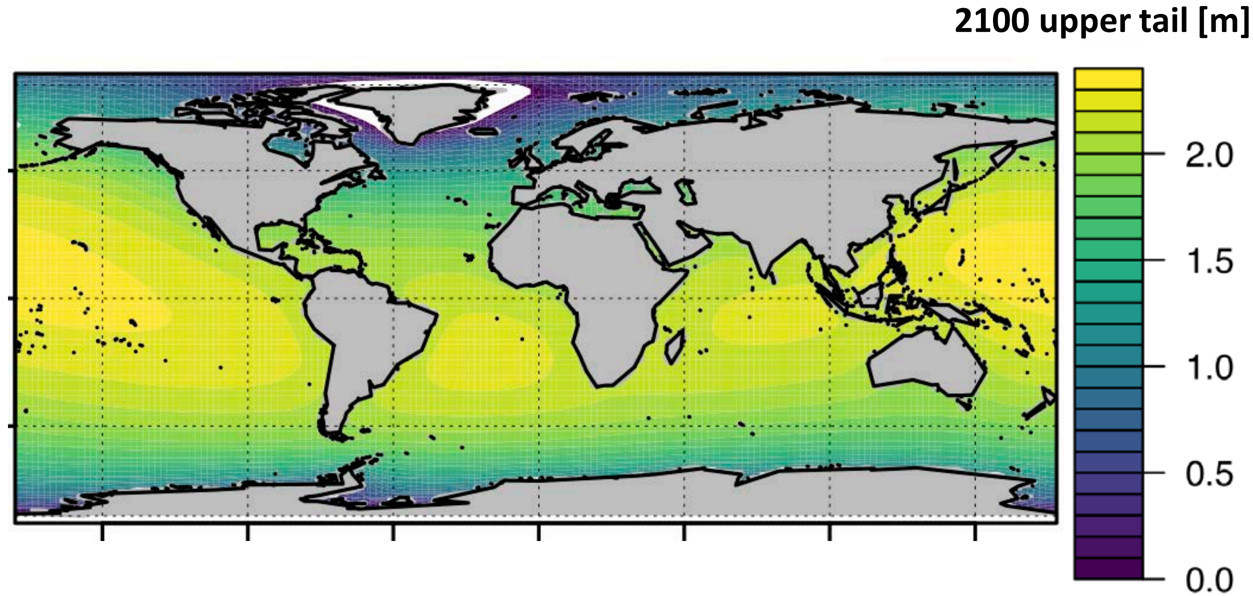
Global to local sea-level rise uncertainty using Hector-BRICK



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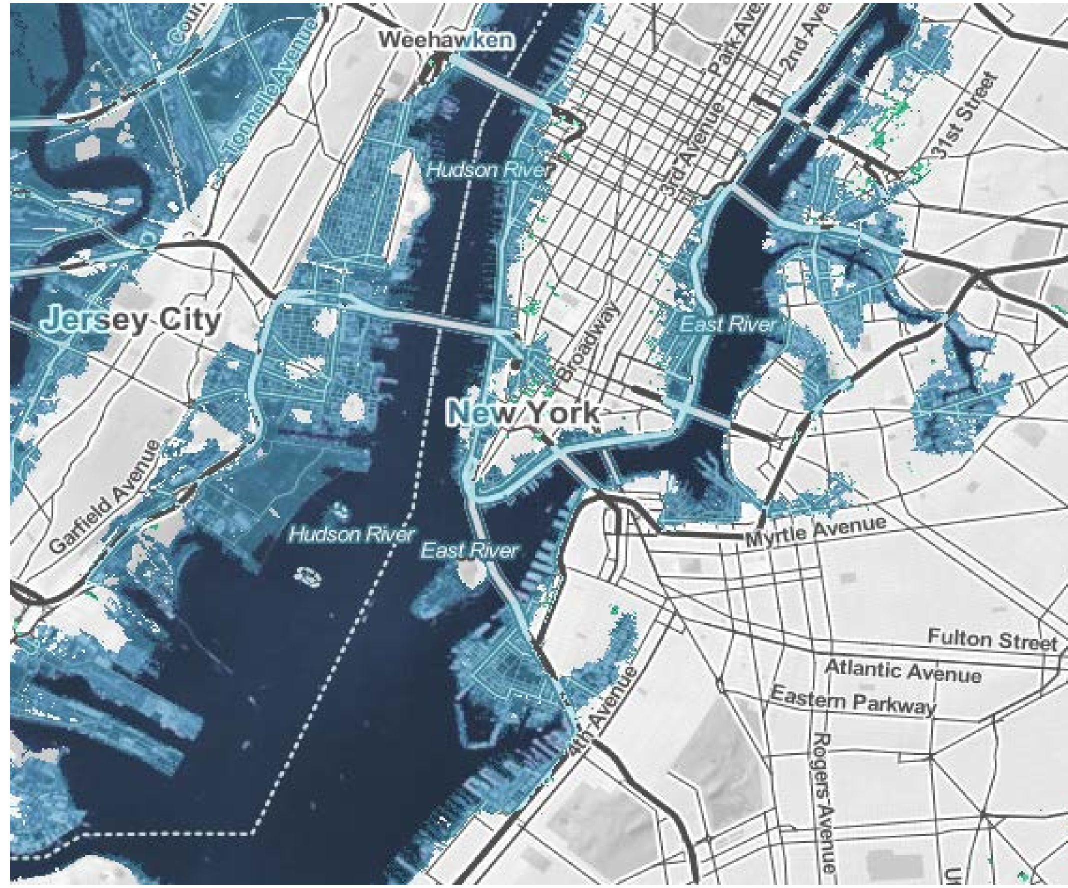
PNNL

