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Interannual, Seasonal, and Event-Scale Variability in the Ross Sea

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The ocean experiences variations at multiple time scales, and each of these variations impacts local and regional biogeochemical cycles. Comparisons among different regions have shown that different processes operate in each region, and that the relative importance of the various processes varies markedly. Comparisons of systems from the Southern Ocean have been difficult, given the relative paucity of data on short, meso-, and large time scales. However, there are currently programs designed to collect data on some of these scales. For example, the Palmer Long-Term Ecological Research (LTER) program conducts surveys each austral summer over a specified grid in the West Antarctic Peninsula region to assess long-term changes in local ecology as it relates to changing ice dynamics. Another program, AMLR (Antarctic Marine Living Resources program), is a series of annual cruises conducted by NOAA in the South Shetlands region, in which directed research is conducted to support the conservation objectives of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR) Treaty. Far fewer studies have focused on the short-term biogeochemical variations, and few programs have addressed the full annual cycle of events within a single region. Hence, the scales of variability and their associated biogeochemical impacts remain largely unknown.

The Ross Sea is a highly productive region that has been a focus of biogeochemical research for a number of decades. Although a modeling study suggests that it is responsible for nearly 30% of the total carbon dioxide uptake in the entire Southern Ocean, few data exist to validate this finding. The Ross Sea was the site of numerous large field efforts in the 1990s, including the U.S. Joint Global Ocean Flux Study (JGOFS; www.jgofs.whoi.edu) and ROAVERRS (Research on Ocean-Atmosphere Variability on Ecosystem Response in the Ross Sea), which assessed seasonal biogeochemical variability. These programs spurred interest in the interannual variability of the region, as ice concentrations were known to vary significantly from year to year. One program that was developed to address this longer-term variability was IVARS (Interannual VAriations in the Ross Sea). Since a major objective of IVARS was to place interannual biogeochemical variability within a seasonal context, a field program was conducted for five consecutive years in the southern Ross

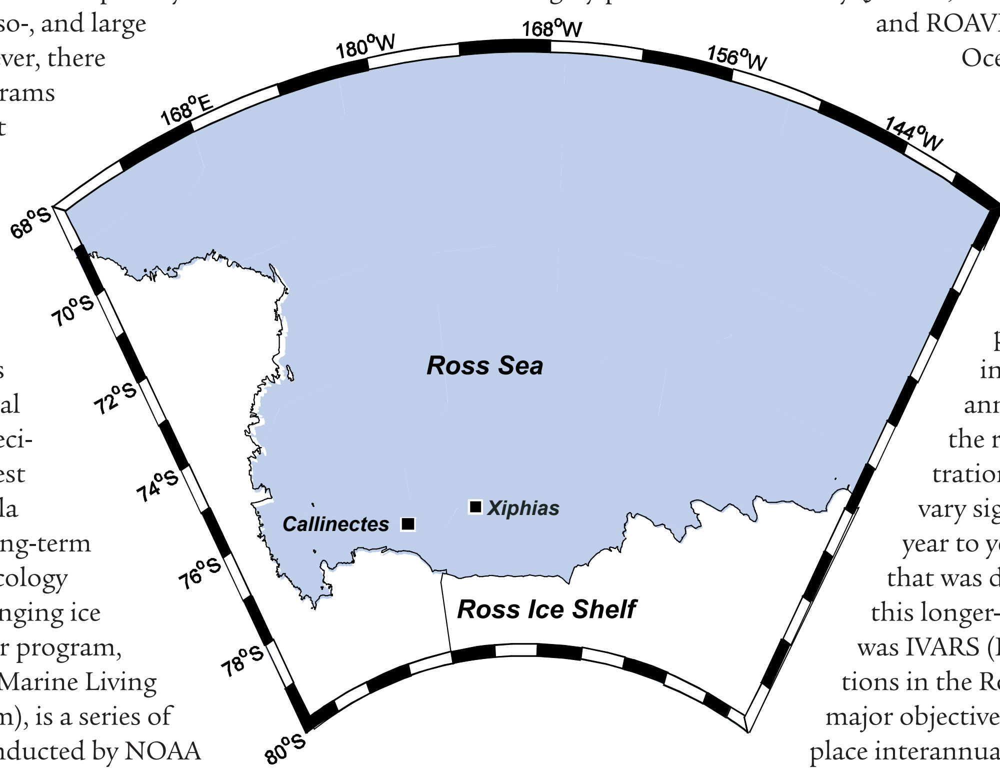


Figure 1. Locations of the two moorings, Callinectes and Xiphias, in the southern Ross Sea.

Sea (2001/2-2005/6). The program included the collection of discrete samples in late December and early February, as well as the deployment of two moorings (Callinectes and Xiphias; Fig. 1). The mooring sites (~600 m water depth) were selected based on historical surveys of the region, from which we expected the western site to be dominated by *P. antarctica*, a polymorphic haptophyte, and the eastern site by diatoms. The moorings were bottom-moored, but also had a surface buoy to which numerous sensors and devices (CTDs, current meters, fluorometers, sediment traps) were attached to monitor conditions within the euphotic zone. The objectives of these surface measurements were to quantify the short-term variations in surface layer properties and to gain insights into the causal mechanisms for these changes. Unfortunately, the moorings were lost during the second year due to exceptionally high ice concentrations, so we focused our analyses on the final three field years.

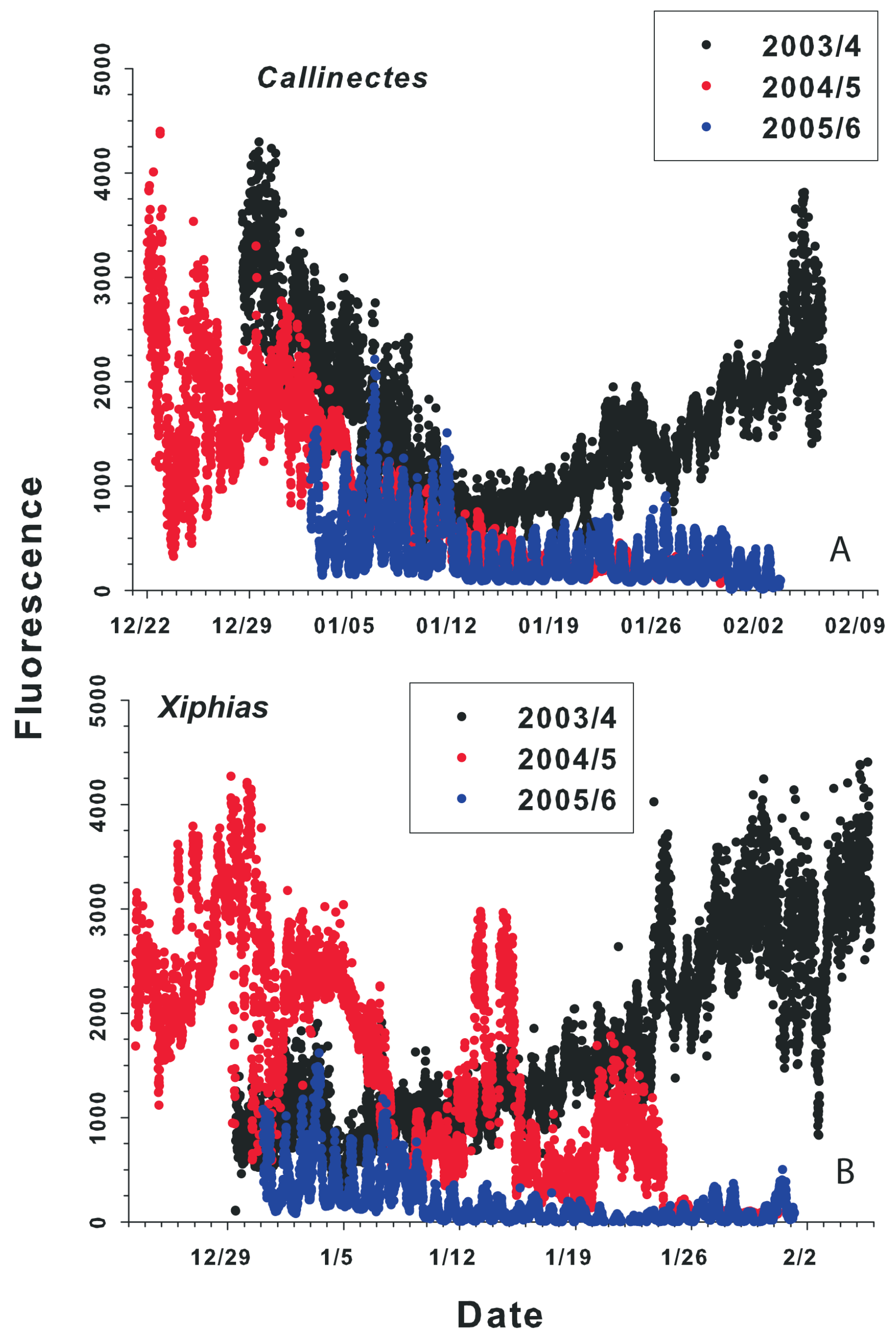


Figure 2. Interannual variations in fluorescence at the two mooring sites in the Ross Sea. 2003/4 was characterized by a substantial secondary bloom, whereas 2004/5 had a unimodal peak punctuated by intermittent events. 2005/6 had extremely low surface biomass. Variations between the two sites were also observed.

