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ABSTRACTS FOR POSTERS

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Using Oceanographic Data in Giovanni-4 and Federated Giovanni: Synergistic Scenarios

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Giovanni-4 (G4) , the next generation of the Geospatial Interactive Online Visualization ANd aNalysis Infrastructure (Giovanni) is now available to the public in Verson 4.13. G4 will fully replace the current Giovanni system (Giovanni-3) at the end of August 2015. G4 offers faster results, more visualization capabilities, and a single user interface through which any data variables in the system can be selected for simultaneous analysis. The Federated Giovanni project is currently adding data variables from partner data centers, which are the Land Processes DAAC (LPDAAC), the Physical Oceanography DAAC (PODAAC), the Ocean Biology Processing Group (OBPG), and the MODIS Adaptive Processing System (MODAPS). The unprecedented side-by-side availability of these data variables in the G4 system can enable improved insight into oceanographic events and processes. Several potential analysis scenarios are presented here, including the impact of severe storms on ocean optical properties and salinity in the coastal zone; depiction of the variable wind regime and chlorophyll concentrations in the equatorial Pacific during El Niño and La Niña events; examination of land vegetation indices, sea surface temperature, and ocean optical properties for coastal regions during drought conditions; and the effect of dust storms on adjacent ocean basins. The scenarios will demonstrate how G4 and Federated Giovanni provide a gateway for to access and visualize remotely sensed data variables that will be of greatest use to a particular research topic.

OCEAN COLOR RETRIEVAL USING MULTIPLE EPSILON VALUES

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Atmospheric correction is one of the most important elements in the ocean color retrieval from space borne measurements. To process a large amount of data from ocean color sensors like SeaWiFS, MODIS, and VIIRS, the Ocean Biology Processing Group (OBPG) at the NASA-GSFC center has adopted an atmospheric correction method that was proposed by Gordon and Wang (GW94) over two decades ago. The method uses the ratio of reflectances in two NIR bands of the sensor and in a complicated way selects an aerosol model, which is then used for atmospheric correction. However, for their method to work, one has to use the single scattering approximation of the radiative transfer in the atmosphere. This implies that the multiple-scattering contribution must be subtracted from the observed reflectances, which incidentally requires an aerosol model that may or may not be the aerosol model that is finally used for atmospheric correction. In this paper we propose a new method where single scattering approximation is not required, and the aerosol optical thickness and Angstrom exponent are determined in a straight forward manner. The new method is also amenable to error propagation techniques, which allows one to determine the effect of aerosol size distribution uncertainties on the retrieved ocean colors. Results from processing MODIS data using the new method will be presented and compared with GW94 method. In addition, some simulation results pertaining to the uncertainties in the micro-physical and optical properties of aerosols on ocean color retrievals will also be presented.

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CHARACTERIZING THE DIURNAL CHANGES IN COASTAL BIO-OPTICAL PROPERTIES

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Coastal processes can change on an hourly time scales, which can impact satellite ocean color bio-optical products. Planning for the future launch of the NASA Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission required characterizing these temporal variations in coastal water optical properties. Ocean color products from overlapping VIIRS orbits (2 looks per day) in conjunction with the same day MODIS orbit create a pseudo-geostationary time series, enabling the quantification of changes in bio-optical processes from ocean color satellite sensors. The Northern Gulf of Mexico diurnal changes in ocean color were characterized by using the overlapping orbits of the VIIRS –NPP ocean color sensor. The changes in ocean color within the 100 minute overlap are dependent on several characteristics with include: a) sensor characterization b) advection of water masses and c) water bio-optical changes. The insitu diurnal changes in ocean color were characterized using above water radiometry from a coastal AERONET (WavCIS CSI-06) site that provides up to 8-10 observations per day (in 15-30 minute increments). These insitu diurnal changes were used to quantify of natural bio-optical fluctuations while validating satellite measurements. The results examine the capability of space-borne sensors to monitor ocean color in dynamic coastal regions that are impacted by tides, re-suspension, and river plume dispersion.

A mechanistic semi-analytical method for remotely sensing sea surface pCO_2 in river-dominated coastal oceans: A case study from the East China Sea

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While satellite remote sensing has become a very useful tool contributing to assessments of sea surface partial pressure of carbon dioxide (pCO_2) that subsequently allow quantification of air-sea CO_2 flux, the application of empirical approaches in coastal oceans has proven challenging owing to the interaction of multiple controlling factors. We propose a ‘‘mechanistic semi-analytic algorithm’’ (MeSAA) to estimate sea surface pCO_2 in river-dominated coastal oceans using satellite data. Observed pCO_2 can be analytically expressed as the sum of individual components controlled by major factors such as thermodynamics (or temperature), mixing, and biology. With marine carbonate system calculations, temperature and mixing effects can be predicted using thermodynamic principles and by assuming conservative two endmember mixing of total dissolved inorganic carbon and total alkalinity (e.g., the Changjiang River and Kuroshio water in the East China Sea, ECS). Next, an integral expression for pCO_2 drawdown due to biological effects can be parameterized using the chlorophyll a concentration (chla). We demonstrate the validity and applicability of the algorithm in the ECS during summertime. Sensitivity analysis shows that errors in empirical coefficients and three input satellite parameters (salinity, SST, chla) have limited influence on the algorithm, and satellite-derived pCO_2 is consistent with underway data, even though no in situ pCO_2 data from the ECS shelves was used to train the algorithm. Our algorithm has more physical and biogeochemical mechanistic meaning than empirical methods, and should be applicable to other similar systems.

PREDICTING THE ICEBERG FROM ITS TIP: RESOLVING INTEGRATED, WATER-COLUMN PARTICLE BIOGEOCHEMISTRY USING MEASUREMENTS FROM JUST THE UPPER OPTICAL DEPTH

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As satellite ocean color algorithms advance to measuring new products other than just chlorophyll *a*, there is a fundamental need to extrapolate surface biogeochemical products such as particulate inorganic carbon (PIC), coccolith concentration, particulate organic carbon (POC) and biogenic silica (BSi) to integrated values throughout the euphotic zone. We summarize the results of 16 cruises throughout the world ocean, measuring such surface and vertical profiles from high latitudes to equatorial waters. We test whether these vertical distributions differ from an assumption of homogeneity, and how the vertical profiles vary from each other and also from the vertical profiles of chlorophyll *a*.

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Phytoplankton size classes for pigments and absorption: CHEMTAX versus chlorophyll *a* weighted coefficients

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In situ absorption and pigment data was acquired for the Mozambique Channel to examine the bio-optical characteristics of phytoplankton size classes with a view towards regional application of satellite data to monitor seasonal and interannual changes in community structure. A comparison is made between phytoplankton groups and size classes estimated by CHEMTAX analysis and by the chlorophyll weighted coefficients of Uitz et al (2006). Weighted coefficients estimated twice the proportion of microphytoplankton and half the proportion of nanophytoplankton at the surface compared to CHEMTAX. Comparable proportions were observed at the deep chlorophyll maximum. In contrast, weighted coefficients estimate about 34 % of the proportion of picophytoplankton at the deep chlorophyll maximum compared to CHEMTAX, while comparable proportions were noted at the surface. Relationships between absorption and chlorophyll *a* for micro-, nano- and picophytoplankton size classes were found to be similar for both CHEMTAX and weighted coefficients. Application of a size class model to satellite data for the Mozambique Channel for austral winter showed that microphytoplankton was dominant along the inshore shelf zones of Mozambique and Madagascar, while nanophytoplankton tended to be more prominent on the outer shelf zones. The southern shelf of Madagascar was populated by both micro- and nanophytoplankton and picophytoplankton dominated offshore of southeast Madagascar. Communities within the Channel comprised both nano- and picophytoplankton, with picophytoplankton tending to be more prominent.

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Dependence of satellite ocean color data products on viewing angles: A comparison between SeaWiFS, MODIS, and VIIRS

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Abstract

Satellite measured radiance and derived geophysical parameters (e.g., remote sensing reflectance or R_{rs}, chlorophyll a concentration, absorption and scattering coefficients, diffuse attenuation coefficients) may show inconsistencies according to the sensor viewing geometry. Data fluctuations based on sensor zenith angle (SZA) can cause variable uncertainties in derived time series, as well as regional or global means. This study analyses single- and merged-sensor datasets from SeaWiFS, MODIS, and VIIRS for the Gulf of Mexico region, finding generally high cross-sensor fidelity for both R_{rs} and derived products. However, pronounced variation within and between satellites was identified as a function of SZA. Such effects are generally restricted to data with SZA above 40°, although large variation exists between satellites and products. The non-tilted MODIS and VIIRS also show residual errors during summer time for SZA < 30° due to imperfect sun glint, while SeaWiFS data indicate imperfect bidirectional reflectance distribution function (BRDF) corrections. Certain R_{rs} bands and products are more resilient to angular dependence in R_{rs} data. Overall, this study provides a framework for interpretation and account of SZA dependence in satellite ocean color data products towards creation of cross-sensor time series as required for analysis of changes on multi-decadal scales. Finally, these findings can inform design and calibration of future geostationary sensors, for which targets have fixed viewing geometry.

Remote monitoring of giant kelp biomass and photosynthetic condition: An evaluation of the potential for the Hyperspectral Infrared Imager (HyspIRI) mission

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This study examines the potential of the Hyperspectral Infrared Imager (HyspIRI) mission for monitoring the biomass and photosynthetic condition of giant kelp forests on global scales. Giant kelp is a highly dynamic foundation species that supports an ecologically and economically important ecosystem found throughout the globe. Satellite, airborne, and field data are used to evaluate the suitability of HyspIRI's spatial, temporal, and spectral coverage for capturing variability in giant kelp biomass and photosynthetic state. We analyze a 28-year time series of giant kelp biomass derived from Landsat satellite imagery in order to identify the dominant temporal modes of variability in giant kelp biomass using the California coast as a model region likely to be relevant to other regions of the globe. Temporal variability in California biomass is compared to the expected availability of cloud-free HyspIRI Visible Shortwave Infrared (VSWIR) views for regions of the world that contain giant kelp populations. Spectral variability is explored by assessing how changes in the photosynthetic condition of giant kelp canopy are exhibited in the reflectance and transmittance of kelp fronds. We compare chlorophyll *a* to carbon ratios (Chl:C) of kelp fronds collected off the coast of California to laboratory and airborne measurements of hyperspectral reflectance in order to develop metrics of kelp photosynthetic condition.

The seasonal cycle dominates giant kelp temporal variability. However, the strength and timing of this cycle varies in both space and time. Our projections of cloud-free HyspIRI coverage indicate that the sensor will be able to capture at least 1 cloud free view each season for nearly all of the global giant kelp habitats illustrating that HyspIRI will resolve the dominant seasonal cycles in giant kelp biomass. A novel spectral index developed here from field observations explained 76% of the variance in Chl:C and was applied to hyperspectral aircraft observations. These results demonstrate that the spatial, temporal, and spectral coverage provided by HyspIRI has the potential to provide new insights into the ecology and biophysiology of giant kelp.

A NEW CARBON-BASED ALGAL BIOMASS PROXY FOR PHOTOACCLIMATION ANALYSIS IN THE MEDITERRANEAN SEA THROUGH OCEAN COLOR DATA

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Photoacclimation changes the intracellular chlorophyll-*a* concentration (*Chl*), and is not currently taken into account by standard ocean color algorithms. *Chl* production is a process enhanced under high nutrient and low light conditions (e.g. winter and spring in the Mediterranean Sea). Historically, *Chl* has been used as a proxy for marine algal biomass but cannot distinguish intracellular and community variations. Here, a Mediterranean Sea specific model (*Mm*) is described, which makes use of SeaWiFS ocean colour imagery of 1998-2007, to analyze the effect of photoacclimation on the phytoplankton seasonal cycle. The *Mm* model is based on the work of Behrenfeld et al. (2005). The model produces a new carbon-based proxy, named *C*, derived from the particulate backscattering coefficient, b_{bp} (λ), to describe the phytoplankton seasonal cycle, particularly for the Mediterranean Sea, where photoacclimation was shown to be of great impact on cellular processes. Results show the *Chl:C* ratio to temporally vary by a factor of 3 to 8, clearly highlighting the dominance of photoacclimation at seasonal and basin scales. Minimum *Chl:C* ratio values are observed during summer, when photo-inhibition is the dominant intracellular process, while maxima are observed in winter and spring when photoacclimation is the most important process. In the productive seasons, proxy *C* is high, while *Chl* drops quickly in response to light increase and nutrient availability. We suggest that the combined use of *C* and *Chl* is strongly needed for a better comprehension of the phytoplankton variability.

PRIMARY PRODUCTIVITY ALGORITHMS IMPLEMENTATIONS

Maxime Benoît-Gagné[1], Emmanuel Devred[1], David Dessailly[2], Simon Bélanger[3] , Marcel Babin[1], Mathieu Ardyna[4] and Eric Rehm[1].

Remote sensing of ocean-color is a powerful tool to assess changes of the marine ecosystem in a warming Arctic Ocean. One of the key parameters to assess the health of the marine ecosystem and monitor its variation over time is primary productivity. Here we present a spectrally resolved, depth integrated primary productivity model (Bélanger et al., 2013) that computes primary productivity at a 3-hour time step. The model uses ancillary data from microwave sensor to derive sea-ice concentration for masking purpose and MODIS data to derive atmospheric properties (i.e., cloud fraction, optical thickness and ozone content) that are fed to a look-up-table to derive spectral irradiance at the sea-surface. Propagation of light through the water column is computed using bio-optical algorithms for IOPs (i.e., absorption and backscattering coefficients) and AOPs (diffuse attenuation coefficient). An implementation of this model that accounts for heterogeneous chlorophyll a vertical profile and phytoplankton phenology (Ardyna et al., 2013) is also presented. These algorithms are regionally tuned for the Arctic. We present a detailed description of the model with a constant chlorophyll a vertical profile and results obtained using MODIS data. Finally, we present brief results regarding the Primary Productivity Algorithm Round Robin-5 (PPARR5).

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Accessing the suitable spectral bands to estimate the total suspended matter in Barra Bonita reservoir (São Paulo State, Brazil)

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Much attention have been devoted to monitor aquatic systems using remote sensing data in order to supply the lack of temporal and spatial data from traditional water monitoring techniques. However, inland waters with high Total Suspended Matter (TSM) concentration, such as Barra Bonita Reservoir in Brazil, still are a challenging due to its complex spectral response that implies hard work to develop models able to estimate TSM concentrations. Therefore, the main goals of this study were 1) to evaluate the suitability of existing bio-optical models in Barra Bonita Reservoir able to retrieve Total Suspended Matter (TSM) concentration; 2) to propose a new algorithm that can retrieve TSM values; and finally 3) to compare and analyze the results from both, literature and proposed models, by using error analysis. Band ratios from literature (considering the similar range of TSM concentration found on the Barra Bonita reservoir) were selected. In addition, a new model was established by using a web-based statistical tool and hyperespectral data from field campaign, which were analyzed the correlation between ratio bands and TSM concentrations. Assessing the results, an existing model was able to retrieve TSM concentration, but the best model was determined by band ratio in the near infrared (NIR) spectral range, resulting in reduced estimation errors, which indicate that models based on NIR region can be used to evaluate complex aquatic systems.

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A NOVEL APPROACH TO FLUORESCENCE QUANTUM YIELD DETERMINATION IN THE SOUTHERN OCEAN

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The fluorescence quantum yield (FQY) of marine phytoplankton refers to the ratio of photons emitted as fluorescence to those absorbed by the individual cells and serves as a first order estimate of photosynthetic efficiency. Chlorophyll concentration, pigment packaging and various photoprotective mechanisms influence FQY. The Southern Ocean is a complex high-nutrient low-chlorophyll region characterised by strong seasonal cycle dynamics. This important regulator of global carbon export is often under sampled due to weather-restricted access and the high cost of research cruises. Initial *in situ* studies will lead to improved understanding of the factors that influence FQY variability and will ultimately allow for enhanced remote sensing capabilities of this important region, furthering investigations into species composition, light environment and nutrient availability from space. A JFE Advantech Multi-Exciter Fluorometer (MFL) was used to derive fluorescence data at 9 different excitation wavelengths; a wavelength-specific FQY was determined by relating these fluorescence data to LED-specific irradiance and spectrally averaged phytoplankton-specific absorption. Initial results indicate that the repurposing of the MFL may serve as an accessible, cost-effective tool to study variability in FQY. This will in turn aid in the development of superior Southern Ocean-specific FQY algorithms and allow for further regional characterisation of phytoplankton dynamics.

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COMPLETING THE FEEDBACK LOOP: THE IMPACT OF CHLOROPHYLL ASSIMILATION OF THE OCEAN STATE.

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In anticipation of the integration of a full biochemical model into the next generation GMAO coupled system, an intermediate solution has been implemented to estimate the penetration depth (1/Kd_PAR) of ocean radiation based on the chlorophyll concentration. The chlorophyll is modeled as a tracer with sources/sinks coming from the assimilation of MODIS chlorophyll data.

Two experiments were conducted with the coupled ocean-atmosphere model. In the first, climatological values of Kd_PAR were used. In the second, observed daily chlorophyll concentrations were assimilated and Kd_PAR was derived according to Morel et al (2007). No other data was assimilated to isolate the effects of the time-evolving chlorophyll field.

The daily MODIS Kd_PAR_morel product was used to validate the skill of the penetration depth estimation and the MERRA-OCEAN re-analysis was used as a benchmark to study the sensitivity of the upper ocean heat content and vertical temperature distribution to the chlorophyll input. In the experiment with daily chlorophyll data assimilation, the penetration depth was estimated more accurately, especially in the tropics. As a result, the temperature bias of the model was reduced. A notably robust albeit small (2-3 percent) improvement was found across the equatorial Pacific ocean, which is a critical region for seasonal to interannual prediction.

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The upcoming NASA PACE mission

E. Boss, L. Remer and the PACE-ST

NASA's PACE (Pre-Aerosol Clouds and ocean Ecosystem) mission will study Earth's aquatic ecology and chemistry, and address the uncertainty in our understanding of clouds and small airborne particles called aerosols which are essential for the understanding earth's energy budget, which controls climate. Measurements made by a radiometer instrument on this mission will allow continuation of the high quality observations on ocean ecology, biogeochemical cycling, and ocean productivity begun by NASA in the late 1980s with the Coastal Zone Color Scanner which was followed by SeaWiFS and MODIS. A polarimeter instrument will improve upon current capability to measure aerosol and cloud properties, aid in atmospheric correction for the ocean color and likely offer new information for ocean retrievals. PACE measurements are likely to have value for terrestrial ecology. Thus, PACE is a comprehensive climate mission that addresses the heart of the climate problem: ocean productivity, global carbon cycle, and the largest uncertainties in our understanding of climate change: aerosols and clouds.

In 2014 a PACE science team (ST) focused on atmospheric correction and inversion of inherent optical properties was competed and selected. Since its inaugural meeting in January 2015, the PACE-ST has begun a series of studies to take advantage of the novel information we expect PACE to gather, including hyperspectral radiometry and a broad spectral range from the Ultraviolet (UV) to the Short Wave Infrared (SWIR). In this presentation we will summarize PACE objectives and likely application as well as the ST objectives and current work.

Synergistic Exploitation of Hyper- and Multispectral Sentinel-Measurements to determine Phytoplankton Functional Types at Best Spatial and Temporal Resolution (SynSenPFT)

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Abstract

To overcome the short-comings of current multi-spectral PFT products (supplying either knowledge on dominant groups or size fractions only, data products with strong linkage to a-priori-information) and PhytoDOAS data products (with only low temporal and spatial coverage), this ESA SEOM project's objective is a substantial improvement of retrieving phytoplankton groups with defined accuracy and good spatial and temporal coverage. This shall be done by developing a synergistic product which contains the Chl-a (biomass) of several PFT by using complementary information from multi- and hyper-spectral satellite ocean colour data. This algorithm can be later applied to produce a synergistic PFT product from TROPOMI (on Sentinel-5-Precursor, Sentinel-4, Sentinel-5) and OLCI (on Sentinel-3).

To enlarge the coverage and to reduce the uncertainty of the PFTs and total Chl-a satellite products, as a ESA-ESRIN funded Sentinel for science synergy research and development (SY-4SCI Synergy R & D) study focusing on PFTs we will

- review available PFT algorithms based on hyper- and multi-spectral datasets;
- develop an improved PFT algorithm by the synergistic use of low spatial resolution hyper-spectral data (i.e. SCIAMACHY) with high spatial multi-spectral data (i.e. MERIS). This can be later adapted to TROPOspheric Monitoring Instrument (TROPOMI, on Sentinel-5Precursor) and Ocean and Land Colour Instrument (OLCI, on Sentinel-3) measurements.
- perform a sensitivity study, based on radiative transfer calculations, to determine the band-set needed by multi-spectral instruments (e.g. OLCI) to retrieve PFTs based on hyper-spectral data (now SCIAMACHY, future TROPOMI) PFT algorithms
- provide a scientific roadmap for future Chl-a and PFT retrievals from ocean colour (multi- and / or hyper-spectral) data

The project started at the end of 2014 and we will show first results obtained within the study.

Ocean color products from hyper-spectral satellite data of SCAIMACHY using Differential Optical Absoprtion Spectroscopy and coupled atmospheric-ocean radiative transfer modelling

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We have explored the potential of hyperspectral satellite information to provide via analytical methods (here we use the differential optical absorption spectroscopy=DOAS) global information on phytoplankton composition, phytoplankton and CDOm fluorescence and light availability. In this presentation we show the specific method principles, the sensitivity and comparison of the retrievals to multi-spectral satellite products, as recently published (Bracher et al. 2009, Sadeghi et al. 2012a and 2012b, Dinter et al. in press, Wolanin et al. 2015, Wolanin et al. re-revised in RSE).

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VISUALISATION AND PROCESSING SUPPORT OF UNCERTAINTIES IN SNAP - ESA'S SENTINEL TOOLBOX

Carsten Brockmann[1], Norman Fomferra[2], Peter Regner[3]

Early 2014 ESA kicked off the new toolbox development for the Sentinel-3 satellite optical mission, supporting OLCI and SLSTR. Like the parallel developments for Sentinel 1 and 2, the Sentinel 3 Toolbox is based on an evolution of the BEAM development platform. This common platform is called SNAP – SentiNel Application Platform.

The Sentinel-3 Toolbox will include generic function for visualisation and analysis of Sentinel 3 OLCI and SLSTR data, as well as specific processing tools such as cloud screening, water constituent retrieval and SST retrieval. The Toolbox will put emphasis on access to remote in-situ databases such as Felyx or MERMAID.

Sentinel data products contain uncertainty quantification for every variable they contain, at per pixel level. For example, in the case of OLCI there will be an uncertainty for the TOA radiances or the chlorophyll concentration. SNAP provides special and novel visualisation tools to support the interactive analysis of the uncertainty, and supports error propagation in its numerical processing tools. The SNAP development is carried out as an agile process, and new requirements can be taken onboard. Since exploitation of uncertainty information is a dynamically evolving field of research, the SNAP developers are very open to discussion and recommendations.

The development of SNAP will be performed in close cooperation of the development teams of all three Sentinel toolboxes in a developer forum. External partners, like the NASA OBPG group (SeaDAS) participate also in the developer forum.

The Sentinel 3 Toolbox Development is funded through the ESA SEOM Programme.

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IDENTIFICATION AND CHARACTERIZATION OF WATER MASSES WITHIN THE COLUMBIA RIVER PLUME USING BOTH TRADITIONAL AND NOVEL STATISTICAL ANALYSES: DOES FUNCTIONAL DATA ANALYSIS IMPROVE WATER MASS CLASSIFICATION?

Jennifer Broughton[1,2], Jonathan Felis[2], Josh Adams[2], Raphael Kudela[1]

In the northern California Current System (nCCS), intermittent seasonal upwelling/downwelling and the Columbia River plume (CRP) create oceanographic structure that enhance phytoplankton growth and form fronts that aggregate prey for marine predators. Water mass classification and detection of fronts provide useful information for resource management and marine spatial planning. Traditionally, water mass classification methods (k-means, fuzzy c-means, or hierarchical clustering) use optically-derived biological and chemical properties from a few wavelengths to derive unique types. Previous bio-optical description of the CRP and surrounding waters relied on satellite-derived ocean color at coarse spatial and spectral resolution. Although data from sensors (e.g., MODIS) are useful for evaluating mesoscale to global-scale (100s – 1000s of km) processes, they are generally insufficient for evaluating finer-scale (1-10 km) ecologically relevant patterns in coastal and estuarine ecosystems. We conducted low-altitude aerial surveys of SST and hyperspectral ocean color along east-west transects spanning continental shelf and slope waters off southern Washington and northern Oregon. These data were used to characterize water masses associated with the nCCS in three steps: 1) along-transect gradients in SST and ocean color to identify and characterize water mass types associated with, and independent from the CRP using k-means clustering, 2) functional Principal Components Analysis (fPCA) to evaluate water masses clustered using spectral shape, and 3) traditional and novel statistical analyses to determine the benefits of including spectral shape when classifying water masses. fPCA identified water masses with unique spectral shapes, but the results were difficult to interpret, indicating that SST is integral in classification.

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Blending two ocean color algorithms to evaluate ultraviolet (UV) optics and photochemistry using the Hyperspectral Imager for the Coastal Ocean (HICO)

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Abstract

Knowledge of light partition into different optically active constitutes particularly chromophoric dissolved organic matter (CDOM) in the ultraviolet (UV) is indispensible for understanding UV dependent biogeochemical issues including photochemical processes in optically complex waters. Herein a new approach is presented to investigate photochemistry by blending two ocean color algorithms, namely the composite Sea*UV* [*Cao et al.*, 2014] and the Sea*CDOM* [*Cao and Miller*, 2014] algorithms, to visible remote sensing reflectance measured using the Hyperspectral Imager for the Coastal Ocean (HICO). As exemplified with photoproduced carbon monoxide (CO) from CDOM photodegradation, we model CO photoproduction at specific depth as well as integrating over the water column and elucidate the mechanism regulating the depth-integrated photoproduction rates in the UV in a dynamic coastal environment. Decoupled retrieving of bio-optical properties such as diffuse attenuation coefficient (K_d) and CDOM absorption coefficient (a_g) in the UV from ocean color observations allows a synoptically dynamic view of CDOM contribution to total light attenuation (a_g/K_d) and will have potential to probe UV processes on regional as well as global scales using remote sensing of ocean color.

MIXED-LAYER DEPTH AND CHL-A VARIABILITY IN THE SOUTHERN OCEAN

Carranza MM[1], ST Gille [1], PJS Franks[1], KS Johnson[2] and JB Girton[3].

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

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

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PHOTOSYNTHETIC PARAMETERS AND BIO-OPTICAL PROPERTIES OF THE PHYTOPLANKTON COMMUNITY IN THE NORTHERN GULF OF MEXICO

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Previous studies of photosynthetic parameters in the northern Gulf of Mexico (NGOM) are limited to the shallow inner-shelf and the immediate plume area of the Mississippi River. Such studies have demonstrated that the spatial and temporal variations were related to river discharge, daily PAR, and temperature, while diel variability was mainly related to nutrients, light (availability and history) and community composition. Here we build on these earlier works and discuss the photosynthetic characteristics across the continental margin of NGOM. We examined relationships of photosynthetic parameters to environmental and bio-optical variables as well as phytoplankton community composition observed during five cruises between January 2009 and March 2010. Parameters of photosynthesis were quantified by photosynthesis versus irradiance (P-E) curves along with analyses of pigments and spectral absorption. Photosynthetic parameters demonstrated marked variability among different phytoplankton groups and across the shelf. The maximum rate of photosynthesis (P_{max}^{B}) normalized to chlorophyll increased from inshore to offshore and was higher in the prochlorophyte and cyanobacteria-dominated communities. The initial slope of the P-E curve (α^{B}) normalized to chlorophyll varied independently of water mass regimes and community structure. Maximum quantum yield of photosynthetic carbon fixation (Φ_{cmax}) differed significantly between water masses, and was higher for diatom-dominated communities. In NGOM, the P_{max}^{B} and α^{B} were positively correlated and were strongly related to the relative abundance of diatoms in comparison to other groups. The results presented in this study will help to model and improve accuracies of phytoplankton primary production and predict future changes from remotely sensed data.

