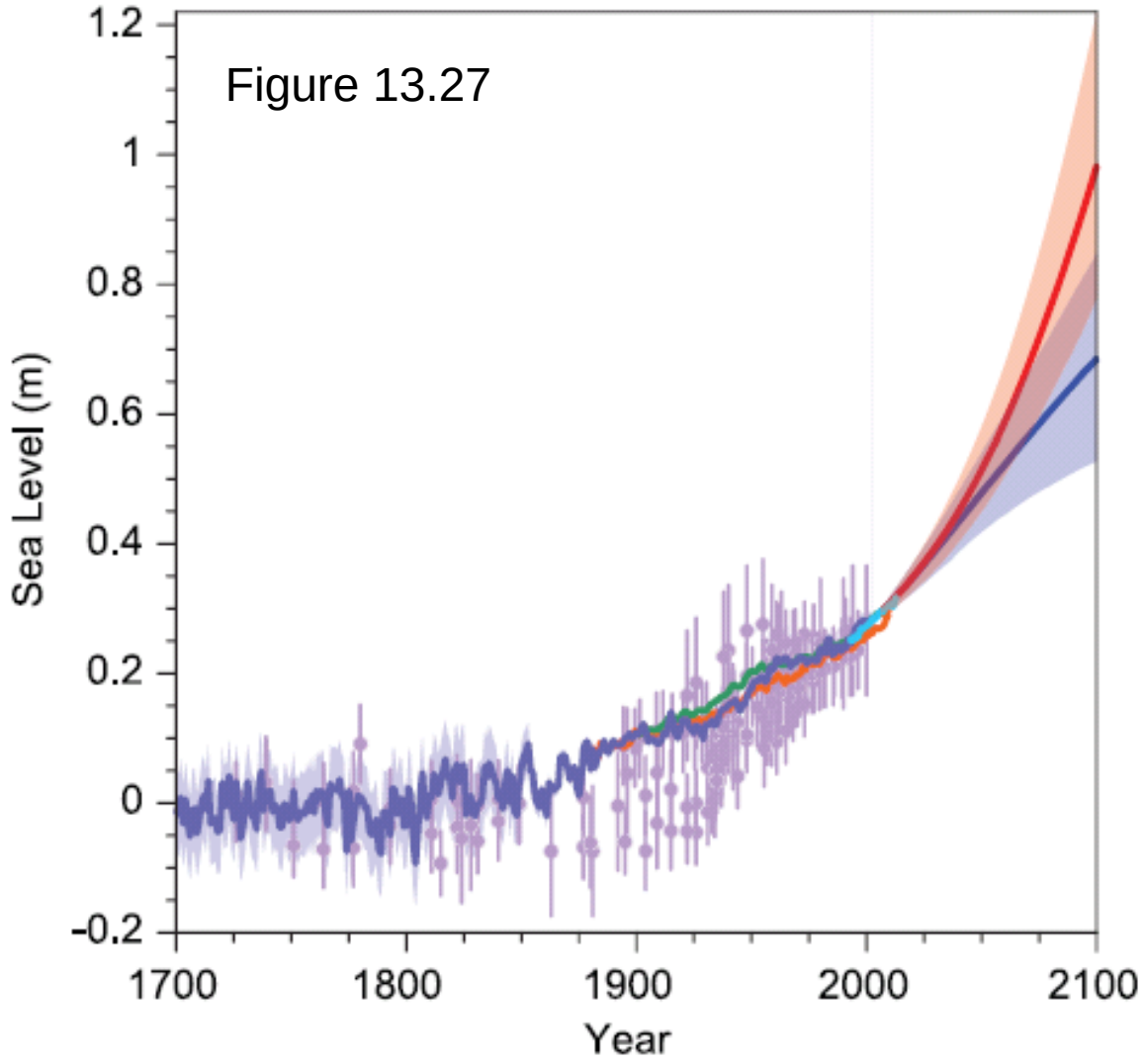
Confidence in projections of GMSLR has increased since AR4

Projections of sea level rise are larger than in the AR4 (after accounting for scenario differences), primarily because of improved modelling of land-ice contributions.

The current state of knowledge does not permit a quantitative assessment of the dependence of rapid ice sheet dynamical change upon the scenario.

Medium confidence in *likely* ranges.

Very likely that the 21st-century mean rate of GMSLR will exceed that of 1971-2010 under all RCPs.