Interannual variations in Ross Sea ice concentration, phytoplankton biomass, and productivity are well established, but the magnitude, significance, and causes of such variability remain unclear. At both sites, we observed substantial interannual *in situ* fluorescence variability (Fig. 2) that rivaled previously observed seasonal variability. Furthermore, despite the close proximity of the two sites (~200 km), we observed significant spatial variability. During the austral summer of 2003/4, fluorescence from the shallowest depth at Callinectes peaked upon deployment, decreased through mid-January, and then increased dramatically until recovery (Fig. 2a). In 2004/5, fluorescence was also high upon deployment, decreased in a manner similar to 2003/4, but did not increase in the summer. In 2005/6, the fluorescence was initially low, and remained low throughout the entire season. During this season, we also observed large diel variations, both at the surface and throughout the water column. In 2003/4, in contrast with Callinectes, Xiphias fluorescence was initially low, but increased substantially through mid-February (Fig. 2b), demonstrating not only strong temporal variability, but significant spatial variability as well. In 2004/5, the temporal pattern was similar to that at Callinectes, with higher amplitude variability at Xiphias. In 2005/6, the temporal fluorescence pattern was again similar between Callinectes and Xiphias (Fig. 2), low throughout the season with marked diel variations.

These observations reveal significant interannual variability in the Ross Sea that rivals seasonal variability, which has long been considered the dominant scale of variability in this region. The observed interannual variability suggests a substantial variation in the forcing of phytoplankton growth and accumulation. Since the majority of recent studies have shown that iron concentrations limit summer growth and photosynthesis, the observed interannual variations imply differential rates of iron inputs. Potential iron sources for this region include aerosols, ice melt, lateral inputs, and advective inputs from below. Aeolian deposition is generally low throughout the Southern Ocean, and while there is a potential for input from nearby Mt. Erebus, the patterns we observed do not appear to be linked to releases from the continent's only active volcano. The two locations were ice-free upon deployment, and would be largely uninfluenced by ice melt during January and February, the periods of maximum interannual variability. Lateral inputs, including those from glacial melt, are somewhat difficult to assess, given the lack of current data for the two sites. However, numerical simulations suggest that lateral inputs are generally small relative to the scales of phytoplankton biomass changes. The last possible driving mechanism, advective input of iron from below, was previously implicated based on hydrographic distributions of water masses. However, there has been no confirmation of the mechanism by which this water penetrates the summer stratification and reaches the surface. It is possible that mesoscale processes result in a significant input of iron to the euphotic zone (in

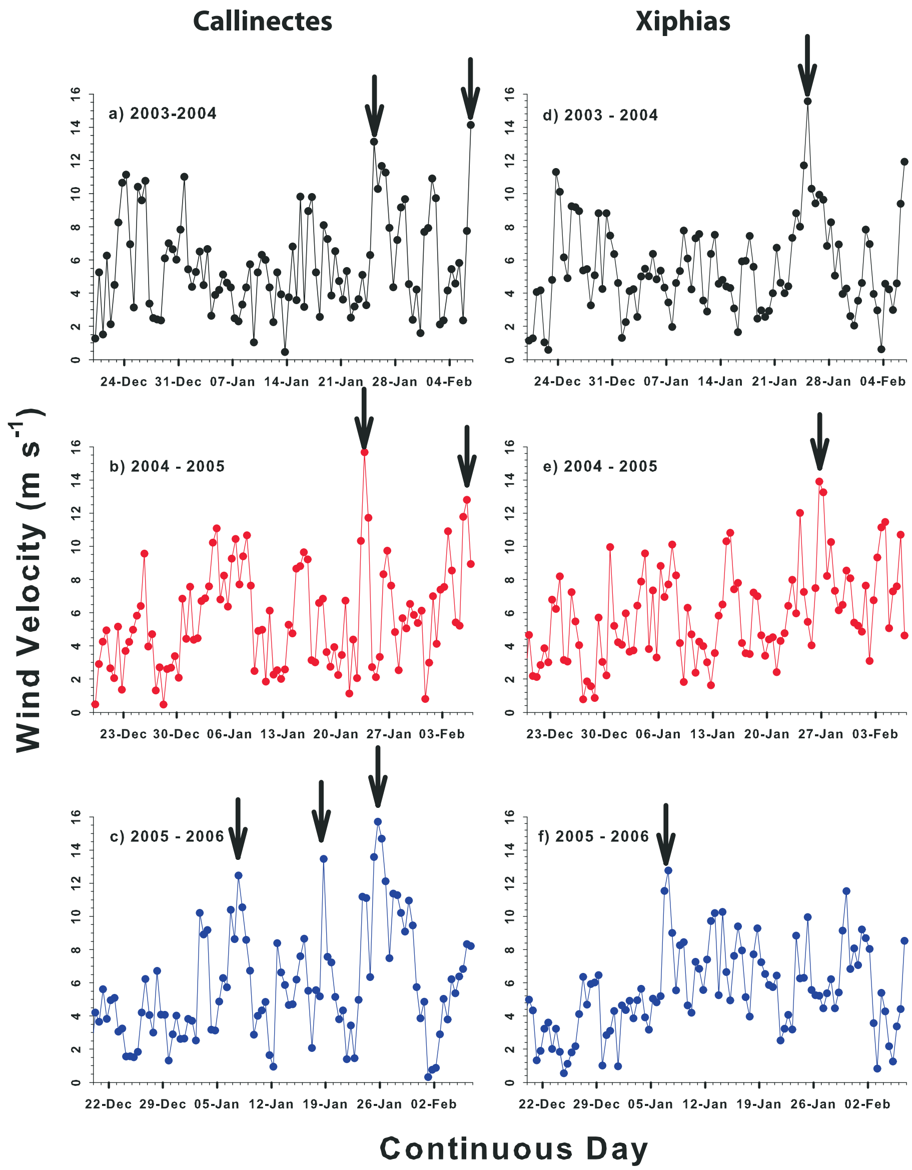


Figure 3. Wind velocities at the two sites. During summer extreme (> 12 m s^{-1}) wind events are uncommon, with 10 being observed in three years. Variations between the two sites were also noted.

a manner similar to that found in the Sargasso Sea for nitrogen), but direct confirmation of that is lacking.

An unexpected feature of our observations was the relatively strong, seemingly stochastic variability that occurred within each season. Examples of such variability include increases observed around 01/01/2005 at Callinectes, and around 01/03/2005 and 01/14/2005 at Xiphias (Fig. 2, red). All of these events resulted in at least a doubling of fluorescence over a very short period of time. These may have been advective events, but the rate of change (an approximate doubling over at least four days, equivalent to a growth rate of ~0.2/day) suggests that these were the result of growth and accumulation within the euphotic zone. Therefore, we hypothesized that the fluorescence peaks represented a response to increased storm-induced vertical mixing. Conversely, periods

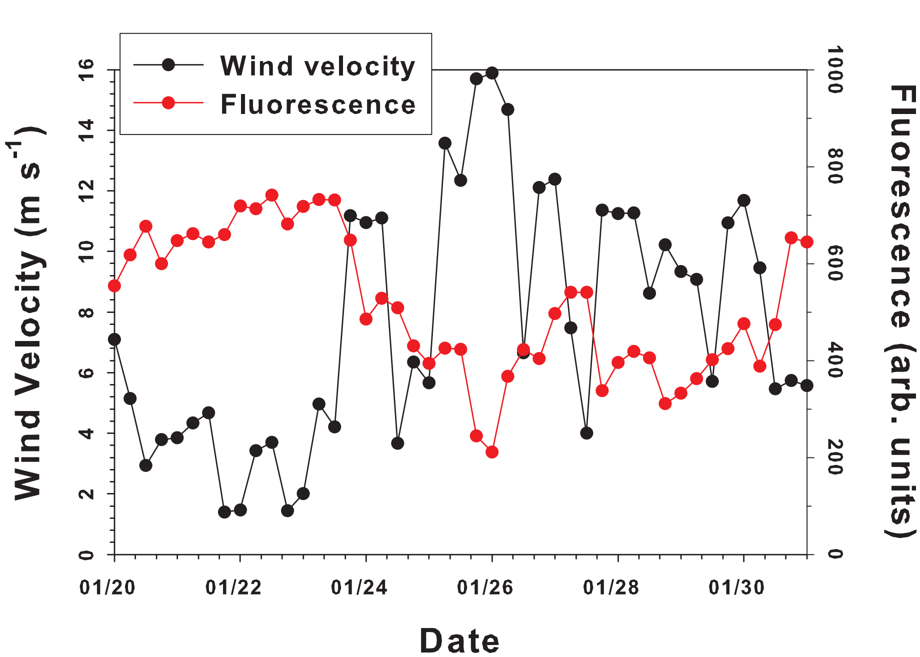


Figure 4. Relationship between wind velocity and fluorescence at Callinectes in January 2006. The rapid increase in wind energy at the surface was tightly coupled to a decrease in fluorescence, which resulted from the mixing of surface and deeper (lower biomass) waters. The reduction in winds allowed for the resumption of rapid growth in the surface layer.

during which there were marked decreases in fluorescence represented a redistribution of biomass over a greater depth.