NOAA Extreme sea-level rise: ~2.5 m (8.2 ft) in 2100

Jeremy Harbeck/NASA



Climatecentral.org

Coastal cities must change

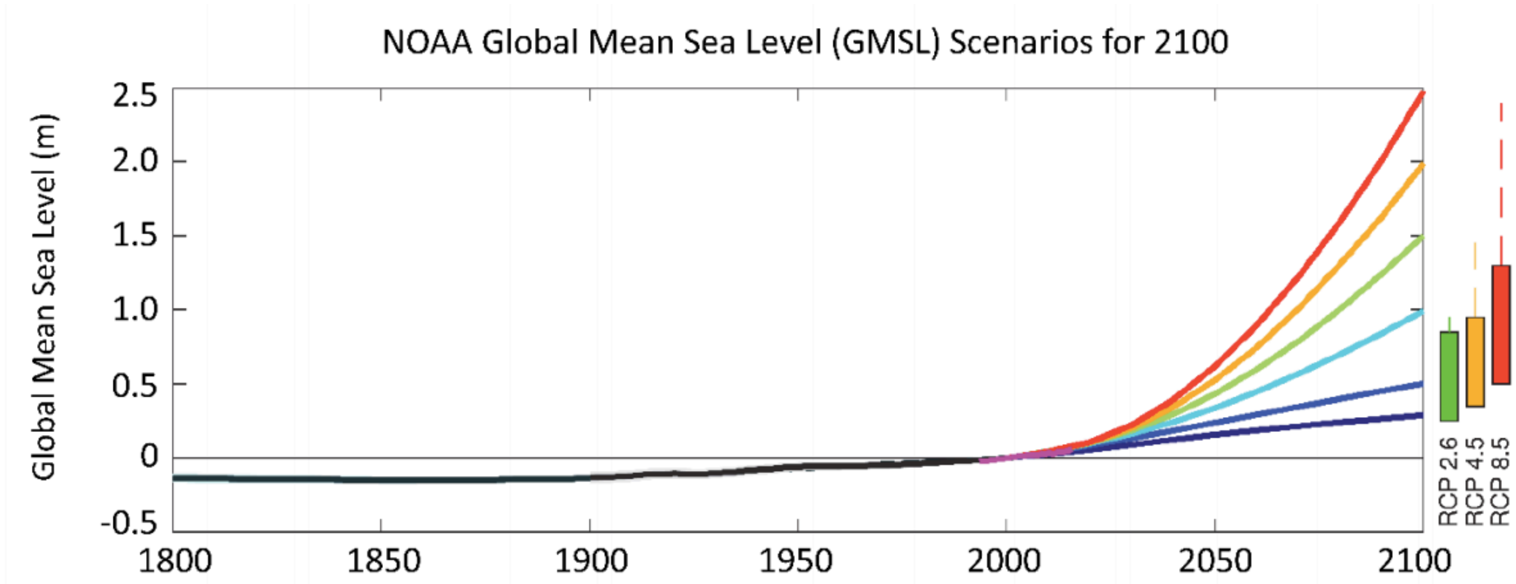
Millions of American homes inundated

Rise continues for centuries

NOAA Technical Report
Sweet et al., 2017

What is the risk of extreme sea-level rise?

Updated understanding of Antarctica (2016)



2014 study

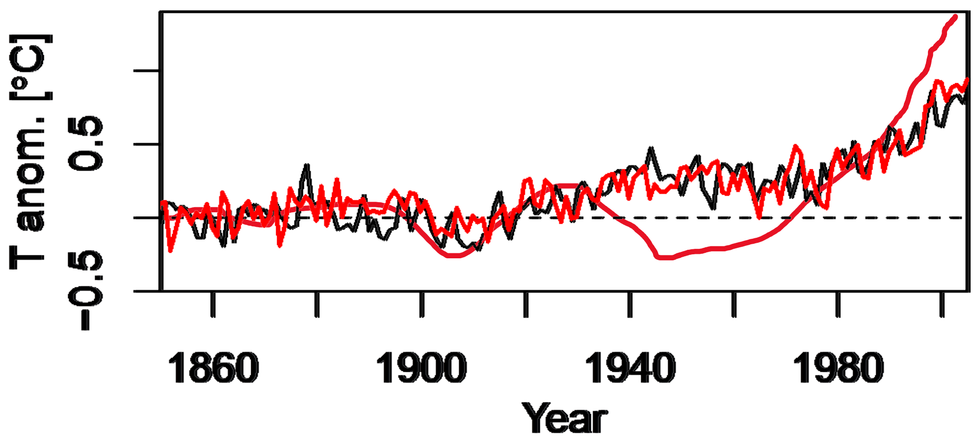
- **Probabilistic assessment is hard**
- **Our assessments evolve as climate science advances**

Fig. 8 from Sweet et al., 2017

A recipe for probabilistic sea-level rise

<u>Ingredients</u>

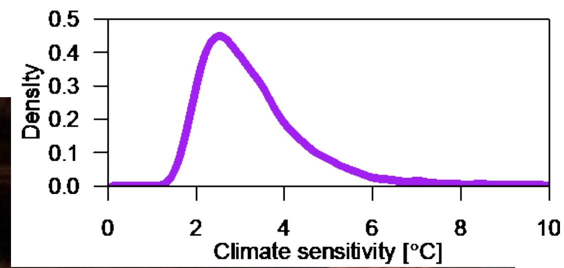
- **Simple Earth system model (Hector-BRICK)**
- **Historical observations of temperature and sea-level contributors**

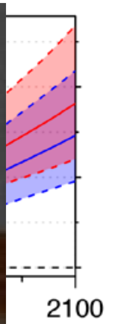


<u>Directions</u>

- **Bayesian model calibration (Markov chain Monte Carlo)**
- **Dozens of parameters**
- **Millions of runs**

