Estimating The Eddy Diffusivity Tensor

Follow-Up to a Discussion at the December 2006 OMWG meeting

The Concept

(outlined by Baylor Fox-Kemper in December)

- Apply the methodology of Plumb and Mahlman (1987) to estimate the three dimensional distribution of all nine components of the eddy diffusivity tensor
- In 2D, assert same eddy diffusivity applies to two tracers:

$$\begin{bmatrix} \overline{v'\tau_1'} & \overline{v'\tau_2'} \\ \overline{w'\tau_1'} & \overline{w'\tau_2'} \end{bmatrix} = -\begin{bmatrix} K_{yy} & K_{yz} \\ K_{zy} & K_{zz} \end{bmatrix} \begin{bmatrix} \overline{\tau_{1,y}} & \overline{\tau_{2,1}} \\ \overline{\tau_{1,z}} & \overline{\tau_{2,z}} \end{bmatrix}$$

- Then

$$\begin{bmatrix} K_{yy} & K_{yz} \\ K_{zy} & K_{zz} \end{bmatrix} = -\begin{bmatrix} \overline{v'\tau_1'} & \overline{v'\tau_2'} \\ \overline{w'\tau_1'} & \overline{w'\tau_2'} \end{bmatrix} \frac{1}{\begin{vmatrix} \overline{\tau_{1,y}} & \overline{\tau_{2,y}} \\ \overline{\tau_{1,z}} & \overline{\tau_{2,z}} \end{vmatrix}} \begin{bmatrix} \overline{\tau_{2,z}} & \overline{-\tau_{2,y}} \\ -\overline{\tau_{1,z}} & \overline{\tau_{1,y}} \end{bmatrix}$$

- Extend to 3D and elaborate following Bratseth (1998)
  - Use more than minimum number of tracers (3) to make the problem formally over-determined
  - Find solution for **K** that minimizes:

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

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

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

The Opportunity

- Following December meeting proposal prepared and sent to IBM Watson Research for use of large Bluegene system:
  - John Dennis (NCAR/CISL)
  - Frank Bryan (NCAR/CGD)
  - Baylor Fox-Kemper (MIT-> CU)
  - Mat Maltrud (LANL)
  - Julie McClean (Scripps/LLNL)
  - Synte Peacock (U. Chicago -> NCAR/CGD)
- Our proposal selected from pool of projects across all disciplines
  - Awarded 110 “rack days” (1 rack = 2k Pes)
  - Very restrictive storage constraints

The Experiment

- Global 0.1° forced ocean simulation based on configuration of Maltrud and McClean (2005) except:
  - Partial bottom cells
  - Climatological monthly mean forcing
- Integration:
  - 10-15 years physics spin-up
  - 5 years passive tracer spin-up
  - 5 year sampling of tracers and fluxes (seasonal statistics)
- Data recovered by portable RAID system via FedEX

