How Are Local Extreme Sea Level Projections Affected by Distinct Storylines in Antarctic Ice Sheet Mass Loss?

Daniel M. Gilford[1] daniel.gilford@rutgers.edu @danielgilford

DJ Rasmussen[2], Robert Kopp[1], Erica Ashe[1], Rob DeConto[3], David Pollard[4]

The AMS Centennial Meeting, January 15 2020

This work: Gilford et al., under review at JGR-Earth Surface

1 RUTGERS Institute of Earth, Ocean, and Atmospheric Sciences

2 PRINCETON UNIVERSITY

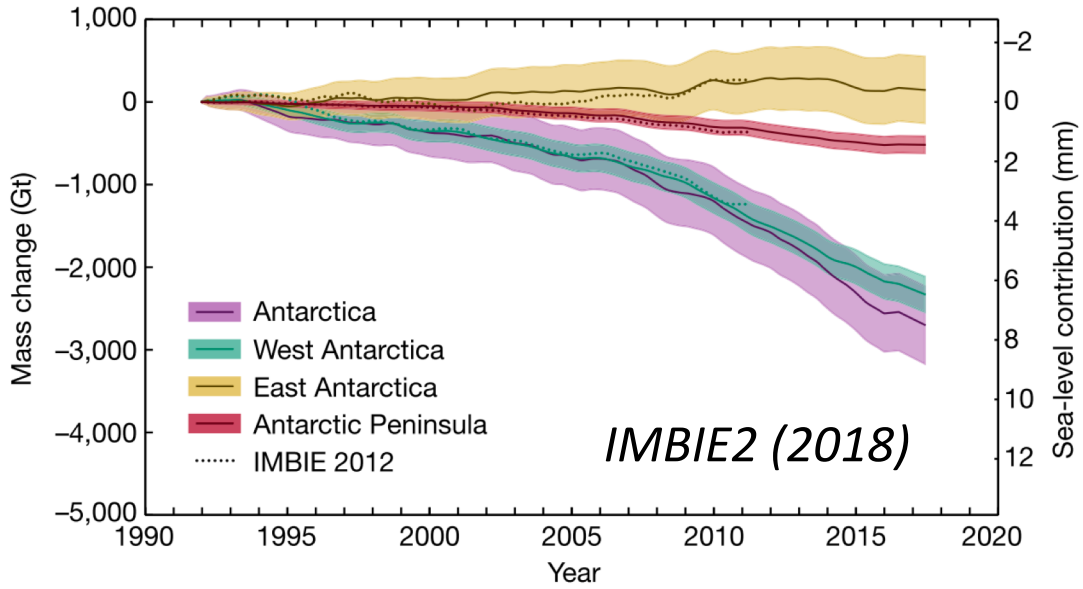
3 UNIVERSITY OF MASSACHUSETTS AMHERST 1863

4 THE PENNSYLVANIA STATE UNIVERSITY 1855

Support From:

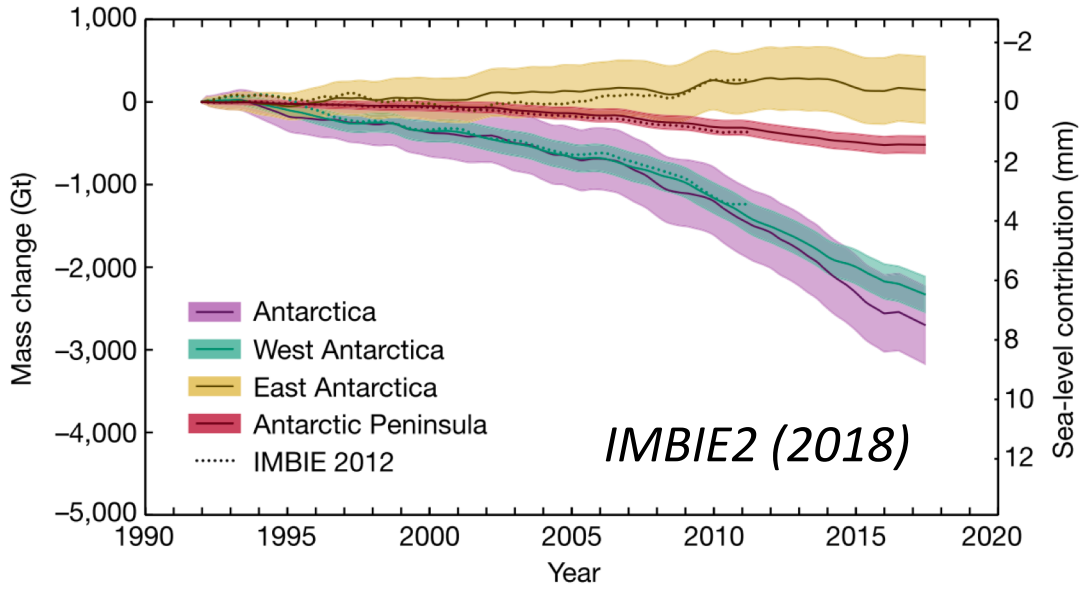
NSF NASA

Antarctic ice-sheet (AIS) mass loss could have disastrous consequences for coastal communities



Iceberg breaking off Pine Island Glacier
(NASA, Nov. 2018)

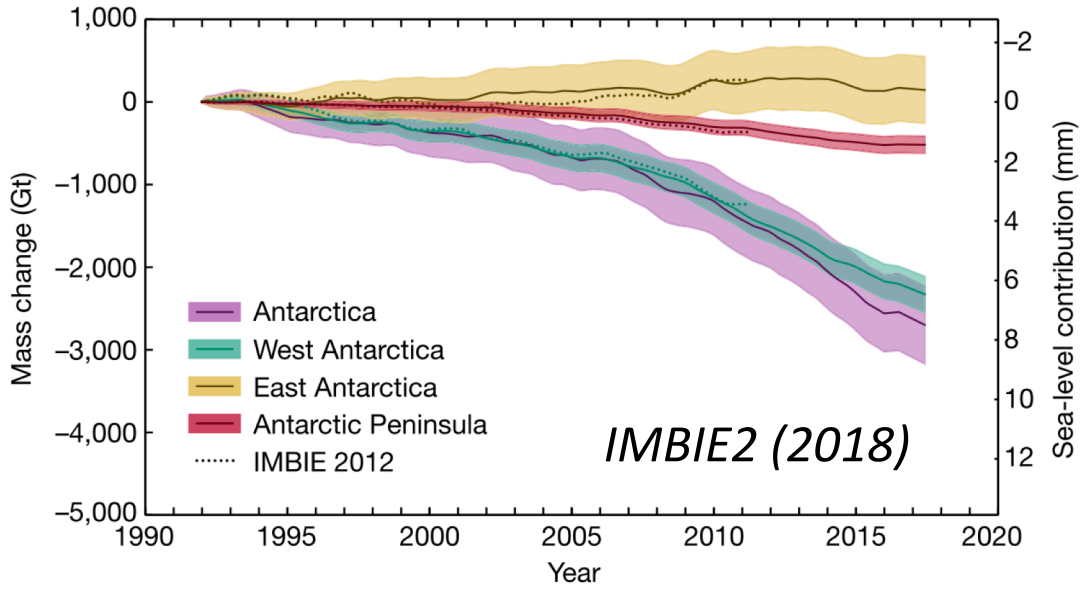
Antarctic ice-sheet (AIS) mass loss could have disastrous consequences for coastal communities



Iceberg breaking off Pine Island Glacier
(NASA, Nov. 2018)

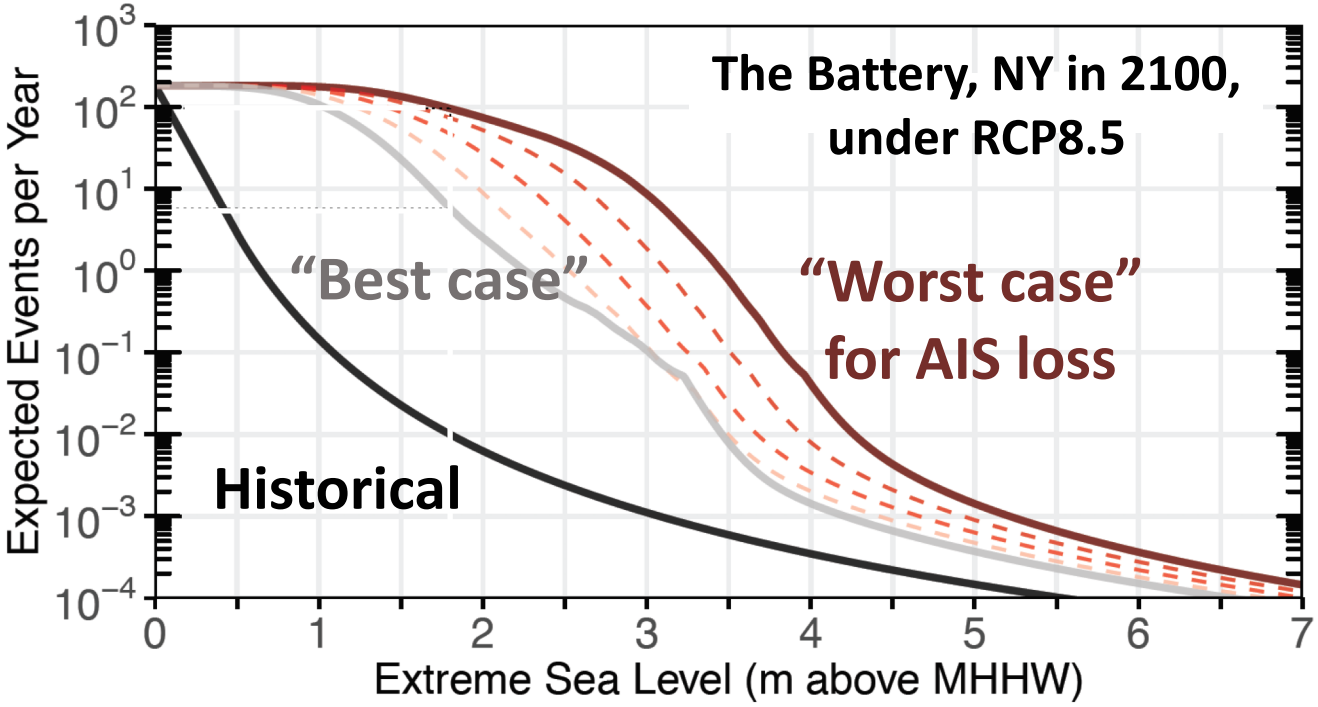
Battery Park Tunnel after Hurricane Sandy

Antarctic ice-sheet (AIS) mass loss could have disastrous consequences for coastal communities



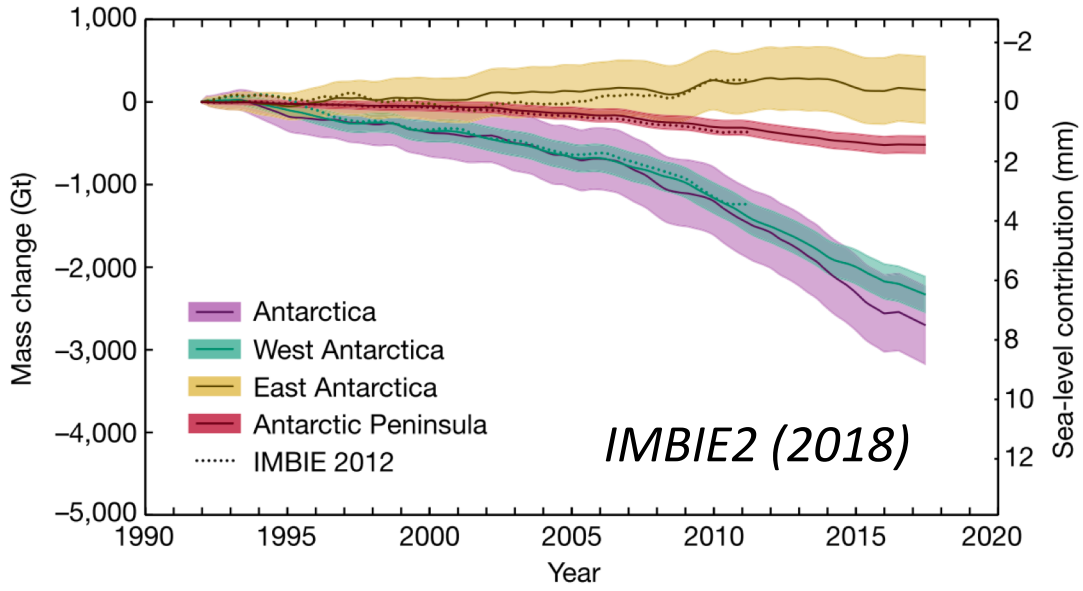
Iceberg breaking off Pine Island Glacier
(NASA, Nov. 2018)