<u>The final dish</u>



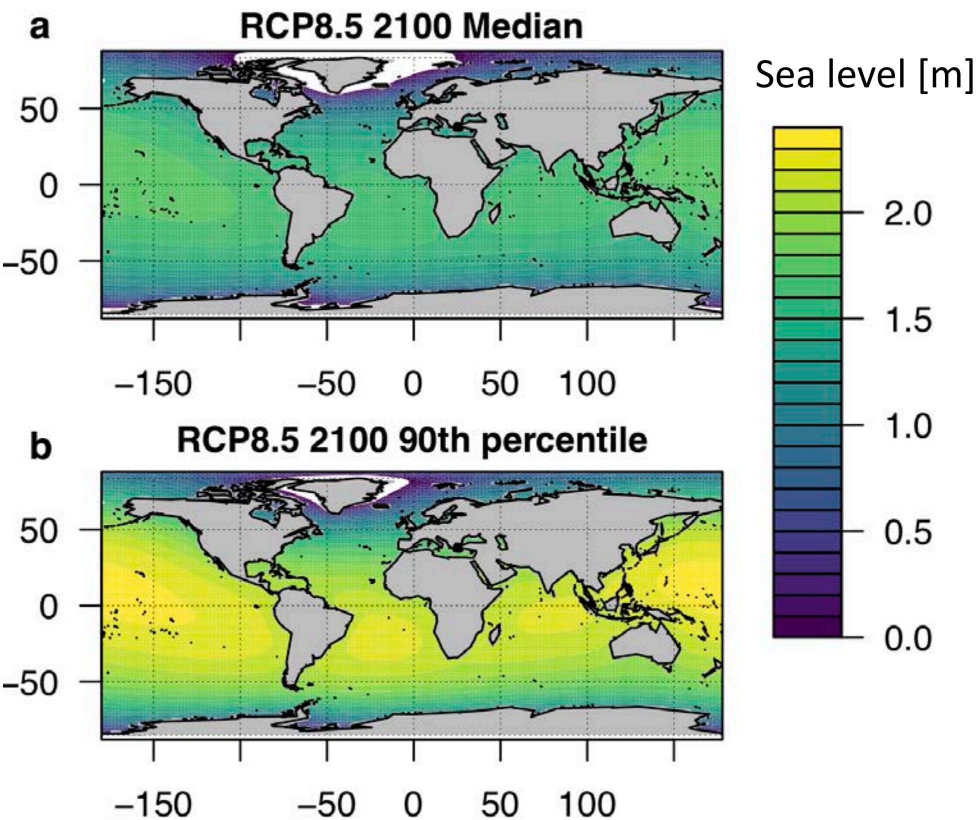


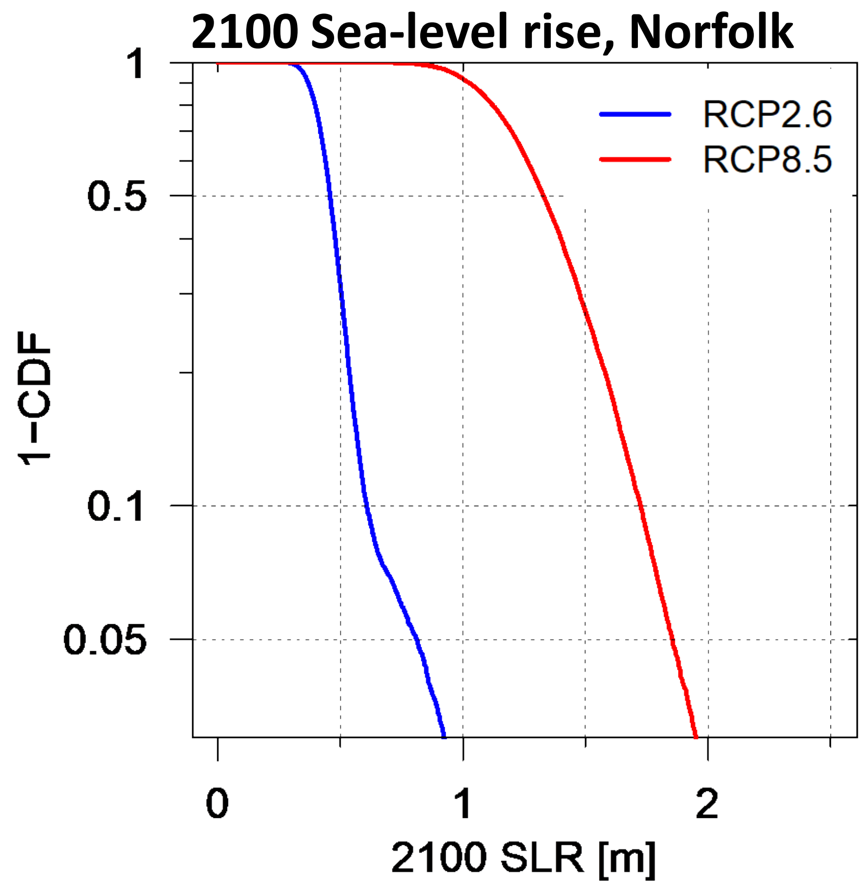
Good model!
Bad model!!

Vega-Westhoff, B., Sriver, R. L., Hartin, C. A., Wong, T. E., & Keller, K. (2019). Impacts of observational constraints related to sea level on estimates of climate sensitivity. *Earth's Future*, 7, 677–690. https://doi.org/10.1029/2018EF001082

Some dessert? Regional sea-level rise

Use fingerprinting (Slangen et al., 2014) to estimate regional changes





Science application: How does climate sensitivity affect sea-level rise upper bound?

Climate sensitivity:

- **Common way to characterize Earth's response to atmospheric CO_2**
- ***The equilibrium temperature response to a doubling of atmospheric CO_2***

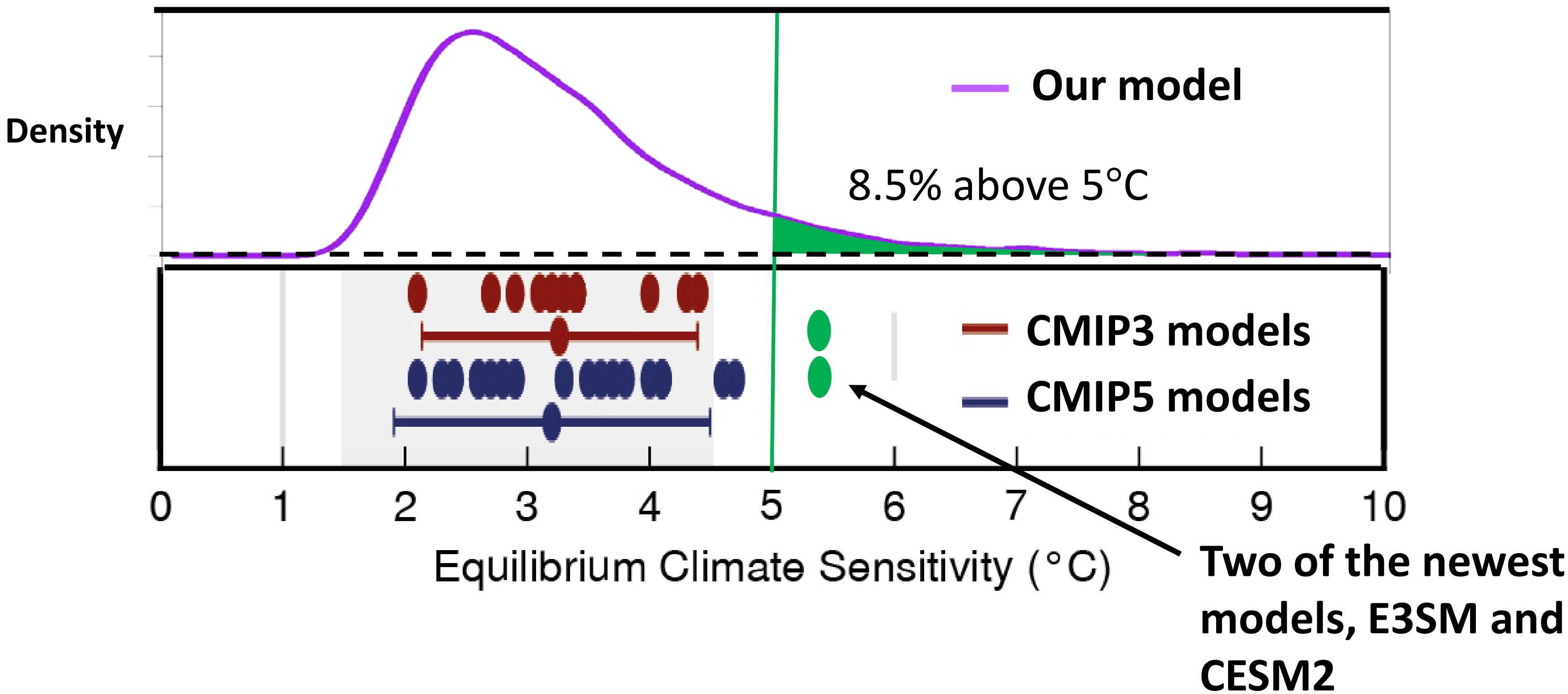
In general:

Higher Climate sensitivity → **Warmer future temperatures** → **More ice melt, more thermal expansion, more sea-level rise**

- **Non-linear responses**
- **Threshold events (Antarctic disintegration)**

Vega-Westhoff, B., Sriver, R. L., Hartin, C., Wong, T. & Keller, K. (2019, Submitted), The role of climate sensitivity in extreme sea-level rise projections, *Geophysical Research Letters*.

