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

# U.S. JGOFS NEWS

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## What Regulates The Efficiency Of The Biological Pump In The Southern Ocean?

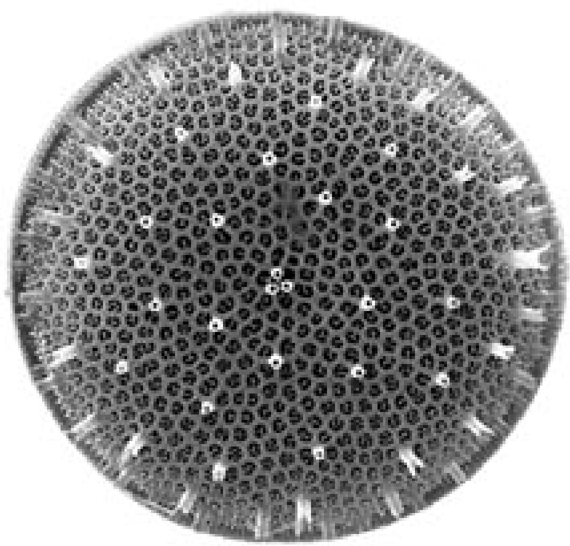
*by Robert F. Anderson*

The Southern Ocean is characterized by both a high rate of nutrient supply to surface waters and a low efficiency of biological utilization, a unique combination. The strong westerly winds that circle Antarctica generate a steady upwelling of nutrient-rich deep water. Only about half of the nutrients brought to the surface in the Southern Ocean are consumed by phytoplankton and exported into deeper waters as biogenic detritus. The unused half is carried back into the deep sea by deep and intermediate waters that form in the Southern Ocean.

We use the term “biological pump” for the set of processes whereby inorganic carbon and nutrients are transformed into organic matter in the sunlit surface waters and transported down through the water column in particulate forms. In terms of its effect on atmospheric carbon dioxide ($CO_2$) levels, the efficiency of the biological pump can be expressed as the fraction of nutrients that is consumed during primary production and exported in organic detritus. Unlike most regions of the global ocean, the efficiency of the Southern Ocean’s biological pump is only about half of its potential maximum.

Interest in the factors regulating nutrient utilization in the Southern Ocean has increased with the discovery that changes in the efficiency of the biological pump may have contributed to the glacial-interglacial pattern of variation in atmospheric $CO_2$ levels, recorded in ice cores. Over the past four glacial cycles, each roughly 100,000 years long, atmospheric $CO_2$ levels dropped from 280 parts per million (ppm) during interglacial peaks to 200 ppm during glacial periods.

The ocean is the only carbon reservoir on earth capable of exchanging the required amount of $CO_2$ with the atmosphere rapidly enough to account for the changes recorded in the ice cores. But we do not yet know how ocean processes induced these changes. Past changes in atmospheric $CO_2$ are also well correlated with the changes in air temperature over Antarctica recorded in ice cores, providing us with a clue that the Southern Ocean may have played a role in regulating glacial-interglacial changes in atmospheric trace gas concentrations.



Scanning electron micrograph of a centric diatom from Ross Sea at magnification of 3600x. *Photo by Dee Breger, Lamont-Doherty Earth Observatory*

Climate-related changes in the efficiency of the Southern Ocean’s biological pump may also affect the ocean’s ability to take up $CO_2$ in the future as levels increase in the atmosphere and the world warms. If we are to make meaningful predictions, however, it is necessary first to understand the processes and conditions that regulate nutrient utilization in the ocean today. Identifying the factors regulating the efficiency of the Southern Ocean’s biological pump was one of the primary objectives of the U.S. JGOFS Antarctic Environment and Southern Ocean Process Study (AESOPS), conducted between August 1996 and April 1998.

Oceanographers have long understood that light and grazing can limit phytoplankton growth and thus nutrient utilization in the Southern Ocean. Light conditions are unfavorable for growth in winter when solar irradiance is low, mixed layers are deep, and sea ice covers huge areas of the Southern Ocean.

Zooplankton grazing can contribute to low phytoplankton biomass as well. Studies of the North Pacific Ocean, another region in which nutrient utilization is below maximum potential efficiency, have found that grazing by zooplankton maintains phytoplankton biomass at levels too low to consume all of the available nutrients. Similar conditions could exist in the Southern Ocean.

Finally, pioneering studies in the late 1980’s by John Martin of Moss Landing Marine Laboratory and by Hein de Baar of the Netherlands Institute for Sea Research suggest that the growth of phytoplankton and nutrient utilization in the Southern Ocean are limited by the availability of iron, an essential micronutrient.

AESOPS was designed to investigate each of these potentially limiting factors. An interdisciplinary study was essential to characterize the physical and chemical conditions under which the phytoplankton grow, as well as the physiological health of the phytoplankton, the structure of the ecosystem, and the flow of carbon and nutrients through the food web. Furthermore, we needed to study these conditions throughout the portion of the year when most growth occurs, because the conditions regulating phytoplankton growth change with the seasons.

AESOPS focused on two distinct regimes: the highly productive continental shelf of the Ross Sea and the open-ocean region of the Antarctic Circumpolar Current (ACC) between New Zealand and the Ross Sea. This report covers the ACC region, describing results from a series of cruises from late austral winter (October 1997) until early autumn (March 1998).

The ACC comprises a series of fronts in which the eastward flow of water is concentrated into high-velocity jets that often extend from the surface to the sea bed. Nutrient-rich Upper Circumpolar Deep Water comes up to the surface between the Antarctic Polar Front (APF) and the southern boundary of the ACC (SBACC).These are located, respectively, at about 61°S and 65°S in the AESOPS region along 170°W.

AESOPS investigators found that the sea ice in this area extended nearly to the APF in September and October and melted back to near the Antarctic continent by February. Fresh water released by melting sea ice contributed to the stratification of the upper water column south of the APF in summer. Shallow mixed layers enhanced light conditions that were favorable for phytoplankton growth.

Mixed-layer depths in late winter exceeded 100 meters and sometimes 200 meters north of the APF. Surface heating, reinforced by the melting of sea ice south of the APF, reduced mixed-layer depths by December. The southward retreat of sea ice from December into February left behind shallow mixed layers, sometimes less than 20 meters.

By early December light conditions were favorable for phytoplankton growth in the region surrounding the APF, as revealed by moored optical sensors as well as by satellite (SeaWiFS) observations of ocean pigments and shipboard observations. High phytoplankton biomass, on the order of 1 milligram of chlorophyll per cubic meter (mg chl/$m^3$), followed the retreating ice edge southward. Chlorophyll concentrations in excess of 0.5 mg chl/$m^3$ were last observed in late February 1998 at 72°S.

We found that concentrations of nitrogen, phosphorus and silicon were generally high throughout the region in late winter. Phytoplankton growth was not limited by macronutrient availability, except north of 55°S where dissolved silicon concentrations were below 10 micromolar (µM).

Although the seasonal increase in phytoplankton biomass was accompanied by drawdown of dissolved nutrients, even the maximum drawdown of dissolved inorganic nitrogen (15 µM between 63° and 65°S in mid January) used up less than than half of the nitrate present at the end of the winter, and substantially less was taken up elsewhere and at other times. In contrast, virtually all of the dissolved silicon in surface waters north of the SBACC (65°S) was consumed by diatoms by mid January. Consumption ranged from 10 µM at 55°S to 60 µM between 63° and 65°S.

Diatoms were abundant in the southward-moving band of high phytoplankton biomass, up to 70%, and their growth was responsible for the dramatic drawdown of dissolved silicon. Species abundances followed a cyclical pattern in space and time. The earliest observations at each latitude found a large number of cells less than 10 microns (µm) in size. As biomass increased, particularly between the APF and the SBACC, the abundance of large diatoms increased as well. At peak times, diatoms larger than 20 µm represented as much as 80% of total phytoplankton biomass.

Following depletion of dissolved silicon in surface waters north of 65°S, phytoplankton biomass declined, as did the relative abundance of diatoms in the phytoplankton assemblage.

