Summary of the Cryosphere v1 Simulation Campaign Overview Manuscript

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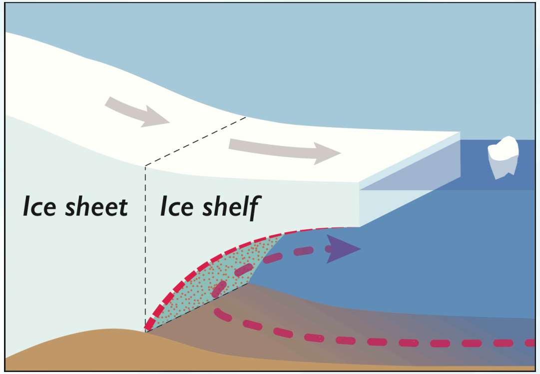
Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

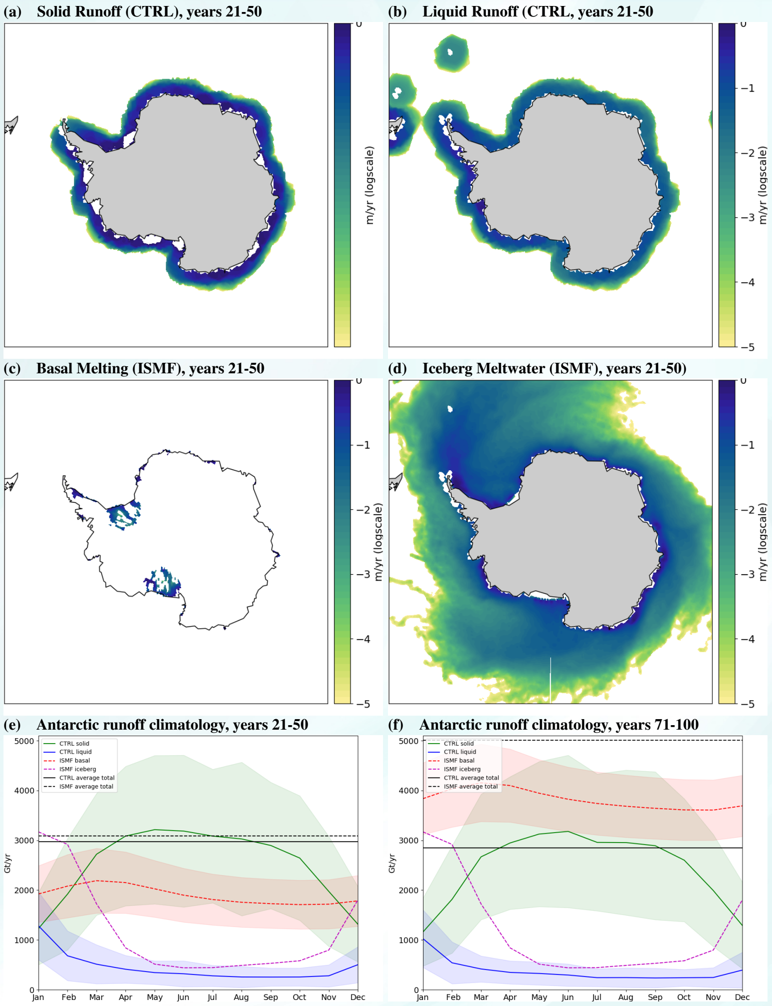
Overview of v1 Cryosphere Simulation Campaign

- E3SM v1 Cryosphere Simulation Campaign began March 2019
- Due to persistent issues in achieving a stable, pre-industrial climate, low-resolution simulation campaign continued through August 2020
- All Cryosphere simulations utilize an ocean mesh extended beneath Antarctic ice shelves, allowing for computation of ice-shelf basal melt (ISMF) rates
- Primary low-resolution simulations in overview paper:
  - B-ISMF: Fully coupled, pre-industrial control with ISMF and standard v1 ocean parameterizations (i.e. constant GM); 100 years
  - B-MGM: Fully coupled, pre-industrial control with ISMF and Modified mesoscale ocean eddy parameterization; 100 years
  - B-CTRL: Fully coupled, pre-industrial control with standard Antarctic runoff, no ISMF, as baseline; 100 years

