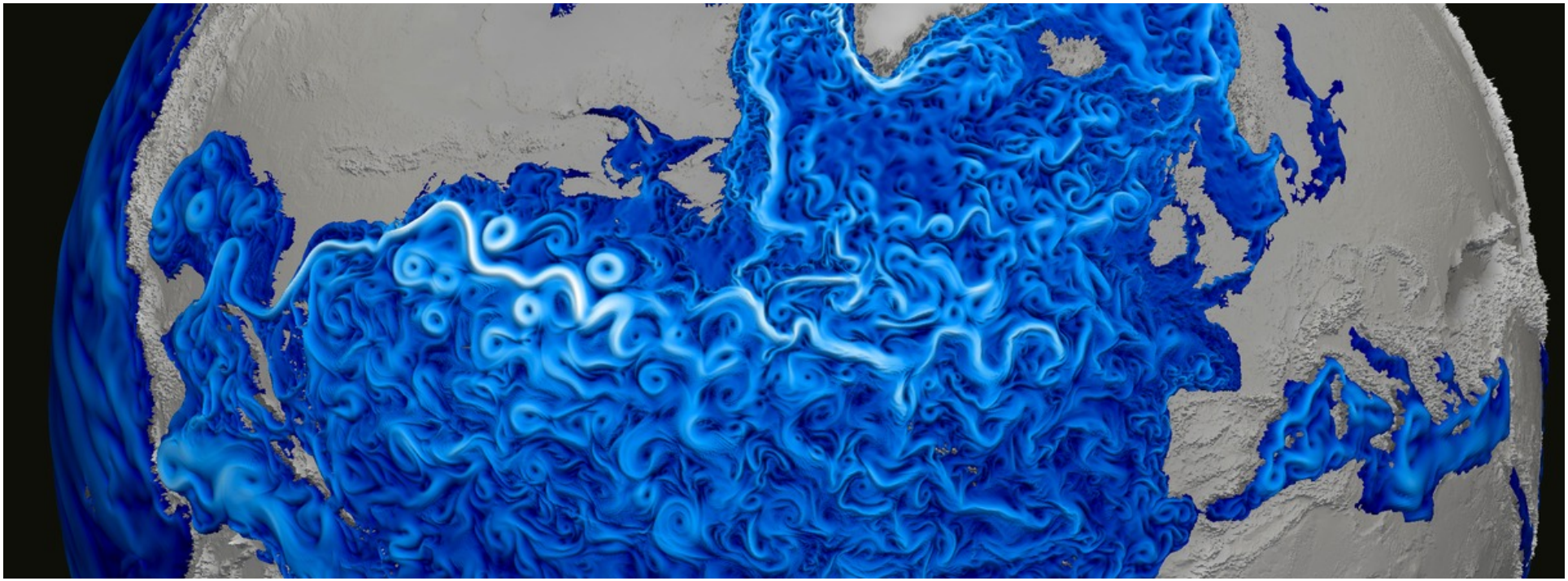
MPAS-Ocean Update

MPAS-Ocean Team

Mark Petersen, Todd Ringler, Douglas Jacobsen, Mathew Maltrud, Phil Jones, Xylar Asay-Davis, Phillip Wolfram, Juan Saenz, David Lee

Los Alamos National Laboratory



MPAS-Ocean: Progress in 2014-2015

- MPAS release 4.0
  - Gent-McWilliams Parameterization
  - KPP vertical mixing within CVMix
  - Multiple I/O streams: run-time specification of write frequency and variables
- In-Situ Analysis and Initial Conditions
- Spin-up of new standard meshes
  - Low-resolution (EC 60-30 km)
  - High-resolution (RRS 15-5 km)
  - Idealized Southern Ocean Configuration
- Residual-Mean prognostic framework
- In-Situ Lagrangian Particles
- CDG high-order advection scheme
- Land-ice/ocean coupling

In-Situ Analysis

Problem: Our ability to produce data is outstripping our ability to manipulate and analyze this data.

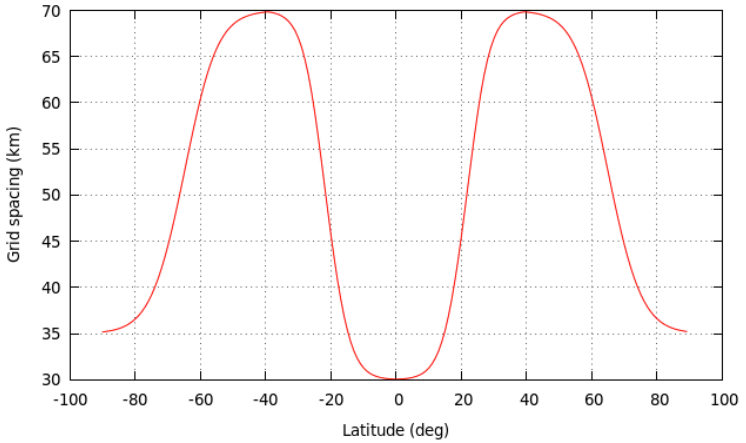
Solution: Analysis tools fully integrated into the model

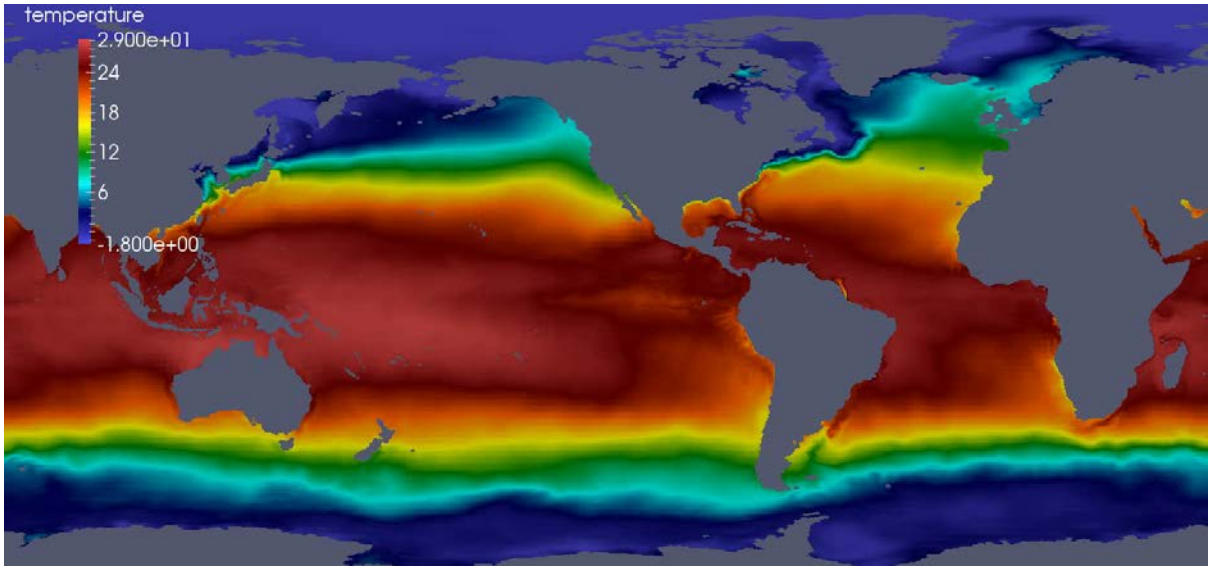
- Analysis members:
  - Global, zonal, and regional statistics
  - Volumetric T/S census
  - Meridional heat transport
  - Eddy diagnostics and census (Woodring et al. 2015)
  - Lagrangian particles (Wolfram et al. JPO 2015)
  - Eliassen-Palm Flux Tensor
- Available in forward mode (in-situ) and analysis mode (post-processing)
- Each analysis member is a separate module, begun from a template.
- Easy for MPAS users to contribute analysis tools back to released code
- New multiple I/O streams: run-time specification of write frequency and variables.
- Publication in press: Woodring, J., M. Petersen, A. Schmeisser, J. Patchett, J. Ahrens, *In Situ Eddy Analysis in a High-Resolution Ocean Climate Model*, SciVis 2015