The seasonal cycle of phytoplankton biomass and species composition was accompanied by changes in the physiological state of the phytoplankton, as well as by changes in the factors regulating their growth and biomass. To the north of the APF, where dissolved silicon concentrations were never high, small cells dominated the phytoplankton assemblage throughout the study.

Photosynthetic efficiency of these small cells was relatively high, as revealed by both shipboard incubations and moored sensors. Maximum biomass-specific photosynthesis rate ($P_b^{opt}$) measured in incubations was around 3 millimoles of carbon per milligram of chlorophyll per day (mmol C/mg chl/d). Incubation studies conducted with water from north of the APF in early spring showed no response of silicon uptake to iron addition, and an increase in total biomass (chlorophyll) by only about a factor of three after two weeks.

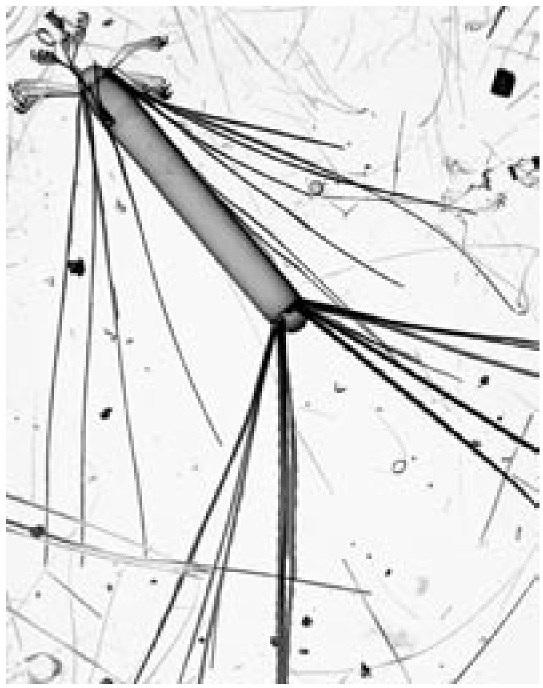
Very different results were obtained south of the APF, where surface dissolved silicon concentrations were high in early spring. There, photosynthetic efficiency was low ($P_b^{opt}$ 1.5 mmol C/mg chl/d), silicon uptake was stimulated by iron addition, and biomass increased by more than a factor of 30 in two weeks in incubated waters receiving 1 nanomolar (nM) iron or more. In early spring, phytoplankton south of the APF were more stressed, with lower photosynthetic efficiencies, than were phytoplankton north of the APF. We consider that increased stress to be due at least partly to iron limitation.

AESOPS investigators observed similar relationships throughout the summer as the boundary between low- and high-silicon waters moved southward. In low-silicon waters to the north of the boundary, small cells dominated the phytoplankton assemblage. Photosynthetic efficiency was high ($P_b^{opt}$ 4-6 mmol C/mg chl/d), uptake was stimulated by silicon additions but not by iron, and biomass increased by a factor of 3 to 5 in shipboard incubations receiving 0.5 to 2.5 nM iron.

In high-silicon waters to the south of the boundary, diatoms were more abundant, photosynthetic efficiency was low ($P_b^{opt}$ 2-3 mmol C/mg chl/d), silicon uptake was stimulated by iron additions but not by silicon, and biomass increased by more than an order of magnitude in shipboard incubations receiving the iron treatment above. These results indicate that diatoms were responsible for consuming 40–60 μM silicon within the zone between the APF and the SBACC, and that they did so while growing under iron-limited conditions of reduced photosynthetic efficiency.

By March phytoplankton biomass had declined to low levels (less than 0.1 to 0.3 mg chl/m$^3$), and cells smaller than 10 μm dominated the phytoplankton assemblage throughout the study area. However, the photosynthetic efficiency of the cells was high throughout the region north of the SBACC. Reduced photosynthetic efficiencies were found only in waters south of the SBACC in the northern portion of the Ross Sea gyre. This pattern was confirmed by agreement between results of shipboard incubations used to determine $P_b^{opt}$ and results of fast repetition rate fluorometry.

The transition from high to low photosynthetic efficiency across the SBACC coincided with a decrease in dissolved iron concentrations from greater than 0.2 nM to the north of the SBACC to less than 0.15 nM to the south. This suggests that the lower photosynthetic efficiency in the northern Ross gyre was associated with iron limitation. This spatial pattern is consistent with the greater supply of iron in waters north of the SBACC from upwelling.



Scanning electron micrograph of a centric diatom from the Ross Sea at magnification of 165X. *Photo by Dee Breger, Lamont-Doherty Earth Observatory*

High concentrations of phytoplankton appeared in SeaWiFS images as far south as 72°S. Unfortunately, the high biomass was short-lived, and the AESOPS ship reached this latitude after the biomass had declined. Thus we do not know which species contributed to the high biomass and what their physiological state was during growth. But we observed the legacy of these phytoplankton in shipboard measurements of the partial pressure of carbon dioxide ($pCO_2$), which were as low as 270 ppm between 70° and 71°S, much lower than the atmospheric $pCO_2$ level of roughly 360 ppm.

Phytoplankton biomass is reduced primarily through grazing. Shipboard experiments showed that microzooplankton grazing consumed about 60-70% of biomass produced by phytoplankton at times when large diatoms were predominant. In late summer, when small cells replaced large diatoms in the assemblage, microzooplankton grazing consumed 95% of phytoplankton growth. This increase reflects the inability of small grazers to consume the much larger diatom cells.

Mesozooplankton capable of consuming large diatoms were low in abundance throughout the year. Consequently, mesozooplankton grazing accounted for only a small portion of phytoplankton growth. Much of the diatom biomass was aggregated into particles that sank rather than being consumed in the surface ocean.

We can best summarize the seasonal cycle of phytoplankton abundance and nutrient utilization in the AESOPS study area by dividing it into three zones. North of the APF, the growth of all phytoplankton taxa is limited primarily by light levels in winter. In summer, the growth rate of large diatoms may be limited by iron, but these cells are able to grow, albeit at a suboptimal rate, until all available silicon is consumed. Their growth is ultimately limited by the availability of silicon rather than grazing. Although small-celled phytoplankton grow with high photosynthetic efficiency, their biomass and thus their uptake of nutrients is limited by microzooplankton grazing.

South of the southern boundary of the ACC, the growth of all taxa is limited by light in winter because of sea ice. Phytoplankton assemblages are dominated by small cells even in summer, apparently because of the lack of iron, which limits growth of large cells. Small-celled species, including pennate diatoms and *Phaeocystis*, have a brief period of growth and high biomass (up to 1 mg chl/m$^3$) in late summer. Nutrient utilization is low because of the short growing season and iron limitation. Our assessment of the seasonal cycle of this zone is somewhat speculative, because AESOPS investigators were unable to make shipboard observations during the period of peak biomass.

AESOPS results show that the most dramatic seasonal changes in phytoplankton biomass and species assemblages occur in the middle zone, between the APF and the SBACC. Low sun angle, ice cover and deep mixed layers limit light levels in winter. Small cells, including *Phaeocystis*, are abundant in early spring and near the edge of the retreating sea ice later in the season. Diatom abundance increases in late spring and early summer until these cells constitute most of phytoplankton biomass.

Despite iron-limited photosynthetic efficiency, we found that diatoms in the middle zone grew until virtually all of the dissolved silicon in the mixed layer was consumed because loss to grazing was low. After the silicon was depleted, aggregation and sinking removed diatom biomass from the surface waters.

Small-celled phytoplankton were present throughout the summer in this zone. Their photosynthetic efficiency was high, suggesting that iron was not a major limitation factor, but their biomass was kept down by zooplankton grazing. Consumption of inorganic nitrogen and phosphorus was limited by the amount of silicon available to support diatom growth and by the high efficiency with which small phytoplankton cells were recycled by the microzooplankton.

