U.S. JGOFS: A Component of the U.S. Global Change Research Program

# U.S. JGOFS NEWS

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## Assessing The Progress Of JGOFS: Highlights Of The Open Science Conference

*by Margaret C. Bowles*

Over the 13 years since it was launched, JGOFS has sponsored several science symposia that have offered opportunities to assess both the progress of the program itself and the evolution of ocean biogeochemistry as a discipline. As knowledge about the ocean's role in global carbon cycling and the response of its systems to environmental perturbations has grown, the scope of the endeavor has broadened considerably.

Some 100 scientists from 13 countries convened in Washington, D.C., in 1990 to assess the first JGOFS field study in the North Atlantic. The second symposium, held in Villefranche-sur-mer midway through the program in 1995, attracted nearly 150 participants from 20 countries. In April, 218 participants from 27 countries came to Bergen, located amid the fjords of western Norway, for the third symposium to be held under JGOFS auspices. Like its predecessors, this conference offered participants the chance to measure the advance of scientific knowledge against the questions that JGOFS was formed to address.

The Bergen conference was organized by Michael Fasham of Southampton Oceanography Centre, U.K., Karin Lochte of the Institut für Ostseeforschung, Germany, and Roger Hanson of the JGOFS International Project Office (IPO) in Bergen. It was sponsored by the Scientific Committee on Oceanic Research

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## Incorporating Iron into a Global Ecosystem Model

*by J. Keith Moore and Scott C. Doney*

One of the main goals of JGOFS is to gain a better understanding of the processes controlling carbon cycling and export in marine ecosystems. A major finding from the process studies and time series stations is that nitrogen available in the euphotic zone is often not the sole factor controlling carbon export. Phytoplankton growth, export production and community structure appear to be governed by the availability of both the macronutrients (nitrate, phosphate and silicate) and the micronutrient iron.

Ocean biogeochemistry models must allow for spatial and temporal variations among potentially limiting nutrients in order to capture marine ecosystem dynamics. We need to account for the effect of iron in particular on production, community structure and carbon export to the deep ocean if models are to be able to predict how climate change might influence ocean biogeochemistry.

We have developed a marine ecosystem model that does just that, building on the data collected during U.S. JGOFS and other field studies, such as the iron fertilization experiments (IronEx) conducted in the equatorial Pacific. Because it incorporates iron dynamics, the model is able to reproduce the high nutrient, low chlorophyll (HNLC) conditions observed in the subarctic Northeast Pacific, the equatorial Pacific and the Southern Ocean.

The numerical model has two size classes of phytoplankton, one class of zooplankton, sinking and non-sinking detrital pools, and the nutrients nitrate, ammonia, dissolved iron and silicate. It does not contain phosphorus at present, although we plan to incorporate it in the near future. The model includes a dissolved iron pool as a nutrient for phytoplankton with sub-surface and atmospheric sources, the latter representing the deposition of mineral dust.

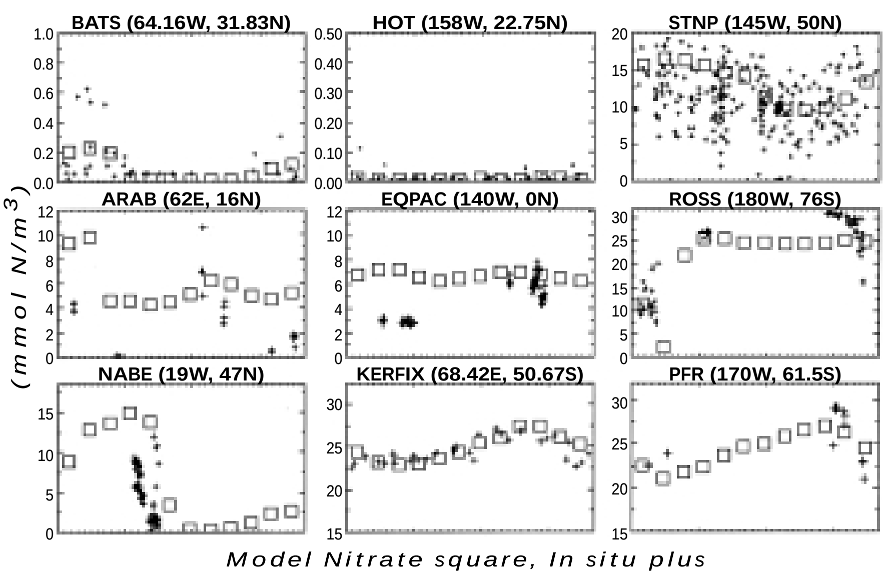


Figure 1: Monthly mixed-layer nitrate concentrations at nine ocean sites. Squares represent modeled values, and crosses represent composites of measurements made at these sites. Some composites are multi-year, and some are not.

The large phytoplankton size class in the model is designed to represent diatoms explicitly. Diatom growth rates can be limited by nitrogen in the form of nitrate or ammonia, iron, silica and/or available light. The growth rates of the generic small phytoplankton in the model can be limited by nitrogen, iron and/or available light. The small phytoplankton have lower half-saturation constants for nutrient uptake and experience stronger grazing pressure than the diatoms. Otherwise growth and light parameters for the two phytoplankton classes are identical.

The model is currently being run on a simple global mixed-layer grid where the forcing factors include sea-surface temperature, surface radiation, mixed-layer depth, vertical velocity at the base of the mixed layer, percent sea-ice cover and atmospheric iron deposition from mineral dust. Atmospheric transport model estimates of dust deposition are used to generate the input fields of iron from the atmosphere. Subsurface nutrient fields, surface radiation, sea surface temperature and mixed-layer depths are derived from climatological databases. Plans call for the eventual incorporation of this ecosystem model into the three-dimensional (3D) climate/ocean model at the National Center for Atmospheric Research.

Mixed-layer averages of *in-situ* data from a number of JGOFS study sites have been compiled for comparison with the results of modeling simulations. These mixed-layer mean values from the JGOFS sites can be obtained via the U.S. JGOFS Synthesis and Modeling Project (SMP) home page. We have been comparing model output with data from the Hawaii Ocean Time-series (HOT) station, the Bermuda Atlantic Time Series (BATS) station, the subarctic Northeast Pacific site at Station PAPA (STNP), the Arabian Sea at the U.S. JGOFS station S7 (ARAB), the equatorial Pacific (EQPAC), the North Atlantic Bloom Experiment (NABE), the KERFIX time-series station in the Southern Ocean (KERFIX), the Ross Sea (ROSS), and the Antarctic Polar Front region (PFR).

Figure 1 shows modeled monthly mixed-layer nitrate concentrations (squares) compared with composites of *in-situ* measurements at the JGOFS sites. Nitrate is depleted all year at the HOT site and seasonally depleted at the BATS and NABE sites. Persistently moderate to high nitrate concentrations exist in the HNLC regions of the North Pacific, equatorial Pacific and the Southern Ocean. Nitrate is not depleted in these areas in the model because of strong iron limitation of diatom growth and strong grazing control of small phytoplankton biomass, which is consistent with *in-situ* observations.

Figure 2: Modeling simulation of iron limitation (grey areas) on diatom growth in surface waters during summer.

Figure 2 shows a modeling simulation of patterns of iron limitation on diatom growth in surface waters in summer (June through August in the Northern Hemisphere and December through February in the Southern Hemisphere). In the regions shown in grey, representing roughly 42% of the global ocean, diatom growth is limited by iron in the summer months. In almost 40% of the ocean, nitrogen limits diatom growth, and in almost 18% of the ocean, silica is the limiting nutrient. Nutrients required by diatoms are replete in less than one percent of the global ocean.

In our modeling simulation, growth is limited by iron in the HNLC regions and by nitrogen in the mid-ocean gyres for both the large and the small phytoplankton. Substantial portions of the equatorial regions and some high-latitude areas exhibit silica limitation for the diatoms. The few areas in which there are always sufficient nutrients for diatoms are primarily those with heavy ice cover and strong light limitation.

Nutrients are replete for the small phytoplankton, on the other hand, over nearly 20% of the ocean, mainly in lower latitudes. Strong grazing pressure prevents small phytoplankton blooms and thus nutrient depletion in most of these areas. Iron limitation for the small phytoplankton occurs in roughly 51% of the total surface ocean.

Our results suggest that these patterns of nutrient limitation are strongly influenced by atmospheric iron deposition and thus may be altered by climatic or anthropogenic processes that affect the transport and deposition of mineral dust over the oceans. Sinking particulate carbon export and primary production in the model are also sensitive to variations in the atmospheric iron source.