To test this hypothesis, we compiled wind data (north and east vectors of the wind fields; 4 times daily) from NSCAT and ERS-2 scatterometer and NCEP reanalysis products (http://podaac.jpl.nasa.gov/DATA_CATALOG/quikscat.html) at locations nearest the mooring sites. Major events (winds > 12 m s^{-1}) were identified and the timing of those events assessed relative to the event-scale decreases (we used decreases, as those would more accurately reflect the physical-biological coupling). For the three years and two sites, there were 10 "significant" wind events (Fig. 3), and for each one there was a large decrease in fluorescence that appeared to be coupled to dilution of the surface layer with low-biomass waters from below. During the time period from January 20-31, 2006, the fluorescence was relatively invariant until January 24, when the winds increased to >11 m s^{-1}. Coincident with this increase, fluorescence at 26 m decreased by >30% (Fig. 4). The decrease occurred at nearly the same time as the winds increased, suggesting at least in this case a tight coupling between winds, vertical mixing and phytoplankton redistribution. Winds decreased substantially for 18 h, but then increased again to nearly 16 m s^{-1}. Fluorescence continued to decrease, and ultimately was reduced to 30% of the pre-event levels. Winds remained quite high for the remainder of the deployment, but at the end of our record they decreased to ~6 m s^{-1}, which was coincident with a return to pre-event fluorescence levels (Fig. 4).

The IVARS fluorometers were not placed within the water column to assess the coupling between winds and phytoplankton redistribution during mixing events, but it does appear that the placement of surface instrumentation can adequately quantify the effects of short-term mixing events. Other studies and models have suggested that storm activity plays an important role in phytoplankton vertical redistribution, nutrient inputs, and export flux. We hope to be able to resolve the effects of such events on export in the near future.

In summary, although the seasonal time scales have long been considered to be the most important with regard to phytoplankton growth, biomass accumulation, and particulate export, IVARS has shown that variability on other time scales can be equally important. Interannual variations, both in terms of quantity (*e.g.*, biomass and productivity) and quality (*e.g.*, assemblage composition), are extremely important, and at present, poorly addressed in numerical models of the Southern Ocean. Most importantly, such variations will have an impact on biogeochemical cycles of the region, and exert strong controls over the vertical flux of organic matter in continental shelf regions. Short-term, event-scale variations can also be significant, not only in redistributing organic matter within the water column and enhancing phytoplankton growth, but in altering the temporal patterns of organic flux to depth. Given that the Ross Sea may account for nearly 30% of the total Southern Ocean carbon sink, understanding the mechanisms, frequency, and controls of the elemental dynamics is essential to understanding the biogeochemistry of the entire region.

center for microbial oceanography: research and education
C-MORE linking genomes to biomes

C-MORE Science Kits

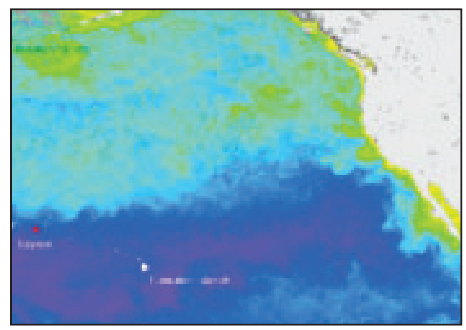
by Kimberley Weersing and Kate Achilles

Need to teach your students about coral reefs but you don't know where to start? Need a lesson on ocean acidification but you aren't familiar with the subject? Let C-MORE do the work! C-MORE has created a set of exciting, portable science kits, each of which provides complete information and supplies necessary for educators to teach their students about a particular topic in ocean science. These easy-to-use Kits are a great resource for any science classroom and are designed for use with a range of grade levels.

Ocean Acidification Kit

Science Kit topics include:

- Ocean Acidification (Grades 6–12): a technology-based exploration of the effects of CO_2 on the marine environment
- Marine Debris (Grades 8–12): a comprehensive scientific and social investigation of plastic marine debris
- Random Sampling (Grades 6–12): an introduction to the statistical analysis of microbial diversity
- Nautical Knots and Maritime Careers (Grades 3–8): practical skills in knot-tying and exposure to career pathways
- Marine Mystery (Grades 3–8): a murder mystery skit about coral reef destruction and DNA testing
- Plankton Lab (Grades 3–12): a kaleidoscope of microscopy and plankton ecology activities

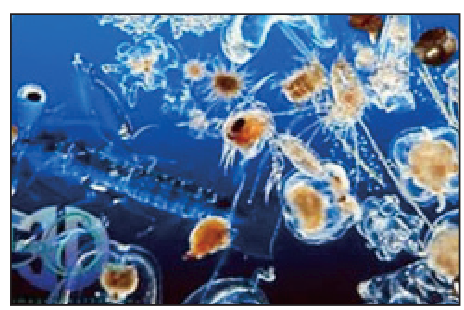


Ocean Color Kit

C-MORE Science Kits were first shared with teachers in July 2008 and they have uniformly received positive acclaim since then:

"These kits have certainly made life teaching environmental science easier."
– D. Weidman, St. Francis School

"[The C-MORE Ocean Acidification Science Kit] was a dream come true for a science teacher."
– B. Bevacqua, Kalaheo High School



Plankton ID Kit

Use of the Science Kits require no previous training, and best of all, they are available for public school teachers to use free of charge*! All kits are available at the University of Hawaii. Select kits are available at Woods Hole Oceanographic Institution, Oregon State University and Monterey Bay Aquarium Research Institute. Please visit our Science Kit website to check for availability in your area.
http://cmore.soest.hawaii.edu/education/teachers/science_kits.htm
Or contact: kits@soest.hawaii.edu

*At this time, delivery is not available; kits must be picked up in person.

Micronutrient-ecosystem interactions in the oceans: Current research and new opportunities

Kathy Barbeau, Robert Anderson, Mak Saito

Micronutrients are defined as elements essential to life, needed in miniscule quantities. Examples of such elements include trace metals like iron (Fe), manganese (Mn), zinc (Zn), cobalt (Co), copper (Cu), and Nickel (Ni). The oceans represent a unique environment in terms of micronutrients, for these elements are not only required for metabolism by marine microorganisms in very small amounts, but (for the most part) they are also present in the surface oceans in vanishingly small abundance - picomolar (10^{-12} mol) to nanomolar (10^{-9} mol) concentrations. The study of how marine phytoplankton and bacteria cope with this extreme scarcity to obtain the cofactors they need to maintain crucial enzymatic functions lies at the heart of the emerging field of marine bioinorganic chemistry. Marine bioinorganic chemistry also encompasses the connections that exist between the micronutrients and the cycles of carbon (C), nitrogen (N), phosphorus (P), and silicon (Si) in the oceans. The interlocking nature of these "elemental connections" means that the micronutrients have an influence on marine ecosystems disproportionate to their abundance in seawater (1).

Advances in the study of micronutrient-ecosystem interactions in the oceans have historically been tied to technological improvements in the sampling and chemical analysis of trace elements in seawater. The advent of trace metal clean techniques revealed for the first time "oceanographically consistent" profiles of trace metals like Fe, Zn, Cd, and Ni, mirroring the smooth "nutrient-type" distributions of N, P, and Si. Thus the involvement of trace metals in the surface uptake and deep regeneration cycles of marine biota was made apparent, along with the potential for metals to act as limiting factors for biological production. Due to subsequent studies of the importance of Fe as a limiting micronutrient, Fe supply is now thought to have a significant influence on ecosystem structure in many areas of the ocean. Interest in the availability of Fe and other bioactive trace metals to marine biota has been spurred by the development of sensitive electrochemical methodologies for the analysis of metal species in seawater. These techniques have demonstrated the importance of organic complexation in the dissolved chemistry of several metals, including Fe, Zn, and Cu. Colloidal forms and redox intermediates also play a significant role in the internal oceanic cycling and bioavailability of some metals such as Fe. Recent reviews of these topics are available (2,3), and considerable research effort is currently being directed at elucidating the complexity of the chemical speciation of trace metals in seawater and understanding how chemical speciation relates to the metal uptake capabilities of marine microorganisms.

The far-reaching effects of micronutrients on ecosystem structure in the oceans are mediated by biochemical relationships that exist between the trace metal micronutrients and other biologically significant elements or limiting factors. The extensive use of Fe in photosynthetic proteins, for example, creates a connection between photosynthetic needs and cellular Fe quotas in phytoplankton such that Fe requirements increase at low light levels. The numerous biological transformations of the nitrogen cycle are mediated by metalloenzymes – among others nitrogen fixation via nitrogenase (containing Fe and Molybdenum (Mo) cofactors), and nitrate uptake via nitrate reductase (also containing Fe and Mo). Uptake of P from dissolved organic forms is facilitated by the Zn-containing enzyme alkaline phosphatase. Inorganic carbon acquisition in marine phytoplankton requires the Zn-containing enzyme carbonic anhydrase. Carbonic anhydrase is one example of several enzymes studied in marine phytoplankton that can substitute different metals in the active site (in this case Zn, Co, or Cd) and phytoplankton have also been shown to have multiple forms of enzymes that perform the same function, but with different metal centers. These and other micronutrient relationships (1) can potentially result in the colimitation of marine primary production by several factors simultaneously (4).

