



GO2 development status

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Workshop on Improving ALE Ocean Modeling

NCWCP

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Circumstantial connection of this talk to ALE

Is the GO2 environment compatible with our ALE building blocks presented this a.m.?

- high-order non-oscillatory subgrid reconstruction for advection
- quadrature-based PGF

GO2 has been run for short periods without these, but they are still being incorporated into the 3D framework

GO1->GO2

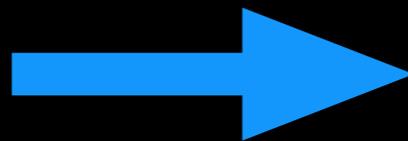
- GO1 known as GISS-ER in CMIPese
- Lat-lon-pressure grid limits future applications
- Starting principle is to merge the best features of GISS-ER (natural BCs, EoS) and GISS-HYCOM (generalized layering)
- Simultaneous migration to cubed-sphere grid

GO2 vertical grid and ALE

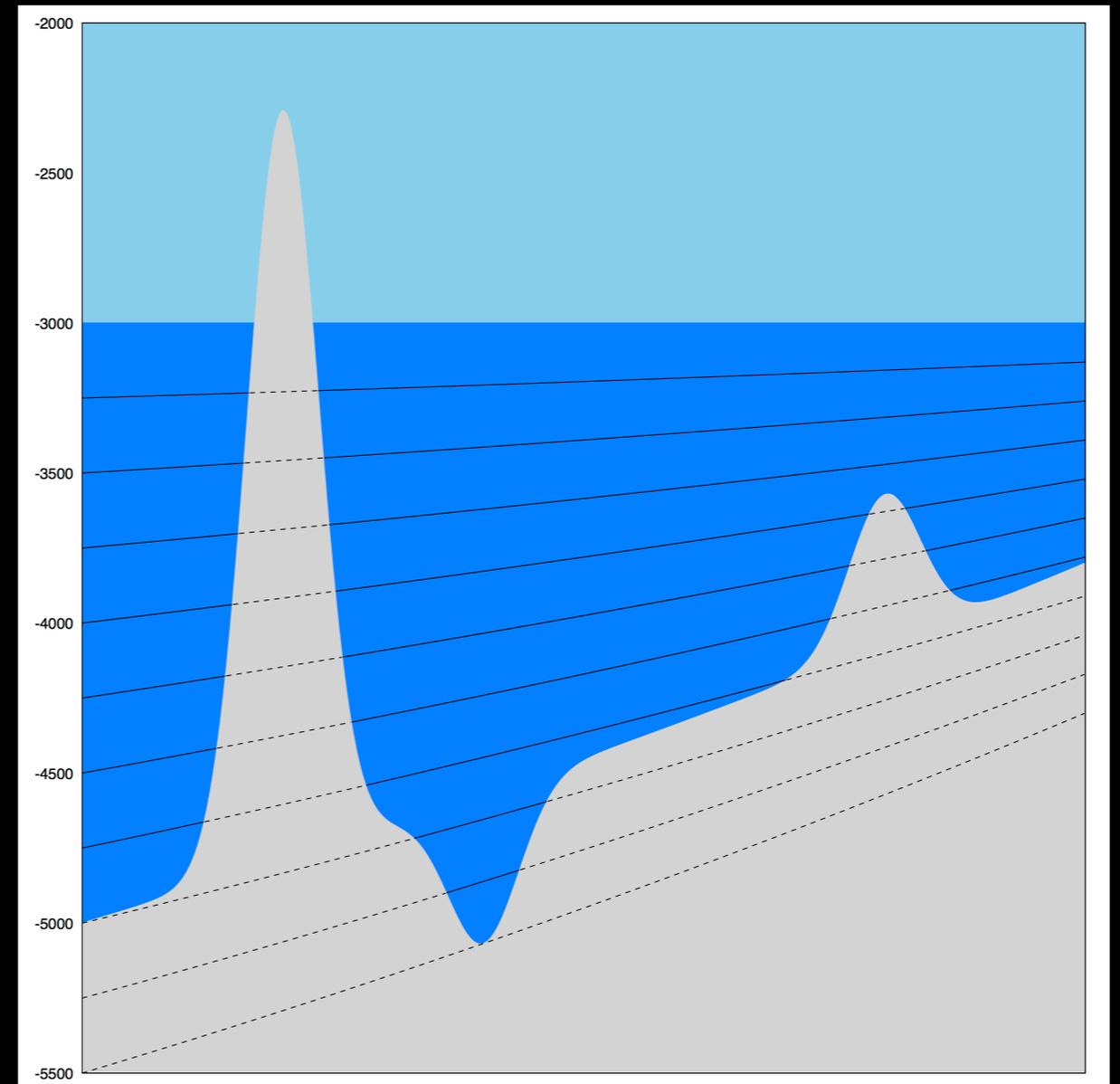
- Initial flavor of ALE will be “weak”: relaxation to a fixed quasi-geometric target layering
- Introduction of quasi-isopycnal layering and strong ALE to follow

GO2 vertical grid and ALE

Initial target layering will be constant-p, but with the regional option for



“steppy-sigma” terrain-following layering near the seafloor following smoothed bathymetry. At typical horizontal resolution, steps dominate so the benefit of this option will likely be confined to overflow regions.



GO2 horizontal grid

Took Route 2 at a 3-way fork in the road:

1. Tripole and/or displaced-pole
2. Cubed Sphere
3. Unstructured

Route 1 less flexible for continental placement and other needs

High-order schemes and other ideas easier to implement on structured meshes than on Route 3. Team size req's.

GO2 cubed-sphere grid

On Rte 2, went off-road at a 2-way fork: neither the

1. Conformal cube a la MITgcm

2. Gnomonic cube like many atmospheric codes

Instead, tried to merge the best features of these 2

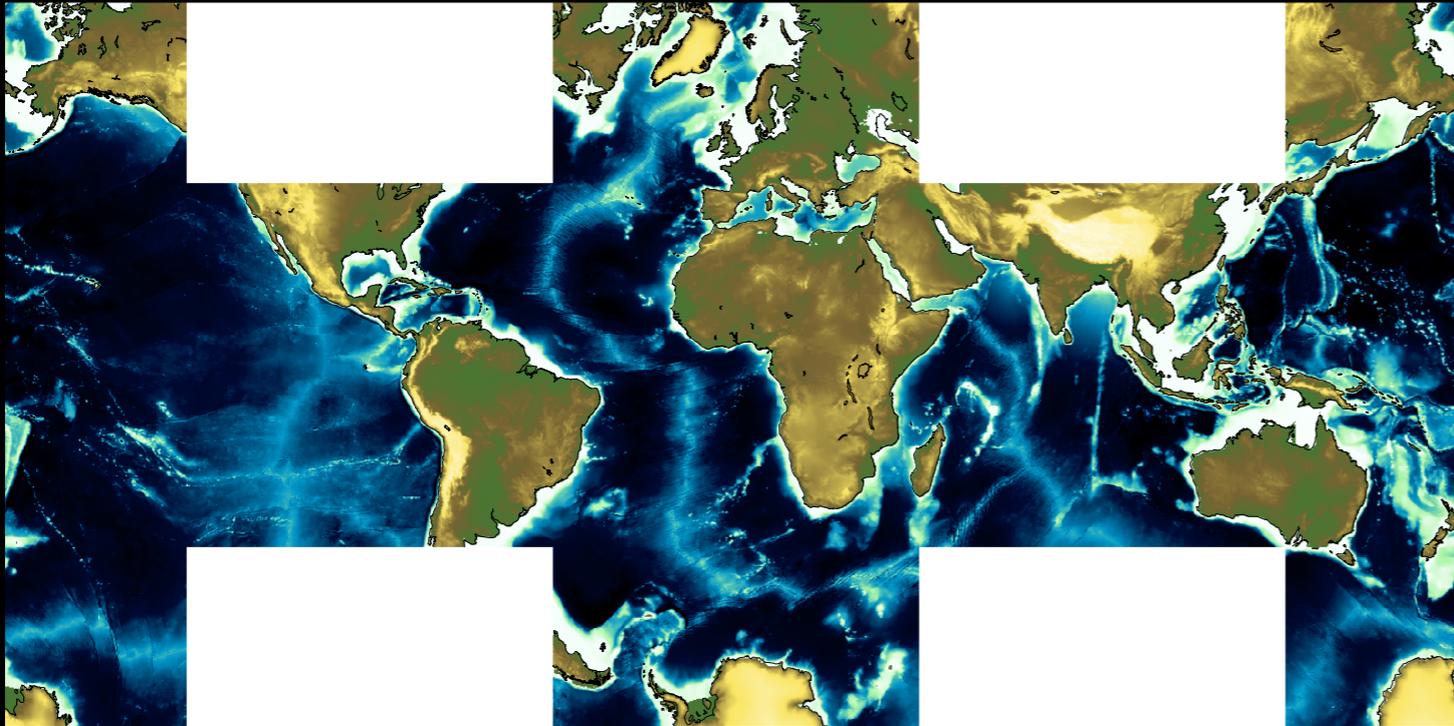
Why yet another CS?

