Understanding sea level rise and variability
Current projections and key uncertainties

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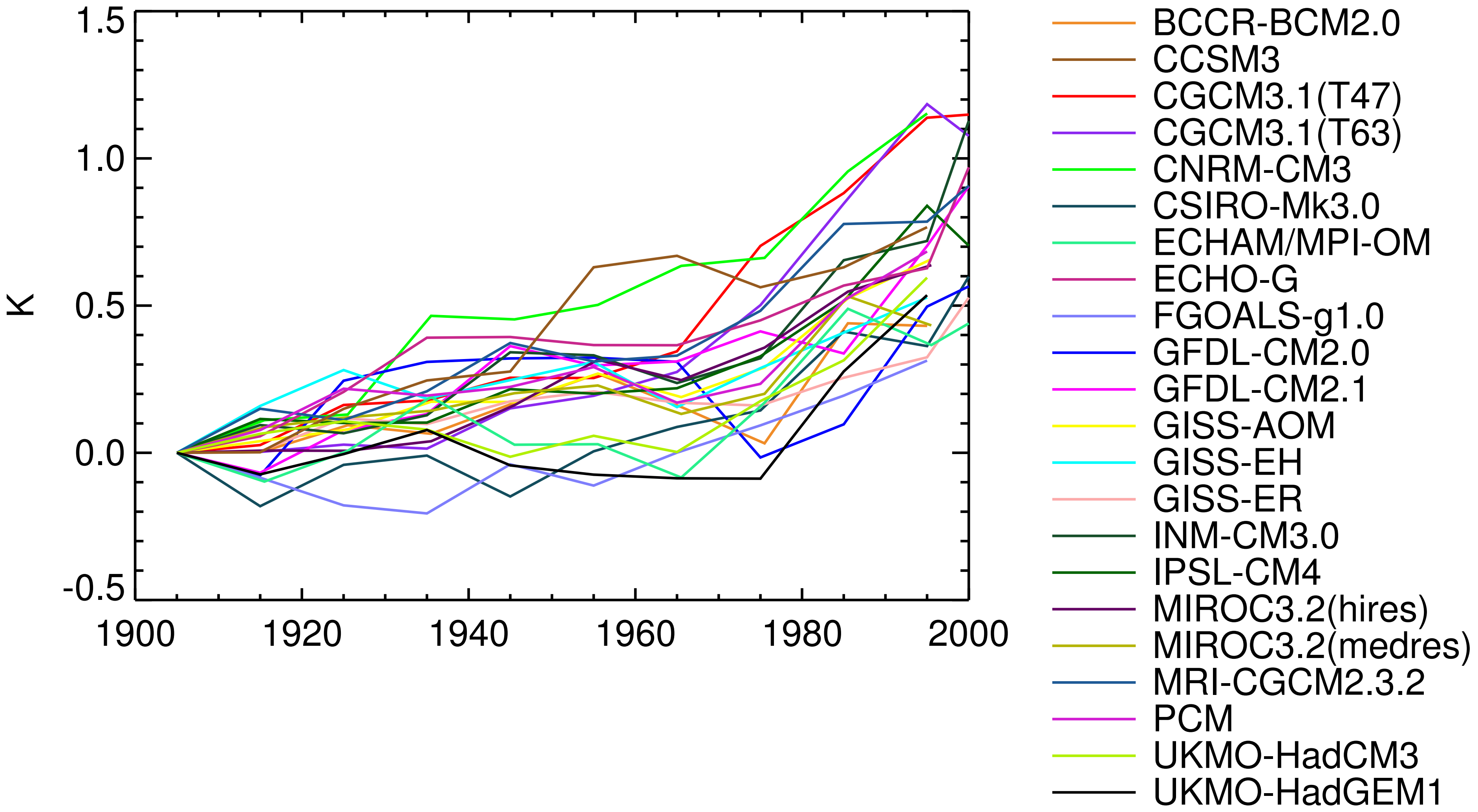
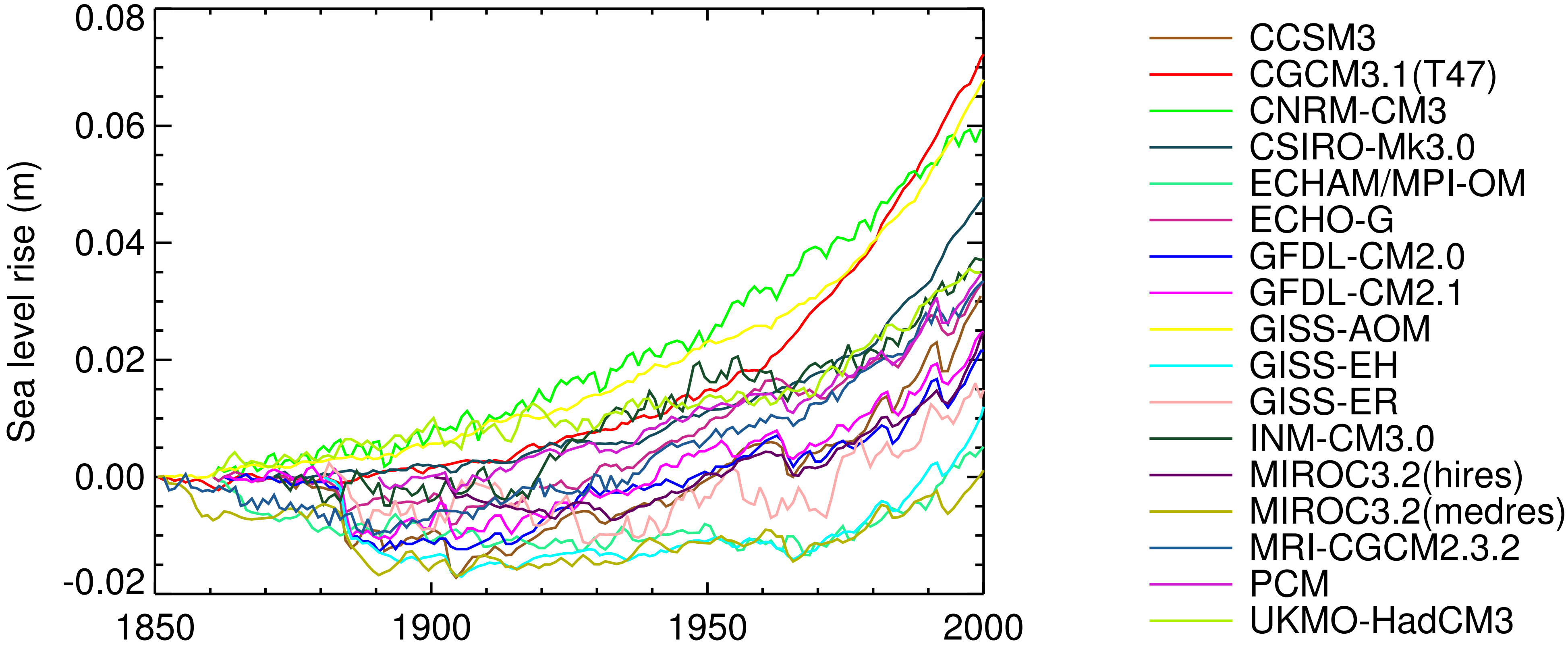
Simulated global average temperature change



