International Ocean Colour Science Meeting 2013

Advancing Global Ocean Colour Observations

SUBMITTED ABSTRACTS

Topical Area

Satellite instrument calibration

Satellite instrument calibration

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DIMITRI: the Database for Imaging Multi-Spectral Instruments and Tools for Radiometric Intercomparison

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Summary

There is a growing use of satellite remote sensing data in the visible and near infrared spectral band range in short and long term environmental monitoring studies; therefore, there is a need to ensure satellite instruments are accurately calibrated. One approach is to compare measurements between two space sensors, at the TOA measurement level, over the same target at the same time, under the same viewing geometries and in identical spectral bands. Such direct comparison also removes the need for in-situ measurements and radiative transfer forward or inverse modeling. The Database for Imaging Multi-Spectral Instruments and Tools for Radiometric Intercomparison (DIMITRI) was developed with this approach and aims towards the goals of the Global Earth Observation System of Systems for an operational radiometric calibration system. DIMITRI is open-source and gives users the capability of long term monitoring of instruments for systematic biases and calibration drift. It was included in the CEOS/IVOS intercomparison of methodologies making use of pseudo-invariant sites for vicarious calibration or for radiometric intercomparisons. A full report is available on the CalVal Portal at: http://calvalportal.ceos.org/cvp/web/guest/ivos/wg4.

DIMITRI functionalities

DIMITRI (Fig 1) comes with a suite of tools for comparison of the L1b radiance and reflectance values originating from various medium resolution sensors over a number of radiometrically homogenous and stable sites (Table 1) at TOA level, within the 400nm – 4µm wavelength range. The date range currently available is 2002 to 2012. DIMITRI has been developed with a user-friendly interface enabling radiometric intercomparisons based on user-selection of a reference sensor, against which other sensors are compared. DIMITRI contains site reflectance averages and standard deviation (and number of valid pixels in the defined region of interest, or ROI), viewing and solar geometries and auxiliary information. Each observation is automatically cloud screened; manual cloud screening is also visually performed using product quicklooks. DIMITRI also provides a platform for radiometric intercalibration from User defined matching parameters: geometric, temporal, cloud

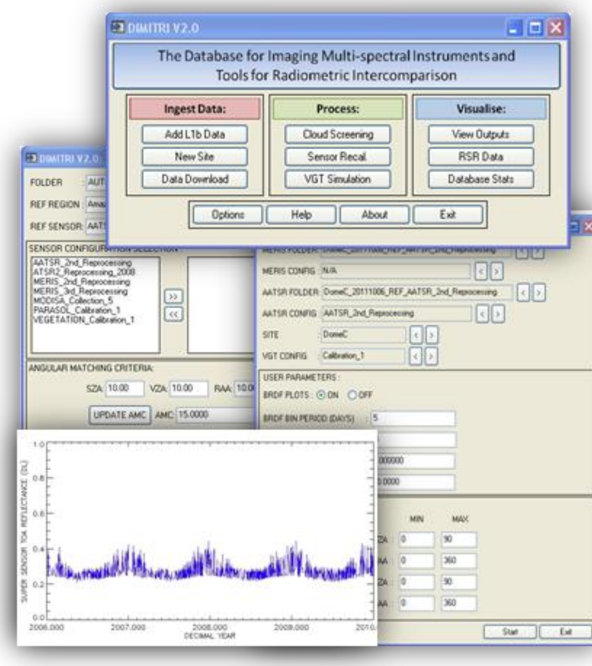

Fig. 1 The DIMITRI graphical user interface

and ROI coverage. Other capabilities and functions include: product reader and data extraction routines, radiometric recalibration & bidirectional reflectance distribution function (BRDF) modelling, quicklook generation with ROI overlays, instrument spectral response comparison tool, VEGETATION simulation.

