Modeling Land-Ice/Ocean Interactions in the Community Earth System Model (CESM)

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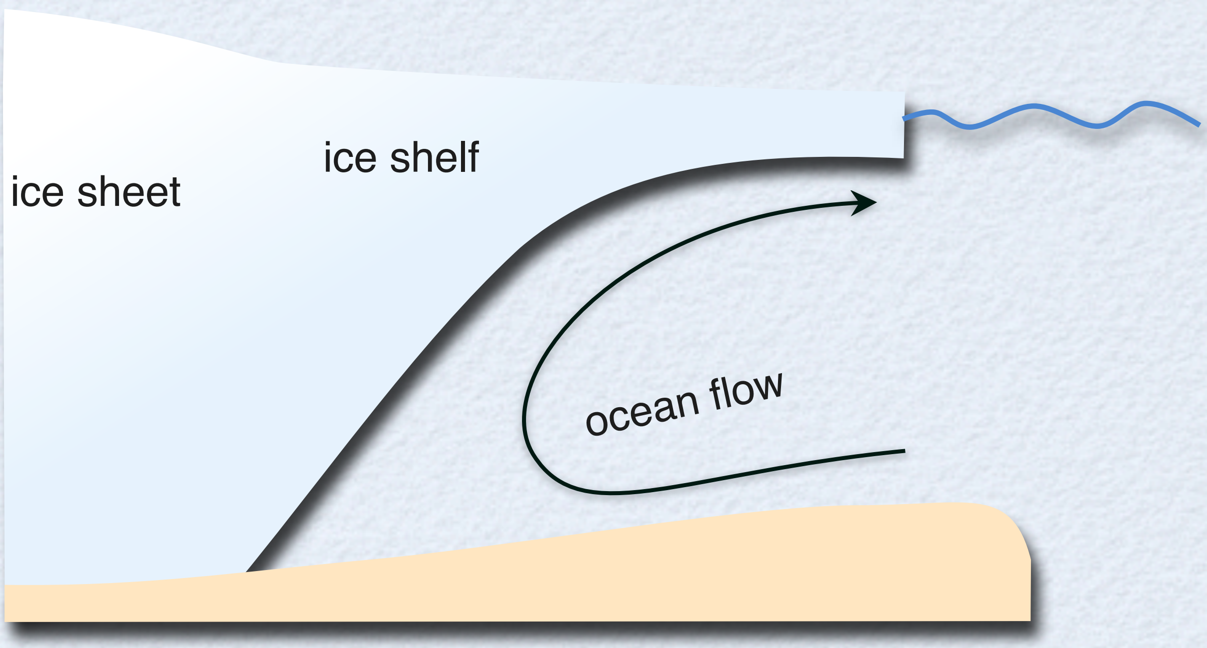
EST. 1943

OUTLINE

- Challenges of Land-ice/ Ocean Coupling
- Boundary Layer Physics
- Immersed Boundary Method
- Partial Cells Method
- New Ocean Model Grid



Challenges of Land-Ice/Ocean Coupling

Challenging Physics:

- Many length scales
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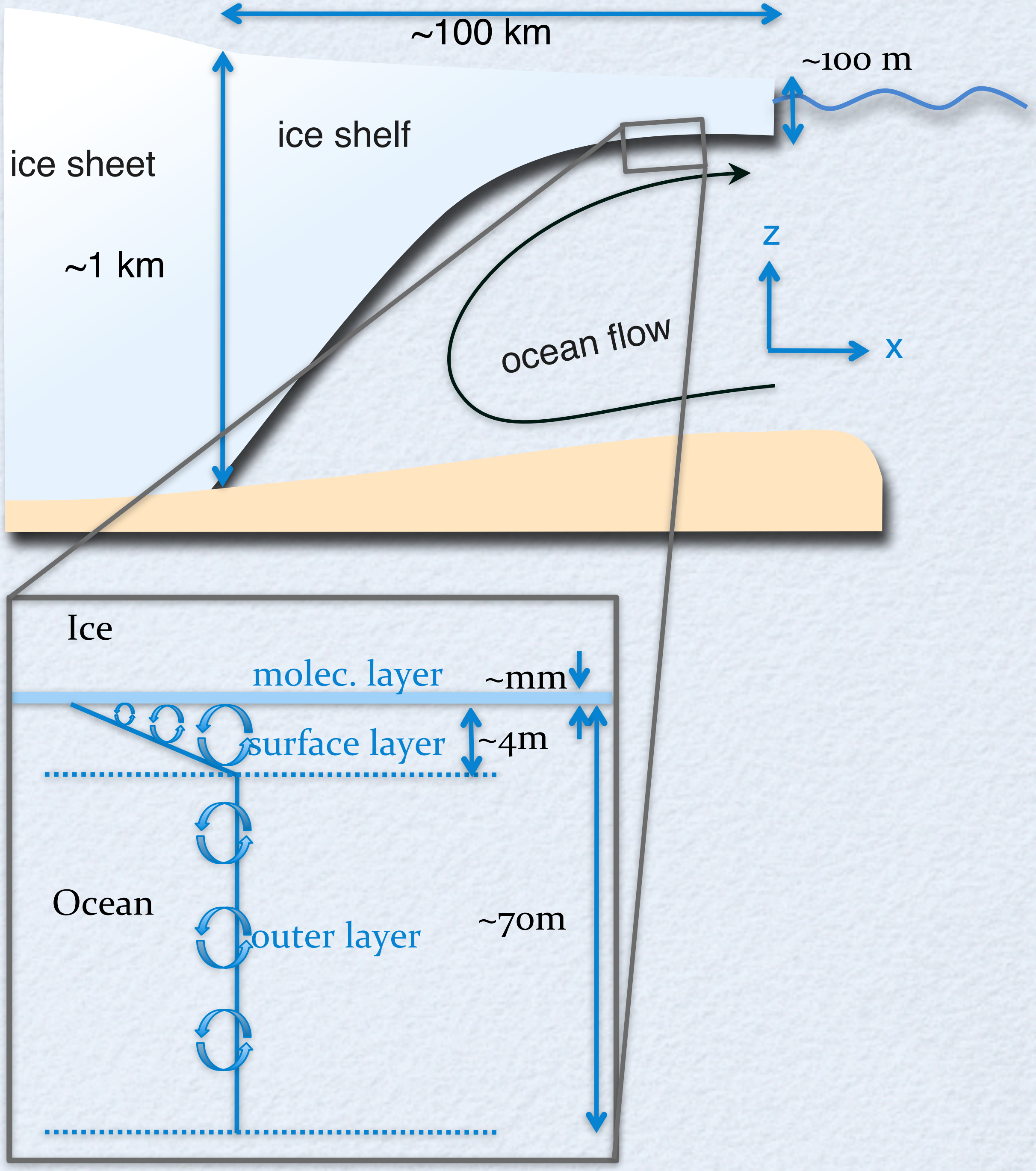

Challenges of Land-Ice/Ocean Coupling

Challenging Physics:

- Many length scales
- Many time scales
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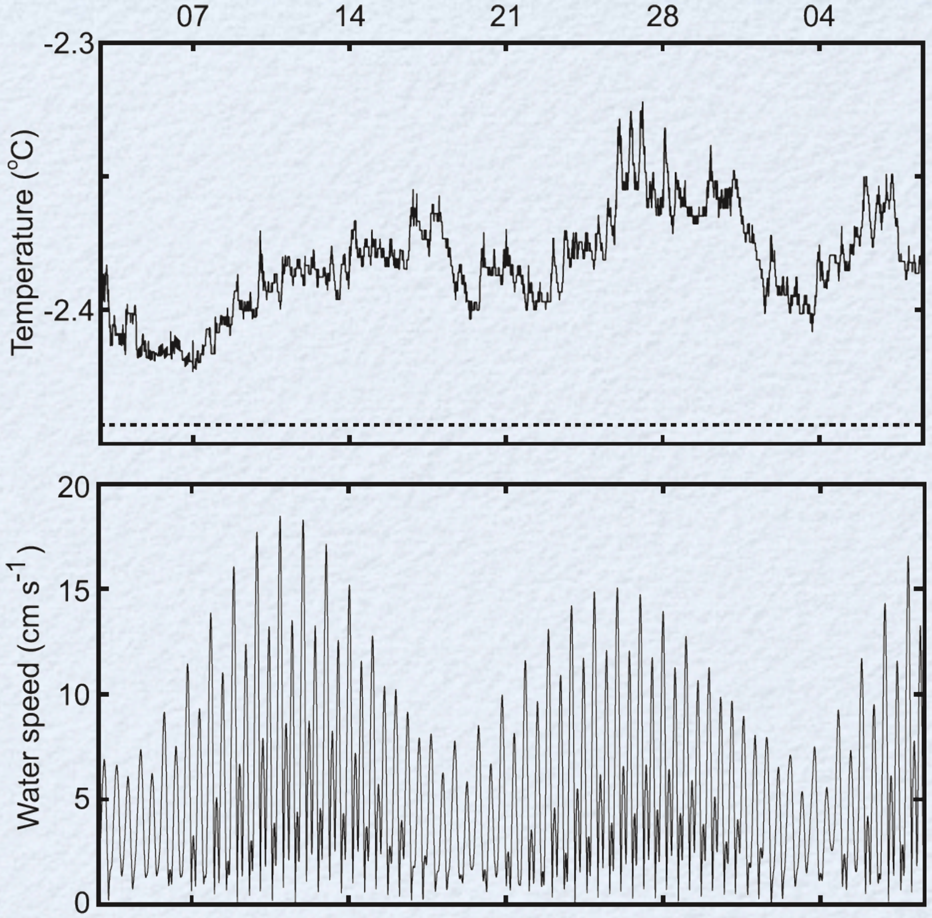
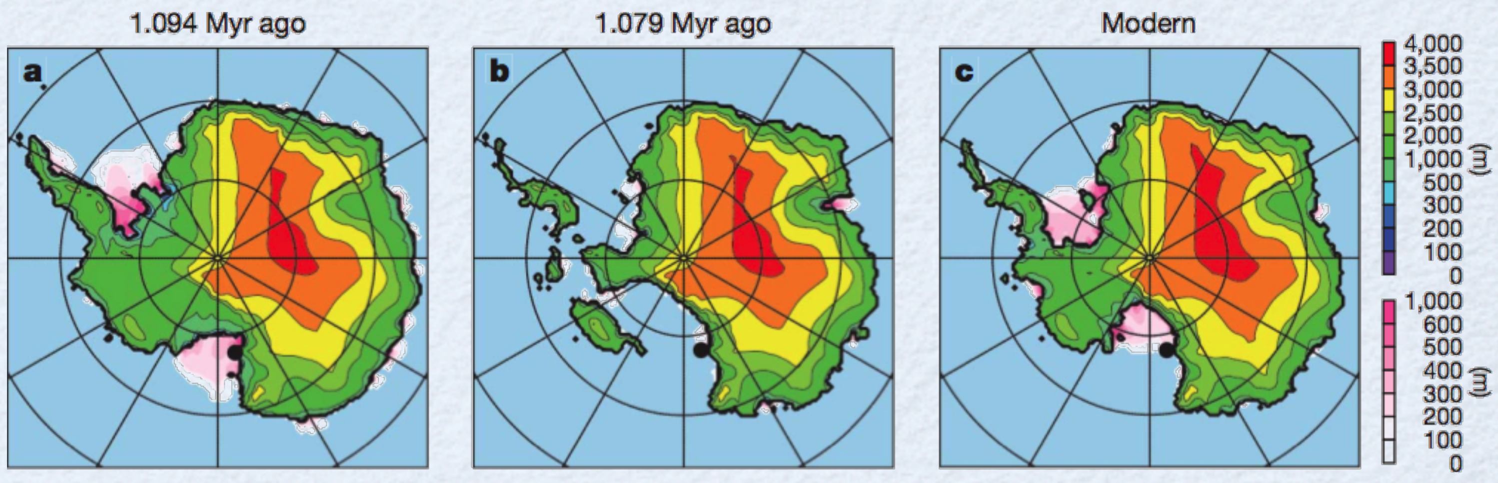


