Statistical modelling of sea level response to the changes in climate forcing

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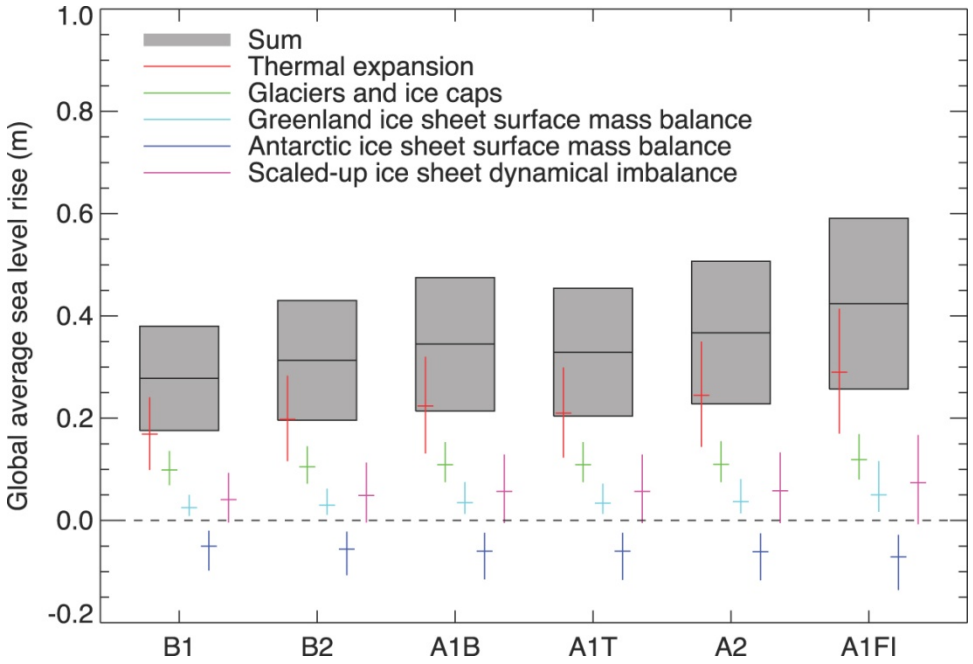
Outline

- Motivation
- Objective
- Description of our model
- Results (reconstruction, projections by 2100, geoengineering)
- Conclusion

