Friday, October 12
Oral Session 10
09:00–10:00

09:00–09:20

POLARIMETRIC RETRIEVALS OF THE REFRACTIVE INDEX OF THE OCEAN SURFACE

A novel and straightforward technique is presented, which allows retrieving the refractive index of the top microlayer of water bodies from polarimetric measurements. The method exploits observations of the NASA GISS airborne Research Scanning Polarimeter in the sunglint region, where the radiance at any given viewing geometry is dominated by the signal originating from the small range of wave slopes oriented precisely to cause specular reflection. Within the glint, the Degree of Linear Polarization is therefore independent on the windspeed and is determined analytically by the Fresnel law as a direct function of the refractive index. A further advantage is linked to the observational wavelength of 2.2 µm, which guarantees the minimization of aerosol interference and therefore the need of an atmospheric correction. The analyzed data were collected during recent field missions, from both low-altitude (B200/UC-12B) and high-altitude (ER2) aircraft. Stable retrievals from flight transects above pure seawater yielded values of refractive index that match closely the values published in the literature. In one case, the aircraft overflew the oil spill caused by the explosion of the Deepwater Horizon offshore platform and detected variations compatible with the presence of an oil slick. The solidity of the presented results, guaranteed by the high polarimetric accuracy of RSP-like sensors, opens the possibility for remote-sensing of other factors or species that similarly affect the refractive index of the top layer of the water surface, including foam/whitecaps, microplastic, seaweed and grass mats.

Matteo Ottaviani, NASA GISS, catullovr@hotmail.com
Jacek Chowdhary, Columbia University /NASA GISS, jacek.chowdhary@nasa.gov

Friday, October 12
Oral Session 10
09:00–10:00

09:20–09:40

MEASUREMENTS OF THE POLARIZED BRDF OF ARCTIC MACROALGAE WITH APPLICATIONS TO MODELLING UNDERWATER LIDAR

The Arctic has been warming steadily for the past few decades causing a reduction in ocean ice-coverage. Consequently, the increased exposure to light has already begun to affect coastal Arctic marine primary productivity, and a regime shift has been observed in some Arctic macroalgal communities where species normally found in cold-temperate waters are seen to occur and survive in Arctic marine ecosystems. There is an urgent need to establish baselines and monitor change in the abundance and diversity of the Arctic marine phytobenthos. Using the absorption, inelastic scattering (fluorescence), and elastic scattering properties of macroalgae excited by lasers, we are developing a LiDAR to carry out surveys of coastal Arctic benthic environments from an autonomous underwater vehicle (AUV). The LiDAR will map the morphology (3-D surface) of the substrate and macroalgal canopy, as well as detect and characterize the macroalgal biomass. Important parameters in designing such a LiDAR are the elastic and fluorescent reflectance properties of Arctic macroalgal targets. Here we present the results of laboratory measurements of the polarized bidirectional reflectance distribution function (BRDF) measurements for both elastic and inelastic scattering (fluorescence), with a particular emphasis on the near-exact backscattering configuration of our LiDAR. Models and in-situ measurements demonstrate two competing approaches for laser detection of macroalgae at a distance: the fluorescent return from laser excitation at 532 nm versus differential absorption from two elastic laser returns (e.g., 473 nm and 532 nm). Spectrofluorescence properties of Arctic macroalgae and the value of using polarization optics are also evaluated.

Eric Rehm, Takuvik / Universite Laval, eric.rehm@takuvik.ulaval.ca
Matthieu Huot, Takuvik / Université Laval, matthieu.huot@takuvik.ulaval.ca
Simon Lambert-Girard, Takuvik / Université Laval, Simon.Lambert-Girard@takuvik.ulaval.ca
Fraser Dalgleish, Harbor Branch Oceanographic Institute / Florida Atlantic Unviersity, fdalgleish@gmail.com
Philippe Archambault, Département de biologie / Université Laval, philippe.archambault@bio.ulaval.ca

