ISMIP-based projections of ocean-forced Antarctic ice loss

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Ice Sheet Model Intercomparison Project for CMIP6 (ISMIP6)

- **Standalone ice sheet experiments for Greenland and Antarctica,** using CMIP6 model-derived forcing to estimate past and future sea level rise and explore uncertainty

- **Coupled climate – ice sheet experiments** to explore ice sheet impacts and feedbacks

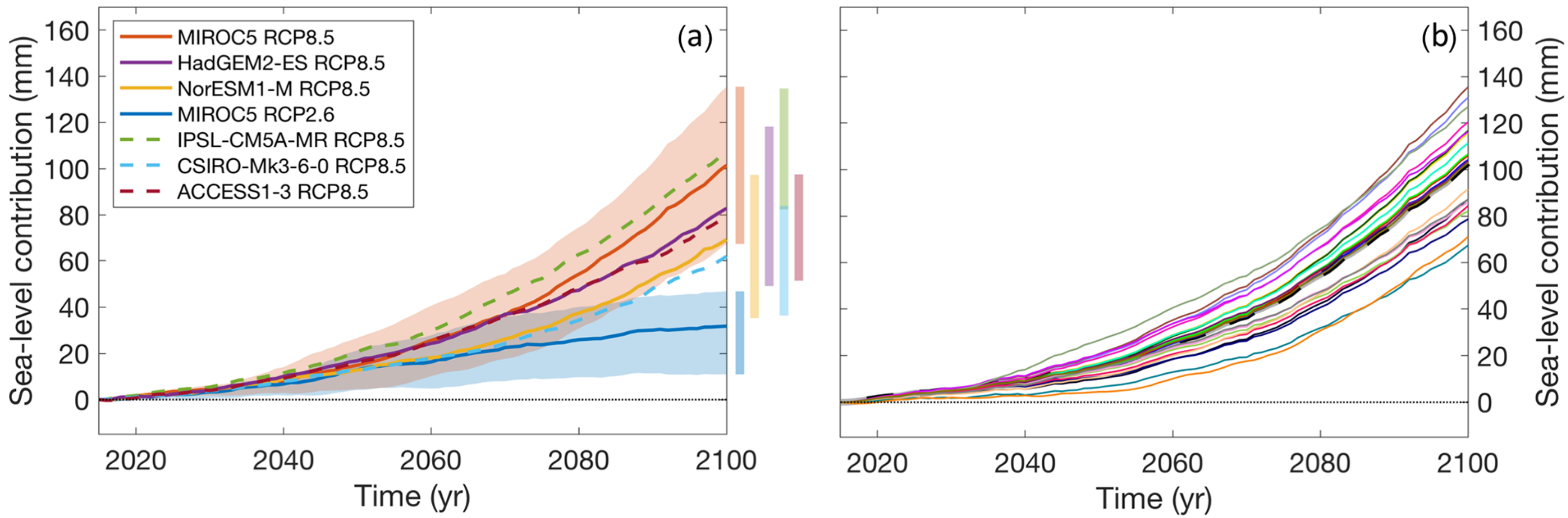
ISMIP6 project leads: Sophie Nowicki (overall), Heiko Goelzer (Greenland), Hélène Seroussi (Antarctica)

http://www.climate-cryosphere.org/wiki/index.php?title=ISMIP6_wiki_page

ISMIP6 Greenland projections

Goelzer et al. (TC, 2020)

- 21 submissions from 14 modeling groups; atmosphere and ocean forcing derived from CMIP models running RCP 2.6 and 8.5 scenarios
- SLR by 2100: **32 ± 17 mm** (RCP2.6), **90 ± 50 mm (**RCP 8.5), mainly from increased surface ablation, with good agreement across models