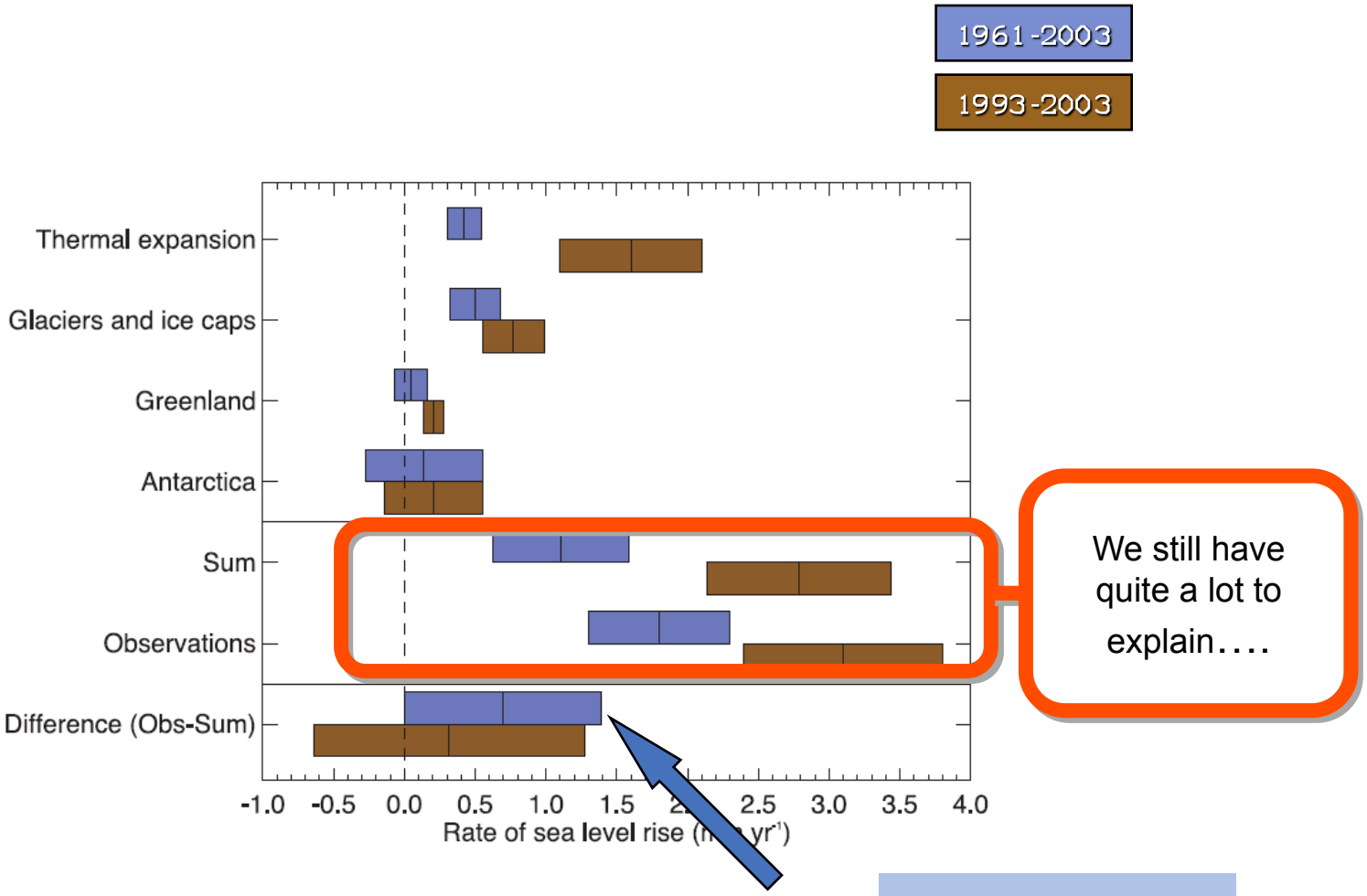
Motivation



1.8°C 2.4°C 2.4°C 2.8°C 3.4°C 4.0°C

IPCC, 2007

Main components of sea level balance



39%

IPCC 4AR (2007)

Motivation

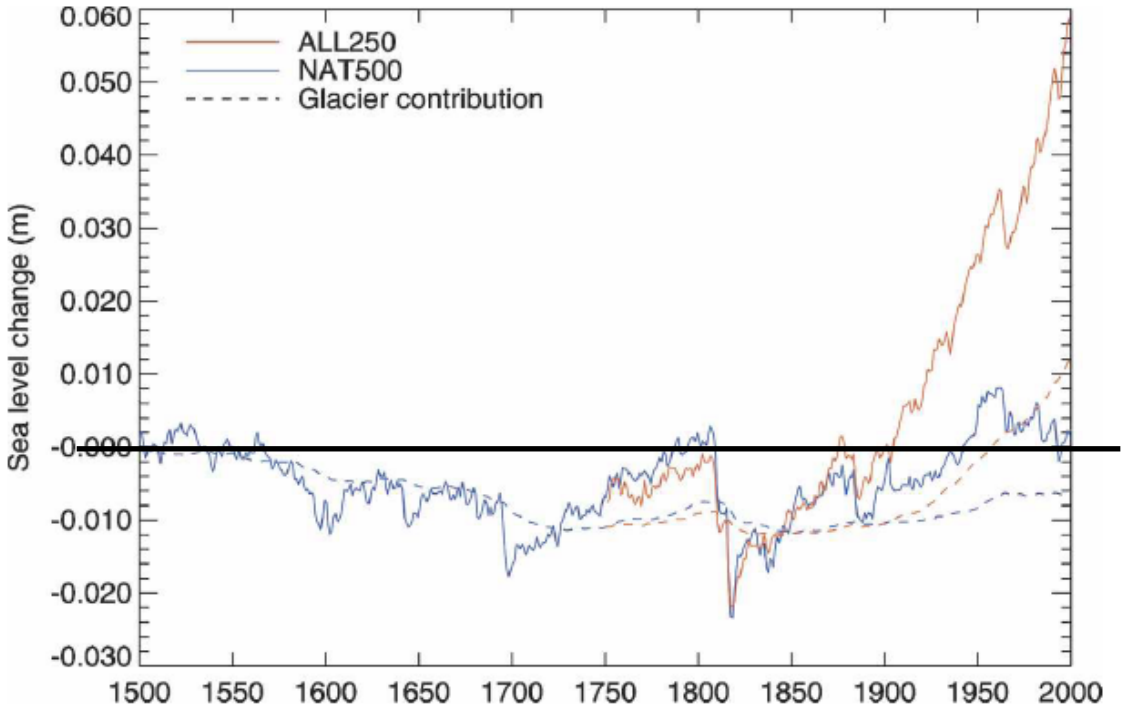


FIG. 9. Annual time series from HadCM3 experiments of global-mean sea level change due to thermal expansion and glacier mass loss.

Gregory et al, 2006, Journal of Climate

Objective

Using statistical model :

- to reconstruct sea level variability for the past 1000 years;
- to project sea level response to changes in radiative forcing by 2100

Model including a response time

$$S_{eq} = aF + b \quad \textbf{(eq. 1)}$$

S=f(F)

Parameters:
(τ, a, b, S_0)

