A.3 Ocean Biology and Biogeochemistry
NNH15ZDA001N - OBB

This program element of NASA's Research Opportunities in Space and Earth Sciences (ROSES) announcement (NNH15ZDA001N) offered opportunities to address research in ocean biology and biogeochemistry to further research goals of the NASA's Earth Science Division. NASA's Earth Science Research aims to utilize global measurements to better understand the Earth system and interactions among its components as steps toward ultimate prediction of Earth system behavior. To achieve this goal, the agency solicited four research topics of interest in this program element: research in ocean ecology, specifically to prepare scientifically for new ocean measurements from the Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) mission or to advance ocean ecology research based on data from historical, existing, and new sensors such as OCO-2; global data set development and modeling activities to enable a predictive understanding of the export and fate of global ocean primary production and its implications for the Earth's carbon cycle, specifically in support of a planned NASA field campaign (EXPORTS) in the Northeast Pacific and North Atlantic Oceans for 2018; studies to support the trilateral Galway Statement on Atlantic Ocean Cooperation of May 2013, among the European Union (EU), Canada, and the United States (US); and successor studies that offer to significantly advance the results of prior NASA Ocean Biology and Biogeochemistry research toward meaningful answers to important NASA goals, relevant US Global Change Research Program, and National Ocean Council carbon cycle and ecosystems research questions, and current and future NASA satellite missions. The purpose of this ROSES program element was to solicit proposals to address the aforementioned research topics using NASA Earth observing satellite data with a goal toward advancing the overarching Earth Science mission and goals.

The advertised budget of this program element was up to $7.5M over three years, with an advertised first year investment of up to $2.5M. Funds will come from the Earth Science Division. The outcome for the Ocean Biology and Biogeochemistry Program is $3.0M for the first year, $2.9M in year two, and $2.4M in year three for a total of $8.3M/three years. Fifteen proposals were selected out of a total of 71 proposals submitted.

Heather Benway/ Woods Hole Oceanographic Institution
Ocean Carbon Biogeochemistry Project Office
15-OBB15-0033

The Ocean Carbon and Biogeochemistry (OCB) Program was created by NSF, NASA, and NOAA in 2006 to promote, plan, and coordinate collaborative, multidisciplinary research opportunities on marine biogeochemical cycling and ecosystem processes within the U.S. and with international partners. OCB leadership consists of a scientific steering committee (SSC); topical subcommittees on ocean acidification, ocean time-series, and ocean fertilization; and the OCB Project Office. OCB supports a network of scientists who work across disciplines such as ocean chemistry, biology, and physics to understand the ocean's role in the global carbon cycle and the response of marine ecosystems and biogeochemical cycles to environmental change. OCB works with federal agency managers and this continually growing network of scientists to cultivate new research areas and opportunities in the US and with international partners. OCB plays multiple important support roles for its network: Organizes and co-sponsors workshops, short courses, working groups and synthesis activities on emerging research issues; serves as a central information hub (websites, email list, newsletter, social media) to distribute scientific news, opportunities, and research highlights; engages with relevant national and international science planning initiatives; develops education and outreach activities and products with the goal of promoting ocean carbon science to broader audiences; and trains the next generation of ocean scientists and engages early career scientists in OCB activities (travel support, networking, mentoring, professional development).

The OCB Project Office coordinates stimulating, high-impact community activities that bring different disciplines together to build communities and advance scientific understanding. Activities proposed here include the annual interdisciplinary summer workshop, we well as community-driven scoping workshops and smaller group activities. To promote cross-fertilization with partner program communities and enhance its community building efforts, OCB will continue to co-sponsor meetings and training activities as appropriate and provide travel support for members of its community to participate in OCB-relevant US and international activities. Through such activities and coordination efforts, OCB provides a unifying framework that brings together otherwise disparate groups of individually funded researchers to address important science questions. Thus far, OCB workshops and activities have provided an effective interdisciplinary model and forum for scientific inquiry and discussion that have yielded numerous benefits to the OCB community, including inspiration for new projects; funding for follow-on activities; manuscripts and special journal volumes; input to US and international science planning; joint activities with partner programs; scientific training opportunities; and education and outreach products and activities.

OCB serves in science communication, outreach, and coordination roles that ultimately benefit its entire network, as well as the broader oceanographic community. OCB is a bottom-up organization that responds to the continually evolving research priorities and needs of its network and engages marine scientists at all career stages. OCB will increase access of US-based scientists to satellite remote sensing training opportunities in an effort to expand usage and applications of satellite data in oceanography and build a more knowledgeable user community. To increase the visibility and efficacy of the program, OCB will add much needed staff capacity to assist with workshop coordination and science planning efforts and reinvigorate its communication and outreach efforts through the use of websites, social media, email, and newsletters.

