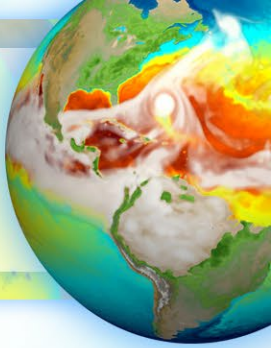
Antarctic ice-shelf basal melting in a variable resolution Earth System Model



Xylar Asay-Davis[1], Alice Barthel[1], Carolyn Begeman[1], Darin Comeau[1], Matthew Hoffman[1], Wuyin Lin[2], Mark Petersen[1], Stephen Price[1], Andrew Roberts[1], Milena Veneziani[1], Luke Van Roekel[1], Jonathan Wolfe[1]

[1] Los Alamos National Laboratory, [2] Brookhaven National Laboratory

EGU General Assembly, 2022

Under cover: The Southern Ocean's connection to sea ice and ice shelves

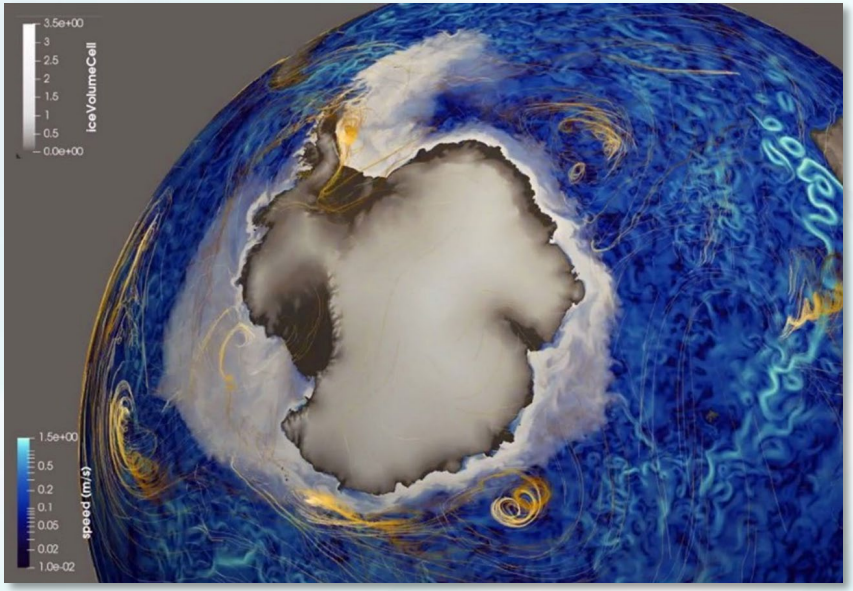
May 23, 2022

E3SM Energy Exascale Earth System Model

U.S. DEPARTMENT OF ENERGY

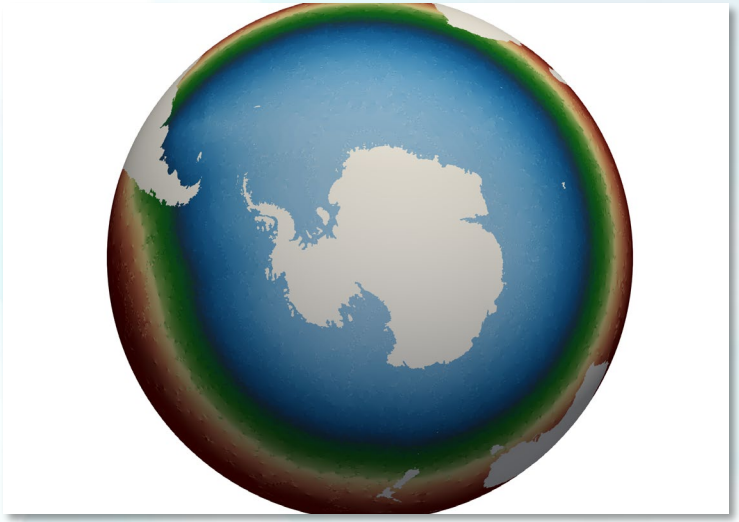
Energy Exascale Earth System Model (E3SM)

- e3sm.org
- Funded by US Department of Energy
- Regional refinement in all components
- Focused on:
  - Water cycle in North America
  - **Antarctic Ice Sheet mass loss**
  - Effects of CO_2 emissions on biogeochemical cycles

