

# Geophysical Fluid Dynamics Laboratory Review

June 30 - July 2, 2009



# Climate and Biogeochemistry in a Turbulent, Adiabatic Ocean

Presented by

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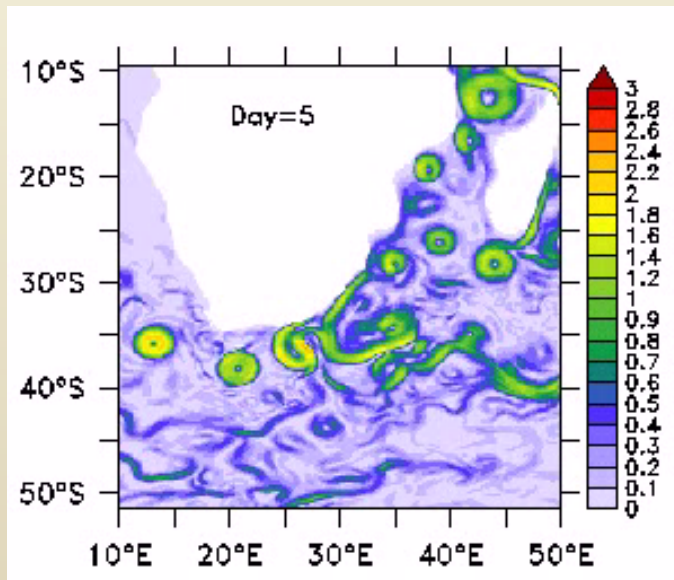
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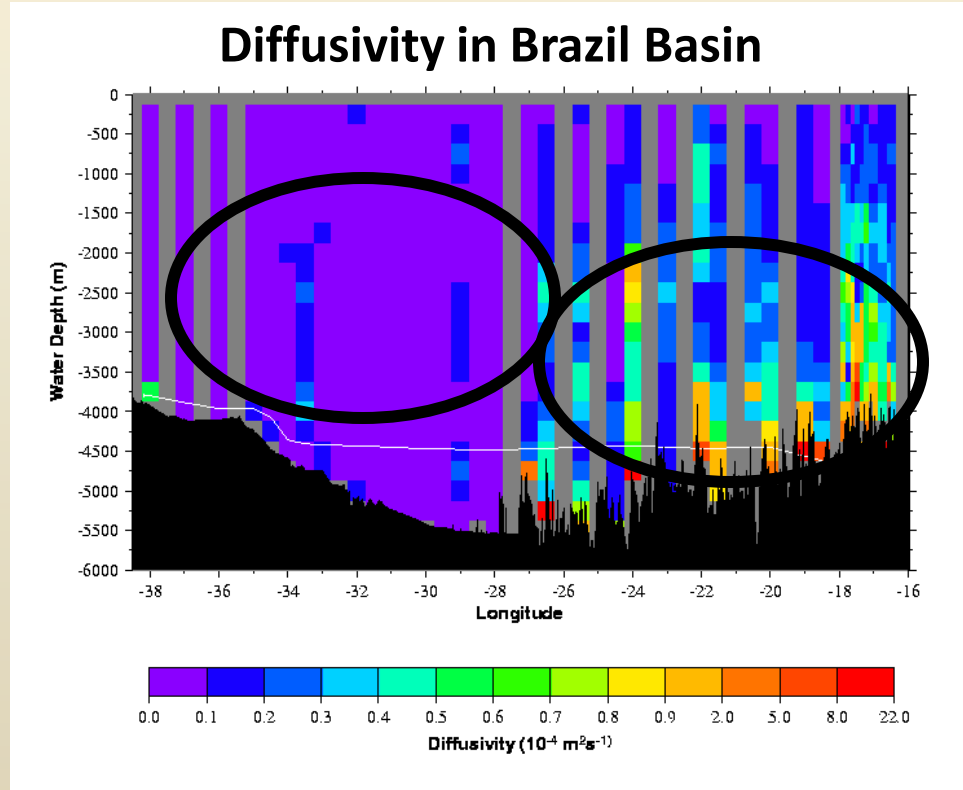


# Turbulent and adiabatic?

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.