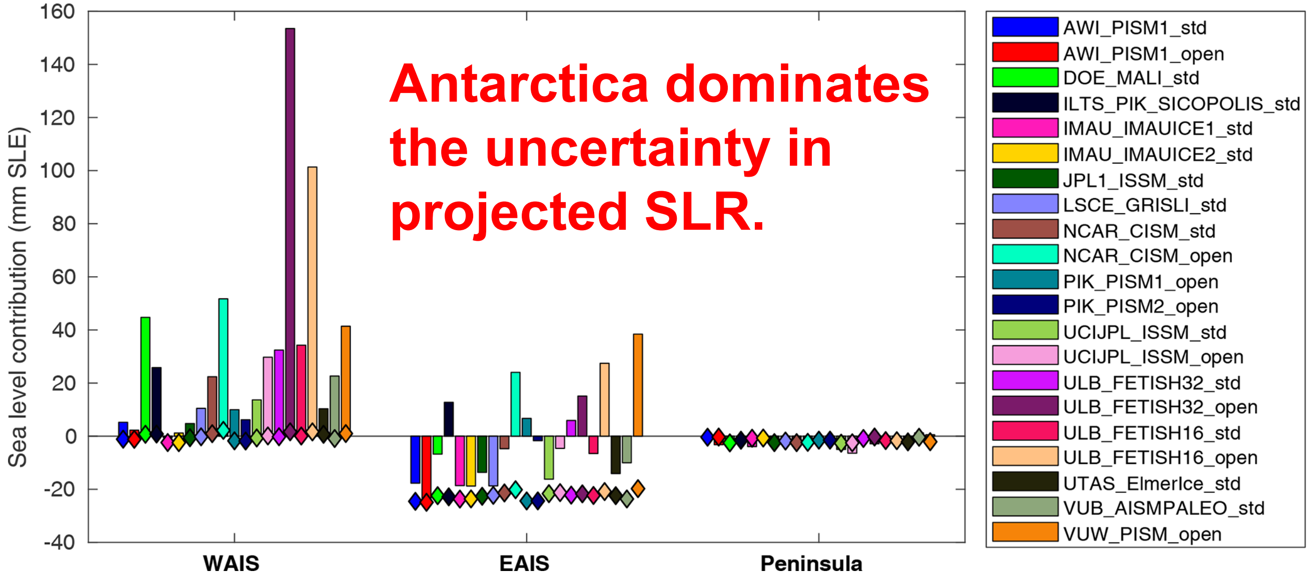


Ensemble mean sea-level projections. Left: All climate models. Right: MIROC-RCP8.5.

ISMIP6 Antarctic projections

Seroussi et al. (TC, 2020)

- 16 submissions from 13 modeling groups; atmosphere and ocean forcing derived from CMIP models running RCP 2.6 and 8.5 scenarios
- Mass loss **up to 180 mm SLE** by 2100 from **West Antarctic Ice Sheet**
- Mass change of **-61 to 83 mm SLE** for East Antarctic Ice Sheet (more snowfall)
- Large uncertainty in **climate forcing** and **ocean-forced melting**