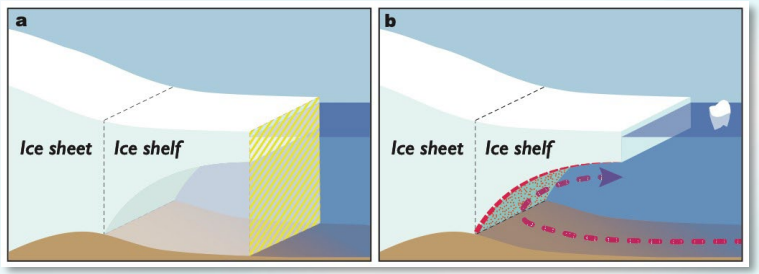


Southern Ocean and Antarctic Focus

- Science Question: How will the atmosphere, ocean, and sea-ice systems mediate sources of sea-level rise from the Antarctic ice sheet over the next 30 years?
- Global domain



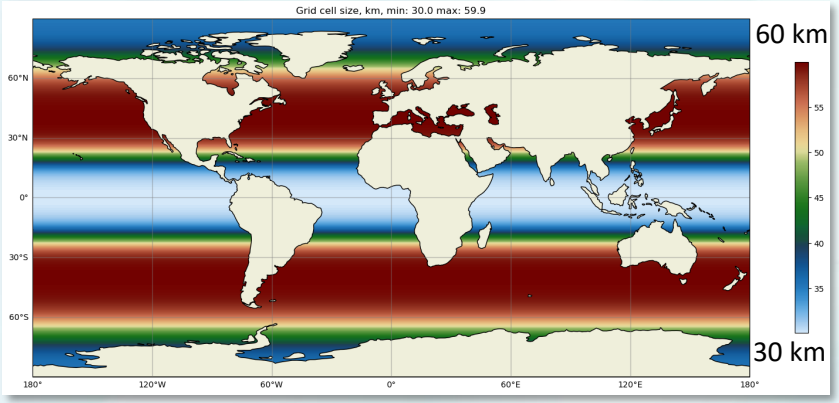
- Includes ice-shelf cavities

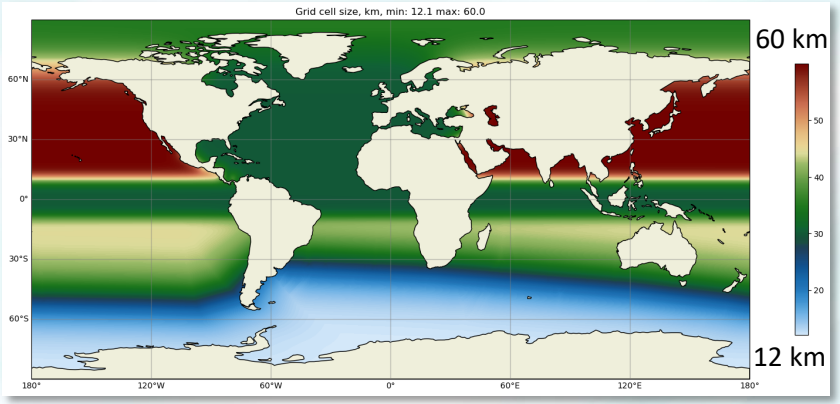


“Low Res” and “Regionally Refined”

- **Low Res (LR)**:
  35 km ocean and sea ice resolution around Antarctica

- **Regionally Refined (RR):**
  12 km ocean and sea ice resolution around Antarctica

