Can ocean-sea ice model-simulated variable sea ice thickness and snow depth improve the ice surface temperature simulation in Antarctic numerical weather prediction?

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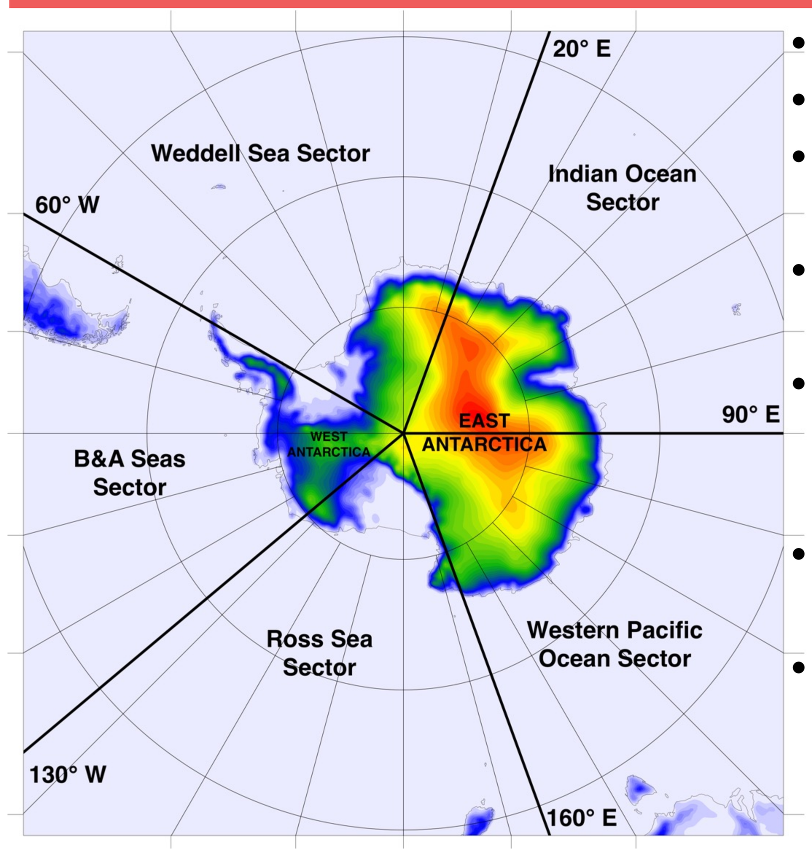
Introduction

- Overly simplified sea-ice representations are typically used for short-term weather forecasts as the boundary conditions of atmospheric process simulations (Hunke et al. 2020), due to computational resource limitations and the demand for timeliness of forecasts .
- However, with the development of more complicated atmosphere-ocean-sea ice fully coupled models (Smith et al. 2018; Yang et al. 2020) and more abundant computational capacity, coupling ocean-ice models into the existing numerical weather prediction (NWP) models becomes a priority direction for future research.
- Some global NWP systems has coupled ocean-sea ice models in Arctic (Smith et al. 2018), while there no research focuses on polar-optimized NWP models in Antarctic.
- The impacts of forcing Antarctic NWP using ocean-sea ice model simulated sea-ice properties are investigated here.

Models and validation data



- Polar WRF 4.1.1 was used for NWP forecast for 2018.
- Simulation domain cover the whole Antarctic sea ice region.
- sea-ice thickness (SIT) and snow height (SNOWH) from two ocean-sea ice models (ACCESS-OM2-01 and GIOMAS).
- ACCESS-OM2 has 0.1^{o} model resolution; 0.56 ^{o} atmospheric forcing from JRA55-do ; No data assimilation.
- GIOMAS has 0.8^{o} model resolution; 2.5^{o} atmospheric forcing from NCEP-NCAR reanalysis; Assimilated SIC from NSIDC.
- LEGOS/CTOH Ka-Ku band altimetry-derived SIT and SNOWH are used to evaluate the model-derived SIT and SNOWH.
- NOAA/NSIDC Climate Data Record (CDR) sea ice concentration (SIC) are used to evaluated model-derived SIC.

