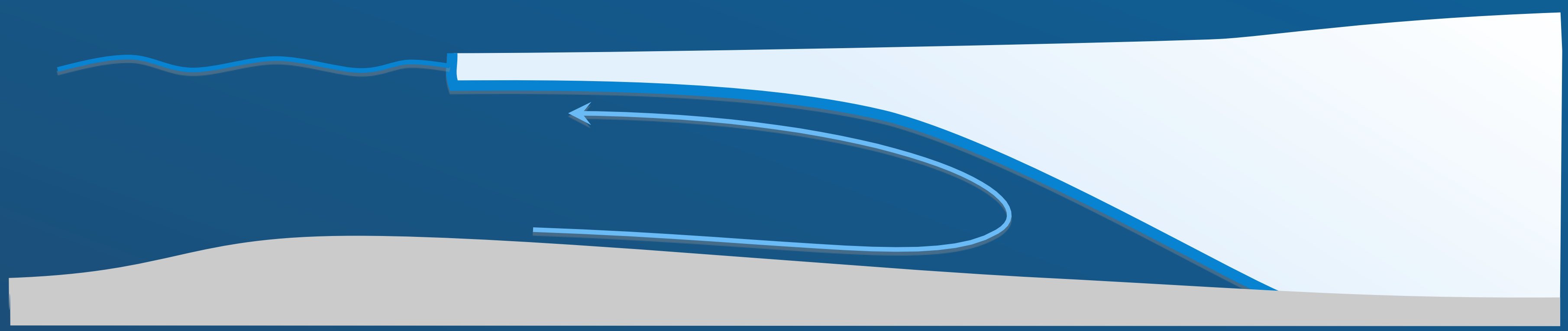
An Update on Modeling Land-ice/ocean Interactions in CESM