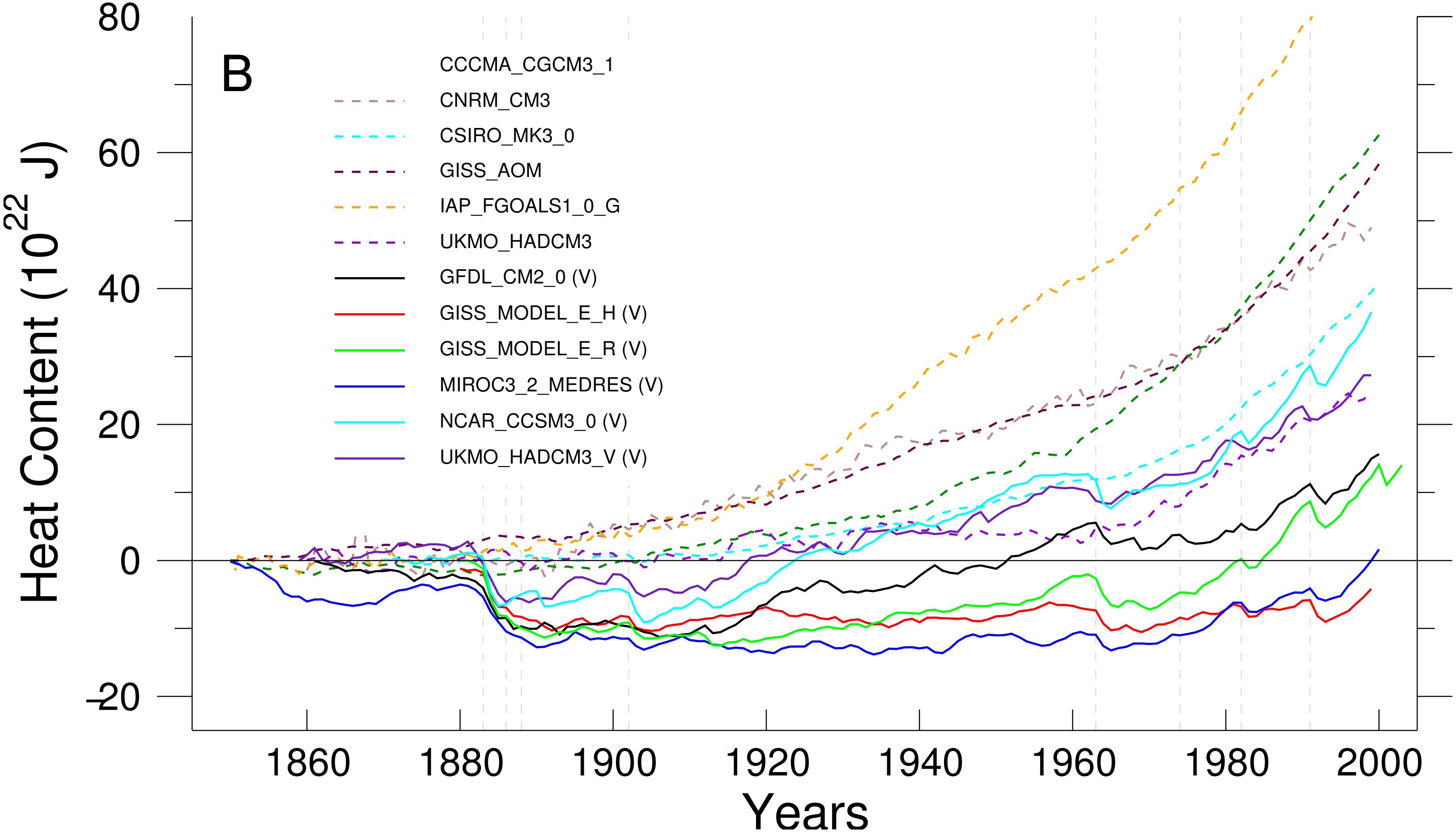
AOGCM results courtesy of PCMDI and modelling groups

Simulated thermal expansion



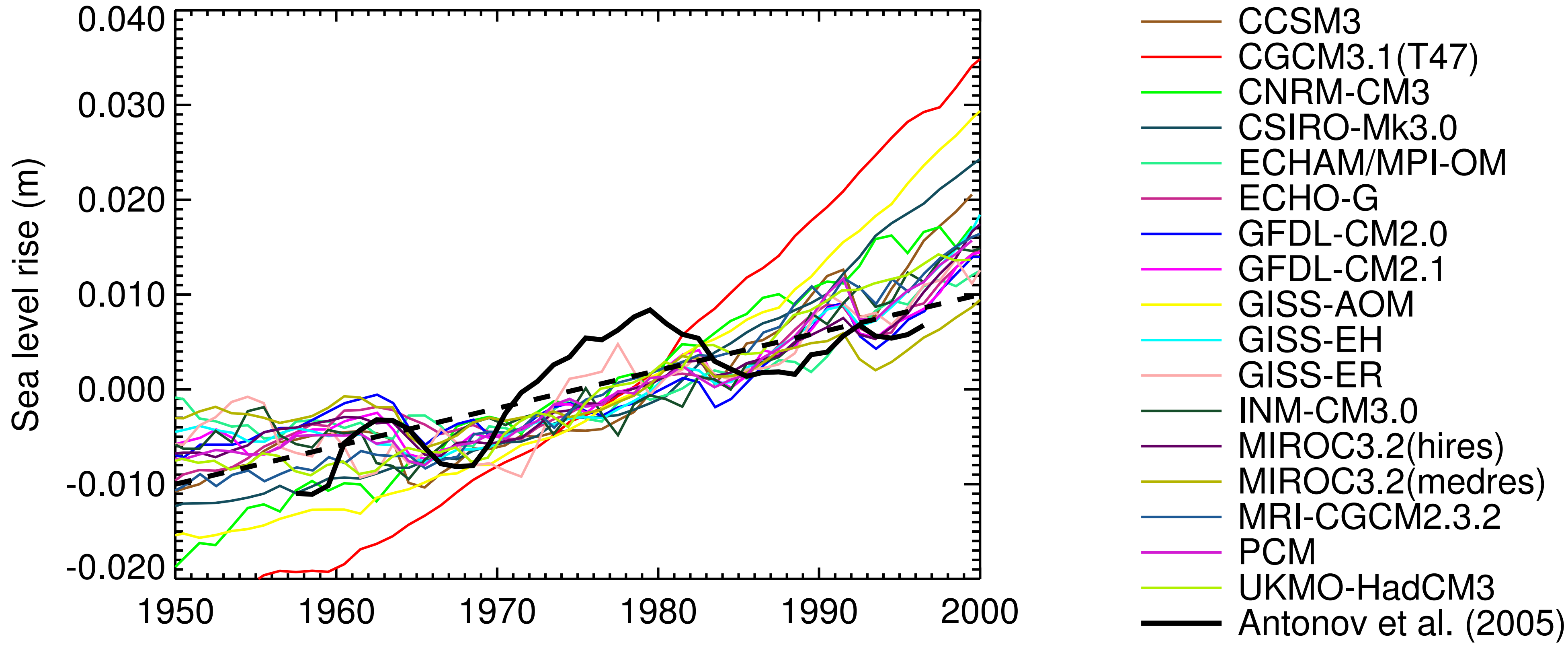
AOGCM results courtesy of PCMDI and modelling groups

Krakatoa explains some of the spread



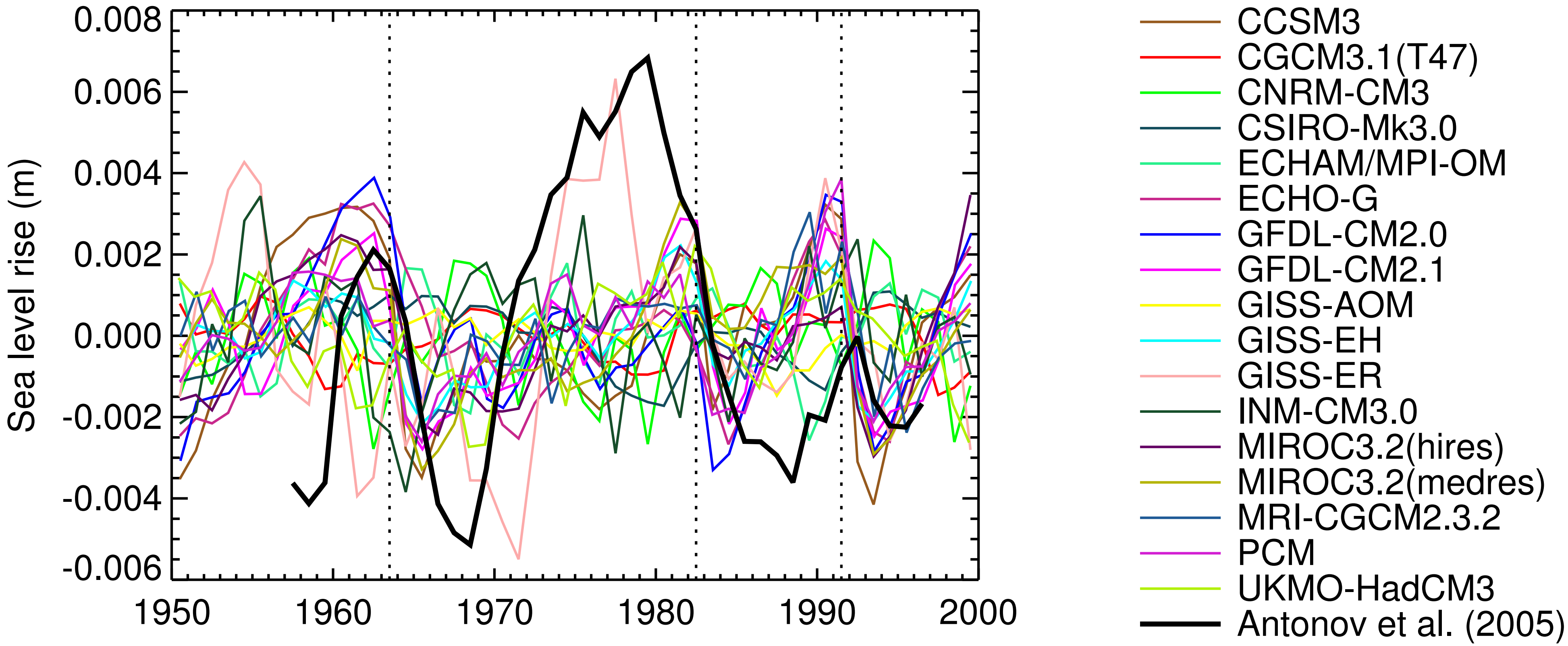
Gleckler et al. (submitted MS)