Rancic conformal cube not quasi-uniform which is problematic at high resolution

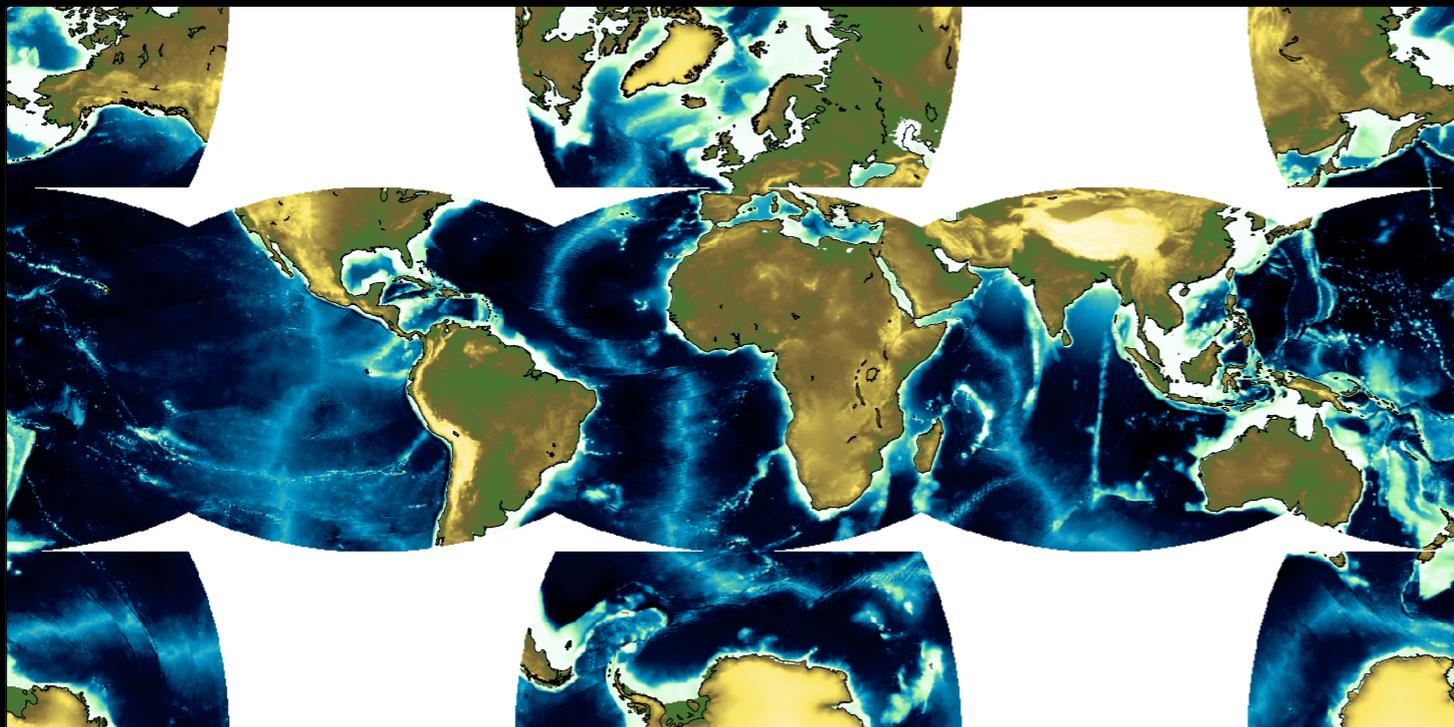
Gnomonic cube is quasi-uniform but not orthogonal. Orthogonality a primary reason for choosing an x-y grid; depatures complicate all operators esp. where masking reduces possible stencil sizes.

New “cube” attempts to combine quasi-uniformity and orthogonality, at the cost of some concentrated complexity...

The world in gridpoint space

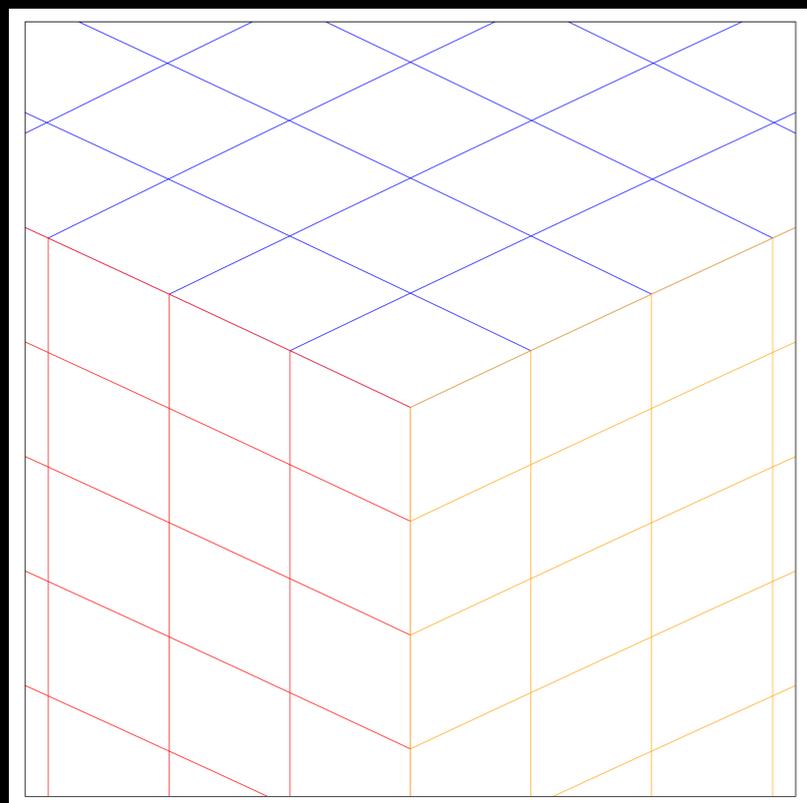
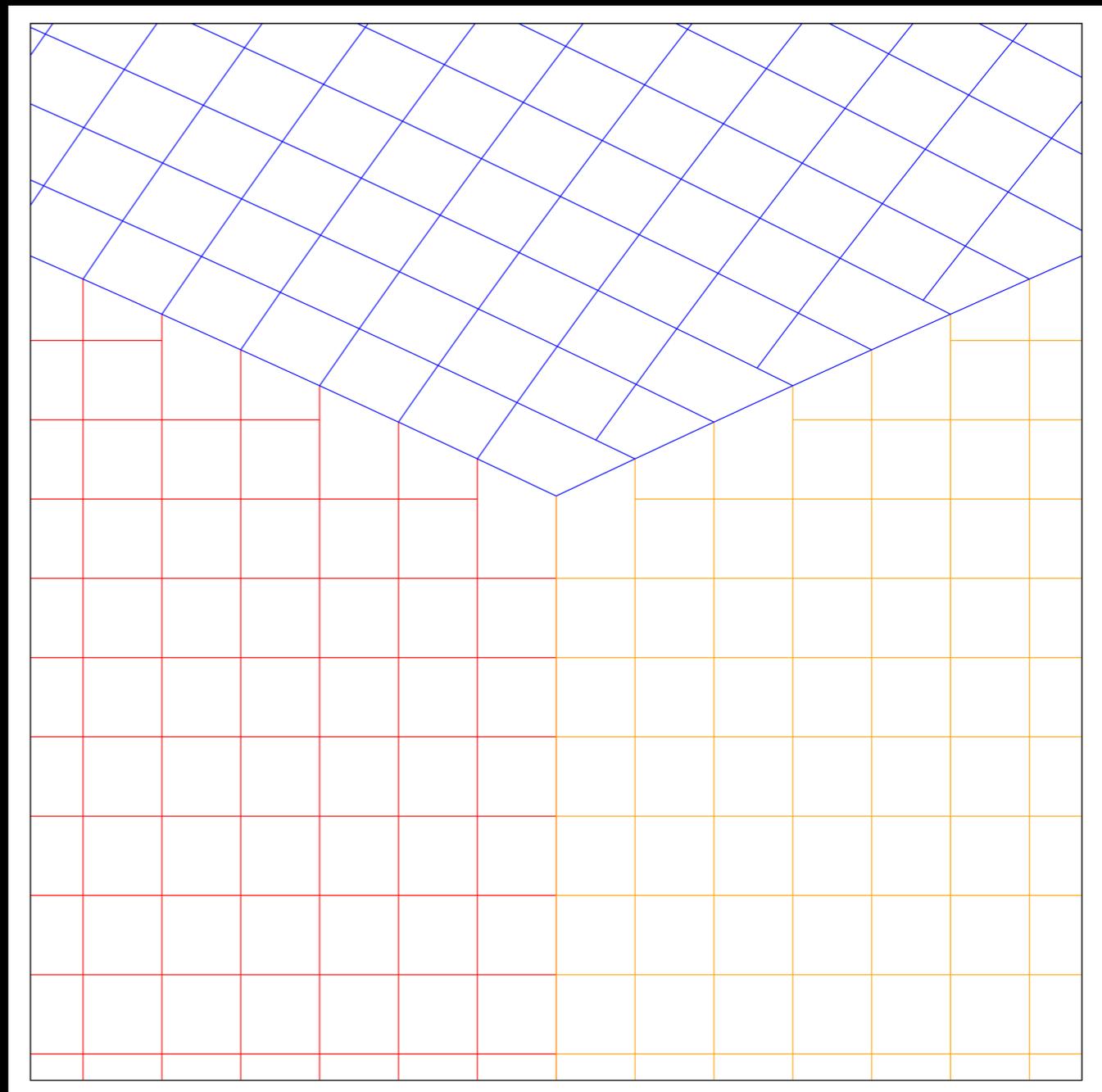


Cubed sphere
(gnomonic)



“Sphered cube”
(conformal)

Sphered cube: semi-structured zone at edges.



Gnomonic CS: discontinuities of gridlines, but not of cell shape

The forest and the trees

Outside a small zone which shrinks with resolution, business as usual for any structured-grid scheme

As features are better resolved with finer grids, techniques for handling the edges should become more accurate

Related to Yin-Yang strategy but edge-cell matching eases implementation. More variations possible than with Y-Y

Mild anisotropies exist but are likely benign

Is the concentrated-complexity strategy workable for target resolutions?

