OCB2019 POSTER ABSTRACTS

Table of Contents (first author index is at end of document)

Plenary Session: Anthropogenic changes in ocean oxygen: Coastal and open ocean perspectives 4

The equatorial undercurrent and the Oxygen Minimum Zone in the Pacific 4

Impacts of atmospheric nitrogen deposition and coastal nitrogen fluxes on oxygen concentrations in Chesapeake Bay 4

An Earth System Model large ensemble with increased access for ocean biogeochemistry 5

Ventilation and oxygen supply of the eastern tropical North Atlantic Oxygen Minimum Zone 5

Plenary Session: Approaches and challenges to understanding biogeochemical cycling across the land-ocean aquatic continuum 7

Temporal changes in nitrous oxide sources and sea-air fluxes in the Southern Benguela 7

Correcting in situ chlorophyll fluorescence time series observations for non-photochemical quenching and tidal variability reveals non-conservative phytoplankton variability in coastal waters 7

Hurricane floodwater impact on optical-biogeochemical properties and carbon fluxes in a large estuary from ocean color 8

Modeling the phytoplankton bloom dynamics on the Northwest Atlantic shelf: spatial heterogeneity and interannual variability 9

Quantifying the sequestration time of remineralized CO_2 in the California Current Ecosystem using the MITgcm lagrangian floats package 9

Optical characterization of water quality in the Long Island Sound 10

Redistribution of particulate matter following marsh lateral erosion in a back-barrier estuary 10

Model-data assessment of Scotian Shelf carbon dynamics: A spatially varied and biologically active system 11

Modeling the biogeochemistry and carbon cycle of the West Antarctic Peninsula 12

Understanding and quantifying carbon export to global oceans through deltaic systems 12

Finite Volume Community Ocean Model (FVCOM) provides high spatio-temporal hydrodynamics to inform biogeochemical wetland-estuarine models. 13

Plenary Session: Calcification and the carbon cycle 13

Autonomous optics of the ocean biological carbon pump: PIC 13

The calcification response of coccolithophores to elevated ocean alkalinity 14

The costs and benefits of calcification on coccolithophore physiology 15

Coccoliths as adsorptive reservoirs 16

Sea-ice loss amplifies summer-time decadal CO_2 increase in the western Arctic Ocean 16

A bay-wide self-regulated pH buffer mechanism in response to eutrophication and acidification in Chesapeake Bay 17

Quantifying processes controlling the surface water carbon dynamics: Case study at the PN Line Time Series data and HOTS Station 18

Plenary Session: Carbon cycle feedbacks from the seafloor 18

Porewater alkalinity in the Bay of Cádiz (north east Atlantic) 18

Anomalous >2000 year old surface ocean radiocarbon points to increased carbon flux from seafloor during deglaciation 19

Plenary Session: The effect of size on ocean processes (allometry) and implications for export 20

Grazer-mediated coexistence of competing phytoplankton species using the Kill-the-Winner functional response 20

Episodic particle flux: A sampling artifact? 20

Running PCA on the world ocean 21

Quantitative size and biomass distributions from particle images: An improved algorithm applied to IFCB observations 21

Environmental controls on pteropod metabolism along the Western Antarctic Peninsula 22

Topic: EXPORTS/Biological Pump 22

EXPORTS: using high resolution studies of thorium-234 at Ocean Station PAPA to elucidate spatial and temporal variability in particle export and attention 22

A visual tour of carbon export pathways by sinking particles across ocean basins, depth, and time 23

Climatological Context for the 2018 North Pacific EXPORTS field campaign 24

Zooplankton metabolism, active flux, and contribution to AOU in the NE Pacific Ocean 24

Tight coupling between herbivorous predation and phytoplankton production in the oligotrophic North Pacific (EXPORTS) 25

Polonium-210 and Lead-210 as tracers of particle export and attenuation on the first EXPORTS cruise at Station PAPA . 26

The EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign 26

Mesozooplankton community structure and diel vertical migration in the subarctic NE Pacific Ocean, Station P 27

Spatial and temporal variability of the biological pump in the northeast Pacific 27

Topic: General OCB Science 28

Zooplankton community response to seasonality at BATS by metabarcoding 28

Remote sensing-derived zooplankton biomass and grazing: Analyzing errors associated with models 28

Glacial deep ocean deoxygenation driven by biologically enhanced air-sea disequilibrium 29

Investigating zooplankton mediation of sinking particle flux in the Sargasso Sea 29

Geostatistical analysis of mesoscale ocean biophysical variability in the western North Atlantic from field observations, remote sensing and numerical modeling 30

Metabolic remodeling under temperature acclimation: A case study in the Shewanella genus 31

Marine viruses stimulate carbon flux to lower and higher trophic levels 32

Distribution of excess alkalinity in the open ocean 32

One million matrices: Size-structured modeling reveals in situ phytoplankton dynamics. 33

Remote sensing of global ocean surface phosphate concentrations 33

Drivers of phytoplankton C:N:P ... 34
Comparing biogeochemical model outputs using neural network ensembles ... 34
Interannual comparison of diatom community composition in the Western Antarctic Peninsula ... 35
The biogeochemical impact of an across-shore filament in the California Current Ecosystem ... 36
Measuring noble gas fluxes at high wind speeds in the SUSTAIN wind-wave tank ... 36
Methods to distinguish phytoplankton groups from remote-sensing reflectance in subtropical waters ... 37
Purified meta-cresol purple dye perturbation: how much will it influence spectrophotometric pH measurement? ... 38
Desynchronization between sea ice and phytoplankton bloom in a changing Antarctic ... 39
Seasonal dynamics of organic carbon in the deep eastern North Pacific ... 39
Plankton population dynamics and food web structure on the Northeast US Shelf (NES-LTER): early indication of seasonal shifts in production regimes ... 40
Springtime coupling between Arctic sea ice export and phytoplankton blooms in the Greenland Sea ... 40
Effects of phytoplankton composition and biominerals on the episodic pulses of particulate organic carbon to abyssal depths ... 41
The NASA and IOCCG protocols renewed: Reestablishing best practices for exceptional in situ measurements ... 42
Synechococcus and *Prochlorococcus*: A tale of two cyanobacteria ... 42
Direct wintertime pCO_2 observations from the Saildrone Gulf Stream Mission ... 43
A global database of size-fractionated POC and PIC concentrations compared to satellite-based estimates ... 43
Anthropogenic Fe and N deposition alters the ecosystem and carbon balance of the southern Indian Ocean ... 44
Automated identification of sinking marine particle images using transfer learning ... 45
The Ocean Twilight Zone Project ... 45
Performance of the Deep-Sea-Durafet pH sensor on a Spray Glider in the Central California Current System ... 46
Data-driven modeling of the distribution of diazotrophs in the global ocean ... 47
Impacts of estuarine dynamics on CO_2 air-sea exchange ... 47
Characterizing the spatiotemporal pCO_2 dynamics associated with water masses in the river-dominated East China Sea 48
Ocean biogeochemistry drives sustained seawater concentrations of persistent organic pollutants ... 48
Rapid adaption of the microbial community to abrupt environmental change in the Gulf of Mexico modeled with the Genome-based EmergeNt Ocean Microbial Ecosystem Model ... 49
To the North Pole and back: A pan-Arctic barium synthesis ... 50
Quantification of dissolved metabolites in seawater and diatom cultures ... 50
Freshening of the western Arctic negates anthropogenic carbon uptake potential ... 51

Topic: Data Management ... 51
BCO-DMO: Accelerating scientific discovery through responsive data management practices ... 51

Index of first authors ... 53

Plenary Session: Anthropogenic changes in ocean oxygen: Coastal and open ocean perspectives

The equatorial undercurrent and the Oxygen Minimum Zone in the Pacific

Busecke, Julius J.M. (Princeton University) jbusecke@princeton.edu
Laure Resplandy (Princeton University), John P. Dunne (NOAA/GFDL)

Warming-driven expansion of the oxygen minimum zone (OMZ) in the equatorial Pacific would bring very low oxygen waters closer to the ocean surface, and possibly impact global carbon/nutrient cycles and local ecosystems. Global coarse Earth System Models (ESMs) show, however, disparate trends that poorly constrain these future changes in the upper OMZ. Using an ESM with a high-resolution ocean (1/10 deg), we show that a realistic representation of the Equatorial Under Current (EUC) dynamics is crucial to represent the upper OMZ structure and its temporal variability. We demonstrate that coarser ESMs commonly misrepresent the EUC, leading to an unrealistic 'tilt' of the OMZ (e.g. shallowing towards the east) and an exaggerated sensitivity to EUC changes overwhelming other important processes like diffusion and biology. This shortcoming compromises the ability to reproduce the OMZ variability and could explain the disparate trends in ESMs projections.

Impacts of atmospheric nitrogen deposition and coastal nitrogen fluxes on oxygen concentrations in Chesapeake Bay

Da, Fei (Virginia Institute of Marine Science) fda@vims.edu
Marjorie Friedrichs (Virginia Institute of Marine Science); Pierre St-Laurent (Virginia Institute of Marine Science)

Although rivers are the primary source of dissolved inorganic nitrogen (DIN) inputs to the Chesapeake Bay, direct atmospheric DIN deposition and coastal DIN concentrations on the continental shelf can also significantly influence hypoxia; however, the relative impact of these additional sources of DIN on Chesapeake Bay hypoxia has not previously been quantified. In this study, the estuarine-carbon-biogeochemistry model embedded in the Regional-Ocean-Modeling-System (ChesROMS-ECB) is used to examine the relative impact of these three DIN sources. Model simulations highlight that DIN from the atmosphere has roughly the same impact on hypoxia as the same gram-for-gram change in riverine DIN loading, although their spatial and temporal distributions are distinct. DIN concentrations on the continental shelf have a similar overall impact on hypoxia as DIN from the atmosphere (~0.2 mg/L); however, atmospheric DIN impacts dissolved oxygen (O_2) concentrations primarily via the decomposition of autochthonous organic matter, whereas coastal DIN concentrations primarily impact O_2 via the decomposition of allochthonous organic matter entering the Bay mouth from the shelf. The impacts of atmospheric DIN deposition and coastal DIN concentrations on hypoxia are greatest in summer and occur farther downstream (southern mesohaline) in wet years than in dry years (northern mesohaline).

Integrated analyses of the relative contributions of all three DIN sources on summer bottom O_2 indicate that impacts of atmospheric deposition are largest in the eastern mesohaline shoals, riverine DIN has dominant impacts in the largest tributaries and the oligohaline Bay, while coastal DIN concentrations are most influential in the polyhaline region.

An Earth System Model large ensemble with increased access for ocean biogeochemistry

Ito, Taka (Georgia Institute of Technology) taka.ito@eas.gatech.edu

Large ensemble (LENS) of comprehensive Earth System Model allows scientists to identify and separate anthropogenic effects on physical and biogeochemical systems from the natural variability. Open sharing of the LENS datasets can lead to groundbreaking research in many subdisciplines of climate science. However, the analysis of model output can be challenging due to its massive data volume. A compressed version of LENS dataset is assembled in order to significantly reduce the data volume while retaining major features of the original output. Such a compact dataset enables rapid data sharing and analysis, accelerating research and discovery. It also allows investigators to have a 'quick look' over the dataset before starting in-depth investigation. The objective of this manuscript is to introduce the highly compressed version of CESM-LENS output (Kay et al., 2015). Considering large-scale marine biogeochemical analyses, the spatial and temporal resolutions of the CESM-LENS is reduced to yearly mean and at the 2°x2° longitude-latitude resolution with 33 vertical z-levels (available at http://rda.ucar.edu/datasets/ds645.0). This resolution is chosen to balance the integrity of large-scale fields and the need to reduce data volume. Historic and RCP8.5 scenario segments are combined into a single time series covering 1920 to 2100. The pre-industrial control is also provided using the same data reduction scheme to allow for drift correction. Each ensemble member can fit within a netCDF file containing 15 physically and biogeochemically relevant variables, and the entire 34 ensemble members can be downloaded within one day using a typical broadband connection. The reduction in both temporal and spatial resolution causes the loss of information, and its effect is assessed for sea surface temperature (SST), subsurface dissolved oxygen (O_2), and air-sea flux of carbon dioxide ($fgCO_2$). Basin-scale averages of a single member as well as the ensemble mean closely follow the original CESM-LENS with the mean biases less than 0.07°C for SST, 0.7 micro-M for O_2 and 0.03 molC/m^2/yr for $fgCO_2$ with the R^2 greater than 0.999 for all basins. For the global means, the mean biases are about an order of magnitude smaller, 0.02°C for SST, 0.08 micro-M for O_2 and 0.002 molC/m^2/yr for $fgCO_2$. The largest basin-scale biases are found in the Arctic region. These initial assessment suggests that the benefit of compact dataset can outweigh minor errors due to the resolution reduction.

Ventilation and oxygen supply of the eastern tropical North Atlantic Oxygen Minimum Zone

Stöven, Tim (GEOMAR Helmholtz Centre for Ocean Research Kiel) tstoeven@geomar.de

Arne Körtzinger (GEOMAR Helmholtz Centre for Ocean Research Kiel)

The Eastern Tropical North Atlantic Oxygen Minimum Zone (ETNA-OMZ) is supplied by two main water masses. The South Atlantic Central Water (SACW) is a relatively cold central water with high oxygen content. The formation area is between 30-40°S north of the Falkland Islands as well as in the Indic Ocean, where it is transported via the Agulhas and Benguela current system towards the Atlantic Ocean. In contrast, the North Atlantic Central Water (NACW) is a relatively warm and salty central water formed in the northern subtropical gyre, carrying less oxygen. The NACW splits into two supply pathways. One pathway goes along the boundary current system off Brazil, where it already mixes with the SACW and then flows along the equatorial current system towards the OMZ region. The second supply pathway is located at the eastern boundary, where the central water enters the OMZ from the north along the Cape Verdi Islands.

The SFB 754 included several tracer surveys of CFC-12 and SF6 in the OMZ and adjacent areas between 2006 and 2018. The data was interpolated to specific density surfaces; the OMZ core at Sigma_Theta=27.0 as well as above and below in the oxycline at 26.8 and 27.2 respectively.
The ventilation timescales and oxygen concentrations were then used to determine the local oxygen utilization rates. The data shows that the SACW and NACW extremely differ in their oxygen supply capacity. Although the SACW is older due to the longer flow pathway, it has ~40 umol/kg less oxygen deficiency in the apparent oxygen utilization (AOU) and ~60 umol/kg more oxygen content at the core density compared to the younger NACW.

The differences in the oxygen content and deficiency are related to the differences in the oxygen solubility at the source region and the biological activity along the flow pathway. The analysis of tracer data from the GLODAP v2 data product clearly shows the differences in oxygen utilizations rates of SACW and the two NACW branches. The eastern NACW branch is affected by much higher consumption / respiration than the western NACW and SACW. The lowest oxygen utilization rates can be found in the SACW in the southwestern Atlantic due to the oligotrophic characteristics of the water body.

Hence, the oxygen supply of the ETNA-OMZ highly depends on the supply of SACW. This central water has a higher oxygen solubility and undergoes less consumption on its way to the OMZ. On the contrary, the eastern NACW transports water with the lowest oxygen concentrations into the OMZ. A change in ventilation can significantly change the OMZ budget. For example, an increase in ventilation of NACW would imply a decrease in the mean age but comes along with a decrease in oxygen. An increase in ventilation by SACW would imply an increase in mean age but also an increase in oxygen.

Plenary Session: Approaches and challenges to understanding biogeochemical cycling across the land-ocean aquatic continuum

Temporal changes in nitrous oxide sources and sea-air fluxes in the Southern Benguela

Bourbonnais, Annie (University of South Carolina) abourbonnais@seoe.sc.edu
Sarah Fawcett, Raquel Flynn, Jessica Burger, and Mark Altabet

N_2O is a potent greenhouse gas and stratospheric ozone depleting substance. The open ocean accounts for up to 30% of total N_2O emissions, but fluxes in highly productive or low-O_2 coastal regions are still poorly quantified. We present N_2O concentration, stable isotope and isotopomer data from Elands Bay, off the west coast of South Africa, during a 10 day experiment in December 2016, and a transect in the southern Benguela sampled in February, during a period of upwelling, and August 2017, during a non upwelling period, to answer 3 questions: 1) what are the sources of water-column N_2O?; 2) what is the temporal variability of N_2O emissions?; and 3) is the sea-air flux of N_2O significant in this region? Our data suggest that the main N_2O source is nitrification/denitrification in sediments in Feb and Aug 2017. We observed a shift in N_2O source(s) in Dec 2016 following an upwelling event, suggesting a different dominant mechanism for N_2O production, e.g., water-column nitrification. N_2O emissions varied greatly, with the highest sea-air fluxes in Feb and Aug 2017 and lowest fluxes in Dec 2016 after an upwelling event. Overall, the N_2O sea-air fluxes in this region (up to 9 µmol m^{-2} d^{-1}) were on average at least one order of magnitude lower than fluxes off Peru but were comparable to fluxes in the Northern Benguela. Better temporal/spatial coverage are needed to estimate overall N_2O emissions from the Benguela Upwelling System as a whole.

