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POSTER ABSTRACTS

Atmospheric Nutrient Deposition: Impacts on Marine Ecosystems and Biogeochemical Cycles

Anthropogenic aerosols and climate variability control decadal variability of dissolved oxygen in the North Pacific

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The Pacific Ocean contains two of the High-Nutrient-Low-Chlorophyll (HNLC) regions, where a scarcity of iron limits biological productivity. Below these surface HNLC regions, one in the subpolar gyre and the other in the tropics, lay some of the most voluminous oxygen minimum zones of the world oceans. Dissolved oxygen concentration in these regions significantly declined in the last several decades. However, mechanisms regulating the oxygen variability in these regions are not well understood. We perform a suite of computational simulations to test the hypothesis that atmospheric pollution over the Pacific Ocean as well as the regional climate variability can change the pattern of biological productivity and the distribution of oxygen in deeper waters. Climate variability modulates the upwelling and nutrient supply to the surface waters, altering the oxygen utilization below. Atmospheric pollutants increase the deposition of soluble iron and fixed nitrogen, further altering the ocean productivity and oxygen utilization. The combined effect is the increased O_2 consumption in the oxygen minimum zone of the tropical Pacific, causing the prominent trends observed over recent decades.

Dust deposition and *Trichodesmium* increase in temperate North Atlantic from 1980-1990's.

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African dust is an important source of iron in the tropical North Atlantic. Ocean fertilization events related to episodes of iron-rich dust input have been extensively described. Traditionally, *Trichodesmium* distribution is thought to be temperature-dependent and iron-limited, thus typically restricted to tropical and subtropical regions. Due to physiological constraints under lower temperatures, unusual populations found at higher latitudes are thought to be the result of drifting and not actively growing or fixing nitrogen. We analyzed over 200,000 in situ observations from the Continuous Plankton Recorder between 38-65N and spanning from 1960-2010. We found persistent basin-wide presence of *Trichodesmium* during the last 50 years. These abundances increased (up to 10-fold in the eastern side of the basin) from about 1983-1997, which may be related to intense dust activity during that same period. This event may have remained unnoticed because it occurred during the time lapse when ocean color satellites were not available (1986-1997) and discrete observations were strongly biased towards tropical latitudes. To show that *Trichodesmium* increase was related to dust deposition, we used NCEP/NCAR reanalysis, to study wind and pressure anomalies from 1960-2000, as well as the precipitation index in the Sahel Region. Timing of increased abundances of *Trichodesmium* coincided with an intense drought in the Sahel region, anomalous pressure systems and strong near surface northward winds (>4m/s) coming out of the Sahel region. Based on in situ sea surface temperature measurements from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS), these populations were growing at temperatures below 17^{o}C. Our results show an episodic conduit for iron-rich meridional winds transporting African dust to higher latitudes. Results also suggest that *Trichodesmium* populations are iron-limited in the temperate North Atlantic and that iron inputs can enhance biogeochemical cycles. This study proposes to include this aeolian iron pathway in Earth System Models and challenges generalized assumptions on *Trichodesmium* latitudinal and temperature ranges.

Biological impact of wet deposition to seasonally oligotrophic waters: Experimental results from the U.S. eastern seaboard

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During July-August 2014, we conducted field research to test the hypothesis that wet deposition events stimulate primary production and algal biomass accumulation in seasonally oligotrophic waters off the U.S. east coast. Here we report results of shipboard bioassay experiments conducted with whole seawater and resident phytoplankton collected from cyclonic eddies over the continental slope to the north and south of the Gulf Stream. Experimental amendments included iron, nitrate, iron+nitrate, iron+nitrate+phosphate, and filtered rainwater. Stimulation of algal community growth rate was inferred from chlorophyll accumulation and inorganic nitrogen drawdown in incubation treatments, relative to unamended control treatments. Results consistently showed no growth stimulation by iron, modest growth stimulation by nitrate and

iron+nitrate, intermediate growth stimulation by rainwater, and highest growth stimulation by iron+nitrate+phosphate. Based on these results and analyses of water-column and atmospheric samples, we surmise that nitrogen (N) was the proximate limiting nutrient for phytoplankton growth, with a secondary limitation imposed by phosphorus (P) availability. The growth stimulated by the addition of rainwater implies that summer rain events stimulate phytoplankton production in these waters by contributing new N (primarily as ammonium) and P.

Oceanic feedbacks limit the impact of atmospheric nitrogen deposition on marine productivity

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Nitrogen is an essential element for life that limits marine productivity throughout much of the surface ocean. While anthropogenic nitrogen emissions and subsequent deposition into the ocean continue to increase at unprecedented rates, impacts on marine ecosystems, productivity and biogeochemistry remain uncertain. Here we conducted atmospheric N deposition simulations to quantify these impacts in a global 3D ocean-biogeochemistry model. The model reveals stabilizing nitrogen cycle feedbacks on the marine nitrogen inventory, in which atmospheric nitrogen deposition causes an immediate decrease in N_2 fixation and a more gradual, but steady increase in denitrification. These feedbacks largely compensate the nitrogen input via atmospheric deposition and reduce the response of global marine productivity and expanding oxygen minimum zones by nearly an order of magnitude, which suggests that predictions neglecting nitrogen cycle feedbacks may yield an unrealistically large response to atmospheric nitrogen deposition. Nevertheless, our simulations still suggest that atmospheric N deposition may significantly contribute to expanding oxygen minimum zones. Our study shows that robust information about patterns and rates of N_2 fixation and denitrification is required to predict the impact of atmospheric nitrogen deposition on marine productivity and oxygen minimum zones.

Comparing the impact of atmospheric nitrogen deposition and wind mixing on biological productivity during storm events

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Recent studies suggest that storms can induce very different biological responses in the coastal waters of the eastern United States. In areas with relatively high nitrate concentrations (>1 μM), storm events are associated with a reduction in chlorophyll-a concentrations attributed to enhanced wind mixing and reduced light availability. In low-nutrient areas (nitrate concentrations <1 μM), storm events are associated with an increase in chlorophyll-a concentrations (up to 15%). Two hypotheses have been

proposed to explain the increased biological activity: (1) entrainment of nutrients to the mixed-layer from wind-induced mixing during the storm event, and (2) Atmospheric Nitrogen Deposition (AND) to the ocean surface. The latter can be particularly significant in coastal regions located downwind of large industrialized areas such as the eastern United States. The DANCE project (Deposition of Atmospheric Nitrogen to Coastal Ecosystems) is funded to investigate these questions in the oligotrophic coastal waters of the eastern US. This interdisciplinary project combines process-oriented field measurements and biogeochemical modeling at the local and regional levels.

In this presentation we use data collected during a summer Lagrangian field experiment between the Delaware Bay and the coastal Carolinas and simulate the biological response to rain events with a 1-D biogeochemical model. The model biological parameters are specifically optimized for this region using data-assimilation. We consider two different cases in order to separate the contribution of AND and mixing during storm events: (1) a case with AND and steady physical conditions, and (2) a case with both AND and time-varying physical conditions (i.e. mixing events). The AND events occurring during the field experiment led to a 105% increase of the NO_3 content in the top 10 meters. The extra nitrogen is consumed by the biological production over a period of *O* (7 days). The increase in productivity is significant near the surface (up to 20% in the top 10 meters) but negligible at deeper depths. Experiments with time-varying physical conditions suggest that the deep injection of nutrients into the mixed-layer during wind-mixing events has a larger impact on the productivity than the atmospheric deposition of nutrients at the surface. Such wind mixing events can result in a 200% increase in the NO_3 content of the top 50 meters and a similar increase in the biological productivity (175% in top 50 meters). These process-oriented experiments will be complemented by realistic simulations at the regional level with a 3-D ocean model (ROMS) forced with historic atmospheric deposition data.

The perturbation of the marine nitrogen cycle by atmospheric deposition

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The anthropogenically-driven increase in the atmospheric deposition of nitrogen onto the ocean has led to detectable changes in the oceanic nitrogen content [Kim et al., 2011, 2014], yet very little is known about how this has impacted the marine nitrogen cycle. We address this gap using the ocean component of the Community Earth System Model v1.2. We forced the model with a transient increase in atmospheric nitrogen deposition from 1850 through 2100 [Lamarque et al., 2013], while keeping all other forcings unchanged. The large increase in the deposition of nitrogen fuels additional productivity over much of the ocean, and especially over the oxygen minimum zones causing their expansion by 5% (1850-2000). Globally, oceanic net primary production changes little, owing to several regions experiencing strong decreases, largely due to stronger limitation by phosphate and iron. Nevertheless, the increased export and the lower oxygen concentrations cause an increase in pelagic and benthic denitrification by about 4%. In addition, the enhanced availability of fixed nitrogen in the surface ocean shrinks the ecological niches for N_2-fixers, causing a substantial decrease in global ocean N_2-fixation (11%). Despite the compensating effects through these negative feedbacks that eliminate about half of the total deposited fixed nitrogen, the anthropogenic nitrogen input forced the upper ocean N-budget substantially out of balance (17 Tg N yr^{-1}). This excess nitrogen accumulates to well above detectable levels and leaves a distinct low ^{15}N imprint - the ^{15}N Haber-Bosch effect - with the potential to dilute climate-driven signals.

Studying Spatial and Temporal Variability in the Ocean with Shipboard and Autonomous Platforms

Macronutrient stoichiometry at the Bermuda Atlantic Time-series Study site and surrounding ocean

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The Redfield Ratio describes the mean elemental composition of carbon, nitrogen, and phosphorus in the world's oceans. Since its introduction, oceanographers have attempted to explain the fundamental mechanisms that drive this ratio, and the implications for biogeochemistry in the surface ocean. Deviations from the canonical ratio have been used to explain a variety of biogeochemical processes, from nutrient limitation (Moore et al. 2013) to nitrogen mass balance (Gruber and Sarmiento 1997), and export flux from the euphotic zone (Singh et al. 2015). The Redfield Ratio in marine particulate organic matter can be driven by dissolved nutrient inputs, community composition, growth rate, detrital particles, or a combination of these factors. Carbon measurements of phytoplankton have been made by optical backscattering (Graff et al. 2015) and flow cytometry (Casey et al. 2013; Wallhead et al. 2014), but nitrogen and phosphorus have received relatively less attention. Martiny et al. (2013) showed latitudinal patterns of phytoplankton stoichiometry which highlighted how smaller prokaryotic cells had higher C:P and N:P ratios, especially in subtropical locations.

In this study, we used cell sorting by flow cytometry to analyze the taxon-specific cellular quotas of carbon, nitrogen, and phosphorus. We sorted populations of *Prochlorococcus*, *Synechococcus*, and small (<30 μm) eukaryotes from a broad latitudinal range in the western north Atlantic Ocean, but focused on the Bermuda Atlantic Time-series Study site (BATS; 31° 40' N, 64° 10' W). Through this analysis, we are able to empirically measure the influence of each of these taxonomic groups on the overall stoichiometry at BATS, connect those data to nutrient input ratios, and imply export flux dynamics. More than fifty samples across the western North Atlantic Ocean were analyzed. When including all samples, *Prochlorococcus*, *Synechococcus*, and eukaryotes respectively had C:N:P ratios of 205:27:1, 233:27:1, and 513:44:1, although eukaryotes had significant variability. We report on deviations from Redfield within populations and how these are influenced by environmental gradients, including nutrient supply rate and ratios. Additionally, we will show how each population contributes to the bulk C:N:P ratio. Understanding the biogeochemical, community, and physiologic basis of stoichiometry will aid in understanding phytoplankton ecology and the biological carbon pump, now and in the future.

References

Casey, J. R., J. P. Aucan, S. R. Goldberg, and M. W. Lomas. 2013. Changes in partitioning of carbon amongst photosynthetic pico- and nano-plankton groups in the Sargasso Sea in response to changes in the North Atlantic Oscillation. Deep-Sea Res. Pt II **93:** 58-70.

Graff, J. R. and others 2015. Analytical phytoplankton carbon measurements spanning diverse ecosystems. Deep-Sea Res. Pt. I **102:** 16-25.

Gruber, N., and J. L. Sarmiento. 1997. Global patterns of marine nitrogen fixation and denitrification. Global Biogeochem. Cy. **11:** 235-266.

Martiny, A. C., J. A. Vrugt, F. W. Primeau, and M. W. Lomas. 2013. Regional variation in the particulate organic carbon to nitrogen ratio in the surface ocean. Global Biogeochem. Cy. **27:** 723-731.

Moore, C. M. and others 2013. Processes and patterns of oceanic nutrient limitation. Nature Geosci **6:** 701-710.

Singh, A., S. E. Baer, U. Riebesell, A. C. Martiny, and M. W. Lomas. 2015. C:N: P stoichiometry at the Bermuda Atlantic Time-series Study station in the North Atlantic Ocean. Biogeosci. Disc. **12:** 9275–9305.

Wallhead, P. J., V. C. Garçon, J. R. Casey, and M. W. Lomas. 2014. Long-term variability of phytoplankton carbon biomass in the Sargasso Sea. Global Biogeochem. Cy.**:** 2013GB004797.

Dissolved oxygen concentration at the PAP site: resolving O_2 annual dynamics at an eddy rich site in the temperate North Atlantic using Seagliders

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The concentration of dissolved oxygen, $c(O_2)$, is one of the most important variables measured in oceanography, influenced both by physical and biological factors. During the OSMOSIS project, 7 Seagliders were used in 3 subsequent missions to measure a multidisciplinary suite of parameters at high frequency in the top 1000 m of the water column for one year, from September 2012 to September 2013. The gliders were deployed at the Porcupine Abyssal Plain (PAP) time series station (nominally at 49° N

16.5° W) and surveyed the area following butterfly- or hourglass-shaped paths. Oxygen concentrations were measured by Aanderaa optodes and calibrated using ship CTD O_2 profiles during 5 deployment and recovery cruises, which were in turn calibrated by Winkler titration of discrete samples.

