Exploring ice sheet model sensitivity to thermal forcing using CISM

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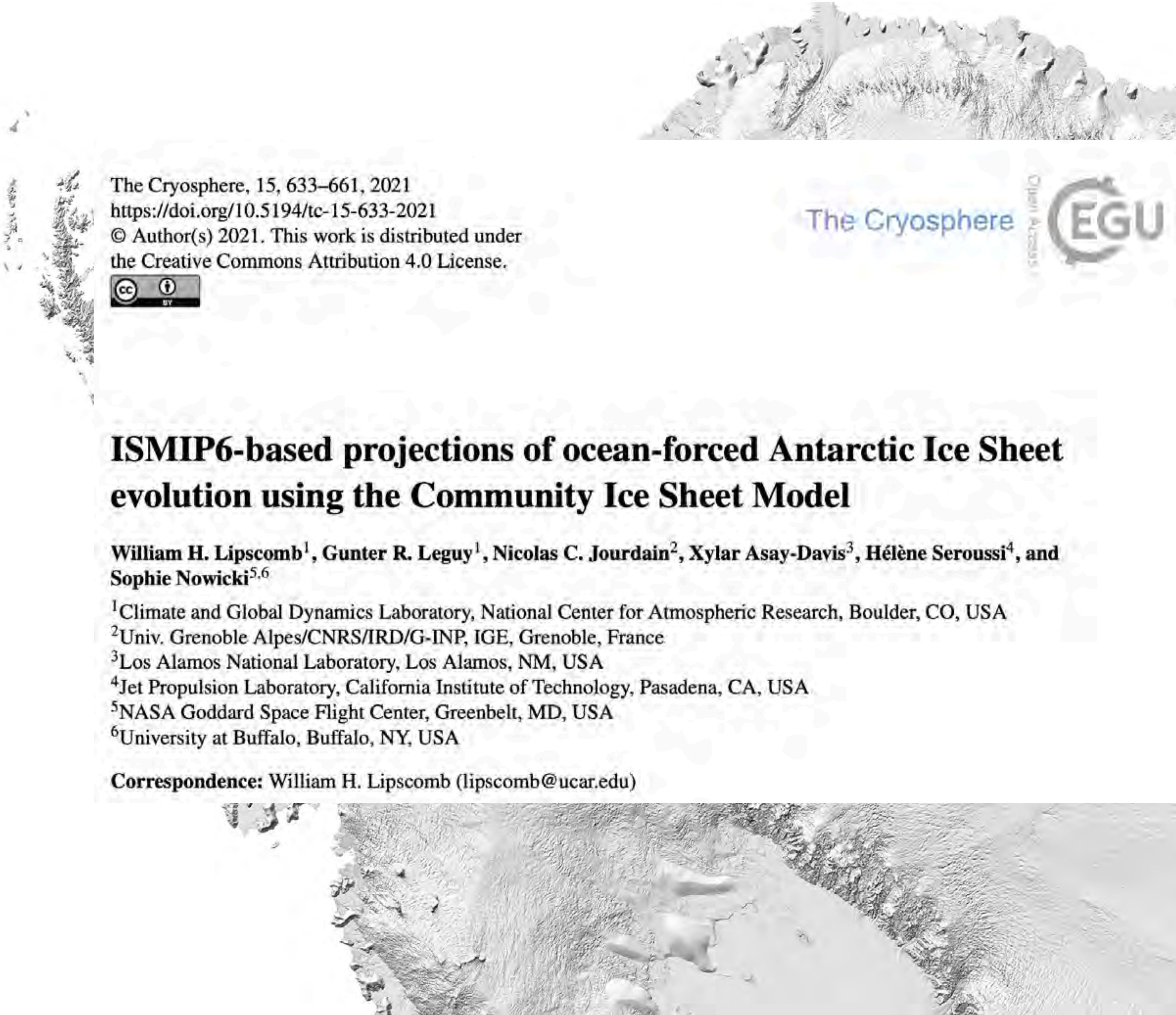
Motivation

You can achieve a similar spun-up state with different sensitivities to ocean warming



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ISMIP6-based projections of ocean-forced Antarctic Ice Sheet evolution using the Community Ice Sheet Model

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You can achieve a similar spun-up state with different sensitivities to ocean warming

Nudge toward observed thickness during spin-up by adjusting C_p (empirical coefficient in basal friction law) and delT (TF correction factor).