Correcting in situ chlorophyll fluorescence time series observations for non-photochemical quenching and tidal variability reveals non-conservative phytoplankton variability in coastal waters

Carberry, Luke (University of California, Santa Barbara) lcarberry@gmail.com
Collin Roesler (Bowdoin College), Susan Drapeau (Bowdoin College)

Chlorophyll fluorometry is one of the most commonly implemented approaches for estimating phytoplankton biomass in situ, despite documented sources of natural variability and instrumental uncertainty in the relationship between in vivo fluorescence and chlorophyll concentration. A number of strategies are employed to minimize errors and quantify natural variability in this relationship in the open ocean. However, the assumptions underlying these approaches are still unsupported in coastal waters due to the short temporal and small spatial scales of variability, despite the demonstrated importance of coastal waters to understanding whole-ocean biogeochemical cycling. The largest source of variability in the in situ chlorophyll fluorometric signal is non-photochemical quenching (NPQ). Typically, unquenched nighttime

observations are interpolated over the quenched daytime interval, but this assumes a spatial homogeneity not found in tidally-impacted coastal waters. Here we present a model that provides a tidally-resolved correction for NPQ in moored chlorophyll fluorescence measurements. The output of the model is a time series of unquenched chlorophyll fluorescence in tidal endmembers (high and low tide extremes), and thus a time series of phytoplankton biomass growth and loss in these endmember populations. Comparison between modeled and measured unquenched time series yield quantification of non-conservative variations in phytoplankton biomass. Tidally-modeled interpolation between these endmember time series yields a highly resolved time series of unquenched daytime chlorophyll fluorescence values at the location of the moored sensor. Such datasets, especially in tandem with biogeochemical variables, provide a critical opportunity for understanding the influence of phytoplankton on biogeochemical cycling at the land-ocean interface.

Hurricane floodwater impact on optical-biogeochemical properties and carbon fluxes in a large estuary from ocean color

D'Sa, Eurico (Louisiana State University) ejdsa@lsu.edu
Ishan Joshi (Scripps Institution of Oceanography), Bingqing Liu (Louisiana State University)

Extreme events such as hurricanes which are increasing in intensity and frequency also have major impact on coastal ecosystems and biogeochemical cycling. During summer 2017, the northern Gulf of Mexico was impacted by Hurricane Harvey, which, after making landfall on the Texas coast, deposited unprecedented rainfall (>500 mm) in the highly industrialized Houston Metropolitan and surrounding areas that resulted in a large pulse of discharge into Galveston Bay and the shelf waters. We used field and satellite ocean color observations (NPP-VIIRS, Sentinel-3A OLCI) combined with tuned semi-analytic (QAA-V), inversion IOP (inherent optical property) and Non-Negative Least Squares (NNLS) algorithms to examine the optical (CDOM/phytoplankton absorption and backscattering coefficients) and biogeochemical (dissolved/particulate organic and suspended matter e.g., DOC, POC, phytoplankton taxonomy and pigment composition) properties in Galveston Bay and surrounding shelf waters following the hurricane passage. Environmental drivers, especially floodwater discharge and winds strongly influenced the spatiotemporal distribution of dissolved/particulate material in the bay and shelf waters following the hurricane passage. Over 10-days during/following the hurricane, ~25.2×10^6 kg C of total organic carbon and ~314.7×10^6 kg of SPM was rapidly exported from Galveston Bay (representing ~0.65% and 0.27% of respective annual Mississippi River fluxes to the Gulf of Mexico), with potential for ecological impacts to shelf waters. The IOP inversion algorithm revealed the dominance of freshwater species (diatom, cyanobacteria and green algae) in the bay under low salinity conditions associated with the discharge of floodwaters that transitioned under more seasonal salinity conditions to an increase in small sized groups such as haptophyte and prochlorophyte. Phytoplankton diagnostic pigments retrieved using an NNLS inversion model based on Sentinel-3A OLCI Chl a maps also confirmed spatiotemporal variations of phytoplankton taxonomy. Overall, this study using field and ocean color data combined with semi-analytical and inversion algorithms provided new insights on the biogeochemical response of a turbid estuarine environment to an extreme flood perturbation.

Modeling the phytoplankton bloom dynamics on the Northwest Atlantic shelf: spatial heterogeneity and interannual variability

Feng, Zhixuan (Woods Hole Oceanographic Institution) zfeng@whoi.edu
Rubao Ji (Woods Hole Oceanographic Institution), Changsheng Chen (University of Massachusetts-Dartmouth), Cabell Davis (Woods Hole Oceanographic Institution),

The Northwest Atlantic Shelf is among the world's fastest warming regions in the recent 3-4 decades. The rapidly changing ocean environment could impact the marine ecosystem across multiple trophic levels and have important socioeconomic implications. To understand spatial heterogeneity and interannual variability in phytoplankton bloom dynamics and relevant physical and biological drivers, we conducted numerical experiments using an intermediate-complexity lower trophic level ecosystem model based on the Finite Volume Community Ocean Model (FVCOM) and validated model results using satellite ocean color data and shipboard measurements of size-fractionated chlorophyll-a. We examined the distinctive nutrient and light limitation conditions that cause spatial variability of phytoplankton bloom magnitude and timing as well as size composition across the Gulf of Maine (GoM) and Mid-Atlantic Bight (MAB) regions. Moreover, we evaluated spatial coherences in terms of the variability of physical and biological quantities at seasonal and interannual time scales. The results allow a better quantification of production regime in the region, and has significant implications for understanding the variability of fisheries populations and assessing the climate impact on physical and biological processes at different spatiotemporal scales.

Quantifying the sequestration time of remineralized CO_2 in the California Current Ecosystem using the MITgcm lagrangian floats package

Irving, John (Florida State University) jpi18@my.fsu.edu
Taylor Shropshire (Florida State University), Michael Stukel (Florida State University)

Particulate organic carbon is transported vertically through three mechanisms of the biological carbon pump. POC can be transported by gravitational sinking, active transport by vertically migrating zooplankton, or physically advected by subduction. These three processes have different impacts on the depths at which this POC is remineralized to CO_2 as the respiration products of heterotrophic microbial and zooplankton metabolisms. The sequestration time scale of regenerated carbon is dependent on the depth that it was remineralized with deeper remineralized CO_2 being sequestered within the ocean for longer periods of time. The goal of this study is to quantify the sequestration time of remineralized CO_2 as a function of remineralization depth. This study was conducted using the MITgcm lagrangian floats package. Remineralized CO_2 was simulated as sets passive particles that were launched in the Southern California Current Ecosystem, a productive coastal upwelling biome. The trajectories of particles from the remineralization depth to the mixed layer provides a sequestration length scale. The model reanalysis data used to force the lagranian simulation ranges from 1994-2015, and these simulations can provide information about the sequestration time of CO_2 during different phases

of ENSO in addition to the analyses comparing remineralization depth. Overall, this project provides insight into the potential for carbon sequestration by the biological carbon pump, and highlights the differences in the sequestration length scale of CO_2 remineralized from particles delivered below the mixed layer by sinking, active transport, or subduction.

Optical characterization of water quality in the Long Island Sound

Menendez, Alana (CUNY City College) alana.menendez@gmail.com
Brice Grunert (CUNY City College); Maria Tzortziou (CUNY City College)

Human populations are disproportionately located in coastal zones, resulting in water quality issues including harmful algal blooms and hypoxia that are exacerbated by climate change. Throughout the U.S., management programs have been enacted to decrease nutrient inputs into coastal waters in an effort to combat these impacts. However, tracking the effectiveness of these management endeavors across space and time is difficult and costly, particularly in urban estuaries where changing demographics, industrial activities, and waste management combine with natural fluctuations in delivery of nutrients and organic matter fueling eutrophic conditions. Satellites provide a means for tracking changing conditions, provided regionally-tuned algorithms accurately retrieve relevant water quality parameters. Beginning in the fall of 2017, optical and chemical water samples have been collected and analyzed across the Long Island Sound and along its major river-to-estuary transects. These datasets provide the foundation for the development of new algorithms for this system that are capable of mapping chlorophyll-a and carbon cycling, allowing us to capture tidal, seasonal, and inter-annual variability. Results show promise for retrieving these parameters across a variety of satellite platforms, which will allow us to better characterize Long Island Sound water quality and its anthropogenic perturbations.

Redistribution of particulate matter following marsh lateral erosion in a back-barrier estuary

Moriarty, Julia (USGS) jmoriarty@usgs.gov
Tarandeep Kalra, Neil Ganju, Zafer Defne

Salt marsh vegetation enhances sedimentation rates and burial of organic carbon in coastal environments. However, wave-induced lateral erosion at the edge of salt marshes releases some of this buried particulate organic carbon (POC) into the estuary. The fate of this material (i.e. the degree to which particulates released during lateral erosion is redeposited on the surface of the marsh, transported to other portions of the estuary, or remineralized and thus removed from the system) has remained difficult to quantify, in part because observations are limited by cost, technology, and safety constraints. These constraints have limited our understanding of how the lateral retreat of marshes affects carbon budgets in coastal systems.

This study uses a numerical modeling approach to quantify the transport and fate of particles released from salt marshes by wave-induced erosion. Specifically, we adapted the Coupled Ocean-

Atmosphere-Wave-Sediment Transport (COAWST) model to account for wave-induced marsh-edge erosion. The model also accounts for tidal and wind-driven circulation, as well as interactions between hydrodynamics and submerged vegetation. The COAWST model has been implemented for Barnegat Bay, New Jersey, USA, a large back-barrier estuary with three inlets connecting the bay to the coastal ocean.

Preliminary model results for March-June 2012 demonstrate that marsh-edge erosion is an order of magnitude faster near barrier-island inlets, where wave thrust is largest, which is consistent with observations. Most of the sediment delivered to the estuary via edge-erosion remains within tens of meters of a marsh edge over the timespan of four months, but about ten percent is resuspended and exported to other regions of the Bay or to the coastal ocean by energetic currents. A greater percentage of the marsh-derived sediment is exported from regions near inlets, compared to more protected and quiescent locations within the estuary. In contrast, deposition on the marsh platform varies with sediment availability in adjacent portions of the estuary. In Barnegat Bay, deposition on the marsh platform is largest in areas within a few kilometers of estuarine channels, where suspended sediment concentrations are largest. Almost a third of this deposition is derived from sediments previously eroded from the marsh.

Model-data assessment of Scotian Shelf carbon dynamics: A spatially varied and biologically active system

Rutherford, Krysten (Dalhousie University) krysten.rutherford@dal.ca
Katja Fennel (Dalhousie University), Arnaud Laurent (Dalhousie University), Dariia Atamanchuk (Dalhousie University), Douglas Wallace (Dalhousie University), Helmuth Thomas (Dalhousie University)

The broad Scotian Shelf off the coast of eastern Canada is located at the dynamic junction of the subpolar and subtropical gyres. Biological processes on this shelf are characterized by strong seasonality, including a large spring bloom in late March. The dynamic circulation and biological activity are reflected in spatially and temporally heterogeneous inorganic carbon and pCO_2 distributions. Observations from a moored buoy provide a multi-year time series of surface pCO_2 measurements, and show a rapid and large drawdown of pCO_2 during the spring bloom on the inner Scotian Shelf. Repeated high-resolution spatial observations from a cross-shelf transect show that surface pCO_2 also changes dramatically across the shelf. The transect observations indicate higher pCO_2 in a thin band directly adjacent to shore (leading to net outgassing) and lower pCO_2 values across the rest of the shelf. In this study, we combined results from our model of the northwest North Atlantic with the aforementioned observations to elucidate the biological and physical processes controlling carbon dynamics on the Scotian Shelf. We specifically aim to address how the regional circulation is impacting the Scotian Shelf pCO_2 distributions and what is driving the inshore outgassing.

Modeling the biogeochemistry and carbon cycle of the West Antarctic Peninsula

Schultz, Cristina (University of Virginia) cs3xm@virginia.edu
Scott Doney (University of Virginia), Gordon Zhang (Woods Hole Oceanographic Institution)

Over the past several decades, the West Antarctic Peninsula (WAP) has undergone physical and ecological changes at a rapid pace, with warming surface ocean and a sharp decrease in the duration of the sea ice season. The impact of these changes in the ocean chemistry and ecosystem are not fully understood and have been investigated by the Palmer-LTER since 1991. Given the data acquisition constraints imposed by weather conditions in this region, an ocean circulation, sea ice and biogeochemistry model was implemented to help fill the gaps in the dataset. The results with the present best case from the suite of sensitivity experiments indicate that the model is able to represent the seasonal and interannual variations observed in the circulation, water mass distribution and sea ice observed in the WAP, and has identified gaps in the observations that could guide improvement of the simulation of the regional biogeochemistry. Comparison of model results with data from the Palmer-LTER project suggests that the large spatial and temporal variability observed in the phytoplankton bloom in the WAP is influenced by variability in the glacial sources of dissolved iron. Seasonal progression of the phytoplankton bloom is well represented in the model, and values of vertically integrated net primary production (NPP) are largely consistent with observations. Although a bias towards lower surface dissolved inorganic carbon (DIC) and alkalinity was identified in the model results, interannual variability was similar to the observed in the Palmer-LTER cruise data.

Understanding and quantifying carbon export to global oceans through deltaic systems

Xue, Z. George (Louisiana State University) zxue@lsu.edu
Kanchan Maiti (LSU), Victor Rivera-Monroy (LSU), Eurico D'Sa (LSU)

The Carbon Export to Global Oceans through Deltaic Systems (CEDS) project focuses on critical carbon processes at the interface of human-natural ecosystems. The project serves as a support for NASA's major strategic goal to advance understanding of the Earth by investigating the transport of carbon at the land-sea interface. The two selected coastal sites are located across one of the world's most dynamic delta systems – the Mississippi river delta, with shrinking Barataria Bay region experiencing significant subsidence and land loss, and the prograding Wax Lake Delta region witnessing fast expansion. The two sites will be investigated to evaluate the fate of carbon at different stages of delta evolution. The analogues of contrasting responses to climate change, sea-level rise, and human activity from these two sites under the same climate conditions are critical to assessing the role of delta systems in carbon export to the coastal oceans on a global scale. The CEDS project will combine remote sensing, oceanography, carbon cycling, and biogeochemistry to quantify different forms of carbon and nitrogen fluxes from two deltaic sites to the coastal ocean, evaluate carbon transformation along salinity gradients, and connect delta carbon and nutrients exported to the coastal ecosystem using a coupled numerical modeling approach. Key biogeochemical processes regulating water and carbon cycling in subtropical

deltaic/coastal systems will be explored and insight gained from the project will be used to predict water and carbon cycle's response to future climate change.

Finite Volume Community Ocean Model (FVCOM) provides high spatio-temporal hydrodynamics to inform biogeochemical wetland-estuarine models.

Ziegler, Lisa (UMCES, Horn Point Lab) lziegler@umces.edu
Raleigh Hood (University of Maryland Center for Environmental Science)

Salt marshes are recognised as one of the most important intertidal habitats within the coastal-wetland interface and play a key role in the biogeochemical cycling of nutrients. The past few decades have seen an increase in human population and activity (agriculture, recreational, domestic). This has contributed to increases in nutrient loads, which have the potential to change marsh biogeochemistry and in turn affect the water quality of an estuary. This study makes use of a high-resolution Finite Volume Ocean Model (FVCOM) used to derive the forcings for a biogeochemical model (the Integrated Compartment Model, or ICM). This poster presents a small scale implementation and use of a fine resolution, unstructured triangular grid (700 m from the open boundary to 30 m in the marsh) to capture temperature, salinity and water circulation variability in the Wheeler Marsh, Housatonic River, as well as further offshore in the river plume for the year 2017. Preliminary results show that the model captures the seasonal patterns of temperature (RMSE = 1.45°C, r = 0.9) and salinity (RMSE = 0.85, psu, r = 0.288) fairly well, however slightly overestimating temperature. The salinity range near the mouth of the river and within the marsh is highly variable (observations indicate high salt water retention within the marsh). Modeled sea surface height farther offshore and NOAA observations at Bridgeport, show a relatively good fit for the high pass filtered signal (RMS = 8.1 m, r = 2.16) in comparison to the low pass filtered signal (RMS = 1.76 m, r = 2.12) (suggesting that tidal fluxes coming from the open boundary might be dampened). Despite the encouraging preliminary results, frther improvements to the model are required. Future work involves upscaling the coupled physical-biogeochemical model approach implemented in a tributary to a large coastal estuary, Long Island Sound (LIS), to gain insight into the impacts of changes in marshes on estuarine water quality over time.

Plenary Session: Calcification and the carbon cycle

Autonomous optics of the ocean biological carbon pump: PIC

Bishop, James (University of California, Berkeley) jkbishop@berkeley.edu
Vinicius Amaral (UCSC), Phoebe Lam (UCSC), Cristina Orrico (Seabird/WETLabs), Todd Wood (Lawrence Berkeley National Laboratory), Thorsten Stezelberger (Lawrence Berkeley National Laboratory).

UC Berkeley, Lawrence Berkeley National Laboratory, and Seabird/WETLabs have developed a fast (10 Hz) digital low-power (~0.5W) sensor that uses cross-polarized transmitted light to detect the photon yield from birefringent particles in the water column. Are birefringent particulates dominated by inorganic carbon (PIC)? The sensor has been deployed on CTDs, and Carbon Explorer floats and has evolved in its design. The September - November 2018 GEOTRACES Meridional Transect, GP15, from the Aleutian Islands to Tahiti along 55°N, 152°W provided a perfect opportunity to validate two sensors each deployed on a separate CTDs surface to depths up to 6000m at 20 stations, many of which were taken in nearly particle free waters. Profiles were validated against PIC analysis of simultaneously collected size-fractionated particulates obtained by large volume in-situ filtration (McLane pump). Sensors reproduced close to digitizing precision on up cast/down casts and confirmed that this new birefringence-based inherent optical property was uniquely different from fluorescence, scattering and beam attenuation coefficient. PIC measured in pump samples was in systematic agreement with sensor profiles at many locations. Of particular note was near 0 values in shallow oxygen deficient waters near 11°N 152°W. Departures occurred in near bottom nepheloid layers in the subarctic N Pacific (which would be expected). Puzzling, but reproducible peaks were found in sensor data at depths deeper than the Chlorophyll maximum in the tropics in regions of strong thermal gradient (near 25°C) which on some occasions did not agree with pump results. SEM imaging of pump samples and thermal cycling experiments with the sensors have been undertaken to investigate whether or not the peaks seen near 25°C are instrumental. At this writing, the sensor easily resolves 5-10 nM variations of PIC in the deep water column (PIC ranges up 0.5-1 μM in our data), we have an immensely rich engineering test framework to advance the sensor to operational status.

