A parametric study of sea level and grounding line projections in the Amundsen Sea sector for coupled solid Earth - ice sheet models

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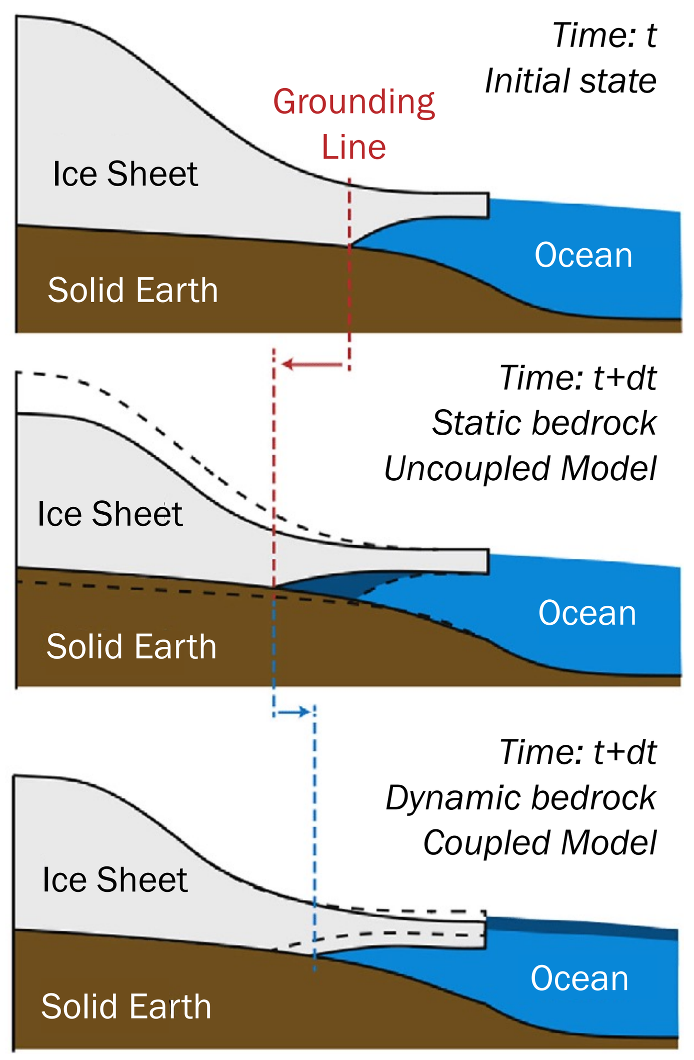
Sharing is encouraged

Introduction

Background & Motivation

Melting ice sheets induce (a) viscoelastic solid Earth uplift and (b) sea surface height change due to gravitational perturbation.
In turn, solid Earth uplift stabilizes the the ice sheets' grounding line.



Coupled solid Earth - ice sheet models have improved grounding line projections. Yet, the model resolutions and solid Earth parametrization necessary to fully capture these interactions remain unclear.

Figure 1 Schematic representation of the grounding line migration in a coupled solid Earth - ice sheet model, adapted from De Boer et al. 2017

Objectives

1. Quantify the stabilizing effect of realistic (viscoelastic) solid Earth
2. Determine coupled models' sensitivity to model resolutions and solid Earth parametrization

Methods

Software: Ice-sheet and Sea-level System Model (ISSM)
Area of study: Thwaites Glacier in the Amundsen sea sector.
Cluster: NASA Advanced Supercomputing (NAS) Electra Skylake nodes
Physics:

- Ice Sheets
  - Surface mass balance (fixed → CESM - SSP 585)
  - Ocean melt (Linear model → PICOP, Pelle et al. 2019)
- Solid Earth
  - Gravity, Rotation, Deformation Model (Adhikari et al. 2016)
  - Background Glacial Isostatic Adjustment (Caron et al. 2018)
  - Mantle rheology: Extended Burgers Material (EBM, Ivins et al. 2020)
- Sea level
  - Fixed sterodynamic change
  - Gravitationally consistent (SLPS, Larour et al. 2020)

