Carbon cycle response to climate variability in the North Atlantic

David Ullman*, Galen A. McKinley¹, Stephanie Dutkiewicz², Val Bennington¹, and Dierk Polzin¹

¹Atmospheric and Oceanic Sciences, University of Wisconsin – Madison, Madison, WI
²Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA

*ullman@wisc.edu www.aos.wisc.edu/~galen

MOTIVATION

Previous work in the North Atlantic indicates:
• Basin is an important carbon sink, absorbing 23% of anthropogenic carbon stored in the oceans (Sabine et al. 2004)
• Basin-integrated CO₂ flux variability is small (McKinley et al. 2004)
• Changes in interior carbon storage may be significant, but mechanisms and connections to surface fluxes are unclear (Festy et al. 2005)

We ask:
• What are the predominant mechanisms of physical variability that determine the variability in surface pCO₂, the surface DIC budget, and air-sea CO₂ fluxes on interannual timescales?

MODEL DESCRIPTION

PHYSICAL MODEL:
• MIT ocean general circulation model configured for North Atlantic domain
• Horizontal resolution of 0.5°F x 0.5°F, 23 vertical levels ranging from 18m at the surface to 500 m at depth
• KPP mixing layer scheme, GM-Redi representation of isopycnal mixing

BIOGEOCHEMICAL MODEL:
• Cycling of carbon, phosphorus, silica, iron, oxygen and alkalinity
• Ecosystem model includes 2 phytoplankton functional types, one zooplankton type and explicit DOM and POM (Dutkiewicz et al., 2005)
• Surface carbonate chemistry (Follows et al., 2006)
• Iron chemistry (Parakkal et al., 2004)
• Air-sea exchange of carbon dioxide and oxygen following Wanninkhof (1992)
• Atmospheric pCO₂ from Mauna Loa observations

IMPLEMENTATION AND DATA COMPARISONS

• Spin up: 81 years physics only (repeating cycle of daily NCEP forcing)
  20 years physical-biogeochemical model, pCO₂ = 345 ppm
• Interannually varying run: 1992 to 2006, daily resolution
• NCEP forcing, relaxation to satellite-driven SST (Reynolds et al., 2002)
• Modeled SSTs compare favorably to satellite-derived observations (r = 0.76) with some discrepancy at end of period. Changes in temperature reflect variability in net surface heating with some lag (Figure 1).
• The modelled amplitude of the seasonal pCO₂ cycle compares favorably to the climatological data of Takahashi et al. (2002). The model also captures the variability in net surface heating with some lag (Figure 1).
• Comparison to observations at Bermuda (Hates et al. 2007) indicate the model is capturing variability in surface pCO₂ quite well (Figure 2). The overestimate of summer pCO₂ is due primarily to underestimation of the summer DIC drawdown.

RESULTS

DISCUSSION AND FUTURE DIRECTIONS

• Interannual variability in pCO₂ is controlled by temperature in the subtropics and by mixing in the subpolar gyre (Figure 4).
• Low variability in overall pCO₂ is due to the balancing of high variability in pCO₂ components (Figure 5).
• Analysis of overall decadal variability would be greatly improved with a longer model run spanning numerous decades.

REFERENCES


We thank to NASA funding.