The phytoplankton assemblage in the HNLC regions is typically dominated by the small phytoplankton. Increasing iron inputs from atmospheric sources eventually shift this pattern to an assemblage dominated by the larger diatoms, sharply increasing the sinking particulate flux out of the mixed layer. These patterns are consistent with field observations in the HNLC regions and suggest that this relatively simple ecosystem model is reliably capturing phytoplankton bloom dynamics in these areas.❖

# Expanding Scope Of U.S. JGOFS SMP Shown At Annual Meeting

*by Scott C. Doney and Joanie A. Kleypas*

The expanding scope of the U.S. JGOFS Synthesis and Modeling Project (SMP) was evident at its annual meeting for principal investigators, held this year at Woods Hole Oceanographic Institution (WHOI) in mid July. Now in its third year of funding, the SMP includes some 50 projects and about 100 scientists.

The five-day workshop attracted some 75 investigators, students, agency representatives and guests. It included a mix of scientific talks and posters, plenary discussions and small working-group meetings. The agenda and detailed abstracts for talks and posters are available via the U.S. JGOFS home page (**http://usjgofs.whoi.edu/mzweb/whoi_agenda.html**).

The main goal of the annual SMP meetings is the sharing of scientific results among participants in the program and the stimulation of cross-project interactions. New and intriguing findings were presented on a range of ocean biogeochemical topics from local one-dimensional (1-D) models to global circulation models and from bacterial dynamics to the ocean uptake of anthropogenic carbon dioxide ($CO_2$). Articles on individual SMP projects will appear in *U.S. JGOFS News*, and electronic preprints and reprints can be found on the U.S. JGOFS SMP web site.

Some of the most exciting work within the SMP involves collaborations among modelers and investigators who conduct field studies and experiments. For example, Robert Armstrong of the State University of New York at Stony Brook gave a talk on work he is doing with Cindy Lee of Stony Brook, Susumu Honjo of WHOI, Stuart Wakeham of Skidaway Institute of Oceanography and John Hedges of the University of Washington. He presented an analysis and simple model showing that the downward flux of inorganic ballast, comprising dust and siliceous and calcareous shells, largely determines the vertical transport of particulate organic matter into the deep ocean. Armstrong is currently developing a new modeling framework from this "bottom-up" perspective.

Several newly funded projects are expanding the focus of the SMP beyond the upper ocean to include processes that take place deeper in the water column, at the sea floor and in the sediments. Honjo and Roger François, also at WHOI, are synthesizing data from deep sediment traps deployed in a wide variety of ocean basins to put together a global picture of export and recycling of biogenic material in the ocean interior. Richard Jahnke of Skidaway is putting together a global synthesis of measurements of deep ocean carbon, silica and nutrient fluxes and sediment accumulation.

Other promising directions involve the application of new techniques, often borrowed from other fields, to traditional marine biogeochemical problems. Jorge Sarmiento and colleagues at Princeton University are importing numerical inverse methods developed for atmospheric models to estimate the regional air-sea fluxes of oxygen as well as natural and anthropogenic $CO_2$. In a complementary study, Paul Robbins and Andrew Dickson of Scripps Institution of Oceanography are using physical oceanographic inversion tools to quantify the zonal transport of carbon species within the ocean.

Evident throughout the meeting was the growing reliance on the unique JGOFS data sets from the time-series stations, the process studies and the global survey for modeling and synthesis. Talks by Chris Sabine of the NOAA Pacific Marine Environmental Laboratory (PMEL), Niki Gruber of Princeton and Robert Key, also of Princeton, demonstrated how the synthesis of the tracer and carbon-system data from the global survey of $CO_2$ in the ocean provides the comprehensive framework for evaluating ocean models as part of the international Ocean Carbon Model Intercomparison Project (OCMIP).

Easy access to the U.S. JGOFS field data sets is critical in this regard. One of the main tasks of the SMP management team and the U.S. JGOFS Data Management Office (DMO) has been to expand the JGOFS data system to encompass the models and data products of the SMP as well. Christine Hammond from the DMO demonstrated an SMP version of the live-access server developed at NOAA/PMEL. The data system allows users to create figures or download data subsets from grided datasets via the Internet. There are plans to expand the capability of the server to include discrete data as well. Although only a few SMP datasets are available as yet, we are in the process of filling out the database with results from the SMP investigators. The SMP live-access server can be reached from the JGOFS home page (**http://usjgofs.whoi.edu/las/**).

Another major goal of the annual SMP meeting is to provide a venue for community activities. The SMP has sponsored three smaller topical workshops over the last year. Reports on the nitrogen fixation and equatorial Pacific workshops have appeared in previous newsletters, and an article on the continental margins workshop is included in this issue.

Time was set aside in Woods Hole for separate meetings of collaborative projects such as OCMIP and the working groups as well as for informal discussions on topical issues. The working groups were asked to assess their current efforts and to redefine goals achievable within the remaining time of the SMP. It was widely noted that the working groups rely heavily on the volunteer (unfunded) work of certain participants, limiting the scope of what can be accom-

*(Cont. on page 5)*

# SMP Workshop Looks At Role Of Continental Margins In Ocean Carbon Cycle

*by Frank E. Muller-Karger*

Members of the U.S. JGOFS Synthesis and Modeling Project (SMP) working group on continental margins got together for a special workshop on July 8, just before the annual meeting of SMP investigators. The focus of the session, held at Woods Hole Oceanographic Institution (WHOI), was on the contribution of the continental margins to global ocean carbon and nutrient budgets and cycles.

Frank Muller-Karger of the University of South Florida serves as chairman and Donald Redalje of the University of Southern Mississippi, co-chairman, of the working group. Other members are Anand Gnanadesikan, Princeton University; Richard Jahnke, Skidaway Institute of Oceanography; Joanie Kleypas, National Center for Atmospheric Research; Dennis McGillicuddy, WHOI; Peter Verity, Skidaway, and James Yoder, University of Rhode Island. Kenneth Brink, WHOI, and Larry Atkinson, Old Dominion University, were invited to participate in the workshop because of their experience with shelf environments. The working group also held several meetings during the SMP sessions that followed.

Processes in the coastal margins of the ocean are relevant to U.S. JGOFS, which has focused on developing a carbon budget based on deep-ocean observations and models. Numerical models used by SMP investigators do not have the spatial resolution that may be required for an accurate assessment of the contribution of continental margins to global budgets.

Estimates of global production based on field observations generally conclude that between 25 and 50% of the global ocean net production takes place in the continental margins, which include the shelves, slopes and rise. Global assessments based on ocean color satellite data also show bands of high pigment concentrations and primary productivity in these regions, beyond the shallow coastal areas that are affected by light reflected from the seafloor. These estimates show a four- to five-fold increase in production in a steep gradient as one goes from open ocean waters into the continental margins.

Evidence is accumulating that much of the particulate organic carbon (POC) generated by primary production on the margins is exported to the seafloor. Estimates of vertical organic particle flux and ocean bottom respiration rates suggest that the ratio of POC flux to primary productivity along continental margins is 20-fold higher than in the open ocean. A conservative estimate, based on work by Richard Jahnke, is that 44% of total global organic carbon flux reaches the bottom of the slope and rise. Since Jahnke examined only areas deeper than 1,000 meters, we do not know how much is deposited in the shallower slopes and shelves. Also unresolved is the question of how much carbon is exported from shelves in dissolved organic form (DOC).

Did JGOFS miss a significant portion of the global ocean carbon flux to the deep ocean? The response from modelers during the SMP meeting was that global carbon models (GCMs) generally account for known oceanic tracer distributions (such as carbon-14 from atomic bomb testing) and that they do not point to any large unaccounted-for source of carbon to the deep ocean. If current GCMs are indeed able to balance the ocean carbon budget, then the question might instead be whether they represent the carbon flux processes in the margins accurately.

Wide discrepancies still exist among the spatial and temporal distribution of tracers generated by various models. While we understand something about why high primary production occurs in the margins, we do not fully understand the scales of variability and processes leading to nutrient supply in these diverse environments. But we know that current global carbon models are under-resolved spatially and in forcing functions like winds. Paradigms and models developed for the deep ocean do not work well in the margins.

Workshop participants concluded that the margins should not be dismissed as regions whose significance in the ocean carbon cycle is limited to recycling. There are unresolved questions about food-web control of the export ratio and carbon burial; DOC input, production and export; processes that supply nutrients, and those that determine the fate of nutrients, such as denitrification.

The recommendations of the continental margins working group to the SMP as a whole include:

1) Quantify the uncertainty introduced by margins in global carbon and nutrient cycling and budget models.

