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Poster 2

LOW ALTITUDE REMOTE SENSING OF SUSPENDED SEDIMENT CONCENTRATION FROM AN UNMANNED AERIAL VEHICLE

Tidally driven sediment transport plays an important role controlling water quality, fate of contaminants, and shoreline morphology. Scientists studying these phenomena have traditionally relied on in situ measurements that often lack spatial coverage required when determining regional sediment budgets. While the capabilities of satellite remote sensing in coastal seas and estuaries has improved in recent years enabling estimates of suspended sediment concentration (SSC) at increasingly finer resolution, the sensors' infrequent overpasses limit their usefulness in estuaries like San Francisco Bay, where resuspension due to waves and tides occur at a time scale of hours. To fill the gap in this technology, we developed a system for remotely sensing surface SSC from an unmanned aerial vehicle (UAV). The platform consists of an off-the-shelf multispectral camera and a downwelling irradiance sensor that provides reflectance observations at a centimeter scale. In order to mitigate sources of measurement error not resolved in traditional satellite imagery, we developed an algorithm that masks areas of sun glint and filters out the effects of wind-generated waves. The system was tested in a series of experiments in the summer of 2017 and spring of 2018 in South San Francisco Bay, during which we compared remotely sensed measurements with in situ hyperspectral reflectance and SSC. This work provides promise that UAVs will be a powerful, flexible, and cost-effective tool in water-quality monitoring and reveals new challenges that must be addressed moving forward.

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Poster 6

PHYTOPLANKTON GROUPS AND ASSEMBLAGES IDENTIFICATION FROM REMOTE SENSING USING PHYSAT

Study of phytoplankton biodiversity is currently important because different functional groups have specifics impacts on ocean biogeochemical cycles. These phytoplankton groups should be observed separately beyond the estimation of chlorophyll-a concentration. Among the various efforts made in the past years, the development of ocean colour algorithms now allows for large spatial and time scale observation of phytoplankton functional groups. Among recently developed methods, PHYSAT enables the detection of different phytoplankton groups from space (Alvain et al., 2008). The method is based on an empirical approach that looks for relationships between specific radiance anomalies in the visible spectra and the presence of specific phytoplankton groups. Initially, PHYSAT identified five phytoplankton groups when they are dominant in waters : diatoms, nanoeukaryotes, Synechococcus-like, Prochlorococcus spp. and Phaeocystis-like. Based on the theoretical study of radiance anomalies, identifying only phytoplankton dominance cases may represent an under-utilization of the information carried by the radiance anomalies (Alvain et al., 2012). In this study, we refined the in-situ analysis in comparison with the initial one (Alvain et al., 2008). This new analysis allows for definition of mixed populations of phytoplankton groups, together with the previous dominant phytoplankton groups. On the other side, the radiance anomalies are classified from a recent process (Rêve-Lamarche et al., 2017). In this study, we found new relationships between radiance anomalies and three new mixed assemblages of phytoplankton: non dominant Prochlorococcus, mixed diatoms and nanoeukaryotes, and mixed Synechococcus-like and Prochlorococcus. Maps of identified dominant groups and assemblages are presented and discussed.

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Poster 10

A NEW APPROACH FOR ESTIMATING TOTAL SUSPENDED SOLIDS (TSS) IN INLAND AND NEARSHORE COASTAL WATERS

Moderate-resolution space-borne sensors (~10-60m spatial sampling) provide synoptic observations of water quality, primary productivity, suspended sediments in inland and nearshore coastal waters. One of the challenging task in modern aquatic remote sensing is the retrieval of concentrations of total suspended solids (TSS), which indirectly decreases the rate of primary production by attenuating the propagation of underwater light field. Currently, the models available in the literature are developed based on remote sensing reflectance (Rrs) in the red and the near-infrared (NIR) region. Although models work well for the regional waters but fails globally/seasonally due to the saturation of Rrs. In this study, we improve TSS retrievals using a two-step procedure; a) develop a machine learning technique for the retrieval of bbp from Rrs, and b) retrieve TSS based on estimated bbp using empirical relationship. The retrieved bbp and TSS are validated using synthetic datasets (simulated using widely-used radiative transfer code for turbid and eutrophic nearshore coastal and inland waters) and in-situ datasets collected from complex turbid waters over the inland and coastal regions. The retrieved bbp statistically shows improvement when compared with the bbp from quasi-analytical model (QAA) and generalized inherent optical properties (GIOP) model. We also explain the reliability of new approach to understand the spatial variation of TSS over coastal and inland waters using Landsat-8 and Sentinel-2A/B images.

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OPTICAL DELINEATION OF THE NELSON-HAYES RIVER PLUME USING CDOM, SUSPENDED SEDIMENT AND SALINITY DATA (HUDSON BAY)

River plume influences the physical and biogeochemical processes operating in the coastal waters. This study attempts to delineate the Nelson-Hayes (NH) River plume (south-west Hudson Bay) using in-situ salinity, Chromophoric Dissolved Organic Matter (CDOM) and suspended sediment (SS) data. The contribution of CDOM to the total absorption coefficient ([aCDOM/at]) at 412 nm must be known to trace the terrigenous flow in the coastal waters. This ratio was found to vary over the range of 0.5 to 0.86 in the sampled locations along a salinity gradient towards the marine domain. An empirical algorithm was developed to retrieve [aCDOM/at] (412 nm) from remote sensing reflectance (Rrs). The absolute uncertainty on the [aCDOM/at] retrieval was 0.14. The uncertainty of Non-Algal Particles (NAP) on the [aCDOM/at] retrieval was determined to distinguish the plume dominated coastal stretch from the non-riverine coastal domain. The estimated aNAP was based on the SS measurement with an approximated 0.1 m^{-1} mass-specific absorption coefficient at 412 nm. It was observed that southern coastal water was characterized with high [aCDOM/at] and [aNAP/at] ratio. Whereas the Northern coastal waters had high [aNAP/at] ratio but a very low [aCDOM/at] ratio, which indicated the absence of the plume water and dominance of non-riverine coastal processes. The in-situ aCDOM and SS variations along the salinity gradient suggested a linear dilution of the constituents with an exception of resuspension of SS observed in-between 5 to 15 PSU. The CDOM-salinity empirical relationship has been exploited to map salinity using Rrs and retrieved aCDOM data.

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DIRECTIONALITY AND POLARISATION EFFECTS ON IN SITU WATER LEAVING RADIANCE UNCERTAINTY

Ocean Colour satellite missions require System Vicarious Calibration (SVC) and validation to meet accuracy requirements for marine products. In recent years, the scientific community put a considerable effort into accuracy improvement of in situ radiometric data. SI traceability and uncertainty evaluation ensure and justify the quality of the measurement. In the context of SVC of the Copernicus Sentinel3A-B/OLCI missions, a revised uncertainty budget for primary products derived from the BOUSSOLE buoy (NW Mediterranean Sea) radiometric measurements was developed. The methodology followed the Guide to the expression of Uncertainty in Measurement (GUM), in particular, Supplement 1 to the GUM guidelines. Monte Carlo Method (MCM) was used to evaluate uncertainty for remote sensing reflectance data obtained from multispectral radiometers mounted on the buoy. Here we extend the same methodology to hyperspectral instruments that also equip the buoy, with additional uncertainty components related to their own characteristics. Moreover, the Bidirectional Reflectance Distribution Function (BRDF) and polarisation effects are included as they were not addressed in the previous version. The results of this study are used to assess the impact of individual uncertainty components, namely BRDF and polarisation, on the overall uncertainty value of the water-leaving radiances or remote sensing reflectances. This knowledge can be used to prioritise future system improvements or new instrument design, as a function of their potential to reduce measurement uncertainty.

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ADVANTAGES AND LIMITATIONS TO THE USE OF OPTICAL MEASUREMENTS TO STUDY SEDIMENT DYNAMICS

Measurements of optical properties have been used for decades to study particle distributions in the ocean. They have been found useful to constrain suspended mass concentration as well as particle intensive properties such as size, composition, packaging (aggregation) and settling velocity. Optical properties, however, provide measurements that are biased, as certain particles (based on size, composition, shape or packaging) contribute to a specific property more than others. Here we study this issue both theoretically as well as by contrasting different optical properties collected simultaneously in a bottom boundary layer, to highlight the utility of such measurements as well as the likely biases we are to encounter using different optical properties to study suspended particles.

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STRONG LINK BETWEEN SURFACE PARTICLE SIZE AND DEEP CARBON FLUX SUGGESTED BY A FAST-GROWING, MULTI-OCEAN AUTONOMOUS DATASET OF OPTICAL BACKSCATTERING

The "biological pump", which transfers organic carbon to the deep ocean, is a major sink of atmospheric CO_2 and the foundation of deep ocean food webs. If ongoing global changes in ocean temperature, circulation, and ecosystems are affecting the biological pump, appropriate response will strongly depend on our ability to monitor the pump at global scale. For this reason, there would be great value in finding quantitative (and ideally mechanistic) relationships between deep carbon flux and surface properties that are measurable at global scale. Here we compare a multi-ocean, multi-year dataset of autonomous measurements of subsurface spikes in optical backscattering (a crude proxy for carbon flux) with corresponding surface estimates of chlorophyll, backscattering, and mean particle size. We find mean particle size in the upper 50 m alone to be a fairly strong predictor of our proxy for 200 m export flux ($r^2 = 0.66$) and a moderate predictor of 700 m "sequestration" flux ($r^2 = 0.5$). Correlation with surface backscattering coefficient was weaker (r^2=0.51 at 200 m and 0.45 at 700 m), and correlation with surface Chl fluorescence was weakest (r^2=0.28 at 200 m and 0.27 at 700 m). Further validation of our carbon flux proxy is necessary before these results can be used to accurately estimate global carbon export, but the finding of such simple, multi-basin relationships between surface and deep particle populations is encouraging.

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EVALUATION OF REMOTE SENSING SENSORS AND ALGORITHMS FOR SEAGRASS PROTECTION IN COASTAL WATERS OF THE NORTHEAST GULF OF MEXICO

Florida estuaries contain one million hectares of seagrass habitat, and the primary determinants of seagrass.abundance and health are the amount and spectral quality of light reaching the seafloor. Working in the Panhandle and Big Bend regions, we have encountered many of the same problems that have vexed other coastal remote sensing scientists: variable river discharges laden with nutrients and CDOM, spatial and temporal changes in optical depth and bottom reflectance, and complex coastal atmospheres. In our subtropical region, the number of useable Modis Aqua or VIIRS scenes drops from 14 in February to fewer than 6 per month during the summer seagrass growing season. In our current project, we will try to I'm crease the utility of remote sensing data for the assessment and protection of the second largest seagrass community in the United States. Drawing on 15 years of in situ seagrass and optical water quality data, we will carry out a retrospective analysis of Modis Aqua, VIIRS, and SeaWiFS imagery. Image segmentation will be used to classify optical depth of subregions, and Rayleigh-corrected reflectance will be used to increase the number of useable summer scenes. Lag analysis will be used to relate remotely sensed optical water to changes in seagrass distribution and abundance.

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OBSERVATION-SYSTEM SIMULATION EXPERIMENTS (OSSES) AND SEASONAL FORECASTS TO SUPPORT EXPORTS

While the role of oceans in the global carbon cycle and its exchanges with the atmosphere are indisputable, it is less clear how the characteristics of the upper oceans determine the vertical transfer of organic matter and how they influence the efficiency of these vertical fluxes. Using the high degree of expertise in OSSEs and data assimilation at the NASA Global Modeling and Assimilation Office (GMAO) we assessed different observational strategies allowing for best use of resources to maximize our understanding of the export fluxes prior to and during the EXPORTS field campaigns. The GMAO atmospheric and ocean seasonal forecast was additionally used to provide hindcast, and 9-month forecast of biogeochemical variables including phytoplankton concentration and composition, productivity rates, and carbon export.

