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*Studying marine biogeochemical cycles and associated ecosystems in the face of environmental change*

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# The Southern Ocean Carbon and Climate Observations and Modeling Program (SOCCOM)

*by Joellen Russell, Jorge Sarmiento, Heidi Cullen, Roberta Hotinski, Ken Johnson, Steve Riser, and Lynne Talley*

We are pleased to announce that the Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) Program has been funded by the NSF Office of Polar Programs (Antarctic Program), with additional support from the NOAA and NASA. SOCCOM is headquartered at Princeton University and is a collaboration of 23 senior researchers from Princeton, Monterey Bay Aquarium Research Institute (MBARI), Scripps Institution of Oceanography (SIO), University of Washington (UW), University of Arizona, Climate Central, University of Miami Rosenstiel School of Marine and Atmospheric Science (RSMAS), Oregon State University (OSU), NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML), NOAA Geophysical Fluid Dynamics Laboratory (GFDL), and NOAA Pacific Marine Environmental Laboratory (PMEL).

## Introduction

SOCCOM is a new 6-year observational and modeling research program focused on the role of the Southern Ocean in the anthropogenic carbon budget, ocean biogeochemistry, and climate change. The operational goal of SOCCOM is to deploy nearly 200 Argo-compatible biogeochemical (BGC) profiling floats equipped with pH, oxygen, nitrate and bio-optical sensors throughout the Southern Ocean waters south of 30°S. These climate-ready BGC-floats will be calibrated at the time of deployment by high accuracy biogeochemical measurements, and they will operate year around, including in ice-covered waters. The data from the BGC-floats will be assimilated by a Southern Ocean State Estimate (SOSE) model *(1)* that incorporates biogeochemical processes, and then this gridded SOSE output will be used to constrain high-resolution coupled atmosphere-ocean model simulations designed to both increase our understanding of Southern Ocean processes and to reduce the uncertainty of projections of the future trajectory of the Earth's carbon, climate and biogeochemistry.

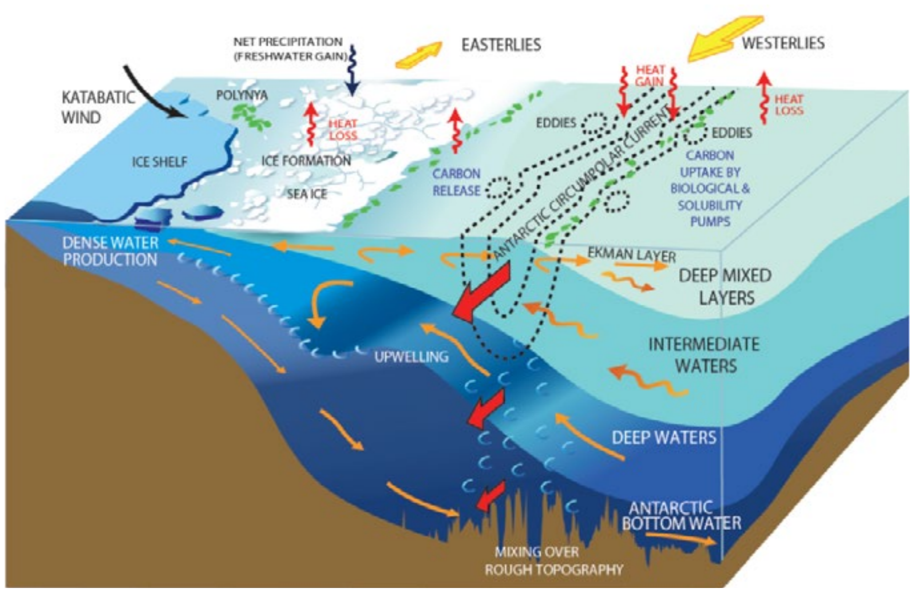
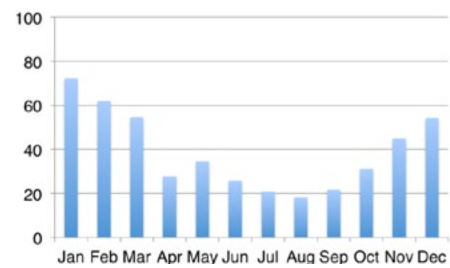


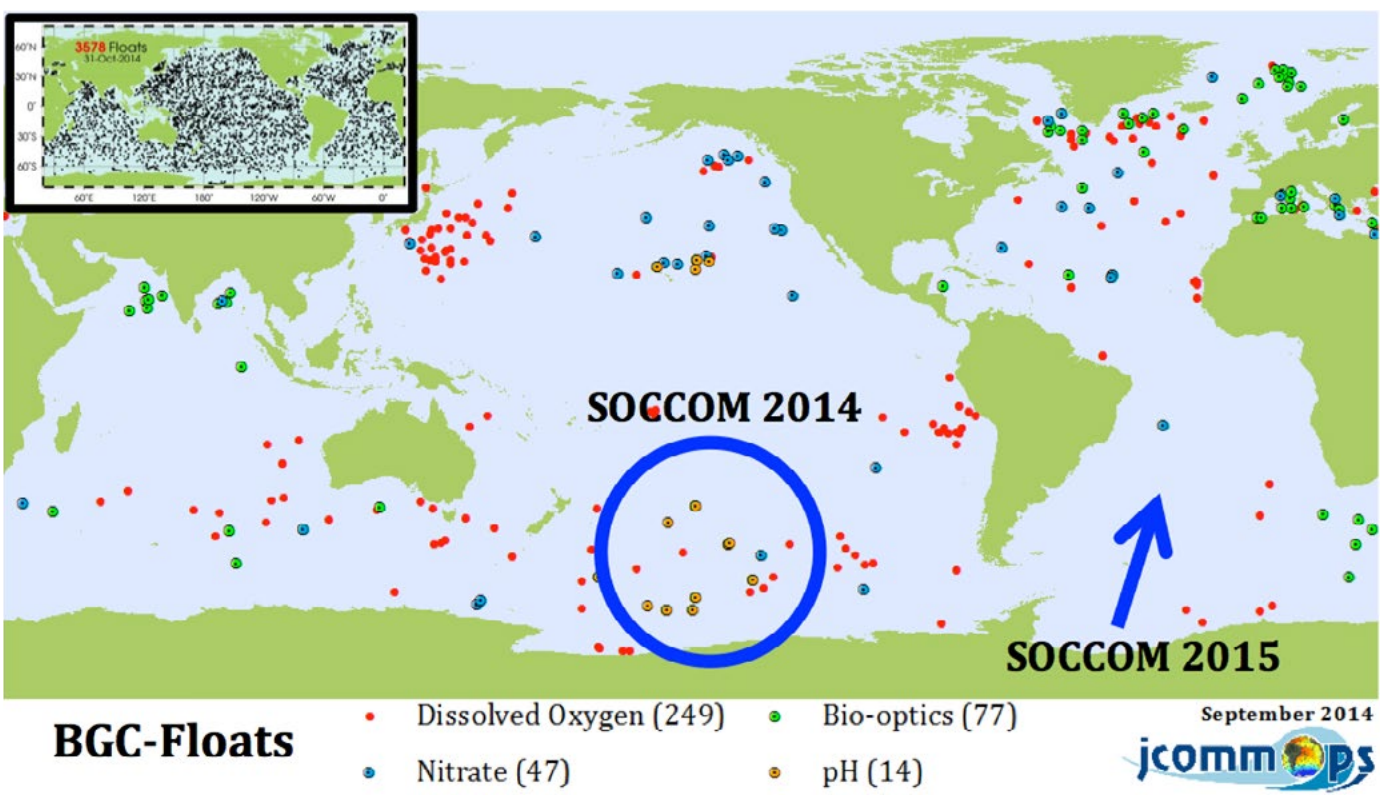

**Figure 1.** Cartoon of Southern Ocean circulation, sea ice, and mixing, with Antarctica on the left. The entire water column interacts with the surface ocean and atmosphere by advection (straight arrows) and mixing (curly arrows) (after **(2-4)**).

The Southern Ocean is the primary gateway through which the intermediate, deep, and bottom waters of the ocean interact with the sea surface and thus the atmosphere (Fig. 1). As a result, the Southern Ocean lends a considerable hand in keeping Earth's temperature hospitable by soaking up a quarter of the carbon being put into the atmosphere by humans and a majority of the planet's excess heat. Yet the Southern Ocean is the least observed and understood region of the world ocean: the inner workings – and global importance – of this ocean that accounts for 30 percent of the world's ocean area remain relatively unknown to scientists, as observations remain hindered by dangerous seas. In addition, simulations from coupled climate models and earth system models are least consistent with respect to the circulation and heat and carbon uptake by the Southern Ocean. It is this scarcity of observations in the Southern Ocean and the inadequacy of earlier models, combined with the Southern Ocean's importance to the Earth's carbon and climate systems, that creates tremendous potential for groundbreaking research in this region. The Southern Ocean has a profound influence on nutrient resupply from the abyss to the surface, which regulates nutrient availability throughout the world ocean *(5, 6)*. Waters of the Southern Ocean are also particularly susceptible to ocean acidification due to excess anthropogenic $CO_2$ uptake and associated reductions in carbonate ion concentrations, which may have profound ecosystem impacts *(7)*. Understanding these connections between the Southern Ocean and the rest of the globe is one of the primary research goals identified by the Scientific Committee for Antarctic Research *(8)*.

The scientific objectives of SOCCOM build on a decade of planning by the ocean science community. In particular, workshops sponsored by the US Ocean Carbon and Biogeochemistry (OCB) program, which focused on building global-scale observing systems for biogeochemistry *(9)* and on developing a science plan for Southern Ocean research *(10)*, played a key role in

**Figure 2.** (Right) Average number of profiles per month for nitrate in the NODC data set from south of 30°S during the period 1985 to 2010. SOCCOM will supply about 700 profiles per month with an array of 150 profiling floats. (Below) 267 of the ~3600 floats currently in the ocean (see inset) are equipped with biogeochemical (BGC) sensors. The location of the planned SOCCOM 2015 float release is indicated.



SOCCOM planning. The grand vision of SOCCOM is to enable a transformative shift in our scientific and public understanding of the role of the vast Southern Ocean in climate change and biogeochemistry by implementing a strategic and optimal mix of innovative and sustained observations of the carbon cycle, and high resolution modeling linked to the observations. In order to achieve this vision, SOCCOM has two overarching scientific goals:

1) *Quantify and understand the role of all regions of the Southern Ocean in carbon cycling, acidification, nutrient cycling, and heat uptake on seasonal, interannual, and longer time scales*
2) *Develop the scientific basis for projecting the contribution of the Southern Ocean to the future trajectory of carbon, acidification, nutrient cycling, and heat uptake*

The autonomous profiling floats with biogeochemical sensors will extend the seasonally limited observations of biogeochemical properties to nearly continuous coverage in time, with horizontal spatial coverage over the entire Southern Ocean (Fig. 2) and vertical coverage deep into the water column (down to 2000 m). This increased coverage, together with SOSE *(1)*, will provide us with an ongoing view of the Southern Ocean, including broad-scale observations for tracking ocean acidification. The climate and biogeochemistry modeling component, including NOAA GFDL's high resolution coupled climate models and Earth System Model (ESMs), will enable us to translate our evolving understanding of the current ocean into a greatly improved long-term view of the future with a strong focus on the role of the Southern Ocean in the global climate.

## Observations

The observational component of the SOCCOM program is led by Lynne Talley (SIO) and Steve Riser (UW). Central to the program are ~200 floats outfitted with biogeochemical sensors that will provide almost continuous information related to the ocean's carbon, nutrient (nitrate, in particular), and oxygen content, both at and deep beneath the surface. The floats are augmented biogeochemical versions of the nearly 4,000 Argo floats deployed worldwide to measure ocean salinity and temperature. The floats will be constructed at UW with sensors designed by SOCCOM Associate Director Ken Johnson (MBARI). SOCCOM marks the first large-scale deployment of these biogeochemical floats (Fig. 2).

