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Using Global Data Sets for Biogeochemical Flux Estimations

by Reiner Schlitzer

Scientists generally agree that global-scale observations of physical and biogeochemical parameters are required to understand the ocean's role in the global climate system and to quantify fluxes of heat, fresh water, nutrients and carbon more accurately. But we also need efficient data management systems that assure consistency and quality and facilitate distribution of and access to data.

Programs such as JGOFS or the World Ocean Circulation Experiment (WOCE), both of which have a substantial data management component, are providing the kind of services required for innovative oceanographic and climate research. Only 10 or 15 years ago, however, the situation was very different. Investigators focused primarily on relatively small data sets, and analyses were typically conducted by cruise or on basin-wide or regional scales. Global-scale questions were difficult to address without large ocean data sets. Exceptions were the Geochemical Sections (GEOSECS) data set and the selected global hydrographic data set assembled by Joseph Reid and Arnold Mantyla of Scripps Institution of Oceanography, both of high quality and widely used. Exchanges between colleagues or data centers were limited and hindered by incompatible formats and the reluctance of investigators to share their data.

Over the last decade, not only has information technology advanced rapidly, allowing easy exchange, storage and interactive analysis of data, but also a much greater willingness to exchange, share and pool data has emerged. This development is attributable in part to the increased national and international cooperation brought about by large programs like WOCE and JGOFS.

These programs are in their final stages, and their data centers are completing their work. WOCE data will be distributed at a final conference to be held in San Antonio, Texas, Nov. 18-22. They will be available on two digital video disks (DVDs) as well as from online servers that contain all WOCE data in a unified format, including data from the global ocean survey of carbon dioxide (CO_2) conducted by U.S. JGOFS scientists on WOCE Hydrographic Programme sections.

To facilitate and promote access to the WOCE data set, I have built integrated global or basin-wide data collections for use with the Ocean Data View (ODV) visualization software (**http://www.awi-bremerhaven.de/GEO/ODV**). Data and software together constitute the Electronic Atlas of WOCE Data (eWOCE), which permits graphical display and interactive analysis of the data in many different ways. With extensive interactive controls and ability to calculate a wide variety of derived quantities, this electronic atlas complements the printed WOCE atlases now in preparation.

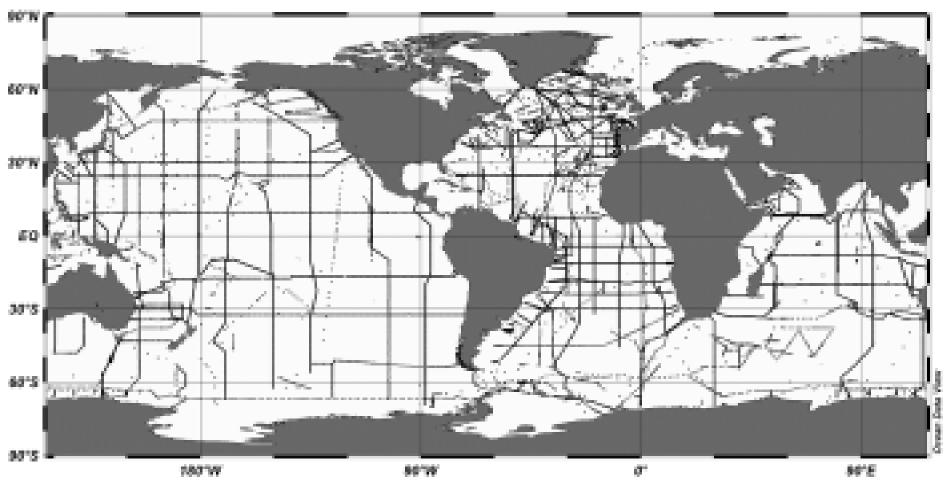

Figure 1: Map of stations with hydrographic, oxygen, nutrient, carbon and tracer data from the WOCE Hydrographic Programme.

Included in eWOCE are hydrographic, oxygen, nutrient, carbon and tracer data from bottle samples collected at more than 18,000 stations worldwide (Figure 1). Also included are high-resolution CTD data, more than a million temperature profiles from expendable bathythermographs, velocity and/or trajectory data from more than 1,300 moored current meters, more than 12,000 surface drifters, more than 1,000 sub-surface floats and more than 240,000 shipboard Acoustic Doppler Current Profiler profiles (Table 1). eWOCE also contains

Continued on page 2

hourly sea-level data from more than 150 tide gauge stations. Gridded data sets of sea-surface temperature, sea-surface height and winds from satellite sensors are available from the WOCE netcdf files. The eWOCE data collections are available on DVD 2 of the final WOCE data release (version 3) or online (**http://www.ewoce.org**).

The WOCE data are of high quality and contain valuable information that can be used to constrain and determine biogeochemical fluxes. For example, Figure 2 shows the oxygen distribution along the P19 hydrographic section in the southeast Pacific. North of 20°S at a depth of about 500 meters one can see a distinct oxygen minimum with levels below 5 micromoles per kilogram. This oxygen minimum is associated with maxima in phosphate, nitrate and carbon (not shown); it is obviously caused by the remineralization of organic material produced in the Peru/Chile upwelling region.

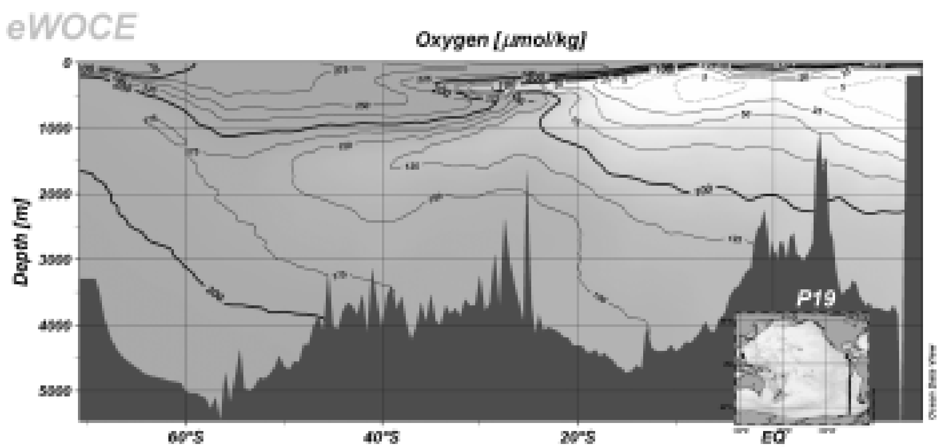

Figure 2: Distribution of oxygen along WOCE Hydrographic Programme section P19 in the southeast Pacific. The pronounced oxygen minimum at a depth of about 500 meters north of 20°S is linked to remineralization of organic material produced in the Peru/Chile upwelling region.

Similar patterns (oxygen minima associated with nutrient maxima) are found in other productive regions of the ocean as well. The biogeochemically induced concentration gradients in the property distributions are large and well documented by the WOCE data. The geographical location, depth range and amplitudes of the observed minima and maxima in the oxygen and nutrient fields reflect the magnitude of the downward particle flux and the depth of maximum remineralization.

Using numerical models that take into account the effect of ocean circulation in addition to biogeochemical phenomena, we can "invert" the observed concentration gradients and determine the associated biogeochemical fluxes and remineralization rates. I describe two different types of inverse models used for biogeochemical problems below.

In the classical form of inverse modeling, developed and applied by Carl Wunsch of Massachusetts Institute of Technology, section data are used in their original form, and budget equations for mass, heat, salt, oxygen, nutrients and various tracers are formulated for the control volumes defined by the intersections of the cruise lines. The Ekman transport and geostrophic flow normal to each section are calculated using wind observations and hydrographic data along the sections. Reference velocities and biogeochemical sources and sinks within the control volumes are treated as unknowns.

This approach typically yields an underdetermined system of linear equations (fewer budget equations than unknown reference velocities and source/sink terms) and requires advanced methods from linear algebra to obtain solutions (singular value decomposition). Errors in the section data affect the righthand sides of equations as well as the matrix coefficients and lead to errors in solutions. Because of this underdetermination, calculation and analysis of the resolution matrix of the systems is very important.