The oxygen-rich mixed layer deepens in fall and winter and gets richer in oxygen when the temperature decreases. The spring bloom did not happen as expected, but instead the presence of a series of small blooms was noted throughout spring and early summer. During summer, the mixed layer became very shallow and oxygen concentrations decreased.

Mixed layer depths based on the difference in oxygen concentration with respect to the concentration at 10 m is compared with estimates based on density difference and chlorophyll fluorescence difference?. The three definitions show agreement when the stratification is strong, but for deep mixed layers they disagree. This comparison might be useful for the detection of a mixing layer where the turbulence is active as opposed to the mixed layer, which would reflect the deepest point reached by turbulence in a recent past.

A subsurface oxygen maximum (SOM) developed along with a deep chlorophyll maximum during the summer and was located just below the mixed layer. At this depth, phytoplankton had favourable light and nutrient conditions to grow and produce oxygen, which was not subject to immediate outgassing. The SOM oxygen concentration was not constant, but decreased, then increased again until the end of the mission. Attempts are also done for the estimation of the net community productivity (NCP) within the SOM and in the mixed layer above.

Intrusions of oxygen rich water were also visible throughout the mission. These are probably due to mesoscale events of horizontal transport of oxygen and/or nutrients that can enhance productivity, particularly at the edge of fronts.

Salinity variability along the eastern continental shelf of Canada and the United States, 1973-2013

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Continental shelf waters located off the east coast of Canada and the United States are part of an along-shelf current system that is comprised of colder, less-saline waters from high latitudes, along with input from rivers. A 41-year analysis (1973-2013) of near-surface salinity using two hydrographic datasets (BIO "Climate" and MEDS) allowed an examination of near-surface salinity within 11 sub-regions, extending from Newfoundland to the DelMarVa/Hatteras shelf. Global mean salinities are lowest within the Gulf of St. Lawrence (30.49) and highest on the DelMarVa/Hatteras shelf (32.72), with largest annual variability within the Gulf of St. Lawrence (ΔS ~2.5). Large annual variability also occurs on the Newfoundland (ΔS ~1.9), Middle Atlantic Bight (ΔS ~2.0), and DelMarVa/Hatteras (ΔS ~2.3) shelves. Long-term trends computed from annual mean near surface salinity were detected along the Newfoundland shelf (+0.011 y^{-1}), western Scotian shelf (-0.007 y^{-1}), Gulf of Maine (-0.014 y^{-1}), Georges Bank (-0.011 y-1), and DelMarVa/Hatteras shelf (+0.024 y^{-1}). A long-term quadratic fit to annual mean salinity from the eastern Scotian shelf displays a salinity increase through 1992 (+0.026 y^{-1}), decreasing thereafter until 2013 (-0.028 y^{-1}). A quadratic fit for the western Grand Banks displays a salinity increase through 2007 (+0.022 y^{-1}), decreasing thereafter (-0.006 y^{-1}). Annual mean salinities from the eastern and Tail of the Grand Banks, Gulf of St. Lawrence, and Middle Atlantic Bight displayed no long-term trends. Inter-annual variability (IAV) of near-surface salinity residuals shows similar small mean squared error (mse) of 0.02-0.04 (relative to each sub-region's respective model fit or mean value) for the four northern-most sub-regions and appear to be coherent. IAV (mse) of near-surface salinity increases for the Gulf of St. Lawrence (~0.19), eastern and western Scotian shelf (~0.09-0.06), Gulf of Maine and Georges Bank (~0.08-0.06), Middle Atlantic Bight (~0.19), and is largest for the DelMarVa/Hatteras shelf (~0.36), with coherent temporal fluctuations between these more southern 7 sub-regions.

An inter-laboratory comparison assessing the quality of seawater carbon dioxide measurements

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Seawater CO_2 measurements are being made with increasing frequency as interest grows in the ocean's response to changing atmospheric CO_2 levels and to climate change. The ultimate usefulness of these measurements depends on the data quality and consistency. An inter-laboratory comparison was undertaken to help evaluate and understand the current reliability of seawater CO_2 measurements. Two seawater test samples of different CO_2 content were prepared according to the usual method for the creation of seawater reference materials in the Dickson Laboratory at Scripps Institution of Oceanography. These two test samples were distributed in duplicate to more than 60 laboratories around the world. The laboratories returned their measurement results for one or more of the following parameters: total alkalinity (A_T), total dissolved inorganic carbon (C_T), and pH, together with information about the methods used and the expected uncertainty of the measurements. The majority of laboratories reported A_T and C_T values for all their measurements that were within 10 μmol kg^{-1} of the assigned values (i.e. within ±0.5%), however few achieved results within 2 μmol kg^{-1} (i.e. within ±0.1%), especially for C_T. Results for the analysis of pH were quite scattered, with little suggestion of a consensus value. The high-CO_2 test sample produced results for both C_T and pH that suggested in many cases that CO_2 was lost during analysis of these parameters. This study thus documents the current quality of seawater CO_2 measurements in the various participating laboratories, and helps provide a better understanding of the likely magnitude of uncertainties in these measurements within the marine science community at the present time. Further improvements will necessarily hinge on adoption of an improved level of training in both measurement technique and of suitable quality control procedures for these measurements.

E. E. Bockmon and A. G. Dickson. An inter-laboratory comparison assessing the quality of seawater carbon dioxide measurements. Marine Chemistry, 171: 36-43, doi:10.1016/j.marchem.2015.02.002, 2015.

Mixed-layer depth, euphotic depth and Chl-a variability in the Southern Ocean

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The Southern Ocean contains some of the ocean's deepest mixed layers. Because deep mixed layers can transport phytoplankton below the euphotic zone, light levels depend on mixed-layer depth (MLD), and phytoplankton growth is hypothesized to be co-limited by iron and light.

Combining satellite ocean color data and fluorescence, backscattering and hydrographic profiles collected by southern elephant seals, EM-APEX, and Argo floats we evaluate the extent to which MLD influences phytoplankton bloom development and the vertical structure of chlorophyll-a (Chl-a) in the Southern Ocean. In situ measurements indicate that surface Chl-a (i.e. mean Chl-a for the upper light penetration depth) is a relatively good proxy of phytoplankton biomass (i.e. depth-integrated Chl-a) within the euphotic zone but gives an inadequate representation of biomass within the mixed layer, particularly in the summer. Although nearly vertically homogeneous Chl-a within the mixed layer prevails in seasonal mean profiles, subsurface Chl-a maxima are not uncommon from spring through fall. Deep Chl-a maxima are found near the base of the mixed layer, closer to the nutrient maximum than the light maximum, suggesting that nutrient limitation (i.e., essentially iron) can play a greater role than light limitation in governing productivity, and that mixing processes at the base of the mixed layer control phytoplankton growth and/or accumulation.

Microbial community influenced by a cyclonic eddy in the North Atlantic Subtropical Gyre

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We conducted a 5-day survey across a cyclonic eddy southeast of the Bermuda Atlantic Time Series station in August 2013, to investigate the influence of the eddy on microbial communities. Samples were collected outside and inside of the eddy from 6 depths between 10 m and 300 m, investigating the hydrographic conditions, dissolved nutrients, and microbial community composition. The communities were studied using high throughput sequencing targeting the 16S rRNA gene (on the Illumina MiSeq platform) and quantitative PCR targeting select groups of diazotrophs. The eddy center had reduced temperatures, salinities, and O_2 concentrations below the DCM, while phosphate concentrations at the surface layers were elevated in this area compared to stations outside the eddy, all suggestive of upwelling. Microbial community showed a shift at 200 m at the eddy center station, the community becoming more similar to communities at 300 m at other stations, supporting the idea of upward movement of the deep water communities at the eddy center. While the overall communities at the euphotic layers were not clearly separated inside and outside of the eddy, proportions of major cyanobacteria at the 10-m depth shifted from *Prochlorococcus* dominated communities outside of the eddy to *Synechococcus* dominated communities in the eddy-influenced waters. Based on quantitative PCR, abundances of a diazotrophic gammaproteobacterium were the highest at a station at the periphery of the eddy. The influence of the eddy on microbial functional groups will be further explored.

Cyanobacteria, too small to sink? Strain-specific contribution of cyanobacteria to the carbon export in the Sargasso Sea

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Pico- and nano-phytoplankton, such as cyanobacteria, dominate the primary production in the Sargasso Sea, with *Synechococcus* being more abundant in the winter, while *Prochlorococcus* in the summer. However, very little is known about their contribution to the carbon export. Here we quantified for the first time the strain specific abundance in the euphotic zone and the contribution of these cyanobacteria to the flux of particulate matter collected with shallow (150 m) particle traps during the spring and the summer of 2012 around the Bermuda Atlantic Time-series Study station by quantitative Polymerase Chain Reaction targeting the 23-16 rDNA internally transcribed spacer region. We found that different strains of *Synechococcus* (clade II and III) and *Prochlorococcus* (strains MIT 9312 and 9313) dominated different seasons. For example, clade II of *Synechococcus* was more abundant than clade III during the spring, contributing between the 10 and 14% to the particulate organic carbon (POC) flux. During the summer 2012 the scenario changed, clade III was the most abundant clade, and the overall *Synechococcus* contribution to the flux was below 2%. In the case of the *Prochlorococcus* community, only the strain adapted to low light intensity (MIT 9312) was found in both seasons, while strain MIT 9313 (adapted to high light intensity) was found only during summer 2012 below 80m. Independent of the distribution and abundances of the different *Prochlorococcus* strains in the water column, their contribution to the downward particle flux in the Sargasso Sea in both seasons was below 1%. It is predicted that cyanobacteria will become more abundant in a future warmer ocean and the Sargasso Sea is the perfect in situ laboratory to study the contribution of pico primary producers to the carbon export today and in a future ocean.

A year-long record of particulate carbon export and net primary production from profiling floats in the Sargasso Sea

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Autonomous sampling platforms such as bio-optical profiling floats are poised to broaden the number and spatiotemporal resolution of observations of the ocean's biological pump. In this study, *in situ* profiles of chlorophyll fluorescence and backscattering were collected at approximately 2-day resolution from two profiling floats in the Sargasso Sea. Net primary production (NPP) was modeled from MODIS photosynthetically available radiation and float data using the Carbon-based Productivity Model (Behrenfeld 2005; Westberry 2008). During drift phases in between vertical profiles, the floats also measured particulate carbon (PC) export by the optical sediment trap method (Bishop et al. 2004; Estapa 2013) at a cycle of depths ranging from 150 m to 1000 m, allowing estimation of the export ratio at approximately weekly time scales. The magnitudes of NPP, PC export, and their annually averaged ratio were generally consistent with observations at the nearby Bermuda Atlantic Time-series Study (BATS) site. PC export and the export ratio were enhanced in the autumn as well as in the spring, and varied over short timescales possibly due to the influence of mesoscale eddies. Estimates of PC remineralization length scales suggested stronger attenuation of flux with depth during summer and early fall. Our analysis shows the importance of integrating NPP and export observations to the same reference depth if they are to be compared. Comparisons of the float-based export ratios to output from several global models show that mechanistic, food-web based models may be best suited to reproduce the observed variability over a range of time scales.

Enabling water column science at Station ALOHA: A profiling mooring system

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Aliasing, undersampling, and lack of sustained long-term measurements continue to be the bane of oceanography. Times series sites such as HOT, BATS, OceanSites, Ocean Networks Canada, and the Ocean Observatories Initiative represent mitigation efforts. Here we propose a cable connected profiling mooring system at Station ALOHA to enable more complete high-resolution temporal and spatial sampling to reduce aliasing of signals (e.g., diel variations, internal waves and tides, submesoscale and mesoscale) and to adaptively and rapidly sample aperiodic episodic temporal and spatial events (e.g., export events to the deep sea, patch and layer phenomena). The proposed system enables a mix of fixed and mobile observations, that with ship, glider, and AUV observations will paint a more complete science picture.

Two sensor-equipped profilers will move vertically with power and communication provided via the seafloor ALOHA Cabled Observatory (ACO). The shallow profiler will run from the subsurface float at ~100 m to the surface and the deep profiler will run from the subsurface float to the bottom (4730 m) docking every few days to recharge. Candidate instruments will obtain microbial and other samples and measure nutrients, bio-optics, pigments, radiance and irradiance, bioacoustics, video, oxygen, pH, trace elements, temperature, salinity, velocity, turbulence, and more.

SCOPE and other projects at ALOHA will be able to use such a system to study the interacting physical and biological processes control the ocean carbon cycle at Station ALOHA. Air-sea gas exchange, vertical entrainment, lateral advection, and net community production are some of the largest contributors to carbon mass balances in this region, known only with large uncertainties. Rapid sampling over shorter time-scales is required to quantify the biogeochemistry and microbial responses to ocean variability on scales from viscosity dominated processes to large storms.

The long-term measurements will shed light on how wind stress momentum is dissipated in the surface mixed layer, and how the associated turbulence modulates the biogeochemistry. The water column between a few hundred meters and the near bottom is largely still unobserved from the point of view of coupling between the biogeochemistry and microbial oceanography and physics. Bottom ACO temperature and velocity results offer clear evidence of sudden cold events (0.02 K over a day or so) often with different T-S (and microbial?) characteristics. These fascinating, continuing results are yet another indicator that the deep sea is far from quiescent, with attendant sampling and interpretation challenges that have global implications.

Satellites to the seafloor: Autonomous science to form a breakthrough in quantifying the global ocean carbon budget

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In 2013-2014, the Keck Institute for Space Studies conducted a study to investigate the premise that autonomous and coordinated groups of heterogeneous mobile robots, working in cooperation with remote sensing and shore-based data assimilation, could significantly advance our ability to obtain the observations needed to quantify the global ocean carbon budget. The study brought together 32 scientists and technologists over two workshops. The KISS study focused on identifying the observational capabilities required to quantify the ocean carbon cycle; assessing the current capabilities in the ocean robotics, autonomous science, and satellite communities; determining the necessary advances to obtain the desired observations; and developing a collaborative research agenda aimed at solving these problems.