Model Resolutions and Parameters: baseline values

Ice Sheet Spatial Resolution	Ice Sheet Time Step	Solid Earth Coupler Frequency	Solid Earth Max Love Number Degree
2 km	2 weeks	1 year	40000

Discussion

Realistic Solid Earth

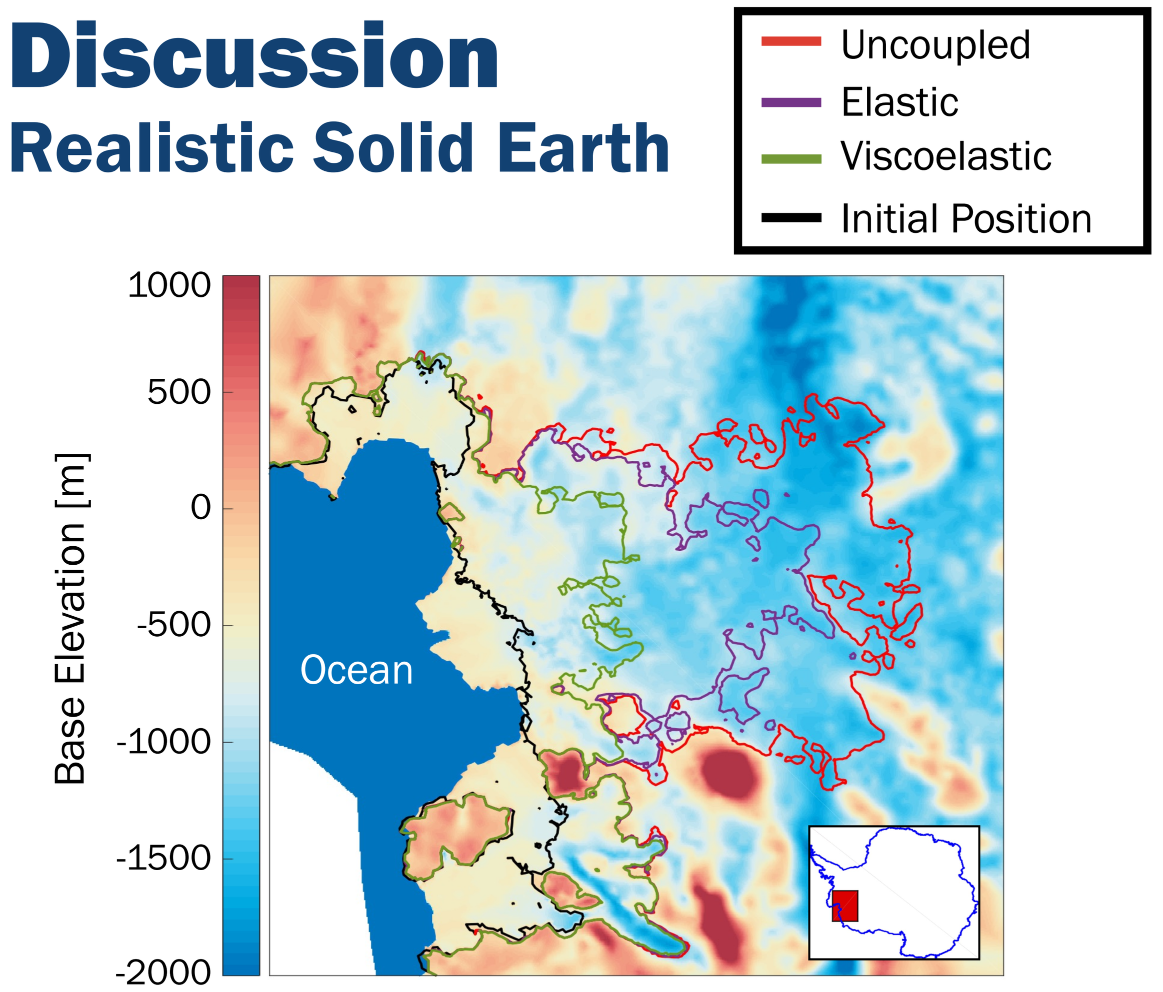


Figure 2 Grounding line projection at year 2350 for Thwaites and Pine Island Glacier (PIG)