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CAN WE USE SATELLITES TO CALIBRATE AIRBORNE LIDAR?

The backscattering coefficient of seawater, defined as the coefficient of scattering at angles > 90 degrees, includes contributions from water and from any particles in the water. The water contribution has a relatively narrow range of values in the ocean, but the particulate contribution depends on the number of particles in the water and their type. Measurements of the particulate backscattering coefficient generally take advantage of the relatively small variability in scattering with angle at angles > 90 degrees to obtain an estimate of the backscattering coefficient from scattering at a single angle. Lidar has been used to infer the backscattering coefficient from scattering at 180 degrees, but this depends on knowledge of the relationship between scattering at this angle and the backscattering coefficient. It also depends on an absolute radiometric calibration, although this can be avoided using high-spectral-resolution lidar. Here, we consider a technique to obtain the backscattering coefficient directly from lidar data by calibration against passive ocean color measurements. The technique does not depend on retrieval of either the lidar calibration coefficient or the relationship between the volume scattering function at 180 degrees and the backscattering coefficient, but can be used to infer both quantities. The only requirement is that the relationship between the scattering parameters not change significantly over the area, depth range, or duration of the measurements. Once the relationship is found, it can be used where the satellite measurements are affected by clouds or vertical structure in the scattering.

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EXPLORING THE RESPONSE OF POLARIZED LIDAR TO BULK PARTICLE PROPERTIES THROUGH COMBINED MODELING AND FIELD STUDIES

Oceanographic LiDAR has become an important tool for revealing the vertical distribution of optical and biogeochemical properties in the ocean, expanding our ability to understand a variety of ocean processes. In addition to the information that can be derived by relating profiles of attenuation and backscatter from a single wavelength LiDAR to profiles of particle concentration, a variety of studies suggest that the polarization state of the return signal may provide additional information regarding the bulk properties of the particles in the scattering volume, including composition and size distribution. While this additional information would significantly improve the scope of oceanographic LiDAR investigations, the development of LiDAR algorithms that exploit the information included in the polarization state of the return signal has not progressed beyond qualitative observations or simple correlation, at least in part due to the lack of sufficient coincident measurements of polarized LiDAR returns and bulk particle properties and the lack of a quantitative framework in which to interpret the processes that contribute to the relationships that have been observed. To address this disparity in our ability to interpret polarized LiDAR return signals, we have developed a Monte Carlo radiative transfer model to explore the depolarization response of a shipboard LiDAR to a variety of bulk particle properties. Here, we present a closure experiment comparing measurements made from a custom built shipboard LiDAR system and a modeling simulation parameterized from in situ measurements of inherent optical properties that can be related to the bulk properties of the particle ensemble.

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DRONES IN SUPPORT OF EARTH OBSERVATION FOR WATER QUALITY MAPPING IN CASE-2 WATERS

Current high-resolution satellite missions like Sentinel-2 and Landsat-8 have proven their use for mapping water quality in case-2 waters. However, cloud cover or low resivit times reduce the final dataset suitable for water quality mapping. Optical sensors mounted under drones can help filling these gaps or serve as validation and calibration data for EO services. But retrieving quantitative data from drone-imagery is challenging and requires correction of geometry, vignetting effects and sky glint. This study shows the workflow behind drone-image processing from raw digital number (DN) to water quality products (TSM and turbidity). An RGB (Sony NEX-6) and multispectral (MicaSense RedEdge) sensor were mounted under an octocopter drone platform. The results and lessons-learned during different field campaigns will be presented. The test-sites include the habor of Breskens (NL) near the Scheldt outlet, characterized by high tidal sediment dynamics, and Loch Leven in Schotland. Finally, in-situ data, drone imagery and satellite products are all interlinked to show the benefits from combining different datasets.

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HIGH RESOLUTION SATELLITE DATA REVEALS MASSIVE EXPORT OF CARBON AND NITROGEN-RICH SEAGRASS WRACK FROM GREATER FLORIDA BAY TO THE OPEN OCEAN AFTER HURRICANE IRMA

Episodic storms are known to be important drivers of ocean ecosystem processes, but the impacts are notoriously difficult to quantify with traditional sampling techniques. Here, we use Sentinel 2A imagery collected 13 September 2017, only days after Hurricane Irma passed directly over the Florida Keys, to quantify massive amounts of floating vegetative material. This Category 4 storm passed directly over the Florida Keys, bringing wind gusts over 35 m s^{-1} and creating turbulence in the water column that scoured the seafloor. The imagery reveals an initial estimate of 40 km^2 of surface drifting seagrass leaves or "wrack" advected under high winds from dense beds of Syringodium filiforme within Greater Florida Bay to the oceanic waters of the Atlantic. In total, this corresponds to export of 9.7 x 1010 gC and 2.7 x 109 gN from the seagrass beds. Elemental analysis of seagrass leaves is consistent with nitrogen-fixation in the beds, which could provide the means to sustain a large export of nitrogen from the meadows. Although wrack can potentially remain floating for months, the ultimate fate of the wrack is to either wash ashore, providing connectivity between marine and terrestrial ecosystems, or sink to the seafloor. If most of the wrack sinks, this single localized event represents 0.3-0.7% of the average daily carbon export of phytoplankton to the seafloor for the entire ocean (5-12 Pg C yr^{-1}). Satellite technology is allowing for more detailed analyses of the important role of episodic events in shaping aquatic ecology and influencing global biogeochemistry.

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CHARACTERIZATION AND VARIABILITY OF PARTICLE SIZE DISTRIBUTION IN GLACIAL BAYS, SPITSBERGEN

Ongoing climate change and global warming provides intense recession and melting of glaciers observed in the polar regions. The recession of glaciers is accompanied by intensification of melt water runoff and mineral particles supply. Particle size distribution (PSD) and concentration of mineral suspended sediment released from melting glaciers is an important factor affecting the light availability in water columns, thus changing underwater light climate for photosynthetic organism. In this study, we investigated the PSD properties and variability in the front of different tidewater glaciers in Hornsund fiord at Spitsbergen based on filtration techniques to obtain concentration of suspended sediment, laser diffractometer (LISST -100x) measurements, CTD, turbidity sensor and XRD – techniques to obtain mineralogical composition of the tested suspension. Sampled sites are under strong influence of freshwater discharge from glacier. The presence of suspended matter introduced with melt water is reflected by highest value of light attenuation in this area compared to the other parts of the fjord. At each stations particulate inorganic matter contributed up to 98% to total suspended matter with the concentration of the particle reaches up to 80 mg/l with the mean PSD slopes ranged from 3,0 to 3,6. The result provide an valuable baseline information of observed range of variability of the optical properties due to glacial runoff and a presence of particles of different mineral origin in the glacial bays.

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PERFORMANCE OF OCEAN COLOR RETRIEVAL ALGORITHMS, VERIFIED AGAINST IN-SITU RADIOMETRIC AND SAMPLE MEASUREMENTS, SHOW ADVANTAGES, PRIMARILY IN COMPLEX WATERS, OF ALGORITHMS THAT AVOIDS DEEP BLUE BANDS

Water quality retrievals from ocean color measurements are recognized to be challenging in complex coastal waters. We compare retrievals using our recently developed neural network (NN) technique with retrievals obtained using other algorithms including OCx, GIOP and Semi-analytical algorithm for both complex and open ocean waters. Waters include Karenia brevis Harmful Algal blooms (KB HABs) in the West Florida Shelf (WFS) and open ocean waters on Atlantic coasts NOAA cruises. The NN technique was developed to make up for the lack of a 678 nm florescence band on VIIRS, important for KB HABs retrievals on MODIS. Instead, NN uses Remote Sensing Reflectance (Rrs) at 486, 551 and 671 nm for VIIRS retrievals. Retrieval accuracies using the different techniques were then compared against simultaneous in-situ radiometric and sample measurements, and, additionally, for HABs retrieval comparisons, against all available in-situ measurements that are nearly simultaneous with VIIRS overpasses over the 2012-2017 period. Analysis of retrieval statistics showed (i) the important impact of relatively short term (15-20 minutes) temporal variations in complex bloom waters on achievable satellite retrieval accuracies, placing limitations on their interpretation. They also showed that (ii) particularly for high chlorophyll bloom waters, better retrieval accuracies were obtained with the NN followed by OCx algorithms. Likely rationales are that the longer Rrs wavelengths used with the NN technique are less vulnerable to atmospheric correction inadequacies than the deeper blue wavelengths used with other algorithms, as well potential for less spectral interference with CDOM in more complex waters at the longer wavelengths.

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REMOTE SENSING OF UV REFLECTANCE TO FACILITATE THE ASSESSMENT OF WATER QUALITY IN AN URBAN COASTAL OCEAN

The Plankton, Aerosol, Cloud and ocean Ecosystem (PACE) mission will carry the Ocean Color Instrument (OCI), a hyperspectral sensor that can facilitate the measurement of water remote-sensing reflectance in the UV-A range (up to 350 nm). This unprecedented capability by a space-borne ocean-color sensor has the potential to enhance our ability to distinguish dissolved organic matter from chlorophyll in the surface ocean and to improve quantitative assessments of ocean carbon dynamics and coastal water quality. In this study, we specifically evaluate the benefit of using hyperspectral and UV remote-sensing reflectance for the assessment of water quality in an urban coastal ocean. During the Fall of 2015, maintenance on the 5-mile outfall pipe of the Hyperion Water Reclamation Plant (Los Angeles Metropolitan Area) prompted the release of treated wastewater in the shallow nearshore waters of Santa Monica Bay for a period of six weeks, where it affected water quality and prompted the closure of nearby beaches. In situ measurements of water-quality indicators, inherent optical properties, and remote-sensing reflectance in the 350-800 nm range (HyperPRO) were collected simultaneously before, during and after the diversion as part of a large sampling effort to monitor the effects of the diversion. These data, along with airborne data acquired by the hyperspectral Portable Remote Imaging SpectroMeter (PRISM) during the diversion, were used to assess the degree to which UV reflectances improved the performances of several empirical and semi-analytical algorithms and helped decipher the source and impacts of the effluent.

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POLARIZED LIGHT SCATTERING PROPERTIES OF EMILIANIA HUXLEYI COCCOLITHS AND COCCOSPHERES

It has been recently suggested that a significant amount of information about coccolithophore blooms could be retrieved by analysis of their light polarization properties. In recent optical modeling work we have shown that light backscattering from Emiliania huxleyi coccoliths is dominated by the reflection from their calcite surfaces. Here, we extend our model to include the polarization signal of backscattered light from E. huxleyi liths. Previous investigations using exact numerical Discrete Dipole Approximation models have assumed a single uniform average index of refraction for the multi crystalline calcite material of the liths while in reality calcite is strongly birefringent. We show that this structured birefringence induces significant depolarization effects which are spatially distributed over the surface of the liths. These effects are completely unaccounted for in exact codes. Using the optic axis structure of liths we have developed an approximate model that allows us to evaluate the effect of this internal depolarization on the overall polarized backscattering of E. huxleyi coccoliths and quantify the difference with the backscattering depolarization computed for a material with a single orientation averaged index.