Friday, October 12
Oral Session 10
09:00–10:00

09:40–10:00

POLARIZED AND TOTAL REFLECTANCE OF SKYLIGHT FROM WIND-ROUGHENED OCEAN SURFACE

Significant uncertainties in the estimation of remote sensing reflectance are associated with the characterization of the ocean surface and removal of the sky component reflected from it, especially in windy conditions. It is primarily determined by the value and spectral dependence of the reflectance coefficient of skylight from wind-roughened ocean surface and affects shipborne, AERONET-Ocean Color and satellite observations. Using a vector radiative transfer code, spectra of the reflectance coefficient and corresponding polarized and total radiances near the ocean surface are simulated for a broad range of parameters, including wind speeds up to 15 m/s, aerosol optical thicknesses of 0-1, wavelengths of 400-900 nm, viewing zenith angles 10-60 deg and several Sun zenith angles. Significant impact on the reflectance coefficient spectra of all these parameters together with the small amount of Sun glint, which is often unavoidable, is demonstrated and results are compared with field measurements using a novel snapshot hyperspectral imager. The effect of such variability of the sea surface reflectance on the shipborne above water and AERONET-OC processing for the derivation of the water leaving radiance and remote sensing reflectance is evaluated in various water and atmospheric conditions. The possibility of using a vertical polarizer in front of above water sensors, which blocks most of the reflected sky radiance, is revisited based on a large in-situ dataset collected by CCNY; the limitations of such an approach are analyzed including residual Sun glint effects and the polarized component of the water leaving radiance.

Alex Gilerson, City College of New York, gilerson@ccny.cuny.edu
Carlos Carrizo, City College of New York, athelus2004@yahoo.com
Robert Foster, Naval Research Laboratory, robert.foster.ctr@nrl.navy.mil

Friday, October 12

Plenary Session 5

10:00–10:40

10:00–10:40

FURTHER STEPS TOWARDS A 4-DIMENSIONAL OCEAN COLOR FIELD FOR OCEAN BIOGEOCHEMISTRY AND CLIMATE STUDIES

Ocean color products are routinely used for the initialization, development and validation of regional to global scale ocean and climate models. In particular, novel satellite estimates of phytoplankton community composition and carbon cycle processes are commonly used to validate simulated marine ecosystem services related to global biogeochemical cycling and climate support. Yet, significant uncertainties remain with respect to the representation of biological and biogeochemical processes in climate models. Here, we discuss recent efforts to better constrain present and future marine ecosystem structure and biogeochemical function based on the analysis of satellite algorithms, mechanistic models, carbon biomass data and HPLC pigment concentrations, and presence-absence observations. We show that estimates of diatom biomass, NPP, silicate production and export differ substantially between observational data products, and that they are dependent on the ecological niche structure and seasonal dynamics of biomass-rich diatom species pertaining to multiple genera. We use species distribution models to extrapolate in situ observations of plankton biomass and diversity to the global scale, and ecological niche analysis to identify the physical and biogeochemical drivers of phyto- and zooplankton biogeography. We show that the habitat suitability patterns of thousands of phytoplankton species can be used to define marine ecoregions with distinct biogeochemical and physical properties, as well as biodiversity patterns, thus linking properties readily observable from space with biological in situ observations. We subsequently highlight challenges associated with the use of ocean color products in global climate applications, and discuss potential future avenues to improve and better integrate different data streams.

Meike Vogt, Institute for Biogeochemistry and Pollutant Dynamics, meike.vogt@env.ethz.ch

Friday, October 12
Oral Session 11
11:30–12:30

11:30–11:50

IDENTIFYING THE OPTIMAL VIEW ANGLE FOR POLARIZATION BASED SKY-GLINT REMOVAL FOR DRONE-BORNE WATER QUALITY PARAMETER ESTIMATION