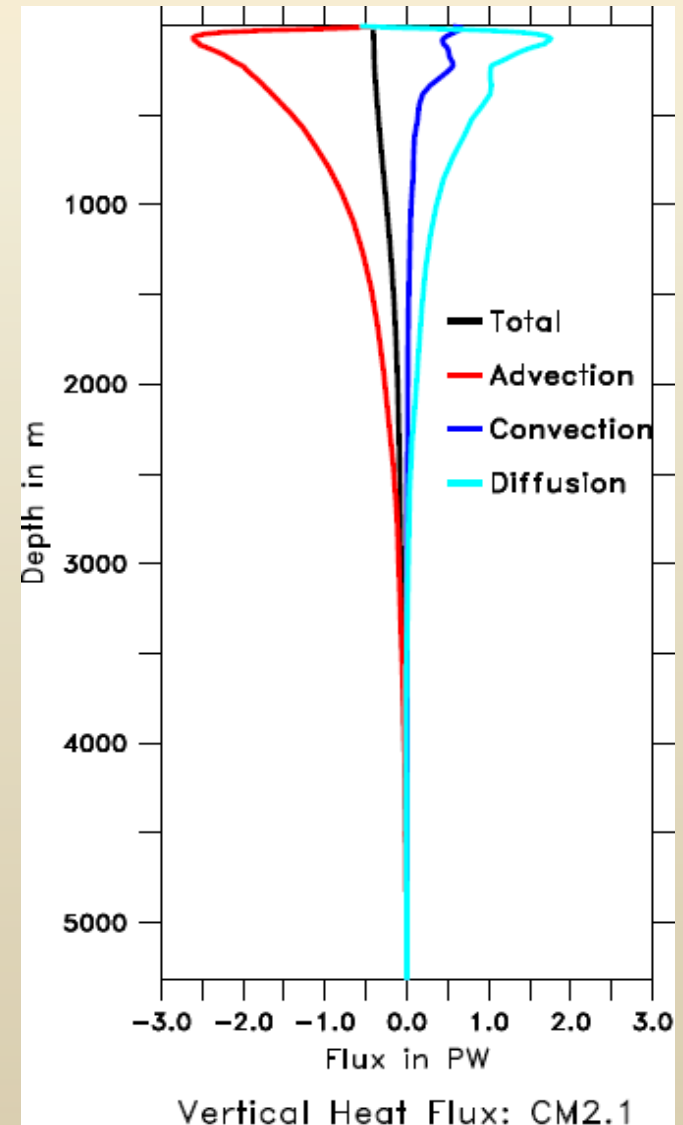


*Polzin et al., (1997)*

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

# Implication: Wind forcing is important

- When internal diffusion is low, winds end up being dominant source of energy

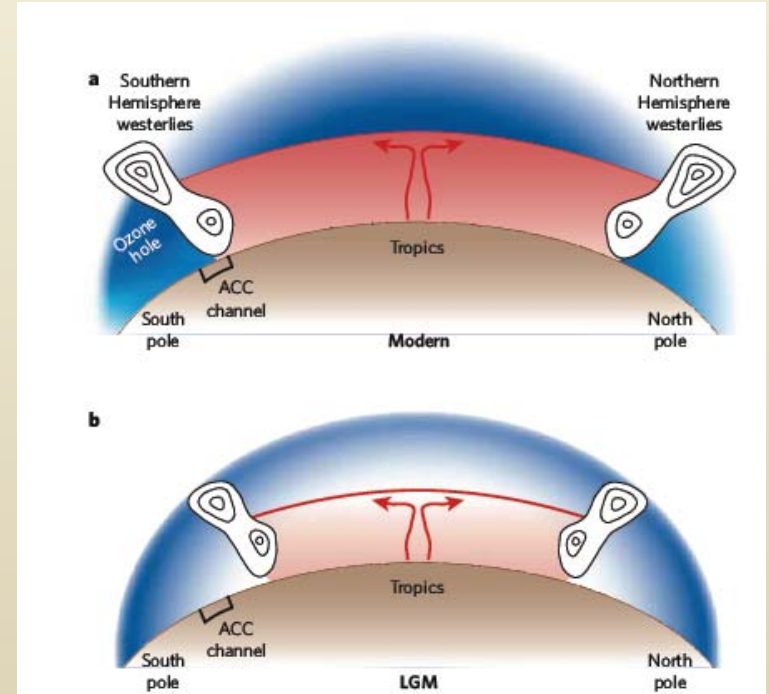


*Toggweiler et al, 1993, 1998; Gnanadesikan, 1999;  
Gnanadesikan and Hallberg, 2000  
Gnanadesikan et al. 2005, 2006, 2007; Fuckar and Vallis, 2008  
Toggweiler and Russell, 2008; Delworth and Zeng, 2008*

