Ocean Carbon and Biogeochemistry News
Studying marine biogeochemical cycles and associated ecosystems in the face of environmental change
Volume 5, Number 1 • Winter 2012

Coastal Carbon Synthesis for the Continental Shelf of the North American Pacific Coast (NAPC): Preliminary Results

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** indicates NAPC or sub-regional (co-)lead.*

Introduction

Although coastal oceans occupy a small percentage of the ocean area or volume, their carbon fluxes are disproportionately large. Primary production, export, and burial of organic material in the coastal ocean occur at rates higher than the open ocean. In particular, coastal upwelling regions undergo exceptional variability in carbon fluxes. During upwelling periods, subsurface water supersaturated in CO_2 and high in nutrients is drawn to the surface by equator-ward winds where it stimulates productivity, and an efficient biological pump works to draw the carbon back down into the sinking organic carbon pool. On the shelf, the organic carbon dynamics and benthic-pelagic coupling determine whether or not the CO_2 will be respired on the shelf and returned to the atmosphere on seasonal timescales, buried in sediments over the long term, or exported past the shelf break and sequestered from the atmo-

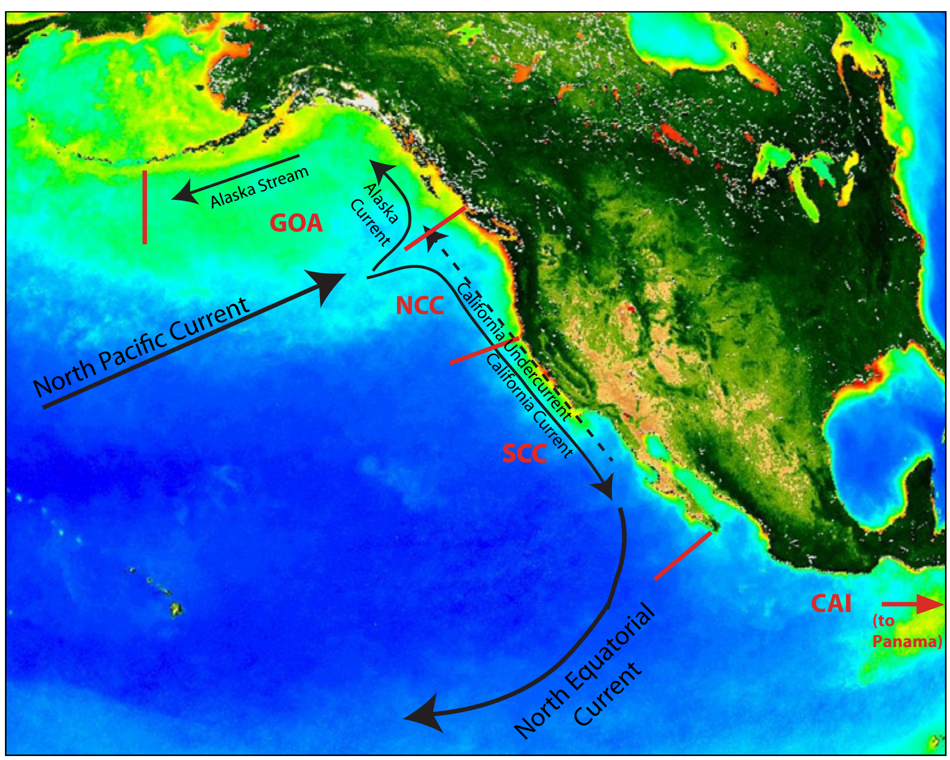

Figure 1. Ocean color map from SEA-WIFS during the summer showing the extent of the North American Pacific Coast coastal synthesis region. The four sub-regions for this synthesis are delineated with red lines at the boundaries: the Central American Isthmus (CAI), Southern California Current (SCC), the Northern California Current (NCC), and the Gulf of Alaska (GOA). Major currents for the region are depicted with solid black lines for surface currents and dotted black lines for subsurface currents.

sphere on timescales corresponding to the ventilation of the permanent thermocline of the North Pacific. The balance between the outgassing of subsurface supersaturated water and the active biological pump determines the carbon budget in these highly variable regions.

The west coast of North America includes a classic eastern boundary upwelling region. In the spring and summer, seasonal northerly winds drive a coastal upwelling circulation characterized by equator-ward flow in the near-surface jets with associated eddies and fronts that extend offshore, particularly in the mid-southern latitudes of the upwelling region. To the north, freshwater and tidal influences become more important in the cross-shelf exchange and the system transitions to a downwelling-dominated shelf.

As part of the North American Carbon Program's Interim Synthesis activities, a coastal carbon synthesis is being performed with the focus being the development of carbon budgets for the main North American coastal regions using the published literature as well as recently generated, unpublished estimates. The main goal is to assess the state of knowledge of coastal carbon budgets and highlight areas of greatest uncertainty to motivate future studies.

The Domain

The Pacific Coast of North America is the longest coastline on the continent, extending from Panama through the Gulf of Alaska. Because carbon cycle drivers vary substantially along this continental margin, we have followed the North American Continental Margins Report in dividing the continental shelf of the west coast of North America into four sub-regions (Fig. 1): the Central American Isthmus (CAI – Panama to the southern tip of Baja California), Southern California Current (SCC – southern tip of Baja California to Cape Mendocino), the Northern California Current (NCC – Cape Mendocino to the northern end of Vancouver Island), and the Gulf of Alaska (GOA – north of Vancouver Island to the Aleutian Archipelago). While all sub-regions experience some degree of seasonal wind-driven upwelling, each sub-region has distinct physics and biogeochemistry. The Pacific coast of the CAI experiences intense, persistent wind events, large eddies, and high waves, which combine to produce upwelling and strong near-shore mixing. In the SCC, the shelf is so narrow that upwelling filaments often spill over onto the water column seaward of the shelf break. Upwelling conditions persist year round due to the favorable wind-forcing year round, and riverine input is minimal. The NCC has broader shelves, seasonal upwelling as well as downwelling, and large river and estuarine inputs, mainly from point sources such as the Columbia and Fraser rivers, and Puget Sound and from multiple small mountainous rivers lining the coastline. The GOA contains the widest shelves on the coastline, is a downwelling-dominated coastal region, and is characterized by strong seasonality typical of high latitudes. Rivers, snowpack and glacier melt combine with strong seasonal precipitation and insolation changes to alter the stratification and circulation of the region, and provide significant inputs of sediment and terrestrial carbon and nutrients. Tidal transport and large eddy features dominate the exchange with the open ocean in this region.

Carbon fluxes of interest from Observations

To maintain consistency with the other North American coastal carbon synthesis groups, we are estimating fluxes at the boundaries between the coastal water column and four key interfaces from observations and models where available: (1) land, (2) atmosphere, (3) sediments, and (4) open ocean. The internal fluxes of primary production, remineralization, and net community production have also been considered. Units used in the analysis are Tg C y^{-1} or g C m^{-2} y^{-1}.

We present preliminary carbon cycle budget numbers for the North American Pacific Coast (NAPC) here (Fig. 2), with an emphasis on the Northern California Current carbon budget, as this effort is farthest along. Source waters for the California Current include the North Pacific Current and the California Current from the north, and the Davidson Current in the winter, and the California Undercurrent from the south.

3.1 Fluxes from land

Riverine delivery of carbon to the ocean across the sub-regions of the NAPC varies by an order of magnitude or more for all three fractions of carbon considered here: dissolved organic carbon (DOC), particulate organic carbon (POC), and dissolved inorganic carbon (DIC) (results of Mayorga, Hartmann, and Moosdorf in preparation for RECCAP chapter on global river carbon fluxes). The lowest DOC, POC, and DIC inputs from land are found in the SCC and reflect the reduced freshwater input compared to other regions. The CAI receives inputs of 1–2 Tg C y^{-1} for all three fractions of river-borne C. NCC and GOA sub-regions generally receive the highest terrestrial loads of C (with the exception of POC in the NCC, all other river C fluxes are >2 Tg C y^{-1}), with the highest DOC load in the NCC and the highest POC and DIC loads in the GOA. A rich literature on watershed sediment yields and riverine delivery of POC to coastal oceans exists, with less frequent reports on DOC yields and delivery (e.g., Needoba and others, in prep.).