$$\frac{\partial S}{\partial t} = (S_{eq} - S)/\tau, \quad \text{(eq.2)}$$

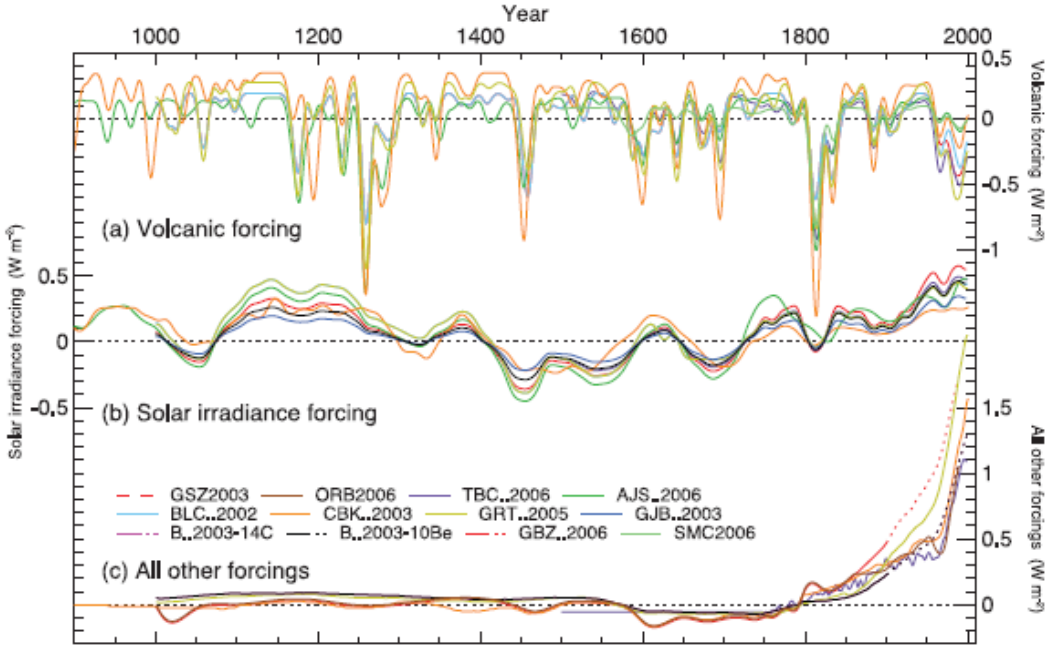
$$S_{eq} = aF + b \quad \text{(eq. 1)}$$

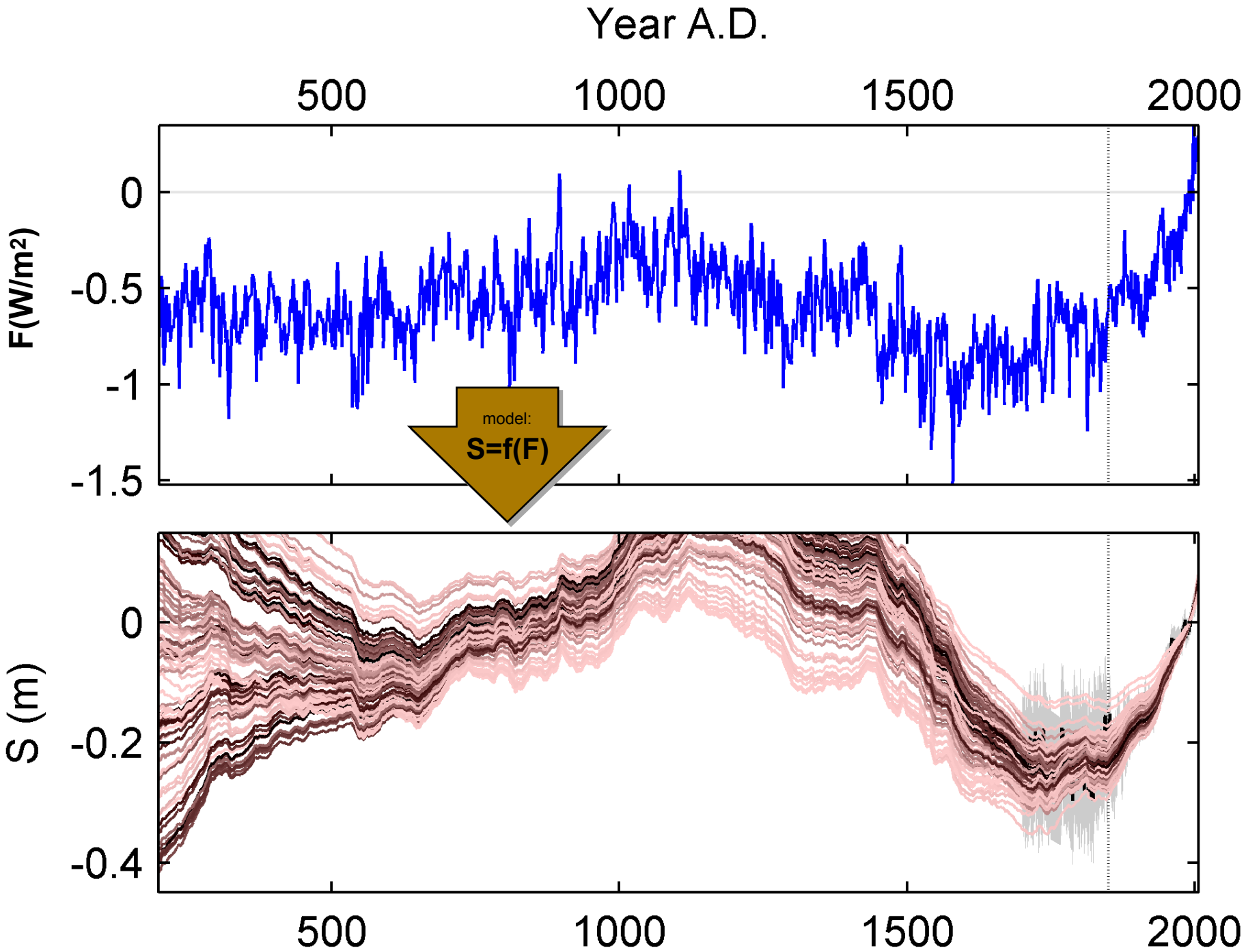
$$\frac{\partial S}{\partial t} = (S_{eq} - S)/\tau, \quad \text{(eq.2)}$$