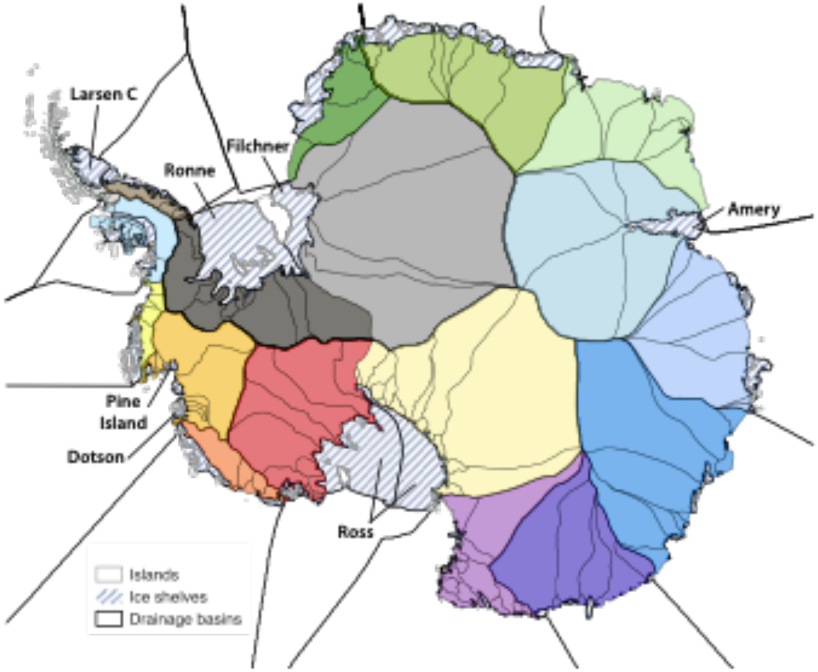


Regional change in ice mass above flotation (mm SLE) under RCP 8.5 forcing from NorESM

Ocean-forced Antarctic projections with CISM

- **Hypothesis:** Ocean warming that is projected to occur by 2100 could drive long-term retreat in West Antarctica, with most SLR after 2100.
- **Method:** Using CISM in the ISMIP6 framework, find the range of multi-century (1950-2500) retreat under a variety of **basal melt schemes** (more or less sensitive to warming near the grounding line) and **ocean-only forcing scenarios** (thermal forcing anomaly from 6 ESMs).

Lipscomb, W. H., Leguy, G. R., Jourdain, N. C., Asay-Davis, X. A., Seroussi, H. and Nowicki, S.: ISMIP6-based projections of ocean-forced Antarctic Ice Sheet evolution using the Community Ice Sheet Model, The Cryosphere, 15, https://doi.org/10.5194/tc-15-1-2021, 2021.

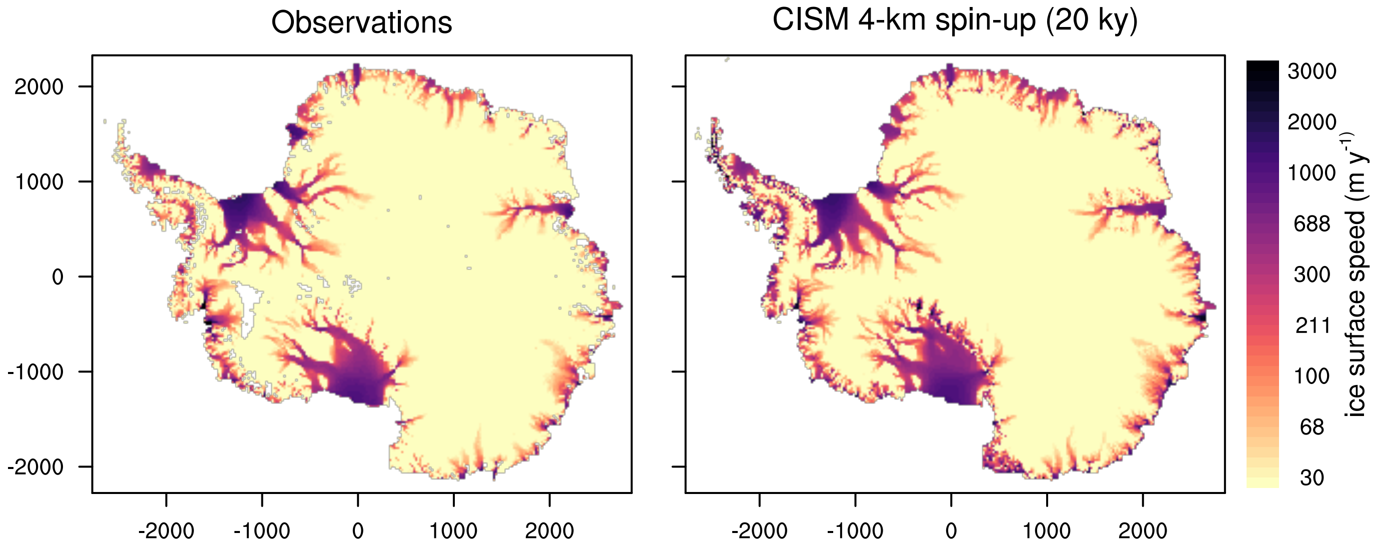


Antarctic sectors (Jourdain et al., 2020). One thermal forcing parameter is tuned in each sector to fit modern grounding-line locations.

