International Ocean Colour Science Meeting 2017

SUBMITTED ABSTRACTS - Alphabetical Order

The Benefit of Increased Temporal Resolution on Monitoring Inland Water Quality

Christiana Ade[1], Erin L. Hestir[2]

Remote sensing of inland water quality requires high spatial resolution to resolve what are often small, narrow, and spatially complex water bodies and high temporal resolution to capture the dynamic nature of changing water quality. Unfortunately, sensors with high revisit frequency have coarse spatial resolution, and most land observing missions with finer spatial resolution do not have the temporal resolution needed to resolve the dynamics of water quality, particularly in tidal systems. Sentinel-2 is a next generation satellite mission that will provide researchers with improved temporal (5 days revisit) and spatial (10m) resolution needed to observe these dynamic ecosystems. When combined with Landsat 8 data we may be able to observe these changes even more frequently. This study evaluates the benefit of increased temporal resolution for global inland water quality monitoring using Sentinel-2A, Landsat 8 and the European Space Agency's Spot-5 Take-5 (S5T5) dataset in the Sacramento San Joaquin Delta, California, USA. Currently the state of California monitors water quality using a suite of *in situ* locations that monitor water quality on a monthly basis. These data were used to calibrate a 2-band Total Suspended Matter (TSM) retrieval algorithm which was independently validated, resulting in detailed TSM maps that capture tidal influence and weekly changes in water quality. Although originally designed for land and vegetation observation, Sentinel-2 and Landsat 8 prove to be useful for monitoring inland water quality.

[1] cade@ncsu.edu
[2] elhestir@ncsu.edu

Endeavors to enhance an accuracy of remote-sensing reflectance from the Geostationary Ocean Color Imager

Jae-Hyun Ahn[1], Young-je Park[2], Wonkook Kim[3], Boram Lee[4]

The process of atmospheric correction and the vicarious calibration for ocean color remote sensing from satellite play a significant role in the ocean color data quality. The first atmospheric correction algorithm for the Geostationary Ocean Color Imager (GOCI) is developed based on the Gordon and Wang (1994) and is partially modified regarding the correction of turbid water reflectance at NIR and aerosol reflectance estimation scheme. The GOCI turbid water atmospheric correction scheme iteratively restores NIR water reflectance by using spectral relationship model of water reflectance between red and two NIR bands. The GOCI aerosol reflectance estimate scheme determines appropriate aerosol models without considering single-scattering domain based on the spectral relationships of aerosol multiple-scattering reflectance between different wavelengths. Vicarious calibration of GOCI gain factors is also applied based on Franz et al. (2007) although GOCI observation area does not completely satisfy requirements of NIR band vicarious calibration. Detail schemes and their related issues of the GOCI atmospheric correction and vicarious calibration will be discussed.

[1] brtnt@kiost.ac.kr, Korea Institute of Ocean Science and Technology, Korea Ocean Satellite Center, Ansan, South Korea

[2] youngjepark@kiost.ac.kr, Korea Institute of Ocean Science and Technology, Korea Ocean Satellite Center, Ansan, South Korea

[3] wkkim@kiost.ac.kr, Korea Institute of Ocean Science and Technology, Korea Ocean Satellite Center, Ansan, South Korea

[4] brlee254@kiost.ac.kr, Korea Institute of Ocean Science and Technology, Korea Ocean Satellite Center, Ansan, South Korea

The MERIS 4th Reprocessing assessment toward S3A/OLCI validation

B. Alhammoud[1], C. Lerebourg[2], L. Bourg[2], J. Delaney[1], P. Goryl[3] and the MVT*

[1] ARGANS Ltd, 1 Davy Road, Derriford, Plymouth. PL6 8BX. UK, email: balhammoud@argans.co.uk

[2]ACRI-ST, 260 route du Pin Montard, Sophia Antipolis, 06600, France

[3]ESA/ESRIN, Via Galileo Galilei, Casella Postale 64, 00044 Frascati, Italy

The MERIS Validation Team (MVT) has been tasked for the assessment of the MERIS 4th Reprocessing, in support of the smooth transition towards Sentinel-3 products and data format.
The purpose of the MVT, and of its activity in particular, is to support and influence this process until the final validated processor delivery for the full archive reprocessing. As such, the focus is on providing the necessary support for algorithm changes and upgrades, validation and protocol definitions, and to provide specific expert support for different components of the validation requirements of the MERIS processing branches. Main objectives are to ensure a reliable source of high-quality validation data, detailed documentation of protocols, as well as quality checks of the validation datasets. Several in-situ radiometric and bio-optical measurements campaign have been performed for inclusion in the MEris Matchup In-situ Database (MERMAID) and to be used for S3A/OLCI validation.
We present an overview of the MVT activities, which include: bio-optical characterisation, evaluation of sub-pixel variability of Inherent and Apparent Optical properties, algal pigment inter-comparisons, quantification of straylight in hyperspectral spectrometers, and AERONET-OC operations and field campaigns in optically complex coastal waters. Then inter-comparison between the 3rd MERIS Reprocessing and the 4th MERIS Reprocessing datasets has been performed. Preliminary results of S3A/OLCI validation will be presented as well.

*MERIS Validation Team: S. Kratzer (SU, Sweden), D. D'Alimonte (CIMA, Portugal), C. Sa (CO-FUL, Portugal), G. Moore (BioOptika, UK), C. Jamet (LOG, France), A. Reinart (TO, Estonia), J. Icely (Sagremarisco, Portugal), J-P. Huot (ESA/ESTEC, Netherlands)

Evaluation of Sentinel-2A Imagery for Regional Lake Water Quality Assessments by Observing Colored Dissolve Organic Matter (CDOM) in Freshwater Lakes in Västerbotten and Jämtland in Northern Sweden

Al-Kharusi, Enass Said (1); Berggren, Martin (1); Tenenbaum, David E. (1); Kutser, Tiit (2)
Institutions: 1: Lund University, Sweden; 2: University of Tartu, Estonia

This study is intended to demonstrate the significant shifts in DOM concentration with space and time within and across inland waters (lakes), which can be acquired by the analysis of DOM concentration using Sentinel-2A imagery. Using a remote sensing method (based on Sentinel-2A data) to evaluate DOM quantity or concentration in freshwater (lakes), optical properties shifts of CDOM of spatial and temporal observations at sites in Västerbotten and Jämtland in Northern Sweden can be understood in terms of the landscape features and hydrological events at those locations. Using Sentinel-2A as a data source for these remote sensing methods can provide an effective approach for estimating CDOM concentrations in water to obtain water quality information regularly and also could help to accurately estimate the CDOM absorption coefficient (a_{CDOM}) via Sentinel-2A data of the study area. The estimation of (a_{CDOM}) by using Sentinel-2A could help to study DOM in inland waters at global scale by using following equation $a_{CDOM}(420)=5.13(B2/B3)^{-2.67}$

Key words: Dissolved Organic Matter component (DOM), water quality, sentinel -2A

Assessing the performance of satellite ocean colour sensors Chlorophyll-a retrievals in the Arabian Gulf

Noora Al-Naimi[1,2], Dionysios E. Raitsos[3,4], Radhouan Ben-Hamadou[2] and Yousria Soliman[2]

The Arabian Gulf, a semi-enclosed subtropical shallow sea, is a highly diverse yet vulnerable marine ecosystem. To sustain and protect this valuable ecosystem from further deterioration, a long-term water quality monitoring system assessing its health is a necessity. Satellite ocean colour sensors offer real-time observational platforms, enabling monitoring of the water quality by measuring chlorophyll-a concentrations (Chl-*a*; an index of phytoplankton biomass) at synoptic scales. Yet, there is no such study assessing the performance of satellite ocean-colour datasets in relation to ground truth data in the Gulf. For the first time in the region, we evaluated the performance of VIIRS and other merged satellite datasets using a unique set of *in situ* Chl-*a* measurements, collected in the central Gulf over 6 recent research cruises (2015-2016). The remotely sensed Chl-*a* observations illustrated adequately the seasonal cycles. A highly significant relationship was found ($r = 0.795$, $p<0.001$), though, a clear overestimation in satellite-derived Chl-*a* concentrations is evident. The first optical depth was calculated to be on average 6-10m depth, and thus, the satellite signal is not capturing the deep chlorophyll maximum (DCM at ~25m). Overall, the ocean colour sensors performance was comparable to other Case II waters in other regions, supporting the use of satellite ocean colour in the Gulf. However, the development of a regional-tuned algorithm is needed, to account for the unique environmental conditions of the Gulf, and ultimately provide a better estimation of surface Chl-*a* in the region.

email: n.alnaimi@qu.edu.qa

[1] Environmental Science Center (ESC), Qatar University (QU), P.O. Box 2317, Doha, Qatar

[2] Department of Biological and Environmental Science, Qatar University (QU), P.O. Box 2317, Doha, Qatar

email: dra@pml.ac.uk

[3] Plymouth Marine Laboratory (PML), Prospect Place, The Hoe, Plymouth PL1 3DH, UK

[4] National Centre for Earth Observation, PML, Plymouth PL1 3DH, UK

email: benhamadou@qu.edu.qa

[2] Department of Biological and Environmental Science, Qatar University (QU), P.O. Box 2317, Doha, Qatar

email: yousra@qu.edu.qa

[2] Department of Biological and Environmental Science, Qatar University (QU), P.O. Box 2317, Doha, Qatar

A threshold based approach for seagrass detection

Ruhul Amin[1] and Heidi Dierssen[2]

[1]bioOptoSense LLC, New Orleans, Louisiana 70115, USA
[2]University of Connecticut Avery Point, 1080 Shennecossett Road, Groton, CT, USA

Seagrass beds are often cited as some of the most productive ecosystems on earth. However, due to human alteration of the coastal zone, seagrass have not fared well worldwide in last century. Increased water turbidity and eutrophication have decreased water clarity and has led to decrease in seagrass as well. Satellite sensors such as Moderate Resolution Imaging Spectroradiometer (MODIS) are preferred for continuous monitoring of seagrass due to their high revisit time. However, these sensors typically have coarser spatial and spectral resolution, which makes it difficult to detect and identify seagrass from other seagrass like feature such as the algal blooms (ex. *Karenia brevis* bloom), sediment plumes, and colored dissolved organic matter (CDOM) plumes. In this study, we present a threshold-based approach for MODIS that utilizes the Red Band Difference (RBD) algorithm and remote sensing reflectance at 547 nm (Rrs547) to detect seagrass around Florida Peninsula. We also assess spatio-temporal variation of seagrass using monthly mean MODIS data from July 2002 to September 2014.

The Australian Integrated Marine Observing System (IMOS) radiometry task team: a community effort towards improved field ocean colour measurements

David Antoine[1], Thomas Schroeder[2], Elizabeth Botha[2], Nagur Cherukuru[2], Arnold Dekker[3], Martina Doblin[4], Peter Fearns[1], Nick Hardman-Mountford[5], Rob Johnson[6], Edward King[7], Wojciech Klonowski[8], Jenny Lovell[7], Tim Malthus[3], Matt Slivkoff[1], Peter Thompson[7], Paul Van Ruth[9]

The Australian research community involved into field radiometry measurements have come together in a "Radiometry task team" (RTT), under the auspices of, and thanks to funding from, the Australian Integrated Marine Observing System (IMOS). The objective is to perform activities that can ultimately improve usability of IMOS radiometric data sets for research purposes as well as for validation of satellite ocean colour products, in particular the new ESA Sentinel 3 OLCI and Sentinel 2 MSI. Another objective is to develop a plan for the evolution of radiometry measurements in IMOS for the next decade. The work of this IMOS RTT can be summarized as follows:

1. Evaluate the degree of consistency or inconsistency among existing sea-going radiometers used in the IMOS and wider Australian bio-optical community, through dedicated laboratory and field experiments. Instruments include hyperspectral and multispectral field radiometers, essentially for above-water radiometry measurements.
2. If needed, improve consistency among these instruments
3. Develop a plan for the evolution of radiometry measurements in the Australian bio-optical research community for the next decade

We will report on what the Australian community learnt from these activities, and how these activities are integrated into a wider International context, in particular through the ESA "Fiducial Reference Measurements for Satellite Ocean Colour" (FRM4SOC) study and the Australian contribution to the Sentinel3 ocean colour validation team.

1 Remote Sensing & Satellite Research Group (RSSRG), Department of Physics and Astronomy, Curtin University, Perth, WA 6845, Australia
2 Aquatic Remote Sensing, CSIRO Oceans and Atmosphere, Brisbane, Dutton Park, QLD 4001, Australia
3 CSIRO Oceans and Atmosphere, Canberra, ACT 2601, Australia
4 C3 - Plant Functional Biology and Climate Change Cluster, University of Technology, Sydney, Broadway NSW 2007, Australia
5 Marine Biophysics group, CSIRO Oceans and Atmosphere, Crawley, WA 6009 Australia
6 Bureau National Operations Centre, Bureau of Meteorology, Hobart, TAS 7001, Australia
7 CSIRO Oceans and Atmosphere, Hobart, TAS 7001, Australia
8 In situ Marine Optics, Bibra Lake WA 6163, Australia
9 SARDI Aquatic Sciences, Primary Industries and Regions SA – PIRSA, Government of South Australia, West Beach SA 5024, Australia

Phytoplankton Phenology in the Marsdiep region of the Dutch Wadden Sea

Behnaz Arabi [1,*], Mhd. Suhyb Salama [1], Marcel R. Wernand [2] and Wouter Verhoef [1]

[1] Faculty of Geo-Information Science and Earth Observation (ITC), Department of Water Resources, University of Twente, P.O. Box 217, 7500AE Enschede, The Netherlands; s.salama@utwente.nl (M.S.S.); w.verhoef@utwente.nl (W.V.)

[2] Department of Coastal Systems, Marine Optics and Remote Sensing, Royal Netherlands Institute for Sea Research (NIOZ), P.O. Box 59, 1790AB Den Burg, Texel, The Netherlands; marcel.wernand@nioz.nl

* Correspondence: b.arabi@utwente.nl or arabi.behnaz@gmail.com; Tel.: +31-534-874-288

Abstract

Monitoring of phytoplankton phenology is essential to understand the changes in the pelagic ecosystem in response to changing environmental conditions. We analyzed 15 years of hyperspectral measurements to investigate the phenological cycle of Chlorophyll-a (Chla) concentration in the Marsdiep region of the Dutch Wadden Sea, the Netherlands. The two-stream radiative transfer model (2SeaColor) was applied to retrieve Chla concentration values from daily hyperspectral measurements recorded from 2002 to 2016 at the NIOZ jetty station. The validation of the 2SeaColor model against ground truth measurements has shown an acceptable accuracy for Chla retrieval (R^2=0.85 and RMSE=2.80 $mg.m^{-3}$). In addition, good agreement was observed between the retrieved Chla concentration changes and those of the ground truth measurements. Next, phenological analysis was performed, using TIMESAT, to detect the temporal dynamics for the Marsdiep region of the Dutch Wadden Sea as expressed by peak and end timing, duration, maximum, rates of increase and decrease, and the bloom Chla concentration integral. Finally, the high degree of temporal variability is highlighted and discussed. Our long-term Chla phenology has significant implications for identifying positive anomaly events and may act as an alert for management actions in this region.

Keywords:

Phenology, Marsdiep, NIOZ jetty, The Wadden Sea, Hyperspectral measurements, 2SeaColor, TIMESAT.

Combined float and satellite-based analysis of carbon export efficiency in the Southern Ocean

Lionel Arteaga (laaq@princeton.edu)*, Nils Haëntjens[+], Emmanuel Boss [+], Ken Johnson [⊕], Jorge L. Sarmiento*

*Princeton University (USA), [+]University of Maine (USA), [⊕]Monterey Bay Aquarium Research Institute (USA)

We combine estimates of Annual Net Community Production (ANCP) (i.e., carbon export) and matching Net Primary Production rates (NPP) from a score of biogeochemical-argo floats deployed in the Southern Ocean (SO) (south of 30^{o}S) and evaluate the relationship between productivity (NPP) and carbon export efficiency (export(e)-ratio) across the SO. We find an inverse relationship between e-ratio and NPP, in line with previous observations derived from particle export estimates. The combined data set of float-ANCP and particle export estimates is used here to derive an empirical equation for the estimation of the e-ratio from NPP in the SO. Inferred carbon export from this equation and satellite-based NPP shows a reduced meridional variability in export estimates across the Southern Ocean (SO) and an overall increase of 0.5 Pg C y^{-1} exported over the whole region, when compared against estimates derived from a positive relationship between e-ratio and NPP. A preliminary analysis of the mechanisms regulating carbon export efficiency suggests that areas of high carbon export are associated with regions of high zooplankton contribution to the total pool of particulate organic carbon.

Impact of tropical cyclones on biogeochemical indicators of the Economic Exclusive Zone of Cuba

Dailé Avila-Alonso[1a,2a], Jan M. Baetens[2b], Rolando Cardenas[1b], Bernard De Baets[2c]

In this work, we assess the biogeochemical response of the waters deeper than 100 m of the Economic Exclusive Zone (EEZ) of Cuba to the passage of twelve tropical cyclones (TCs) in the period 2002-2012. The average chlorophyll-a (chl-a) and particulate inorganic carbon (PIC) concentration, sea surface temperature, fluorescence line height (FLH) before and after the passage of TCs were obtained from 8-day composites of MODIS-Aqua and MERIS. In this way, we identified two patterns of the chl-a spatial distribution after the passage of TCs that match those of the FLH. Firstly, average chl-a increases throughout the EEZ [0.08 (before) to 0.12 mg m^{-3} (after)], and secondly, a higher regional chl-a of up to 2.15 mg m^{-3} was observed after the TCs passage. The latter agrees with a surface cooling of the ocean. We also observed the Island Mass Effect, which leads to an organic fertilization of the oceanic adjacent basins. Besides, PIC on average rose from $6.29x10^{-4}$ before to $2x10^{-3}$ mol m^{-3} after TCs passage, which probably counteracts the acidification process throughout the central Caribbean region. These results will be incorporated in a spatially explicit individual-based model of the shrimp species *Farfantepenaeus notialis* in the waters of Cuba, considering phytoplankton (as a function of the remotely-sensed chl-a concentration) as its main food source. This will deepen our understanding of the biology and ecology of *F. notialis*, while the model will also be used to increase the sustainability of fisheries in this region.

[1]Planetary Science Laboratory, Department of Physics, Universidad Central "Marta Abreu" de Las Villas, Camajuaní Road $5^{1/2}$ Km, Santa Clara, Villa Clara, Cuba. [1a]davila@uclv.cu; [1b]rcardenas@uclv.edu.cu

[2]KERMIT, Department of Mathematical Modelling, Statistics and Bioinformatics, Ghent University, Coupure links, 653, 9000 Ghent, Belgium. [2a]daile.avilaalonso@ugent.be; [2b]jan.baetens@ugent.be; [2c]bernard.debaets@ugent.be

Remote sensing of sea surface pCO_2 in the Bering Sea in summer based on a Mechanistic Semi-Analytical Algorithm (MeSAA)

Yan Bai, Xuelian Song, Xianqiang He

State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

The Bering Sea, one of the largest and most productive marginal seas, is a crucial carbon sink for the marine carbonate system. However, restricted by the tough observation conditions, few underway datasets of sea surface partial pressure of carbon dioxide (pCO_2) have been obtained. In this study, pCO_2 in the Bering Sea from July to September was derived based on a mechanistic semi-analytical algorithm (MeSAA). It was assumed that the observed pCO_2 can be analytically expressed as the sum of individual components controlled by major factors. First, a reference water mass that was minimally influenced by biology and mixing was identified in the central basin, and then thermodynamic and biological effects were parameterized for the entire area. Finally, we estimated pCO_2 with satellite temperature and chlorophyll data. Satellite results agreed well with the underway observations. Our study suggested that throughout the Bering Sea the biological effect on pCO_2 was more than twice as important as temperature, and contributions of other effects were relatively small. Furthermore, satellite observations demonstrate that the spring phytoplankton bloom had a delayed effect on summer pCO_2 but that the influence of this biological event varied regionally; it was more significant on the continental slope, with a later bloom, than that on the shelf with an early bloom. Overall, the MeSAA algorithm was not only able to estimate pCO_2 in the Bering Sea for the first time, but also provided a quantitative analysis of the contribution of various processes that influence pCO_2.

Combining glider optical, hydrographic and chemical measurements to derive water column net primary production and net community production

William M. Balch[1], Bruce C. Bowler[2], David T. Drapeau[3]

Bigelow Laboratory for Ocean Sciences, 60 Bigelow Drive, POB 380, East Boothbay, ME 04544 USA

Gliders provide unprecedented abilities to observe the ocean environment, at fine space and time scales not traditionally available to ships. Measuring variability in biological rates over time scales of days has been difficult to document from gliders since this requires: a) the ability to sample the same water parcel twice and b) robust optical proxies to convert measured IOPs to actual biogeochemical quantities. We've been deploying Slocum Electric gliders seasonally across the Gulf of Maine as part of a program called GNATS (the Gulf of Maine North Atlantic Time Series) since 2008. We here describe a method to do repeated sampling of a water mass based on its hydrographic properties, then demonstrate how glider optical, hydrographic and chemical estimates, combined with canonical Redfield assumptions, can be used to infer rates of net primary production and net community production over the water column. The strengths and limitations of the approach will be presented as well as discussion of improvements on the technique using dual glider missions. Finally, we will discuss whether the coastal waters of the Gulf of Maine are net heterotrophic or net autotrophic based on glider optical observations.

[1]bbalch@bigelow.org; [2]bbowler@bigelow.org; [3]ddrapeau@bigelow.org

Fiducial Reference Measurements for Satellite Ocean Colour: FRM4SOC

Andrew Banks (NPL), Craig Donlon (ESA), Christophe Lerebourg (ACRI-ST), Kevin Ruddick (RBINS), Gavin Tilstone (PML), Riho Vendt (TO)

The FRM4SOC project, with funding from ESA, has been structured to provide support for evaluating and improving the state of the art in ocean colour validation through a series of comparisons under the auspices of the Committee on Earth Observation Satellites (CEOS) Working Group on Calibration & Validation and in support of the CEOS ocean colour virtual constellation. FRM4SOC also strives to help fulfil the International Ocean Colour Coordinating Group (IOCCG) in situ ocean colour radiometry white paper objectives and contribute to the relevant IOCCG working groups and task forces (e.g. the working group on uncertainties in ocean colour remote sensing and the ocean colour satellite sensor calibration task force). The project makes a fundamental contribution to the European system for monitoring the Earth (Copernicus) through its core role of working to ensure that ground-based measurements of ocean colour parameters are traceable to SI standards. This is in support of ensuring high quality and accurate Copernicus satellite mission data, in particular Sentinel-2 MSI and Sentinel-3 OLCI ocean colour products. The FRM4SOC project also contributes directly to the work of ESA and EUMETSAT to ensure that these instruments are validated in orbit.

Phytoplankton size structure related to a cyclonic eddy in the southwest Indian Ocean

R Barlow[1,2], T Lamont[3,2], R Brewin[4]

A size class model was applied to MODIS Aqua ocean colour data to determine variations in micro-, nano-, and picophytoplankton contributing to total chlorophyll *a* related to a cyclonic eddy located southwest of Madagascar during austral winter 2013. Sea Surface Height indicated the location of the eddy close to the southern extension of the South East Madagascar Current (SEMC). Interaction between the cyclonic eddy and the SEMC resulted in water with elevated chlorophyll being advected from the southern Madagascar shelf along the northern inshore edge of the SEMC and entrained into the eddy. The fractional contribution of size classes revealed a nano-picophytoplankton community within the eddy during 26 June-3 July and the presence of microphytoplankton in the cyclonic flow on the outer boundary. By 12-19 July, microphytoplankton was entrained further into the centre of the eddy, contributing to a mixed micro-nanophytoplankton community. Nanophytoplankton tended to be more dominant in the eddy during 20-27 July as the eddy evolved, with microphytoplankton still being significant. The picophytoplankton proportion was low within the eddy between 12 and 27 July, but comprised a significant component of the phytoplankton biomass in low chlorophyll waters within the SEMC between Madagascar and the cyclonic eddy.

[1]Bayworld Centre for Research & Education, Cape Town, South Africa
[2]Marine Research Institute & Department of Oceanography, University of Cape Town, South Africa
[3]Oceans & Coastal Research, Department of Environmental Affairs, Cape Town, South Africa
[4]Plymouth Marine Laboratory, Plymouth, United Kingdom

[1]rgb.barlow@gmail.com
[3]tarron.lamont@gmail.com
[4]robr@pml.ac.uk

Human Impacts in Coastal Ecosystems in Puerto Rico (HICE-PR): A remote sensing, hydrologic, ecologic and socio-economic assessment with management implications

Barreto-Orta, Maritza[1], Juan L. Torres-Peréz[2], Luis Santiago[1], Jorge Ortiz[1], Shimelis Setegn [3], Liane Guild[4], Carlos Ramos-Scharrón[5], Roy Armstrong[6]

ABSTRACT

An interdisciplinary team of scientists collaborated on the project *Human Impacts in Coastal Ecosystems in Puerto Rico (HICE-PR)*. The main goal is to evaluate the impacts of Land Cover and Land Use Changes (LCLUC) on the quality and extent of Coastal Marine Ecosystems (CMEs) in two priority watersheds located in Puerto Rico. We present a summary of an evaluation of LCLUC, CMEs, hydrological, and socio-economic components in both watersheds. From 1977 to 2010, findings indicated important LCLUC showing a substantial shift from agricultural areas to forests and rangeland. We are presently preparing the 2016 land cover maps using Landsat 8 Operational Land Imager (OLI) imagery to identify LCLUC, focusing on identifying present trends in agriculture practices and man-made infrastructure. Findings highlight the importance of vegetation cover in maintaining low soil erosion rates and suggest that unpaved access roads are the most dominant sources of sediment at the farm scale, so watershed agricultural and built infrastructure trends are particularly relevant. Decrease in coral cover was identified in CMEs with proximity to the river mouth in both watersheds. Findings suggest that sediment river discharge is one of the factors likely having a strong association with the quality and distribution of some CMEs in study sites. The group is also currently identifying public policy changes that may have influenced LCLUC and the distribution and quality of CMEs. The analysis is particularly relevant, where there is an ongoing controversy between agricultural and natural resource groups because of land designations in the area.

[1]University of Puerto Rico, Rio Piedras Campus; maritza.barreto@upr.edu; santiago.luis47@gmail.com: jorgeortiz.ites@gmail.com

[2]Bay Area Environmental Research Institute/NASA Ames Research Center, MS 245-4, PO Box 1, Moffett Field, CA 94035: juan.l.torresperez@nasa.gov

[3]Florida International University: ssetegn@fiu.edu

[4]NASA Ames Research Center, MS 245-4, PO Box 1, Moffett Field, CA 94035: liane.s.guild@nasa.gov>

[5]University of Texas at Austin: ramos@austin.utexas.edu

[6]Remote Sensing Consultants: royaarmstrong@yahoo.com

A wavelet analysis on high frequency bio-optical properties in the northwestern Mediterranean Sea (BOUSSOLE site)

Bellacicco, M.,[1], Antoine, D.,[1,2], Vellucci, V.,[1], and D'Ortenzio, F.,[1]

The study of the temporal cycles of bio-optical properties in the ocean is a fundamental topic from a satellite perspective. It allows to understand its dynamics, to study the ecosystem functioning, and to relate specific processes to other detectable cycles. A wavelet analysis has been applied to high frequency field observations of bio-optical properties at the BOUSSOLE site, in order to decompose, describe and estimate the spectral characteristics of optical signals as a function of time. The primary goal of the study is the identification of different period frequencies (from diel variability to annual cycle) and their temporal evolution. The wavelet analysis is based on the Fourier method. It fits with bio-optical data because the time series is not stationary, which is a pre-requisite for its application. A cross-wavelet analysis has also been applied to pairs of bio-optical time-series which provides relevant information to identify dependencies in the bio-optical response to environmental impacts on surface water. Results on chlorophyll fluorescence, particle backscattering and beam attenuation coefficient show high signals in late autumn, winter and spring. They are related to the spring phytoplankton blooms, the intensity of mixing, and the nutrient and light availability. During winter and spring the bio-optical parameters (b_{bp} vs. Fls, c_p vs. Fls) are in phase, whereas during summer they are out of phase. The spectral analyses show that the high signal frequencies are distributed from daily to yearly scales.

[1]Laboratoire d'Océanographie de Villefranche (LOV), 06230, Villefranche-sur-Mer, France
Marco.Bellacicco@obs-vlfr.fr
enzo@obs-vlfr.fr
dortenzio@obs-vlfr.fr

[2]Remote Sensing and Satellite Research Group, Department of Physics, Astronomy and Medical Radiation Sciences, Curtin University, GPO Box U1987, Perth, Western Australia 6845, Australia
antoine@obs-vlfr.fr

On the spatial-temporal distribution of non-algal particles from space and its impact on global ocean carbon budgets

Bellacicco, M.[1,2], Volpe, G.[1], Pitarch, J.[1], Brando, V.[1], Landolfi, A.[3], Briggs, N.[2], Colella, S.[1], Marullo, S.[4], and Santoleri, R[1]

In the last decade phytoplankton has been commonly studied from space. However non-algal particles (NAP) analysis, including heterotrophic bacteria and virus, are relatively recent. A thorough assessment of the distribution and dynamics of NAP could help to improve the understanding of marine ecosystems. In this work, global monthly climatologies of the NAP fraction that varies independent from chlorophyll are derived from the satellite particulate backscattering coefficient (b_{bp}) and chlorophyll (Chl). NAP is computed at pixel scale using the 18 years of ESA OC-CCI v3 monthly satellite data. We find a clear seasonal pattern of NAP from northern to southern oceans, following the patterns of Chl which is associated with seasonal biological production. High NAP values are always found in productive regions like polar seas, the North Atlantic blooms area and the equatorial Pacific, as well as shelf regions (i.e. Patagonian shelf) affected by upwelling regimes. In contrast, the poor Chl and b_{bp} relationship prevents accurate NAP estimations in oligotrophic areas like the sub-tropical gyres. Accurate NAP calculations for different regions and seasons will improve our understanding of phytoplankton dynamics and its impact on global ocean carbon budget.

[1]Institute of Atmospheric Sciences and Climate (ISAC)-CNR, Rome, Italy
marco.bellacicco@artov.isac.cnr.it
gianluca.volpe@cnr.it
simone.colella@cnr.it
v.brando@isac.cnr.it
j.pitarch@isac.cnr.it
rosalia.santoleri@artov.isac.cnr.it

[2]Laboratoire d'Océanographie de Villefranche sur Mer (LOV), Villefranche sur Mer, France
Marco.Bellacicco@obs-vlfr.fr
natebriggs@gmail.com

[3]GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel, Marine Biogeochemical Modelling, Düsternbrooker Weg 20, 24105 Kiel, Germany
alandolfi@geomar.de

[4]Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Frascati, Italy
salvatore.marullo@enea.it

USING MODIS OCEAN COLOR DATA TO ASSESS SPATIAL DISTRIBUTION OF CHLOROPYLL-A IN THE BAY OF BOUISMAIL

S. Benzouai[1,a,b], *N. Chabi*[2,a], *N.I Dib*[3,a] *Y.Smara* [4,b]

1. INTRODUCTION

Pollution of seas and oceans seems to be increasing more and more. Coastal zones are main receptacle of inland waters, they are discharges of watersheds from urban areas, agriculture or industries. The bay of Bousmail is an example of a disturbed coastal zone by a variety of polluting activities. Its water quality is considerably getting degraded. Thereby, eutrophication is acknowledged as one of the major human induced stressors which has to be monitored and reduced [1]. In order to understand and assess the extent of this pollution, sea campaigns were carried out during 2015 spring. Then, several parameters, indicators of water quality, have been measured.

Ocean color remote sensing from sun-synchronous polar orbiting satellites has become well-established as a tool for extracting information on phytoplankton and suspended particulate matter and related processes in regional seas [2]. In this study, we focused on comparing in-situ and retrieved Chlorophyll-a from Modis images.

However, a strong cloud coverage omnipresent above study area limited the number of stations whose in-situ and extracted Ch-a values could be compared. We present in this study the results we have obtained.

2. METHODS AND MATERIALS

2.1 Study area

The bay of Bou Ismail overlooks the Mediterranean sea and is situated to the west of Algiers, it is bounded to the East by Sidi Fredj in the wilaya of Algiers and to the west of the Chenoua mountain in the wilaya of Tipaza. It has an area of 509 km2, with a linear distance of 58 km. The opening of the bay is oriented along a north-west axis of about 48 km [3].The morphology of the Bou Ismail bay is composed of rocky coasts, cliffs and beaches [3].

2.2 Data

The data set consists of in-situ Ch-a, measured with the UV-1800 spectrophotometry method [4], and Moderate Resolution Imaging Spectoradiometer Modis L2 OC data, published by NASA/GSFC/OBPG with a lag of 44 days due to the significant cloud cover present above the study area.

The Materials used are essentially: filters made of fiberglass porosity of 0.45 µm (GF/F_47 mm), spectrophotometer type UV-1800 (CHIMQDZU), quartz tanks, Acetone 90%, Deionized water; concentrated hydrochloric acid (0.3 mol / l), suspension of magnesium carbonate (mgCO3). The homogenized sample is filtered and then the filter is recovered, folded and placed on aluminum foil. In order to ensure good preservation, a few drops of magnesium carbonate are added, which prevents the degradation of the chlorophyll and is stored in the freezer. The cartography of in-situ Ch-a distribution in the bay is done by using QGis [5]. The exploitation of satellite data is done by using Seadas software [6].

3. RESULTS

The Ch-a in the waters of Bou-Ismail Bay vary from 0.2136 µg/l determined for the majority of stations to a maximum of 1.068 µg /l at station 20 (Fig. 1), with an average of 0.397 µg/l and a standard deviation of 0.233.

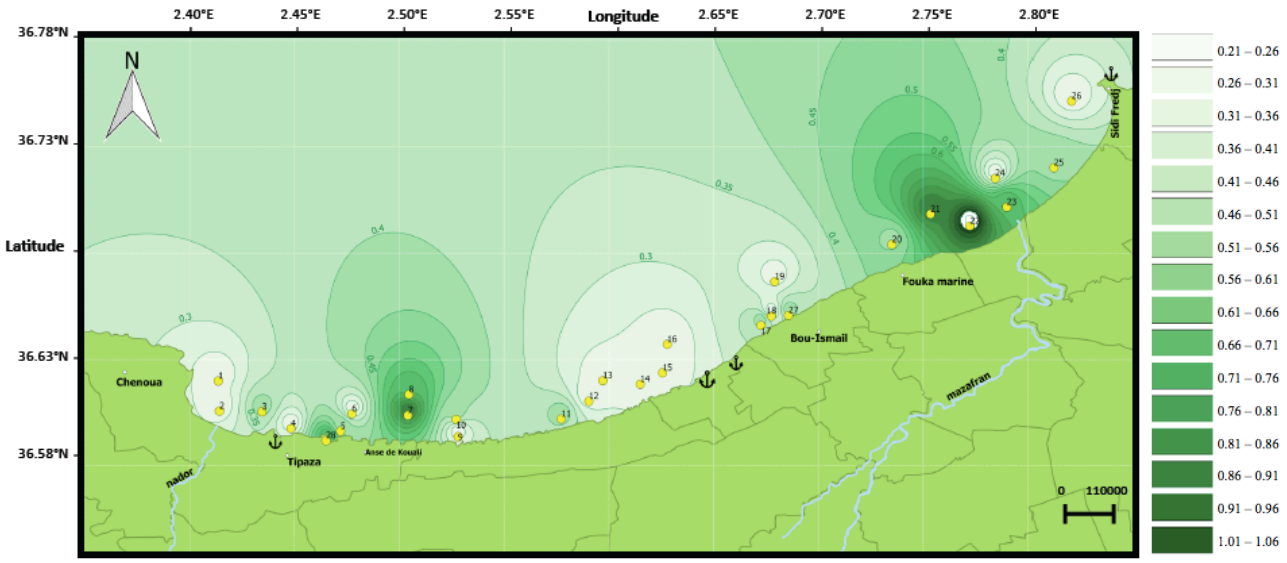

Figure 1: Spatial Distribution of measured Ch-a in the Bay of BouIsmail

The important cloud cover, above the study area, did not allow the reduction of the time lag between measured and retrieved Ch-a values. And even on the exploitable satellite image found with a lag of 44 days, the extraction algorithms fail in coastal areas (Fig. 2). Among 28 sampled stations, only 10 matching point Ch-a could be compared.

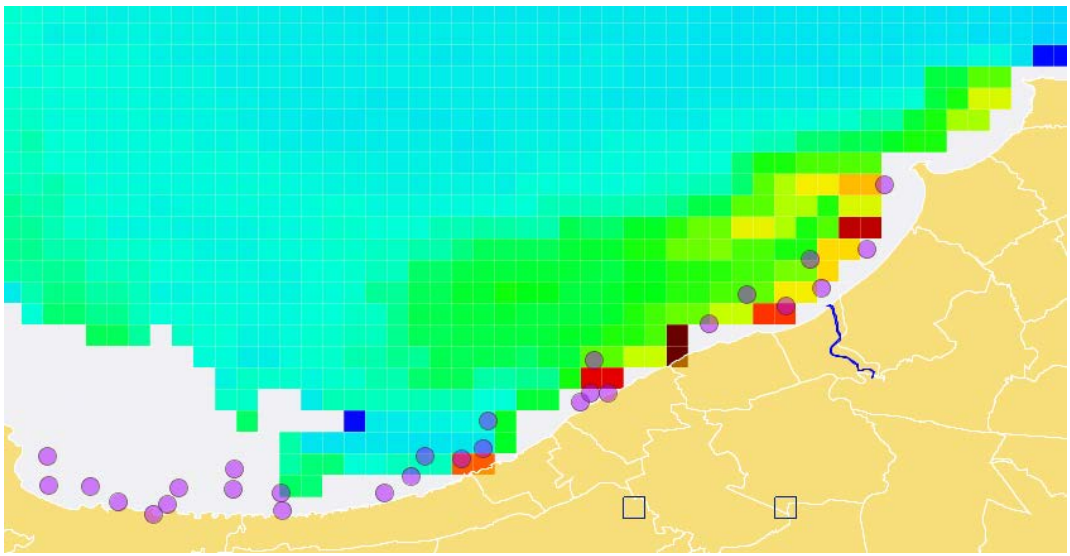

Figure 2: Spatial Distribution of Modis retrieved Ch-a in the Bay of Bouismail

Both retrieved Ch-a by OCI [7] and OC3 [8] algorithms vary respectively from 0.1708 mg/m^{-3} to 5.4599 mg/m^{-3}, with an average of 1.292 mg/m^{-3} and a standard deviation of 1.875 which already shows that the ranges of values are in the same order of magnitude taking into account the temporal offset of few days. It is also noted that at station 15, values of measured and retrieved Ch-a are exactly the same, and that the minimum value measured, equal to 0.21, is close to the extracted one, 0.1708, which is also present in 3 stations out of 10. On the other hand, the station 21, located near the Oued Mazafran, has the maximum value of retrieved Ch-a which is near the station 20 that has the maximal measured Ch-a (Fig. 1). It can indicate eutrophication problem in this area since the nitrite values are very low. Significant concentrations of chlorophyll-a show possible consummation of nitrites by chlorophyll-a during growth. In the end, we found that satellite derived Ch-a is compliant with laboratory derived Ch-a and show the same fact: Significant Ch-a values at the mouth of Oued Mazafran.

4. CONCLUSION

This study does not intend to replace a calibration/validation procedure necessary for the combined use of geophysical variables derived from satellite images and those sampled from sea campaigns. However, in the absence of a permanent observation system in Bouismail Bay where it is not easy to have a calm sea and clear sky during the same day, the ocean color data published by NASA/GSFC/OBPG are very interesting. Therefore, even with a spatial resolution of 1 km and extraction fails at in coastal areas, Modis data can contribute considerably in marine environmental studies.

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[a] Ecole Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral, Campus universitaire Bois des Cars, Dely Brahim 16320 Algiers, Algeria
[b] Université des Sciences et de la Technologie "Houari Boumediene", Faculté d'Electronique et d'Informatique, Laboratoire de Traitement d'Images et Rayonnement (LTIR), BP n°32, El-Alia, 16111, Bab-Ezzouar, Algiers, Algeria.
[1]s.benzouai@gmail.com,[2]nacichabienssmal@gmail.com, [3]dnadiraimane@gmail.com, [4]yousmara@yahoo.com

Hyperspectral instruments the valuable but challenging way forward

A Bialek[1], V. Vellucci[2], C. Greenwell[1], N. Fox[1], D. Antoine[3]

Ocean-Colour remote sensing measurements are a crucial source of information about the biological and biogeochemical properties of oceans, and the climate quality of the Earth system; however they are also one of the most challenging. The oceans absorb much more light than the continents, so instruments on-board satellites need to be sensitive enough to detect small changes of light emerging from the water. Therefore, to obtain quality assured ocean colour data products, there is a need for system vicarious calibration (SVC).

Instruments semi-permanently mounted on buoys provide in situ measurements for SVC purposes, it is then essential to fully establish their performance and estimate a robust uncertainty budget for the in situ derived data.

Hyperspectral instruments allow to collect more data than their multispectral equivalent; they reduce the need of spectral normalisation and their data can be matched with any satellite ocean colour sensor. Nevertheless, it is common to find disagreements in data collected with off the shelf hyperspectral and multispectral instruments. We present the results of hyperspectral instrument characterisation from a subset of the BOUSSOLE buoy radiometers. Then we propose a set of correction coefficients for measurements that allow operators to compensate for the complex hyperspectral instrument performance.

[1] National Physical Laboratory, Teddington, TW11 0LW, UK.

[2] Sorbonne Universités, UPMC Univ Paris 06, INSU-CNRS, Laboratoire d'Océanographie de Villefranche, 06230, Villefranche-sur-Mer, France.

[3] Remote Sensing and Satellite Research Group, Department of Physics & Astronomy, Curtin University, Perth, WA 6845, Australia.

Remote sensing indicators for enhanced monitoring of algal bloom conditions on Lake Winnipeg, 2002-2011.

Binding, C. E.[1], Greenberg, T. A.[1], McCullough, G.[2], Watson, S.B.[1], Paige, E.[3]

[1]Water Science and Technology Directorate, Environment and Climate Change Canada, 867 Lakeshore Rd, Burlington, Ontario, Canada, L7S 1A1

[2]Centre for Earth Observations Science, Department of Environment and Geography, University of Manitoba, Winnipeg, Canada, R3T 2N2

[3]Water Quality Management Section, Department of Sustainable Development, 200 Saulteaux Crescent, Winnipeg, Manitoba, R3J 3W3

Dramatic increases in nutrient loading and phytoplankton biomass over the last few decades, accompanied by marked shifts in algal community composition towards the dominance of cyanobacteria blooms, have driven widespread concern over the health of Lake Winnipeg in Manitoba, Canada. The watershed, spanning an area of approximately one million km^2, has experienced considerable change since the middle of the last century brought about by intensified agricultural practices and livestock production, urban development, and changing hydrology, causing the acceleration in nutrient loading which has led to an increase in the frequency, severity and extent of blooms. Comprehensive lake-wide observations of the extent and severity of algal blooms on the lake are critical to assessing the lake's health status, its response to implemented nutrient management practices, as well as further understanding processes driving bloom conditions. We demonstrate the application of the MERIS Maximum Chlorophyll Index (MCI) to monitoring algal bloom occurrences on Lake Winnipeg in anticipation of transitioning to operational bloom monitoring and reporting using sentinel-3's OLCI. We present quantitative indicators for algal bloom extent, severity, and duration, which have allowed reliable estimates of seasonal and year to year variability in bloom conditions. Bloom conditions are analysed in the context of in-lake and watershed processes in order to gain further insight on the drivers of bloom events on the lake. We show the strong dependence of inter-annual variability in bloom severity on both total phosphorous loadings to the lake and summer lake temperatures.

Revisiting Ocean Color algorithms for chlorophyll a and particulate organic carbon in the Southern Ocean using biogeochemical floats

Nils Haëntjens, Emmanuel Boss, and Lynne D. Talley

The Southern Ocean (SO) ecosystem plays a key role in the carbon cycles by sinking a major part (43 %) of the anthropogenic CO2 , and being an important source of nutrients for primary producers. However, the undersampling of the SO biogeochemical properties limits our understanding of the mechanisms taking place in this remote area. The Southern Ocean Carbon and Climate Observing and Modeling project (SOCCOM) has been deploying a large number of autonomous biogeochemical floats to study the SO (as of December 2016, 74 floats out of 200 have been deployed). SOCCOM floats measurements can be used to extend remote sensing chla and POC products under the clouds or during the polar night as well as adding the depth dimension to the satellites image in the SO.

Chlorophyll a (chla) concentrations measured by fluorometers (exciting/detecting light at 470/685 nm) embedded on the floats and particulate organic carbon (POC) concentrations derived from backscattering coefficients (at 700 nm) were calibrated with samples collected during the floats' deployment cruise. Float chla and POC were compared with products derived from observations of MODIS and VIIRS sensors.

We find the Ocean Color Index (OCI) global algorithm to agree well with the matchups (within 9 %, on average, for the Visible Infrared Imaging Radioneter Suite (VIIRS) and 12 %, on average, for the Moderate Resolution Imaging Spectroradiometer Aqua (MODIS)). SO specific algorithms estimating chla are biased by a factor of ~**2** . The POC algorithm currently used by NASA agrees well with the floats.

Estimation of phytoplankton accessory pigments from hyperspectral reflectance spectra: Toward a global algorithm

Alison P. Chase, Emmanuel Boss, Ivona Cetinic, and Wayne Slade

Phytoplankton community composition in the ocean is complex and highly variable over a wide range of space and time scales. Able to cover these scales, remote-sensing reflectance spectra can be measured both by satellite and by in situ radiometers. The spectral shape of reflectance in the open ocean is dominated by the particles in the water, mainly phytoplankton and co-varying non-algal particles. We investigated the use of in situ hyperspectral remote-sensing reflectance measurements to detect phytoplankton pigments, by using an inversion algorithm that defines phytoplankton pigment absorption by a sum of Gaussian functions. The inverted amplitudes of the Gaussian functions representing pigment absorption are compared to coincident High Performance Liquid Chromatography measurements of pigment concentration, and we determined strong predictive capability for chlorophylls *a*, *b*, c_1+c_2, and the photoprotective carotenoids. We also tested the estimation of pigment concentrations based on the relationships of co-variation between chlorophyll *a* and the accessory pigments, and investigated the spectral residuals in both reflectance and absorption data after removing a chlorophyll-based average absorption spectrum. We found reduced errors in pigment estimation based on the relationships of co-variation versus the inversion method, and no strong relationship between spectral residuals and pigments. Ultimately, we are able to estimate concentrations of three chlorophylls and the photoprotective carotenoids, noting that further work is necessary to address the challenge of extracting information from hyperspectral optical measurements beyond the information that can be determined from chlorophyll *a* and its co-variation with other pigments.

Toward a documentation of the remineralization from satellite in the Peruvian Oxygen Minimum Zone

M. Bretagnon[1,2], A. Paulmier[1], V. Garçon[1], B. Dewitte[1,3,4,5], J. Sudre[1], S. Illig[1,6]

Eastern Boundary Upwelling Systems are among the most productive zones of the world ocean. When high oxygen requirement for the organic matter (OM) degradation is associated with low subsurface ventilation, formation of oxygen minimum zone (OMZ) occurs. In such zone, the OM fate is a key question as it impacts marine ecosystems and climate. Indeed, low oxygen concentrations are expected to preserve OM and enhance the carbon sequestration. However, high and diverse microbial activity reported in these zones may foster OM remineralization, with production of greenhouse gases, nitrogen loss and intensify the respiratory barrier. Despite its impacts, the OM fate remains poorly documented.
We focus on the Peruvian OMZ to explore the feasibility of documenting the remineralization mechanism by satellite. In this highly productive region with a shallow oxycline, CO_2, N_2O and O_2 air-sea fluxes are expected to be strong. *In situ* data from the AMOP project indicate that oxygenation events trigger OM remineralization, and that the intensity of the upper particles flux modulates the remineralization efficiency. Satellite observations, supplying synoptic view with high-frequency information, are ideal tool to extend the preliminary results on a wider area. While physical observations (wind, SST) potentially allow documenting oxygenation events, ocean colour is expected to give information on the concentration and the lability of particles, which are able to host an important microbial activity. Especially, PFTs could modulate the particles sinking rate, and thus impact their degradation. Ocean colour and derived products may thus enable a better understanding of the oceanic carbon cycle.

[1,2] marine.bretagnon@legos.obs-mip.fr

[1] aurelien.paulmier@legos.obs-mip.fr, veronique.garcon@legos.obs-mip.fr, joel.sudre@legos.obs-mip.fr

[1,3,4,5] boris.dewitte@legos.obs-mip.fr

[1,6] serena.illig@legos.obs-mip.fr

[1.] LEGOS, Laboratoire d'Études en Géophysique et Océanographie Spatiales (CNES-CNRS-IRD-UPS), Toulouse, France
[2.] ACRI-ST, Sophia-Antipolis, France
[3.] Departamento de Biología, Facultad de Ciencias del Mar, Universidad Católica del Norte, Coquimbo, Chile
[4.] Millennium Nucleus for Ecology and Sustainable Management of Oceanic Islands (ESMOI), Coquimbo, Chile
[5.] Centro de Estudios Avanzado en Zonas Áridas (CEAZA), Coquimbo, Chile
[6.] Department of Oceanography, MARE Institute, LMI ICEMASA, University of Cape Town, Cape Town, South Africa

Use of Ocean Color data to assess phytoplankton response to nutrient pressure under EU Directives

Brito[1], A.C, Garrido, P.[1], Gameiro, C.[1], Cabrita, T.[2], Nogueira, M.[3]

The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) aim at evaluating the ecological and environmental status of European coastal waters. This is a rather complex task and requires the use of long-term time-series to assess the effect of anthropogenic pressure on biological communities and the whole ecosystem.
Due to their importance as primary producer, phytoplankton is a key component of marine ecosystems. Moreover, by having a fast response to nutrient changes, these microalgae are considered particularly important for the evaluation of ecosystem health.
In this study, a phytoplankton database containing *in-situ* chlorophyll *a* measurements were used to validate the CMEMS' chlorophyll *a* product obtained through the application of OC5CI algorithm for the western Iberia region. These satellite data were then used to calculate the chlorophyll *a* 90^{th} percentile, which is considered an appropriate indicator of coastal phytoplankton blooms. The highest annual values of chlorophyll *a* 90^{th} percentiles (up to ~4-5 $mg.m^{-3}$) were observed in the northern Portuguese coastal zone and Galicia, from Peniche to Finisterra. Nutrient and oxygen observations were also used to identify the areas with the highest anthropogenic influence. The effective use of satellite remote sensing for monitoring the water quality of marine waters is of outstanding importance.

Affiliations:
[1]MARE-ULisboa
[2]CEG/IGOT-ULISBOA
[3]IPMA

Section: Applications, user services and tools

The in-situ data and validation results of third version of the ocean-colour products from the ESA Ocean Colour Climate Change Initiative.

A. Valente[1], V. Brotas[1], O. Clements[2], A. Chuprin[2], M. Grant[2], S. Groom[2], T. Jackson[2], S. Sathyendranath[2]

In this work, the compiled set of global bio-optical *in situ* data used for validation and uncertainty characterization of 3rd version of ocean-colour products from the ESA Ocean Colour Climate Change Initiative (OC-CCI), as well preliminary results of the validation exercise are presented. The compiled set of *in situ* data is an extended version of the dataset described by Valente et al. [Earth Syst. Sci. Data, 8, 235–252 (2016)]. The extended version presented here has an increased temporal coverage (1997-2015) and more *in situ* data sources. Description is given of the in situ data sources and of the methodologies used in order to compile all data (homogenization between different sources of data, quality control, removal of duplicated data and merging of all data). The final set of compiled data contains a total number of 50617 remote-sensing reflectances, 66226 chlorophyll-a concentrations, 1869 algal pigment absorption coefficients, 1654 detrital and coloured dissolved organic matter absorption coefficients, 792 particle backscattering coefficients and 2447 diffuse attenuation coefficients for downwelling irradiance. The complete archive has been organised into a database, and will be accessible through standardised data services. This will allow the data to be visualised and queried by users through web based visualisation tools such as the OC-CCI data portal (https://www.oceancolour.org/portal/). Spatial and temporal distributions of the compiled observations are discussed. Finally, key findings of the validation of the OC-CCI v3.0 product and a quantitative assessment of the product performance relative to the GCOS requirements for the Essential Climate Variables (ECVs) are given.

1 – MARE, Faculdade de Ciências, Universidade de Lisboa, 1749-016, Lisboa, Portugal

2 - Plymouth Marine Laboratory, Prospect Place, Plymouth, PL1 3DH, UK

adovalente@fc.ul.pt; vbrotas@fc.ul.pt; olcl@pml.ac.uk; ach@pml.ac.uk; mggr@pml.ac.uk; sbg@pml.ac.uk; thja@pml.ac.uk; ssat@pml.ac.uk

Do we need to account for adjacency effects in ocean colour observations of coastal waters?

Barbara Bulgarelli[1] and Giuseppe Zibordi[2]

The detectability of adjacency effects (AE) in ocean colour remote sensing by SeaWiFS, MODIS-Aqua, MERIS, OLCI, OLI and MSI is theoretically cross-compared for typical observation conditions up to 36 km offshore (20 km for MSI). A wide range of terrestrial land covers and seawater types usually encountered in European coastal environments is considered. Simulations fully account for multiple scattering, sea surface roughness, off-nadir sensor and solar geometries. A harmonized cross-comparison is ensured by adjusting the radiometric sensitivity of each sensor to the same input radiance. Results show that for highly sensitive sensors like MODIS-Aqua, MERIS-RR and OLCI-RR, AE are always above the sensor noise level (NL), except for AE from green vegetation at red wavelengths. For less sensitive sensors like SeaWiFS, MERIS-FR, OLCI-FR, OLI and MSI, highly reflecting land covers (such as snow, dry vegetation, white sand and concrete) induce AE always above sensor NL, while AE at visible wavelengths from green vegetation and bare soil may become lower than NL at shorter distance from the coast. Such distance increases with the radiometric performance of the sensor. AE sensitivity to the seawater type occurs at sole blue wavelengths. Notably, for an atmospheric correction scheme inferring the aerosol properties from the NIR wavelengths, perturbations induced by AE at NIR and visible wavelengths might compensate each other. As a consequence, biases induced by AE on radiometric products (i.e., the water-leaving radiance) are not directly correlated to the intensity of the reflectance of the nearby land.

[1] Joint Research Centre of the European Commission – Ispra (I)
barbara.bulgarelli@ec.europa.eu

[2] Joint Research Centre of the European Commission – Ispra (I)
giuseppe.zibordi@ec.europa.eu

Pseudo-nitzschia blooms and Domoic Acid events – Preliminary evaluation of tools and methodologies from the Californian risk assessment service

Gema Casal[1], Caroline Cusack[1], Clarissa Anderson[2] and Joe Silke[1]

ABSTRACT

Understanding the occurrence and movement of Harmful Algal Blooms (HABs) is a key environmental, economic and societal factor in coastal areas. The global nature and impacts of HABs requires the establishment of international programmes and a cooperative approach. Moreover, given that HAB events do not respect national boundaries, cross region networking and scientific development are required to achieve early HAB warnings and improve management strategies. In Ireland, a comprehensive coastal HAB monitoring programme exists. There is, however, a need to overcome the lack of biological and chemical data in offshore waters. In this study, a preliminary evaluation of tools and methodologies developed in a Californian risk assessment service was carried out. Existing statistical threshold models for predicting blooms of *Pseudo-nitzschia,* particulate domoic acid (pDA), and cellular domoic acid (cDA) were tested in Irish waters using hydrographic, optical and chemical observations. Preliminary results show the existence of some limitations to test the full performance of the methodology applied in California and suggest the need of developing specific regional models and thresholds for Irish coastal waters.