James Churnside/ Office of Oceanic and Atmospheric Research, Boulder
Lidar data mining in support of EXPORTS
15-OBB15-0023

The intended proposal will be for a data mining exercise to support upcoming EXPORTS activities. The premise of this work is that the vertical distribution of chlorophyll in the ocean affects primary productivity and, eventually, the export of carbon to the deep ocean. The implication of this premise is that vertically-resolved remote sensing (i.e., lidar) may provide a significant contribution to the EXPORTS goals. We intend to investigate this using existing data from three lidars, along with supporting in situ measurements. The first lidar to consider is the CALIOP cloud/aerosol lidar on the CALIPSO satellite, because of its global coverage. We have demonstrated that this lidar can detect sub-surface plankton layers, although the vertical resolution is not as good as one would like for this application. To reduce the effects of surface reflection, the work will concentrate on the data collected with the lidar pointed off nadir and on the cross-polarized data. Lidar data from the region near Ocean Station P will be compared with in situ data from that station. Lidar data from the North Atlantic will be compared with in situ data from the 2008 North Atlantic Bloom Experiment. The second lidar is the NASA airborne High Spectral Resolution Lidar (HSRL). Data from the SABOR field campaign will be used to compare HSRL data with the extensive in situ data set collected during that campaign. In addition, the advantages and disadvantages of the HSRL technique will be investigated. The third lidar is the NOAA Airborne Oceanographic Lidar, for which extensive data exist from 17 years of field measurements. This lidar is similar to the CALIOP, except that it has much finer depth resolution in the ocean.

Stephanie Dutkiewicz/ Massachusetts Institute of Technology
Assessing Ecosystem Vulnerability to Climate Change through Optics, Imagery and Models
15-OBB15-0002

We seek to understand pathways in which ecosystems are subject to change and to quantify states of ecological vulnerability. Ocean color imagery provides an unprecedented view of the surface ocean but lacks depth information and details of community composition and biodiversity. Depth distributions of communities are important in ecological structuring and functioning. Species composition and biodiversity will directly affect ecosystem vulnerability. We propose to use existing satellite measurements, particularly ocean color, in situ datasets, along with numerical model output and theory to address spatial, temporal and depth-dependent changes to marine ecosystems with a focus on how best to detect these changes and characterize vulnerability using satellite measurements. Specifically we ask,

- How have ecosystems changed over the last few decades and how will they continue to change in a future warming world, and how well can we capture these changes from satellite measurements?
- How interconnected are deep and surface communities, do they have differing levels of vulnerability, and how are they changing in relation to each other?

- What are the regional variations in vulnerability of the marine ecosystems?
- How can we best determine and quantify ecological vulnerability metrics using a combination of ocean color imagery and a numerical model?

We propose a unique and integrative project utilizing the ecosystem modeling skills of the group at MIT and the skills at using ocean color and in situ measurements from the group at MTU. We will address the questions posed above with a study that will have the following components:

1) Utilize in situ observations, satellite imagery and model output to determine how best to infer deep phytoplankton communities from ocean color and physical imagery.
2) Use model output and theoretical understanding to construct three-dimensional ecologically distinct regions (â€œecoregionsâ€•), and confirm with in situ observations.
3) Construct a framework using a combination of physical and optical properties (especially satellite measurements) that can detect the three dimensional ecoregions from (2) remotely.
4) Explore how well satellite measurement will be able to captures changes in communities at the surface and depth on seasonal, interannual and decadal timescales, and for 21st Century scenarios using techniques constructed in (1) - (3)
5) Develop vulnerability metrics that are linked to satellite measurement, particularly using the movement of ecoregion boundaries and shifts in community structures.
6) Establish a benchmark of environmental change and vulnerability for decades (1997 â€“ present) prior to the launch of PACE; Explore how the increase in spectral resolution anticipated for the PACE mission will improve the ability to monitor changes relative to current and historic ocean color instruments

The proposed research is directly aimed at preparing scientifically for new ocean measurements from the PACE mission while growing understanding of vulnerabilities and response of ocean ecosystems to environmental change. By specifically planning to produce vulnerability metrics it meets the goal to better inform monitoring, management, and decision and policy makers. A graduate student will be provided a highly interdisciplinary environment gaining both ocean color and numerical model expertise.

Alexander Gilerson/ City College of New York
Retrieval of Characteristics of Water Constituents from near Surface and Satellite Polarimetric Observations
15-OBB15-0027

Remote sensing (RS) measurements which include the polarimetric characteristics of light provide more intrinsic information about micro and macro- physical properties of aerosols/hydrosols than standard RS measurements. It is planned that future NASA satellite PACE mission will have a polarimeter on board. Under current NASA funding using vector radiative transfer (VRT) simulations for a coupled ocean-atmosphere system and various measurements advantages of the polarimetric observations were successfully demonstrated for the retrieval of the ratio of attenuation-to-absorption coefficients (c/a) in water, coefficients themselves as well as some microphysical properties of hydrosols. During NASA SABOR cruise in water measurements were combined with above water continuous underway observations by the HyperSAS-POL instrument on the ship and with airborne measurements of the NASA GISS Research Scanning Polarimeter. To resolve an issue of a glint (sky + Sun) correction for the upwelling polarized signal from a wind driven ocean surface and various atmospheres and observation conditions Monte Carlo and VRT simulations were employed to develop related reflectance and transmittance matrices.

Collected polarimeteric reflectance data above and below water in the SABOR cruise and more recently in NOAA VIIRS validation cruises 2014-2015 together with in situ and flow through measurements and bio-chemical data open a strong potential for further establishment of relationships between polarimetric observations above water with microphysical characteristics of ocean particulates. Thus accurate matchups between measured polarization characteristics and properties of in-water particulates strongly depend on the in-water scattering matrices. Full matrices were not measured directly in any of the cruises mentioned above but can be constructed with some assumptions based on the set of measured microphysical parameters of particulates which should lead to the establishment of the additional connections between the degree of polarization and particle characteristics. Using sensitivity studies through VRT simulations and matchups between in situ and RSP data possible expansion of these relationships to the TOA level will be evaluated. Combined VRT and Monte Carlo based approach for polarized sky-sun glint correction for a wind driven ocean surface with variable aerosol loadings will be fully developed for improved estimation of polarized remote sensing reflectance in above water measurements for various atmospheric and observational conditions.

