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

U.S. JGOFS NEWS

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JGOFS & WOCE Cooperate On Ocean CO_2 Survey

Carbon dioxide (CO_2) lies at the heart of a class of fundamentally interesting ocean problems. As bicarbonate (HCO_3^-) it is a significant part of the "salt" of seawater; as solid calcium carbonate ($CaCO_3$) it forms coral reefs, sea shells and the white cliffs of Dover, and as a gas it is exchanged between air and sea, fixed during photosynthesis and produced during organic matter decomposition.

These natural cycles are vast. The amount of photosynthesis that takes place in the upper ocean, for instance, is almost equal to that occurring on all the continents put together. Vast though these signals may be, however, they are being encroached upon increasingly by the activities of man.

The broad concept is simple. Carbon dioxide, which is currently released into the atmosphere at a rate of about 5.5 billion tons per year from the burning of coal and oil, tends to be absorbed by the ocean. The reaction is a familiar one, analogous to the attack of carbonic acid in rainfall on limestone.

In this case, however, only CO_2 gas exchange with alkaline seawater is involved, and the rate of physical mixing in the ocean sets the pace. The result is that about 2.5 billion tons of CO_2 per year are absorbed by the ocean and mixed into the abyss.

Behind this simple scheme lies enormous complexity. What happens if the rate changes? What if the great biological cycle of carbon is perturbed? Do we just say this, or can we measure it? Are the operating principles really understood?

Two of the principal ocean observing programs, the Joint Global Ocean Flux Study (JGOFS) and the World Ocean Circulation Experiment (WOCE), have forged links to tackle these problems under the sponsorship in the U.S. of the National Science Foundation and the Department of Energy (DOE). The National

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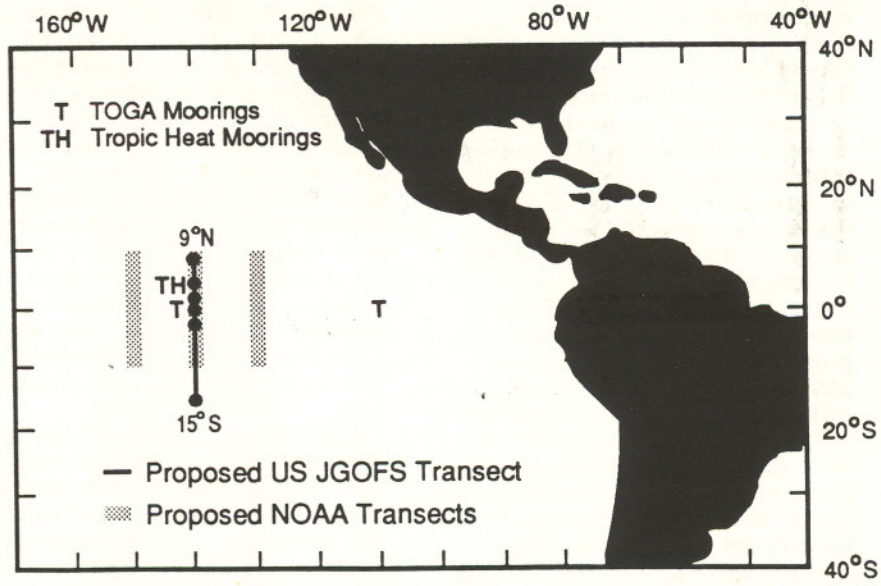

U.S. JGOFS and NOAA researchers are coordinating plans for cruises in the equatorial Pacific in 1991-92. The proposed U.S. JGOFS field program calls for process studies and flux measurements at sites along a transect at 140°W from 9°N to 15°S. NOAA scientists are proposing shorter transects along 130°, 140° and 150°W to study conditions upstream and downstream of the JGOFS study sites. Certain JGOFS stations will coincide with moorings deployed by the TOGA and Tropic Heat programs.

Update On Planning For Equatorial Pacific Study

As the next major field program of the Joint Global Ocean Flux Study (JGOFS) takes shape, the team charged with organizing U.S. participation in it has acquired a new member. R.J. Toggweiler, a National Oceanic and Atmospheric Administration (NOAA) scientist at the Geophysical Fluid Dynamics Laboratory (GFDL) at Princeton University, is joining "Eq Pac" coordinators Margaret Leinen, University of Rhode Island, and James Murray, University of Washington, to help with U.S. planning for a process study to take place in the equatorial Pacific Ocean in 1991-92.

Toggweiler will undertake the task of coordinating projected NOAA activities in the Pacific with U.S. JGOFS studies to be sponsored by the National Science Foundation. He and several other NOAA scientists are planning to submit a proposal for measurements on NOAA cruises that are designed to overlap NSF-sponsored cruises in the planned study area. The JGOFS proposed studies will be conducted along a transect at 140°W (see figure). The NOAA cruises will flank the JGOFS ones, putting a box around the JGOFS transect, Toggweiler said.

Along with GFDL colleague Jorge Sarmiento, Toggweiler will also be host to an Equatorial Pacific Modeling Workshop, to be held in Princeton in September. The meeting will focus on biological and chemical interactions predicted by three-dimensional circulation models incorporating explicit ecosystem components. One aim of the workshop is to make modeling results available to guide the upcoming field program.

For the immediate future, the planning team is focusing its efforts on an international Pacific workshop this month in Tokyo. Leinen is serving as chairman for the workshop, which is bringing JGOFS participants from a number of countries together in order to coordinate their science plans and logistics.

A draft science plan for U.S. JGOFS

(Cont. on page 8)

WOCE – (Cont. from page 1)

Oceanic and Atmospheric Administration's new ocean carbon program will provide important additional capability.

Early WOCE documents included plans for an ocean carbon dioxide observing program, and at a key meeting held at the National Academy of Sciences in November 1986 Roger Revelle of the University of California at San Diego and Peter Brewer of Woods Hole Oceanographic Institution addressed this issue. It soon became clear in the discussion that followed that the technical demands of such a survey and the breadth of subject matter would strain the resources of WOCE and divert them from the program's primary goal of determining the physical circulation of the ocean.

The organizers of WOCE generously offered to make space available on their global survey cruises, should a group of independent scientists wish to take advantage of the opportunity to carry out a CO_2 survey. That meeting also witnessed the drafting of a proposal for the Scientific Committee on Oceanic Research (SCOR) to unify the loose international coalition of scientists working on biogeochemical problems into what is now JGOFS.

Although a number of U.S. federal agencies were interested in the oceanic carbon dioxide problem, no focal point for discussion or resolution of problems existed at that time. Recognizing this need, the Ocean Studies Board (OSB) of the National Academy of Sciences created a CO_2 panel that has worked hard to advance the science necessary to tackle the problem. The efforts of its member scientists have borne fruit.

The history of ocean CO_2 measurements is somewhat troubling. While individual measurements can be made with apparent high precision, the linkage of all the components through commonly used equations frequently runs into trouble.

The signal sought is often small. The CO_2 panel identified an accuracy and precision of ± 1 µmole CO_2/kg as necessary (about the rate of increase of CO_2 invasion worldwide), yet measurements made by different techniques on the GEOSECS program in the 1970's frequently differed by more than 15 times that amount. No acceptable chemical standard existed, and the equations used were confusing even to insiders.