Results of global river carbon flux models suggest that >50% of dissolved

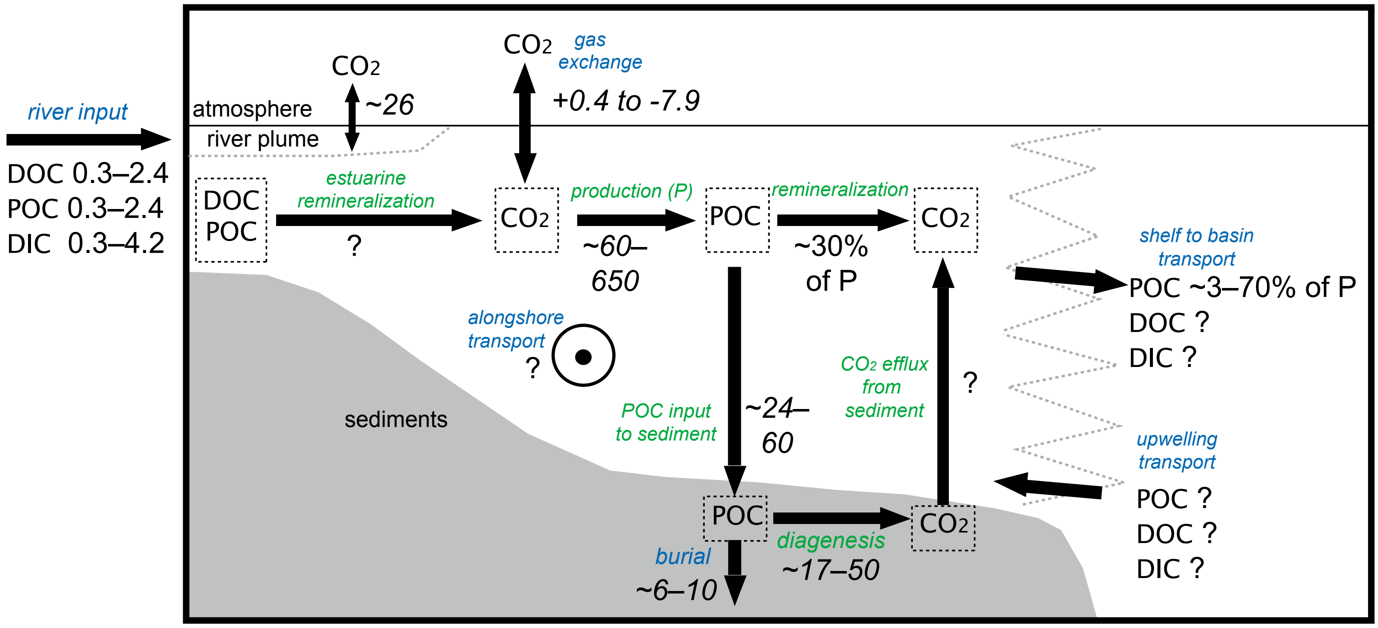

Figure 2. Generalized diagram of a coastal carbon cycle for the North American Pacific Coast, with terrestrial input fluxes in Tg C y^{-1} and all other flux estimates in g C m^{-2} y^{-1} (in italics to highlight difference in units). Physical fluxes across key interfaces are indicated with blue labels, and biological transformations in green. Question marks indicate that annual flux rates or percentages are not available. Base diagram courtesy of J. Mathis and N. Bates.

carbon (i.e. DIC + DOC) inputs to the NCC and SCC come from the largest rivers in each region, whereas only ˜30% of POC inputs come from major rivers, with the remainder being contributed largely by small mountainous rivers (SMRs). The literature on SMRs indicates considerable complexity in the dispersal and deposition of POC inputs once they arrive in the coastal ocean, such that cross-shelf transport percentages, burial rates, etc., can vary substantially offshore from these watersheds. More work is needed to integrate and extrapolate observational POC measurements in order to be able to compare model estimates with observational estimates in any detail.

3.2 Air-sea fluxes

The net exchange of CO_2 with the atmosphere across the NAPC is characterized by strong spatial and temporal variation and reflects complex interactions between biological uptake of nutrients and degassing of nutrient- and CO_2-rich upwelled waters. The simplest observational estimates of air-sea flux for typically small coastal areas are computed from pCO_2 measurements and wind- and temperature-based exchange coefficients. Purely observational studies cannot always provide annual estimates of net air-sea CO_2 exchange because available data generally have limited spatial and temporal coverage relative to the system variability. Consequently, a more detailed treatment and synthesis of these studies is needed to put them in context with the larger scale estimates; this will be done in upcoming publications resulting from this synthesis effort.

A growing number of coastal air-sea flux studies have used extrapolation techniques to estimate fluxes across the coastal oceans on regional to continental scales. The coastal ocean chapter of the First State of the Carbon Cycle Report (*SOCCR*) suggests that the mean annual flux across the entire NAPC region (8–55°N) within a degree of the coast is a weak source of CO_2 to the atmosphere (2.1 ± 17.1 Tg C y^{-1}), with the three 1°x1° boxes offshore from the coast being net sinks of -3.7 to -7.0 Tg C y^{-1} with the uncertainty (reflecting seasonal variability) decreasing toward the open ocean.

Breaking down the *SOCCR* synthesis using our sub-regions, the CAI and the SCC appear to be sources of CO_2 to the atmosphere, and the NCC and GOA sinks. An estimate by Hales and co-authors using self-organizing maps of biogeochemical regions along with mechanistic relationships for estimating surface pCO_2 suggests that the region between 22° and 55°N is a sink (-14 ± 14 Tg C y^{-1}). Although the geographic domains of the *SOCCR* estimate and that of Hales and co-authors do not entirely overlap, ongoing work by Alin, Hales, and others uses the same approach as Hales and co-authors over a region more comparable to the *SOCCR* domain (5–50°N), and addresses the role of seasonal variability more explicitly to improve annual air-sea flux estimates; these results suggest that the region is an even larger sink. Examining the *SOCCR* results and those of Hales, Alin, and co-authors on a per-unit-area basis may thus yield more meaningful insights; there is still a wide range of flux estimates at the scale of the largest estimates (Fig. 2). When the per-area flux estimates in 5–10° latitude bands are compared, the range increases as a result of reduced spatial averaging, and follows the pattern of a larger source or weaker sink at low latitudes and a stronger sink at higher latitudes (for an overall range of +33 to -25 g C m^{-2} y^{-1} from 8 to 55°N).

Results of an extrapolation from the SCC by Pennington and others suggest that on an annual basis, the CO_2 fluxes between the atmosphere and ocean balance to zero. They found the physical upwelling of CO_2 nearshore in the spring and summer to be offset mostly by biological drawdown offshore in the fall and winter. This highlights the need for increased temporal coverage for observations and improved extrapolation and modeling studies.

Several observational studies by Evans, Hales, and co-authors as well as modeling studies by Ianson, Bianucci, and co-authors indicate that the biological pump and preformed nutrients in the NCC are sufficient to drive CO_2 drawdown from the atmosphere, making the region a net sink, which is consistent with all of the larger-scale modeled and extrapolated estimates above.

Freshwater inputs in the NCC and GOA also influence air-sea CO_2 flux and coastal carbon dynamics, although there are no published studies to date explicitly examining the effects of river estuaries and plumes on air-sea exchange along the northern NAPC margin. Evans and co-authors have a study in revision estimating the net air-sea flux of the Columbia River estuary at ~26 g C m^{-2} y^{-1}, which is offset by net uptake in the river plume and is lower than estimates from other estuaries with similar typologies. We are not aware of other estimates that isolate the effects of freshwater input from larger regional averages.

A coupled physical-biogeochemical model for the California Current from 31° to 45°N (0–800 km offshore) suggests that the whole analysis domain of the model acts as a net source of CO_2 to the atmosphere, outgassing 7.5±0.6 Tg C yr^{-1} (~5 g C m^{-2} y^{-1}), where the ± uncertainty represents model-generated internal and interannual variability (Turi, Lachkar, and Gruber, in prep.). The model indicates that all but the northernmost extent of the domain (~42–45°N) acts as a net source of CO_2 to the atmosphere.