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ANALYSIS OF THE APERTURE WINDOW FOR THE NEW BB METER DESIGN

We have been developing a new in situ meter for a direct accurate measurement of the backscattering coefficient bb. An important aspect of our new meter design is the entrance aperture to the detector; it requires what is generally referred to as a cosine collector. Various cosine collector designs have been described in the literature, but none have the accuracy, efficiency, and durability that we require for this new bb meter. Consequently, a new cosine detector geometry has been developed. It is basically a metal aperture on the surface of a clear quartz window that has a slight cylindrically shaped depression. With this design, photons incident on the detector aperture will pass through the water-quartz interface and into the quartz with a high efficiency that is relatively independent of the angle of incidence on the aperture. For the proposed design, the average transmission into the quartz would be 99.8% over all angles of incidence from 0° to 90° and peak-to-peak variations in the transmission across this range of angles of incidence would be less than 0.12%. Note that light scattered from the laser beam at 90˚ is incident on the detector aperture at a 0˚ angle of incidence, and backscattered light at 180˚ is incident at 90˚. Consequently, all of the scattered light will be transmitted to the detector with approximately 99.8% efficiency. The theoretical analysis of this aperture design will be presented and a new improvement based on the thickness of the aperture plate will be described.

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SEASONAL VARIATION AND MODELING OF PHYTOPLANKTON, NITRATE AND TEMPERATURE AT SANTA CATALINA ISLAND, USA

We combine remotely-sensed proxies for phytoplankton, in situ measured nutrients, and light and temperature models to understand the spring bloom around Santa Catalina Island, California, USA, and contrast it with that found at nearby San Nicolas Island. Phytoplankton is estimated from the chlorophyll product obtained from the Moderate Resolution Imaging Spectroradiometer on the Earth Observing System satellite Aqua (MODIS-AQUA). Measurements of nitrate are provided by the California Cooperative Oceanic Fisheries Investigations (CalCOFI) program and the temperature model is derived from long-duration measurements made around Santa Catalina and within the Southern California Bight. We find an island mass effect associated with San Nicolas, that is, some chlorophyll originates near the island. This signal is most evident during the fall after the typical spring phytoplankton bloom subsides. In contrast, there is a relative dearth of chlorophyll around Santa Catalina Island and its seasonal modulation corresponds to the spring bloom, implying the dynamics are much simpler for this island. Previous studies of temperature near Santa Catalina indicate that a simple one-dimensional model of temperature diffusion explains well the seasonal and at-depth modulations found there. We couple the temperature-derived vertical diffusion coefficient with nitrate measurements to make a simple one-dimensional model relating chlorophyll, insolation and nitrate for Santa Catalina.

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IOPS MEASUREMENTS DURING BOUSSOLE MONTHLY CRUISES (NW MEDITERRANEAN SEA)

The BOUSSOLE project has been building a long-term time series of in situ bio-optical measurements in the NW Mediterranean Sea since 2001. The aim is to support vicarious calibration of observations by ocean color remote sensing satellites, validation of the geophysical products derived from these observations, and fundamental research in bio-optics. Data are continuously acquired by a dedicated mooring since September 2003. In addition, since July 2001, monthly servicing cruises to the BOUSSOLE site give complementary measurements to those acquired by the mooring through the collection of optical profiles and CTD casts with water sampling. Operations include discrete sampling for analysis of phytoplankton pigments, total suspended matter, and absorption by phytoplankton, non-algal particles and colored dissolved organic matter. New instrumentation for measurements of inherent optical properties (IOPs) has been added from December 2011. The package includes a hyperspectral absorption meter (Hobilabs a-Sphere), a multispectral backscattering meter (Hobilabs Hydroscat-6) and a multispectral beam transmissometer (Hobilabs Gamma-4). Here we show examples of IOPs time series from data acquired during BOUSSOLE monthly cruises. We also present some aspects of the protocols that have been set up for maintaining and calibrating these instruments in order to improve data quality. Furthermore, an intercomparison of the same variables obtained with different instruments deployed simultaneously during cruises or operating on the mooring is used to quantify uncertainty budgets in IOP measurements.

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OCEAN COLOUR GLOBAL TIME SERIES FOR USE IN CLIMATE STUDIES

Spectrally-resolved water-leaving radiance and chlorophyll concentration are recognised as Essential Climate Variables (ECV) by the Global Climate Observing System. Global time-series of these ECVs are key to studying phytoplankton dynamics at seasonal and inter-annual scales, and understanding the role of phytoplankton in marine biogeochemistry, the global carbon cycle and the response of marine ecosystems to climate variability. Generation of a long time-series of ocean-colour data is not a trivial task: there are a number of atmospheric correction and product retrieval algorithms; satellites have finite life-spans, so data from individual sensors from late 1997-date, with differing sensor characteristics, need to be merged without introducing artefacts. ESA's Ocean Colour Climate Change Initiative is undertaking research addressing these requirements, with support from NOAA, NASA and a large community of global climate researchers, marine ecosystem modellers and remote sensing scientists. Products are validated against fiducial reference measurements; uncertainty characteristics, quantified on a pixel-by-pixel basis, facilitate applications and interpretations consistent with the quality of the data. Continuity in ocean-colour ECV production is vital to support continued use by the scientific community and will be sustained through the European Copernicus Climate Change Service programme. This presentation will discuss the prospects to develop the ocean-colour ECV through: addition of new sensors, notably the Sentinel-3 OLCI series; potential increases in data resolution (e.g. spatially global 300m from OLCI and temporally though geostationary missions); and integration with in situ observing systems, notably the BioArgo programme to investigate the 3D structure of the ocean.

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ATMOSPHERIC CORRECTION OF SENTINEL-2 AND LANDSAT 8 FOR SATELLITE DERIVED BATHYMETRY

Many coastal areas in remote locations have either never been charted or are still reliant on charts prepared in the 1700's. Boat-based surveys are prohibitively expensive, so the potential of mapping bathymetry using optical satellite imagery is of high interest to environmental agencies, private industry and hydrographic offices. Freely available global-scale data from Landsat 8, and especially Sentinel-2, further focus this interest. Methods using inversion of radiative transfer models offer the potential for large-scale robust bathymetric mapping without the need for known depths for calibration, but these methods are highly sensitive to accurate atmospheric correction. Small errors in estimating the primary unknowns (surface glint and aerosols) can introduce systematic errors in bathymetry estimates: a common issue for many standard atmospheric corrections. This paper presents a method of atmospheric correction specifically for model-inversion applications of high spatial resolution satellite data (pixels < 30 m). The method works by using the model to be inverted itself to constrain the possible water-leaving reflectances, and includes correction for variable and constant pixel-to-pixel glint. The method has been applied to over 70 Sentinel-2 and Landsat 8 images of coral reefs from three locations in Australia, Africa and Mexico. In an almost fully automated mode with no ancillary data, no calibration data or manual adjustments the method produces good results to 20 m depth in over two-thirds of the images, judged by comparison to in-situ echo-sound data. Interestingly results for Sentinel-2 show a slight bias compared to Landsat 8, possibly indicative of a relative calibration discrepancy.

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Poster 90

EVALUATION OF OPTICAL BACKSCATTER PROXIES FOR PARTICLE CONCENTRATION AND SIZE

Marine particles affect the cycling of carbon and nutrients, they transport contaminants, and they influence the attenuation of light in the water column. The magnitude of the effects of particles on these processes are determined by particle concentration and size, which can change rapidly due to particle production and consumption, flocculation and deflocculation, and deposition and erosion. Optical backscatter has been used successfully for decades to measure changes in particle concentration, despite theoretically based concern over the effect of variable particle size on the correlation between the backscattering coefficient and suspended particulate mass (SPM) concentration. More recently, the slope exponent of the backscatter spectrum has been shown to be a useful proxy for particle size. These results suggest that the relatively simply measurement of backscatter at two wavelengths can provide information on particle concentration and size, but they also raise a paradox: the backscattering coefficient is relatively insensitive to particle size, yet the spectrum of the backscattering coefficient is correlated with size. We use observations of particle size, SPM and multi-wavelength backscattering coefficients from several different environments to investigate the correlation between particle size and 1) the backscatter spectral slope and 2) the mass specific backscattering coefficient. Results show that the spectral slope is correlated with size and that the mass-specific backscattering coefficient is not. The results also show that in some environments, the backscattering coefficient and its spectral slope are better proxies for particle concentration and size than the particulate attenuation coefficient and its spectral slope.

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CORAL REEF AIRBORNE LABORATORY

The COral Reef Airborne Laboratory (CORAL) investigation is a 4-year mission, funded under the NASA Earth Venture Suborbital-2 Program, to produce the first comprehensive assessment of reef condition for a large portion of the world's coral reefs. CORAL has deployed the state-of-the-art airborne imaging spectrometer PRISM (NASA JPL) across the Great Barrier Reef, Hawaii, the Mariana Islands, Palau, and Florida. There are 355 total flightlines collectively covering ~75,000 km^2; observed reef area is yet to be determined, but is estimated at ~10,000 km^2, which is 2% of the world's reef area. The core geophysical parameter products from CORAL are benthic cover and benthic community primary productivity and calcification. These products have been validated via simultaneous in-water measurements of water-leaving reflectance, water optical properties, bottom reflectance, benthic community composition, and benthic community metabolism. CORAL image products are being analyzed geospatially against a set of biogeophysical variables that are often invoked to explain changes in coral reef systems. The result will be a set of quantitative, empirical models that can be used to estimate current reef condition and forecast how reefs may respond to various biological, physical and chemical changes in the world's ocean. The aim of this presentation is to describe the breadth of CORAL's data, observations, and findings to the scientific community.

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DYNAMICS OF THE WETLAND VEGETATION IN LARGE LAKES OF THE YANGTZE PLAIN IN RESPONSE TO BOTH FERTILIZER CONSUMPTION AND CLIMATIC CHANGES

Using moderate-resolution imaging spectroradiometer (MODIS) data that cover the 15-year period from 2000 to 2014 and a phenology-based classification method, the long-term changes in the wetland vegetation of 25 large lakes on the Yangtze Plain were obtained. The classification method was developed based on the phenological information extracted from time series of MODIS observations, which demonstrated mean user's/producer's accuracies of 76.17% and 84.58%, respectively. The first comprehensive record of the spatial distribution and temporal dynamics of wetland vegetation in the large lakes on the Yangtze Plain was created. Of the 25 lakes examined, 17 showed a decreasing trend of vegetation area percentages (VAPs) during the study period, and 7 were statistically significant ($p<0.05$). The same number of lakes was found to display decreasing trends in vegetation greenness over this 15-year period, and these decreasing trends were statistically significant ($p<0.05$) for 11 of the lakes. Substantially fewer lakes showed increases in either their VAPs or their vegetation greenness values. Analysis using a multiple general linear model revealed that the amounts of chemical fertilizer used for farmlands surrounding the lakes, precipitation, daily sunshine hours, temperature and water turbidity played the most important roles in regulating the interannual changes in vegetation greenness in 40% (10/25), 12% (3/25), 4% (1/25), 20% (5/25) and 12% (3/25) of the lake wetlands, respectively. On average, the combined effects of these five driving factors above explained 89.08±7.89% of the variation in greenness over this 15-year period for the 25 lakes.