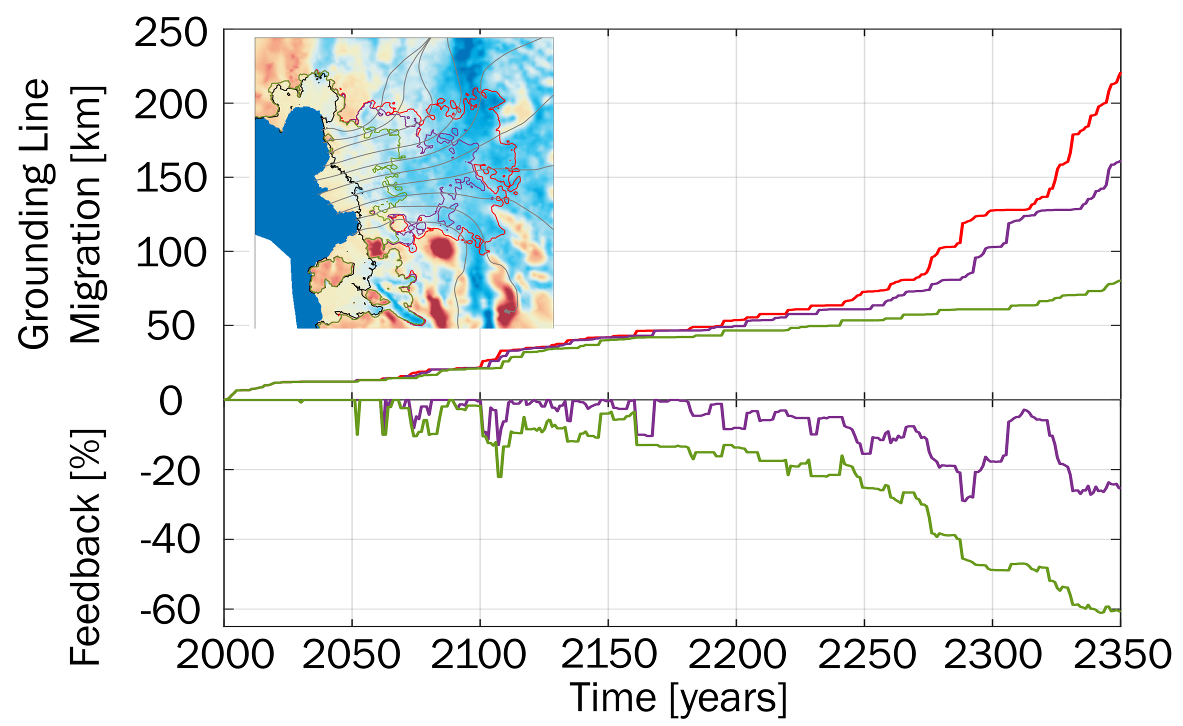


Figure 3 Average grounding line migration (top) and corresponding solid Earth feedback (bottom) over 10 flowlines (gray lines on inset)