Apriori constraints

- $\tau > 0$, $\tau < 5000$
- $b > 0$, $b < 5$ m
- $a > 0$
- $|S_0| < 0.5$ m

Inverse problem

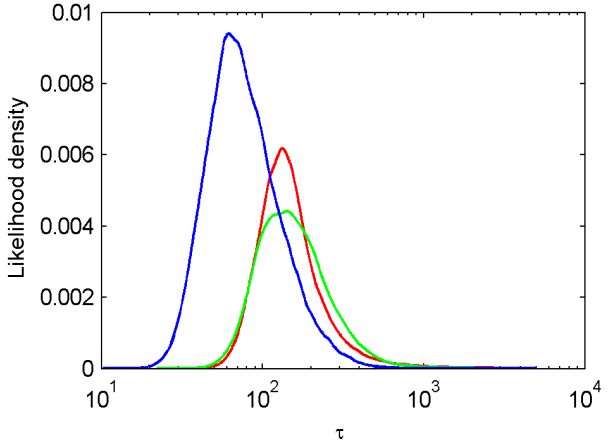


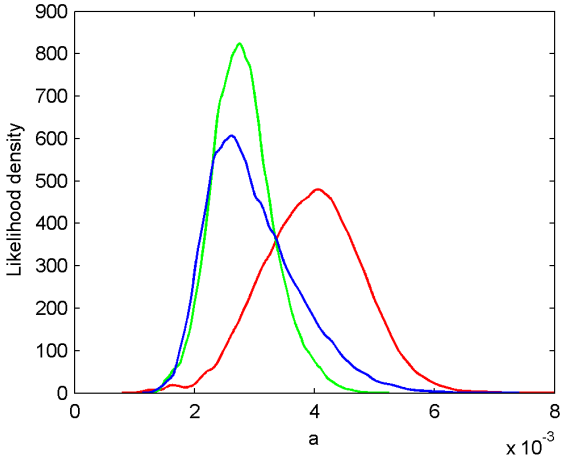

Year A.D.
500
1000
1500
2000
F(W/m²)
0
-0.5
-1
-1.5
model:
S=f(F)
S (m)
0
-0.2
-0.4
500
1000
1500
2000

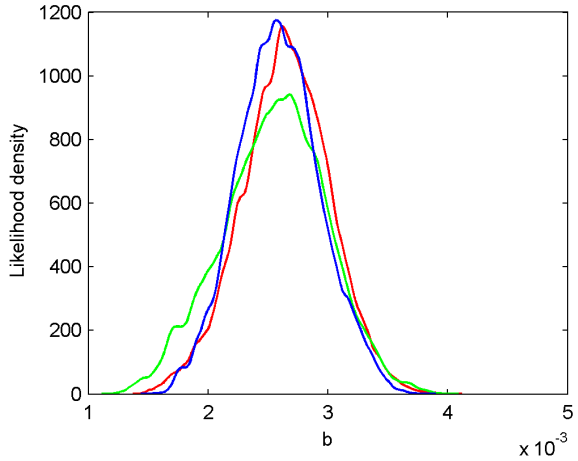
$$S_{eq} = aF + b \quad \textbf{(eq. 1)}$$

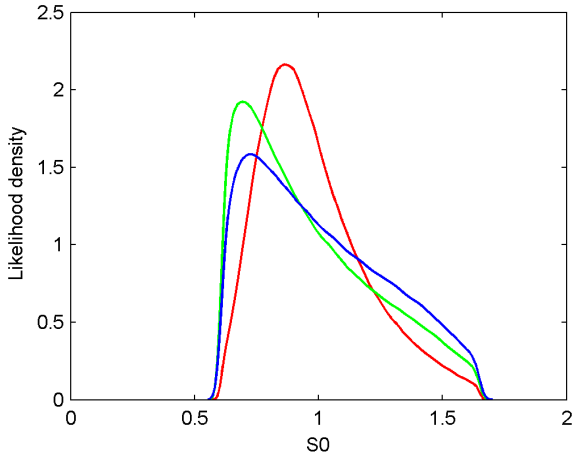
$$\frac{\partial S}{\partial t} = (S_{eq} - S)/\tau, \quad \text{(eq.2)}$$