Additional data will be collected during cruises of opportunity and from the Long Island Sound Coastal Observatory (LISCO) platform for the validation of the developed models. Data collected during current as well as proposed project will be used to develop unique polarimetric hyperspectral datasets for various water, atmospheric and observation conditions. The proposed datasets are critical for the evaluation of the advantages of the polarimetric observations in PACE and other OC missions, development of the advanced algorithms for the retrieval of characteristics of water particulates and atmospheric correction models.

Maxim Gorbunov/ Rutgers University, New Brunswick
Measuring Chlorophyll Fluorescence Lifetimes in the Global Ocean to Interpret Satellite-Based Solar Induced Fluorescence Yields
15-OBB15-0010

The spatial distribution of phytoplankton biomass and its photophysiological responses to the environment in the upper ocean potentially can be inferred from satellite platforms (e.g., MODIS and, historically, MERIS) by analyzing the variations in solar induced fluorescence (SIF) originating from chlorophyll a. Although the SIF algorithm is potentially most advantageous in Case 2 waters, where DOM and suspended sediments interfere with chlorophyll algorithms based on blue-green water leaving radiances, the application of SIF to understanding either phytoplankton photophysiology or carbon fixation on a global scale has not yet been achieved. The variability in SIF quantum yields appears to correlate with environmental forcing, but the mechanisms responsible for and the interpretation of this variability are fundamentally not known due to very limited field studies of biophysically related processes. Within the framework of the NASA OBB funded project on â€œThe application of lifetime analyses in the upper ocean to the interpretation of satellite-based, solar induced chlorophyll fluorescence signals (NNX08AC24G), we designed and constructed a sea-going instrument package to directly and simultaneously measure lifetimes and quantum yields of phytoplankton chlorophyll a fluorescence in the ocean. The quantum yields are accurately calculated from picosecond-resolved measurements of fluorescence lifetimes and allowed for the first validation and calibration of the satellite-based retrievals of SIF quantum yields. This novel technology was deployed on ten cruises in the Atlantic, Pacific, Arctic, and Southern oceans spanning five years to infer the variability in phytoplankton physiology and SIF signals in major biogeochemical provinces of the ocean. The combination of amplitude-based variable fluorescence and lifetime measurements allowed us to deduce the global budgets of fate of solar radiation absorbed by phytoplankton for the first time. The results of this research are summarized in a paper in Science (Lin et al. 2016).

Here we propose to expand these robust and highly sensitive technologies to elucidate the patterns of global distributions of quantum yields of chlorophyll fluorescence in the ocean. This effort is essential to interpreting the variability of satellite-based retrievals of SIF quantum yields in relation to phytoplankton photophysiological responses to environmental forcing; e.g. nutrient availability on basin, meso-scale, and smaller spatial scales. Specifically, we propose to construct and deploy a network of five paired, calibrated instruments to be used by the oceanographic community throughout the world. The resulting data will be analyzed and archived at Rutgers University and distributed to the community via collaboration with the ocean color program at GSFC.

We envision that this project will provide the scientific background for the interpretation of the variability in solar induced fluorescence signals in the ocean, help to improve MODIS chlorophyll based biomass algorithms (and potentially follow-on sensors on other satellites), and provide crucial physiological information needed for better estimates of primary production from remote sensing of the ocean color and solar induced fluorescence. We suggest that relating the space-based estimates to in situ measurements of chlorophyll fluorescence lifetimes will provide a pathway to robustly observe how photobiological energy utilization and dissipation processes in the global ocean potentially change in the future.

Chris Hostetler/ NASA Langley Research Center
Advancing Airborne and Spaceborne Lidar for Ocean Biology and Biogeochemistry Applications
15-OBB15-0070

The Cloud-Aerosol Lidar with Orthogonal Polarization on the CALIPSO satellite has shown that ocean subsurface retrievals are possible from space. However, the CALIOP instrument was not designed for ocean profiling and has limitations for this application. Interest in space-based ocean lidar measurements is increasing and was called for by the Aerosols-Clouds-Ecosystems Science Working Group and white paper inputs to the current Decadal Survey. Our studies show that such measurements can penetrate through up to 70% of the ocean euphotic zone to characterize biomass features far out of reach of traditional passive sensors and would therefore dramatically enhance the accuracy of global plant biomass and carbon estimates. Our team at NASA Langley Research Center has developed an airborne prototype atmosphere and ocean profiling lidar (HSRL-1) and deployed it on the SABOR mission in 2014 as part of our Ocean Biology and Biogeochemistry (OBB) project funded in FY13-15 (Proposal number 12-OBB12-0063). This successful OBB project proved that the high spectral resolution lidar (HSRL) technique that we employed on that instrument could indeed provide accurate profiles of diffuse attenuation and particulate backscatter measurements at 532 nm. The diffuse attenuation profile provides information on the availability of light for photosynthesis as a function of depth, and the particulate backscatter profile can be used to derive vertically resolved profiles of phytoplankton biomass and particulate organic carbon. Since submitting that proposal, our team was also funded to upgrade our more advanced HSRL-2 instrument to enable ocean profiling at 355 and 532 nm and add fluorescence channels for chlorophyll and colored dissolved organic matter (cDOM). This project is submitted as a successor to our earlier OBB-funded project (Proposal number 12-OBB12-0063) in response to Section 2.4 in the A.3 Appendix to the ROSES announcement. Under this project, we will (1) refine the retrievals developed and demonstrated under our earlier award and conduct comprehensive comparisons of the retrieved products against in situ and remote sensing measurements, (2) develop ocean-relevant retrieval algorithms for our more advanced HSRL-2 instrument, (3) assess the benefits and capabilities of a future spaceborne ocean-profiling HSRL instrument, including sampling studies and expected random and systematic errors, and (4) provide consultation to the OBB community on the capabilities and applications of airborne and spaceborne lidar for ocean applications.