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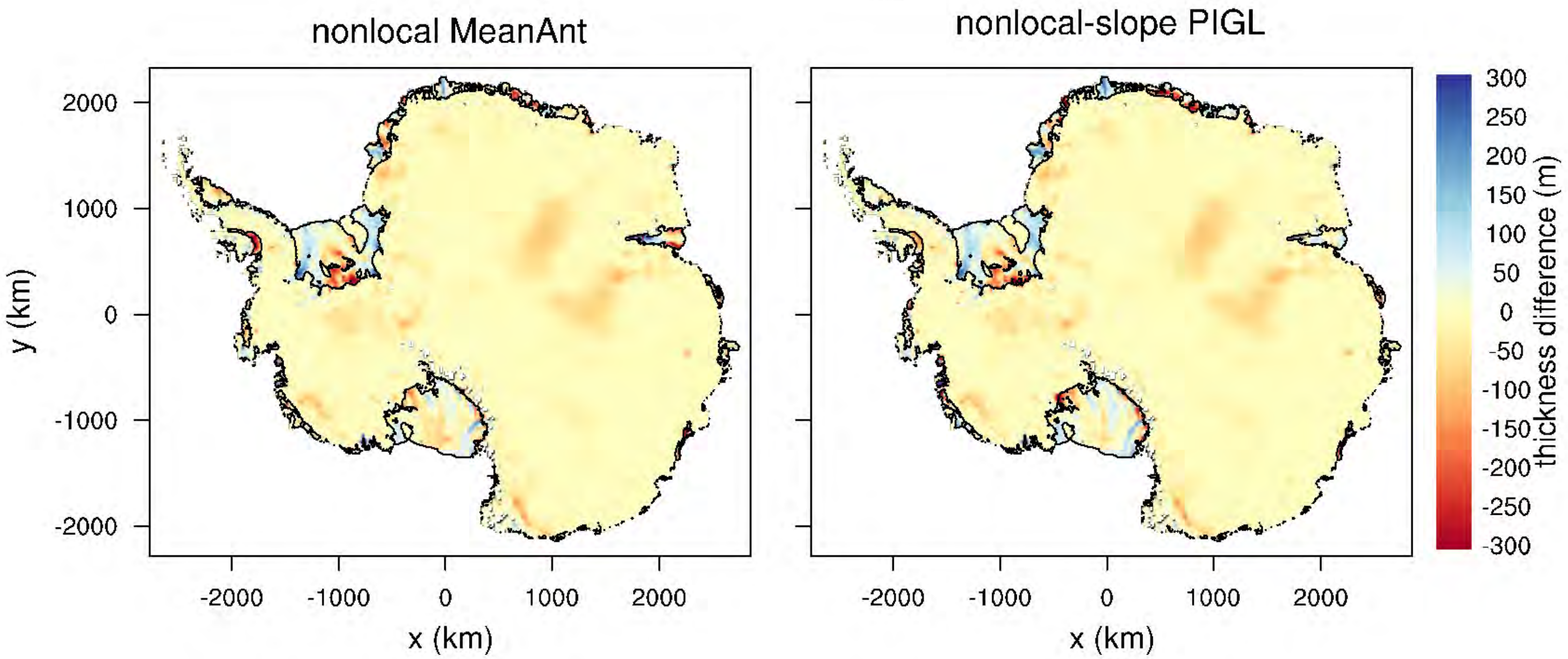

Nudge toward observed thickness during spin-up by adjusting C_p (empirical coefficient in basal friction law) and delT (TF correction factor).

Lipscomb et al., 2021

There are a couple of parameters that have been found to be very important in the sensitivity of the ice sheet

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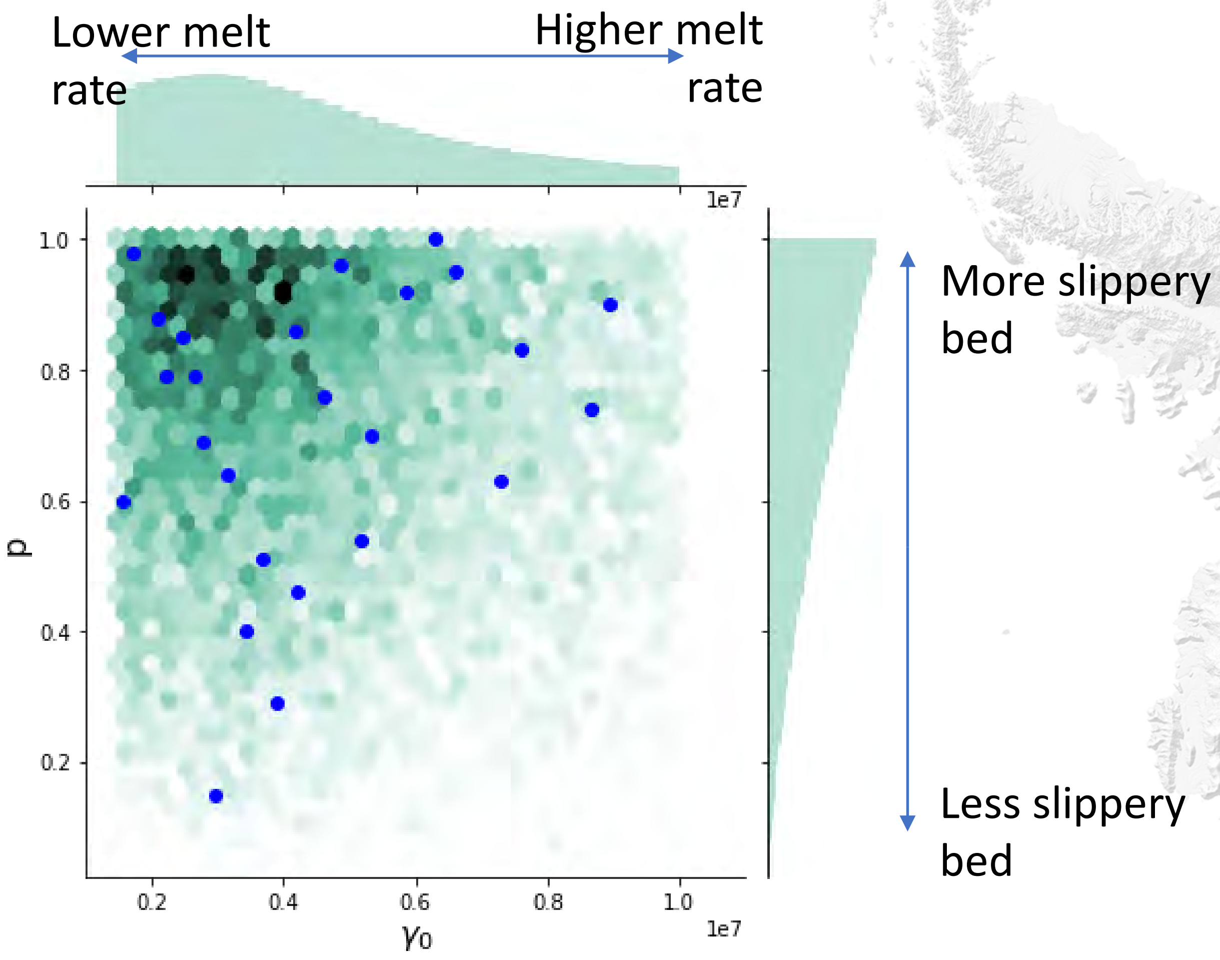
- **$\boldsymbol{\gamma}$** (a constant in the thermal forcing parameterization that describes how much melt occurs per ocean warming forcing) (ie. sensitivity to warming)

