Simulations of ice-shelf cavities in POP

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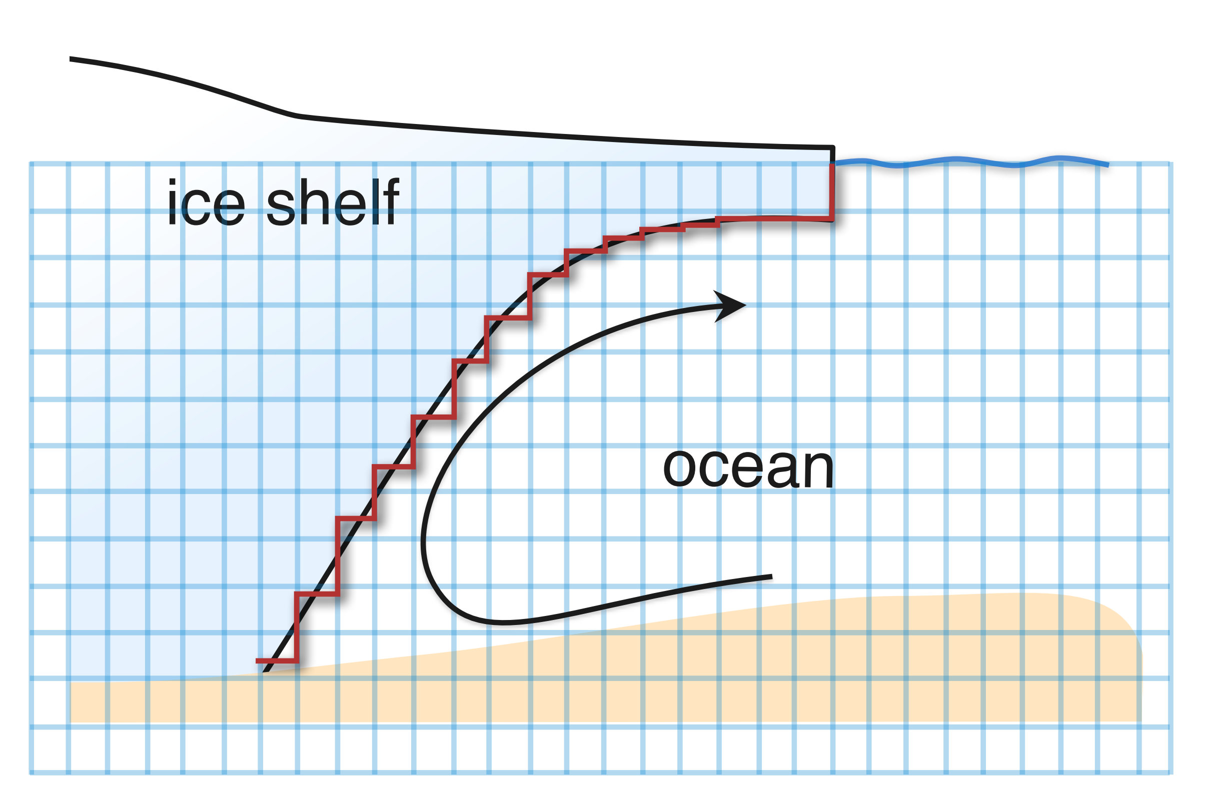
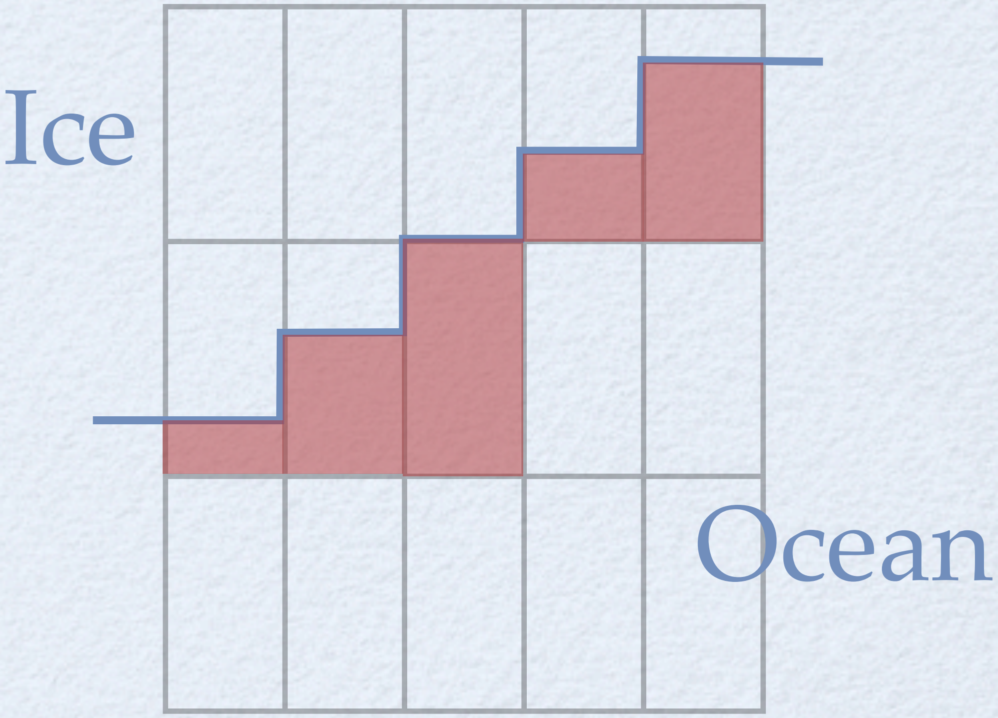
Ice-sheet/Ocean interface in POP

- Funded under the DOE *IMPACTS* project on abrupt climate change



- Modified version of POP: *POP2X* includes ocean cavities under ice shelves

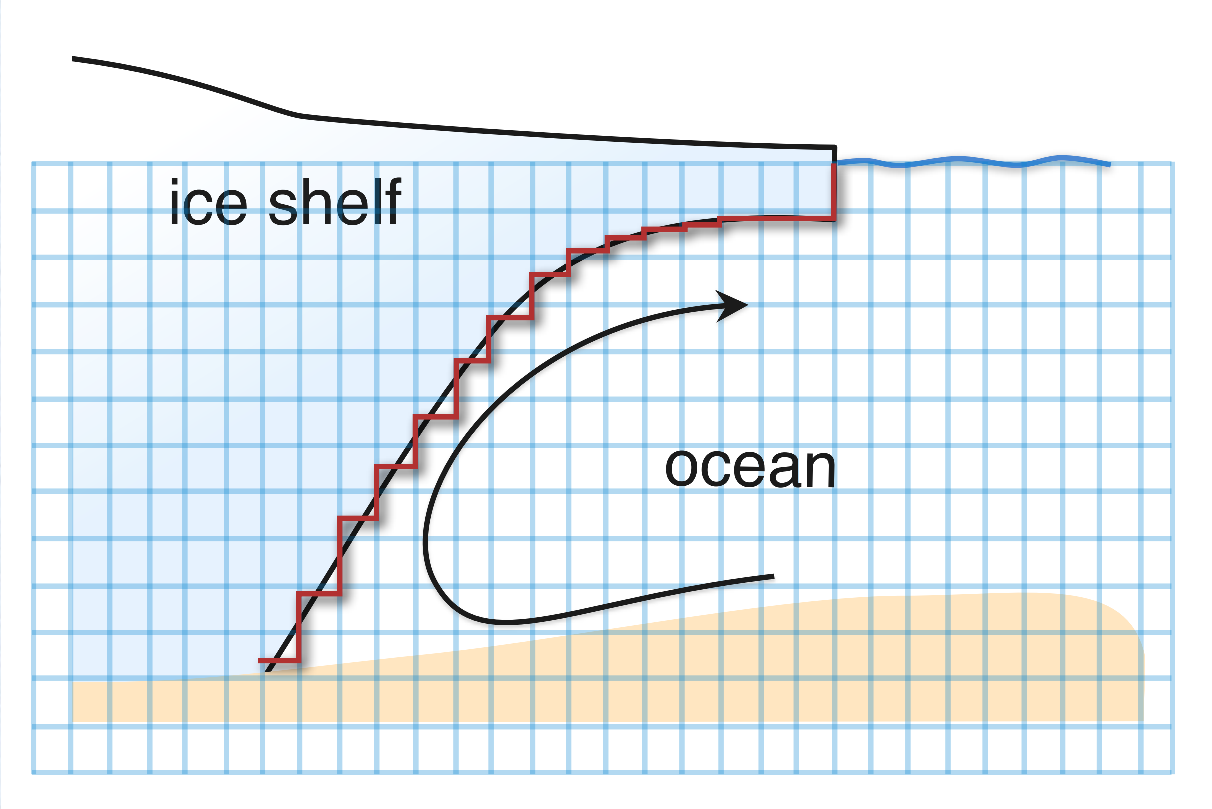
- Ice/ocean boundary defined by partial-top cells (analogous to partial-bottom cells)