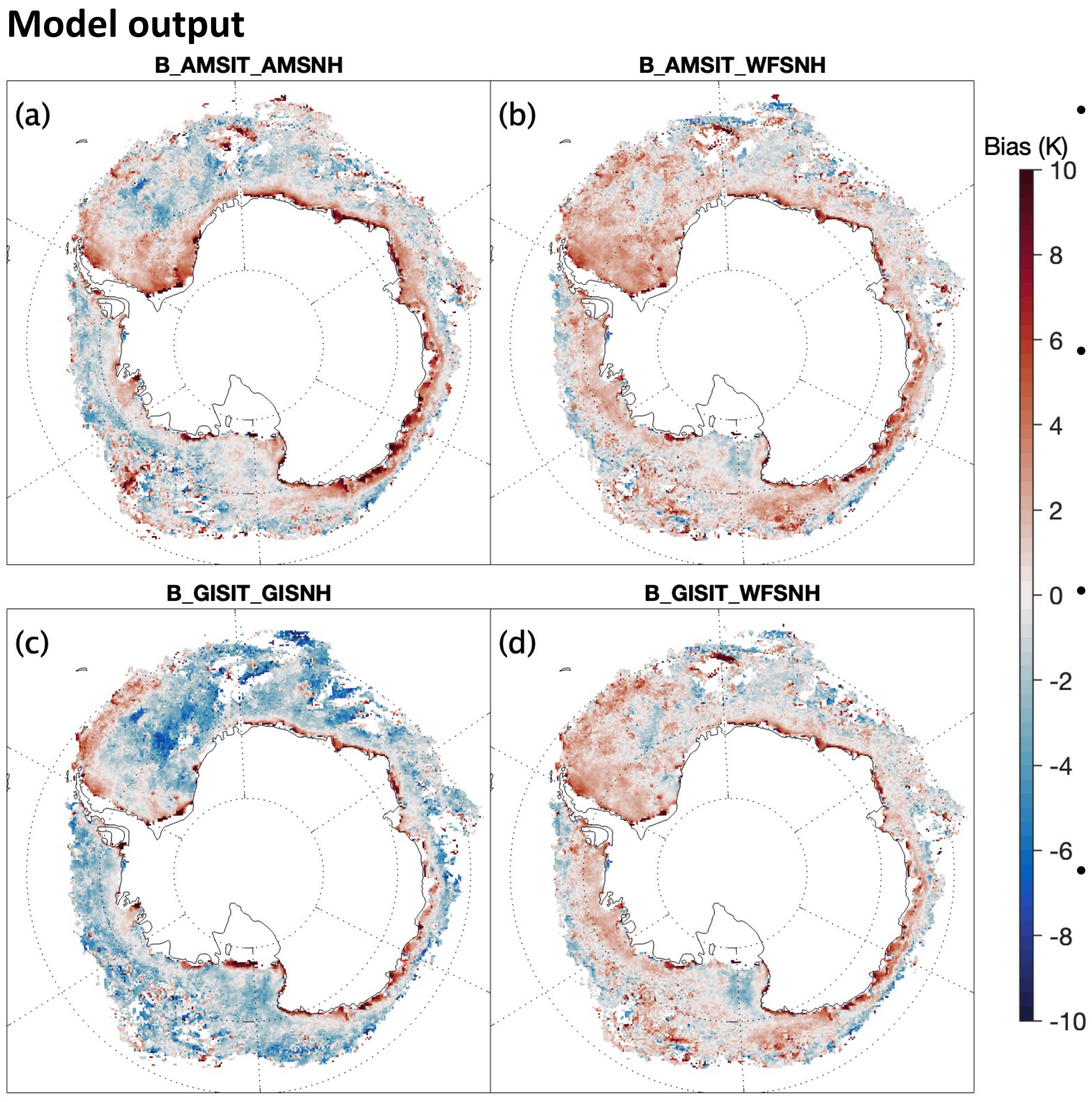
Results

Experiment design

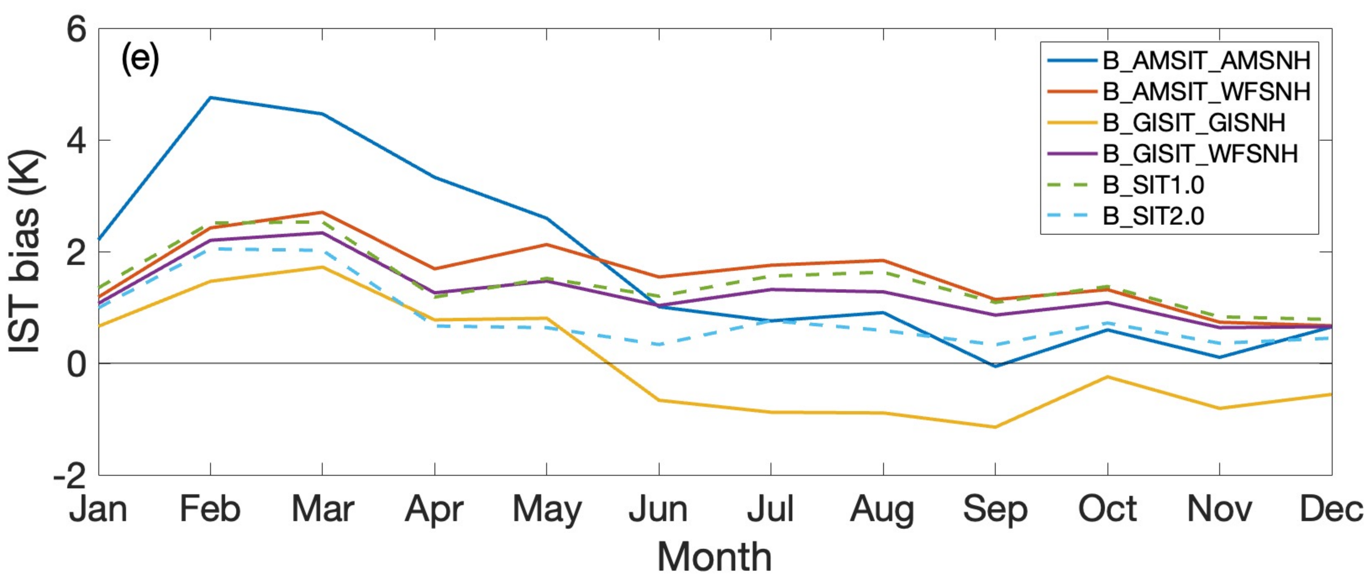
	SIC	Sea-ice thickness	Snow depth on sea ice
B_SIT1.0	NSIDC prescribed	1 m prescribed	5 cm for lower bound, WRF modelled
B_SIT2.0	NSIDC prescribed	2 m prescribed	5 cm for lower bound, WRF modelled
B_GISIT_WFSNH	NSIDC prescribed	GIOMAS prescribed daily	5 cm for lower bound, WRF modelled
B_GISIT_GISNH	NSIDC prescribed	GIOMAS prescribed daily	GIOMAS prescribed daily
B_AMSIT_WFSNH	NSIDC prescribed	ACCESS-OM2 prescribed daily	5 cm for lower bound, WRF modelled
B_AMSIT_AMSNH	NSIDC prescribed	ACCESS-OM2 prescribed daily	ACCESS-OM2 prescribed daily

- SIT and SNOWH from ACCESS-OM2 and GIOMAS have been included in Polar WRF as part of the lower boundary conditions.
- Two experiments with prescribed constant SITs (1 m and 2 m) are simulated as a benchmark for other simulations.