Spectral camera systems deployed on drone platforms can assess the substantial spatial and temporal variability in water quality parameters that occurs in complex ocean regions such as the very nearshore. Sun- and sky-glint are two of the largest sources of inaccuracy for drone-based optical water quality assessment. We present a new viewing geometry for drone-borne spectral cameras, which when combined with a polarization-based sky-glint correction technique enables higher accuracy and repeatability measurements, without assuming sky homogeneity. We ascertained the optimal view angle for this polarization-based glint correction through a study at the Martha's Vineyard Coastal Observatory in the coastal northwest Atlantic Ocean, where we deployed a hyperspectral line scan camera with an integrated polarizer for a two-month period in spring 2018. The instrument was positioned with a water viewing geometry of 135 degrees from the solar plane at noon in early March, with the spatial dimension observing from 36 degrees to 54 degrees from nadir. A concurrently deployed in situ chlorophyll fluorometer provided a parallel reference dataset of in water chlorophyll concentration. The resulting multi-month dataset provided information on the optimal angles for maximizing accuracy and minimizing variance in optically predicted chlorophyll concentrations, even when accounting for pitch inaccuracies from any future uses on drone platforms. Finally, we compared the accuracy and repeatability of polarization based glint correction technique to a sky-radiance based correction technique. From this study we determine the accuracy limitations of the polarization based sky-glint correction technique for drone-borne mapping applications in a variety of environmental conditions.

Ryan O'Shea, Woods Hole Oceanographic Institution (WHOI), oshea1@mit.edu
Samuel Laney, Woods Hole Oceanographic Institution, slaney@whoi.edu

Friday, October 12
Oral Session 11
11:30–12:30

11:50–12:10

IMPROVING ESTIMATIONS OF REFLECTED SKY LIGHT AT THE AIR-WATER INTERFACE FROM ABOVE-WATER RADIOMETRY

Networking of automated above-water sensors has proved to be the most effective way to provide validation data for earth observation optical missions. However, when deriving the water-leaving reflectance from above-water sensors, the contribution of the surface-reflected sky light and sun glint need to be estimated and removed from the total upwelling surface radiance measured by the sensor. The sky-light may be accurately estimated by simultaneously measuring the total upwelling radiance and the sky radiance in the direction of the region of the sky that reflects into the sea-viewing sensor. However the fraction of the sky-light that is actually reflected by the water surface to the sensor, rs, remains the most critical aspect when deriving the water leaving reflectance from above-water measurement. The fraction rs varies with illumination and viewing geometry, atmospheric conditions and wavelength as well as polarization and sea state. An accurate estimation of the latter is very challenging, particularly because these environmental variables are largely affected by the contribution of continuously changing wave conditions at the water surface. In the present study we investigate how estimations of these parameters, and subsequently rs, may be improved by (1) measuring the total upwelling radiance at viewing geometries that differ from the currently recommended above-water measurement protocol and (2) taking into account the entire spectral range. The main objective is to provide accurate rs estimations in the aim to improve water-leaving reflectance measurements with a focus on above-water hyperspectral sensors.

Clemence Goyens, Royal Belgian Institute of Natural Sciences (RBINS), cgoyens@naturalsciences.be, https://orcid.org/0000-0002-8036-6082
Kevin Ruddick, Royal Belgian Institute of Natural Sciences (RBINS), kruddick@naturalsciences.be

Friday, October 12
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SPACEBORNE OCEAN COLOR REMOTE SENSING IN THE UV-A PART OF THE SPECTRUM

Including hyperspectral UV-A radiance in observations by the OCI and polarimeter instruments onboard the NASA/PACE mission offers new opportunities for atmospheric correction and ocean color product retrievals that were not possible with heritage ocean color sensors. But studying these new opportunities by means of RT computations for UV-A radiance comes also with the need to more carefully consider (i) enhanced scattering in atmosphere and ocean of UV-A radiance; and (ii) changes in UV-A atmosphere and ocean scattering properties. In this talk, we first evaluate regime changes in light scattering contributions to TOA observations over oceans changes when comparing VIS to UV-A radiance. We then discuss implications for atmospheric correction and ocean color retrievals. A particularly challenging case is constraining variations in the amount and height of brown carbon aerosols in the atmosphere when there are simultaneous changes occurring in CDOM concentrations in the ocean. Both these substances exhibit similar absorption spectra in the UV-A which confounds the separation of their impact on spaceborne radiance. We examine the use of multiangle polarimetric remote sensing data to facilitate such separations.