Diligent staff work by Mary Hope Katsouros of the OSB produced solutions to various problems. Standards for atmospheric measurements, long established at the laboratory of David Keeling of Scripps Institution of Oceanography, are now being transferred to the National Institute of Science and Technology laboratory of William Dorko. For ocean water, the panel awaits standards from Andrew Dickson, also of Scripps.

Measurement of CO_2 in seawater by gas extraction and coulometry, pioneered by Kenneth Johnson of the University of Rhode Island, has now been adopted as the primary technique and can yield the desired precision. New constants and equations by Catherine Goyet and Alain Poisson of the University of Paris have helped to clear up confusion.

With these tools in hand, the panel examined WOCE plans. An interagency agreement, initiated with the help of Frederick Koomanoff of DOE and continued by his successor Ari Patrinos, produced an announcement of opportunity last summer for CO_2 surveys on the first of the WOCE Hydrographic Program (WHP) cruises.

When the West German research vessel *Meteor* set out from Ushuaia, Argentina, Jan. 23 on the first WOCE cruise, one of the investigators on board was David Chipman of Lamont-Doherty Geological Observatory. He was the first to carry out a CO_2 project under the DOE Carbon Dioxide Research program.

The cruise track (WOCE-HP S1/A21) was south and east across the Drake Passage to Antarctica, eastward across the Weddell Sea and finally northward to Cape Town, South Africa, where the cruise ended March 8. Chief scientist for the cruise was Wolfgang Roether.

Among the researchers who conducted CO_2 measurements during last year's JGOFS North Atlantic Bloom Experiment is David Chipman, shown here working in the laboratory aboard R/V *Atlantis II*. Chipman is a scientist at Lamont-Doherty Geological Observatory.
(Photo by Craig Dickson)

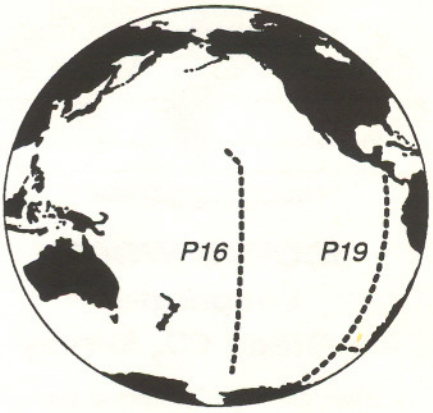

Figure 1: WOCE cruises P16 and P19, scheduled for late 1990 and early 1991, will include surveys of oceanic CO_2 by JGOFS investigators.

Figure 1 shows P16 and P19, the two lines to be surveyed on the next WOCE cruises, beginning in November 1990 and continuing until February 1991.

Five scientific groups have received funding to take on various aspects of the oceanic CO_2 problem on these cruises, both in the Pacific. Principal investigators are Ray Weiss, Scripps; David Keeling, Scripps; Douglas Wallace, Brookhaven National Laboratories; Taro Takahashi, Lamont–Doherty, and Peter Brewer, Woods Hole Oceanographic Institution.

They will observe an ocean now contaminated with fossil fuel CO_2 down to a depth of about 750 meters, in which carbonate ion ($CO_3^=$) has been significantly reduced (about 10%) from its abundance in surface waters in pre-industrial times. They will seek to balance the classic Redfield equation, which fundamentally characterizes the cycle of organic matter in the ocean on which marine life depends. And they will be able to observe the great exchanges of these living gases between air and sea.

These fundamental data will document the burden of carbon carried by the oceans and, through linkage of models calibrated by the radio tracer carbon-14, will contribute to predictions for a world rich in greenhouse gases. This venture will form a fundamental part of the JGOFS global survey; similar projects are getting underway in other member nations of the JGOFS family.

Liaison Facilitates WOCE-JGOFS Interaction

by Hugh D. Livingston

As the Joint Global Ocean Flux Study (JGOFS) and the World Ocean Circulation Experiment (WOCE) have moved forward over the past few years, it has become increasingly clear that both programs stand to benefit from coordination in planning and implementation, in part because their scientific achievements together are likely to add up to considerably more than those developed separately.

The practical considerations of ship scheduling dictate that cruise planning be closely coordinated. Because the data sets collected will be of mutual interest, data management systems need to be compatible. Recognizing the importance of maintaining strong ties between WOCE and JGOFS, the planning offices of both programs are increasing their efforts to strengthen their links and interactions at both national and international levels. Coordination with other global oceanic programs, such as the International Global Atmospheric Chemistry Programme, is also developing in the same framework.

Interactions between the two programs on the international level have been healthy. Peter Koltermann, head of the WOCE International Project Office (IPO) in Wormley, United Kingdom, noted that "on the international level WOCE and JGOFS, to my knowledge, have had a very good and intensive relationship. JGOFS is the one global program WOCE constantly talks to, not the least because Mike Fasham is here on site, and Liz Tidmarsh is in another WOCE loop." Fasham is vice chairman of the JGOFS executive committee and architect of the JGOFS science plan, and Tidmarsh serves as executive secretary for both the international JGOFS program and its parent body, the Scientific Committee on Oceanic Research (SCOR).

With the establishment of the JGOFS scientific office in Kiel, West Germany, in November, international cooperation between JGOFS and WOCE is moving on to a more formal and continuous stage. The location of the new office will allow Koltermann and JGOFS executive scientist Geoffrey Evans to interact frequently.

On the other side of the Atlantic, interaction is also steadily increasing. The international WOCE Hydrographic Programme Office (WHP) is

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Moored Instrument Observations Offer Time-Series Insights For Studies Of Ocean Fluxes

by Tommy D. Dickey

Significant changes in the physical, biological, chemical and optical properties of the upper ocean occur on time scales varying from a few hours to weeks, seasons or years. In order to understand the processes that govern upper ocean systems and their interactions with the atmosphere and the depths, we need to be able to collect data frequently and over long periods of time in order to capture potentially significant short-term variations as well as seasonal and interannual changes.

Oceanographers have been interested in seasonal changes in upper-ocean variables and processes such as primary production for several decades. Much of our present understanding of the seasonal cycle of primary production and its relationship to the flux of carbon in the upper ocean is based on studies conducted by D.W. Menzel and John Ryther in the late 1950s and early 1960s. These researchers collected physical and biological data relevant to primary production on a bi-weekly basis at Hydrostation S near Bermuda from late 1957 through 1960.

The recent surge of interest in understanding the flux of carbon in the ocean and between the atmosphere and the ocean has stimulated new approaches to the problem of sampling the upper ocean. Remote sensing with satellite color imagery, for example, has become an important means of estimating ocean pigments and thus primary production.

Recent advances in moored measurement systems are also improving our ability to collect a wide range of information about the upper ocean. Researchers from a variety of disciplines are using instruments moored to buoys to collect data on time scales previously possible only for physical oceanographic measurements. Physical and bio-optical measurements can be made from moored instruments every few minutes for periods up to six months, a sampling rate some 20,000 times that possible for Menzel and Ryther.

One of the primary objectives of the Biowatt Program, an interdisciplinary effort sponsored by the Office of Naval Research, is to develop predictive models of the temporal and spatial variability of optical properties and bioluminescence in the open ocean. During Biowatt studies in the Sargasso Sea, collaborative groups from the University of Southern California (Tom Dickey) and from Lamont-Doherty Geological Observatory (John Marra) collected samples from moored instruments (Fig. 1) located at 34°N, 70°W every four minutes during three consecutive deployment periods from Feb. 28 through Nov. 23, 1987.