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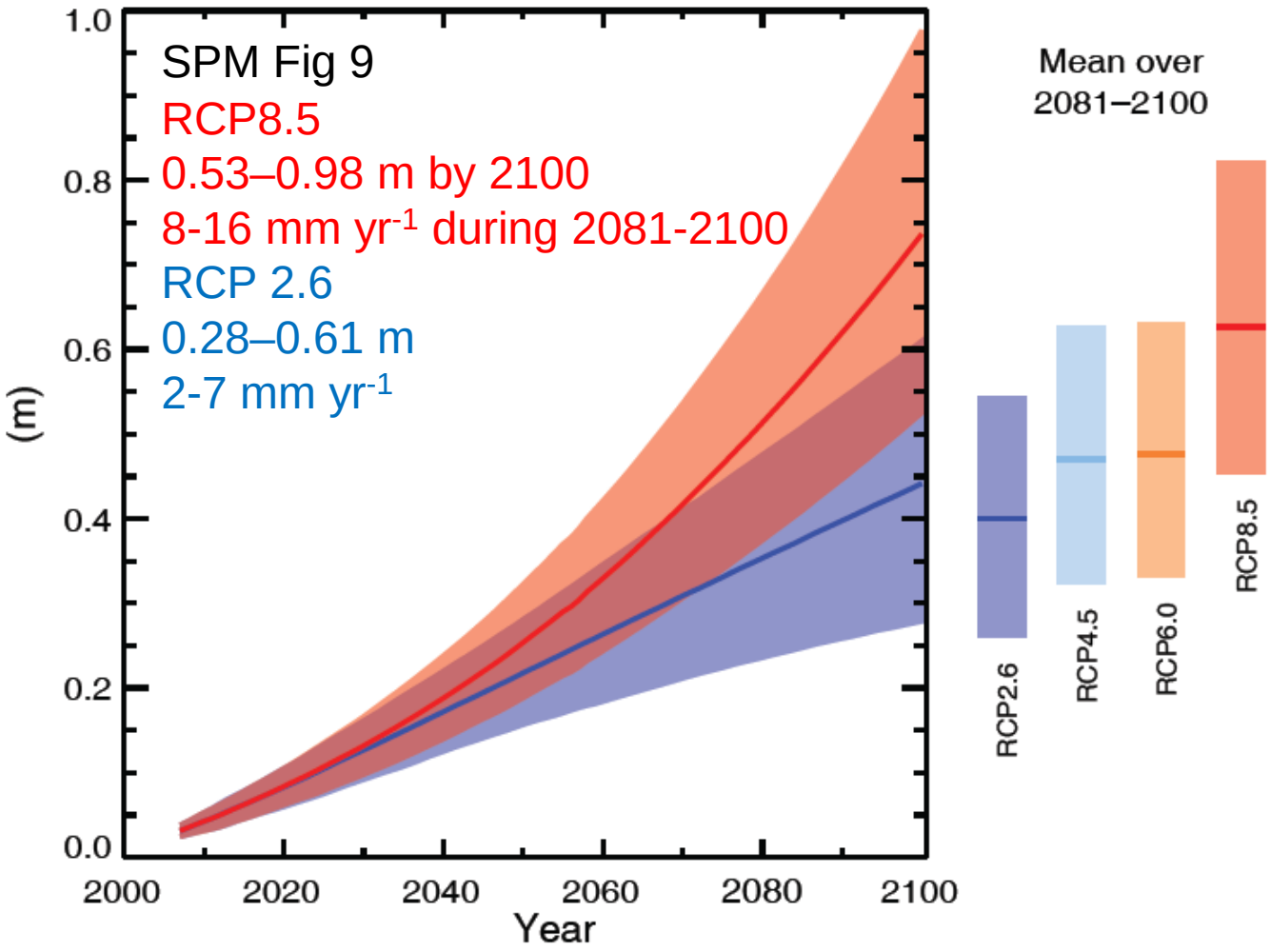
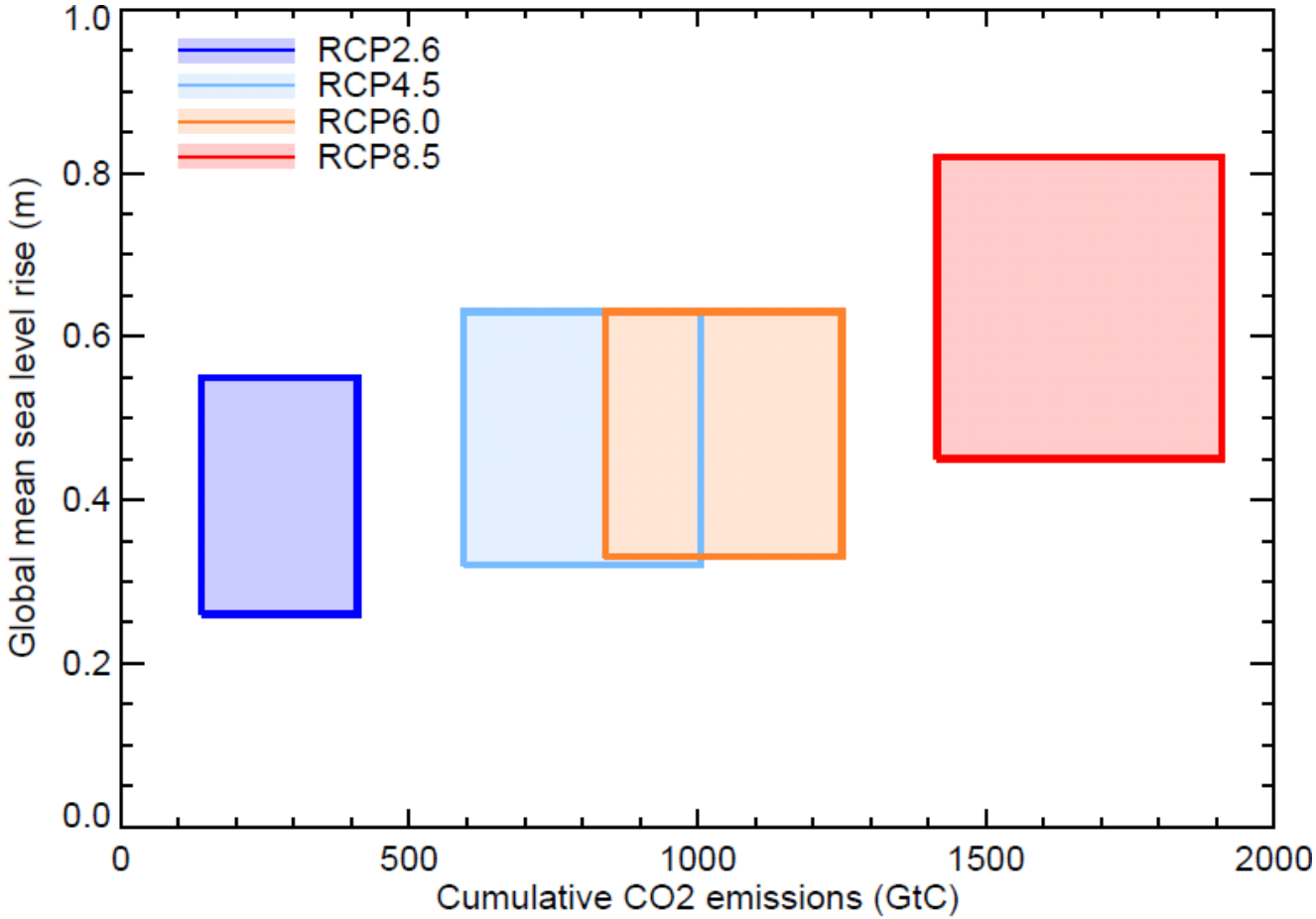
Projections of 21st-century GMSLR under RCPs