The calcification response of coccolithophores to elevated ocean alkalinity

Gill, Sophie (University of Oxford Earth Sciences Department) sophie.gill@earth.ox.ac.uk
Rosalind Rickaby, Gideon Henderson (Both at University of Oxford)

The alkalinity of seawater sets the overall capacity of the ocean to hold carbon dioxide in dissolved forms. Variations in past alkalinity, related to changing weathering or carbonate compensation, may have played an important role in moderating or controlling past variations of atmospheric pCO_2. Future manipulation of ocean alkalinity by direct addition of suitable chemicals to seawater, or through enhanced weathering on land, has also been suggested as one possible route to intentionally draw CO_2 from the modern atmosphere and mitigate the impacts of future climate change [1]. Although we know an increasing amount about how species and ecosystems respond to changes in pH, we know much less about their response to changes in alkalinity. Calcifying plankton play a crucial role in modulating the surface ocean carbonate system and its buffering of alkalinity perturbations [2]. Here we investigate the growth and calcification response of two different species of coccolithophores (*E. huxleyi and G. oceanica*) to elevated ocean alkalinity through a series of carefully designed batch culture laboratory experiments. Alkalinity is raised by addition of $NaHCO_3$. Future work will involve addition of $Ca(OH)_2$ These differing elevated alkalinity treatments allow us to constrain whether factors other than raised alkalinity affect plankton growth and/or calcification; $NaHCO_3$ addition raises DIC in solution without altering the Ca^{2+}, whereas addition of $Ca(OH)_2$ raises Ca^{2+} with possible impact on calcification (Ca has also been suggested to be toxic in high levels to several species of plankton [3]). We will show how physiology and calcification respond to these two different modes of alkalinity manipulation.

[1] Renforth, P., Henderson, G., 2017. Assessing ocean alkalinity for carbon sequestration. Rev. Geophys. [2] Boudreau, B.P., Middelburg, J.J., Luo, Y., 2018. The role of calcification in carbonate compensation. Nat. Geosci. 11, 894. [3] Müller, M.N., Barcelos e Ramos, J., Schulz, K.G., Riebesell, U., Kaźmierczak, J., Gallo, F., Mackinder, L., Li, Y., Nesterenko, P.N., Trull, T.W., Hallegraeff, G.M., 2015. Phytoplankton calcification as an effective mechanism to alleviate cellular calcium poisoning. Biogeosciences 12, 6493–6501.

The costs and benefits of calcification on coccolithophore physiology

Grubb, Austin (Rutgers University) austin.grubb@marine.rutgers.edu
Jason R. Latham (Rutgers University), Christopher T. Johns (Rutgers University), Kimberlee Thamatrakoln (Rutgers University), and Kay D. Bidle (Rutgers University)

Phytoplankton are important to the global carbon cycle as they fix carbon into organic matter and are major contributors to the biological pump. Coccolithophores are globally distributed phytoplankton that produce heavy calcium carbonate plates known as coccoliths, which ballasts organic matter stimulating carbon export to the deep ocean and sediments. However, the process of calcification also produces carbon dioxide, raising questions over whether coccolithophores are a net sink or source of carbon dioxide in the atmosphere. Despite their crucial role in the global carbon cycle, the cellular role of calcification in coccolithophores remains speculative. Here, we use calcified and non-calcified ('naked') phenotypes of an identical genetic strain of *Emiliania huxleyi* to investigate the light-driven physiological costs and benefits of calcification. Naked and calcified *E. huxleyi* cells were acclimated to a range of growth irradiances (25-2000 μmol photons m^{-2} s^{-1}) which represent the vertical structure of light in the euphotic zone. We found that calcification scales with growth irradiance. In calcified cells, the maximum photosynthetic efficiency (Fv/Fm) and functional cross section of photosystem II (σPSII) did not change across all growth irradiances tested. In contrast, Fv/Fm and σPSII in naked cells decreased at high light with Fv/Fm being significantly higher at low light compared to calcified cells. The maximum rate of photosynthesis (Pmax) was 55-200% higher in calcified cells at all light irradiances, while the dissipation of energy via non-photochemical quenching (NPQ) at high light was lower. These phenotypic differences between σPSII and NPQ are consistent with a protective role of coccoliths in scattering light. However, this scattering is also associated with enhanced electron transport rates. The higher Pmax of calcified cells did not translate into higher growth, suggesting these cells experience additional energetic costs associated with calcification. Respiration was ~15% higher in calcified cells in the light and ~13% in the dark. The exudation of excess carbon through the production of transparent exopolymeric particles (TEP) was also higher (~30%) in calcified cells at all light irradiances tested. This study highlights the cost and benefits of calcification to coccolithophore physiology, and ongoing work focuses on investigating carbon fixation rates and macromolecular pool size differences between calcified and naked cells.

Coccoliths as adsorptive reservoirs

Johns, Christopher (Rutgers University) cjohns89@marine.rutgers.edu
Alex Matthews, Karen Bondoc, Kay Bidle (All at Rutgers University)

A defining characteristic of marine coccolithophores is their production of calcium carbonate coccoliths, a nanopatterned biomineral that impacts the global carbon cycle and allows us to view these unicellular planktonic protists from Earth-observing satellites. The most abundant species of coccolithophore, *Emiliania huxleyi*, forms massive mesoscale (hundreds of kilometers) blooms across the global ocean, but especially the North Atlantic. These blooms are routinely terminated by double-stranded DNA (dsDNA) coccolithoviruses (EhVs), triggering a massive release of free coccoliths, and facilitating carbon export to the deep ocean. Coccolith biominerals are subcellularly produced in a golgi-derived coccolith-deposition vesicle. Within this vesicle, coccoliths are coated in diverse organic matter constituents, which is thought to help with patterning and provides inherent constitutive properties. Fully mature coccoliths are extruded through the cell membrane and scaffolded to the cell surface forming the coccosphere. Coccolith morphology can vary within *E. huxleyi*, allowing for the grouping of similar coccolith morphologies into various `morphotypes'. Within natural populations this likely results in variable coccolith morphotype-dependent ecosystem interactions. At the same, the cellular and ecological purpose of calcification remains somewhat uncertain. Several hypotheses have been proposed to explain the ecophysiological roles of coccoliths, such as protection against predators (grazers) and pathogens (viruses). Recent work has linked the role of calcification as a deterrent of viral infection, resulting in massive coccolith shedding; however, the ecosystem impacts of free coccoliths and their function in host-virus interactions is not well understood. Currently, our findings show that free coccoliths are highly adsorptive, to both free viruses and *E. huxleyi* cells. Adsorption dynamics are not only morphotype-dependent, but likely driven by the presence of certain macromolecules contained within coccolith-associated organic matter. This observation suggests that coccoliths interact with both cellular and colloidal organic matter, which will likely impact encounter rates between hosts and viruses. These findings highlight a previously unknown linkage between biomineral nanoarchitecture and interactive ecological processes. Ultimately these coccolith adsorptive properties provide important insight into the broader ecophysiological role of calcification, and elude to important mechanisms impacting the marine carbon cycle.

Sea-ice loss amplifies summer-time decadal CO_2 increase in the western Arctic Ocean

Ouyang, Zhangxian (University of Delaware) ouyzhx@udel.edu
Di Qi (Third Institute of Oceanography, Xiamen, China), Liqi Chen (Third Institute of Oceanography, Xiamen, China), Taro Takahashi(Lamont-Doherty Earth Observatory of Columbia University), Wenli Zhong (Ocean University of China), Michael D. DeGrandpre (University of Montana), Baoshan Chen (University of Delaware), Zhongyong Gao(Third Institute of Oceanography, Xiamen, China), Shigeto Nishino (Japan Agency for Marine-Earth Science and Technology), Akihiko Murata (Japan Agency for Marine-Earth Science and Technology), Heng

Sun(Third Institute of Oceanography, Xiamen, China), Lisa L. Robbins (University of South Florida), Meibing Jin (International Arctic Research Center, Fairbanks), Wei-Jun Cai (University of Delaware)

Arctic Ocean is considered as a major sink for atmospheric CO_2 because of its low partial pressure of CO_2 (pCO_2), which governs the transfer rate and direction of CO_2 across the sea surface. While the Arctic Ocean has experienced rapid warming and sea-ice loss, its long-term pCO_2 trends and seasonal variation are poorly known. Here we report decadal changes of summer-time sea surface pCO_2 from 1994-2017 in the western Arctic Ocean. We find widely variable changes in sea surface pCO_2 with an increase rate twice higher than that of the atmosphere CO_2 in the ice-free deep Canada Basin, which is contrasted with no significant change in the shallow waters of the Chukchi Sea shelf. The reduced ice concentration in the Canada Basin facilitated an enhanced CO_2 uptake and an amplified seasonal variation of pCO_2, while strong biological uptake of CO_2 in the shelf waters held pCO_2 lower and less seasonal difference over years. These unique seasonal behaviors suggest that the summer-time CO_2 sink intensity during the low ice period in the Canada Basin would be rapidly reduced due to the enhanced air-sea CO_2 exchange. In contrast, the Chukchi Sea CO_2 sink would be intensified due to the increasing air-sea CO_2 difference and sustained biological removal. Improved understanding of processes regulating seasonal variability of oceans is essential for reliable forecasting of multi-decadal response of the ocean carbon cycle to climate change.

A bay-wide self-regulated pH buffer mechanism in response to eutrophication and acidification in Chesapeake Bay

Su, Jianzhong (University of Delaware) jzsu@udel.edu
Wei-Jun Cai (University of Delaware), Jean Brodeur (University of Delaware), Baoshan Chen (University of Delaware), Najid Hussain (University of Delaware), Yichen Yao (University of Delaware), Chaoying Ni (University of Delaware), Jeremy Testa (Chesapeake Biological Laboratory), Ming Li (Horn Point Laboratory), Xiaohui Xie (Horn Point Laboratory), Wenfei Ni (Horn Point Laboratory), K. Michael Scaboo (University of Delaware), Yuanyuan Xu (University of Delaware), Jeffrey Cornwell (Horn Point Laboratory), Cassie Gurbisz (St. Mary's College of Maryland), Michael S. Owens (Horn Point Laboratory), George G. Waldbusser (Oregon State University), Minhan Dai (Xiamen University), W. Michael Kemp (Horn Point Laboratory)

Additions of CO_2 and acid from the atmosphere, biological respiration, and oxidation of reduced chemical species have led to enhanced acidification in estuarine and coastal waters. However, less is known about how eutrophic and seasonally hypoxic water bodies resist coastal acidification. Using calcium and carbonate chemistry data from the Chesapeake Bay, geochemical model analysis, and mineralogical analysis, we reveal a bay-wide self-regulated pH buffer mechanism via spatially-decoupled $CaCO_3$ formation and dissolution to resist coastal eutrophication and acidification. In summer, strong photosynthesis of submerged aquatic vegetation (SAV) in the uppermost bay and alongshore shallow areas assimilates considerable nutrients, and generates super high pH and $CaCO_3$ saturation state environments, which facilitate abiotic and biotic $CaCO_3$

formation. These $CaCO_3$ solids are subsequently focused into the corrosive subsurface water of seaward regions, and dissolve to buffer pH decreases caused by aerobic respiration, thus providing relatively stable pH conditions. This SAV-driven pH buffer mechanism will only be amplified with future nutrient load reductions and SAV recovery. Our study demonstrates that coastal ecosystems can further promote their own recovery in complex, sometimes unpredictable ways as humans decrease anthropogenic stressors by policy management.

Quantifying processes controlling the surface water carbon dynamics: Case study at the PN Line Time Series data and HOTS Station

Tsao, Shou En (Institute of Oceanography, National Taiwan University) samueltsao@gmail.com
P.Y. Shen (Institute of Oceanography, National Taiwan University), C.M. Tseng (Institute of Oceanography, National Taiwan University)

The East China Sea being one of the largest continental shelf sea and a strong sink for atmospheric CO_2, is a region of complex physical and biogeochemical interaction heavily influenced by both the Changjiang and the Kuroshio. In the past while many studies show that strong biological activity in Changjiang river plume support a strong carbon sink especially in summer, few studies have been made to investigate the carbonate chemistry pattern further away in the Kuroshio dominated region. We organized DIC, TA as well as the hydrography data measured by the JMA from 2010-2017 at the PN-line as a time series data representing the carbonate chemistry for the Kuroshio surface water within the ECS. Our aim is to understand the dynamical controls of surface water carbon for the more ocean-dominated water away from the Changjiang to help us better understand the mechanism for the CO_2 air sea flux in the ECS. We present a simplified model incorporating gridded satellite and insitu observation data to model a continuous DIC and pCO_2 time series, and by decomposing salinity change (dS) into evaporation/precipitation (dS ep) and physical mixing(dS phy), we quantify the dominant processes controlling surface water DIC at different season: air sea exchange, biological uptake, Precipitation/evaporation, mixing. We compare the results from the PN-line with the results at the HOTS station with the same methodology applied and found that the surface water carbon in the PN-line is on average lower due to higher primary production. In addition, the DIC time series shows a comparatively larger seasonal variability due to precipitation/evaporation process and mixing process, which is primarily due to the clear wet and dry seasonal pattern in the monsoon area. Our results suggest that at a consideration of the salinity effect on DIC and TA may provide improvement for more accurate estimation in modelling air sea flux.

Plenary Session: Carbon cycle feedbacks from the seafloor

Porewater alkalinity in the Bay of Cádiz (north east Atlantic)

Guerra, Roberta (University of Bologna, Italy) roberta.guerra@unibo.it
Silvia Montanari (University of Bologna, Italy), Teodora Ortega (Universidad de Cádiz, Spain)

Recent studies have debated the potential importance of alkalinity production in shallow coastal sediments to the global ocean alkalinity budget, suggesting that the benthic alkalinity source could act as negative feedback to rising atmospheric CO_2 conditions and ocean acidification. At present, the limited quantitative understanding of benthic alkalinity fluxes from shallow coastal areas contrasts with the potential significance of coastal sediments to the global carbon cycle.

This study was conducted in the Bay of Cádiz (30°31' N, 6°15' E), a shallow coastal ecosystem covering an area of 152 km^2 (max. depth of 7 m) connected to the North East Atlantic. Cores of surface sediment and near-bottom waters were collected in Summer 2016 at two locations (RSP and SPC) within the Bay of Cádiz. Concentrations of carbonate and non-carbonate (dissolved ammonia, phosphate, silicate, borate and sulfate) constituents of total alkalinty (AT) were analyzed in near-bottom and pore water and their sediment-water diffusive fluxes (J) were estimated using Fick's Law.

Pore water AT increased with depth, as did the concentrations of other parameters (excluding sulphate), and ranged from 3240 and 21,240 µmol/kg and 3545 and 6130 µmol/kg at RSP and SPC, respectively. Total concentration of non-carbonate alkalinity (N-CIBs) in pore water followed the same trend, varying between 7.1 – 172 and 7.2 – 45 µmol/kg, respectively, with N-CIBs accounting for 0.2 – 1.1 % of AT at RSP, and 0.3 - 0.7% of AT at SPC.

The benthic alkalinity generation in the Bay of Cádiz varied from 280 to 2900 µmol/m^2/day, and was in the range of alkalinity effluxes measured in the coastal sediments of the Baltic Sea and the North Sea; AT efflux was dominated by carbonate alkalinity with non-carbonate inorganic bases (N-CIBs) contributing as low as 1 -3 %. The alkalinity release from the sediment in the Bay of Cadiz could have a significant impact on the carbonate system, and thus on the pCO_2 regulating the exchange of CO_2 between the atmosphere and the sea in the coastal North East Atlantic.

Anomalous >2000 year old surface ocean radiocarbon points to increased carbon flux from seafloor during deglaciation

Rafter, Patrick (UC Irvine) prafter@uci.edu
José D. Carriquiry (UABC), Juan-Carlos Herguera (CICESE), Mathis P. Hain (UCSC), Evan A. Solomon (UW), and John R. Southon (UCI)

Seafloor volcanism may influence ice age terminations by increasing the global inventory of the greenhouse gas CO_2. However, the case for increasing CO_2 flux from deep-sea volcanism requires: (i) evidence of variable C flux and (ii) explaining why CO_2 flux did not lower global seawater pH. Here, we construct a regional, glacial-interglacial carbon budget of the volcanically-active Gulf of California using microfossil ^{14}C reconstructions and find results consistent with the addition of geologic carbon related to local seafloor volcanism during the deglaciation. Given that sedimentary carbonates are generally preserved during the deglaciation, we argue the added carbon was in the form of ^{14}C-free bicarbonate associated with known Gulf sedimentary processes including magma-driven alteration of deep sediments and microbial oxidation of thermogenic methane.