Their multi-variable moored systems (MVMS) instrument packages were deployed at eight depths from 10 meters to 160 meters. The instruments measured horizontal currents, temperature, photosynthetically available radiation (PAR), beam attenuation coefficient, chlorophyll fluorescence and dissolved oxygen.

Time-series measurements of currents (daily vector averages) and the latter four variables (2h filtered) are shown in Fig. 2 . The bio-optical variables all exhibit diurnal variation throughout the euphotic layer as well as a large transient phytoplankton bloom on day 86. The bloom is also

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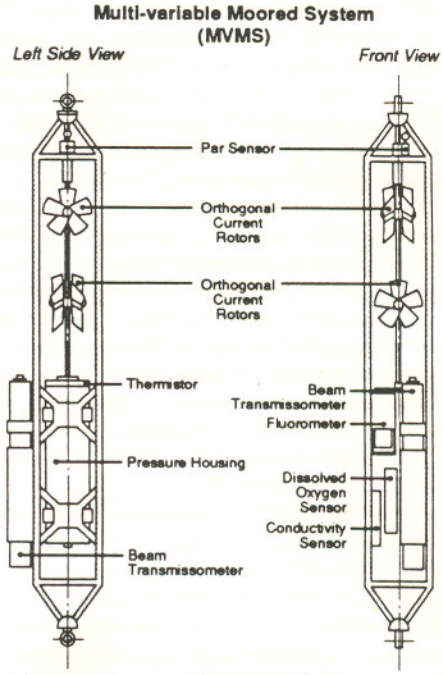

Fig. 1 Schematic diagrams of the Biowatt multi-variable moored system.

Commentary: U.S. JGOFS Long-Range Science Plan

by Peter G. Brewer

With the completion of a long-range plan after equally long debate, U.S. participation in the Joint Global Ocean Flux Study takes an important step. How the strategy in this plan evolved, how it will crystallize into hard science, and how we can treat it as a living document are genuinely interesting questions.

Scientists do not like to write plans, at least not long-range ones. A plan signifies a commitment to a long-term course of action. And the essence of science is following the path of discovery, which can lurch in unpredictable directions, leaving plans and those trapped in them in disarray. Those least fettered and most nimble seem least at risk.

Modern ocean programs on the large scale, however, require resources beyond a nimble and well-trained mind. Ships, satellites, computers, funding and the development of new skills all require long lead times and therefore the making of plans.

U.S. JGOFS strategy evolved some time ago into an experimental system with three major components: time-series measurements, process studies and a global survey. The addition of numerical modeling and data management strategies completed the picture, and all aspects of the program will make use of ocean color data from satellites.

So well established are these themes that they are now unquestioned. But it was not always so, and the history of debate within the community is worth reviewing.

Shortly after the meeting that gave birth to GOFS, a cacophony of opinion arose. In the minds of some, GOFS was a sort of funding agency, to which one should write requesting or demanding an experiment off a particular state or coastal laboratory. Others saw a need to define the project by the inclusion or exclusion of a given measurement skill. (Tell me, now, is Element X in or out?) Still others insisted on a magisterial view: "You have to decide whether this will be fundamentally model- or data-driven; they are quite different." In the end, reason won out.

U.S. JGOFS is firmly positioned within the U.S. Global Change Research Program (CES 1989), and the observation of change inevitably requires some commitment to measurement over time. The specifics of the variables to be measured, the duration and frequency of the observations and the logistics required are all to be resolved in the free market of professional science. Yet the plan must see to it that this happens, and it must frame the debate.

A program that titled itself "global" at conception has something to live up to. The acquisition of data on the scale of a trans-oceanic cruise is the most basic and traditional ocean science experience; one cannot imagine the field without it. And such a strategy readily scales up to a global survey. The GEOSECS program of the 1970's provides an example.

Concerns about data utility force a hard look at the costs and benefits of such a survey, and the plan treats this issue with caution. Acknowledging the value to JGOFS of the upcoming World Ocean Circulation Experiment global survey and the data it will provide, the plan includes a carbon dioxide measurement program to be conducted on WOCE cruises. The aim is to balance the right-hand side of the Redfield equation and document the fossil fuel invasion of the CO_2 cycle. Planners are considering the possibility of an optics/pigments project under the WOCE umbrella as well, although the logistics present a problem.

An independent JGOFS survey of particle flux, trace gas, pigment, sedimentary and radioisotope signals will take place when earlier phases of the global survey program are secure. One draft for such a project envisions a program with about 20 sections, about one quarter of the WOCE hydrographic survey.

The North Atlantic Bloom Experiment, a JGOFS pilot project conducted last year, demonstrated the feasibility of conducting process studies as part of the U.S. JGOFS plan. Recognizing that in key areas we do not know how to describe critical processes, differing climatological responses, for example, we look to process studies not just for data but for understanding of the process being investigated. Thus knowledge may be encapsulated in a changed equation or couched in a different set of scientific principles.

The burden is large. Timing of field work can be critically important, and veterans of the bruising, draining and all-encompassing experience that constitutes a modern expedition know that strikes, political coups, ship failures or simple equipment losses at sea or in transit can devastate such a program. The effort, moreover, lends itself to questions along the lines of "What, exactly, did you learn?", while a data-intensive survey rolls along more easily.

The U.S. JGOFS steering committee has chosen wisely in focusing on these strategies, and all who have participated in the debate that produced the long-range plan have contributed to its formulation. Particular recognition must go to Otis Brown for shepherding the plan through its final stages with grace and skill.

Execution of the plan will require the work of many. The evolution of the time-series stations into virtual national observatories and the selection and development of candidate process studies in a world of rapidly increasing knowledge will occupy the steering committee for years to come. Important ties such as that with WOCE and the nascent relationship with International Global Atmospheric Chemistry (IGAC) program must not be taken for granted but carefully nurtured instead. The course of events so far shows that the community can rise to the challenge.

The U.S. plan cannot stand alone, for JGOFS is a true international program with lively and assertive contributions from all sides. Those currently drafting the JGOFS international plan have the advantage of having seen many national statements first.

It is clear that the broad themes above will hold, but the details will necessarily differ. One cannot, for example, expect a direct Chinese contribution to a U.S. station off Bermuda. But common lessons learned can be transmitted through the JGOFS process and contribute to establishing the needed ocean observing systems.

The selection of process studies and the provision and coordination of national resources to attack them will be keenly contested issues in the JGOFS agenda. In this debate the U.S. plan plays a major and evolving role.

A New Iron Age, Or A Ferric Fantasy

by John H. Martin

I first became interested in iron in the ocean at a U.S. JGOFS steering committee meeting in San Francisco during December 1986 at which Bruce Frost of the University of Washington gave an excellent briefing on the abundance of unused major nutrients in the offshore waters surrounding Antarctica.

Bruce outlined various hypotheses concerned with cold temperatures, low light levels, high grazing rates and the like. After his presentation I told him that I enjoyed his talk, but that the real reason for the nonutilization of major nutrients was Fe deficiency, after all.