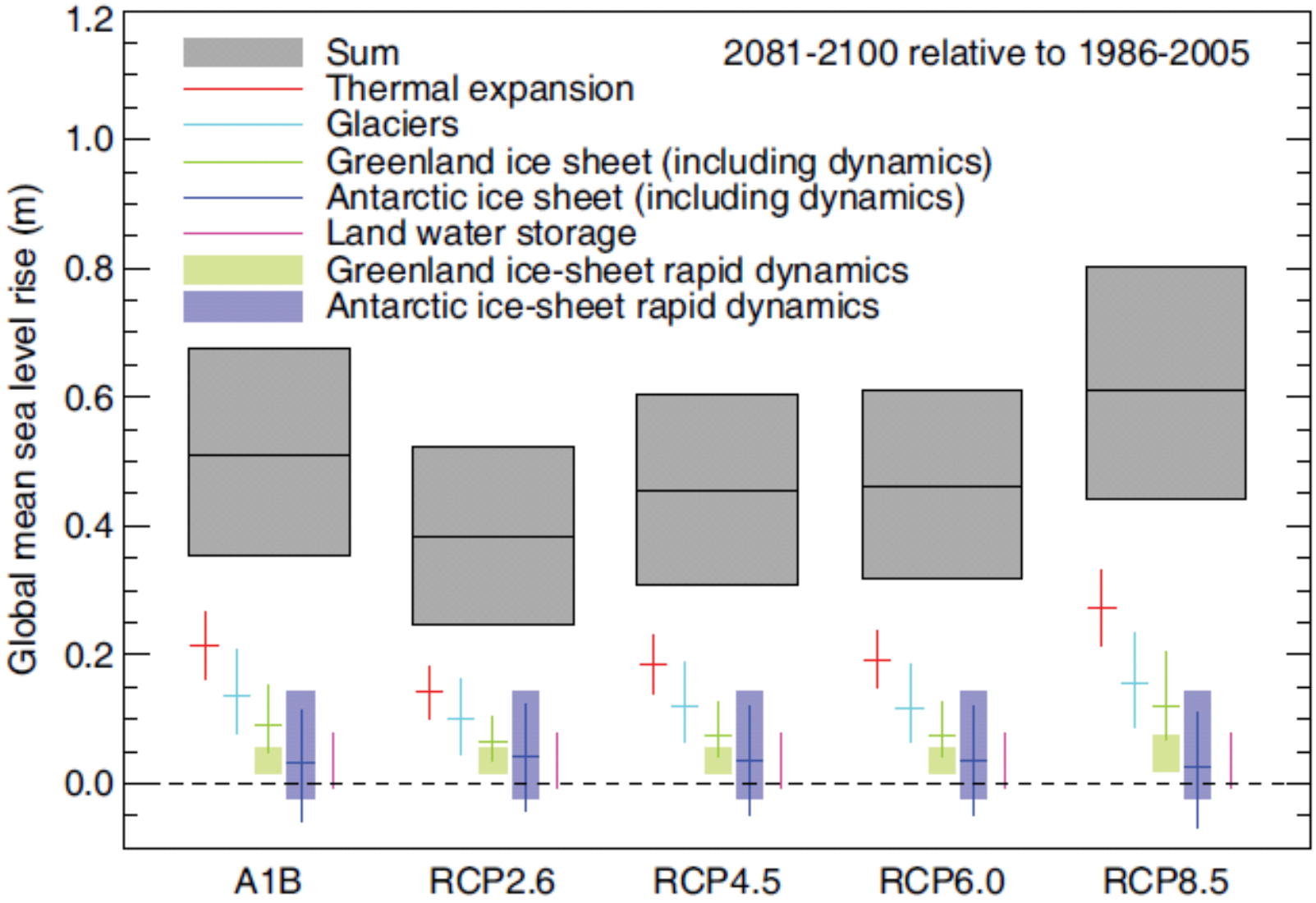


Relationship between GMSLR and CO_2 emissions



Unlike surface temperature change, GMSLR depends on the pathway of CO_2 emissions, not only on the total. Earlier emissions lead to greater GMSLR.