Plenary Session: The effect of size on ocean processes (allometry) and implications for export

Grazer-mediated coexistence of competing phytoplankton species using the Kill-the-Winner functional response

Archibald, Kevin (Woods Hole Oceanographic Institution) karchibald@whoi.edu

One mechanism that supports the high diversity that is observed in phytoplankton communities is grazing pressure by zooplankton. Grazing promotes diversity by allowing coexistence between competitors in situations which would otherwise lead to competitive exclusion and extinction of all but the most fit species. We used the "Kill-the-Winner" functional response to show how grazer preference and switching behaviors by zooplankton can increase diversity in a size-structured nutrient-phytoplankton-zooplankton (NPZ) model. We examined the theoretical mechanisms that allow coexistence and determined the parametric criteria for coexistence under a variety of different grazing scenarios. We also identified potential problems with the functional response related to emergent behaviors that result in non-intuitive biological dynamics.

Episodic particle flux: A sampling artifact?

Estapa, Meg (Skidmore College) mestapa@skidmore.edu
Melissa Omand (University of Rhode Island), Colleen Durkin (Moss Landing Marine Laboratory)

The distribution of sinking particle flux in time and space may reflect the patchiness of processes that contribute to the biological carbon pump. However, characterizing the true, spatiotemporal variability in particle flux is complicated by the different sampling scales of observational technologies. We show data from several recent studies that illustrate how the measured variability in particle flux is influenced by the sampling scale and the size distribution of sinking particles.

During winter 2017 in the California Current, an upward-looking timelapse camera mounted beneath a sediment trap with a 72 mm diameter gel collector was co-deployed alongside a transmissometer used as an optical sediment trap (OST), with sampling beam cross-section of ~7 mm. A timeseries of cumulative particle area flux subsampled from the camera images qualitatively resembles the optical attenuance flux timeseries from the transmissometer,

suggesting that time variability in optical attenuance flux measured over the beam area reflects the arrival of large, rare particles. For a given flux size distribution, we show that there is an optimal minimum sampling area that will capture the 'true' flux timeseries for this size distribution.

We test this idea using data collected during the 2019 EXPORTS campaign in the North Pacific, using the variance-to-mean ratio of particle attenuance (or cross-sectional area) flux as a measure of flux variability. We compare observations collected using subsampled gel traps and co-deployed OSTs at different times during the course of the month-long cruise to determine whether these methods are sufficient to identify periods of true episodicity in the biological pump.

Running PCA on the world ocean

Oddo, Matias (The University of British Columbia) moddo@eoas.ubc.ca

As terrestrial animals we know of land ecoregions like grasslands, deserts, tundras, and rainforests. It is the variability of nutrients and energy that differentiates one ecoregion from another. But what are the ecoregions of the ocean? Regrettably, the most widely used oceanic partitions, like EEZs, are not based in ecologically-meaningful criteria. In order to study and steward marine resources, the boundaries between ecoregions should be congruent with an ecosystem's ability to support life, which is in turn determined by the energetic and nutritional signature of the local seawater. This present study successfully applies unsupervised machine learning to a myriad of biogeochemical World Ocean sea surface data - first Principal Component Analysis (PCA) and then hierarchical clustering - to identify the location and strength of emergent boundaries between marine ecoregions.

Quantitative size and biomass distributions from particle images: An improved algorithm applied to IFCB observations

Sosik, Heidi (Woods Hole Oceanographic Institution) hsosik@whoi.edu
Emily E. Peacock (Woods Hole Oceanographic Institution), E. Taylor Crockford (Woods Hole Oceanographic Institution), Kevin Archibald (Woods Hole Oceanographic Institution), Bethany Fowler (Woods Hole Oceanographic Institution), Alexi Shalapyonok (Woods Hole Oceanographic Institution) and Collin S. Roesler (Bowdoin College)

Automated imaging is a powerful approach for detailed characterization of plankton and other particles that impact ocean optical properties, structure food webs, and influence carbon cycling and export processes. Quantitative interpretation of images is essential to produce size and biomass estimates that are unbiased and consistent across different particle types and different measurement systems. Here we show step-by-step evaluation of a new algorithm for analysis of Imaging FlowCytobot (IFCB) data and show that it produces quantitative particle sizes that are consistent with independent assessments. We recommend that this new algorithm (ifcb-analysis, v4) should replace the current standard (v2) in the IFCB user community for applications where quantitative particle sizing is a priority. All IFCB data collected during EXPORTS and SPIROPA cruises in 2018 have been reprocessed and new products are available from the IFCB dashboard (https://ifcb-data.whoi.edu/EXPORTS; https://ifcb-data.whoi.edu/SPIROPA).

Environmental controls on pteropod metabolism along the Western Antarctic Peninsula

Thibodeau, Tricia (Virginia Institute of Marine Science) psthibodeau@vims.edu
Deborah K. Steinberg (Virginia Institute of Marine Science), Amy E. Maas (Bermuda Institute of Ocean Science)

The pteropod (pelagic snail), *Limacina helicina antarctica*, is one of the most abundant zooplankton taxa in the WAP and is an important grazer of phytoplankton and potential prey for higher trophic levels. However, little is known about long-term and regional environmental impacts, such as warming and food availability, on *L. antarctica* metabolism in the Southern Ocean. The Western Antarctic Peninsula (WAP) is a highly dynamic and productive region of the Southern Ocean that has undergone rapid warming and significant change, with unprecedented increases in air and sea surface temperature and ocean heat content in the past half century. Therefore, this region represents a natural laboratory in which gradients of environmental influences can act as analogs for predicted future change in other regions of the Antarctic. In addition, there are few recorded metabolic rates for *Limacina* spp., which are important for determining allometric relationships describing its contribution to biogeochemical cycling. We measured the effects of shifting food availability and seawater temperature on *L. antarctica* metabolism (respiration and excretion) by conducting shipboard experiments exposing L. antarctica to decreased phytoplankton (food) and elevated temperature conditions. Highest respiration rates were observed under higher temperature and lower food conditions. Respiration and urea excretion trends were similar with highest rates for both recorded ~4°C. Ammonium excretion rate increased linearly with increasing temperature and dissolved organic carbon excretion rate was highest under low food conditions. Phosphate excretion rate was not significantly different among treatments. These insights into the metabolic response of zooplankton to ocean variability increase our understanding of natural system dynamics and potential future response to climate change.

Topic: EXPORTS/Biological Pump

EXPORTS: using high resolution studies of thorium-234 at Ocean Station PAPA to elucidate spatial and temporal variability in particle export and attention

Buesseler, Ken (Woods Hole Oceanographic Institution) kbuesseler@whoi.edu

C. Benitez-Nelson (U. So. Carolina, W. Burt (U. Vancouver), S. Clevenger (WHOI), J. Drysdale (WHOI), C. Durkin (MLML), M. Estapa (Skidmore), R. Francois (U. Vancouver), M. Omand (URI), L. Presplandy (Princeton), M Roca-Marti (WHOI), B. Umhau (U. So. Carolina), A. Wyatt (Princeton)

The EXPORTS (Exports Processes in the Ocean from RemoTe Sensing) Program focuses on linking remotely sensed properties to the physical, chemical, and biological regime that controls the magnitude and composition of material that is transferred from surface waters to depth. To this end, we used the naturally occurring radionuclide thorium-234 (half-life = 24.1 d), as a tracer of sinking particle fluxes. The disequilibrium between ^{234}Th and its soluble parent, uranium-238, provides quantitative information on particle export and remineralization at scales similar to the physical and biological processes that influence particulate carbon (PC) and associated elemental fluxes. We present results from over 850 measurements of ^{234}Th as part of the first NASA supported EXPORTS cruise in the NE Atlantic at Ocean Station PAPA, as well as additional ^{234}Th data collected two weeks later as part of the Canadian Line P program. Our high resolution vertical (13 -18 depths), horizontal (17 -19 stations) and temporal (56 profiles in 28 days) sampling allowed us to map zones of particle formation, remineralization, and flux in a Lagrangian fashion that will be linked to other EXPORTS measurements. Remarkable consistency across ^{234}Th profiles suggests that variability in the processes that lead to particle flux are relatively small during this time of year and fluxes are relatively low. Closer examination of PC/^{234}Th ratio on sinking particles collected using in situ pumps provides insight into how PC fluxes have varied in response to changes in the biogeochemical regime. Overall, the maximum PC flux is estimated to be 5 mmol C/m^2/d, with rapid attenuation below the euphotic zone. Overall the site has a low efficiency for the biological carbon pump.

A visual tour of carbon export pathways by sinking particles across ocean basins, depth, and time

Durkin, Colleen (Moss Landing Marine Laboratories) cdurkin@mlml.calstate.edu
Ken Buesseler (Woods Hole Oceanographic Institution), Ivona Cetinic (NASA Goddard Space Flight Center), Margaret Estapa (Skidmore College), Christine Huffard (Monterey Bay Aquarium Research Institute), Melissa Omand (University of Rhode Island), Jessica Sheu (San Jose State University), Ken Smith (Monterey Bay Aquarium Research Institute), Stephanie Wilson (independent scholar)

We observed and quantified the biological mechanisms of carbon export via sinking particles through a variety of particle-resolving imaging methods employed across ocean basins from the upper mesopelagic to the abyssal seafloor. In the upper mesopelagic, sinking particles were collected by drifting sediment traps containing gel layers that were deployed for between 1 and 5 days at various locations the North Atlantic and North Pacific. On the abyssal seafloor, sinking particles were imaged by the "Sedimentation Event Sensor", a bottom-moored imaging sediment trap that resolves changes in flux over time at a single location off coastal California (Station M). In the subtropical North Pacific, detrital aggregates dominated carbon flux into the mesopelagic. In contrast, carbon flux into the mesopelagic in the coastal and subarctic North Pacific was dominated by sinking fecal pellets produced by crustaceous and gelatinous zooplankton. At

abyssal depths, sinking carbon was primarily composed of detrital aggregates during the winter and of salp and crustacean fecal pellets during the spring. In the North Atlantic at the New England shelf break, carbon flux into the mesopelagic was dominated by sinking phytodetrital aggregates in the fall and crustacean fecal pellets in the early summer. Different particle types attenuated differently with depth. These observations resolve particle-specific mechanisms of the biological carbon pump across environments, seasons, and how they change with depth. These data could help improve mechanistic models of the ocean carbon cycle.

Climatological Context for the 2018 North Pacific EXPORTS field campaign

Long, Jacqueline (MBARI) jlong@mbari.org
Andrea J. Fassbender (MBARI), William Z. Haskell (MBARI)

Remote sensing, biogeochemical (BGC) profiling float, and mooring observations are used to develop climatologies of upper ocean biology, chemistry, and physics near Ocean Station Papa (OSP), providing broader context for the August 2018 NASA EXPORTS field campaign. Commonly applied satellite algorithms for computing net primary production and e-ratio are paired to create nine climatological estimates of carbon export from ~17 years of Moderate Resolution Imaging Spectroradiometer (MODIS) remote sensing observations. Similarly, ~10 years of historical biogeochemical profiling float observations from the region are used to make climatologies for chemical and physical ocean variables. 2018 satellite and profiling float observations are then compared with the aforementioned climatologies to determine how "normal" ocean conditions were during the field campaign year, relative to the long-term mean. Additionally, the newly deployed BGC profiling floats in the region are equipped pH sensors from which sea surface pCO_2 values can be estimated. These estimates are compared to sea surface climatologies of pCO_2 developed from >10-years of NOAA OSP mooring observations. This contextual analysis is supporting ongoing profiling float and glider research related to the NASA EXPORTS field campaign in the North Pacific.

Zooplankton metabolism, active flux, and contribution to AOU in the NE Pacific Ocean

Maas, Amy (Bermuda Institute of Ocean Sciences) amy.maas@bios.edu
Andrea Miccoli (BIOS), Joseph Cope (VIMS), Karen Stamieszkin (VIMS), Deborah Steinberg (VIMS)

The structure of the planktonic food web plays a fundamental role in regulating air-sea exchange of carbon dioxide (CO_2) and the export of organic C to the deep ocean (the biological pump). One of the major pathways for flux of CO_2 from the surface to the deep is via active transport by migration of zooplankton. Diel vertically migrating zooplankton feed in the surface waters at night and metabolize this ingested carbon in the mesopelagic zone during the day as respiratory CO_2, dissolved organic carbon (DOC) and fecal pellets (POC). Active transport is arguably the least sampled of the export pathways, in part due to the difficulties of determining community metabolic rates. Diel vertical migrators, as well as full-time residents of the mesopelagic zone, also contribute to the patterns of apparent oxygen utilization (AOU) and metabolism in this zone. The objective of this work was to compare methodologies for quantifying zooplankton active flux and midwater metabolism. Zooplankton were collected in the subarctic NE Pacific as part of the NASA EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) project. We conducted individual species metabolic experiments under in situ conditions as well as enzymatic analyses of the electron transport system (ETS) from whole community samples. These were scaled to community flux based on allometric assumptions and zooplankton biomass measurements from vertically stratified net tows (MOCNESS). As predicted by allometry, smaller size classes exhibited higher weight-specific respiratory capacity in ETS assays. Metabolic experiments validated allometric relationships for respiratory CO_2, while migrator DOC excretion indicated higher DOC production than predicted for some taxonomic groups.

Tight coupling between herbivorous predation and phytoplankton production in the oligotrophic North Pacific (EXPORTS)

McNair, Heather (URI Graduate School of Oceanography) hmcnair@uri.edu
Françoise Morison, Ewelina Rubin, Susanne Menden-Deuer (All URI Graduate School of Oceanography)

Grazing by herbivorous protists (microzooplankton) directly affects primary and export production. Yet predictive understanding of this key ocean carbon export variable remains limited. To better resolve predation impacts on primary production, and phytoplankton abundance and size spectra, we quantified phytoplankton growth and loss rates within the interdisciplinary efforts of the North Pacific EXPORTS cruise. During the cruise, picoeukaryotes and Synechococcus dominated the phytoplankton community. Concurrent measurements of phytoplankton growth and protistan herbivory experiments within the euphotic zone showed primary production was rapidly consumed by predation with a strong proportionality between growth rates (-0.1 to 0.4 d^{-1}) and grazing rates (0 to 0.6 d^{-1}). On balance, both growth and grazing rates were low (<0.2 d^{-1}) and tightly coupled. However, group-specific predation rates differed with size-selective grazing preferentially removing larger cells, such that the grazing rate on nanoeukaryotes was three times that of Synechococcus. Below the euphotic zone where phytoplankton were unable to grow, we measured grazing rate of 0.005 d^{-1} using a novel method. These combined results suggest that while phytoplankton growth is likely resource limited in the euphotic zone, herbivorous protists grazing removes any new phytoplankton production and continues to contribute to phytoplankton losses continue below the euphotic zone. The size-specific grazing rates suggest that grazers play a key role in structuring the size spectrum of the phytoplankton community. These results establish grazing as a key component of driving both the biomass and size-structure of the surface phytoplankton community as the source for export production.

Polonium-210 and Lead-210 as tracers of particle export and attenuation on the first EXPORTS cruise at Station PAPA

Roca Martí, Montserrat (Woods Hole Oceanographic Institution) mrocamarti@whoi.edu
Meg Estapa (Skidmore College), Pere Masqué (Edith Cowan University & Universitat Autònoma de Barcelona), Ken Buesseler (Woods Hole Oceanographic Institution)

The EXPORTS (EXports Processes in the Ocean from RemoTe Sensing) Program focuses on linking remotely sensed properties to the processes that control the export of ocean primary production from surface waters to depth. Here we present preliminary results from the naturally-occurring radionuclide pair ^{210}Po /^{210}Pb as part of the first NASA supported EXPORTS cruise in the NE Pacific at Station PAPA (August-September 2018). ^{210}Po and ^{210}Pb have been used to quantify sinking particle fluxes and their attenuation below the euphotic zone at a seasonal scale. These estimates will be compared to other methods with shorter time scales, ^{234}Th (weeks) and sediment traps (days), with the aim to provide a wider perspective into particle export and remineralization in the upper 500 m of the water column. Remarkable consistency between seawater profiles of ^{210}Po and ^{234}Th sampled over a period of three weeks suggests that the variability in the processes that lead to particle flux was relatively small over the summer. Particulate organic carbon (PC) fluxes have been estimated using the PC/^{210}Po ratio on size-fractionated particles collected using in-situ pumps. Overall, we show low PC export fluxes (< 5 mmol C m^{-2} d^{-1}) at 100 m decreasing rapidly below the well-lit surface ocean.

The EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign

Siegel, David (UC Santa Barbara) david.siegel@ucsb.edu
Ivona Cetinic (NASA GSFC) and the EXPORTS Science Team

The goal of the EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign 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. EXPORTS builds upon decades of NASA- and NSF-supported research assessing global net primary production from space and is designed to deliver science of significant societal relevance by better characterizing the fate of organic carbon in the ocean from future satellite ocean color instruments. The first EXPORTS field deployment was conducted in August-September 2018 near Station P in the Northeast Pacific Ocean. This poster presentation will present the Northeast Pacific field deployment focusing on the coordinated deployment of multiple ships and robots to understand and quantify the multiple pathways by which fixed organic carbon is exported into the ocean interior.

