NeverWorld 2
The idealized component of the Eddy Energy and Ocean Transport CPT

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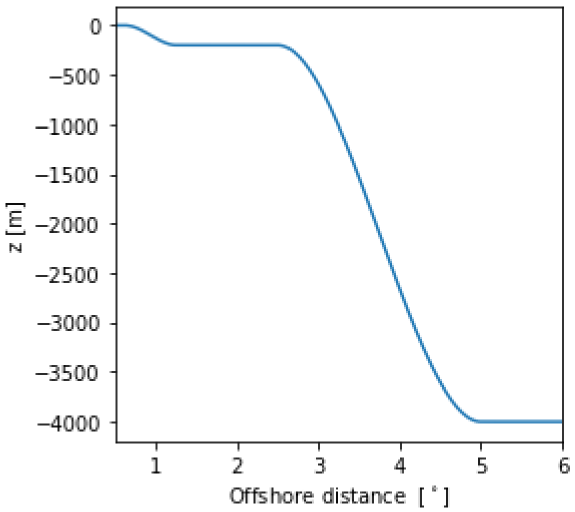
NeverWorld 2

- Goal
  - Testbed for implementation and evaluation of extant (and future) SGS eddy parameterizations
  - Fair treatment and test of all parameterizations
- Why idealized?
  - Implementation and evaluation need a ground truth
  - Can afford ultra-fine resolution
  - Simpler to understand
  - Sandbox to develop analyses
  - Just a stepping stone
    - Next stage is to apply much of what we are doing with NW2, to a realistic ocean model (OM4_05)
- Why "2" or new?
  - Zonally uniform channel models miss role of topography
  - NeverWorld 1 from Khani et al, 2019; Jansen et al 2019
    - single hemisphere
    - wanted to revisit topographic roughness
  - Considered "Hogglantic"s and other idealized configurations
    - Opted for simpler adiabatic option
    - We want to be able control topographic "spectrum"

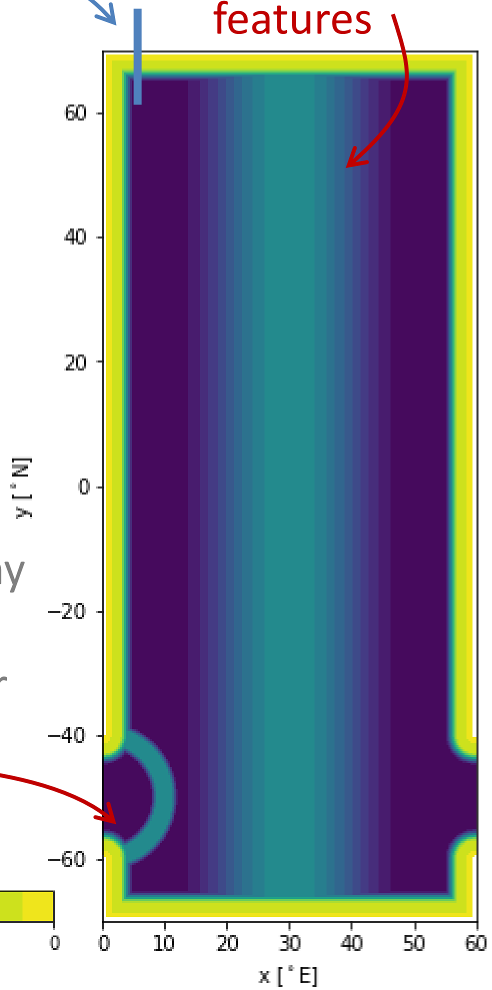
NeverWorld 2 details

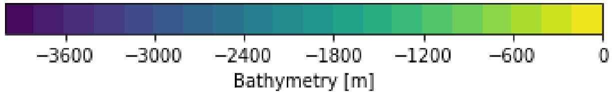
Extends *Khani et al., 2019; Jansen et al., 2019*