The theoretical basis of micronutrient colimitation in marine ecosystems is well understood based on biochemical and ecological principles, and colimitation has been demonstrated in various laboratory studies with phytoplankton. Documenting the effects of colimitation and related linkages between biogeochemical cycles in oceanographic field settings, however, remains difficult. Delineating the intricate and sometimes subtle relationships that exist between colimiting factors and ecosystem structure in the field will require an integrated observational approach that combines multiple tools, including incubation techniques, sensitive measurements of multiple chemical parameters, and cellular-level diagnostics. Recent field studies indicate that there are great possibilities for progress in this area. Jakuba et al. (5) studied the relationship between Co, Zn, and P in surface waters of the western North Atlantic, documenting strong depletion in the concentration of both metals in the southern Sargasso Sea, coincident with extremely low dissolved inorganic P and increased activity of alkaline phosphatase, the metalloenzyme involved in the cleavage of phosphate monoesters to facilitate P acquisition from the dissolved organic P pool. In the subarctic Northeast Pacific, Semeniuk et al. (6) used the short-lived radioisotope ^{67}Cu to examine the relationship between phytoplankton Fe limitation status and Cu requirements on a transect along Line P from Fe-rich coastal waters out to Fe-limited Ocean Station PAPA. Results indicate that Fe limitation may modulate the Cu demands of some component of the natural phytoplankton community in the >20-µm size class, presumably due to the use of Cu in the multi-Cu-containing oxidases that are part of the high-affinity Fe transport system in some phytoplankton. In stratified regions of the eastern North Pacific, Hopkinson and Barbeau (7) employed a matrix of microcosm manipulation experiments to document the effects of Fe-light colimitation on phytoplankton communities at the subsurface chlorophyll maximum, below surface waters more commonly characterized as macronutrient-limited.

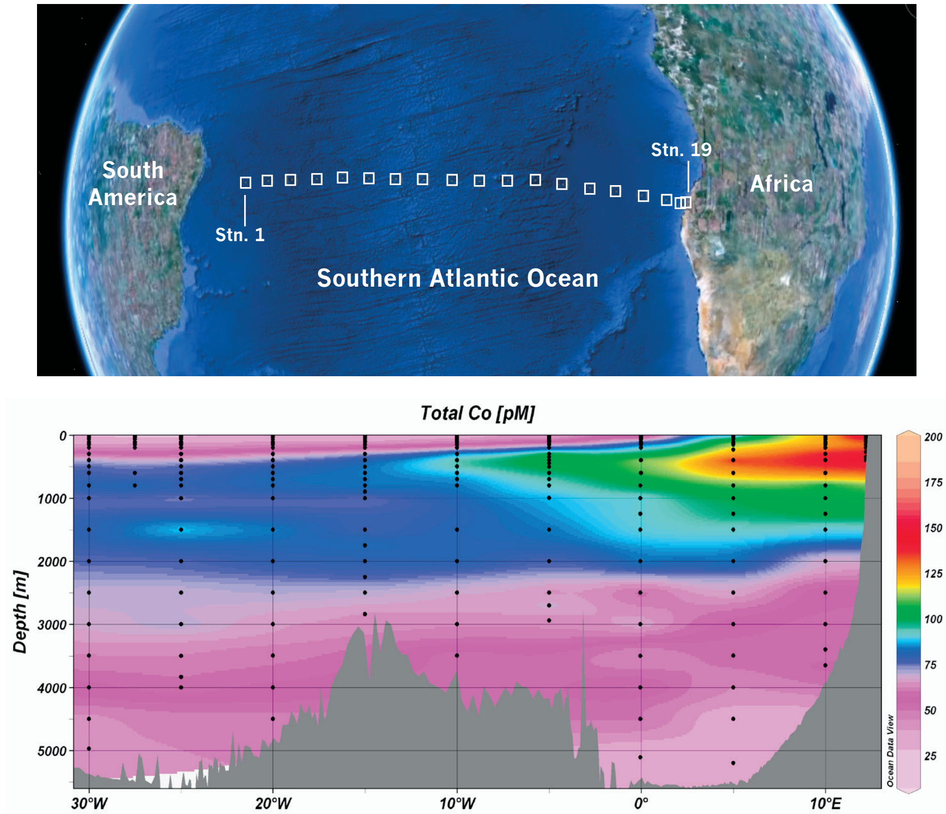


Figure 1. Top panel: Cruise track from the CoFeMUG South Atlantic cruise in November 2007 (Chief Scientist: Mak Saito). The main zonal section was sampled to full-depth for bioactive trace metals and nutrients.
Bottom panel: Co section along the cruise track. Note the surface depletion across much of the basin and the large Co plume from the Benguelan Upwelling system in the eastern boundary. The Co section was produced by Abigail Noble, a graduate student in Saito's laboratory (manuscript in preparation).

As individual field programs demonstrate success, it becomes feasible to consider more extensive studies of the sensitivity of marine ecosystems to variability in the concentration and speciation of micronutrients, together with the consequences for the marine biogeochemical cycles of carbon and major nutrients. Related processes affecting micronutrients and in need of expanded field investigation include active uptake by cells, complexation by organic chelators, and adsorption to particle surfaces. The complex interplay between micronutrients, macronutrients, and marine ecosystems is ripe for large-scale exploration, but the task is challenging. Fortunately, a number of international programs with relevant interests and necessary expertise have already been established, including GEOTRACES, SOLAS, and IMBER. Each program contributes expertise to cover essential components of a global study of micronutrient - ecosystem interactions. GEOTRACES will establish global distributions of micronutrients and quantify their principal sources and sinks. SOLAS will examine the response of organisms in the surface ocean to changing environmental conditions, including micronutrient supply, as well as the impact of these changes on marine biogeochemical cycles. IMBER holds overlapping interests with SOLAS concerning marine biogeochemical cycles, but also brings critical expertise in end-to-end marine ecosystems. Working together, these programs can tease apart the key factors linking micronutrients, ecosystems, and the ocean carbon cycle.

The first ocean section of the U.S. GEOTRACES program is currently in the planning stage for 2010. Already, however, a recent cruise has realized the benefits of combining a GEOTRACES-caliber data set on micronutrient distributions with a process-oriented approach to studying micronutrient-ecosystem interactions. In November 2007, Mak Saito of the Woods Hole Oceanographic Institution (WHOI) led a research

Cont. on page 10

Exploring the feasibility of an *in situ* mesoscale carbon addition experiment

by Veronica Lance, Lamont-Doherty Earth Observatory

To understand the impact of increased atmospheric CO_2 on ocean ecosystems and biogeochemistry, it is desirable to mimic expected future conditions in a natural environment. A workshop to explore an *in situ* open ocean mesoscale CO_2 perturbation experiment that would simulate the oceanic conditions expected towards the end of this century was held at Lamont-Doherty Earth Observatory (LDEO) at Columbia University March 23-24, 2009 in Palisades, New York, USA. The objective was to evaluate the current understanding of the potential effects of carbon chemistry and pH changes in response to increased atmospheric pCO_2 on open ocean ecosystems and biogeochemical cycling and to examine the scientific justification and logistical feasibility of an *in situ* open ocean mesoscale CO_2/pH perturbation experiment. The fifteen participants represented fields of modeling and physical, geochemical and biological oceanography. Results of the meeting include: 1) scientific justification of a large-scale open ocean experiment; 2) a vision of a semi-enclosed experimental design; 3) prioritization of two potential experimental locations along with justifications for each site; 4) anticipated biological and geochemical responses; 5) appropriate observations and measurements necessary to document experimental responses; and 6) adapting ecosystem modeling approaches for predictive capabilities.

Figure 1. Photo of a tuna pen which might be modified into an experimental maricorral.

Add	Salt	t(°C)	TA	pH	Total CO_2	pCO_2	HCO_3	CO_3	Re	Ωar
Initial	35	18	2300	8.1	2024	336	1817	196	10.1	3
CO_2	**35**	**18**	**2300**	**7.9**	**2123**	**577**	**1970**	**134**	**12.7**	**2.1**
Acid	**35**	**18**	**2195**	**7.9**	**2023**	**550**	**1877**	**128**	**12.5**	**2.0**
Initial	35	4	2300	8.1	2131	333	1991	123	13.4	1.8
CO_2	**35**	**4**	**2300**	**7.9**	**2206**	**556**	**2094**	**82**	**16.5**	**1.2**
Acid	**35**	**4**	**2224**	**7.9**	**2132**	**537**	**2024**	**79**	**16.4**	**1.2**

Table 1. Response of the inorganic carbon system to CO_2 vs. acid additions corresponding to a pH change of 0.2. Abbreviations: Add = addition method. Initial = initial conditions. Following lines show the change due to either CO_2 additions or acid addition for a temperature of 18°C (first 4 lines) or 4°C (last three lines). TA = total alkalinity; HCO_3 = bicarbonate concentration (μmol kg-1); CO_3 = carbonate concentration (μmol kg-1); Re = Revelle factor; Ωar = aragonite saturation state. Calculations using the Excel worksheet of Pierrot coded after the program of Lewis and Wallace (http://cdiac.ornl.gov/oceans/co$_2$rprt.html).

