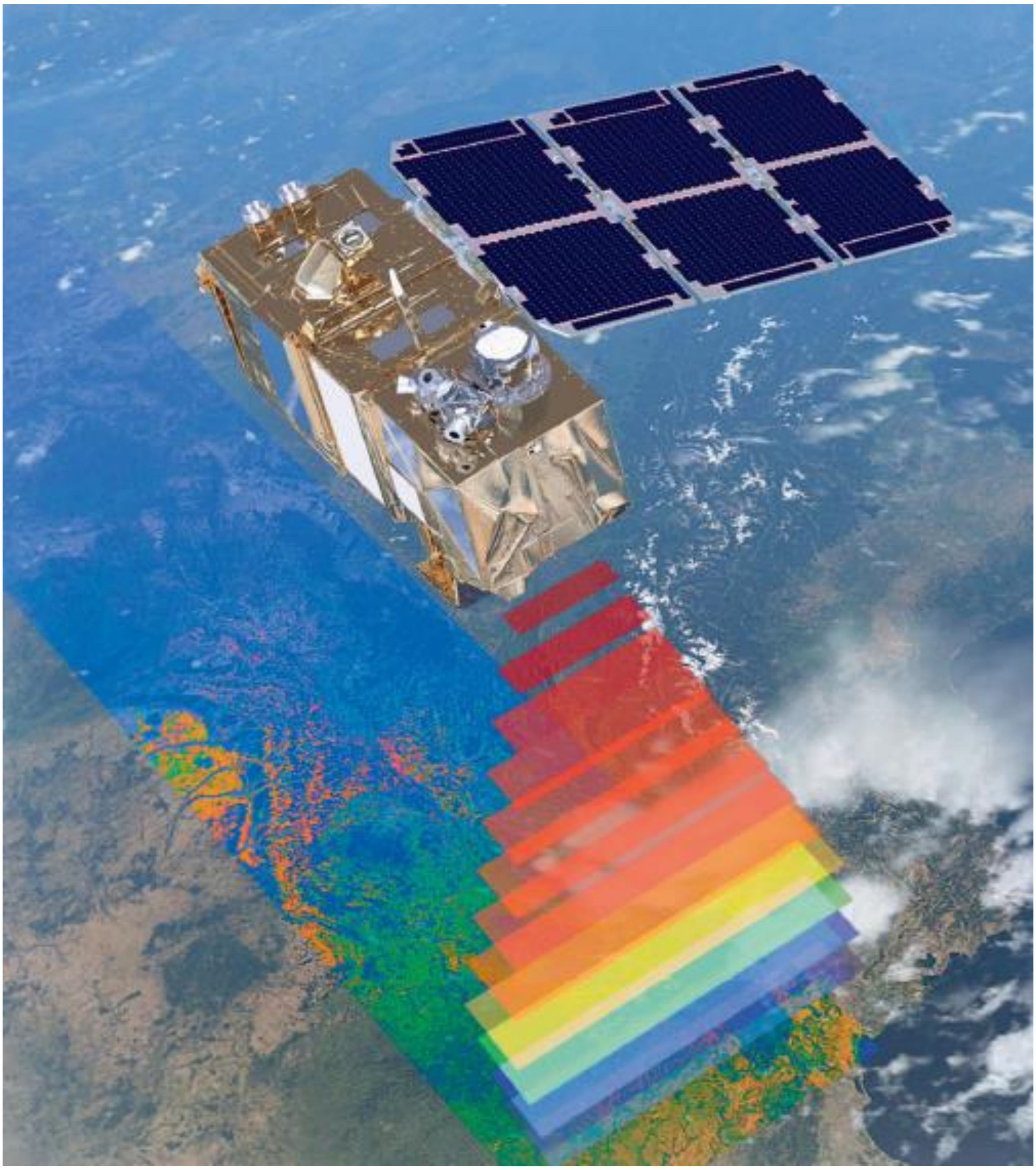
fiducial reference measurements for satellite ocean colour

FRM4SOC International Workshop

4-5 October 2018

NPL, Teddington, UK



Contents

Introduction

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).