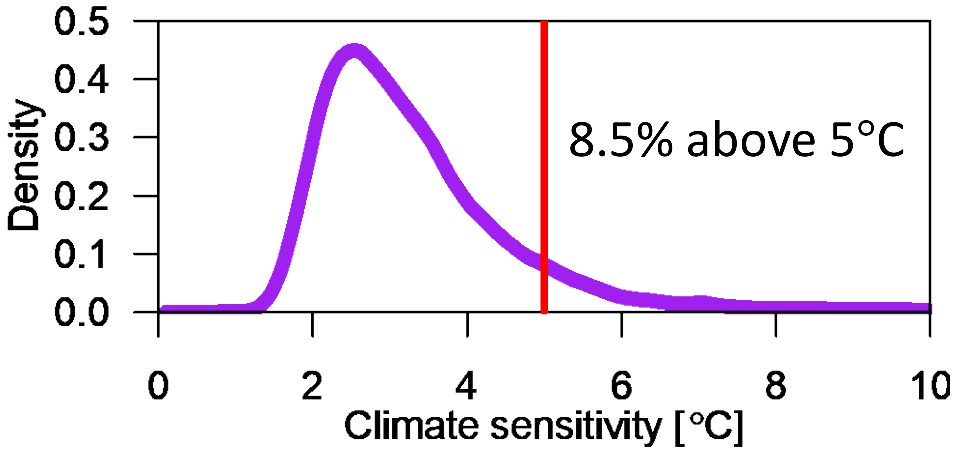
High climate sensitivity is plausible

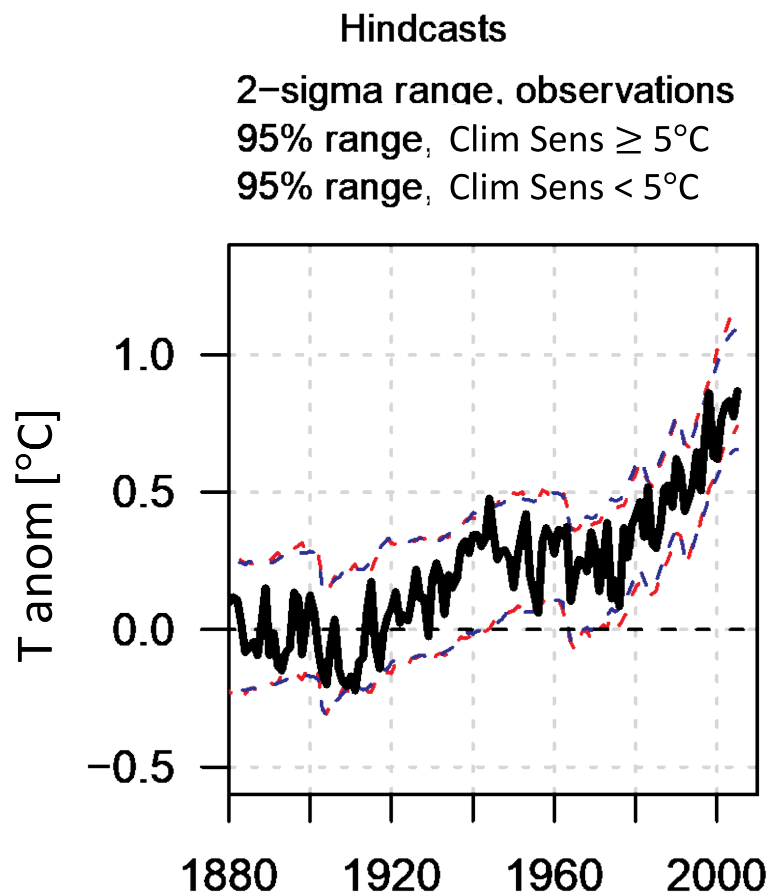


How would such a high climate sensitivity affect extreme sea-level rise?

Box 12.2 Fig 1 from IPCC AR5, 2014

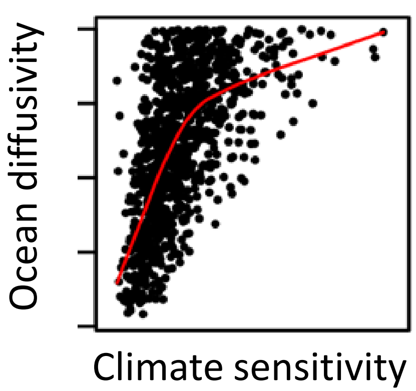
High climate sensitivity is plausible (continued)

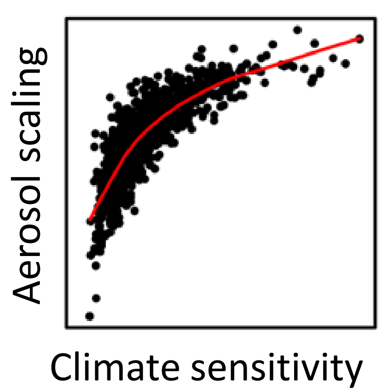




High climate sensitivity realizations match observations. *How*?

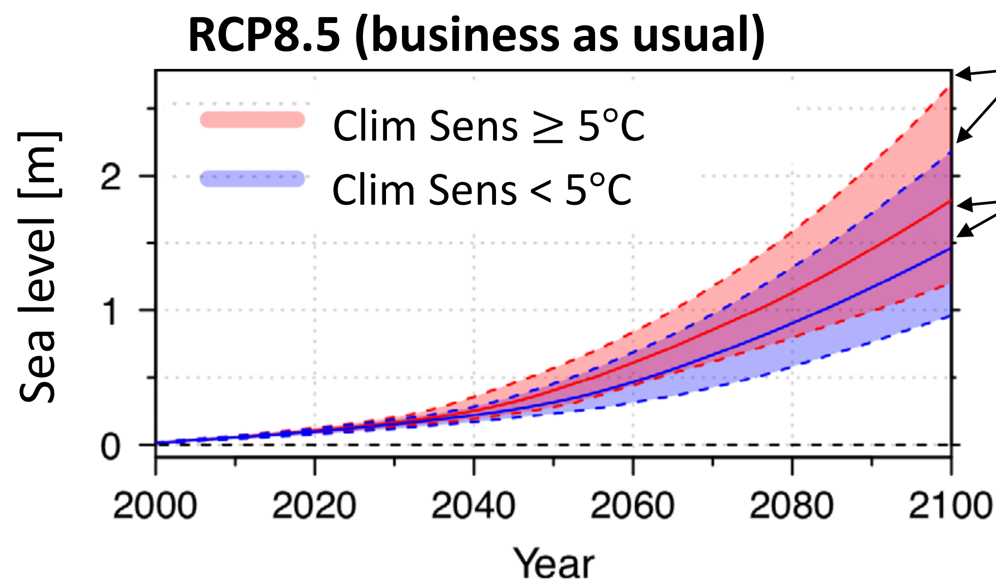
- **Other uncertain parameters** **compensate**





How would such a high climate sensitivity affect extreme sea-level rise?

