Estimating the Eddy Diffusivity From High-Resolution Passive Tracer Simulations

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Objective

Use high resolution simulations to inform our choices in the design, tuning, and testing of parameterizations for coarse resolution models

- Seek the full 9 element diffusivity tensor as function of space (and possibly season) within a realistic global ocean circulation
- We are not starting with a particular mixing parameterization in mind
- Assume a linear relationship between the turbulent eddy fluxes and the large-scale tracer gradients
- Assume the same diffusivity tensor applies to all tracers
- Assess the structure of the tensor predicted by any parameterization against the diagnosed tensor

Methodology

- Follow experimental design of Plumb and Mahlman (1987)
- Consider two passive tracers in 2D:

$$\begin{bmatrix} v'q_1' & v'q_2' \\ w'q_1' & w'q_2' \end{bmatrix} = -\begin{bmatrix} K_{yy} & K_{yz} \\ K_{zy} & K_{zz} \end{bmatrix} \begin{bmatrix} \frac{\partial \overline{q}_1}{\partial y} & \frac{\partial \overline{q}_2}{\partial y} \\ \frac{\partial \overline{q}_1}{\partial z} & \frac{\partial \overline{q}_2}{\partial z} \end{bmatrix}$$

- Four equations in four unknowns:

$$\begin{bmatrix} K_{yy} & K_{yz} \\ K_{zy} & K_{zz} \end{bmatrix} = -\begin{bmatrix} v'q_1' & v'q_2' \\ w'q_1' & w'q_2' \end{bmatrix} \frac{1}{\begin{vmatrix} \frac{\partial \overline{q}_1}{\partial y} & \frac{\partial \overline{q}_2}{\partial y} \\ \frac{\partial \overline{q}_1}{\partial z} & \frac{\partial \overline{q}_2}{\partial z} \end{vmatrix}} \begin{bmatrix} \frac{\partial \overline{q}_2}{\partial z} & -\frac{\partial \overline{q}_2}{\partial y} \\ -\frac{\partial \overline{q}_1}{\partial z} & \frac{\partial \overline{q}_1}{\partial y} \end{bmatrix}$$

Extend to 3D Following Bratseth (1998)

- Need at least three tracers in 3D
- We will solve an over-determined problem using nine passive tracers:

$$\frac{Dq_i}{Dt} = -\frac{1}{\tau_i}(q_i - \hat{q}_i)$$

$$\hat{q}_{1,4,7} \propto \varphi \qquad \tau_{1-3} = 180\,days$$

$$\hat{q}_{2,5,8} \propto \sin(\lambda) \qquad \tau_{4-6} = 365\,days$$

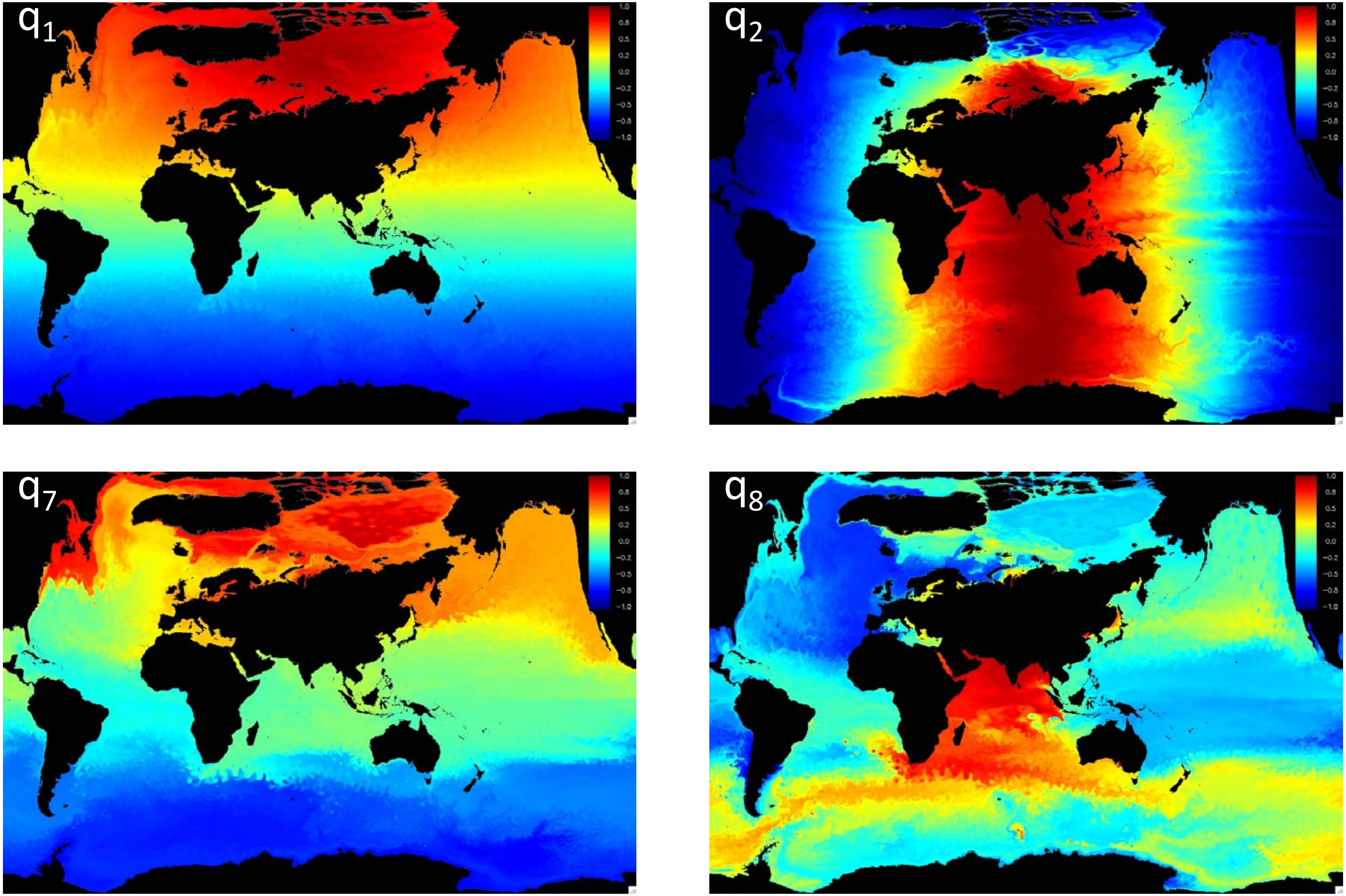
$$\hat{q}_{3,6,9} \propto z \qquad \tau_{7-9} = \infty$$

- Supplemented with active tracers (T, S, PV) as needed

Model Configuration

- Global 0.1° dipole configuration of Maltrud and McClean (2006) modified by:
  - Partial bottom cells
  - Lower biharmonic dissipation
  - Climatological monthly mean forcing
  - Extensive software optimization to run on IBM Bluegene system
- 13 year spin-up from WOCE SAC hydrography
- 10 year tracer simulation

Solution After 10 Years of Simulation



- Coarsen 5-year time-mean gradients and eddy fluxes from 0.1° to 2°
  - *still exploring alternative methods for this step*
- Find solution for **K** on coarse grid that minimizes:

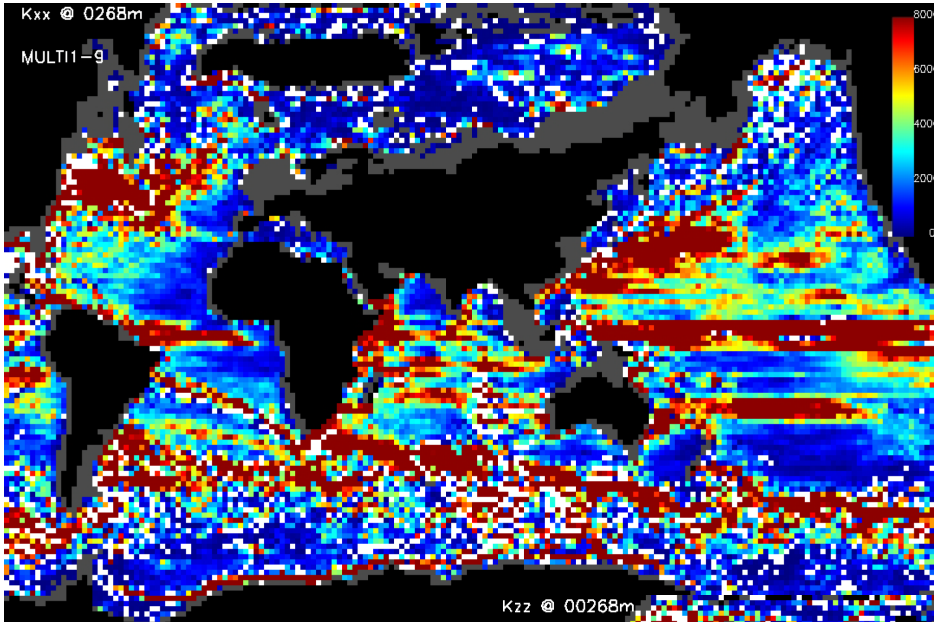
$$J_u = \sum_i W_{ui}(u'q'_i + K_{xx}\frac{\partial \overline{q}_i}{\partial x} + K_{xy}\frac{\partial \overline{q}_i}{\partial y} + K_{zz}\frac{\partial \overline{q}_i}{\partial z})^2$$

$$J_v = \sum_i W_{vi}(v'q'_i + K_{yx}\frac{\partial \overline{q}_i}{\partial x} + K_{yy}\frac{\partial \overline{q}_i}{\partial y} + K_{yz}\frac{\partial \overline{q}_i}{\partial z})^2$$

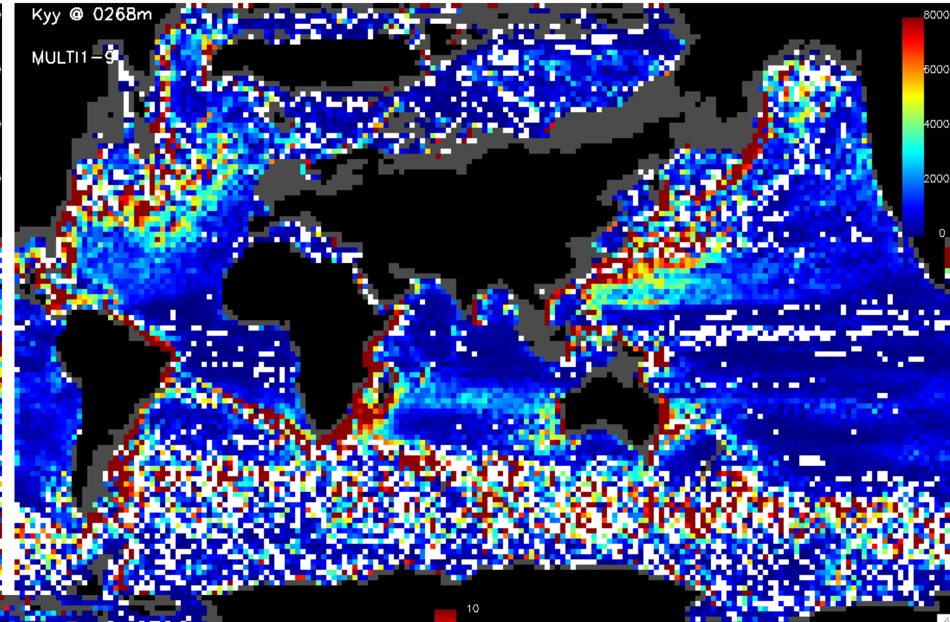
$$J_w = \sum_i W_{wi}(w'q'_i + K_{zx}\frac{\partial \overline{q}_i}{\partial x} + K_{zy}\frac{\partial \overline{q}_i}{\partial y} + K_{zz}\frac{\partial \overline{q}_i}{\partial z})^2$$