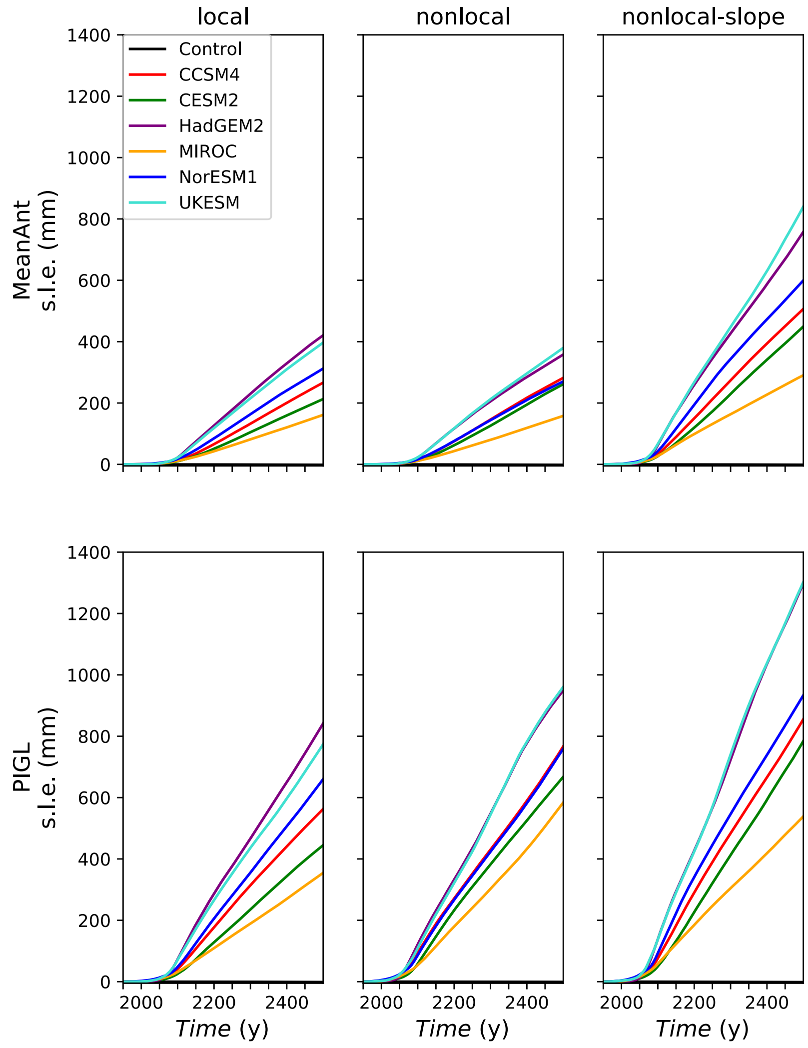
CISM Antarctic projections: Spin-up

- SMB from regional climate model (RACMO2); ocean thermal forcing from modern climatology (extrapolated beneath ice shelves)
- For each basal melt scheme, adjust basal friction parameters (beneath grounded ice) and basal melting parameters (beneath ice shelves) to match observed ice thickness.
- At the end of each 20-kyr spin-up, there is good agreement with observed ice thickness and surface speed.

Surface ice speed from observations (left) and 20 ky CISM spin-up (right).