Jenkins et al. 2010

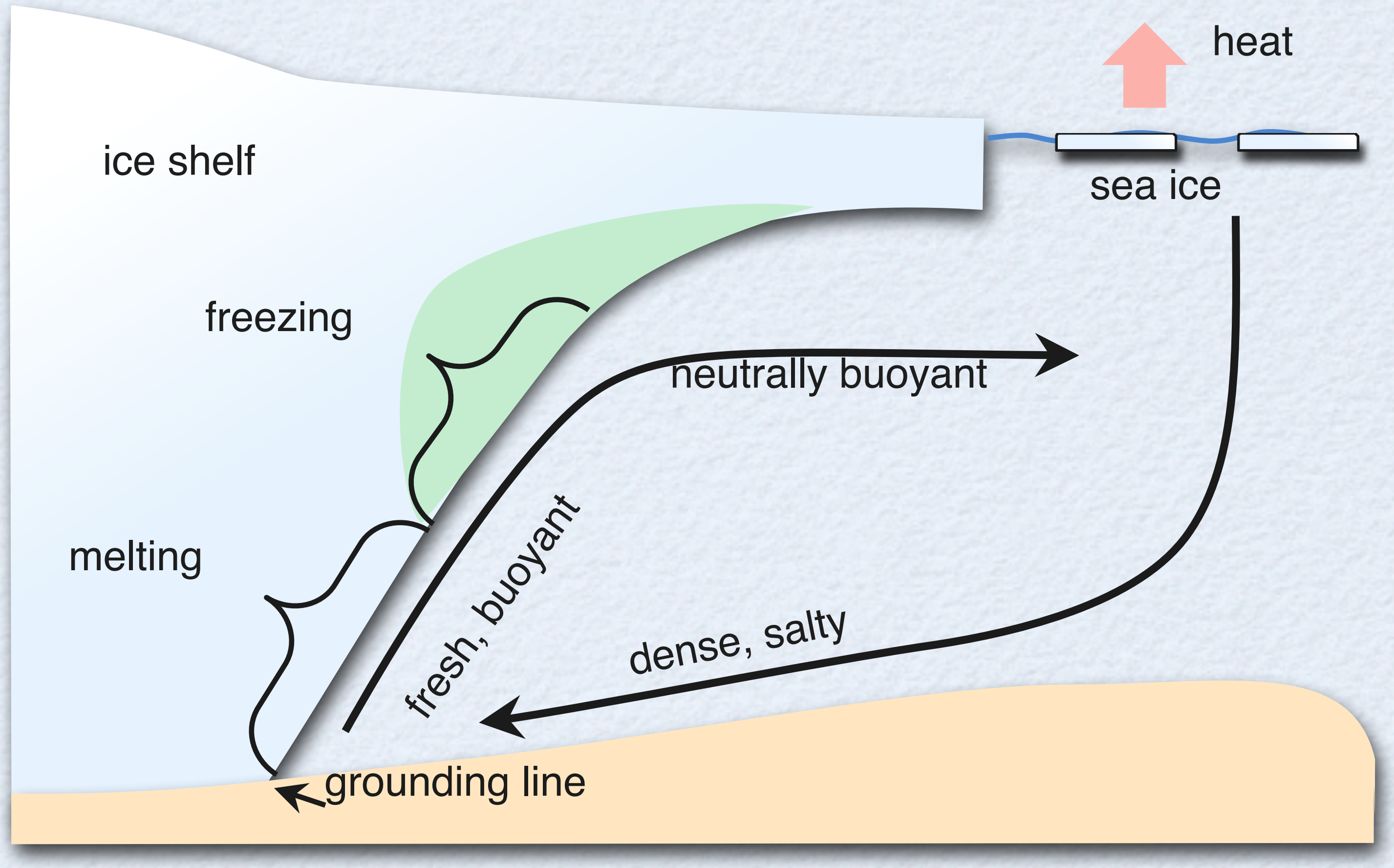


Pollard and DeConto 2009

Challenges of Land-Ice/Ocean Coupling

Challenging Physics:

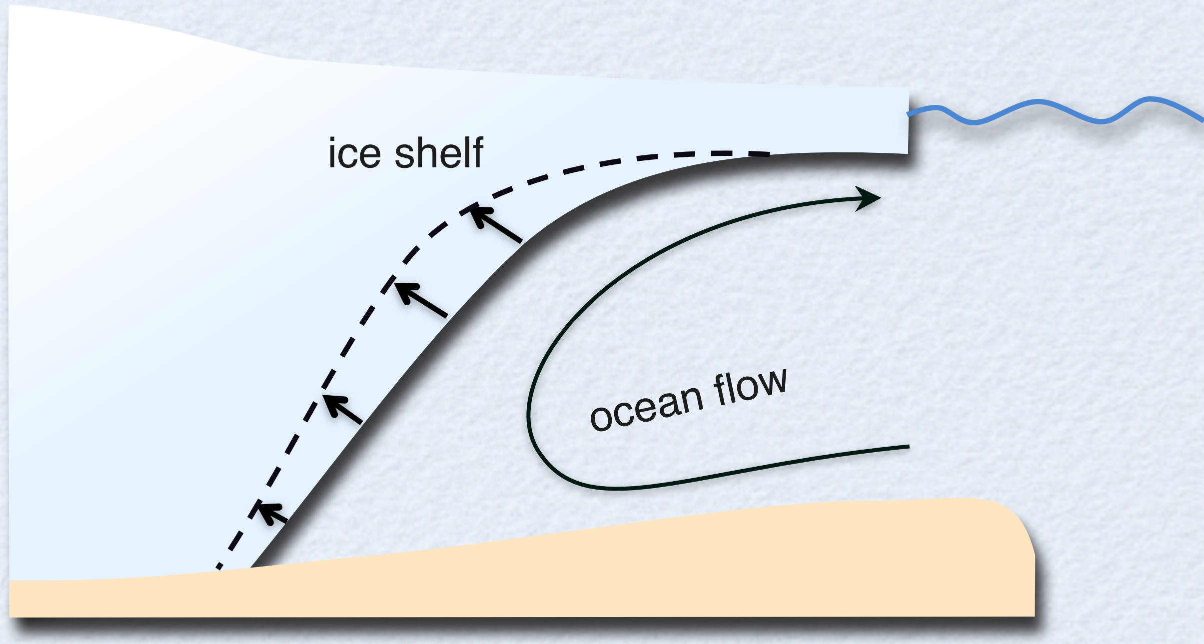
- Many length scales
- Many time scales
- Many processes