This KISS study, Satellites to the Seafloor, identified the vertical flux of carbon through the water column as a scientific focus, with an awareness that coupling between lateral and vertical fluxes also needs to be addressed. We determined that the understanding of three key marine carbon cycle processes would benefit from improved observational capabilities: (i) the export of carbon from the surface ocean, including its fine horizontal variability; (ii) the evolution of carbon through the "twilight zone" (*sub-euphotic layer)* where the bulk of *remineralization* occurs; and (iii) the flux of carbon through the seafloor and the identification of physical processes associated with its variability. Patchiness, or intermittency, which characterizes *biogeochemical cycling*, at least in the upper ocean (few hundred meters), and potentially throughout the water column, arose as a major theme of the study. Patchiness presents a major observational challenge, including matching robots and communication modalities to spatial and temporal scales.
The study developed a technical vision for a coordinated network of ocean robots and satellites that autonomously interprets data and communicates sampling strategies that lead to effective resolution of the coupling between physical and biogeochemical dynamics. The observational capabilities afforded by this paradigm will improve estimates of how patchy distributions contribute to larger-scale carbon cycle budgets. This vision formed the basis for focusing on three technology areas: (i) sensors, (ii) marine robotics, and (iii) information exchange. Implementation of the vision will require a large number of assets, each with individual requirements for re-tasking, data communication and assimilation, and health monitoring. Thus autonomy is a crucial part of the proposed vision. Autonomy will allow humans to focus on tasks they are uniquely suited for, such as data interpretation and high-level decision-making.

Workshop homepage (including final report): http://www.kiss.caltech.edu/study/seafloor/

Fixed point Open Ocean Observatory network ($FixO^3$): Multidisciplinary observations from the air-sea interface to the deep seafloor

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The Fixed point Open Ocean Observatory network ($FixO^3$, http://www.fixo3.eu/) integrates 23 European open ocean fixed point observatories and improves access to these infrastructures for the broader community. These provide multidisciplinary observations in all parts of the oceans from the air-sea interface to the deep seafloor. Started in September 2013 with a budget of 7 Million Euros over 4 years, the project has 29 partners drawn from academia, research institutions and SME's coordinated by the National Oceanography Centre, UK.

We present an overview of the programme's achievements in the first two years and the activities of the 12 Work Packages, which have the objectives to:

- integrate and harmonise the current procedures and processes
- offer free access to observatory infrastructures to those who do not have such access, and free and open data services and products
- innovate and enhance the current capability for multidisciplinary in situ ocean observation

Open ocean observation is a high priority for European marine and maritime activities. $FixO^3$ provides important data and services to address the Marine Strategy Framework Directive and in support of the European Integrated Maritime Policy. $FixO^3$ provides a strong integrated framework of open ocean facilities in the Atlantic from the Arctic to the Antarctic and throughout the Mediterranean, enabling an integrated, regional and multidisciplinary approach to understand natural and anthropogenic change in the ocean.

A control volume approach for estimating nitrous oxide production and consumption in the Chesapeake Bay

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Nitrous oxide (N_2O) emissions to the atmosphere from coastal areas, and the timescales over which they vary, are poorly understood. To better characterize N_2O dynamics in the Chesapeake Bay, we measured N_2O and nitrification rates in August and September 2013 in the mesohaline region of the Chesapeake Bay during low oxygen conditions. Surface N_2O saturation values ranged from 95 to 231% with the northern-most transect being a sink for atmospheric N_2O. Ammonium oxidation rates were greatest at the interface between ammonium-rich bottom water and oxygenated surface water, ranging between 14.8 and 133.2 nM h^{-1}. N_2O profiles suggest a source of N_2O at the pycnocline and N_2O

consumption below the pycnocline. An engineering 'control volume' budget was used to estimate N_2O production and consumption along a 21 km region in the Chesapeake Bay. Advective and diffusive processes were separated from internal N_2O production and consumption processes, yielding estimates of N_2O production and consumption between -0.05 to 0.06 nM h^{-1}; these values agree with estimates of N_2O production from nitrification rate measurements and reasonably explain N_2O concentration profiles. Our study shows that N_2O emissions from the Chesapeake Bay are variable over multiple time and spatial scales and that the Bay can act as both a source and a sink for N_2O during stratified summer conditions.

Oxygen metabolism and pH in coastal ecosystems: The Eddy Covariance Hydrogen ion and Oxygen Exchange System (ECHOES)

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An aquatic eddy covariance (EC) system was developed to measure the exchange of oxygen (O_2) and hydrogen ions (H^+) across the sediment-water interface. The system employs O_2 optodes and a newly developed micro-flow cell H^+ ion selective field effect transistor; these sensors displayed sufficient precision and rapid enough response times to measure concentration changes associated with turbulent exchange. Discrete samples of total alkalinity and dissolved inorganic carbon (DIC) were used to determine the background carbonate chemistry of the water column and relate the O_2 and H^+ fluxes to benthic processes. The ECHOES system was deployed in a eutrophic estuary (Waquoit Bay, Massachusetts, USA), and revealed that the benthos was a sink for acidity during the day and a source of acidity during the night, with H^+ and O_2 fluxes of ± 0.0001 and ± 10 mmol m^{-2} h^{-1}, respectively. H^+ and O_2 fluxes were also determined using benthic flux chambers, for comparison with the EC rates. Chamber fluxes determined in 0.25 h intervals co-varied with EC fluxes but were ~4 times lower in magnitude. This difference was likely due to suppressed porewater advection in the chambers and changes in the chemistry of the enclosed chamber overlying water. The individual H^+ and O_2 fluxes were highly correlated in each data set (EC and chambers), and both methods yielded H^+ fluxes that could not be explained by O_2 metabolism alone. The ECHOES system provides a new tool for determining the influence of benthic biogeochemical cycling on coastal ocean acidification and carbon cycling.

From the past to the future: Understanding ocean and climate variability through the CARIACO Ocean Time-Series

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The CARIACO Ocean Time-Series project, located in the Cariaco Basin off the coast of Venezuela, seeks to understand the relationships between hydrography, primary production, community composition, microbial activity, particle fluxes, and element cycling in the water column, and how variations in these processes are preserved in sediments accumulating in this anoxic basin. This Time-Series program is a model for national ocean observing programs in Central/South America, and has been developed as a community facility platform with open access to all data generated during the project (http://imars.marine.usf.edu/cariaco). CARIACO uses autonomous and shipboard measurements to understand ecological and biogeochemical changes in the tropical continental margin of Northern South America and how these relate to regional and global climatic and ocean variability. Sediment traps, moored at 5 depths for over two decades, link changes in the composition and magnitude of sinking fluxes to upper ocean variability in productivity and the microbial community that exists throughout the water column, especially at the oxic-anoxic interface. The automated sediment trap measurements have effectively captured episodic and short-lived events (e.g., earthquakes, floods, etc.), which are missed by shipboard measurements, while also enabling long term trends in particle flux to be observed. Similarly, shipboard measurements have discovered a biological community shift, from large to smaller taxa, caused by regional changes in the physical regime. The magnitude and composition of the sinking flux has changed in response to this community shift. "Excess" sinking particulate fluxes have been measured at depth, and it is hypothesized that biologically mediated coagulation of suspended particles within the redoxcline contributes to this enhanced flux at and below the oxic/anoxic interface. The chemoautotrophic community that resides at the interface has different carbon fixation pathways which result in the production of more enriched particulate organic carbon. Leveraging on the strengths of both types of observational platforms has enabled a deeper understanding of the dynamics of the Cariaco Basin. The observations of CARIACO are critical for better understanding the biological pump on upwelling-dominated continental margins, and to predict potential impacts of climate change on its carbon sequestration efficiency.

An integrated observation system of biogeochemical time-series

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Time-series studies have clearly demonstrated interannual to decadal-scale variability in ocean biogeochemical processes. They play a critical role in documenting and evaluating mechanisms of how marine ecosystems respond to changes in climate. Ship-based biogeochemical monitoring is critical to understand ocean changes, in particular variations related to ocean biogeochemical cycles, ecology, biodiversity and carbon export. Most of these time-series are located in continental margins, biologically and geochemically active areas of the biosphere which exchange large amounts of material with the open oceans. However, ship-based time-series have limited temporal and spatial resolution. Ocean technology has leaped to the aid of scientists by providing them with cost-effective tools that can take measurements of some biogeochemical variables autonomously, i.e. sensors on autonomous platforms. These autonomous measurements are complementary to efforts carried out by traditional ship-based sampling, with the aim of improving data coverage worldwide. Together with satellite remote sensing, these observational platforms constitute the building blocks of a true international global biogeochemical ocean monitoring program. Yet, there are still gaps between ship and autonomous platforms, which prevent their full integration into a true, global observing system. This gap is born out of lack of in-depth knowledge of the technology available, lack of community coordination and a disconnect between data gathering by autonomous sensors and data quality. The scientific community has recognized this major obstacle and has been working towards a better integration of time-series efforts, both ship-based and autonomous, to achieve a comprehensive and holisting understanding of our changing ocean. Here we present information on the most recent biogeochemical time-series activities, such as the International Time-Series Network (http://www.whoi.edu/website/TS-network/home; http://www.unesco.org/new/en/natural-sciences/ioc-oceans/sections-and-programmes/ocean-sciences/biogeochemical-time-series/), the International Group for Marine Ecological Time Series (IGMETS; http://www.igmets.net/), and the training course on biogeochemical sensors (http://www.ioccp.org/sensorscourse). By pooling together time-series resources, it will be possible to compile an assessment of changing biogeochemistry and ecosystem dynamics at a global scale. Strong support by the scientific community and long-term commitment by nations is required to maintain these critical ocean observation systems.

Net and gross productivity during a Lagrangian experiment in coastal California

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We have quantified biological productivity during a six-day Lagrangian experiment in Monterey Bay, CA, using in situ gas tracers. Net community productivity was quantified from continuous mixed layer measurements of the O_2/Ar ratio (using an underway mass spectrometer) and vertical profiles of O_2 concentration and O_2/Ar. Gross primary productivity was quantified from discrete measurements of the triple oxygen isotope composition of O_2. A potential disadvantage of the in situ method, particularly in upwelling regions, is that inaccurate parameterization of the physically driven fluxes of O_2 can bias productivity calculations. To improve estimates of air-sea gas exchange and to detect large mixing events, we collected continuous and discrete measurements of the five stable noble gases throughout the cruise. To quantify and account for vertical fluxes of O_2, we used profiles of diapycnal diffusivity quantified using ~6-hourly microstructure shear probe profiles. We observed large diurnal variability in net community productivity, and an increase toward the end of the cruise. Additionally, we have compared our in situ measurements of productivity with concurrent incubation-based methods measuring the uptake of $^{15}NH_4^+$ (regenerated production), $^{15}NO_3^-$ (new production), and ^{14}C-labeled inorganic carbon (net primary production).

Recent change in the Southern Ocean carbonate system based on time-series observations in the Drake Passage

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A 13-year time series from the Drake Passage suggests that the uptake of carbon in the Southern Ocean has substantially increased providing critical support for the increase in annual global ocean carbon uptake. Here, we present underway observations of the partial pressure of CO_2 in surface water (pCO_{2surf}), sea surface temperature (SST), and salinity. Air-sea CO_2 flux is calculated from the difference between pCO_{2surf} and atmospheric CO_2 (pCO_{2atm}) and estimates of the gas transfer velocity calculated using several wind products. Underway observations are combined with discrete measurements of total CO_2 (TCO_2), PO_4^{3-}, and $Si(OH)_4$ to estimate surface pH, carbonate ion concentration [CO_3^{2-}], and the saturation states of aragonite (Ω_{arag}) and calcite (Ω_{calc}). Trends in pCO_{2surf} decline from north to south within the Drake Passage with the pCO_{2surf} trend north of the Antarctic Polar Front (APF) close to the atmospheric pCO_2 (pCO_{2atm}) trend and the pCO_{2surf} trend south of the APF lower than the pCO_{2atm} trend. An analysis of the drivers of pCO_{2surf} indicates that a summer decline in SST and the lack of an increase in winter surface TCO_2 is responsible for increasing CO_2 flux into the ocean south of the APF. The lack of a trend in the winter surface TCO_2 also provides temporary stability in the carbonate system, which is close to undersaturation with respect to aragonite.

Biogeochemistry from gliders at HOT and BATS

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At the Hawaii Ocean Time-series (HOT) and Bermuda Atlantic Time-series Study (BATS), autonomous, underwater gliders equipped with biogeochemical sensors observe the oceans for months at a time, sampling spatiotemporal scales missed by the ship-based programs. Over the last decade, glider data augmented by a foundation of time-series observations have shed light on biogeochemical dynamics occuring spatially at meso- and submesoscales and temporally on scales from diel to annual.

During the 2012 HOE-DYLAN experiment near HOT Station ALOHA we discovered a small but quantifiable diel cycle in mixed layer dissolved oxygen as measured by the Seaglider. These cycles are the consequence of daytime photosynthesis and nighttime respiration. The magnitude is indicative of the rate of GPP. During the 2012 summer, mixed layer GPP averaged 1.8 mmol O_2 m^{-3} d^{-1} using the in situ diel method, matching a rate of 1.8 mmol O_2 m^{-3} d^{-1} determined from the triple oxygen isotope method in September, 2012. GPP was ~3.2 times the magnitude of NPP(^{14}C) which averaged 0.58 mmol C m^{-3} d^{-1} over the 2012 summer.

Bermuda Institute of Ocean Sciences (BIOS) glider 'Anna' was deployed through March and April, 2015 to observe the progression of the spring bloom near BATS. Initially, the bloom had a strong surface expression visible in ocean color, but progressed to a subsurface. The highest chlorophyll fluorescence was observed during the transition period, when the glide was between cyclonic and anticyclonic eddies. Remote sensing of chlorophyll (VIIRS-NPP-8D-9km) and HYCOM sea surface height (Global 1/12º analysis) illustrate the role of eddy stirring in advecting oligotrophic water from the south to the BATS site.

