An Update on LANL's Method for Simulating Dynamic Ice Shelves in POP

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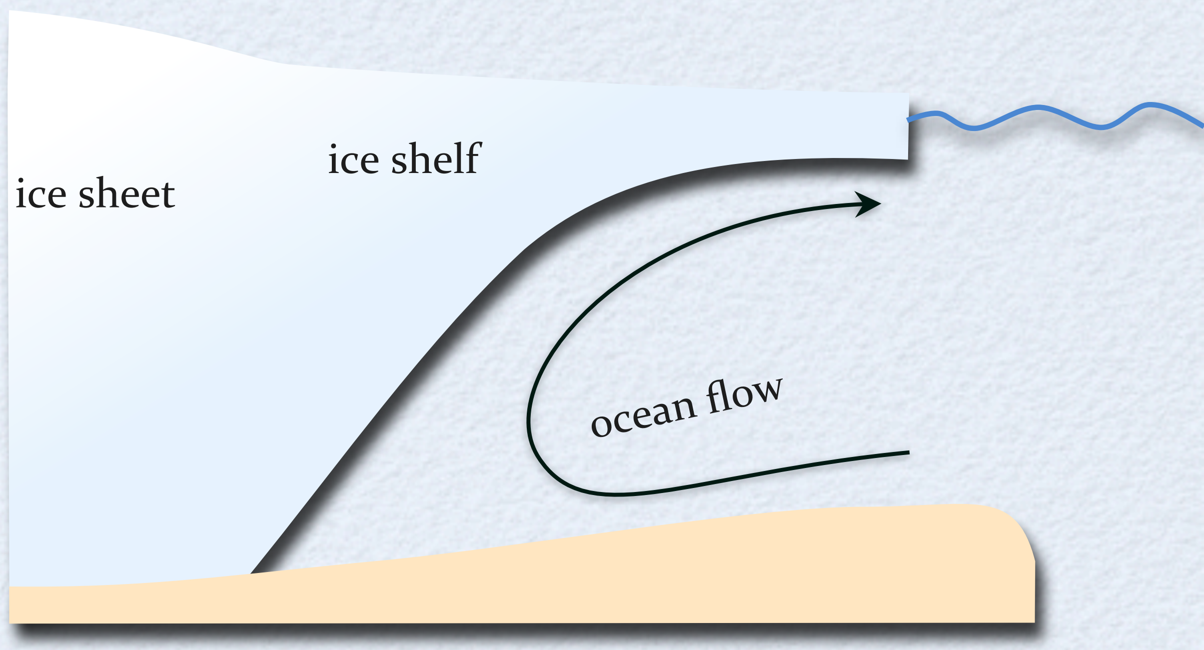
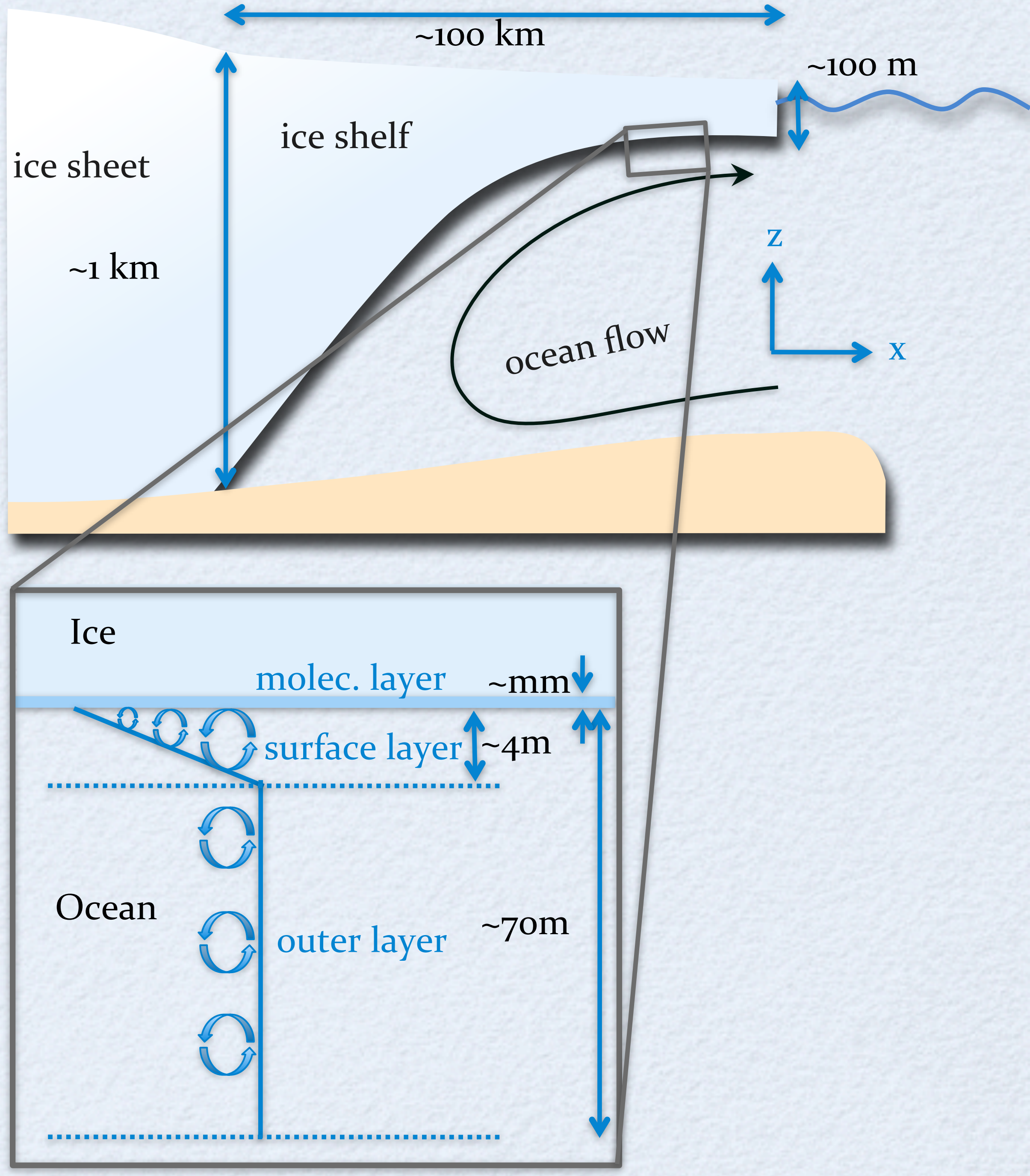
OUTLINE

- Boundary Layer Physics
- Immersed Boundary Method
- Partial Cells Method
- New Ocean Model Grid



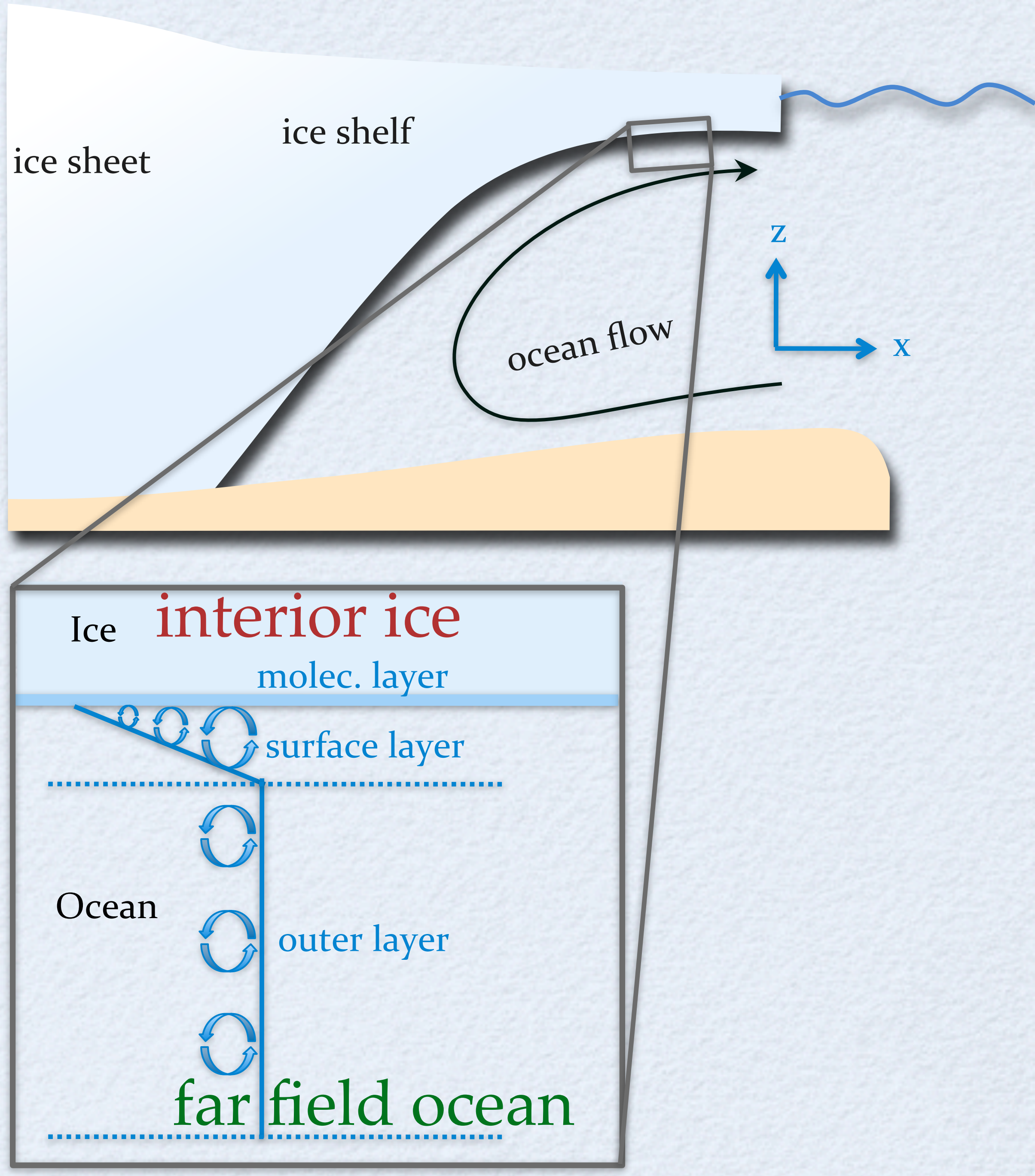
Boundary Layer Physics

- *Very few* observations under ice shelves:
- So, using boundary layer theory validated under **sea ice** (McPhee 2008)
- Includes stabilizing effect of **stratification**, very important for rapid melting



