Simulations of ice-shelf cavities in POP

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Ice-sheet/Ocean interface in POP

- Funded under the DOE IMPACTS project on abrupt climate change
- Modified version of POP: *POP2X* includes ocean cavities under ice shelves
- Ice/ocean boundary defined by *partial-top cells* (analogous to partial-bottom cells)
- Based on Losch 2008: static ice shelves in MITgcm
Following Losch 2008, “boundary layer” below partial top cells:

- Salt/heat from melting/freezing mixes into both partial cell and next cell below (reduces noise at expense of extra mixing)

- “boundary layer” does not resolve true boundary layer physics
Following Losch 2008, “boundary layer” below partial top cells:

\[ \alpha \equiv \frac{\delta z_k}{\Delta z_k} \]

\[ \bar{T} = \alpha T_k + (1 - \alpha) T_{k+1} \]

\[ Q_k = \alpha Q_{\text{melt}}(\bar{T}, T_f, \ldots) \]

\[ Q_{k+1} = (1 - \alpha) Q_{\text{melt}}(\bar{T}, T_f, \ldots) \]
- Ice Shelf-Ocean Model Intercomparison Project (ISOMIP; Hunter 2006)
- Uniform initial temperature ($T$) and salinity ($S$), and zero velocity ($u$)
- Spin up to steady state
- High horizontal and vertical diffusion of $u$, $T$ and $S$ compared to real ocean
ISOMIP Expt. 1 Comparison

POP

Losch 2008
**Isomip Expt. 1 Comparison**

POP

Losch 2008

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**Diagram 1:**

- **Title:** $\psi_{\text{overt}}$ (Sv)
- **Axes:** Depth (m) vs. Latitude
- **Legend:** Color scale from -0.1 to 0.1

**Diagram 2:**

- **Title:** Overturning stream function [Sv]
- **Axes:** Depth [m] vs. Latitude [° N]
- **Legend:** Color scale from 0.02 to 0.1
**ISOMIP Expt. 1 Comparison**

POP

Losch 2008

![Graphs showing melt rate comparison between POP and Losch 2008 models.](image-url)
Sim. with Idealized Geometry

- Expt. 6 from Grosfeld et al. 1997
- Bathymetry mimics Ronne-Filchner: troughs; deepens to the south; northern basin (Weddell Sea)
- Closed box (not periodic in either direction)
Linearly sloped ice shelf covers southern 40% of domain

Open ocean:
- zonal wind stress
- melting/freezing by simplified sea-ice model
Sim. with Idealized Geometry

Expt. 6 from Grosfeld et al. 1997
Partial Cells Method

Vertical “wetting” and “drying” of cells:

- Tracers in new “wetted” cells conservatively distributed from neighboring cell(s)

Wetting
dz
**Partial Cells Method**

Vertical “wetting” and “drying” of cells:

- Tracers in new “wetted” cells conservatively distributed from neighboring cell(s)
- Tracers in old “dried” cells conservatively distributed to neighbor(s)
What about horizontal “wetting” and “drying” as the grounding line moves?

Potentially more complicated:

- either cell can be arbitrarily thin
- or cells “pop” from zero thickness to finite thickness in a single time step
Partial Cells Method

- Pros:
  - Static interface tested with other ocean models
  - Similar to bathymetry
**Partial Cells Method**

- **Pros:**
  - Static *interface* tested with other ocean models
  - Similar to *bathymetry*
- **Cons:**
  - Stair-step geometry can lead to noisy fields
  - How to handle infinitesimally thin cells?
  - How to handle wetting at grounding line?
Existing POP grid: No cavities under ice shelves
**In progress: sim. of Southern Ocean (no ice shelves yet)**

- Existing POP grid: No cavities under ice shelves
- New POP grid: Ice shelves replace by open ocean
- Bathymetry from RTOPO-1 data set (Timmermann et al. 2010)
Future work: Moving Boundaries

- **Immersed Boundary Method**
  - includes **ghost cells** adjacent to boundary
  - implicit representation of sloped interface geometry
  - As ice sheet retreats, **ghost cells** become **new ocean cells**
  - no partial cells, so never have infinitesimally thin cells
Future Work

- Experiments:
  - Regional experiments in Weddell and Amundsen Sea domains
  - Southern Ocean domain

- Methods:
  - Dynamic ice/ocean interface with ghost-cell immersed boundary method
  - Offline coupling (and later full coupling) to ice-sheet model