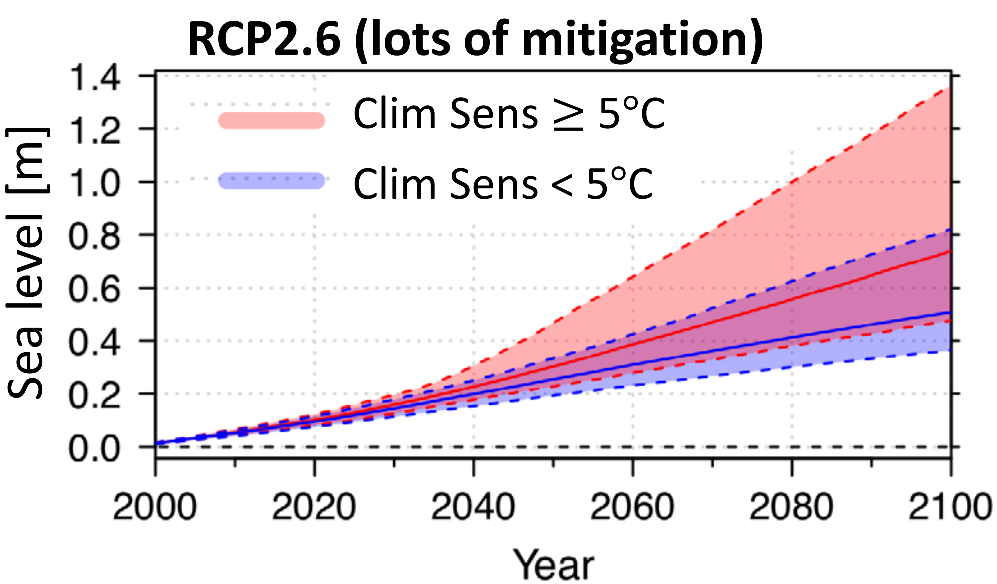
High climate sensitivity affects the upper bound of sea level



Upper bounds (of 95% range)

medians

2100 95% ranges
Clim Sens ≥ 5°C: 1.2 – 2.7 m
Clim Sens < 5°C: 1.0 – 2.2 m



2100 95% ranges
Clim Sens ≥ 5°C: 0.5 – 1.4 m
Clim Sens < 5°C: 0.4 – 0.8 m

Upper bound: highly affected by climate sensitivity

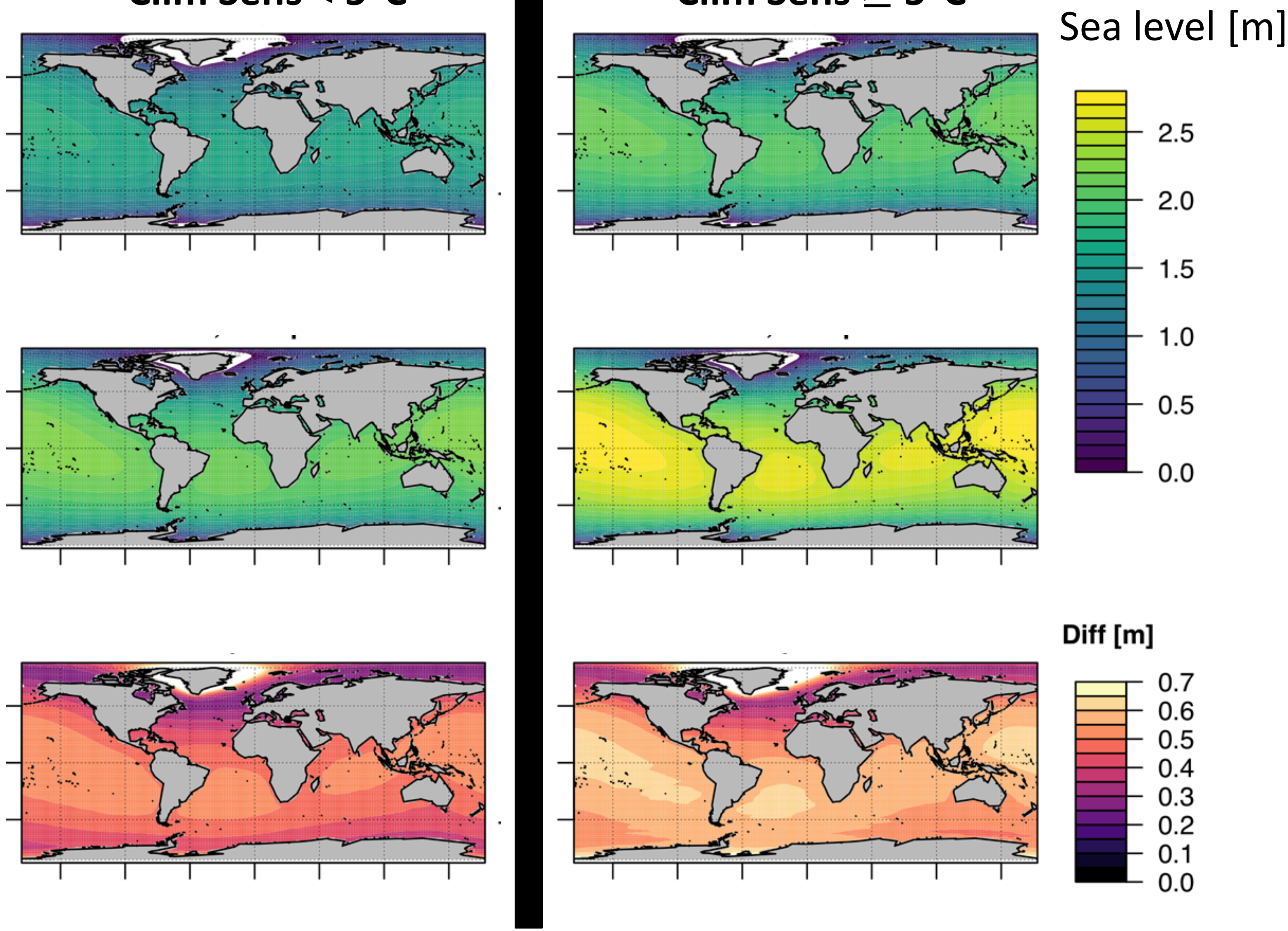
Impact of high climate sensitivity seen on regional scale

