Climate and Biogeochemistry in a Turbulent, Adiabatic Ocean

Presented by
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While ocean is turbulent both horizontally and vertically....

Diffusivities associated with along-isopycnal motion are often eight orders of magnitude larger than those across isopycnals.

This directly contradicts old diffusive picture of overturning! What’s important in the new picture?

Polzin et al., (1997)
When internal diffusion is low, winds end up being dominant source of energy

Implication: Wind forcing is important

Toggweiler et al, 1993, 1998; Gnanadesikan, 1999; Gnanadesikan and Hallberg, 2000
Toggweiler and Russell, 2008; Delworth and Zeng, 2008
Implication: Wind forcing is important

- When internal diffusion is low, winds end up being dominant source of energy
- *Shifts* in winds may be really important!
- But density still matters

*What does the dominance of wind imply about thermohaline stability?*

Implication: Eddies are important

- Parameterizations may be insufficient to capture mean eddy effects

Hallberg and Gnanadesikan, 2001
Hallberg and Gnanadesikan, 2006
Parameterizations may be insufficient to capture mean eddy effects

Eddies may provide significant buffering of these changes

**How do eddies act in a fully coupled context on centennial scales?**

*Hallberg and Gnanadesikan, 2001*
*Hallberg and Gnanadesikan, 2006*

Winds increased by 20%~10 Sv extra Ekman transport.
• All else being equal, increasing SO watermass transformation increases SO uptake

• But not all is equal if eddies compensate, storage doesn’t change

Winds change thermocline depth

GM coefficient changed to match winds.

Mignone et al., 2006; Russell et al., 2006
• All else being equal, increasing SO watermass transformation increases SO uptake
• But not all is equal if eddies compensate, storage doesn’t change
• Wind shifts may matter

How does this balance work in a fully coupled system?

Mignone et al., 2006; Russell et al., 2006
• **Strong Southern Ocean coupling to deep water (strong winds)**
  – Less storage of carbon
  – High atmospheric pCO2

• **Weak Southern Ocean coupling to deep water (weak winds)**
  – More storage of carbon
  – Low atmospheric pCO2

• **May play a role in 100K cycles**

Model simulations show potential impact comparable to iron fertilization

How does this depend on the details of deep water formation in ESMs?

Toggweiler, 1999
Toggweiler et al., 2003a,b, 2008; Marinov et al., 2006, 2008a,b
• Changing chlorophyll (hence absorption profile) affects SSTs - with implications for circulation, ENSO and cyclogenesis

• Coupling and transport play an important role

• Regionality matters

Sweeney et al., 2005; Anderson et al., 2007,2009; Gnanadesikan and Anderson, 2009; Gnanadesikan et al. (in prep.)
• Eliminating unphysically large background diffusion brings other processes into play: winds, eddies, solar absorption, spatially-dependent mixing

• These processes matter for carbon uptake, biogeochemical cycling - may be important for physical climate