In the past, this approach has mostly been used by physical oceanographers to obtain absolute flow velocities and integrated mass heat and salt fluxes across sections. However, it has also been used to determine meridional nutrient and carbon fluxes as well as the remineralization rates of particulate organic matter and opal. A global physical/biogeochemical analysis using the full WOCE data set as depicted in Figure 1 is underway.

The disadvantage of the classical inverse modeling approach is that measurements must be available for all surfaces of the control volumes. For time-varying parameters such as anthropogenic carbon or chlorofluorocarbons (CFCs), repeat measurements on all surfaces must be available at regular time intervals to estimate rates of change over time within the box. These data requirements unnecessarily restrict the spatial resolution of the models. In addition, logistical and financial limitations will always prevent us from obtaining enough transient tracer measurements to meet these requirements.

I have recently developed a modified inverse modeling strategy that decouples the model grid layout from geographical data distribution and is able to utilize a wide variety of observations, including transient tracers with possibly sparse data coverage. One objective of the model is to estimate export production and

continued on page 14

Advances Highlighted At Summer Meeting Of U.S. JGOFS SMP Investigators

by Scott C. Doney and Joan A. Kleypas

U.S. JGOFS Synthesis and Modeling Project (SMP) investigators held their fifth annual summer workshop at the Woods Hole Oceanographic Institution (WHOI) in July. Our reports on these meetings track not only the scientific advances of the project but also the progress of the SMP "experiment," which has brought together scientists from an extraordinary range of oceanographic disciplines. An overwhelming conclusion of this meeting, the last of the big SMP workshops, is that the SMP is succeeding in fostering beneficial collaborations among individual investigators and helping to reshape the overall approach to ocean carbon-cycle science.

More than 90 participants attended the meeting, which followed a format like that of the Gordon Conferences. The meeting was organized around four plenary sessions: *The Southern Ocean - Paleo and Present, Food Webs, Global-Scale Synthesis of the Carbon Cycle*, and *SMP Goals and Accomplishments*. The format allowed ample time for freewheeling discussion.

The *SMP Goals and Accomplishments* session, led by David Siegel of the University of California at Santa Barbara (UCSB), Hugh Ducklow of the Virginia Institute of Marine Science and Robert Key of Princeton University, provided an interesting assessment of SMP progress towards its overall goal of synthesizing knowledge gained from U.S. JGOFS and related studies into models that reflect the current understanding of the ocean carbon cycle and its uncertainties. A breakdown of SMP projects within disciplinary and geographic categories (Table 1) shows that the program has broadly addressed the first two main elements: global and regional mass balances, and mechanistic controls on local carbon balances. The third element, extrapolation, monitoring and prediction, builds on the first two elements and has yet to be tackled decisively.

During the workshop, John Dunne of Princeton conducted an informal but imaginative survey among the participants. He asked three questions:

• What is the major contribution of JGOFS to ocean biogeochemical modeling?

• What is the major change in thought since the SMP Implementation Plan?

• What is the most pressing uncertainty in biogeochemical modeling?

The responses reflect common perceptions about the main accomplishments and remaining tasks of the SMP. The most commonly mentioned JGOFS contributions were the production of quality data sets for model evaluation and enhanced interactions among field investigators and modelers. The role of biological complexity in ocean carbon cycling was cited by most who responded to the second question. The most pressing uncertainties mentioned had to do with remineralization and dissolution in the twilight zone, the role of the Southern Ocean and ocean margins, and our limited predictive capability.

Science Highlights

In the *Global-Scale Synthesis* session, complementary talks on anthropogenic carbon dioxide (CO_2) by Nicolas Gruber of the University of California at Los Angeles and Christopher Sabine of the University of Washington highlighted the strong dependencies between observations and modeling. Sabine's total ocean inventory estimate (102 ± 6 petagrams of carbon for the period from the beginning of the industrial era through 1994) is based on a synthesis of the global data set amassed by JGOFS investigators on World Ocean Circulation Experiment (WOCE) hydrographic sections. It provides a high-quality baseline against which future increases in anthropogenic CO_2 in the ocean can be measured.

Gruber presented a summary of the Ocean Carbon Model Intercomparison Project (OCMIP), which produced a somewhat higher estimate (121 ± 12 Pg C for the period through 1990). The OCMIP simulations, along with inverse modeling results, also show broad agreement on how carbon uptake varies regionally. For example, oceans south of 36°S appear to be responsible for about 40% of the global ocean uptake of anthropogenic CO_2.

Reiner Schlitzer of the Alfred Wegener Institute for Polar and Marine Research in Bremerhaven, Germany, presented an ocean inverse calculation in which biogeochemical flux estimates were derived from observed large-scale inorganic carbon, oxygen and nutrient fields and the flow field from a circulation model (see article in this issue). His model demonstrated remarkable skill at reproducing observations of marine productivity, particle fluxes, remineralization rates and air-sea gas exchange rates over most of the globe. The main differences occurred in the Southern Ocean, where simulated export production is much higher than satellite-based estimates. Biogeochemical inverse models, likely to become more widespread in the future, depend on having high-quality, publicly-available data sets such as the one collected during the global CO_2 survey.

Robert Anderson of Lamont-Doherty Earth Observatory introduced the *Southern Ocean -Paleo and Present* session with a talk on how light, grazing, iron and silica limit productivity over the seasonal cycle in the Antarctic Circumpolar Current. He showed that different factors exert control over growth, biomass, community structure and export from season to season and place to place.

Roger François of WHOI followed with a presentation on the hypothesis that higher Southern Ocean productivity during the last glacial maximum (LGM) led to a reduction in atmospheric CO_2. Data from sedimentary cores, including measurements of clay flux, diatom assemblages, nitrogen isotope ratios, ratios of cadmium to calcium, and biogenic barium accumulation, provide equivocal results. But François argued that increases in iron could have allowed higher seasonal drawdown of nutrients in the extended glacial seasonal ice zone.

Keith Moore of the University of California at Irvine discussed model simulations in which increased levels of iron in wind-borne dust during the LGM enhanced primary production south of 30°S by as much as 50% and the export of particulate organic carbon by more than double current levels. Plenary discussion highlighted the potential role of multi-element limitation, cellular composition and functional group dynamics. A particular example raised by Jorge Sarmiento and Katsumi Matsumoto of Princeton and Mark Brzezinski of UCSB suggests that elevated levels of iron during glacial periods shift Southern Ocean diatom ratios of silicon to nitrogen, leading to substantial export of silicon to the rest of the ocean and correspondingly large changes in the carbon cycle.

David Karl of the University of Hawaii and Paul Falkowski of Rutgers University presented fascinating plenary talks on the importance of biological detail in determining ecosystem function and response during the *Food Webs* session, organized by Edward Laws of the University of Hawaii and Raleigh Hood of Horn Point Laboratory. Karl argued for a resounding "yes" to the question posed by Richard Eppley in 1984: Do we need to know the full natural history of the plankton to satisfy JGOFS objectives? Falkowski and Karl highlighted the ecological importance of a wide-ranging set of factors, including viruses, vitamins, evolutionary history and genomics, and unusual microbial physiologies.

Final Phase of the SMP

Funds were awarded for a final five SMP grants this year, bringing the total to 65. The focus of the program is now shifting toward the orchestration of a larger-scale synthesis of the ocean carbon cycle. Considerable effort has already gone into various community projects. Examples include the merged U.S. JGOFS process study data products and the on-line data retrieval system developed through the joint efforts of the U.S JGOFS Data Management Office staff and investigators at the University of Washington and the NOAA Pacific Marine Environmental Laboratory. Other projects include the global synthesis of ocean carbonate system parameters and nutrients coordinated by the Global Ocean Data Analysis Project (GLODAP) group.

The SMP is also producing a series of research paper collections in issues of *Deep-Sea Research II*. The first volume was published in early 2002, and a second is expected in mid-2003.

With two more years remaining, SMP participants are interested in producing tangible results beyond data archives and journal papers. A variety of ideas have been put forward. These include articles for broader audiences on the ocean carbon cycle, a marine ecological modeling "tool bench," educational materials for primary and secondary-school students as well as undergraduate and graduate students, an intercomparison of state-of-the-art ecosystem models in one or more ocean general circulation models, experiments designed for future ocean observing networks, and climate-change scenarios. One idea with strong support is to use the 2003 summer meeting as the basis for a set of review papers on ocean carbon-cycle synthesis and modeling.

