Further consideration of GM under testbed-based parameter estimation

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What we had done, one year ago:

Southern Ocean Testbed GM Calibration

LA-UR-11-11969

Jim Gattiker, Matthew Hecht

November 10, 2011

- Had done Parameter Estimation on older, constant-coefficient GM,
- Based then on a single metric (horizontally averaged temperature)

The Testbed approach

based on systematic Parameter Estimation

- Many uncertain parameters in climate models
  - Some parameters more important than others
- So, one performs many "sensitivity runs"
  - Not entirely avoidable, but…
- We explore a more rigorous and systematic approach.

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The eddy scheme in the CESM POP

- Form of Gent-McWilliams isopycnal transport and mixing scheme
  - From thermocline to depths, overall coefficient is reduced as stratification weakens
  - Reduction limited to 90%

(see Danabasoglu and Marshall, 2007)

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We vary these
2 parameters

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How have eddy scheme parameter values been determined, in the past?

- Poleward heat transport in the North Atlantic
- Drake Passage mass transport
- Biases in water masses, at large scale
  - Abyssal stratification
- Heat transport across the Southern Ocean

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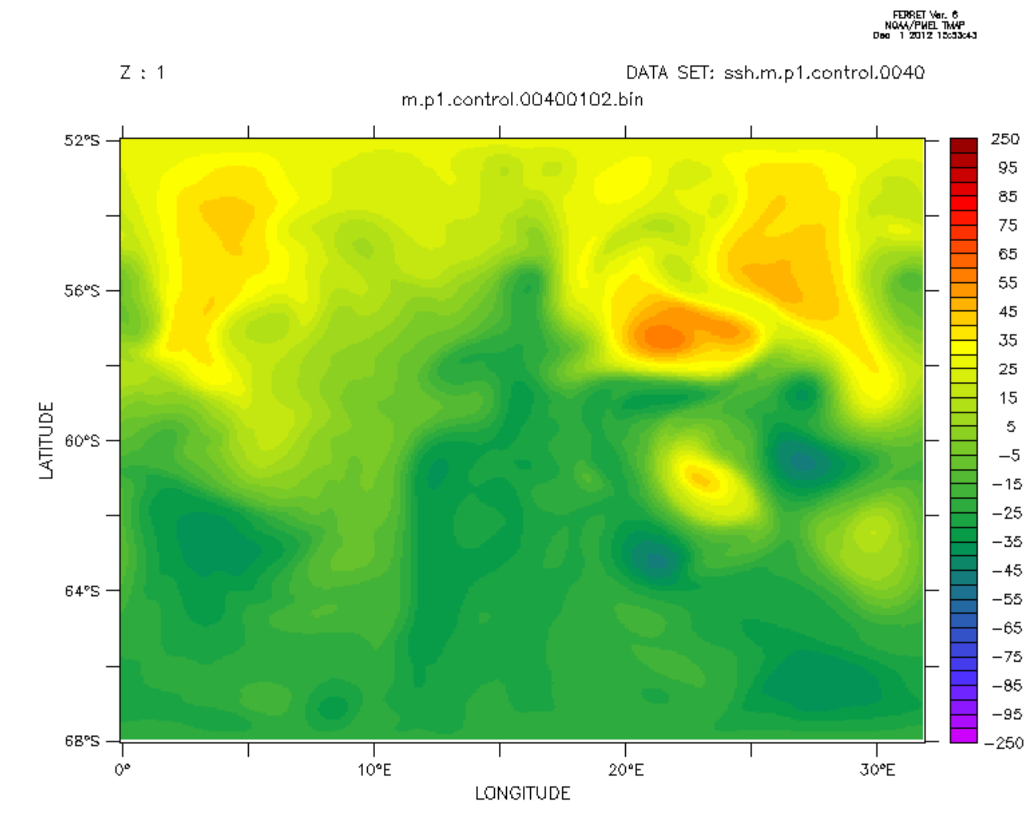
An alternative – use high resolution simulation as the target

- Realistic simulation, or idealized.
  - We present an idealized study
  - Use tractable simplified configuration, compare to high res runs with resolved physics
    - target simulations standing in for observations



Sea surface height (cm)

(Note that hi res can also be used to directly determine mixing coefficients, but this is not what we do here.)

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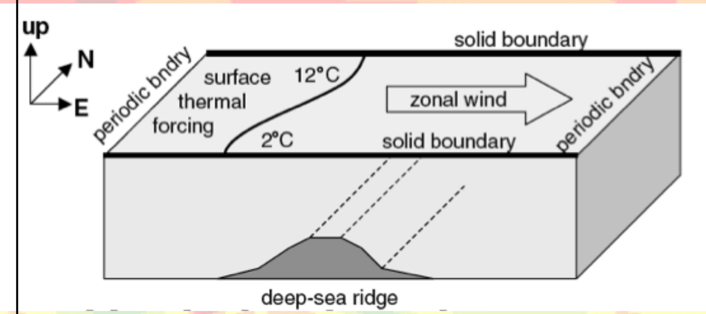
Testbed context:
Idealized Southern Ocean

Datasets:

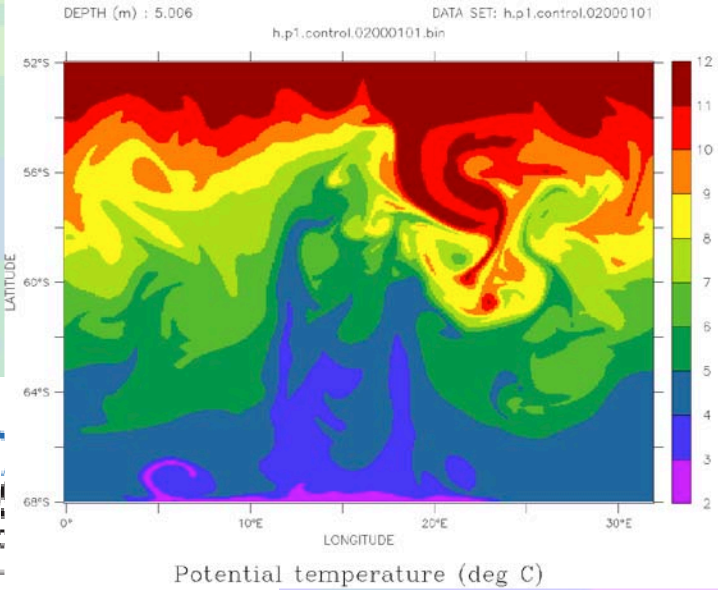
Reference run of 0.1-degree channel model without GM.