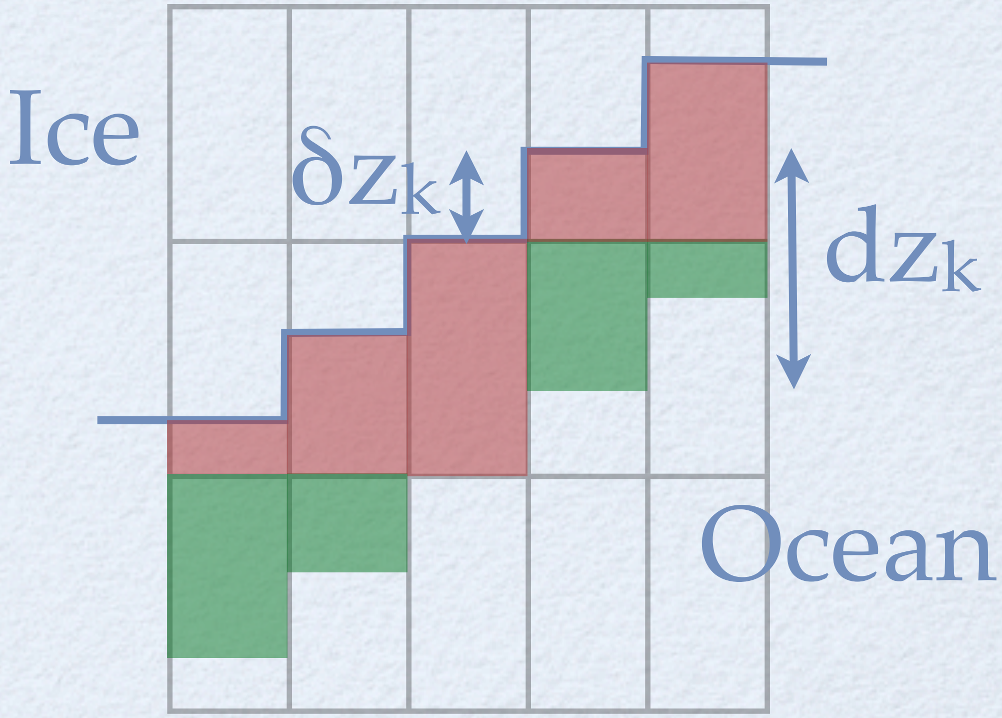


- Based on Losch 2008: static ice shelves in MITgcm

Partial Cells Method

- 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





Partial Cells Method

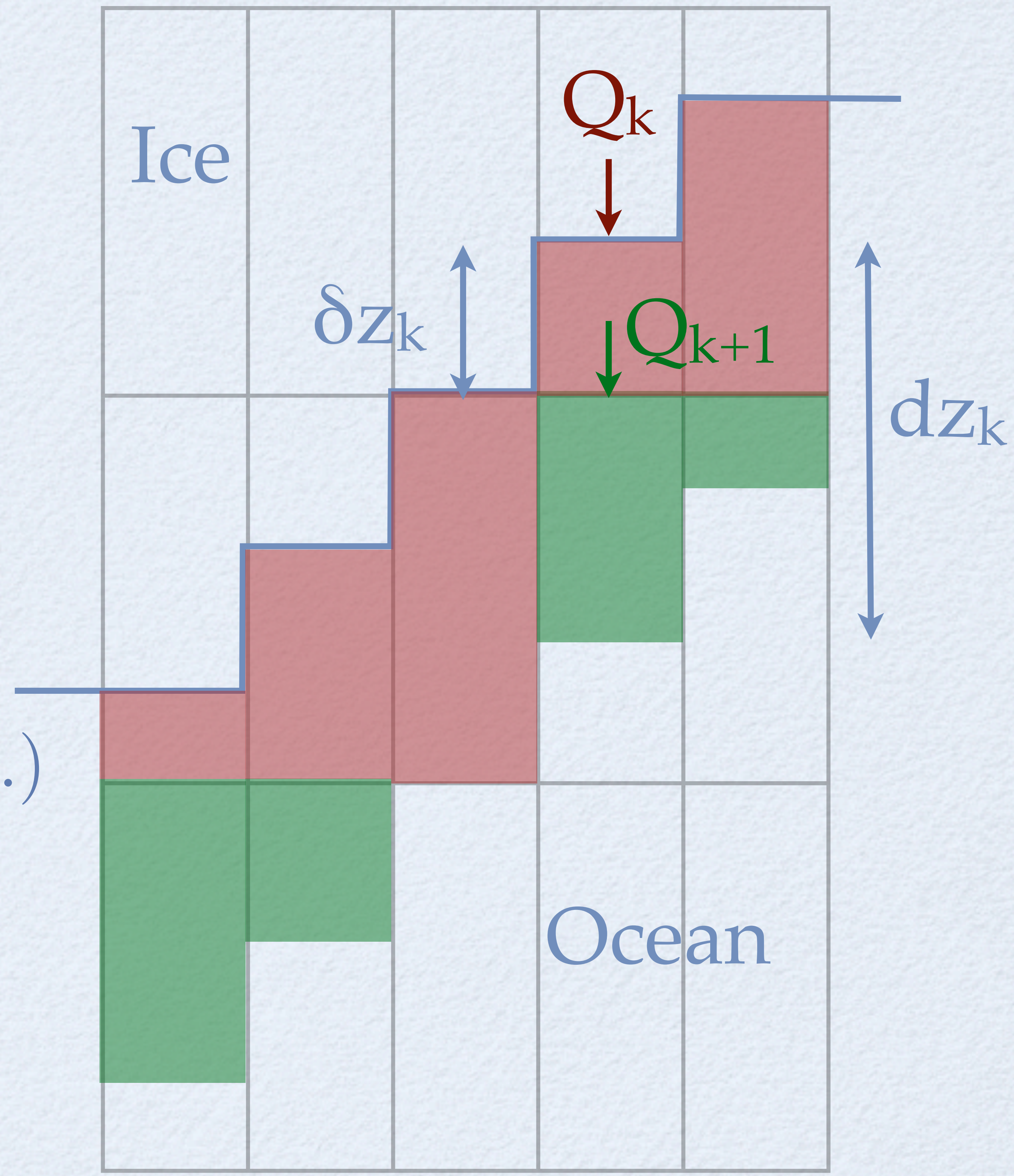
- Following Losch 2008, "boundary layer" below partial top cells:

$$\alpha \equiv \delta z_k / \Delta z_k$$

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

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

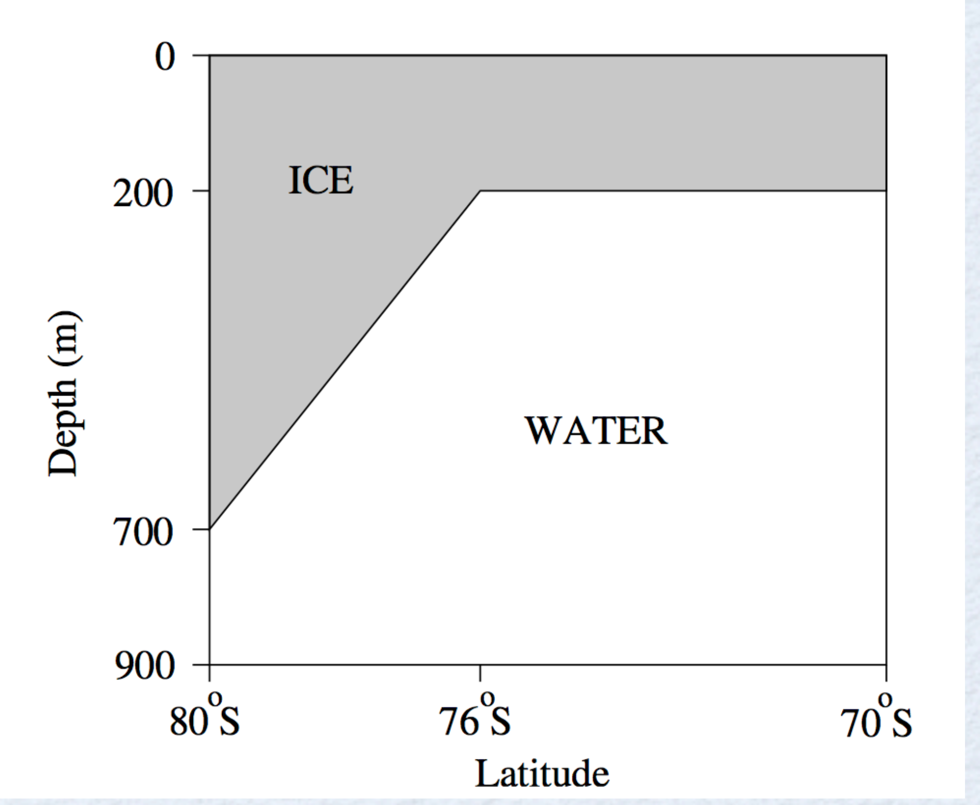
$$Q_{k+1} = (1-\alpha) Q_{\text{melt}}(\bar{T}, T_f, \ldots)$$