2) Include continental margins explicitly in SMP planning and in any new global carbon/nutrient cycle initiative.

3) Incorporate continental margins into global carbon cycling models. It is important to identify the margin processes that are either improperly parameterized or missing in GCMs. A testbed program for coupled open ocean-margins models may be required.

4) Take advantage of the interest in coastal zones and margins at the international level, as evidenced by the Land-Ocean Interactions in the Coastal Zone (LOICZ) program, to obtain baseline productivity rates in different marginal systems and an idea of how processes vary among them.

5) Identify relevant questions. Some examples are:

What is the role of cross-shelf particulate organic transport?

What is the role of shelf/slope sources of iron?

What is the role of sedimentary transport or burial of carbon?

Should shelves be regarded as temporary storage or permanent burial

## Hebel Has The HOT Stuff

*by David Karl and Roger Lukas*


On June 23, Dale V. Hebel completed his 100th cruise for the Hawaii Ocean Time-series (HOT) program. His accomplishments are more remarkable, however, than this number indicates. Over the 12 years since HOT began, Dale has not only participated in most of the almost monthly cruises to Station ALOHA, he has also taken part in field studies in Antarctica during his periodic "vacations" from HOT.

Dale has been an integral component of the HOT program since 1988. He received his graduate training at Moss Landing Marine Laboratories where he worked on trace metals in marine snow with George Knauer and John Martin. After receiving his master's degree, he worked as director of laboratory services for an environmental company. The skills that he gained in this private-sector position proved invaluable to the newly-emerging HOT program.

Since 1988, Dale has been responsible for overseeing all U.S. JGOFS HOT program analyses, including quality control and quality assurance protocols and interlaboratory comparisons; since 1993, he has been a HOT co-principal investigator. Over the past 12 years he has evaluated, refined and, when necessary, developed new methods for use in the oligotrophic North Pacific Ocean. He has also served as chief scientist on nearly half of the HOT cruises. In between cruises, he has been the principal analyst for several crucial data sets, including dissolved inorganic carbon, alkalinity and particulate inorganic carbon.

Throughout this demanding decade, Dale has maintained a focused, goal-oriented work ethic and a "can-do" attitude. Every time-series program has one or more unsung heroes; Dale is certainly at the top of our long list of HOT contributors. Mahalo nui loa for a job well done!❖

*Continental Margins–(Cont. from page 4)*

sites for carbon?

What are the effects of shelf-bound processes like denitrification?

How can coastal observing systems support global assessments conducted by the SMP?

A variety of exciting developments are underway with respect to modeling the interactions between the deep ocean and the continental margins. These new initiatives take two forms: high-resolution regional models of the continental shelf that extend outward to the deep sea, and deep-ocean models that reach inward toward the continental shelf. Examples of the former include various National Oceanographic Partnership Program (NOPP) projects focused on the west coast. An example of the latter is the spectral element model created by Dale Haidvogel of Rutgers University. Future work on the ocean carbon cycle would benefit greatly from linkage with both approaches for modeling interactions between the continental shelf and the deep ocean.

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*SMP Annual Meeting–(Cont. from page 3)*

plished. The working group structure of the SMP changed this summer with the disbanding of the satellite biogeochemistry group and the broadening of the nitrogen fixation working group's mandate to include a focus on functional groups. Working group reports will be available via the SMP home page this fall.

A successful result of working group deliberations was the identification of scientific gaps in the current SMP research program. Groups came forward with draft proposals for three more workshops. Topics would be calcification, trace-metal biogeochemistry, and aphotic or "twilight zone" remineralization and transport.

As the SMP reaches its mid point, we are devoting considerable thought to the problem of how to meet our overall objectives within the limited amount of time and resources remaining. Among other objectives, the SMP is striving to encapsulate the improved understanding gained from the JGOFS field programs into a series of validated regional and global ocean carbon-cycle models. Meeting participants identified several efforts to develop and evaluate community models. Among the foci of these efforts are food web synthesis and modeling, regional 1-D model test-beds, and global coupled ecosystem-biogeochemistry modeling. These integrative, community efforts, crucial for the overall JGOFS synthesis of the ocean carbon cycle, will not be accomplished without adequate funding. Meeting participants agreed that high priority should be given to such system-level synthesis and modeling projects in the final two rounds of SMP funding.

This summer's meeting had a notably different flavor from the previous two. One of the major challenges of past meetings was fostering interaction among investigators from a variety of disciplines and traditions. The "birds of a feather" tendency is a natural barrier to cooperation in different "flocks." This year interdisciplinary cooperation and problem-solving reached new levels. The 2001 SMP annual meeting will also be held in Woods Hole in July.❖

# Antarctic Polar Front Zone The Focus Of AESOPS Workshop

*by Robert F. Anderson*

Thirty-nine participants in the U.S. JGOFS Antarctic Environment and Southern Ocean Process Study (AESOPS) gathered in late June at Oregon State University in Corvallis to advance the interpretation and synthesis of AESOPS results collected within the Antarctic Polar Front Zone (APFZ).

The AESOPS field program, carried out between 1996 and 1998, spanned two study areas, the Ross Sea and the APFZ. Because APFZ cruises took place primarily during the 1997-98 field season, investigators were unable to complete the generation and processing of data from this region in time for earlier workshops. Thus a three-day workshop focusing exclusively on the APFZ was organized as the final group event of the AESOPS program with the goals of facilitating collaboration among investigators and accelerating the synthesis of AESOPS data.

Assigning the term APFZ to the whole region outside of the Ross Sea that was studied during AESOPS is not entirely correct. AESOPS investigators studied biogeochemical processes in diverse systems, ranging from the Subantarctic Zone in the north to the Ross Sea Gyre, well to the south of the Antarctic Circumpolar Current. Indeed, clarifying the complex nomenclature applied to the multiple zonal systems examined during AESOPS was one of the first items of business for the workshop.

Although a portion of the workshop was directed toward resolving apparent inconsistencies in results obtained by different methods, such as those used for measuring particulate organic carbon (POC), more effort was devoted to looking at the large interrelated data sets produced during the study together. The detailed physical structure of the fronts and the seasonal evolution of hydrographic conditions had been described at earlier workshops, together with the integrated biogeochemical response shown in the drawdown of nutrients and dissolved inorganic carbon.

Participants in the APFZ workshop saw for the first time, however, the corresponding seasonal evolution of the phytoplankton species, which initiate the sequence of processes that leads eventually to the export of biogenic material to the depths. Quantitative estimates were presented for the flow of carbon through major components of the food web, ranging from microheterotrophs to mesozooplankton. Participants were also treated to provocative hints that productivity, as well as the physiological state of the phytoplankton, may be correlated with natural variability in the abundance of iron within the study region.

Within AESOPS, as with all the JGOFS field programs, investigators employed many different methods to evaluate new and export production as part of the larger effort to assess the efficiency of the biological pump and its response to changing environmental conditions. Workshop participants were delighted to find remarkable consistency among the various estimates, far better than one would expect given the precision ascribed to each method.

Estimates of primary production and export were compared with fluxes measured at mid depth with sediment traps and at the sea bed with benthic landers and corers to assess not only the depth dependence of the regeneration of biogenic material, but also the relative regeneration rates of organic carbon and opal. As suggested by previous studies, organic matter was regenerated far more rapidly than opal. In contrast to previous studies, however, AESOPS investigators using improved methods determined that the overall preservation and burial of opal in Southern Ocean sediments is far less than believed previously.

Workshop participants made preliminary efforts to compare AESOPS findings with those of other national JGOFS field programs in the Southern Ocean. For example, comparably high export fluxes were observed by AESOPS investigators in the southwest Pacific and by participants in the French ANTARES program in the Indian sector of the Southern Ocean. Whereas maximum export fluxes observed during AESOPS originated within the Seasonal Ice Zone (SIZ), however, maximum fluxes recorded by ANTARES occurred within the Permanently Open Ocean Zone (POOZ), located north of the SIZ but south of the Antarctic Polar Front.

As a result of this initial assessment, workshop participants agreed that much could be learned about the role of environmental conditions in regulating ecosystem structure and carbon fluxes in the Southern Ocean by careful comparison of results from the various JGOFS field programs. Support for international synthesis of JGOFS findings was strongly encouraged.