Model output



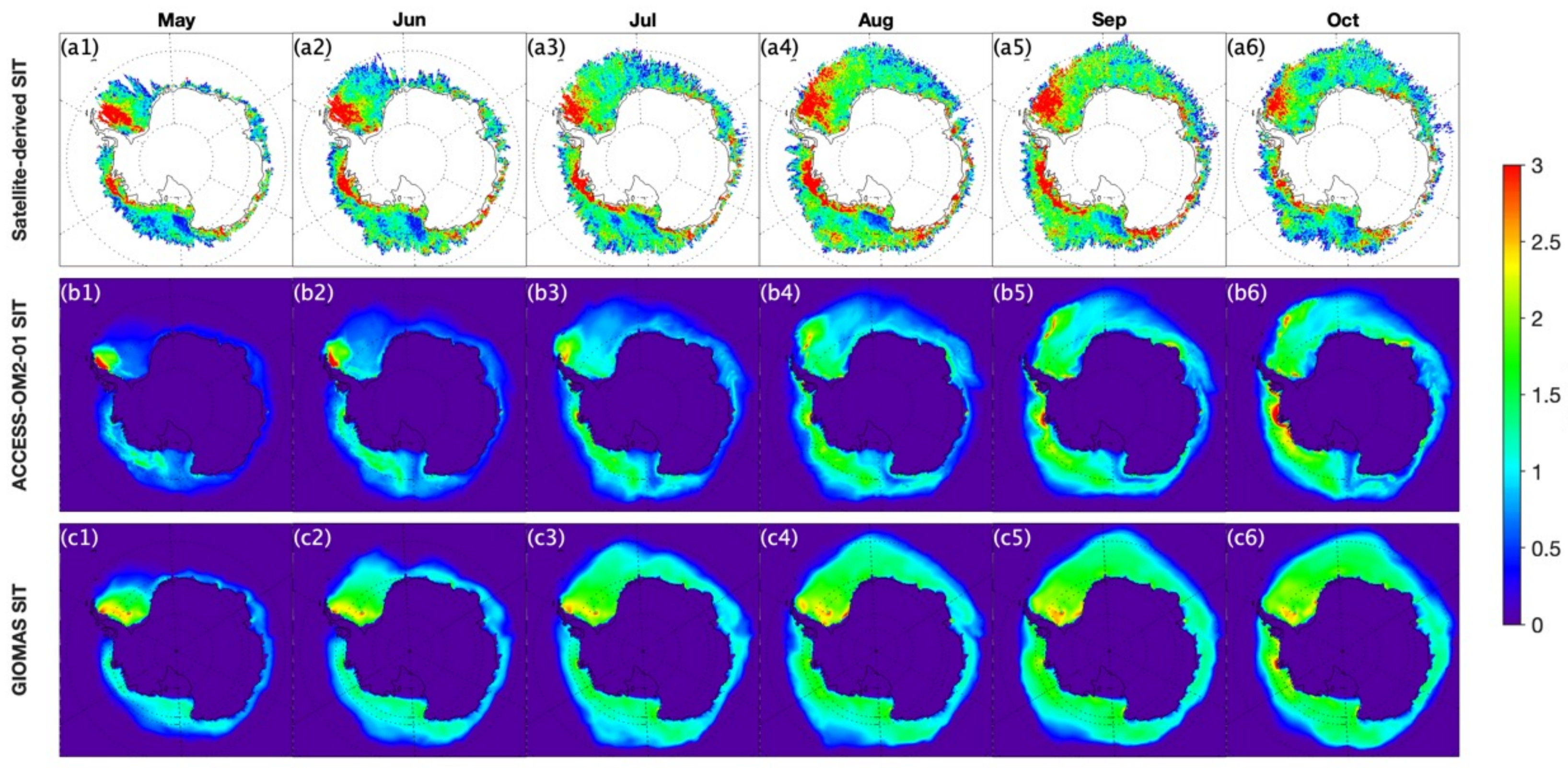
- The IST shows a warm bias over most of the sea ice area when SIT only is prescribed from either ice-ocean model output (B_AMSIT_WFSNH and B_GISIT_WFSNH).
- When ACCESS-OM2 SNOWH is also included into Polar WRF (B_AMSIT_AMSNH), the IST warm bias is notably reduced, and some regions shift to showing a cold bias (from b to a).
- The IST bias pattern changes from a mostly warm bias (d) to a mostly cold bias (c), with an especially strong cold bias in the eastern Weddell Sea When GIOMAS SNOWH is also included into Polar WRF (B_GIST_GISNH).
- All four experiments show a strong warm bias in the sea ice regions near the western Weddell Sea and around the Antarctic coast.



IST bias from the four variable SIT and/or SNOWH experiments and two experiments using a constant SIT