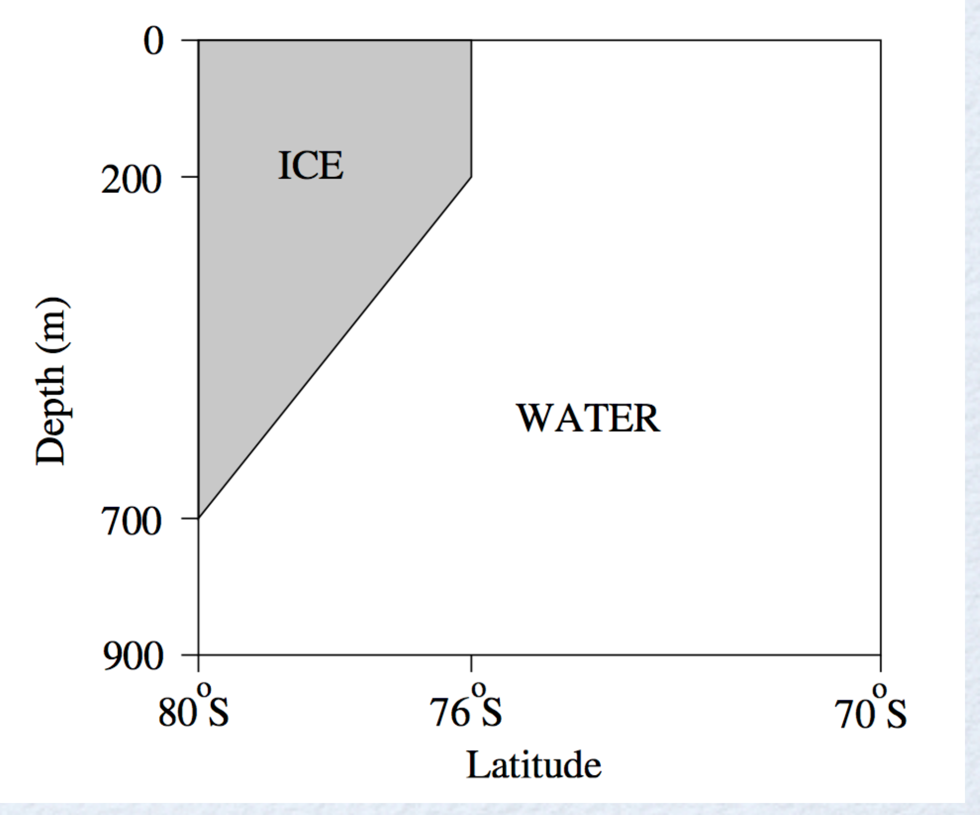
ISOMIP

- 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

Expt. 1

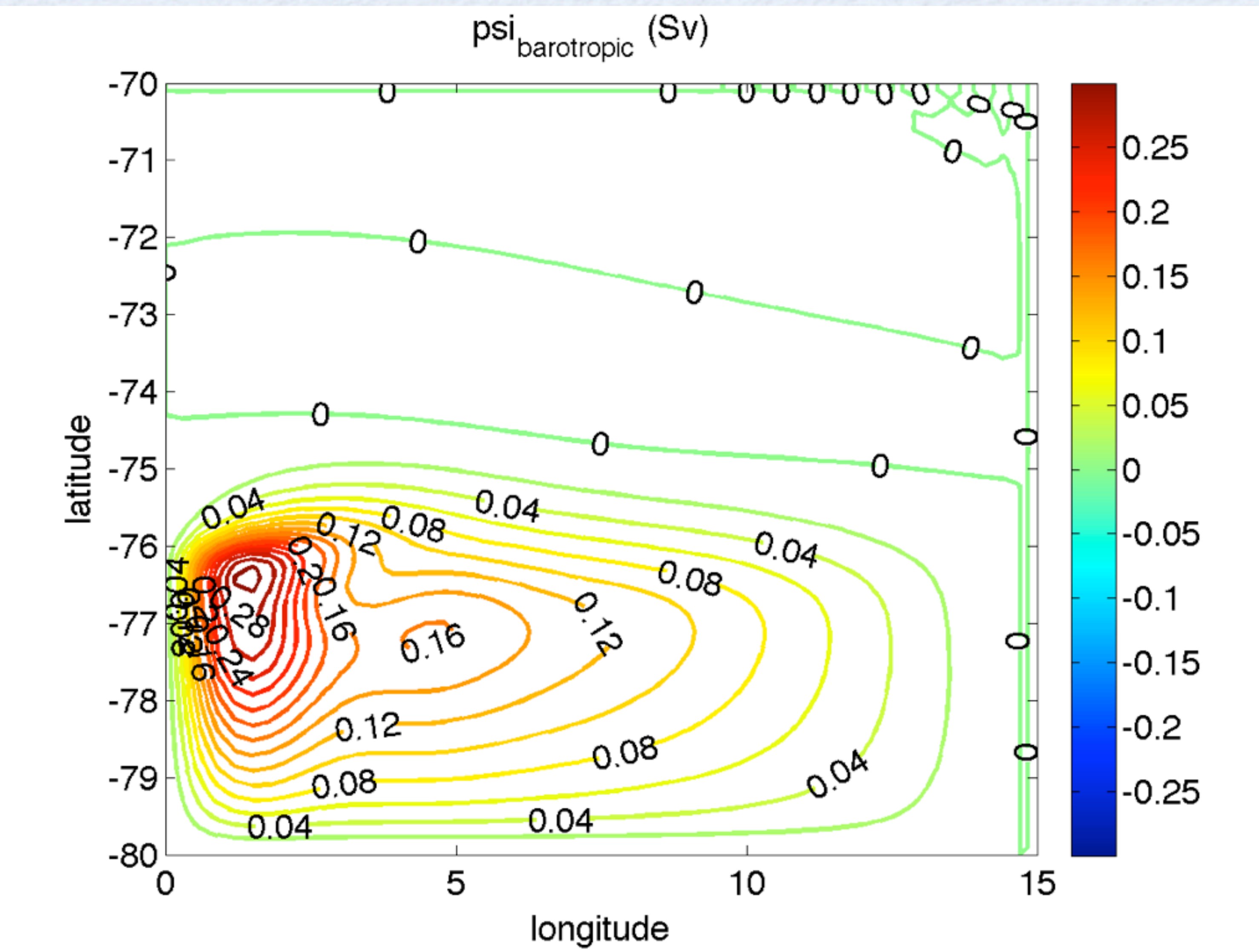


Expt. 2

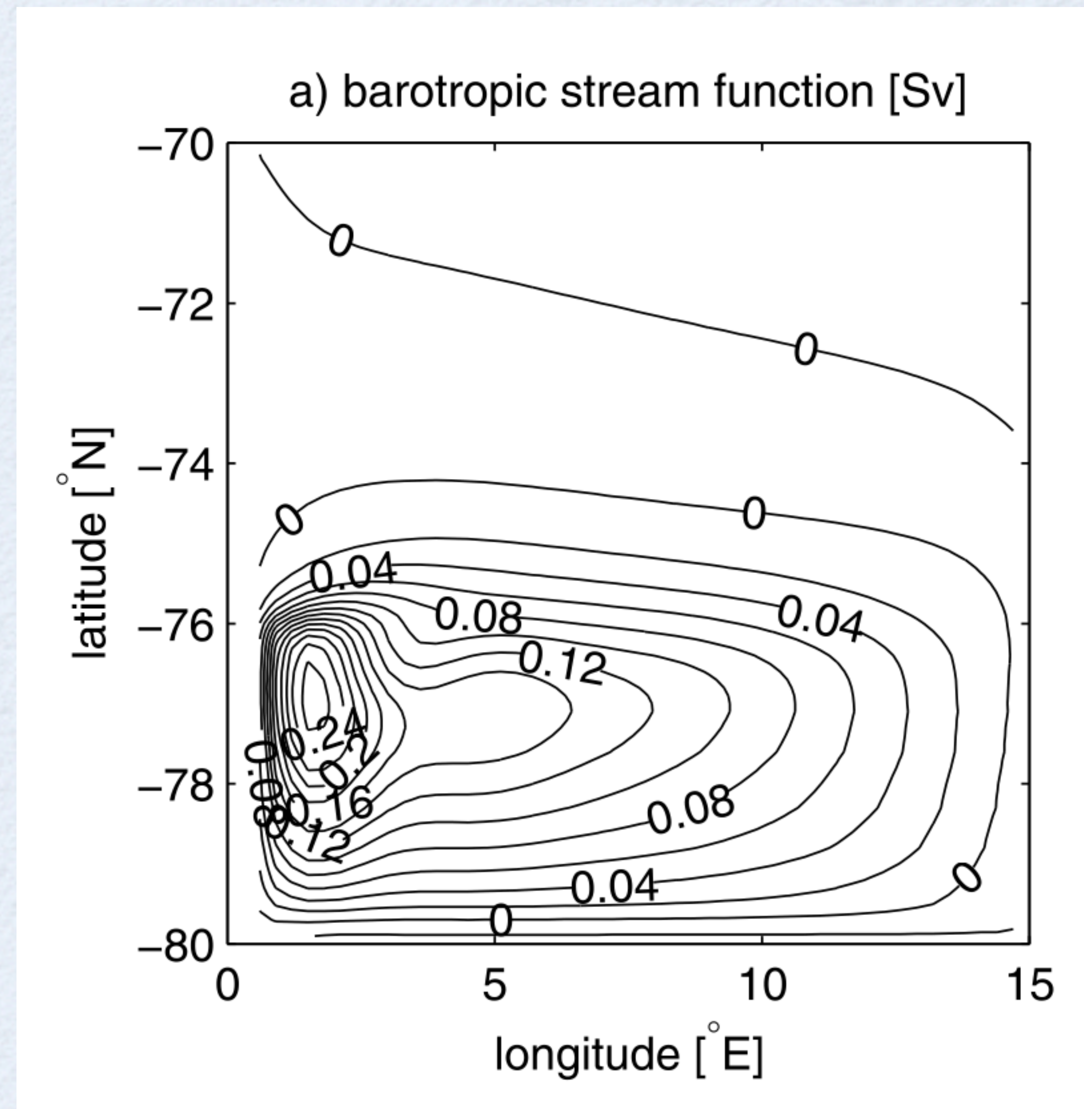


ISOMIP Expt. 1 Comparison