For those of us from the northeastern U.S., the few days spent in Corvallis provided the most satisfying taste of summer we have experienced so far this year. Workshop participants enjoyed the splendid weather in addition to superb logistical support throughout the session. ❖

*Continental Margins–(Cont. from page 5)*

In summary, the question remains whether JGOFS missed a significant portion of the global ocean carbon flux into the ocean by omission or inaccurate parameterization of continental margin processes. The working group recommends that these regions be considered properly in any future program focusing on global ocean carbon and nutrient assessments. The U.S. JGOFS SMP can facilitate this process by identifying key scientific questions concerning the continental margins and encouraging funding to address them in future programs.❖

# EDOCC: Proposed Initiative Focuses On Biological Responses To Ocean Ecosystem Perturbations

*by Douglas G. Capone and Ricardo Letelier*

During several blustery and snowy days last March, a group of oceanographers huddled together at Timberline Lodge on Oregon's Mount Hood for a workshop on the proposed Ecological Determinants of Oceanic Carbon Cycling (EDOCC) initiative. The meeting was supported by the National Science Foundation (NSF). Its purposes were to identify key issues in biological and biogeochemical oceanography that would improve our knowledge of ocean carbon cycling and to convey this information to NSF and other federal agencies as an advisory report for their development of strategic programs on ocean carbon cycling in accordance with the interagency Carbon Cycle Science Plan.

Doug Capone of the University of Southern California and Ricardo Letelier of Oregon State University served as coordinators for the EDOCC workshop with the help of an organizing committee comprising Penny Chisholm of the Massachusetts Institute of Technology, Hugh Ducklow of the Virginia Institute of Marine Science, Paul Falkowski of Rutgers University, Dennis McGillicuddy of Woods Hole Oceanographic Institution and Jon Zehr of the University of California at Santa Cruz.

The workshop paralleled and complemented other community planning efforts, such as the Ocean Carbon Transport, Exchanges and Transformations (OCTET) initiative and the Surface Ocean-Lower Atmosphere Study (SOLAS). Thirty-seven participants, including experts on phytoplankton, zooplankton, benthic and microbial ecology, biogeochemistry, limnology, physical and chemical oceanography, ecosystem modeling and remote sensing as well as representatives from NSF and the USC Sea Grant program contributed to spirited and insightful discussions.

As its point of departure, the EDOCC workshop took two broad questions in the realm of ocean biogeochemistry that had been identified in an earlier NSF-sponsored review and planning workshop titled Ocean Ecology: Understanding and Vision for Research (OEUVRE). These questions were:

1. How do environmental and biotic factors determine the distributions and activities of key species or functional groups important to biogeochemical cycles in space and time?
2. What are the important interactions among marine biota, global climate and biogeochemistry?

Participants in the EDOCC workshop sought to identify areas of research where augmented effort could improve our mechanistic understanding of factors structuring biological communities and the biological responses to ecosystem perturbations. They also sought to identify important potential feedbacks from the biota to the ecosystem that could add to system resilience or to shifts in state (stabilizing versus destabilizing feedbacks). The ultimate goal of this augmented effort is to develop the capacity to predict the responses of ocean ecosystems to climate change and the implications of those responses for carbon processing.

Four major subthemes for research emerged from the discussions and subsequent report preparation: the physical forcing controlling food-web dynamics and carbon fluxes, biological interactions controlling food web dynamics and carbon fluxes, chemical-biological interactions controlling carbon fluxes, and ecosystem changes and carbon-cycle feedbacks.

Workshop participants also articulated several specific research questions. They included issues relating to foodwebs, such as: How can we better conceptualize marine food webs? What are the food-web structures characteristic of major ocean biomes, and what controls these configurations? How are these controls modulated in space and time to produce observed distributions? What is the role of the continental margins in the production, cycling and transfer of carbon? What controls massive episodic blooms of various species of organisms?

Important biogeochemical questions were raised as well. They included: What are the controls on vertical and horizontal structure of organic matter, its remineralization and its relationship to the ventilation of the sea? What controls the carbon-to-carbonate ratio in the downward flux of particles, and how does it control the partial pressure of carbon dioxide ($CO_2$) in surface waters? What controls the balance between nitrogen fixation and denitrification in the world's oceans? What are the possibilities for and dynamics of feedbacks in ocean biogeochemistry as mediated by changes in atmospheric $CO_2$? These and other questions posed in the workshop report are examples but not an exhaustive or prioritized list.

A draft report is currently being circulated to the scientific community for input and comment. It is available online (**http://picasso.oce.orst.edu/ORSOO/EDOCC/**).❖

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

JGOFS

JOINT GLOBAL OCEAN FLUX STUDY

# Volunteer Observing Ship Program Yields New $CO_2$ Data For The North Pacific

*by Paulette P. Murphy, Yukihiro Nojiri and C.S. Wong*

More than four year's worth of samples collected aboard merchant ship *Skaugran* are adding substantially to the data set of carbon dioxide ($CO_2$) measurements for the surface waters of the North Pacific. MS *Skaugran* served as a volunteer observing ship between March 1995 and September 1999 as she carried cargo between western North America and Japan.

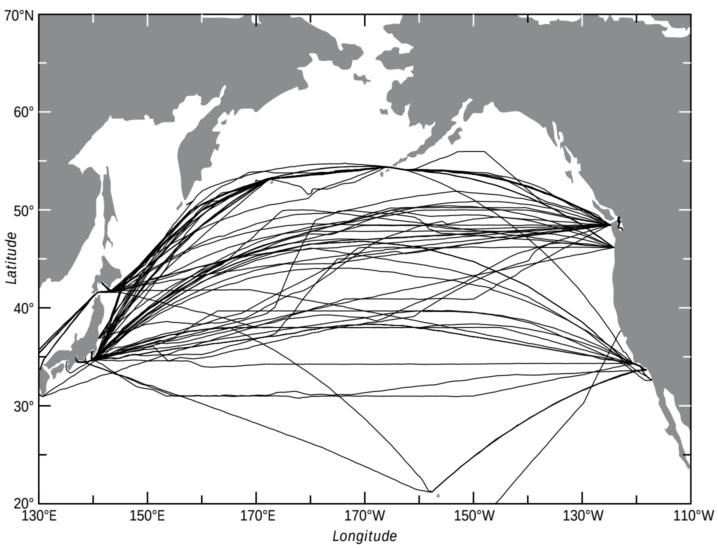



Figure 1: Cruise tracks of MS *Skaugran* between March 1995 and September 1999.

The data were collected as part of a bilateral collaboration between the National Institute for Environmental Studies (NIES) in Japan and the Institute of Ocean Sciences (IOS) in Canada. With funding from the Environment Agency of Japan and the Canadian Department of Fisheries and Oceans and Natural Resources Canada, Yukihiro Nojiri of NIES and C.S. Wong of IOS were able to install a suite of analytical equipment aboard the ship for underway sampling of the partial pressure of $CO_2$ ($pCO_2$) in the air and surface seawater and a variety of other measurements.

Operated by Seaboard International Shipping Co. of Canada, MS *Skaugran* made eight or nine round-trip crossings each year (Figure 1). Each crossing took roughly 12-13 days. Westbound legs generally followed a great circle route from Vancouver through the Gulf of Alaska into the Bering Sea and along the Kuril Islands to Japan. Eastbound routes were generally further south between 35° and 50°N and were much more variable.

Underway measurements of $pCO_2$ in air and surface water were made during each crossing. Discrete water samples were taken for laboratory measurements of salinity, nutrients, total dissolved inorganic carbon (DIC), carbon-13 isotope in DIC, total alkalinity and plankton pigments. Discrete air samples were also taken for atmospheric $CO_2$ analysis.

Instruments were located in a container mounted on the deck and in the engine room. The container laboratory contained equipment that monitored meteorological data, atmospheric chemical concentrations and ship position, logging data each minute. The engine room contained the equipment for drawing discrete water samples and making semi-continuous measurements of temperature, salinity, chlorophyll fluorescence, pH and $pCO_2$. Three data loggers recorded results from the thermosalinograph and chemical monitoring systems each minute.

There were novel aspects to this observational program. Two side-by-side systems were used to measure $pCO_2$ over an extended period of time. One was a rapid response system with a bubbling equilibrator designed by Takashi Kimoto of the Research Institute of Oceanochemistry, Japan. The second system involved hourly monitoring and a showerhead equilibrator. Comparison of $pCO_2$ results from the two systems over three years showed good agreement, on the order of +/- 2 microatmospheres (µatm), for later crossings but large differences, roughly 10 µatm, during the set-up and training period.

Another novel aspect of this program was the new rapid response system. Continuous measurements using the rapid response system indicated dramatically more variability in $pCO_2$ levels in some regions than the hourly data showed. This result has important ramifications for sampling in regions of high biological production and/or regions with large gradients in temperature and salinity.

