Ocean Carbon and Biogeochemistry
Studying marine biogeochemical cycles and associated ecosystems in the face of environmental change
News
Volume 5, Number 3 • Fall 2012

An Autonomous Study of the Subpolar North Atlantic Spring Bloom — NAB08

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The subpolar North Atlantic and its challenges

The subpolar North Atlantic plays a major role in the global carbon cycle and is responsible for more than 20% of net global ocean CO_2 uptake (Sabine et al., 2004) as a consequence of both the cooling of northward flowing water, *the solubility pump*, and the net export of organic carbon, *the biological pump*. In this region, explosive growth of diatoms occurs in late April and May, during the annual event commonly known as the North Atlantic spring bloom (Ducklow and Harris, 1993). This springtime increase in phytoplankton biomass is accompanied by a significant drawdown in the carbon dioxide content of surface waters (Watson et al., 1991) and by a rapid flux of aggregates of fresh phytoplankton from the surface to the sea floor (Lampitt, 1985). The timing of the subpolar spring bloom varies interannually (Henson et al., 2009), presenting logistical challenges for scheduling ship-based studies of the spring bloom. The inherent patchiness, so clearly seen in ocean color satellite imagery (Fig. 1), presents analogous challenges to coherently understanding the temporal trajectory of the bloom. Without measurement schemes capable of resolving 4-D variability at scales of kilometers and days, efforts to understand the bloom's temporal evolution are hampered.

Autonomous sampling with an array of mobile platforms capable of two-way communication and adaptive sampling, provides a strategy to overcome limitations of using ships, moorings or satellites alone – ships cannot practically provide the desired persistence, and scheduling can be problematic, moorings measure only in 1-D, and ocean color satellites see only surface waters in cloud-free conditions. As pointed out by Scott

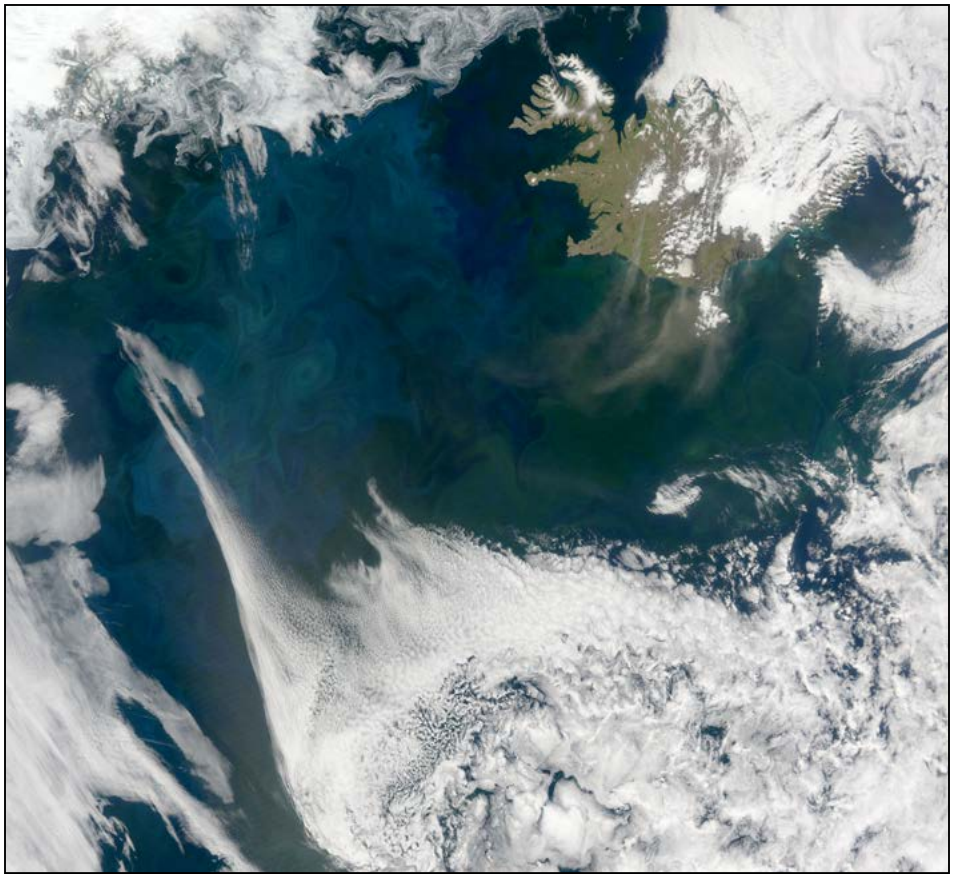

Figure 1: Ocean color satellite image of the North Atlantic bloom. Credit: NASA Earth Observatory (http://earthobservatory.nasa.gov/IOTD/view.php?id=7830).

Doney in the Fall 2011 *OCB News*, "Individual platforms and networks also have their own specific limitations on the suite of properties that can be measured and on the accuracy and precision of the resulting data... .A solution is to integrate multiple sampling approaches with models and process studies, but this requires an in-depth understanding of the relationship among observations..." In the NAB08 study described in this newsletter we developed an integrated, patch-scale observing system that exploited complementary capabilities of autonomous platforms, ship-based measurements, and satellites to address the observational challenges of: (i) characterizing temporal evolution of a patch; (ii) collecting quantitative, high-quality measures of physical, biological, and biogeochemical parameters at short temporal and spatial scales; (iii) relating detailed processes within the patch to larger spatial scales; and iv) maintaining these activities across a time span long enough to capture an entire bloom cycle.

We undertook an intensive program to study the North Atlantic spring bloom (NAB08) in the Iceland Basin between April and June 2008 using a combination of four Seagliders and a heavily instrumented Lagrangian float, ships, and ocean color and altimetry satellites. The autonomous platforms carried sensors necessary to quantify the evolution of the bloom and changes in key biogeochemical variables (Table 1), many of which were redundant to mitigate risk. They were deployed near the JGOFS site (60˚N, 20˚W; Fig. 2) in early April from the Icelandic research vessel *Bjarni Saemundsson*, well in advance of the beginning of the bloom. The Lagrangian float, similar to that described in D'Asaro (2003), followed the motion of the mixed layer, thereby defining a water-following coordinate system. The float tracked a patch, making measurements many times per hour

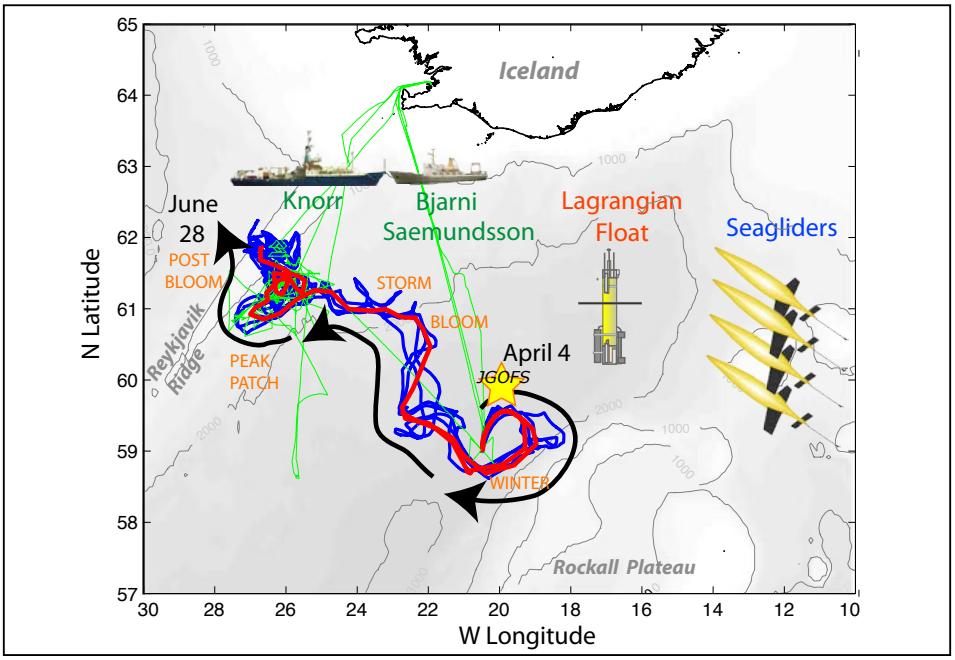

Figure 2. Tracks of float, gliders and ships during NAB08 experiment. Modified from Alkire et al. (2012).

as the bloom within the patch evolved. Once per day, the float communicated data to the University of Washington's Applied Physics Laboratory in Seattle via Iridium satellite, and then made its daily vertical profile from the surface to 230 m before resuming its drift mode in the upper mixed layer. The Seagliders surveyed an approximately 20 km-wide volume around the float, providing high-resolution measurements of both the patch and surrounding waters. They profiled about four times per day to a depth of 1000 m, relaying data home after each dive sequence and receiving updated navigation instructions, based on the anticipated trajectory of the float over the next 24 hours.

Float measurements continued through late May, and Seagliders through late June. Over the three-month period, the autonomous platforms observed the transition from deep winter mixed layers in early April, with high concentration of nitrate and low concentrations of phytoplankton and particulate organic carbon (POC), to an early May diatom bloom with decreasing nitrate and increasing phytoplankton, POC, and oxygen concentrations. As silicic acid (measured from the ship) became depleted, the phytoplankton community transitioned from large diatoms to small (pico) phytoplankton (Sieracki, *pers. comm.)*. Observations ended in late June with low nitrate and moderate phytoplankton but high POC concentrations equivalent to those at the peak of the diatom bloom.

An integral component of the autonomous experiment was a series of four cruises, three short cruises on the *R/V Bjarni Saemundsson* and a three-week process cruise in May on the *R/V Knorr* in which a number of OCB colleagues from the U.S. and Europe participated (Fig. 3). These cruises enabled us to rigorously calibrate and inter-calibrate sensors on all platforms, and to produce a data set of interdisciplinary, high-quality autonomous measurements. An aggressive program of field inter-calibration exercises was conducted multiple times for each platform, with simultaneous ship CTD and platform profiles taken in close proximity (˜100 m). For example, seven O_2 sensors were calibrated within 2 µmol O_2/kg

Table 1. Sensors used in the NAB08 experiment; LF = Lagrangian float, G = Seaglider, S = ship.

Sensor	Manufacturer	Platform	Accuracy/ Precision
T, S	SeaBird	LF, G, S	0.001C, 0.003
Vertical velocity (pressure)	Druck	LF	30/0.1 cm
Beam c (660 nm), c_p – 1st proxy for POC	WET Labs C-Star	LF, S	0.01/0.001 m^{-1}
Optical backscatter (700 nm), b_{bp} – 2nd proxy for POC	WET Labs FLNTU and ECO Puck	LF, S G	3 x 10-4/10-5 m^{-1}
Chlorophyll fluorescence (Ex 470 nm), proxy for phytoplankton biomass	WET Labs FLNTU and ECO Puck	LF, S G	~0.027 µg L^{-1} (accuracy varies with physiology)
PAR (irradiance)	LI-COR and Biospherical	LF S	± 5%, NIST traceable
Hyperspectral downwelling and upwelling (ir)radiance	Trios	LF	± 5%, NIST traceable
Dissolved O_2	SBE 43	LF, G, S	3/0.05 µmol kg^{-1}
	Aanderra Optode	LF, G	4/1 µmol kg^{-1}
Nitrate	Satlantic ISUS	LF	1/0.3 µM
Satellite chlorophyll	NASA	MODIS	~35%

with ~300 Winkler samples and 10 optical backscattering sensors were inter-calibrated within 1 x 10^{-4} m^{-1} (note that these sensors were additionally calibrated at the factory *en masse* before and after the experiment).

Several optical proxies were developed for key parameters that allowed us to project a more limited number of detailed biological and biogeochemical measurements onto a rich data set of autonomous observations. For example, over 320 chemical POC measurements were used to derive optical proxies for POC based on both beam attenuation and backscattering (Cetinić et al., 2012). Shipboard analyses of community composition using a flow cytometer and Flow CAM were projected onto broader spatial scales based on an optical 'community index.' This index (i.e., the ratio of chlorophyll fluorescence to optical backscatter) was a factor of two higher for diatom-dominated communities vs. microbial loop-dominated communities. This approach provides a model for addressing the challenge of acquiring "...an in-depth understanding of the relationship among observations..." It allows leveraging of critical but difficult shipboard measurements that cannot be obtained at appropriate scope and resolution onto arrays of autonomous sensors that can sample for much longer times, over broader regions, and at higher spatial resolutions. Quality-controlled NAB08 data and a series of detailed calibration reports, including all processing steps are available through BCO-DMO (http://osprey.bcodmo.org/project.cfm?flag=view&id=102&sortby=project), as described by Fennel et al. (2011).

