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The Ocean is HOT: *20 years of Hawaii Ocean Time-Series Research in the North Pacific Subtropical Gyre*

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In October of 2008, the Hawaii Ocean Time-series program (HOT) celebrated its 205th research expedition to Station ALOHA (A Long Term Oligotrophic Habitat Assessment; 22° 45′ N, 158° W; Figure 1). The successful completion of HOT-205 marked 20 years of near monthly observations at this field outpost in the North Pacific Subtropical Gyre (NPSG). The journey from a fledging ocean time-series program to one celebrating 20 years of service traces a remarkable history. Together with our sister program in the Atlantic, the Bermuda Atlantic Time-series Study (BATS), HOT remains dedicated to providing the oceanographic community with high quality data on the mean ecosystem state of the NPSG and its temporal variability. In this article we highlight examples where the sustained observing efforts at Station ALOHA are providing important insights into the nature of ecosystem change in the NPSG The HOT data record (http://hahana.soest.hawaii.edu/hot/hot_jgofs.html and www.soest.hawaii.edu/HOT_WOCE/) provides an unprecedented historical context for refining our understanding of the often subtle linkages between ocean-climate and marine biogeochemistry. Without these time-series observations, many of the processes controlling biogeochemical cycles in the NPSG would remain obscured by the inherent complexity of the oceanic habitat.

One of the unique attributes of time-series research is that it simultaneously provokes both retrospection and anticipation. Originally, both BATS and HOT were designed to characterize subtle long-term changes in environments that we believed were stable and far removed from the influence of human activity. As such, they were envisioned to provide a baseline for identifying anthropogenic impacts on other marine environments. However, the temporal trends that have emerged from these programs suggest that, even in these quasi-stable ocean systems, gradual environmental change can often result in abrupt shifts from the equilibrium state. We are just beginning to understand how changes in the frequency and intensity of such perturbations may affect the ecosystem structure and associated elemental cycling.

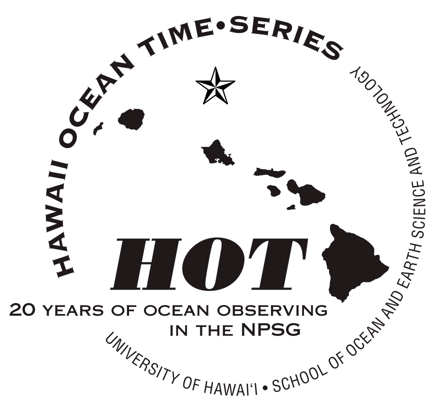


Figure 1. In October 2008, the Hawaii Ocean Time-series (HOT) program celebrated 20 years of sustained measurements at Station ALOHA (22° 45´N, 158° W) in the North Pacific Subtropical Gyre.

HOT research began under the auspices of two large oceanographic programs, the World Ocean Circulation Experiment (WOCE) and the Joint Global Flux Study (JGOFS), and continues with input from the Ocean Carbon & Biogeochemistry (OCB) and Climate Variability & Predictability (CLIVAR) programs. In the formative stages of JGOFS and WOCE, time-series research was recognized as central to improving understanding of the ocean's sensitivity to global climate change. A central motivation for infusing time-series research into these oceanographic programs was to provide information on how open ocean ecosystems were changing in response to increasing anthropogenic carbon emissions HOT was begun and continues to be led by scientists at the University of Hawaii with funding for the core science provided by the U.S. National Science Foundation. Station ALOHA was selected as the HOT field site because it is a deep ocean (~4725 m) location that is both suitably distant (100 km) from the nearest island mass and relatively close to a major port (Honolulu). Sampling is restricted to a 10 km radius circle around the nominal position of Station ALOHA.

Prior to the initiation of HOT and early in the program's evolution, observational studies focused on the remote subtropical Pacific were infrequent or typically not long enough in duration to adequately resolve many of the modes of natural variability we now recognize as important in controlling biogeochemistry. As recently as the 1990s, we had little understanding of the important time scales over which the vast ocean gyres exhibited change. The geographic isolation of the NPSG combined with the relatively subdued seasonality in physical forcing that typifies subtropical pelagic habitats were believed to minimize perturbations, leading to a relatively stable plankton community structure. With more than 20 years of near-monthly measurements in hand, we now recognize that the NPSG is both physically and ecologically dynamic, forced by a myriad of processes that operate over time scales ranging from episodic to multi-decadal In particular, HOT observations have highlighted three important modes of temporal variability in the NPSG that include: secular or multi-decadal trends, seasonal to decadal scale cyclic dynamics, and episodic or event scale processes that impact the systems over weeks to months.

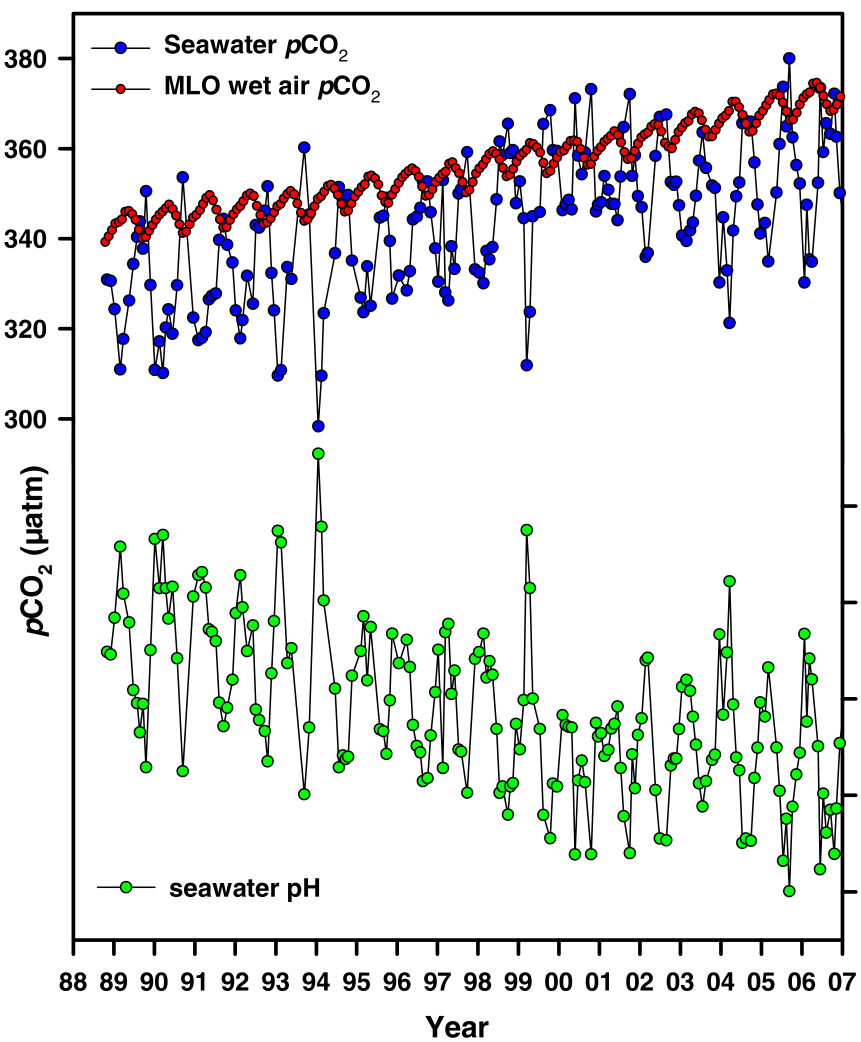


Figure 2. Time-series measurements of mixed layer seawater pCO_2 (blue circles) and pH (green circles) at Station ALOHA. Also shown are wet-air pCO_2 determinations calculated from in situ atmospheric measurements (red circles) at the Mauna Loa Observatory (MLO) in Hawaii.

Among the initial objectives of HOT were to improve our understanding of temporal variability in ocean carbon inventories in the NPSG and to quantify carbon fluxes across the air-sea interface. The vast size and buffering capacity of oceanic carbon pools together with large natural variations in ocean-atmosphere carbon fluxes made this objective a daunting task. The two decade records of ocean CO_2 system measurements at HOT and BATS now convincingly document decadal-scale accumulations of inorganic carbon in the upper ocean in direct response to accumulating CO_2 in the atmosphere. These changes in oceanic carbon inventories have increased seawater pCO_2 (Figure 2), with accompanying secular changes in seawater pH Since the beginning of HOT, pCO_2 at Station ALOHA has increased at a rate of ~2 µatm yr^{-1} and mixed layer pH has declined by 0.04 units, equivalent to ~10% increase in seawater H^+ ion concentrations (Figure 2). The consequences of such changes to the seawater carbonate system on ocean biogeochemistry remain largely unknown.