OCEAN COLOR ALGORITHM UNCERTAINTY EVALUATION USING MONTE CARLO COMPUTATIONAL METHODS

Joaquín E. Chaves[1, 2], P. Jeremy Werdell[2], & Christopher W. Proctor[1, 2]

The large global datasets used for the development of algorithms to estimate ocean color-derived biogeochemical parameters from space-borne sensors, such as chlorophyll-*a* (C_a), assemble observations from a variety of *in situ* optical sensors and analytical laboratory protocols, contributed over a period of years by dozens of investigators worldwide. Each algorithm-derived magnitude ideally must be ascribed a measure of uncertainty. In practice, that objective remains challenging. The establishment of uncertainty budgets for derived parameters through classical error propagation approaches is rendered impractical, if not intractable, by the complexity and heterogeneity within algorithm development datasets. An alternative approach is to use Monte Carlo statistical methods to mine the observation variability embedded in calibration datasets to establish measures of uncertainty. We present preliminary results from Monte Carlo exercises aimed at establishing uncertainty measures for C_a algorithms developed with the NASA bio-Optical Marine Algorithm Data set (NOMAD). NOMAD is a publicly available, global, high quality *in situ* bio-optical data set for use in ocean color algorithm development and satellite product validation activities. The dataset includes coincident observations of water-leaving radiances, surface irradiances, downwelling attenuation coefficients, and C_a concentrations contributed by the ocean color research community. We applied Monte Carlo by introducing various forms of randomization in the data reduction techniques used to develop NOMAD from the community-contributed observations to assess the uncertainty of selected ocean color algorithms. This approach also presents the opportunity to execute sensitivity analysis experiments to assess the contribution of the various sources of variability to algorithm uncertainty budgets.

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Monitoring time-series variations in the suspended sediment distribution using GOCI around the Heuksan mud belt

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Abstract

Analysis of suspended particulate matter (SPM) is a key to understanding the turbulent quantities of sediment flow in the Heuksan mud belt (HMB) located along the southwestern coast of the Korean Peninsula. The purpose of this study was to investigate intra-annual variability in remotely sensed SPM derived from the Geostationary Ocean Color Imager (GOCI) and sea surface temperature (SST) based on the Advanced Very High Resolution Radiometer (AVHRR), respectively, around the HMB over a period of 1 year (2013). Monthly composite SPM images showed pronounced seasonal changes in turbid water. The extent of turbid water increased during the winter season along Gomso Bay to Jangsado, whereas it decreased during the summer months from Yeonggwang to Sinan. A comparison of monthly composite SST images and wind data showed that the northwesterly winds of monsoons and net heat loss from the sea surface to the atmosphere resulted in vigorous vertical mixing of shallow coastal waters in winter. The tongue-shaped thermohaline front, monsoon winds, and bathymetry limited the spread of SPM at the southern part of the HMB in winter. In conclusion, seasonal dynamics of sediment movement around the HMB can be effectively detected using GOCI.

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Case studies for polarimetric airborne remote sensing observations of coastal waters: atmospheric correction for aerosols and thin cirrus clouds.

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A major challenge for spaceborne observations of ocean color is to correct for atmospheric scattering, which typically contributes ≥85% to the top-of-atmosphere (TOA) radiance and varies substantially with aerosols. Ocean color missions traditionally analyze TOA radiance in the near-infrared (NIR), where the ocean is black, to constrain the TOA atmospheric scattering in the visible (VIS). However, this procedure is limited by insufficient sensitivity of NIR radiance to absorption and vertical distribution of aerosols, and by uncertainties in the extrapolation of aerosol properties from the NIR to the VIS.

To improve atmospheric correction for ocean color observations, one needs to change the traditional procedure for this correction and/or increase the aerosol information. The instruments proposed for the Pre-Aerosol, Clouds, and ocean Ecosystem (**PACE**) mission include ultraviolet and Oxygen A-band observations, as well as multispectral and multiangle polarimetry, to increase the aerosol information content. However no studies have been performed on whether such observations contain sufficient aerosol information, and on how to use this information, to substantially improve atmospheric correction.

To study the atmospheric correction capabilities of **PACE**-like instruments, we are conducting field experiments off the Coast of California to obtain high-altitude airborne and *in-situ* observations of water-leaving radiance. The airborne data sets consist of hyperspectral radiance between 380-2500 nm by the Airborne Visible/Infrared Imaging Spectrometer, and narrow-band multiangle polarimetric data between 410-2250 nm by the Research Scanning Polarimeter. We will discuss examples of atmospheric correction, and show the potential of retrieving the ocean color in the presence of thin cirrus clouds.

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INTEGRATION OF SATELLITE DATA AND IN-SITU MEASUREMENTS FOR COASTAL WATER QUALITY MONITORING: THE IONIAN SEA CASE STUDY

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Coastal zones are complex and dynamic ecosystems representing one of the most productive areas of the Earth, often exposed to different natural and anthropic risks. For these reasons it is necessary to implement an integrated monitoring system able to ensure timely and accurate identification of any possible sign of degradation. The integration of satellite and in-situ data can improve the continuous observation of a specific area, allowing also for a calibration, at local scale, of the satellite data/products.

In the framework of the IOSMOS (IOnian Sea water quality MOnitoring by Satellite data) and MOMEDAS (MOnitoraggio delle acque del mar MEditerraneo mediante DAti Satellitari) projects, advanced satellite data analysis techniques were developed and tested; in particular, the RST (Robust Satellite Technique) approach has been applied to more than 10 years of MODIS-Ocean Colour products in order to identify the areas at highest level of degradation and/or at greatest potential risk along Ionian coasts (south of Italy). Following RST approach, anomalous space-time variations of chlorophyll–a (chl-a) concentration have been identified taking into account the site history (in terms of expected values and normal variability of the selected parameter) which was obtained from the multi-temporal satellite products analysis.

Besides, specific measurements campaigns have been carried out, along Ionian coasts collecting in-situ (radiometric and chemical/physical measurements) and airborne (radiometric measurements) data, in order to assess the MODIS chl-a algorithm accuracy in this specific condition (e.g. shallow waters), as well as to calibrate it at local scale.

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Retrieval of color producing agents in Case 2 waters using Landsat 8

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Abstract

New approaches need to be considered to solve the current high demand for color producing agent (CPA) retrievals over Case 2 waters. Standard retrieval algorithms are known to fail over highly turbid Case 2 waters because they were developed specifically for the Case 1 waters. Landsat 8 provides an improved signal-to-noise ratio (SNR) and a new spectral coastal aerosol band in the blue. This additional information provides means to tackle this retrieval endeavor. A look-up-table (LUT) and spectrum-matching methodology was implemented to simultaneously retrieve CPAs, taking advantage of Landsat 8's new features. A LUT of spectral remote-sensing reflectances (Rrs) with different concentration of CPAs was produced using the in-water radiative transfer model Hydrolight. A model-based empirical line method (MoB-ELM) algorithm was developed to atmospherically correct the Landsat 8 imagery and allow direct comparison with the LUT of Rrs. This MoB-ELM atmospheric correction algorithm uses pseudo-invariant features (PIFs) from the image, ground-truth data and the Hydrolight model.

The retrieval algorithm was applied over two Landsat 8 scenes and shows a root mean squared error (RMSE) as a percentage of range of about 10% for Chlorophyll-*a* and total suspended solid (TSS), and about 5% for colored dissolved organic matter (CDOM) when compared with ground-truth data. The CPA concentration maps exhibit expected trends of low concentrations in clear water and higher concentrations in turbid water. These results show that the Landsat 8 satellite can be utilized over Case 2 waters as long as a careful atmospheric correction is applied.

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CHARACTERIZATION OF PHYTOPLANKTON SIZE STRUCTURE IN CENTRAL CHILE USING A REMOTE SENSING APPROACH

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Phytoplankton size plays a fundamental role in biogeochemical cycles of the ocean, influencing photosynthesis, nutrient acquisition and structure of the food web in surface waters, as well as carbon export to the deep ocean. Recent studies have characterized the size structure of phytoplankton (as chlorophyll-a: Chl-a) through biogeochemical modeling and/or algorithms applied to satellite data of Chl-a. In this study, total and size-fractionated Chl-a in situ data (micro-, nano-, and picoplankton) collected from the upwelling area time series (St. 18, ~36.5°S, July 2004 - November 2009) and the adjacent frontal zone (FZ, 36.50-36.75°S, 73.10-74.50°W, 3-7 February 2014) off central Chile were used to parameterize a phytoplankton size-structured model (Brewin et al., 2010) applied to Chl-a satellite data (MODIS-A, resol. 1 km and 4 km, respectively). The correlation between in situ and satellite total Chl-a data was high (r~0.75 for St. 18 and r~0.79 for FZ) when we use the average of Chl-a values in the upper layer (0-20 m and 0-5 m, respectively). The model applied generated series for micro-, nano-, and picoplankton fractions from satellite Chl-a data; the correlations between them and the original series was St. 18: r~0.70, r~0.59, r~-0.06; FZ: r~0.21, r~0.86, r~0.77. The results also indicated a total Chl-a increase associated with a higher contribution of microplankton compared with the smaller fractions. A better adjustment of the data and model is necessary and this could be achieved by including HPLC analysis (High-performance liquid chromatography) and absorption coefficients of light in each of the phytoplankton size classes.

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14 YEARS OF MODIS-DERIVED TIMING OF SPRING PHYTOPLANKTON BLOOM IN THE SALISH SEA, CANADA.

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The Fraser River sockeye salmon fishery is one of the most important for British Columbia, and the stocks have generally declined in the past decade in part due to the variability of the timing of phytoplankton bloom in the Salish Sea. 14 years of MODIS imagery were analyzed to derive the timing of spring phytoplankton bloom in the Salish Sea. First, the (i) standard NIR, (ii) SWIR, and (iii) modified MUMM+SWIR atmospheric correction methods were evaluated against AERONET and in situ reflectance data. The results showed that NIR (R^2_{443nm}= 0.76, N=661 AERONET; R^2_{489nm}= 0.68, N=34 in situ spectra) and MUMM+SWIR (R^2_{443nm}= 0.74, N=662; R^2_{489nm}= 0.45, N=22) behaved similarly, except for the higher performance of the MUMM+SWIR in the 443nm band. Second, evaluation of the OC3M derived Chla retrievals for the different atmospheric correction methods revealed superior accuracy for the MUMM+SWIR corrected imagery (R^2=0.7, slope=0.89, N=16 for +/-1hr). Improved accuracy is possible with regional Chla models using the fluorescence and/or red/green wavelengths. Third, Chla products were organized into 8-days composites, and the median Chla values were extracted from north and central regions to define year day of spring bloom initiation (YD_I). For the central region, YD_I generally occurs from mid-late March to early-mid April. The most delayed YD_I was mid-April in 2010, and the earliest in 2004 and 2009 in the beginning of March. The north region shows earlier YD_I from 2004-2008 and 2012; however, in the last years a similar trend as the central region was observed.

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BYPASSING CONVENTIONAL ATMSOPHERIC CORRECTION PROCEDURES IN THE RETRIEVAL OF OCEAN COLOUR PRODUCTS: A NOVEL STATISTICAL APPROACH

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Achieving accurate atmospheric correction of satellite measured radiance over optically complex waters is notoriously challenging, often meaning that ocean colour products cannot be reliably derived in regions such as coastal waters and inland water bodies. Using a straightforward statistical technique, we derive models to estimate chlorophyll a and inherent optical properties (IOPs) from top of atmosphere satellite products, to which no atmospheric correction is applied. The approach is first developed and tested on the NASA NOMAD global validation dataset and found to perform very well for the estimation of chlorophyll a (R2 = 0.82, N = 344) and spectral IOPs including total, particulate, dissolved and phytoplankton absorption ($R^2(\lambda)$ = 0.81-0.84, N = 149-163) and particulate backscattering ($R^2(\lambda)$ = 0.78-0.81, N = 108). The technique is then applied to MERIS data from an optically complex estuarine body of water in Canada's east coast and yields very encouraging results, with R^2 values of 0.72 (N = 34) for chlorophyll a and spectral phytoplankton absorption of 0.93-0.97 (N = 23). We propose that this technique could offer a means to derive accurate ocean colour products in scenarios where it may otherwise not be possible.

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Hyperspectral Imager for the Coastal Ocean (HICO): Five Years on the International Space Station

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The Hyperspectral Imager for the Coastal Ocean (HICO) was built to measure in-water properties of complex coastal regions. HICO enabled synoptic coverage of coastal regions with100-meter spatial resolution for sampling the variability and spatial irregularity of coastal waters; and high spectral resolution to untangle the signals from chlorophyll, colored dissolved organic matter, suspended sediments and varying bottom types. HICO was built by the Naval Research Laboratory in 18 months using many commercial off-the-shelf components. It was installed on the International Space Station (ISS) in September 2009 as a one year demonstration of innovative space technologies. The success of HICO and HICO science led to an extension of support from ONR (three years) and NASA (an additional two years). HICO's operations ended in September 2014 after HICO's computer was unable to recover from a severe radiation hit received during an X-class solar storm. Most of the HICO scenes taken over sites worldwide are available now, and will remain accessible to researchers through the NASA Ocean Color website http://oceancolor.gsfc.nasa.gov/ and the Oregon State University HICO website http://hico.coas.oregonstate.edu. Overall HICO has been a huge success, far exceeding the initial expectations and providing 10,000 scenes of the coastal ocean and other sites that will provide useful scientific insights for years to come. To date there are 48 conference publications and 24 reviewed publications on HICO and HICO data.

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Particle backscattering coefficient and its relation to biogeochemical properties in the Southern Atlantic and Southeastern Pacific

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Marine particle backscattering coefficient (b_{bp}) data collected in the Southern Atlantic and Southeastern Pacific during the February-March 2015 R/V Melville MV1102 cruise were analyzed in relation to biogeochemical properties. Measurements were made at 59 locations during fixed stations, where vertical profiles were acquired, and en route (flow-through system). The $b_{bp}(555)$ varied from 0.0011-0.0043 m^{-1}. Fractionation experiments revealed a lower contribution of submicron particles (<0.7 µm) to b_{bp} (33±8%), however with a strong linear relationship with the chlorophyll-*a* concentration (Chl*a*) (r^2, 0.81) and the concentration of heterotrophic bacteria (r^2, 0.43). The magnitude and spectral slope of the b_{bp} of the submicron fraction also had a strong relation with the slope of the particle size distribution (PSD) from 0.5-3 µm (r^2, 0.90 and 0.80), indicating a tight covariation between the tiny submicron particles with the pico-sized PSD (which also covaried with Chl*a* (r_s,-0.59)). The b_{bp} of the larger fraction had a dispersive power law relationship with Chl*a* (r^2, 0.13), but a stronger linear relation with particulate organic carbon (r^2, 0.55) and particulate inorganic carbon (PIC) (r^2, 0.84). The higher contribution of larger particles to b_{bp} was associated with the greater proportion of detritus (r_s, 0.44), higher concentration of micro diatoms and presence of coccoliths. Suspended minerals deposited from Aeolian dust also likely contribute to the higher b_{bp} in the study region. Such sources strongly affect b_{bp}, but cause dispersion in the b_{bp} vs. Chl*a* relationship, whereas the smaller fraction (i.e., submicron detritus and subpico cells) is more tied to the trophic level.

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Hybridspectral Alternative for Remote Profiling of Optical Observations for NASA Satellites (HARPOONS)

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We are developing a compact, mobile, and autonomous optical system to meet or exceed the optical in situ calibration performance requirements established by the PACE Science Definition Team. HARPOONS has been under development for ~10 years through NASA investments in various Small Business Innovative Research (SBIR) and Internal Research and Development (IR&D) projects. As a result, most subsystems are at TRL 6 or higher. Here we propose to take several of the sub-systems at TRL < 6 through a technical development process to TRL > 6. The HARPOONS system integration and field commissioning will be done off Kawaihae Harbor (HI) followed by ocean deployments off Lanai (HI) for comparison with MOBY. After completion of these oceanic deployments, HARPOONS will be operationally demonstrated in clear waters off the southwest coast of Puerto Rico, near the field station of the Department of Marine Sciences, University of Puerto Rico (UPR). The goal for HARPOONS deployment logistics is to maximize the collection of data during satellite overpasses while minimizing deployment costs. HARPOONS will be 100% commercially available, and simple and inexpensive to operate relative to present technologies. This will allow domestic and international partners to deploy additional systems at various locations, helping to further maximize the collection of vicarious in situ calibration data.

System description

HARPOONS has four components (**Figure 1**): a) a Wave Glider (WG) autonomous vehicle; b) an above-water global solar irradiance instrument (spectrally matched to the in-water system) to be mounted on the WG); c) a Compact-Hybridspectral Radiometer (C-HyR) optical package (integrated to and towed by the WG) that periodically slowly profiles between the surface and ~5m; and d) a Compact-Optical Sensor for Planetary Radiant Energy (C-OSPREy) mounted on a fixed stationary coastal platform near the vicarious calibration site.

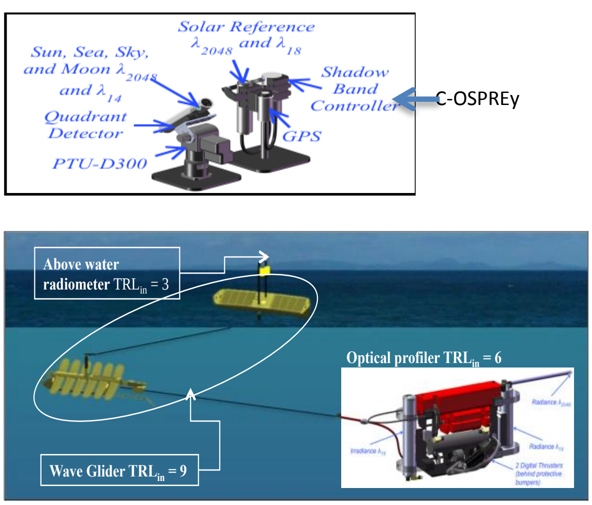

Figure 1. The HARPOONS system showing the Optical profiler tethered to the Wave Glider. The above water radiometer is shown on the Wave Glider. The C-OSPREy system will be

The above-water global solar irradiance instrument

This hybridspectral instrument has 18 highly accurate silicon photodetector (SiP) microradiometers with 10 decades of dynamic range spanning 320–875 nm plus a Compact Grating Spectrometer (CGS) with 2,048 pixels spanning 190–1,050 nm that exceeds next-generation vicarious calibration requirements. The CGS comprises an imaging grating, optical port, and a CCD detector with electric shutter to minimize integration times. The instrument is compact (74×30×76 mm^3), thermally stable, and has a Full Width at Half Maximum (FWHM) less than 2.2 nm (UV–VIS) and 2.5 nm (NIR). The spectrometer core is a blazed, flat field grating for light dispersion and imaging. The CGS has excellent stability coupled with very low stray light and high reliability in rough environments. The TRL is 3, we propose to take it to a TRL> 6.

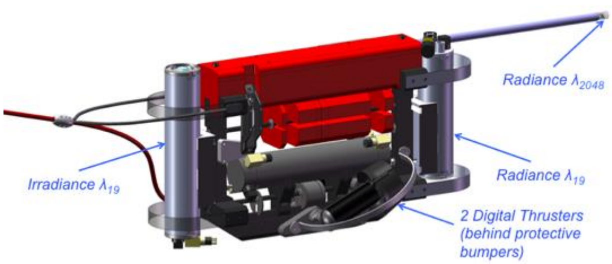

Figure 2. The in water optical profiler to be towed

The in-water optical profiler (C-HyR)

The C-HyR profiler (**Figure 2**) has three optical apertures and a pair of digital thrusters for maintaining viewing angle stability. The first optical aperture contains an upwelling Radiance Collector Assembly (RCA) for making hyperspectral (CGS spectrograph discussed above) observations very close to the sea surface. To ensure accurate measurements of highly attenuated wavebands near the sea surface, the diaphragm of a high-resolution pressure transducer is located adjacent to the radiance aperture of the RCA.

The second and third optical apertures are for a downward irradiance and upwelling radiance, E_d and L_u, respectively, sensors. Both instruments are standard 19-channel SiP microradiometers spanning 320–875 nm with10 nm bandwidth. The use of the CGS spectrograph in the solar reference and RCA allows for the derivation of hyperspectral water leaving radiances, L_W (λ), plus normalized forms, e.g., R_{rs} and $[L_W]_N$ per NASA protocols. The E_d observations are used in the determination of the extrapolation interval, and the L_W microradiometer measurements are used to independently verify the overlapping CGS L_W determinations, which include a recursive self-shading evaluation involving the RCA L_u observations. The profiler has a kite-shaped backplane with tunable ballast, a hydrobaric buoyancy chamber, plus pitch and roll adjustments, to provide unprecedented stability and vertical resolution in near-surface waters. The profiler data are of sufficient resolution and quality to show that the uncertainties in the execution of data sampling protocols are measurable at the 1% and 1 cm level.

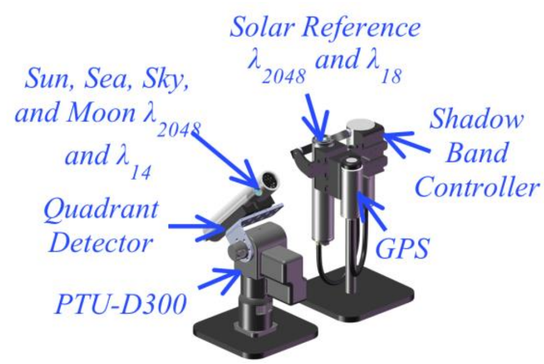

Figure 3. C-OSPREy with main optical components. C-OSPREy would be deployed on the rooftop of the Bio-optical laboratory at the field station of the Department of Marine Sciences ~ 15 nm from the HARPOONS deployment area.

The optical profiler has a TRL > 6, but the CGS spectrograph to be added to the system has a TRL = 3.

The Compact-Optical Sensors for Planetary Radiant Energy (C-OSPREy)

A C-OSPREy (**Figure 3**) instrument will be deployed on the coast near the in-water vicarious calibration station. It provides calibration and validation data from fixed platforms, and will be used for photometry measurements in support of atmospheric characterizations. The C-OSPREy is autonomous and is pointed using a COTS military-grade tracker and a quadrant detector to measure the Sun and sky, plus the Moon for diurnal measurements and stability monitoring. The hybridspectral coverage is 190–1,050 nm (CGS) and 320–1,640 nm (SiP), with the former including a filter wheel for 3-axis polarimetry. The protocols for solar and lunar tracking, as well as the derivation of atmospheric data products from sky measurements, are provided by Hooker et al. (2012) and permit the derivation of the aerosol optical depth (AOD), aerosol single scattering albedo (SSA), total column, and precipitable water vapor (PWV). C-OSPREy is a mature system (TRL > 6), but for this application we need to integrate into it a neutral density filter-wheel subsystem which has a TRL = 3.

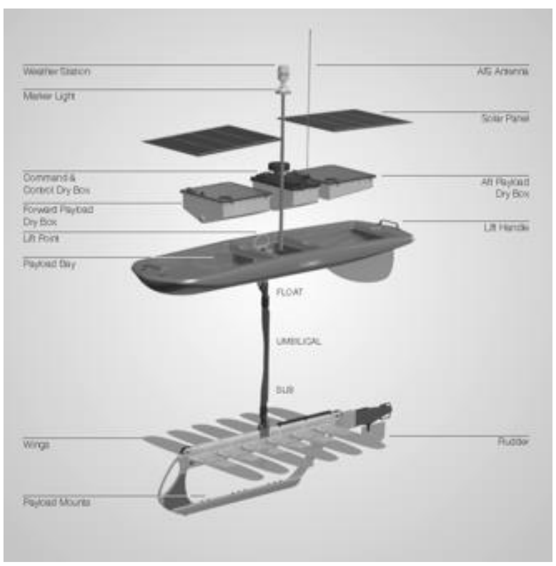

Figure 4. The Wave Glider. Picture shows all the main components of a standard system. The above water irradiance sensor will be mounted on the glider's float.

The Wave Glider

The Liquid Robotics WG (**Figure 4**) is a wave-powered surface vessel, with the advantage that it is almost never becalmed because it harnesses energy from ocean waves of very small amplitude. In calm and rough seas alike, the WG is able to maintain a headway of ~1–2 knots along an assigned course or keep station to within a 40 m watch circle. It has been ocean-tested, from carrying out Pacific Ocean crossings to covering over 2,700 nautical miles in the Arctic, while recording and transmitting nearly 900,000 temperature measurements.

A WG consists of a surface Float plus an underwater Sub joined by a 6 m umbilical with electrical and strength members. Its propulsion technology utilizes wave energy for thrust and solar panels for charging batteries. The thrust mechanism is purely mechanical and provides limitless propulsion. The batteries provide power for command and control electronics, a thrudder module, plus payload sensors in the Float and Sub, or towed behind either (the proposed C-HyR system is towed behind the Float). The core electronics include a GPS for precision navigation, long and short-range communications, a weather station, and an Automatic Identification System (AIS) receiver, which is used for collision avoidance If payload sensors are mounted on or towed behind the Sub, power and telemetry is via the umbilical; otherwise power and telemetry is via the Float (the most expansive option, which is used here). A WG is two-person portable, air-freight compatible, and can be deployed using a small boat or dock (water depth permitting), so it can be deployed rapidly in remote locations. A WG is a robust platform (one survived Super Storm Sandy while collecting data) and are already used to tow underwater instrumentation in operational settings. The towing capability has been tested under relevant operational conditions, so the TRL of the WG is 9.

Project Status

Through the end of the first six months of the project we have completed the procurement of all major hardware and taken delivery of the latest generation WG. Fabrication of the optical profiler and OSPREy system is proceeding on schedule. Preliminary data collected in North Pacific with a prototype C-HyR profiler (Figure 5) shows the system is performing as expected, wherein the larger dark circles are the SiP microradiometers and the smaller light circles are the CGS spectrograph. The data at the lower end of the PACE domain of 350-900 nm, distinguish this technology beyond PACE requirements. The data were collected within a coastal water mass as part of a joint campaign with our Japanese collaborator Dr. Koji Suzuki aboard the R/V *Hakuho Maru* (KH-15-1). Although pigment analyses for the contemporaneous water sample are not available yet, the data were obtained in eutrophic conditions. The spectra are from a water depth of 0.3–1.5 m and establish an ability to collect data at near-surface depths and obtain good results. The platform orientation for the spectra are pitch to within 0.6° and roll to within 3.3°, i.e., to within a vertical tilt of 5°. The spectrograph integration time was 100–200 ms. A profile extending down to as little as 1 m (this profile goes to a bit more than 3 m) allows our state-of-the-art data processor (PROSIT) to derive all the usual data products, e.g., L_W, R_{rs}, $[L_W]_N$, the OC band-ratio products, etc., so the anticipated 5 m profiles from the WG will be sufficient for mission success. The spectrograph data reveal challenges in the NIR, but there are sufficient data for signal processing and the number of SiP microradiometer NIR channels will be increased to improve data quality at low signal-to-noise levels.

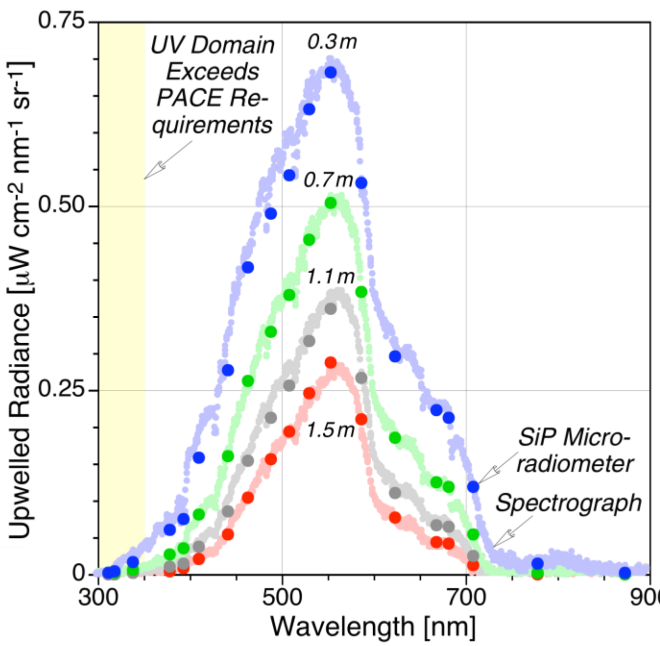

Figure 5. Example of data collected with the C-HyR profiler on board the R/V Hakuro Maru.

Improvements to water quality monitoring through the inclusion of ocean colour products correlated with in-situ water quality gradients for the Great Barrier Reef

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There has been a well-recognized link between declining water quality and the ecological health of coastal ecosystems for the Great Barrier Reef (hereafter GBR) .A strong driver of water quality change in the GBR is the pulsed or intermittent nature of terrestrial inputs into marine coastal ecosystems. Delivery of potentially detrimental terrestrial inputs–freshwater, sediments, nutrients and toxicants typically via flood plumes will be exacerbated under modelled climate change scenarios and presents an on-going risk to the resilience and survival of inshore GBR ecosystems. The consequence of changing weather and degraded water quality has had profound impacts on the Queensland coastal area, but may also be the driver of large scale reported decline in the many inshore seagrass systems and coral reefs, with concerns for the recovery potential of these impacted ecosystems if extreme weather events become more frequent. The influence of extreme weather conditions will be presented in context of wet season water quality data collected within the Great Barrier Reef Marine Monitoring program, including the spatial and temporal extent of the water quality conditions as measured by in-situ sampling and satellite imagery, particularly through the use of ocean colour correlated with water quality gradients.

