Recent POP Developments

Mathew Maltrud

LANL

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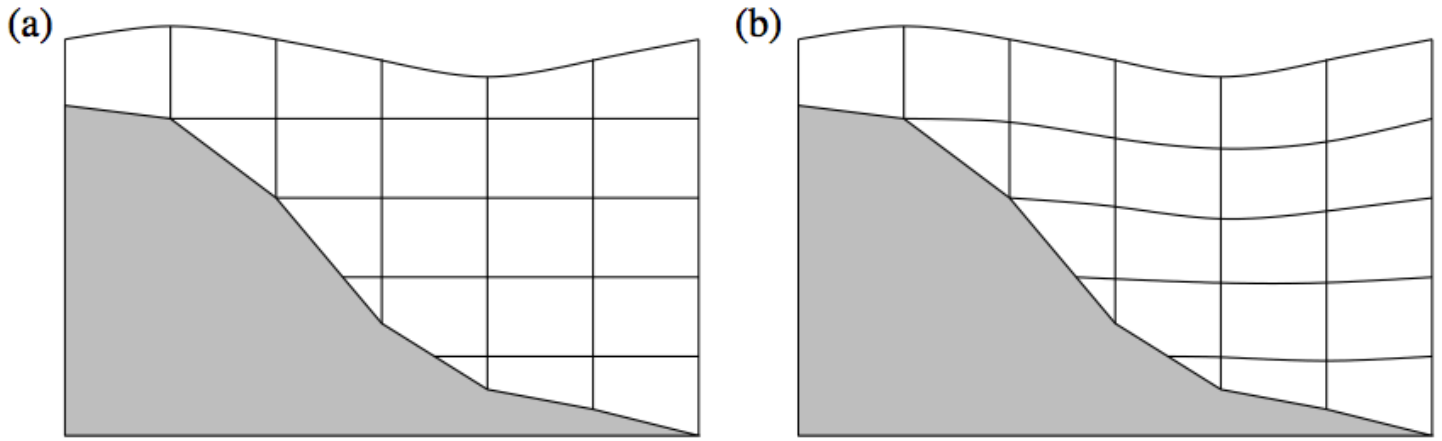
Los Alamos NATIONAL LABORATORY

Outline

- z* vertical coordinate, Adcroft and Campin (*2004*)
  - Formulation
  - Implementation
  - Results
- Circulation beneath ice shelves
  - Formulation
  - Results
- POP GPU tests

z* Vertical Coordinate

invaluable help from Matthew Hecht, Mark Petersen, Todd Ringler



from Adcroft and Campin (2004)

- distributes free surface fluctuations throughout the water column
  - Enables thinner layers without worries about $|\eta| > dz_1$

z* Formulation

- Currently, variable thickness only allowed in top layer of tracer equation (linear free surface)

$$(1+\xi_k^{n+1})T_k^{n+1} = (1+\xi_k^{n-1})T_k^{n-1} + 2\delta tF$$

$$\xi_k = \frac{\eta}{dz_k}\delta_{1,k}$$

- Now need thickness weighted tracer equation for all levels

$$h_k^{n+1}T_k^{n+1} = h_k^{n-1}T_k^{n-1} + 2\delta t\hat{F}$$

z* Formulation

- Instead of prognostic thickness equation, specify *h* distribution

$$h_k^* = dz_k(1 + \frac{\eta}{H})$$

- Extra term accounting for grid motion

$$h_k^{n+1} T_k^{n+1} = h_k^{n-1} T_k^{n-1} + 2\delta t \hat{F} + G(w_k^*)$$

$$w_k^* = w_{surface}(1 - \frac{z_k}{H})$$

Conservation Issues

- Linear free surface does not *locally* conserve tracer in top layer
  - Lateral fluxes use nominal layer thickness dz_1, not $dz_1 + \eta$
  - Does guarantee *global* conservation

z* Conservation Issues

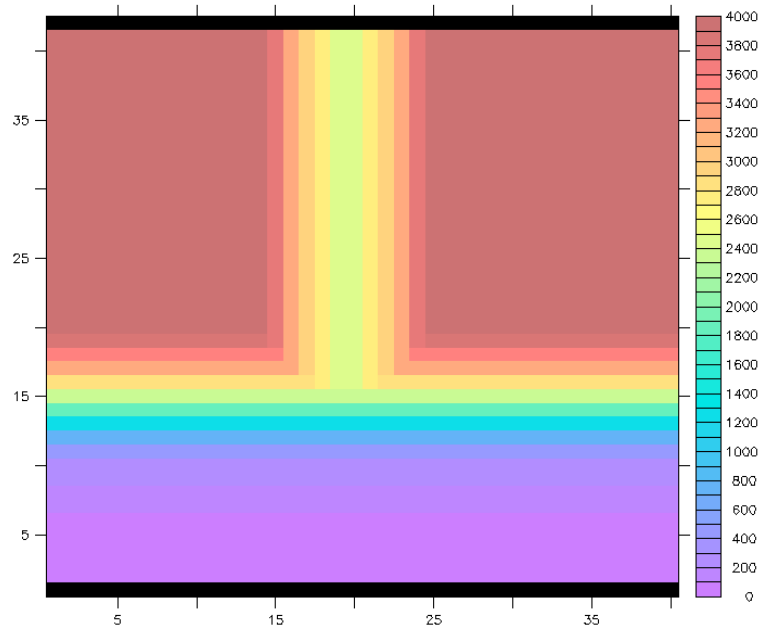
- Same lack of local conservation, but now at *all* levels
  - Still have global conservation due to using nominal dz_k for lateral fluxes
  - Bottom level is now more like the *top* level in variable surface layer