[1]Marine Institute, Rinville, Oranmore, Co.Galway, Ireland; gema.casal@gmail.com, caroline.cusack@marine.ie, joe.silke@marine.ie

[2]University of California, Santa Cruz (UCSC), California; clrander@ucsc.edu

Monte Carlo model study of the "skylight-blocked approach" for measuring water-leaving radiance: self-shading and boat perturbation to the light field

Alexandre Castagna[1], Heidi Dierssen[2], Quinten Vanhellemont[3] and Wim Vyverman[1]

Water-leaving radiance (L_w), or its equivalent, water-leaving reflectance (ρ_w), is a key parameter for remote sensing applications. It is fundamental for algorithm development and validation of atmospheric compensation for orbital or airborne sensors, but also useful as direct information for estimating biogeochemical properties. From the different methods available for estimation of L_w, the skylight-blocked approach (SBA) is promising for inland water radiometry because of the potential presence of shallow waters, submerged vegetation and natural or artificial surrounding structures, all of which create difficulties for the application of classical approaches. In this method, the tip of the foreoptics of the sensor is placed just beneath the water surface, effectively removing the contribution from specular reflection of the skylight. The SBA approach, however, results in some degree of self-shading and can be impacted by shading of the associated platform used for deployment (e.g., an inflatable boat or a pontoon), causing underestimates in L_w that are challenging to quantify empirically. Here, we use a three dimensional backward Monte Carlo radiative transfer model in a simple setting to study first order effects of self-shadowing and platform perturbation to the light field. We also perform *in situ* measurements in productive inland waters in Belgium comparing estimations with SBA and classical approaches. Recommendations for deployment of sensor and measurement protocols, as well shading correction are provided.

1 - Ghent University, Ghent 9000, East Flanders, Belgium.

alexandre.castagna@ugent.be

wim.vyverman@ugent.be

2 - University of Connecticut, Groton, CT 06340, USA.

heidi.dierssen@uconn.edu

3 - Royal Belgian Institute of Natural Sciences, Brussels 1000, Belgium.

quinten.vanhellemont@naturalsciences.be

OLCI Validation Activities in the Northwest Atlantic

C. Caverhill[1], E. Devred[1], C. Fuentes-Yaco[1], E. Horne[1],T. Perry[1], G.N.W. White III[1], C. Lerebourg[2] and T. Jaegler[2]
[1]Bedford Institute of Oceanography, 1 Challenger Drive, Dartmouth, Nova Scotia, Canada
[2]S3MPC (Sentinel-3 Mission Performance Center)

ABSTRACT: The Sentinel-3 validation team at the Bedford Institute of Oceanography (BIO), located on Canada's east coast, has done a preliminary assessment of the performance of OLCI L2 products in waters off the coast of Nova Scotia and Newfoundland and in the Labrador Sea. Three types of comparisons have been made. The first comparison looks at *in situ* reflectance measurements in two different coastal areas compared to OLCI's remote sensing reflectance values. The second compares *in situ* HPLC chlorophyll measurements from the 2016 Labrador Sea mission with OLCI's CHL_OC4ME and CHL_NN products. A third comparison is carried out between chlorophyll values from the flow-thru system onboard the CCGS Hudson during the 2016 Labrador Sea mission and OLCI's CHL_OC4ME product.

[1]Bedford Institute of Oceanography, 1 Challenger Drive, Dartmouth, Nova Scotia, Canada
[2]S3MPC (Sentinel-3 Mission Performance Center)

Corresponding author's email address: carla.caverhill@dfo-mpo.gc.ca

Eddy-enhanced 2000-km long phytoplankton bloom in the oligotrophic western North Pacific Subtropical Gyre in summer 2003

Chun Hoe Chow[1,*], Wee Cheah[2,*], Jen-Hua Tai[3]

This study reports the largest summer phytoplankton bloom ever recorded in the western part of the oligotrophic North Pacific Subtropical Gyre. The rare and striking ~2000-km long phytoplankton bloom lasted over a month in summer 2003. Using a combination of satellite-derived estimates of chlorophyll, net primary production, eddy kinetic energy, and concomitance field observations of temperature profiles measured during the bloom period, we show that the extensive bloom in 2003 was driven by the exceptionally strong eddies. The extremely strong eddy currents swiftly spread the high chlorophyll waters to the east and west at the same time with a speed faster than the speed of eddy westward motion, which differ from the current understanding of eddy-induced blooms that are westward-propagating driven by the eddy westward motion. The extraordinary 2003 summertime bloom not only resulted in an increase in chlorophyll six times of the mean values, but also collectively fixed an additional 5 Tera grams of carbon during the one-month bloom period.

[1] Email: kilmerchow@mail.nsysu.edu.tw
Department of Oceanography, National Sun Yat-sen University, Taiwan
[2] Email: weecheah@gate.sinica.edu.tw
Research Center for Environmental Changes, Academia Sinica, Taiwan
[3] Email: jhtai@gate.sinica.edu.tw
Research Center for Environmental Changes, Academia Sinica, Taiwan
[*]These authors contributed equally to this work

Novel advances in Ocean Color remote sensing: retrievals from combined airborne polarization/lidar data

Jacek Chowdhary [1], Li Liu [1], Snorre Stamnes [2], Yongxiang Hu [2], Chris Hostetler [2], Wayne Slade [3], Yvona Cetinić [4], Brian Cairns [5], Michael Mishchenko [5].

Space-borne studies of coastal oceans are important because these ecosystems are responsible for the biogeochemical cycling of many materials. As the oceans are changing and as the world population increases, these coastal ecosystems will be first to feel the impact of sea rise, oceanic acidification, waste pollution, and land run-off. However, such ecosystems are notoriously difficult to study from space because *(i)* they exhibit small-scale variations; *(ii)* aerosols exhibit significant variations over coastal regions; and *(iii)* light reflected by the adjacent land is often bright.

Polarimetric remote sensing has successfully been used to retrieve aerosols over land. That is because surface polarization is spectrally gray, as opposed to the brightness of light reflected by land. This implies that polarimetry can be used for atmospheric correction (*AC*) at much coarser spatial resolutions than the actual spatial variation of water scenes.

Lidar remote sensing has a small surface footprint that is ideal for studying coastal waters. Furthermore, lidar return signals are not affected by the presence of nearby clouds and land surfaces, and provide unique scattering information on both aerosols and hydrosols. A new emerging ocean product obtained from lidar observations is the morphology of phytoplankton.

The addition of polarization/lidar (PoLi) data for ocean color missions therefore provides a breakthrough in *AC* over coastal waters, and offers new information about plankton morphology. We evaluate these retrieval capabilities using (1) airborne PoLi and ship-based *in-situ* measurements from the SABOR campaign; and (2) the latest advances in scattering matrix computation for non-spherical, inhomogeneous phytoplankton.

1. Columbia University, 2880 Broadway, New York, NY 10025, USA
2. NASA/LaRC, Mail Stop 475, NASA Langley Research Center, Hampton, VA 23681-2199, USA
3. Sequoia Scientific, Inc., 2700 Richards Road, Suite 107, Bellevue, WA 98005, USA
4. NASA/GSFC, Building 028, Mail Code 616.2, Greenbelt, MD 20771, USA
5. NASA/GISS, 2880 Broadway, New York, NY 10025, USA

"Assessment of empirical and semi-analytical chlorophyll-a (Chl-a) algorithms in the Gulf of Taranto (eastern Mediterranean)"

E. CIANCIA[1], I. COVIELLO[2], C. DI POLITO[1], T. LACAVA[2], A. MADONIA[3], M. MARCELLI [3], S. PASCUCCI[2], A. PALOMBO[2], N. PERGOLA[2], V. PIERMATTEI[3], S. PIGNATTI[2], F. SANTINI[2], V. SATRIANO[1], V. TRAMUTOLI[1]

(1) School of Engineering, University of Basilicata, Potenza, Italy

(2) National Research Council, Institute of Methodologies for Environmental Analysis, Tito Scalo (PZ), Italy

(3) University of Tuscia, Laboratory of Experimental Oceanology and Marine Ecology, Civitavecchia (RM), Italy

The estimation of chlorophyll-a (chl-a) concentration from satellite measurements can allow to interpret changes in the marine environment at global and regional scales. To this aim, the empirical and semi-analytical chl-a algorithms are the mostly used, mainly because of their easy implementation. However, these algorithms, developed to be suitable at global scale, have shown poor accuracy when applied in site-specific conditions. Furthermore, the chl-a retrieval from satellite measurements is often problematic in optically complex waters, such as in the Gulf of Taranto (GoT – eastern Mediterranean).
In this work, we evaluated the performance of two standard *color ratio* algorithms for MODIS (Moderate Resolution Imaging Spectroradiometer) data, such as OC3M and MedOC3, and two semi-analytical ones, GSM (Garver–Siegel–Maritorena model) and GIOP (Generalized Inherent Optical Properties), using in situ chl-a data, collected in the GoT, during several recent oceanographic cruises.
The influence of optical active constituents and the low accuracy of standard atmospheric correction (NASA-based) negatively affected the performance of the two empirical algorithms, causing a great chl-a concentration overestimation. Even the implementation of the MUMM atmospheric correction method, specifically developed for coastal waters, resulted in a slight improvement in the chl-a retrieval.
On the other hand, the two semi-analytical algorithms showed better statistical results, with no significant deviation from the ground data. The local tuning of the bio-optical parameters allowed to obtain significant improvement in the chl-a concentration accuracy.
These results are finally interpreted and discussed in order to define an operational chl-a algorithm for the area of interest.

1 Via Nazario Sauro, 85 - 85100 Potenza, Italy
(emanuele.ciancia@unibas.it; carmine.dipolito@unibas.it; valeria.satriano@unibas.it; valerio.tramutoli@unibas.it)

2 C.da S. Loja - Zona Industriale - 85050 Tito Scalo (PZ), Italy
(irina.coviello@imaa.cnr.it; teodosio.lacava@imaa.cnr.it; simone.pascucci@imaa.cnr.it; angelo.palombo@imaa.cnr.it; nicola.pergola@imaa.cnr.it; stefano.pignatti@imaa.cnr.it; federico.santini@imaa.cnr.it)

3 Via S.M. in Gradi n.4, 01100 Viterbo, Italy
(alice_madonia@unitus.it; marcomarcell@unitus.it; v.piermattei@unitus.it)

Assessing Diurnal Variability of Biogeochemical Processes using the Geostationary Ocean Color Imager (GOCI)

Javier Concha[a,b], Antonio Mannino[a], Bryan Franz[a] and Wonkook Kim[c]
[a] *Ocean Ecology Lab, NASA Goddard Space Flight Center, Greenbelt, MD, USA*
[b] *Universities Space Research Association, Columbia, MD, USA*
[c] *Korean Institute of Ocean Science and Technology, Ansan-si, South Korea*

Abstract

Short-term (hours) biological and biogeochemical processes cannot be captured by heritage ocean color satellites because their temporal resolution is limited to potentially one clear image per day. Geostationary satellites, such as the Geostationary Ocean Color Imager (GOCI), allow the study of these short-term processes because their orbits permit the collection of multiple images throughout each day. In order to be able to detect the changes in the water properties caused by these processes, the levels of uncertainties introduced by the instrument and/or algorithms need to be assessed first. This work presents a study of the variability during the day over a water region of low-productivity with the assumption that only small changes in the water properties occur during the day over the area of study. The complete GOCI mission data were processed to level 2 using the SeaDAS/l2gen package. Filtering criteria were applied to assure the quality of the data. Relative differences with respect to the daily mean were calculated for each time of the day. Also, the relationship between the solar zenith angle and remote sensing reflectances was analyzed. The GOCI time series was compared to the MODIS/Aqua and Suomi-NPP VIIRS missions. Preliminary results suggest that the last two images of the day deviate significantly from the prior six hourly images, presenting errors on the order of 30% or higher in the blue and green bands, and higher than 50% in the red bands. Additionally, the atmospheric correction begins to fail for solar zenith angles greater than 60 degrees.

Suspended Particulate Matter dynamics in the surface waters of the Gironde plume

Authors: Sorin Constantin[a], David Doxaran[a], Anna Derkacheva[a], Stefani Novoa[a], Héloïse Lavigne[b], Quinten Vanhellemont[b]

Gironde estuary, one of the largest in Europe, is an important source of Suspended Particulate Matter (SPM) for the outer shelf area. Several factors contribute to the magnitude and dynamics of the SPM plume, such as the river discharge rates, tidal currents, swell and wind. In order to better understand its behavior, satellite data acquired by MODIS (Moderate Resolution Imaging Spectroradiometer) and SEVIRI (Spinning Enhanced Visible and InfraRed Imager) sensors were used, in conjunctions with a significant collection of in-situ measurements (i.e. autonomous turbidity data recorded in a fixed location over a four months period). Regional relationships were applied to satellite data to retrieve SPM concentrations. The main findings of the study are related to the dynamics of the sediment plume in correlation with several governing factors. Increased river discharge rates determine higher plume magnitudes, with a very good correlation between these two parameters up to a specific limit. Above this limit, a "saturation" effect is visible, with a reduction in sediment supply outside the estuary. Tidal regime plays also a very important role in the process, with ebb periods (and mainly during low waters) and high tidal ranges corresponding to the most extensive sediment plumes. Although MODIS images were extremely useful for this study (three complete years of data were analyzed), at sub-daily time scale geostationary satellite data proved to be an extremely useful source of information. Despite the reduced spatial and spectral resolution, daily variations of SPM are well observed.

[a] Laboratoire d'Océanographie de Villefranche, UMR7093, CNRS-UPMC, 181 Chemin du Lazaret, 06230 Villefranche-sur-Mer, France

- sorin@obs-vlfr.fr
- doxaran@obs-vlfr.fr
- der_a@mail.ru
- snovoa@gmail.com

[b] Royal Belgian Institute for Natural Sciences (RBINS), Operational Directorate Natural Environment, Gulledelle 100, 1200 Brussels, Belgium

- hlavigne@naturalsciences.be
- qvanhellemont@naturalsciences.be

The effects of the physical and climatic variables on time series of MERIS product algal pigment index 1 in the SW of Portugal: Sagres

Clara Cordeiro[a,b,1], Sónia Cristina[c,d,2], Priscila Costa Goela[c,3], John Icely[c,d,4], Samantha Lavender[e,5],Alice Newton[c,f,6]

The decomposition of the time series of Medium Resolution Imaging Spectrometer (MERIS) products into seasonal, trend and irregular components was useful for a better understanding of temporal variability of the MERIS products from Sagres in the SW Portugal between 2002-2012. The Seasonal-Trend decomposition method based on Loess (STL) is a nonparametric filtering procedure that decomposes a time series into the three components. The STL decomposition has advantages over other decomposition methods: specifically, it is robust against outliers and the seasonal component can change over time. Based on STL, a method of seasonal adjustment called stl.fit was developed to search for the "best" model that best captures the dynamic structure of the time series, according to a measure of accuracy. The seasonally adjusted time series will be used to compare the effects of the climate index (North Atlantic Oscillation) and the physical variables, sea surface temperature and Ekman transport (Q_x and Q_y) on total chlorophyll *a*, represented by the MERIS product algal pigment index 1(API1), using Generalized Linear Models and Generalized Additive Models.

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[a]Faculty of Sciences and Technology (FCT), University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal
[b]Centro de Estatística e Aplicações (CEAUL), Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal
[c]Centre for Marine and Environmental Research (CIMA), University of Algarve, 8005-139 Faro, Portugal
[d]Sagremarisco Lda., 8650-999 Vila do Bispo, Portugal
[e]Pixalytics Ltd., 1 Davy Road, Plymouth Science Park, Plymouth, Devon PL6 8BX, UK
[f]NILU-IMPEC, 2027 Kjeller, Norway

[1]ccordei@ualg.pt
[2]cristina.scv@gmail.com
[3]priscila.goela@gmail.com
[4]john.icely@gmail.com
[5]slavender@pixalytics.com
[6]anewton@ualg.pt

Ferry Ocean Colour Observation System (FOCOS): acquisition of autonomous, continuous *in situ* above-water hyperspectral reflectance data from ferry platforms for validation of Sentinel-3 imagery

Maycira Costa[1], Ziwei Wang[1], Nathan Vandenberg[1], Andrea Hilborn[1], Svetlana Esenkulova[2]

Monitoring productivity of the Canadian west coast requires data on proper spatial-temporal scales, which can be provided by operational ocean colour satellites such as Sentinel-3. However, present limitations on the use of satellite imagery to derive accurate chlorophyll concentrations (Chla) arise from the lack of sufficient *in situ* measurements for validation of imagery atmospheric correction and development of algorithms to estimate Chla. In two different routes of BC Ferries vessels crossing the Salish Sea, we installed hyperspectral radiometers to measure sea surface and sky radiance and total irradiance with solar tracking capability that permits autonomous operation (HyperSAS Solar Tracker). Data from the sensors are streamed in near real time to ONC facilities at the University of Victoria and downloaded using Oceans 2.0. An application (PySciDON) with batch mode capability applies calibration to the raw data stream for each sensor, dark measurements correction, time and wavelength interpolation, meteorological flags, data time binning, and satellites band simulations. We present water leaving reflectance data acquired with the FOCOS system and Sentinel 3 (L2 reprocessed, C2RCC correction) in the summer of 2016, approximately 500 measurements. These represent condition in which diatoms dominated in June and reflectance ($R_{wrs\ 560nm}$) values vary from 0.015 – 0.025 sr^{-1}, and an unexpected coccolithophores bloom in July and August (400 - ~40000 cells per mL) with R_{wrs} about 0.045 sr^{-1}. Sentinel 3 R_{wrs} shows an absolute percentage difference 30% lower than FOCOS R_{wrs} in the longer blue, green, and red bands, and the blue-green ratio difference is less than 8%.

[1]University of Victoria; contact (maycira@uvic.ca)

[2]Pacific Salmon Foundation

Monte Carlo model study of the "skylight-blocked approach" for measuring water-leaving radiance: self-shading and boat perturbation to the light field

Alexandre Castagna[1], Heidi Dierssen[2], Quinten Vanhellemont[3] and Wim Vyverman[1]

Water-leaving radiance (L_w), or its equivalent, water-leaving reflectance (ρ_w), is a key parameter for remote sensing applications. It is fundamental for algorithm development and validation of atmospheric compensation for orbital or airborne sensors, but also useful as direct information for estimating biogeochemical properties. From the different methods available for estimation of L_w, the skylight-blocked approach (SBA) is promising for inland water radiometry because of the potential presence of shallow waters, submerged vegetation and natural or artificial surrounding structures, all of which create difficulties for the application of classical approaches. In this method, the tip of the foreoptics of the sensor is placed just beneath the water surface, effectively removing the contribution from specular reflection of the skylight. The SBA approach, however, results in some degree of self-shading and can be impacted by shading of the associated platform used for deployment (e.g., an inflatable boat or a pontoon), causing underestimates in L_w that are challenging to quantify empirically. Here, we use a three dimensional backward Monte Carlo radiative transfer model in a simple setting to study first order effects of self-shadowing and platform perturbation to the light field. We also perform *in situ* measurements in productive inland waters in Belgium comparing estimations with SBA and classical approaches. Recommendations for deployment of sensor and measurement protocols, as well shading correction are provided.

1 - Ghent University, Ghent 9000, East Flanders, Belgium.

alexandre.castagna@ugent.be

wim.vyverman@ugent.be

2 - University of Connecticut, Groton, CT 06340, USA.

heidi.dierssen@uconn.edu

3 - Royal Belgian Institute of Natural Sciences, Brussels 1000, Belgium.

quinten.vanhellemont@naturalsciences.be

Validation of water leaving reflectance and API 1 from MERIS to OLCI off Sagres in the SW of Portugal

Sónia Cristina[a,b,1], Priscila Costa Goela[a,2], John Icely[a,b,3], Alice Newton[a,c,4]

Since 2008 an extensive validation study has been carried out off Sagres between the eras for the Medium Resolution Imaging Spectrometer (MERIS) and the Ocean and Land Colour Instrument (OLCI)) to provide a bio-optical characterisation of the SW coastal Portuguese waters. Regular sampling campaigns have collected radiometric measurements and water samples to determine in water constituents at three stations A, B and C at 2, 10 and 18 km from the coast, respectively.

The present study shows: (i) an overview of validation between the *in situ* and MERIS water leaving reflectance ($\rho_w(\lambda)$) and the total chlorophyll *a* concentration (TChl*a*), that is retrieved by the standard algorithm OC4Me (also known as the standard Algal Pigment Index 1 (API1)); (ii) a preliminary validation of the same products acquired by OLCI at Sagres. In addition, the Improved Contrast between Ocean and Land (ICOL) processor was applied to the MERIS products to correct for coastal adjacency effects. A matchup analysis was applied to the datasets and the uncertainties assessed for the MERIS products using the scattering and the bias as absolute and signed biased percent differences and the coefficient of determination r^2

Throughout the validation campaign from 2008 till 2012 and 2016 the Sagres waters have consistently shown the characteristics of Case 1 waters, enabling the evaluation of adjacency effects independent of the usual covarying inputs from the land. Nonetheless, periodic upwelling events off Sagres ensure a wide range of chlorophyll and reflectance values, suitable for the validation of remote sensing products.

[a]Centre for Marine and Environmental Research (CIMA), University of Algarve, 8005-139 Faro, Portugal
[b]Sagremarisco Lda., 8650-999 Vila do Bispo, Portugal
[c]NILU-IMPEC, 2027 Kjeller, Norway

[1]cristina.scv@gmail.com
[2]priscila.goela@gmail.com
[3]john.icely@gmail.com
[4]anewton@ualg.pt

Effects of integration time on in-water radiometric profiles (250 words max)

Davide D'Alimonte[1], Giuseppe Zibordi[2] and Tamito Kajiyama[1]

In-situ radiometry underpins any ocean color mission and obviously Sentine-3/OLCI. This requires comprehensive characterizations of uncertainties affecting in situ radiometric data products. The present work investigates the integration time effect on downward irradiance E_d, upward irradiance E_u and upwelling radiance L_u acquired with free-fall hyperspectral systems. Analyzed quantities are the subsurface value and the diffuse attenuation coefficient derived with the linear and the non-linear regression. The analysis relies on optical profiles simulated for oligotrophic waters (Case-1), as well as waters dominated by the Colored Dissolved Organic Matter (CDOM) and Non-Algal Particles (NAP). Alternative depths are considered for each radiometric value resulting from the accumulation of photons (*integration*) over time intervals between 8 and 2048 ms: 1) the depths corresponding to the beginning of each integration interval (FST); 2) those corresponding to the end of each integration interval (LST); 3) the averages of FST and LST values (AVG); and finally 4) the values weighted accounting for the diffuse attenuation coefficient of water (WGT). Results document that the effects of integration time can bias results (>5%). Cases are provided by the reduction of E_u and L_u profiles obtained with FST or LST depths when the optical system is deployed faster than 0.4 ms^{-1} in CDOM-dominated waters. Perturbations due to the focusing of sea-surface facets oppositely affect biases due to the data integration and log-transformation in the linear regression case. The study confirms the fair applicability of the AVG depth in virtue of limited effects of the integration time on subsurface data products.

[1]Centre for Marine and Environmental Research – CIMA, University of Algarve, Campus of Gambelas, Faro, Portugal, Email: davide.dalimonte@gmail.com

[2]European Commission, Joint Research Centre, Institute for Environment and Sustainability, Ispra, Italy.

Monitoring water dynamics with drone and satellite data

Liesbeth De Keukelaere[1]*, Dries Raymaekers*[1]*, Boudewijn Decrop*[2]*, Mark Bollen*[2]*, Els Knaeps*[1]

Monitoring of sediment concentrations in water bodies can be challenging as plumes can vary rapidly in space and time. In-situ sampling reveals only a part of the total dynamics, therefore this study uses an integrated approach by combining data from different sources: in-situ, remote sensing and sediment models. The remote sensing data is delivered by satellite imagery, proving historical information at large spatial extent, and dedicated drone campaigns employing a simple RGB camera (Sony-NEX). The advantage of drone data is their near-real-time monitoring capability, their flexibility and their high spatial resolution. But retrieving sediment concentrations from unmanned systems over water bodies is a challenging task and requires the correction of geometry, vignetting effects and sky glint.

Drone campaigns were organized at three test sites: the harbor of Zeebrugge (Belgium), Scheldt river (Belgium) and the port of Breskens (the Netherlands). The acquired data are put in a spatial data infrastructure together with satellite data and sediment models, allowing data analysis which can support decision makers.

[1] Vlaams Insituut voor Technologisch Onderzoek (VITO), Remote Sensing Unit; 2400 Mol, Belgium
- liesbeth.dekeukelaere@vito.be, dries.raymaekers@vito.be, els.knaeps@vito.be

[2] International Marine & Dredging Consultant (IMDC), 2018 Antwerp, Belgium
- boudewijn.decrop@imdc.be, mark.bollen@imdc.be

The mixing events of the oligotrophic South Atlantic analyzed by synoptic observations

Flavia T. Delcourt[1] and Paulo H. R. Calil[2]

Laboratório de Dinâmica e Modelagem Oceânica – DinaMO
Universidade Federal do Rio Grande (FURG)

The South Atlantic oligotrophic ocean is considered a desert region were chlorophyll-a concentration is sparse and primary production increase is difficult to observe. Around the Vitória-Trindade Submarine Seamounts (VTSS) the variability of the mixed layer depth (MLD) is a consequence of the water column stratification set by the regional circulation, with a strong seasonal cycle ranging from 20 m in summer to 150 m in winter. We analyzed three years of vertical profiles from a Bio-Argo float in combination with satellite ocean color observations from VIIRS mission. An accurate bio-physical view of the region was improved, once the floats and the remote products presented high resolution data capable enough to infer the biogeochemical correlation with optical properties from satellite data. The profiler allows to sample the variability of the oligotrophic region, elucidating the annual cycle of the sea temperature, chlorophyll-a concentration, salinity and dissolved oxygen. The derived MLD controls the entrainment of chlorophyll-a to the surface and the upper-layer homogeneity, responsible for the primary production in the euphotic zone. The strong stratification of the water column and the mixing events associated to the MLD deepening were the base to investigate the mesoscale processes from altimetry data. From the adjust of the Vertically Generalized Production Model (VGPM) algorithm with remote high resolution daily data, primary production was estimated in regional scales.

[1]flaviadelcourt@furg.br
[2]paulo.calil@furg.br

Minho River plume characterization using MODIS imagery and numerical modelling (Delft3D-FLOW)

M. Des[1], M.C. Sousa[2], M. deCastro[1], D. Fernández-Nóvoa[1], M. Gómez-Gesteira[1]

Minho River flows into the North Atlantic Ocean at the NW of the Iberian Peninsula, a high primary production area. This flow represents one of the most important inputs of sediments and freshwater to the zone. The aim of our study is to get a better agreement between the modelled river plume and the turbid plume observed with satellite imagery. In this sense, the turbid plume was characterized using ocean color images from Moderate Resolution Imaging Spectroradiometer sensor (MODIS) and the river plume was modelled by means of Delft3D-FLOW model. Data inputs for the model were provide by Copernicus Marine Environment Monitoring Service and by the "Unidade de Observación e Prediccion Meteorolóxica" (MeteoGalicia). Model outputs, from a hydrodynamic simulation from 1 April to 15 May (1998), were validated with *in situ* data. Sea surface elevation was compared with tidal gauges and the vertical structure accuracy was verified comparing salinity, temperature and horizontal velocity vertical profiles with CTD and current meter data collected in a survey.

To analyze and compare turbid and modelled plumes, firstly we delimit the plume area using the model output, which is compared with the plume observed in MODIS images under different water-leaving-radiance. This permits to determine which is the most suitable radiance band and the appropriate turbidity limit for the plume delimitation in the study area. Finally, the limit obtained using this methodology is compared with the turbid limit obtained correlating the river discharge and the water-leaving-radiance in the area near to the estuary mouth.

[1] (mdes, mdecastro, diefernandez, mggesteira)@vigo.es EPhysLab (Environmental Physics laboratory), Facultad de Ciencias, Universidad de Vigo, 32004 Ourense, Spain

[2] mcsousa@ua.pt CESAM, Departamento de Física, Universidade de Aveiro, 3810-193 Aveiro, Portugal

Remote sensing of HAB in the Bay of Fundy based on an ecological approach

Devred E.[1], Martin J.[1], Sathyendranath S.[2], Stuart V.[1], Platt T.[2], Horne E.[1], Forget M.H.[3] and Smith P.[1]

The Gulf of Maine and Bay of Fundy system (United States – Canada) is subject to recurrent harmful algal blooms of the dinoflagellate *Alexandrium fundyense* spp. during the spring and summer months. These have a profound impact on the fisheries economy, including aquaculture. Filter feeding organisms such as bivalves, concentrate the toxin produced by *A. fundyese* such that they are unfit for human consumption at levels of *A. fundyense* as low as 200 cell.L^{-1}. Such low cell abundances cannot be directly detected by ocean colour remote sensing. We have used an ecological approach to determine the risk of toxic levels of HABs in the Bay of Fundy using information on occurrence of diatoms (derived from Ocean Colour) and Sea Surface Temperature. The approach consists of providing three levels of warning (green, orange and red) from which possible toxic levels of HABs can be inferred. Two datasets (development, N = 74 and validation N = 38) of coincidental satellite-derived SST and probability of occurrence of diatoms, as well as in situ cell counts of *A. fundyense* were used in the study. Results show an overall success rate of 70% at identifying HAB conditions, with low instances of false negative responses (less than 7%).

[1] Bedford Institute of Oceanography, Fisheries and Oceans Canada, 1 Challenger Drive, Dartmouth, NS, B2Y 4A2, Canada

[2] Plymouth Marine Laboratory, Prospect Place, the Hoe, Plymouth, Pl1 3DH, United Kingdom

[3] Takuvik, Département de Biologie, Université Laval, 1045 Avenue de la Médecine, Québec, Québec, G1V 0A6, Canada

Corresponding author address : emmanuel.devred@dfo-mpo.gc.ca

On the representativeness and accuracy of downwelling radiation measurements at the sea surface on an elastic beacon: the first year of measurements on the Lampedusa Oceanic Observatory

Alcide di Sarra, Carlo Bommarito, Fabrizio Anello, Tatiana Di Iorio, Daniela Meloni, Francesco Monteleone, Giandomenico Pace, Salvatore Piacentino, and Damiano Sferlazzo.

Laboratory for Observations and Analyses of Earth and Climate, ENEA, Italy

An oceanographic buoy has been deployed in August 2015 about 3.3 miles South West of the island of Lampedusa, at 35.49°N, 12.47°E, in the central Mediterranean Sea. The buoy was developed within the Italian RITMARE flagship project. The buoy is an elastic beacon type and is intended to study air-sea interactions, underwater radiation, and oceanographic properties. The buoy measurements complement the atmospheric observations carried out since 1997 at the Station for Climate Observations on the island of Lampedusa (www.lampedusa.enea.it; 35.52°N, 12.63°E), which is located about 15 km ENE of the buoy.

Measurements of downwelling shortwave and longwave irradiances have been carried out since September 2015 with a Kipp and Zonen CMP21 pyranometer and a CGR4 pyrgeometer, respectively. The radiometers are mounted on a small platform at about 7 m above sea level, on an arm protruding southward of the buoy. High time resolution data, at 1 Hz, have been acquired since December 2015, together with the sensors' attitude.

Data from the period December 2015-December 2016 are analyzed and compared with measurements made on land at the Station for Climate Observations at 50 m above mean sea level. The analysis has been carried out with the aim of determining accuracy, representativeness and limitations of the measurements made on the buoy. In particular, the influence of the following factors has been investigated: sensor attitude; dome cleanness; albedo, and altitude on sea level. An annual cycle of shortwave and longwave irradiances and associated estimated accuracies are presented.

Interpreting backscattering in the Southern Ocean

Heidi M. Dierssen[1], Kaylan Randolph[1], Shungudzemwoyo Garaba[1]

The Southern Ocean ranges from highly productive coastal regions of the Antarctic Peninsula to the oligotrophic regions of the South Indian Ocean and many different sources of particles exist within this gradient that contribute to particulate backscattering. Assemblages of diatoms, coccolithophores, and *Phaeocystis* dominate different zones of the region, as well as inorganic particle sources such as detached coccoliths, bubbles injected from breaking waves, and glacial flour from melting of land-based glaciers. This diversity creates unique influences on remote sensing algorithms. For example, remotely derived estimates of backscattering provide a means to estimate calcite concentrations, but coccolithophores are not found in the coldest waters near the Antarctic continent where high backscattering is attributed to glacial flour and near-surface colonial forms of *Phaeocystis*. Inversion modeling of the volume scattering function measured along the Polar Front prone to high winds suggests that different populations of bubble contribute as much as 25% of the total particulate backscattering. Moreover, recent research has shown that proteins represent over 50% of the biomass of phytoplankton near the Antarctic Peninsula with C:N ratios as low as 5. Such differences will alter biogeochemical relationships between particulate backscattering and carbon. Here, we evaluate the relative contributions of these particle assemblages to the total backscattering for different zones of the Southern Ocean using optical data collected during recent cruises of the Atlantic and Indian sectors of the Southern Ocean with an aim towards improving retrievals of remote sensing products in this expansive and sensitive region of the world ocean.

[1]heidi.dierssen@uconn.edu, University of Connecticut Marine Sciences

Coastal water extraction algorithm for Landsat-8 OLI based on spectral analysis and the Hue-Saturation-Value based approach

Dat Dinh Ngoc [1, 3], Hubert Loisel[1, 2, 3], Cedric Jamet[3], Vincent Vantrepotte[3], Lucile Duforêt-Gaurier[3], Chung Doan Minh[1]

[1]Space Technology Institute, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam

[2]Hanoi International Laboratory of Oceanography, University of Science and Technology of Hanoi, 18 Hoang Quoc Viet, Cau Giay, Hanoi, Vietnam

[3]Laboratoire d'Océanologie et de Géosciences, Université du Littoral-Côte-d'Opale, 32 avenue Foch, Wimereux, France

Abstract: For all visible imagery, clouds are impacting the quantity and quality of the observation, directly by hiding part of the scene and indirectly by their shadows. A certain level of confusion could occur for detection of clouds over turbid (i.e. bright) waters and for detection of their shadows over the dark waters. Cloud masks developed over waters are usually based on the assumption that the marine reflectance is close to zero in the near-infrared (NIR). This is valid over the open ocean, but coastal turbid waters may have a higher NIR reflectance due to suspended matter and non-maritime aerosols. Cloud-free pixels are sometimes classified as clouds, leading to a loss of data, which can be huge for turbid waters. Cloud shadows and thin cloud masking are particularly important when dealing with high spatial resolution data such as those delivered by Operational Land Imager (OLI) sensor on Landsat-8. Some algorithms exist for cloud shadow detection but they are based on cloud height estimates, which are very difficult to assess, or on the use of thermal channels which are not always available. In the frame of this study, we developed a new cloud masking tool for OLI which is based on the Rayleigh corrected top of atmosphere reflectance within the whole spectrum, as well as on the use of the Hue-Saturation-Value (HSV) based approach. Training dataset for algorithm development and testing dataset were randomly selected over different areas around the world. The present algorithm shows generally better performance than the latest version of Fmask (the standard mask algorithm for Landsat-8) over the testing data set.

Analysis on chlorophyll absorption coefficient in Yellow Sea and East China Sea

Jing Ding[1], Qingjun Song[2], Xiaomin Ye[3]

The inherent optical properties (IOPs) of water mass are only related to biogeochemical characteristics of water constituents which don't change with incoming radiation. The optical characteristics in Yellow Sea and East China Sea are most complex and variable, especially with large content of suspended matter. Based on the large, high quality in-situ data sets derived in Yellow Sea and East China Sea in various seasons, the empirical models of phytoplankton chlorophyll specific absorption coefficient have been developed for different types of water body. According to the data sets of up to 184 stations measured in spring, summer and autumn, we found that the ocean color parameters change quickly in different stations. The concentrations of chlorophyll vary from 0.50 to 15.16ug/L, whereas the suspended matter concentration from 0.60 to 1762mg/L and the CDOM absorption at 400nm from 0.083 to 0.420m^{-1}. In much clear waters and lowly turbid waters, in most cases the concentrations of suspended matter less than 5mg/L, the specific absorption coefficient of chlorophyll could be well described with the power equation suggested by Bricaud (1995). The correlation coefficient of the empirical model could be up to 80% in blue bands. Despite that, in more turbid waters, the correlation coefficient of chlorophyll specific absorption model declined to about 50%. In this case, the TSM concentration is less than 20-30mg/L. Considering the much difficult characteristics of China coastal waters, these empirical models of chlorophyll specific absorption coefficient may be reasonable and a good choice for the construction of semi-analytic models of ocean color remote sensing in this area.

Institute: National Satellite Ocean Application Service, SOA, China.

Address: Dahuisi Road, 8#, Haidian District, Beijing, China, 100081.

Email: 1. dingjing@mail.nsoas.org.cn; 2. kingdream@mail.nsoas.org.cn; 3. yxm@mail.nsoas.org.cn.

Software Package for an Adaptive Satellite-based Sampling for Ocean campaigns: SPASSO

A. M. Doglioli[1], A. A. Petrenko[1], F. Nencioli[2], F. d'Ovidio[3], L. Rousselet[1], A. Della Penna[1], A. Ody[1], J.-M. André[1], L. Berline[1], C. Yohia[4], M.Libes[4]

The variability of the horizontal (sub)mesoscale circulation strongly affects the marine environment fields and the biogeochemical budgets. It represents a real challenge for *in situ* measurements as samplings only a few tens of kilometers or weeks apart may be representative of very different situations. The software package SPASSO (www.mio.univ-amu.fr/SPASSO) has been developed to overcome this problem. Based on NRT acquisition of satellite altimetry and ocean color, and model predictions, maps of dynamical structures such as fronts, eddies and filaments, in addition to chlorophyll and SST, are automatically generated. This helps to guide the *in situ* sampling strategy as well as the interpretation of collected observations. The cruises LATEX (2010), KEOPS2 (2011), STRASSE (2012), OUTPACE (2015), OSCAHR (2015) and SeaQUEST (2015) have benefited from this adaptive strategy. In 2017, SPASSO will applied during the PEACETIME campaign in the Mediterranean and SARGASSES in the N-W Atlantic. The latter being dedicated to *Sargassum sp.*, floating algae indexes, such as aFAI- (MODIS/VIIRS) and MCI (OLCI-Sentinel3) will be implemented in SPASSO. A comparison between *Sargassum* detections and delayed time SPASSO maps from January 2017 is underway. It will allow a better understanding of the raft distributions and transport, in the perspective of the campaign. This poster will illustrate the improvement provided by SPASSO in the *in situ* sampling strategy of the OUTPACE and OSCHAR field campaigns, as well as in the SARGASSES campaign preparation.

1. Aix-Marseille University, Mediterranean Institute of Oceanography (MIO), CNRS/INSU, IRD, UM 110, Campus universitaire de Luminy, case 901, 13288 Marseille cedex 09, France ; andrea.doglioli@mio.osupytheas.fr; anne.petrenko@mio.osupytheas.fr; louise.rousselet@mio.osupytheas.fr; anouck.ody@mio.osupytheas.fr; jean-michel.andre@mio.osupytheas.fr; leo.berline@mio.osupytheas.fr

2. Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, United Kingdom ; fne@pml.ac.uk

3. Sorbonne Universités (UPMC, Université Paris 06)-CNRS-IRD-MNHN, LOCEAN Laboratory, 4 Place Jussieu, 75005 Paris, France ; Francesco.dOvidio@locean.upmc.fr

4. UMS 3470 OSU Institut Pytheas, Aix-Marseille Université, CNRS/INSU,IRD, Toulon Université ; Christophe.YOHIA@univ-amu.fr; maurice.libes@osupytheas.fr

Validation of ocean colour satellite products in European coastal waters as part of the EU-FP7 HIGHROC project

David Doxaran[1], Sorin Constantin[1], Carole Lebreton[2], Veronique Creach[3], Elisa Capuzzo[3], Kate Collingridge[3], Tom Hull[3], Kai Sørensen[4], Anna Birgitta Ledang[4], Sabine Marty[4], Rodney Forster[5], Els Knaeps[6], Dimitry Van der Zande[7] and Kevin Ruddick[7]

Numerous high-quality match-ups between field measurements and satellite data are used to assess the uncertainties associated to satellite products developed in various European coastal waters as part of the HIGHROC project (www.highroc.eu). Satellite products include the spectral remote-sensing reflectance signal (Rrs, in sr^{-1}), water turbidity (T, in FNU), vertical diffuse attenuation coefficient of Photosynthetically Available Radiation (KdPAR, in m^{-1}), concentrations of suspended particulate matter (SPM, in $g.m^{-3}$) and chlorophyll-a (Chla, in $mg.m^{-3}$).High and medium spatial resolution satellite data respectively recorded by the L8-OLI and S2-MSI sensors ('S2plus' data) and by the MODIS, VIIRS and OLCI sensors ('S3plus' data) are processed using both general and regional algorithms developed in the project. Field measurements are recorded during oceanographic cruises, onboard instrumented ferries and by autonomous sensors on fixed platforms such as Aeronet-OC stations and SmartBuoys.

At all sites satisfactory results are obtained for Rrs match-ups, especially in the green, red and near-infrared parts of the spectrum (NRMSE lower than 20%), with slightly higher differences in the blue part of the spectrum. This first step constitutes a validation of the atmospheric corrections. Positive results are obtained when comparing satellite-derived products (T, SPM, and KdPAR) to field data, with typical differences (NRMSE) lower than 20% despite the wide ranges covered by these parameters (e.g., SPM varying from 0,2 to 300 $g.m^{-3}$). The remote sensing of Chla concentrations is less satsifactory (NRMSE of 30% and sometimes higher) in coastal waters dominated by non-algal particles where the use of the blue-to-green Rrs ratio reaches its limit.

[1] Laboratoire d'Océanographie de Villefranche LOV UMR7093 CNRS/UPMC, France
doxaran@obs-vlfr.fr, sorin@obs-vlfr.fr
[2] Brockmann Consult, Germany
carole.lebreton@brockmann-consult.de
[3] Cefas Laboratory, UK
Veronique.creach@cefas.co.uk, Elisa.capuzzo@cefas.co.uk, kate.collingridge@cefas.co.uk, tom.hull@cefas.co.uk
[4] Norsk Institutt for VAnnforskning (NIVA), Norway
kai.sorensen@niva.no, AnnaBirgitta.Ledang@niva.no, Sabine.Marty@niva.no
[5] Institute of Estuarine & Coastal Studies (IECS), University of Hull, UK
R.Forster@hull.ac.uk
[6] VITO, Belgium
els.knaeps@vito.be
[7] Royal Belgian Institute of Natural Sciences (RBINS), Belgium
dimitry.vanderzande@naturalsciences.be, kruddick@naturalsciences.be

The FLuorescence EXplorer FLEX – ESA's Earth Explorer 8

M. Drusch[1], M. Francois[1], R. Bock[1], A. Elvfing[1], J. Moreno[2]

In November 2015, FLEX was selected as Earth Explorer 8. The FLEX mission concept foresees a small satellite flying in convoy with Sentinel-3 with the primary mission objective to quantify terrestrial photosynthetic activity and plant stress by mapping vegetation fluorescence over land.

Sentinel-3 instruments will provide information related to the atmospheric state and land-surface characterization needed for the retrieval and interpretation of the fluorescence signal, covering the visible spectrum with OLCI and dual-angle visible/infrared and thermal infrared with SLSTR. The FLEX space segment consists of a single satellite carrying a high-resolution imaging spectrometer. The instrument, referred to as FLuORescence Imaging Spectrometer (FLORIS), will acquire data in the 500– 780 nm spectral range, with a sampling of 0.1 nm in the oxygen O_2-A (759–769 nm) and O_2-B (686–697 nm) bands. The spectral range from 500 to 677 nm will be fully covered with a spectral resolution of 3 nm and a spectral sampling of 2 nm. All measurements will be provided with an on-ground spatial resolution of 300 × 300 m^2 and a swath width of 150 km. The baseline requirement for the spatial coverage is land areas, including all in-land waters, and coastal waters within 50 km of any land. However, this requirement can evolve if sufficient interest from the ocean color community in receiving the data is expressed.

We will present the FLEX mission concept, the instrument, and offer the opportunity to discuss requirements related to the data acquisition data products, and data processing.

[1]ESA, Noordwijk, The Netherlands
[2]University of Valencia, Valencia, Spain

Monitoring water turbidity in Apalachicola Bay, Florida using combined Landsat5 TM imagery and field observations

Ishan D. Joshi[1], Eurico J. D'Sa[1], Christopher L. Osburn[2], Thomas S. Bianchi[3]

Apalachicola Bay, a productive shallow estuarine system located in the northeast Gulf of Mexico is well-known for its high water quality and oyster yields. Turbidity is an optical index of water quality and in many cases directly linked to amounts of suspended particulate matter. Although the bay has three data-logger stations to monitor water turbidity, these are inadequate to provide a synoptic view of estuarine water dynamics and its effects on the bay's turbidity. In this study, we present a robust Landsat5 TM-based empirical algorithm with seasonal thresholds to obtain estuarine-scale high-resolution turbidity maps (~30m) using long-time series (2006-2011) of Landsat5 TM imagery and in situ turbidity measurements. Data mining techniques such as principal component analysis, and classification tree-based models were utilized to decipher time-series for examining variations in physical forcings, and their effects on diurnal and seasonal variability in turbidity in Apalachicola Bay. Turbidity maps of extreme events, such as the Apalachicola River floods, passages of the cold fronts, and the hurricane landfall, revealed important information about spatial patterns of water dynamics and turbidity-levels which were previously poorly known/unknown possibly due to scarcity of field observations. The performance of the proposed algorithm has shown promising results on the latest Landsat sensor, Landsat8 OLI, which indicates that the strategy of water quality monitoring presented in this study can be used for long-term monitoring of water turbidity in Apalachicola Bay for supporting the goal of US EPA's Clean Water Act to protect human health and the environment.

[1]ijoshi1@lsu.edu, ejdsa@lsu.edu, Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA 70803, USA

[2]closburn@ncsu.edu, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, NC USA

[3]tbianchi@ufl.edu, Department of Geological Sciences, University of Florida, Gainesville, FL, USA

Surface CDOM optical properties and absorption budget in the New Zealand sector of the Southern Ocean during austral summer

Eurico J. D'Sa[1*], Hyun-cheol Kim[2]

Sea surface chromophoric dissolved organic matter (CDOM) absorption properties were examined in the New Zealand sector of the Southern Ocean along a transect encompassing various hydrographic fronts associated with the Antarctic Circumpolar Current during summer. Phytoplankton chlorophyll, dissolved organic carbon (DOC) and CDOM absorption were observed to be most elevated off the New Zealand shore and then decreased to low values (chlorophyll: 0.21 $\pm$ 0.06 mg m^{-3}; DOC: 54.19 $\pm$ 4.02 μM; and CDOM absorption coefficient (a_g325): 0.097 ± 0.061 m^{-1}) between the Subtropical (STF) and Antarctic Polar Fronts. Increases in phytoplankton biomass and DOC concentrations between the fronts were associated with meanders or eddies observed in satellite surface salinity and chlorophyll imagery. Overall, CDOM absorption was the dominant contributor to total absorption at 443 nm with implications for ocean color. A latitudinal increase in a_g325 and corresponding decrease in spectral slope S (μm^{-1}) poleward from the STF appeared to be due to a combination of factors including, decreasing CDOM photooxidation, upwelling of high-CDOM waters or bacterial CDOM production in the Antarctic Zone. a_g325 was positively correlated to chlorophyll indicating biological control. Parallel factor analysis (PARAFAC) of fluorescence spectra identified two protein-like and two humic-like components common in the global ocean with patterns of distribution that appeared influenced by both physical and biological processes. This study provides insights into surface CDOM optical properties and its transformation along a complex topographically influenced sector of the Southern Ocean that could be used to trace changes linked to the meridional overturning circulation.

[1]ejdsa@lsu.edu**,** Department of Oceanography and Coastal Sciences, Louisiana State University, Baton Rouge, LA, USA
[2]kimhc@kopri.re.kr, Korea Polar Research Institute, Incheon, S. Korea

Dynamics of colored dissolved organic matter in Pacific Islands: an application of ocean color remote sensing.

Dupouy, C.[1,*], Martias, C.[1,*], Singh, A.[2], Koliyavu, T.[2], Wattelez[1,*], G.[1], Lefèvre, J.[3], Lal, S.[4], Douillet, P.[1,*], Tedetti, M.[1], E. Holland[2]

[1] Aix-Marseille University, Toulon University, CNRS, IRD, Mediterranean Institute of Oceanography (MIO), UM 110, 13288, Marseille, Cedex 09, FRANCE,
[2] PACE-SD, Pacific Centre for Environment and Sustainable Development, The University of the South Pacific, Laucala Campus, Suva, FIJI,
[3] LEGOS, IRD, CNRS, Toulouse, CEDEX, FRANCE
[4] Department of Oceanography, University of Hawaii at Manoa, Hawaii, USA.

Email : cecile.dupouy@ird.fr

[*] IRD, Centre of Noumea, BP A5, 98848 New Caledonia

The Pacific lagoon health (New Caledonia and Fiji Island) is of prime importance for local island populations for food picking, local fisheries, water renewal and transport, recreation activities. High run offs due to rain carrying abundant chromophoric dissolved organic matter (CDOM) and particle loads may impact the functioning of ecosystems while rivers and sewage effluents may induce localized impacts. Special events of CDOM inputs along a coast-offshore continuum can be shown with Aqua MODIS satellite data. Moreover, monthly in situ data acquisition leads to validate and complete satellite observations. Indeed spectrofluorimetry analyses (excitation-emission matrices) of CDOM made in laboratory allow to identify and quantify CDOM sources and eventually points out anthropogenic pollution. This study is a project funded by GOPS, IRD and PACE-SD (USP).

- Coastal and inland water studies

Cecile.dupouy@ird.fr,chloe.martias@ird.fr,awnesh.singh@usp.ac.fj,koliyavu@yahoo.com,guillaume.wattelez@ird.fr,Jerome.lefevre@ird.fr, marc.tedetti@ird.fr, pascal.douillet@ird.fr, elisabeth.holland@usp.ac.fj, shilpashupriyalal@gmail.com

Presenter: DUPOUY C

International Ocean Colour Science Meeting, Lisbon, Portugal, 15-19 May 2017

“Exploring New Capabilities for Global Ocean Colour innovative applications”

Isaac Dura[1]

More than 10 years ago, ESA kicked off the Technology Transfer Programme Office (TTPO). Their mission is to inspire, and facilitate the use of space technology, systems and know-how for non-space applications.

ESA has been very active, promoting this program in the entrepreneurial scene, for example the 26th of November 2016, ESA sponsored the Junction hackaton in Helsinki, where there were more than 1400 competitors. ESA offered, one of the two main prizes to the best idea for the Arctic, the application HeraSpace.

HeraSpace proposed an app for optimising ocean fishing standards and best practices. Combining Copernicus satellite data with actual fishing data, fishing routes and selection could eventually be drastically improved.

Particularly interesting were the features aimed at supporting sustainable exploitation of Arctic resources. ESA link from the Junction event.

The HeraSpace team is composed for an international and highly experienced team, which is adding high doses of innovation, putting together a hype tech stack conformed, by real time data from the EUMETSAT Sentinel 3 Marine Copernicus satellite from ESA, and the Blockchain which warranties that the data performs in an unhackable system.

The HeraSpace algorithm, uses data from the Sentinel 3 satellite launched by ESA in 2014, particularly interesting is the use of the OLCI, in order to analyze the existence of chlorophyll.

The data retrieved from the Sentinel 3 satellite, delivers a very high quality real time data, contemplating variables like temperature, salinity, deep of the waters, pollution and levels of O2.

This data is crossed, with data from an expert knowledge DB (seafood domain), the preferences of the user seafood company, and of course, another input is coming from the DB of the different legal regulations of each region.

From the dynamical & real time intersection of all the mentioned inputs, HeraSpace builds the best possible route, in order to increase the company revenue, avoid administrative fines, and warranty the sustainability of the raw material (seafood).

The space tech stack is served by the Blockchain, making sure that the optimal routes can´t be hacked (copied) by pirates, and it warranties in front of the administration that the company, complies with the current legal regulations. This is due to the unhackable Blockchain connection, built by HeraSpace between the administration, and the seafood enterprises.

The toolbox for the Sentinel-3 satellite optical mission, supporting OLCI and SLSTR is of critical importance for HeraSpace. Like the parallel developments for Sentinel 1 and 2, the Sentinel 3 Toolbox is based on an evolution of the BEAM development platform. This common platform is called SNAP – SentiNel Application Platform.

With the use of the Copernicus data access, his graphical user interface and the Open Data Protocol

(ODATA). HeraSpace uses two dedicated Application Program Interfaces (API) for accessing the EO data stored in the file downloaded, using the OData protocol which accepts REST web services.

OData Service Root URI for the CODA Web Service

https://coda.eumetsat.int/odata/v1

CODA Web Service Resource Paths:

/Products /Collections

Query Options admitted by the CODA Web Service:

$format: Specifies the HTTP response format of the record e.g. XML or JSON;
$filter: Specifies an expression or function that must evaluate to true for a record to be returned in the collection;
$orderby: Determines what values are used to order a collection of records;
$select: Specifies a subset of properties to return;
$skip: Sets the number of records to skip before it retrieves records in a collection;
$top: Determines the maximum number of records to return;

The default response format is Atom[RFC4287], a XML-based document format that describes Collections of related information known as “feeds”.

The resulting products from the query can be filtered by ingestionDate, evictionDate, and also by UUID (Unique User Identifier).

They are served to the user in MD5 downloads, that can be checked using the CODA Checksum function, in order to confirm the quality of the data with respect to the original one.

Once HeraSpace will be deployed in the ESA cloud servers (Red Hat Enterprise Linux), HeraSpace will moderate the seafood industry, helping to measure the captures, boosting sustainability, and maintaining a healthy ocean ecosystem.

1. Email: isaacdura@heraspace.com Address: OsterBrooksWeg 14 b, Schenefeld, Hamburg. Germany.

http://www.esa.int/spaceinimages/Images/2016/11/Junction_ESA_Arctic_Special_Prize_winner_HeraSpace

Ecological Provinces and their Remote Signatures

Stephanie Dutkiewicz, Oliver Jahn and Mick Follows

We use a numerical global physical-biogeochemical-ecosystem model to explore the biogeography and remote signature of ecological provinces in the oceans. Ecological provinces here are defined geographically by similarity in ecosystem structure. Examining these provinces will be helpful for understanding marine foodwebs, controls on the carbon cycle and how these may change in the future. The model differentiates phytoplankton in terms of trophic strategy (autotrophy versus mixotrophy), biogeochemical function (e.g. silicifiers, nitrogen fixers), cell size (Equivalent Spherical Diameters ranging from 0.6 to >200um), and pigment composition. Complemented by a size structured population of grazers, the model sustains the global co-existence of several tens of phytoplankton types with strong seasonal and regional selection. Because this model includes an explicit radiative transfer and spectral treatment of irradiance, it also provides output that is similar to data provided by ocean color instruments. We define ecological provinces based on both the different combinations of co-existing biogeochemical functional types, and also by the number of size classes that co-occur. We find about 20 distinct provinces with large regional coverage. These provinces are three dimensional, showing distinct differences between the surface and the deep Chlorophyll maximum in many regions of the model ocean. The provinces are also dynamic, with large scale shifts over the seasonal cycle. We will present preliminary work investigating the signatures of these provinces from variables that can be detected remotely: sea-surface temperature, sea-surface height, as well as remotely sensed reflectance.

stephd@mit.edu, Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge MA 02139 USA

Spatio-temporal study of phytoplankton groups in the Levantine basin using Ocean Color data

Roy El Hourany[1, a, c], Marie Abboud-Abi Saab[2, b], Ghaleb Faour[3, a], Julien Brajard[4, c], Michel Crépon[5, c], Sylvie Thiria[6, c]

Our study revolves around the classification of phytoplankton groups and identifying biogeographic regions in the oligotrophic open waters of the Levantine basin-Eastern Mediterranean Sea using satellite ocean color data and in situ measurements.

The phytoplankton community dynamic in the open waters of this region is still ambiguous. For that, a long temporal *in-situ* database of monthly phytoplankton counts was invested, between 2002 and 2014 at a pelagic station near the Lebanese shores, belonging to the Levantine basin waters. This *in-situ* database was coupled with remote sensing reflectance at different wavelength, chlorophyll-a concentration (Chl-*a*) and sea surface temperature (SST) data issued from daily MODIS Aqua images. The classification of the compiled data was made using Kohonen self-organizing maps (SOM), which is a type of artificial neural network that is trained using unsupervised learning to produce a clustering of the input data. As a result, both microphytoplankton and nanophytoplankton groups were identified, revealing a non-linear relationship between in-situ counts and satellite data. The nanophytoplankton fraction dominated the open sea, and the microphytoplankton were confined to the coast due to nutrient exigency.

In parallel, in order to generalize this finding, a SOM was applied to monthly climatology Chl-*a* and SST cycles issued from MODIS Aqua data to observe similar behaving waters (so-called "bio-regions") in the Levantine basin. Therefore, confined bio-regions were segregated, hinting a management by the local currents. Thus, the generalization of the relationship between phytoplankton counts and ocean color data in the Levantine basin will be rigorously evaluated in latter studies.