- **p** (impacts the basal slipperiness, particularly in marine-based ice)

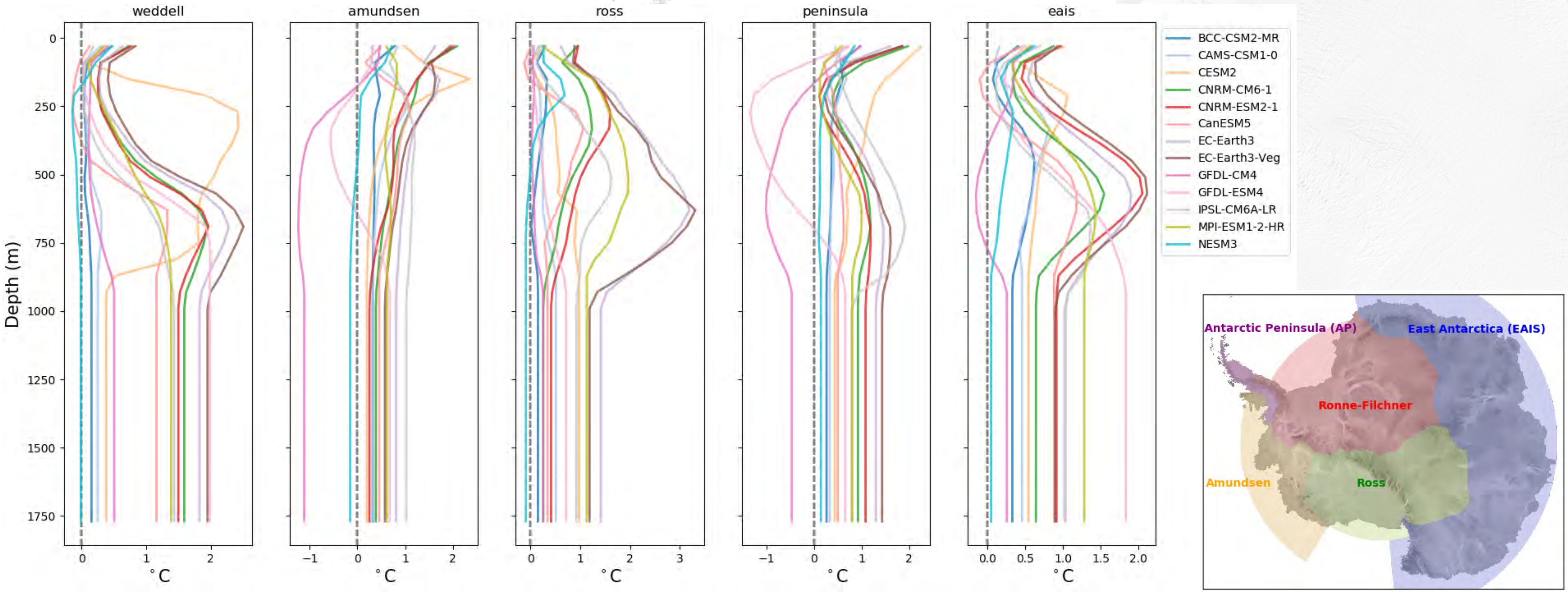
We ran a 25-member ensemble of spin-ups (10 - 20 ka) with the following combinations of p and $\boldsymbol{\gamma}$