The workshop began with a discussion of an uncontained *in situ* open ocean CO_2 addition experiment that would be valuable for testing effects of surface ocean CO_2 increases on open ocean ecosystems and biogeochemical cycling. Such an experiment would be challenging, but potentially achievable. However, an eddy-scale CO_2 infusion would require extraordinary funding resources (~ \$10's of millions). Alternative approaches to a full-scale *in situ* experiment that might be more practical and would represent an enhancement to mesocosm experiments were discussed, including: 1) very small-scale *in situ* open ocean perturbations; 2) natural CO_2 gradients (spatial or temporal); 3) closed-system mesocosms; 4) large, semi-enclosed "maricorrals." The merits and drawbacks of each were continually revisited as ideas progressed.

In an effort to retain the benefits of an *in situ* experiment but reduce the logistical challenges of patch dilution and shear, semi-enclosed maricorral structures were envisioned (Fig. 1). Maricorrals would need to be large enough to minimize container effects

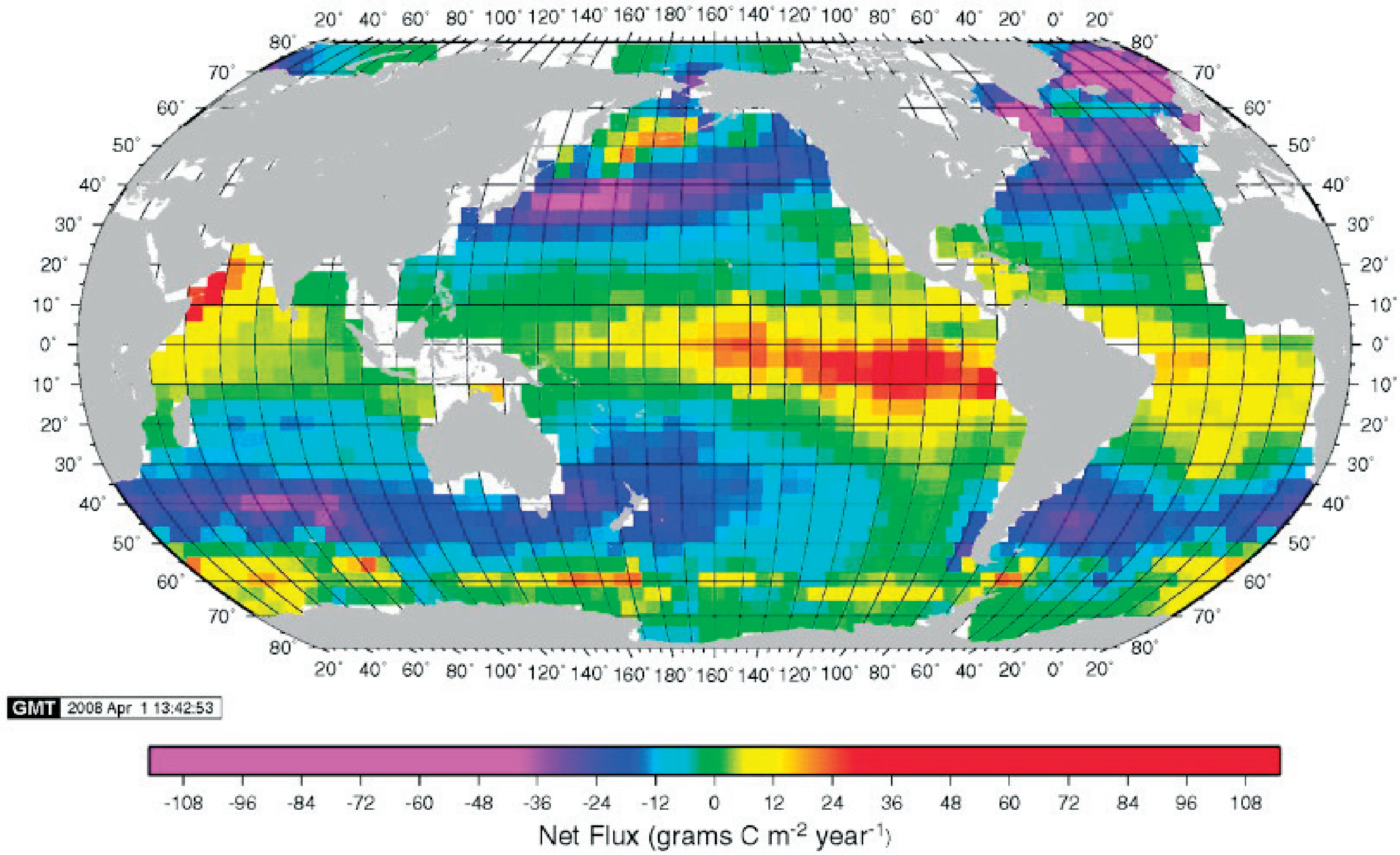


Figure 2. Climatological mean annual sea–air CO_2 flux (g-C m^{-2} yr^{-1}) for the reference year 2000 (non-El Niño conditions) from Takahashi et al., 2009.

(*e.g.*, potential biofouling, shading, small-scale turbulence), maximize sampling volume, and be inclusive of higher trophic levels. Utilizing maricorrals would provide an additional benefit of multiple treatments (i.e. gradients) or replicates. The design, engineering, and deployment of these structures could be efficiently accomplished by partnering with mariculture or oil service industries.

A CO_2 gas addition would most closely mimic the direct effects of increased atmospheric pCO_2. However, the logistical benefit of using an acidification method to achieve a 0.2 decrease in pH and a ~200 µatm increase in pCO_2 was considered as a possible trade-off. Perturbation methods differ in that with a CO_2 addition the total CO_2 (DIC) would increase but alkalinity would remain constant, whereas with a mineral acid addition, an increase in pCO_2 would occur by decrease in alkalinity (Table 1). Inert tracer gases SF6 and ^{3}He would be added so that advection/dilution of the perturbed waters could be tracked and gas exchange could be quantified.

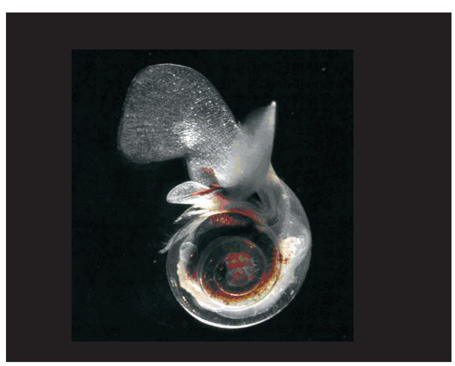


Figure 3. Photo of the pteropod *Limacina helicina*, a tiny (a few mm) calcifying planktonic mollusc that is an important food source for higher trophic levels. *Photo courtesy of Russ Hopcroft, University of Alaska, Fairbanks/NOAA.*

In addition to technical challenges, there may be legal (and political) challenges in intentionally acidifying a patch of ocean. Difficulties in obtaining permits may become a major concern for any future open ocean addition-type experiments even though a CO_2 or acid addition is not expected to be a form of fertilization.

Due to spatial variability of current global pCO_2 and CO_2 fluxes, the results of a CO_2 addition or acidification experiment would likely vary in different locations (Fig. 2). Two major oceanic regions, the subtropical Pacific and the high latitude ocean, were prioritized as candidates for a CO_2 manipulation. Characteristics that make each region useful for such a study were specified.

A review of the current literature from laboratory and field experiments revealed many gaps in our current state of knowledge regarding likely responses of organisms due to pH and CO_2 changes. However, some overall hypotheses about open ocean responses were formulated. In summary, we generally predict: 1) changes in elemental ratios; 2) changes in assemblages, community, trophic relationships (bacterial, phytoplankton, zooplankton and higher); 3) higher N-fixation rates; and 4) lower calcification rates (Fig. 3).

Maricorral conditions probably could be maintained for a period on the order of weeks. Because the biogeochemical responses are predicted to be subtle rather than a bloom-like response experienced during iron fertilization experiments, detecting geochemical feedback signals or changes in export (either quantity or stoichiometry) may be difficult over this time period. Also noted were other effects that would not be tested by such a perturbation experiment such as temperature effects, changes in meteorology and hydrography (*e.g.,* winds, mixing depths, clouds), long-term adaptation of biological communities, and deep ocean geochemical feedbacks.

Three major categories of observations are necessary for a successful CO_2 perturbation experiment: 1) those to monitor the geochemical experimental environment (i.e. chemical changes as a direct effect of lower pH and shift in carbonate equilibrium; 2) those that will target biological responses; 3) those that might detect changes in biogeochemistry due to feedback from the biological response. As usual, the answer to the question of what to measure was "everything." However, critical observations and measurements were identified and prioritized. Some observations are more critical at early stages of the experiment while others will be more important later. Tactics for how to best sample multiple large maricorrals were briefly addressed.