Participants

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Details correct at time of going to print

Agenda

All timings are approximate

	Programme: Day 1, Thursday 04 October	
09:00	Arrival at reception where you will be given your security pass and directed to the workshop location - Refreshments	NPL staff / NPL Reception F16
	Session 1: Introduction	
09:20	FRM4SOC Welcome	N. Fox (NPL)/ T. Casal (ESA)
09:30	Keynote: *The need for FRM*	C. Donlon (ESA)
	Session 2: Copernicus and Agency needs. Chair: D. Antoine	F16 Auditorium
10:00	Keynote: *The importance of FRM in ocean colour satellite data validation for EUMETSAT*	E. Kwiatkowska (EUMETSAT)
10:30	Keynote: *The importance of FRM in ocean colour satellite data validation for NASA*	P. Bontempi (NASA-GSFC)
11:00	Refreshments and poster session	F16
11:45	Keynote: *The importance of FRM in operational ocean colour products for Copernicus / CMEMS*	R. Santoleri (CNR)
12:15	Lunch	F16
	Session 3: FRM4SOC project results Chair: T. Casal	F16 Auditorium
13:15	FRM4SOC Overview	R. Vendt (TO)
13:30	FRM4SOC LCE-1	A. Bialek (NPL)
14:00	FRM4SOC LCE-2	J. Kuusk (TO)
14:30	FRM4SOC Field Protocols	K. Ruddick (RBINS)
15:00	FRM4SOC OCRs Review	K. Ruddick (RBINS)
15:15	Refreshments	F16
16:10	FRM4SOC FICE AAOT	G. Tilstone (PML)
16:40	FRM4SOC OC-SVC	C. Lerebourg (ACRI-ST)
17:00	Towards Uncertainty and Error Correlation Evaluation for the Sentinel-3 OLCI Level 1 Product	S. Hunt (NPL)
17:20	Day 1 wrap-up	R. Vendt (TO)
17:35	Icebreaker / workshop dinner	F16 / External location
	Close of Day 1	

	Programme: Day 2, Tuesday 17 October	
Time	**Activity / Session**	**Presenter / Location**
08:45	Arrival and Refreshments	NPL Entrance / F16
	Session 4: Improvements in OCR Chair: G. Zibordi	F16 Auditorium
09:00	Keynote: Sea-Bird Scientific radiometric measurements: *Current evaluations and future opportunities for Ocean Colour vicarious calibration and validation*	Andrew Barnard (Seabird)
09:30	Keynote: Cimel	Stephane Victori (Cimel)
10:00	*The skylight-blocked approach as a direct measure of water-leaving radiance*	Heidi Dierssen (University of Connecticut/Flanders Marine Institute/VLIZ)
10:20	WATERHYPERNET – *A network of hyperspectral radiometers for multi-satellite water reflectance validation*	Kevin Ruddick (RBINS)
10:40	Keynote: *Comprehensive characterization of RAMSES hyper-spectral radiometers*	Giuseppe Zibordi (JRC)
11:10	Refreshments	F16 CS6\CS7
	Session 5: Satellite ocean colour validation Chair: K. Ruddick	F16 Auditorium
11:25	Keynote: *AERONET-OC: network status, quality control of data and recent advances*	Giuseppe Zibordi (JRC)
11:45	*CoastVal: Ocean Colour Validation Activities in Coastal and Inland Waters*	Sinead McGlynn (TechWorks Marine)
12:05	*An autonomous solar tracking measurement platform for offshore use* + practical demonstration	Dieter Vansteenwegen (Flanders Marine Institute/VLIZ)
12:25	Lunch	NPL Reception
	Session 6: FRM in OC-SVC Chair: P. Bontempi	F16 Auditorium
13:10	Keynote: *The metrological basis for MOBY*	Carol Johnson (NIST)
13:40	Keynote: *Heading to our 20s; Some reflections from the BOUSSOLE project*	David Antione (LOV/Curtin)
	Session 7: Panel Discussion Session *Towards FRM for all validation of satellite ocean colour data – a scientific roadmap* Chair: C. Donlon	F16
14:10	Panel discussion	
15:15	Refreshments	F16
15:30	Panel discussion (continued)	
16:45	Session summary and workshop wrap-up	A. Bialek/ R.Vendt/ C.Donlon
	End of Workshop	

Abstracts

Please note that some abstracts were unavailable at time of going to press.