Empirical likelihood probability density functions of the model parameters

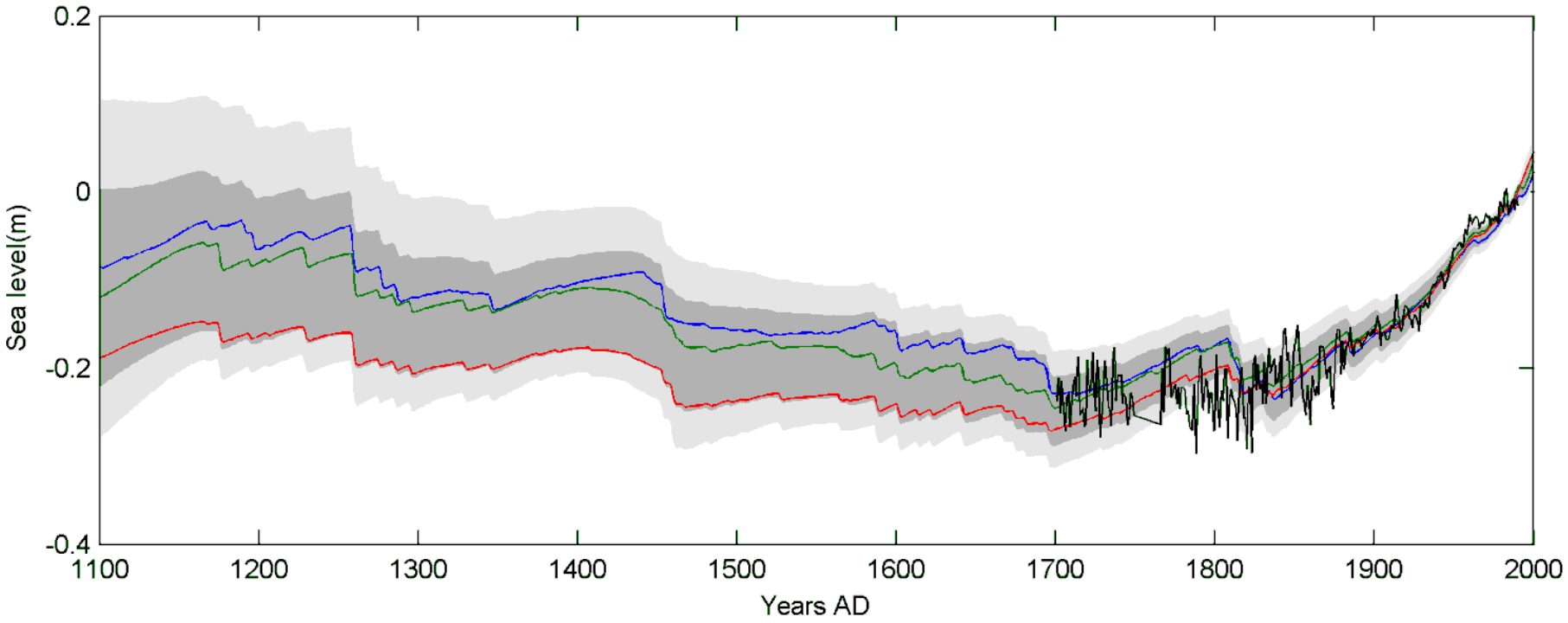






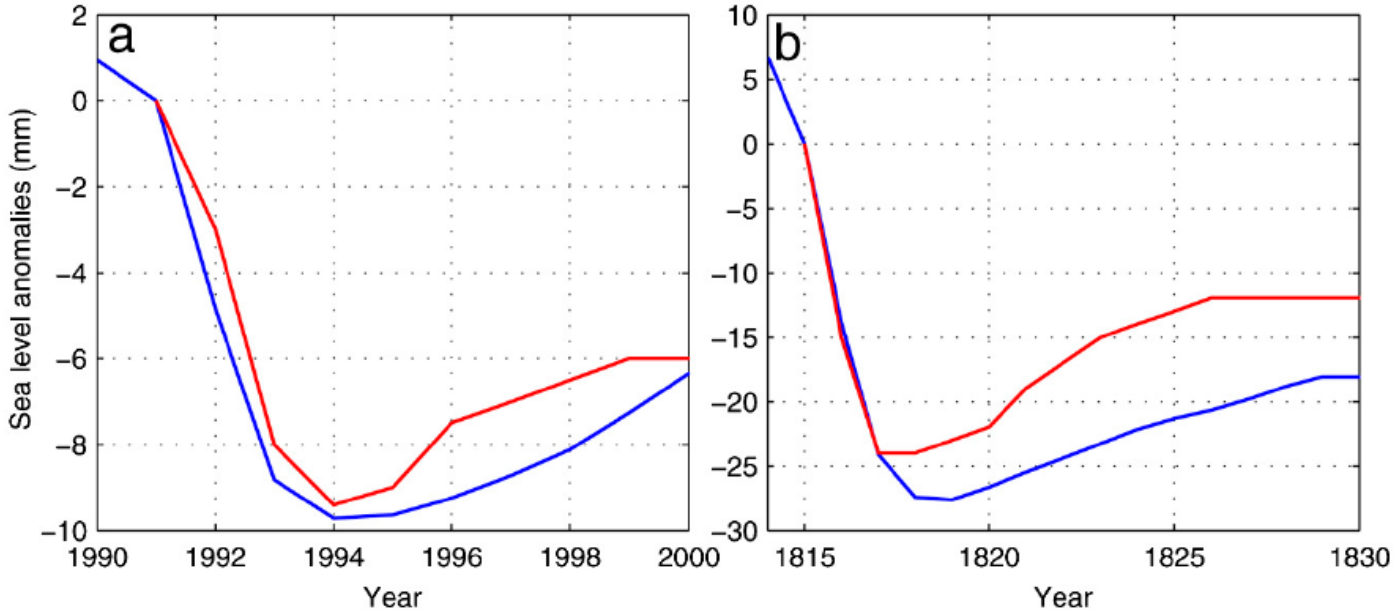


Results



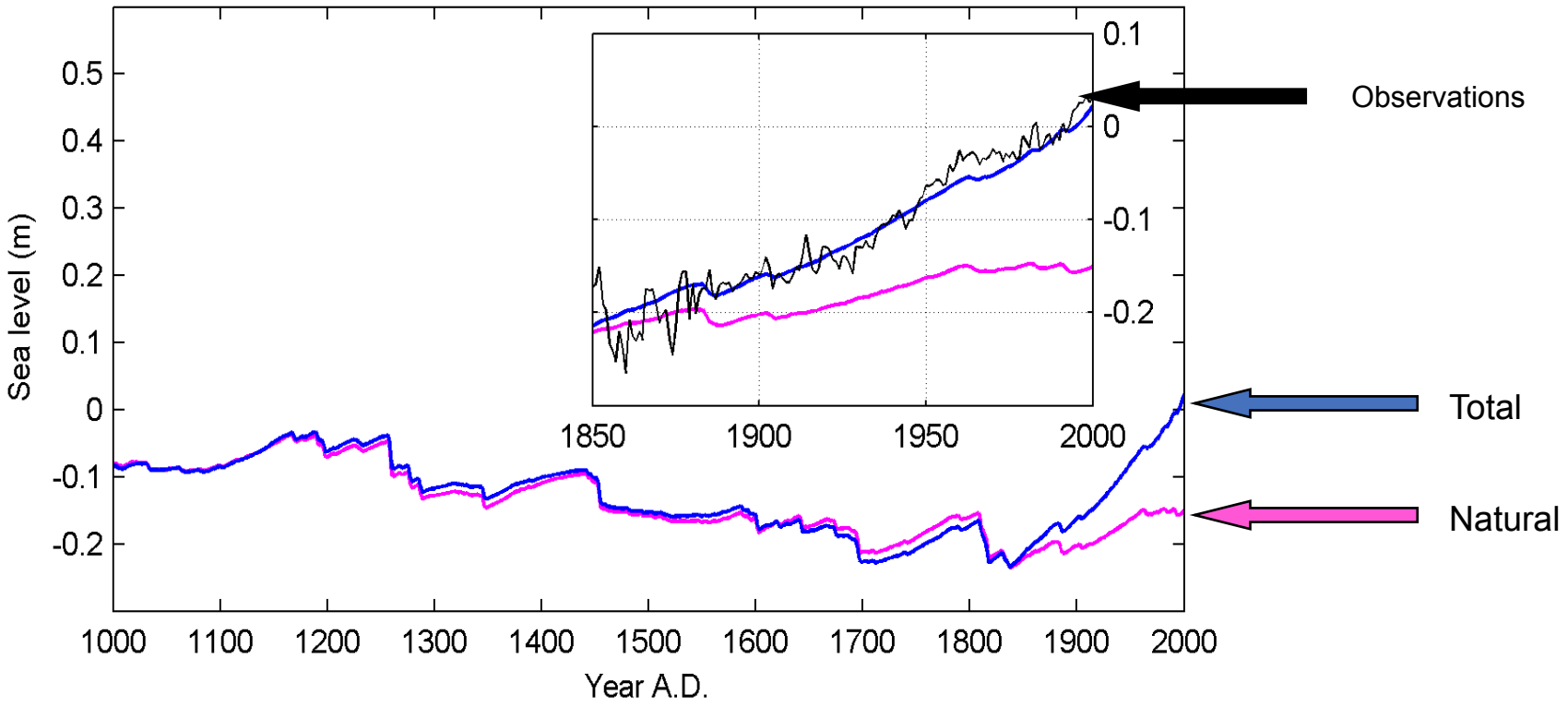