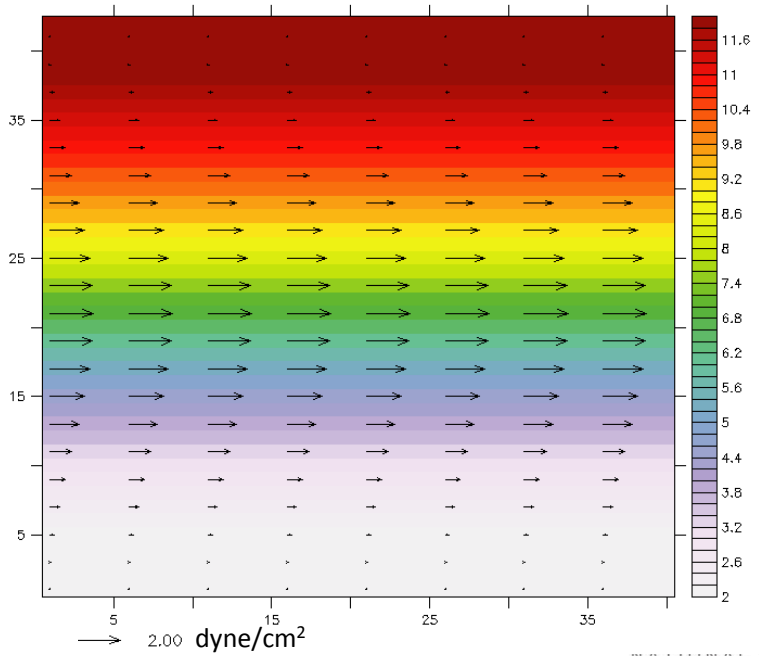
Momentum Equation

- Unchanged except for pressure gradient
  - New term due to slope of grid reminiscent of σ-coordinate models
  - Slopes much smaller than typical σ reduces errors
  - Still, may be necessary to handle with care
- Pressure averaging issue
  - Predictor step gives provisional η^{n+1}
  - Unclear if possible to also get provisional h_k
- Use nominal dz_k for lateral fluxes

Channel Test Problem

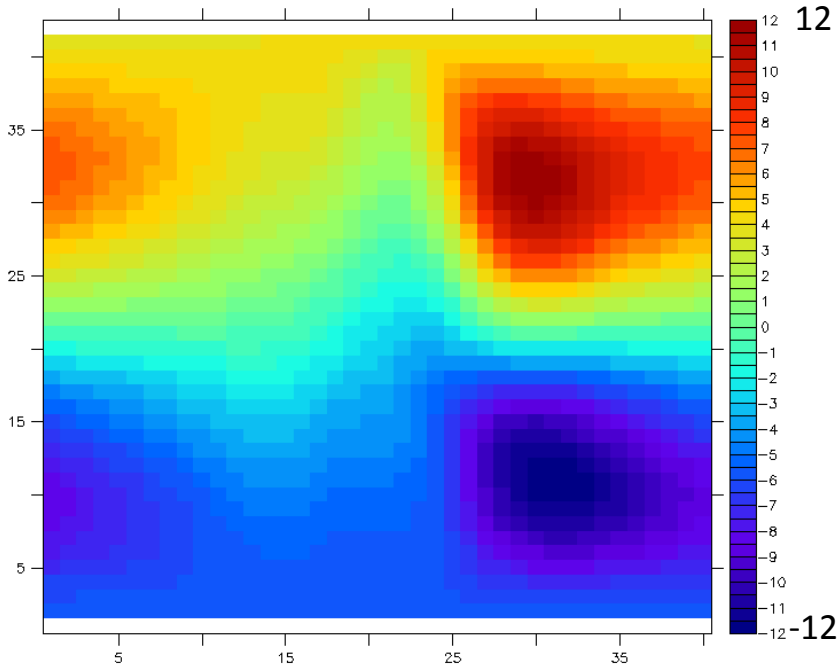
- ~30 km grid, 34 levels, partial bottom cells
- Constant diffusivities in horizontal (∇^2) and vertical (implicit)
- Restoring of SST (30 day timescale), constant salinity
- Zonal wind stress (time invariant)
- No grid-slope pressure gradient term, centered advection





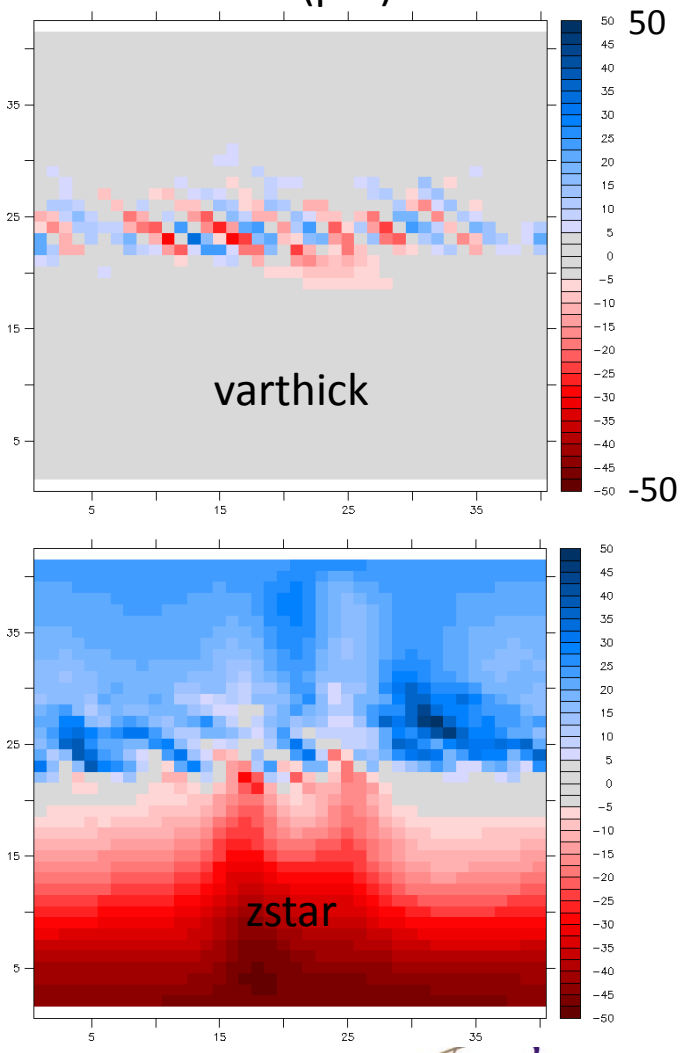
Results after 1 Year

SSH (cm) from Standard CESM POP



ΔSSH (μm)