[a] National Center for Remote Sensing, National Council for Scientific Research (CNRS), Beirut, Lebanon
[b] National Center for Marine Sciences, National Council for Scientific Research (CNRS), Batroun, Lebanon
[c] Laboratoire d'Océanographie et du Climat: Expérimentation et Approches Numériques—Institut Pierre Simon Laplace, Université Pierre et Marie Curie, BC 100, 4 place Jussieu, 75005 Paris, France;

[1] roy.hourany.00@hotmail.com
[2] mabisaab@cnrs.edu.lb
[3] gfaour@cnrs.edu.lb
[4] julien.brajard@locean.upmc.fr
[5] michel.crepon@locean-ipsl.upmc.fr
[6] sylvie.thiria@locean-ipsl.upmc.fr

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Using MERIS Sun Stimulated Fluorescence to Analyse Phytoplankton Dynamics in the Arctic

Jan Riad El Kassar [1], Jürgen Fischer [2], Rene Preusker [3] , Lena Katharina Kritten [4]

Fluorescence line height (FLH) and chlorophyll content MERIS datasets for the years 2003 to 2011 have been used to analyze the phytoplankton dynamics in the Arctic Ocean. The chlorophyll content has been taken from the Algal_1 dataset (AL1) and FLH has been processed from MERIS Level 2 water leaving reflectances. FLH has been normalized with MERIS Level 2 Photosynthetically Active Radiation (PAR). The study is limited to open ocean waters.

Monthly composites on a 0.1 x 0.1 rectangular grid have been used to create a time series of spatially averaged FLH/PAR and AL1 for the study domain for the months April to October. While AL1 showed a sinusoidal curve with peaks in summer, the FLH/PAR signal peaked in late spring and autumn with a minimum during summer.

A correlation and regression analysis between FLH/PAR and AL1 showed unimodal distributions in spring (April, May) and October with a significant linear correlation. In summer (June, July, August) and September the analysis showed bimodal distributions of FLH/PAR, indicating two separate regimes. While the upper regime showed the same linear relation as found in spring and late autumn, the lower one shows no linear correlation in the summer months.

The two regimes of the summer months were also highly visible in the stereographic plots of FLH/PAR, revealing coherent spatial patterns. The areas with high FLH/PAR are aligned to ocean currents adhering water with higher temperature and salinity in the Arctic Ocean, changing the stratification and thus altering the vertical distribution of phytoplankton.

1. jan.elkassar@met.fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
2. juergen.fischer@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
3. rene.preusker@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
4. lena.kritten@wew.fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin

The impact of temporal changes on algorithms for retrieval of *Karenia brevis* harmful algal blooms in the West Florida Shelf.

Ahmed El-Habashi,[a] Vincent Lovko[b], and Sam Ahmed[a]

We examine the impact of temporal changes on satellite retrievals of *Karenia brevis* Harmful Algal blooms (*KB* HABS) in the West Florida Shelf (WFS). These impacts are compared for retrievals from both VIIRS and MODIS-A using a number of retrieval techniques. The comparisons include our recently developed neural network (NN) technique, which uses as inputs Remote Sensing Reflectances at 486, 551 and 671 and 488, 555 and 667 nm respectively, for VIIRS and MODIS-A retrievals. Other techniques included OCI/OC3, GIOP and Semi-analytical algorithms. The accuracy of VIIRS retrievals using these techniques were then compared against all in-situ measurements available over the 2012-2016 period for which concurrent or near concurrent match ups could be obtained with VIIRS retrievals. Analysis of retrieval statistics showed that the highest accuracy was obtained with NN. The analyses also highlighted the impact of temporal variabilities on retrieval accuracies. Thus they showed the importance of having a shorter overlap time window between in-situ measurement and satellite retrieval. Retrievals with a 15 minute overlap time window showed very significantly improved retrieval accuracies over those attained with a 100 minute overlap time window. These results are believed to reflect the impact of temporal variabilities. They underline limitations on attainable satellite retrieval accuracies. Variability associated with *KB* HABs retrievals in the WFS also appear to be confirmed from consecutive overlapping VIIRS and MODIS-A images recently obtained for WFS *KB* Blooms, as well as from the results of recent field measurements.

[a]The City College of New York, Optical Remote Sensing Laboratory, Department of Electrical Engineering, 160 Convent Ave, New York, NY 10031, USA; aelhaba00@citymail.cuny.edu (A.E.); ahmed@ccny.cuny.edu (S.A.); Tel.: +1-212-650-7250; Fax: +1-212-650-8249

[b]Mote Marine Laboratories, Sarasota FL; vlovko@mote.org (V.L.)

Space and Time Variability of MODIS/AQUA derived OC and SST parameters on two major complex seamount systems (Great Meteor and Madeira-Tore)

Ricardo Fernandes[1], Clara Loureiro[1], Catharina Pieper[2], Gonçalo Piedade[1] and Ana Martins[2]

Under the framework of BIOMETORE project, several oceanographic cruises took place on two major complex seamount systems (Great Meteor and Madeira-Tore). In this study, we combine Level-2 MODIS/AQUA-1 km resolution Ocean Color (e.g. Chla, PIC, POC) and Thermal IR imagery (SST), and *in situ* oceanographic data (CTDs taken aboard R/Vs "Gago Coutinho" and "Noruega") to describe near-surface space (seamount areas: Meteor, Irving, Tyro, Atlantis, Pico do Sul, Josephine, and Gorringe) and time (August/September/October 2015 and 2016) OC and SST distributions. Monthly averages and ratios among parameters were calculated for each seamount area to detect and follow patterns of variability on all seamounts. Chla trends show similarity with POC ones (increase with latitude and proximity to the coast), while PIC and SST show reverse patterns. Some exceptions are identified. In 2015 and 2016 Chla, PIC, POC and SST three-month averages were 0.09 mg m^{-3}, 0,29x10^{-4} mol m^{-3}, 36.85 mg m^{-3}, 24.45 ^{o}C and 0.07 mg m^{-3}, 0,22x10^{-4} mol m^{-3}, 32.14 mg m^{-3}, 24.37 ^{o}C, respectively. The normalized coefficients of variation (CV) indicate that SSTs do not vary with time and location. With the exception of Gorringe Bank, Chla and POC co-vary. Highest CV is found on PIC concentrations achieving 117% on October 2016 in Pico do Sul. Chla:PIC ratios generally increase with time/space, suggesting the proximity to land areas. Other ratios were analysed to infer seamounts processes evolution with time. These results are encouraging, suggesting that remote sensors provide valuable tools for detecting synoptic space/time processes variability in open ocean areas.

[1] IMAR-Instituto do Mar, Okeanos R&D Centre, Department of Oceanography and Fisheries, University of the Azores, 9901-862 Horta, Faial, Azores. ricardofernandesal@gmail.com; c.angela.m.loureiro@gmail.com; goncalojopi@gmail.com

[2] Okeanos R&D Centre, Department of Oceanography and Fisheries, University of the Azores, 9901-862 Horta, Faial, Azores. Email addresses: catharina.pieper@gmail.com; ana.mp.martins@uac.pt

Testing the accuracy of MODIS radiance to detect river plumes by means of IBI salinity data

D. Fernández-Nóvoa[1], M. deCastro[1], M. Des[1], X. Costoya[1], R. Mendes[2], M. Gómez-Gesteira[1]

River plumes are formed in the adjacent coastal areas to river mouths by the transport of material discharged by the rivers, including sediments, nutrients, organic material, pollutants or freshwater. Therefore, river plumes present a great impact in the ocean water due to affect several parameters as light availability, coastal circulation, productivity, erosion-sedimentation processes or temperature. For these reasons is of great importance their knowledge and predictability. For that, radiance obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) represents a good choice due to the high spatial (250m) and temporal (daily) resolution provided, which allows analyzing the fine spatial and temporal structure of plumes as well as their response to the main forcing. MODIS radiance measures the ocean color generated by suspended material provided by river discharge, which is in good correlation with the surface salinity, the natural tracer of river plumes. However, could exist some differences in the frontal region between surface salinity and the turbidity measured by MODIS. Therefore, it is necessary to analyze the relation between both variables in order to know MODIS capability to detect each plume. This analysis was made for the most important Iberian rivers using salinity data provided by the Atlantic-Iberian Biscay Irish-Ocean Physics Reanalysis (IBI) database, which is included in the Copernicus Marine Service. High correlations between turbidity and surface salinity were found for rivers debouching in the northwest Atlantic coast, intermediate correlations for rivers in the southwest Atlantic coast and finally, low correlations for rivers debouching in the Mediterranean coast.

[1]Environmental Physics Laboratory, Science Faculty, University of Vigo, 32004 Ourense, Spain

{diefernandez, mdecastro, mdes, xurxocostoya, mggesteira}@uvigo.es

[2]CESAM, Physics Department, University of Aveiro, Aveiro 3810-193, Portugal

{rpsm}@ua.pt

Impacts of a wastewater diversion event on the water quality of Santa Monica Bay, California: Insights from remote sensing and the optical properties and compositional indicators of DOM

Cédric G Fichot[1], Karl Kaiser[2], Rebecca Trinh[3], Jesus M. Duran[4], Michelle M. Gierach[5], Benjamin Holt[6], and Curtis Cash[7]

The Hyperion Water Reclamation Plant is the largest sewage treatment facility in the Los Angeles Metropolitan Area. It releases a daily average of 230 million gallons of secondary treated effluent into Santa Monica Bay via a pipe outfall located 5 miles from the coast. During the Fall of 2015, maintenance on the pipe prompted the diversion of the effluent to an older 1-mile outfall and the release of wastewater in the shallow (~10 m) nearshore waters of the Bay for a period of six weeks. The diversion prompted the closure of the nearby beaches and had significant impacts on the water quality of the Bay. Water samples and field measurements were routinely collected before, during and after the diversion as part of a large sampling effort led by the City of Los Angeles to monitor the effects of the diversion. Here, we used ocean-color remote sensing, *in situ* measurements of apparent optical properties, and *in situ* measurements of optical and compositional indicators of dissolved organic matter (DOM) to assess some of the impacts of the diversion on the water quality of the Bay. The DOM optical and chemical indicators were used to discriminate between various sources of organic matter coming from the effluent, runoff, and phytoplankton blooms.

[1]*Department of Earth and Environment, Boston University, Boston, MA, USA*
cgfichot@bu.edu

[2]*Departments of Marine Sciences and Oceanography, Texas A&M University, Galveston, TX, USA*
kaiserk@tamug.edu

[3]*Lamont Doherty Earth Observatory, Department of Earth and Environmental Science, Columbia University, Palisades, NY, USA*
rtrinh@ldeo.columbia.edu

[4]*Departments of Marine Sciences and Oceanography, Texas A&M University, Galveston, TX, USA*
jesusduran@email.tamug.edu

[5]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA*
Michelle.Gierach@jpl.nasa.gov

[6]*Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA*
benjamin.m.holt@jpl.nasa.gov

[7]*City of Los Angeles, Los Angeles, CA, USA*
curtis.cash@lacity.org

Multi-decadal trends in surface ocean chlorophyll concentrations through physical environmental conditions using a statistical approach.

A supervised learning approach (Support Vector Machine; SVM) is used to create a statistical model linking satellite-derived ocean surface chlorophyll concentration (Chl) with physical parameters from atmospheric (ERA-40) and oceanic (NEMO) reanalyses over 1998-2010. The comparison between satellite *vs*. SVM-derived Chl demonstrates the efficiency of our method to assess Chl interannual variability and trends at global and regional scales. Then, this statistical model is applied to estimate Chl over 1979-2010 and assess global and regional decadal variabilities. While several regions of the ocean show significant trends on this multi-decadal time scale, some are rather driven by interannual and decadal cycles. Indeed, most of the oligotrophic gyres show a decreasing trend in Chl over the last 30-years, mostly due to an increase of stratification of the upper part of the water column. By contrast, the equatorial Pacific shows an increasing trend and a strong correlation to ENSO. Other regions (i.e. high latitudes, Indian Ocean) do not show significant trends for the 1979-2010 period, contrasting with results obtained when only considering the 1998-2010 period. This difference may be explained by the coincidence of the SeaWiFS launch in late 1997 and an exceptionnally strong El Niño/La Niña transition.

Clément Fontana[1], Elodie Martinez[1], Raphaëlle Sauzède[1], Christophe Menkes[2], Matthieu Lengaigne[3,4], Thomas Gorgues[5].

[1] Ecosystèmes Insulaires Océaniens (EIO, UMR-241), IRD, Ifremer, UPF and ILM, Tahiti, French Polynesia.

[2] Laboratoire d'Océanographie et du Climat: Expérimentations et Approches Numériques, Sorbonne Universités, UPMC Université Paris 06, IPSL, UMR/CNRS/IRD/MNHN, B.P.A5-98848, Noumea, New Caledonia.

[3] IndoFrench Cell for Water Sciences, IISc-NIO-IITM–IRD Joint International Laboratory, NIO, Goa, India

[4] LOCEANIPSL, Sorbonne Universités (UPMC, Univ Paris 06)-CNRS-IRD-MNHN, Paris, France

[5] Laboratoire d'Océanographie Physique et Spatiale CNRS/IFREMER/IRD/UBO, Institut Universitaire et Européen de la Mer, Plouzané, France

Compact deshadowing of aerial hyperspectral images

João Fortuna, Harald Martens

Hyperspectral images from e.g. manned/unmanned aircraft and satellites create Quantitative Big Data. Moreover, the measured images are affected by several types of phenomena. For instance, varying lighting conditions can make interpretation and quantification of ground phenomena difficult: variations in sunlight spectrum throughout the day due to atmospheric pollution, shadows from clouds and shadows caused by natural or man-made structures create selectivity problems that complicate the use of such images.

Here we present a generic method for compact representation of the valid information in hyperspectral images, including a preprocessing that can remove the effects of shadows and other spectral light source variations. The procedure can also be used to remove other unwanted but known effects.

Images resulting from this processing step are more easily analyzed visually by humans. In addition, the preprocessed ground and illumination images have simpler structure, so the performance of the qualitative clustering algorithms and quantitative prediction methods can also be improved.

Results are shown for hyperspectral data from the Hyperion sensor on-board the Earth Observing-1 (EO-1) satellite, as well as data from NASA's AVIRIS instrument.

joao.fortuna@ntnu.no

Continuous Optical Measurements for Calibration/Validation of Ocean Color Sensors

Robert Foster[1], Ahmed El-Habashi[1], Matteo Ottaviani[1], Eder Herrera[1], Alex Gilerson[1], Sherwin Ladner[2], Robert Arnone[3], Mike Ondrusek[4]

[1]The Optical Remote Sensing Laboratory, The City College of New York, 160 Convent Ave, New York, NY 10031

[2]U.S. Naval Research Laboratory, 1009 Balch Blvd., Stennis Space Center, MS 39529

[3]University of Southern Mississippi, 1020 Balch Blvd., Stennis Space Center, MS 39529

[4]NOAA/NESDIS/STAR, 5200 Auth Rd., Camp Springs, MD 20714

Acquiring high-quality in-situ measurements of remote sensing reflectance (R_{rs}) is extremely important for calibration and validation of orbiting ocean color sensors, such as MODIS-AQUA, NPP-VIIRS and the upcoming JPSS-VIIRS instruments. Typically, a full suite of instrumentation is deployed coincident with the satellite overpass, so as to capture a representative picture of the ocean's inherent optical properties (IOPs) for inter-comparison with satellite retrievals of the same quantities. The in-situ measurements should ideally be repeated several times spatially so as to gauge the variability within one satellite pixel. However, since atmospheric and oceanic conditions may change rapidly, satellite imagery is only considered to be representative within a short period of time (<3 hours). Much of this time is spent transiting between stations, resulting in fewer available measurements for comparison. For these reasons, continuous underway observations from water-sampling systems are of limited utility without simultaneous radiometric measurements of R_{rs}. We demonstrate that this gap can be filled by the continuous-operation of our hyper-spectral radiometer (HyperSAS-POL). Improvement in the quality and quantity of satellite match-ups is shown using this system in combination with continuous underway flowthru measurements of water IOPs. Additionally, this instrument measures the polarization state of the atmosphere and ocean which can be used for the discrimination of biogenic vs mineral hydrosol particles, the retrieval of the total attenuation coefficient, and for constraining aerosol/hydrosol microphysics in atmosphere-ocean models.

Validation of WISP-3 measurements with in situ data at an offshore aquaculture in the SW Portugal.

Bruno D.D. Fragoso[a,b], Semhar Ghebrehiwot[c], Marnix Laanen[c], Sónia Cristina[a,b], Priscila Goela[a,b], John D. Icely[a,b], Alice Newton.[b,d]

The EU funded "AQUAculture USEr driven operational Remote Sensing information services project" (AQUAUSERS) was a user driven project for the aquaculture industry that aimed to provide the industry with relevant and timely information based on the most recent satellite data and innovative optical *in situ* measurements. The Water Insight Spectrometer (WISP-3) is a handheld instrument which can provide measurements of the optical parameters Chlorophyll-a (Chl-a), Total Suspended Matter (TSM), Coloured Dissolved Organic Matter (CDOM), and the Spectral Diffuse Attenuation Coefficient (Kd). WISP-3 optical measurements, water samples for chlorophyll-a and TSM, were collected between March 2014 and November 2016 at an offshore aquaculture site off Sagres on the SW Portugal. The optical measurements were done according to the WISP user manual, ensuring an azimuth angle of ~ 135° relative to the sun to avoid direct reflectance effects (sun glint), and with a zenith angle over 30° above the horizon. A total of 329 measurements were made, but only those spectra that passed the automatic quality control were used. The Chl-a concentrations from the WISP-3 measurements at Sagres were derived from the OC4 algorithm used for the MERIS sensor (Medium Resolution Imaging Spectrometer), whilst the TSM concentrations derived from optical spectra, where a simple band ratio R(0-,720)/R(0-,500) was used for the validation of the dataset. Results will be presented from the validation of the *in situ* chlorophyll-a and TSM vs WISP-3 derived parameters.

a) Facultad de Ciencias del Mar y Ambientales, University of Cadiz, Campus de Puerto Real, Polígono San Pedro s/n, Puerto Real, 11519, Cadiz, Spain.
b) CIMA -FCT, Ed 7, University of Algarve, Campus de Gambelas, 8005-139 Faro, Portugal.
c) Water Insight BV, Netherlands, Marijkeweg 22, Wageningen 6709 PG, Netherlands
d) NILU-IMPEC PO Box 100, 2027 KJELLER, Norway.
e) Sagremarisco - Viveiros de Marisco Lda, Apartado 21, 8650-999 Vila do Bispo, Portugal.

1) fragoso.b@gmail.com
2) ghebrehiwot@waterinsight.nl
3) laanen@waterinsight.nl
4) cristina.scv@gmail.com
5) priscila.goela@gmail.com
6) john.icely@gmail.com
7) anewton.ualg@gmail.com

Estimating Ocean Raman Scattering from potential PACE OCI Hyper-Spectral Measurements in 5 nm Bands Shifted by 1.5 nm

Robert Frouin, Jing Tan

Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA

Ocean Raman scattering can be inferred from satellite hyper-spectral measurements in small spectral intervals over which solar irradiance exhibits sufficient fluctuations to separate the inelastic (Raman) signal from the elastic signal that correlates with the solar irradiance. The method consists of regressing linearly the top-of-atmosphere (TOA) signal in 5 nm bands shifted by 1.5 nm with respect to the solar irradiance. These measurements are possible with the PACE Ocean Color Instrument (OCI). Since atmospheric scattering radiance and elastic water-leaving radiance are proportional to solar irradiance, the ordinate at the origin gives access to the Raman water-leaving radiance. Suitable spectral intervals were determined, i.e., 398.5-412.5 nm, 436.5-452.5, 473.5-484.5 nm, and 509.5-519.5 nm. In these intervals, the Raman scattering signal is fairly constant, but strongly dependent on absorption by oceanic constituents. Without any correction for spectral variation of the elastic and non-elastic signals, and even in the absence of noise, large and unacceptable errors are obtained on the Raman water-leaving radiance estimates. However, the goodness of the regression fit is sensitive to the water absorption properties, even in the presence of noise, providing a way to accurately correct for spectral effects by examining the correlation coefficient change with absorption properties and selecting the maximum correlation coefficient. Using this procedure, the Raman water-leaving radiance can be retrieved with sufficient accuracy (similar to the standard deviation of the Raman signal within a given spectral interval), but only when random noise in the TOA signal is less than 0.1% in magnitude.

Ocean Color Remote Sensing Using Polarization Properties of Reflected Sunlight

Robert Frouin[1], Lydwine Gross[2]

[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, USA
[2]Capgemini, Space Unit, Toulouse, France

Ocean color remote sensing can be accomplished using top-of-atmosphere (TOA) non-polarized reflectance instead of total reflectance. The approach has several advantages: (1) the contribution of the water body to the TOA signal is generally enhanced, except over optically thick atmospheres (due to multiple scattering), (2) Sun glint is much less an issue (light reflected by the wavy surface is strongly polarized), and (3) using polarization information in addition to spectral information in the near infrared and shortwave infrared in a classic atmospheric correction scheme facilitates determining the aerosol type (e.g., polarized rate is sensitive to index of refraction). Importantly, sensitivity of the non-polarized water reflectance to chlorophyll concentration (and other biogeochemical variables) is adequate. An atmospheric correction scheme based on principal component analysis applied to simulated Plankton, Aerosols, Clouds, and Ecosystems (PACE) data in the Ocean Color Instrument (OCI) aggregated spectral bands indicates significant improvement in water reflectance retrievals when working with TOA non-polarized reflectance, with RMS errors reduced by 28% at 350 nm, 36% at 443 nm, 25% at 550 nm, and 18% at 665 nm.

Airborne shortwave infrared sensor as a tool to monitor ocean plastic pollution

Shungu Garaba [a,b], Jen Aitken [b,c], Heidi M. Dierssen [a], Laurent Lebreton [b,d] , Robert Marthouse [c], Julia Reisser [b] and Boyan Slat [b]

Ocean plastic pollution is a major environmental issue that requires better knowledge on the spatio-temporal distribution of contamination levels. Recent research has been conducted on naturally harvested marine plastic debris and common virgin plastic pellets (Garaba and Dierssen, submitted 2017). Spectral reflectance of these harvested marine plastics had notable absorption features at 931, 1215, 1417 and 1732 nm. In addition, spectra of the virgin pellets was used to establish a spectral reference library important in identifying polymer source of unknown spectra of marine harvested plastics. With an intervening atmosphere, plastics or synthetic hydrocarbons were reasonably mapped using NASA AVIRIS imagery and remote sensing algorithms established by Garaba and Dierssen (submitted 2017). Here, we demonstrate the potential of an ITRES SASI-600 hyperspectral imager with a spectral range in the shortwave infrared spectrum (SWIR, 950 - 2450 nm at 15 nm spectral sampling intervals, 100 bands) to remotely detect floating marine plastic debris. We analysed sensor data collected during the first-ever aerial survey on 2 and 6 October 2016 of the so-called Great Pacific Garbage Patch (GPGP), located between California and Hawaii. After a five hours transit from San Francisco to the GPGP area, the C-130 Hercules aircraft dropped to an altitude of 400 m, surveying 311 km^2 of sea surface, at 140 knots speed at a spatial resolution of 0.5 x 1.2 m pixels for the SASI imager and 10 cm for the RGB camera. Although vast expanses of plastic debris were not detected, spectral information from the SASI imagery showed patches of floating debris with spectral absorption features at 1215 and 1732 nm that are unique to marine plastics and observable through an intervening atmosphere. The spectra were compared to the spectral reference library of plastics to identify the closest matching synthetic polymers. This hyperspectral SWIR imagery remote sensing of floating plastic debris provides proof-of-concept results that remote sensing in SWIR wavebands can be used to identify floating marine plastics.

Corresponding author: shungu.garaba@uconn.edu

[a] Department of Marine Sciences, Avery Point Campus, University of Connecticut, 1080 Shennecossett Road, Groton, CT 06340, USA

[b] The Ocean Cleanup Foundation, Martinus Nijhofflaan 2, 2624 ES Delft, The Netherlands

[c] Teledyne Optech Inc., 7225 Stennis Airport Road 40 Kiln, MS 39665, USA

[d] The Modelling House, 8/2 Scarborough Terrace, Mt Victoria 6011 Wellington, New Zealand

Satellite-Derived Variability of Photosynthetically Available Radiation over the Tropical Oceans

Jing Tan, Robert Frouin

Scripps Institution of Oceanography, University of California San Diego, la Jolla, California, USA

The seasonal and inter-annual variability of photosynthetically available radiation (PAR) over the tropical oceans is examined using satellite imagery acquired from 1997 to 2016 by Sea-Wide Field-of-View Sensor (SeaWiFS), Moderate Resolution Imaging Spectroradiometer (MODIS), Medium Resolution Imaging Spectrometer (MERIS), and Visible Infrared Imaging Radiometer Suite (VIIRS). Spatial and temporal biases between monthly PAR estimates at 9 km resolution from different instruments are determined and corrected, resulting in a consistent time series over the 20-year record. Empirical orthogonal function (EOF) analysis is performed with both seasonal and non-seasonal PAR signals, and linear trends are quantified. Seasonal cycles dominate PAR variability, with the first three seasonal EOF modes explaining 84.9% of the total variance. The seasonal patterns are related to solar position and monsoon. Canonical El Niño Southern Oscillation (ENSO) and Modoki ENSO drive the two leading non-seasonal EOF modes, respectively, with a correlation coefficient of 0.86 between the first mode and the multivariate ENSO Index and 0.51 between the second mode and the El Nino Modoki Index. PAR decreases significantly (around -0.2 % $year^{-1}$) in the central equatorial and eastern Pacific and increases significantly (around 0.2 % $year^{-1}$) in the central Pacific around latitude 10˚S. These changes are consistent with patterns of cloud change evidenced in the satellite cloud record and predicted by global climate models. The long-term satellite PAR dataset enables correlative studies to elucidate the causes of phytoplankton variability in the tropical oceans, i.e., the role of light versus temperature and nutrients.

Quality Monitoring of an Operational Service for Ocean Colour Products based on Satellite Observations

Philippe Garnesson

In the frame of an ESA DUE project, called GlobColour, ACRI-ST Company has set up in 2005 a service which provides to the users Ocean Colour Products based on Satellite Observations.

Since 2008, the service is operated 7/7 days. It provides long-times series (1997-present) and Near Real Time (NRT) daily products based on SeaWIFS, MERIS , MODIS-A and VIIRS-N sensors.

GlobColour also serves the Copernicus Marine Environmental Service (CMEMS) and will be in charge in the coming months to disseminate the new Copernicus Sentinel-3 OLCI marine level-3 products at Global Level.

To monitor the quality of the NRT products, the level-2 upstream data coming from spatial agencies are systematically inter-compared. Synthetic maps and plots are daily generated. It has demonstrated some discrependencies between VIIRS and MODIS during the last years (it can vary temporally and spatially). The output products are also compared to climatology and In-situ observation. The results are daily reported on a web site http://cmems.acri.fr/ in the frame of CMEMS activities and will be extended to OLCI when publically available.

Philippe.Garnesson@acri-st.fr, , ACRI-ST, 260 route du Pin Montard, BP234, 06904 Sophia Antipolis, France.

Oyster aquaculture from space: monitoring chlorophyll consumption using Sentinel2

Pierre Gernez [1], David Doxaran [2], Laurent Barillé [1]

The red and near-infared (NIR) algorithm developed by Gons et al. (2005) for the Medium resolution imaging spectrometer (MERIS) was updated and applied to the Multispectral Imager (MSI) onboard Sentinel2 to retrieve chlorophyll *a* (chl) concentration in turbid coastal waters. Bourgneuf Bay along the French Atlantic coast was used here as a study site for water quality monitoring in the environmentally and economically important intertidal zones. The spatial distribution and temporal variability of Sentinel2-derived chl and suspended particulate matter (SPM) concentration were analyzed at the scale of an oyster farm over a variety of tidal conditions. Sentinel2 imagery was then coupled with shellfish ecophysiological modeling to analyze the influence of tide-driven chl and SPM dynamics on oyster clearance and chl consumption rate. Within the studied oyster farming site, chl consumption rate mirrored the changes in chl concentration during neap tides, whereas oyster clearance and chl consumption rates were both negatively impacted by high SPM concentration during spring tides.

[1] Mer Molécules Santé (MMS), Université de Nantes, Nantes, France.

[2] Laboratoire d'Océanographie de Villefranche (LOV), CNRS-UMPC, Villefranche sur mer, France.

Hyperspectral imaging system for Ocean Color observations

Alex Gilerson, Carlos Carrizo, Robert Foster, Andrii Golovin, Tom Legbandt, Fred Moshary

The Optical Remote Sensing Laboratory, the City College of New York, 160 Convent Ave, New York, NY 10031

Hyperspectral imaging of the ocean is usually implemented in the push-broom mode when cross track and wavelength dependent data are registered on a photo-detecting sensor and along track data are acquired along trajectory as the sensor, typically installed on an airborne platform, moves with the plane. This approach has significant limitations such as preventing imaging from stationary or slow moving platforms like ships, helicopters, etc. We introduce a snapshot hyperspectral imaging system for ocean observations based on a novel optical technology. This system provides hyperspectral data for each of the 50x50 pixels in the image acquired at 138 wavelengths in the range 450-1000nm with 14 bit digitization and a typical integration time of few milliseconds. Results of full calibration and characterization of the system is provided as well as the results of first experiments for ocean monitoring applications.

Email addresses:

gilerson@ccny.cuny.edu

ccarrizo@ccny.cuny.edu

rfoster01@citymail.cuny.edu

agolovin@ccny.cuny.edu

legbandt@ccny.cuny.edu

moshary@ccny.cuny.edu

Bio-optical measurements off the Southwest Coast of Portugal for ESA ocean colour sensors validation purposes

Priscila Costa Goela[a,1], Sónia Cristina[a,b,2], John Icely[a,b,3], Alice Newton[a,c,4]

An extensive validation program of ESA ocean colour sensors took place in the Southwest coast of Portugal, since 2008 (MERIS) till 2015 (OLCI). In this program, measurements were made for total chlorophyll *a* (TChl*a*) and ancillary pigments, spectral coefficients of phytoplankton, detrital and dissolved components of absorption, and water leaving reflectances. Several analytical methods were tested and the datasets were analyzed, allowing for an effective characterization of the optical properties of the region. This data was subsequently used for development and training of ocean colour algorithms.

This work presents the main outcomes of the research, focusing on: a) phytoplankton absorption coefficients and its relationship with the dynamics and size structure of microplankton communities during the study period; b) ranges of TChl*a* concentration and comparison of different measurement methods, namely spectrophotometry and high pressure liquid chromatography; c) the use of such data to develop regionalized algorithms for the retrieval of TChl*a*; and d) the influence of geophysical factors in the phytoplankton dynamics and consequent optical responses, giving special attention to upwelling events.

The region is highly dynamic in terms of bio-optical parameters, and upwelling effects prevail over coastal inputs when it comes to driving the dynamics of the phytoplankton community. As the dynamics of the phytoplankton community is so clearly reflected by the bio-optical properties of the water column, it is probable that the region is mostly Case-1 type of waters; although long-term studies and analysis of time series of inherent optical properties should be performed to confirm this hypothesis.

[a]Centre for Marine and Environmental Research (CIMA), University of Algarve, 8005-139 Faro, Portugal
[b]Sagremarisco Lda., 8650-999 Vila do Bispo, Portugal
[c]NILU-IMPEC, 2027 Kjeller, Norway

[1]priscila.goela@gmail.com
[2]cristina.scv@gmail.com
[3]john.icely@gmail.com
[4]anewton@ualg.pt

Phytoplankton physiology and export fluxes from space: Ironing out satellite-based solar-induced chlorophyll fluorescence yields

Maxim Y. Gorbunov[1], Jisoo Park[2], Fedor Kuzminov[3], Hanzhi Lin[4], and Paul G. Falkowski[5]

The fate and export of net primary production in the global ocean is tightly coupled to and largely controlled by the physiological state of primary producers. Most intense events of carbon sequestration into the ocean interior are observed when phytoplankton become physiologically stressed due to shortage of nutrients. With the launch of MODIS and MERIS satellites, it became theoretically possible to assess phytoplankton physiology from remotely sensed estimates of the quantum yields of solar-induced chlorophyll fluorescence, but the development and implementation of remote sensing algorithms have been restricted by the fundamental lack of knowledge of related mechanisms and by the lack of instrumentation for *in situ* measurements of the quantum yields in the ocean. Our recent development of portable picosecond lifetime instruments for *in situ* measurements of fluorescence lifetimes and quantum yields offers a unique tool to fill this critical gap and to validate/calibrate satellite-based retrievals of the quantum yields. Here, we present the first extensive measurements of chlorophyll fluorescence lifetimes *in situ* in the global ocean, relate these signals to phytoplankton photophysiology and nutrient stress, and compare these *in situ* measurements with satellite-based retrievals to understand the variability and controls of phytoplankton physiology in the global ocean. We further discuss the new capabilities of fluorescence kinetic measurements for exploration of photosynthetic processes in the ocean and for improving remote sensing algorithms.

[1)] gorbunov@marine.rutgers.edu; Department of Marine and Coastal Sciences, Rutgers University, NJ, USA
[2)] jspark@kopri.re.kr; Korea Polar Research Institute, Incheon, Korea
[3)] fedor.kouzminov@gmail.com; Department of Marine and Coastal Sciences, Rutgers University, NJ, USA
[4)] youralfred@gmail.com; Department of Marine and Coastal Sciences, Rutgers University, NJ, USA
[5)] falko@marine.rutgers.edu; Department of Marine and Coastal Sciences, Rutgers University, NJ, USA

Atmospheric correction of OLCI imagery over very turbid waters using the RED/NIR/SWIR bands

Gossn J.I.[1], Ruddick K.G.[2], Dogliotti A.I.[3], Nechad B.[4]

Atmospheric correction using near infrared bands (700nm-900nm) may work for clear to moderately turbid waters, but generally fails for extreme turbidities because of flattening of the water reflectance spectrum. The use of SWIR bands at 1.6µm and/or 2.3µm can be effective in extremely turbid waters, but adds significantly to the mission cost. The new 1016nm band on OLCI may help improving atmospheric correction in turbid waters at a lower marginal cost.

In this work, we endeavored to find 'atmospheric invariant' quantities to construct an atmospheric correction scheme over turbid waters. We found that if we choose a series of spectrally-close band triplets (such as 620nm-709nm-779nm), the Rayleigh-corrected reflectance of the 'middle' band after baseline subtraction (baseline residual, BLR) is essentially independent on the atmospheric conditions (including for very hazy scenes). In this work, we used three consecutive band triplets of the group of bands 620-709-779-865-1016nm to relate these three BLRs to water reflectance. To establish this relation, we used in-situ radiometric data from the La Plata Estuary (Argentina), Gironde River (France), Scheldt Estuary and Belgian Coast. We also performed a match-up analysis between OLCI and in situ-radiometric data from two measurement campaigns in a Fishermen's Pier in La Plata Estuary on January 6th-26th, 2017.
Comparison between satellite and in-situ measurements suggests that using three BLRs together effectively removes the aerosol signal. Although the BLR algorithm still needs to be improved for extremely high water turbidities, we obtained a plausible correlation between in-situ and OLCI Rayleigh-corrected BLRs from the match-up analysis.

[1] Instituto de Astronomía y Física del Espacio, CONICET/UBA, Argentina. gossn@iafe.uba.ar
[2] Royal Belgian Institute of Natural Sciences, Brussels, Belgium. kruddick@naturalsciences.be
[3] Instituto de Astronomía y Física del Espacio, CONICET/UBA, Argentina. adogliotti@iafe.uba.ar
[4] Royal Belgian Institute of Natural Sciences, Brussels, Belgium. bnechad@naturalsciences.be

Evaluation of adjacent sea-ice contamination in ocean color data at the vicinity of the ice edge

Goyens C.[1], Matsuoka A.[2], Cornet C.[3], Babin M.[4] and Bélanger S.[5]

Polar regions are characterized by an optical environment of extreme contrasts between bright sea-ice and dark ice free water. The adjacency effect of sea-ice in ocean color images will tend to reduce the sharp boundary between these two distinctive surface types. This compromises the accuracy of the ocean color products (e.g., Belanger et al., 2007; Wang and Shi, 2009). Indeed, most current standard atmospheric correction methods ignore sea-ice contamination (e.g., L2GEN and MEGS). Others implicitly consider both sub-pixel sea-ice contamination and adjacency effect in their atmospheric path radiance (e.g., POLYMER). Based on top of atmosphere reflectance simulated with a 3-dimensional radiative transfer model (3DMPCOL, Cornet et al., 2010), the present study evaluates how sea-ice contamination of the remote sensing signal affects the different atmospheric correction methods (Fig. 1). In addition, a sensitivity study is conducted to evaluate the extent of adjacent sea-ice contamination in ocean color images. The probability that a photon is scattered by the adjacent ice pixel towards the sensor is estimated as a function of (1) wavelength, (2) distance to the ice edge, (3) illumination and viewing geometry, (4) atmospheric turbidity and (5) surface reflectance. Results confirm the large errors in remote sensing reflectance resulting from sea-ice contamination. The study also provides avenues for improving these algorithms in presence of sea-ice floes. This is illustrated with a nadir-viewing Landsat-8 image (Fig. 2).

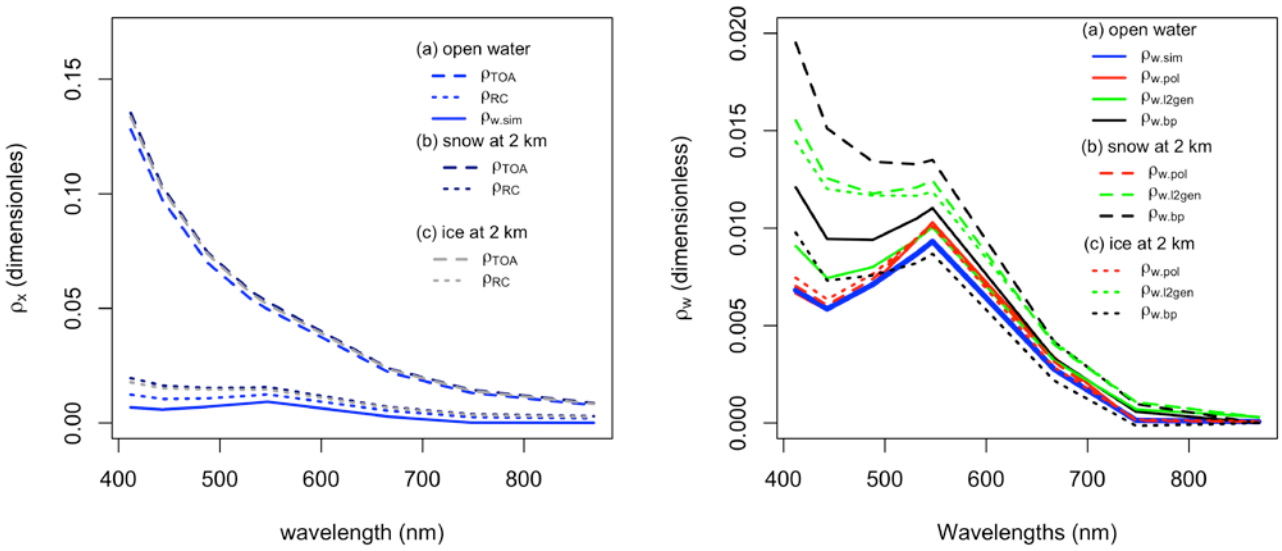

Figure 1. Left panel: Simulated water reflectance, $\rho_w(\lambda)$, top-of-atmosphere, $\rho_{TOA}(\lambda)$ and rayleigh-corrected reflectance, $\rho_{rc}(\lambda)$. $\rho_{TOA}(\lambda)$ (dashed line) and $\rho_{rc}(\lambda)$ (dotted line) spectra are shown for the following three scenarios in different colors. Scenario (a) (in blue) assumes water reflectance for all pixels. Scenario (b) (in dark blue) assumes a reflectance of a pixel to be snow located 2 km away and the others representing reflectance of water. Scenario (c) (in grey) assumes a reflectance of a pixel to be bare-ice located 2 km away and the others

being reflectance of water. Right panel: Simulated water reflectance, $\rho_{w.sim}(\lambda)$ (solid blue line) is re-drawn from the left panel. Three different atmospheric correction (AC) algorithms are considered: POLYMER (red), NASA standard L2GEN (green), and Black Pixel Assumption, BP (black). The spectral water reflectance estimated with each AC method is referred to as $\rho_{w.pol}(\lambda)$, $\rho_{w.l2gen}(\lambda)$ and $\rho_{w.bp}(\lambda)$.

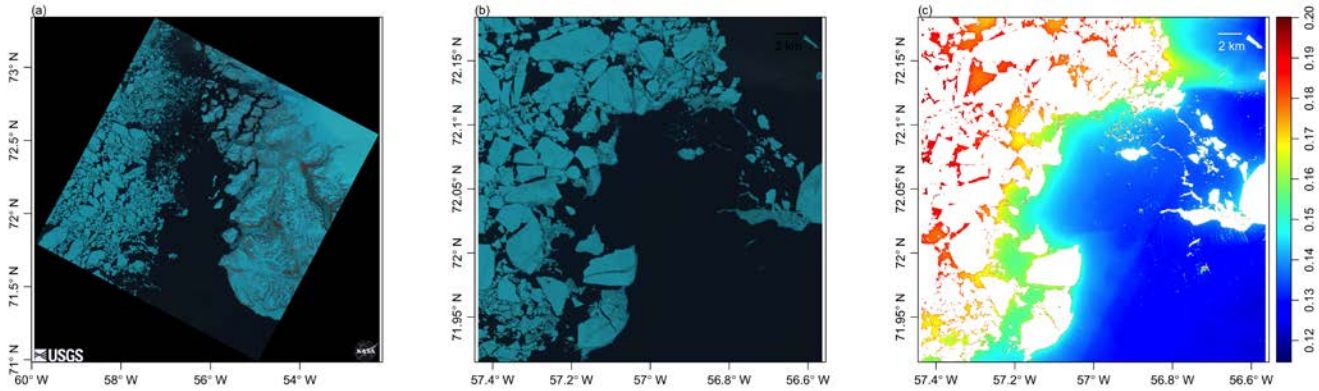

Figure 2. True color nadir viewing Landsat-8 Tile LC80160092014153 taken in the Ban Bay on June 2, 2014 (a), subset of the Landsat-8 Tile LC80160092014153 (b) and top-of-atmosphere reflectance over the water pixels at 443 nm over a subset of the Lansat-8 Tile (c).

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[1.] Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, QC G5L 3A, Canada, Email: clemence.goyens@takuvik.ulaval.ca
[2.] CERC sur la télédétection de la nouvelle frontière arctique du Canada, Takuvik Joint International Laboratory, Université Laval (Canada) - CNRS (France) , 1045, Avenue de la Médecine, Québec QC G1V 0A6, Canada , Email: atsushi.Matsuoka@takuvik.ulaval.ca
[3.] Laboratoire d'Optique Atmosphérique, UMR CNRS 8518, Université des Sciences et Technologies de Lille, Villeneuve d'Ascq, France, Email: celine.cornet@univ-lille1.fr
[4.] CERC sur la télédétection de la nouvelle frontière arctique du Canada, Takuvik Joint International Laboratory, Université Laval (Canada) - CNRS (France) , 1045, Avenue de la Médecine, Québec QC G1V 0A6, Canada , Email: marcel.Babin@takuvik.ulaval.ca
[5.] Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, QC G5L 3A, Canada, Email: Simon_Belanger@uqar.ca

Demonstration of Sentinel-2 capabilities for coastal waters applications

Lydwine Gross[1], Nicolas Susperrégui[2], Philippe Goryl[3]

The purpose of this project was to show the added value of Sentinel 2 to the survey of coastal areas, putting forward first the use of its spatial resolution, which starts at 10 meters and allows us to monitor very detailed areas, at a scale of a small city, second, the use of its spectral resolution, which allows the survey of shallow and turbid waters (namely “case 2” waters) as of open ocean (namely “case 1” waters) and third, the use of its revisiting elapsed time (at most five days everywhere if we use both Sentinel 2A and Sentinel 2B).

In order to achieve this goal, we performed an atmospheric correction of S2A-MSI level 1C products and bio-optics estimations of water content over different areas on the planet: Bayonne area (France) where there is a mucilage pollution problem which impacts local fishermen, the Gironde estuary in France, Den Haag estuary in the Netherlands, Rio de La Plata (Buenos Aires estuary), the Baltic sea above Kiel and Flensburg (Germany). The methodology we used for this demonstration is based on Machine Learning techniques (Principal component Analysis and Multi-Layered Perceptrons). Theoretical performance of the atmospheric correction is computed using realistic simulated water leaving reflectance at 15 wavelengths from 412 to 2135 nm, generated using all kind of atmosphere and surface conditions (solar zenith angles, aerosols loading, wind speed,…) over open ocean and coastal waters (sediments loading going up to 2 $g.m^{-2}$). Mean RMS error over all wavelengths is 0.00334 with no bias.

1: lydwine.grosscolzy@capgemini.com, Capgemini Technology Services, 109 avenue Eisenhower - BP 53655 - 31086 Toulouse Cedex 1, France

2 : n.susperregui@institutdesmilieuxaquatiques.fr, Institut des Milieux Aquatiques, 1 rue de Donzac - BP 106, 64 101 Bayonne Cedex, France

3: Philippe.Goryl@esa.int, ESA ESRIN, Via Galileo Galilei, 00044 Frascati RM, Italia

Optically estimating CDOM composition across diverse spectral ranges

Brice Grunert, Colleen Mouw, Audrey Barnett

Satellite remote sensing of colored dissolved organic matter (CDOM) has focused on CDOM absorption (a_{CDOM}) at a reference wavelength, as its magnitude provides insight into the underwater light field and large-scale biogeochemical processes. CDOM spectral slope, S_{CDOM}, has been treated as a constant parameter despite significant regional and temporal variability. S_{CDOM} and other optical metrics provide insights into CDOM composition, processing, food web dynamics, and carbon cycling. However, much of this work relies on fluorescence techniques or a_{CDOM} in spectral ranges unavailable to current and planned satellite sensors (e.g. <300 nm). Recently, a new method for fitting specific chromophores in a_{CDOM} spectra with Gaussian components was proposed, but the feasibility of adapting this method to wavelengths anticipated with future hyperspectral satellite remote sensing ($\lambda > 350$) has not been addressed. Here, we applied the Gaussian decomposition method to publicly available a_{CDOM} spectra to investigate if the retrieved S_{CDOM} and Gaussian components provide insight into CDOM composition and degradative state. We iteratively decreased the spectral range considered and analyzed the number, location and magnitude of fitted Gaussian components to determine how sensitive the components are to the spectral range considered. We compared the fitted slope from the Gaussian decomposition approach to absorption-based indices that indicate CDOM composition to determine the ability of satellite-derived slope to inform the analysis and modeling of large-scale biogeochemical processes. By analyzing these CDOM metrics across diverse biogeochemical provinces, we present implications of the observed variability for remote sensing of CDOM characteristics via S_{CDOM}.

Coastal High Acquisition Rate Radiometers for Innovative Environmental Research (C-HARRIER) Mission beginning in 2017

Guild, Liane[1], Stanford Hooker[2], Raphael Kudela[3], John Morrow[4], Stephen Dunagan[1], James Eilers[1], and Lauren Fahey[5]

C-HARRIER enhances an existing airborne radiometer suite for improved apparent optical property (AOP) measurements in coastal and inland waters that have been challenging for satellites due to technical remote sensing gaps. Relative to open ocean remote sensing, the coastal zone is optically complex and highly dynamic in space (both vertically and horizontally) and time. Measurements supporting coastal water quality, phytoplankton dynamics, plumes, and blooms necessitate sensors with a high signal-to-noise ratio (SNR), particularly in the visible range, as well as high spatial and temporal resolution. The technical gap in calibration, validation, and research (CVR) activities using ocean imagery is the sparse distribution of AERONET stations (atmospheric measurements) in open and coastal oceans, and exacerbated by the almost complete lack of coincident ocean color and atmospheric measurements collected at stations all needed to correct the imagery. A C-HARRIER mission enables simultaneous CVR measurements of ocean and atmospheric radiance from an airborne platform collecting larger spatial domain measurements during a satellite overpass or while simultaneously collecting ocean color imagery on the same aircraft. The NASA Ames Coastal Airborne In-situ Radiometers (C-AIR) and Goddard Compact-Airborne Environmental Radiometers for Oceanography (C-AERO) consist of highly accurate microradiometers with enhanced spectral range (320-1640 nm), matching wavebands, and calibration traceability for high fidelity AOP measurements. The SWIR channels advance the state of the art for characterizing aerosol optical depth and optimizing atmospheric correction schemes to improve the derivation of remotely sensed water-leaving radiances, while the UV channels allow for exploration of "anchor" points for constraining aerosol models.

[1]NASA Ames Research Center, MS 245-4, PO Box 1, Moffett Field, CA 94035, USA, liane.s.guild@nasa.gov, stephen.e.dunagan@nasa.gov, james.a.eilers@nasa.gov

[2]NASA Goddard Space Flight Center, Greenbelt, MD, USA, stanford.b.hooker@nasa.gov

[3]University of California, Santa Cruz, Santa Cruz, CA, USA, kudela@ucsc.edu

[4]Biospherical Instruments, Inc., San Diego, CA, USA, morrow@biospherical.com

[5]Bay Area Environmental Research Institute/NASA Ames Research Center, Moffett Field, CA, USA, lauren.e.fahey@nasa.gov

Remote Sensing of *Trichodesmium* spp. mats in the open ocean of the Southwestern Tropical Pacific

G. Rousset[1], C. Dupouy[2], F. De Boissieu[3], J. Lefèvre[4], M. Rodier[5], S. Laran[6], V. Ridoux[6], G. Roudault[7], L. Gardes[8], C.Menkes[1]

Trichodesmium is considered the main nitrogen-fixing species, especially in the South Pacific region a hot spot for diazotrophy. Due to the paucity of in situ observations, alternative methods for estimating the presence of Trichodesmium must be sought to evaluate the global impact of these species onto primary production. Toward that end, a number of satellite-derived algorithms have been derived to detect the presence of Trichodesmium surface blooms. To date, estimating the statistically robust accuracy of these methods is rendered almost impossible by the paucity of in situ measurements. Here, we use a series of new cruises as well as airborne observational surveys in the South western Tropical Pacific to estimate the statistical agreement between these methods and the in situ measurements. We use the MODIS 250m to perform such estimations and show that previously published methods bear some limitations and problems in the South Pacific (resolution, clouds, atmospheric correction, etc.).

[1] *LOCEAN, Noumea, New Caledonia*
[2] *AMU, Toulon Univ. CNRS, IRD, M.I.O., Noumea, New Caledonia,*
[3] *IRSTEA, Montpellier, France*
[4] *LEGOS, IRD, Noumea, New Caledonia*
[5] *EIO, IRD, Tahiti, French Polynesia*
[6] *Observatoire PELAGIS - La Rochelle U., CNRS, La Rochelle,*
[7], *UMR LEMAR, IRD, Plouzané, France*
[8] *Agence Française pour la Biodiversité, Nouméa, New Caledonia*

Guillaume.rousset@.fr, Christophe.menkes@ird.fr,

Cecile.dupouy@ird.fr,

florian.deboissieu@irstea.fr,

jerome.lefevre@ird.fr,

martine.rodier@ird.fr,

slaran@univ-lr.fr,vridoux@univ-lr.fr,

gildas.roudaut@ird.fr,

lionel.gardes@afbiodiversite.fr

Presenter: DUPOUY C

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Machine learning approaches to coastal water quality monitoring using LandSat TM and ETM+ data

Sidrah Hafeez[1] and Dr. Charles Man-sing WONG[2]

Department of Land Surveying & Geo-Informatics, The Hong Kong Polytechnic University
Kowloon, Hong Kong

Since coastal waters are sensitive marine ecosystem and vulnerable to pollution from anthropogenic activities. It is important to monitor water quality in these areas. This study attempts to estimate spatial concertation of six optically active water quality parameters, chlorophyll-a (chl-*a*), phaeo-pigment (PAHE), turbidity (TURB), suspended solids (SS), volatile suspended solids (VSS) and secchi disk depth (SDD) over Hong Kong's coastal waters. Three machine learning approaches including neural network (NN), random forest (RF) and support vector machine (SVM) were evaluated for regression and classification tasks. Twelve years Landsat TM and ETM+ data (21 images) with 58 *in-situ* observation (2000-2012) resulted in 238 samples, which were used for models development. 70% data was used for training of machine learning methods and 30% for testing. Results shows that RF outperform the two machine learning approaches, yielding calibration R^2 0.96, 0.97, 0.97, 0.97 and 0.96 and RMSE were 0.98 µg/L, 1.71 NTU, 1.22 mg/L, 0.29 m and 0.24 mg/L while estimating chl-*a,* TURB, SS, SDD and VSS respectively. NN outperformed the two machine learning approaches in case of (PAHE) estimation with R^2 0.85 and RMSE 0.56 µg/L. Three machine learning methods were then used for classification task. 10-fold cross validation was used to assess the performance of classification method. RF performed best with 92% accuracy (kapa statistics 0.89, RMSE 0.15) and NN results were also very close to RF with 90 % accuracy (kapa statistics 0.86, RMSE 0.18). Satellite data with machine learning approaches is considerable approach to estimate spatial variably of water quality parameter and classification of coastal waters.

1. Sidrah.hafeez@connect.polyu.hk
2. ls.charles@polyu.edu.hk

Systemic development status of GOCI-II Ground Segment(G2GS)

Hee-Jeong Han[1] , Jae-Moo Heo[1], Hyun Yang[1], Seongick Cho[1], Sunghee Kwak[2], Taekyung Lee[2], Youngje Park[1]

In 2019, the GOCI-II, second geostationary ocean color sensor of the Republic of Korea, will be launched and its ground segment will be operated regularly. According to GOCI-II specification which is higher than GOCI, we have to develop new ground segment (GS) systems to meet several requirements like timeliness, accuracy, availability, consistency. System development is composed of a. development of data processing algorithms/systems, b. development of ground-based operation systems, and c. development of GS infrastructure. Data processing algorithms are newly developed by applying several bands that have been added to the GOCI-II, and the existing GOCI algorithms will be reused after verification. G2GS systems are developed with six subsystems, data acquisition (DAS), data correction (DCS), data processing (ODPS), data management (DMS), operations and quality management (OQMS), precision correction (PCS). The GS infrastructure will be newly installed in KIOST complex in Busan. The system designed to satisfy the system requirements with the latest IT technologies like automation, parallel processing, optimization, high-performance hardware. The current detailed design has reached the end of the course, completing the interface, screen, component, class, and data diagram design. The system will be finalized in 2018, and tested until launch of GOCI-II. Also, separate data analysis software and data distribution systems for user will be provided after launch.

han77@kiost.ac.kr
[1]Korea Institute of Ocean Science and Technology, Korean Ocean Satellite Center, Ansan, Korea 15627
jaemu@kiost.ac.kr
[1]Korea Institute of Ocean Science and Technology, Korean Ocean Satellite Center, Ansan, Korea 15627
yanghyun@kiost.ac.kr
[1]Korea Institute of Ocean Science and Technology, ICT R&D Unit, Ansan, Korea 15627
sicho@kiost.ac.kr
[1]Korea Institute of Ocean Science and Technology, Korean Ocean Satellite Center, Ansan, Korea 15627
shkwak@satreci.co.kr
[2]Satrec Initiative Co. ltd, Daejeon, Korea 34051
tklee@satreci.co.kr
[2]Satrec Initiative Co. ltd, Daejeon, Korea 34051
youngjepark@kiost.ac.kr
[1]Korea Institute of Ocean Science and Technology, Office of Vice president, Ansan, Korea 15627

The Re-analysis for satellite retrieved Chlorophyll-a in East China Sea

Zengzhou Hao, Delu pan, Fang Gong, Xianqiang He

State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, China, (hzyx80@sio.org.cn)

Satellite observation is an important way to understanding the variation of marine environments. It is noted that the satellite-retrieved raw ocean color products, such as the chlorophyll, have some missing data on large area where the clouds and heavy aerosols covered or other reasons. In order to monitor their changes and assess their influence on the marine ecosystems or climate, the long-term synchronous and full covered data are needed. The Geostationary Ocean Color Image (GOCI), which is one of sensors onboard COMS Geostationary satellite, observes the East China Sea hourly during the daytime (8 times observation in daytime) and provides nice opportunity to show the diurnal variation of the marine environment which different from the multi-satellite observations during a day. In this study, the hourly remote sensing data of Chlorophyll-a on 2015 in the East China Sea is reconstructed and re-analyzed using the Data Interpolation Empirical Orthogonal Functions (DINEOF) and Optimal Interpolation (OI). The error and variability are examined by some selected valid observations. The results show that the re-analyzed chlorophyll-a products could reveal its tempo-spatial variation features basically and can describe or reappear the Chlorophyll-a distribution characteristics in multi-scale processes.