Ambiguity in future Antarctic mass loss drives uncertainty in future flooding hazards



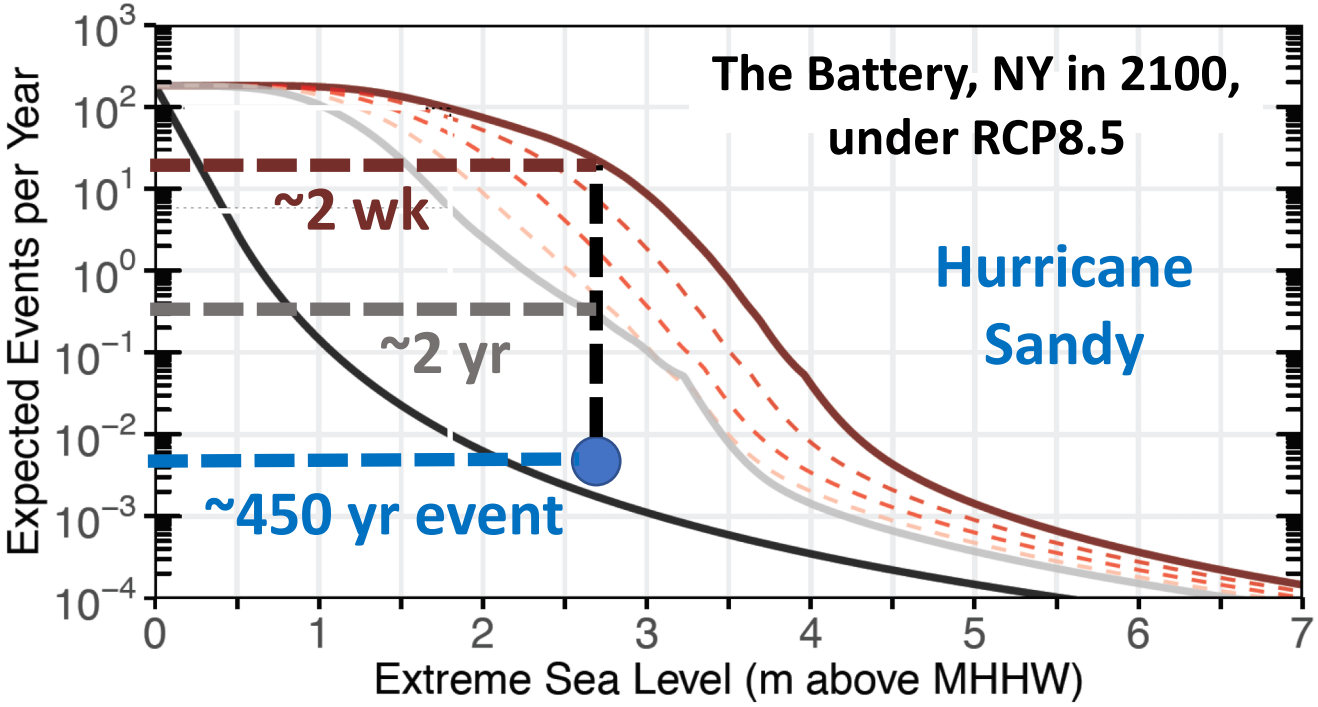
Rasmussen et al. (2019)

Antarctic ice-sheet (AIS) mass loss could have disastrous consequences for coastal communities



Iceberg breaking off Pine Island Glacier
(NASA, Nov. 2018)

Ambiguity in future Antarctic mass loss drives uncertainty in future flooding hazards



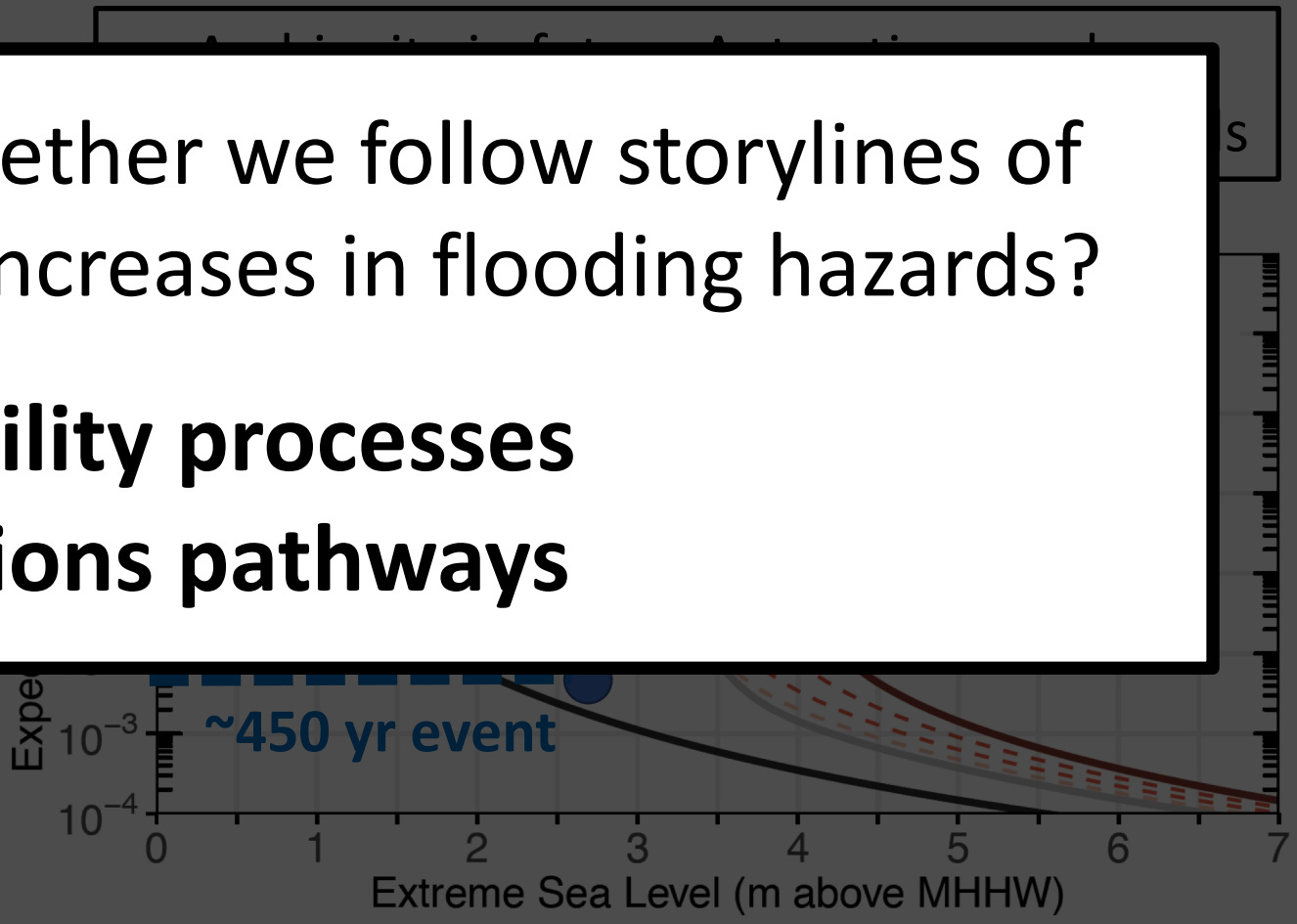
Rasmussen et al. (2019)

Antarctic ice-sheet (AIS) mass loss could have disastrous consequences for coastal communities

Q: What determines whether we follow storylines of moderate and extreme increases in flooding hazards?

1. **Instability processes**
2. **Emissions pathways**

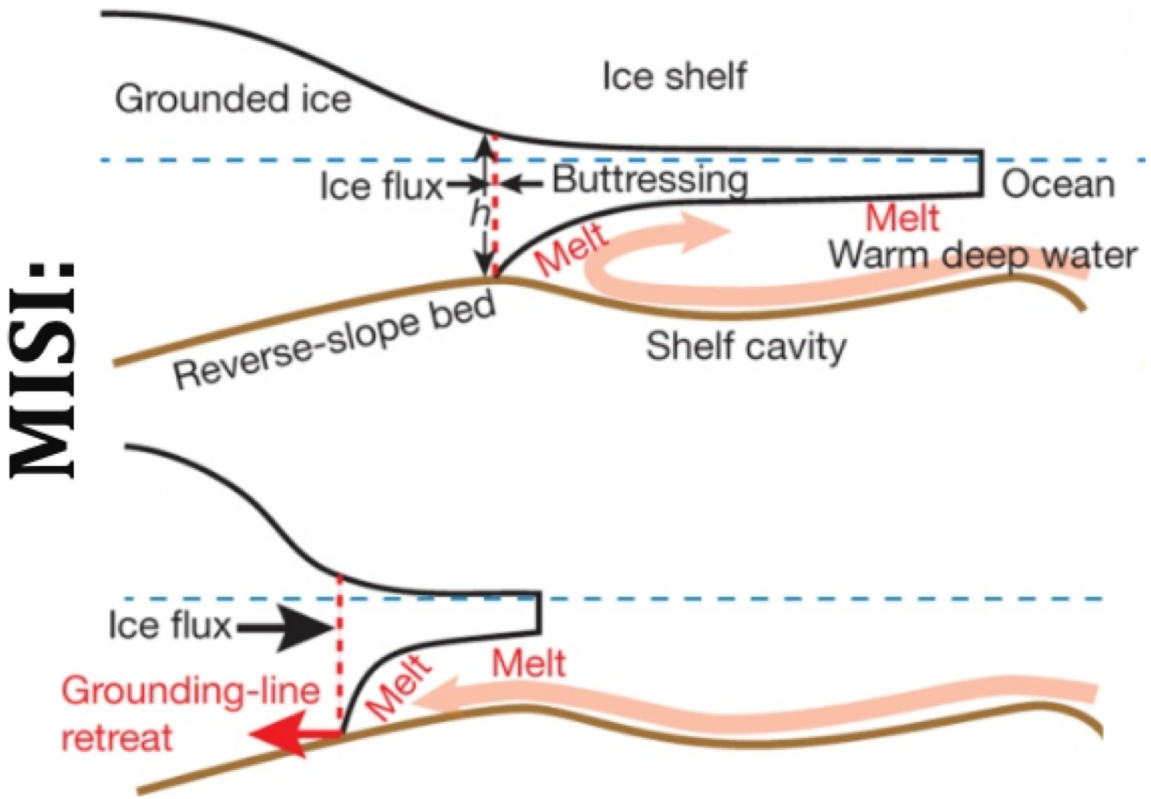
Iceberg breaking off Pine Island Glacier
(NASA, Nov. 2018)



