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Poster 1

WATERSAT IMAGING SPECTROMETER EXPERIMENT (WISE) FOR CANADIAN MICROSATELLITE MISSION

The Canadian Space Agency (CSA) undertook a pre-Phase A concept study for a near-UV-visible-near-IR hyperspectral microsatellite mission, referred to as the WaterSat, for monitoring coastal oceans, estuaries and inland water bodies. To help advance the WaterSat mission study and elevate its technology readiness level, CSA awarded a contract to ITRES to design and build an airborne WaterSat Imaging Spectrometer Experiment (WISE) instrument. The WISE instrument was built and commissioned in early-2018. Comprehensive lab and airborne tests validated WISE's instrument design, robustness and suitability for science applications in costal oceans, estuaries and inland water bodies. The WISE instrument consists of three key subsystems: 1. fore-optics; 2. imaging spectrometer; 3. CCD with its readout, control electronics and software. WISE's fore-optics is a novel wide-angle, diffraction-limited two-mirror telecentric system. WISE's imaging spectrometer is an innovative compact modified-Dyson design based on an ITRES' patent technology. WISE also incorporates a custom-designed high-speed low-noise CCD with superb sensitivity and dynamic range. This combination yields a high-performance hyperspectral imaging system with excellent SNR. Both spatial and spectral distortions are less than 0.1 pixel. The WISE instrument acquires 1500 spatial pixels spanning a 39.46 degree-FOV, up to 288 spectral bands covering a spectral range of 358nm to 992nm with a 2.20nm/pixel average dispersion. It occupies a volume of less than 0.06m^3, weighs less than 10kg and consumes less than 70W. In addition to supporting CSA's WaterSat mission study, WISE's technological innovations will also support CSA's Coastal Ocean Color Imager (COCI) joint feasibility study with NASA and NRL.

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THEORETICAL INVESTIGATION OF THE USE OF THE PARTICULATE BACKSCATTERING SPECTRUM TO OBTAIN THE PARTICLE SIZE DISTRIBUTION

Knowledge about the size, composition, and distribution of particles in the global ocean has led to breakthroughs in understanding surface ecosystem dynamics as well as the ocean's role in the Earth's carbon cycle. Remote sensing has recently become a powerful tool for characterizing the global particle size distribution (PSD) on globally relevant spatio-temporal scales through the use of bio-optical algorithms. Here we extend the results of Boss et al. (2001) evaluating the relationship between the slope of a log-log PSD and the beam attenuation spectrum to explore the relationship between the shape of the particulate backscatter (bbp) spectrum and the PSD. We use Mie theory to model bbp spectra to test limitations of inversion methods for determining PSD distribution from bbp spectra by varying particle indices of refraction, integration limits, particle shape from spherical, etc. We find strong relationships between the bbp slope and log-log PSD slopes for typical open ocean conditions (Chl concentrations < 2 mg m^{-3}, PSD slopes > 3.5). Correspondence is not as good for shallow PSD environments, such as coastal and upwelling regions. This is in contradiction with the Boss et al. (2001) analysis of beam attenuation spectra, which showed good correspondence with PSD slopes for eutrophic waters but not for oligotrophic environments. Additionally, we explore the relationship between PSD and the backscattering spectra of coated spheres and hexahedrals. Future work will involve adding and testing particulate absorption spectra to the algorithm and testing the theoretical limits in a variety of ocean environments, particularly eutrophic environments.

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GLIMPSES OF THE BIO-OPTICAL VARIABILITY IN COASTAL WATERS OF WESTERN AUSTRALIA FROM A "THETIS" PROFILER MOORED OFF PERTH

A WET Labs "Thetis" moored profiler was deployed off Perth, Western Australia, in an attempt to start characterizing bio-optical variability in coastal waters (depth ~60m) of this Eastern Indian Ocean environment. Objectives also include evaluating diel variability in bio-optical and other properties in view of determining ecosystem productivity, and delivering reflectance matchups for current ocean color remote sensing satellite missions (in particular the Copernicus Sentinels). Collected parameters include temperature and salinity (SeaBird SBE49), dissolved oxygen (SeaBird SBE43), chlorophyll and CDOM fluorescence and optical particle backscattering (at 470, 532 and 700 nm) (two WET Labs EcoBB2FLs), total hyperspectral attenuation and absorption (WET Labs AC-S), upwelling radiance at nadir and downward irradiance (hyperspectral; Satlantic HyperOCR series). Data were first collected in October and November 2017, with 0-50m profiles at dawn, midday and dusk. Additional data started to be collected from mid February 2018, with only one profile at 11am each day. Water optical properties are as expected for an oligo- to mesotrophic environment, where surface chlorophyll concentrations are minimum in summer (November) of about 0.1 mg m^{-3}, and increase up to about 0.5 mg m^{-3} when fall begins in April. Higher concentrations, up to about 1 mg m^{-3} are observed at depths around 30-40m. Preliminary results indicate that bio-optical relationships would conform to average models. Reflectance matchups show some underestimation of the reflectance in the blue by the Sentinel3A/OLCI sensor.

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Poster 13

A NEW PARADIGM FOR OCEAN COLOR SATELLITE CALIBRATION AND VALIDATION: ACCURATE MEASUREMENTS OF HYPERSPECTRAL WATER LEAVING RADIANCE FROM AUTONOMOUS PROFILING FLOATS (HYPERNAV)

Ocean color satellites require routine in-orbit verification and vicarious calibration to maintain accuracy over the mission lifetime and between satellites. The majority of vicarious calibration and validation activities for ocean color satellites are carried out in areas of uniform oceanic and atmospheric optical properties using in situ radiometric data collected from fixed mooring installations or oceanographic ships. These methods have limitations in spatial coverage and in the cost of maintenance and operation. A spatially extensive network of vicarious calibration match-up data points would aid in reducing vicarious calibration uncertainty. To meet these needs, we have developed a new approach to ocean color satellite vicarious calibration and validation. Our system (HYPERNAV) combines accurate, reliable and stable hyperspectral radiometric instruments with autonomous profiling float technologies to provide a cost effective, unattended means for vicarious calibration over periods of years in the open ocean. We present data from laboratory and field experiments of the HYPERNAV system used to characterize system performance and to quantify the end-to-end radiance uncertainty budget. We present match-up comparisons of HYPERNAV field data and coincident water leaving radiance measurements from ocean color satellites, demonstrating the capabilities of the system to provide new vicarious calibration paradigm for ocean-color remote-sensing satellites.

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Poster 17

BENEFITS OF A GEOSTATIONARY SENSOR FOR DAILY SATELLITE PRODUCTS

Nowadays, satellite ocean color observations represent one of the most used tools to study ocean optical, biological, and biogeochemical properties. Generally, satellite products are available at daily, weekly, monthly, seasonal and annual temporal resolutions. Specifically, the daily products are derived from a few passages per day, as captured by the polar satellite sensors, and can be successively optimal interpolated with climatological data (e.g., monthly or seasonal). Our goal is to demonstrate the potential benefits of having high-temporal resolution observations from space to reduce errors in the reconstructed biogeochemical daily products (e.g. surface chlorophyll). To this aim, we developed a method combining model and satellite observations. We first simulated observations by a geostationary satellite using hourly outputs from CMEMS biogeochemical model, in the Baltic Sea. Then cloud masks, as obtained from SEVIRI, are overlapped to the simulations. Finally, the application of the Multi-Channel Singular Spectral Analysis (M-SSA) allowed us to fill the data gaps, generated mostly by clouds, obtaining a gap-filled hourly image. Two cases are discussed: i) a simulation based on synthetic polar sensor with limited passages per day, and ii) a simulation of geostationary sensor with hourly observations from 09.00 to 17.00 in local time. As expected, the results show that the RMSE errors are significantly decreased using hourly observations. Future research work will be to apply the present method to the GOCI data, the solely available ocean colour geostationary satellite sensor.

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SUSPENDED PARTICLES CHARACTERISTICS AROUND MUSSEL FARMS IN HORSENS FJORD AND LIMFJORD, DENMARK – PRELIMINARY RESULT

The differences in particle characteristics were assessed between areas inside and outside the mussel farms. The analyses based on empirical data of particle volume concentration (PVC), LISST-100X B, and SPM, gravimetric method, which were obtained during a campaign in Sept. 2017 on three mussel farms located in Denmark fjords: Horsens and Limfjord. Despite observed values of PVC and SPM were higher in Limfjord waters than in Horsens Fjord, which was related to different hydrological conditions, similar differences were observed between inside and outside waters of mussel farms. Inside farms all measured quantity parameters were lower than outside. Differences between parameters median values inside and outside the farms were up to 40%, of SPM 33% of Total PVC and 52% of particles number. Particles size distribution slope were higher inside the farms, what suggests small particles domination. Presented results document depletion and shift towards smaller sizes of suspended particles in the area of mussel farms, as foreseen by eco hydrodynamic models. Consequently, particles depletion changes optical properties of water by increasing water transparency. The phenomenon allows for use optical or remote sensing methods for control of water quality around mussel farms.

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SPATIAL, TEMPORAL AND SEASONAL VARIABILITY IN OPTICAL PROPERTIES IN THE NORTHERN ADRIATIC SEA

The Northern Adriatic Sea is presently the area within the Mediterranena Sea,where river plumes show the most significant influence, as several rivers discharge high amount of freshwater in this semi-enclosed regional sea. These freshwater discharges and associated particulate and dissolved matter inputs have a significant effect, both on the physical and biogeochemical properties of the whole basin. We present a characterization of the spatial, temporal and seasonal variability in optical properties and composition of particulate and dissolved matter in the Northern Adriatic Sea based on several research voyages (May 2012, February 2014, November 2014, March 2015). We measured bulk and apportioned inherent optical properties (IOPs) as well as apparent optical properties (AOPs), biogeochemical properties and particle size distribution, in different riverine discharge conditions as well as during the tidal cycle. We observed a significant variability in the shape and amplitude factors controlling the IOPs and the concentration- specifics IOPs (SIOPs) across several optical water types. The variability of the IOPs and SIOPs parameters was analysed in view of parameterising retrieval algorithms for the adaptive inversion approach (Brando et al., 2012) and the optical water type approaches (e.g. Melin et al., 2011; Moore et al 2014; Vantrepotte et al., 2012) to accurately retrieve chlorophyll and suspended matter concentrations in these complex coastal waters.

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THE IMPACT OF WATER CONSTITUENTS ON RADIATIVE HEAT TRANSFER IN THE OPEN OCEAN AND SHELF SEAS

We estimate the contribution of optically active water constituents (OACs), i.e. phytoplankton, CDOM and inorganic suspended sediments, to energy fluxes in the upper ocean and across the air-sea interface using a coupled bio-optical-ocean-atmosphere model. Our aim is to understand how heterogeneity in OACs in shelf seas affects the characteristics of sub-mesoscale vertical turbulent mixing and advective fluxes, through feedbacks with upper ocean heating rates and water density. We consider selected shelf sea regions (western Baltic Sea, Laptev Sea and New York/New Jersey Sea Bight) characterized by different freshwater and nutrient regimes, and complex bio-optical and hydrodynamic processes. We assess the impact of highly variable concentrations of OACs on heating rates. Modelled heating rates are evaluated against more rigourous co-located heating rate calculations performed using a dedicated atmosphere-ocean radiative transfer model. We show in different regional shelf seas how upper ocean heating rates induced by OACs contribute to the seasonal modulation of thermal energy fluxes across the ocean-atmosphere interface. We discuss the consequences for regional weather forecasting and climate change research.