FRM4SOC LCE-1 preliminary results

Agnieszka Bialek, Claire Greenwell, Sarah Taylor, William Servantes, Teresa Goodman, Emma Woolliams, Andrew Banks , Nigel Fox

All Fiducial Reference Measurements (FRM) must have documented SI traceability. To demonstrate an example of such documentation for Ocean Colour measurements in the frame of the FRM4SOC project, a laboratory comparison of commonly used standards for absolute radiometric calibration of in situ radiometers was conducted. It comprised of two parts, the irradiance standards comparison and radiance calibration round robin. The irradiance comparison was piloted by NPL using our measurement facilities to test so-called 1 kW FEL lamps from several participants worldwide. Then two radiometers were sent in turn to each participant for radiance round robin exercise.

The preliminary results of that comparison show an agreement better than 1.5% between various types of irradiance standards for wavelengths above 400 nm. The radiance results for the majority of participants agree within 3%. The exception from that can be explained by the measurements errors that influence radiance measurements uncertainty. The importance of proper use of calibration standards, such as irradiance standard burn-out time after the calibration and 0:45 reflectance factor calibration for reflectance standard, was stressed during the comparison. The main outcome of this exercise is a validation of individual participant absolute calibration standards, measurement methods and uncertainty budget evaluation. The uncertainty for radiance calibration typically at the level of 2.5% k=2 can be expected.

The Importance of Fiducial Reference Measurements (FRM) in Ocean Color Satellite Data Validation at NASA

Paula Bontempi (NASA Headquarters) and Sean Bailey (NASA Goddard Space Flight Center)

Fiducial reference measurements are essential for establishing the measurement uncertainties and scientific utility of satellite-based ocean color data products. It was not long after the launch of the proof-of-concept mission, the Coastal Zone Color Scanner (CZCS) in 1978 that NASA realized the importance of collecting high quality ground-based reference measurement to assess satellite data quality (Gordon et al., 1983). The lessons learned with the CZCS experience led NASA to include a strong calibration and validation component as part of the Sea-viewing Wide-Field-of-view Sensor (SeaWiFS) mission concept in the early 1990s (McClain et al, 1992), and launched in 1997. Prior to SeaWiFS, missions often focused on spacecraft and instrument engineering at the expense of post-launch instrument performance and algorithm development, including calibration and validation. Gordon (1998) demonstrated that for the atmospheric correction of ocean color sensors to achieve the required uncertainty in surface reflectance, the top-of-atmosphere calibration would need to be known to better than +/- 0.5%, or four times better than prelaunch calibration has been demonstrated to achieve. Consequently, a vicarious calibration of the instrument/atmospheric correction system is required. For this, high quality reference measurements are paramount. The Marine Optical BuoY (MOBY, operated by the National Atmospheric and Oceanic Administration, NOAA) has served as the source of these FRM vicarious calibration data for NASA missions, beginning with SeaWiFS in 1997. The SeaWiFS approach to vicarious calibration and instrument validation proved successful and has served as the model all NASA's ocean color efforts since, a valuable utility with new approaches planned NASA's latest ocean color endeavor – the Plankton, Aerosol, Cloud, ocean Ecosystem mission.