Coastal shelf and slope



Large scale topographic features

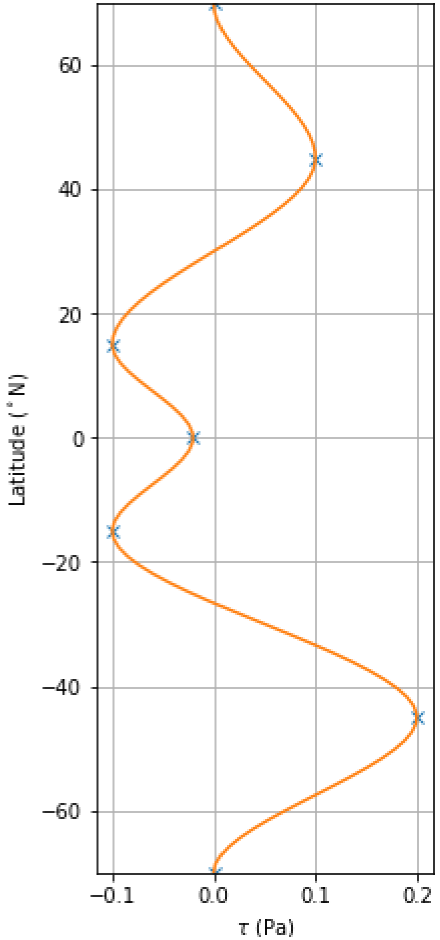




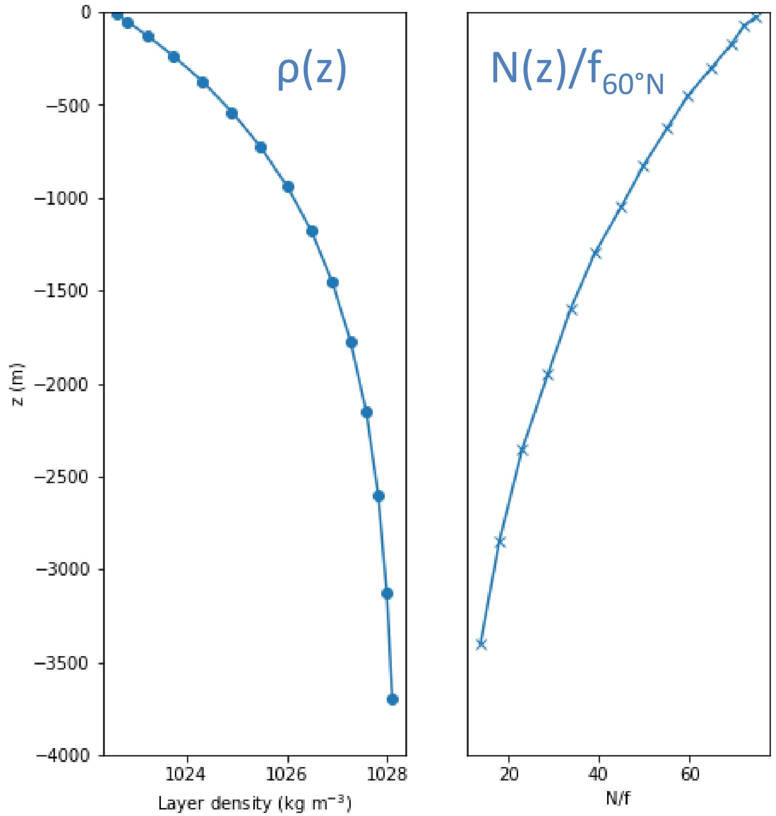
- Initial simplest topography with sufficient features
  - may add features later

Ridge blocking reentrant channel

Fixed zonal winds



- 15 layers, exponential stratification
- ADIABATIC (no buoyancy forcing)
  - may revisit later



- spherical grid

NeverWorld 2 model

- Stacked Shallow Water Equations

$$\partial_t v_k + q_k \hat{k} \times (vh)_k + \nabla K_k + \sum_{l=1}^{k} g'_{l-\frac{1}{2}} \nabla \eta_{l-\frac{1}{2}}$$

$$= \frac{1}{\rho_c} \partial_z \tau + \partial_z \kappa_v \partial_z v - \nabla A_s \cdot \nabla^3 v$$