Clim Sens < 5°C | Clim Sens ≥ 5°C

2100 median

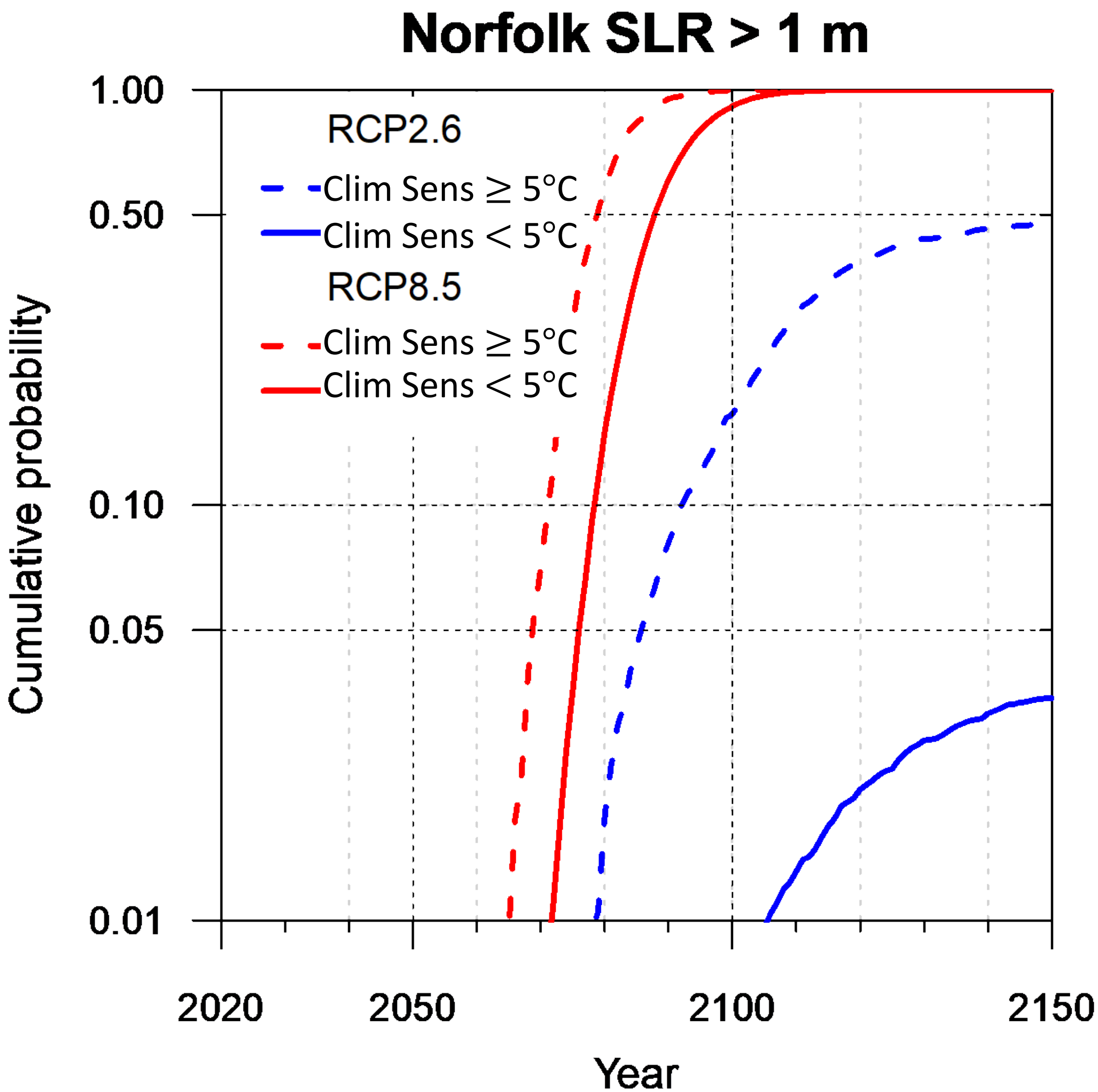
2100 90%

2100 90% - median



Largest effect in equatorial region (away from land ice melt)

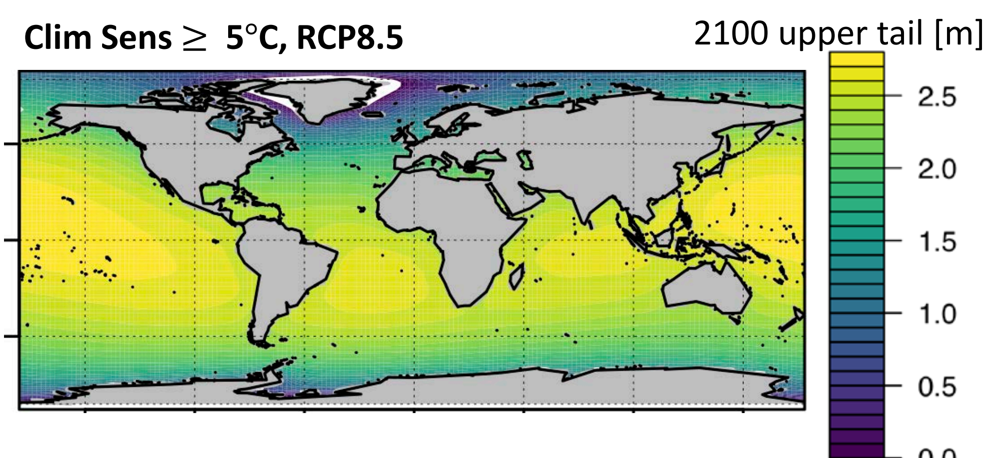
High climate sensitivity affects sea-level thresholds

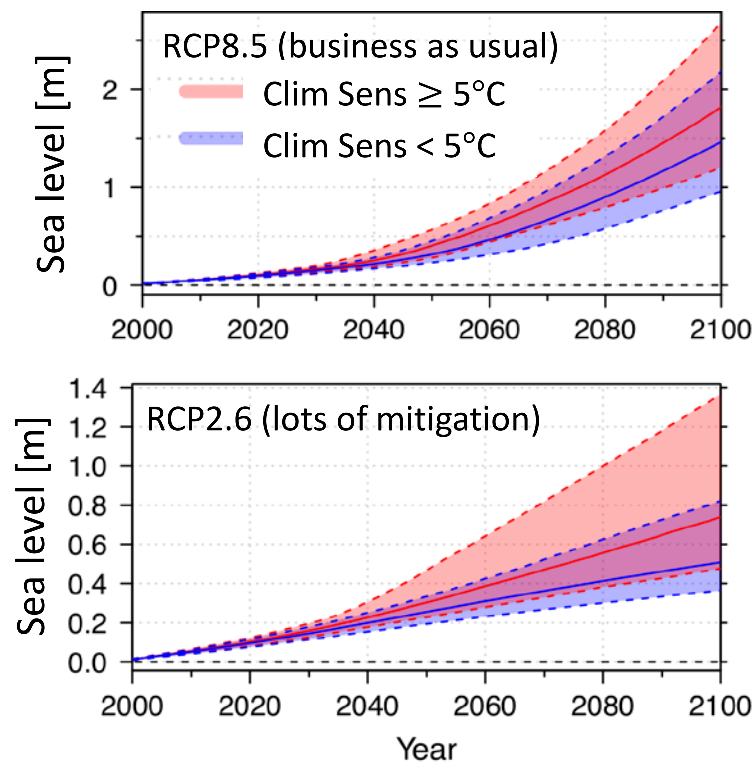


- **Earlier threshold crossing for high climate sensitivity**
- **In RCP2.6, the threshold crossing depends critically on climate sensitivity**

Summary

1. **Hector-BRICK = tool for probabilistic sea-level rise, including regional scale**
2. **We investigate relationship between climate sensitivity and sea-level rise**
3. **Particular increase in the upper bound of sea-level projections**





References

Hector-BRICK:

- Vega-Westhoff, B., Sriver, R. L., Hartin, C. A., Wong, T. E., & Keller, K. (2019). Impacts of observational constraints related to sea level on estimates of climate sensitivity. *Earth's Future*, 7, 677– 690. https://doi.org/10.1029/2018EF001082
- Vega-Westhoff, B., Sriver, R. L., Hartin, C., Wong, T. & Keller, K. (2019, Submitted), The role of climate sensitivity in extreme sea-level rise projections, *Geophysical Research Letters*.