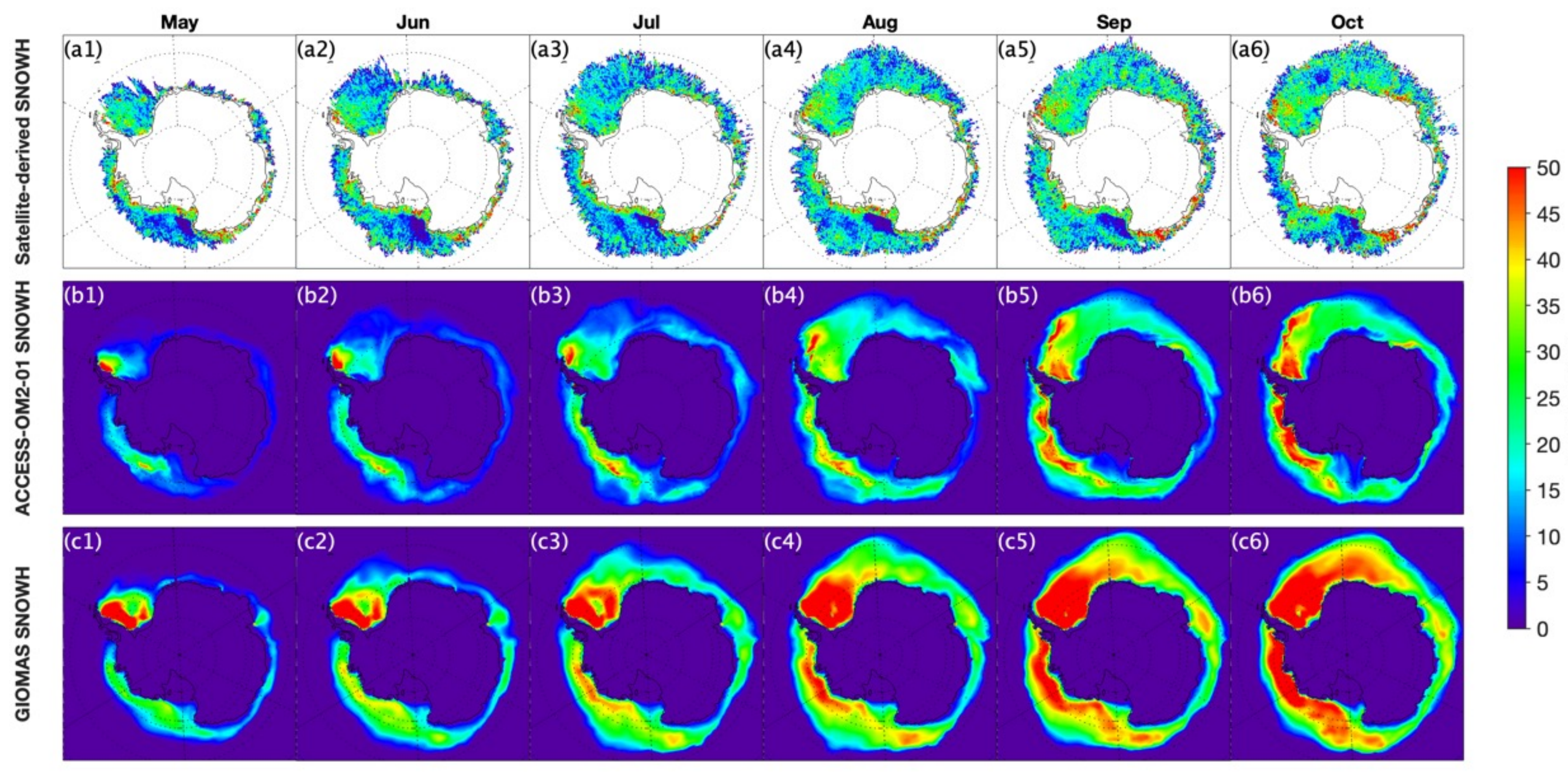
- B_GISIT_GISNH shows a cold bias from July to December.
- Other experiments show warm biases in all months.
- Experiments with variable SIT show similar warm biases as the 1 m SIT experiment.
- B_AMSIT_AMSNH shows a marked warm bias from January to May, while shows the best forecast skill in terms of bias of all the experiments after August.