Table 1: Sensors and sites included in the DIMITRI V2.0 database

SENSOR	Supplier
AATSR (Envisat)	ESA
MERIS, 2nd & 3rd reprocessing (Envisat)	ESA
ATSR-2 (ERS-2)	ESA
MODIS-A (Aqua)	NASA
POLDER-3 (Parasol)	CNES
VEGETATION-2 (SPOT5)	CNES

Site	Site type
Salar de Uyuni, Bolivia	Salt lake
Libya-4, Libyan Desert	Desert
Dome-Concordia, Antarctica	Snow
Tuz Golu, Turkey	Salt Lake
Amazon Forest	Vegetation
BOUSSOLE, Mediterranean Sea	Marine
South Pacific Gyre (SPG)	Marine
Southern Indian Ocean (SIO)	Marine

DIMITRI methodologies

Two methodologies are presently implemented in DIMITRI:

1. **Radiometric intercomparison based on angular and temporal matching:** Concomittant observations ("doublets") made under similar geometry and within a defined temporal window are intercompared at similar spectral bands. This assumes the TOA reflectance angular distribution obeys the principle of reciprocity and is symmetrical with respect to the principal plane [1]. The day offset and strictness of angular matching between observations of two sensors, as well as the allowable cloud cover percentage values can be user defined, and the closest geometric match is selected and stored in the time series. It is estimated that the systematic uncertainty of this methodology is approximately 3%, and its random uncertainty component approximately 2%. For intercalibration, doublets are intercompared, and a least squares regression used to apply a polynomial fit to the temporal differences between the calibration and reference sensor doublets for each intercomparable band, from which the entire calibration sensor time series can be recalibrated over a validation site to the same radiometric scale as the reference sensor. The two complete time series over the validation site are then stored as a "super sensor" time series.

2. **Radiometric intercomparison of VEGETATION simulated and actual observations:** DIMITRI makes use of the super sensor time series from methodology 1 to fit a 3-parameter BRDF model to all observations falling within a defined binning period, for each spectral band corresponding to a reference sensor, MERIS (with the 1.6 µm band coming from ATSR-2). These spectral BRDF models are used to simulate TOA spectra (corrected for the atmospheric gaseous absorption transmission) at the date and in the geometry of VEGETATION-2 acquisitions, then ultimately convolved with VEGETATION-2 spectral responses, and compared to the observed VEGETATION-2 reflectances [2].

How to get DIMITRI:

DIMITRI is maintained by ESA and ARGANS, and is freely available at http://www.argans.co.uk/dimitri/.

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Spatio-temporal variability of water quality parameters in the Van Diemen Gulf coastal waters from 10 years of MERIS Reduced Resolution Satellite Data.

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Summary

The Van Diemen Gulf is a poorly flushed, semi-enclosed embayment of Northern Australia characterised by shallow but optically deep coastal waters (<30m) and a large tidal range (3-8m). High energy local tide currents and seasonal winds provide the main mixing mechanism. The adjacent land is scarcely populated but increasing pressure is placed on the marine environment through expanding fishing and shipping activities, as well as industrial development for oil and gas production and climate change. Despite its environmental and cultural richness, very few studies have reported on the spatio-temporal ecological changes of Van Diemen Gulf's coastal waters over the past decade. This study will present, for the first time, the results of a climatology and time-series analysis to assess change in three main water quality parameters, namely chlorophyll-a, suspended sediment and coloured dissolved organic matter (CDOM), over a period of 10 years (2002-2012).

Introduction

The marine environment of the Northern Territory (Australia) is one of the least human-impacted coastal regions on the planet [1]. Part of this unique coastline is the Van Diemen Gulf, which stretches over an area of ~14,000 km^2 and connects to the Arafura Sea by the Clarence and Dundas straits (*Figure 1*). The oceanographic complexity of the region has long been recognized [2], and enhanced mixing and seasonal upwelling contribute to the sustaining of a persistently turbid surface layer at the edge of the continental shelf throughout the year [3]. While heavy tropical rainfall during the wet season (November-March) produces significant freshwater discharges of sediments, CDOM and nutrients into the Gulf, south-easterly winds transport dry, warm air over the region during the dry season (May-September) and generate the upwelling of cooler, nutrient-rich water. The months of April and October are transition months [4]. The scientific knowledge of material fluxes over space and time in the Van Diemen Gulf is currently very limited and a detailed understanding of these processes is required for future monitoring. This is of particular importance if the frequency and intensity of rainfall continue to increase in this region in the future [5]. With the recent end of the MEdium Resolution Imaging Spectrometer (MERIS) mission, water quality change detection with moderate resolution (1 km) satellite data now relies on Moderate Resolution Imaging Spectroradiometer (MODIS). However the potential of the full mission of MERIS reduced resolution imagery can provide a wealth of information for coastal waters. For this study, Chlorophyll-a, CDOM and total suspended matter derived from 10 years of MERIS Case-2 algorithm FUB [6] will be used to quantify trends.