Low Resolution Mesh: EC 60-30 km

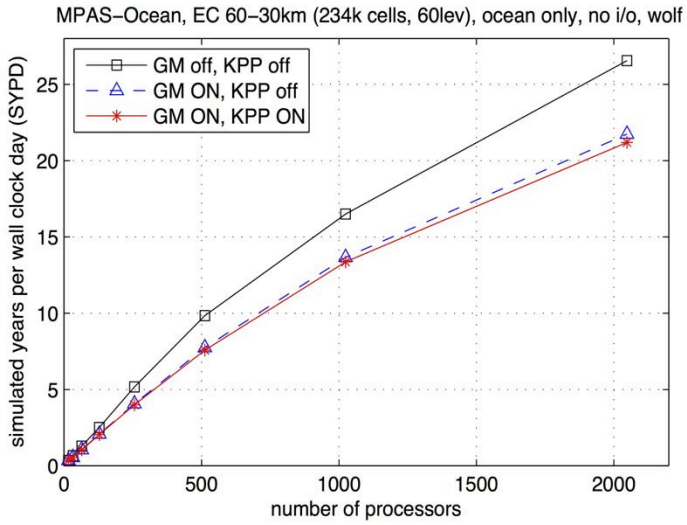
- EC: requires Eddy Closure, i.e. GM is on.
- 234k horizontal cells: compare to POP 1 degree (86k cells)
- 100 vertical levels, z-star coordinate
- CORE-II six-hourly forcing underway

Grid cell size



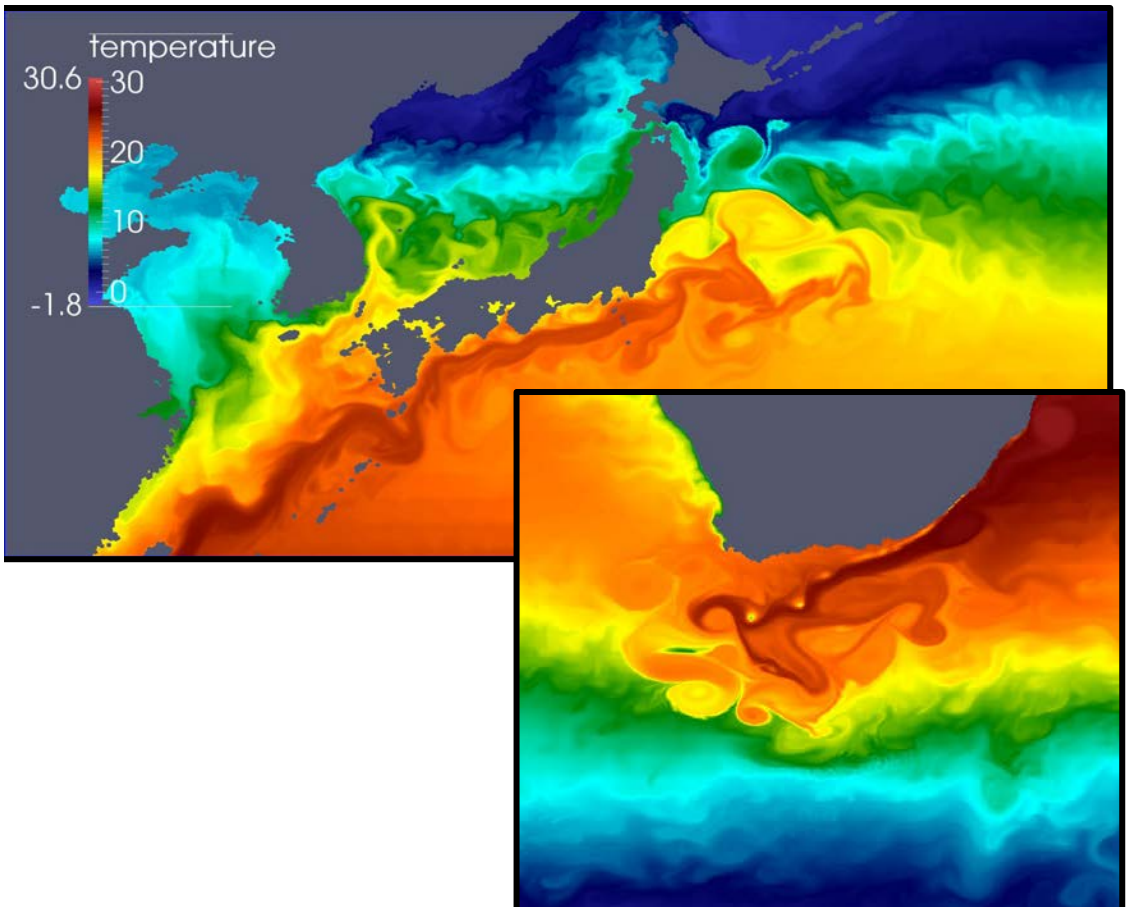


Performance



High Resolution Mesh: RRS 15-5 km

- RRS: Rossby Radius Scaling
- 5.8M horizontal cells, 100 levels.
  Compare to POP 0.1 degree (5.4M cells)
- Ocean-only spin-up underway