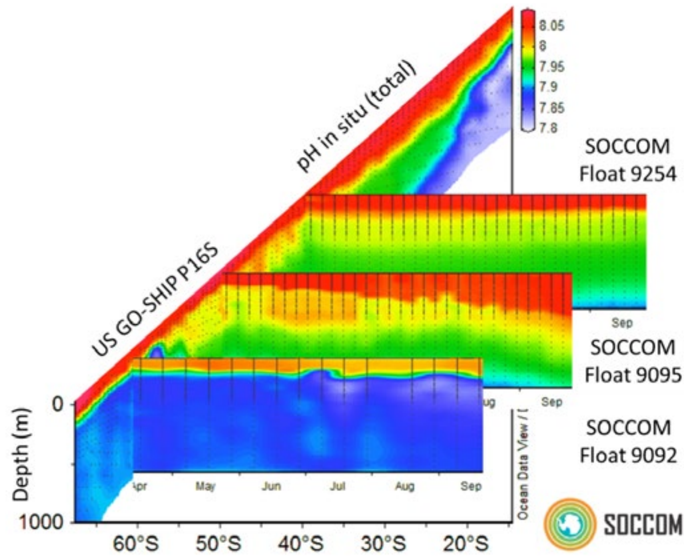



**Figure 3.** The meridional section of pH observed in the upper 1000 m along 150°W in March to May of 2014 during the US GO-SHIP P16S cruise is shown on the diagonal. The temporal sections of pH observed by three APEX profiling floats, which were constructed at the University of Washington and equipped with Deep-Sea DuraFET pH sensors built and calibrated at MBARI, are shown in the horizontal sections. Floats were launched at 60°S, 50°S and 40°S and profiled at 10 or 5 day intervals. P16S data were downloaded from the CLIVAR and Carbon Hydrographic Data Office (cchdo.ucsd.edu) and float data were downloaded at the FloatViz web site (www.mbari.org/chemsensor/floatviz.htm). P16S laboratory pH measurements were converted to in situ values using CO2SYS.

NOAA's Climate Program Office will provide half of the basic Argo floats. NASA will support a complementary project involving researchers at the University of Maine and Rutgers University that will equip the floats with bio-optical sensors intended to gather data about biological processes in the water column. Float deployment, data analysis, and data assimilation will be led by SIO.

SOCCOM was initiated with the deployment of an array of pre-SOCCOM BGC-floats in March-April 2014 as a test of the proposed methodology. BGC-floats were deployed on the US GO-SHIP P16S cruise from Tasmania to 68°S, 150°W and then north along 150°W to Tahiti, with a hydrocast at each BGC-float deployment to obtain bottle samples for calibration of biogeochemical float data. These were the first profiling floats with pH sensors deployed in the Southern Ocean, and they have already returned a mean of 31 pH profiles/month in the austral winter months of June, July and August (exceeding by 600% the average reporting rate for this region over the past 25 years). Early results from this cruise can be seen in

Fig. 3. In the next phase of the SOCCOM observational program, 12 BGC-floats will be deployed in December 2014 on a cruise aboard Germany's R/V *Polarstern*. Following the paradigm of the Argo program, all of the data from these BGC-floats will be made immediately available to the public for research and educational purposes. The raw and adjusted data are reported in real time at http://www.mbari.org/soccom.

SOCCOM floats will increase the monthly biogeochemical data currently coming out of the Southern Ocean by 10 to 30 times. These data will be used to assess and improve the latest high-resolution ESMs, which will allow for a better understanding of the Southern Ocean and improved projections of Earth's climate. An expanded biogeochemical data set will also facilitate more rigorous monitoring of acidification and associated ecosystem impacts in Southern Ocean waters. In keeping with SOCCOM's knowledge sharing, or "broader impacts" component, all of the data collected will be freely available to the public, researchers, and industry.

In addition to our planned cruises (Fig. 2), we welcome and are actively pursuing international partnerships, particularly to provide opportunities for float deployments and extend the BGC-float array (http://soccom.princeton.edu/content/deployment-opportunities). Please contact Dr. Roberta Hotinski, SOCCOM Project Manager, at soccom@princeton.edu regarding possible opportunities for collaboration.

## Modeling

SOCCOM's modeling component will rely heavily on SOCCOM float data in order to assess and constrain simulations of Southern Ocean biogeochemistry, which is virtually impossible with current observational data sets. Using a new generation of high-resolution ESMs, researchers will examine variability and change in ocean biogeochemistry, heat uptake and distribution. SOCCOM's modeling component has three main tasks:

1) *Develop observationally based metrics*: SOCCOM's assessment tools will be applied to the available climate simulations from CMIP5, as well as to newly available high-resolution ESM simulations. Our goal is to improve our understanding of the uptake of carbon and heat by the Southern Ocean. An important part of the modeling team's focus

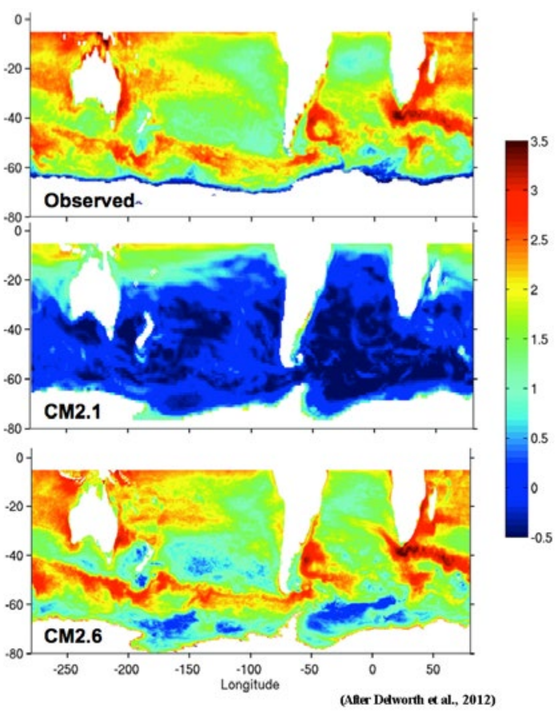



**Figure 4.** Eddy Kinetic Energy (EKE, $cm^2 s^{-2}$, logarithmic scale). (a) Observations; (b) the GFDL CM2.1 model with 1° horizontal resolution; (c) the GFDL CM2.6 model with 0.1° horizontal resolution (adapted from *11*).

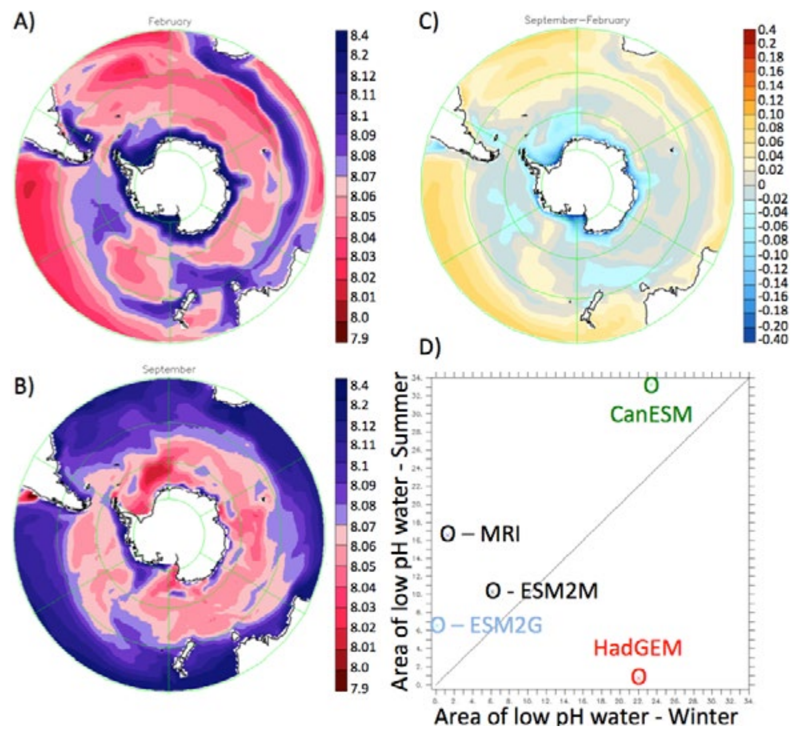



**Figure 5.** Simulated surface pH from the GFDL-ESM2M Earth System Model for A) Summer (February); B) Winter (September); C) Winter minus Summer. Panel D) shows the area of surface water below 8.05 pH units (south of 40°S, in 106 $km^2$) in the Summer vs. the Winter for 5 of the CMIP5 ESMs. All Summers and Winters are averaged for model years 2001-2005.

is to develop standardized analysis packages and diagnostics to be shared with the community through the SOCCOM web portal and the University of Arizona's Southern Ocean Climate Model Atlas.

2) *Perform a series of wind experiments in high-resolution ESMs*: In the wind experiments, we will examine the relative roles of winds vs. stratification in ocean heat uptake to improve our overall predictive understanding of the ocean's role in climate.
3) *Design and implement a Southern Ocean Model Intercomparison Program (SOMIP)*: The development of a SOMIP is aimed at improving the assessment of this and the next generation of climate models, especially as the climate community begins preparations for the next IPCC Report in 2020. We have already received positive feedback in support of a SOMIP from several other climate modeling centers in the US and abroad.

The climate modeling component of SOCCOM is led by Joellen Russell (University of Arizona), with substantial input on biogeochemical modeling from SOCCOM Director Jorge Sarmiento (Princeton University). Russell will lead a team of scientists to design a series of observationally based metrics (carbon, temperature, nutrients, heat flux and transport, salt, overturning, wind stress, etc.) to evaluate model performance and improve representation of key processes in the Southern Ocean in order to reduce uncertainties in future projections. Researchers from NOAA GFDL will carry out high-resolution earth system simulations (Fig. 4, adapted from *11*) in support of the modeling effort. Igor Kamenkovich (RSMAS) has conducted a series of Observing System Simulation Experiments (OSSEs), which demonstrate that our proposed 6-year strategy will provide powerful constraints on biogeochemical state estimates (SOSE), and that maintaining an array of nearly 150 floats is sufficient to provide large-scale, as well as regional mapping of major carbon fluxes and pH. As can be seen in Fig. 5, simulations of Southern Ocean surface pH from different ESMs vary widely and seasonal differences within each model are striking. Laurie Juranek (OSU) will lead the effort to validate the new SOCCOM pH sensors using the other float data (oxygen and temperature *(12)*) and to extend the algorithms for application to aragonite saturation, DIC, and total alkalinity.

## Outreach and Communication

While the science itself is central, communicating the results to scientists outside the SOCCOM collaboration will be a crucial part of the program, as will explaining the research and its importance to the broader public, without whose support science such as this would not exist. SOCCOM's outreach component is led by Dr. Heidi Cullen, Chief Scientist at Climate Central, a nonprofit organization consisting of scientists and journalists whose goal is to create broader impacts on public policy by informing policy makers, researchers, and the general public about climate research. In order to accomplish these goals, Climate Central will help Princeton create a web portal where scientists can find technical information about SOCCOM research, and where data from the project's floats will be made available for anyone to download. There will also be a public web portal where SOCCOM science will be presented in the form of stories, images, videos, graphics and other media that will be engaging to non-scientists.

To keep up with the latest project developments, please visit the SOCCOM website and consider attending the SOCCOM Town Hall preceding the 2014 AGU Fall Meeting in San Francisco.