The tedium before any glory

Types of almost- but not-fully-oceanographic tests

- SW wave propagation
- High-order advection
- Sloping-layers PGF

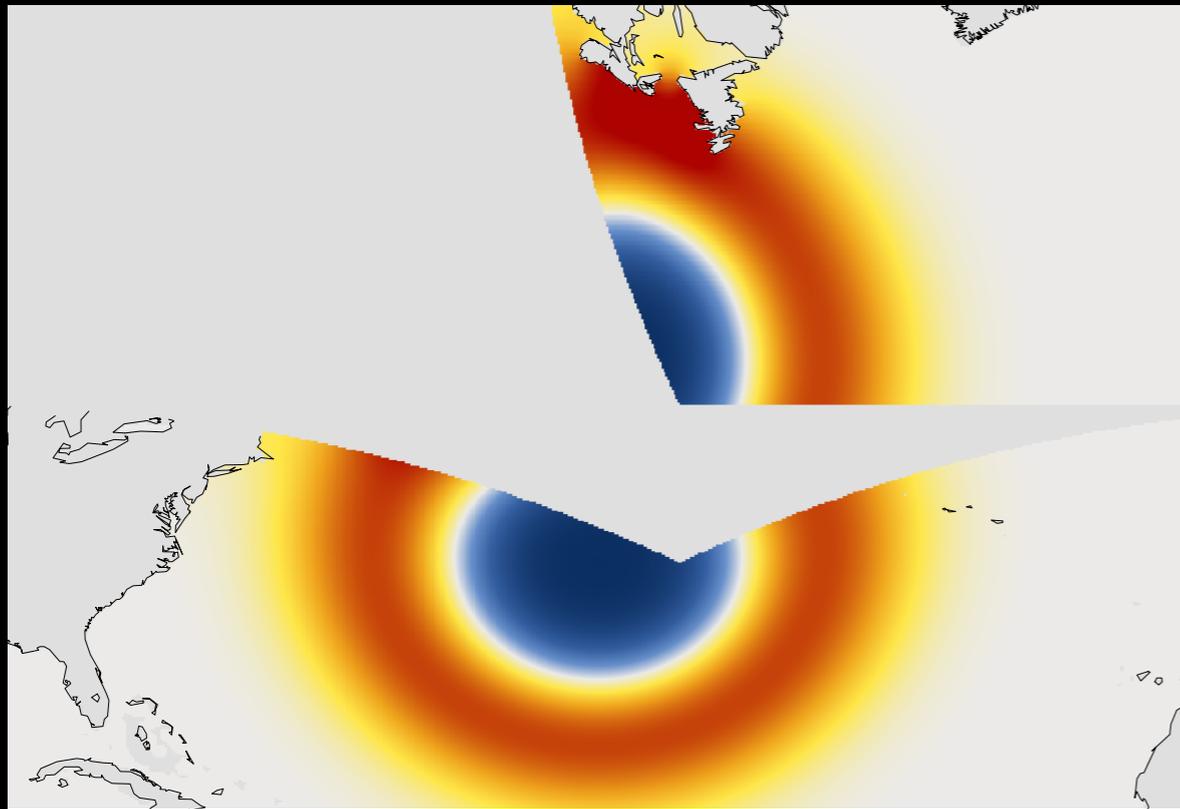
being run as part of the construction of near-edge versions of all operators, which must handle missing data and more complicated parallelism

SW wave propagation

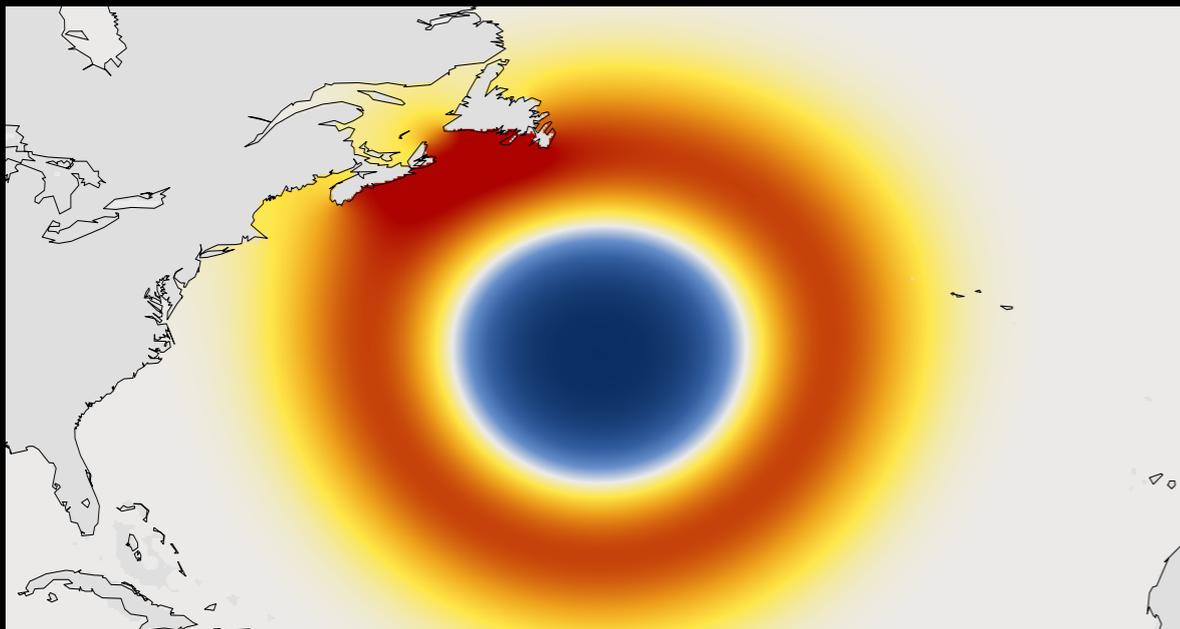
Exercises gradient operator

Gradients normal to cell edges in semi-structured zone calculated from 2D polynomials; missing data affect stencil choice and may lower the degree. Polynomials currently 2nd-degree to match order away from cube edges