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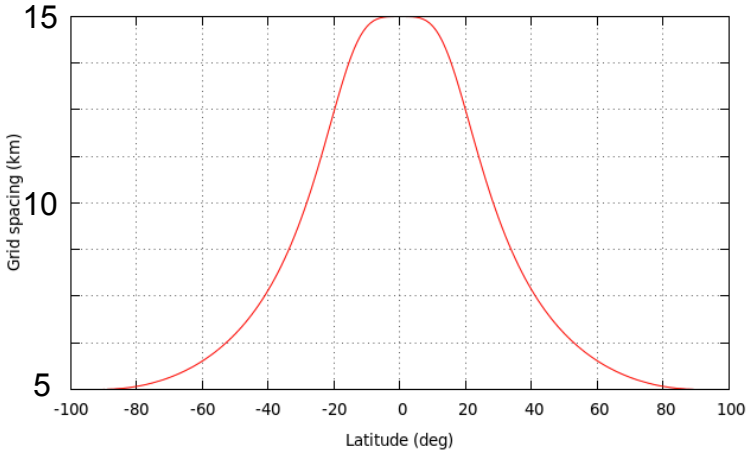

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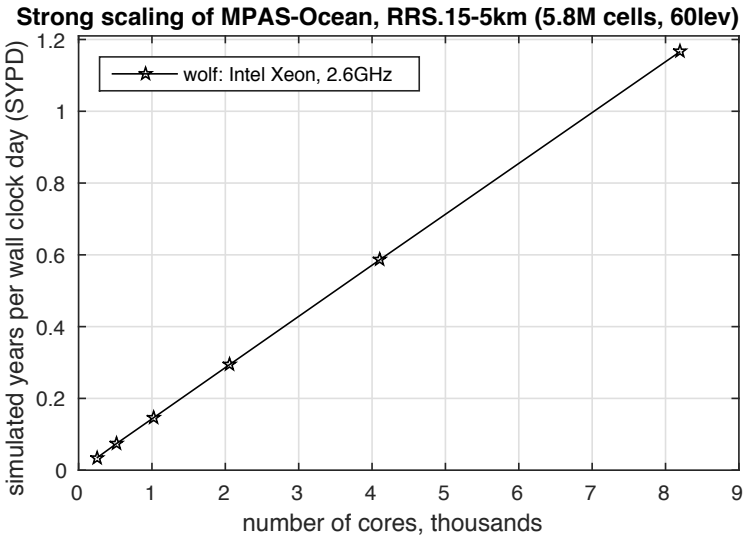
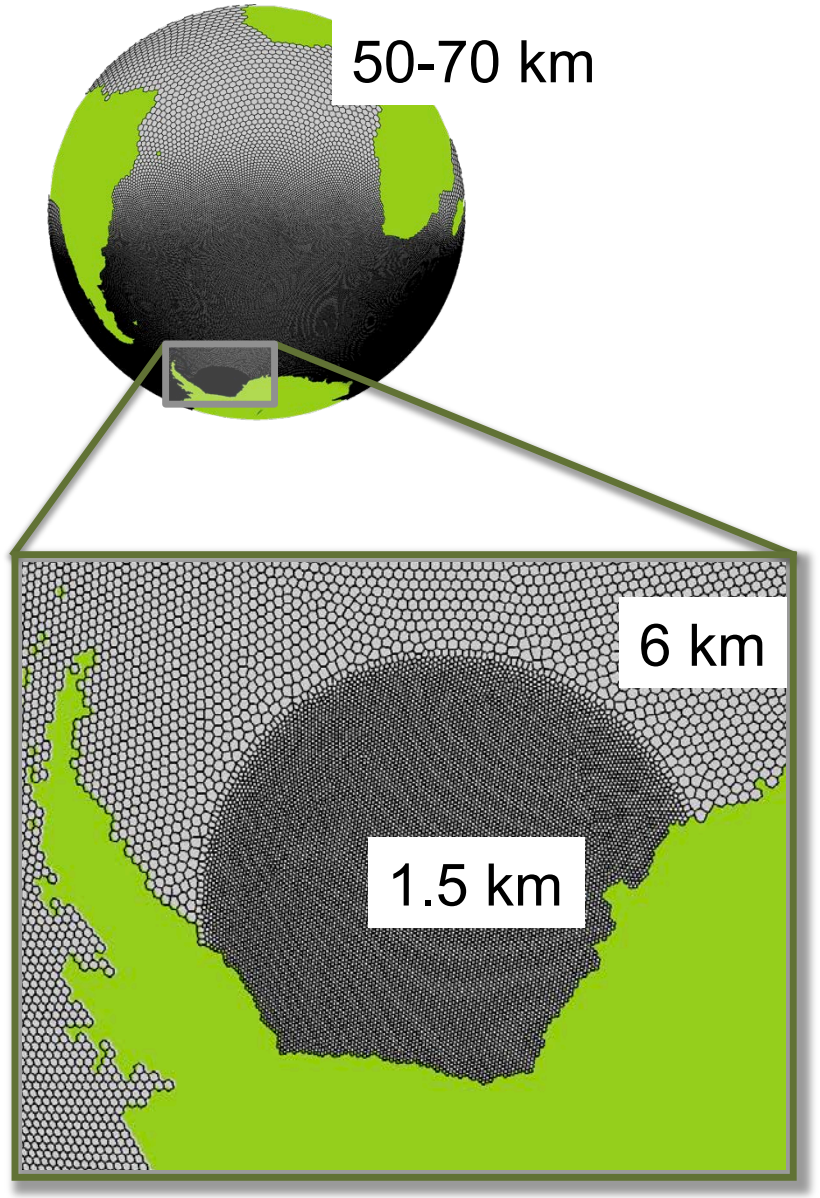


Southern Ocean-Enhanced Mesh

- Captures eddy dynamics of Southern ocean without eddy closure scheme.
- May include refined embayments for sub-ice shelf dynamics
- Collaboration with NCAR (B. Large, SCIDAC) to analyze and remedy biases in Southern Ocean uptake.
- In planning stages