Export of organic matter from the euphotic zone is regulated by the conditions described above. Throughout the study region, particularly in the middle zone, maximum export followed the peak in primary production by about a month, reflecting the slow accumulation of ungrazed diatoms in surface waters. Export declined while conditions other than silicon availability remained favorable for phytoplankton growth in waters north of the SBACC. Small phytoplankton were recycled efficiently by microzooplankton, limiting the export of organic matter in late summer.

Unlike most other oceanic regimes, a large fraction of the phytoplankton biomass produced each year in the Southern Ocean is exported below 100 meters, despite iron limitation on diatom growth and grazing pressure on small phytoplankton. High export efficiency is typical of regions that experience short-lived blooms, such as the North Atlantic Ocean and the Arabian Sea. Nonetheless, export efficiency in the region of the Southern Ocean studied by AESOPS exceeded that of any other region studied during U.S. JGOFS.

AESOPS measurements show an annual average export efficiency of 15% in the northern zone, 30% in the middle zone and 50% in the southern zone. Despite a low to modest annual rate of primary production, therefore, the annual flux of organic matter exported from surface waters in the AESOPS study area is one of the highest observed in any pelagic region. The high export efficiency and flux of this region reflect the low grazing pressure on diatoms, which, in turn, leads to low recycling efficiency of diatomaceous material.

AESOPS afforded us an unprecedented opportunity to observe the seasonal cycle in ecosystem structure and the flow of carbon through the food web, revealing a complex array of factors regulating nutrient utilization that would not have been evident in a short-term study. Phytoplankton growth and the efficiency of nutrient utilization are regulated at different times and in different places by light, grazing, iron and dissolved silicon. Models used to simulate glacial-interglacial changes and to predict future trends in atmospheric $CO_2$ must account for these factors.

JGOFS process studies represent only the first step toward understanding the factors regulating the efficiency of the Southern Ocean's biological pump. We know that the southwest Pacific sector studied by AESOPS investigators is not entirely representative of the entire Southern Ocean. We need to look at factors regulating spatial variability of nutrient utilization. Environmental conditions in the Southern Ocean vary greatly from year to year. The impact of this interannual variability on the efficiency of the biological pump remains to be determined.

We also need to explore the sensitivity of the factors regulating nutrient utilization to climate change. These sensitivities must be incorporated into models of the oceanic carbon cycle before meaningful simulations can be made of the Southern Ocean's past, present and future role in the regulation of atmospheric $CO_2$ levels.

Finally, interannual variability in physical factors such as wind stress, sea-surface temperature or sea-ice extent in the Southern Ocean tends to follow semi-regular patterns. Surface winds and related features are influenced by the Southern Hemisphere Annular Mode, a seasaw pattern in the surface pressure gradient between the South Pole and the Southern Ocean. Wave-like patterns in surface forcing exhibit features of both standing waves (Antarctic Dipole) and propagating waves (Antarctic Circumpolar Wave). Future studies should make use of these patterns of interannual variability as a natural laboratory in which to examine and quantify the sensitivity to climate change of the Southern Ocean's biological pump.

*(Editor's note: Robert Anderson of Lamont-Doherty Earth Observatory, along with Walker Smith of the Virginia Institute of Marine Sciences, provided scientific coordination for AESOPS, the last U.S. JGOFS field program.)*

# Carbon Cycling Through Planktonic Food Webs: Using Inverse Analysis To Synthesize U.S. JGOFS Data

*by Tammi L. Richardson and Robert M. Daniels*

The Synthesis and Modeling Project (SMP), final phase of U.S. JGOFS, is designed to synthesize data collected during field investigations into models that reflect our current understanding of the ocean carbon cycle. One of the specific goals of the SMP is to identify the mechanistic controls on local carbon balances in order to develop regional and global syntheses.

George Jackson of Texas A&M University, Hugh Ducklow of the Virginia Institute of Marine Science and Michael Roman of Horn Point Environmental Laboratory are leading an SMP project designed to address this particular goal. We are examining the role of planktonic food webs in mediating carbon flux in three ocean regions studied during JGOFS: the equatorial Pacific, the North Atlantic and the Arabian Sea. Our goal is to synthesize JGOFS measurements into a complete picture of plankton trophic dynamics that highlights the role of food-web components in controlling carbon transfers, particle export and dissolved organic carbon (DOC) production.

We are focusing on trophic interactions among plankton of varying size classes and the ways in which they affect the flux of carbon within and out of the euphotic zone. While some interactions between components of a food web are relatively easy to quantify, such as zooplankton grazing on phytoplankton, others are difficult or impossible to measure in the field. In this study, we are using inverse analysis techniques to estimate values for the unmeasured fluxes.

The family of analytical methods known generally as inverse analyses got its beginning in the physical sciences. These methods are used to infer properties of systems when insufficient data are available to determine them unambiguously. Canadian scientists Alain Vézina and Trevor Platt of the Bedford Institute of Oceanography first applied this approach to marine food webs in a study in which they estimated all food-web interactions from a limited set of measurements.

The underlying tenet of the inverse approach as applied to food-web modeling is that simple mass balance equations and known biological relationships constrain calculated fluxes, provided that some data on food-web structure and fluxes are available. For convenience, the approach usually assumes that biomass in any compartment of the model, such as phytoplankton or zooplankton, is in steady state; the total flux into each compartment is equal to the flux out of it.

Our inverse calculations incor-

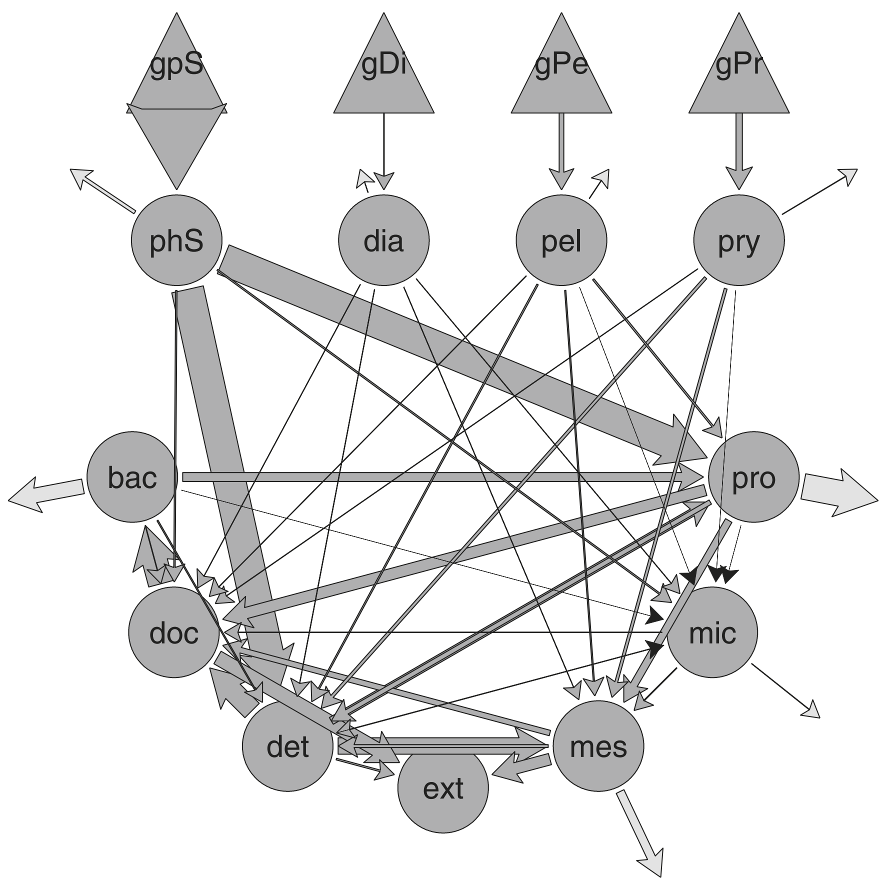



Figure 1: Model of planktonic food web for the eastern equatorial Pacific using data from the first U.S. JGOFS Equatorial Pacific Process Study time-series cruise in spring 1992. Compartments of the model are: gross primary productivity (GPP) of picoplankton (gpS), GPP of diatoms (gDi), GPP of pelagophytes (gPe), GPP of prymnesiophytes (gPr), picoplankton (phS), diatoms (dia), pelagophytes (pry), protozoans (pro), microzooplankton (mic), mesozooplankton (mes), bacteria (bac), dissolved organic carbon (doc), detritus (det), and a compartment for flux out of the eutrophic zone (ext). The largest flux (gpS to phS) equals 83 mmol C/m²/d; the size of all other arrows is proportional to this flux.

porate data available from the JGOFS database for each of our model systems **(http://usjgofs.whoi.edu/jg/dir/jgofs/)**. They include values for primary production, microzooplankton grazing, mesozooplankton grazing, bacterial production and estimates of vertical carbon flux based on thorium-234 ($^{234}$Th) measurements. In all models, the number of known equations is smaller than the total number of possible fluxes. In mathematical parlance, this indicates that we have an underdetermined system for which there are an infinite number of solutions.