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ANALYSIS OF THE SUN-STIMULATED CHLOROPHYLL FLUORESCENCE SIGNAL IN VIEW OF THE CURRENT AND FORTHCOMING SATELLITE MISSIONS

Phytoplankton organisms are able to change the observed light field through absorption, scattering and inelastic processes, such as fluorescence. Within this study we focus on the impact of fluorescence spectral features on the remote sensing reflectance (Rrs) signal, in the red and NIR wavelengths range of the visible electromagnetic spectrum. The Hydrolight code, parametrized with specific inherent optical properties of a clear lake (Garda, Italy), was run by changing the concentrations of chlorophyll-a [chl-a], total suspended matter and of the fluorescence quantum yield. The key parameter in the simulations was the Rrs peak position (Rrs-pp): to evaluate accurately these values, we parametrized the Rrs curves as sum of several components gaussian in shape (multipeak function). The values obtained were then displayed in a xy graph, for increasing [chl-a]: when fluorescence prevails (low total suspended matter and high quantum yield), a characteristic linear trend was found. On the other hand, when the elastic scattering dominates, a saturation trend was found. An exponential asymptotic function effectively matched the global Rrs-pp trends. At low [chl-a] and regardless the quantum yield, all the Rrs-pp curves show a linear growth. When elastic scattering prevails, the slopes is accentuated and the intercept lies around 688 nm. Contrariwise, when fluorescence dominates, the slope decrease and the intercept is settled to 685 nm, corresponding to the chlorophyll-a fluorescence peak emission. These results will be then evaluated with respect to experimental data gathered in the field and from airborne imaging spectrometry and Sentinel-3B (FLEX configuration).

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VALIDATION OF SATELLITE-BASED SEA SURFACE SALINITY (SSS) AROUND KOREAN COASTAL WATERS IN TERMS OF THE COMPARISON WITH THE MODEL-BASED MAPPING

Retrieving sea surface salinity (SSS) from satellite remote sensing is still challenging especially near the coast due to its spatial and temporal resolution compared to the dynamic variations of coastal water characteristics. As SSS can be a good indicator of short- or long-term changes in ocean environment and consequently the climate changes, many attempts have been made to mapping SSS in the wide area of ocean surface, although little has been successful particularly in the coastal area. In this study, satellite-derived coloured dissolved organic matter (CDOM) from the Geostationary Ocean Colour Imager (GOCI) of the surface water in the coastal area in the mid-western coastal area of Korean peninsula was applied to the mapping SSS, based on the well-known idea that CDOM absorption property has a strong correlation with SSS in the area that influenced by freshwater inflow. Empirical relationships between CDOM absorption and SSS are derived from in-situ measurement collected at the Gyeonggi-bay located in the middle of the west coast of Korean peninsula. The results were compared and validated with that from a model-based mapping.

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THE BASE OF THE FOOD WEB AND ITS KEY PLAYERS: CASE STUDY OF THE OLIGOTROPHIC SOUTHERN ADRIATIC SEA

The common knowledge points to picophytoplankton as the most important primary producer in the oligotrophic southern Adriatic Sea, and wintertime deep convection to be the main driver of the whole food web dynamics. In order to test this theory, an interdisciplinary research composed of two winter cruises was conducted along the coast-open sea transect, from surface to aphotic layers of water column. To recognize key players of the base of the food web, we combined physical, chemical and bio-optical measurements with molecular and microscopical signatures of plankton communities. Apparent oxygen utilization (AOU) had positive values, indicating respiration, mainly from heterotrophic bacteria, as a main process in the area. The photosynthetic component of picoplankton was dominated by cyanobacteria, while eukaryotic picoplankton was 95% hetero- or mixo- trophic and 5% photoautotrophic, supporting the respiration processes within the microbial food web. Our findings suggest that chlorophyll rich waters, encountered on larger depths, have to originate in surface layers, then being transported to aphotic layers by a strong wintertime convection event. Due its short duration, such convective mixing may go undetected, but its consequences are highly visible through increased phytoplankton abundance and Chl a concentration in the surface, as well as in deeper layers of the water column. Our findings emphasize the importance of wintertime deep convection in the southern Adriatic Sea for primary production. However, this study suggests that the respiration is the main process for the food web dynamic in the southern Adriatic Sea.

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INTEGRATION OF OPTICAL REMOTE SENSING DATA FOR SUSTAINABLE FISHING AND AQUACULTURE ACTIVITIES

Identification of the most favorable areas for fishing and monitoring of aquaculture activities, based on modern techniques, are essential for a sustainable development. Nevertheless, these tasks have become challenging due to fish stocks decreasing trend and intense human pressure on coastal habitats. Earth Observation data can be successfully used to raise the efficiency of fishing and aquaculture efforts. The SkyFISH platform, developed as a CMEMS downstream service, is a dedicated web-based service that can be used by the end-users as a decision support tool for finding the most favorable fishing zones or analyze the suitability of specific areas for aquaculture activities and monitoring of the existing ones. The area of interest covered by the service is the north-western Black Sea basin. SkyFISH takes advantage of the wealth of data delivered under Copernicus program (CMEMS) and other data sources. Analyses of water quality parameters, based on optical remote sensing information, are a core component of the service. Selection of the most appropriate products was essential for insuring the quality of the service. This was performed taking into consideration the characteristics of the area of interest (optical complex waters) and based on validation activities (using in-situ data). Apart from the products ingested in the system as added-value products, development of new ones was also required. Such an example is the regional adapted turbidity product, computed based on a local derived algorithm and which gives a more realistic view compared to the existing general valid algorithms.

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SATELLITE REMOTE SENSING OF THE HARMFUL ALGAE ALEXANDRIUM FUNDYENSE IN THE BAY OF FUNDY: AN ECOLOGICAL APPROACH

Alexandrium Fundyense spp. is a dinoflagellate that produces paralytic shellfish poisoning (PSP) toxins in the Bay of Fundy (BoF) and neighbouring Gulf of Maine. The toxins accumulate in shellfish through filter-feeding and can be fatal to vertebrate consumers. Recurrence of blooms of A. fundyense in the BoF leads every year to the closure of shellfish harvesting and causes issues to aquaculture. Given the patchy nature of A. fundyense bloom over large areas, satellite remote sensing represents an asset to monitor the dynamic of this algae. However, direct remote sensing of A. fundyense is challenging due to i) the low abundance (are as low as 200 cells·L−1) at which toxicity is detected in shellfish harvesting areas, and ii) its spectral signature to similar to that of other phytoplankton. Here we used an ecological approach based on sea-surface temperature and occurrence of diatoms derived by satellite to provide a warning system made of three levels: green for low abundance of A. fundyense (< 150 cell.L^{-1}), orange for non-conclusive information and red for potentially high abundance of A. fundyense. Blooms of A. fundyense are known to occur after the termination of the spring diatom bloom when temperature increases. A sensitivity study that uses in situ abundance of A. fundyense and coincidental sea-surface temperature (AVHRR) and occurrence of diatoms (SeaWIFS) between 1998 and 2007 was performed to find thresholds that trigger one level of warning or the other. Spatial and temporal variation of A. fundyes blooms in the BoF was studied.

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Poster 53

SATURATION OF WATER REFLECTANCE IN EXTREMELY TURBID MEDIA BASED ON FIELD MEASUREMENTS, SATELLITE DATA AND BIO-OPTICAL MODELLING – CAN WE USE THIS TO ESTIMATE SUSPENDED PARTICLE CONCENTRATION AND TYPE?

Evidence of water reflectance saturation in extremely turbid media is highlighted based on field measurements and atmospherically-corrected satellite data recorded over three estuarine zones, namely over the highly turbid Subei Shallow Bank (China), Gironde (France) and Yellow River (China) estuarine waters. This saturation is obvious in visible spectral bands, i.e., in the blue, green and even red spectral regions when the concentration of suspended particulate matter (SPM) reaches then exceeds 100 to 1000 $g.m^{-3}$. The validity of several bio-optical semi-analytical models is assessed in the case of highly turbid waters, based on comparisons with outputs of the Hydrolight radiative transfer model. The most suitable models are finally used to reproduce the observed saturation then, by inversion, to retrieve information on the SPM mass-specific inherent optical properties, more precisely on the SPM mass-specific backscattering to absorption ratio. These findings open new perspectives for the remote sensing of SPM size distribution and composition information, but also to constrain ocean color inversion algorithms and retrieve the contribution of, e.g., colored dissolved organic matter. For example, a reflectance spectrum, e.g. from a single satellite data pixel, may allow for SPM concentration retrieval in the red as well as SPM type (absorption/backscatter ratio) in the blue.

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NANO- AND MICRO-PLANKTON DIVERSITY ACROSS LATITUDINAL GRADIENTS IN THE NORTH PACIFIC

Phytoplanktonic cyanobacteria, diatoms, coccolithophores, as well as microzooplanktonic ciliates and dinoflagellates are the main plankton resident in the surface layers of the North Pacific Ocean. In this heterogeneous biome, spanning the oligotrophic subtropics to the HNLC regions of the subarctic, species have developed a variety of trophic strategies including N_2 fixation, symbiosis and mixotrophy to alleviate the limitation of nutrients. We have used the Imaging Flow CytoBot (IFCB) to examine nano- and micro-plankton diversity in the North Pacific and have found strong evidence of tightly coupled trophic dynamics across biomes. The diversity and particle size distribution of the autotrophic community vary predictably with biomes: large centric diatoms like Asterolampra and Thalassiosira dominate the nutrient-rich subarctic whereas symbioses of Rhizosolenia or Chaetoceros with the cyanobacteria Richelia dominate the oligotrophic subtropical gyre. This N_2 fixer is associated with mesoscale eddies in the subtropical gyre, like Trichodesmium and Crocosphaera. Under nutrients depletion, picoplanktonic bacteria feed mixotrophic dinoflagellates, leading to the coupling of their temporal and spatial distributions within the oligotrophic biome and at the transition zone between biomes. This way mixotrophic dinoflagellates (specifically Lepidodinium and Heterocapsa spp.) serve as a trophic link between small autotrophs, numerically dominant in the Pacific Ocean, and microzooplanktonic organisms like Balanion (ciliate) or Gyrodinium (heterotrophic dinoflagellate). The North Pacific biomes have evolved to optimize the efficiency of CO_2 assimilation and its transfer within the food web, yielding to flexible estimates of Net Community Production.

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CAN RAYLEIGH-CORRECTED REFLECTANCE BE USED FOR COASTAL AND INLAND WATER APPLICATIONS?

Using Moderate Resolution Imaging Spectroradiometer (MODIS) data covering a large area (almost the entire middle and lower reaches of the Yangtze River Basin and the Yangtze River Estuary) between 2002 and 2016, the uncertainties and applicability of Rrc (Rayleigh-corrected reflectance) in ocean color studies have been investigated. We first examined the correlation between a quality-controlled reflectance product that was generated using a shortwave-infrared (SWIR) based atmospheric correction method (Rrs_swir), and Rrc. Improved relationships between these two products were found for all MODIS bands if a subtraction of the Rrc at 1240-nm was utilized as the aerosol correction for Rrc of other bands. The robust correlations between the two products allow for Rrs_swir to be replaced with Rrc-1240 converted reflectance (denoted as Rrs_rrc-1240) in water applications. In situ validations further demonstrated the accuracy levels between usable Rrs_rrc-1240 and Rrs_swir data are comparable in most MODIS wavelengths. The most striking superiority of Rrs_rrc-1240 over Rrs_swir is the pronounced increase in data coverage (especially in small waters), where the percentage of usable observations (PUOs) of the former are several times or even more than one order of magnitude higher than the latter. The differences in PUOs were mostly due to perturbations of the land adjacency effects (LAEs) on the SWIR-based atmospheric correction, and such effects could also explain the reduced PUOs in smaller water bodies. The use of Rrs_rrc-1240 could enhance the capability of tracking short/long term dynamics and create new possibilities for inland water system monitoring at the basin scale.