A.3 Ocean Biology and Biogeochemistry
NNH15ZDA001N - OBB

Chuanmin Hu/ University Of South Florida, Tampa
Distribution and Abundance of Pelagic Sargassum and Their Linkage with Environmental Changes in the Intra-Americas Sea and Tropical Atlantic: An Interdisciplinary Assessment
15-OBB15-0020

This proposal addresses two topics of the NNH15ZDA001N-OBB RFP: Topic 2.1 (ocean ecology, especially to prepare for the PACE mission) and Topic 2.4 (Successor studies of previously OBB-funded projects).

Pelagic Sargassum macroalgae serve as an ecologically important habitat for many marine animals, while excessive Sargassum beaching has become an increasing nuisance since 2011. Sargassum may also affect ocean's biogeochemistry through modulating nutrient cycles and releasing colored dissolved organic matter. However, to date, except for a handful of studies, our knowledge in these areas is only next to nil.

Previous mapping efforts, based mainly on MERIS measurements, showed bloom patterns in the Intra-Americas Sea (IAS). However, these preliminary results are subject to revisit because of the simple methods used in the estimates and because of lack of MERIS coverage after April 2012. Furthermore, the unprecedented Sargassum beaching events in the Caribbean in 2015 calls for a better understanding of its long-term trend in both distribution and abundance.
Two projects have been funded by the NASA OBB program (NNX13AD08G, NNX14AL98G), to assess the Deepwater Horizon oil spill in the NE Gulf of Mexico (GOM) and to provide near real-time imagery to help track Sargassum, respectively. These funded projects led to ground-breaking work of using Landsat and MODIS to map Sargassum, with significant progress being made to date, for example the discovery of the Great Atlantic Sargassum Belt. One conclusion from these results is that Sargassum abundance and biomass may have been significantly underestimated in the past.

Based on these preliminary results, the ultimate goal is two-fold: to study Sargassum distribution and abundance as well as to understand the driving factors using existing sensors and environmental variables, and to design and test algorithms specifically for PACE and existing multi-band sensors. Specifically, the project has the following objectives:

1) Design, implement, and test PACE-compatible algorithms to detect and quantify Sargassum, from which algorithms to use existing multi-band sensors are also improved
2) Provide the best estimates of total Sargassum biomass (and pigments and C, N, P, Fe) and distributions, their seasonality, inter-annual variability, and long-term trend with uncertainty estimates
3) Determine dominate environmental factors (nutrient availability, weather fluctuations, ocean mixing and circulation, etc) that drive the inter-annual variability and long-term trend in the distribution patterns
4) Document how Sargassum populations are connected between the GOM, Tropical Atlantic, and other regions of the IAS
5) Improve existing data products in the current Sargassum Watch System to better serve the community and provide management decision support.

The project will be conducted through multi-sensor remote sensing, carefully designed fieldwork, laboratory measurements, and integrated data analysis by an inter-disciplinary team. The project will leverage on currently funded GoMRI cruise surveys and cruise surveys by our partners to save ship cost.

The project will make significant contributions to NASA goals and in particular to this RFP for two reasons: 1) it is perfectly suitable to address questions specified in Topic 2.1 as it will not only provide for the first time the long-term trend of Sargassum abundance but also lead to better understanding of the environmental factors driving the short-term changes and long-term trend. Furthermore, current sensors (MODIS and Landsat) and future sensors (PACE) are used not only for research but also to better inform monitoring, management, and decision and policy makers. 2) it is based on results from previously OBB-funded research, which will make significant advancement from the results obtained to date. The project is also relevant to other NASA themes, for example Ecological Forecasting, Biodiversity, and Applied Science.

Michael Lomas/ Bigelow Laboratory For Ocean Sciences
Response of Phytoplankton Community Composition and Biomass to Climate: Development of Optical and Pigment Fingerprint Libraries to evaluate Phytoplankton Functional Type (PFT) estimates from Satellite Products
15-OBB15-0061

The Earth's ocean ecosystems are comprised of a myriad of physical, chemical, and biological processes that create adaptive and resilient ecological communities. These ecosystems are an integral part of the planet's biogeochemical cycles (e.g., carbon, nitrogen, phosphorus, silica, iron, etc.), which, in turn, are coupled to and influenced by the planet's climate; the ocean's biological carbon pump is one such cycle (Volk and Hoffert, 1985). The strength and efficiency of the biological pump are controlled by particulate organic carbon (POC) production near the surface and its trophic remineralization with depth (Buesseler et al., 2007; Neuer et al., 2002), which is extensively regulated by the distribution and abundance of phytoplankton functional types (PFTs).