More information about the 2002 summer meeting is available via the U.S. JGOFS home page (**http://usjgofs.whoi.edu/mzweb/whoi_agenda_2001.html**). Many of the plenary talks are available via this page. The 2003 summer meeting will be held in Woods Hole July 21-25.

Table 1: Summary of US JGOFS Synthesis and Modeling funded projects by approach, geographic distribution, process and data sources. Note that some projects fit into multiple categories.

Total Number of Projects	65
Main Approach:	
Synthesis	22
Modeling	33
Remote Sensing	8
SMP Management	2
Geographic Distribution:	
Global Synthesis	17
Global Modeling	7
Regional Synthesis and Modeling	27
HOT & BATS Time-series	3
Arabian Sea	1
Equatorial Pacific	2
Southern Ocean	4
North Atlantic	4
Pacific	3
Tropical Pacific & Atlantic	3
Multiple JGOFS Sites	2
Subtropical/Subpolar Gyres	1
Ocean Margins	4
Process:	
Biological/Physical Interactions	9
Euphotic Zone Production and Export	16
Subsurface Transport/Remineralization	6
Sediments	3
Projects using data from:	
Global survey & climatological data	19
Time-series measurements	9
Process studies	14
Satellite ocean color	13
General JGOFS and other data	18

Illuminating The Twilight Zone: The Effects Of Biological Activity On Midwater Particle Flux

by Adrian B. Burd and George A. Jackson

JGOFS has contributed to a dramatic increase in our knowledge and understanding of biological activity and particle production in the surface ocean in recent years. In contrast, we know comparatively little about the biological phenomena of the mesopelagic region, which have a significant effect on the flux of particles through the water column. On average, only 10% of the particulate material sinking below 100 meters reaches a depth of 1,000 meters.

This decrease is frequently described in models of the ocean carbon cycle by means of a power-law (or sometimes an exponential) function normalized either to the flux at some depth or to primary production. A weakness of such formulations is that they do not represent the spatial and temporal variability in biological activity that is the primary cause of these changes.

Recent work by several research groups has focused interest on this midwater or mesopelagic zone and demonstrated its importance for understanding the cycling of elements in the ocean. U.S. JGOFS sponsored a meeting, held in San Antonio, Texas, last March, to discuss the role of this region in the flux of particles from the surface ocean to the depths.

This midwater zone receives insufficient light for photosynthesis but enough to be detected and utilized by deep-sea animals. For this reason, it is often referred to as "the twilight zone." For JGOFS, the importance of this region lies in its effect on particle flux. Particulate material settling out of the euphotic zone carries with it organic material that can be utilized by microbial and zooplankton communities in the mesopelagic zone.

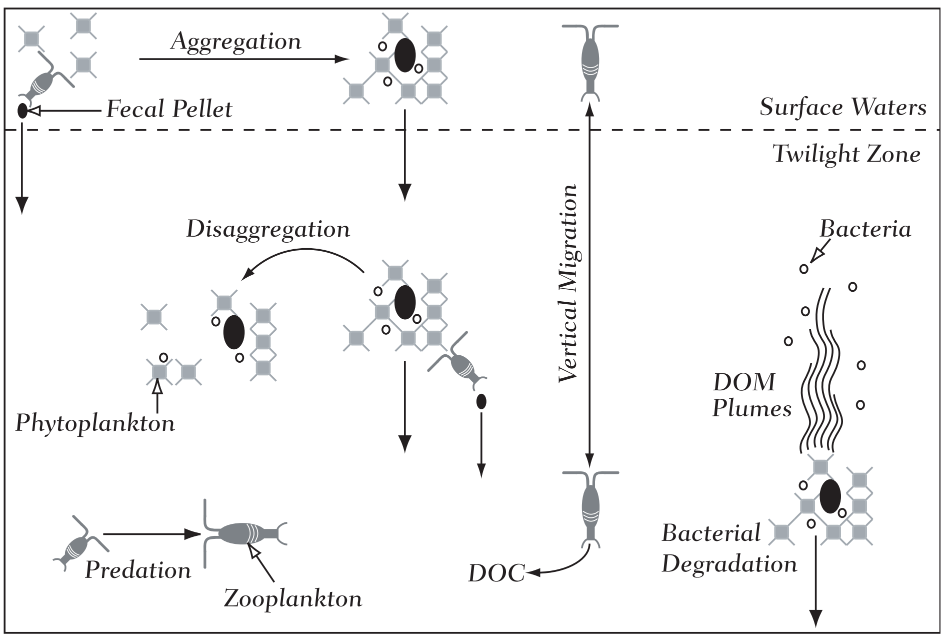

Figure 1: The biological processes affecting particle flux in the twilight zone. Open circles represent bacteria, both free-living and attached to particles; ovals represent zooplankton fecal pellets.

If particulate material were not affected by midwater communities, the role that the ocean plays in the global carbon cycle would be easier to discern. Virtually all of the organic carbon sinking out of the surface ocean would reach the bottom, where it would be consumed or incorporated into the sediments. But biological activity transforms this carbon at shallower depths, affecting the time required for it to reappear in surface waters. If particulate organic carbon (POC) is converted into dissolved organic carbon (DOC) at depths within the range of deep mixing, it can reappear in surface water relatively rapidly. If conversion occurs deeper in the water column, on the other hand, millennia may pass before this carbon resurfaces.

Physical properties of particles, such as diameter and density, influence the sinking rates of particles and therefore the time they spend in the twilight zone. Physical processes of coagulation (or aggregation) and disaggregation affect these properties by modifying the distribution of particle sizes.

The role of organisms in changing these particle properties is less well understood. For example, sloppy zooplankton feeding can lead to the formation of small, slowly sinking or suspended particles. Other processes can alter the composition of particles, thereby changing the effect of the inorganic ballast material on the rate at which particles sink.

The particle flux is affected by two biological communities: the microbes and the zooplankton. The relative contribution of these two groups remains unknown. Estimates in different studies show that either group of organisms can account by itself for all of the observed changes in particle flux. This oversubscription to carbon consumption makes the relative roles uncertain. It also hampers our understanding of the relationship between spatial and temporal variations in the particle flux and similar variations in the midwater communities.

Free-living bacteria, those not attached to particulate material, form the main component of the microbial community in the midwater region. However, microbes attached to particles have the greater effect on particle flux because they break down the particulate organic material, either by converting it into dissolved compounds that leak out or by consuming and respiring it themselves. We do not know the relative contribution of these two activities. One unanswered question is how microbes maintain their populations while attached to sinking particles.

Linked to the problem of microbial population dynamics is the observation that the microbial community on particles changes with depth as the relative numbers of Archaea increase. It is unclear how rapidly and in what manner these microbial communities can respond to changes in the particle flux. We also do not know how the formation of a trail of solubilized organic matter affects the ability of free-living microbes to exist in temporary "hot spots" and enables zooplankton to find these particles.

Zooplankton living in the mesopelagic zone consume sinking particulate material, thus affecting the flux directly. However, they also affect the flux in subtler ways. Zooplankton have been observed feeding on the detritus of both phytoplankton and zooplankton. Through sloppy feeding they convert some of the larger, rapidly-settling particles into smaller, slower-settling ones. They also produce fecal pellets, which settle quickly; they excrete material as dissolved organic material, and they respire some of what they consume.

The vertical migration of zooplankton is another factor in the flux of carbon out of the surface waters. Migrating organisms usually spend the night at the surface and swim to depths of several hundred meters for the day. Although many of these organisms retain material in their gut for longer periods of time than do the non-migrating species, this pathway is not the main means by which material is transported below about 200-300 meters. These organisms can also transport a significant amount of DOC. Estimates by Richard Lampitt of the Southampton Oceanography Centre, UK, Deborah Steinberg of the Virginia Institute of Marine Sciences and others indicate that active sinking flux makes up only a few percent of the particle flux, but that active DOC flux can be as much as 40% of the passive POC flux.

How do midwater communities respond to changes in particle flux? Although this is still largely unknown, there are some indications that effects can be profound. Research in the Arabian Sea by Karen Wishner of the University of Rhode Island and colleagues has shown that the reproductive cycle of the copepod *Lucicutia grandis* is tied to increases in particle flux resulting from the monsoons in the area. However, these organisms cannot rely solely on particle flux for food, and many midwater detritivores are also carnivores. Thus food-web structure complicates the task of following the trail of carbon through the mesopelagic zone.