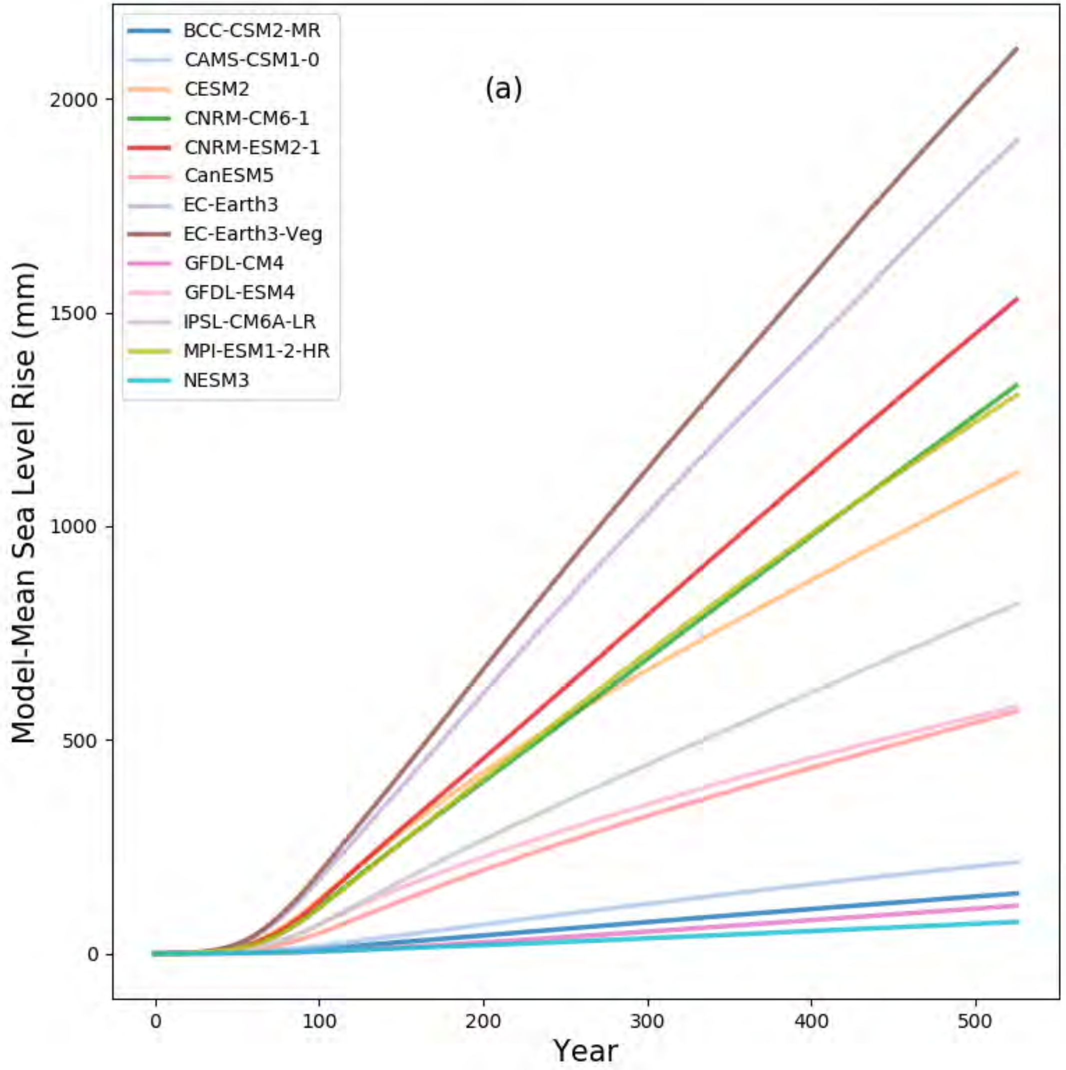
- The weighting strategy for p is stronger toward p=1.
  p ∈ [0:1]

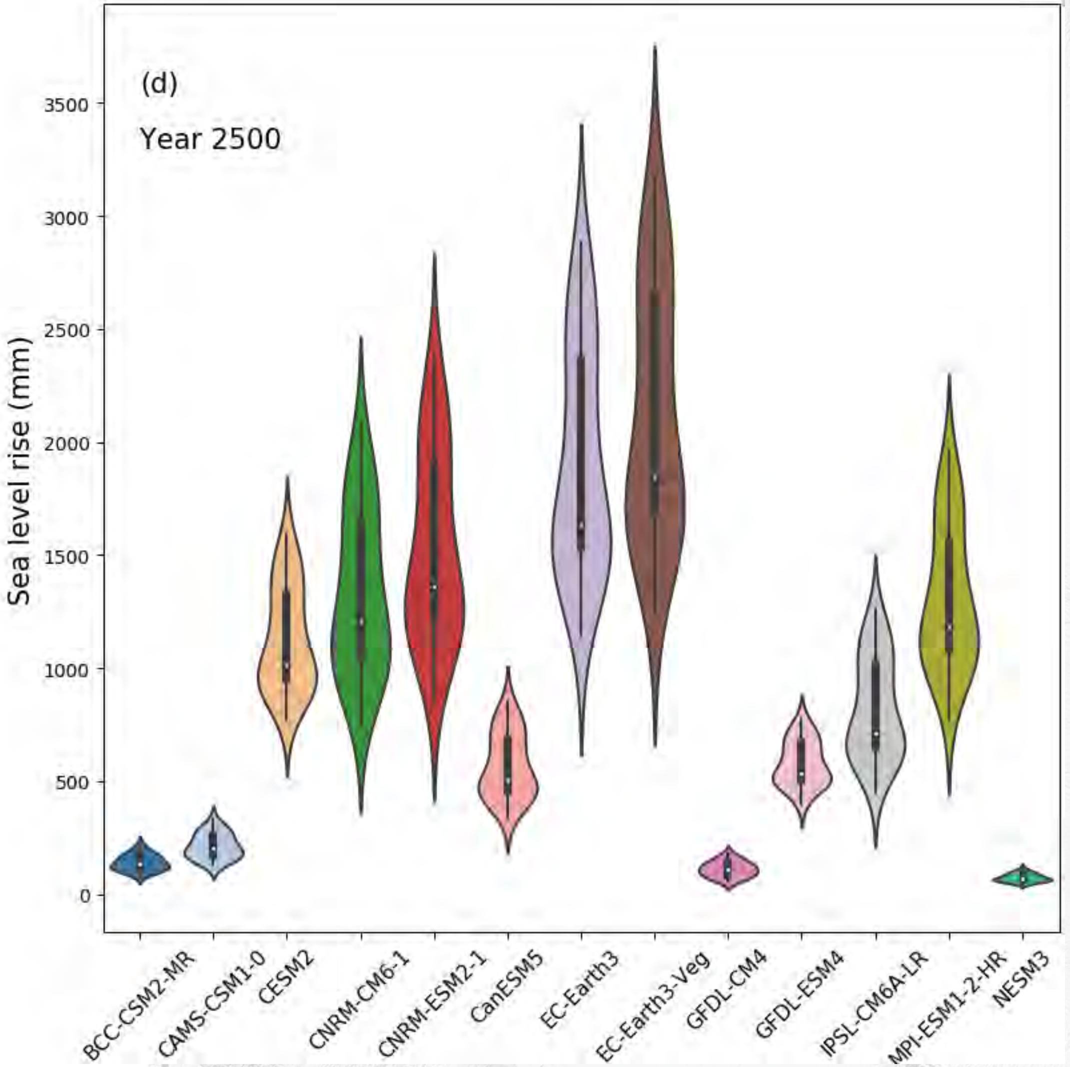
- The weighting strategy for $\boldsymbol{\gamma}$ is stronger toward the lower end of the range .
  $\boldsymbol{\gamma}$ ∈ [1.47e6 : 1e7]