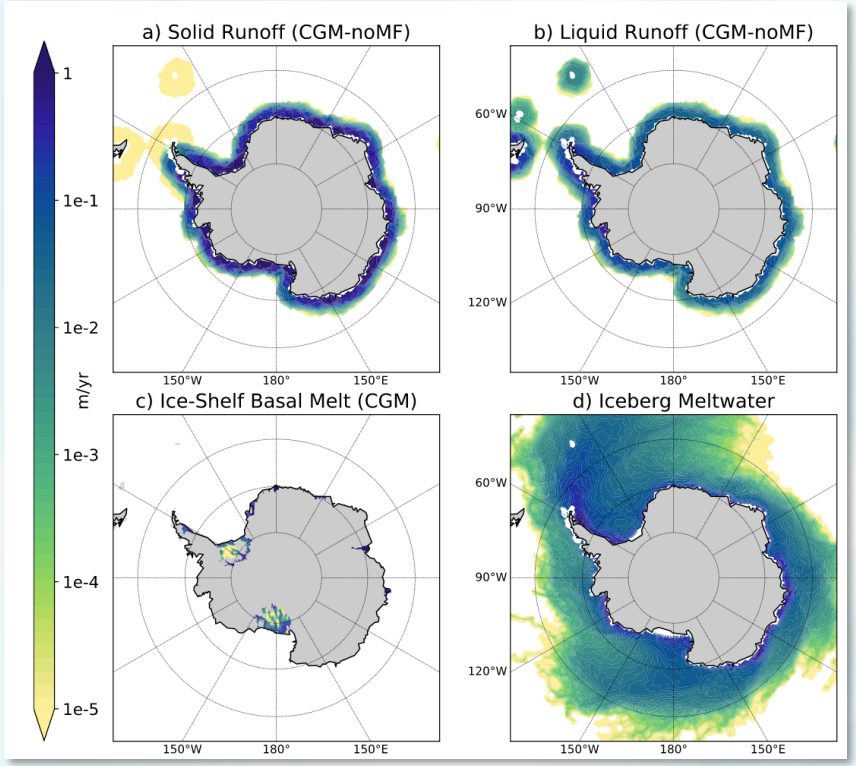




More realistic ice-shelf and iceberg melt

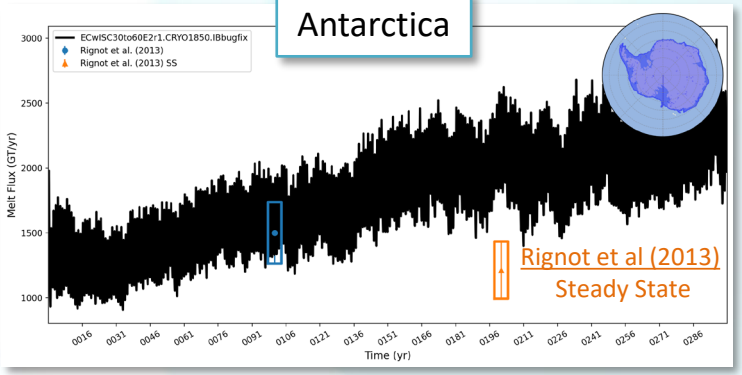
- Standard Antarctic runoff: snow and meltwater immediately routed to coast

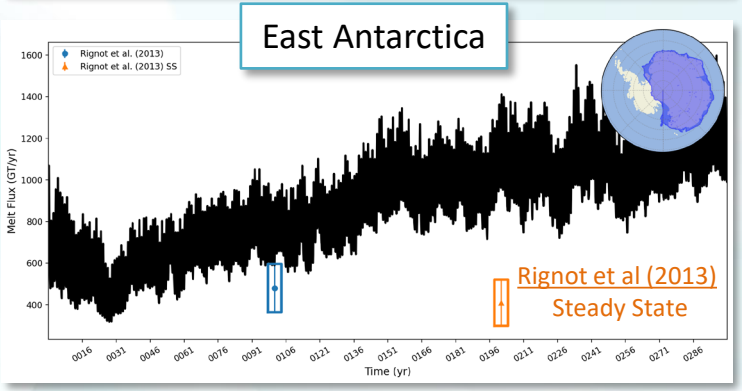
- E3SM Antarctic freshwater fluxes:
  - **prognostic ice-shelf basal melt**
  - **prescribed iceberg melt** (climatology from Mireno et al. 2016)



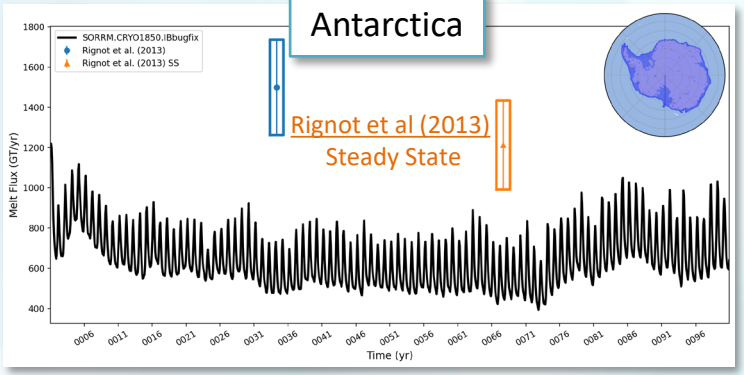
Melt rates: early E3SM preindustrial simulations