A synergistic effort in improved biogeochemical modeling was suggested. Current ecosystem models are ineffective at predicting anticipated experimental responses. Energy and substrate trade-offs to organisms must be identified and quantified to predict changes to communities in response to CO_2 perturbation over longer time scales.

A more detailed report is available at http://www.ldeo.columbia.edu/~vlance/CO2WorkshopReportonWEB 16Jun09.pdf

Support for this workshop was provided by the LDEO Climate Center, the LDEO Advisory Board Innovation Fund and NSF – ADVANCE of the Earth Institute, all at Columbia University.

Micronutrient-ecosystem, cont. from page 8

cruise aboard the R/V *Knorr* entitled CoFeMUG (Cobalt, Fe and Microbes from the Upwelling to the Gyre). With assistance from Carl Lamborg, Phoebe Lam, and Chad Hammerschmidt, this cruise was converted to a full ocean depth GEOTRACES-compliant zonal section across the South Atlantic. The cruise track included the oligotrophic waters of the South Atlantic Gyre and transition to the highly productive Benguela Upwelling system. WHOI graduate student Abigail Noble produced a full depth dissolved cobalt section on this cruise that revealed a large plume of Co emanating from the Benguela Upwelling system across much of the South Atlantic basin (Figure 1). Complementing the novel Co distribution data, incubation experiments conducted on the CoFeMUG cruise demonstrated cobalt-nitrate and iron-nitrate colimitation at two different depths in the upper water column, in a gyre region that ecosystem models predict to be solely nitrogen-limited. The CoFeMUG cruise effectively demonstrates how international GEOTRACES and related programs can make major contributions to our understanding of the biogeochemistry of micronutrients such as Co.

Interactions between the micronutrients and the carbon cycle play a key role in structuring marine ecosystems. These relationships and their sensitivity to changes in the physical environment must be incorporated into future generations of ocean models to improve predictions of the ocean's response to global change. With the relevant programs in place, the oceanographic community now has the opportunity to make a major advance in research on marine ecosystems and biogeochemical cycles. Within the U.S. it is appropriate to take action through the Ocean Carbon and Biogeochemistry (OCB) program, as OCB represents the interests of SOLAS and IMBER, while maintaining a close relationship with GEOTRACES. A special session at the upcoming OCB summer workshop will provide a forum for community discussion of these opportunities.

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OCB Update

Important OCB Dates

June 8-11, 2009: New Frontiers in Southern Ocean Biogeochemistry and Ecosystem Research (Princeton, NJ)

July 1, 2009: OCB scoping workshop proposals due (solicitation)

July 20-23, 2009: OCB Summer Workshop (Woods Hole, MA)

Fall 2009 (dates TBA): Ocean Acidification Short Course (Woods Hole, MA)

2009 OCB Summer Workshop Preview

This year's OCB Summer Workshop will include the following sessions:

- *The Next U.S. Carbon Cycle Science Plan*
- *Observing Systems and Time-Series*
- *The Future of OCB Research in the Southern Ocean*
- *Ocean Acidification: Frontiers in Understanding Physiological and Ecological Responses*
- *Implementing Research at the Intersection of Ocean Chemistry and Biology*
- *NACP/OCB Coastal Interim Synthesis Activities*

Detailed session descriptions accompanied by links to relevant documents and websites are available on the workshop website. We're looking forward to a productive and stimulating meeting!

OCB Releases Next Scoping Workshop Solicitation

The solicitation can be downloaded from the OCB website. Please note that the submission deadline is **July 1, 2009**. Decisions will be made by September 2009, so that planning can get underway for a 2010 workshop. We look forward to receiving your proposals.

OCB Travel Support

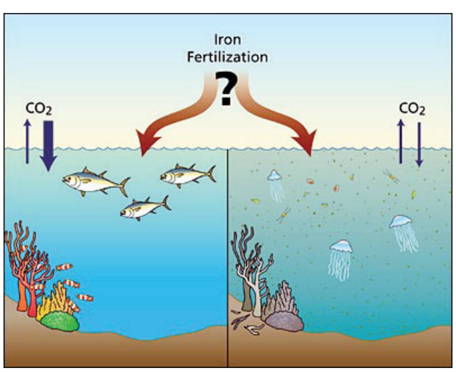
In an ongoing effort to strengthen ties to other U.S. and international carbon cycle science programs (*e.g.*, IMBER, SOLAS, IOCCP, etc.), the OCB Project Office has limited funds for U.S. (OCB) participation in workshops and meetings that advance the programmatic mission of OCB. Given these very limited resources, we prioritize participation in workshops and meetings that will result in a tangible product or outcome to promote OCB scientific implementation and community building. For scientific interest, the Project Office maintains a continually updated list of OCB-relevant national and international scientific meetings, and we encourage the OCB community to seek support directly from federal agencies via the proposal submission process for participation in these meetings. If you would like to request targeted programmatic travel support from the Project Office, please provide a one-page description of the meeting, including its programmatic importance to OCB, detailing the amount of your request. Please bear in mind that OCB is a U.S. program, and therefore our priority is to support U.S. scientists. Travel support requests are typically <$2-3K, but under unusual circumstances, the OCB Project Office will consider requests up to $5-10K. Proposals should be sent directly to the OCB Project Office.

Examples of previous OCB Project Office travel awards include:

- OCB Ocean Time-Series Advisory Committee members' participation in an international time-series workshop focused on community planning to sustain and enhance the use of open-ocean time-series observations

- U.S./OCB ocean acidification researchers' participation in an international workshop focused on developing a Guide for Best Practices in Ocean Acidification Research and Data Reporting

OCB Forms Subcommittee on Ocean Fertilization



Buesseler (1999), WHOI Annual Report, Illustration by Jack Cook (WHOI).

The OCB Scientific Steering Committee has realized the need for a subcommittee to help OCB stay connected to ocean fertilization science and policy activities. Ken Buesseler has agreed to serve as the chair for this committeeand is currently working to finalize its membership. One of the first charges of the committee will be to work with the OCB Project Office to develop a dedicated web page for ocean fertilization resources.

Ocean Acidification

Studying ocean acidification's effects on marine ecoystems and biogeochemistry

2009 Federal Ocean Acidification Research And Monitoring Act Passes Congress

The Federal Ocean Acidification Research And Monitoring (FOARAM) Act passed Congress in late March 2009.

OCB Ocean Acidification White Paper

In conjunction with the passing of the FOARAM Act, the OCB Ocean Acidification Subcommittee released a white paper entitled "Ocean Acidification: Recommended Strategy for a U.S. National Research Program" that lays critical foundation for a U.S. ocean acidification research program.

EPA's Notice of Data Availability (NODA) on Ocean Acidification

EPA recently requested comments on "Ocean Acidification and Marine pH Water Quality Criteria." The OCB Ocean Acidification Subcommittee, the OCB Project Office, and the OCB community worked together to draft an OCB response to six of the seven topics listed in the NODA. The OCB response was submitted to the EPA on June 15, 2009. The final response has been distributed to the OCB community and is available on the OCB website.

OCB to Host Ocean Acidification Short Course in Fall 2009

Ocean acidification is a high-priority OCB research topic that has recently been the focus of multiple workshops, white papers, and reports, and there is great urgency among members of the national and international research communities to plan and conduct viable and compelling experiments that will improve our understanding of the potential biogeochemical and ecological impacts of ocean acidification. The OCB Project Office and the Ocean Acidification Subcommittee are developing a hands-on ocean acidification short course that will convene members of the biological and chemical oceanography research communities to gain mutual insights on optimal ocean acidification experimental design. The short course will build on the recommendations from the Guide to Best Practices in Ocean Acidification Research and Data Reporting, and would provide a mechanism for educating scientists on appropriate chemical and biological techniques and protocols related to ocean acidification.

The course will take place in Fall 2009 (dates TBA) on the Woods Hole Oceanographic Institution (WHOI) and Marine Biological Laboratory (MBL) campuses in Woods Hole, MA, and will include lecture, laboratory, and field components. The course will accommodate 50-60 participants (including instructors) from the OCB community, and will primarily target junior to mid-level faculty and post-doctoral scientists from the U.S.

The OCB Project Office will send an announcement to the OCB community when more details become available.

NRC Study on Ocean Acidification

The National Research Council of the National Academy of Sciences has assembled a panel of 12 scientists to undertake a study, "Development of an Integrated Science Strategy for Ocean Acidification Monitoring, Research, and Impacts Assessment," to examine the impacts of ocean acidification on fisheries, marine mammals, coral reefs, and other natural resources. Two OCB documents, the ocean acidification white paper and the ocean acidification scoping workshop report will provide a strong foundation for this NRC study.

Ocean Acidification Resources for Scientists

With oversight from the OCB Ocean Acidification Subcommittee, the OCB Project Office is developing a new website as a clearinghouse of ocean acidification news and informa-

Cont. on page 13

International Ocean Acidification News

Community review of the Guide to Best Practices in Ocean Acidification Research and Data Reporting is open until July 15, 2009.