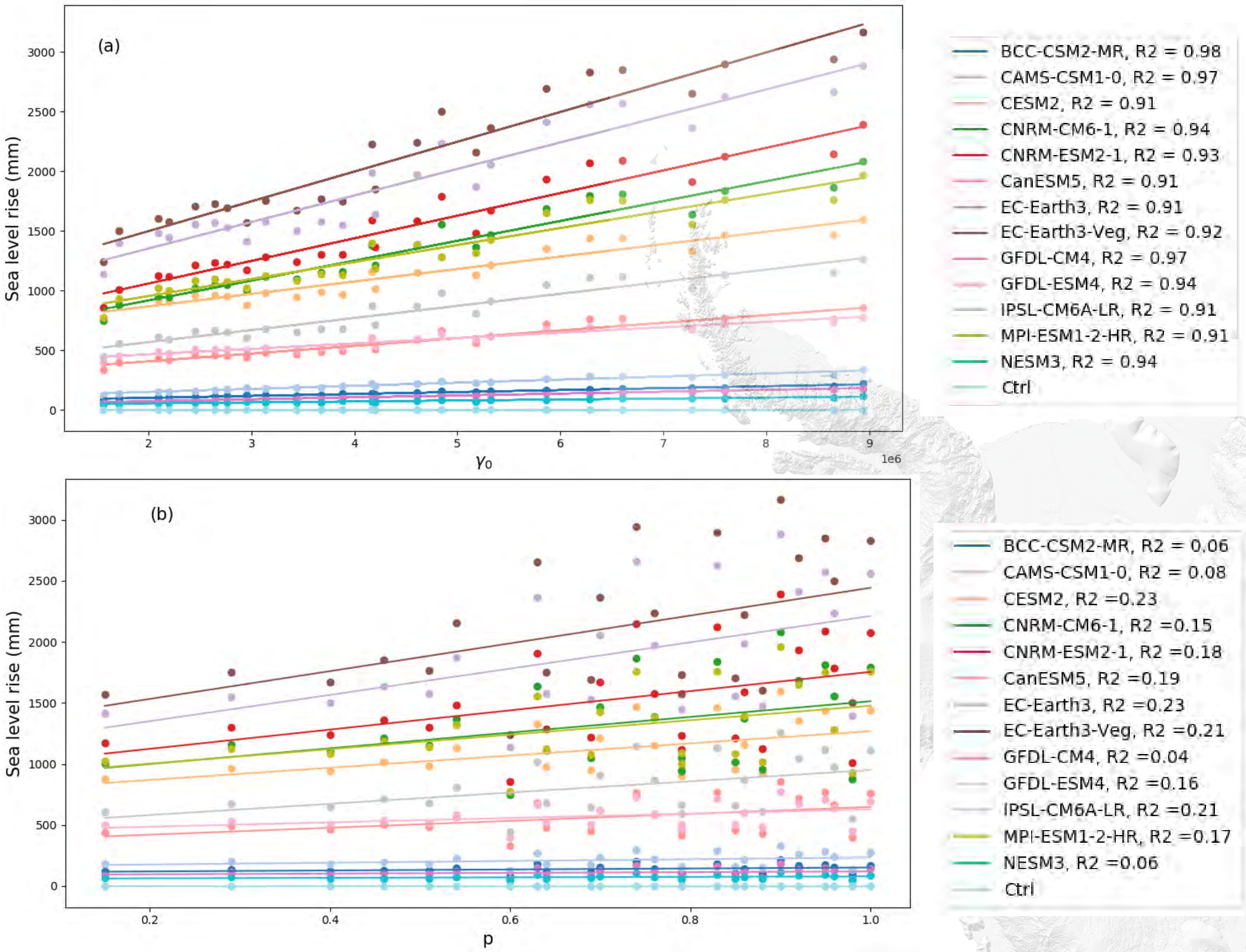
We force each CISM spin-up with thermal forcing anomalies derived from 13 CMIP6 models