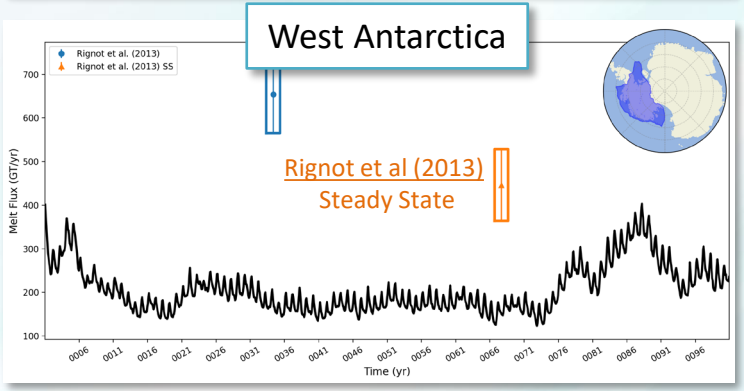
Low Res





Regionally Refined



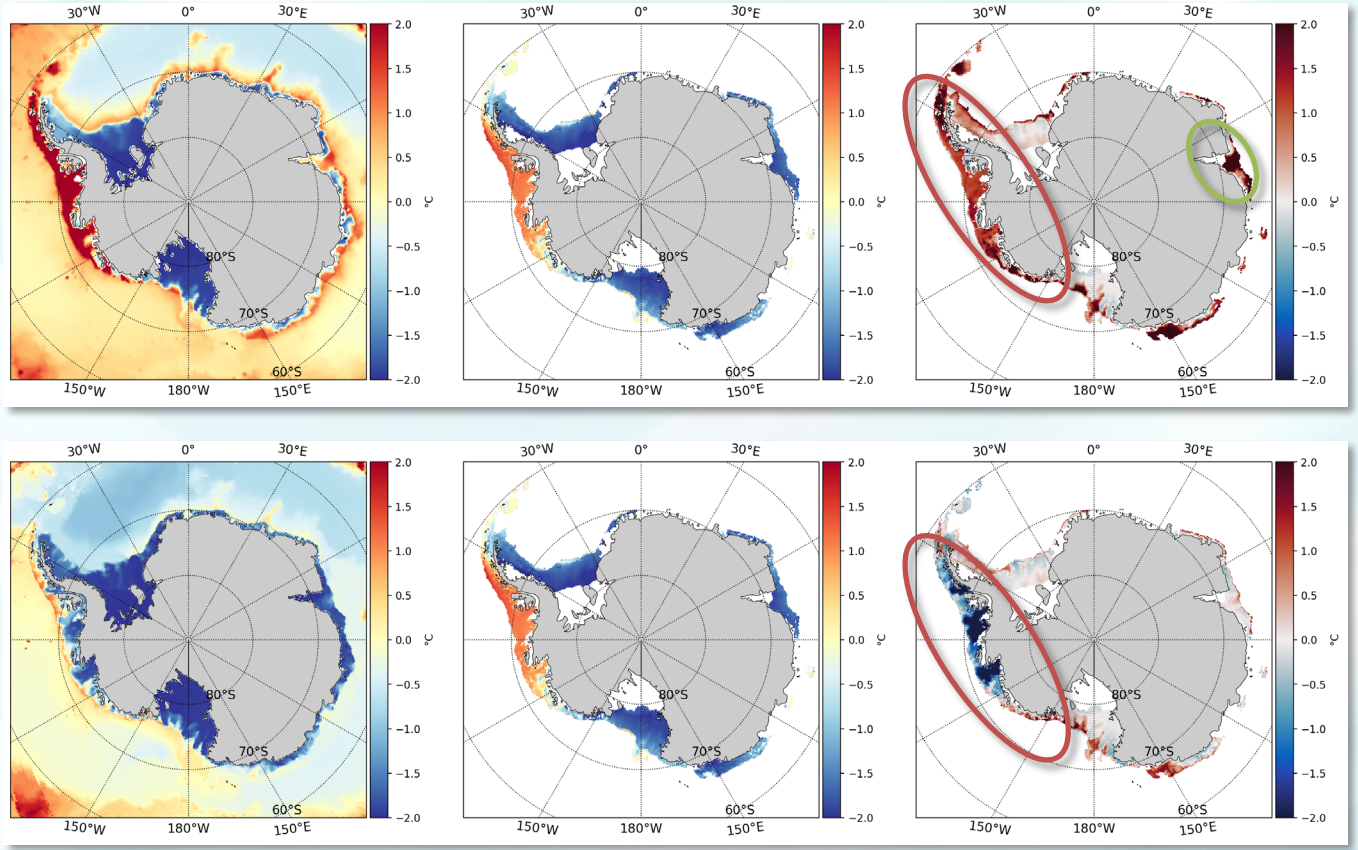


Seafloor temperature (years 91-100)