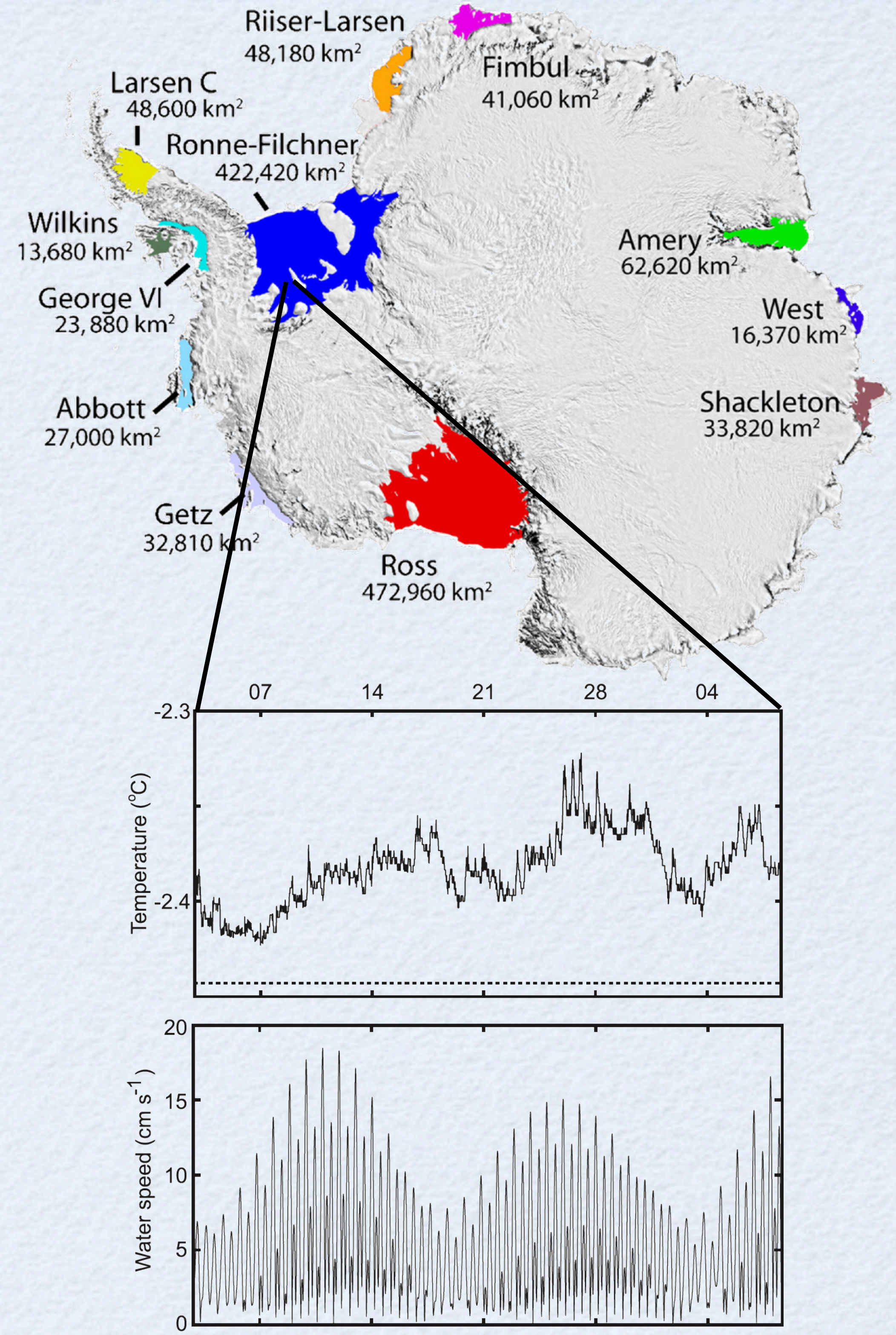
Boundary Layer Physics

- Requires:
  - far field ocean temp., velocity, salinity
  - interior ice temperature
- Gives at interface:
  - heat flux
  - salt flux
  - momentum flux
  - mass flux



Boundary Layer Physics

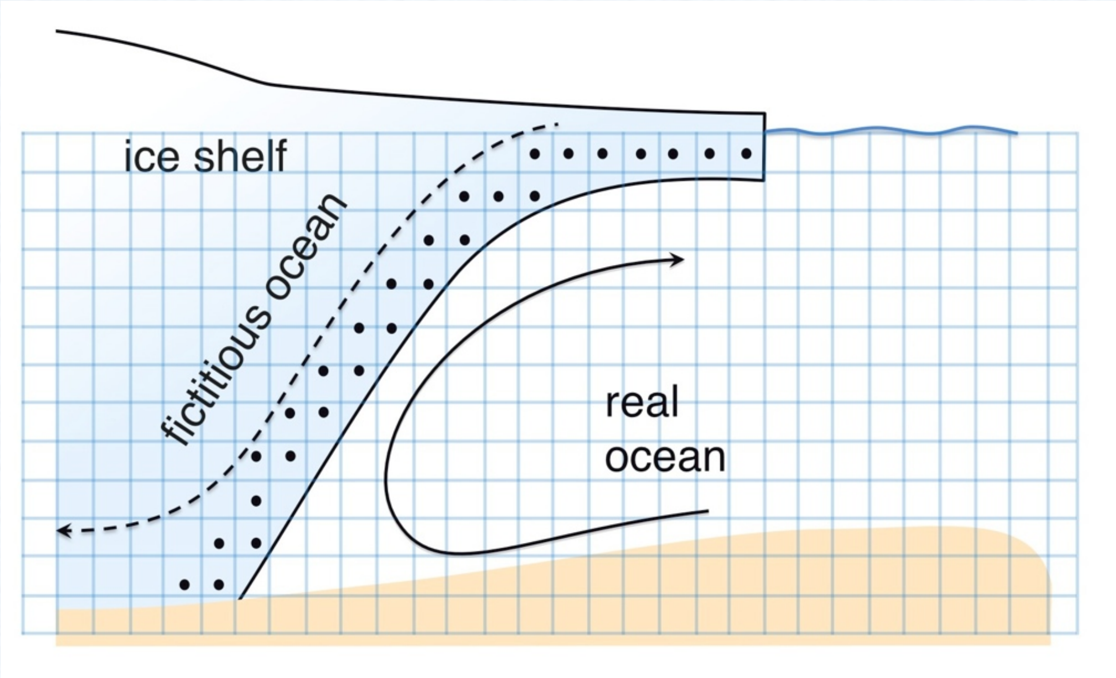
- 2 coeffs. are calibrated using measurements under Ronne Ice Shelf (Jenkins et al. 2010)
    - Surface roughness
    - Molec. transport coeff.
- More calibration data expected in coming years (Fimbul, Larsen C, George VI, Pine Island Ice Shelves)