# 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

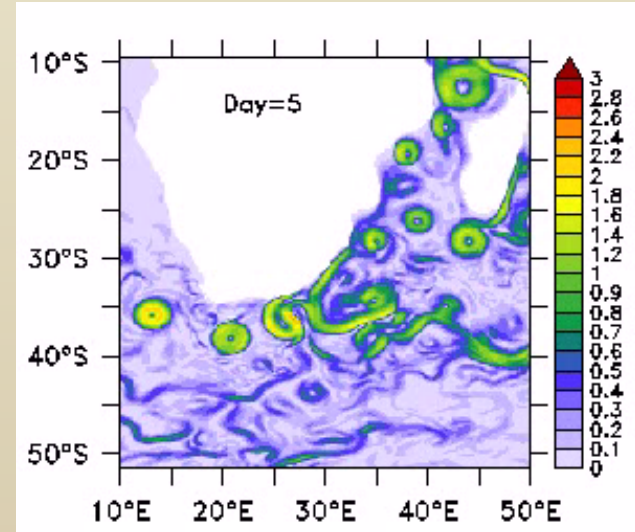
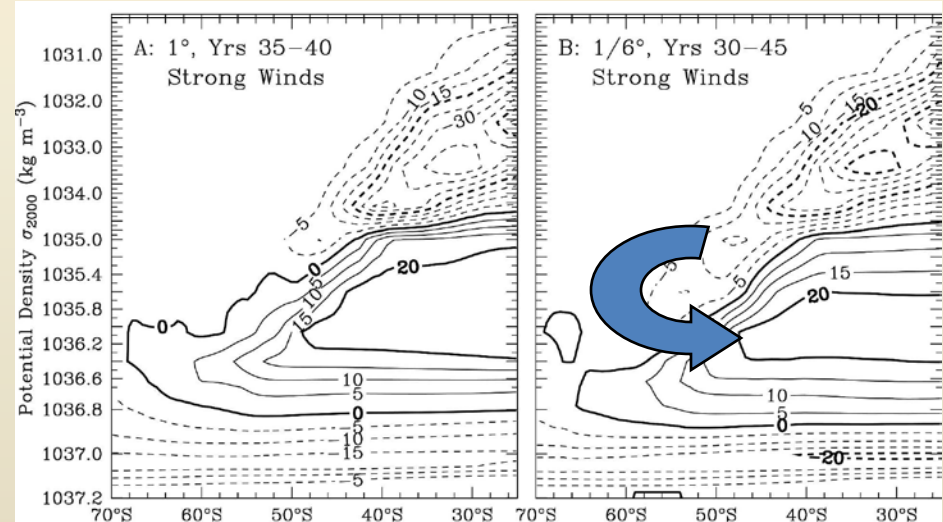
***What does the dominance of wind imply about thermohaline stability?***



*Toggweiler et al, 1993, 1998; Gnanadesikan, 1999;  
Gnanadesikan and Hallberg, 2000  
Gnanadesikan et al. 2005, 2006, 2007; Fuckar and Vallis, 2008  
Toggweiler and Russell, 2008; Delworth and Zeng, 2008*