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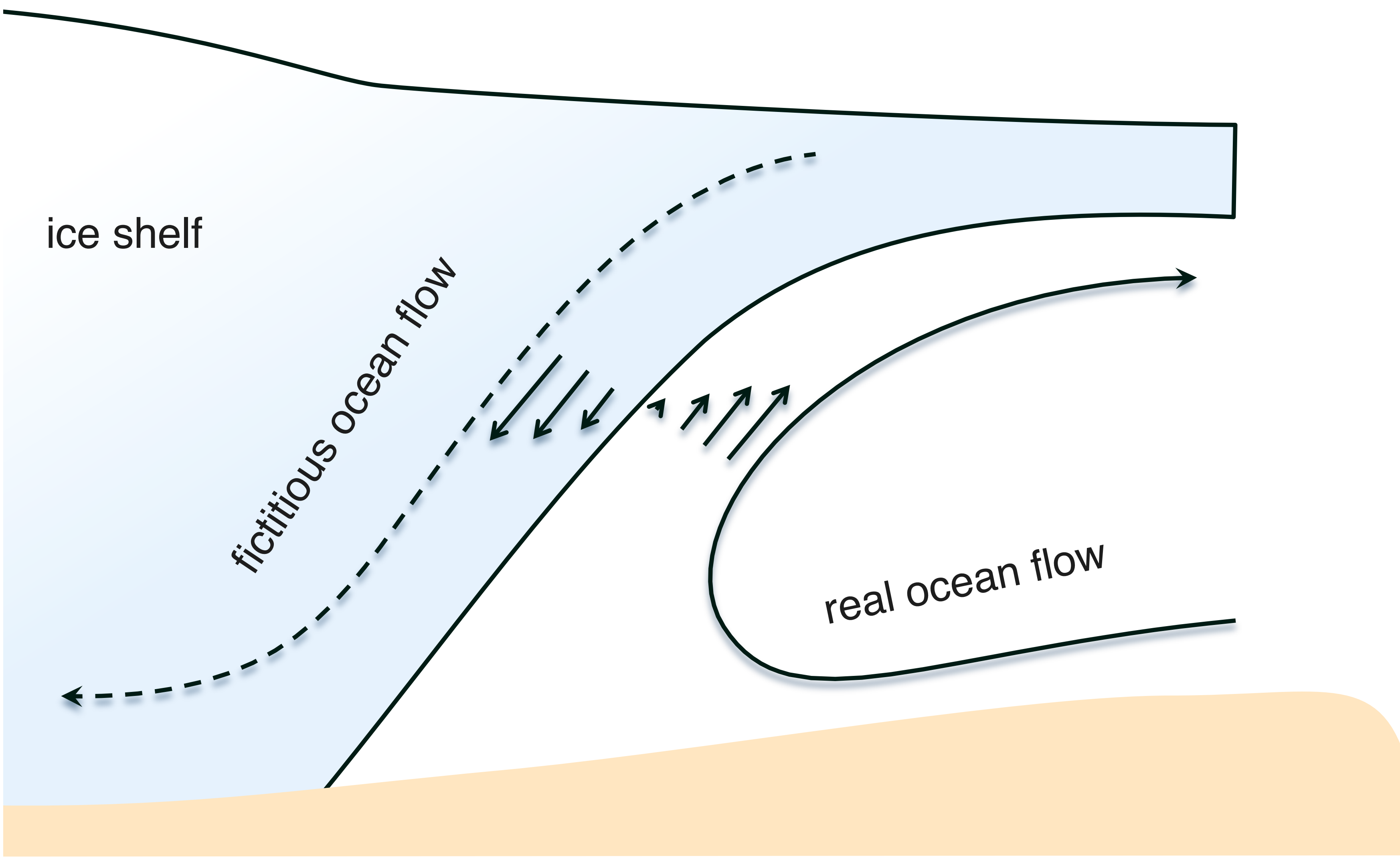