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OCEAN PROFILING LIDAR MEASUREMENTS: LINKING FAST ATMOSPHERIC PROCESSES AND LONG TERM CLIMATE

Clouds and aerosols can change the amount of solar radiation that are absorbed by the Earth system. However, the atmosphere and land surfaces both have very limited heat capacity, and thus radiative heating/cooling associated with atmospheric and land processes is of short duration (a month or less), unless those processes impact the ocean, which has a huge heat capacity and thus longer "climate memory". The deeper the radiative impact reaches within the ocean, the longer it remains stored in the system (e.g., decades for heating below the mixed layer). Net absorption of solar radiation by the ocean mixed-layer is the driver of inter-annual changes in radiative heating of the ocean and cooling of the atmosphere, which in turn also drives the global water cycle. The degree of absorption in the mixed layer determines the amount of solar radiation reaching beyond the mixed-layer. Thus, the vertical distribution of phytoplankton may have a huge impact on the inter-annual variations of energy/water cycle and global ocean temperature at multi-decadal or longer time scales by impacting the vertical distribution of solar radiation within the ocean. Ocean profiling lidar can be a first step in studying vertical distribution of absorption of solar radiation within and possibly beyond the ocean mixed-layer in tropical and subtropical waters. For this study, we examine the relevant processes governing absorption in the mixed layer and beyond using a simplified coupled ocean-atmospheric model and assess the potential for ocean profiling lidar to provide global data to better quantify climate-relevant ocean heating.

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Poster 106

EVALUATION OF ATMOSPHERIC CORRECTION ALGORITHMS OVER CONTRASTED COASTAL WATERS FOR MSI ON SENTINEL-2

The ESA S2-SEOM project aims at reviewing and evaluating the current algorithms developed for the MSI sensor on-board Sentinel-2 for retrieving the marine reflectance over coastal and inland waters. In the end, the processing chain will be made available to the users community. Cloud masks, cloud shadow masks, topographic shadows masks and glint masks resp. correction procedures are also being investigated. Several atmospheric correction algorithms for MSI have been developed and proposed. While some of them are only dedicated to correcting atmospheric effects over land, others have been specifically designed for ocean activities. In the frame of this project, six algorithms are benchmarked, among them: MAJA (Hagolle et al., 2010, 2015), Sen2Cor (Wilm et al., 2016), Polymer (Steinmetz et al., 2011), NASA (Pahvelan et al., 2017) and ICOR (Sterckx et al., 2014, 2015). The LAC algorithm has been specifically consolidated in the frame of this project and aims at taking advantage of having a scene with a large variability of radiometry as observing both land and water and which blends specificities of these two types of observations. Validation of the atmospheric correction schemes will be presented for selected MSI images of French Guiana and the eastern English Channel for which in situ validation measurements have been collected in 2016 and 2017 using TriOS and ASD FieldSpec 4 radiometers. Further images over European coastal and inland waters are being inspected, to indicate the respective performances of cloud masks, cloud shadow masks and glint algorithms.

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Poster 110

MEASURING BIO-OPTICAL PROPERTIES IN COASTAL WATERS OF THE LAPTEV SEA AND LENA RIVER FOR THE IMPROVEMENT OF OCEAN COLOR ALGORITHMS

Thermal degradation of permafrost and intensified coastal erosion result in remobilization of organic carbon in the Arctic coastal areas, changing transport pathways and the magnitude of land-to-sea fluxes. Near-coastal waters in the Laptev Sea show extremely high absorption by colored dissolved organic matter (aCDOM), most of which derives from the huge discharge of the Lena River. Satellite retrievals of aCDOM and a strong relationship between aCDOM and dissolved organic carbon (DOC) in river-influenced waters offer the potential to identify DOC transport pathways and changes of fluxes. To retrieve aCDOM in Arctic coastal waters, Ocean Color processors and bio-optical models require bio-optical properties parametrized for a specific region. However, we lack in situ information. For example, the contribution of CDOM to the total absorption coefficient and the exponential slopes of aCDOM and non-algal particle absorption (aNAP) are unknown and often set constant in bio-optical models. To parameterize these properties, inherent optical properties (IOPs), apparent optical properties (AOPs) and the concentrations of constituents were simultaneously measured in situ in coastal waters of the Laptev Sea and in the Lena River. These unique multi-year observations show extreme spatial and temporal variations within the transition zone from river to ocean. Turbulent and chaotic regional processes, such as the spring ice break-up and mixing processes of river-, melt- and sea-water, result in rapid changes of optical properties. We implement the observed variability of parameters to semi analytical algorithms. With this we aim to improve the satellite retrieval of aCDOM in optically complex Arctic coastal waters.

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DETECTING SARGASSUM BLOOMS AND PLASTIC MARINE DEBRIS FROM HIGH RESOLUTION MULTISPECTRAL SATELLITE DATA

Since 2011 blooms of Sargassum macroalgae have increased in Caribbean Sea leading to several problems to tourism and economy. Additionally, river discharge and alteration of ocean currents influence marine environment of the second largest barrier reef in the world as they lead to plastic debris accumulation. Although remote sensing is an effective tool for the detection and identification of marine pollution, there is a relative small number of studies on monitoring plastic marine debris from high-resolution satellite data. To this end, in this paper, we propose a classification procedure for distinguishing plastic marine debris from sargassum blooms based on high-resolution Landsat-8 and Sentinel-2 data in Caribbean Sea. Extracted spectral profiles indicated similar spectral patterns with the literature with certain reflectance peaks for the Sargassum at 783nm and plastic marine debris at 865nm. Ocean color (Chl-a and TSM), meteorological parameters (wind speed and precipitation) and sea surface temperature were also studied in order to estimate debris trajectories. The studied difference in the spectra behavior of sargassum and plastic debris was exploited in order to classify and distinguish them. The procedure was compared and evaluated against the FAI Index as well as available in situ data.

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THE EFFECTS OF INSTRUMENT TEMPERATURE AND INTEGRATION TIME ON ABSOLUTE RADIOMETRIC CALIBRATION FOR HYPERSPECTRAL RADIOMETERS.

Absolute radiometric calibrations were performed on number of hyperspectral instruments that are commonly used for ocean colour algorithm development, validation and general marine research in Australia. Measurements were performed at different temperatures and (where applicable) integration times to assess the applicability of a given lab-based radiometric calibration to those conditions likely to be encountered in the field. For all spectrometers, sensor temperature was found to have an influence on the spectral calibration coefficient magnitudes - up to 0.56%/°C for blue wavelengths and -0.42%/°C for NIR wavelengths, suggesting that a spectral approach for temperature correction should be investigated for all such devices, and especially when they are to be used outside typical calibration facility "room" temperatures. Integration time linearity was also investigated, and nonlinearities were observed. In general, the commercial spectrometers were stable within ±4% across different integration times likely to be used in the field. Trends were consistent, so there is a possibility that further compensating the instrument's response to integration time will improve the accuracy of these devices.

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WATER MASS FORMATION AND BIOGEOCHEMICAL RESPONSE IN THE NORTHERN RED SEA

Numerical simulations and remote sensing studies have characterized the northern Red Sea (NRS) as the region where Red Sea Outflow Water (RSOW) and occasionally deep water is formed. Until now, no substantive in situ studies exist to describe the physical and biochemical processes in the NRS. Weakening stratification and winter cooling during December 2015 - January 2016 preconditioned the upper layer facilitate upward entrainment of intermediate water, that with coastal mixing leads to formation of RSOW. Glider observations that include temperature, salinity, oxygen, carbon dissolved organic matter (CDOM), chlorophyll fluorescence (CHL) and multi-wavelength optical backscatter have been used to characterize and trace the water masses. Modeling studies suggested that the circulation in this region is dominated by a cyclonic gyre. Our results verified the presence of a cyclonic circulation in the center of the NRS that upwells nutrients into the euphotic layer. In addition, deep winter mixing entrained nutrients into the euphotic zone resulting enhancement of the phytoplankton biomass. These mixing events dispersed the phytoplankton from the deep chlorophyll maximum throughout the mixed layer (ML) increasing the chlorophyll signature detected by ocean color imagery. However, the magnitude of increase offshore during winter due to the cyclonic circulation's associated upwelling was much greater than the increase due to nearshore mixing. This study reveals that AUVs platforms and their associated optical measurements provided significant insight into key physical and biochemical processes within the region.

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Poster 126

A 55-YEAR TIME SERIES STATION FOR PRIMARY PRODUCTION IN THE ADRIATIC SEA: DATA CORRECTION, EXTRACTION OF PHOTOSYNTHESIS PARAMETERS, AND REGIME SHIFTS

In 1962, a series of in situ primary production measurements began in the Adriatic Sea, at a station near the island of Vis. To this day, the data set has accumulated over 55 years of monthly measurements through the photic zone. The measurements are conducted over a six-hour period around noon, and the average rate extrapolated linearly over daylength to calculate daily production. Here, a non-linear primary production model is used to correct these estimates for potential overestimation of daily production due to linear extrapolation. The assimilation numbers are recovered from the measured production profiles and subsequently used to model production at depth. Using the recovered parameters the model explained 87% of variability in measured normalized production at depth. The model is then used to calculate daily production at depth and it is observed to give on average 20% lower daily production at depth than the estimates based on linear extrapolation. Afterwards, watercolumn production is calculated and here the model predicted on average 26% lower watercolumn production. With the recovered parameters and the known magnitude of the overestimation, the time series of watercolumn production is then re-established with the non-linearly corrected data. During this 55 year period distinct regimes are observed, which are classified with a regime shift detection method. It is then demonstrated how the recovered parameters can be used in a remote sensing application.

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AN EMPIRICAL ORTHOGONAL FUNCTION APPROACH TO DERIVE CYANOBACTERIA:EUKARYOTIC ALGAE RATIOS USING BOTTOM OF RAYLEIGH REFLECTANCE DATA

Eutrophication and increasing prevalence of potentially toxic cyanobacterial blooms occurring in inland water bodies and coastal regions is quickly becoming a global issue. Quantitative detection of chlorophyll in these scenarios by remote sensing techniques are plagued by uncertainties due to lack of appropriate atmospheric corrections and spatial resolution. However, cyanobacteria have distinct spectral features that enable them to be identified from optical information and the bright nature of eutrophic waters allow these features to be seen without the requirement of a full atmospheric correction. In this study, we investigated the sensitivity of cyanobacteria detection using partial atmospherically corrected data using a synthetic database of varying chlorophyll concentrations and ratios of cyanobacteria to eukaryotic algae. The synthetic Rrs database is also modelled to Bottom of Rayleigh Reflectance (BRR) using varying atmospheric profiles and inclusion of an adjacency effect. Through this, we have developed an EOF analysis method to derive cyanobacteria:eukaryotic algae ratios using optical reflectance measurements. Multi-nonlinear regression models were developed using principal component scores derived from the EOF analysis of normalized hyperspectral and multi-spectral Rrs and BRR synthetic data and matchup cyanobacteria:eukaryotic ratios. The models performed with high success and showcases how a partial atmospheric correction still preserves necessary spectral variation. To demonstrate the method in an operational sense, the EOF approach was applied to both Sentinel 3 OLCI and Sentinel 2 MSI imagery. Based on the ratio of cyanobacteria:eukaryotes, new empirical models are currently being developed with the intention of deriving more accurate chlorophyll concentrations for cyanobacteria dominated scenarios.

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SEASONAL VARIABILITY OF THE DIFFUSE LIGHT FIELD IN RELATION TO THE MIXED-LAYER DEPTH AND THE SUCCESSION OF PHYTOPLANKTON ASSEMBLAGES

Seasonal attenuation patterns of downwelling irradiance and upwelling radiance in temperate coastal waters are dependent on dynamic changes in the physical, chemical and biological conditions of the water column. High-quality in situ observations of the diffuse light field coupled with bio-optical properties are particularly important for ocean color remote sensing validation and evaluation of biogeochemical processes in a column of water. The objective of this study is to characterize the seasonal variability of the diffuse light field in relation to the mixed layer depth (MLD) and succession of phytoplankton assemblages. Monthly field measurements of physical and biological parameters were conducted in the coastal waters of Sagami Bay from May 2016 to May 2018. Two transitional optical conditions were observed throughout the study: MLD > Zeu (1% euphotic depth) during winter, and MLD < Zeu from spring to fall. Phytoplankton biomass was highest (Avg: >3.0 mgChl-a m^{-3}) during the spring-summer season following the shoaling of the MLD (Avg: ~12 m). Analysis of multi-excitation fluorescence and pigments suggest the high phytoplankton biomass during the spring-summer season was dominated by brown algae, followed by cyanobacteria during the late-summer when the MLD < Zeu. Green algae and cryptophytes relatively dominated the water column when the MLD > Zeu. Preliminary results suggests the seasonal succession of phytoplankton assemblages in the water column are dependent on the spectral quality of the diffuse light field, which simultaneously alters the attenuation characteristics of downwelling irradiance and upwelling radiance.