Following the Spring Bloom

The NAB08 study led to new insights into the workings of the North Atlantic spring bloom, some of which will be elaborated in future newsletters. The characteristic patchiness of the subpolar North Atlantic spring bloom has its origins in the mechanism responsible for bloom onset. Using a combination of NAB08 observations, satellite data, and a model, Mahadevan et al. (2012) showed that the upper ocean restratification that controlled the development and timing of the NAB08 bloom was driven by submesoscale mixed layer eddies acting to slump the basin-scale meridional density gradient, rather than by Sverdrup's (1953) springtime solar heating of the upper ocean. Springtime mixed layer restratification can be thought of as a competition of processes. Mixing driven by wind forcing (dependent on both speed and direction relative to mixed layer horizontal density gradient; Thomas and Lee, 2005) and surface buoyancy loss act to maintain deep mixed layers. Mixed layer eddies act to stratify the mixed layer by converting lateral density gradients into vertical contrast. The NAB08 mixed layer restratified while the net surface heat flux was still cooling, but winds had weakened and turned sufficiently to allow the mixed layer eddies to overcome wind-driven mixing. The result is a patchy bloom, and one that begins 20

Table 2. Comparison of carbon flux estimates (modified from Briggs et al., 2011).

Dates	Publication	Flux source	Depth (m)	Flux estimate (mg C m^{-2} d^{-1})	Glider flux (mg C m^{-2} d^{-1})
23–27 April	Alkire et al., 2012	Float NO_3 and O_2	60	516	80*
24 April – 20 May	Bagniewski et al., 2011	Model	100	620-730	280
6–13 May	Alkire et al., 2012	Float NO_3 and O_2	60	984	688*
7–13 May	Martin et al., 2011	Thorium profile	100	360 - 620	524
14–15 May	Martin et al., 2011	Sediment trap	600	154**	146
14–15 May	Martin et al., 2011	Sediment trap	750	164**	71

* Depths are the same for each paired estimated, except for comparisons with Alkire et al. (2012) where glider flux estimates were not considered reliable at 60 m, therefore 100 m flux was used.

** Between 34 and 41% of POC in 14-15 May sediment traps were associated with resting spores of the chain-forming diatom *Chaetoceros* (Rynearson et al., *pers. comm.*).

to 30 days earlier than would occur by warming. Similar conditions exist in other subpolar seas, suggesting that this mechanism could control timing of bloom initiation over broad regions. Understanding the mechanism responsible for bloom timing, and potential phenological repercussions up the food web, is important for developing ecosystem scenarios in response to climate change.

A major accomplishment of NAB08 was tracking a phytoplankton patch to construct biogeochemical budgets. By working within a Lagrangian frame, temporal changes were clearly separated from spatial variations. Net community production (NCP) was computed from budgets of nitrate drawdown and oxygen evolution, corrected for air-sea flux (Alkire et al., 2012). Net primary production (NPP) was computed from ship-measured photosynthesis vs. irradiance curves collected during the cruises and float measurements of phytoplankton biomass and irradiance (Gudmundsson, *pers. comm.*). Early in the bloom, NPP and NCP were very similar, suggesting mostly new production. During the main diatom bloom, NPP exceeded NCP by ~ 25%, suggesting an increased importance of nutrient recycling. A large respiration event occurred at bloom termination, with minimal NCP but with continuing high NPP.

Apparent export of POC was computed as the difference between NCP and the inventory of POC, measured by the float. One uncertainty in the estimation of export was the potential accumulation of dissolved organic carbon, which was not measured. During the main bloom, the export ratio from the mixed layer approached 70%. At the peak of the diatom bloom, ~12% of the POC stock was exported per day, while after depletion of silicic acid and transition to a picophytoplankton community, less than 4% of the POC was exported per day. Community-dependent export rates, coupled with maps of phytoplankton biomass, can generate time series maps of POC export, incorporating the spatial patchiness.

Maximal estimates of apparent organic carbon export calculated from float data amounted to ~90 and ~570 mmol C m^{-2} during the early and main blooms, respectively. A comparison with independent fluxes derived from deep sediment traps and thorium disequilibrium kinetics (Martin et al., 2011) and from optical estimates of sinking aggregates (Briggs et al., 2011) suggests that much of the exported carbon was remineralized above 150 m. Table 2 compares estimates of carbon flux for these different approaches. On the 14 May deep sediment trap deployments, POC was dominated by resting spores of the chain-forming diatom *Chaetoceros* (Rynearson, Richardson, Lampitt, Poulton, *pers. comm.*), a form of packaged organic carbon that is highly resistant to microbial degradation.

A one-dimensional NPZ model was optimized using float data (Bagniewski et al., 2011). Although lack of zooplankton data prevented zooplankton parameters from being well constrained, variational optimization showed that using available float data helped constrain most of the phytoplankton parameters (photosynthetic, growth, and mortality rates) to accuracies better than 15%. These results are encouraging, and suggest that inclusion of biological and biogeochemical sensors should lead to advances in ecological and biogeochemical modeling (Fennel et al., 2011).

In collaboration with COSEE-Ocean Systems, a series of five webinars were produced (http://cosee.umaine.edu/programs/webinars/nab/), primarily directed at secondary school teachers. They described the multi-faceted

Figure 3. OCB collaborators during R/V Knorr process cruise in May 2008. Credit: Dane Wojcicki.

nature of this complex experiment and provided participants with a rich body of educational resources, including linked concept maps aligned with National Science Education Standards and access to datasets that have been translated into classroom activities. Simplified NAB08 data sets and Excel-based activities are provided on the website for classroom use.

Summary

The subpolar North Atlantic plays a key role in the global ocean carbon cycle. Documenting change in this and other remote and seasonally (or permanently) inhospitable regions is essential for understanding mechanisms and developing models of how ocean ecosystems and elemental cycles will respond to changing climate forcing. NAB08 successfully carried out an autonomous study of an important annual phenomenon in the ocean – the North Atlantic spring bloom. The autonomous component provided critical timing (arrival before the start of the bloom), persistence (throughout the entire diatom bloom), 4-D resolution (repeated 3-D sampling in the patch-following frame) and proxy sensors (to project labor-intensive ship-based biogeochemical and biological measurements onto simpler but autonomous measurements at much greater spatial scales). The ship component provided the means for calibration and inter-calibration of autonomous sensors and development of optical proxies. Satellites and models were key to interpretations and analyses. NAB08 provides a model for how to leverage critical but difficult shipboard measurements that cannot be obtained at appropriate scope and resolution onto arrays of autonomous sensors that can sample for much longer times, over broader regions, and at higher spatial resolutions. Future newsletters will explore specific findings of the project in more detail.

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Satellite Ocean Colour Radiometry and the Role of the International Ocean Colour Coordinating Group (IOCCG)

Venetia Stuart, IOCCG Project Scientist

Background

The International Ocean Colour Coordinating Group (IOCCG) was established in 1996 with the aim of developing consensus and synthesis on a global scale in the subject area of satellite ocean colour radiometry (OCR). It operates as an Affiliated Program of the Scientific Committee on Oceanic Research (SCOR) and comprises a rotating committee of representatives from each of the major international space agencies that provide ocean colour data, as well as representatives from the scientific community that use ocean colour data for research and applications (see ioccg.org/about/members.html for current list of members). Space agencies contribute financially to the IOCCG and carry out the decisions endorsed by the group, while the scientific members address current research issues and make recommendations. David Antoine of the Laboratoire d'Océanographie de Villefranche (France) serves as the current IOCCG Chairman while James Yoder (WHOI, USA) serves as the past-Chair.

Ocean Colour Radiometry Products

The main product of remote sensing of ocean colour is the concentration of chlorophyll-a, which is used as an index of phytoplankton biomass. Phytoplankton standing stocks are responsible for transforming carbon dioxide into organic carbon, and so play a major role in global climate change. Ocean colour radiometry is our only means of quantifying the base of the marine food web from space, and can be used to examine the biological and biogeochemical processes of marine ecosystems on synoptic scales with a temporal resolution of 1–2 days (Fig. 1). With the advent of more complex and sophis-

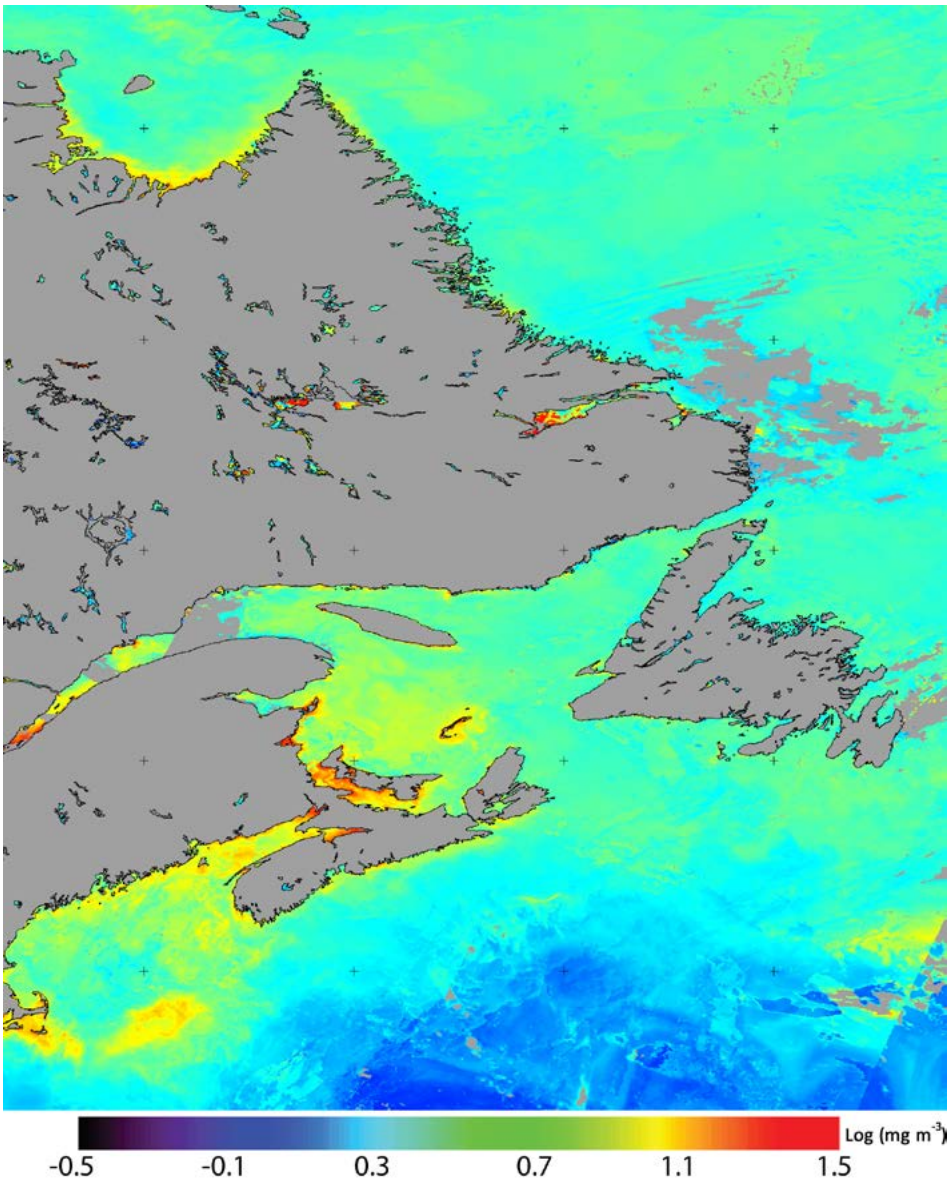


Figure 1: Satellite composite chlorophyll image of the east coast of USA and Canada, captured by ESA's MERIS sensor from 3–9 September, 2010. Elevated chlorophyll concentrations over Georges Bank are clearly visible. Credit: European Space Agency (image courtesy of César Fuentes-Yaco, Bedford Institute of Oceanography/St. Andrews Biological Station, DFO, Canada).

ticated ocean-colour sensors in orbit, it is now possible to retrieve a wide range of products from space, with an astounding range of applications. Besides the concentration of chlorophyll-a, it is also possible to retrieve products such as the concentration of total suspended matter, coloured dissolved organic material, particulate organic and inorganic carbon, primary production, aerosol properties, and phytoplankton functional types, to name but a few. These products can be used to understand the role of the oceans in the global carbon cycle, quantify the impacts of climate variability and change, assess ocean ecosystem health and productivity, and manage ocean ecosystems and resources (fisheries and aquaculture).