European Program on Ocean Acidification (EPOCA) annual meeting (invitation only): June 30-July 2, 2009, Plymouth, UK

New Programs

UK Ocean Acidification Programme (Natural Environment Research Council and Department for Environment, Food & Rural Affairs), Contact: Michael Webb

German ocean acidification programme: Biological Impacts of Ocean ACIDification (BIOACID), Contact: Ulf Riebesell

OCB to Host Summer Student

This summer, the OCB Project Office is providing support for an undergraduate student to participate in the Partnership Education Program recently established by the Woods Hole Diversity Initiative. PEP will bring 12-15 students to Woods Hole each summer for an integrated program of internships and course work. The 2009 PEP course is entitled "Topics in Ocean and Environmental Sciences: Global Climate Change," and will run from June 2-30, and the ensuing research internships will run for 6-8 weeks in July and August. Additionally, PEP students will participate in seminars, workshops, a day-long at-sea experience, field trips, career development activities, including the opportunity for informal interviews, and will attend occasional lectures at participating Woods Hole science institutions throughout the summer.

For the 2009 PEP course, OCB will host Melissa Pinard, a junior at Morgan State University in Baltimore, MD working on her degree in Chemistry. She is from the island of Dominica, and is a member of the Caribbean Student Association at Morgan State. In addition to conducting research in the Chemistry department, Melissa tutors high school and undergraduate students in science and mathematics. She eventually plans to pursue graduate work in analytical and environmental chemistry.

Melissa is interested in chemical oceanography, marine biology, and ecosystem management. Two scientists at WHOI, Drs. Anne Cohen and Dan McCorkle, will mentor Melissa on a laboratory-based project to evaluate the sensitivity of larval shell formation by commercially valuable shellfish (oysters, scallops, quahogs) to the changes in seawater saturation state (ocean acidification) projected over the next century.

Welcome to Woods Hole, Melissa!

Ocean Acidification Update, cont. from page 12

tional resources to support the ocean acidification research community. We will make an announcement to the OCB community when the website is ready for public viewing.

Recent Ocean Acidification Documents and Reports

Anderson, D. et al. (2009). The role of scientific ocean drilling in understanding ocean acidification, Summary of the Ocean Acidification and Marine Carbon Cycling Thematic Working Group Meeting, 7-9 January 2009, Miami, FL, U.S. Science Support Program, 9 pp.

Congressional Research Service report on ocean acidification (2009)

Current: The Journal of Marine Education featuring: "Ocean Acidification -From Impacts to Policy Opportunities" (February 2009). Permission has been granted to OCB to post this special issue of Current published by The National Marine Educators Association (NMEA). For more information about the NMEA, please visit their website

Doney, S. (2009). The consequences of human-driven ocean acidification for marine life, F1000 Biology Reports 1:36, 4pp., doi: 10.3410/B1-36.

Fabry, V. J., C. Langdon, W. M. Balch, A. G. Dickson, R. A. Feely, B. Hales, D. A. Hutchins, J. A. Kleypas, and C. L. Sabine (2009): Present and future impacts of ocean acidification on marine ecosystems and biogeochemical cycles, Report of the Ocean Carbon and Biogeochemistry Scoping Workshop on Ocean Acidification Research (UCSD, Scripps Institution of Oceanography; 9–11 October 2007)

OCB Subcommittee on Ocean Acidification (2009). Ocean Acidification - Recommended Strategy for a U.S. National Research Program, Ocean Carbon and Biogeochemistry Program, 14 pp.

Orr, J.C., K. Caldeira, V. Fabry, J.-P. Gattuso, P. Haugan, P. Lehodey, S. Pantoja, H.-O. Pörtner, U. Riebesell, T. Trull, M. Hood, E. Urban, and W. Broadgate. Research Priorities for Ocean Acidification, report from the Second Symposium on the Ocean in a High-CO_2 World (Monaco, October 6-9, 2008) convened by SCOR, UNESCO-IOC, IAEA, and IGBP, 25 pp., Monaco Declaration

Doney, S.C. (2009). Ocean acidification, Flotsam & Jetsam, Massachusetts Marine Educators, Vol. 38, Issue 1 (Summer 2009), 1-15, http://www.massmarineeducators.org. Metrics: EC, ED.

OCB Scoping Workshop Summary: Moss Landing, CA ·April 28-30, 2009

Observing Biogeochemical Cycles at Global Scales With Profiling Floats and Gliders

by Kenneth Johnson (MBARI)

Rapid advances in chemical and biological sensors and the platforms that carry them are underway. It is now feasible to consider the deployment of a global array of autonomous platforms equipped with biogeochemical sensors that would be integrated with remotely sensed observations and biogeochemical models with data assimilation, to provide real time and quantitative assessments of significant components of the ocean carbon cycle. A U.S. OCB Scoping Workshop was held at the Monterey Bay Aquarium Research Institute from April 28-30, 2009 to review technology developments in platforms and sensors, assess scientific progress in applications of such systems, and plan for experiments that would test our capabilities to operate integrated observing systems with *in situ* sensors and biogeochemical models. These experiments would extend over several years at a regional spatial resolution and deliver calibrated, real-time outputs. The ultimate goal of the workshop was to assess the feasibility of operating a global array and to identify the missing technological components that might be required.

Sixty-two participants from academic and industrial institutions in ten countries attended the meeting. These participants came from a broad spectrum of backgrounds, including experts with experience in the development of float and glider platforms, investigators with experience in development of biogeochemical sensor systems, and scientists with experience in the operation of large sensor arrays, such as the Argo system. The majority of attendees comprised carbon cycle scientists, some familiar with autonomous sensor systems and many new to these systems. Critical to operation of a sensor network is integration of the data streams with numerical models, and a number of participants had backgrounds in biogeochemical modeling. Attendees also included representatives of federal agencies and private foundations.

Sensor systems for a variety of biogeochemical properties are now available (*e.g.*, oxygen, nitrate, chlorophyll fluorescence, light scattering or attenuation by particles, and downwelling irradiance) and deployed for extended periods on floats and gliders. Other sensors are being developed, with some preliminary deployments on these platforms, but lacking extended deployments to date (*e.g.*, gas tension devices, carbon flux sensors, pCO_2). Finally, there is a suite of sensors in development that appear to have the potential of operation from long endurance, autonomous platforms in the near future (*e.g.*, particulate inorganic carbon, pH). Some sensors, such as oxygen and bio-optics (chlorophyll fluorescence and light scattering), have been operated successfully on platforms such as profiling floats for periods in excess of three years with little or no evidence of sensor drift. These successes have led to the deployment of surprisingly large numbers of chemical and biological sensors on autonomous platforms. As an example, there are now more than two hundred profiling floats in the Argo array equipped with oxygen sensors. The number of oxygen measurements made from autonomous platforms and delivered to on-line data systems far exceeds the number of measurements being made from ships and reported to national databases. These sensor systems are being used in a variety of studies to assess rates of net community production, carbon export, the impacts of mesoscale events on carbon cycling, and to test long standing paradigms such as the Sverdrup Hypothesis on the effects of mixing depth and timing of the spring bloom.

While it was clear from the participants that systems are maturing and exciting science is being done (*e.g.*, see the September 2008 special issue of Limnology and Oceanography on Autonomous and Lagrangian Platforms and Sensors), there remain critical steps that require refinement. These include development of protocols to ensure sensor intercomparability, development of absolute calibration standards to ensure data sets are of climate research quality, and integration of observations with models. The workshop focused much of the planning on outlining a variety of multi-year experiments that would incorporate these needed refinements. These experiments included studies of the annual cycles of net community production in the Northwest Pacific and the impact of productivity on atmospheric carbon dioxide uptake in this region, carbon export and productivity over full annual cycles in the North Atlantic, processes that drive the biogeochemical properties of mode waters formed in the Southern Ocean, and interactions of oxygen and nitrogen cycles in the Eastern Tropical North Pacific. A metric for success of the workshop will be the degree to which these or related studies are implemented in the near future.

A full workshop report is under development and presentations given at the workshop will be posted on the workshop website.

NACP/OCB Interim Coastal Synthesis Update

The objective of the Coastal Interim Synthesis Activity is to stimulate the synthesis and publication of recent observational and modeling results on carbon cycle fluxes and processes along the North American continental margin. The current state of knowledge of the magnitude, spatial distribution, and interannual variability of carbon sources and sinks in coastal waters is incomplete. Thus, the goal of this activity is to synthesize individual, small-scale studies across broader spatial and temporal scales to improve quantitative assessments of the North American coastal carbon cycle. Because the coastal oceans have important and complex linkages with terrestrial, atmospheric, and open ocean biogeochemical cycles, we encourage the participation of researchers focused on both organic and inorganic carbon, as well as nitrogen and phosphorous cycle topics related to carbon balance and related issues such as hypoxia impacts on continental margins.