Bruce smiled, covered his ears and said that it was too simple and he didn't want to hear about it. Jim McCarthy of Harvard University's Museum of Comparative Zoology joined us and soon said that he didn't want to hear about iron either. Naturally, this good-natured challenge made me all the more anxious to tell them about it. In order to do so, I had to quit bluffing and see if there really was any serious evidence for oceanic Fe deficiency.

After I returned to my office at Moss Landing Marine Laboratories, I started to go through the clutter on my desk. After some frantic digging, I found a top-quality Fe data set produced by my MLML associate Mike Gordon plus a reprint from Bob Duce, the famed atmospheric chemist from the University of Rhode Island.

Bob estimated that fallout of iron-rich atmospheric dust provided about 50% of the Fe needed by open-ocean phytoplankton. I plugged Mike Gordon's latest Fe numbers into Bob's formula, and the new estimate suggested that 95%, not 50%, of the phytoplankton's Fe requirement had to come from fallout from the atmosphere. It also suggested that the deep ocean water in the Pacific, once raised to the surface, was basically infertile because it didn't contain enough iron to allow the phytoplankton to make use of the available NO_3.

From my old days with Bob Duce in the IDOE (International Decade of Ocean Exploration) Pollutant Transfer Program, I recalled that the dust input into the Antarctic was very low. Looking for a more recent Antarctic estimate, I came across the French/Soviet Vostok ice core work of De Angelis and his colleagues, which showed that the present-day dust level was indeed very low. During the ice ages, however, it had been much higher.

Illustration by E. Paul Oberlander

My investigation led me onward to the scenario created by talented Princeton modelers Jorge Sarmiento and Robbie Toggweiler concerning atmospheric carbon dioxide, the biological pump and the use or nonuse of major nutrients in the Southern Ocean.

Then another French/Soviet team of glaciologists (Barnola et al.) published their CO_2 data from the Vostok ice core. When the Vostok Fe data were superimposed on the CO_2 data, the result was a striking inverse relationship. Mutterings increased from the growing numbers of Fe skeptics.

A desire to learn more about the Antarctic led me to a review of the expedition of the British research vessel *Discovery*. Those were the days (1925-27) when persons were persons and the scientists were gone for three years!

Sir Alister Hardy F.R.S. describes this monumental effort in writing, water color and fascinating detail in his book *Great Waters*. The British scientists went to the Antarctic to study the relationship between phytoplankton, krill and the whale fishery.

While reading the book through my iron-glazed eyes, I looked for evidence in support of the Fe hypothesis and noted the mention of great abundance of phytoplankton and krill, not to mention whales, on the shallow, iron-rich South Georgia whaling grounds. To my surprise and

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JGOFS-IGAC Cooperation Planned On Ocean/ Atmosphere Interactions

Recognizing their common interest in understanding the biogeochemical exchanges between the atmosphere and the ocean, a working group of representatives of the Joint Global Ocean Flux Study (JGOFS), the International Global Atmospheric Chemistry (IGAC) program and the International Geosphere-Biosphere Programme (IGBP) got together in San Francisco last December to define overlapping areas of interest and look for ways to work together.

Peter Liss from IGBP served as chairman. Also attending were IGBP representatives Patrick Holligan and James McCarthy. JGOFS participants were Richard Gammon, Margaret Leinen and John Martin. Robert Charlson, Robert Duce and Joseph Prospero represented IGAC, and David Hurd attended from the National Science Foundation.

The meeting was held under the aegis of IGBP's Coordinating Panel 2. Both JGOFS and IGAC have been designated as IGBP core programs.

Participants agreed that certain important biogeochemical interactions require interdisciplinary investigation. JGOFS and IGAC are linked, the meeting report noted, by "the recognition that the living ocean strongly modifies the trace gas composition of the atmosphere and that, for climate prediction, experimental and modeling studies of this interaction are required, and further that atmospheric deposition can affect ocean productivity."

Among the scientific topics discussed was the issue of atmospheric inputs to the oceans. Discussion focused on three aspects of the problem: the effect of clouds and ozone on the quantity and quality of light at the ocean surface; the deposition of continental dust as a source of iron for open ocean phytoplankton, and the supply of nutrients such as nitrogen and ammonium to the surface waters in the form of aerosols.

Ocean inputs to the atmosphere formed the next topic. Workshop participants discussed the role of emissions of dimethylsulfide, a byproduct of algal metabolism, in the atmospheric sulfur budget, the formation of cloud condensation nuclei and the acid-base chemistry of rainwater. Also discussed were a

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Moored – (Cont. from page 3)

evident in the concurrent bio-optical data (spectral radiance and irradiance) obtained from bio-optical moored systems by the University of California at Santa Barbara (Ray Smith). This spring bloom coincided with a shoaling of the mixed-layer depth from greater than 160 meters to 30 meters within two days.

The time-series records of beam attenuation coefficient, chlorophyll fluorescence and dissolved oxygen have also been sub-sampled at bi-weekly intervals in order to illustrate the difference in variability that can be inferred from high-frequency sampling versus low-frequency sampling. It is apparent that we cannot capture the high degree of variability associated with processes such as diurnal particle production and transient blooms with sampling every two weeks.

It is now possible to carry out time-series analyses, such as spectra, coherence and the like, with variables including beam transmission, chlorophyll fluorescence and dissolved oxygen as well as currents and temperature. It is important to note that many of the observations described here, such as PAR, fluorescence, beam attenuation coefficient and dissolved oxygen, can be used with models to generate time-series records of biomass and/or primary production and thus to make estimates of organic carbon fluxes.

Concurrent physical, bio-optical and chemical observations such as these are critical to data interpretation and modeling. Physical information, such as mixing time scales, stratification and advection, for example, is vital to our understanding of biological, optical and geochemical processes.

Although we have advanced considerably in our ability to sample marine ecosystems, there are several important variables we need to include in future high-resolution measurements. Among them are dissolved carbon dioxide and plant nutrients, such as nitrates, nitrites, phosphates and silicates. Although we can determine oxygen fluxes across the air-sea interface using mooring meteorological data and near-surface dissolved oxygen concentration measurements, we also need time-series measurements of carbon dioxide. An effective dissolved CO_2 sensor will make such measurements possible.