‘cbk_2003’- blue;
‘gsz2003’- red;
‘grt_2005’- dark green;

How good is our model?



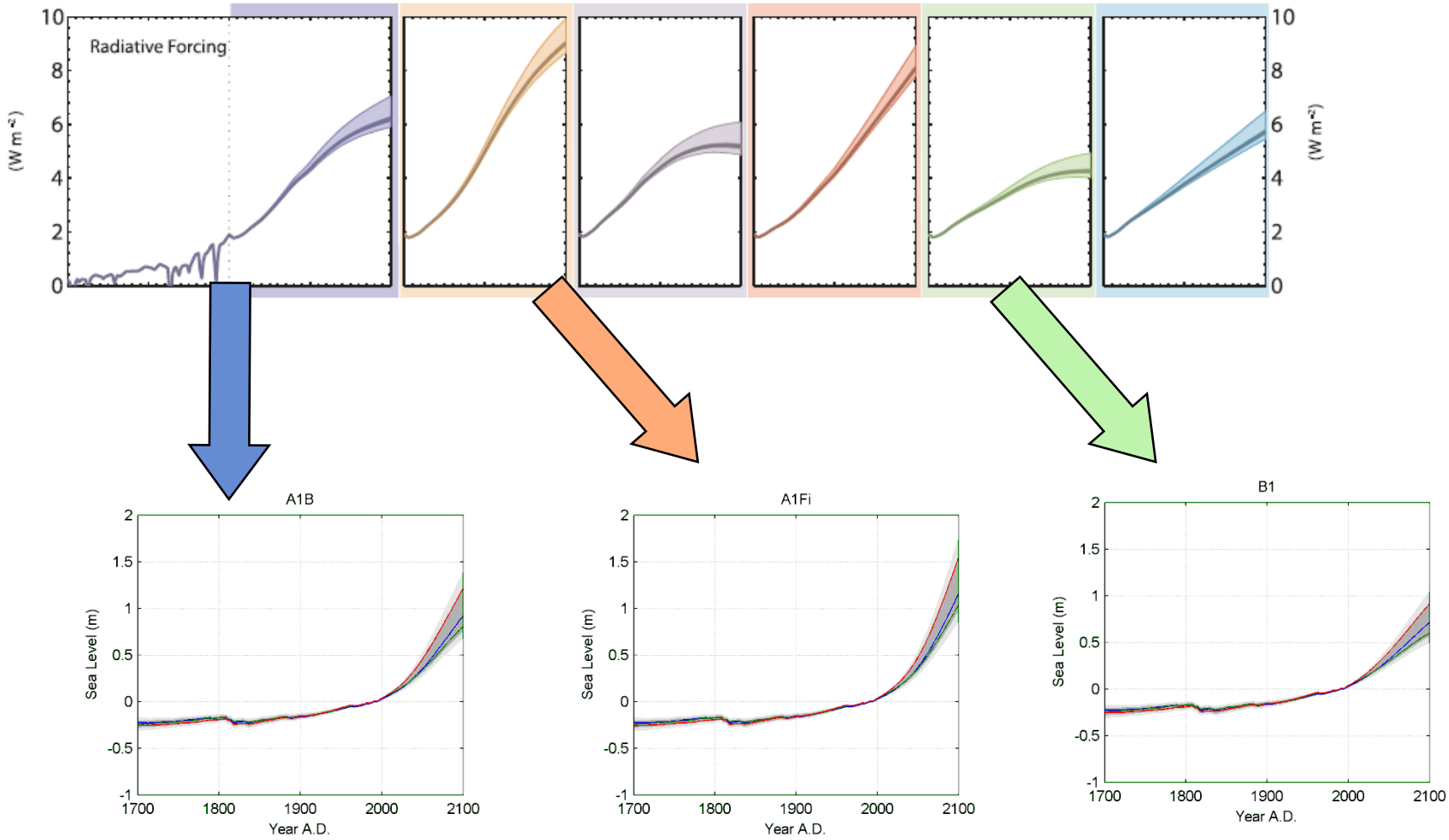
Moore et al, 2010, PNAS, www.pnas.org/cgi/doi/10.1073/pnas.1008153107