Dynamic hyper-viscosity

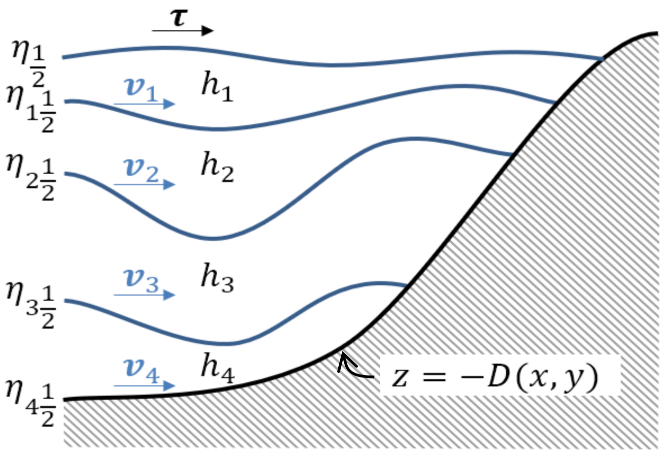
$$\partial_t h_k + \nabla \cdot (vh)_k = 0$$

$$\eta_{k-\frac{1}{2}} = -D + \sum_{l=k}^{N} h_l$$

$$q_k = \frac{f + \nabla \times v_k}{h_k}$$

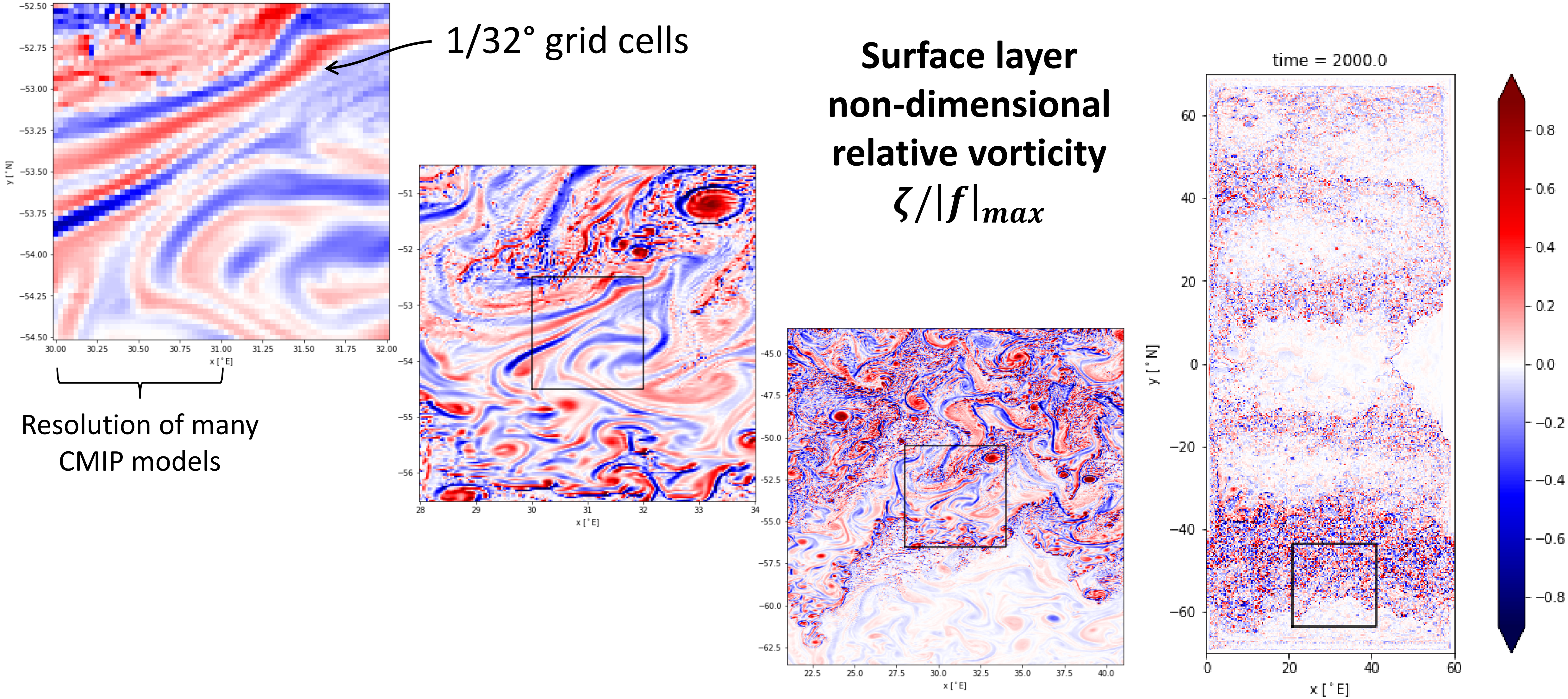
$$K_k = \frac{1}{2} |v_k|^2$$

$$g'_{k-\frac{1}{2}} = g \frac{\rho_{k-1} - \rho_k}{\rho_c}$$



- Cheap
  (not much more than QG)
- Can span the equator
  (unlike QG)
- Same code (MOM6) as used in the realistic models (GFDL's OM4 and CESM2.2)
  - LANL is duplicating setups w. MPAS-O
- Strictly adiabatic
  - No complications from mixed layers, mixing, etc.