CISM Antarctic projections: SLR by 2500



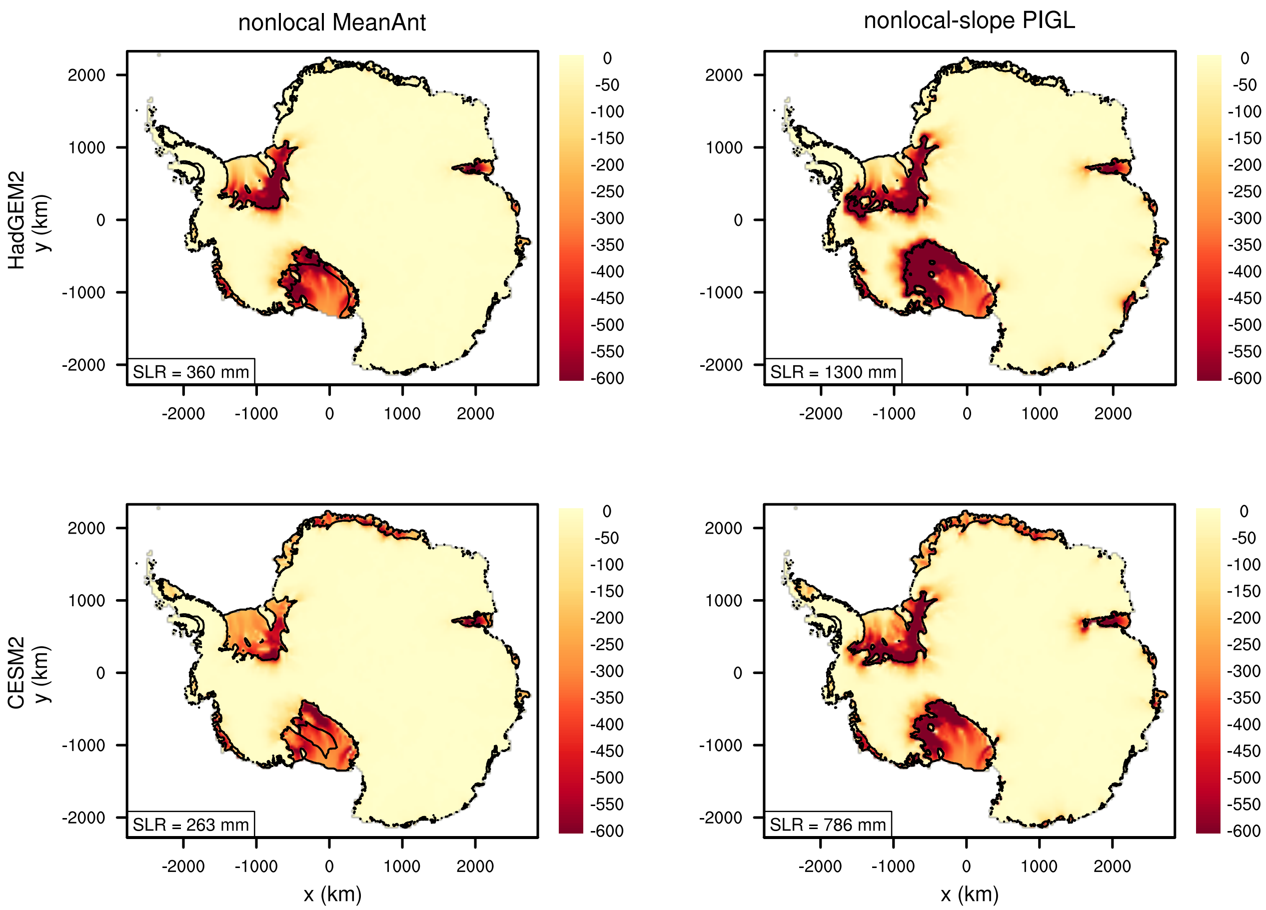
Melt scheme calibration.
Top: Lower sensitivity of melt rate to thermal forcing.
Bottom: Higher sensitivity.

Melt scheme physics.
Left: Depends on local forcing only.
Center: Depends on both local and regional forcing.
Right: Depends on local and regional forcing, and on basal slope.

In each panel, there is one line per climate model, plus a control.

SLR by 2500 ranges from 150 mm to 1300 mm.

CISM Antarctic projections: Ice thinning and retreat



Ice thickness change (m) by 2500.

Left: Low melt sensitivity.

Right: High sensitivity.

Top : HadGEM2 (high ocean warming).

Bottom: CESM2 (moderate ocean warming).