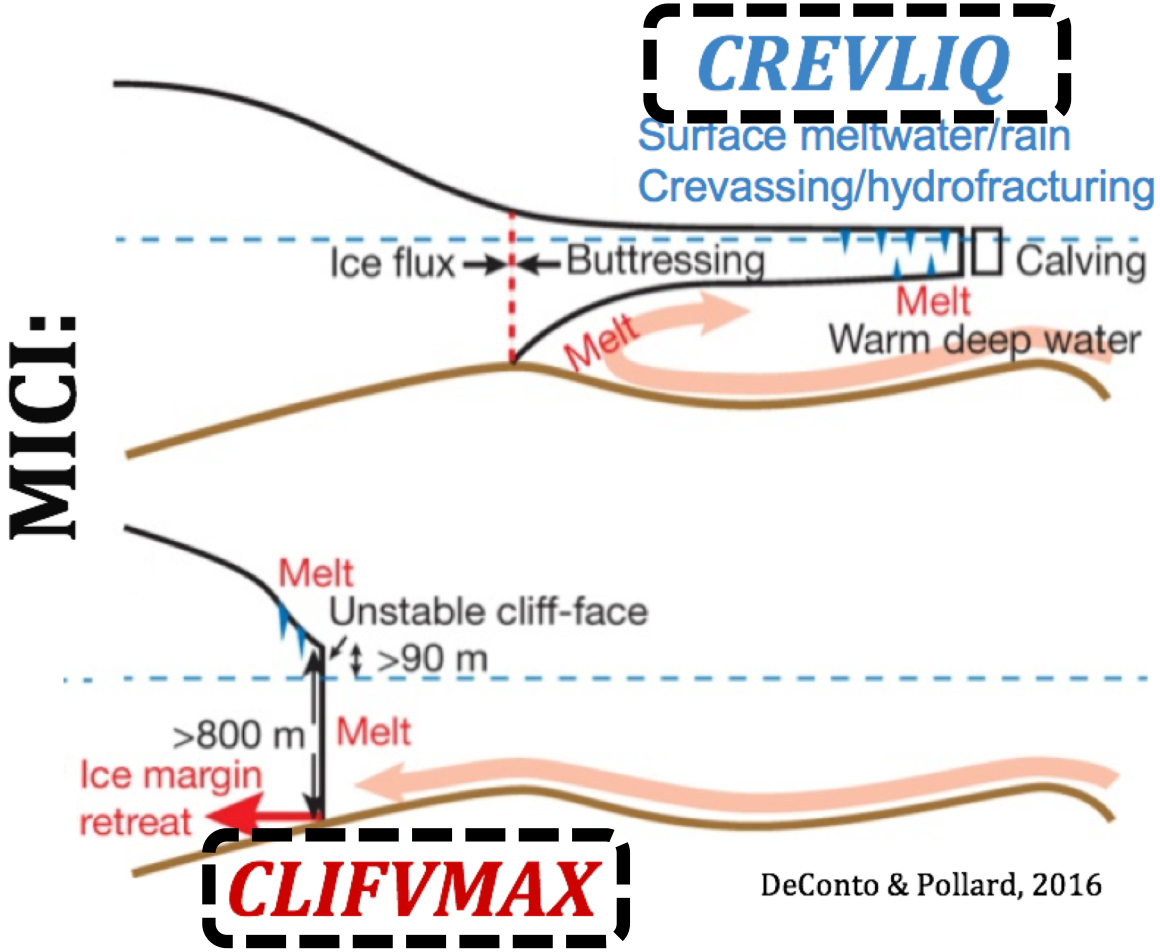
Rasmussen et al. (2019)

Instabilities distinguish the "best" and "worst" outcomes

Marine Ice Sheet Instability

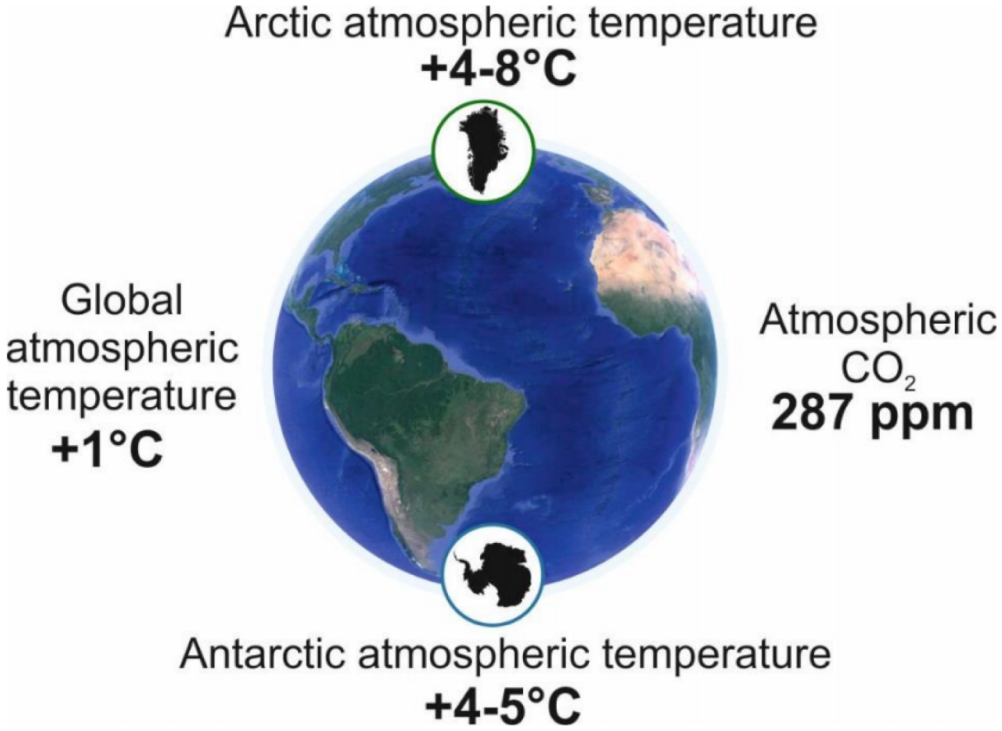


Marine Ice Cliff Instability

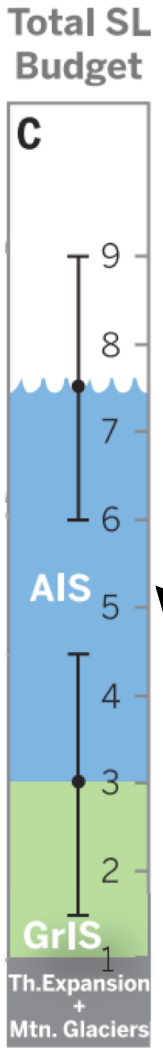


Ice mass loss storylines are informed by paleo sea levels

A promising warm period analog is the **Last Interglacial (LIG, ~125,000 yrs ago)**



Rovere and Barlow (QUIGS 2019)



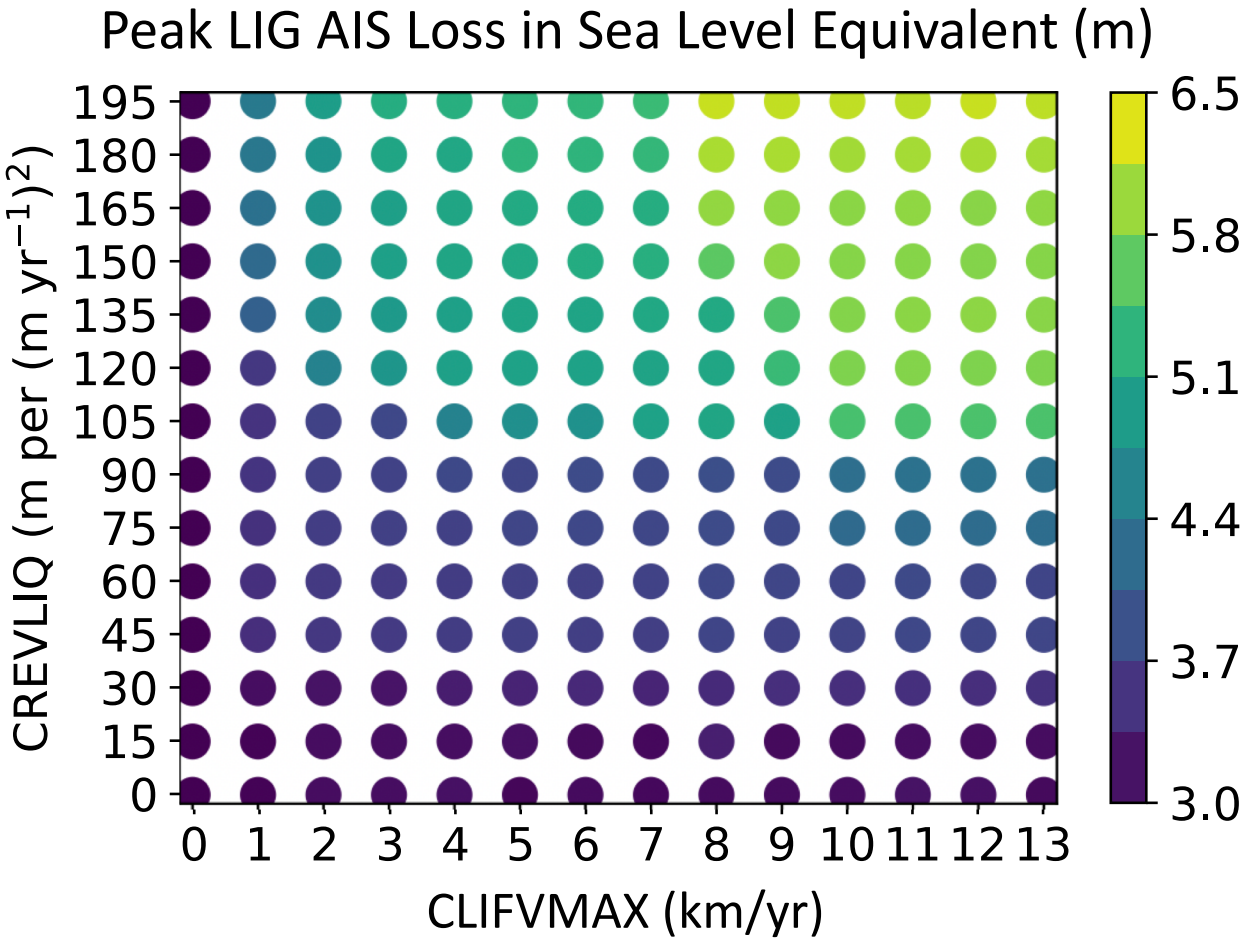
Dutton et al. (2015)