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# Ocean anoxia: New insights raise new questions

*by Curtis Deutsch, Lex VanGeen, Will Berelson, Bob Thunell*

**Abstract**: Changes in the North Pacific anoxic zone over the 20th century, established through a collaboration between sediment geochemists and biogeochemical modelers, imply a wind-driven contraction of the Oxygen Minimum Zone (OMZ) that counters the trend of ocean deoxygenation.

The oxygen ($O_2$) content of the deep sea is a major driver of marine ecosystems and biogeochemical cycles. As $O_2$ concentrations fall, the habitability for aerobic animals steadily declines *(1)*. Over evolutionary time scales, low-$O_2$ environments have provided a strong selective pressure for highly adapted animals, while oxygenation has been linked to major periods of species diversification. On time scales of individual organisms, low $O_2$ acts as a barrier for the largest diurnal animal migration on the planet *(2)*. When the advance of low-$O_2$ water masses exceeds the capacity of ecosystems to migrate or acclimate, ecosystem collapses can result. Such collapses have been documented with alarming consequences and increasing frequency *(3, 4)*.

Microbial communities and their activities are also altered by $O_2$. The nitrogen metabolism of bacteria yields a more efficient production of $N_2O$ at low $O_2$. When $O_2$ becomes completely depleted ("anoxia"), bacteria convert bioavailable nitrogen (N) to inert $N_2$ gas *(5)*, yielding widespread N limitation of phytoplankton over much of the ocean surface. The influence of these $O_2$-deficient zones (ODZs) thus extends well beyond their small volumes to encompass much of the surface ocean of the low latitudes where N limitation of plankton growth can be directly traced to these regions.

In addition to its mechanistic influence, the global distribution of $O_2$ has long provided valuable diagnostic information. The ventilation of the ocean interior has commonly been illuminated by the presence of high $O_2$ concentrations reaching into the thermocline. As $O_2$ is consumed by respiration in the dark ocean, the rates of that process have been estimated using inverse models based on $O_2$. Finally, the net respiratory $O_2$ consumption has been used to estimate the oceanic storage of carbon from the "biological pump," and the perturbation from fossil fuel $CO_2$ *(6)*.

Because of the importance of $O_2$ as both a tracer and driver of oceanic processes, the historical database of dissolved $O_2$ is extensive, second only to the twin hydrographic variables temperature and salinity. Over the past ~15 years, the analysis of these historical data has revealed declines in $O_2$ concentrations that are in some cases large and persistent over decades. Over the same period, ocean models were predicting large changes in $O_2$ driven by changing solubility and circulation as the climate warms *(7)*, a phenomenon well documented in the paleoceanographic literature *(8)*. A warmer climate is expected to greatly deplete the physical supply of $O_2$ to the sea by decreasing surface gas solubility and the rates of deep-water ventilation. Thus emerged the early signs of a major modern chemical perturbation associated with human activity, but reaching remote parts of the open ocean from the central North Pacific *(9)* to the Subantarctic *(10)*.

The ability to detect multi-decadal changes in the ocean is greater for $O_2$ than for many other biogeochemical tracers, and is growing rapidly due to advances in sensor technology and autonomous platforms like Argo. The detection and attribution of anthropogenic changes in the ocean is conceptually similar to the problem faced by the physical climate community in the 1990s *(11)*, but its challenges may prove more stringent. First, the historical baseline data are quite sparse in several key oceanic regions, including both 1) the Southern Ocean, where most deep and intermediate waters originate, and 2) the tropical ocean, where $O_2$ levels are naturally at their lowest levels and therefore closest to the most severe biological thresholds. Second, low-frequency variability in the oceanic thermocline is rife. Because oceanic water masses can be isolated from the surface for decades, they can integrate the slowly evolving components of natural climate variability *(12)*, giving rise to changing water properties that can masquerade as a trend, even in a stationary climate. In this context, the historical record is still relatively short. These caveats are particularly severe for the tropical ODZ, where waters are old (and thus easily able to accrue multi-decadal variability), and data are sparse.

The sedimentary archive provides a unique way to circumvent these inherent limitations of the instrumental record. Because their sensitivity is greatest at the lowest $O_2$ levels, they are particularly well suited to examine the ODZ. Indeed, proxies of seawater oxygenation from marine sediments have been among the best lines of evidence in support of a link between climate warming and low-$O_2$ expansion. Several proxies have been developed as indicators of bottom water oxygenation, including sediment laminations, trace metals, and foraminiferal assemblages.

Anoxia in the water column can also be detected in the sediments, thanks to the geochemical signature of $NO_3$ removal from anoxic water. The reduction of $NO_3$, ultimately to $N_2$ gas, removes the light isotope ($^{14}N$) at a slightly faster rate than the heavy one ($^{15}N$), leaving the remaining $NO_3$ with a higher $^{15}N/^{14}N$ ratio (denoted $\delta^{15}N$). When this water upwells to the surface, its $NO_3$ gets incorporated into surface biomass. Provided the surface $NO_3$ is completely consumed, the isotope ratio of the ODZ gets transferred into the sinking organic matter, and then into the sediments. In contrast to the other proxies that can map the changes in bottom water, the $\delta^{15}N$ provides a unique measure of the total rate of N removal, and thus the approximate volume of the ODZ, most of which is not even in contact with sediments.

A new set of sediment records and model simulations has recently revealed coherent regional changes in the world's largest ODZ, in the North Pacific, since the mid 19$^{th}$-century *(13)* (Fig. 1). The records, which come from 3 sites along the North American margin, imply an increase in denitrification rate since ~1990, consistent with the decline of $O_2$ that has been observed throughout the eastern Pacific over that time. However, this brief expansion was preceded by the opposite trend – a reduction of denitrification rates – over most of the 20$^{th}$ century. The proxy data thus imply that for most of the period of anthropogenic warming, the anoxic zone of the Pacific was shrinking. Model simulations predicted such an evolution of the ODZ, but with minimal data to substantiate it. The addition of N isotopes to the same model yields a new and direct comparison between a model- and data-based reconstruction of the past, with remarkable consistency. More importantly, the model-data agreement permits the underlying mechanisms to be examined and tested.

The crucial driving force behind both the recent expansion of the ODZ and its earlier and longer contraction appears to be the equatorial trade winds. Because the trade winds cause the upwelling that supplies most of the nutrients to fuel biological productivity in the tropical Pacific, a slackening of these winds reduces the rate of particle flux to the deep ocean, and the subsequent respiration that both sustains the ODZ and the associated rates of denitrification recorded in the sediment $\delta^{15}N$ . This link is found in model simulations, and confirmed by the correlation between $\delta^{15}N$ and the observed sea level pressure gradient across the equatorial Pacific, whose long-term weakening is attributed to greenhouse warming *(14)*. Thus, the data and model together imply that changes in biological respiration – not the $O_2$ supply from physical circulation - are the dominant driver of ODZ variability on decadal to century time scales, and that these should cause the ODZ to contract in spite of the ocean's overall loss of $O_2$.

These surprising results raise a number of questions. First, how general is the link between tropical winds and the OMZ? Within the Pacific, the anoxic zone is but a small portion of the broader OMZ, and is confined to its eastern boundary. Its variations in volume do not necessarily reflect the changes in oxygenation of the entire thermocline. Nor are the ODZs in the South Pacific or Arabian Sea or the weaker OMZ of the Atlantic Ocean necessarily following the same forcing. Second, the ongoing changes in the anoxic zone over the coming decades will likely depend on uncertain trends in the structure of the trade winds. Whether and when the apparent dominance of decadal variability in the North Pacific over the past two decades gives way to the expected weakening of the Walker Circulation, will probably be the key to changes in Pacific anoxia in the coming decades. Third, what consequences have such long-term and large-amplitude changes in N loss had for the N cycle of the broader Pacific basin? Large trends in the stoichiometry and the isotope ratios of N reservoirs have been documented in the subtropical gyre. Whether the changes in denitrification could impact these remains to be seen. Finally, how can we reconcile a warming-induced contraction of the anoxic OMZ due to trade wind slackening, with the geologic evidence for larger anoxic zones in warm interglacial climates? As the stratification of mid and high latitudes reduces the $O_2$ supply to deeper layers, this could overwhelm the reduced respiration rates in the tropics, returning the ODZ to the expansion that prevailed during deglaciations. We currently do not know whether this occurs over a centennial time scale of lower thermocline ventilation, or through the longer scale over which the abyssal Pacific loses $O_2$.

These questions, and likely many more, will need to be answered before we can claim full understanding of the response of the tropical OMZ to climate change, or reliably predict its implications for tropical ecosystems and biogeochemical cycles. This understanding will most fruitfully be pursued through the merging of data analysis with model simulation, and through a synthesis of multiple mechanisms acting across a range of time scales.

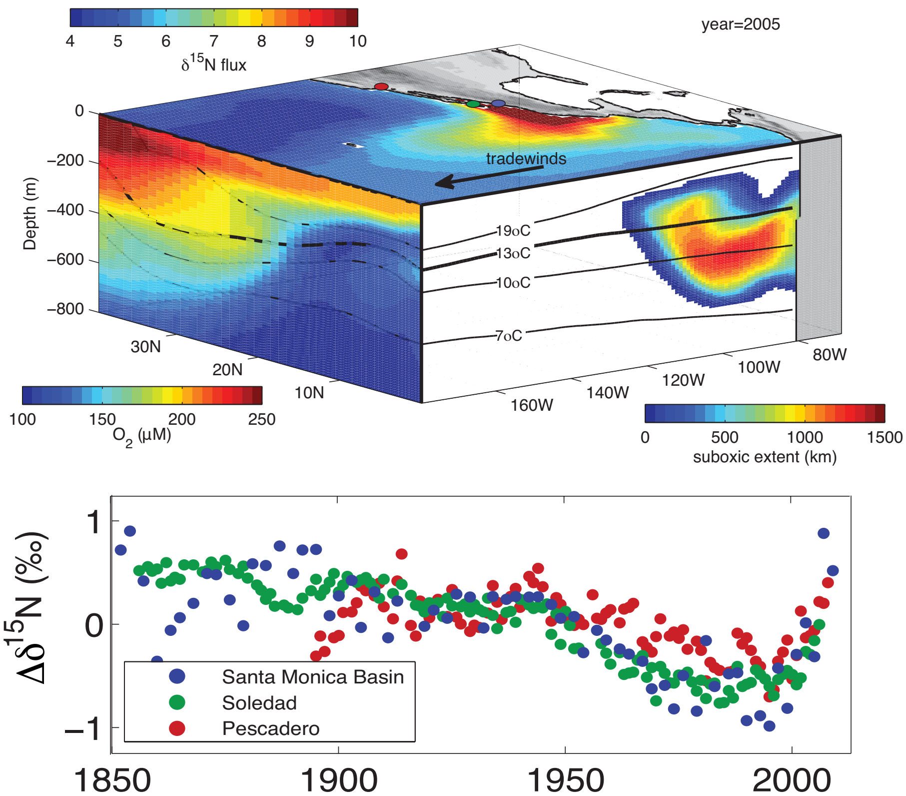


**Figure 1.** Eastern Tropical North Pacific anoxia in space (upper panel) and time (lower panel). Sections of $O_2$ concentration (eastern cube face) and meridional extent of anoxic water (southern cube face) are shown from model hindcast simulations of the late 20th century (1958-2005). Lines represent isotherms whose depth variations modulate the rates of respiration in low-$O_2$ water. The simulated N isotope ratio of exported organic matter (upper cube face) shows the effect of denitrification in anoxic waters upwelled from below. Changes in that ratio in both model runs and in sediment cores show a consistent and coherent large-scale fluctuation.

