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

Losch 2008
- 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)
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
"Wetting" and "drying" of cells:

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

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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