Projections of 21st-century GMSLR under RCPs



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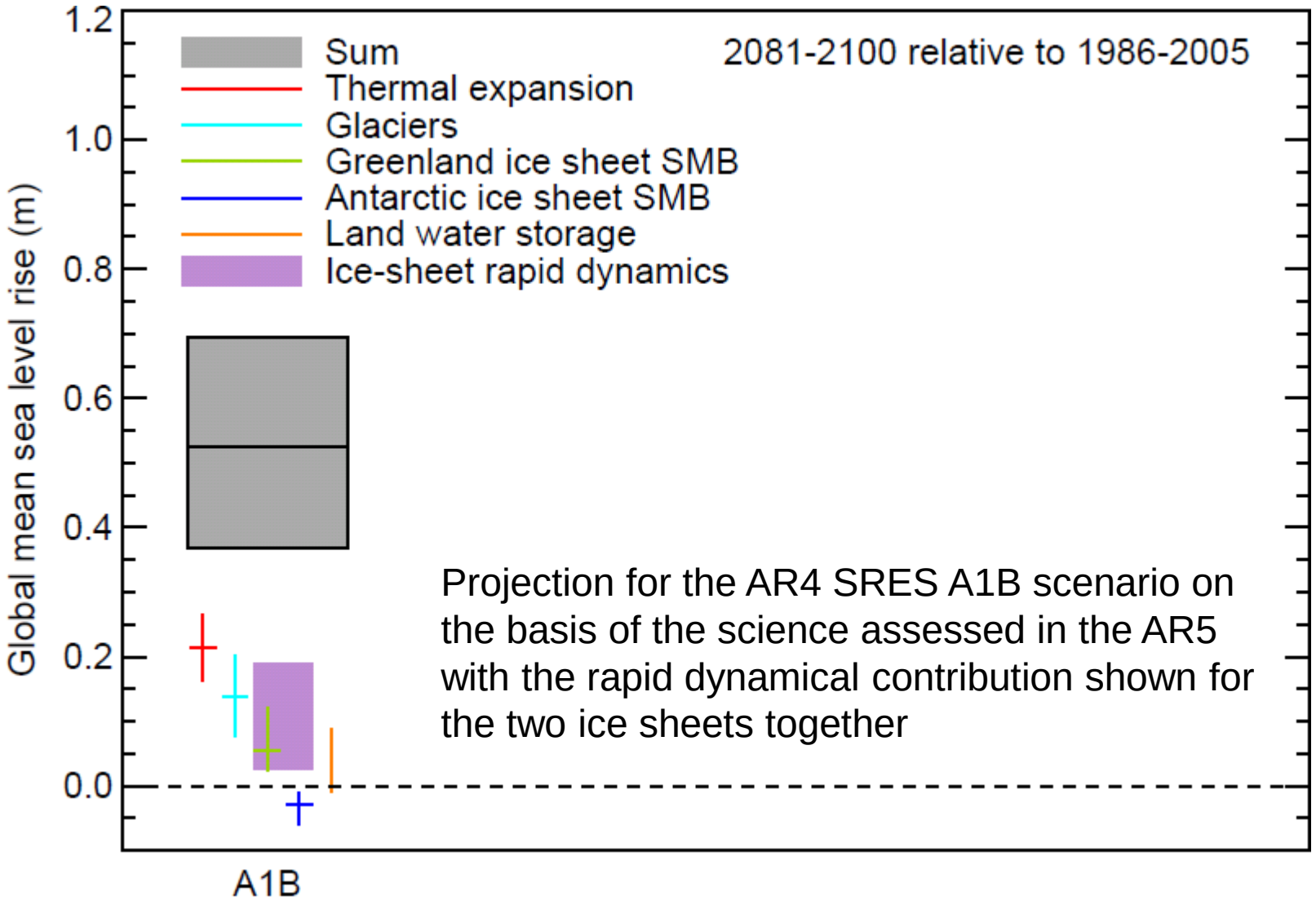
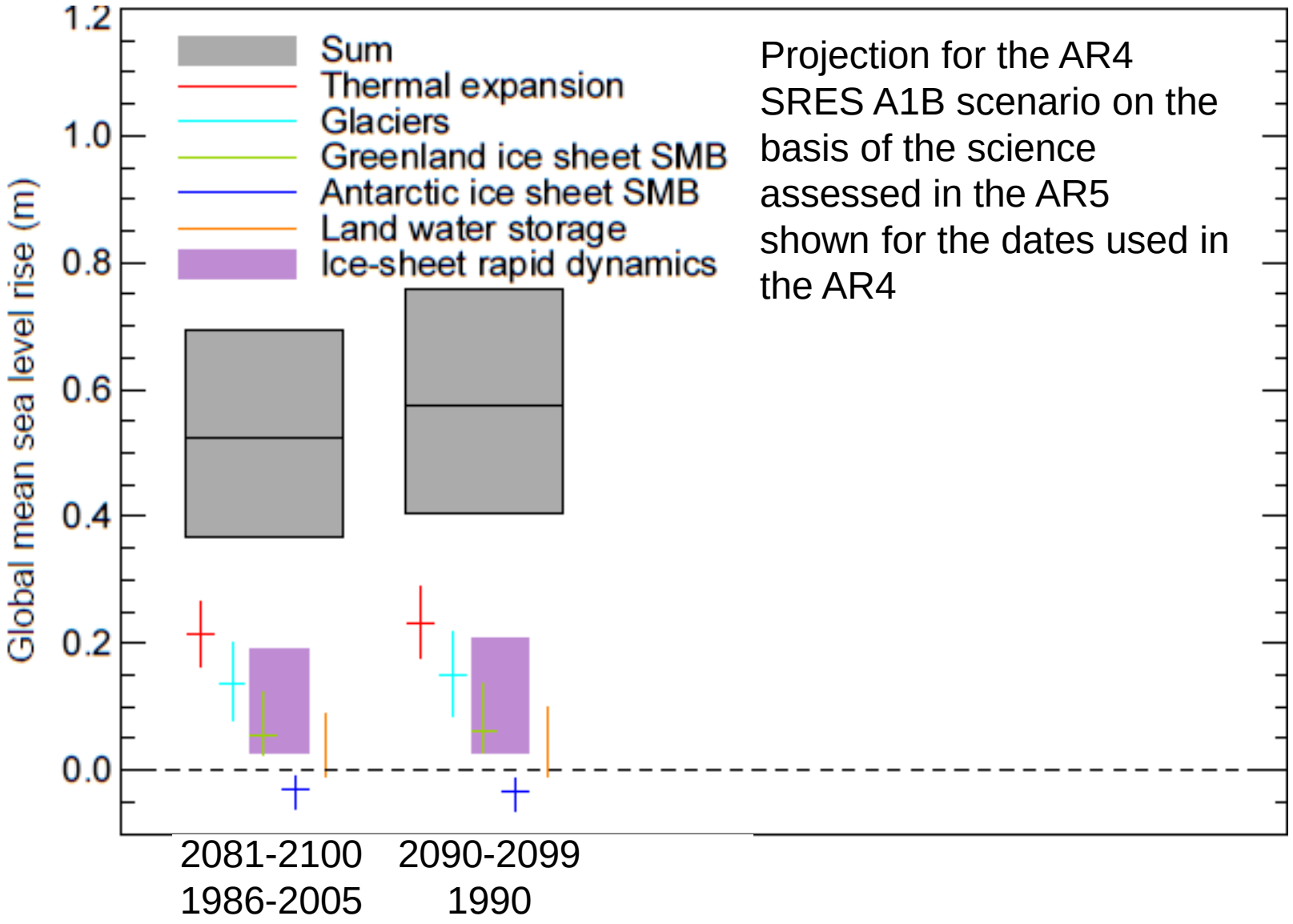
Comparison with AR4 projections