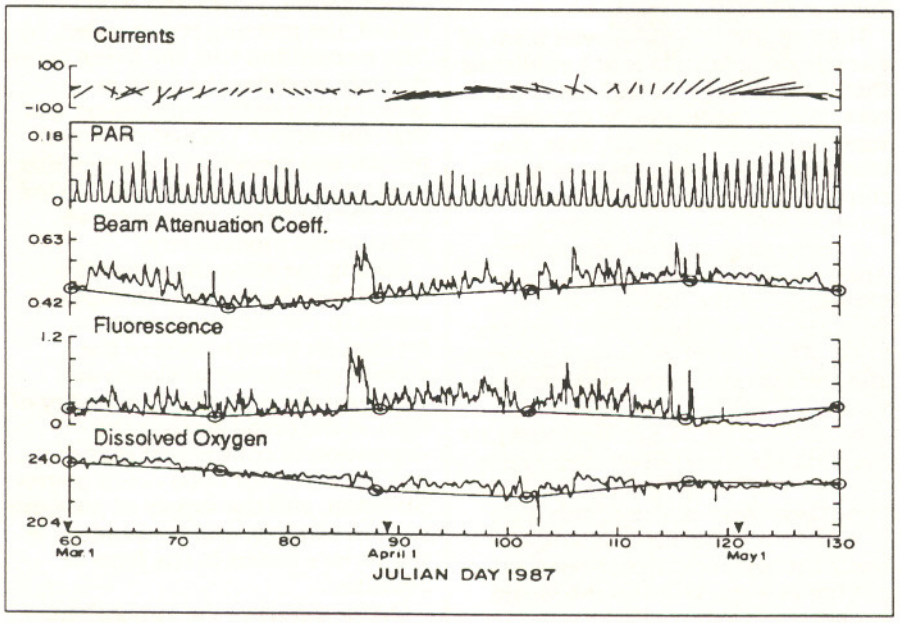


Fig. 2 Time series of daily averaged vector currents (in cm/sec) and two-hour filtered PAR (in X1021 quanta/m2/sec), beam attenuation coefficient (in 1/m), chlorophyll fluorescence (in µg chl-a/l) and dissolved oxygen (in µM) taken from the 20 MVMS during the first deployment of the Biowatt mooring. Currents were very low as the springtime stratification (not shown) began on JD 86 (mixed layer shoaling from greater than 160m to about 30m). A major transient springtime bloom shows in the beam attenuation coefficient and chlorophyll fluorescence time series. Bi-weekly sub-sampled data are indicated with circles connected by straight lines. The undersampling problem of previous data sets is apparent.

Biowatt researchers launch a multi-variable moored system instrument package and buoy.

Observations from moorings, ships and satellites all have their advantages and disadvantages in sampling. Moored observations will be of the greatest benefit to process studies if they are used in conjunction with shipboard measurements that are as yet beyond the capability of moored instrumentation technology. Moored observations will also enhance greatly the usefulness of remote sensing observations of ocean color. Our ability to monitor changes over the long term and predict future changes in global carbon fluxes will benefit from the acquisition of data from each of these sampling methods.

JGOFS-IGAC – (Cont. from page 5)

variety of other biogenic gases and surface ocean abiotic reactions.

Those attending the workshop agreed that better understanding of feedback processes is essential to developing the ability to predict environmental changes. They concluded that strong links between JGOFS and the IGAC program are needed to unravel the relationships between biological and chemical processes.

The workshop report called for establishment of formal relationships between JGOFS and IGAC steering committees, joint planning and exchange of working group members and the development of new joint studies stressing integration and overlap between the two programs.

SCIENTIFIC COMMITTEE ON OCEANIC RESEARCH

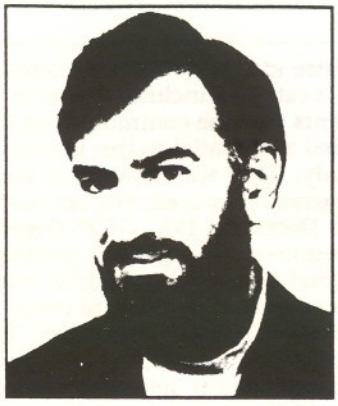
JGOFS

JOINT GLOBAL OCEAN FLUX STUDY

International News

Canadian Scientist Takes Up Post As JGOFS Executive

by Margaret C. Bowles



Geoffrey T. Evans

With the appointment of an executive scientist for its newly established international planning office at the Institut für Meereskunde at Kiel University in West Germany, the Joint Global Ocean Flux Study has acquired a manager for the flow of ideas and information among its constituent parts.

Directing the traffic will be Canadian scientist Geoffrey T. Evans, who packed up both his mathematical models and his viola and moved to Kiel in mid February. On loan from the Science Branch of the Department of Fisheries and Oceans in St. John's, Newfoundland, Evans will be fully supported by the Canadian government during his two years in Kiel.

How does he envision his new job? "JGOFS has all sorts of countries, objectives and players. It's the executive scientist's job to make sure ideas flow smoothly amongst them. That's what I'm aiming for," he noted. "I'll be keeping track of things, helping the steering committee draft agendas and passing things on to those who are interested."

The new executive scientist is also charged with providing liaison between JGOFS and other international research programs, such as the International Geosphere-Biosphere Program, the World Ocean Circulation Experiment or the International Global Atmospheric Chemistry Programme, in addition to collecting information on national activities and science plans within JGOFS.

Responsibility for administration of funds, development of budgets and proposals, JGOFS publications and liaison with the such bodies as the Scientific Committee on Oceanic Research (SCOR) will remain with JGOFS executive secretary Elizabeth Tidmarsh in the SCOR office at Dalhousie University, Halifax, Nova Scotia. The two offices will collaborate on the promotion of the program and staff support for the JGOFS committee.

A mathematician by training, Evans has participated in modeling projects that are linked to the North Atlantic Bloom Experiment and to future JGOFS field programs. A member of the SCOR working group on JGOFS modeling, he has worked with a group at Princeton's Geophysical Fluid Dynamics Laboratory headed by Jorge Sarmiento and with other American and British colleagues on developing a three-dimensional plankton model of the North Atlantic that links biological processes and ocean circulation. They hope that this model will be of use in the forthcoming process studies in the Pacific as well, Evans said.

He himself is working on restricted versions of this model, such as one might use for an isolated water column. A question that interests him is whether it is possible to make a food-chain model that allows for differences in the way various kinds of phytoplankton interact with their environment.

"Is it possible to make a model with diatoms and coccolithophores and so on and keep them all around? It's really important for the aims of JGOFS. These different types take up carbon in different ways. After you have a model that can handle keeping all these species around, you can ask questions about the relative abundance of these species in a geographic location and what their distribution means for carbon uptake," he said.

Evans has also served as an associate editor for the Canadian Journal of Fisheries and Aquatic Sciences for the last two years and has contributed his modeling and quantitative skills to fisheries problems in Canada, including questions of population density and catch distributions.

He expects to spend roughly half his time in Kiel attending to administrative duties and the other half on JGOFS-related research. His own work should benefit, he noted, by his stay at the Institut für Meereskunde and a chance to interact regularly with a larger group of colleagues. "I'm a little isolated in St. John's," he said . "I need to be kept honest."

As for his role as JGOFS executive scientist, "it's a chance to mess up something really important," Evans proffered with a chuckle. "I would like to make models and ideas about modeling a part of JGOFS projects at every step," he added. "Model early and often."

A member in good standing of the Newfoundland Symphony Orchestra's viola section, Evans hopes to find a group to play with in Kiel. Playing viola in a community orchestra has enhanced his perspective on the efforts of interdisciplinary groups, he noted.

He and his wife, Marjorie, are looking forward to the challenges and opportunities ahead. "It's definitely an adventure," Evans said. "I'll be making it up as I go along."

SCOR To Convene Planning Meeting On Resource Coordination For JGOFS

The Scientific Committee on Oceanic Research (SCOR) has announced plans to convene a meeting in Paris during May for chairmen of the national JGOFS committees and senior representatives of various funding agencies. The purpose is to discuss the establishment of mechanisms for facilitating international coordination of resources for future JGOFS field programs.

In a letter to prospective participants in the planning meeting, SCOR President J.-O. Stromberg noted the successful international collaboration demon-

(Cont. on page 9)

Soviet Workshop Held On Ocean Fluxes & Ecology

Among the recent activities of the Soviet National Committee for JGOFS was a workshop on global fluxes and ecology in the oceans, held in the Caucasian city of Nalchik last December. Leader of the meeting was Prof. Alexander P. Lisitzyn, chairman of the Soviet JGOFS committee.