Time-series are critical for discerning low-frequency natural fluctuations in Earth's climate from those linked to anthropogenic perturbations. Over its many years of observations, HOT program research has been active in defining our understanding of how basin-scale climate oscillations, including the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), influence ecosystem behavior. Phase shifts associated with these quasi-periodic basin-scale climate fluctuations appear linked to variations in physical forcing at ALOHA with attendant consequences for ocean biogeochemistry and ecology. For example, most of the initial phases of HOT program observations in the early 1990s were made during a period of relatively weak El Niño-favorable

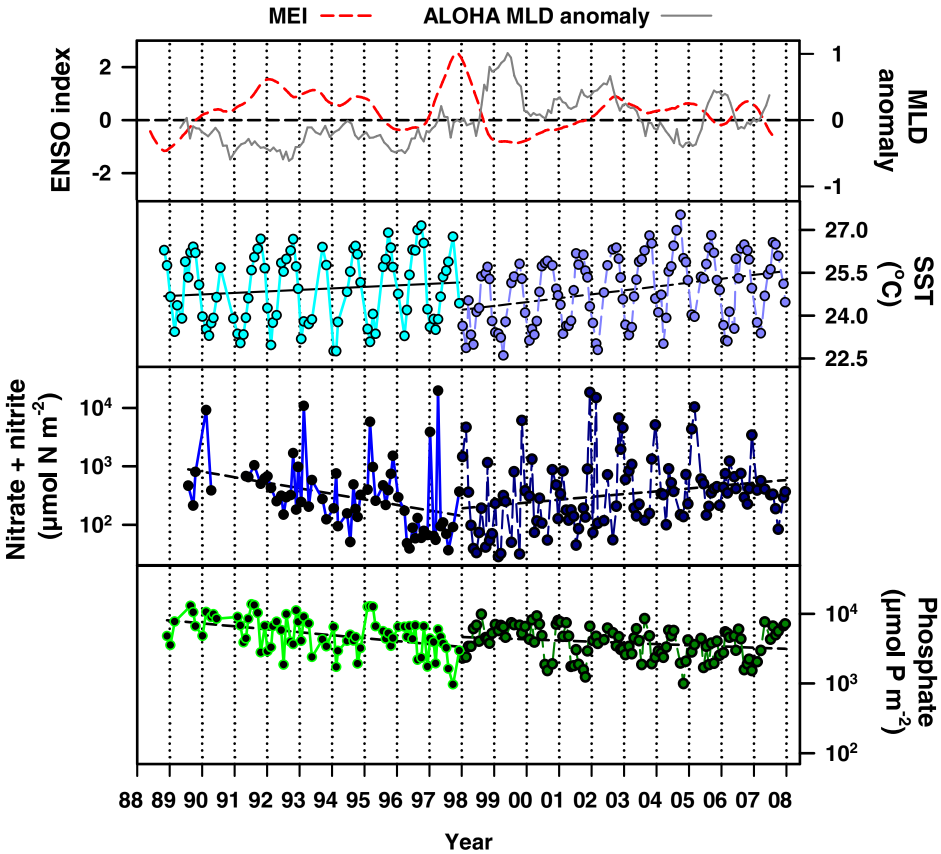


Figure 3. Temporal variability in mixing, temperature, and nutrient inventories (0-100 m) at Station ALOHA in relationship to the Multivariate ENSO Index (MEI). Top plot depicts a 10-point running mean of the standardized mixed layer depth anomaly at Station ALOHA, 1988-2007 (grey line); red dashed line is 10-point running mean of MEI (http://www.cdc.noaa.gov/people/klaus.wolter/MEI/table.html).

forcing, HOT program measurements provide unprecedented information for helping to validate models that may improve our understanding of such dynamics.

In addition to the utility of HOT program data for untangling low frequency ecosystem variability, the monthly-scale sampling at Station ALOHA provides a robust dataset for examining key cyclic variations in ocean dynamics. We now have a robust seasonal climatology on which to evaluate potential long-term changes in the mean ecosystem state of the NPSG. Not surprisingly, some of the most striking examples of seasonality can be found in physical properties of the upper ocean. Although the daily incident irradiance reaches its annual maximum in mid-summer, upper ocean temperatures do not peak until the early fall (Figure 4), and these seasonal-scale alterations in physics play a strong role in shaping ocean biogeochemistry Seasonality in physical dynamics were well known prior to the time-series at ALOHA, however, many of the resulting biogeochemical responses would likely not have been predicted. For example, despite the late winter mixing of nitrate into the upper ocean, rates of primary production are greatest in the mid-summer, coinciding with seasonal maxima in daily light flux (Figure 4). This seasonal dynamic is very different from BATS, where the interactions between stratification, nutrient availability, and primary productivity result in a more "classic" spring bloom-like scenario. Equally remarkable, despite occurring when nutrient inventories are at their annual minima, the summertime increases in primary production observed at ALOHA also coincide with periods of elevated zooplankton biomass and peak particulate matter export from the upper ocean, indicators of enhanced material fluxes up the food web and out of the euphotic zone. Prior to HOT program measurements, we likely would not

conditions. Such conditions coincided with a prolonged period of anomalously shallow mixed layers at Station ALOHA, which apparently limited vertical entrainment of nutrients (Figure 3). This condition was hypothesized to enhance the growth of N_2 fixing microorganisms, with a concomitant drawdown in upper ocean phosphate.

However, further examination of HOT data suggests that our ability to predict the responses of key ecosystem variables to basin-scale climate forcing remains poor. Unlike the El Niño favorable period of the early 1990s, the end of the strong El Niño occurring in 1997-1998 coincided with a drop in sea surface temperatures and increases in salinity, which together resulted in a period of increased mixing (Figure 3). One potential consequence of these changes in upper ocean physics is an apparent enhancement in nutrient entrainment, as reflected by increased upper ocean (0-100 m) inventories of nitrate (Figure 3) and changes in the isotopic composition of particulate material. Intriguingly, despite increased levels of nitrate, concentrations of phosphate continued to decline during this period. Such results presumably reflect a complex interaction between climate, biology and physics in shaping the stoichiometery of upper ocean nutrient pools. It remains unclear why the upper ocean exhibited such different behavior during these ENSO fluctuations. Although these dynamics emphasize that we currently do not adequately understand the linkages between ecosystem behavior and large-scale climate have predicted that in a permanently oligotrophic environment such as the NPSG, primary production and carbon export would appear more seasonally tuned to changes in solar irradiation than to nutrient infusions to the euphotic zone via mixing.

Not surprisingly, the sustained time-series datasets become increasingly more valuable with the passage of time. Ocean observations at and around ALOHA are beginning to provide insight into the importance of aperiodic or infrequent dynamics. Overprinted on secular and cyclic scale forcing are event-scale processes that impart distinct signatures on the time-series record. Often these events are driven by the active mesoscale physical field encompassing Station ALOHA.

Eddies and planetary waves have been shown to comprise important sources of variability on water column properties at ALOHA. Not only do some of these features transport waters of anomalous characteristics into the ALOHA region, but they can also simultaneously perturb nutrient gradients relative to the vertical irradiance field. Moreover, energy dissipation by these mesoscale physical features results in a cascade of sub-mesoscale processes that further exacerbate seascape variability.

Despite increased awareness of the importance of mesoscale dynamics on ocean biology, observations at ALOHA provide abundant evidence that we still have a lot to learn regarding the linkages between physics and biogeochemistry. For example, annually recurring summer phytoplankton blooms observed around ALOHA often appear loosely connected to the mesoscale physical field; however, it's still unclear whether this reflects the role of physics in aggregating plankton biomass or whether such increased biomass stems from some indirect enhancement of plankton physiology by the mesoscale environment. Advances in satellite oceanography have enhanced the contextual information for examining the coupling of ocean physics (via sea surface altimetry) and biology (via ocean color) around ALOHA. By combining these satellite products with the monthly shipboard occupations and moored platform measurements near ALOHA, HOT maintains a near-continuous, watchful eye over ecosystem dynamics in the NPSG.

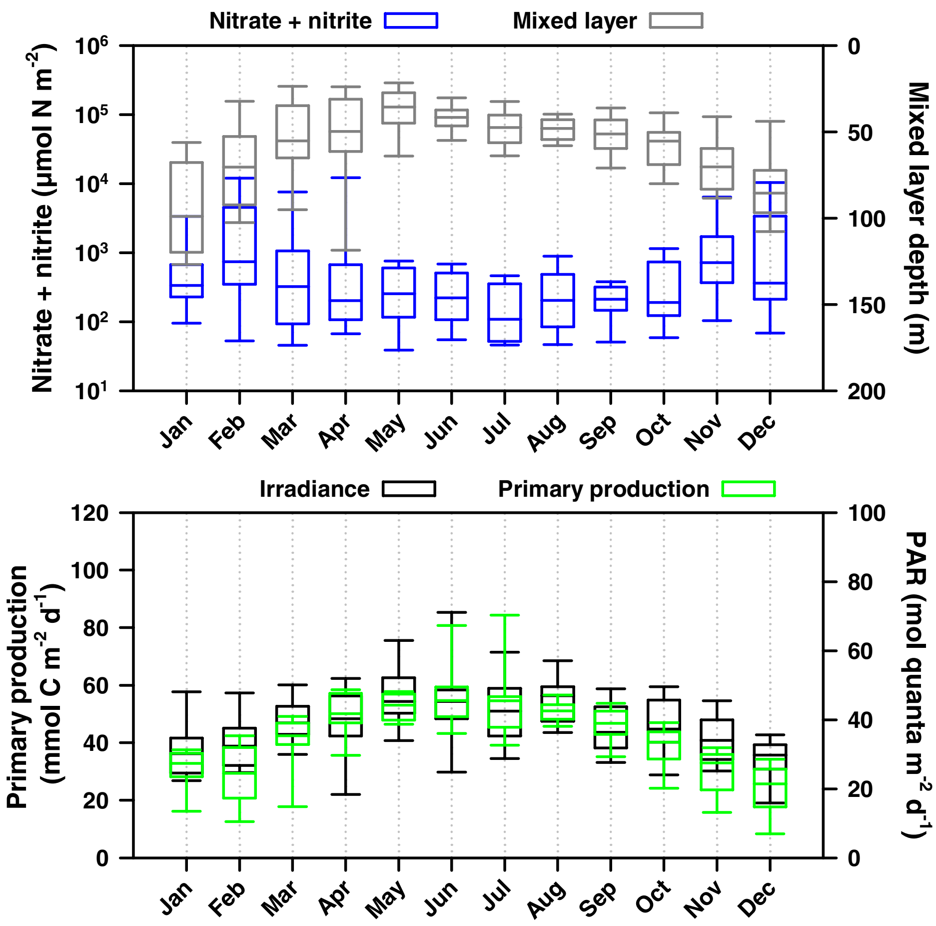


Figure 4. Monthly HOT program climatology of mixed layer depths and depth integrated (0-100 m) nitrate + nitrite inventories (top plot), and incident flux of photosynthetically available radiation (PAR) and depth-integrated (0-100 m) primary production (bottom plot) at Station ALOHA.