Waves in a spherical pond

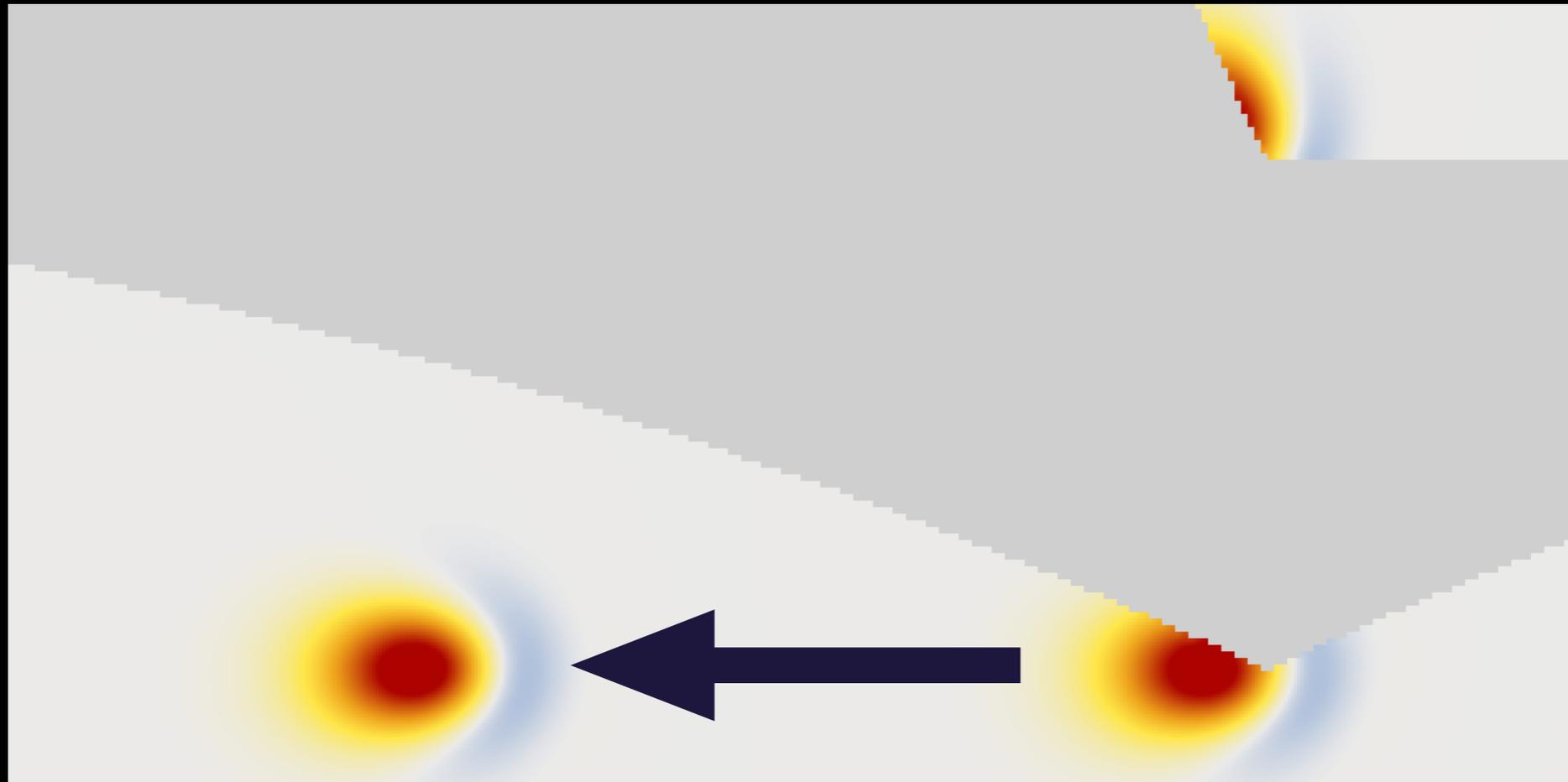


Native grid



Regridded

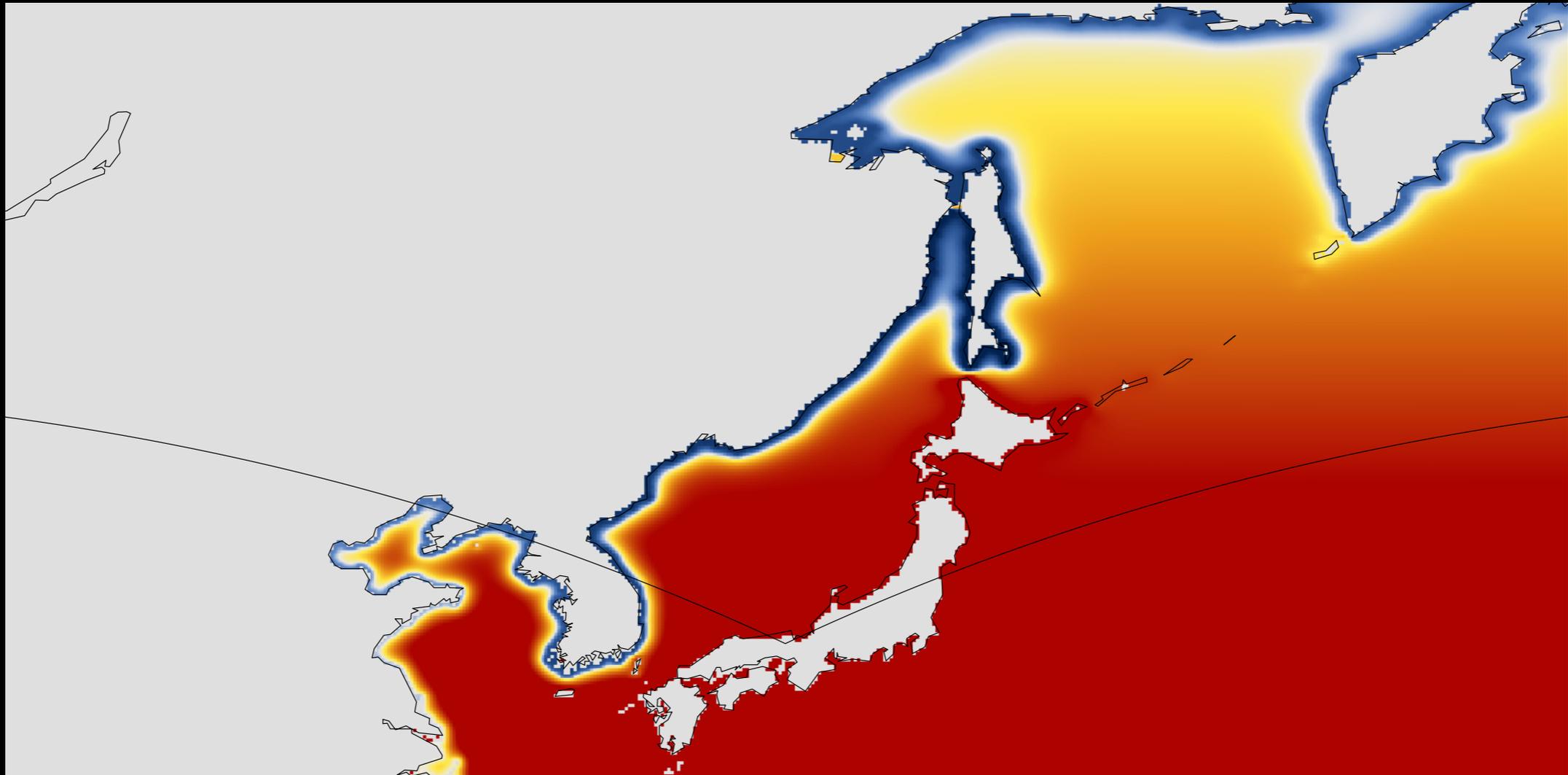
Rossby wave



$T_2 > T_1$

T_1

Coastal Kelvin wave



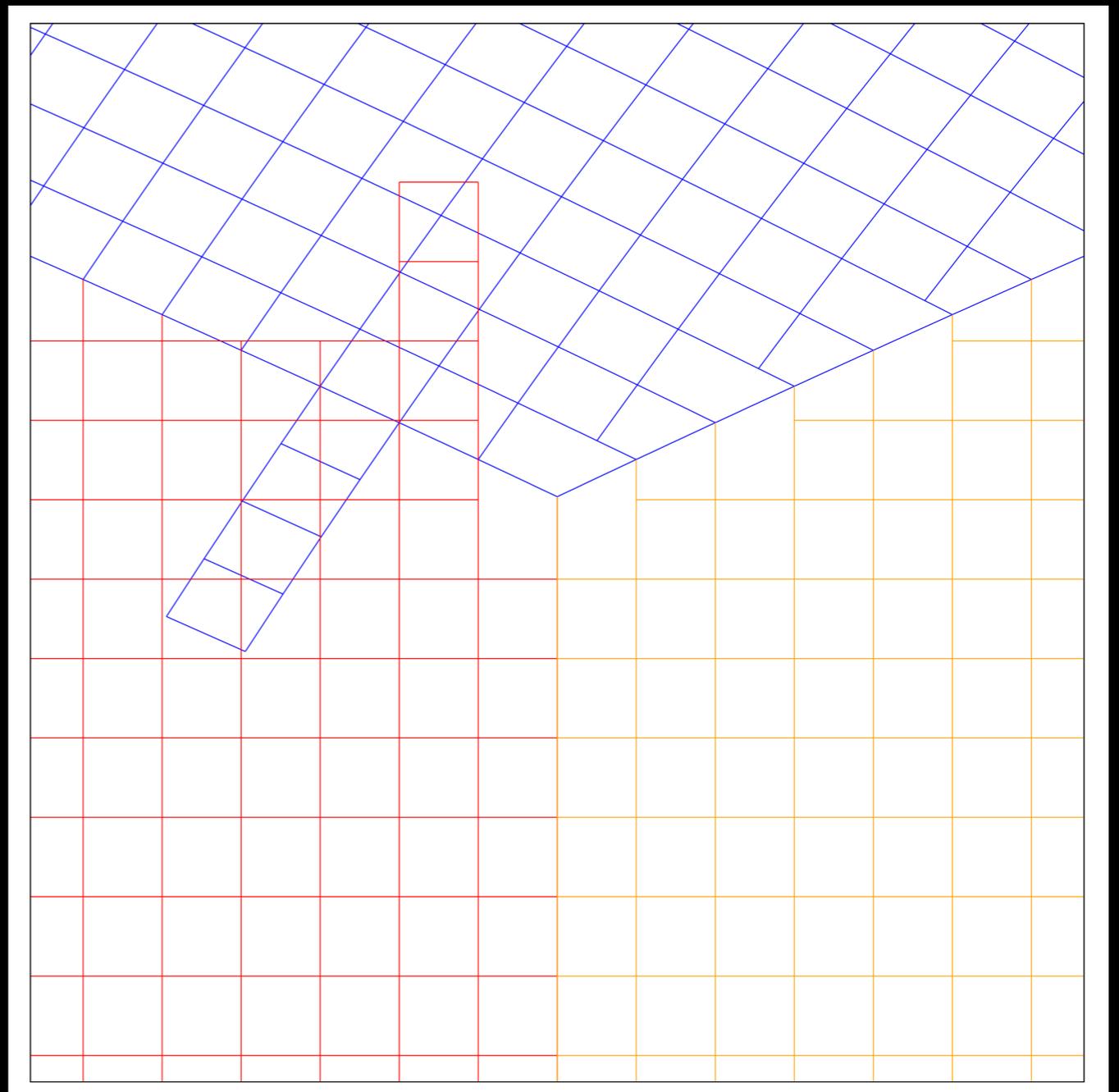
Rossby radius: ~ 2 gridpoints

Advection

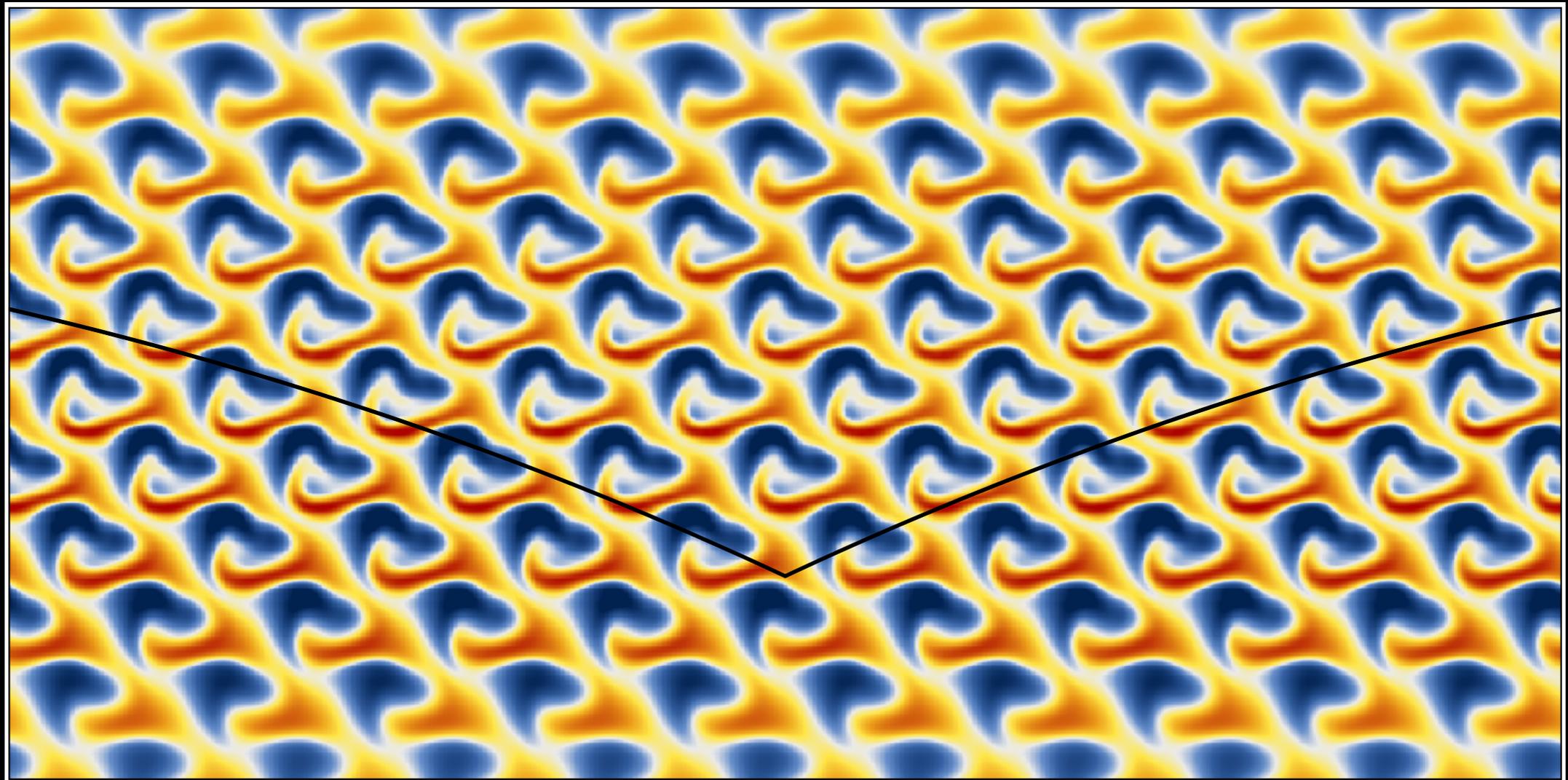
Higher-order schemes such as PQM require large stencils.