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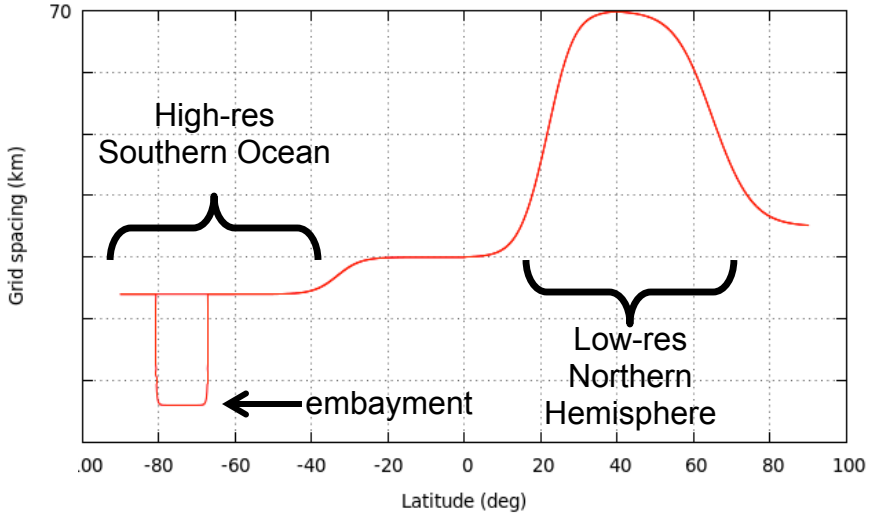
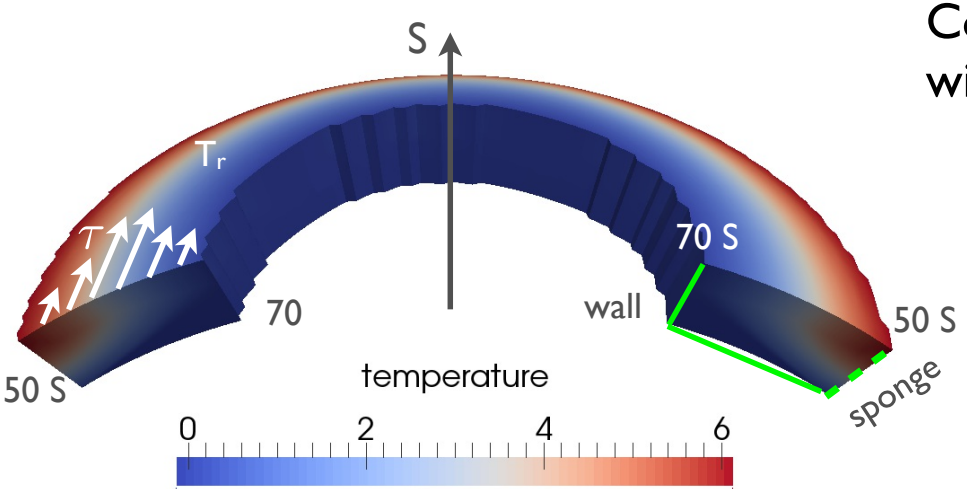


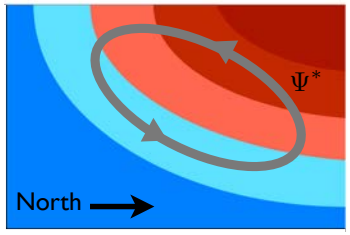
Parameterizing eddies in a residual-mean prognostic framework

Saenz, J.A., Q. Chen, T.D. Ringler, In Press: Prognostic residual-mean flow in an ocean general circulation model and its relation to prognostic Eulerian-mean flow. J. Phys. Oceanogr.



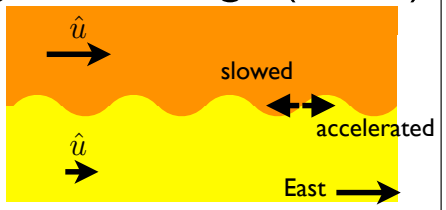
Conventional eddy param. with bolus velocity:

$$\mathbf{u}_* = -\frac{\partial}{\partial z}\left(A\,\mathbf{S}\right)$$



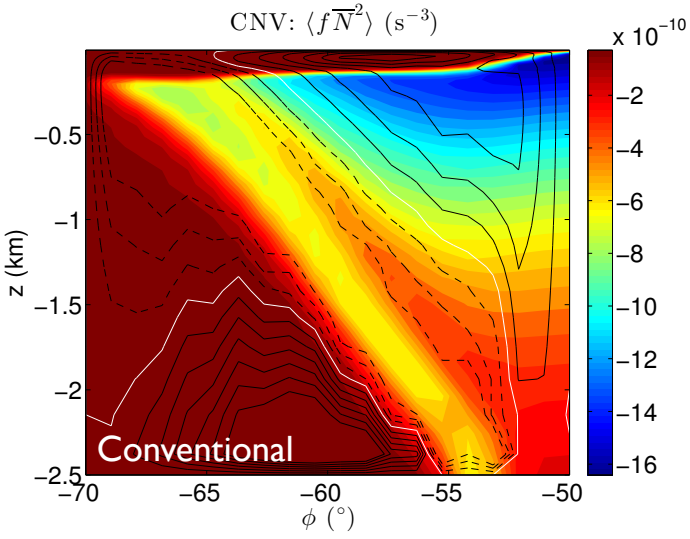
Param. in residual-mean framework, using thickness-weighted average (TWA), as a force:

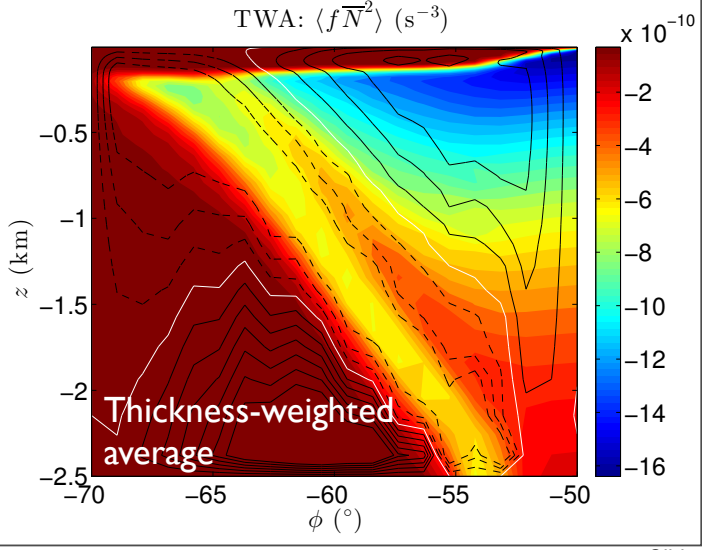
$$f\frac{\overline{\sigma' v'}}{\overline{\sigma}} = f v_*$$