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ON THE USE OF SPACE-BASED POLARIMETRIC MEASUREMENTS FOR OCEAN COLOUR REMOTE SENSING – HERITAGE AND PERSPECTIVE

The polarization of the light within the water body has been already documented, and very well described from in-situ measurements. This signature mostly results from the process of scattering by all the constituents of the water body: the molecular water itself, but also hydrosols, phytoplankton and particles. Mie scattering calculations demonstrated the sensitivity of Polarization with the chemical and physical properties of marine particles (nature and quantity of particle, refractive index, size, shape…). As roughly for the scalar radiance, the marine polarised radiance once propagated to the top-of-atmosphere layer remains small and contributes to less than 10-20% of the total polarized radiance depending on the water type. Observation of the polarization from space have been experienced based on POLDER sensors. While for open ocean, the atmospheric correction or the accuracy of the estimation of the surface wind speed could be improved, it was possible to retrieve a significant water leaving polarized reflectance for bright waters. Alternatively, a new approach proposes to analyse the parallel polarized contribution with respect to the scattering plane, which reduces significantly the perturbing contribution from surface reflection. Despite these past studies, the potential of polarization from spaced-borne measurements remains largely un-exploited for ocean colour purposes. The 3MI mission, a POLDER follow-on improved instrument on-board EPS-SG, will offer beyond 2021 the opportunity for a long-term time series acquisition in fully operational framework. Applications to marine analysis will be therefore possible. Other polarimetric information could also be available from SGLI/GCOM-C, OCI/PACE or DPC/GF-5.

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CHLOROPHYLL-A ALGORITHMS FOR SOUTHWEST TROPICAL PACIFIC WATERS

The NASA OBPG operational surface chlorophyll-a algorithms, i.e., OC3 and combined OCI-OC3, are evaluated for Southwest Tropical Pacific (SWTP) oligotrophic waters using bio-optical data collected during the February-March 2015 OUTPACE cruise. Total chlorophyll-a concentration (TChl-a) obtained from in situ "remote sensing" reflectance measurements is underestimated by a factor of approximately 2 in the range 0.02-0.8 mg/m^3, which is explained by a much lower diffuse attenuation coefficient than the average coefficient for world-wide conditions, especially in the blue. The pure seawater absorption coefficient in the near ultraviolet and visible, estimated from data at the clearest stations, agrees with the most recent determination. Application of the algorithms to MODIS-A imagery reveals a much noisier spatial field using OC3 than combined OCI-OC3, with semi-variance reduced from 0.01 to 0.001 (logarithmic scale) at one pixel distance, confirming previous studies. A sensitivity study further indicates that OCI is very robust to atmospheric correction uncertainties, but more impacted than OC3 by phytoplankton type variability in its applicability domain. A normalized "remote sensing" reflectance difference (NDPI) offers a good compromise in terms of resistance to both atmospheric correction and phytoplankton type noise. Time series of monthly MODIS-A TChl-a in the SWTP during 2003-2017 expose, not only the higher values, but also a much larger seasonal cycle when generated with NDPI, adjusted on the OUTPACE data, than OC3 and combined OCI-OC3, with consequences on standing stock and production assessments, and point to the lack of generality in the standard algorithms routinely applied, even for Case 1 waters.

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FACING THE CHALLENGES IMPOSED BY VARIABLE CLOUD COVER ON OPTICAL FIELD MEASUREMENTS

Cloudy skies, in particular broken clouds with variable shadowing of the sun, cause illumination conditions that are usually considered to produce non-evaluable measurements for passive optical instruments. For this reason, passive spectrometers are usually utilized only at clear sky conditions, thus recording of continuos data sets can be heavily hampered by the weather conditions. We analysed a series of spectral measurements made under such unfavourable illumination conditions for their potential of reconstructing reflectance spectra and deriving colored dissolved organic matter (CDOM), phytoplankton and total suspended matter (TSM) concentrations. We found that in-water measurements of downwelling irradiance allowed estimating the concentration of absorbing water constituents (CDOM, phytoplankton), yet not TSM. A major challenge for above-water measurements are the reflections at the water surface, which can exceed the water reflectance by orders of magnitude. Applying an adapted spectral model for specular reflections demonstrated the potential for estimating phytoplankton and TSM concentration, but not for CDOM. These results may indicate the possibility of all-weather monitoring with optical measurements from various platforms operated below clouds such as ships, buoys, unmanned aerial vehicles or aircrafts.

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BIO-OPTICAL PROPERTIES OF THE BARENTS AND NORWEGIAN SEAS SURFACE LAYER IN SUMMER 2017

A comparative study of the surface layer bio-optical properties of the Barents and Norwegian Seas in the summer of 2017 is carried out. Ship data were obtained during the 68th cruise of the R/V "Akademik Mstislav Keldysh" (June-August 2017). Using a flow-through system, the fluorescence intensities of chlorophyll "a" and dissolved organic matter, salinity and temperature of the surface layer water along the ship's route were continuously recorded. At the sampling stations, the reflectance spectra were measured. Samples were taken for spectral fluorescence and absorbance measurements performed with a laser spectrometer and an ICAM. The results are compared with the data of direct determinations of the chlorophyll concentration. In the Barents Sea, the results of ship measurements are compared with the data of MODIS and OLCI satellite scanners. Frequent continuous cloudiness prevented the use of ocean color data for the Norwegian Sea. A comparative study of the fluorescence, absorption, and reflectance spectra has shown the possibility of carrying out a rapid assessment of the phytoplankton species composition and its concentration. In particular, these data made it possible to determine the phytoplankton dominant species during mass bloom recorded in the Barents Sea: diatoms and coccolithophores. The change in the coefficients of the regression equation of chlorophyll fluorescence intensity and its concentration determined by direct methods for different regions is shown. The data processing and analysis were funded by RFBR according to the research project No.18-35-00525. The shipboard data were obtained within the RSF grant (project No.14-50-00095).

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MOVING UP THE FOOD CHAIN; SATELLITE BASED ESTIMATES OF HETEROTROPHIC RATES AND CARBON EXPORT POTENTIAL

Surface ocean organic particles, specifically total particulate organic carbon (POC) and one of its constituents, phytoplankton carbon (Cphyto), represent important components of the marine carbon cycle. Empirically derived optical proxies for these carbon pools applied to satellite retrievals of particulate backscattering offer global coverage of POC and Cphyto. POC and Cphyto display distinct spatial and temporal patterns associated with oceanic provinces, often with similar seasonal patterns but distinctly different from the pattern in Cphyto:POC ratio. While the concentrations of these organic particles are in and of themselves interesting, understanding the processes that drive their variability are important for understanding the fate of carbon in the marine environment. The particles we measure and observe in the ocean represent the particulate matter that has escaped a multitude of loss processes (e.g. viral lysis, grazing, bacterial degradation, physical removal). We investigated the patterns in organic particle pools, as well as Cphyto:POC, relative to s0me of the dominant loss processes, including bacterial carbon demand and zooplankton grazing, measured over a wide range of oceanic conditions. In doing so, we found relationships that allow us to evaluate rates of these dominant heterotrophic processes at the global scale. This approach will provide a better understanding of the balance between loss processes impacting patterns in Cphyto and POC. Perhaps more importantly, it allows us to explore where and when particulate carbon in the surface ocean is more likely to be recycled in the mixed layer or exported to the deep ocean.

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ERROR ASSESSMENT OF MULTI-SOURCE SATELLITE-DERIVED SEA ICE LEADS PRODUCTS

Arctic sea ice is undergoing dramatic changes in the context of global climate change. Satellite observation data shows a decreasing Arctic sea ice extent about 13% every decade in recent years, accompany with an accelerate thinning. Sea ice leads as a dynamics and thermodynamic driven sea ice features, it is the important heat flux window for the ocean and atmosphere, especially during wintertime. Poor performance of model simulation and the lack of long series satellite observation data with high resolution limited our focus on characterizing and understanding the variability of Arctic sea ice leads. Hence there is a rising demand for high resolution and accuracy sea ice leads product. A daily AMSRE based product with 6.25 km spatial resolution from 2002 to 2011 and a daily MODIS based product with 1.5 km spatial resolution from 2003 to 2015 and a daily Advanced-MODIS based product with 1 km spatial resolution from 2002 to 2017 have been introduced in this passage. In this context, Synthetic Aperture Radar images are employed to quantify these three kinds of sea ice leads products. Our results highlight that the AMSRE product has a consistent overestimation in pan-Arctic, the MODIS product has a significant omission in Beaufort Sea and a remarkable misclassification in GIN (Greenland, Iceland and Norway), and the A-MODIS product adjusts the accuracy of leads discrimination and can be useful to apply in forecast model.

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HOLISTIC APPROACH OF OCEAN OBSERVATION WITH THE MULTI-WATER BIOGEO-OPTICAL ALGORITHM ONNS

We introduce a novel in-water algorithm, specially designed to retrieve water quality parameters from Sentinel-3 OLCI satellite data (ONNS, the OLCI Neural Network Swarm algorithm). The aim of the development is to provide a single algorithm that is suitable to all natural waters, from oligotrophic ocean waters to very turbid coastal or highly absorbing inland waters. For this purpose, a fuzzy logic optical water type classification scheme is applied in conjunction with a set of specific neural networks. The algorithm retrieves different concentrations of water constituents, inherent and apparent optical properties, and a colour index. All products are self-consistent and form optical closure, which is basis for an uncertainty estimate. We illustrate the sensitivity of ONNS to different atmospheric corrections, using Sentinel-3 OLCI data of various regions. Results of ONNS are water-type-wise compared to standard ocean colour products and in situ observations.

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SEAWATER TRANSPARENCY IN THE JAPAN SEA

Seawater transparency is a measure of how clear the seawater is, which is related to the depth that light can penetrate seawater. Solar energy is a source for ocean biological activity because aquatic plants need sunlight for photosynthesis. Thus, transparency is often used as an indicator of water quality. In this study, the attenuation coefficient at 490 nm (Kd490) derived from Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Aqua satellite is used as an index of seawater transparency. The Ensemble Empirical Mode Decomposition (EEMD) and the Empirical Orthogonal Function (EOF) methods are used to investigate the seawater transparency in the Japan Sea (East Sea). The time series of monthly Kd490 shows a higher high value in April and a lower high value in November. A significant increasing trend of Kd490 is also found, which implies that the seawater is getting opaque. The EEMD analysis decomposes monthly Kd490 data into six modes. It contains biannual, annual, and interannual (2-7 years) cycles. Comparing with the distribution of chlorophyll-a concentration, the biannual period of Kd490 is caused by the spring bloom and the fall bloom of chlorophyll. The first EOF mode contains 76.95% of the total variance of the data, which displays high Kd490 values around the coastal areas of the north Japan Sea and its principal component shows an increasing trend from 2003 to 2017.

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PERFORMANCE OF A COMPRESSIVE IMAGER IN VISUALLY DEGRADED ENVIRONMENT

Resource efficiency is a critical element for sensing from unmanned platforms. A Compressive Line Sensing (CLS) imager can achieve this goal through optimization of source and receiver configuration, which allows offsetting resource requirements. For example, low pixel count receiver can be used, along with selected illumination (pattern), to reduce energy cost and data storage requirement. Scattering in visually degraded environment such as underwater comes from particulates and optical turbulence, the result of index of refraction fluctuations from typically temperature and salinity gradients. We setup a CLS system to explore its effectiveness in such degraded environments. A series of experiments were carried out at the Naval Research Lab Simulated Turbulence and Turbidity Environment (SiTTE), where the imaging path was subjected to various optical turbulence intensities and turbidities, with corresponding codebook modelled and optimized. The experimental results with different settings are presented. We discuss setup limitations, as well as improvement plans.

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ABSOLUTE CALIBRATION LISST-VSF EYEBALL MEASUREMENT

LISST-VSF is the first commercial instrument developed by SEQUOIA Inc. measuring in situ volume scattering function (VSF) from 0.094 to 150 degree as well as the P12 and P22 scattering element of the Mueller matrix. A LISST-VSF consists two components, a LISST and an Eyeball optics. The LISST measures VSF at small angles (<15°) using ring detectors and are absolutely calibrated. The eyeball component measures VSF at large angles (>15°) with two photomultiplier tubes (PMT) but are not calibrated. The relative calibration is performed in the data processing package by scaling Eyeball measured-VSF at 15° to LISST ring detector measured VSF at the same angle. This relative calibration works in most cases but will fail in relatively clear waters due to weak forward scattering by small particles. Also, this requires a background, representing pure water or pure seawater, to be determined beforehand. Because of difficulty in preparing pure water or pure seawater, the background is typically prepared by passing water through a 0.2 µm. This however, would preclude any possibility of studying particles of sizes < 0.2 µm, which could play a significant role in backscattering. We report a series lab experiments using standard beads of different sizes and concentrations to develop an absolute calibration for the LISST-VSF.