Effective management of the coastal zone in the Great Barrier Reef is of particular importance in light of the recent UNESCO report on coastal pressures in the GBR and the potential to place the GBR on its "World Heritage in Danger" list. Current water quality management needs of the managing authorities rely upon both remotely-sensed and in situ data. Existing remote sensing products require significant interpretation to successfully describe various water quality parameters at reef locations. Ongoing work also includes the modelling of river contaminants, such as suspended solids (TSS) and particulate nitrogen (PN) validated with MODIS derived products. These MODIS products have proven valuable for quantifying the effects of river plumes on seagrass and coral reef habitats. Eventually, we hope to integrate MODIS products with model tracers, enabling us to predict how MODIS derived plumes will change under different catchment management strategies

Hyperspectral HICO imagery reveals yellow fluorescing ciliate bloom in Long Island Sound, USA

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Abstract: *Mesodinium rubrum* is a widespread marine ciliate that "enslaves" chloroplasts ingested from its cryptophyte algae prey. This mixotrophic ciliate can aggregate into massive red-colored blooms in estuarine waters, but little is known about its distribution or contribution to primary production. A September 2012 hyperspectral image from the HICO sensor aboard the International Space Station revealed intense red waters in Long Island Sound populated by a massive bloom of *M. rubrum* (10^6 cells L^{-1}). Genetic data confirmed the identity of the chloroplast as a cryptophyte that was actively photosynthesizing, duplicating DNA, and synthesizing proteins. Microscopy indicated extremely high abundance of its yellow fluorescing signature pigment phycoerythrin. Cell abundance was quantified in the ocean color image using an algorithm based on unique yellow fluorescence from its signature pigment phycoerythrin. Future development of hyperspectral satellites (e.g., PACE) will allow for better enumeration of these globally widespread protists known to have one of the highest marine primary production rates.

USING HIGH SPATIAL RESOLUTION SATELLITE IMAGERY TO DETECT FINE SCALE SEDIMENT FEATURES IN THE RIO DE LA PLATA TURBID WATERS

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The Río de la Plata (RdP) river, located at 35°S on the Atlantic west coast, is considered among the most turbid waters of the world. This system is of great social, ecological and economical importance for the countries on its shores, Argentina and Uruguay. The Capital cities of those countries (Buenos Aires and Montevideo), the most important harbors of the region, and many industrial poles are located on its coasts. Moreover, the estuary constitutes the main source of drinking water for the millions of inhabitants in the region. As a consequence the river is constantly under pressure from human activities and environmental changes. Current global ocean color sensors such as MODIS provides medium resolution (250 and 500 m) imagery for coastal applications, however for certain studies finer resolution is required. In this study, we analyzed the capability of sensors originally designed for land observations for detecting fine scale structures in the turbid waters of RdP. The quality of the retrieved reflectance and turbidity values from Landsat 8/OLI (30 m) and Pléiades (2 m) are assessed using *in situ* measurements. Then we explored different features that can be identified by sensors with increasing spatial resolution and their potential usefulness for different applications such as: a) providing quantitative information for sediment transport studies to understand the pattern of the main tributaries plumes located the along the RdP estuary, b) identifying features produced by small scale water discharges, c) detecting near shore currents, and d) identifying complex hydrodynamic features in the maximum turbidity zone.

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Field measurements of the spectral particulate light backscattering coefficient in turbid coastal waters: validity of measurement corrections recommended for widely-used sensors

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Abstract (250 words)

Light backscattering by suspended particles in natural waters is a key parameter in marine optics and ocean colour remote sensing. The particulate backscattering coefficient is correlated to the concentration of suspended solids and its spectral variations are supposed to be representative of the particle size distribution, especially in sediment-dominated coastal and estuarine waters. However field measurements of the particulate backscattering coefficient in such waters is problematic mainly due to the (i) saturation of most sensors initially developed for the open ocean and (ii) difficult correction of light attenuation along the sensor pathlength. These are the main reasons why only very few accurate b_{bp} measurements have been reported for turbid coastal waters.
Based on Monte Carlo simulations, we reproduce measurements carried out in virtual turbid coastal waters using widely-used scattering sensors (Wetlabs ECO-BB and Hobilabs Hydroscat) and assess the validity of measurements corrections recommended by the manufacturers. Our results confirm that measurement made with the small ECO-BB sensors should only be corrected for absorption losses along photon pathength but suggest a revision of the User Guide provided by Wetlabs. Data recorded using the larger Hydroscat (4 and 6) sensors should be corrected for both absorption and scattering losses, as stated by Hobilabs, but the recommended sigma correction is proved to fail in (highly) scattering waters. An improved sigma correction is proposed, tested and validated based on field measurements (optical closure).

Numerical model laboratory for exploring uncertainty in satellite derived chlorophyll-a

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Satellite ocean colour observations have provided the biogeochemical modelling community an unprecedented evaluation product on global scale and at regular and frequent intervals: satellite derived ocean surface chlorophyll-a (chl-a). However the uncertainties of the satellite derived chl-a are not well documented. Here we present a global three-dimensional biogeochemical, ecosystem, and radiative transfer numerical model that acts as a virtual laboratory to explore some of the uncertainties. The model resolves sufficient details of the marine ecosystem, water optical constituents as well as explicit upwelling irradiance. We can therefore calculate a "satellite-like" derived chl-a from the model reflectance output and compare this to the model "actual" chl-a. We find that the satellite-like product has substantial low biases at high latitudes and also estimates spring blooms as much as two months too early relative to model "actual" chl-a in those regions. These uncertainties should be kept in mind when using satellite derived chl-a as an evaluation product for biogeochemical models. We show how our model can also be used to explore uncertainties that result from the scarcity of observations used to calculate the chl-a/reflectance ratio algorithms, as well as the role that CDOM, non-algal particles, and differences in phytoplankton optical properties play into the inherent uncertainties.

A YEAR-LONG RECORD OF PARTICULATE CARBON EXPORT AND NET PRIMARY PRODUCTION FROM PROFILING FLOATS IN THE SARGASSO SEA

Margaret L. Estapa

Autonomous sampling platforms such as bio-optical profiling floats are poised to broaden the number and spatiotemporal resolution of observations of the ocean's biological pump. In this study, *in situ* profiles of chlorophyll fluorescence (corrected for non-photochemical quenching and scaled to match MODIS-Aqua) and backscattering were collected at approximately 2-day resolution from two profiling floats in the Sargasso Sea. The data were used, in conjunction with MODIS photosynthetically-available radiation, to derive depth-resolved, net primary production (NPP) using the CbPM model (Behrenfeld et al., 2005; Westberry et al., 2008). During drift phases in between vertical profiles, the floats also measured particulate carbon (PC) export by the optical sediment trap method (Bishop et al. 2004; Estapa 2013) at a cycle of depths ranging from 150 m to 1000 m. The magnitudes of NPP, PC export, and their annually-averaged ratio were generally consistent with observations at the nearby Bermuda Atlantic Timeseries Study (BATS) site. Seasonally-resolved PC remineralization length scales were derived from the depth-resolved PC flux observations. The results suggested that during summer and early fall, the recycling-dominated ecosystems of the Sargasso Sea strongly attenuate sinking PC as a function of depth, while remineralization of sinking particles is less intense during spring and late fall. Also implied is the importance of integrating NPP and export observations to the same reference depth if they are to be compared.

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Effects of cloud adjacency on TOA radiance and ocean color products: A statistical assessment

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Abstract: Ocean color measurements near clouds suffer from the cloud adjacent effects (AEs), leading to ~50% of the cloud-free ocean data flagged as low quality. Yet, quantitative assessment of such effects is not available, not to mention how to minimize or correct them. The goal of this study is therefore to quantify such effects on top-of-atmosphere (TOA) radiance and ocean color data products for MODIS/Terra, MODIS/Aqua, and SeaWiFS measurements. The estimation was based on statistics and an objective method applied to carefully selected clear-water scenes (N>20 for each instrument), where the ocean properties are relatively homogeneous. The AE was quantified as the relative difference between the near-cloud pixels and pixels at least 20 km away from any cloud. Results show that the AEs on TOA radiance share similar patterns among the three missions, which decrease sharply with increasing distance from cloud edges, and the AEs increase monotonously with increasing wavelengths. Disenable memory effects (MEs) are also observed on cloud-adjacent pixels of both MODIS measurements following the scan directions, representing >15% of the total adjacency effects in TOA radiance. The AEs on the retrieved remote sensing reflectance (R_{rs}) data products are different among the three missions, leading to different patterns in the chlorophyll-a (Chl-a) and normalized Florescence Line Height (nFLH) data products. Large AEs (>50%) are observed in nFLH of both MODIS measurements, likely due to the opposite AEs on R_{rs} between 667 and 678 nm. Finally, when the OCI Chl-a algorithm is used, the current MODIS stray-light masking window (5x7) to remove the AEs can be relaxed to 3x3 without sacrificing data quality, leading to >40% of the previously masked low-quality data being recovered.

Keywords: Cloud adjacency effects, Memory effects, Stray light, Ocean color, TOA radiance, Remote sensing reflectance (R_{rs}), Chl-a, OCI, MODIS, SeaWiFS

High-resolution remote sensing for water quality monitoring in the California Bay-Delta

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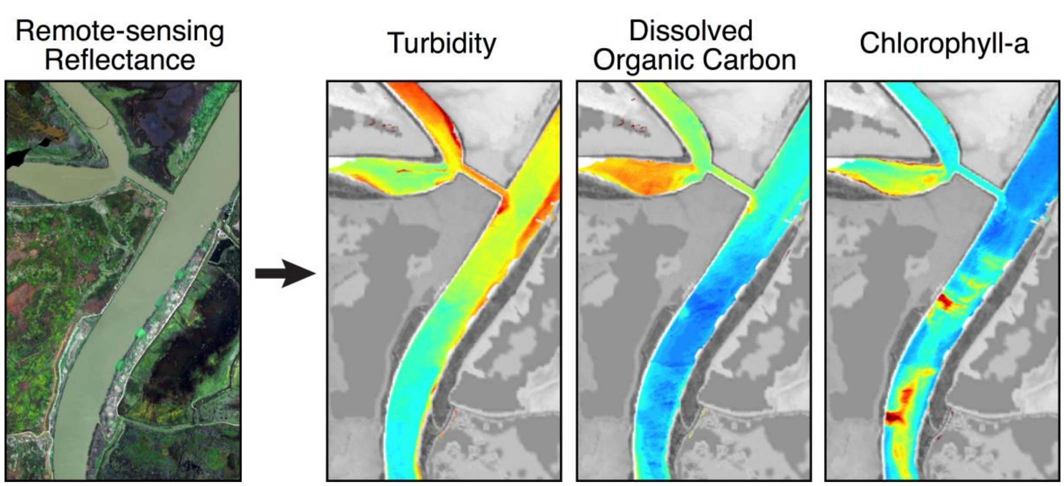
ABSTRACT

The Bay-Delta is a major source of freshwater for California and a profoundly human-impacted environment. Water quality monitoring is critical to the management of this important water resource and ecosystem. State and federal agencies rely primarily on a system of fixed water-quality monitoring stations to understand this system or inform their decisions, but the limited spatial coverage often proves limiting in such an heterogeneous and dynamic ecosystem. Here, we show how the latest remote-sensing technology can facilitate the monitoring of important water quality indicators at high spatial resolution (e.g., meters) over large areas, and enhance our understanding of the Bay-Delta system. Hyperspectral radiometry from the airborne Portable Remote Imaging SpectroMeter (PRISM) was used to derive very detailed and distinct spatial distributions of turbidity, dissolved organic carbon (DOC) concentration, and chlorophyll-a concentration in a Bay-Delta region influenced by wetlands and human activities. The remotely sensed DOC also provided insights on the distribution of methylmercury in the study area. High-resolution remote sensing can facilitate the detection of point-source pollution, help assess the complex, diffuse impacts of wetland restoration and climate change on water quality and ecosystem productivity and health, and inform decision-making about the management of this important natural resource.



Full Suite of IOP measurements using an Automated Flow-through System

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Abstract: While underway measurements of selected IOPs have been conducted for several years, few datasets of complete IOPs have been collected. Here we present a method using two valves and an automated switching controller, which allows for the measurement of whole water, 0.2 μm filtered water, and distilled water with all instruments. The system was first used on a cruise from Tasmania to the Ross Sea to Tahiti (CLIVAR 16S), and some preliminary results are presented here. Parameters measured were: a_g, a_{pg}, c_{pg}, b_p, b_{b650}, b_b/b, chlorophyll- and CDOM fluorescence, temperature, and salinity. To compare measurements of ship's uncontaminated seawater to those of *in situ* water, profiles were made each day while on station with an IOP package containing similar instrumentation.

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BIO-OPTICAL CHARACTERISTICS ALONG THE STRAIT OF MAGALLANES

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The Strait of Magallanes at the tip of South-America connects the Atlantic and Pacific Oceans. Artisanal fisheries, as well as aquaculture, are actively developed in the region. Here we analyze the variability in the absorption by phytoplankton (a_{ph}(440)), non-pigmented particles, NPP (a_{NPP}(440)), and CDOM (a_y(440)) measured along the strait in late summer 2011. MODIS-Aqua PAR, 4-km, Level 3 monthly composite data showed that the western sector was a permanent low-light environment (~ 25 mol quanta $m^{-2}d^{-1}$, due to heavy clouds and rainy conditions) while the eastern sector had relatively higher irradiances (~ 40 mol quanta $m^{-2}d^{-1}$). In the Patagonian Shelf total absorption was dominated by phytoplankton (maximum a_{ph}(440)=0.265 m^{-1}), while in the Atlantic Sector of the strait, the major contributor was NPP (maximum a_{NPP}(440)=0.138 m^{-1}), and in the Pacific Sector of the strait CDOM contributed up to 80% of the total absorption (a_y(440)=0.232 m^{-1}). These changes could be related to the input of fresh water from glaciers melting and rain on the Pacific Sector (a_y(440) vs salinity r_S -0.98). Chlorophyll-a concentration (Chla) ranged from 4.77 mg m^{-3} in the Patagonian Shelf to 0.55 mg m^{-3} in the Pacific Sector. The carbon biomass (C) was composed in its majority by pico-phytoplankton and secondly by the nano-phytoplankton, with exception of the Atlantic Sector where the micro-phytoplankton dominated. C:Chla ratios were very low (average 6.9) as a result from photo-acclimation to this extreme low light environment, which seems to be the major factor affecting phytoplankton in this region.

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Bayesian Atmospheric Correction of Ocean-Color Imagery in the Presence of Absorbing Aerosols

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The ability of a Bayesian methodology to invert satellite ocean-color data in the presence of absorbing aerosols is evaluated theoretically and experimentally. The solution of the inverse problem is expressed as a probability distribution, which measures the likelihood of encountering specific values of the spectral water reflectance, given the observed spectral top-of-atmosphere reflectance. Expectation and covariance are computed, which gives for each pixel an estimate of the water reflectance and a measure of its uncertainty. Spectral information in the visible to near infrared, including at wavelengths sensitive to aerosol absorption, is used. Theoretical performance is generally good, with water reflectance biases between -0.001 and 0.001 and standard deviations <0.005 in the blue for pollution- and continental-type aerosols. Application to SeaWiFS imagery of the Sea of Japan and East China Sea acquired during dust events provides water reflectance retrievals with less spatial noise than the standard SeaDAS algorithm and more realistic values compared with in situ measurements (negative biases significantly reduced). Further improvements are expected by observing in the ultraviolet, where the influence of absorbing aerosols is larger. Auxiliary information about aerosol characteristics, such as optical thickness and vertical distribution, obtained for example from an aerosol transport model, would help to reduce retrieval uncertainties (with additional prior information some of the possible solutions would become less likely).

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A REMOTE SENSING DIAGNOSTIC MODEL FOR PLANKTONIC DMSP, THE PRECURSOR OF THE CLIMATE-COOLING GAS DMS

Martí Galí, Emmanuel Devred, Maurice Levasseur and Marcel Babin

Dimethylsulfoniopropionate (DMSP) is a ubiquitous phytoplankton metabolite and the main precursor of the biogenic gas dimethylsulfide (DMS) in the oceans' surface. Thus, the ability to predict DMSP concentration from environmental variables is essential to better oceanic sulfur emission. Here we used DMSP and ancillary measurements from a global database to develop a remote sensing algorithm for DMSP in the upper mixed layer. Over 55% of DMSP variability (log_{10} scale) is explained by in situ chlorophyll *a* (Chl) after dividing the database into two subsets, according to “stratified” and “mixed” water column criteria, based on the ratio between euphotic layer depth (Z_{eu}) and mixed layer depth (MLD). Up to 70% of the variability is explained when adding sea surface temperature (SST) and $log_{10}(Z_{eu}/MLD)$ as predictors for the stratified and mixed subsets, respectively. Besides, particulate inorganic carbon is used as an additional DMSP proxy in coccolithophore blooms. Validation on satellite Chl match-ups indicates that the algorithm predicts DMSP with a mean absolute percentage error typically ranging from 40 to 60% (linear space), a root-mean-squared error spanning from 0.20 to 0.30 (log_{10} space), and R^2 ranging from 0.45 to 0.72 (log_{10} space). We use the algorithm to produce a monthly global climatology, and estimate that planktonic DMSP synthesis amounts to at least 5% of oceanic primary production. We also show that the algorithm can resolve interannual variations at the regional scale. Our work fills an important gap in marine sulfur biogeochemistry and represents a step forward toward improved diagnosis of DMS emission.

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Hyperspectral Lambertian Equivalent Reflectance from marine plastics

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Abstract

Plastic pollution is a widespread and persistent problem for benthic, pelagic and littoral marine environments. Reports suggest that 60-80 % of marine debris is from plastic products and such products can be ingested by a wide variety of marine organisms. Furthermore, large patches of debris have been reported in the North Pacific and North Atlantic gyres, in particular, yet the spatial extent and concentration of plastic products has not been quantified. Here, we investigate the potential to observe plastic products using ocean color remote sensing and proposed new sensor technology (e.g., PACE). Plastics possess distinct optical features in the near-infrared to the shortwave infrared spectrum that are used in automated industrial sorting of typical household plastic waste. We measured optical features of plastic samples using a hyperspectral field spectrometer over a wavelength range from 350 nm to 2500 nm. Measured Lambertian Equivalent Reflectance (*LER)* revealed spectral dips at 850, 1150, 1350 and 1700 nm. A sensitivity analysis will be conducted to evaluate the concentration of floating plastic products that can be detected using these spectral features. Implications of this research are also aimed towards establishing robust indices or approaches to discriminate plastic *LER* in ocean color information.

APPLICATION OF BIO-OPTICAL MODELING TOOLS TO REMOTELY SENSED DATA FOR ROUTINE MONITORING OF WATER QUALITY CHANGES IN DRINKING WATER RESERVOIRS IN SOUTHERN CALIFORNIA

Seyoum Yami Gebremariam[1], Rich Yates[2], Ric De Leon[1]

Availability of remotely sensed (satellite) data with high spectral, temporal and spatial resolution sufficient to depict the dynamics of drinking water supply reservoirs presents a unique opportunity for developing satellite-based lake and reservoir water quality monitoring tools. While applied remote sensing research over the last three decades have clearly shown a greater potential of using remotely sensed data for water quality management of coastal and inland waterbodies, satellite-based tools that are useful for operative monitoring purpose of drinking water reservoirs are still not well developed. Moreover, with harmful algal blooms more often threatening drinking water supplies due to changing climate and continued nutrient pollution entering water ways, lake and reservoir managers need unconventional monitoring tools that allow them to proactively manage water quality problems. Towards this end, we conducted feasibility study on bio-optical modeling tools to determine their capability to allow operative monitoring of drinking water reservoirs. We retrospectively applied bio-optical tools to LANDSAT ETM+ and AQUA MODIS data to characterize various algal bloom events encountered in recent years in multiple reservoirs operated by the Metropolitan Water District of Southern California (MWDSC) and gaged the potential of these remotely sensed data use for routine monitoring of reservoir operations. Results indicate that remotely sensed data can be used for operational monitoring of MWDSC's reservoirs but uncertainties still exist in identifying phytoplankton functional groups and population succession partly due to lack of pigment-based chemotaxonomic data.

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CHALLENGES TO VALIDATING MODIS IMAGERY FOR MONITORING WATER QUALITY ON LAKE VICTORIA

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Abstract

Lake Victoria is the largest freshwater lake in Africa, and covers an area of 68,800 km^2. It is transboundary surrounded by Uganda, Kenya and Tanzania. Lake Victoria is a key ecosystem providing sustenance, livelihood, recreation etc to a population of over 20million people directly, and over 100 million people indirectly through River Nile which originates from Lake Victoria. This certainly provides a case for the need of a rigorous, reliable and regular source of information regarding the lake's water quality. The existing traditional methods of determining water quality cannot fit the bill, hence the interest in Satellite Remote Sensing. Satellite imagery brings with it the advantage of regularly collected data which is easily accessible and gives a synoptic perspective of the whole lake. The validation process involves comparing satellite derived water quality parameters with in-situ observations collected the traditional way. Some of the challenges encountered in this validation include: persistent cloud cover, cost of expeditions, the size of the lake means that only a small portion of the lake can be monitored at a time, there were even times when satellite overpass missed out the study area of interest. The preliminary results nonetheless show that satellite derived lake surface temperature strongly correlates with in-situ temperature measurements. We still haven't been able to correlate satellite derived ocean colour with in-situ observations, which we hope to remedy by exploring the use of 'ships of opportunity' which ply the route between Jinja in Uganda and Mwanza in Tanzania or Kisumu in Kenya.

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Evaluation of Hyperspectral Airborne PRISM Imagery in the Coastal Ocean

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The NASA/JPL airborne Portable Remote Imaging SpectroMeter (PRISM) was developed to address measurement challenges of the optically complex coastal and inland water environments. PRISM is a push-broom spectrometer (350-1050nm @ 2.83nm sampling) with high signal-to-noise ratio (500 at 450 nm), low sensitivity to polarization (<1%), and high spectral uniformity (> 95%). The objective of this study is to evaluate the performance of PRISM in the coastal ocean, such as its utility for discrimination of phytoplankton functional types using the Phytoplankton Detection with Optics (PHYDOTax) algorithm. Results presented are from the April 2014 field campaign of Monterey Bay.

Retrieval of macro –and micro-physical properties of oceanic hydrosols from polarimetric observations and polarized sky glint correction

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Remote sensing relies mainly on measurements of scalar radiance to retrieve properties of aerosols and hydrosols. However, it is recognized that including the polarimetric characteristics of the light in measurements provides more intrinsic information about scattering particles. Relationships to retrieve the micro and macro- physical properties of the oceanic hydrosols were analytically developed based on vector radiative transfer (VRT) simulations. Specifically, we investigated the relationship between the observed degree of linear polarization (DoLP) and the ratio of attenuation-to-absorption coefficients (c/a) in the water, from which the scattering coefficient is readily computed for different bio-optical models of Case I and II waters. This relationship was parameterized for multiple sensor zenith angles, azimuth angles relative to the Sun's principal plane, and solar zenith angles. The relationship was tested and validated against a dataset of *in-situ* measurements using a custom built underwater polarimeter and an in-water instrument package (WET Labs ac-s) that measures the absorption and attenuation coefficients. Also, the polarized light at the top of the atmosphere is analyzed to assess the impact of aerosol species and optical thickness on the relationship used in the developed retrieval algorithms. To validate relationships from above water observations, a sun-tracking HyperSAS-POL system was deployed during two research cruises (SABOR and VIIRS) in 2014. First results of a Monte-Carlo based glint (sky + Sun) correction scheme for the upwelling polarized signal through a windy ocean surface and comparison with HyperSAS-POL measurements is also presented.

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Variability of the seawater bio-optical properties in the near-surface layer on the transition from the Baltic to the White Sea from data of satellite and shipboard measurements

Dmitry Glukhovets

A goal of this work is the comparative analysis of results of satellite (MODIS-Aqua) and shipboard measurements of seawater bio-optical properties in the near-surface layer, carried out during the 127-th scientific cruise of R/V "Professor Shtokman" from Kaliningrad to Arkhangelsk, 26 July – 5 August 2014. The shipboard data include spectra of seawater fluorescence induced at two excitation wavelengths (401 and 532 nm), the seawater attenuation coefficient, concentrations of chlorophyll and different phytoplankton species measured on 40 seawater samples from 0 and 4 m depth.

A good agreement between the changes in the fluorescence spectra and the spectral remote sensing reflectance $R_{rs}(\lambda)$ from the Baltic to the Barents Seas was observed; the main factors determining changes in the $R_{rs}(\lambda)$, such as high concentration of the color dissolved organic matter (CDOM) in the Baltic Sea and coccolithophore blooms in the Barents Sea were revealed. The connection between the fluorescence spectra, chlorophyll concentration and phytoplankton is analyzed. The regional algorithm for assessment of the coccolithophore concentration in the Barents Sea from satellite data is validated.

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Mitigating socio-economic losses from massive *Noctiluca* blooms along the coast of Oman using ocean color and coupled physical-biogeochemical modeling

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Abstract

Over the past decade, the western Arabian Sea has witnessed a nearly three-fold increase in summer-time phytoplankton biomass due to intensification of the southwest monsoon (SWM) winds and wind-driven coastal upwelling as a result of Eurasian warming and the decline in snow cover extent over southwest Asia and the Himalayan-Tibetan Plateau region. The impacts of the warming trend have not been confined to the SWM alone. During the northeast monsoon (NEM) also, the Arabian Sea has been experiencing unprecedented blooms of a mixotrophic dinoflagellate, *Noctiluca scintillans.* First seen in smaller numbers off the coast of Oman, *Noctiluca* blooms have now become more pervasive and widespread throughout the northern Arabian Sea replacing diatoms as the dominant winter-time bloom forming phytoplankton. We show that these large annual blooms of *Noctiluca* blooms are being fuelled by the spread of hypoxia and are disrupting the traditional food chain of the Arabian Sea. This presentation will highlight new results from a Indo-US-Oman satellite and coupled physical biological modeling effort aimed at 1) investigating the origins of *Noctiluca* and its unique ecophysiological characteristics and, 2) developing based decision support tools specifically geared towards mitigating large socio-economic losses being caused by massive *Noctiluca* blooms along the coast of the Sultanate of Oman.

CHLOROPHYLL FLUORESCENCE LIFETIMES IN THE OCEAN AND PHYTOPLANKTON PHYSIOLOGY INFERRED FROM SPACE

Maxim Gorbunov[1], Hanzhi Lin[2], Fedor I. Kuzminov[3], Jisoo Park[4], San-Hoon Lee[5], and Paul G. Falkowski[6]

Variable chlorophyll fluorescence is the most sensitive, non-destructive signal detectable in the upper ocean that reflects instantaneous phytoplankton photophysiology. Over the past two decades, many hundreds of thousands of discrete *in situ* measurements of variable fluorescence have been made using active ship-based fluorometers. These instruments have been used to follow phytoplankton photophysiology in response to iron fertilization, across eddies along meridional transects, and many other phenomena. With the launch of the MODIS and MERIS satellites, which possess the capability of detecting solar induced chlorophyll fluorescence signals from the global ocean, it became theoretically possible to calculate the quantum yield of chlorophyll fluorescence from space. However, it is impossible to directly verify the relationship between solar induced fluorescence yields retrieved from satellite-based observations and the photophysiological status of phytoplankton based on the signals obtained from conventional active fluorometers. One solution to this problem is to measure chlorophyll fluorescence lifetimes *in situ*. Fluorescence lifetimes are inherently related to the absolute quantum yield of fluorescence. Here we provide the first extensive measurements of chlorophyll fluorescence lifetimes *in situ* in the global ocean and compare them with satellite-based retrievals to understand the variability in phytoplankton physiology in the global ocean.

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Role of the in water light field and water column structure on phytoplankton composition in the eastern Bering Sea

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We present analysis of phytoplankton community composition as it relates to the in water light field and water column physical structure in the eastern Bering Sea. Absorption attributed to phytoplankton, non-algal particles (NAP) and colored dissolved organic matter (CDOM) within the surface mixed layer and near the pycnocline were determined through bio-optical profiles or discrete measurements. Phytoplankton taxa and cell size composition were determined from pigment biomarkers following both CHEMTAX and the Uitz et al. (2006) diagnostic pigment methodology. The relative importance of water column physical structure (temperature, stratification, time since ice retreat), nutrient fields and spectral light field (spectral radiometry and absorption) is explored relative to the resulting phytoplankton community composition. Chlorophyll as a proxy of phytoplankton abundance has been used to explore the role of water column physical structure, nutrient fields and the spectral light field in sub-Arctic and Arctic systems to date. Previous studies have noted the large role of CDOM in structuring the spectral light field in this region. These results contribute to understanding the impact of CDOM on structuring phytoplankton community composition and understanding phytoplankton community response to water column physical structure largely dominated by dynamic sea ice extent and duration.