Runs of 0.8-degree channel model:

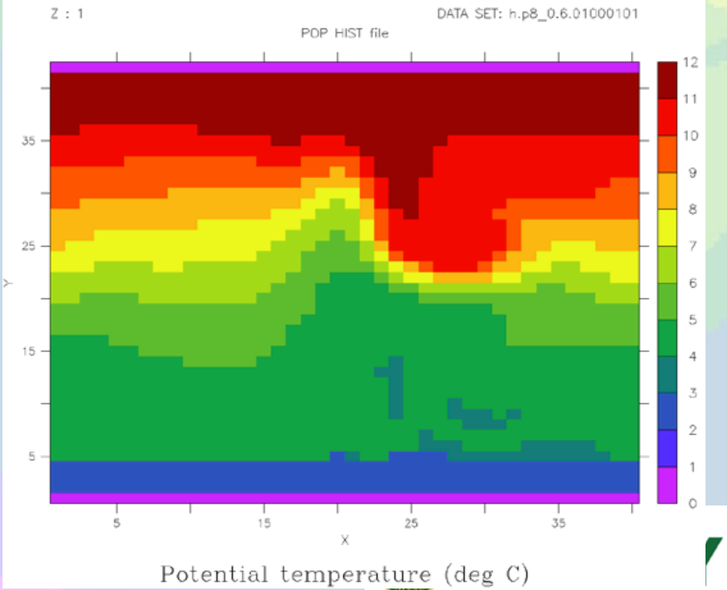
- 11 over 1-parameter GM (GM Overall Scale)
- 60 over 2-parameter GM (+ GM Stratification Tapering Limit)
- 90 over 3-parameter GM (+ GM Slope Limit - prospective)



SST, 0.1° (5.5 km) grid spacing



SST, 0.8° (44 km) grid spacing



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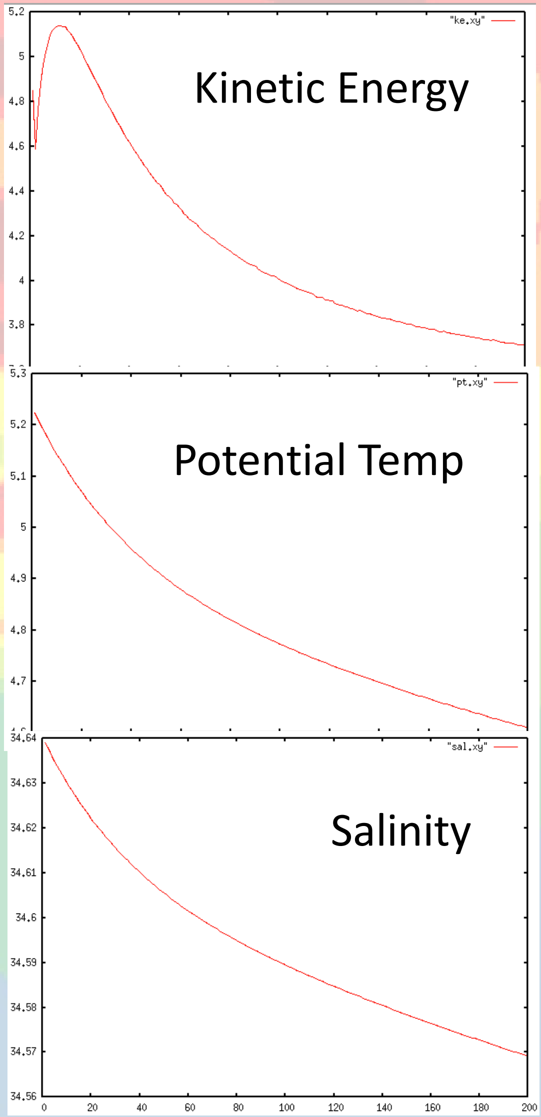
Equilibration of idealized Southern Ocean

200 year sim's at 0.8 degree resolution



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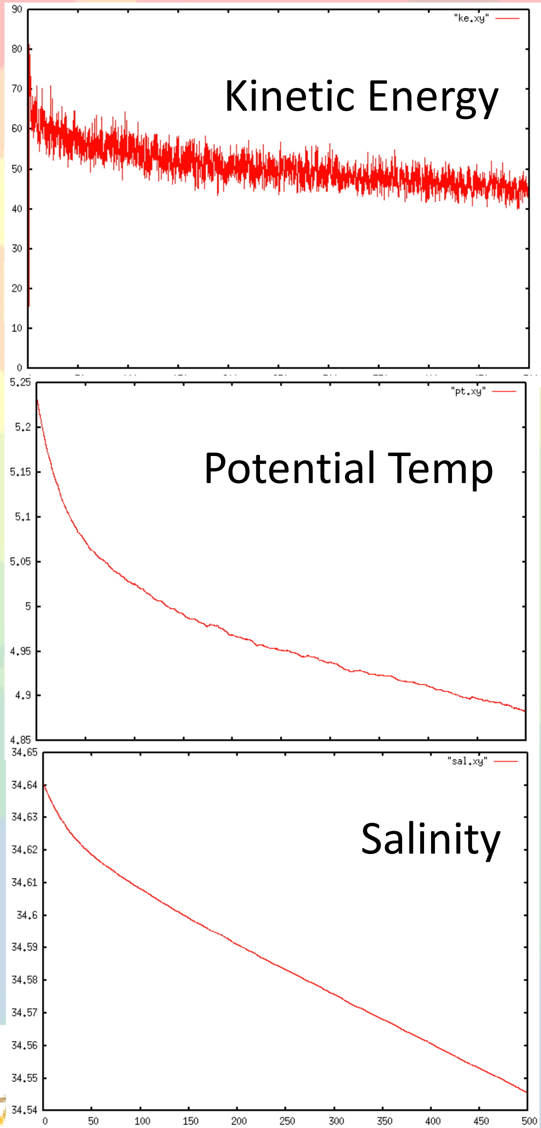
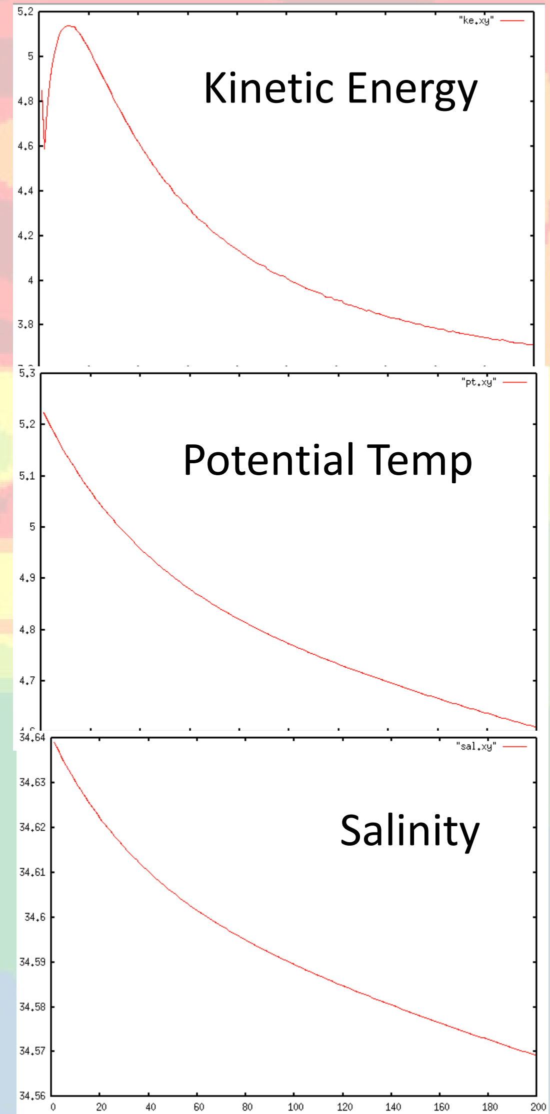
Equilibration of idealized Southern Ocean