Physical explanations



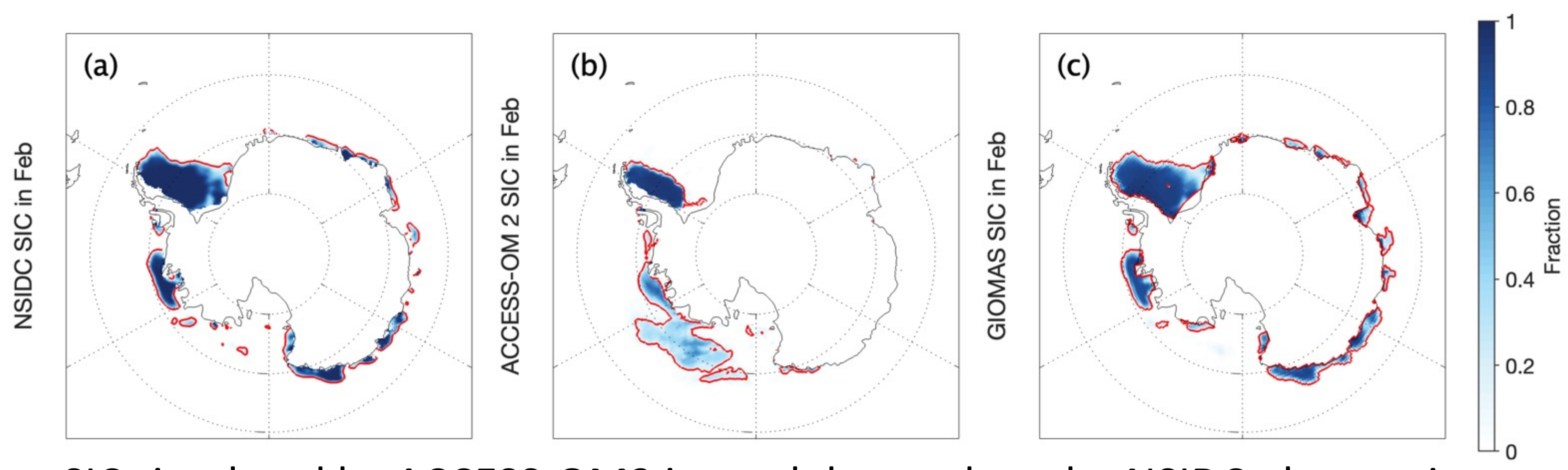
Satellite-estimated (upper) and ACCESS-OM2-01 (middle) and GIOMAS (bottom) model-derived SIT.

- Both models underestimate SIT in the Weddell Sea
- ACCESS-OM2 more realistically simulates the polynya and sea ice production near the Ross Ice Shelf due to the finer resolution than GIOMAS.
- ACCESS-OM2 better simulates the distinctive thickness boundary between MYI and FYI in Weddell Sea.
- ACCESS-OM2 underestimates the SIT in the Weddell Sea



Satellite-estimated (upper) and ACCESS-OM2-01 (middle) and GIOMAS (bottom) model-derived SIT.

- Both models show larger difference in SNOWH than SIT compared to satellite.
- GIOMAS considerably overestimates SNOWH in most areas, especially in west Antarctica.
- The simulation of SNOWH by ACCESS-OM2 is much more reasonable.



SIC simulated by ACCESS-OM2 is much lower than the NSIDC observations in the Weddell Sea in Antarctic summer.

- GIOMAS assimilates satellite-derived SIC while ACCESS-OM2 does not.

Conclusion

- Putting ACCESS-OM2 and GIOMAS simulated SIT and SNOWH into the Polar WRF model does not produce a strong improvement in forecast skill for surface temperature due to their relatively larger errors in NWP timescale.
- However, good results were achieved when the ACCESS-OM2 SIT and SNOWH were included during the winter months, when the SIT and SNOWH simulations were improved thanks to the complex sea ice dynamics and thermodynamic simulations.
- It is expected that the IST forecast skill can be improved in Polar WRF when including ocean-sea ice model simulated SIT and SNOWH, after assimilation of the satellite-based SIC as well as using a more complex and finer spatial scale simulation of sea-ice processes.
- Future work could consider coupling a complex sea-ice model with satellite and in-situ sea ice data assimilation capability into the Polar WRF model to achieve more accurate results.

Acknowledgements

Hunke, E., Allard, R., Blain, P., Blockley, E., Feltham, D., Fichefet, T., et al. (2020). Should Sea-Ice Modeling Tools Designed for Climate Research Be Used for Short-Term Forecasting? *Current Climate Change Reports*, *6*(4), 121–136. https://doi.org/10.1007/s40641-020-00162-y

Smith, G. C., Bélanger, J.-M., Roy, F., Pellerin, P., Ritchie, H., Onu, K., et al. (2018). Impact of Coupling with an Ice–Ocean Model on Global Medium-Range NWP Forecast Skill. *Monthly Weather Review*, *146*(4), 1157–1180. https://doi.org/10.1175/MWR-D-17-0157.1

Yang, C., Liu, J., & Xu, S. (2020). Seasonal Arctic Sea Ice Prediction Using a Newly Developed Fully Coupled Regional Model With the Assimilation of Satellite Sea Ice Observations. *Journal of Advances in Modeling Earth Systems*, *12*(5), 1–25. https://doi.org/10.1029/2019MS001938