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NASA COAST AND OCEANIA AIRBORNE MISSIONS IN SUPPORT OF COASTAL ECOSYSTEM AND WATER QUALITY RESEARCH

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Worldwide, coastal marine ecosystems are exposed to land-based sources of pollution and sedimentation from anthropogenic activities including agriculture and coastal development. Ocean color products from satellite sensors provide information on chlorophyll (phytoplankton pigment), sediments, and colored dissolved organic matter. Further, ship-based in-water measurements and emerging airborne measurements provide *in situ* data for the vicarious calibration of current and next generation satellite ocean color sensors and to validate the algorithms that use these observations. Recent NASA airborne missions over Monterey Bay, CA, have demonstrated novel above- and in-water measurement capabilities supporting a combined airborne sensor approach (imaging spectrometer, microradiometers, and a sun photometer). The results characterize coastal atmospheric and aquatic properties through an end-to-end assessment of image acquisition, atmospheric correction, algorithm application, plus sea-truth observations from state-of-the-art instrument systems. Utilizing an imaging spectrometer optimized in the blue to green spectral domain enables higher signal for detection of the relatively dark radiance measurements from marine and freshwater ecosystem features. The novel airborne instrument, Coastal Airborne In-situ Radiometers (C-AIR) provides measurements of apparent optical properties with high dynamic range and fidelity for deriving exact water leaving radiances at the land-ocean boundary, including radiometrically shallow aquatic ecosystems. Simultaneous measurements supporting empirical atmospheric correction of image data were accomplished using the Ames Airborne Tracking Sunphotometer (AATS-14). Flight operations are presented for the instrument payloads using the CIRPAS Twin Otter flown over Monterey Bay during the seasonal fall algal bloom in 2011 (COAST) and 2013 (OCEANIA) to support bio-optical measurements of phytoplankton for coastal zone research.

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THE USE OF VOLUNTEER MONITORING FOR THE DEVELOPMENT OF WISCONSIN'S STATEWIDE LANDSAT 8 WATER CLARITY PRODUCTS

Daniela Gurlin and Steven R. Greb

Water quality monitoring is an integral part of water resource management. Monitoring will insure sustainable use of our aquatic resources and track short and long-term changes resulting from anthropogenic influences such as shoreline development, eutrophication, and climate change. Current water quality monitoring budgets can constrain the assessment of ecosystem health, evaluation of environmental problems, and determination of the success of management actions using conventional methods of periodic *in-situ* water quality monitoring in terms of spatial and temporal coverage. Remote sensing presents a cost efficient complementary approach for a more comprehensive assessment of our aquatic resources. Aquatic remote sensing activities at the Wisconsin Department of Natural Resources include the systematic processing of Landsat 8 OLI data for the retrieval of water clarity, the use of satellite retrieved water clarity data for the assessment of trends in water quality, and the development of new interactive ways to present the satellite retrieved water clarity data for public use. These activities are supported through volunteer monitoring data collected for hundreds of lakes on Landsat 8 image acquisition dates for algorithm calibration and validation and the derived water clarity products include average summer lake water clarities for General Condition Assessments and water clarity maps for the State of Wisconsin. Insights are provided in the steps for the development of Wisconsin's statewide Landsat 8 water clarity products and the challenges in future improvements of these products.

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Integration of bio-optical profiling floats within an Indian Ocean biogeochemical observing system.

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The integration of robotic profiling floats with next-generation optical sensors (bio-profilers) is enabling measurement of optical proxies for several biogeochemical variables in remote areas of the ocean that were previously inaccessible to observation, except through occasional snapshots from ship-based expeditions. While Earth observation satellites can measure optical proxies of several of these quantities (chlorophyll, CDOM, light scattering), their field of view is restricted to the surface layer (first optical depth) of the ocean. Simultaneous measurement from bio-profilers and satellites provides the potential to derive a dynamic 3D view of biogeochemical dynamics at the basin and global scale. Understanding the capabilities and stability of these sensors for prolonged deployments, development of standardised quality control (QC) procedures and investigation of optimised deployment configurations are all key challenges for including bio-profilers in basin-scale ocean observing systems. Here we describe results that address these challenges from a joint project between Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Indian National Institute of Oceanography (CSIR-NIO), the Indian National Centre for Ocean Information Services (INCOIS) and the Indian Ocean regional program office of the Intergovernmental Oceanographic Commission (IOC). We address QC issues, comparisons with ocean colour remote sensing and considerations for capturing high-frequency and mesoscale variability in observing system design.

A practical method for on-orbit estimation of polarization response of satellite ocean color sensor

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Polarization response is an important factor influencing the accuracy of radiance measurement for satellite ocean color sensors, which would change with on-orbit time. In this study, a practical method is proposed for on-orbit estimation of polarization response. Firstly, the linear polarization components of the Stokes vector entering the sensor are estimated by a vector radiative transfer model of the coupled ocean-atmosphere system. Secondly, the real radiance entering the sensor is estimated by another high-accuracy ocean color sensor using the cross-calibration method. Finally, based on the estimated linear polarization components and real radiance, the polarization response coefficients are derived by the least squares method. The proposed method is tested by applying it to the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite, and the derived polarization factors are consistent with the prelaunch values, indicating the reliability of the proposed method. In addition, our results reveal that the contribution of aerosol scattering should be included in the estimation of the linear polarization components of the Stokes vector at the top-of-atmosphere, especially for long wavelengths.

REMOTE SENSING OF SEAGRASS ENVIRONMENTS USING A CANOPY MODEL AND UNCERTAINTY PROPAGATION

John Hedley[1], Heidi Dierssen[2], Brandon Russell[3]

Seagrass meadows are important components of the coastal zone, playing key roles in preservation of biodiversity, coastal stabilisation and blue carbon budgets. Remote sensing of the meadows themselves, and associated water column processes such as terrigenous inputs or the consequences of eutrophication, requires an understanding of the optical properties of these systems and associated uncertainties. The reflectance of a seagrass meadow measured by a satellite or airborne sensor is the result of a complex interaction of the overlying water column and the canopy bi-directional reflectance distribution function (BRDF) - itself a result of canopy structure and position, and leaf and sediment optical properties.

We have used a 3-dimensonal radiative transfer model to produce a simplified physics-based parameterised model for canopy reflectance, dependent on canopy density (leaf area index) and other factors. In particular we have quantified the uncertainties in reflectance due to canopy structure, leaf position and sediment on leaf surfaces. Using a model inversion methodology an algorithm for mapping seagrass leaf area index and water column properties, with per-pixel error bars on all quantities, has been developed. The algorithm was applied to hyperspectral airborne data of Florida Bay collected by the Portable Remote Imaging Spectrometer (PRISM). Estimated leaf area indexes agreed well, uncertainties were high due to substantial coverage of leaves by sediment at this site. Sensitivity analysis shows BRDF effects due to canopy position and solar-view angle geometry can lead significant variation in the water leaving reflectance, giving further scope to refine the model.

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CONTROLS ON PHYTOPLANKTON AND PARTICLE DISTRIBUTIONS IN THE SANTA BARBARA CHANNEL, CALIFORNIA

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In coastal waters, bio-optical properties and carbon fluxes are often determined by how advective currents, tides, internal waves, re-suspension, stratification, mixing and river outflows interact over various time and spatial scales. To understand what controls particle distribution in the optically complex and productive Santa Barbara Channel (SBC), satellite ocean color data for the larger SBC was complemented with highly resolved (~0.5 Hz, ~100m horizontally, ~0.5m vertically) glider-derived measurements of temperature, salinity, chlorophyll and CDOM fluorescence, spectral backscatter and dissolved oxygen obtained across the innershelf SBC over various seasons and stratification conditions. The data allowed detailed characterization of bloom developments, establishment of cross-shelf gradients of phytoplankton and their relationship to local and mesoscale physical forcings, formation of intermediate nepheloid layers, and the effect of storms in augmenting sediment re-suspension. While the seasonal cycle was responsible for much of the variability in optical properties throughout the channel, strong episodic events dominated variability in phytoplankton and optical backscatter measurements in the innershelf. Overall, variability in suspended particle loads was well explained by changes in significant wave height, whereas the occurrence of phytoplankton blooms was linked to changes in larger-scale circulation patterns, exemplifying the impacts of local versus remote controls on particle distributions.

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Applications of Lidar Systems for Ocean Ecosystem Research

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Global estimates of phytoplankton biomass (Cphyto) and particulate organic carbon (POC) have traditionally been made using passive ocean color measurements. Recently, data from the CALIOP sensor on the CALIPSO satellite have provided the first measurements of these two key carbon cycle stocks from a space-based lidar. CALIOP was not designed for subsurface ocean retrievals. Nevertheless, global distributions of surface layer C_{phyto} and POC retrieved with CALIOP compare well with independent assessments using MODIS passive ocean color data. This success suggests a potentially important future role for space lidar measurements in global ocean plankton research, particularly for a lidar system optimized for water column profiling. To this end, the NASA Langley airborne High Spectral Resolution Lidar (HSRL) was recently modified for ocean research to increase vertical resolution and to provide independent vertically-resolved retrievals of the diffuse attenuation coefficient (K_d) and particulate backscatter (b_{bp}). The advanced airborne HSRL was deployed in July-August of 2014 on the Ship-Aircraft Bio-Optical Research (SABOR) experiment to overfly ship-based optical measurements. Correlations of lidar-derived b_{bp} with in situ ship-based measurements and lidar-derived K_d with MODIS retrievals during SABOR were excellent. Our poster will provide results from the CALIOP and HSRL studies and ideas on the scalability of the HSRL technique to space for global ocean profiling.

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SEASONAL AND SPATIAL DYNAMICS OF SUSPENDED PARTICULATE MATTER FROM THE COASTAL AQUACULTURE PLUME TO THE NEARSHORE REEF IN THE SOUTH CENTRAL RED SEA USING *IN SITU* OPTICAL MEASUREMENTS

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It has been observed that the coastal aquaculture facility in Al-Lith is one of the few major anthropogenic wastewater inputs in the eastern coast of the south central Red Sea. In this study, we characterized the suspended particulate matter (SPM) of the water strongly affected by the discharge water and those, not affected, close to the nearshore reef. Particle size distribution (PSD), particulate beam attenuation coefficient (c_p), and chlorophyll a fluorescence were measured during several field cruises in winter, spring, summer and fall. The temperature and salinity of the plume fluctuate according to the seasonal and spatial variability, associated to changes in SPM along the water column (size and concentration). In the plume, c_p was significantly higher by a factor of 2 to 25 related to the different environmental conditions. Indeed microbial analysis (bacteria and cyanobacteria) revealed significantly higher cell counts and different community structure in the discharge water than the non-affected water. This plume is the one source of anthropogenic input from land in the region and affects the biogeochemical processes that control the input, transport and fate of SPM to the nearshore water.

Applications of Remote Sensing to the Study of Estuarine Physics: Suspended Sediment Dynamics in the Columbia River Estuary

Austin S. Hudson[1], Stefan A. Talke[2]

Estuarine circulation and its associated transport processes drive the environmental integrity of many near-shore habitats (the coastal ocean, rivers, estuaries and emergent wetlands). A thorough understanding and consideration of this circulation is, therefore, vital in the proper management of these habitats. The aim of this study is to bring together hydrodynamic theory and new satellite observations in the Columbia River Estuary to increase our understanding of estuarine circulation and transport. Surface reflectance measurements gathered by the Moderate Imaging Spectroradiometer (MODIS) are first compared to in situ observations to develop an empirical model for remotely derived surface turbidity. Results indicate that MODIS data significantly correlate with in situ measurements of turbidity throughout the CRE. MODIS observations are then compared to hydrodynamic model results to explore the physical processes that drive the spatial distribution of the turbidity field. Although the response varies throughout the system, global levels of turbidity are most sensitive to fluvial and tidal inputs and increase during spring tides and high river flow. The location of the estuarine turbidity maximum (ETM) is highly dynamic and typically migrates downstream as the tidal velocity or river flow increases. The ETM becomes trapped near river kilometer 20, however, and the presence of strong topography in this region suggests a link between bottom topography and sediment transport.

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APPLICATION OF SATELLITE DERIVED SIZE-FRACTIONATED PRIMARY PRODUCTION ESTIMATES TO IMPROVE MODELS OF FISHERIES PRODUCTION POTENTIAL IN THE NORTHEAST US CONTINENTAL SHELF LARGE MARINE ECOSYSTEM

Kimberly Hyde[1], Michael Fogarty[2],

Advancements in satellite derived phytoplankton size class and primary production models, in addition to updated trophic transfer efficiency models, allow for key improvements to fisheries production potential estimates. In our simplified food web approach, two pathways are recognized for the transfer of primary production to higher trophic levels; direct grazing by mesozooplankton, principally on diatoms (microplankton); and transfer of nano-picoplankton production through the microbial food web. Here we use satellite remote sensing models of phytoplankton size classes and an empirical relationship derived from *in situ* measurements to estimate size-fractionated primary production in multiple regions of the Northeast US Continental Shelf (NES), including the Gulf of Maine, Georges Bank and Mid-Atlantic Bight. The fractions of microplankton and nano-picoplankton production are then traced through a simplified food web to determine the production potential at multiple trophic levels. Total primary production in the NES ranges from 200-300 gC m^{-2} yr^{-1} and total production of the ecosystem is ~1700×10^6 metric tonnes. While the fraction of nano-picoplankton production in the NES is often greater than 75%, inefficiencies in the transfer of carbon through the microbial food web results in less than 5% of this production being available at harvestable trophic levels. Accordingly, the primary production derived from microplankton, 20-30%, ultimately controls fish production and sets constraints on the amount of production available to be extracted from the ecosystem at sustainable levels.

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UTILISING OPTICAL WATER CLASSIFICATION FOR PIXEL-BY-PIXEL ASSIGNMENT OF UNCERTAINTIES IN A MERGED OCEAN-COLOUR PRODUCT.

T. Jackson[1], S.Sathyendranath[1], F. Melin[2], S. Groom[1].

The Ocean-Colour Climate Change Initiative project is tasked with providing a multi-sensor global dataset of ocean-colour products that are of sufficient quality for use in climate research and is produced with associated per-pixel uncertainty estimates. The metrics used for the uncertainty characterisation are the root-mean-square difference and bias, from which the standard deviation can also be computed. The uncertainties are estimated on the basis of comparison with *in situ* observations, matched to each of the satellite products. The *in situ* database includes significant contributions from MERMAID, SeaBASS and NOMAD and we are thankful for their contribution. To provide product uncertainties on a pixel-by-pixel basis, using the *in situ* match-ups, an extrapolation scheme is required. For this work an optical classification scheme based upon the work of Moore et al. (2009) was used to partition the product uncertainties. This classification scheme has now been extended in the version 2 of the OC-CCI products to improve confidence in uncertainty estimates for regions that were poorly classified previously, such as the central gyres. The OC-CCI project has succeeded in providing high-quality merged ocean-colour products with associated uncertainty estimates. Further improvements and product releases are planned for the next two years. Currently, OC-CCI is exploring the incorporation of data from additional sensors into the merged data, as well as improving algorithm performance in optically-complex waters.

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Evaluation of the diffuse attenuation coefficient $K_d(\lambda)$ algorithms in optically complex waters along the eastern Australian coast.

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Shelf waters along the east coast of Australia are optically complex as they are influenced by both by land processes as well as those of the Pacific Ocean that surrounds it. They are also impacted by extreme events such as tropical cyclones and periodic flood discharges. The diffuse attenuation coefficient, Kd(λ) is a fundamental radiometric parameter that is used to assess the light availability, water quality and general health of the ecosystem. Pelagic productivity and biological biodiversity are directly linked to light penetration and ocean depth hence aquatic environmental monitoring relies on precise estimates of Kd over open and coastal waters derived from remote sensing data.

To evaluate the performance remotely sensed Kd, an inter-comparison exercise was conducted on existing empirical and semi-analytical algorithms. Six algorithms have been included in this exercise (Brando et al., 2012; Jamet et al., 2012; Morel and Maritorena (2001); NASA; Tiwari and Shanmugam, 2013; Wang et al., 2009) for the MODIS-AQUA sensor. These algorithms have been evaluated using in-situ measurements of the remote-sensing reflectances (Rrs) collected in four contrasted regions along the east coast of Australia (covering tropical and subtropical regions) between 2010 and 2013. The inter-comparison exercise show that it is difficult to precisely estimate Kd in the region with values of the relative error varying between 51% (Jamet et al.) and 278% (NASA). Validation results for other MODIS-AQUA wavelengths will also be presented. Processing of MODIS-AQUA images with the best algorithm will be presented over the Great Barrier Reef.

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CALIBRATION AND VALIDATION OF A SEAPRISM RADIOMETER FOR AERONET-OC

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The global Aerosol Robotic Network for Ocean Color (AERONET-OC) program utilizes AERONET sun photometers modified for in-air observations of ocean waters situated on oil drilling platforms, off-shore lighthouses, or other platforms that meet the AERONET-OC site requirements. The measurements provide estimates of the water-leaving radiance and are a source of validation data for ocean color satellite sensors. Accurate, validated retrievals at these sites, which present both spatially and temporally complex waters and atmospheres, aid in many aspects of the ocean color problem. In this study, we characterized and calibrated one instrument from the AERONET-OC network – SeaPRISM0080 – using the NIST Spectral Irradiance and Radiance responsivity Calibrations using Uniform Sources (SIRCUS) facility. A laser-illuminated integrating sphere of known radiance mapped out the absolute radiance responsivity for 7 of the 8 AERONET-OC bands. We validated these results using NIST calibrated lamp-illuminated integrating spheres. Finally, we compared the results to calibrations from the AERONET facility at NASA/GSFC and the Joint Research Centre in Italy. The results agree within the estimated uncertainties. Along the way, we determined that a specific interpretation to the way the SeaPRISM080 processed data internally was required in order to make sense of results acquired using the RS232 interface protocol. We demonstrated this was a valid interpretation by comparing this NIST custom data acquisition procedure to a firmware version in the SeaPRISM080 control unit.

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REGIONALLY OPTIMIZED MERGER OF MODIS-AQUA and VIIRS CHLOROPHYLL ALGORITHMS

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ABSTRACT

The standard ocean chlorophyll (Chla) products from current satellite sensors MODIS-Aqua and VIIRS underestimate at medium and high *in situ* Chla concentrations and have approximately 9% bias between each other in the California Current. By using the regional optimization approach of Kahru et al. (2012) we minimized the differences between satellite estimates and *in situ* match-ups as well as between estimates of the two satellite sensors, and created improved empirical algorithms for both sensors. The regionally optimized Chla estimates from MODIS-Aqua and VIIRS are equivalent to standard *chlor_a* estimates at low Chla but have higher retrievals at medium to high *in situ* Chla. The merged Chla datasets from MODIS-Aqua and VIIRS have no bias between each other and can be merged to improve the temporal frequency, spatial coverage and to extend the merged time series.

Challenges of absorbing aerosols in atmospheric correction for ocean color retrievals

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Satellite remote sensing of ocean color is a critical tool for assessing the productivity of marine ecosystems and monitoring changes resulting from climatic or environmental influences. Yet water-leaving radiance comprises less than 10% of the signal measured from space, making correction for absorption and scattering by the intervening atmosphere imperative. Traditional ocean color retrieval algorithms utilize a standard set of aerosol models and the assumption of negligible water-leaving radiance in the near-infrared. Modern improvements have been developed to handle absorbing aerosols such as urban particulates in coastal areas and transported desert dust over the open ocean, where ocean fertilization can impact biological productivity at the base of the marine food chain. Even so, imperfect knowledge of the absorbing aerosol optical properties or their height distribution results in well-documented sources of error. In the UV, which future spaceborne spectrometry plans to exploit to improve the separation of chlorophyll from colored dissolved organic matter (CDOM) as well use to quantify different phytosynthetic pigments contributing to light absorption spectra, the problem of UV-enhanced absorption and nonsphericity of certain aerosol types are amplified due to the increased Rayleigh and aerosol optical depth, especially at off-nadir view angles.

Multi-angle spectro-polarimetric measurements have been advocated as an additional tool to better understand and retrieve the aerosol properties needed for atmospheric correction for ocean color retrievals. The central concern of the work to be described is the assessment of the effects of absorbing aerosol properties on water leaving radiance measurement uncertainty by neglecting UV-enhanced absorption of carbonaceous particles and by not accounting for dust nonsphericity.

The phase matrices for the spherical smoke particles were calculated using a standard Mie code, while those for non-spherical dust particles were calculated using the numerical approach described by Dubovik et al., 2006. A vector Markov Chain radiative transfer code including bio-optical models was used to quantitatively evaluate in water leaving radiances between atmospheres containing realistic UV-enhanced and non-spherical aerosols and the SEADAS carbonaceous and dust-like aerosol models.

Deriving diel changes of the backscattering coefficient of oceanic particulate matter from diel changes in apparent optical properties: a case study in the Mediterranean Sea (BOUSSOLE site).

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Ocean color sensors placed on low-Earth-orbits enable quasi-daily measurements of ocean water properties. However the typical "every other day" sampling of these satellites (under cloud-free conditions) is a serious limitation when aiming at rapidly changing oceanic phenomena, such as biogeochemical processes occurring at hourly scale (e.g., phytoplankton photosynthesis). New opportunities is now becoming available from ocean color sensor on geostationary satellites. Such sensors can record the ocean reflectance hourly throughout the course of a day and be used as a tool for extracting information on the diel changes of the particulate backscattering coefficient, b_{bp}, and used it as a proxy net community production. However, it requires that existing inversion algorithms are capable of retrieving b_{bp} under the changing observation conditions encountered during a day. In this study, we show that the b_{bp} diel cycle observed *in situ* is large enough to generate a measurable diel variability in reflectance. Significant differences have been observed between the b_{bp} values retrieved from radiometric quantities and those obtained from the *in situ* measurements, questioning the performance of the inversion algorithm and their applicability to derive the b_{bp} diel cycle from radiometric measurements taken at different time of a day. We found that inversion algorithm might still be not applicable to derive b_{bp} at several time of a day due to their link on bio-optical relationships established from global database. The inversion of radiometric measurements in view of deriving the b_{bp} diel variability is therefore challenged.

Monitoring the Eastern Tropical Pacific Tuna Fishery from Space

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With support from NASA's Ecological Forecasting program, we are developing a Tuna Stock Assessment Support System (TSASS), which merges time series of satellite imagery, the ECCO-2 global ocean circulation estimates, climatology from field surveys, and fisheries data on catch and effort. The purpose of this software is to incorporate information on oceanographic conditions into stock assessment for the tuna fishery of the eastern tropical Pacific Ocean. This fishery, which is international and covers thousands of kilometers of ocean surface, is managed by the Inter-American Tropical Tuna Commission, which has gathered a high quality, spatially and temporally resolved 50-year record of catch and effort of skipjack, bigeye, and yellowfin tuna by both long-line and purse seine vessels. TSASS is a plug-in into EASY, a 4-dimensional (latitude, longitude, depth, and time) marine geographic information system. Our analyses of fishery data, remote sensing imagery of sea surface temperature, chlorophyll, and height, and ocean model flow fields provide key information to manage the fishery. This information support definition of the habitat of the 3 species of tuna as determined by sea surface water temperature, concentration of chlorophyll, the depth of the hypoxic layer, and patterns in circulation), estimation of the rates of recruitment of yellowfin tuna, and optimal placement of fishery closure regions to limit catch and by-catch. Our poster will present hypotheses of linkages between surface chlorophyll, the hypoxic layer, circulation, and the rich tuna fishing grounds. We will also demonstrate the TSASS software.

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LAKE ERIE WATER RESOURCES:

Utilizing NASA Satellite Data to Detect Harmful Algal Blooms in the Western Basin of Lake Erie

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Harmful algal bloom events, or HABs, have increased in Lake Erie and are negatively impacting drinking water supplies, as well as fisheries and property values. HAB events also pose a risk to water resources around the world, drawing various stakeholders to take steps toward mitigation efforts and to better understand its effects on nearby communities. Remote sensing is proving to be a useful tool for HAB detection, and can be applied in areas of the world where *in-situ* data is either inaccessible or extremely costly. To validate the precision of remote sensing in detecting HAB events, the NASA DEVELOP team at the Ames Research Center applied two indices to satellite imagery obtained over Lake Erie. The indices were compared against *in-situ* data to assess satellite accuracy statistics. These indices included Floating Algal Index (FAI) and Normalized Difference Turbidity Index (NDTI). Both indices were applied to remotely-sensed products from NASA Earth Observing System's Landsat 5 Thematic Mapper, Landsat 8 Operational Land Imager, and Terra Moderate-Resolution Imaging Spectrometer (MODIS), as well as data from the Hyperspectral Imager for the Coastal Ocean (HICO) aboard the International Space Station (ISS). The National Geospatial-Intelligence Agency (NGA), National Center of Water Quality Research (NCWQR), the University of Toledo, and the Great Lakes and St. Lawrence Cities Initiative (GLSLCI) utilize these methods and end-results to evaluate the potential of applying these indices within Lake Erie and other regions of the world.

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APPROACHES TO OCEAN COLOR STUDIES USING SEADAS

Daniel Knowles Jr.[1], Don Shea[2], Chris Proctor[3], Sean Bailey[4]

Various approaches to image visualization and the analysis of ocean color satellite data were developed which utilize the SeaDAS software. SeaDAS is a comprehensive image analysis software package developed and maintained by NASA (in collaboration with the developers of ESA's BEAM software) for the processing, display, analysis, and quality control of ocean color data. Each methodology, though specific in nature, presents concepts which are readily customizable by the user for their own specific applications. This poster illustrates and overviews results which were achieved using these approaches which include the following: cloud edge masking; population density masking; ocean floor and deep water masking; regional polygon masking; integration of field measurements with satellite derived data; cross satellite comparisons; hybrid true color images which optimize land and water features separately. Many of these approaches are also applicable to the current BEAM (and in the future the Sentinel Toolbox which will serve as the core to the SeaDAS) software.

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SPATIAL AND TEMPORAL VARIABILITY OF COCCOLITHOPHORE BLOOMS

IN THE BARENTS SEA FROM SATELLITE OCEAN COLOR DATA

Oleg Kopelevich, Sergey Sheberstov, Svetlana Vazyulya, Inna Sahling, Vladimir Burenkov

The results of our previous studies of coccolithophore blooms in the Barents Sea based on SeaWiFS and MODIS-Aqua satellite data 1998-2012 are available at site http://optics.ocean.ru. They include the mean monthly distributions of coccolithophore concentration N_{coc} in July-September, derived by a regional algorithm which was developed by using directly measured data on coccolithophore and coccolith concentrations from the ship cruises of 2004 and 2009 and the optical characteristics of coccolithophore (Voss et al. 1998).

In the current presentation, some new results are presented including data of 2013 and 2014. The next topics are considered:

- difference between the spectral remote sensing reflectance in the areas of coccolithophore blooms and beyond them;
- an improved regional algorithm to derive concentration of coccolithophoride cells; comparison with the standard PIC algorithm;
- duration of the bloom cycles and its variability;
- spatial structure of the blooms;
- analysis of the role of different climatic factors (the sea surface temperature SST, the surface photosynthetically available radiation PAR and the surface wind speed W) in inter-annual variability of the coccolithophore blooms;

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PHYTOPLANKTON PHENOLOGY FROM OCEAN COLOR ALGORITHMS AND EARTH SYSTEM MODELS

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Recent bio-optical algorithm developments have focused on products beyond total chlorophyll, such as phytoplankton functional types (PFTs). Characterization of the spatio-temporal variability of the PFTs is essential for understanding the structure and function of oceanic ecosystems and their role in the carbon cycle and climate. Biogeochemical routines of Earth System models need to take into account various PFTs and satellite PFT data sets can play a pivotal role in informing and/or validating the models. It is thus important to inter-compare the existing PFT algorithms, which define the PFTs differently and rely on different sets of assumptions and theoretical bases, making direct comparison of retrieved variables non-trivial. Here, we compared the emergent phenology of 10 PFT satellite algorithms and 7 climate models from the CMIP5 model suite. The satellite algorithms were applied to (mostly) SeaWiFS monthly reflectance data for the 2003-2007 period. The phenological analysis was performed on the fraction of microplankton or diatoms for the satellite algorithms and on the diatom biomass for the climate models. The seasonal cycle was modeled as a sum of sinusoidal harmonics, derived from the Discrete Fourier Transform of the variable time series. Peak analysis was applied to the modeled signal and the following phenological parameters were quantified: seasonal amplitude, percent seasonal variance, month of maximum, and bloom duration. Secondary blooms occur in many areas and were also quantified. The algorithms and the models were quantitatively compared based on these emergent phenological parameters, revealing spatial patterns of agreement and disagreement.

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Remotely-sensed phytoplankton size structure around Southern Africa.