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INFLUENCE OF VARIABLE ATMOSPHERIC CORRECTION PROCESSING ON SATELLITE IMAGERY ON PHYSICS-BASED SEAGRASS DETECTION ALGORITHM

This study examined the effect of different atmospheric correction methods on the surface reflectance and the determination of seagrass distribution and density. The methods employed the standard Harris ENVI package algorithms for radiometric corrections to top of atmosphere radiance and reflectance followed by atmospheric contribution corrections to the scene. Calibration approach incorporated both the image metadata gains and offsets as well as the post launch vicarious calibration coefficients. The resulting images were corrected for atmospheric contribution by application of a dark object subtraction technique that incorporated a Rayleigh scattering approximation of the shorter wavelengths to the atmospheric contribution. Modtran and 6S was also applied to the radiometric calibrated data for alternative approach to atmospheric contribution. The resulting seagrass density maps demonstrate the sensitivity the preprocessing steps have on the final estimates for seagrass density and subsequent carbon determinations.

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A FEASIBILITY STUDY IN COMBINING GEOSTATIONARY SATELLITE DATA WITH HYDRODYNAMICS FOR SPIM PROFILES RECOVERY

The present study deals with the fusion of ocean colour satellite data with hydrodynamic simulations of waves and currents, in order to retrieve Suspended Particulate Inorganic Matter (SPIM) concentrations in the water column. The fusion methodology involves time series analysis and combines 1D-vertical spatial clustering and temporal pattern learning through Self Organising Maps (SOM) and Hidden Markov Models (HMM) respectively. The method is able to recover not only total SPIM concentrations but also concentrations of particles in different size classes (here 1 silt/fine and 5 sand/coarse classes). A statistical knowledge base of SPIM in-depth profiles is built from a 15 months period simulation performed by a hydrosedimentary model based on a Regional Ocean Modelling System (ROMS) realistic configuration for the English Channel. This ROMS simulation is a benchmark against which results can be compared. This simulation serves also to derive SPIM synthetic measurements for the upcoming geostationary MTG/FCI satellite sensor, adding an instrumental noise to SPIM total concentration surface values, and including data gaps corresponding to nights and frequent clouds in this area. Twin experiments were then performed while computing hourly time series of SPIM vertical profiles at one geographical point located in the highly dynamic waters near the Isle of Wight. Results show that waves and currents are the main parameters needed for the recovery of the coarse particles (sands), but satellite data are required for the fine ones (silts). They also show the nowcasting of satellite data (using DINEOF for instance) dramatically increases accuracy of the silt recovery.

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FIRST AUTONOMOUS BIO-OPTICAL PROFILING FLOAT IN THE RED SEA: A USEFUL TOOL TO ESTIMATE PARTICULATE ORGANIC CARBON EXPORT

The mesopelagic zone of the Red Sea, the region between 150 and 1000 m, represents an extreme environment due to low food concentrations, high temperatures and low oxygen waters. Some studies revealed that mesopelagic migrators are an important component of the biological pump, since they feed near the surface during the night and defecate at depth during day. It has also been suggested that the mixed-layer pump could play a fundamental role in carbon export from surface to the deep ocean in this region. However, the processes responsible this export into the mesopelagic are still poorly quantified and understood due to lack of observations. Using autonomous optical backscattering observations made by profiling floats, we will investigate the seasonal carbon export flux into the mesopelagic layer. Specifically, we will present results on the role of the deepening of the mixed layer depth during winter as a mechanism to export carbon into the mesopelagic. Thus this study will attempt, for the first time, to estimate particulate organic carbon fluxes and to improve our understanding of the biological carbon pump in the Red Sea.

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MULTISPECTRAL CLASSIFICATION OF GULF OF MAINE SURFACE WATERS: SEASONAL AND INTERANNUAL VARIABILITY

Bio-optically, Gulf of Maine (GOM) surface waters are strongly heterogeneous, exhibiting highly variable distributions in both time and space of suspended sediment, colored dissolved organic matter (CDOM), and phytoplankton. The concentration of non-algal components strongly impacts water optical properties in the GOM, rendering the standard NASA chlorophyll algorithm suspect. However, spectral signatures of the water are well quantified by satellite-based multispectral reflectance measurements. Here, we identify the spectral signatures of dominant water types present in the GOM using monthly composite SeaWiFS and MODIS data from 1998-2016. A merged multivariate clustering approach, including Self-Organizing Maps and hierarchical clustering, is used to group dominant spectral signatures across time and space. Remapped results provide a climatological view of bio-optical water types and the interannual variability of their distribution. Results indicate the same 2-3 spectral water types dominate the central GOM interannually. Several less spatially predominant water types are present mainly along the coast and over George's Bank, varying in location seasonally. Spectral signatures of the water types suggest they range from relatively clear waters, mixed waters dominated by suspended sediments, and waters dominated by CDOM and phytoplankton. Water type interannual variability and quantified trends suggest that in recent years, the central GOM experienced a shift in the dominant water type in September and November. This shift appears to be from clearer water, to water dominated by CDOM and phytoplankton. These results provide new satellite ocean color views of GOM variability over seasonal and interannual time scales.

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CALIBRATION AND VALIDATION OF A NEW INSTRUMENT FOR MEASURING THE ANGULAR LIGHT SCATTERING PROPERTIES OF SEAWATER

Despite the relative importance of the volume scattering function (VSF), the ocean optics community has historically relied on theoretical models and a limited dataset of measurements made using custom-built instruments. A new instrument (LISST-VSF, Sequoia Scientific) capable of in situ operation has recently become commercially available to provide measurements of the VSF and the degree of linear polarization (DoLP) of scattered light at 532 nm with high angular resolution within the range of scattering angles from ~0.1° to 155°. A thorough and independent characterization, calibration, and validation of the instrument has been completed. We describe laboratory experiments using 6 different diameter NIST certified polystyrene bead standards coupled with theoretical light scattering calculations to both evaluate instrument performance and to develop angle-dependent calibration correction functions for improved estimates of the VSF and DoLP. For the VSF, corrections on the order of 150 – 200% were required for nearly all scattering angles. Following correction, measured VSF values agree well with the theoretical VSF with a median absolute percent difference (MAPD) of 3.92% and a mean bias (MB) of -0.028 m^{-1} sr^{-1}. Similarly, the correction yielded improved comparisons of measured DoLP values with theoretical estimates (MAPD of 4.44% and MB of 0.017). The corrections for both VSF and DoLP were further validated through comparison with an independent multi-angle light scattering meter (DAWN-EOS, Wyatt Technologies). The improved measurement capabilities are used to investigate variability in the VSF and DoLP for natural seawater samples representing distinctly different assemblages of suspended particulate matter.

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REGIONAL OCEAN COLOR ALGORITHM: ADAPTATION FOR THE INLAND WATERS STUDY

The present work discusses an original bio-optical algorithm allowing to estimate concentration of phytoplankton pigments, absorption of gelbstoff and detritus and backscattering by suspended particulate matter in coastal waters of Black Sea using spectral reflectance data. The algorithm is based on series of field measurements conducted in 2002 – 2004 in coastal waters of Northern Black Sea. The measurements included hyperspectral sea reflectance in range 390 – 700 nm with 5 nm step and volume scattering function in angular range 0.8 – 178°, allowing to calculate seawater backscattering. Water samples were collected in order to measure pigment content and absorption by gelbstoff and detritus in the laboratory. The resulting algorithm uses semi-analytical expression for spectral reflectance and a specially designed optimization procedure to calculate the above-mentioned seawater characteristics. Results show good agreement with data of direct measurements of pigment concentration, absorption and scattering. Results of application of the algorithm to the satellite data (SeaWiFS, MODIS) showed higher correlation with direct measurements than standard satellite products. The distinction of the optimization procedure consists in calculating each seawater characteristic in separate spectral site in iterative way. It allows to adjust the algorithm to different bio-optical conditions by changing these spectral sites. The present work shows an attempt to apply the algorithm to the data obtained at Gorky reservoir on Volga River and indicates the prospects of further research in order to develop a regional bio-optical algorithm for monitoring inland waters with high pigment and nonliving organic content using satellite color scanners.

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Poster 129

INHERENT OPTICAL PROPERTIES OF THE BALTIC SEA IN COMPARISON TO OTHER SEAS AND OCEANS

The specific IOPs of the Baltic Sea were evaluated and compared to a global Reference Data Set (RDS), covering a wide range of optical provinces.Ternary plots of relative absorption at 442 nm showed CDOM dominance over phytoplankton and non-algal particle absorption (NAP). At 670 nm, the distribution of Baltic measurements was not different from case 1 waters. Chl a retrieval was shown to be improved by red-ratio algorithms. For correct retrieval of CDOM from MERIS data, a different CDOM slope over the Baltic Sea is required. The CDOM absorption slope, SCDOM,was significantly higher in the NW Baltic Sea: 0.018(+/-0.002) compared to 0.016(+/-0.005) for the RDS. Chl a-specific absorption and ad [SPM]*(442) and its spectral slope did not differ significantly. The comparison to the MERIS RMD showed that the SNAP slope was generally much higher (0.011+/-0.003) than assumed in the RMD (0.0072+/-0.00108), and that the SPM-scattering slope was also higher (0.547+/-0.188) vs. 0.4. SPM-specific scattering was much higher (1.016+/-0.326 m^2*g^{-1}) vs. 0.578 m^2*g^{-1} in RMD. SPM retrieval could be improved by applying local specific scattering. A novel method was implemented to derive the phase function(PF) from AC9 and VSF-3 data. b_tilda was calculated fitting a Fournier–Forand PF to the normalized VSF data. b_tilda was similar to Petzold, but the PF differed in the backwards direction. Some of the sIOPs showed a bimodal distribution, indicating different water types i.e. coastal vs. open sea. To improve remote sensing retrieval from Baltic Sea data, one should apply different parameterization to these distinct water types.

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ADAPTING CURRENT STATE OF ART: A MULTI-SENSOR APPROACH FOR MONITORING CYANOBACTERIAL HARMFUL ALGAL BLOOMS ALONG FRESHWATER-MARINE CONTINUUM

Cyanobacterial Harmful Algal Blooms (CyanoHABs) have become a major water quality and public health issue in aquatic environments where they can degrade habitats through fish kills, and potentially affect human and animal health via their toxins. Despite their significant economic impacts, major risks posed to environment, ecosystem, human and animal health there is no established rapid monitoring program to periodically evaluate the spatial distribution of CyanoHABs in inland and coastal waters. This study investigated the potential of synergistic use of multiple satellite sensors (Sentinel 3- OLCI, Sentinel 2-MSI, Terra/MODIS, Landsat 8-OLI) for identifying the occurrence, extent, intensity, and duration of CyanoHABs along freshwater-marine continuum. A case study of historic CyanoHAB event in Lake Okeechobee and St. Lucie River Estuary (SLRE) was analyzed, which caused state of emergency in many counties of Florida during summer 2016. The analysis involved a novel way to utilize multi-platform data to track the bloom pattern using floating algal index, normalized difference chlorophyll index, and cyanobacteria cell density maps. Spatio-temporal maps from multiple sensors revealed that, the bloom was transported from Lake Okeechobee towards SLRE through a C-44 canal. The significantly large amount (237 billion gallons) of discharged water from Lake Okeechobee might have reduced the salinity level of SLRE and supported the bloom formation in this estuarine system. The multi-sensor approach presented in this study will allow accurate, inexpensive and rapid monitoring of CyanoHABs and help water resource, environmental and human health managers to identify potential areas of concern to take necessary action in advance.