Atmosphere and sunglint correction of Landsat-8 and Sentinel-2 data for water quality monitoring of lakes from space (TELQUEL project)

Tristan Harmel[1,2], Malik Chami[3,4], Thierry Tormos[5], Nathalie Reynaud[2], Pierre-Alain Danis[5]

Monitoring water quality from space relies primarily on our ability to retrieve the water-leaving radiance from satellite measurements. This can be achieved after accurate removal of the atmosphere and water surface signals. On the other hand, remote sensing of small lakes and reservoirs requires high spatial resolution capabilities. Recently, two decameter spatial-resolution satellites were launched, Sentinel-2 A and B (ESA), providing extended dataset in the continuation of that initiated by the Landsat missions (NASA). However, the near-nadir viewing geometries of those satellites make them very vulnerable to sunglint contamination (i.e., sunlight reflected on the air-water interface).

In this poster, the atmospheric correction and deglinting chain developed for the TELQUEL project (CNES) is presented. Atmospheric correction (AC) is based on precise radiative transfer computations and ancillary data from the AERONET network. Sunglint correction is achieved simultaneously to the AC step. For a given pixel, the sunglint contribution is estimated from the shortwave-infrared (SWIR) part of the spectrum. Then, the sunglint signal is extrapolated toward the near-infrared and visible bands based on its proper optical properties. We showed that the spectral variation of bidirectional reflectance distribution function (BRDF) related to the sunglint is around 30% from the SWIR to the blue bands of Sentinel-2. Application of the TELQUEL chain on hundreds of Sentinel-2 and Landsat-8 images demonstrates that sunglint patterns are satisfactorily removed over the entire images whatever the altitude of the observed target. Comparison with ground-based data showed strong correlation between satellite and *in situ* data (R^2~0.9).

1. Sorbonne Universités, UPMC Univ Paris 06, INSU-CNRS, Laboratoire d'Océanographie de Villefranche, 181 Chemin du Lazaret, 06230 Villefranche sur Mer, France
2. Irstea, UR RECOVER, Pôle AFB-Irstea Hydroécologie des Plans d'eau, 3275 route Cézanne, F-13182 Aix-en-Provence, France
3. Sorbonne Universités, UPMC Univ Paris 06, INSU-CNRS, Laboratoire Atmosphères Milieux Observations Spatiales (LATMOS), 4 place Jussieu 75252 Paris Cédex 5, France
4. Institut Universitaire de France, 1, rue Descartes, 75231 Paris Cedex 05, France
5. Agence Française pour la Biodiversité, Pôle AFB-Irstea Hydroécologie des Plans d'eau, UR RECOVER, 3275 route Cézanne F-13182 Aix-en-Provence, France

Cross-calibration of the Chinese geostationary satellite GF-4 based on the GOCI data

Xianqiang He, Delu Pan, Yan Bai

State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

GF-4 is the Chinese high resolution geostationary satellite, which was launched on Dec. 29, 2015. It has the spatial resolution about 50m, and cover about 500km*500km areas for each image. In addition, GF-4 has very high temporal resolution up to several minutes per image. The design life for GF-4 is 8 years. Although the GF-4 is not design for the ocean color remote sensing, it has capacity to monitoring the high dynamic of the suspended particles (TSM) in the turbid coastal waters. There are four width bands which can be used to retrieve the ocean color information, including the 0.45-0.52μm, 0.52-0.60μm, 0.63-0.69μm and 0.76-0.90μm. Unfortunately, GF-4 has no onboard calibration instrument. In this study, we used the Geostationary Ocean Color Imager (GOCI) onboard the COMS satellite to calibrate the GF-4. The GOCI is the world's first geostationary satellite ocean color sensor, which has high radiance calibration accuracy and signal to noise ratio. Considering the different geometries of the sun and sensor angles, the upward radiances entering the GF-4 were simulated based on the GOCI data, and the calibration coefficients were derived. Finally, an atmospheric correction algorithm was developed for the GF-4 data, and the results showed that GF-4 can monitoring the TSM dynamic in the coastal waters.

Seasonal to long-term variability of chlorophyll, suspended particles and CDOM in Long Island Sound, USA

Fernanda Henderikx Freitas[1] and Heidi Dierssen[2]

Remote sensing of biogeochemical properties in estuarine waters has long been challenging. In these regions, phytoplankton blooms and suspended sediment plumes evolve rapidly and optical properties are convoluted by the presence of dissolved and particulate materials of various compositions. Here, we use 14 years of MODIS-Aqua remote sensing reflectances (Rrs) to derive proxies for phytoplankton, suspended particles, and color dissolved organic matter (CDOM) distributions at Long Island Sound. Validation of Rrs with in situ data showed encouraging results for all wavelengths except 412nm and 443nm. An alternative approach to estimate chlorophyll a concentrations (Chl) using MODIS wavelengths in the red portion of the spectrum was developed, with improved results over the standard ocean color products. Analysis revealed a decreasing trend in Chl of 11% over the 14-year period, consistent with long-term nutrient reductions, while seasonality showed prevalence of summer/fall blooms in surface waters, which is consistent with yearly hypoxia patterns but inconsistent with previous studies. CDOM was estimated as the signal difference between the standard and red-band Chl approaches. Particle backscatter (bbp) was estimated using an optimized version of the QAA bio-optical algorithm. EOF analysis was used to extract spatial-temporal patterns of variability in optical parameters, as well as to evaluate connections with physical forcings. Results showed that bbp distribution at LIS, for instance, is largely modulated by surface gravity wave activity, despite intense contribution of stormwater discharge to the system. These observations demonstrate the importance of regional tuning to a more accurate depiction of bio-optical variability in optically-complex waters.

[1,2] University of Connecticut, Groton, CT 06340
[1] fernanda@eri.ucsb.edu
[2] heidi.dierssen@uconn.edu

Improving spatial surface chlorophyll-a data of the Canadian west coast through multi-sensor merging and cloud-filling interpolation

Andrea Hilborn[1], Maycira Costa[2]

ABSTRACT

The Salish Sea of British Columbia, Canada, is a highly productive marine region in which the study of phytoplankton phenology is of key relevance. However, in these waters, retrieving surface chlorophyll-a (chla) data from satellite-based sensors is hindered by cloud cover, oceanic optical complexity, and seasonal light conditions. The objective of this analysis is to improve the spatio-temporal coverage of chla data in the Salish Sea in two components: (1) integration of data from multiple satellite-based ocean colour sensors, and (2) increase spatial coverage using an EOF-based interpolation. The final goal of these efforts is to improve the quantitative, regional descriptions of phytoplankton bloom phenology achievable in this region by ocean colour remote sensing. To address the first objective, chla data was retrieved from the MODIS-Aqua and Suomi-NPP VIIRS sensors through a combination of SWIR and MUMM atmospheric correction paired with OC3 chlorophyll algorithms. Chla retrievals from both sensors were assessed relative to a dataset of ferry-based flow-through fluorescence measurements. Secondly, the data-interpolating empirical orthogonal functions method (DINEOF) was applied to the L3 chla dataset. This was tested for sensitivity to study area size, time period and input dataset type (i.e. daily vs. weekly L3BIN). The implementations were validated relative to the original time series and a cross-validation data subset, showing the daily image time series divided annually are reconstructed effectively (95.6% explained variance, RMSE=1.6 mg/m^3, R= 0.92). The final application was to describe phenology characteristics for the region, for which a threshold-based method was applied.

1. andreahilborn@gmail.com; University of Victoria, 3800 Finnerty Road, Victoria, British Columbia, Canada, V8P 5C2
2. maycira@uvic.ca; University of Victoria, 3800 Finnerty Road, Victoria, British Columbia, Canada, V8P 5C2

Adding a dinoflagellate PFT for the California Current System

Houskeeper, Henry[1]; Kudela, Raphael[2]

Ocean color remote sensing of the California Current System (CCS) has shown trends of increasing surface chlorophyll-a concentration (Chla) and primary productivity [1],[2],[3]. However, blooms of different phytoplankton types exhibit different effects on the remote sensing estimation of Chla [4], as well as on the environment, and phytoplankton blooms measured *in situ* indicate a shift in the region's dominant phytoplankton type, from diatoms to dinoflagellates, following the summer of 2004 [5].

Partitioning remotely sensed Chla into different phytoplankton functional types (PFTs) for the CCS is necessary to interpret trends in primary productivity and to understand ecosystem shifts that may accompany changes in measured Chla. Radiance anomaly PFT methods such as PHYSAT [6] have successfully characterized diatoms in optically simple waters, but adding a dinoflagellate PFT has been challenging because of dinoflagellates' low but ubiquitous presence in open ocean waters. In Monterey Bay, CA, a marine sanctuary in the central CCS, seasonal diatom and dinoflagellate blooms drive first order variability in Chla, and produce high-biomass blooms on time scales appropriate for characterization with ocean color sensors (days-weeks). We evaluate the addition of a dinoflagellate PFT for this region using a radiance anomaly method adopted from PHYSAT, and compare high biomass bloom signals. We show a radiance anomaly timeseries for the region, and compare with phytoplankton blooms measured *in situ* to both validate and test possible applications of this approach for observing regional phytoplankton community shifts.

[1]hhouskee@ucsc.edu; University of California, Santa Cruz, Ocean Sciences Department, Santa Cruz, CA 95064, USA

[2]kudela@ucsc.edu; University of California, Santa Cruz, Ocean Sciences Department, Santa Cruz, CA 95064, USA

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Thermal gradients shape spatial distribution of *Microcystis* in Lake Kinneret

Aya Hozumi[1], Ilia Ostrovsky[2], Assaf Sukenik[3], Hezi Gildor[4]

Phytoplankton abundance and composition can alter the water quality of the lake. In the case of Lake Kinneret, a winter-spring bloom of *Microcystis* spp., a toxin-producing cyanobacterium, occurs and affects the water quality of this freshwater reservoir. High-spatial resolution (<10cm) of *Microcystis*' subsurface distribution was measured at stations using a laser diffractometer (LISST) and lab analyses (e.g. FlowCam, spectrofluorometer) during the bloom in 2017. It is important to resolve the vertical distribution near the surface because *Microcystis* control their buoyancy to aggregate at the surface, which can be disrupted by mixing caused by wind, currents, etc. Observations showed the vertical distribution of *Microcystis* was closely related to thermoclines. They responded to multiple thermoclines that were often near the surface (<0.2 and ~1.2m) and had varied thermal gradients (0.2-3˚C). Meteorological data indicated higher air temperature and lower wind speed, both of which contribute to a stable water column, coincides with stronger *Microcystis* volumetric concentration gradients ($1.3x10^6$ vs $1x10^5 \mu l l^{-1}$). We then investigated the feasibility to estimate *Microcystis* concentrations from MODIS/VIIRS 4km resolution data by comparing them with *in-situ* measurements. Use of OLCI-3A 1km resolution data instead will improve the scarcity of data from low-spatial resolution and cloud coverage. The OLCI-3A observations will examine how wind and currents influence the surface horizontal patchiness observed in the lake. Understanding the environmental conditions that shape the 3D distribution of *Microcystis* will lead to predictions of the intensity, timing, and spatial variability of its blooms at Lake Kinneret and aid in the water quality management.

[1] aya.hozumi@mail.huji.ac.il, The Fredy & Nadine Herrmann Institute of Earth Sciences, The Hebrew University Givat Ram, Jerusalem Israel
[2] ostrovsky@ocean.org.il, Kinneret Limnological Laboratory, P.O.B. 447, Migdal Israel
[3] assaf@ocean.org.il, Kinneret Limnological Laboratory, P.O.B. 447, Migdal Israel
[4] hezi.gildor@mail.huji.ac.il, The Fredy & Nadine Herrmann Institute of Earth Sciences, The Hebrew University Givat Ram, Jerusalem Israel

Applications of ocean color data in fisheries science and management

Kimberly Hyde[1], Geret DePiper[2], Kara Dodge[2], Michael Fogarty[2], Kevin Friedland[1], Robert Gamble[2], Brian Grieve[1], John Hoey[1], Veronica Lance[3], John Manderson[4], Darien Mizuta[5], David McElroy[2], Mike Morin[1], Ryan Morse[1], Chris Orphanides[1], David Richardson[1], Vincent Saba[6], Michelle Tomlinson[7], Howard Townsend[8], Ronald Vogel[9], Mark Wuenschel[2]

Ocean color data have tremendous potential for use in science and management of living marine resources. At the NOAA Northeast Fisheries Science Center (NEFSC), ocean color satellite data are used for a wide range of operational and research applications including ecosystem modeling, habitat modeling, fisheries bycatch models, aquaculture siting, and protected species assessments. In addition, ocean color products are used to study ecosystem productivity, species distribution, recruitment success, fish condition, and fishing trends. Near-real-time applications include adaptive sampling for targeted species and the potential of combining satellite data with real-time measurements collected from fishing vessels to detect the duration of convergence and divergence zones, which are critical to investigating fishery dependent catch rates. Long-term science quality time series of satellite data are crucial for characterizing and monitoring changes of marine ecosystems and its resulting influence on the phytoplankton community and living marine resources. Most NEFSC fisheries research and management are conducted on the continental shelf within the 200 mile economic zone, thus there is a critical need for high quality, regionally tuned ocean color products in the near shore regions. Other remote sensing products and requirements identified by NEFSC fisheries scientists include gap filled chlorophyll products that incorporate data merged from multiple satellites, frontal gradient indices, and estimates of size fractionated primary production. Convenient access to suitable satellite data products, including regionally tailored products, is necessary to support the NEFSC mission.

[1] NOAA Northeast Fisheries Science Center, Narragansett Laboratory, 28 Tarzwell Dr., Narragansett, RI 02882, USA; kimberly.hyde@noaa.gov, , kevin.friedland@noaa.gov, brian.grieve@noaa.gov, john.hoey@noaa.gov, mike.morin@noaa.gov, ryan.morse@noaa.gov, chris.orphanides@noaa.gov, david.richardson@noaa.gov
[2] NOAA Northeast Fisheries Science Center, Woods Hole Laboratory, 166 Water St., Woods Hole, MA 02543, USA; geret.depiper@noaa.gov, kara.dodge@gmail.com, michael.fogarty@noaa.gov, robert.gamble@noaa.gov, david.mcelroy@noaa.gov, mark.wuenschel@noaa.gov
[3] NOAA CoastWatch/OceanWatch Program, 5830 University Research Court, College Park, MD 20740, USA; veronica.lance@noaa.gov; and Global Science and Technology, Greenbelt, MD 20770, USA
[4] NOAA Northeast Fisheries Science Center, James J. Howard Marine Sciences Laboratory, 74 Magruder Rd., Sandy Hook Highlands, NJ 07732, USA; john.manderson@noaa.gov
[5] NOAA Northeast Fisheries Science Center, Milford Laboratory, 212 Rogers Ave., Milford CT 06460, USA; darien.mizuta@noaa.gov
[6] NOAA Northeast Fisheries Science Center, Geophysical Fluid Dynamics Laboratory, 201 Forrestral Rd., Princeton, NJ 08540, USA; vincent.saba@noaa.gov
[7] NOAA National Ocean Service, 1305 East-West Highway, Silver Spring, MD 20910, USA; michelle.tomlinson@noaa.gov
[8] NOAA National Marine Fisheries Service, Cooperative Oxford Laboratory, 904 S. Morris Street, Oxford, MD 02543, USA; howard.townsend@noaa.gov

[9] NOAA CoastWatch East Coast Node, 5830 University Research Court, College Park, MD 20740, USA; ronald.vogel@noaa.gov; and S M Resources Corporation, Ashburn, VA 20146, USA

ASSESSMENT OF ATMOSPHERIC CORRECTION SCHEMES ABOVE THE ST LAWRENCE ESTUARY.

Thomas Jaegler[2] and Simon Bélanger[1,2]

Ocean color water-leaving radiance retrieval over the St Lawrence estuary remains problematic with frequent negative reflectance in the blue using the NASA standard atmospheric correction (AC) algorithms (Gordon and Wang 1994; Bailey et al 2010). In situ observations revealed that these estuarine waters are could not be considered as turbid following the criteria proposed by Morel and Bélanger (2006). Using radiometric measurements from a network of autonomous buoys (Bélanger et al., 2017), we performed a matchup exercise comparing in situ radiometric data and satellite (MODIS, VIIRS) data acquire from 2013 to 2016. We found systematic negative bias at all visible bands. In the blue bands, up to 50% and 15% of the R_{rs} retrieval were negative at 412 nm and 443 nm, respectively. The objective of this project is to further investigate the potential causes resulting in such a systematic underestimation of the water-leaving radiance retrieval over the SLE. We will test the standard atmospheric correction (AC) algorithm apply to MODIS and VIIRS to compare the Rrs(NIR) retrievals with in situ measurements. Finally, we will test the performance of alternative AC algorithms, including the BMW (Jiang and Wang, 2014) and the ESA standard neural network (Doerffer and Schiller, 2007) adapted for coastal environment (C2RCC, Brockman et al, 2016).

[1] *ARCTUS inc.,* 300 Allée des Ursulines, Rimouski, QC G5L 3A1, *Rimouski, QC, Canada,* *tj@arctus.ca*,

[2] UQAR, 300 Allée des Ursulines, Rimouski, QC G5L 3A1, *Rimouski, QC, Canada,* *simon_belanger@uqar.ca*

Impact of the pixel size on the estimation of the marine reflectance

Jamet, C.[1], D., Ding Ngoc[2], X., Mériaux[1], A., Cauvin[1] and H., Loisel[1]

The fundamental parameter in ocean colour is the remote sensing reflectance, Rrs. It is related to the inherent optical properties of the seawater (IOPs) . Rrs is a non-linear function of the backscattering and absorption coefficients of the seawater. This non-linearity has long been investigated from radiative transfer calculations and field measurements (Lee et al., 2012). For validation purposes, where in situ measurements are performed at a much smaller spatial scale than the investigated pixel, and with the future ocean color missions characterized by different spatial resolutions, it is timely to investigate the behavior of this non-linearity with the spatial scale considered. It is necessary to investigate how the definition/estimation of Rrs as a function of IOPs can be applied to a satellite pixel and how the change of resolution can impact the estimation of this parameter (and subsequent biogeochemical parameters) as the products at low resolution are not necessarily arithmetic or geometric means of those at higher resolution, especially in coastal waters. Continuous in-situ measurements of physical and optical parameters from a bot-wing have acquired in the Eastern English Channel and French Guyana over a grid of 1-by-1bm, simulating different pixel sizes. These variability of these parameters are analyzed along their transects and compared to satellite images from MODIS-AQUA, VIIRS, Sentinel-2, LANDSAT-8 and Sentinel-3. The optimal ground resolution are determined for each transect and compared to previous works.

[1] cedric.jamet@univ-littoral.fr, Univ. Littoral Cote d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France

[2] dndat.gis@gmail.com, Space Technology Institute, Vietnam Academy of Sciences and Technlogy, Hanoï, Vietnam

[1] arnaud.cauvin@univ-littoral.fr, Univ. Littoral Cote d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France

[1] xavier.meriaux@univ-littoral.fr, Univ. Littoral Cote d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France

[1] hubert.loisel@univ-littoral.fr, Univ. Littoral Cote d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France

OLCI data products comparison in the Atlantic off Portugal

Tamito Kajiyama [1], Davide D'Alimonte [1], Carolina Sá [2], and Vanda Brotas [2]

Quality assessments of OLCI radiometric and derived data products are presented based on field measurements and product maps comparison in the Atlantic off the southwestern Iberian Peninsula. Investigated data products are OLCI level 2 remote sensing reflectance (Rrs), Chlorophyll-*a* concentration (Chl-*a*) estimates by the OLCI OC4ME and CHL_NN algorithms, and total suspended matter (TSM) concentration estimated by the TSM_NN scheme. A match-up analysis using field radiometric data collected at 14 stations in the studied area in August-September 2016 shows that OLCI spectral Rrs values over- and underestimate the reference values in the blue-green and red regions, respectively (between 11 and 23% in the 413–560 nm interval and −29% at 665 nm). Coincident Chl-*a* match-ups report a positive bias (39%) in OLCI OC4ME estimates, as well as a negative bias (−29%) in OLCI CHL_NN values. A product map comparison using 11 selected OLCI images in May-August 2016 is further conducted to assess the documented biases by comparing OLCI pigment index maps with equivalent products computed using regional Multi-Layer Perceptron (MLP) neural networks trained with two independent datasets collected in the region (referred to as ATLP and SGRS MLPs). The overestimation trend of OLCI OC4ME values is consistently confirmed when compared with ATLP and SGRS MLP product maps (positive biases of 37±4% and 36%±7% on average, respectively, where error bars indicate standard deviation). Similar analyses of the CHL_NN maps also report negative biases (−59±12% and −63±17%) as well as for TSM_NN products (−12±16% when applying an ATLP MLP for TSM retrieval).

Affiliations:

1. Centre for Marine and Environmental Research (CIMA), University of Algarve, Campus of Gambelas, 8005–139 Faro, Portugal
2. Marine and Environmental Sciences Centre (MARE), Faculty of Sciences, University of Lisbon, Campo Grande, 1749–016 Lisbon, Portugal

Hyperspectral chlorophyll-a fluorescence simulations in optically complex and stratified waters

Therese Keck, Lena Kritten, René Preusker, Jürgen Fischer

Retrieving optically active constituents (OACs) in coastal and inland waters is still an highly challenging issue due to very different water types and their optically complex characteristics. In oder to disentangle the constituents in remote sensing data, bio-optical models and radiative transfer codes are used. Hence, the parameterisation of the OACs' spectral inherent optical properties (IOPs) have a major impact on a succesful retrieval. In case 2 waters, reflectance spectra can be similar although there are different OAC mixtures because the constituents' spectral IOPs sum up. Conventional algorithms based on little spectral information like the blue-green ratios for chlorophyll-a concentration become indistinct.
Exploiting hyperspectral simulations and sensors, we can use the information of more spectral features. The chlorophyll-a fluorescence at 682 nm offers the opportunity to estimate a phytoplankton content in the presence of coloured dissolved organic matter (cdom) and sediments. Additionally, the natural vertical stratification of phytoplankton is heterogeneous which has a non-linear influence on the fluorescence signal. Therefore, applying various bio-optical models and vertical profiles, we simulate hyperspectral radiance and reflectance spectra in and above the water body with the radiative transfer code MOMO (Matrix Operator Model [Hollstein et al., 2014]). The simulations and additional field data are used to obtain water OACs in inland and coastal zones based on the chlorophyll-a fluorescence which can be measured by up-coming hyperspectral remote sensing instruments like EnMAP.

Institute for Space Sciences, Freie Universität Berlin, Carl-Heinrich-Becker-Weg 6-10, 12165 Berlin, Germany

therese.keck@wew.fu-berlin.de
lena.kritten@wew.fu-berlin.de
rene.preusker@wew.fu-berlin.de
juergen.fischer@wew.fu-berlin.de

Natural variability of light absorption by suspended particles with chlorophyll a concentrations in the Red Sea

Malika Kheireddine[1], Emanuele Organelli[2], Mustapha Ouhssain[1, 3, 4], and Burton H. Jones[1]

[1]King Abdullah University of Science and Technology (KAUST), Red Sea Research Center (RSRC), Biological and Environmental Sciences and Engineering Division (BESE), Bioscience program, Thuwal, 23955-6900, Saudi Arabia

[2] Plymouth Marine Laboratory, Plymouth

[3]Sorbonne Université, UPMC Univ Paris 06, UMR 7093, LOV, Observatoire Oceanologique, F-06230 Villefranche-Sur-Mer, France

[4]CNRS, UMR 7093, LOV, Observatoire Oceanologique, F-06230 Villefranche-Sur-Mer, France

Absorption properties of phytoplankton and non-algal particles (NAPs) were measured from the southern to the northern Red Sea within the EEZ of Saudi Arabia. Chlorophyll-specific phytoplankton absorption coefficients at 443 and 676 nm were higher than expected from global relationships for open ocean waters as a function of chlorophyll a concentration, [Chl a]. This result suggests that peculiar pigment composition and cell size tends to be responsible of this overestimation than in other regions at similar [Chl a]. The phytoplankton size parameter, Sf, derived from phytoplankton absorption spectra, and the concentration of accessory pigments proved to be useful for interpreting the resulting relationship between Chlorophyll-specific phytoplankton absorption and chlorophyll concentration in Red Sea waters. Our results suggest that the variability in phytoplankton absorption in Red Sea waters is caused mainly by changes in phytoplankton cell size and secondary by variations in the concentrations of accessory pigments. The contribution of absorption by NAPs to total particulate absorption was weak (17.3 ± 16 %) and no relationship between NAPs absorption coefficient at 440 nm and [Chl a] was observed. The quantification and understanding of the causes of variability in relationships between phytoplankton absorption and [Chl a] are essential for improving our ability to retrieve biogeochemical parameters from in situ and ocean colour remote sensing in Red Sea waters.

Evaluating the performance of empirical models through time series observations for the estimation of key water quality parameters in coastal waters

A.Kikaki[1], K.Karantzalos[2], V.Kapsimalis[3], H. Kontoyannis[4], G.Assimakopoulou[5], S. Zervoudaki[6]

Assessing the quality of coastal waters is one of the most essential issues in order to ensure environmental protection and public health. During the last decades several empirical models have been proposed for the estimation of key water quality parameters like chlorophyll-a, salinity and temperature. The main validation procedure is based on the calculated determination coefficient indicating the success rate of the established correlation between the in-situ and satellite observations. In this study a number of empirical models were applied on multitemporal high resolution data in coastal regions where in-situ data were also available. Time-series observations were extracted for several locations. The comparison and assessment of the predicted values across the miltitemporal dataset was performed against the in-situ data. The results from this study highlighted different aspects of the employed models, their performance, consistency and sensitivity.

[1] Remote Sensing Laboratory, National Technical University of Athens, Heroon Polytecneiou 9, 15780, Zografou, Greece. Email: akikakh@hotmail.com

[2] Remote Sensing Laboratory, National Technical University of Athens, Heroon Polytecneiou 9, 15780, Zografou, Greece. Email: karank@central.ntua.gr

[3] Institute of Oceanography, ,Hellenic Centre of Marine Research, 46.7 km Athens-Sounio Avenue, Mavro Lithari, 19013, Anavissos, Greece. Email: kapsim@hcmr.gr

[4] Institute of Oceanography, ,Hellenic Centre of Marine Research, 46.7 km Athens-Sounio Avenue, Mavro Lithari, 19013, Anavissos, Greece. Email: hk@ath.hcmr.gr

[5] Institute of Oceanography, ,Hellenic Centre of Marine Research, 46.7 km Athens-Sounio Avenue, Mavro Lithari, 19013, Anavissos, Greece. Email: gogo@hcmr.gr

[6] Institute of Oceanography, ,Hellenic Centre of Marine Research, 46.7 km Athens-Sounio Avenue, Mavro Lithari, 19013, Anavissos, Greece. Email: Tanya@hcmr.gr

SeaDAS: NASA Analysis Software Tools for Earth-Viewing Satellite Data

Daniel Knowles Jr.[1], Sean Bailey[2]

SeaDAS is visualization, processing, and analysis software for use with Earth-viewing satellite data. This open-source NASA software, (current version 7.4), enables users to work with all levels of OB.DAAC (Ocean Biology Distributed Active Archive Center) data. This is the official distribution source of the NASA OCSSW (Ocean Color Science SoftWare) processors (such as l2gen, l2bin, l3mapgen, etc.). These processors use the latest accepted NASA OBPG (Ocean Biology Processing Group) algorithms, which includes atmospheric correction. SeaDAS provides tools to retrieve and use the same coincident ancillary measurements used in NASA's official data processing stream. SeaDAS processing provides a standardized data format across a multitude of satellites, currently fully supporting over 16 missions. The visualization and analysis tools can be used on many other missions. SeaDAS allows for integration of field measurement data for comparison with satellite data. NASA provides strong user support for SeaDAS. Scientific data products can be exported from SeaDAS in formatted files readily readable by many third party GIS analysis packages.

1. daniel.s.knowles@nasa.gov
2. sean.w.bailey@nasa.gov

Estimation of Chlorophyll-a in eutrophic inland waters using Sentinel 3 Ocean and Land Color Instrument: First Impressions

Jeremy Kravitz [1], Mark Matthews [2], Derek Griffith [3]

Eutrophication and increasing prevalence of potentially toxic cyanobacterial blooms in South Africa's reservoir lakes is becoming a major concern and requires direct attention. The highly successful Medium Resolution Imaging Spectrometer (MERIS) provided unprecedented capabilities for remote sensing of inland water quality and algal identification until its unfortunate termination in 2012. The European Space Agency hopes to continue that success with the recently launched Ocean and Land Color Instrument (OLCI) aboard the Sentinel 3 satellite. The success of the mission will depend on extensive validation efforts for the development of accurate and robust in-water algorithms. One of the biggest hurdles to algorithm validation for inland water bodies is the difficulty of performing an accurate atmospheric correction. High turbidity and proximity to land pixels make traditional correction schemes unsuitable for inland waters. The objective of this study is to assess the potential of OLCI for the monitoring of trophic status of small inland water bodies within South Africa. Radiometric errors associated with OLCI Top of Atmosphere (TOA) radiances will be assessed by validating with in-situ measurements of water color radiometry modelled to Top of Atmosphere. An evaluation of algorithms for estimating chl-a using OLCI is performed using radiative transfer, neural network, and band difference type models while the uncertainties and limitations of using a full or partial atmospheric correction procedure are explored. Initial results illustrate the difficulty of performing a successful full atmospheric correction over small inland water targets with standard neural network processors performing worst.

[1] PhD Student, Department of Oceanography, University of Cape Town, South Africa; 0715345337; Jeremy.kravitz@gmail.com

[2] Director, CyanoLakes(Pty) Ltd, Cape Town, South Africa; 0217121663; mark@cyanolakes.com

[3] Optical Systems Analyst, Council for Scientific and Industrial Research, Pretoria, South Africa; 0128414392; dgriffith@csir.co.za

Quantitative Incorporation of Phytoplankton Chlorophyll Fluorescence into a Numeric Radiative Transfer Model of the Atmosphere-Ocean System

Lena Katharina Kritten [1], Jürgen Fischer [2], Therese Keck [3], Rene Preusker [4]

Beside heat, fluorescence is the main process in chlorophyll that emits absorbed solar energy, which is not used by photosynthesis. Since the chlorophyll fluorescence signal can be observed by ocean color satellite instruments, it has the potential to provide information on the amount and state of phytoplankton in open ocean, coastal and inland waters. In particular OLCI on Sentinel 3 and its predecessor MERIS on Envisat have a dedicated band for the fluorescence peak at around 680nm. However, for a quantitative exploitation of the fluorescence signal, a radiative transfer modelling that incorporates fluorescence is indispensable. We extended our radiative transfer code MOMO [1] and included the possibility to simulate the fluorescence signal for the in-water radiance, the water leaving radiance as well as the top of atmosphere signal. We will present the physical background, implementation details and a first validation.

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1. lena.kritten@wew.fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
2. juergen.fischer@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
3. therese.keck@wew.fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
4. rene.preusker@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin

Phytoplankton bloom phenology patterns off SW Iberia (NE Atlantic)

Lilian Anne Krug[a], Trevor Platt[b], Shubha Sathyendranath[c], Ana B. Barbosa[a],

This study aimed to evaluate phytoplankton bloom phenology off SW Iberian Peninsula (SWIP) during a 18-year period (1997-2015), and its linkages to climate variability. Pixel-based phenological indices (PIs), derived from remotely sensed chlorophyll-a concentration (Chl-a), included number of blooms per year, average bloom duration, total bloom duration per year, main bloom onset, and Chl-a peak value and timing. Based on statistically non-correlated climatological PIs maps, SWIP was partitioned into five units, two offshore, one shelf-edge and two coastal regions, highlighting the relevance of region-specific oceanographic and coastal processes as drivers of phytoplankton bloom dynamics. Overall, offshore regions presented fewer but more prolonged bloom events (1-2 events/year; 12-20 weeks/event), whereas coastal regions showed multiple short bloom episodes (4-5 events/year; 3-6 weeks/event). The onset of the main bloom (event leading to the highest Chl-a within each year) occurred between November and March, during the convective mixed-layer deepening, earlier over offshore regions and later over the coastal region under upwelling influence. Chl-a peak timing was usually observed during late-winter to early spring (mid-March to early-April) in most regions. Yet, a slight anticipation of peak timing (mid-February) was detected over the narrow, highly productive Gulf of Cadiz coastal region. A significant interannual increase in average bloom duration was detected over offshore and shelf-edge regions. This pattern was linked to changes in the timing of mixed layer depth deepening and shoaling onset, eventually leading to an extension of phytoplankton dilution period.

[a]University of the Algarve/ Centre for Marine and Environmental Research (CIMA), Campus de Gambelas, 8005-139 Faro, Portugal.

[b]Plymouth Marine Laboratory (PML). Prospect Place, The Hoe, PL1 3DH, Plymouth, Devon, United Kingdom.

[c]National Centre for Earth Observation, Plymouth Marine Laboratory, Prospect Place, The Hoe, PL1 3DH, Plymouth, Devon, United Kingdom

lakrug@ualg.pt, tplatt@dal.ca, ssat@pml.ac.uk, abarbosa@ualg.pt

Environmental damage assessment of conflict-affected coastal waters in Eastern Ukraine using ocean color

Tetyana Kuchma
National University of Kyiv-Mohyla Academy, Kyiv, Ukraine
Institute of agroecology and natural management, Kyiv, Ukraine
tanyakuchma@gmail.com

The military action in eastern Ukraine started from May 2014 among other devastating consequences affected the inland and coastal ecosystems by decreasing the water quality. Water samples of the Siversky Donets river demonstrated that the level of sulphates exceeds 5 times and nitrates more than two times as compared to maximum permissible concentrations. Soil samples revealed a considerable amount of heavy metals at the shell explosion sites, located in close proximity to Azov sea coastal waters. To this day the large area remains inaccessible for ground field studies. The research was focus on the application of ocean color imagery for the environmental damage assessment of conflict-affected Azov sea coastal waters. The dynamics of Sea Surface Temperature and chlorophyll a concentration over 10-year period were studied using Modis imagery and Sea Surface Salinity data since 2009 was analyzed using SMOS data as water quality indicators to detect changes due to hostilities influence. The study includes the assessment of hostilities influence on phytoplankton functions in Azov Sea coastal areas, in particular the harmful algae bloom frequency and spatial distribution was calculated for the period of 2014-2016.

"Monitoring suspended particulate matter (SPM) concentration anomalies in coastal waters: application of the Robust Satellite Techniques (RST) to MODIS-Aqua data"

C. DI POLITO[1], E. CIANCIA[1], I. COVIELLO[2], D. DOXARAN[3], T. LACAVA[2], N. PERGOLA[2], V. SATRIANO[1], V. TRAMUTOLI[1]

(1) School of Engineering, University of Basilicata, Potenza, Italy

(2) National Research Council, Institute of Methodologies for Environmental Analysis, Tito Scalo (PZ), Italy

(3) Laboratoire d'Océanographie de Villefranche (LOV), CNRS/UPMC, Villefranche Sur Mer, France

River discharge affects Suspended Particulate Matter (SPM) dynamics and variability in coastal areas, contributing to the onset of possible environmental degradation situations. An increase in SPM controls water turbidity within the water column with a direct effect on water warming processes and on dissolved oxygen concentration variability, representing a stress factor for many pelagic and benthic organisms. Ocean colour satellite data have already demonstrated their effectiveness for monitoring SPM dynamics, even if with a main limit due to the low accuracy of the proposed algorithms when applied in regions different from those where they have been calibrated. In this work, results achieved implementing the Robust Satellite Techniques (RST) approach using MODIS-Aqua data for monitoring SPM concentration variability in the coastal waters of Basilicata Region (southern Italy - eastern Mediterranean), are presented. RST is a differential multi-temporal approach, which allows identifying significant statistical variations of the investigated signal regardless its absolute value, which could be biased by the above-mentioned issue. The extreme hydrological event that affected Basilicata Region coastal waters in December 2013 was studied, finding anomalous SPM concentrations in the days just after the flood wave peak. Furthermore, a long-term analysis (2003-2015 period) of the detected anomalies for the month of December allowed identifying areas where the SPM concentration was higher than the values usually registered, taking also into account its natural variability. In conclusion, the RST methodology, implemented on SPM data, showed to be a useful tool to better understand the behavior of coastal waters and improve monitoring activities.

1) Via Nazario Sauro, 85 - 85100 Potenza, Italy
(carmine.dipolito@unibas.it; e.ciancia@unibas.it;valeria; valeria.satriano@unibas.it; valerio.tramutoli@unibas.it)

2) C.da S. Loja - Zona Industriale - 85050 Tito Scalo (PZ), Italy
(irina.coviello@imaa.cnr.it; teodosio.lacava@imaa.cnr.it; nicola.pergola@imaa.cnr.it)

3) Chemin du Lazaret, 181 - 06230 Villefranche-sur-Mer, France
(david.doxaran@obs-vlfr.fr)

Interannual phytoplankton size structure in the Benguela Upwelling System.

T. Lamont[1,2], R.G. Barlow[3,2], R.J.W. Brewin[4]

[1] Oceans & Coastal Research, Department of Environmental Affairs, Private Bag X4390, Cape Town, 8000, South Africa
[2] Marine Research Institute and Department of Oceanography, University of Cape Town, Private Bag X3, Rondebosch, 7701, South Africa
[3] Bayworld Centre for Research & Education, 5 Riesling Road, Constantia, 7806, Cape Town, South Africa
[4] Plymouth Marine Laboratory (PML), Prospect Place, The Hoe, Plymouth, PL1 3DH, UK

Corresponding author email: tarron.lamont@gmail.com

The three-component model of Brewin et al. (2010) computes fractional contributions of three phytoplankton size classes (micro-, nano-, picophytoplankton) to the overall chlorophyll *a* (chla) concentration. Using *in situ* HPLC data, model coefficients were fine-tuned for application to the Benguela Upwelling System (BUS). The refined model was applied to monthly averages of SeaWiFS (1997-2007) and MODIS Aqua (2002-2015) chla in three regions of the BUS, namely northern Benguela (NB), southern Benguela (SB), and the Agulhas Bank (AB). The 1 mg m^{-3} chla contour was used to further sub-divide each region into shelf and open ocean domains. Annual (July-June) means of chla and fractional contributions of micro-, nano-, and picophytoplankton were computed and linear regressions were calculated for both SeaWiFS and MODIS Aqua time series. On the shelf, micro-phytoplankton comprised 63-73 % of the total chla in NB, 67-75 % in SB, and 50-66 % in the AB region. Nano-phytoplankton proportions on the shelf were 23-31 % in NB, 21-28 % in SB, and 23-38 % in the AB region, while higher proportions (45-48 %) were noted in the open ocean domains. Picophytoplankton proportions were lower (4-6 %) in the NB and SB shelf regions and slightly higher (8-12 %) in the AB region, while values were 24-36 % in the open ocean domains. SeaWiFS chla showed a significant positive linear trend on the NB shelf, while SeaWiFS picophytoplankton proportion on the AB shelf showed a significant linear increase. These trends are not evident in the MODIS Aqua time series.

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NOAA in situ validation activities for satellite ocean color products and related ocean science research

Veronica P. Lance,[1,2,3]* Michael Ondrusek,[1] Heng Gu [1,2,4], Menghua Wang[1] and NOAA VIIRS Cruise, VIIRS Cal/Val, MOBY and Aeronet-OC Team Members[5]

[1]NOAA/NESDIS Center for Satellite Applications and Research (STAR), 5830 University Research Court, College Park, MD 20740, USA; [2]NOAA CoastWatch/OceanWatch, 5830 University Research Court, College Park, MD 20740, USA; [3]Global Science and Technology, Inc., 7855 Walker Drive, Suite 200, Greenbelt, MD 20770, USA; [4]Digital MindTrust, 4031 University Drive, Ste. 100, Fairfax, VA 22030, USA; [5]See below;

Abstract

The NOAA/STAR Ocean Color Program takes an "end-to-end" approach to the production of high quality "fit for purpose" satellite ocean color products that support applications in all NOAA Line Offices, as well as external (both research and applied) users. In situ validation of satellite data is essential to this process.

The primary components of our NOAA in situ activities are:

- Annual operational oceanographic cruises dedicated to satellite validation objectives, especially in support of VIIRS, supported by Joint Polar-orbiting Satellite System (JPSS) and NOAA Office of Marine and Aviation Operations (OMAO)
- Local research and validation on Chesapeake Bay
- Observations provided by University-based calibration/validation team partners
- Participation on cruises of opportunity in collaboration with
    - Other NOAA Line Offices
    - External partners including other agencies and international entities
- NIST traceable calibration of field instruments in our optical laboratory
- Support of the Marine Optical Buoy (MOBY)
- Support of 4 AERONET-OC sites (US West Coast, Gulf of Mexico, Long Island Sound and Lake Erie)
- Data provider to NOAA National Centers for Environmental Information (NCEI) who formally steward and archive our in situ cruise data collections
- And, (*in development*), data repository and distribution portal through NOAA CoastWatch/OceanWatch

Contact author: Veronica.Lance@NOAA.gov

[1]NOAA/NESDIS Center for Satellite Applications and Research (STAR), 5830 University Research Court, College Park, MD 20740, USA; [2]NOAA CoastWatch/OceanWatch, 5830 University Research Court, College Park, MD 20740, USA; [3]Global Science and Technology, Inc., 7855 Walker Drive, Suite 200, Greenbelt, MD 20770, USA; [4]Digital MindTrust, 4031 University Drive, Ste. 100, Fairfax, VA 22030, USA; [5]See below;

NOAA VIIRS Cruise, VIIRS Cal/Val, MOBY and Aeronet-OC Team Members[5]

Robert Arnone,[a] Jennifer Cannizzaro,[b] Carlos Carrizo,[c] Joaquin Chaves,[d,e] Alex Chekalyuk,[f] David English,[b] Hui Feng,[g] Robert Foster, [c] Scott Freeman, [d,e] Bill Gibson,[h] Joaquim Goes,[f] Helga do Rosario Gomes,[f]

Wesley Goode,[i] Ahmed el Habashi, [c] Brent Holben,[d] Amir Ibrahim,[c] B. Carol Johnson,[j] Burt Jones,[k] Charles Kovach,[b,l,m] Sherwin Ladner,[i] Ivan Lalovic,[n] Junfang Lin,[o] Antonio Mannino,[d] Kali McKee,[f] Timothy Moore,[g] Jasmine Nahorniak,[n] Aimee Neeley,[d,e] Matteo Ottaviani,[c] Matthew Ragan,[j] Steve Ruberg,[p] Eric Stengel,[k] Nicole Stockley,[q] Shaojie Sun,[b] Marco Talone,[r] Michael Twardowski,[q] Ryan Vandermeulen,[a,d,e] Kenneth Voss,[s] Quoqing Wang,[o] Jianwei Wei,[o] Giuseppe Zibordi,[r] Laura Zoffoli[o]

[a]University of Southern Mississippi; [b]University of South Florida; [c]City College of New York; [d]NASA Goddard Space Flight Center; [e]Science Systems and Applications, Inc.; [f]Lamont-Doherty Earth Observatory at Columbia University; [g]University of New Hampshire; [h]Louisana State University; [i]Naval Research Laboratory (Stennis); jNational Institute of Standards and Technology; [j]University of Southern California; [k]NOAA/STAR; [l]Global Science and Technology, Inc.; [m]Oregon State University; [n]University of Massachussets – Boston; [o]NOAA/GLERL; [p]Florida Atlantic University; [q]Joint Research Centre, [s]University of Miami

Validity ranges of chlorophyll-a algorithms in coastal waters

Héloïse Lavigne[1], Kevin Ruddick[1], Quinten Vanhellemont[1], Dimitry Van der Zande[1]

Royal Belgian Institute of Natural Sciences, Operational Directorate Natural Environment, Gulledelle 100, B-1200, Brussels, Belgium

The use of satellite chlorophyll a (Chl-a) data in coastal and inland water for applications such as eutrophication monitoring and algae bloom detection requires careful quality control. Standard products from medium resolution sensors such as MODIS, VIIRS and OLCI are easily generated but their quality is highly variable according to the optical conditions and the algorithm used. For example, blue/green ratio algorithms are known to fail in waters with high non-algae absorption. Red/near infrared algorithms may work well in high Chl-a, high backscatter conditions, but will suffer from a detection limit problem for low chlorophyll and/or low backscatter waters. The interest in much higher spatial resolution data from sensors such as Landsat-8/OLI and Sentinel-2/MSI, with less suitable spectral band sets and higher noise, adds to quality problems. The objective of this study is to determine the range of validity of various Chl-a retrieval algorithms and to provide simple quality control tests for flagging suspect data.

Performances of case-2 (based on red/NIR reflectance) and case-1 algorithms (blue/green band ratio algorithms) are tested against the Coast Colour Round Robin reflectance dataset. This synthetic dataset was generated by radiative transfer model to represent the whole range of water quality parameters observed in coastal waters. Then, objective criteria based on reflectance are sought to define the domain of validity of each couple algorithm/sensor. Results are finally applied to Sentinel-3/OLCI and Sentinel-2/MSI images of Belgian coastal waters.

Annual new production in the southwestern East/Japan Sea estimated from satellite-derived surface nitrate concentration

Sang Heon Lee[1], HuiTae Joo[1], Dabin Lee[1], Jae Hyung Lee[1], and Seung-Hyun Son[2]

[1]Department of Oceanography, Pusan National University, Geumjeong-gu, Busan 46241, Korea

[2]CIRA, Colorado State University, Fort Collins, CO 80523, USA

Many dramatic changes in environmental conditions such as physical and chemical properties as well as biological characteristics have been reported in the East/Japan Sea. The southwestern East/Japan Sea is a high productivity region compared with other part of the East/Japan Sea. However, recently a decreasing trend in the annual primary production was observed from 2003 to 2012. The new production based on nitrate is very important to understand how much portion of primary production passed on to higher trophic levels in the marine ecosystem. Here, we focus on the inter-annual variation in the annual new production and try to find the main controlling factor for the variation in the southwestern East/Japan Sea. Long-term annual new productions were estimated from MODIS-aqua satellite-derived surface nitrate concentration from 2003 to 2015. A strong positive relationship was found between field-measured nitrate concentration and sea surface nitrate concentration estimated from the regional-adjusted algorithm for the southwestern East/Japan Sea. No general trend was found in the annual new production estimated from the satellite-derived surface nitrate concentration in the southwestern East/Japan Sea during our study period. The annual new production ranged from 41.7 μM in 2009 to 62.8 μM in 2011. Relatively, lower annual new productions were appeared during 2007 to 2009. A strong relationship was observed between the annual new production and the sea surface temperature on February during the study period ($y=-11.461x+180.52$, $R^2=0.8796$, $P<0.01$, $n=13$). Overall, the average annual new production was 54.5 g C m^{-2} yr^{-1} in the southwestern East/Japan Sea for 13 years from 2003 to 2015. This annual new production derived from satellite is rather lower than field-measured new productions in the southwestern East/Japan Sea. We further discuss on the several reasons for the discrepancy.

Keywords: New production, surface nitrate concentration, primary production, East/Japan Sea

Long-term Pattern of the Sea Surface Nitrate Concentration Estimated from Remote Sensing in the Ulleung Basin, East/Japan Sea

Dabin Lee[1a], Jae Hyung Lee[1b], HuiTae Joo[1c], SeungHyun Son[2d], and Sang Heon Lee[1e]

The productivity of Ulleung Basin (UB) was reported as a high productivity region called as "biological hot spot" of the East/Japan Sea, based on the recent studies with field measurements and ocean color data. However, the decline trend of annual primary production in the UB was found over the recent decade from 2003 to 2012 and the major driving factors are not clearly determined. Generally, the primary production strongly depends on the upward nitrate concentration from the deep water in the UB. Thus, we investigated the long-term variation of nitrate concentration to find a potential reason for the recent decline of the annual primary production in the UB. Based on the relationships, which was previously reported, of SSN-SST-Chl derived from MODIS-Aqua L3, we estimated surface nitrate concentration (SSN) from July 2002 to December 2016 in the UB. A strong relationship between satellite-derived SSN and in-situ SSN from the Korea Oceanographic Data Center ($y=0.6131x+1.4498$, $R^2=0.6477$, $P<0.01$, $n=326$) was found and could be used to provide a high spatial resolution of SSN concentration in the UB. The seasonal pattern of the MODIS-derived SSN concentration, high during winter and spring seasons and low during summer and fall, clearly shows a typical pattern in mid-latitude oceans. The satellite-derived SSN concentration had the maximum of 8.3 μmol L^{-1} and the minimum of 0.16 μmol L^{-1} in March 2010 and September 2010, respectively. These concentrations of the SSN estimated in this study are comparable to the previous reported range from the field measurements in the UB. Ultimately, we will discuss about the recent decline pattern of annual primary production in the UB based on the long-term pattern of SSN.

[1]Department of Oceanography, Pusan National University, Geumjeong-gu, Busan 46241, Korea

[2]CIRA, Colorado State University, Fort Collins, CO 80523, USA

[a]ldb1370@pusan.ac.kr, [b]tlyljh78@pusan.ac.kr, [c]huitae@pusan.ac.kr, [d]oceancolor.son@gmail.com, [e]sanglee@pusan.ac.kr

Keywords: Sea surface nitrate, Ulleung Basin, Primary production, East/Japan Sea

SELF-SHADING ASSOCIATED WITH AN SBA SYSTEM FOR MEASUREMENT OF WATER-LEAVING RADIANCE AND ITS CORRECTION

ZHEHAI SHANG [1], ZHONGPING LEE [1], QING DONG [2]

[1] School for the Environment, University of Massachusetts, Boston, Boston, Massachusetts 02125

[2] College of Ocean and Earth Sciences, Xiamen University

Xiamen, China

The shading error associated with the water-leaving radiance (L_w) measured via the Skylight Blocked Approach (SBA, Lee *et al.* 2013) is characterized by Monte Carlo simulations, and it is found this error is in a range of ~1-50% under most water properties and solar positions. A model for estimating this shading error is further developed, and eventually a scheme to correct this error based on the shaded measurements is proposed and evaluated. It is found that the shade-corrected value in the visible domain is within 3% of the true value, which thus indicates that with the SBA scheme we can not only obtain high precision, but also high accuracy, L_w in the field.

Implementation of System Vicarious Calibration and status on OLCI product validation.

Christophe Lerebourg[1], Ludovic Bourg[1], Antoine Mangin[1], Nicolas Lamquin[1], Steffen Dransfeld[2], Ewa Kwiatkowska[3]

[1]ACRI-ST; [2]ESRIN; [3]EUMETSAT;

Sentinel-3A (S3A), carrying the Ocean and Land Colour Instrument (OLCI), was successfully launched on February 16th 2016. It was the first of the series planned by the European Commission (EC) in the frame of COPERNICUS Sentinel program. Sentinel-3B is planned for launch in late 2017, bearing identical instruments, thus improving the global Earth coverage. The OLCI series providing global coverage at 300m resolution will therefore represent a major breakthrough in the family of ocean colour sensors.

For being an operational mission feeding in downstream Copernicus services like CMEMS, it is essential to ensure descent product quality prior public release. This supposes the implementation of System Vicarious Calibration (SVC). SVC is implemented in most ocean colour missions to improve product quality. NIR and visible bands SVC are dealt with separately. Procedures to derive NIR bands vicarious gains can vary from one sensor to the other but there are limited constraints with data availability as it relies on oligotrophic region of the ocean and does not require in situ measurements. The main constrain stands for visible bands vicarious calibration as it relies on satellite observations matching very high quality in situ measurements. For the time being, only two ground stations can provide sufficiently high quality data for this purpose: BOUSSOLE in the Mediterranean Sea and MOBy in the Pacific Ocean. After only one year of operation, the number of vicarious calibration grade matchups was not enough to ensure statistically reliable gains. An alternative procedure based on global daily climatologies has therefore been developed to produce SVC in the expected time frame.

In this presentation, the SVC procedure implemented will be described together with quantitative results of the impact on product validation.

ProVal : First data from a new Argo profiler dedicated to high quality radiometric measurements

E. Leymarie[1], C. Penkerc'h[2], E. Vellucci[3], C. Lerebourg[4], D. Antoine[5], H. Claustre[6]

Following the recommendation of the International Ocean Color Coordinating Group in 2011 (IOCCG report #11), the Laboratoire d'Oceanographie de Villefranche (LOV) has developed a new profiling float dedicated to the validation of ocean color remote sensing data. Taking advantage of our experience in both Argo floats and radiometric measurements, we have developed the so-called ProVal float based on a two-arm design that allows sensor redundancy and shading reduction. ProVal measures downwelling irradiance and upwelling radiance at seven wavelengths with a special concern for the data quality for this type of platform. It also measures the downwelling PAR, the fluorescence of Chla and CDOM, and, finally the backscattering coefficient at 700nm. ProVal is designed to monitor all year round these Apparent and Inherent Optical Properties of the water column simultaneously with ocean color satellite observations. These match-ups are deeply required for the global ocean but especially in areas with known bio-optics anomalies such as the Southern Ocean or the Mediterranean Sea.

After a description of the original concept of our platform based on a new float designed by NKE (PROVOR CTS5) combined with a new acquisition board developed on our specifications, we present first data of these floats taken during several deployments in the Mediterranean Sea and from the first two operational floats deployed since last October in the Southern Ocean close to Kerguelen. Comparisons with OLCI and BOUSSOLE products will also be presented.

1- leymarie@obs-vlfr.fr, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France
2- penkerch@obs-vlfr.fr, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France
3- vellucci@obs-vlfr.fr, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France
4- Christophe.Lerebourg@acri-st.fr, ACRI-ST, Biot, France
5- david.antoine@curtin.edu.au, Remote Sensing and Satellite Research Group, Curtin University, Perth, Australia
6- claustre@obs-vlfr.fr, Laboratoire d'Océanographie de Villefranche, 06230 Villefranche-sur-Mer, France

Improving SWIR-based atmospheric correction approach for MODIS-Terra measurements in highly turbid waters: A case study in Lake Taihu

Junsheng Li[1], Chuanmin Hu[2]

Abstract: Shortwave Infrared (SWIR) bands based atmospheric correction approach has been well validated in highly turbid coastal and inland waters with Moderate Resolution Imaging Spectroradiometer (MODIS) on the satellite Aqua, but few with MODIS on the satellite Terra. After NASA Ocean Biology Processing Group finished an ocean color reprocessing of the full MODIS-Terra mission based on improved calibration on 2010, it is urgent to further study the atmospheric correction for MODIS-Terra measurements in highly turbid waters. We select a highly turbid water, Lake Taihu in China, as the study area, and validate the SWIR based atmospheric correction approach for MODIS-Terra measurements based on a lot of coincident in situ measured reflectance spectra data. Firstly, we assessed the noises in three SWIR bands of MODIS-Terra, and proposed a noise reduction method, which can effectively reduce the stripe noises in the SWIR bands. Secondly, we did vicarious calibration of SWIR bands based on open ocean data, and then did vicarious calibration of visible to near-infrared (VIS-NIR) bands based on coincident in situ reflectance spectra data, which significantly increased the atmospheric correction accuracy. Thirdly, we evaluated the accuracy of atmospheric correction based on different SWIR band combinations, finding that (1240, 1640) based atmospheric correction had highest accuracy. We further compared atmospheric correction results of MODIS-Terra with MODIS-Aqua, and found similar accuracy. Then, we produced time series of atmospheric correction products of MODIS-Terra from 2000-2015, and analyzed their spatial-temporal distribution patterns. Finally, we discussed the applicability of the methods and findings in this study.

[1] Key Laboratory of Digital Earth Science, Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing 100094, China. lijs@radi.ac.cn

[2] College of Marine Science, University of South Florida, 140 Seventh Avenue, South, St. Petersburg, FL 33701, USA. huc@usf.edu

UNCERTAINTY ESTIMATES IN THE RETRIVAL OF SEA BOTTOM REFLECTANCE SPECTRA USING VERY HIGH RESOLUTION MULTISPECTRAL SATELLITE DATA

Soo Chin Liew[1]

Retrieving sea bottom reflectance spectra from above-water reflectance measured at a finite number of spectral bands is intrinsically an underdetermined problem. If N spectral bands are used, the number of unknown parameters to be retrieved is always more than N, i.e. the bottom reflectance at N spectral bands plus the water depth and several parameters for the intrinsic optical properties (IOPs) of water. In this project, we investigated the uncertainty in estimating sea bottom reflectance spectra using a water-column correction algorithm. Test data were generated using the standard shallow water reflectance equation with water depth ranging from 0.1 m to 30 m, for various IOPs representing different water types, and with several arbitrary sea bottom reflectance spectra. The spectral response functions of WorldView-2 satellite (with 8 spectral bands) were used to calculate the effective water reflectance. In the retrieval process, the water IOPs were assumed to be known and the sea bottom was assumed to consist of two end-members representing vegetated and sandy bottoms. In practice, the water IOPs could be estimated from the reflectance of deep water adjacent to the shallow region. Thus, the remaining three unknown parameters could be retrieved from 8 spectral bands using a spectral fitting method. Errors were introduced to the IOP values used in the retrieval process and the propagation of errors to the retrieved water depth and sea bottom reflectance spectra was studied.