OceanSITES format and Ocean Observatory Output harmonisation: Past, present and future

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The Global Ocean Observing System (GOOS) initiative was launched in 1991, and was the first step in creating a global view of ocean observations. In 1999 oceanographers at the OceanObs conference envisioned a "global system of eulerian observatories" which evolved into the OceanSITES project. OceanSITES has been generously supported by individual oceanographic institutes and agencies across the globe, as well as by the WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology (under JCOMMOPS). The project is directed by the needs of research scientists, but has a strong data management com- ponent, with an international team developing content standards, metadata specifications, and NetCDF templates for many types of in situ oceanographic data.

The OceanSITES NetCDF format specification is intended as a robust data exchange and archive format specif- ically for time-series observatory data from the deep ocean. First released in February 2006, it has evolved to build on and extend internationally recognised standards such as the Climate and Forecast (CF) standard, BODC vocabularies, ISO formats and vocabularies, and in version 1.3, released in 2014, ACDD (Attribute Convention for Dataset Discovery). The success of the OceanSITES format has inspired other observational groups, such as autonomous vehicles and ships of opportunity, to also use the format and today it is fulfilling the original concept of providing a coherent set of data from eurerian observatories.

Data in the OceanSITES format are served by two Global Data Assembly Centres (GDACs), one at Coriolis, in France, at ftp://ftp.ifremer.fr/ifremer/oceansites/ and one at the US NDBC, at ftp://data.ndbc.noaa.gov/data/oceansites/. These two centres serve over 26,800 OceanSITES format data files from 93 moorings. The use of standardized and controlled features enables the files held at the OceanSITES GDACs to be electronically discoverable and ensures the widest access to the data.

The OceanSITES initiative has always been truly international, and in Europe the first project to include Ocean- SITES as part of its outputs was ANIMATE(2002-2005), where 3 moorings and 5 partners shared equipment, methods and analysis effort and produced their final outputs in OceanSITES format. Subsequent European projects, MERSEA (2004-2008) and EuroSITES (2008-2011) built on that early success and the current European project FixO3 encompasses 23 moorings and 29 partners, all of whom are committed to producing data in OceanSITES format.

The global OceanSITES partnership continues to grow; in 2014 the Australian Integrated Marine Observing Sys- tem (IMOS) started delivering data to the OceanSITES FTP, and files and India, South Korea and Japan are also active members of the OceanSITES community. As illustrated in figure 1 the OceanSITES sites cover the entire globe, and the format has now matured enough to be taken up by other user groups.

GO-SHIP, a global, ship-based hydrographic program, shares technical management with OceanSITES through JCOMMOPS, and has its roots in WOCE Hydrography. This program complements OceanSITES and directly contributes to the mooring data holdings by providing repeated CTD and bottle profiles at specific locations. GO- SHIP hydrographic data adds a source of time-series profiles and are provided in the OceanSITES file structure to facilitate full data interoperability. GO-SHIP has worked closely with the OceanSITES program, and this interaction has produced an unexpected side benefit - all data in the GO-SHIP database will be offered the robust and CF-compliant OceanSITES format beginning in 2015.

The MyOcean European ocean monitoring and forecasting project has been in existence since 2009, and has successfully used the OceanSITES format as a unifying paradigm. MyOcean daily receives hundreds of data files from across Europe, and distributes the data from drifter buoys, moorings and tide gauges in OceanSITES format. These in-situ data are essential for both model verification points and for assimilation into the models.

The use of the OceanSITES format now exceeds the hopes and expectations of the original OceanObs vision in 1999 and the stewardship of the format development, extension and documentation is in the expert care of the international OceanSITES Data Management Team.

The annual cycle of gross primary production, net community production and export efficiency across the North Pacific Ocean

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Accurate estimates of the rates and efficiency of biological carbon export from the surface to the deep ocean are essential in describing and mechanistically understanding the ocean's role in the global carbon cycle. However, observations of these parameters are generally limited to snapshot measurements in a single season or time-series measurements at a single location, limiting our understanding of how biological carbon export varies over broad spatial and temporal scales. In this study, we measured triple oxygen isotopes and oxygen/argon dissolved gas ratios as non-incubation based geochemical tracers of gross primary production (GPP) and net community production (NCP) on sixteen container ship transects across the North Pacific from 2008-2012, allowing us to estimate rates and efficiency of biological carbon export throughout full annual cycle across the entire North Pacific basin (140°E – 125°W, 32°N – 50°N). Estimates of GPP and NCP were derived by constructing mixed layer tracer budgets that account for the impact of advection, mixing and entrainment.

We find that despite higher rates of GPP, NCP and export efficiency in the western portions of the basin during spring, summer and fall, the annual NCP rate and export efficiency are greater in the east than the west (1.5 ± 0.2 mol C m^{-2} yr^{-1} east of 160°W, decreasing to 1.0 ± 0.5 mol C m^{-2} yr^{-1} between 170°E and 160°W and 0.6 ± 1.5 mol C m^{-2} yr^{-1} west of 170°E; export ratios of 0.105 ± 0.021 east of 160°W, decreasing to 0.052 ± 0.031 between 170°E and 160°W and 0.028 ± 0.068 west of 170°E). This is due to deeper winter time mixed layer depths in the west, which reduce effective carbon export by ventilating remineralized carbon exported during summer stratification (70-88% ventilated west of 160°W, as compared to only 18% east of 160°W).

Our productivity rates for the region east of 160°W are consistent with previous estimates for primary and export production at Ocean Station Papa in the eastern subarctic. However, in the more dynamic region west of 170°E influenced by the Kuroshio and Oyashio currents, we find higher GPP, lower NCP and lower export efficiency than previous estimates at Station KNOT in the western subarctic. These results highlight the need to measure productivity rates over broader spatial areas, especially in regions of high variability, and to observe throughout the full annual cycle including winter entrainment and ventilation in order to accurately estimate the rate and efficiency of carbon sequestration via the ocean's biological pump.

Spatial variations in primary production and carbon export rates across the North Pacific: Estimates from satellite algorithms, a biogeochemical model and tracer measurements from ships of opportunity

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Rates of primary production and organic carbon export from the surface ocean are key processes in ocean biogeochemical cycling but are challenging to estimate over broad spatial and temporal scales. Although biogeochemical models and satellite observations have been the primary means to resolve broad spatial variability in productivity and export, validation by in situ estimates is lacking for most ocean regions. Time series stations play a key role in this validation (i.e. Emerson 2013), but cannot assess spatial variability. We present estimates of net primary production (NPP) estimated from triple oxygen isotopes (TOI) and net community production (NCP) estimates from dissolved oxygen/argon ratios (O_2/Ar) from four summertime (May-August) ship of opportunity transects across the North Pacific in 2011-2012 which provide the means to resolve basin-wide spatial (as well as temporal) variability. We compare the spatial trends in these in situ estimates of NPP and NCP with those derived from two satellite productivity algorithms (the chlorophyll-based vertically generalized productivity model [VGPM] and the carbon-based productivity model [CbPM] which when coupled with export ratio

model of Laws et al., 2000 yield NCP estimates) and with estimates from a global biogeochemistry model [Community Earth System Model, CESM].

For NPP, the in situ TOI-based estimates showed a consistent westward increase in summer based on four cruises during May-Aug when biases in the TOI method are minimal (Nicholson et al., 2014). Satellite-based NPP estimates from VGPM most closely matched the in situ NPP and captured the basin-wide spatial pattern. In contrast, NPP estimates from CbPM CESM were lower than the in situ estimates and failed to show the significant NPP increase in the region influenced by the Kuroshio and Oyashio Currents in the western-most portion of the basin. For NCP, in contrast, CbPM estimates agreed well with in situ estimates based on O_2/Ar while VGPM and CESM often overestimated NCP. In situ estimates of the export or e-ratio (NCP/NPP) from the mixed layer based on O_2/Ar and TOI were consistently lower than e-ratio predicted by CESM and by Laws et al. (2000) with a particularly strong discrepancy in the eastern portion of the basin.

The NPP, NCP and e-ratio results presented here underscore the need for volunteer ship based time series observations to determine large scale spatial trends and validate satellite and model based estimates of global ocean productivity and export rates.

Oxygen and nitrogen sensing gas floats

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Observations of dissolved nitrogen gas (N_2) in the ocean are used as tracers of bubble mediated air-sea gas exchange [McNeil et al, 2010], to quantify net community metabolism [Emerson and Stump, 2010], and to investigate denitrification processes in oxygen deficient zones [Altabet et al, 2012]. We present a new Teflon-membrane Gas Tension Device (GTD) and methodology for measuring dissolved N_2 and apply it to two different types of profiling floats. The GTD measures the total pressure of dissolved gasses by diffusing them across a membrane and measuring the pressure on the backside. The new version utilizes a 4/1000" thick by 2" diameter Teflon-membrane, which offers significant improvements over previous versions in response time and immunity to hydrostatic pressure. Use of the sensor on deep profiling floats has highlighted the effect of hydrostatic pressure on dissolved gas solubilities. We will present laboratory data characterizing the new GTD and demonstrating the hydrostatic pressure dependence of Henry's Law. GTD's were field tested on two APL/UW GasFloats, and one APEX GasFloat, deployed in the Eastern Tropical North Pacific (ETNP) for 15 days during May 2014. The floats profiled between the surface and 400 m depth and concurrently measured O_2 (by SBE-43 or Aanderaa optode). The N_2-profiles from the GTDs are validated against independently measured N_2/Ar ratio data collected during the deployment.

Porthole: Evolving biological carbon pump research

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The 'biological carbon pump' (BCP) is estimated to sequester ~5-15 Gt C yr^{-1} and supports diverse communities that populate ~97% of the ocean's volume. The amount of C sequestered and hence atmospheric CO_2 levels are sensitive to the vertical profile of organic carbon and its remineralisation length scale (RLS). However, there is still no consensus on the variability of and controls over these BCP features after more than four decades of study. Progress toward understanding the BCP has been hampered by an inability to make sustained observations of the water column over suitable timescales, even seasonally. The maturation of long-range autonomous underwater vehicles (AUVs) and optics provide a new opportunity to make a step change in understanding of BCP functioning, i.e. a Porthole view of the BCP. Here, we illustrate capability to make never-before-feasible measurements of the evolution of seasonal change in the transfer of particulate C from surface to seafloor. We can achieve a major advancement by synoptically measuring, for the first time, the change in particle size- and type-distributions throughout the water column along with the associated plankton ecology. This can facilitate RLS hypothesis testing over a full bloom/pulse season of several months.

Climate change evaluated at marine time-series stations: The Antares Network, an effort of the Americas in long-term studies.

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Ocean observing programs are the key to understanding the impact of long-term natural events on coastal and ocean resources. The Antares Network is an effort of scientists throughout the Americas to build such a program as a component of the global ChloroGIN Network. With participants from Canada and USA, the Antares Network has observing systems on the Atlantic (Colombia, Venezuela, Brazil and Argentina) and Pacific Oceans (Chile, Ecuador, Colombia and Mexico). These stations represent specific biogeographic and biogeochemical sites, and collect, on a regular basis, in situ biogeochemical measurements of the water column. These time-series have been conducting their sampling for several years (from 2 – 20+ years). To complement the in situ measurements, satellite observations are utilized. In order to determine if these different sites show evidence of changing ocean conditions, we generated time series of remote sensing (CZCS, OCTS, SeaWiFS, MODIS-Aqua, MERIS, VIIRS and AVHRR) products and carried out match-ups between *in situ* and satellite data. Preliminary results using cluster analysis showed four groups: 1) Cartagena and Ubatuba; 2) CARIACO; 3) EGI-Argentina and EPEA-Argentina and 4) Pacific (TS?), suggesting that chlorophyll and temperature has changed differently depending on the region. A trend analysis with AVHRR data shows an increase in sea surface temperature (SST) in Cartagena, Ubatuba, and CARIACO. The rest of the stations don't show a significant change. While many sites show trends in temperature and chlorophyll, they may be part of natural cycles such as the Atlantic Multidecadal Oscillation Index (AMO). Longer in situ biogeochemical

time-series records are needed to tease out natural from anthropogenic forcing, to and improve the accuracy of prediction models, and to understand what the impact of these changing ocean conditions will be on coastal ecosystems.

High-resolution oxygen and fluorescence sections reveal submesoscale hotspots of productivity and respiration

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Mesoscale and submesoscale processes likely stimulate phytoplankton productivity and export production. These small-scale processes may be responsible for delivering to the euphotic zone a significant fraction of the nutrients required to support primary production in oligotrophic regions of the ocean. Here we present data with spatial resolution of 1 m in the vertical and < 2km in the horizontal by utilizing towed undulating instrumentation to obtain synoptic cross-sections of physical and biogeochemical properties in the upper ocean. The towed Video Plankton Recorder (VPR-II) in the tropical Atlantic collected profiles of oxygen, fluorescence, temperature and salinity in the upper 140 m of the water column. The data reveal remarkable "hotspots" with elevated fluorescence and decreased oxygen, both of which are likely the result of intense submesoscale upwelling. Many of these hotspots in the lower half of the euphotic zone have a decrease in oxygen compared to source waters estimated from contiguous temperature and salinity surfaces. Thus, these hotspots appear to more often be areas of net respiration than areas of net production — although the inferred changes in oxygen are subject to uncertainty in the determination of the source of the upwelled waters. We characterize the distribution of these hotspots and present a conceptual model outlining their possible generation and decline. Simultaneous measurements of O_2/Ar in the mixed layer from a shipboard mass spectrometer quantify rates of surface net community production. We find that the subsurface biological hotspots are often expressed as an increase in mixed layer rates of net community production, in spite of the decrease in oxygen in the subsurface hotspots themselves.