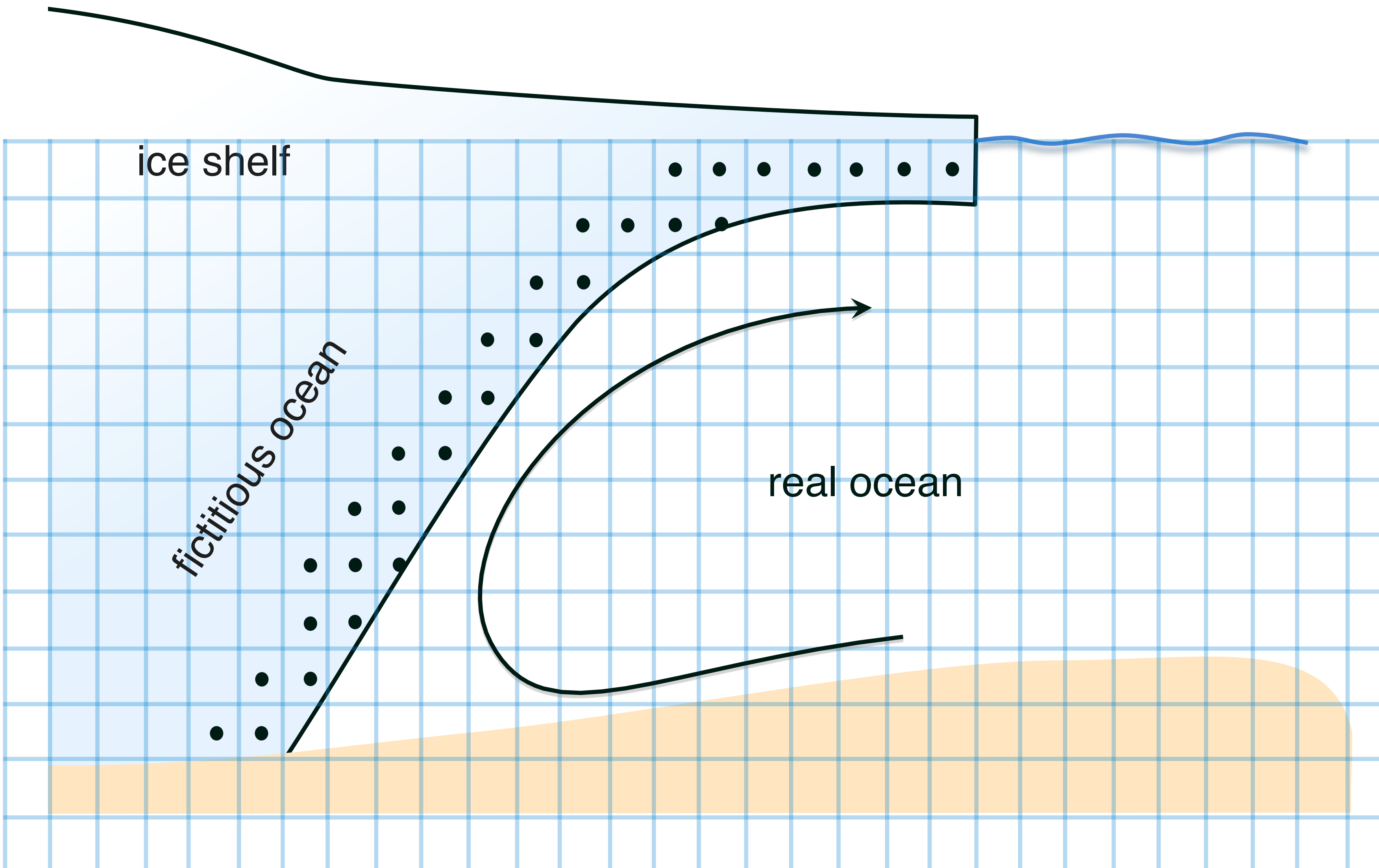
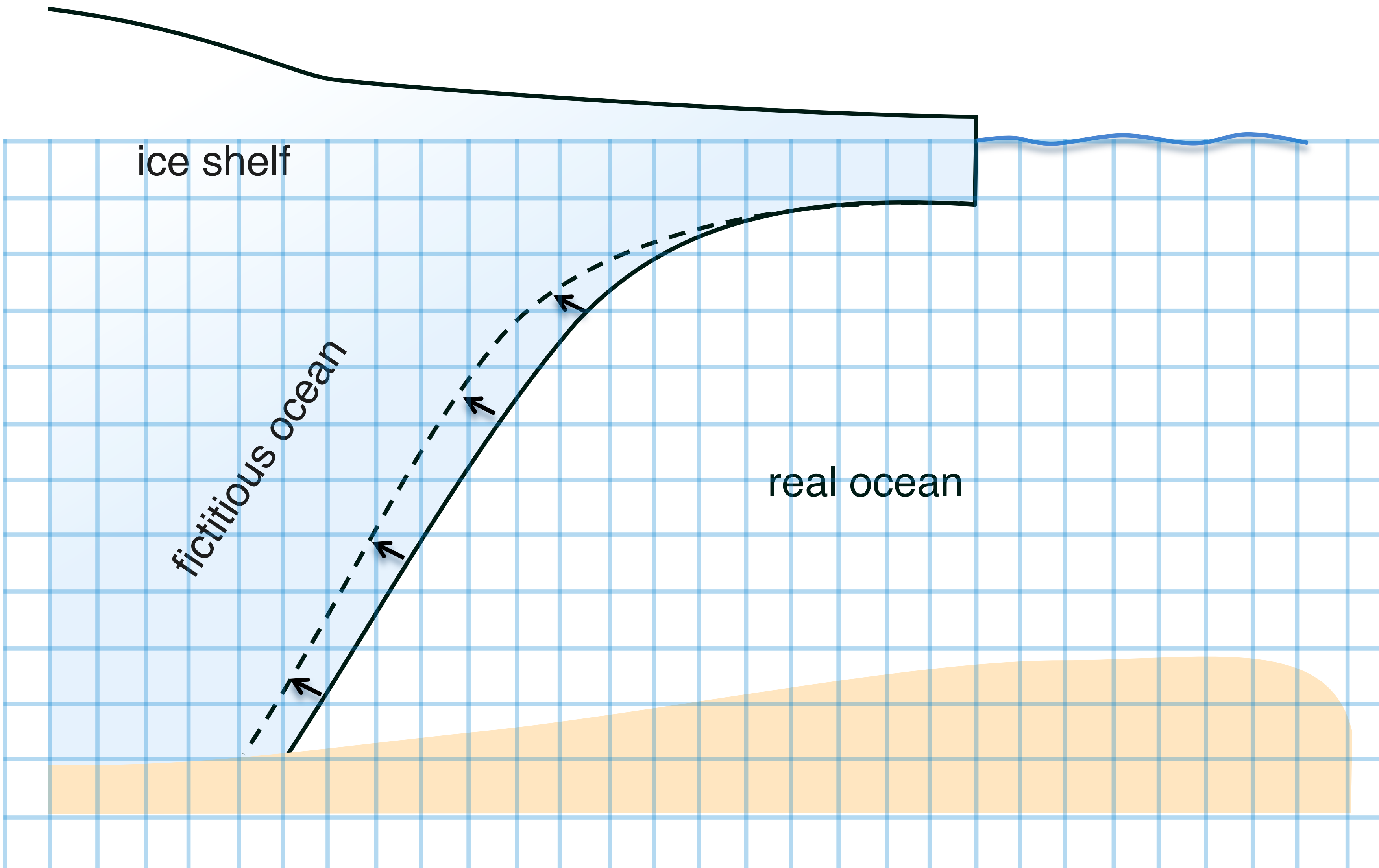
Ocean/Ice Shelf Coupling