Modeling can play an important role in understanding these systems. Reiner Schlitzer of the Alfred Wegener Institute for Polar and Marine Research, Germany, has used the technique of inverse modeling to infer the rate of remineralization with depth from observed global distributions of nutrients. Such models indicate substantial spatial variability in remineralization rates, which suggests that simple relationships between depth and particle flux need to be changed to describe regional variations.

Food-web models, such as those developed by ourselves and Lars Stemmann of Texas A&M University, show that fluctuations in the biological community can have dramatic consequences for the particle flux reaching the ocean sediments. Stemmann's modeling results, when compared with field data, show the importance of including both microbes and zooplankton in models.

Surface-water communities can have an effect on mid-water processes as well because their composition affects the sinking and aggregation rates and the composition of sedimenting particles. For example, salps produce relatively large, rapidly sinking fecal pellets. A surface bloom of salps can result in the transport of carbon from the surface to the sediments with little processing in midwater. The vertical migration of zooplankton provides food to midwater carnivores as well as DOC from excretion. The surface waters thus form a filter between the sunlight and the midwater communities.

The consensus of the participants at the San Antonio meeting was that we need to develop programs to investigate the twilight zone. These programs should be designed to investigate the system as a whole and to include simultaneous measurements of microbial, zooplankton and particle compartments. More information on the workshop is available via the U.S. JGOFS home page (**http://usjgofs.whoi.edu/mzweb/midwater.html**).

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Time-Series Programs Look To The Future

by Michael W. Lomas

The complex physical and biogeochemical interactions that regulate ocean carbon fluxes include random physical events, subtle fluctuations in community structure and function, natural climate cycles and the effects of human activity. The belief that these interactions should be observed on a regular basis over long periods of time led U.S. JGOFS to establish the Bermuda Atlantic Time-series Study (BATS) in the subtropical North Atlantic and the Hawaii Ocean Time-series (HOT) study in the North Pacific gyre in 1988. A decade and a half later, we are finding that the some of the paradigms that guided our research on ocean ecosystems are insufficient and that new perspectives are emerging to provide a foundation for continued investigations.

In order to synthesize results as well as to plan for future time-series activities, 52 scientists and students gathered in Vancouver, British Columbia in early April for a time-series workshop. The meeting, "Shifting Paradigms: A U.S. JGOFS Ocean Time-series Summit," focused on current and emerging knowledge of ocean biogeochemistry, scales of spatial and temporal variability, and gaps in our understanding of ocean physics, biology and biogeochemistry that need to be addressed in future research.

Organizers of the workshop were BATS representatives Michael Lomas, Nicholas Bates and Anthony Knap of the Bermuda Biological Station for Research, and HOT representatives John Dore, David Karl and Roger Lukas of the University of Hawaii.

The meeting offered a combination of invited keynote presentations, discussion groups and contributed oral and poster presentations. Keynote presentations emphasized several critical components of present and future ocean time-series studies. Karl and Lukas spoke on changing biogeochemical paradigms and the Ocean Observatories Initiative respectively. Raleigh Hood of Horn Point Environmental Laboratory gave a talk on the current status and future directions of open-ocean modeling, and Deborah Steinberg of the Virginia Institute of Marine Science made a presentation on education and training of students.

Discussion groups compared and contrasted system properties in the North Atlantic and the North Pacific Oceans with the aim of identifying knowledge shortfalls, while contributed talks related the details of individual studies.

As with most scientific endeavors, new questions have arisen as we have made progress on the old during the course of the JGOFS time-series programs. The answers obtained could profoundly affect our understanding of the marine carbon cycle.

For example, one of the most provocative findings associated with the time-series studies is the rediscovery of the importance of biological diversity and complexity, particularly among the prokaryotes. The association of diversity with an array of metabolic pathways should provide fresh insights into the turnover of the dissolved organic matter pool and the processes that uncouple energy and carbon pathways in the ocean.

Building on our existing knowledge, how do we proceed to answer new questions? First, continuing time-series studies at both existing sites and additional sites in key regions is essential for distinguishing natural variability in biogeochemical cycles from anthropogenically induced changes.

Long-term studies also require the careful and gradual integration of new methodologies. For instance, the standard set of measurements, designed to fit the dominant ocean paradigms at the inception of BATS and HOT, has expanded and become more rigorous with the development of new technologies, opportunities and paradigms. This evolution is especially important as modeling and synthesis efforts refocus observational and experimental studies in new directions.

Second, revised conceptual biogeochemical models and new mechanistic theories need to be developed to incorporate our everchanging views of ocean ecosystems. Sufficient data now exist to generate explicit hypotheses that can be directly tested by process-oriented studies in conjunction with the time-series programs. The need for large-scale hypothesis testing in the ocean has become increasingly important with the growing appreciation of the non-linearity of ocean processes and the possibility of feedback mechanisms between large and small-scale processes.

Third, ecosystem-scale perturbation experiments, including controlled volume experiments, should be conducted to achieve a mechanistic understanding of the biological and biogeochemical processes operating in the subtropical ocean gyres and elsewhere in the ocean. A correlated experimental design would include controlled-volume experiments that emphasize processes and mechanisms within the four-dimensional context of biological and physical variability.

Such experiments would benefit from the development of improved sensors for key biogeochemical variables, from contemporaneous studies using a variety of platforms (moorings, profiling floats, gliders, cabled bottom observatories) to link different scales, and from broadening the base of sites to reflect inter-regional variability. Participants in the Vancouver meeting expressed sup-

(Cont. on page 9)

Workshop Investigates Role Of Iron Dynamics In Ocean Carbon Cycle

by Kenneth S. Johnson, J. Keith Moore and Walker O. Smith Jr.

Under the aegis of the U.S. JGOFS Synthesis and Modeling Project (SMP), a group of modelers and investigators got together at the Monterey Bay Aquarium Research Institute in Moss Landing, California, in mid June to assess advances and identify gaps in our understanding of the role of iron in ocean productivity and export.

The three-day workshop, titled "Iron Dynamics in the Carbon Cycle," attracted 30 participants.

Its goals were:

- to synthesize recent results from field observations and experiments and modeling efforts;
- to look at how models incorporate iron dynamics and to determine whether new information exists that could improve representations in models;
- to identify critical gaps in our knowledge of the marine iron cycle that are hampering modeling efforts and to provide suggestions for future research.

The meeting began with a series of plenary talks that summarized results from JGOFS field studies, open-ocean fertilization experiments, experimental studies of iron chemistry and bioavailability and recent studies in the coastal zone. Two other talks reviewed the incorporation of iron into ecosystem models and general circulation models. The second and third days were devoted to sessions on topics such as the role of iron-binding ligands, external iron sources, bioavailability and the status of these processes in models. Some of the highlights and recommendations of the meeting follow.

Over the last 15 years, scientists have become increasingly aware of the role of iron in regulating rates of carbon cycling and the accumulation of standing stocks of particulate organic carbon. Incorporation of iron dynamics into biogeochemical models has dramatically improved our ability to simulate ecosystem processes in the ocean. But there are still large uncertainties in our understanding of the chemistry and biology of iron that hamper our ability to model ocean biogeochemical cycling and to predict the response of marine ecosystems to changes in climate.

A global database of dissolved iron distributions in the ocean is a critical requirement for large-scale modeling efforts. The difficulties inherent in measuring very low levels of iron have hampered the accumulation of such a database. Meeting participants concluded that, with serious efforts at intercalibration, it would be feasible to begin large-scale efforts to map global distributions of iron and other biogeochemically significant trace elements.

The deposition of mineral dust in the ocean is a key source of iron. Although efforts to model the transport and deposition of mineral dust are increasing in complexity and accuracy, observations are lacking. Significant efforts to develop autonomous, moored instruments to measure aerosol concentrations and deposition are underway and should be encouraged. The solubility of iron in aerosols remains uncertain, as does the relative importance of wet and dry deposition.

Continental margins also supply a large amount of iron from sedimentary sources. Despite this source, presentations at the workshop demonstrated that coastal iron limitation can play a major role in regulating coastal ocean ecosystem rates, biomass and structure. Iron inputs from the continental margins into the deep ocean are not yet included in any of the global iron models.