Nojiri and his colleagues have synthesized data from the first two years of measurements by assuming that variability in the difference between $pCO_2$ in surface waters and the atmosphere ($\Delta pCO_2$) within a small ocean

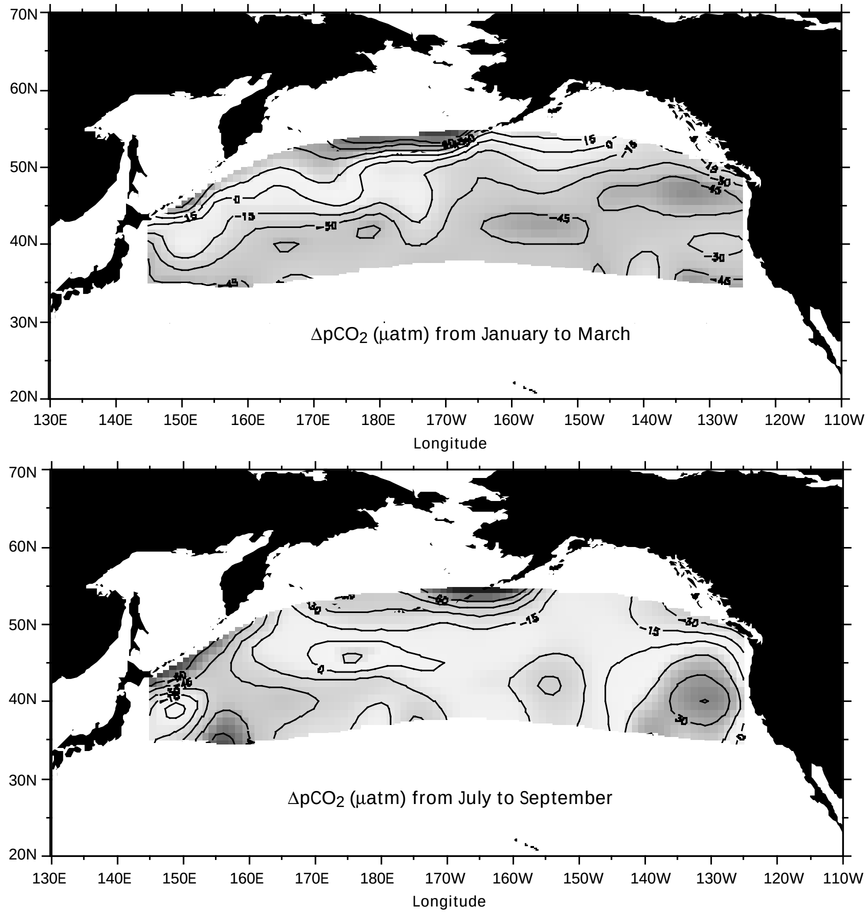



Figure 2: Distribution of $\Delta pCO_2$ values in the North Pacific between January and March (panel a) and between July and September (panel b) in microatmospheres.

grid box could be expressed as a function of latitude and time. This approach utilizes data only, rather than correlations with other sea-surface parameters, to estimate basin-scale means.

Seasonal maps of $\Delta pCO_2$ values were created from the functions for each grid box (Figure 2). The maps clearly indicate that the seasonal variation in $pCO_2$ levels in the Gulf of Alaska is very small. In the Bering Sea, the seasonal variation in $pCO_2$ was the largest we observed, with minimum levels in summer and maximum in winter. The western subarctic Pacific showed large seasonal amplitude, with decreasing $pCO_2$ levels in the spring bloom and increasing levels in the winter associated with vertical mixing. In the mid-latitude Pacific, seasonal warming and cooling of surface ocean caused decreasing $pCO_2$ levels in autumn and increasing levels in spring. The annual averaged $\Delta pCO_2$ map showed that the mid-latitude North Pacific takes up a relatively large amount of $CO_2$ annually. The maps are consistent in general with those created by Taro Takahashi of Lamont-Doherty Earth Observatory and his colleagues and provide an independent assessment with a new data set.

Forthcoming work using these data includes an analysis of the seasonal and geographical patterns observed in the four-year data set as well as an analysis of the spatial variability of $pCO_2$ and fluxes in the North Pacific.

A new volunteer observing ship program got underway in November 1999 aboard MS *Alligator Hope*, a container ship operated by the International Marine Transportation Company of Japan that sails between Tokyo and Seattle and Vancouver at five-week intervals. An almost entirely new suite of equipment includes two identical systems for $pCO_2$ measurements, allowing for complete temporal coverage. Both systems use a new tandem equilibrator design that combines bubbling and static mixing components. Completely continuous with fast response and better accuracy than the bubbling equilibrator alone, it utilizes a similar simple, valveless, flow-through design. The new systems are more automated to reduce the necessity for monitoring by shipboard personnel.

As of June, the ship had completed seven round trips. NIES is planning to make these data public online as soon as possible after the data are recovered. When the arrangements are complete, the goal will be to make data available within one month.

The first two years of data from the MS *Skaugran* monitoring program have been prepared for online access by the Marine Information Research Center of Japan. They are available from the Center for Global Environment Research (CGER) at **http://www.cger.nies.go.jp** or **http://www.mirc.jha.or.jp/minnano/CGER_NIES/skaugran/index.html**❖

Y. Nojiri

MS *Skaugran* in port.

*Science Conference– from page 1*

(SCOR), the International Geosphere-Biosphere Programme (IGBP), the European Union, the Intergovernmental Oceanographic Commission, the Research Council of Norway, the University of Bergen, the Institute of Marine Research, the Norwegian Polar Institute, the Nansen Environmental and Remote Sensing Center, the Norwegian Directorate of Fisheries and the City of Bergen.

Titled "Ocean Biogeochemistry: A New Paradigm," the conference highlighted field investigations and modeling studies in 58 talks and 110 posters, organized in 10 sessions focusing on particular themes in ocean biogeochemistry. Parallel sessions on regional issues, a presentation on IGBP plans for future carbon research, a session on the future of research in ocean biogeochemistry and a concluding discussion of remaining challenges rounded out the five-day schedule.

JGOFS chairman Hugh Ducklow of the Virginia Institute of Marine Sciences opened the session on ocean biogeochemical regimes with a discussion of approaches to the problem of creating a functional taxonomy of ocean systems. He suggested, as an example, that new knowledge about variability in microbial populations and related levels of production and consumption of dissolved organic carbon (DOC) be put to work to help distinguish among biogeochemical regimes. These factors help us understand how carbon in the surface water is partitioned between dissolved and particulate forms and how its export into the depths is regulated, Ducklow said.

M. Bowles

Beatriz Baliño discusses local arrangements.

How much of the carbon, nitrogen and phosphorus that flows into the coastal zones and marginal seas of the globe makes its way into the deep ocean or the atmosphere? In his keynote talk on continental margin exchanges, Chen-Tung Arthur Chen of National Sun-Yat Sen University, Taiwan, observed that most of the influx of organic carbon is recycled in the coastal zones, lessening the likelihood that the ocean margins could account for the missing anthropogenic carbon dioxide ($CO_2$). Studies of processes in these regions indicate that they are net exporters of nitrogen to the atmosphere and importers of $CO_2$, he said.

One of most noteworthy accomplishments of JGOFS has been the amassing of a comprehensive set of carbonate system measurements from much of the global ocean. Andrew Watson of the University of East Anglia, chairman of the session on $CO_2$ fluxes in the global ocean, noted that improvements in methods and the availability of certified reference materials, distributed to investigators in some 20 countries around the world, have made it possible to arrive at more accurate figures for regional uptake and release of $CO_2$ and to calculate the distribution of anthropogenic $CO_2$ in the ocean. Measurements over the last decade have documented the importance of biological effects on the air-sea flux of $CO_2$, an issue that was under debate when JGOFS got underway.

Understanding the magnitude and causes of interannual variability remains a challenge for investigators interested in predicting the effects of changing climate on the ocean's capacity to take up $CO_2$. In his talk, Richard Feely of the NOAA Pacific Marine Environmental Laboratory presented the case for linkages between the large-scale climatic shifts of El Niño-Southern Oscillation (ENSO) cycles and interannual variation in levels of $CO_2$ released into the atmosphere in the central equatorial Pacific.

Paul Falkowski of Rutgers University launched the session on regional and global primary production and export with a discussion of strategies for extrapolating measurements of primary productivity to larger temporal and spatial scales. Access to large data sets collected in diverse regions of the ocean as well as remote-sensing observations from satellites is critical, he noted. Marine productivity, estimated at 45 to 50 gigatons of carbon per year, represents roughly 42% of the global total. Talks during this session detailed improvements in methods for estimating both production and export as well as in understanding the physical phenomena that control variability on a range of scales.