BRICK:

- Wong, T. E., Bakker, A. M. R., Ruckert, K., Applegate, P., Slangen, A. B. A., & Keller, K. (2017). BRICK v0.2, a simple, accessible, and transparent model framework for climate and regional sea-level projections. *Geoscientific Model Development*, *10*(7), 2741–2760. https://doi.org/10.5194/gmd-10-2741-2017

Fingerprinting basis:

- Slangen, A. B. A., Carson, M., Katsman, C. A., van de Wal, R. S. W., Köhl, A., Vermeersen, L. L. A., & Stammer, D. (2014). Projecting twenty-first century regional sea level changes. *Climatic Change*, *124*(1–2), 317–332. https://doi.org/10.1007/s10584-014-1080-9

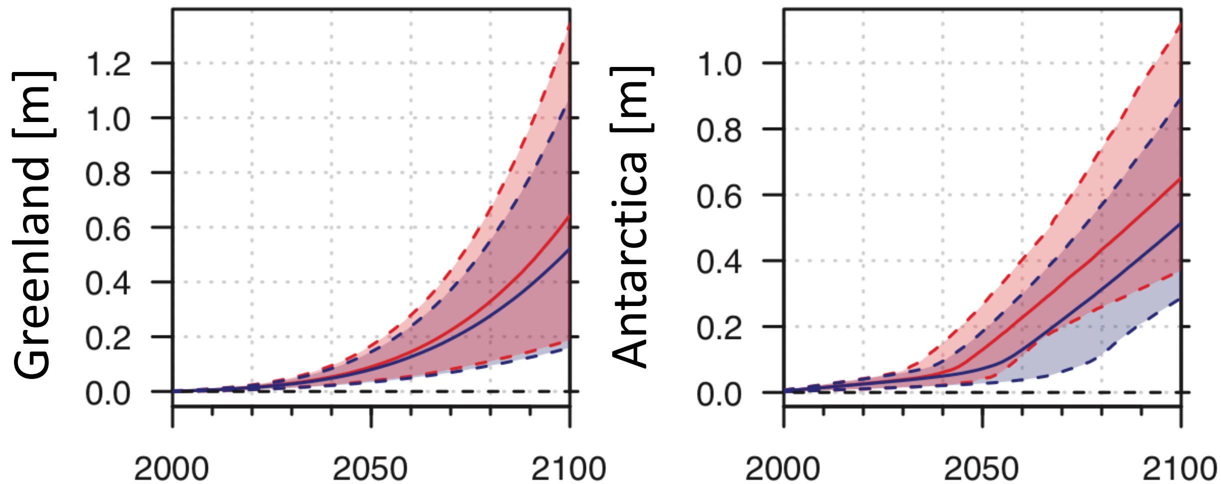
NOAA 2017 Extreme sea level:

- Kopp, R. E., R.M. Horton, C.M. Little, J.X. Mitrovica, M. Oppenheimer, D.J. Rasmussen, B. Strauss, C. Tebaldi. (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. Earth's Future, 2(8), 383-406.
- DeConto, R. M. and Pollard, D. (2016). Contribution of Antarctica to past and future sea-level rise. Nature, 531(7596), 591-597.
- Sweet, W.V., R.E. Kopp, C.P. Weaver, J. Obeysekera, R.M. Horton, E.R. Thieler, and C. Zervas, 2017: *Global and Regional Sea Level Rise Scenarios for the United States*. NOAA Technical Report NOS CO-OPS 083. NOAA/NOS Center for Operational Oceanographic Products and Services.

Supplemental: Upper bound changes are due to Antarctica and Greenland

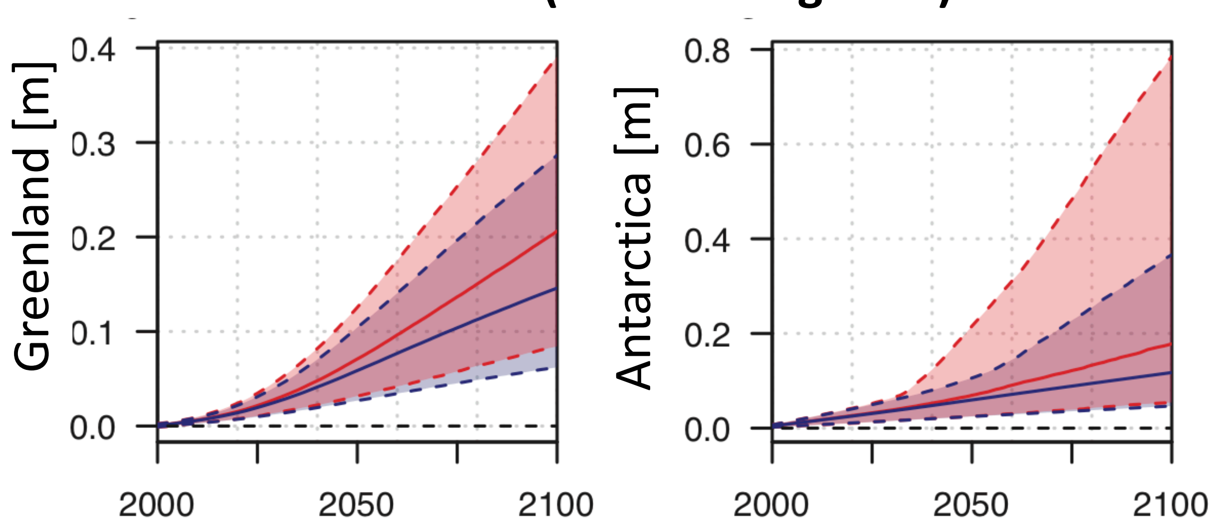
Clim Sens ≥ 5°C
Clim Sens < 5°C

RCP8.5 (business as usual)