Jacek Chowdhary, Columbia University & NASA/GISS, jacek.chowdhary@nasa.gov
Kostas Tsigaridis, Columbia University, kostas.tsigaridis@columbia.edu
Norm Nelson, University of California, Santa Barbara, norm@eri.ucsb.edu

Friday, October 12
Oral Session 12
14:00–15:20

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ZOOPLANKTON SUPER-SWARMS DETECTED FROM SPACE

The occurrence of super-swarms of the zooplankton Calanus finmarchicus in northern coastal waters off Norway has been known since early years of the 20th century, probably longer. For the first time we can report direct observation of these super-swarms from space using RGB imagery from the VIIRS ocean colour sensor. Extensive red patches in VIIRS imagery are shown to coincide with high concentrations of C. finmarchicus. Using serial addition measurements in a PSICAM absorption meter, we show that the red pigmentation of C. finmarchicus is sufficient to influence remote sensing reflectance. This is the first time a metazoan zooplankton species has been observed from space. There are important implications for monitoring this species which supports many commercially important fish stocks in the North Atlantic and which is itself commercially harvested for astaxanthin pigment. This study also raises fundamental questions about the potential influence of large, relatively sparse, coloured particles on ocean colour remote sensing signals and our ability to adequately measure associated optical properties in situ. In this case, by absorbing blue photons and reducing blue reflectance values, the presence of high concentrations of zooplankton negatively impact on the performance of blue-green reflectance ratio algorithms for chlorophyll concentration and diffuse attenuation. However, none of the currently available in situ IOP sensors have a sufficiently large sample volume to adequately sample these particles leading to a systematic underestimation of their presence and optical significance.

David McKee, University of Strathclyde, david.mckee@strath.ac.uk
Suunje Basedow, UiT The Arctic University of Norway, sunnje.basedow@uit.no
Ina Lefering, University of Strathclyde, katharina.lefering@strath.ac.uk
Astthor Gislason, Marine and Freshwater Research Institute, Reykjavik, astthor.gislason@hafogvatn.is
Malin Daase, UiT The Arctic University of Norway, malin.daase@uit.no
Emilia Trudnowska, Pollish Academy of Sciences, Sopot, emilia@iopan.pl
Einar Egeland, Nord University, Bodo, einar.s.egeland@nord.no
Marvin Choquet, Nord University, Bodo, marvin.choquet@nord.no
Stig Falk-Petersen, Akvaplan-niva AS, stig.falk.petersen@akvaplan.niva.no

Friday, October 12
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RESOLVING COASTAL OCEAN PARTICLE CHARACTERISTICS AND DYNAMICS USING A STATIONARY UNDERWATER IMAGING SYSTEM

Marine aggregates of biogenic origin, known as marine snow, are considered to play an important role in the oceans particle flux. These aggregates are the major vector for the transfer of carbon from the upper ocean to deeper layers and a potential food source for zooplankton. However, our mechanistic understanding of the processes controlling the biological carbon pump is limited by a lack of observational data at appropriate scales. This is especially true for coastal and marginal seas, which play a key role in the global carbon cycle by linking the terrestrial, oceanic, and atmospheric carbon reservoirs, but are still to a large extent ignored in global carbon budgets. We here present results from a novel underwater observatory which has been recently deployed in the North Sea. The cabled underwater observatory combines a remote-controlled underwater camera and an Acoustic Doppler Current Profiler allowing continuous and automatic small-scale observations of marine aggregates and zooplankton in near real-time covering temporal scales from seconds to several months. We present zooplankton and particle small-scale distribution patterns and provide indirect evidence of copepods feeding on marine snow aggregates. Furthermore, we observed differences in sinking speeds and utilization by zooplankton due to the origin and size of marine snow and linkages of primary production as observed by remote sensing to particle concentrations in the water column. Our observations highlight the significance of aggregates in marine ecosystems and provide new insights into particle dynamics to better understand and quantify the variability of the oceans biological carbon pump.