NeverWorld 2 solution

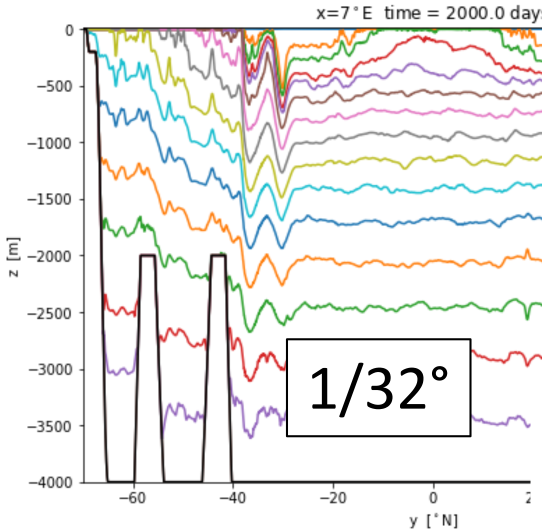


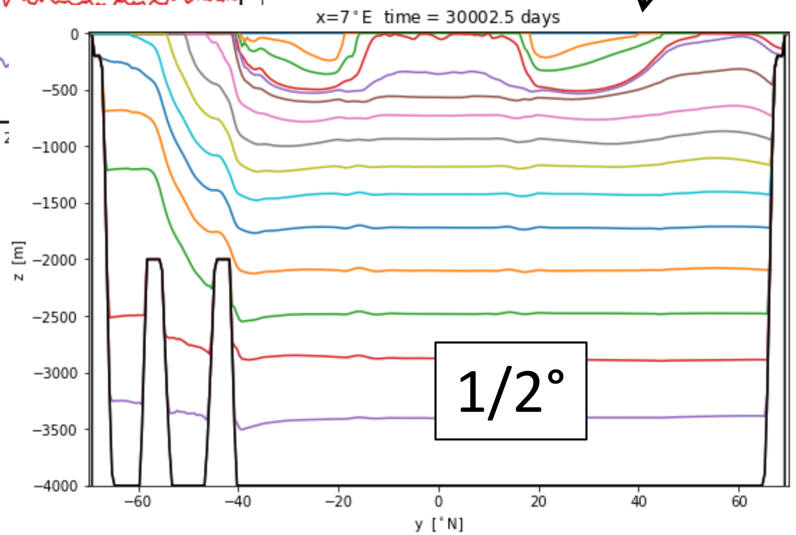
Surface layer non-dimensional relative vorticity
$\zeta / |f|_{max}$

The parameterization task

- Treat fine resolution as "truth"

$$\partial_t h_k^f + \nabla \cdot \left(v^f h^f\right)_k = 0$$





*Using continuity as an example, but all model equations, + auxiliary equations, are considered

- What SGS fluxes yield a coarse resolution model with as similar solution as possible

$$\partial_t h_k^c + \nabla \cdot (v^c h^c)_k = -\nabla \cdot (\langle v'h' \rangle^{SGS})_k$$

– Must define "similar"
  - Coarsening / filtering operators
  - Metrics e.g. $A_c h^c = \int_{A_c} h^f \, dA$

– Parameterization inputs?

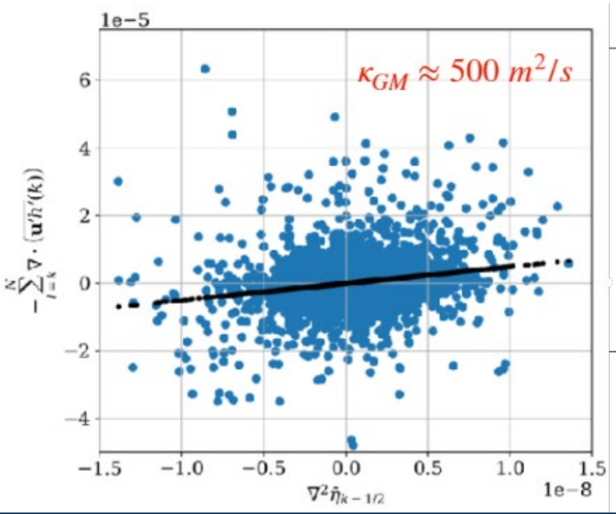
$$\langle v'h' \rangle^{SGS} = f(v_1^c; h_1^c; v_2^c; h_2^c; \ldots; ?)$$