Taken as a whole, the various estimates disagree as to whether the entire region is a source or a sink. However, while the magnitude and sign of the net annual flux vary across studies, the pattern of a low-latitude source (or weaker sink) and a high-latitude sink (or stronger sink) is consistent across models and observations. The high spatial and temporal variability in $p\mathrm{CO}_2$ observed in this region results in the large uncertainties and conflicting conclusions across the NAPC region. Further, the studies mentioned here all differ in their geographic extent (both latitude range and distance offshore), making direct comparison of regional flux results less than straightforward. Consistent spatial extent (for models and extrapolations) and increased temporal coverage (for observations, models, and extrapolations) would improve the comparability of estimates.

3.3 Carbon fluxes at the sediment-water interface

Detailed comparative studies have been done on the effects of oxygen exposure time on sediment burial and burial efficiency relative to the delivery of sediment to the ocean floor in at least a few locations along the NAPC. A series of studies by Hartnett, Devol, and co-authors compared sediment diagenesis on the Washington and Mexican continental shelves and slopes, and indicated that burial efficiency ranged from 17 to 36% depending on oxygen exposure, with higher burial efficiencies on the Mexican shelf/slope, where the oxygen deficiency is stronger at shallower depths. On the Washington shelf/slope, they found that delivery of organic carbon to the sediment surface was on the order of ~60 g C m^{-2} y^{-1}, of which ~50 g C m^{-2} y^{-1} was remineralized and ~10 g C m^{-2} y^{-1} ultimately buried. In contrast, on the Mexican shelf and upper slope, organic carbon inputs, remineralization, and burial were estimated at ~24–27 g C m^{-2} y^{-1}, ~17–21 g C m^{-2} y^{-1}, and ~6–7.5 g C m^{-2} y^{-1}, respectively. Data compiled from sediment trap studies and extrapolated from observations in the SCC by Pennington and others found delivery of carbon by vertical sinking to the sediments at 100 m to be ~60 g C m^{-2} y^{-1}. Estimates for the flux of carbon to 100 m from Martin, Pilskaln, and Berelson range from 42–86 g C m^{-2} y^{-1} from various sub-regions of the SCC. More work is needed to compile other estimates across the full NAPC study region.

3.4 Cross-shelf exchange

Cross-shelf exchange of carbon occurs in the California Current System mostly in response to wind-driven circulation and eddies, but river plumes and tides have been shown to enhance offshore transport in the NCC. In the extrapolation from observations of Pennington and others, the export of organic carbon to sediments in the SCC is less than 10% of the total production. A data-driven budget performed by Hales and co-authors for oxygen and POC on the Oregon coast suggested the majority of the production is exported off-shelf, and another study by Keister and others found large amounts of zooplankton biomass exported hundreds of kilometers offshore.

Published modeling results from the SCC have also shown the majority of the productivity to be exported from the shelf. Within 100 km of the modeled coast, Turi and co-authors (in prep.) observed a significant decoupling of local biologically produced organic carbon (NCP: net community production) and vertically exported organic carbon. Between 55% (SCC) to 75% (NCC) of multi-year average NCP is exported below the euphotic zone, while the rest is transported offshore. In their offshore domains, this decoupling does not occur; all locally produced organic carbon is exported to below the euphotic zone. A model by Ianson and Allen for the Vancouver shelf finds less than half of the productivity is exported from the shelf. *In situ* measurements from the SCC also suggest a large spatial decoupling between new and export production due to offshore POC transport.

Both published and more recent modeling results from Gruber, Turi, and co-authors indicate that lateral offshore fluxes are responsible for a large transport of dissolved inorganic carbon (DIC) to the open ocean, whereof ~50% stems from upwelling and the rest from lateral alongshore advection in multi-year averages. The northern SCC experiences the largest upwelling and offshore transport fluxes in terms of DIC transport per unit time and surface area in the model.

Uncertainties in these estimates are high, again due to the large spatial and temporal variability in the region. Comparisons between published studies and more recent results are hindered by the different spatial domains used for describing the key carbon fluxes. Effort is needed to compare model estimates over the same spatial extent and to compare models and observations at locations throughout the domain.

3.5 Production and Remineralization

Within the NAPC, the fixation of CO_2 through photosynthesis in the water column of the California Current during the upwelling season is among the highest rates in the world ocean. Tremendous variability exists on the shelf in both space and time. Historical observations from the NCC by Anderson indicate that primary production fluxes range by a factor of three between the open ocean, river plume, and the upwelling region, with the highest values occurring in the upwelling region (~150 g C m^{-2} y^{-1}). Areal estimates of net primary production measurements along the Oregon and Washington coastlines also show an order of magnitude of variability (range in mean values in the NCC from studies by Small, Menzies, Anderson, Perry, and co-authors: ~60–650 g C m^{-2} y^{-1}).

Synthesis and extrapolation of data from the SCC by Pennington and others resulted in total production estimates in the middle of the wide range reported above (345 g C m^{-2} y^{-1}). By comparison, satellite estimates by Kahru and co-authors of primary production in the SCC (calibrated with *in situ* CalCOFI data) suggest estimates of 430–520 g C m^{-2} y^{-1} for the region from 0–100 km offshore.

Model results from Turi and co-authors identify the highest net primary production (~170–230 g C m^{-2} y^{-1}) in the SCC nearshore region, compared to ~140 g C m^{-2} y^{-1} in the NCC nearshore region. Biological productivity in their model is 2 (NCC) to 3.5 (SCC) times higher in the nearshore domains compared to the offshore domains.

Remineralization of organic matter on the shelf remains one of the least constrained fluxes in this region (with the exception of remineralization rates at the sediment-water interface in section 3.3). Modeling results by Spitz and co-authors from the Oregon coast indicate that up to a third of the primary productivity is respired on the shelf.

Further work is needed to reconcile the discrepancies in estimates of primary production generated by way of *in situ* measurements, satellite-based estimates, and models. Additional work is also planned to determine whether further information on remineralization rates in the NAPC exists.

Summary and Outlook

The preliminary carbon budget for the Pacific Coast of North America (Fig. 2) cannot be viewed as a single, coherent budget at this time. Discrepancies in the spatial extent of many estimates make direct comparisons difficult. Despite considerable remaining uncertainty, the best known fluxes appear to be the air-sea exchange of CO_2 and terrestrial inputs. The least constrained fluxes are remineralization, cross-shelf exchange, and carbon metabolism in estuaries. Spatial trends were typically consistent among models and observations, but the magnitude of the fluxes varied widely. While more modeling and observational studies exist than are presented here, relevant fluxes for the carbon budget were often unreported. In the short term, the fluxes described above will be refined by additional synthesis and analysis of existing data and models, with a goal of publishing a series of coordinated papers on carbon budgets in the four sub-regions, as well as possible cross-regional syntheses on process areas such as air-sea exchange. In the long-term, investments in research and monitoring will be needed to better constrain the fluxes of many of the highly variable regions described in this report. Members of the community are urged to contact Simone Alin to contribute information and/or expertise to this ongoing synthesis effort.

Natural Iron Fertilization in the Southern Ocean: Kerguelen Ocean and Plateau Compared Study (KEOPS) Completes Second Cruise

by Stéphane Blain (Microbial Oceanography Laboratory, Université Pierre et Marie Curie)

The Southern Ocean is an important region for the global carbon cycle because it represents an important CO_2 sink. The magnitude of this sink in the present and in the past is still highly debated. A recent study (Le Quéré et al., 2007) showed that the Southern Ocean CO_2 sink has weakened between 1987 and 2004 by 0.08 pg C yr^{-1}, very likely due to the increase of Southern Ocean winds related to climate change. Theory and modelling studies also point out the sensitivity of atmospheric CO_2 to changes in ocean biology in the Southern Ocean. This sensitivity is related to nutrient utilization in the surface waters. Studies suggest that increasing the deep ocean ventilation due to increased vertical mixing or enhancement of Southern Ocean winds would result in an increase in atmospheric CO_2. In contrast, stratification of the Southern Ocean would deplete surface nutrients, which would decrease atmospheric CO_2. In the surface waters of the Southern Ocean, the utilization of nutrients is strongly limited by the availability of iron, as demonstrated

Figure 1: Ocean color image of the bloom on November 11, 2011. The black squares denote KEOPS-2 station locations. The grey surface at 49°S, 70°E is Kerguelen Island. Color scale: Chlorophyll concentration (µg L^{-1})