A wide range of initiatives from scientific and technical issues to capacity-building efforts in both developing and developed countries are addressed by the IOCCG Committee. Furthermore, the IOCCG is taking a leadership role in helping to ensure the continuity and consistency of the ocean-colour data stream through the Ocean Colour Radiometry-Virtual Constellation (OCR-VC).

IOCCG Scientific Working Groups

An important focus of the IOCCG is the establishment of specialised scientific working groups that investigate various aspects of ocean-colour technology and its applications. Generally, the end product of these working groups is the publication of an IOCCG monograph on the topic, which has evolved into the highly-acclaimed IOCCG Report Series. To date, twelve IOCCG monographs have been published by scientific working groups (see ioccg.org/reports_ioccg.html) with a number of other working groups nearing completion. These reports are widely cited in the scientific literature and are seen as the definitive work on the topic.

The IOCCG report series (Fig. 2) started with a report edited by Prof. André Morel on *Minimum Requirements for an Operational Ocean-Colour Sensor for the Open Ocean* (IOCCG Report 1, 1998). Information contained in this report has been critical for the design of operational ocean colour sensors for many years. Satellite instruments and missions are currently evolving beyond traditional measurements, which had led to the publication of

Figure 2: IOCCG Report Series and other IOCCG publications (available from www.ioccg.org/reports_ioccg.html)

the latest IOCCG report on this topic (soon to be in press) entitled *Mission Requirements for Future Ocean-Colour Sensors* (IOCCG Report 13). Other IOCCG reports have addressed remote sensing of ocean colour in coastal and estuarine waters (IOCCG Report 3, 2000), highlighted key issues for binning and merging ocean-colour data (IOCCG Reports 4 and 6, 2004; 2007), provided a comprehensive evaluation of societal benefits and applications of ocean-colour radiometry, including fisheries (IOCCG Reports 7 and 8, 2008; 2009), and provided a broad summary of ocean colour algorithms and atmospheric correction algorithms (IOCCG Reports 5 and 10, 2006; 2010). In addition, IOCCG working groups have addressed the requirement for complementary ocean colour missions (IOCCG Report 2, 1999), ocean colour remote sensing from a geostationary platform (IOCCG Report 12, 2012), partitioning the ocean into ecological provinces (IOCCG Report 9, 2009),

and examining the feasibility of equipping Argo floats with bio-optical sensors to validate ocean colour data (IOCCG Report 11, 2011). Current IOCCG working groups are focusing on other topical issues such as remote sensing of phytoplankton functional types, ocean colour remote sensing in Polar Seas, and remote sensing of harmful algal blooms (see ioccg.org/groups_ioccg.html for list of current working groups). The highly anticipated reports from these working groups should be published in the near future.

Continuity and Consistency of the Ocean Colour Data Stream

Another important issue being addressed by the IOCCG is the continuity and consistency of ocean colour radiometry datasets (Fig. 3). An uninterrupted, decades-long, well-calibrated global ocean colour time series is a very valuable observational resource for climate studies. However, the data requirements for ocean colour applications are so diverse that a single satellite sensor cannot possibly meet all ocean colour needs, so data from multiple missions will have to be used to augment data availability. A continuous time-series of observations can be generated by merging multiple satellite data sets and requiring consistency in the calibration, algorithms, and data products. These data streams can support research needs (e.g., investigating the impact of climate variability and change), as well as applications related to fisheries, coastal zone management, and water quality monitoring. International cooperation among the many space agencies is essential if we are to assemble inter-operable ocean-colour data products from multiple satellite missions operated by different space agencies. These issues are currently being addressed by the IOCCG through the Ocean Colour Radiometry-Virtual Constellation (OCR-VC), which comprises a number of international space agencies that are working together to add value to individual missions (e.g., through cross-calibration, improved validation, and data merging). The OCR-VC aims at producing sustained ocean-colour radiometry data records of well calibrated and validated satellite data from measurements obtained across multiple satellites.

Within the OCR-VC framework, the *International Network for Sensor Inter-comparison and Uncertainty Assessment for Ocean Color Radiometry* (INSITU-OCR) initiative aims at integrating and rationalizing inter-agency efforts on satellite sensor inter-comparisons and uncertainty assessment for remote sensing products, with particular emphasis on requirements addressing the generation of ocean colour Essential Climate Variables (ECV) as proposed by the Global Climate Observing System (GCOS). Under the guidance of the IOCCG, representatives of space agencies and institutions supporting INSITU-OCR (chaired

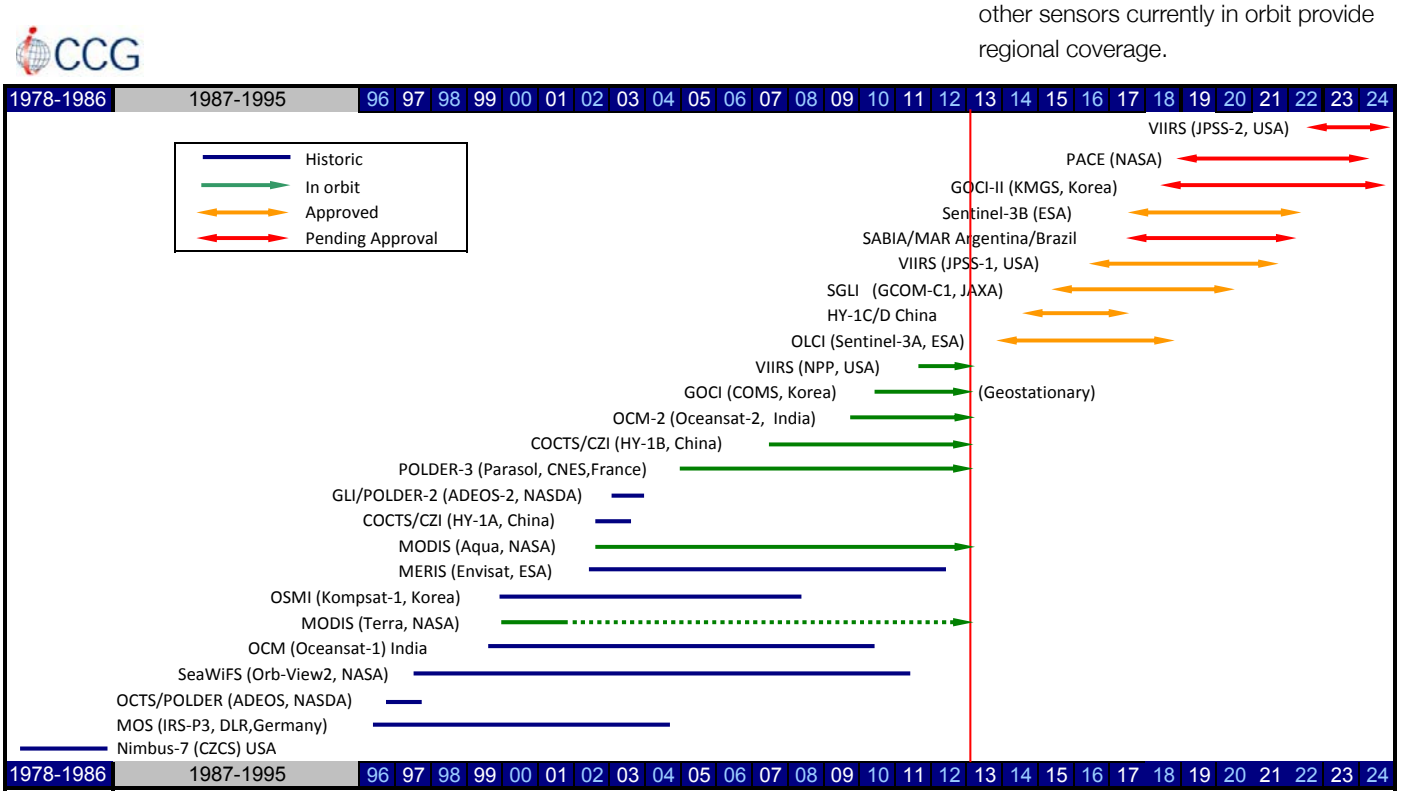


Figure 3: Timeline of satellite ocean colour sensors. Current sensors (green) providing routine global ocean colour data include MODIS-Aqua (USA) and VIIRS (Suomi-NPP, USA), while near-future global ocean colour sensors (orange) include OLCI (ESA), SGLI (JAXA) and VIIRS (JPSS-1, USA). All the other sensors currently in orbit provide regional coverage.

by Sean Bailey, NASA and Giuseppe Zibordi, JRC, EU) agreed on a series of recommendations that are critical to ensure high accuracy and consistency among products from present and future ocean-colour missions. These recommendations will be published in the form of a White Paper.

A related initiative is the recent establishment of an IOCCG Task Force on *Ocean Colour ECV Assessment* to carry out an independent evaluation of ocean colour ECV products outside of space agencies. This working group is chaired by James Yoder (WHOI, USA) and Nicolas Hoepffner (JRC, EU), and will assess the ocean colour ECV products from different agencies, including independent ground-truthing, and comparison to target requirements as defined by GCOS, thus helping to establish confidence limits for a long and coherent time-series of global ocean-colour ECV products. This working group held its first meeting in Glasgow, Scotland (7 October 2012) prior to the Ocean Optics conference.

International Ocean Colour Science Meeting

The IOCCG Committee recognises that it is important to maintain consultation and interaction with the broader ocean colour user community to help the IOCCG in its oversight role and to expose critical issues of concern. For this reason, the IOCCG has decided to conduct a series of international ocean colour science and consultation meetings in different parts of the world - provisionally every two years. These meetings will provide a forum for discussion of various topics related to ocean colour radiometry and will engage ocean colour scientists from around the world. The format of the meetings will include invited keynote speakers, town hall sessions with a significant amount of time allowed for discussions, information talks by space agency representatives, splinter sessions on predefined topics of interest, and poster sessions to highlight the latest research in the field of ocean colour radiometry.

The first meeting will take place in Germany from 6 – 8 May 2013, and will be co-sponsored by a number of agencies including NASA, EUMETSAT, ESA and CNES (see ioccg.org/Meetings/IOCS-1/iocs.html for the first announcement). The meeting is open to the entire ocean colour community, and representatives from all international space agencies will be present. Participants will be encouraged to take part in discussion sessions on all aspects of ocean colour radiometry, including those related to ocean colour algorithm development, calibration and validation, ocean colour data products and formats, as well as long-term agency plans. Recommendations issued from the meetings will be carried to space agencies to encourage them to implement concrete actions. These meetings will ultimately lead to the strengthening of the international ocean colour scientific community by engaging a wide range of users from around the world.

Education & Outreach

Another strong focus of the IOCCG is training and capacity-building. Since its inception, the IOCCG has sponsored and conducted over twenty training courses on the theory and applications of ocean-colour data, thus helping to broaden the user community, particularly in developing countries. This year the IOCCG focussed on high-level training of bright young researchers by conducting an advanced Summer Lecture Series entitled *"Frontiers in Ocean Optics and Ocean Colour Science,"* which took place in Villefranche-sur-Mer, France (2 – 14 July 2012). The course was dedicated to advanced training in the fundamentals of ocean optics, bio-optics and ocean colour, and focussed specifically on current critical issues of concern in ocean colour science. A total of 106 excellent and deserving applications were received from students around the world, and the IOCCG Selections Committee had an extremely difficult job in choosing the final 17 students (from 12 different countries). Thirteen renowned ocean colour specialists delivered in-depth lectures and practical sessions, with a significant portion of the course being dedicated to interactive discussion sessions between the students and lecturers. Students were exposed to a wide array of current topics in ocean colour which provided an invaluable insight into research questions and approaches that could be applied to both their current research and their future careers.