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IMPACT OF DIFFERENT ENVIRONMENTAL COMPONENTS ON LIGHT AVAILABILITY FOR PRIMARY PRODUCERS AT THE GREEN EDGE ICE CAMP

Arctic marine ecosystems are fueled by the production of algal biomass. While the growth of phytoplankton (single-celled algae suspended in seawater) was believed to be largely limited to the period when Arctic Ocean seasonal ice cover was decreasing (Jul-Oct), massive blooms of phytoplankton occurring under sea ice in the spring were recently documented. It is currently impossible to determine the extent of this phenomenon and its contribution, perhaps major, to annual marine primary production, as the mechanisms controlling the dynamics of phytoplankton blooms under sea ice are poorly understood. The most recent observations to understand this phenomenon suggest that phytoplankton growth under sea ice is largely conditioned by access to underwater light, which is determined by the presence of snow, sea ice, leads and melt ponds. However, the impact of clouds on light and, in turn, on the spring bloom dynamics of phytoplankton, has never been closely examined. Yet, the omnipresence of clouds in the Arctic strongly constrains light. Many environmental components were measured at a coastal Baffin Bay location during the Green Edge 2015 and 2016 field campaign. Using in situ and satellite observations, we evaluate how the snow, sea ice, melt ponds, and clouds impact light availability for phytoplankton at a very local scale for the spring and summer seasons.

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THE MYSTERY OF SECCHI DISK DEPTH RELATIONSHIPS

Secchi disk depth (ZSD) is a measurement of water clarity via visual observations and there have been roughly a million of ZSD measurements of the global oceans, lakes and rivers since its invention in the 1860's. This data is critical to evaluate the change of oceanic environments in century-long timeframes. However, there have been long-standing mysteries that the widely observed and consistent relationship between ZSD and the diffuse attenuation coefficient of photosynthetic available radiation (KPAR) could not be explained with the theoretical Secchi depth model adopted by the community in the past six decades. There are also puzzles about the appropriate "constant" for the product of ZSD times KPAR. Here, we use both numerical simulations and historical data, along with a new theory and model regarding ZSD, to resolve these long-lasting mysteries regarding the Secchi depth relationships. The results not only resolve these long-standing puzzles associated with these observations, but also unify the relationships published in the literature. In particular, the ratio of euphotic-zone depth (Zeu) to ZSD is found ~3.5 for all waters, which is ~45% greater than the consensus value of ~2.4 suggested in the past for clear waters. In addition, the new model validates an empirical relationship between ZSD and chlorophyll concentration (Chl) developed for global oceanic waters. These results provide a strong support for the interpretation and application of ZSD data for the study of global oceans under a changing climate.

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PROVAL: A PROFILING FLOAT DEDICATED TO RADIOMETRIC MEASUREMENTS

In-situ high quality measurements of radiometric quantities are mandatory to enable a "system vicarious calibration" (SVC) of satellite sensors dedicated to Ocean Color Radiometry (OCR) as well as to validate their derived products. These data are especially needed for remote areas poorly covered by oceanographic cruises, areas where atmospheric properties are poorly constrained and in areas with known bio-optical anomalies. This necessity is particularly critical during the early stages of an OCR satellite activity. Autonomous profiling floats have revolutionized oceanography by massively increasing the number of profiles; we argue here that dedicated floats could provide a strong foundation for global SVC. The ProVal float measures downward irradiance and upwelling radiance at seven wavelengths on two arms that allow radiometer redundancy and shading mitigation. We analyzed more than 500 profiles sampled in the Southern Ocean and Mediterranean Sea to date. We find that 45% and 85% of data in the surface layer exhibit tilts lower than 10° in the Southern Ocean and Mediterranean Sea respectively. From comparison between the redundant sensors the maximal relative drift is estimated by less than 0.2% per month over a year. Floats deployed in the Mediterranean Sea were recovered allowing post-deployment calibrations of radiometers that confirmed the low sensor drift. In addition, platform shading, estimated from the difference between the two radiometers, shows good agreement with Monte-Carlo simulations. Finally, comparisons of Remote Sensing Reflectance with the OLCI sensor (Sentinel-3A) show results in agreement with other sources of in-situ data but with extended coverage capabilities.

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DEVELOPING A NEW OCEAN COLOR ALGORITHM OF THE PAN-ARCTIC OCEAN: A SYNTHETIC APPROACH

As evidenced by a recent dramatic decrease of sea ice in both area and thickness of the Arctic Ocean (AO), primary production (PP) of the AO is likely increasing, as many remote sensing studies have suggested. It is well acknowledged that chlorophyll a concentration (chl a) is an essential variable for an estimate of PP. However, the performance of chl algorithms for the Arctic Ocean have not been thouroughly evaluated, especially in and around the several large river plumes dominated by CDOM that may significantly bias pan-Arctic primary production estimates. To overcome this issue, we first built a large in situ optical database of high-quality remote sensing reflectance at the Pan-Arctic scale. These data were subsequently used for tuning the original Garver-Seigel-Maritorena model (GSM01) for application to Arctic waters. Within the optical variability observed in natural waters, a bootstrap method was used to examine the performance of an algorithm that requires estimates for parameters including chl a specific absorption coefficients (aph-star), spectral decay constant for colored detrital matter absorption (s_cdm), and the power-law exponent for particle backscattering coefficient (s_bbp). A scoring system proposed by Brewin et al. (2015) was used to objectively determine the best combination of the parameters. Results show that the apparent percent difference of chl a estimates using the Arctic-tuned algorithm improved by 15% relative to the original one. The influence of the new chl a estimates on PP estimate relative to the original ones will be discussed.

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MODELING PHYTOPLANKTON ABSORPTION IN INLAND RESERVOIR WATER

In the retrieval of inherent optical properties (IOPs) from remote sensing reflectance of water, models for the wavelength dependence of absorption and backscattering coefficients are often needed. The main constituents that affect the water leaving reflectance are the suspended particles, phytoplankton and coloured dissolved organic matter (CDOM). We found that the existing model that works well for the absorption spectrum of phytoplankton in sea waters is not sufficiently accurate for the types of phytoplankton existing in the inland reservoirs of Singapore. In order to obtain a better fit of the measured remote sensing reflectrance spectra to the computed spectra, the phytoplankton absorption spectrum is modeled by a series of Gaussian peaks from 400 nm to 750 nm which mimc the absorption due to various pigments present in phytoplankton other than chlorophyll-a. The strengths of the absorption peaks are derived from the measured remote sensing reflectance. The phytoplankton absorption model is incorporated into a semi-empirical water reflectance model for retrieving the absorption and backscattering coefficients of water constituents using the spectral optimization technique. Field measurement campaigns were conducted to obtain in-situ data of remote sensing reflectance together with water quality parameters such as the turbidity, chlorophyll concentration (Chl) and CDOM absorption spectra. The retrieved phytoplankton absorption strength near 670 nm correlates well with the in-situ Chl with a coefficient of determination (R-squared) greater than 0.7. The retrieved absorption strengths of the other absorption peaks can potentially be used for phytoplankton type identification.

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HIGHLY RESOLVED DATA SET ON DIFFERENT PHYTOPLANKTON PIGMENTS AND FUNCTIONAL TYPES RETRIEVED FROM UNDERWAY SPECTROPHOTOMETRY IN THE FRAM STRAIT

Four approaches to estimate phytoplankton pigment concentration from particulate absorption spectra, namely Gaussian decomposition, singular value decomposition, neural network and empirical orthogonal function analysis, are evaluated and intercompared and finally evaluated. The neural network model is found to best estimate 14 phytoplankton pigments concentrations (r ranges from 0.45 to 0.96, log10 based RMSE ranges from 0.005 to 0.248). The estimated pigments concentrations are further exploited based on CHEMTAX analysis to derive phytoplankton functional types (PFTs). By the application of this method to the particulate absorption spectra collected by underway spectrophotometry during three summer cruises in 2015 - 2017 to the Fram Strait (European Arctic Ocean), continuous surface PFTs are estimated along the cruise course.

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A SATELLITE VIEW OF THE PARTICULATE ORGANIC CARBON AND ITS ALGAL AND NON-ALGAL CARBON POOLS

A recent inter-comparison exercise of different ocean colour algorithms for estimating particulate organic carbon (POC) over open ocean waters have shown that the algorithms proposed by Loisel et al. (2002), based on the particulate backscattering coefficient, bbp, and the one documented by Stramski et al. (1998), based on the blue to green reflectance ratio, provided the best performances (Evers-King, et al., 2017). The recent inverse model by Loisel et al. (2018) for estimating bbp from OCR has been applied over a large match-up dataset to re-assess the POC vs. bbp relationship used in Loisel et al. (2002). The chlorophyll-a concentration, Chla, is specifically considered in this model to account for the impact of the trophic regime on the bbp to POC dependency. Further, the conceptual model by Sathyendranath et al. (2009) used to infer phytoplankton carbon, Cphy, as a function of Chla has been revisited based on a large in situ data set of POC and Chla. These different algorithms have been then applied to ocean color satellite data to map, over open ocean waters, the bulk POC, as well as the particulate carbon pool associated with algal, Cphy, and non-algal, CNAC, components. The spatio-temporal patterns of the later parameters (as well as of the Cphy/Chla ratio) are analyzed and discussed.

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BIO-OPTICAL PROPERTIES OF SURFACE WATERS ON THE EAST GREENLAND SHELF AND IN FRAM STRAIT (ARCTIC OCEAN)

Almost 80% of water exchange between Arctic and global ocean occurs in the Fram Strait, where two optically contrasting water masses are encountered: the West Spitsbergen Current transports warm and saline Atlantic Water (AW) northward, while Polar Water (PW) is carried southward by East Greenland Current. Bio-optical properties of distinct water masses in surface ocean were characterized in study area along a section along 79°N, between Spitsbergen and Greenland, on the east Greenland shelf, and in the Dijmphna Sund in late summer of 2015 and 2016. We observed highest average values of particulate, ap(l) and phytoplankton pigment absorption, aph(l), coefficient at 443 and 670 nm in AW. The average values of detrital absorption coefficient, ad(l), at both selected wavelengths was highest in surface layer affected by sea-ice melt water. On average, the ap(l), aph(l), and ad(l) values were lowest in PW. Phytoplankton biomass was relatively low at the end of summer; and observed average chlorophyll a, Chla, concentration was 1.02, 0.65 and 0.35 mg*m^{-3}, in AW, PW and sea-ice melt water, respectively. We derived bio-optical relationships between Chla and ap(l), aph(l). The most significant correlation between, Chla and aph(443), aph(670) was observed in AW and melt water while in PW this relationship was less significant. We have also observed weaker (but statistically significant) correlation between ad(443) and ad(670) in melt water. Derived empirical relationship can be applied as for the efficient method for study phytoplankton dynamics and for improvement of ocean color remote sensing algorithms in the region.

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CHLOROPHYLL CONCENTRATIONS IN LARGE MARINE ECOSYSTEMS AROUND SOUTH AND WESTERN CENTRAL AMERICA: VARIABILITY, 20-YEAR TRENDS, AND IMPLICATIONS FOR FISHERIES

The Patagonia (PLME), South Brazil (SBLME), Humboldt (HLME), and Pacific Coastal Central America (PCACLME) Large Marine Ecosystems (LMEs) around South and Western Central America support high primary productivity and fisheries catch. The goal of this study is to examine the variability and longer-term trends in chlorophyll concentrations in the PLME, SBLME, HLME, and PCACLME, and to discuss implications for higher trophic levels. We use a combination of high-resolution satellite-derived chlorophyll concentration data from SeaWiFS (1997-2006) and MODIS Aqua (2002-2017) to examine spatio-temporal variability and analyze the record-length linear trends. We use monthly composites (2 km pixel-1) for the period of overlap between sensors (2002-2006) to compare retrievals and develop corrections using linear regressions. We then combine SeaWiFS (1997-2006) and corrected MODIS (2007-2017) data to generate the longest time series to date in the above-mentioned ecosystems. Results revealed significant increases in chlorophyll concentrations in large areas of PLME (78.23%) and HLME (43.03%) during the past 20 years, with important potential implications for trophic interactions. For SBLME (26.35%) and PCACLME (13.35%), increasing trends were detected only in small regions. We discuss the environmental factors controlling these trends and the effects of changes in chlorophyll dynamics on the reproductive success of two ecologically and commercially important fish species, the argentine hake Merluccius hubbsi and the anchovy Engraulis anchoita. In the current context of climate change, these results contribute to a better understanding of the effects of environmental change on ecosystem dynamics and present new tools to assess longer-term trends in satellite-derived chlorophyll concentrations.