The episodic nature of mesoscale physical processes combined with their inherent spatiotemporal complexity makes sampling of these events logistically challenging. However, the sustained sampling at Station ALOHA increases the probability of detecting and sampling such events. During the 156 HOT shipboard occupations of Station ALOHA between October 1992 (the beginning of high-frequency satellite altimetry measurements in this region) and October 2007, HOT has sampled 32 occasions where sea surface height anomalies (SSHa) were greater than 1 standard deviation above the mean for this region, and 31 occasions where SSHa were more than 1 standard deviation below the mean for this region (Table 1). Analyses of the relationships between SSHa and nutrient inventories, nutrient stoichiometries, and rates of primary production suggest the influences of mesoscale features in the well-lit regions of the euphotic zone are often subtle or difficult to detect (Table 1). In contrast, throughout the dimly-lit lower euphotic zone, mesoscale forcing appears to have a significant role in controlling nutrient availability at Station ALOHA. This region of the upper ocean includes the persistent deep chlorophyll maximum layer, suggesting plankton assemblages associated with this feature may undergo more frequent, event scale perturbation than assemblages living in the well-lit upper ocean. Rapid biological utilization of nutrients delivered to the highly energetic region of the upper ocean by mesoscale events likely obscures the influence of these events on nutrient concentrations. Moreover, the large seasonal variations in nutrient concentrations and productivity in the upper euphotic zone may overshadow detection of potential forcing by mesoscale processes.

In the preceding examples, we have sought to identify intriguing ocean dynamics that were not yet recognized or only poorly understood prior to the initiation of the HOT program. In addition to characterization of time varying ocean processes, HOT has also provided an invaluable platform for numerous process-oriented research programs. These studies have provided remarkable value to the HOT core measurement suite. Notable among these valued-adding programs is the Center for Microbial Oceanography: Research and Education (CMORE), a NSF-funded Science and Technology Center focused on understanding the genetic and physiological underpinnings of microorganism control on ocean biogeochemistry. After 20 years of monthly-scale measurements, HOT has developed an improved understanding of processes occurring over seasonal to interannual scales, but we are only beginning to capture ocean variability occurring at the extremes of our sampling resolution, including high-frequency (semi-diurnal to weekly) and low-frequency (interdecadal to multi-decadal) dynamics. Further characterization of high frequency variability may allow us to better understand the scales at which planktonic assemblages are structured in these oligotrophic environments, while resolving lower frequency dynamics may provide insights into the stability and resilience of these pelagic systems. In all, the sustained efforts at HOT and BATS have begun to provide the scientific community with comprehensive oceanographic climate data records.

To foster continued community involvement and awareness of ocean time-series research in the post-JGOFS era, HOT is actively working with the Ocean Time-Series Advisory Committee (OTSAC) formed by OCB. This committee serves as an important mechanism for community input to the leaders of the ongoing time-series programs, helping to guide research activities at these sites. Scientists working with HOT, BATS, and the CArbon Retention In A Colored Ocean (CARIACO) time-series have been actively working with this committee to enhance the effectiveness of these programs and to facilitate coordination of science, including intercomparison of methodologies. HOT continues to welcome and encourage community participation in steering the future course for program science. The remarkable insight and surprises that the existing ocean time-series programs have provided continue to fuel strong support for these research outposts. We remain optimistic that through continuation of exacting and persistent science, HOT will remain a cornerstone of oceanographic research for many years to come and continue to revise the way we view the sea.

Table 1. The influence of mesoscale physical forcing on average (± standard deviation (SD)) nutrient inventories, stoichiometries, and primary production in the well-lit (0-100 m) and dimly-lit (100-200 m) regions of the upper ocean at Station ALOHA (1992-2007). Also shown is average particulate matter export at ALOHA. Variables are binned according to sea surface height anomalies (SSHa) in the ALOHA region; negative SSHa indicates HOT cruise occurred when SSHa were >1 SD below the regional mean; average SSHa indicates HOT cruise coincided with period when SSHa were <1 SD from the regional mean; and positive SSHa indicates HOT cruise took place when SSHa were >1 SD above the regional mean.

Variable	Negative SSHa	Average SSHa	Positive SSHa
Observations	31	92	32
SSHa (cm)	-16 to -7	-6 to 6	7 to 15
Nitrate + nitrite (mmol N m^{-2})			
0-100 m	2.0 (±4.8)	1.0 (±2.6)	0.57 (±1.3)
100-200 m	184 (±80)*	119 (±55)	75 (±32)**
Phosphate (mmol P m^{-2})			
0-100 m	4.3 (±2.1)	4.4 (±2.2)	4.9 (±2.8)
100-200 m	19 (±6.9)*	14 (±5.1)	11 (±3.4)**
N+ N : PO_4^{3-} (mol : mol)			
0-100 m	0.43 (±0.90)	0.26 (±0.54)	0.13 (±0.28)
100-200 m	9.6 (±2.2)	8.8 (±5.8)	7.4 (±3.9)
^{14}C-PP (mmol C m^{-2} d^{-1})			
0-100 m	40.5 (±12.4)	39.5 (±9.64)	36.2 (±9.31)
100-200 m	4.90 (±3.31)	4.31 (±2.46)	3.83 (±1.84)
Particulate matter export @150 m			
mmol C m^{-2} d^{-1}	2.6 (±0.81)	2.3 (±0.76)	2.3 (±0.73)
mmol N m^{-2} d^{-1}	0.32 (±0.11)	0.29 (±0.10)	0.28 (±0.09)
nmol P m^{-2} d^{-1}	11 (±4.6)	11 (±4.2)	9.4 (±3.2)

Asterisks indicate property mean is significantly different from the average SSHa condition.

center for microbial oceanography: research and education

C-MORE *linking genomes to biomes*

C-MORE's education program is "K through Grey". In the last (Oct 2008) issue of *OCB News*, we described some opportunities for K-12 teachers. In this issue, we describe two online activities for kids.

Microbe Personality Quiz: Which microbe are you?

This activity is designed to teach about microbes in a fun, engaging way. Kids are presented with pairs of statements. In each pair, they are asked to choose the statement that best matches their personality. Their answers take them along a dichotomous key. For example, the first pair of statements is:

My bedroom is well-organized and everything is placed where it belongs.

My bedroom is messy and only I know where to find anything.

Choosing A puts kids along the track of well-organized eukaryotes, whereas choosing B sends them along the prokaryote track. Subsequent pairs of statements ask them to further define their personality. Eventually, they are matched with their microbial soulmate.

Test Your Microbe IQ

Do you have science savvy? Are you a master of the microbial universe? Here's a chance to test your knowledge. Take this microbial IQ quiz to find out whether you really are an ace when it comes to algae! When you're finished, you can enter to win a Giant Microbe© plush toy in our monthly raffle! High performers also earn a color certificate of achievement, which they can print out.

Here's a sample question to get you started. Which of the following is thought to be the earliest form of life? Your choices are:

A) Dinosaurs
B) Coniferous trees
C) Microbes
D) Trilobites

If you picked (C) Microbes, you are well on your way to earning a certificate of achievement.