One way to reduce the number of solutions and to get a realistic answer is to apply a set of biological constraints that provides upper and lower bounds on the estimated rates of biological processes. These constraints are based on relationships published in the literature. For example, phytoplankton respiration is usually considered to be between 5% and 30% of gross primary productivity.

Biomass information, also available from the database, is incorporated into the constraint equations. Mesozooplankton respiration, for example, is considered to be no more than the maximum specific respiration, a function of body size and temperature, multiplied by the mesozooplankton biomass.

Application of constraints reduces the space of possible solutions, but does not produce a unique solution. To arrive at a solution that describes all the fluxes in the system, the inverse approach employs the principle of parsimony and assumes that the minimization of the least squares produces the "best" solution.

The inverse analysis result gives values for all fluxes of carbon within the planktonic food web. After these interactions have been quantified, we can examine such questions as the fate of the primary production, the composition of protozoan, microzooplankton and mesozooplankton diets and their role in carbon export, or the role of various compartments in the recycling of carbon through the system.

The following example illustrates the uses of this approach. Food webs constructed with data from the first time-series cruise of the U.S. JGOFS Equatorial Pacific Process Study (EqPac) in spring 1992 reflect the importance of the picoplankton to total primary production in the system (Figure 1). The picoplankton had the highest calculated gross primary productivity, roughly 83 millimoles of carbon per square meter per day (mmol C/m$^2$/d), while the productivity of the pelagophytes (5 mmol C/m$^2$/d), diatoms (less than 1 mmol C/m$^2$/d), and prymnesiophytes (8 mmol C/m$^2$/d) was substantially lower.

Protozoan grazers (less than 20 microns in size) consumed 43% of the total primary production directly and 48% of the picoplankton production. Picoplankton made up more than 60% of the protozoan diet; the remainder included bacteria, detritus and pelagophytes.

In these models we have assumed that the mesozooplankton, primarily copepods, do not consume the picophytoplankton directly. Calculations of export vectors using network analysis routines, however, show that the mesozooplankton play a relatively important role in the export of picoplankton carbon from the system, even though they do not consume picoplankton directly. A large percentage of picoplankton primary production gets exported indirectly through mesozooplankton grazing on protozoa, microzooplankton and detritus.

Data synthesis using the inverse approach also allows us to identify critical gaps or inconsistencies in existing measurements. Using the U.S. JGOFS EqPac time-series data, we calculated a DOC export from the euphotic zone of 17 mmol C/m$^2$/d (Figure 1). We assume that this number represents the possible export of DOC through horizontal advection.

Previous estimates of this export flux by Richard Feely of the NOAA Pacific Environmental Marine Laboratory and his colleagues were roughly 8 mmol C/m$^2$/d. Thus we believe that export of DOC by horizontal advection is probably greater than previously calculated for this system and that larger flux amounts are required to balance the system.

In our North Atlantic modeling efforts, we are finding that DOC excretion, another estimated flux, is extremely important. Bacterial production values suggest that approximately 53% of net primary production in the system is excreted as DOC, which is taken up by the bacteria.

The ultimate goal of our research is to compare interactions and fluxes among ecosystems of varying trophic structures and under varying environmental change scenarios. Modifications may allow us to identify components of the planktonic food webs that are particularly sensitive to environmental perturbations such as changes in temperature, nutrient availability or grazing pressure. Programs for doing inverse calculations are available from the "homegrown software" section of George Jackson's Ecosystem Modeling Group web site **(http://oceanography.tamu.edu/ecomodel/Software/software.html).**

*(Editor's note: Tammi Richardson is an assistant research scientist in the Department of Oceanography at Texas A&M University, and Robert Daniels is a graduate student working with Hugh Ducklow at the Virginia Institute of Marine Science.)*

## JGOFS Final Open Science Conference Program, May 5–8, 2003
### U.S. National Academy of Sciences, Washington, D.C. USA

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| **Sunday, 4 May: Early Registration and Reception** | |
| 1730-1930 | JGOFS Registration and Reception (U.S. National Academy of Sciences) |
| **Day 1–Monday, 5 May** | |
| 0830-0900 | WELCOME AND INTRODUCTION<br>Hugh Ducklow, Virginia Institute of Marine Science<br>Mark Abbott, Oregon State University |
| **Session I. OCEAN COLOR TO OCEAN DYNAMICS** • CHAIR: Trevor Platt, Bedford Institute of Oceanography | |
| 0900-1000 | Reenvisioning the Ocean: The View from Space<br>SPEAKER: Mark Abbott, Oregon State University<br>COMMENTATOR: Dave Siegel, University of California, Santa Barbara |
| 1000-1030 | BREAK |
| 1030-1130 | Constraining Fluxes at the Top: Advances in Quantifying Air-Sea Carbon Dioxide Fluxes during the JGOFS Decade<br>SPEAKER: Rik Wanninkhof, AOML/NOAA<br>COMMENTATOR: Richard Feely, PMEL/NOAA |
| 1130-1230 | Storage of Carbon in the Oceans: Observational Constraints<br>SPEAKER: Nicolas Gruber, University of California, Los Angeles<br>COMMENTATOR: Nick Bates, Bermuda Biological Station for Research, Inc. |
| 1230-1400 | LUNCH |
| **Session II. JGOFS CONNECTIONS** • CHAIR: Robert Anderson, Lamont-Doherty Earth Observatory | |
| 1400-1430 | WOCE – Links to JGOFS Biogeochemistry • Carl Wunsch, Massachusetts Institute of Technology |
| 1430-1500 | GLOBEC – Links to JGOFS Biogeochemistry • Roger Harris, Plymouth Marine Laboratory |
| 1500-1530 | SOLAS – Links to JGOFS Biogeochemistry • Peter Liss, University of East Anglia |
| 1530-1730 | **Poster Session I:**<br>**Theme 1:** Carbon Dioxide, CHAIR: Bronte Tilbrook, CSIRO Marine Research<br>**Theme 2:** Ocean Color, CHAIR: Mary-Elena Carr, Jet Propulsion Laboratory<br>**Region 1:** North Atlantic, CHAIR: Véronique Garçon, LEGOS, Centre National de la Recherche Scientifique<br>**Region 2:** Equatorial Pacific, CHAIR: Robert Le Borgne, Centre Institut de Recherche pour le Developpement<br>**Region 3:** North Pacific, CHAIR: Toshiro Saino, Nagoya University |
| **Day 2–Tuesday, 6 May** | |
| **Session III. ECOSYSTEM STRUCTURE AND DYNAMICS**<br>CHAIR: Bernt Zeitzschel, Institut für Meereskunde an der Universität Kiel | |
| 0830-0930 | Plankton Species Determine Biogeochemical Fluxes: From Scenarios to a Global Picture<br>SPEAKER: TBA<br>COMMENTATOR: Tony Michaels, University of Southern California |
| 0930-1030 | Co-limitation of Major Phytoplankton Groups by Light and Multiple Nutrients as Control of the Marine Carbon Cycle<br>SPEAKER: Hein de Baar, Royal Netherlands Institute for Sea Research • COMMENTATOR: Ed Laws, University of Hawaii |