Forcing at “Ghost” points



Moving boundaries



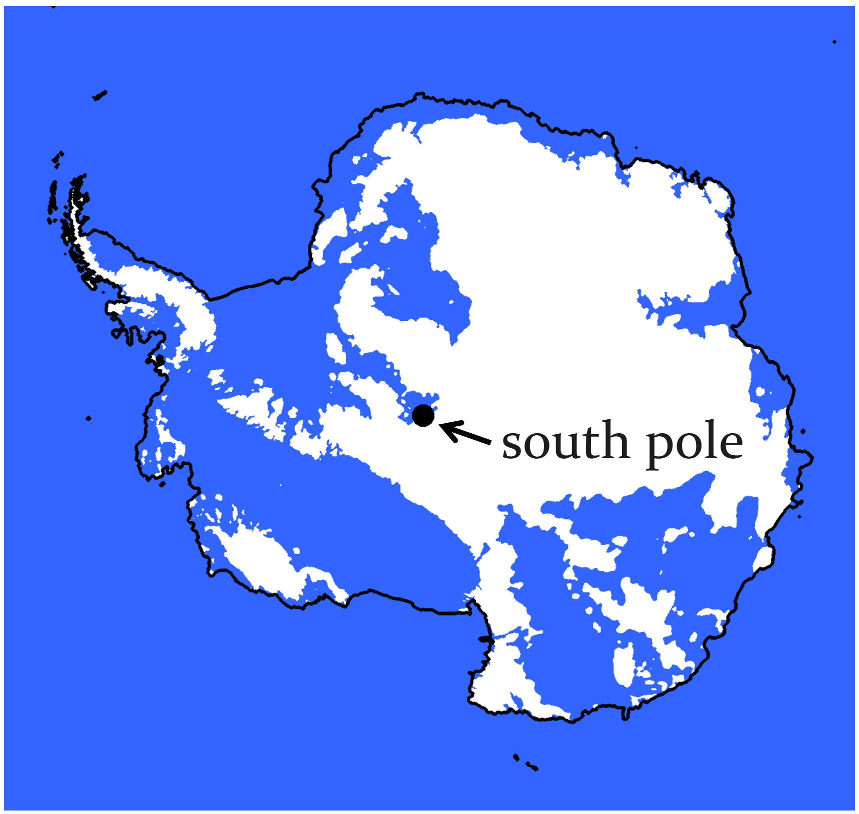
Subroutines called from existing POP

- `POP_InitializeIceShelf`
  - Allocate memory, set up interface geometry, etc.
- `POP_IceShelfComputeSurfaceVerticalVelocity`
  - Computes *w* at surface so that *w*=0 at interface
- `POP_IceShelfStoreVerticalVelocity`
  - Stores *w(x,y,z)* (was not needed previously in POP)
- `POP_IceShelfForce`
  - Computes boundary fluxes
  - Modify final *u, v, w, T* and *S* at ghost points to satisfy boundary conditions

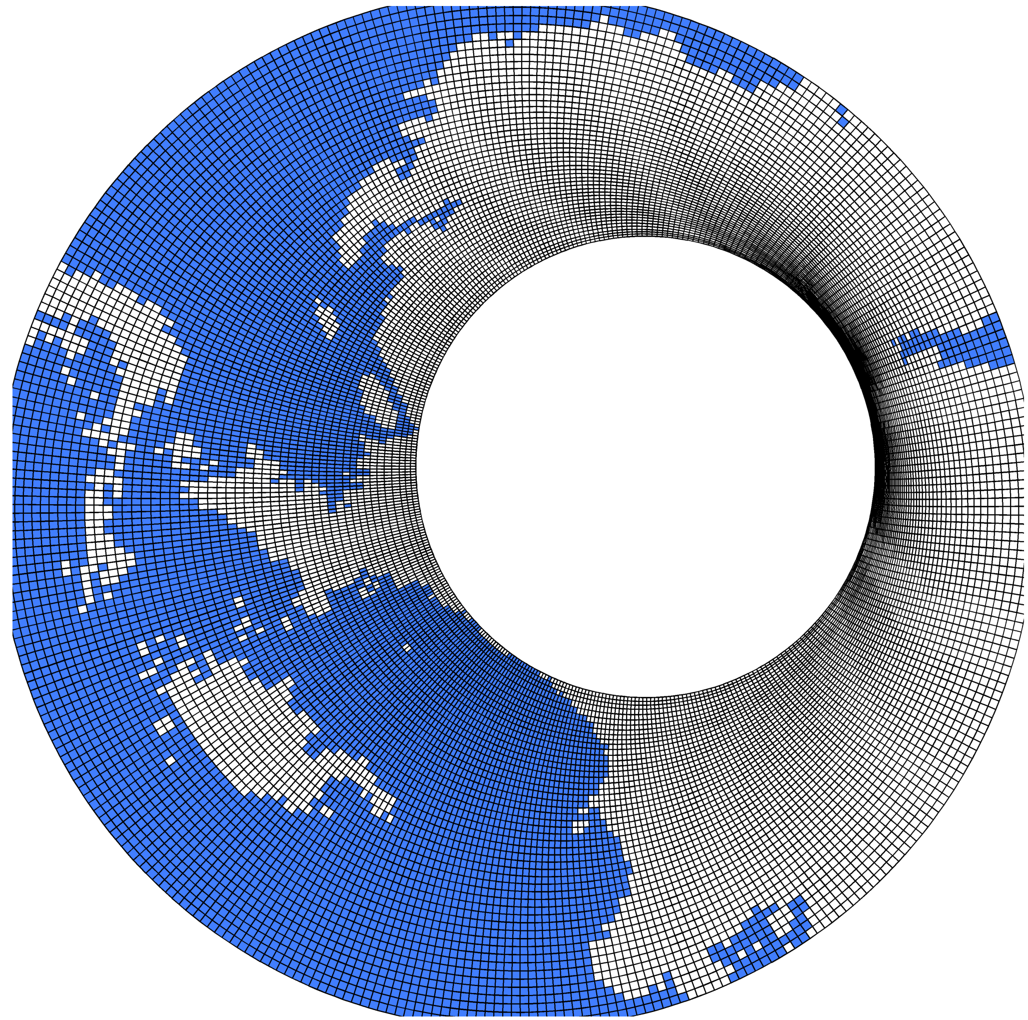
Coupling to Glimmer-CISM

- Fields passed to POP from Glimmer-CISM
  - boundary height (i.e., geometry of the interface)
  - grounded ice fraction
  - floating ice fraction
  - 2 coefficients for computing the heat flux into the ice
- Fields passed from Glimmer-CISM to POP
  - ice mass flux
  - heat flux into the ice