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OPTICAL ASSESSMENT OF RIVERINE INPUTS INTO ARCTIC COASTAL MARGINS

Arctic coastal margins receive large inputs of dissolved and particulate matter from the river systems that drain adjacent continental landmasses. These inputs are expected to increase dramatically over the coming decades due to climate-driven melting of Arctic continental permafrost. To better understand the sources and fates of riverine carbon in Arctic coastal margins, a three-year study is underway near Prudhoe Bay, Alaska that uses optical approaches to investigate seasonality and variability in Arctic riverine inputs by comparing two nearby river systems: the Kuparuk and the Sagavanirktok. These two rivers drain different types of terrestrial biomes and their optical signatures are expected to provide insight into possible source-river differences in organic and inorganic matter transport into these coastal, seasonally ice-covered waters. Optical sensor suites have been deployed on in situ landers for annual-scale assessments, along with autonomous packages embedded in the sea ice for shorter-term measurements of the spring freshet as it travels into the coastal ocean under landfast sea ice. Direct sampling of the rivers during the freshet event itself, and during open water seasons when possible, provides critical data regarding the optical and chemical composition of incoming and resident dissolved and particulate matter. Such a multifaceted approach, combining autonomous optical measurements with periodic direct sampling, is essential for reducing uncertainties about key aspects of the organic carbon cycle in these logistically challenging to sample Arctic coastal waters.

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A LAGRANGIAN FRAMEWORK FOR ANALYSIS AND INTERPRETATION OF OCEAN-COLOR SATELLITE DATA

Optical properties of the well-lit upper layer of the ocean are strongly influenced by the microscopic drifting photosynthetic organisms embedded within it - the phytoplankton. In remote parts of the ocean, distant from the coast and from the seabed, there is no obvious spatially fixed reference frame for describing phytoplankton dynamics. Thus, a natural perspective for studying phytoplankton dynamics and its imprint on ocean optics, ecology and biogeochemistry is to follow the trajectories of water parcels in which the organisms are embedded. With the advent of satellite oceanography, Lagrangian interpretation of satellite data has provided valuable information on different aspects of phytoplankton dynamics, including spatio-temporal changes in bio-optical properties, bloom initiation and termination, biodiversity, and export of carbon to the deep ocean. In this presentation we will discuss a recently-developed framework for Lagrangian interpretation of ocean color satellite data. The approach taken, which is based on integrating ocean color, temperature and altimetry satellite data, and relays on unambiguous identification of distinct water patches, will be demonstrated on case studies from different parts of the World Ocean.

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RETRIEVAL OF SUN-INDUCED CHLOROPHYLL FLUORESCENCE FROM OPTICAL PROFILER OBSERVATIONS: A THEORETICAL STUDY

Phytoplankton photosynthesis accounts for up to half of global primary production. Its variations are largely related to changes in phytoplankton physiology, but the global characterization of physiological status is still extremely challenging. Sun-induced chlorophyll fluorescence (SICF) has proven a useful tool to provide rich source of physiological information of phytoplankton. Traditionally, the SICF is retrieved from chlorophyll fluorescence height (FLH) separated from water-leaving radiance using a simple linear approximation between two wavelengths on either side of chlorophyll-a emission spectrum. However, the rude estimation sometimes provides FLH with big uncertainties and further results in unreliable interpretation of SICF. Based on radiative transfer simulations, we here present a new method to derive SICF from convectional optical profiler observations (or optical buoy). This new method takes advantage of the difference of upwelling and downwelling diffused attenuation coefficients (KLu and Kd). Results show that this new method works very well for different water types (chlorophyll-a concentration varying from 0.01 to 10 mg/m^3), with an overall difference of less than 1% between the retrievals and true values. The novel method also explorers a new way to accurately correct the impact of chlorophyll fluorescence on leaving signal acquired by remote sensing platforms (e.g., satellite). This method opens a door for the study of phytoplankton physiology and photosynthesis processes in the aquatic environments.

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BIDIRECTIONAL REFLECTANCE OF OCEAN WATERS: RE-EXAMINING VARIABILITY OF THE F/Q FACTOR IN OPTICALLY COMPLEX WATERS

The relationship between remote sensing reflectance, Rrs, and the inherent optical properties of the ocean (primarily absorption, a, and backscattering, bb) is described by the bidirectional reflectance distribution function (BRDF). Early work on this topic returned relationships for Rrs on both bb/a and bb/(a+bb) with associated variability in the relationships dealt with by variable estimates of f/Q and by adding 2nd-order terms. Recent work (Hlaing et al., 2012) has shown that Case-2 waters can be better represented by wavelength-dependent, 3rd-order polynomials operating on bb/(a+bb). More recently, there is evidence of a growing misunderstanding emerging in the community that suggests that the simpler bb/a relationships are inappropriate for Case-2 waters. In this study we use extensive Hydrolight simulations to generate a synthetic data set of spectral Rrs, a and bb values for a range of solar and sensor angles. Using a wider range of constituent concentrations than the earlier Hlaing et al. study, we find that the BRDF is well-modelled using 5th-order polynomials to ensure equivalent performance across the full range of simulated concentrations, that the BRDF is not significantly wavelength dependent and that performance of bb/a and bb/(a+bb) variants are essentially equivalent. Together with the Hlaing et al. study, these results point the way to a simple but effective set of relationships for relating Rrs, a, and bb that are sufficiently robust for operational use over the vast majority of marine waters. Demonstration that BRDF is adequately parameterised on bb/a significantly simplifies the route to spectral deconvolution of Rrs signals.

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INVESTIGATING THE PHYTOPLANKTON DIVERSITY IN THE GREAT CALCITE BELT: PERSPECTIVES FROM HYPER- AND MULTI-SPECTRAL SATELLITE RETRIEVALS AND NUMERICAL MODELING

This study highlights benefits and challenges of applying coupled physical/biogeochemical modeling and the synergistic use of different satellite retrieval algorithms for investigating the phytoplankton diversity in the Great Calcite Belt. This area is of great interest for understanding biogeochemical cycling and ecosystem functioning under present climate changes observed in the Southern Ocean. Our coupled model simulations of the phenology of various Phytoplankton Functional Types (PFT) are based on a version of the Darwin biogeochemical model coupled to the MITgcm ocean general circulation model, where both - the physical (including sea ice) and biogeochemical modules - are adapted for the Southern Ocean. The biogeochemical module, among 42 biogeochemical compartments, describes 6 various phytoplankton functional types: analogues of (large) diatoms, other micro-phytoplankton, prochlorophytes, other pico-phytoplankton (including small diatoms to represent required diversity in diatoms), nitrogen fixing phytoplankton and coccolithophores (as nano-phytoplankton with corrected physiology to account for high affinity for nutrients and ability to escape grazing control). As satellite-based PFT information, we consider products of the Differential Optical Absorption Spectroscopy applied to Phytoplankton (PhytoDOAS) using SCIAMACHY and OMI hyper-spectral optical satellite measurements. We also address aspects of combining this information synergistically (SynSenPFT) with the phytoplankton composition retrieved with OC-PFT based on multi-spectral optical satellite data (OC-CCI) and obtained by numerical modelling to allow for long time-series on the Southern Ocean phytoplankton diversity. To evaluate the satellite retrievals and model simulations we use in situ PFT observations obtained by a diagnostic pigment analysis as well as by scanning electron microscopy.

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EXPLOITATION OF LARGE IN SITU DATABASE OBSERVATIONS TO SUPPORT CROSS QUALITY CONTROL AND CONSISTENCY ASSESSMENT WITH OCEAN COLOUR

The European Copernicus programme provides a unique opportunity of accessing under the same umbrella to satellite ocean color data from Sentinel-3A and 3B (through the Ocean Colour Thematic Assembly Centre – OC-TAC) and coincident in situ data from various observation campaigns worldwide. This opportunity has been exploited in the frame of CMEMS activities to do cross-calibration from one dataset (EO-based) to the other one (in-situ based). This exercise does not intend to provide validation of one dataset compared to the other since for many data, the final accuracy is not well known. It is, instead, being use for quality assessment and data flagging. For instance we compare Chlorophyll-a surface concentration derived from Ocean Colour and its proxy derived from in situ fluorimeter (both of them potentially impacted by different sources of uncertainty). A methodology has been derived to systematically compare in situ and EO datasets and to provide recommendations on flagging strategy to apply on each of the dataset. This was done in the context of the European H2020-Atlantos project. It has been further exploited in the context of the Copernicus Marine Service. The results of both exercises will be presented at Ocean Optics XXIV.

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DEVELOPMENT OF ALGORITHMS FOR DETERMINATION OF WATER INHERENT OPTICAL PROPERTIES AND END USERS PRODUCTS FROM SENTINEL 3 OLCI DATA AND VALIDATION USING NORWEGIAN FERRYBOX DATA

To improve the data quality of remote sensing reflectance (Rrs), water inherent optical properties (IOP) and satellite end users products derived from the Sentinel-3 OLCI sensor, a comprehensive method for atmospheric correction and IOP retrieval has been developed based on data from Norwegian fjords and coastal water areas. Special emphasis is placed on accurate retrieval of Rrs values and water IOPs over open ocean as well as over cDOM rich and turbid coastal or inland water. Match-up data obtained from the Norwegian national FerryBox network (NorSOOP) has been used for validation. Along the Norwegian coast, from Bergen to Kirkenes, through the Barents Sea, or the North Sea, the NorSOOP ferries network is covering a large diversity of water types. The FerryBox systems measure core parameters such as salinity, temperature, oxygen, turbidity, cDOM and chlorophyll fluorescence, wind speed and direction, and hyperspectral above water reflectance. The NorSOOP Ferrybox network provides crucial insight into the dynamics of environmental conditions and a large and diverse dataset for remote sensing algorithms validation.

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VALIDATION OF SATELLITE RADIOMETRIC PRODUCTS FROM MULTIPLE MISSIONS: SYNTHESIS AND ANALYSIS

After 20 years of operational global ocean color missions and 16 years of activity by the ocean color component of the Aerosol Robotic Network (AERONET-OC), it is possible to take stock of validation results and draw general conclusions about the behavior of a standard atmospheric correction applied to SeaWiFS, MERIS, MODIS (A/T) and VIIRS. This study makes use of AERONET-OC radiometry data covering a large range of optical properties and collected at 5 coastal sites, in the northern Adriatic, Baltic (2 sites) and western Black (2) seas. For each site and satellite mission, the number of satellite match-ups is numbering tens to hundreds. Across missions and sites, the spectrum of RMS differences between satellite and field values of remote sensing reflectance most often shows a decrease with wavelength, with values in the blue generally between 0.0008 and 0.0025 sr^{-1}. Usually, the distribution of differences shows an approximately normal shape, which allows a statistical interpretation of the associated RMS differences. Average relative differences (in %) display a large variability, with values nearing 10% in the middle range of wavelengths and increasing in a typical horseshoe shape towards the blue and red bands. Differences appear to be well correlated across the spectrum. Furthermore, using match-ups common to several missions, some differences appear significantly correlated across missions, implying that part of the differences is not random. Considering the issue of representativeness and the uncertainties associated with field measurements, the interpretation of the observed differences in terms of uncertainty estimates is discussed.