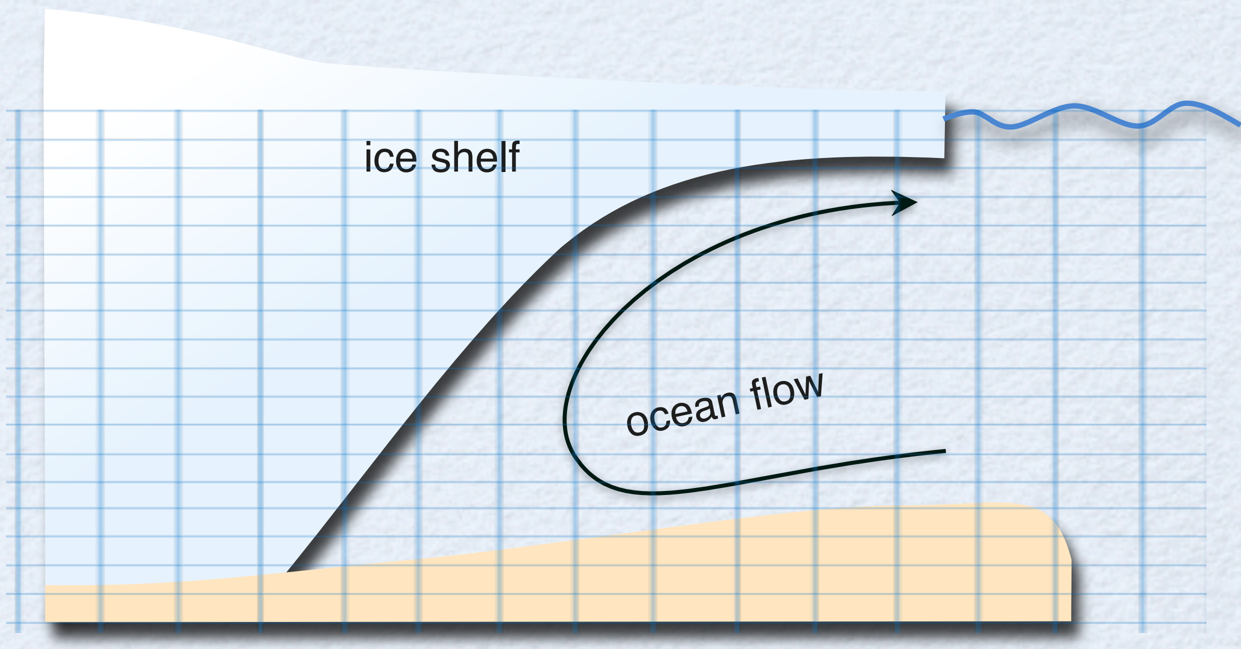


Challenges of Land-Ice/Ocean Coupling

Challenging Numerics:

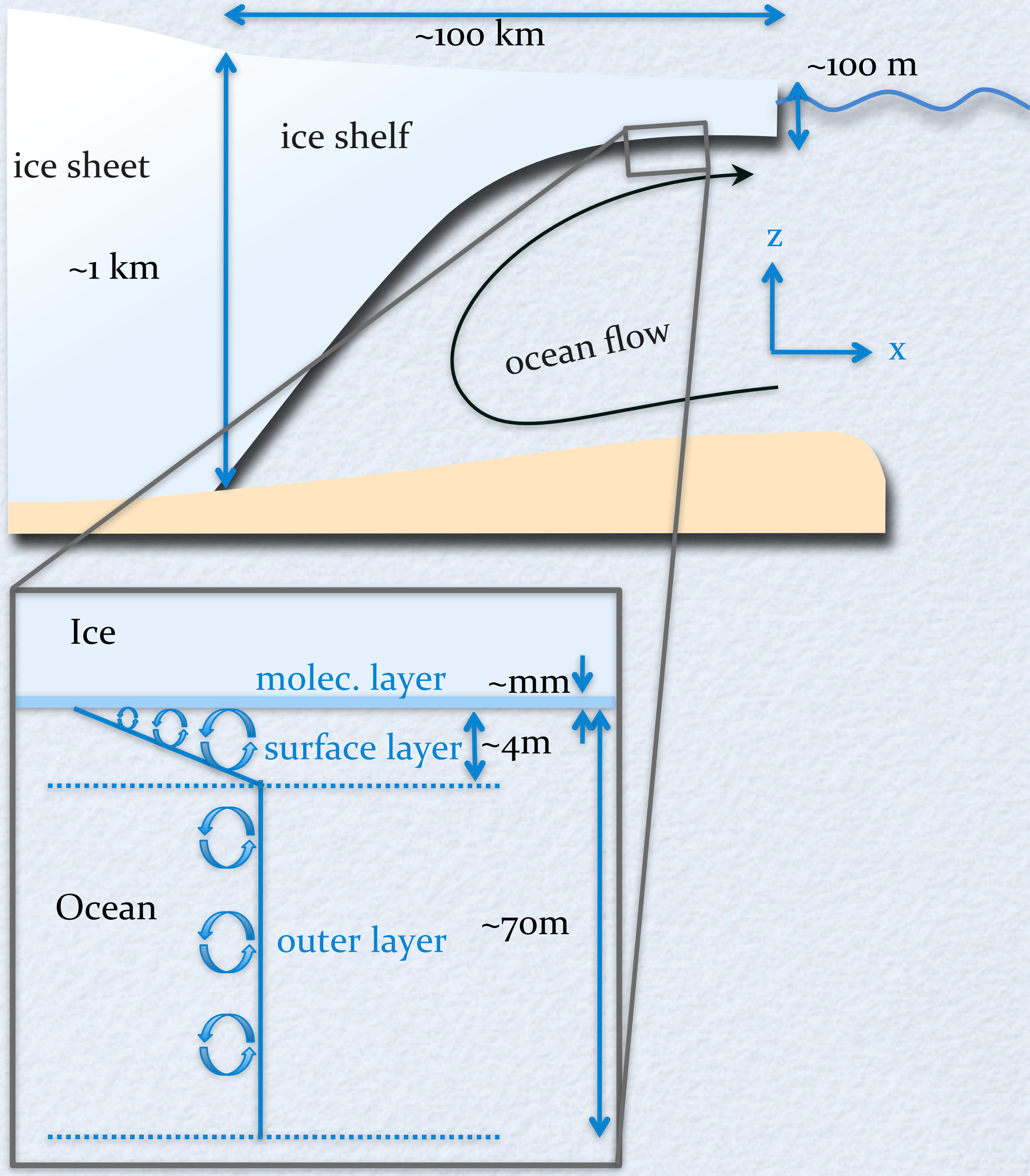
- Moving boundaries
- Anisotropic grids ($\Delta x \gg \Delta z$)
- Under-resolved physics