POP

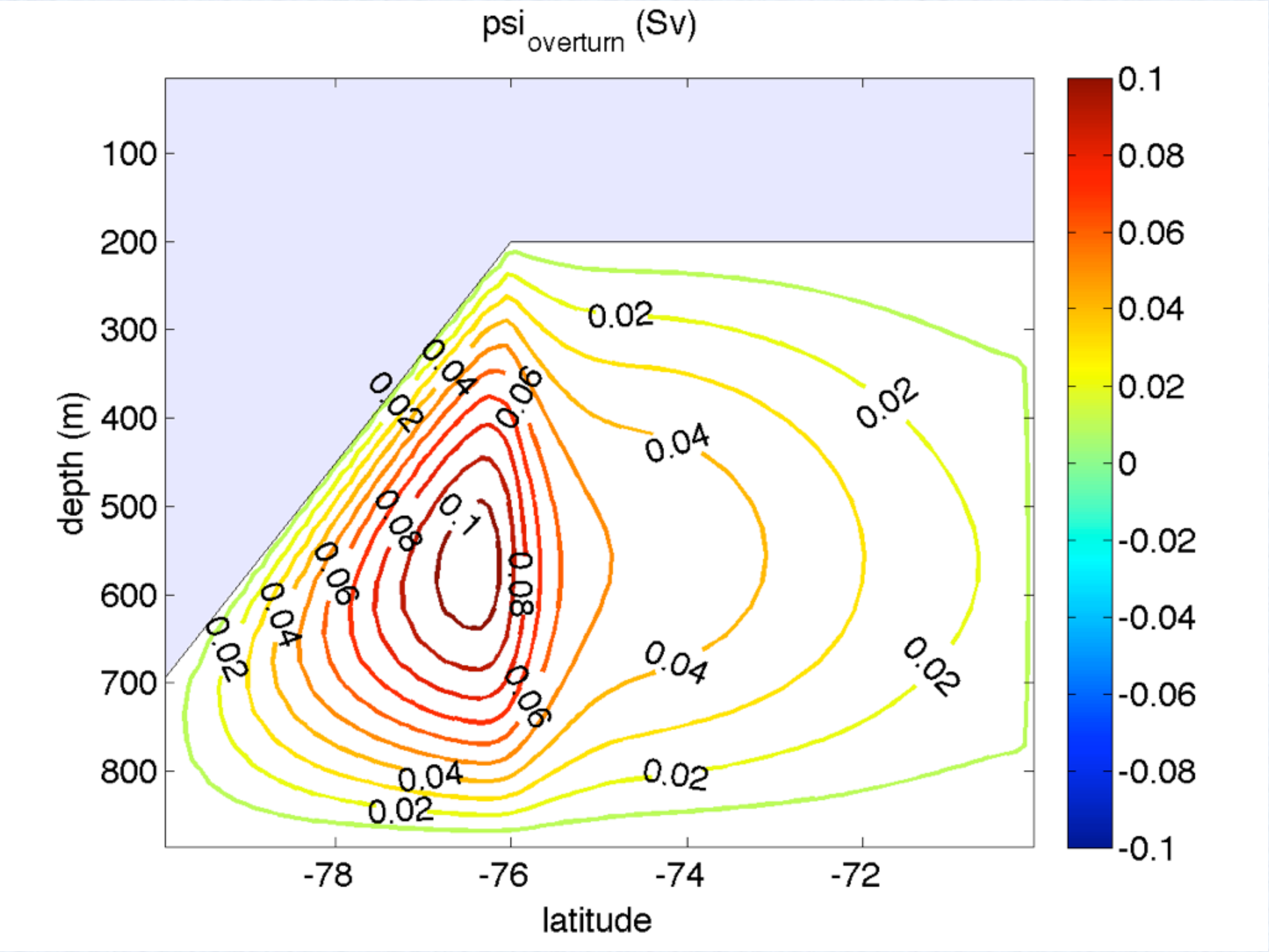


Losch 2008



isomip Expt. 1 Comparison

POP



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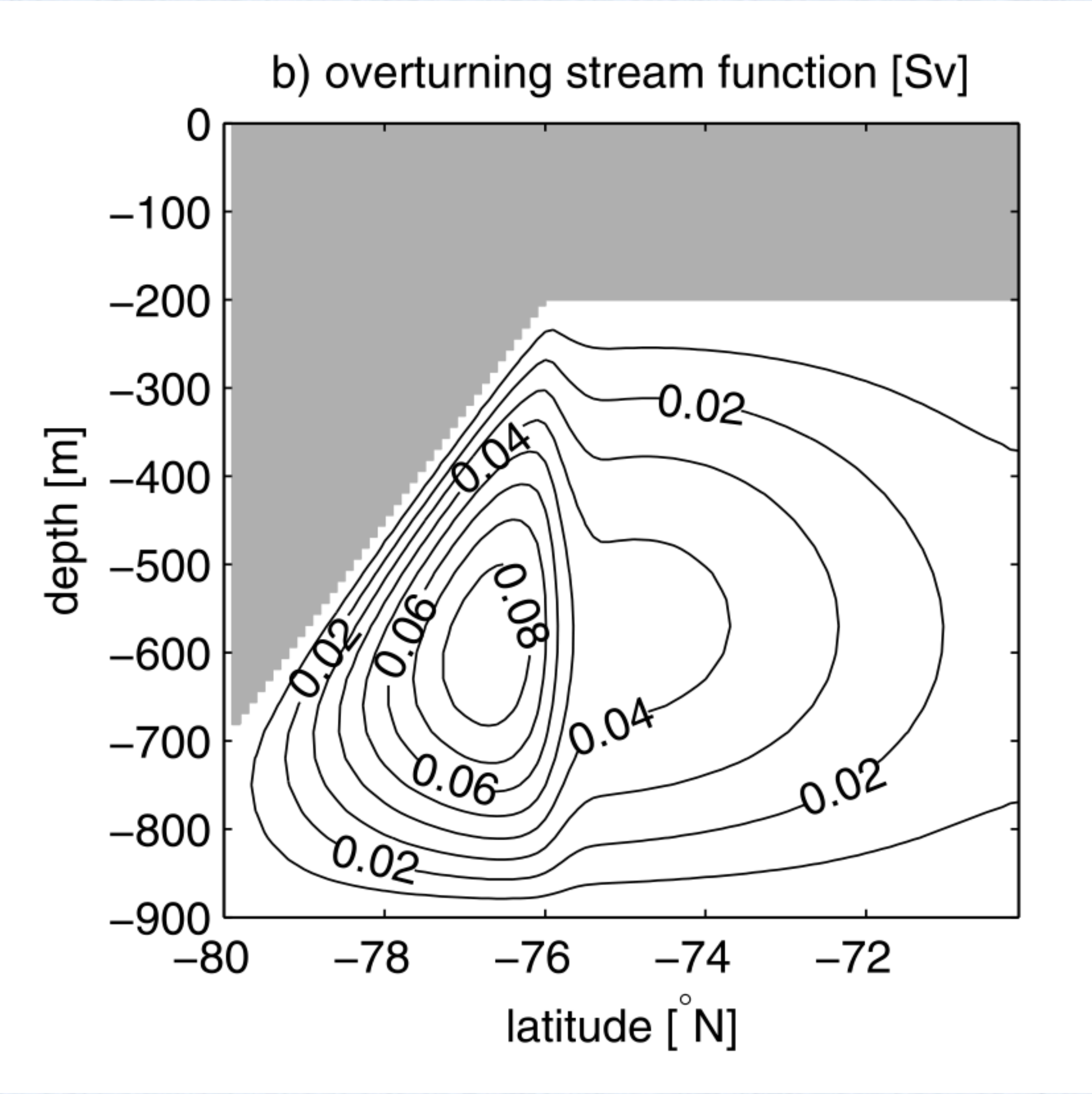
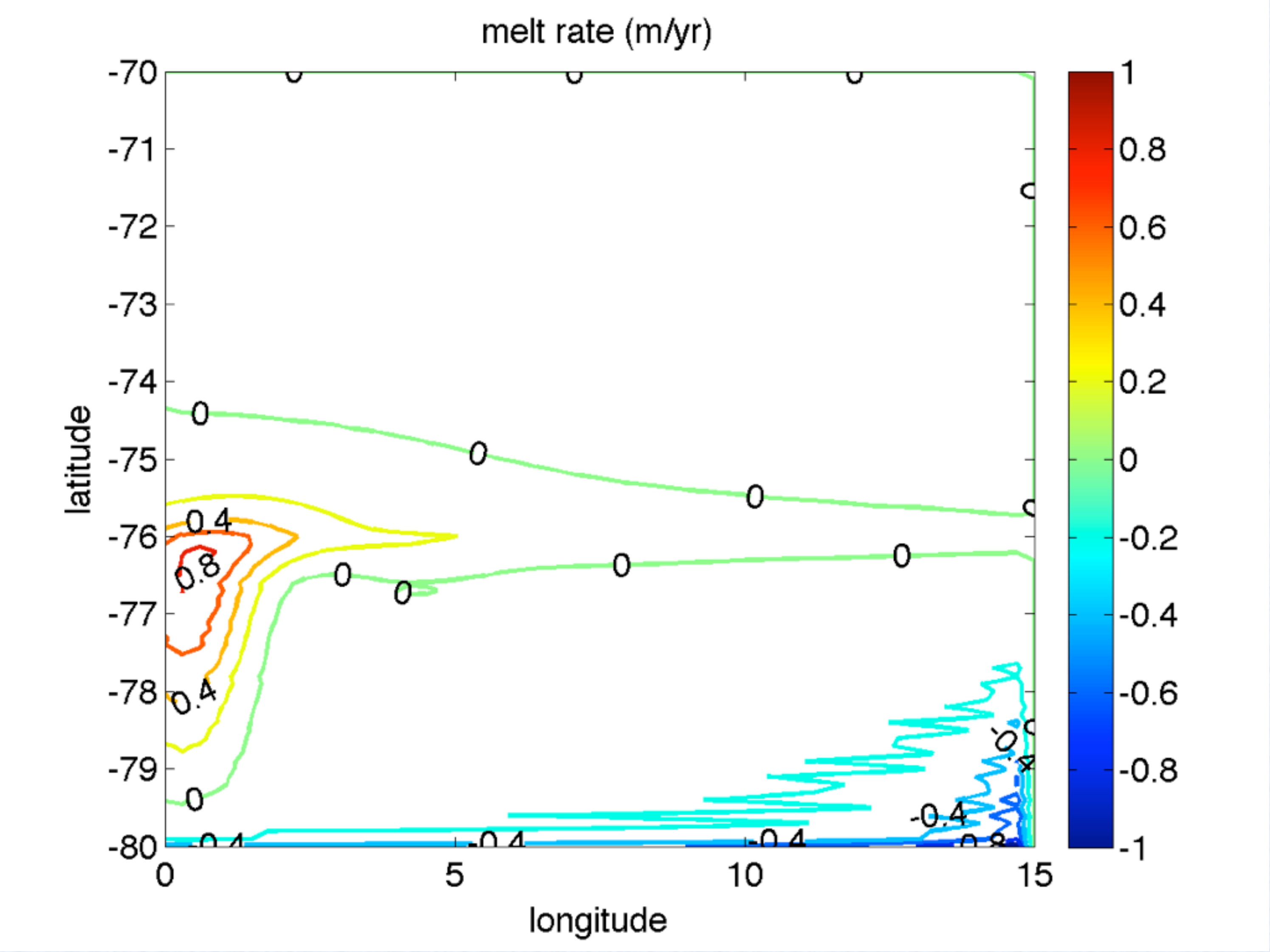


