Examining the Responses of the Ocean Carbon Cycle to Climate Change using an Idealized Model

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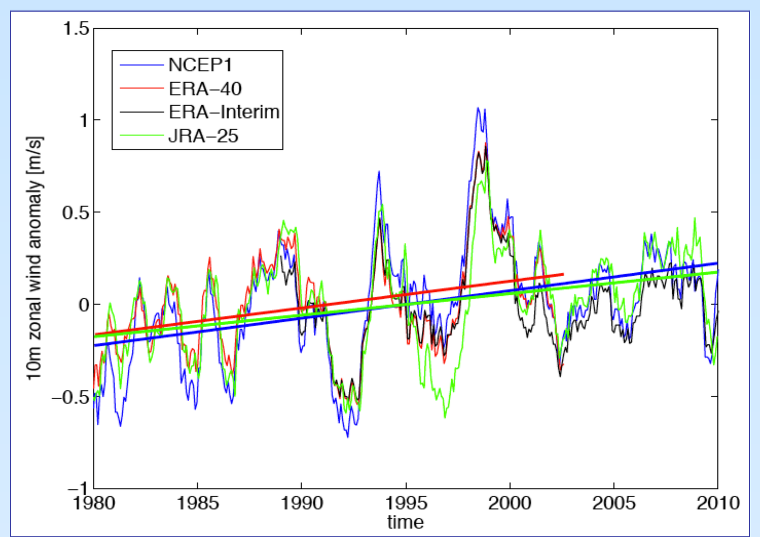
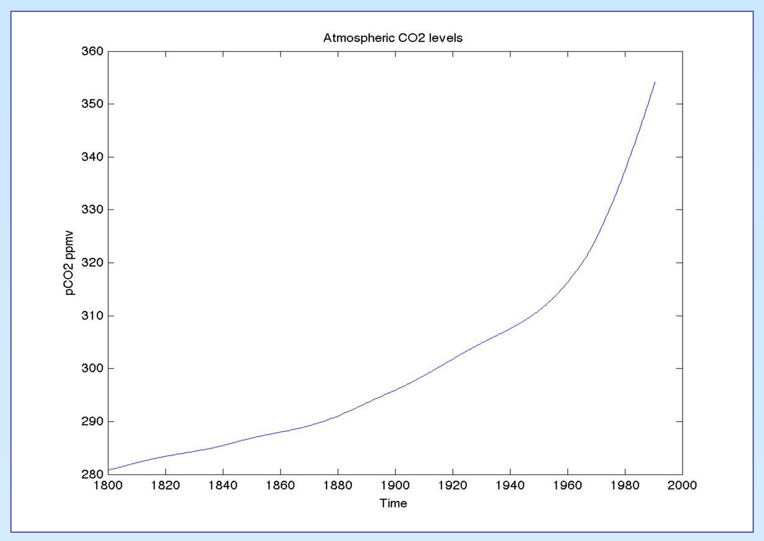
Introduction

We created a six box ocean-atmosphere model as a tool to examine the responses of the ocean carbon cycle to climate change. The model incorporates the biogeochemical and physical processes in the oceans as well as the air-sea gas exchange, providing a visual representation of the ongoing intra-ocean transfers.

Atmospheric and ice core observations have shown that pCO2 levels have been rising over the last two hundred years, while Southern Ocean wind stresses have been increasing since the 1980s. The box model allows for the incorporation of these changes to see how it affects CO2 uptake in different regions and how it will affect the aforementioned processes.

•What is the oceanic response to increasing pCO2 levels and increasing Southern Ocean winds?