The Coastal Interim Synthesis Activity was initiated at the 2008 OCB summer workshop and is divided geographically into five regions—East Coast (including Gulf of Maine), West Coast, Gulf of Mexico, Arctic (including marginal seas such as the Bering, Chukchi, Beaufort, and Baffin-Labrador), and Great Lakes. There are currently 65 registered participants on the Coastal Synthesis wiki site. Discussions among some members of this group at the 2009 NACP PI meeting in San Diego, CA Feb. 17-20 resulted in two preliminary goals for this activity:

Phase 1. Regional Carbon Budgets

The first phase of the coastal synthesis will be to develop a carbon budget for each region based on a compilation of existing data, which will require literature searches, web searches of databases, etc. For regions with existing capability to do so, preliminary budgets will also be generated based on regional coastal ocean models. The following participants have volunteered to take the lead with this activity:

East coast:
Ray Najjar, Marjy Friedrichs
West coast:
Simone Alin, Burke Hales
Gulf of Mexico:
Steve Lohrenz, Paula Coble
Great Lakes:
Galen McKinley
Arctic:
Jeremy Mathis

If you would like to contribute to any of the above regional coastal syntheses, please contact the appropriate regional leader(s).

Phase 2. Community Modeling and Database Development

The second phase of the coastal synthesis will involve a more extensive community model-data comparison to refine regional carbon budgets. For this activity, we will engage the larger community to agree on specifics of the comparison exercise. It is important that the regional syntheses remain consistent in the treatment of fluxes (*e.g.*, air-sea, terrestrial-marine, sediment-water, etc.) and internal processes (*e.g.*, production, remineralization). During this phase, participants will work with data managers to develop a coastal carbon database that is readily accessible to modelers.

A proposal has been submitted to the Carbon Cycle Interagency Working Group requesting support for data mining efforts and two community workshops over the next 1-2 years to set initial conditions for coastal synthesis activities, provide uniformity in data and metadata formatting, and encourage collaborative projects that result in publications of results of the budgeting and modeling efforts. The first community workshop is tentatively planned for late 2009/early 2010.

IOCCP Update

IOCCP Welcomes Kathy Tedesco as New Director

The Intergovernmental Oceanographic Commission of UNESCO and the Scientific Committee on Oceanic Research are pleased to announce that Dr. Kathy Tedesco has been appointed as the new director of the IOCCP, effective 2 March. Acting project director Maria Hood will continue to work part-time for the IOCCP to assist the new director. Kathy comes to the IOCCP from the U.S. Geological Survey in St. Petersburg, Florida where she has been working as an oceanographer for the past two years. Prior to this, she served as Program Manager for the Global Carbon Cycle Program (GCC) in the Climate Program Office at the National Oceanic and Atmospheric Administration.

OCB 2009/2010 Activities Calendar

OCB Activities

June 8-11, 2009: New Frontiers in Southern Ocean Biogeochemistry and Ecosystem Research (Princeton, NJ)

July 20-23, 2009: OCB Summer Workshop (Woods Hole, MA)

Fall 2009 (dates TBA): Ocean Acidification Short Course (Woods Hole, MA)

OCB-Relevant Activities

2009

June 8-July 17: Microbial Oceanography: Genomes to Biomes, a laboratory-field training course, University of Hawaii, Manoa

June 21-26: 2009 Goldschmidt Conference: "Challenges to Our Volatile Planet," Davos, Switzerland

June 22-26: 3rd GLOBEC Open Science meeting, Victoria, BC

July 6-7: 1st PAGES Young Scientists meeting, Corvallis, OR

July 6-17: Marine Phytoplankton Taxonomy Workshop, Plymouth, UK

July 13-17: Decadal variations of the ocean's interior carbon cycle: Synthesis and vulnerabilities, Ascona, Switzerland

August 2-7: Gordon Research Conference on Chemical Oceanography, Tilton School, Tilton, NH

August 2-14: Marine Ecosystems and Climate: Modeling and Analysis of Observed Variability, Boulder, Colorado

August 3-15: 4th SOLAS Summer School, Corsica, France

August 5-7: Open NASA Earth Science workshop on global aerosol, cloud and ocean ecology science, Santa Fe, NM

September 1-4: AGU Chapman Conference on the Biological Carbon Pump of the Oceans, Brockenhurst, Hampshire, England

September 8-10: British Ecological Society Annual Meeting, University of Hertfordshire, UK; Special session on ocean acidification

September 13-19: International Carbon Dioxide Conference, Jena, Germany

September 14-17: 4th Warnemünde Turbulence Days (WTD) on Internal Waves and Turbulence in Coastal Seas, Isle of Vilm, Germany

September 16-18: Workshop on Ocean Biology Observatories, Mestre, Italy, Contact: Ed Urban

September 21-25: Ocean Obs 2009: Ocean Information for Society: Sustaining the Benefits, Realizing the Potential, Venice, Italy

October 5-9: CarboOcean Final Conference, Bergen, Norway, Contact: Christoph Heinze

November 16-19: SOLAS Open Science Conference, Barcelona, Spain

December 7-18: UN Climate Change Conference, Copenhagen, Denmark

December 14-18: Fall American Geophysical Union meeting, San Francisco, CA

2010

February 22-26: 2010 Ocean Sciences Meeting: From Observation to Prediction in the 21st Century, Portland, OR

June 6-11: ASLO Summer Meeting, Joint Meeting with the North American Benthological Society, Santa Fe, NM

OCB Funding Opportunities

July 1, 2009: OCB Scoping Workshop proposals due, please submit to OCB Project Office. Download solicitation

July 13, 2009: National Institute of Standards and Technology - Recovery Act Measurement Science and Engineering Research Grants Program

August 15, 2009: NSF Chemical Oceanography and Biological Oceanography proposal submission targets

September 10, 2009: NASA ROSES 2009 Interdisciplinary Research in Earth Science (IDS) (A. 22) (Subelement 2: Impacts of Varying or Changing Climate, Local Weather, and Land Use on Watersheds and their Connected Coastal Environments); Proposals due (NOI due July 10, 2009); solicitation (pdf)

November 17, 2009: NSF Dynamics of Coupled Natural and Human Systems

NSF Interdisciplinary Opportunities

(see OCB website for details)

- Understanding How Earth's Biological Systems Respond to and Influence Its Physical and Chemical Condition (BIO and GEO)
- Interactions among Earth's Environment, Society and the Economy (GEO and SBE)
- NSF cooperative research opportunities with the European Commission and European scientists

Developing a New U.S. Carbon Cycle Science Plan

A working group of 27 scientists was formed in 2008 under the United States Carbon Cycle Science Program's (CCSP) Science Steering Group to review the 1999 "A U.S. Carbon Cycle Science Plan" and to develop an updated strategy for research on the global carbon cycle to be conducted by U.S. researchers for the period from 2010 to 2020. Information about the working group can be found at the USCCSP web site. In late March 2009, the U.S. CCSP working group released the USGCRP/CCSP Strategic Planning Building Block on the global carbon cycle. This is a short document summarizing the current status of the science plan. Based on the community input received so far, the working group has identified three overarching questions to be addressed in the coming decade:

1) How do natural processes and human actions affect the carbon cycle, on land, in the atmosphere, and in the oceans?

2) How do policy and management decisions affect the levels of atmospheric carbon dioxide and methane?

3) How are ecosystems, species, and resources impacted by increasing greenhouse gas concentrations, the associated changes in climate, and carbon management decisions?

The first question encompasses the primary focus of the 1999 science questions, with an enlarged emphasis on human processes and added emphasis on understanding the role of methane, the second most important carbon-based greenhouse gas in the global carbon cycle. The second and third questions address the new priorities identified by the current working group. You can read and comment on the building blocks document at http://carboncyclescience.blogspot.com/

On June 1-2, 2009, the Working Group met again to begin fleshing out the full details of the plan, and your input will be needed to ensure that the ocean carbon cycle receives appropriate attention under the listed priorities. Development of the Carbon Cycle Science Plan will be one of the topics addressed at the OCB summer workshop this July. In the meantime, the ocean representatives of the CCSP Working Group (Bob Anderson, Debbie Bronk, Steve Lohrenz, Galen McKinley, Chris Sabine (chair)) are seeking your input on the following questions as the new plan starts to materialize:

Based on the three overarching questions identified for the new plan, what are the priorities for ocean carbon research in the next decade?

The new overarching questions place a much stronger emphasis on human dimensions. How will/should this affect the OCB community and how we conduct our science?

What is an appropriate balance between basic carbon cycle research and research aimed at providing information for policy and decision support?

The 1999 U.S. Carbon Cycle Science Plan spurred the creation of both OCB and the North American Carbon Program. NACP investigators are actively debating the directions and priorities for carbon cycle research over the next decade, and we strongly urge the ocean community to get involved in these discussions.

SOLAS Update

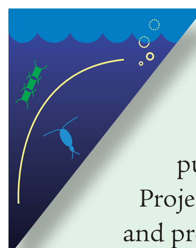
November 16-19, 2009: SOLAS Open Science Conference, Barcelona, Spain (link to conference registration)

Get involved in the programme:

Propose a discussion session on a topic of interest

Present your research during the poster sessions

If you are interested in submitting a poster abstract or discussion session proposal, the deadline is **July 31, 2009**.



OCB News

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