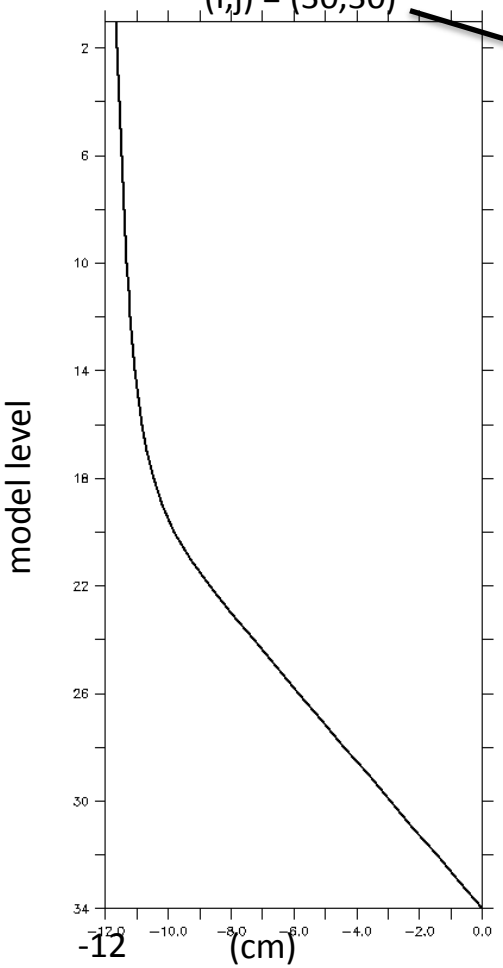
New POP



z* diagnostics

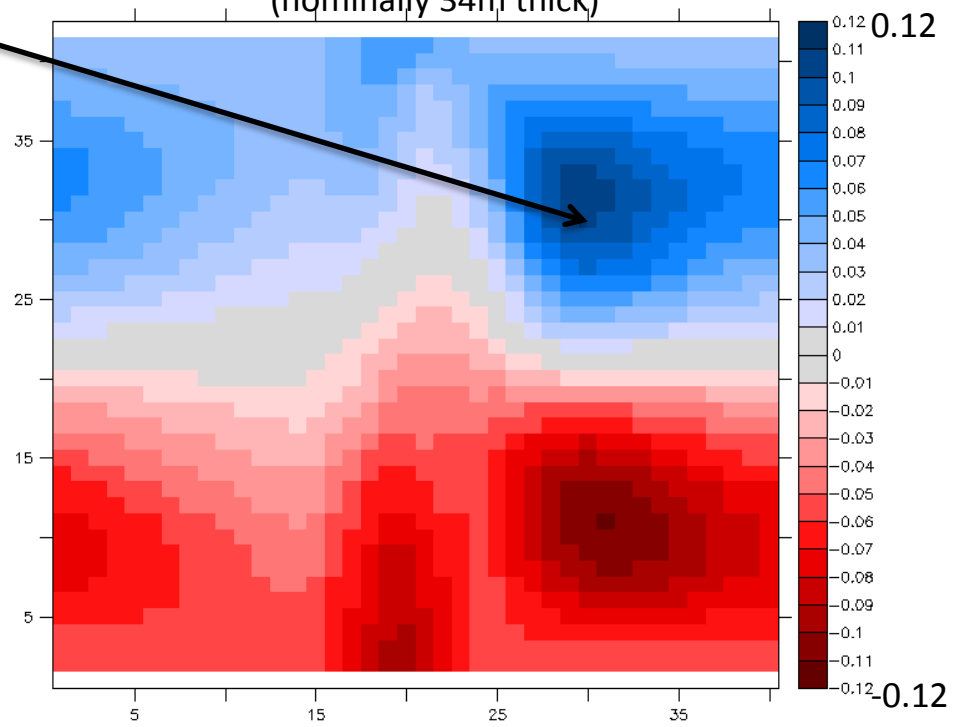
Δdepth to bottom of model level

(I,j) = (30,30)



Δthickness of 250m model level (cm)

(nominally 34m thick)