In November 2012, the IOCCG will also co-sponsor an introductory training course on *Methods and Application of Satellite Remote Sensing in African Coastal and Regional Seas* (El Jadida, Morocco, 6 – 16 November, 2012), organized primarily by the Joint Research Centre (EU) and open to participants from Africa and surrounding islands. This training course will provide the theoretical basis of satellite-based optical radiometry, and will highlight key applications in monitoring and managing the coastal zone, and in protecting marine ecosystems and resources. These diverse types of training courses help to augment the number of ocean-colour data users around the world, and also help to create a high-level research community with the necessary background and skills to address current critical issues, especially those related to global climate variability and change.

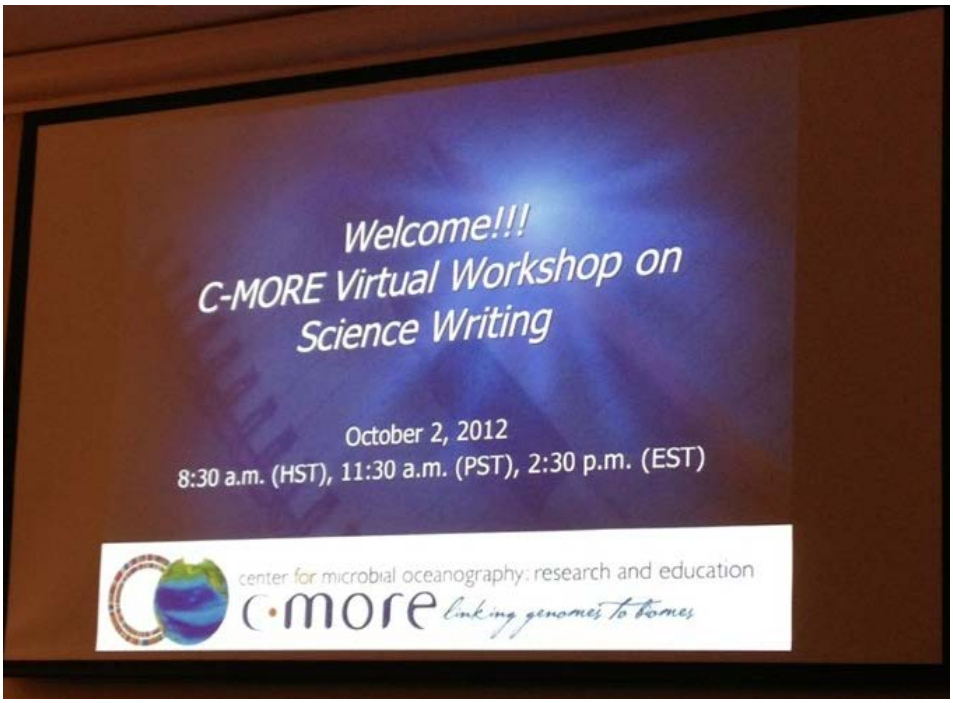
C-MORE hosts a Virtual Workshop on Science Writing

By Shimi Rii (Department of Oceanography, University of Hawai'i SOEST)

The morning (in Hawai'i, afternoon on the East Coast) started with a picture of a 7th grader describing a scientist before and after a visit to a science laboratory. The 'before' depicted a balding man in a labcoat, with green tornado-shaped liquid whirling out of an Erlenmeyer flask, and the 'after' showed a pretty, blue-eyed brunette dressed in a teal blouse and slacks.

"The thing is, if I asked my adult friends to do the same activity, they would draw the same thing," joked the moderator, Shimi Rii, a Ph.D. graduate student in the Department of Oceanography at the University of Hawai'i at Mānoa. Rii went on to describe how the public's perception of the scientific persona is disconnected from reality, and that it is the scientists' responsibility to break down this barrier.

The goal of the 2.5-hour-long virtual workshop, hosted by the Center for Microbial Oceanography: Research and Education (C-MORE)'s Professional Development Training Program, was to help scientists communicate more effectively with the public by providing tips on utilizing narrative language and journalistic structure elements to describe scientific concepts. The workshop linked



four academic institutions (University of Hawai'i, Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, and University of California, Santa Cruz) using Polycom videoconferencing equipment, and three guest speakers called in via Skype to University of Hawai'i. There were 31 participants across institutions, including 1 undergraduate, 20 graduate students, 7 postdoctoral fellows, 2 technicians, and 1 early-career Research Scientist.

The first section of the workshop, entitled "Importance of Writing for Scientists," addressed how the public's characterization of scientists in modern times is distorted by the Albert Einstein-esque image burned into their brains from years of scientist depictions in popular culture. The "mad scientist" has yet to permeate the everyday lives of non-scientists, except during Halloween each year. Consequently, the general public remains in fear of large words and field-specific acronyms, primarily due to lack of exposure.

In addition, the word 'science' doesn't mean the same to everyone. Science to scientists is the pursuit of knowledge of how things work, piecing together the big picture of the amazing world around us. Taking that knowledge one step further results in potential solutions to global challenges we face today concerning the health of our planet and people. In the news media, science represents a tool to address complex social problems. Thus, it is no surprise that in return for public funding, people have high expectations of scientists: to produce the best possible science, and to produce something that directly benefits society. Mix together fear, disappoint-

ment, and skepticism, and the result is a general mistrust of scientists.

In her 1997 presidential address to the American Association for the Advancement of Science (AAAS), Jane Lubchenco, now the Under Secretary of Commerce for Oceans and Atmosphere, issued a call for a new "social contract" that committed scientists "to communicate their knowledge and understanding widely in order to inform decisions of individuals and institutions." In order to "change the culture of Ocean Science," scientists must "become bilingual" and tackle these central questions: 1) How do we balance good storytelling and scientific integrity to capture the public's attention? 2) How do we develop and deliver a take-home message that people will understand and retain?

The first guest speaker was Judith Connor, Ph.D., Director of Information and Technology Dissemination at the Monterey Bay Aquarium Research Institute (MBARI). Connor, as she likes to be called, is an energetic woman who possesses the youthful vitality of a twenty-something-year-old embarking on her first research cruise. She commented on how she interfaces with the Monterey Bay Aquarium and how she uses science writing in educational materials such as curricula, natural history books, and annual reports, as well as in public outreach such as news stories, press releases, and exhibit development and graphics. She told the workshop participants about her career journey at MBARI, and how she learned more about marine biology while writing natural history books than she did during her Ph.D. program. She encouraged everyone from undergraduates to experienced scientists to get out there and share their science with the public.

The second section of the workshop, entitled "The Nuts and Bolts of Science Writing," focused on

the mechanics and structure of good science writing. In addition to types of articles (breaking news or trend story), scientists were introduced to the Inverted Pyramid of Journalists, which dictates that the most important information is placed in the beginning of the text. Therefore, a typical news story would start off with an attention-grabbing "lede," followed immediately by the "nutgraf," which is the 'beating heart' of the article. The "body" contains the details and scientific evidence supporting the nutgraf, typically presented by facts and direct quotes of the leading researchers in the field, and the article ends with a "kicker," a snappy, moving, one-line ending that wraps up the article with a graceful bow.

Since scientists do well with protocols, much note taking ensued during this section. This was followed by an emphasis on using narrative language to turn the article into a compelling story. By using our five senses, the participants were encouraged to pay attention to details such as the type of tree and the dog's name – not the pore size of filters or the brand name of the DNA extraction kit. Dynamic detail, when used correctly, can set the pace and create tension in the story; when used incorrectly, details become just a myriad of useless words.

The guest speaker for this section, George Johnson of the *New York Times,* spoke about his experience with finishing his most recent manuscript, *The Cancer Chronicles,* which combined personal experience and many years of research. He also commented on his recent article on lightning featured in the August issue of *National Geographic Magazine,* and on how he set up alternating scenes of being in the field and in the laboratory throughout the article. Fresh off the brain press from his book on cancer, he repeatedly referred to lightning as cancer, provoking small smiles from his audience: "We didn't end up getting a shot of the cancer but it was okay." His unintentional slip-ups symbolized to the participants the enormous toll research, any research, takes on a dedicated human being, scientist or non-scientist.

The final speaker for the workshop, during the third section entitled "Practice Makes Perfect," was Tim Appenzeller, Chief Magazine Editor for *Nature*. A former science editor and writer for the *National Geographic Magazine,* he won the 2005 Walter Sullivan Award for Excellence in Sci-

ence Journalism from the American Geophysical Union for his article "The Case of the Missing Carbon." He described from an editor's point of view "What Editors Like and Dislike."

"The trouble with editors is that you can't escape them, they never seem to get your point, and they have no respect for your time," informed Tim.

Calling in from his London home right around his children's bedtime, Tim seemed relaxed and dedicated as he described the process of successfully pitching a story to an editor, dos and don'ts when filing a story, and dealing with edits. A question arose from the participants about the selection process by editors for which articles make it into a magazine, and whether the number of web views is factored into the process. Tim recounted that though web views indicate popularity with the general reader, it is usually a gut feeling of the editor by reading the pitches. However, he said that it is often the most unusual articles, such as a Buddhist statue carved into a meteorite, that end up getting more web traffic than expected.

As the participants thanked Tim for calling in, the workshop shifted gears to review the pre-assigned homework.

First, they reviewed four science news articles written about the hotly contested first usage date of fire. Articles were published in *Associated Press, Nature News, New Scientist,* and *Science Now.* Huei-Ting Lin, a graduate student at the University of Hawai'i, described how the *Associated Press* article seemed to her a collection of facts structured into short sentences, making it easy to read but not necessarily enjoyable. She indicated that the use of definite statements was unusual to her, since, as a scientist, she is used to using softer language, such as "suggested," or "imply," in relation to her data. This fueled a discussion of how, contrary to what scientists are accustomed to, dramatic and sensational language captures and generally appeals to the public. The article in *Science Now* took a different approach from the other three, by using a more narrative language in its lede and painting a picture of our ancestors roaming the fields. This lede evoked many different opinions on the various types of style and preference of each reader.

Next, the workshop participants shared the first 150 words, or the lede, of a news article about their own research projects. After hearing a few ledes, scientists agreed that the use of anthropomorphic analogies and illustrating a scene — a teabag for describing particulate and dissolved organic carbon (Donn Viviani, University of Hawai'i), using an oxymoron such as a giant virus (Chris Schvarcz, University of Hawai'i), standing at the bow of the ship and watching the ocean breathe (Julie Robidart, Ph.D., University of California, Santa Cruz) — allowed readers to relate to the article, thereby successfully arresting public attention. "Bring them in through their door, and send them out through yours," advised Tim Appenzeller during his call. It truly was an amazing feat of organization and technology to be able to intimately discuss aspects of science writing over 5000 miles across the land and the sea.

The C-MORE Virtual Workshop on Science Writing ended with a "kicker": "Let's be the marine Steve Jobs," a quote taken from Holly Bik of deepseanews.com, a website whose mission statement is to "demystify and humanize science in an open conversation that instills passion, awe, and responsibility for the oceans." Workshop participants were encouraged to infiltrate the words in the community with scientists' words, to start a dialogue with a non-scientist friend or family, and be representatives of the new culture of ocean science — one that is filled with less jargon, more hair, and a pen.

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

#OHCO2What?
New Directions at the Ocean in a High-CO_2 World Meeting

Sarah Cooley, OCB

Five hundred and forty participants from 37 countries convened in Monterey, California this September for the third Ocean in a High-CO_2 World Symposium. Presentations focused chiefly on ocean acidification (OA) and its interactions with other environmental stressors, a logical outgrowth of prior Symposiums (see "Prior Symposiums" box). But many other things were new in this meeting. It was much larger and topically broader than before, warranting parallel sessions. In addition, many scientists (at all career levels!) embraced social media to discuss meeting highlights on the side.