AOGCMs have a range of trends in recent decades

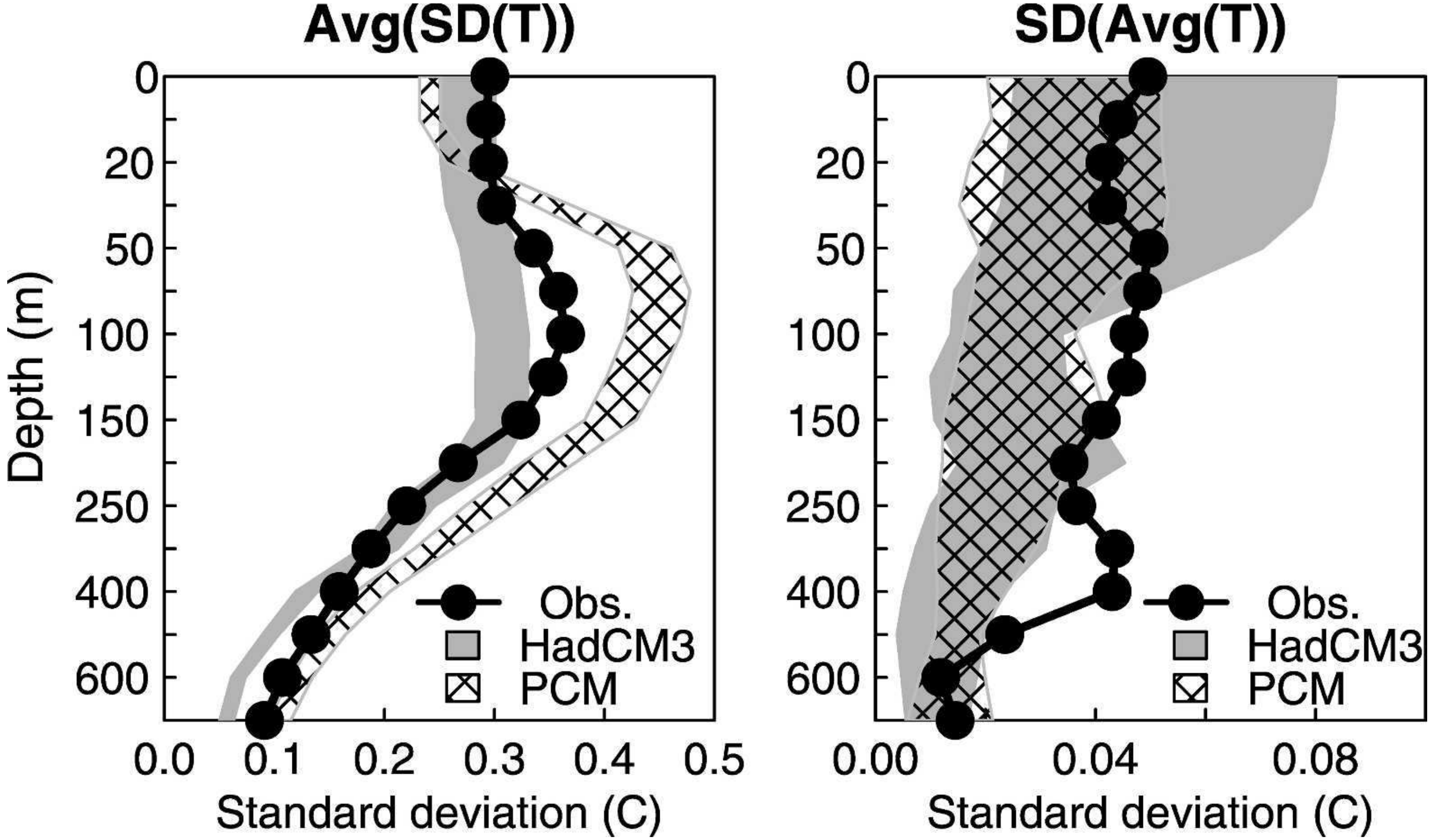


Antonov et al. (2005) 0.40 ± 0.05 mm yr^{-1}, AOGCMs 0.54 ± 0.26

AOGCMs have less variability than ocean temperature analyses

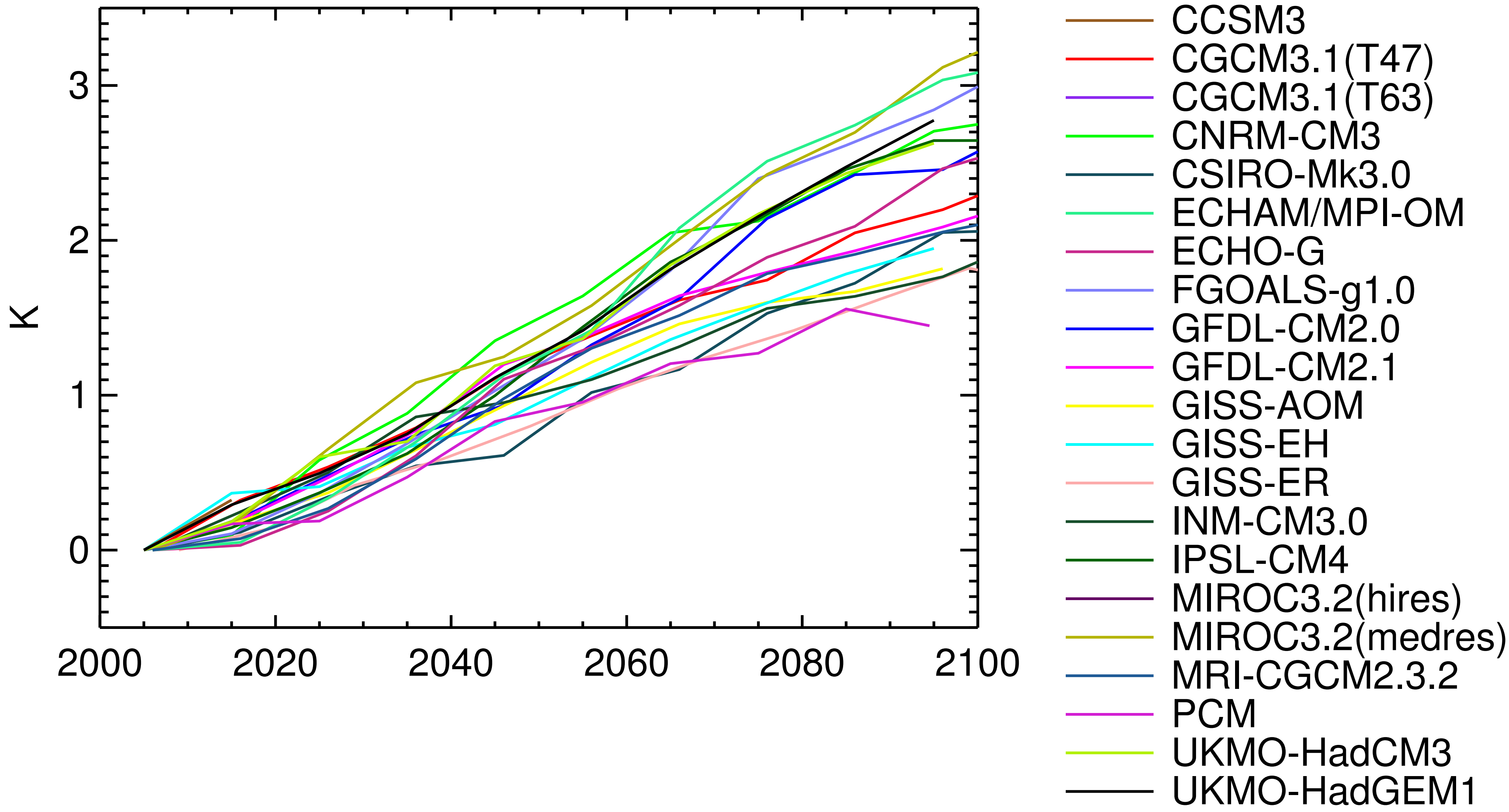


Ocean temperature variability as a function of depth



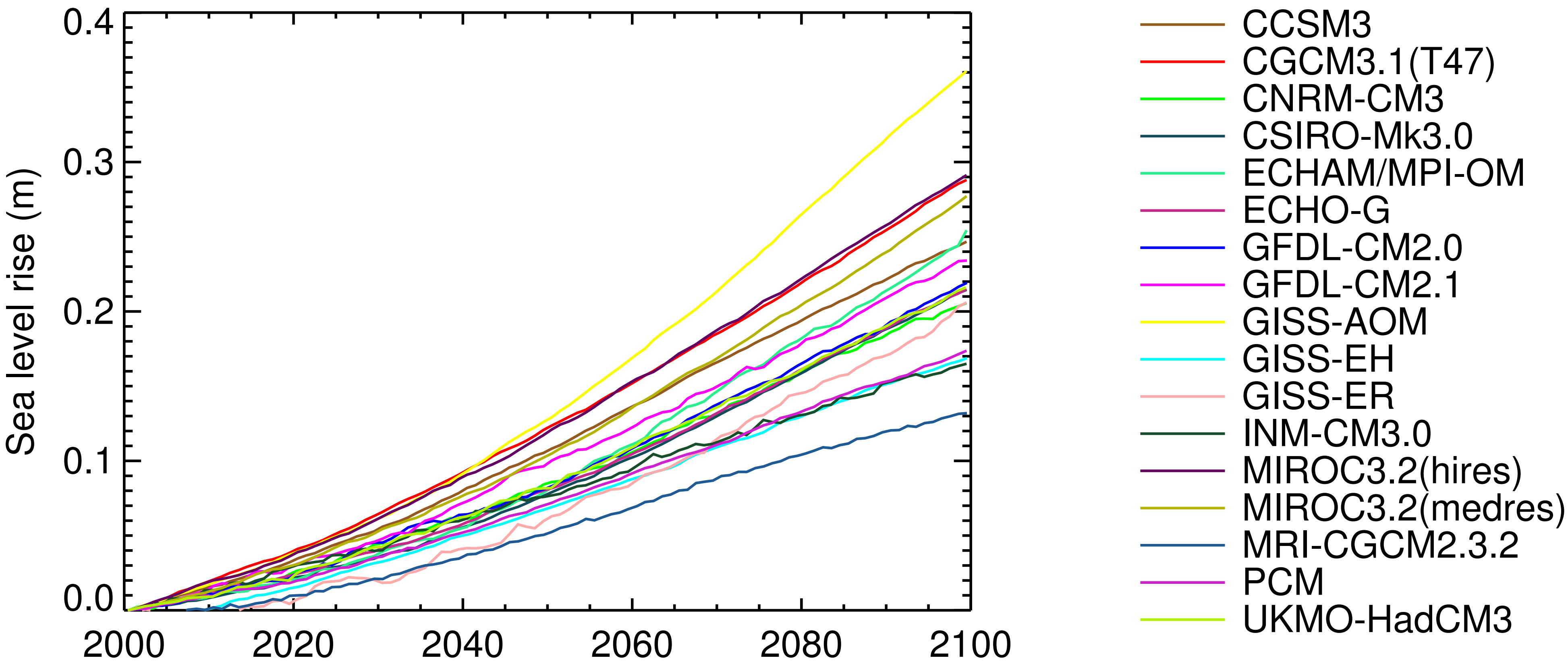
Pierce et al. (2006)

Simulated temperature change under scenario A1B



AOGCM results courtesy of PCMDI and modelling groups

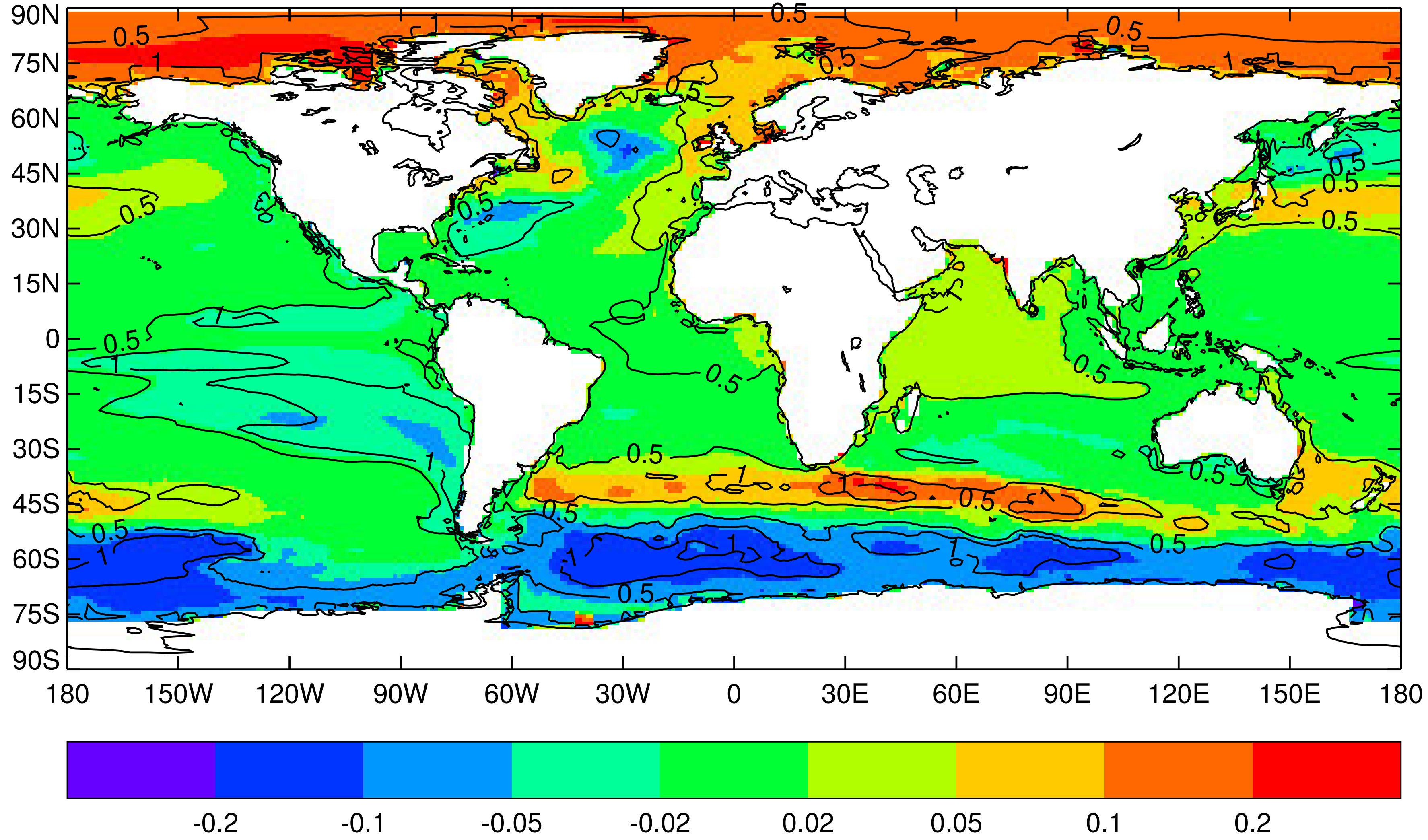
Simulated thermal expansion under scenario A1B