The factors governing the export of carbon from the surface ocean to the deeper waters and the sediments of the sea floor received further consideration in the session of water-column biogeochemistry below the euphotic zone, led by Paul Tréguer of the Institut Universitaire Européen de la Mer. Tréguer pointed to an ongoing reassessment of the role of dissolved organic matter in the ocean carbon cycle, noting that DOC might represent as much as 60% of the total export flux.

Robert Armstrong of the University of New York at Stonybrook presented evidence from both modeling efforts and field studies that particulate organic carbon (POC) requires protection from mineral ballast to sink through the water column without degradation. "How much ballast carries stuff to the bottom? It affects whether organic carbon is remineralized shallow or deep," he said.

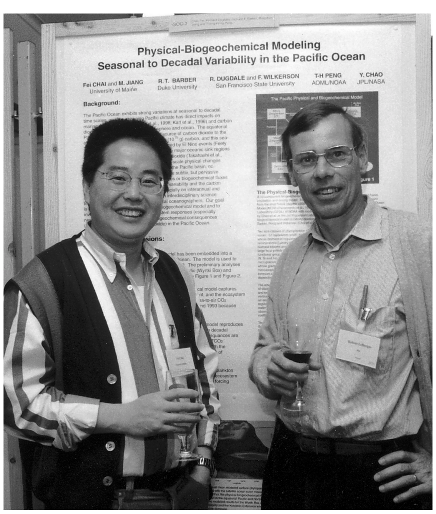
The importance of species composition and size structure of planktonic communities in the regulation of the export of carbon from the upper ocean has become steadily more apparent during the JGOFS decade. Talks during the session on this topic, led by Michael Landry of the University of Hawaii, pointed out relationships between shifts in nutrient availability, physical factors such as stratification, the presence or absence of particular species and production/export ratios.

M. Bowles

Arthur Chen, Mike Fasham and Dick Barber chair final session on conference highlights and future challenges.

Citing JGOFS results from the equatorial Pacific in particular, Richard Barber of Duke University proposed a two-state model of food-web variability that juxtaposed a balanced, "background" food web characterized by small plankton and recycling of materials against an episodic, "bloom" food web dominated by large plankton and increased export of materials out of the surface ocean. These two food webs coexist and are relatively independent, Barber said.

The sediments of the seafloor represent the largest buffer on earth and the final repository of carbon from the water column. In her keynote talk on deep ocean fluxes, Karin Lochte noted the importance of gaining a better understanding of the lateral flux of materials from the continental margins, which supply about half of the deep ocean POC flux. She and other speakers presented assessments of the information to be gleaned about the effects of climate change on ocean productivity in the sedimentary record.




M. Bowles

Fei Chai, University of Maine, left, and Robert LeBorgne, Station Marine d'Endoume, Marseille, review the posters.

Stressing the benefits during JGOFS of cooperation between field researchers and modelers, Scott Doney of the National Center for Atmospheric Research led off the discussion of global ocean carbon and ecosystem modeling with a review of advances in ocean biogeochemical modeling and problems yet to be solved. His talk and those that followed described efforts to incorporate factors such as iron fertilization, multiple nutrient limitation, plankton community structure and mesoscale time and space variability in modeling simulations. For example, Olivier Aumont of the Laboratoire des Sciences du Climat et de l'Environnement described a successful effort to simulate the characteristics of high-nutrient, low-chlorophyll regions with a model that included both iron and silicate limitation as well as multiple size fractions of both phytoplankton and zooplankton.

Efforts to ascertain the effects of environmental changes on ocean systems and to identify positive and negative feedback mechanisms were described in the session on feedback processes and climate change, led by Philip Boyd of the University of Otago. Modeling studies suggest that increased stratification and reduction of ocean circulation as a result of climate warming will have effects on nutrient and dissolved oxygen supplies and thus upon marine food webs and export production. Field experiments described in another talk suggest that increased $CO_2$ levels will slow down calcium carbonate production and reduce buffering capacity in surface waters.

In the final session on temporal variability of ocean biogeochemistry, keynote speaker David Karl of the University of Hawaii made the case for long-term studies of the sort conducted at the JGOFS time-series stations. He illustrated his argument for consistent measurements over long time periods with the evidence for a fundamental shift in nutrient limitation from nitrogen to phosphorus in the ecosystem of the North Pacific oligotrophic gyre, a result of warming and stratification of surface waters, which favors the growth of nitrogen-fixing organisms. Other speakers linked interannual variability in plankton community structure, productivity and carbon cycling to large-scale climate patterns such as ENSO and North Atlantic Oscillation (NAO) cycles.

IPO staff members Beatriz Baliño and Judith Stokke organized an gala series of cultural events for conference participants, beginning with a reception sponsored by the City of Bergen at an art museum. Dinner amidst the exhibits at the Bergen Aquarium the next evening was followed by a polished performance of traditional dances of the region and an invitation to join in. The conference dinner on the last night was held aboard the three-masted barque *Statsraad Lehmkuhl*, docked in Bergen Harbor. A folk band entertained guests between courses featuring regional cuisine. The endlessly fascinating sights of Bergen and the scenic splendor of its setting provided formidable competition to science for conferees' time during their five days in this beautiful city.❖

# Southern Ocean Symposium Focuses On Climate Change And Carbon Cycle

*by Walker O. Smith, Jr.*

More than 200 researchers from 19 countries convened in Brest, France, in July for the third international JGOFS symposium on the Southern Ocean. The conference, "The Southern Ocean: Climatic Changes and the Cycle of Carbon," highlighted the field studies and models of various national JGOFS efforts in more than 50 talks and 150 posters.

The meeting was organized around six major questions with invited lectures and group discussions on each:

• What role does the Southern Ocean play in the contemporary global carbon cycle?

• What controls the magnitude and variability of primary production and fate of particles?

• What are the major features of spatial and temporal variability in the physical and chemical environments and the key biotic factors?

• What is the effect of sea ice on carbon fluxes in and to the Southern Ocean?

• How has the role of the Southern Ocean changed in the past?

• How might its role change in the future?

Conference participants presented results indicating that the Southern Ocean now takes up a significant net amount of carbon dioxide ($CO_2$) from the atmosphere. Located between 35°S and 60°S, this sink is more pronounced in the Atlantic and Indian sectors and less evident in the eastern Pacific sector. It is attributed to the juxtaposition of the cooling effect on warm subtropical waters and biological production in nutrient-rich subantarctic waters.

South of 50°S, the net uptake is estimated to be about 0.6 gigatons of carbon per year (Gt C/yr), roughly 30% of the global ocean uptake of $CO_2$. Because of the Antarctic Circumpolar Wave, the interannual variability of the net atmospheric $CO_2$ sink is estimated to be +/- 0.2 Gt C/yr. The penetration of $CO_2$ from anthropogenic sources is extensive south of 50°S, but its storage is low because it is transported northward rapidly along isopycnal surfaces into the Subtropical Convergence.

Access to satellite data has made possible more realistic estimates of the primary productivity in different regions of the Southern Ocean. Estimates for average primary productivity now range between 60 and 100 grams of carbon per square meter per year, three to five times higher than those deduced from extrapolated carbon-14 measurements in the 1990s.

Various presentations detailed the evidence for limitation of primary productivity by iron and/or silicic acid. Results from the Southern Ocean Iron Release Experiment (SOIREE), conducted south of Australia in early 1999, indicated that polar organisms react rapidly to additional dissolved iron in surface waters, although export of biogenic material from the euphotic layer seems to lag well behind production.

Discussions also focused on fluxes of carbon within the Southern Ocean. Inverse modelling efforts show that export of biogenic matter from the surface layer is very efficient in the region. However, this is not consistent with estimates of fluxes derived from remote sensing data. There are also significant differences between results from studies of export from the euphotic layer and studies of biogenic fluxes in deeper waters and at the water-sediment interface. Understanding the processes that control remineralization and recycling in the "twilight zone" (between 100 and 1,000 meters) should be a high priority for future programs.

It became clear during the conference that earlier assumptions of latitudinal bands with contrasting marine environments around the Antarctic continent are not necessarily valid. Numerous satellite images reveal the importance of west-east gradients in algal biomass and productivity. These are probably related to the deposition of windborne trace metals east of the southern tip of the American continent and the subantarctic islands. Participants also questioned the real significance of the Antarctic Polar Front as a physical, chemical and biological frontier.