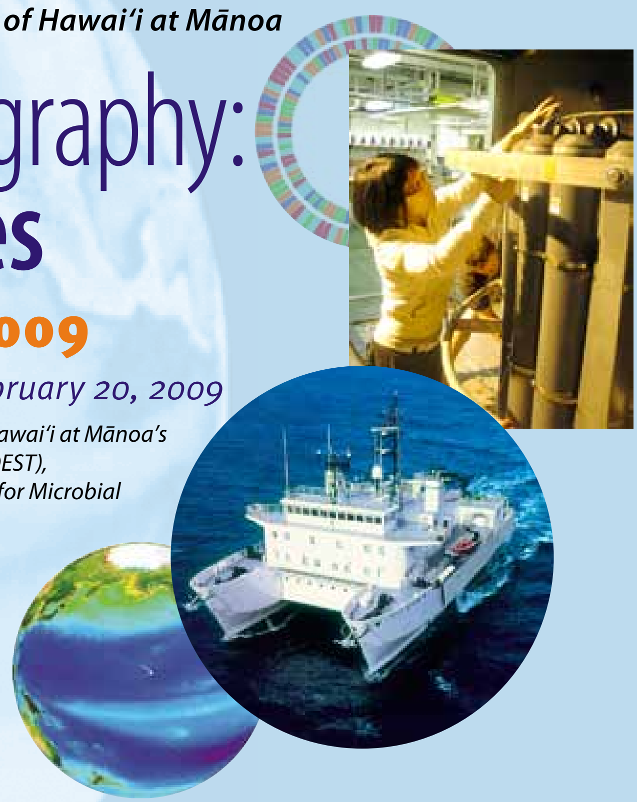
Check out these activities in the Kids Korner section of the C-MORE website. http://cmore.soest.hawaii.edu/education/kidskorner/index.htm

A teacher's guide to the dichotomous key is available on http://cmore.soest.hawaii.edu/education/teachers/documents/Personality_paths.pdf

Your feedback is very welcome. Please send all comments to weersing@hawaii.edu.

A laboratory-field training course at the University of Hawai'i at Mānoa

Microbial Oceanography: **Genomes to Biomes**



June 08 to July 17, 2009

Application Deadline: February 20, 2009

Sponsored by the Agouron Institute, the University of Hawai'i at Mānoa's School of Ocean and Earth Science and Technology (SOEST), the National Science Foundation (NSF), and the Center for Microbial Oceanography: Research and Education (C-MORE)

The 2009 summer course is offered to graduate students and postdoctoral scholars with interests in marine microbiology and biological oceanography. The course will be lead and directed by Drs. Matthew Church, Ed DeLong, David Karl, Michael Rappé, and Grieg Steward.

For course information and application materials, please visit **cmore.soest.hawaii.edu/agouron/2009/**

Marinobacter aquaeolei image courtesy JGI.

Carbon Dioxide Variability in the Gulf of Trieste: A New Coastal Carbon Time-series Station and EU/US Collaboration

D. Turk, V. Malacic, M. D. DeGrandpre, and W. R. McGillis

The importance of oceanographic time-series for understanding the processes controlling ocean carbon and biogeochemical cycles and the need for international collaboration in supporting and coordinating such efforts has recently been a topic of discussion at OCB workshops. A coastal time-series station VIDA has been launched in the Gulf of Trieste (GOT) in the northern Adriatic, with significant investment from the EU and Slovenia. It also benefits from international collaboration between the Marine Biological Station Piran, Slovenia and US scientists from the University of Montana and Columbia University. Their combined efforts are focused on inorganic carbon cycling in this unique coastal environment.

Coastal marine regions such as the GOT are strongly affected by changes in climate and weather, and play an important role in biological productivity and air-sea CO_2 fluxes. These regions serve as critical links between terrestrial and open-ocean carbon cycling, and potentially contribute large uncertainties to the estimate of anthropogenic CO_2 uptake based on the marine surface pCO_2 distribution. To date, in-depth studies of carbon cycling in coastal waters have been limited mostly to coastal transects that provide interesting snapshots of carbon dynamics. The most comprehensive continental shelf CO_2 flux database currently available (*1*) does not include measurements from the coastal waters of the Mediterranean, and no CO_2 flux data are presently available from the northern Adriatic Sea. Limited data sets, coupled with the complexity of the coastal system, make it difficult to discern the processes governing carbon and nutrient dynamics and the response of these processes to physical forcing in the atmosphere and ocean.

The GOT is a semi-enclosed Mediterranean basin situated in the northern part of the Adriatic Sea (Figure 1), reaching a maximum depth of ~25 m at its center. Though limited in size (~650 km²), the GOT strongly influences the hydrographic properties of the Adriatic Sea (*2*). The complex dynamics that characterize this area are collectively due to freshwater inputs from rivers, northward-flowing water masses along the eastern Adriatic coast, tidal dynamics, and atmospheric forcing. In particular, during Bora wind gales, wind speeds can exceed 30 m s^{-1}, producing a water outflow from the Gulf at the surface, and an inflow at depth, along with strong vertical mixing (*3*). Modeling studies have shown that Bora winds significantly affect heat fluxes (*4*), and while previous studies under high-wind conditions have shown increased CO_2 fluxes, no such studies have been performed in the northern Adriatic.

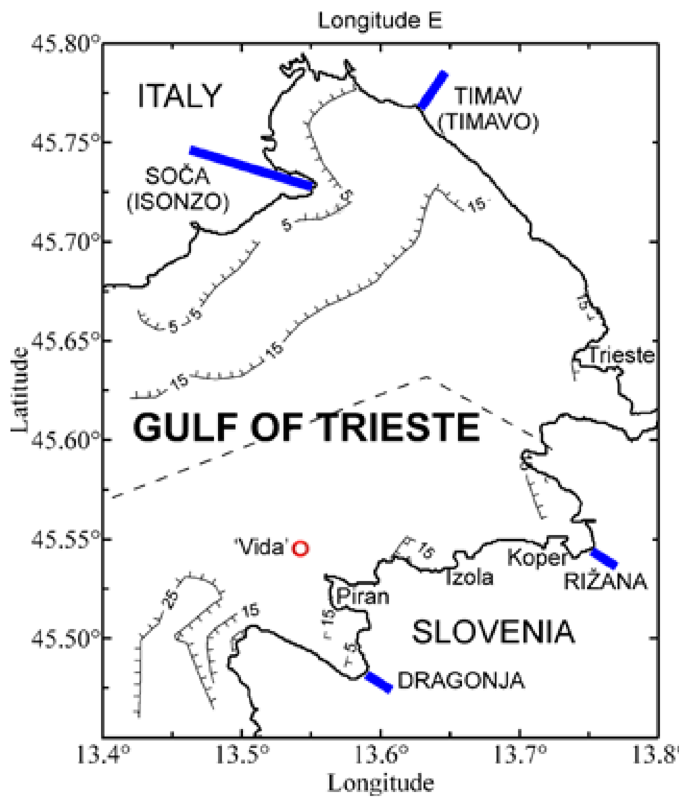


Figure 1. Schematic of the northern Adriatic Sea. The area of interest is a shallow, nearshore location with the time-series station VIDA. The system's hydrographic and meteorological conditions are strongly influenced by the proximity to land and rivers (marked in blue). Large inputs from rivers, such as the Soca (or Isonzo), and the isobaths showing the shallow depth of the Gulf of Trieste illustrate how the system may be significantly influenced by these regional environmental conditions. A moored CO_2 instrument is deployed at 3 m depth on the Piran buoy VIDA.

The GOT area is also affected by riverine inputs that provide the basin with significant flows of freshwater and terrestrially derived nutrients (Figure 1). Freshwater enters the Gulf mainly along the shallow northwestern coast, with the Isonzo River being the dominant source. Freshwater inputs from the karstic Timavo-Reka River and rivers along the southeastern coast such as the Dragonja and Rizana (Figure 1) are comparatively small and have not been recognized as significant contributors to physical and

Figure 2: Piran Buoy VIDA located at 45° 32' 55.68" N, 13° 33' 1.89" E anchored 2.28 km from shore.

biogeochemical processes in the GOT. The Po River on the western side of the northern Adriatic may influence the southern end of the GOT, depending on Bora winds and ambient stratification. Isonzo River discharge typically ranges from 90-130 $m^3 s^{-1}$, and sometimes exceeds 1500 $m^3 s^{-1}$. These exceptionally high flows often occur in spring during snowmelt and in the fall due to increased precipitation, and may cause a marked drop in surface salinities along the northern coastline. Previous work (5) has shown that river plumes not only reduce coastal salinity, but also introduce water with a lower inorganic carbon content, which results in lower $p$$CO_2$ values (e.g., 200 ppm in the Amazon River Plume). To date, no data have been collected to examine riverine influences on CO_2 dynamics in the GOT.

Furthermore, the northern Adriatic is one of the most biologically productive regions in the Mediterranean (6). Studies in the GOT have shown that seasonal plankton dynamics appear to be strongly related to Isonzo river runoff (7), and have also indicated that annual phytoplankton biomass is more closely tied to the excess freshwater discharge during the spring than to annual average discharge. This may be the same for dissolved inorganic carbon (DIC), but the effect of these blooms on the magnitude and distribution of CO_2 is unknown.

The unique combination of environmental influences described above makes this region an excellent study site for air-sea interaction, and the relationship between biology and carbon chemistry. Time-series station VIDA (Figure 2) will advance global understanding of marine CO_2 cycling by providing 1) a valuable data set from an area where such information is currently unavailable; 2) new insights into the environmental conditions controlling CO_2 dynamics in enclosed seas and coastal margins; and 3) information on coastal air-sea CO_2 fluxes under high-wind conditions.

The main objectives of this collaborative effort are to collect and utilize the first measurements of CO_2 in the GOT to 1) Determine whether the Gulf of Trieste in the northern Adriatic Sea is a sink or source of atmospheric CO_2; 2) Study temporal (diurnal, seasonal, and interannual) and spatial variability of air-sea CO_2 fluxes; and 3) Identify and quantify the biological and physical controls of air-sea carbon dynamics in coastal waters of the northern Adriatic Sea over this range of scales. Specifically, we will consider the effects of excess riverine input, eutrophication, phytoplankton blooms, net community metabolism, and high Bora wind events. Since we envision that additional chemical measurements (pH, alkalinity, DIC) will be obtained from VIDA in the future, we will also study the impacts of anthropogenic CO_2 and ocean acidification on marine biogeochemistry and ecosystems in the northern Adriatic.