Most of the thinning and grounding-line retreat are in the **Ross** and **Filchner-Ronne** sectors.

Not much retreat in the **Amundsen** sector.

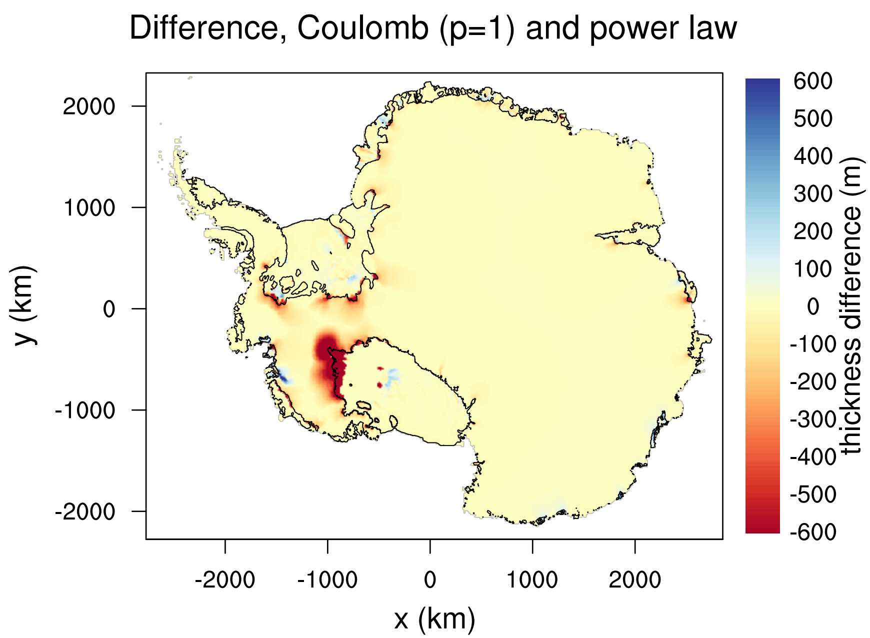
CISM Antarctic projections: Sensitivity

Low sensitivity to **stress balance approximation** (depth-integrated v. 3D)

Moderate sensitivity to **grid resolution** (2, 4 and 8 km) and **prescribed ice-shelf collapse**

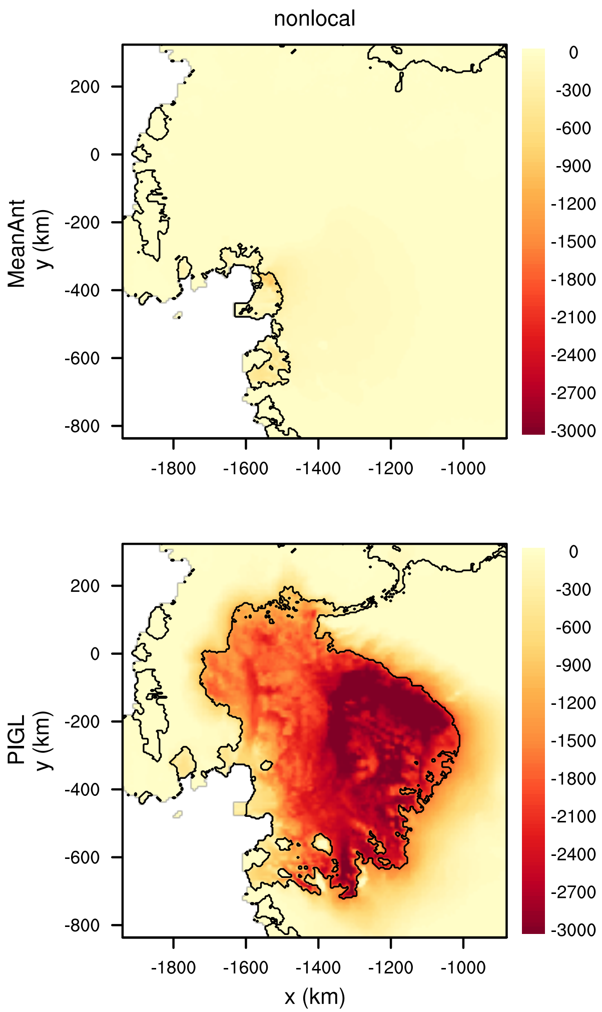
High sensitivity to the **basal friction law**