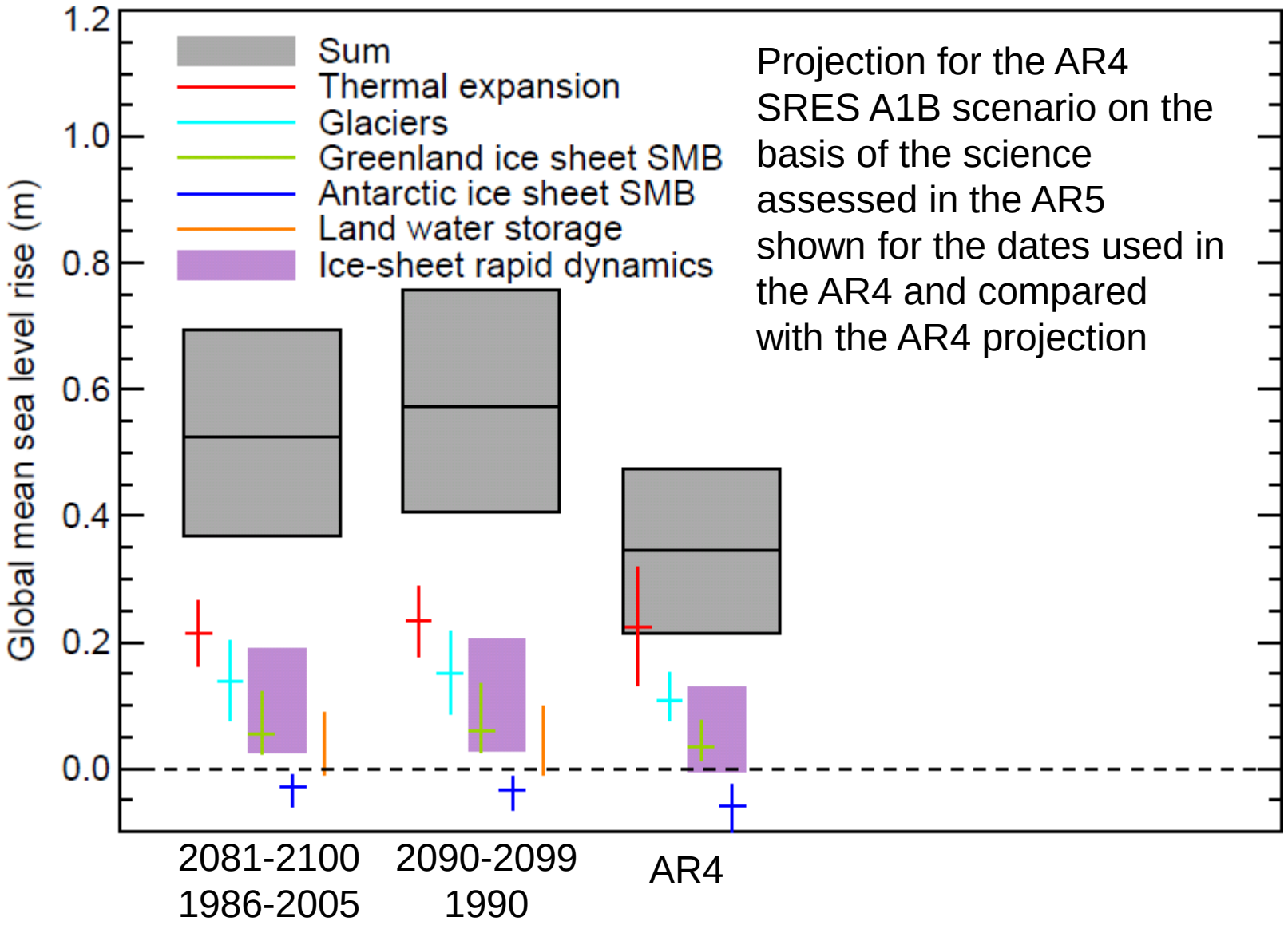


Comparison with AR4 projections

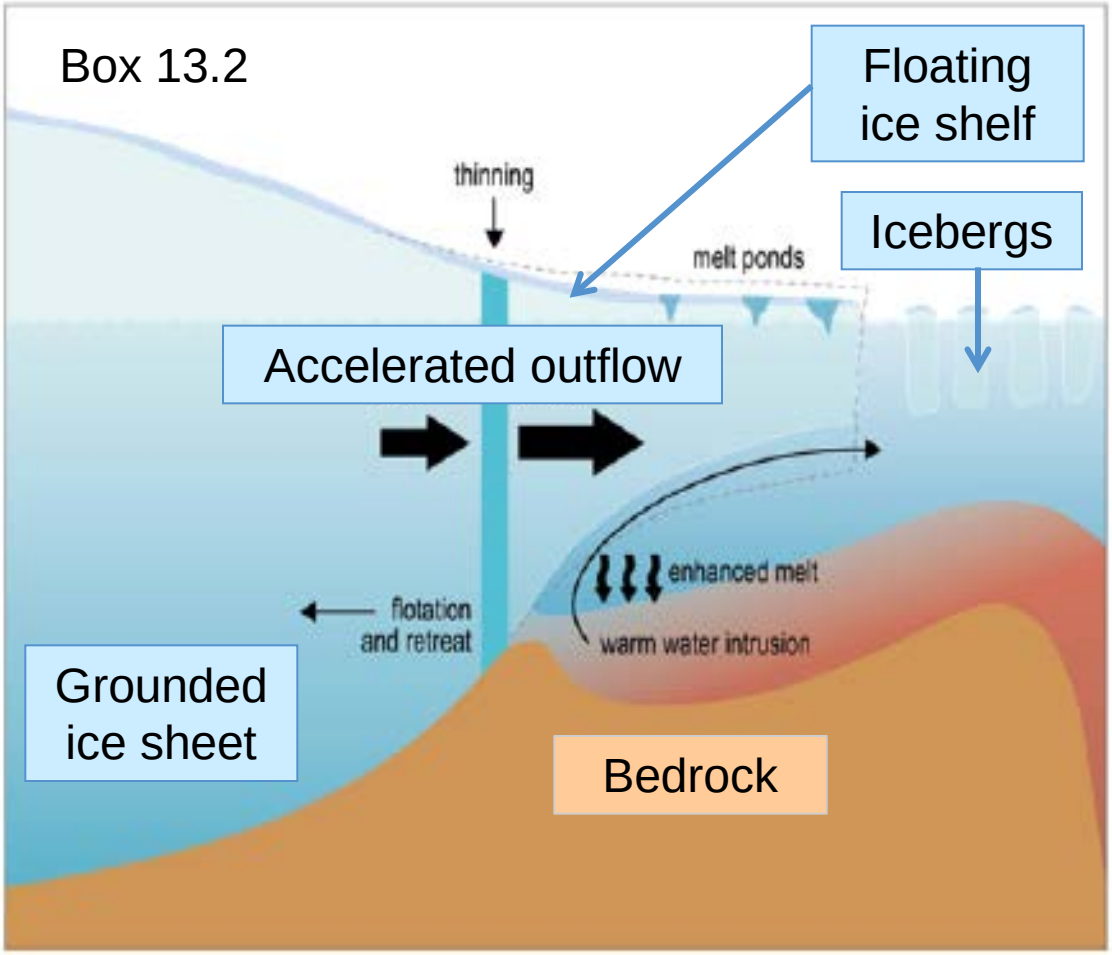


Projection for the AR4 SRES A1B scenario on the basis of the science assessed in the AR5 shown for the dates used in the AR4