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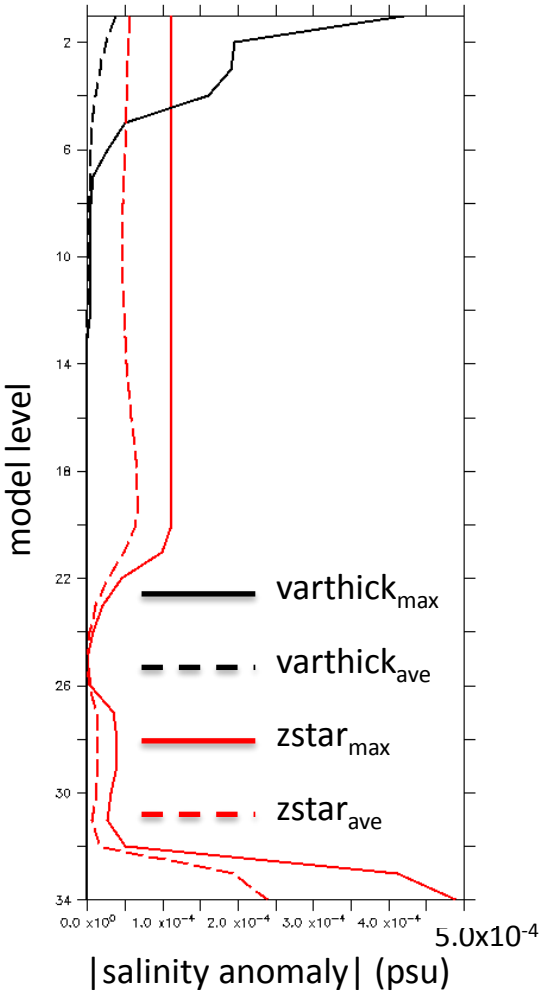
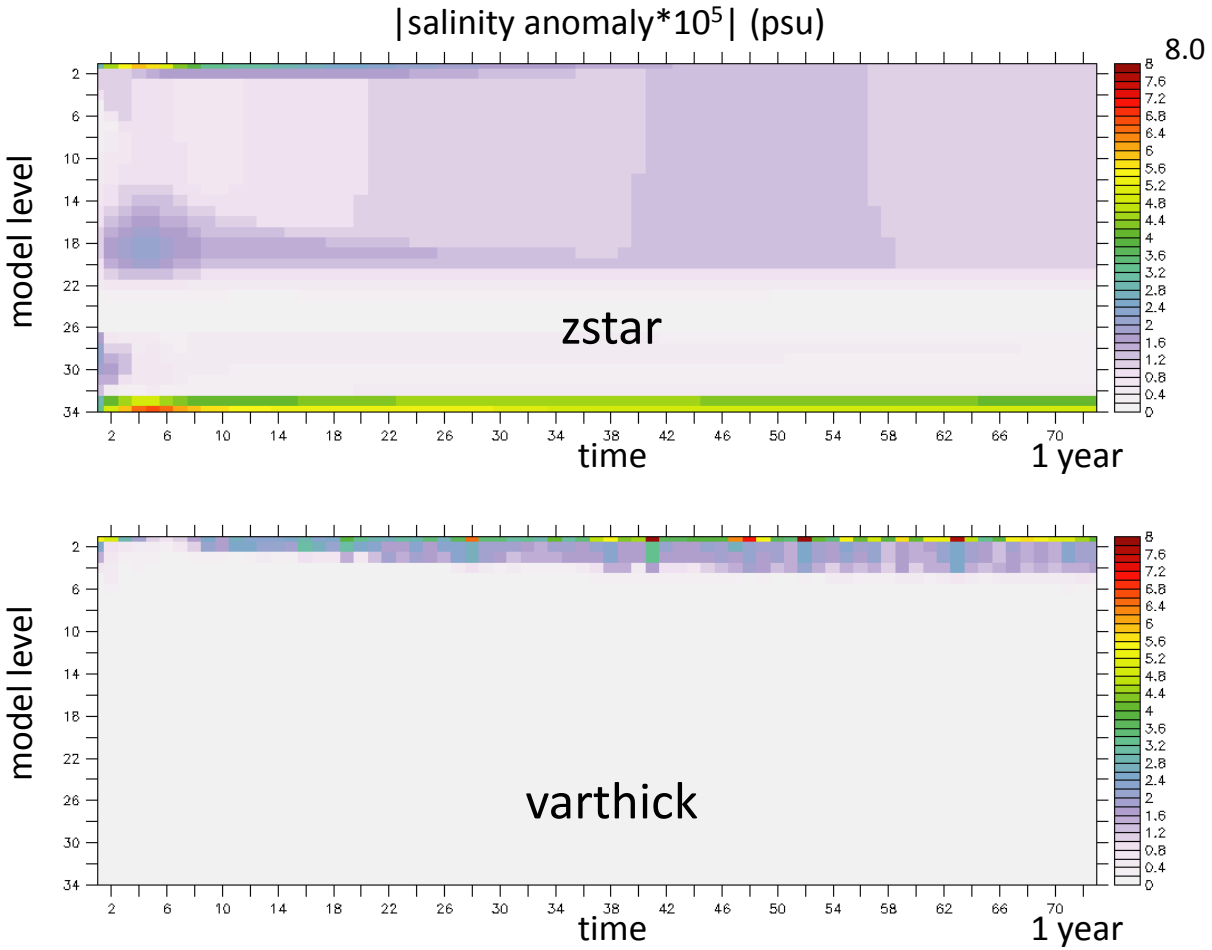
Salinity Diagnostics

