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

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

IPCC, 2007
We still have quite a lot to explain....

39%
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

\[ S_{eq} = aF + b \]  \hspace{1cm} (eq. 1)

\[ \frac{\partial S}{\partial t} = \frac{(S_{eq} - S)}{\tau} , \hspace{1cm} (eq.2) \]
Apriori constraints

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

\[ \frac{\partial S}{\partial t} = \frac{(S_{eq} - S)}{\tau} \quad (\text{eq. 2}) \]

- \( \tau > 0 \), \( \tau < 5000 \)
- \( b > 0 \), \( b < 5 \) m
- \( a > 0 \)
- \( |S_0| < 0.5 \) m
Inverse problem

(a) Volcanic forcing

(b) Solar irradiance forcing

(c) All other forcings
model: $S = f(F)$
Empirical likelihood probability density functions of the model parameters

\[ S_{eq} = aF + b \quad (eq. 1) \]
\[ \frac{\partial S}{\partial t} = \frac{(S_{eq} - S)}{\tau}, \quad (eq. 2) \]
Results

'cbk_2003'- blue;
'gsz2003'- red;
'grt_2005'- dark green;
How good is our model?

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 (2.4 degree)

Geoengineering?


RCP8.5  RCP4.5  RCP3PD

Sea level (m)

-0.5  0  0.5  1  1.5

1900  2000  2100
Year AD

-1.56 W/m2
-4 W/m2
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.