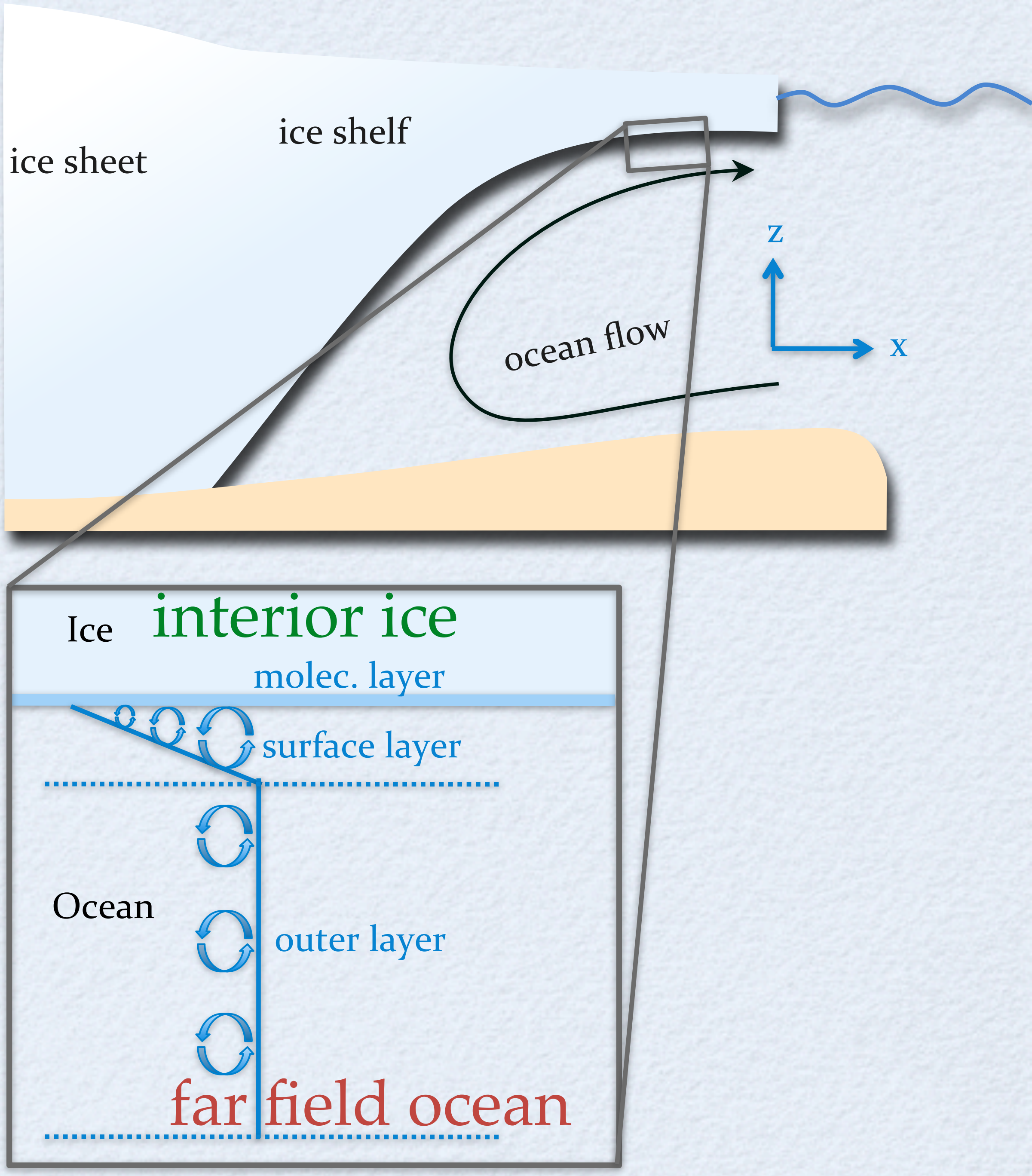
Boundary Layer Physics

- *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

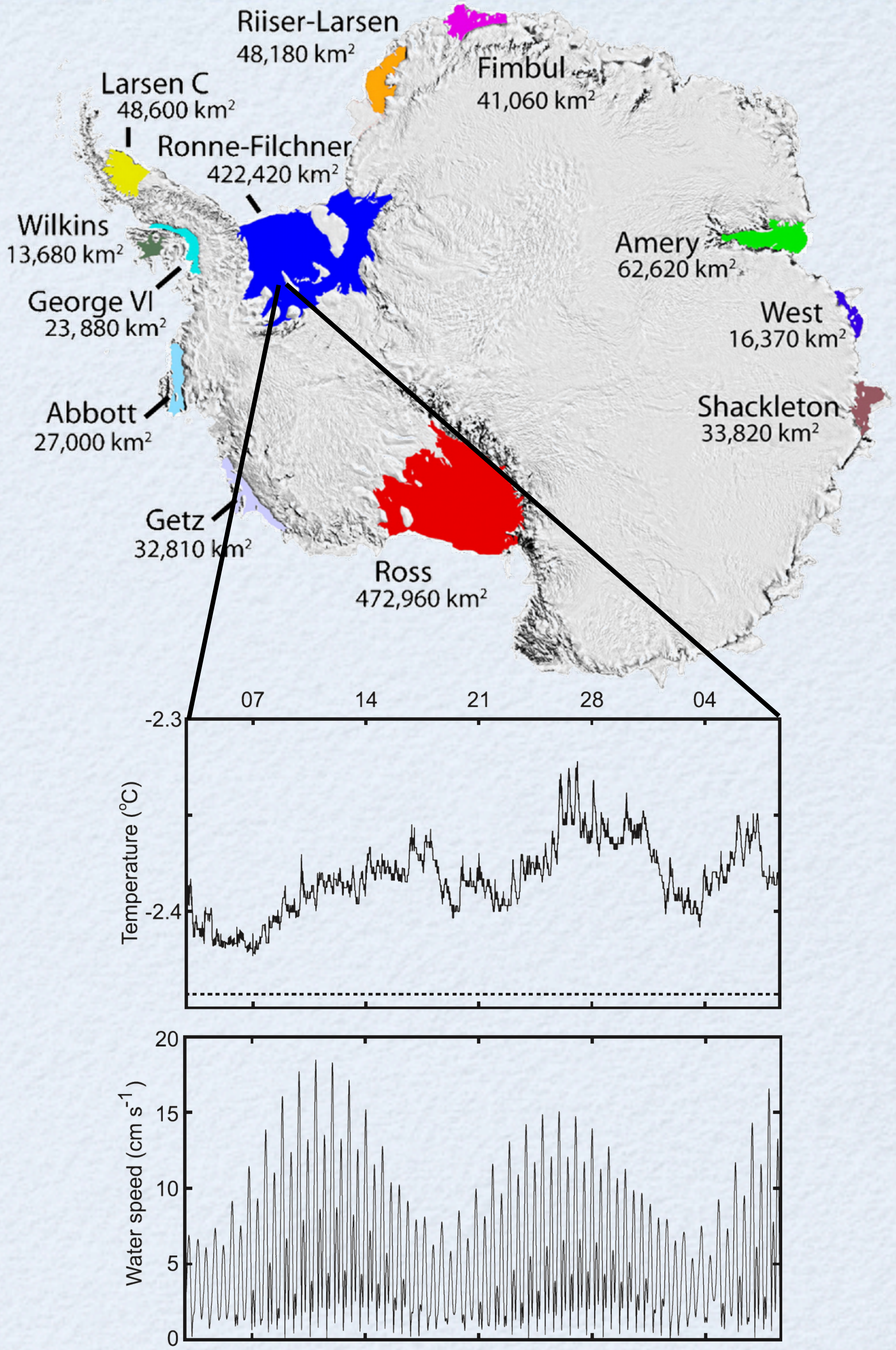
- Requires:
  - far field ocean temp., velocity, salinity
  - interior ice temperature
- Gives at interface:
  - heat flux
  - salt flux
  - momentum flux
  - mass flux



Boundary Layer Physics

- 2 coeffs. are calibrated using measurements under Ronne Ice Shelf (Jenkins et al. 2010)
  - Surface roughness
  - Molec. transport coeff.

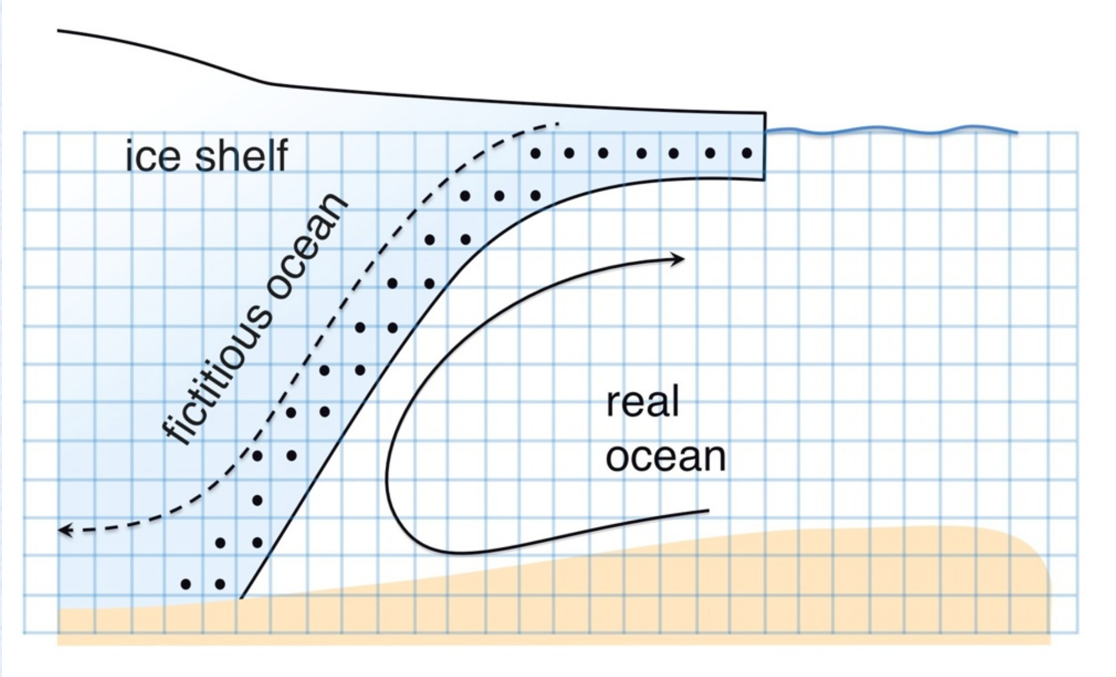
- More calibration data expected in coming years (Fimbul, Larsen C and George VI Ice Shelves)