[1]S. C. Liew, Centre for Remote Imaging, Sensing and Processing, National University of Singapore, 10 Lower Kent Ridge Road, Blk S17 Level 2, Singapore 119076. (scliew@nus.edu.sg)

Title : “CNES support to Ocean colour science”
Authors: Anne Lifermann, Philippe Escudier, Bertrand Fougnie (CNES)

The presentation will highlight the actions conducted by CNES in the field of Ocean Colour, at Agency level (IOCCG membership, cooperations, studies, calibration activities, development of applications …) and through support of scientific laboratories.

Development and characterisation of radiometric instruments at the laboratories of Tartu Observatory

Ilmar Ansko[1], Joel Kuusk[2], Martin Ligi[3], Anu Reinart[4], Viktor Vabson[5], Riho Vendt[6]

Tartu Observatory, Observatooriumi 1, Tõravere, Nõo Parish, 61602, Tartu county, Estonia

Tartu Observatory has a modern well equipped laboratory complex for research, calibration and testing. Three rooms in cleanroom environment (EN ISO 14644 Class 8) are available for optical measurements. The other laboratories include workstations for developing new technologies, prototyping, and assembly; testing facilities for climatic, thermal-vacuum, mechanical shock, vibration, and electromagnetic compatibility (EMC); workshops for mechanical construction and repair works of scientific instruments. The laboratory rooms have automatic temperature and humidity control.

At the optical laboratories of TO, measurements and calibrations for spectral responsivity (irradiance and radiance) of radiometric sensors in the wavelength range (340…1500) nm are performed. The sensors can be tested and characterised also for angular responsivity, uniformity of the flat-field view, inherent stray light, and thermal effects. Several types of radiometers commonly used for Ocean Colour Radiometry (e.g. TriOS RAMSES, Satlantic TACCS, Water Insight WISP-3) are regularly tested and calibrated.

The irradiance and/or radiance of light sources can be calibrated in the wavelength range of (340…1500) nm. Optical power of sources in the range 5 µW…100 mW, and in the wavelength range (250…3000) nm can also be measured.

For establishment and maintenance of the metrological traceability, the reference standards and measuring instruments of the optical laboratory are regularly calibrated at National Metrology Institutes. In period between subsequent calibrations different technics are used to monitor the stability of the reference instruments. The measurement uncertainty is carefully studied and evaluated, obtained uncertainty estimates verified by inter-comparison measurements, comparison results analysed, and Calibration and Measurement Capabilities - CMCs of the laboratory respectively elaborated. The quality management procedures are being developed and applied.

Tartu Observatory, Observatooriumi 1, Tõravere, Nõo Parish, 61602, Tartu county, Estonia

1 – jazov@to.ee

2 – Joel.Kuusk@to.ee

3 – Martin.Ligi@to.ee

4 – Anu.Reinart@to.ee

5 – Viktor.Vabson@to.ee

6 – Riho.Vendt@to.ee

Earth Observation-based Services for Monitoring and Reporting of Ecological Status (EOMORES)

Martin Ligi[1], Mirjam Randla[2], Krista Alikas[3], Annelies Hommersom[4]

The H2020 project EOMORES will develop operational monitoring and reporting services for inland and coastal water quality based on a combination of the most up-to-date satellite data, innovative in situ instruments and ecological models.

Lakes, reservoirs and coastal water bodies constitute essential components of the hydrological and biogeochemical water cycles, and influence many aspects of ecology, economy, and human welfare, providing ecosystem services in multiple and sometimes conflicting ways. Knowledge about the state of inland and coastal water bodies is therefore of great interest.

EOMORES will develop information services to support international, national and regional authorities responsible for monitoring, management and reporting of water quality as well as private entities dealing with water quality such as dredging companies. These services will be based on Earth observation (Sentinel 1, 2 and 3), autonomous optical in situ sensors, and ecological models. The validated data from these components will be flexibly combined into higher-level products to fit the users' information requirements such as aggregated lake-wide indicators of the ecological status for Water Framework Directive reporting or early warning of cyanobacterial scums based on a combination of in situ measurements and model forecasts.

Three service concepts are envisaged: 1) operational water quality monitoring and forecasting for water management, 2) implementation of validated EO-based water quality indicators for WFD and other reporting and 3) historic compilation of data for specific ecological analysis.

The services are expected to result in lower operational costs, more reliable and more timely water quality datasets for water managers.

1-3 Tartu Observatory, Observatooriumi 1, Tõravere, Nõo Parish, 61602, Tartu county, Estonia

4 Water Insight, Marijkeweg 22,6709 PG Wageningen, the Netherlands

1 – Martin.Ligi@to.ee

2 – Mirjam.Randla@to.ee

3 – Krista.Alikas@to.ee

4 – hommersom@waterinsight.nl

Remote sensing of Phytoplankton Size Distribution in Northwest Atlantics: Algorithms validation, adjustment, and application

Xiaohan Liu, Emmanuel Devred, Carla Caverhill, Stephanie Clay and Reba McIver
Bedford Institute of Oceanography, 1 Challenger Dr., Dartmouth, NS, Canada, B2Y 4A2
Email: Xiaohan.liu@dfo-mpo.gc.ca

Abstract: Phytoplankton community and size distribution (PSD) can be linked to changes in the oceanic environment. It also provides important information on the oceanic biogeochemical processes and the transfer of energy between different trophic levels. In this study, we first improved the parameters of the diagnostic pigment analysis (DPA) to obtain a reliable estimate of PSD, using the in-situ High-Performance Liquid Chromatography (HPLC) measurements collected in the Scotian Shelf and Gulf of Maine during the past 20 years. Further, the existing PSD retrieval algorithms were also evaluated, based on the in-situ HPLC measurements and the match-up ocean color products (e.g. remote sensing reflectance and chlorophyll-a concentration) from SeaWiFS, MERIS, MODIS, VIIRS and OLCI missions. Finally, the algorithm with the best reliability was applied to the time series of ocean color data (1998 – present) in order to better understand the impact of climate change on the phytoplankton assemblages in the Northwest Atlantics. This study can also facilitate the understanding of the oceanic biochemical processes in the Northwest Atlantics (e.g. calcification, silicification, nitrogen fixation, or dimethyl sulfide production).

Reconstruction of Missing Data in the VIIRS Global Ocean Color Images Using the DINEOF Method

Xiaoming Liu[1,2] and Menghua Wang[1]

[1]NOAA/NESDIS Center for Satellite Applications and Research (STAR)
E/RA3, 5830 University Research Ct., College Park, MD 20740, USA

[2]CIRA, Colorado State University, Fort Collins, CO, USA

Ocean color data are critical for monitoring and understanding of biological and ecological processes and phenomena, and it is also a very important source of input data for physical and biogeochemical ocean models. For example, the satellite-derived diffuse attenuation coefficient for the photosynthetically available radiation (PAR), K_d(PAR), is used to estimate heat flux within the upper water column in global and regional ocean numerical models. The Visible Infrared Imaging Radiometer Suite (VIIRS) on Suomi National Polar-orbiting Partnership (SNPP) has been providing global ocean color data since its launch in Oct. 2011. However, there are lots of missing pixels in the original VIIRS-measured ocean color images due to clouds and various other reasons. The Data Interpolating Empirical Orthogonal Function (DINEOF) is a method to reconstruct missing data in geophysical datasets based on Empirical Orthogonal Function (EOF). In this presentation, the DINEOF is applied to VIIRS-derived global Level-3 binned ocean color data of 9-km resolution and the DINEOF reconstructed ocean color data are used to fill in the gap of missing data. In particular, daily, 8-day and monthly VIIRS global Level-3 binned ocean color data, including chlorophyll-a concentration, K_d(PAR), K_d(490), as well as normalized water-leaving radiance spectra ($nL_w(\lambda)$) in the five VIIRS visible bands, are tested. To validate the reconstructed data, a set of original good pixels in the VIIRS images are selected randomly and treated as missing pixels in the DINEOF process, so that the reconstructed pixels can be compared with the original data for validation. Results of quantitative evaluations of the reconstructed pixels of all ocean color products in all test cases will be presented and discussed.

Highly resolved underway observations of marine inherent optical properties for estimating near-surface chlorophyll-a in the Fram Strait on large spatial scale

Yangyang Liu[a, b,*], Rüdiger Röttgers[c], Marta Ramírez-Pérez[d], Tilman Dinter[a, e], Sebastian Hellmann[a, e], Sonja Wiegmann[a], Astrid Bracher[a, e]

Key words: phytoplankton, Chl-a, AC-S, absorption, attenuation, MODIS, VIRRS, OLCI

Remote sensing of ocean color in the Arctic region is greatly limited and suffers from the lack of in situ observations for validation. The AC-S hyperspectral spectrophotometer, which is widely used to measure marine inherent optical properties (IOPs), markedly facilitates the provision of in situ chlorophyll a concentration (Chl-a) observations with improved resolution of time and space. However, data quality control remains challenging because of biofouling and instrumental instability. In this study, we established a ship-based flow-through system equipped with of an AC-S and conducted continuous underway measurements of hyperspectral IOPs during two summer cruises in 2015 and 2016 to the Fram Strait. A correction scheme based on Slade et al. (2010) was modified and adapted for the Fram Strait to obtain hyperspectral particulate absorption. Results show that the corrected particulate absorption spectra are comparable to discrete filter-pad measurements of particulate absorption. Continuous near-surface Chl-a was retrieved from the quality controlled hyperspectral particulate absorption. The AC-S based Chl-a were then used to validate MODIS-Aqua, -Terra and VIRRS L2 Chl-a products. In addition, the Chl-a data derived from the L1 products of Sentinel-3 sensor OLCI with POLYMER atmospheric correction method were validated. Generally, in situ and satellite Chl-a is linearly related. The AC-S based Chl-a is proven to be a much more adequate data source for satellite validation by providing more collocations both to satellite overpass and within a single satellite pixel. To the best of our knowledge, this is the first time that Chl-a derived from OLCI data were evaluated.

[a]Alfred-Wegener-Institute Helmholtz Centre for Polar and Marine Research, Bussestr. 24, 27570 Bremerhaven, Germany

[b]Faculty of Biology and Chemistry (FB2), University of Bremen, PO Box 330440, 28334 Bremen, Germany

[c]Helmholtz Zentrum Geesthacht, Center for Materials and Coastal Research, Max-Planck-Str. 1, 21502 Geesthacht, Germany

[d]Department of Physical and Technological Oceanography, Institute of Marine Sciences (ICM-CSIC), Passeig Marítim de la Barceloneta 37-49, 08003 Barcelona, Spain

[e]Institute of Environmental Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

Lobanova P.V.[1], Bashmachnikov I.L.[1,2], Brotas V.[3], Tilstone G.[4]

Accuracy assessment of satellite derived primary production models in the Northeast Atlantic using ESA OC-CCI data

Satellite derived primary production models allow estimation of primary production of marine phytoplankton (PP) on regional and global scales. However, the choice of model is primarily determined by its ability to reflect changes in photosynthetic rates as a function of the underwater light field. The model performance usually increase when using local and regional photoadaptive parameters, which depend on physiological state of phytoplankton communities. In addition, remote sensing algorithms for reconstruction of bio-optical and oceanographic parameters may not be sufficiently accurate in reproducing the actual field measurements, which further affect the modeled PP.

In this study, we compare three different PP models in the Northeast Atlantic Ocean (20-65 N, 5-40 W) in 1998-2013 covering four biogeographical provinces, and validate them against 95 in situ PP measurements. Two of the models are based on the remotely measured chlorophyll-a concentration: Vertically Generated Production Model (VGPM) and Platt and Sathyendranath Model (PSM). The third one, Absorption Based Model (Aph-PP), is based on the remotely measured coefficient of light absorption by phytoplankton pigments.

The results show that accuracy of the three models is regionally dependent with evident advantages and disadvantages depending on the Northeast Atlantic province tested. Overall stations however, PSM is found to be more accurate and explains 61% of in situ PP variance, with a slight underestimate.

[1] – St. Petersburg State University, St. Petersburg, Russia, pl19@mail.ru

[2] - Nansen International Environmental and Remote Sensing Centre, St. Petersburg, Russia, igorb1969@mail.ru

[3] - Marine and Environmental Sciences Centre/ Centro de Oceanografia, Faculdade de Ciências, Universidade de Lisboa, Lisbon, Portugal, vbrotas@fc.ul.pt

[4] – Plymouth Marine Laboratory, Plymouth, England, GHTI@pml.ac.uk

Estimating the high latitude phytoplankton diversity based on multi- and hyper-spectral satellite retrievals

S. N. Losa[1], M. A. Soppa[1], J. Oelker[2], T. Dinter[1], M. Losch[1], S. Dutkiewicz[3], A. Richter[2], V. Rozanov[2], J. P. Burrows[2] and A. Bracher[1,2]

[1]Alfred Wegener Institute Helmholtz Center for Polar and Marine Research, Am Handelshafen 12, 27570 Bremerhaven, Germany

[2]Institute of Environmental Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany

[3]Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA

With a focus at high latitudes, Information on phytoplankton compositions - diatom, coccolithophore, cyanobacteria - retrieved with PhytoDOAS (Bracher et al. 2009, Sadeghi et al. 2012) from available hyper-spectral optical satellite measurements (SCIAMACHY and OMI) is synergistically combined via an optimal interpolation technique with multi-spectral optical OC-CCI-based satellite data (Soppa et al. 2014). When combining the hyper- and multispectral retrievals, we assess various designs with different spatial radiuses and time windows of the data influence. The results are supported by a modeling study: The dynamics of diatoms and coccolithophores among other six phytoplankton types are simulated with the DARWIN biogeochemical model (Follows et al. 2007, Dutkiewicz et al. 2015) coupled to the Massachusetts Institute of Technology General Circulation Model (MITgcm Group 2012). Evaluation is done with *in situ* high precision liquid chromatography (HPLC) measurements.

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e-mail: Svetlana Losa Svetlana.Losa@awi.de
Mariana Altenburg Soppa Mariana.Altenburg.Soppa@awi.de
Julia Oelker oelker@iup.physik.uni-bremen.de
Tilman Dinter Tilman.Dinter@awi.de
Martin Losch martin.losch@awi.de
Stephanie Dutkiewicz stephdut@mit.edu
Andreas Richter richter@iup.physik.uni-bremen.de
John P. Burrows burrows@iup.physik.uni-bremen.de
Vladimir Rozanov rozanov@iup.physik.uni-bremen.de
Astrid Bracher Astrid.Bracher@awi.de

Diurnal changes of a harmful algal bloom in the East China Sea observed from GOCI measurements

Xiulin Lou[1] and Chuanmin Hu[2]

Harmful algal blooms (HABs) in the East China Sea (ECS) have been reported every year in the last decade, and satellite remote sensing has often been used to study the bloom size and duration. Using measurements from the Geo-stationary Ocean Color Imager (GOCI), we studied diurnal changes of a HAB of the dinoflagellate P. donghaiense in the ECS in May 2011. A red tide index (RI) was developed from the Rayleigh-corrected reflectance (R_{rc}) data at 443, 490 and 555 nm, and proven effective in delineating the P. donghaiense bloom in sediment-rich waters. The hourly RI images on 29 and 30 April 2011 showed consistent bloom evolution through the course of a day, with physical locations driven by tides while its surface expression increased significantly from early morning to early afternoon. The maximum coverage of the HAB at 2:30 pm on 29 April 2011 reached 6620 km^2. While the short-term changes in the surface expression could be a result of the horizontal dilution due to tides, vertical migration of the dinoflagellate from early morning to afternoon may be a dominant reason. The case study here demonstrates the unique value of a geostationary satellite ocean color sensor in revealing short-term dynamics of HABs.

1. Xiulin Lou, email: lxl@sio.org.cn, address: Second Institute of Oceanography, State Oceanic Administration, Hangzhou, 310012, China.

2. Chuanmin Hu, email: huc@usf.edu, address: College of Marine Science, University of South Florida, St. Petersburg, FL 33701, USA.

Diurnal variability in optical properties and carbon stocks as indicators of biogeochemical cycling

Antonio Mannino[1], Carlos Del Castillo[1], Marjorie Friedrichs[2], Peter Hernes[3], Patricia Matrai[4], Joseph Salisbury[5], Maria, Tzortziou[6],

[1] NASA Goddard Space Flight Center, Code 616.1, Greenbelt, MD 20771, USA
[2] Virginia Institute of Marine Science, 1208 Greate Rd, Gloucester Point, VA , 23062, USA
[3] University of California-Davis, 129 Veihmeyer Hall, Davis, CA 95616, USA
[4] Bigelow Laboratory for Ocean Science, PO Box 380, East Boothbay, ME 04544, USA
[5] University of New Hampshire, Durham, NH 03824, USA
[6] City College of New York, Office MR#931, 160 Convent Ave. & W. 138th St., New York, NY 10031, USA

Arctic-COLORS is a proposed field campaign under consideration by NASA's Ocean Biology and Biogeochemistry Program that aims to quantify the response of the Arctic coastal environment to global change and anthropogenic disturbances – an imperative for developing mitigation and adaptation strategies for the region. The Arctic-COLORS field campaign is unprecedented, as it represents the first attempt to study the nearshore coastal Arctic (from riverine deltas and estuaries out to the coastal sea) as an integrated land-oceanatmosphere-biosphere system. The overarching objective of Arctic-COLORS is to quantify the coupled biogeochemical/ecological response of the Arctic nearshore system to rapidly changing terrestrial fluxes and ice conditions. This focus on land-ocean interactions in the nearshore coastal zone is a unique contribution of Arctic-COLORS compared to other NASA field campaigns in polar regions. The science of our field campaign will focus on three key science themes and several overarching science questions per theme:
(1) Effect of land on nearshore Arctic biogeochemistry
(2) Effect of ice on nearshore Arctic biogeochemistry
(3) Effects of future change (warming land and melting ice) on nearshore Arctic biogeochemistry
This field campaign will be composed of an integrative measurement approach utilizing a broad range of proven sampling approaches from a multitude of platforms including autonomous vehicles to achieve sufficient seasonal and spatial coverage to resolve the science questions proposed by the Arctic-COLORS team as well as remote sensing and development of coupled physical-biogeochemical models.

Diurnal variability in optical properties and carbon stocks as indicators of biogeochemical cycling

Antonio Mannino[1], Michael Novak[2], Joseph Salisbury[3], Wonkook Kim[4], Javier Concha[5], Maria, Tzortziou[6], Margaret Mulholland[7]

[1] NASA Goddard Space Flight Center, Code 616.1, Greenbelt, MD 20771, USA
[2] NASA Goddard Space Flight Center/SSAI, Code 616.1, Greenbelt, MD 20771, USA
[3] University of New Hampshire, Durham, NH 03824, USA
[4] KIOST Korea Ocean Satellite Center, 787 Haean-ro(st), Sangrok-Gu, Ansan-Shi, Gyunggi-Do, Korea 426-744, Republic of Korea
[5] NASA Goddard Space Flight Center/USRA-GESTAR, Code 616.2, Greenbelt, MD 20771, USA
[6] City College of New York, Office MR#931, 160 Convent Ave. & W. 138th St., New York, NY 10031, USA
[7] Old Dominion University, 4600 Elkhorn Avenue, Norfolk, VA 23529, USA

On diurnal scales, biological, photochemical, and biogeochemical processes are regulated by the variation in solar radiation. Other physical factors, such as tides, river discharge, estuarine and coastal ocean circulation, wind-driven mixing, etc., impart further variability on biological and biogeochemical processes on diurnal to multi-day time scales. Efforts to determine the temporal frequency required from geostationary ocean color satellites to discern diurnal variability in optical properties and derived products including carbon stocks, fluxes, primary production and biogeochemical cycling culminated in a series of field campaigns in the Chesapeake Bay, northern Gulf of Mexico and Korean coastal seas with support from the NASA GEO-CAPE mission pre-formulation activities. Near-surface drogues were released and tracked in quasi-lagrangian space to monitor diurnal changes in community production, carbon and nitrogen stocks and optical properties. Significant diurnal variation in optical properties, particulate organic carbon and nitrogen, chlorophyll-a, and nutrients were measured. However, diurnal changes in dissolved organic carbon and colored dissolved organic matter absorption were generally small. Field measurements from Korean coastal waters are compared with GOCI satellite observations. Our results suggest that satellite observations at hourly frequency are desirable to capture diurnal variability in optical properties, carbon stocks and net production within coastal ecosystems.

Revisiting the influence of tropical instability waves on chlorophyll variability near the Marquesas Islands

E. Martinez[1], H. Raapoto[1], and C. Maes[2]

The Marquesas in the Central South Pacific are small isolated islands that experience strong biological enhancement. This is particularly emphasized during La Niña events. It has been hypothesized that this enhancement is induced by the southward advection of iron-rich waters upwelled along the equator through Tropical Instability Waves (TIWs). Here, we challenge this hypothesis by combining satellite observations with ocean reanalyses and convergent fronts from small-scale dynamics deduced from Lagrangian diagnostics. Our results show that not only is the archipelago influenced through advection of equatorial waters caused by TIWs, but there is an additional requirement, which is immediate mixing with local waters to assist potential iron induced phytoplankton growth. The advected flow by itself appears to disperse and stir, and therefore shape, the existing phytoplankton plume. Thus, phytoplankton increase during La Niña appears to be induced by both basin scale changes in ocean dynamics and a local Island Mass Effect.

[1] IRD, UPF, ILM, Ifremer, Écosystèmes Insulaires Océaniens (EIO), Tahiti, French Polynesia

[2] Université Brest, Ifremer, CNRS, IRD, Laboratoire d 'Océanographie Physique et Spatiale (LOPS), IUEM, Brest, France

Variability of apparent and inherent optical properties of sediment-laden waters in large river basins

J.M. Martinez[1], H. Roig[2], R. Condé de Piscoya[3], R. Espinoza Villar[2], S. Pinet[1], H. Bernini[2], I.Rêgo[2], D. Olivetti[2], A. Martinelli[4], E. Robert[1], W. Santini[1], B. Lartiges[1], C. Gosset[1], G.Chelotti[2]

[1]GET, Université de Toulouse, IRD, CNRS, UPS, CNES, 14 av. E. Belin, 31400 Toulouse, France
[2]Instituto de Geociências, Universidade de Brasília, Campus Universitário Darcy Ribeiro, ICC Centro, 70910-900 Brasília(DF), Brazil
[3]Brazilian Water Agency, Setor Policial, área 5, Quadra 3, Bloco "M", Sala 116, 70610-200 Brasilia (DF), Brazil
[4]Geological Survey of Brazil, Avenida André Araújo, 2010, Manaus (AM), Brazil

Monitoring of inland water quality using remote sensing data represents a major challenge for water color research due to the complexity of their optical properties relative to oceanic and coastal waters (i.e., Case 1 and 2 waters). Furthermore, there is a lack of systematic studies of rivers and lakes across the world documenting the variability of the AOPs/IOPs in these areas to establish the foundation for the remote sensing-based operational monitoring of inland waters. In particular, it is necessary to consider the whole watershed, instead of a specific river/lake, and to determine the variation of AOPs/IOPs as a function of the hydrological cycle.

In this work, we present a synthesis of radiometric measurements that we realized over different watersheds in South America and Western Africa representing more than 700 hundred sampling stations collected over sediment-laden waters. Additional measurements of particle size distribution (PSD) and mineralogy made possible to use bio-optical models with realistic parameters adapted to sediment transport in rivers. We demonstrate that PSD strongly controls the Rrs/SPM concentration relationship in most catchments. As an example, we show that a 3-micrometer seasonal variation in the median particle size cause a significant hysteresis in the Rrs/SPM relationship in the Madeira River. Finally, we show that a unique retrieval model based on band ratio (Rrs ratio at red and infrared) makes possible to robustly retrieve SPM concentrations over all studied rivers (Relative RMSE of 21 %) for concentrations larger than 100 $mg.l^{-1}$.

Bio-optical variability in Sognefjord and Trondheimsfjord, Norway.

V. J. Mascarenhas[1], D. Voß[1], J. Wollschlaeger[1,2], O. Zielinski[1]

[1] University of Oldenburg, Institute for Chemistry and Biology of the Marine Environment, 26129 Oldenburg, Germany

[2] Centre for Material and Coastal Research, Helmholtz Centre Geesthacht, 21502, Geesthacht, Germany.

Penetration of sunlight into the sea and its interaction with sea water, dissolved as well as particulate suspended materials is an important physical phenomenon in the ocean that governs the light availability and associated biological processes like primary production or plankton distribution in the water column. With an aim to study the bio-optical variability, water optical types and 1% spectral light availability, hydrographical, and hyperspectral optical (downwelling irradiance and upwelling radiance) profiles were measured along fjord transects in Sognefjord and Trondheimsfjord, Norway. In concurrence, water samples were collected and analyzed via visible spectrophotometry, fluorometry, and gravimetry to quantify and derive inherent optical properties of the water constituents. An absorption model as a function of OACs is developed for Sognefjord using multiple regression analysis. Euphotic depth decreased from outer to inner fjord sections. Optical classification revealed Trondheimsfjord as CDOM dominated case2 water optical type at lower wavelengths (412-555 nm) while phytoplankton dominated case2 type at 665nm. Sognefjord however exhibited much greater optical complexity with differences in water optical types at a single wavelength.

veloisa.john.mascarenhas@uni-oldenburg.de

daniela.voss@uni-oldenburg.de

jochen.wollschlaeger@uni-oldenburg.de

oliver.zielinski@uni-oldenburg.de

From toes to top-of-atmosphere: Fowler's Sneaker Depth a citizen scientist index of water clarity for the Chesapeake Bay

Lachlan I.W. McKinna,[1,2] Ivona Cetinić,[1,3] and Benjamin Crooke[1,4]

Fowler's Sneaker Depth (FSD) is a visually-discerned citizen scientist measure of water clarity for the Patuxent River, USA. Retired Maryland State Senator Bernie Fowler first recorded FSD in 1988 in order to engage the general public about local water quality issues. Each June at annual "wade-in" events, a collection of community members, led by Bernie Fowler, slowly wade into Patuxent River. The FSD is then determined as the depth at which the observer's sneakers are no longer visible. These community events have resulted in a 28 year record of water clarity. While useful, these *in situ* measurements represent only a snapshot in time and are not able to resolve inter- and intra-annual variability. In this study, we developed a proof-of-concept algorithm for deriving FSD from spectroradiometric ocean color imagery. Our objectives were twofold: (i) devise a conceptually simple FSD algorithm suitable for communicating remote-sensing concepts with citizen scientists, and (ii) evaluate the FSD algorithm using spatiotemporally rich ocean color datasets. The algorithm uses a hyperbolic function to relate water clarity to red-end remote sensing reflectances at 645 nm, $R_{rs}(645)$, and was formulated using radiative transfer modeling and *in situ* FSD measurements. We then applied the algorithm to Landsat-8 and MODIS Aqua datasets. The derived FSD time-series were then compared with environmental factors such as river discharge, total suspended solids, and chlorophyll concentration to explore local drivers of water clarity. With further development, the FSD may prove to be a useful tool for delivering scientifically relevant results and for informing and engaging local policy makers and stakeholders.

[1]NASA Goddard Space Flight Center, Code 616, Greenbelt, MD 20771, USA
[2]Science Applications International Corporation, McLean, VA 22102, USA
[3]GESTAR/Universities Space Research Association, Columbia, MD 21046, USA
[4]Sandy Spring Friends School, Sandy Spring, MD, 20860, USA

Variability of chlorophyll-a concentration in the Gulf of Guinea and its relation to physical oceanographic variables

Frédéric MELIN[(1)], Karen NIETO[(2)]

The Gulf of Guinea represents a wide tract of the African coast with complex and rich coastal ecosystems undergoing various pressures. The seasonal variations of satellite-derived chlorophyll-a concentration (Chla) along the Gulf of Guinea and their relations with physical oceanographic variables are analyzed using satellite observations covering the period 2002-2012. The effects of sea surface temperature (SST), sea level anomalies (SLA), winds, geostrophic currents, eddy kinetic energy, mesoscale eddies and fronts, as well as river discharge, are considered on a monthly time scale. In this region with very challenging conditions for atmospheric corrections, the study is allowed by the unprecedented coverage given by the multi-mission products distributed by the ESA Ocean Colour Climate Change Initiative (OC-CCI). The physical variables serve as potential predictors in a statistical Boosted Regression Tree model. The western-most domain, from Guinea-Bissau to Sierra Leone, is associated with upwelling properties in boreal winter and appears to share some characteristics with the overall Northwest African upwelling system. The region of Ivory Coast and Ghana also has upwelling properties but the main upwelling season is in boreal summer. In general upwelling conditions with cold SST, negative SLA, fairly strong frontal activity, and moderate winds, appear as the environmental window most favorable to high Chla values. Finally, the systems associated with the coasts of Nigeria to Gabon show some mixed properties with a significant influence of river discharge on the Chla variability. This has more general implications in terms of optical properties in the region.

(1) frederic.melin@ec.europa.eu, (2) karen.nieto@gmail.com

European Commission, Joint Research Centre, via Fermi 2749, 21027 ISPRA (Italy)

Detection of Internal Waves using MODIS True Colour Images and Study of its Effects on Chlorophyll Concentration in the Bay of Bengal

Tensubam Chinglen Meetei[1], Mihir Kumar Dash[2], Jithendra Raju Nadimpalli[3], Subhra Prakash Dey[4]

Abstract

Sunglint areas in the MODIS true colour imageries are used for the detection of internal waves in the Bay of Bengal for two years i.e. 2015 and 2016. We found that internal wave activities are more prominent in the Andaman Sea i.e. southeast part of the Bay of Bengal. South to Car Nicobar Island is found to be a site for generation of internal waves. Investigation of underwater topography of the region found the presence of a sill in this region, which is responsible for the generation of internal waves. It is evident from the MODIS imageries that two internal waves are radiated towards east and west direction of the sill. The speed, direction of propagation and distance between wave packets are also been computed. These large waves help in upwelling cold, dense and nutrient rich water below the pycnocline to near surface layer and hence can affect the chlorophyll concentration along its propagation. GSM merged MODIS-VIIRS chlorophyll-a (8-days and monthly) data are used and analysed for the given period to study its effects on chlorophyll concentration. From the analysis, it is confirmed that there is an increase in chlorophyll concentration south of Car Nicobar Islands and is found to be extended in the direction of propagation of the internal waves. Use of MODIS true colour images is limited to areas under cloud cover. Therefore, Sentinel SAR image data sets are used to further detect and study internal waves for the areas out of sunglint regions and also for the areas under cloud cover.

[1] Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, email: chinglenforever@gmail.com

[2] Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, West Bengal-721302, email: mihir@coral.iitkgp.ernet.in

[3] Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, West Bengal-721302, email: jithuraju1290@gmail.com

[4] Centre for Oceans, Rivers, Atmosphere and Land Sciences (CORAL), Indian Institute of Technology Kharagpur, West Bengal-721302, email: subhra@coral.iitkgp.ernet.in

On thermal and color identification of submarine groundwater discharges to a coastal lagoon using UAVs

Renato Mendes[1], Trent Lukaczyk[1,2], João M. Dias[3], João Borges de Sousa[1]

Submarine groundwater discharges (SGD) typically are small-scale features displaying very high spatial and temporal variability, which make its evaluation difficult. Inputs may consist of fresh, brackish and/or recirculated sea water that could contribute to often unaccounted marine/riverine budgets. Therefore, identification and measurement of associated water properties are challenging tasks.

Ria de Aveiro is a shallow coastal and tidal-driven lagoon in Portugal, whose hydrodynamics is actually well predictable. However, most numerical models predictions do not adjust well to water temperature and salinity observations in restricted lagoon areas. Thus, SGD seems to be a plausible explanation to those disagreements. Remote sensing with Unmanned Aerial Vehicles (UAVs) is a viable alternative to conventional orbital platforms for acquiring high-resolution data to properly identify SGD at lagoon scale.

Recent developments in UAV platforms, such as Vertical Take Off and Landing (VTOL) airplanes have yielded vehicles capable of low-altitude long-endurance flights with minimal logistic footprint. This technology permits sampling over large areas and high frequency coverage of a broad spectrum of imaging wavelengths. The falling cost of this technology further permits the scaling of operations with multiple vehicles flying concurrently to cover larger areas more frequently.

Here is presented a combination of aerial thermal infrared and color surveys to map surface water temperature and identify possible positions and spatial extents of SGD plumes. UAV based infrared and color imagery combined with in-situ observations of nutrients, salinity and temperature is a promising method to produce new integrated approaches to quantify the effects of SGD.

[1]LSTS, Department of Electrical and Computer Engineering, School of Engineering (FEUP), University of Porto, Portugal (rpsm@fe.up.pt; jtasso@fe.up.pt)
[2]FlightWave Aerospace Systems, Santa Monica, California, USA (trent@flightwave.aero)
[3]CESAM, Physics Department, University of Aveiro, Aveiro, Portugal (joao.dias@ua.pt)

On observation of seaward propagating internal solitary waves using Sentinel-2A ocean color imagery

Renato Mendes[1], Américo S. Ribeiro[2], Magda C. Sousa[2], João G. Rodrigues[3], Jorge M. Magalhães[4], João M. Dias[2], José C. B. da Silva[4], João Borges de Sousa[1]

Internal waves (IWs) are typically the most energetic high-frequency events in the coastal ocean. These large-wavelength waves are difficult to measure with in situ or shipboard instruments. Therefore, remote sensing has been the main tool for IW observations. Although IWs have been observed in the Portuguese offshore region using from satellite-based remote, here are presented IW evidence captured by the Multi-Spectral Instrument (MSI) aboard of the new European Space Agency's Sentinel-2A satellite. The 10-meter resolution of the MSI sensor makes IW features easy to identify in ocean color imagery.

Images acquired during 2015 summer in the western Portuguese coast show significant IW activity in the region of influence of Sado River near the city of Setúbal. The majority of the observations present IWs propagating onshore towards shallow waters up to 20 to 30 m deep. However, a seaward propagating packet of IWs is observed in the region of influence of the Sado River, representing one of the first episodes identified with this feature.

From the analysis of remote sensing images and numerical modeling ocean predictions, this study presents plausible explanations for this waves' generation mechanism: 1) local Baines forcing owing to a very steep slope off the estuary mouth; 2) IW reflection at a step-like see floor meeting the estuarine slope; 3) thermal stratification effect on high ebb estuarine flow.

This study offers the outlook of using Sentinel-2A ocean color imagery for physical studies in coastal areas, in particular about nonlinear IWs.

[1]LSTS, Department of Electrical and Computer Engineering, School of Engineering (FEUP), University of Porto, Portugal (rpsm@fe.up.pt; jtasso@fe.up.pt)
[2]CESAM, Physics Department, University of Aveiro, Aveiro, Portugal (americosribeiro@ua.pt; mcsousa@ua.pt; joao.dias@ua.pt)
[3]HIDROMOD, Modelação em Engenharia, Lisboa, Portugal (hidromod@hidromod.com)
[4]Department of Geosciences, Environment, and Spatial Planning, and CIIMAR, University of Porto, Porto, Portugal (jdasilva@fc.up.pt; jmagalhaes@fc.ul.pt)

Space Technologies for Inland Water Monitoring.

Vivianne K. Meta
Geomatic Engineer
LocateIT Ltd, Nairobi, KENYA
Email: vivmarita@gmail.com

Key Words: *Space technologies, environmental planning, water monitoring, environmental management*

The growing availability of earth observation data for instance, from platforms such as the Copernicus program and recent advancements in Space technologies are pushing usage to new frontiers in ocean science - be it in the diversity of the applications; the level of precision & detail of the information gathered; or in the ability to converge the three pillars of Space technology, namely; earth observation, communication and navigation in this era of big data and internet of things (IoT).

This poster highlights a case study from Lake Naivasha to articulate the opportunities offered to support prudent environmental monitoring. The case brings out two support areas that Space technologies offer to governments, non-governmental actors and other stakeholders. First, is the pivotal role these technologies play in environmental monitoring. Second, are operation answers that Space technologies readily avail in support of the DPSIR Framework (Drivers, Pressures, State of environment, Impacts, and Responses) to support sound environmental planning.

This poster demonstrates the inalienable place of Space technologies in environmental management. The focus is on the outputs of a research on Mapping of Macrophytes (water hyacinth and papyrus) in Lake Naivasha done using high resolution optical Earth Observation (EO) data and in-situ data. The EO data used was the Sentinel-2 satellite imagery and In-situ data collected on the same day of the Sentinel-2 overpass to ensure minimal mismatch between the locations of the macrophytes on the lake and on the satellite image to be used for processing and interpretation.

OCView - interactive online visualization and monitoring tool for satellite ocean color data imagery

Karlis Mikelsons[1,2] and Menghua Wang[1]

We present OCView – an online ocean color visualization tool with monitoring and some evaluation capabilities. Developed by NOAA Ocean Color Science Team, it relies on OpenLayers JavaScript library for interactive multi-resolution display. While the primary data source is the Visible Infrared Imaging Radiometer Suite (VIIRS), data from other sensors such as the Sentinel-3 Ocean and Land Color Instrument (OLCI), and the Geostationary Ocean Color Imager (GOCI) are also available. Simple navigation in time allows to select any day from the mission-long imagery archive, and the imagery is continuous across the dateline. OCView features the true color, derived from Rayleigh corrected top-of-atmosphere reflectances in red, green, and blue bands, as well as various Level-2 daily ocean color data products, which can be overlaid over the true color imagery layer. This combination allows to identify the causes for no retrievals, such as clouds, sun glint, or other atmospheric conditions. In addition to daily data products, time averaged data product imagery is also available, including 8-day and monthly averages, as well as climatology. Additional data layers display granule boundaries and coastlines. OCView allows to switch easily between imagery from different sensors, different data streams, data products, and time averages, thus enabling efficient imagery inter-comparison. New experimental and custom user data products can be incorporated for evaluation purposes. Fast interactive display of imagery allows to identify artifacts with spatial correlations, such as suboptimal cloud and ice masking, striping, or other instrument performance related differences.

[1] NOAA/NESDIS Center for Satellite Applications and Research, 5830 University Research Ct., College Park, Maryland 20740, USA
[2] Global Science and Technology, Inc., Greenbelt, Maryland 20770, USA

Quantifying uncertainty in airborne hyperspectral ocean color measurements

W. David Miller

Airborne hyperspectral ocean color remote sensing is a valuable tool to differentiate and quantify optically complex coastal and inland waters, particularity in areas where the bottom is visible. Airborne systems permit repeated coverage of areas on shorter time scales and smaller spatial scales than most satellite systems. In order to have confidence in the products developed from these systems, we need to quantify the uncertainty of input parameters used by many ocean color algorithms, namely remote sensing reflectance. We present results showing the comparison between atmospherically corrected hyperspectral ocean color imagery and coincidentally collected ground-truth data (surface reflectance and in-water constituents) in order to characterize the accuracy of the airborne data. We find that after careful calibration and atmospheric correction, mean absolute percent errors on par with those obtained for satellite ocean color systems in clear water (~6-25%).

U.S. Naval Research Laboratory, Remote Sensing Division, Coastal Ocean Remote Sensing Branch, 4555 Overlook Ave SW, Washington, DC, 20375, dave.miller@nrl.navy.mil

ShellEye project: Satellite monitoring for early warning of water quality risks to shellfish farms

Peter I. Miller[1], Andrey Kurekin[1], Hayley Evers-King[1], Jamie Shutler[2], Wiebke Schmidt[2], Carlos Campos[3], and Keith Davidson[4]

1: Remote Sensing Group, Plymouth Marine Laboratory, Prospect Place, Plymouth PL1 3DH, UK. E-mail pim@pml.ac.uk.

This talk will present the recent development of satellite ocean colour and modelling tools for monitoring and forecasting water quality for the finfish and shellfish aquaculture industries. The ocean colour monitoring tools are designed to provide information on the environmental conditions around aquaculture sites and potentially give shellfish farmers warning of the occurrence of harmful algal blooms (HABs) and microbiological pollution from sewage discharges. More specifically, we are working to extend the range of HAB species (*Karenia mikimotoi*, *Pseudo-nitzschia*, *Pseudo-chattonella*) that can be identified using satellite data (MODIS, VIIRS and Sentinel-3 OLCI), building on our ocean colour classification approach that has been successfully applied to providing early warnings for salmon farmers in Scotland. Secondly, we are advancing the fusion of higher resolution Sentinel-2/Landsat-8 data and meteorological data to investigate warning of increased microbiological contaminants due to continuous and storm overflow discharges.

Incidents of poor water quality can result in periodic closures of shellfish farms and mortality at finfish farms, which have substantial financial impacts on businesses and can undermine consumer confidence in shellfish products. Therefore, knowledge and new technology resulting from this project aims to directly benefit members of the shellfish industry, through the development of an operational service for advanced water quality bulletins. We are working in partnership with 5 aquaculture farms in England and Scotland, in order to benefit from industry expertise before and during a pilot of the service. This research is ongoing through the 4-year ShellEye project (www.shelleye.org), funded by UK research councils BBSRC and NERC.

2: Centre for Geography, Environment and Society, University of Exeter, Penryn Campus, Penryn, TR10 9FE, United Kingdom
3: Centre for Environment, Fisheries & Aquaculture Science (Cefas), Weymouth Laboratory, Barrack Road, Weymouth, DT4 8UB, United Kingdom
4: Scottish Association for Marine Science, Scottish Marine Institute, Oban, PA37 1QA, Scotland

Interannual variation of SPM distribution on the Yellow Sea using newly developed semi-analytical model-based SPM algorithm

Jee-Eun Min and Joo-Hyung Ryu

The Yellow Sea is the world-famous high turbidity waters, where is connected to the world's third-longest river - Yangtze River. Various researches for the SPM (suspended particulate matter) concentration, coastal erosion/deposition, movement of ocean current, and water quality are performed in the Yellow Sea and East China Sea. Several SPM algorithms have been developed, but those algorithms showed the under-estimation problems for the highly turbid waters. So we developed new SPM algorithm to overcome the limitation of existing algorithms. Newly developed SPM algorithm was verified and compared with the other SPM algorithms develop for the Northeast Asian Sea using in-situ dataset collected on the sea area around the Korean Peninsula. The new SPM algorithm showed best correlation(r=0.77) and slope (0.99) values, and smallest error values (RMSE=29.2 g/m^3, APD=3.16%, RPD=53.34%). Newly developed SPM algorithm represented the high performance on the east coastal part of the China with SPM concentration over 300 g/m^3 as well as the west coastal part of Korean Peninsula with SPM concentration over 100 g/m^3, contrastively low performance of the existing algorithms. High SPM values were observed in the winter and spring seasons with the northwest monsoon. Especially, the SPM values around the estuarine part of the Yangtze River and the coastal area of the Jiangsu Province represented higher than 300 g/m^3. Its spatial distribution shows a tongue's shape toward to the south-east direction. On the contrary, it shows low SPM value in the whole Yellow Sea area in summer and autumn seasons.

jemin@kiost.ac.kr

Korea Ocean Satellite Center (KOSC), Korea Institute of Ocean Science & Technology (KIOST)
787 Haean-ro(st.) Sangnok-gu, Ansan-si, Gyeonggi-do, 15627, Korea

Estimating particulate inorganic carbon concentration from ocean color measurements using a reflectance difference approach.

Catherine Mitchell[1], Chuanmin Hu[2], Bruce Bowler[1], Dave Drapeau[1] and William M. Balch[1]

A new algorithm for estimating particulate inorganic carbon (PIC) concentrations from ocean color measurements is presented. PIC plays an important role in the global carbon cycle through the oceanic carbonate pump, therefore accurate estimations of PIC concentrations from satellite remote sensing are crucial for observing changes on a global scale. A global dataset was created from field and satellite observations for investigating the relationship between PIC concentrations and differences in the remote sensing reflectance (R_{rs}) at green, red and near-infrared (NIR) wavebands. Three color indices were defined from the reflectance differences: two as the relative height of R_{rs}(667) above a baseline running between R_{rs}(547) and an R_{rs} in the NIR (either 748 nm or 869 nm), and one as the difference between R_{rs}(547) and R_{rs}(667). All three color indices were found to explain around 80% of the variance in field-measured PIC. But, due to the lack of availability of R_{rs}(NIR) in the standard ocean color data products, most of the further analysis presented uses the color index determined from only two bands. The new two-band color index algorithm was found to retrieve PIC concentrations more accurately than the current standard algorithm used in generating PIC data products. Application of the new algorithm to satellite imagery revealed patterns on the global scale as observed from field measurements. The new algorithm was more resistant to atmospheric correction errors and residual errors in whitecap and sun glint corrections, as seen by a reduction in the speckling and patchiness in the satellite-derived PIC images.

[1]Bigelow Laboratory for Ocean Sciences, 60 Bigelow Dr, PO Box 380, East Boothbay, ME 04544, USA.

[2]College of Marine Science, University of South Florida, St. Petersburg, Florida, USA.

Evaluation and improvement of the OLCI atmospheric correction over coastal waters: Validation and improvements of OLCI ocean color products

Mograne M. Ah.[1], C. Jamet[2], H. Loisel[3], X. Mériaux[4] and A. Cauvin[5]

On-broad of the ESA Sentinel-3A satellite, two sensors are of interest for studying the ocean color over coastal waters: OLCI dedicated to the ocean color remote sensing and SLSTR dedicated to the sea surface temperature remote sensing. OLCI and SLSTR fields of view are co-located, potentially allowing the improvements of the ocean color retrievals. The accuracy of these latter parameters depends on the atmospheric correction processing which consists of removing the contribution of the atmosphere, i.e. Rayleigh and aerosol components from the total measured reflectance at the top of the atmosphere.

Over open ocean waters, the NIR atmospheric correction scheme is performed using the NIR black pixel assumption. Over coastal waters, such hypothesis cannot be used. To deal with that, a OLCI/SLSTR synergy atmospheric correction scheme is proposed combining the black pixel hypothesis in the UV and SWIR bands of OLCI (400 and 1020 nm) and the SWIR ones from SLSTR (1610 and 2250 nm).

The accuracy of the proposed atmospheric correction scheme will be presented through simulated data sets. Match-up exercise results of the L2 OLCI official R_{rs} products will be also presented, over the Eastern English Channel and French Guiana using radiometry data sets collected by an ASD FieldSpec 4 spectro-photometer instrument with a spectral range from 350 to 2500 nm. The data quality of the official OLCI L2 R_{rs} products of the Bright Pixel and Neural Network atmospheric correction algorithms will be compared with the potential of the new proposed OLCI/SLSTR synergy atmospheric correction scheme.

[1] mohamed-abdelillah.mograne@univ-littoral.fr, Univ. Littoral Côte d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France.

[2] Corresponding author, cedric.jamet@univ-littoral.fr, Univ. Littoral Côte d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France.

[3] hubert.loisel@univ-littoral.fr, Univ. Littoral Côte d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France.

[4] xavier.meriaux@univ-littoral.fr, Univ. Littoral Côte d'Opale, Univ. Lille, CNRS, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France.

[5] arnaud.cauvin@univ-littoral.fr, CNRS, Univ. Lille, Univ. Littoral Côte d'Opale, UMR 8187, LOG, Laboratoire d'Océanologie et de Géosciences, F 62930 Wimereux, France.

The Cornell Satellite Remote Sensing Program

Bruce C. Monger

The increasing need to understand ocean biology and biogeochemistry problems at global scales has fueled an ever-expanding constellation of ocean observing satellites that collectively generate an extraordinary volume and variety of satellite ocean data. The wide range of satellite data types and data sources can be overwhelming to many researchers who want to begin to incorporate satellite observations into their research. And in response to this problem, a summer satellite remote sensing training program was begun back in 1998 that provides an intensive hands-on introduction to the practical computer skills needed to work independently to acquire, analyze and visualize remotely sensed data.

The course focuses a lot of attention on processing ocean color satellite data from raw radiance values to mapped chlorophyll and related derived geophysical products using SeaDAS software in conjunction with python processing scripts. Attention is also given to other satellite sensors and geophysical data product types (e.g., Level-3 SST, Ocean Wind Speed and Sea Surface Height). An extremely important feature of the course is to develop good *Python* programming skills needed to effectively make use of satellite image data to answer important oceanographic questions.

To date, the summer program held on the Cornell campus has trained 235 participants of which 59 have been international. The same training program has also been held in 1) Bangkok Thailand in 2009, 2) Cordoba Argentina in 2015 and 3) Suva Fiji in 2017. With approximates 80 additional participants in total that were trained.

e-mail: bcm3@cornell.edu
Mail Address: Department of Earth and Atmospheric Sciences, 4124 Snee Hall, Cornell University, Ithaca, NY 14853, USA

Title: Initial results from SeaPRISM measurements in the summer of 2016 in western Lake Erie

Authors: Tim Moore (UNH), Hui Feng (UNH), Steve Ruberg (NOAA GLERL), Menghua Wang (NOAA NESDIS), Ron Muzzi (NOAA GLERL), Steve Constant (NOAA GLERL), and Kyle Beadle (NOAA GLERL)

In the summer of 2016, a SeaWiFS Photometer Revision for Incident Surface Measurements (SeaPRISM) – a 9-channel above-water multi-spectral autonomous sun photometer - was deployed in western Lake Erie, serving dual roles as a Cal/Val site supporting remote sensing data product evaluation (including VIIRS, MODIS, Sentinel-3 OLCI, Landsat-8, and Sentinel-2 MSI), and as an observational system for real-time monitoring of water quality for the NOAA Great Lakes Environmental Research Laboratory Harmful Algal Bloom program. The SeaPRISM was operational from July 19 to September 9, 2016, serving as a precursor to a new 12-channel version for 2017 deployment. The data collected observed different water conditions, ranging from cyanobacteria blooms to clearer waters from the Detroit River plume. The SeaPRISM data provide a window into the optical dynamics of this region, including the diurnal development floating cyanobacteria mats, and matchup data sets with satellite sensors. A NOAA buoy with water quality sensors that measured continuously was located next to the SeaPRISM, and the combined data sets shed important light on lake processes and the ability of optical sensors and bio-optical algorithms to monitor and detect water quality in rapidly changing environment.

Exploring the capabilities of Landsat8-OLI and Sentinel2-MSI satellite data to remotely sense the size distribution and composition of suspended particles in river plumes.

Morin G.P.[1], Marty S.[2], Doxaran D.[1], Ody A.[3], Harmel T.[1,4], Constantin S.[1]

Ocean colour science have recently benefited from high spatial resolution satellite data from OLI-L8, MSI-S2, allowing the monitoring of fine coastal processes.
We present results from three coastal rivers plumes draining geologically contrasted watersheds in NW Mediterranean Sea: the Rhône, Var and Paillon. We realized sampling and *in situ* measurements of turbidity, remote-sensing reflectance (Rrs), inherent optical properties (IOPs), and particle size distribution (PSD) that we compared to high resolution (L8, S2) satellite data.
Preliminary results demonstrate that:
1 - In the Rhône and Var river plumes Rrs display typical water reflectance patterns of low to highly turbid waters, while the Paillon river plume displays abnormal patterns with very high Rrs values in the visible spectral region even for low turbidity. We suspect the combined effect of finer flocs size in Paillon plume than in Var plume (D50 of 212µm against 422µm), and higher content in smectite (clays) and carbonates to significantly impact the optical properties of particles (mass-specific back-scattering coefficient) in the Paillon.
2 – *in situ* Rrs compare very well with MSI-S2 data when applying atmospheric corrections developed at LOV, which shows the ability of L8 and S2 to document river plumes of limited areas as efficiently as major rivers ones.
This regional study case brings results to constrain the relative effects of PSD - mineral compositions on satellite Rrs, in order to adapt ocean colour algorithms to retrieve such information from high resolution satellite data.

1 Laboratoire d'Océanographie de Villefranche sur Mer (LOV), UMR 7093, CNRS/UPMC, F-06230 Villefranche Sur Mer Cedex, France. morin@obs-vlfr.fr, doxaran@obs-vlfr.fr, sorin@obs-vlfr.fr
2 Norwegian Institute for Water Research, Oslo, Norway. sabine.marty@niva.no
3 Aix-Marseille University, Mediterranean Institute of Oceanography (MIO), CNRS/INSU, IRD, UM 110, Campus universitaire de Luminy, case 901, 13288, Marseille cedex 09, France. anouck.ody@mio.osupytheas.fr
4 Irstea, UR RECOVER, Pôle AFB-Irstea Hydroécologie des Plans d'eau, 3275 route Cézanne, F-13182 Aix-en-Provence, France. harmel@obs-vlfr.fr

GLOBAL SHIFTS IN PHYTOPLANKTON COMMUNITY SIZE STRUCTURE IN RESPONSE TO ENVIRONMENTAL CONTROLS

Colleen B. Mouw[1] and Audrey Ciochetto[2]

Global phytoplankton communities have been changing in response to a shifting climate. This is most easily highlighted in research at long-term ocean time series sites such as BATS and CARIACO that have documented shifts in species composition towards the dominance of smaller-celled phytoplankton linked directly to trends in the physical drivers of nutrient availability in these systems. Such changes have far reaching implications for the magnitude and efficiency of the biological carbon pump and for the structure and function of higher trophic levels. We aim to explore changing patterns in phytoplankton community diversity, specifically as it relates to cell size distribution, on a global scale in response to environmental controls. Utilizing advances in detecting phytoplankton functional types from ocean color satellite imagery we retrieve the proportional contributions of micro- and pico-plankton to the total phytoplankton community across the continuous ocean color satellite record from 1997 to the present. We characterize spatial and temporal variability and trends in community size structure on seasonal, inter-annual and long-term time scales in relation to physical drivers of the system.

[1]cmouw@uri.edu, University of Rhode Island, Graduate School of Oceanography, 215 South Ferry Road, Narragansett, RI, USA
[2]audreyciochetto@uri.edu, University of Rhode Island, Graduate School of Oceanography, 215 South Ferry Road, Narragansett, RI, USA

Improving suspended solids monitoring during dredging operations in the Guadalquivir estuary (SW Spain) using high-resolution remote sensing imagery

Isabel Caballero[1], Gabriel Navarro[1]

Dredging operations and disposal of extracted materials is a frequent practice in several ports along the SW Spanish coast. Specifically, periodic dredging maintenance of the Guadalquivir navigation channel every year is undertaken from its mouth to where it accesses the Port of Seville. Effective mapping of sediments for the duration of dredging works is mandatory to maintain acceptable water quality levels for both wildlife and humans and to further evaluate the environmental impact. The last major dredging project was undertaken from October to December 2016 along the estuary navigation channel, which represents a significant opportunity to investigate the consequences of these activities on water quality.

Within this context, cost effective Remote Sensing technologies provide significant improvement at monitoring turbidity and suspended solids compared to the routine standard networks established by marine consulting agencies. In this study we present the fine-scale inspection of the dredging-induced suspended solids with the use of high resolution optical data from different satellites: Landsat-8 (30 m), Sentinel-2A (10 m), Worldview-2 (50 cm) and Worldview-3 (30 cm). These platforms reveal improved monitoring at unprecedented resolution with accuracy to detect the spatial patterns of the turbidity plume generated by the dredging operations near the port lock in Seville. These efforts can be high-quality baseline programs to not only improve the cost effective understanding of dredging actions but also to analyze the post dredging monitoring, to support the assistance of operational and policy needs for water quality and to validate the existing estuarine hydrodynamic models.

1. Marine Science Institute of Andalusia (ICMAN-CSIC),
Campus Universitario Río San Pedro s/n, 11510 Puerto Real (Cádiz), SPAIN;
isabel.caballero@icman.csic.es; gabriel.navarro@icman.csic.es

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Watercolour and spatio-temporal visibility of New Zealand lakes

Uyen Nguyen[1*], Moritz Lehmann[1] and David Hamilton[1]

[1]Environmental Research Institute, The University of Waikato, Hamilton, New Zealand
[*]Correspondent author email: *unguyen@waikato.ac.nz*

New Zealand lakes are an important resource for national economy and tourism in the country. These lake characteristics have a wide range of states and mixing regimes because of different levels of nutrient and enriched geomorphic inputs. From peat lakes to deep clear lakes performs diverse biodiversity and habitat. Lake management agencies have been using different measurement methods to collect water quality indicator for the assessment and monitoring. However, availability data of many lakes are still limited of retrieving historical and continuous lake information for understanding lake characteristics and water quality at regional and national scale, particularly in distance or remote areas that may not have any ground-based monitoring program. Therefore, satellite observations can be a complementary tool according to the need of a high spatio-temporal resolution and cost-effective option for the synoptic long-term lake monitoring purpose. In this study, we present preliminary results of using Landsat 8 data for 3820 New Zealand lakes from 2013 to 2016 to (i) explore how visibility of a lake in term of cloud cover constraints and satellite overpass period; and (ii) provide an initial assessment of the colour of the lake using dominant wavelength from Landsat 8 bands. This is the first approach of developing specific algorithms for the retrieval of water quality parameters processing along with field data collection from the in-situ and hyperspectral measurement.