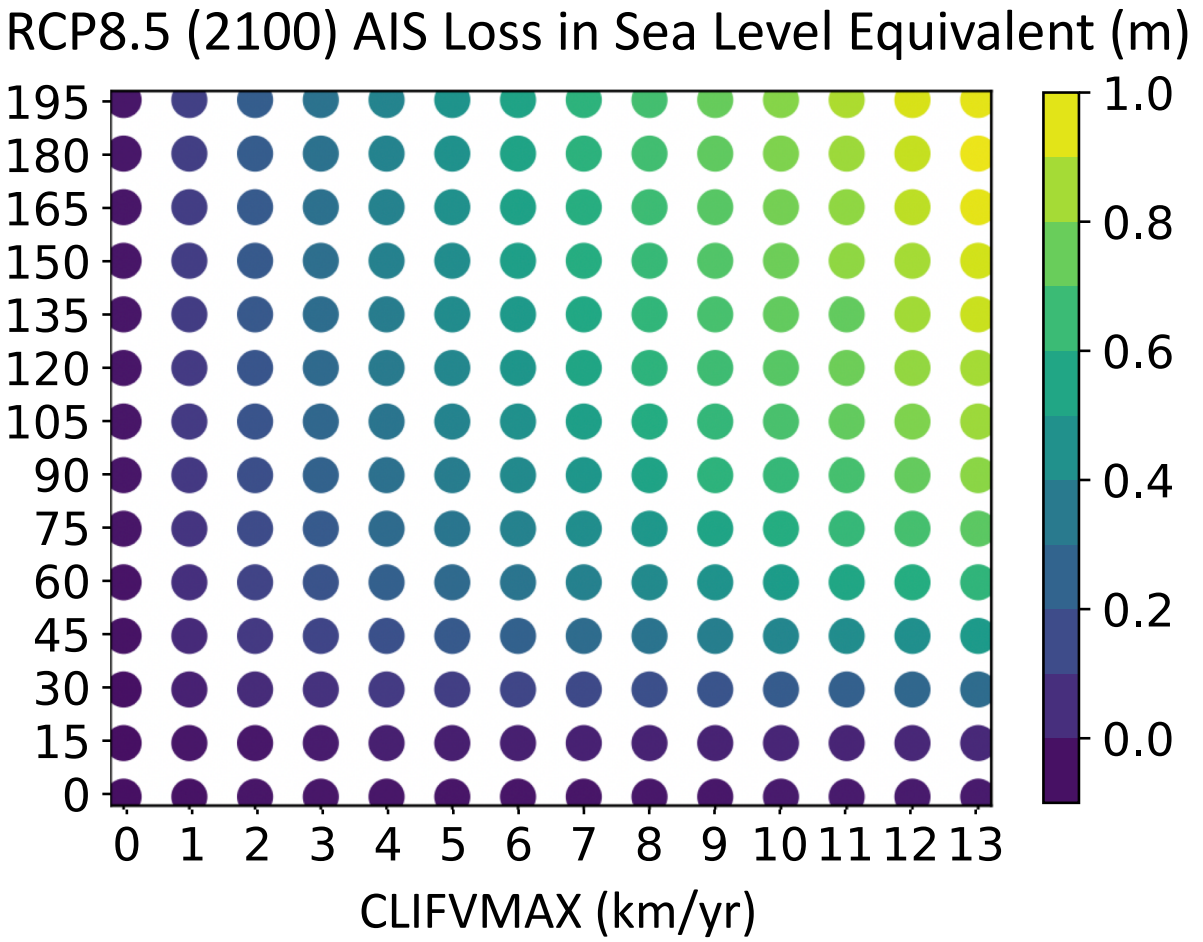
Budgetary analyses are used to examine LIG sea level:

- AIS ≈ Total Sea Level
  - Greenland
  - Thermal Expansion
  - Mountain Glaciers

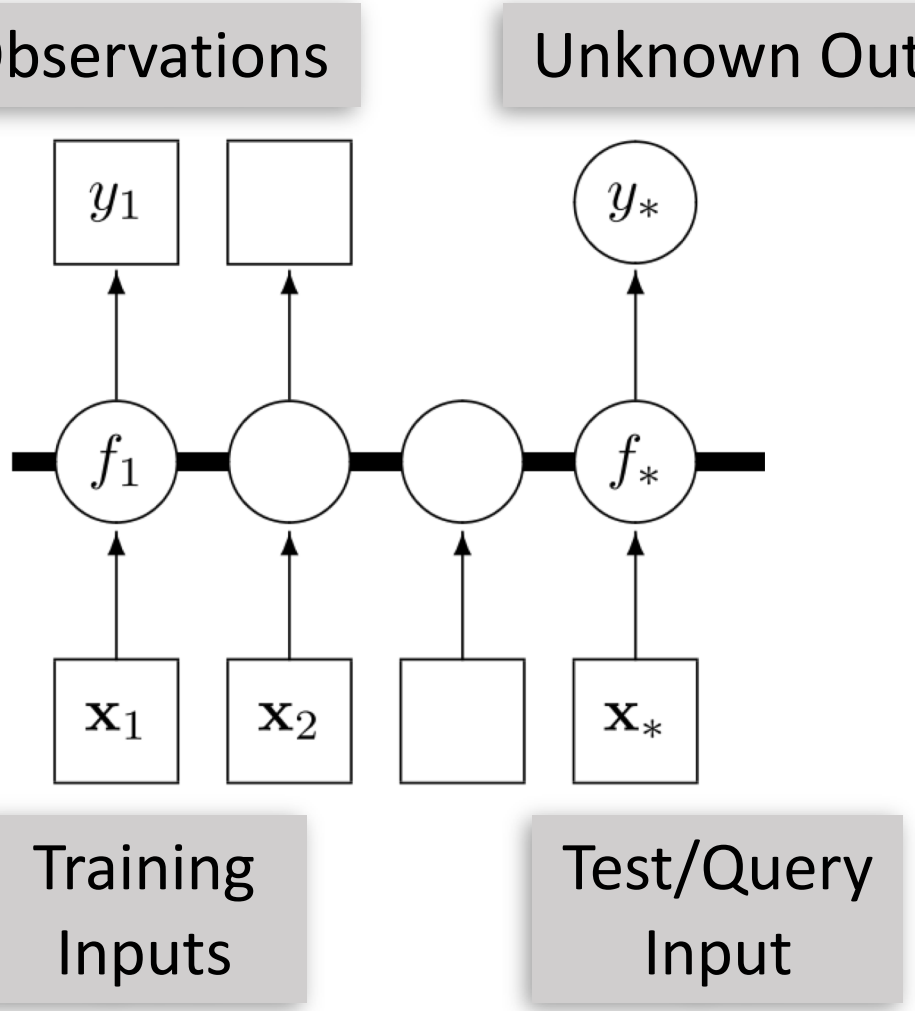
Peak AIS loss ~ 3 to 6 m

Ice-sheet model ensembles: LIG peak and future high emission (RCP8.5) scenarios





Emulate with Gaussian Process Modeling



- Non-parametric: there are a distribution of **functions** consistent with observations
- These functions are jointly Gaussian, e.g.

$$f = \mathcal{N}(\mu(x), k(x, x'))$$

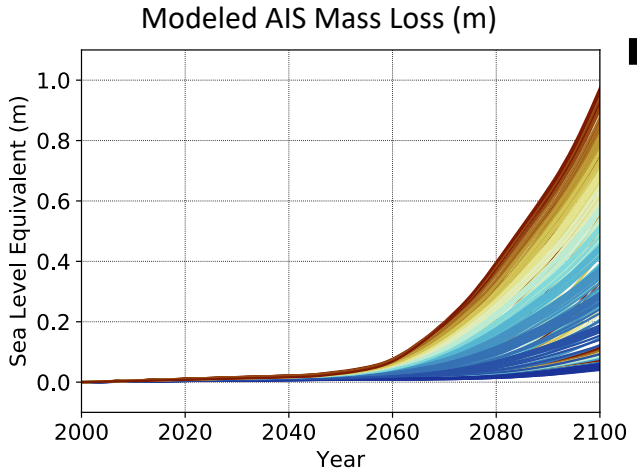
- Uncertainty inherently provided

For more details: Rasmussen and Williams (2006), http://www.gaussianprocess.org/gpml/chapters/RW.pdf

Ice-sheet model ensembles: LIG peak and future high emission (RCP8.5) scenarios

Discrete Inputs:

CREVLIQ, CLIFVMAX, time (for RCP2.6 and RCP8.5)