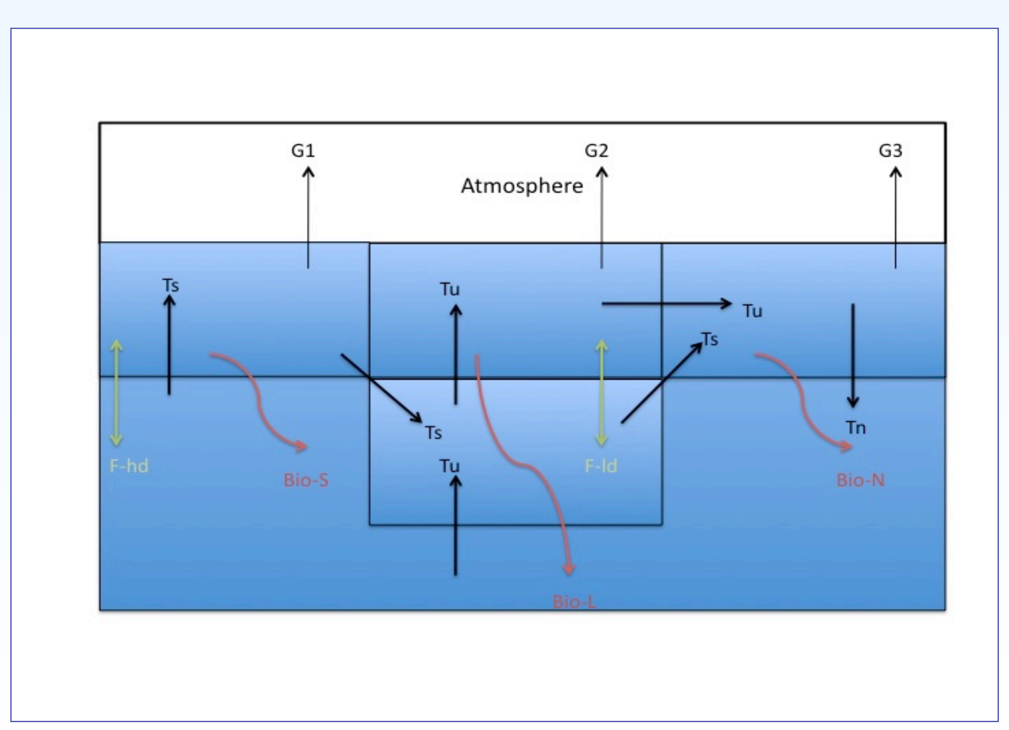
Methods

•We developed the model somewhat based on previous modeling studies by Gnanadesikan [1999] and Toggweiler and Sarmiento [1984]. The global ocean is divided into the Northern Atlantic (1), Southern Ocean (2) , Tropics (3), Thermocline (4), and Abyss (5). The model conserves mass, nutrient and carbon values in the system. The atmosphere is included to represent air-sea gas exchange with the three surface boxes.

•The nutrient cycle is calculated using phosphate as the limiting nutrient.

•Equations for carbon assume equilibrium at the surface. The carbon is transported to the interior ocean by physical circulation and sinking organic particles.

•Observed atmospheric pCO2 from 1800-1990.5 is used to integrate the model forward with a simple time-stepping scheme.