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# Important Dates

**December 12-14, 2014:** Ocean's Carbon and Heat Uptake: Uncertainties and Metrics, a joint US CLIVAR/OCB workshop (San Francisco, CA)
**June 22-July 1, 2015:** Instrumenting our oceans for better observation: A training course on autonomous biogeochemical sensors (Sven Lovén Center for Marine Sciences, Kristineberg, Sweden)
**July 20-23, 2015:** OCB Summer Workshop (Woods Hole, MA)

# Recent Meetings and Activities

## A Report from the 2014 OCB Summer Workshop July 21-24, 2014 (Woods Hole, MA)

*By Heather Benway*

The 9th annual Ocean Carbon & Biogeochemistry summer workshop, sponsored by NSF and NASA, convened 178 participants from July 21-24, 2014 at the Woods Hole Oceanographic Institution in Woods Hole, MA.

### Plenary sessions

This year's summer workshop featured four plenary sessions:

- *The Coupled North Atlantic-Arctic System: Processes and Dynamics*
- *The Biological Pump: Transport Mechanisms and Mesopelagic Processes*
- *Advances in our Understanding of the Role of Sea Ice in the Global Carbon Cycle*
- *The Ocean Observatories Initiative (OOI): Opportunities for the OCB Community*

The first plenary session *The Coupled North Atlantic-Arctic System: Processes and Dynamics* opened with a talk by Eileen Hofmann (ODU) summarizing the discussions and outcomes of an international North Atlantic-Arctic planning workshop in April 2014 to establish the framework for an international multidisciplinary research initiative that will examine key components of the North Atlantic-Arctic system. This planning meeting and the science plan that will emerge from it were the impetus for this plenary session. The session was divided into two parts, with a first set of talks on *Physical Circulation and Climate* followed by a series of talks on *Marine Ecosystems and Biogeochemistry*. The *Physical Circulation and Climate* mini-session started with a talk by Young-Oh Kwon (WHOI) on recent variability of the Atlantic Meridional Overturning Circulation (AMOC) and deep western boundary current pathways and transports as measured by the UK-US Rapid Climate Change (RAPID)-Meridional Overturning Circulation & Heat Flux Array (MOCHA) at 26.5°N and the Overturning in the Subpolar North Atlantic Program (OSNAP). Dennis McGillicuddy talked about smaller-scale (submeso- to mesoscale) circulation in the North Atlantic and applications of shipboard, sediment trap, and satellite data, as well as eddy-resolving (0.1° resolution) models to study the initiation and evolution of bloom events. Andrey Proshutinsky (WHOI) spoke about freshwater accumulation in the Beaufort Gyre, a dominant Arctic atmosphere-ocean circulation feature, and the implications of a shift from an anticyclonic to a cyclonic circulation regime for northern hemisphere climate. Jim Overland (NOAA/PMEL) described recent trends of warming and sea ice loss and implications for major weather patterns and climate. The *Marine Ecosystems and Biogeochemistry* mini-session started with a talk by Andy Pershing (GMRI) on how Northwestern Atlantic marine ecosystems are responding to warming and freshening, including shifts in the plankton community, introduction of new species, and geographic shifts in Maine lobster landings. Tatiana Rynearson (URI) described the species composition throughout the evolution of a typical North Atlantic bloom and showed very clear examples of why we need to study individual taxa and the array of species-specific processes and phases (e.g., resting

*Chaetoceros* spores) that strongly influence biogeochemical fluxes to depth. Paty Matrai (Bigelow) spoke about how sea ice loss is expected to influence primary production in different parts of the Arctic Ocean via changes in light penetration, stratification, and nutrient supply. Jeremy Mathis (NOAA/PMEL) concluded the session with a talk on the increasing prevalence of undersaturated waters and associated mechanisms in Pacific Arctic waters, including a glimpse at promising new autonomous platforms that could greatly expand observational coverage in these high latitude waters.

The second plenary session *The Biological Pump: Transport Mechanisms and Mesopelagic Processes* included a morning session on different mechanisms of carbon transport to the ocean interior and an afternoon session focusing on key physical, chemical, and biological processes in the mesopelagic zone that influence carbon export. The first session on transport mechanisms started with three short overview talks on the following transport mechanisms to set the stage for more focused talks later on: Passive particle flux (Ken Buesseler, WHOI), vertical migration (Debbie Steinberg, VIMS), and physical delivery of dissolved organic matter and subsequent microbial processing (Craig Carlson, UCSB). The focused talks kicked off with a status update by Henry Bittig (GEOMAR) on available autonomous sensors and recent applications for quantifying carbon fluxes and remineralization rates associated with the biological pump. Stephanie Wilson (Bangor Univ.) then spoke about the importance of zooplankton size and community structure, fecal pellet production, feeding ecology, and trophic interactions to better understand and quantify zooplankton-mediated fluxes. Adrian Burd (UGA) spoke about aggregation and disaggregation theory and the current state of knowledge of underlying physical and biological variables (e.g., particle size spectra, stickiness, settling velocity, etc.). Carol Arnosti (UNC) then spoke about the role of microbial enzyme activity in the ocean carbon cycle and showed recently measured water column profiles of enzyme activity from the South Atlantic and Arctic. The afternoon session on mesopelagic processes started with an overview talk by Sarah Giering (NOC) on the mesopelagic carbon budget and the associated balance of organic matter flux and respiration. Alyson Santoro (UMCES) spoke about nitrifying bacteria and the use of different molecular tools and geochemical approaches for measuring mesopelagic nitrogen remineralization. Ben Van Mooy (WHOI) then spoke about production of infochemicals called polyunsaturated aldehydes (PUAs) by diatoms and how they influence degradation and sinking of organic matter. Christina De La Rocha

(Université de Bretagne Occidentale) talked about how minerals can influence POC export by adding ballast, protecting against destruction, and influencing aggregation speed. Santiago Hernández-León (Univ. of Las Palmas) gave a presentation on how micronektonic organisms, particularly mesopelagic fish, contribute to the export of organic material from the surface to the deep ocean. This plenary session concluded with an update from David Siegel (UCSB) on the status of EXPORTS (Export Processes in the Ocean form RemoTe Sensing), a proposed NASA field campaign to predict the state of the biological carbon pump from satellite and other observations.

The third plenary session *Advances in our Understanding of the Role of Sea Ice in the Global Carbon Cycle* kicked off with a presentation by Ted Maksym (WHOI), who described current trends in sea ice and underlying processing driving these trends in the Arctic and Antarctic. The next two talks focused on the implications of changing sea ice cover for biogeochemical cycles. First, Clara Deal (Univ. Alaska, Fairbanks) spoke about large-scale biogeochemical cycling, and then Nick Bates (BIOS) focused on key processes affecting $CO_2$ cycling within and under the sea ice, highlighting the need to better understand the role of processes like brine rejection and melt ponds in carbon cycling. Bruno Delille (Univ. of Liège) talked about seasonal changes and associated controls on air-ice $CO_2$ fluxes, and highlighted the need for improved seasonal coverage (more fall and winter measurements) and further investigation of the large air-ice flux discrepancies between micrometeorological ($F_{CO2}$) and chamber measurements. Brice Loose (URI) showed that parameterizations based on wind speed alone are not effective in sea ice zones and talked about the importance of processes such as shear and buoyant convection in the ice-ocean boundary layer in driving air-sea exchange in these regions. He also shared results of a recent laboratory experiment *GAPS: (Gas Transfer through Polar Sea ice)*. Manfredi Manizza (SIO) concluded the session with a talk on key processes and future needs for improving models of the carbon cycle in polar oceans.

A final plenary session *The Ocean Observatories Initiative (OOI): Opportunities for the OCB Community* included a presentation (Oscar Schofield, Rutgers) and Q&A panel (Tim Cowles, COL, Kendra Daly, USF, and Oscar Schofield, Rutgers) to bring members of the OCB community up to speed on OCB-relevant observational assets, OOI status, and deployment time lines, and initiate a constructive community dialog to voice questions and concerns surrounding rising infrastructure costs, sensor calibration procedures, and OOI metrics of success.

In addition to the plenary and poster sessions, this year's workshop included many important community updates, activities, and discussions. Bethany Jenkins (URI) and Mak Saito (WHOI) led a discussion on ocean 'omics data infrastructure needs to provide input to a newly funded NSF "ECOGEO" RCN. Mike Lomas (Bigelow) provided a summary of a recent OCB scoping workshop *Improving predictive biogeochemical models through single cell-based analyses of marine plankton physiological plasticity, genetic diversity and evolutionary processes*. Joellen Russell (Univ. Arizona) shared recent activities and findings of the joint U.S. CLIVAR/OCB working group *Southern Ocean Heat and Carbon Uptake*. Joe Salisbury (UNH) gave an update on a new NASA Arctic scoping study *Arctic-COLORS*.

Glenn Page and Fritz Holznagel (SustainaMetrix) gave a presentation summarizing the results of a community survey on the OCB Program conducted earlier in the year as part of a formal external review process, and led a community discussion on distilling the message of what OCB is and what its key functions are. Participants also had the opportunity to contribute to a draft historical time line of ocean carbon scientific and programmatic developments in the decades leading up to and in the first decade of OCB.

There were reports from international partner programs and initiatives IMBER and Future Earth (Eileen Hofmann, ODU) and IOCCP (Laura Lorenzoni, USF). NASA and NSF program managers provided agency updates. Graduate students gave short presentations on their research interests. BCO-DMO (Biological and Chemical Oceanography Data Management Office) staff provided one-on-one tutorials for workshop participants.

For more information, including links to the talks and webcast footage, please visit the workshop website or contact Heather Benway.

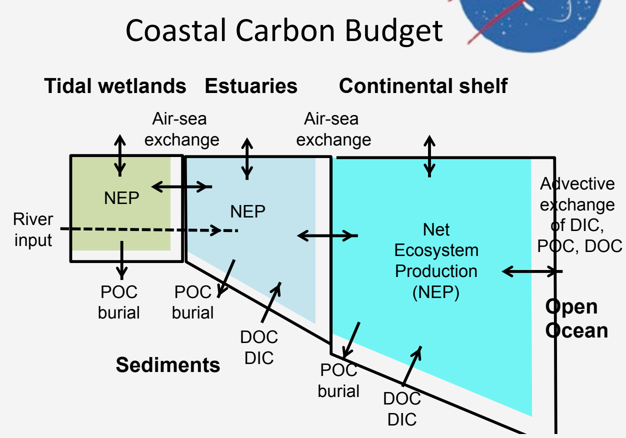
# Coastal Carbon Synthesis (CCARS) Community Workshop

**August 19-21, 2014 (Woods Hole, MA)**

*By Heather Benway (OCB) and Marjy Friedrichs (VIMS), edited by Gyami Shrestha (US Carbon Cycle Science Program, USGCRP)*

## The Development of an Interdisciplinary Science Plan for North American Coastal Carbon Research

- The Coastal CARbon Synthesis (CCARS) Workshop was held August 19-21, 2014 in Woods Hole, MA and brought together ~60 researchers with representation and support from multiple federal agencies (NASA, USGS, NOAA, NSF).
- The CCARS activity brings together scientists involved in two core elements of the USGCRP: the North American Carbon Program (NACP) and the Ocean Carbon and Biogeochemistry Program (OCB).
- Outcomes of past regional activities directed toward "diagnosis" were discussed; major uncertainties in fluxes and gaps in observational coverage were highlighted.
- Science plan deliverable to USGCRP Carbon Cycle Interagency Working Group expected early 2015




- Core science plan recommendations were outlined, designed to help agencies prioritize future investments in coastal carbon cycle research. These recommendations are designed to help the community move from "diagnosis" toward "attribution", "prediction" and "decision support".
- Key areas identified for future research include:
  - Algorithm development for relevant satellite products (terrestrial and ocean) in all coastal regions of North America.
  - Importance of future hyperspectral/geostationary satellites
  - Field studies at sentinel sites, including observations of difficult fluxes, e.g. respiration, lateral exchanges.
  - Two-way nested models, including coupled biogeochemical-hydrodynamic models, estuarine, wetland and benthic models.