# Implication: Eddies are important

- Parameterizations may be insufficient to capture mean eddy effects



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

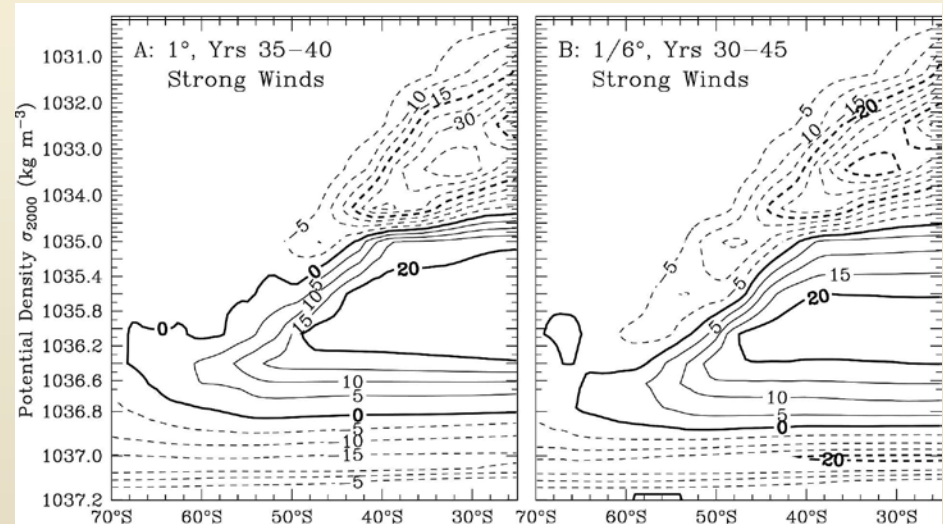
# Implication: Eddies are important

- 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*

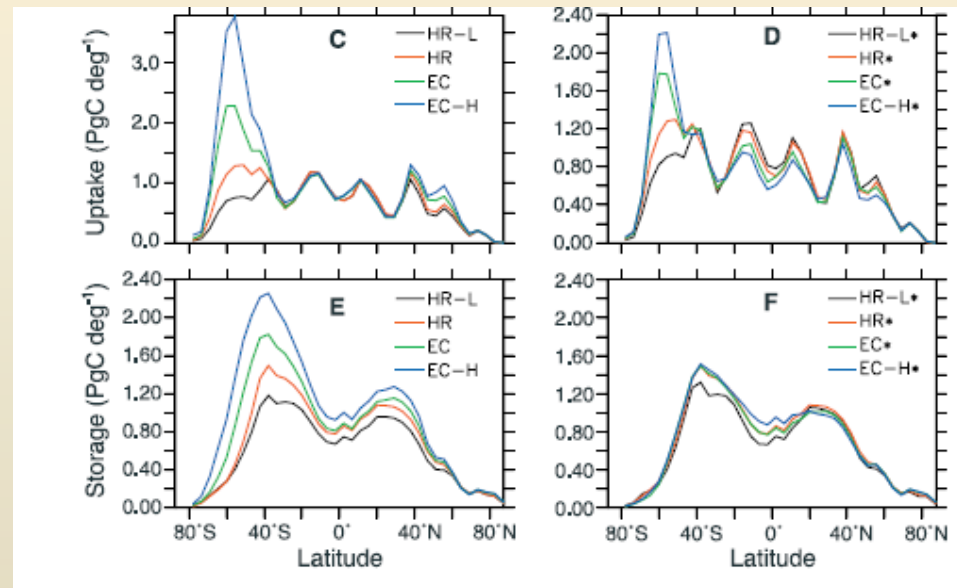
*Hallberg and Gnanadesikan, 2006*



Winds increased by 20%~ 10 Sv extra Ekman transport.