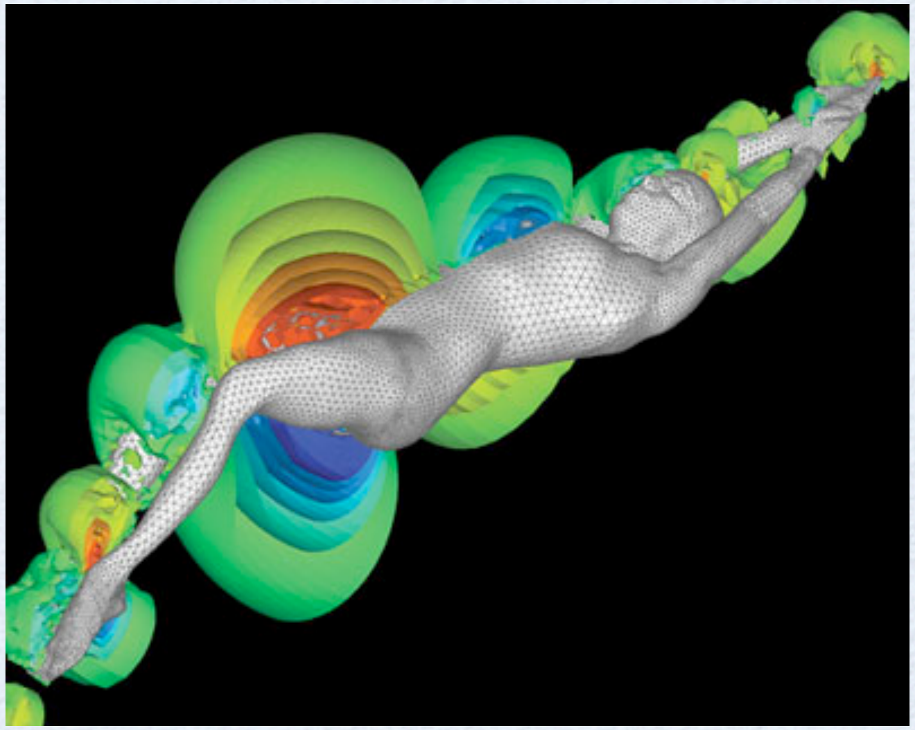


Jenkins et al. 2010

Immersed Boundary Method

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

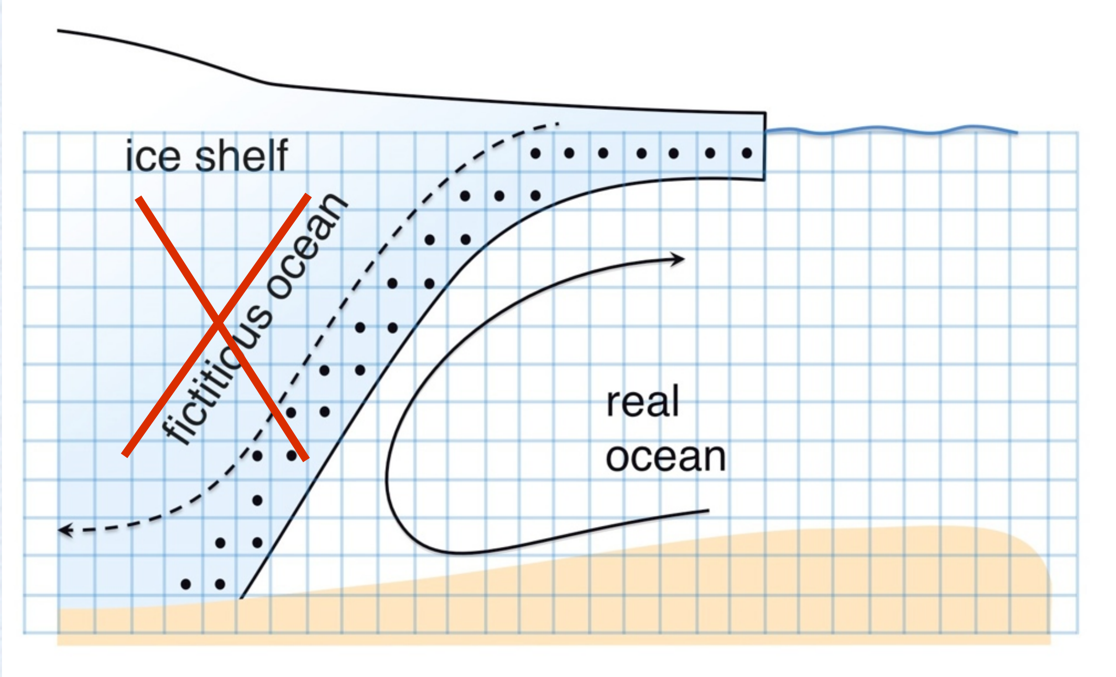




Mittal: Pressure near Swimmer

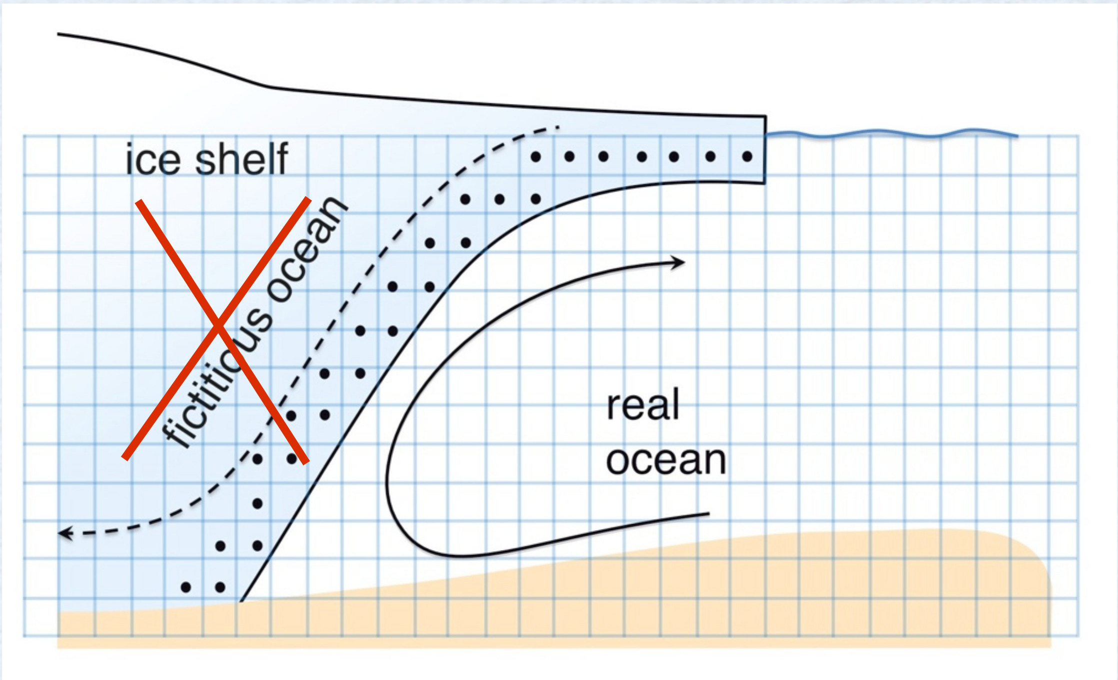
Immersed Boundary Method

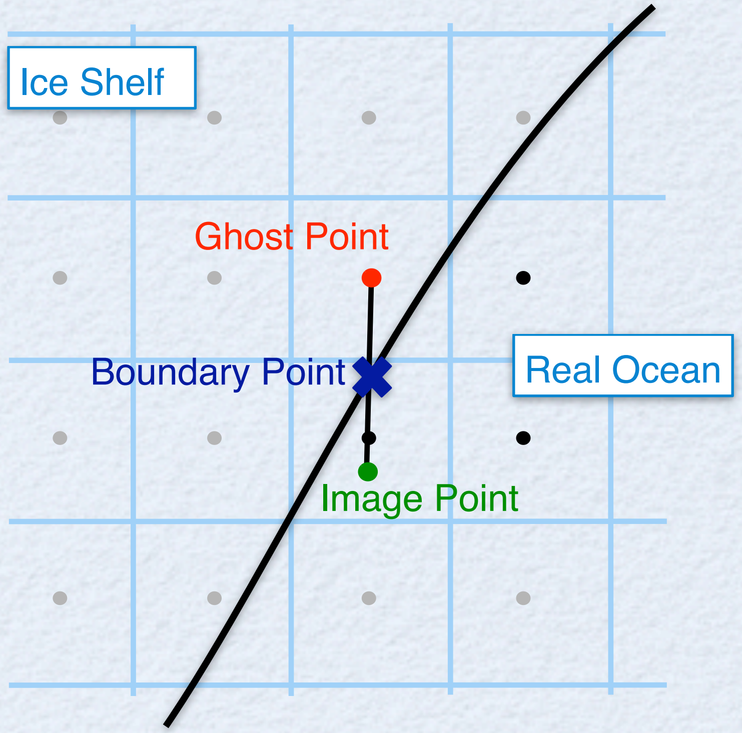
- Handle complex, moving boundaries on fixed grids
- Fictitious flow (interior to solid surface) in many fluid dynamics applications
- Not feasible in POP ocean model (very anisotropic, barotropic/baroclinic splitting, etc.)



Immersed Boundary Method

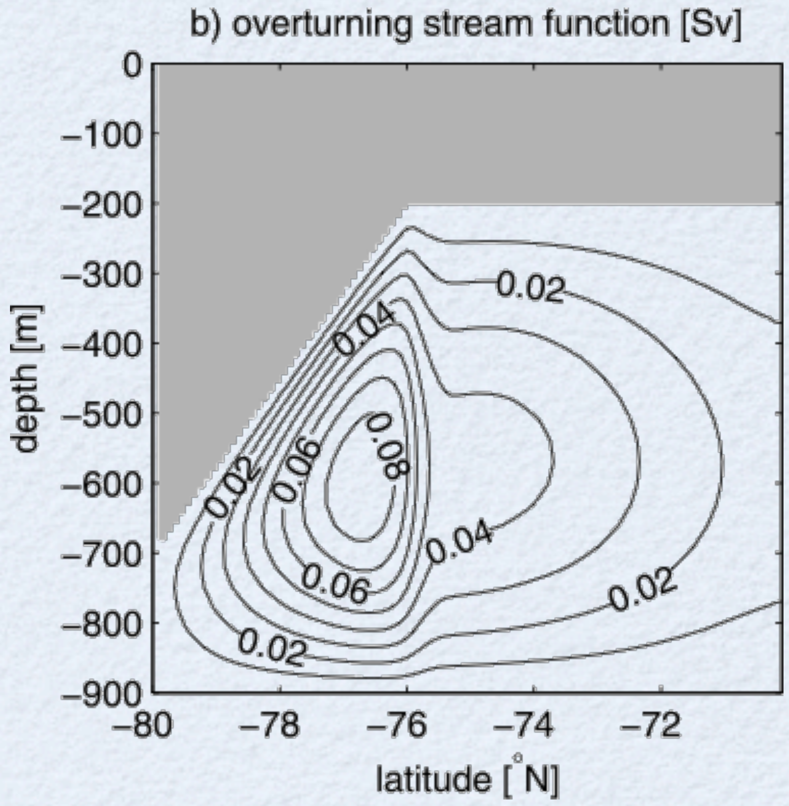
- Handle complex, moving boundaries on fixed grids
- Include only ghost points adjacent to boundary (not full fictitious flow)
- Extrapolate fluid values from image points to ghost points using boundary conditions (mass, heat and salt fluxes)