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| 1030-1100 | BREAK |
| 1100-1200 | Linking Surface Ocean and the Deep Sea<br>SPEAKER: TBA COMMENTATOR: TBA |
| 1200-1300 | Climate Sensitivity: What Observations Tell Us about Model Predictions<br>SPEAKER: Corinne Le Quéré, Max-Planck Institut für Biogeochemie<br>COMMENTATOR: Jorge Sarmiento, Princeton University |
| 1300-1430 | LUNCH |
| **Session IV. OCEAN MARGINS AND BENTHIC PROCESSES** • Chair: Kon-Kee Liu, National Taiwan University | |
| 1430-1500 | Examining Human Impacts on Global Biogeochemical Cycling Via the Coastal Zone and Ocean Margins • Liana Talaue-McManus, University of Miami |
| 1500-1530 | Benthic Processes • Rick Jahnke, Skidaway Institute of Oceanography |
| 1530-1600 | Seeing the Past through JGOFS Spectacles • Thomas Pedersen, University of British Columbia |
| 1600-1630 | Discussion/Question Period – Kon-Kee Liu, National Taiwan University |
| 1630-1830 | **Poster Session II:**<br>**Theme1:** Plankton Community Structure, CHAIR: Renato Quiñones, University of Concepción<br>**Theme 2:** Euphotic Zone Production/Export, CHAIR: Patrick Monfray, Centre National de la Recherche Scientifique<br>**Theme 3:** Time-Series Studies, CHAIR: Tony Knap, Bermuda Biological Station for Research<br>**Region1:** Ocean Margins, CHAIR: Huasheng Hong, Xiamen University |
| **Day 3–Wednesday, 7 May** | |
| **Session V. DATA ASSIMILATION AND MODELLING** • CHAIR: John Steele, Woods Hole Oceanographic Institution | |
| 0830-0900 | Modelling Biogeochemical Fluxes in the Ocean – How Far Have We Gotten?<br>Andreas Oschlies, Institut für Meereskunde an der Universität Kiel |
| 0900-0930 | The Internal Weather of the Sea and its Influences on Ocean Biogeochemistry: Findings from JGOFS Studies • Dennis McGillicuddy, Woods Hole Oceanographic Institution |
| 0930-1000 | Using Inverse Models to Estimate Biogeochemical Fluxes – Achievements and Limitations<br>Reiner Schlitzer, Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung |
| 1000-1030 | Discussion/Question Period – John Steele, Woods Hole Oceanographic Institution |
| 1030-1100 | BREAK |
| **Session VI. HIGHLIGHTS OF THE JGOFS ERA** • CHAIR: John Field, University of Cape Town | |
| 1100-1130 | Iron Limitation • Phil Boyd, Univerity of Otago |
| 1130-1200 | The Life and Times of Marine Particles: The JGOFS Story<br>Ken Buesseler, Woods Hole Oceanographic Institution |
| 1200-1230 | New Technologies and their Roles in Advancing Biogeochemical Science during the JGOFS Era<br>Tommy Dickey, University of California, Santa Barbara |
| 1230-1300 | Discussion/Question Period • John Field, University of Cape Town |
| 1300-1430 | LUNCH |
| **Session VII. FUTURE PROGRAMS** • CHAIR: Peter Burkill, Southampton Oceanography Centre | |
| 1430-1450 | Ocean Futures in Biogeochemistry – Julie Hall, National Institute of Water and Atmospheric Research |

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| 1450-1510 | Role of Ocean Observing Systems in Ocean Research - Larry Atkinson, Old Dominion University |
| 1510-1530 | Oceans in the Earth System: Sailing into the Sea of Excitement<br>Will Steffen, International Geosphere-Biosphere Programme |
| 1530-1730 | **Poster Session III**<br>**Theme 1:** Mesopelagic, Chair: Richard Lampitt, Southampton Oceanography Centre<br>**Theme 2:** Deep Ocean/Benthos/Paleoceanography,<br>Chair: Anitra Ingalls, Harvard University<br>**Theme 3:** Global Synthesis/Ecosystem Modeling,<br>Chair: Scott Doney, Woods Hole Oceanographic Institution<br>**Region 1:** Arabian Sea, Chair: Sharon Smith, University of Miami<br>**Region 2:** Southern Ocean, Chair: Paul Tréguer, Institut Universitaire Européen de la Mer |
| 1800-1930 | Keynote Lecture at Smithsonian National Museum of Natural History, Baird Auditorium,<br>"Global Climate Policy: Where is the World Headed?"<br>Speaker: Carol M. Browner, The Albright Group |
| 1930-2100 | Reception to follow in Museum Rotunda |
| **Session VIII. OCEAN DYNAMICS IN EARTH SYSTEM SCIENCE,**<br>Chair: Hugh Ducklow, Virginia Institute of Marine Science | |
| 0830-0930 | Why and How We Created JGOFS and the Lessons Learned • Speakers: Peter Brewer, Monterey Bay Aquarium Research Institute; James McCarthy, Harvard University |
| 0930-1015 | Ocean Biogeochemistry in the Earth System • Berrien Moore III, University of New Hampshire |
| 1015-1030 | Further Discussion/Questions • Hugh Ducklow, Virginia Institute of Marine Science |
| 1030-1100 | BREAK |
| 1100-1200 | JGOFS Accomplishments and New Challenges • Speaker: David Karl, University of Hawaii<br>Commentator: Mark Abbott, Oregon State University |
| 1200-1215 | Epilogue – Margaret Leinen, National Science Foundation |
| 1300-1600 | CONFERENCE BANQUET • (Potomac River Lunch Cruise) |

## Final NSF Grants Made For Synthesis And Modeling Project

Five projects received funding during 2002 for the U.S. JGOFS Synthesis and Modeling Project (SMP) in the fifth and final round of grants from the National Science Foundation. Investigators, their institutional affiliations and their projects are:

- Will Berelson, University of Southern California; William Balch, Bigelow Laboratories for Ocean Sciences; Richard Feely, NOAA Pacific Marine Environmental Laboratory (PMEL); Raymond Najjar, Pennsylvania State University, and Christopher Sabine, University of Washington and NOAA/PMEL: "Production and dissolution of calcium carbonate in the global ocean: A synthesis and modeling project."
- Fei Chai, University of Maine; Richard Dugdale and Frances Wilkerson, San Francisco State University; Richard Barber, Duke University, and Tsung-Hung Peng, NOAA Atlantic Oceanographic and Meteorological Laboratory: "Biogeochemical modeling of carbon partitioning in the Pacific: the role of Si and Fe in regulating production by siliceous and calcifying phytoplankton."
- Scott Doney, Woods Hole Oceanographic Institution, and J. Keith Moore, University of California at Irvine: "The role of ecosystem dynamics in the global carbon cycle: A JGOFS model-data synthesis."
- Wilford Gardner and Alexey Mishonov, Texas A&M University: "Transmissometer data validation and correction for the Hawaii Ocean Time-series and Bermuda Atlantic Time-series data sets."
- Nicolas Gruber, University of California at Los Angeles; Christopher Sabine and Rolf Sonnerup, University of Washington and NOAA/PMEL; John Bullister, NOAA/PMEL, and Robert Key, Princeton University: "Global assessment and synthesis of data-based estimates of anthropogenic $CO_2$ in the ocean."

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

JGOFS

JOINT GLOBAL OCEAN FLUX STUDY

# Planning Underway For OCEANS

*by Julie Hall and Penelope Cooke*

The International Geosphere-Biosphere Programme (IGBP) and the Scientific Committee On Oceanic Research (SCOR) are sponsoring the development of a new project, titled Ocean Biogeochemistry and Ecosystem Analysis (OCEANS), as part of the second phase of IGBP. Its goal is to understand the sensitivity of the ocean to global change, focusing on biogeochemical cycles, marine food webs and their interactions in the context of the broader earth system.