From MERIS to OLCI: validation of satellite ocean colour at Sagres, Portugal

Sónia Cristina, John Icely, Bruno Fragoso, Sergei Danchenko, Gerald Moore, Alice Newton

The Medium Resolution Imaging Spectrometer (MERIS) and, subsequently the Ocean and Land Colour Instrument (OLCI) ocean colour sensors have been validated since 2008 off Sagres in the SW of Portugal. This validation site has provided in situ radiometric measurements and water samples to determine in situ constituents from 2, 10 and 18 km off the coast. Several high quality matchups have been achieved, due to clear sky conditions and minimal sea-bottom reflectance. In general, the Sagres site is dominated by phytoplankton with only limited terrestrial inputs supplying total suspended matter and coloured dissolved organic matter. Nonetheless, a wide range of reflectance and chlorophyll values can be observed because of the periodic algal blooms from the upwelling events at this site.

The sampling conditions at Sagres have been particularly cost effective and efficient as boats used for cetacean watching are available at short notice for sampling campaigns, and are relatively inexpensive compared to the costs of ship time for normal oceanographic research campaigns. The uncertainties related to the MERIS and OLCI products after the matchup analysis of the data sets are assessed with the scattering and the bias as absolute and signed biased percent differences and with the coefficient of determination. The statistical results for MERIS and OLCI water leaving reflectance show improvements from inshore (2 Km) to offshore (18 km). This result suggested the presence of adjacency effects and possible limitations in the aerosol models near the coast. The application of data from the in situ measurements and the satellite products from the Sentinel-3/OLCI mission is making an important contribution to marine resource management both for the aquaculture sector and for the touristic activities that are important economic activities expanding at Sagres.

The skylight-blocked approach as a direct measure of water-leaving radiance

Heidi M. Dierssen, Zhongping Lee, Alexandre Castagna, Rodrigo Garcia and Zhehai Shang.

Remote sensing reflectance, Rrs, is expressed as the water-leaving radiance (Lw) normalized to incident irradiance on the sea surface (Ed(0+)), where Ed(0+) can be directly measured with a radiometer. Traditionally, Lw is derived from measurements made either above the sea surface or in the water. Measurements made above the sea surface must be corrected for surface-reflected direct and diffuse skylight while measurements made from within the water column must be extrapolated to a theoretical depth just beneath the sea surface (0−) and then numerically extrapolated across the air-water interface (0+). Artifacts in the derived Lw are known to occur with both methods, primarily because sea surfaces are complex with ripples and waves that make an exact delineation of 0- challenging, create underwater focusing that cannot merely be averaged out over time, and reflect different sectors of skylight into an above-water sensor. For inland small water bodies, moreover, radiance reflected off the water surface can be impacted by adjacent vegetation and other terrestrial features. Hence, the skylight-blocked approach has recently been put forth as a direct measure of Lw. The sensor head is fixed above-water and outfitted with a black cone inserted in the water to block the reflected skylight, thus measuring water-leaving radiance directly. Potential shading of the underwater photon flux by the cone is quantified through Monte Carlo modeling for different water and sky conditions. This new method has been extensively tested in a wide range of open ocean, coastal, and inland waters and compared with traditional methods. Uncertainties by this skylight-blocked approach are on the order of ~1-10% for the 400-700 nm range for deep blue waters to turbid coastal waters as well as shallow coral reef systems. We contend that this method is optimal for retrieving both the shape and magnitude of Lw under a wide array of conditions.

Towards Uncertainty and Error Correlation Evaluation for the Sentinel-3 OLCI Level 1 Product

Sam Hunt

The Ocean and Land Colour Instrument (OLCI) is a key payload carried by the Sentinel-3A and B constellation of satellites, which is capable of providing a global sun-glint free ocean colour product within 2 days. The instrument is a push broom imaging spectrometer designed to produce wide-swath, multi-channel images of the Earth's surface in the visible to the near infrared spectral region.

A metrologically rigorous evaluation of pixel-level uncertainty and pixel-to-pixel error-correlation in the Level 1 product is vital for a meaningful quantification of the quality of the data. Additionally, this information is required to propagate uncertainty through further processing steps to Level 2 and beyond. This is extremely important for many applications, in particular for the generation of climate data records. Presented here is such an uncertainty analysis for the OLCI Level 1 product, which aims to fully respect the JGCM Guide to the Expression of Uncertainty in Measurement by applying the uncertainty evaluation and reporting techniques developed within the H2020 FIDUCEO project.