Conservative remapping generates “extension” stencils.

Outflow DOF for subgrid schemes such as SOM may be synthesized from them.



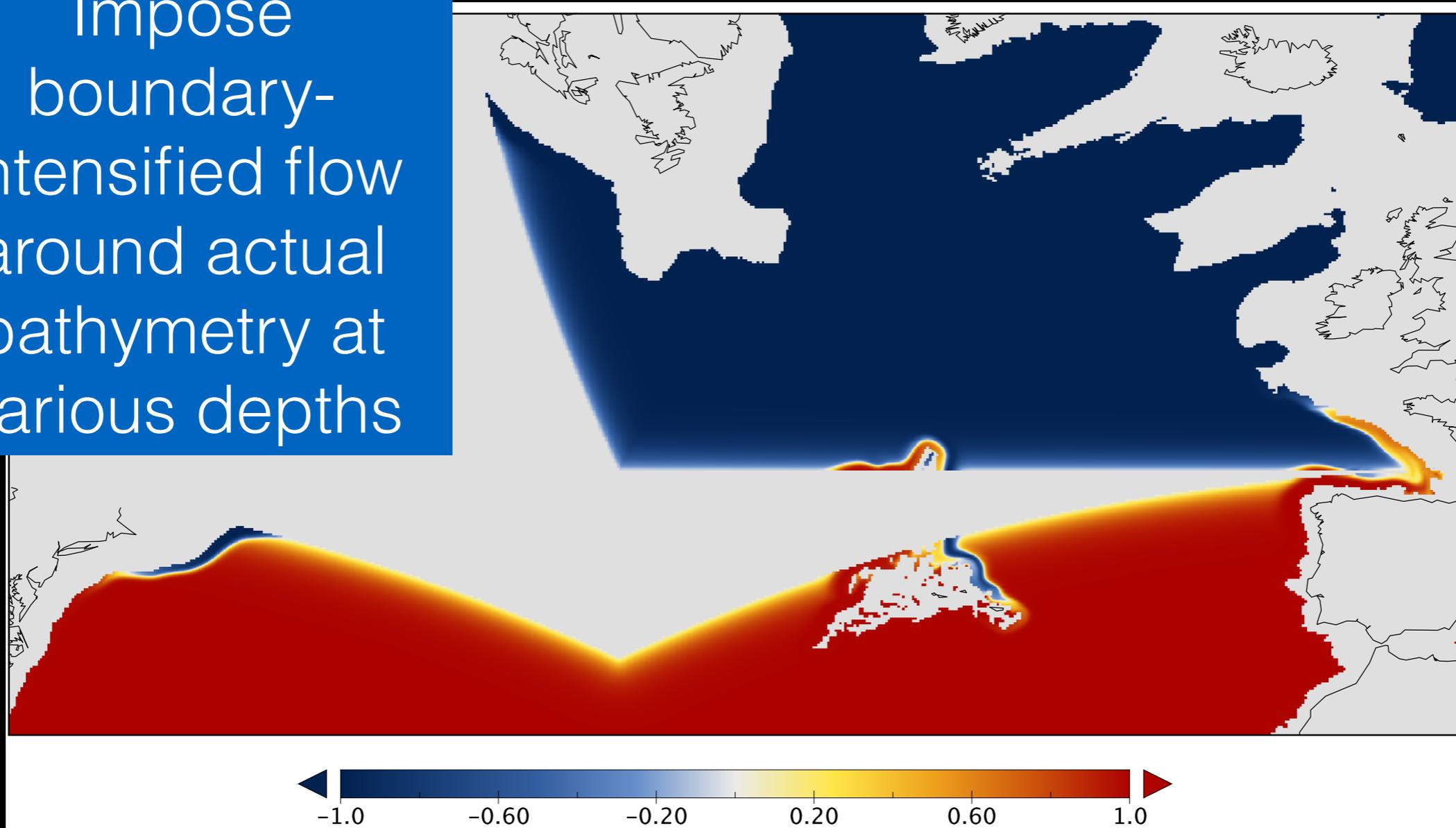
Tracer advection test 1



Moving vortices with 16-gridpoint wavelength.
No significant distortion at edges.

Tracer advection test 2

Impose boundary-intensified flow around actual bathymetry at various depths

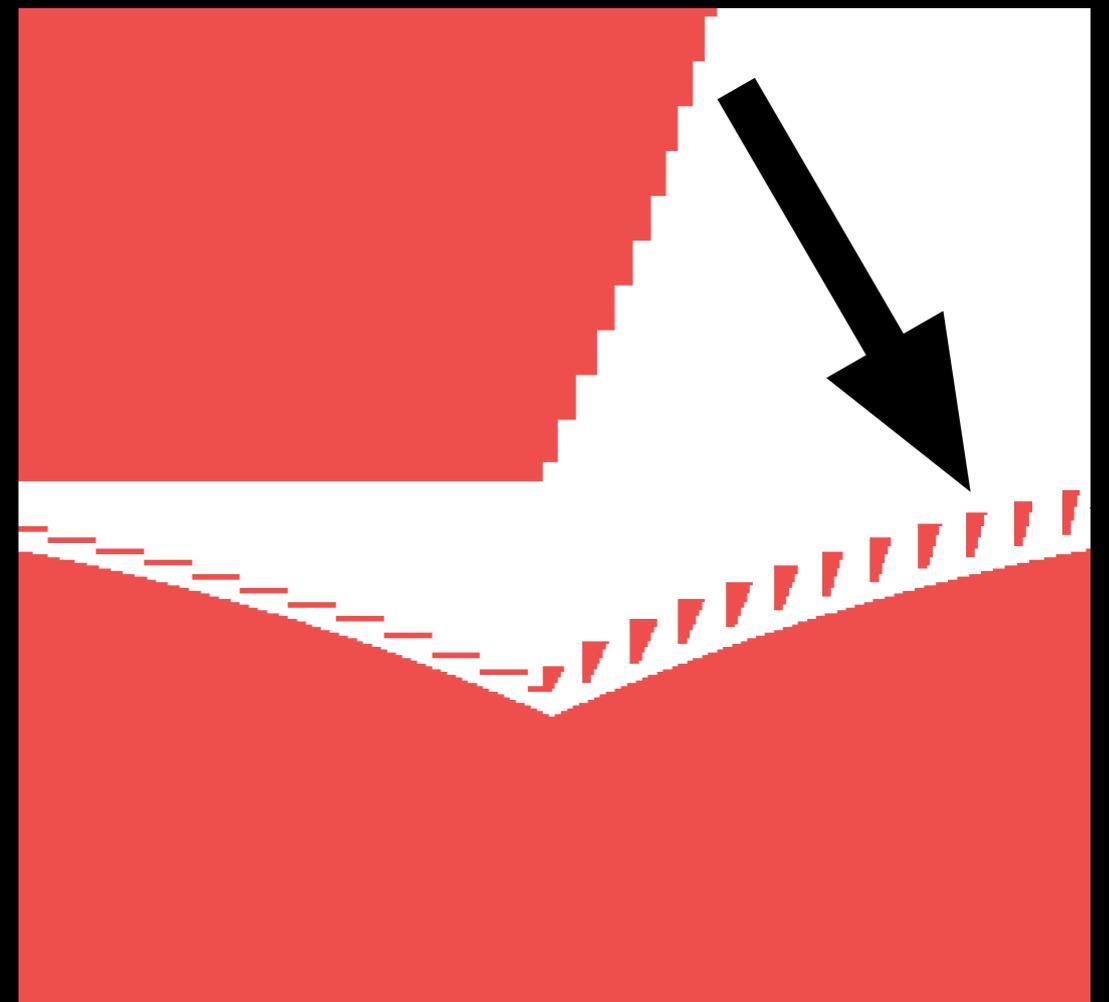


Flow-generated discontinuities prevented from overshooting by WENO scheme. Careful treatment of “walls” needed in semistructured zone.

Parallelism

Load balancing must compensate for extra expense in semistructured zone. Strategies:

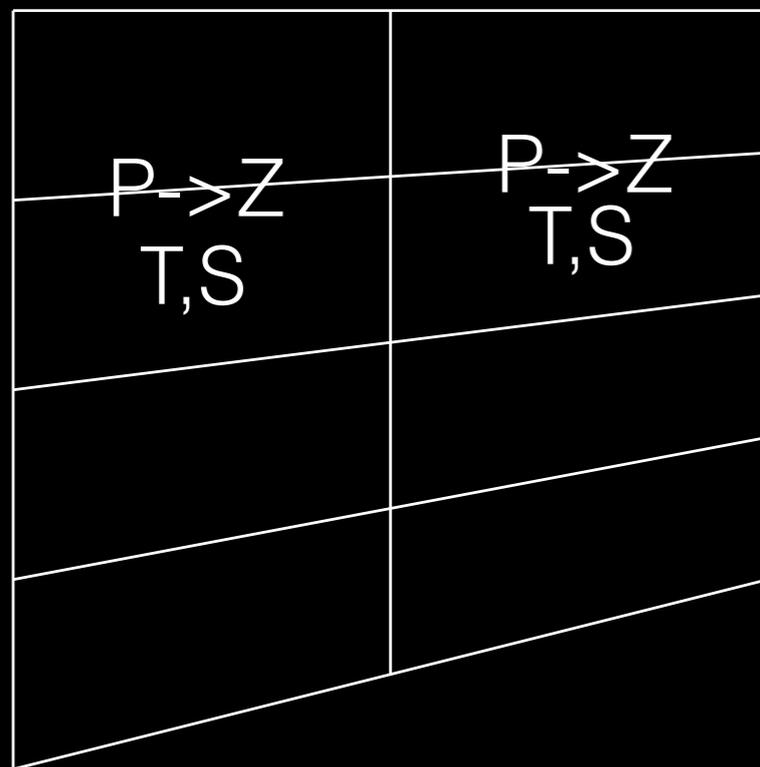
- Smaller per-processor domains near edges
- Shifted domains increase locality for larger-stencil ops