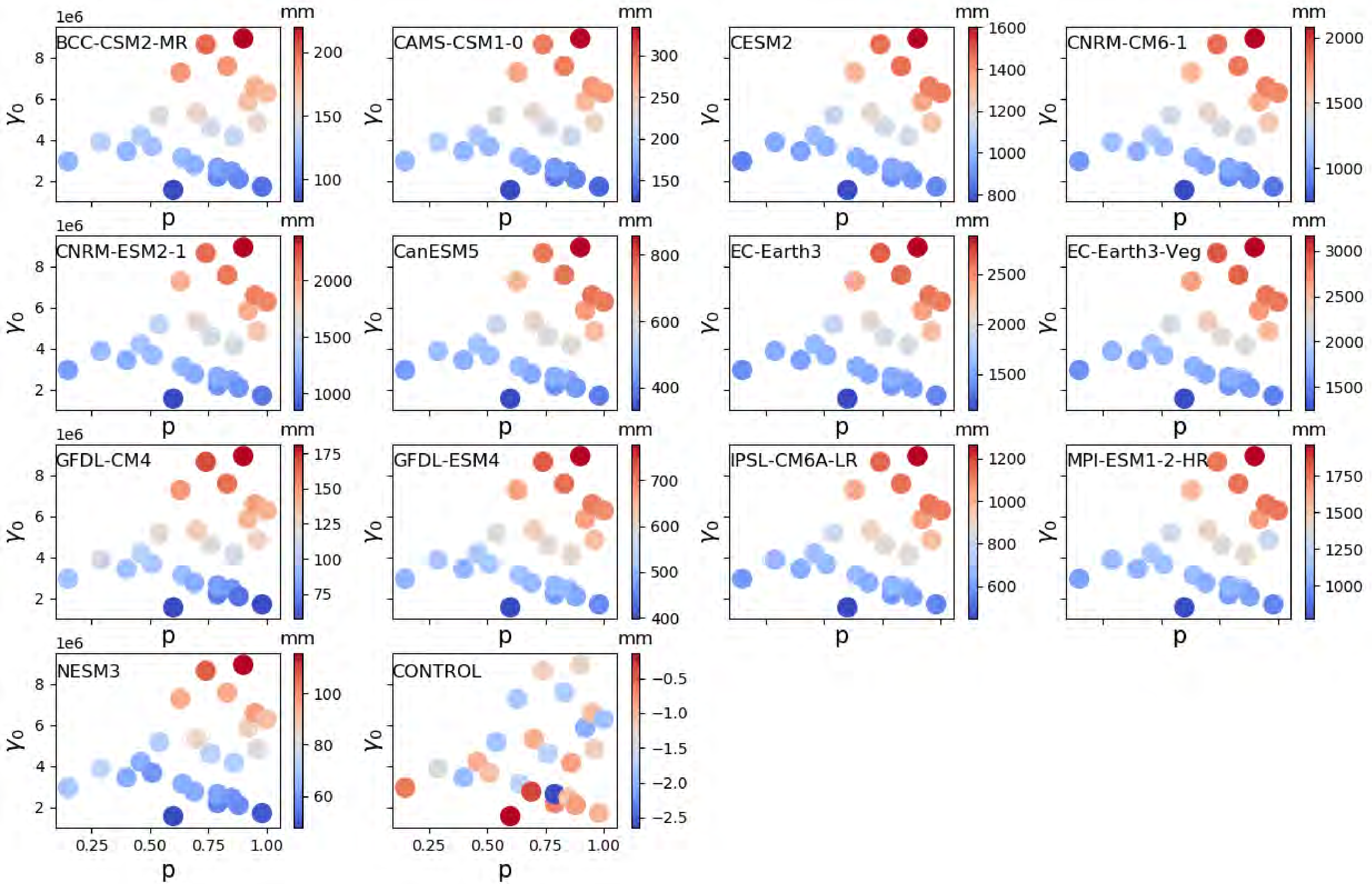
Final SLR after 500 years show large spread depending on forcing and on p & $\boldsymbol{\gamma}$ choice







Generally, continent-wide mass loss is more strongly controlled by $\boldsymbol{\gamma}$ than by p.



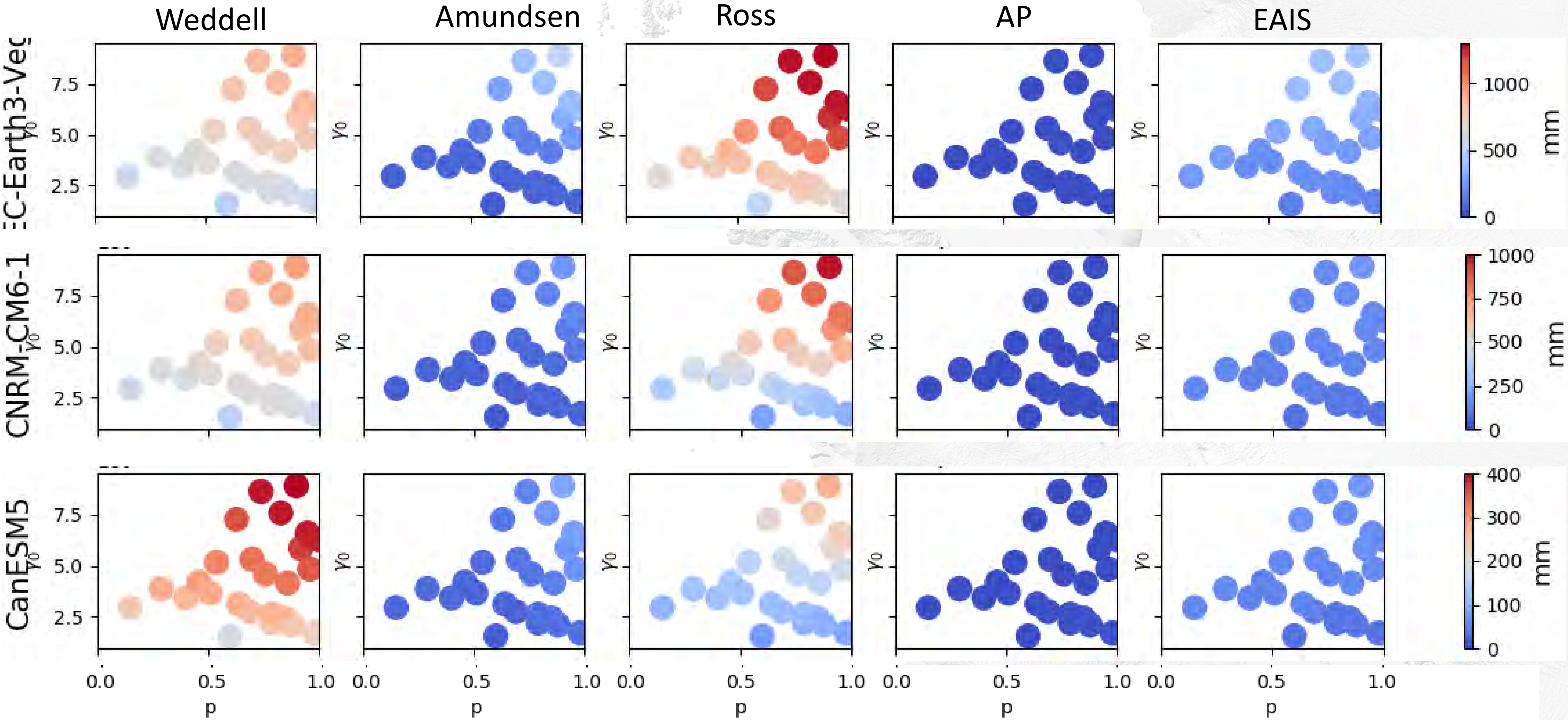
Sea level contributions can only become significant under a certain parameter space:

- p>0.6 and $\boldsymbol{\gamma} > 5\text{x}10^6$

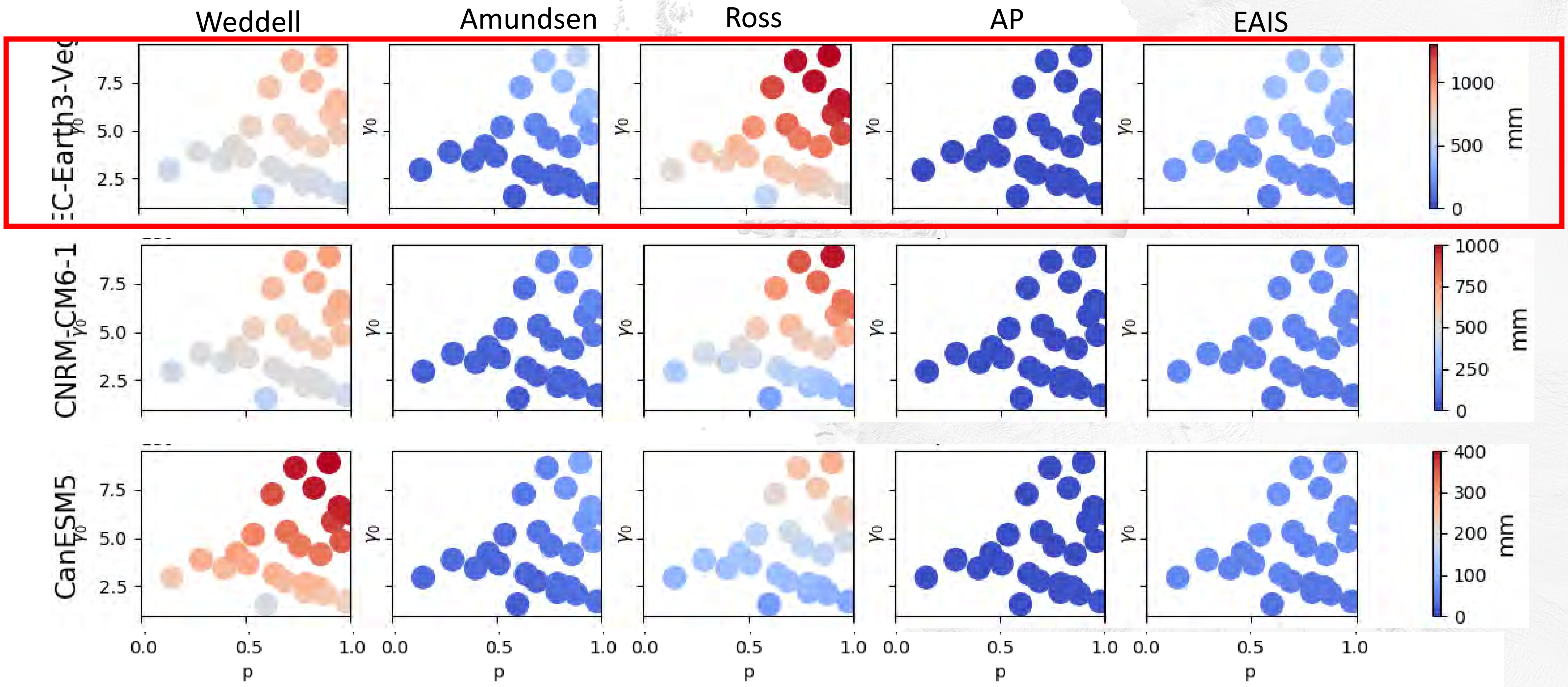
When p>0.6, the effective pressure is large enough to reduce the impact of the applied thermal forcing

When $\boldsymbol{\gamma} > 5\text{x}10^6$, melt rates become high enough to drive rapid mass loss