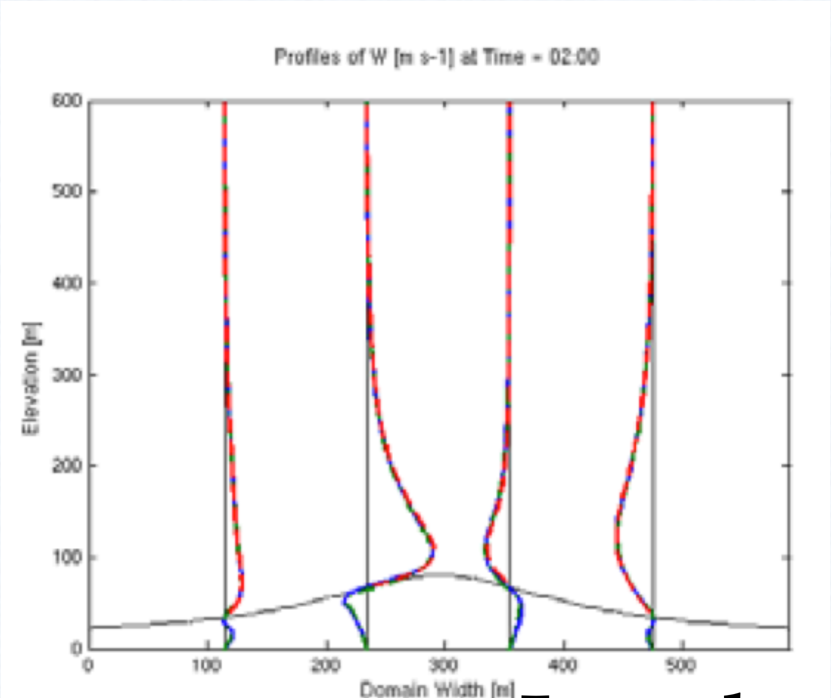


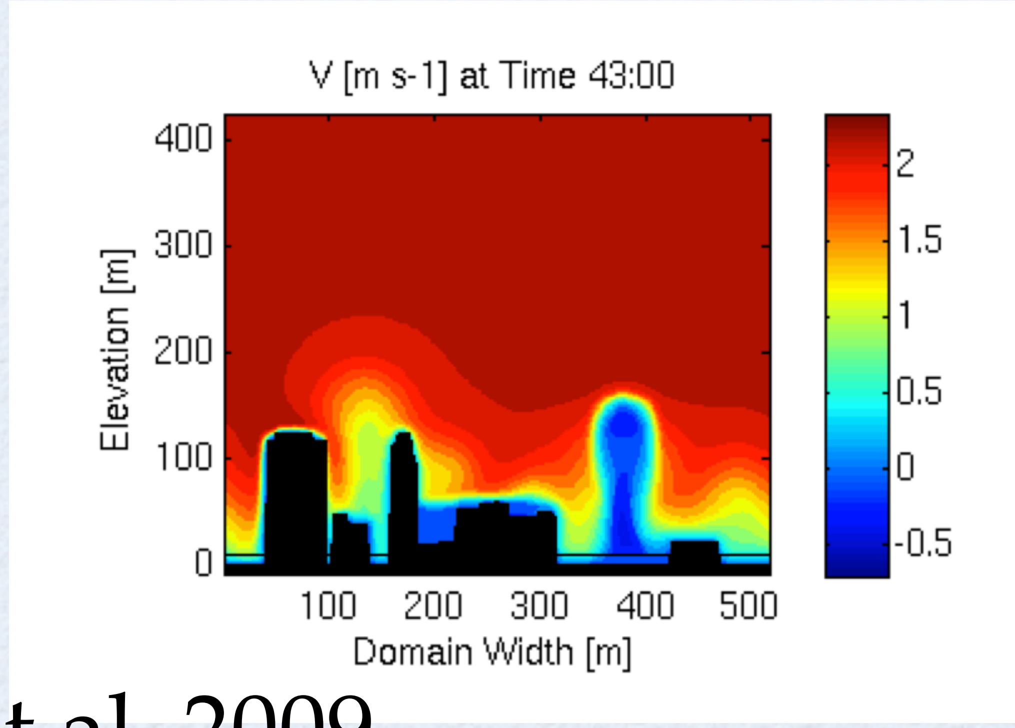
Jenkins et al. 2010

Immersed Boundary Method

- Handle complex, moving boundaries on fixed grids
- Fictitious flow (interior to solid surface) in many fluid dynamics applications



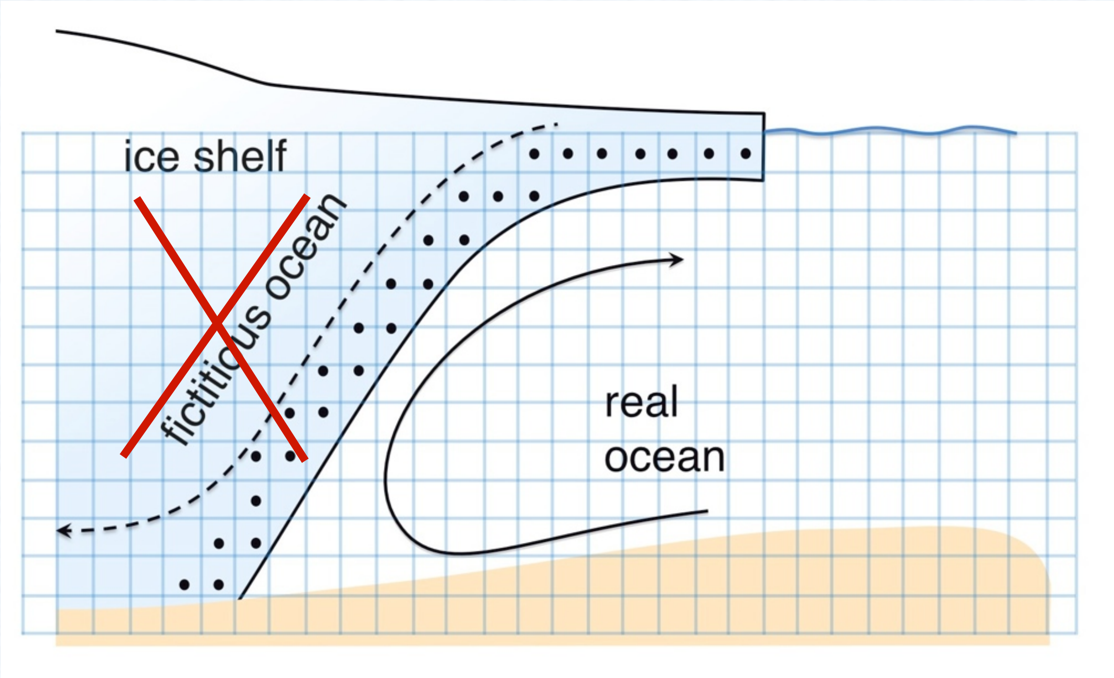




Lundquist et al. 2009

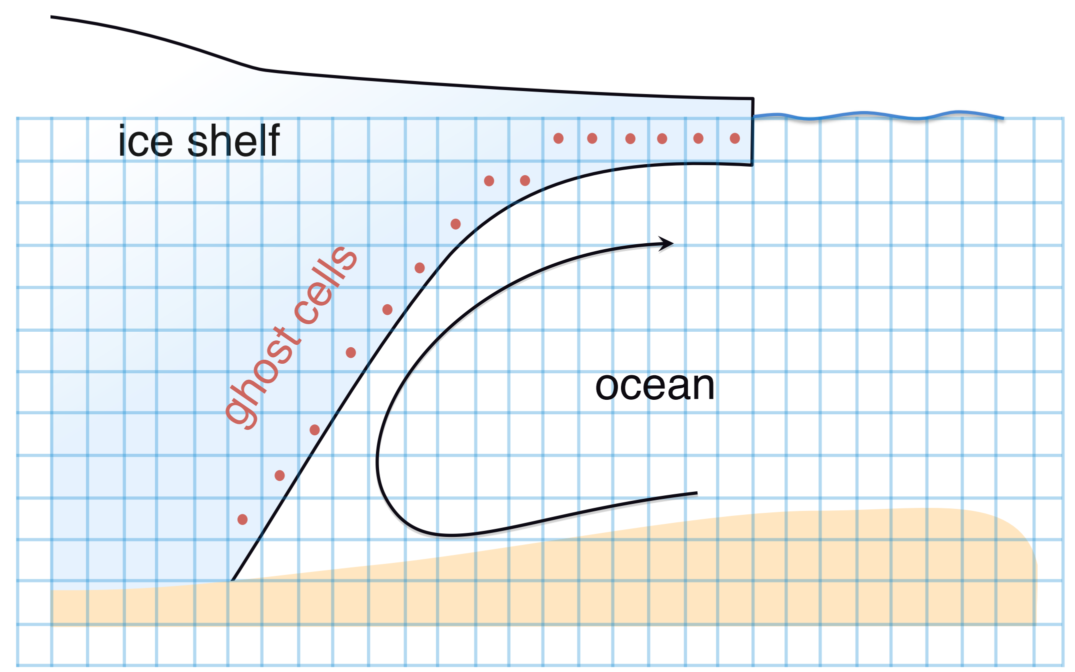
Immersed Boundary Method

- Handle complex, moving boundaries on fixed grids
- Fictitious flow (interior to solid surface) in many fluid dynamics applications
- Not feasible in POP ocean model (very anisotropic, barotropic/baroclinic splitting)