Planetary PV

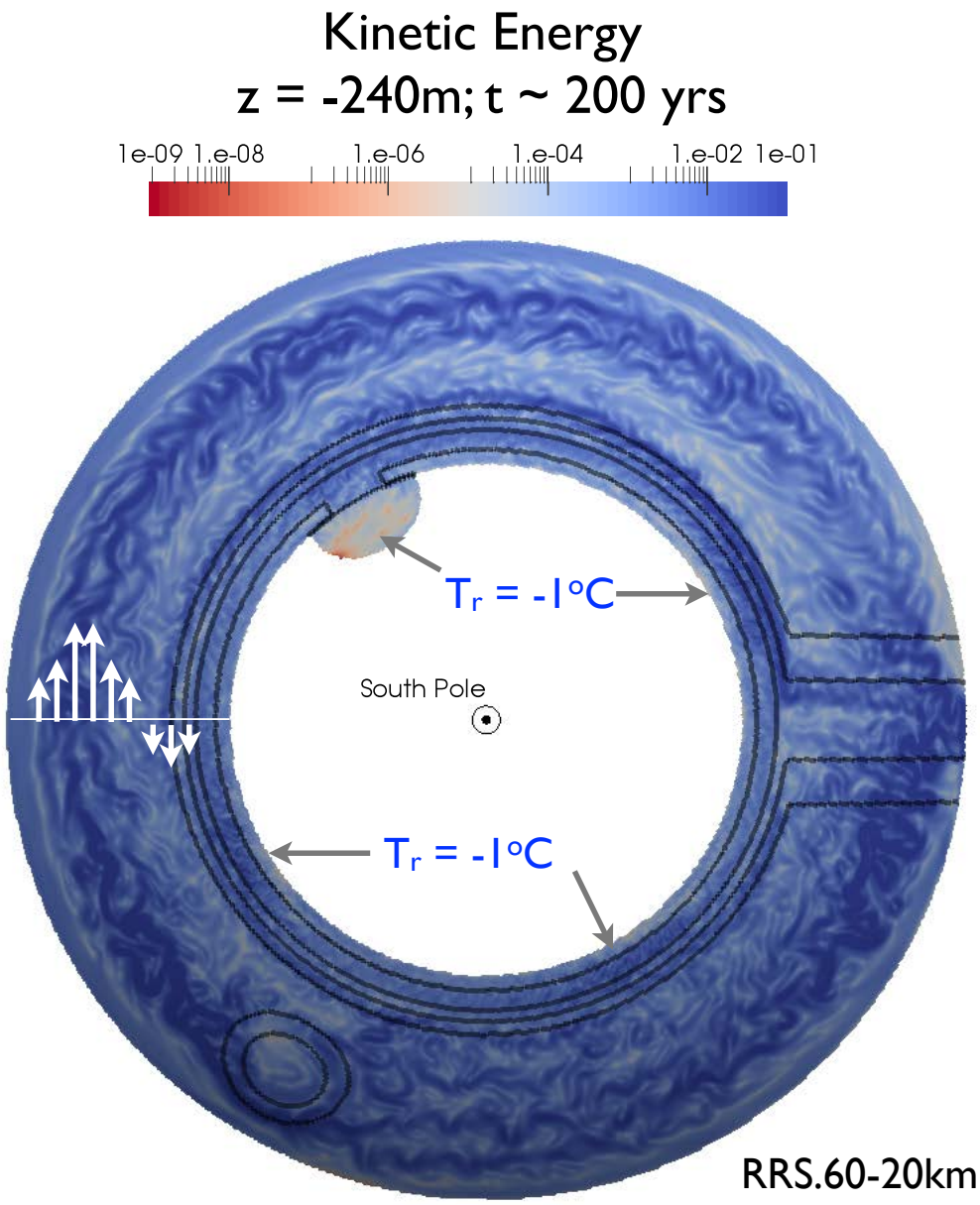
$$f\ \overline{N}^2$$





An Idealized configuration of the Southern Ocean

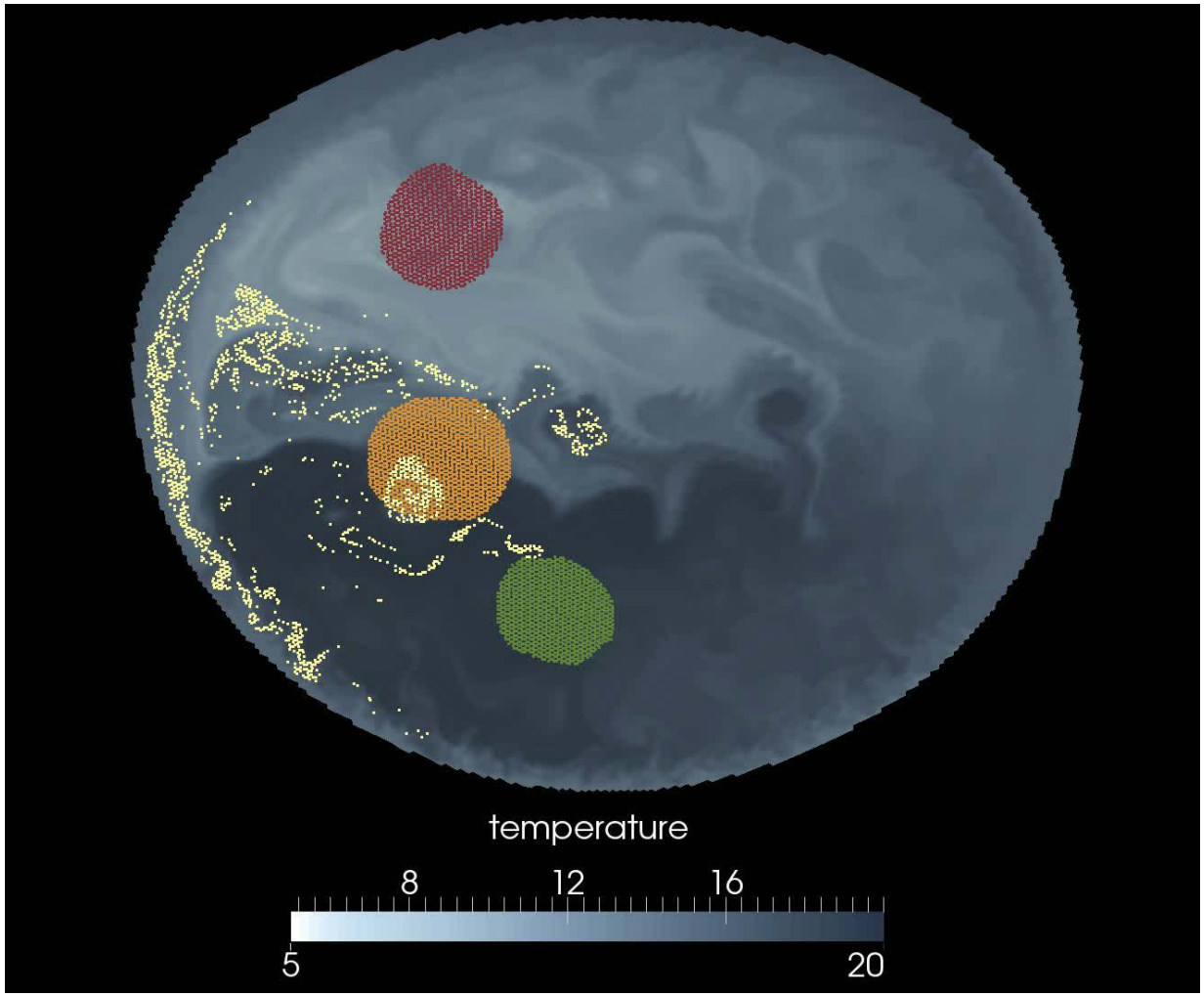
- To investigate eddy-mean flow interaction with E-P flux tensor
- Lateral restoring leads to a $N^2(z)$ that produces a 1st Rossby radius of deformation of 12 km.
- Lateral restoring independent of longitude.
- Embayments/shelf for the creation and study of "AABW" creation and fate. Temperature restored to -1°C.
- Imposed wind stresses and heat fluxes over main channel.
- Provides stepping stone to simulations including static ice shelves and utilizing ~1 km resolution in embayments.