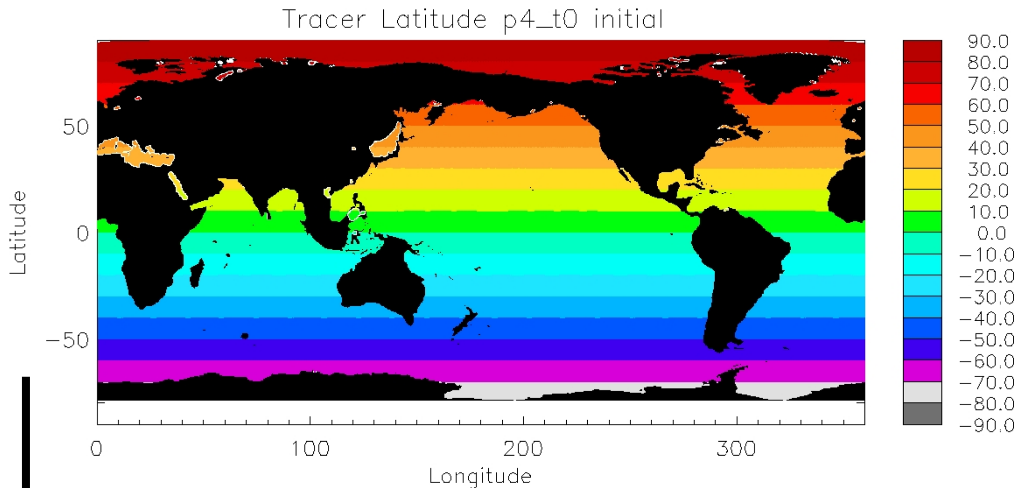
Research Challenges and Opportunites

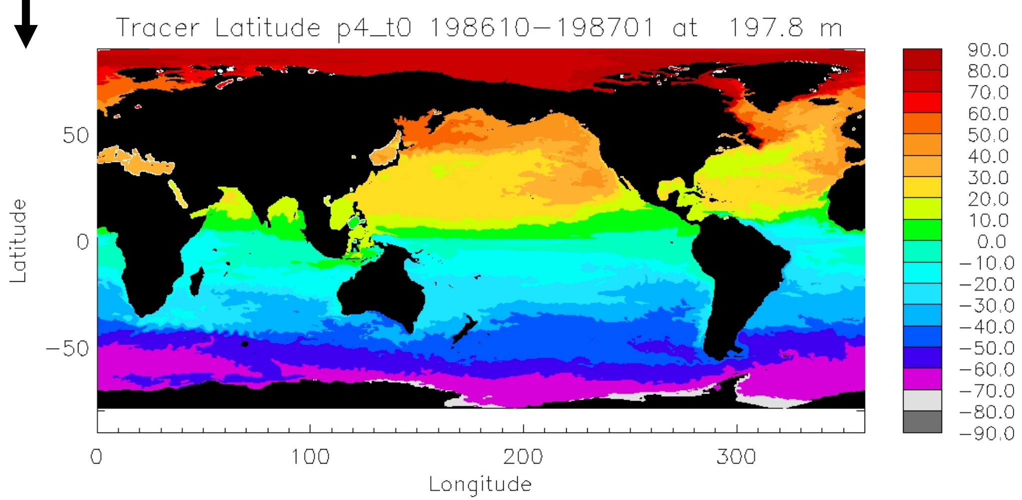
- Defining initial tracer distributions and forcing to keep tracers independent:
  - Θ, S, PV, IA, $\sim z$, $\sim\phi$, $\sim\cos(\lambda)$
  - Preliminary experiments currently underway with 0.4° model
- Dealing with rotational component of eddy tracer flux?
- Defining the averaging/coarsening procedure (conservation, dependence of the results on scales etc)
- Optimization methods

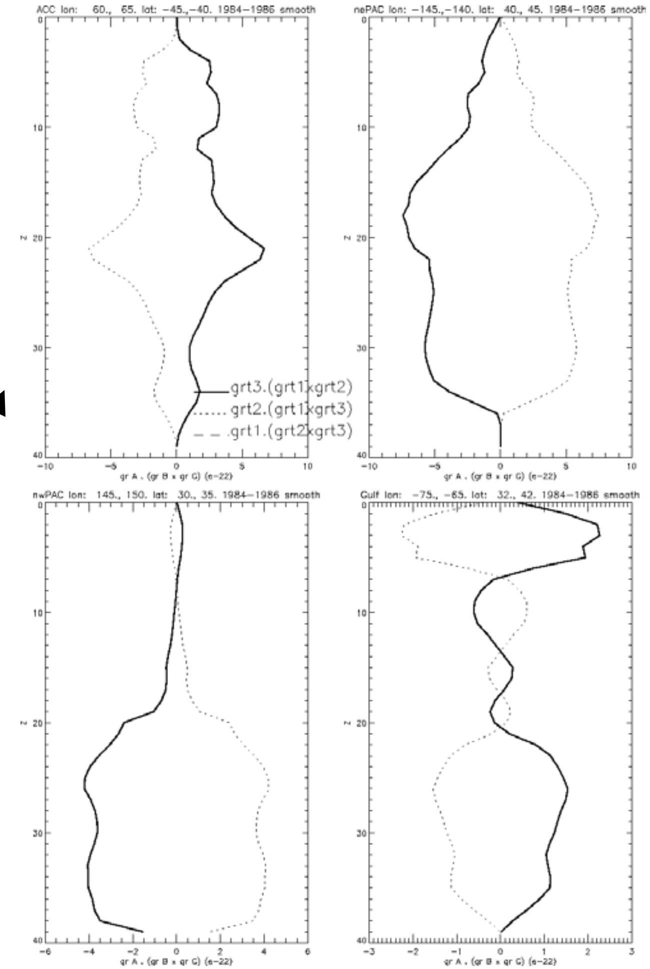
$$\frac{\partial q_i}{\partial t} = -\nabla \bullet (\vec{u} q_i) + \ldots + \gamma_i(\vec{x})[q_i(t_0) - q_i]$$

$$q_i(t_0) \propto \phi$$

$$|A| = \nabla q_1 \bullet (\nabla q_2 \times \nabla q_3)$$







Technical Challenges

- Need to run on 16k to 32k PEs
  - Excellent scalability demonstrated on BGW with POP benchmark
- But:
  - Need scalable parallel IO (basically done)
  - Finding problems at high processor counts in POP communication infrastructure (have leads for fixes)
  - Apparent memory leak in vendor MPI implementation currently precluding long runs