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IMPACTS OF THE DISTRIBUTIONS OF CYANOBACTERIA POPULATIONS IN LAKE ERIE ON REMOTE SENSING

Freshwater cyanobacteria blooms occur in lake systems throughout the world, and are believed to be increasing in duration and intensity due to a variety of reasons including climate change. The expansion of outbreaks is of concern because of the toxins often associated with cyanobacteria blooms are a health risk to humans and animal life. However, knowledge gaps in optical properties of cyanobacteria impair interpretations of remote sensing products. Further, the eco-physiology of cyanobacteria varies across genera in regards to tolerance to light exposure, which can partly be controlled by buoyancy regulation via gas vesicles. The vertical and horizontal distributions of cyanobacteria are partly a reflection of these light tolerances and/or preferences, and impact the quality of light leaving the water. A detailed study of the distributions of cyanobacteria and their optical properties was conducted in Lake Erie in August 2014 during bloom conditions. Using a combination of optical profiling systems, digital holography and aircraft LIDAR, we observed horizontal variations in two different cyanobacteria populations occupying adjacent and connected water sub-systems within the western basin of Lake Erie. The two populations comprise Microcystis and Planktothrix dominated genera, and vertical differentiation was observed. Both genera contain gas vesicles, which in addition to buoyancy regulation, increase backscatter properties to the cells and associated colonial aggregates. The difference in vertical structure had a profound effect on the remote sensing reflectance, providing insight into interpreting bio-optical signals. This has broad relevance to lake systems with similar cyanobacteria in the context of remote sensing.

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A REMOTE SENSING APPROACH FOR TEMPORAL VARIABILITY OF PHYTOPLANKTON FUNCTIONAL TYPES IN ALBORAN SEA

During the last two decades, several satellite algorithms have been proposed to retrieve information about phytoplankton groups using ocean colour data. One of these algorithms, the so-called PHYSAT-Med, was developed specifically for the Mediterranean Sea due to the optical peculiarities of this basin. The method allows detection from ocean colour images of the most dominant Mediterranean phytoplankton groups, such as nanoeukaryotes, Prochlorococcus, Synechococcus, diatoms, coccolithophorids and Phaeocystis-like phytoplankton. Here, we present a new version of PHYSAT-Med applied to the recently released database of remote sensing data, namely Ocean Colour – Climate Change Initiative (OC-CCI), consisting in a multi-sensor, global, ocean-colour product that merges observations from three different sensors. The OC-CCI temporal coverage comprises the range September 1997- December 2015. In this work, the PHYSAT-Med updated version has been used to analyse the annual cycles of major phytoplankton groups in the Alboran Sea and extract periodic components of variability using wavelet analysis. Results confirmed previous patterns indicating the dominance of Synechococcus and Prochlorococcus throughout the year and particularly during spring and summer months respectively, whereas nanoeukaryotes seem to dominate during autumn-winter months. The method also reproduced the diatoms blooms normally detected during the spring season (March to April). According to the PHYSAT-Med OC-CCI outputs, the algorithm represents a useful tool for the spatio-temporal monitoring of dominant phytoplankton groups in Alboran Sea.

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PROTOCOLS FOR PROCESSING AND MEASURING PARTICULATE ORGANIC CARBON (POC) SAMPLES: ASSESSING THE EFFICIENCY OF ACIDIFICATION METHODS USED TO REMOVE THE INORGANIC FRACTION OF PARTICULATE CARBON SAMPLES COLLECTED ON GLASS FIBER FILTERS

Total Particulate Carbon (PC) is comprised of particle organic carbon (POC) and particulate inorganic carbon (PIC). The accurate determination of the contributions of each is integral to studies of biogeochemsity and carbon cycling in natural waters. Removal of inorganic carbon so that the remaining organic material can be measured is typically carried out by acidification techniques. Previous round robin studies have shown that PC measured at several different laboratories can agree to within a few percent. However, when the same labs attempted to measure POC, the agreement significantly decreased. This is likely due to fundamental differences in methodology, which may cause errors due to incomplete removal of inorganic carbon that is subsequently measured as part of the organic fraction. Alternatively, the acidification process may remove some of the organic carbon through volatilization or other processes before analysis. Dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) adsorbed onto the filters can also contribute to errors in PC and POC measurements. Current POC algorithms use empirical relationships between POC concentration and optical measurements, such as Remote sensing reflectance (Rrs), to estimate surface POC distributions. Therefore, it is essential to have accurate laboratory measurements of PC and its constituents. This study used cultures of coccolith forming Emiliania huxleyi and other non-lith forming cultures to test and compare different acidification methods and sample processing procedures.

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OPTICAL PROPERTIES OF DARK WATER EVENTS IN PUERTO RICAN OLIGOTROPHIC ENVIRONMENTS

Dark water events (DWE) are commonly found in coastal areas associated with wetlands or river outfalls, rich in organic humic matter. In Puerto Rico (PR), DWE can be found along the insular shelf and beyond in oligotrophic waters. These areas are usually associated to extensive coral reefs and seagrass habitats. Satellite imagery from Sentinel-3 (S3) was used to detect and assess the fate of these water masses. Field water samples in southwestern PR were analyzed for total suspended sediments, Colored Dissolved Organic Matter (CDOM), dissolved organic carbon and chlorophyll a. Field optical data were collected with a profiling Satlantic HyperPro, a GER-1500 field spectroradiometer, and a Hydroscat-6 backscattering meter. Dark water events were identified at nine S3 images in 2017-2018. Satellite data products were extracted inside and outside of these DWE while field data were used to validate ocean color remote sensing products. A dark water index (DWI) was used to discriminate these events from the surrounding clear oligotrophic waters. Preliminary data suggests an index of 7 or less (mean = 5) define DWE, while values above 7 (mean = 12.3) are associated with clear waters. The S3 ADG443_NN satellite product value inside the DWE (mean = 0.027) is double the values of clear waters. Reflectance values of S3 Band 1 (400 nm) outside the DWE is two times (mean = 0.025) the values inside the DWE. These data suggest that the highest contribution to the DWE optical signal is by CDOM. Field data will be used to validate this.

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MULTI-YEAR GEOSTATIONARY OCEAN COLOR IMAGER (GOCI) RECORD: COMPARISON WITH MODIS AND VIIRS

The first ocean color sensor on a geostationary orbit, Geostationary Ocean Color Imager (GOCI) onboard the Communication, Ocean, and Meteorological Satellite (COMS) has been operated for about eight years. The GOCI has a unique capability to examine hourly ocean color variability over seas between Korea, China, and Japan of which area is about 2500 km x 2500 km. The North-East Asia region where the GOCI observational domain covers is characterized by large regional diversity in ocean optical properties: clear water over the north western Pacific, less clear water over the East Sea/Japan Sea, and extremely turbid water in the coastal area of the Yellow Sea. Recently, the version 2 GOCI ocean color products with improved atmospheric correction method was newly released by Korean Ocean Satellite Center (KOSC). A new GOCI Chl-a algorithm proper to this regional sea domain has been created using in situ observation, and consistent validation efforts of the GOCI algorithm using the in situ measurements have been performed. Although multi-decadal ocean color records from NASA's legacy ocean color satellites (SeaWiFS, MODIS, VIIRS) had been well established, multi-year variability of the GOCI ocean color products over the North-East Asia has been less focused. For the application of the GOCI for climate application, this study will examine the consistency between with the GOCI data and the well-known, long-term ocean color record. The inter-satellite comparison on climatology, monthly, short-term variability of chlorophyll-a and remote sensing reflectance will be examined over diverse ocean optical environments within the North-East Asia region.

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CLASSIFYING INLAND AND COASTAL WATERS USING PCA AND MULTINOMIAL LOGIT MODEL

Satellite Sentinel-3 provides us data sufficient enough for monitoring optically complex inland and coastal waters. Algorithms for predicting the amount of optically active substances (OAS) from the data are often failing because of the complexity of the waters. Algorithms applicable for some waters might not be suitable for others. Classifying waters prior to assessing the percentage of OAS in water makes it possible to determine the best algorithm for each of the measured spectra. In this study, reflectance spectra of waters are used to divide waters into 5 pre-defined types: Clear, Moderate, Turbid, Very turbid and Brown. First, principal component analysis (PCA) is used to reduce the dimensionality of the data. It emerges that 99% of the divergence in the data is describable with just the first four orthogonal principal components. Using these components as predictor variables in multinomial logistic regression, a model for predicting probabilites of a reflectance spectrum to belong to each of the 5 water types is created. Given that the water type with the highest probability is assigned as the predicted water type, over 80% of the spectra are classified correctly.

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DIATOM ASSEMBLAGES IDENTIFICATION FROM REMOTE SENSING USING PHYSAT

PHYSAT currently allows for the qualitative detection of five main phytoplankton groups from ocean-color measurements. Even though PHYSAT products are widely used in various applications and projects, the approach is limited by the fact it identifies only dominant phytoplankton groups. This current limitation is due to the use of biomarker pigment ratios for establishing empirical relationships between in-situ information and specific ocean-color radiance anomalies in open ocean waters. However, theoretical explanations of PHYSAT suggests that it could be possible to detect more than dominance cases but move more toward phytoplanktonic assemblage detection. Thus, to evaluate the potential of PHYSAT for the detection of phytoplankton assemblages, we took advantage of the Continuous Plankton Recorder (CPR) survey, collected in both the English Channel and the North Sea. The available CPR dataset contains information on diatom abundance in two large areas of the North Sea for the period 1998-2010. Using this unique dataset, recurrent diatom assemblages were retrieved based on classification of CPR samples. Six diatom assemblages were identified in-situ, each having indicators taxa or species. Once this first step was completed, the in-situ analysis was used to empirically associate the diatom assemblages with specific PHYSAT spectral anomalies. This step was facilitated by the use of previous classifications of regional radiance anomalies in terms of shape and amplitude, coupled with phenological tools. Through a matchup exercise, three CPR assemblages were associated with specific radiance anomalies. The maps of detection of these specific radiances anomalies are in close agreement with current in-situ ecological knowledge.

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MEASUREMENTS OF THE VOLUME SCATTERING FUNCTION IN NORWEGIAN FJORDS AND ARCTIC WATERS

Accurate quantitative observations of ocean particles such as phytoplankton are becoming increasingly important, but can be difficult to obtain in coastal and Arctic waters. Improving remote sensing accuracy and developing new optical in-situ methods requires improved measurements of inherent optical properties of water constituents, for instance the volume scattering function (VSF). This function characterizes the ability of particles to scatter light in a given direction. The VSF of water constituents has been measured sparingly, especially in situ. This is due to the technical difficulty of the measurements, in particular in the forward scattering direction. There is a high demand on instrument dynamical range; the ratio of forward to backward scattered radiance may be larger than 107. The LISST-VSF instrument (Sequoia Scientific, Inc.) measures the VSF between 0.1˚ and 155˚ at 515 nm. A laser beam is sent into the sampling chamber, and the large-angle (15˚-155˚) part is measured by an eyeball detector, while the forward scattering (0.1˚-15˚) is measured by a ring detector. The instrument has been used in field work in fjords around Bergen, Norway, and in polar regions north of Svalbard, giving VSF profiles down to varying depths in both coastal Case II and Arctic waters. Initial laboratory measurements show good agreement with Mie theory for plastic spheres. The fjord water measurements agree well with the Petzold measurements for coastal waters, but there is some deviation in the forward scattering regime, implying regional or instrumental differences.