Partial Cells Method

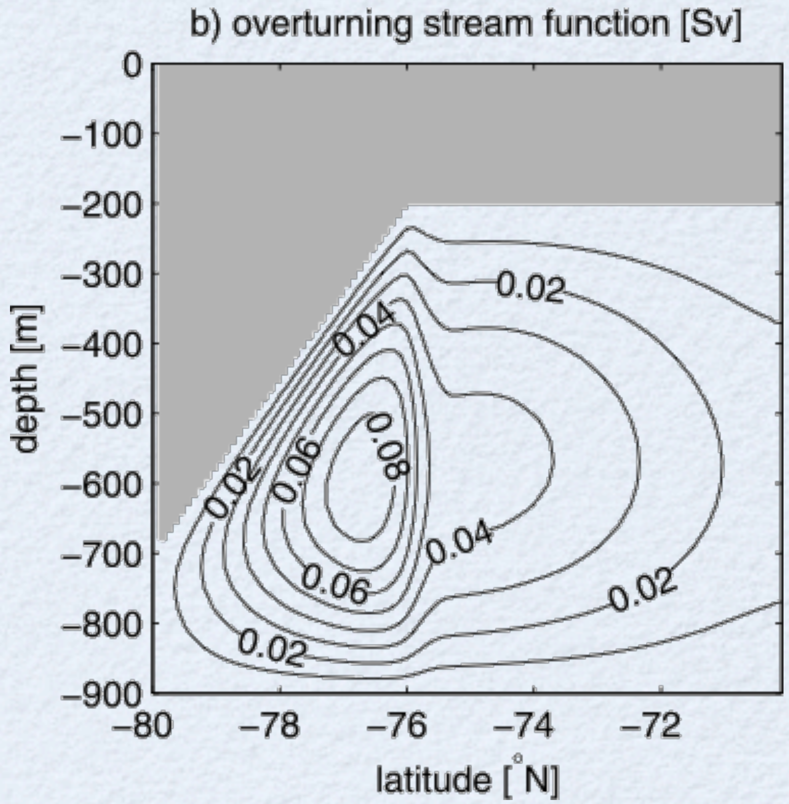
- Interface by partial cells, like bathymetry
- No ghost cells/fictitious flow
- Based on Losch 2008: static ice shelves in MITgcm



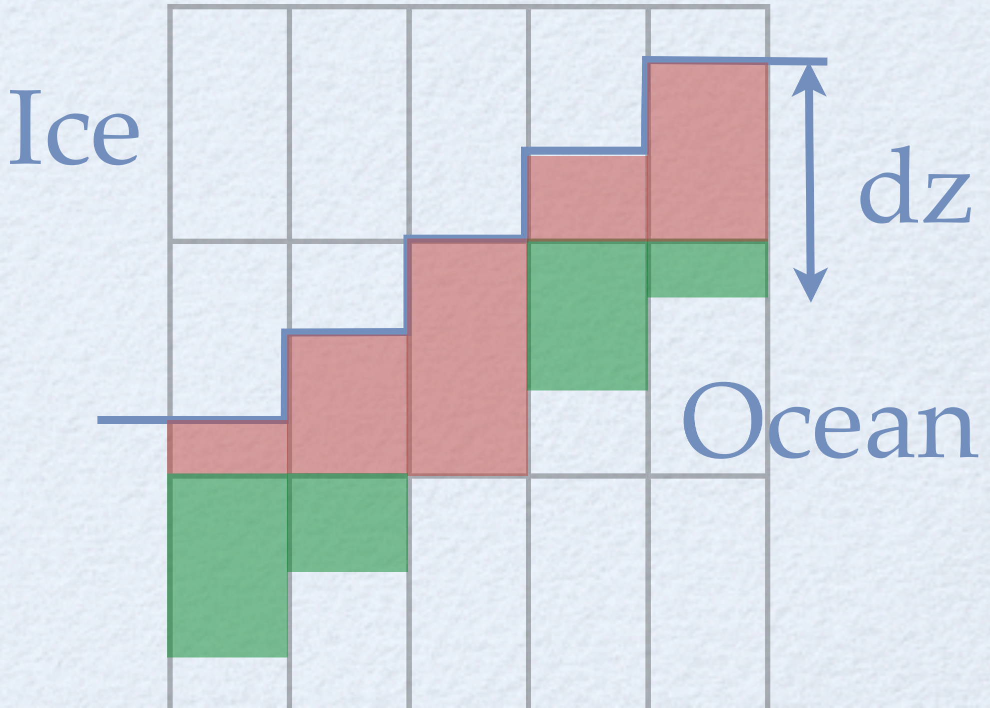
Losch 2008

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)

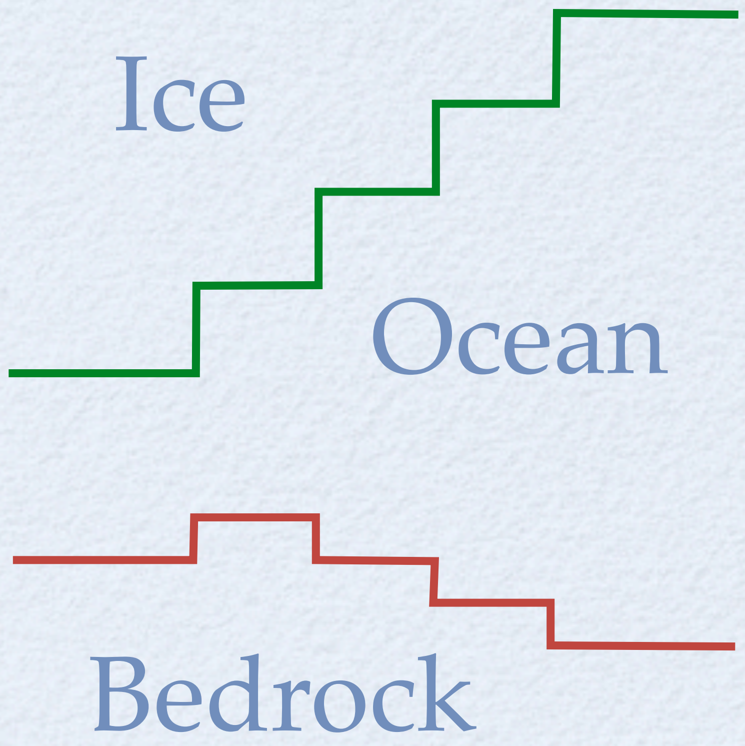


Losch 2008



Partial Cells Method

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



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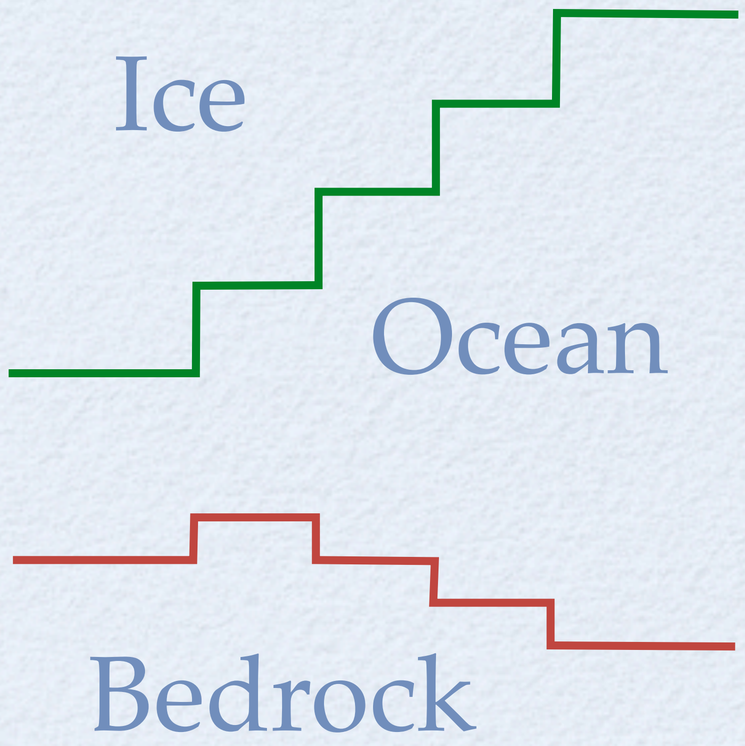
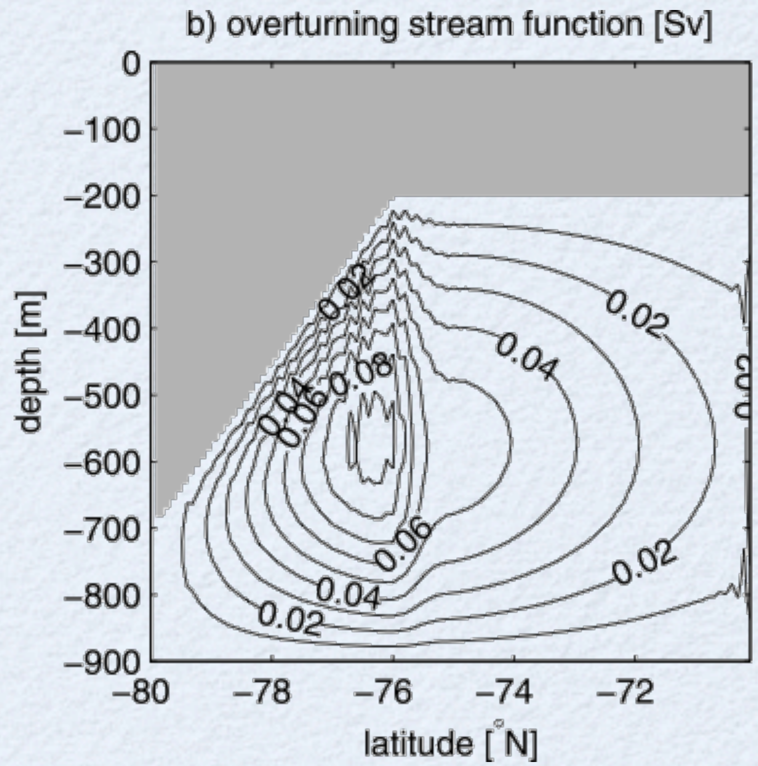