200 year sim's at 0.8 degree resolution →

500 year sim. at 0.1 degree resolution ←



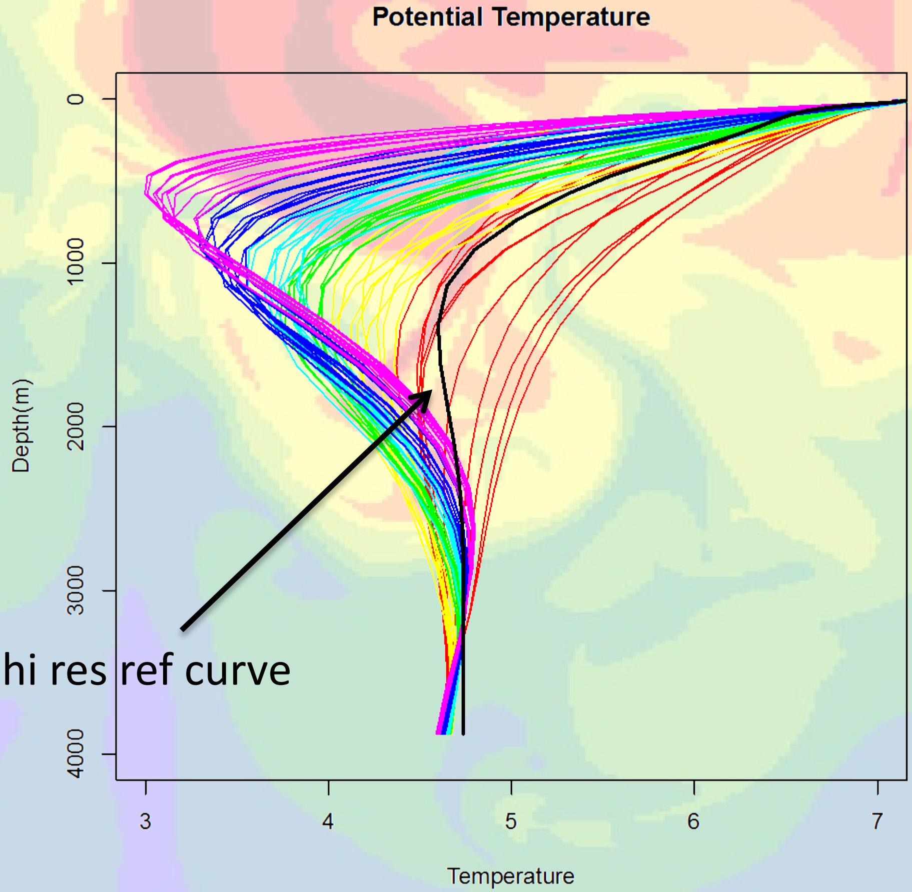
(See Ward and Hogg, Ocn. Modelling 2011, for relevant discussion of equilibration)

Evaluation:

Simple, effective "metrics"

Potential temperature as a function of depth (horizontally averaged):

Also for Salinity, density



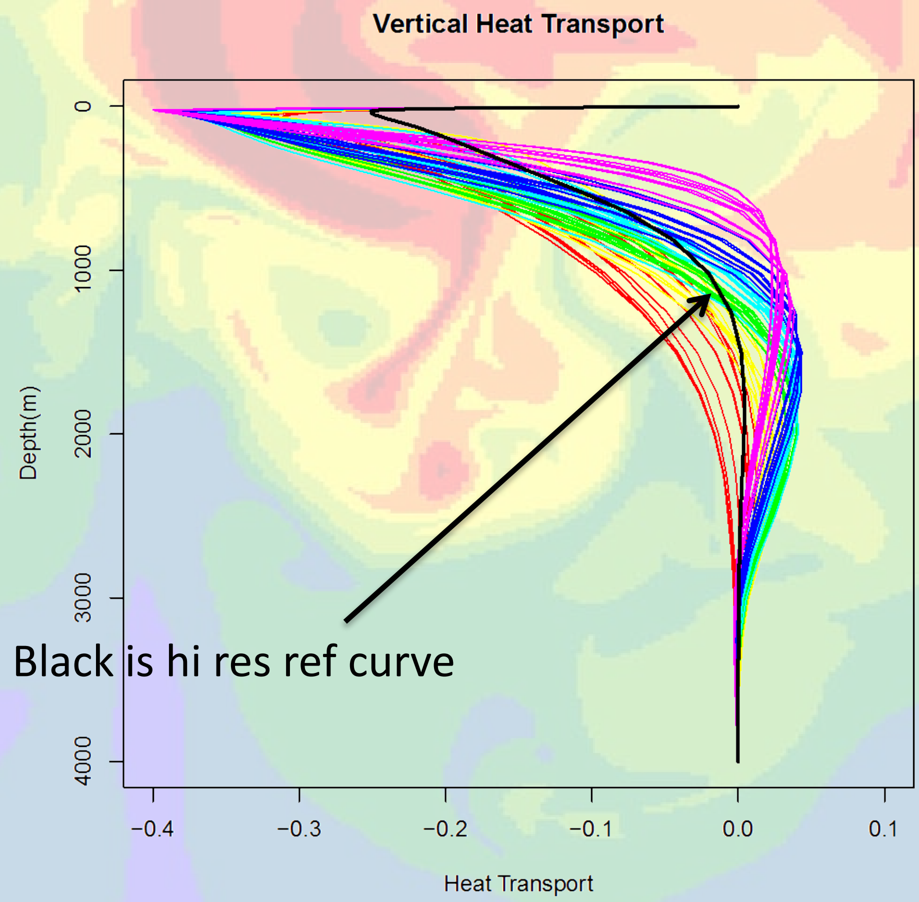
Black is hi res ref curve

This had proven useful in evaluation of LANS-alpha (Petersen, Hecht, Holm and Wingate papers, 2008).