New POP grid



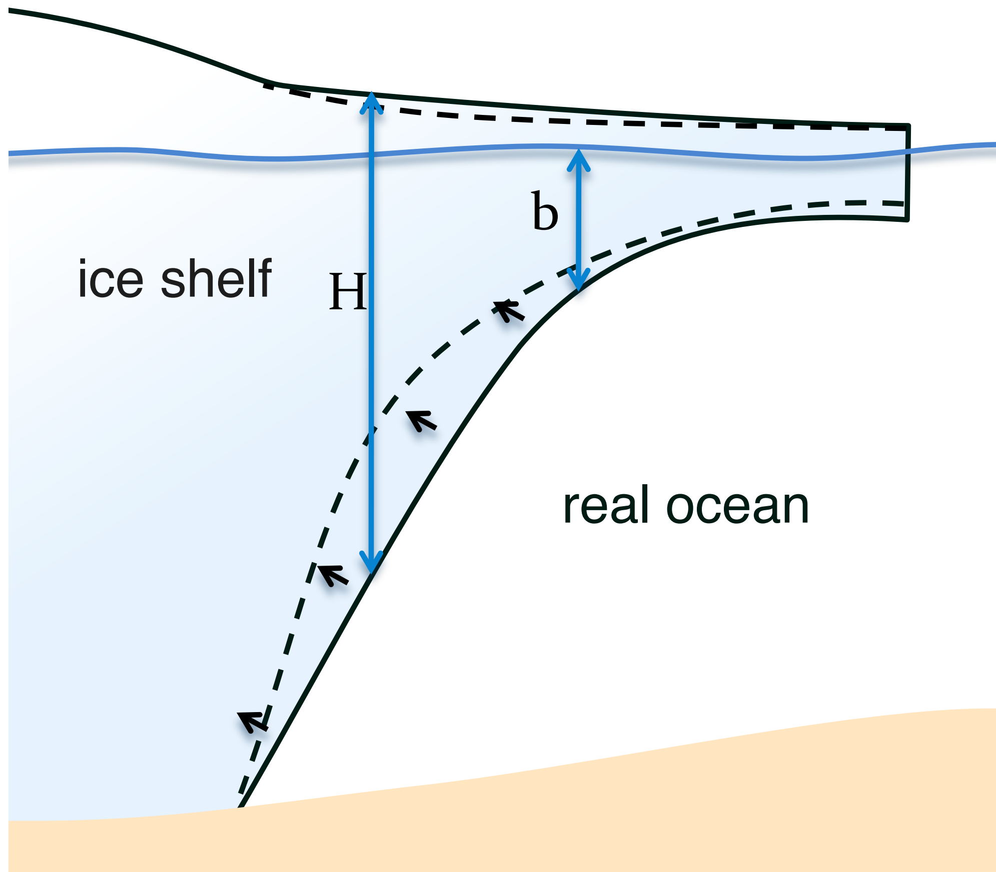
Blue regions: bedrock below sea level



New orthogonal grid with “south pole” in East Antarctica. Matches existing POP grid at 70°S.

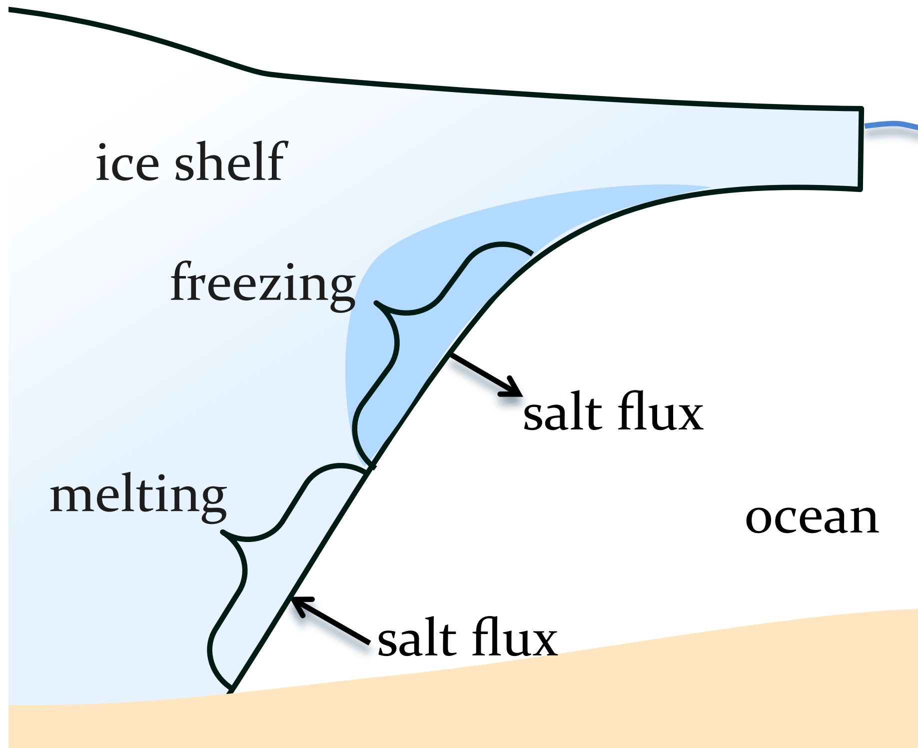
Mass/volume conservation

- Glimmer-CISM maintains ice geometry by Archimedes principle
  - $\rho_i/\rho_w = b/H$
- Volume of "real" ocean is not constant
- But sea level cannot change, so mass not conserved
- IBM and boundary conditions expected to work well with future mass-conserving scheme for POP