CDIAC data management and archival support for a high-frequency atmospheric and seawater pCO_2 data set from 14 open ocean moorings

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Rising atmospheric carbon dioxide (CO_2) and climate change are increasing ocean temperatures and affecting ocean chemistry (e.g., ocean acidification). Monitoring these important changes using ships and other platforms generates large amounts of data from heterogenous sources. Since its inception in 1993, when it became a member of the DOE/NOAA Ocean Carbon Science Team engaged in the World Ocean Circulation Experiment (WOCE), the CDIAC Ocean Carbon Data Management Project has been organizing, quality assuring, documenting, archiving and distributing ocean carbon-related data collected via a number of U.S. and international ocean-observing programs. CDIAC's ocean carbon data collection includes discrete and underway measurements from a variety of platforms (e.g., research ships, commercial ships, buoys) in all oceans from the surface to seafloor. One important project at CDIAC is the data management support for the Global CO_2 Time-series and Moorings Project. This poster will describe the collaboration between NOAA/PMEL Mooring group and CDIAC in the data management and archival of a high-frequency atmospheric and seawater pCO_2 data from 14 open ocean sites using moored autonomous systems. Advancements in the ocean carbon observation network over the last decade, such as the development and deployment of Moored Autonomous pCO_2 (MAPCO2) systems, have dramatically improved our ability to characterize ocean climate, sea-air gas exchange, and biogeochemical processes. The Moored Autonomous pCO_2 ($MAPCO_2$) system provides high-resolution surface seawater and atmospheric CO_2 data that can help us understand inter-annual, seasonal, and sub-seasonal dynamics and provide constrains on the impact of short-term biogeochemical variability on CO_2 fluxes. CDIAC NDP-092 provides a description of the data as well as the methods and data quality control involved in developing an open-ocean $MAPCO_2$ data set including over 100,000 individual atmospheric and seawater pCO_2 measurements on 14 surface buoys from 2004 through 2011. The climate-quality data provided by the $MAPCO_2$ have allowed for the establishment of open-ocean observatories to track surface ocean pCO_2 changes around the globe. Data are available at doi:10.3334/CDIAC/OTG.TSM_NDP092 and http://cdiac.ornl.gov/oceans/Moorings/ndp092.

Sampling once… Using data multiple times

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Marine ecosystem variability shows large fluctuations on a wide variety of scales, from seconds to millennia and from local to global. This limits our ability to observe these systems and to develop good tools to predict how changes in the environment may affect their physical and biological properties. It also limits our ability to differentiate anthropogenic from natural processes. An example is how difficult it is to compare data collected in different sampling locations and at different times. Time-series data help resolve both short- and longer-term scales of variability and provide context for traditional process-oriented studies. Time-series projects focusing on biogeochemical and ecological observations have yielded important scientific results. They have helped to: (i) evaluate the statistical significance of the ranges of variability of many parameters and environmental variables and biological communities, and (ii) quantify and evaluate the dimension of the interactions between key physical/chemical oceanographic processes and biological rates in plankton communities. As a result, time series are helping estimate warming rates and trends as well as the effects of global change on biota. They have established reference baselines to evaluate the magnitude of environmental perturbations and estimate recovery times on biodiversity and productivity of specific trophic levels. In spite of their scientific value, marine time series are difficult to maintain over time because of costs and availability of trained personnel. Only a few survive beyond a decade.

There is great potential in sharing and combining marine data sets from different time-series programs from around the world. This allows for comparisons of changes occurring in distant locations, and helps detect changes that occur at broad scales, perhaps even global scales, and to distinguish them from local imbalances or fluctuation. Sharing data can have important economic and social benefits. For instance, efficient use of existing marine data represents a significant cost saving from the 2 billion Euros spent each year now in the EU collecting and accessing to marine data. From the social point of view, the demand from different stakeholders for answers to the challenges posed by changes in the marine environment is growing rapidly. Sharing and accessing time series data would reduce the uncertainties in the management of marine resources and ecosystem services.

The UNESCO IOC advocates that: (i) an observation not made today is lost forever, (ii) existing observations are lost if not made accessible, (iii) the collective value of data sets is greater than its dispersed value, and (iv) open access to standardised time series data must be pursued as a common, coordinated international goal.

Using MLR algorithms to predict pH and Ω_{Arag} and evaluate pH sensor performance on SOCCOM biogeochemical Argo profiling floats in the Southern Ocean

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The Southern Ocean accounts for as much as 50% of the annual uptake of anthropogenic carbon dioxide from the atmosphere and, as such, the region is highly vulnerable to acidification over the coming decades. Examining the magnitude and spatial changes of pH and aragonite saturation state is critical for understanding the Southern Ocean's response to continued increases of this greenhouse gas. Here we demonstrate the ability to obtain accurate estimates of pH and aragonite saturation state (Ω_{Arag}) from the SOCCOM Argo profiling floats equipped oxygen and pH sensors in the Southern Ocean. Using the recent GO-SHIP hydrographic S4P, P15S and P16S cruise data we developed empirical algorithms to predict pH and Ω_{Arag} using different combinations of discrete observations of temperature, salinity, nitrate, dissolved O_2, and pressure. We obtained R^2 values of 0.981 (pH^N), 0.964 (pH^{Ox}), and 0.993 (Ω_{Arag}) and RMS errors of 0.010 (pH^N), 0.008 (pH^{Ox}), and 0.052 (Ω_{Arag}). We applied the algorithms to the Argo profiling float data to produce time-series of estimated pH and Ω_{Arag} in the upper water column of the Southern Ocean south of 45°S. Comparison to independent pH data collected on the floats indicated that the algorithm-based estimates are robust to within ± 0.03 for pH and that the algorithms can be used to evaluate pH sensor performance by comparing values in deep water. The results show strong seasonal trends with both pH and Ω_{Arag} reaching their maximum values in the austral summer and fall. The seasonal changes can be as high as 0.05 for pH and 0.1 for Ω_{Arag}.

Evolving Views on Physical, Ecological, and Biogeochemical Underpinnings of Plankton Blooms

Phylogenetic and photo-physiological characterization of newly isolated diatoms from the Ross Sea (Antarctica)

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The high primary productivity in the Ross Sea (Antarctica), which is dominated by diatoms and prymnesiophytes, affects many ecological and biogeochemical processes in the Southern Ocean. In this project, newly isolated diatoms from the Ross Sea were identified by molecular barcoding of both the V4 region of the 18S rDNA gene and the rDNA internal transcribed spacer (ITS) region. Sequencing of both the ITS and V4 regions yielded good differentiation for certain taxa but the lack of comparative ITS sequences in the NCBI BLAST database limited species level identification. A subset of six diatom isolates (two differentiated to the genus *Pseudo-nitzschia* and four to the genus *Fragilariopsis*) were characterized physiologically and compared to two well-studied *Phaeocystis antarctica* strains (CCMP 1374 and CCMP 1871) in terms of growth rates and photo-physiological response to five different irradiance levels (5, 25, 65, 150 and 250 μmol photons m^{-2} s^{-1}). The photo-physiological response was determined by three parameters: 1) the maximum photochemical efficiency of photosystem II (PS II; F_v/F_m), 2) the effective absorption cross-section of PS II (σ_{PSII}), and 3) the connectivity between PS II reaction centers (p). Differences between the diatoms and *Phaeocystis antarctica* in growth rate and photo-physiology were found, but within-genus differences were considerable. All cultures were affected by both low and high irradiance (5 and 150 μmol photons m^{-2} s^{-1}), yet *Fragilariopsis* isolates were generally less affected by high irradiance than *Phaeocystis antarctica* or *Pseudo-nitzchia* isolates.

Triggering of phytoplankton bloom onset in the Southern Ocean

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There are currently multiple hypotheses that exist to explain the biological-physical mechanisms that lead to the onset of the spring phytoplankton bloom. Several of theses hypotheses include Sverdrup's critical depth hypothesis, disturbance-recovery, and critical turbulence. New in situ bio-optical data from Southern Ocean Carbon and Climate Modeling (SOCCOM) floats can provide insight on the mechanisms that trigger phytoplankton blooms in the spring. By comparing changes in chlorophyll to changes in

physical drivers such as mixed-layer depth (MLD) and surface heat fluxes we can gauge whether these hypotheses are related or mutually exclusive. In addition to the temporal relationship of chlorophyll and physical drivers, we consider the shape of the chlorophyll profile and differences of surface versus column or mixed layer integrated chlorophyll to conclude on the validity of proposed hypotheses. In our approach, we also test the sensitivity of our results to the definitions of bloom onset, and mixed-layer depth. Our preliminary results show that there is a strong relationship between heat flux and phytoplankton growth during the spring bloom. There is a less significant relationship between the MLD and bloom timing but we have yet to reach a concrete conclusion.

Prototyping global earth system models at high resolution: The role of comprehensiveness touchstones across trade-offs of resolution, comprehensiveness and simulation length

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The development of next generation Earth System Models (ESM) demands fundamental configuration decisions across three axes of computational constraint: resolution, complexity and simulation length. One of the representational aspirations driving current development is to capture the global ocean mesoscale (i.e. ocean weather) in coupled carbon-climate ESMs. This resolution constraint poses extreme limitations on both complexity (i.e. the number of biogeochemical tracers) and simulation length. The present study explores a novel experimental design in which a series of touchstones across the axes of resolution (100 km to 10 km), complexity (30 tracer full biogeochemistry to 6, 3, and 1 tracer approximations), and simulation length (millennia to decades) are explored to estimate baseline biogeochemical simulation characteristics and the biogeochemical response to climate change. Along the axis of complexity, we find biogeochemical fidelity largely reproduced with a 6-tracer version of our full 30-tracer module, which is very promising for high resolution applications. However, further reduction down to 3 tracers revealed much more pronounced biases in baseline simulation characteristics. Further, we find critical differences in simulation characteristics in the 3-tracer version, across resolutions, that challenge mechanistic attribution. Although these deficiencies may reflect specific aspects of our 3-tracer model design and are the topic of further research for future improvement, they illustrate the great challenge of adequately representing the key processes with such a small number of tracers. Nonetheless, we find that sensitivity of the biogeochemistry to climate change across the complexity bear many similarities, giving us some support that the differences we see across resolutions may indicate robust differences in biogeochemical response across resolutions.

Uncertainties in the timing of the Spring Bloom from Space

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Satellite ocean colour observations have allowed us an unprecedented tool to explore the spring bloom over large spatial scale. Often timeseries of satellite derived ocean surface chlorophyll-a (chl-a) are used to determine the timing of the peak of the bloom. However in situ evaluation of the satellite derived chl-a (obtained from a reflectance ratio algorithm) remain sparse, and the uncertainties of the satellite derived chl-a are not well known. Here we present a global three-dimensional biogeochemical, ecosystem, and radiative transfer numerical model that acts as a virtual laboratory to explore some of the uncertainties. The model resolves sufficient details of the marine ecosystem, water optical constituents as well as explicit upwelling irradiance. We can, for instance, construct "real colour" images of our model ocean. Here we present "satellite-like" derived chl-a calculated from the model reflectance output (similar to that done for MODIS and SeaWiFS chl-a) and compare this to the model "actual" chl-a. The model "satellite-like" derived chl-a compares better to MODIS chl-a than the model "actual" chl-a. We find that the satellite-like product has substantial low biases at high latitudes. And we find that in many regions the peak of the spring bloom found from model "actual" chl-a and the "satellite-like" derived chl-a can be as much as a month out of phase. The peak of the bloom from either chl-a product also does not necessarily match the peak of phytoplankton carbon biomass. Thus we suggest care when defining the peak of the spring bloom from space, especially when used as an evaluation tool for model spring bloom timing.

Characterizing Southern Ocean diatom community composition to establish ecologically relevant culture representatives for iron physiology experiments

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Southern Ocean (SO) diatoms are predicted to be growth limited for iron, an essential protein cofactor. We are particularly interested in delineating the iron stress response in SO diatoms as they are the base of the SO food web. To develop ecologically relevant laboratory models, we established a culture collection of >300 isolates from two austral summer and winter cruises conducted in 2013-2014. To identify SO species with broad iron tolerance, we characterized *in situ* diatom community composition across regions of varying iron levels. This was accomplished via high-throughput sequencing of the

variable V4 region of the 18S rDNA amplified with diatom-targeted primers. *Fragilariopsis sp.* and *Pseudo-nitzschia sp.* dominated most of the sampled areas. We are currently determining the phylogenetic resolution we achieve with the V4 region by comparing isolate and community amplicon data. As our culture collection contains representatives of the major taxa identified with molecular barcoding, we will be able to conduct iron physiology experiments with relevant culture representatives. This will allow us to probe the physiological status of diatoms important in different regions of the SO, and to determine if iron limitation is experienced more or less severely in different diatoms.

Mapping the Polar Front and implications for Southern Ocean biogeochemistry

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The Antarctic Polar Front (PF) is an important biogeochemical divide in the Southern Ocean, marking the boundary between silicate-rich and silicate-poor waters and therefore distinct phytoplankton communities of diatoms (silicifiers) and coccolithophores (calcifiers). Despite low chlorophyll-*a* concentrations throughout most of the Southern Ocean, elevated levels have been found to characterize the PF, particularly where the flow interacts with bathymetric features. While excursions of the front from its mean position are likely to be small in regions where bottom topography shapes its path, a few studies have linked variability and trends in frontal locations to large-scale modes of climate variability and changes in the wind field. Indeed, the Southern Ocean has warmed and freshened and the westerlies have strengthened and shifted poleward. Determining frontal location, structure, and variability is therefore crucial: since the PF is associated with large-scale gradients in temperature, nutrients, and distinct biological communities, changes in the location of the PF could cause changes in biological productivity and biogeography. Most PF studies have identified historical mean positions using hydrographic or infrared satellite sea surface temperature (SST) data, with methods suffering from sparse sampling or cloud contamination, respectively. Here, we map the circumpolar path of the PF on a daily and weekly basis using SST observations (2002-2014) from cloud-penetrating microwave radiometers. As we ultimately aim to better describe PF and biogeochemical co-variability in space and time, these maps will be used to quantify spatio-temporal variability in the PF throughout the Southern Ocean on intra-annual to inter-annual time scales.

