Simulating Oceanic Carbon Sequestration with Isopycnal and Cartesian Models

Rainer Bleck, PI, Los Alamos National Laboratory
Fei Chai, University of Maine
Shaoping Chu, Los Alamos National Laboratory
Francisco Chavez, MBARI
David J. Erickson III*, ORNL
Scott Elliott, Los Alamos National Laboratory
Mathew Maltrud, Los Alamos National Laboratory
DOE/OBER Program Manager: Anjuli Bamzai

Summary

The goal of the project is to simulate and predict the ability of the ocean to sequest anthropogenic CO2. This project is using these 2 very different ocean physics models to assess the possibility and efficiency of sequestering CO2 in the ocean. We have introduced a surface ocean ecosystem model into two global numerical models of ocean circulation. The global distribution of inert and biogeochemical tracers has been simulated with both models are being compared to observations. This project has advanced the state-of-the-art of the science and has contributed directly to the mission of both MICS and OBER.

We have contributed to this research effort, in collaboration with LANL and university scientists, by engaging in coupled physico-biogeochemical modeling of the two sequestration scenarios, (i) enhancement of oceanic CO2 uptake by iron fertilization of phytoplankton, and (ii) deep-sea injection of liquefied CO2. Modeling of the first-mentioned process (sequestration through iron fertilization) clearly must focus on the complex biogeochemical processes in the upper ocean that control the effectiveness of the so-called carbon pump. Preliminary results from iron fertilization studies using the Los Alamos POP code suggest that global carbon flux across the 100 m depth horizon is enhanced by about 2 by 24 patches distributed in the equatorial regions and the Southern Ocean.

One factor likely to determine the effectiveness of intentional carbon removal from the atmosphere through iron fertilization is the rate at which material is truly ``sequestered", i.e., subducted into the oceanic subsurface layers. Once water masses leave the photic zone, their ultimate fate is determined largely by 3-D transport and diffusion processes that set the rate at which wind and buoyancy forces ventilate the thermocline and the oceanic abyss.

* 865-574-3136, ericksondj@ornl.gov

The hydrodynamical core of HYCOM is still undergoing limited development and has not been tested as extensively. For this reason, we include here a relatively broad discussion of its present state. Like its predecessor MICOM, HYCOM resolves the vertical structure of the deep ocean in terms of a number of isopycnal (constant potential density) layers. The aspect setting HYCOM apart from MICOM is that coordinate surfaces rising up from the deep ocean level off to become fixed-depth surfaces while the isopycnals they follow outcrop at the sea surface. As such, it represents an ``engineering compromise" between the requirements for high vertical resolution near the surface and for isopycnal coordinate representation. The assured existence of nicely spaced coordinate layers at shallow depths regardless of the sign or magnitude of the vertical density gradient eliminates the main shortcoming of MICOM, namely, the lack of near-surface coordinate layers in unstratified water columns. Availability of constant-depth layers (whose number and spacing can be manipulated at compile time) beneath the ocean surface is essential for modeling biogeochemical processes in the photic zone. With the minimum layer thickness being controlled by a simple parameter, experimentation to obtain the optimal vertical resolution for biogeochemical modeling becomes particularly easy. Fig. 1 Shows how the ecosystem model computes surface ocean DMS flux in the POP version of the model, one of the simulations that will address CO2 sequestration.

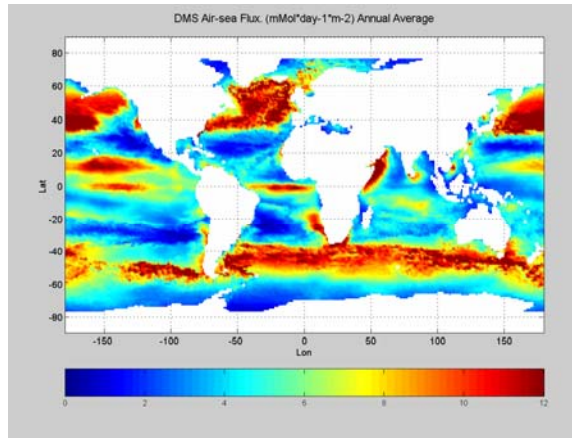

Figure 1. Global distribution of DMS flux from the ocean to the atmosphere in the POP based ecosystem model that is being implemented for use as a carbon sequestration model. The units are mMol DMS m^{-2}, day^{-1}. (Chu et al., Earth Interactions, In press, 2004.)