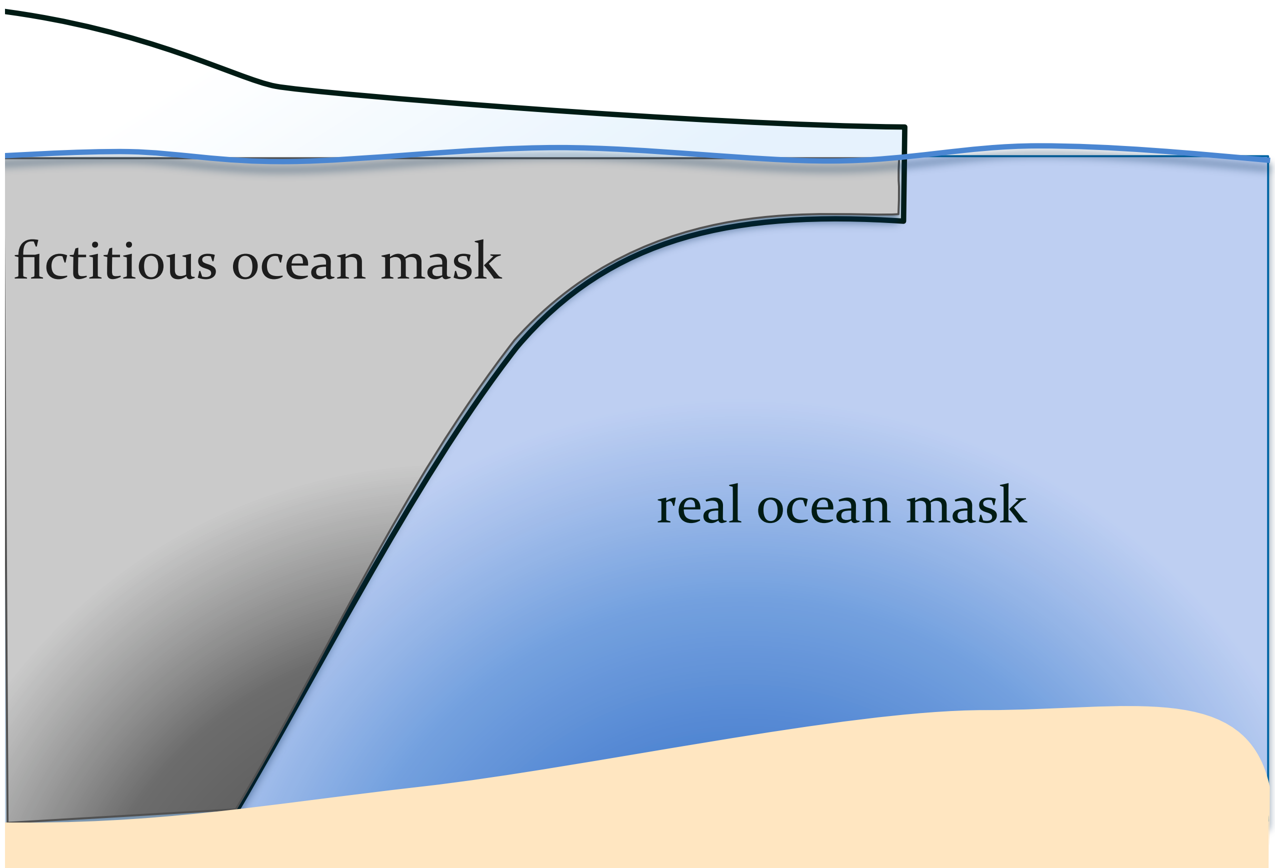
Spreading virtual salt fluxes

- POP is volume-conserving rather than mass-conserving
- Therefore, fresh water mass flux must be represented as *virtual salt flux*
- Strong salinity anomalies can build up in grid cells neighboring boundary
- Currently, same salt diffusion near boundary as elsewhere in ocean
- In future, may need higher turbulent diffusion near boundary