O_2/Ar and $^{17}\Delta$-based net and gross biological production reveal an annual cycle in export efficiency in a coastal upwelling region

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A common observation in studies of biological production and carbon export in the oceans has been that ecosystems with higher nutrient input (i.e. upwelling zones, high latitudes, etc.) typically have higher export efficiency (export/gross production) than ecosystems that are nutrient limited. However, there have been few time-series studies in high-efficiency regimes to investigate how biological pump efficiency changes through time. O_2/Ar ratios and the triple oxygen isotope composition (TOI; ^{17}D) of dissolved O_2 have been used in many regions to simultaneously estimate net (NOP) and gross oxygen production (GOP) in the surface ocean. Both NOP and GOP can be stoichiometrically related to carbon production and therefore, the NOP/GOP ratio reflects the efficiency of an ecosystem to export, rather than recycle, organic carbon. This approach has been a significant advancement in marine geochemistry, however it has been limited in coastal upwelling regions because vertical transport is often difficult to determine. In this study, profiles of O_2/Ar and TOI were combined with concurrent estimates of upwelling velocity and eddy diffusivity, based on water column budgets of ^{7}Be ($t_{1/2}$=53d) and ^{234}Th ($t_{1/2}$=24d), and wind-speed estimates at the San Pedro Ocean Time-series (SPOT) in the Southern California Bight. This approach is able to resolve the dynamics of upwelling and eddy diffusivity over the same timescale as the dissolved oxygen approach and biological bloom development (~ 2 weeks). Mass balances for oxygen and its isotopes were based in a 1-D, non-steady state, two-box model of the euphotic zone. Observations of both at ~ two week intervals over two annual upwelling cycles were used to constrain non-steady state model parameters.

During 18 months between January 2013 and June 2014, upwelling velocities ranged from 0.0 ± 0.5 to 2.8 ± 1.4 m d^{-1} at SPOT, which typically agreed within uncertainty with the Bakun Index, a pressure-field based approach. GOP rates ranged from 134 ± 62 to 665 ± 164 mmol m^{-2} d^{-1} and NOP ranged 13 ± 23 to 210 ± 63 mmol m^{-2} d^{-1}, which translates to Net Community Production (NCP) in the euphotic zone of up to 150 mmol m^{-2} d^{-1}. Using estimates of particulate export from sediment traps and a ^{234}Th budget, and estimates of DOC:POC remineralization below the euphotic zone, we constructed an organic carbon budget in the upper 200m. Euphotic zone NOP/GOP ratios ranged from 0.06 ± 0.10 to 0.63 ± 0.27 and peaked just following the initiation of upwelling, but prior to the maximum in upwelling velocity and GOP. Results of this study show: 1.) it is possible to apply the dissolved O_2/Ar and TOI tracer pair to estimate production rates along the ocean margins, 2.) export efficiency in this ecosystem follows a repeated annual pattern (highest in early spring, lowest in fall), likely influenced by the timing of upwelling initiation and the composition/structure of the biological community during the transition from winter into the spring upwelling season, 3.) there is a vertical gradient in export efficiency, typically higher beneath the mixed layer than within, and 4.) export efficiency slowly increased from its annual low in October to January, similar to a previously documented pattern in the North Atlantic, suggesting that the initiation of spring blooms in temperate coastal upwelling regions may be fundamentally similar to those in high latitudes.

A more productive, but different, ocean after mitigation

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Reversibility studies suggest a lagged recovery of global mean sea surface temperatures after mitigation, raising the question of the marine net primary production (NPP) response. Here we assess NPP reversibility with a mitigation scenario in which projected Representative Concentration Pathway (RCP8.5) forcings are applied out to 2100, and then reversed over the course of the following century in a fully coupled carbon-climate earth system model. In contrast to the temperature lag, we find a rapid increase in global mean NPP, including an overshoot to values above contemporary means. The NPP overshoot arises from a transient imbalance between the cooling surface ocean and residual warmth in subsurface waters, which weakens upper ocean density gradients, resulting in deeper mixing and enhanced surface nitrate. We also find a marine ecosystem regime shift as persistent silicate depletion results in increased prevalence of large, non-diatom phytoplankton.

Drivers of future changes in export production in marine ecosystem models

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Marine particle export production (EP) has profound effects on oceanic carbon uptake. While much work has been spend on the drivers of net primary production (NPP) to explain projected changes in EP by marine ecosystem models, the drivers of changes in particle formation and particle sinking have received less attention. Here, we compare future projections generated by four different marine ecosystem models under IPCC's high emission scenario RCP8.5 with respect to changes in EP over the 21st century. Models suggest decreases in EP between -1% and -12%, however the drivers for the changes are substantially different. Net primary production decreases in all but one model. Remineralization rates increase in the low and intermediate latitudes in three models, driven by either warming-induced increases in remineralization or slower particle sinking, and show insignificant changes in the remaining model. Among the analysed models, the response of particle formation to climate change is the most uncertain process with models not agreeing on magnitude and direction of change. This lack of agreement results from large differences in the relative importance of phytodetritus, faecal pellet production and zooplankton mortality losses for particle formation.

Submesoscale frontal heterogeneity enhances phytoplankton chlorophyll in the North Pacific Subtropical Gyre

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Subtropical gyres contribute significantly to global ocean productivity due to their large extent. As the climate warms, the strength of these gyres as a biological carbon pump is predicted to diminish due to increased stratification and depleted surface nutrients. We present new results suggesting that the impact of submesoscale physics on phytoplankton dynamics may offset the warming-induced weakening of the carbon pump. A new statistical tool was developed to quantify spatial heterogeneities from 1-km resolution satellite observations of Sea Surface Temperature. We demonstrate that chlorophyll concentrations in the North Pacific Subtropical Gyre are enhanced by submesoscale frontal heterogeneity, with an average increase of 32% (max. 73%) during the early spring. The magnitude of this enhancement is comparable to observed decline due to warming. These results highlight the need for an understanding of variability in short-term, fine-scale physics in order to predict the response of marine ecosystems to projected climate changes.

Potential impact of climate change on the Intra-Americas Sea: A dynamic downscaling of the CMIP5 model projections

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This study examines the potential impact of anthropogenic greenhouse warming on the Intra-Americas Sea (IAS, Caribbean Sea and Gulf of Mexico) by downscaling the Coupled Model Intercomparison Project phase-5 (CMIP5) model simulations under historical and two future emission scenarios using an eddy-resolving resolution regional ocean model. The simulated volume transport by the western boundary current system in the IAS, including the Caribbean Current, Yucatan Current and Loop Current (LC), is reduced by 20-25% during the 21st century, consistent with a similar rate of reduction in the Atlantic Meridional Overturning Circulation (AMOC). The effect of the LC in the present climate is to warm the Gulf of Mexico (GoM). Therefore, the reduced LC and the associated weakening of the warm transient LC eddies have a cooling impact in the GoM, particularly during boreal spring in the northern deep basin, in agreement with an earlier dynamic downscaling study. In contrast to the reduced warming in the northern deep GoM, the downscaled model predicts an intense warming in the shallow ($\leq$ 200 m)

northeastern gulf shelf especially during boreal summer since there is no effective mechanism to dissipate the increased surface heating. Potential implications of the regionally distinctive warming trend pattern in the GoM on the marine ecosystems and hurricane intensifications during landfall are discussed. This study also explores the effects of 20th century warming and climate variability in the IAS using the regional ocean model forced with observed surface flux fields. The main modes of sea surface temperature variability in the IAS are linked to the Atlantic Multidecadal Oscillation and a meridional dipole pattern between the GoM and Caribbean Sea. It is also shown that variability of the IAS western boundary current system in the 20th century is largely driven by wind stress curl in the Sverdrup interior and the AMOC.

Temperature dependence of ocean heterotrophic prokaryotic production

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Marine bacteria and archaea, collectively termed prokaryotes, play a key role in the ecosystem by controlling the cycling of organic matter and nutrients in the ocean. Using a unique dataset (>13,500 samples), we assess for the first time the temperature dependence of prokaryotic heterotrophic production (PHP) in epi- (0–200 m), meso- (201–1,000m) and bathypelagic waters (1,001–4,000 m) of the global ocean. Here, we show that the temperature dependence of PHP is fundamentally different between these major oceanic depth layers, with an estimated ecosystem-level activation energy (E_a) of 36 ± 7 kJ mol^{-1} for the epipelagic, 53 ± 11 kJ mol^{-1} for the mesopelagic and 202 ± 48 kJ mol^{-1} for the bathypelagic realm. We suggest that the increasing temperature dependence with depth is related to the parallel vertical gradient in refractory compounds. These numbers predict an increased PHP of about 5, 8 and 39% in the epi-, meso- and bathypelagic ocean, respectively, in response to a water temperature increase by 1ºC. Hence, there is indication that a major, thus far underestimated feedback mechanism exists between future bathypelagic ocean warming and heterotrophic prokaryotic activity.

Optimality-based model analysis of nitrogen and phosphorus cycling in mesocosm experiments of the Peruvian Upwelling Region

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We analyse two short-term shipboard mesocosm experiments inoculated with *in situ* plankton communities of the Peruvian coastal upwelling and amended with different amounts of inorganic nitrogen (N) and phosphorus (P). The zooplankton assemblage of the northern experiment (PU1) was dominated by dinoflagellates and that of the southern experiment (PU2) by ciliates. Zooplankton biomass declined in PU1 in spite of ample food but increased in PU2 throughout the experiments. In both experiments, dissolved organic P (DOP) accumulated in low-N:P amended mesocosms, whereas dissolved organic N (DON) rose rapidly within the first days everywhere.

We employ an optimality-based plankton ecosystem model (OPEM) to analyse the differential behaviour of the mesocosms, which cannot be explained by the available observations alone. The OPEM simulates variable stoichiometry in plankton and dissolved organic matter dynamics, and is used to derive and address several hypotheses which might explain the observations: (1) DOP accumulation in low-N:P amendments may be due to preferential DIP utilisation by bacteria. (2) The apparently paradoxical initial DON accumulation may hint to a significant N pool, which was not detected by the measurements. (3) Active prey switching by the zooplankton compartments and prey toxicity might explain the differences in phytoplankton and zooplankton population development among the mesocosms.

Fine scale phytoplankton diversity of Galveston Bay: Imaging FlowCytobot grants insight into microbial community dynamics.

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Galveston Bay, the largest watershed in Texas, is impacted by anthropogenic nutrient inputs from two growing major cities: Houston and Dallas-Fort Worth. Expansion of the Panama Canal in 2016 will lead to an increase in shipping into Galveston Bay, which in turn will lead to an increase in discharge of ballast water into the bay. These two inputs combined are likely to lead to an increase in invasive phytoplankton species and nutrient inputs and ultimately an increase in the frequency of algal blooms, some of which may be harmful. Because of this, it is important to understand the current phytoplankton diversity in order to know which harmful algal species are present, when they are abundant, and when they are most likely to produce blooms. Ultimately this information will provide early detection, avoid human illness from shellfish poisoning and possibly lead to regulation of nutrient inputs. Historically, diatoms have been found to be the most abundant phytoplankton in the winter and spring, when nutrient inputs into Galveston Bay are higher due to increased freshwater inflows. Small flagellates and cyanobacteria have been found to be the most abundant phytoplankton during times of warmer weather and low nutrient inputs due to low freshwater inflows into Galveston Bay. Daily samples are being taken from Galveston Bay near the entrance to the Gulf of Mexico. These samples will be examined with an Imaging FlowCytobot to document community composition shifts down to lowest practical identification level. Diversity will be assessed with traditional indices including the Shannon-Weiner and Simpson's diversity indices. Compared to previous studies, this approach will allow us to characterize much finer scale community composition changes concurrently with those in temperature and salinity. This information will also provide a library of phytoplankton types in Galveston Bay and, with concurrent water quality data, will be used to develop predictive tools or determine under which scenarios if any, harmful algal blooms are more likely to occur.

Strong sensitivity of seasonal phasing of Southern Ocean carbon fluxes and upper ocean biogeochemistry to wind stirring

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Here we test the hypothesis that winds have an important role in determining the rate of exchange of CO_2 between the atmosphere and ocean through wind stirring over the Southern Ocean. The scientific interest is in the impact of winds through shear-induced turbulence, as opposed to geostrophic turbulence. This is tested with a sensitivity study using an ad hoc parameterization of wind stirring in an ocean carbon cycle model, where the objective is to identify the way in which perturbations to the vertical density structure of the planetary boundary layer in the ocean impacts the carbon cycle and ocean biogeochemistry.

Wind stirring leads to reduced uptake of CO_2 by the Southern Ocean over the period 2000-2006, with a relative reduction with wind stirring on the order of $PgCyr^{-1}$ over the region south of 45°S. This impacts not only the mean carbon uptake, but also the phasing of the seasonal cycle of carbon and other ocean biogeochemical tracers.

Importantly, enhanced wind stirring delays the seasonal onset of stratification, and this has large impacts on both entrainment and the biological pump. It is also found that there is a strong reduction on the order of 25-30% in the concentrations of NO_3 exported in Subantarctic Mode Water (SAMW) to wind stirring. This finds expression not only locally over the Southern Ocean, but also over larger scales through the impact on nutrient transports. In summery, the large sensitivity identified with the ad hoc wind stirring parameterization offers support for the importance of wind stirring for global ocean biogeochemistry through its impact over the Southern Ocean.