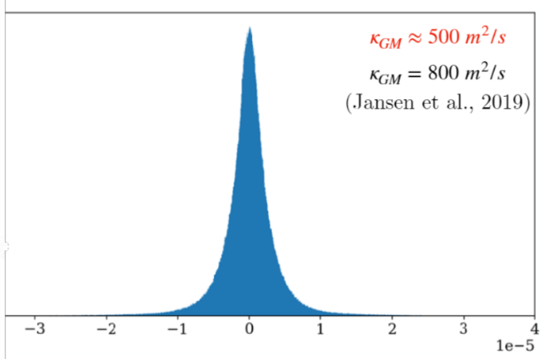
  - Model of eddy energy? Non-local?

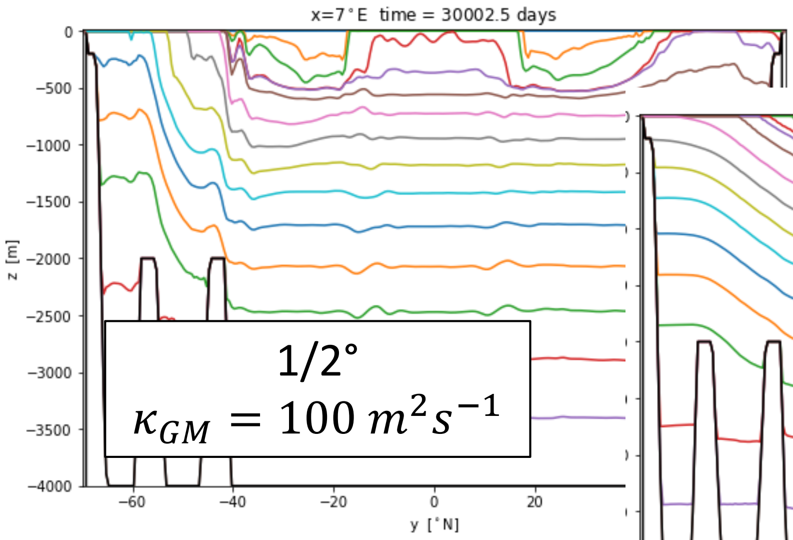
Evaluate parameterizations offline

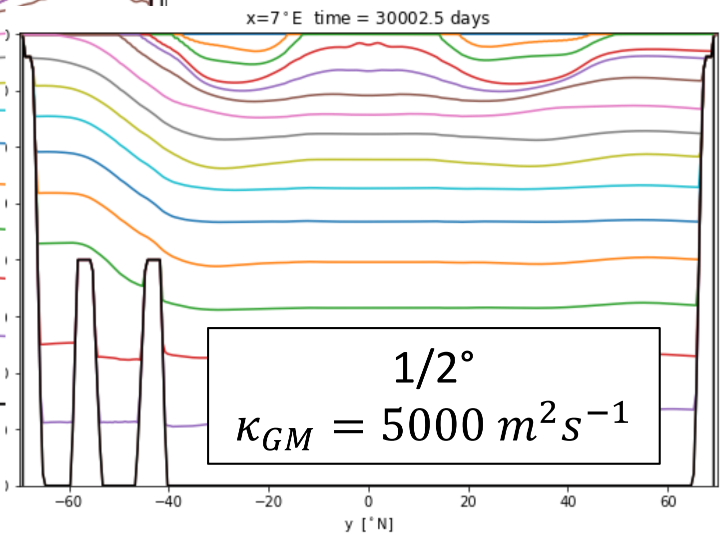
- Offline analysis of high-resolution data
  - Coarsening & filtering
  - Testing/optimization of free parameters in parameterizations
  - (Derivation of parameterizations)
- Online evaluation
  - Optimize whole model solution

    Similar to *Jansen et al., 2019*
  - Assumes
    - correct form of parameterizations
    - rest of coarse model is not biased