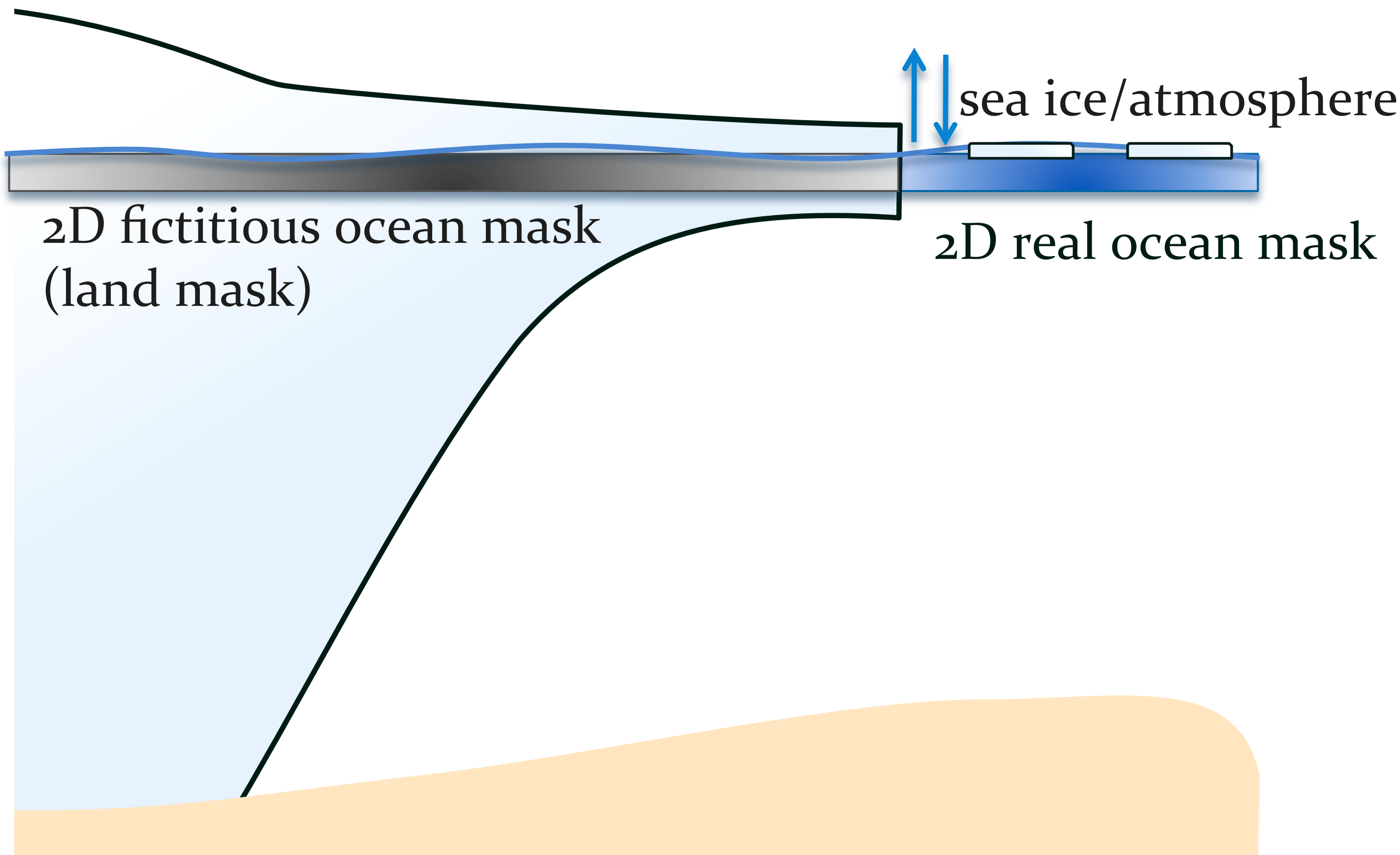
Real vs. fictitious ocean: diagnostics

- Global diagnostics must be integrated only over "real" ocean (similar to *partial bottom cells*)



Real vs. fictitious ocean: coupling

- Sea ice/atmosphere flux coupling only at interface with "real" ocean (a time-dependent "land mask")