Just a decade ago, the role of iron in controlling ocean biogeochemical processes was the subject of intense debate. Since then, eight open-ocean iron fertilization experiments (Table 1) have shown that rates of primary production and biomass accumulation are enhanced following the addition of iron. Iron enrichment experiments conducted in bottles during U.S. JGOFS field studies have shown remarkable agreement in the level of iron that stimulates a community response.

Although we basically understand the role of iron in the onset of phytoplankton blooms, we know far less about the fate of the carbon produced in the open-ocean iron enrichment experiments and thus about how iron affects carbon export, a key variable in regulating atmospheric CO_2 levels. Discussions at the meeting suggested that small-scale fertilization experiments may not achieve the high levels of biomass conducive to carbon export. Horizontal diffusion appears to dilute the patches, and particle concentrations do not reach a point where aggregation and sinking occurs. Workshop participants recommended that future experiments be conducted in regions such as the equatorial Pacific where carbon export is easier to observe and that the experiments be on a large enough scale to increase the chances of observing export.

Workshop discussions also revealed how little we know about how dissolved iron is removed from the upper ocean through adsorption and scavenging onto particles. We need to know how this process varies with particle concentrations, sinking fluxes and iron and ligand concentrations.

Although most models assume that iron is recycled in similar ways and at similar rates as the macronutrients, observations over the last decade suggest that ratios of iron to carbon are much more variable than nitrogen/carbon or nitrogen/phosphorus ratios in plankton and the water. Detailed measurements of key elemental ratios using clean techniques could answer many of our remaining questions about iron and carbon cycling in the ocean.

Much discussion at the workshop focused on iron speciation and the role of ligands in regulating biological availability and biogeochemical cycling. More than 99% of the dissolved iron in the upper ocean is bound up with organic molecules. Currently ligands that bind iron are only crudely represented in models. The sources, sinks, lifetimes and turnover rates between ligand pools and the processes that govern these transformations are largely unknown.

The bioavailability of dissolved and particulate forms of iron is also not well known. Phytoplankton and bacteria have many ways of acquiring iron. Photochemistry also causes cycling of iron among different chemical species, thereby modifying its availability. Some degree of specificity may exist in the forms of iron taken up by prokaryotes and eukaryotes.

Great progress has been made in recent years in understanding the links between nitrogen fixation and marine iron cycling. The iron requirements of *Trichodesmium* species, key nitrogen-fixing bacteria, are roughly 10 times higher than those of most open-ocean phytoplankton. Recent fieldwork suggests that nitrogen fixation in parts of the North Atlantic where dust deposition is high is limited by phosphorus rather than by iron. But iron and/or light may be limiting nitrogen fixation rates over much of the remaining subtropical and tropical ocean. Marine ecosystem models are now beginning to include nitrogen fixers.

We now recognize iron as a keystone regulator of biogeochemical functioning in the ocean. But it is also clear that the chemistry of iron can be complex. Modelers at the meeting asked for well-constrained parameters that could lead to relatively simple equations for iron chemistry. In fact, many of the areas in which we have developed a reasonable database of reliable observations do lend themselves to simple parameterizations. The key question is whether additional work will continue to support such basic parameterizations or whether it will demonstrate that the system is so complicated that simple models will be of little use.

A complete report on the workshop is available via the U.S. JGOFS SMP home page (**http://usjgofs.whoi.edu/mzweb/iron/iron_rpt.html**).

(Editor's note: Ken Johnson of the Monterey Bay Aquarium Research Institute, Keith Moore of the University of California at Irvine, and Walker Smith of the Virginia Institute of Marine Science organized the U.S. JGOFS workshop on iron dynamics in the carbon cycle.)

Table 1: A summary of open-ocean iron enrichment experiments to date

experiment	location	date	observations
IronEx I	equatorial Pacific	1993	3-fold increase in chlorophyll, patch subducted 4 days into experiment
IronEx II	equatorial Pacific	1996	10-fold increase in chlorophyll, 90 μatm drawdown in CO_2, 5μM drawdown in NO_3
SOIREE	Southern Ocean Pacific sector	1999	south of APFZ, 6-fold increase in chlorophyll, 25 μatm drawdown in CO_2, 2 μM drawdown in NO_3
EisenEx I	Southern Ocean Atlantic sector	2000	dispersion into eddy, 4-fold increase in chlorophyll
SEEDS	western subarctic Pacific Ocean	2001	40-fold increase in chlorophyll, 13 μM drawdown in NO_3
SOFeX North	Southern Ocean Pacific sector	2002	north of the APFZ, greater than 10-fold increase in chlorophyll, greater than 40 μatm drawdown in CO_2
SOFeX South	Southern Ocean Pacific Sector	2002	south of the APFZ, greater than 10-fold increase in chloropyll, greater than 40 μatm drawdown in CO_2
SERIES	eastern subarctic Pacific Ocean	2002	greater than 10-fold increase in chlorophyll more than 5 μm NO_3 drawdown

Time-Series Workshop–from page 7

port for a cabled observatory at HOT Station ALOHA, to be supported by the National Science Foundation and augmented with additional projects.

Fourth, characterizing the temporal and spatial scales of biological diversity is both desirable in its own right and an important means of generating a better understanding of the relationships between specific taxa and their functions. As molecular-level methods in the fields of genomics, proteomics and bioinformatics become more commonplace in oceanography, sample archives from the time-series studies will be an invaluable resource for documenting long-term changes.

Lastly, additional synthesis of present data sets as well as comparisons with paleoceanographic data sets will allow us to achieve a better understanding of key variables for constraining predictions of future climate changes and biogeochemical responses of the ocean.

New Developments Enhance Access To U.S. JGOFS Data Sets

by David M. Glover and Cynthia L. Chandler

A number of U.S. JGOFS Data Management Office (DMO) accomplishments over the last year are making it steadily easier for scientists to gain access to data from U.S. JGOFS field studies and the Synthesis and Modeling Project (SMP). The data sets are almost all in and through the process of quality control, merged data products are increasingly available, work has begun on CD-ROMs for distribution at the final JGOFS conference next spring, and a new version of the U.S. JGOFS Live Access Server (LAS) interface will be available shortly.

In collaboration with colleagues at the University of Washington and the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Laboratory (PMEL), DMO staff members have been working on providing investigators with a useful interface for visualizing, reformatting and selecting subsets of U.S. JGOFS field data and model output. Version 6 of the LAS interface will provide access to both the gridded data products of the SMP and the profile data collected during the North Atlantic Bloom Experiment (NABE), the Equatorial Pacific Process Study (EqPac), the Arabian Sea Process Study (ASPS) and the Antarctic Environment and Southern Ocean Process Study (AESOPS).

In addition to its former capabilities, the new interface now provides metadata plot views that allow investigators to see when, where and how much data have been collected. In LAS version 6, gridded and profile data will be accessible from a single window, allowing direct comparisons between model output and field data. Improvements in the hierarchical structure in which the data are organized and presented should facilitate thematic grouping of parameters according to general disciplinary and interdisciplinary topics. New capabilities include a "history page" of previous plots, ways of filtering out unwanted variables, stations and cruises in selecting a subset of data, and a new depth-versus-time view for station-depth cruise track plots. LAS version 6 should be available by the end of the year and will be announced on the U.S. JGOFS web site (**http://usjgofs.whoi.edu**).

The long process of collecting the data, subjecting them to quality control procedures and tracking down the few outstanding bits and pieces is close to an end. Through the diligent efforts of David Schneider and George Heimerdinger, every data set that could be collected has been tracked down and added to the U.S. JGOFS database. Table 1 shows the inventory statistics for each of the process studies.

Completion of the data inventory has allowed us to merge data from individual cruises into larger products. Merged data products are logical supersets of all data collected during the same process study using a common collection device, such as a CTD or Niskin bottle. Before they are merged, data files have to be checked to ensure that all parameters have common but exclusive names and units. Common names are necessary because the merging process keys on parameter names; the names must be exclusive to ensure the integrity of the merged data product.

This effort is complete for the data sets from the Arabian Sea and Southern Ocean process studies, and work is progressing on the North Atlantic and equatorial Pacific studies. So far we have generated merged products for CTD, trace-metal-clean and Niskin bottle data, and we are exploring the feasibility of generating merged products for zooplankton and sediment trap data.