AOGCM results courtesy of PCMDI and modelling groups

Model spread is due to differences in climate sensitivity and ocean heat uptake efficiency.

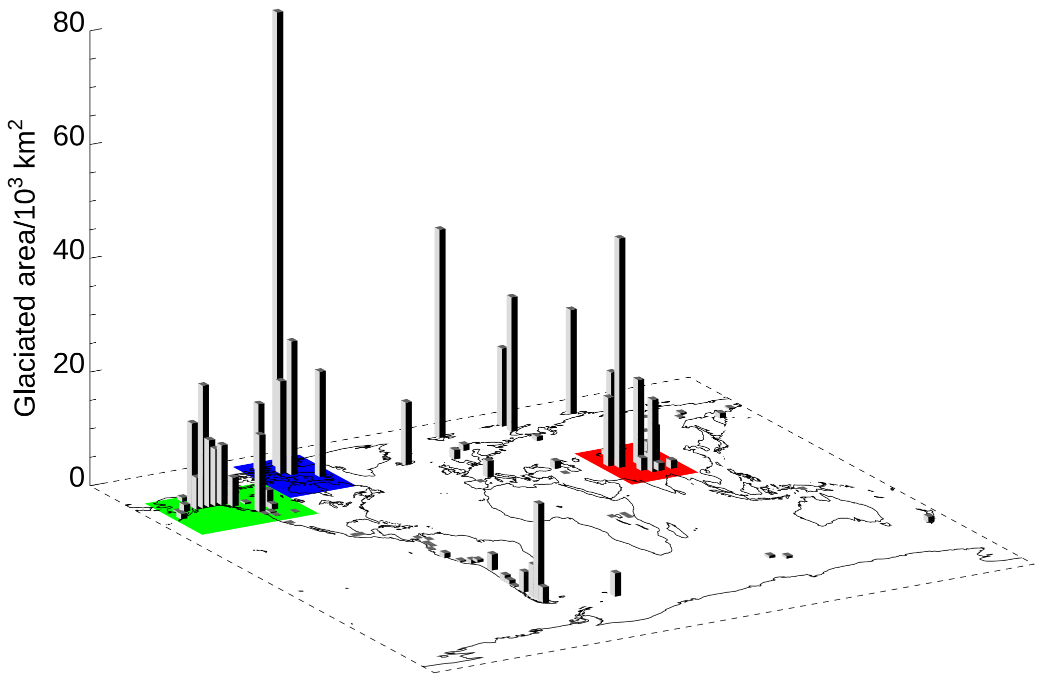
Geographical pattern of simulated sea level change



Colours in m

AOGCM results courtesy of PCMDI and modelling groups

Simulation of glacier surface mass balance change



Glacier contribution to rate of sea level rise is calculated as

$$-\frac{1}{A_o}\sum_i b_i A_i \Delta T_i$$

(A_o ocean area, b_i, A_i, ΔT_i mass balance sensitivity, area and temperature anomaly for region i). If