Klas Ove Moeller, Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, klas.moeller@hzg.de
Boris Cisewski, Thuenen Institute, boris.cisewski@thuenen.de
Philipp Fischer, Alfred Wegener Institute / Center for Scientific Diving & In situ Ecology, philipp.fischer@awi.de

Friday, October 12
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EFFECT OF LIGHT ON THE CHLOROPHYLL-TO-CARBON RATIO IN NATURAL POPULATIONS OF PHYTOPLANKTON

The photo-acclimation model of Geider et al. (1996) and the analytic solution to the model provided by Jackson et al. (2017) show how the chlorophyll-to-carbon ratio of phytoplankton depends uniquely on the ratio of available light to the photoadaptation parameter, which can be estimated from photosynthesis-irradiance experiments. However, the model also contains an unknown parameter: the maximum carbon-to-chlorophyll ratio. We have some evidence from culture measurements that it depends on phytoplankton type (Geider et al. 1997). However, we have very limited information on its variability under natural oceanic conditions. In this presentation, we use direct field observations of phytoplankton carbon and chlorophyll to infer values of maximum chlorophyll-to-carbon ratio in natural populations. We also explore whether this parameter can be estimated indirectly from field measurements of primary production. We analyse how the results can be extended to calculate phytoplankton carbon from satellite data.

Shubha Sathyendranath, Plymouth Marine Laboratory, ssat@pml.ac.uk
Trevor Platt, Plymouth Marine Laboratory, tplatt@pml.ac.uk
Žarko Kovač, Institute of Oceanography and Fisheries, Split, Croatia, kovac@izor.hr
Thomas Jackson, Plymouth Marine Laboratory, thja@pml.ac.uk
James Dingle, Plymouth Marine Laboratory, jad@pml.ac.uk
Peter Franks, Scripps Institution of Oceanography, pfranks@ucsd.edu
Emilio Marañon, Departamento de Ecología y Biología Animal, Universidade de Vigo, em@uvigo.es

Friday, October 12
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EVALUATION OF CHLOROPHYLL-A AND POC MODIS AQUA PRODUCTS IN THE SOUTHERN OCEAN

The Southern Ocean plays a critical role in the evolution of global climate. A better understanding of the system is necessary to predict the climate trajectory of the 21st century, and an accurate estimate of phytoplankton biomass is key to being able to do so. In this study, MODIS Aqua Level 2 (nominal 1 km × 1 km resolution) chlorophyll-a (CSat) and Particulate Organic Carbon (POC) products are evaluated by comparison with in-situ data from 11 research cruises (2008-2017) across multiple seasons, including measurements of POC and chlorophyll-a from both High Performance Liquid Chromatography (CHPLC) and fluorometry (CFluo). Contrary to a number of previous studies, results show that the global chlorophyll-a algorithm performed well when comparing satellite estimates to HPLC measurements. Using a strict comparison criteria (time window of ±12 h and mean satellite chlorophyll from a 5×5 pixel box centered on the in-situ location), the median CSat:Cin-situ ratios were 0.89 (N = 46) and 0.49 (N = 73) for CHPLC and CFluo respectively. The mean relative difference (MRD) and mean relative absolute difference were lower for the CHPLC comparison (-5.8% and 36.2% respectively), than for the CFluo comparison (-35% and 54%). Differences between CHPLC and CFluo were associated with the presence of Diatoms containing chlorophyll-c pigments, which induced an overestimation of chlorophyll-a when measured fluorometrically due to a potential overlap of the chlorophyll-a and chlorophyll-c emission spectra. The global POC algorithm also performed well with a median POCSat:POCin-situ ratio of 0.92 (N = 43) and a MRD of 11.8%.

Sandy Thomalla, SOCCO / CSIR, sandy.thomalla@gmail.com, https://orcid.org/0000-0002-6802-520X
William Moutier, CSIR / UCT, william.moutier@gmail.com
Stewart Bernard, CSIR, william.moutier@gmail.com
Galina Wind, NASA, gala.wind@nasa.gov
Thomas Ryan-Keogh, CSIR, gala.wind@nasa.gov
Marie Smith, CSIR, ocean.chiq@gmail.com