We propose a bio-optical laboratory study to develop a more extensive phytoplankton spectral library that will be coupled with satellite radiance products and existing time-series datasets of PFTs to improve our ability to observe and predict changes in PFTs in response to climate change and the consequent impacts on the biological carbon pump. Specifically we will (Figure 1):

1) Compare phytoplankton spectral shape PFT algorithms (PHYDOTax, Palacios et al., 2015) and HPLC-based pigment distributions of PFTs with direct observations of PFT distributions at Ocean time-series sites.

2) Conduct controlled laboratory experiments for each major PFT quantifying changes in optical fingerprints, pigment content and Chl-a and POC normalized pigment ratios in response to climate change variables in multi-stressor experiments.

3) Refine existing PFT algorithms by incorporating new measurements of changes in optical properties and pigment content of cultures grown under conditions representative of future climate change.

4) Re-compare the algorithms derived in task 2 and 3 above to the time-series observations to assess 1) if there is improvement in agreement between in situ observations and satellite products and 2) the ability of these new algorithms to detect observed ecosystem changes.

We will leverage access to the facilities of the National Center for Marine Algae and Microbiota (NCMA) at Bigelow Laboratory and grow representatives of each PFT in semi-continuous cultures in conditions representative of present and future ocean conditions. Mannino's group will collect a spectral library of these taxa that will consist of hyperspectral UV-Vis absorbance and multi-spectral and -angular scattering properties and apply radiative transfer numerical modeling to derive hyperspectral UV-Vis reflectance. This experimental spectral library will be used to refine and evaluate the PHYDOTax approach (Palacios et al., 2015) for our open ocean study regions and other spectral shape-based algorithms for retrieval of PFTs from the PACE and other hyperspectral and multi-spectral ocean color sensors.

We will validate these PFT approaches using data from the Bermuda Atlantic Time-series Study (BATS) site, which has a >20-year record of monthly optical scattering, absorption and remote sensing reflectance measurements (Bermuda BioOptics Program), HPLC pigments (Lomas et al., 2013), and a ~20yr record of PFTs, for pico- and nanophytoplankton (Wallhead et al., 2013), and has been shown to experience strong variability in seasonal forcing as well as longer term climate oscillations (e.g., North Atlantic Oscillation). We will also use the Atlantic Zone Monitoring Program phytoplankton time-series from the Scotian Shelf to provide a contrast in PFT abundance and physical regime. These time-series will allow us to investigate both temporal and spatial patterns in the North Atlantic Ocean.

This Proposal responds to Section A.3 Ocean Biology and Biogeochemistry, subsection 2.1 Research in Ocean Ecology. Specifically it fits the objectives of the PACE science mission and will provide much needed information on improved phytoplankton functional type algorithms.

Amala Mahadevan/ Woods Hole Oceanographic Institution
Modeling studies for EXPORTS in a Dynamic Ocean Environment
15-OBB15-0038

Particulate organic matter (POM) in the upper ocean is subject to advection by near-surface velocities related to the dynamics of eddies, fronts and mixed layer instabilities. This advection influences both the horizontal and vertical distributions of POM. When advective motion is coupled to the differential sinking rates of various classes of POM, a sorting effect emerges. Slower sinking or neutrally buoyant particles are advected with the water, while faster sinking particles are quicker to descend from the surface ocean that typically has higher velocities. In

order to relate the surface production of POM to its export flux at depth, we will consider the interaction between a submesoscale-resolving flow field and particles characterized by a spectrum of sinking velocities. As the particles sink, their mass and sinking velocity may be transformed by remineralization, aggregation and disaggregation.
Our objectives are: (1) To characterize the vertical transport of POM as a function of the flow field, the POM mass and sinking distributions, and the patchiness of productivity; and (2) To assess the ability of various configurations of an observing system (autonomous and ship-based) to characterize these fluxes. Our results will improve our ability to interpret observational data and to suggest strategies for employing a system of observing assets for the EXPORTS field campaigns.

We will use a three-dimensional, submesoscale-resolving Process Study Ocean Model (PSOM) configured for 3 regions where observational Seaglider datasets can be mined. These are the 2008 North Atlantic Bloom experiment (NAB08; 61â—¦N, 26â—¦W), the OSMOSIS field campaign at the site of the Porcupine Abyssal Plain (PAP; 49â—¦N, 16â—¦W) and Ocean Station Papa (OSP; 50â—¦N, 145â—¦W) in the North Pacific. Datasets from each of these regions will be used to initialize the model with realistic vertical and horizontal density gradients, nutrient fields, and seasonally appropriate wind stresses, heat fluxes and light. The production of POM from an NPZD model will be used to seed virtual particles with a spectrum of characteristics (masses and sinking velocities) to represent the diversity of the particulate pool. We will characterize the depth-dependent export flux in different particle classes in relation to physical conditions and the upper ocean detrital particle production. We will characterize the sensitivity of model POM export to (1) a spectrum of particle characteristics and the transformation of these characteristics (e.g. sinking speed and mass) with time, (2) the surface supply of POM from patchy productivity, and (3) variable physical settings (seasonally dependent stratification and mixed layer properties, fronts and eddies) at each of the field sites.

An integrated suite of Observing System Simulation Experiments (OSSEs) will enable us to test the ability of a suite of mixed autonomous assets, including floats, gliders, towed profilers and sediment traps to accurately characterize export pathways at submesoscale resolution. OSSEs will be designed to test adaptive sampling of frontal features guided by surface properties accessible by remote sensing, and to determine the optimal deployment of sediment traps based on the statistical funnel of particles sampled by a trap at depth. Our activities will address a number of the fundamental mechanisms of POM export identified by the EXPORTS Science Plan and will inform the design and implementation of EXPORTS field campaigns in a number of ways, ranging from a mechanistic understanding of processes, characterization of export, and planning of observational strategies.