Experimental Design

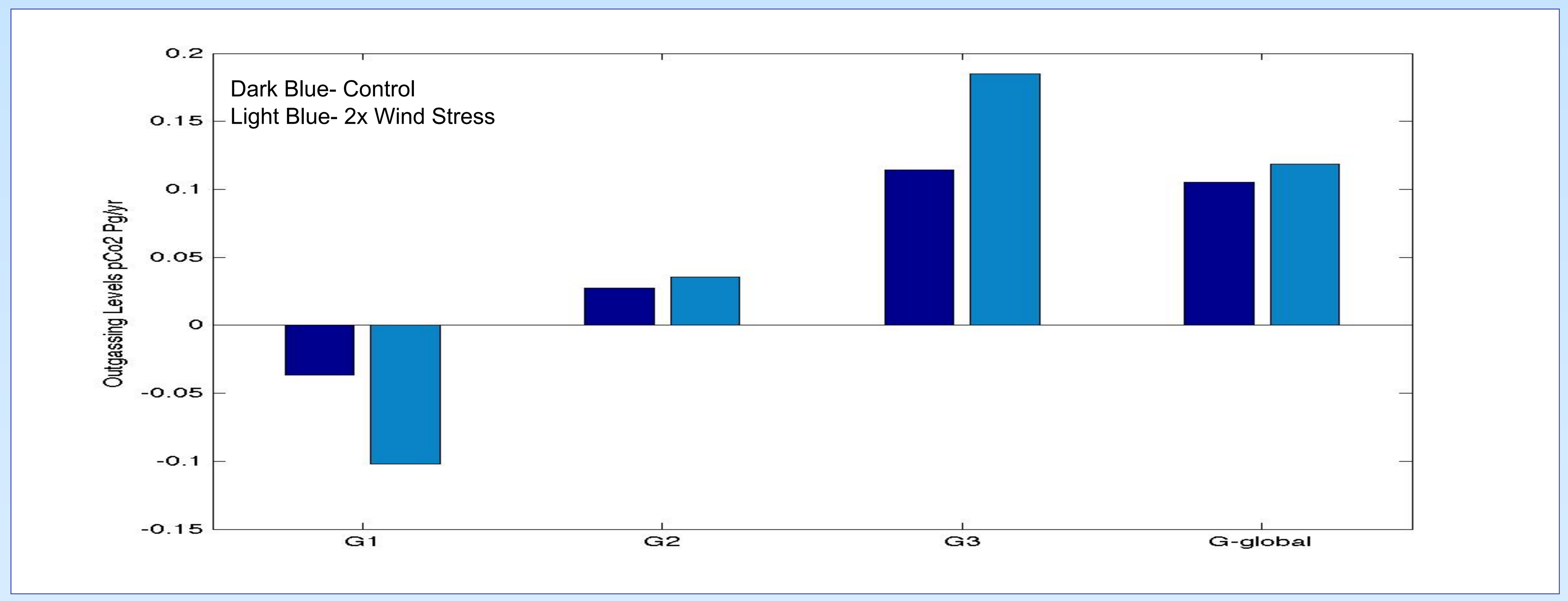
We perform two model simulations to examine the effect of wind stress over the Southern Ocean:

•Control simulation
- Wind stress is similar to climatology (long term mean values)

•Doubled wind stress simulation
- Wind stress is doubled relative to the control to represent the ongoing and future climate change

