HUGO, H2O, and NEPTUNE projects), and (2) moored-buoy observatories providing the platform to telemeter data back to shore using commercial telecommunications satellites. Figure 1 depicts a mid-ocean installation with instrumentation at the air-sea interface, in the water column, and at and within the sea floor typical of installations throughout the various elements of the OOI.

The National Science Board approved the OOI in 2000, and the President's budget for FY04 included the initiative for funding in FY06 for a period of 5 years, at a total cost of nearly $210 million. As the project approaches reality, the organizational structure of the initiative will change substantially. The DEOS Committee will end its activities early in 2004 as the new Program Office begins. The overall structure of the program is playfully depicted in Figure 2, reflecting the author's favorite cocktail. The OOI comprises a number of investments, including the observatory infrastructure, project management, data management, and core instrumentation. The available MRE-FC funding is restricted to the pimento in the stuffed olive. The larger ORION program encapsulates the OOI, but includes the larger program of science funding, education, and outreach; and the bulk of the instrumentation, and mobile platforms, including a greatly enhanced demand for the use of modern oceanographic ships and tools, especially remotely operated vehicles.

The OOI and the Integrated Ocean Observing System

The National Ocean Partnership Program, through the Ocean.US interagency office (http://www.ocean.us), is sponsoring the Integrated Ocean Observing System (IOOS) to focus on operational oceanographic needs. The IOOS will focus primarily on the mission-oriented needs of agencies such as NOAA, NASA, and the U.S. Navy. The research and technological developments within ORION will provide essential support for the IOOS. The cabled and moored components of the OOI will serve as test beds and incubator sites for the development of new technologies, as well as advanced modeling capabilities essential to the evolution of the IOOS.

OOI Planning Workshops

A number of workshops have been held so far this year, and a final one—with an anticipated 200–300 participants—will be held at the Caribe Hilton, San Juan, Puerto Rico, on 4–8 January 2004. More information and registration is available at http://www.orionprogram.org.

The purpose of this workshop will be to draft an initial science plan (iSP) for ORION. The advisory committee structure of the program office for the OOI will use the iSP for drafting long-term and FY06 science plans.

Other recent workshops related to DEOS planning include:

- Linkages between the Ocean Observatories Initiative and the Integrated Ocean Drilling Program, 15–16 July 2003; Seattle
- The Next Generation In-Situ Biological And Chemical Sensors in the Ocean, 13–16 July 2003; Woods Hole Oceanographic Institution
- Cyberinfrastructure for Sensor Networks, 11–14 August 2003; Scripps Institution of Oceanography
- Regional Network Science Planning, 7–10 October 2003; San Francisco

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MEETINGS

Assessing Contributions of JGOFS; Previewing Studies in Ocean Ecology, Biogeochemistry

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Despite impediments to travel imposed by global political and health concerns, 332 scientists and students from 32 countries gathered in Washington, D.C. in early May to celebrate the conclusion of the Joint Global Ocean Flux Study (JGOFS), and to assess both its accomplishments and the future course of research in ocean ecology and biogeochemistry.

Launched in 1987 under the auspices of the Scientific Committee on Oceanic Research (SCOR), JGOFS became the first core project of the International Geosphere-Biosphere Programme (IGBP) 2 years later as its first field studies were getting underway. Global in scope and multinational and interdisciplinary from its inception, JGOFS adopted two major goals: to understand the processes controlling the cycling of carbon and other biogenic elements in the ocean and their exchange with the atmosphere and the sea floor, and to advance our capacity to predict the response of ocean systems to anthropogenic perturbations.

JGOFS field studies and modeling projects brought together a wide variety of approaches to the assessment of the ocean's role in the global carbon cycle, integrating geochemistry, biology, and physics, and making use of remote sensing data on ocean properties as well as in-situ measurements and computer simulations. Field programs included process studies in major ocean regions; a global survey of carbon dioxide (CO_2) in the ocean, conducted in cooperation with the World Ocean Circulation Experiment (WOCE); and long-term time-series studies at key sites, some of which will continue into the future.

From the beginning, JGOFS planners committed resources to the development of an open, accessible, and comprehensive data base. Individual national programs are handling access to JGOFS data in different ways; for example, all U.S. JGOFS data are accessible via the program's Web site (http://usjgofs.whoi.edu), and publication of a series of data CD-ROMs is underway.

Over the years since it was launched, JGOFS has sponsored a series of symposia designed to measure the advance of scientific knowledge against the questions the study was designed to address. The final open science conference, "A Sea of Change: JGOFS Accomplishments and the Future of Ocean Biogeochemistry," was held at the U.S. National Academies facility, the site of the first international JGOFS meeting in 1990.

JGOFS contributions and directions for future research emerged from presentations at the conference. Plenary sessions with keynote speakers and commentators addressed a series of broad topics, including ocean color observations from space, air-sea fluxes of CO_2, ocean carbon transport and storage, ecosystem community structure and dynamics, ocean margins and benthic processes, the paleoceanographic perspective, data assimilation and modeling, iron limitation, particle export flux, and new technologies for biogeochemical observations. JGOFS history, links among JGOFS and other major ocean programs past and present, ocean biogeochemistry in the context of Earth system science, and future ventures in ocean biogeochemistry were explored as well.