Recently, a pilot study was conducted with time-series measurements of air temperature (T_a), sea surface temperature (SST), sea surface salinity (SSS), bottom temperature (T_b), wind speed and currents, and aqueous $p$$CO_2$ from VIDA (Figure 3). Aqueous $p$$CO_2$ was measured with an autonomous sensor (SAMI-CO_2 Sunburst Sensors LLC). The measurements were performed at 3 m depth at 15-min

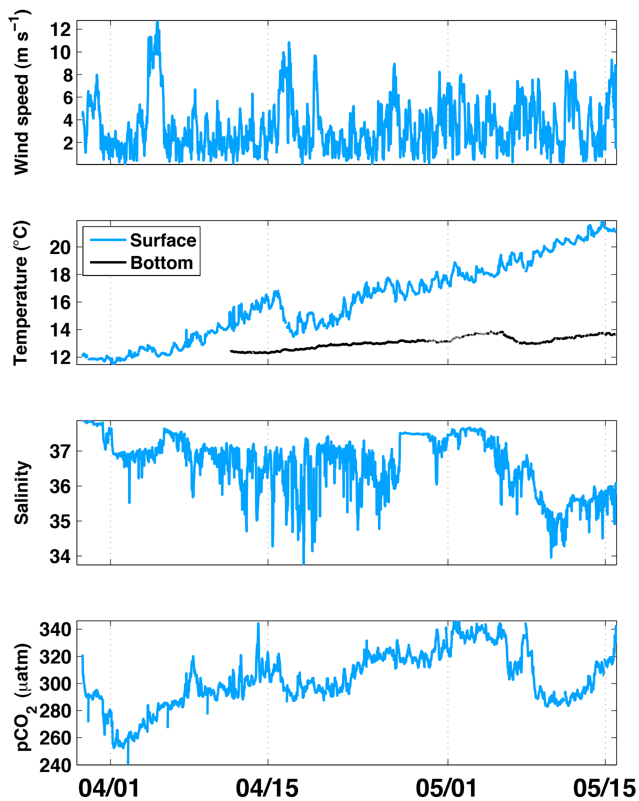


Figure 3: Time-series of wind speed (panel 1, top), SST (blue) and bottom temperature T_b (black) (panel 2), SSS (panel 3), and $p$$CO_2$ (panel 4, bottom) at the time-series station VIDA from April 1 – May 31, 2007.

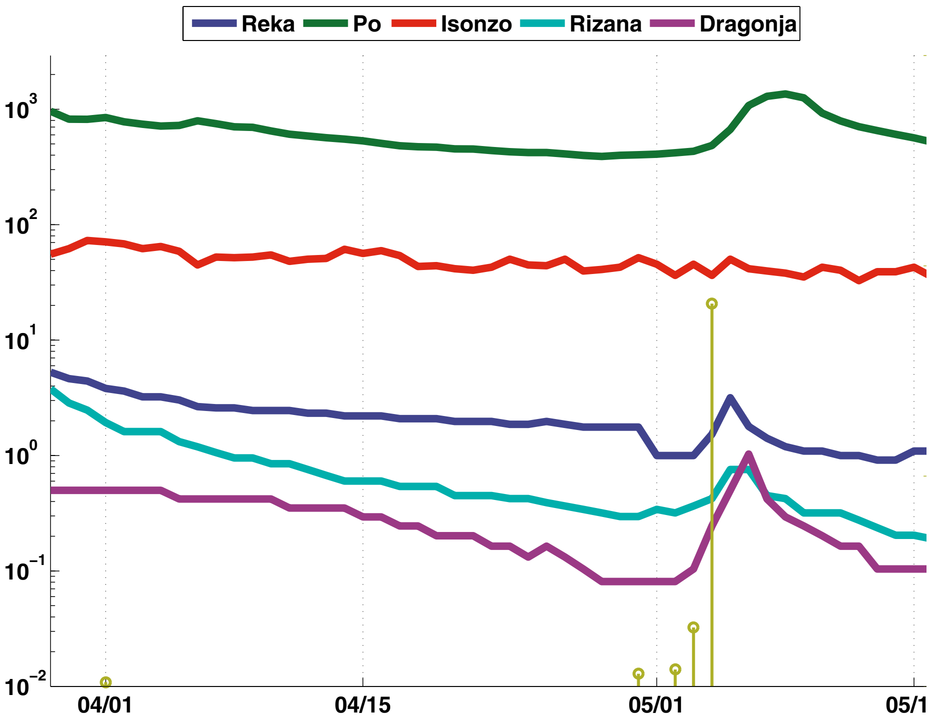


Figure 4: Daily flow rates for five northern Adriatic rivers (Timavo-Reka, Isonzo, Rizana, Dragonja, Po) and rainfall data from the meteorological station in Portoroz, Slovenia.

intervals. These measurements were combined with chlorophyll-a concentrations estimated from SeaWiFS ocean color and daily flow rates for rivers (Slovenian Environmental Agency (ARSO)) that influence the GOT (Isonzo, Rižana, Dragonja, Timavo-Reka, Po), as shown in Figure 1.

During the time period of our measurements (April 1-May 31, 2007), we observed primarily light winds with an average speed of 4.7 m s^{-1}, although there was a two-day period (April 5-6) marking stronger (>10 m s^{-1}) winds. The upper ocean evolved from a salinity-driven stratification in April to a temperature-driven stratification in May. The water pCO_2 ranged from 260-340 µatm, but dropped abruptly by ~60 µatm on April 2 and May 8, 2007, both of which coincided with reduced salinities. Eight-day mean SeaWiFS chlorophyll-a data from VIDA's 2007 position (Piran) and the 3x3- and 5x5-pixel regions centered on the buoy location show an increase of 0.5 and 1.5 mg m^{-3} during the periods from April 2-10 and May 9-17, 2007 (data not shown), respectively. This increase may be associated with increased river nutrient input and stratification.

Daily flow rates for the northern Adriatic rivers (Timavo-Reka, Isonzo, Rizana, and Po) and daily rainfall from a meteorological station in Portoroz, Slovenia are presented in Figure 4. All rivers except the Isonzo showed increased discharge between May 6-8, 2007 due primarily to a rain event on May 4. Although Po flow rates are significantly higher than other rivers, the satellite SST images indicate that the Po plume had not yet reached VIDA's location at the time of our observations. Our data suggest that the Timavo-Reka River, which drains a Karst terrain, was primarily responsible for the observed decrease in salinity, with smaller contributions from rivers Dragonja and Rizana. The average air-sea CO_2 flux during the April/May study period indicated a sink of 4.9 mmol m^{-2} d^{-1}, primarily driven by variations in wind speed.

Preliminary results indicate that: 1) The GOT was a sink for atmospheric CO_2 in late spring of 2007; 2) Aqueous pCO_2 was influenced by fresh water input from rivers and biological production associated with high nutrient input; and 3) Surface water pCO_2 showed a strong correlation with SST and a reasonable correlation with SSS during the presence of the river plume. Spatial surveys of air and water pCO_2, salinity, temperature, dissolved oxygen, pH, total alkalinity (Talk), and DIC will be performed to study changes in seawater chemistry and potential impacts of coastal acidification on marine biogeochemistry and ecosystems. Modeling efforts are also coming together to further examine these processes in the northern Adriatic.

This is an exciting new collaboration to study the carbon cycle in the Mediterranean. The results of this study will be incorporated into the wider scope of the upcoming Mediterranean carbon cycle efforts within the FP 7 EU program and possibly the European Science Foundation (ESF) (both EU mechanisms that allow US participation) and related international programs and activities (i.e. SOLAS, IMBER, and ESF- European Cooperation in Science and Technology (COST) activities). We look forward to interactions with the OCB community.

Contact: Daniela Turk

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OCB Welcomes New Scientific Steering Committee Members

OCB just completed its election of four new Scientific Steering Committee (SSC) members. We would like to welcome Kendra Daly (University of South Florida), a zooplankton ecologist with expertise in biological and chemical sensor development, Curtis Deutsch (University of California, Los Angeles), a modeler who specializes in connections between ocean biogeochemistry and climate, Mary Jane Perry (University of Maine), whose research focuses on photosynthetic production and biological optics, and Walker Smith (Virginia Institute of Marine Science), a phytoplankton ecologist with extensive experience in the Southern Ocean. We would also like to thank departing SSC members Galen McKinley (University of Wisconsin, Madison) and Mark Ohman (Scripps Institution of Oceanography) for their dedicated service to the SSC over the past three years. They have contributed a great deal to the conceptual evolution and implementation of OCB during its critical inaugural period.

The OCB SSC, established in February 2006 jointly by NSF, NASA and NOAA, promotes, plans, and coordinates collaborative, multidisciplinary research opportunities related to carbon cycling and associated marine biogeochemical cycles and ecosystem processes. SSC members serve a term of 3 years with approximately 1/3 membership turnover per year. For more information on OCB and its current SSC, please visit www.us-ocb.org/about.