Anthropogenic forcing dominates sea level rise since 1850



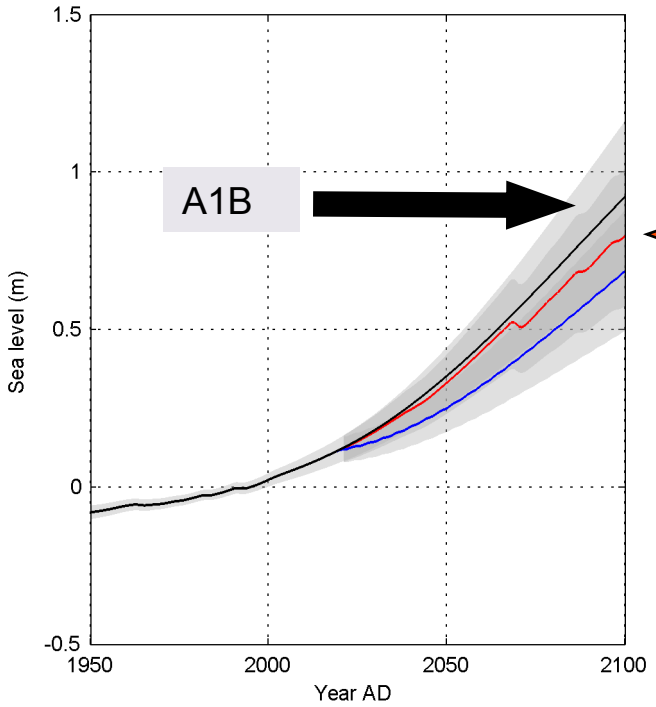
Jevrejeva et al. 2009, GRL

IPCC radiative forcing scenarios



Jevrejeva et al. 2010, GRL

Response to changes in natural forcings



A1B

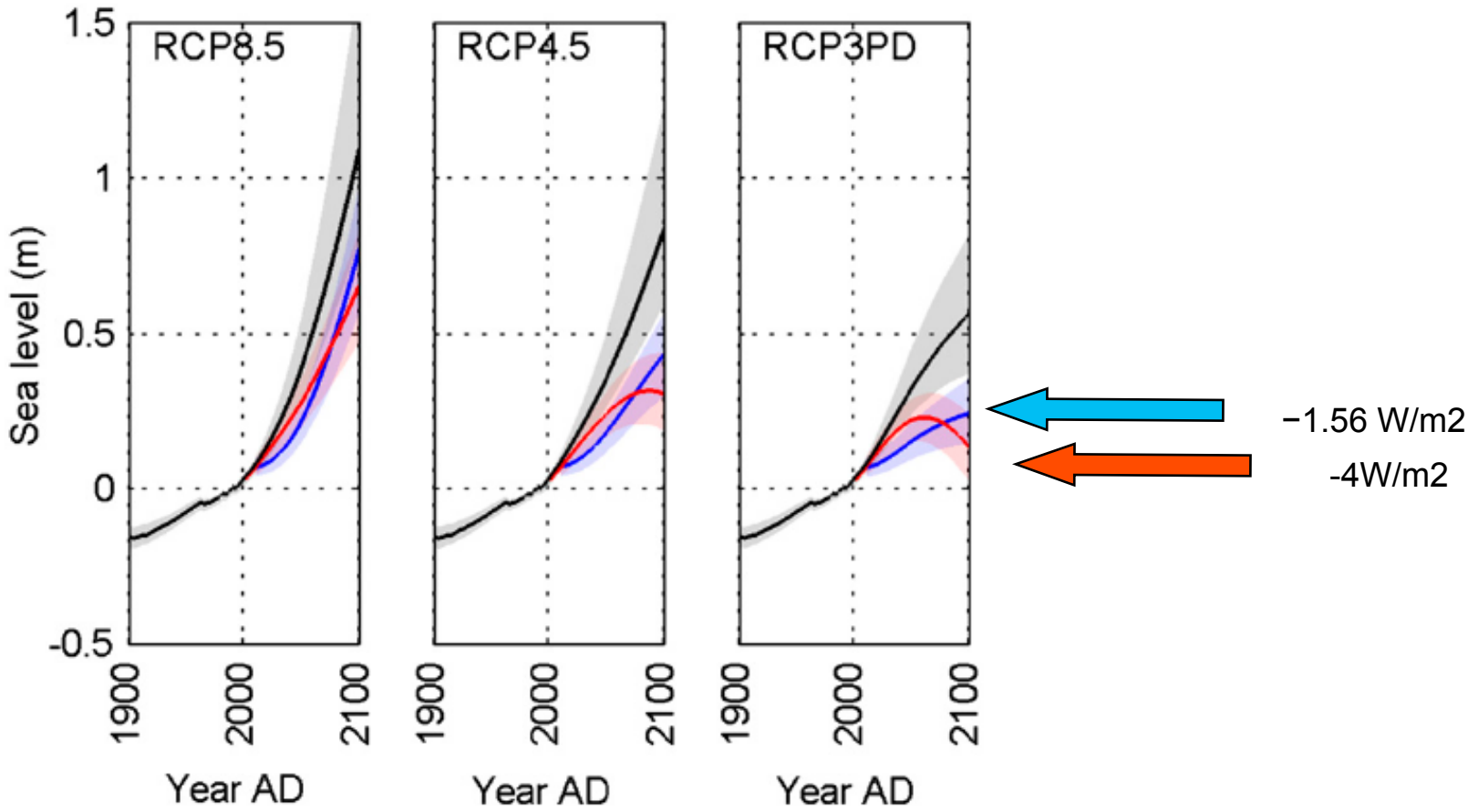
13th century volcanic eruptions

Pinatubo every 2 years

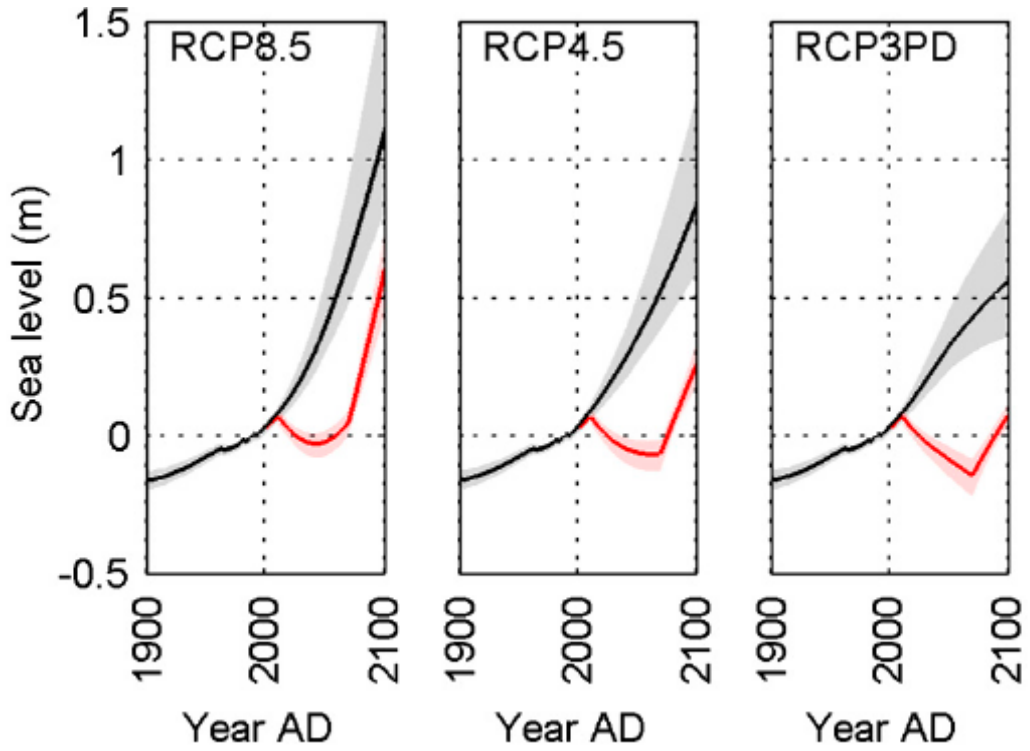
A1B (2.4 degree)

Jevrejeva S, Moore JC, Grinsted A (2010) How will sea level respond to changes in natural and anthropogenic forcings by 2100? Geophys Res Lett 37:L07703 101029/2010GL042947

Geoengineering?



Moore et al. www.pnas.org/cgi/doi/10.1073/pnas.1008153107



Moore et al. www.pnas.org/cgi/doi/10.1073/pnas.1008153107

Conclusion

- We use a delayed response statistical model to attribute the past 1000 years of sea level variability to various natural (volcanic and solar radiative) and anthropogenic (greenhouse gases and aerosols) forcings and estimate sea level rise by 2100 .
- With six IPCC radiative forcing scenarios we estimate sea level rise of 0.6-1.6 m, with confidence limits of 0.5 m and 1.8 m by 2100.
- Projected impacts of solar and volcanic radiative forcings account only for, at maximum, 5% of total sea level rise.
- As alternatives to the IPCC projections, even the most intense century of volcanic forcing from the past 1000 years would result in 10-15 cm potential reduction of sea level rise .
- Substituting geoengineering for greenhouse emission control would be to load future generations with enormous risk