Patricia Matrai/ Bigelow Laboratory For Ocean Sciences
Primary production changes across the Subarctic Atlantic: The physical and ecological roles of surface advection
15-OBB15-0057

A.3 Ocean Biology and Biogeochemistry
NNH15ZDA001N - OBB

The ongoing changes in the circulation of the Subarctic Atlantic are, without question, impacting its marine ecosystems, yet our quantitative understanding of such ecological change(s) remains meager. A fundamental challenge is to predict whether net primary production (NetPP) in this region will increase or decrease under changing northerly and southerly advective flows. Here, we suggest that the balance will depend on regional bottom-up drivers (e.g., stratification, nutrient and light availability, community composition) and top-down drivers (e.g., grazing).

A growing understanding of the surface and deep overflows, counterflows, and recirculation patterns within the Subarctic Atlantic is emerging that indicates stronger influences of the Atlantic surface Water (AW) and Arctic-origin Water (ArW) on each other and on the average circulation patterns within the Subarctic Atlantic than previously thought. We define the Subarctic Atlantic as the region encompassed by the Greenland-Iceland-Norwegian (GIN), Irminger and Labrador Seas, where warmer and saltier AWladen with nutrients, plankton and detritus moves north in multiple branches into the Labrador Sea, into the GIN Seas and, eventually, into the Arctic Ocean. Fresher and colder ArWwith sea ice, low nutrients, low plankton and high colored dissolved organic matter moves southwards along the edge of the eastern Greenland and western Labrador Seas and into the N. Atlantic.

Here, we will focus on the balance of NetPP in the Subarctic Atlantic as affected by (i) advective losses and gains within this region at large-scales interaction with respect to boundary conditions in the temperate N. Atlantic and Arctic Oceans; (ii) lateral and vertical â€œexportâ€• production within sub-regions of the Subarctic Atlantic at intermediate scales; and (iii) advective and local processes controlling NetPP in the Subarctic Atlantic region. Our questions include the following:

- (Q1) What bottom-up (physical and chemical) factors control the NetPP levels in the Subarctic Atlantic, where and when? (Q2) What are the controls of seasonal and sub-seasonal variabilities and trends in the SubArctic Atlantic? (Q3) What is the balance between local and advected NetPP in the Subarctic Atlantic during the growth season?

- We propose to use a hierarchy of models including a full 3D, coupled, biogeochemical-physical model at regional scale (SINMOD) and a specialized 1D satellite ocean color model for phytoplankton NetPP (UQAR-Takuvik), both of which are exceptionally well tuned to high latitudes. Model simulations will be done in concert with mining historical field and satellite data to better understand the temporal evolution of NetPP and its physical and ecological controls over an average annual cycle in the Subarctic Atlantic.

- Our results will shed light if the magnitude of NetPP will increase or decrease due to enhanced stratification (warmer AW or fresher ArW conditions, less nutrients) and grazing (immigrating or returning zooplankton). Alternatively, less sea ice in Fram Strait and the Greenland Sea may result in more and earlier open waters and less stratification that may lead to higher NetPP values, as has been predicted north and east of Spitsbergen. A northwards shift in NetPP due to enhanced AW advection is expected.

- Our project responds to the ROSES 2015 A.3 OBB (amended) activity 2.3 Research In Support of the Galway Statement: North Atlantic-Arctic Oceanographic Processes by focusing on the exchanges across, and processes within, the Subarctic Atlantic and their effect on NetPP, in a region located north of the NASA-sponsored EXPORTS selected N. Atlantic field site, with a team of Canadian, Danish, Norwegian and US researchers. Our project will openly share all field data assembled as well as promote researcher mobility by including a postdoctoral fellow and a part-time graduate student, both of whom will gain international networking and experience.

Dennis McGillicuddy/ Woods Hole Oceanographic Institution
Mechanisms Controlling Mesoscale/Submesoscale Hotspots in Net Community Production/Export, with Simulation-Based Studies on how to Sample Them
15-OBB15-0030

The physical, biological and geochemical processes that lead to the transfer of carbon from the surface to the deep ocean via the biological pump vary on a tremendously wide range of scales. Net community production (NCP) provides the fuel for the biological pump, and recent observations indicate substantial variability of NCP on spatial scales of less than 30 km (the submesoscale) and time scales of days. Large scale field experiments are currently being planned for the North Atlantic and North Pacific as part of the EXPORTS project, yet our understanding of how to grapple with these scales of variability in NCP and export production remains incomplete. We propose to use a coupled physical-biogeochemical model together with existing high-resolution measurements oxygen and NCP to investigate the role of mesoscale and submesoscale processes in upper ocean ecosystem dynamics and carbon flux. This combination of observations and models will be used to assess sampling strategies for the EXPORTS field campaign, providing an objective basis on which to assess the spatial and temporal scales on which various observing assets should be deployed.

Our specific objectives are to:

1. Test the oxygen dynamics recently incorporated into an existing biogeochemical model (LOBSTER; LÃ©vy et al. 2012; Resplandy et al. 2012).