The seasonal waxing and waning of sea ice around Antarctica is one of the largest physical signals on Earth. Although sea ice in winter precludes the exchange of $CO_2$ and other gases with the atmosphere in large parts of the region, it can also support intense biotic activity, especially in the coastal and continental shelf zone. More information about the sea-ice ecosystem is required to understand the Southern Ocean's air-sea gas exchanges.

During the last decade, attention has focused on the Ross Sea and its production, export, nutrient cycles and interannual variations. Studies have reported substantial deviations from classical Redfield elemental ratios. The carbon export flux associated with the phytoplankton *Phaeocystis antarctica* represents a potentially important alternative to the classical export pathway that begins with diatoms. Because *Phaeocystis* blooms lead to substantial emissions of dimethyl sulfide (DMS), the role of this organism may be more important than we thought. In addition to more knowledge about the seasonal ice zone, we need to develop a better understanding of the role of key antarctic species in carbon transformations.

Although it is clear that the biogeochemistry of the Southern Ocean is sensitive to climate change, investigators disagree about what happened to the biological pump during past glacial maxima. One major debate concerns variations in the location of the frontal zone that delineates the northern Southern Ocean. Because this front appears to be constrained by topography, the northward shift of the frontal zone during the last glacial maximum is now questioned. One

# SOLAS Open Science Conference Attracts Broad Participation

*by Douglas W.R. Wallace*

The Institut für Meereskunde (IfM) in Kiel, Germany, served as host for the first open science conference of the Surface Ocean Lower Atmosphere Study (SOLAS) last February. The conference, held in the nearby resort village of Damp, brought together more than 250 scientists from 22 countries and a wide variety of disciplines.

Proposed as a new international global-change research programme linking the oceanographic and atmospheric sciences, SOLAS is now moving into an advanced stage of planning. Its goal is to achieve a quantitative understanding of critical biogeochemical and physical interactions between the ocean and the atmosphere and the ways in which they affect and are affected by changes in climate.

Conference participants represented many fields, including physical, chemical and biological oceanography, atmospheric chemistry and physics, paleo-oceanography, remote sensing, and biogeochemical and climate modeling. They shared a common interest in achieving a better understanding of the complex interactions between marine biogeochemistry, atmospheric chemistry and physics and climate.

Researchers from these various disciplines have had limited opportunities for interdisciplinary collaboration in the past. The SOLAS conference provided an opportunity for atmospheric scientists to talk with their marine counterparts. The key scientific questions of SOLAS require that these diverse groups work together to achieve a new scientific understanding of ocean/atmosphere interactions and their susceptibility to perturbation.

The conference included a set of keynote talks, discussion groups and poster sessions. Robert Duce from the U.S. gave the introductory remarks. Keynote speakers and topics were:

- Scott Doney, U.S., and Peter Liss, U.K.: "How might changes in climate-driven physical forcing affect upper-ocean biogeochemistry and air-sea fluxes?"
- William Jenkins, U.K.: "Observational and modelling aspects of mixed-layer physics in SOLAS."
- Véronique Garçon, France: "Modelling biogeochemistry in the upper ocean."
- Richard Barber, U.S.: "How much might the atmospheric delivery of marine nutrients, such as iron and nitrogen, change, and would such changes have global implications?"
- Neil Blough, U.S.: "Are changes in the spectrum and intensity of radiation likely to affect the production of trace gases in the surface ocean?"
- Meinrat Andreae, Germany: "How much might marine biological sulphur emissions change in the future; what would cause such changes, and would they have climatic implications?"
- Caroline Leck, Sweden: "Can marine emissions of gases and particles have a biogenic control on climate?"
- Leonard Barrie, Canada: "Modelling oxidation and aerosol processes in the marine atmosphere."
- David Farmer, Canada: "Air-sea measurement techniques in SOLAS."
- Andrew Watson, U.K.: "Are changes in marine biogeochemistry in the next century likely to have a significant influence on the net oceanic uptake of $CO_2$?"
- Mary-Elena Carr, U.S.: "What is the role of remote sensing in SOLAS?"
- Toshiro Saino, Japan: "What is the role of marine time series in SOLAS?"
- Graeme Pearman, Australia: "What is the role of atmospheric time series in SOLAS?"

National SOLAS committees have been formed in Canada, France, Germany, India, Japan, The Netherlands, Norway, Sweden, Taiwan, the U.K. and the U.S. In other countries, plans are developing for participation in SOLAS. The European attendees at the conference proposed and approved, in principle, a strong, coordinated European SOLAS initiative.

The open science conference was supported by the European Commission Research Directorate, the IfM, the Scientific Committee on Oceanic Research and the World Meteorological Organization as well as funding agencies in Canada, Germany and the U.S. The full programme of the conference, with reports from the discussion groups and abstracts of posters presented, is available via the SOLAS home page (**http://www.ifm.uni-kiel.de/ch/solas/prog.html**).

Following the conference, a small editorial team met in the U.S. during May to work on a draft science plan. This draft plan is currently posted on the international SOLAS web site at the address noted above. Comments are welcome. After the plan is in final form, it will be circulated and presented to international scientific organizations.❖

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*Southern Ocean – (Cont. from page 12)*

scenario suggests that primary productivity increased north of the polar front because of enhanced aeolian inputs and the northward penetration of nutrients, especially silicic acid. But south of the front, production of diatoms declined. The change in nitrate utilization is explained by increased production of *Phaeocystis*, which leaves no record in sediments.

The conference concluded with a banquet at the Oceanopolis aquarium. It featured foods of the region, along with a fine variety of French wines and music by a traditional Bretagne band. A final treat was the arrival in Brest of the tall ships from North America. Congratulations are due to Paul Tréguer and members of the Institut Universitaire Européen de la Mer and of the Institut Français pour la Recherche et la Technologie Polaires, who devoted many months and much energy to organizing the meeting. C'etait merveilleux!❖

# DMTT Focuses On Availability And Preservation Of JGOFS Data

*by Margarita E. Conkright*

Members of the JGOFS Data Management Task Team (DMTT) assembled in Kiel, Germany, in June to review the status and availability of data collected during JGOFS field programs and to make plans for the future. The task team includes representatives from eight of the nations that participate in JGOFS.

Margarita Conkright of the U.S. National Ocean Data Center (NODC) took over the chairmanship of the DMTT last January from Roy Lowry of the British Oceanographic Data Centre (BODC). Lowry continues as a member of the task team, as do Graham Glenn of the Canadian Marine Environmental Data Service (MEDS), Brian Griffiths from the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia, Christine Hammond of the U.S. JGOFS Data Management Office (DMO), Marie-Paule Labaied of the Observatoire Océanologique in Villefranche, France, Takeharu Miyake of the Japan Oceanographic Data Center (JODC) in Tokyo, and Jaswant Sarupria of the National Institute of Oceanography (NIO) in Goa, India.

The task team has a new member from Germany. Joachim Herrmann of the Institut für Meereskunde (IfM) in Kiel joined his colleagues at the meeting. Also attending was Beatriz Baliño, assistant executive scientist of the JGOFS International Planning Office (IPO).

The primary concern of the DMTT is the availability and long-term archiving of the JGOFS data. Currently some JGOFS data are available on CD-ROMs, some online, and some only from the investigators who collected them. Estimates of the data available from DMTT participants are shown in Table 1. It does not include the wealth of data gathered by JGOFS national projects that are not represented in the DMTT.

DMTT members decided to focus their efforts during the remainder of JGOFS on several specific activities. One is to seek funding for the production of a JGOFS master data set. The goal is to obtain all available JGOFS data from participating nations and investigators, to convert the data to a single format and to make them available online and on CD-ROMs. In addition, JGOFS projects and data would be described in the U.S. National Aeronautics and Space Administration's Global Change Master Directory (GCMD), including products from synthesis efforts. Another task is to set priorities for acquiring and archiving the data of countries represented in the DMTT and to create an inventory on the availability of these data.

DMTT members will be encouraged to attend meetings of the JGOFS regional synthesis groups, which focus on the equatorial Pacific, the Southern Ocean, the North Atlantic and the Indian Ocean. For example, Griffiths participated in the Southern Ocean conference held in Brest, France, in June and was able to identify data sets and products relevant to JGOFS from countries not represented in the DMTT.

Members reported on the activities of their national programs at the DMTT meeting. Griffiths noted that Australian JGOFS data will be stored at the CSIRO Division of Marine Research in Hobart. Included will be data from the western equatorial Pacific from cruises between 1990 and 2000. A preliminary CD-ROM has been prepared for the 1990-1993 cruises, and data from the later cruises will be available in the future. The archive will also include data from the Southern Ocean, including survey cruises along WOCE Hydrographic Programme lines and a variety of process-study cruises, available by spring 2001.