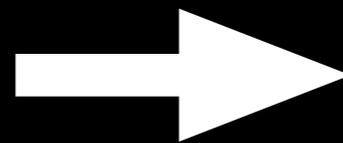
Sloping-layers PGF

Interpolations/derivatives in semistructured zone to construct hydrostatically consistent 2-column input to FV-style PGF

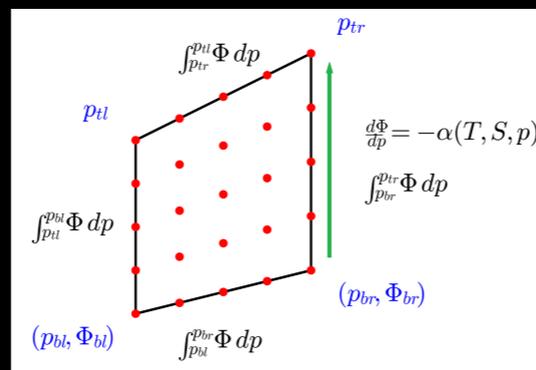
Forward



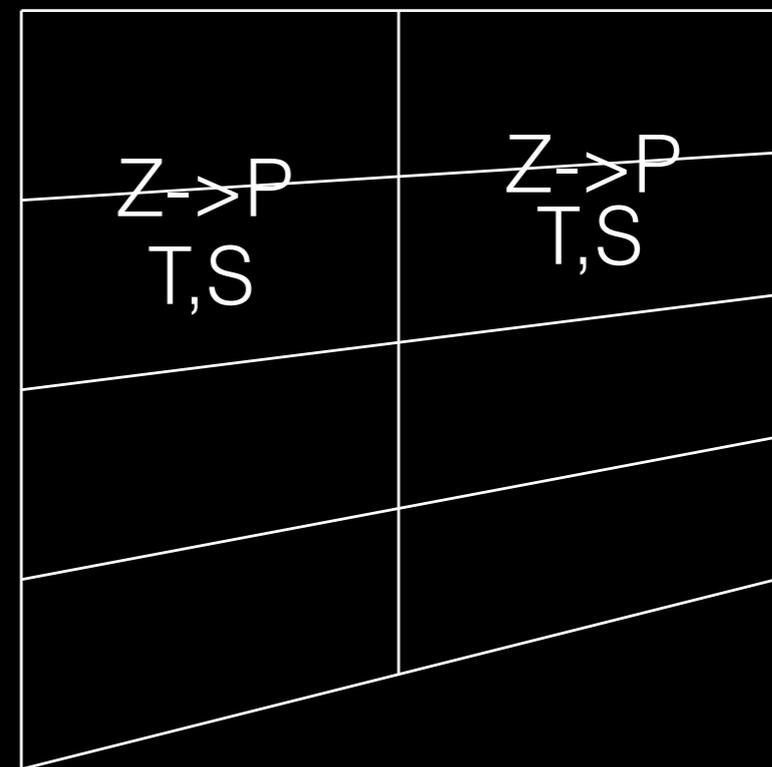
Interpolation



T,S,Z

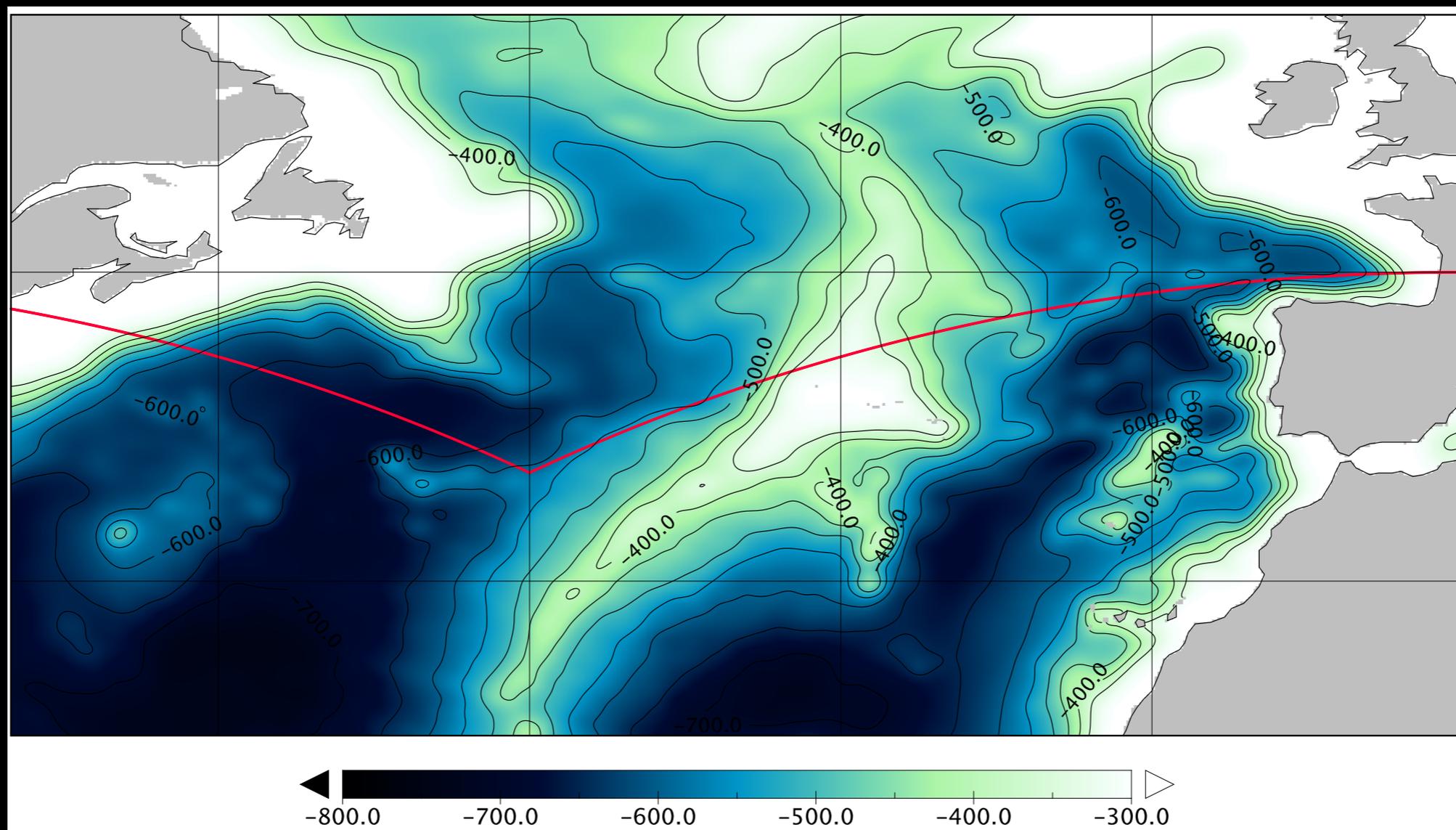


Inverse



Sloping-layers PGF test 1

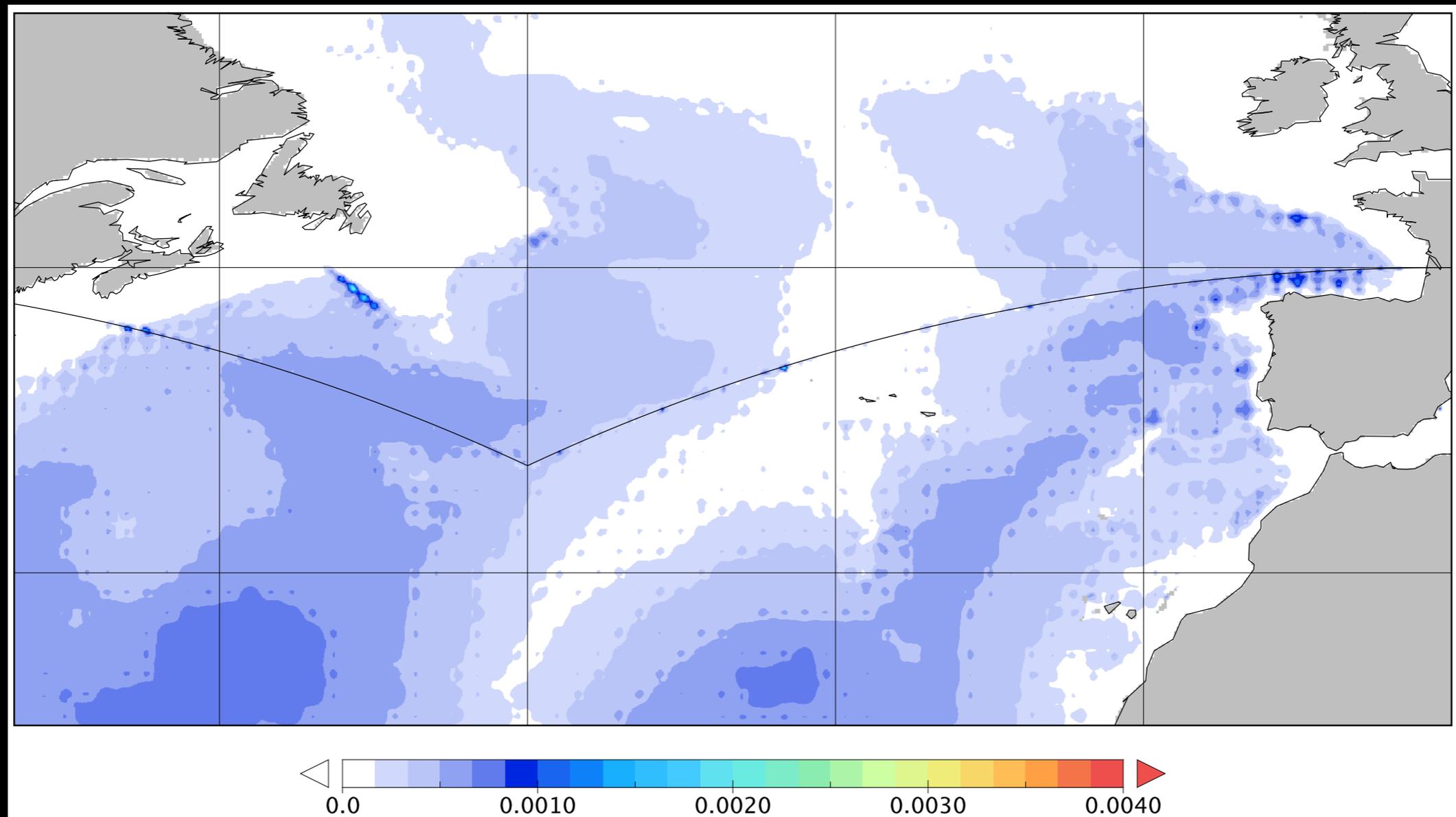
Compare baroclinic PGF in pressure and terrain-following coordinates, esp. at cube edges