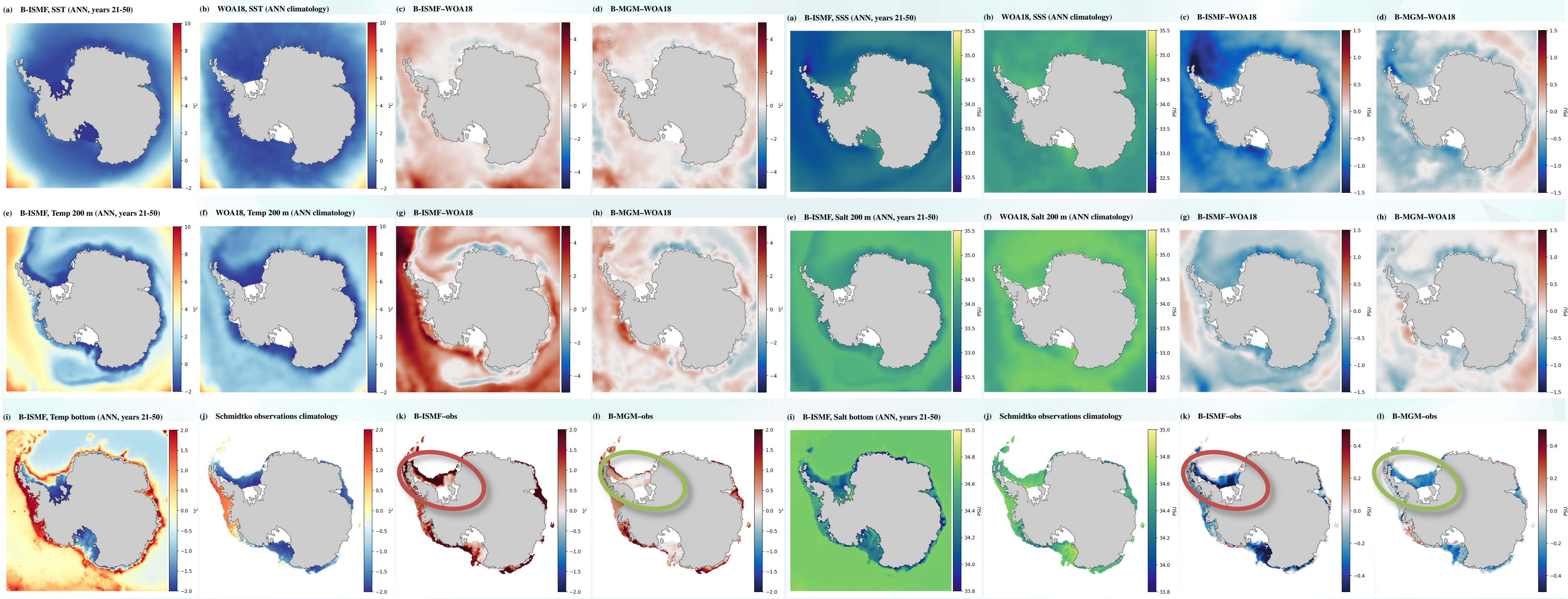


Antarctic runoff

- Cryosphere simulations replace standard Antarctic runoff with prognostic ice-shelf basal melt rates and prescribed iceberg forcing, to avoid ‘double-counting’.
- Spatial maps of standard solid and liquid runoff compared to prognostic basal melting and iceberg melting demonstrate spatial biases of runoff in standard approach.
- Time series of runoff terms also demonstrate seasonal biases in the timings of these terms.