This analysis is divided in to three steps: (1) establishing the measurement function and determining the sources of error that lead to the uncertainty for each term in the measurement function; (2) studying and evaluating the uncertainty and the error-correlation of each error source identified and reporting this in FIDUCEO-style "Effects Tables"; (3) providing this data to users, for which an approach is recommended.

FRM4SOC LCE-2 - Indoor

J. Kuusk, V. Vabson, I. Ansko, R. Vendt.

Laboratory Comparison Experiment LCE-2 was organized in the frame of the FRM4SOC project with the aim to link the ocean colour field measurements to the SI-traceable calibration and verify whether different instruments measuring the same object will provide consistent results within the expected uncertainty limits. All the radiometers participating in LCE-2 were radiometrically calibrated in Tartu Observatory just before the experiment by using SI-traceable radiometric calibration standards. The LCE-2 experiment was divided into two parts – indoor and outdoor experiment. The indoor experiment was used to determine best possible agreement between commonly used ocean colour radiometers. The factors that could possibly affect the measurements were minimized and the measurements were carried out in a controlled laboratory environment closely matching the conditions during radiometric calibration. All the participants measured the same stable radiance and irradiance sources and reported the results with associated uncertainty budgets to the pilot. While the initially submitted results included some outliers, all the disagreements could be explained and were caused by either human errors or differences in the data processing algorithms.

FRM4SOC LCE-2 - Outdoor

J. Kuusk, V. Vabson, I. Ansko, R. Vendt.

Compared to the indoor exercise, the outdoor experiment of the Laboratory Comparison Experiment LCE-2 was a step towards actual in situ ocean colour measurements. Downwelling solar irradiance and sky and water radiance were measured and intercompared, but no derived ocean colour parameters such as water-leaving radiance or remote sensing reflectance were calculated. There were a few notable differences compared to the indoor experiment: ambient temperature was roughly 15 ˚C lower than during the radiometric calibration of the radiometers; spectral composition of the target signal (sky, water) was different compared to the radiometric calibration standard (incandescent source); the angular distribution of downwelling irradiance was significantly different than during radiometric calibration (normal illumination); due to variable nature of natural illumination it was not possible to measure the targets using different integration times.

Due to non-ideal performance of radiometers (nonlinear response, temperature dependence, spectral stray light, deviation from cosine response, etc.) all these differences between conditions during laboratory calibration and field measurements contribute to the measurement uncertainty. Compared to the indoor measurements, outdoor variability between radiance sensors in average was about two times larger, and for irradiance sensors more than five times larger. The rather different behaviour of TrioOS RAMSES and Santlantic HyperOCR sensor groups should be noted. For the RAMSES group, variability of the radiance sensors during indoor and outdoor exercises were almost identical and the increase of the total outdoor variability was caused by the HyperOCR sensors. For the irradiance measurements, the deviation of HyperOCR sensors from consensus value of the group was very small. The group of RAMSES sensors was responsible for the increase of mean variability in the case of irradiance sensors.

System Vicarious Calibration of Copernicus Ocean Colour sensors

Christophe Lerebourg, Ludovic Bourg, Nicolas Lamquin

Copernicus, with the sentinel series, has committed to long term Earth Observation programs. Within this program, OLCI (Ocean and Land Colour Instrument), on-board the Sentinel-3 series is the spear-head for ocean biogeochemical monitoring. Fundamental for the creation of Climate Data Records of Essential Climate Variables like chlorophyll concentration, OLCI is also of prime importance for the development of water quality monitoring services in the coastal region where most of the anthropogenic activities take place. The fundamental variable measured by and ocean colour sensor, from which are derived biogeochemical variables, is the radiometry. It is therefore essential to ensure its quality and traceability if we are to provide reliable products. System Vicarious Calibration (SVC) is the mandatory step to achieve the quality requirements of Ocean Colour radiometric products. Part of the FRM4SOC objectives was dedicated to open discussions within the community and reach a consensus the long term SVC of Copernicus sensors. All aspects of SVC have been addressed with a special emphasis on the ground infrastructure and procedures to ensure SI traceability. This presentation will summarise the outcome of these discussions as well as a status SVC implementation for OLCI on-board S3A.