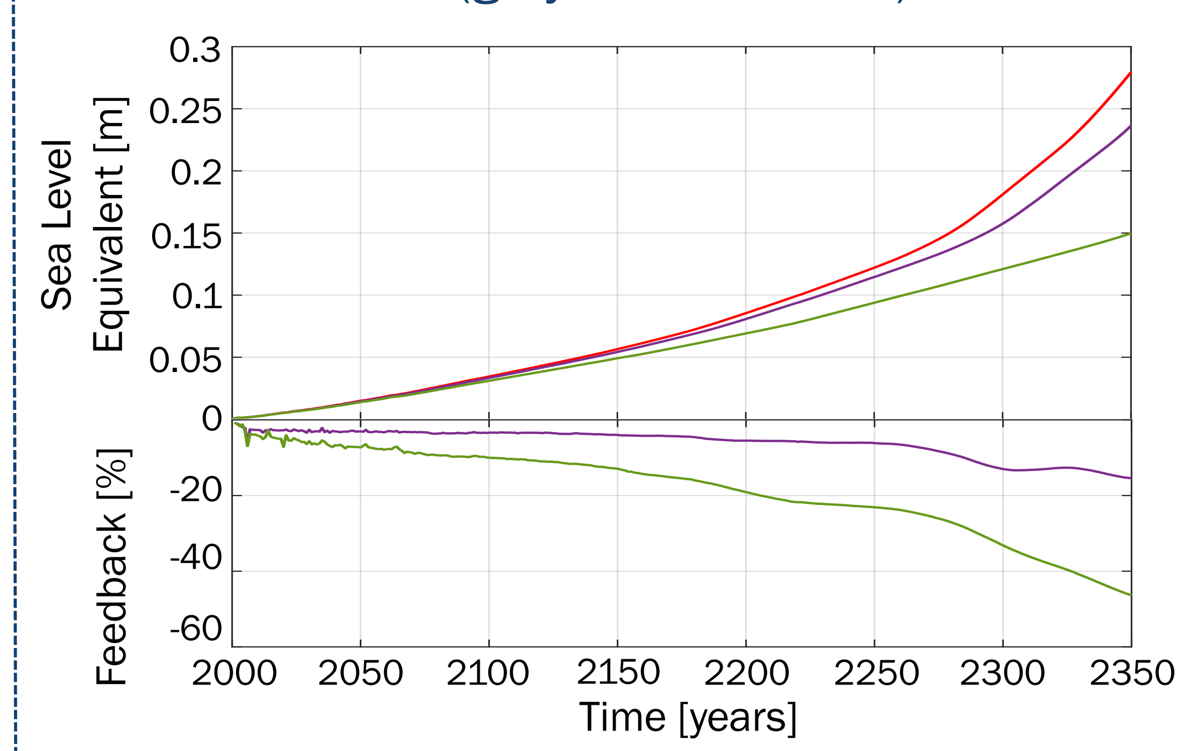


Figure 4 Sea level change contribution (top) and corresponding solid Earth feedback (bottom)