Evaluation:
Simple, effective "metrics"

Vertical heat transport(horizontally integrated):

Also for Salinity



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Model Qualification with Methods from Uncertainty Quantification

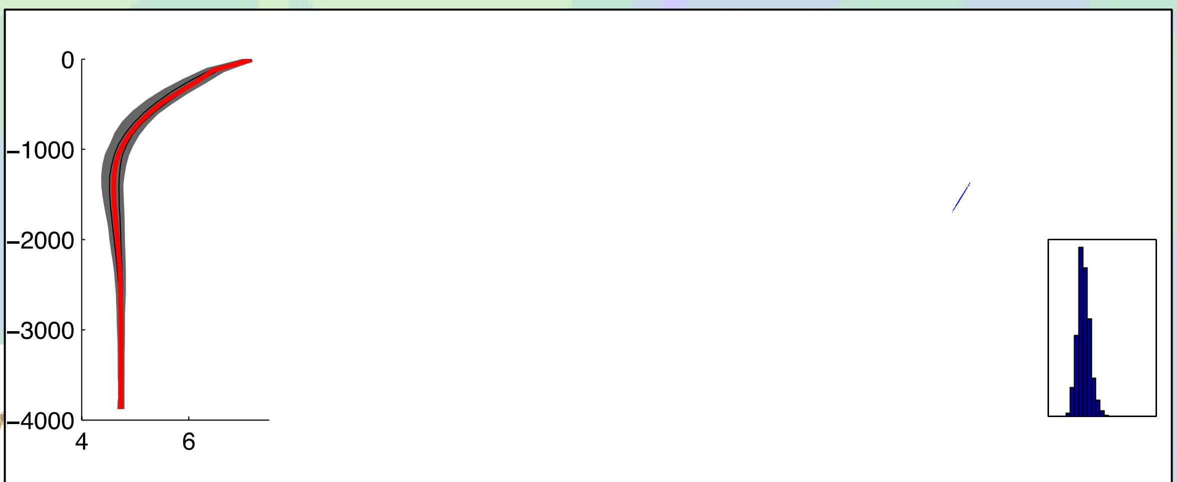
Uncertainty Quantification: Assess uncertainty by comparing model to data

Model Qualification: Score model performance.

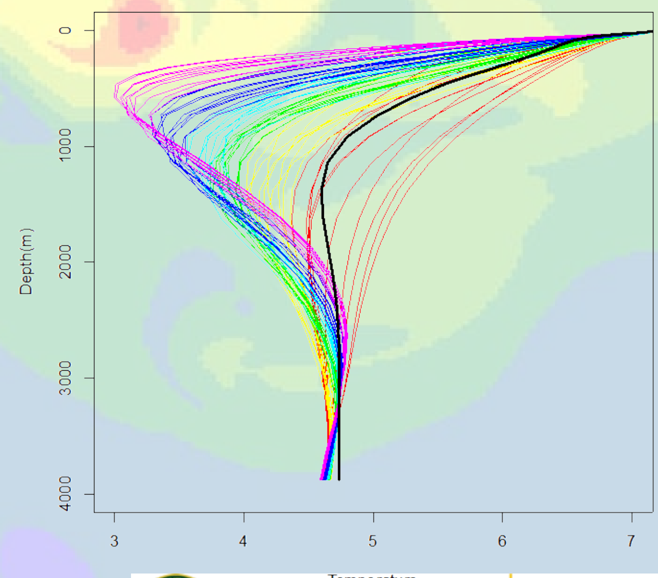
Why UQ? Need to assess the impact of uncertain parameters.

- Gaussian process emulator allows dense sampling of parameter distributions
- Calibration of free parameters gives domain of interest
- Structural discrepancy of calibrated model leads to performance score

Predicted target Structural discrepancyModel error Calibrated parameters



Potential Temperature



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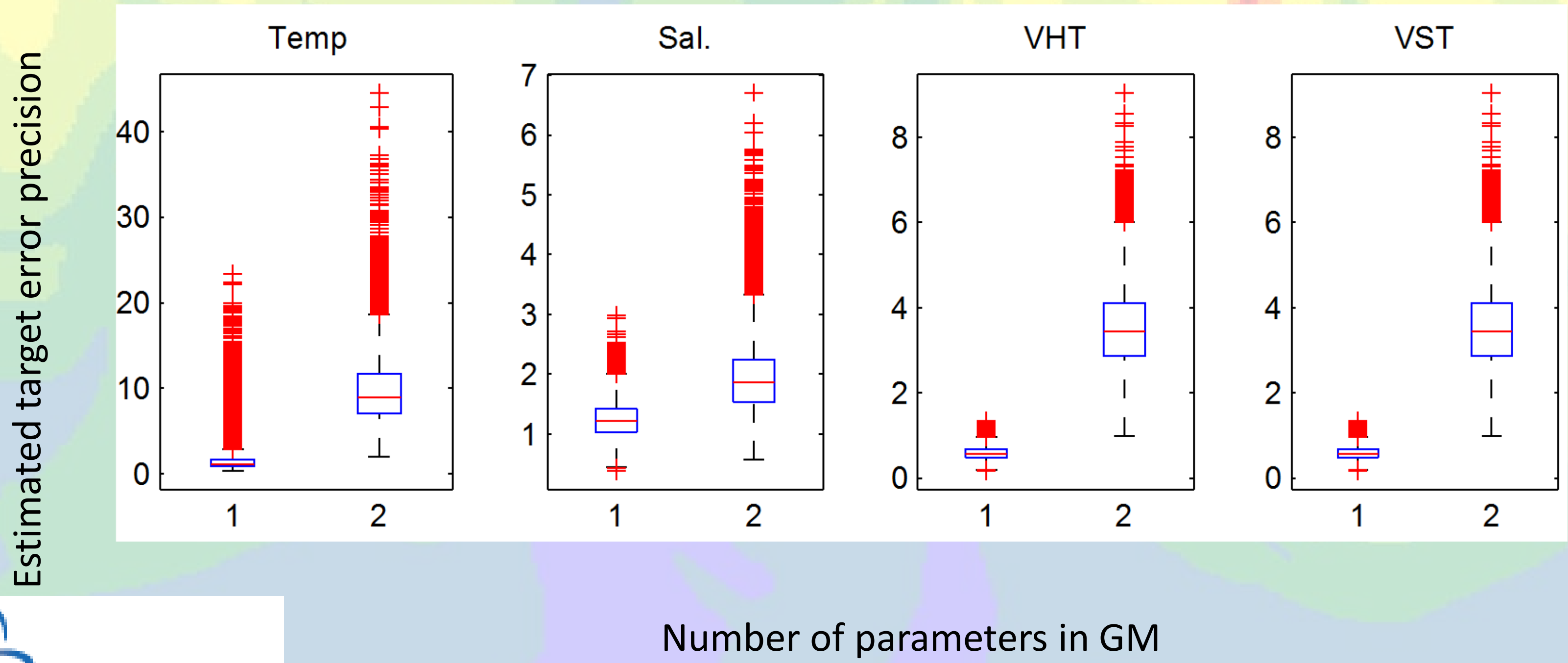
Summary measure for model qualification

Discrepancy magnitude can be summarized with a target variability term

Result shows 2-parameter GM is better than 1-parameter GM in all metrics.