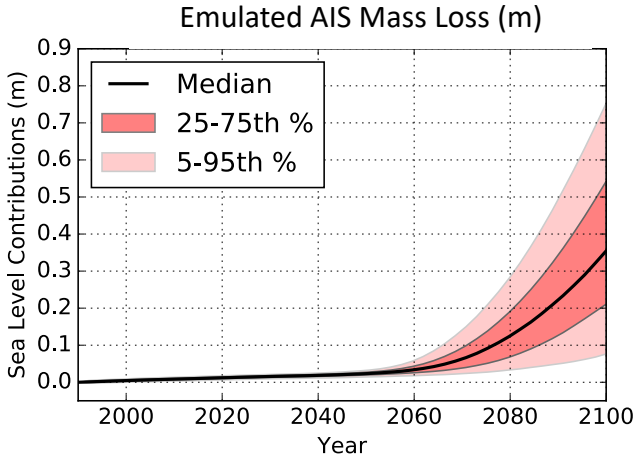


Gaussian Process Modeling

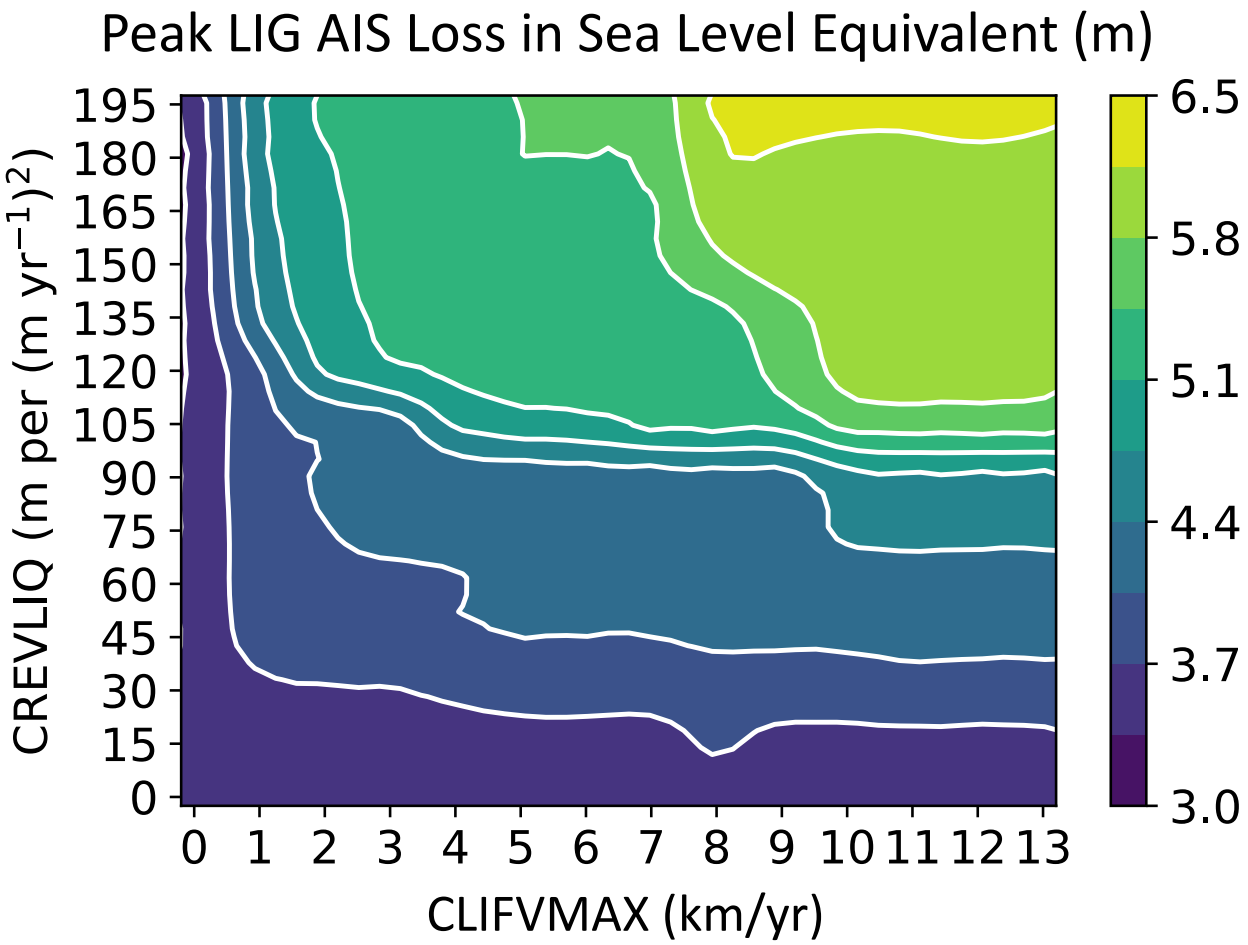
$$f = \mathcal{N}(\mu(x), k(x, x'))$$

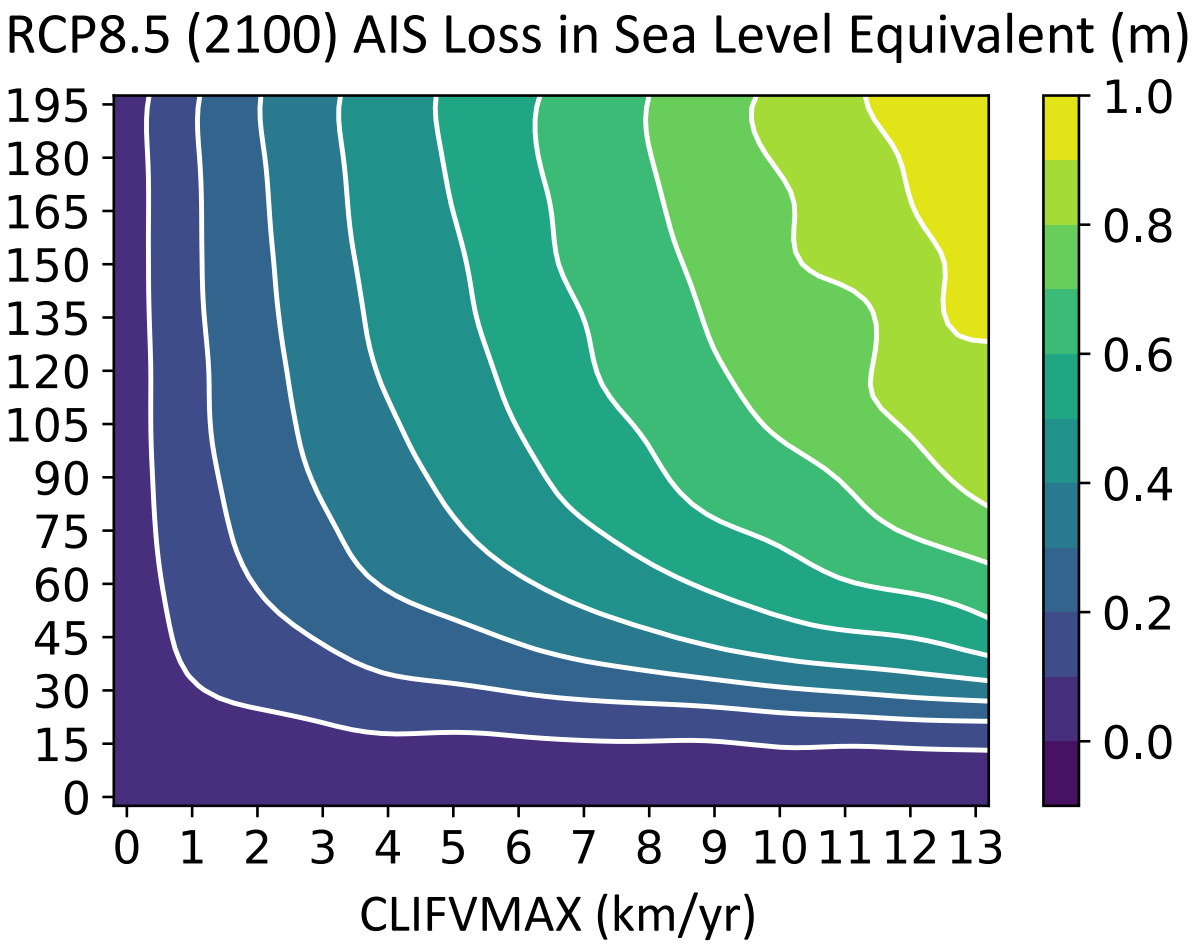
Continuous Output:

AIS Mass Loss in Sea Level Equivalent

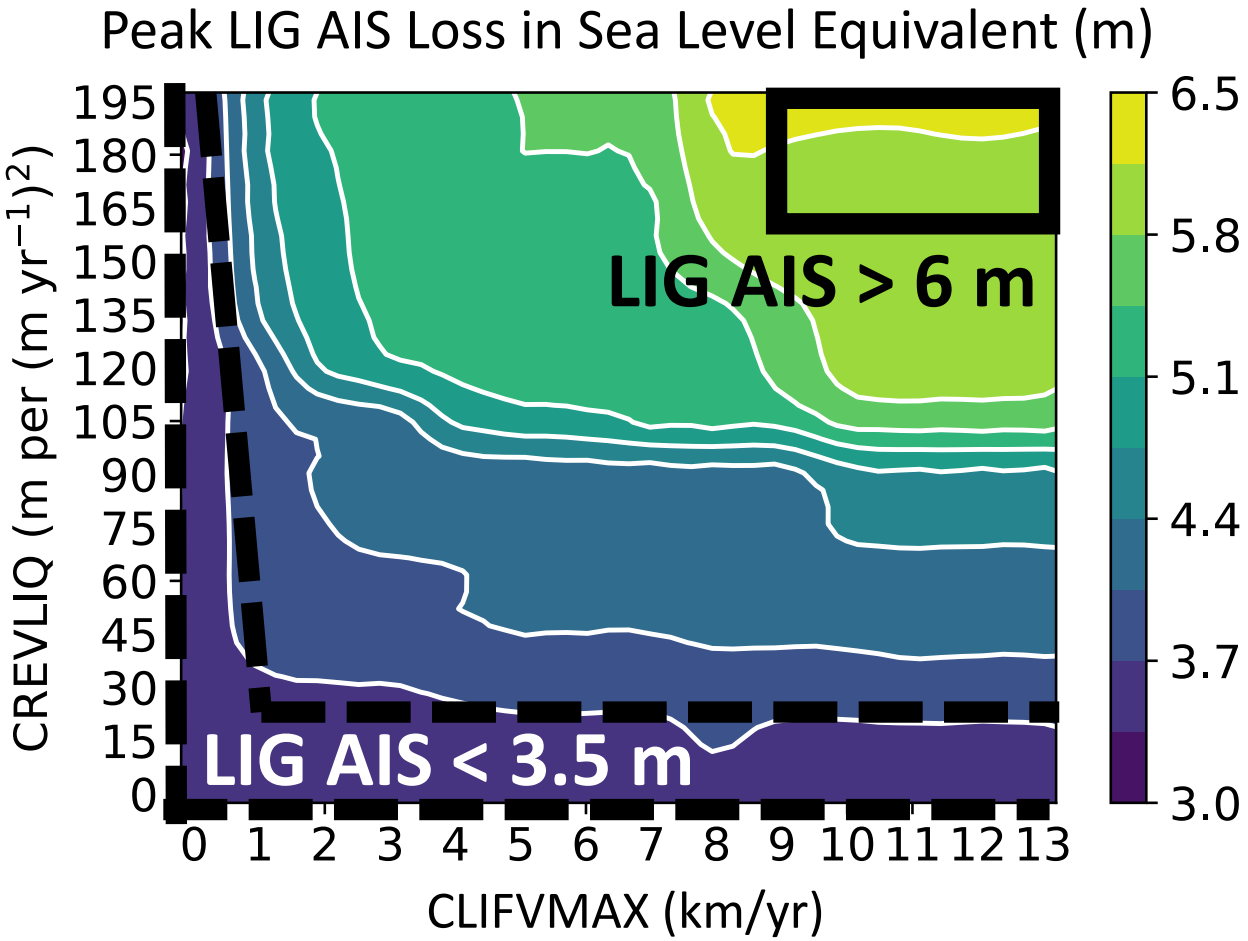


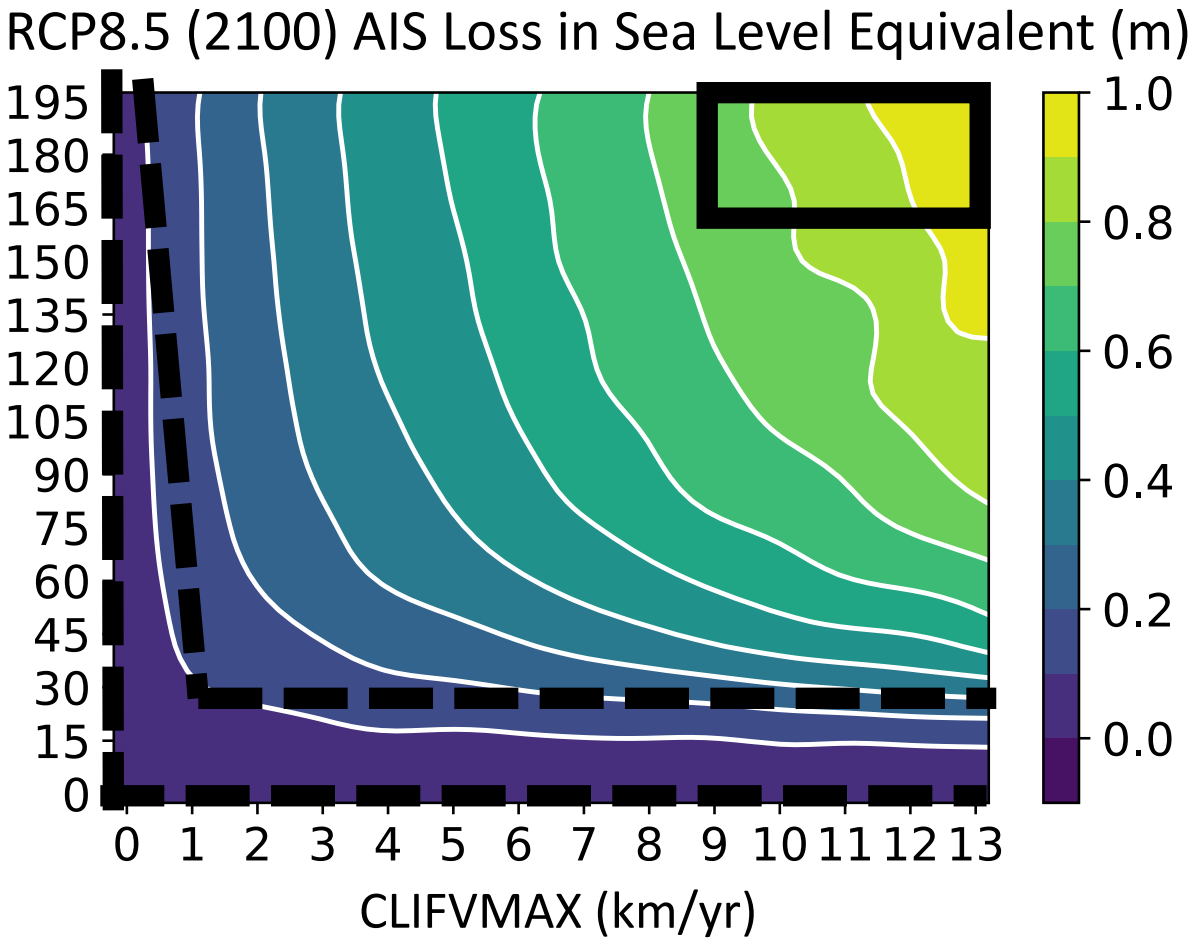
The emulator and Bayesian inference link model parameters, the LIG, and future sea-level projections