A Coastal CARbon Synthesis (CCARS) community workshop was held at the Woods Hole Oceanographic Institution (WHOI) in Woods Hole, MA from August 19-21, 2014 with representation and support from multiple federal agencies (NASA, USGS, NOAA, NSF). Since its initiation in 2007, this long-term CCARS activity has brought together scientists involved in two core elements of the USGCRP: the North American Carbon Program (NACP) and the Ocean Carbon and Biogeochemistry Program (OCB). Sixty scientists working in different coastal systems of North America attended the workshop. Throughout the discussions that took place during plenary and breakout and poster sessions, participants distilled near-term coastal carbon science priorities, including coastal observations, modeling approaches and developments, and process studies. These will be summarized in a science plan that will be developed in the Fall of 2014.

The workshop opened with an overview talk on the current status and recent history of coastal carbon science in the U.S., including relevant programmatic and scientific developments such as the coastal synthesis activities (2008-present) that have been coordinated by OCB and NACP. The first plenary session of the workshop focused on key coastal carbon fluxes, exchanges, and processes spanning the land-ocean continuum. This included terrestrial inputs from rivers and groundwater, fluxes in tidal wetlands and their exchanges with estuarine and shelf waters, fluxes within estuarine and shelf waters such as air-sea, burial rates and sedimentary processes, biological processing (primary production, net ecosystem production), and exchange between coastal and open ocean waters. A second plenary session included regionally focused talks on the outcomes of the OCB/NACP coastal synthesis activities, including the current status of regional coastal carbon budgets (east coast, west coast, Gulf coast, Arctic, Great Lakes).

Following the two plenary sessions, the workshop format shifted to smaller group discussions to highlight key issues and help formulate priorities for moving forward. The first breakout session focused on coastal fluxes and processes, with participants breaking out into the following five groups: Air-sea exchange, terrestrial inputs, estuarine and tidal wetland fluxes, biological transformations, and carbon loss terms (burial, exchange with open ocean). Discussions during Breakout 1 focused on addressing the remaining unknowns for each process that significantly hinder our quantitative and predictive understanding of the coastal carbon cycle. Participants brainstormed ideas for observing needs and process and modeling studies to improve future flux predictions, taking into consideration relevant time and space scales.

The second and third breakout sessions were divided into five groups by region, including east coast, west coast, Gulf of Mexico, Great Lakes, and Arctic. In Breakout 2, participants focused on identifying key observations within each region that would significantly improve flux estimates in coastal carbon budgets. Breakout 3 focused on the integration of observations and models to help scale up from relatively limited coastal data sets.

Presentations are available on http://www.whoi.edu/website/ccars/agenda.

# EarthCube Oceanography and Geobiology Environmental ‘Omics (ECOGEO) Research Coordination Network is online!

*By Elisha M. Wood-Charlson (Univ. Hawai‘i)*

Has your environmental research ‘dabbled’ in the realm of ‘omics? Are you interested in working with a broader community to help plan the way forward to build widely available facilities and cyberinfrastructures that will provide access to ‘omics-based databases and enable analyses research for the whole community?

We invite you to join the EarthCube Oceanography and Geobiology Environmental ‘Omics (ECOGEO) Research Coordination Network (RCN)! ECOGEO is a recently NSF-funded RCN led by Dr. Ed DeLong (Univ. Hawai‘i). ECOGEO’s mission is to **identify community needs and develop necessary plans to create a federated cyberinfrastructure to enable ocean and geobiology environmental ‘omics**.

The website has links on how to become a member of EarthCube and join our RCN and how to sign up for our listserv.

In addition to the RCN site, **we are also conducting a BRIEF research survey** aimed at identifying community needs with respect to ‘omics research. Please take 5-15 minutes to participate in the survey, as this will help create the foundation of our RCN’s mission.

We look forward to working with you to create a new, community-supported way to do ‘omics research.

If you have any questions, please contact Elisha Wood-Charlson, our communications project manager (email: ecogeo.rcn@gmail.com)

# Workshop on autonomous pH sensor best practices

**August 4-8, 2014 (La Jolla, CA)**
*by Todd Martz*

From Aug 4-8, 2014, a pH sensor training workshop was held at Scripps Institution of Oceanography, University of California, San Diego through support by OCB and the University of California Office of the President. The five-day workshop consisted of nineteen participants and nine organizers, led by Todd Martz (Scripps), Andrew Dickson (Scripps), and Gretchen Hofmann (University of California, Santa Barbara). The workshop participants deployed fifteen pH sensors along with seven conductivity-temperature sensors in a 6,000 liter test tank for three days. In addition to learning to deploy sensors, participants collected and analyzed bottle samples for $CO_2$ system properties including pH, total alkalinity, and total dissolved inorganic carbon. Participants then combined the results from bottle samples and sensor data to generate a high quality time series of seawater pH in the tank, over the course of an extreme $CO_2$ event (saturation with $CO_2$(s)) (Fig. 1).

With primarily hands-on activities aimed at best practices for autonomous chemical sensors, this workshop was among the first of its kind. The International Ocean Carbon Coordination Project (http://www.ioccp.org) is currently planning a similar workshop for June-July 2015, aimed at a broader suite of chemical sensors.

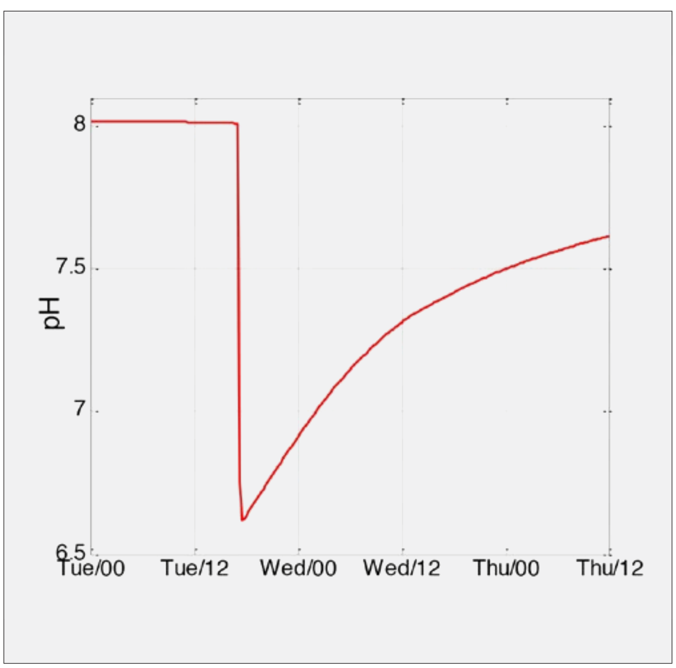



**Figure 1.** pH time-series (based on bottle samples and sensor data) developed by course participants over the course of an extreme $CO_2$ event in the test tank at Scripps.


Participants of the pH sensor training workshop

The following feedback was received from participants following the workshop:

*"The [sensor workshop] was an extremely valuable source of information and a necessary training for anyone planning to utilize [autonomous pH electrodes]. The workshop provided everything from general carbonate chemistry lectures from some of oceanography's leading scientists, hands-on training for electrode deployment, and a comprehensive understanding of electrode theory and the accepted methods for calibration and quality control to ensure quality data. All scientists including students, technicians, and professors applying carbonate chemistry in their research would benefit from the training and the Martz lab has done an excellent job organizing the workshop and providing valuable, relevant information in a restricted time frame. As the science community increases their use of autonomous pH sensors, this workshop was both timely and crucial to ensure that data collected to monitor changes in oceanic carbonate chemistry in response to global climate change can be compared across groups and over time."* —Andrea Kealoha, Hawaii Pacific University

*"[T]he workshop provided both the theoretical and hands-on training necessary to collect high-quality pH data from autonomous sensors … participants learned to service instruments, change batteries, operate the instrument software, deploy sensors, collect and analyze discrete bottle samples in order to calibrate the sensor, and quality control the sensor data. … I now have a better understanding of everything from the sensor operations theory to field deployment considerations in coastal zones. The emphasis on hands-on training in the workshop allowed workshop*

*participants to cement their new theoretical knowledge with the hands-on experience necessary for successful deployments. … Most of the workshop participants were early career scientists and thus the workshop also provided an important peer networking opportunity. I am very thankful for OCB support for this workshop and hope that OCB continues to support future iterations of this workshop."*
—David Koweek, Stanford

*"In the context our of research group's use of pH sensors, all of my concerns and questions were answered and I feel that I can move forward with our research knowing the advantages and limitations to these instruments. While it is clear that no oceanographic sensor is without its shortcomings, the lessons in "best practices" and troubleshooting tips gained at the workshop will go a long way in establishing a dependable standard operating procedure for our lab and help us overcome difficulties experienced in the past. I appreciated Dr. Martz's unbiased view on the pros and cons of each pH sensor and found the students in his lab to be incredibly knowledgeable on not just autonomous pH sensors, but on the various methods of analysis of seawater carbonate chemistry. Overall, this workshop succeeded in training me how to operate the 3 available pH sensors, the "best practices" in maintaining these instruments while deployed, and has helped better shape my opinion on which sensors would be best for our uses in the field."*
—Coulson Lantz, California State University, Northridge

# Partner Programs

IMBER

Call for proposals for workshops for IMBER IMBIZO lV October 26-30, 2015 (Trieste, Italy) – proposal submission deadline: **December 8, 2014**

New decision support tool IMBER-ADApT (Assessment based on Description, Responses and Appraisal for a Typology) to respond to global change - Calling for case studies, dealing particularly with marine fisheries and aquaculture

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solas

Register and submit abstracts for SOLAS Open Science Conference (September 7-11, 2015, Kiel, Germany)

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International Ocean Carbon Coordination Project IOCCP

Summer Course on biogeochemical sensors: *Instrumenting our oceans for better observation* (June 22-July 1, 2015, Sven Lovén Center for Marine Sciences, Kristineberg, Sweden)

4th Intercalibration Exercise for Nutrients (IOCCP/JAMSTEC) – confirm participation by **November 30, 2014**

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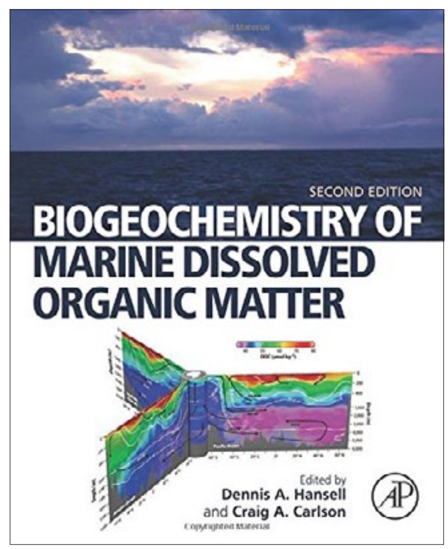
North American Carbon Program

Register for 5th North American Carbon Program Principal Investigators Meeting


# Ocean Acidification News

- Reminder: please contribute to the OA-ICC data compilation on the biological response to ocean acidification!
- US Government Accountability Office (GAO) publishes report on federal response to ocean acidification
- Updated synthesis of *Impacts of Ocean Acidification on Marine Biodiversity*
- New video (a product of a collaborative New Zealand-United States workshop *Future proofing New Zealand's shellfish aquaculture: Monitoring and adaptation to ocean acidification*) highlights ocean acidification as an issue with the potential to affect the New Zealand shellfish aquaculture industry
- ASLO seeking authors to complete an L&O e-lecture series on ocean acidification: The submission deadline is **March 31, 2015**. If you are interested, please contact Dr. Jennifer Cherrier (LOlectures-editor@aslo.org), the editor for L&O e-Lectures and share your idea. Author teams are encouraged.

