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Public Comment for the Record
U.S. Commission on Ocean Policy
1120 20th Street, NW
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Dear Ocean Commissioners,

We would like to suggest specific ideas and recommendations on policy and implementation of critical research needed on the ocean carbon cycle. We, the Ocean Carbon Cycle Research Working Group, meet at the invitation of the National Science Foundation's Division of Ocean Sciences.

Ocean biology and chemistry respond to climate, nutrient supplies, and atmospheric inputs. Conversely, marine biogeochemical processes influence atmospheric levels of greenhouse gases and, hence, climate. Reliable predictions of future climate change will depend on models that accurately depict the complex interactions among multiple factors affecting earth's climate system, and on an accurate understanding of feedbacks within the terrestrial and ocean carbon cycles that affect future fate of atmospheric carbon dioxide (CO_2).

Of the CO_2 released by fossil fuel combustion and deforestation to the atmosphere, approximately one third has already been taken up by the ocean, about one third remains in the atmosphere, and the remainder is thought at present to be accumulating in the terrestrial biosphere. Future climate scenarios will depend on whether these fractions stay the same, or whether feedbacks resulting from changes in the marine and terrestrial carbon cycles change them.

While our understanding of the oceanic carbon cycle has improved dramatically in the last decade, we cannot yet predict probable ocean responses to global change. Similarly we have not yet developed the capability to address the physical, chemical and biological feedbacks to atmospheric CO_2. A quantitative understanding of the ocean carbon cycle is a necessary but certainly not a sufficient condition for addressing these issues. Credible projections of the ocean carbon cycle response to climate perturbation will not be possible without a much more detailed, mechanistic understanding of the processes controlling the partitioning of carbon among the marine, terrestrial and atmospheric reservoirs. One of the critical components needed to answer these questions is an improved understanding of the past, present and future variability of the ocean carbon cycle especially as it relates to the air-sea and land-sea exchange of carbon.

Several important research questions must be addressed:

- What are the critical components of the ocean carbon cycle regulating the partitioning of CO_2 between the atmosphere and the ocean, and how can we improve prediction of the response and feedback of these processes to changes in environmental conditions (e.g., due to global warming)?

- What are the potential responses of marine ecosystems and ocean biogeochemical cycles to climate?

- How do we adequately characterize the non-steady state behavior of oceanic systems? How do components of the ocean system - physical and ecological - move between semi-stable states? What are the feedbacks inherent in the system?

- How can we more realistically represent biological, physical and chemical processes in ocean carbon cycle models?

In conducting this research, we must execute a *coordinated* and *directed* interdisciplinary and interagency program of ocean carbon research in biogeochemistry, ecology and ocean circulation with strong ties to exchanges with the atmosphere and land. At the same time, we must maintain a diversified portfolio of research efforts spanning from single investigator to multidisciplinary groups in our assault on defining the role of the ocean in the carbon cycle and global change processes. It is incumbent on us to promote new perspectives and approaches to these complex issues.

We must continue to maintain and improve our oceanographic technology development, including our oceanographic research fleet, unmanned observing vehicles and sensors, and satellites. Maintaining a modern, well-equipped research fleet is a basic requirement for a healthy and vigorous research program in the ocean sciences. Many important chemical and biological variables cannot now be observed with unmanned vehicles and sensors, and this will remain true for the foreseeable future. It is imperative that remote or unattended sensors be developed to measure previously unmeasured parameters of scientific importance. However, these new techniques almost always begin as ship-borne analyses, often remaining in that style for years or decades. Global observations from a variety of satellite sensors are an excellent means to address spatial and temporal variability of several surface biological and physical processes that control global CO_2 dynamics. In this regard, SeaWiFS data has proven to be crucial in our studies of the ocean carbon cycle, and the newer MODIS is becoming useful for ocean color measurements. However, even MODIS is scheduled only through 2005, so longer term planning is necessary.

Several time-series stations have been established over the past decade to observe long-term changes in biogeochemical parameters in the open ocean. For example, the Hawaiian Ocean Time (HOT) series and the Bermuda Atlantic Time Series (BATS) have been measuring parameters of interest to the carbon cycle for the past 15 years. Observing the response and feedbacks of ecosystem structure and carbon fluxes over time provides the most direct and unambiguous strategy to determine the sensitivity of these variables to changing climate. For this reason, continued long-term support of these time-series stations is strongly recommended. Because the current time-series sites represent a narrow range of oceanographic provinces and are sampled only monthly, we strongly recommend that new time-series sites, which are representative of higher and lower latitude and coastal environments, and which include more continuous sampling, be initiated. New technological developments in unattended observing systems, including new platforms and new sensors, will be a key issue in augmenting the number of time-series stations in a broad and cost-effective manner.

The recent WOCE/JGOFS global carbon survey is providing the first comprehensive inventory of anthropogenic CO_2 in the ocean. These data provide a valuable baseline to determine the possible large scale effects of global warming on the ocean's biogeochemistry, whether due to changes in stratification, circulation, or perturbations such as in dust deposition on the ocean's surface. To predict long-term climate change and man's effect on the rate of change, we must continue to sample the ocean for dissolved carbon components in a global survey mode. Paleoceanographic studies are needed, as well, as they provide information from prehistoric time periods on the ocean's response to changes in environmental forcing.

Seagoing process studies are another key element of the strategy for future research on the ocean carbon cycle. Focussed process studies are required to improve our knowledge of poorly understood ocean processes, regimes and subsystems. Process studies include direct manipulation of the ocean environment, such as iron enrichment experiments, as well as systematic observations of "natural experiments" such as El Niño. Such studies are essential for furthering our understanding the basic mechanisms controlling the ocean carbon cycle, and can be used to evaluate the host of physical, biological, and chemical feedbacks on the ocean's uptake of carbon. For example, we need to continue studies of subsurface reservoirs that trap large quantities of potentially releasable carbon (e.g., gas hydrates), and how that release is affected by climate change.

Thanks for your attention.

Sincerely,

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