Bottom Reflectance Retrieval in Shallow Rivers: Lab Spectroradiometry Experiments

Milad Niroumand-Jadidi [a, b, c], Alfonso Vitti [a], and Nima Pahlevan[d]

Remote sensing techniques can enhance our understanding of fluvial systems by retrieving spatially and temporally explicit information on substrate types and compositions. Characterization of bed type is of particular importance for modeling morphology and habitats in riverine environments. This research aims at investigating the applicability of water column correction approaches to retrieve bottom reflectances in very shallow rivers. We solved for the diffuse attenuation coefficient (k_d), i.e., the key parameter for water column correction, using the magnitude of water-leaving radiance observed for different known depths and over a homogenous bottom type. Further, spectroradiometric experiments are performed under a controlled condition in a hydraulic lab. A set of spectral reflectances is collected over a water flume with gravel bed in the presence and absence of submerged vegetation while the water level is increased with 1 cm increments up to 40 cm. We applied our proposed methodology on the spectra convolved with WorldView-2 spectral responses to examine its effectiveness for riverbed mapping. Our results indicate that in shallow fluvial systems when the bathymetry is known the k_d can readily be retrieved. Knowing the $k_d(\lambda)$, the retrieved reflectances for vegetated and non-vegetated gravel beds showed good agreements with those observed over dry beds as reference spectra. Moreover, vegetation indices yield much more accurate results in detection of submerged vegetation using retrieved bottom reflectances rather than those observed above the water surface. The methodology can be extended for a wide range of rivers with a similar morphology and water column properties.

[a] Department of Civil, Environmental and Mechanical Engineering, University of Trento, Via Mesiano, 77 - 38123 Trento, Italy, email: m.niroumand@unitn.it

[b] Department of Biology, Chemistry and Pharmacy, Freie Universität Berlin, Altensteinstraße 6, 14195 Berlin, Germany

[c] Leibniz-Institute of Freshwater Ecology and Inland Fisheries, Müggelseedamm 310, 12587 Berlin, Germany

[d] NASA Goddard Space Flight Center, 8800 Greenbelt Rd, Greenbelt, MD, 20771, United States

Remote sensing reflectance variability along an intense HAB event in Southern Brazil

Noernberg, M.A.; Luz, L.F.G; Silva, E.F.F.; Mafra Jr., L.L.

Federal University of Paraná, Center for Marine Studies, Av. Beira Mar, s/n, Pontal do Paraná, Paraná, Zip Code: 83255-976, Brazil

Changes in phytoplankton species composition and concentration are a central feature of marine ecosystem dynamics. Harmful algal blooms (HAB) are severe ecological disasters threatening aquatic systems throughout the world, and our ability in detecting and monitoring them should be improved. On June 2016, a major *Dinophysis* cf. *acuminata* bloom hit the southern Brazilian coast causing damage to the local mariculture along its trajectory. This led the authorities to issue the shellfish harvesting ban in Santa Catarina and Paraná states. During its peak the bloom reached an area of 201 km^2 along the coast of Paraná state. An extensive sampling effort was accomplished during the 4 weeks in which the bloom continued to affect water quality along the Paraná coast. In order to monitor its passage and evolution, we performed weekly sampling cruises in estuarine and inner shelf regions. Remote sensing reflectance (R_{rs}) data were performed with Fieldspec ASD. Measurements of the absorption coefficients of colored dissolved organic matter, phytoplankton and non-algal particles were obtained together with environmental parameters (water temperature, salinity, Secchi depths, and chlorophyll and particulate matter concentrations). The greatest abundances of the species (about 1,310,000 cells.L^{-1}) were associated with salinity lower than 28 on the inner shelf. Previous results show the R_{rs} spectra varying according the abundances of the species. The more abundant the flatter the spectrum with peaks between 570 and 580 nm. This set of data accompanying the evolution of the bloom will contribute to improve our ability in detecting and monitoring *Dinophysis* cf. *acuminata* HAB.

Protocols for the Measurement of Chromophoric Dissolved Organic Matter (CDOM): Updates and Recommendations from the CDOM working Group

Michael G. Novak[1,2], Antonio Mannino[1], Norm Nelson[3], Eurico D'Sa[4], Richard Miller[5], Jeremy Werdell[1], Rosanna Del Vecchio[6], Carlos Del Castillo[1], Joaquin Chaves[1,2], Jean Francois-Berthon[7], Emmanuel Boss[8], Maria Tzortziou[6], Aimee Neeley[1,2], Scott Freeman[1,2], Annick Bricaud[9], Rüdiger Röttgers[10], Atsushi Matsuoka[9,11], Mathias Belz[12], Neil Blough[13]

Chromophoric Dissolved Organic Matter (CDOM) is an important optically active component ubiquitous in all natural waters. The absorptive properties of CDOM and its strong relationship to the concentration of Dissolved Organic Carbon (DOC) allow it to be used as a powerful tool for tracing water masses and modelling carbon budgets. However, CDOM in the open ocean can be extremely low and difficult to measure accurately in the field as well as in the laboratory setting using conventional spectrophotometers. Over the last two decades, several instruments were developed to increase the sensitivity of measuring low absorbing CDOM samples. Limitations using these different instruments have been identified and described, however the current Ocean Optics protocols do not address the procedure nor the error associated with these measurements. Therefore a CDOM working group comprised of international researchers was established to update and refine the protocols. A large portion of the effort was focused on long path length spectroscopy using liquid core waveguides developed by World Precision Instruments. One inherent challenge with these instruments is that the refractive indices of samples (salinity) in the waveguide produce an apparent negative absorption spectra when referenced to pure water. Several methods were tested to correct for the offset and the results will be presented with an outline of the updated protocol. In addition, a consensus reference material was developed and a large array of filter compositions used for filtering CDOM and DOC samples were tested for contamination.

1 NASA Goddard Space Flight Center Ocean Ecology LAB Greenbelt, MD
2. Science Systems and Applications inc. Lanham, MD.
3. University of California Santa Barbara Earth Research Institute Santa Barbara, CA
4. Louisiana State University Coastal Studies Institute Baton Rouge, Louisiana
5. Department of Geological Sciences and the Institute for Coastal Science and Policy East Carolina University Greenville, NC
6. University of Maryland Earth Science System Interdisciplinary College Park, MD
7. Joint Research Center Ispra, Italy
8. Maine in Situ Sound and Color Lab University of Maine Orono, Maine
9 Laboratoire d'Océanographie de Villefranche Villefranche-sur-Mer Cedex, France
MD
10. Helmholtz-Zentrum Geesthacht Center for Materials and Coastal Research Geesthacht, Germany
11. Takuvic University Laval Quebec, Canada
12. World Precision Instruments Berlin, Germany
13. University of Maryland Department of Chemistry and Biochemistry

Discrete Biogeochemical Measurements Collected from the KORUS-OC Field campaign: An Assessment of Satellite Products using In Situ Data

Michael G. Novak [1, 2], Antonio Mannino[1], and Javier A. Concha[1]

In the spring of 2016, as part of the Korea-United States Ocean Color (KORUS-OC) study, a group of international oceanic and atmospheric scientist participated in an 18 day research cruise around the Korean peninsula. The research focused on linking satellite and in situ measurements of ocean color and biogeochemical parameters as well as quantifying the composition of the atmosphere. The peninsula is surrounded by two highly dynamic seas, the East Sea/Sea of Japan and the Yellow Sea, where surface properties can change on the order of minutes to hours. Korea currently operates the first ever geostationary ocean color instrument (GOCI) which is focused on the region and is building a second-generation sensor called GOCI-II. GOCI produces images eight times a day, approximately every hour during daylight hours, allowing detection of surface processes that evolve on shorter temporal scales. Surface and subsurface discrete samples were collected for biogeochemical analyses from coastal and offshore transects and during lagrangian drifter experiments. These results were compared to satellite standard ocean color products as well as other regional tailored algorithms. In addition, these measurements will help assess what the requirements are for future ocean color and geostationary ocean color missions to remotely sense changes of this magnitude on short temporal and small spatial scales.

1 NASA Goddard Space Flight Center Ocean Ecology LAB Greenbelt, MD
2. Science Systems and Applications inc. Lanham, MD.

High quality *Sargassum* mapping in the W-Atlantic with OLCI (Sentinel-3): Implications for *Sargassum* raft detection, monitoring and dynamics understanding.

A. Ody[1], J.-M. André[1], L. Berline[1], C. Chevalier[1], A. M. Doglioli[1], A. A. Petrenko[1], J. F. R. Gower[2], S. A. King[3]

Since 2011, holopelagic *Sargassum spp.* algae, commonly found in the Sargassum Sea, repeatedly stranded on Caribbean coasts causing large ecological, societal and economical damages. Their origin as well as the causes of their arrival in the Caribbean are still unknown. Taking advantage of their high spatial and temporal resolution and coverage, ocean color satellites were used to map *Sargassum* using specific spectral index i.e. MCI for MERIS (Gower et al., 2006) and FAI/aFAi for MODIS/VIIRS (Hu, 2009; Wang and Hu, 2016), providing a first understanding of their large scale distribution and dynamics over the North and central Atlantic. A more detailed analysis is however drastically limited by the important cloud coverage that masks *Sargassum* raft and generates artifacts. The recently launched OLCI/sentinel-3 ocean color sensor should improve the observation and monitoring of *Sargassum* by (i) increasing the number of sensors available and diminishing cloud masking, (ii) providing high quality *Sargassum* maps with a 300 m spatial resolution allowing a more detailed characterization of *Sargassum* raft dimension and shape, and (iii) enabling the direct application of the MERIS/MCI spectral index, particularly adapted to *Sargassum* detection as based on the 709 nm OLCI/MERIS band well sensitive to the "shifted red-edge" of floating vegetation, and relatively unaffected by cloud effect. The results presented here first illustrate the high quality of OLCI/MCI *Sargassum* mapping. Secondly, OLCI/MCI and aFAI/MODIS maps will be confronted to the fields of various environment parameters to understand the structure of *Sargassum* raft and their transport toward the lesser Antilles.

1. Aix-Marseille University, Mediterranean Institute of Oceanography (MIO), CNRS/INSU, IRD, UM 110, Campus universitaire de Luminy, case 901, 13288 Marseille cedex 09, France.
2. Institute of Ocean Sciences, Fisheries and Ocean Canada, Sidney, BC, Canada
3. Sea This Consulting, Nanaimo, BC, Canada

Concentration, transport, fluxes and dynamics of suspended sediments along a continuum from rivers to river plumes using high spatial resolution ocean color satellite data.

A. Ody[1], D. Doxaran[2], S. Novoa[3], G. Morin[2], A. Gangloff[4], R. Verney[4], I. Pairaud[5], F. Bourin[6]

Quality of coastal waters is directly affected by terrestrial substances transported by rivers. It is thus of primer importance to (i) better understand the transport of particles from rivers to coastal waters, (ii) better quantify the fluxes and mass of sediments that reach the coastal zone and (iii) better understand the river plume area and dynamics through different forcings. The new capabilities of recent ocean color satellite sensors represent an efficient way to assess these questions. Here, we present a study of the Rhône River sediment transport based on OLI (Landsat-8) and MODIS (Aqua and Terra) data. The high resolution of OLI allows estimating sediment concentration inside the river. OLI transect from inside the river to the offshore part of the plume shows that sediment concentration drastically decreases when particles reach the ocean, illustrating dilution, flocculation and sedimentation processes. The distance from the mouth of this drastic decrease seems increasing with river freshwater discharge. The MODIS temporal resolution and coverage allow providing robust relationships between river freshwater discharge and river mouth sediment concentration as well as plume sediment mass and area. Comparison between solid discharge that reaches the river mouth and mass of the surface river plume suggests that only ~10% of the sediment mass stay within surface waters while ~90 % settle. Suspended sediment concentration as well as relationships with river discharge are in good agreement with in situ data confirming the potential of satellite data for sediment transport understanding and monitoring of solid fluxes at river mouths.

1. Aix-Marseille University, Mediterranean Institute of Oceanography (MIO), CNRS/INSU, IRD, UM 110, Campus universitaire de Luminy, case 901, 13288 Marseille cedex 09, France; anouck.ody@mio.osupytheas.fr

2. Laboratoire d'Océanographie de Villefranche sur Mer (LOV), UMR 7093, CNRS/UPMC, F-06230 Villefranche Sur Mer Cedex, France; david.doxaran@obs-vlfr.fr (D.D.); guillaume.morin@obs-vlfr.fr

3. Centro de Investigation Cooperativa en Biomateriales CIC biomaGUNE, Miramon Pasealekua, 182, 20009 Donostia, Gipuzkoa ; Snovoa@cicbiomagune.es

4. IFREMER, Centre Bretagne, Laboratoire de Dynamique Hydro-Sédimentaire, F-29280 Brest, France; Romaric.Verney@ifremer.fr ; aurelien.gangloff@ifremer.fr

5. IFREMER, Centre Méditerranée, Laboratoire Environnement Ressources Provence Azur Corse, F-83507 La Seyne sur Mer, France; Ivane.Pairaud@ifremer.fr

6. Centre de Formation et de Recherche sur les Environnements Méditerranéens (CEFREM), UMR 5110, CNRS/UPVD, F-66100 Perpignan, France; fbourrin@univ-perp.fr

Improved temporal and spatial resolution of hyper-spectral phytoplankton functional type products

Julia Oelker[1], Tilman Dinter[2], Vladimir R. Rozanov[3], Andreas Richter[4], John P. Burrows[5], Astrid Bracher[6]

Hyper-spectral satellite data offer a unique way to distinguish different phytoplankton groups from space. Due to the high spectral resolution of hyper-spectral sensors compared to multi-spectral ones, the difference in absorption spectra can more easily be exploited to discriminate different phytoplankton groups. Up until now, no global hyper-spectral sensors specifically designed for ocean color applications are in operation. However, phytoplankton functional types (PFTs) such as cyanobacteria, diatoms, and coccolithophores have been successfully retrieved from hyper-spectral data recorded by satellites designed for atmospheric trace gas retrievals. So far, global PFT data sets have been retrieved from hyper-spectral SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Cartography) data using Phytoplankton Differential Optical Absorption Spectroscopy (PhytoDOAS). The difference in absorption spectra of different PFTs are exploited in the PhytoDOAS method to retrieve up to three PFTs simultaneously. Here, we will present PFT data sets with improved temporal and spatial resolution from the hyper-spectral Ozone Monitoring Instrument (OMI) in comparison with the older SCIAMACHY PFT data. The work gives an outlook on PFT retrievals that can be done on data from the TROPOMI (TROPOspheric Monitoring Instrument) sensor which inherited its design from OMI and is onboard Sentinel-5P planned to be launched this year. Among hyper-spectral sensors, TROPOMI has a record spatial resolution of 7 km by 7 km that compares to multi-spectral data such as the OC-CCI data set.

[1] oelker@iup.physik.uni-bremen.de, Institute of Environmental Physics, University of Bremen, 28359 Bremen, Germany
[2] tilman.dinter@awi.de, Alfred-Wegener-Insitute for Polar and Marine Research, 27568 Bremerhaven, Germany
[3] rozanov@iup.physik.uni-bremen.de, Institute of Environmental Physics, University of Bremen, 28359 Bremen, Germany
[4] richter@iup.physik.uni-bremen.de, Institute of Environmental Physics, University of Bremen, 28359 Bremen, Germany
[5] burrows@iup.physik.uni-bremen.de, Institute of Environmental Physics, University of Bremen, 28359 Bremen, Germany
[6] astrid.bracher@awi.de, Alfred-Wegener-Insitute for Polar and Marine Research, 27568 Bremerhaven, Germany

Investigation of Namibian sulfur plumes using different earth observation missions

Thomas Ohde

The objective of this study was the investigation of coastal sulfur plumes in the northern Benguela upwelling system using data sets of satellite sensors in the visible, infrared and microwave spectral range combined with in-situ measurements. Their relations to wind- and upwelling conditions were analyzed. The reflectance maxima of sulfur spectra at 559.6 nm were used to study their seasonal and interannual intensity.
The surface sulfur plumes can be clearly distinguished from other optical water types by their special spectral signatures. They were characterized by very high reflectances in the entire spectral range due to the high backscattering of small sulfur particles in the surface water layer. Up to 28.5 % of the incident solar radiation can be backscattered. More than 23000 sulfur spectra were identified in the MERIS data set between the years 2002 and 2012.
The seasonal variability of coastal sulfur plumes in the northern Benguela system between 18° S and 28° S was characterized by well pronounced main and off-seasons. The highest median intensities were observed in February with the beginning of the upwelling season. The intensities were nearly constant between March and June but low between July and November during the upwelling main season. Special strong events were observed in May and December. The interannual variability was characterized by short phases of very high intensity interrupted by phases of low intensity. The highest intensities were observed in the years 2005 and 2010. Low intensities were found before 2004 and between 2006 and 2009.

thomas.ohde@legos.obs-mip.fr

Laboratoire d'Etudes en Géophysique et Océanographie Spatiales
14 Avenue Edouard Belin, Toulouse, 31400, France

Using fisheries monitoring surveys to assess ocean color products off continental Portugal

P.B. Oliveira[1], E. Henriques[2], V. Marques[3], Â. Nascimento[4], C. Nunes[5], M.M. Angélico[6]

The Portuguese Institute for the Ocean and Atmosphere (IPMA) carries out regular fisheries monitoring surveys, mainly in the frame of the European Union Data Collection Framework (DCF) Programme. The different surveys cover most of the west and south Iberian Atlantic continental shelf and typically take place in spring, summer and autumn. In spite of the tight schedule and the intensive onboard work to collect the fisheries information, the use of continuous recording instruments and efforts coordination has allowed the collection of relevant data to assess the quality of ocean colour products in the region. The results of continuous underway measurements of surface temperature, salinity and fluorescence, together with vertical profiles of the same parameters, along cross-shelf transects, are presented for the most recent cruises. The *in situ* data is used to evaluate the quality of ocean colour products delivered through Copernicus Marine Environment Monitoring Service (CMEMS), ESA and NASA data hubs.

Address: IPMA - Instituto Português do Mar e da Atmosfera, Av. Alfredo Magalhães Ramalho, 6, 1495-165 Lisboa, Portugal
1 - pboliveira@ipma.pt; 2 - ehenriques@ipma.pt; 3 - vmarques@ipma.pt; 4 - angela.nascimento@ipma.pt
5 - cnunes@ipma.pt; 6 - mmangelico@ipma.pt

Particle size distribution and optical proxies along the Atlantic Meridional Transect

Emanuele Organelli, Giorgio Dall'Olmo, Robert Brewin, Glen Tarran, Gavin Tilstone

Characterising marine particle size distributions (PSD) is important because it enables scientists to improve understanding of ecosystems, biogeochemical cycles and the magnitude of the global carbon budget. Due to a paucity of field observations, proxies of PSD, such as the spectral light attenuation and backscattering properties of particles suspended in the water have been proposed for quantifying particle size, both in situ and from space. However, it is still unclear how the relationships between PSD and optical proxies vary spatially and temporally across the world's oceans. This lack of knowledge generates high uncertainties in satellite-derived products, especially in oligotrophic open-ocean waters.

During the 2016 Atlantic Meridional Transect cruise (AMT26), measurements of PSD and optical properties have been acquired in the most oligotrophic surface waters of the Atlantic Ocean. Particle size was measured by a Coulter counter within the range 0.5-60 µm, in several repetitions and for simultaneous samples collected during CTD casts and in flow-through mode from the ship's clean seawater supply. Particle light attenuation and backscattering coefficients were simultaneously collected at several wavelengths and used to derive optical proxies.

Here, we discuss the observed relationships between PSD and its proxies along the transect, and we compare our results with those of other studies. The uncertainty and error budget associated to each measurement are also presented. Recommendations will finally be provided to support particle size retrieval and validation from space, and the implications for studying the ocean carbon cycle will be highlighted.

Address:

Plymouth Marine Laboratory, Prospect Place, The Hoe, PL1 3DH Plymouth UNITED KINGDOM

Email: emo@pml.ac.uk; gdal@pml.ac.uk; robr@pml.ac.uk; gat@pml.ac.uk; GHTI@pml.ac.uk

Satellite Data Products for Coral Reef Health, Southwestern Puerto Rico

Suhey Ortiz-Rosa[1], William J. Hernández[1,2], Roy A. Armstrong[1,3,4], María A. Cardona-Maldonado[3], Omar López[3] and Myrna J. Santiago[4]

Bio-optical Oceanography Laboratory, Department of Marine Sciences
University of Puerto Rico- Mayagüez PO Box 9000 Mayagüez PR 00981

Remote sensing was used to monitor land-based sources of pollution (LBSP) as well as chlorophyll dynamics in southwestern Puerto Rico. Studies on spatial and temporal changes in chlorophyll-*a* and turbidity have been used as a proxy to determine coral reef health. The influence of LBSP on coral reefs and coastal water quality were assessed by combining GIS and RS, which provides large spatial and temporal coverage. We used imagery from Landsat 8 OLI and Sentinel 2 to understand biogeochemical processes from Gúanica Bay to La Parguera Natural Reserve. *In situ* data were collected during satellite overpasses for cal/val and inter-calibration with field sensors. Chlorophyll-*a*, an indicator of phytoplankton biomass, can be related to nutrient availability, while turbidity affects light transmittance into coral reef ecosystems. Chlorophyll values, which ranged from 0.1 to 8 µg/L, were mostly influenced by river discharges. Total Suspended Solids (TSS) values, which ranged from 1-30 mg/L, combined with satellite imagery, showed variability of sediment sources as well as sediment resuspension in coastal areas. Chlorophyll and TSS product retrievals from satellites in this area show high uncertainties from the influence of bottom albedo signal in clear, shallow areas and from land pixel contamination near the coast. Our results can be used by resource managers to monitor the impact of LBSP over reef areas and to implement mitigation actions.

[1]NOAA-CREST UPR Mayagüez, suhey.ortiz@upr.edu, roy.armstrong@upr.edu
[2]Global Science and Technology Inc., william.hernandez@upr.edu
[3]UPR Mayagüez, maria.cardonamaldonado@upr.edu, omar.lopez2@upr.edu
[4]NOAA-NCAS UPR Mayagüez, myrna.santiago@upr.edu

[1,2,3,4] Bio-optical Oceanography Laboratory, Department of Marine Sciences
University of Puerto Rico- Mayagüez PO Box 9000 Mayagüez PR 00981

Seasonal variability in Bio-optical properties along the Coastal Waters off Cochin

Vishnu. P, S [a *], Shaju. S, S [b], Nashad M [c], Ajith Joseph C [a], Mini Raman [d], Nandini Menon [e], Mohamed Hatha [a], Mohandas A [f]

Abstract

Spatial variability in bio-optical properties of the different seasons *viz* Spring Inter Monsoon (SIM), South West Monsoon (SWM), Fall Inter Monsoon (FIM) and Winter Monsoon (WM) along the coastal water off Cochin were studied. During SWM period experiences strong upwelling, vertical mixing and considerable inflow of freshwater discharge from estuary, leading to increased productivity. Chlorophyll *a* concentration was highly variable during SWM with an average value of 6.56 ± 3.51 mg m^{-3}. There exists a week relationship between Chl_*a*, TSM and a_{CDOM} 443 due to the large contribution of inorganic particles discharged from Cochin estuary. The observed non linearity between Chl_*a* and a^*_{ph} could due to the phytoplankton pigment packaging effect and shift in the phytoplankton species composition. During the study period a_{ph} 670 was strongly correlated with Chl_*a* than a_{ph} 443, this could be attributed to the accessory pigment absorption dominating more than Chl_*a* in the blue part of the spectrum. Seven different absorption spectra were identified based on the shape, each spectra reveals the characteristics of dominant phytoplankton species. The Barmouth region was dominated with highly turbid waters during the entire period of study. During SIM, the distribution of CDOM controlled by the decomposition of phytoplankton biomass and the river discharge, whereas during SWM, CDOM was only controlled by river discharge. During the study period the relative absorption of detritus dominates the relative absorption of phytoplankton and CDOM. The study reveals the complexity in Bio-optical properties along the coastal waters off Cochin.

Key words: Bio-optical properties**;** Chlorophyll *a*; Phytoplankton; Pigment packaging; CDOM; Detritus; Coastal waters off Cochin

[a] psvishnu2014@gmail.com, Cochin university of Science and Technology (CUSAT), Department of Marine Biology, Microbiology and Bio-chemistry School of Marine science, Fine Arts Avenue, Cochin 682016, India; [b] shaju.peringammala@gmail.com, Naval Physical Oceanographic Laboratory (NPOL), NGO Quarters, Thrikkakara, Vazhakkala, Kochi, Kerala 682021, India; [c] nasharocks22@gmail.com, Fishery Survey of India, Port Blair Base, Phoenix Bay Jetty PB-744101, Andaman and Nicobar Islands;

[d] mraman@sac.isro.gov.in, Space Application Centre (SAC), Indian Space Research Organization (ISRO), Ahmedabad-300015, India; [e] nandinimenon@yahoo.com, Nansen Environmental Research Centre (India) (NERCI), 6A Oxford Business Centre, Cochin-682016, India; [f] mohandas@cusat.ac.in, Cochin University of Science and Technology National Centre for Aquatic Animal Health PB No.2341, Fine Arts Avenue COCHIN-682 016, Kerala.

Towards Consistent Landsat-Sentinel-2 Products over Coastal/Inland Waters

N. Pahlevan[a,b], S. Sarkar, S. Chittimalli[a,c], and S. Subramanian[a,d]

[a]NASA Goddard Space Flight Center, 8800 Greenbelt Road,
Greenbelt MD 20771 USA
[b]Science Systems Applications Inc., 10210 Greenbelt Road, Lanham, MD USA 20706
[c]University Space Research Association, NASA Goddard Space Flight Center
Greenbelt, MD 20771 USA
[d]University of Maryland, Department of Geographical Sciences, College Park, MD, USA

Corresponding author:
Phone: +1-301-614-6684; Fax: +1-301-614-5269; Email: nima.pahlevan@nasa.gov

Keyword: Intercalibration, Atmospheric correction, coastal/inland waters, Landsat/Sentinel-2

Abstract

Although designed for land science applications, the Operational Land Imager (OLI) and the twin MutiSpectral Imager (MSI) onboard Landsat-8 and Sentinel-2, respectively, are capable of providing reasonable aquatic science products over coastal/inland waters where coarse-resolution ocean color imagers fail to provide valid observations. Consistent, multi-mission aquatic science products require consistent top-of-atmosphere (TOA) observations and a robust atmospheric correction suited for aquatic systems to enable reliable satellite-based monitoring of water quality. In this presentation, we provide analyses on a) the intercalibration consistency of Landsat-8/Sentinel-2A analyzed at the near-simultaneous nadir overpasses (SNOs) over bodies of water and b) the quality of the downstream atmospherically corrected products, namely remote sensing reflectance (R_{rs}) products. These products are validated against in-situ data at the Ocean Color component of AERONET sites (AERONET-OC). In addition to in-situ validations, we also compare the results of the atmospheric corrections at SNOs to understand how calibration discrepancies at TOA propagate to the products. The end goal is to better understand and quantify the discrepancies in higher-level products (e.g., chlorophyll-a concentrations).

Assessment of the MCC method to estimate sea surface currents in highly turbid coastal waters from GOCI

Zifeng Hu[1], Delu Pan[1], Xianqiang He[1]

Previous studies have demonstrated that the Geostationary Ocean Color Imager (GOCI) could retrieve sea surface currents accurately in low-moderate turbid coastal waters, based on maximum cross correlation (MCC) technique. However, its performance in highly turbid waters remains unclear. In this study, the MCC method is used to derive hourly sea surface currents in Hangzhou Bay (HZB) with highly turbid waters from the GOCI data, and its performance is examined by in situ measurements and model simulations. The results show that the GOCI-derived sea surface currents can catch tidal phase variations well, yet the performance of the derived velocity is not as good as the previous studies in low-moderate turbid waters. The reason may be due to the rapid deposition and resuspension processes of suspended particulate matter in high turbidity waters, which contaminate the MCC pattern tracking. The GOCI-derived deposition and resuspension rates can reach up to about 190 and 270 mg l^{-1} h^{-1} in HZB, respectively, which demonstrates that the potential of geostationary ocean color imagery in deriving the suspended particle deposition and resuspension rates.

[1]Email: pandelu@sio.org.cn, State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

Determining the level of uncertainty between *in situ* and MODIS satellite-derived chlorophyll-*α* estimations in the optically complex North Aegean Sea waters.

Anastasia Papadopoulou[1,3], Panos Drakopoulos[2,3], Stella Psarra[3], Aris Karageorgis[3], Anna Lagaria[3], Nektarios Spyridakis[3] and Vassilis Zervakis[4]

Although ocean color remote sensing is a useful tool for mapping chlorophyll-*α* concentration, in the optically complex waters of the North Aegean Sea, the empirical bio-optical algorithms for the estimation of the near surface concentration of chlorophyll-*α* seem to not perform efficiently. This study examined the accuracy of four different MODIS chlorophyll empirical bio-optical algorithms: OC2M, OC3M, MedOC3 and OC2M-HI. The vertical distribution of the *in situ* weighted chlorophyll-*α* concentration was obtained by applying two different approaches: a) the PAR-approach, where photosynthetically active radiation was measured with a hyperspectral irradiance meter, and (b) the Chl-approach, where surface chlorophyll-*α* values were determined via the high performance liquid chromatography (HPLC) and the fluorometric technique. Satellite chlorophyll-*α* concentrations were estimated by a) the Reflectance-approach, in which surface reflectance values were produced from the *in situ* downwelling spectral irradiance and upwelling spectral radiance field measurements and by b) the satellite Chl-approach, in which MODIS daily Level-2 chlorophyll-*α* datasets were produced with the OC2M and OC3M bio-optical algorithms, through the SeaWiFS Data Analysis System (SeaDAS). It was found that the standard NASA algorithms, OC2M and OC3M overestimate the surface chlorophyll-*α* concentration more than 26%, while the OC2M-HI and the MedOC3 regional empirical bio-optical algorithm tend to provide very low errors. However, the existence of uncertainties between field and satellite chlorophyll-*α* concentration measurements and the limited optical field observations require new approaches for the development of a regional ocean color algorithm in the North Aegean Sea.

[1]Democritus University of Thrace, Department of Environmental Engineering, 67100, Xanthi, Greece; nastakpa84@hotmail.com
[2]Technological Educational Institute of Athens, Lab. of Optical Metrology, Dep. of Optics and Optometry, 12210 Athens, Greece
[3]Hellenic Centre for Marine Research, Institute of Oceanography, 46.7 km Athens-Sounio Avenue, Mavro Lithari, 19013 Anavyssos, Greece
[4]University of the Aegean, Department of Marine Sciences, 81100, Mytilene, Greece

Assessment of VIIRS chlorophyll-a algorithms using underway spectrophotometry

Silvia Pardo (spa@pml.ac.uk)[1] , Robert Brewin[1,2], Giorgio Dall'Olmo[1,2], Gavin Tilstone[1]

[1] Plymouth Marine Laboratory (PML), Prospect Place, The Hoe, Plymouth PL1 3DH, UK. [2] National Centre for Earth Observation, PML, Plymouth PL1 3DH, UK

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument has been, since its origins, intended as an improvement and extension of NASA's Moderate Resolution Imaging Spectroradiometer-Aqua (MODIS-Aqua) sensor. Its role has become even more important in the past two years, due to the degradation of MODIS-Aqua and delays in the launch of Sentinel-3. There is, therefore, a dependency on the use of VIIRS for continuing and enhancing satellite ocean-colour time series data, such as those produced by the ESA Climate Change Initiative and the Copernicus Marine Environment Monitoring Service. However, there have been few studies assessing the performance of VIIRS ocean-colour products. In this work we use in-situ data collected on the Atlantic Meridional Transect (AMT) to validate VIIRS chlorophyll algorithms in a range of biogeochemical conditions and optical water types. The AMT program has been one of the most valuable sources of high quality in-situ measurements for remote sensing over the past 20 years, and the recent incorporation of flow-through optical sensors on the AMT's underway system has allowed the sampling frequency to increase to quasi-continuous acquisition. To match this improvement, we have developed a robust match-up procedure that takes into account homogeneity, quality and spatial variability issues. The results obtained when comparing VIIRS L2-derived chlorophyll values with the corresponding AMT measurements show that VIIRS satellite chlorophyll retrievals are comparable in performance with previous sensors (e.g. MERIS), supporting its role as the current default ocean-colour provider. The validation 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 chlorophyll for the upcoming Sentinel data streams.

POLYNYA FORMATION AND PHENOLOGY, AND THEIR SIGNIFICANCE IN POLAR ECOSYSTEM

Jisoo Park, Edward K. Shin, Eunho Ko, Taewook Park, SangHoon Lee

Polynya is a unique portion of polar ecosystem where its open water is surrounded by sea ice. Many species' lives depend on polynya, and their lives are an integral part of their surrounding food web. Therefore, change in polynya phenology can alter, or even disrupt, the polar food web. As such, it is important to understand the polynya phenology. Despite polynya's significance in the polar ecosystem, there are still many unfamiliar aspects of polynya. Why some polynyas have certain formation patterns while other polynyas do not is unclear, for instance. Our aim is to organize relevant polynya data, reveal insightful polynya characteristics, and discern polynya's potential impact. We investigated to what extent the physical polynya parameters, such as polynya opening date, polynya duration, maximum area and its date, and number or proportion of days over 50% of maximum area affects polynya phenology. By looking for correlations between such parameters and the highest mean/median chlorophyll-a concentration of each season and their respective dates, we hope to develop a thorough understanding of the relationship between the physical input and biological output. We focused on Antarctic polynyas, and we are especially interested in the types of environment that contribute to distinct correlations. There could be differences in ratios (x/total in A has significant correlation while y/total in B does not) between different environments. For example, East or locally affected polynyas may have different ratios than those of West or globally affected polynyas. We acquired 1978–2016 sea ice concentration data from http://nsidc.org and 1997–2016 chlorophyll-a concentration data from http://hermes.acri.fr. We omitted 1987–1988 sea ice concentration data because it failed to record any data from Dec 3, 1987 to Jan 12, 1988. We are also interested in the causation and the implications of our findings. Understanding the driving force behind the physical parameters of polynya would allow us to predict what sort of effect a polynya can have on its ecology. Consequently, deeper polynya phenology comprehension would allow us to better monitor and sustain our planet's health.

jspark@kopri.re.kr
Korea Polar Research Institute, 26 Songdomirae-ro, Yeonsu-Gu, Incheon, Republic of Korea

SPOT images associated with the Turbidity of the Upper Gulf of California

JESÚS A. AGUILAR-MALDONADO[1, 2*]; EDUARDO SANTAMARÍA-DEL-ÁNGEL[1]; JESÚS PENA-REGUEIRO[3]
MARÍA-TERESA SEBASTIÁ-FRASQUET[4]

[1]*Facultad de Ciencias Marinas, Universidad Autónoma de Baja California (Mexico)*
[2]*Alumni PhD postgraduate program in Coastal Oceanography FCM-UABC (Mexico)*
[3]*Alumni PhD Universitat Politècnica de València (Spain)*
[4]*Institut d´investigació per a la gestió integrada de zones costaneres, Universitat Politècnica de València (Spain)*
**Corresponding author: jesusaguilarmaldonado@gmail.com*

The mapping of turbidity derived from satellite and aerial imagery observations has become a valuable tool for identifying and monitoring their distribution at lower cost and higher frequency. In this sense, the images of MODIS, Terra and Aqua sensors have been used in research to determine the spatio-temporal variability of turbidity concentrations from their reflectances (R_{rs}), at a maximum spatial resolution of 250 m. To improve this spatial resolution, higher resolution images, such as SPOT images, have been tested in optically complex waters. In this work the spatial temporal patterns of turbidity in the Upper Gulf of California (UGC) are described starting from the association of 73 SPOT images of the sensors 2, 4, 5 and 6 from years 2008 to 2013, against in situ data observed with Secchi disk during cruises in this period. The UGC has been selected to develop this research, since it is considered an extremely turbid place, which has recorded values of Secchi disk between 0.15 and 1.5 m. Results showed a positive correlation between SPOT ($S2_{610\text{-}680}$) and the Secchi disk data (Pearson coefficient). The images were organized in scenarios that allowed a better understanding of the phenomenon under study, according to: 1) scene date, 2) season 3) tidal condition, live or dead, and 4) tidal movement in flow or reflow. The standardized spatial anomalies of all the data analyzed allowed to classify the results according to their level of turbidity, where -2 *SD* and 2 *SD* are the limits to know if a data is anomalous. In general coastal waters were those that presented higher levels of turbidity, while offshore waters showed lower values of turbidity.

[1, 2] jesusaguilarmaldonado@gmail.com

[3] jepere@doctor.upv.es

[4] mtsebastia@hma.upv.es

Implementation of ocean optics protocols to estimate Optically Active Constituents (OAC) from water samples collected during the Atlantic Lidar Optical Measurements Experiment 2015 (ALOMEx'15): results and validation with Satellite measurements

Pennucci G. [1], Sanjuan V.[1], Russo A.[1] and Coelho E.[1]

One of the main requirements for a comprehensive characterisation of water column optical properties is the simultaneous acquisition of physical and biological parameters that are traditionally observed using satellites, ships and moorings, especially in dynamic areas. The Atlantic Lidar Optical Measurements Experiment 2015 (ALOMEx '15), conducted from 31 October to 12 November 2015, provides the first attempt at determining *in situ* measurement uncertainties by comparing instrument specific calibrations and measurement protocols. The cruise was conducted in two coastal areas: the Alboran Sea and the Sahara Upwelling region (23-32 N, 9-17 W).

We describe the post-processing NASA ocean optics protocols that were implemented at CMRE to analyze bio-optical and radiometric measurements performed simultaneously with satellite overpasses (*i.e.* from the Moderate Resolution Imaging Spectroradiometer, MODIS, and the Visible Infrared Imaging Radiometer Suite, VIIRS). During the experiment, a Saharan dust phenomenon occurred above the sampled area providing an unprecedented opportunity to investigate the influence of dust deposition on chlorophyll dynamics. Specifically, the analysis of the available ALOMEx'15 measurements may help scientists to understand the impact of aerosols on corrections for satellite ocean data, leading to better ocean color products (*e.g.* atmospheric correction and ocean color algorithms), especially in the presence of dust or other anthropogenic pollutants. We thus analyse match-up comparisons between the coincident (+/- 1hour) *in situ* and satellite measurements and historical satellite retrievals to investigate dynamics and seasonal variability of the area. Results corroborate the hypothesis that the biasing of satellite chlorophyll retrievals is correlated with high dust presence in air.

Correspondence to pennucci@cmre.nato.int

Affiliation:

[1] NATO Science and Technology Organization - Centre for Maritime Research and Experimentation (STO-CMRE), Viale San Bartolomeo 400, 19126 La Spezia, Italy.

Atmospheric correction of satellite (Sentinel-2) images over Dutch inland waters

S.W.M. Peters, A. Hommersom, P. Groetsch, K. Poser, M. Laanen, S. Ghbrehiwot

There are no uniform tools for the atmospheric correction of any high resolution satellite images of Sentinel 2, Sentinel 3, Landsat 8, SPOT, Formosat, Worldview etc. Furthermore, some satellite data does not come with appropriate or accurate calibration coefficients to provide the starting point for atmospheric correction, namely top of atmosphere radiance. Ancillary data required for atmospheric correction such as estimates of O3, NO2, H2O etc. is often missing or difficult to retrieve for small areas. One practical way to overcome this lack of tools and calibration is to perform atmospheric correction based on ground observations of water leaving radiance. This contribution will discuss the obvious disadvantages (calibration on one pixel only) and advantages (valid for any satellite, but to what spatial extent?) of such approach and the requirements and protocols for surface reflectance measurements. Results over larger areas in the Netherlands show (for inland water systems) that spatial patterns of Chlorophyll-a are quite consistent. Temporal dynamics are consistent with field observations and knowledge of water system behaviour.

Peters@waterinsight.nl

Hommersom@waterinsight.nl

Groetsch@waterinsight.nl

Poser@waterinsight.nl

Laanen@waterinsight.nl

Ghbrehiwot@waterinsight.nl

All authors at:

Water Insight BV.

Marijkeweg 22

6709 PG Wageningen

The Netherlands

Cloud processing for ocean colour research and applications

Eirini Politi[1], R. Scarrott[1], E. Tuohy[1], M. Terra Homem[2], H. Caumont[3], N. Grosso[2], A. Mangin[4], N. Catarino[2], S. Clerc[5]

Pollution and changing coastal processes due to climate change and intensified human activities affect coastal regions in various ways, causing loss of aquatic life and degradation of vulnerable habitats. To fully understand how the aquatic environment is changing, a combination of methods and disciplines is required. However, such approaches often require Big Data and Real-Time (RT) information to ensure timeliness in risk prediction, assessment and management. In addition, identifying suitable datasets from the plethora of data repositories that currently exist can be challenging. As optical satellite datasets continue to increase in quantity and quality, processing has become slower and demanding of better, often faster, computing facilities. To address these issues, two projects are developing online platforms to bring geospatial data, processing and coastal communities together in collaborative cloud-based environments.

The Coastal Thematic Exploitation Platform (C-TEP) and Coastal Water Research Synergy Framework (Co-ReSyF) projects are developing cloud platforms to maximise processing effort and task orchestration. Users will be able to access, view and process satellite data, and visualise and share their outputs on the same platform. This will allow faster processing and innovative data synergies, by advancing collaboration between different scientific communities. With core research applications currently including applied ocean colour research to support fisheries and aquaculture and exploitation of data-rich chlorophyll-a time series to explore oceanic processes and links to marine ecology, the C-TEP and Co-ReSyF capabilities will be further enhanced by their users, who will be able to upload their own ocean colour algorithms and processors onto these systems.

[1] Centre for Marine and Renewable Energy, University College Cork, Cork, Ireland

(EPoliti: eirini.politi@ucc.ie; RScarrott: r.scarrott@ucc.ie; ETuohy: eimear.tuohy@ucc.ie)

[2] DEIMOS Engenharia S.A., Lisbon, Portugal

(MTerra-Homem: miguel.terra@elecnor.com; NGrosso: nuno.grosso@deimos.com.pt; NCatarino: nuno.catarino@deimos.com.pt)

[3] TERRADUE, Rome, Italy

(HCaumont: herve.caumont@terradue.com)

[4] ACRI-HE, Sophia-Antipolis, France

(AMangin: antoine.mangin@acri-st.fr)

[5] ACRI-ST, Sophia-Antipolis, France

(SClerc: sebastien.clerc@acri-st.fr)

Using diurnal variations in a lab experiment to verify the applicability of Mie calculations to phytoplankton

Carina Poulin[1], Xiaodong Zhang[2] and Yannick Huot[1]

Mie scattering theory is often used to estimate optical properties of oceanic particles, which are assumed to be homogeneous spheres. Several studies concluded that it underestimates the backscattering coefficient. Although including a shell to the spheres modeled to represent the cell membranes of phytoplankton increases the levels of backscattering, there is still uncertainty in the representativeness of these models.

We aimed to reproduce the diurnal variations of the optical properties measured on cultures with a Mie model. We used the ancillary experimental measurements of chlorophyll, carbon and the cell size distributions measured with a Coulter Counter to deduct realistic variations of the real and imaginary parts of the refractive index and to determine b_p, b_{bp} and β_p from the Mie calculations. We simulated the effect of small particles (0.2 – 1.12 μm) with a Junge distribution of constant refractive index. We further included a coating to the cells in the model, using thicknesses and refractive indexes from literature. We also performed a sensitivity analysis to find out the range of results that can be obtained with Mie and realistic inputs.

We found out that the refractive index of the shell has the strongest influence on the Mie results, followed by the core's refractive index. Variations of the Mie input parameters for the shell characteristics can lead to a difference of a factor of about 5 to 10 for realistic combinations which allows us to, in most case, reproduce the measurements. Non-spherical particles models are also compared to Mie's.

250 words

1: Université de Sherbrooke,
2500, boulevard de l'Université
Sherbrooke (Québec), Canada
J1K 2R1

2: University of North Dakota,
Clifford Hall Room 326,
4149 University Ave Stop 9011
Grand Forks, ND 58202-9011

The impact of the variability of OLCIs spectral response over the field of view on simulated water leaving reflectance and retrieved IOPs

Rene Preusker [1], Lena Katharina Kritten[2], Jürgen Fischer[3]

The ocean color instrument OLCI, in orbit since 2016, as well as its predecessor MERIS show specific viewing angle and camera dependent variations of the spectral response of their bands. In particular, the band central wavelengths vary over the field of view in the order of 1nm. The spectral responses of all bands as well as their viewing angle dependency have been characterized before launch and further been verified within the commissioning phase. However, conventional retrievals of ocean constituents, which are based on water leaving reflectance do not incorporate these information.

Here we quantitatively assess the impact of the instrumental spectral variability on the corresponding water leaving reflectance for different water types. This is realized by convoluting spectrally highly resolved simulations with the spectral response functions of OLCI, considering their full variability. Further, the found spectral sensitivity is associated with the sensitivity of the water leaving reflectance to specific IOPs. This eventually translates the negligence of the precise spectral band characterization into an additional uncertainty of the IOPs.

1. rene.preusker@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
2. lena.kritten@wew.fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin
3. juergen.fischer@fu-berlin.de; Institut für Weltraumwissenschaften, Freie Universität Berlin

On the diurnal changes of cyanobacterial blooms and their environmental controls: A Taihu Lake case study

Dr. Lin Qi[1]; Prof. Zhongping Lee[2]; Prof. Chuanmin Hu[3]; Prof. Ronghua Ma[4]

[1]State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, China;

[2]School for the Environment, University of Massachusetts Boston, Boston, MA, USA;

[3]College of Marine Science, University of South Florida, St. Petersburg, FL, USA;

[4]State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 73 East Beijing Road, Nanjing 210008, China

It has long been observed through laboratory and field experiments that cyanobacteria *Microcystis aeruginosa* (also called blue-green algae) can move vertically in the water column during a day to adapt to the light and nutrient environments, and such movements have been attributed to changes in the algae's physiological state in response to changes in environmental conditions such as light and wind. However, to date, there has been no systematic study to document their vertical movements at synoptic and long-term scales in natural waters, not to mention their linkage with environmental controls at the same scales. Using Taihu Lake as the study region, this research will take advantage of the frequent and long-term measurements (8 times per day, 2011 - 2017) from a geostationary satellite sensor (GOCI) to fill these knowledge gaps, with specific objectives to 1) develop proper algorithms to detect and quantify algae blooms (surface scums), 2) establish long-term statistics of seasonality and spatial distributions of the "hotspot" regions where diurnal changes are most often observed, and 3) study how light, wind, and water clarity inter-play to affect these patterns. The research will also compare with results obtained from less frequent measurements (once per day) to evaluate potential biases in these latter results in order to establish a more robust long-term time series from GOCI to better evaluate long-term bloom changes and provide more accurate information for management.

EQCO Project – Poster Abstract

List of authors: Caroline Quod (Telespazio, France), Joanne Nightingale (National Physical Laboratory, UK)

Environmental information is of crucial importance. It helps to understand how our planet and its climate are changing, the role played by human activities in these changes and how these will influence our daily lives.

Copernicus Climate Change Service (C3S) will provide access to data and information that will enable environmental and societal challenges associated with human-induced climate changes to be evaluated. The main goal is to combine observations of the climate system with the latest science to develop authoritative, quality-assured information about the past, current and future states of the climate in Europe and worldwide.

The Climate Data Store (CDS), core of the C3S, will be the interface for providing access to data such as geophysical information and observations needed to analyse the climate change indicators in a consistent and harmonised way.

One of the main components from the CDS relies on the development and implementation of an Evaluation and Quality Control (EQC) framework that will ensure the observations (satellite and *in situ*) provided through the C3S Climate Data Store, are:

1. Traceable,
2. Adequately documented
3. Assessed for uncertainty
4. Understandable thanks to user guidance

A bottom-up approach is considered for collecting requirements for this information through end user interaction. A dedicated survey is now available and will be presented during the poster session.

Sensing coral reef connectivity pathways from space

Dionysios E. Raitsos[1,2,*], Robert J.W. Brewin[1,2], Peng Zhan[3], Denis Dreano[3], Yaswant Pradhan[4], Gerrit B. Nanninga[3,5], Ibrahim Hoteit[3]

Coral reefs — the rainforests of the marine realm — rely on inter-habitat connectivity to maintain immunity, biodiversity and ecosystem resilience. Biophysical dispersal models can simulate patterns of connectivity in coral reef ecosystems; yet, in many tropical regions uncertainties arise due to inadequate oceanographic knowledge and data. Here we provide evidence that satellite observations of geostrophic currents can be used to drive biophysical dispersal models and estimate larval connectivity pathways over meso/large scales (10s-100s km). Predicted connectivity is remarkably consistent with genetic population data, demonstrating that circulation features (eddies and surface currents) formulate physical pathways for gene flow in a large tropical ecosystem, the Red Sea. In agreement with the genetic population structure of a range of coral reef organisms, we find the southern basin to be relatively isolated in terms of physical connectivity and identify the central Red Sea as a key source region that should receive conservation priority. Our analysis lays the foundation for a cost-effective tool to sense biophysical connectivity pathways remotely from space, supporting coastal management in remote regions worldwide.

1 - Plymouth Marine Laboratory (PML), Plymouth, UK
2 - National Centre for Earth Observation, PML, Plymouth, UK
dra@pml.ac.uk
robr@pml.ac.uk

3 - King Abdullah University for Science and Technology (KAUST), Thuwal, KSA
peng.zhan@kaust.edu.sa
denis.dreano@kaust.edu.sa
ibrahim.hoteit@kaust.edu.sa

4 - Met Office, FitzRoy Road, Exeter, UK
yaswant.pradhan@metoffice.gov.uk

5 - University of Cambridge, Cambridge, UK
gbn23@cam.ac.uk

Light field observations from space for ocean biology and biogeochemistry: New products

Didier Ramon[1], R. Frouin[2], F. Steinmetz[3], D. Jolivet[4], M. Compiègne[5],

Within the ESA SEOM (Scientific Exploitation of Operational Missions) program, and in particular the PPP (PAR for Primary Production, http://www.esa-par.net) project, we have completed the classical PAR product (the daily amount of light quanta between 400 and 700 nm reaching the surface per unit area, under clear and cloudy pixels) and computed a first series of other radiative quantities for which the community manifested interest: the scalar PAR below the surface and its uncertainty, the spectral shape of PAR, and the average cosine for total light below the surface. We present the algorithms and some example maps from MERIS imagery.

1. dr@hygeos.com
HYGEOS, 165 av. de Bretagne, 59000 Lille, France
2. rfrouin@ucsd.edu
Scripps Institution of Oceanography, La Jolla, USA
3. fs@hygeos.com
HYGEOS
4. dj@hygeos.com
HYGEOS
5. mc@hygeos.com
HYGEOS

Explore Sea Ice trends by resampling

M. Rosário Ramos[a,b,1], Clara Cordeiro[c,d,2]

This study analyses the trends of the Sea Ice Extent in the Northern Hemisphere (NH) time series, provided by MASIE-NH. Previous researches point out to a statistically significant decrease of Sea ice extent. It is well known that special attention should be given when data are autocorrelated or highly skewed, in the way that affects the reliability of the trend test. Therefore, trend analysis is still an important problem in time series analysis.
In order to overcome the weakness of the classical tests, we analyse the performance of two trend tests, t-test and Mann-Kendall, and combined with a resampling technique. The comparison is conducted through a simulation study, considering a set of underlying slopes and different values of autocorrelation. The order of autocorrelation structure is estimated by the best fitting model obtained through the AIC information criterion.

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[a]Universidade Aberta, Rua da Escola Politécnica 141, 1269-001 Lisboa, Portugal.
[b]Centro de Matemática, Aplicações Fundamentais e Investigação Operacional(CMAF-CIO), Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016.
[c]Faculdade de Ciências e Tecnologia, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal.
[d]Centro de Estatística e Aplicações (CEAUL), Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal

[1]MariaR.Ramos@uab.pt
[2]ccordei@ualg.pt

Marine and Coastal Applications of Landsat-8/OLI and Sentinel-2A/MSI data in Trinidad and Tobago

[1]Deanesh Ramsewak, [1]Sunil Ramnath, [1]Priya Pollard, [1]Darnell John.

ABSTRACT

Trinidad and Tobago is a twin island nation located at the southeastern tip of the Caribbean archipelago. As with many small island states its coastal zone is complex, consisting of dynamic ecosystems such as mangroves and coral reefs. These wetlands are of critical importance and are under constant natural and anthropogenic stresses. Integrated monitoring systems are therefore necessary to highlight as early as possible any indication of degradation. Earth observation data, like those from Landsat-8 (L8) - Operational Land Imager (OLI) (launched in February 2013) and Sentinel-2A (S2A) - Multispectral imager (MSI) (operational since June 2015) are key to such monitoring systems. This paper presents preliminary results of the application of L8 and S2A imagery to coastal and marine mapping studies around the islands of Trinidad and Tobago. A comparison of turbidity and chlorophyll-a products extracted from S2A using algorithms in ACOLITE v20170113.0 software, are provided for the Gulf of Paria region while image data from both L8 and S2A was used in an attempt to discriminate among mangrove species in the islands' key terrestrial wetland system. Finally, the use of S2A imagery for *Sargassum* seaweed detection and mapping is also illustrated. ACOLITE v20170113, SNAP v5.0.3 and ArcGIS v10.4 software were used for processing and manipulating satellite image data. The Sentinel-2B (S2B) satellite which was launched from the Guiana Space Center (CSG) in Kourou, French Guiana on March 7th 2017 will soon provide new imagery to the earth observation community. S2B will join its twin Sentinel-2A (S2A) satellite in providing free high resolution data to the public. The addition of S2B means that very soon the 10 day re-imaging period of S2A will be cut in half. It is expected that after the commissioning phase is completed (mid-June 2017), the highly anticipated data products of S2B will be incorporated into these research applications.

Keywords: Turbidity, Chlorophyll-a, Mangrove, *Sargassum*, Remote Sensing, Landsat-8/Operational Land Imager (OLI), Sentinel-2A/MSI, Coastal mapping, Trinidad and Tobago.

[1]Marine Sciences Department, The University of Trinidad and Tobago, Chaguaramas Campus, 2nd Avenue North, Western Main Road, Chaguaramas, Trinidad and Tobago.
(Deanesh.Ramsewak@utt.edu.tt)

Construction of multi-year time series profiles of suspended particulate inorganic matter concentrations from highly dynamic coastal waters of the English Channel using self-organizing maps and hidden Markov model.

P.R. Renosh[1a], F. Jourdin[2b], AA. Charantonis[3c], K. Yala[4a], F. Badran[5a], S. Thiria[6c], N. Guillou[7d], F. Gohin[8e]

[a)] Laboratoire CEDRIC, Conservatoire National des Arts et Métiers (CNAM), Paris, France
[b)] Service hydrographique et océanographique de la Marine (SHOM), Brest, France
[c)] Laboratoire d'océanographie et du climat : expérimentations et approches numériques (LOCEAN), Paris, France
[d)] Laboratoire de Génie Côtier et Environnement (LGCE), Cerema/DTecEMF/DS, Plouzané, France
[e)] ODE-DYNECO-PELAGOS, Ifremer, Centre de Bretagne, Technople Brest-Iroise, Plouzané, France

Abstract

Hydro-sedimentary models have been widely used for deriving suspended particulate matter concentrations from the coastal and estuarine waters. These hydro-sedimentary models are computationally and technically expensive in nature. Here we have used computationally cheap, well established methodology of self-organizing maps along with hidden Markov model to derive profiles of suspended particulate inorganic matter (SPIM). This methodology works on two different data sets called “Hidden” and “Observable”. We have used 15 months (27-September 2007 to 30-December 2008) hourly profiles of SPIM from Regional Ocean Modeling System (ROMS) hydro-sedimentary model as a hidden data. The observable data are mainly forcing parameters such as wave parameters (Hs and Hs-50 (50 days)) from Wave watch 3 (WW3-Homere) and barotropic currents (Ubar and Vbar) from IBI reanalysis data. These observable data are also hourly sampled from the surface from 01-February 2002 to 31-December 2012.