Immersed Boundary Method

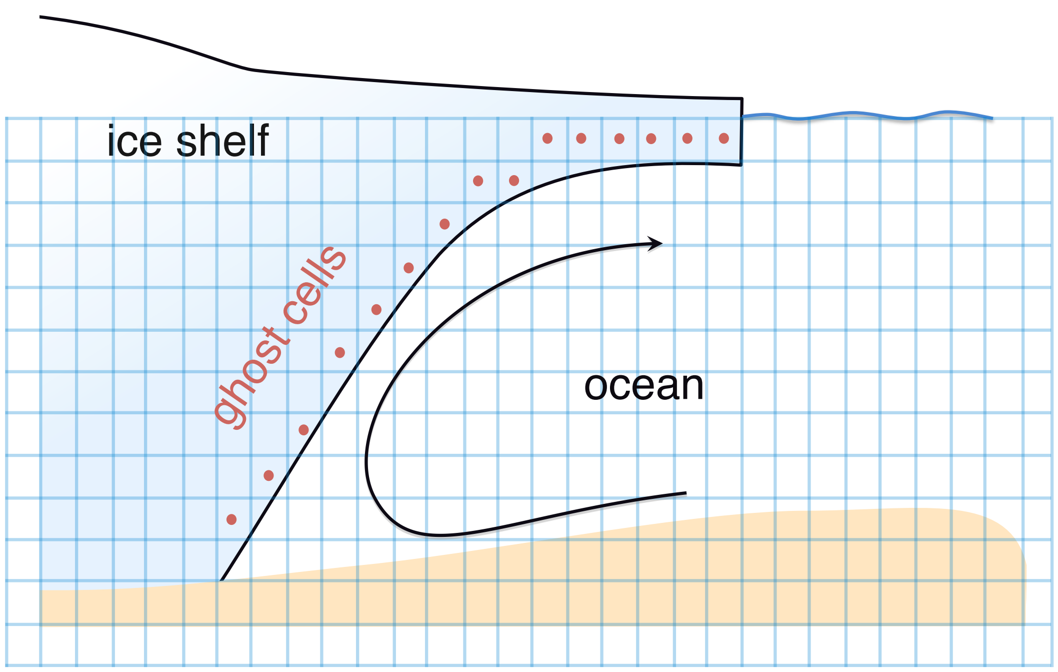
- Include only ghost cells adjacent to boundary (not full fictitious flow)



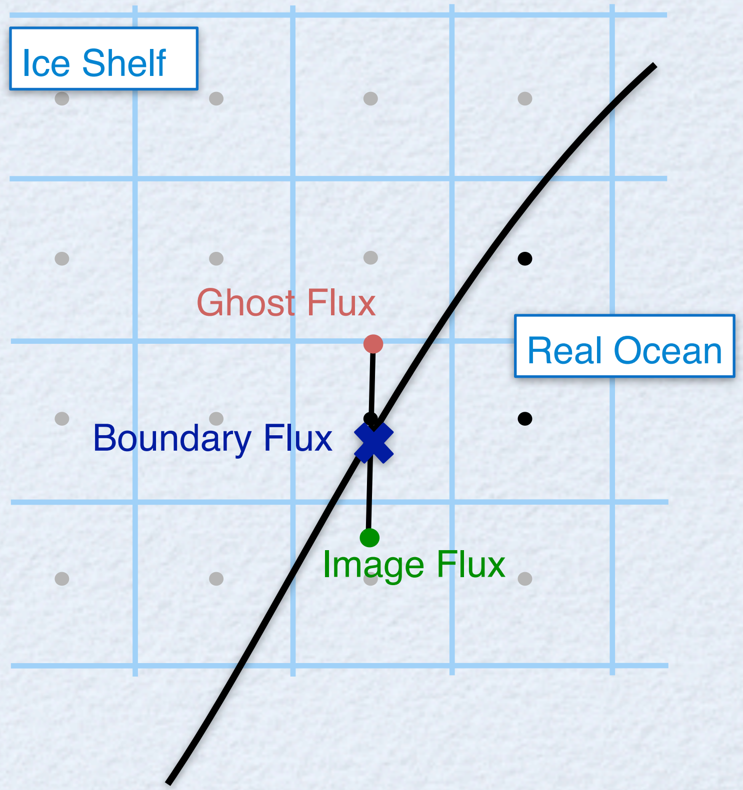
a)

Immersed Boundary Method

- Include only ghost cells adjacent to boundary (not full fictitious flow)
- Interpolate flux at an image point
- Extrapolate flux to a ghost point using the boundary condition (momentum, heat or salt flux)

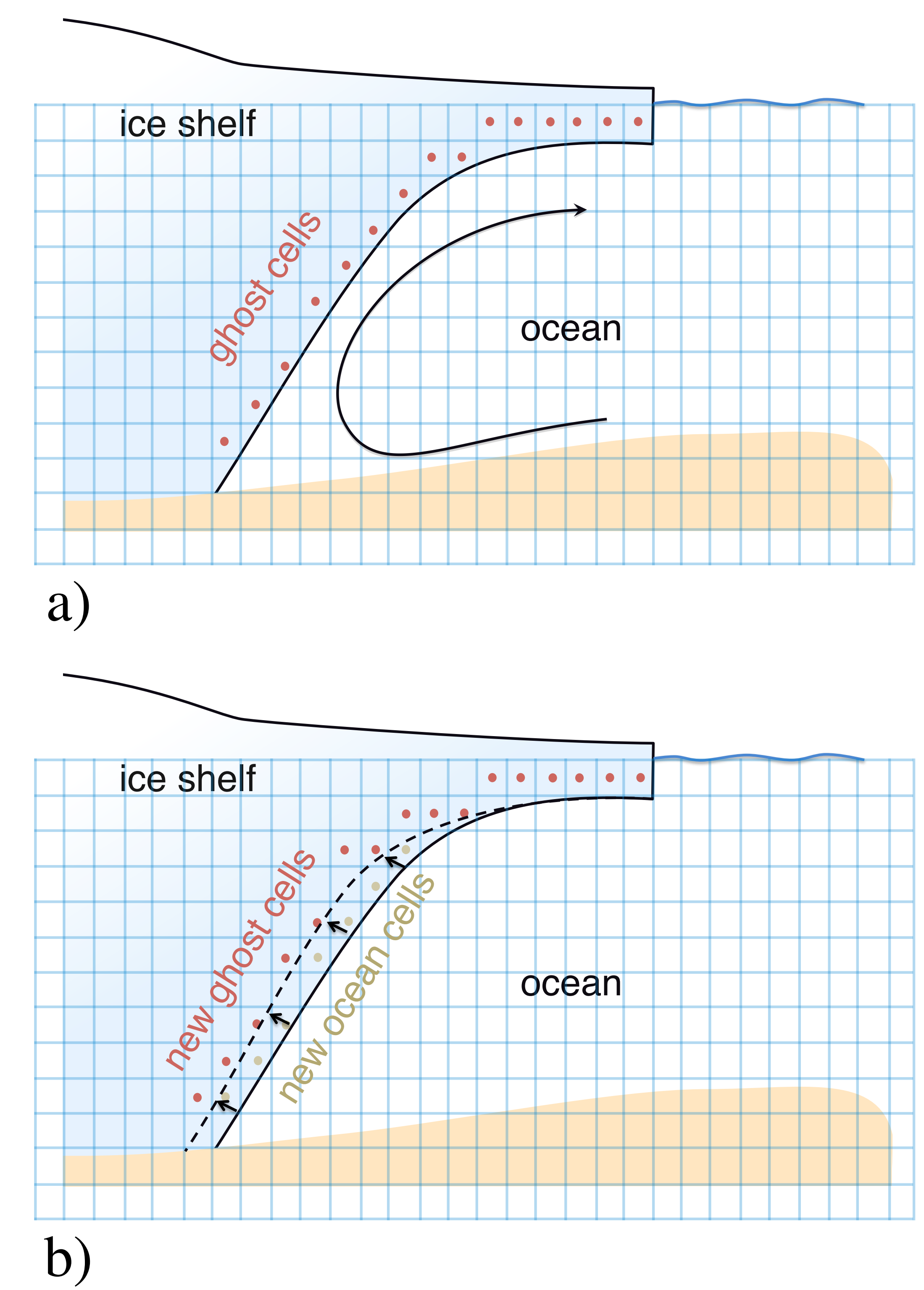


a)



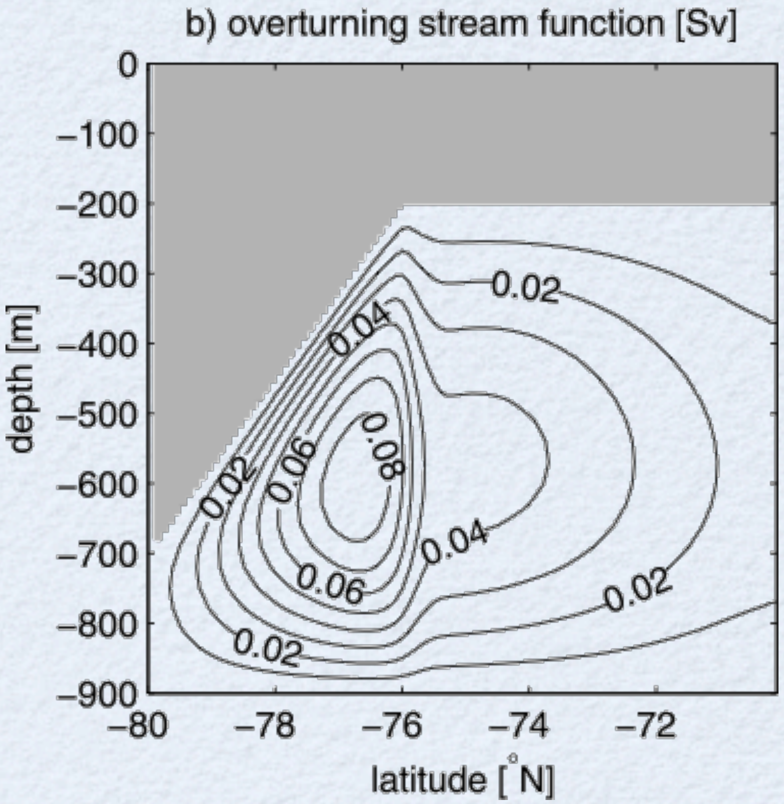
Immersed Boundary Method

- Include only ghost cells adjacent to boundary (not full fictitious flow)
- Interpolate flux at an image point
- Extrapolate flux to a ghost point using the boundary condition (momentum, heat or salt flux)
- As ice sheet/shelf retreats, ghost cells become new ocean cells