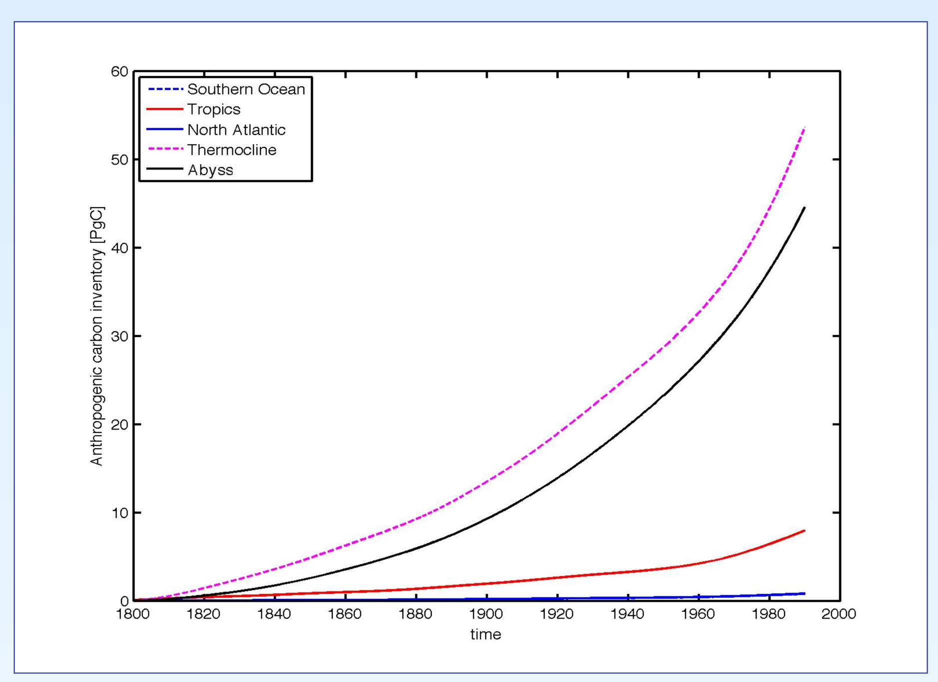
Results

•A. Control versus 2x Wind Stress Ocean Carbon Uptake in 1990

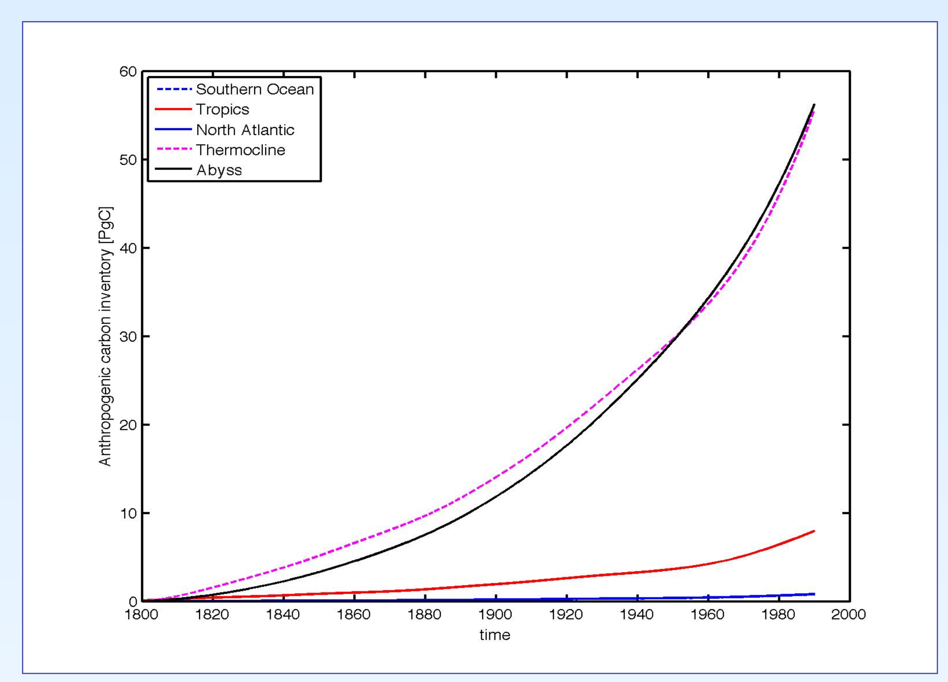


•B. Anthropogenic CO2 Inventory

Control

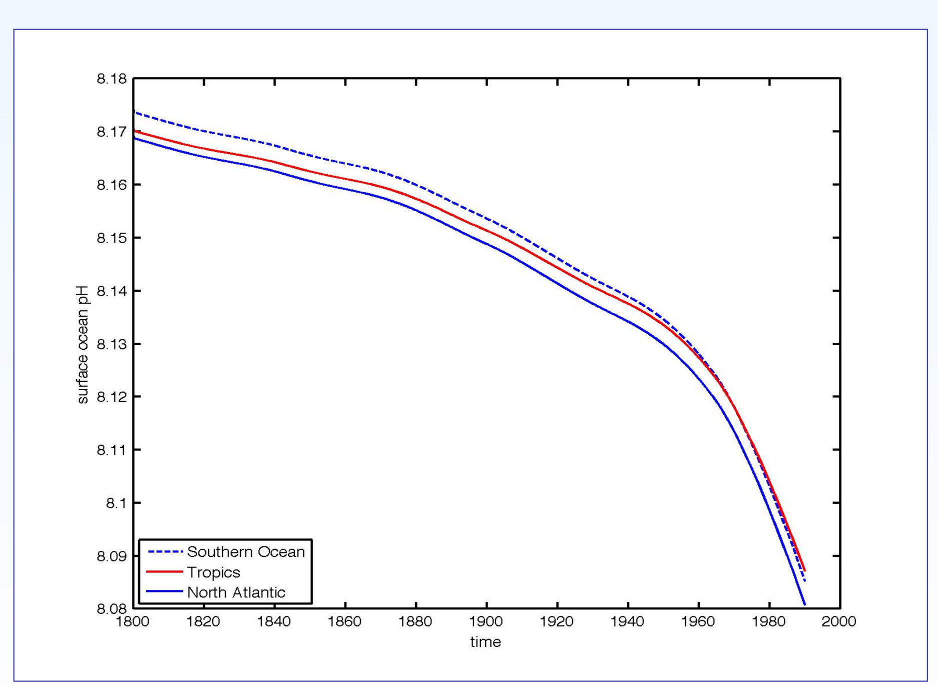


2x Wind Stress

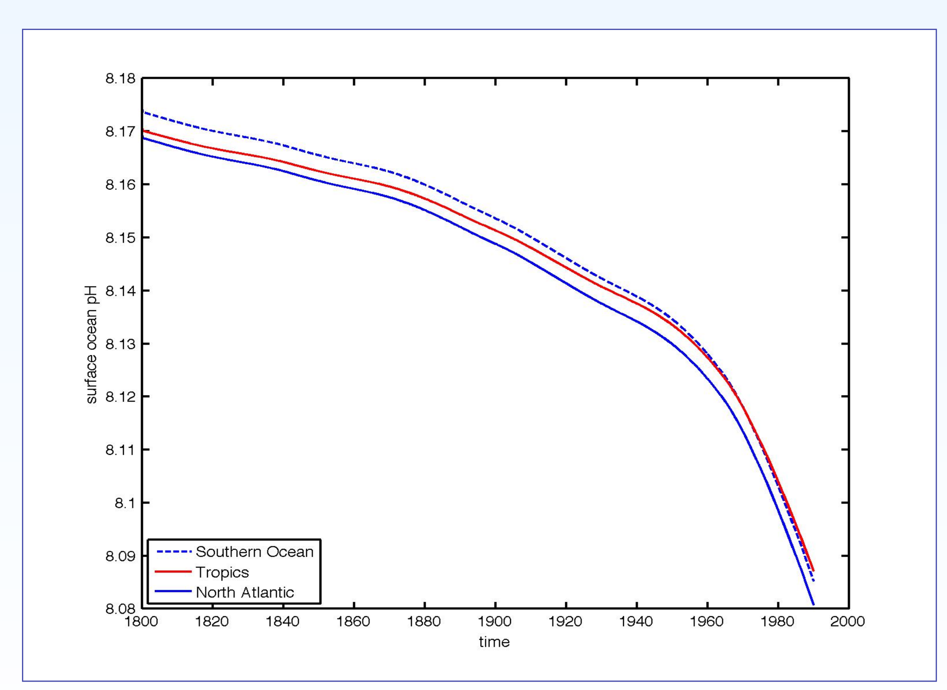


•C. Surface pH

Control



2x Wind Stress



Conclusions

•A. When wind stress is increased over the Southern Ocean, air-sea carbon flux varies widely to compensate for the changes in ocean transport. The Southern Ocean will emit more CO2 to the atmosphere due to the increased upwelling.

•B. Globally, there is little variation in uptake amounts associated with the wind stress increase. Increased emission from the Southern Ocean is compensated by the increased uptake in the North Atlantic.

•C. While there are no changes in pH levels due to wind stress, there is a general trend towards increasing acidity due to increasing anthropogenic carbon uptake.

Acknowledgements

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References

Follows, Michael J., Taka Ito, and Stephanie Dutkiewicz. 2006. On the solution of the carbonate chemistry system in ocean biogeochemistry models. *Ocean Modeling 12:290*

Follows, Mick, and Temel Oguz,eds. 2005. The Ocean Carbon Cycle and Climate. Norwell: Kluwer Publishers 2005.

Gnanadesikan, Anand. 1999. A Simple Predictive Model for the Structure of the Ocean Pycnocline. *Science* 2077:2077-2079

Sarmiento, Jorge L., and J.R. Toggweiler. 1984. A new model for the role of the oceans in determining atmospheric Pco2. *Nature* 308:621-624

Sarmiento, Jorge L., and Nicolas Gruber. Ocean Biogeochemical Dynamics. Princeton: Princeton University Press, 2006.

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