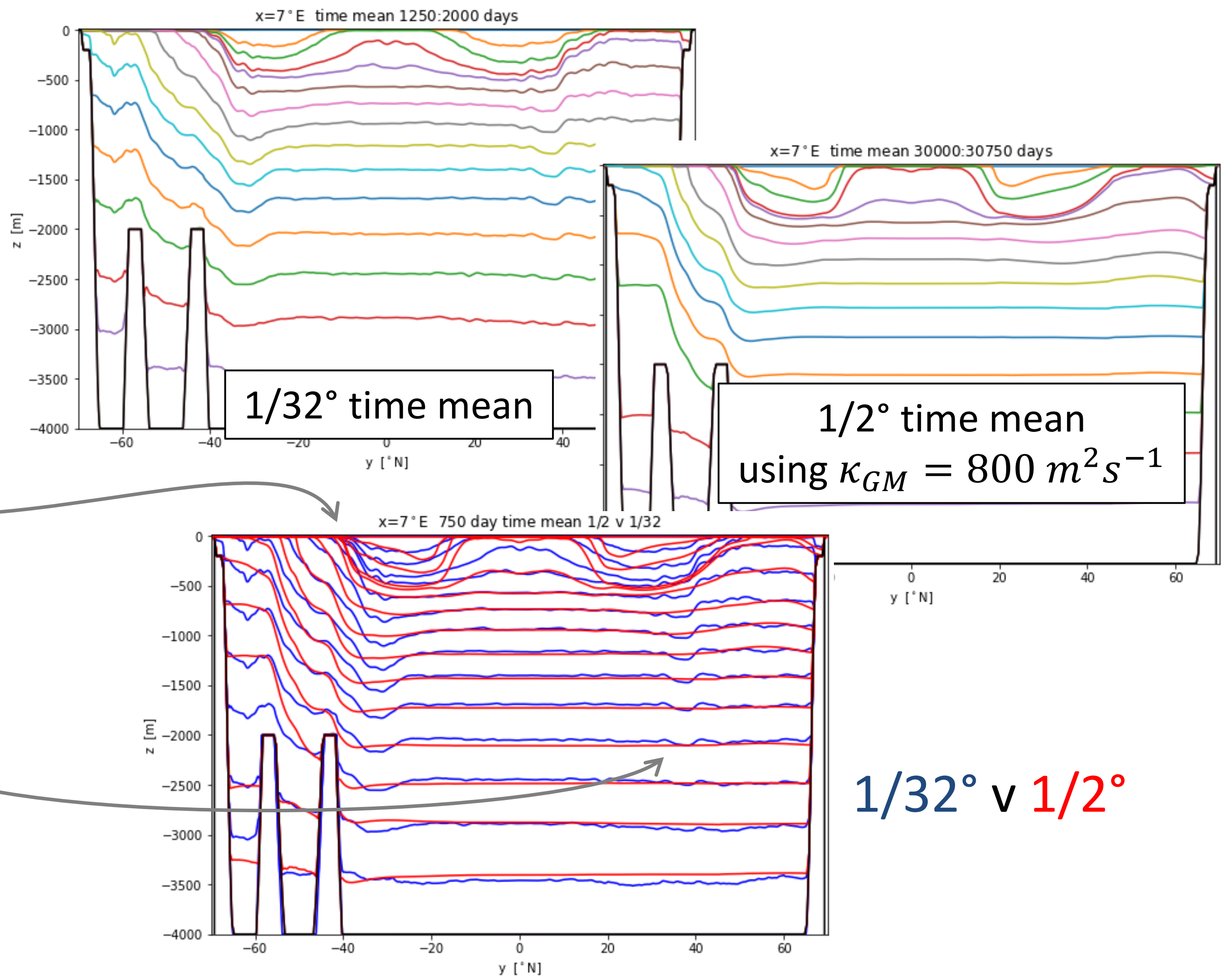




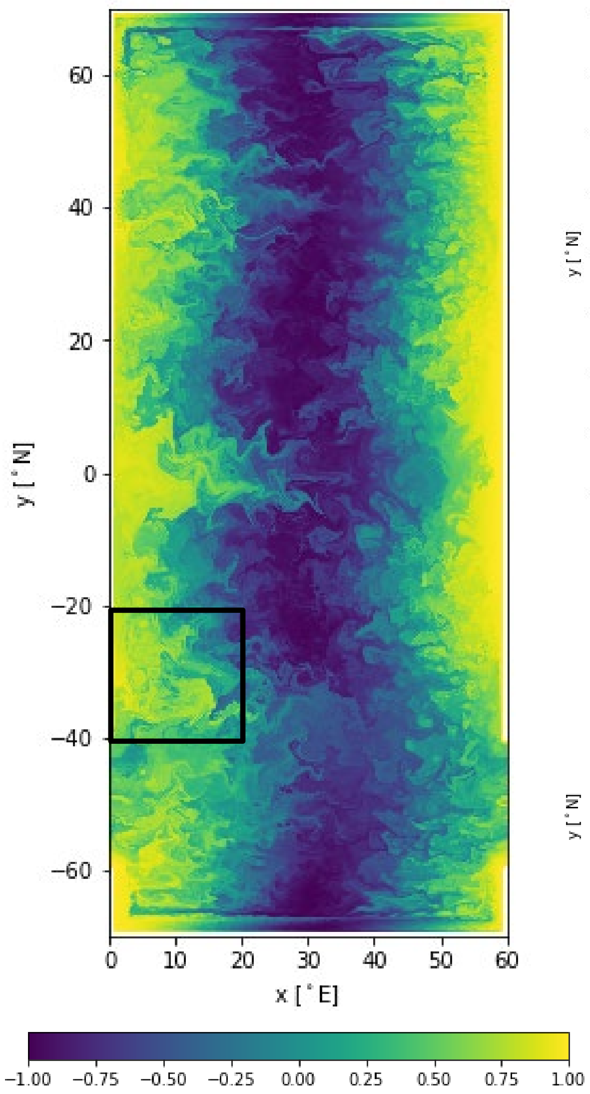


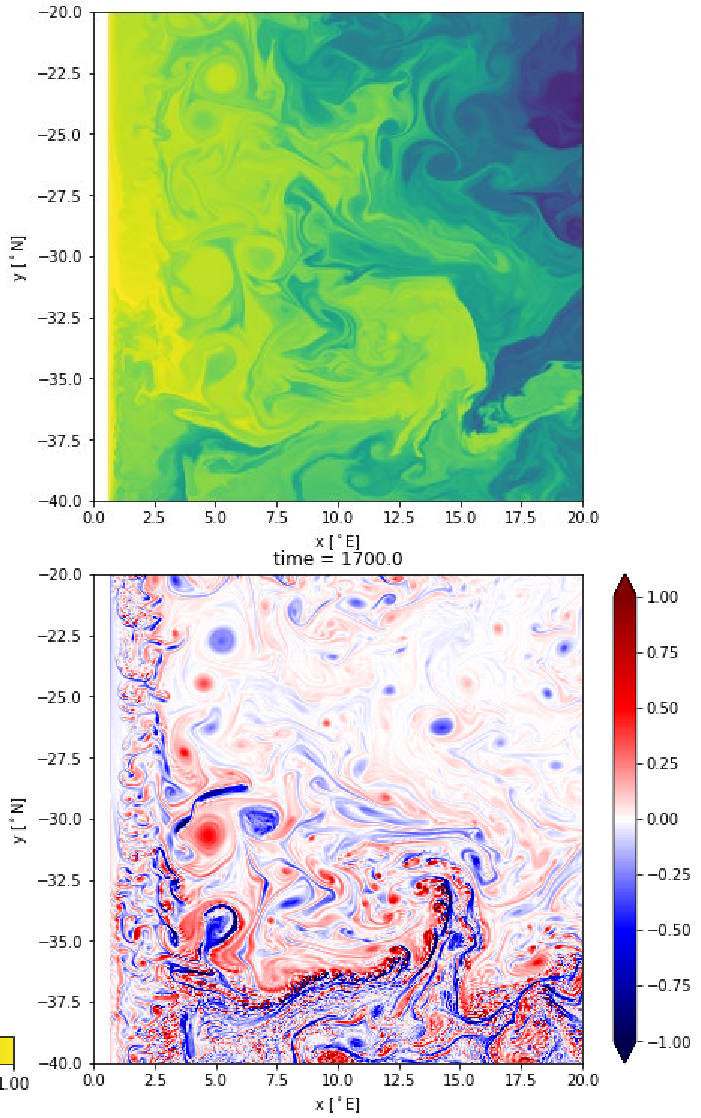
Testing parameterizations online

- Comparison of time-mean state across resolution
  - active parameterizations in coarse model
- Systematic biases
  - Largest biases are often near topography
    - likely due to standing eddies
  - Large scale biases in interior
    - deficiency of existing parameterizations