Bedrock topography

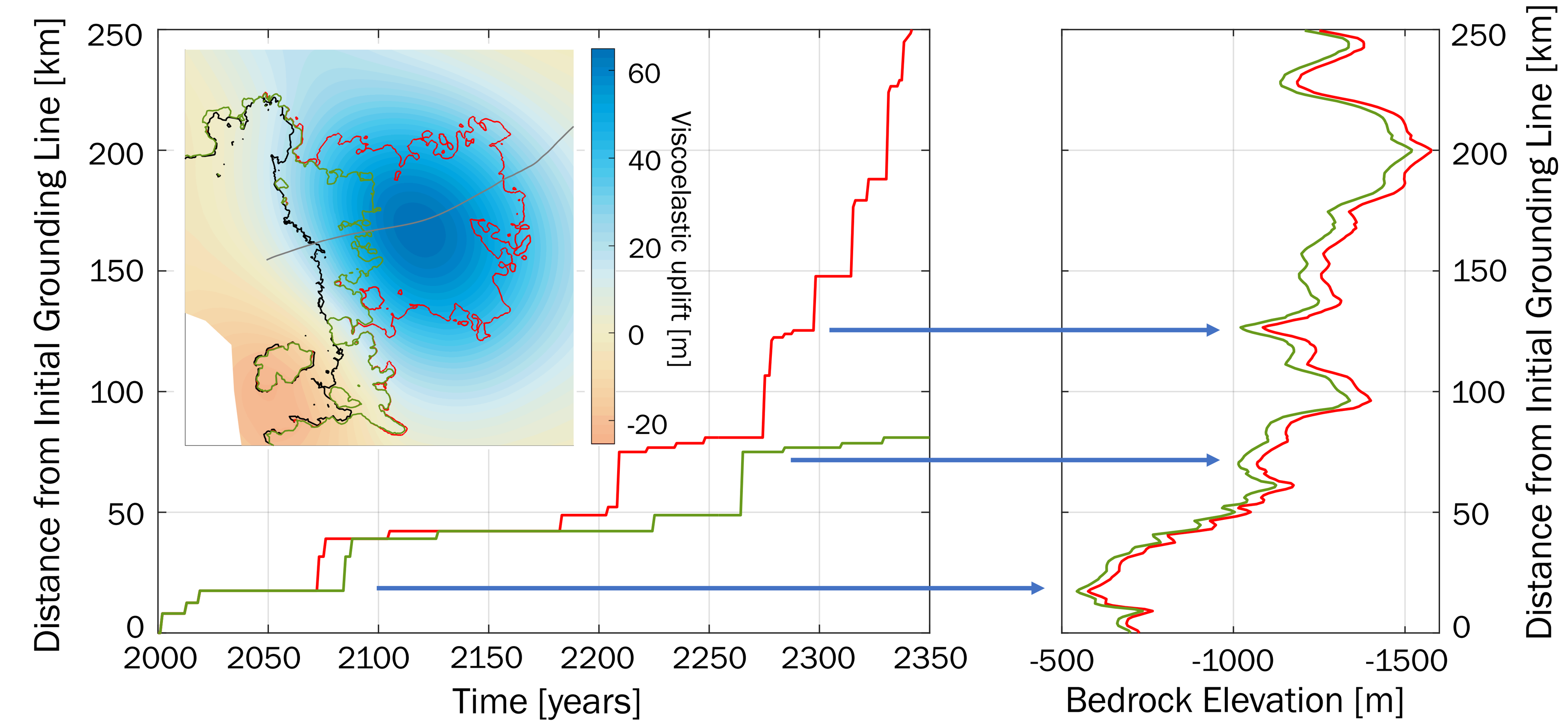


Figure 5 Grounding line migration (left) & bedrock at year 2350 (right) along the center flowline (gray on inset). The inset shows viscoelastic bed uplift at year 2350