Representative variation of an upper-ocean layer depth (m) in the terrain-following system

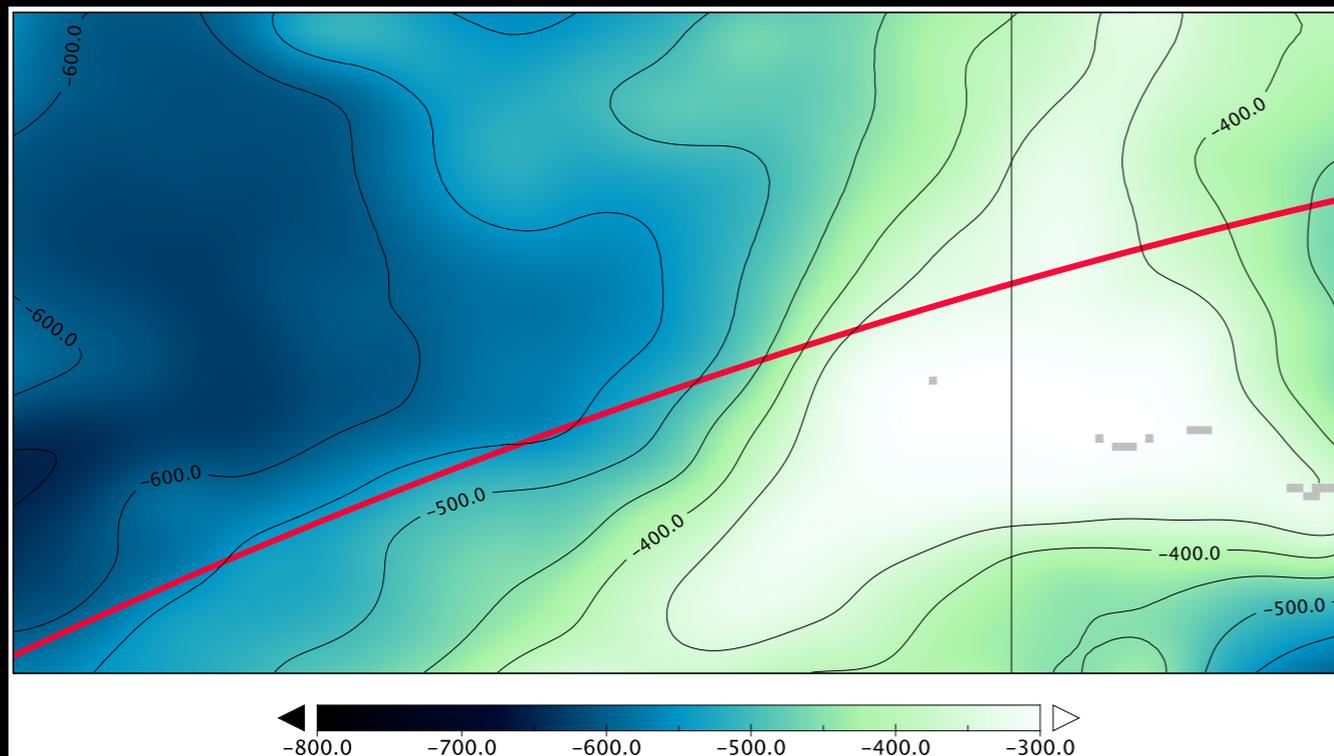
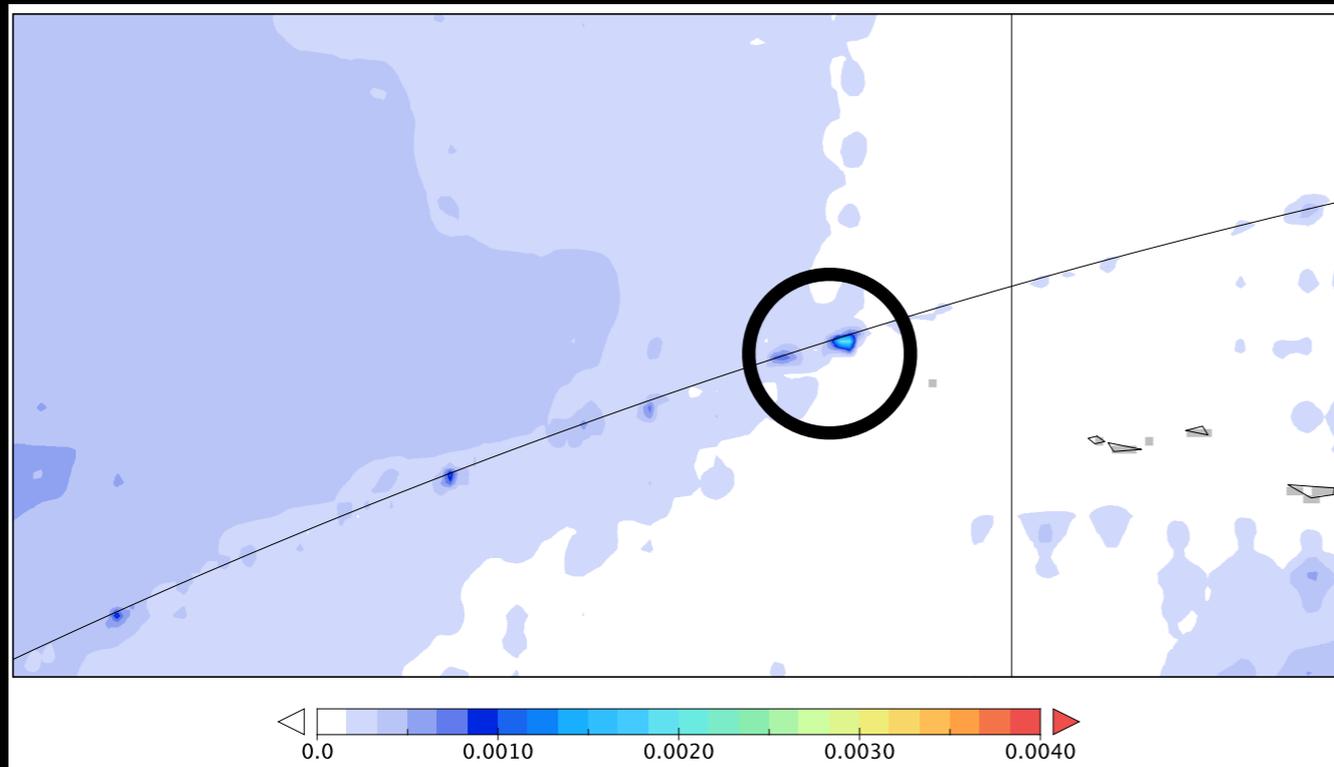
Sloping-layers PGF test 1

Pointwise relative “error” in sloping system generally $\ll 1\%$



Wavelength of baroclinic perturbation: 16 gridpoints

Sloping-layers PGF test 1



Pointwise relative “error” in sloping system can be amplified at cube edges but absolute error is small compared to peak magnitude.

Errors in the resting-state test also small.

Near-term directions

- Finishing in-progress steps
- Sea ice dynamics
- NIMBY

Longer-term directions

- Regional refinement
- Atmosphere

Sea ice dynamics

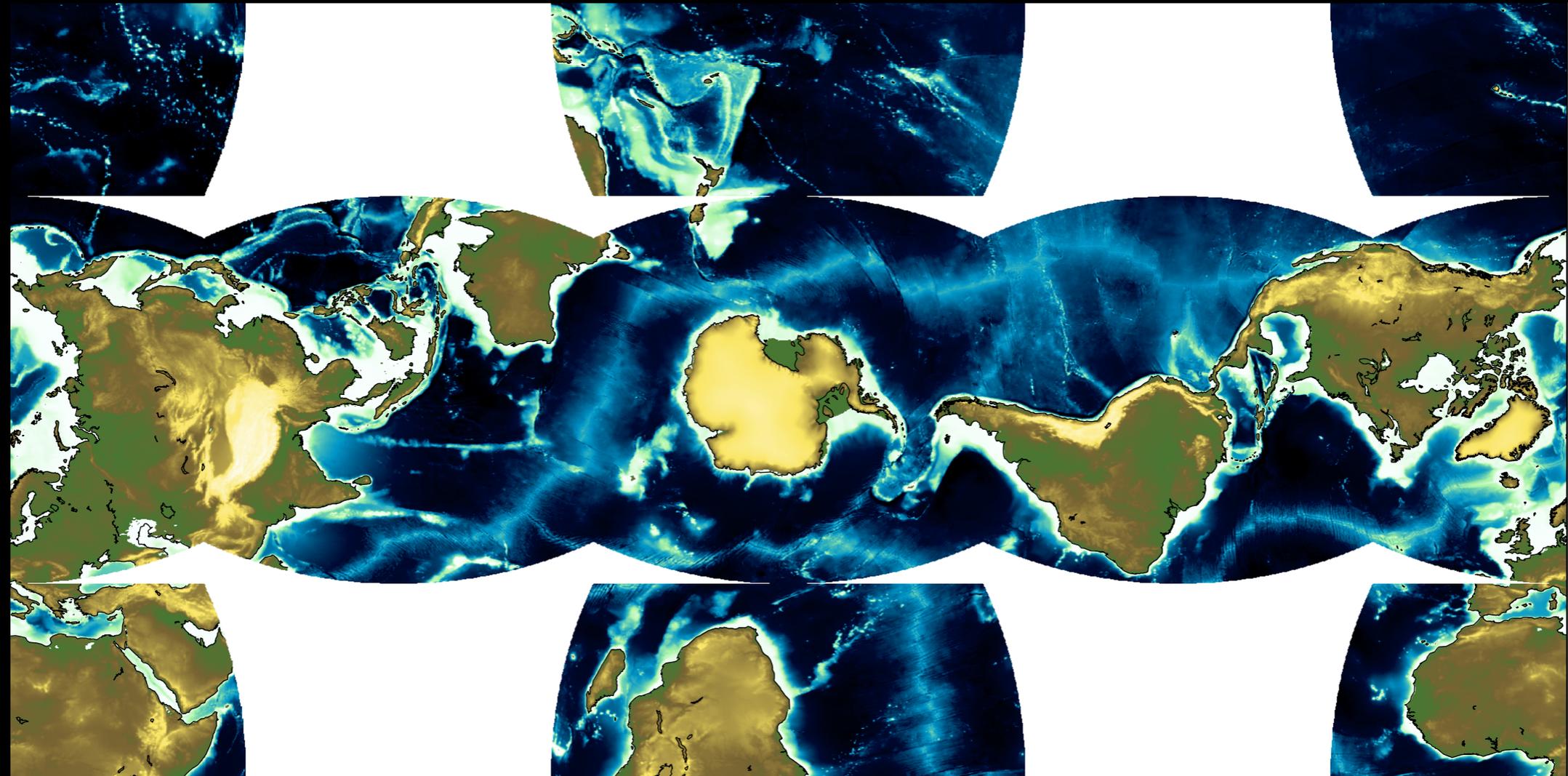
Initially, should be straightforward since ice does not reach cube edges for current climate and vanilla orientations of the grid w.r.t. continents