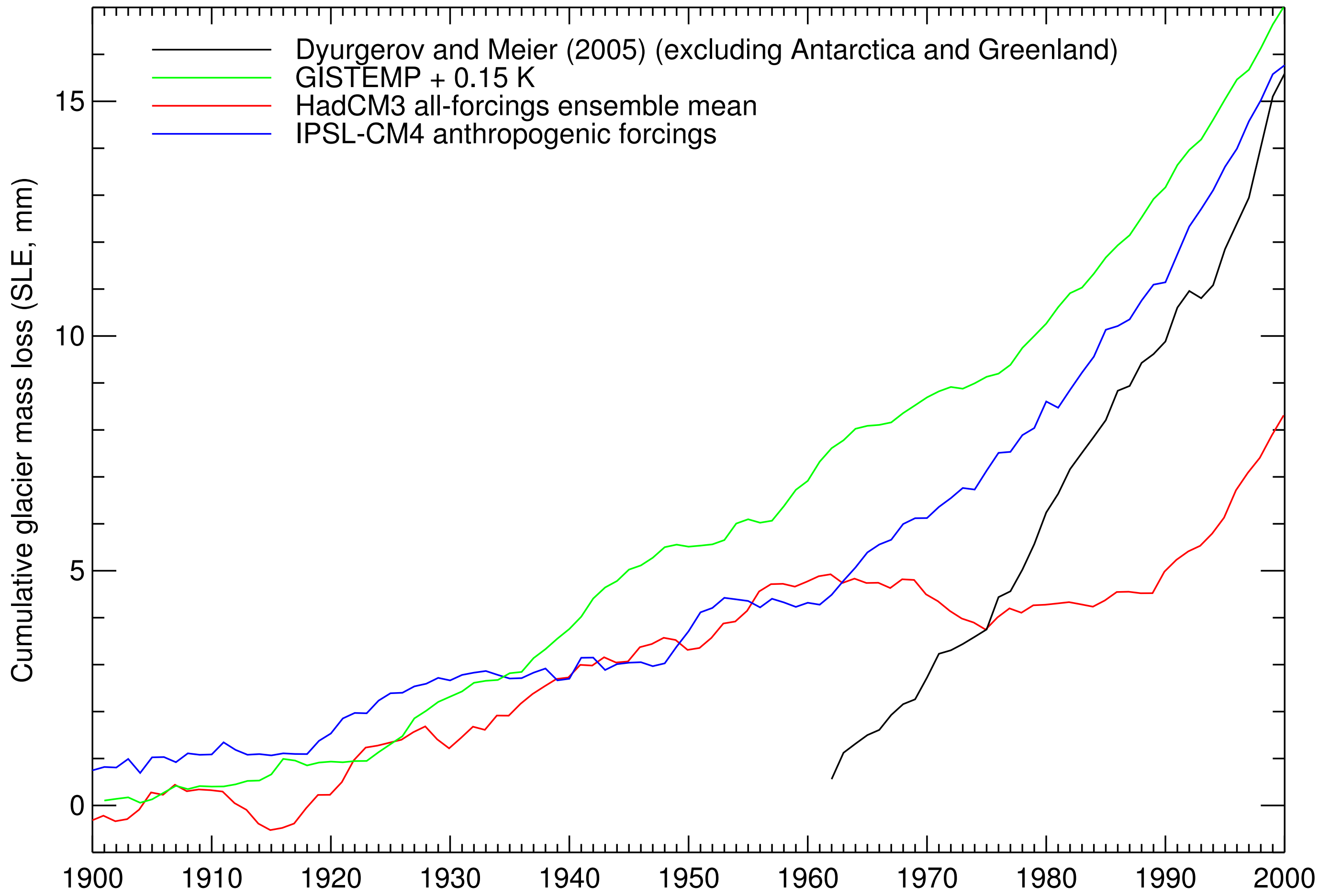
$$\Delta T_i = R_i \Delta T - \theta_i$$

(ΔT global temperature anomaly), the rate can be written

$$b_g(\Delta T - \theta).$$

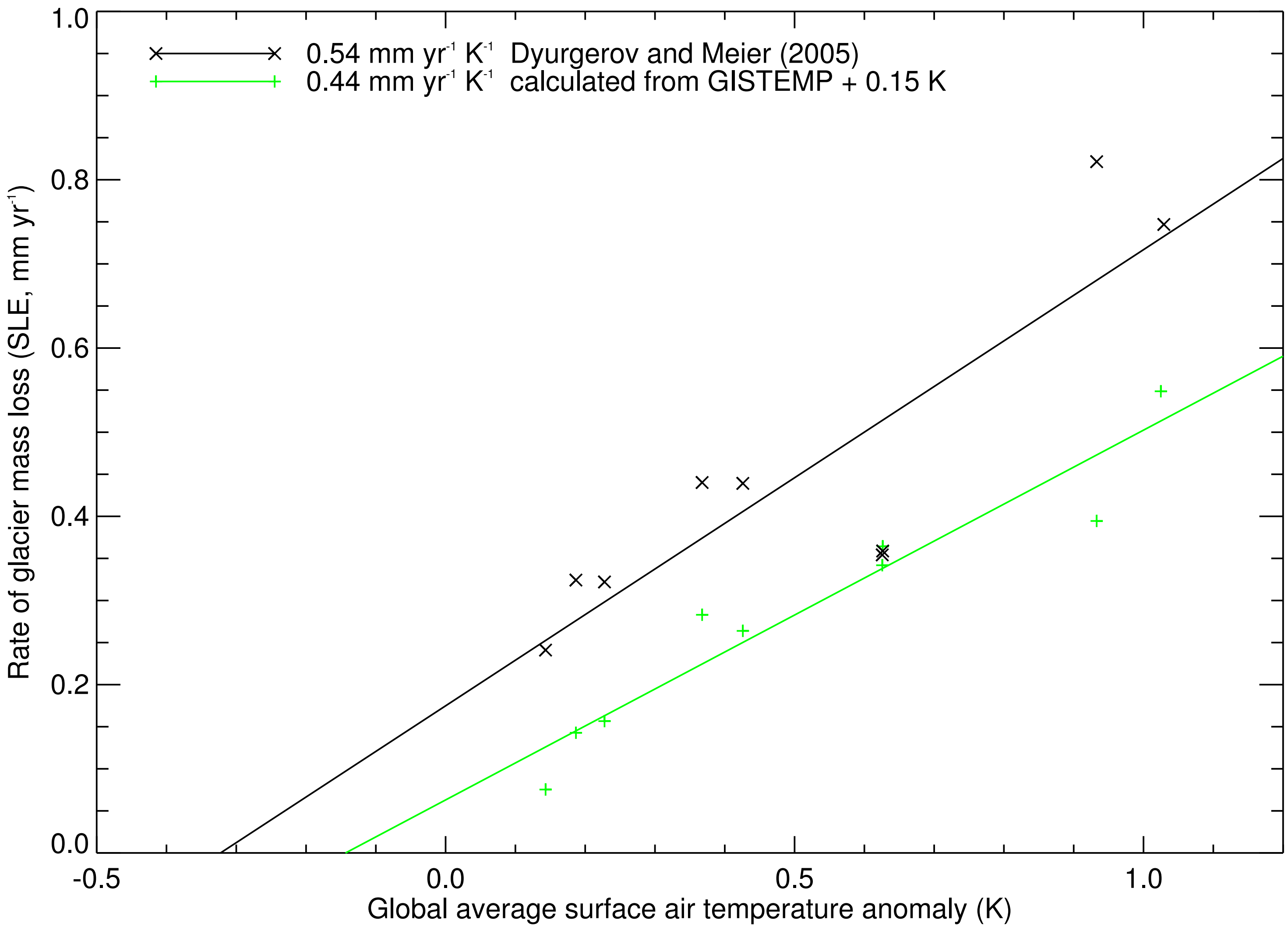
Zuo and Oerlemans (1997)
Gregory and Oerlemans (1998)