isomip Expt. 1 Comparison

POP



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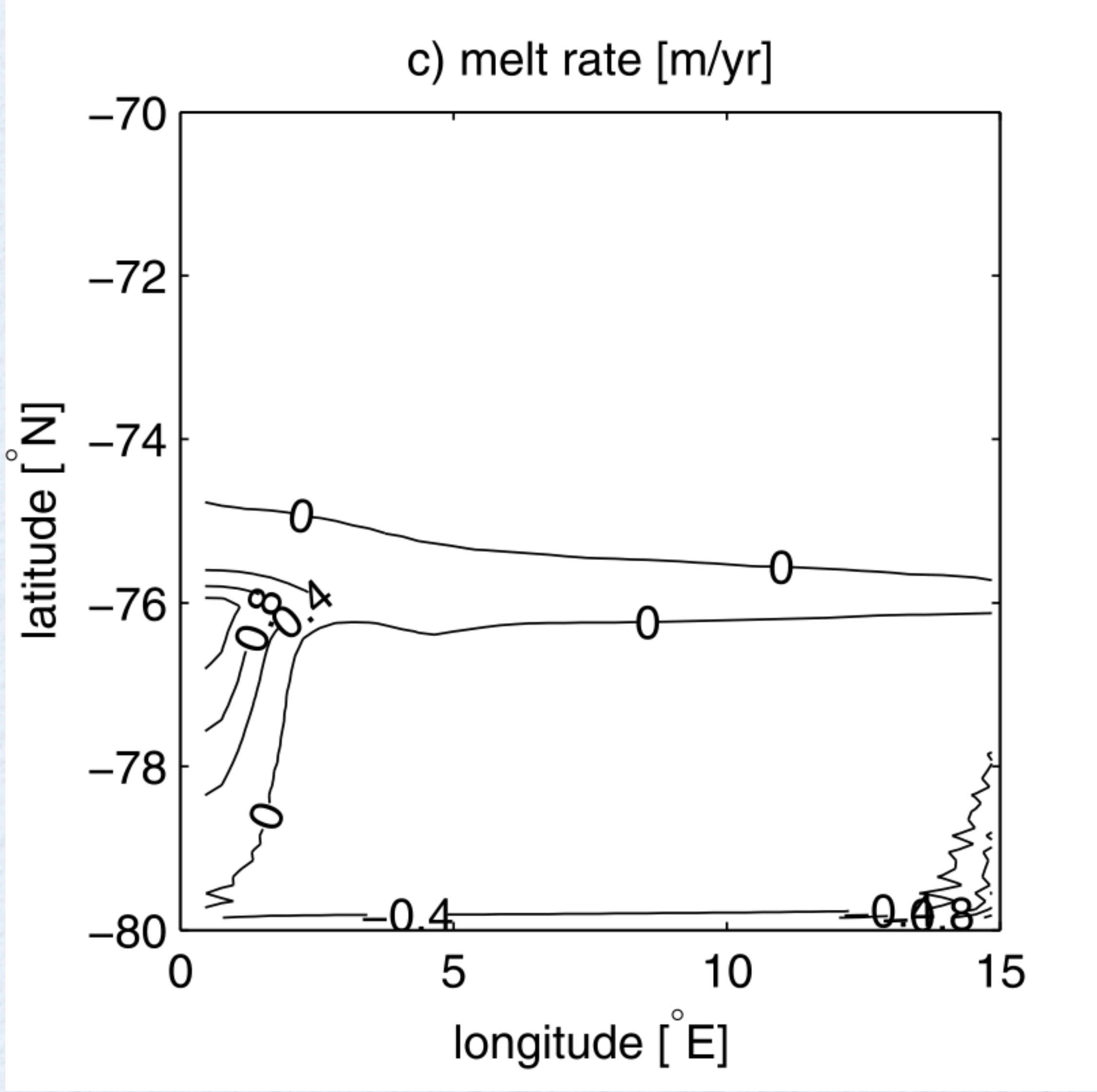
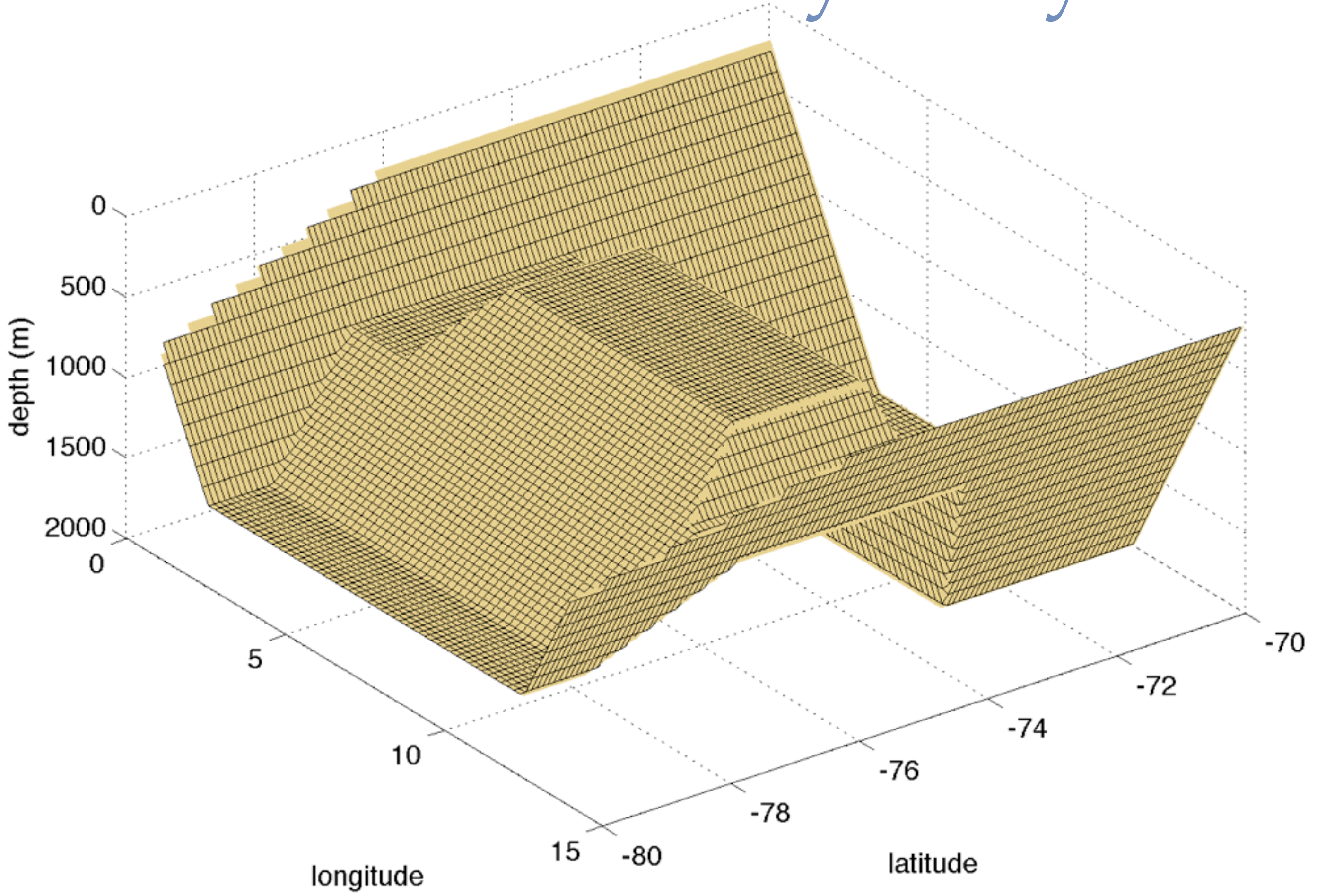
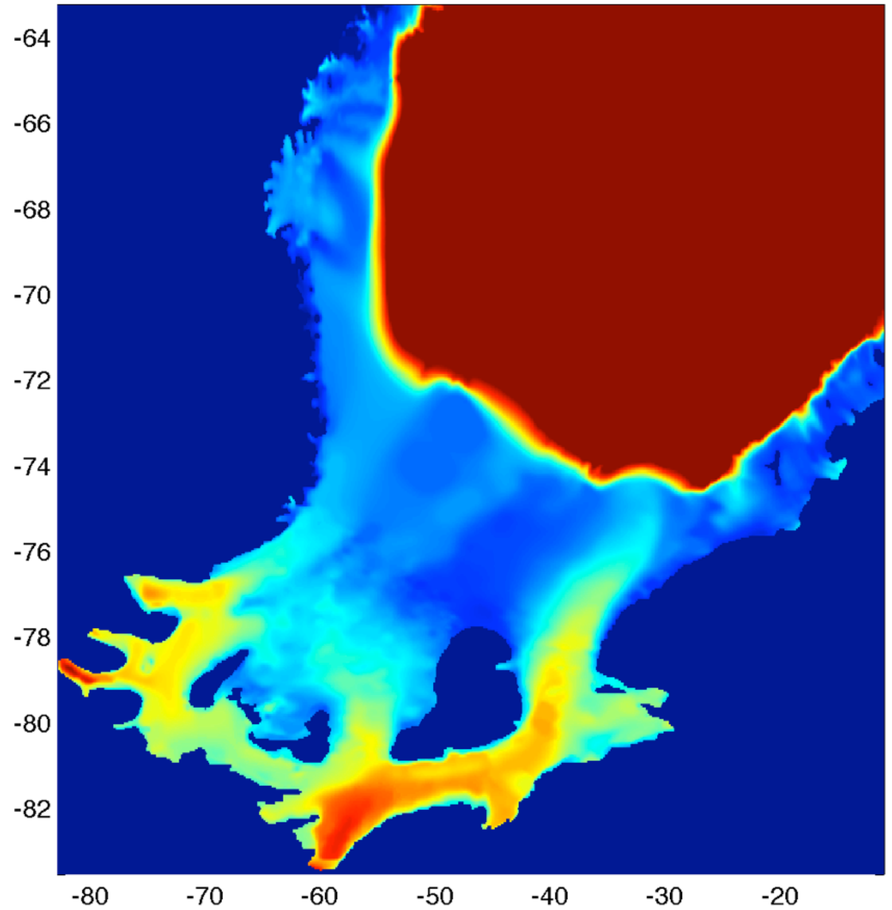


Sim. with Idealized Geometry

Idealized Bathymetry



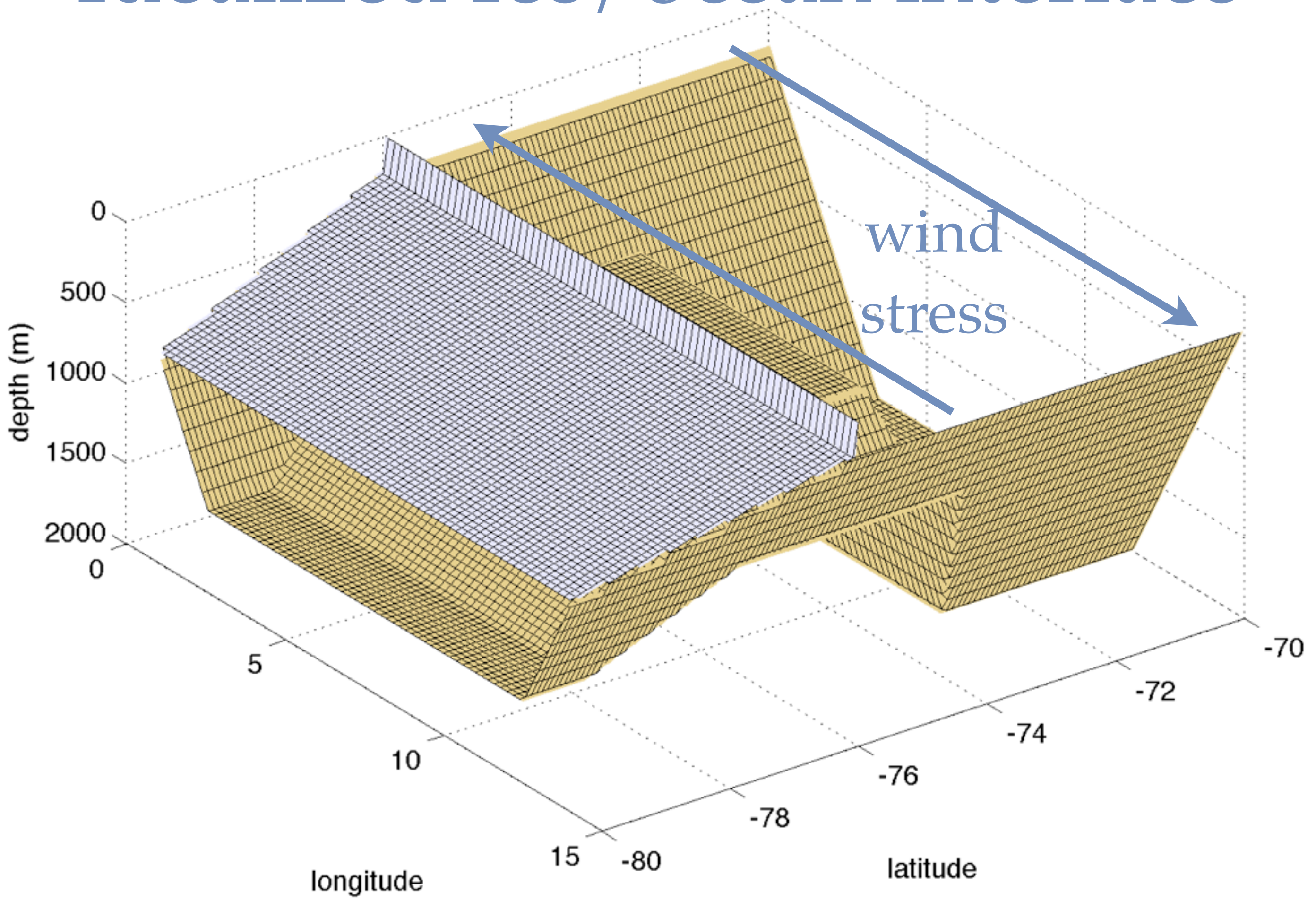
Ronne-Filchner



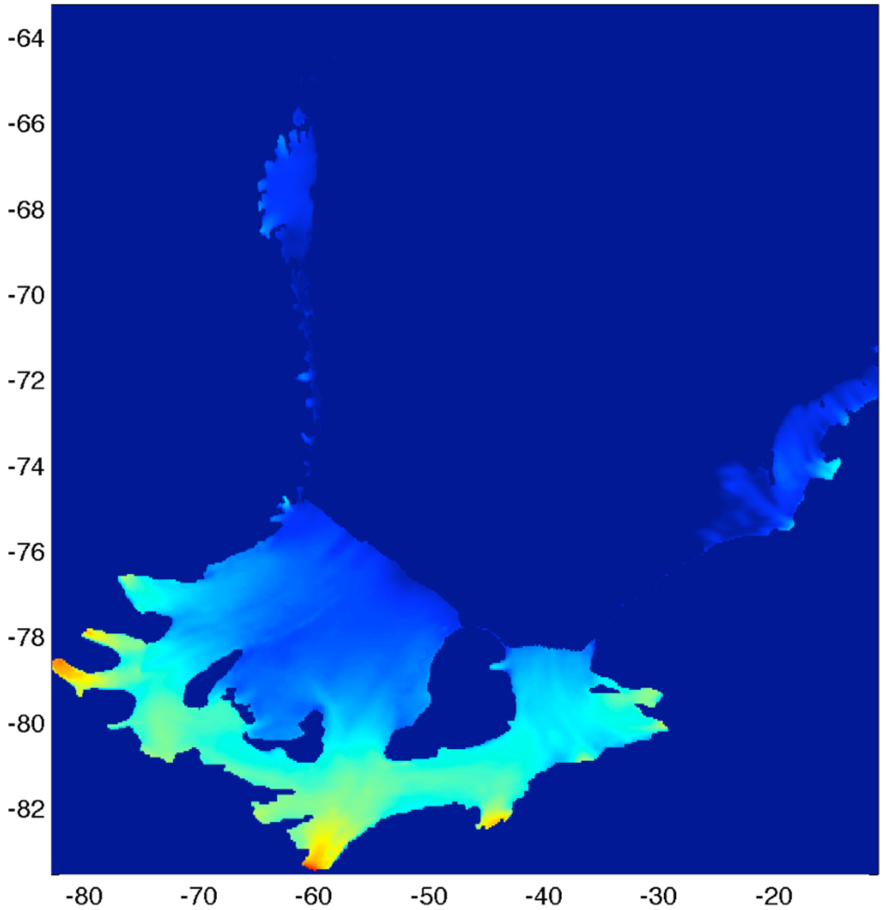
- Expt. 6 from Grosfeld et al. 1997
- Bathymetry mimics Ronne-Filchner: troughs; deepens to the south; northern basin (Weddell Sea)
- Closed box (not periodic in either direction)