The workshop was organized by several of the institutes of the USSR Academy of Sciences. Among the seven foreign scientists participating was JGOFS committee member Klaus Kremling of the Federal Republic of Germany. Representatives from some 14 Soviet research institutions and organizations took part.

Topics of papers read at the workshop included particle flux, primary productivity, fate of organic and inorganic carbon and the geochemistry of suspension in both the open ocean and the inner seas. Geochemical and biochemical processes in the regions of oceanic hydrothemal vents were discussed. Participants also focused their attention on the impact of human activity on the marine environment and atmosphere.

At the end of the workshop, the Soviet scientists presented a preliminary draft of their national program for JGOFS. The final plan was presented at the recently concluded JGOFS Science Committee meeting in Kiel.

The national JGOFS program of the Peoples' Republic of China has launched its own newsletter. The first issue, in April 1989, introduced its readers to JGOFS history and planning, relationships with other global programs such as WOCE, IGBP and IGAC and the establishment and activities of the PRC's national committee.

NOAA Issues Announcement For Climate & Global Change Program

The National Oceanic and Atmospheric Administration (NOAA) has announced FY 1990 priorities, funding levels and deadlines for its Climate and Global Change Program, begun in FY 1989. The long-term objective of the program is to develop reliable predictions of global climate change and associated regional implications on time scales ranging from seasons to centuries.

Total resources available for extramural projects in FY 1990 will be roughly $3.8 million, $0.4 million of which will go to support a postdoctoral program in climate modeling and $1.2 million of which is for projects begun in FY 1989. Roughly $2.2 million is available to outside investigators for new projects.

Deadline for proposals is May 1. The agency plans to entertain and give priority attention to individual proposals in these areas: climate diagnostics and data base development; modeling; global hydrological cycle; trace gas studies, and ocean observations, circulation and biogeochemical cycling.

More information is available from Eileen Shea, executive secretary for the Climate and Global Change Program, or David Goodrich, program manager for Ocean Circulation Studies. Address and phone number for both: NOAA Office of Climatic and Atmospheric Research, 6010 Executive Blvd., Rm. 825, Rockville, MD, 20852, 301-443-8415.

Update – (Cont. from page 1)

studies in the equatorial Pacific, prepared by Murray and Leinen, was endorsed by the U.S. JGOFS Steering Committee at its meeting in January. Copies are available from the U.S. JGOFS Planning Office at Woods Hole Oceanographic Institution. Following the release of the plan, NSF issued a preliminary announcement of opportunity calling for proposals.

In order to address a number of questions that have arisen with regard to the structure and process of proposal submission, the planning office has circulated an update designed to provide further information on these matters. More information will be available following the Tokyo meeting.

Proposals should follow these guidelines:

1. The U.S. JGOFS Steering Committee recommends an open submission of logistics proposals covering, at minimum, ship time, routine water sampling, hydrography (T, S, O_2 and nutrients, including NH_4) and communications and logistics support. Additional measurements and operations may be added to the list for this proposal after the Tokyo meeting. NSF will entertain more than one such proposal.

2. NSF/U.S. JGOFS Steering Committee identified measurements: This category includes measurements that the committee has identified as essential to this process study. They will include the core program measurements outlined in the December 1987 GOFS Overview document. Competitive proposals to make all or some of these measurements are expected to result from the submission process. The technology should, at minimum, meet standards developed during the 1989 North Atlantic Bloom Experiment.

3. PI identified measurements: These fall outside the above categories and are such as will be deemed useful after review. They could include, for example, DOC/DON, other pigments, floating traps, trace metals or radioisotopes. These will also be competitive proposals submitted for review.

Proposals submitted could cover items under 2 and 3 within a single proposal. An HPLC proposal, for example, could also cover basic chlorophyll. A review panel will match proposals with needs and recommend the preferred set of funding actions, taking into account such factors as professional skills, completeness and cost.

The planning office is responsible for making sure that NSF receives at least one basic proposal as outlined above. To determine that the minimum set of NSF/SC identified measurements are covered in the suite of proposals submitted, the planning office requests copies of all submitted proposals.

In addition, following the advice of the U.S. JGOFS Steering and Executive committees, the planning office will prepare an overview for the NSF special review panel that will make final funding recommendations to NSF. Proposers are free to decide whether they wish to honor this request for proposal copies. It is not mandatory that they do so.

Workshop Participants Discuss Relationship Between Marine Productivity and Oceanic CO_2 Uptake

by Hugh W. Ducklow

WHOI photographer Craig Dickson captured this picture of Hugh Ducklow during last year's North Atlantic Bloom Experiment as he was preparing to launch an XBT from the deck of R/V *Atlantis II*. Ducklow served as chief scientist during the third leg of the program.

A group of oceanographers and biologists met last December at the National Research Council's headquarters in Washington, D.C., to consider the scientific feasibility of intervening in the oceanic carbon cycle to enhance the biological uptake of carbon dioxide by stimulating marine photosynthesis.

Most experts agree that global temperatures will rise over the next century in response to the accumulation of greenhouse gases, including CO_2, in the atmosphere. They generally agree as well that the major global sink for the atmospheric CO_2 is the oceanic carbon cycle, the primary focus of JGOFS research. But the mechanisms of oceanic CO_2 uptake and their relative importance remain the subject of vigorous debate, as do the policies we should implement to reduce the effects of global warming and the atmospheric carbon dioxide burden

The workshop was convened jointly by Oscar Zaborsky, chairman of the NRC's Board on Biology, and Adam Heller, professor of engineering at the University of Texas, Austin. Chairman of the meeting was Richard Barber of the Monterey Bay Aquarium Research Institute (MBARI). Those attending included U.S. JGOFS steering committee members Hugh Ducklow (Univ. Md.), John Martin (Moss Landing) and James Yoder (URI) as well as Jorge Sarmiento (Princeton), Dale Kiefer and Richard Dugdale (USC), Nathan Tolbert (Chicago), Charles Yentsch (Bigelow) and Marlon Lewis (NASA).

The central focus of the workshop was on the efficiency of operation of the "biological pump." The term refers to a group of biogeochemical and physical processes that fix organic matter as new production and export (or pump) it from the surface into the deep sea, primarily in the form of sinking particles. Although most experts do not think that it plays a net role in sequestering fossil fuel in the contemporary (and hypothetical) steady-state ocean, many recognize the potential capacity of these mechanisms to respond to climate change and alter the ocean-atmosphere CO_2 balance dramatically.

In the vast expanses of the Equatorial and Southern oceans where nitrate, the principal nutrient limiting new production, is never depleted, the biological pump is particularly inefficient. The workshop considered means by which its efficiency could be raised, increasing new production and deposition of carbon in the deep ocean, away from the atmosphere for centuries to millennia.

Although some discussion centered on biotechnological or other means by which the phytoplankton themselves could be made more productive, workshop participants devoted most of their attention to the iron limitation hypothesis recently revived by John Martin. He has calculated that annual iron fertilization of the Southern Ocean could result in significant increases in new production and carbon export. Sarmiento calculated that complete NO_3 drawdown could possibly decrease the current rate of atmospheric CO_2 accumulation by about 50% but noted that fossil fuel additions are still expected to rise into the next century.