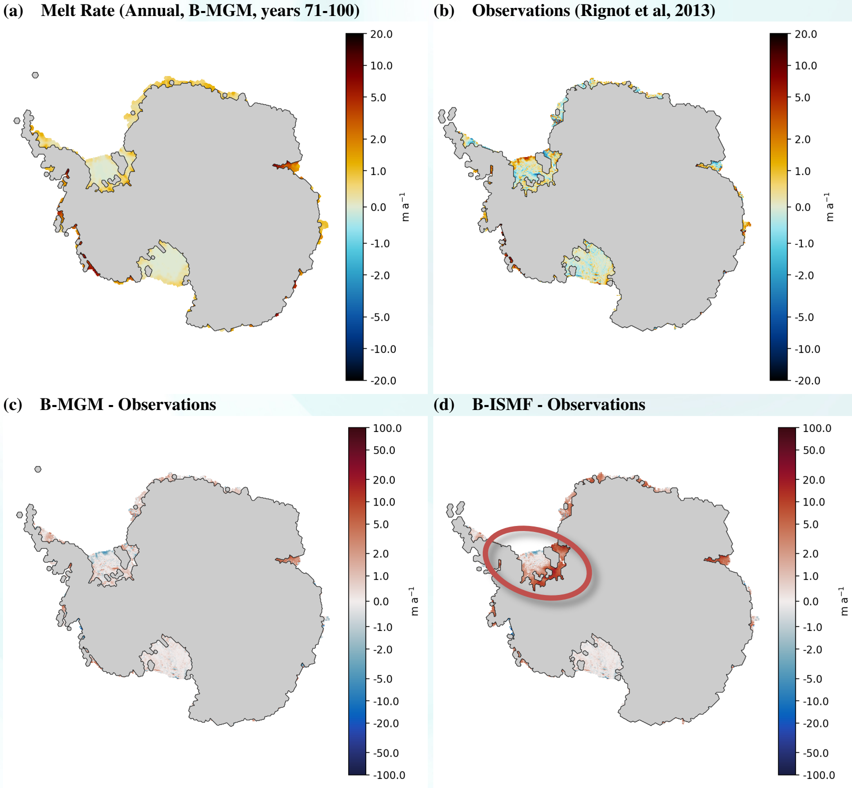


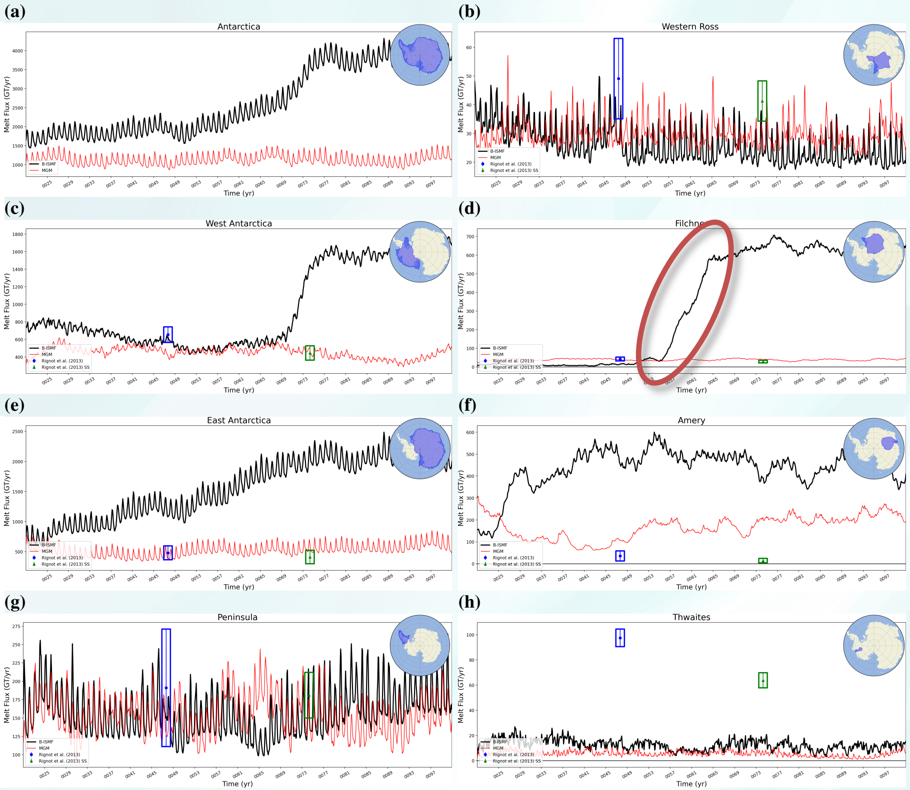
Potential temperature and salinity



In the original simulation B-ISMF, strong biases are seen under the Filchner-Ronne Ice Shelf (FRIS) (red); the modified B-MGM run successfully mitigated these important biases (green).