OCEANS will seek a comprehensive understanding of the effects of climate and human activity on the structure, function, diversity and stability of food webs and on the biogeochemical pathways, transfers and cycling of elements in the ocean, as well as the effects of the underlying physical dynamics. It will also strive for a mechanistic and predictive understanding of the ways in which these systems respond to changes in global climate patterns, such as the El Niño-Southern Oscillation and the North Atlantic Oscillation, and anthropogenic perturbations.

The new project will work closely with established IGBP projects, including Global Ocean Ecosystem Dynamics (GLOBEC), Land-Ocean Interactions in the Coastal Zone (LOICZ), and the Surface Ocean-Lower Atmosphere Study (SOLAS). It is intended to build on results from JGOFS and other ocean research programmes.

As part of the effort to put together a science plan and implementation strategy for OCEANS, the IGBP and SCOR sponsored an open science conference, held in Paris, France, in early January. The main purpose of the conference was to gather input from the scientific community to assist in the development of the scientific focus of the new project.

The conference began with 15 plenary lectures. Among the topics addressed were past and future ocean conditions; approaches to modeling ocean biogeochemical fluxes, populations and food webs; mesoscale processes; temporal changes in ocean biogeochemistry; trace metals as micronutrients; carbon and nutrient fluxes; marine food webs; key species and biogeochemical fluxes, and the presentation of ocean sciences to broader audiences.

The lectures were followed by working group discussions. The working groups were asked to identify and set priorities among key research questions and to assess what we need to know in order to answer these questions. They were also asked to identify promising approaches, emerging technologies and regional considerations.

In addition to the working group discussions, short oral reports were given on current national and international activities and any future plans relevant to the development of the OCEANS project. Some 200 posters were presented as well; the abstracts are available at the OCEANS web site **(http://www.igbp.kva.se/obe/)**. The conference was attended by 370 participants from 36 countries.

The conference concluded with a summary presentation by Patrick Holligan of Southampton Oceanography Centre. This summary, the conference programme, abstracts and final working group reports are all available via the OCEANS web site.

The OCEANS Transition Team is using input from the working groups, plenary speakers, comments sent to the web site and other material to identify the key science themes and questions that will form the scientific focus of the new project. A full draft of the OCEANS science plan/implementation strategy, to be produced as a single document, will be made available via email and the web site in the fall of 2003. We encourage those interested to read and comment on this draft. We hope to complete the final science plan and implementation strategy by the end of 2003 for review by IGBP and SCOR.

*(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. Penelope Cooke is serving as research assistant to the team.)*

# JGOFS Steering Committee Holds Penultimate Meeting In Chile

*by Roger B. Hanson*

The JGOFS Scientific Steering Committee (SSC) ventured into the Southern Hemisphere for its 17th annual meeting last September. Participants received a warm welcome at the airport in Concepción, Chile, from our host, SSC member Renato Quiñones. Later in the week, the University of Concepción entertained the SSC with a tour of the campus and a reception in the evening at the Casa del Arte.

SSC chairman Hugh Ducklow led the meeting of 13 members from eight countries. Also attending were Wendy Broadgate, Deputy Director for Natural Sciences of the International Geosphere-Biosphere Programme (IGBP) and the staff of the JGOFS International Project Office. The meeting focused on the activities of the regional and global synthesis groups and the completion of their terms of reference, upcoming events in preparation for the end of JGOFS and future international initiatives in ocean biogeochemistry.

JGOFS SSC annual meeting attendees include: front row (l to r), Toshiro Saino, Véronique Garçon, Hugh Ducklow, Renato Quiñones, Judith Stokke; back row (l to r), Sturle Litland, Bronte Tilbrook, Paul Tréguer, Peter Haugan, Reiner Schlitzer, Dennis Hansell, Patrick Monfray, Robert Le Borgne, Robert Anderson, Bernard Avril, Roger Hanson. Missing from the photo are Sharon Smith and Wendy Broadgate.

Ducklow opened the meeting with thanks to Quiñones and the University of Concepción for their hospitality. One of the first orders of business was an expression of appreciation for Michael Fasham of the Southampton Oceanography Centre for completing the Bergen Open Science Conference book, which will be published in March by Springer-Verlag in the IGBP Global Change Science Series.

The JGOFS Global Synthesis Working Group (GSWG), responsible for putting the "G" into JGOFS synthesis and modelling efforts, held a successful and productive modelling workshop in Ispra, Italy, in June 2002. Reiner Schlitzer, chairman of the GSWG, and Patrick Monfray of the joint JGOFS/Global Analysis, Interpretation and Modelling (GAIM) Task Team chaired the workshop. They reported that the European Union Joint Research Centre provided excellent facilities for the workshop participants. Conclusions and recommendations from the workshop are expected soon.

The JGOFS Indian Ocean Synthesis Group, chaired by Sharon Smith, is well along in putting together a regional synthesis on the biogeochemistry and ecosystem feedbacks of the Arabian Sea. A forthcoming Springer-Verlag book follows on JGOFS Report No. 35 and will make an important contribution to the IGBP science series. The book will be a synthesis of 11 *Deep-Sea Research (DSR) II* volumes and other literature on the Arabian Sea.

The latest equatorial Pacific synthesis work was published in June 2002 in *DSR II* volume 49 (13-14). Following this publication, the JGOFS Equatorial Pacific Synthesis and Modelling Group, chaired by Robert Le Borgne, organized a workshop last September, described in this issue in an article by Le Borgne and Fei Chai of the University of Maine, U.S.

The JGOFS Continental Margins Task Team continues its synthesis work on carbon and nutrient fluxes across the continental margins. A global synthesis workshop, chaired by Larry Atkinson of Old Dominion University, U.S., and Richard Jahnke of Skidaway Institute of Oceanography, U.S., met in December to organize the international contributions and draft a book proposal to the IGBP science series. Kon-Kee Liu of National Taiwan University, Taipei, leads the editorial group and oversees the technical manager for the 50 chapters. Publication is expected in early 2004.

Until the end of this year, JGOFS data managers, led by Data Management Task Team chairman Margarita Conkright, will focus on archiving the completed national JGOFS data sets for future generations of scien-

*(Cont. on page 13)*

# Update On JGOFS Data And Information Management

*by Bernard Avril*

Over the last year, the JGOFS Data Management Task Team (DMTT) has undertaken a number of activities with the assistance of the International Project Office (IPO). Some of the most important are highlighted in this update on the task of locating, organizing and preserving the vast array of data collected by JGOFS investigators from many nations over more than a decade.

**New Web Site Launched**

Last July, the IPO launched a new JGOFS Internet site **(http://www.uib.no/jgofs)** with three objectives in mind. The first is to improve the overall organisation of the site and to make it more "user friendly." The second is to preserve accumulated JGOFS knowledge with minimal support until the programme ends in December 2003. And the third is to facilitate the handover of information to future ocean biogeochemistry and ecology programmes as part of the JGOFS legacy. The IPO welcomes suggestions for improving the quality and long-term value of the web site. Specific efforts have been made to exhibit JGOFS achievements in data management and to increase the visibility of proper data management in the marine sciences **(http://www.uib.no/jgofs/DMTT/dmtt.html)**.

**Data Rescue Meeting**

One of the goals of the DMTT and the IPO is to identify, document and collect all data and associated metadata from JGOFS studies. Accordingly the IPO invited representatives of countries that participated in JGOFS but are not represented on the DMTT to a "data rescue" meeting, held in Ispra, Italy, in June 2002 to learn about their JGOFS activities, to encourage them to contribute their data to the proposed International JGOFS Master Data Set, and to discuss with them the technical details of transfering, integrating, distributing and archiving their data sets and metadata.