Partial cells method

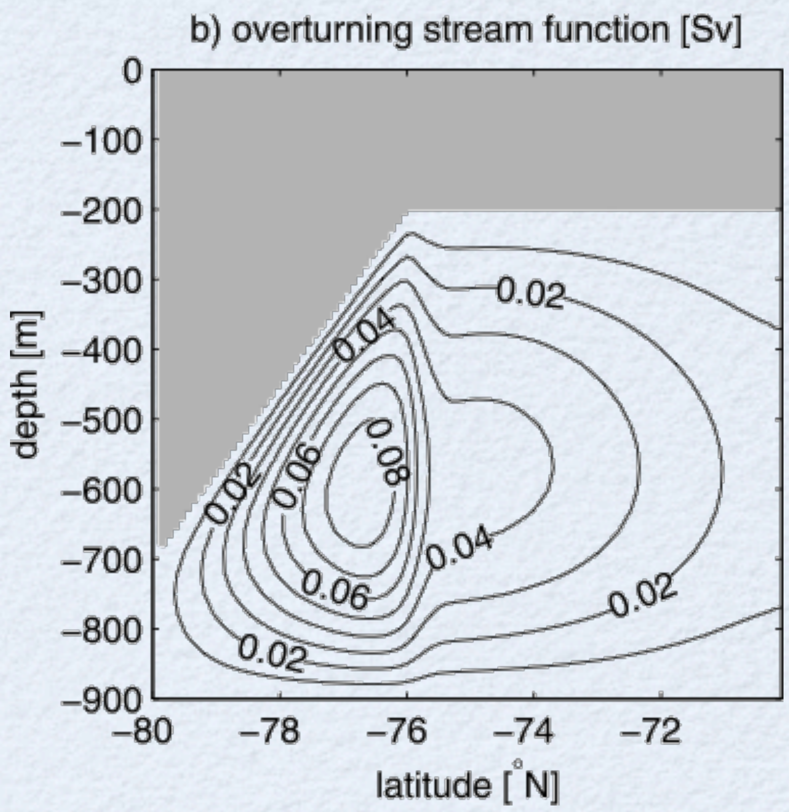
- Interface by partial cells, like bathymetry
- No ghost cells/fictitious flow
- Based on Losch 2008: static ice shelves in MITgcm



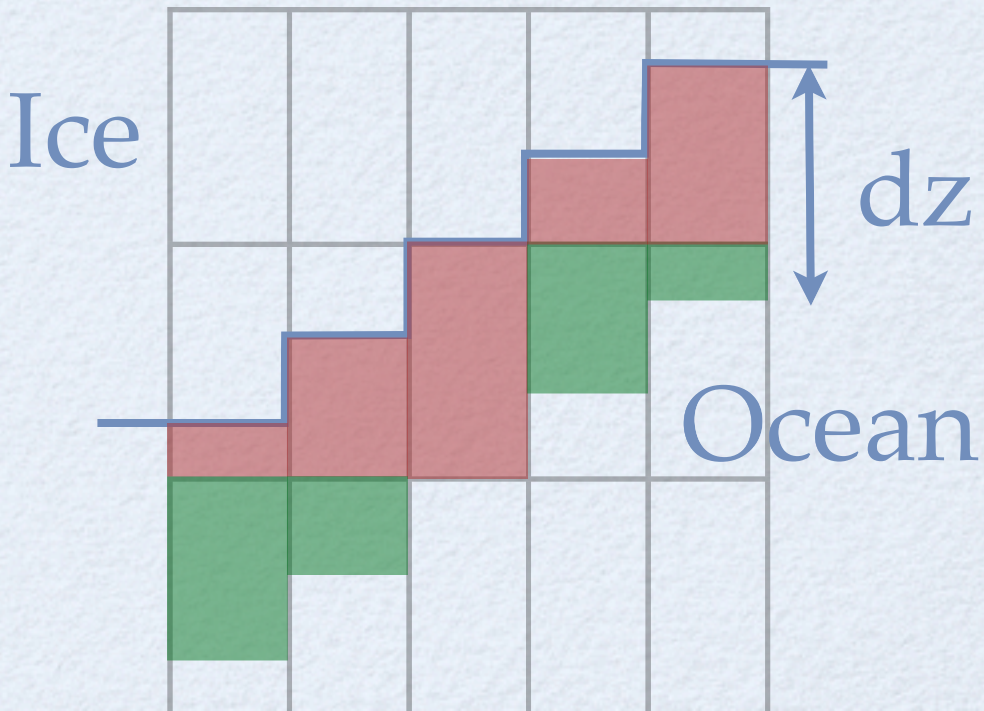
Losch 2008

Partial Cells Method

- Interface by partial cells, like bathymetry
- No ghost cells/fictitious flow
- Based on Losch 2008: static ice shelves in MITgcm
- Salt/heat from melting/freezing mixes into both partial cell and next cell below (reduces noise)