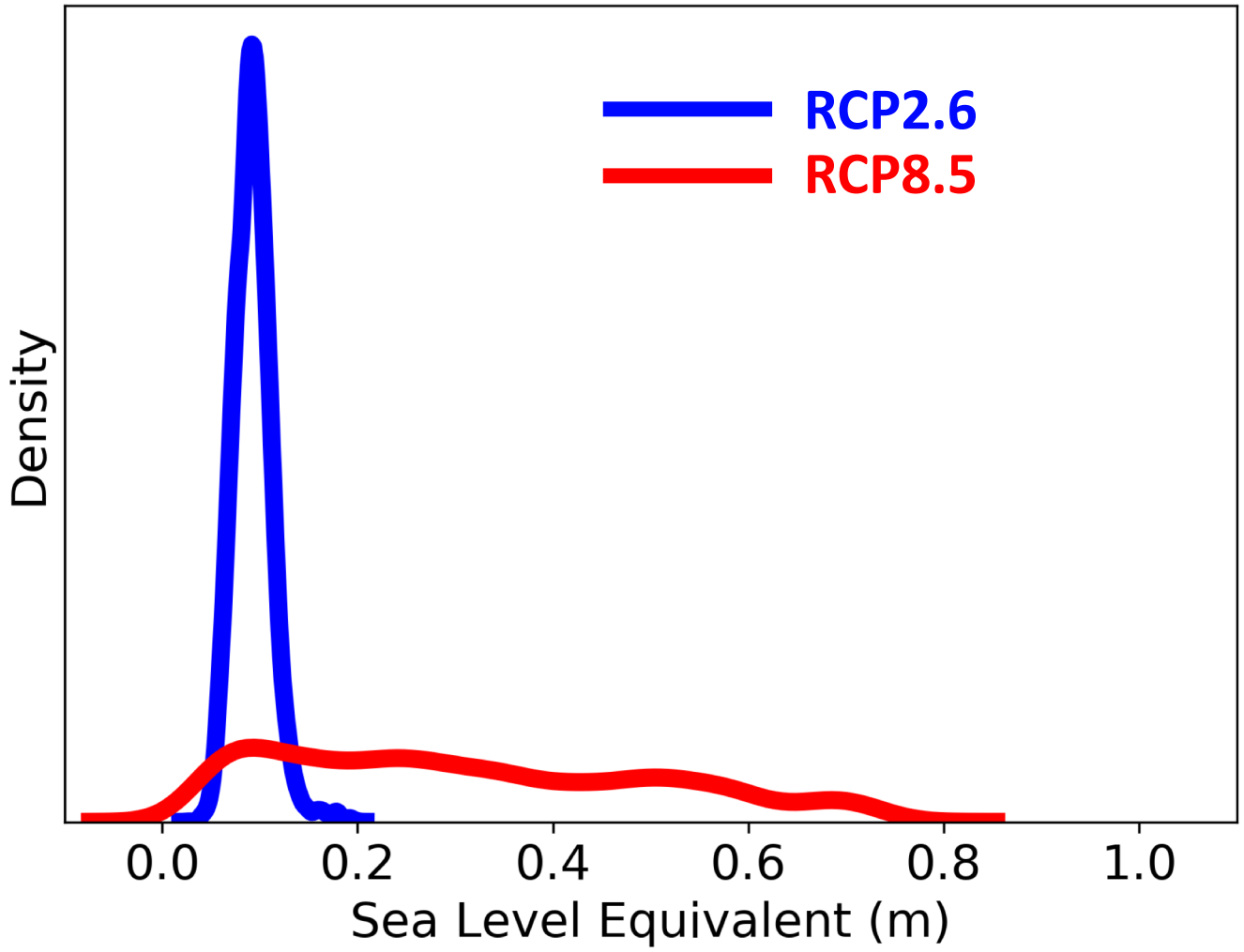


The emulator and Bayesian inference link model parameters, the LIG, and future sea-level projections





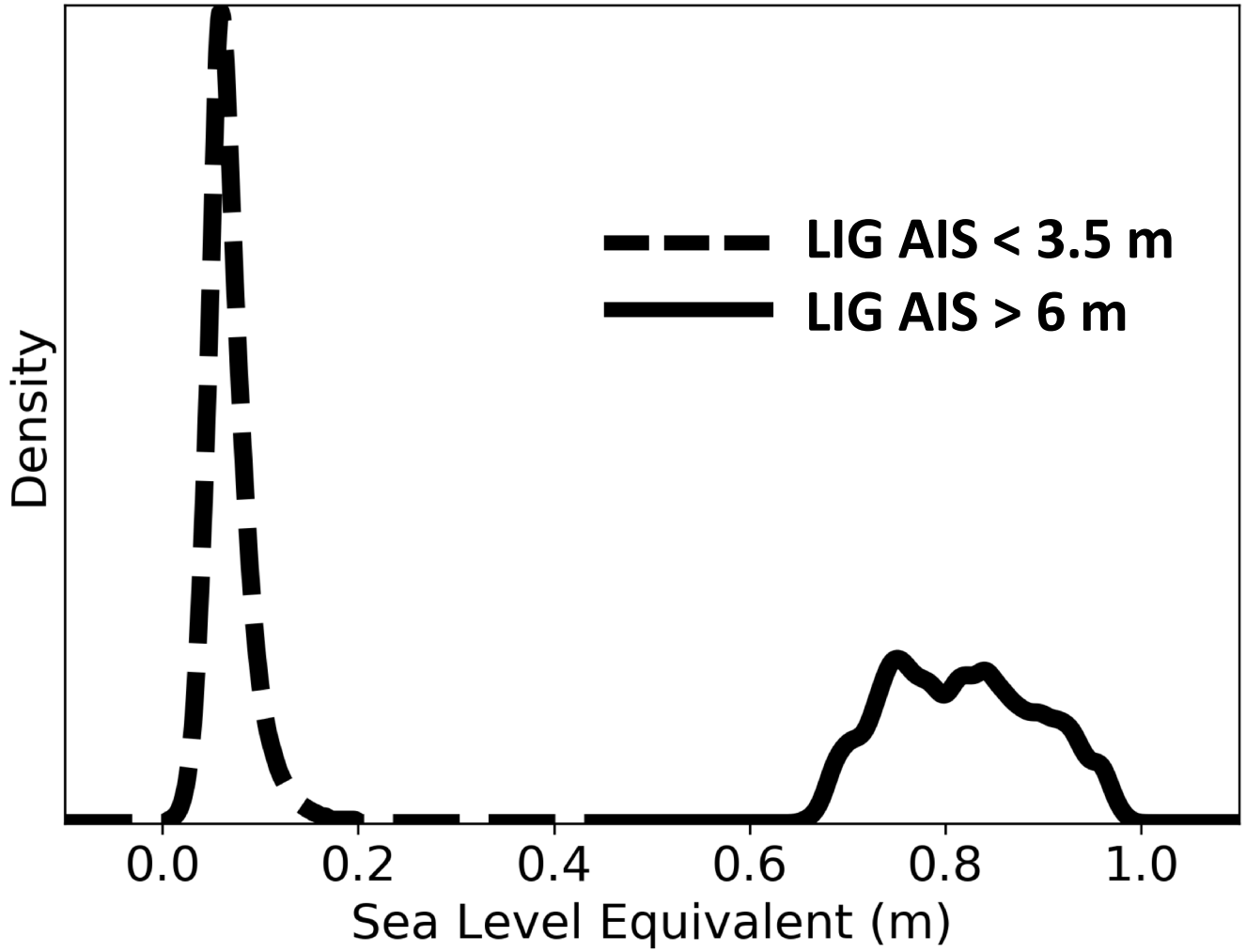
Probability distributions reflect differences in possible futures



Low future emissions:
Relatively constrained and modest AIS mass loss

High future emissions:
Substantial ambiguity and potential for very high AIS mass loss

Probability distributions reflect differences in possible futures

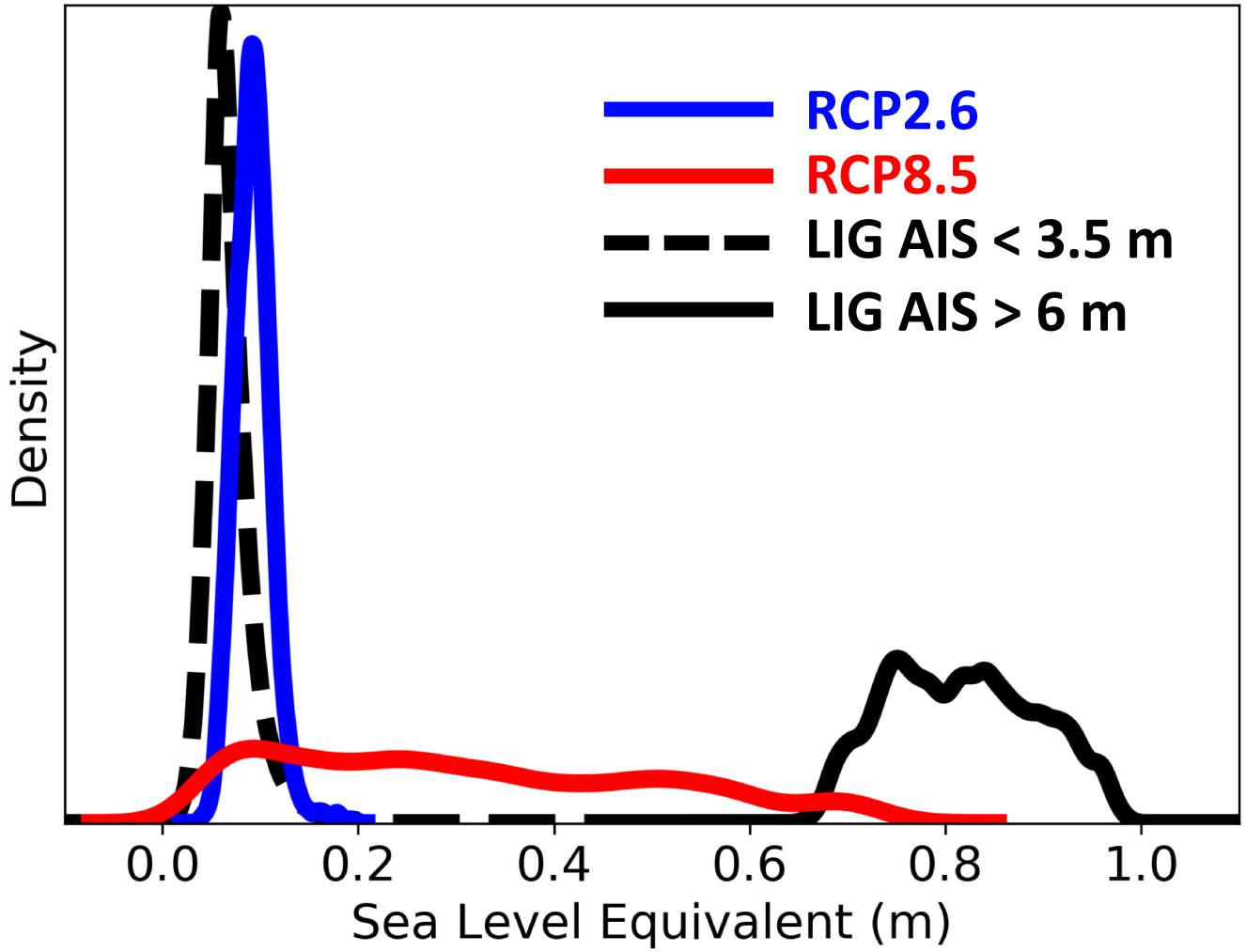


Low LIG contributions:
Relatively constrained and modest AIS mass loss

High LIG contributions:
More ambiguity and very high AIS mass loss

(all under RCP8.5)