In preparation for the final JGOFS Open Science Conference (OSC) in Washington, D.C., next May, we have begun creating CD-ROMs with all of the U.S. JGOFS process study data and merged products. These discs will be the first in a series of CD-ROMs containing the final data products of U.S. JGOFS.

At the OSC, we hope to distribute without charge volumes one and two of this collection. Each CD-ROM will contain process study data, the merged data products generated from those data, and custom-built software that will allow the user to navigate and extract the desired information from a variety of platforms. Also included will be extensive documentation (HTML format) pertaining to methodology, units of measurement, principal investigators involved, and other pertinent facts and information. Future CD-ROMs will contain products from other components of U.S. JGOFS, including the SMP.

We have learned a number of valuable lessons about data management over the last decade. First, for international, multidisciplinary programs such as JGOFS, a centralized data facility that can serve both as a quality-control center and as a distribution hub is of paramount importance. Second, regardless of data distribution schemes, an *a priori* set of parameter names, associated

(Cont. on page 12)

Table 1: Inventory Statistics For U.S. JGOFS Process Studies

Process study	total number of data entities	data entities submitted to DMO	percent of total submitted to DMO
NABE	46	46	100
EqPac	206	202	98
Arabian Sea	174	172	99
AESOPS	318	301	95

Aloha *Kilo Moana:* The Oceanographer Joins The Fleet

by David M. Karl

Research vessel *Kilo Moana* sailed into Honolulu harbor on Sept. 3 to begin service as the newest Auxiliary General Oceanographic Research (AGOR) ship in the University National Oceanographic Laboratory Systems (UNOLS) fleet. This state-of-the-art vessel, whose name means "oceanographer" in Hawaiian, is the first AGOR to be constructed on a Small Waterplane Area Twin Hull (SWATH) design. The unique hull will provide a comfortable, stable platform for multidisciplinary marine research in diverse ocean regions.

RV *Kilo Moana* was built in Jacksonville, Florida, by American Marine, Inc. The Naval Sea Systems Command was the program manager for the Oceanographer of the U.S. Navy, sponsor of the new ship. The University of Hawaii will operate the vessel from its marine expeditionary center in Honolulu for the academic ocean research community.

Courtesy of SOEST, University of Hawaii

R/V *Kilo Moana*

With an overall length of 186 feet and a beam of 88 feet, RV *Kilo Moana* has ample exterior deck space and 3,000 square feet of dedicated interior science space, including both general-purpose and specialized laboratories. She is equipped with both deep-water and shallow-water multibeam echo sounders capable of accurate sea-floor mapping at any depth in the ocean, dynamic positioning, and a complement of winches, cranes and other handling gear. The 48 berths include 31 for scientists. Powered by two diesel electric motors, the vessel has a range of 10,000 nautical miles at 11 knots and can stay at sea for up to 50 days.

Captain of the new ship is Gray Drewry, who is no stranger to JGOFS. Captain Drewry served aboard R/V *Thomas G. Thompson* and helped to support the U.S. JGOFS Equatorial Pacific and Arabian Sea process studies.

On Sept. 22, following a brief provisioning period in Honolulu, RV *Kilo Moana* steamed to Hawaii Ocean Time-series (HOT) Station ALOHA at 22°45'N, 150°W to begin its career in support of ocean science. This inaugural expedition, led by Anthony Michaels and Douglas Capone of the University of Southern California, focused on the processes controlling primary production in the ocean. Later this fall, HOT scientists will return to Station ALOHA aboard the new ship to continue the monthly sampling program that has been underway at this site since 1988.

Correction

The following figure was omitted from the last issue of *U.S. JGOFS News* (11,4). It should have been Figure 2 on page 7 in an article by Michael W. Lomas titled "Climate Patterns, Phytoplankton Community Composition And Ocean Carbon Fluxes." We regret the error.

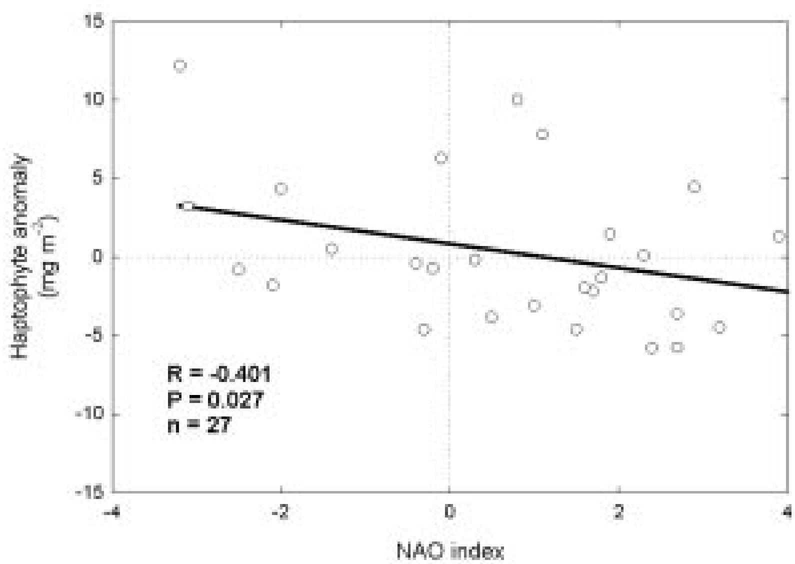

Figure 2: Correlation between the haptophyte-specific chlorophyll anomaly and the North Atlantic Oscillation (NAO) index during the winter/spring bloom period at the Bermuda Atlantic Time-Series Study (BATS) station in the Sargasso Sea. Haptopyte pigment values are integrated over the 140 meters and given here in milligrams per cubic meter. The solid line represents the best fit to the data points.

New Building at USM Celebrates Contributions Of George Knauer

by David M. Karl

In 1979, George Knauer and John Martin of Moss Landing Marine Laboratories and Kenneth Bruland of the University of California at Santa Cruz published a paper in *Deep-Sea Research* on the flux of particulate matter from the base of the euphotic zone to the ocean depths and launched a new subdiscipline of marine biogeochemistry. Along with carbon, nitrogen and phosphorus export data and estimates of mesopelagic zone remineralization rates, Knauer and his colleagues presented the design for a conceptually simple collection device, the particle interceptor trap or PIT. A few years later, they organized an international, multidisciplinary field program to investigate the rates and mechanisms of the production and export of organic matter in the euphotic zone. The decade-long research program that emerged, Vertical Transport and Exchange or VERTEX, was a key precursor to JGOFS.

In 1984, the National Academy of Sciences sponsored a workshop in Woods Hole that produced the blueprint for the U.S. Global Ocean Flux Study (GOFS), later known as U.S. JGOFS. At that meeting, Knauer summarized what had been learned during VERTEX and what he thought still needed to be done. He later served as a member of the GOFS steering committee for several years.

In 1987, Knauer chaired a U.S. GOFS workshop on ocean margins (*U.S. GOFS Planning Report No. 6*), the results and implications of which were hotly debated for more than a decade. A year later, he and Vernon Asper of the University of Southern Mississippi organized and chaired an international workshop on sediment trap technology and sampling (*U.S. GOFS Planning Report No. 10*).

Photo courtesy of G. Knauer

Founding director George Knauer, third from right, was honored at groundbreaking ceremonies for the new George A. Knauer Marine Science Building at the University of Southern Mississippi on April 23.

Knauer is also well known for his pioneering research on zooplankton metabolism and fecal pellet production rates, marine snow composition and dynamics, and the role of trace metals in ecosystem function. For many years, he and Martin collaborated on these and other important research projects as they built a world-class facility at the Moss Landing Marine Laboratories.

In 1985, Knauer resigned his position at Moss Landing and moved across the country to begin a new phase of his career as the first director of the College of Marine Science at the University of Southern Mississippi (USM). At that time the new academic program was housed entirely in a few trailers, without plumbing or other amenities. Through his leadership, vision and perseverance, Knauer built a superb team of young faculty members, including Vernon Asper, Donald Redalje, Steven Lohrenz and Alan Shiller, that put Hattiesburg and USM on the map. A few years after putting together the foundation for a credible marine education and research program, he retired from academic life to pursue other interests.