LIGHT: A tool for understanding mesoscale mixing

Lagrangian In-situ, Global, High-performance particle Tracking

- In-situ particle tracking with native spatial and temporal resolution
- High-performance (same number of particles as cells)



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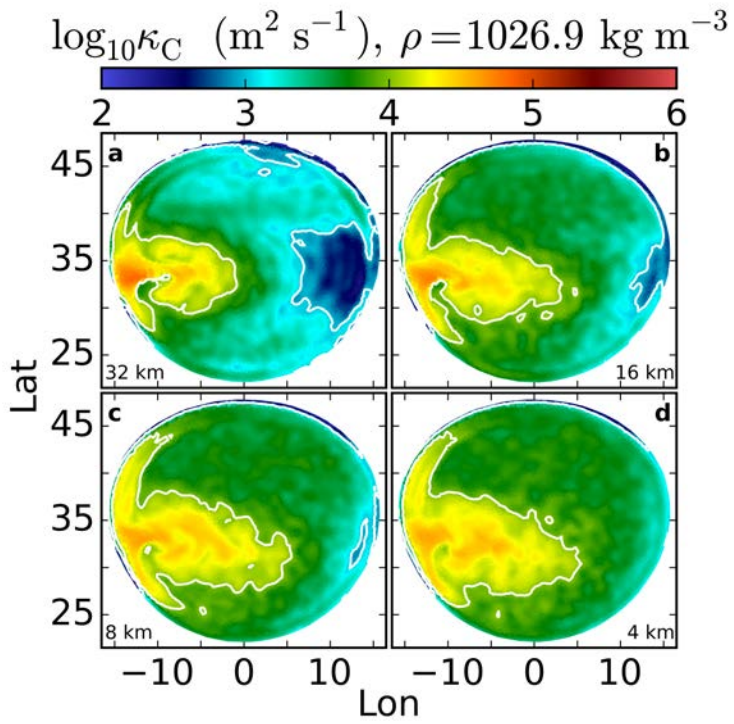


Diffusivities estimated with LIGHT cluster of particles at four simulation resolutions, from eddy permitting to eddy resolving.

- Scientific application: Diffusivity calculation
  - Cluster statistics in double-gyre basin
  - Potential density constrained (isopycnal)

See poster OMWG-8 by Phillip Wolfram

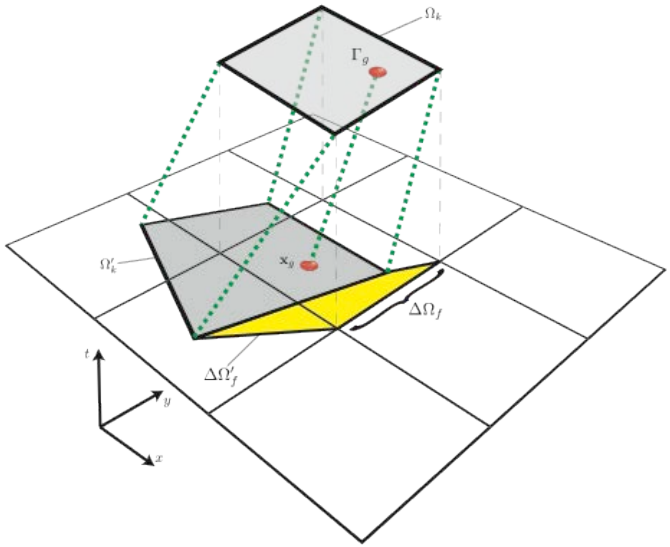
see Wolfram et al. JPO, in press

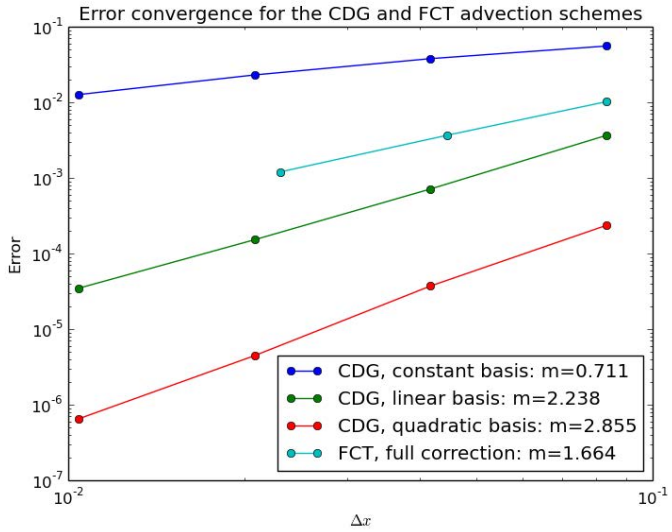
High Order Tracer Advection

Characteristic Discontinuous Galerkin (CDG)

- New advection scheme for improved scaling with an increasing number of tracers and relaxed CFL
- Tracer field represented by a high order series of trial functions in each cell, *k*,

$$hq(\vec{x}, t) = \sum_j c^n_{k,j} \phi_j(\vec{x}, t)$$





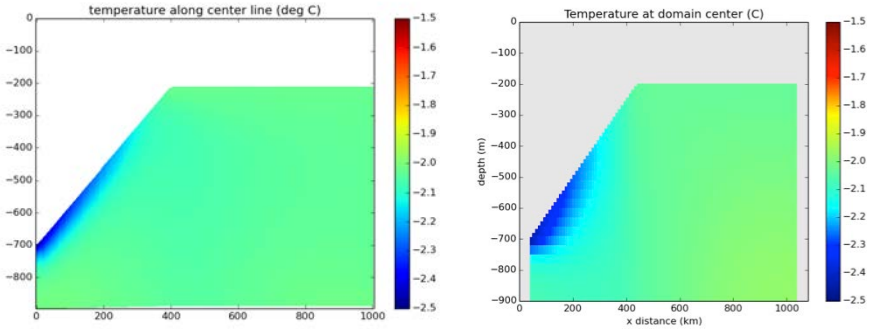
Each face is traced back in time along characteristics and the polygon made by this face and its "pre-image" is integrated to determine the flux through the face.