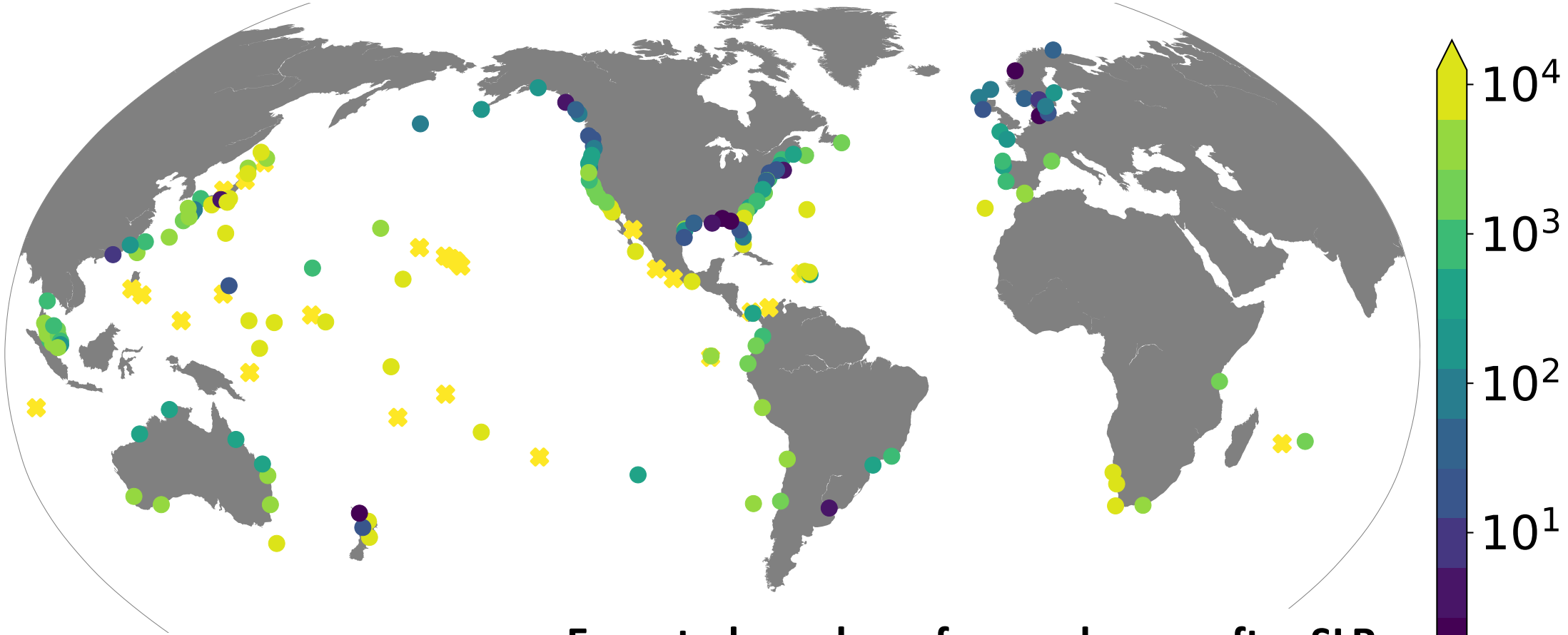
Probability distributions reflect differences in possible futures



A better understanding of past sea levels, especially on margins, would reduce ambiguity

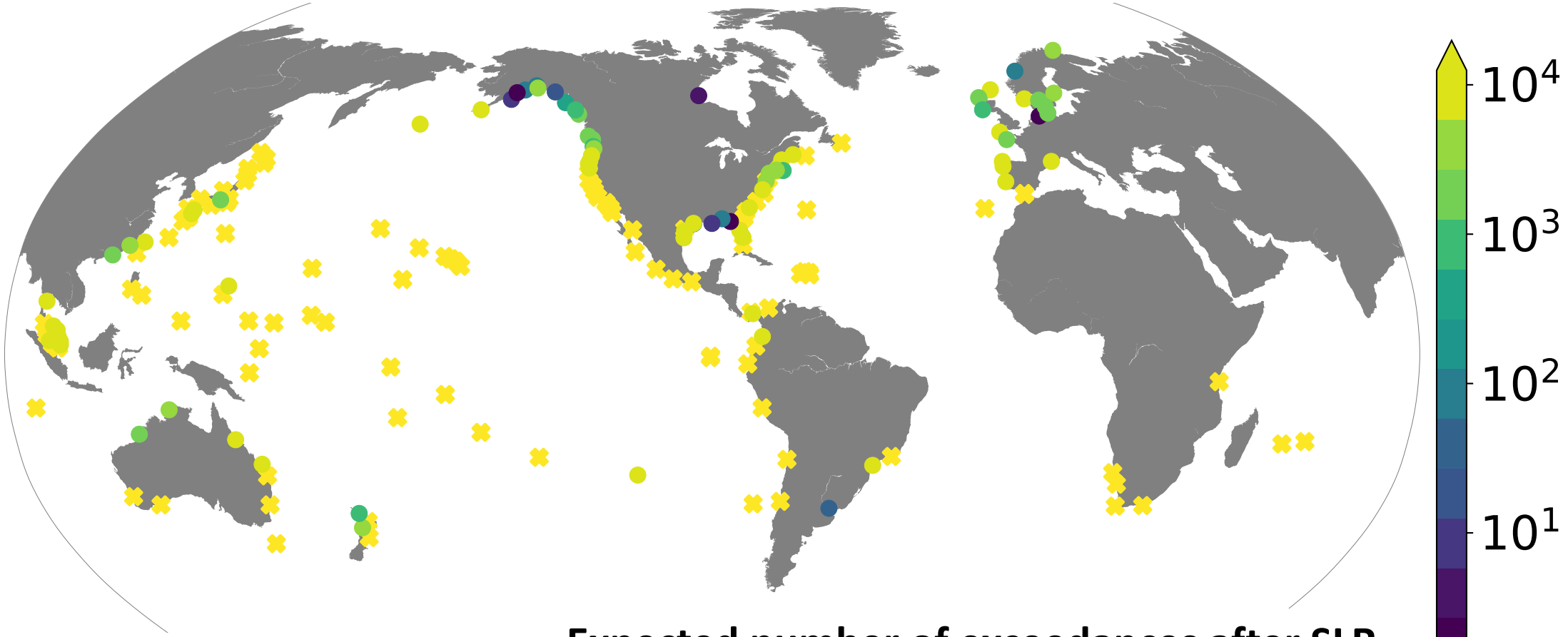
Emulation permits fully continuous probabilistic projections of sea level change & the integration of constraints…

Extreme Sea Level Amplification Factor (100-yr Event; 2100; **RCP2.6**)



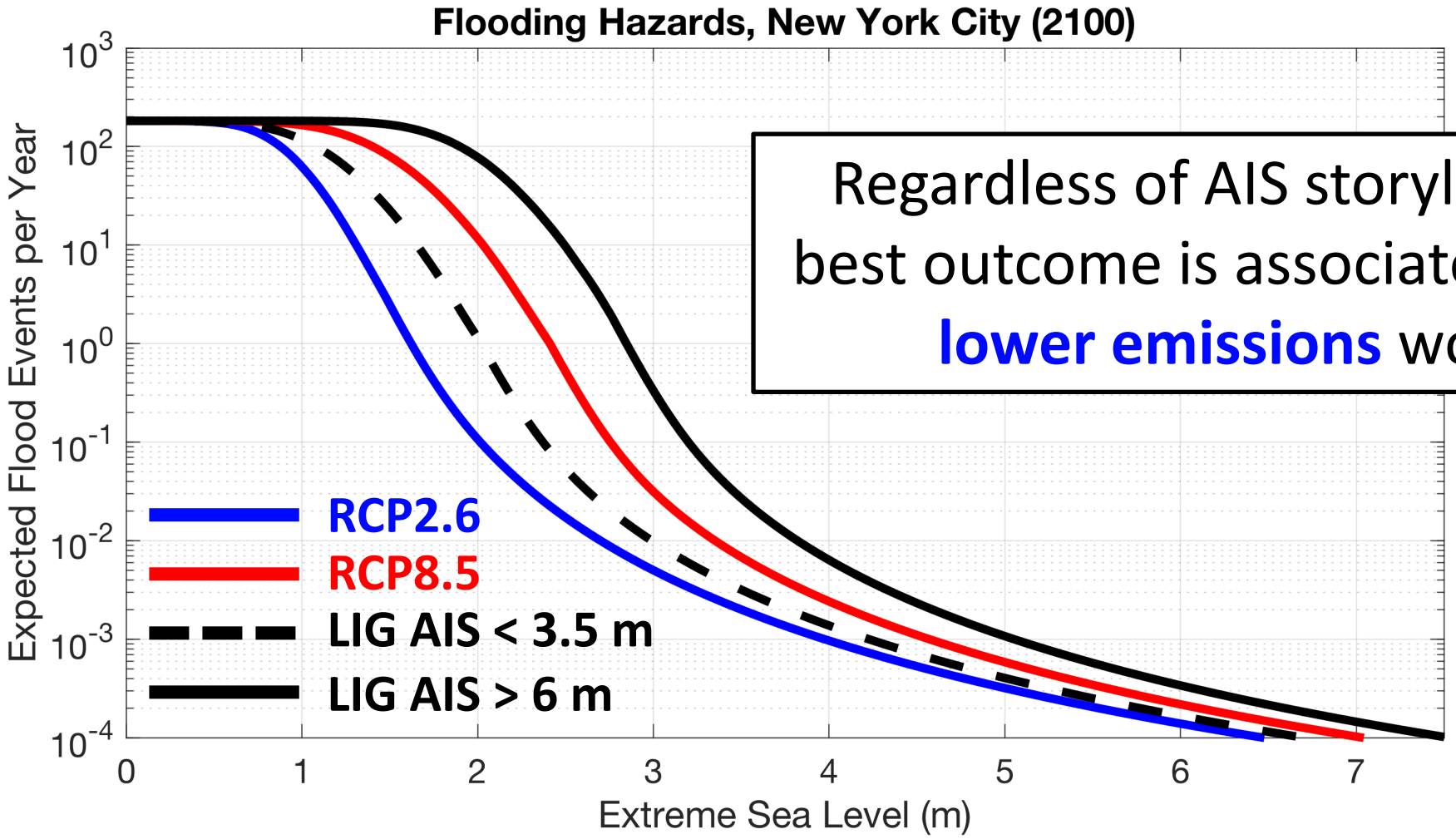
$$\textbf{Amplification Factor} = \frac{\textbf{Expected number of exceedances after SLR}}{\textbf{Historical number of exceedances}}$$

Extreme Sea Level Amplification Factor (100-yr Event; 2100; **RCP8.5**)



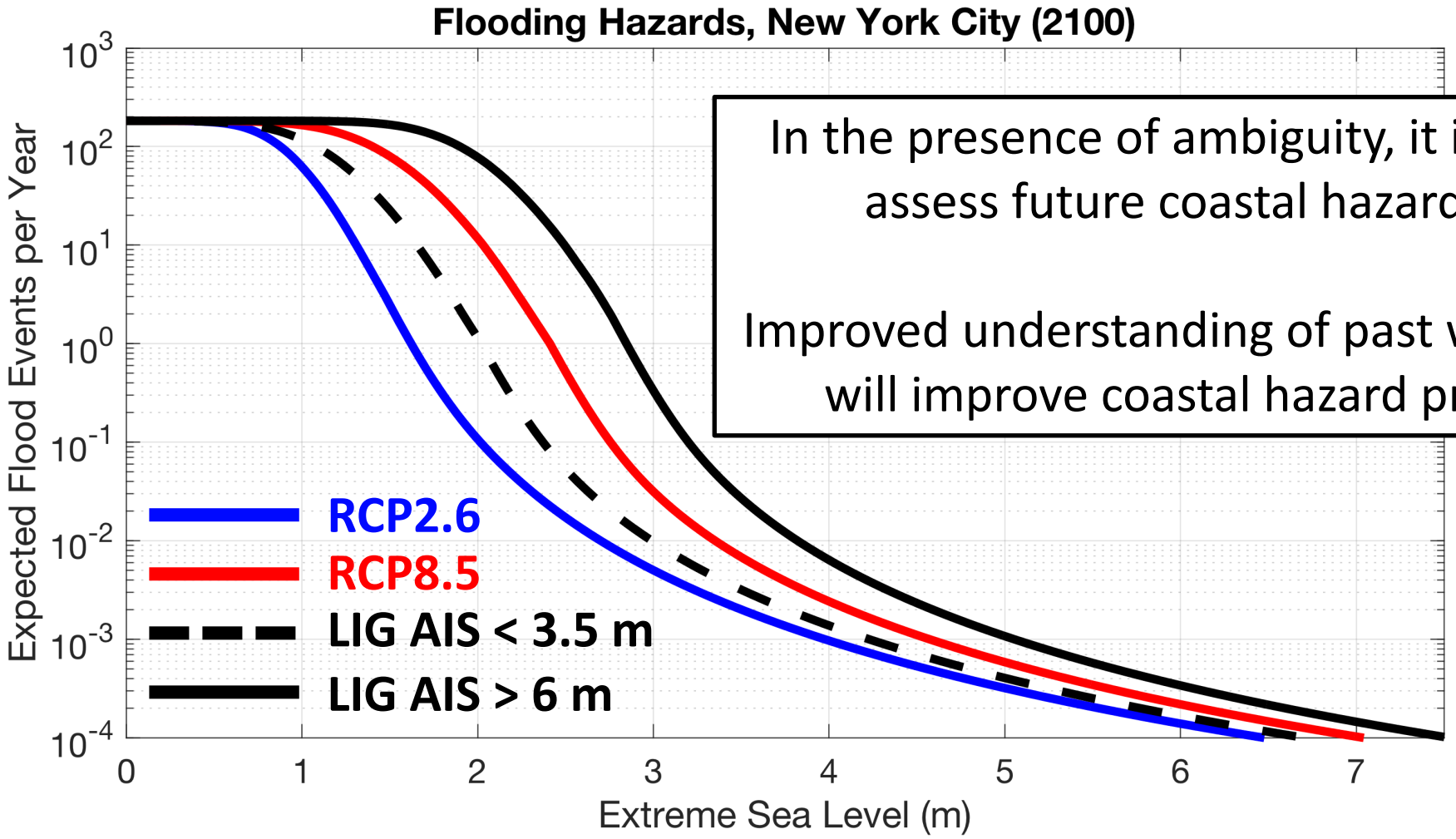
$$\textbf{Amplification Factor} = \frac{\textbf{Expected number of exceedances after SLR}}{\textbf{Historical number of exceedances}}$$