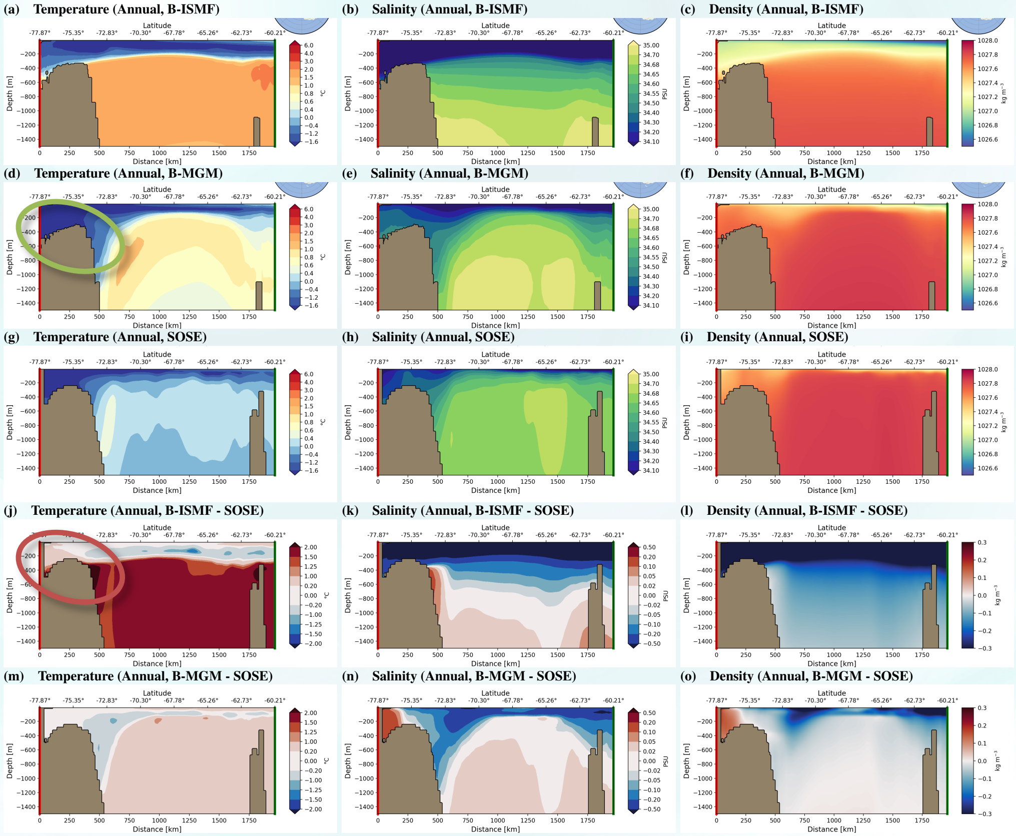
Ice-Shelf Basal Melt Rates





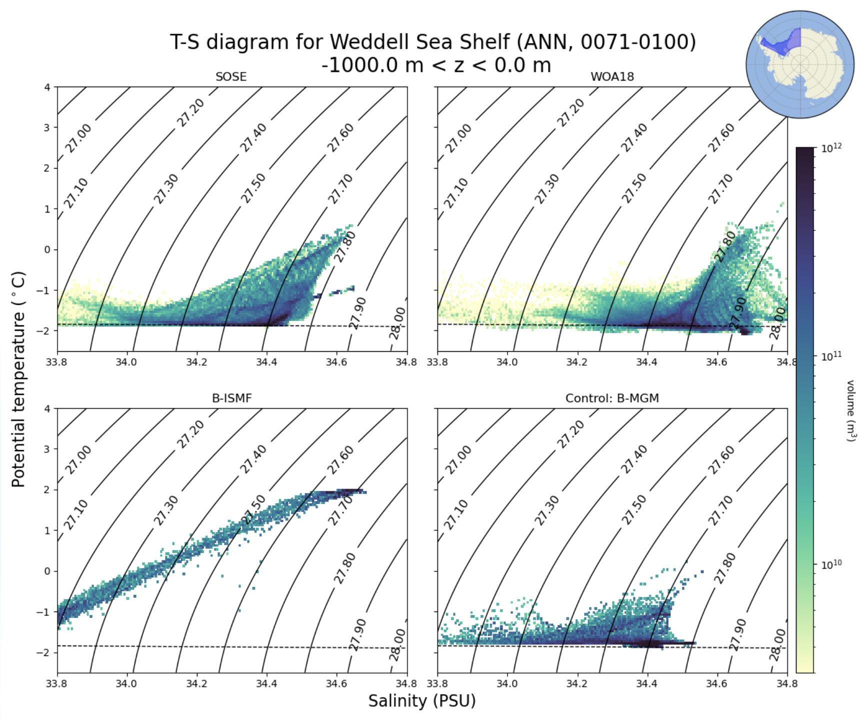
Large temperature and salinity biases in B-ISMF under FRIS resulted in a rapid transition to high melt regime (d) and produced an unphysical climate (relative to present-day observations); B-MGM mitigated these biases and has stable melt rates.