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PARAMETERIZATION OF THE SPECTRAL LIGHT ABSORPTION COEFFICIENT OF PHYTOPLANKTON IN THE BALTIC SEA: GENERAL, MONTHLY AND TWO-COMPONENT VARIANTS OF APPROXIMATION FORMULAS

Approximate formulas for parameterization of the light absorption coefficient by phytoplankton aph in the surface waters of the Baltic Sea have been developed. Over a thousand of absorption spectra (in a range: 350-750 nm) registered during nine years of research conducted in different months of the year and in various regions of the southern and central Baltic, were used to develop these parameterizations. The analysed empirical material was characterized by a wide range of variability: the total chlorophyll a concentration (Tchla) varied between 0.3 and more than 140 mg m^{-3}, the relative proportion of the sum of all accessory pigments concentrations relative to chlorophyll a (acc.pigm./Tchla) varied between 0.21 and 1.5, whereas the absorption coefficients aph at individual light wavelengths changed by almost three orders of magnitude. Using the collected material, various variants of parameterization formulas were developed. Among them are parameterizations in the "classic" form of a power function (with Tchla as the only variable), as well as an example of two-component formula (the product of the power and exponential functions, with Tchla and acc.pigm./Tchla as variables). A distinct difference between general version of one-component parameterization and its variants developed for individual months of the year have been documented. In contrast to the general parameterization both the monthly and the two-component variants allow, at least partially, taking into account the variability of pigment composition occurring throughout the year within the examined Baltic phytoplankton populations.

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SPM MONITORING SINCE THE TOHUKU TSUNAMI IN 2011 WITH GOCI IMAGES

The devastating moment magnitude Mw9.0 earthquake that struck the north-eastern part of Japan on 11 March 2011 triggered a massive tsunami with several large waves that inflicted heavy damage on the Fukushima Dai-ichi nuclear power plant. Because SPM can carry contaminants radionuclides from run off of continental watershed, we studied the SPM distribution in the marine area since the tsunami in 2011. The first study analyzed the distribution one day after the tsunami, the second during the 6 following month and the last the distribution after the typhoons since 2011. GOCI sensor is the only geostationary sensor (GEO) dedicated to the ocean water color. With a frequency of 8 images per day and a high sensitivity to water color, GOCI is the best suited sensor to monitor the temporal evolution of suspended matters. Its geographical coverage is limited around the Korean Peninsula (110 ° E to 145 ° E, 24 ° N to 48 ° N) but this area also covers Japan. Flow rates of rivers and their 134Cs and 137Cs contamination helped us to deduce the SPM discharge (g/s) and the contamination discharge (Bq/s). Contamination can also be mapped around the river mouth assuming that the SPM are equally contaminated. In situ measurements were used for validation purpose.

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AUTOMATED FLOW THROUGH CALIBRATIONS OF BACKSCATTERING AND FLUORESCENCE SENSORS

Active optical instrumentation require robust calibrations throughout the lifetime of the instruments to ensure accurate in situ measurements. For remote data gathering onboard fleets of autonomous vehicles accurate and repeatable laboratory calibrations are necessary to guarantee intra-sensor comparability. Advances in backscattering and fluorescence sensor signal processing have widened the range of valid measurements leading to the requirement for a wider range of calibration target concentration and combinations of targets. Thus while single target point calibrations are not sufficient to characterize wide range instruments, increasing the number of target and target combinations to adequately describe instrument performance with current methods is not viable with respect to measurement variance, time and cost to calibrate. We describe a new calibration system that automates the process for backscattering and fluorescence instruments. The new system improves the variance and coherence of the measurements made in the calibration system, improving basic performance in areas such as noise in the presence of a steady state signal.

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ABSORPTION PROPERTIES OF CDOM ALONG THE NORWEGIAN COAST AND IMPLICATIONS FOR FERRYBOX OBSERVATIONS

A challenge for the optical remote sensing of Norwegian waters is the very high absorption by colored dissolved organic matter (cDOM), observed to be dominating the absorption below 600 nm regardless of seasons in some regions. There is also a very high variation in the cDOM optical properties along the coast, regionally and seasonally. The Norwegian ship of opportunity FerryBox network goes through a diverse array of water types from Germany in the South, along almost the whole Norwegian coast, through the Barents Sea up to Svalbard in the North and through the North Sea to Iceland in the West. A new national infrastructure program called NorSOOP will develop and extend the present network with new lines in the Arctic and Antarctic as well as new instrumentation, including cDOM fluorescence sensors and flow through absorption measurements. The cDOM measurements on our FerryBoxes already has and will continue to increase our understanding of the cDOM variation. We present cDOM fluorescence and spectral absorption data that show both seasonal and regional differences in magnitude, absorption, and the salinity dependency of the slope, as well as the application of this data for satellite validation.

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CALIBRATION UNCERTAINTY BUDGET FOR SEA-BIRD SCIENTIFIC RADIOMETERS

In-situ and above water radiometers are a critical for validating Ocean Color Satellite measurements, used to monitor in-water constituents of the global ocean. The calibration process, the instrument response characterization, and environmental measurement effects all contribute to the overall uncertainty budget of the radiometric measurement. An integral part of this uncertainty traceability chain is accurate laboratory calibration of radiometric sensors. In 2017, Sea-Bird Scientific transitioned the manufacturing of radiometric products from the Halifax, Nova Scotia CA (Satlantic, LTD) facility to the Philomath, Oregon USA (WET Labs, Inc.) facility. As part of this transition, the radiometer calibration facility was reproduced at the Philomath site. In order to maintain accuracy, Sea-Bird Scientific conducted an extensive cross facility set of round robin experiments to quantify uncertainties between our laboratories and . These efforts insured that the radiometric calibration uncertainty were maintained at 3-4%, or improved as part of the manufacturing transition process. This work will review efforts to reproduce the radiometric calibration facility in Philomath and processes established to maintain or reduce uncertainty due to calibration. At each site, four independent calibrations were performed with a secondary source, NIST traceable FEL lamp for the following radiometer products: Hyperspectral (HOCR), Microseries-504 (channels for 380, 412, 443, 490, 555nm and PAR), and Microseries-507 radiometers (channels for 412, 443, 490, 555, 590, 620 665, 683, 705, 865nm, and PAR) and PAR sensors. A calibration uncertainty budget is presented for calibrated sensors and recommendations are presented to further reduce the uncertainty budget for the Philomath site.

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AMT4SENTINELFRM RADIOMETRIC VALIDATION OF SENTINEL-3A OLCI

The Atlantic Meridional Transect (AMT) program has been one of the most valuable sources of high quality in situ measurements for remote sensing over the past 20 years. The Copernicus Sentinel Atlantic Meridional Transect Fiducial Reference Measurements Campaign (AMT4SentinelFRM) makes use of the AMT platform to provide Fiducial Reference Measurements (FRM) to validate Sentinel ocean colour and sea surface temperature satellite products. In this work we present the results of the validation of Sentinel-3A OLCI (Ocean and Land Colour Instrument) using above-water radiometric in situ data collected during the AMT26 (2016) and AMT27 (2017) field campaigns. We employ pre-and post-cruise calibration to generate post-cruise uncertainty budgets for our optical instruments (HyperSAS and TriOS radiometers), to quantify the overall uncertainty of each FRM and to identify and correct for biases. Quality-control procedures are then defined to ensure FRMs are of accuracy compatible for satellite validation. Finally, we perform a comprehensive accuracy assessment of Sentinel-3 OLCI level 2 remote sensing reflectances over a range of conditions, using a robust match-up procedure that takes into account homogeneity, quality and spatial variability issues. The FRM methodology presented here offers a clear advantage in the number and quality of match-ups over traditional techniques, providing a decisive tool for algorithm development and validation of satellite products for the Sentinel data streams.

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OPTICAL PROPERTIES OF FOREL-ULE WATER TYPES

The Forel-Ule (FU) scale consists of 21 standard colors and was originally conceived as a visual comparator for indexing the color of natural waters. Archived in-situ FU data constitute the longest time series of color of oceans seas and lakes since more than a century, with currently more than 200000 measurements publicly available. Recently, the FU scale was spectrally characterized and projected into the CIE (x,y) space. Subsequently, accurate algorithms to calculate the FU index from ocean color data were developed. Our contribution takes advantage of all these technical developments and applies the FU algorithm to global ESA-OC-CCI climatologies. Results show that the global climatological CCI reflectances (Rrs) lay between the FU indexes FU 1 and 14, with the highest 7 likely corresponding to high-CDOM inland waters. All oligotrophic oceans saturate at FU=1, confirming a somewhat rough resolution the the FU scale in the lower end. By clustering the CCI Rrs with the calculated FU, we define the FU optical water types (OTWs). These classes are also associated to derived inherent and apparent optical properties for every FU. Additionally, the FU OWTs are compared to other OTWs in the CIE (x,y) space. The advantages and limitations of each are discussed.

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STUDY OF VARIABILITY OF SUSPENDED PARTICLES PROPERTIES IN WESTERN-ESTONIAN COASTAL AREAS USING IN-SITU AND SATELLITE DATA

The Western-Estonian bays under investigation are shallow areas where suspended particles in water have two provenances, river input and storm resuspension. These complex waters are also dominated by CDOM coming from the rivers. Study with algorithms found in the literature showed that area specific algorithms are needed. The data set is composed of IOPs, reflectance, particle size distribution and water samples laboratory analyses. This data was compared with Sentinel-2 products. IOP data analyzes showed that suspended matter's inherent optical properties are highly variable within a season and location. Even the parameters like backscattering probability (2 – 3 times difference between locations and years) and specific SPM backscattering coefficient (0.4 – 1.7 compared to the yearly averages), that are usually used in algorithms as constants, vary in a large range. The main purpose of this study is to show the variation of particle size distribution and nature and it's correlation with the backscattering coefficients. The bigger the backscattering coefficient, the smaller are the particles. River outflow is composed of aggregated fine clay, whereas sea bottom of sand and mud. Additionally, time-series maps of particle concentration variability within seasons, stormy events and calm periods are analyzed. In order to increase the applicability of the study, the study sites are compared to a region of freshwater influence of a river Têt, which is similar in size but is located in Southern-France where the climate is warmer, river is torrential and sediments are dominant optically active substances.

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SPATIAL VARIABILITY IN THE PHOTOPHYSIOLOGICAL RESPONSE OF PHYTOPLANKTON THROUGHOUT THE SOUTHERN OCEAN

Phytoplankton photophysiology in the Southern Ocean (SO) is generally controlled by bottom-up processes, namely limited concentrations of bioavailable trace metals and variability in light. Spatial differences in environmental conditions and the taxon-specific responses to those conditions results in spatial heterogeneity of phytoplankton photophysiology across the SO. However, our understanding of the dominant drivers of this heterogeneity as well as its consequences is limited. We present a spatial analysis of phytoplankton bulk community photophysiological parameters recorded using flow-through and bench-top fast repetition rate chlorophyll-a fluorometers during the Austral Summer of 2016/2017 as part of the Antarctic Circumnavigation Expedition on-board the RV Akademik Tryoshikov. Continuous measurements of single turnover fluorescence induction are analysed for the spatial patterns in the efficiency of light harvesting (PhiPSII and SigmaPSII), regulation of the PSII turnover time (TauPSII) and induction of non-photochemical quenching (NSVPSII). Fluorescence light curves revealed the spatial heterogeneity in electron transport parameters (ETRRCII, alphaRCII and EKRCII). The maximum rate of electron transport was highly variable across the voyage track. Phytoplankton communities in the Indian and Atlantic Ocean sectors with higher chlorophyll-a, higher POC biomass and dominated by microplankton demonstrated higher light use efficiencies (alphaRCII and SigmaPSII) and lower electron transport saturation irradiances (EKRCII). The depth-distribution of dark-regulated photosynthetic traits was also investigated using discrete depth samples at 26 stations along the voyage track. The influence of environmental conditions and phytoplankton community structure and biomass on the phytoplankton photophysiological response is explored.