Several overview speakers at the Symposium framed our knowledge and confidence about OA relative to time. Early on, the oceanographic community felt confident, despite limited knowledge, that OA represented a clear stressor for specific marine organisms (Figure 1). As our knowledge grew, nuanced responses became apparent as conflicting experimental results emerged. Our confidence in our understanding was shaken. Symposium speakers suggested that prior to this meeting, we were somewhere in the "valley" of Figure 1. But with more time and knowledge, our confidence in our ability to predict OA's impacts on organisms and ecosystems will grow. We will be able to incorporate understanding of mechanistic responses and thresholds, as well as uncertainties, into projections. This will lead to a long-term development of confidence that grows steadily as the science matures. This year's Monterey Symposium contributed a great deal to the maturation of OA science and the long-term increase in our knowledge and confidence about OA.

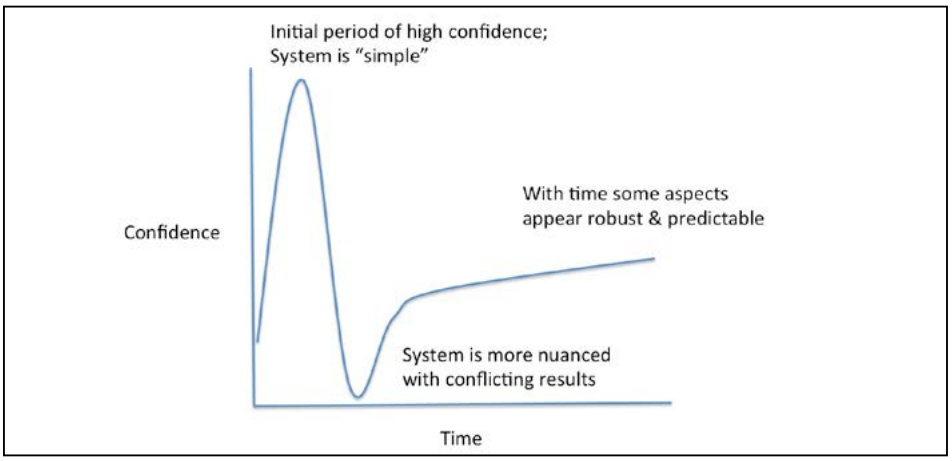


Figure 1: As time and our knowledge have progressed, our confidence in our ability to predict OA's impacts has varied. (Courtesy S. Doney, WHOI)

Building on the two previous Symposiums, the meeting organizers and co-sponsors for this year's third Symposium designed the meeting to explore the current state of ocean acidification science in a multi-stressor context (Figure 2). Plenaries, which are archived online, explored the overall knowledge context into which this year's presentations would fit by reviewing OA science history; physiological and evolutionary means for adjusting to ocean acidification and other stressors; OA's interaction with other Earth system processes, now and in the past; ecosystem-level consequences of OA; and links between OA and the human system such as economics and policy. Parallel sessions then explored the details surrounding these topics with oral presentations and posters. Abstracts for all presentations are available online. Fully half of the presentations focused on organismal responses, with the other half focusing on other aspects of OA (Figure 3). These studies examined the full range of organism types (Figure 4).

This Symposium also specifically promoted interactions among scientists and communicators. Several activities were designed by meeting co-sponsor COMPASS (Communication Partnership for Science and the Sea) to acquaint scientists and journalists. During COMPASS's communications workshop before the Symposium, 23 OA researchers were coached on how to communicate better with nonscientists via activities such as role-play interviews with senior science journalists. Attendees were also persuaded to join Twitter, which helped broaden the dialogue about Symposium activities and science (#OHCO2W) to interested listeners who weren't even in Monterey. COMPASS also hosted a panel discussion and an icebreaker event to promote discussion among the 20 Media Fellows and other Symposium attendees about research directions and interesting results.

Figure 2

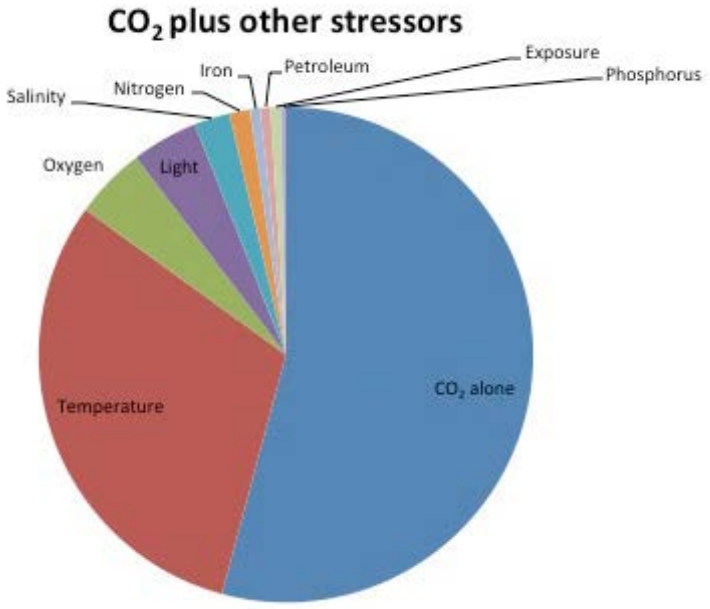


Figure 2: Nearly half the abstracts submitted to the Symposium focused on how other stressors, in addition to CO_2, acted on organisms and ecosystems. (Courtesy E. Urban, SCOR)

Figure 3

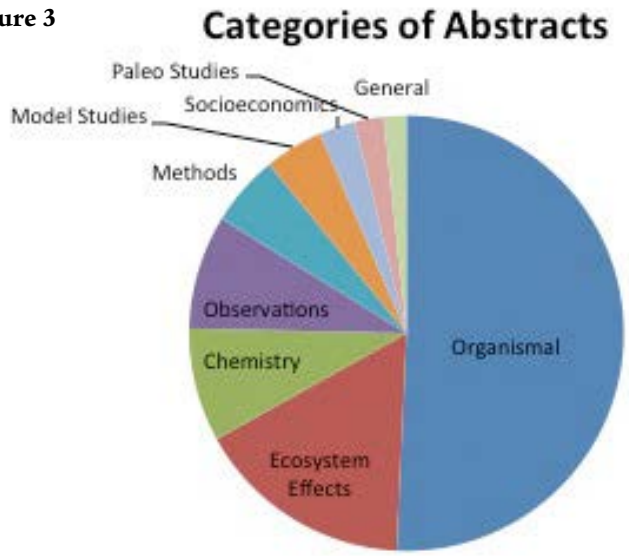


Figure 3: More than half the abstracts submitted to the Symposium examined organismal responses to OA (Courtesy E. Urban, SCOR)

Figure. 4

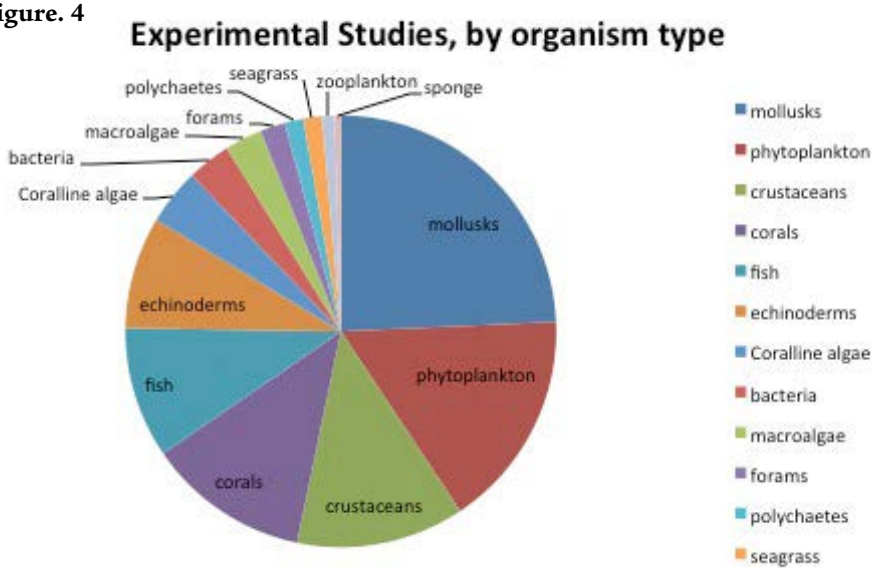


Figure 4: Studies presented at the Symposium examined the full range of organism types (Courtesy E. Urban, SCOR)

Prior Ocean in a High CO_2 World Symposiums

The multi-stressor perspective of this year's third Symposium reflected a significant evolution in thinking since the first Symposium in 2004. Initially, scientists discussed the ocean CO_2 uptake that was mitigating climate change. Throughout the 2004 meeting, concern grew about the chemical and biological consequences of anthropogenic CO_2 uptake by the ocean. The second Symposium in 2008 focused specifically on OA and emphasized the need for communicating about OA with social scientists and policymakers. Concerned scientists summarized what was known and outlined future goals in the Monaco Declaration in 2009.

The Monaco Declaration laid out four goals after the 2008 (second) Symposium on the Ocean in a High CO_2 World: 1) Promote research on ocean acidification. 2) Build links between economists and scientists. 3) Help improve communication between policymakers and scientists. 4) Prevent severe damages from ocean acidification by developing plans to cut emissions. The third OHCO2W meeting, just concluded in Monterey, CA, contributed strongly to goals 1 and 3.

Side events at the Ocean in a High-CO_2 World Symposium

NOAA OAP funded scientists' discussion

S. Cooley, OCB

On Monday evening, the NOAA OA Program (OAP) hosted an open 90-minute discussion for OAP-funded scientists. Scientists from NOAA labs as well as from the academic research community attended to put faces with names and to talk about the main aims of ongoing research. The discussion identified complementary areas among research projects going on now, including the new projects just funded by the recent NOAA Center for Sponsored Coastal Ocean Research (CSCOR) grants (with OAP resources).

Coral Reef OA Monitoring Portfolio

Dwight Gledhill, NOAA OAP

On Tuesday evening, a small group convened to discuss the outcomes of the August workshop on developing the Coral Reef Ocean Acidification Monitoring Portfolio sponsored by the NOAA OA program, the NOAA Coral Reef Conservation Program, and the National Coral Reef Institute at the Nova Southeastern University Oceanographic Center. This workshop sought to define a suite of indices to include as part of long-term coral reef monitoring efforts most valuable for discerning specific attribution of changes in coral reef ecosystems in response to ocean acidification.

The workshop identified a preliminary listing of high-level strategic indices around which a coral reef observing network would ideally be geared. These indices would be derived from a suite of not only biogeochemical, but also ecological measures. The changing status of these indices over time would serve to aid in assigning specific attribution to ocean acidification, although it was recognized that there will likely be multiple factors contributing to the observed changes. These indices addressed five thematic focus areas:

1. Effects of OA on coral reef water chemistry
2. Effects of OA on coral reef community metabolism
3. Effects of OA on coral reef organisms
4. Effects of OA on coral reef ecosystem biodiversity
5. Effects of OA on coral reef dissolution and bioerosion

The final workshop outcomes are intended to inform national and international long-term OA monitoring efforts within coral reef ecosystems. The Town Hall offered the participants an opportunity to vet the preliminary indices that have been proposed and to contribute additional input to the final document report.

C-CAN lunch

Andrew Dickson, UC San Diego;
Diane Pleschner-Steele, C-CAN

One of the side events affiliated with the meeting was a lunchtime panel on Wednesday (September 26th) sponsored by C-CAN (the California Current Acidification Network) together with the NOAA Ocean Acidification Program. The room was crowded (possibly because of the lunch provided) and the session comprised brief presentations by panel members (Andrew Dickson, UC San Diego; Libby Jewett, NOAA; and Jean-Pierre Gattuso, LOV, Villefranche) followed by questions and comments from the audience (moderated by Jan Newton, U Washington). The focus of the presentations and discussions was on the practicalities of planning and implementing an effective ocean acidification observing network.

Andrew Dickson described the work of the C-CAN group (an *ad hoc* regional collaboration of academic scientists, commercial fishing and aquaculture interests together with state and federal resource managers) who came together in an effort to better understand the drivers of ocean acidification along the U.S. West Coast, and its likely impacts on organisms along the coast (see http://c-can.msi.ucsb.edu). A key problem identified by C-CAN was that most current carbon chemistry data along the U.S. West Coast are unsuitable for the needs of C-CAN stakeholders. For example, the carbon chemistry is often not measured at locations that coincide with biological studies and existing measurements are not of uniform quality. The immediate goal is therefore to establish a network of observations along the U.S. West Coast that can provide a picture of what is happening (with regard to the CO_2 system) in the locations where the organisms of interest are living. This will better inform biological studies, and could enable improved management practices.