# Community Announcements




### Publications and Education resources

- The US Repeat Hydrography CO2/Tracer Program (GO-SHIP): Accomplishments from the first decadal survey. has been jointly published by US CLIVAR and OCB
- 2nd edition of *Biogeochemistry of Marine Dissolved Organic Matter* is now available (Editors: D.A. Hansell and C.A. Carlson): Available from Elsevier On line and Amazon.com
- New L&O e-lecture on the biological pump: Neuer, Susanne, Morten Iversen, and Gerhard Fischer. 2014. The Ocean's Biological Carbon Pump as Part of the Global Carbon Cycle. *Limnol. Oceanogr.* e-Lectures, doi:10.4319/lol.2014.sneuer.miversen.gfischer.9
- Revised North Atlantic-Arctic science plan now available on the International North Atlantic-Arctic research planning website

### Research tools

- Updated Global Carbon Atlas, including global and national $CO_2$ emissions to 2013, and the translation of the Atlas into 4 additional languages (French, Chinese Mandarin, Russian, Spanish, in addition to English) (Global Carbon Project)
- Updated Global Carbon Budget (Global Carbon Project)
- CDIAC Publication *An observation-based global monthly gridded sea surface $pCO_2$ product from 1998 through 2011 and its monthly climatology* (Landschützer et al., 2014)
- CDIAC Publication *NDP-094: Climatological Distributions of pH, $pCO_2$, Total $CO_2$, Alkalinity, and CaCO3 Saturation in the Global Surface Ocean* (Takahashi et al., 2014)

# Eco-DAS XI spotlights science communication

*By Elisha M. Wood-Charlson, Lydia Baker, Paul Kemp*
*Center for Microbial Oceanography: Research and Education, Department of Oceanography, University of Hawai'i at Mānoa*

Ecological Dissertations in the Aquatic Sciences (Eco-DAS) is an NSF-sponsored symposium series that brings the next generation of aquatic scientists to Hawai'i with the aim of fostering interdisciplinary collaboration. This year's Eco-DAS XI hosted 35 participants. The majority was from the USA, but researchers from Canada, Sweden, Spain, and Australia were also able to participate, thanks to additional travel support from ASLO. The symposium typically consists of a series of research presentations by attendees, followed by several days of cross-discipline discussion that eventually leads into a dozen (or so) collaborative chapters. Previous Eco-DAS proceedings are available through ASLO.

This year, the co-organizers (Paul Kemp, Lydia Baker, Elisha Wood-Charlson - University of Hawai'i at Mānoa, and Adrienne Sponberg - ASLO) modified the Eco-DAS communication strategy, with the goal of getting participants to think collaboratively, earlier. As one might expect for recent PhDs, Eco-DAS presentations tend to focus on a particular ecosystem (limnic/marine, pelagic/benthic, nearshore/offshore) and/or methodology (biogeochemical, molecular, modeling, etc.). Reaching beyond an inherently specialized PhD thesis, and across the natural diversity in aquatic science research, can often be challenging. This is especially true when our research spans vast scales (e.g., microbes to global models) and requires unique, specialized vocabulary (i.e. jargon). With the aim of rapidly overcoming these collaborative challenges, several new communication strategies (written and verbal) were put to the test.

Prior to the 2014 symposium, participants were tasked with writing a concise (500 words or less), jargon- and acronym-free summary of their collaborative chapters. These were available to the Eco-DAS XI community as a resource while they were working on their communication- and collaboration-focused presentations. The most surprising outcome of this exercise was that, when given a little background information about their audience, the participants created chapter summaries that were almost completely free of jargon, especially when compared to the chapter outlines they submitted with their initial applications. This suggests that scientists are aware of words that define our special research niches, and we can adjust our communication to reach beyond the familiar and speak to non-specialists.

The first few days of the symposium are always focused on getting ideas on the table. This year, the typical research talk was abandoned for an innovative new format that promoted interdisciplinary science communication and early collaboration. Participants were asked to present their research, chapter ideas, and potential areas of collaboration (distilled from the online summaries) in a concise, relatively 'jargon-free' manner. Their research was to be briefly summarized in ~3 minutes (challenging after completing an entire PhD…), saving time for them to present their chapter ideas and how they might fit into collaborations with people they had not yet met. Each group of three presenters formed a discussion panel, and the panelists were given time to pass around collaboration ideas developed on-the-spot from their presentations, either between themselves, or with members of the audience regardless of specialty.

The new format for chapter summaries and presentations appeared to be a success. Even before meeting the other participants, everyone was able to make connections to other chapter ideas. During the symposium, post-talk discussions were enthusiastic and often extended into coffee breaks during the day and well into the dinner hours after. All participants were actively engaged throughout the 2.5 days of presentations, making suggestions about opportunities for the speakers to collaborate, as well as making connections to themselves and others in the audience. Eco-DAS XI discussions typically focused on important linkages that need to be addressed in aquatic science research. These are nicely illustrated by comparing a word cloud constructed from the participants' proposed chapters to one constructed from topics that came up during discussion of the presentations (Figure 1). Notably, keywords like "scale," "model," and "interactions" became much more prominent during discussion, while fundamental words such as "ecosystems" and "change" were important in both. These new connections

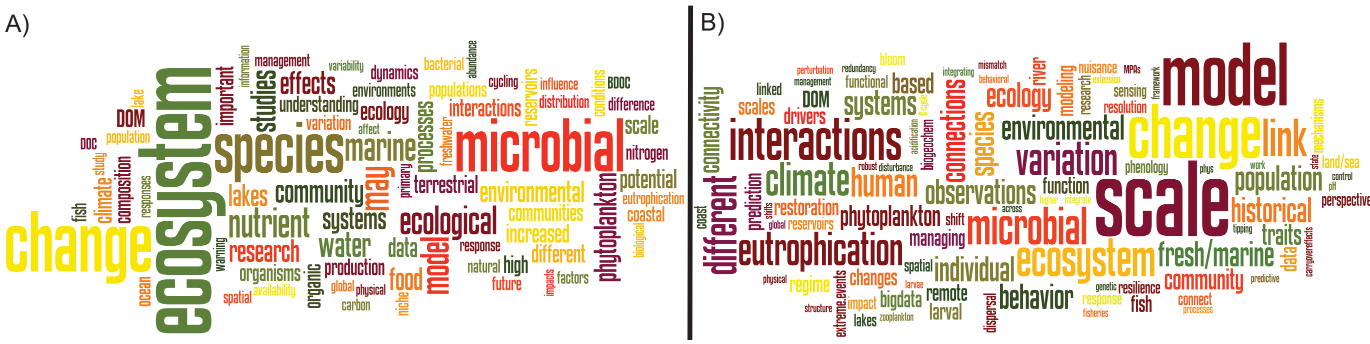



**Figure 1.** Word clouds created from A) proposed chapters submitted by Eco-DAS participants prior to the symposium and B) discussions about presentations during the symposium. Word clouds present the abundance of words used in a script proportional to their size in the image (created at wordle.net).

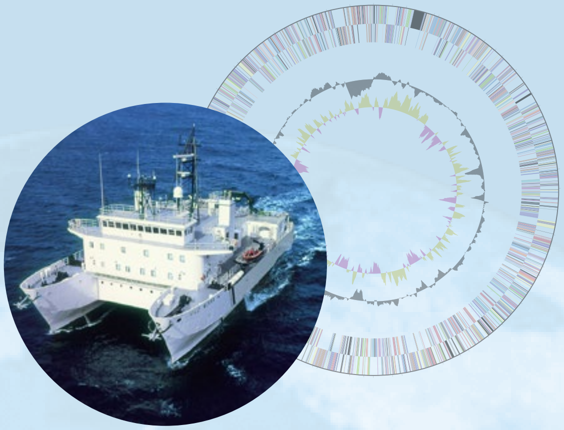
should result in very interesting synthesis chapters. Many of the resulting Eco-DAS XI chapters will be available towards the end of 2015 in ASLO's L&O Bulletin and other aquatic science-related journals.

Even though the collaborative discussions were quite effective, no presentation went completely without jargon. When the group was asked, "How many of you heard at least one jargon word during the presentations?" everyone raised a hand. To emphasize that we commonly use words in aquatic science that we may not think of as jargon, Elisha invented a game she dubbed "Jargon Taboo." Each participant received an index card with a jargon word they had used during their presentation or in the discussion time. Their task was to use the Eco-DAS XI community to help translate their jargon into a scientifically acceptable, yet more accessible, replacement word or phrase. Many people commented that this activity was one of the more challenging segments of the symposium. Although the chapter summaries did away with most of the specialized jargon, this activity suggests that aquatic scientists commonly use words not typically recognized as jargon. These more accepted jargon words may require a community effort to translate until a wider audience, ideally one outside the aquatic sciences, can understand them. The organizers are planning to develop an aquatic science community forum with this in mind, which will be seeded with terms and translations from this Jargon Taboo exercise.

With a little instruction and training, the participants of Eco-DAS XI excelled in cross-disciplinary science communication. This is due, in no small part, to the exceptional participants of the symposium, who took on the challenge with an open mind. In fact when asked, "how many of you have done some science communication?" we were quite surprised that more than half of the participants had already been interviewed for TV or radio! It appears that the next-generation of aquatic scientists are embracing the challenge of communicating their science to a broader audience as part of their professional careers. In fact, one of this year's collaborative chapters (with over 10 authors) will focus on highlighting the need for science communication training for graduate students, along with recommendations for PhD programs to get on board and some resources to get people started. In the end, an easy pairing of our communication strategies with the inherent experience of this group is really what made Eco-DAS XI a success.

# OCB now hosts four C-MORE Science Kits in Woods Hole

OCB currently hosts three C-MORE Science Kits: Ocean acidification, marine mystery, and ocean conveyor belt. The ocean acidification kit (two lessons, grades 6-12) familiarizes students with the causes and consequences of ocean acidification. The ocean conveyor belt kit (four lessons, grades 8-12) 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. With the 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. The marine debris kit focuses primarily on plastic marine debris. Students critically examine data and samples and take part in activities that explore the causes, geographical distribution, and biological impacts of marine debris. Teachers along the eastern seaboard may use these kits for free. To reserve a kit, please submit a request.



2014 Summer Course participants on board R/V *Kilo Moana*

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

# Microbial Oceanography: **Genomes to Biomes**

## May 26 to June 26, 2015

*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 2015 summer course is offered to graduate students, postdoctoral scholars, and early career faculty with interests in marine microbiology and biological oceanography.