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OPTICAL PROPERTIES OF FINE SUB-MICRON PARTICLES ON AMAZON FLOODPLAIN LAKES: THE ROLE OF THE 0.2-0.7 GAP ON TOTAL ABSORPTION AND SCATTERING COEFFICIENTS

The impact of sub-micron particles on total absorption and scattering coefficients has been investigated in different aquatic environments with results showing low impact. At the Amazon floodplain lakes, however, the choice of different pore size filters to separate dissolved and particulate matter can have a significant impact on both coefficients. In this study the role of the 0.2-0.7 gap was investigated in Amazon floodplain lakes. The first set of sampled lakes is located within the first and largest Sustainable Development Reserve in Brazil dedicated to the protection of the Amazonian floodplain, whist the remaining lakes are located in a human impacted region of the Amazon basin. Moreover, the lakes are also affected by the interplay of the Amazon and Tapajos rivers, what brings high variability to their optical properties. Measurements were taken with a 10 cm AC-S on deck, after filtration by a 0.2 and 0.7 micron filters. Laboratory spectrophotometry and Scanning Electron Microscopy (SEM) were also performed to validate ACS measurements and investigate the nature of sub-micron particles. Results show that the 0.2-0.7 gap can represent up to 40% of the particulate absorption coefficient depending on the lake hydrological characteristics and proximity to the Amazon and Tapajos rivers. The same impact was not observed in the scattering coefficient reaching only up to 10% of the total scattering coefficient. SEM also demonstrated that the 0.2-0.7 gap presented a significant load of inorganic material which indicates that the absorption coefficient is not only related to the organic fraction of the particulate.

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VALIDATION OF SENTINEL-2 MAXIMUM CHLOROPHYLL-A INDEX FOR US WATERS

Chlorophyll-a concentration can serve as a proxy for phytoplankton biomass, an indicator of increased anthropogenic nutrient stress, and a measure of nuisance algal blooms. Here, we compare chlorophyll-a concentrations derived from satellite imagery to those obtained by in situ sampling. Satellite chlorophyll-a concentrations were derived from the European Space Agency's (ESA) Sentinel-2 MultiSpectral Instrument using the Maximum Chlorophyll Index (MCI). In situ data from the Water Quality Portal, serves data collected by state, federal, and tribal groups across the United States, was quality assured and entered in the Field Integrated Exploratory Lakes Database (FIELD) for validation. Initial data screening included cloud free satellite scenes, sampling depth < 2 meters, sampling distance from shore > 60 meters, and within ±3, 5, and 10 days of the satellite overpass. The spectral reflectance (before atmospheric correction) and Bottom of Rayleigh Reflection (BRR, Rayleigh removed) were evaluated as options for MCI implementation within ESA's Sentinel Application Platform software. Validation regression results and statistical distributions for derived MCI are presented and evaluated for >300 lakes, reservoirs, and estuaries. The intended outcome of this work is to use this satellite product to inform trophic status and eutrophication level assessments across the United States.

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DOES LEVEL-2 SATELLITE OCEAN COLOR VALIDATION HOLD FOR GRIDDED LEVEL-3 SATELLITE OCEAN COLOR PRODUCTS?

Satellite ocean color retrievals are typically validated against in situ measurements for Level-2 (L2) satellite data, defined as geophysical satellite retrievals stored at the native spatiotemporal swath resolution. However, many ocean color satellite data users employ Level-3 data in their research, which are geophysical satellite variables that have been resampled to a georeferenced grid over a defined period of time (e.g. – day, month, or year at 4- or 9-km). This study evaluates whether L2 satellite chlorophyll-a validation results are representative for 4-km L3-binned chlorophyll-a data. Both MODIS-Aqua and VIIRS-SNPP L2 and L3 chlorophyll-a retrievals from the OCI algorithm are validated against in situ chlorophyll-a data from a 2014 Atlantic Meridional Transect cruise using the recently developed stand-alone satellite validation matchup tools by the Ocean Biology Processing Group. Two key results will be discussed. 1) Reasonable agreement exists between validation statistics at both data levels, with the L3 data slightly outperforming L2 relative to the in situ data. 2) The number of L3 matchups is more than three times greater than the number of L2 matchups due to the L3 gridding methodology, validation matchup exclusion criteria applied to the L2 data, and differing temporal matchup windows between daily L3 data and the plus-minus 3-hour time window used in locating L2 satellite data.

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A GENERALIZED ALGORITHM FOR RETRIEVAL OF THE CHLOROPHYLL CONCENTRATION FROM SATELLITE DATA IN COASTAL AND INLAND WATERS

With the advent of many new generation sensors designed to provide frequent, high-spatial resolution, visible and near-infrared images, satellite optical remote sensing has been increasingly recognized as an effective method for producing synoptic maps of phytoplankton biomass distribution in the coastal zones and associated inland water systems. Recent studies have reported that there is a large uncertainty in chlorophyll concentration products for inland and coastal waters generated based on the remote sensing data using the traditional reflectance ratio algorithms and the red-NIR algorithms. To overcome the limitation of these algorithms, this work proposes a generalized algorithm for retrieval of the chlorophyll concentration from both multispectral and hyperspectral data and provides a rigorous validation of the algorithm products using independent in-situ data. Further, this study demonstrates the performance of the generalized algorithm and traditional algorithms based a variety of satellite remote sensing data from the contrasting inland, coastal and ocean environments. Results from the new algorithm showed good agreement with measured data with the errors in the desirable limits. The new algorithm is more advantageous in terms of the retrieval accuracy, wider applicability, and compatibility with modern satellite optical remote sensing sensors.

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THE EXPORT PROCESSES IN THE OCEAN FROM REMOTE SENSING (EXPORTS) NORTHEAST PACIFIC FIELD CAMPAIGN

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

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COMPARISON OF GOCI AND VIIRS OCEAN COLOR PRODUCTS IN THE WESTERN PACIFIC REGION

The first geostationary ocean color satellite sensor, Korean Geostationary Ocean Color Imager (GOCI), which has eight spectral bands from the blue to the near-infrared (NIR) wavelengths, has the unique capability with hourly measurements during daytime to provide short-/long-term environmental monitoring such as water optical, biological, and biogeochemical variability in the marine ecosystem. GOCI measurements cover the western Pacific region, including Bohai and East China Seas, which are one of the most turbid regions in the world. It has been shown that GOCI ocean color products such as normalized water-leaving radiance spectra derived using an iterative NIR-corrected atmospheric correction algorithm are significantly improved compared with the original GOCI products. In this presentation, we show results of GOCI ocean color products from its entire mission derived from the Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system to characterize diurnal, seasonal, and interannual variations in water optical, biological, and biogeochemical properties. In addition, GOCI ocean color products are compared with those of the Visible Infrared Imaging Radiometer Suite (VIIRS) using the NIR and shortwave infrared (SWIR) combined atmospheric correction method. GOCI and VIIRS ocean color products are also compared with in situ measurements. It will be shown that VIIRS ocean color products are quite accurate and highly stable in open oceans, and much improved in highly turbid coastal and inland waters. Furthermore, GOCI measurements are important to provide diurnal information that the polar sensor cannot provide. Some detailed data analyses and discussions for GOCI and VIIRS results will be provided.

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RELIABLE RETRIEVAL OF ATMOSPHERIC AND AQUATIC PARAMETERS IN COMPLEX ENVIRONMENTS BASED ON MULTILAYER NEURAL NETWORKS AND COMPREHENSIVE RADIATIVE TRANSFER SIMULATIONS

Standard atmospheric correction (AC) algorithms work well in open ocean areas where the water inherent optical properties (IOPs) are correlated with pigmented particles, but in turbid coastal water, they often exhibit large inaccuracies that may lead to negative water-leaving radiances (Lw) or remote sensing reflectances (Rrs). We describe new algorithms for retrieval of atmospheric and water parameters based on a multilayer neural network (MLNN) machine learning method. We use a radiative transfer model for the coupled atmosphere-water system to simulate top of the atmosphere (TOA) radiances (Ltoa) and Rrs values simultaneously, and use this dataset to train a MLNN to derive the aerosol optical depth (AOD) and Rrs values directly from Ltoa radiances. The method has been validated using both synthetic data and Aerosol Robotic Network – Ocean Color (AERONET–OC) measurements. A separate algorithm has been developed to retrieve aquatic parameters from the Rrs values. Application of these algorithms to MODIS Aqua images in several coastal areas shows that they are accurate (no negative Rrs values), robust, and resilient to contamination due to sunglint or adjacency effects of land and cloud edges. The MLNN algorithms are very fast and suitable for operational use. They have been extended for application to extreme atmospheric conditions (strongly polluted continental aerosols) over turbid coastal water by including appropriate aerosol and ocean bio-optical models. Results of applying these extended MLNN algorithms to VIIRS images over areas with extreme atmospheric and marine conditions (such as the Yellow Sea and the East China Sea) will be presented.

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DETECTION OF HARMFUL ALGAL BLOOMS THROUGH THE COMBINATION OF (SENTINEL-3) OPTICAL SATELLITE DATA WITH ECOLOGICAL ASSOCIATIONS

High frequency monitoring through satellite remote sensing has been beneficial in protecting public and environmental health in several key US waterways. In most instances, the success of these tools relies on strong optical signatures of some high biomass harmful algal bloom species (HABs). Some nearly monospecific blooms, like Karenia in the Gulf of Mexico and Microcystis in Lake Erie, so dominate their environment at certain times that they are readily identifiable with optical satellites. In Chesapeake Bay, a variety of dense algal blooms appear. While these can be detected from satellite, they cannot necessarily be distinguished only with satellite data. Examples range from mono-specific blooms of Alexandrium monilatum and Margalefidinium polykrikoides in the southern bay, to both monospecific and mixed assemblage blooms of dinoflagellates and diatoms in the northern bay. However, these mixed assemblages may be identifiable by combining satellite algorithms with additional ecological data. An approach using optical detection combined with ecological associations may aid in further classification of blooms (e.g., Heterocapsa blooms during the winter). Several algorithms applied to the Sentinel-3 Ocean and Land Colour Imager (OLCI) have improved our ability to detect and characterize algal blooms at higher resolution. Heuristic models constructed with information regarding the ecological niche of individual species (time of year; bloom succession; salinity, temperature and nutrient regimes), can enhance the satellite data, leading to the potential for a real-time monitoring system for HAB events in Chesapeake Bay.

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AIRBORNE LUNAR SPECTRAL IRRADIANCE (AIR-LUSI) MISSION

Ocean color data records from space require extremely accurate and consistent calibration across multiple years and multiple missions. It is largely recognized that the Moon is the most stable radiometric natural reference for Earth-observing satellites. However, the Moon's full utility as an absolute calibration source has yet to be realized because of significant biases in our knowledge of lunar spectral irradiance. The Airborne LUnar Spectral Irradiance (air-LUSI) mission has the objective to measure lunar spectral irradiance to an unprecedented level of accuracy: <0.3% (k=1) uncertainty. This is to be accomplished by advancing a ground-based instrument system to fly on a NASA ER-2 aircraft above 90% of Earth's atmosphere, providing a new capability to potentially acquire SI-traceable lunar spectral irradiance over different lunar phases and libration angles. Initially, the air-LUSI measurements can be used to enhance the Robotic Lunar Observatory (ROLO) model of exo-atmospheric lunar spectral irradiance. The mission outcome is expected to greatly improve the accuracy of our knowledge of the Moon as a stable reference for calibration and inter-calibration of Earth-observing satellite instruments over long time periods, from the past into the future. This will greatly improve calibration for space-based ocean color measurements such as from SeaWiFS, MODIS, VIIRS and eventually PACE, which are highly sensitive to calibration drifts.