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The three-component model of Brewin et al. (2010) computes fractional contributions of three phytoplankton size classes (micro-, nano-, picophytoplankton) to the overall chlorophyll *a* concentration. Using in situ HPLC data, model coefficients were fine-tuned for application to the southern African marine region. The refined model was applied to seasonal climatologies of MODIS Aqua chlorophyll *a* around Southern Africa during summer and winter. During summer, high chlorophyll *a* was limited to shelf regions along the coasts of Southern Africa and Madagascar, while values < 0.1 mg m^{-3} occurred over most of the open ocean between the equator and 40°S. Between 40°S and 45°S, elevated concentrations (up to 0.5 mg m^{-3}) were associated with the Subtropical Convergence zone. During winter, chlorophyll *a* values up to 0.5 mg m^{-3} extended over a much larger area of the open ocean, with low values (< 0.1 mg m^{-3}) restricted to subtropical gyres and the Mozambique Channel. During both seasons, micro-phytoplankton comprised more than 50 % of the total chlorophyll *a* in shelf regions, and less than 10 % in the open ocean, while the converse was true for pico-phytoplankton. During summer, nano-phytoplankton tended to dominate in smaller zones along the edges of the continental shelves and in the Subtropical Convergence zone, while in winter, they were distributed over a larger area and contributed more to the total chlorophyll *a*. Characterizing spatial and temporal variations in phytoplankton size structure will enable the influence of climate change and variability in different ecosystems to be evaluated.

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Dedicated NOAA/VIIRS Ocean Color Calibration/Validation Cruise: Cruise objectives and scope of observations.

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The NOAA/STAR Ocean Color team is focused on "end-to-end" production of ocean color satellite products. In situ validation of satellite data is essential to producing the high-quality products required and expected by the international ocean color remote sensing community. In November 2014, a 10-day cruise aboard the NOAA Ship *Nancy Foster* in the western Atlantic along the US mid-east coast with the primary aim of in situ calibration and validation of the Visible Infrared Imaging Radiometer Suite (VIIRS) instrument onboard the Suomi National Polar-orbiting Partnership (SNPP) satellite. This was the first NOAA dedicated VIIRS ocean color validation cruise supported through the NOAA Office of Marine and Air Operations. Collaborating groups included: Naval Research Laboratory; University of Southern Mississippi; City College of New York; University of Massachusetts at Boston; University of South Florida; University of Miami; Lamont-Doherty Earth Observatory at Columbia University; the National Institute of Standards and Technology, NASA/Goddard Space Flight Center and the Joint Research Centre of the European Commission. We present the scope of the observations of inherent and apparent optical properties made in support of the three primary objectives: 1) VIIRS ocean color validation; 2) uncertainty characterization of in situ ocean color measurements and 3) optical characterization of ocean variability. Cruise data will be reposited at NOAA CoastWatch/OceanWatch for convenient public access and will be archived as required by NOAA. A second dedicated VIIRS ocean color cruise is planned for late 2015 and additional NOAA ocean color cruises are anticipated for different regions in the future.

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- **AN ENSEMBLE APPROACH TO ATMOSPHERIC CORRECTION OVER OPTICALLY COMPLEX WATERS**

Samantha Lavender[1]

Traditionally, ocean colour atmospheric correction (AC) approaches have used the information available at the processing time (near real time data) or updated calibration / meteorological data for offline processing. However the resources required for data reprocessing are reducing as datasets are kept online, and multi-core processing has become common place. Therefore, reprocessing can be carried more frequently and potentially in an iterative way.

Also, the AC code typically runs on a pixel-by-pixel basis and so lacks both spatial and temporal awareness of variability. Therefore, the AC outcome can potentially be optimised by using all the information / knowledge gained from the image itself alongside the time-series of remotely sensed data available for an area of interest. The premise is that the more the AC code is run for a geographical / temporal location the more it understands by remembering previous solutions.

The implementation is being tested on a combination of MERIS, MODIS, SeaWiFS, HICO and Landsat satellite imagery with the AC run over the land as well as water to allow for estimates of coastal vegetation and the correction of estuarine and inland waters.

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IMPACT OF THE OCEANIC CIRCULATION ON THE PHYTOPLANKTON PHENOLOGY: A CASE STUDY IN THE IONIAN SEA

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The Ionian circulation is dominated by a basin-scale meander, which changes on a decadal time-scale from cyclonic to anticyclonic and vice versa. This phenomenon, named the Bimodal Oscillating System (BiOS), affects the nutrient field and even though that has never been demonstrated, it is also expected to impact on phytoplankton bloom.

Based on phytoplankton phenological metrics applied to ocean colour data, we investigated the influence of BiOS on the phytoplankton seasonality in the North Ionian Sea. Daily ocean colour chlorophyll products developed by the Climate Change Initiative program (http://www.esa-oceancolour-cci.org/) were used and, specific phenological metrics were computed on annual time-series to characterize the different bloom events which were observed. Then, these metrics associated with the cyclonic and anticyclonic regimes were compared.

Results showed that although the initiation date of the first bloom event is not affected by BiOS, the initiation date of the strongest bloom event is impacted. On average, when circulation is cyclonic, the strongest bloom event starts in early February whereas it starts in mid-December when circulation is anticyclonic. The magnitude of the highest bloom event is also larger during the cyclonic period than during the anticyclonic one. Therefore, our results show that in addition to surface heat fluxes, oceanic circulation contributes largely, to modification of the phytoplankton phenology. We hypothesized that the observed seasonal changes in surface chlorophyll concentration could have large implications in phytoplankton seasonal dynamics and primary production.

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Predicting hypoxia with MODIS/Aqua observed Mississippi River plume dynamics on the Louisiana continental shelf

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Larger rivers are the primary interface between terrestrial and ocean environments, and serve as major sources of buoyancy and dissolved and particulate materials to the associated coastal ocean margins. Here, we employ a river plume color index (RPI) to detect Mississippi River plume on the Louisiana continental shelf from MODIS/Aqua images. Time-series of Mississippi River plume spatial and temporal variations were used to investigate their influencing factors and the relation with hypoxia. The river plume color index successfully detected Mississippi River plume on the Louisiana continental shelf, and an 11-year time-series (2003-2014) revealed great spatial and seasonal dynamics, which were primarily regulated by wind-driven local circulation and the loop-eddy current system. River plume size had a significant negative correlation with hypoxia, explaining > 50% variation in hypoxia size and volume. Prediction of hypoxia size and volume was improved by including Chla derived from MODIS. This study demonstrate that ocean color satellites provide scientists and environmental managers a unique tool for understanding the biological and physical process of hypoxia.

Secchi Disk Depth: Theoretical interpretation of the most common water quality product

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Secchi disk depth (SDD), a measurement of the maximum viewable depth of a white or black-and-white disk with a diameter 20-30 cm when lowered into water, holds the longest (from at least 1880's) records of water transparency. Because of the easy and low-cost nature, SDD has been the most common product for assessing water quality by professionals and seagoers. Theoretical interpretations of SDD have also been established since 1950's, which generally follow the same Law of Contrast Reduction adopted for visual ranging in air established 90 years ago. However, it is found that the assumptions adopted in this theory do not match the observation of a Secchi disk in water. We developed a new theoretical model to interpret SDD based on radiative transfer along with an overhaul of the Law of Contrast Reduction. This model is subsequently validated using SDD data of a wide range of environments, with results showing excellent agreement between measured and theoretically predicted SDD ranging from < 1 m to > 30 m. The new theory and mechanistic model have profound impacts on both the understanding of visibility and the generation of global SDD product from ocean color remote sensing for the monitoring of water quality.

Regional chlorophyll-a algorithms in the Arctic Ocean and their effect on NPP estimates

Kate Lewis, Gert van Dijken, & Kevin Arrigo

The Arctic is warming at approximately twice the global rate in response to anthropogenic climate change, resulting in disappearing sea ice, increased open water area, a longer growing season, and increased annual net primary production (NPP) by 30% (Arrigo & van Dijken 2014).

To quantify changes in NPP, models require inputs of chlorophyll *a* concentrations (Chl *a*), which serve as a biomass proxy for phytoplankton. While global ocean color algorithms are useful for global estimates of Chl *a*, the algorithms are prone to errors at high latitudes for two main reasons. First, high latitude systems are severely underrepresented in the calibration of global Chl *a* algorithms. Second, the Arctic Ocean deviates from global trends because of the bio-optics of the region resulting from high pigment-packaging and high CDOM concentrations.

In this study, we compare satellite retrievals of Chl *a* and the resultant NPP estimates against in situ data from recent oceanographic cruises in the Chukchi Sea to identify the best Chl *a* product to use in estimating NPP for various regions of the Arctic Ocean.

REMOTE SENSING OF FRESHWATER CYANOBACTERIA: FOCUS ON ESTIMATING LOW CONCENTRATION OF PHYCOCYANIN

Linhai Li [1], Lin Li [2]

As one type of harmful algal blooms, toxic cyanobacterial blooms severely impact health of the environment, animals, and people. Over the past decade, optical remote sensing has been an important tool for monitoring cyanobacterial blooms of inland waters, which is often achieved by detecting phycocyanin (PC), a pigment used as a proxy of freshwater cyanobacteria. Although many efforts have been made to retrieve PC concentrations from remote sensing reflectance (Rrs), yet it is still a challenging task to accurately estimate low PC concentrations (e.g. less than 20 mg m^{-3}) and few studies are devoted to address this issue. In this study, PC concentrations were determined upon the absorption coefficients derived from Rrs using Inherent optical property (IOP) Inversion Model for Inland Waters (IIMIW), an IOP inversion model developed specifically for inland waters. Results indicate that the PC concentrations lower than 20 mg m^{-3} can be predicted for most of the water samples collected in reservoirs and rivers of Australia and central Indiana. Despite of further efforts needed, the results confirm that detection of cyanobacteria in their early growth period is possible, which is critical for issuing an early warning of cyanobacterial blooms.

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UNCERTAINTY ESTIMATES IN THE RETRIVAL OF WATER DEPTH AND TURBIDITY IN TURBID COASTAL WATERS USING VERY HIGH RESOLUTION SATELLITES DATA

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High spatial resolution satellite sensors typically have a small number of broad spectral bands and are not optimal for deriving ocean color products. The WorldView-2 satellite provides very high resolution data in eight spectral bands in the visible to near-infrared region. The additional spectral bands provide an opportunity to test algorithms for retrieving the water depth, bottom albedo and intrinsic optical properties of coastal sea water. Here we investigate the uncertainty in estimating water depth and turbidity using the 8-band WorldView-2 data in turbid coastal waters. The standard shallow water reflectance equation is used to compute remote sensing reflectance of coastal sea waters with water depth ranging from 0.1 m to 30 m, and for different values of intrinsic optical properties representative of turbid coastal waters. The spectral response functions of WorldView-2 spectral bands are used to calculate the effective reflectance of each spectral band. These sets of simulated reflectance spectra are then used to retrieve the water depth, absorption and backscattering coefficients using an iterative spectral fitting algorithm. The backscattering coefficient at 550 nm is taken as a proxy for water turbidity. During the retrieval iteration, the fitting algorithm does not seek for the minimum RMS. Instead, all sets of the fitting parameters (water depth, bottom albedo, IOPs) that produce an RMS value within the noise level are treated as acceptable solutions. The statistical behaviors of these acceptable fitting parameters are analyzed to give an indication of the uncertain estimates of the retrieved water depth and turbidity.

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BIOGEOCHEMICAL CHARACTERIZATION OF OPTICALLY COMPLEX COASTAL WATERS USING UNDERWAY AND IN SITU HYPERSPECTRAL OBSERVATIONS

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Optically complex coastal waters present a challenge for ocean color remote sensing because of the high degree of spatial heterogeneity and limitations in the performance of algorithms. Ship-based underway hyperspectral observations of remote sensing reflectance provide a means for improved spatial resolution and greater degrees of freedom for semi-analytical algorithms. Here, we describe a series of complementary observations of surface hyperspectral radiance and irradiance and in situ measurements of apparent and inherent optical properties and key constituents in coastal waters of the northern Gulf of Mexico. The Satlantic HyerSAS-UV system was used to provide above-water measurements of radiance and irradiance, as well as extended spectral range into the UV-B, thereby yielding broad spatial and temporal coverage and higher frequency sampling. The extensive coverage facilitated comparisons to satellite-derived remote sensing reflectance, but also extended observations into regions not accessible by satellite. In addition to radiometry measurements, discrete profiles of spectral absorption and backscattering were determined using a WETLabs, Inc. ac-s absorption/attenuation meter and bb9 backscattering meter, respectively. Spectrophotometric measurements of particulate and dissolved absorption were also made using conventional methods. These in situ measurements were compared to inherent optical properties estimated by inversion of the HyperSAS reflectance using the quasi-analytical algorithm (QAA v6). In general, the QAA products provided a good representation of the in situ observations over a wide range of conditions. Results illustrate the utility of remote sensing reflectance as means of characterizing distributions of biogeochemical properties in an optically complex coastal regime, the Mississippi River outflow region.

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Suspended particulate matter variability of the global coastal waters

over the MERIS time period.

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Satellite remote sensing now allows for the collection of various physical and biological parameters at regional and global scales and at different temporal resolutions which are not accessible to other sampling methods. The first objective of the GlobCoast project (www.foresea.fr/globcoast/) is to assess and analyze the seasonal, inter-annual, and decadal evolution of the global coastal waters in terms of biogeochemical composition as revealed from satellite ocean colour observations. Here, we present the temporal variability (seasonal and long term trend) patterns of the suspended particulate matter, SPM, over the global coastal ocean over the last decade. For that purpose, a new global SPM algorithm combined with a new atmospheric correction algorithm, have been developed, evaluated, and applied to the MERIS (2002-2012) archive. Then, the temporal variability schemes of SPM are presented, and specific Hot Spot areas are identified. At last, the impact of waves and swell on this variability is analyzed at global scale.

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Impact of the temporal binning algorithm on ocean color products: application to the SeaWiFS time period.

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The assessment of the seasonal, inter-annual, and long-term trends of the inversed ocean color products of surface oceanic waters requires temporal binning algorithms (TBA). The impact of the TBA on the remote sensing reflectance, R_{rs}, and chlorophyll-a concentration, *Chl*, spatio-temporal patterns are examined at global scale over the SeaWiFS time period. Three different ways of averaging (arithmetic, geometric, and maximum likelihood) and three bio-optical algorithms (OC4v6, CIA, and GSM) have been specifically considered. The main objectives of this study are **i)** to evaluate the temporal averaging uncertainty introduced by selecting the monthly R_{rs} instead of the daily R_{rs} to generate monthly *Chl* products; **ii)** to evaluate if this TBA related uncertainty is algorithm dependant; and **iii)** to assess the impact of temporal binning algorithms on the long term trends.

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CHLOROPHYLL-A SEASONAL VARIABILITY IN AUSTRALIAN WATERS

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Surface Chl-a concentration used as an indicator of marine primary productivity is one of the key factors in understanding biogeochemical processes and exchanges in the ocean system. Satellite ocean colour observations provide high spatial and temporal resolution maps of Chl-a concentration, but need to be linked with model information to understand the physical and biological processes that drive variability.

We use a 10-year time series of MODIS chl_OC3 to characterise the meso-scale patterns of seasonal and inter-annual variability in surface Chl-a and compare these with outputs from the Ocean Forecasting Australia Model. Two model runs with different forcing fluxes are compared to test the contributions of physical drivers versus the bio-geochemical components. Fourier series analysis revealed some agreement in characteristics of the annual and semi-annual cycles of Chl-a as well as some areas of significant difference between data and models. Examples are given that illustrate differences in processes captured by the two versions of the model.

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An alternative approach to determine critical angle of contrast reversal and surface roughness of natural oil slicks under sun glint

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Abstract: The critical angle is the angle at which the contrast of natural oil slicks reverse their contrasts against the background seawater, which is related to the surface roughness of oil slicks and seawater. Accurate determination of the critical angle could help estimate surface roughness of both oil slicks and seawater. In this study, the angle between the viewing direction and the direction of mirror reflection is found to be a good indicator for quantifying the critical angle, and the former can be calculated from the solar/viewing geometry from observations of the Moderate Resolution Imaging Spectroradiometer (MODIS). The oil slicks in the Gulf of Mexico were first delineated using a customized segmentation approach to remove noise and applya morphological filter. Then, from the histograms of the brightness values of the delineated oil slicks, the range of the critical angle was determined. An optimal critical angle between oil slicks and seawater was then determined from statistical and regressional analyses in this range. Such a determined critical angle corresponds to the best fitting between the modeled and observed surface roughness of oil slicks and seawater.

Keywords: Sunglint, critical angle, oil slicks, surface roughness, MODIS.

ARCTIC-COLORS - COASTAL LAND OCEAN INTERACTIONS IN THE ARCTIC

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Arctic-COLORS is a Field Campaign Scoping Study funded by NASA's Ocean Biology and Biogeochemistry Program that aims to improve understanding and prediction of land-ocean interactions in a rapidly changing Arctic coastal zone, and assess vulnerability, response, feedbacks and resilience of coastal ecosystems, communities and natural resources to current and future pressures. Our project goal is to develop a report for NASA that describes and justifies the design of an integrative, interdisciplinary oceanographic field campaign program that addresses high priority science questions related to land-ocean interactions in the Arctic, and assess the impacts of natural and anthropogenic changes on coastal ocean biology, biogeochemistry and biodiversity. This field campaign will be composed of multiple research cruises with sufficient seasonal and spatial coverage to resolve the science questions proposed by the Arctic-COLORS team. The science in our field campaign will be focused on five overarching questions:

1. How do coastal Arctic biogeochemical transformation zones impact terrestrial, riverine, atmospheric, and coastal materials across the continuum of Arctic rivers, estuaries and the continental shelf?
2. How do Arctic riverine, atmospheric, and other fluxes of constituents effect changes in coastal ecology?
3. How does thawing of Arctic permafrost—either directly through coastal erosion or indirectly through changing freshwater loads—translate to quantitative changes in coastal ecology and biogeochemistry?
4. How do changing snow and ice conditions and coastal circulation effect changes in estuarine and coastal ecology and biogeochemistry?
5. How do changing environmental (short-term) and climate (long-term) conditions alter the region's availability and use of ecosystem services?

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OPTIMIZATION OF INSTRUMENT REQUIREMENTS FOR NASA'S GEOSTATIONARY COASTAL AND AIR POLLUTION EVENTS MISSION CONCEPT BASED ON SENSOR CAPABILITY AND COST STUDIES

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NASA's GEOstationary Coastal and Air Pollution Events (GEO-CAPE) mission concept recommended by the U.S. National Research Council (2007) focuses on measurements of atmospheric trace gases and aerosols and aquatic coastal ecology and biogeochemistry from geostationary orbit (35,786 km altitude). Geostationary offers the capability to image the same regions multiple times each day, which is critical to study process within estuaries and coastal oceans where the physical, biological and chemical processes react on short time scales from seconds to days. From geostationary orbit, a sensor can stare at the target location to gain sufficient signal-to-noise (SNR) to retrieve ocean reflectance during low light conditions (early morning and late afternoon) and at high satellite view angles. Furthermore, the flexibility of scanning throughout the day allows for greater opportunity to obtain non-cloudy pixels at any given location due to temporal variability in cloud cover. Three instrument design lab (IDL) studies were commissioned in 2014 to design and cost two implementations for geostationary ocean color instruments (1) Wide-Angle Spectrometer (WAS) and (2) Filter Radiometer (FR) and (3) a cost scaling study to compare the costs for implementing different science performance requirements. These studies intended to allow the assessment of the impact of various science requirements, including spatial and spectral resolution, spectral range, scanning rate and SNR, on the instrument cost. Multiple instrument concepts were examined to capture a broader range of costs that might be associated with different types of instruments. Results on the cost versus capability will be presented.

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OCEAN COLOR DATA RECORDS WITH UNCERTAINTIES FOR NASA MEaSUREs

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The NASA MEaSUREs (Making Earth System Data Records for Use in Research Environments) project emphasizes the development of Earth System Data Records (ESDRs) to study the Earth system processes, variability and trends and for use in modeling efforts. As part of MEaSUREs, we are developing a set of ocean color products that are not currently available through NASA or other space agencies. Most of these datasets will also have an associated pixel-by-pixel uncertainty product. The products that have been or will be developed for MEaSURES use data from SeaWiFS, MODIS-AQUA and MERIS and include a merged chlorophyll product from each sensor operational product, a one-stop-shop reflectance product that combines the level-3 reflectance from the three sensors (19 bands), a model-based merged reflectance product and several high spatial resolution regional products from the combination of level-2 data. The data and uncertainty products are processed and distributed by ERI at UCSB for evaluation by the community. The MEaSUREs ocean color products that are currently available and future products are presented.

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PUSHING THE LIMITS OF ATMOSPHERIC CORRECTION OVER VERY TURBID WATERS

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Capability of ocean colour sensor to provide sea surface reflectance over sediment-dominated waters relies on the so-called Bright Pixel Atmospheric Correction (BPAC). The challenge is to decouple marine and atmospheric signal in the near-infrared (NIR), so that the classical atmospheric correction can properly operate as if over clear waters. Inspection of recent satellite data over the Amazon plume, Rio de la Plata river and smaller estuaries shows evidence that growing turbidity is still a limiting factor and generally yields to complete failure of the atmospheric correction.

The present work is a successive attempt to push the limits of the BPAC. The core element is a coupled atmosphere-hydrological model defined by a set of free variables (sediment concentration and aerosol) and fixed constants (spectral shape of inherent optical properties). Information is restricted to NIR bands in order to avoid too large uncertainties in the model, due to lower absorption of pure seawater near the visible and larger absorption of non-modelled components; also we discard SWIR bands, not present on most of past and future sensors.

We first demonstrate that inversion is mathematically ambiguous at high turbidity for some band combinations, what explains the classical confusion between aerosol and sediment. We then show that the problem can be solved unambiguously through a $\chi 2$ minimization method on three NIR bands, taking into account input uncertainties. Finally particulate absorption is identified as a key modelling parameter. MERIS maps and validation results demonstrate the significance of these findings for future data processing.

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Merging glider and ocean color data to accurately estimate phytoplankton biomass in Oregon's coastal waters

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Long-term deployments of vertically-profiling platforms are becoming more common, providing a data-rich source of *in situ* ocean parameters ideal for pairing with satellite remote sensing data, particularly in areas with persistent cloud coverage. Regional development of methods that couple satellite and in situ data in ways that maximize the descriptive power of each is one of the crucial next steps in oceanographic research. For example, subsurface chlorophyll-a (chl-a) maxima often occur below the first optical depth (FOD), the maximum depth covered by satellite chl-a. In these cases, the sensors effectively miss a majority of phytoplankton biomass. Here we develop methods to merge 5 years of Slocum glider profiles and ocean color data in Oregon's coastal waters in order to quantify the occurrence of chl-a within the full euphotic zone and to improve biomass estimations in this region. This work includes two primary goals. First, the relative accuracy, precision, and uncertainty of the datasets are assessed, including comparison of vertical glider profiles of chl-a concentration, corrected to account for non-photochemical quenching, to satellite retrievals. Secondly, we have characterized the vertical distribution of chl-a and scattering and determined the seasonality and frequency of chl-a features below the FOD. We will discuss results of this study relative to physical and chemical forcing within the region.

A RAMAN SCATTERING CORRECTION ALGORITHM FOR OPERATONAL OCEAN-COLOR DATA PROCESSING

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Most existing ocean-color inversion algorithms largely ignore trans-spectral processes. Once such process is Raman scattering whereby water molecules absorb and re-emit photons at wavelengths different to, and typically longer than, the excitation (absorption) wavelength. Radiative transfer studies have shown that the Raman scattering process can contribute significantly to the remote-sensing reflectance, R_{rs}, particularly in clear oceanic waters. Approaches have been developed whereby the Raman scattering contribution to the remote-sensing reflectance, R_{rs}^{RC}, can be quantified. An algorithm for computing R_{rs}^{RC} and thence correcting R_{rs} for Raman scattering effects has recently been incorporated into the NASA Ocean Biology Processing Group's processing code, L2GEN. Here we present inherent optical properties (IOPs) derived from the MODIS Aqua time series using the default configuration of the Generalized Inherent Optical Properties (GIOP) algorithm. IOPs derived with/without the Raman scattering correction are compared and quantitatively evaluated using *in situ* matchup data. The Raman scattering correction scheme currently supports a range of past/present ocean-color missions including, but not limited to: OCTS, SeaWiFS, MODIS-Terra, MODIS-Aqua, MERIS, and VIIRS.

UNCERTAINTY ESTIMATES FOR REMOTE SENSING REFLECTANCE DERIVED FROM THE COMPARISON BETWEEN MISSIONS

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Assigning uncertainty to ocean-color satellite products is a requirement to allow an informed use of these data. To answer this, uncertainty estimates are derived using the comparison of coincident daily records of the remote sensing reflectance R_{RS} derived from three missions, MERIS, MODIS and SeaWiFS, with the same processing chain. The approach is spatially resolved and produces the part σ of the R_{RS} uncertainty budget not affected by biases. The global average of σ decreases with wavelength from approximately 0.7-0.9 10^{-3} sr^{-1} at 412 nm to 0.05-0.1 10^{-3} sr^{-1} at the red band. The distribution of σ shows a restricted spatial variability and small variations with season, which makes the multi-annual global distribution of σ an estimate applicable to all retrievals of existing missions. The comparison of σ with other uncertainty estimates derived from field data or with the support of algorithms provides a consistent picture. When translated in relative terms, the distribution of σ suggests that the objective of a 5% accuracy is fulfilled between 412 and 490 nm for oligotrophic waters (chlorophyll-a concentration below 0.1 mg m^{-3}). This study also illustrates comparison statistics. The mean absolute relative difference shows a characteristic U-shape with both ends at blue and red wavelengths inversely related to the amplitude of R_{RS}. On average and for the considered data sets, SeaWiFS R_{RS} tend to be slightly higher than MODIS R_{RS}, which in turn appear higher than MERIS R_{RS}. Biases between mission-specific R_{RS} may exhibit a seasonal dependence, particularly in the subtropical belt.

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DESTRIPING ALGORITHM FOR IMPROVED SATELLITE-DERIVED OCEAN COLOR PRODUCT IMAGERY

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While modern multi-detector radiometers (such as VIIRS-SNPP and MODIS-Aqua) offer improved image resolution and signal-to-noise ratio among other performance benefits, multi-detector arrangement in a whisk-broom scanner design gives rise to striping in satellite imagery due to various sources, which cannot be perfectly corrected by sensor calibration. Striping is more prominent in ocean color imagery, where it can strongly distort image gradients. Recently, Bouali and Ignatov (2014) [J. Atmos. Oceanic Technol., **31**, 150–163 (2014)] introduced a new approach to remove relatively small detector performance related striping from thermal infrared bands (TOA radiances) for improved sea surface temperature data. We show that this methodology, with appropriately chosen parameters and adjustments, can also be applied to remove striping of much larger variance from the solar reflective band data. Specifically, we modify and apply this new approach to remove striping from satellite-derived normalized water-leaving radiance spectra $nL_w(\lambda)$ (not TOA radiances) obtained from solar reflective bands. The results show a significant improvement in image quality for both $nL_w(\lambda)$ spectra and $nL_w(\lambda)$-derived ocean biological and biogeochemical products such as chlorophyll-a concentration and water diffuse attenuation coefficient at the wavelength of 490 nm $K_d(490)$. It is emphasized that destriping is only applied to $nL_w(\lambda)$ spectra, not $nL_w(\lambda)$-derived products. While this work is focused on removing striping artifacts from moderate resolution whiskbroom scanner type sensor data, it is expected to be applicable to destripe imagery from higher resolution pushbroom scanner type sensors.

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VALIDATION OF THE VIIRS PARTICULATE INORGANIC CARBON ALGORITHM

Catherine Mitchell[1], William M. Balch[2], Bruce Bowler[2], Dave Drapeau[2], Laura Lubelyck[2]

Coccolithophores have a significant impact on the global carbon cycles, with the calcification of coccolithophores accounting for the majority of pelagic calcite production. The scattering nature of coccolithophores allowed the development of algorithms to estimate the concentration of particulate inorganic carbon (PIC) using satellite data. A two-band and three-band merged algorithm for PIC was initially implemented with MODIS. To provide continuity of the PIC product with newer satellite missions, an evaluation of the PIC algorithm with the VIIRS sensor aboard the Suomi NPP satellite platform is presented here. Field data were acquired on two international cruises plus the Gulf of Maine North Atlantic Time Series (GNATS) program. PIC measurements were made using the acid-labile backscattering technique as well as with ICPOES measurements of discrete samples. Due to the short time period since the launch of VIIRS this shipboard validation dataset does not yet encompass the full range of PIC measurements previously observed; there are no ship measurements from “bright” coccolithophore blooms. The quality of the match-ups between ship measurements and the satellite overpass were rated according to the elapsed time and the number of valid pixels in a 5x5 pixel region centred on the station. Initial results show reasonable recoveries for match-ups within three hours and with more than 50% of the 5x5 region containing valid patches.