CoastVal: Ocean Colour Validation Activities in Coastal and Inland Waters

Charlotte O'Kelly, Karl Moore, Sinéad McGlynn

The aim of the CoastVal project is to develop and deploy a buoy platform dedicated to validation of satellite ocean colour data products for coastal areas in high latitude waters. This ESA-funded project is part of the Sentinel 2 and 3 Validation Team activities, contributing to the overall calibration and validation activities for both missions.

A buoy-based platform dedicated to validation of satellite ocean colour products for coastal areas in high latitude waters is presented. The platform consists of a suite of 5 hyperspectral radiometers, including an in-air downwelling irradiance sensor and a pair of upwelling radiance and downwelling irradiance sensors positioned at two depths with fixed separation. The platform also includes ancillary sensors such as chlorophyll, turbidity as well as temperature, conductivity, dissolved oxygen and pH to characterise the water column. The platform is also supplied with a tilt and heading sensor to record buoy attitude during data acquisition and to correct for variations with respect to solar zenith angle and azimuth. The tilt sensor measures pitch and roll at high frequency compared to the hyperspectral sensors so that radiometric data acquired outside a certain tilt range can be removed from the inversion dataset.

The platform has been purposely designed to minimise the uncertainty in the radiance observations while also providing a robust system to withstand high currents and rough sea states. The project is ongoing until Q3 2018, with a successful test deployment of the buoy and sensors in December 2017. The final deployment of the system at the mouth of Dublin Bay took place in August 2018, with all instruments successfully streaming data and the processing and quality control well underway. The current status of the deployed system and the analysis required to produce radiometric products for comparisons with the satellite observations will be presented.

WATERHYPERNET - A network of hyperspectral radiometers for multi-satellite water reflectance validation

Kevin Ruddick, Dieter Vansteenwegen, Quinten Vanhellemont, Matthew Beck, David Doxaran, Ana Dogliotti, Dimitry Van der Zande, André Cattrijsse.

A network of hyperspectral radiometers is being developed for radiometric validation of satellite missions. This network follows closely the AERONET-OC federation concept [Zibordi et al, 2009] but uses the TRIOS/RAMSES hyperspectral radiometer. The instrument system consists of one radiance and one irradiance sensor on a pointing robot, controlled by a microprocessor and supplemented with GPS, inclinometer and video camera data feeds. The measurement protocol is based on the abovewater method of [Mobley, 1999], but includes additional scenarios for different viewing zenith and azimuth configurations. The systems will be deployed initially in Belgian coastal and inland waters, then at HYPERMAQ project partner sites in Argentina and France before full international expansion. The network will provide water reflectance data for the radiometric validation of all visible and near infrared bands of all optical missions, including Sentinel-2A&B, Sentinel-3A&B, PROBA-V, MODIS-AQUA&TERRA, VIIRS, Landsat-8, Pléiades, CHRIS-PROBA, MSG-SEVIRI … ENMAP, PACE, MTG and ... any future optical missions, including nanosatellites. This presentation will provide the general context as well as showing the advantages of hyperspectral radiometry for the validation of both mulitispectral and hyperspectral satellite missions.

Radiometric field inter-comparison of remote sensing reflectance in the Adriatic Sea.

Gavin Tilstone, Giorgio Dall'Olmo, Davide D'Alimonte, Martin Hieronymi, Martin Ligi, Joel Kusk, Ilmar Ansko, Maycira Costa, Vincenzo Velluci, Astrid Bracher.