Diagonal Components @ 268m

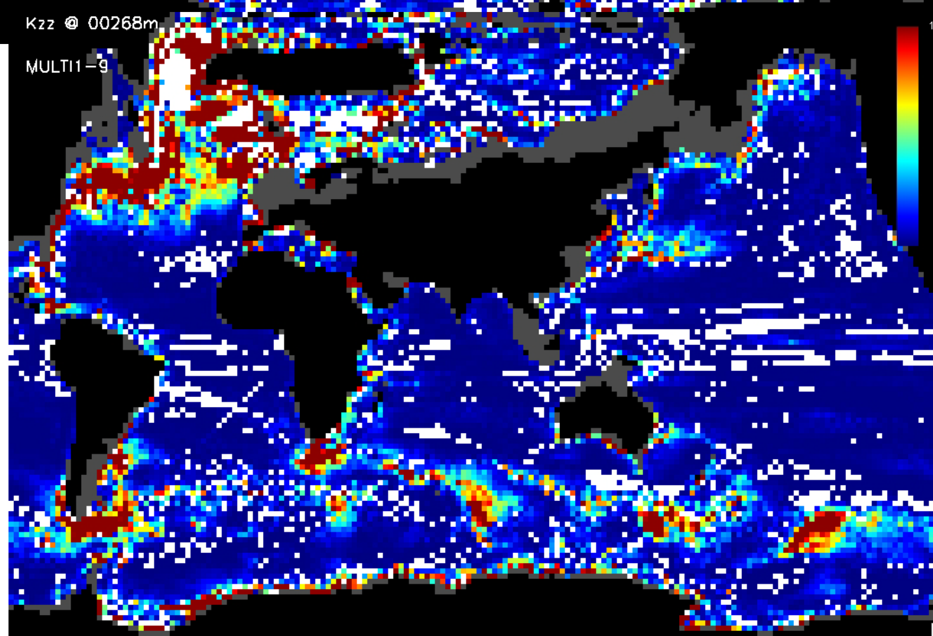
K_{xx}



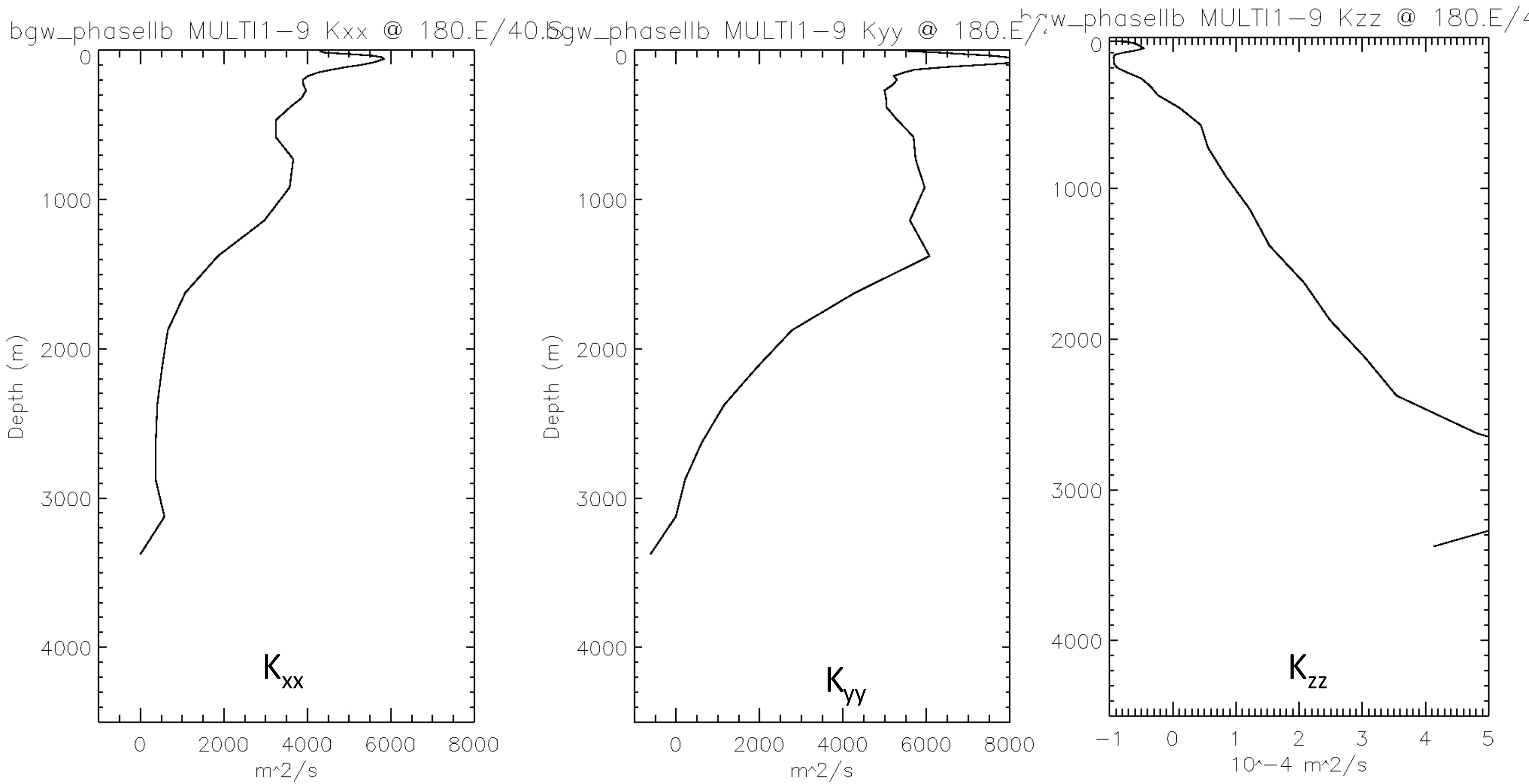
K_{yy}



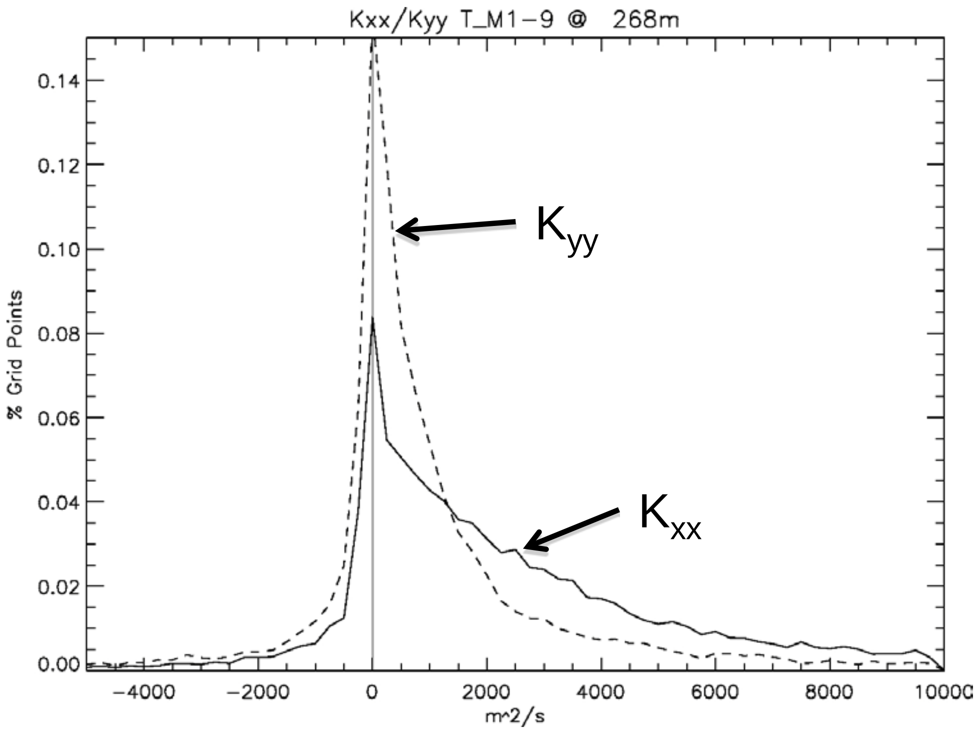
K_{zz}