The profiles of SPIM have been derived from 4 different stations in the English Channel by holding 15 months hidden data of ROMS output as a real representation of the ocean. For the validation purpose, these derived surface concentrations of SPIM have been compared with the satellite derived SPIM. The 11 years of derived SPIM and the satellite SPIM are in range and we could also produce the yearly fluctuations in the SPIM data. The temporal sections of SPIM are well correlated with the Hs and resultant velocity infers the influence of tidal currents and waves on the derived SPIM concentrations.

Keywords: Suspended particulate inorganic matter, Self-organizing maps, Hidden Markov model, English Channel, ROMS

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1 pr.renosh@gmail.com CNAM, Laboratoire CEDRIC, 292, Rue Saint Martin, 75003 Paris, France.
2 frederic.jourdin@shom.fr SHOM, 13, rue du Chatellier, 29603 Brest, France.
3 anastase-alexandre.charantonis@locean-ipsl.upmc.fr LOCEAN, Jussieu, 75005 Paris, France.
4 yala-khalil@hotmail.fr CNAM, Laboratoire CEDRIC, 292, Rue Saint Martin, 75003 Paris, France.
5 fouad.badran@cnam.fr CNAM, Laboratoire CEDRIC, 292, Rue Saint Martin, 75003 Paris, France.
6 sylvie.thiria@locean-ipsl.upmc.fr LOCEAN, Jussieu, 75005 Paris, France.
7 nicolas.guillou@cerema.fr LGCE, Cerema/DTecEMF/DS, 29280 Plouzané, France.
8 Francis.Gohin@ifremer.fr IFREMER/DYNECO/PELAGOS, CS 10070, 29280 Plouzané, France.

Does size matter? A contribution from the Equivalent Algal Populations (EAP) model on the feasibility of PFT detection from satellite ocean colour data

L. Robertson Lain (1) , S. Bernard (1, 2), S. Thomalla (2), S. Dutkiewicz (3)
lislrobertson@gmail.com

How viable is Phytoplankton Functional Type detection from satellite ocean colour data? We contribute to this discussion using the Equivalent Algal Populations model to simulate water-leaving reflectances for two different phytoplankton assemblage successions in the Southern Ocean. The second-order optical effects of phytoplankton in this size-based model are isolated via the use of Rrs(phi), the contribution to Rrs due only to changes in assemblage effective diameter. Reflectances are modelled with high spectral resolution, identifying particular spectral regions sensitive to the second-order PFT signal, and improving understanding of causal optical relationships as phytoplankton interact with other in-water constituents in their light environment.

1 Department of Oceanography, University of Cape Town, RSA
2 Centre for Scientific & Industrial Research (CSIR), 15 Lower Hope Rd, Rosebank, Cape Town
3 Massachusetts Institute of Technology, 77 Massachusetts Ave, Cambridge MA, USA

Evaluation of MODIS-Aqua Ocean Colour Products in the Southern Atlantic and Continental Margin off Chile

Natalia Rudorff[1]; Robert Frouin[2]; Milton Kampel[1]

MODIS-Aqua ocean colour radiance (OCR) products were compared to in situ data obtained during the February-March 2011 R/V Melville cruise across the Southern Atlantic and Continental Margin off Chile. Collocated match-ups were obtained within a ±3h window for the remote sensing reflectance (R_{rs}) and particle backscattering coefficient (b_{bp}) collected at fixed stations, and a ±6h window for en route measurements. The R_{rs} at 412 and 555nm had higher relative percent differences (RPD) (13 and 11%), whereas at 443 and 488nm the RPDs were closer to required values for high quality OCR products (<5%). The phytoplankton absorption coefficient (at 443nm) and chlorophyll-a concentration had RPDs ranging from 33 and 34% (GIOP with class-specific parameterizations), to 54 and 58% (QAA). The coloured dissolved and particulate organic matter (CDM) absorption coefficient and b_{bp} (at 443nm) were best retrieved with GSM (37% and 16% RPD, respectively). The b_{bp} spectral slope (QAA) was reasonably retrieved (0.53 R2), whereas the CDM spectral slope and index were highly dispersive (<0.11 R2). Despite the good b_{bp} retrievals, the particulate organic matter (POC) empirical model performed better than b_{bp} -based models, with 25% RPD compared to 40-50%. The results indicate that: i) more accurate R_{rs} at shorter wavelengths are required for CDM related products; ii) the GIOP framework has potential to improve OCR products, especially related to phytoplankton, but better parameterizations are required for the bulk inversion; iii) POC algorithms based on b_{bp} relationships are limited by site specific relations, and need further improvements for applications on carbon studies.

[1]natalia.rudorff@inpe.br; National Institute for Space Research (INPE), Center for Weather Forecasting and Climate Studies (CPTEC), Dutra km 39, Cachoeira Paulista, SP, Brazil
[1]milton@dsr.inpe.br; National Institute for Space Research (INPE), Av. dos Astronautas, 1758, São José dos Campos, SP, Brazil
[2] rfrouin@ucsd.edu; Scripps Institution of Oceanography, University of California San Diego,8810 Shellback Way, La Jolla, CA 92037, USA

The Korea-US Ocean Color Cruise (KORUS OC) in support of Geo-stationary Ocean Color Missions

Joseph Salisbury, Ocean Processes Analysis Laboratory, University of New Hampshire, Durham, NH

Antonio Mannino, Ocean Ecology Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD

In this presentation we give an overview of the KORUS cruise, which was designed to study the physical, biological and chemical processes giving rise to spatial and temporal variability in ocean color parameters. We discuss the data collected, its processing status and the unique opportunities for interdisciplinary studies afforded by combined oceanic and atmospheric air quality field campaigns. Our study domain exhibited significant variability in time and space and we show preliminary data demonstrating diurnal phytoplankton production (net), sediment resuspension, riverine plume dynamics and unique suspended particle distributions. Finally we discuss the application of these data to improvements for ocean color satellite data processing and highlight the challenges imposed by rapidly changing light fields, algal and non-algal particle loads and atmospheric aerosols.

Ocean Color data in a tool to support Aquaculture management

Sá[1], C., Couto[1], A.B, Brito[1], A.C, Brotas[1], V., Eleveld[2], M., Dale[3], T., Poser[4], K. and Laanen[4], M.

Satellite remote sensing (RS) can be an effective tool in providing near-real time (NRT) support to aquaculture managers by monitoring environmental parameters that impact its activities. Within the FP7 AQUA-USERS project, user's requirements were evaluated to identify what relevant information could be provided in an easily accessible way.
Users were interested in information on weather and sea state conditions, together with water temperature and chlorophyll-*a* (Chl-*a*) concentration data. The latter was highlighted to be a relevant indicator of food availability (e.g. for bivalve aquaculture) and an important indicator of water quality. However, for effective evaluation and decision making, these parameters should indicate gradients and fluctuations in the environmental conditions. For that purpose, natural variability was evaluated using 10 years of satellite ocean-color data (i.e. MERIS FR, 2002-2012). For all the user's sites a regional-specific time-series was determined.
For each time-series the 10th, 50th, and, 90th percentiles, mean and standard deviation, were computed for each 7 days of the year. Each of these statistics was further filtered using a harmonic fitting. These provide the users with a reference of natural variability for their sites at any time of the year and should provide alert conditions to site managers. The success of these indicators are however tightly dependent on the quality of the satellite products for the specific study sites.
The data were made available to users through an app for operational testing. Accessing the app, users can compare NRT measurements with climatological data, save new measurements and analyze trends.

Affiliations:
[1] MARE-ULisboa, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal
[2]Deltares, Netherlands
[3]Norsk institutt for vannforskning, Gaustadaleen 21, 0349 Oslo, Norway
[4]Water Insight BV, Marijkeweg 22, Wageningen 6709 PG, Netherlands

Section: Applications, user services and tools

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

Violeta Sanjuan Calzado[1], David McKee[2], Kenneth Voss[3], Charles Trees[1]

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

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

[1]Centre for Maritime Research and Experimentation NATO, La Spezia, Italy

[2]Department of Physics, University of Strathclyde, Glasgow, Scotland, U.K.

[3]Physics Department, University of Miami, U.S.

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A new vicarious calibration site in the central Mediterranean Sea: the integrated oceanographic and atmospheric climate observatory at Lampedusa.

Santoleri R.[1], Colella S.[1], di Sarra A.[2], Bommarito C.[2], Volpe G.[1], Bergamasco A.[3], Marullo S.[4,1], Artale V.[4,1], Sferlazzo D.[2], Meloni D.[2], Monteleone F.[2], Pace G.[2], Piacentino S.[2], Anello F.[2], Di Iorio T.[2]

Under the umbrella of the RITMARE Italian flagship program an oceanographic buoy was deployed in August 2015 at a depth of 74 m about 3.3 miles South-West of the island of Lampedusa, in the central Mediterranean Sea. This area is characterized by oligotrophic conditions (chlorophyll-a < 0.2 mg/m3) and generally associated with temporally stable atmospheric conditions, low cloudiness and low aerosol load (AOT(865nm) < 0.15). The buoy is an integration of the Station for Climate Observations on the island of Lampedusa, which is part of the EMSO research infrastructure. The atmospheric section of the observatory is operational since 1997 and mostly dedicated to long-term measurements of atmospheric parameters relevant for climate studies. A large set of instruments are operational at the Atmospheric and Oceanographic observatories, allowing for a detailed characterization of the atmospheric structure and composition, of the marine optical and oceanographic properties, and of the air-sea interactions. The available observations and the characteristics, make this integrated observatory particularly suitable for validation studies of satellite measurements, and for the vicarious calibration of ocean colour sensors. A first set of optical radiometers for the characterization of the marine optical properties has been deployed. They include two sets of 7-band upwelling and downwelling Irradiance and upwelling Radiance sensors, deployed at depths of 2.5 and 6 meters to better characterize the surface Remote Sensing Reflectance field for the calibration and validation of satellite observations. Other instruments installed are CTD, O2, temperature sensors and above-water instruments for meteorological parameters and surface energy budget studies.

[1]Institute of Atmospheric Sciences and Climate (ISAC) - CNR, Rome, Italy, r.santoleri@isac.cnr.it, simone.colella@cnr.it

[2]Laboratory for Observations and Analyses of Earth and Climate, ENEA, Italy, alcide.disarra@enea.it

[3]Institute for Coastal Marine Environment (IAMC) - CNR, Italy

[4]Sustainability Department, ENEA, Italy

Dissolved organic carbon for coastal waters off Sarawak, Borneo from Space

NIVEDITA SANWLANI[1], NAGUR CHERUKURU[2], PATRICK MARTIN[1], MORITZ MÜLLER[3], AAZANI MUJAHID[4]
[1]*Asian School of the Environment, Nanyang Technological University, Singapore*
[2]*CSIRO Oceans and Atmosphere, Canberra, Australia*
[3]*Swineburne University of Technology, Kuching, Malaysia*
[4]*Universiti Malaysia Sarawak, Kuching, Malaysia*

The rising export of dissolved organic carbon (DOC) from peatlands is of great environmental concern as it represents a potential loss of carbon from long-term stores to downstream aquatic systems and ultimately, to the atmosphere, through mineralization. Tropical peatlands in Southeast Asia are believed to account for >10% of the global land-to-ocean DOC flux, and thus represents a quantitatively important link in the marine carbon cycle and biological pump. However, we currently know little about the terrestrially-derived DOC fluxes to the coastal seas, and its role in the marine biogeochemistry, especially in South-East Asia.

This study aims to quantify spatial distribution pattern and seasonal variability and dynamics of peatland-derived DOC in the coastal waters of Sarawak, Borneo, using satellite remote sensing. Coastal waters of Sarawak receive large DOC inputs from peat-draining estuaries, and satellite ocean colour data provide a valuable tool to measure DOC across broad geographic regions and its transport mechanism. We will present results evaluating the performance of different algorithms for estimating DOC concentration for tropical South-East Asian waters from Moderate Resolution Imaging Spectroradiometer data on-board Aqua in this region. Our results reveal substantial inputs of DOC from Sarawak rivers, with strong horizontal gradients, and generally higher concentrations during the northeast monsoon than the south-west monsoon.

Interpolated fields of satellite-derived multi-algorithm chlorophyll-a estimates at Global and European scales in the frame of the European Copernicus-Marine Environment Monitoring Service.

Bertrand Saulquin[1], Francis Gohin [2], Odile Fanton d'Andon[1]

[1]ACRI-ST 260 Route du Pin Montard, 06904 Sophia-Antipolis, France; [2]Ifremer, Pointe du Diable, 29280 Plouzané, Brest, France

Abstract

The level-4 daily chl-a interpolated products are a combination of a water typed merge of chl-a estimates and an optimal interpolation based on the kriging method with regional anisotropic models. The interpolated products basically provide a global continuous (cloud-free) estimation of the daily surface chl-a concentration at 4 km resolution over the world and 1 km resolution over the Europe. The analysed products spare end users to consider both the typical lack of observation during cloudy conditions and the historical multiplicity of available algorithms involved by case 1 (oligotrophic) and case 2 (turbid) water considerations. These products gather MODIS[1], MERIS[2], SeaWiFS[3], VIIRS[4] and OLCI[5] daily observations from 1998 to now. At our knowledge this product is the first analysis of the

[1] Moderate Resolution Imaging Spectroradiometer

[2] MEdium Resolution Imaging Spectrometer

[3] Sea-viewing Wide Field-of-view Sensor

[4] Visible Infrared Imaging Radiometer Suite

[5]Ocean and Land Colour Instrument

daily chlorophyll-a surface concentration for the global ocean. A total product uncertainty, i.e. a combination of the interpolation and the product error, is provided for each pixel. The analyses are freely distributed in the frame of the Copernicus - Marine environment monitoring service ftp://cmems.isac.cnr.it/Core/OCEANCOLOUR_GLO_CHL_L4_NRT_OBSERVATIONS_009_033/dataset-oc-glo-chl-multi-l4-oi_4km_daily-rt-v01 (register first: http://marine.copernicus.eu/web/56-user-registration-form.php).

Keywords

Daily chlorophyll-a observed from space; optimal interpolation; anisotropic covariance; total uncertainty estimates.

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Sen2Water: multi-water atmospheric corrections for the Sentinels 2

Bertrand Saulquin[1], François-Régis Martin Lauzer[1]

[1]ACRI-ST 260 Route du Pin Montard, 06904 Sophia-Antipolis, France;

Abstract

From the Top Of Atmosphere (TOA) observations, unmixing the water signal from the atmospheric signal is challenging as multiple sets of solution of vector$\{\rho_{aer}(\lambda), \rho_w(\lambda), \mathrm{T}(\lambda)\}$ are possible for a single set of TOA observations. To enhance inversion reliability, we introduce spatial-regularisation factors, from 30 km to 300m resolution, and water-typed cost functions. We show that the integration of, spatial gradients onto the aerosol optical thicknesses, and changes of the cost function to converge towards non-negative and physically possible $\rho_w(\lambda)$, provide real improvements to inverse the low frequency atmospheric signal and the high frequency (in coastal areas) $\rho_w(\lambda)$. We show validation results on the Aeronet-OC sites, and comparisons with the Sen2cor ESA processor and the AP2 (neural network) OLCI estimates. The V0 of the Sen2Water processor is fully parallelised and is able to process one S2 image at 60m resolution in 2-3 minutes using 16 CPUs.

Keywords

Sentinels 2 operational atmospheric corrections in coastal waters; inversion with spatial constraints, inversion with modified cost functions for non-negative and physically possible $\rho_w(\lambda)$.

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Vertical distribution and seasonal variability of biogeochemical properties in the North Atlantic inferred from innovative learning-based methods

R. Sauzède[1], H. Claustre[2], J. Uitz[2], C. Fontana[1], E. Martinez[1], A. Poteau[2] and C. Schmechtig[2]

Ocean color observations enable the estimation of bio-optical proxies of phytoplankton biomass in the surface layer of the ocean quasi-synoptically. In parallel, the Argo program distributes vertical profiles of the ocean physical properties with a high spatio-temporal resolution. Thus, we developed new learning-based methods taking advantage of these high spatio-temporal resolutions to infer the seasonal vertical distribution of phytoplankton biomass, associated community composition and key biogeochemical parameters in the North Atlantic (40°N-70°N; 0°W-80°W). First, the SOCA (for merged Satellite Ocean Color and Argo data) method is regionally trained using concurrent vertical profiles of temperature, salinity, and bio-optical properties collected from Biogeochemical-Argo floats matched up with satellite bio-optical products. It allows retrieving the seasonal 3D distribution of (1) chlorophyll a concentration and phytoplankton community size indices and (2) particulate backscattering coefficient from climatological data of temperature, salinity and ocean color. We also used the CANYON (for CArbonate system and Nutrients concentration from hYdrological properties and Oxygen using a Neural-network) method which has been newly developed and trained at global scale with concurrent vertical profiles of temperature, salinity and oxygen concentration from the GLODAPv2 database. It allows retrieving the seasonal 3D distribution of macronutrients and carbonate system parameters in the North Atlantic from climatological data of temperature, salinity and oxygen. Combining these two methods, a new vision of the seasonal vertical variability of key complementary biogeochemical parameters is provided for the North Atlantic area.

[1]: Ecosystemes Insulaires Océaniens (EIO, UMR-241), IRD, Ifremer, UPF and ILM, Tahiti, French Polynesia

[2]: Sorbonne Universités, UPMC Univ Paris 06, CNRS-INSU, Observatoire Océanologique de Villefranche, Laboratoire d'Océanographie de Villefranche, 181 Chemin du Lazaret, 06230 Villefranche-Sur-Mer, France

Cyanobacteria Assessment Network (CyAN) satellite mobile device application.

Blake A. Schaeffer[*a], Robyn N. Conmy[b], Michael Galvin[c], Amber Ignatius[d], John M. Johnston[c], Darryl Keith[e], Ross S. Lunetta[a], Rajbir Parmar[c], Kurt Wolfe[c]

[a]National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, USA

[b]National Risk Management Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH, 45268, USA

[c]National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA, 30605, USA

[d]Oak Ridge Institute for Science and Engineering (ORISE), National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, GA, 30605, USA

[e]National Health and Environmental Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Narragansett, RI, 02882, USA

The timely distribution of satellite derived data is necessary for adaptive water quality management decision making. Prompt dissemination of remotely sensed water quality data enables public warnings within days and the ability to issue seasonal assessments in the same calendar year. Distribution of satellite-derived water quality products also assists with more targeted deployment of existing federal, state, tribal, and municipal water quality monitoring. Specifically, software platforms that permit timely, useful, and cost-effective delivery of information from satellites are required to help managers respond to cyanobacterial and nuisance algal blooms. The Cyanobacteria Assessment Network (CyAN) mobile application uses satellite-derived information from the European Space Agency Ocean Land Color Instrument (OLCI) onboard Sentinel-3 to help make initial water quality assessments and quickly alert managers to potential problems and emerging threats related to cyanobacteria abundance. With the CyAN mobile application, water quality managers will have a user friendly platform that will reduce the complexities associated with harnessing satellite data to make fast, efficient initial assessments. The CyAN app will support the viewing of water quality at continental to lake shed scales in near-real time to put cyanobacteria abundance data directly the hands of water quality managers and stakeholders.

Sometime R^2 just ain't enough:
Approaches to more robust algorithm assessment.

Bridget Seegers[1], Blake Schaeffer[2], Richard Stumpf[3], and Jeremy Werdell[4]

Satellite ocean color algorithms are critical for global estimation and mapping of phytoplankton, which provide indicators of marine ecosystems health and diversity and link to economically important measures such as fisheries production, water quality, and recreational opportunities. Ocean color algorithms are becoming increasingly important in scientific modeling and to support resource manager decision making. Following, finely tuned algorithms that are well-evaluated are desired by a wide dynamic range of users – yet, the most common approaches and protocols for algorithm evaluation and quantification of improved performance are not robust, nor has consensus on their use been achieved. The poster presents a variety of metrics to evaluate algorithm performance and strategic approaches to combine metrics for algorithm evaluation, including spatial temporal image assessment.

bridget.n.seegers@nasa.gov, Schaeffer.blake@epa.gov, Richard.stumpf@noaa.gov, Jeremy.werdell@nasa.gov

[1] USRA, NASA Goddard Space Flight Center
[2] US EPA, Office of Research and Development
[3] NOAA National Ocean Service, National Centers for Coastal Ocean Science
[4] NASA Goddard Space Flight Center

Monitoring urban black and odorous waters Using Remote Sensing

Qian Shen[1], Junsheng Li[2], Hongye Cao[3] and Bing Zhang[4]

Urban sewage emissions increase and water pollution becomes serious. Urban black and odorous waters (BOWs) are the key improvement issues for China government in the next five years. The study areas include urban built-up areas in Beijing, Shenyang, Changchun. We measured in-situ remote sensing reflectance, water quality parameters and inherent optical papameters. Based on these data, we classified BOWs into seven classes via the normalized reflectance spectra. Also, we provided a new classification tree for the seven classes of BOWs. After comparison of general waters collected from Hunhe river and other Northern lakes and reservoirs, a new identification method called saturability algorithm for heavy BOWs is provided. If saturability threshold less than or equal to 0.16, the water will be viewed as heavy BOWs, otherwise it will be general waters. We used 75% samples to build the model and 25% samples to validate the model. The results showed the recognition accuracy was over 83% for BOWs and 88% for general waters. At last, the method is applied on one high-resolution GF-2 remote sensing image covering one part of Shenyang. The distribution of BOWs accorded with the field investigation situation. This work presents a potential way for identifying heavy BOWs using high-resolution satellite images.

1. shenqian@radi.ac.cn, No. 9 Dengzhuang South Road, Haidian District, Beijing
2. lijs@radi.ac.cn, No. 9 Dengzhuang South Road, Haidian District, Beijing
3. 1033897003@qq.com, No. 9 Dengzhuang South Road, Haidian District, Beijing
4. zb@radi.ac.cn, No. 9 Dengzhuang South Road, Haidian District, Beijing

High resolution views of heterogeneous distribution of suspended particulate matter (SPM) in a world-class estuary from space

Fang Shen, Rugang Tang, Pei Shang, Yanqun Pan
State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, China. Email: fshen@sklec.ecnu.edu.cn

The Yangtze (Changjiang) Estuary is a world-class big estuary with three-order branches and four outlets. Each bifurcate tributary is of different runoff split ratio. The SPM exhibits the heterogeneous distribution in the estuary. Moreover, such distribution can change with time due to the impact of interaction of tidal current and river flow. Multi-mission lower-spatial resolution views of SPM in the Yangtze estuary and validation are acceptable (Shen et al. 2014) but still lack of details. The SPM seasonal and annual variations from lower-resolution long-term satellite observation and its response to recent decease of the Yangtze River discharge was observed (Shen et al. 2013). High-temporal resolution geostationary for the SPM diurnal variability is effectively detected and has successfully been applied to retrieve the bottom critical shear stress through combined with the sediment transportation dynamic model (Ge et al. 2015). However, more details of the SPM heterogeneous distribution in small and complex estuaries can be detected by current high-spatial resolution satellite observations (Vanhellemont & Ruddick, 2014). Recently, China launched series high-resolution satellite missions, e.g., GF-1 in 2013 and GF-2 in 2014. Multi-mission high-spatial resolution satellites (GF-1/WFV, Landsat-8/OLI, Sentinel-2/MSI) views of the top-of-atmosphere radiance, atmospheric correctly remote-sensing reflectance and derived SPM recently carried out cross-comparison in order to enhance our confidences for data use (Shang & Shen, 2016; Paper in prep). Results from different methods of atmospheric correction were compared. GOCI and *in situ* data were used for verifying the accuracy and reliability of derived-SPM. Results show that derived-SPM has a good correlation between four sensors. SPM derived from Landsat-8/OLI and GOCI shows a better correlation with field measurements, followed by GF-1/WFV. High-spatial resolution satellites can satisfy the detection of the SPM heterogeneous details in such the complex estuary with natural passages and man-made channels.

A New Algorithm Deriving VIIRS Particle Backscattering Coefficient $b_{bp}(\lambda)$ Products in the Global Highly Turbid Waters

Wei Shi[1,2,*], Menghua Wang[1]

[1]National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
Center for Satellite Applications and Research
College Park, Maryland, USA

[2]Cooperative Institute for Research in the Atmosphere at Colorado State University,
Fort Collins, Colorado, USA

In coastal and inland waters, the water-leaving radiance spectra are determined by inherent optical properties (IOPs) in the water-column. The complex features of the IOPs make accurate retrieval of IOPs challenging. This presentation shows that remote-sensing reflectance model in the turbid waters can be significantly simplified at the near-infrared (NIR) wavelengths, thus particle backscattering coefficient ($b_{bp}(\lambda)$) can be derived from normalized water-leaving radiance spectra $nL_w(\lambda)$ at the NIR wavelengths. Using the HYDROLIGHT simulated water-leaving radiance spectra, we show that the $b_{bp}(\lambda)$ values derived with the NIR IOP algorithm generally match well with the true $b_{bp}(\lambda)$ values in the coastal and inland waters. Specifically, $nL_w(\lambda)$ spectra at the NIR bands are derived using the shortwave infrared (SWIR)-based atmospheric correction algorithm from the Visible Infrared Imaging Radiometer Suite (VIIRS) over turbid coastal and inland waters. We use VIIRS-derived $nL_w(\lambda)$ spectra at 745 and 862 nm to produce the particle backscattering coefficient ($b_{bp}(\lambda)$) products in world highly turbid coastal and inland waters such as China's east coastal region, Amazon River estuary, La Plata River estuary, and Mississippi River estuary. Seasonal and interannual variability of VIIRS $b_{bp}(\lambda)$ data in these regions is characterized and quantified. Furthermore, $b_{bp}(\lambda)$ products derived in the NIR IOP approach are compared with those from other IOP algorithms such as the quasi-analytical algorithm (QAA) and the generalized inherent optical properties (GIOP).

Chesapeake Bay Export of Dissolved Organic Carbon from Space-borne Data

Sergio R. Signorini[1,2]
Antonio Mannino[2]
Marjorie A. M. Friedrichs[3]
Pierre St. Laurent[3]
John Wilkin[4]

Estuaries play an important role in transforming riverine nutrients and carbon before they are exported to the adjacent continental shelf. Land-estuarine-ocean biogeochemical modeling systems, evaluated with in situ and satellite data, are invaluable tools to quantify riverine nitrogen and carbon inputs, within-estuary nitrogen/carbon transformation processes and the ultimate export of nitrogen and carbon to the coastal ocean. This study specifically focuses on the export of dissolved organic carbon (DOC) from Chesapeake Bay to the adjacent shelf in the Middle Atlantic Bight (MAB).

We applied ocean color satellite algorithms to retrieve estuarine DOC concentrations and combine them with output from a physical circulation model to quantify coastal DOC fluxes. The satellite DOC time series originates from a combined 17-year record of SeaWiFS and MODIS Aqua (1998-2014) 1-km daily data (https://oceancolor.gsfc.nasa.gov/). DOC profiles required to compute the tracer fluxes at the mouth of the bay were produced using a feed-forward neural networks model (NnetM) trained with in situ data (salinity (S), temperature (T), and DOC). The 3D (x, y, z, t) DOC concentrations were then computed using profile shapes from the NnetM with T and S inputs from the physical model and the surface DOC derived from the satellite retrievals.

The seasonal and interannual variability of estuarine DOC export are analyzed based on the 17-year time series at the mouth of the Bay. Results from this study can be used to improve the assessment of the Bay's potential to produce organic carbon and to estimate the total carbon budget for the MAB.

[1]Science Applications International Corp., 8800 Greenbelt Road, Greenbelt, MD 20771, USA
sergio.r.signorini@saic.com
[2]NASA Goddard Space Flight Center, 8800 Greenbelt Road, Greenbelt, MD 20771, USA
sergio.signorini@nasa.gov , antonio.mannino@nasa.gov
[3]Virginia Institute of Marine Science, College of William & Mary, 1208 Great Road, Gloucester Point, VA 23062, USA
marjy@vims.edu, pst-laurent@vims.edu
[4]Department of Marine and Coastal Sciences, Rutgers University, 71 Dudley Road, New Brunswick, NJ 08901, USA
wilkin@marine.rutgers.edu

Optical water type classification of OLCI reflectance data in optically complex coastal waters

Marié Smith [a]

The use of optical water type (OWT) classification has gained popularity in recent years within the field of ocean colour remote sensing. This technique is often applied to remotely sensed reflectance data as a means to identify and map water types with characteristic spectral features, e.g. harmful algal blooms or river plumes; or for the application and blending of water type-appropriate algorithms aimed at improving the accuracy of satellite product retrievals over dynamic ranges of bio-optical conditions.

This study demonstrates the application of a regional OWT classification framework on reflectance data from the new ocean and land colour instrument (OLCI). This framework, which is optimized for the productive coastal waters of the southern Benguela, was originally designed for utility with reflectance data from the medium resolution imaging spectrometer (MERIS). However, the instrument continuity between MERIS and OLCI, particularly similar spectral band configuration and algorithm types, facilitated the adaptation of the OWT classification framework for application to OLCI. These sensors offer good spectral coverage in the red-NIR needed for accurate quantitative retrievals of Chl-a in the eutrophic waters of the southern Benguela. The OWT classification framework facilitates regional operational harmful algal bloom monitoring and coastal water quality management over highly dynamic ranges of phytoplankton biomass concentrations.

[a] MSmith2@csir.co.za, CSIR, Cape Town, South Africa

Characterising Pelagic Biodiversity Hotspots and their dynamics in the high seas by means of satellite information.

Alice Soccodato[1], Francesco D'Ovidio[2], Silvia De Monte[3], Marina Levy[2], Severine Alvain[4], Bernard Queguiner[1]

Understanding the mechanisms responsible for the development of areas of high biodiversity is essential to assess the state of the pelagic ecosystem and for the management of its resources. However, information obtained by campaigns and observation networks is still sparse and hinders the improvement of our knowledge about the functioning of the ecosystem and of conservation policies. The index developed here identified regions of increased plankton diversity using satellite detected 'fluid dynamical niches' characterized by different dominant plankton communities. Mesoscale regions containing a mosaic of contrasted communities are marked by this algorithm as biodiversity hotspot candidates. This index provides global maps that satisfy primary macroecological relations and responded positively to a validation based on both model and in situ data. I found a preliminary general positive relationship between these regions and regions characterized by high cross-taxa diversity of higher levels of the trophic chain at the global scale. These maps can therefore be compared to information about the distribution of top predator species target for conservation policies and more widely biodiversity of consumers at both global scale and more specific regional scales. Future work will investigate the potential of these regions to 'attract/develop' diversity and/or abundance of superior guilds of the food web and to identify pelagic biodiversity hotspots and their dynamics using satellite derived ecological proxies. Results will be capital to demonstrate that satellite products can be used as ecological proxies to determine sensible areas for biodiversity conservation and to monitor environmental and ecological shifts in the pelagic realm.

[1] Aix-Marseille University, Mediterranean Institute of Oceanography (MIO), CNRS/INSU, IRD, UM 110, Campus universitaire de Luminy, case 901, 13288 Marseille cedex 09, France.
Alice.soccodato@mio.osupytheas.fr; Bernard.queguiner@mio.osupytheas.fr

[2] Sorbonne Université (UPMC, Paris 6)/CNRS/UPMC/IRD/MNHN, LOCEAN-IPSL, 4 place Jussieu, 75005 Paris, France.
Francesco.dovidio@locean-ipsl.upmc.fr; Marina.levy@locean-ipsl.upmc.fr

[3] Ecole Normale Supérieure, Institut de Biologie de l'ENS (IBENS), UMR CNRS 8197 and INSERM U1024, 46 rue d'Ulm, 75005 Paris, France.
Demonte@biologie.ens.fr

[4] Laboratoire d'Oceanologie et de Geosciences, CNRS-ULCO-Universite´ Lille Nord de France, 62930 Wimereux, France.
Severine.alvain@cnrs.fr

Development of the MNIR-SWIR and AA atmospheric correction and suspended sediment concentration algorithms and their validation in the coastal waters of the East China Sea

Leonid Sokoletsky[1], Fang Shen[2], Yang Xianping[3]

Mapping of suspended sediment concentration (SSC) can be achieved from the modern space-based optical sensors such as MODIS, MERIS, SeaWiFS, and GOCI using reliable atmospheric correction and SSC algorithms. We have developed two different atmospheric correction (AC) and one SSC algorithms. The both AC algorithms, namely, modified near-infrared—short-wave infrared (MNIR-SWIR) and analytical approximation (AA), and SSC algorithm as well, were validated in the coastal waters of the East China Sea. The algorithms developed were compared for the spectral surface remote-sensing reflectance R_{rs}(□) and SSC both with *in situ* measurements and the atmospheric radiative transfer Second Simulation of a Satellite Signal in the Solar Spectrum (6S) algorithm. We show validation results and give recommendations for the further use of satellite ocean color algorithms.

State Key Laboratory of Estuarine and Coastal Research, *East China Normal University*, *Shanghai*, *China*

[1] sokoletsky.leonid@gmail.com

[2] fshen@sklec.ecnu.edu.cn

[3] 735196447@qq.com

Comparison of GOCI and VIIRS Ocean Color Products in the Western Pacific Region

SeungHyun Son[1,2], Menghua Wang[1], and Lide Jiang[1,2]

[1]NOAA/NESDIS, Center for Satellite Applications and Research (STAR)
E/RA3, 5830 University Research Ct., College Park, MD 20740, USA

[2]CIRA, Colorado State University, Fort Collins, CO, USA

ABSTRACT

The Geostationary Ocean Color Imager (GOCI) onboard the Korean Communication, Ocean, and Meteorological Satellite (COMS) is the first geostationary ocean color satellite sensor with eight spectral bands from the blue to the near-infrared (NIR) wavelengths in 412-865 nm. The unique capability of GOCI with hourly measurements during daytime (i.e., eight images per day from around local time of 9:00 to 16:00 o'clock) can effectively provide short- and long-term regional ocean environmental monitoring such as water optical, biological, and biogeochemical variability of the ocean ecosystem. In fact, the western Pacific region, which is covered by GOCI measurement, has one of the most turbid waters in the world. A recent study showed that the GOCI ocean color products such as normalized water-leaving radiance spectra, $nL_w(\lambda)$, for GOCI coverage region derived using an iterative NIR-corrected atmospheric correction algorithm were significantly improved compared with the original GOCI data products and have a comparable data quality as MODIS-Aqua in this region.

In this presentation, we show more results of GOCI ocean color products from March 2011 to October 2016 derived from the NOAA Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system to characterize seasonal and interannual variations in optical, biological, and biogeochemical properties in the western Pacific region, including the Bohai Sea, Yellow Sea, and East China Sea. In addition, the GOCI ocean color products are compared with those of the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (SNPP) in open ocean and coastal/inland waters using MSL12 with the NIR and shortwave infrared (SWIR) combined atmospheric correction method. It has been shown that the VIIRS ocean color products are quite accurate and highly stable in open ocean waters, and have much improved results in coastal and inland waters. Some detailed data analyses and discussions for GOCI and VIIRS results will be provided.

Evaluation of VIIRS Ocean Color Products in Open Ocean and Coastal/Inland Waters

SeungHyun Son[1,2] and Menghua Wang[1]

[1]NOAA/NESDIS Center for Satellite Applications and Research (STAR), College Park, MD 20740, USA

[2]CIRA, Colorado State University, Fort Collins, CO 80523, USA

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ABSTRACT

The Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (SNPP) is a multi-disciplinary sensor with 22 spectral bands, similar to the Moderate Resolution Imaging Spectroradiometer (MODIS), to provide observations for the Earth's atmosphere, land, and ocean properties. In this presentation, we provide extensive evaluations and assessments of VIIRS ocean color products including normalized water-leaving radiance spectra, chlorophyll-a concentration, and diffuse attenuation coefficient at 490 nm over global open oceans and turbid coastal/inland waters. In particular, we evaluate VIIRS ocean color products derived using the near-infrared (NIR)-based, shortwave infrared (SWIR)-based, and NIR-SWIR combined atmospheric correction methods in the turbid coastal and inland waters. VIIRS ocean color products derived from the NOAA Multi-Sensor Level-1 to Level-2 (MSL12) ocean color data processing system are evaluated and compared with in situ radiometric measurements from the Marine Optical Buoy (MOBY) in the waters off Hawaii and several AERONET-OC sites, as well as from MODIS ocean color data. In addition, VIIRS results are also compared with those from the Korean Geostationary Ocean Color Imager (GOCI) over the highly turbid China's coastal region. Our results show that VIIRS ocean color products are quite accurate and highly stable compared with in situ measurements in open ocean waters. For coastal and inland waters, VIIRS ocean color data using the NIR-SWIR atmospheric correction are quite reasonable and have much improved results compared with those from MODIS. Some detailed data analyses and discussions for VIIRS, MODIS, and GOCI results will be provided.

ATMOSPHERIC CORRECTION FOR HYPERSPECTRAL OCEAN COLOUR REMOTE SENSING FOR THE UPCOMING EnMAP MISSION (ACENMAP)

Mariana A. Soppa[1], Tilman Dinter[1], Vladimir Rozanov[2], Hajo Krasemann[3] and Astrid Bracher[1,2]

A critical step for obtaining accurate retrievals of ocean colour remote sensing over waters from hyperspectral imagery is an effective atmospheric correction. Opposed to multispectral imagery, atmospheric scattering and absorbers have to be considered differently at the various spectral bands. Another challenge is the low signal of most water surfaces, which makes the atmospheric correction a crucial task to derive for the hyperspectral satellite mission EnMAP (Environmental Mapping and Analysis Program), with its expected signal-to-noise ratio, reliable water leaving reflectance measurements. The major goal of this project, ACENMAP, is to develop an efficient atmospheric correction over water with defined uncertainties. With simulated data by the coupled atmosphere-ocean radiative transfer model (RTM) SCIATRAN, atmospheric absorbing and scattering effects on TOA reflectance can be precisely located and accounted for in the correction scheme, as well as other effects as glint and due to the proximity to the coast (e.g. mixed land-water pixels). These simulations will also be used to develop a correction scheme for these effects, as well as for estimating water leaving reflectance from TOA reflectance data. The uncertainty will be derived from RTM simulations, intercomparison and validation with *in situ* water leaving reflectance and satellite TOA reflectance from multispectral sensors (e.g. MERIS). The developed algorithm will be tested on HICO and SCIAMACHY data (downscaled to EnMAP spectral resolution but keeping the spatial resolution) before EnMAP operation. After verification, the atmospheric correction scheme allowing the retrieval of water leaving reflectance will be implemented into the EnMAP box.

[1]Alfred Wegener Institute, Bussestraße 24, D-27570 Bremerhaven, Germany, Email: msoppa@awi.de, tdinter@awi.de, abracher@awi.de

[2]Institute for Environmental Physics, University Bremen, Otto-Hahn-Allee 1, D-28359 Bremen, Germany, Email: rozanov@iup.physik.uni-bremen.de

[3]Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Str. 1, Geesthacht 21502, Germany, Email: hajo.krasemann@hzg.de

PROBA-V for Turbidity mapping in turbid coastal areas

Sindy Sterckx, Els Knaeps, Liesbeth De Keukelaere

To monitor the coastal areas a 250 m spatial resolution is often put forward (e.g. MODIS 250 m channels, MERIS, Sentinel-3). However this spatial resolution might be inadequate for small scale features in near shore areas such as ports and estuaries i.e. areas which are facing intensified anthropogenic pressures from maintenance of capital dredging activities, large scale construction works etc. In such cases, a 100 m PROBA-V product might be a significant added value. Although designed as a land mission only, the PROBA-V instrument, providing a daily coverage at 300 m and a 5-daily coverage at 100m resolution, opens opportunities for the retrieval of coastal products.
Here we present algorithms for atmospheric correction and turbidity applied to the PROBA-V coastal data. For the atmospheric correction of the PROBA-V data, the in-house developed OPERA, OPERational Atmospheric correction code, is used. Turbidity is estimated based on the PROBA-V RED band following the semi-analytical algorithm described in Nechad et al. (2009, 2010). Results for a 2-year PROBA-V time series over the North Sea are presented. Validation is performed for the aerosol optical thickness (AOT), reflectance and turbidity products based on in-situ information from Aeronet(-OC) stations, fixed turbidity buoys and dedicated *in situ* sampling. Finally an indirect validation is performed through cross-comparison of spatial and temporal patterns against MODIS 250 Turbidity data .

Flemish Institute for Technological Research (VITO), Remote Sensing Unit, 2400 Mol, Belgium – sindy.sterckx@vito.be; els.knaeps@vito.be; Liesbeth.Dekeukelaere@vito.be

Assessing uncertainties in scattering correction algorithms for reflective tube absorption measurements

Nicole Stockley[1], Rüdiger Röttgers[2], David McKee[3], James Sullivan[1], Michael Twardowski[1]

Accurate measurements of the inherent optical properties (IOPs) are essential to environmental optical research, in particular remote sensing applications. The absorption and backscattering coefficients form the link between remote sensing reflectance (Rrs) and the biogeochemical constituents of natural waters. Thus, measurements of these parameters with sufficient accuracy and well-defined uncertainties are required for the development, refinement, and validation of remote sensing algorithms. While substantial progress has been made in developing instrumentation to make such measurements, significant sources of uncertainty remain, especially relating to the difficulty of differentiating between the processes of absorption, scattering, and direct transmission. In the widely used WET Labs spectrophotometers (ac-9 and ac-s), the absorption measurement is made using a reflective flow path in which all scattered light is not collected by the detector, resulting in an overestimation of true absorption. Several methods have been proposed to compensate for this scattering error, of which three general methods are commonly used. The effectiveness of these methods relies on assumptions that have associated bias errors in many cases. As a result, modifications to these standard methods have been proposed that attempt to reduce these errors. Performance of these standard methods as well as a novel correction based on concurrent volume scattering function measurements was assessed by comparing results to absorption measurements made with a rigorously characterized, bench top integrating cavity device. This evaluation provides guidance for the application of scattering correction schemes to reflective tube absorption measurements for both existing and future data sets.

[1]Nicole Stockley (nstockley@fau.edu), James Sullivan (jsullivan@fau.edu), Michael Twardowski (mtwardowski@fau.edu); Harbor Branch Oceanographic Institute, Florida Atlantic University, Fort Pierce, Florida, USA

[2]Rüdiger Röttgers (rroettgers@hzg.de); Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany

[3]David McKee (david.mckee@strath.ac.uk); Department of Physics, University of Strathclyde, Glasgow, United Kingdom

Observations of Severe Algal Blooms in Estuaries and Lakes with OLCI

Richard P. Stumpf
Michelle C. Tomlinson
Timothy T. Wynne
Jennifer Wolny
Andrew Meredith
Todd Egerton
George Bullerjahn
Danielle Dupuy
Travis Briggs

The Ocean Land Colour Instrument (OLCI) has bands that allow algorithms suitable for detecting severe and harmful algal blooms (HABs). Blooms in U.S. estuaries and lakes include cyanobacteria and dinoflagellates. These eutrophic waters can have high and variable amounts of suspended sediment and colored dissolved organic matter (CDOM), which can interfere with algorithms that are based on blue bands; the high turbidity, scums, or moderate sunglint can also lead to erroneous atmospheric correction. The bands in the red and "red edge" reflected infrared can provide information on the potential presence of high concentrations of phycocyanin, an indicator of cyanobacteria, and on the presence of blooms that show either chlorophyll fluorescence or chlorophyll absorption. In addition, certain algorithms (like spectral shape algorithms) can reduce the need for atmospheric correction. Because the OLCI has bands equivalent to those on MERIS, algorithms used for detecting blooms with MERIS can provide useful information on similar blooms with OLCI. One product, the cyanobacterial chlorophyll index (CI), can be produced for MODIS as well, and a combined MODIS/MERIS time series has been developed for Lake Erie. We have begun comparisons of OLCI and MODIS for the CI product in order to assure consistency of MODIS in crossing the time gap from MERIS to OLCI for cyanobacterial blooms in large lakes. Examples of other robust algorithms show differences in blooms of true algae, indicating potential methods for monitoring of these blooms. Examples include blooms from Florida, Chesapeake Bay, and Lake Erie.

Remotely sensed phytoplankton size classes in the Yellow Sea and the East China Sea

Xuerong Sun [1, a], Fang Shen [2, a], Richard G.J. Bellerby [3a, b], Yangyang Liu [4, a], Rugang Tang [5, a]

Phytoplankton size structure plays an important role in marine ecological and biogeochemical processes. Nowadays, phytoplankton size classes (PSCs) have been well studied in the oceanic waters, while a better understanding of coastal and estuarine systems is required. In this study, PSCs derived from *in situ* HPLC (high performance liquid chromatography) pigment concentration and SFF (size-fractionated filtration) were investigated in the Yellow Sea and the East China Sea which are distinctive turbid coastal and shelf seas and affected by world-class large river plumes, in 2014. Results revealed that nanoplankton has a great contribution to surface chlorophyll-a concentration, followed by picoplankton and microplankton. We proposed an improvement on the parameterization of the three-component model, and results of validation indicated that the improved algorithm provided an appropriate estimation of PSCs in the coastal Case 2 water by remote sensing as well. The improved algorithm was applied to hourly GOCI (Geostationary Ocean Color Imager) chlorophyll-a concentration products, suggesting that diurnal variations of chlorophyll-a concentration and size-fractionated percentage contributions are closely related to the light condition and environmental characteristics of the area. Meanwhile, both environmental factors and their seasonal variations are key components in affecting the characteristics of annual variation of PSCs varied in different regions.

a State Key Laboratory of Estuarine and Coastal Research, East China Normal University, 3663 Zhongshan N. Road, Shanghai 200062, China.
b Norwegian Institute for Water Research, Thormøhlensgt. 53 D, 5006 Bergen, Norway

1. 52152601003@ecnu.cn
2. fshen@sklec.ecnu.edu.cn
3. richard.bellerby@niva.no
4. 450184097@qq.com
5. 939170809@qq.com

Sun glint requirement for the remote detection of surface oil films

Shaojie Sun[1] and Chuanmin Hu[2]

Abstract: Natural oil slicks in the western Gulf of Mexico are used to determine the sun glint threshold required for optical remote sensing of oil films. The threshold is determined using the same-day image pairs collected by MODIS Terra (MODIST), MODIS Aqua (MODISA), and VIIRS (N = 2297 images) over the same oil slick locations where at least one of the sensors captures the oil slicks. For each sensor, statistics of sun glint strengths, represented by the normalized glint reflectance (L_{GN}, sr^{-1}), when oil slicks can and cannot be observed is generated. The L_{GN} threshold for oil film detections is determined to be 10^{-5}–10^{-6} sr^{-1} for MODIST and MODISA, and 10^{-6}–10^{-7} sr^{-1} for VIIRS. Below these thresholds, no oil films can be detected, while above these thresholds oil films can always be detected except near the critical-angle zone where oil slicks reverse their contrast against the background water.

[1]College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL 33701, USA; suns@mail.usf.edu

[2]College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL 33701, USA; huc@usf.edu

SNPP VIIRS Reflective solar bands calibration improvements and updates

Junqiang Sun[1,2] and Menghua Wang[1]

[1]NOAA National Environmental Satellite, Data, and Information Service, Center for Satellite Applications and Research, E/RA3, 5830 University Research Ct., College Park, MD 20740, USA
[2]Global Science and Technology, 7855 Walker Drive, Suite 200, Greenbelt, MD 20770, USA

The Suomi National Polar-orbiting Partnership (SNPP) Visible Infrared Imaging Radiometer Suite (VIIRS) has been on orbit for more than five years. The radiometric calibration of reflective solar bands (RSBs) recently has reached a mature stage. Numerous improvements have been made in the standard RSB calibration methodology for the sensor data records (SDR), which is the starting for the higher-level environmental data records (EDR) and science products. This presentation will address the following: the good performance of the SNPP VIIRS RSBs, the RSB calibration improvements, and the success of the RSB SDR reprocessing for ocean color EDR using the improved RSB LUTs.

Radiometric evaluation of the SNPP VIIRS reflective solar band sensor data records via inter-sensor comparison with Aqua MODIS

Mike Chu[a,b], Junqiang Sun[a,c] and Menghua Wang[a]

[a]NOAA National Environmental Satellite, Data and Information Service,
Center for Statellite Applications and Research,
E/RA3, 5830 University Research Ct., College Park, MD 20740
[b]Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO, 80523
[c]Global Science and Technology, 7855 Walker Drive, Suite 200, Greenbelt, MD 20770, USA

ABSTRACT

The Visible Infrared Imaging Radiometer Suite (VIIRS) in the Suomi National Polar-orbiting Partnership (SNPP) satellite has been on orbit for over five years since its launch on 28 October 2011. An inter-sensor radiometric comparison is carried out, against the MODerate-resolution Imaging Spectroradiometer (MODIS) unit onboard the Aqua satellite, to evaluate the accuracy of the sensor data for SNPP VIIRS Bands M1−M8. The official sensor data record (SDR) generated by the Interface Processing Data Segment (IDPS) as well as an independent version generated by the NOAA Ocean Color (OC) Team are tested. The result shows that OC SDRs demonstrate much better agreement with Aqua MODIS, including less variation, more accurate match, and no large discrepancy at the beginning of the VIIRS mission. The result also finds a ~1% drift in the Aqua MODIS Band 8 sensor data.

Key Words: VIIRS, MODIS, Aqua, RSB, Inter-sensor comparison, Intercalibration, SNO.

Vicarious calibration of FY-3B MERSI reflective solar bands and feed back from ocean color products

Ling Sun

Medium Resolution Spectral Imager (MERSI) is a keystone instrument onboard Fengyun-3 (FY-3), the second generation of polar-orbiting meteorological satellites in China. FY-3B MERSI is the second unit in the series and still in operation, which was launched on November 5, 2010, in a sun-synchronous afternoon orbit with a local equator-crossing time of 1:30 PM in ascending node. FY-3 MERSI provides global coverage of top-of-atmosphere (TOA) radiances used for a broad range of scientific studies of the Earth's system including ocean color. Nineteen of the 20 MERSI spectral bands are reflective solar bands (RSBs) from 412 nm to 2130 nm, which cannot be absolutely calibrated onboard. The long-term on-orbit response changes are relatively large at visible spectral bands. The overall degradation for 412 nm of FY-3B MERSI is about 29% until the end of 2016. To implement the on-orbit calibration updates, a multisite calibration tracking method has been developed to monitor the RSB radiometric response variation, and a daily calibration updating model is applied. The radiometric data quality after daily calibration is monitored using Aqua MODIS. This paper presents the calibration of FY-3B MERSI RSBs accounting for the temporal variation of radiometric response, demonstrates the results of the MERSI L1 radiometric data quality, as well as the standard L2 ocean color product.

sunling@cma.gov.cn

National Satellite Meteorological Center, China Meteorological Administration

No.46, Zhongguancun South Street, District Haidian, Beijing 100081, China

The Black Sea chlorophyll-a algorithms comparison for SeaWiFS and MODIS-Aqua instruments

V.V. Suslin[1], T.Ya. Churilova[2], Z.Z. Finenko[2], S. Moncheva[3], M. Lee[1]

[1] Marine Hydrophysical Instutute, RAS, 2 Kapitanskaya str., Sevastopol, 299011, Russian Federation
[2] Kovalevsky Institute of Marine Biological Research, RAS, 2 Nakhimov Ave., Sevastopol, 299011, Russian Federation
[3] Institute of Oceanology, BAS, Varna, 9000, Bulgaria

Keywords: regional algorithm, chlorophyll-a, Black Sea, ocean color scanner

Abstract

In this presentation, the comparison of global [O`Reilly et al. 1998] and two [Kopelevich et al. 2004, Suslin and Churilova 2016] regional chlorophyll-a algorithms for SeaWiFS and MODIS-Agua instruments is given. As a criterion, we use in situ measurements data of the chlorophyll-a concentration in the upper sea layer during 1997 – 2016. The in situ measurements are obtained from various sources: personal contacts, public databases, scientific papers and research vessel cruises. Filtered by special set of flags/masks level-2 ocean color data (SeaWiFS-MLAC and MODIS-Aqua-LAC) and in situ measurements were made in the same day. These data set are used in comparison. The total number of such points was 206 for SeaWiFS and 148 for MODIS-Aqua. The mentioned above algorithms advantages and disadvantages are discussed in the presentation.

Acknowledgments

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On the characterization of a class of in-situ hyperspectral radiometers

Marco Talone, Giuseppe Zibordi, and Lukasz Jankowsky

Optical radiometers are commonly used to produce in situ reference measurements in support of indirect calibration (i.e., vicarious calibration) or validation activities. Generic requirements on the accuracy of in situ radiometric measurements in those cases indicate the need to restrict uncertainties below 5%, which implies the adoption of strict measurement protocols and an accurate characterization and calibration of instruments.

The poster summarizes two recent studies on the characterization of a class of hyperspectral radiometers widely used by the ocean color community, namely TriOS RAMSES-ACC and -ARC. The analysis is centered on the polarimetric sensitivity and on temperature responsivity. Uncertainties on both water-leaving radiance and remote-sensing reflectance related to those effects are quantified and discussed.

All the authors are with the Water and Marine Resources Unit, Directorate for Sustainable Resources, Joint Research Centre of the European Commission, 21027 Ispra, Italy.

Emails: marco.talone@ec.europa.eu, giuseppe.zibordi@ec.europa.eu, lukasz.jankowsky@ext.ec.europa.eu

A semi-analytical MERIS green-red band algorithm for identifying phytoplankton bloom types in the East China Sea

Bangyi Tao[1], Delu Pan[2], Zhihua Mao[3]

A new bio-optical algorithm based on the green and red bands of the Medium Resolution Imaging Spectrometer (MERIS) is developed to differentiate the harmful algal blooms of *Prorocentrum donghaiense Lu* (*P. donghaiense*) from diatom blooms in the East China Sea (ECS). Specifically, a novel green-red index (GRI), actually an indicator for *a*(510) of bloom waters, is retrieved from a semi-analytical bio-optical model based on the green and red bands of phytoplankton-absorption and backscattering spectra. In addition, a MERIS-based diatom index (DI_{MERIS}) is derived by adjusting a Moderate Resolution Imaging Spectroradiometer (MODIS) diatom index algorithm to the MERIS bands. Finally, bloom types are effectively differentiated in the feature spaces of the green-red index and DI_{MERIS}. Compared with three previous MERIS-based quasi-analytical algorithm (QAA) algorithms and three existing classification methods, the proposed GRI and classification method have the best discrimination performance when using the MERIS data. Further validations of the algorithm by using several MERIS image series and near-concurrent in-situ observations indicate that our algorithm yields the best classification accuracy and thus can be used to reliably detect and classify *P. donghaiense* and diatom blooms in the ECS. This is the first time that the MERIS data have been used to identify bloom types in the ECS. Our algorithm can also be used for the successor of the MERIS, the Ocean and Land Color Instrument, which will aid the long-term observation of species succession in the ECS.

[1]Email: taobangyi@sio.org.cn, State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China
[2]Email: pandelu@sio.org.cn, State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China
[3]Email: mao@sio.org.cn, State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, China

Reconstructing Optical Properties in the Mediterranean Sea: Data and Models

authors: Elena Terzić[1,6], Paolo Lazzari[2], Emanuele Organelli[3], Fabrizio D'Ortenzio[4], Stefano Salon[5]

In the present work we have analysed a Bio-Argo data set comprised of 31 floats for the period between 2012 and 2016 in the Mediterranean Sea.

The quality-checked profiles of downward planar irradiance (Ed) and chlorophyll *a* concentration have enabled a comparison with the hyperspectral state-of-the-art bio-optical model by Morel and co-authors[1],[2].

The verification of the model has been done by comparing the depth derivatives of Ed - the diffuse attenuation coefficients (Kd) - and by therefore examining the adequacy of taking only chlorophyll *a* as a proxy for all biogenic components, merging impacts of phytoplankton, particulate and colored dissolved organic matter into one term.

Furthermore, a 1-dimensional simulation has been carried out in the OGSTM-BFM model[3], following trajectories of each float and considering Ed profiles for the photosynthetically active radiation (PAR) as our light model. Due to an augmented data set from Bio-Argo floats we have carried out a revised regression analysis between Kd PAR and Kd 490[2] and proposed modified coefficients to derive Kd PAR from Kd 490. The simulations were aimed to be consistent with data measured by float sensors, especially in terms of deep chlorophyll maximum (DCM) and chlorophyll *a* concentration magnitudes. We tested few light models, as well as modified physiological parameters in order to estimate the impact of each of the physical/biological terms. These results will be useful to improve the optical module of the operational biogeochemical Mediterranean Sea model presently embedded within the Copernicus Marine Environment Monitoring Services.

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[1] OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy (eterzic@inogs.it)

[2] OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy (plazzari@inogs.it)

[3] Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, UK (emo@pml.ac.uk)

[4] Laboratoire d'Océanographie de Villefranche, Villefranche-sur-Mer, France (dortenzio@obs-vlfr.fr)

[5] OGS - Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Trieste, Italy (ssalon@inogs.it)

[6] Università di Trieste, Dipartimento di Matematica e Geoscienze, Trieste, Italy

Radiometric validation of atmospheric correction for Sentinel-3A, MODIS-Aqua and VIIRS in the Baltic Sea.