Mesozooplankton community structure and diel vertical migration in the subarctic NE Pacific Ocean, Station P

Steinberg, Deborah (Virginia Institute of Marine Science) debbies@vims.edu
Karen Stamieszkin (Virginia Institute of Marine Science), Amy Maas (Bermuda Institute of Ocean Sciences), and Joseph Cope (Virginia Institute of Marine Science)

The structure of zooplankton communities plays a key role in determining the fate of net primary production, the composition and sinking rate of particles, and thus the export of organic matter to the deep ocean. We characterized vertical structure and diel changes in zooplankton size-fractioned biomass and species abundance at Station P in the subarctic NE Pacific in August-September, 2018 as part of the NASA EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) project. We used a MOCNESS to conduct depth-stratified day/night net sampling through the epi- and mesopelagic zones (0-1000m). The majority of the biomass was in the larger (>2mm) size fractions, typical for zooplankton fauna of subarctic regions. Diel vertical migration (DVM) is evident in all day/night pairs, with a mesopelagic biomass peak in the day usually at 300-400m, and the highest increase in biomass in the surface 0-50 m layer waters at night (mean night:day biomass ratio = 7.7). Salps were strong migrators, residing between 300-750m during the day, and migrating into the surface 50 or 100m at night. We were surprised to find a consistent, short-distance DVM by Neocalanus cristatus copepods from the 50-100m layer in the day into the top 0-50m at night; this species is also a key seasonal migrator in this region. While biomass size structure was typical of subarctic fauna, epipelagic biomass at Station P during EXPORTS was up to an order of magnitude lower than measured in the western subarctic Pacific in August in a previous study (VERTIGO), likely due to lower (Fe-limited) productivity at Station P. These data will be used for scaling up our experimental work on zooplankton fecal pellet production and metabolism to the community level to quantify the importance of zooplankton-mediated export pathways in this region.

Spatial and temporal variability of the biological pump in the northeast Pacific

Wyatt, Abigale (Princeton University) awyatt@princeton.edu
Laure Resplandy (Princeton University), Ken Buesseler (WHOI)

We examine the variability of the ocean biological pump, a process that exports particulate carbon from the surface to the deep ocean, using observations from the NASA EXPORTS cruise, historical data and results from a high-resolution GFDL Earth System Model. Preliminary results indicate that the model captures surface temperature mesoscale variability (1-100 km) observed during the cruise and the seasonal cycle captured by historical data sets. We also see model phytoplankton and zooplankton biomass have higher interannual variability, coincident with higher export variability during the cruise period.

Topic: General OCB Science

Zooplankton community response to seasonality at BATS by metabarcoding

Blanco-Bercial, Leocadio (Bermuda Institute of Ocean Sciences) leocadio@bios.edu

The diversity and specific composition of zooplankton communities have a direct effect on the ecosystem services (e.g. carbon export) and structure of ocean food webs. In areas where diversity is high, a detailed characterization of the whole community can represent a hurdle that prevents a complete understanding of those processes and interactions. One such region is the Sargasso Sea, where zooplankton diversity is among the highest in the world oceans. As a consequence, at the Bermuda Atlantic Time-series Study location, most research has focused on zooplankton biomass or on particular groups. To provide new insight into the total community composition at the BATS site, in this study the zooplankton community is investigated by means of metabarcoding of the 18S V9 hypervariable region. Day and night samples from a full year (2015) show the signature of diel vertical migration, driven by those groups with a higher representation in the metabarcoding reads. Seasonal ordination was detected after transformation and, similarly to temperate regions, four seasons could be differentiated based on community composition (post-spring bloom, summer stratification, fall mixing event and winter mixing), with no correspondence with the zooplankton biomass patterns. This community ordination showed correlation with the measured vertical flux, highlighting the need of understanding community regimes, even in theoretically stable regions such as the oligotrophic ocean, to advance in our understanding of zooplankton-mediated processes.

Remote sensing-derived zooplankton biomass and grazing: Analyzing errors associated with models

Chaichitehrani, Nazanin (UMCES, Horn Point Lab) nchaichitehrani@umces.edu
Victoria J. Coles (UMCES, Horn Point Lab), Taylor Shropshire (Florida State University), Michael R. Stukel (Florida State University), Greg Silsbe (UMCES, Horn Point Lab)

Marine zooplankton occupy multiple trophic levels in pelagic food webs. Zooplankton play a central role in the ocean carbon cycle and mediate carbon sequestration in the ocean. However, it is laborious to quantify spatio-temporal distributions of zooplankton from ships. Satellite ocean color datasets provide us with global synoptic surveys of phytoplankton dynamics with much greater temporal and spatial coverage than can be done with field sampling. Unlike phytoplankton, zooplankton do not depend on pigments for energy capture thus measurements from ocean color satellites can not directly measure their abundance. However, spatial and temporal information on zooplankton distribution can potentially be obtained through models that link satellite-derived products (e.g., phytoplankton biomass, size spectra, and net primary productivity) to estimate of zooplankton biomass and grazing rates. Yet, the uncertainties and error associated with these models and their input products are not well constrained. Here we test two such models; (1) a food-web model developed by Siegel et al. (2014) that derives a mass

balance in the mixed layer and (2) an inversion of slightly simplified ecosystem model equations (here the North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) (Kishi et al., 2007)). These two models estimate zooplankton grazing in three size classes as a function of parameters which can be derived from remote sensing. The estimated grazing rates from the food-web model and NEMURO and zooplankton biomass from NEMURO are compared with modeled grazing rates and zooplankton biomass from a coupled NEMURO-HYCOM model in order to determine uncertainty estimates. We evaluated the error associated with the entrainment term in the food-web model, and the results support that the food-web performed better without including the entrainment processes in the simulation of zooplankton grazing rates in a system like the Gulf of Mexico. Uncertainties related to errors in estimating mixed layer depth and to the method for calculating the growth rate of phytoplankton are also evaluated. The two models are applied to satellite data to estimate zooplankton grazing rates and biomass in the Gulf of Mexico. This study demonstrates how remotely-sensed synoptic observations of zooplankton distribution may provide a means of assessing the role of fronts and eddies in driving trophic transfer in the ocean.

Glacial deep ocean deoxygenation driven by biologically enhanced air-sea disequilibrium

Cliff, Ellen (University of Oxford) ellen.cliff@earth.ox.ac.uk
Samar Khatiwala (University of Oxford), Andreas Schmittner (Oregon State University)

A long-held assumption in studies of ocean (de)oxygenation is that air-sea exchange of O_2 (especially when compared to CO_2) is sufficiently rapidly that surface ocean oxygen is near equilibrium. However, the recent release of World Ocean Atlas 18 and float data demonstrate widespread O_2 disequilibrium with large regions showing seasonal or yearlong over- and under-saturation. Here we use an observationally-constrained earth system model to quantify the physical and biological contributions to equilibrium and disequilibrium of O_2 using a novel decomposition method. The biological component of O_2 is split into disequilibrium and soft tissue regeneration components. Applying this approach to the study of glacial-interglacial O_2 variations, we find only a 6% (27 Pmol) increase of O_2 due to changes in physics from the pre-industrial (PI) to the Last Glacial Maximum (LGM) while a net loss of 32 Pmol O_2 is observed. This loss is driven by the enhancement of biologically mediated O2 disequilibrium which increases from contributing removal of 10% of O_2 in the PI to removing nearly a third of the O_2 inventory in the LGM. Our results are largely consistent with an updated qualitative set of O_2 proxy data. Perturbation experiments show that lower temperatures and circulation changes (which decreased export production) increased O_2 in the LGM model while enhancement of biologically mediated disequilibrium caused by sea ice and higher iron fluxes lead to oxygen depletion with the latter effect dominating. This finding is contrary to the widely held notion that deep ocean glacial de-oxygenation is caused by increased efficiency of the biological pump.

Investigating zooplankton mediation of sinking particle flux in the Sargasso Sea

Cruz, Bianca N. (Arizona State University) susanne.neuer@asu.edu
Susanne Neuer (Arizona State University), Lindsey Cunningham (Arizona State University), Rachel Parsons (Bermuda Institute for Ocean Sciences), Leocadio Blanco-Bercial (Bermuda Institute for Ocean Sciences) and Amy Maas (Bermuda Institute for Ocean Sciences)

Plankton derived, microscopic and macroscopic aggregates make up the majority of the particulate organic carbon (POC) flux in the ocean. While the quantity and composition of export flux is generally well known, we lack an understanding of the relative contribution of different particle types to flux, as well as the origin and transport mechanism of the sinking particles. When measuring the contribution of phytodetrital, fecal pellet-nucleated aggregates, and fecal pellets to carbon flux in Spring 2018 at the Bermuda Atlantic Time-Series Study station (BATS) using gel-traps, we found phytodetrital aggregates to dominate particle number, but fecal pellet-nucleated aggregates and fecal pellets to dominate POC flux below the euphotic zone. At the same time, incubating euphotic zone water in roller tanks from the same cruise did not result in formation of visible aggregates. These two observations lead us to hypothesize that zooplankton mediation of particle formation is necessary to produce sinking particles in this oligotrophic ocean region. In addition to fecal pellets, this could be in the form of discarded feeding houses, slime produced by pteropods and by crustacean molts which are often seen embedded in our gel trap aggregates. In this presentation, we will present first results of a recent experiment that tested the above hypothesis by adding various species of pteropods and crustaceans to roller tanks for 12 hours before the start of the incubation period. Despite the experiment coinciding with a low productivity period in the Sargasso Sea, we could find evidence of fecal pellet mediated aggregates in the crustacean treatments as well as the remains of discarded prey in the pteropods treatments. We will discuss the results of this experiment in the context of insights gained from the particle spectrum and the microbial community found in gel traps deployed during the same season.

Geostatistical analysis of mesoscale ocean biophysical variability in the western North Atlantic from field observations, remote sensing and numerical modeling

Doney, Scott (University of Virginia) sdoney@virginia.edu
Rachel Eveleth (Oberlin College), David Glover (Woods Hole Oceanographic Institution), Ivan Lima (Woods Hole Oceanographic Institution), Matt Long (National Center for Atmospheric Research), Minwei Zhang (University of South Florida), Alison Chase (University of Maine)

The western North Atlantic Ocean is home to one of the largest, most reliable marine biological carbon uptake events each year and as such plays a role in global climate. Technological advances have continued to expose phytoplankton bloom dynamics at increasingly smaller scales. In this study we build off of remote sensing-based investigations, to address how the magnitude and spatial scale of biological patchiness varies in time and space in the North Atlantic using a 0.1 degree eddy-resolving coupled Community Earth System Model simulation. We use the geostatistical semi-variogram approach to quantify the scales of mesoscale variability of surface Chlorophyll concentration in 2-D across the western North Atlantic. This approach exposes a pronounced seasonal cycle in resolved spatial variability in the subpolar gyre with a lagging, though less defined, minimum in spatial range. The mesoscale model compares well against satellite analyses, the two displaying similar regional patterns in resolved variability, though the model expresses a greater magnitude of variability (and coefficient of variation) overall in the subpolar gyre than SeaWiFS and MODIS. Further comparisons of model variability with aircraft and ship-based surveys of surface Chlorophyll from the North Atlantic Aerosols and Marine Ecosystem Study (NAMES) support the conclusion that the model simulation is underestimating true variability when and where chlorophyll concentrations are low, while also overestimating patchiness during larger blooms.

Metabolic remodeling under temperature acclimation: A case study in the Shewanella genus

Dufault-Thompson, Keith (University of Rhode Island) keitht547@uri.edu
Chang Nie (State Key Laboratory of Microbial Metabolism, Shanghai Jiao Tong University, China), Fengping Wang (State Key Laboratory of Microbial Metabolism, Shanghai Jiao Tong University, China), Ying Zhang (University of Rhode Island)

Temperature has influences on microbial community composition and activity and can affect how larger scale biogeochemical cycles function within ecosystems. Acclimation to different growth temperatures in bacteria involves physiological changes at multiple levels including broad transcriptional adjustments, production of temperature adapted enzymes, and shifts in macromolecule composition. A central component of acclimation to different environments is the organism's ability to modulate its metabolic processes to cope with the new conditions. Specific changes in metabolism, like the production of cryoprotectant compounds, can be directly linked to their physiological significance; however, an increasing number of case studies have demonstrated the potential roles of other metabolic processes, including the central metabolism, in mediating homeostasis at different temperatures. Bacteria of the Shewanella genus are notable for their diverse metabolic capabilities and adaptations to a wide range of temperature regimes, from coastal waters, to deep marine sediments, and to the polar regions. Here, we analyze the molecular mechanisms underlying such metabolic flexibility by using a psychrophilic organism of the Shewanella genus, *S. psychrophila* WP2 (WP2), as a model to investigate the modulation of metabolic pathways during temperatures acclimation. A genome-scale model (GEM) was reconstructed based on ortholog mapping to existing models of Shewanella followed by the manual curation of species-specific genes. Thermodynamic constraints were applied in the simulation of metabolic fluxes, and three distinct temperature regimes were examined through metabolic simulations, including the strain's optimal growth temperature (15°C), the ambient temperature at the site of isolation (4°C), and the maximum reported growth temperature (20°C). The model simulation was matched with concurrent experimental growth measurements and transcriptome profiling. Taken together, this study revealed several metabolic processes contributing to the acclimation of WP2 to different temperatures and highlighted the potential involvement of energy metabolism, amino acids metabolism, and nucleotides metabolism in temperature-mediated metabolic remodeling.

Marine viruses stimulate carbon flux to lower and higher trophic levels

Floge, Sheri (Wake Forest University) floges@wfu.edu
David Fields (Bigelow Laboratory for Ocean Sciences), Jesica Waller (State of Maine Department of Marine Resources), Matthew Sullivan (The Ohio State University)

Ocean virus infections are thought to catalyze the largest single carbon (C) flux from plankton to dissolved organic matter (DOM), and have for decades been predicted to 'shunt' C away from larger organisms and reduce export from the euphotic zone. While virus-mediated release of dissolved organic C (DOC) has been quantified along with a concomitant increase in heterotrophic bacterial growth, the consequent reduction in upward trophic transfer and export has been modeled but not directly measured. Further, the viral shunt paradigm is inconsistent with recent global genetic surveys and modeling that suggest that viruses are correlated with C export from open ocean surface waters. Here we quantitatively evaluate the viral shunt paradigm by measuring how viruses impacted C cycling in laboratory and field microbial communities. Using an isotopically labeled basal picoautotroph (*Ostreococcus tauri*), C flow was traced through a culture-based multitrophic plankton community with and without the lytic *Ostreococcus* tauri virus (OtV5). The data show that viruses stimulated DOC production and bacterial growth, consistent with the viral shunt paradigm, but also increased C transfer from the basal picoautotroph to larger community members, including the mesozooplankter *Acartia tonsa*. In addition, mesozooplankton fecal pellet production rates were higher in the presence of viruses, providing an additional mechanism linking viruses with enhanced C export. Parallel measurements using virus enrichment of a natural Atlantic Ocean plankton community also showed that viruses stimulated C flux both downward to heterotrophic bacteria and upward to mesozooplankton. Together these findings provide baseline data to integrate viruses into ecosystem models and suggest that viruses not only 'shunt' but also 'shuttle' C in complex planktonic food webs.

Distribution of excess alkalinity in the open ocean

Fong, Michael (Scripps Institution of Oceanography) mbfong@ucsd.edu
Andrew Dickson (Scripps Institution of Oceanography)

It has been widely observed, from a large number of carefully calibrated state-of-the-art CO_2 measurements on various cruises in the open ocean, that there exists a systematic discrepancy between directly measured total alkalinity and the value of this parameter as calculated from concurrent measurements of pH and dissolved inorganic carbon. From an analysis of the consistency of CO_2 measurements on four GO-SHIP cruises, we found that part of this discrepancy can be explained by a combination of small systematic errors in the dissociation constants of carbonic acid, the total boron-salinity ratio, and the CO_2 measurements. However, there remains a significant residual discrepancy (an "excess alkalinity") that can only be explained by an unaccounted contribution to the measured total alkalinity. We hypothesize that this unaccounted contribution to total alkalinity may be from an organic source. Our analysis of the excess alkalinity

in three ocean basins suggests that this hypothesized organic alkalinity may be ubiquitous in the open ocean and has a vertical and geographic distribution.

One million matrices: Size-structured modeling reveals in situ phytoplankton dynamics.

Fowler, Bethany (Woods Hole Oceanographic Institution) bfowler@whoi.edu
Michael G. Neubert (Woods Hole Oceanographic Institution), Kristen R. Hunter-Cevera (Marine Biological Laboratory), Andrew R. Solow (Woods Hole Oceanographic Institution), and Heidi M. Sosik (Woods Hole Oceanographic Institution)

The picoeukaryotes are an abundant and diverse group of marine photosynthetic plankton. Understanding their population dynamics is key to understanding the role they play in the marine food web and in global biogeochemical cycling. Phytoplankton vital rates are difficult to quantify in situ due to their large population sizes, short generation times, and high mortality from viral lysis and zooplankton grazing. Building from the work of Sosik et al. (2003), we fit a matrix population model to a 15-year time series of observations of individual cell size and pigmentation. Using the model, we are able to 1) identify apparent populations within the picoeukaryote assemblage, 2) estimate rates of cell division and loss and 3) investigate how those rates change over time. We find that the picoeukaryotes at Martha's Vineyard Coastal Observatory follow a strong seasonal cycle, with division rates ranging from an average of 0.1 day^{-1} in January to 2.1 day^{-1} in August. Division and loss rates are seen to be closely coupled throughout the year and to increase with increasing sea surface temperature in the spring. Over the 24-hour cycle, loss rates are not constant, and our analysis suggests that the picoeukaryotes may be preferentially grazed or subject to viral lysis during daylight hours. This work demonstrates that our population model can be usefully applied to heterogeneous phytoplankton groups and can be a powerful tool for studying their ecology in a natural system.