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INTERDISCIPLINARY COORDINATED EXPERIMENT OF THE SOUTHERN OCEAN CARBON CYCLE (ICESOCC) – A FIELD CAMPAIGN SCOPING PROJECT

B, Greg Mitchell

Accurate estimates in time and space of organic carbon export to the ocean interior via plankton net community production (NCP) for the global oceans (the oceanic biological pump) is essential for understanding the feedback between NCP, atmospheric CO_2 and climate. Since integrated, multi-sensor satellite observations of many ocean variables are required to estimate NCP from space, the problem is an interdisciplinary and complex challenge. Satellite ocean color sensors are a fundamental component in estimating spatial and temporal variations in NCP. Therefore, NASA's PACE mission (NASA-PACE 2012), a mission included in NASA's Climate Architecture Plan (NASA-CAP, 2010), specifies a need for field programs to improve satellite algorithms and models to reduce uncertainties in our estimates of NCP. In particular, models indicate that the Southern Ocean plays a large role in climate cycles. The "*Interdisciplinary Coordinated Experiment of the Southern Ocean Carbon Cycle (ICESOCC)*" project is a NASA-funded field campaign scoping effort. The ICESOCC team will integrate the input from scientific experts in ocean, atmosphere, ice physics, biogeochemistry, advanced observational tools (ship, autonomous, atmospheric gases and dust, cryosphere dynamics, winds), and models, to create a recommendation to NASA for field observations required to constrain uncertainty of the Southern Ocean carbon cycle. The most successful result will be highly interdisciplinary and will require diverse observational methods of the ocean, the atmosphere and the cryosphere. Input from the international scientific community is requested to ensure a robust global plan in the final recommendation to be submitted to NASA by early 2016.

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IMPROVED SEA SURFACE REFLECTANCE CALCULATIONS USING FULLY RESOLVED SEA SURFACES AND POLARIZED RAY TRACING

Curtis Mobley

Accurate prediction of sea surface reflectance is required for subtraction of sun glint and reflected sky radiances from measured total upwelling radiances. Surface reflectances are usually estimated using either analytical or single-scattering Monte Carlo simulations based on the Cox-Munk wind-speed wave-slope model. Although the Cox-Munk equations do a reasonable job of describing sea surface slope statistics, they cannot resolve wave elevations. Proper simulation of surface reflectance requires three things. First, the sea surface must account for both elevation and slope statistics at all spatial scales from long gravity waves (which dominate the elevation variance) to short gravity and capillary waves (which contribute much of the slope variance). Second, effects of wave shadowing and multiple scattering between waves (which become important for large incident angles from the surface normal) must be modeled. Finally, the reflectance calculations must account for polarization. The first requirement can be met if sea surfaces are simulated using Fourier transform techniques based on wave variance spectra. The second and third requirements are met by using Monte Carlo ray tracing that includes multiple scattering and the full Stokes vector formulation for polarization.

Compared to estimates based on unpolarized ray tracing with Cox-Munk surfaces, irradiance reflectances are of order 10% different for fully resolved surfaces and polarized ray tracing. Differences can be tens of percent or greater for radiance reflectances, depending on the solar zenith angle, sky polarization, wind speed, and viewing direction. The new algorithms and code are computationally efficient and allow for improved predictions of sun glint and sky reflectance as needed to estimate the water-leaving radiance.

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ALGORITHM DEVELOPMENT FOR PREDICTING BIODIVERSITY BASED ON PHYTOPLANKTON HYPERSPECTRAL ABSORPTION.

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Abstract

Ocean color remote sensing has provided the scientific community with unprecedented global coverage of chlorophyll a, an indicator of phytoplankton biomass. Together, satellite-derived chlorophyll a and knowledge of Phytoplankton Functional Types (PFTs) improve our understanding of marine ecosystem response to climate change and the resulting alterations to marine biogeochemical cycles. Concentrations of pigments associated with several PFTs were estimated using singular value decomposition and NNLS techniques on phytoplankton absorption spectra images created using empirical relationships and satellite observations. Comparison of the modeled versus in situ measured absorption spectra (400-700 nm) showed linear correlations values (r^2) ranged from 0.79 – 0.99, with ~ 25% lower r^2 values in the UV region. The prediction of phytoplankton produced r^2 values that ranged from 0.40 to 0.93. Results showed that individual PFTs had unique distributions related to both sea surface temperature (SST), nutrient concentration and to a lesser degree photosynthetically available radiation (PAR). Overall, species shifts were observed in coastal, mid-ocean, and open ocean. Broad shifts of diatoms were observed as their relative abundance decreased in summer with dinoflagellates. In contrast, concentrations of prymnesiophytes became more abundant in summer. Those phytoplankton in lesser abundance overall increased in abundance during. Complex patterns of phytoplankton functional type distribution underly the important between adaptation to light, temperature, and nutrients in the Atlantic Bight. Shifts in phytoplankton functional groups show flexibility in carbon biomass within the Carbon Cycle.

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THE REMOTE SENSING REFLECTANCE EMPIRICAL ORTHOGONAL FUNCTIONS FOR MARGINAL SEAS OF THE NORTH PACIFIC

Georgii S. Moiseenko

A number of statistical and analytical methods are used in the satellite remote sensing for the description of the optical properties variability. One of them is the statistical approach based on the empirical orthogonal functions (EOF) analysis. The essence of the method is to represent each measured spectrum as a vector in a multidimensional space with the empirical orthogonal functions as a basis. The main problem of this method is the choice of the basis. Empirical orthogonal functions – the most significant eigenvectors of the remote-sensing reflectance covariance matrix – in the general case depends on the measured set of data, which can vary depending on the area of the research and the time interval when data are collected. If the annual array of the remote sensing reflectance is used to calculate the covariance matrix, the most part of variability is taken into account. After that, regression equations can be used to connect the estimated parameters of sea water with coefficients of expansion of the remote sensing reflectance into a series with EOFs as a basis.

The main features of empirical orthogonal functions of remote sensing reflectance for the Japan Sea, the Sea of Okhotsk and the Bering Sea are presented. The annual sets of MODIS Aqua data are used for each sea; the time period is 2003 – 2014 years.

The comparative analysis of the results shows that in main features the empirical orthogonal functions are similar for all seas.

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Influence of weather patterns on stocks and fluxes of suspended particulate matter in the Saint Lawrence Estuary: a story based on MODIS-Aqua measurements

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Abstract

Short- (daily) and long-term (years) variations on concentration of suspended particulate matter (C_{SPM}) and chlorophyll a (chl a), two important water quality indicators, were analyzed in the Saint Lawrence Estuary (SLE) based on optical measurements derived from MODIS-Aqua (footprint = 4.5 km) and salinity simulations obtained with a regional circulation model (hereafter LASSO). Monthly changes of C_{SPM} and chl a during April and September of 2002-present were related to variability of four atmospheric modes (Multiple ENSO Index, MEI, North Atlantic Oscillation, NAO, Atlantic Meridional Oscillation, AMO, and Arctic Oscillation, AO) and two environmental variables (river discharge and wind speed). The atmospheric correction of TOA radiances was performed based on Wang's NIR-SWIR algorithm, and pixels near the coast were corrected by adjacency effects. C_{SPM} was calculated using a regional empirical regression based on remote sensing reflectance at 678 nm. Likewise, the absorption coefficient of phytoplankton at 443 nm (a_{ph}(443)), a proxy of chl a, was estimated by using a semi-empirical hybrid model based on QAA-modified functions and relationships between salinity and inherent optical properties. The impact of transient turbidity events on C_{SPM} and a_{ph} (443) were investigated after the passage of storms with different intensity. In general, preliminary results highlighted the increasing importance of short-term phenomena on determining distribution of particulates along the SLE, and their exchange between the SLE and the Gulf of Saint Lawrence.

Title: Evolution of optical signatures in western Lake Erie as related to HAB formation and senescence

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Abstract: In 2014, a harmful algal bloom (HAB) began in western Lake Erie in late July and continued into October. Over this time period, a variety of instrumentation utilized on cruises captured the optical temporal and spatial variability of the bloom. Hyperspectral radiometry was measured from late June through early November at NOAA sites, and in mid-August a multi-day field survey yielded detailed measurements of the horizontal and vertical optical structure of the water in the western basin. These measurements included hyperspectral radiometry, microscopic holographic imagery, absorption and scattering characteristics of the water column. We observed water types from HAB-free waters of the Detroit River plume, to floating *Microcystis* mats near Maumee Bay. We also observed a transition from *Microcystis*- to *Planktothrix*-dominated waters transiting east into the central basin. Based on these data sets, an optical picture of the evolution of the water over the span of the bloom has emerged, which contain many interesting aspects of the environmental variability of the basin over space and time. These results have important implications for remote sensing algorithms and applications.

A Remote Sensing Perspective on Spatial Scales of Variation in Biogeophysical Properties of Water

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Using remote sensing for understanding the effects of environmental changes and anthropogenic activities on estuarine and coastal waters requires the capability to measure and track complex biogeophysical and biogeochemical processes in water. A key sensor design consideration is the minimum spatial resolution required to optically resolve estuarine and coastal features and processes that are of interest. Quantitative information on spatial scales of bio-optical variation in near-shore waters and the expected ability to capture this variation at various spatial resolutions would provide a valuable and essential guideline while deciding on the spatial characteristics of a future remote sensor. We have analyzed continuous, along-track measurements of temperature and salinity of water and absorption and scattering properties of particulates and dissolved organic matter collected using flow-through instruments (AC-9, AC-s) deployed from a ship and airborne lidar from Long Island Sound, Gulf of Maine, and the North Pacific Ocean. We analyzed the ratio of sub-pixel variability to between-pixel variability and autocorrelation as a function of spatial sampling interval to understand the trade-off between the spatial resolution of a sensor and the spatial information contained within an image. For example, within coastal waters, we found a clear break in the spatial information content for particulate backscattering and attenuation at a spatial resolution of approximately 200 m. Decreasing the resolution to less than 200 m offered significant gains in spatial information, whereas increasing the spatial resolution beyond 200 m resulted in only moderate loss of spatial information.

PHYTOPLANKTON SIZE IMPACT ON EXPORT FLUX IN THE GLOBAL OCEAN

Colleen B. Mouw[1], Audrey Barnett[1], Galen A. McKinley[2]

The efficiency of the biological pump of carbon to the deep ocean depends largely on the biologically-mediated export of carbon from the surface ocean and its remineralization with depth. Global satellite studies thus far have focused on the use of chlorophyll concentration and primary production to understand the role of phytoplankton in these processes. Recent satellite retrievals of phytoplankton composition now allow for the size of phytoplankton cells to be considered in the biological pump at large scales. The goal of this study is to improve understanding of how phytoplankton size structure controls particle export and remineralization. Particulate organic carbon (POC) flux observations from sediment traps and 234-Thorium were compiled across the global ocean and the distribution of the data is presented. Annual climatologies of primary production, percent microplankton, and POC flux at key time series locations and within biogeochemical provinces were compiled. Sinking velocity was calculated to align surface production with POC flux. Parameters that characterize POC flux vs. depth (export flux ratio, labile fraction and remineralization length scale) were fit to the aligned dataset. Times of the year dominated by different size compositions were identified and fit separately in regions of the ocean where phytoplankton cell size varied enough over the annual cycle. Cell size impacts were observed in export flux and remineralization length scales. Generally, periods dominated by small cells had lower transfer efficiency and greater export flux than periods when microplankton comprised a greater proportion of the phytoplankton community.

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Neural Network Technique for Gap-Filling of Satellite Ocean Color Observations for Use in Numerical Modeling

Sudhir Nadiga[1], Vladimir Krasnopolsky[2], Avichal Mehra[3], Eric Bayler[4], and David Behringer[5]

This poster examines using a Neural Network (NN) technique for gap-filling by linking ocean color variability – primarily driven by biological processes – with the physical processes of the upper ocean. Satellite-derived surface variables – sea-surface temperature (SST), sea-surface height (SSH) and sea-surface salinity (SSS) fields – are used as signatures of upper-ocean dynamics. NN employ adaptive weights that are tuned using statistical learning (training) algorithms with past data sets, and provide robustness with respect to random noise and fault-tolerance. NN training, a complicated nonlinear optimization task, is done once for a particular application. The trained NN is then repeatedly applied to new data, providing accurate and fast emulations. This study uses Visible Imaging Infrared Radiometer Suite (VIIRS) ocean color fields, satellite SSS/SSH/SST fields, and gridded vertical profiles of temperature (T) and salinity (S) from ARGO. All data sets were interpolated to the same spatial (one-degree latitude-longitude) grid and temporal resolution (daily) for 2012-2014. The NN technique is trained for two years and tested on the remaining year; however, by rotating the time series, we are able to cover all three years. The NN output are assessed for: (i) bias, (ii) variability, (iii) root-mean-square error (RMSE), and (iv) cross-correlations. Additionally, we evaluate a Jacobian to estimate the impact of each input (SSH, SSS, SST, T and S) on the NN ocean color estimates and the differences between an ensemble of NNs vs a single NN.

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Bering Sea Optical and Biological Properties from MODIS-Aqua

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The Bering Sea is characterized by unique bio-optical properties, which cause unsatisfactory performance of global ocean color algorithms for retrieval of chlorophyll-a (Chl-a). In this presentation, we evaluate the normalized water-leaving radiance $nL_w(\lambda)$ and Chl-a in the eastern Bering Sea that are derived from MODIS-Aqua by comparing them to in situ data. The MODIS-derived $nL_w(\lambda)$ showed good agreement with in situ-measured $nL_w(\lambda)$. The mean ratios between them for wavelengths 412, 443, 488, and 551 nm ranged from 1.097–1.280, with reasonably accurate blue-green radiance ratios in $nL_w(\lambda)$ that were used as input for deriving Chl-a. However, compared to in situ data, existing global and regional Chl-a algorithms either overestimate or underestimate Chl-a in the eastern Bering Sea. Therefore, we propose a new algorithm for estimating Chl-a using a blended approach that was tested and applied to MODIS-Aqua images. The histogram distributions of MODIS-Aqua-derived and in situ-measured Chl-a data show that Chl-a data derived using the new algorithm agree reasonably well to in situ measurements. Annual, seasonal, and monthly composite $nL_w(\lambda)$ and Chl-a images are produced for the period of 2003 to 2013 in order to interpret the long-term spatial and temporal patterns of $nL_w(\lambda)$ and Chl-a. The $nL_w(\lambda)$ spectra show strong spectral dependence on seasonal variability with distinct spatial patterns. Although strong seasonal and interannual variability has been observed in Chl-a, there is no apparent trend of either increase or decrease in phytoplankton biomass associated with variability in the physical environment for the 11 years of the study period.

A report from a community-lead spectral absorption workshop to update the NASA Inherent Optical Properties Protocol for measuring particle absorption

Aimee Neeley[1]

The "NASA Ocean Optics Protocols for Satellite Ocean Color Validation" are community-vetted

protocols that were first synthesized as part of the Sensor Intercomparison and Merger for Biological and Interdisciplinary Studies (SIMBIOS). This standard set of protocols, when followed explicitly, provides community-wide measurement consistency and accuracy that are necessary for minimizing measurement and data processing errors in multi-mission satellite algorithm development and validation. The protocols are living documents with topics separated into different volumes so each could be revised independently as standards and technology improve over time. However, the last revision to the protocols was in 2003 and, as such, they are due for an update. One of the overarching goals of the NASA Ocean Ecology Laboratory Field Support Group (FSG) is the revision and distribution of community-vetted protocols for in situ data collection, processing and analysis. To this end, the NASA FSG hosted an absorption workshop June 11-13 2014 at NASA Goddard Space Flight Center, bringing together an international collaboration of spectral absorption experts. The workshop focused on spectral particle absorption and updating the protocols used to separate its phytoplankton and detrital spectral components. The ultimate deliverable will be a revised version of the Inherent Optical

Properties Protocol (IOP; Revision 4, Vol. IV, 2003) that includes both liquid and filter pad techniques for measuring spectral particle absorption. The revised protocol will be made publicly available upon completion.

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EVALUATION OF BIO-OPTICAL MODELS FOR DISCRIMINATING PHYTOPLANKTON FUNCTIONAL TYPES IN THE CHUKCHI SEA

Aimee Neeley[1] and Lora Harris[2]

The vulnerability of the Arctic coastlines to climate change has become a well-studied question. Thinner ice and longer summers in the warmer Arctic are predicted results of climate change. Less ice means more light penetrating the water column. The influence of climate change on nutrient and carbon input from river runoff and thawing permafrost are difficult to predict. Current nutrient data for the Arctic Ocean are scarce. The consequences to phytoplankton community composition and, subsequently, on such processes as CO_2 drawdown and primary productivity are not well understood.

Phytoplankton species are separated into phytoplankton functional types (PFTs) based on similar morphological and physiological characteristics. Bio-optical models have been developed to use satellite-derived products to discriminate PFTs, a recommended field measurement for the future NASA Pre-Aerosol, Clouds and ocean Ecosystem mission (PACE). The proposed 5 nm spectral resolution of the new ocean color sensor will improve detection of PFTs by discriminating finer optical features not detected at the spectral resolution of current satellite-borne instruments. In preparation for PACE, new and advanced PFT models are under development that require accurate data for validation.

Phytoplankton pigment data have long been collected from coastal and estuarine environments and are widely used to model phytoplankton size structure (Micro-, Nano-, and Picoplankton) or PFT abundances using two well-known methods: Diagnostic Pigment Analysis (DPA) and Chemical Taxonomy (ChemTax), respectively. Here we present the results of an effort to evaluate bio-optical PFT models based either on biomass (Chlorophyll a) or on light absorption properties of phytoplankton using data from the Chukchi Sea. PFT model performance is evaluated using flow cytometric data and output from DPA and ChemTax. Relative strengths of the model approaches are presented in the context of model needs for understanding anticipated changes in response to climate for this Arctic coastal ecosystem.

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Light and life beneath sea ice in Baffin Bay: transmission of sunlight through sea ice and influence on the phytoplankton spring bloom.

Griet Neukermans, Guislain Bécu, Eric Rehm, and Marcel Babin

In the framework of the GreenEdge project (http://www.greenedgeproject.info/), we measured spectral downwelling irradiance above and below sea ice in Baffin Bay (Nunavut, Canada) from 10 April till 10 June 2015 with a ruggedized C-OPS instrument (*Biospherical*). Measurements were made every other day in two locations forty meters apart, which differed substantially in ice and snow cover. We present the impact of ice, snow, and melt ponds on 1) the amount and color of sunlight transmitted through sea ice, 2) the spectral diffuse attenuation coefficient, and 3) the concentration of microalgae. The strong patchiness of light and life beneath sea ice demonstrated here poses challenges for monitoring blooms of microalgae beneath Arctic sea ice.

PROTOCOLS FOR THE MEASUREMENT OF CDOM ABSORPTION USING DIFFERENT TECHNOLOGIES AND TECHNIQUES: RESULTS FROM THE THIRD NASA CDOM WORSKSHOP ROUND ROBIN

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Chromophoric Dissolved Organic Matter (CDOM) is a major optical constituent of inland waters, estuaries, coastal ocean, and open ocean. This significant contribution of CDOM to aquatic optical properties requires quantitation and characterization of CDOM spectral absorption for development and evaluation of ocean color satellite remote sensing algorithms. CDOM absorption can be quite high in coastal regions; however from coastal to open ocean waters, the CDOM decreases significantly and becomes much more difficult to quantify accurately. UltraPath instruments (long-pathlength spectrophotometer) and Liquid Waveguide Capillary Cell (LWCC) technology were developed to resolve the CDOM absorbance sensitivity issues and have been in use for over a decade to quantify CDOM absorption. However, developing a correction method to account for the spectral offset caused by the refraction index of dissolved salts has been challenging. As part of the NASA CDOM absorption protocol working group, a third Round Robin experiment was carried out in 2015 with U.S. and international participants. Extremely low CDOM seawater collected from the South Pacific near Tahiti was distributed to the group and measured following the same protocol within the same 48 hour period. Three different salt correction methods were evaluated using NaCl dissolved in Ultrapure water. In addition, two freshwater solutions of different concentrations of Suwanee River Fulvic Acid (SRFA) were measured in order to characterize them for the use as consensus reference material to monitor the performance and relative accuracy of absorbance measurements from various instruments. These samples were measured with Ultrapath and LWCC instruments as well as conventional double-beam spectrophotometers, ac-meters, and an a-sphere. The results were analyzed to ascertain the amount of error and variability associated with these instruments and technology and in development of a community consensus protocol.

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Assessing the spatial and temporal dynamics of suspended particles in the Rhône River plume based on high resolution ocean colour satellite data.

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River plumes are associated to complex and highly dynamic physical and chemical processes, making them difficult to study based on scarce field observations. However, the recent capabilities improvement of ocean colour satellite sensors have made of them an efficient way to assess and monitor river plume dynamics. The prime objectives of this study are to i) test and compare the capabilities in terms of spectral, spatial and temporal resolution of three complementary satellite sensors, L8/OLI, AQUA&TERRA/MODIS and MSG-2/ SEVIRI, for the mapping of suspended particulate matter (SPM) in the moderately turbid waters of the Rhône River plume, and ii) describe the dynamics of SPM in the Rhône River plume using these high spatial and temporal data. Regional relationships between remote-sensing reflectance (Rrs) and SPM concentration are established based on in situ data; the best results obtained are linear relationships between the SPM concentration and Rrs in the red spectral band of the three sensors. Results show that the three sensors provide pretty consistent and complementary observations for the mapping of SPM concentration on the Rhône River plume. OLI and MODIS spatial resolutions (30m, 250-500-1000 m) well reproduce the SPM concentration and plume shape but their temporal resolution (16 days and 1 day, respectively) is limited to study short-term events. Because of its low spatial resolution (~ 4km), SEVIRI tends to slightly underestimate the SPM concentration compared to other sensors and in-situ data. However, its high temporal resolution (15min) makes of it a powerful tool to study the daily dynamics of the Rhône River plume.

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THE PROBABILITY MAPPING INDEX AND OCEAN COLOR DATA

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Spatial and temporal patterns of change in ocean color data can be used as indicators for the onsets of different oceanic processes. Using NASA's archive of SeaWiFS and MODIS-Aqua data (both in excess of 10-year continuous global coverage) a new metric has been developed to analyze how often an observed change in various ocean color-derived products takes place on a pixel by pixel basis. Changes that occur once a year or even once a month are readily detectable above baseline conditions, and the spatial patterns of those changes help confirm the process identification. Working with spatial and/or temporal derivatives, it is possible to calculate the empirical probability that an observed change has been met or exceeded over the satellite record at any given pixel. The probability mapping index [-log10(prob)] makes it easy to visualize where low-probability changes are taking place. This approach has been successfully used to detect the onsets of infrequent submarine volcanic eruptions, based on their impact on the surrounding chlorophyll and backscatter retrievals. Upwelling of nutrient rich, deep water is also examined using temporal derivatives of chlorophyll and sea surface temperature. Eddy pumping, frontal systems, and topographic upwelling over seamounts can be discriminated using this metric.

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RADIOMETRIC MEASUREMENTS BY BIO-ARGO FLOATS AS A RESOURCE FOR BIO-OPTICAL PRODUCT VALIDATION

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Thanks to a new generation of Bio-Argo floats equipped with channels for PAR (Photosynthetically Available Irradiance) and downward irradiance measurements at selected wavelengths (i.e., 380, 412 and 490 nm), the number of radiometric measurements has been dramatically increasing for very diverse open ocean systems. More than 6000 radiometric profiles have so far been acquired around solar noon in the upper 250 m of the ocean. These radiometric profiles are acquired by Bio-Argo floats simultaneously to other key biogeochemical and bio-optical variables (chlorophyll *a*, CDOM, backscattering coefficient). Hence, they represent a fruitful data source for defining the bio-optical status of the oceans and validating bio-optical products.

As these radiometric data are out of operator's control and collected regardless of meteorological conditions, specific data processing procedures must be developed. Here, we present a data quality-control procedure that accounts for identification of dark signals, clouds, spikes and wave-focusing occurrences. Diffuse attenuation coefficients (K_d) are then derived from these quality-controlled profiles. An analysis of the spectral K_d variability in the surface ocean at the global and regional scale (e.g., Mediterranean Sea, North Atlantic sub-polar and sub-tropical gyres) shows the potential of Bio-Argo floats for identifying oceanic regions with optical properties departing from global bio-optical relationships. Finally, the good comparison observed between satellite-derived K_d values and their Bio-Argo counterparts highlights how a fleet of floats equipped with radiometric sensors can also be a useful resource for satellite product validation.

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OPTIMIZING LONGITUDE LOCATION FOR THE GEO-CAPE MISSION:

A SPATIO-TEMPORAL RADIOMETRIC ANALYSIS

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The Geo-stationary Coastal and Air Pollution Event (Geo-CPAE) is amongst the NASA Tier-2 missions with a goal for launch in late 2020's. Early analysis based on geometric Air Mass Fraction (AMF) showed that a ~95W orbit enables a ~ 7-hr window for imaging dynamic coastal/ocean waters around the coasts of the North and South American continents. This study further complements the previous study by examining the effective signal-to-noise ratio across Geo-CAPE's field of regard (FOR). For this analysis, the climatological SeaWiFS-derived ocean color data were incorporated into a forward (atmospheric) radiative transfer model to predict the top-of-atmosphere signal. The spatio-temporal effective SNR (eSNR) is then estimated by computing TOA signal fraction and the desired (science-derived) SNRs in time and space. The diurnal eSNR, the viewing geometry, and the prioritized regions (NE USA, NW USA, and Eastern Coasts of Brazil) collectively determine the optimal longitude for Geo-CAPE.

BRINGING THE OCEAN INTO FINER FOCUS AT THE LAND-SEA INTERFACE THROUGH THE NASA COAST, OCEANIA, AND HyspIRI SUBORBITAL MISSIONS

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Monterey Bay, CA is highly productive and lies within the California Current System. It is characterized by seasonal upwelling, harmful algal blooms, and episodic terrestrial run-off. High-quality ocean color measurements and algorithms are needed to characterize water quality in these typically Case 2 waters. Accurate ocean color retrievals nearshore are often confounded by inadequate atmospheric correction. The recent NASA COAST, OCEANIA, and HyspIRI suborbital missions used novel instruments in a multi-sensor, multi-platform approach to collect simultaneous atmospheric column, surface, and in-water measurements to characterize ocean color through improvements in instrument dynamic range and attention to atmospheric correction. High-level objectives included characterizing the coastal ocean through end-to-end assessment of image acquisition, atmospheric correction, algorithm application, and sea-truth observations to improve vicarious calibration and validation of satellite ocean color products. Our specific objective was to conduct sensitivity analyses of two atmospheric correction algorithms, Tafkaa Tabular and Second Simulation of a Satellite Signal in the Solar Spectrum (6S) for correction of imaging spectrometer data using input parameters of atmospheric aerosol optical depth and column water vapor obtained from the Ames Airborne Tracking Sunphotometer (AATS-14) collected during COAST. Use of the high dynamic-range, in-water Compact-Optical Profiling System (C-OPS) and above-water Coastal Airborne In-situ Radiometers (C-AIR) with matched wavelength channels enabled accurate observations of exact water-leaving radiance to validate imagery and atmospheric correction. Knowledge gained from these missions will improve vicarious cal/val of legacy (MODIS) and future (PACE, GEO-CAPE, HyspIRI) satellite sensors and hyperspectral atmospheric correction algorithms to better characterize coastal ecosystems using ocean color.

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SINGLE-PARTICLE OPTICS APPROACH IN STUDYING INHERENT OPTICAL PROPERTIES OF MINERAL PARTICLES AND OPTICAL VARIABILITY OF AQUATIC SYSTEMS

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Light attenuation by suspended particles in aquatic systems is an important physical process regulating water clarity (thus water quality) as well as the magnitudes and the spectral features of remote-sensing reflectance. Mineral (or inorganic) particles are a key component of the optical regimes of water masses because of their higher refractive indices as compared with algal and detrital particles, especially for coastal and inland waters where mixed particle assemblages are more prevalent than in the open oceans. A unique individual particle analysis (IPA) technique (scanning electron microscopy interfaced with automated image and X-ray analyses; SAX) has been used to provide characterizations of the light-attenuating attributes (size, shape, and composition) of individual mineral particles collected from diverse freshwater systems in North America, including the Great Lakes and the Finger Lakes of New York. IPA results are used in Mie theory calculations of absorption, scattering, and backscattering coefficients (i.e., inherent optical properties, IOPs) of the mineral particle populations. We have documented the application of this single-particle optics approach (termed SAX–Mie) in the following areas: (1) partitioning the bulk particulate IOPs into contributing components (e.g., algal particles, calcite, clay minerals), (2) advancing our understanding of the optical variability of natural waters (e.g., backscattering ratio as a function of the composition of particle assemblages), (3) pursuing closure of optical modeling (particulate scattering and backscattering) with bulk measurements (promising results documented), and (4) acquiring surface water 'ground-truth' for remote-sensing algorithm development.