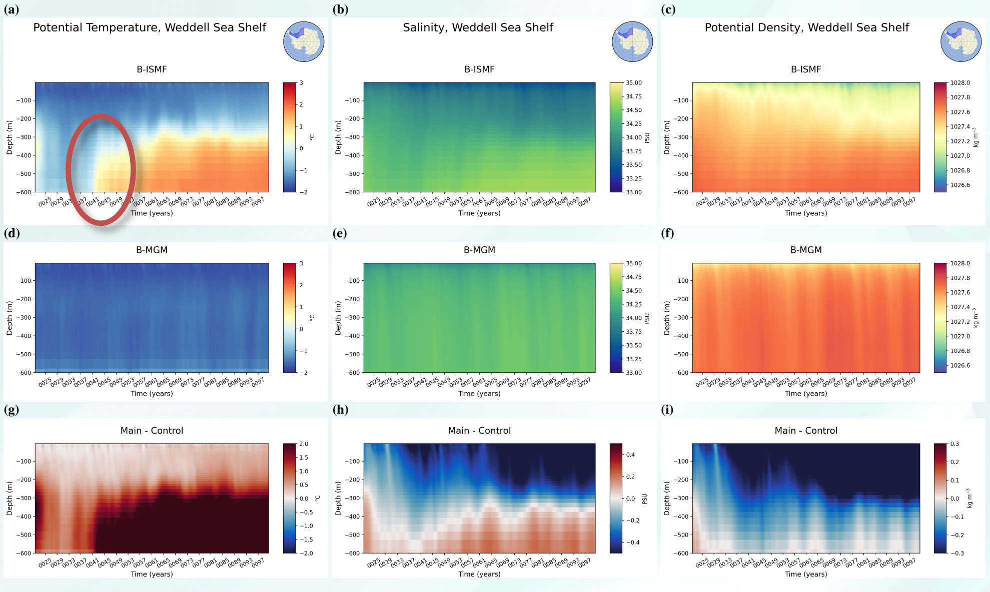
Weddell Sea Transects



B-MGM preserves the Antarctic Slope Front (green), preventing warm water at depth from accessing the continental shelf. In the B-ISMF run, this warm water reaches the shelf (red) and triggers an instability to a high-melt regime.