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Poster 209

TOWARDS LARGE-SCALE ESTIMATES OF PHOTOSYNTHETIC COMPETENCY: AN ASSESSMENT OF IRON STRESS AND OTHER ENVIRONMENTAL FACTORS ON NON-PHOTOCHEMICAL QUENCHING IN NATURAL PHYTOPLANKTON COMMUNITIES

The synoptic assessment of phytoplankton photosynthetic competency over large temporal and spatial scales is a crucial requirement for improved estimates of oceanic primary productivity. The quantum yield of chlorophyll fluorescence, which can be estimated from space, is currently the only direct measure reflecting the physiological state of phytoplankton on large scales. However, quantitative interpretation of the fluorescence quantum yield is hampered by a lack of understanding of the drivers of non-photochemical quenching (NPQ). NPQ is caused by an upregulation of heat dissipation of excess absorbed light energy in the antennae of photosystem II at high light, and it serves to protect the photosynthetic apparatus of the phytoplankton. While sensitivity of NPQ to the light acclimation state of phytoplankton has been demonstrated, other drivers of NPQ, including Fe status and species composition, remain to be examined. During a recent research voyage in the Southern Ocean, we conducted 4 short-term (~48h) deck incubation experiments to investigate the relationship between NPQ and iron limitation, probing NPQ with rapid light curves measured by fast repetition rate fluorometry (FRRF). HPLC samples were taken to elucidate the community composition in the respective incubations. The high-light results indicate increased NPQ in iron-stressed phytoplankton. Rapid light curves were also measured on natural phytoplankton assemblages in order to compare NPQ as estimated with an FRRF to an apparent quantum yield of phytoplankton fluorescence. The latter was derived from underway fluorescence, photosynthetically active radiation, and chlorophyll-a estimates based on the absorption line height at 683 nm, measured with an ac-9.

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VALIDATION OF MERIS CHLOROPHYLL FOR INLAND US WATERS

Lakes, rivers, and reservoirs are important to society by providing drinking water, recreational opportunities, and critical habitat. As part of the Cyanobacteria Assessment Network (CyAN) project NASA produced the first full MERIS daily time series (2002-2012) for more than 1800 lakes across the US for a variety of products. The historic inland waters dataset allows for the ability to look for changes in the waterbodies over time. Chlorophyll is a proxy for biomass, which can be used as an indicator of ecosystem health and waterbody trophic status and therefore, the validation of the chlorophyll algorithms for inland waters is important. The validation effort looked at a variety of chlorophyll concentration algorithms including the maximum chlorophyll index (MCI), the maximum peak height (MPH), the standard Ocean Color algorithm (OC4), and a chlorophyll estimate based on the Cyanobacteria Index (CI) algorithm. In situ dataset for validation match-ups was from the USGS Field Integrated Exploratory Lakes Database (FIELD). This effort is the first full contiguous US validation for MERIS chlorophyll for lakes and reservoirs.

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GF-2 OBSERVATIONS OF URBAN BLACK-AND-ODOROUS WATER BODIES IN BEIJING CITY, CHINA

The situation of urban black-and-odorous water (BOW) in China and developing countries is serious. Remote sensing can monitor the 'black' not monitor the 'odour' of BOW, thus, mainly via the color. There have been very few researches allowing high-resolution images to be used for studying urban BOW water quality. A novel approach was used with data from the GF-2 satellite images to identify the BOW from non-BOW in Beijing city, China. The latest data from the government (http://www.hcstzz.com/) indicate that the total length of BOW in the river in Beijing is about 280 km, the number of river sections is 61. We conducted field experiments in Beijing on two occasions, namely, August 28-29, 2016, September 20, 2017. We collected 53 BOW samples and 5 ordinary water samples. Through the analysis of the remote sensing reflectance of the BOW and ordinary water, we found that the reflectance spectra of BOW in green - red band is gentler than the ordinary water. The approach involves first deriving a black-and-odorous water index (BOI) based on the fused 1 m GF-2 reflectance data at blue (514nm), green (546nm), red (656nm) bands and then determining the BOI threshold value (0.05) to separate the BOW and non-BOW. The fifteen 1m GF-2 images covered the whole built-up area in Beijing, about 2500 km^2. The BOW distributed mainly the Southeast of Beijing. In addition to the open list of BOW, there are still many BOW. The BOI needs further verification in other cities.

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Poster 221

DEVELOPING AN INSTRUMENT FOR MEASUREMENT OF PARTICLE SIZE DISTRIBUTION IN SHIP-BASED UNDERWAY FLOW-THROUGH SYSTEMS

Particle size distribution (PSD) is a fundamental environmental measurement, with diverse biogeochemical applications including carbon cycle science, ecosystem and fisheries modeling, and harmful algal bloom detection/prediction. There is optimism that estimates of PSD will be available from ocean color measurements (such as NASA's planned PACE mission), and will be able to help constrain ecosystem/carbon models and estimates of primary production. However, natural PSD variability is not well understood due to the challenges of routine measurement, and there exists little field data over large space and time scales. We have developed a flow-through particle sizing instrument that covers a wide size range and is designed for integration into shipboard flow-through/underway systems. Key challenges addressed in this work and presented here were to (1) extend the particle size range to submicron sizes using wide angle detectors, wavelength selection, and polarized measurement; and (2) adapt the laser scattering measurement system to underway seawater flow-through system with a high degree of automation.

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Poster 225

ALGORITHM FOR LOW-SALINITY PLUME IN THE EAST CHINA SEA DURING THE SUMMER SEASON USING TWO-STEP EMPIRICAL APPROACH FOR GOCI AND MODIS SATELLITE SENSORS

To detect and trace offshore surface low-salinity water (LSW) in the East China Sea, a proxy was developed using surface water beam attenuation coefficient (cp), and salinity matched with synchronous GOCI and MODIS satellite data from 15-year summer cruises (2003-2017) using a two-step empirical approach. First, a relationship between in situ salinity and cp was obtained. Second, in situ cp was matched with GOCI and MODIS radiance ratios of all available blue-to-green wavelengths. Finally, satellite-derived surface salinity was determined directly by combining the two empirical relationships, providing a robust estimate over a range of salinities (22-34 psu). Our algorithm was then compared with other salinity algorithms based on CDOM. This significantly improves the limited spatial and temporal resolution of surface salinity distribution obtained by shipboard sampling. The resulting correlation is best explained as mixing between low-salinity plume waters and around normal saline waters. The empirical relationships were used to map satellite-derived salinity using the average of GOCI images during each summer cruise. As expected for summer, spatial patterns of LSW plumes with high cp were connected to the mouth of the Changjiang River and extended to the east-northeast. Saline water with lower cp was confined to the warm current and upper slope in the eastern part of the study area. This proxy approach can be applied throughout the region of shipboard sampling for more detailed coverage and analysis.

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OPTICAL RETRIEVAL OF THE MEAN DIAMETER OF SUSPENDED MINERAL AND ORGANIC PARTICLES

A significant factor in the study of the biogeochemistry of coastal and open ocean waters is the nature of and particle size distribution (PSD) of the suspended matter. For modeling purposes the mean particle size is often used to characterize at the first order the various particle chemical relations and the important sorption/desorption relations of suspended particles. The first step in biogeochemical studies is to characterize the nature of suspended particles, i.e. the relative amounts of suspended mineral matter and suspended organic matter. We have done this for several stations of our March 2016 two week field campaign conducted a on the shelf/slope in the northern Gulf of Mexico near the Mississippi River Delta. Combining these data with the volume total scattering coefficient at the stations yields the true mass-specific scattering cross section of the suspended mineral matter and the suspended organic matter. The theoretical derivation of the mass-specific scattering cross section involves the particle diameter that generates that cross section. Thus we derive a mean particle size for the suspended minerals and the suspended organics. We also have LISST data for the total particle suite at each station and the derived mean particle sizes will be checked against the LISST distributions with techniques derived by Risović to characterize the PSD. The nature of the organic mean particles will be investigated further with HPLC data on the the pigmentation of the suspended organics.

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REMOTELY SENSED PHYTOPLANKTON SIZE CLASSES IN THE ENTIRE CONTINENTAL SHELF SEA OF CHINA

Phytoplankton size classes (PSCs) play a critical role in exploring marine ecological and biogeochemical processes. Remote sensing has been regarded as the most important tool for acquiring the continuous observational data spatially and temporally, however, satellite-derived PSCs is still quite limited for optically complex coastal oceans. The Bohai Sea (BS), Yellow Sea (YS) and East China Sea (ECS) which host one of the most turbid coastal and shelf seas globally were taken as an example in this study. Using in situ pigment data and sea surface temperature(SST), parameters of three-component model were adjusted and an improved algorithm for PSCs retrieval was proposed. PSCs derived from images revealed that microplankton was dominant in the BS, YS and the nearshore ECS and nanoplankton distributed widely in the entire study area, while picoplankton mainly distributed in the offshore ECS in April, which was consistent with in situ investigation. Validation indicated that the improved algorithm provided a more accurate estimation of PSCs. Diurnal variations of PSCs were mainly affected by tidal currents and light intensity depending on different water types. Monthly variations in PSCs were captured in the YS, which had significant correlations with environmental factors, such as SST and mixed layer depth. These illustrated that the improved algorithm can provide worthwhile information of long-term spatial-temporal changes of PSCs for a better understanding and assessing of the marine ecosystem functioning in the continental shelf sea of China.

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PLANKTON MODELS FOR ANALYSES OF UNDERWATER LIGHT AND OF OCEAN COLOR REMOTE SENSING

Plankton exhibit a wide range of size distributions, shapes, and internal structures. However most studies that focus on light scattering by plankton particles assume that these particle have spherical shapes and that they are completely homogeneous. It is known that such assumptions lead to discrepancies in the amount of light scattered backwards. Furthermore, the assumption of spherical shapes leads to disagreement with ocean depth profiles of lidar depolarization ratios. To investigate the relative importance of plankton shapes and internal structures in RT and retrieval studies of underwater light scattering, computations were initialized to compare the scattering matrices for 4 classes of particles: (I) homogeneous and spherical; (II) homogeneous and non-spherical; (III) inhomogeneous and spherical; and (IV) inhomogeneous and non-spherical. We used existing data on plankton scattering functions, degree of linear polarization, lidar depolarization ratios, and aspect ratios to constrain shape distributions and internal structures.

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OPTICAL WATER TYPE GUIDED APPROACH FOR INLAND WATERS OAS ALGORITHMS

The availability of free remote sensing data with good spectral, spatial and temporal resolution of inland and coastal waters has generated wide interest in how to use remote sensing capabilities to monitor water quality. These waters are optically complex and influenced by colour dissolved organic matter, phytoplankton and an amount of suspended sediments. Also, remote sensing products quality have large variation according to water characteristics and algorithms used. Therefore, the remote sensing of optically complex waters is more challenging, and standards products often fail. In this study, we use optical water type classification based on reflectance spectra to divide waters into 5 types: Clear, Moderate, Turbid, Very turbid and Brown. Classification shows, different optical water type is associated with different specific bio-optical condition and each water type has different reflectance spectrum. Furthermore, we investigate Chl-a, TSM and CDOM published algorithms and tested against pre-classified in situ measured data. Finally, we present for each optical water type best algorithms and results are also applied on Sentinel-3 and Sentinel-2 data.