# Impacts: Winds and eddies affect uptake of anthropogenic carbon

- 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*

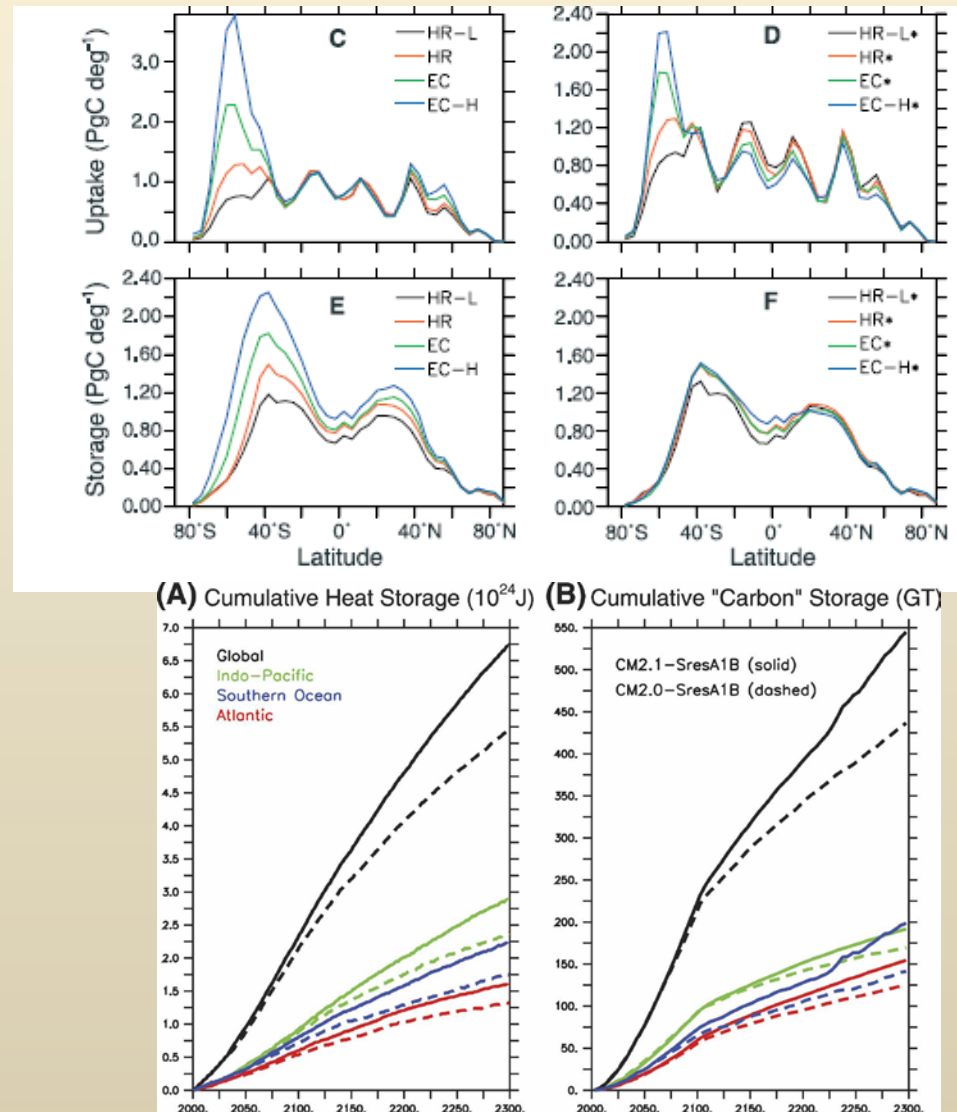


# Impacts: Winds and eddies affect uptake of anthropogenic carbon

- 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*



# Impacts: Different circulations can also change biological storage of carbon

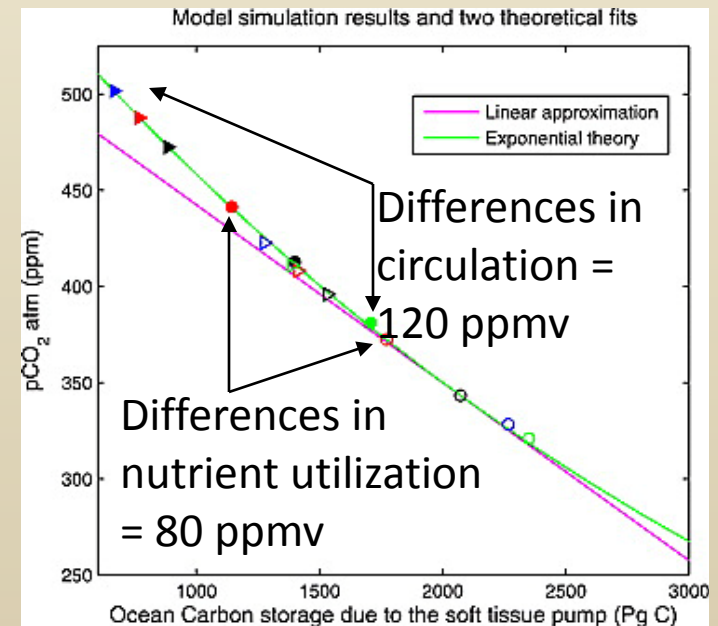
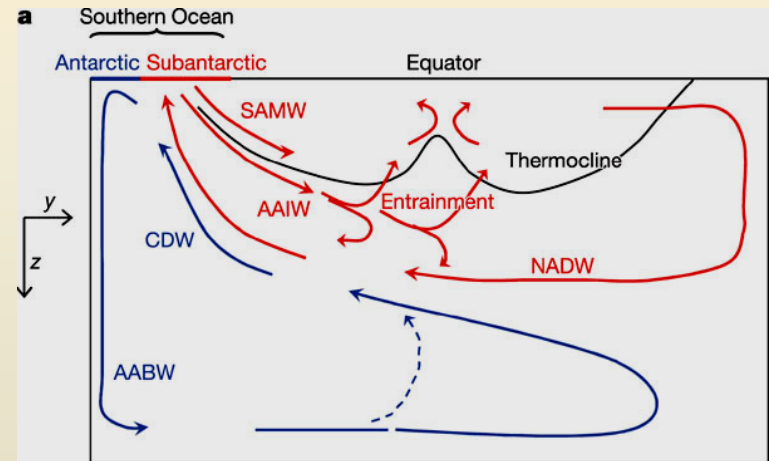
- **Strong Southern Ocean coupling to deep water (strong winds)**
  - Less storage of carbon
  - High atmospheric pCO<sub>2</sub>
- **Weak Southern Ocean coupling to deep water (weak winds)**
  - More storage of carbon
  - Low atmospheric pCO<sub>2</sub>
- **May play a role in 100K cycles**