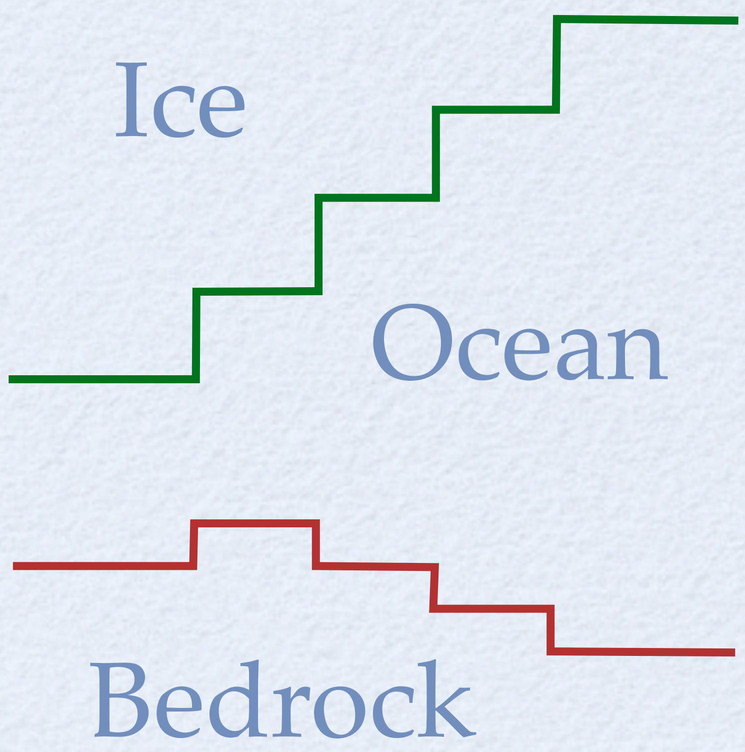


Losch 2008



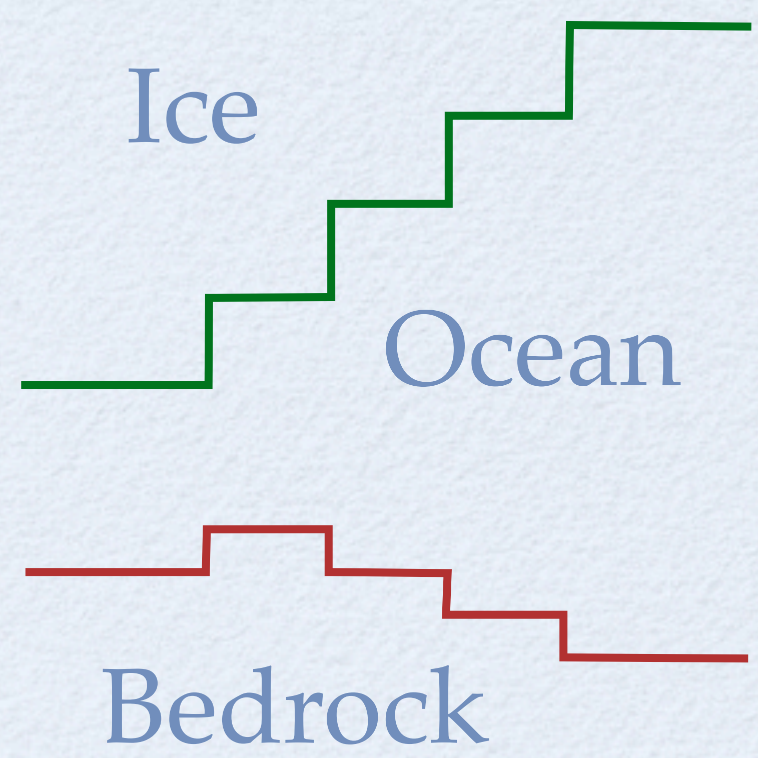
Partial Cells Method

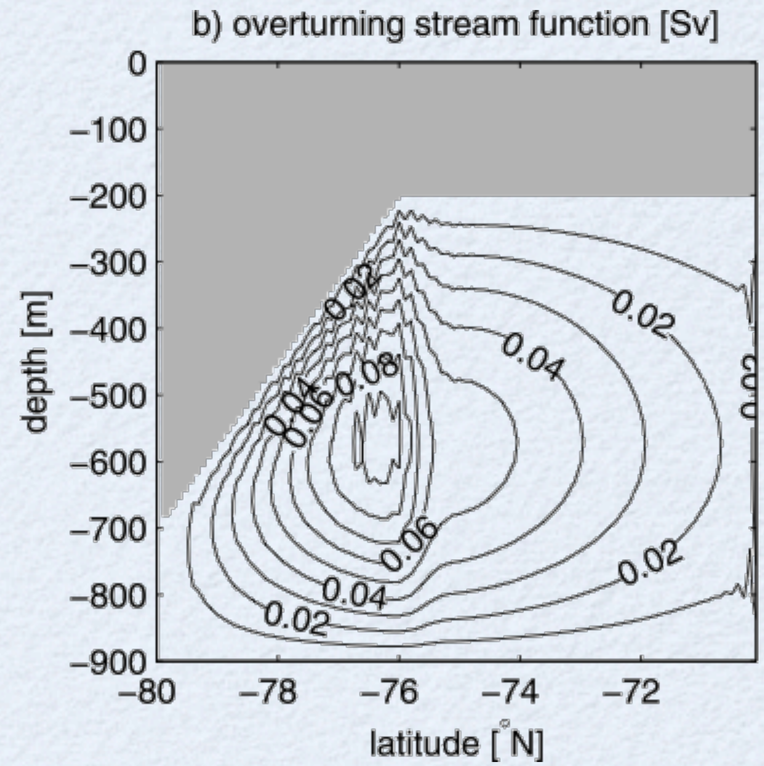
- Pros:
  - Static interface tested with other ocean models
  - Similar to bathymetry
  - Same boundary conditions as IBM



Partial Cells Method

- Pros:
  - Static interface tested with other ocean models
  - Similar to bathymetry
  - Same boundary conditions as IBM
- Cons:
  - Designed for static ice shelves
  - Stair-step geometry can lead to noisy fields
  - How to handle infinitesimally thin cells?





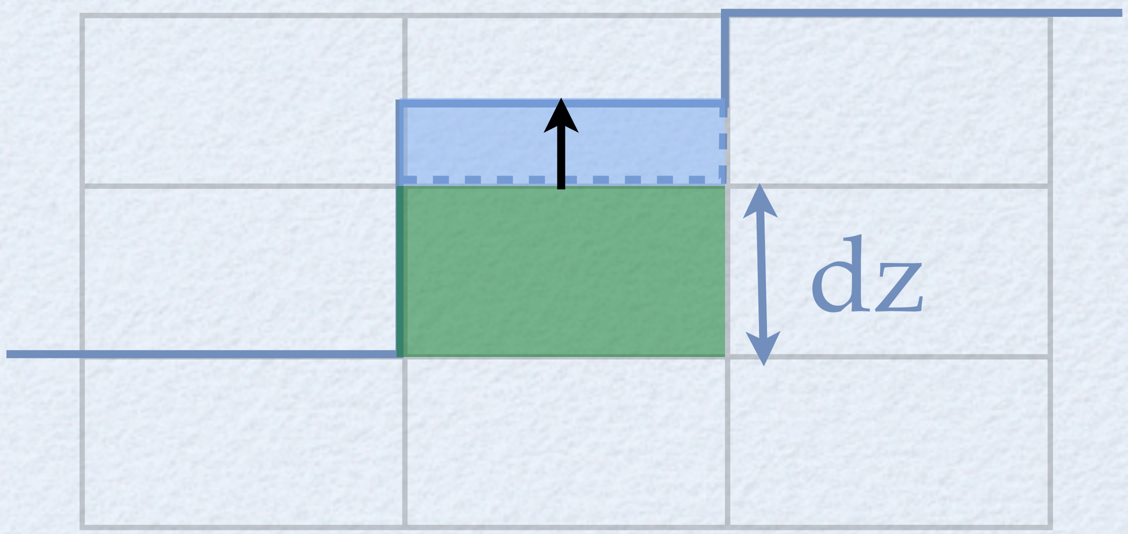
Losch 2008

Partial Cells Method

"Wetting" and "drying" of cells:

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

Wetting

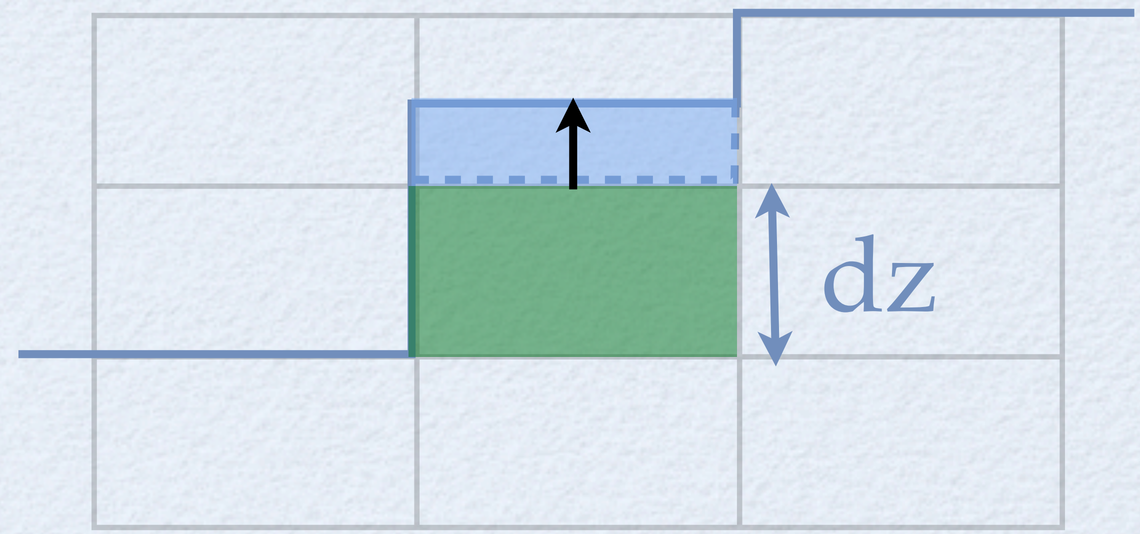


Partial Cells Method

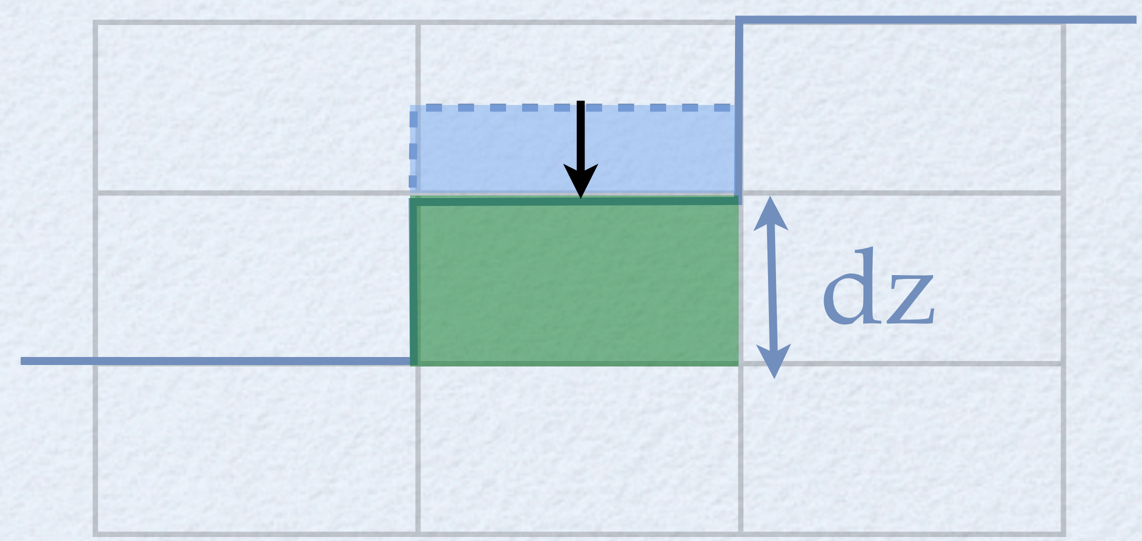
"Wetting" and "drying" of cells:

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

Wetting

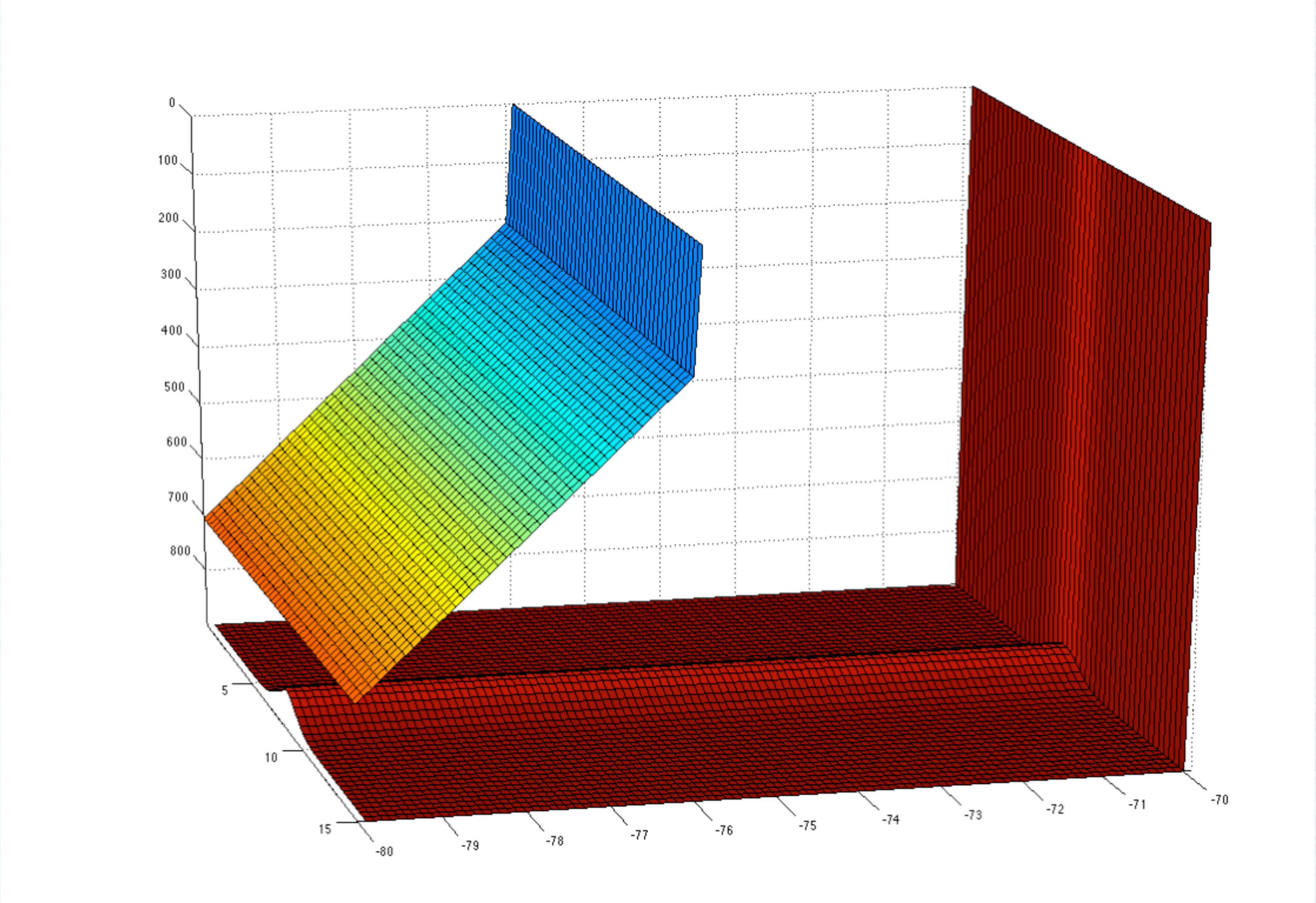


Drying



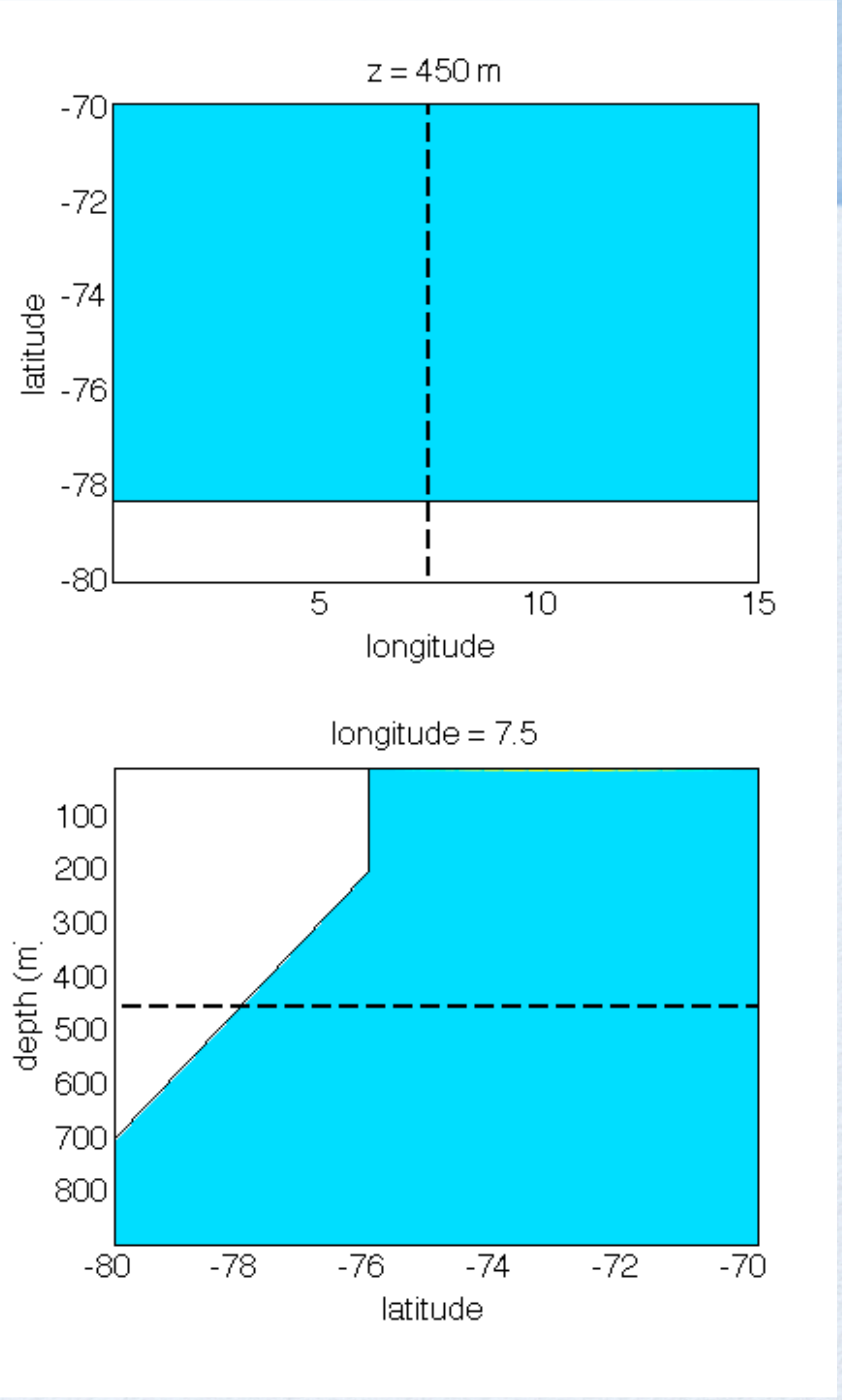
Current State

- POP has been modified to support a top vertical index



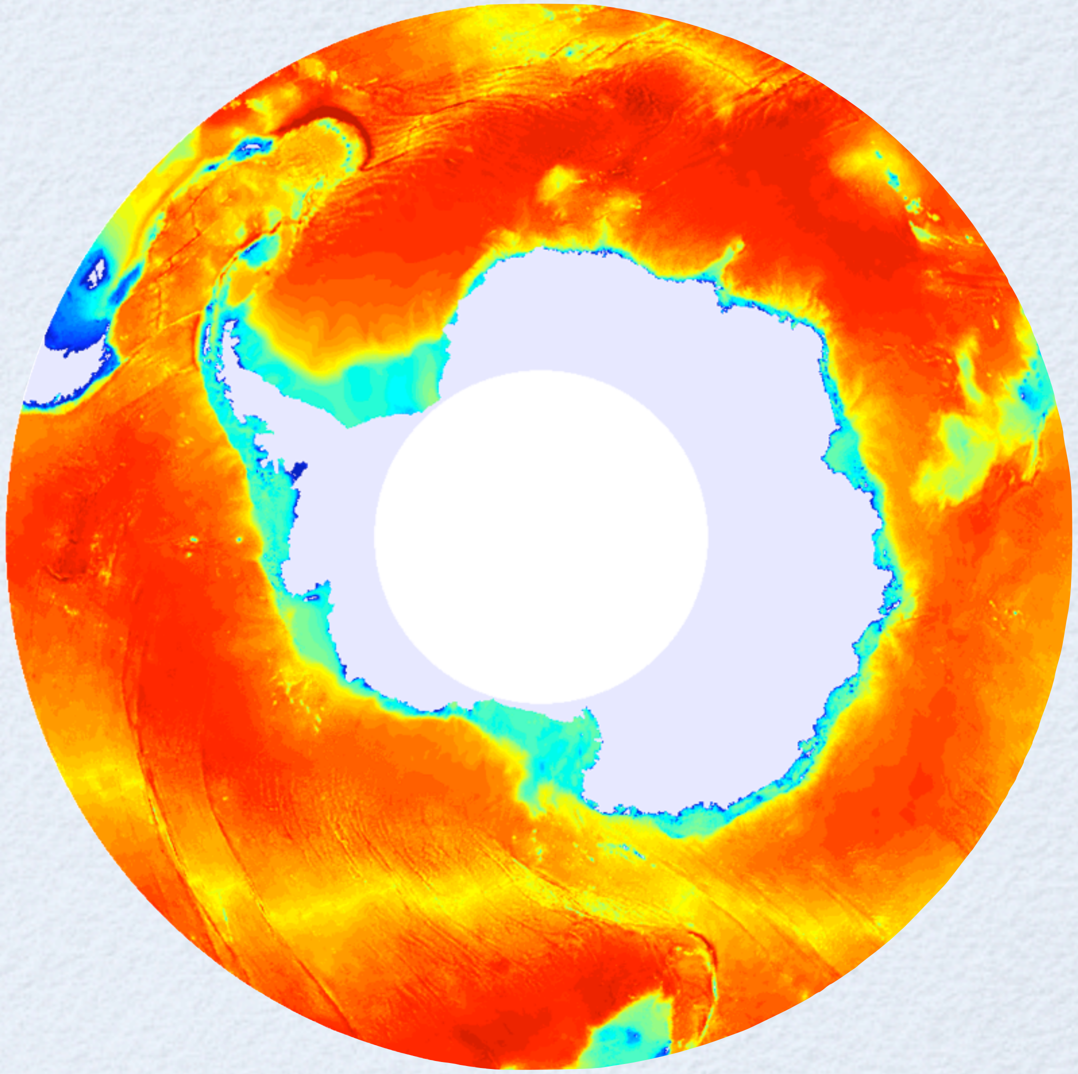
Current State

- POP has been modified to support a top vertical index
- Momentum advection/ diffusion successful
- Debugging tracer advection/ diffusion, pressure gradient
- Implementing thermodynamic boundary conditions