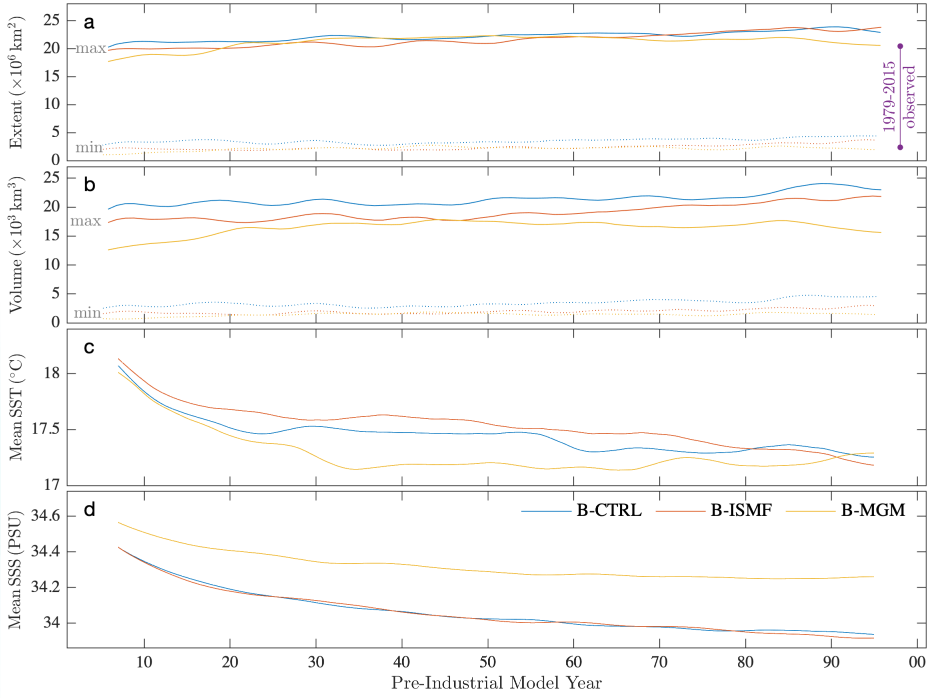
Weddell Sea

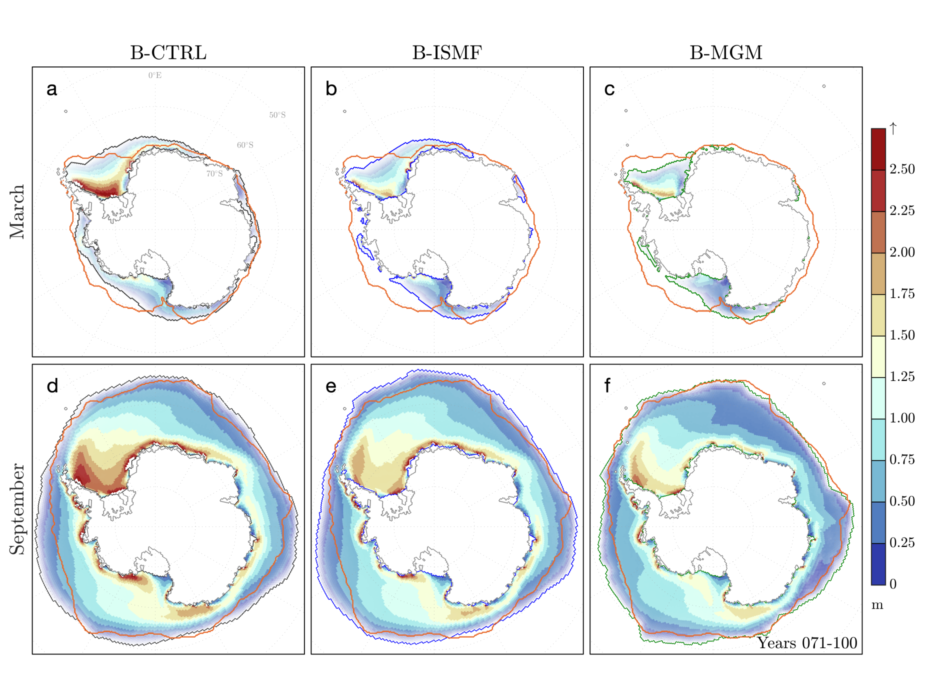




In the B-ISMF simulation, the Hövmoller plot (a) shows intrusions of warm, deep water onto the shelf at shallow depths beginning around year 40, which precede the rapid rise in melt rates under FRIS around year 55. T-S properties are also improved in B-MGM relative to observations (WOA18) and state estimate (SOSE).