E3SM | Schmidtko et al (2014) | Difference

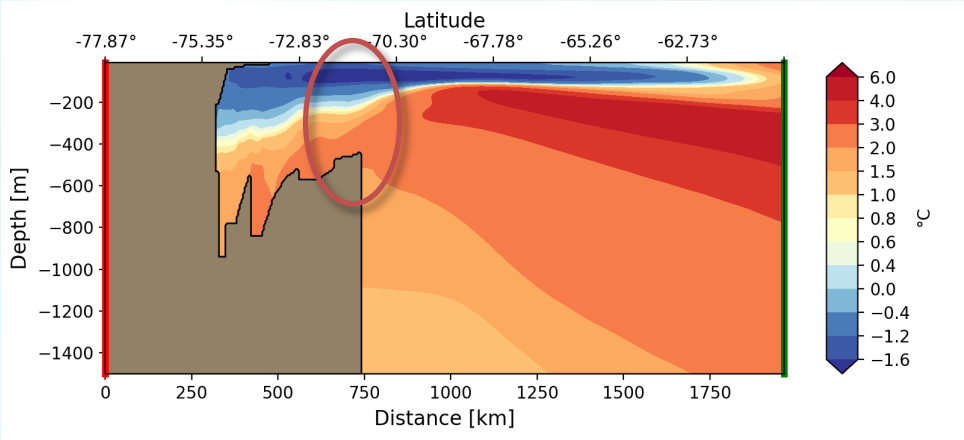
Low Res

Regionally Refined

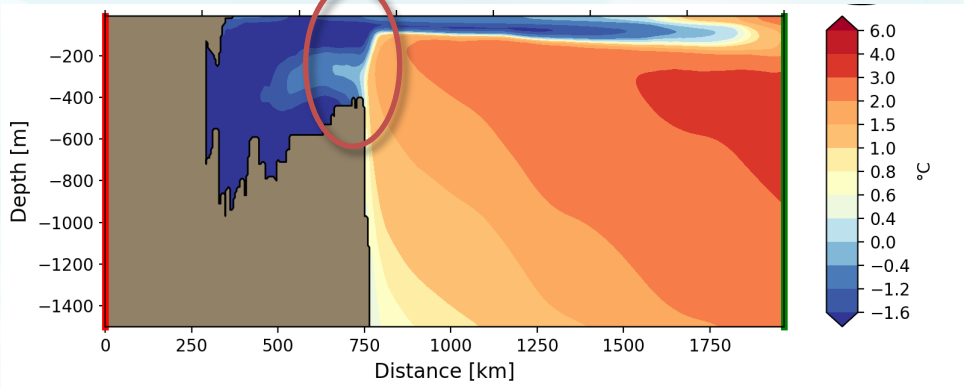


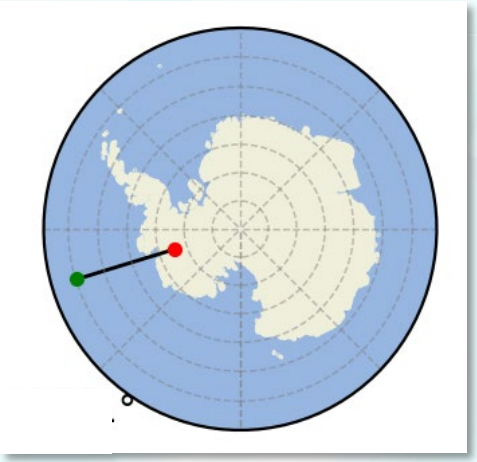
Amundsen Sea Transect

Low Res



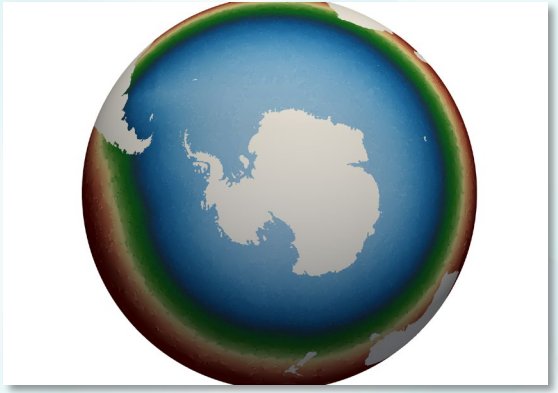
Regionally Refined

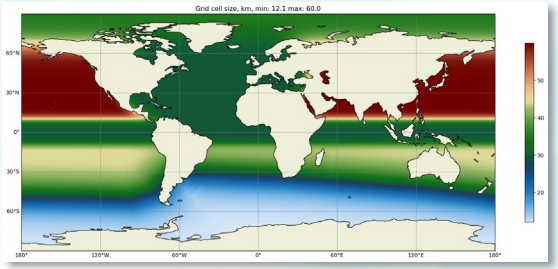




Gent-McWilliams (GM) Eddy Parameterization

- Many flavors of GM (functions depth, stratification, res., Rossby radius, etc.)
- Transition between full GM (typical ESM ocean) and no GM (eddy resolving) an active area of research