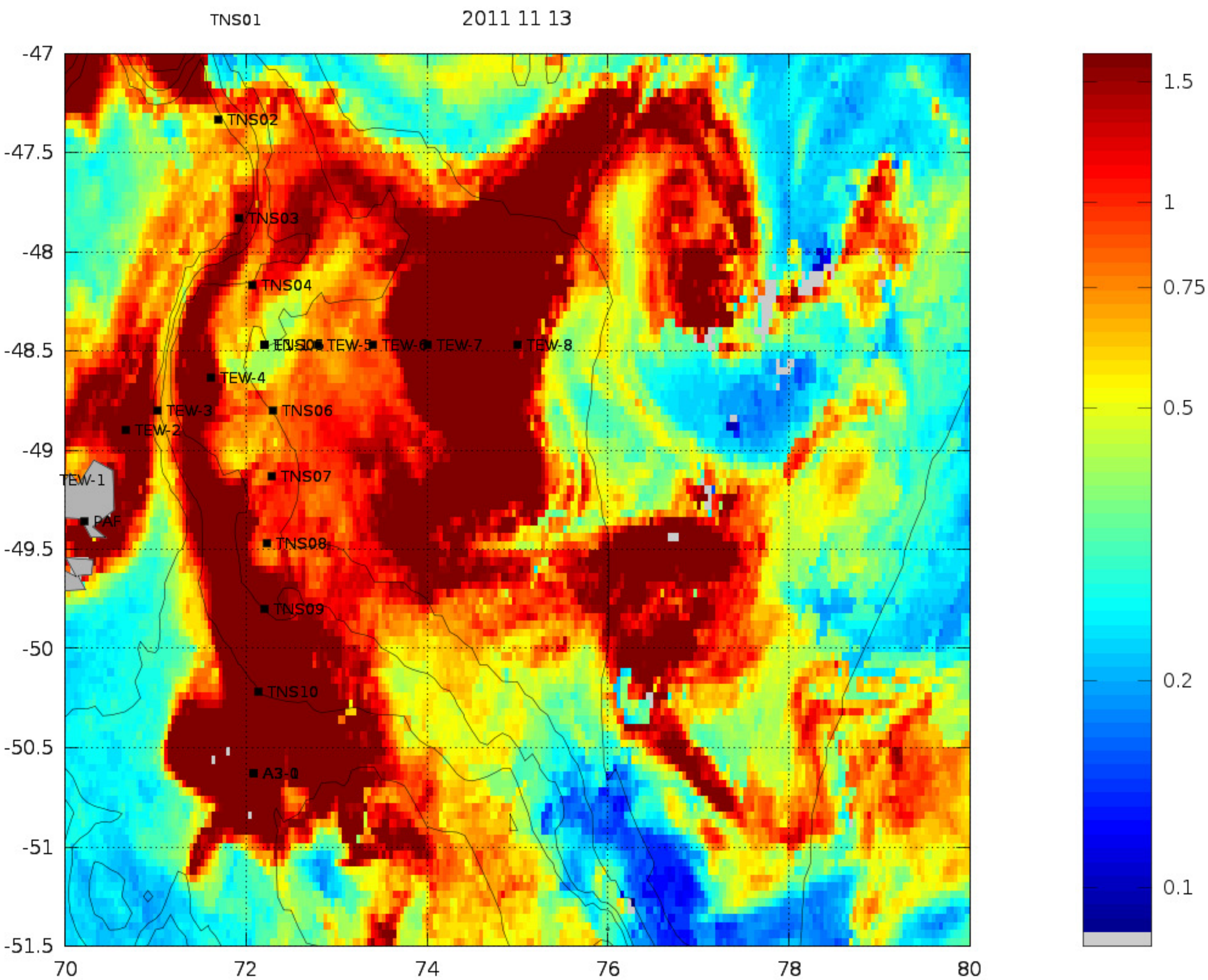

Photo 1: R/V *Marion Dufresne* during KEOPS-2 cruise. Note the heli-deck full of laboratory containers.

by artificial and natural iron fertilization experiments (Blain et al., 2007; Boyd et al., 2007). Therefore, fertilization (natural or artificial) of this region is expected to have a large impact on atmospheric CO_2 uptake. However, other properties such as elemental ratios and gas exchange must also be considered.

Numerous expeditions have confirmed the presence of heavy biomass in the vicinity of islands in the Southern Ocean. Today, ocean color satellite images provide daily snapshots of surface water chlorophyll concentrations, thus revealing information about the spatial distribution and temporal variability of these blooms. As part of the KErguelen Ocean and Plateau compared Study (KEOPS), a cruise, KEOPS-1, took place in January-February 2005 to investigate the annual bloom developing above the Kerguelen Plateau. KEOPS-1 confirmed that natural iron fertilization was the primary driver of the bloom (Blain et al., 2007). Furthermore, this experiment demonstrated that the efficiency of natural iron fertilization, defined as the ratio of carbon exported to the amount of iron supplied, was 10-100 times higher than the efficiency of previous artificial iron fertilization experiments (Boyd et al., 2007).

We found that the large phytoplankton bloom over the Kerguelen Plateau in the Southern Ocean was sustained by the supply of iron and major nutrients to surface waters from deep water below, suggesting enhanced vertical mixing as the primary mode of iron addition, as opposed to dust deposition from above. In the context of the iron hypothesis, the results of KEOPS are relevant to paleo-scenarios in which more iron would have been supplied by Antarctic upwelling during glacial periods. However, the mode of iron addition above the Kerguelen plateau and the concomitant supply of major nutrients are not indicative of iron fertilization by episodic dust deposition. Therefore, KEOPS-1 is not an appropriate analog against which to evaluate geo-engineering proposals of large-scale artificial Fe fertilization experiments for CO_2 mitigation. The continuous fertilization of surface waters of the Kerguelen Plateau drove a complete change in the ecosystem with important consequences for biogeochemical fluxes (Blain et al., 2008 and other papers http://www.obs-vlfr.fr/keops2). These changes were not as straightforward as a simple increase in the rates and processes observed in the unfertilized area. KEOPS-1 demonstrated the importance of natural laboratories like the Kerguelen Plateau to augment our understanding of ocean iron fertilization, but we have only scratched the surface in terms of new discoveries in this area.

KEOPS-2 was designed to further investigate this natural laboratory and address new questions:

1.) Which processes supply and retain bioavailable iron in surface waters, and on what time scales do they occur?
2.) What is the degree of coupling/decoupling between the Fe, C, N, P, and Si cycles in the fertilized region?
3.) Can we characterize the pathways that lead to the remineralization or export of organic matter produced in surface waters?
4.) How is the biological diversity affected by natural iron fertilization?
5.) Can we understand the seasonal and interannual variability of the bloom?

The bloom around Kerguelen can be divided into two different regions. During KEOPS-1 we focused on the bloom region located above the plateau between Kerguelen and Heard. This bloom was relatively well constrained by the bathymetry, which facilitated the comparison between the fertilized and unfertilized areas. Though fruitful, this approach had a few drawbacks. For example, the export of carbon in the deep water could not be studied due to the relatively shallow bathymetry (~500 m). The other region where blooms have been observed is located east of Kerguelen Island (Fig. 1). The bloom starts earlier in the season and extends over deep waters up to 4,000 m. In this region, iron is more likely supplied by horizontal transport, making the mechanism of iron fertilization quite different from that observed during KEOPS-1.

The KEOPS-2 cruise took place

in October-November 2011 aboard the R/V *Marion Dufresne* (Photo 1). This timing enabled us to sample the pre-bloom conditions (i.e. winter iron concentrations), and then track the development of the bloom. The bloom located east of Kerguelen is highly variable in space and time due to mesoscale processes, making the sampling strategy more challenging. Therefore, real-time satellite images (ocean color and altimetry) in combination with the trajectories of 50 drifters released during the first part of the cruise were used to carefully choose station locations. Utilizing this strategy, the scientists of the KEOPS-2 international consortium (France, Belgium, Australia, Chili, South Korea, UK, USA) conducted a successful multidisciplinary study. We carried out 359 deck operations during 36 station occupations. The sampling strategy included the following:

- Full water column sampling using classical and trace metal-clean rosettes, in situ pumps, and plankton nets
- Surface sediment sampling using multicorers
- Drifting sediment traps to sample sinking material
- Argo and Bio-Argo floats
- Two moorings equipped with sediment traps, which were left at two different sites for collection of exported material throughout the entire season

During the cruise, members of the scientific party (Photo 2) conducted numerous chemical analyses (e.g., dissolved iron concentrations), process studies (e.g., deck incubations, perturbation experiments in microcosms, continuous cultures of natural bacterial communities, incubations of sediment cores, etc.), and microscopic observations of living phytoplankton

Photo 2: KEOPS-2 team leaving the roaring forties.

and zooplankton. Samples have been distributed to laboratories on land, and will be analyzed in the coming months using published techniques. Initial KEOPS-2 results will be discussed during the post-cruise meeting in September 2012.