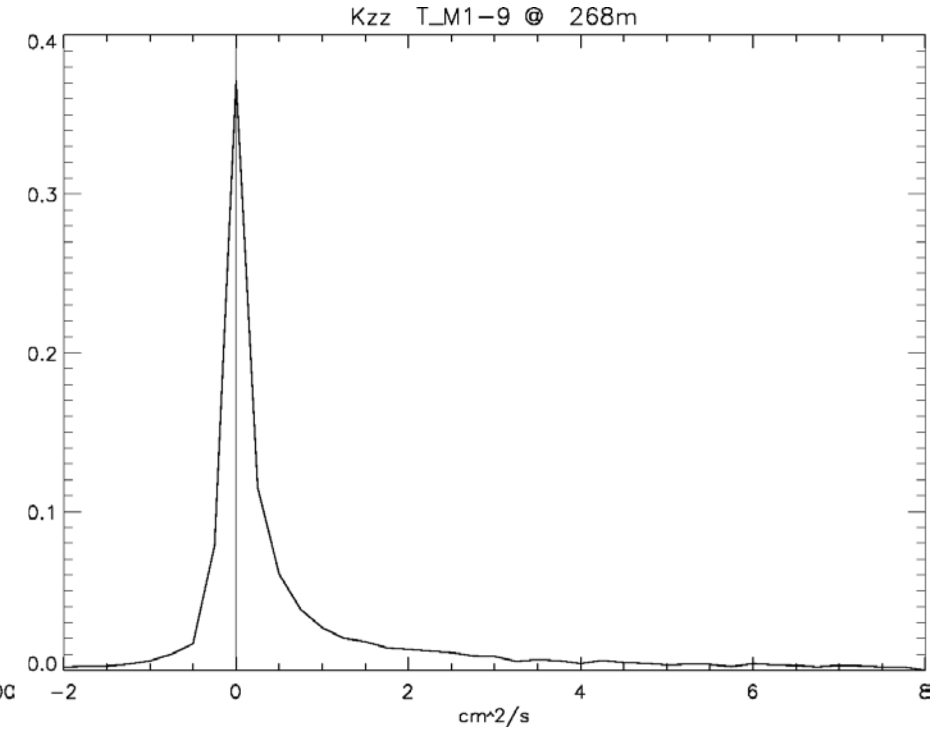


Vertical Distribution in ACC

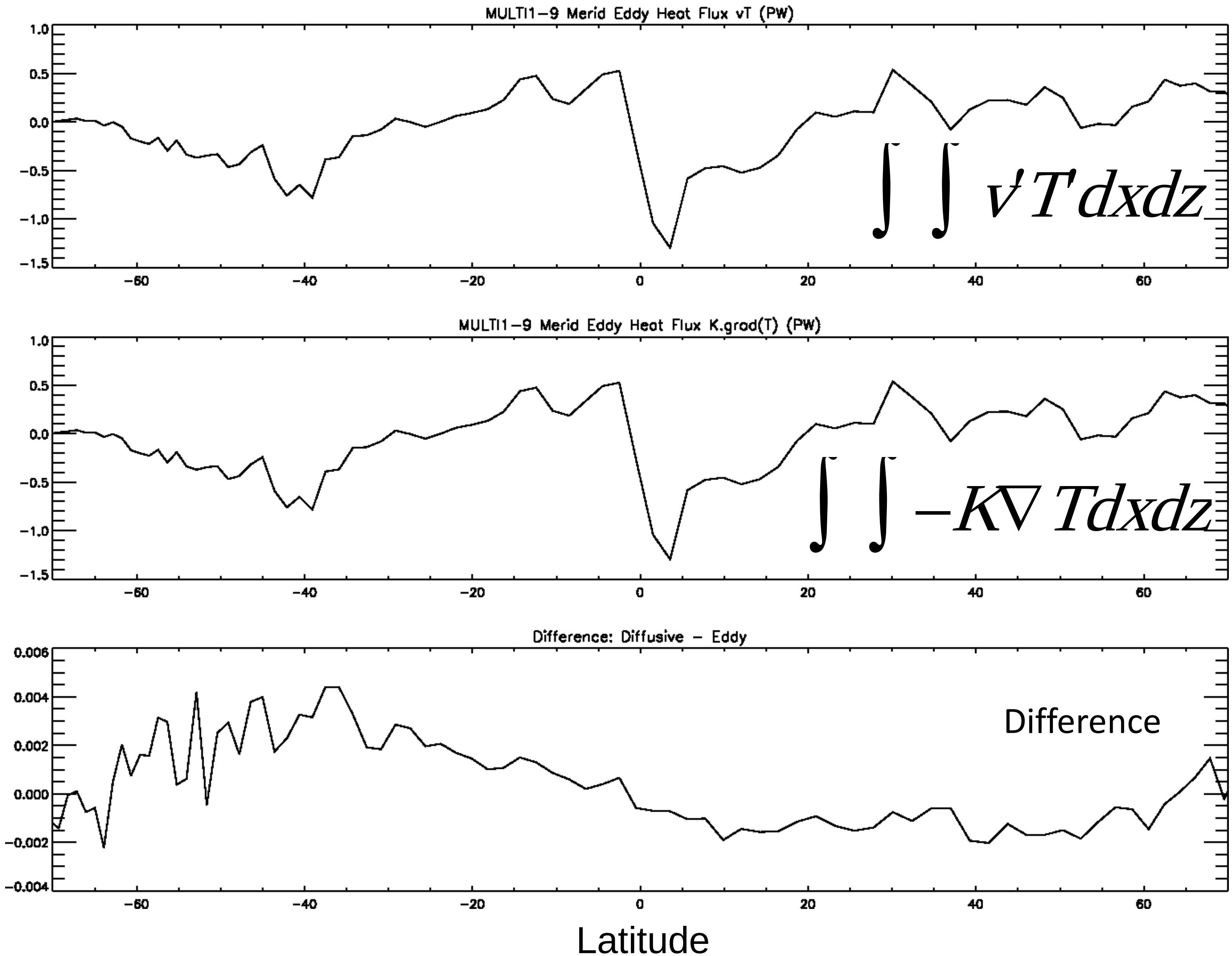


Freq. Distribution of Diagonal Elements





Testing the Diffusive Parameterization



Conclusions

- A solution for **K** looks feasible for a large fraction of the ocean using the Bratseth method.
- There is some sensitivity to the details in the choice of space-time coarsening.
- There is weak sensitivity to the choice of weighting in the minimization
- It remains to be seen if we can use the resulting K to assess the formulation of extant or proposed parameterizations.