Comparison with AR4 projections



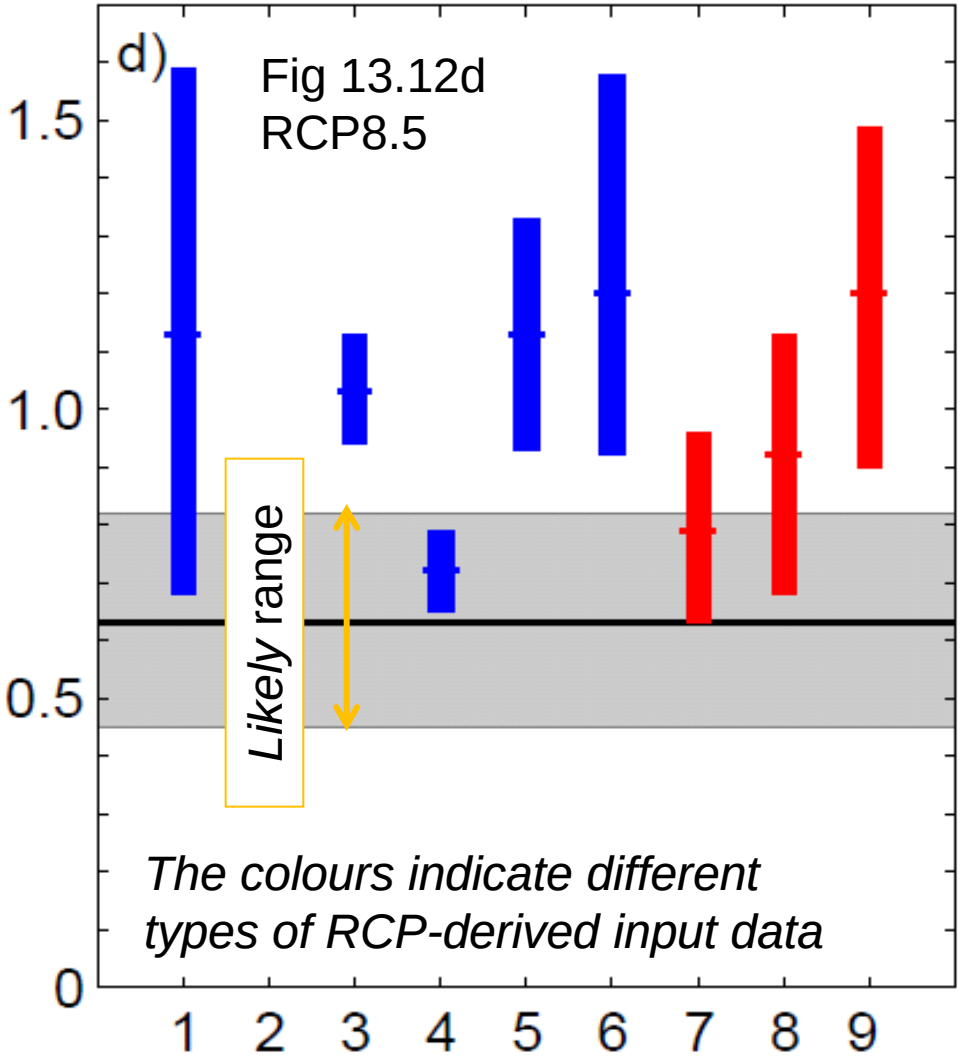
Rapid increase in ice sheet outflow



Only the collapse of marine-based sectors of the Antarctic ice sheet, if initiated, could cause GMSL to rise substantially above the *likely* range during the 21st century.

Medium confidence that this additional contribution would not exceed several tenths of a metre.

There is currently insufficient evidence to evaluate the probability of specific levels above the assessed *likely* range



In nearly every case, the semi-empirical model 95-percentile is higher than the process-based *likely* range.

There is no evidence that ice-sheet dynamical change is the explanation for the higher projections.

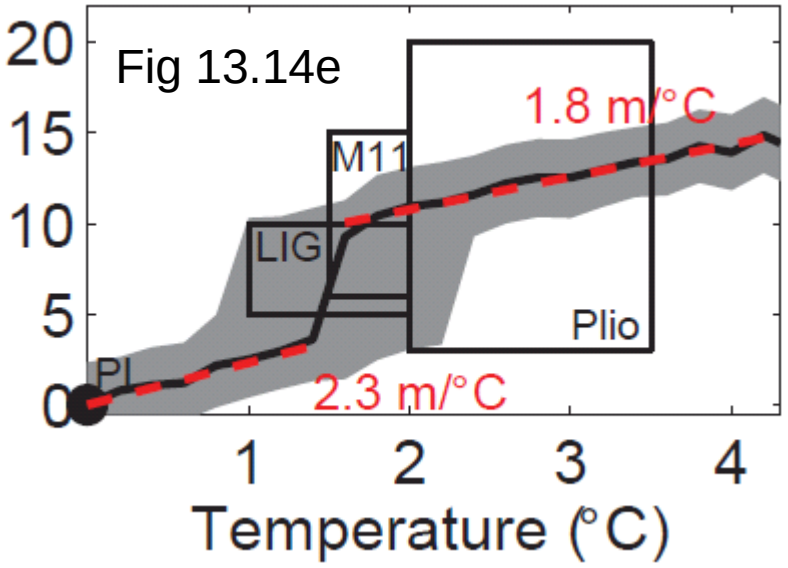
There is no consensus in the scientific community about the reliability of semi-empirical models, and thus there is *low confidence* in their projections.

Commitment to sea level rise and irreversibility

It is *virtually certain* that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions.