Model Sensitivity

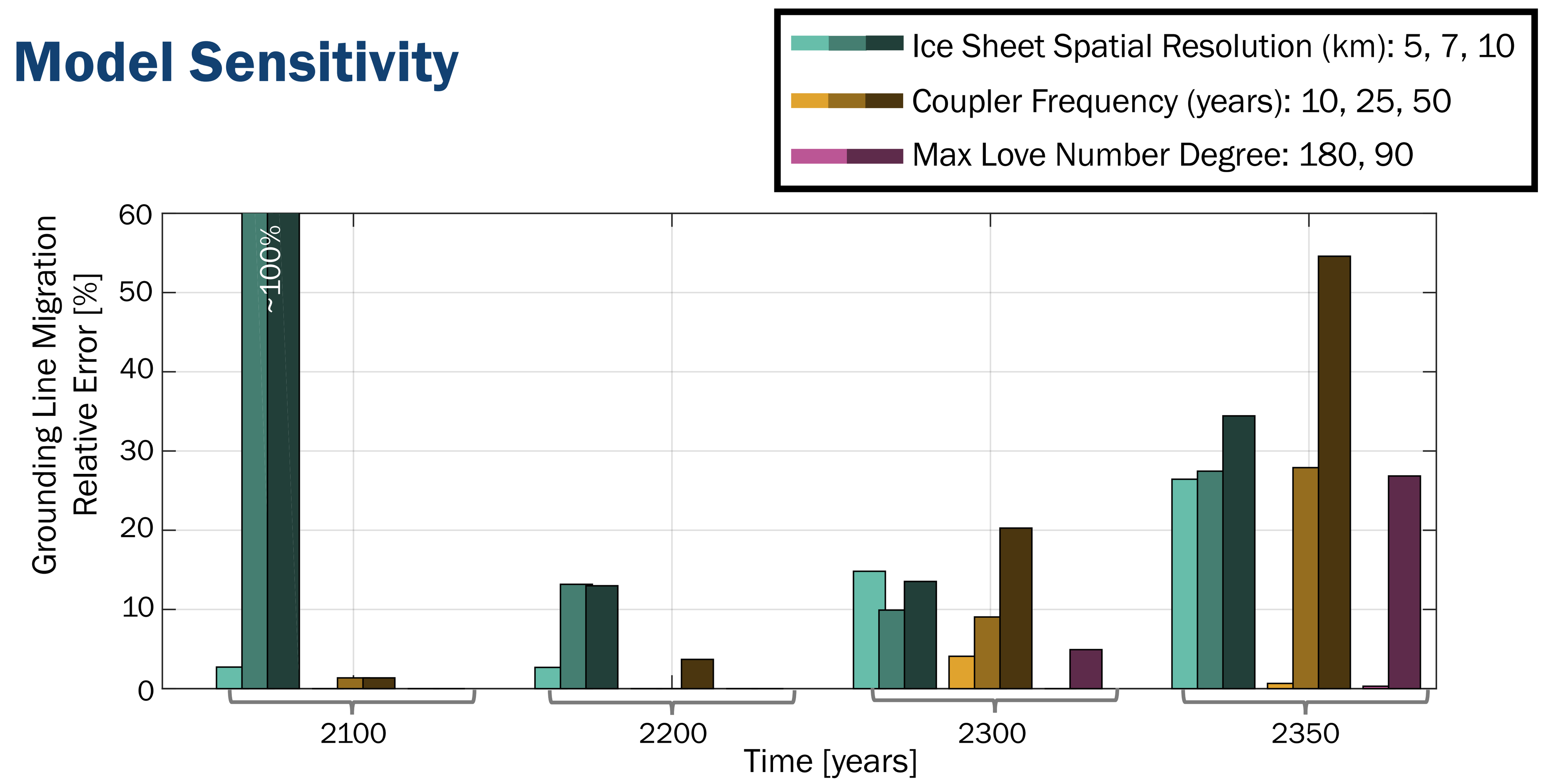


Figure 6 Relative error to baseline for Thwaites' grounding line migration