See poster OMWG-3 by David Lee

Ocean / Land Ice Coupling

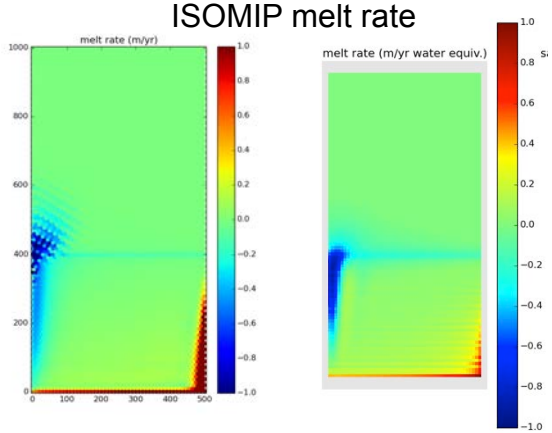
- Validating ice-shelf cavities in MPAS-O with ISOMIP (Ice Shelf-Ocean Model Intercomparison Project)
  - 20 vertical layers, nonlinear EOS, after 20 years

ISOMIP temperature (vertical slice)



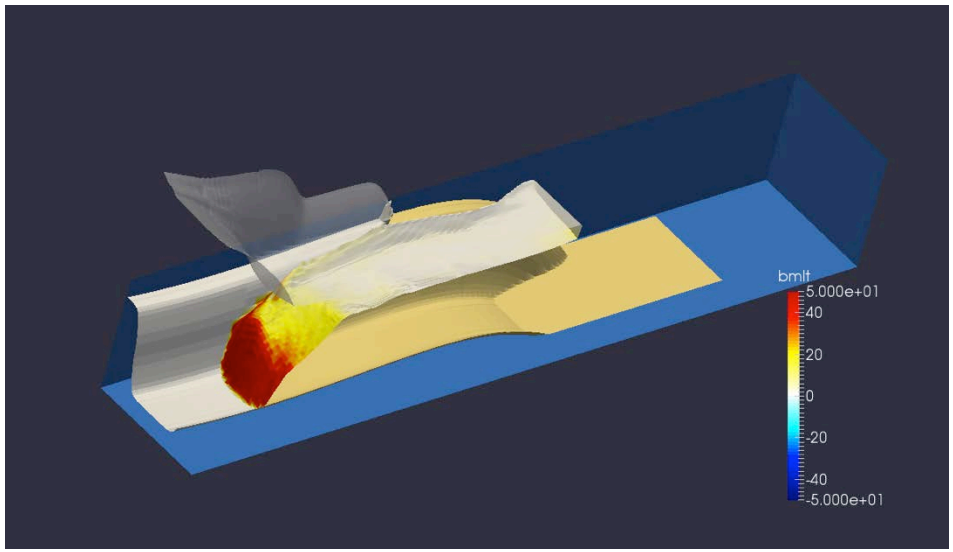
MPAS-O POP

ISOMIP melt rate



MPAS-O POP

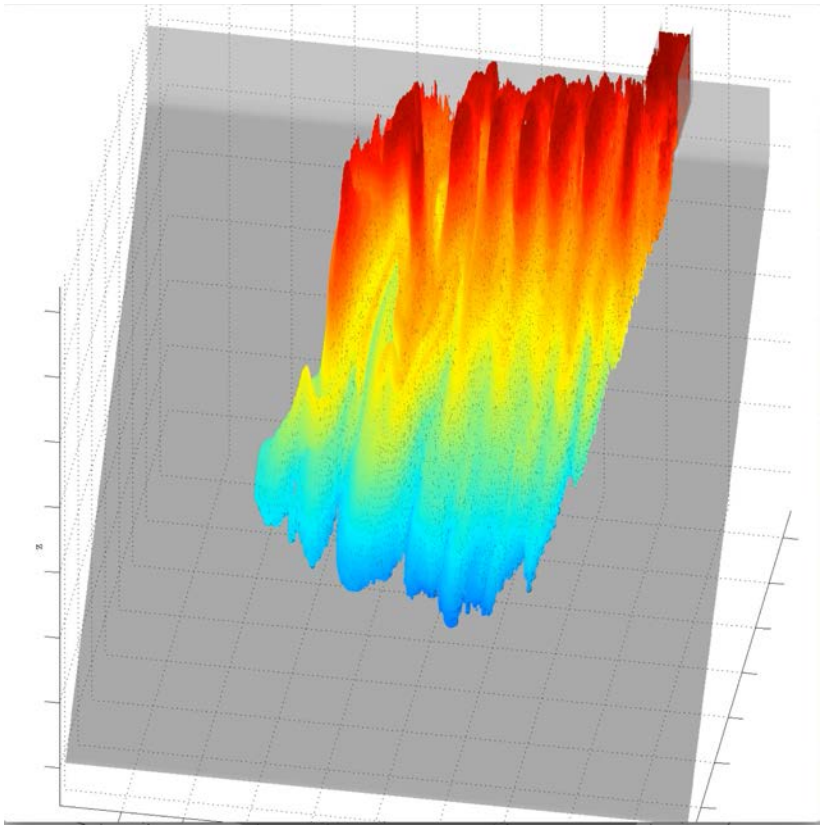
- New idealized test cases (MIPs) designed for a community effort:
  - **MISMIP+**: land ice only
  - **ISOMIP+**: ocean only with shelf cavities
  - **MISOMIP1**: coupled land ice-ocean
- Work led by Xylar Asay-Davis