For course information, please visit

**cmore.soest.hawaii.edu/summercourse**

AGOURON INSTITUTE

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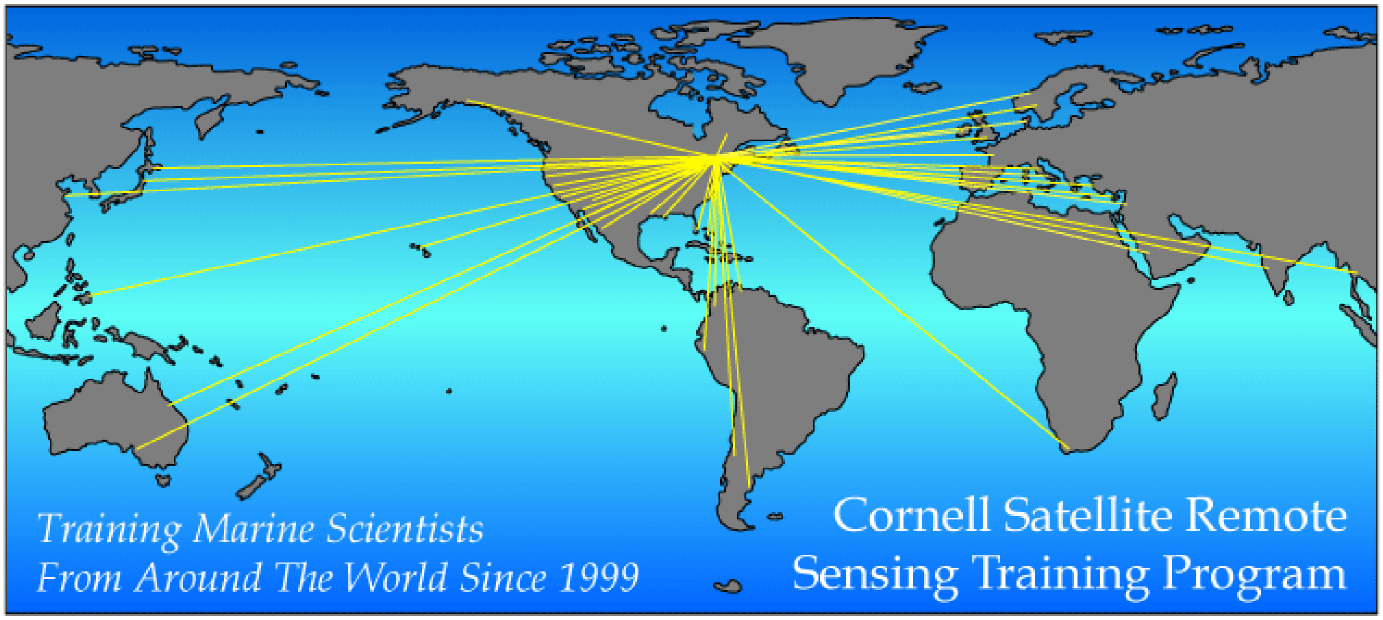
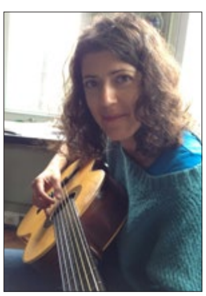
UNIVERSITY OF HAWAI'I AT MĀNOA

C-MORE

# OCB supports student participation in the Cornell Satellite Remote Sensing Training Program




Every year at Cornell University, Dr. Bruce Monger and colleagues coordinate and run an intensive 2-week summer training course on satellite remote sensing techniques. In an effort to promote more widespread and effective use of satellite remote sensing data in OCB research and offer more hands-on training opportunities for early career scientists in the OCB community, the OCB Project Office provided tuition, housing, and travel support for five early career scientists, including graduate students and postdocs, to take the course, which was offered May 30-June 13, 2014. Below are some of their reflections on the training program.



**Anna Cabré (University of Pennsylvania)**
Anna works in the 'Ocean Biogeochemistry and Climate Change' group at the University of Pennsylvania as a postdoctoral researcher. Their group (led by Irina Marinov) looks at global connections and patterns in the physical ocean, and the consequences for biogeochemistry. Our experience is based in analyzing earth system simulations, but we are eager to incorporate satellite data to complement it.

*"The 'Remote Sensing' class at Cornell University was extremely helpful to achieve this transition. Dealing with observational datasets when coming from a theoretical background is overwhelming, but this class was perfect to get into the satellite language. Bruce is an amazing scientist and above all, a unique person who brought warmth and motivation to the class. We learned about biological algorithms and retrieval of Chl from satellite data, as well as other useful datasets such as winds, temperature and sea surface height. Since then, our group has been analyzing particle size from satellite data and putting it in the context of biogeochemical simulations."*

**Emily Cira (Texas A&M University - Corpus Christi)**
Emily is a Ph. D. student in the Coastal and Marine Systems Science Program at Texas A&M University – Corpus Christi, working under the advisement of Dr. Michael Wetz. Her dissertation research focus is the phytoplankton dynamics of Baffin Bay, Texas. In particular, she is interested in how the phytoplankton dynamics of this system vary on spatial and temporal scales, and how they are influenced by environmental factors, like large-scale seasonal wind patterns.

*"The Cornell Ocean Remote Sensing Course far exceeded my expectations – I went into the course with very little experience using satellite data, and I left two short weeks later feeling capable of processing satellite images on my own. While Dr. Monger provided the necessary theory, much of the course was spent in the computer lab where I was able to practice downloading and processing data specific to my research interest in coastal water quality. Dr. Monger always made himself available to work through questions with students one-on-one; these were some of the most valuable learning moments for me throughout the two-week course. I have already begun applying some of the practical skills I learned to my dissertation research and I can already see how having this experience will be a tremendous asset moving forward. The Cornell Ocean Remote Sensing Course was an exceptional experience and I am very thankful to OCB for providing the funding for me to attend."*

**Katie Glodzik (University of Florida)**
Katie is a second-year PhD student in Wildlife Ecology and a Water Institute Fellow at University of Florida, studying river flow change impacts to estuarine salinity and coastal forest. She has experience evaluating sea level rise and saltwater intrusion impacts to wetlands, including biogeochemical changes and wetland migration. During her first year at UF, she realized remote sensing could be a valuable tool for measuring estuarine salinity (since salinity is correlated with colored dissolved organic matter) and for identifying salinity-stressed vegetation. She had geospatial analysis experience from her Master of Environmental Management at Duke University, but she had hardly used remote sensing.

*"The course at Cornell gave a great overview of remote sensing principles, available data sources, and interpretation techniques. Since it was a hands-on training course, I now feel equipped to build my own algorithms for deriving colored dissolved organic matter and to interpret raw data."*

**Randy Jones (Virginia Institute of Marine Science)**
Randy Jones is currently a master's student in Walker Smith's lab at the Virginia Institute of Marine Science, College of William and Mary. His research is part of a larger effort to understand how food web interactions may influence penguin prey availability in the waters offshore of the Cape Crozier Adélie penguin colony, located in the southwestern Ross Sea, Antarctica. An autonomous underwater Seaglider deployed in the colony's foraging region during the winter of 2012-2013 provided a data set of physical and biological variables to better understand the distribution of phytoplankton in a relatively small (25x50 km) study area. Randy's research efforts have focused on utilizing the glider data set to understand event-scale perturbations in the seasonal progression of the phytoplankton bloom, due to water mass and wind mixing and changes to bloom forcing. One of his goals is to incorporate regional data sources, such as satellite observations, to understand the glider observations in the context of the larger region.

*"Bruce Monger's satellite remote sensing training course can best be described as invaluable. His long-running course at Cornell consists of two weeks of engaging and informative classroom work and lectures, which are interspersed daily with ample lab time spent practicing concepts, running through processing procedures, and performing analyses with tools he has developed and with those that are available from the larger ocean color community. With the course, I gained valuable skill sets in two widely used programming languages (IDL and Python) that are the basis for the processing and analysis of remote sensing data from a variety of satellite platforms. Following my return to Virginia, I have been able to*

*quickly take Bruce's tools and analyses along with my improved understanding of remote sensing science and set up the same functionality for processing satellite data on our high-performance computing systems. This has allowed me to incorporate analyses of ocean color into my research work in the southwestern Ross Sea in ways that augment our Seaglider and shipboard observations. I believe this course will truly enhance our understanding of the phytoplankton dynamics there. My participation in this great course would not be possible without funding from the OCB office and for this I am very grateful."*

**Francisco Soto-Santiago (Universidad de Puerto Rico en Río Piedras)**

Francisco's main goal is to integrate his knowledge on coral reefs to the human dimensions within these natural systems. This will help to create better conservation and management techniques and develop human/natural relationships in a more sustainable way. He is also interested on how global climate change affects coral reef dynamics through time. Furthermore, he finds interesting the interactions between other invertebrates and algae to coral growth and development. He wants to integrate other research fields such as education, history, anthropology and sociology, among others to his coral reef interests. This will provide him with stronger tools to address problems within coral reef ecosystems.

*"The course was a great experience that helped me to get a better sense of how to work with remote sensing data in coral reef ecosystems and how to begin to develop new ideas on that subject. I am planning to use the techniques learned in the course to develop a project about historical patterns of sedimentation within coral reef ecosystems in eastern Puerto Rico. This has never been done in my country and it will help to address coral reef management problems in the area."*

# OCB sends students to Second IOCCG Summer Lecture Series

## *Frontiers in Ocean Optics and Ocean Color Science*

IOCCG International Ocean Colour Coordinating Group

The second IOCCG Summer Lecture Series, dedicated to high-level training in the fundamentals of ocean optics, bio-optics and ocean color remote sensing took place at the Laboratoire d'Océanographie de Villefranche (LOV), in Villefranche-sur-Mer, France from July 21 – August 2, 2014. The emphasis of the course was on current critical issues in ocean color science, and consisted of lectures by specialists, as well as a few hands-on practical sessions. OCB provided travel support for 3 U.S. graduate students to participate in the lecture series. Below are some of their reflections on the lecture series.

**James Allen (University of California, Santa Barbara)**

James Allen obtained his B.S. in Meteorology from the University of Tennessee at Martin and is in his second year as a Ph.D. student at the University of California, Santa Barbara, working with Prof. David Siegel. He is currently studying optical oceanography and its use as a tool for understanding biogeochemical processes throughout the ocean. One of the goals for his research is to utilize ocean color spectra with a novel algorithm to more effectively determine the size and distribution of phytoplankton on a global scale.

*"The IOCCG 2014 Summer Lecture Series was a very strong class that helped me understand many different topics as I progress in my career as an optical oceanographer. It was the perfect setting to bond*

*with my peers from around the world while building professional relationships with everyone involved. It was extremely relevant to my research, and I was able to immediately use this knowledge in my ongoing projects. The course was made up of a combination of hands-on, theoretical, and applied work that walked us through everything from Mie Theory to calibrating and using an AC-S to running semi-analytic ocean color inversion models. I am very excited to be able to collaborate with everyone in the future!"*

**Natalie Freeman, Univ. of Colorado, Boulder**

Natalie Freeman has a M.S. in Atmospheric and Oceanic Sciences from the University of Colorado at Boulder and a B.S. in Mathematics with an applied concentration in Statistics from the University of Kansas in Lawrence, KS. Natalie is currently a Ph.D. candidate, research assistant, and National Science Foundation Graduate Research Fellow. She works with Dr. Nicole Lovenduski, at the Institute of Arctic and Alpine Research, investigating Southern Ocean acidification and is currently using remote sensing to identify and quantify changes in the ocean carbon cycle, such as changing calcite concentrations and calcification rates of certain phytoplankton.

*"I consider it a great honor to have been given the opportunity to attend the 2nd IOCCG Summer Lecture Series. Amazing memories, valuable contacts and new friendships were made with the students and lecturers in beautiful Villefranche-sur-Mer! What an extraordinary experience it was to be surrounded by such a diverse group of scientists doing cutting-edge research within the ocean color community – an opportunity that is not available to me at my home institution. This lecture series was extremely organized and informative; an opinion I know is shared by all who attended; #1, top notch! The amount of material shared and the quality of lecture content, in addition to the hands-on experience, exceeded my expectations, helped to improve and expand my current understanding and knowledge of ocean optics as applied to my current research, and will significantly impact and inform my future research. My gratitude is beyond words. I truly appreciated the various forms of assistance and support from the IOCCG coordinators, as well as from everyone involved with the OCB Program. Thank you, OCB, for your continued support of my research and your very generous investment in my education, as well as in my future. I will take the experiences, the memories AND the knowledge with me always."*

**Matt McCarthy, University of South Florida**

Matt was born and raised in Gainesville, Florida and graduated from the University of Florida with a B.A. in Anthropology in 2009. He earned his M.S. in Marine Science from the University of North Carolina - Wilmington in 2013 and is currently working on his Ph.D. in Biological Oceanography at the University of South Florida's College of Marine Science. He is working with a team in the Institute for Marine Remote Sensing (IMaRS), led by Dr. Frank Muller-Karger, researching the influences of climate change and extreme weather events on water quality in estuaries around the Gulf of Mexico and Puerto Rico.