Poster sessions were organized by region as well as topic. The former included the North Atlantic, equatorial Pacific, North Pacific, Arabian Sea, Southern Ocean, and ocean margins. The latter included CO_2, ocean color, plankton community structure, euphotic zone production and export, the meso-pelagic zone, the deep ocean and seafloor, paleoceanography, time-series studies, and global synthesis and modeling.

Contributions of JGOFS

Conference presentations highlighted JGOFS contributions to a better understanding of the ocean's role in the global carbon cycle and likely responses to changing climate conditions in at least three broad areas. How much carbon is taken up and stored in various regions of the ocean, and how might this change in the future? What role do food web structure and biological processes play in the partitioning of carbon into different pools? How does carbon get from the surface waters to the deep ocean and seafloor, where it can be sequestered for millennia to eons?

Data amassed during the survey and previous ocean studies indicate a globally integrated net CO_2 flux into the ocean of roughly 2.1 petagrams of carbon per year. This flux varies greatly from one region to another; the largest uptake occurs in the North Atlantic and Southern Ocean, whereas the equatorial regions, particularly in the Pacific, show a substantial net release of carbon into the atmosphere. The ocean is the largest sink for anthropogenic CO_2 at present, taking up more than one-third of total emissions from human activities. Modeling studies suggest the possibility of positive feedback with atmospheric warming, reducing the ocean's capacity to take up CO_2.

JGOFS studies demonstrated links between changes in large-scale climate patterns, such as the North Atlantic Oscillation and the El Niño-Southern Oscillation, and variations in the exchange of CO_2 between the ocean and atmosphere. They also indicated the importance of the continental margins in ocean CO_2 uptake, a critical issue for future study.

JGOFS process and time-series studies showed that plankton food web structure and dynamics have significant effects on the size and partitioning of the ocean carbon flux among organic and inorganic, dissolved and particulate forms. Phytoplankton size classes differ greatly in their contribution to surface blooms and to the timing and volume of material exported from the surface ocean to the meso-pelagic zone and deeper waters.

Zooplankton measurements showed that although larger species add variability and dominate the export of material from the euphotic zone, the micro-zooplankton provide the background that ultimately dominates the cycling of carbon and other elements through the water column. JGOFS studies also documented the overall domination of ocean biomass and flux by microbes, including autotrophic pico- and nanoplankton, *Archaea*, bacteria, and protozoan grazers.

New discoveries about the role of element limitation on phytoplankton growth and abundance emerged from a number of studies. Open-ocean experiments tested the hypothesis that iron limits phytoplankton growth and abundance in regions with sufficient supplies of nitrogen and phosphorus. Data from time-series studies in oligotrophic ocean gyres show a long-term shift in the ratio of nitrogen to phosphorus in particulate matter, and suggest a link between the warmer, calmer conditions that accompany a high frequency of El Niño events and the growth of nitrogen-fixing cyanobacteria.

The quest to understand how carbon gets from the ocean surface to the seafloor sediments produced a number of lessons for JGOFS scientists. Just as it is insufficient to rely solely on satellite data on pigments as a measure of surface productivity, so too is it insufficient to rely solely on particulate organic material collected in sediment traps at various depths as a measure of ocean export flux.

A significant discovery was the importance of dissolved organic carbon (DOC), which comprises 20% of the total ocean export flux on the global scale. Although processes governing DOC formation, export, decomposition, and geographic distribution are not well understood, it is interesting to note that the cycling and export of carbon south of the Antarctic Polar Front are dominated by particle fluxes; almost no carbon is exported in the form of DOC in that region.

JGOFS field and modeling studies have yielded insights into the importance of the inorganic fractions of the particle flux. Inorganic "ballast" protects organic material from decomposition in the water column, and affects the rate and extent of particle sedimentation and re-mineralization. Food web structure and windborne materials have an impact on the formation and effects of this ballast.

Among the lessons learned during JGOFS is the importance of improving methods of measurement, and establishing common standards that permit effective comparison of results. Measurements of both DOC and dissolved inorganic carbon (DIC) benefited from the development of reliable seawater standards. Advances in trace-metal free sampling techniques made it possible to carry out effective iron-enrichment experiments in the open ocean. Improvements in remote sensing technology, autonomous underwater vehicles, and sensors for long-term deployment on buoys also advanced biogeochemical research during the JGOFS era.

Another lesson learned is the importance of determining temporal and spatial scales relevant to particular questions. Long-term studies and the development of continuously recording instruments have made it possible to capture small and meso-scale events in time and space that have a disproportionate effect on variability in ocean properties.

In her keynote lecture, former Environmental Protection Agency administrator Carol M. Browner discussed the role of scientists in the formulation of governmental climate policies. In her concluding address, Margaret Leinen of the U.S. National Science Foundation applauded JGOFS for broad goals and a focused vision, noting the importance of intertwining observations and experiments with modeling, the value of cooperation among large ocean programs such as JGOFS and WOCE, and the utility of the data management system created under JGOFS as a model for future programs.

Rather than publishing a conference proceedings, organizers of the JGOFS conference are making available the plenary presentations themselves, as well as the poster abstracts. The talks can be downloaded in either pdf or html format, or as Powerpoint files from the U.S. JGOFS Web site (http://usjgofs.whoi.edu/osc2003/talks.html). The response thus far has been substantial; visitors to the site downloaded more than 3800 files during the first month that the talks were available.

"A Sea of Change: JGOFS Accomplishments and the Future of Ocean Biogeochemistry" was held 5–8 May 2003.

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