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STUDY OF THE COMPLEMENTARITY AND THE FUSION OF THE IMAGES THAT WILL BE PROVIDED BY THE FUTURE SATELLITE SENSORS OLCI/SENTINEL-3 AND FCI/METEOSAT THIRD GENERATION

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With this study, our objective is to merge the information that will be provided by complementary sensors in order to get enough information to detect and monitor marine phenomena. On one hand we have the next generation meteorological satellite, like Meteosat Third Generation (MTG) with the onboard Flexible Combined Imager (FCI) that will provide images with very high temporal resolution, but reduced spatial and spectral resolutions. On the other hand, the next European ocean color sensor, Ocean Land Color Instrument (OLCI) on Sentinel 3, will acquire images with a medium spatial resolution and a high spectral resolution but with only 3 days frequency.

In this communication we present a preliminary study on the sensitivity of these 2 sensors for the estimation of water composition.

Because these 2 sensors are currently under development, we describe the process to provide simulated images. The first step consists in generating the dynamic maps of Chlorophyll, Suspended Matter and Colored Dissolved Organic Matter and using these maps as inputs of the Hydrolight radiative transfer model to eventually compute the remote sensing reflectance images over the sensor spectral bands. The atmospheric part and the sensor noise are not considered yet in the simulation process.

The first step of the fusion consists in increasing the spatial resolution of FCI to reach the OLCI one (300 m) and the second step consists in retrieving the missing OLCI channels of the first fusion product. This is achieved thanks to Lee's radiative model. We thus obtain the OLCI images with the FCI acquisition frequency with a Relative Average Spectral Errors (RASEs) varying between 6 and 29%. The results will be explained and discussed as well as the next steps of the study in order to achieve the objectives.

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THE SEABASS VALIDATION SYSTEM: REDSIGNED TOOLS AND ONLINE RESOURCES FOR OCEAN COLOR SATELLITE MATCH-UPS

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Based upon the established SeaWiFS Bio-optical Archive and Storage System (SeaBASS), a powerful web-based search engine was redesigned and a series of new tools and online resources were created for enhancing evaluation of ocean color satellite validation results. SeaBASS is NASA's repository for in situ oceanographic datasets that are used for the continuous ground-truth comparisons necessary to ensure and improve the accuracy of global geophysical measurements made by ocean color satellite sensors. Most SeaBASS architecture was originally built over a decade ago and has now been revamped, including the new interface and features of the validation search engine on the SeaBASS website. The validation search engine allows users to search for coincident satellite-to-in situ measurements or compare satellite-to-satellite measurements at common location. Validation search queries can be performed on a list of standard products (such as Rrs, chlorophyll a concentration, or GIOP products) for any ocean color satellite data maintained by NASA, including SeaWiFS, MODIS Aqua and Terra, MERIS and VIIRS. Additional special data sources have been incorporated into the search engine including multiple AERONET-OC (Aerosol Robotic Network) sites as well as validation results from MOBY (Marine Optical Buoy). Search query results can be downloaded and online tools provide maps, plots and statistics for analysis of results. These new and updated capabilities have greatly increased the power and speed with which SeaBASS users can evaluate a wide set of oceanographic products.

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VIIRS observations of a *Karenia brevis* bloom in the Northeastern Gulf of Mexico in the absence of a fluorescence band

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Abstract: VIIRS has been shown to provide consistent ocean color observations for the global ocean, yet its lack of a fluorescence band affects its ability to detect and quantify *Karenia brevis* harmful algal blooms in waters rich in colored dissolved organic matter (CDOM). Such a deficiency has been demonstrated for a *K. brevis* bloom in the Northeastern Gulf of Mexico in summer 2014. Here, using data collected in the field and by VIIRS and MODIS, we demonstrate that such a deficiency may be overcome through a recently developed Red-Green-Chlorophyll-Index (RGCI) algorithm. The concept for this algorithm was first applied to near-concurrent (±4 hours) VIIRS reflectance data and field-measured Chla to develop a local Chla algorithm. The algorithm was then validated using independent Chla data collected from a flow-through system, with mean relative uncertainties of ~30% for Chla ranging between 0.5 – 30 mg m^{-3} (R^2 = 0.78, N = 75). Further comparison with concurrent MODIS Aqua normalized fluorescence line height (nFLH) data showed that VIIRS RGCI Chla also provided similar spatial patterns as MODIS nFLH, suggesting that VIIRS RGCI may be used as a surrogate of MODIS nFLH in the absence of a fluorescence band. The success may be partially attributed to the 20-nm bandwidth of the VIIRS 671-nm band that covers a portion of the solar stimulated fluorescence from the bloom, as shown by its comparison with the MODIS 667-nm band (10-nm bandwidth) from bloom and non-bloom waters. Whether such observations can be extended to other turbid coastal waters, however, still remains to be tested.

Radiative Transfer accurate tool for Ocean Colour

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Monte Carlo (MC) Radiative Transfer Codes (RTC) have been considered for long to be slow. The emergence of easily programmable Graphical Processing Unit (GPU) has enabled to massively parallelize, and thus dramatically speed up MC RTC, using only a desktop PC equipped with an additional standard graphics card. We present here the code SMART-G (Speed-up Monte-carlo Advanced Radiative Transfer code using GPU), that calculates spectral polarized radiances in the coupled ocean-atmosphere system. We give some examples where the performance and capabilities of MC RTC codes rank first when looking for a simulation and/or inversion tool: spherical geometry, PAR estimation, horizontal inhomogeneities of surface albedo (adjacency effects), and potentially Line by Line in narrow bands

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Title : **Temporal variability of Arctic ice-edge blooms in a period of declining ice cover**

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Abstract :

During the past few decades, the Arctic Ocean has been facing rapid changes at spatial and temporal scales. This fragile environment is increasingly influenced by a warming climate. The loss of the sea-ice cover strongly impacts the dynamic of biological cycles. Studying the response of primary producers, which are key organisms at the base of the food web, is fundamental to a better understanding of their response to this changing environment. Ice-edge blooms are significant spring features that develop rapidly in springtime, during the Arctic melt season. They contribute to a significant part of the total annual primary production. These short-lived blooms are difficult to study in the field given their remote location and the harsh environmental conditions. The use of remote sensing is therefore a very appropriate tool to monitor them. Moreover, satellites provide ocean colour observations on decadal and pan-Arctic scales making them suitable to detect any significant trends in the distribution and phenology of ice-edge blooms occurring in the Arctic Ocean. Here, we report on temporal variability and changing dynamic of Arctic ice-edge blooms over the last decade using satellite ocean colour data from the MODIS sensor. Our results show a northward progression of these blooms.

THE REMOTE SENSING ESTIMATION OF SHALLOW WATER OPTICAL PROPERTIES AND APPLICATION TO THE HABITAT MAPPING.

Liisa Rohtla

The availability of the photosynthetically active radiation (PAR) is one of the limiting factors for the benthic habitats distribution in costal zones. In the coastal waters, the proportion of optically active constituents may vary significantly, which changes the water transparency, and amount of light energy penetrating to the bottom. Water quality and the euphotic zone lower limits are estimated from in situ data and from ocean color satellite data. In situ data was collected over the period 2010-2012 for the Baltic Sea shallow costal water areas. Bio-optical measurements were accompanied with benthic cover detection (video data and biomass samples). Satellite observations provide global coverage of the water quality properties at high spatial and temporal resolution. We were using MERIS and MODIS standard products for water quality, Kd(PAR) and euphotic zone estimation. In situ measured irradiance was used in conjunction with satellite estimated parameters to calculate the residual energy at the lower limits of benthic algal cover.

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RECENT DECADAL TRENDS IN GLOBAL PHYTOPLANKTON COMPOSITION

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Abstract
Identifying major trends in biogeochemical composition of the oceans is essential to improve our understanding of biological responses to climate forcing. Using the NASA Ocean Biogeochemical Model with ocean color data assimilation, we assessed the trends in phytoplankton composition (diatoms, cyanobacteria, coccolithophores and chlorophytes) at a global scale for 1998-2012. We related these trends to physical conditions (surface temperature, surface photosynthetically available radiation [PAR] and mixed layer depth [MLD]) and nutrients (iron, silicate and nitrate). We found a significant global decline in diatoms (-1.22% y^{-1}, $P<0.05$) that was associated with a significant shallowing of the MLD (-0.20% y^{-1}), a significant increase in PAR (0.09% y^{-1}) and a significant decline in nitrate (-0.38% y^{-1}). The global decline in diatoms was mostly attributed to their decline in the North Pacific (-1.00% y^{-1}) where the MLD shallowed significantly and resulted in a decline in all three nutrients. Regionally, there was a decline in nutrients in the northernmost latitudes that coincided with a significant decline in diatoms (North Pacific, -1.00% y^{-1}) and chlorophytes (North Atlantic, -9.70% y^{-1}). In the northern mid-latitudes (North Central Pacific and Atlantic) where nutrients were more scarce, a decline in nutrients led to a significant decline in the smaller cyanobacteria (North Central Pacific, -0.72% y^{-1}; Atlantic, -1.56% y^{-1}) and coccolithophores (North Central Atlantic, -2.06% y^{-1}). These results provide a first insight into the existence of trends in phytoplankton composition over the maturing satellite ocean color era and illustrate how changes in the conditions of the oceans may have affected them.

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Pan-sharpening to improve spatial resolution of optical remote sensing with examples from SEVIRI (3km/1km), Landsat-8 (30m/15m) and Pléiades (2m/70cm)

Quinten Vanhellemont and Kevin Ruddick

Landsat-8 data has proved to be very successful in mapping suspended matter in coastal waters, revealing features such as turbid wakes behind offshore structures, sediment in/outflow at harbour mouths, dredger plumes, etc. In addition to the 30m multispectral bands there is a "panchromatic" band giving 15m spatial resolution and hence potentially even finer scale data. In fact, many satellite remote sensing missions designed for land or meteorological applications are designed with a broad "panchromatic" band with higher spatial resolution than the standard multispectral bands. At one extreme the very high resolution Pléiades mission gives 2m multispectral data and 70cm panchromatic data on demand. At the other extreme the geostationary SEVIRI sensor gives data every 5 minutes with a spatial resolution at nadir (0°, 0°) of 3km*3km for the red (0.6µm) band and a nadir spatial resolution of 1km*1km for the "HRV" (High Resolution Visible) panchromatic band.

The present study investigates the exploitation of these very broad spectral bands for improving the spatial resolution of maps of suspended particulate matter. A physically-based theoretical framework for pan-sharpening of multispectral imagery is described, based on the work of [Neukermans et al, 2012]. This is applied to remote sensing imagery of SPM from SEVIRI, Landsat-8 and Pléiades. The validity of the pan-sharpened imagery is assessed.

[Neukermans, G, Ruddick KG, Greenwood N. 2012. Diurnal variability of turbidity and light attenuation in the southern North Sea from the SEVIRI geostationary sensor. Remote Sensing of Environment. 124:564-580.]

UNCERTAINTIES OF SENTINEL-3-OLCI OCEAN COLOUR PRODUCTS: SIMULATION BASED ON APEX ACQUISITIONS

M.S. Salama[a], S. Sterckx[b] and E. Knaeps[b]

In this poster we simulate Sentinel-3 Ocean and Land Colour Instrument (OLCI) observations from hyperspectral data and estimate the uncertainties of derived inherent optical properties (IOPs). Hyperspectral data were obtained from APEX (Airborne Prism Experiment) acquisitions over the Dutch Wadden Sea. APEX data are atmospherically corrected using MODTRAN computations and verified with in-situ measurements. The resulting values of water leaving reflectance from APEX are then convolved with the spectral response function of OLCI, aggregated to its spatial resolution and propagated to the top of atmosphere (TOA). On this simulated TOA OLCI data set we apply commonly used atmospheric correction and retrieval schemes. We suggest and evaluate a model for OLCI to estimate the uncertainties of derived IOPs. Finally, we verify the resulting uncertainties using in-situ measurements matching the time of APEX flight-lines and discuss the accuracy of OLCI products of IOPs in light of the used atmospheric correction and retrieval schemes.

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The problems of estimation of bioproductivity in the Russian Eastern Arctic by the remote sensing methods

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In the work the natural and instrumental factors are considered which lead to the errors of remote sensing measurements of basic parameters characterized bioproductivity in seawater of Russian eastern Arctic. Comparative analysis of chlorophyll-a concentrations between obtained using flow fluorometric measurements received on a board vessel, and chlorophyll-a concentrations calculated by MODIS-Aqua and VIIRS satellite data of ocean color was conducted. The data at board of ship were adjusted to standard spectrophotometric measurements and vertical depth distribution of phytoplankton. Research by array data were carried out to Bering and Chukchi Seas, De Long Strait and it were obtained in August 2013. In the analyzed waters of the Bering Sea and the Eastern Arctic radiometer VIIRS gave more accurate measurements of chlorophyll-a concentration as compared to using MODIS satellite data with processing procedures № 2013.1. Both VIIRS and MODIS-Aqua overestimated viewed from satellite chl-a concentrations in the waters of the Eastern Arctic in august of 2013. It is associated with a high relative content of colored organic matter in the upper layers of the sea, which misinterpreted by the global bio-optical algorithms as an additional contribution of phytoplankton. The satellite data in De Long Strait did not give a complete picture of the total biomass of phytoplankton, integrated in depth, since the bulk of phytoplankton with chl-a concentration 10-20 mg/m3 are located at the depths of 3-5% of surface light level and in the upper layers only chl-a concentrations in 0.1-0.3 mg/m3 diapason are observed.

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THE RADIOMETRIC PROCESSING SOFTWARE (RPS) TOOL: ALGORITHM, DATA PROTOCOL AND MERGING FOR HYPERSPECTRAL FREE FALLING RADIOMETERS

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Abstract : A data processing protocol and a software is presented for hyperspectral radiometric data from free-falling profiling systems whose acquisition can be strongly affected by surface perturbations (Zaneveld et al., 2001, D'Alimonte et al., 2010). The presented data processing protocol focuses on 1) the minimization of high frequency fluctuations on the incident radiant field with data filtering and normalization techniques and 2) reduction of wave-induced uncertainties with best fit radiometric data in the surface layer of the water column.

Processing methodologies are presented for data acquired in single cast mode, long deep radiometric profiles, and multi cast mode, consisting on a series of short shallow consecutive profiles for best radiometric data in the top layer of the water column (Zibordi et al., 2004) by increasing the depth resolution and data density of the casts. The algorithm presents the possibility of merging single and multi-cast acquisitions when both are available and reasonably coincident in space and time. Merging is performed thought the K-matching technique; using K calculated values from the single cast to estimate rescaled Ed and Lu profiles beneath the multicast depth. This procedure generates full depth radiometric profiles with significant reduction of wave induced uncertainties in the surface layer of the water column, better suited for ecosystem modeling and optical closure studies, as rapid, time dependent fluctuations have been reduced.

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EXTENDING SURFACE BIO-OPTICAL PROPERTIES TO DEPTH: A NEURAL NETWORK FOR MERGING OCEAN COLOR AND ARGO DATA

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The present study examines the potential of coupling ocean color observations with Argo (temperature/salinity) profiles to infer the vertical distribution of chlorophyll *a* concentration (Chla), phytoplankton community size indices (PCSIs) and particulate backscattering coefficient (b_{bp}). Two artificial neural networks (ANNs) are developed: one to retrieve Chla and PCSIs and the second for b_{bp}. These ANNs are trained and validated using databases of vertical profiles of temperature, salinity, and bio-optical properties collected by Bio-Argo floats, and concomitant satellite-derived products. Two main input components are needed to retrieve the vertical distribution of the bio-optical parameters: (1) a surface component, i.e. satellite-based estimates computed from 9-km, 8-day MODIS Aqua composites and (2) vertically-resolved physical properties derived from temperature and salinity profiles measured by Argo floats. Both ANNs are validated using 20% of the entire database (chosen randomly). The accuracy of the estimated bio-optical properties is very promising (i.e. median absolute percent difference comprised between 40 and 55% for Chla and PCSIs retrievals and of 18% for b_{bp} retrieval). A second validation is presented and based on a dataset acquired by four Bio-Argo floats not integrated in the MLP training and validation databases and chosen in four major oceanic basins. Again, the retrieval of the bio-optical properties is very consistent and the accuracy is very satisfactory (i.e. median absolute percent difference of 18%). The *in situ* data collected for training the ANNs are representative of the global open-ocean in terms of trophic and oceanographic conditions, making the proposed methods applicable to most open-ocean waters.

Decadal Changes of Water Properties in the Aral Sea Observed by MODIS-Aqua

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ABSTRACT

Twelve-year MODIS-Aqua observations (2002–2013) are used to quantitatively assess the water property changes in the Aral Sea. The shortwave infrared (SWIR) atmospheric correction algorithm is required and used to derive normalized water-leaving radiance spectra $nL_w(\lambda)$ in the region. A simple bottom effect index algorithm is developed to identify and discriminate the pixels with the benthic contributions using satellite-derived $nL_w(\lambda)$ in the red and near-infrared (NIR) wavelengths. We used radiance ratio $nL_w(555)/nL_w(443)$ as a surrogate to characterize the spatial and temporal variations of chlorophyll-a (Chl-a) in the Aral Sea. Both seasonal variability and significant interannual changes were observed when the Aral Sea desiccated between 2002 and 2013. All three regions of the Aral Sea show increased $nL_w(555)/nL_w(443)$ ratio and the diffuse attenuation coefficient at the wavelength of 490 nm ($K_d(490)$) during the fall season. Of the three regions, the North Aral Sea has had the least interannual variability, while South-East (SE) Aral Sea experienced drastic changes. Waters in the SE Aral Sea are the most turbid with significantly higher $K_d(490)$ than those in the other two sub-regions. $K_d(490)$ gradually increased from ~2 m^{-1} in 2002 to ~3.5 m^{-1} after 2008 in the SE Aral Sea. In comparison, both radiance ratio $nL_w(555)/nL_w(443)$ and $K_d(490)$ were relatively stable for the North Aral Sea. In the South-West (SW) Aral Sea, however, $nL_w(555)/nL_w(443)$ values reached peaks in the fall of 2007 and 2010. A possible link between the Aral Sea water property change and the regional climate variation is also discussed.

Satellite Derived Primary Productivity Estimates for Lake Michigan

Robert A. Shuchman[1], Gary L. Fahnenstiel [1], Michael Sayers[1], George Leshkevich[2]

A new Case II water color satellite algorithm to estimate primary production (PP) has been generated and evaluated for Lakes Michigan, Huron, and Superior. The Great Lakes Primary Productivity Model (GLPPM) is based on a mechanistic model developed by Fee (1972), and following the methods of Lang and Fahnenstiel (1995), that utilizes remotely sensed observations as input for model variables. The Color Producing Agent Algorithm (CPA-A) is a full spectrum three color component retrieval approach used to derive chlorophyll *a* values and the diffuse attenuation coefficient (K_d) for Photosynthetically Active Radiation (PAR). The GLPPM was validated in all three Lakes using an independent in-situ data set. MODIS derived PP estimates were used to quantify annual primary production for Lakes Michigan, Huron, and Superior in the post-*Dreissenid* invasion period from 2010-2013. Significant differences in chlorophyll distribution were noted between Lakes, however similar differences in lake wide areal production were not observed. Significant differences in mid-summer lake surface temperature among Lakes, and therefore phytoplankton photosynthesis efficiency, contribute substantially to the observed trends. Annual total carbon fixation was calculated for each Lake at 4.9, 4.7, and 6.6 Tg C/year for Lakes Michigan, Huron, and Superior respectively. There were no significant trends in PP observed in the four year analysis period, indicating Lake PP has stabilized post- *Dreissenid* invasion.
The GLPPM can be used to generate PP time series estimates dating back to 1997 and will contribute to improved assessment of Great Lakes PP changes resulting from *Dreissenid* mussel invasion and climatic change.

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PRELIMINARY ASSESSMENT OF SATELLITE SPATIAL RESOLUTION REQUIRED TO CAPTURE SPATIAL DYNAMICS OF PHYTOPLANKTON AND CDOM ACROSS ESTUARIES AND ADJACENT COASTAL OCEAN

Sergio R. Signorini[1]
Bryan A. Franz[2]
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The goal of this effort is to study the spatial distribution of phytoplankton and CDOM (chromophoric dissolved organic matter) within several river mouths and plume regions for the purpose of determining spatial resolution requirements necessary to capture the intrinsic variability from remote sensing measurements. Our approach utilizes full-resolution data from MERIS (300 m), HICO (90 m), and Landsat (30 m) in the Chesapeake Bay estuary, Mississippi Delta, and adjacent coastal oceans (estuary plumes), which was processed to remote-sensing reflectance (Rrs) and used as input to algorithms of chlorophyll (Chl) and CDOM absorption coefficient at 412 nm (ag412). In this preliminary study we used satellite sensors with different resolutions and simple statistical methods to identify some initial thresholds and sensitivities related to the behavior of estuarine plumes. Further analysis are planned using more sophisticated statistical approaches applied to multiple regions and larger image collections. Uncertainties for algorithm retrievals were computed based on the expected Rrs noise and in situ algorithm error estimates. The Rrs noise was derived from the sensor signal-to-noise model, propagated through the atmospheric correction process. Sensor noise has a significant impact on the retrieved property variance. Analysis of the variance within boxes with increasing pixel sizes around a set of test stations showed that the normalized standard deviation (NSTD, coefficient of variation; %) changes with increasing pixel size. For Landsat NSTD is larger in regions having the lowest property concentrations, while the opposite behavior is observed for MERIS (mainly due to the sensor's noise characteristics).

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The CAFE Model: A Next-Generation Net Primary Production Model

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Abstract:

This poster describes the on-going development of the CAFE model (Carbon, Absorption, Fluorescence, and Euphotic Resolved), a next-generation approach to model global net phytoplankton production and growth rates from ocean color imagery. A central component to this model is an improved mechanistic understanding of phytoplankton photoacclimation in the global ocean (Behrenfeld et al. submitted). The CAFE model parameterizes this new photoacclimation model in terms of cellular stoichiometry (light-harvesting capacity to carbon) and photo-physiology (the light saturation parameter E_K). These data are then applied to ocean color imagery to explore phytoplankton phenology and productivity across major oceanic biomes.

Optical water type persistence in South African coastal waters from ten years of MERIS data

Marié Smith[1] and Stewart Bernard[2]

This study provides an assessment of the spatial and temporal persistence of the dominant optical water types in the coastal waters of South Africa. The optical water types were defined by Fuzzy C-Means clustering of a remote sensing reflectance (R_{rs}) database consisting of a combination of *in situ*, synthetic and extracted satellite data. Image classification was performed on reduced resolution reflectance data from the Medium Resolution Imaging Spectrometer (MERIS) for the period of 2002 – 2012. This study represents the first time series analysis of ocean colour data across multiple water types for the entire South African coast. The persistence maps provide information on the seasonality and interannual variability of the optical water types; this information is useful in the selection and parameterization of regionally appropriate ocean colour algorithms. The frequency of low total membership areas could indicate potential missing water types or the need for improved atmospheric correction algorithms, while the quantity of valid pixels for the time series gives insight into the data quality and persistence of cloud bands along the coast. These time series classification techniques can be utilized to assess, for example, the persistence of potentially harmful high biomass dinoflagellate blooms, or the prevalence and spatial extent of turbid, highly scattering waters at particular estuaries.

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Seasonal and Interannual Variations in Water Optical and Biogeochemical Properties Measured by the Geostationary Ocean Color Imager (GOCI)

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ABSTRACT

The first geostationary ocean color satellite sensor, Geostationary Ocean Color Imager (GOCI) onboard South Korean Communication, Ocean, and Meteorological Satellite (COMS), was launched in June of 2010. GOCI has 8 spectral bands covering 412-865 nm, can monitor and measure ocean phenomenon over a local area of the western Pacific region. In collaboration with Korean scientists, the NOAA team has produced improved GOCI ocean color products. The GOCI-derived ocean color data can be used to effectively monitor ocean phenomenon in the region such as tide-induced re-suspension of sediments, diurnal variation of ocean optical and biogeochemical properties, and horizontal advection of river discharge. In this presentation, we use four-year GOCI ocean color data to characterize seasonal and interannual variations in water optical and biogeochemical properties in the western Pacific region. In addition, some extensive results of GOCI-measured ocean diurnal variations are shown in various coastal regions of the Bohai Sea, Yellow Sea, and East China Sea. With possibly eight-time measurements daily, GOCI provides a unique capability to monitor the ocean environments in near real-time, and GOCI data can be used to address the diurnal variability in the ecosystem of the GOCI coverage region. The GOCI results demonstrate that GOCI can effectively provide real-time monitoring of water optical, biological, and biogeochemical variability of the ocean ecosystem in the region.

Diffuse attenuation coefficient of the photosynthetically available radiation K_d(PAR) for global open ocean and coastal waters

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ABSTRACT

Satellite-based observations of the diffuse attenuation coefficient for the downwelling spectral irradiance at the wavelength of 490 nm, K_d(490), and the diffuse attenuation coefficient for the downwelling photosynthetically available radiation (PAR), K_d(PAR), in the ocean can play important roles for ocean-atmospheric circulation model, biogeochemical model, and ecosystem models. Since existing K_d(PAR) models for the satellite ocean color data have wide regional variations, we need to improve K_d(PAR) model for the global ocean applications. In this presentation, we propose a new blended K_d(PAR) model from satellite measurements. The new method has been assessed using in situ optical measurements from the NASA SeaBASS database, and is applied to the MODIS and VIIRS to derive K_d(PAR) products and compared with in situ measurements. Results show that there are significant improvements in model-derived K_d(PAR) values using the new approach, compared to those from some existing K_d(PAR) algorithms. In addition, matchup comparisons between MODIS-derived and in situ-measured K_d(PAR) data for the global ocean show a good agreement. Synoptic maps of MODIS- and VIIRS-derived K_d(PAR) data generated using the new method provide very similar and consistent spatial patterns in the US east coastal region. Monthly maps of VIIRS-derived K_d(PAR) data for the global ocean are also generated using the new K_d(PAR) model, and provide spatial and temporal K_d(PAR) distributions, showing consistent results with those from the previous studies. Thus, our results show that satellite-derived K_d(PAR) data can be used as an important input for ocean-atmospheric circulation, biogeochemical, and ecosystem models.

Seasonal Anomalies as Proxies for Phytoplankton Community Response to Climate Trends on a Temperate Continental Shelf

Heidi M. Sosik[1,2], Emily E. Peacock[1,3], E. Taylor Crockford[1,4], Robert J. Olson[1,5]

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

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Inferring Inherent Optical Properties and Ocean Impurity Profiles from Apparent Optical Properties

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Abstract:

An experiment conducted by the Centre for Maritime Research and Experimentation in the Ligurian Sea in March 2009 provided paired vertical profiles of nadir-viewing radiances and downward irradiances as well as inherent optical properties (IOPs, absorption, scattering and backscattering coefficients). An inversion algorithm was implemented to retrieve IOPs from apparent optical properties (AOPs, radiance reflectance, irradiance reflectance, and diffuse attenuation coefficient derived from the radiometric measurements. Then another inversion algorithm was developed to infer vertical profiles of water impurity concentrations, including chlorophyll-*a* concentration, non-algal particle concentration and colored dissolved organic matter from the retrieved IOPs based on a bio-optical model. The algorithm was tested on a synthetic dataset and found to give reliable results with a better than 1% accuracy. When the algorithm was applied to the dataset collected in the Ligurian Sea it was found that good retrievals of IOPs could be obtained for sufficiently deep waters. This requirement needs to be satisfied in order to obtain a good estimation of the backscattering coefficient. For such radiometric measurements a correlation of 0.88, 0.96 and 0.93 was found between retrieved and measured absorption, scattering and backscattering coefficients, respectively. A comparison between ocean impurity values derived from the measured IOPs} and it *in-situ* measured values, yielded a correlation of 0.72, 0.79, and 0.75 for chlorophyll-*a* concentration, non-algal particle concentration, and absorption coefficient of colored dissolved organic matter at 443 nm, respectively. This comparison indicates that adjustments to the bio-optical model are needed in order to obtain a better match between inferred and measured impurity values of the water in the Ligurian Sea using the methodology described here.

Consistency analysis of ocean color products at high latitudes

François Steinmetz[1], P.-Y. Deschamps[2], D. Ramon[3]

There is a growing interest in the observation of the Arctic Ocean by remote sensing, because this rapidly changing region plays a crucial role in the context of climate change. However, there are several challenges to the observation of ocean color from low earth orbit radiometers in this region: in particular, a lower sun elevation further reduces the relative contribution of the ocean reflectance to the top of atmosphere signal, thus increasing the uncertainties on the estimated parameters. We propose a method to assess how the ocean color products evolve when the optical path length through the atmosphere (the air mass) increases. This generic method uses satellite observation of the Arctic Ocean; no in-situ data are required. We present results of this method applied to MERIS, MODIS and SeaWiFS, and compare different atmospheric correction algorithms: the Gordon & Wang algorithm, and the Polymer algorithm.