- Regionally Refined tests include:
  - GM off around Antarctica (our early test)
  - GM full strength around Antarctica (same as low resolution)
  - GM tapered both horizontally and vertically around Antarctica
    - Vertical taper of Visbeck et al. 1997
    - Horizontal taper: function of resolution / Rossby radius





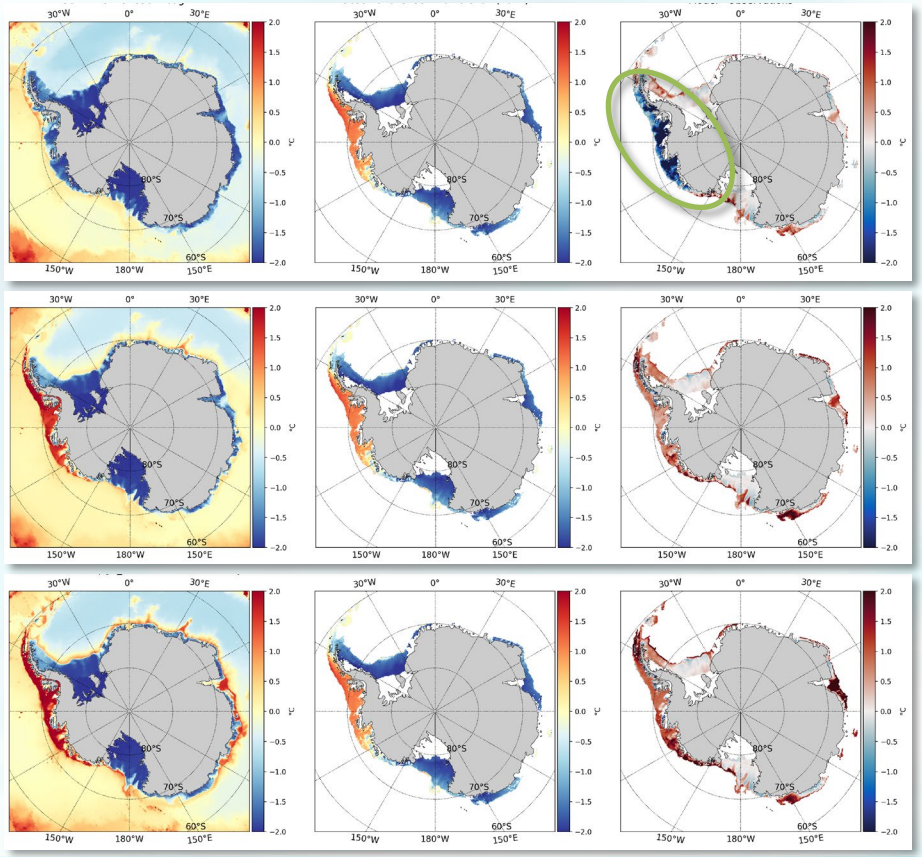
RR Seafloor temperatures (years 41-50)

E3SM | Schmidtko et al (2014) | Difference

GM off

GM tapered both horiz. and vert.