- Cons:
  - Tested only for static ice shelves
  - Stair-step geometry can lead to noisy fields



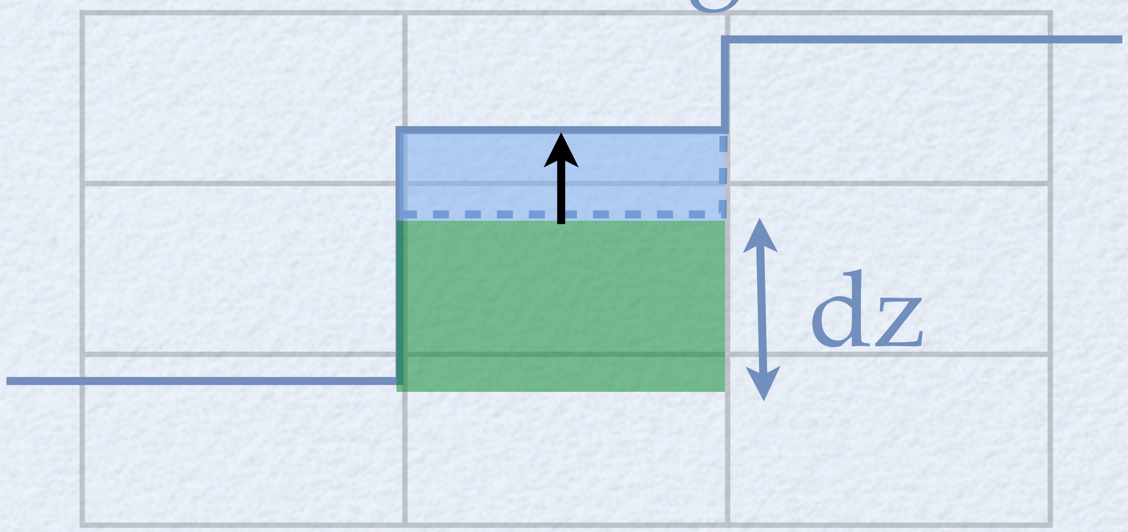
Losch 2008

Partial Cells Method

"Wetting" and "drying" of cells:

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

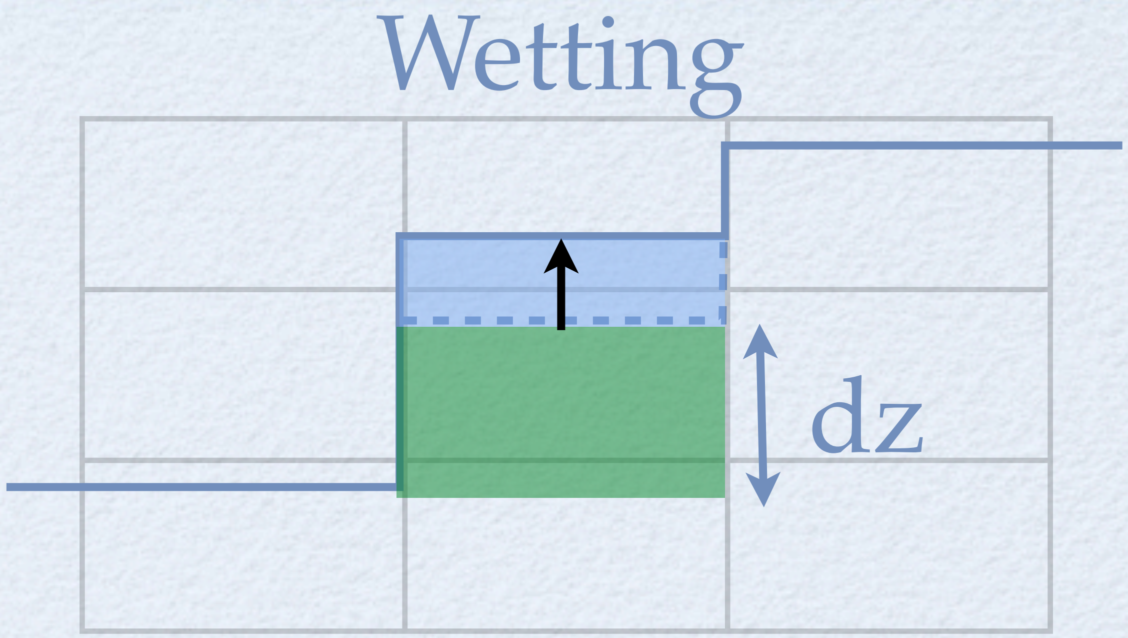
Wetting

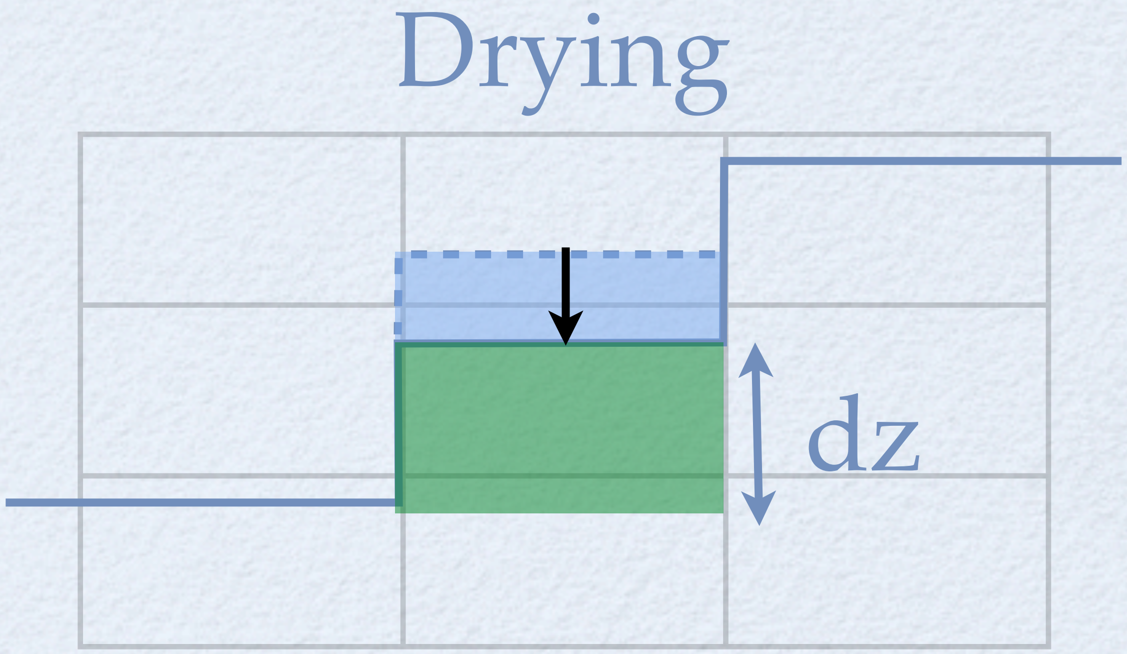


Partial Cells Method

"Wetting" and "drying" of cells:

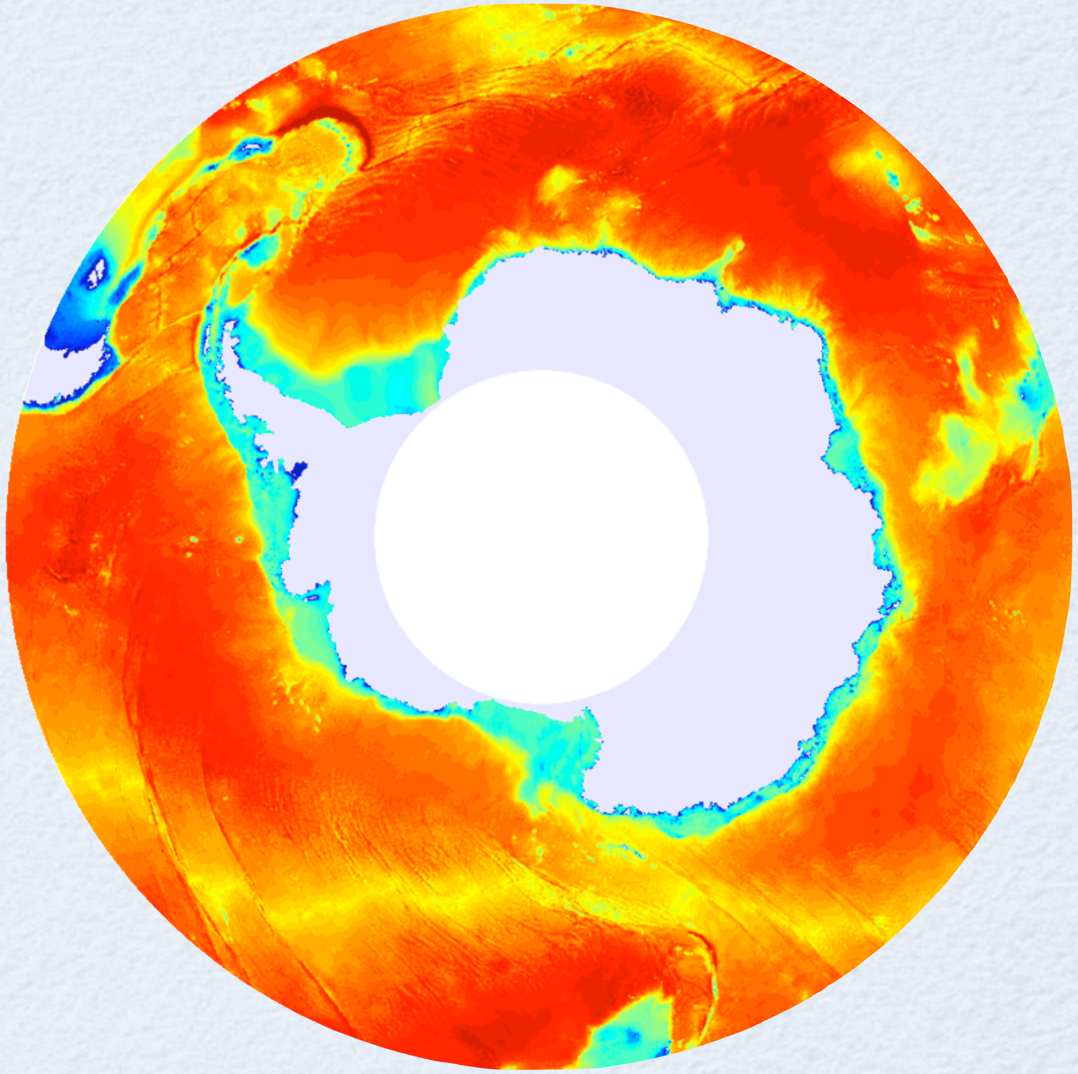
- Tracers in new "wetted" cells conservatively distributed *from* neighboring cell(s)
- Tracers in old "dried" cells conservatively distributed *to* neighbor(s)