The workshop concluded with the finding that "it is conceptually feasible to slow the increase in atmospheric CO_2 levels through enhanced new primary production in the oceans ..." and recommended a pilot study to explore further the technical and scientific feasibility of iron fertilization to enhance the sequestration of carbon dioxide via the biological pump. Such a study is described in the forthcoming U.S. JGOFS Long-Range Plan.

SCOR – (Cont. from page 7)

strated in the 1989 North Atlantic Bloom Experiment. He added, however, that this study arose in part from the "fortuitous convergence" of national plans for work in the North Atlantic that predated the organization of JGOFS.

"The development of plans for further field components of JGOFS require that SCOR and its Committee for JGOFS develop a mechanism for the provision and coordination of the national resources necessary for undertaking such a major international experiment. At present no organizal structure exists for discussion of these concerns," he pointed out.

"The aim is to bring the scientists together with the government people to talk about what we are going to need and how to develop a structure so that countries can contribute resources," JGOFS executive secretary Elizabeth Tidmarsh said. "We need to talk about the schedules for the process studies or the data centers with those able to provide the wherewithall.

"We already have interagency coordination at the national level, and we need it at the international level," she added.

Robert Corell of the U.S. National Science Foundation will serve as chairman for the meeting, to be held at the headquarters of the International Council of Scientific Unions (ICSU) in Paris, May 22-23. The meeting is designed to provide agency representatives with information on JGOFS needs as well as agreement on a mechanism for coordinating resources.

Bloom Symposium Planned

An international conference on the JGOFS North Atlantic Bloom Experiment will be held Nov. 26 to 28 at the National Academy of Sciences in Washington, D.C. More information will be forthcoming as the planning for the symposium proceeds.

U.S. JGOFS Projects And Investigators: A Partial List

Abstracts for all projects funded as part of the U.S. Joint Global Ocean Flux Study are on file and available from the U.S. JGOFS Planning Office, Woods Hole Oceanographic Institution, Woods Hole, MA, 02543. Some of the current proposals, principal investigators and their institutions are listed below. The June newsletter will contain the rest of them.

U.S JGOFS Planning Office

"Planning the Global Ocean Flux Program," Peter Brewer, Woods Hole Oceanographic Institution.

Long Lead Time

"Photosynthesis and Calcification by Blooms of the Coccolithophore *Emiliana huxleyi* in the Gulf of Maine," William Balch, University of Miami; Patrick Holligan, Bigelow Laboratory for Ocean Sciences;

"Data Management for the Global Ocean Flux Study," James Bishop, Lamont-Doherty Geological Observatory; Glenn Flierl, Massachusetts Institute of Technology; David Glover, WHOI;

"Surface Ocean Oxygen Fluxes," Steven Emerson and Paul Quay, University of Washington;

"The Hydromechanics of Sediment Traps in the Oceanic Environment: Key to Accurate Particle Flux Measurements," Giselher Gust, Peter Betzer and Robert Byrne, University of South Florida Marine Sciences Institute;

"A High Resolution Time-Series Particle Interceptor Trap," George Knauer and Vernon Asper, University of Southern Mississippi;

"Ocean-Basin Scale Modeling of Plankton Dynamics in the North Atlantic and Eastern North Pacific," Joseph Wroblewski, Memorial University of Newfoundland;

North Atlantic Bloom Study

"Reactive Radionuclides in the Eastern North Atlantic, Joint Global Ocean Flux Study," Michael Bacon, Ken Buesseler and Hugh Livingston, WHOI; J. Kirk Cochran, State University of New York at Stonybrook;

"The Oxygen Balance during the Spring Bloom in the North Atlantic Ocean," Michael Bender, University of Rhode Island;

"Quality Assurance Procedures for the Analysis of Photosynthetic Pigments," Robert Bidigare and Mahlon Kennicutt, Texas A&M University;

"Carbon Dioxide Measurements on the Global Ocean Flux Pilot Study," Peter Brewer, WHOI;

"RUI: 20 West: The Northeast Atlantic Spring Bloom Experiment Bio-Optical Profiling," William Broenkow, Moss Landing Marine Laboratories;

"Biogenic Particles, Microbial Production and DOM Dynamics in the North Atlantic Spring Bloom," Hugh Ducklow, Horn Point Environmental Laboratories, University of Maryland;

"Fluxes of Dissolved Inorganic Nitrogen (DIN) and Dissolved Organic Matter (DOM) during the Spring Bloom in the Temperate North Atlantic Ocean: Magnitude and Control Mechanisms," Christopher Garside, Bigelow Laboratory for Ocean Sciences;

"Bottom Tethered Sediment Trap Array Experiment, GOFS Level 1," Susumu Honjo, WHOI;

"Primary Production Measurements for the 20-West Program," John Marra and Christopher Langdon, Lamont-Doherty;

"REU: GOFS North Atlantic Bloom: Level 1 DOC/DON, POC/PON Studies," John Martin, Moss Landing;

"Development of a Shipboard Digital (CCD) Image Acquisition System for Characterizing Pico- and Nanoplankton Populations by Fluorescence Microscopy," Michael Sieracki, Virginia Institute of Marine Sciences;

"CTD/Hydrographic Support for the GOFS North Atlantic Spring Bloom Experiment," James Swift, Scripps Institution of Oceanography;

"Investigation of the CO_2 System during the 1989 GOFS Expedition in the North Atlantic," Taro Takahashi, Lamont-Doherty;

"The Impact of Protozoan Zooplankton on the Structure, Composition and Fate of the North Atlantic Spring Bloom," Peter Verity, Skidaway Institute of Oceanography; Michael Sieraki, VIMS, and Diane Stoecker, WHOI.

Liaison – (Cont. from page 3)

located in the same building at Woods Hole Oceanographic Institution as the U.S. JGOFS Planning Office. The proximity of the two offices facilitates communication on JGOFS participation on WHP Global Survey cruises and on long-term ship scheduling.

JGOFS planning office executive scientist Hugh Livingston will also be providing liaison with the U.S.WOCE Office in College Station, Texas. This office has overall responsibility for U.S. participation in the WOCE program, including coordination with U.S . JGOFS, and for international coordination of U.S. WOCE components.

Under the sponsorship of the National Science Foundation, a series of formal meetings on U.S. JGOFS/ WOCE interactions began with a session at The Oceanography Society meeting in Monterey last August. The next meeting was held in Washington, D.C., on April 2.

Topics discussed included JGOFS participation in WHP cruises, data management, modeling, carbon-14 analyses at the Accelerator Mass Spectrometer facility at Woods Hole and interprogram planning.

U.S. JGOFS News

A Publication of the U.S. JGOFS 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). It is published quarterly on behalf of the U.S. Steering Committee for JGOFS. We welcome your comments and contributions for publication.

To obtain a free subscription, write to:

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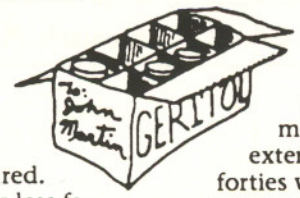
Iron Age – (cont. from page 5)

delight, Hardy mentions Fe on page 489. "The greater richness of the neritic areas remains inexplicable unless we assume that minute quantities of ... iron ... derived from the land, exert a strongly favorable influence on diatom growth."