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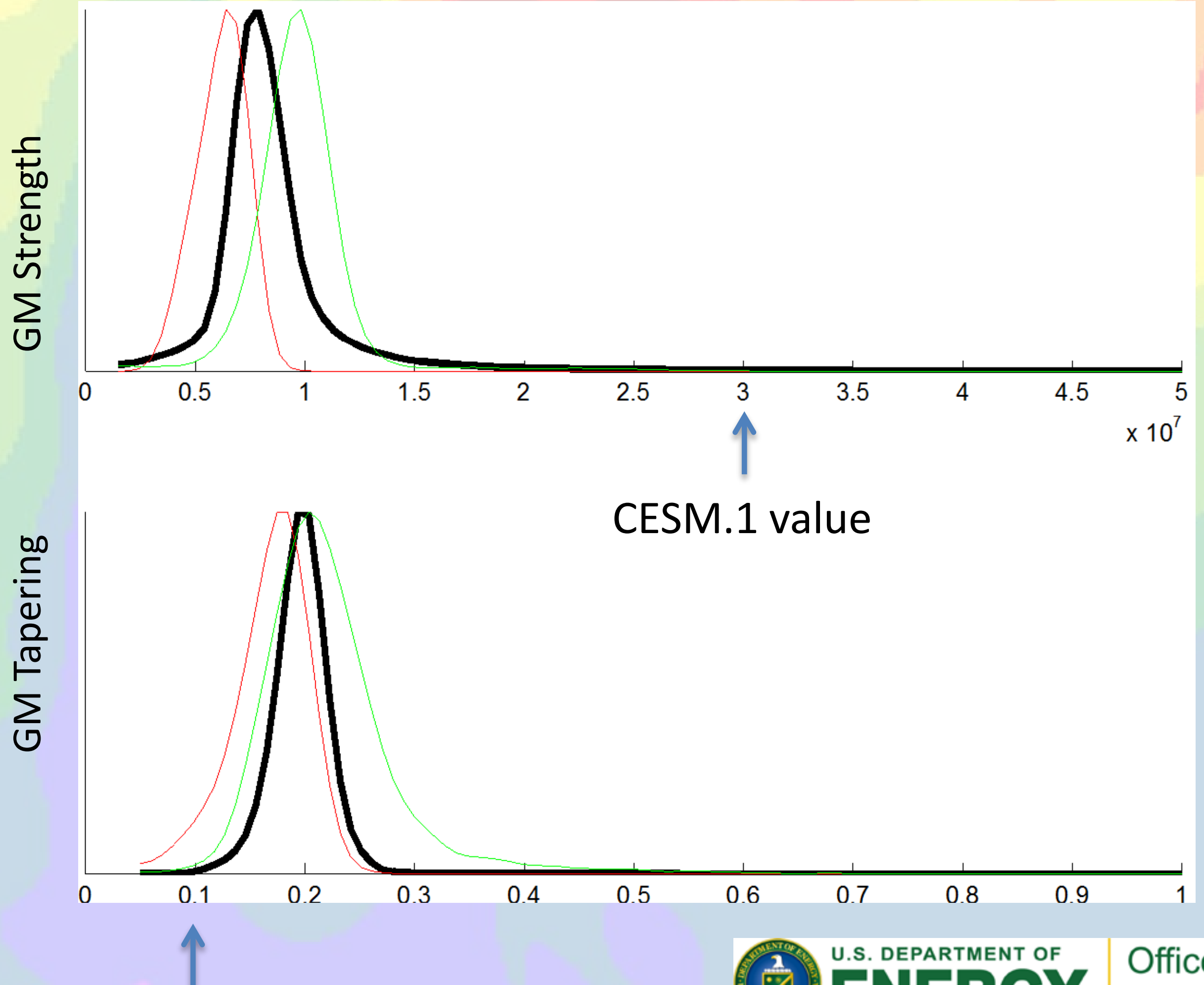
Hierarchical Models Combine Information from Metrics

Hierarchical distribution on parameters combines information appropriate to their degree of independence.

Illustration with

- the two parameters:
  - GM Strength,
  - GM Tapering
- based on two metrics:
  - Temperature vs. depth
  - Salinity vs. depth…