To achieve this, C-CAN is seeking resources to reduce the barriers to making seawater CO_2 measurements of sufficient quality by providing explicit guidance as to how best to make such measurements, and also to develop the necessary data infrastructure (perhaps in collaboration with the

regional associations of IOOS) for combining the various individual data sets produced into a coherent network.

Libby Jewett provided a broader national perspective of ocean acidification observing planning, based largely on a recent workshop held at the University of Washington (http://www.pmel.noaa.gov/co2/OA2012Workshop/WorkshopHome.html). This detailed the broad range of environments to be studied (both around the shores of the U.S. and further afield) and the wide range of observing assets that may be used for this. She noted that workshop participants had indicated that there would be two distinct goals for such observations: first understanding the physical and chemical conditions of the environment (with, perhaps, some limited bio-optical information); second, and less clearly laid out as yet, there is an undoubted need to assess the ecosystem response to changes in these conditions. Some of this work is currently being supported by NOAA, but much is still in the planning stages.

Finally, Jean-Pierre Gattuso described some of the lessons that had been learned from the EPOCA program, and described briefly the new Ocean Acidification International Coordination Centre which will be based at the International Atomic Energy Agency (IAEA) in Monaco and overseen by an international advisory board. In particular he emphasized the role of the new center in establishing and promulgating "best practices" as well as in encouraging an increase in observing capacity around the world.

The presentations, questions, and discussion helped to emphasize the current status of ocean acidification observing over these various scales. There is broad agreement that simple chemical and physical variables such as salinity, temperature, oxygen, and CO_2 chemistry should be measured in any ocean acidification observing network; however, there is no consensus as to the suite of biological parameters that should be considered integral to ocean acidification observations. Indeed it was felt that these might well vary depending on the ecological system under study.

Essentially the field is in its infancy and, as yet, there is insufficient capacity to make the geographically extensive measurements even of physical and chemical parameters that will be needed. Various panel and audience members reiterated the need to address this in the near future, particularly on a regional basis.

Effective practices for OA communication and education workshop

Sarah Cooley, OCB; Laura Francis, Channel Islands National Marine Sanctuary

After the Symposium, more than 90 people gathered for the Effective Practices for Ocean Acidification Communication and Education Workshop, organized by the West Coast National Marine Sanctuaries and the Monterey Bay Aquarium Research Institute. This workshop brought together OA scientists and the community of educators and communicators from sanctuaries, reserves, parks, aquariums, NGOs, and science centers who are teaching the public about OA.

Laura Francis, the workshop organizer, remarked, "This was a wonderful (and somewhat rare) opportunity for scientists, informal and formal educators, resource managers and stakeholders to come together" around ocean acidification. As participants learned more, they "discussed how best to communicate it to different audiences, and how to inspire action," two key issues that haven't been addressed much yet.

This dynamic two-day gathering first reviewed the state of OA science after the Symposium, the state of public knowledge about OA, and ways to communicate about OA. An evening reception shared teaching and outreach activities on OA. The second day was devoted to developing effective messages and person- or place-based stories about OA.

The major outcomes of the workshop were to identify key messages, case studies, actions and research literature related to OA for smaller, self-selected working groups to continue to refine following the workshop. A final workshop report summarizing the pre-workshop needs assessment, panel discussions, breakout group sessions, and the post-workshop evaluation will be completed at the end of the year. NOAA is also developing an ocean acidification education action plan that will incorporate the outcomes from the workshop and working groups.

The workshop organizers and participants are now keeping the momentum going by creating an OA Communicators Facebook group, a wiki containing the workshop presentations and materials and progress reports from the working groups, and an email list to keep the participants in touch. OCB will use the OCB mailing list to circulate information on how to connect with these resources as they become available.

Workshop on UK-US research collaboration

Sarah Cooley, OCB; Jim Barry, MBARI

After the main meeting, thirty-three participants met at Hopkins Marine Station just down the coast from the Monterey Conference Center in a two-day workshop discussing

how to assess the effects of ocean acidification on the structure and function of ecosystems.

Thirty-three participants explored topics including: Model approaches to scale-up from single-species studies to population and community levels; the utility of various experimental data for modelers; use of long-term observations, natural gradients, or manipulative experiments; and mechanisms to promote collaboration among disciplines. The group discussed the value and roles of integrating observational, experimental, and modeling studies to advance understanding of mechanisms influencing species' performance and ecosystem function, as well as predictions of ecosystem change, in response to changes in carbonate chemistry associated with ocean acidification.

The group plans to organize an OA ecosystems working group, with a proposed major goal of coordinating or initiating a global network among groups collecting comparable long-term ecological observations at local/regional scales. This approach is expected to broaden the context of projects focused on patterns in ecological communities over gradients in carbonate chemistry on local to regional scales, and allow a global comparison of ecosystem responses to the developing pattern of ocean acidification. Toward this effort, the group also plans to promote future joint activities and collaborations, and convene a second meeting to advance these goals.

This workshop was designed to follow up on the recent UK-US Collaboration Development Award Programme, which sought to foster collaborative ocean acidification research between the two nations. The original program supported travel and meetings during January–March 2011 that laid the groundwork for future proposals; this meeting was designed to bring together expert OA modelers and experimentalists, principally from the U.K. and the U.S., while capitalizing on the OHCO2W Symposium to reduce organizational and travel costs. This meeting was supported by OCB and the Global Issues Group from the British Embassy.

OCB-OA News

- Kim Yates (USGS) has joined Jeremy Mathis as the other OCB Ocean Acidification subcommittee co-chair
- OCB coordinates updated version of Ocean Acidification FAQs, with assistance from the UK Ocean Acidification Research Programme for preparation of the printable PDF
- OCB, BCO-DMO, and NOAA Ocean Acidification Program co-hosted a booth at the 3rd Symposium on the Ocean in a High-CO_2 World (September 24–27, 2012, Monterey, CA)
- OCB's Sarah Cooley and NOAA Ocean Acidification Program's Libby Jewett have joined the scientific advisory board for the Ocean Acidification International Coordination Centre, based at the International Atomic Energy Agency Environment Laboratories in Monaco
- OCB has begun planning for the next U.S. Ocean Acidification PI meeting (September 2013, venue TBD)

Important Dates

- **November 28–30, 2012:** International Time-Series Methods Workshop (BIOS, Bermuda)
- **December 5, 2012:** U.S. CLIVAR/OCB Ocean Carbon Uptake Working Group meeting (San Francisco, CA)
- **December 7–8, 2012:** U.S. CLIVAR/OCB Southern Ocean Working Group meeting (San Francisco, CA)
- **March 27–28, 2013:** Gulf of Mexico coastal synthesis team meeting (St. Petersburg, FL)
- **July 22–25, 2013:** Annual OCB Summer Workshop (Woods Hole, MA) — Please send your ideas for the 2013 OCB Summer Workshop to the OCB Project Office

OCB issues statement in response to recent iron dumping off west coast of Canada

In late summer 2012, a fishing boat was chartered and 100 metric tons of iron-rich dust was added to the waters off western Canada. The apparent aim was to aid the recovery of local salmon fisheries while using the carbon credit income to offset the costs of the experiment. In August 2012, a phytoplankton bloom on the order of ~10,000-20,000 km^2 occurred in this region. Although natural processes cannot be ruled out, this bloom was easily visible in satellite observations, consistent with the reported location of the iron addition. This perturbation occurred despite international moratoriums prohibiting ocean iron fertilization experiments other than those approved as legitimate scientific research (e.g., London Convention and Protocol). This event underscores how easy it is for corporations or private individuals willing to disregard these agreements to manipulate ocean ecosystems. Similar events are likely to occur in the future by individuals or groups seeking to profit from carbon credits or enhance local fisheries. However, we lack adequate knowledge to predict the outcomes, especially over larger spatial and temporal scales.

The U.S. Ocean Carbon and Biogeochemistry (OCB) Program is in support of well-controlled in-situ ocean perturbation experiments, such as iron enrichment or pumping deep waters to the surface, to better understand ocean processes and predict ecosystem responses to added ocean nutrients. However, this research should be considered experimental and not suitable for trading of carbon credits. It should be planned, organized, and reported in a transparent manner that upholds rigorous scientific standards and complies with international protocols for open dumping. Unless there is a reasonable permitting process and funding for such activities through federal or high seas intergovernmental sponsors, this work will continue to be done by "rogue geoengineers." An improved scientific understanding is needed to predict the outcomes and associated risks for the environment and potential for altering the efficacy by which carbon is taken up by the ocean and sequestered on longer time scales. To go forward without this understanding at this time is simply irresponsible to both our science and to the marine ecosystems we study.

For more informational resources on ocean fertilization research, please visit the OCB ocean fertilization website. The content of this letter reflects the opinion of the undersigned parties, but not necessarily that of any funding agency supporting OCB researchers.

The OCB Scientific Steering Committee

Members of the OCB Ocean Fertilization Subcommittee (K. Buesseler, F. Chai, K. Daly, D. Karl)

The OCB Project Office (contact: Heather Benway, hbenway@whoi.edu)

One if by space, two if by sea — Views of a changing ocean

A Report from the 2012 OCB Summer Workshop

by Heather Benway

The 7th annual Ocean Carbon & Biogeochemistry summer workshop, sponsored by NSF, NASA, and NOAA, convened a record of 175 participants from July 16–19, 2012 at the Woods Hole Oceanographic Institution in Woods Hole, MA.

Plenary sessions

This year's summer workshop included a little something for everyone in the form of five plenary sessions:

- *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.*

The first plenary session, *Multiple stressors in marine ecosystems,* included presentations by Jorge Sarmiento, Lisa Levin, Wei-Jun Cai, and Niki Gruber on the compounded effects of stressors like warming, hypoxia, acidification, nutrient runoff, and storm activity on marine resources such as fisheries and on different marine ecosystems such as upwelling margins, coastal river-dominated environments, and the deep ocean. The session ended with a presentation by Phil Boyd on recent and future research activities, workshops, and products related to multiple stressors research, including two upcoming Gordon Research Conferences in 2014 (Contact: Dave Hutchins) and 2016 (Contact: Phil Boyd) and a special issue in *Marine Ecology Progress Series* (publication in late 2012). The community discussion that followed addressed issues of research scale, ranging from micro- to global-scale questions; observational priorities, including micro-sensors to monitor organism response, a combination of shipboard, satellite, and autonomous measurement campaigns, and improved coverage of the coastal and deep oceans; and a more deliberate dialog between biologists and geochemists to study organism response to multiple stressors and effectively incorporate theories of evolution and physiology into process studies and model architecture.

The *Ocean biogeochemistry from satellite data* session kicked off with a tutorial on satellite ocean color remote sensing by Dave Siegel. Mike Behrenfeld and Carlos Del Castillo then gave presentations on the NASA Pre-Aerosol, Cloud, ocean Ecosystem (PACE) (or Pelagic and Coastal Ecosystems (PaCE)) mission, including key science questions, measurement requirements, and implementation strategies outlined in the PaCE Science Definition Team report. The community discussion that followed focused on prioritizing OCB research needs with regard to satellite ocean color data and the importance of calibration and validation studies preceding the mission launch, which is currently scheduled for 2019.

The *Land-ocean transport and linkages with global change* session included presentations by Valier Galy, Steve Lohrenz, and Neal Blair that characterized physical and biogeochemical processes and quantified carbon fluxes in rivers, coastal plumes, and continental margin sediments, respectively. The final talk by Peter Raymond focused on the impacts of human land use changes on river dissolved inorganic carbon (DIC) fluxes. Community discussion highlights included comments on the importance of long-term river and coastal/estuarine data sets to monitor changes in land-ocean carbon fluxes and key observational gaps in rivers and coastal zones; variable sampling resolution (temporal and spatial) needs across the land-ocean continuum; challenges of modeling coastal processes due to large differences in scale between land and open ocean; and identifying funding sources for comprehensive studies across the land-ocean interface that engage terrestrial, river, and ocean scientists.