*"I had been told by my lab mates and peers before the trip that this would be a very useful and memorable experience for a young ocean color scientist like myself. My high expectations were quickly exceeded upon arriving in the picturesque Villefranche-sur-mer and meeting the diverse, global community of ocean color scientist attendees and lecturers.*

*After the first few days of lectures I recall thinking to myself that this is the best preparation for my upcoming comprehensive exams that I could imagine. The material incorporated intuitive reviews of the basic ocean color remote sensing principles from some of the most successful and erudite members of our community before building on those fundamentals with more advanced theory and methodology lectures. The practical sessions that had students rotate between stations were fantastic for confirming and solidifying the theory previously presented. Having the lecturers there to walk students through the stations and explain through their own experiences the concepts we were learning was invaluable, albeit intimidating at times. As an Education Officer for a local volunteer group working with teenagers interested in marine science, some of the practical stations gave me great ideas of how to present remote sensing concepts to young people in exciting and memorable ways.*

*For my research, the lectures and practical by Kevin Ruddick and his colleague, Quentin, were the most interesting. My group works with MODIS to study coastal water quality, but I also utilize Landsat and WorldView-2 imagery for coastal land-sea interface applications. I was excited to learn about his group's use of Landsat 8 for studying coastal turbid waters, and will follow their work as I hope to adapt it to my own research.*

*One of the greatest but most understated advantages to experiences like this is the opportunity to meet and get to know other young professional scientists from different countries and cultures. Not only do we all work on different projects, but we've taken different routes and encountered various challenges along the way. Together we can discuss scientific, cultural, social, economic and political circumstances that shape our professional development, and learn about the situations facing peers from different regions of the world. We are very much a global community, but communication through email, phone conversations and conference proceedings does not adequately facilitate the development of professional relationships the way that fully-immersed lecture series like this do.*

*This was ultimately an invaluable experience for me to learn more about advanced concepts in my field, meet the preeminent scholars whom I hope to emulate, and interface with my generation's scientific community. I feel better prepared as a young ocean color scientist, and believe that I formed good relationships with many of the attendees and lecturers that will last throughout my career. Thank you very much to the IOCCG, administrators, lecturers and colleagues for making it such a useful and enjoyable experience!"*

# OCB supports student participation in IMBER ClimECO4


IMBER focuses on the interactions and linkages between biogeochemical cycles and food webs, including humans, with the aim of improving the predictive capacity for marine ecosystems increasingly affected by global change. The fourth IMBER summer school, ClimEco4, continued IMBER's focus on fostering research at the interface of natural and human systems. The course included lectures and activities focused on indices of climate change, climate impacts, and ecosystem services, and how these are linked to indices for socio-economic and policy information in relation to climate-ecosystem interactions.

**Pamela Barrett (University of Washington)**
Pamela Barrett is a PhD candidate in the School of Oceanography and a graduate fellow in the IGERT Program on Ocean Change at the University of Washington working with Dr. Joseph Resing. She studies the biogeochemical cycling of iron and other trace metals in the surface ocean, focusing on the role of particulate matter in controlling trace metal supply and removal.

Pamela received a M.S. in chemical oceanography from the University of Washington in 2012. Prior to beginning graduate work at the UW, she earned a B.S. in chemistry and B.A. in political science from the University of Rochester and taught high school science in the Oakland Unified School District.

*"Attending the IMBER ClimEco4 summer school gave me the opportunity to learn from international and multidisciplinary researchers in a small, participation-based setting. The lecturers introduced a range of modeling tools and techniques, some of which I have been able to incorporate into my own projects. The summer school sessions also produced many useful discussions concerning how to best connect and collaborate with social scientists and policy-makers to develop science-based policy options."*

**Yang "Cathy" Feng (Virginia Institute of Marine Science)**
Cathy is currently a postdoctoral research associate in the Biological Sciences department at the Virginia Institute of Marine Science. In her interdisciplinary research, she explores the interaction among marine physical environments, biogeochemical cycles and ecosystems using a modeling approach.

*"Thanks OCB for the travel support to IMBER ClimECO4 summer school. The whole experience was so awesome! As a scientist working in academia, I spend most of my time publishing my results without thinking about how useful they are. The summer school helped me realize what the management world cares about, learn skills to communicate with managers, and motivated my thinking about the practical use of my modeling work for supporting high-stakes decision making in marine environmental management. It was also a great opportunity to build connections with early career scientists, policy makers and managers from different countries, which provides the possibility to work together to improve global ocean environments, ecosystem services and sustainability in the future."*

**Xujing Davis (Woods Hole Oceanographic Institution)**
Xujing is a physical oceanographer that focuses on the role of air-sea interactions in climate-scale processes. She earned her Ph.D. in 2008 from the University of Rhode Island and M.S. in 2002 from Florida State University, both in physical oceanography. She comes from China originally and obtained both a B.S. and M.S. in Marine Meteorology from the Ocean University of China before coming to the U.S. As a postdoctoral researcher and research associate at the Wood Hole Oceanographic Institution, her focus has evolved in an increasingly interdisciplinary direction, with attention towards the biological and biogeochemical ties to ocean circulation dynamics.

*"The ClimECO4 summer school offered an exceptional opportunity to further develop these interests, and added new experiences in the assessment and policy aspects directly relevant to such work. I am very interested in expanding my knowledge associated with the impact of climate change on marine ecosystems and particularly how to bridge this scientific research with assessment, policy and management. I think that ClimECO4 offered exactly such opportunity and I benefited greatly from this valuable summer program."*

**Massimo Di Stefano (University of New Hampshire)**
Massimo Di Stefano is currently a Ph.D. student in the Oceanography program at the University of New Hampshire. He is conducting his research under the direction of Dr. Larry Mayer at The Center for Coastal and Ocean Mapping - Joint Hydrographic Center (CCOM-JHC).

After graduating with a Master's Degree in Environmental Science from "Istituto Universitario Partenophe" (Naples - IT), specializing in Marine Ecosystems, Massimo moved to the US to work as a software engineer on staff at the Tetherless World Constellation (Rensselaer Polytechnic Institute - RPI) in collaboration with the Woods Hole Oceanographic Institution (WHOI) on the ECO-OP (Employing Cyber Infrastructure Data Technologies to Facilitate Integrated Ecosystem Approach for Climate Impacts in North East & California Large Marine Ecosystems) project with Professor Peter Fox and collaborators from WHOI.

A founding member of GFOSS.it, the Italian community of users and developers of Geographic Free/Open-Source Software (GFOSS) and charter member of OSGeo, Massimo has spent more than 10 years developing Geographical Free and Open Source Software, with current development activities in GRASS, OSSIM, QGIS and OSGeo Live projects.

*"The ClimEco4 summer school in Shanghai was an awesome experience and it definitely surpassed my expectations. Thank you so much to OCB for the support!*

*I was most impressed by the interactions across multiple disciplines at this summer school, as well as the quality of the lectures. We also had really interesting debates, as we made up quite a unique group of professionals with a wide range of skill sets. Attending this summer school has been an invaluable opportunity to share my work with other researchers.*

*I particularly enjoyed the discussions around data access, metadata curation, and reproducibility of research, which are all very related to my interest in open access to software and data. It was very interesting to realize how researchers from very different fields are met with very similar problems. The "take home message" for me is that communication between scientists, and multidisciplinary approaches are the key to solve complex problems like climate change."*

**Jesse Lopez (Oregon Health and Science University)**

Jesse is a Ph.D. candidate in Environmental Science and Engineering at Oregon Health and Science University and a Department of Energy Computational Science Graduate Fellow. His graduate work is focused on studying sediment dynamics and potential influences on biogeochemical processes in the Columbia River estuary using high-resolution numerical models and observations. His research interests lie broadly at the intersection of environmental studies, high-performance computing, and data analysis. Jesse is also a former mathematics teacher and AmeriCorps alumni who completed undergraduate studies in history and mathematics at the University of Washington.

*"I had a great experience working with and learning from a diverse group of experts from around the world about the many facets of identifying, understanding, and potentially ameliorating perturbations to established biogeochemical patterns. The workshop provided critically important training in scientific content and methodology, as well as effective means of communicating to non-specialists. The training helped to make me a more knowledgeable and productive scientist and has led to potential future collaborations."*

# Calendar

*Please note that we maintain an up-to-date calendar on the OCB website.*
**OCB-led activity **OCB co-sponsorship or travel support*

| 2014 | |
|---|---|
| December 8-12 | Arctic Change conference (Ottawa, Canada) |
| December 12-14 | Ocean's Carbon and Heat Uptake: Uncertainties and Metrics - A joint US CLIVAR/OCB workshop (San Francisco, CA) |
| December 15-19 | 2014 Fall American Geophysical Union (AGU) Meeting (San Francisco, CA) |

| 2015 | |
|---|---|
| January 26-29 | 5th North American Carbon Program (NACP) Principal Investigators Meeting (Washington, DC) |
| February 12-16 | 2015 AAAS meeting (San Jose, CA) |
| February 22-27 | 2015 Aquatic Sciences Meeting: Global And Regional Perspectives — North Meets South (Granada, Spain) |
| March 21-22 | Workshop on Effects of climate change on the biologically-driven ocean carbon pumps (Santos, Brazil) |
| March 23-27 | Third International Symposium on Effects of climate change on the world's oceans (Santos, Brazil) |
| April 20-24 | 2015 NASA Carbon Cycle and Ecosystems Joint Science Workshop (College Park, MD) |
| April 23-30 | Arctic Summit Science Week (Toyama, Japan) |
| May 4-8 | 47th International Liège Colloquium on Ocean Dynamics Marine Environmental Monitoring, Modeling and Prediction (Liège, Belgium) |
| May 18-21 | 7th International Symposium on Gas Transfer at Water Surfaces (Seattle, WA) |
| May 26-June 26 | C-MORE Summer Course (Honolulu, HI) |
| June 16-18 | International Ocean Color Science Meeting (San Francisco, CA) |
| June 23-25 | Atlantic Meridional Transect (AMT) Open Science Conference (Plymouth, UK) |
| July 20-23 | 2015 OCB Summer Workshop (Woods Hole, MA) |
| July 26-31 | Gordon Conference Chemical Oceanography (Holderness, NH) |
| September 7-11 | SOLAS Open Science Conference 2015 (Kiel, Germany) |
| October 26-30 | IMBER IMBIZO IV - Marine and human systems Addressing multiple scales and multiple stressors (Trieste, Italy) |

# Upcoming Funding Opportunities

*For more information, please visit OCB's funding opportunities web page. The OCB calendar also lists upcoming deadlines.*

### Rolling Submissions

- NSF Research Coordination Networks (RCN)
- NASA ROSES Rapid Response and Novel Research in Earth Science
- NASA ROSES Fellowships for Early Career Researchers (current fellows)
- NASA ROSES Topical Workshops, Symposia, and Conferences

| 2014 | |
|---|---|
| November 18 | NSF Dynamics of Coupled Natural and Human Systems (CNH) proposal deadline |
| December 15 | NOAA/NOS/NCCOS/CSCOR Harmful Algal Bloom full proposal deadline |

| 2015 | |
|---|---|
| February 15 | NSF Chemical Oceanography and Biological Oceanography proposal targets |
| February 15 | NSF Ocean Technology and Interdisciplinary Coordination proposal deadline |
| August 15 | NSF Chemical Oceanography and Biological Oceanography proposal targets |
| October 2 | NSF Coastal SEES proposal deadline |
| October 19 | NSF Arctic Research Opportunities proposal deadline |