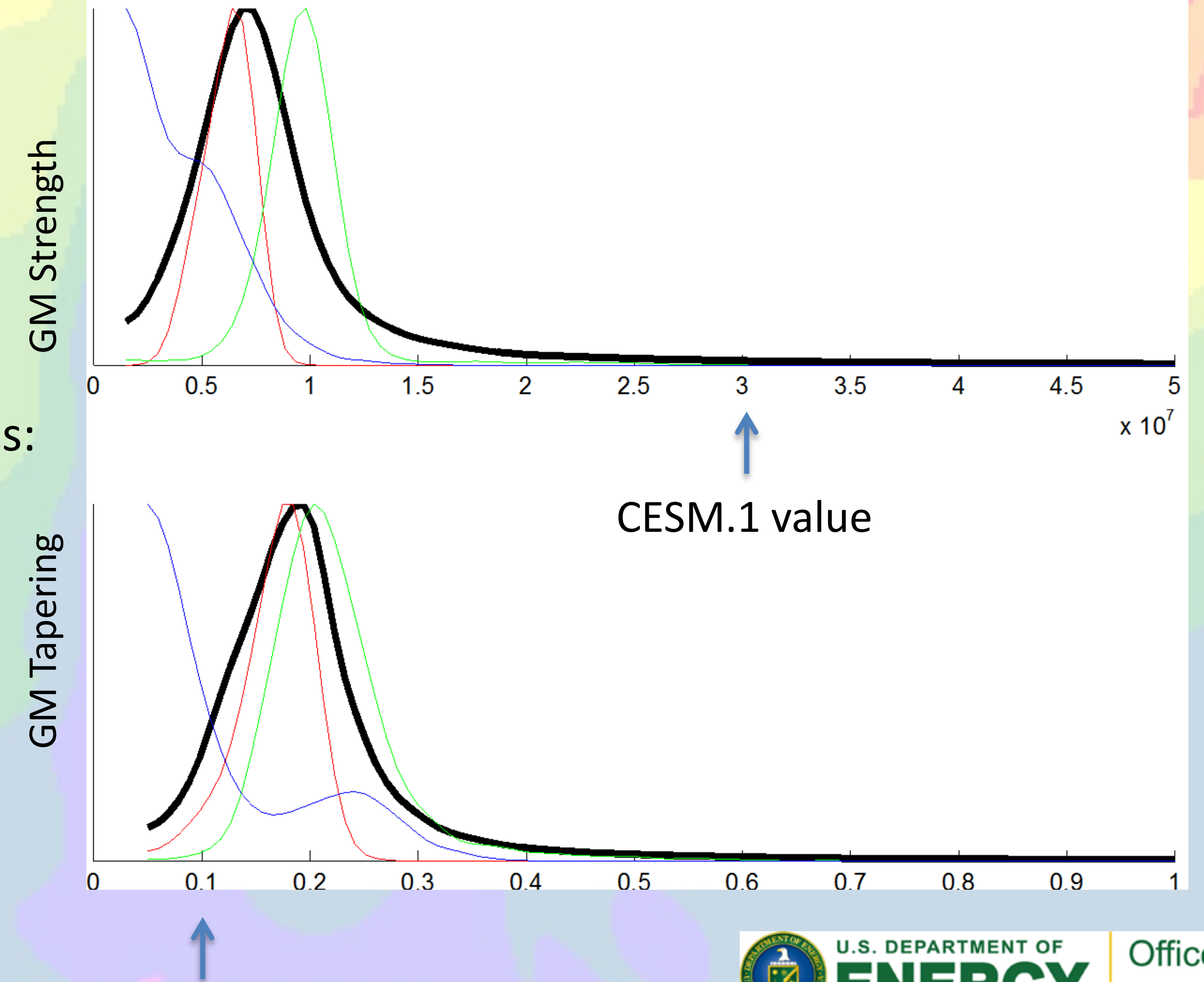


Hierarchical Models Combine Information from Metrics

Hierarchical distribution on parameters combines information appropriate to their degree of independence.

Illustration with

- the two parameters:
  - GM Strength,
  - GM Tapering
- based on three metrics:
  - Temperature vs. depth
  - Salinity vs. depth
  - Density vs. depth

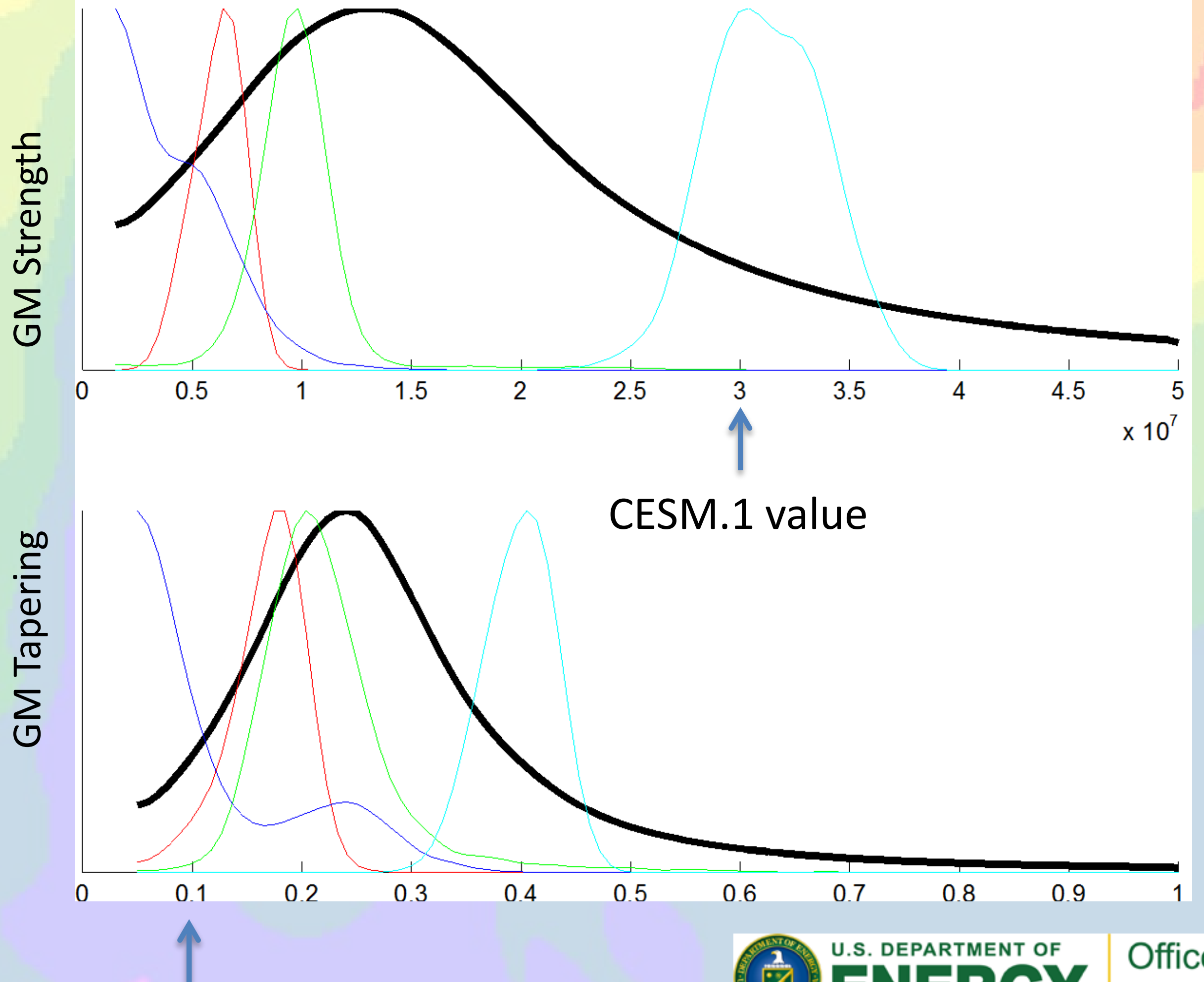


Hierarchical Models Combine Information from Metrics

Hierarchical distribution on parameters combines information appropriate to their degree of independence.