Sim. with Idealized Geometry

Idealized Ice / ocean interface



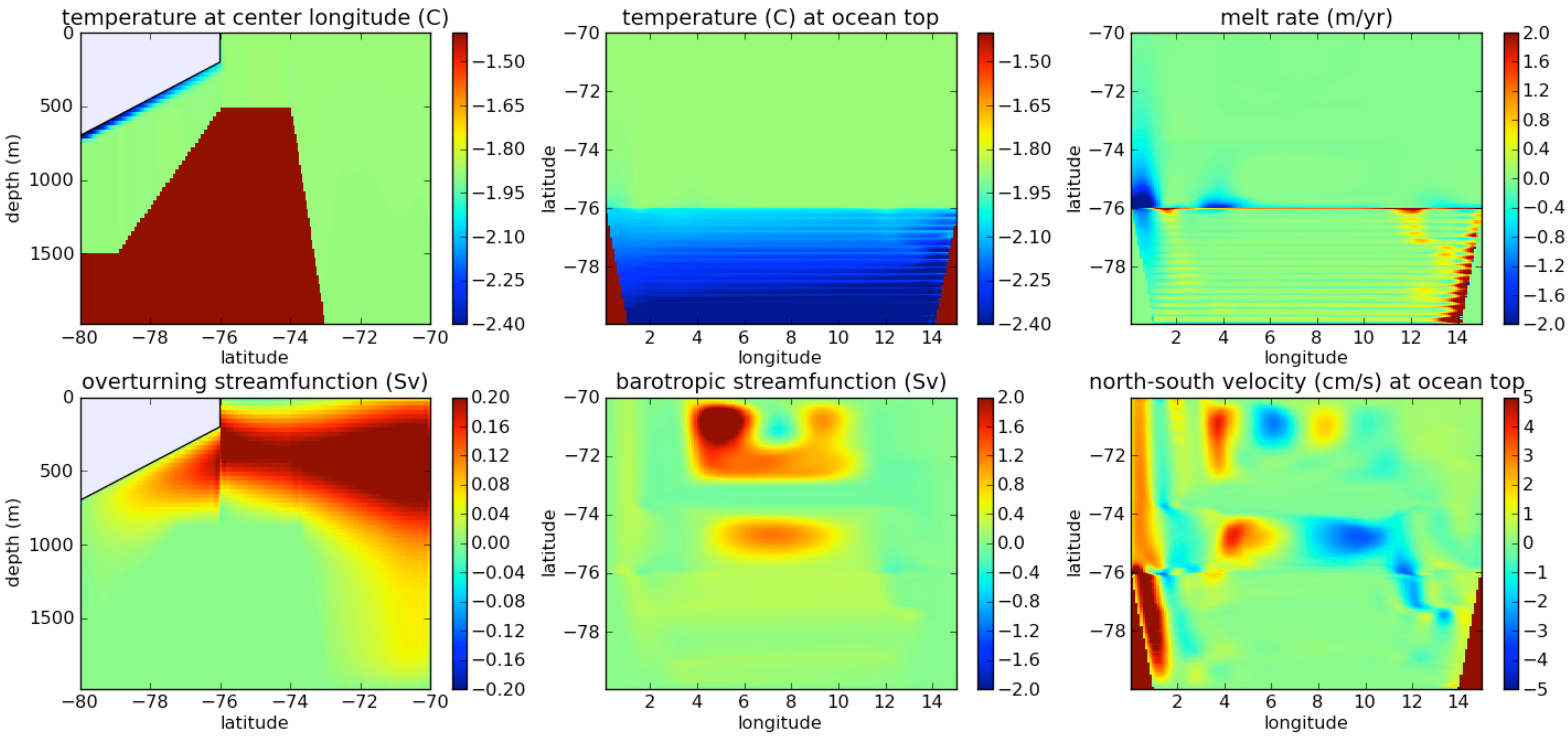
Ronne-Filchner



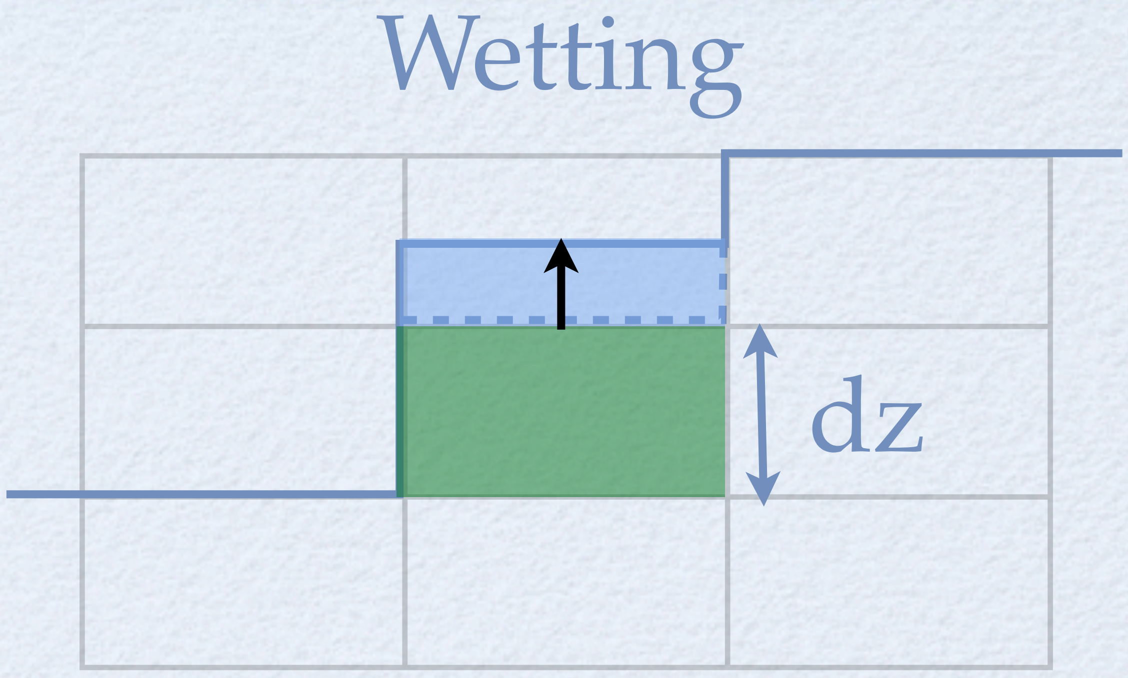
- Linearly sloped ice shelf covers southern 40% of domain
- Open ocean:
  - zonal wind stress
  - melting / freezing by simplified sea-ice model

Sim. with Idealized Geometry

Expt. 6 from Grosfeld et al. 1997



Partial Cells Method



Vertical "wetting" and "drying" of cells:

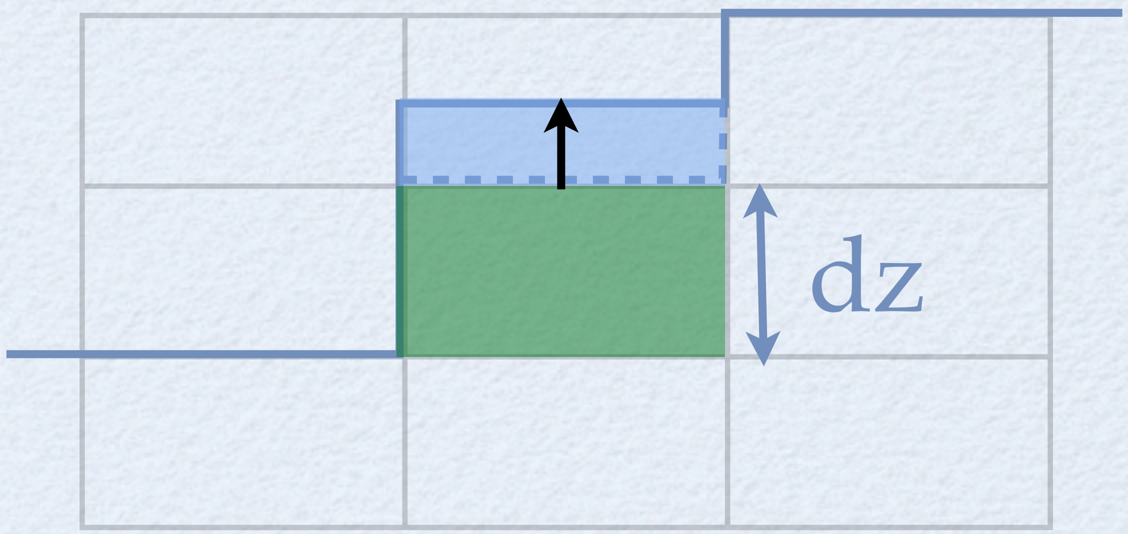
- Tracers in new "wetted" cells conservatively distributed *from* neighboring cell(s)

Partial Cells Method

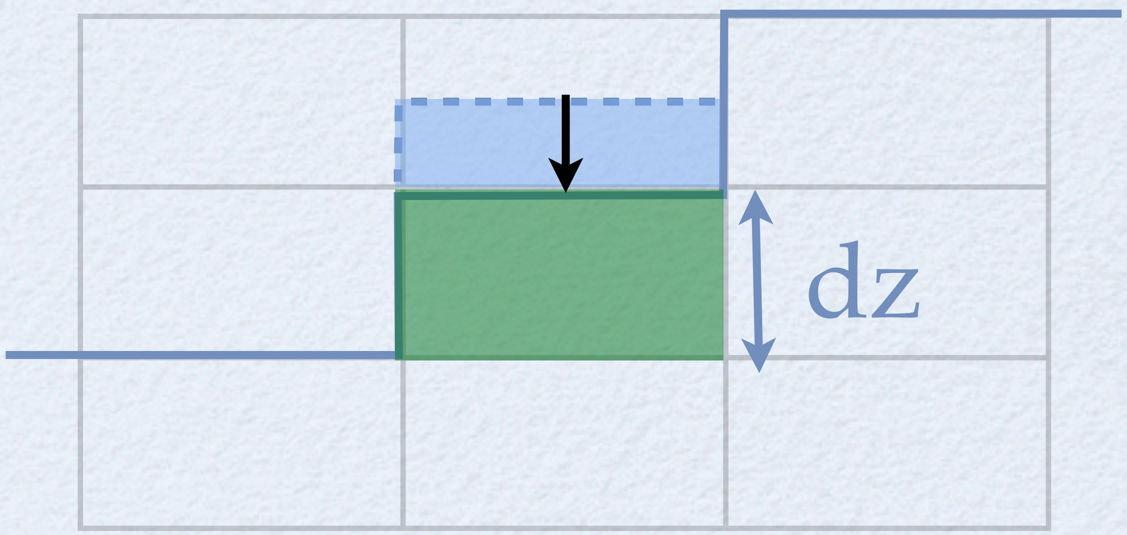
Vertical "wetting" and "drying" of cells:

- Tracers in new "wetted" cells conservatively distributed *from* neighboring cell(s)
- Tracers in old "dried" cells conservatively distributed *to* neighbor(s)

Wetting



Drying



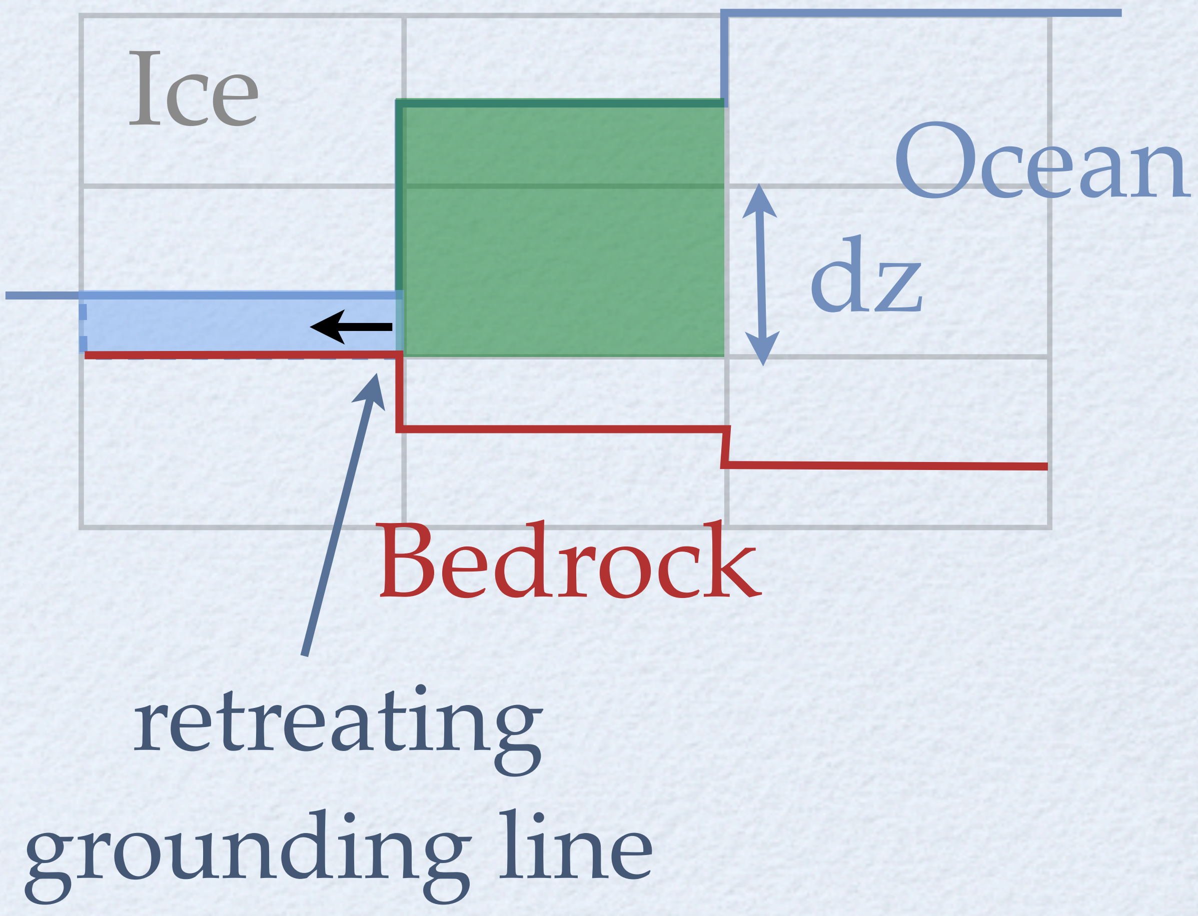
Partial Cells Method

What about horizontal "wetting" and "drying" as the grounding line moves?

Potentially more complicated:

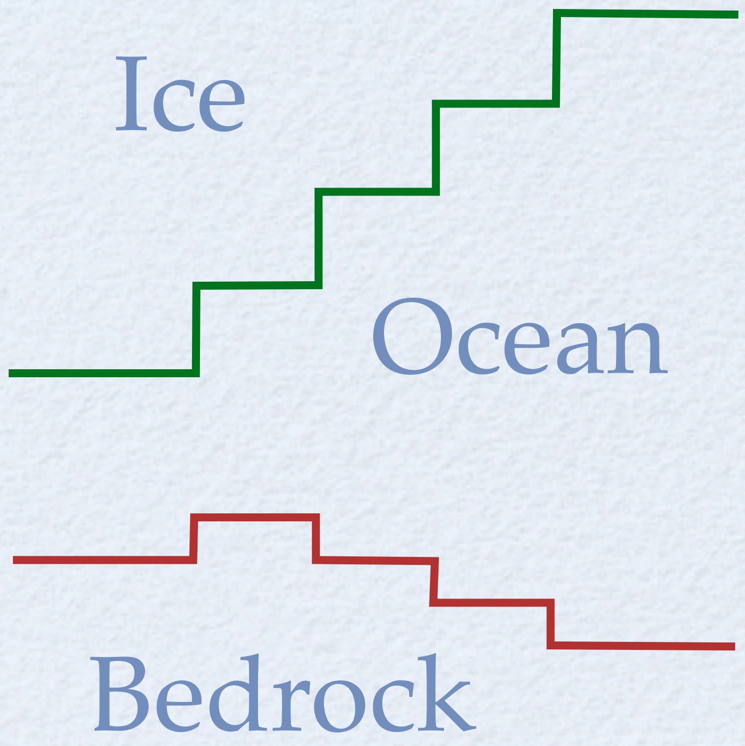
- either cell can be arbitrarily thin
- or cells "pop" from zero thickness to finite thickness in a single time step

horizontal wetting



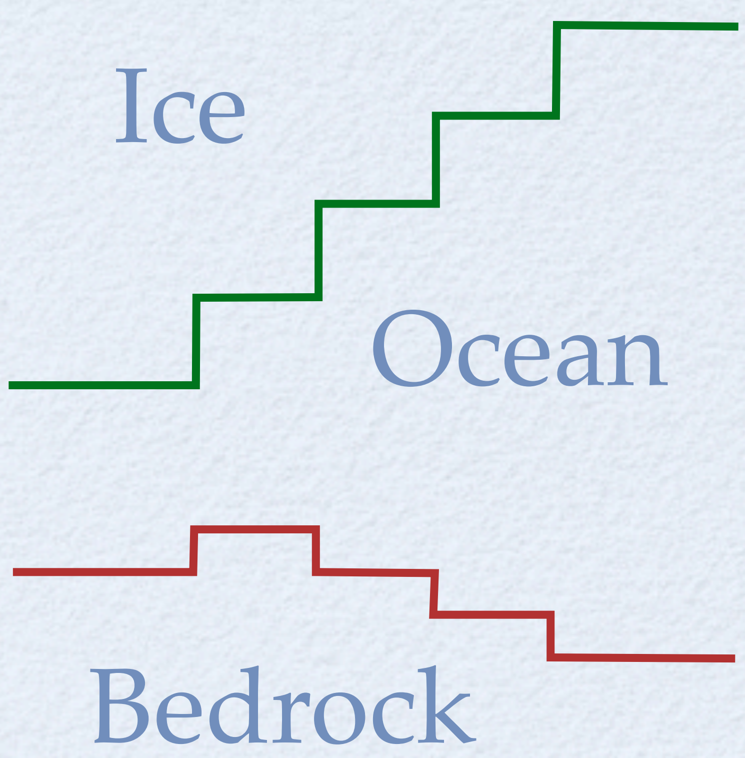
Partial Cells Method

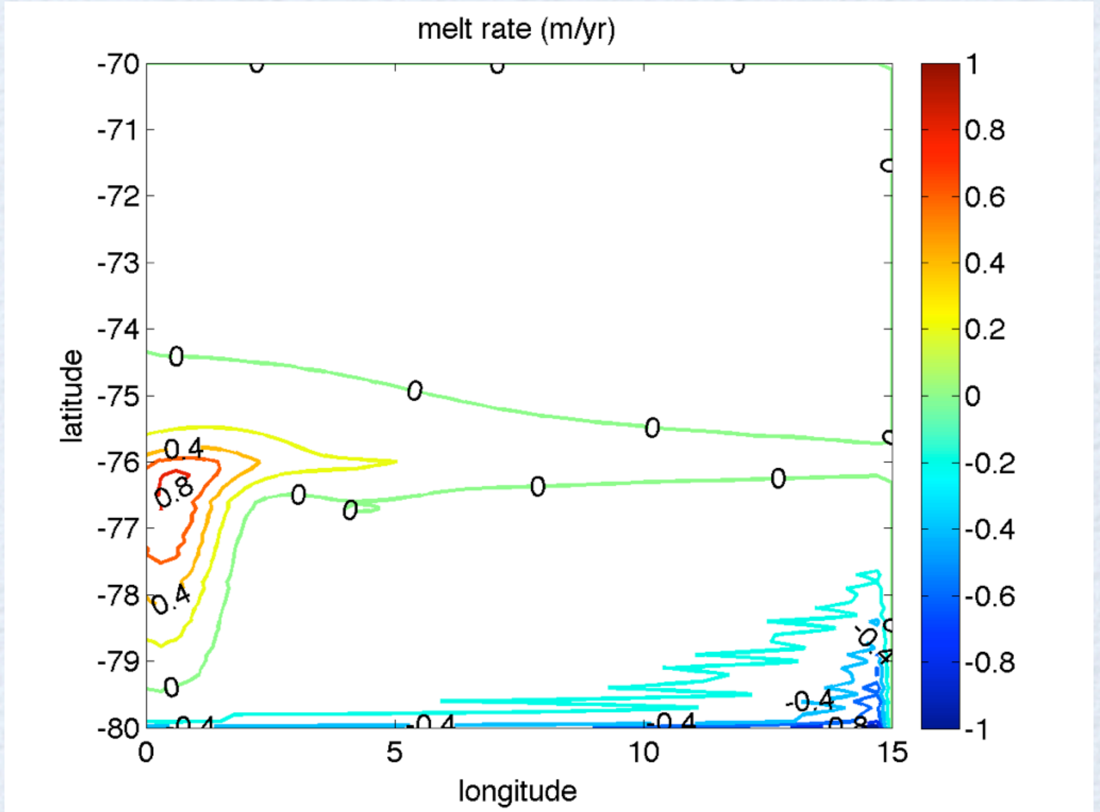
- Pros:
  - Static interface tested with other ocean models
  - Similar to bathymetry