Global glacier contribution to sea level rise

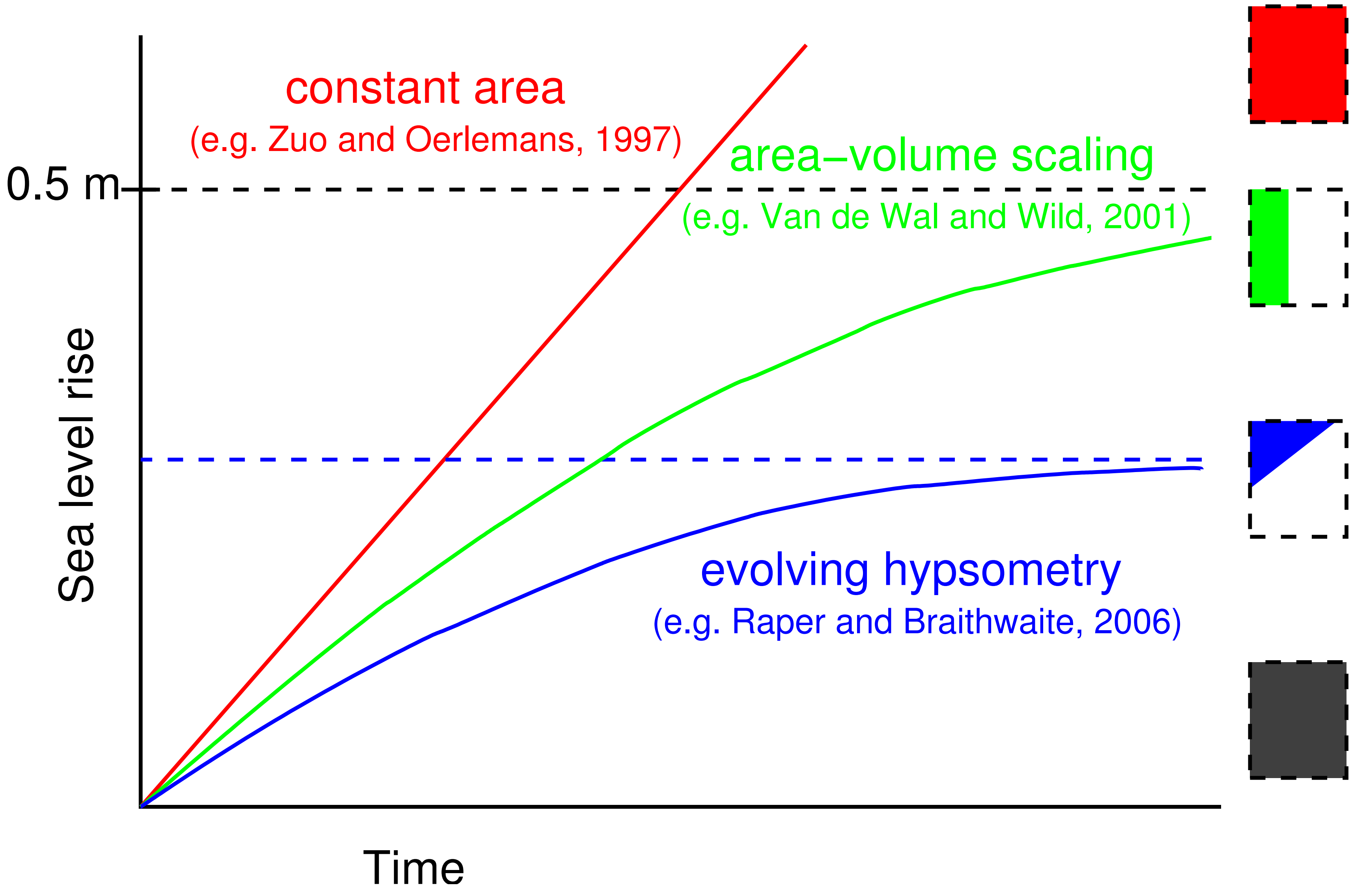


Calculated from observed (GISTEMP) and AOGCM-simulated temperatures, compared with an observational estimate.

Global glacier mass balance as a function of ΔT



Effect of glacier hypsometry



Simulation of ice-sheet surface mass balance change

Huybrechts et al. (2004) scaled geographical patterns of temperature and precipitation change from high-resolution climate models according to the ice-sheet area-average changes from AOGCMs.

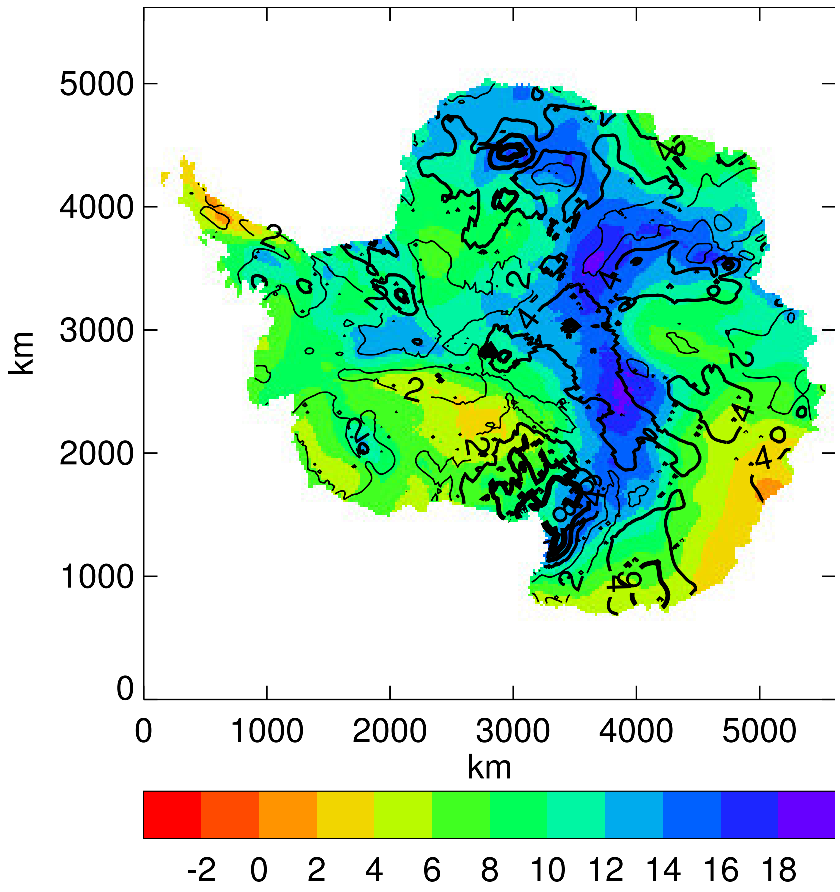
Gregory and Huybrechts (in press) repeated this with five high-resolution models.

The high-resolution climate change is input to a 20-km ice-sheet mass balance calculation.

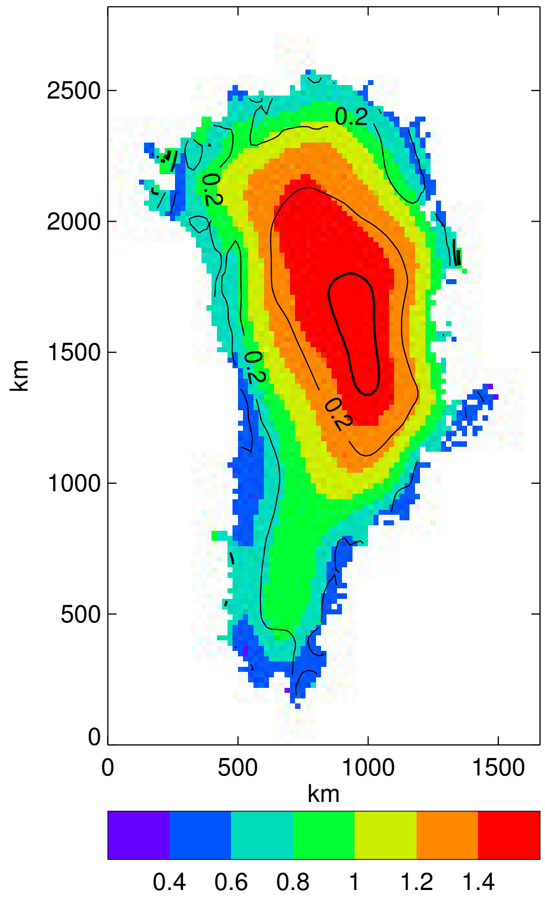
Thus we obtain ice-sheet surface mass balance perturbation (SLE) as a function of ice-sheet area-average temperature and precipitation change.

Ensemble-mean high-resolution GCM patterns

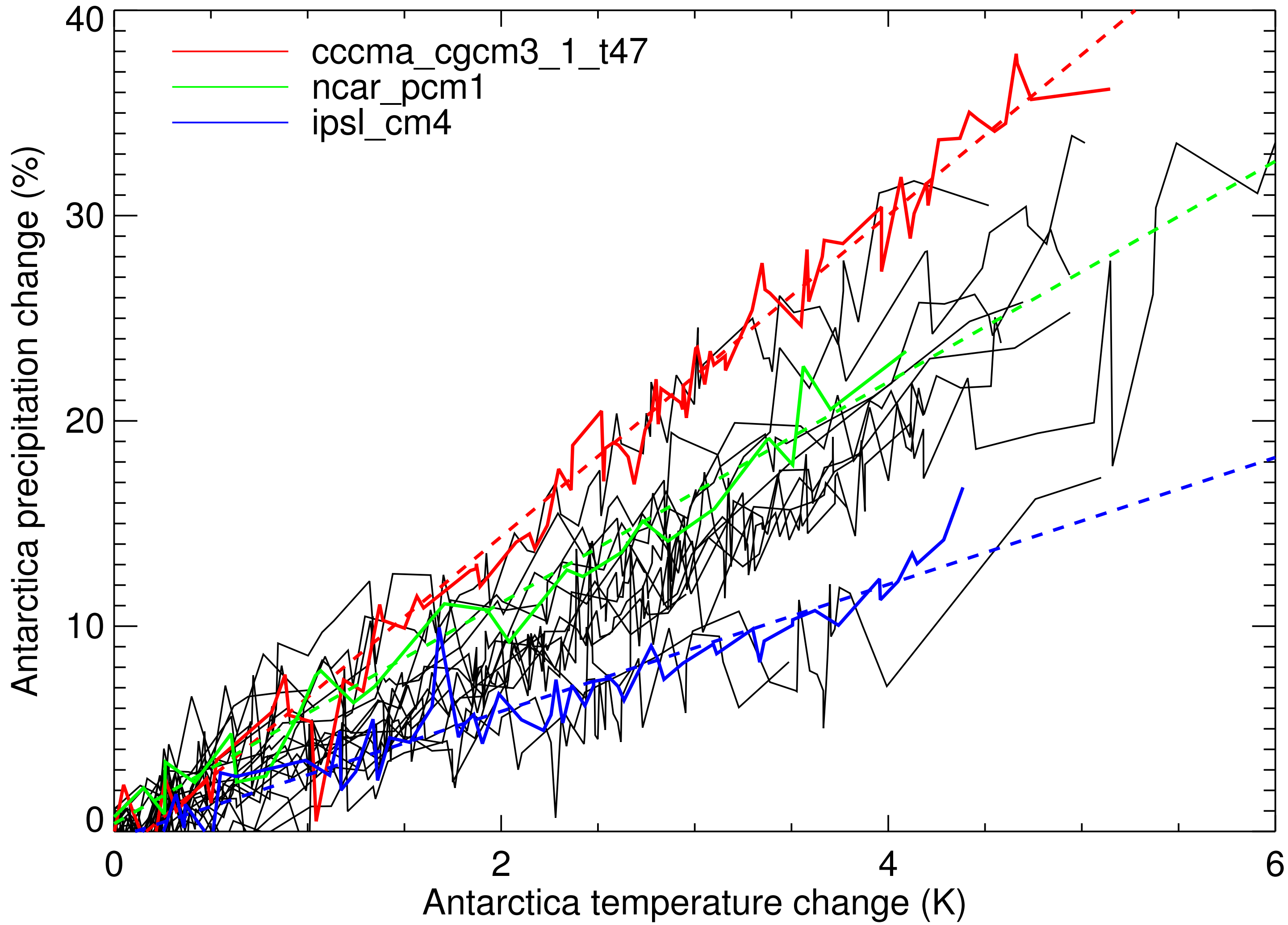
Annual precipitation change (%)
(10% area-average)