An OCB Co-Sponsored International Time-Series Meeting

Changing Times: Summary of the International Time-Series Meeting, November 5-7, 2008

Chris Sabine

Despite repeated acknowledgement by the international community that time-series stations are critical for understanding the processes controlling ocean carbon and biogeochemical cycles, maintaining funding support for these platforms has been difficult. Without a coordinated network of scientists using the stations in an organized effort, the community has become dispersed, and research carried out on the stations has focused more on individual PI-based investigations or sensor development. Without international support, it is possible that many stations will not continue in the future.

In 1999, an international group of scientists formed the OceanSITES program to develop a coordinated, interdisciplinary international network of stations, research programs, and scientists to sustain and enhance the use of time-series observations. Although the physical oceanographic community is strongly tied into OceanSITES, the biogeochemical community still lacks coordination. To support and strengthen the ocean carbon and biogeochemical time-series effort, the International Ocean Carbon Coordination Project (IOCCP), OceanSITES, Partnership for Observation of the Global Oceans (POGO), and OCB sponsored a workshop to mobilize the community to participate in this international network and to highlight the critical research that can only be carried out using time-series (both shipboard and autonomous) observations.

The workshop in La Jolla, CA convened 40 participants from 17 countries to review the scientific rationale for sustained time-series observations of carbon and biogeochemistry; the value of networking observations; existing global, regional, and national programs; needs, interests and emerging issues; technology and development issues; and collaboration and networking needs, interests, and possibilities. The workshop included plenary talks, brief presentations of time-series stations from all 17 countries, and break-out groups to compile basin-scale observing system information, identify the major science drivers and development priorities for the next 5-10 years, and identify regional needs and opportunities for networking and coordination.

While many of the carbon and biogeochemistry time-series stations were appropriate for coordination within the OceanSITES framework (e.g., open-ocean, Eulerian, and open data policy), other stations and biogeochemical observation programs were not. The workshop participants agreed to work in collaboration with OceanSITES where appropriate, but also to develop an inventory of all carbon and biogeochemistry observing programs to facilitate coordination and communication amongst them. This inventory would be restricted to observation programs that are meant to be long-term, and would not include process studies or one-off experiments.

For more information and to download the complete workshop report, please visit the workshop website.

Ocean Acidification Update

2009 Federal Ocean Acidification Research And Monitoring Act Update

On January 15, 2009, the Senate approved the Federal Ocean Acidification Research And Monitoring (FOARAM Act of 2009) Bill (Subtitle D of Senate Bill S. 22). The bill is currently under consideration in the House (H.R. 14).

OCB Ocean Acidification White Paper

Ocean acidification is a high priority research topic identified by OCB. The far-reaching effects of ocean acidification on marine biogeochemical cycles and biology, combined with the increasing interest in the topic both nationally and internationally, prompted the OCB-SSC to recommend the formation of an Ocean Acidification Subcommittee. The Subcommittee is being co-chaired by Joan Kleypas (NCAR) and Richard Feely (NOAA/PMEL). With approval from the OCB-SSC, the Ocean Acidification subcommittee members were invited from the U.S. community of researchers. The collective expertise of the Subcommittee encompasses the broad spectrum of topics relevant to ocean acidification.

Recently, Subcommittee members prepared a white paper that outlines a U.S. national ocean acidification research strategy. This OCB white paper will be distributed broadly to those affiliated with ongoing national and international ocean acidification programs and activities, and will be integral to the development of a national ocean acidification research agenda.

NRC Study on Ocean Acidification

The National Research Council of the National Academy of Sciences is assembling a panel of 10-12 scientists to undertake an 18-month study to examine the impacts of ocean acidification on fisheries, marine mammals, coral reefs, and other natural resources. The committee membership will include expertise in chemical and biological oceanography, marine ecology, physiology, ocean-climate modeling, paleoceanography, and resource management and economics. Two OCB documents, the ocean acidification white paper and the ocean acidification scoping workshop report will provide a strong foundation for the NRC study.

OceanObs09 Whitepaper: "An Ocean Acidification Observational Network"

Richard Feely recently solicited input for a community white paper for the OceanObs09 Conference next fall. The white paper would contribute to two sessions at the conference: 1) Large-scale physical properties and 2) Carbon and ecosystems, and will outline a strategy for a global ocean acidification observing system in the major ocean basins and marginal seas, warm water coral reefs, coastal margins, tropical to subtropical open-ocean regions, and high-latitude regions. The white paper will provide observing program recommendations, including temporal and spatial sampling requirements, core variables, measurement methods and protocols, data sharing and release policy, data assembly and archival, data products and synthesis activities, together with a proposal for a sustained network of ocean acidification observations. Please contact Richard Feely for more information.

EPOCA Best Practices Workshop for Ocean Acidification Research

November 19-21, 2008, Kiel, Germany

Maria Hood, Ulf Riebesell, Jean-Pierre Gattuso, Anne-Marin Nisumaa, and Lina Hansson on behalf of all workshop participants

The Best Practices Workshop convened approximately 40 scientists from 10 countries at IFM-GEOMAR in Kiel, Germany to establish an international agreement on best practices for ocean acidification research. The workshop was sponsored by the European Project on Ocean Acidification (EPOCA), the International Ocean Carbon Coordination Project (IOCCP), the Ocean Carbon and Biogeochemistry Program (OCB), and the Kiel "Future Ocean" Excellence Cluster. It covered seawater carbonate chemistry, experimental design of perturbation experiments, measurements of CO_2-sensitive processes, and data reporting and usage. The participants agreed on the recommendations that would appear in a guide as well as on authors and timelines for drafting each section.

While this first workshop was kept necessarily small, the development of the best practices guide is meant to be an open community-wide activity. To view presentations from the meeting, the timeline for drafting and reviewing the guide, and a list of contacts, please visit the EPOCA Best Practices webpage.

OCB Co-Sponsors International Mesopelagic Workshop

Ecological and Biogeochemical Interactions in the Mesopelagic Zone: A Workshop Summary

Debbie Steinberg and Hiroaki Saito

The mesopelagic zone, between ~100-1000 m, is a zone of significant decomposition, recycling, and repackaging of particulate and dissolved organic matter. The interplay between biological and geochemical processes in this zone has significant effects on the magnitude of the biological pump, which in part regulates atmospheric CO_2, and hence can impact climate. While important processes regulating organic matter transformations and remineralization in the mesopelagic can be tightly coupled with the euphotic zone, the time and space scales of these processes are different in the mesopelagic, which is critical to predicting the ability of the biological pump to sequester carbon in the deep ocean.

The aim of the mesopelagic workshop was to identify the current state of our knowledge about mesopelagic food-web processes, particle flux and dynamics, and biogeochemical cycling, and to identify gaps in our knowledge to be pursued in future research programs.

The workshop addressed the following topics: Mesopelagic particulate and dissolved organic matter (POM and DOM) distribution, characterization, and flux; planktonic food web controls on vertical transport, cycling, and composition of POM and DOM; linking microbial and metazoan diversity to function; ecological and biogeochemical approaches to estimating remineralization rates; models; methods and new technologies; regional comparisons in food-web structure and biogeochemistry; potential responses of the mesopelagic to environmental change; and future research in the mesopelagic zone. A special issue of *Deep-Sea Research II*, "Ecological and Biogeochemical Processes in the Dark Ocean," is being assembled that will include a collection of papers from the meso- and bathypelagic zone workshop participants. Here, we briefly present some of the major conclusions from our discussions, and some key issues and challenges for the future.

The rapid attenuation of sinking POC with depth and the steep gradient of other biogeochemical properties is a unique characteristic of the mesopelagic zone compared to the epipelagic and bathypelagic zones. However, current models (*e.g.*, 'Martin curve'-type regressions, ballast model) do not adequately represent the vertical profiles of POM/DOM, nutrients, and oxygen in the (upper) mesopelagic zone. The relative importance of DOC advection, sinking POC flux, and lateral processes to mesopelagic carbon and nutrient input needs to be better quantified. Key issues that still need to be addressed include impacts of advection, episodic events, and regional, temporal, and elemental variations in flux attenuation.

Metazoans and microbes play different roles in controlling vertical transport, cycling, and composition of POM and DOM. The community structure of mesopelagic microbes is closely tied to organic matter composition, and metazoans directly affect organic matter cycling in the mesopelagic through their grazing and metabolism. There also exists a tight coupling between epipelagic and mesopelagic ecosystems via vertical migration behavior of zooplankton, nekton, and top predators. Future studies linking mesopelagic microbial and metazoan diversity to function will require knowledge of microbial and metazoan food web structure, their spatial and temporal distributions (*e.g.,* in relation to oxygen or particle gradients, "hot spots," diel or lunar cycles), and interactions between metazoans and microbes.

We have also learned that carbon inputs and respiration in the dark ocean (mesopelagic and bathypelagic) do not balance, and suggest either an overestimation of both geochemical and ecological estimates of respiration, or an underestimation of POC export. While carbon transport by metazoan vertical migration, lateral advection of suspended POC, chemosynthesis, or comparisons on different time scales may contribute in part to the discrepancy, we need to improve the database of "reliable" measurements in the dark ocean (*e.g.,* increased sensitivity of respiration measurements).