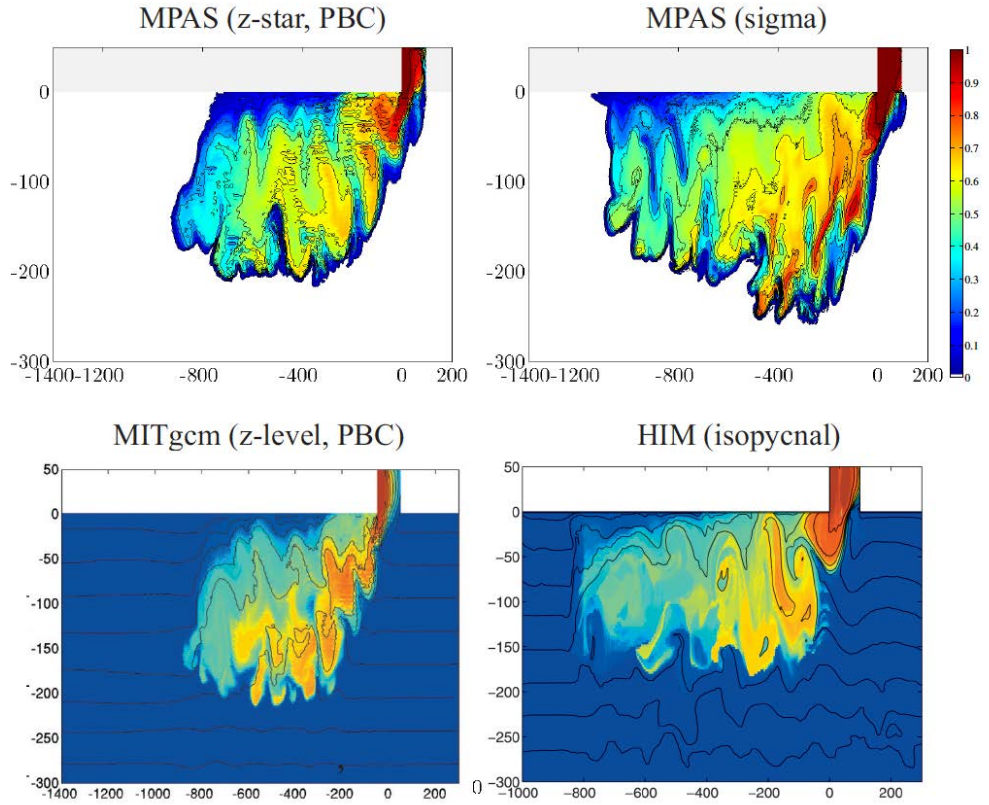


Example result from **MISOMIP** using POP-BISICLES

Overflow and Entrainment

- DOME idealized overflow configuration: Legg et al (2006, 2009)
- Study of vertical coordinate, resolution, and vertical viscosity
- Vertical grids ranging in thickness from 15 m to 120 m were tested.
- Vertical resolution of 60 m are sufficient in this configuration



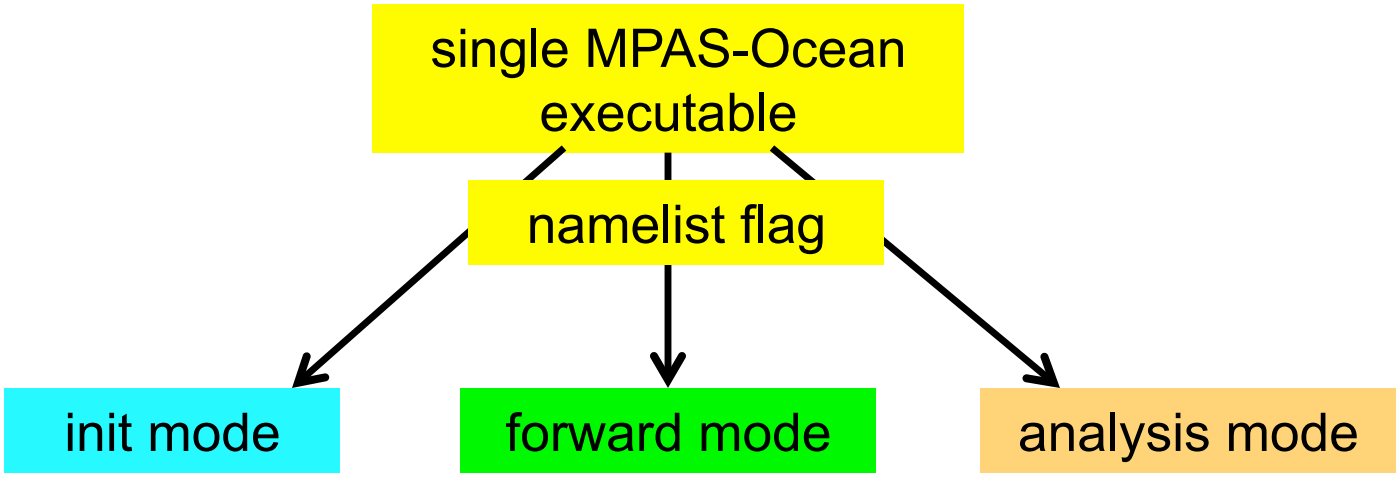


Publication: Reckinger, S.M., M.R. Petersen, S.J. Reckinger, *A study of overflow simulations using MPAS-Ocean: vertical grids, resolution, and viscosity*, Ocean Modeling, in review

MPAS-Ocean: Tasks for coming year

- Working towards ACME V1.0 freeze Nov 1
- Coupling and testing within ACME
- CORE-forced and fully coupled simulations on:
  - Low-resolution mesh (EC 60-30 km)
  - High-resolution mesh (RRS 15-5 km)
  - Southern Ocean enhanced mesh
- Evaluation with active MPAS-CICE
- Biogeochemistry column library within MPAS
- Land-ice/ocean coupling and physics: idealized to realistic
- Initial condition generation
- Additional in-situ analysis

Multiple run modes



- **init mode:** Creation of initial conditions, both idealized and realistic
- **analysis mode:** post-processing analysis, applied to restart files.
- All modes have access to MPAS infrastructure (mesh, i/o, operators)
- All modes fully parallelized and scale like the forward model.
- All code in same repository
- Brings init and analysis under design and peer-review standards

MPAS-Ocean: Publications in 2014-2015

- Petersen, M.R., D. Jacobsen, T.D. Ringler, M.E. Maltrud, M. Hecht, 2015. *Evaluation of the Arbitrary Langrangian-Eulerian vertical coordinate in the MPAS-Ocean Model*. Ocean Modelling 86, 93-113
- Saenz, J.A., Q. Chen, T.D. Ringler, *Prognostic residual-mean flow in an ocean general circulation model and its relation to prognostic Eulerian-mean flow,* J. Phys. Oceanography, in Press
- Wolfram, P.J., T.D. Ringler, M.E. Maltrud, D.W. Jacobsen, M.R. Petersen, *Diagnosing isopycnal diffusivity in an eddying, idealized mid-latitude ocean basin via Lagrangian In-situ, Global, High-performance particle Tracking (LIGHT),* J. Phys. Oceanography, in Press
- Woodring, J., M. Petersen, A. Schmeisser, J. Patchett, J. Ahrens, *In Situ Eddy Analysis in a High-Resolution Ocean Climate Model*, SciVis 2015, in press
- Reckinger, S.M., M.R. Petersen, S.J. Reckinger, *A study of overflow simulations using MPAS-Ocean: vertical grids, resolution, and viscosity*, Ocean Modeling, in review