But...

Interaction with the barotropic mode to be explored

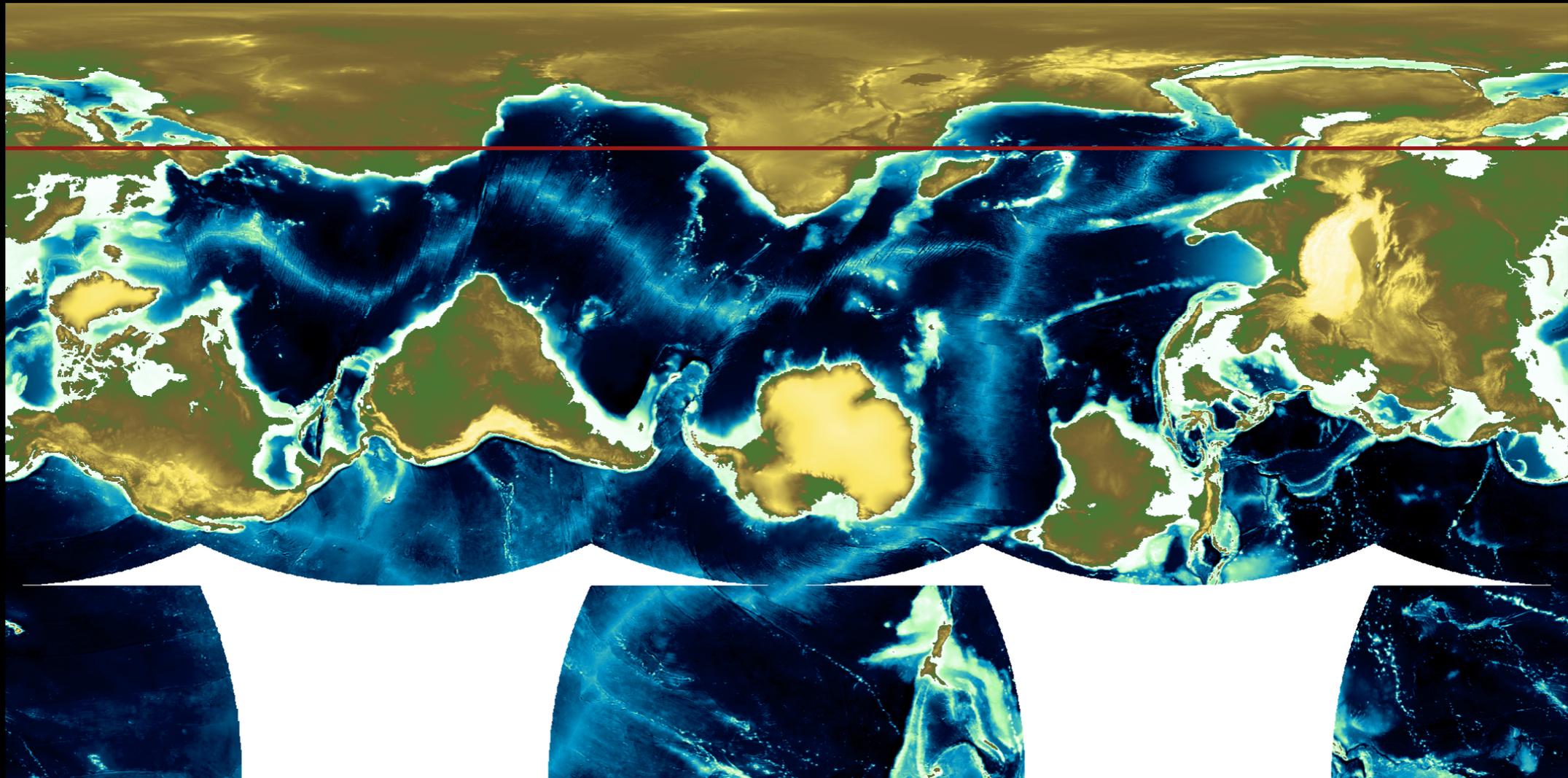
Grid-independent rheology and solver questions remain

NIMBY 1



Minimizes intersections of edges and coastlines

NIMBY 2



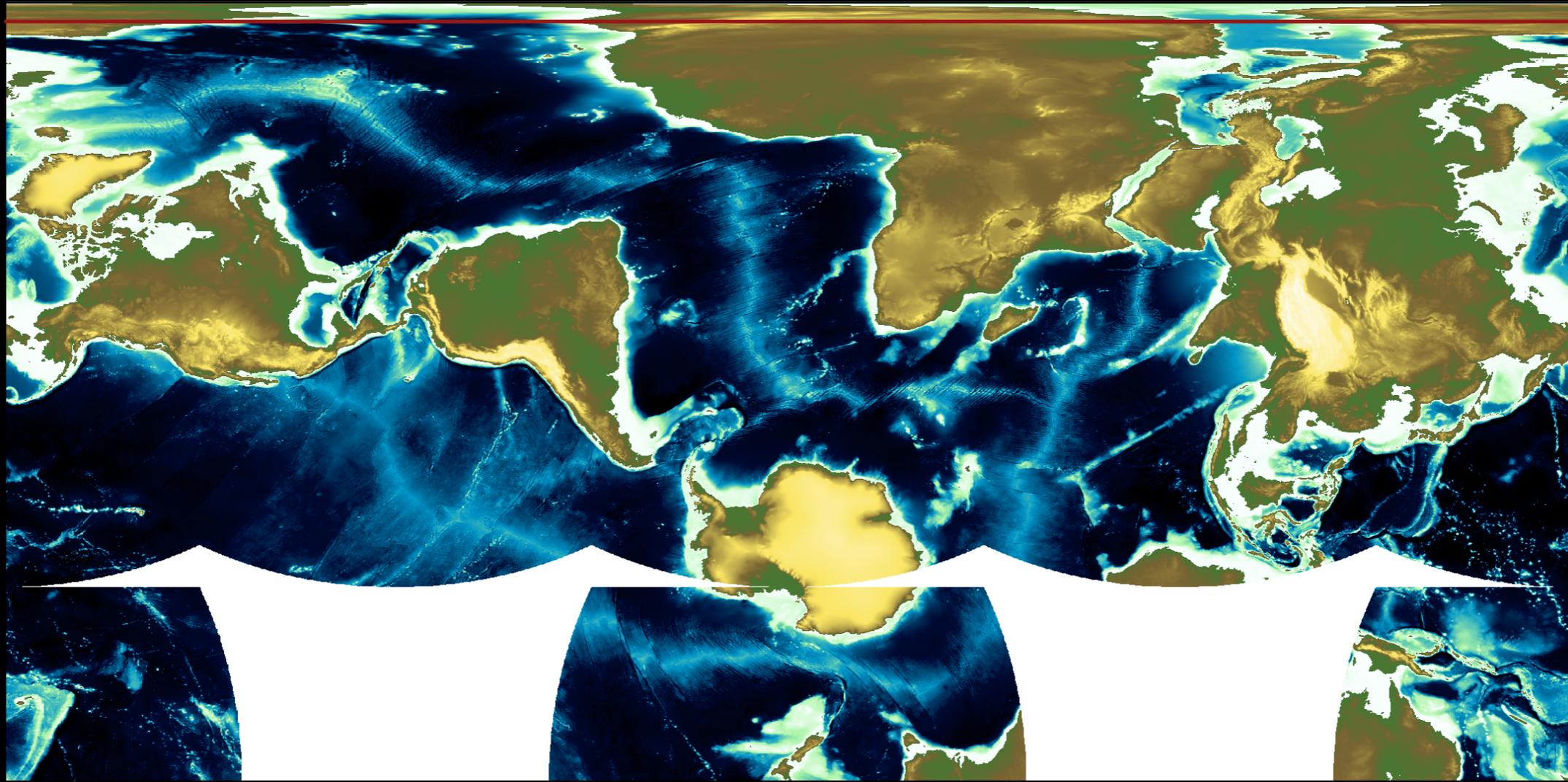
Half-cube - no edge intersections with coastlines.
Dipole cap could be placed at _____

Regional refinement

Not a design goal of a structured grid, but options to explore include:

- half-cube + pole(s)-on-land (PIMBY)
- shrink one cube face
- quadtrees, AMR, etc.

PIMBY example



Regional refinement at Gibraltar via transition to dipole grid at cutoff line (+ stretched latitudes on approach)

Summary

Horizontal gridding approach proving

- workable (but interchangeable with fallbacks)
- compatible with ALE-enabling methods



Operational incorporation of newer pieces is underway