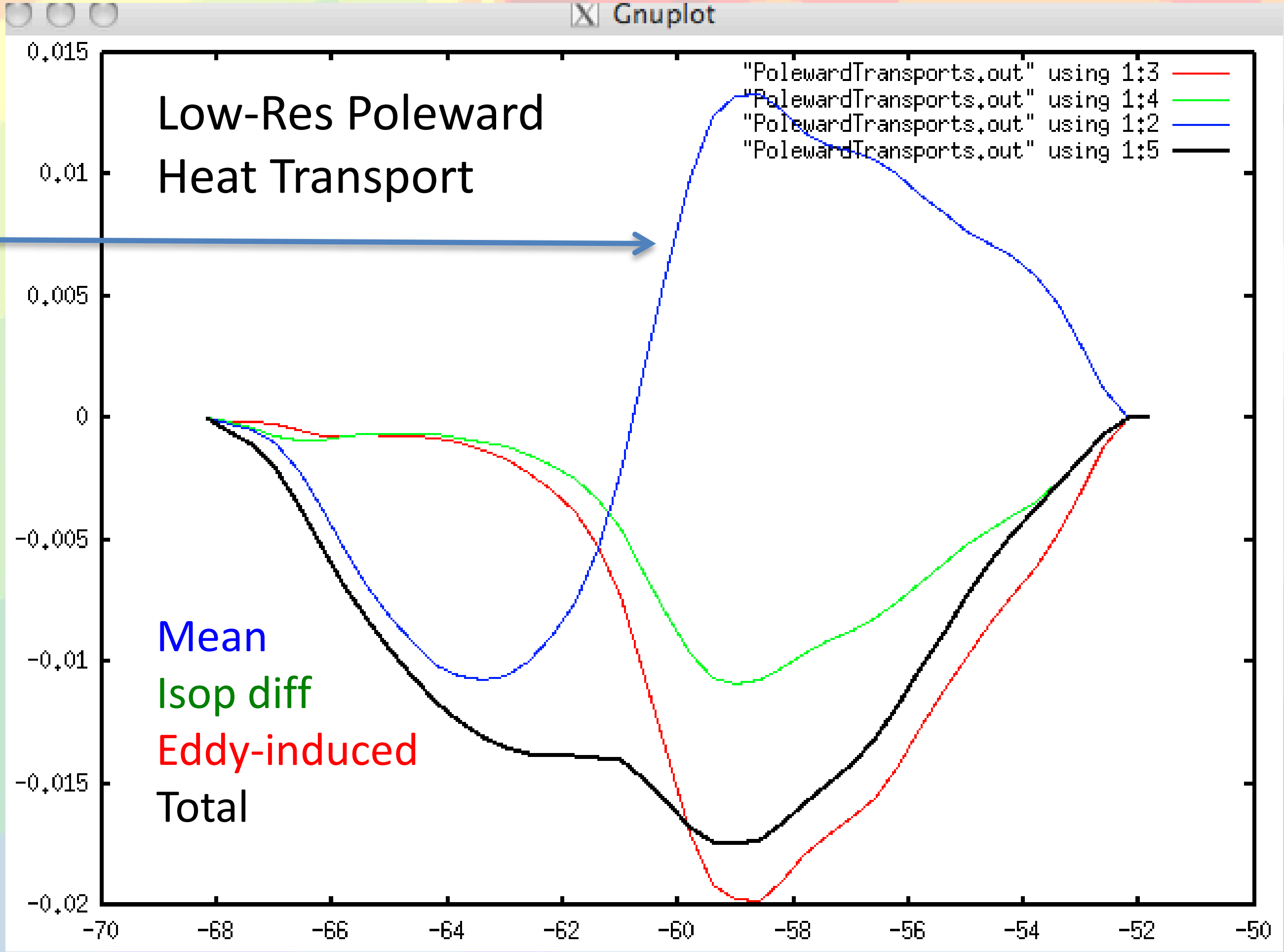
Illustration with

- the two parameters:
  - GM Strength,
  - GM Tapering
- based on four metrics:
  - Temperature vs. depth
  - Salinity vs. depth
  - Density vs. depth
  - Vertical heat transport



Aside: would be natural to use poleward transports as metric

Over much of the domain, time-mean transport sends heat *towards* the equator



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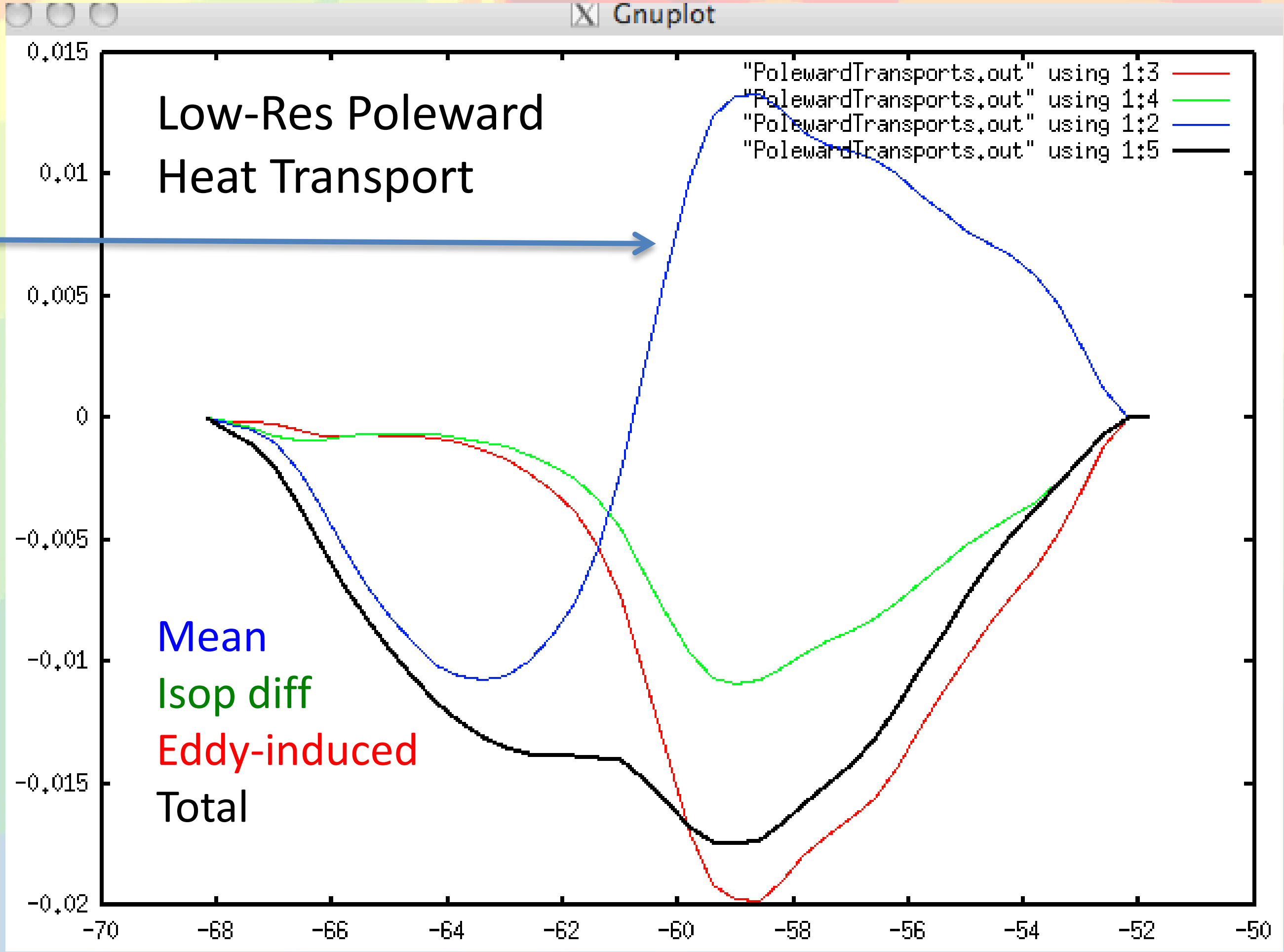
Over much of the domain, time-mean transport sends heat *towards* the equator