Gavin H. Tilstone[1], Silvia Pardo[2], Stefan G.H. Simis[3], Nick Selmes[4], Ping Qin[5].

Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth PL1 3DH, UK,

[5]College of Information Science and Engineering, Ocean University of China, Qingdao, China

ABSTRACT

The Baltic Sea is a semi-enclosed sea that is optically dominated by coloured dissolved organic material (CDOM) and has relatively low sun elevation which makes accurate ocean colour remote sensing challenging in these waters. Previous studies in this region mainly focused on the validation and improvement of standard Chlorophyll-a (Chl *a*) and attenuation coefficient (k_d) ocean colour products. The primary input to derive these is the water-leaving radiance (L_w) or remote sensing reflectance (R_{rs}) and it is therefore fundamental to obtain the most accurate L_w or R_{rs} before deriving higher level products. To this end, the retrieval accuracy of R_{rs} from Sentinel-3A OLCI using four atmospheric correction processors was assessed against shipborne R_{rs} using an autonomous platform (~700 measurements). The four processors tested were the Case 2 Regional CoastColour processor (C2R-CC), the OLCI ground segment processor (MEGS), L2gen and POLYMER which were compared with the standard AC processors available for MODIS-Aqua and VIIRS. The results outline which are the most accurate AC processors for the Baltic Sea. The research has implications for other high absorption, low scattering properties waters such as the Arctic Ocean, Yellow Sea, Black Sea, coastal regions adjacent to the CDOM-rich estuaries such as the Amazon.

[1]ghti@pml.ac.uk; [2]spa@pml.ac.uk; [3]stsi@pml.ac.uk; [4]nse@pml.ac.uk; [5]appletsin@ouc.edu.cn

An optical algorithm to estimate downwelling diffuse attenuation coefficient in the Red Sea

S. P. Tiwari[1], B. Kürten[1], M. Ouhssain[1], B. H. Jones[1]

The band ratio optical algorithm is developed for retrieval of diffuse attenuation coefficient $K_d(490)$ in the Red Sea using a comprehensive HYDROLIGHT simulated data set (N = 5000). We found a very strong relationship between the $K_d(490)$ and remote sensing reflectance ratios, with an excellent correlation coefficient (R^2 = 0.9955) and less RMSE = 0.03921. An algorithm applied on simulated (used to create an optical algorithm) and three independent data sets such as NASA-NOMAD, Satellite SeaWiFS match-ups, and RSRC in situ dataset. Since the valid in situ data points in the Red Sea is limited, therefore, first two NASA global datasets were also used to assess the performance of the new algorithm in the open ocean where chlorophyll values are less than or equal to 0.5 mg m^{-3}. The validation results are excellent in terms of basic standard errors. The efficacy of the present algorithm is also tested on MODIS-Aqua images acquired over the Red Sea. It is found that the present algorithm makes good retrievals of $K_d(490)$ and capturing the spatial characteristics of blooms and physical oceanographic features in the Red Sea. These results suggest that the present algorithm has the potential to provide improved $K_d(490)$ values and captured the spatial features of the phytoplankton blooms and physical oceanographic processes, these are useful to monitor the water clarity and provide the information on light availability as an input to the primary productivity models for the photosynthesis.

Address: King Abdullah University of Science and Technology (KAUST), Red Sea Research Center (RSRC), Biological and Environmental Sciences & Engineering Division (BESE), Bioscience program, Thuwal, 23955-6900, Saudi Arabia

Surya.tiwari@kaust.edu.sa

Benjamin.kurten@kaust.edu.sa

Mustapha.ouhssain@kaust.edu.sa

Burton.jones@kaust.edu.sa

Assessment of the long-term trends of the connections between the catchment physical properties, lake morphometric characteristics, meteorological data, and dissolved organic carbon in Estonian and Swedish lakes

Toming, Kaire [1,2,4], Kutser, Tiit [1], Nõges, Tiina[2], Alikas, Krista[3], Tranvik, Lars J.[4]

Dissolved organic carbon (DOC) is a very important water parameter and factors controlling the DOC concentrations in lakes and also the export from the catchment, are of great interest. Combining remote sensing capabilities and detailed *in situ* studies gives us opportunity to study long-term trends between catchment characteristics and lakes DOC concentrations and use this information in different climate or carbon cycle models for future prognosis. The main aim of the study is to assess the long-term trends of the connections between the catchment physical properties (land cover, land use, area, slope, soil), lake morphometric characteristics (surface, volume, depth), meteorological and hydrological data (air temperature, precipitations, solar radiation, runoff) and DOC in three Estonian (Peipsi, Võrtsjärv, Ülemiste) and four Swedish lakes (Vänern, Vättern, Mälaren, Erken) on the basis of *in situ* data and satellite products. We hypothesize that (1) catchment physical properties, lake morphometry and meteorological/hydrological variables influence the DOC concentration in the studied lakes, but the variance they explain differs; (2) land cover and land use in the catchment area of the lakes together with meteorological/hydrological variables determines mostly the variance of DOC in the studied lakes; (3) the greater is the catchment: lake area ratio (Ohle's index) and the slope the stronger is the effect of the catchment to the DOC concentrations of the studied lakes, especially in rainy years.

[1]Estonian Marine Institute, University of Tartu, Mäealuse 14, Tallinn, Estonia; kaire.toming.001@ut.ee

[2]Centre for Limnology, Estonian University of Life Sciences, Kreutzwaldi 5, Tartu, Estonia

[3]Tartu Observatory, Observatooriumi 1, Tõravere, Tartumaa, Estonia

[4]Department of Limnology, Uppsala University, Norbyvägen 18D, Uppsala, Sweden

Validation of the Sentinel-2 Multispectral Imager imagery in the coastal waters of the Baltic Sea.

Toming, Kaire [1,2*], Kutser, Tiit [1], Paavel, Birgot[1]

Water remote sensing has been used to provide the information about the color of water and to determine the concentrations of optically active substances like chlorophyll *a* (Chl *a*), total suspended matter (TSM), and colored dissolved organic matter (CDOM) for more than 30 years. The recent launches of new satellites with improved radiometric, spectral and spatial resolutions as well as temporal coverage (like Sentinel-2A,-2B; Sentinel-3A) have opened new possibilities in coastal water studies. The imagery of Sentinel-2 is with 10 m, 20 m and 60 m spatial resolution, data are acquired in 13 spectral bands and radiometric resolution of the sensor is 12-bit. Revisit time of Sentinel-2 is five days. However, at higher latitudes, like in Estonia, the revisit time will be almost every second day because of the overlapping orbits. The aim of the study was: (1) to validate the performance of the Sen2cor atmospheric correction module and (2) to test the suitability of Sentinel-2 MSI data for mapping different coastal water quality parameters (Chl *a*, TSM and CDOM) by means of band ratio type algorithms, which have demonstrated good performance in previous coastal waters remote sensing studies using other multispectral sensors. *In situ* data (above water remote sensing reflectance, Chl *a*, TSM, CDOM and Secchi depth) were collected from the surface layer of Estonian coastal waters during 6 field campaigns in 2016. Reflectance data collected in the field suggest that the Sen2cor atmospheric correction performs relatively well and Sentinel-2 MSI data has great potential for coastal water remote sensing.

[1]Estonian Marine Institute, University of Tartu, Mäealuse 14, Tallinn, Estonia; kaire.toming.001@ut.ee

[2]Centre for Limnology, Estonian University of Life Sciences, Kreutzwaldi 5, Tartu, Estonia

TELQUEL project : Calibrating bio-optical models for retrieving ecological parameters of lakes from SENTINEL-2 and LANDSAT 8

Tormos, T.[1], Harmel, T.[2], Chami, M.[3], Reynaud, N.[2], Danis, P.-A.[1]

Recent progresses in optical sensors both in spatial, temporal, spectral and radiometric resolution (e.g., MSI on Sentinel-2 and OLI on Landsat 8) offer further potential in ocean colour science over smaller water surfaces. The aim of the TELQUEL (TELedetection de la Qualité des Lacs, TOSCA CNES project) is to investigate these potentialities especially for lakes and reservoirs in (i) documenting their specific optical properties, and from this knowledge (ii) developing a dedicated operational processing chain from level-1 images to biogeophysical products (transparency, TSM, ChlA, CDOM…). There is a great expectation about these products both by scientist, manager and stakeholder communities. They would largely complete the in-situ data from national monitoring not enough precise in time and space for correctly estimating the ecological status (required by the water framework directive) and understanding the functioning of these ecosystems. This poster deals with the calibration and validation of bio-optical algorithms commonly used in ocean color domain for deriving transparency, ChlA and CDOM parameters both from Sentinel-2 and Landsat 8 level 2 images (water leaving reflectances). The level 2 images were obtained from the TELQUEL atmospheric correction and deglinting chain presented in this conference. Calibrations were computed using optical and biogeophysical data collected from several field campaigns over two French reservoirs. Results are promising but have to be consolidated using more cal/val data representative of lakes and reservoirs color variability. This is the major challenge in the years to come.

[1]French Biodiversity Agency, UR RECOVER, Lakes research center, 3275 route Cézanne F-13182, Aix-en-Provence, France
[2]Irstea, UR RECOVER, Lakes research center, 3275 route Cézanne, F-13182 Aix-en-Provence, France
[3] UPMC , UMR CNRS 7093, Villefranche-sur-Mer

Introducing New Zealand Centre for Space Science Technology

Rosa Trancoso[1], Peter McComb[1], David Johnson[1]

New Zealand (NZ) has the fourth largest Exclusive Economic Zone in the world (4 million km2) and 15000 km of coastline, and therefore a great responsibility in monitoring and managing its resources while maintaining balanced marine habitats and sustainable economic activities. Remote sensing is an effective tool to complement expensive oceanographic in-situ local information, allowing a global perspective and optimizing data collection efforts.

The recently created Centre for Space Science Technology (CSST) (www.csst.co.nz) aims to aggregate and build knowledge on NZ-focused remote sensing information, enabling regional businesses to use these data more effectively. Tailored products and services are to be developed in a pyramid-like structure, where new added value layers are built by partners and made available to the users community.

As one of the founding partners and a company experienced in dealing with operational systems and large ocean and atmospheric datasets, MetOcean Solutions (MSL) (www.metocean.co.nz) will be involved in developing ocean related products such as high-resolution ocean turbidity, water mass boundaries location, oil spill tracking algorithm, just to name a few. MSL will also contribute to base layer products, short range weather forecasting and data assimilation capabilities by providing an early data exchange platform through the extension of its APIs that allow for discoverable, fast-access and ready-usable geospatial datasets, whether it's archived, real time or forecast data.

This poster aims to put forward NZ goals in remote sensing and kick-start international data and knowledge exchange.

[1] r.trancoso@metocean.co.nz, 3/17 Nobs Line, Strandon, 4312 New Plymouth, New Zealand

Global and diffuse Photosynthetically Active Radiation in the central Mediterranean: ground-based measurements, satellite comparisons and effects of aerosols and clouds.

P. Trisolino[1,4], A. di Sarra[1], D. Meloni[1], G. Pace[1], F. Anello[2], C. Bommarito[2], F. Monteleone[2], S. Piacentino[2] and D. Sferlazzo[3]

Measurements of Photosynthetically Active Radiation (PAR) have been carried out at the Atmospheric Observatory of the ENEA station for climate observations on the island of Lampedusa, in the central Mediterranean (35.52°N, 12.63°E; http://www.lampedusa.enea.it). The long-term dataset is constituted of PAR observations that were started in 2002. The global and diffuse PAR are derived from PAR radiometers and Multifilter Rotating Shadowband Radiometer observations using the methodology described by Trisolino et al. (2016). In this study, we investigate the effects of aerosols and clouds on PAR based on the 2002-2016 dataset. We related the PAR components to the aerosol optical properties (aerosol optical depth, τ, Ångström exponent, α, and single-scattering albedo, ω). Clear sky data at the mean Sun-Earth distance at fixed solar zenith angle have been selected to investigate the aerosol effect. The global PAR component generally decreases for increasing τ, while the diffuse component increases. This effect significantly depends on the solar zenith angle, and appears to depend on the aerosol properties (both α and ω). The existing dataset allows a comparison with satellite estimates over an extended time interval and to investigate the performance of different sensors and algorithms. The collected data are compared with the MODIS record. A small-scale field experiment has been planned at Lampedusa to investigate the relationship linking PAR irradiance and actinic flux in the atmosphere and underwater. The collected dataset will be also used to improve primary productivity models, implement a detailed atmospheric correction and provide a verification of OLCI satellite observations.

P. Trisolino pamela.trisolino@enea.it
A. di Sarra alcide.disarra@enea.it
D. Meloni daniela.meloni@enea.it
G. Pace giandomenico.pace@enea.it
F. Anello fabrizio.anello@enea.it
C. Bommarito carlo.bommarito@enea.it
F. Monteleone francesco.monteleone@enea.it
S. Piacentino salvatore.piacentino@enea.it
D. Sferlazzo damiano.sferlazzo@enea.it

[1] *ENEA, Laboratory for Observations and Analyses of Earth and Climate, via Anguillarese 301 - 00123 Rome, Italy*
[2] *ENEA, Laboratory for Observations and Analyses of Earth and Climate, piazza Ignazio Florio 24 – 90139 Palermo, Italy*
[3] *ENEA, Laboratory for Observations and Analyses of Earth and Climate, Contrada Capo Grecale – 92010 Lampedusa (AG), Italy*
[4] *Department of Ecological and Biological Sciences, Tuscia University, Largo dell'Università - 01100* Viterbo, Italy

Title: Bio-optical algorithm for particulate organic carbon (POC) assessment in coastal waters.

Authors:

Tran Trung Kien, Hubert Loisel, Lucile Duforêt-Gaurier, Xavier Meriaux.
Laboratory of Oceanology and Geosciences, University of Littoral Côte d'Opale, UMR CNRS 8187 LOG, MREN, 62930 Wimereux, France.

Abstract: The study aims at examining the performance of existing POC algorithms for coastal waters and improving surface coastal bio-optical algorithm for POC assessment. Bio-optical in-situ data collected in variation contrasted coastal water environments (285 stations from 16 field cruises performed from 2006 to 2015 in coastal water of French Guyana, English Channel, Europe and Viet Nam Sea). Empirical as well as semi-analytical published algorithms have been tested against this in-situ database for which POC ranges between 65.414 to 5743.51 mg m^{-3}. The performances of these algorithms are then discussed. At last, a new simple algorithm, combines with a classification approach, is proposed as an alternative approach in order to assess POC in such complex bio-optical waters.

Key words: Particulate Organic Carbon (POC), bio-optical algorithm, semi-analytical algorithm, coastal water

Estimating Suspended Particles Concentrations using Satellite and in-situ Ocean Colour Measurements in the Region of Fresh Water Influence of River Evros - North Aegean Sea, Greece.

Tsapanou, A.[1], Drakopoulos, P.G.[2], Oikonomou, E.[3] and Poulos, S.[1]

This study investigates the potential of remotely sensed data to map surface suspended particulate matter (SPM) in the continental shelf area of the North-East Aegean, Alexandroupolis Gulf, Greece, and by comparing the results from two different satellite sensors. Initially, simultaneous above water ocean colour measurements were validated against SPM field data and compared to a concurrent Landsat-8 image, obtained on low Evros river discharge period (June 2016). The satellite imagery was atmospherically corrected and Landsat-8 Surface Reflectance data were generated from the Landsat Surface Reflectance Code (LaSRC) provided by US Geological Survey. The computed remote sensing reflectance values (Rrs) from Landsat-8 were converted into SPM by adopting an algorithm based on single band analysis. After validation, Landsat-8 and Sentinel_2A images were processed from the same study area but in the high river discharge period (December 2015).

A comparison between Landsat-8 estimations of SPM and concurrent optical measurements at 19 stations indicates that satellite derived concentrations tend to overestimate sea-truth, a trend also found in the Sentinel_2A-derived SPM values. We discuss further improvements required in coupled studies of SPM retrieval within the coastal zone, the relationship between the examined remote sensors, as well as the necessity to evaluate the satellite performance not only at surface but within the water column utilizing in-situ measurements.

[1]*Department of Geology & Geoenvironment, National & Kapodistrian University of Athens, Athens, Greece,* atsapanou@geol.uoa.gr, poulos@geol.uoa.gr

[2]*Department of Optics and Optometry, Technological Educational Institute of Athens, Athens, Greece,* pdrak@teiath.gr

[3]*Department of Civil Engineering and Surveying & Geoinformation, Technological Educational Institute of Athens, Athens, Greece,* eoikonomou@teiath.gr

Next generation ocean color algorithm development: backscattering, absorption, and phase function effects on asymptotic light fields in seawater

Twardowski[1], M.S., and A. Tonizzo[2]

The average cosine of the light field in the asymptotic regime $\bar{\mu}_\infty$ is one of the only apparent optical properties (AOPs) that is an inherent optical property (IOP), i.e., it is dependent only on the absorption and scattering properties of the water column. Asymptotic theory is based on the principle that the shape of the light field with depth gradually transforms from being dependent on the surface light field to being constant and azimuthally symmetric. Because of the close link between asymptotic light fields and IOPs, radiative transfer approximations (RTAs) for the asymptotic regime have been adapted to rigorous algorithms describing surface remote sensing reflectance in terms of the IOPs (Zaneveld 1995). For such algorithms to have utility, $\bar{\mu}_\infty$ must be parameterized in terms of IOPs useful for ocean color. With this motivation, $\bar{\mu}_\infty$ was approximated as a function of the ratio of backscattering to absorption. Additional variables in assessments were the fraction of pure seawater in backscattering and representative phase functions for particles. Analytical expressions for multi-order polynomial fits are provided for $\bar{\mu}_\infty$ for all variables. Percent absolute errors were only 3.4% for the model fit for the entire data set. Additionally, a key assumption by Zaneveld (1995) that the attenuation coefficient for upwelling nadir radiance in surface waters should be approximately equivalent to the attenuation coefficient in the asymptotic regime was confirmed. Results thus provide justification, as well as readily applied relationships, for the targeted application of asymptotic parameters in ocean color RTAs for the surface ocean.

[1]Harbor Branch Oceanographic Institute, 5600 US 1 N, Ft. Pierce, FL 34946; mtwardo.alt@gmail.com
[2]TF LLC, 30-77 31st St. #1, Astoria, NY, USA 11102

Integration of Sentinel-2 and LANDSAT for cyanobacteria scum distribution mapping in hypereutrophic Curonian Lagoon

Vaičiūtė, D[1]., Bresciani, M.[2], Cazzaniga, I.[3] and Giardino C.[4]

Cyanobacteria blooms have recently been one of the major impact factor compromising lakes and lagoons ecosystems equilibrium. Extremely developed bloom conditions appear as a thick surface cyanobacteria layer (scum). In this study a series of Sentinel-2A (MSI) and LANDSAT-8 (OLI) satellites images acquired in summer periods of most recent years were used to investigate the distribution of cyanobacteria scum in the hypereutrophic Curonian Lagoon (Lithuanian and Russian part). Presence/absence of cyanobacteria scum was estimated by semi-empirical band ratio algorithm applied to images after atmospheric correction with the 6SV. Simply thresholds algorithms based on band ratio use the bands across the red and near-infrared spectral regions. Radiometric measurements acquired with WISP-3, resampled according to spectral characteristics of MSI bands, compared with atmospheric corrected Rrs products acquired synchronously, show a good agreement. In addition, in order to compare OLI and MSI products, we compared band ratio calculated between band 4 and 3 on one MSI and one OLI synchronous images. Again good agreement was shown by the analysis (R^2=0.93).
The analysis indicated pronounced spatial variability of cyanobacteria scum mainly occurring in early July-late October with the max area of 40,000 ha. Different accumulation features is mainly influenced by ambient weather conditions. Respect to the ecological role of scum event, its formation, temporal and spatial evolution is of great interest and therefore the retrospective analysis covering more than 30 years, i.e. nearly entire series of Landsat missions and integrating Sentinel-2 data, will be performed in the near future.

[1]Klaipeda University, H. Manto 84, LT 92294, Klaipeda, Lithuania, diana.vaiciute@jmtc.ku.lt
[2]CNR-IREA, Optical Remote Sensing-Water group, Via Corti, 12 Milan, Italy, bresciani.m@irea.cnr.it
[3]CNR-IREA, Optical Remote Sensing-Water group, Via Corti, 12 Milan, Italy, cazzaniga.i@irea.cnr.it
[4]CNR-IREA, Optical Remote Sensing-Water group, Via Corti, 12 Milan, Italy, giardino.c@irea.cnr.it

Optical classification of the Lower Amazon waters

Aline de Matos Valerio [1], Milton Kampel[1], Vincent Vantrepotte [2], Nicholas D. Ward [3,4], Henrique O. Sawakuchi [5], Diani Fernanda da Silva Less [6], Joel Diniz [6], Vania Neu [7], Alan C. Cunha [6], Alex V.Krusche [5], Jeffrey E. Richey [4]

Optical water types were identified from an in situ data set of concomitant biogeochemical and optical parameters collected in the Amazon River and its tributaries as Tapajos, Xingu, Paru, Jari and Jaraçu rivers as well as the Great Lake Curuai, all belonging to the Lower Amazon region (i.e. the 900 km final portion of the Amazon River). Data (48 measurements) were collected at different discharge conditions (rising, high, falling and low water) during the 2014-2016 time period. The optical classification performed on the normalized reflectance spectra in order to focus on the spectral shape allowed to define four optical classes. Whereas all the samples of the Amazon River water were classified in the same optical class independently of the season, the optical quality of the Amazon tributaries show a strong seasonal variability in relationship with the hydrological dynamics of the Amazon River. Each class was associated with a specific bio-optical and biogeochemical environment assessed from the corresponding values of coloured dissolved organic matter absorption coefficient (a_{CDOM}), particulate matter absorption coefficient (a_p), chlorophyll-*a* (chl-*a*), and suspended particulate matter concentration (SPM) and associated ratios (a_{CDOM}/a_p). The bio-optical characterization of the Lower Amazon waters represents a first step for developing inversion models adjusted to the optical complexity of this region.

[1] Instituto Nacional de Pesquisas Espaciais - INPE
Caixa Postal 515 - 12227-010 - São José dos Campos - SP, Brasil
{alineval, milton}@dsr.inpe.br

[2] Centre National de la Recherche Scientifique - CNRS
USR3456, 97334 Cayenne, French Guiana
vincent.vantrepotte@univ-littoral.fr

[3]Marine Science Laboratory, Pacific Northwest National Laboratory
Sequim, Washington, United States of America
nickward@gmail.com

[4] University of Washington – UW
98195, Seattle, United States of America
jrichey@uw.edu

[5] Universidade de São Paulo - USP/CENA
Caixa Postal 96 - 13416-000 - Piracicaba - SP, Brasil
riqueoliveira@yahoo.com.br
alex@cena.usp.br

[6] Universidade Federal do Amapá – UNIFAP
Caixa Postal 261 – 68906-970 - Macapá - AP, Brasil
{diani.engambiental, alancunha12 }@gmail.com
jemdiniz@yahoo.com.br

[7] Universidade Federal Rural da Amazônia – UFRA
Caixa Postal 917 - 66077-530 – Belém - PA, Brasil
vania.neu@ufra.edu.br

Atmospheric correction for coastal and inland water application of very high resolution satellite imagery

Quinten Vanhellemont

Royal Belgian Institute of Natural Sciences (RBINS), Gulledelle 100, 1200 Brussels, Belgium,
quinten.vanhellemont@naturalsciences.be

Coastal and inland waters can be characterized by very dynamic variability on short temporal and spatial scales. Very high spatial resolution satellite imagery (<10 m) can provide new insights into sediment transport processes in and around ports and offshore constructions. Furthermore it can be used to provide remotely sensed observations for specific case studies in small or narrow water bodies, to assess sub-pixel scale effects in medium resolution imagery and to characterize fixed validation sites for traditional ocean colour sensors. There are generally no standard atmospherically corrected products over water for the very high resolution sensors and using existing approaches poor results may be obtained for water applications.

In this poster a generic algorithm for the atmospheric correction of very high resolution optical satellite imagery is presented. The algorithm takes advantage of multiple dark targets in the scene, which are spatially resolved, and switches to the best bands and targets for the determination of the aerosol signal. The algorithm is applied to imagery from the Pléiades constellation for inland and coastal sites, and is validated with AERONET and AERONET-OC data. Pléiades is a series of two identical, pointable satellites with four broad spectral bands (blue, green, red, and NIR) and a panchromatic channel respectively at 2.8 and 0.7 m spatial resolution. A practical application of monitoring dredging activities and small scale sediment transport around the port of Zeebrugge is demonstrated. The impact of the monitoring station on which the AERONET-OC instrument is mounted is assessed, both in terms of the optical signal of the structure and its shadow, and the structure's impact on the local spatial variability.

Assessing trophic state of global inland waters using a MODIS-derived water color index

Shenglei Wang[1], Junsheng Li[2] , Bing Zhang[3]

Abstract

Eutrophication of inland waters has been a serious water environmental problem throughout the world. Remote sensing technologies can be used to assess trophic state of inland waters by retrieving water quality parameters, but suffer from the difficulty in applied in large area. In this paper, we proposed a new remote sensing method to assess the trophic states of inland waters located in different regions of the world. Firstly, extracting Forel-Ule index (FUI) of large and middle inland waters based on MODIS images; and then, assessing trophic states of inland waters based on the relationship analysis between FUI and water Trophic State Index (TSI). We applied this method to assess trophic states of total 1423 global large and middle inland waters (areas larger than 25 km^2) in the year of 2012.The overall accuracy is 77.8%, validated with the trophic states dataset of 90 waters around the world from published papers and authorized online databases. In the global inland waters in our study, eutrophic, mesotrophic, and oligotrophic waters account for 38.2%, 55.5%, and 6.3%, respectively. As for spatial distribution, waters with oligotrophic state are mainly concentrated in regions: central Asia, northern North America, and southern South America. Waters with eutrophic state dominated in the regions: eastern and southern Asia, eastern Africa and southeast North America. Moreover, we found that eutrophication of water bodies tend to distributed in regions with high population density, moderate GDP level, high air temperature and low altitude.

[1]*wangsl@radi.ac.cn; Key Laboratory of Digital Earth, Instituteof Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing100094, China; University of Chinese Academy of Science, Beijing 100049, China*

[2]*lijs@radi.ac.cn; Key Laboratory of Digital Earth, Instituteof Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing100094, China*

[3]*zb@radi.ac.cn; Key Laboratory of Digital Earth, Instituteof Remote Sensing and Digital Earth, Chinese Academy of Sciences, Beijing100094, China*

A New Algorithm Deriving VIIRS Particle Backscattering Coefficient $b_{bp}(\lambda)$ Products in the Global Highly Turbid Waters

Wei Shi[1,2,*], Menghua Wang[1]

[1]National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
Center for Satellite Applications and Research
College Park, Maryland, USA

[2]Cooperative Institute for Research in the Atmosphere at Colorado State University,
Fort Collins, Colorado, USA

In coastal and inland waters, the water-leaving radiance spectra are determined by inherent optical properties (IOPs) in the water-column. The complex features of the IOPs make accurate retrieval of IOPs challenging. This presentation shows that remote-sensing reflectance model in the turbid waters can be significantly simplified at the near-infrared (NIR) wavelengths, thus particle backscattering coefficient ($b_{bp}(\lambda)$) can be derived from normalized water-leaving radiance spectra $nL_w(\lambda)$ at the NIR wavelengths. Using the HYDROLIGHT simulated water-leaving radiance spectra, we show that the $b_{bp}(\lambda)$ values derived with the NIR IOP algorithm generally match well with the true $b_{bp}(\lambda)$ values in the coastal and inland waters. Specifically, $nL_w(\lambda)$ spectra at the NIR bands are derived using the shortwave infrared (SWIR)-based atmospheric correction algorithm from the Visible Infrared Imaging Radiometer Suite (VIIRS) over turbid coastal and inland waters. We use VIIRS-derived $nL_w(\lambda)$ spectra at 745 and 862 nm to produce the particle backscattering coefficient ($b_{bp}(\lambda)$) products in world highly turbid coastal and inland waters such as China's east coastal region, Amazon River estuary, La Plata River estuary, and Mississippi River estuary. Seasonal and interannual variability of VIIRS $b_{bp}(\lambda)$ data in these regions is characterized and quantified. Furthermore, $b_{bp}(\lambda)$ products derived in the NIR IOP approach are compared with those from other IOP algorithms such as the quasi-analytical algorithm (QAA) and the generalized inherent optical properties (GIOP).

Oyster aquaculture site selection using Landsat 8

Jordan Snyder[1*], Emmanuel Boss [2], Ryan Weatherbee [3], Damian Brady [4], Carter Newell[5]

ABSTRACT

The spatial resolution of global ocean color satellites is too coarse to provide usable data within many estuaries in the state of Maine (USA), which has ~3,500 miles of tidal shoreline within 220 miles of linear coast. The more recent Landsat 8 satellite has both the spatial resolution and the necessary signal-to-noise ratio to provide temperature and ocean color derived products along complex coastlines. Maine has a growing aquaculture industry, which makes it a prime case-study for using Landsat 8 to provide products suitable for aquaculture site selection. We collected the relevant Landsat 8 scenes, filtered out clouds, atmospherically corrected the top-of-the-atmosphere radiances, derived time varying fields (repeat time of Landsat 8 is 16 days) of temperature (100 m resolution), suspended materials and chlorophyll-a concentrations (30 m resolution). We used a vicarious atmospheric correction approach, which for the thermal band (10), was accomplished by regressions with coincident, already atmospherically corrected, AVHRR SST images. For the ocean color bands we determined the optimal per-scene aerosol optical thickness (angstrom) by requiring a zero minimum $R_{rs}(443)$ measured from very humic lakes (high CDOM). We validated the remote-sensing-based products at several *in-situ* locations where monitoring buoys and programs are in place. Validated fields were used to build the Oyster Growth Suitability Index that has revealed promising areas for oyster aquaculture. The approach used and the data collected to date show potential for other applications in marine coastal environments, including water quality monitoring and ecosystem management.

[1] jordan.snyder@maine.edu, Marine In-situ Sound and Color Lab, University of Maine, School of Marine Sciences, Orono, ME, USA

[2] emmanuel.boss@maine.edu, Marine In-situ Sound and Color Lab, University of Maine, School of Marine Sciences, Orono, ME, USA

[3] ryan.a.weatherbee@maine.edu, Satellite Oceanography Data Lab, University of Maine, School of Marine Sciences, Orono, ME, USA

[4] damian.brady@maine.edu, Darling Marine Center, University of Maine, School of Marine Sciences, Walpole, ME, USA

[5] musselsandoysters@gmail.com, Maine Shellfish R&D, Damariscotta, ME, USA

A Preliminary Validation of Reflectance and Chlorophyll-*a* Retrievals from OLCI Data

Wesley J. Moses[1], Vasily Povazhnyi[2], Vladislav Saprygin[2], Anatoly A. Gitelson[3], Sergey Berdnikov[2], and Viktoria Gerasyuk[2]

[1]U.S. Naval Research Laboratory, Washington, DC 20375, U.S.A.
[2]Southern Scientific Center of the Russian Academy of Sciences, Rostov-on-Don, Russia
[2]Israel Institute of Technology (Technion), Haifa 320000, Israel

Corresponding Author: Wesley J. Moses (wesley.moses@nrl.navy.mil)

Abstract

We have previously demonstrated using a number of datasets from various geographic locations that data from the MEdium Resolution Imaging Spectrometer (MERIS) can be used to accurately estimate chlorophyll-*a* (chl-*a*) concentration and thereby monitor water quality in coastal, estuarine, and inland waters. However, the loss of MERIS in 2012 left a significant gap in high-quality ocean color data at a global scale, which was recently filled by the launch of the Ocean Land Colour Instrument (OLCI) onboard the satellite Sentinel-3A. Using *in situ* measurements of reflectance and chl-*a* concentrations obtained from a number of stations in Taganrog Bay in Russia, we have performed a preliminary validation of OLCI data. The goal was two-pronged: (i) to quantitatively validate OLCI reflectance and chl-*a* retrieval and (ii) to compare the relationships between *in situ* chl-*a* concentration and two-band and three-band near-infrared (NIR)-red reflectance ratios obtained from OLCI data with those previously obtained from MERIS data for the same water body. The results are encouraging and demonstrate the potential of OLCI to provide accurate retrievals of biophysical parameters for monitoring water quality in coastal, estuarine, and inland waters.

BioArgo data: Providing a window into subsurface injections driving chlorophyll blooms in the oligotrophic North Pacific

Cara Wilson

Ocean color satellite data have observed summer blooms of chlorophyll that consistently develop in the oligotrophic North Pacific Ocean in the region between Hawaii and 30°N. Episodic injections of subsurface nutrients have been hypothesized to fuel these blooms, but the exact mechanism is unknown. Here I examine oxygen data from 13 BioArgo floats deployed near Hawaii between September 2002 to April 2016 to look for evidence of subsurface mixing that could be driving the development of the surface chlorophyll features. Twelve injection events (defined as oxygen values < 2 standard deviations below the mean at 100 m depth) were observed. Nine (75%) of the events happened in winter (Dec-Mar), when surface chlorophyll blooms do not generally develop. While most of the events were short-lived (< 5 days), several events lasted a month or two. An event that began in August 2014, and lasted almost 2 months, is examined in detail. The start of the event preceded by a few days the development of a surface increase in chlorophyll in the surrounding area evident from satellite data.

Environmental Research Division, Southwest Fisheries Science Center, NMFS, NOAA, Monterey, CA USA
cara.wilson@noaa.gov

Comparison between MODIS and Sentinel-3 chlorophyll products and Bio-Argo measurements in the Indian and the Pacific Ocean

Bożena Wojtasiewicz[1], Nick Hardman-Mountford[2], Dirk Slawinski[3], Tom Trull[4] and David Antoine[5]

Validation of geophysical products derived from satellite ocean colour sensors requires determination of in-water spectral downward irradiance $E_d(\lambda)$ and upwelling radiance $L_u(\lambda)$, together with derived properties, both near the surface and as vertical profiles. Autonomous floats equipped with bio-optical and biogeochemical sensors can be a useful and cost-effective tool for collecting validation data especially in the remote parts of the oceans. We analysed more than a 1000 profiles obtained over less than 2 years of operation from 7 floats in the Pacific and Indian Oceans. We identified more than 200 chlorophyll concentration matchups with MODIS and more than 60 for Sentinel-3. We also compared the retrievals of chlorophyll *a* concentration between both MODIS and Sentinel-3. Both MODIS and OLCI data showed good agreement with float data with correlation coefficients greater than 0.7. For MODIS products the best agreement was observed for chlorophyll concentrations obtained with the use of the OCI algorithm.

[1] bozena.wojtasiewicz@csiro.au, CSIRO Oceans & Atmosphere, Indian Ocean Marine Research Centre, Crawley, Western Australia, Australia

[2] nick.hardman-mountford@csiro.au, CSIRO Oceans & Atmosphere, Indian Ocean Marine Research Centre, Crawley, Western Australia, Australia

[3] dirk.slawinski@csiro.au, CSIRO Oceans & Atmosphere, Indian Ocean Marine Research Centre, Crawley, Western Australia, Australia

[4] tom.trull@csiro.au, CSIRO Oceans & Atmosphere and Antarctic Climate and Ecosystems Cooperative Research Centre Hobart TAS 7001, Australia

[5] david.antoine@curtin.edu.au, Remote Sensing and Satellite Research Group, Department of Physics and Astronomy, Curtin University, Perth, WA 6845, Australia; Sorbonne Universités, UPMC Univ Paris 06, INSU-CNRS, Laboratoire d'Océanographie de Villefranche, Villefranche-sur-mer, France

Remote sensing reflectance output from a biogeochemical model as additional information for management of water quality on the Great Barrier Reef.

CSIRO Coastal Environmental Modelling Team (John Andrewartha[1], Mark Baird[2], Mike Herzfeld[3], Emlyn Jones[4], Mathieu Mongin[5], Nugzar Margvelashvili[6], Farhan Rizwi[7], Barbara Robson[8], Jenny Skerratt[9], Karen Wild-Allen[10], Monika Wozniak[11])

The Great Barrier Reef (BGR) is a 2000 km long reef and lagoon complex, which is a UNESCO World Heritage Area between the Australia's north-eastern coastline and the Coral Sea. Although GBR is known as one of the best managed reef systems in the world, coral cover has declined over the last decades and research based management and policy is needed. A wealth of information that is crucial for coastal water monitoring and management is carried by ocean colour data, retrieved from satellite optical radiometers. However, one of the main limitation of using optical remote sensing is lack of data for areas covered by clouds. Therefore, as an addition to satellite measurements we present a skilful optical model which simulates remote sensing reflectance (R_{rs}) in 8 spectral bands equivalent to MODIS spectral bands. Comparison of simulated R_{rs} in the first six months of 2013 showed that the maximum RMS error 0.0075 sr-1, with a maximum bias of 0.004 sr-1. A snapshot comparison shows good correspondence, even in optically-complex waters. The R_{rs} at 488, 547 and 667 nm can be used in an additive colour model to create simulated true colour that can be compared directly to the observed true colour of the same day.

Oceans & Atmospheres, CSIRO, Hobart, TAS, Australia

E-mails: [1]John.Andrewartha@csiro.au, [2]Mark.Baird@csiro.au, [3]Mike.Herzfeld@csiro.au, [4]Emlyn.Jones@csiro.au, [5]Mathieu.Mongin@csiro.au, [6]Nugzar.Margvelashvili@csiro.au, [7]Farhan.Rizwi@csiro.au, [8]Barbara.Robson@csiro.au, [9]Jenny.Skerratt@csiro.au, [10]Karen.Wild-Allen@csiro.au, [11]Monika.Wozniak @csiro.au

Phytoplankton Group Identification Using Hyperspectral Remote Sensing Reflectance

Hongyan Xi, Martin Hieronymi, Hajo Krasemann, Rüdiger Röttgers

Abstract:

The present study investigates the bio-geo-optical boundaries for the possibility to identify major phytoplankton groups from hyperspectral ocean color data. A dataset of simulated remote sensing reflectance spectra, $R_{rs}(\lambda)$, was used. The simulation was based on measurements of five phytoplankton light absorption spectra representing five phytoplankton spectral groups. As part of a database compiled within the ESA SEOM C2X project, the C2X dataset contains 10^5 different water cases, including cases typical for clearest natural waters as well as for extreme absorbing and extreme scattering waters. As a test dataset, a second independent dataset of simulated $R_{rs}(\lambda)$ used light absorption spectra of 128 cultures from six phytoplankton taxonomic groups to represent natural variability. Spectra of the test dataset are compared with spectra from the C2X dataset to evaluate to which extent the five spectral groups can be correctly identified under different optical conditions. The results showed that the identification is generally effective, except for waters with very low contribution by phytoplankton and for waters dominated by non-algal particles (NAP), whereas contribution by CDOM plays only a minor role. To verify the applicability of the presented approach for natural waters, tests using in situ $R_{rs}(\lambda)$ collected in different waters (German Bight, Baltic Sea, British coastal waters, and Lake Taihu (China)) were carried out and the predicted dominant phytoplankton groups matched well with in situ measurements or documented results. This study provides an efficient approach, which can be promisingly applied to hyperspectral sensors, for identifying phytoplankton spectral groups purely based on $R_{rs}(\lambda)$ spectra.

Institute for Coastal Research, Helmholtz-Zentrum Geesthacht, Max-Planck-Str. 1, Geestahcht 21502, Germany

hongyan.xi@hzg.de; martin.hieronymi@hzg.de, hajo.krasemann@hzg.de; rroettgers@hzg.de

Variability of light absorption properties in optically complex inland waters of Lake Chaohu, China

Kun Xue [1,2], Yuchao Zhang [1], Hongtao Duan [1], Ronghua Ma [1,*]

[1] State Key Laboratory of Lake Science and Environment, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, 73 East Beijing Road, Nanjing 210008, China;

[2] University of Chinese Academy of Sciences, Beijing 100049, China

[*] Corresponding author e-mail: rhma@niglas.ac.cn
Tel.: +86-025-8688-2168; Fax: +86-025-5771-4759.

Abstract: Absorption coefficients of phytoplankton, colored detrital matter (CDM), non-algal particles (NAP), colored dissolved organic matter (CDOM), and their relative contributions to total non-water absorption ($a_{t\text{-}w}$) are essential variables for bio-optical and radiative transfer models. Light absorption properties showed large range and variability sampled at 194 stations throughout Lake Chaohu between May 2013 and April 2015. The $a_{t\text{-}w}$ was dominated by phytoplankton absorption (a_{ph}) and NAP absorption (a_d). The contribution of CDOM absorption to $a_{t\text{-}w}$ was lower than 30%. Phytoplankton and NAP were the primary sources of spatial and vertical variability in absorption properties. Light absorption by CDOM, though significant in magnitude, was relatively constant. CDM absorption (a_{dg}) was dominated by NAP. The spatial variation of the absorption coefficients from each of the optically active constituents were driven by several main inflow rivers in the western and middle part of Lake Chaohu. Algal blooms and bottom resuspension contributed to vertical variability as observed by phytoplankton and NAP profiles. Specific absorption of phytoplankton had significant spatial and seasonal variations without vertical variation. The spectral slope of absorption showed no significant spatial variability ($p > 0.05$). Variations of absorption could increase the difficulty of applying the remote sensing algorithm in optically complex waters. Parameters and relationships presented in this study provide useful information for bio-optical models and remote sensing of lakes similar to Lake Chaohu in terms of optical properties.

Neural network algorithms for detecting *Cochlodinium polykrikoides* blooms

Sinjae Yoo[1,2], Yeseul Kim[1,2,*], Young Baek Son[1]

[1] *Jeju International Marine Science Center for Research & Education, KIOST, South Korea*

[2] *Ocean Science and Technology School, Korea Maritime and Ocean University/Korea Institute of Ocean and Science Technology Joint Program, Busan, South Korea*

Corresponding e-mail: sjyoo@kiost.ac.kr

This study is to develop detection algorithms for the blooms of *Cochlodinium polykrikoides*, which has caused serious HABs for more than two decades in Korean waters. Various algorithms have been proposed to detect HABs. However, most of those algorithms are empirical and therefore limited in their applicability in the coastal areas where bio-optical conditions are highly variable spatially and temporally. In a previous study, we have shown that remote sensing reflectance of *Cochlodinium polykrikoides* exhibit a distinctive depression in the blue-green wavelength band (Kim et al., Optics Express, 2016) based on a large data set of remote sensing reflectance simulated using HydroLight and IOCCG data. We also showed that *Cochlodinium polykrikoides* can be clearly separated from unspecified phytoplankton assemblages in the two waveband ratio space (Rrs(555)/Rrs(531), Rrs(488)/Rrs(443)). Based on this, we are developing neural network algorithms for in-water and satellite applications. Our preliminary test using simulated and satellite data shows that the success rate of the in-water algorithm ranges from 71.6% (chl-a > 5 mg m^{-3}) to 89.8% (chl-a > 30 mg m^{-3}). We also compare the performance of neural network algorithms for satellite data.

Assessment of satellite-based chlorophyll-a algorithms in coastal waters: An example of Jinhae Bay, South Korea

Joo-Eun Yoon[1,*], Il-Nam Kim[1], SeungHyun Son[2], Ki-Tae Park[3], Jae-Hyun Lim[4]

[1]Department of Marine Science, Incheon National University, Incheon 22012, South Korea
[2]CIRA/Colorado State University & NOAA/NESDIS, Fort Collins, CO, USA
[3]Division of Polar Climate Sciences, Korea Polar Research Institute, Incheon 21990, South Korea
[4]National Institute of Fisheries Science, Busan, South Korea
[*]E-mail: jeyoon@inu.ac.kr

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ABSTRACT

The first geostationary ocean color sensor, Geostationary Ocean Color Imager (GOCI), onboard the Korean Communication, Ocean and Meteorological Satellite (COMS) was launched in 2010 with focus on monitoring marine ecosystems in the Korean waters. GOCI has a capability to provide ocean color data such as chlorophyll-a (Chl-a) concentrations with the higher temporal (hourly during the day time, 8 times per day) and spatial (nominally 500 x 500 m) resolution in the Korean waters. Estimating satellite-based Chl-a concentrations has been still challenging in the coastal waters as have optically complex water properties (e.g., non-algal interference and turbidity).

Jinhae Bay (JB; 34.8–35.2°N, 128.4–128.8°E), located in the southern coast of South Korea, has been suffered from environmental problems such as eutrophication, harmful algal bloom, and hypoxia since 1980's due to rapidly increased anthropogenic activities (i.e., agriculture and industrialization). Hence, coastal ecosystem conservation in this region has been regarded as an important social-economic-scientific issue.

The main purpose in this study is (1) to assess the current available ocean color algorithms used for coastal waters to apply the JB environment via the comparison of satellite-based Chl-a estimates with in-situ Chl-a measurements (data source from National Institute of Fisheries Science coastal environmental monitoring program 2011–2016), and (2) to provide a base of satellite-based long-term monitoring system to investigate anthropogenic impacts on coastal ecosystem.

Light backscattering properties of suspended particulate matter and retrieval of particulate concentration in the Yangtze estuary

X. Yu, M.S. Salama, F. Shen and W. Verhoef

Particulate scattering and backscattering coefficients have traditionally been used to quantify the concentration of suspended particulate matter (SPM). A large *in-situ* data set of SPM, particulate scattering (b), backscattering (b_b) and remote sensing reflectance (R_{rs}) had been collected from various instruments during two cruise campaigns in July 2011 and March 2013 in the Yangtze estuary, one of the world's most turbid coastal waters. A robust relationship between b_b and SPM concentration is observed from the *in-situ* data set, which allows us to map SPM distributions from GOCI images (Geostationary Ocean Color Imager, 2010 -), which provides 8 images per day from 00:16 UTC to 07:16 UTC. The GOCI standard atmospheric correction algorithm implemented in GDPS (GOCI Data Processing System) generates an acceptable error when validated with field measured R_{rs} for the 16 match-ups, which were collected within 1h of GOCI overpass. b_b is firstly retrieved from atmospherically corrected GOCI L2P products using the 2SeaColor model (Salama and Verhoef, 2015; Yu et al., 2016). SPM is then derived from the b_b-SPM relationship. Statistics results show that the accuracy of retrieved SPM from our model (RMSE=17.49 mg/L, R^2=0.935, N=16) is improved with respect to the GOCI standard SPM products (RMSE=37.57 mg/L, R^2=0.911, N=16). A time-series of SPM maps during a tide cycle on March 6th of 2013 is further presented to provide a thorough insight into the response of SPM variation to the tide in the Yangtze estuary.

Soft Classification Based Chlorophyll-a Estimation Algorithm by Remote Sensing in Inland Water

Fangfang Zhang[1], Junsheng Li[1*], Qian Shen[1], Bing Zhang[1]

Abstract: Chlorophyll-a concentration (C_{chla}) estimation is an important area of water color remote sensing, while it is always difficult in inland water, because the complex of inland water cause bad universality of C_{chla} estimation models. In this study, we presented a new C_{chla} estimation algorithm, which is called soft classification (or fuzzy classification) based estimation algorithm (SCEA). For SCEA, we classify the water as several clusters and extract its center of gravity firstly. Secondly, we calculate spectral angle distance (SAD) to the center of gravity of each cluster and convert to weight. Thirdly, C_{chla} estimation models of each cluster are optimized according to the spectral characteristics. Lastly, we got final C_{chla} from preliminary C_{chla} of each cluster estimation model multiply by weight. We estimate C_{chla} during 2003-2012 by MERIS data to test SCEA in Taihu Lake of China. The relative error is 35.6%, and root mean square error is 7.6 mg/m^3. The result showed the robustness of SCEA is good.

1 Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, No. 9 Dengzhuang South Road, Haidian District, Beijing 100094, China; E-Mails: zhangff07@radi.ac.cn (F.Z.); lijs@radi.ac.cn (J.L); shenqian@radi.ac.cn (Q.S.); zb@radi.ac.cn (B.Z.)

A MODIS-based novel method to distinguish surface cyanobacterial scums and aquatic macrophytes in Lake Taihu

Yuchao Zhang[1], Qichun Liang[2], Ronghua Ma[3] , Steven Loiselle[4], Jing Li[5] and Minqi Hu[6]

Satellite remote sensing can be an effective alternative for mapping cyanobacterial scums and aquatic macrophyte distribution over large areas compared with traditional ship's site-specific samplings. However, similar optical spectra characteristics between aquatic macrophytes and cyanobacterial scums in red and near infrared (NIR) wavebands create a barrier to their discrimination when they co-occur. We developed a new cyanobacteria and macrophytes index (CMI) based on a blue, a green and a shortwave infrared band to separate waters with cyanobacterial scums from those dominated by aquatic macrophytes, and a turbid water index (TWI) to avoid interference from high turbid waters typical of shallow lakes. Combining CMI, TWI and the floating algae index (FAI), we used a novel classification approach to discriminate lake water, cyanobacteria blooms, submerged macrophytes and emergent/floating macrophytes using MODIS imagery in the large shallow and eutrophic Lake Taihu (China). Thresholds for CMI, TWI and FAI were determined by statistical analysis for a 2010-2016 MODIS Aqua time series. We validated the accuracy of our approach by in-situ reflectance spectra, field investigations and high spatial resolution HJ-CCD data. The user's accuracy was 88%, 79%, 85% and 93% for submerged macrophytes, emergent/floating macrophytes, cyanobacterial scums and lake water, respectively. This new approach allows for the coincident determination of the distributions of cyanobacteria blooms and aquatic macrophytes in eutrophic shallow lakes. We also discuss the utility of the approach with respect to masking clouds, black waters and atmospheric effects, and its mixed-pixel effects.

1.Key Laboratory of Watershed Geographic Sciences, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing 210008, China; yczhang@niglas.ac.cn
2.University of Chinese Academy of Sciences, Beijing 100049, China; qichunl@qq.com
3.Key Laboratory of Watershed Geographic Sciences, Nanjing Institute of Geography and Limnology, Chinese Academy of Sciences, Nanjing 210008, China; rhma@niglas.ac.cn
4. Dipartimento di Biotecnologie, Chimica e Farmacia, University of Siena, CSGI, Via Aldo Moro 2, Siena53100, Italy; loiselle@unisi.it
5. University of Chinese Academy of Sciences, Beijing 100049, China; crystalleegis@163.com
6. University of Chinese Academy of Sciences, Beijing 100049, China; huminqi16@mails.ucas.ac.cn

Stereo observation of submarine sand waves using ASTER sun glitter imagery

Huaguo Zhang

In this paper, submarine sand waves have been studied with the stereo images from ASTER, which is an optical sensor on board the Terra satellite. The previous imaging geometrical model has been improved, and the difference in view angle among pixels are considered. We found that the brightness reversal frequently occur in the stereo imagery of submarine sand waves. Based on the imaging geometry model, inter-action model of current-topography and sun glitter radiance transfer model, a simulation model has been developed for sun glitter from submarine sand wave in multiple viewing angles. The cases of nadir-looking and back-looking have been simulated with the model, respectively. The results show the following differences between the two views angles, which have been also observed in the ASTER images. Both tendency and extent of the simulated radiance are in good agreement with those in actual images. In nadir view, obvious difference has been observed between the normalized significant radiance from smooth and rough facets. It increases with the increasing viewing angle to a peak and then decreases. However, in most cases, the difference in back view is smaller, and shows an opposite tendency regarding viewing angle. Thus, nadir-looking images seem more suitable for water depth retrieval of sand waves.

E-Mail: zhanghg@163.com
State Key Laboratory of Satellite Ocean Environment Dynamic, Second Institute of Oceanography, State Oceanic Administration, Hangzhou, 310012, China

Optical characterization of suspended particles along two estuarine transects using VIIRS data

Guangming Zheng[*,1,2], Paul M. DiGiacomo[1]

[1]*NOAA/NESDIS/STAR, NOAA Center for Weather and Climate Prediction (NCWCP), 5830 University Research Court, College Park, MD 20740, U.S.A.*

[2]*Global Science & Technology, Inc., 7855 Walker Drive, Greenbelt, MD 20770, U.S.A.*

[*]Corresponding author: Guangming Zheng, E-mail: guangming.zheng@noaa.gov

Abstract

Field data collected in estuaries sometimes show a unique spatial pattern of a chlorophyll maximum located next to a turbidity maximum. The turbidity maximum is sustained mainly by currents, whereas the chlorophyll maximum represents a combined effect of light limitation, nutrient limitation, and grazing pressure, the study of which has important implications for many fields of aquatic research. However, the turbidity-chlorophyll maxima feature was never observed with satellite data before owing to a lack of suitable models that can distinguish phytoplankton from nonalgal matter in optically complex waters. Here we used the generalized stacked-constraints model (GSCM) to accomplish this task. The light absorption coefficients of phytoplankton, $a_{ph}(\lambda)$, and nonalgal particles, $a_d(\lambda)$, were derived from VIIRS data for the Chesapeake and Delaware Bays using the GSCM. Seasonal climatologies (2012−2016) of $a_{ph}(\lambda)$, $a_d(\lambda)$, and the particulate backscattering coefficient, $b_{bp}(\lambda)$, calculated along the axial transects suggest that the turbidity-chlorophyll maxima can be identifiable with satellite data. In our study locations in both bays we observed a $a_{ph}(\lambda)$ maximum seaward of the coincident $a_d(\lambda)$ and $b_{bp}(\lambda)$ maximum in spring and summer but not in fall and winter. The GSCM-derived nonalgal particulate absorption $a_d(\lambda)$ is well correlated with total particulate backscattering $b_{bp}(\lambda)$ in spring, summer, and winter, and less so in fall, suggesting that organic degradation products might have contributed significantly to $a_d(\lambda)$ in the fall, whereas in other seasons riverine minerals dominate $a_d(\lambda)$ exclusively. These results demonstrate the effectiveness of using GSCM for advanced water quality applications and biogeochemical research in coastal waters.

Simulation of the sunglint polarization components vary with refractive indices: Implications for oil slicks detection in critical angle

Yang Zhou[1, 2], Yingcheng Lu[1, 2, 3], Yongxue Liu[3, 5], Zhihua Mao[2], Weixian Qian[4], Mengqiu Wang[3], Jing Shi[1, 2], Yansha Wen[1, 2], Jiang Xu[4], Shaojie Sun[3], and Minwei Zhang[3]

Abstract: The critical angle where the oil slicks and oil-free seawater brightness reversal occurs, is often shown as an area of uncertainty due to the different roughness and surface Fresnel reflection. Detecting oil slicks from the seawater background in these areas using optical sensors is, therefore, a challenge. Polarized optical remote sensing has the potential to solve this problem but how to do this has not yet been fully worked out. Here, a polarized optical remote sensing model incorporating the Stokes vector, the Mueller matrix and the Cox-Munk model is used to simulate the polarization state of sunlight reflected off oil slicks and seawater. The degree of polarization (DOP), a key parameter to describe the polarization state of sunglint, varies with the refractive index of the medium at the interface and viewing angles. The modeled DOP indicated that oil slicks can be distinguished from the surrounding seawater where there is sunglint, especially at the modeled critical angle. The DOP is most sensitive to the refractive index in the specular reflection direction and the sum of the solar and sensor zenith angles is 82.6°. The difference in the normalized Stokes parameter Q_{gn} between the oil slick and the seawater is bigger than the background signal, implying that it can be used to distinguish oil slicks from seawater. The primary Stokes parameters of solar irradiance and sunglint radiance reflected from oil slicks and seawater surface can be collected by ground-based or satellite polarized optical sensors, which means this study has future practical significance.

Correspond to: Y. Zhou (youngchou1912@163.com), Y. Lu (luyc@nju.edu.cn), Y. Liu (yongxue@nju.edu.cn), Z. Mao (mao@sio.org.cn), W. Qian (developer_plus@163.com), M. Wang (mengqiu@mail.usf.edu), J. Shi (shijing19931027@163.com), Y. Wen (15062283573@163.com), J. Xu (xujiangstart@163.com), S. Sun (suns@mail.usf.edu), M. Zhang (minweizhang@mail.usf.edu).

[1] *International Institute for Earth System Science, Nanjing University, 210046, China*

[2] *State Key Laboratory of Satellite Ocean Environment Dynamics (Second Institute of Oceanography, SOA), State Oceanic Administration, Hangzhou, Zhejiang, 310012, China*

[3] *College of Marine Science, University of South Florida, St. Petersburg, FL 33701, USA*

[4] *School of Electronic Optical Engineering, Nanjing University of Science and Science and Technology, Nanjing, 210094, China*

[5] *Department of Geographic Information Science, Nanjing University, Nanjing, Jiangsu, 210023, China.*