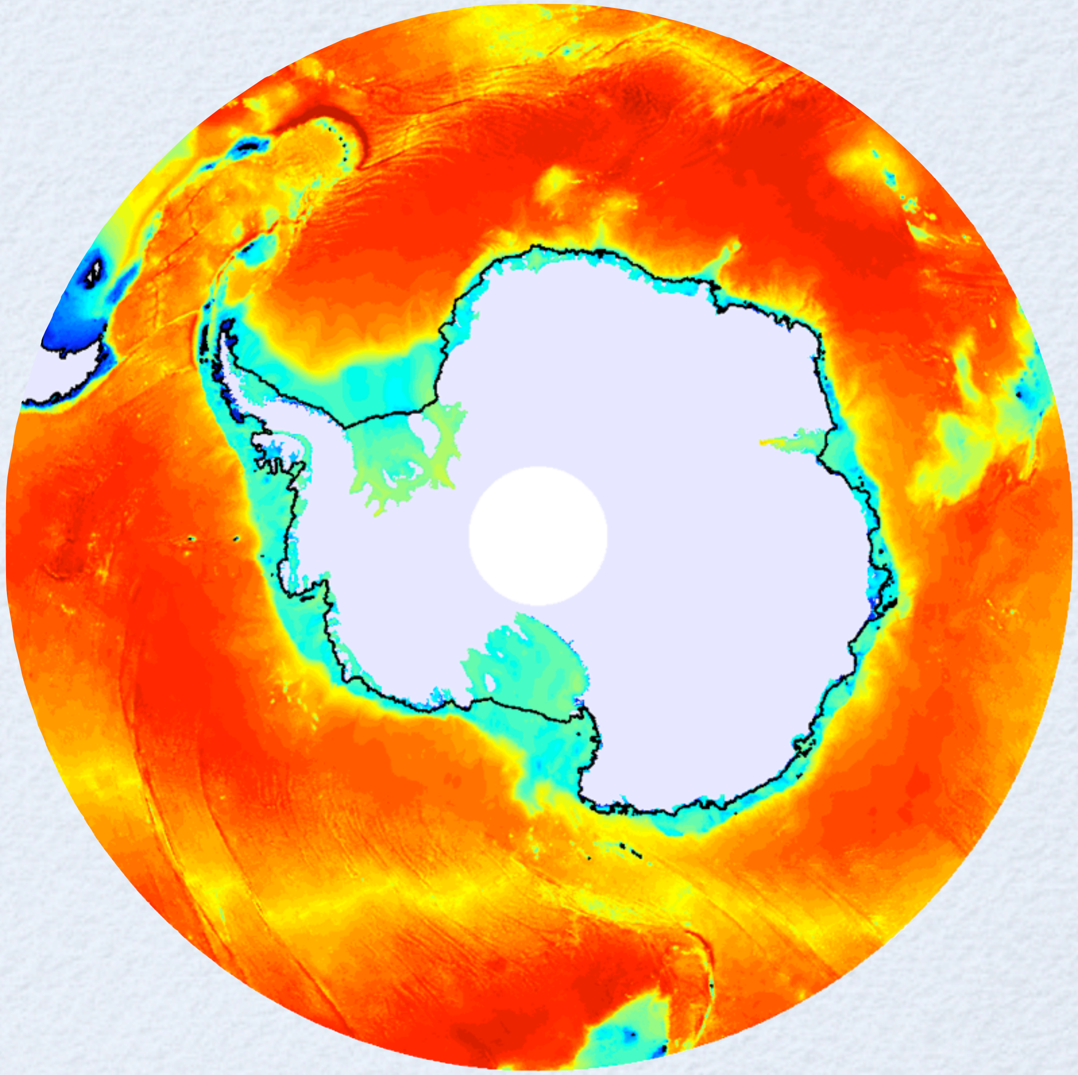
New Ocean Model Grid

- Working with Mat Maltrud at LANL
- Existing POP grid: No cavities under ice shelves

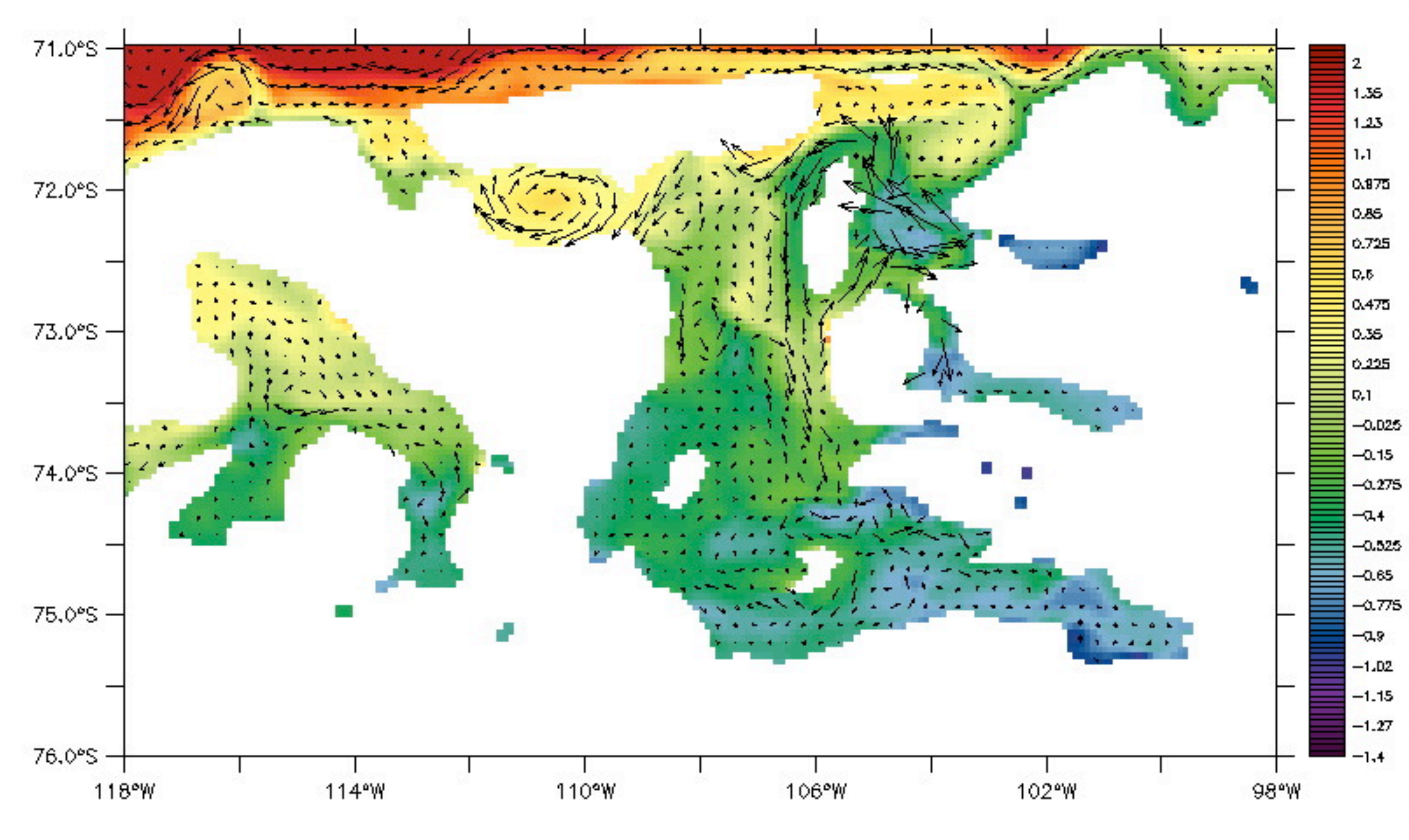


New Ocean Model Grid

- Working with Mat Maltrud at LANL
- 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)



New Ocean Model Grid



Model temperature and velocity vectors in the Amundsen Sea at 579 m depth after 2 simulated years.

FUTURE WORK

- Finish debugging static shelves (both partial-cell and immersed-boundary methods)
- Ice Shelf-Ocean Model Intercomarison Project (ISOMIP) experiments
- Regional experiments in Weddell and Amundsen Sea domains