Knauer was recently called out of retirement to participate in the ground-breaking ceremony for the George A. Knauer Marine Science Building, a new 17,000-square-foot marine science laboratory. This honor is a well-deserved recognition of his life-long commitment to research, education and community service.

U.S. JGOFS Data Sets–From page 10

methods and preferred units must be established. Third, regardless of how sophisticated virtual data systems become, none can be operated successfully in an unattended mode for very long, and certainly none can detect bad data when they arrive at the data center. People who check and recheck the data submitted by scientists are essential to the success of any plan for establishing a long-term, high-quality database.

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

JGOFS

JOINT GLOBAL OCEAN FLUX STUDY

Update On JGOFS Open Science Conference

The final JGOFS Open Science Conference (OSC) is taking shape as speakers are signed up, poster sessions organized and events planned. Titled "A Sea of Change: JGOFS Accomplishments and the Future of Ocean Biogeochemistry," the conference will be held at the National Academy of Sciences (NAS) in Washington, D.C., May 5-8, 2003.

Invitations to the OSC, mailed in early October, include the schedule of events, registration information and hotel reservation forms, a call for poster abstracts, and a welcome to the conference and to Washington from JGOFS Scientific Steering Committee chair Hugh Ducklow and Debbie Steinberg, chair of the conference program steering committee. Registration by Jan. 15, 2003, is encouraged as the savings will be considerable.

Abstracts for posters must be submitted by Jan. 15, 2003, either electronically at the web site given below or on a 3.5-inch diskette mailed to the U.S. JGOFS Planning Office. Acceptances will be sent in early March, and abstracts must be posted on the conference web site by late March. Hotel reservations should be completed by April 1.

The purpose of the conference is to provide scientists from around the world an opportunity to report on JGOFS contributions to our larger understanding of the ocean carbon cycle and its interaction with global climate. Plenary and poster sessions will address a wide variety of topical and regional issues.

On the first day, a morning plenary session on ocean color and ocean dynamics will feature talks on envisioning the ocean from space, quantifying air-sea fluxes of carbon dioxide (CO_2), and carbon storage. The afternoon session will focus on JGOFS connections with other international ocean programs, with talks on the World Ocean Circulation Experiment (WOCE), Global Ocean Ecosystems Dynamics (GLOBEC), and the upcoming Surface Ocean - Lower Atmosphere Study (SOLAS).

The second day will begin with a plenary session on ecosystem structure and dynamics, with talks on the role of plankton species in biogeochemical fluxes, co-limitation of primary production by light and nutrients, links between the surface and deep ocean, and climate sensitivity in models. The afternoon session on ocean margins and benthic processes will have talks on the role of coastal regions and ocean margins in the anthropogenic impact on biogeochemical cycles, benthic processes, and seeing the past in the light of JGOFS findings.

On the third day, the first plenary session will focus on data assimilation and modelling, with talks on modelling ocean biogeochemical fluxes, effects of the "internal weather of the sea" on ocean biogeochemistry, and using inverse models to estimate biogeochemical fluxes. A second session will focus on highlights of the JGOFS era, including iron limitation, particle fluxes and new technologies. Future programs will be the topic of a third session that afternoon, with talks on ocean futures in biogeochemistry, ocean observing systems, and the ocean in the larger earth system.

Talks on the last morning will take a look at the larger picture. The final session will feature talks on how and why JGOFS was created, ocean biogeochemistry in the earth system, JGOFS accomplishments and new challenges, and an epilogue.

Poster sessions, each focusing on particular themes and regions of the global ocean, will be presented each afternoon after the talks. The first session will include posters on CO_2, ocean color, the North Atlantic, the equatorial Pacific and the North Pacific. Themes of the second poster session include plankton community structure, euphotic zone production and export, time-series studies and ocean margins. The third session will feature posters on the mesopelagic zone, the benthos and paleo-oceanography, global synthesis and ecosystem modeling, the Arabian Sea and the Southern Ocean.

A highlight of the OSC will be the keynote lecture at 6 P.M. on May 7 at the Smithsonian National Museum of Natural History. Carol Browner, administrator of the U.S. Environmental Protection Agency during the administration of President Clinton, will give a talk titled "Global Climate Policy: Where is the World Headed?" A reception and opportunity to see a portion of the museum will follow.

Other events planned include a reception in the NAS Great Hall the evening before the conference starts and a luncheon cruise along the Potomac River after it ends. More information about the OSC is available from Mary Zawoysky at the U.S. JGOFS Planning Office (**mzawoysky@whoi.edu**) or at the OSC web site (**http://usjgofs.whoi.edu/osc2003.html)**.

Flux Estimations–From page 2

remineralization rates compatible with the oxygen, nutrient and carbon observations.

As Figure 3 shows, the first step involves simulation of the various tracers, given an initial flow field, export production and remineralization, as is true for other biogeochemical models. The innovative part concerns the comparison between simulated fields and data. This is traditionally done subjectively, and modifications of flows and/or biogeochemical parameters are devised on the basis of visual comparisons of measured and modeled fields.

In this approach, the "adjoint method" is used to translate model/data misfits into improvements of velocity and biogeochemical parameters that are guaranteed to produce more realistic model fields in the next simulations. In essence, the adjoint method involves propagating the model/data misfits backwards in time and space throught the model, allowing one to compute the sensitivities of the model/data misfit to a suite of model parameters such as the flow field or biogeochemical rates. Using these sensitivities, one can adjust model parameters iteratively to improve solutions.

The adjoint method has been successfully applied in a global physical/biogeochemical model, and simulations have yielded global and regional estimates of organic carbon export fluxes. Comparisons with productivity estimates from satellite imagery have revealed significant discrepancies in the Southern Ocean, where relatively small productivity estimates from satellite-mounted instruments were found to be incompatible with *in-situ* measurements of water-column biogeochemistry.

The number of studies applying inverse methods to the determination of biogeochemical fluxes in the ocean is still small compared to forward modeling approaches. The lack of large, globally-integrated data sets needed for inverse calculations is probably a factor. However, the amount of data available has increased enormously in recent years, and the upcoming release of JGOFS and WOCE data offers an unprecedented opportunity to undertake more inverse data evaluation projects.

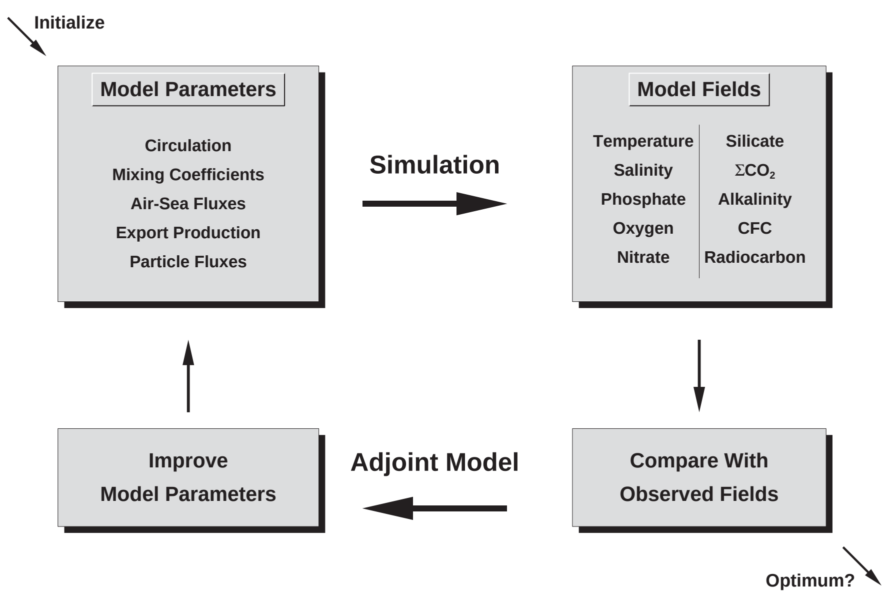

Figure 3: Schematic diagram of an inverse model that incorporates irregularly spaced and possibly sparse hydrographic, nutrient, carbon and tracer data to estimate ocean circulation and nutrient and carbon fluxes. Application of the adjoint method is the key step that allows automatic fitting of the model to the data.

Table 1: Summary of data sets contained in the Electronic Atlas of WOCE Data (eWOCE). These data are available in Ocean Data View format on DVD 2 of the final WOCE data release (version 3) or online at **(http://www.ewoce.org)**.