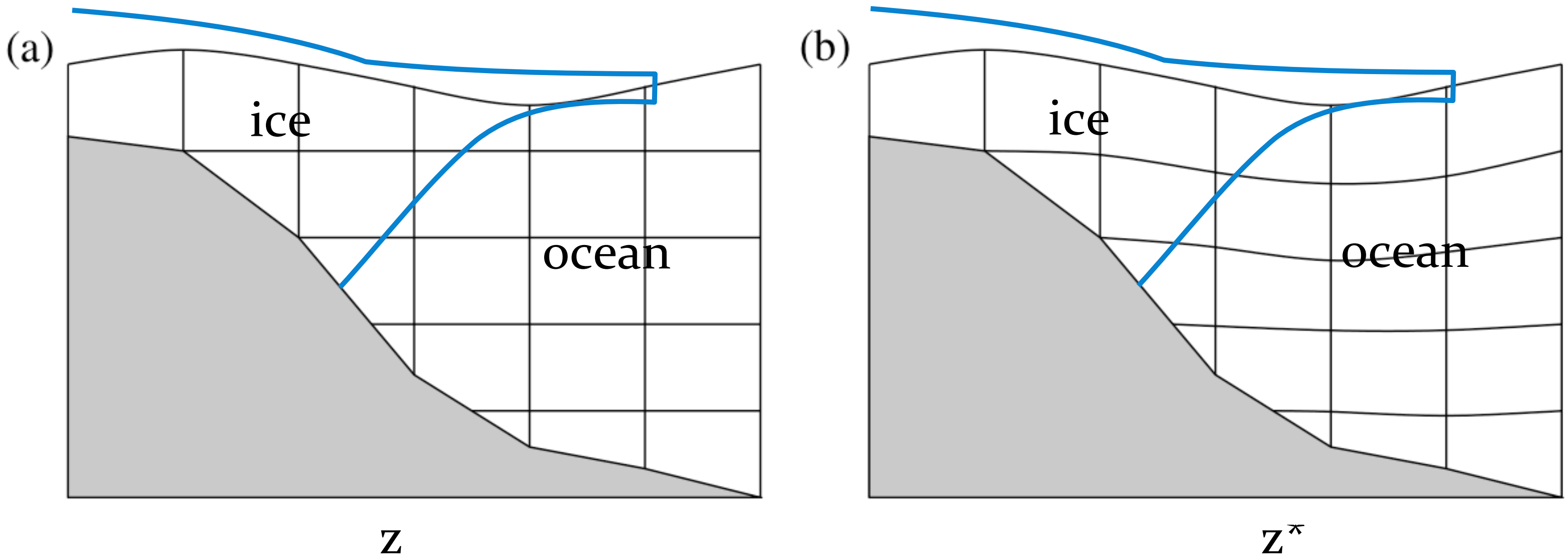


Natural freshwater fluxes

- POP is likely to move to mass-conserving *natural freshwater fluxes* instead of virtual salt fluxes
  - Can handle sea level can change

- The proposed implementation:
  - z^* *coordinates* that adjust to variable sea surface height
  - removing *linearization assumption* currently involved in POP's barotropic/baroclinic splitting

Z*coordinates and the IBM



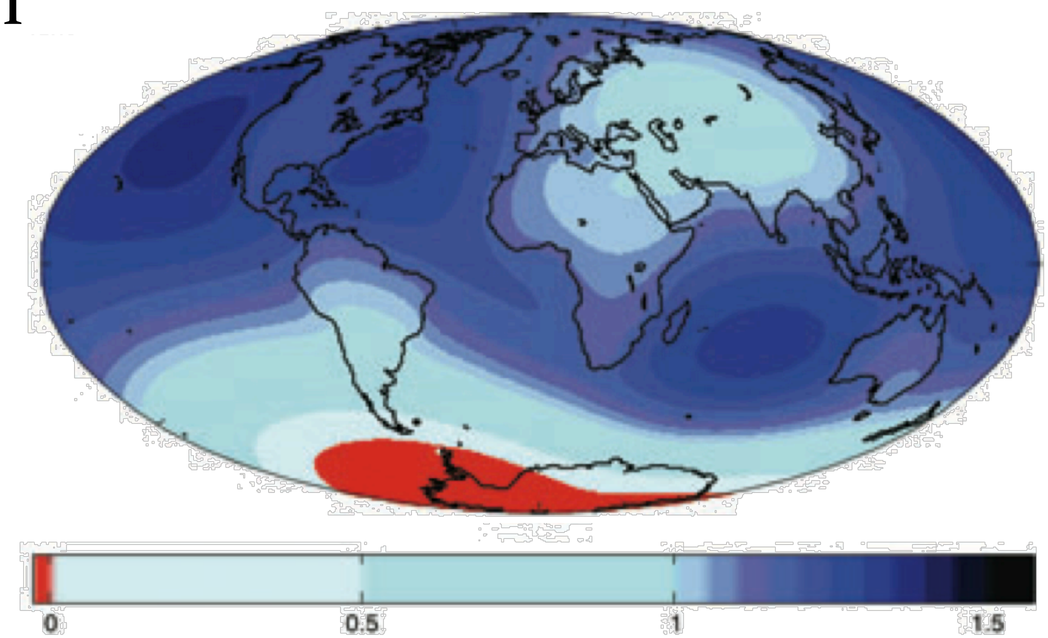
- z* vertical coordinate stretches the grid to follow the barotropic mode (Adcroft and Campin 2004)
- IBM more challenging (but still possible) because boundary geometry changes *quickly* in time relative to grid

Removing linearization assumption

- Barotropic mode currently advanced in time by implicit linear solution of *linearized* system for sea surface height
- Linearization must be removed for z* coordinates
- Currently, the IBM implementation does not modify the sea surface height solution (same in real and fictitious ocean)
- So, probably the IBM is unaffected by the removal of linearization assumption

Gravitationally self-consistent sea level

- Melting land ice can have a significant, spatially variable effect on sea level
- Currently, cannot be represented very well in POP (maybe change bathymetry once a decade?)
- Natural freshwater fluxes would help!



Gomez et al. 2009

Conclusions

- The immersed boundary method (still) appears to be a promising method for representing the ice/ocean interface
- A few development challenges remain, primarily related to coupling to other model components
- Future POP development to provide natural freshwater fluxes will in some ways simplify (better sea level) and in some ways complicate (rapidly changing boundary geometry) the model of the ice/ocean interface