For more information, please visit the KEOPS web site.

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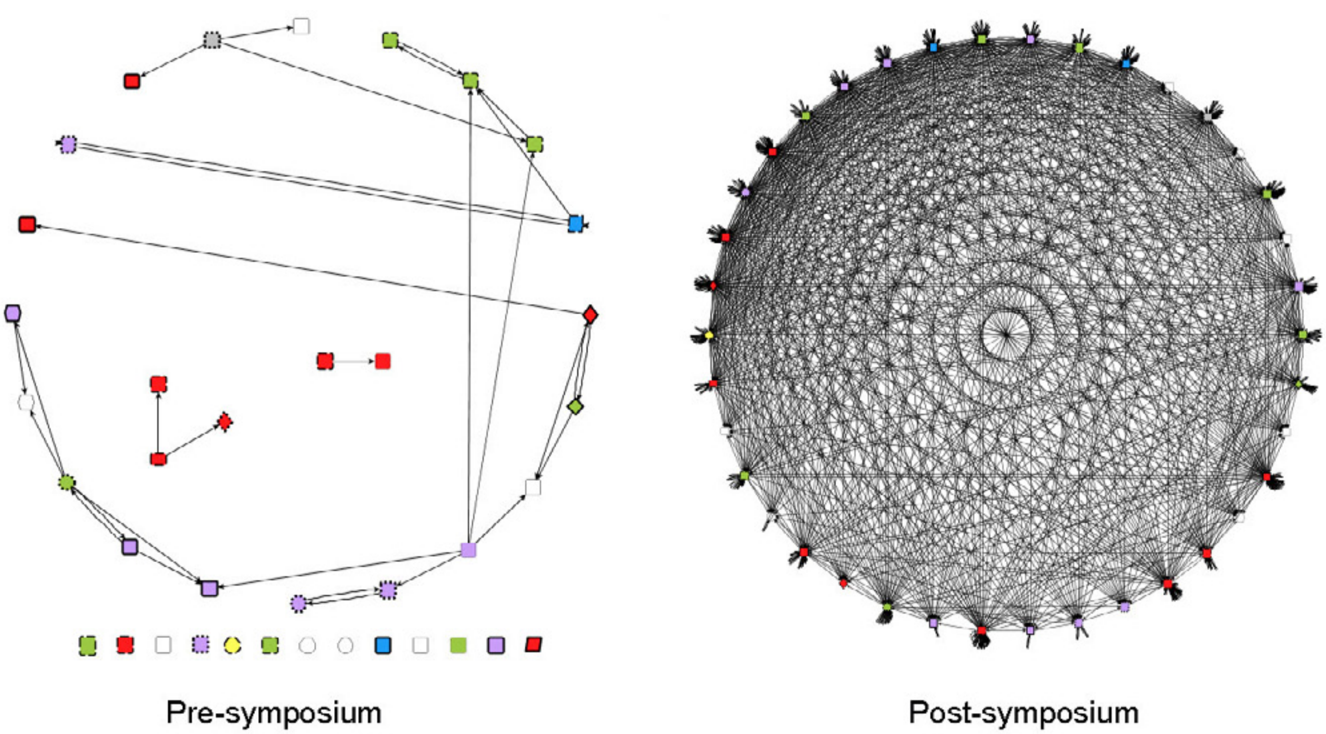
Ecological Dissertations in the Aquatic Sciences

by Paul Kemp (Center for Microbial Oceanography: Research and Education)

The Eco-DAS (pronounced eco-days) symposia are held every two years in Honolulu, Hawai`i, and are hosted by the Center for Microbial Oceanography: Research and Education at the University of Hawai`i. Early career symposia often focus on research presentations and career-building skills. Eco-DAS includes both of these important activities, but its primary focus is on interdisciplinary collaboration. From the start, participants are challenged to reach across disciplinary lines, not only to listen to their peers in other fields but also to work with them toward a common goal. The mission of every participant is to come away from the symposium with new possibilities for research partnerships, and a new appreciation of the value of interdisciplinary research. This overarching goal is emphasized throughout the symposium. Eco-DAS includes ample time for participants to present their research via short talks. Many of the participants have never met, and because their research fields are so diverse they are often unaware of each other's work. However, these presentations serve only as the foundation on which to build partnerships. The highlight and the most visible product of each symposium is the proceedings volume, an open-access, peer-reviewed e-book. The contents of the e-book are entirely the result of creative collaborations built during the weeklong symposium.

Each applicant is asked to provide a substantive outline of a proposed chapter that establishes the broader context and importance of their work to date, highlighting its potential for cross-disciplinary impact and interdisciplinary research. The successful applicants share these outlines and are encouraged to contact one another before they arrive in Hawai`i for the symposium. During the symposium, participants are given ample time to interact, to find common ground and ideas. Very often, the original chapter proposals are dropped in favor of new collaborations that emerge during the symposium, or proposed chapters are joined as

Figure 1. Directed network graph showing all the positive responses to the statement "I trust this person's scientific expertise." Many more positive connections are evident following the symposium than were seen before the symposium. Trust in another person's scientific expertise is among the most important requirements for professional collaboration.



participants find that their ideas are complementary. The 2008 symposium began with 38 original proposals. Participants were free to pursue, modify, or abandon any of their ideas. Seventeen new proposals emerged by the end of the symposium, most of them containing elements of several of the original ideas. The self-organized author teams continued to develop their ideas following the symposium, and ultimately, nine chapters were included in the proceedings volume published by the Association for the Sciences of Limnology and Oceanography (ASLO). The chapters cover topics as diverse as: climate and anthropogenic change, hydrologic landscapes, estuarine macrophyte communities, micro-scale ecology, global carbon cycling, meta-communities and exotic invasions, sea level rise and wetlands, species redundancy, and molecular ecological tools. The complete volume is available in open access via the ASLO website: http://www.aslo.org/books/ecodas8/. Similarly, the 2010 symposium began with 36 original proposals, and nine chapters will be published in mid-2012.

In addition to the proceedings volume, participants have a full week to interact with agency personnel, senior scientists, journal editors, and each other. They can ask the difficult questions that confront new graduates: What are my career options? Is there a best strategy for success? How can I gain the skills that my graduate education didn't provide? What can I do to increase my chances of funding? What do I do if my manuscript is rejected? How does anyone get funding for a completely new idea? It's remarkable how difficult it is to get answers to these questions during a typical course of academic training. The symposium is a unique opportunity to share experiences and ask questions of willing, helpful mentors.

Symposium participants see parallels to their own ideas in other disciplines and discover opportunities to develop their ideas in ways they had not considered before. Most importantly, they build new connections to other early-career scientists that may last a lifetime, and they gain new professional resources in the form of contacts and knowledgeable experts that they can turn to for help. Each symposium is evaluated to ensure that its goals are met. Participants are asked to indicate their level of agreement with statements such as "I trust this person's scientific expertise," "I would ask this person for advice," and "I have communicated with this person," first before and then after participating in the symposium. Their responses overwhelmingly show that the symposium greatly increases the potential for future interactions (Fig. 1). By the end of the symposium, the participants aren't just aware of on another. They have already collaborated, will continue to collaborate for several months, and will probably work together again in the future.

Eco-DAS X will be held in October 2012, and at this time applications are being submitted. As for the previous symposia, I expect an exciting, idea-filled, thought-provoking and thoroughly exhausting week (one of my favorite comments from the 2008 evaluation was "I'm exhausted, but I'd do it again in a heartbeat!"). The creative ideas generated during Eco-DAS X will emerge as an open access e-book in 2014 – just in time to start preparing for Eco-DAS XI!

OCB Hosts Three C-MORE Science Kits in Woods Hole

OCB hosts three C-MORE Science Kits: Ocean acidification, marine mystery, and ocean conveyor belt.