2. Carry out high-resolution (1/54Â°) coupled physical-biological simulations in an idealized North Atlantic domain.

3. Compare simulated and observed hotspots in net community production.

4. Revise the biogeochemical model as systematic discrepancies warrant.

5. Simulate sampling of environmental conditions in hotspots of net community production from the model solutions with a suite of remote sensing instruments (altimetry, ocean color, SST) using the space/time parameters specific to each platform.

6. Evaluate the accuracy with which hotspots in net community production can be reconstructed using these satellite data sets.

7. Carry out Observing System Simulation Experiments (OSSEs) to provide guidance for in situ process studies such as EXPORTS.

The proposed research thus incorporates multiple satellite missions together with in situ data and numerical models to improve our understanding of physical-biological interactions at the mesoscale and submesoscale. Our specific emphasis on processes regulating new production and export flux and associated sampling issues are directly relevant to theme 2.2 of solicitation NNH15ZDA001N-OBB, Global Data Sets and Modeling In Support of Planned Northeast Pacific and North Atlantic Export Flux Studies.

Timothy Moore/ University of New Hampshire, Durham
Using Remote Sensing and Field Investigations of Suspended Sediments to Determine the Role of Resuspension Events on Nutrient Dynamics and Phytoplankton Responses in Western Lake Erie
15-OBB15-0005

We are proposing to study the biogeochemical interactions between sediment resuspension and algal growth in western Lake Erie using a combination of in situ observations, laboratory experiments, model development and ocean color remote sensing data. Our main hypothesis is that wind-induced sediment resuspension events release bioavailable nutrients into the water column, and stimulate algal blooms including harmful cyanobacteria in western Lake Erie. Our proposal is directed towards NASA's Ocean Biology and Biogeochemistry program section 2.1, and is well suited to fit within this program.

The current paradigm is that spring runoff and associated nutrient loading of western Lake Erie primarily through the Maumee River dictates the intensity of summer cyanobacteria blooms, which contain toxic species. Despite substantial research efforts, the mechanisms and drivers of these blooms are still poorly understood, as there is a time lag of months between the spring loading and the summer bloom peak.

A knowledge gap exists in how these events are connected, although there are theories. Our proposal will specifically address one of the possible mechanisms for nutrient delivery to the water column spurring algal growth in the summer sediment resupension from wind events and coupled with biogeochemical release of nutrients into the water column. Our previous work in western Lake Erie provides some evidence that initiation of algal blooms in the summertime are linked to sediment resuspension events, but the degree to which resuspended sediments contribute to fueling the massive cyanobacteria blooms is unknown. We propose to quantify this mechanism on short time scales with in situ instruments deployed on two buoys to continuously measure in-water properties, and with laboratory experiments on resuspension of sediment cores collected in the western basin, nutrient fluxes and growth of cyanobacteria.

We will use optical properties as proxies to relate sediments with nutrients, and use remote sensing data to estimate nutrient availability across the western basin. We will use the remote sensing data to derive a seasonal estimate of the nutrient loading from sediment resuspension that can be directly compared to river nutrient loading during the spring and summer.

The major outcomes of the study will be:

- Quantification of nutrient release through resuspension as a function of total suspended solids (TSS) derived from erosion chamber experiments and linked to cyanobacteria growth experiments.
- Quantification of TSS through optical models and associated nutrient release from in situ sensors at high temporal resolution at the two buoy sites.
- Quantification of basin-wide phytoplankton response through satellite ocean color observations that will lead to seasonal estimates for basin-wide internal loading.
- Evaluation of the loading estimates from the combined field work, lab experiments and satellite data that will be directly compared to spring and summer loading through river runoff, providing a measure of relevance for the role of resuspension in fueling algal blooms in western Lake Erie.

As we will be measuring continuous in-water optical properties, our data will be available and valuable to the PACE bio-optical and atmospheric correction modeling community which is currently defining the science requirements for the NASA PACE satellite. In addition, the same data sets will be available and valuable to ESA with the recent launch of the Sentinel-3 satellite for the same reasons. More broadly, there will be benefits to agencies and scientists involved with ocean color satellite missions, specifically those which are seeking to improve their product quality in coastal and lake applications.

Cynthia Nevison/ University Of Colorado, Boulder
Understanding Export Production in High-Latitude Oceans Using Atmospheric Gas Observations, Remote Sensing and Models
15-OBB15-0024

The ability to constrain and detect changes in oceanic export flux (EF) is critical to accurately predicting the impact of ocean biota on atmospheric CO_2. In past work, which has focused on the Southern Ocean, we have shown that remotely sensed ocean color and atmospheric potential oxygen (APO) data are valuable and complementary metrics for evaluating the ocean carbon cycle. Ocean color products provide high-resolution, near-simultaneous spatial coverage, but satellite-based EF is a higher order product derived from Chl data with relatively high uncertainty. APO data provide a broad-scale, regionally-integrated constraint on the absolute magnitude of EF and further provide information about subsurface ventilation processes that are not captured by ocean color measurements.

Our ongoing analysis has revealed that some of the most significant trends in both ocean color and APO data are occurring in the North Pacific, with qualitatively consistent changes observed in both of these wholly independent but complementary datasets. In this proposal, we will explore the North Pacific APO and ocean color trends in the context of our ongoing work to use APO data to constrain satellite EF products. In addition, using datasets developed during our study of the Southern Ocean, we will synthesize satellite-based EF and APO data as complementary metrics for evaluating CMIP5 coupled carbon-climate models and develop ECCO2-Darwin and ECCOv4 as process-based modeling tools that inform this synthesis.