Model simulations show potential impact comparable to iron fertilization

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

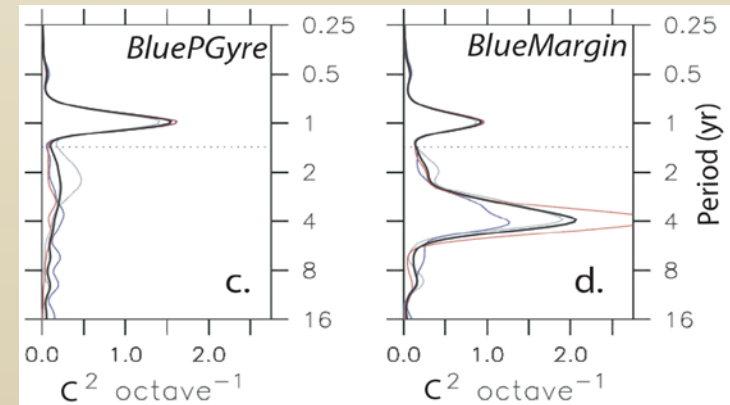
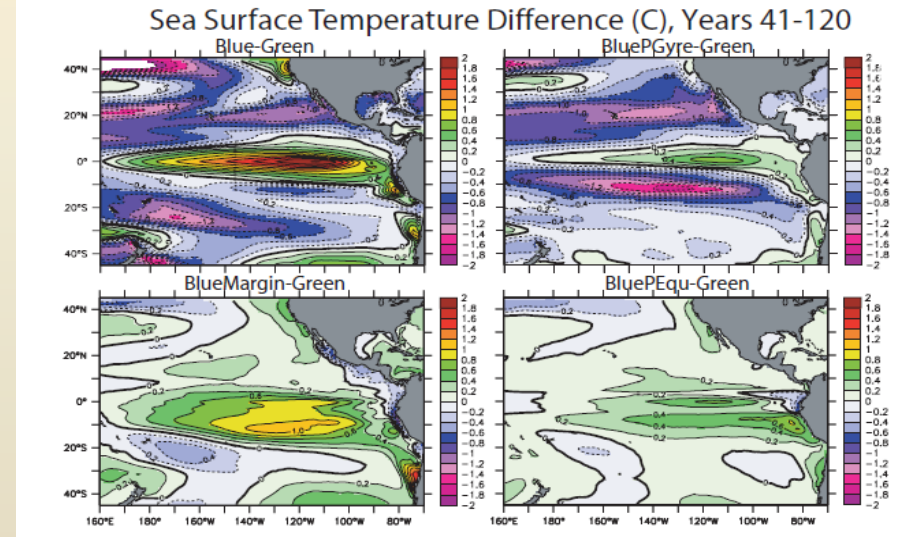
Toggweiler, 1999

Toggweiler et al., 2003a,b, 2008; Marinov et al., 2006, 2008a,b



# Impacts: More sensitivity to ocean shortwave absorption

- 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

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