Ocean acidification kit (grades 6-12)

This two-lesson kit familiarizes students with the causes and consequences of ocean acidification: Lesson 1 includes a simple hands-on experiment, a short PowerPoint, and optional readings with worksheets. In Lesson 2, students conduct a more in-depth experiment with electronic probes to simulate the process of ocean acidification. Learn more about this kit.

Ocean conveyor belt kit (grades 8-12)

This four-lesson kit introduces students to some fundamental concepts in oceanography, including ocean circulation, nutrient cycling, and variations in the chemical, biological, and physical properties of seawater through hands-on and computer-based experiments. Learn more about this kit.

Marine mystery kit (grades 3-8)

Students learn about the causes of coral reef destruction by assuming various character roles in this marine murder-mystery. As they determine who killed Seymour Coral, students learn the basics of DNA testing. Suspects include global warming, sedimentation, and other threats facing coral reefs today. Learn more about this kit.

To Request a Kit

Teachers along the eastern seaboard may use these kits for free. To reserve a kit, please submit a request at: http://cmore.soest.hawaii.edu/education/teachers/science_kits/requestform.htm

ACID OCEAN

Katherine Allen

Katherine Allen is a 5th-year Ph.D. student at LDEO and Columbia University, working with Bärbel Hönisch on the role of the ocean in past climate change.

I am a wild carbon atom,
To others I've sometimes been bound,
Not locked in some hard, rocky stratum,
I'm telling you: I get around!

As carbon dioxide I spewed
Forth during floods of basalt
The P-T, some folks have been rude:
They say that it's partly my fault!

About 50 million years passed;
The air got too crowded for me.
My buddies and I then in-gassed
Down into the salty sea.

There, we broke up some water
Stole an H and an O.
The leftover H found C fodder,
It was hot, reefs struggled to grow.

Oh baby, the early Cretaceous,
Now that was a happenin' time.
Plankton were rife and bodacious;
I left the party with lime.

On the seafloor I rested, just chillin',
Then my neighbors and I were dissolved!
They're still on the hunt for the villain;
Some say methane was involved.

I'll tell you, if you want to learn
Of acidifications now past:
For sea bugs to feel that harsh burn,
The pH change has to be fast.

If acid's more rapid than base
(if it beats out the weathering flux)
Then carbonate shells lose the race ...
For some critters, that really sucks.

So what? pH's varied since life began;
Many things drop it or spike it.
I've seen crazy things, but this modern world, Man ...
I've never seen anything like it!

OA Subcommittee Membership

Four members of the OA subcommittee will be rotating off the committee this spring: Scott Doney, Victoria Fabry, Richard Feely, and Lisa Robbins. The OCB Project Office would like to thank them for serving on the OA subcommittee during its inaugural period. They have been critical in helping found the subcommittee and leading and advising input into OCB-supported activities such as offering information and guidance to federal research agencies, facilitating OCB-OA activities like the short course and the OA PI meeting, and many more. We would particularly like to recognize the leadership of co-chair Richard Feely, whose involvement in the subcommittee has provided vital cross-links to other national and international organizations, helpful perspective on ocean acidification activities of all types, and strong guidance throughout the subcommittee's existence. All of the departing subcommittee members will be missed!

Third Symposium on The Ocean in a High-CO_2 World:

Travel Support for Early-Career Scientists and Developing Country Scientists

by Ed Urban (Scientific Committee on Oceanic Research)

A consortium of institutions and organizations from Monterey, California will host the third symposium on The Ocean in a High-CO_2 World on 21-24 September 2012 (see symposium Web site at http://www.highco2-iii.org/main.cfm?cid=2259). Like the first two symposia in this series, the Monterey symposium is expected to attract many of the world's leading ocean scientists to discuss the impacts of ocean acidification on marine organisms, ecosystems, and biogeochemical cycles, as well as social and economic consequences of ocean acidification. The first three days of the symposium will feature plenary, parallel, and poster sessions that will provide an opportunity for presentations of the latest scientific results and discussions of the state of research in ocean acidification. The fourth day will focus on the policy implications of ocean acidification, starting with a summary of the scientific presentations and continuing with panels of eminent policymakers who will comment on how the science of ocean acidification is impacting policy at national and international levels.

Symposium organizers are planning special networking activities for early-career scientists and will offer mentoring opportunities for those who request a mentor. Special travel support will be available for early-career scientists and scientists from developing countries and countries with economies in transition (see http://www.scor-int.org/Eligible_Countries.pdf). Travel grants for early-career scientists will be limited to applicants who are Ph.D. students and individuals who have received their Ph.D.s within 5 years of the beginning of the symposium. A small number of travel grants will be available for scientists from developing countries who are more than 5 years beyond their Ph.D.s. Registration fees will be waived for travel grant recipients.

Application Process for Travel Grants—Applications for travel support will consist of three parts: (1) an abstract to present a poster or an oral presentation in a parallel session, (2) a letter expressing the applicant's research interests and interest in participating in the symposium, and (3) a supporting letter from the applicant's adviser, supervisor, or organization official. Award of travel support will depend on the abstract being accepted. Application materials should be submitted to the SCOR Secretariat (secretariat at scor-int.org) by the abstract deadline, **1 April 2012**. Applicants will receive notice of the outcome of their applications by **31 May 2012**.

The Third Symposium on The Ocean in a High-CO_2 World is convened by the Scientific Committee on Oceanic Research, the Intergovernmental Oceanographic Commission of UNESCO, and the International Geosphere – Biosphere Programme.

OCB Publishes Open Letter About Ocean Acidification

OCB recently posted an open letter on the OCB-OA website that reviews ocean acidification as an issue of global relevance, with far-reaching effects that could become stronger once combined with other stressors like warming, deoxygenation, and pollution. The letter recommends that decision makers take actions to promote reduction of the current rate of ocean acidification, improvement of the current state of knowledge by supporting research and monitoring, enhance ecosystem resilience by promoting ecosystem-based management, and continued research into adaptation strategies applicable to natural and human communities. This letter is intended to underscore the importance of considering ocean acidification in international forums that include decision makers, such as the upcoming Planet Under Pressure meeting, the Rio+20 meeting, and the Ocean in a High-CO_2 World III meeting.

Ocean Acidification at Ocean Sciences 2012

Ocean acidification was a popular topic at February's TOS/ASLO/AGU Ocean Sciences meeting, held in Salt Lake City. One communication workshop and three special sessions focused on specifically on aspects of ocean acidification, although many more sessions included talks and posters relevant to ocean acidification science. Presentations described the effects of ocean acidification on numerous species (phytoplankton, corals, shellfish, fish, pteropods, bacteria, and more) and environments (including high-latitude regions, coastal zones, the Great Lakes, and deep-sea ecosystems), by itself and in combination with other stressors. Other presentations focused on the geochemical aspects of ocean acidification, including detection, attribution, and the effects of other simultaneous geophysical changes. The meeting abstract book is now available online in PDF format, and abstracts are also searchable online.

Recent and Upcoming Ocean Acidification Workshops

by Jan Newton (University of Washington)

The NOAA Ocean Acidification Program Office has been working with the University of Washington and the Integrated Ocean Observing System (IOOS) Regional Association, the Northwest Association of Networked Ocean Observing Systems (NANOOS), to convene two invitational workshops in 2012, one on integrating ocean acidification (OA) data management for the nation, and one on defining a global network for OA monitoring. Libby Jewett (NOAA OA), Dick Feely (NOAA PMEL), and Jan Newton (UW & NANOOS) are working with others to plan and conduct these two workshops.

The OA data management workshop was held March 13-15, 2012 in Seattle, WA, and hosted representatives from NOAA National Oceanographic Data Center (NODC), NOAA Fisheries, Observation and Modeling groups, IOOS, the NSF-funded Biological and Chemical Oceanography Data Management Office (BCO-DMO), the NSF-funded Ocean Observatories Initiative (OOI), NASA, the Ocean Biogeographic Information System (OBIS) USA, USGS, the DOE Carbon Dioxide Information Analysis Center (CDIAC), OceanSITES, and various investigators involved in observations, experiments, modeling, and satellite research. The goal of the workshop was to establish a framework for the handling of ocean acidification data that makes it possible for users to locate, understand and utilize relevant data in support of scientific research and resource management. Outcomes will include a shared vision for integrated OA data management and an initial OA Integrated Data Management Plan with an emphasis on near-term (2-year) goals.