Ramped oxidation of particulate organic carbon from the Southern Ocean Great Calcite Belt

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The long-term storage of particulate organic carbon (POC) exported from the surface ocean is limited by remineralization in the mesopelagic zone. Remineralization is evident in shifts in organic matter composition concurrent with attenuation of POC flux inside this depth interval. Here, we present the first comparisons of euphotic and mesopelagic zone POC composition using ramped oxidation. Samples come from the Great Calcite Belt region, which includes variable primary productivity and phytoplankton community assemblages. ^{234}Th-derived POC and biomineral fluxes in this region suggest that different phytoplankton assemblages are associated with distinct POC transfer regimes through the water column. The data show that diatom-rich communities export more labile POC that degrades vigorously in the mesopelagic zone, while the opposite occurs in coccolithophore-rich communities. To extend this hypothesis, we oxidized POC from a diatom-rich and coccolithophore-rich site of the Great Calcite Belt region at 5°C/minute from 100°C- 700°C. Resulting thermograms highlighted differences in the thermal stability of POC between the stations as well as among depths. We explore the implications of interpreting thermal stability as a proxy for biochemical stability in the context of the stated hypothesis and discuss its methodological caveats.

Seaglider observations of phytoplankton spring bloom development in the North Atlantic Ocean.

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Intense vernal phytoplankton blooms contribute to making the subpolar North Atlantic Ocean a highly significant region for sequestration of atmospheric CO_2. Calling into question Sverdrup's classic theory, recent studies showed spring blooms can form in winter-early spring when the mixed layer is deep. Here, we studied phytoplankton spring

bloom development using a dataset collected in the Northeast Atlantic Ocean (49 °N, 17 °W) by two autonomous underwater Seagliders. Flying around the sampling area (20x20 km^2) the Seagliders obtained vertical profiles of bio-optical and physical properties, multiple times per day over one year (September 2012 – September 2013).

Seaglider data showed phytoplankton concentrations started increasing in the beginning of February, two months before the permanent restratification of the ocean mixed layer. Gradual accumulation of phytoplankton stocks occurred under diverse wind/heat flux conditions and was in general explained by increasing surface light intensity. Several specific processes that supported short-term blooms in winter were also identified in the dataset. Enhanced growth was observed due to slumping of strong lateral buoyancy gradients and trapping of phytoplankton near the surface during low positive heat flux and weak wind forcing. When full restratification occurred in April, subsequent intensification of the bloom was low. Further, a simple 1-D model was used to investigate the potential role of grazers in bloom initiation. Our results suggest that, in the absence of nutrient limitation, prolonged pre-restratification growth of phytoplankton can enhance grazing pressure, thus reducing the magnitude of subsequent blooms.

Phytoplankton blooms in Mexico: An initiative using marine optics as a basis for monitoring programs

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Ocean color and optical remote sensing techniques have become a useful tool to study coastal problems such as harmful algal blooms (HABs) and water pollution. Utilizing the changes in ocean color induced by phytoplankton blooms, we proposed here a technique using in situ optical data to determine if there is a phytoplankton bloom, characterize the bloom stage, and the phytoplankton composition of the bloom. Data were collected during two sampling campaigns: one from August 27th to 30th, 2011 in Dzilam de Bravo (Yucatan) and Holbox Island (Quintana Roo), Mexico, and the second campaign from September 22nd to 24th, 2011 in the Bank of Campeche, Campeche, Mexico. Optical in situ data were analyzed for a total of 30 stations. For each station, discrete samples were collected for phytoplankton identification and enumeration and determination of chlorophyll-a concentration and absorption coefficients (particulate material (a_p), phytoplankton (a_{ph}), detritus (a_d), and colored dissolved organic matter (a_g)). Most of the samples were collected near the surface. Principal component analysis (PCA) with a numerical solution was used to explore the associations among stations using the absorption coefficients, chlorophyll-a and total phytoplankton abundance. To comprehensively summarize all the information produced by each of the variables, a multi-dimensional index was derived based on the first standardized empirical orthogonal function. We refer to the index as the inherent optical properties (IOP) index. A positive IOP index indicated bloom conditions were present, while a negative index indicated non-bloom conditions. Once the samples were classified by bloom condition, we attempted to determine the phytoplankton group that constituted the bloom. The spectral shape of a_{ph} was calculated and a spectral shape index was derived using a_{ph} in the green and the blue part of the spectrum. Finally, a blue/red ratio was calculated to determine the dominant phytoplankton population. The IOP index was successful in classifying stations as having bloom or non-bloom conditions. The spectral shape analysis gave promising results regarding the group composition. Additional analyses, with different phytoplankton groups and taxa, are required to further test this ratio. A final classification scheme using the IOP index and the blue/red ratio is proposed to determine the bloom condition (operational, non-operational bloom and non-bloom) and dominant size of the phytoplankton responsible for the bloom. This technique can provide insightful information about the bloom that cannot be obtained using traditional counting methods. These results highlight the importance of optical data as a resource when monitoring phytoplankton blooms.

Nutrient co-limitation of phytoplankton in the central North Pacific Subtropical Gyre

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Nitrogen is considered the primary nutrient limiting phytoplankton growth and production throughout the North Pacific Subtropical Gyre (NPSG). In August-September of 2014, we conducted nutrient enrichment experiments at several sites along a transect from San Diego (CA) to Hawaii and observed nitrogen-phosphorus co-limitation of phytoplankton in the central NPSG, to the northeast of the Hawaii Islands. Two full-factorial experiments were conducted with the addition of a combined nitrogen (N) source (nitrate, ammonium and urea at the final concentration of 2.5 μM), phosphate (P) (0.20 μM), ferric iron (2.0 nM) and all combinations of the three nutrients. While addition of N in one experiment resulted in increased chlorophyll a concentrations and rates of carbon fixation, the addition of N+P yielded an even higher increase. In the second experiment, amendments with N had no effect on the phytoplankton community,

and addition of N+P had an increase in chlorophyll a and rates of primary production after 48h of incubation. High inorganic phosphate uptake rates were also observed at the station where the second experiment was done indicating unusually low P availability for this region. Diazotrophic blooms are common in this area in summer, and it is possible that P was depleted as a result of such blooms. Future work will investigate if the observed limitation of phytoplankton growth and productivity by P availability in the NPSG was related to diazotroph productivity or was the result of favorable El Niño conditions and a possible shift in phytoplankton community.

Seasonal anomalies as proxies for phytoplankton community response to climate trends on a temperate continental shelf

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Phytoplankton community structure and dynamics have profound effects on the entire ecosystem, but insufficiently sustained and detailed observations have limited our ability to quantify their vulnerability and responses to on-going changes in coastal oceans. A multi-year time series at the Martha's Vineyard Coastal Observatory (MVCO) is beginning to hint at trends and possible mechanisms of phytoplankton community response in New England Shelf waters. We are exploring whether these suggestive trends are robust and relevant for understanding responses to climate change. We use a combination of detailed in situ sampling including automated flow cytometry for phytoplankton characterization and regional remote sensing products. Our approach capitalizes on the "natural experiments" that occur in response to event-scale dynamics, large amplitude seasonal cycles, and interannual perturbations associated with forcing at the regional scale and larger (e.g., anomalous winters). Initial findings show that important aspects of phytoplankton community structure and its temporal dynamics exhibit patterns of variability associated with changes in water temperature at seasonal, interannual, and multiyear scales. Important examples include picocyanobacteria, which are more abundant during warmer winters and have been systematically increasing in abundance and biomass over the last decade, and a dominant species of diatom, which typically has larger amplitude blooms in colder years. In the former case, temperature dependence appears linked to a direct physiological impact on division rate, while in the latter case, temperature-dependent mortality from a lethal parasite is implicated. General patterns of seasonality can be retrieved from optical proxies and satellite products, but important details about interannual and multiyear trends remain challenging to detect.

Exploring drivers of picoeukaryote diversity and spatial distribution patterns in the North Atlantic

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Picoeukaryotes are important primary producers in the western North Atlantic, including the oligotrophic subtropics where cyanobacteria may be numerically more abundant, but picoeukaryotes dominate in biomass. In the northern region high nutrient concentrations, including phosphorus (P), support picoeukaryote growth. In the oligotrophic subtropical North Atlantic, primary production is limited by P availability. Here, picoeukaryote blooms are associated with deep mixing events when dissolved organic phosphorus (DOP) concentrations are at a maximum. Using molecular analyses, we investigated the diversity and distribution patterns of picoeukaryotes in samples collected from the North Atlantic across a natural P gradient. As has been previously shown, the prasinophytes *Micromonas*, *Bathycoccus*, and *Ostreococcus* were found to be common picoeukaryotes to this region, however their relative abundance was not evenly distributed as *Ostreococcus* dominated in the P-deficient subtropical waters. The cellular response to changes in P availability and how it differs among these picoeukaryotes is poorly understood. In an effort to elucidate the metabolic mechanisms that may be driving these distribution patterns, we are investigating the physiological and molecular responses of *Micromonas*, *Bathycoccus*, and *Ostreococcus* when grown under P-replete and P-deficient conditions. DOP is an important nutrient source for phytoplankton in oligotrophic oceans, thus we also characterize the cellular response in cells grown with ATP. To date, the response in *Micromonas* has been investigated. *Micromonas* exhibited an extensive response to P deficiency that included increasing alkaline phosphatase activity and reducing cellular P. Genes that function in sulfolipid substitution and P uptake increased in expression, suggesting cells were reallocating cellular P and increasing P acquisition. The response in cells grown with ATP elicted a similar, but muted response when compared to the P-deficient treatment. This work improves our understanding of picoeukaryote distribution patterns and the metabolic mechanisms that may be driving them.

Interactive effects of iron and temperature on Antarctic diatoms and *Phaeocystis antarctica*

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We examined the effects of iron availability and temperature increases on several dominant phytoplankton groups isolated from the Ross Sea, Antarctica. Three diatoms, *Pseudo-nitzschia subcurvata*, *Chaetoceros* sp., *Fragilariopsis cylindrus*, and the prymnesiophyte, *Phaeocystis antarctica* were growing individually in four treatments, 0°C iron-limited (+1 nM Fe), 0°C iron-replete (+500 nM Fe), 4°C iron-limited, and 4°C iron-replete. *Pseudo-nitzschia subcurvata* was tested at both high (HN) and low nutrient levels (LN). Fe additions significantly increased the growth rates of all the phytoplankton tested at both 0°C and 4°C. While the effect of temperature varied, temperature increase significantly stimulated the growth rates of both Fe-limited and Fe-replete cultures of *P. subcurvata* HN and *F. cylindrus*, but only Fe-replete cultures of *P. subcurvata* LN and *Chaetoceros* sp. The growth rates of the prymnesiophyte *P. antarctica* were not significantly affected by the 4°C temperature increase. In addition, temperature increase and Fe addition synergistically promoted the growth rates of *P. subcurvata* LN and *P. subcurvata* HN. The diversified responses of these phytoplankton to Fe addition and temperature increase may help to explain the current spatial and temporal distributions of diatoms and prymnesiophytes in the Southern Ocean. *P. subcurvata* may benefit from the synergistic effects of temperature increase and Fe addition relative to *P. antarctica,* thus any potential future warming and altered iron supplies may act together to shift the composition of the phytoplankton community in the Ross Sea.

General Interest

Planktonic food webs within two Sargasso Sea eddies

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Mesoscale eddies are common features in the Sargasso Sea that disrupt the vertical structure of the water column and isolate water masses. In our study we utilized these phenomena as natural laboratories to investigate trophic interactions within planktonic communities. In spring and summer 2011 we sampled eddies of differing rotation: an anticyclone (downwelling) and cyclone (upwelling), respectively. We quantified rates of size-fractionated net primary productivity (NPP), size-fractionated zooplankton grazing, bacterial productivity, and particulate carbon export. Integrated rates of NPP were lower in the spring anticyclone (93.9 mg C m^{-2} d^{-1}) compared with the summer cyclone (146.1 ± 5.5 mg C m^{-2} d^{-1}); however, trap-collected particle export was greater in the anticyclone (by 30.1 mg C m^{-2} d^{-1}). Trophic interactions modify carbon export from the euphotic zone; therefore we incorporated our carbon rates into inverse food web models. Reconstructions gave a more complete snapshot of the planktonic food web, including flows we did not measure at sea. The models indicated that microzooplankton grazing of dead particulate matter (detritus) was primarily responsible for a difference in total carbon export between the two eddies. In the cyclone, microzooplankton fed predominantly on detritus; while in the anticyclone their diets consisted of nearly equal parts detritus and direct grazing on small phytoplankton (< 2 mm). We also observed increased contributions to DOC in the cyclone (from sloppy feeding and large phytoplankton exudation) that was then consumed by bacteria. These factors resulted in a reduced particulate carbon pool available for export in the summer cyclone. These data demonstrate the important role trophic interactions play in regulating the flow of carbon within and outside of the euphotic zone in the Sargasso Sea.