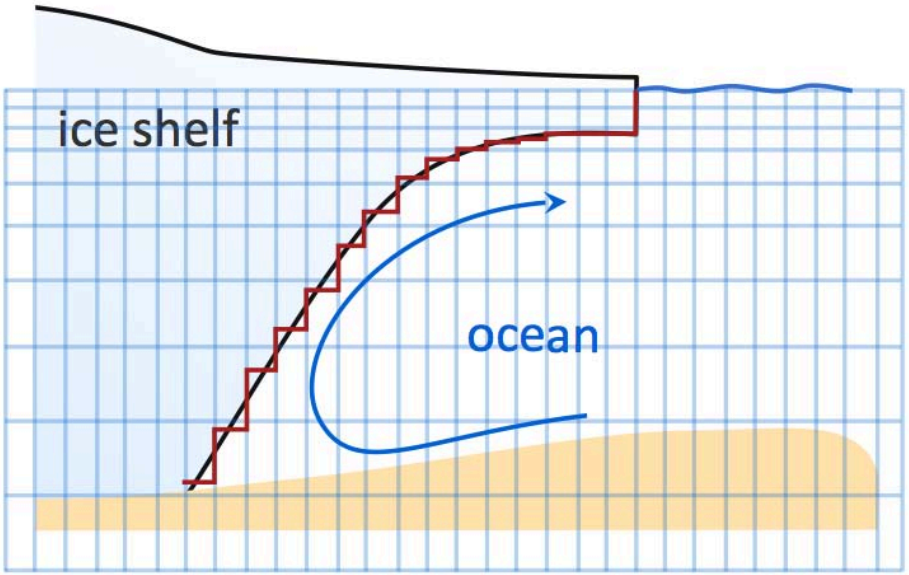




Ice Shelves in POP

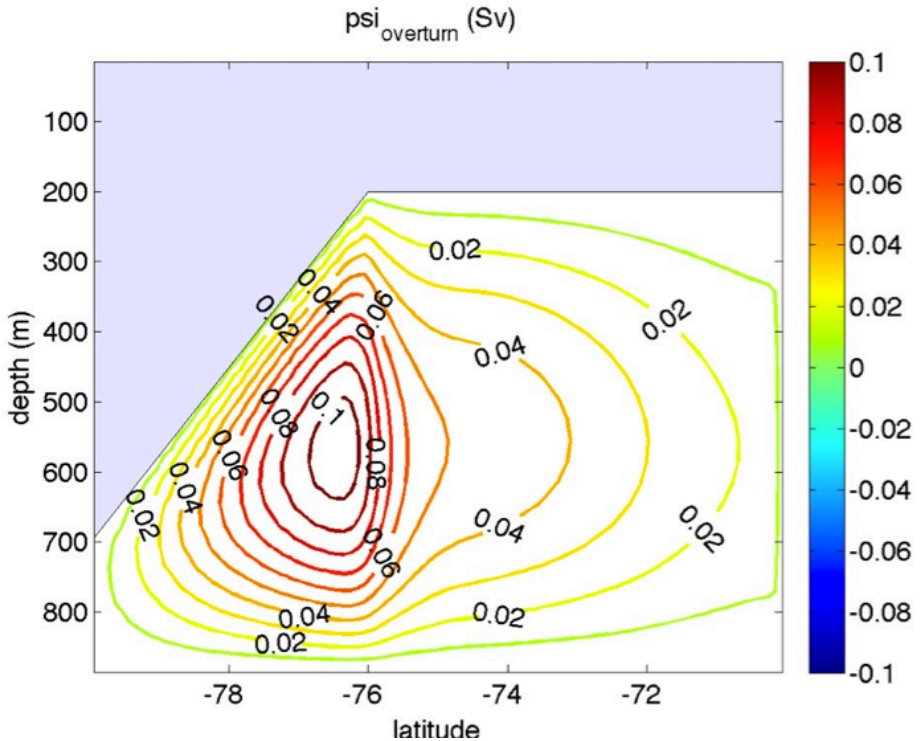
development by Xylar Asay-Davis

- Immersed Boundary Method put on back burner
- Implemented method of Losch (2008)
  - Partial top cells
  - Applied surface pressure from overlying ice
  - k-loops from KTT(i,j) to KMT(i,j)
  - mods to some differential operators