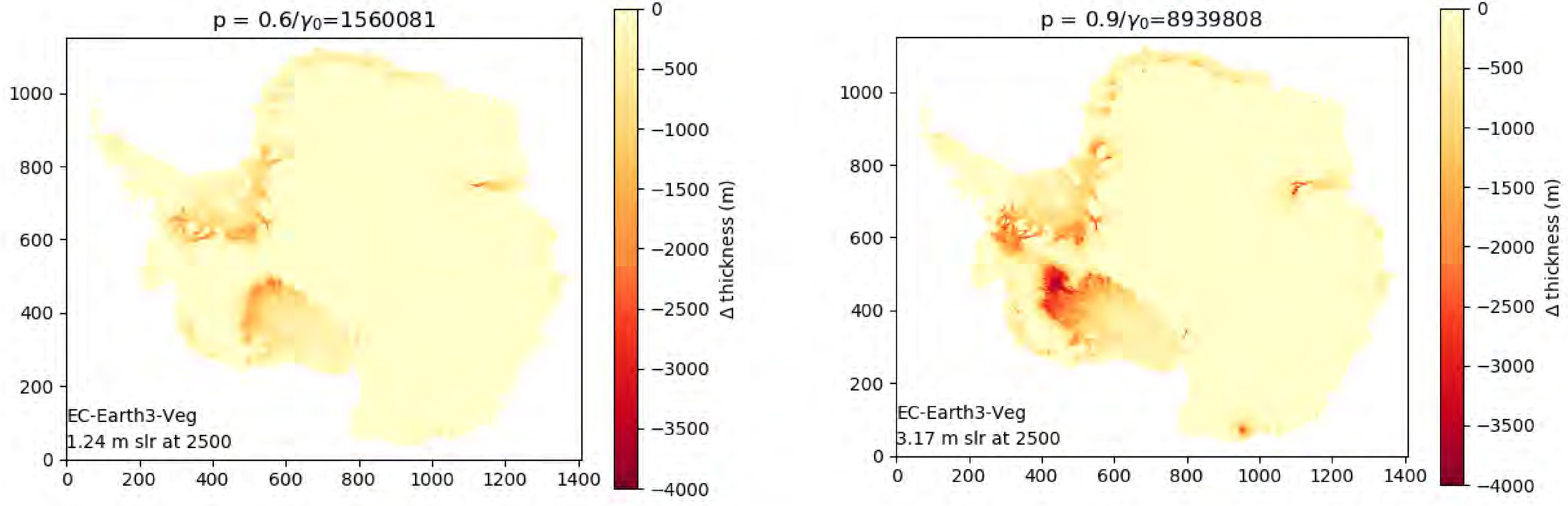
Regional analysis shows that the majority of mass loss in these experiments occurs in the Ross and Ronne-Filchner, little in the Amundsen



Regional break-down shows that the majority of mass loss in these experiments occurs in the Ross and Ronne-Filchner, little in the Amundsen

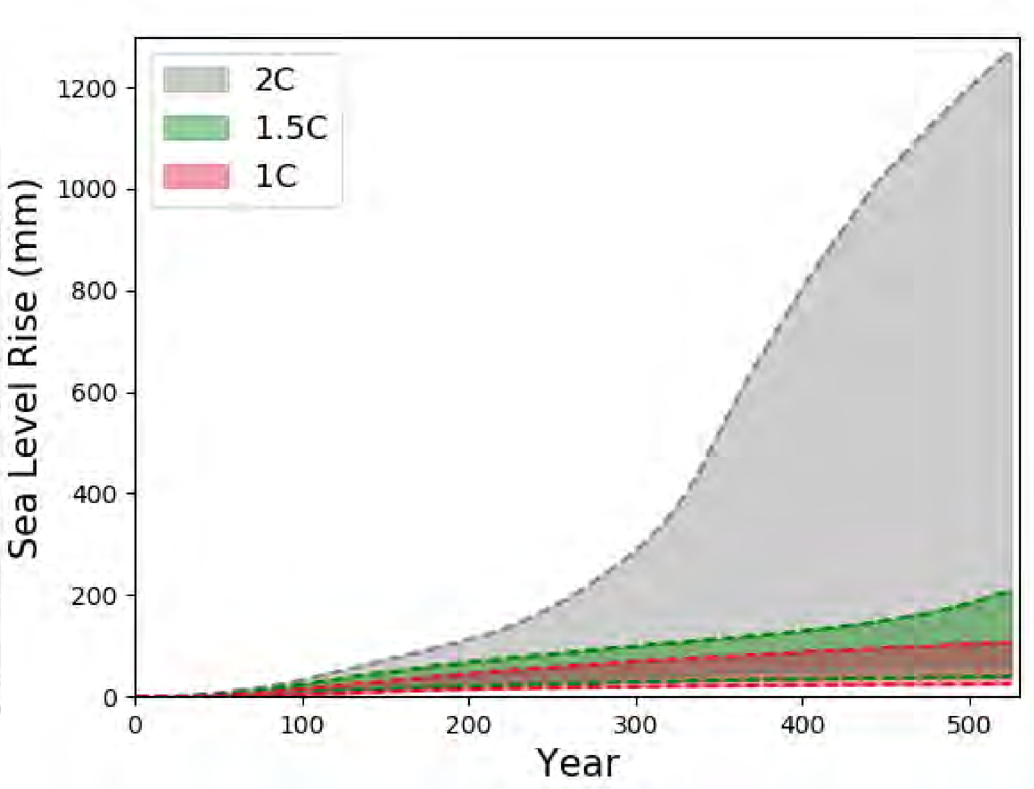


Up to 2m sea level rise difference within 500 years by choosing a different p & $\boldsymbol{\gamma}$



Synthetic Amundsen-focused experiments reveal a combined temperature threshold, and parameter space that results in large mass loss

- Synthetic Thermal Forcing in just the Amundsen of 1°C, 1.5°C and 2°C
- Similar parameter thresholds are discovered as in the CMIP6-forced runs: **Significant mass loss occurs only when $p>0.6$ and $\gamma>5\text{x}10^6$.**
- When TF anomalies between 1.5-2°C, mass loss can really take off because topographic pinning points can be overcome.



Key take-home messages

- Significant mass loss under the following conditions:
  - Low basal friction near the grounding line (p>0.6)
  - High sensitivity of melt rates to thermal forcing ($\boldsymbol{\gamma}$>5X10^5)
  - Sufficient thermal forcing anomalies
- The choice of p and $\boldsymbol{\gamma}$ alone can impact multi-century sea level predictions by up to 2m.
- Under CMIP6 forcing, Ross and Ronne-Filchner dominate continental mass loss.
- Large-scale Amundsen exhibits mix of ocean, ice and temperature thresholds that together determine the sensitivity of the sector.