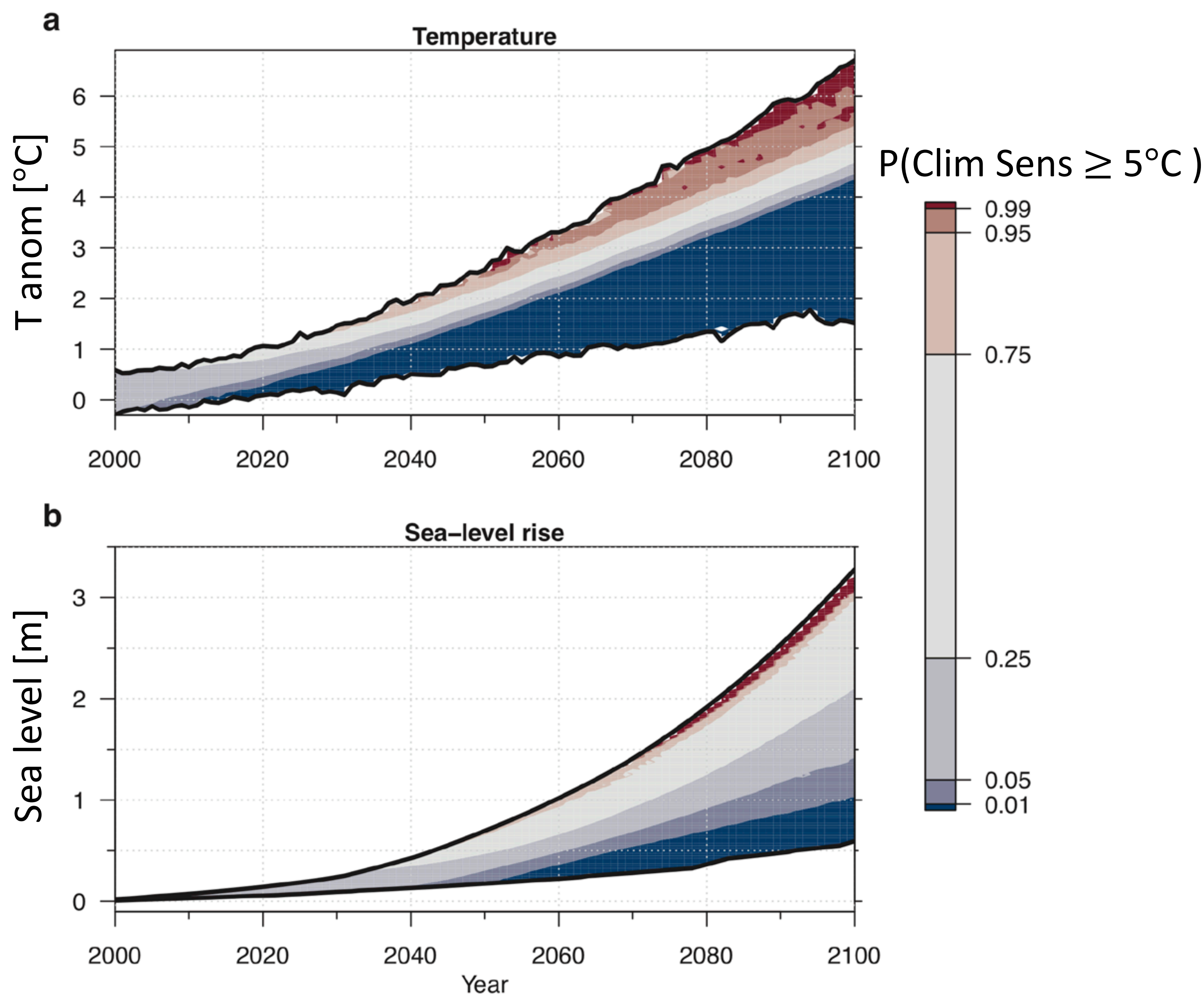
Again, upper bounds most affected by climate sensitivity.

RCP2.6 (lots of mitigation)

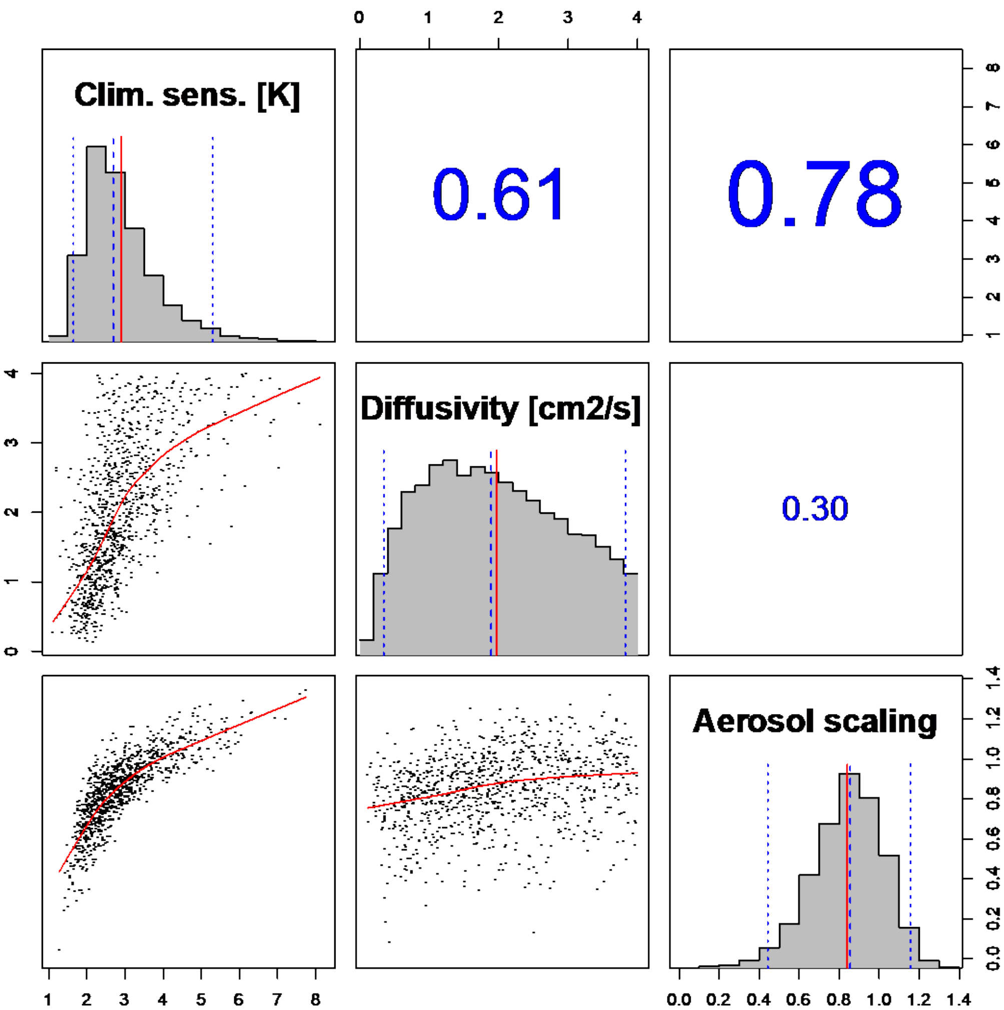


Biggest effect on Antarctica upper bound for RCP2.6! Melt threshold?

Supplemental: Future learning about climate sensitivity



Supplemental: climate parameter correlations



Supplemental: Additional information on the calibration

Currently, only using forcing-constrained Hector runs

Full methods outlined in Bakker et al. (2017)

- 4 parallel million run chains for each calibration
- Gelman and Rubin diagnostic for convergence
- Robust adaptive metropolis algorithm (Vihola, 2012)
- Antarctic ice sheet model calibrated separately with paleoclimate data
- Combine both calibrations and do rejection sampling w.r.t. total sea level

Supplemental: Additional info on BRICK components

Glaciers and ice caps (GIC) – Wigley and Raper (2005), also used in MAGICC climate model

Greenland ice sheet (GIS) – SIMPLE (Simple Ice-sheet Mode for Projecting Large Ensembles) - Bakker et al. (2016)

Antarctic ice sheet (AIS) – DAIS (Danish Center for Earth System Science Antarctic Ice sheet) model – Schaffer (2014)

Thermal expansion – explicitly calculated from DOECLIM ocean heat with the expansion coefficient as a free parameter

Supplemental: Data sets used

Temperature obs – HadCRUT4 (Morice et al., 2012)

Global SLR obs – Church and White (2011)

Glacier and small ice caps – National Snow and Ice Data Center

Greenland ice sheet mass balance – Sasgen et al. (2012)

IPCC land water storage and thermosteric expansion trends

Reconstructed temperatures and sea level for DAIS calibration – summarized in Schaffer et al., (2014)

Historical/projection forcings and emissions – RCPs (Meinshausen et al., 2011)