WoceBtl and **WoceCTD**: Hydrographic, oxygen, nutrient, carbon and tracer data from WOCE Hydrographic Program (more than 18,000 stations, separate data collections for bottle and CTD data)

uot_atlantic, **uot_indian**, **uot_pacific**, and **uot_hdlines**: More than 1 million temperature and salinity profiles from Upper Ocean Thermal Program (organized by ocean basins; separate data collection for high density lines)

WoceCM: Velocity and hydrographic data for more than 1,300 moored current meters from the Current Meter Program

WoceSVP: Trajectories and velocity data for more than 12,000 drifters from the Surface Velocity Program (daily data organized by years, 1979-2000)

subsurface_Floats: Trajectories as well as velocity and temperature data for 1,040 floats from the Subsurface Float Program

shipboard_ADCP: Shipboard ADCP velocity profiles for more than 240,000 stations and 540 cruises from the ADCP Program

sss: Sea-surface temperature and salinity data from the Sea Surface Salinity Program (more than 400,000 samples)

pfloatProfiles: More than 31,000 temperature and salinity profiles from more than 1,600 profiling floats

seaLevel_delay: Hourly sea-level data for 161 stations from the delayed-mode Sea Level Program (1900-2000)

seaLevel_fast: Hourly sea-level data for 129 stations from the fast-delivery Sea Level Program (1985-2001)

Gridded data sets of sea-surface temperature, sea-surface height and winds from satellite sensors are available in netcdf files on DVD 2 of the WOCE V3 release.

OCEANS Rising: Open Science Conference Planned for New IGBP Project

by Julie Hall

The International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee on Ocean Research (SCOR) are sponsoring an open science conference next January for Ocean Biogeochemistry and Ecosystems Analysis (OCEANS), a new 10-year project that will be part of the next phase of the IGBP. The conference is designed to gather information and ideas from the scientific community that will help project planners to develop a science plan and implementation strategy.

OCEANS is intended to build on results from JGOFS and other ocean research programmes. Its primary goal is to understand the sensitivity of the ocean to global change within the context of the broader earth system, focusing on biogeochemical cycles, marine food webs and their interactions. It will seek a comprehensive understanding of the effects of climate, human activity and the physical dynamics of the ocean on food web dynamics and the cycling of elements. It will also strive for mechanistic and predictive understanding of how marine ecosystems and biogeochemical cycles respond to natural climate variability and anthropogenic perturbations and how they, in turn, affect climate, ocean physics and marine resources (Figure 1).

Some areas of the ocean are likely to be particularly sensitive to long-term changes; these will be the focus of intensive study. These “hot spots” occur in critical domains such as regions of upwelling and deep mixing, continental margins, high-latitude areas, the sediment-water interface, the mesopelagic layer and intermediate waters.

The OCEANS Open Science Conference will be held Jan. 7-10, 2003, in Paris, France. The overarching questions for discussion at the conference are:

• How does global change, represented by changes in natural climatic modalities and anthropogenic perturbations, affect marine biogeochemical cycles and ecosystem dynamics?

• How do these effects alter the mechanistic relationship between element cycling and ecosystem dynamics?

• What are the mechanisms for feedback between these alterations and other components of the larger earth system?

The conference will feature plenary presentations that address the three overarching questions from different perspectives. It will also include posters presented by participants and two full days of working group discussions, which will be summarized on the final day of the meeting. Oct. 15 is the deadline for abstracts and early registration.

Working group discussions will focus on the following topics:

1. Trace elements in ecological and biogeochemical processes
2. Physical constraints on biogeochemical cycling and marine food webs
3. Climatic modulation of organic matter fluxes
4. Direct effects of anthropogenic carbon dioxide on biogeochemical cycles and ecosystems
5. Integrating food-web dynamics from end to end
6. Continental margins
7. The mesopelagic layer
8. Biogeochemical hotspots, choke points, triggers, switches and non-linear responses
9. Feedbacks to the earth system
10. Coupled models of biogeochemical cycles and ecosystems

The recently formed OCEANS transition team will draw on all contributions to the open science conference in developing the science plan and implementation strategy for the new project. More information about the OCEANS Open Science Conference, including registration details and the full programme, is available via the IGBP home page at **http://www.igbp.kva.se/obe/**

(Editor’s note: Julie Hall, a scientist at the National Institute of Water and Atmospheric Research in Hamilton, New Zealand, is chairman of the OCEANS Transition Team.)

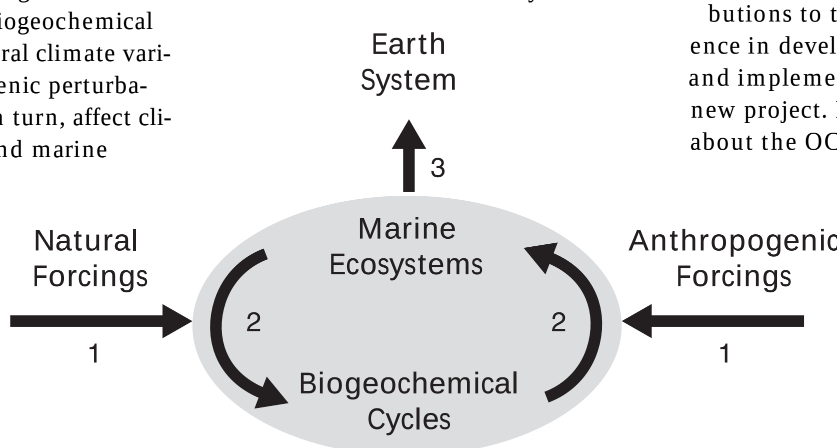

Figure 1: The scientific questions underlying the Ocean Biogeochemistry and Ecosystems Analysis (OCEANS) project focus on the effects of natural climatic cycles and anthropogenic perturbations on biogeochemical cycles and marine ecosystems, how changes alter the relationships between elemental cycles and ecosystems, and how these alterations, in turn, affect other components of the earth system.

• U.S. JGOFS Calendar 2002 •

23-25 October: U.S. JGOFS Scientific Steering Committee meeting, Old Town Alexandria, VA. Contact: Ken Buesseler, U.S. JGOFS Planning Office, Woods Hole Oceanographic Institution, Woods Hole, MA (**kbuesseler@whoi.edu**).

2003

7-10 January: International Open Science Conference "OCEANS: Ocean Biogeochemistry and Ecosystem Analysis," Paris, France. Contact: SCOR Secretariat (**scor@dmv.com**).

5-8 May: JGOFS Open Science Conference, "A Sea of Change: JGOFS Accomplishments and the Future of Ocean Biogeochemistry," National Academy of Sciences, Washington, D.C., USA. Contact: Mary Zawoysky, U.S. JGOFS Planning Office, WHOI, Woods Hole, MA (**mzawoysky@whoi.edu**).

5-8 May: JGOFS Scientific Steering Committee meeting, Washington, D.C., USA. Contact: Roger Hanson, JGOFS International Project Office, Bergen, Norway (**Roger.Hanson@jgofs.uib.no**).

21-25 July: U.S. JGOFS Synthesis and Modeling Project workshop, Woods Hole Oceanographic Institution, Woods Hole. Contact: Scott Doney, WHOI (**sdoney@whoi.edu**), or Joan Kleypas, National Center for Atmospheric Research, Boulder, CO (**kleypas@ncar.ucar.edu**).

Getting Access to U.S. JGOFS Data and Information

Information on the U.S. JGOFS program and access to all U.S. JGOFS data can be obtained through the U.S. JGOFS Home Page on the World Wide Web:

http://usjgofs.whoi.edu/

Inquiries may be addressed to the U.S. JGOFS data management office via electronic mail to **dmomail@dataone.whoi.edu** or by phone to David Schneider (508-289-2873).
Data from U.S. JGOFS process study cruises are available through the U.S. JGOFS data management system at the Web site above.
Data from the U.S. JGOFS time-series programs are also available via the World Wide Web at the following sites:
HOT **http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html**
BATS **http://www.bbsr.edu/ctd**
Data from the Survey of Carbon Dioxide in the Oceans are available from the Carbon Dioxide Information Analysis Center at
http://cdiac.esd.ornl.gov/oceans/home.html

U.S. JGOFS News

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We welcome your comments and contributions for publication.

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