Satellite monitoring of Boston Harbor Water Quality: Past and future

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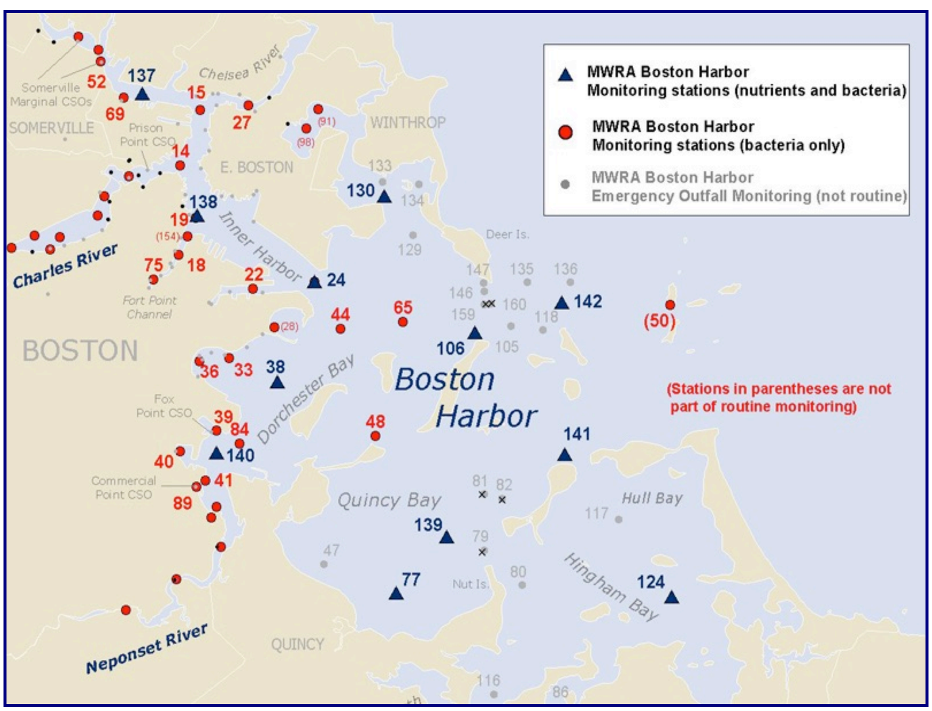
The transformation of Boston Harbor from the "dirtiest harbor in the country" to a National Park Area can be considered the most extensive and expensive estuarine recovery in the world. The Landsat program provides long-term periodic, spatially explicit capabilities to monitor water quality. Designed to monitor changes in land resources, Landsat data has not been utilized to its maximum extent in aquatic science due to a lack of in-water measurements coordinated with satellite observations, a relatively low radiometric sensitivity, and a lack of understanding of the dynamic coastal environment. An extensive water quality dataset exists in Boston Harbor due to a lawsuit requiring the monitoring and harbor clean-up in 1991. Perhaps the best case study for establishing satellite remote sensing for routine water quality monitoring exists in Boston Harbor. This project aims to use ground-truthed sampling coordinated with Landsat 8 overpass and ambient monitoring from buoys to create surface maps of chlorophyll, dissolved organic matter, and total suspended solids in Boston Harbor. By integrating remote sensing water quality monitoring in the future, we will enhance our ability to manage our valuable coastal resources in a more sustainable and resilient manner.



Evaluation of errors in satellite estimates of primary production and export production in the Southern Ocean

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Many algorithms have been developed to estimate ocean primary production and export production from remotely sensed satellite data. The results of these algorithms are routinely used to evaluate climate trends and to calibrate global and regional earth system models. However, when the estimates of these satellite algorithms are compared to in situ measurements, the satellite estimates explain only a small portion of the total variance and the errors are large. We evaluate the magnitude of errors in satellite estimates of primary production and export production of the Southern Ocean caused by different factors and make recommendations for building optimized algorithms.

Preferential utilization of marine DOP and its role in shaping global patterns of productivity, nitrogen fixation, and closing gyre phosphorus budgets

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Phosphorus (P) is necessary for sustenance of marine ecosystems, however concentrations of the major nutrient form, phosphate, are often exceedingly low (nM range) in low latitude surface waters. Concentrations of dissolved organic phosphorus (DOP) are often 1-2 orders of magnitude larger than phosphate and may provide an alternative P source to plankton in these systems. We investigate this question by compiling the first global ocean dataset of high-quality DOP measurements. Evaluation of DOP remineralization stoichiometry reveals its preferential utilization in the upper ocean and thermocline relative to DOC and DON, suggesting an enhanced role for DOP recycling in providing the necessary ecosystem P. Working with the Biogeochemical Ecosystem Cycling (BEC) ocean biogeochemistry model, we find that both faster recycling of DOP (relative to C and N) and direct uptake of DOP by marine phytoplankton are required for the model to capture the observed open ocean distribution of DOP and marine DOM stoichiometry. Inclusion of these phosphorus cycle dynamics in the BEC model increases global ocean primary productivity and carbon export, largely via an increase in the rate of nitrogen fixation by diazotrophs in the low latitudes, when compared with an ocean operating with Redfield nutrient stoichiometry. We next investigate the transport pathways of DOP to the subtropical gyres where the role of DOP as an alternative P source is largest. We find that 20-55% of ecosystem P in the five ocean gyres is delivered via the lateral advective transport of DOP from the gyre margins.

Together with the advection of phosphate, lateral transport of DOP and phosphate close the P budgets for the five subtropical ocean gyre ecosystems.

ARCTIC-COLORS - COastal Land Ocean inteRactions in the Arctic

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Arctic-COLORS is a Field Campaign Scoping Study funded by NASA's Ocean Biology and Biogeochemistry Program that aims to improve understanding and prediction of land-ocean interactions in a rapidly changing Arctic coastal zone, and assess vulnerability, response, feedbacks and resilience of coastal ecosystems, communities and natural resources to current and future pressures. Our project goal is to develop a report for NASA that describes and justifies the design of an integrative, interdisciplinary oceanographic field campaign program that addresses high priority science questions related to land-ocean interactions in the Arctic, and assess the impacts of natural and anthropogenic changes on coastal ocean biology, biogeochemistry and biodiversity. This field campaign will be composed of multiple research cruises with sufficient seasonal and spatial coverage to resolve the science questions proposed by the Arctic-COLORS team as well as remote sensing and development of coupled physical-biogeochemical models. A predictive understanding of the relative impacts of terrigenous, hydrological, atmospheric and oceanic fluxes on Arctic coastal ecology and biogeochemistry is critically needed. Arctic-COLORS will address these challenges by (i) using spatial-temporal products derived from NASA's remotely-sensed data to extend field observations to larger spatial and longer temporal scales, and (ii) by integrating satellite and field observations with coupled physical-biogeochemical models. The science in our field campaign will be focused on five overarching questions:

1. How do coastal Arctic biogeochemical transformation zones impact terrestrial, riverine, atmospheric, and coastal materials across the continuum of Arctic rivers, estuaries and the continental shelf?

2. How do Arctic riverine, atmospheric, and other fluxes of constituents effect changes in coastal ecology?

3. How does thawing of Arctic permafrost—either directly through coastal erosion or indirectly through changing freshwater loads—translate to quantitative changes in coastal ecology and biogeochemistry?

4. How do changing snow and ice conditions and coastal circulation effect changes in estuarine and coastal ecology and biogeochemistry?

5. How do changing environmental (short-term) and climate (long-term) conditions alter the region's availability and use of ecosystem services?

Synergistic impacts of population growth, urbanization, and climate change on watersheds and coastal ecology of the northeastern United States

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The overall goal of this project is to quantify the impacts of human population growth and associated land-use changes on the biogeochemistry and ecology of the Chesapeake and Delaware estuaries and the adjacent continental shelf waters. Our focus will be on these particular estuaries, as they are the most vulnerable in the U.S. because of the high population density in their watersheds and the high degree of climate change they are experiencing, including increases in temperature, sea level, precipitation, and precipitation intensity. To achieve this goal we will refine and link a suite of models including a terrestrial ecosystem model for the watersheds, a coupled biogeochemical-oxygen-circulation model with estuarine grids nested in a shelf model, and shellfish models for both Eastern oysters (*Crassostrea virginica*) and Atlantic surfclams (*Spisula solidissima*). We have already calibrated and evaluated these models individually with remote sensing products and historical in situ data. Here we will improve and more fully evaluate the linked modeling system through the analysis of satellite remote sensing products, including phytoplankton functional types, optical properties, and organic carbon cycling. Simulations will extend from the 1950s to the present, allowing us to identify how impacts of land-use changes and climate changes on coastal ecological processes have varied over the past 60 years. The integrated modeling system will be used to generate a core "all processes" simulation, as well as simulations representing: (1) climate only, including historical climate variability/change while keeping other variables unchanged since the 1950s; (2) land cover change and management practices only, including effects of land conversions while detrending the climate forcing and fixing other input data at 1950s values; and (3) nitrogen input only, including the changing nitrogen fertilization in cropland and nitrogen deposition impacts, while assuming that climate and land-use patterns are held constant at 1950s values. The analysis of these four simulations will allow us to satisfy our overall objective, as well as specific objectives concerning the impacts of human activity in the watershed on the riverine delivery to the coast, phytoplankton speciation, hypoxia, and shellfish.

Infrared imaging: A tool to study the impact of breaking waves on the marine environment

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Whitecaps formed by breaking waves are dynamic ocean features which evolve quickly and have markedly different properties at different lifetime stages. Active whitecaps W_A accompany the turbulent mixing during breaking, residual whitecaps W_B are almost motionless foam left behind. The relative contributions of W_A and W_B to air-sea interaction processes differ, therefore, accurate parameterization of momentum, heat, and mass transfers across the air-sea interface due to breaking waves, requires separate quantification of whitecap stages.

We pursue whitecap separation using infrared (IR) imaging which distinguishes W_A and W_B as bright and dark patches on the ocean surface. Whitecaps were captured using simultaneous IR and visible imaging during a 2012 field campaign aboard R/V FLIP. IR images were used to quantify the lifetime stages and characteristics of W_A and W_B, and show IR imaging is a valuable tool for studying the influence of breaking waves on the marine environment.

Explicit iron-ligand coupling in the CESM-BEC

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Iron-binding ligands are thought to exert significant control over dissolved iron distributions and iron residence time in the ocean. Their explicit representation in biogeochemical ocean models can help to elucidate the unknowns associated with iron-binding ligand distributions, their sources and sinks, and their influence on dissolved iron concentrations. In this study, we explicitly simulate iron-binding ligands and assess their impact on dissolved iron distributions and present some preliminary results. Modeled iron-binding ligands influence dissolved iron distributions through their modulation of iron scavenging rates, which is a function of the sinking particle flux and remineralization. The source for iron-ligands in our model is remineralization of POM and DOM. We find that simulation of a single ligand source from POC, DOC and DOCr remineralization can explain dissolved iron distributions well. We also find that simulated dissolved iron better matches observations with highly saturating ligand concentrations for the upper ocean. This contradicts the idea that ligand and dissolved iron concentrations closely match one another.

Monitoring and predicting the export and fate of global ocean net primary production: The EXPORTS science plan

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Ocean ecosystems play a critical role in the Earth's carbon cycle and its quantification on global scales remains one of the greatest challenges in global ocean biogeochemistry. The goal of the EXport Processes in the Ocean from Remote Sensing (EXPORTS) science plan is to develop a predictive understanding of the export and fate of global ocean primary production and its implications for the Earth's carbon cycle in present and future climates. NASA's satellite ocean-color data record has revolutionized our understanding of global marine systems. EXPORTS is designed to advance the utility of NASA ocean color assets to predict how changes in ocean primary production will impact the global carbon cycle. EXPORTS will create a predictive understanding of both the export of organic carbon from the euphotic zone and its fate in the underlying "twilight zone" (depths of 500 m or more) where variable fractions of exported organic carbon are respired back to CO_2. Ultimately, it is the sequestration of deep organic carbon transport that defines the impact of ocean biota on atmospheric CO_2 levels and hence climate. EXPORTS will generate a new, detailed understanding of ocean carbon transport processes and pathways linking upper ocean phytoplankton processes to the export and fate of organic matter in the underlying twilight zone using a combination of field campaigns, remote sensing and numerical modeling. The overarching objective for EXPORTS is to ensure the success of future satellite missions by establishing *mechanistic* relationships between remotely sensed signals and carbon cycle processes. Through a process-oriented approach, EXPORTS will foster new insights on ocean carbon cycling that will maximize its societal relevance and be a key component in the U.S. investment to understand Earth as an integrated system.

Mesozooplankton grazing effects on particle size spectra

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Oceanic particle size spectra can be used to explain and predict variability in carbon export, since larger particles are more likely to sink to depth than small particles. The distribution of biogenic particle size in the pelagic surface ocean is the result of many variables and processes, including nutrient availability, primary productivity, aggregation, remineralization, and grazing. We conducted a series of grazing experiments to test the hypothesis that mesozooplankton shift particle size spectra toward larger particles, via grazing and egestion of relatively large fecal pellets. These experiments were carried out over several months, and used natural communities of mesozooplankton and their microbial prey, collected offshore of the Damariscotta River in the Gulf of Maine. We analyzed the samples using Fluid Imaging Technologies' FlowCam®, a particle imaging system. With this equipment, we processed live samples, decreasing the likelihood of losing or damaging fragile particles, and thereby lessening sources of error in commonly used preservation and enumeration protocols. Our results show how the plankton size spectrum changes as the Gulf of Maine progresses through a seasonal cycle, and reveal mesozooplankton prey preferences. Contrary to the results of previous prey selectivity experiments, we found that a complete mesozooplankton community tends to be "evolved" to fit its prey, such that most prey categories are grazed evenly. We also explore the relationship of grazing community size structure to its effect on the overall biogenic particle size spectrum. We conclude that mesozooplankton grazing does increase particle size, and therefore increases the likelihood for carbon export from the surface ocean.

Air-sea exchange of CO_2 in the East China Sea: Present synthesis and future changes

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The role of the productive East China Sea (ECS) in regulating the anthropogenic CO_2 and effect of environmental changes on CO_2 uptake changes are being revealed gradually. Here we report the synthesis of time-series data of the annual mean CO_2 fluxes since 1950 based on both observations and model calculation. This assessment of annual CO_2 uptake is more reliable and complete, compared to previous estimates, in terms of temporal and spatial coverage. Additionally, the CO_2 time-series exhibits distinct seasonal pattern and also reveals apparent inter-annual variations. The flux seasonality shows a strong sink in spring and a weak source in the period from late summer to mid fall. The weak sink status during warm periods in summer-fall is fairly sensitive to changes of pCO_2 and may easily shift from a sink to a source due to environmental changes. Finally, the effects of the Changjiang river discharge (CRD) and the Kuroshio strength on the CO_2 uptake have been discerned and future changes due to the CRD fluctuation are examined; i.e. how the CO_2 uptake in the ECS is controlled by the CRD fluctuation and the Kuroshio strength, which, in turn, are influenced by climate change and anthropogenic forcing, has been investigated as well.