Craig Carlson opened the *Integrating measurements across multiple time and space scales* session with a brief presentation on recent and upcoming U.S. and international ocean time-series activities to update the community and provide historical context for the session. The first two plenary speakers shared scientific insights gained from the Ocean Station Papa time-series (Steve Emerson) and the long-standing partnership between the California Current Ecosystem LTER and CalCOFI (California Cooperative Oceanic Fisheries Investigations) to monitor the effects of climate change on the biogeochemistry and ecology of the California Current system (Mark Ohman). Katja Fennel combined observations and model simulations in a presentation on nutrient limitation and hypoxia in the Gulf of Mexico. In the final plenary talk, Galen McKinley presented the ocean carbon findings from the REgional Carbon Cycle Assessment and Processes (RECCAP) effort, including contemporary anthropogenic carbon flux and inventory estimates for the global ocean. In a discussion that followed this session the community addressed the importance of

One if by space, two if by sea — Views of a changing ocean (cont.)

both global (e.g., satellite) and regional (e.g., shipboard, time-series) characterization of key mechanisms controlling ocean carbon fluxes, which requires a combination of satellites, autonomous measurements, ocean time-series, and data synthesis activities. Another highlight of this discussion was the need to better align experimental and sampling approaches (in both time and space) with the inherent nonlinearities (i.e. tipping points) observed in ocean physics and biology.

Jeremy Mathis opened the plenary session *New observations from an Arctic Ocean in rapid transition* with an overview of scientific findings from the NASA-funded ICESCAPE (Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment) ocean field campaign, including recent changes in physics, biogeochemistry, and marine ecosystems of the central and western Arctic, the Chukchi and Beaufort Seas, and river-dominated coastal regions. Leif Anderson provided an Atlantic perspective on changing Arctic carbon fluxes in a presentation that addressed links to regional climate indices such as the North Atlantic Oscillation (NAO), deep ocean ventilation, seasonal sea ice coverage, permafrost thaw, and primary productivity. Peter Griffith then gave a brief overview of the Arctic-Boreal Vulnerability Experiment (ABoVE), a NASA terrestrial ecology field campaign focused on characterizing processes controlling soil carbon in the Arctic and Boreal regions and examining implications of permafrost thaw for terrestrial and marine ecosystems. In the community discussion that followed, participants raised important research questions surrounding the implications of permafrost thaw for the coastal oceans (e.g., organic matter flux and composition, nutrient ratios, species composition and biodiversity, etc.) and identified important coastal marine observing components that collectively span the wide range of scales in the coastal zone, including ships, weather stations, eddy flux towers, vegetation sampling, and remote sensing.

Other meeting highlights

In addition to the stimulating plenary sessions, this year's summer workshop included an overview presentation by Bill Jenkins of preliminary results from the U.S. GEOTRACES North Atlantic cruise; a brief report from Bob Anderson on behalf of International GEOTRACES; a report from Jim Moffett on progress made since the Molecular Biology of Biogeochemistry OCB scoping workshop in 2010 toward the integration of molecular and biogeochemical measurements at sea, including a pilot cruise GEOMICS (Genome-Enabled Ocean Microbiology Integrated with Chemical Surveys) along Line P in the North Pacific in May 2012; an update on the North American coastal carbon synthesis being coordinated by OCB and the North American Carbon Program (NACP); a community discussion moderated by SSC chair Kendra Daly of OCB research and observing priorities in light of the 2011 U.S. Carbon Cycle Science Plan (for summary points from this discussion, please contact Heather Benway); agency funding updates from NASA, NOAA, and NSF program managers; engaging talks by graduate students to showcase their research interests; and daily poster sessions organized by the plenary themes.

In addition to a packed workshop agenda, Cyndy Chandler conducted three hands-on BCO-DMO (Biological and Chemical Oceanography Data Management Office) tutorials featuring the new data search interface, which were well attended by the workshop participants.

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

Can OCB help you?

OCB can help you share new results, distribute education and outreach products, assist in the development of outreach materials or connect you with other PIs in the community with similar interests. If you have news items (announcements, new findings, education and outreach products, etc.) you would like to share with the OCB community via our email list and/or website, please contact the OCB Project Office.

OCB Informational Resources

- OCB Policies and Procedures: A community guide on OCB's programmatic mission, objectives, and operating procedures
- OCB Ocean Acidification Website
- OCB Ocean Fertilization Website
- Subscribe or post to the OCB email list

A view towards integrated Earth System models:

Human-nature interactions in the marine world

The Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) project organises a summer school as part of its ClimECO (climate and ecosystems) series every second year. This year, ClimECO$_3$ was held at the Middle East Technical University in Ankara, Turkey from 23–28 July 2012, and focused on the interface between marine ecosystem biogeochemistry, physical (including climate) drivers, food webs, and socio-economic systems, with a strong emphasis on interactions between humans and natural systems, and how best to simulate these using integrated Earth System models.

The summer school convened 10 lecturers, including biogeochemists, ecologists, ecosystem modelers, and social scientists. Because of the hands-on nature of the training, only 50 participants were selected, including MSc and PhD students, postdocs, and early career scientists. They too represented a variety of disciplines, hailing from 25 countries across five continents.

The course consisted of lectures each morning (which were live-streamed), hands-on exercises with different models in the afternoons, and group projects to develop a conceptual model for a system. There was also a poster session, and prizes were awarded for the best presentations. The winners were: Samiya Selim (University of Sheffield, U.K.), Ekin Akoglu (Middle East Technical University, Turkey), Jorge Martinez-Rey (Laboratoire des Sciences du Climat et de l'Environnement (LSCE), France), and Eyram Koku Apetcho (International Chair in Mathematical Physics and Applications (ICMPA), Benin).

The course opened with an overview of integrated Earth System and socio-economic models. Beth Fulton (CSIRO, Australia) spoke about integrated end-to-end models and how they are used. Hezi Gildor (The Hebrew University of Jerusalem, Israel) discussed physical-biological-chemical interactions, and Markus Jochum (University of Copenhagen, Denmark) demonstrated how well models reproduce feedbacks in the Earth System.

The next two days focused on modeling low- and high-trophic level processes and human interactions. Raghu Murtugudde (University of Maryland, USA) talked about the connections between the earth, life, and sustainability. Baris Salihoglu (Middle East Technical University, Turkey) discussed processes and model representations of the microbial web and plankton. Human interactions with biogeochemical cycles, including climate change, ocean acidification, and deoxygenation, were presented by Laurent Bopp (LSCE, France). Eileen Hofmann (Old Dominion University, USA) considered population dynamics models versus individual-based models. Then Jacopo Baggio (Arizona State University, USA), Ingrid van Putten (CSIRO, Australia), and Rashid Sumaila (University of British Columbia, Canada) discussed the incorporation of human systems into Earth System models, and various modeling approaches for marine populations and social networks.

The week ended with presentations of the modeling projects that the students had developed for problems, such as the link between corruption and overfishing, the effect of communication networks, and the impact of changing predator-prey relationships. They were excellent, and all were considered worthy of further development and publication. Of course there was also some after-hours entertainment, the highlight being the final dinner, complete with a belly dancer that had everyone up and dancing in no time.

In closing, the summer school was interesting, beneficial, and a lot of fun.

On behalf of IMBER, I would like to thank OCB for the very generous co-sponsorship that enabled six U.S. participants to attend.

Lisa Maddison
Deputy Executive Officer
IMBER International Project Office
Bergen, Norway

Community Resources

Data and Research

- LDEO Underway pCO_2 Database Version 2011 is now available at CDIAC
- Global Alliance of Continuous Plankton Recorder Surveys (GACS)

Communication, Education, and Outreach

- Tracers in the Sea by W. H. Broecker & T.-H. Peng now available as pdf
- Updated Ocean Acidification Frequently Asked Questions
- Friday Harbor Research Apprenticeship on Ocean Acidification, Spring Quarter 2013 (15 units), Lead Instructor: James Murray (UW, Ocean) — For more information, please contact Jim Murray (206-543-4730, jmurray@uw.edu)

Reports, Reviews, etc.

- Williamson P. et al., in press. Ocean fertilization for geoengineering: a review of effectiveness, environmental impacts and emerging governance. Process Safety and Environmental Protection. doi: 10.1016/j.psep.2012.10.007. Article (subscription required).
- *Current Opinion in Environmental Sustainability* special issue on aquatic and marine systems (Editors: I. Perry, A. Bundy, E. Hofmann)

Partner Activities and Co-Sponsorships

Joint Scientific Working Groups with U.S. CLIVAR

Both joint working groups have new websites (links below), and will be holding their first group meetings in conjunction with the 2012 Fall AGU Meeting in San Francisco, CA.

- Oceanic carbon uptake in the CMIP5 models (Co-Chairs: Annalisa Bracco, Curtis Deutsch, Taka Ito)
- Heat and carbon uptake by the Southern Ocean (Co-Chairs: Joellen Russell, Igor Kamenkovich)

NACP/OCB Coastal Synthesis Activities

OCB continues its partnership with the North American Carbon Program (NACP) to coordinate and facilitate research activities to refine carbon budgets for the coastal regions of North America. The Gulf of Mexico regional team meeting will take place **March 27–28, 2013 in St. Petersburg, FL**. To view the status of coastal carbon budgets for different regions of the North American coast, please view articles published in previous issues of the OCB newsletter (east coast, west coast, Gulf of Mexico, Arctic, Great Lakes). Please note that the east coast budget was updated as a result of the east coast team meeting in January 2012. Results are available in the meeting report. To get regular regional updates, please visit the Coastal Synthesis Wiki Site.

Partner Program Updates

IMBER

- IMBIZO III (January 28–31 in Goa, India), IMBER data management workshop on **January 27**!
- 2nd CLIOTOP (CLimate Impacts on Oceanic TOp Predators) Symposium: *Certainty of change in pelagic systems – detection, attribution, prediction and adaptation* (February 11–15, 2013 in Noumea, New Caledonia)

SOLAS

- 2013 SOLAS Summer School (August 23–September 2, 2013 in Xiamen, China)

IOCCP

- New IOCCP director: Maciej Telszewski
- SOCAT 2 quality control exercise underway (August–October 2012) – contact: Maciej Telszewski
- IOCCP co-sponsoring International Time-Series Methods Workshop November 28–30, 2012 (BIOS, Bermuda)

U.S. CLIVAR

- Visit the new U.S. CLIVAR website
- U.S. CLIVAR Town Hall Meeting at Fall AGU (Tuesday Dec. 4, 12:30–1:30, Moscone West Room 2016) to discuss Science Plan for the Post-2013 Era
- Latest issue of U.S. CLIVAR Variations newsletter

A View Towards Integrated Earth System Models:

Human-Nature Interactions in the Marine World

Student reflections on IMBER ClimECO$_3$

In July 2012, OCB provided support for 6 U.S. students and postdocs to participate in the IMBER ClimECO$_3$ Summer School. Below are some of their impressions from this year's course.

"ClimECO3 provided me with a great opportunity to interact with researchers from the natural and social sciences that are working on topics related to oceans and climate change and impacts on society...I believe this is the beginning of a new community of researchers who can help bridge this critical gap."

— Shuwen Zhang

Enrique Montes
(University of South Florida)

"The IMBER ClimECO$_3$ summer school exceeded my expectations in multiple aspects. First, the organizers were very successful at designing a workshop that was suited for an audience with a wide range of backgrounds and expertise in the modeling field, without compromising the depth and scope of the lectures. Second, the lecturers presented different examples of how modeling tools can provide insights into complex ocean-human interactions relevant to the participants' research in their home countries beyond the conventional atmospheric CO_2 increase and global warming scenarios. These included the use of modeling techniques for developing fisheries management strategies in environments heavily impacted by human activity or defining the legal framework for regulating multiple uses of coastal areas in a sustainable manner. Third, through a combination of lectures and hands-on exercises and open discussions, the lecturers were very effective at demystifying and making accessible the use of numerical modeling for people outside this field, which in itself is quite a challenging task.