Remote sensing of global ocean surface phosphate concentrations

Garcia, Catherine (University of California, Irvine) catgar@uci.edu
Toby Westberry (Oregon State University), Michael Behrenfeld (Oregon State University), Adam Martiny (University of California, Irvine)

Regional variations in dissolved inorganic phosphate (DIP) influence cellular physiology, ocean productivity, and cycling between bio-limiting nutrients. However, we have not developed a robust global remote sensing (RS) estimate of surface DIP. Here, we aim to assess the variation in DIP using a mechanistic framework capturing multiple axes of variation including latitudinal, between tropical upwelling vs downwelling regions, among subtropical gyres and between polar oceans. We then matched 34 RS inputs to each axes variation and used artificial neural network analysis to predict the observed distribution of DIP. The RS inputs of sea surface temperature, absorbance at 443nm, physiological iron stress and dust deposition, and sea surface salinity captured 73% of total variation in surface DIP. Uncertainty in predicting ultralow DIP among

oligotrophic regions is improved with high sensitivity measurements but remains a large source of variation. The contribution of two RS inputs associated with iron deposition indicates the importance of micronutrient co-limitation in estimating regional DIP drawdown. By examining the interactions among the inputs and DIP in major ocean biomes, we find an unsupervised neural network model matches our mechanistic understanding. Thus, the combination of a mechanistic model for nutrient supply and demand combined with artificial neural networks provided a robust basis for developing a remote sensing estimation of surface DIP.

Drivers of phytoplankton C:N:P

Hagstrom, George (Princeton University) georgehagstrom@gmail.com
Catherine Garcia (University of California, Irvine), Simon Levin (Princeton University), Adam Martiny (Princeton University)

Phytoplankton stoichiometry (here C:N:P) links ocean carbon to the cycling of other elements, such as nitrogen and phosphorus. Phytoplankton C:N:P varies substantially across ocean biomes and environmental conditions, adding complexity to ocean biogeochemical dynamics and suggesting the need for more advanced quantitative models. Here we develop a trait-based model of phytoplankton C:N:P based on subcellular allocations to photosynthesis, biosynthesis, and nitrogen and phosphorus uptake. This model predicts cellular allocations using local environmental conditions and measures of nutrient supply. We place the model in a Bayesian statistics framework using an extensive global compilation of C:N:P and environmental data. Our model successfully fits the broad patterns of global C:N:P, and also sheds light on competing hypotheses for the drivers of C:N:P that have been difficult to distinguish due to strong environmental covariation. We identify counterintuitive patterns in C:N:P across tropical and subtropical biomes which have outwardly similar environmental conditions and explore how nutrient supply rates can be used to predict C:N:P there. Lastly, we propose that our C:N:P model can be more broadly useful in predicting the dynamics and export of ocean carbon.

Comparing biogeochemical model outputs using neural network ensembles

Holder, Christopher (Johns Hopkins University) cholder2@jhu.edu
Anand Gnanadesikan (Johns Hopkins University)

Earth system models (ESMs) show differences in their outputs because of contrasting intrinsic relationships and variations in the way these limitations interact with the physical model. Visualizing the reasons for the differences in output can be difficult given the time needed to run each simulation. Neural networks have previously been used as emulators in ESMs which greatly reduces the computational time, but few efforts have tried using neural networks to study the differences in ESM output.

We applied neural network ensembles (NNEs) to three versions of a biogeochemical model that were governed by the same biological model, but had variations in their inputs and physical parameters. The NNEs exhibited R^2 values near 0.98 between the predictions and observations. Additionally, when an NNE trained on one version of the biogeochemical model was given the inputs for the other two versions, the R^2 values were equally high.

To study the differences in output between the three versions of the biogeochemical model, we provided each NNE with an artificial set of observations. One predictor was allowed to vary across its min-max range, while the other variables were held at a constant value. This sensitivity analysis showed nearly identical predictions for each variable, regardless of the version used for training each NNE.

Given the success of these preliminary results, our results suggest a potential use for NNEs as diagnostic tools to view differences in apparent relationships between models. In future research, we plan to apply these techniques to models of varying complexity to visualize how variables affect phytoplankton biomass between ESMs.

Interannual comparison of diatom community composition in the Western Antarctic Peninsula

Holland, Laura (University of Rhode Island) lzfilliger@uri.edu
Alexa R. Sterling (University of Rhode Island), Kristen N. Buck (University of South Florida), P. Dreux Chappell (Old Dominion University), Kevin R. Arrigo (Stanford University), Anton Post (Florida Atlantic University), Bethany D. Jenkins (University of Rhode Island)

Diatoms are a large group of eukaryotic phytoplankton that play an important role in Southern Ocean (SO) primary production and biogeochemical cycling. In the SO, their growth is often limited by iron (Fe), a micronutrient required for their photosynthetic apparatus. In the Western Antarctic Peninsula (WAP), a continental shelf break separates Fe-rich inshore waters from high nutrient, low chlorophyll Fe-limited offshore waters. The WAP ecosystem is also heavily influenced by the annual sea-ice retreat that occurs during the summer, relieving phytoplankton of light limitation and changing the surrounding water chemistry. Our previous work in a broader SO area indicates Fe and salinity are important environmental factors in shaping diatom communities, likely due to this annual sea-ice melt. To determine whether these factors shape the surface diatom communities in the WAP region, we used high-throughput sequencing of the variable V4 region of the 18S rDNA amplified with diatom-targeted primers to characterize in situ communities during two early austral summer cruises in 2014 and 2016. Bioinformatic analysis suggests that WAP diatom communities are generally stable between sampling years but differ by their proximity to the WAP coast (inshore versus offshore). Sequences from the genera *Fragilariopsis* and *Corethron* are more abundant within inshore stations, while those from the genera *Pseudo-nitzschia*, *Chaetoceros*, and *Cylindrotheca* are more prevalent in offshore stations. Dissolved Fe (dFe) measurements from both cruises confirm low dFe (<1 nM) concentrations in offshore stations versus higher dFe (>1 nM) concentrations in inshore stations. Comparison of community data and corresponding physicochemical data (Fe, salinity, light availability, etc.) will elucidate major drivers of community composition and whether changes in dFe concentrations correspond to specific diatom assemblages. In addition, trends in community structure will be determined using statistical analyses of co-occurrence data. Diatom genera differ in their cell size,

morphology, frustule (cell wall) silicification, and preference as prey by grazers, making some species more likely to impact carbon sequestration than others. Therefore, assessing diatom community structure will be important for determining species-specific contributions to biogeochemical cycling in the WAP.

The biogeochemical impact of an across-shore filament in the California Current Ecosystem

Kelly, Thomas (Florida State University) tbk14@fsu.edu
Ralf Goericke (Scripps Institution of Oceanography), Mark D Ohman (Scripps Institution of Oceanography), Hajoon Song (Yonsei University), Michael R Stukel (Florida State University)

Coastal upwelling biomes are known for dramatic lateral gradients in nutrient concentrations and biomass due to the complex and intermittent physical forcings acting in the euphotic zone. For example, the coast of California is known for energetic eddies, fronts and coastal filaments. The biogeochemical consequences of these meso- and submesoscale phenomenon has long been an active area of research; yet with ongoing development of higher resolution ocean models, advancements in remote sensing platforms, and improved in situ sampling, there has been growing interest in integrating the effects of these dynamic physical structures into biogeochemical models.

Here we present data from two quasi-synoptic surveys of a coastal filament (width: ~50 km) wherein recently upwelled and coastal waters were transported 100's of kilometers offshore within days. Both surveys, conducted as a part of the CCE-LTER research program consisted of ~400 oblique casts of a towed CTD instrument (SeaSoar) along approximately 800 km of cruise track off the central California coast. These direct observations of T, S, O_2, Chl-a, and beam attenuation were merged with a 3D physical, data-assimilative ocean model (ROMS 4DVARS) to derive across-shore and alongshore fluxes of nutrients, biomass, and particulate organic carbon. We compare these advective fluxes to spatially integrated rates of productivity and find that the across-shore advective input of nutrients led to a 10-fold increase in local primary production within the filament compared to surrounding waters. The mass flux (e.g.., POC) associated with the filament was substantial and transferred up to 8,600 mol C d^{-1} via across-shore advection.

Measuring noble gas fluxes at high wind speeds in the SUSTAIN wind-wave tank

Kinjo, Lumi (Wellesley College) rachel.stanley@wellesley.edu
Andrew Wyatt Smith (University of Miami), Callie Krevanko (Wellesley College), Emily Kopp (Wellesley College), Danielle Aldrett (Wellesley College), Helene Alt (Wellesley College), Brian Haus (University of Miami), Rachel Stanley (Wellesley College)

Gas exchange at high wind speed is not well understood—few studies have been conducted at wind speeds above 15 ms^{-1} and significant disagreement exists between gas exchange models at high wind speeds. In particular, the flux due to bubbles is not explicitly included in many gas exchange models, despite the fact that bubble-mediated gas exchange becomes increasingly important at higher wind speeds. The goal of the research presented here is to quantify air-sea gas exchange under high wind speeds and to examine the relationship between noble gas measurements, bubble spectra, wave-type, and water temperature. Noble gases serve as excellent tracers for this purpose, as they are biologically and chemically inert, and have a wide range of solubility and diffusivity that responds differently to physical forcing.

Over the course of five days in July, 2018, we conducted 35 experiments at the SUrge STructure Atmospheric InteractioN (SUSTAIN) wind-wave tank with wind speeds 20 - 50 ms^{-1}, water temperatures at 20°C, 26°C, and 32°C, and wave conditions including uniform waves (regularly breaking waves) and JONSWAP waves (random, real ocean-like waves). Continuous Ne, Ar, Kr, and Xe ratio measurements were obtained by a Gas Equilibration Mass Spectrometer (GEMS). Additionally, discrete noble gases were collected at the beginning of select experiments and at the end of all experiments for He, Ne, Ar, Kr, and Xe. Bubble size and volume spectra was obtained using an underwater shadowgraph imaging device. Other physical measurements such as continuous salinity, water temperature, wind/wave velocities, and atmospheric pressure were also obtained.

Our result from the conditions with the highest saturation anomalies suggests that steady state saturation anomalies of gases level off as wind speed increases. Additionally, both the temperature dependence of noble gas saturation anomalies and the coherence between bubble surface area spectra and saturation anomalies suggest that partially dissolving bubbles may have an important flux contribution at higher wind speeds. Since the SUSTAIN wind-wave tank is much shallower than the real ocean, we cannot directly apply our results in the ocean to make predictions. Nonetheless, the relationship between gas flux and bubble size spectra, wind, and wave conditions learned from this work provide us with important insights to improve gas exchange models.

Methods to distinguish phytoplankton groups from remote-sensing reflectance in subtropical waters

Lange, Priscila (NASA GSFC / USRA) priscila.lange@nasa.gov
Ivona Cetinic (NASA GSFC/USRA), Giorgio Dall'Olmo (Plymouth Marine Laboratory), Ryan Vandermeulen (NASA GSFC), Aimee Neeley (NASA GSFC), Jeremy Werdell (NASA GSFC)

Primary production in the tropical open ocean is dominated by the smallest phytoplankton, with the contribution of picocyanobacteria and picoeukaryotes alternating as a function of nutrient availability. As nutrients increase in surface waters, towards the equatorial upwelling region and the edges of subtropical gyres, the dominance of picocyanobacteria is suppressed by the contribution of pico- and nano-eukaryotes, until the concentration of nutrients becomes high enough to support the growth of large (micro-) phytoplankton such as diatoms and dinoflagellates. As colored dissolved organic matter (CDOM) and inorganic suspended particles occur in low concentrations in oligotrophic subtropical waters, changes in the spectral shape of remote-sensing reflectance (Rrs) – the normalized spectra of light exiting the water column - are predominantly attributed to varying concentrations of living cells (phytoplankton and bacteria). Furthermore, considering the smooth exponential spectral shape of the absorption by CDOM and the low absorption by seawater in shorter wavelengths of the visible spectrum (400-550 nm), such variations in the shape of Rrs are mostly attributed to the varying absorption and scattering properties of phytoplankton cells in the surface waters of subtropical regions. As part of the NASA PACE mission (Plankton, Aerosol, Cloud, ocean Ecosystem), we investigate mechanisms to use hyperspectral Rrs information to retrieve major phytoplankton groups in the world's oceans. Here we use changes in the Rrs spectral shape at the 400-550 nm region to discriminate areas where phytoplankton communities are dominated by picocyanobacteria or co-dominated by cyanobacteria and picoeukaryotes in subtropical oceanic waters. The second derivative of Rrs hyperspectral signatures was used to emphasize changes in the shape of standardized Rrs curves that are strongly correlated with the contribution of picocyanobacteria or picoeukaryotes in oligotrophic waters. This allowed the detection of a tilt in the Rrs curve at ~455 nm that possibly varies as a function of the availability of CDOM (including amino-acids used by picocyanobacteria) and the absorption of photosynthetic pigments by picoeukaryotes, when these are present. As nanoeukaryotes become more abundant, the absorption of light by their pigments increases in a way that causes a flattening of the Rrs in this spectral region, allowing the discrimination of areas dominated by larger phytoplankton cells (i.e. not picoeukaryotes). This method provides a useful, light-processing tool to discriminate two major phytoplankton groups that present severely different nutrient requirements, thus influencing element paths on biogeochemical cycles. This discrimination can potentially improve biogeochemical models in tropical and subtropical areas. The results provide a broad view of the distribution of these two major phytoplankton groups in oligotrophic waters, which can potentially lead to an improvement of our understanding about the influence of phytoplankton on biogeochemical cycles and the food web dynamics in the subtropical open ocean.

Purified meta-cresol purple dye perturbation: how much will it influence spectrophotometric pH measurement?

Li, Xinyu (University of Delaware) xinyuli@udel.edu
Maribel I. García-Ibáñez (University of Delaware), Baoshan Chen (University of Delaware), Yuanyuan Xu(University of Delaware), Wei-Jun Cai (University of Delaware)

Ocean acidification, a phenomenon of seawater pH decreasing due to increasing atmospheric CO_2, has a vital global effect on the seawater chemistry, marine biology, and global ecosystems. Ocean acidification is a subtle, long-term process, which indicates high-quality pH data with high accuracy and precision are needed to better evaluate and understand this ongoing process. Spectrophotometric pH measurement is the most accurate and precise pH measurement that we know so far. However, it still has some measurement uncertainties due to dye perturbation that needs to be evaluated. This paper would give a comprehensive assessment of the dye perturbation on the seawater sample pH and the correction method to eliminate dye perturbation. We conducted numerical simulations on CO2SYS, a program for seawater CO_2 calculations, to examine the pH changes of seawater samples caused by dye addition and reveal the seawater sample pH change mechanisms. The simulation results suggested that the pH changes of the seawater sample due to dye addition are related to the seawater sample pH, the indicator dye pH and the seawater properties like total alkalinity (TA). We also assessed the empirical dye perturbation correction method using East Coast Ocean Acidification(ECOA2) cruise data. The empirical method of

eliminating dye perturbation may lead to positive uncertainty at high pH and negative uncertainty at low pH. Compared to the numerical simulation results, the field measurement results show larger uncertainties caused by the dye addition. Here, we suggested that the double dye addition experiments should be done under a wide range of pH and total alkalinity samples to eliminate dye perturbation. As for the small number of samples, multiple volume dye addition experiments are recommended. This dye perturbation evaluation and correction will help with acquiring high-quality pH data and detecting the long term anthropogenic-driven changes in the seawater carbonate system over decadal time scales.

Desynchronization between sea ice and phytoplankton bloom in a changing Antarctic

Li, Yun (University of South Florida) yunli@usf.edu
Rubao Ji (WHOI), Meibing Jin (University of Alaska, Fairbanks)

In high-latitude oceans, sea ice can modulate virtually all environmental resources (e.g., light, nutrient) that constrain phytoplankton bloom, and the time synchrony between sea ice and phytoplankton bloom shapes the fundamental seasonal regimes for carbon export and ecosystem structure. Under climate change, the seasonal schedule of sea ice and phytoplankton bloom undergoes considerable changes, leading to ramifications for the imbalance between physical and biological carbon pumps, as well as the efficiency of trophic interactions in a narrow seasonal window.

Using long-term satellite remote sensing of sea ice concentration and ocean color, in combination with a Community Earth System Model (CESM), we developed a novel method and quantitatively assessed the spatial and temporal patterns of time synchrony between sea ice and phytoplankton bloom in the changing Antarctic. Here we show that desynchronization between seasonal sea ice retreat and phytoplankton bloom is already occurring in the Antarctic from the early 2000s, with remarkable increase of asynchronous area in the Southwestern Pacific Ocean. Despite a recent expansion of Antarctic seasonal ice zone (SIZ), in the newly formed SIZ at relatively lower latitudes, or in the inner SIZ where sea ice retreat became much earlier than previous decades, we found that too-early ice retreat triggers light-limitation and hampers the ice-bloom synchrony. Our results suggest that enlarging time misalignment between seasonal ice-free period and phytoplankton bloom can potentially alter the efficiency of carbon pumps and the fitness of living organisms.

Seasonal dynamics of organic carbon in the deep eastern North Pacific

Lopez, Chelsi N. (University of Miami RSMAS) chelsi.lopez@rsmas.miami.edu
Sarah K. Bercovici (University of Washington), Monica V. Orellana (University of Washington), Dennis A. Hansell (University of Miami RSMAS)

Organic carbon is a vital product of ocean primary production and an important factor for sequestration of atmospheric carbon, but most consideration of production has been in the euphotic zone. Here we consider the variability of total organic carbon (TOC) in the deep ocean of the northeast Pacific, where no such observations exist. Samples from throughout the water column were collected seasonally in 2017 on the Line P transect, a productive area, to characterize seasonal variability in organic carbon of the meso- and bathypelagic and to better understand the dynamics and survival of organic carbon on a monthly time scale. Variance in concentration (i.e. high heterogeneity) at >250 meters during winter, spring, and summer suggest that biogenic particles sinking from the upper ocean are seasonally delivering carbon to depth that is observable in the total organic carbon fraction. It is this carbon that will support the deep microbial heterotroph community and thus aid in sequestration of CO_2 via the biological pump.