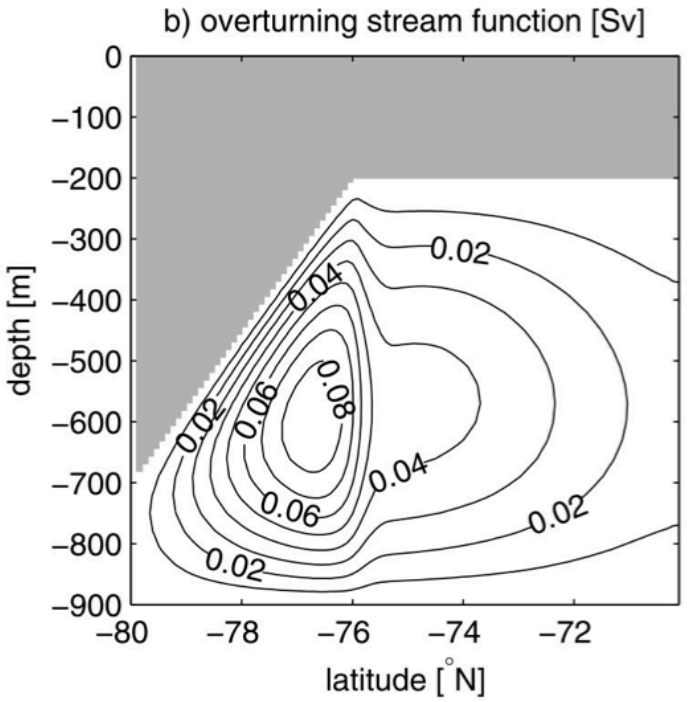


Validation

ISOMIP Test Case #1



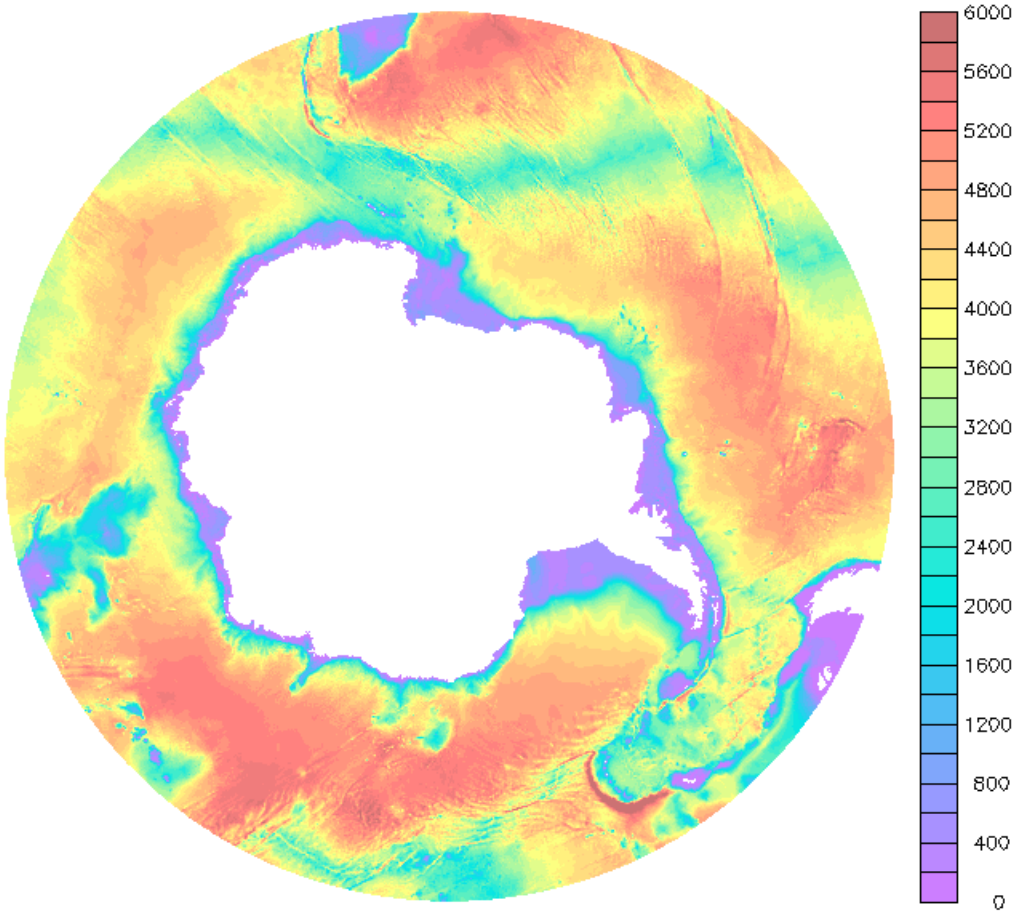
POP



Losch (2008)