This summer school was also an excellent stage for networking and sharing ideas through poster sessions and group activities, which will very likely result in scientific publications and future research endeavors. For example, I personally had the opportunity to establish a research collaboration with Jacopo Baggio, one of the summer school lecturers who is a postdoctoral research fellow in social sciences at Arizona State University, to investigate how the crash of the sardine fisheries in the southern Caribbean has affected coastal communities in Venezuela, where crime rates have increased steeply, using sardine landings and oceanographic data in combination with agent-based models (ABM). I also had insightful discussions with lecturers and participants about the power of numerical modeling for studying the effects of climate variability on marine resources. Most of the summer school participants also benefited from exchanging ideas with instructors and peers, and built the same type of collaborations. Finally, this learning experience had an impact on my own research sooner than I anticipated. As a result of the course, I was able to include a simple model in a paper to address comments from a reviewer, which I otherwise would not have considered doing. I'm convinced that participating in this workshop will shape my future research and most likely that of my summer school peers."

Enrique Montes did his Bachelor's degree in biology at the Universidad Central de Venezuela (Caracas, Venezuela) focusing on freshwater ecosystems. Enrique came to the U.S. in 2006 with a Fulbright fellowship to do his Ph.D. in oceanography at the University of South Florida (USF) College of Marine Science under the guidance of Frank Muller-Karger. For his dissertation, Enrique studied seasonal changes in the geochemistry of sinking particles in the Cariaco Basin (Venezuela) using free-drifting and moored sediment traps with the aim of improving the interpretation of the paleoclimatic archive stored in the basin's sea-floor sediments. He also gained experience in satellite remote sensing and image processing to assess primary production and surface chlorophyll patterns in the Cariaco Basin and their connections to large-scale oceanographic processes in the eastern Caribbean. Enrique is currently a postdoctoral research associate at the Institute for Marine Remote Sensing (USF); his current research focuses on understanding the impacts of environmental/climate variability on marine ecosystems and resources in the southern Caribbean within the framework of the CARIACO Ocean Time-series program funded by the National Science Foundation.

Alexis Santos
(University of Wisconsin, Madison)

"The IMBER ClimECO$_3$ summer school provided a small, international forum that included a very informative "hands-on" approach to demonstrating tools that can be useful to include a human component in our research. As a result, the school facilitated international scientific discourse that many of us have little or no exposure to from our studies. With such a globally diverse presence at the school, we were able to practice scientific communication across continents and study areas. As a person with little modeling experience, it was nice to attend the lectures and understand them just as well as a person with years of environmental modeling behind them. I also enjoyed being challenged to expand my scientific inquiry to include humans in our research system instead of separate from it."

Alexis Santos has a B.S. in Chemistry with a minor in Environmental Studies from Southwestern University in Georgetown, Texas. For most of her undergraduate career, she studied the stream ecology and population dynamics of a species of salamander that is an endangered species candidate. Through this research and her coursework, Alexis became interested in the impacts of a changing environment on chemical and biological processes. Alexis is currently a graduate student at the University of Wisconsin-Madison in the Department of Atmospheric and Oceanic Sciences. Her current project with Dr. Galen McKinley entails examining the variations in nutrient movement due to gyre structural changes in the North Atlantic Ocean.

Paul Suprenand
(University of South Florida)

"The IMBER ClimECO$_3$ summer school was certainly one of the most rewarding and useful international workshops I have attended. As a marine scientist with a multidisciplinary background who works on multidisciplinary projects, I was hoping to expand my knowledge of multidisciplinary approaches to address a wide range of research questions concerning human-ecosystem interactions. I was not disappointed. It became quickly evident that the speakers and the methods and approaches they utilize were of the highest caliber. I am currently working to employ many of the skills learned during the workshop to address environmental influences in the Antarctic ecosystem."

Paul Suprenand received his bachelor's degree in Environmental Studies from the University of Colorado at Boulder in 2001, and his master's degree in Environmental Science and Engineering from the Colorado School of Mines in 2006. In addition to his degrees he has several years of professional experience working as a scientist in aquatic toxicology, wildlife conservation, and biotechnology. Paul is currently a Ph.D. candidate at the University of South Florida's College of Marine Science working to understand key environmental parameters that influence Antarctic zooplankton. His research encompasses ecology, physiology, and modeling. Paul also has extensive field experience in the Arctic Ocean, Southern Ocean, and eastern tropical Pacific. Paul has received national awards for his academic excellence. He also teaches college courses part-time.

Shuwen Zhang
(University of Rhode Island)

"The integrated approach of this year's ClimECO$_3$ summer school program, combining earth system models, human-nature interactions, and socioeconomics in a changing marine system aligned well with my research interests, which cross traditional boundaries between biogeochemical, ecological, and physical disciplines. Attending this six-day summer school helped me forge new ground in marine ecosystem research at the interface between social and natural sciences. ClimECO$_3$ provided me with a great opportunity to interact with researchers from the natural and social sciences that are working on topics related to oceans and climate change and impacts on society. By meeting so many researchers from different cultures and countries with the same scientific concerns and aspirations, I believe this is the beginning of a new community of researchers who can help bridge this critical gap."

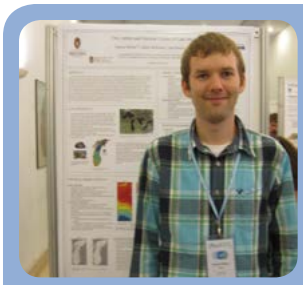
Shuwen Zhang obtained her Bachelor's Degree from the Ocean University of China, and is currently a Ph.D. candidate at the University of Rhode Island Graduate School of Oceanography, working with Dr. Lewis M Rothstein and his collaborators. They are exploring the biogeography and biodiversity of the U.S. northeastern shelf using a coupled physical model (ROMS, Regional Ocean Modeling System) and an ecosystem model (DARWIN).

Luis Huckstadt
(University of California, Santa Cruz)

"I attended the IMBER Summer School with the intention of learning about ecosystem modeling, and with a particular interest in Individual Based Models (IBMs), in order to be prepared for the new professional challenges that I will be facing as a postdoctoral researcher studying upper trophic level species in marine ecosystems. The lecturers did a superb job at presenting us with information and tools on the different aspects of modeling, from individual to ecosystems, which I consider very useful for my research. However, this workshop reached further than I anticipated, and I enjoyed the multidisciplinary approach of the workshop, spanning basic oceanography to economics, which exposed us to new perspectives of ecosystem modeling that we were not necessarily familiar with due to our own professional bias. I found it rewarding to see how the field has developed to include the human dimension in marine ecosystem modeling exercises, including social and economic aspects."

Luis A. Huckstadt is a postdoctoral researcher in the Department of Ecology and Evolutionary Biology at the University of California, Santa Cruz. He received his Doctoral degree in Ocean Sciences in 2012 (University of California Santa Cruz), and his Masters degree in Oceanography in 2005 (Universidad de Concepcion, Chile). Dr. Huckstadt's research has been focused on the spatial and trophic ecology of apex predators in upwelling ecosystems and polar ecosystems. Early in his career, he conducted research on the interactions between marine mammals and fisheries, specifically the impacts of this human activity on sea lions, but also on the impact that sea lions might have on the fishing sector, particularly with regards to small-scale fisheries. Over the past five years, Dr. Huckstadt has conducted research in the waters surrounding the Antarctic continent, investigating the association between oceanographic features and foraging and searching behaviors displayed by top predators of the Southern Ocean. He has also been doing stable isotope analysis (SIA) to study long-term foraging ecology and monitor possible shifts in dietary composition and habitat use of these species, as well as to determine the degree of niche overlap or partitioning between them.

Currently, Dr. Huckstadt continues his research on polar latitudes species, developing habitat models for different species of Antarctic top predators, along with investigating feeding ecology using SIA. Dr. Huckstadt is also involved in a new scientific program aiming at developing an Individual Based Model (IBM) for endothermic marine top predators as part of a major ecosystem-level modeling effort for the California Current System.



Darren Pilcher obtained undergraduate degrees in chemistry (major) and history (minor) from Beloit College in Beloit, WI. During the summer of his junior year, he did a DAAD (German Academic Exchange Service) RISE (Research Internships in Science and Engineering) summer internship at GEOMAR in Kiel, Germany, during which he calibrated and tested an in situ equilibration system for measuring nitrous oxide and methane in seawater. Upon returning to Wisconsin, he decided to pursue ocean biogeochemistry and entered graduate school at the University of Wisconsin-Madison as a research assistant for Dr. Galen McKinley. His research has focused on Great Lakes carbon cycling using the MIT general circulation model. In 2011, he also participated in the CLIVAR A10 research cruise as a CFCs/SF6 operator.

Darren Pilcher
(University of Wisconsin, Madison)

"I had a great experience at the IMBER ClimECO$_3$ summer school in Ankara, Turkey, as it brought together a terrific group of international faculty and students. I was interested in learning how to model higher trophic organisms and benthic invertebrates, since my prior ecosystem modeling experience consisted primarily of NPZD models. Furthermore, I was intrigued by the social/human interactions that can be incorporated. It has been a long-term goal of my Lake Michigan project to incorporate invasive *Dreissena* mussels. Thus, the summer school has not only given me new insight into how I can directly model the mussels, but also how I can expand the project to model how human policy implementation can affect mussel populations. I greatly appreciate the funding provided by OCB, which enabled me to attend the summer school and, through lectures and interactions with the faculty and students, gain critical insight into incorporating human interactions into ecosystem models."

OCB Calendar

We maintain an up-to-date calendar on the OCB website. ***OCB activity, partner activity, or co-sponsorship***	
2012	
November 5–9:	Pan Oceanic Remote Sensing Conference (Kochi, Kerala, India)
November 6–16:	Satellite Monitoring of the Seas 2012 Africa (Morocco)
November 19–21:	Group on Earth Observations (GEO) Task "Oceans and Society: Blue Planet" Kick-Off Symposium (Foz do Iguacu, Brazil)
November 28–30*:	International Time-Series Methods Workshop (BIOS, Bermuda)
December 3–7:	2012 AGU Fall Meeting (San Francisco, CA)
2013	
January 21–23:	Gulf of Mexico Oil Spill & Ecosystem Science Conference (New Orleans, LA)
January 28–31*:	IMBER IMBIZO III: The future of marine biogeochemistry, ecosystems and societies (Goa, India) (IMBER data management workshop on January 27!)
February 4–7:	2013 NACP All-Investigators Meeting (Albuquerque, NM)
February 11–15:	2nd CLIOTOP (CLimate Impacts on Oceanic TOp Predators) Symposium: *Certainty of change in pelagic systems – detection, attribution, prediction and adaptation* (Noumea, New Caledonia)
February 11–16:	4th PAGES Open Science Meeting (Goa, India) (includes 2nd PAGES Young Scientists meeting Feb. 11–12)
February 17–22:	ASLO 2013 Aquatic Sciences Meeting (New Orleans, LA)
March 4–6:	MAREMIP/ EUR-OCEANS/ IMBER/ GREENCYCLES II Workshop: Impact of climate change on marine ecosystems (Paris, France)

OCB Calendar (cont.)

2013 (cont.)	
March 9-10:	Gordon Research Seminar (GRS) on Polar Marine Science (Ventura, CA)
March 10-15:	Gordon Research Conference (GRC) on Polar Marine Science (Ventura, CA)
March 27–28*:	NACP/OCB Gulf of Mexico coastal synthesis team meeting (St. Petersburg, FL)
May 6–8:	First International Ocean Colour Science meeting (Frankfurt, Germany)
May 13–17*:	45th International Liege Colloquium on Ocean Dynamics (Liège, Belgium)
June 3–7:	9th International Carbon Dioxide Conference (ICDC9) (Beijing, China)
July 22–25*:	Annual OCB Summer Workshop (Woods Hole, MA)
Aug 23–Sept 2:	2013 SOLAS Summer School (Xiamen, China)

OCB-RELEVANT FUNDING OPPORTUNITIES

- **November 20, 2012:** Dynamics of Coupled Natural and Human Systems (CNH) proposal deadline
- **December 3, 2012:** NSF Science, Engineering and Education for Sustainability (SEES) Fellows full proposal deadline
- **December 4, 2012:** NSF Ocean Acidification proposal deadline
- **December 20, 2012:** Belmont Forum and G8 Research Councils Initiative on Multilateral Research Funding International Opportunities Fund full proposal deadline
- **February 4, 2013:** NSF Research Coordination Networks (RCN) proposal deadline (SEES Track)
- **February 15, 2013:** NSF Chemical and Biological Oceanography proposal deadlines
- **February 15, 2013:** NSF Ocean Technology and Interdisciplinary Coordination proposal deadline

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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