The OA monitoring workshop will be held June 26-28, 2012 in Seattle, WA, and will include representatives from around the world. The principal goals of this international workshop are to: (1) design the components and locations of an international ocean acidification observing network that includes repeat hydrographic surveys, underway measurements on volunteer observing ships, moorings, floats, and gliders, leveraging existing networks and programs wherever possible; (2) identify measurement parameters and performance metrics for each major component of the observing system; and (3) develop a strategy for data quality assurance and distribution.

The results of both workshops will be summarized in future editions of this newsletter. In the meantime, for more information, please contact Jan Newton.

Important Dates

- **July 16-19, 2012:** OCB Summer Workshop (Woods Hole Oceanographic Institution, Woods Hole, MA)

OCB Scientific Steering Committee (SSC) Membership Changes

We would like to welcome our five newest OCB SSC members, who bring a wealth of expertise to the SSC:

Simone Alin (NOAA/PMEL)—ocean acidification, coastal carbon chemistry

Barney Balch (Bigelow)—marine bio-optics, biocalcification, ocean color algorithm development

Sonya Dyhrman (WHOI)—phytoplankton physiological ecology, application of molecular approaches to study ocean biogeochemistry

Ricardo Letelier (OSU) —marine bio-optics, phytoplankton ecology, satellite remote sensing

Jorge Sarmiento (Princeton)—marine biogeochemical cycling (C, N, O, etc.), ocean circulation tracers, general circulation models to study impacts of climate change on ocean biogeochemistry and biology

Scott Doney (WHOI) will remain on the SSC as an *ex officio* member. On behalf of the OCB Project Office and the broader OCB community, we sincerely thank our departing SSC members **Curtis Deutsch (UCLA)**, **Richard Feely (NOAA/PMEL)**, **Mary Jane Perry (Univ. of Maine)**, **Chris Sabine (NOAA/PMEL)**, and **Walker Smith (VIMS)**. The implementation of a program of this breadth is an enormous challenge, and their service to the community has been indispensable. More information on the OCB SSC, including its charge and terms of reference, can be found on the OCB website.

OCB Informational Resources

- OCB Policies and Procedures: A community guide on OCB's programmatic mission, objectives, and operating procedures
- Coastal Synthesis Activity - join a regional email list, visit the coastal synthesis wiki site or the initial (Dec. 2010) coastal synthesis workshop website
- OCB Ocean Acidification Website
- OCB Ocean Fertilization Website
- Subscribe or post to the OCB email list

Partner Program Updates

IMBER

- ClimECO3 summer school (July 23-28, 2012, Ankara, Turkey) — OCB will provide travel support for U.S. participants!
- IMBIZO III (January 28-31 in Goa, India)

SOLAS

- Open Science Conference (May 7-10, 2012, Cle Elum, WA USA)

Recent and Upcoming Meetings and Activities

OCB and U.S. CLIVAR to Fund Two Joint Working Groups

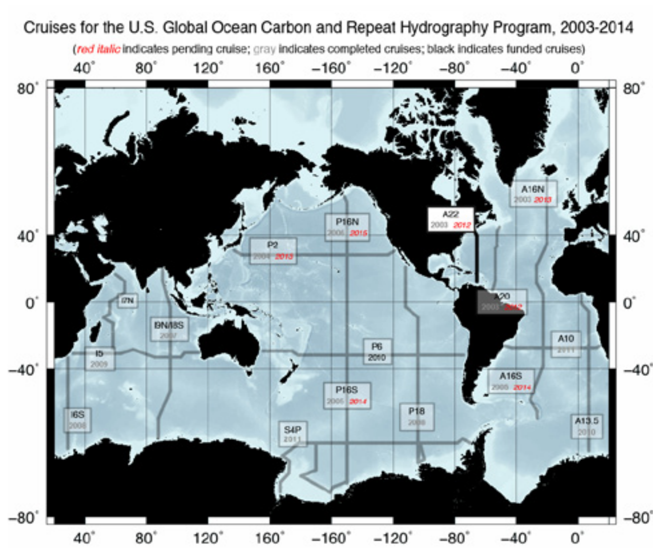
A joint science session with the U.S. Climate Variability and Predictability (CLIVAR) Program at the 2011 OCB Summer workshop provided an opportunity to merge the physical climate and ocean circulation expertise of the CLIVAR community with the biogeochemical cycling and marine ecosystem expertise of the OCB community to explore overlapping scientific interests. In fall 2011, the OCB and U.S. CLIVAR Project Offices issued an open solicitation for joint working groups to address targeted scientific questions of interest to both programs. Following a joint review process by the U.S. CLIVAR and OCB SSCs, two working groups are being supported:

- ***Oceanic carbon uptake in the CMIP5 models*** (Working group co-chairs: Annalisa Bracco, Curtis Deutsch, Taka Ito)
- ***Heat and Carbon Uptake by the Southern Ocean*** (Working group co-chairs: Joellen Russell, Igor Kamenkovich)

The CMIP5 (Coupled Model Intercomparison Project phase 5) working group will be analyzing an archive of publically available CMIP5 simulations to better characterize the physical and biogeochemical processes controlling ocean carbon uptake in the North Atlantic, tropical Pacific, and Southern Ocean. The Southern Ocean working group will be using a combination of data and models (and developing data/model metrics) to explore Southern Ocean response to climate change, with an emphasis on examining the importance of mesoscale eddies in heat and carbon uptake. The co-chairs are currently finalizing working group membership and planning an initial teleconference among their members. These working groups will have a lifetime of 3 years, culminating in a joint science workshop in 2014 to highlight the scientific findings and outcomes of the two working groups.

OCB Polls Community on CO_2/Repeat Hydrography Program

OCB is currently gathering feedback from the community on usage of CLIVAR CO_2/Repeat Hydrography data and identify publications that have used these data. This program has been in operation for almost a decade now, and has involved systematic and global re-occupation of select WOCE/JGOFS hydrographic sections to quantify changes in storage and transport of heat, fresh water, CO_2, and related parameters. These hydrographic surveys have yielded rich, comprehensive data sets that integrate the scientific needs of the carbon, hydrography, and tracer communities. In addition to efficiency and cost savings, this coordinated field campaign has yielded interdisciplinary scientific advances that well exceed those of individual programs. These advances have contributed to the following overlapping scientific objectives: Data for model calibration and validation, carbon system studies, heat and freshwater storage and flux studies, deep and shallow water mass and ventilation studies, and calibration of autonomous sensors.



Related links:

[CLIVAR/CO_2 Repeat Hydrography home page]

[CLIVAR/CO_2 Repeat Hydrography data centers]

[CLIVAR and Carbon Hydrographic Data Office (CCHDO)]

[CDIAC database for ocean CO_2]

[International Go-Ship program]

Your feedback is important to the future of this program. Please take 5 minutes to complete a short web survey on your CLIVAR CO_2/Repeat Hydrography data usage and outcomes (publications). Survey responses will be compiled and communicated directly to oversight committee co-chairs and agency representatives.

Community Resources

Publications and Reports

- WCRP action plan on research activities of surface fluxes
- Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society
- 2011 U.S. Carbon Cycle Science Plan
- Final version of the Honolulu Declaration produced at the 13th Annual POGO meeting

Data and Research

- Surface Ocean CO_2 Atlas (SOCAT) version 1.5
- Ocean Data View v. 4.4.2 available for download
- CO_2SYS for MATLAB updated to v1.1 (available for download at CDIAC)
- Guidelines from Taro Takahashi on pCO_2 and fCO_2 data
- New 2010 Global Carbon Budget
- VIIRS "first light" ocean chlorophyll image

Communication and Outreach

- OCB open letter on ocean acidification

Recent and Upcoming Meetings and Activities, Cont'd.