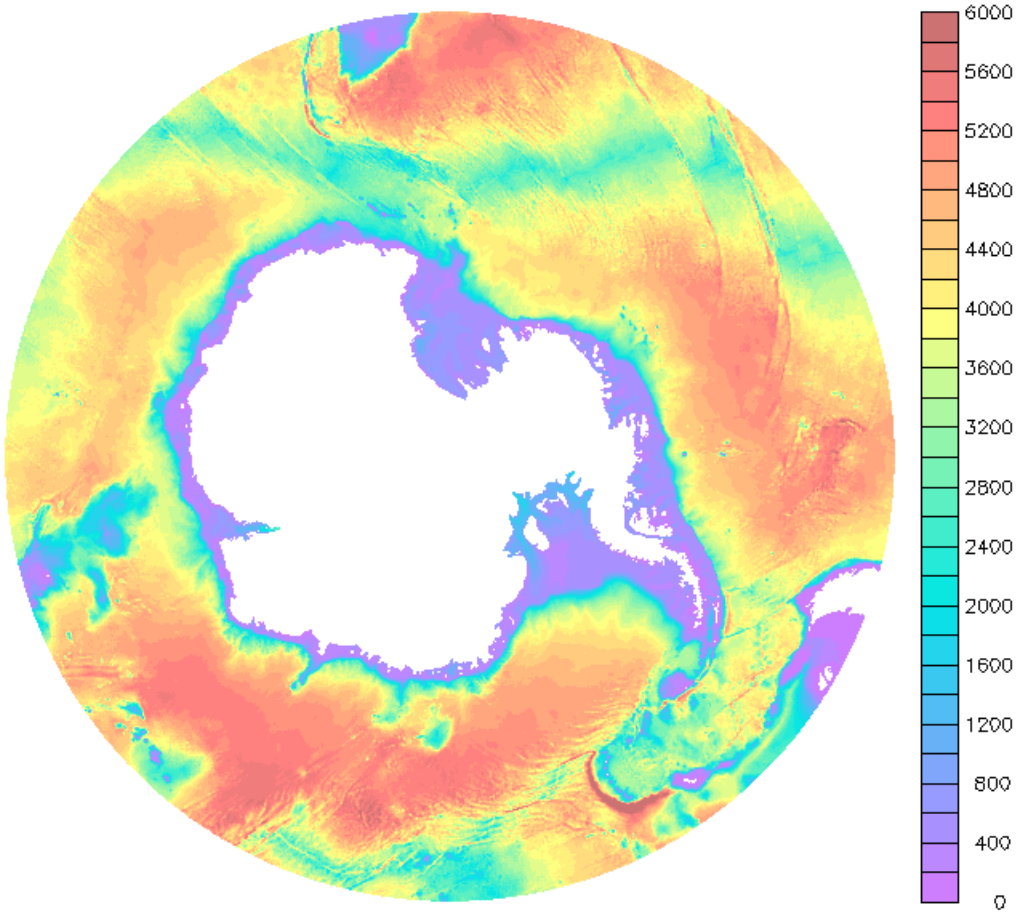
0.1° Southern Ocean

- South of 51°S from tx0.1v2 grid



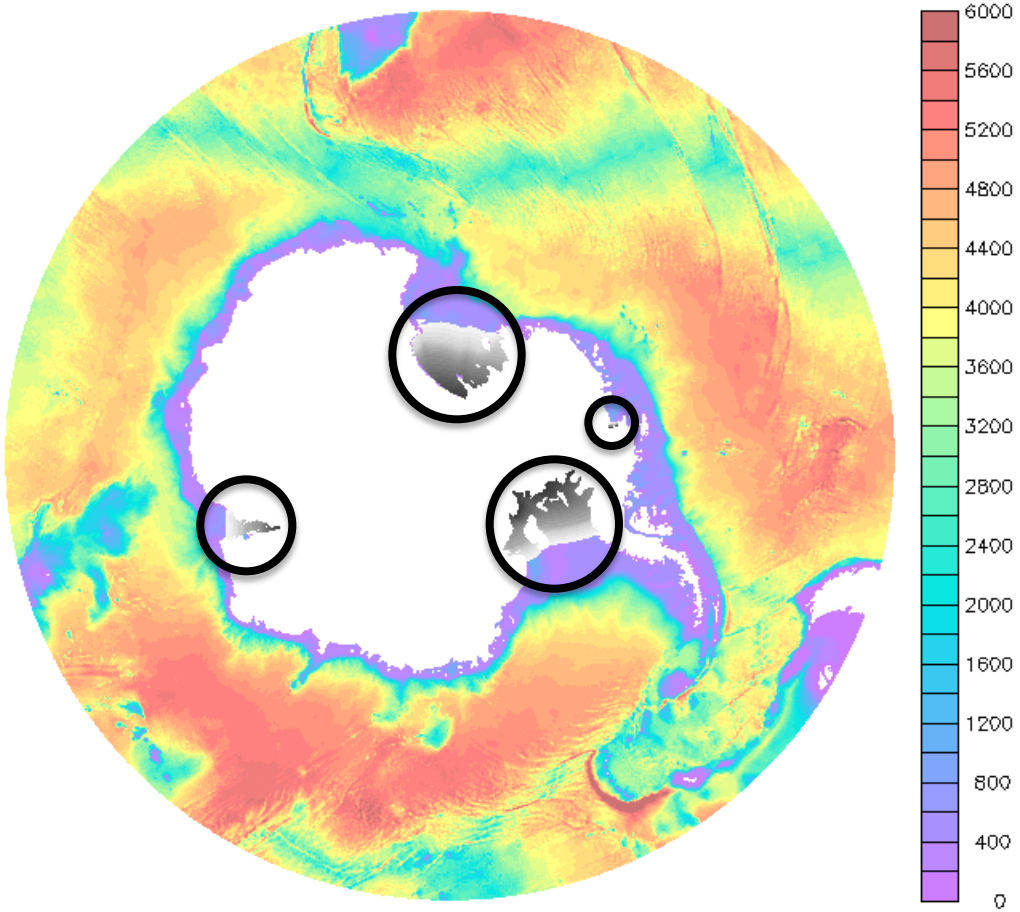
0.1° Southern Ocean

- Extended further south, bedrock defines coast



0.1° Southern Ocean

- 4 idealized ice shelves



0.1° Southern Ocean

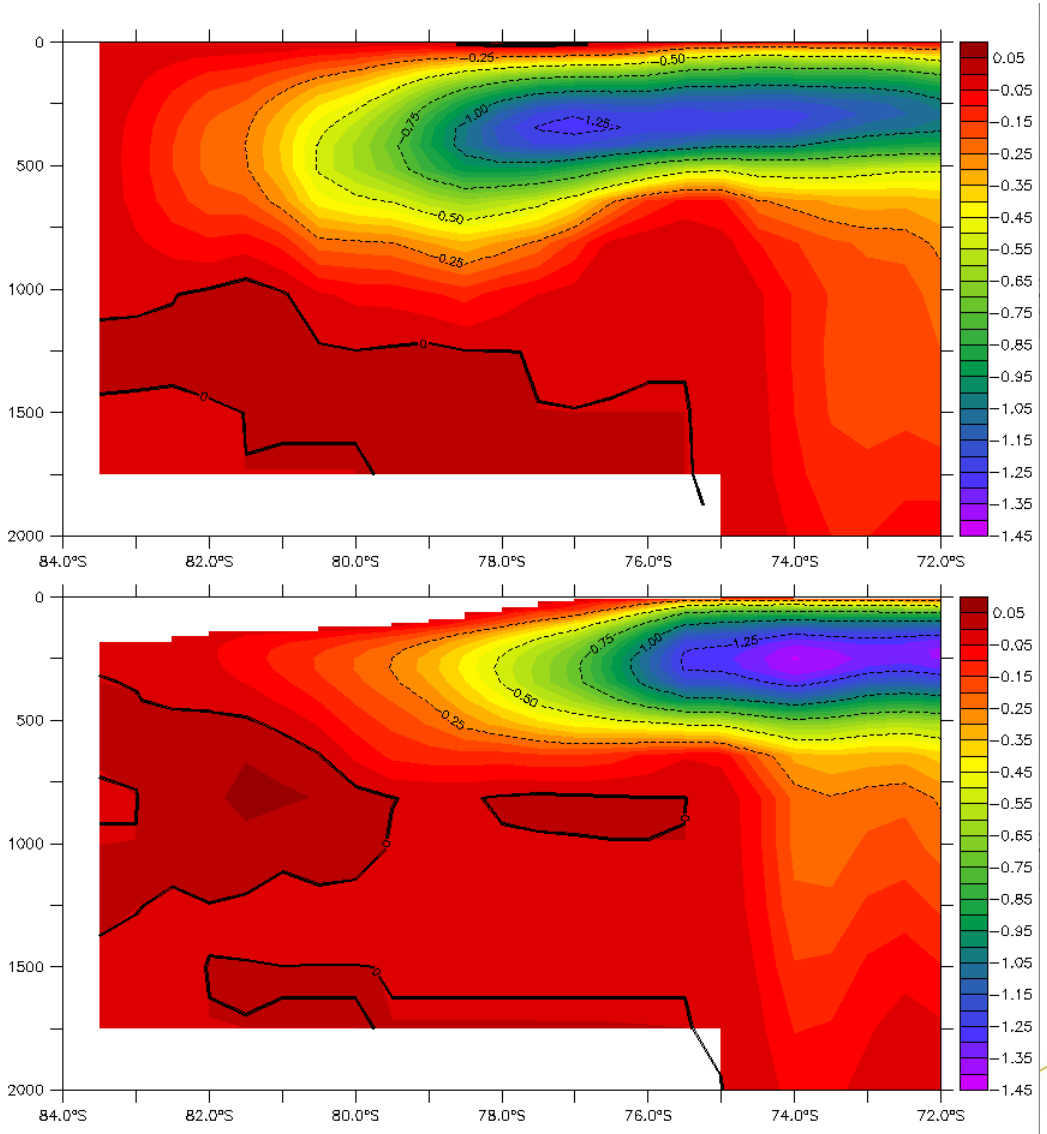
- Restoring of T,S at northern boundary
- Monthly normal year forcing
- 2 cases
  - No ice shelves
    - restoring of SST, SSS
  - 4 idealized ice shelves
    - T,S fluxes calculated at ice-ocean interface