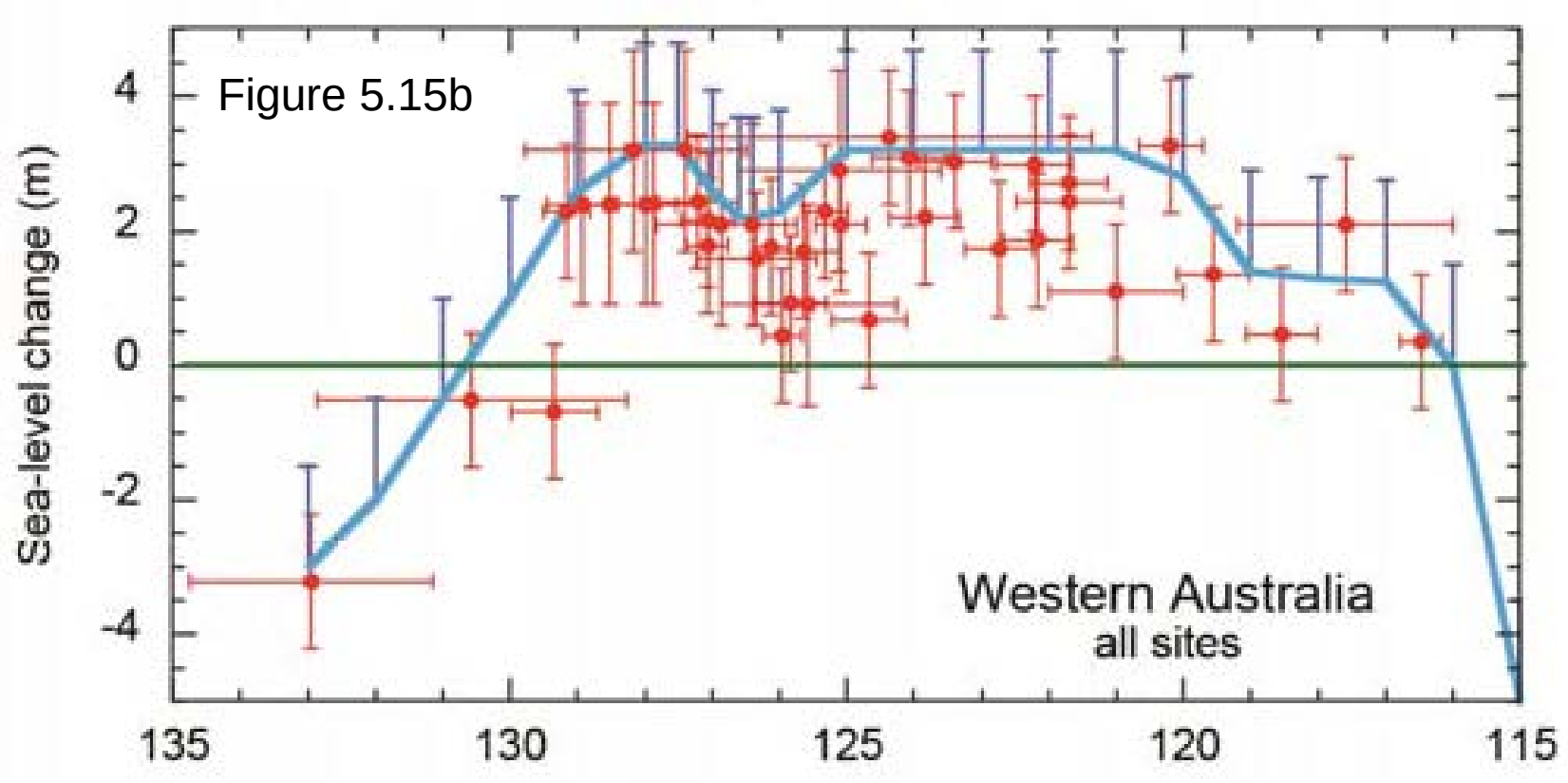
Medium confidence that GMSL rise by 2300 will be less than 1 m for a radiative forcing corresponding to CO_2 concentrations below 500 ppm, but 1 to more than 3 m for 700–1500 ppm.

Larger sea level rise could result from sustained mass loss by ice sheets, and some part of the mass loss might be irreversible.



Sustained warming greater than a certain threshold above preindustrial would lead to the near-complete loss of the Greenland ice sheet (*high confidence*). The threshold is estimated to be greater than 1°C (*low confidence*) but less than 4°C (*medium confidence*) global mean warming with respect to preindustrial.

Maximum global mean sea level during the last interglacial period was, for several thousand years, at least 5 m higher than present (*very high confidence*)



The Greenland ice sheet *very likely* contributed between 1.4 and 4.3 m, implying with *medium confidence* an additional contribution from the Antarctic ice sheet.

Regional sea level rise by the end of the 21st century

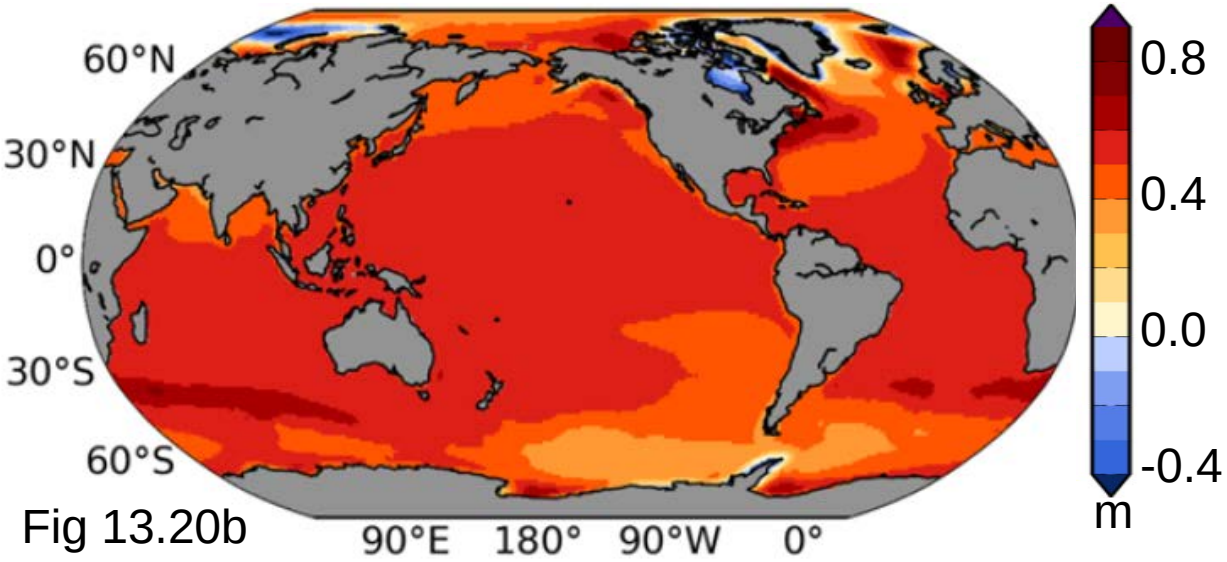


Fig 13.20b

It is *very likely* that sea level will rise in more than about 95% of the ocean area.