The aim of this field inter-comparison was to quantify the differences between in- and above-water optical systems, sensors and methods on a stable Oceanographic platform in the northern Adriatic Sea. The inter-comparison was conducted at the Acqua Alta Oceanographic Tower (AAOT) from 09 to 19 July 2018, to assess differences between 8 measurement systems. Prior to the inter-comparison, the absolute radiometric calibration of all sensors was carried out using the same standards and methods at the same reference laboratory (University of Tartu). Measurements were performed at the AAOT under near ideal conditions, on the same deployment frame, under clear sky conditions, relatively low sun zenith angles and moderately low sea state. The preliminary results show that for Ed(0+,λ), there was generally good agreement with differences of <5% between institutes, except for one institute which exhibited a systematic bias in the data. For Lsky(λ) and Lt(λ) the differences in above water between institutes were consistently <5%. For Lsky(λ), there was an apparent difference in values between sensor types (SALTANTIC v TRIOS) possibly arising from differences in the angular response of the sensors. For Rrs(λ), the differences were higher. Both TRIOS and SATLANTIC above water systems had differences of <30%, but the differences between above water and in water systems were larger and probably due to variability in viewing angle correction that is required when processing the data to Rrs(λ). The results are discussed in relation to viewing geometry angle, the influence that input parameters have on the computation of Rrs(λ) and using different air-sea interface reflection coefficients in the processing of Rrs(λ).

An autonomous solar tracking measurement platform for offshore use

Dieter Vansteenwegen

Gathering ground truthing data can be a challenging and costly undertaking. Aiming to create new algorithms for remote sensing of SPM and chlorophyll concentration, the Hypermaq project needs offshore irradiance and water and sky radiance measurements. Coinciding these measurements with selected satellite overpasses adds another layer of complexity. An autonomous measurement system enhances temporal data resolution at reduced costs. Measurement cycles are made at regular intervals throughout the day and consist of a list of measurements in relation to the position of the sun according to a user-defined protocol. Deployment in varying environments and conditions demands a high degree of customizability. Additional instruments will be added over time, and component choices will depend on availability and requirements. This calls for a modular approach. The setup is built around an embedded controller running a Linux operating system, ensuring compatibility with future hardware. Location and time are gathered from a connected GNSS receiver, and allow calculation of the sun position. A pan/tilt head then rotates the instruments to correct azimuth and elevation angles, based on user defined offsets for each measurement step. Data is stored in a SQLite database and sent to a land-based server every day. Power can be provided by mains supply or batteries. While designed specifically for hyperspectral radiometers, the platform can easily be extended to suit other measurement purposes. A number of these platforms can be installed to form a worldwide hyperspectral validation network.

Sea-Bird Scientific radiometric measurements: Current evaluations and future opportunities for Ocean Color vicarious calibration and validation.

Andrew Barnard, CTO Sea-Bird Scientific

Sea-Bird Scientific has an extensive background of radiometric sensor development, manufacturing and calibration, including participating in several independent laboratory and field intercomparison activities over the course of its history. More recently, Sea-Bird Scientific has undertaken several projects focused on addressing the current and evolving needs of radiometric sensing of the oceans. These activities include the following: 1) conducting an extensive study to quantify and verify the uncertainty of the radiometric calibration processes between two Sea-Bird Scientific facilities; 2) participating in the European Space Agency sponsored Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC) exercises, and 3) developing a new autonomous hyperspectral radiometric sensing capability to provide accurate radiance measurements to support ocean color satellite system vicarious calibration under the funding auspices of NASA. Each of these activities shared a common goal of quantifying the uncertainties of radiometric sensors. We present an overview of each of these activities, summarizing the uncertainties revealed within each study and their implications for the future of ocean color satellite remote sensing vicarious calibration and validation.

Interactive Presentations

An uncertainty budget for the radiometry component of the BOUSSOLE project, as derived using a Monte Carto Method

Agnieszka Bialek, Vincenzo Vellucci, Bernard Gentili, David Antoine and Nigel Fox

The BOUSSOLE (Bouée pour l'acquisition d'une Série Optique à Long Terme) project's main objective is to provide a long-term time series of optical properties and radiometric quantities in support of calibration and validation activities of satellite ocean colour missions and bio-optical research in oceanic waters. The buoy is in continuous operation since 2003 and provided system vicarious calibration (SVC) data for the European MERIS instrument on-board ENVISAT, and continue doing so for the Copernicus Sentinel 3 satellites series. In this context, an uncertainty budget, rigorously tied to the international system of units (SI), for the buoy radiometric measurements and derived apparent optical properties is presented.