National representatives were invited to attend from Belgium, Italy, The Netherlands, Norway and Spain. Participants in the meeting were DMTT chairwoman Margarita Conkright of the U.S. National Oceanographic Data Center (NODC); JGOFS Global Synthesis Working Group (GSWG) chairman Reiner Schlitzer; JGOFS/GAIM Task Team chairman Patrick Monfray; Maaike Vancauwenberghe of the Federal Office for Scientific, Technical and Cultural Affairs, Belgium; Cesare Corselli of the Milano-Bicocca University, Italy; Taco de Bruin of The Netherlands Institute for Sea Research; Jan-Roger Andersen of the Norsk Marint Datasenter, Norway; Aida Fernández Ríos of the Instituto de Investigaciones Marinas, Spain; Michael Diepenbroek of the World Data Centre for Marine Environmental Sciences (WDC-MARE), Germany; Charles Trees of the U.S. National Aeronautics and Space Administration; Nicolas Hoeppfner of the European Union Joint Research Centre, Italy, and Bernard Avril of the JGOFS IPO.

The national representatives benefited from a clear overview of international data management collaboration, from the expertise of the DMTT and the World Data Centres and from the development of tools dedicated to data management and visualization. They also gained insights into ocean modelling, thanks to the presentations and comments by the modellers. On the other hand, the national presentations provided valuable information about relevant projects, cruises and data sets.

Scientists were encouraged to collaborate with the WDC system for future studies as well as for JGOFS data sets. Conkright pointed out that one central, unique place for data sets is better for scientists, and this should be the WDC system.

She noted, further, that original quality control (QC) flags are not removed in data sets deposited in the WDC system; new QC flags are added instead. Different versions are labelled with unique date stamps and digital object identifiers. When QC flags are not consistent or when errors are found by the WDC, the data originator is contacted for comments. The final products identify the scientists associated with each variable in the data set and their institutions, in addition to the data submitters and their institutions.

Since that meeting, the various countries represented have made significant progress with regard to data management matters related to JGOFS science. For example, the Dutch JGOFS data sets are currently being transferred into the WDC system, several CD-ROMs with specific data sets from various countries are being completed, and a new national oceanographic data centre has been organised in Italy. More information about the Ispra meeting is available via the JGOFS home page **(http://www.uib.no/jgofs/Publications/other_pub/Ispra_Data_June2002.pdf)**.

**JGOFS Core Parameters**

With help from the IPO, DMTT members have updated the list of JGOFS core parameters, along with the most common units and metadata. Last fall, the members of the JGOFS Scientific Steering Committee (SSC), the DMTT and the IPO reached a consensus on a minimum list of JGOFS parameters that participating national programs should focus on in their submissions to the JGOFS master data set.

The core parameters list was published in JGOFS Report no. 37 in

August 2002 in almost final form. It is available via the JGOFS web site **(http://www.uib.no/jgofs/Publications/Report_Series/JGOFS_37.pdf).**

**Final Data Products**

The ultimate purpose of the DMTT is to provide scientists with a comprehensive biogeochemical data set in a common file and format for use not only in current modelling and synthesis activities, but also in future global change studies. The task team is currently finalizing the compilation of major JGOFS data contributions.

The Pangaea information system initiative for JGOFS at the World Data Centre for Marine Environmental Sciences (WDC-MARE) is continuing (see description in *U.S. JGOFS News* 11:4, pp. 18-19). Its goal is full accessibility and long-term archiving of all JGOFS data and metadata through the WDC system. Yet the pace has been slow because of the lack of basic funding. Members of the Pangaea team met in January in Bremen, Germany, with JGOFS representatives to assess the Pangaea initiative with regard to production of the JGOFS master data set **(see http://www.uib.no/jgofs/Publications/other_pub/JGOFS-PANGAEA_Bremen2003.pdf)**.

The work plan developed in Bremen was discussed further at a DMTT meeting in mid March, held at the British Oceanographic Data Centre (BODC) in Bidston, UK. Attending the meeting were DMTT chairwoman Margarita Conkright, Cynthia Chandler of the U.S. JGOFS Data Management Office, Jaswant Sarupria of the Indian National Oceanographic Data Centre, Marie-Paule Torre of the JGOFS-France/Processus Biogéochimiques dans l'Océan et Flux (PROOF) Data Management Office, Joachim Herrmann of the German JGOFS Data Management Office, Roy Lowry of the BOFS Data Management Office, BODC, GSWG chairman Reiner Schlitzer, and Bernard Avril of the JGOFS IPO.

DMTT members agreed on an overall plan for final JGOFS data products with the following components:

- Each JGOFS contributing country with DMTT representation will finalize its own data products before March 31, preferably as CD-ROMs or on an ftp site.
- The DMTT, with help from the JGOFS IPO, will organize the production of an international data DVD, to be titled "International JGOFS Data Collection, 1988-2000. Volume 1: discrete data sets." This DVD will be distributed during the JGOFS Open Science Conference, to be held in Washington, D.C., in May.
- This DVD will include an integral copy of all JGOFS CD-ROMs and data products available by March 31. For already published products, reproduction agreements have been secured or are being sought. The DMTT will hold the copyright for this DVD product, which will be structured by countries, projects and cruises as much as possible. The whole product will include 10 contributions never previously released. The U.S. NODC has agreed to organize the production of the master copy of the DVD and 1,000 copies, with financial help from the JGOFS IPO.
- The DMTT supports the plan of the Pangaea team to publish a second volume in 2004 or 2005, to be titled "International JGOFS Data Collection. Volume 2: integrated data sets." All data sets in this volume should be accessible in a common file and data format through the Pangaea user and visualization interface and be organised by project, cruise and data set for each parameter. The DMTT and IPO will continue to work with the Pangaea team until JGOFS comes to an end in December.

*Steering Committee –from page 11*

tists. In another article in this issue, JGOFS assistant executive scientist Bernard Avril provides an update on data management.

Looking forward to the JGOFS Open Science Conference, to be held in Washington, D.C., in May, the SSC discussed the programme and complimented Debbie Steinberg of the Virginia Institute of Marine Science, U.S., on her excellent job as chairman of the OSC Science Programme Steering Committee. Through Steinberg's efforts, Carol M. Browner, a former administrator of the U.S. Environmental Protection Agency, has agreed to give the OSC keynote lecture at the Smithsonian National Museum of Natural History.

The SSC also expressed appreciation for the efforts of the U.S. JGOFS Planning Office staff, which has been responsible for OSC logistics. SSC members anticipate strong, creative regional and global synthesis presentations from the groups, teams and national programs represented and interesting theme posters from the broader scientific community.

Participants in JGOFS are now looking forward to a new international programme titled Ocean Biogeochemistry and Ecosystem Analysis (OCEANS). Broadgate reviewed the scope of planning meetings and formation of a transition team for OCEANS. Under the sponsorship of the IGBP and the Scientific Committee on Oceanic Research (SCOR), the OCEANS Transition Team organized an open science conference, held in Paris in January. OCEANS Transition Team chairman Julie Hall and assistant Penelope Cooke describe the conference in an article elsewhere in this issue.

The final JGOFS SSC meeting will be held during the JGOFS Open Science Conference in Washington, D.C., in May. More information on JGOFS activities is available via the JGOFS home page **(http://www.uib.no/jgofs/jgofs.html)**.

# JGOFS Equatorial Pacific Synthesis and Modelling Group Holds Workshop

*by Fei Chai and Robert Le Borgne*

Investigators and modellers interested in the synthesis of equatorial Pacific Ocean research got together last September in a coastal town in Maine for a workshop organized by the JGOFS Equatorial Pacific Synthesis and Modelling Group (EPSMG). Twenty-five participants representing six countries attended the workshop, held at the Darling Marine Center of the University of Maine.

This event followed the publication of a special issue of *Deep-Sea Research II* (Vol. 49, No. 13-14), coordinated by the EPSMG and dedicated to the synthesis and modelling of the equatorial Pacific. After the completion of this project, EPSMG members felt that ongoing equatorial Pacific modelling activities could benefit from the new ideas and concepts emerging from the synthesis and organized the workshop to bring modellers and synthesis leaders together.