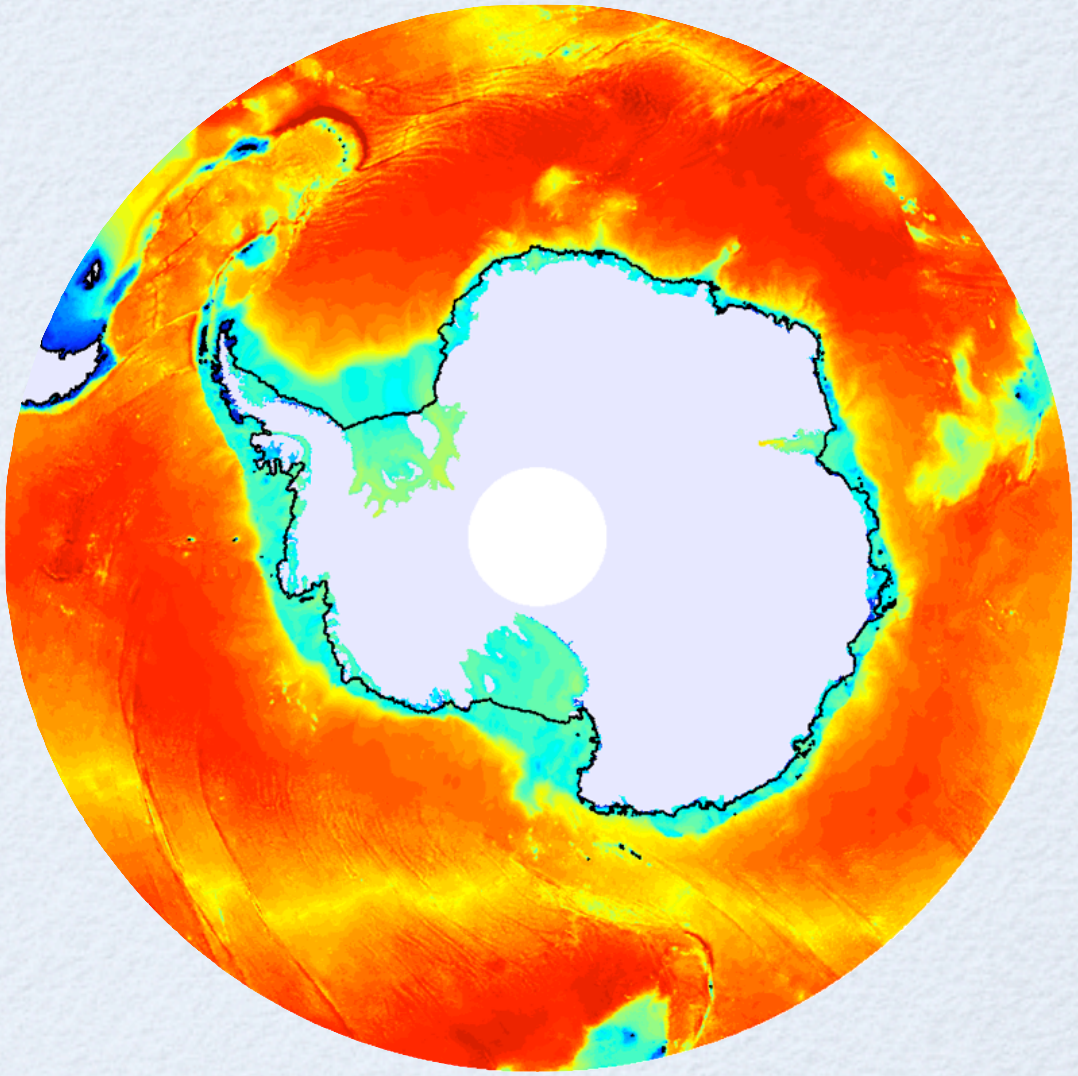
New Ocean Model Grid

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

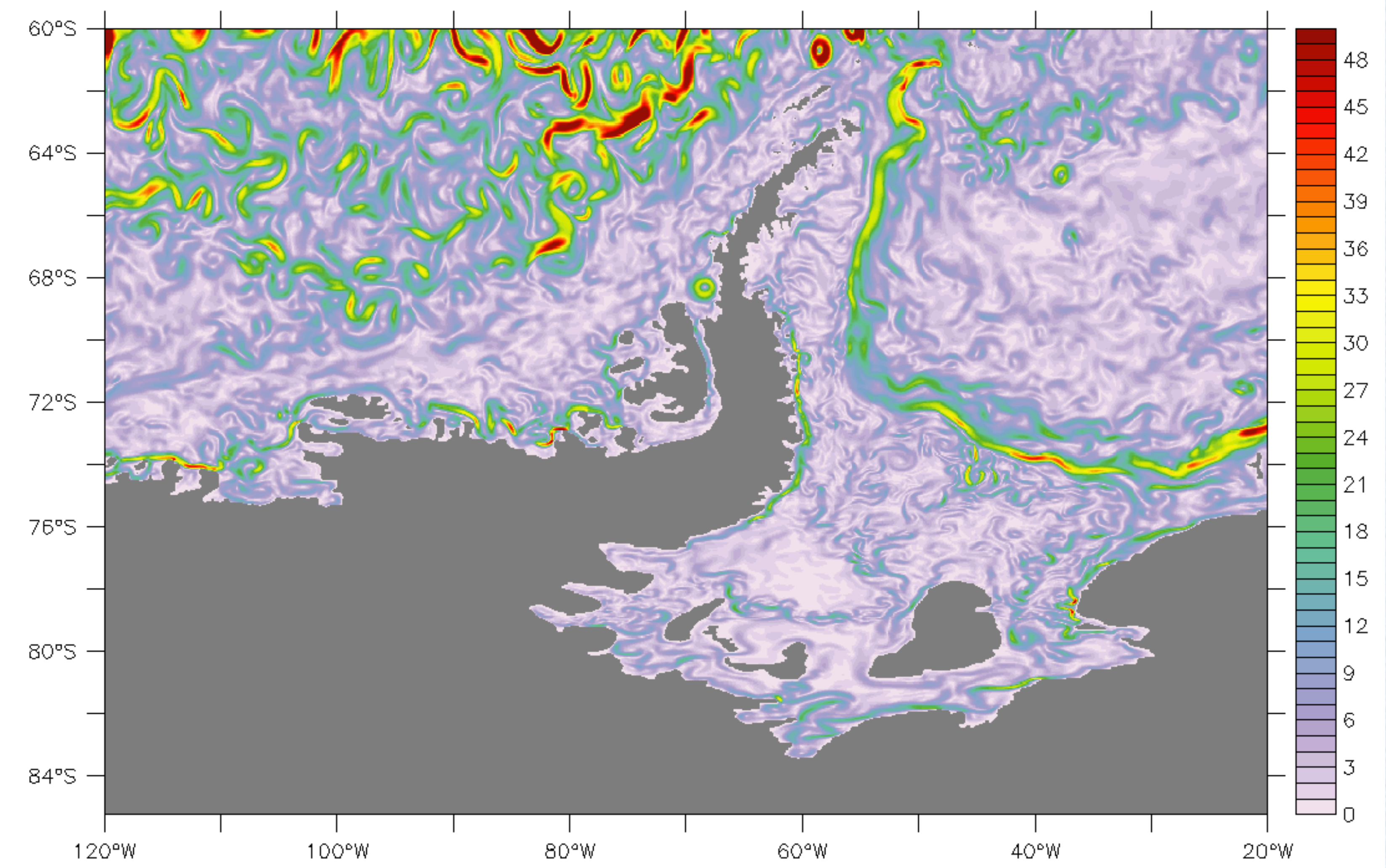


New ocean model grid

- 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



Ocean speed (cm/s) at 15 m depth after 1-month

- Mat Maltrud's spin-up simulation with new grid
- Next step: include static ice shelves on this grid

Summary

- Ongoing implementing both Immersed Boundary Method (without fictitious flow) and Partial Cells Method in POP
- New POP grid that will be able to handle Antarctic ice shelves
- Next steps: tests of ocean dynamics under static ice shelves with both idealized and realistic geometries