Present biological models in the mesopelagic zone used in global climate models are little more advanced than Martin-curve type regressions, and the community will need to move beyond this. Particle size distributions and the coagulation models that describe them are useful tools for studying the mesopelagic. Efficiency of carbon utilization is a key parameter that needs to be better quantified for use in models, as is relating particle properties such as mass and sinking velocity to size. To provide useful examples of the way forward, models also need to better describe animal dynamics in the mesopelagic (*e.g.,* vertical migration, predator-prey interactions) and fish distribution and behavior (incorporating feeding and mortality rates).

Future research programs in the mesopelagic zone should integrate across disciplines (chemistry, microbiology, ecology, physics), and throughout the water column (tie into surface processes). The location of future studies may include time-series sites, places of contrast or with strong gradients, and where effects of global change are large. Spatial and temporal variability must be considered. It is recommended that the focus be on key species or functional groups, with an effort not only to measure stocks, but to understand mechanisms (for contribution to mechanistic models). Characterization of physical processes (*e.g.*, lateral advection, deep and mode water formation) is important for constraining mesopelagic carbon and nutrient budgets. Technological advances such as pressure samplers for measuring *in situ* respiration, neutrally buoyant sediment trap designs, Remotely Operated Vehicles (ROVs) with sampling capabilities, and AUVs and floats for increased spatial coverage, and underwater observatories for long-term monitoring will help address some of the future challenges in understanding ecology and biogeochemistry of the mesopelagic zone.

To view presentations from the IMBER IMBIZO Mesopelagic workshop, please visit the workshop website.

OCB To Participate in North American Carbon Program 2nd All-Investigators Meeting

The objective of the NACP coastal 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, a critical unknown in the North American carbon budget. If you are interested in participating in the coastal synthesis activities, please visit the NACP interim synthesis activities website and click on the email list link for your region of interest, and you will be prompted to enter your email address and set up a password. To facilitate communication between and within the regional coastal synthesis groups, the NACP office has also set up a wiki. NACP/OCB researchers will present some of the findings of the NACP Interim Synthesis Activity at the 2009 2nd NACP All-Investigators Meeting, which will be held February 17-20, 2009 in San Diego, CA. Please visit http://www.nacarbon.org/meeting_2009/agenda.htm to view the full agenda. In addition to the talks and breakout sessions outlined below, there will be a poster session on the Coastal Synthesis activities on 2/19 at 2 pm.

Coastal Plenary Session (2/18 at 2 pm)

- Toward understanding of carbon fluxes in the coastal oceans: Synthesis activities for the U.S. East Coast and the Gulf of Mexico (Lohrenz *et al.*)
- Recent (and future) advances in carbon cycle Synthesis along the North American Pacific Coast (Alin *et al.*)
- Diagnosing carbon dynamics in diverse ocean environments using *in situ* optical and remotely-sensed data (Salisbury *et al.*)

Coastal Breakout Sessions

2/18, 3 pm: Sampling on the east and west coastal environments of the U.S. for carbon cycling (Chairs: Antonio Mannino, Burke Hales)

2/18, 5 pm: Challenges of modeling the carbon cycle in the oceans (Chairs: Marjy Friedrichs, Raymond Najjar, Eileen Hofmann)

2/19, 5 pm: Coastal interim synthesis planning session* (Chairs: Paula Coble, Simone Alin) **On the basis of what the community decides during this breakout session, the organizers will submit a proposal for funding to hold a series of workshops (following the NACP Meeting) to further develop the coastal synthesis activities.*

Other Coastal Talks

2/17, 2 pm: Carbon measurements along the North American continental margins (Sabine et al.)

2/19, 12 pm: A new method for evaluating the ocean acidification of coastal waters using chemical and hydrographic data (Feely *et al.*)

U.S. Carbon Cycle Science Plan Update

A U.S. Carbon Cycle Science Plan (Sarmiento and Wofsy, 1999) was developed in 1998, published in 1999, and is now essentially 10 years old. Much has been learned, and there is no doubt much yet to be done, but it is time to take a fresh look at the scientific questions and priorities detailed in that report. The carbon cycle science working group will be responsible for developing an updated, revised, or new science plan for U.S. carbon cycle science, identifying challenges and priorities for the next decade (~2010-2020), and involving the broader community.

It is important to note that the 1999 plan, produced by the scientific community, was the single most important and influential input into the Carbon Cycle chapter of the 2003 Strategic Plan for the U.S. Climate Change Science Program (CCSP). The U.S. CCSP is now working on a minor update of its 2003 Strategic Plan and intends to draft a major revision in 2009. CCSP leaders have asked the Carbon Cycle Interagency Working Group (CCIWG) to identify by February 2009 the "building blocks" it will use to develop its contribution to the revised strategic plan.

The Carbon Cycle Science Working Group Co-Leaders invite everyone to provide ideas and suggestions on how to best define the scope and focus of the plan and to expand the three preliminary, overarching questions into a meaningful strategy for coordinated U.S. carbon cycle research over the next decade. This can be done through discussion opportunities at upcoming meetings such as the NACP All-Investigators meeting or the OCB 2009 Summer Workshop, or directly through the U.S. Carbon Cycle Science Program website.

See list of Carbon Cycle Working Group Co-Leaders and Members on page 16

2008 Activity

June/July 2008	Co-leads of Carbon Cycle Science Working Group (CCS WG) appointed
Sept/Oct 2008	CCS WG members appointed
Nov 17-18, 2008	First meeting of CCS WG
Dec 2008	*Eos* Workshop Report (Community and Stakeholder Outreach)
Dec 9-10 2008	CCS WG co-leads report to Carbon Cycle Scientific Steering Group

Projected Timeline

Feb 2009	3-5-page white paper for CCSP describing main thrusts of revised plan
Feb 16-19 2009	North American Carbon Program (NACP) 2nd All-Investigators mtg and second mtg of CCS WG
Summer 2009	OCB Annual Summer Workshop and Third mtg of CCSWG
Sept 2009	CCS WG co-leads present plan at International CO_2 Conf.
Fall 2009	Revised U.S. CCS Plan (first complete rough draft)
Fall 2009	CCS WG Writing Team mtg
Spr/Sum 2010	Complete the writing of the next U.S. Carbon Cycle Science Plan

Points of Broad Consensus from Initial Workshop

- A major reframing of the 1999 Plan is not necessary
- The 1999 Plan remains both intellectually and structurally sound
- Considerable progress has been made on some objectives in the 1999 Plan
- Some new directions should join a list of continuing objectives (*e.g.,* ocean acidification)
- Need to embrace new objectives without further subdividing static budget pie
- Many questions are never fully answered so key is to understand uncertainty and value of reducing uncertainty
- Desirable to have broad community and stakeholder input into new Plan
- Human activities are an important part of the global carbon cycle
- The boundaries of the global carbon cycle program are not absolute and the program needs to be responsive to and interactive with other research programs

Three overarching scientific questions were tentatively proposed by the working group for the new plan:

1) What processes and feedbacks/mechanisms control the dynamics of atmospheric CO_2 and CH_4 (and how)?
2) What are the impacts of the changing carbon cycle (and associated changes in climate) on ecosystems?
3) How will carbon stocks and fluxes respond to policy and carbon management strategies?

Ocean Fertilization Update

Upcoming Event

A Meeting of the Intersessional Technical Working Group on Ocean Fertilization will be held at IMO Headquarters in London from February 9-13, 2009. The Working Group will address the development of an assessment framework on ocean fertilization and the preparation of an initial draft of an information document summarizing the current state of knowledge on ocean fertilization. The Environmental Protection Agency will be leading this effort for the U.S. government in collaboration with other federal agencies.

Recent History

May 2008

United Nations Convention for Biodiversity (CBD) declared moratorium on commercial iron fertilization activities (section C)

October 31, 2008

London Convention adopted resolution on ocean fertilization:

"Ocean fertilization activities, other than legitimate scientific research should not be allowed."

"....scientific research proposals should be assessed on a case-by-case basis using an assessment framework to be developed by the Scientific Groups under the London Convention and Protocol."

January 26, 2009

LOHAFEX (Indo-German scientific experiment in Southern Ocean) experiment was approved by the German Ministry of Education and Research <press release>

SOLAS Update

Email: solas@uea.ac.uk Website: http://www.solas-int.org/

Project Office News

Over the past year, the SOLAS International Project Office has seen some changes, and whilst wishing Dr. Jeffrey Hare and Dr. Justin Ho every success as they return to the USA and Australia, respectively, they have welcomed Dr. Emily Brévière back from her secondment at IGBP as Executive Officer and Miss Georgia Bayliss-Brown has been promoted to Project Officer.

Products: SOLAS E-Bulletin (monthly) and SOLAS Newsletter

Upcoming Events: August 3-15, 2009 (Cargèse, Corsica): SOLAS Summer School and November 16-19, 2009 (Barcelona, Spain): SOLAS Open Science Conference

Scientific Steering Committee: SOLAS thanks its departing Scientific Steering Committee members Osvaldo Ulloa (Chile), Barry Huebert (USA), Christiane Lancelot (Belgium), and Truls Johannessen (Norway), and welcomes Shigenobu Takeda (Japan) as SOLAS Vice-Chair, assisting SOLAS chair Douglas Wallace (Germany), and new Committee members Cécile Guieu (France), Patricia Quinn (USA), Rafel Simó (Spain), and Minhan Dai (China).