The workshop comprised four half-day sessions of presentations and discussions. The first session was devoted to observations of large-scale phenomena, including the Pacific Decadal Oscillation (PDO), the 1997-1998 El Niño cycle, the effects of tropical instability waves (TIWs) on biological productivity and the carbon cycle, and zonal and latitudinal variations. Presentations on these topics demonstrated that our understanding of large-scale, physical-biogeochemical interactions has advanced substantially since the beginning of JGOFS field studies in the equatorial Pacific in 1989.

Workshop participants also discussed the effects of climate variation on the zonal extensions of the warm pool in the west and the upwelling or high nutrient-low chlorophyll (HNLC) area in the east, with corresponding effects on carbon export via the biological pump and the air-sea flux of carbon dioxide ($CO_2$).

The second session was devoted to presentations on the biological pump within the HNLC and warm-pool areas. Talks covered microbial communities and their role in total and new production, co-limitation of phytoplankton productivity by silicon and iron, and the balance between phototrophic production and grazing. Although the community structure of the smallest planktonic organisms and their production levels are now well known for this region, our knowledge of iron and silicon distribution and utilization is more fragmentary. Studies of these elements should be an integral part of any future multidisciplinary field program planned for the equatorial Pacific.

Workshop participants also considered long-term variations in ocean carbon cycling and the biological pump. We have gained a fair amount of knowledge of the interannual variability in air-sea $CO_2$ flux in the equatorial Pacific, thanks to intensive field measurements over the last decade. For decadal or longer time scales, however, air-sea $CO_2$ flux values estimated by ocean physical-biogeochemical models as well as by atmospheric inverse models do not agree well with field observations. Continuing monitoring is needed for both trace-gas fluxes and biogeochemical variables.

A series of presentations on current ecosystem modelling activities followed the sessions on field observations. A serious effort is under way to incorporate variation in phytoplankton species assemblages in response to nutrient availability into ecosystem models. Several modelling presentations addressed the role of iron as a regulating nutrient in the equatorial Pacific. Although advances have been made in this area, more iron measurements as well as better understanding of iron chemistry are needed to improve model structures.

The equatorial Pacific is among the regions included in a "test-bed" project, in which a suite of one-dimensional ecosystem models are incorporated into a common framework of physical processes using the same physical forcing. As part of this project, data assimilation techniques are being employed to evaluate and improve model performance.

The final workshop session was devoted to the large-scale modelling projects of various kinds. Among the topics were eddy-resolving simulations, modelling of the ecosystem in the subtropical North Pacific gyre and a comparison with ecosystems in the equatorial Pacific, El Niño-Southern Oscillation (ENSO) simulations and decadal variations, and assessment of the effect of ENSO variability on tuna fisheries in the warm pool.

This last session demonstrated the very significant progress achieved over the past three years since the U.S. JGOFS Synthesis and Modeling Project (SMP) workshop on the equatorial Pacific ecosystem, held in November 1999 at Old Dominion University in Norfolk, Virginia. In addition, the tuna fisheries modelling work in the equatorial Pacific showed a good example of cooperation between JGOFS and Global Ocean Ecosystem Dynamics (GLOBEC) investigators.

Concluding discussions focused on comparisons between the equatorial Pacific and different equatorial zones or other JGOFS field studies, the modelling of the organic carbon pump and the role of diatom production in regulating climate variability. In his final remarks, Robert Le Borgne discussed the future of equatorial Pacific studies.

Our understanding of physical and biogeochemical processes in the equatorial Pacific Ocean has advanced significantly, thanks to the impressive field studies of the last 10 years and the availability of data from biological and chemical sensors mounted on Tropical Atmosphere-Ocean (TAO) moorings. The knowledge gained has improved physical-biogeochemical modelling capability for the equatorial Pacific.

Workshop participants felt that new field programs should be encouraged, with particular emphasis on iron distribution and cycling, the combined effects of iron and silicon in regulating phytoplankton production and its effects on the carbon cycle, and multidisciplinary detailed studies of TIWs and their influence on the carbon cycle. Ongoing monitoring of biological and chemical variables should be supported as well.

Finally, participants suggested that a training workshop should be organized for doctoral and post-doctoral students, focusing on physical and biogeochemical processes taking place in the equatorial Pacific. This would help ensure the training of new scientists with renewed interest in future studies of the region.

*(Editor's note: Fei Chai of the University of Maine and Robert Le Borgne of the Institut de Recherche pour le Developpement (IRD) in Nouméa, New Caledonia, were co-conveners of the Equatorial Pacific Synthesis and Modelling Workshop.)*

## Final Call For JGOFS Publications

The JGOFS International Project Office is currently putting together a final list of JGOFS peer-reviewed publications that will be published as a JGOFS report. The deadline for submission of references or of the publications themselves for this list is May 31, 2003. Please contact Bernard Avril at **Bernard.Avril@jgofs.uib.no** or mail publications to him at the JGOFS International Project Office, SMR, University of Bergen, PO Box 7800, N-5020 Bergen, Norway.

# International Workshop To Launch Planning for GEOSECS II

International efforts to put together a coordinated global study are underway among geochemists and oceanographers interested in the marine biogeochemical cycles of trace elements and selected isotopic tracers. The primary objectives of the proposed study are:

- To determine global distributions of selected trace elements and isotopic tracers in the ocean;
- To evaluate the oceanic sources, sinks and internal cycling of these elements and thereby characterize more completely their global biogeochemical cycles.

Achieving these goals will provide information useful across the breadth of ocean and climate research. Such a study would provide better tracers of ocean circulation, better tools with which to evaluate processes involved in the ocean carbon cycle, insight into the limiting micronutrients that regulate ecosystem structure, improved understanding of proxies used in paleoceanography, and assessment of the transport and fate of pollutants.

The proposed study will adopt many of the scientific objectives of the Geochemical Ocean Sections Study (GEOSECS), conducted in the 1970's, and it will be conducted in the spirit of global exploration and discovery that led to the exciting advances made during GEOSECS. The emerging program has thus come to be known as GEOSECS II.

With support from the U.S. National Science Foundation, the Centre National de la Recherche Scientifique (CNRS), and the Observatoire Midi-Pyrénées, program organizers will hold an international planning workshop for GEOSECS II April 13-16 in Toulouse, France. The primary objectives of the workshop are:

1. To define the research problems of highest priority pertaining to the marine biogeochemical cycles of trace elements and related isotopic tracers;
2. To begin designing a field program to address the research problems identified in fulfilling the first objective above.

Workshop results will be organized into a draft science plan and presented to the broader oceanographic community via the GEOSECS II web site (**http://www.ldeo.columbia.edu/res/proj/geosecs2/**). Following a period of comment and review, the draft science plan will be refined and put into final form. The completed science plan is intended to serve as a basis for seeking support from national and international funding agencies.

More information can be obtained from the web site or from any member of the GEOSECS II planning committee.

**GEOSECS II Planning Committee**

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**31 March - April 2:** U.S. JGOFS Regional Ecosystem Modeling Testbed Workshop, Old Dominion University (ODU), Norfolk, VA. Contact: Marjorie Friedrichs, ODU **(marjy@ccpo.odu.edu).**

**4 May:** 18th JGOFS Scientific Steering Committee meeting, Washington, D.C., USA. Contact: Roger Hanson, JGOFS International Project Office, Bergen, Norway **(Roger.Hanson@jgofs.uib.no).**

**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, Woods Hole Oceanographic Institution, Woods Hole, MA **(mzawoysky@whoi.edu).**

**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

Published by the U.S. JGOFS Scientific Steering Committee

**Editor:** Margaret C. Bowles

**Designer:** Jeannine M. Pires

U.S. JGOFS News reports on U.S. contributions to the Joint Global Ocean Flux Study (JGOFS) of the Scientific Committee on Oceanic Research (SCOR), a permanent committee of the International Council of Scientific Unions (ICSU). JGOFS is a core project of the International Geosphere-Biosphere Programme (IGBP).

We welcome your comments and contributions for publication.

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