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MAPPING WATER TURBIDITY USING DAILY METRE-SCALE SATELLITE IMAGERY

Landsat 8 and Sentinel-2A/B data has impressed the water remote sensing community in recent years. For certain applications or regions, a higher spatial resolution and temporal frequency is still needed. Commercial satellite constellations could provide an opportunity for up to daily high resolution mapping of water turbidity. Significant challenges exist related to the processing and atmospheric correction for sensors with limited broad spectral bands. PlanetScope (PS) and RapidEye (RE) are two constellations of optical imaging satellites operated by Planet Labs Ltd. PS consists of 100+ nanosatellites which can together provide daily global coverage at 3 m spatial resolution. The imager on PS has four wide spectral bands (Blue, Green, Red, NIR), and offers water turbidity mapping capabilities using the Red or NIR wavelengths. RE is a 5 satellite constellation with a 5 m ground resolution and offers spectral coverage in 5 bands (Blue, Green, Red, Red-Edge and NIR). Similarly, RE can provide turbidity estimates from the Red, Red-Edge and NIR bands, and with the Red-Edge offers the potential for assessing the chlorophyll a absorption in turbid productive waters. Together these satellites could offer improved capabilities of monitoring turbidity and water quality. We present the dark spectrum fitting aerosol correction originally developed for Pléiades (Vanhellemont and Ruddick, submitted), adapted to PS and RE. Surface reflectance and turbidity derived from both satellite constellations is compared with multi-site in situ measurements. Consistency of several PS imagers is evaluated with near-simultaneous overpasses. Turbid water chlorophyll mapping using the Red-Edge bands on RE is demonstrated.

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MULTILAYER APPROACH TO PLANKTON ANALYSES IN CONTRASTING TROPHIC SYSTEMS OF NORTH PACIFIC

The plankton community was sampled during the Sea2Space Particle Investigation Expedition in winter 2017 along the trophic gradient transect (four stations) from Hawaii to Columbia River. The phytoplankton was investigated using LM, SEM and pigment analyses, while whole plankton community (bacteria and heterotrophs) was in detail identified via high-throughput sequencing of 16S rRNA and 18S rRNA genes. According to microscopy, the phytoplankton community was mainly comprised of coccolithophores (35.5%), diatoms (25.2%) and dinoflagellates (19.5%), while cryptophytes, phytoflagellates, silicoflagellates and others contributed with 19.8%. Chemotaxonomic results are congruent with the microscopy mainly in case of diatoms, coccolithophores and cryptophytes whose bioindicator pigments were high in concentration. Bacterial community was dominated with Alphaproteobacteria (52.6%), Gammaproteobacteria (16.6%), Cyanobacteria (8.5%) and Bacteroidetes (3.7%) throughout all stations, while Actinobacteria (5.1%) and Deltaproteobacteria (2.6%) were higher in number in samples taken from greater depth and closer to the coastline. Eukaryotic community diversity was assessed in ultraplankton fraction (0.2 – 5 microns) and greater than 5 microns. Ultraplankton eukaryotes were dominated with parasitic dinoflagellates (order Syndiniales, 41.7%), other Dinophyceae (10.7%) and Stramenopiles (11.8%), while higher production by green algae (Mamiellophyceae, 12.7%) was observed in eutrophic samples. Eukaryotes greater than 5 microns showed different composition, dominating by metazoan sequences (mainly Arthropoda and Cnidaria) and larger dinoflagellates, while primary producers were scarce. This study provided important and useful results to be used in development of algorithms and sensor calibration in orbital satellites by which it will be possible to observe the subtle color differences of the ocean.

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VIIRS OCEAN COLOR PRODUCTS FROM SNPP AND NOAA-20

In this presentation, we provide an overview of the progress on producing accurate global ocean color products from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (SNPP) and NOAA-20 satellites. SNPP and NOAA-20 were launched on October 28, 2011 and November 18, 2017, respectively. VIIRS global standard ocean color products include normalized water-leaving radiance spectra nLw at VIIRS five spectral bands, chlorophyll-a (Chl-a) concentration, water diffuse attenuation coefficients at the wavelength of 490 nm, Kd(490), and at the domain of photosynthetically available radiation (PAR), Kd(PAR). In addition, new products of nLw at VIIRS imaging I1-band (638 nm for SNPP and 642 nm for NOAA-20) and a quality assurance (QA) score are now included. VIIRS global ocean color products are being routinely produced using the Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system. Specifically, we describe our effort for the improvements of MSL12, particularly over coastal and inland waters, as well as some evaluations with in situ data from the Marine Optical Buoy (MOBY) and various AERONET-OC sites. Furthermore, we provide VIIRS ocean color data from both SNPP and NOAA-20, as well as from merged global Chl-a and Kd(490) data from the two VIIRS sensors, showing significantly improved data coverage. Some examples from the recently developed data gap-filling technique for VIIRS-SNPP are also presented and discussed.

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UNEXPECTED LACK OF PHYTOPLANKTON BIOMASS IN NATURALLY IRON FERTILIZED WATERS NEAR HEARD AND MCDONALD ISLANDS IN THE SOUTHERN OCEAN

Phytoplankton are responsible for about 50% of global primary production and for the sequestration of carbon in the ocean through the biological pump. The Southern Ocean is the largest high-nutrient low-chlorophyll (HNLC) region in the global oceans, where the phytoplankton primary production is mostly controlled by the availability of iron. The Kerguelen Plateau is one of the regions in the Southern Ocean where massive algal blooms occur as a result of natural iron fertilization. However, time series analysis of a consistent ocean colour climate data record (OC-CCI), from 1997 to 2015, revealed chlorophyll concentrations located close to Heard and McDonald islands are much lower than on the central Kerguelen Plateau. Further investigation of these waters was undertaken during the HEOBI (Heard Earth-Ocean-Biosphere Interactions) voyage onboard RV Investigator between 8th January and 26th February 2016. Surface chlorophyll concentrations derived from HPLC confirmed that low phytoplankton biomass persists in the vicinity of the islands, as observed in the ocean colour data, despite high levels of iron prevailing. The analysis of pigment and optical data also revealed a shift in the phytoplankton size structure in this region, from a microphytoplankton to nanophytoplankton dominated community. We explore a number of possible explanations for this high nutrient, high iron (Fe), low chlorophyll (HNHFeLC) phenomenon, including dilution of biomass by deep mixing, light limitation, zooplankton grazing, local circulation and sinking enhanced by the presence of resuspended sediments and draw conclusions on the implications for ocean modelling estimates of ocean carbon fixation and sequestration.

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REFLECTANCE OF FLOATING MACROALGAE IN SEA SURFACE WATER: OBSERVATION AND SIMULATION

The occurence of floating macroalgal blooms increased in worldwide oceans in the past decade. Optical remote sensing is the primary tool for the detection and biomass estimation of floating macroalgae. However, the spectral characteristics of floating macroalgae in sea surface waters were seldom investigated. In this work, two typical floating macroalgae were collected: green macroalgae (Ulva spp), and brown macroalgae (Sargassum); the sea surface reflectance of these two types of macroalgae in surface water were measured under controlled conditions in field work, and different reflectance curves were presented. Meanwhile, the sea surface reflectance of the submerged floating macrogael in different water depths were simulated through a simplified optical model. The simulated reflectance and the field ones show good consistency, which suggests that the submerging effects of water on macroalgae can be quantified and the model of estimating the biomass of submerged macroalgae may be established.

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BIO-OPTICAL CHARACTERISTICS OF MESOSCALE EDDIES IN THE RED SEA

Mesoscale eddies have a significant role in the physical and biogeochemical dynamics of the Red Sea. Until recently, limited in situ studies could not capture the seasonal and biogeochemical variability of the mesoscale eddies in the Red Sea. The present study aims to exam the bio-optical properties of the eddies, with a particular focus on colored dissolved organic matter (CDOM), chlorophyll fluorescence (CHL) and multi-wavelength optical backscatter. Glider observations now provide extended time series observations in the central and northern Red Sea where significant mesoscale eddy activity is observed. This study discusses the effect of eddies on the relationship between backscattering, chlorophyll and CDOM, and their spatial and temporal variability. In addition, the glider observations better inform us how to interpret satellite remote sensed ocean color for this region. In the Red Sea, ocean color has been an important tracer for mesoscale eddies. The results show that remotely sensed chlorophyll may be influenced by components other than phytoplankton chlorophyll. Additional components including optical backscatter and CDOM, may contribute to the ocean color signature and derive from either the coastal region, or from Gulf of Aden water transported northward. Optical measurements not only characterize the spatial and temporal variability of phytoplankton chlorophyll, suspended particles and CDOM, but inform us about important subsurface physical processes associated with eddies, water mass transport, mixing dynamics which cannot be detected or resolved from remote sensing.

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LIGHT SCATTERING BY WATER: THE DEPOLARIZATION RATIO AND ITS VARIATIONS WITH SALINITY

It is well recognized that one key challenge in further improving our understanding of seawater scattering is the better knowledge of depolarization ratio of water and its variation with salinity. The current uncertainties in this parameter are +/-50%, more than 100 times the uncertainty of any other fundamental physical parameter used in computing the scattering by water. The current value of 0.039 was determined in 1976 by Farinato and Rowell for pure water. However, there has been no verification of their findings, nor any additional studies on the effect of sea salts. Theoretically, disassociated salts ions are expected to produce a change in the anisotropy of the solution, and thus also in the depolarization ratio. We made multiple experiments using a multi-angle light scattering instrument DAWN EOS (Wyatt Technologies) to quantify the depolarization ratio of pure water and its variation with salinity at 532 nm. The experiments differed in how the pure seawater was prepared. In each experiment, 10 – 12 samples were prepared to cover a range of salinity from 0 to 40 PSU. For each sample, the polarized volume scattering functions were measured at 18 angles from 22.45 to 147 degrees. Preliminary analysis indicates that the results are more or less consistent between the experiments. For pure water, our values agree with Farinato and Rowell's value of 0.039 within 10%. The depolarization ratio exhibits a tendency to increase with salinity nonlinearly, increasing by approximately 40% at 40 PSU compared with pure water.

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TOWARD AN ESTIMATE OF SHALLOW WATER CARBON BURIAL FROM SPACE: QUANTITATIVE REMOTE SENSING OF SEAGRASS DISTRIBUTION AND DENSITY USING HIGH SPATIAL RESOLUTION MULTISPECTRAL IMAGERY

Advances in understanding the optics of shallow water environments, combined with improved spatial resolution now enable seagrass ecosystems to be monitored from orbiting multispectral platforms such as WorldView-2, WorldView-3 and Landsat-8. These highly productive ecosystems contribute significantly to total ocean net primary production, blue carbon burial and export to adjacent ecosystems, even though they occupy only 0.4% of the vegetated coastal habitat. However, large uncertainty in global estimates results from poorly constrained knowledge of global seagrass coverage, retional disparities in data availability and significant differences in the nature of seagrass ecosystem function derived from differences among species. Although seagrasses from Virginia and the eastern Gulf of Mexico generate similar amounts of above-ground biomass in dense meadows, the Gulf populations allocate far more biomass to below-ground structures, further enhancing the potential of these populations to sequester organic carbon in shallow water. We are exploring methods to utilize archived images from high spatial resolution multispectral sensors to develop an inventory of seagrass abundance & distribution in the Chesapeake Bay and Eastern Gulf of Mexico. Maps of seagrass distribution and above-ground biomass are derived from the imagery using an optical algorithm that requires knowledge of bathymetry and water column transparency. These in turn are being used to train machine learning algorithms to extract similar information for scenes where ancillary data are unavailable, and to help more clearly identify the boundary between submerged vegetation and optically deep water in the imagery.

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