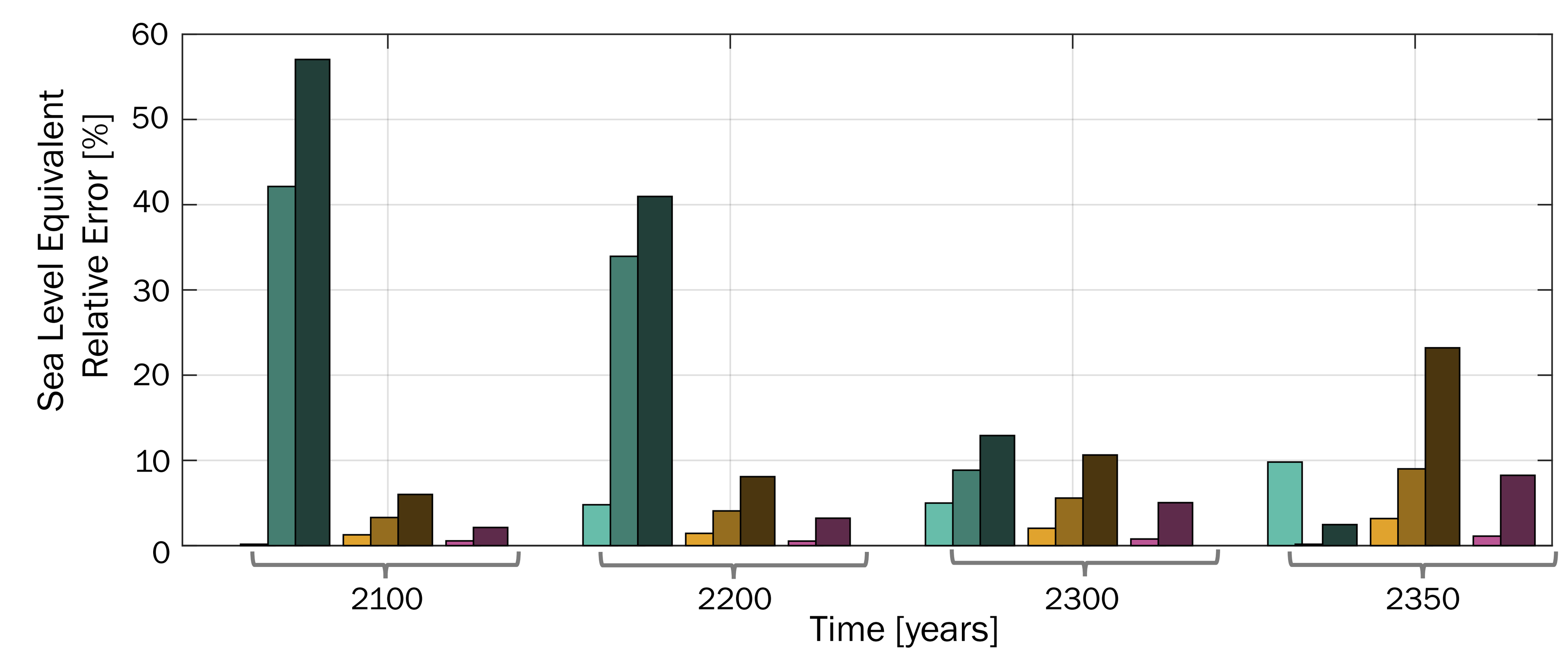


Figure 7 Relative error to baseline for Thwaites & PIG sea level change contribution