Weddell Sea Overturning

years 20 -24 average

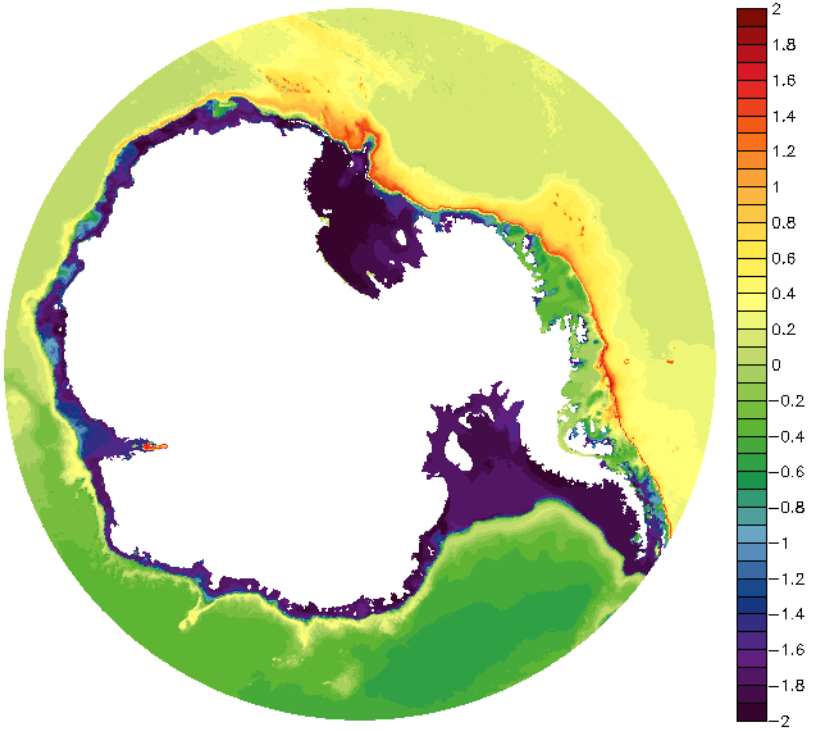
No Ice Shelves

Idealized Ice Shelves

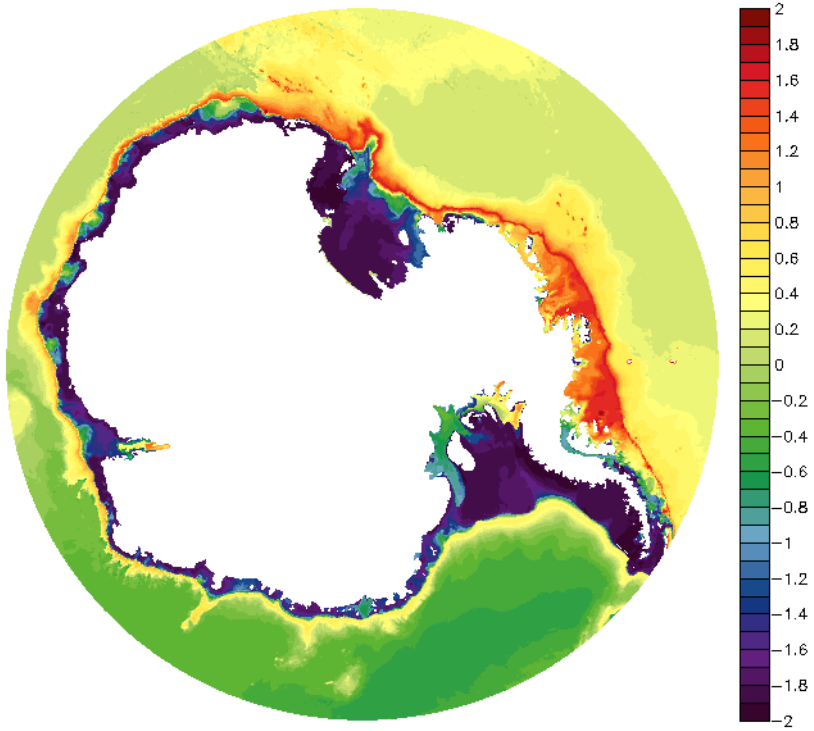


Bottom Temperature (°C)

years 20 -24 average



No Ice Shelves



Idealized Ice Shelves

Next Steps (z*)

- Pressure gradient
- What thickness to use for vertical derivatives in diffusion/Richardson Number/GM slopes
- Realistic global runs
- Performance/memory
- Restart
- Merge with Robert filter

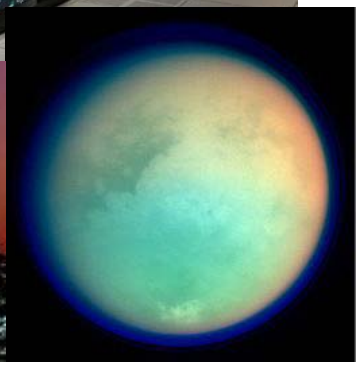
Next Steps (Ice Shelves)

- More validation
- Realistic shelf geometry
- Higher vertical resolution
- KPP modifications
- Improved ice-ocean transfer
- Global domain (including Greenland)

POP for GPUs/Titan, Moonlight

Phil Jones

- GPU needs
  - Expose parallelism at lower levels
  - Provide enough work for vectors
  - Data transfer expensive
- Refactoring
  - Focus on momentum
  - Push k-loops down
  - OpenACC not up to task
  - CUDA Fortran (esp. data txfr)
- Results
- Next up (before INCITE)
  - Tracers
  - Index/loop reordering
  - Tavg
  - abstractions
  - Titan



Routine	2 cores, no GPU	2 cores, GPU	16 cores, no GPU
vmix_exp_mom	1.99	0.00	0.32
hmix_mom_del2	2.73	0.01	0.44
advect_momentum	4.73	0.02	0.70
device_copy	0.00	4.68	0.00