Plankton population dynamics and food web structure on the Northeast US Shelf (NES-LTER): early indication of seasonal shifts in production regimes

Marrec, Pierre (University of Rhode Island, Graduate School of Oceanography) pmarrec@uri.edu
Heather McNair, Gayantonia Franzè, Françoise Morison, Jacob Strock, Susanne Menden-Deuer (All at University of Rhode Island)

Within the framework of the Northeast US Shelf (NES) Long-Term Ecological Research (LTER) project, we investigated plankton population dynamics based on phytoplankton growth and microzooplankton grazing rates. During two winters (Feb. 2018 and Feb. 2019) and a summer (Jul. 2018) week-long cruises, we performed series of dilution experiments (at 5-6 stations located along a transect from Martha's Vineyard to the shelf break) to quantify in-situ phytoplankton growth and grazing mortality. During both winter and summer, coastal waters were colder and fresher than waters at the shelf break. The phytoplankton community structure was dominated by large cells (> 20 µm) in winter and by small cells (< 5 µm) in summer, with higher biomass at the coast than offshore. Growth rates (µ) appeared to be temperature dependent with values below 0.5 d^{-1} in winter and up to 1.4 d^{-1} in summer, whereas grazing rates (g) were not. The percentage of primary production consumed (%PP) suggested a more efficient transfer of energy at the first trophic levels in winter (%PP > 50%) than during summer (%PP < 20%), highlighting a winter simple food chain with high-export potential and during summer a microbial loop dominated food web meeting low-export conditions. We observed important spatial variability along the shelf between coastal and offshore waters, as well as interannual variability between both winter cruises. Such variability supports the need for an optimized sampling strategy over the shelf and the requirement of long-term research efforts to identify the mechanisms that control primary production and its relative contribution to trophic transfer and carbon export.

Springtime coupling between Arctic sea ice export and phytoplankton blooms in the Greenland Sea

Mayot, Nicolas (Bigelow Laboratory for Ocean Sciences) nmayot@bigelow.org

Patricia Matrai (Bigelow Laboratory for Ocean Sciences), Adelaida Arjona (Harvard University), Christian Marchese (ARCTUS inc.), Thomas Jaegler (ARCTUS inc.), Simon Bélanger (ARCTUS inc.).

Climatic model projections suggest a substantial decrease of sea ice export into the outflow areas of the Arctic Ocean over the 21st century. Fram Strait, located in the Greenland Sea sector, is the principal gateway for ice export from the Arctic Ocean. The consequences for the Greenland Sea of the predicted lower sea ice flux through Fram Strait on its ocean dynamics and primary production remain unknown. By using the most recent 16 years (2003-2018) of satellite imagery available and hydrographic in situ observations, the role of exported Arctic sea ice in the water column stratification and phytoplankton production of the Greenland Sea is evaluated. The springtime Arctic sea ice export through Fram Strait has a strong interannual variability and influences the sea ice extent and distribution in the Greenland Sea. Years with high Arctic sea ice flux mostly resulted in high sea ice concentration in the Greenland Sea, which can trigger a strong salinity-based water column stratification of the basin and an earlier spring phytoplankton bloom associated with high primary production levels. Similarly, years with low Arctic sea ice flux through Fram Strait were mostly associated with a delayed phytoplankton spring bloom in the Greenland Basin, because of a weak water column stratification. This work emphasized the particularity of the Greenland Sea as being a transition zone between the Arctic and Atlantic Oceans where the springtime phytoplankton production is under the influence of exported Arctic sea ice.

Effects of phytoplankton composition and biominerals on the episodic pulses of particulate organic carbon to abyssal depths

Michaud, Cynthia (Moss Landing Marine Laboratories) cmichaud@mlml.calstate.edu
Kenneth L. Smith, Jr. (Monterey Bay Aquarium Research Institute), Christine L. Huffard (Monterey Bay Aquarium Research Institute), Colleen A. Durkin (Moss Landing Marine Laboratories)

The biological pump transports carbon to depth through physical mixing and gravitational sinking of organic particles. Carbon that sinks to the seafloor is consumed by benthic organisms who rely on the carbon as their source of food. Station M is a long-term deep-sea study site in the Northeast Pacific where large episodic pulses of particulate organic carbon (POC) sinking to the sea floor have been recorded for the past 29 years. The episodic pulses of POC have increased in the past decade, driving a long-term increase in carbon export. The goal of this study is to resolve the role of phytoplankton in driving the high POC pulses. Samples from sediment traps were analyzed by microscopy to determine phytoplankton community composition within sinking material. Biogenic silica and particulate inorganic carbon (PIC) were measured in the particles to test whether mineral ballasting may be driving the large pulses of POC sinking to depth. Preliminary results indicate that biogenic silica: POC is not significantly different between high and low flux events on average, but further work will resolve how this varies among individual events. Sinking particles contain a different community composition during high flux events compared with lower flux periods. Particles sinking during low flux periods are relatively enriched in phytoplankton

cells compared to particles sinking during high flux events. Additional analyses will resolve the phytoplankton types driving these compositional differences and resolve their variability among high flux events. These data will help resolve the ecological mechanisms driving episodic pulses of POC to the abyssal seafloor and why it might be changing.

The NASA and IOCCG protocols renewed: Reestablishing best practices for exceptional in situ measurements

Neeley, Aimee (NASA Goddard Space Flight Center/SSAI) aimee.neeley@nasa.gov
Antonio Mannino (NASA Goddard Space Flight Center), Venetia Stuart (IOCCG)

In situ optical and biogeochemical in- and above-water measurements are critical for calibration and validation of satellite ocean color radiometry data products, and for refinement of ocean color algorithms. During the SeaWiFS era, NASA commissioned the development of a series of ocean optical measurement protocols, which have served as international reference standards ever since, and have promoted the collection and assembly of climate quality, ocean optical datasets by the global ocean color community. Over the past few years, NASA has sponsored several international workshops (sometimes in conjunction with IOCCG) with subject matter experts to update and develop new community consensus field measurement protocols for ocean color sensor validation. Newly-drafted protocols are available to the international user community on the IOCCG webpage for a period of time for public comment and access and associate editorial board review, before they are accepted as international reference standards. Finalized protocols receive a version number and digital object identifier from IODE Ocean Best Practices. The updated protocols are intended to be "living" documents, periodically updated as methods and technologies advance.
Recent finalized protocols include:

1) Volume 1.0: The Absorption Coefficient Protocol
2) Volume 2.0: Beam Transmission and Attenuation Coefficient

Additional protocols not listed on the IOCCG website are currently in production, including (but not limited to) those for the measurement and analysis of particulate organic carbon, primary productivity, and colored dissolved organic matter. Please see the IOCCG website to access completed protocols and to view protocols available for community input.
http://ioccg.org/what-we-do/ioccg-publications/ocean-optics-protocols-satellite-ocean-colour-sensor-validation/

Synechococcus and *Prochlorococcus*: A tale of two cyanobacteria

Neuer, Susanne (Arizona State University) susanne.neuer@asu.edu
Bianca N. Cruz (Arizona State University), Francesca DeMartini (Arizona State University)

The picocyanobacteria *Synechococcus* and *Prochlorococcus* dominate primary production in oligotrophic ocean regions, but there are stark differences in their role in ocean biogeochemistry. Using DNA-based analyses of particle trap material, *Synechococcus* were found to be overrepresented in particles compared to the water column in the Sargasso Sea, in contrast to *Prochlorococcus*, which were underrepresented. Additionally, in a global regression-based modelling analysis of metagenomics data collected during the Tara Oceans expedition, *Synechococcus* were found to be highly correlated with carbon export in the subtropical oligotrophic ocean, in contrast to *Prochlorococcus*. *Synechococcus* are also often found in zooplankton fecal pellets. We will show data from laboratory studies that show a greater propensity for aggregation in *Synechococcus*, and will discuss how aggregation and its influence in prey utilization by zooplankton might lead to differences in the sinking of these abundant picocyanobacteria in the ocean.

Direct wintertime pCO_2 observations from the Saildrone Gulf Stream Mission

Nickford, Sarah (University of Rhode Island) sarah_nickford@uri.edu
Jaime B. Palter (University of Rhode Island)

Western boundary currents, such as the Gulf Stream, are thought to be hot spots of ocean carbon dioxide uptake. In these regions, the maximum CO_2 flux occurs wintertime, when in-situ observations are most sparse due to intense weather conditions that challenge sampling from ships. Moreover, the short spatial and temporal scales of variability require dense sampling to resolve the influence of the currents on gas exchange. We show the capability of an Autonomous Surface Vehicle (ASV), called Saildrone, for collecting transformative measurements in the Gulf Stream region during a February 2019 deployment. The Saildrone is a high-endurance (>3 months), fast moving (1-8 knots) ASV that carries a large payload of meteorological and oceanographic sensors. For our deployment, it was equipped with the PMEL-designed $ASVCO_2$ system, which measures pCO_2 in both the atmosphere and the ocean with climate-quality (2 μatm) accuracy using 2-point calibrations before every measurement. With pCO_2, sea surface temperature, salinity, and near-surface wind measurements, we calculate CO_2 fluxes in the cold, nutrient rich Slope Sea, across the Gulf Stream, and into the warm, nutrient poor Sargasso Sea during active convection. On our planned 30-day mission, Saildrone collected 18 days of pCO_2 data as it completed five crossings of the Gulf Stream before 7 m waves caused a leak in the $ASVCO_2$ system. We find that atmospheric pCO_2 varies by 18 μatm while oceanic pCO_2 varies by 43 μatm. The measured air-sea gradient in pCO_2 (ΔpCO_2) averages -51.3 μatm, which is 46% higher than the February climatology of Takahashi (2009) and 58% higher than that of Landschutzer et al. (2013) in the same region, implying a greater ocean uptake than would be inferred from the climatologies. We hypothesize that the ΔpCO_2 in such climatologies may be biased because of chronic under-sampling in winter when heat loss drives a strong increase in oceanic CO_2 solubility and vertical nutrient fluxes stimulate enhanced phytoplankton productivity.

A global database of size-fractionated POC and PIC concentrations compared to satellite-based estimates

Pavia, Frank (Lamont-Doherty Earth Observatory) fpavia@ldeo.columbia.edu

Phoebe J. Lam (University of California Santa Cruz), James K. Bishop (University of California Berkeley), Lucas J. Gloege (Lamont-Doherty Earth Observatory), Robert F. Anderson (Lamont-Doherty Earth Observatory)

The production, export, and subsurface regeneration/dissolution rates of particulate organic carbon (POC) and particulate inorganic carbon (PIC) largely control the vertical gradients in oceanic dissolved inorganic carbon and alkalinity, setting the ocean's capacity for the uptake and storage of atmospheric CO_2. Algorithms have been developed to relate optical parameters measured by satellites to surface concentrations of both PIC and POC, but subsurface flux attenuation due to POC regeneration and PIC dissolution have been more difficult to quantify. To better understand processes involved in the export and recycling of PIC and POC, we present results from a global database of size-fractionated (0.8-51 micron (SSF) and >51 micron (LSF) size classes) PIC and POC measurements collected by in-situ filtration.

We find size-fractionated variability in PIC:POC ratios between SSF, LSF, and bottom-moored sediment trap particulates, which may reflect the relative contributions of different-sized $CaCO_3$ producers to the sinking PIC flux. We will discuss the implications of our results for the ability of the recently developed ^{230}Th-normalization method to be applied not only to mesopelagic POC regeneration, but also to water column PIC dissolution. We also compare surface measurements to estimates of POC (Stramski et al. 2008) and PIC (Balch et al. 2005, Gordon et al. 2001) from MODIS satellite observations, finding satellite-derived POC to be consistently offset higher than our measurements. Measurements of PIC and POC made on samples collected by ¬in-situ filtration may have a key role to play for the validation of existing satellite algorithms, and could provide unprecedented information on the particle sizes of PIC and POC in the surface ocean that could be used to constrain future satellite observations.

Anthropogenic Fe and N deposition alters the ecosystem and carbon balance of the southern Indian Ocean

Pham, Anh (Georgia Institute of Technology) anhlpham@gatech.edu
Takamitsu Ito (Georgia Institute of Technology)

Phytoplankton growth in the Indian Ocean is generally limited by macronutrients (N, P) in the north and by micronutrient (Fe) in the south. We hypothesize that increasing deposition of N and Fe due to human activities will lead to significant responses from the Indian Ocean ecosystem. Previous modeling studies investigated the impacts of anthropogenic nutrient deposition; however, the modeled responses have been uncertain due to rather crude parameterizations and incomplete representation of the Fe cycling. This study examines the sensitivity of regional productivity and carbon uptake using an ocean ecosystem model with improved Fe parameterizations. It includes multiple Fe sources and represents internal Fe cycling modulated by scavenging, desorption, and complexation with multiple spatially-varying ligand classes. The ecosystem model includes six phytoplankton functional groups. A suite of sensitivity simulations shows that increased Fe deposition stimulates diatom productivity of the southern Indian Ocean poleward of 40°S. Anthropogenic N flux plays a relatively minor role there. In contrast, diatom

production weakens north of 40°S due to the P depletion and it is outcompeted by coccolithophores, which has a lower P demand than diatom. The simulated enhancement in the coccolithophore production coincides with the satellite observation of elevated calcite production. These changes in diatom and coccolithophore production weaken the organic pump and strengthen the carbonate pump, altering the sign and patterns of regional air-sea carbon fluxes. These changes together increase the carbon uptake in the poleward of 40°S and decrease it in the equatorward. Our results imply elevated sensitivity of ecosystem and carbon fluxes in and near the water mass boundaries of the southern Indian Ocean.

Automated identification of sinking marine particle images using transfer learning

Sheu, Jessica (San José State University) jsheu@ucdavis.edu
Colleen A. Durkin (Moss Landing Marine Laboratories)

Advancement in oceanographic imaging-based methods has increased our ability to observe individually-resolved marine particles and organisms from many locations, across space, and over time. Analyzing these large imaging datasets has required the development of computational tools to rapidly categorize images. Inception v3 is an image recognition model that had already been trained on thousands of image classes, but not on the ocean particle classes (aggregate, copepod, detritus, etc.) in our datasets. By applying transfer learning, a method that retrains an already-developed model for another related task, we have redirected the classification capabilities of Inception v3 to work with our images. We have been training and testing models on datasets from 2 separate sources: images collected by a deep ocean imaging sediment trap moored off coastal California (the sediment event sensor, SES), and micrographs of gel layers deployed in mesopelagic-drifting sediment traps in 6 different coastal and open ocean environments. After manually categorizing SES particles and testing the resulting model on new images, we achieved 96% accuracy. We further manually categorized and trained models on subsets of the mesopelagic gel trap micrograph datasets, finding that particle classes with greater numbers of representative images (i.e., aggregates, long fecal pellets) consistently received higher accuracy and precision. Therefore, model accuracy increases as more images are added to the training dataset. We believe that this image classification model and library of categorized particle images will be useful for future image-based particle studies and will enable large image datasets to be analyzed in greater biological detail.

The Ocean Twilight Zone Project

Sosik, Heidi M. (Woods Hole Oceanographic Institution) hsosik@whoi.edu
Andrew D. Bowen, Kenneth O. Buesseler, Annette F. Govindarajan, Porter H. Hoagland, Jonathan C. Howland, Di Jin, Andone C. Lavery, Joel K. Llopiz, Laurence P. Madin, Simon R. Thorrold, Peter H. Wiebe, Dana R. Yoerger (All at Woods Hole Oceanographic Institution)

The Ocean Twilight Zone (OTZ) project is a six-year, large-scale, interdisciplinary research effort to transform understanding of mesopelagic ecosystems, inform high-seas regulatory decision-

making, and ultimately enhance ocean stewardship. The OTZ project's scientific goals are to advance knowledge of mesopelagic biomass and biodiversity, food web linkages, life histories and behaviors, and carbon cycle/climate influence. Aligned with our scientific goals, we are developing new observing technologies, platforms, and sampling strategies. It is through this unique combination of innovative engineering and field research that we can advance our research goals. These approaches include the use of new towed platforms for acoustic and optical determination of plankton biomass, identification and daily migrations (Deep-See); the development of autonomous underwater vehicles to capture plankton behavior (Mesobot); combining these sensor platforms with sampling for species identification using eDNA techniques; tagging and tracking of mid-water fish and larger predators who feed in the mesopelagic; designing and testing cheaper and more distributed ways of quantifying particle and animal abundances (MINIONS); and improving our ability to directly and indirectly measure the composition and magnitude of the sinking flux of particles and transport into the deep sea (TZEX). A series of OTZ sponsored research cruises are in progress, with focused efforts in the Northwest Atlantic and leveraged opportunities to access a broad range of locations, including collaboration with NASA EXPORTS.

Much of the twilight zone lies beyond national boundaries, in the "high seas" where relatively few laws or regulations apply, and mid-water fisheries efforts are being considered. This gives great urgency to our efforts to build a body of knowledge to support science-based policies that ensure ecosystem health and sustainable, equitable use of twilight zone resources. A related goal is quantifying the economic value of these resources and their ability to impact the carbon cycle and hence climate. Public audiences need to be introduced to the twilight zone and engaged in direct and meaningful ways. While based within WHOI, OTZ collaborations extend throughout the US and international research community to help meet the ambitious goals of accelerating the pace of discovery and bringing science, technology and society together to foster sustainable interactions between people and the ocean.