Specific tasks include:

1) Develop improved satellite ocean color-based estimates of export flux (EF), with a special focus on improving estimates of the annual cycle as well as detecting trends in timing and magnitude. One problem in monitoring the annual cycle is the gap in coverage in the large bands of ice-free waters between ~50Â° - 65Â° latitude in both hemispheres, which encompass large regions of the North Pacific, North Atlantic and Southern Oceans. Production likely occurs during the missing data in these regions, which are characterized by high ef-ratios relative to the global ocean, but the pixels are routinely excluded during processing of ocean color data, due to clouds or high solar zenith angles.

2) Use the eddy-resolving ECCO2-Darwin optimization system to improve our understanding of the relationship between NPP, NCP, EF and surface O2 fluxes. Techniques for understanding this relationship using ECCO2-Darwin are being developed for the Southern Ocean under current NASA funding and will be extended in this new proposal to the North Pacific and North Atlantic.

3) Synthesize ocean color data and in situ measurements of atmospheric potential oxygen (APO) to understand and reconcile trends observed in both datasets over the past 20 years, which indicate significant shifts in the timing and magnitude of ocean productivity in the North Pacific. This step will involve a series of atmospheric transport model simulations forced with air-sea O2 fluxes derived from steps 1 and 2 as well as from the CMIP5 ocean model archive.

The proposed project targets multiple elements of the NASA Ocean Biology and Biogeochemistry solicitation, including subelements 2.2-2.4, by quantifying of the magnitude, efficiency, and variability of ocean export production. It targets subelement 2.2 in particular, due to its use of complementary APO data at multiple monitoring sites in the North Pacific. It is a logical extension to the North Pacific and North Atlantic of model and analysis tools developed for the Southern Ocean under current NASA funding (NNX14AL80G).

Cecile Rousseaux/ Universities Space Research Association, Columbia
Observation-System Simulation Experiments (OSSEs) and Seasonal Forecasts to Support EXPORTS
15-OBB15-0004

While the role of oceans in the global carbon cycle and its exchanges with the atmosphere are indisputable, it is less clear how the characteristics of the upper oceans determine the vertical transfer of organic matter and how they influence the efficiency of these vertical fluxes. Using the expertise in OSSEs at the NASA Global Modeling and Assimilation Office (GMAO) we will assess different observational strategies allowing for best use of resources to maximize our understanding of the export fluxes prior to the EXPORTS field campaigns. The state-of-the-art GMAO model will allow us to test these observational strategies at different spatial and temporal scales to inform various aspects of the planning. These simulation experiments will provide the locations, frequency and parameters needed to represent the ocean carbon pathways over a range of contrasting ecosystem/carbon cycle states. Additionally, the combination of expertise at GMAO in seasonal to decadal forecast with the expertise of NASA GISS in decadal to century changes will provide short- and long-term forecasts of biogeochemical parameters involved in carbon export. These forecasts will help in assessing how representative the various sampling strategies are for seasonal and decadal variability and changes. The representation of the export of primary production from the surface waters to the deep ocean in the NASA Ocean Biogeochemical Model will be used to assess future responses to changes in ocean ecosystems and carbon transport.

David Siegel/ University Of California, Santa Barbara
Data Mining Global Ocean Ecosystem & Carbon Cycling Observations for EXPORTS Planning & Synthesis
15-OBB15-0034

The biological carbon pump is thought to export ~10 Pg C each year from the surface ocean to ocean's interior largely in the form of settling organic particles. The monitoring and prediction of global carbon export and time scales for its sequestration remain important unknowns of the ocean's carbon cycle. To attack this problem, NASA is implementing the EXport Processes in the Ocean from RemoTe Sensing (EXPORTS) field campaign. The goal of EXPORTS is to gain a predictive understanding of the export and fates of global ocean net primary production (NPP). The EXPORTS Science Plan focuses on quantifying the pathways in which NPP is exported from the upper ocean and is sequestered at depth. The EXPORTS field campaign as planned will likely observe maybe eight distinct ecosystem / carbon cycling states; yet its plan is to answer its science questions by performing longitudinal analyses of observations made across a range of states. Unfortunately the statistical confidence in these results may be quite poor as only a small number of realizations may be afforded from the field program alone. The good news is that there are many sites where high quality ecosystem / carbon cycling observations are available from online repositories and literature accounts from previous and on-going research programs.

Because of the available of these data, the data mining of available observations is an integral part of the EXPORTS Science Plan and likely critical to its success.

Here, we propose a pilot study to assess how to address the EXPORTS Science Questions by data mining previous observations. Specifically, our proposed objectives are to:

- Collect and collate available global ocean ecosystem and carbon cycling field observations useful for addressing the EXPORTS Science Questions,
- Construct EXPORTS data products and wiring diagrams from available data and distribute and publish them for their wide use, and
- Evaluate the use of the mined data products for assessing the EXPORTS Science Questions and developing advanced satellite algorithms and numerical models.

Although the geographic focus for the collection of useful data is global, an emphasis will be made for assembling data from the North Atlantic and Northeast Pacific sites that are the planned locations for the EXPORTS field campaign efforts. By completing the objectives of the proposed work, we will clearly contribute to the EXPORTS planning and risk reduction process conducted by the EXPORTS Science Definition Team. Our request responds to Sub-Element 2.2 (and to a lesser degree Sub-Element 2.3) in the 2015 ROSES Ocean Biology and Biogeochemistry Program Element A3.