Sea ice metrics

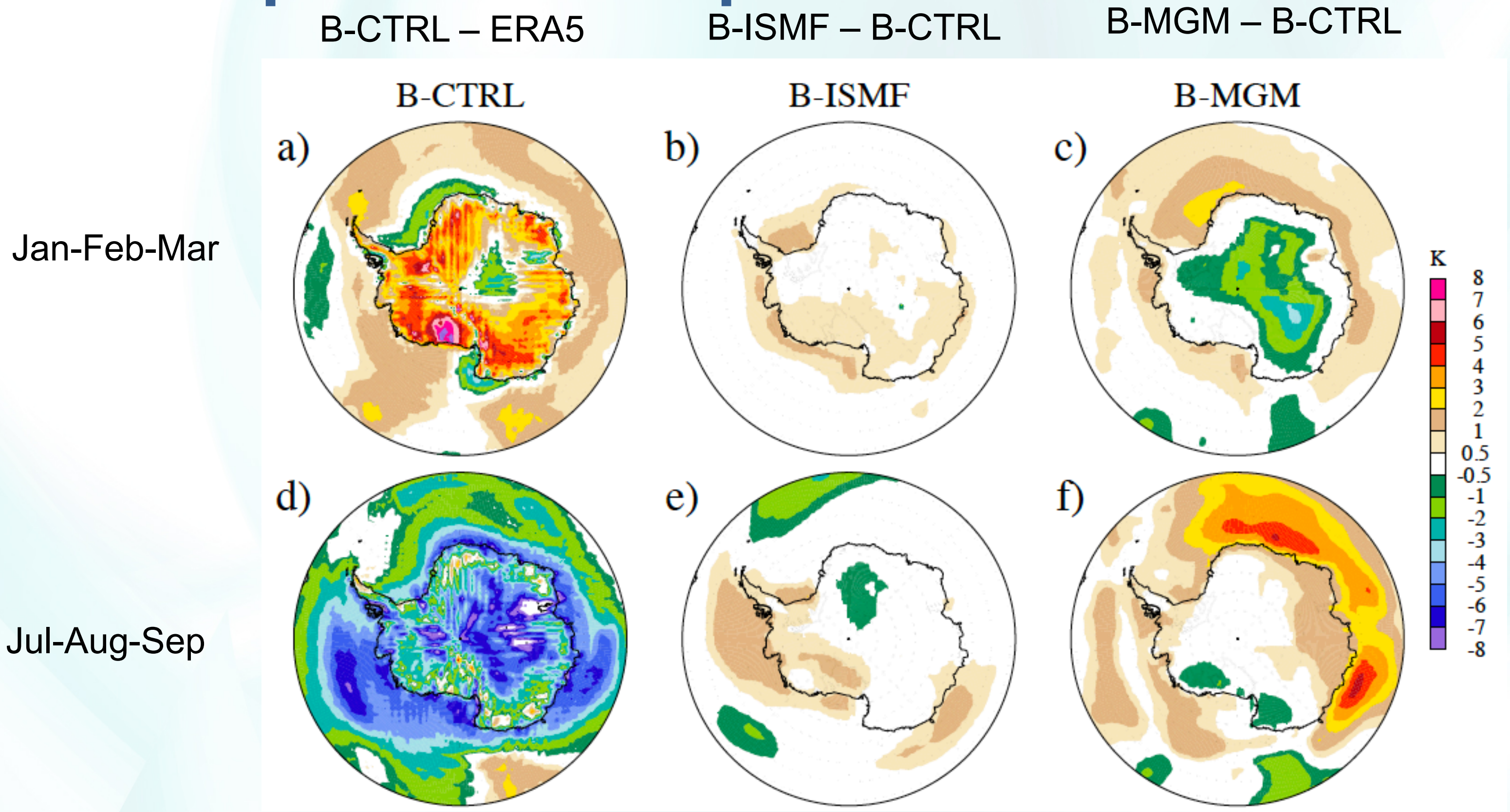




Validation of sea ice component. Left: 5 year low-pass filtered Southern Ocean maximum and minimum extent and volume, with historical observational range from Meier et al 2017 for reference.

Right: Sea ice thickness with orange contours of sea ice extent corresponding to the same observational data set.

Atmosphere 2m temperature



Validation of atmosphere component: 2m air temperature comparing B-CTRL to ERA5 observations, and then the B-ISMF, B-MGM simulations compared to control.

Summary

- E3SM v1 Cryosphere Simulation Campaign ran from March 2019 – August 2020
- Represent first Earth system model simulations with the capability of calculating ice-shelf basal melt fluxes, a key factor in projecting the Antarctic Ice Sheet contribution to sea-level rise.
- Significant biases in Southern Ocean temperature and salinity led to some large ice-shelves transitioning to a high-melt regime, far from present-day conditions.
- Modifying the ocean mesoscale eddy parameterization mitigated much of these biases, and produced a simulation with stable ice-shelf basal melt rates.
- Overview manuscript for v1 Cryosphere Simulation Campaign in prep, aim to submit October 2020.

Acknowledgements: This research used resources granted by an ALCC allocation at the National Energy Research Scientific Computing Center (U.S. DOE contract DE-AC02-05CH11231), supported by the Office of Science of the U.S. Department of Energy.