Partial Cells Method

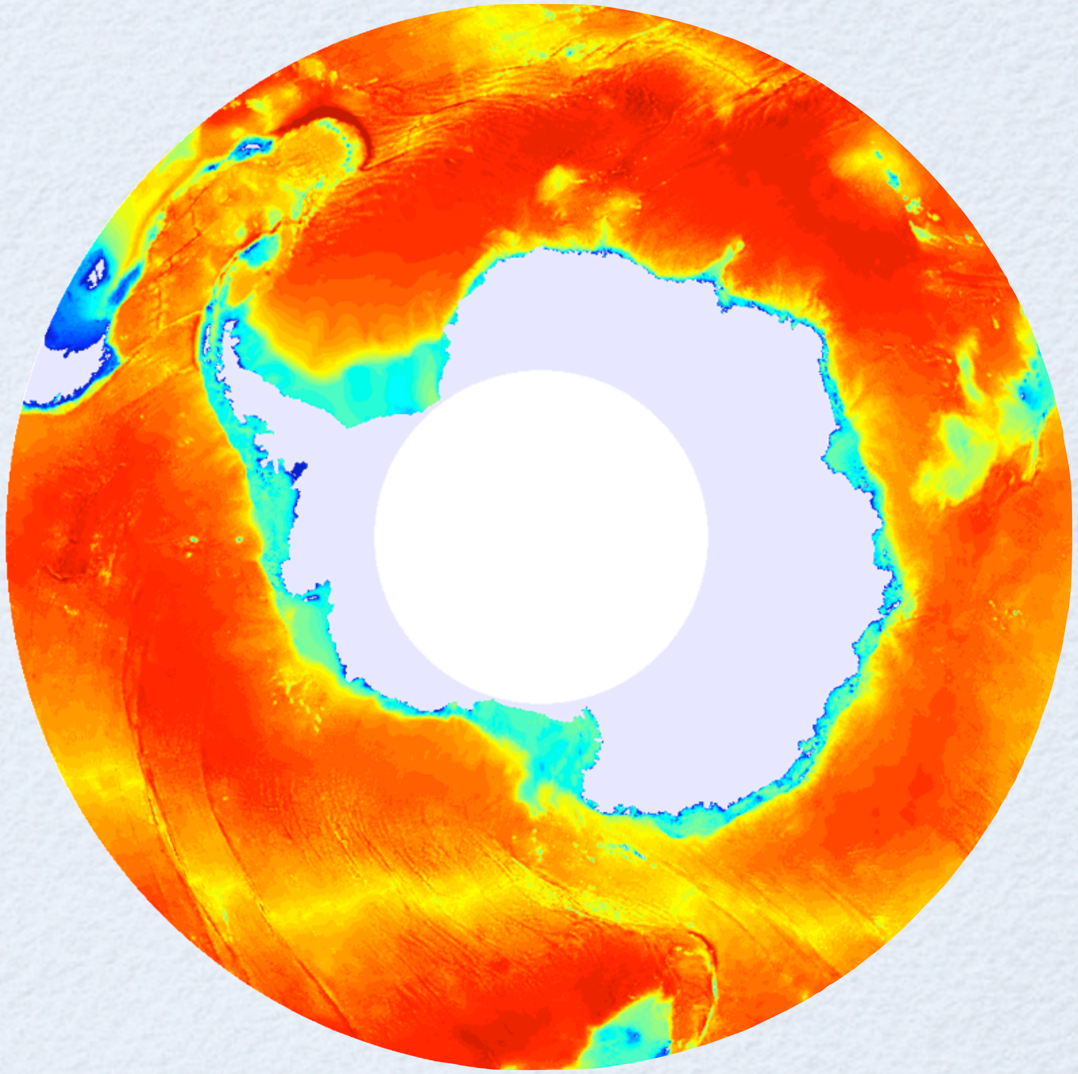
- Pros:
  - Static interface tested with other ocean models
  - Similar to bathymetry
- Cons:
  - Stair-step geometry can lead to noisy fields
  - How to handle infinitesimally thin cells?
  - How to handle wetting at grounding line?





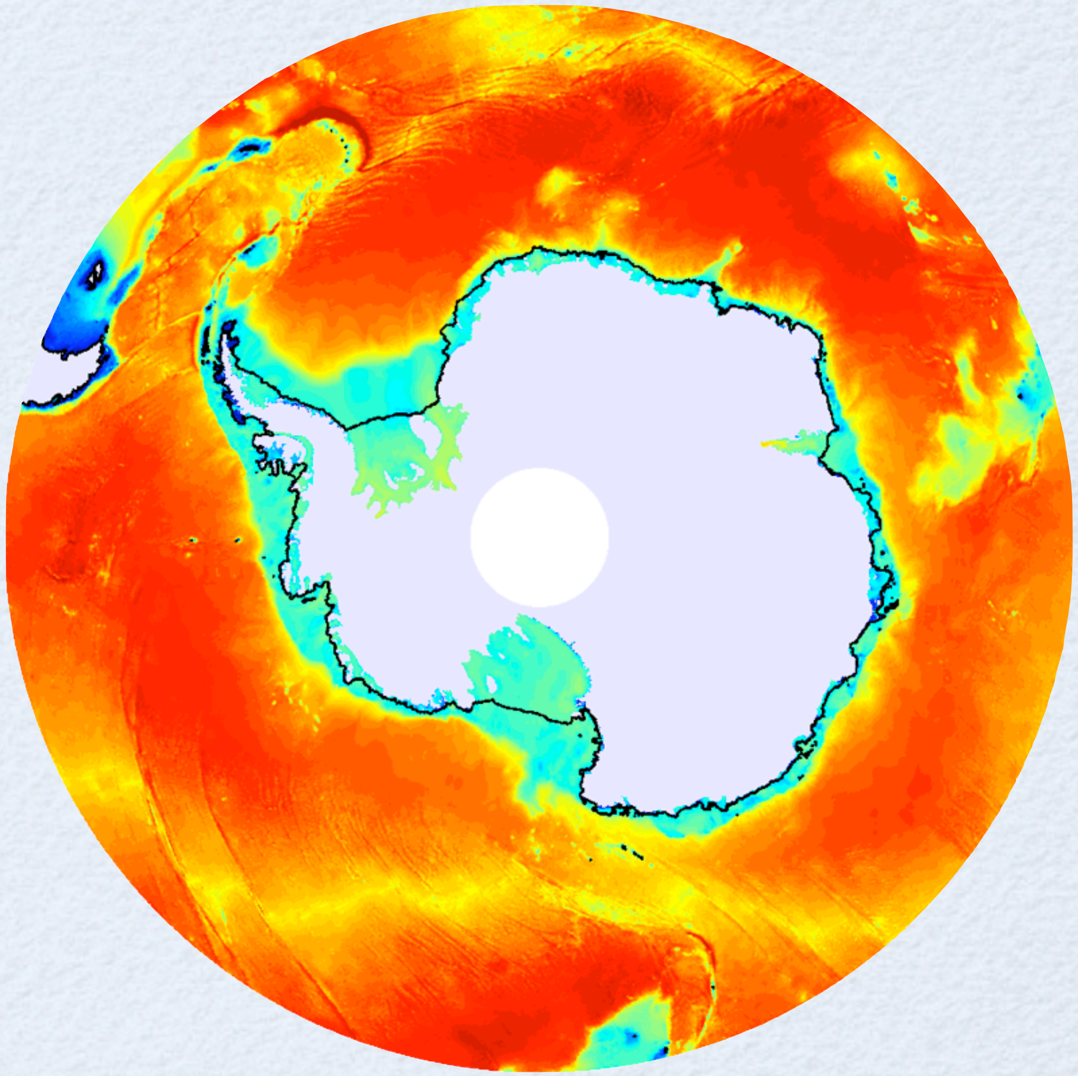
In progress: sim. of Southern Ocean (no ice shelves yet)

- Existing POP grid: No cavities under ice shelves



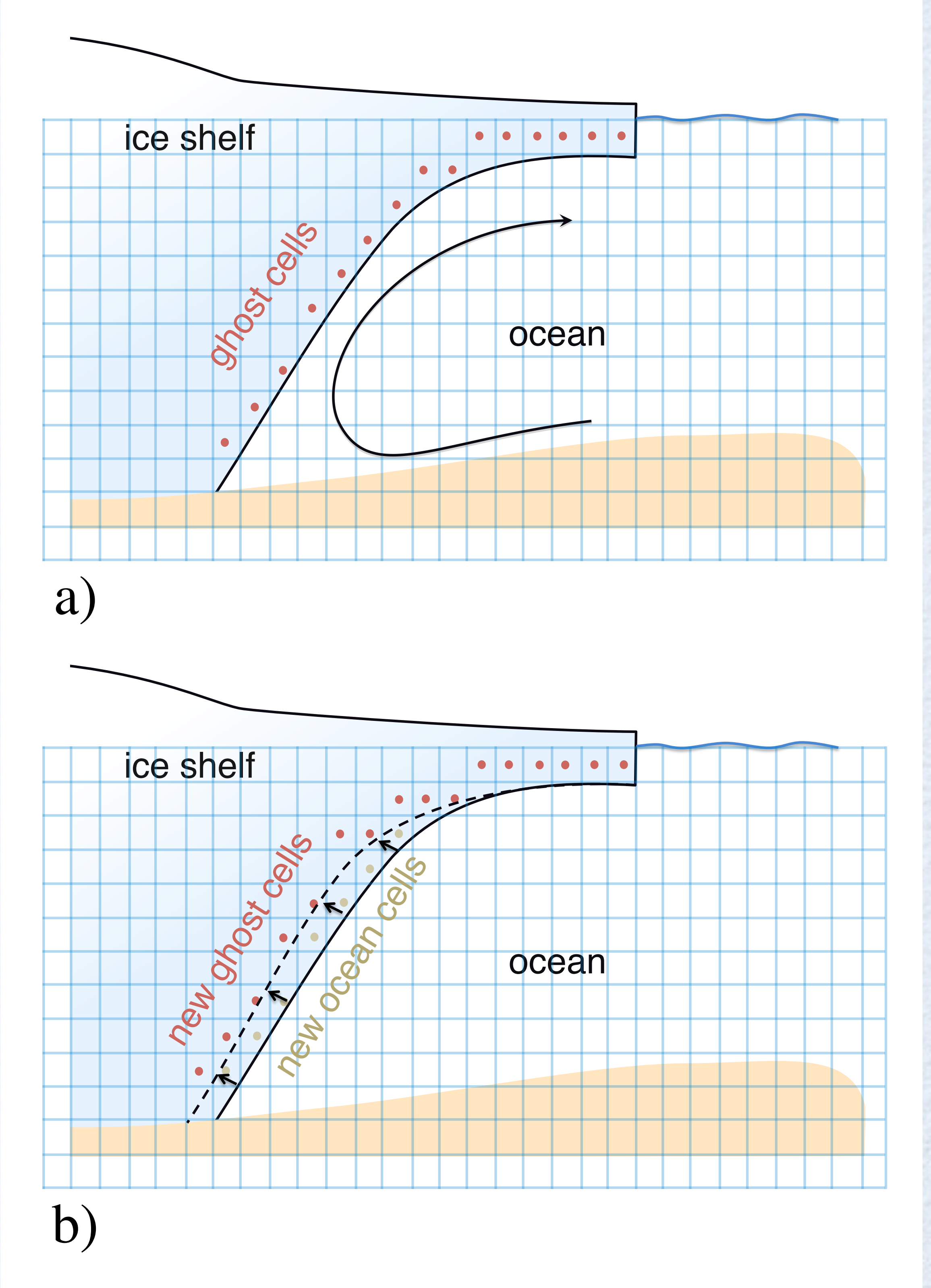
In progress: sim. of Southern Ocean (no ice shelves yet)

- 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