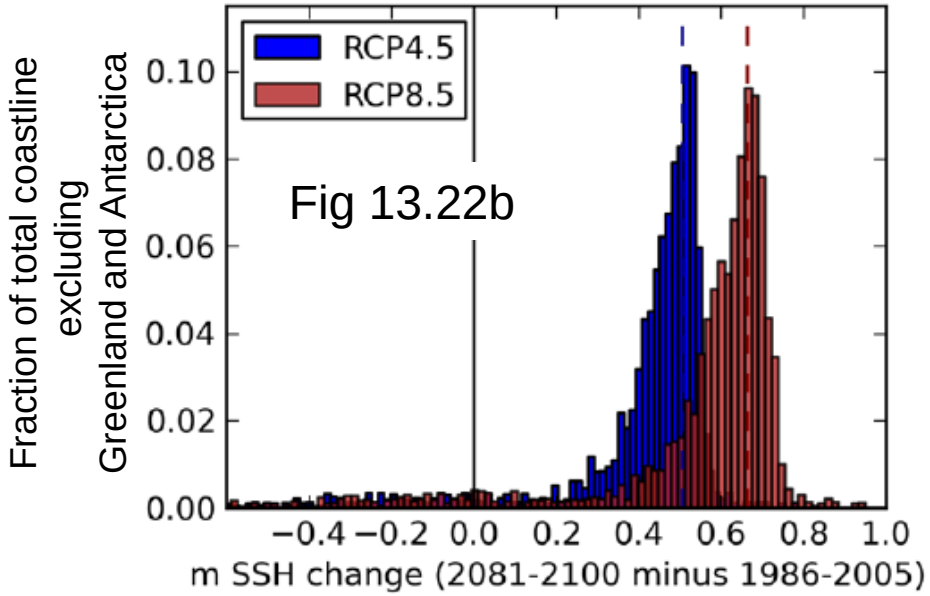


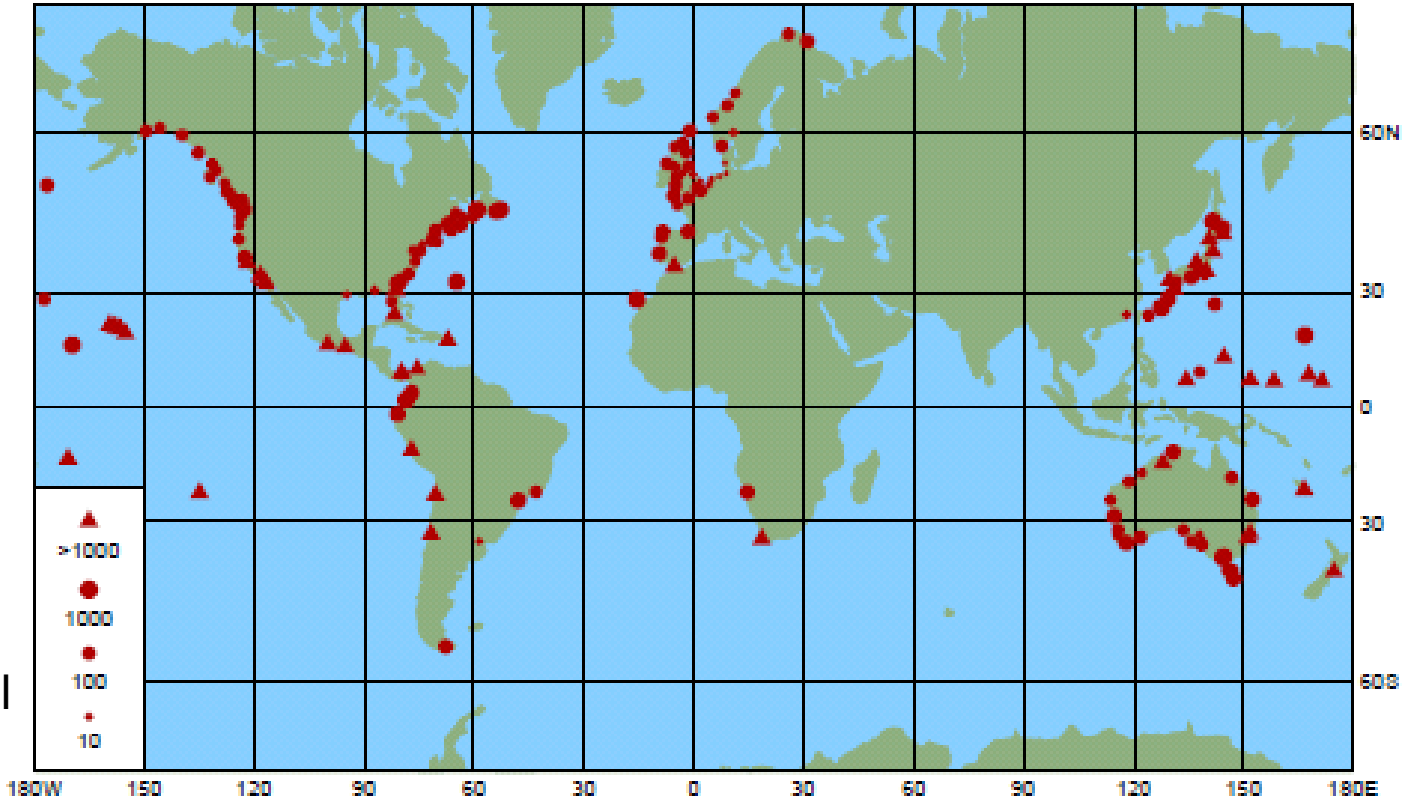
Fig 13.22b

About 70% of the coastlines worldwide are projected to experience sea level change within 20% of the global mean sea level change.

It is *very likely* that there will be a significant increase in the occurrence of future sea level extremes

This is primarily the result of an increase in local mean sea level. For instance, for a rise of 0.5 m, there are large increases in the frequency of extreme events.

Fig 13.25a



Multiplication factor for the frequency of a given sea level extreme.

Summary of main points for sea level

GMSLR during 1901–2010 can be accounted for by ocean thermal expansion, ice loss by glaciers and ice sheets, and change in liquid water storage on land.

It is *very likely* that the 21st-century mean rate of GMSLR under all RCPs will exceed that of 1971–2010, due to the same processes.

A *likely* range of GMSLR for 2081–2100 compared with 1986–2005, depending on emissions (0.40 [0.26–0.55] m for RCP2.6, 0.63 [0.45–0.82] m for RCP8.5), can be projected with *medium confidence*, including the contribution from ice-sheet rapid dynamics. The collapse of marine-based sectors of the Antarctic Ice Sheet, if initiated, would add no more than several tenths of a meter during the 21st century (*medium confidence*).

It is *very likely* that sea level will rise in more than about 95% of the ocean area.

It is *very likely* that there will be a significant increase in the occurrence of future sea level extremes.

It is *virtually certain* that global mean sea level rise will continue for many centuries beyond 2100, with the amount of rise dependent on future emissions.