Performance of the Deep-Sea-Durafet pH sensor on a Spray Glider in the Central California Current System

Takeshita, Yuichiro (MBARI) yui@mbari.org
Brent Jones, Thom Maughan, Scott Jensen, Peter Walz, and Kenneth Johnson (All at MBARI)

The California Current System is thought to be particularly vulnerable to ocean acidification, yet pH remains chronically undersampled along this coast, limiting our ability to make accurate projections of pH conditions and to assess the impacts of ocean acidification. In order to address this technological need, we have integrated the Deep-Sea-Durafet, a solid state pH sensor utilized on profiling floats, onto a Spray Glider and have successfully operated it to 1000 m and a month long mission. We present results from three deployments utilizing two separate pH sensors, in and near Monterey Bay. Discrete samples were collected near the time of deployment and recovery for each mission, and preliminary results suggest that pH calibration can shift between the lab and the field by up to 0.05. However, using a single point correction based on either a discrete sample or by comparison to a deep pH reference (as done on profiling floats), glider pH agrees to discrete samples to ± 0.014 (RMSE) throughout the water column. We discuss some lessons learned from

operating this pH sensor, and propose a calibration protocol for Deep-Sea-Durafet pH sensors operated on gliders.

Data-driven modeling of the distribution of diazotrophs in the global ocean

Tang, Weiyi (Duke University) weiyi.tang@duke.edu
Nicolas Cassar (Duke University)

Diazotrophs play a critical role in the biogeochemical cycling of nitrogen, carbon and other elements in the global ocean. Despite their well-recognized role, the diversity, abundance and distribution of diazotrophs in the world's ocean remain poorly characterized largely due to the lack of observations. In this study, we update the marine diazotrophs database and assess regulating factors of diazotrophs at the global scale. Our meta-analysis more than doubles the number of observations in the previous database. Using linear and nonlinear regressions, we find that temperature sets upper bounds with other variables including light and nutrients modulating the distributions for the abundances of *Trichodesmium*, UCYN-A, UCYN-B and *Richelia*. We further apply a random forest algorithm to estimate the global distributions of these diazotrophic groups. The data-driven estimates agree well with independent field observations but show substantial discrepancies with prognostic models. The distinct ecophysiological preferences of the diazotrophic groups highlighted by our study argues for separate parameterizations of different diazotrophs in model simulations.

Impacts of estuarine dynamics on CO_2 air-sea exchange

Thomas, Jennifer (Woods Hole Oceanographic Institution) jenniferthomas@whoi.edu
Malcolm Scully (Woods Hole Oceanographic Institution)

Estuaries are proposed to play an important role in the global carbon budget, but there are considerable spatial and temporal uncertainties in their atmospheric fluxes of CO_2. Along-estuary measurements have shown that CO_2 partial pressure, from which estuary outgassing is derived, decreases rapidly away from the freshwater end member. Current estimates of estuarine contribution to CO_2 flux into the atmosphere may be biased high due to measurements of surface CO_2 partial pressure being made primarily in low salinity regions of estuaries, where low pH and low alkalinity favor greater speciation of inorganic carbon as CO_2 gas. Additionally, diurnal and seasonal variations have not been resolved. Here, we use a model to develop a better understanding of how circulation and mixing affect net air-sea CO_2 flux across an entire estuary. Analyses are done on a yearlong simulation of the Chesapeake Bay using the Regional Ocean Modelling System (ROMS), which includes a simple biogeochemical model for first order inorganic carbon dynamics. Air-sea fluxes of CO_2 and O_2 are compared with net ecosystem metabolism (NEM), and we contrast the complex spatial and temporal variations of these fluxes. There are times when the signs of the integrated fluxes are in agreement with the NEM (e.g., net heterotrophic conditions with influx of O_2 and outgassing of CO_2), but there are numerous times when CO_2 fluxes are smaller or in the opposite direction than suggested by the NEM. How, when,

and where these fluxes occur is strongly modulated by the underlying estuarine physics, which aid in our understanding of estuarine carbon flux.

Characterizing the spatiotemporal pCO_2 dynamics associated with water masses in the river-dominated East China Sea

Tseng, Chun-Mao (Institute of Oceanography, National Taiwan University)
cmtseng99@ntu.edu.tw
Po-Yuan Shen, Yi-Chun Yang, Shou-En Tsao, Chun-Mao Tseng (All Institute of Oceanography, National Taiwan University)

Limited knowledge exists concerning seasonal alternation and dynamics of sea surface CO_2 uptake in coastal oceans for the monsoon-influenced and large river-dominated marginal seas. The East China Sea (ECS) receives a huge amount of nutrients through riverine inputs from Changjiang and Kuroshio subsurface upwelling from China coastal. It is subjected to mixing variations of water masses with seasonal monsoon alternation, such as the nutrient-rich and less saline Changjiang Diluted water (CDW, S < 31) and warm, saline and nutrient-depleted waters, including shelf mixed (SMW, 31 < S < 33) and Taiwan Warm Current and Kuroshio waters (KW, S > 33). In this study, we collected the field partial pressure data of CO_2 (pCO_2) from 2003 to 2011 during the 8 seasonal cruises in the ECS. Sea surface pCO_2 in the ECS showed the highest values in autumn (381.1 ± 10.6 μatm, n=2), followed by summer (350.7 ± 31.8, n=3), winter (347.2, n=1).), spring (317.3 ± 39.2, n=2). As a whole, the annual CO_2 uptake averaged 1.6 ± 1.6 mol C m^{-2} yr^{-1} with a strong sink in winter 4.0 Mt C and spring of cold season 2.07, a weak sink in summer 0.25, and in autumn 0.09. Area changes of water masses in the ECS, e.g., %KW increased from ~57% in spring to 81% in winter seasonally affect CO_2 distribution and its air-sea exchange in the ECS. In warm seasons, KW and SMW are mainly controlled by temperature effect and CDW by biological effect; in cold seasons, temperature and vertical mixing effects mainly control the whole. Overall, the KW mainly presents a summer weak source to a winter sink (-3.3~1 Mole C m^{-2} yr^{-1}) and CDW with strong sinks, except autumn, but its contribution is limited due to %area of the total less than 10%. So, the role of the ECS regarding the CO_2 uptake is mainly governed by the KW and SMW due to seasonally physical effects related to monsoon-alternation, while by the CDW biological effect contributed from Changjiang riverine nutrients is merely 20%.

Ocean biogeochemistry drives sustained seawater concentrations of persistent organic pollutants

Wagner, Charlotte (Harvard University) cwagner@g.harvard.edy
Colin Thackray (Harvard University), Elsie M Sunderland (Harvard University)

Many persistent organic pollutants (POPs) produced by human activity persist in the global oceans, bioaccumulate in marine food webs, and pose health risks to wildlife and humans. POPs are now ubiquitously detected in most seawater and have been linked to many deleterious

changes such as declining global killer whale populations. Both primary releases and marine biogeochemical cycles affect the distribution and accumulation of POPs in the global oceans and the influence of ongoing climate driven changes in marine ecosystems is poorly understood. Here we present a global budget for four neutral polychlorinated biphenyls (PCBs) and perfluorooctanoic sulfonate (PFOS) in the world's oceans based on a 3-D ocean simulation that includes embedded ecology (MITgcm + Darwin model). We track the temporal evolution and spatial distribution of both compounds by forcing the model with previously published historical atmospheric PCB deposition data and riverine inputs of PFOS. We find that removal with particle settling has effectively removed 75% of PCBs that have entered the ocean since the onset of production but is not an important transport mechanism for PFOS, thus extending its lifetime in the surface ocean. Wind speed, light penetration, and ocean circulation exert a stronger and more variable influence on volatile pollutants with lower particle affinity, like PCB-28. In the Arctic, changes in Arctic sea-ice, temperature and windspeed have increased evasion of lighter molecular weight PCBs, and increased deposition of heavier molecular weight congeners. We conclude that improved understanding of interactions of anthropogenic chemicals with natural global biogeochemical cycles is essential for anticipating long-term risks to marine ecosystems. These compounds may also serve as effective tracers of how changes occurring in the Anthropocene are affecting the world's oceans.

Rapid adaption of the microbial community to abrupt environmental change in the Gulf of Mexico modeled with the Genome-based EmergeNt Ocean Microbial Ecosystem Model

Wang, Jiaze (UMCES, Horn Point Lab) jwang@umces.edu
Victoria Coles (UMCES, Horn Point Lab); Thomas B. Kelly (Florida State University); Olivia U. Mason (Florida State University); Taylor Shropshire (Florida State University); Micheal R. Stukel (Florida State University)

Microbial communities in the ocean are impacted by both natural and anthropogenic drivers (e.g. increasing temperature, ocean acidification, hypoxia, eutrophication, deep-water oil exploration, etc.). Information on how the microbial communities respond to major perturbations is central to understanding ecosystem resilience in a changing ocean as well as its role in modulating biogeochemical cycles. A new version of the Genome-based EmergeNt Ocean Microbial Ecosystem Model (GENOME Model) is adapted to represent microbial communities that are able to degrade hydrocarbons in Gulf of Mexico. The model is used to test how the communities respond to a major perturbation- the Deepwater Horizon (DwH) Oil Spill in the Gulf of Mexico. Hydrocarbon degradation is simulated as a function of the biomass and availability of limiting energy and nutrient substrates. Genes encoding for hydrocarbon degradation processes relevant to the region are expressed in the model. The microbial communities in the model are equilibrated to hydrocarbon concentrations resulting from natural oil seeps, then community shifts in response to the DwH Oil Spill external driver are investigated. Microbial community structures associated with local environmental conditions are compared with in situ observations including meta-transcriptomics. The model simulates lower species diversity and elevated biomass in the deep oil plume after the blow out. Boom-and-bust cycles of microbial succession with the order of propane,

ethane, and methane are captured in the model. Realistic oxygen and nitrate depletions in the oil plume layer are also resolved by the model. This emergent, trait-based model allows us to assess the role of natural seep sites in priming the ecosystem and to understand the resilience of microbial community under major perturbations.

To the North Pole and back: A pan-Arctic barium synthesis

Whitmore, Laura (University of Southern Mississippi) laura.whitmore@usm.edu
Tristan Horner (Woods Hole Oceanographic Institute), Phoebe Lam (University of California), Chantal Mears (Helmolz Center Geesthacht), Rob Rember (University of Alaska Fairbanks), Frank Dehairs (Vrije Universiteit Brussels), Helmuth Thomas (Helmholtz Center Geesthacht), Yang Xiang (University of California), Alan Shiller (University of Southern Mississippi)

Barium has previously been used as a proxy for productivity within, and for freshwater discharge into, the Arctic Ocean. These applications require that Ba exhibits largely conservative behavior, an assumption that may require re-evaluation given rapid ongoing changes in this basin. Utilizing data from several cruises, mainly associated with the 2015 GEOTRACES campaigns in the Arctic Ocean, we quantify the non-conservative sources and sinks of Ba using multiple approaches. By comparing the observed dissolved Ba to an estimate of conservative Ba, we determined in the western Arctic basins there must be an additional source of Ba (i.e., observed Ba > conservative Ba), such as a shelf source, at depths typically associated with Pacific-derived waters. Surface waters tended to have a deficit (i.e., obs. Ba < cons. Ba), which is consistent with removal of Ba via biological scavenging. Furthermore, a basin-wide mass balance approach indicates that 40 - 50% of the dissolved Ba budget has a shelf source, a factor roughly 4 times greater than estimates from other shelf areas. Integrating dissolved and particulate Ba data, we investigate whether (and where) these higher Ba fluxes are balanced within the basin.

Quantification of dissolved metabolites in seawater and diatom cultures

Widner, Brittany (Woods Hole Oceanographic Institution) bwidner@whoi.edu
Melissa Kido Soule (Woods Hole Oceanographic Institution), Frank Ferrer-Gonzalez (University of Georgia), Mary Ann Moran (University of Georgia), Elizabeth Kujawinski (Woods Hole Oceanographic Institution)

Marine microbes both require and produce dissolved organic matter (DOM) through their metabolic and growth processes. Of the large, diverse DOM pool, many small, polar molecules are highly bioavailable and cycle rapidly in the marine environment, but little is known about the fate of these molecules, largely because of methodological hurdles in measuring their dissolved concentrations. For example, sulfonate-containing molecules, including 2,3-dihydroxypropane-1-sulfonate (DHPS) and isethionate, have been implicated in key phytoplankton-bacterial interactions but cannot be accurately quantified using current methods. These and other small, polar compounds are not well extracted from seawater and are therefore not available for identification and quantification by mass spectrometry. We have developed a pre-extraction

derivatization method for liquid chromatography mass spectrometry (LC-MS)-based quantification of dissolved metabolites in seawater. With this new method, we are able to extract and quantify DHPS, isethionate, and 60 other metabolites that were not accessible to previous methods. We will present new results on the dynamics of polar metabolites in phytoplankton-bacteria co-cultures and oligotrophic seawater. Ultimately these methodological improvements will lead to a better understanding of marine microbial community and ecosystem interactions.

Freshening of the western Arctic negates anthropogenic carbon uptake potential

Woosley, Ryan (Massachusetts Institute of Technology) rwoosley@mit.edu
Frank J. Millero (University of Miami, RSMAS)

As human activities increase the atmospheric concentration of carbon dioxide (CO_2), the oceans are known to absorb a significant portion. The Arctic Ocean has long been considered to have enormous potential to sequester anthropogenic CO_2, and mitigate emissions. The frigid waters make CO_2 more soluble, and as sea ice melts, greater surface area is exposed to absorb CO_2. However, sparse data has made quantifying the amount of anthropogenic CO_2 in the Arctic difficult, stimulating much debate over the basin's contribution to CO_2 sequestration from the atmosphere. Here we show, from direct measurements spanning two decades, that despite increased atmospheric CO_2, total dissolved inorganic carbon has actually decreased, with minimal anthropogenic CO_2 uptake. The reduction in dissolved CO_2 results from a dilution of total alkalinity by increased freshwater supply, particularly river water. Changes in the freshwater budget of the western Arctic override its uptake potential, resulting in a weak sink, or possibly source of CO_2.

Topic: Data Management

BCO-DMO: Accelerating scientific discovery through responsive data management practices

Shepherd, Adam (Woods Hole Oceanographic Institution) dkinkade@whoi.edu
Danie Kinkade, Mathew Biddle, Nancy Copley, Christina Haskins, Karen Soenen, Shannon Rauch, Amber York, Mak Saito, Peter Wiebe (All Woods Hole Oceanographic Institution)

Oceanographic data, when well-documented and stewarded toward preservation, have the potential to accelerate new science and facilitate our understanding of complex natural systems. The Biological and Chemical Oceanography Data Management Office (BCO-DMO) is funded by the NSF to document and manage marine ecosystem data, ensuring their discovery and access, and facilitating their reuse.

The task of curating and providing access to research data is a collaborative process, with associated actors and critical activities occurring throughout the data's life cycle. BCO-DMO supports all phases of the data life cycle and works closely with investigators to ensure open access of well-documented project data and information. Supporting this curation process is a flexible cyberinfrastructure that provides the means for data submission, discovery, and access; ultimately enabling reuse.

Based upon community feedback, this infrastructure is undergoing evaluation and improvement to better meet oceanographic research needs. This poster will describe some of the strategic enhancements coming to BCO-DMO, and presents an opportunity for you to provide feedback on enhancements yet to come. We invite you to think about your own research workflow of searching and accessing new data for research, and to provide your feedback through the poster's interactive sections. Your input will help BCO-DMO improve its service to the research community.

Index of first authors

Archibald, Kevin, 20

Bishop, James, 13
Blanco-Bercial, Leocadio, 28
Bourbonnais, Annie, 7
Buesseler, Ken, 22
Busecke, Julius J.M., 4
Carberry, Luke, 7
Chaichitehrani, Nazanin, 28
Cliff, Ellen, 29
Cruz, Bianca N., 30

D'Sa, Eurico, 8
Da, Fei, 4
Doney, Scott, 30
Dufault-Thompson, Keith, 31
Durkin, Colleen, 23
Estapa, Meg, 20

Feng, Zhixuan, 9
Floge, Sheri, 32
Fong, Michael, 32
Fowler, Bethany, 33

Garcia, Catherine, 33
Gill, Sophie, 14
Grubb, Austin, 15
Guerra, Roberta, 19

Hagstrom, George, 34
Holder, Christopher, 34
Holland, Laura, 35

Irving, John, 9
Ito, Taka, 5

Johns, Christopher, 16

Kelly, Thomas, 36
Kinjo, Lumi, 36

Lange, Priscila, 37
Li, Xinyu, 38
Li, Yun, 39
Long, Jacqueline, 24
Lopez, Chelsi N., 39

Maas, Amy, 24
Marrec, Pierre, 40
Mayot, Nicolas, 40
McNair, Heather, 25
Menendez, Alana, 10
Michaud, Cynthia, 41
Moriarty, Julia, 10

Neeley, Aimee, 42
Neuer, Susanne, 42
Nickford, Sarah, 43

Oddo, Matias, 21
Ouyang, Zhangxian, 16

Pavia, Frank, 43
Pham, Anh, 44
Rafter, Patrick, 19
Roca Martí, Montserrat, 26
Rutherford, Krysten, 11

Schultz, Cristina, 12
Shepherd, Adam, 51
Sheu, Jessica, 45
Siegel, David, 26
Sosik, Heidi, 21, 45
Steinberg, Deborah, 27
Stöven, Tim, 5
Su, Jianzhong, 17

Takeshita, Yuichiro, 46
Tang, Weiyi, 47
Thibodeau, Tricia, 22
Thomas, Jennifer, 47
Tsao, Shou En, 18
Tseng, Chun-Mao, 48

Wagner, Charlotte, 48
Wang, Jiaze, 49
Whitmore, Laura, 50
Widner, Brittany, 50
Woosley, Ryan, 51
Wyatt, Abigale, 27

Xue, Z. George, 12

Ziegler, Lisa, 13