IOCCP Update

Global Ocean Ship-based Hydrographic Investigations Panel (GO-SHIP)

Following an action set at the International Repeat Hydrography and Carbon Workshop in Japan (November 2005), the IOCCP and CLIVAR, with input from SOLAS and IMBER, established GO-SHIP to bring together interests from physical hydrography, carbon, biogeochemistry, Argo, OceanSITES, and other users and collectors of hydrographic data, to develop guidelines and advice for the development of a globally coordinated network of sustained ship-based hydrographic sections that will become an integral component of the ocean observing system.

GO-SHIP panel members include Masao Fukasawa (JAMSTEC, Japan), Chris Sabine (NOAA, USA), Bernadette Sloyan (CSIRO, Australia), Toste Tanhua and Arne Koertzinger (IFM-GEOMAR, Germany), Gregory Johnson (NOAA, USA), and Nicolas Gruber (ETH, Switzerland).

Current activities include the revision of the 1994 WOCE Hydrographic Manual and development of a white paper for OceanObs09 for a sustained global program of ship-based hydrography building on the foundations of WOCE/JGOFS and CLIVAR. A website for integrated hydrography is under development, and an email list has been developed to facilitate communication in the hydrography community. To join this list, send an email to sympa@lists.unesco.org with "subscribe go-ship" in the subject line. For more information, please visit www.ioccp.org (>Hydrography >GO-SHIP).

A Global Sea-Surface Carbon Observing System: Assessment of Sea Surface CO_2 and Air-Sea CO_2 Fluxes

Ute Schuster and Piedro Monteiro are leading the development of a white paper for OceanObs09 to outline a roadmap for a system of coordinated surface ocean carbon measurements for the next 10 years that combines VOS, buoys, moorings, gliders, and other platforms making surface CO_2 measurements. The white paper will outline the current state and achievements of the sea surface carbon observing network as well as its limitations, and develop strategic goals for enhancing the network to achieve science goals. For more information, please contact Ute Schuster.

The Surface Ocean CO_2 Atlas (SOCAT) Project

At the "Surface Ocean CO_2 Variability and Vulnerability" (SOCOVV) workshop (April 2007), participants agreed to establish a global surface CO_2 data set that would bring together, in a common format, all publicly available fCO_2 (fugacity of CO_2) data for the surface oceans. The data set builds on work started in 2001 by Dorothee Bakker as part of the ORFOIS project, and now continues as part of the CARBOOCEAN project. Are Olsen and Benjamin Pfeil have compiled data from >2000 cruises (1968 to 2007) with >5 million measurements. This data set will be published as a 2nd-level quality controlled, global surface ocean fCO_2 data set following agreed procedures and regional review, and will serve as a foundation upon which the community will continue to build in the future. The data set will be made available via Live-Access Server in late 2009.

SOCAT has held two technical workshops to discuss 1st and 2nd level QC procedures, and a coastal work-

SOCAT continued on page 18

Carbon Cycle—from page 14

Carbon Cycle Science Working Group Co-Leaders	
Anna Michalak	University of Michigan
Robert Jackson	Duke University
Gregg Marland	Oak Ridge National Laboratory
Chris Sabine	NOAA/PMEL
Carbon Cycle Science Working Group Members	
Robert Anderson	Lamont-Doherty Earth Observatory
Deborah Bronk	Virginia Institute of Marine Science
Kenneth Davis	Pennsylvania State University
Ruth DeFries	Columbia University
Lisa Dilling	University of Colorado
Andy Jacobson	University of Colorado
Matthew Kahn	UCLA
Steve Lohrenz	University of Southern Mississippi
Galen McKinley	University of Wisconsin, Madison
Berrien Moore	University of New Hampshire
Dennis Ojima	The Heinz Center for Science, Economics, and the Environment
James Randerson	University of California, Irvine
Steven Running	University of Montana
Brent Sohngen	Ohio State University
Pieter Tans	NOAA Earth System Research Laboratory
Peter E. Thornton	Oak Ridge National Laboratory
Steven Wofsy	Harvard University
Ning Zeng	University of Maryland
David McGuire	U.S. Geological Survey
Stephen Ogle	Colorado State University
F. Stuart Chapin III	University of Alaska
Scott Denning	Colorado State University

U.S. GEOTRACES

The Implementation Plan for the U.S. GEOTRACES North Atlantic Section is now available here. This document provides the scientific rationale for the section as well as general guidelines for investigators who wish to participate. The Pacific Section Implementation Workshop took place October 1-3, 2008 in Los Angeles, CA (contacts: Jim Moffett and Chris German).

OCB

2009 Activities Calendar

OCB WORKSHOPS

April 28-30: OCB Scoping Workshop: Observing Biogeochemical Cycles at Global Scales with Profiling Floats and Gliders, Moss Landing, CA

June 8-11: OCB Scoping Workshop: New Frontiers in Southern Ocean Biogeochemistry and Ecosystem Research, Princeton, NJ

July 20-23: OCB Summer Science Workshop, Woods Hole, MA

OCB-RELATED ACTIVITIES

February 9-13: Meeting of the Intersessional Technical Working Group on Ocean Fertilization, IMO Headquarters, London

February 10–12: 2009 International Nutrients Scale System (INSS) Workshop, UNESCO Headquarters, Paris

February 17–20: 2nd NACP All-Investigators Meeting, San Diego, CA

February 22-24: Skidaway Institute of Oceanography Geochemistry Symposium, Savannah, GA

February 24-27: Training workshop on the fundamentals of carbon biogeochemistry, Bergen, Norway (download informational flyer from OCB meetings page)

March 2-6: 11th Pacific Science Inter-Congress, Tahiti, French Polynesia, Session 2: "Climate Change and Ocean Acidification" Co-Chairs: Julie Cole and Jean-Pierre Gattuso

March 10-12: Climate change: Global risks, challenges, and decisions, Copenhagen, Denmark

March 10-12: Gulf of Mexico Alliance Nutrient Criteria Research Framework Workshop, New Orleans, LA

March 23-26: GREENHOUSE 2009: Climate change and resources, Perth, Australia

March 25-27: The 3rd Argo Science Workshop: The Future of Argo, Hangzhou, China

March 30-April 3: MARIANDA spring workshop on DIC and Alkalinity measurements, Kiel, Germany

April 19-24: OS8 Open session on SOLAS and sensitivity of marine ecosystems and biogeochemical cycles to climate change, EGU General Assembly, Vienna, Austria

April 26-30: Social Challenges of Global Change - International Human Dimensions Programme on Global Environmental Change (IHDP) Open Meeting, Bonn, Germany

May 18-22: International Association for Great Lakes Research (IAGLR) 52nd Annual Conference, Toledo, OH, Special session on Great Lakes carbon (Contact: Galen McKinley)

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

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

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

November 30-December 11: UN Climate Change Conference, Copenhagen, Denmark

OPPORTUNITIES

OCB Projects and Field Opportunities

OCB Projects include any project that falls within the broad scientific themes of OCB,

OCB Overarching Scientific Themes

Improve understanding and prediction of:

- oceanic uptake and release of atmospheric CO_2 and other greenhouse gases;
- climate-sensitivities of biogeochemical cycles and interactions with ecosystem structure

OCB Currently Identified Priorities

- Ocean acidification
- Terrestrial/coastal carbon fluxes and exchanges
- Climate sensitivities of and change in ecosystem structure and associated impacts on biogeochemical cycles
- Mesopelagic ecological and biogeochemical interactions
- Benthic-pelagic feedbacks on biogeochemical cycles
- Ocean carbon uptake and storage

and is self-identified by the PI(s) as an OCB activity. Current OCB projects include a combination of individual PI grants and mid-sized projects (multiple PIs), with a view toward larger coordinated studies. We are continually building on the project list for the OCB webpage and invite you to send us information about any of your projects that you feel address the broad scientific themes of OCB. We have also included a heading for "Upcoming Field Opportunities" on the OCB projects page to help scientists in the OCB community gain access to potential data collection opportunities and build new collaborations. Please be as specific as you can when advertising or seeking to participate in upcoming field opportunities (e.g., cruise dates, locations, measurement capabilities, etc.). Please send all information about OCB projects and upcoming or ongoing field campaigns to Heather Benway.

FUNDING OPPORTUNITIES

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

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

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

NSF Emerging Topics in Biogeochemical Cycles: Proposals must cross disciplinary boundaries of two or more divisions in NSF Geosciences (e.g. ATM, EAR, OCE) or of at least one division in Geosciences a nd a division in another NSF directorate. Relevant proposals are to be submitted to an existing NSF Geosciences (GEO) program according to the program's regular target or deadline dates. A GEO program must be identified as the lead program.

SOCAT—*from page 16*

shop was held in January in Kiel to discuss special needs for coastal zone data in the SOCAT data set. A regional workshop for the Pacific and Indian Oceans will be held from March 18-20 in Japan. A regional workshop for the Atlantic and Southern Ocean regions will be held this summer. For more information: http://www.ioccp.org (>Synthesis Groups >SOCAT).

CORRECTION

We would like to report a correction to the previous report of the 2008 OCB Summer Workshop published in the Fall OCB newsletter. In the description of presentations from theme 2, the second sentence, referring to Samar Khatiwala's talk, should read: **"One speaker described the application of transit-time distributions to reconstructions of anthropogenic carbon uptake in the world's oceans."**

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