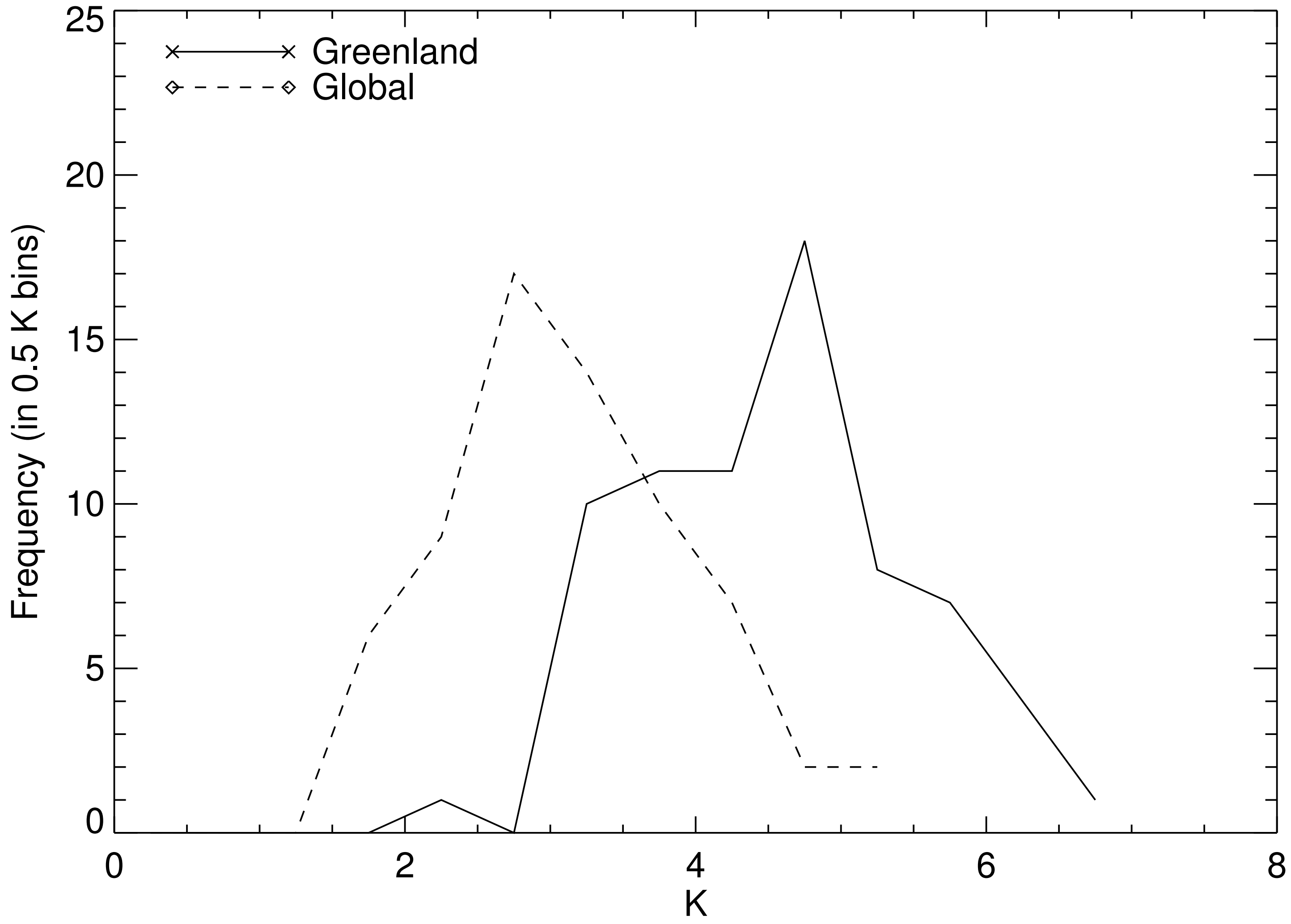
Summer temperature change (K)
(1 K area-average)



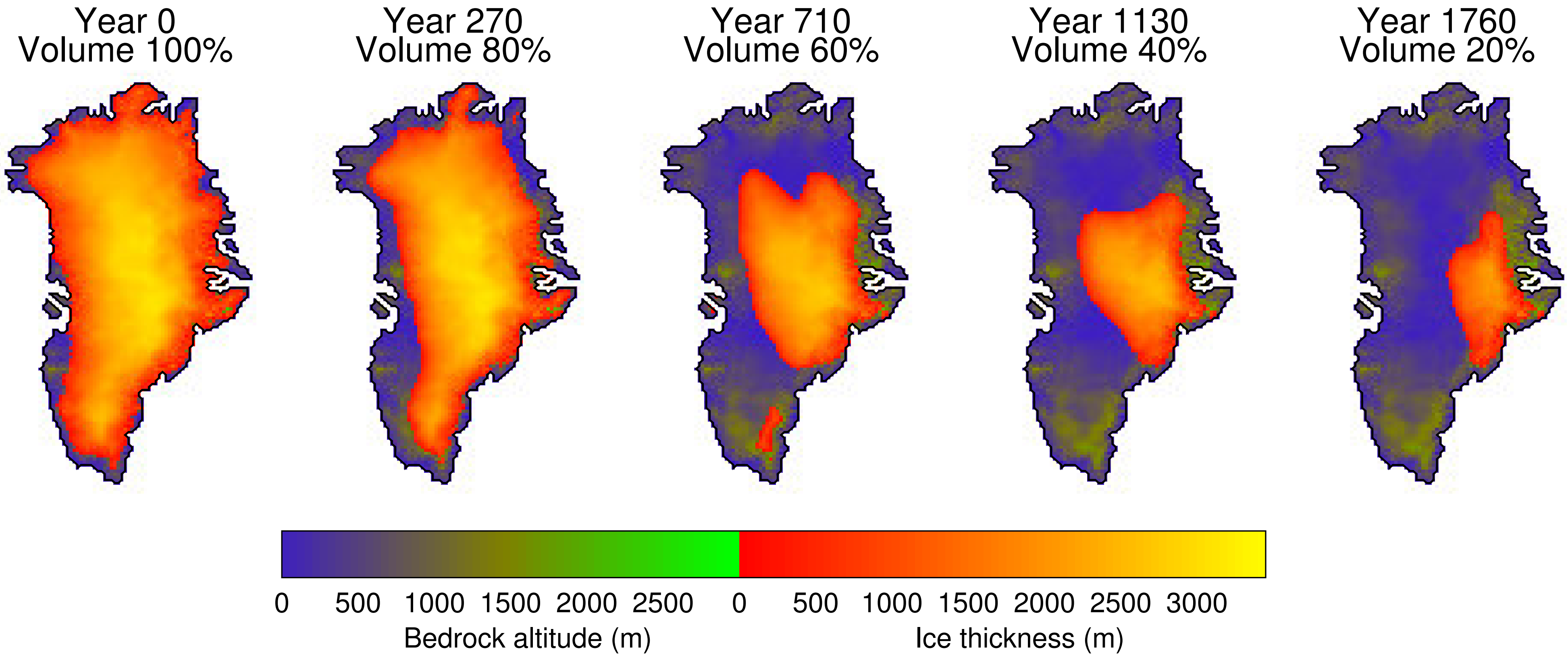
Precipitation rises linearly with temperature