GM full strength

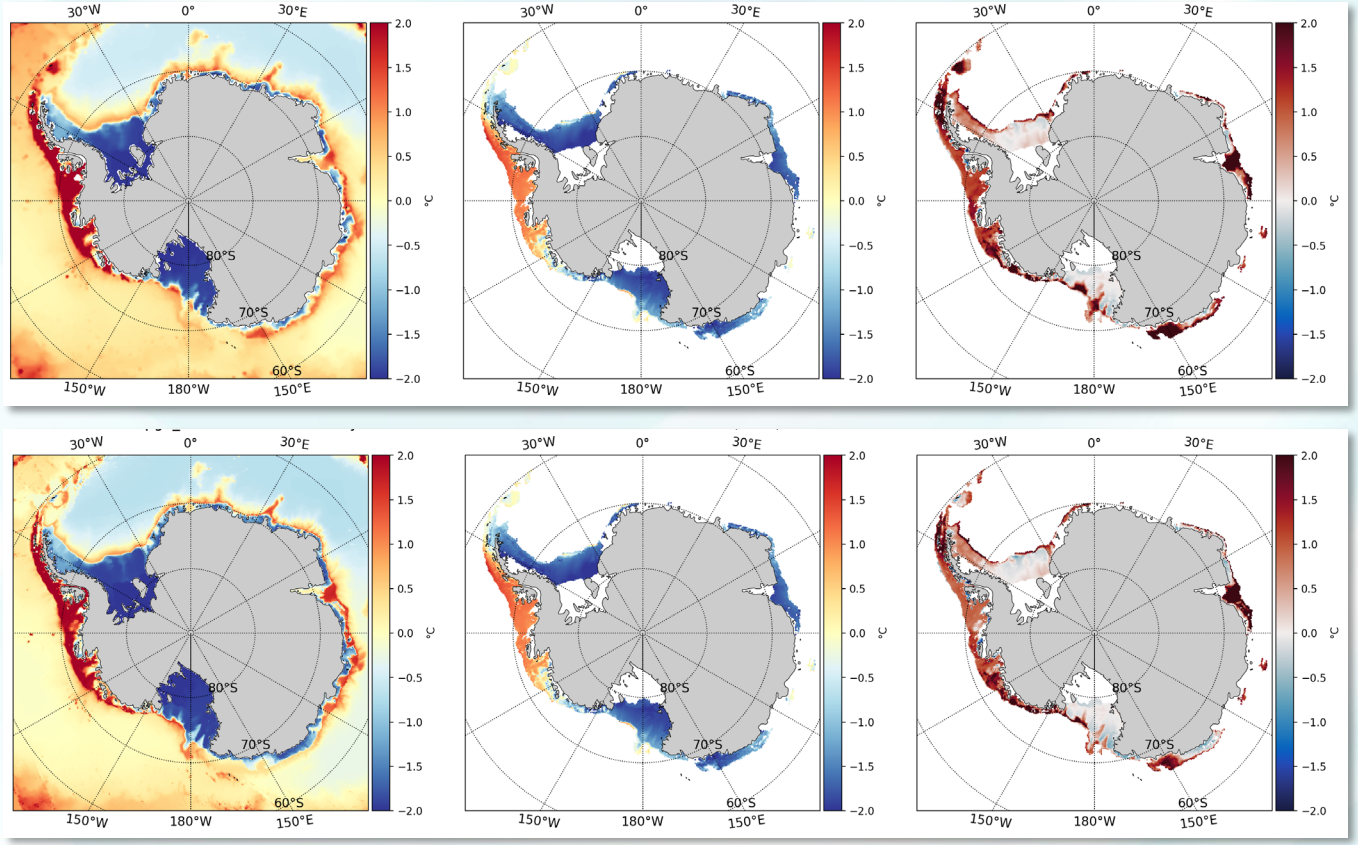


Seafloor temperature: GM full strength

E3SM | Schmidtko et al (2014) | Difference

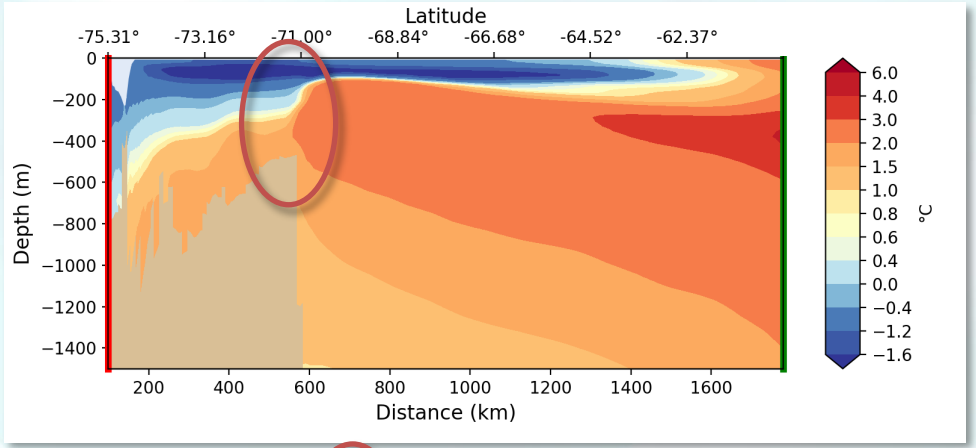
Low Res

Regionally Refined

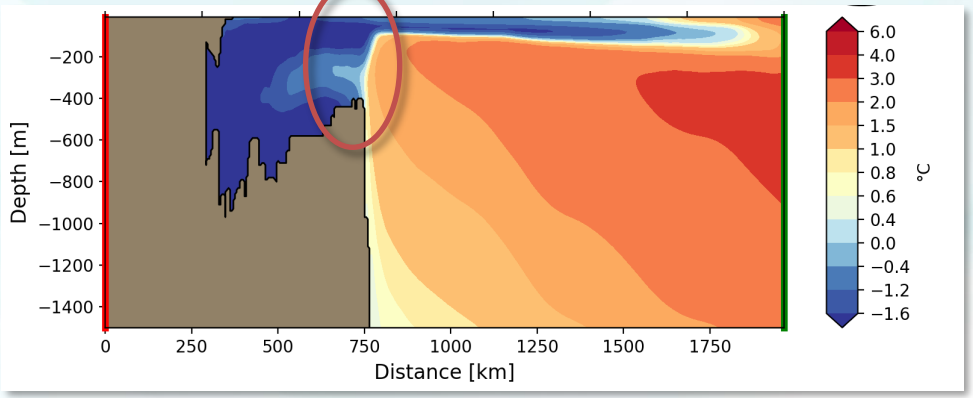


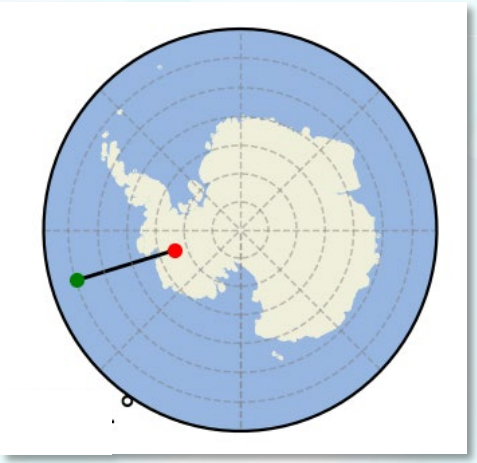
Amundsen Sea Transect

Regionally Refined with GM taper



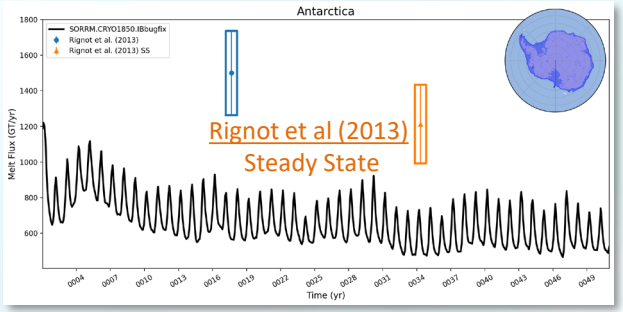
Regionally Refined without GM



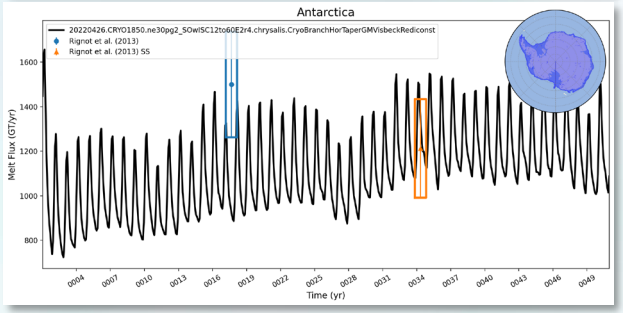


Regionally Refined melt rates

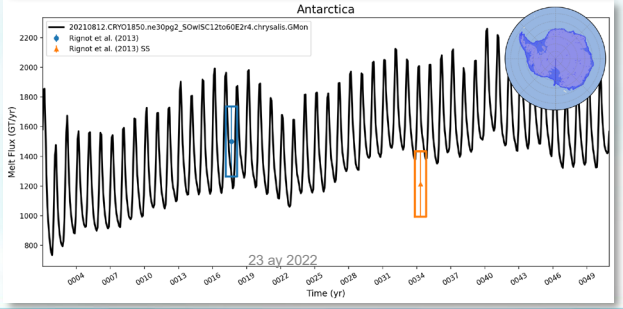
GM off



GM tapered both horiz. and vert.



GM full strength



Summary

- E3SM version 2 using:
  - Regional refinement around Antarctica
  - Ice shelf cavities with prognostic basal melt
- So far, preindustrial simulations show:
  - **Low res** (~35 km): warm biases, strong melt
  - **Regionally Refined** (~12 km): less warm, reasonable overall melt
  - Modifying/tuning **Gent-McWilliams** (GM) eddy parameterization a big help!
- Further exploration of GM and basal melt parameters in E3SM v3