Future local flood events strongly depend on the storyline of AIS mass loss



Regardless of AIS storyline, the best outcome is associated with a **lower emissions** world

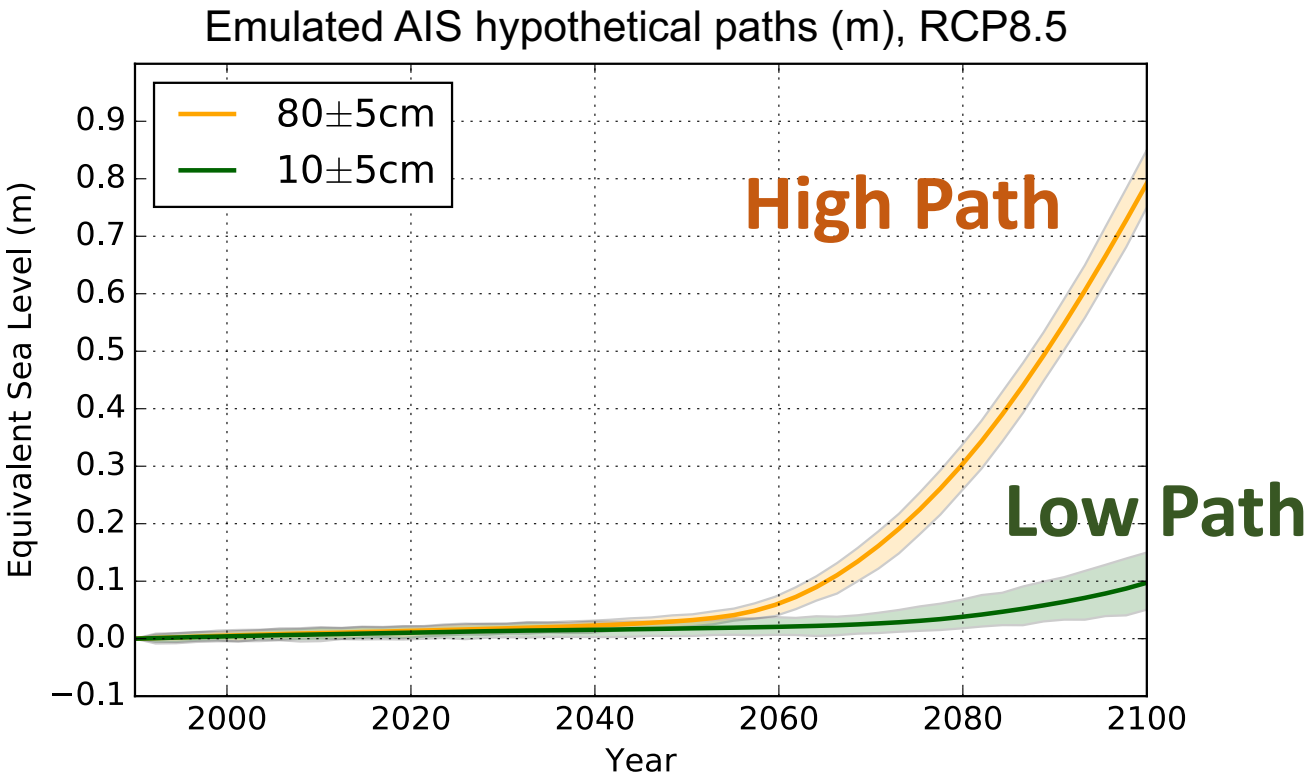
Future local flood events strongly depend on the storyline of AIS mass loss



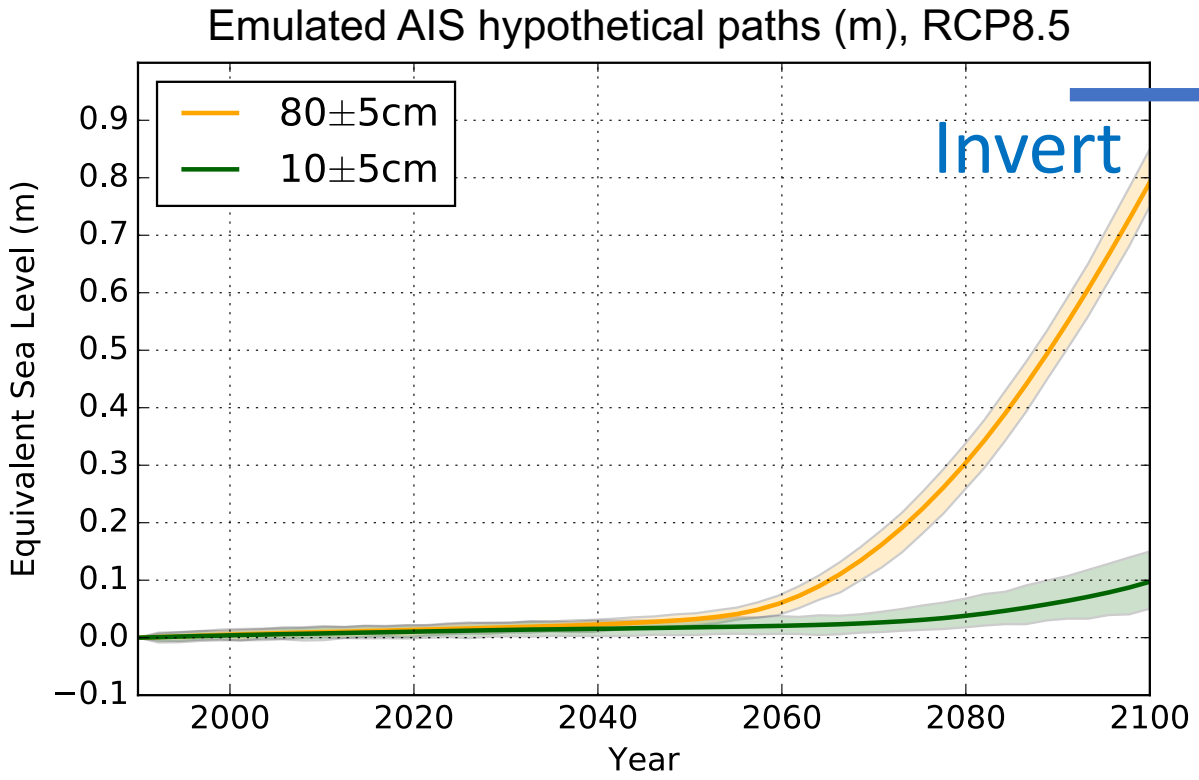
In the presence of ambiguity, it is difficult to assess future coastal hazards, but…

Improved understanding of past warm periods will improve coastal hazard predictions

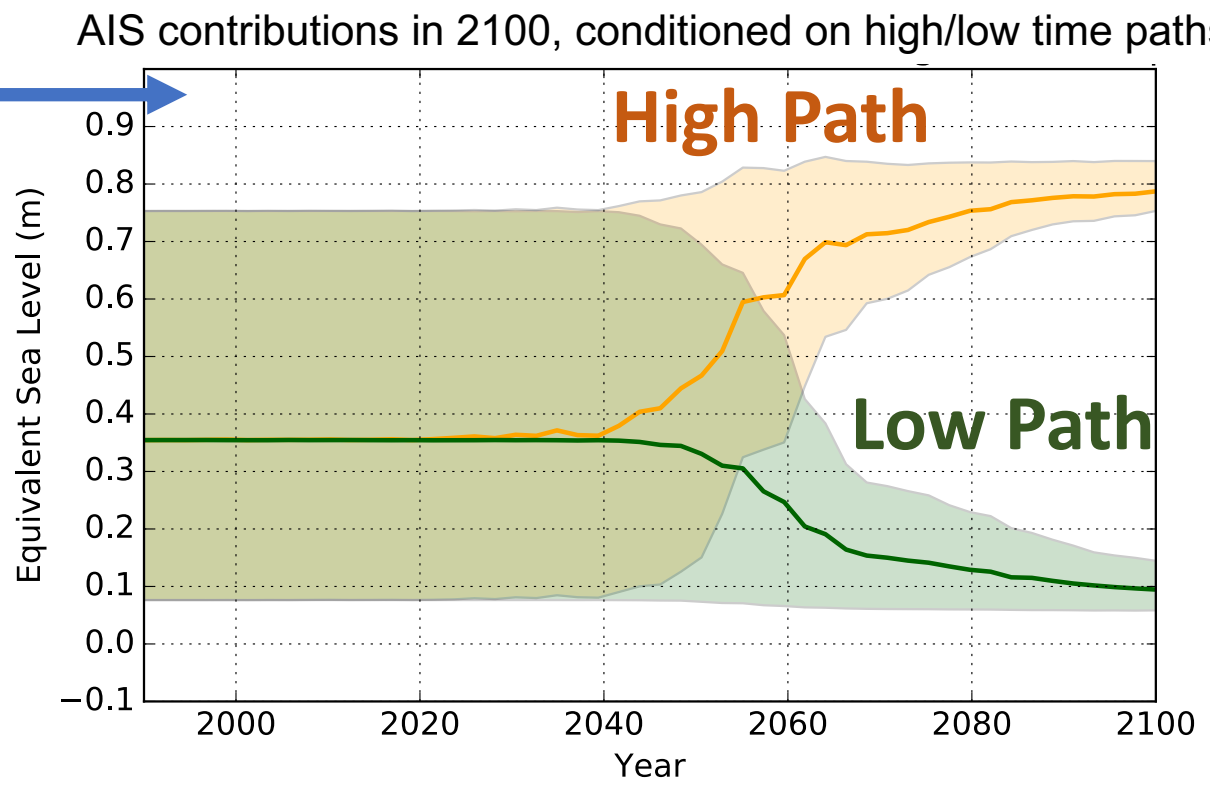
When will we learn which storyline we are following?



When will we learn which storyline we are following?



Invert



At any given time, what AIS sea level contributions are possible in 2100?

→ By ~2060 with 90% confidence we may observe whether we are on a **high sea level** path or a **low sea level** path