About 10 years before I was born, these scientists were already talking about Fe deficency limiting phytoplankton growth in the Antarctic.

Another avenue led to Baron Justin von Liebig's law of the minimum. The father of modern organic chemistry and agricultural chemistry as well, von Liebig was the first to realize that the growth of a plant would stop when its minimum requirement for an essential element or compound was not met.

Iron in the oceans appears to offer an example of his law. In agricultural terms, it looks as though the addition of about a half an ounce of Fe per acre might produce a Southern Ocean phytoplankton bloom. A few back-of-the-envelope calculations suggest that massive fertilization of the ocean is feasible since so little Fe is required.



I first said this more or less facetiously at a Journal Club lecture at Woods Hole Oceanographic Institution in July 1988. I estimated that, with 300,000 tons of Fe, the Southern Ocean phytoplankton could bloom and remove two billion tons of carbon dioxide.

Putting on my best Dr. Strangelove accent, I suggested that with half a ship load of Fe (our largest ships, ultra-large crude carriers, have a capacity of 550,000 tons) I could give you an ice age. After which we all had beer on the lawn outside Redfield Laboratory.

In the spring of 1989, however, people began to take this idea seriously. Can the Southern Ocean be fertilized with Fe to stimulate the active removal of CO_2 from the atmosphere? The question has divided those interested into three camps with three points of view.

1. The whole business about Fe is nonsense and should be forgotten (this is from my closest friends and colleagues).

2. Fe fertilization is our salvation; it will enable us to remove CO_2 from the atmosphere and lessen global warming (not to mention all the extra krill and whales we can produce).

3. This is a typical American quick fix. Instead of taking the hard road of reducing CO_2 emissions, we will scatter some Fe around and in the process ruin the Antarctic environment.

Meanwhile a FAX is rolling in from R/V *Polar Duke* in the Ross Sea. Steve Fitzwater and Mike Gordon, highly skilled MLML analysts who are able to collect water without adding extraneous Fe, report the results of an experiment at 72°30'S, performed under ambient light (Jan. 26 to Feb 6) and temperature conditions (O°C).

"John," the message began, "the addition of minute amounts of Fe caused the phytoplankton to take up five times more nitrate than did the phytoplankton in the controls without Fe. What was the score of the superbowl?"

Another step has been taken towards proving the case for iron. But this is just the southern edge of a 2,000-mile-wide band of major nutrient-rich water that extends north to the roaring forties with their 70-knot winds and 40-foot seas.

So there I was having fun with a "Geritol fix for the ocean," answering letters from Dennis Leblanc (Approvisionnement de Navires) of Sept-Iles, Quebec.

"Dear Dennis: I am glad you have 300,000 tons of high-grade (66%) Fe ore and a ship. I can't tell you where to deliver it yet, but stay in touch ... when people start yelling at me about rabbits in Australia, mongooses in Hawaii, sparrows in New York, drug bugs in Colombia, Ice 9 and other great man-induced ecological disasters."

Whether similar Fe fears are real or false is open to debate. The ferruginous feline (sorry) is out of the bag, for better or worse (see Hugh Ducklow's article in this issue). What to do?

We can ignore it, like most of my colleagues, and hope that it all goes away. Nevertheless, Fe research will go forward, if not with oceanographers, then with atmospheric chemists, cellular physiologists and chemical engineers. The biggest danger, in my view, is that large-scale iron fertilization will occur without the necessary understanding of just what will happen on scales ranging from single cells to ecosystems.

It isn't too hard to imagine another hot summer. People are rioting in New York; the smog level is down to one foot in L.A.; the corn is wilting in Iowa. In answer to the cries of "Do something about the greenhouse!" someone suggests spraying some Fe around in the Antarctic.

And as the planes took off, circled the field and headed south, someone was heard to say...

Regardless of what we think about iron and its potential for good or evil, we have to learn more about what it does on the cellular level. And we have to have a good idea about what will happen to entire ecosystems if massive fertilization is attempted.

We can learn much from experiments on the appropriate scale, tens to hundreds of kilometers, in which conditions are carefully managed and controlled. We can find out which species will thrive at the expense of which others and decide whether the effects are good, bad or indifferent. The collective talents of the JGOFS community could make a real contribution to this task.

It Must Be Right; It's In The Encyclopedia

You can look JGOFS up in the Encyclopedia Brittanica as of 1990.

D. James Baker of the Joint Oceanographic Institutions, Inc., has included a description of the North Atlantic Bloom Experiment, JGOFS's first major field study, in his article "Oceanography 1989,"a review of events, issues and findings in the field for the Encyclopedia Brittanica Yearbook.

The article notes that "the bloom experiment was planned as a pilot study for a decade-long international investigation aimed at understanding the links between biogeochemical cycles in the ocean and global climate change. It represents the first large-scale exploration of the spring phytoplankton bloom, an annual event hypothesized to affect the cycling of carbon dioxide between the atmosphere and the ocean.

"The event, analogous to the springtime greening of the land surface, has been estimated to account for up to half of the annual transport of oceanic carbon into the deep water by biological processes."

• U.S. JGOFS Calendar 1990 •

17-20 April: JGOFS Pacific Planning Workshop, Tokyo, Japan. Contact: M. Leinen, University of Rhode Island, Kingston, RI.

8-11 May: WOCE Scientific Steering Group, Washington, DC. Contact: P. Koltermann, WOCE.IPO, IOS, Wormley, U.K.

15-17 May: U.S. JGOFS Steering Committee meeting, Bermuda Biological Station for Research, Bermuda. Contact: H. Livingston, Woods Hole Oceanographic Institution, Woods Hole, MA.

21-25 May: "Oceanography from Space 1990," Venice, Italy. Contact: J. Gower, IOS, Sydney, B.C., Canada.

22-23 May: JGOFS Resource Coordination Meeting, ICSU Headquarters, Paris, France. Contact: E. Tidmarsh, Dalhousie University, Halifax, N.S., Canada.

3-6 July: SCOR-SCAR, "Biogeochemistry and the Circulation of Water Masses in the Southern Ocean," Brest, France. Contact: P. Treguer , Université Bretagne Occid., Brest.

3-7 September: IGBP Scientific Advisory Panel, Paris. Contact: IGBP Secretariat, Stockholm, Sweden.

5-7 September: Equatorial Pacific Modeling Workshop, Princeton, NJ. Contact: R. Toggweiler, GFDL, Princeton.

2-4 October: SCOR General Meeting, Rostock, G.D.R. Contact: E.Tidmarsh, Dalhousie University, Halifax, N.S., Canada.

26-28 November: International Scientific Conference on the JGOFS North Atlantic Bloom Experiment, Washington, DC. Contact: E. Tidmarsh, Dalhousie University, Halifax, N.S., Canada.

29 November: JGOFS Executive Meeting, Washington, DC. Contact: E. Tidmarsh, Dalhousie University, Halifax, N.S., Canada.

The Biogeochemical Ocean Flux Study (BOFS), the United Kingdom's JGOFS program, publishes a newsletter titled "BOFS News and Views." Those interested in receiving this publication should contact: Carol Turley, Editor, Plymouth Marine Laboratory, Citadel Hill, Plymouth, PL1 2PB.

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