Taking advantage of the adiabatic mode

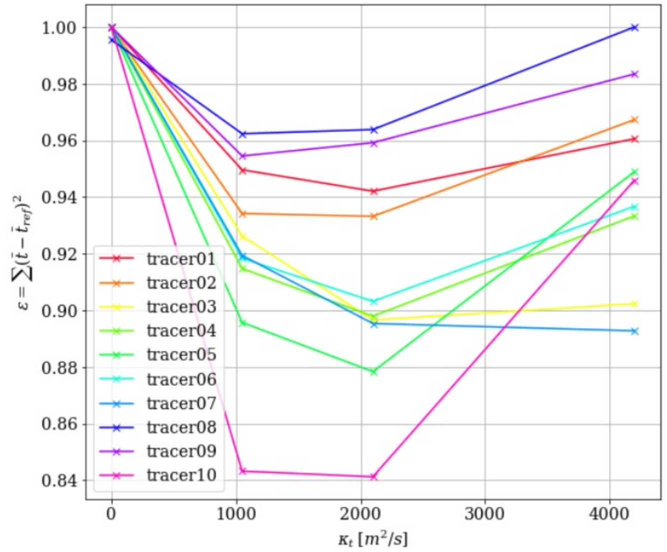




- Using passive tracers to test neutral diffusion parameterization

$$\partial_t(h_k^c\theta_k^c) + \nabla\cdot\left(\left((v^c h^c)_k + \langle v'h'\rangle^{SGS}\right)\theta_k^c\right) = -\nabla\cdot\left(h_k^c \kappa_{tr} \nabla_h \theta_k^c\right)_k$$

  – Can optimize tracer diffusivities without affecting circulation

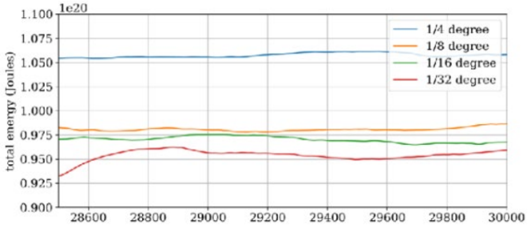


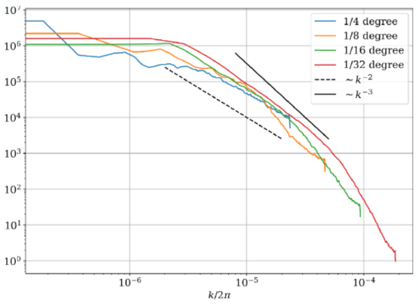
Also, e.g. *Bachman et al., 2015, 2020*

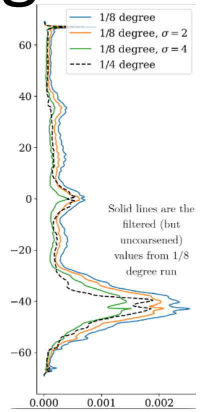
Status and next steps

To date:

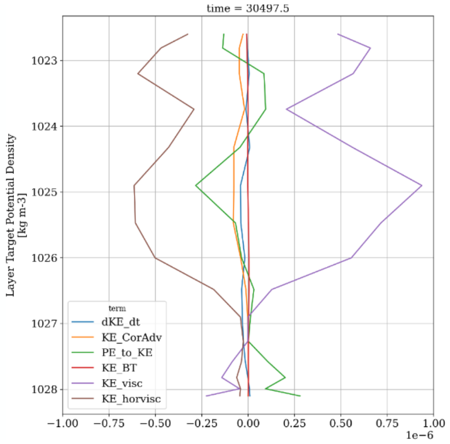
- Designing NW2 and examining solution







  - Accelerated fine-res initialization
- Checking diagnostics and closing budgets
- Developing analyses and metrics



Next up:

- Systematic evaluations of parameterizations
  - Long check list of NW2 evaluations
    - Constant κ GM, Visbeck et al., 1997, Danabasoglu & Marshall, 2007, Jansen, 2019, Bachman, 2019, Kong & Jansen, 2020Anstey & Zanna, 2017, Zanna & Bolton, 2020, Klocker & Abernathy, 2014, …
- Evaluation in realistic model configurations
- Add range of resolutions

Postdoc @Princeton, apply by 15th