- *Power law*: Large friction near grounding line (standard runs)
- *Coulomb law*: Zero friction at grounding line

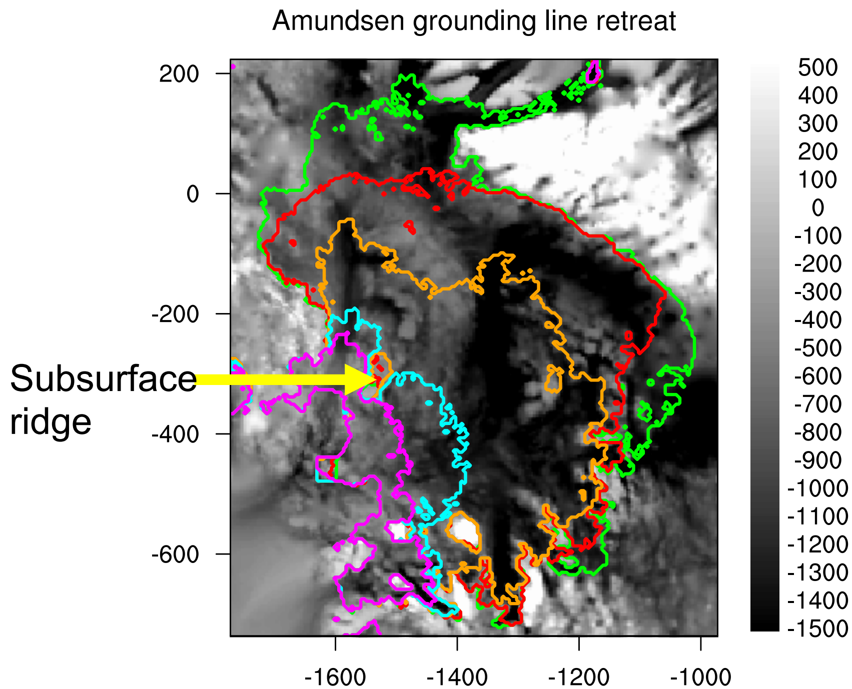


Difference in ice thickness (m) at year 2500 between runs with Coulomb basal friction and power-law friction. These runs use a high-sensitivity melt scheme and high-warming climate model (UKESM).

Threshold behavior for the Amundsen sector



Ice thickness change (m) by 2500



In most runs (upper left), Amundsen retreat is modest.

In some runs with Coulomb friction and high melt sensitivity (lower left, upper right), the Amundsen sector collapses, raising sea level by > 1 m.

Once the ice retreats past a shallow ridge between Pine Island and Thwaites Glaciers, collapse is inevitable.

Conclusions

- Antarctic mass loss in standalone ice sheet models is sensitive to poorly constrained factors in basal melt parameterizations and basal friction laws, and to the climate model providing the thermal forcing.
- Projected SLR by 2500 varies by more than an order of magnitude (150 mm to ~3 m) between low-end and high-end projections.
- Ice in several sectors (Ross, Filchner-Ronne, and possibly Amundsen) could retreat irreversibly over several centuries, as a result of ocean warming that could occur by 2100.

Future work

- Use ice velocity data (in addition to ice thickness) to better constrain the initial state.
- Develop more realistic, physics-based schemes for basal friction, iceberg calving, and sub-ice-shelf melting.
- Follow-up ISMIP6 project: Long-term Antarctic projections and thresholds
- Support Antarctica and multiple ice sheets in CESM (talk by Bill Sacks)
    - We can then run Antarctic projections with CISM forced by temperature and salinity from POP, and later from MOM6.
    - The coarse resolution of global ocean models remains a challenge.