Warming threshold for negative surface mass balance in Greenland



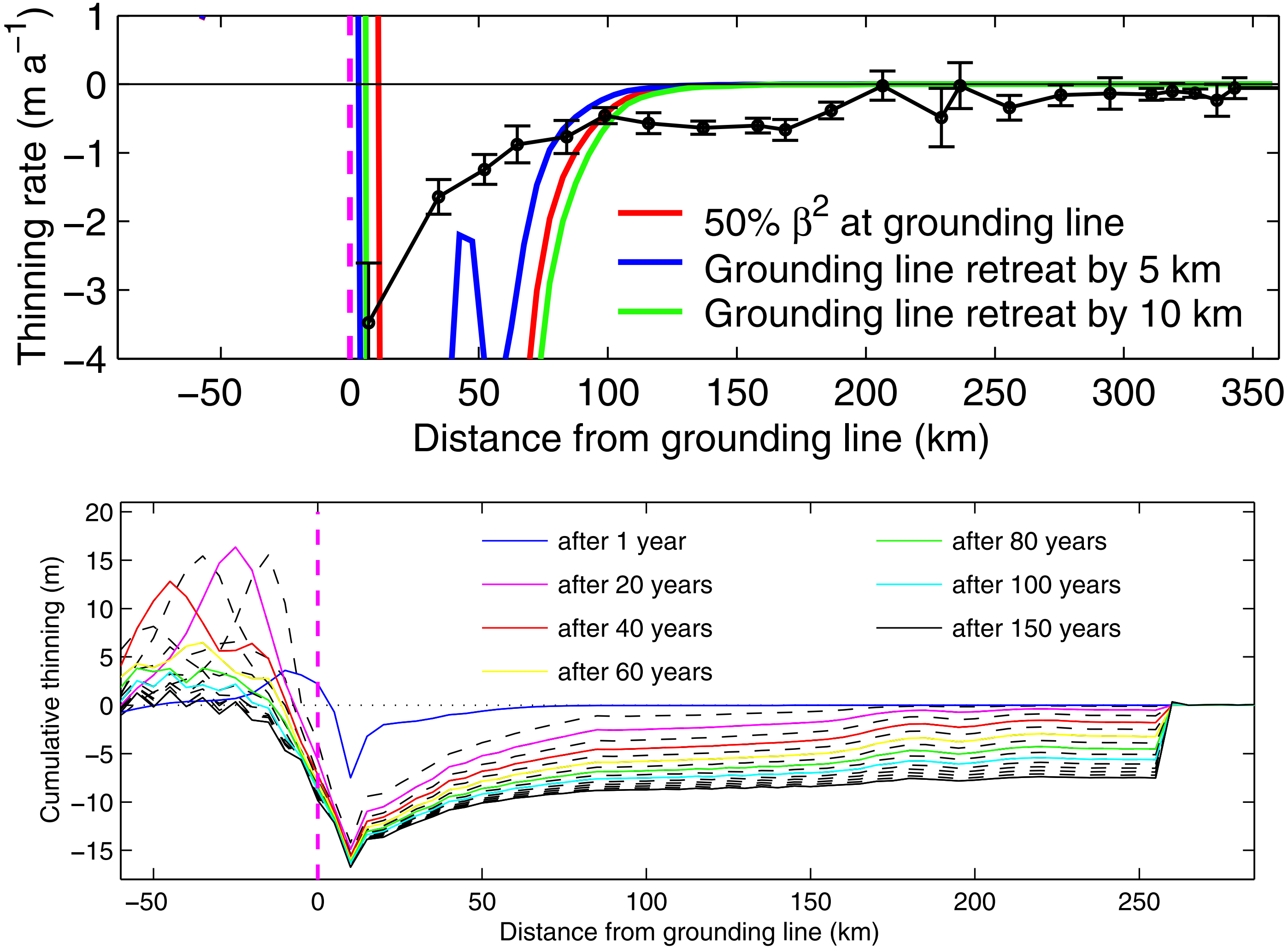
Future evolution of the Greenland ice sheet



Ridley et al. (2005)

Not including any effects tending to produce rapid dynamical acceleration.

Dynamical changes in the West Antarctic ice sheet



Payne et al. (2004)

Summary

AOGCM output can be used to simulate sea level rise due to thermal expansion and land ice change

Scenario and climate sensitivity are major uncertainties for making projections

Uncertainties—thermal expansion

Global ocean heat uptake varies among models, reflecting differences in interior transport processes

Geographical patterns of sea level change show substantial differences

Simulated decadal variability of ocean heat content is smaller than in observational analyses

Uncertainties—glaciers and ice caps

Treatment of the evolution of hypsometry and the "unperturbed" state

Mass balance sensitivity to temperature (in general, to climate change)

Geographical patterns of temperature and precipitation change

Role of rapid dynamical response to climate change

Uncertainties—ice sheets

Magnitude of increase in precipitation

Geographical and seasonal pattern of change in temperature over the ice sheets

Possibility of lubrication of ice flow caused by surface runoff

Dependence of basal melting of ice shelves on ocean climate change

Vulnerability of ice shelves to surface climate change

Dynamical response of ice streams to melting at the grounding line and to removal of ice shelves

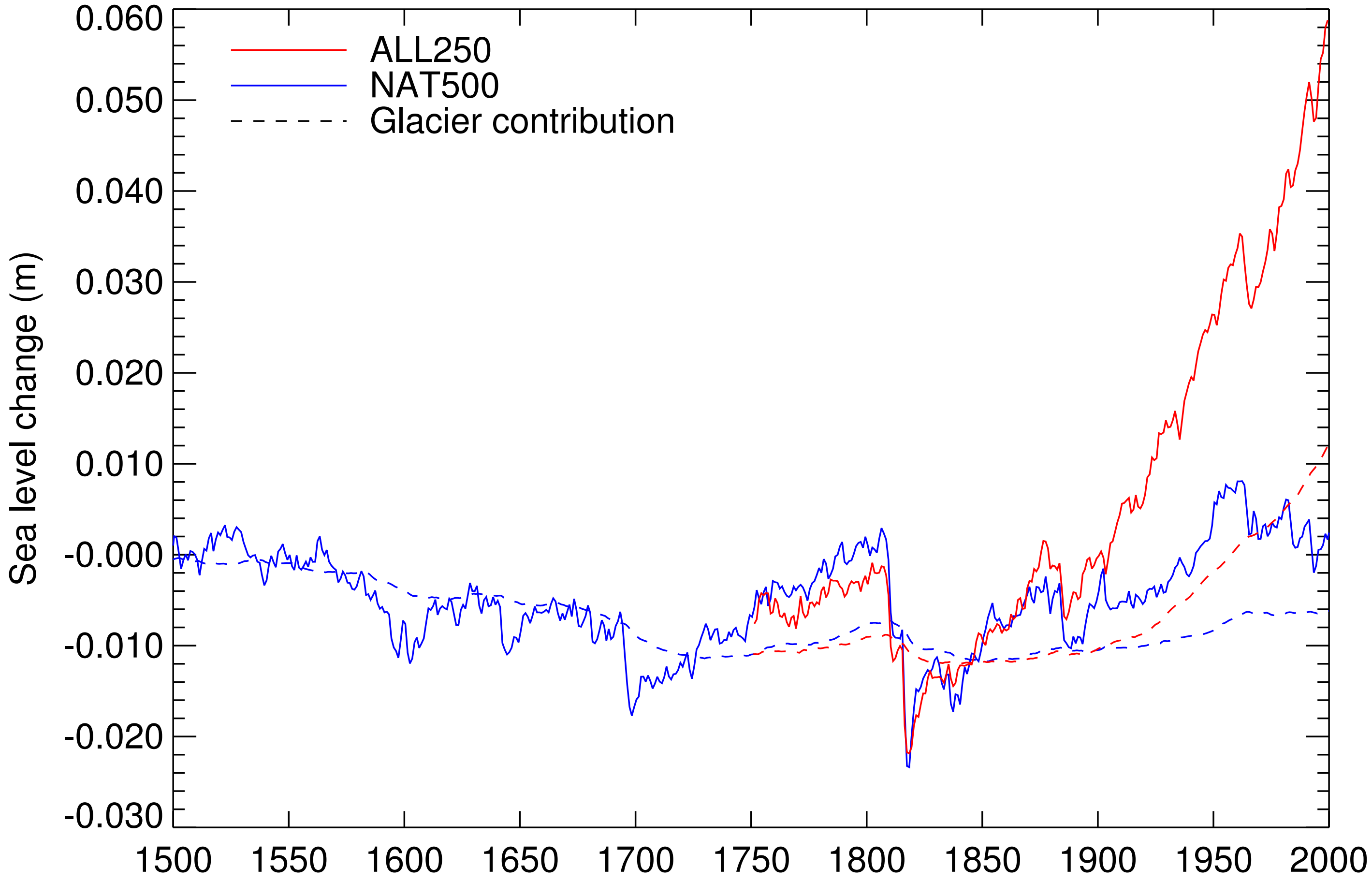
Retreat of grounding line as a feedback on dynamical change

Possibility of developing ice streams in slow-moving areas of ice sheets

Uncertainties—total

Models of the major terms (thermal expansion and glaciers) give results agreeing reasonably well with corresponding observational estimates for the 20th century—but they don't add up to $\sim$1.5 mm yr^{-1}!

Simulation of historical sea level change



Gregory et al. (in press)