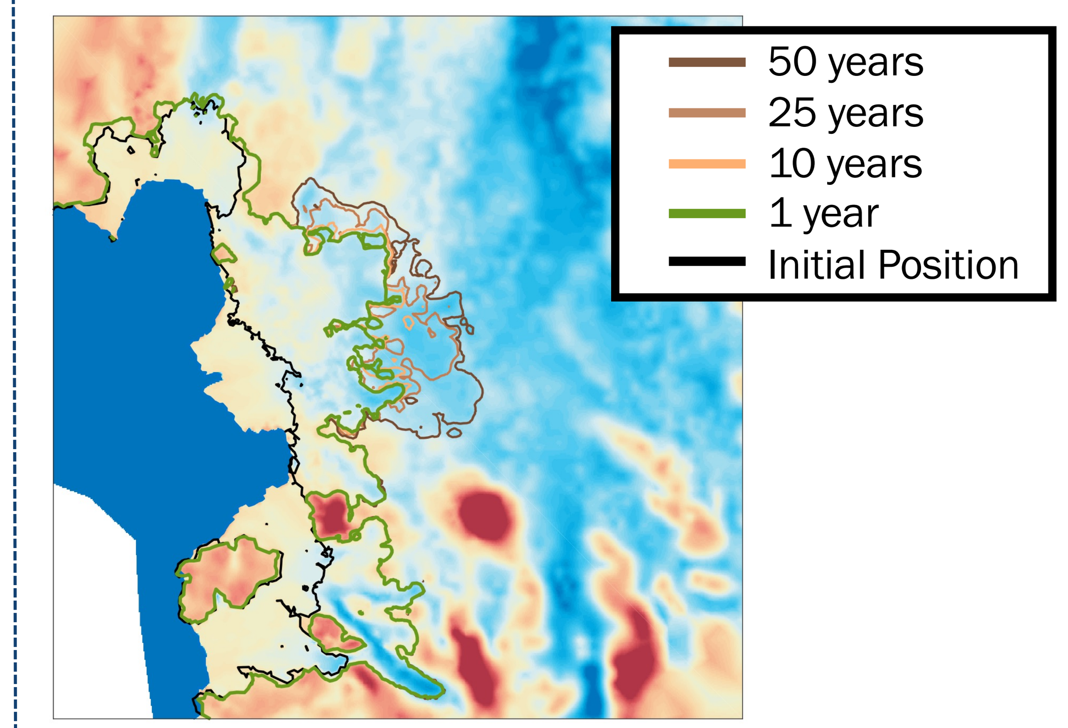


Figure 8 Grounding line at year 2350 for different coupler frequencies

Conclusion

Work in Progress

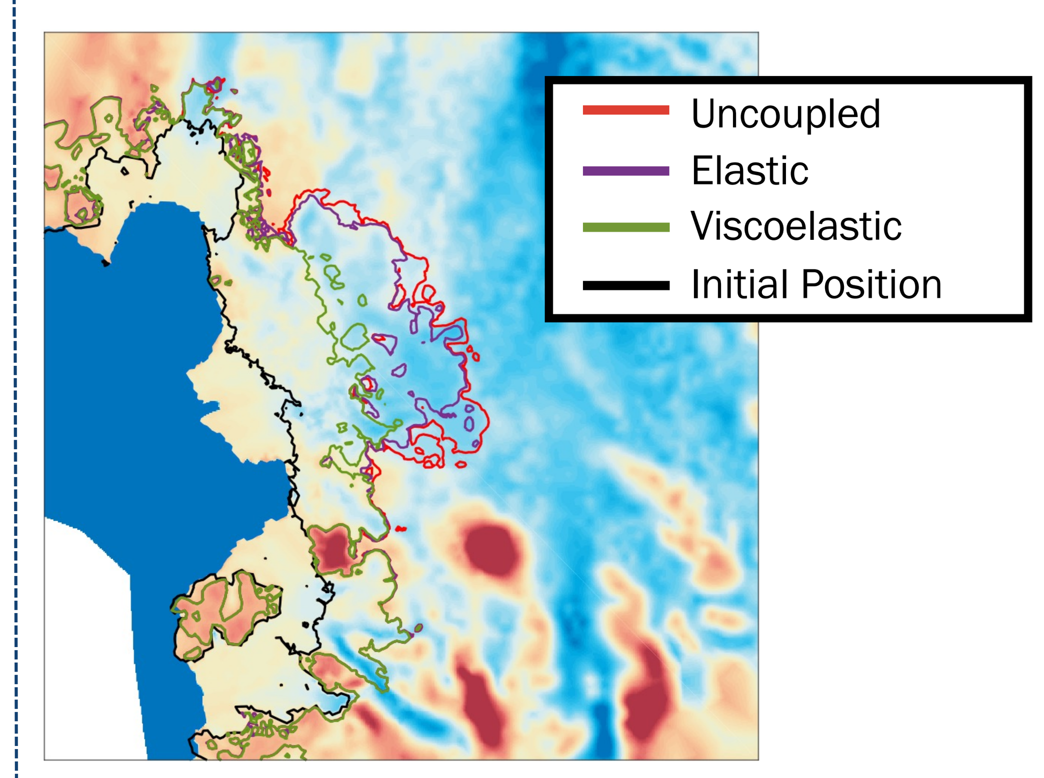


Figure 9 Grounding line at year 2350 with PICOP ocean melt and CESM climatology

Takeaways

- Viscoelastic solid Earth slows down Thwaites' collapse with negative feedbacks at year 2350:
  - 61% on grounding line (vs. 25% for Elastic)
  - 46% on sea level contribution (vs. 19% for Elastic)
- Solid Earth uplift reinforces the ice sheet's anchoring on bedrock topographic peaks.
- Model sensitivity is governed by ice sheet spatial resolution in the short term. In the longer term (after 2200) the studied solid Earth parameters become equally important.
- Necessary conditions on solid Earth parametrization to keep error to baseline below 5%:
  - Coupler frequency ≤ 10 year
  - Max love number degree ≥180