**Table 1: JGOFS data available through the DMTT**

| Country | Region | Data Available |
|---|---|---|
| Australia | Equatorial Pacific | 95% |
| | Southern Ocean | 0-80% (dep. on parameter) |
| Canada | Atlantic Ocean | 60-70% |
| | Northeast Pacific (SOEP) | 80% |
| | Northeast Pacific (Line P, Alaska Gyre) | 80% |
| | Gulf of St. Lawrence | 100% |
| France | Southern Ocean (Antares) | 80-95% |
| | Southern Ocean (KERFIX) | 90% |
| | Mediterranean Sea (Dyfamed) | 60-100% |
| | Mediterranean Sea (Ecomarge) | CTD only |
| | Mediterranean Sea (Frontal) | 90% |
| | Atlantic Ocean (Medatlante) | Unknown |
| | Tropical Atlantic (Eumeli) | 95% |
| | Equatorial Pacific (Epope) | 97% |
| Germany | North Atlantic | 75% |
| | Indian Ocean | 75% |
| | Southern Ocean | Unknown |
| India | Arabian Sea | 100% |
| Japan | Northwest Pacific (NOPACCS) | 100% |
| | MASFLEX | 100% |
| United Kingdom | North Atlantic (NABE) | 80-95% |
| | Arabian Sea (Arabesque) | 80-95% |
| | North Atlantic (LOIS) | 80-95% |
| | North Atlantic (PRIME) | 80-95% |
| United States | North Atlantic (NABE) | 100% |
| | Equatorial Pacific (EqPac) | 99% |
| | Arabian Sea (ASPS) | 99% |
| | Southern Ocean (AESOPS) | 67% |
| | Hawaii Ocean Time-series (HOT) | 100% |
| | Bermuda-Atlantic Time-Series (BATS) | 100% |

Starting with the North Atlantic Bloom Experiment (NABE) in 1989, the Canadian JGOFS program has conducted field studies in regions surrounding North America. Glenn reported that MEDS, the Canadian JGOFS data center, has been able to acquire data for the Atlantic Ocean, the Gulf of St. Lawrence and northeast Pacific, including the Shelf-Ocean Exchange Project (SOEP), Line P and the Alaska Gyre. These data are available online and will soon be released on CD-ROM.

Projects of JGOFS-France include studies of fluxes in the Southern Ocean (ANTARES), atmospheric dynamics and fluxes in the western Mediterranean and Ligurian Sea (DYFAMED), ecology of the continental margins (ECOMARGE), processes in the equatorial Pacific (EPOPE), fluxes in euphotic, mesotrophic and oligotrophic regimes in the tropical North Atlantic (EUMELI), physical, chemical and biological interactions in the oceanic fronts (FRONTAL), the biogeochemical evolution of the deep Mediterranean (MEDATLANTE), and the productivity of pelagic oceanic systems (PROSOPE), as well as a time-series study in the Southern Ocean (KERFIX). Labaied reported that many of these data sets are available online, and the equatorial Pacific data will soon be released on CD-ROM.

German JGOFS data from cruises in the Indian Ocean and the North Atlantic are managed at the Institut für Meereskunde (IfM) in Kiel and are available upon request from the data manager. The North Atlantic data set includes some data from related programs, such as the European time-series station in the Canary Islands (ESTOC) and three long-term moorings in the northeastern Atlantic. German Southern Ocean data are archived in Bremerhaven, and their availability is unknown. Herrmann reported that current efforts at IfM are focused on completing a detailed inventory of the metadata for each cruise, which will help identify missing data and the investigator responsible.

Sarupria reported that the JGOFS-India program in the Arabian Sea was completed in 1999, and the data were published in the JGOFS-INDIA Arabian Sea Process Study CD-ROM. It includes all data gathered between 1992 and 1997 on seven cruises. JGOFS-India scientists are hoping to carry out a similar study in the Bay of Bengal.

Miyake reported on JGOFS-related projects of Japan. They include the Northwest Pacific Carbon Cycle Study (NOPACCS) from 1990 to 1996, WOCE hydrographic program cruises, ongoing ship-of-opportunity measurements in the North Pacific, the ongoing SubArctic Gyre Experiment (SAGE), ongoing time-series observations in the western subarctic Pacific (KNOT), a study of the role of ocean fluxes in the geosphere and biosphere from 1991 to 1993, the Marginal Sea Flux Experiment (MASFLEX) from 1992 to 1997, and a study of the eastern tropical Pacific.

Lowry noted that most of the U.K. JGOFS data, which are managed at BODC, have been published on CD-ROM. These data sets include studies in the North Atlantic (NABE) and the Arabian Sea (Arabesque). Recent CD-ROMs include related data sets: the Land Ocean Interaction Study (LOIS) and Plankton Reactivity in the Marine Environment (PRIME). In addition, BOFS Sterna data from the Southern Ocean and Kiel Sea Rover data are available on request to BODC.

Hammond reported that data from every U.S. JGOFS field study are available online via the U.S. JGOFS home page. Virtually all data from the North Atlantic, equatorial Pacific and Arabian Sea process studies can be obtained online and about 67% of the data from the Southern Ocean process study (AESOPS). Data from the U.S. Hawaii Ocean Time-series (HOT) and Bermuda Atlantic Time-Series (BATS) studies are available online from the University of Hawaii and from Bermuda Biological Station for Research respectively. HOT has also published a CD-ROM with data through 1999. Data from the U.S. portion of the global survey of $CO_2$ are available from the Carbon Dioxide Information Analysis Center (CDIAC).

Baliño reported that plans are underway to centralize all Norwegian JGOFS data and release them on CD-ROM. Norwegian JGOFS has carried out research in the Greenland, Iceland and Norwegian seas between 1990 and 1997, including Carbon profiles in the Nordic Seas (CARNOR) between 1990 and 1992, Carbon and Deep Water Circulation in the Nordic Seas (CARDEEP/ESOP-2) between 1993 and 1997, a time-series study between 1990 and 1994, and the Ocean Margin Exchange Project (OMEX) between 1994 and 1995.

**Table 2: JGOFS and related data products**

| CD-ROMS | Source | Status |
|---|---|---|
| Biogeochemical Ocean Flux Study (BOFS) | BODC | Released |
| Ocean Margin Exchange Project (OMEX I) | BODC | Released |
| Plankton Reactivity in the Marine Environment (PRIME) | BODC | Released |
| Arabesque (Arabian Sea) | BODC | Released |
| Hawaii Ocean Time-series (HOT) | Univ. Hawaii | Released |
| JGOFS International Collection: Arabian Sea | IPO | Released |
| JGOFS-INDIA | NIO | Released |
| Australian Equatorial Pacific | CSIRO | Winter 2000 |
| Northwest Pacific Carbon Cycle Study | JODC | Released |
| Japan zooplankton data (ODATE Collection 1951-1990) | JODC | Released |
| Equatorial Pacific | France | 2000-2001 |
| Canadian JGOFS In-Situ Data Collection | MEDS | Winter 2000 |
| **Online Data** | | |
| U.S. JGOFS | DMO, U.S. | |
| Canadian JGOFS | MEDS, Canada | |
| German JGOFS | IFM, Germany | |
| JGOFS France | Villefranche, France | |

**18-21 September:** Biogeochemical Cycles: German Contribution to JGOFS, Bremen, Germany. Contact: Gerold Wefer, Universität Bremen.

**22-26 September:** IGBP-SCOR Ocean Biogeochemistry Workshop, Plymouth, U.K. Contact: Elizabeth Gross, SCOR, The Johns Hopkins University, Baltimore, MD.

**16-20 October:** IGBP Global Carbon Cycle Synthesis Workshop, University of New Hampshire, Durham, NH. Contact: Kathy Hibbard, GAIM International Project Office, University of New Hampshire.

2001

**27 Feb.-1 March:** U.S. JGOFS Scientific Steering Committee meeting, Santa Barbara, California. Contact: Ken Buesseler, U.S. JGOFS Planning Office, Woods Hole Oceanographic Institution, Woods Hole, MA.

**8-9 July:** JGOFS Scientific Steering Committee meeting, Amsterdam, The Netherlands. Contact: Roger Hanson, JGOFS International Project Office, Universitet Bergen, Norway.

**10-13 July:** IGBP Open Science Conference, “Challenges of a Changing Earth,” Amsterdam, The Netherlands. Contact: CONGREX HOLLAND BV, Amsterdam.

### 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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