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PAR MEASUREMENTS IN THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA)

PAR (Photosynthetic Active Radiation) vertical profiles that were obtained from casts with the Sea and Sun MSS90 microstructure probe in the southern part of the Gulf of Trieste near buoy Vida were analyzed in the years from 2011 to 2015. PAR fortnightly profiles were explored with the linear fit of decrease with the depth of logarithm of PAR, normalized with its value in the air. The inverse relation between the coefficient of PAR attenuation and the Secchi disk depth was also validated. Also, other relations (e.g. the bi-exponential non-linear decrease of PAR with depth) were explored. Our findings about the attenuation of PAR and the Secchi disk depth are in line with the study conducted decades ago for the north-eastern part of the Gulf of Trieste (Stravisi, 1999). Furthermore, the initial values of PAR profiles measured with the Sea & Sun probe in the air before the cast were validated with the PAR values measured continuously on buoy Vida, about 100 m away from the profiling measurement station.

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TINDER FOR THE OCEAN: AN INTUITIVE, SIMPLE, AND EFFECTIVE SPECTRAL MATCHING ALGORITHM FOR OCEAN COLOR

The optical classification of ocean/lake water using the full spectrum of remote sensing reflectance (RRS) can be used to optimally quantify and visualize how similar water bodies are related across time and space in terms of optical properties. Unfortunately, many spectral classification techniques applied to ocean color RRS (e.g. PCA, EOF, hierarchical clusters, fuzzy c-means, etc.) yield dimensionless modes or regionally specific results which 1) require the user to build relationships with large training datasets, and 2) are challenging to interpret without some a priori knowledge of the data. Here, we propose methodology to employ a universal, unsupervised classification system by which to summarize RRS data with a quantitative and mappable output. The simple weighted average of the RRS wavelengths, constrained by the relative intensity of each channel, outputs an Apparent Visible Wavelength (in units of nm). This tool is a simple and robust way for users to visualize and quantify trends in spectral RRS in terms of its apparent dominant color, which, inherently relates to a specific spectral shape and a unique combination of absorption and scattering properties. We statistically quantify errors and correlations on a global scale, over multi- and hyper-spectral datasets, and further demonstrate its utility in spatio-temporal analyses (e.g. where on the globe are changes in RRS spectral shape occurring and exactly how is it changing?). The simplicity of the algorithm demonstrates a potential utility for enhancing water-type classifications, semi-analytical inversions, decision-trees, functional type distinction, algorithm blending, quality control checks, as well as empirical algorithm development.

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SPATIO-TEMPORAL PATTERNS OF WATER BODIES AND SUSPENDED PARTICLES IN LOWER MEKONG BASIN FROM HIGH SPATIAL RESOLUTION IMAGERY

The availability of High Resolution Imagery (spatial, spectral, and radiometric) with an increased time of revisiting (Landsat-8 and now Sentinel-2) opens the way to a more detailed observation of coastal zones and inland waters and offers an incomparable tool for water composition monitoring such as the suspended particulate matter (SPM). Quantifying the SPM budget in the Lower Mekong Basin (LMB) including the Mekong river, the Tonlé Sap lake and the Bassac delta from remote sensing analysis constitutes an important challenge as SPM is a key parameter in numerous economic and societal aspects such as coastal management, navigation ability, erosion and accumulation of sediments, transport of pollutants, fisheries productivity, and drinking water resource, etc. However, this budget is still not properly understood. The main reasons are that: 1) most of standard atmospheric corrections over coastal and inland waters may fail and 2) coastal and inland waters are optically complex; as a consequence it impacts the accuracy of SPM algorithms and therefore the retrieval of accurate SPM values from satellites. The main objective of the VolTransMESKONG (CNES/TOSCA) project consists in improving our understanding of the spatio-temporal patterns changes of 1) water body extents including flooding event or dam impacts and 2) SPM for rich turbid environments exceeding 1000 NTU for instance.

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MULTIPLE NEUTRAL DENSITY FILTERS PROVIDE ROBUST AIR CALIBRATIONS OF TRANSMISSOMETERS

Transmissometers measure the optical density of seawater between a light source and a detector. We report on the development of a technique using multiple neutral density filters to track transmissometer performance. Typically, water and air calibrations are used to monitor changes over an instruments life. Water calibrations require a well constrained water source and are often difficult or impossible perform in the field. Air tracking is simpler and for single wavelength transmissometers has been the standard for many years. However, both air and water calibrations only yield maximum or zero attenuation values and do not address changes in instrument response with variable target loading, i.e. we assume transmissometers are linearly driven Beer's Law instruments. Because this is generally true, measurement artifacts that occur from unclean optical surfaces including biofouling can be addressed by adjusting the offset of the instrument to an assumed minimal value in the field. This then leaves us with an instrument that is very useful for monitoring larger signals at the ocean margins but at the cost of smoothing away the smaller signals of the ocean interior. Multiple filters offer the advantage of a statistical measure of the transmissometer's performance over the range of the instrument. The technique is simple enough to be used routinely in monitoring an instrument over time, it is particularly powerful as a deployment check of performance, and can be used to adjust data post deployment.

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SENSITIVITY OF INHERENT OPTICAL PROPERTIES FROM OCEAN REFLECTANCE INVERSION MODELS TO SATELLITE INSTRUMENT WAVELENGTH SUITES

The community seeks to develop CDRs/ECVs from satellite measurements of ocean color, the continuous data record from which now exceeds twenty years. Space agencies will launch additional instruments in the coming decade that will continue this data record, including the NASA Plankton, Aerosol, Cloud, ocean Ecosystem (PACE) spectrometer. Semi-analytical algorithms (SAAs) provide one mechanism for estimating IOPs from satellite measurements of ocean color. SAAs use contrasting optical signatures for absorbing and scattering components within the spectral bands detected by the satellite to determine IOP magnitudes. Their performance, therefore, depends on the spectral resolution of radiometric measurement used as input, which is driven by the spectral resolution of the satellite radiometer. SAAs refinement and IOP time-series continue, but few studies have explored differences in derived products that stem simply from the use of different suites of input radiometric measurements. A CDR/ECV spanning SeaWiFS, MODIS, OLCI, and PACE, for example, would include IOPs derived using varied wavelength suites if all available wavelengths were considered. Different combinations of input radiometry conceivably yield differences in IOPs that exceed the magnitude of observable environmental change in a CDR. We quantified the magnitude of change in derived IOPs associated with the use of different suites of satellite radiometry. The implication of ignoring such an analysis is a prolonged inability to distinguish between algorithmic and environmental contributions to trends and anomalies in the IOP time-series. A secondary benefit is the quantification of improvement in IOP retrievals realized using the increased spectral resolution to be provided by PACE.

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GLOBAL RETRIEVAL ALGORITHMS FOR PHYTOPLANKTON FUNCTIONAL TYPES (PFTS): TOWARD THE APPLICATIONS TO OLCI AND GLOBCOLOUR MERGED PRODUCTS

With integrated use of extensive in situ measurements from various cruises in different regions, this study focuses on PFT retrieval algorithms that are then applied to Sentinel-3 (S3) OLCI data and merged ocean colour (OC) products from CMEMS GlobColour archive. The main retrieved PFTs should include at least diatoms, haptophytes, prokaryotic phytoplankton, and more if possible. Previously investigated retrieval methods, empirical orthogonal functions (EOF) for pigment concentrations estimation (Bracher et al. 2015) and ocean reflectance inversion model (ORM) (Werdell et al. 2014) for PFT discrimination, are tested and adapted potentially with full use of our current available in situ measurements from various campaigns worldwide, in which we have a number of collocated remote sensing reflectance spectra (Rrs) and HPLC pigments in addition to other bio-optical measurements. Algorithms are tested and compared by both taking hyperspectral and multispectral in situ Rrs as input data, and the multispectral based approach is later on applied to the above mentioned satellite data. Performances of both EOF- and ORM-based approaches are assessed statistically and cross-validated, with results showing that both could well predict chlorophyll-a concentrations for diatoms and haptophytes but less good for prokaryotes. In a next step these algorithms are adapted to satellite OC data collocated to an even larger in-situ PFT database derived from HPLC phytoplankton pigments. This is to eventually develop the global satellite PFT products for long-term observation, updated timely with more available OLCI data in the future, and intercompared the results with other existing PFT products (e.g. PhytoDOAS, OC-PFT, SynSenPFT).

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DISSOLVED ORGANIC MATTER COMPOSITION IN ARCTIC DRIFT ICE AND SURFACE WATERS NORTH OF SVALBARD ON THE ONSET OF MELT SEASON

We investigated spectral properties of dissolved organic matter (DOM) absorption and fluorescence properties in the drift sea ice and open waters in spring 2015, north of Svalbard – during the "TRANSSIZ" expedition (on board of the FS Polarstern). The PARAFAC model was derived to assess the DOM composition based on measured Excitation-Emission Matrix spectra (EEM). The four-component PARAFAC model has been successfully validated. The PAPRAFAC model identified one protein-like component (C1) and three humic-like components (C2-C4). The DOM fluorescence intensity in open waters was lowest and the humic components dominated the DOM composition. The total fluorescence Itot increased in under ice water by 33.3% compared to open waters but not significant changes in DOM composition were observed. The DOM fluoresces intensity in the ice bottom layer was 26.6 and 68.9% higher compared to UIW and OW, respectively. The fluorescence DOM intensity in the ice cores was lowest in its middle layer. We have observed a significant change in DOM composition in the sea ice. The fluorescence intensity of protein-like component C1 was 1.5 times higher than a sum of fluoresce intensity of remaining humic-like components C2-C4. We have also observed a significant correlation of fluorescence intensity of protein-like component C1 and chlorophyll a concentration in the sea ice indicating in situ production of organic matter. The spectral indices: the ratio between fluorescence intensity of identified protein-like components to humic-like components, Ip/Ih and SUVA(254) were highest in the sea ice bottom layer, while humification index, HIX, values were found lowest there.

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A SIMPLE AUTOMATED DYNAMIC THRESHOLD EXTRACTION METHOD FOR THE CLASSIFICATION OF LARGE WATER BODIES FROM LANDSAT-8 OLI WATER INDEX IMAGES

Traditional manual methods of extracting water bodies from remote sensing images cannot satisfy the requirements for mass processing of remote sensing data, and new automated methods are complicated and require a large amount of auxiliary data. The histogram bimodal method is a frequently used objective tool for threshold selection in image segmentation. However, automatically calculating the threshold is difficult because of complex surfaces and image noise, which lead to imperfect twin peaks. To overcome these difficulties, we developed an operational automated water extraction method. This method does not require the identification of twin histogram peaks but instead seeks minimum values in the threshold range to achieve an automated dynamic threshold. We calibrated the method for 18 lakes in China using Landsat 8 Operational Land Imager images, for which the relative error (RE) and coefficient of determination (R2) for threshold accuracy were 2.1% and 0.96, respectively. The RE of area accuracy was 0.59%. The advantages of the method lie in its simplicity and minimal requirements for auxiliary data while still achieving an accuracy comparable to that of other automatic water extraction methods. It can be applied to mass remote sensing data to calculate water thresholds and automatically extract large water bodies.

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KEEPING AN EYEONWATER

Natural water color measurements are based on multi- and hyper-spectral measurements performed in the field and from space. A simpler approach to determine the color of natural waters is by means of the Forel-Ule color comparator scale, a scale that has been applied globally and extensively by oceanographers and limnologists since the 19th century. Since 2015 the EyeOnWater app and website aim to involve citizens in the observation of ocean color based on the Forel-Ule color comparator scale. Since then, over 4500 observations were gathered on a global scale, including open ocean, coastal and inland water measurements. Here we present a first statistical analysis of data availability, regional and temporal distribution. Furthermore we identify hot spots of EoW activities and connect them with historical measurements from the past century, a database of over 280.000 observations. We conclude with an outlook on the next steps of EoW, both in terms of technological development and its scientific valorization.

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