The study focuses on a subset of data that matches quality criteria generally used for SVC of satellite sensors. A traditional approach following the Guide to the expression of Uncertainty in Measurement (GUM) is used to evaluate uncertainties associated with the absolute radiometric calibration of instruments deployed on the buoy. Uncertainties associated with in situ measurements and data processing are identified and assessed separately. Calibration and in situ uncertainty components with their probability distribution functions are then used as inputs and propagated through a Monte Carlo Method (MCM) model, following the Supplement 1 to the GUM guidelines. The final product uncertainty is derived from the probability distribution function of the model outputs.

The same methodology will be applied to further BOUSSOLE products and extended to datasets requiring less strict quality criteria, e.g., validation, time series analysis or model assimilation.

Fiducial Reference Measurements for Satellite Ocean Colour (FRM4SOC)

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

Fiducial Reference Measurements (FRM) are a suite of independent ground measurements that provide the maximum return on investment for a satellite mission by delivering, to users, the required confidence in data products, in the form of independent validation results and satellite measurement uncertainty estimation, over the entire end-to-end duration of a satellite mission. The FRM must have documented traceability to SI units (in terms of an unbroken chain of calibrations and comparisons); be independent from the satellite retrieval process; have evaluated uncertainty budgets for all FRM instruments and measurement procedures applied; have defined and adhered-to protocols/community-wide management practices (measurement, processing, archive, documents etc.); and be openly available for independent scrutiny. The FRM4SOC project, initiated and funded by the European Space Agency (ESA), has followed these principles organising a series of comparison exercises in order to provide support for evaluating and improving the state of the art in Ocean Colour Radiometry (OCR) with the objective of establishing and maintaining SI traceable ground-based FRM for satellite OCR. FRM4SOC, thus makes a fundamental contribution to the European system for monitoring the Earth (Copernicus). The project events were organised 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. The structure, objectives, principles of methodology and major events of the project introduced.

Validation of remote sensing algorithms using the Norwegian ship of opportunity network (NorSOOP)

S. Marty, P. Jaccard, M. Norli, A.L. King, K. Sørensen, K. Stamnes and J. J. Stamnes.

Along the Norwegian coast, from Bergen to Kirkenes, through the Barents Sea, and the North Sea, the NorSOOP ferries network is covering a large diversity of water types and provides crucial insight into the dynamics of environmental conditions. The FerryBox systems measure core parameters such as salinity, temperature, oxygen, turbidity, cDOM and chlorophyll fluorescence, wind speed and direction, and hyperspectral above water reflectance. The NorSOOP accurate calibrations and quality controls provide a high-quality dataset for atmospheric correction and water inherent optical properties retrieval algorithms validation.

Use of the satellite technologies for the monitoring the quality of seawater. Application to the Algerian littoral Mediterranean.

Nacira Tahenni

Remote sensing information on the surface of the ocean can provide much of the information needed to assess and improve the quality of seawater. The approach is based on measurements and in situ sampling. Satellite images calibrated from the data measured in situ provide continuous information on the aquatic environment and can be used to estimate, with a reasonable approximation, the factors affecting the quality of the water. The objective of this article is to establish the correlations between the optical properties of seawater and the physiochemical parameters. We present the relation between the dummies of the water quality of the Oran coast and the calculated reflectance of each pixel from the physical model of radiometric correction. In situ measurements calculated from a LANDSAT and MODIS satellite image. Finally, the linear relation are established with the reflectances. The inversion of these relations allows to obtain images transformed from the image processing software in order to estimate for each pixel the distribution of the parameters studied (degree of pollution).
Key words: Seawater quality, satellite image, coastal area, reflectances.