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ELABORATION OF PROCEDURE FOR OCEAN WATER MAIN PRIMARY FEATURES CONCENTRATIONS RETRIEVAL FROM OCEAN COLOR REMOTE SENSING DATA.

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Methods of empirical determination of chlorophyll-a and CDOM concentrations from hyperspectral ocean color data in case of various ratios between concentrations of a chlorophyll-a and CDOM are considered. The study was carried out on water areas of the Japan Sea, East China Sea, Okhotsk Sea, Barents Sea, Chukchi Sea in waters of various optical types during 2009-2013. Basing on a collected array of field data, the research group devised the technique for tuning of regional empirical algorithms for chlorophyll-a and CDOM concentrations retrieval, taking into account the distinction of their contributions into ocean color. Most suitable spectral channels for modern ocean color satellite scanners also were defined. At the same time, concentrations of a chlorophyll-a and CDOM were retrieved using of model for remote sensing reflectance. Then comparison of efficiency for both approaches was carried out.

NEAR REAL TIME OPERATIONAL CHLOROPHYLL MAPS CALCULATION FOR MARINE APPLICATIONS

Jacques Stum[(1)], Hamid Tebri[(1)], Patrick Lehodey[(1)], Inna Senina[(1)], Eric Greiner[(1)], Marc Lucas[(1)] and François Steinmetz[(2)]

CLS operates since 2002 a near real time (NRT) oceanography data service for scientific, institutional or private users (support to fishery management, or to the offshore oil and gas industry). A large panel of data are made available in NRT in an operational way, to provide information on the current state of the ocean . These data include satellite data (chlorophyll-a, SST, altimetry), oceanographic model outputs (MERCATOR model), and weather forecasts (wind and wave data, hurricane alerts). This poster first gives an overview of the dedicated chlorophyll processing used to derive the chlorophyll maps. For example, VIIRS chlorophyll is computed from VIIRS L1A products from NASA/OBPG using the Polymer processor, and comparisons with SeaDAS derived chlorophyll are shown. Finally, the poster provides examples of derived value-added products that use these chlorophyll maps (e.g., high resolution surface currents, primary productivity, monitoring and management of marine species).

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VIIRS Reflective Solar Bands Calibration Improvements with Hybrid Approach

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ABSTRACT

The on-orbit calibration of the reflective solar bands (RSBs) of the Visible Infrared Imaging Radiometer Suite (VIIRS) and the result from the analysis of the up-to-date 3.5 years of mission data are presented. The VIIRS solar diffuser (SD) and lunar calibration methodologies are discussed, and the calibration coefficients, called F-factors, for the RSBs are given for the latest reincarnation. The coefficients derived from the two calibrations are compared and the uncertainties of the calibrations are discussed. Each calibration has advantages and disadvantages. Lunar calibration can provide long-term stable calibration coefficients, while SD/SDSM calibration is feasible every orbit. By combining the calibration coefficients of SD and lunar calibration, we produce a set of lookup tables (LUTs) that is the optimal result up to date and its accuracy level is estimated at ~0.2%. This hybrid approach highlights an important progress in calibration and it is made possible by the design change in VIIRS instrument layout allowing both the SD and the Moon to be viewed by RSB to be at the same angle of incidence (AOI). We assess the improvement to the ocean color products by comparing the official output to the new result and show the significant improvement.

UPDATING THE HPLC AND FLUOROMETRIC PIGMENT ANALYSIS PROTOCOLS

Crystal S. Thomas

The NASA Ocean Optics Protocols for Satellite Ocean Color Sensor validation (hereafter referred to as OOPs) comprise a comprehensive manual for practical instrument use and method guidance for bio-optical and radiometric measurements. However, the OOPs were last updated 12 years ago, in 2003. Knowledge and instrument technologies have advanced, and the OOPs need to be updated to reflect newer information. Several OOPs are currently under review or in the process of revision; this poster provides information on possible updates to both the HPLC and fluorometric pigment analysis protocols. I am also seeking ideas and input regarding the scope and nature of the revisions from other researchers and analysts in these fields.

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HUMAN IMPACTS TO COASTAL ECOSYSTEMS IN PUERTO RICO (HICE-PR): THE GUÁNICA AND MANATÍ WATERSHEDS IN PUERTO RICO

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For several decades Puerto Rico's coastal and marine ecosystems (CMEs) have suffered the effects of anthropogenic stresses associated to population growth and varying land use. Here we present an overview of the first year of findings of a NASA-funded project that studies human impacts in two priority watersheds (Manatí and Guánica). The project includes remote sensing analysis and hydrological, ecological and socio-economic modeling to provide a multi-decadal assessment of change of CMEs. The project's main goal is to evaluate the impacts of land use/land cover changes on the quality and extent of CMEs in priority watersheds in the north and south coasts of Puerto Rico. This project will include imagery from Landsat 8 to assess coastal ecosystems extent. Habitat and species distribution maps will be created by incorporating field and remotely-sensed data into an Ecological Niche Factor Analysis. The social component will allow us to study the valuation of specific CMEs attributes from the stakeholder's point of view. A preliminary assessment shows a range in coral cover from 0.2-30% depending on the site (Guánica) whereas apparently healthy corals dominate the reef in the north coast (Manatí). Historic and current imagery is being collected for land cover/land use change analysis, and a database of inputs for hydrological modeling is underway. Preliminary results show dynamic historical shoreline changes in beaches located west of the Manatí river mouth, and a degradation of water quality in Guánica possibly being one of the main factors affecting the actual condition of its CMEs.

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Impacts of Population Growth on the San Francisco Bay and Delta Ecosystem (SFE)

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One challenge facing Earth system science is to understand and quantify the impacts and feedbacks of human influences on rivers, estuaries, and coastal zone ecology especially in regions of high population density like the San Francisco Bay and Delta Ecosystem (SFE). The goal of our NASA Interdisciplinary science project is to put in place a modeling framework to inform stewardship of freshwater and marine resources within the SFE and adjacent ocean ecosystems. Our SFE project combines four components: (1) satellite observations, (MERIS, HICO, Landsat-8, and in the future Sentinel-3); (2) field observations (nutrients, phytoplankton, suspended sediments, CDOM, and optical properties); (3) the CoSiNE ecological model integrated with (4) a SELFE hydrological model of the SFE. Here we present initial remote sensing results using three instruments; MERIS-FR (300m GSD, 15 ocean bands, CoastColour coastal products, 2002-2012), the Hyperspectral Imager for the Coastal Ocean (HICO, 100 m GSD, hyperspectral imager, 2009-2014) and Landsat-8 (30 m GSD with a limited land-oriented band set, ongoing). The MERIS data are used to provide a 10 year time series to compare drought and non-drought years and for model validation. HICO and Landsat-8 data provide the high resolution needed to resolve features in the rivers and shipping channels.

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SATELLITE OCEAN COLOUR OBSERVATIONS FROM NASA'S PACE MISSION: APPLICATIONS AND SOCIETAL BENEFITS

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The PACE (Pre- Aerosol, Clouds and ocean Ecosystems) mission is a strategic Climate Continuity mission, included in NASA's 2010 plan: "Responding to the Challenge of Climate and Environmental Change: NASA's Plan for a Climate-Centric Architecture for Earth Observations and Applications from Space". On a polar orbit, PACE will make climate-quality global measurements that are essential for understanding ocean biology, biogeochemistry and ecology, and determining how the ocean's role in global biogeochemical cycling and ocean ecology both affects and is affected by climate change.

With advanced global remote sensing capabilities that include high spectral-resolution imaging, extended spectral coverage, improved spatial resolution in coastal waters, enhanced atmospheric correction and higher signal-to-noise, PACE is expected to provide high quality observations that, over the long-term, will contribute to an extended time series of records on inland, coastal and ocean ecosystems—all of which have substantial value beyond basic science and research. The combination of climate-quality, global atmospheric and oceanic observations provided by the PACE mission will provide a unique capability to help understand changes that affect our ecosystem services, implement science-based management strategies of coastal, marine and inland aquatic resources, and support assessments, policy analyses, and design approaches to plan adaptation and responses to impacts of climate change. Here we discuss the PACE applications program, the new capabilities afforded by this future satellite mission, and how they could potentially advance applications across a range of areas, including Oceans, Climate, Water Resources, Ecological Forecasting, Disasters, Human Health and Air Quality.

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INLAND AND COASTAL WATER APPLCIATIONS OF OCEAN COLOUR OBSERVATIONS FROM A GEOSTATIONARY ORBIT

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Nearshore environments are among the most vulnerable yet economically valuable ecosystems on Earth. Estuaries and coastal oceans are critically important as essential habitat for marine life, as highly productive ecosystems, as a strong economic driver for coastal communities, and as a highly dynamic interface between land and ocean biogeochemical cycles. Still, our present capabilities to observe inland and coastal water dynamics from space are limited in their temporal, spatial, and spectral resolution. These limitations, in turn, constrain our ability to monitor and understand physical and biogeochemical processes in nearshore environments, or predict the response and resilience of nearshore ecosystems to current and future pressures including sea level rise, coastal urbanization, and anthropogenic pollution.

On a geostationary orbit, and with high spatial resolution and hyper-spectral capabilities, NASA's Decadal Survey mission GEO-CAPE (GEO-stationary for Coastal and Air Pollution Events) will provide, for the first time, a satellite view of diurnal dynamics, evolution of processes, and episodic events along the near-shore waters of the United States. GEO-CAPE will observe U.S. lakes, estuaries, and coastal regions at sufficient temporal and spatial scales to resolve near-shore processes, tides, coastal fronts, and eddies, track sediments and pollutants, capture diurnal biogeochemical processes and rates of transformation, monitor harmful algal blooms, oil spills, water-quality, and coastal hazards. Here we discuss the societal benefits and unique applications value of GEO-CAPE ocean colour observations and data products, to identify potential user communities (e.g., operational users, managers, policy implementers) and allow integration of end-user needs into future mission planning.

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ENHANCED SATELLITE REMOTE SENSING OF COASTAL WATERS USING SPATIALLY IMPROVED BIO-OPTICAL PRODUCTS FROM SNPP-VIIRS

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Abstract

The spatial dynamics of coastal and inland regions are highly variable and monitoring these waters with ocean color remote sensors requires increased spatial resolution capabilities. A procedure for the spatial enhancement of ocean color products, including chlorophyll and inherent optical properties (IOPs), is developed using a sharpened visible water-leaving radiance spectrum for the Visible Infrared Imaging Radiometer Suite (VIIRS). A new approach for spectral sharpening is developed by utilizing the spatial covariance of the spectral bands for sharpening the M bands (412, 443, 486, 551, 671 nm; 750-m resolution) with the I-1 band (645 nm; 375-m resolution). The spectral shape remains consistent by the use of a dynamic, wavelength-specific spatial resolution ratio that is weighted as a function of the relationship between proximate I- and M-band variance at each pixel. A comparison of bio-optical satellite products at 375-m and 750-m spatial resolution with *in situ* measurements of water leaving radiance and bio-optical properties show an improved capability of the VIIRS 375-m products in turbid and optically complex waters, such as the Chesapeake Bay and Mississippi River Plume. We demonstrate that the increased spatial resolution improves the ability for VIIRS to characterize bio-optical properties in coastal waters. The benefit of a semi-analytical approach to band sharpening is that is can potentially be applied to other satellite sensors that have wide bandwidth, high spatial resolution bands.

Applications of (very) high resolution optical satellite data in coastal waters

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In contrast to moderate resolution (>250 m) satellite sensors, high resolution satellite (<1-100 m) sensors can spatially resolve coastal processes, sea surface effects (sun/sky glint, waves, foam, floating vegetation or blooms), and impacts of human activities. Additionally, high resolution data can be used for assessing or even characterizing validation sites for moderate resolution satellites that still have the big advantage of near-daily revisit times. The question to what extent the measurement platforms or ships themselves influence the signal measured by the satellite might be answerable with high resolution data (Ruddick et al., 2014).

This poster will present some of the new applications that have become apparent since the launch and free distribution of high quality imagery from the Operational Land Imager (OLI) on Landsat-8. With 30 m imagery, the monitoring of the near-shore environment, offshore constructions, dredging and shipping activities, and small scale sediment transport becomes feasible (Vanhellemont and Ruddick, 2015, 2014). Landsat-8 imagery is used to delineate areas of high spatial variability within typical moderate resolution pixel sizes in Belgian coastal waters, and the impact of fixed structures and ships is assessed. Very high resolution imagery from Pléiades (2.8 m resampled to 2 m) reveals high spatial variability in surface suspended matter concentration even within 30 m pixels. Spatially resolved waves, glint, foam, objects and their shadows represent new processing challenges for high resolution data. A proper cloud and cloud shadow masking becomes important for high resolution imagery.

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The West Mediterranean BioOptics Cruise Series

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A series of three cruises were conducted in the western Mediterranean Sea during springs of 2012, 2013, and 2014. Hydrological and bio-optical data were taken with the broad aim of characterizing the basin phytoplankton distribution. The 2013 cruise was mainly coastal, whereas the other two were more oriented towards the open ocean sampling. Standard CTD casts with associated water sampling were performed in correspondence of all radiometric measurements. HPLC-derived chlorophyll and associated pigments were extracted at discrete depths. This is a preliminary analysis of the data collected during these cruises. Despite the limited size of the basin, the three cruises experienced very different bio-optical conditions.

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VIIRS Ocean Color Products

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ABSTRACT

The Suomi National Polar-orbiting Partnership (SNPP) has been successfully launched on October 28, 2011. The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the SNPP, which has 22 spectral bands (from visible to infrared) similar to the NASA's Moderate Resolution Imaging Spectroradiometer (MODIS), is a multi-disciplinary sensor providing observations for the Earth's atmosphere, land, and ocean properties. In this presentation, we provide some extensive evaluations and assessments of VIIRS ocean color data products, or ocean color Environmental Data Records (EDR), including normalized water-leaving radiance spectra $nL_w(\lambda)$ at VIIRS five spectral bands and chlorophyll-a concentration, and diffuse attenuation coefficient at 490 nm $K_d(490)$ (and at the photosynthetically available radiation $K_d(PAR)$). Specifically, VIIRS ocean color products derived from the NOAA Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system, which is the NOAA official data processing system, are evaluated and compared with those from in situ measurements, as well as ocean color data derived from MODIS-Aqua. In addition, VIIRS Sensor Data Records (SDR) or Level-1B data have been evaluated, showing ocean color products are extremely sensitive to the SDR data quality. In particular, VIIRS SDR and ocean color EDR have been compared with a series of in situ data from the Marine Optical Buoy (MOBY) in the waters off Hawaii. Our results show that VIIRS is capable of providing high-quality global ocean color products in support of the science researches and operational applications. Our vicarious calibration effort for improving VIIRS ocean color products will also be discussed.

AN EMPIRICAL APPROACH FOR QUALITY SCREENING OF THE SATELLITE OCEAN COLOR DATA

Jianwei Wei [1], and Zhongping Lee [1]

Satellite ocean color remote sensing provides unprecedented coverage of the global oceans. Due to the inherent difficulties such as instrument calibration and subsequent data corrections, the ocean color data are subjected to errors and uncertainties. Although continuous efforts are devoted to the CAL/VAL of the ocean color, there exist no criteria for assurance of the validity of the available ocean color data. In this study, we present an empirical but independent approach for quality control and screening of the satellite ocean color data. The criteria are sought from the aggregate data of hyper-spectral remote sensing reflectance (Rrs) collected from a wide of range of oceanic waters. We first established the end members for the ocean color. Further, we clustered the in situ Rrs spectra into various categories, each of which is characterized by specific spectral slopes and Rrs values. These empirical criteria were further used to scrutinize the ocean color data by MODIS Aqua sensor (412, 443,488, 531, 547, 667, and 678 nm). The pixels, which are likely incorrectly calibrated, were identified from the ocean color images. The effects of the data screening on various levels of ocean color products were evaluated.

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INTERANNUAL AND INTERSENSOR CHLOROPHYLL VARIABILITY AT PENÍNSULA VALDÉS, ARGENTINA

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SeaWiFS, MODIS and VIIRS sensors now provide an 18-year time series of chlorophyll data for the western South Atlantic which includes Península Valdés (PV), Argentina, an important calving ground for southern right whales (*Eubalaena australis*) These datasets were examined in the region of PV, in an attempt to understand the cause for a recent sudden increase in right whale calf mortality off PV. PV is located on the northern Patagonian coast of Argentina, south of Golfo San Matías (GSM) and situated between two gulfs, Golfo San José (GSJ) which opens to the north, and Golfo Nuevo (GN) which opens to the south. The average number of deaths went from < 6 deaths/year from 1971-2004 to 65 deaths/year in 2005-2014. Phytoplankton dynamics appear to have changed in the PV region since the 1990s. Spring phytoplankton blooms are a normal seasonal feature, and historically springtime chl values reached ~ 2 mg/m^3. In 2004 a large bloom developed, with average chl > 20 chl mg/m^3 in all three gulfs. Since then large-magnitude blooms (chl > 5 mg/m^3) have occurred in GN almost every year (2007, 2008, 2010, 2012-2014). Large magnitude blooms do not occur as often in GSM and GSJ. The three sensors differ considerably in the chl values of these blooms. The MODIS bloom values being consistently higher than those from SeaWiFS but in better agreement with VIIRS values. Possible causes for differences in bloom values between the sensors will be discussed.

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A MOORED DESCRIPTION OF THE ANNUAL SPRING BLOOM IN THE NORTHWEST MEDITERRANEAN SEA

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The BOUSSOLE bio-optical mooring offers a detailed understanding of oceanographic quantities for the ocean's surface in the Ligurian Basin of the Mediterranean Sea. Downward irradiance is measured by Multi-Spectral Radiometers on the mooring, one at the surface, one at 4m, and one at 9m; these measurements allow an attenuation spectrum for the upper ocean layer to be computed. The mooring's attenuation spectrum is optimized to locally-derived optical coefficients, arriving at high-frequency, depth-averaged chlorophyll concentrations. The result is a new bio-optical technique for determining chlorophyll from a moored platform. The annual chlorophyll bloom is immediately evident in the signal, normally peaking in March with values of approximately 5 mg/m^3, before returning to values less than 1 mg/m^3 in the summer. The BOUSSOLE time-series length shows an interannual variability of two months in bloom initiation (Feb-April) and a factor of 3 in the bloom magnitude (2-6 mg/m^3). Before bloom initiation hypotheses could potentially be discussed, a full understanding of the preconditioning, heat budgets, and chlorophyll magnitude must be described. To this goal, the monthly hydrographic cruises give a synoptic, full-profile understanding, while the mooring provides frequent surface conditions during the dynamic Spring Bloom.

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NOAA Okeanos Ocean Color Operational Product System: Status and Prospective

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ABSTRACT

NOAA CoastWatch Okeanos Ocean Color Operational Product System is a flexible, expandable Linux system capable of processing multiple ocean color products satellite streams, e.g., Sea-viewing Wide Field-of-view Sensor, MEdium Resolution Imaging Spectrometer, Moderate-resolution Imaging Spectroradiometer (MODIS)/Aqua and MODIS/Terra, by using the CoastWatch Automatic Processing Software (CWAPS) including the Multi-Sensor Level (MSL) 12 algorithm. Current Okeanos system has evolved over time from an isolated VMWare environment to a system that incorporates the latest NESDIS Environmental Satellite Processing Center (ESPC) VMware technology that is consistent with the proposed future IT architecture. Since 2006, a series of OC operational products have been created from multiple satellite sensors in the Okeanos system. Current OC products include daily chlorophyll concentration (anomaly), water turbidity, remote sensing reflectance, and chlorophyll frontal products from MODIS/Aqua. The OC products have been widely applied to USA local and state ecosystem research, ecosystem observations, and fisheries managements for coastal and regional forecasting of ocean water quality, phytoplankton concentrations, and primary production. OC products will be extended to Suomi National Polar-orbiting Partnership (S-NPP) and Joint Polar Satellite System (JPSS) Visible/Infrared Imager Radiometer Suite (VIIRS) and other upcoming ocean color sensors in the next few years.

Recent efforts also provide a newly developed comprehensive Quality Assurance (QA) tool for monitoring Okeanos system, OC products processing and quality, associated with the GUI and web-based monitoring tools, referring to http://www.ospo.noaa.gov/Products/ocean/color_new/color.htm. The new QA monitoring tool includes the following advanced features applicable for MODIS/Aqua, NPP/VIIRS, and JPSS/VIIRS OC products. 1) Monitoring system performance, product processing, and product quality in near real time; 2) Monitoring the performance and stability of the system; 3) Monitoring the availability and quality of OC products with time; 4) Detecting anomalous OC products due to low valid pixels, deficient OC algorithm, or mis-matching OC products between the Near Infrared (NIR) from the NASA L2gen OC package and the Near Infrared - Short Wave Infrared (NIR-SWIR) algorithm from the NOAA OC processing package (Courtesy of Menghua Wang); 5) Notifying users of suspicious OC products and system problems.

It is expected that the Okeanos ocean color operational system in combination with the new QA monitoring tool will more efficiently ensure availability and quality of satellite operational OC products from Okeanos system to the user community. The QA tool also will provide much useful information of OC products quality and statistics to the OC user community.

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ASSESSING THE UNCERTAINTY OF THE OCEAN WATER BIDIRECTIONAL REFLECTANCE MODEL

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In ocean color remote sensing, the bidirectional reflectance of the ocean water is used to correct the effects of the angular dependence of the water leaving radiance. This angular distribution is quantified by the f and Q factors, where the f factor is the irradiance reflectance; and the Q factor is the ratio of upward irradiance to the in-water slant upward radiance. Morel, Antoine, and Gentili (2002) have created a look-up-table (LUT) of the f and Q factors based on bio-optical models and radiative transfer simulations (hereafter referring to as MAG2002). In this work we access the uncertainty of the MAG2002 LUT by independent radiative transfer simulations with variant ocean water inherent optical properties (IOPs). The radiative transfer model used in this work is the vector radiative transfer (VRT) model for coupled atmosphere and ocean systems based on the successive order of scattering method. An ocean water bio-optical model has been combined with the VRT model to calculate the f/Q factors systematically. The overall differences among this work and the MAG2002 LUT are smaller than ±10% for 81% of the cases covering all wavelengths, Chlorophyll a concentrations, and solar and viewing geometries. These differences are due to the different choices of ocean IOPs. The uncertainty of the f/Q factor is studied by perturbing three IOPs: I. particle scattering coefficient; II. absorption coefficient of the colored dissolved organic matter (CDOM); III. ocean water depolarization. This study contributes to understand the uncertainty of ocean color remote sensing.

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A method for mapping submarine sand waves using multi-angle optical sun glitter remote sensing images

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Abstract. Submarine sand waves are visible in optical sun glitter remote sensing images and multi-angle observations can provide valuable information. In this paper, we present a method for bathymetric mapping of submarine sand waves using multi-angle sun glitter information from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) stereo imagery. Based on a multi-angle image geometry model and a sun glitter radiance transfer model, sea surface roughness is derived using multi-angle sun glitter images. These results are then used for water depth inversions based on the Alpers-Hennings model, supported by a few true depth data points (sounding data). Case study results show that the inversion and true depths match well, with high correlation coefficients and root mean square errors (RMSEs) from 1.45 m to 2.47 m, and relative errors from 5.48% to 8.12%. The proposed method has some advantages over previous methods in that it requires fewer true depth data points, it does not require environmental parameters or knowledge of the sand-wave morphology and it is relatively simple to operate. On this basis, we conclude that this method is effective in mapping submarine sand waves and we anticipate that it will also be applicable to other similar topography types.

Keywords: multi-angle; sun glitter remote sensing; submarine sand waves; bathymetric mapping

Application of AISA measurements for water quality and benthic habitat mapping in optically shallow waters: challenges in radiometric calibration and atmospheric correction

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Abstract

An Airborne Imaging Spectrometer for Applications (AISA) hyperspectral imager was deployed on a manned aircraft flown at 1305m altitude to collect data over optically shallow waters in the Florida Keys with the ultimate goal of mapping water quality and benthic habitats. As a first step, we developed a practical approach to effect an atmospheric correction (AC) to derive surface remote sensing reflectance (R_{rs}) of aquatic environments using radiative transfer simulations and constraints obtained from field spectral R_{rs} measurements. Lookup tables (LUTs) for Rayleigh scattering and aerosol scattering are generated using MODTRAN. For each pixel, Rayleigh scattering is interpolated using the Rayleigh LUTs. Two NIR bands near 748nm and 850nm were selected to find the atmospheric parameters for calculating aerosol scattering. The iterative approach based on spectral relationships between two NIR bands and one red band are employed to account for the non-zero reflectance at NIR bands. Simulations and comparison with concurrent in situ R_{rs} measurements show the possibility of error in the radiometric calibration of AISA, for which a definitive assessment cannot be made due to lack of enough concurrent in situ measurements. The need for noise reduction and the difficulty in applying vicarious calibration are discussed to help advance the design of future AISA missions.

Keywords: Airborne remote sensing; Atmospheric correction; Ocean color; AISA; Vicarious calibration; MODTRAN; Noise reduction

Dissociated absorption coefficients of phytoplankton, non-algal particles, and dissolved organic matter in the Chesapeake Bay obtained from MODIS data

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Abstract

The light absorption coefficients of phytoplankton, $a_{ph}(\lambda)$, nonalgal particles, $a_d(\lambda)$, and colored dissolved organic matter (CDOM), $a_g(\lambda)$, are essential biogeochemical parameters and water quality indicators in coastal and inland waters, where the spectral shapes of these coefficients can be highly variable and neither $a_d(\lambda)$ nor $a_g(\lambda)$ necessarily covary with $a_{ph}(\lambda)$. Previous studies attempting to quantify these coefficients rely on algorithms that inadequately or fail to address these absorption complexities and sometimes entail inter-dependence among derived variables. Here we present these coefficients in the Chesapeake Bay derived using a two-step approach from satellite. First, we inverted MODIS reflectance data to derive the total non-water absorption, $a_{nw}(\lambda)$, and total particulate backscattering, $b_{bp}(\lambda)$, coefficients with the Quasi-Analytical Algorithm (QAA). Next, we partitioned the QAA-derived $a_{nw}(\lambda)$ into $a_{ph}(\lambda)$, $a_d(\lambda)$, and $a_g(\lambda)$ using the Generalized Stacked-Constraints Model (GSCM) which accounts for absorption complexities in typical Chesapeake Bay waters. Mathematically dissociated absorption components were achieved with our approach. The degree of correlation among $a_{ph}(\lambda)$, $a_d(\lambda)$, and $a_g(\lambda)$ varies with both time and location, which appear reasonable considering the diversity of factors affecting each coefficient. We also note that among the satellite-derived variables $b_{bp}(\lambda)$ correlates best with $a_d(\lambda)$ while least with $a_{ph}(\lambda)$, consistent with field observations reported for this region. While the validity of our results requires further evaluation using field data, it is the first time that independent information about these water constituents was effectively extracted from satellite data, a capability crucial to conducting biogeochemical research and water quality management in coastal and inland waters.

PHYTOPLANKTON PHENOLOGY IN TROPICAL ENVIRONMENTS: EXAMPLES ALONG THE SOUTHWESTERN ATLANTIC COAST (BRAZIL)

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Phytoplankton constitute the base of the trophic web in marine environments and their abundance is coupled to all upper trophic levels. Seasonal variability has been well described in temperate and polar latitudes, but information about bloom occurrence and timing are relatively scarce in tropical latitudes. MODIS-Aqua chlorophyll-*a* (Chl) climatology (2002-2011) is obtained for three continental shelf/slope regions along the Brazilian coast: MARSEAL (32-37.5˚W, 8.5-13.5˚S), AMBES (36-42˚W, 18-22˚S) and CAMPOS (39-42˚W, 22-24˚S) basins. The annual bloom is modeled by adjusting to a Gaussian function and start is considered as 5% above the annual median. Sea surface temperature (SST), winds, mixed layer depth (MLD) and euphotic zone depth (ZEU) are analyzed for the same regions. In the three regions, the annual blooms started in the austral summer-autumn and Chl peaks occurred during winter, even when SST is lower in winter and beginning of spring. In low latitudes light is not a limiting factor to promote phytoplanktonic growth, instead nutrients availability is poor in the euphotic zone. Increase in MLD caused by higher wind intensity and lower vertical instability of the water column are responsible for nutrient input in the euphotic zone. Over the shelf, rainfall regime, terrestrial transport by rivers, and material re-suspension caused by cold front passages also influence the winter blooms. From North to South, over the shelf blooms last longer and are lower in magnitude. Over the slope, instead, duration are similar and peaks more intense.

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