But eddy components deliver strong poleward heat transport



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Aside: would be natural to use poleward transports as metric

Over much of the domain, time-mean transport sends heat *towards* the equator

But eddy components deliver strong poleward heat transport

At Fall AGU (2012), Ryan Abernathy showed that High Res eddying case does this too – when there's no ridge.

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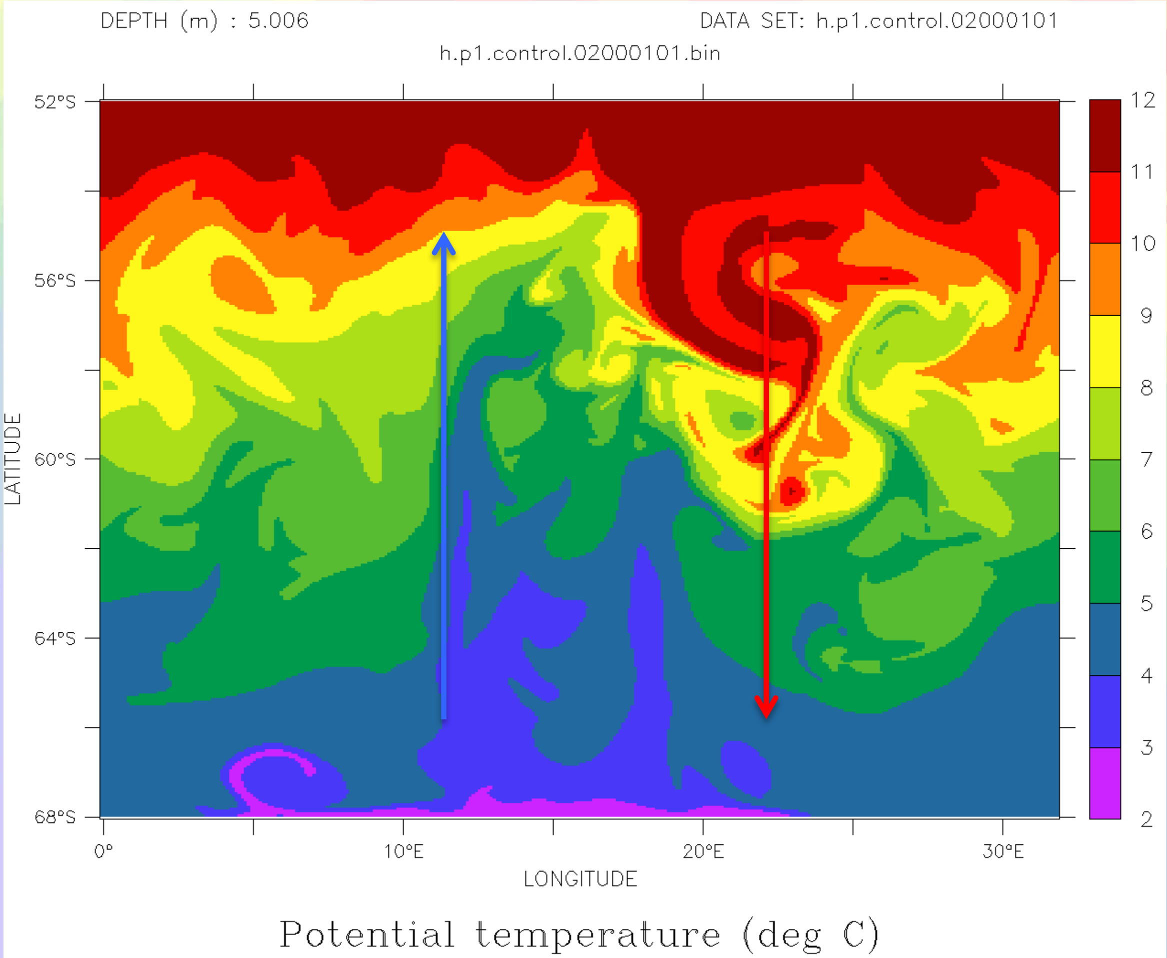
Aside: would be natural to use poleward transports as metric

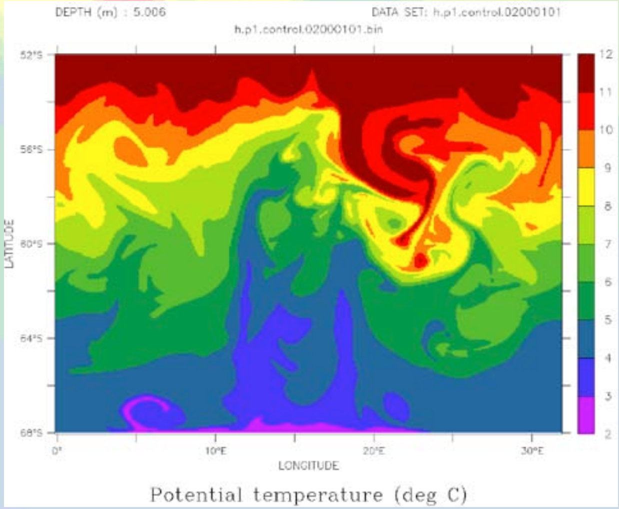
When there's a ridge, time-mean includes the "standing eddy", which delivers heat poleward – takes over much of poleward heat transport.



Aside: would be natural to use poleward transports as metric

When there's a ridge, time-mean includes the "standing eddy", which delivers heat poleward – takes over much of poleward heat transport.

Here, high and low res mean flows are qualitatively similar, but differ quantitatively. How then can we expect the eddy transports to match quantitatively?



Potential temperature (deg C)

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Comment

- Success depends on appropriate choice of problem, identification of effective metrics

Conclusions, to date

- The stratification-dependence of GM coefficient is advantageous
  - New form of GM is better than the old
- Parameter Estimation supports a lower value of the overall coefficient, with less severe tapering
  - Results subject to refinement, as we fill out development of metrics
- Can use these values in ocean component of climate system model,
  - or perform Parameter Estimation in global configuration
- Testbed may provide context in which to evaluate new ideas for eddy mixing schemes