OCB Convenes Town Hall on Development of Global Autonomous Biogeochemical Observing System at Ocean Sciences 2012

On February 20, in conjunction with the 2012 Ocean Sciences meeting, OCB scientists Ken Johnson (MBARI), Mary Jane Perry (Univ. of Maine), and Hervé Claustre (Observatoire Océanologique de Villefranche) convened a Town Hall meeting ***"Current progress towards development of a global ocean biogeochemical observing system"*** to discuss the status of efforts to develop a global biogeochemical observing system that is similar to the Argo Program. This meeting was tied to Special Session 085 (Development of a Global Ocean Biogeochemical Observing System Based on Profiling Floats and Gliders). The Town Hall meeting attracted a great deal of community interest, convening >180 scientists. The meeting included brief discussions of funded and proposed regional experiments, including the northwest Pacific, Arctic, Mediterranean, North Atlantic, and Southern Ocean. Participants discussed critical next steps in advancing a large-scale program, including an implementation plan describing a comprehensive vision for a global autonomous observing system that leverages ongoing and planned regional experiments. Participants of this meeting, as well as a recent meeting of the SOLAS-IMBER Carbon Subgroup 2, also discussed the immediate need for universal quality control protocols for autonomous data, including the establishment of data quality criteria and standardized methods for dealing with issues of sensor calibration and drift. OCB hopes to partner with SOLAS and IMBER to develop a small international team of scientists to develop universal best practices for autonomous data sets.

2012 OCB Summer Workshop

July 16-19, 2012 (Woods Hole, MA)

This year's meeting will include sessions on the following cross-disciplinary themes:

- Multiple stressors in marine ecosystems
- Ocean biogeochemistry from satellite data
- Land-ocean transport and linkages with global change
- Integrating measurements across multiple time and space scales
- New observations from an Arctic Ocean in rapid transition

Please visit the meeting website to register and download a draft agenda! The registration deadline is **June 10, 2012.** Please note that this year, limited travel support will be provided for students. Details will be available after registration has closed.

NACP/OCB Coastal Synthesis Update

U.S. East Coast Carbon Cycle Synthesis Workshop

January 19-20, 2012 - Virginia Institute for Marine Science

Organizers: M. Friedrichs, W.-J. Cai, and R. Najjar

Coastal regions, despite covering a small fraction of the earth's surface, are important in the global carbon cycle because rates of carbon fixation, remineralization, and burial are much higher than the global average. While a significant amount of research relevant to the carbon cycle has been conducted in coastal regions, it has tended to fall along disciplinary and regional lines, creating a need for synthesis. In 2009, the Ocean Carbon and Biogeochemistry (OCB) Program and the North American Carbon Program (NACP) began a synthesis activity with a focus to develop carbon budgets for the five main coastal regions of North America: the Arctic Coast, the Atlantic Coast, the Gulf Coast, the Pacific Coast, and the Great Lakes. The main goal of this NSF- and NASA-funded workshop was to bring together carbon cycle scientists studying the east coast of the United States to develop a carbon budget for the region.

The workshop hosted 35 scientists, which were organized ahead of time into eight teams, each corresponding to a major term in the regional carbon budget: riverine input, estuarine fluxes, tidal wetland fluxes, air-sea exchange, sediment-water exchange, exchange at the ocean boundary, primary production, and respiration and net community production. These flux teams synthesized literature and, in several cases, made greatly improved flux estimates before the workshop. At the workshop, flux syntheses were presented and discussed, short-term (6-12 months) plans to improve flux estimates were formulated, and long-term recommendations for research were made. A preliminary, revised carbon budget for the region was developed at the end of the workshop.

Dramatic improvements in the regional carbon budget were made for riverine input, tidal wetland fluxes, air-sea exchange, and sediment-water exchange. Four distinct estimates of riverine inputs of dissolved and particulate carbon were made, and it now appears that coastal waters of the eastern U.S. receive 4-11 Tg C yr^{-1} from land via rivers, a greatly improved estimate over previous syntheses. For the first time, a tidal wetlands carbon budget for the U.S. east coast was developed, including terms for net primary production, burial, and carbon export to estuaries. Estimates of coastal air-sea CO_2 exchange were made using an observational synthesis, a statistical model for data extrapolation, and a 3-D biogeochemical model. Finally, first estimates were made for sinking particle fluxes, sediment remineralization, and burial at the regional scale.

Practical plans were made to further refine and improve flux estimates, including uncertainties, in the eight categories over the next 6-12 months. Numerical models will be used to constrain several fluxes, including cross-shelf exchange, which is very difficult to estimate at the regional scale from observations alone. Remote sensing algorithms will be used to further improve primary production estimates.

Several overarching themes emerged from the workshop. First, it was clear that discussions and interactions at the workshop were synergistic, with knowledge being created as a result of sharing information across disciplines. Second, it was found that the strong heterogeneity and variability within coastal systems demands innovative methods for scaling up local flux estimates. Third, because of the difficulty in quantifying flux errors in coastal systems (resulting, in part, from their heterogeneity), it behooves us to make as many independent estimates of a given flux as possible. Fourth, and finally, numerical models, with their strong physical basis and internal consistency, are a powerful complement to observations for constraining carbon fluxes in the coastal zone.

OCB Calendar

2012	
March 26–29:	Planet Under Pressure: new knowledge towards solutions (London, UK)
April 22–27:	International Polar Year 2012 From Knowledge to Action (Montréal, Canada)
April 22–27:	European Geosciences Union General Assembly 2012 (Vienna, Austria)
April 24–27:	OCEANS OF CHANGE 2nd ICES/PICES Conference for Early Career Scientists (Majorca Island, Spain)
May 7–10:	SOLAS Open Science Conference (Cle Elum, WA)
May 7–11:	44th International Liege Colloquium on Ocean dynamics remote sensing of colour, temperature and salinity - New challenges and opportunities (Liege, Belgium)
May 15–19:	2nd International Symposium: Effect of climate change on the world's oceans (Yeosu, Korea)
May 29–July 6:	Center for Microbial Oceanography: Research and Education (CMORE) summer course (University of Hawaii)
June 17–July 7:	BIOS Summer Course: *Microbial Oceanography - The Biogeochemistry, Ecology and Genomics of Oceanic Microbial Ecosystems* (Bermuda)
June 20–22:	Rio+20 United Nations Conference on Sustainable Development (UNCSD) (Rio de Janeiro, Brazil)
June 20–22:	NASA Workshop for Remote Sensing of Coastal and Inland Waters (Madison, WI)
June 24–29:	2012 Marine Microbes Gordon Research Conference (Tuscany, Italy)
July 2–14:	IOCCG Summer lecture series 2012: Frontiers in ocean optics (Villefranche-Sur-Mer, France)
July 8–13:	18th Conference on Air-Sea Interaction (Boston, MA)
July 8–13:	ASLO Aquatic Sciences Meeting (Lake Biwa, Japan)
July 9–13:	21st International Radiocarbon Conference (Paris, France)
July 9–13:	12th International Coral Reef Symposium (Cairns, Australia)
July 13–25:	XXXII SCAR Open Science Conference - Natural and anthropogenic forcing on the Antarctic and Southern Ocean climate system (Portland, OR)

2012 cont.	
July 16–19:	OCB Summer Workshop (Woods Hole, MA)
July 23–28:	IMBER ClimECO3 Summer School (Ankara, Turkey)
September 3–6:	Bjerknes Centre open science conference: Climate change in high latitudes (Bergen, Norway)
September 3–6:	15th Biennial Challenger Conference for Marine Science on "Ocean challenges in the 21st century" (Norwich, UK)
September 10–13:	2012 LTER All Scientists Meeting - The unique role of the LTER network in the Anthropocene: Collaborative science across scales (Estes Park, CO)
September 24–27:	Third Symposium on the Ocean in a High-CO_2 World (Monterey, CA)
October 7–11:	DISCO XXIII and PODS VII (Lihue, Kaua'i)
October 13–20:	DISCCRS VII Interdisciplinary Climate Change Research Symposium (Colorado Springs, CO)
December 6–10:	2012 AGU Fall Meeting (San Francisco, CA)
2013	
January 28–31:	IMBER IMBIZO III: The future of marine biogeochemistry, ecosystems and societies (Goa, India)
February 4–8:	2013 Ameriflux and NACP All Investigators Meeting (Venue TBD)

OCB-RELEVANT FUNDING OPPORTUNITIES

- **April 20, 2012:** NASA ROSES-11: Carbon Monitoring System Program in Earth Science
- **May 15, 2012:** NSF Partnerships for International Research and Education (PIRE)
- **May 31, 2012:** NSF Office of Polar Programs Antarctic Research Proposal deadline
- **August 15, 2012:** NSF Biological and Chemical Oceanography proposal targets

OCB News

is an electronic newsletter that is published by the OCB Project Office. Current and previous issues of OCB News can be downloaded from: www.us-ocb.org/publications/newsletters.html

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