Discussion and conclusion

Land to coast freshwater discharges during the wet season months result in an increase of the suspended sediment concentrations in the surface waters, which is likely to limit light penetration and in turn, phytoplankton growth. During the dry season however, the waters are likely dominated by coloured dissolved organic matter and a generally higher phytoplankton biomass is observed [7] due to upwelling of nutrients.

Figure 1 From left to right: (a) Location of the study region with a colour shaded bathymetry and MERIS images showing typical (b) dry and (c) wet season conditions. The two major rivers are shown (SAR: South Alligator River and EAR: East Alligator River)

The absorption properties sampled during the first bio-optical campaign in April 2012 (transition month) helped characterise this system as optically complex. MERIS FUB Case-2 algorithm has been proven to perform generally well in CDOM-dominated temperate waters [8] but its performance remains yet to be tested in the tropical waters of the Van Diemen Gulf. There is an evident lack of in situ measurements for the validation of satellite ocean colour algorithms for those waters however, mainly due to the remoteness of the region. Thus to optically characterise this marine environment and for the validation (and parameterisation) of the satellite algorithms, more bio-optical campaigns are needed.

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ABSOLUTE CALIBRATION OF SEAWIFS USING RAYLEIGH SCATTERING

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Summary

This paper presents the assessment of the SeaWiFS absolute calibration using the Rayleigh signal above oceanic surfaces. Results obtained in the frame of this study show a high stability of the absolute calibration and a slight temporal calibration drift from 2005.

Introduction

The “Rayleigh calibration method” developed by the French Space Agency (CNES) and used in the frame of this study to assess the absolute calibration of the SeaWiFS instrument, is based on the exploitation of Top Of Atmosphere (TOA) signal measured above oceanic surfaces in the short wavelengths, i.e. from blue to red regions (<700 nm). This signal mainly corresponds to the molecular scattering signal (Rayleigh signal) which can reach 90% of the total signal. The other contributions to the TOA signal are linked to the aerosol amount and type, the marine surface reflectance which is driven by several parameters such as chlorophyll concentration, water sediments and foam presence. Consequently, considering conditions minimizing the influence of the non-Rayleigh contributions, it is possible to assess the variation of the absolute calibration coefficients comparing measured and simulated observations. In this context, CNES has developed an operational multi-sensors calibration software environment (MUSCLE) [1] allowing to assess the absolute calibration of several instruments. The “Rayleigh method” is one of the techniques implemented in MUSCLE. This environment is coupled to the SADE database [2] which includes appropriate observations for applying the selected calibration method.

Discussion

Our study of which the results are details in [3], is split into several steps:

1. Collection and pre-processing of SeaWiFS products: SeaWiFS data acquired over the six operational oceanic areas defined in Fougnie et al. [4] are exploited in the frame of this study. These areas correspond to oligotrophic areas chosen for their spatial homogeneity and their low and stable seasonal variation in chlorophyll concentration. SeaWIFS L1A GAC products have been pre-processed to generate TOA reflectances.

2. Development of a filtering tool to select appropriate SeaWiFS observations for Rayleigh calibration and insertion into the SADE database: This selection is based on the minimization of the non-Rayleigh contributions applying several successive criteria: observations located sufficiently far from coastal areas, non-cloudy observations or sufficiently far from clouds to avoid adjacency effects, observations with low wind speed in order to limit the foam influence, observations sufficiently far from sunglint conditions, observations with low aerosols concentration at 865 nm, non-degraded quality observations.

3. Assessment of the SeaWiFS absolute calibration for the visible bands (< 700 nm) using the Rayleigh method available through the MUSCLE environment. The Rayleigh absolute calibration method [5] consists in comparing, for each observation, the SeaWiFS TOA reflectance assuming a reference calibration to evaluate with the corresponding TOA reflectance simulated using a Radiative Transfer model. The ratio defined as measured

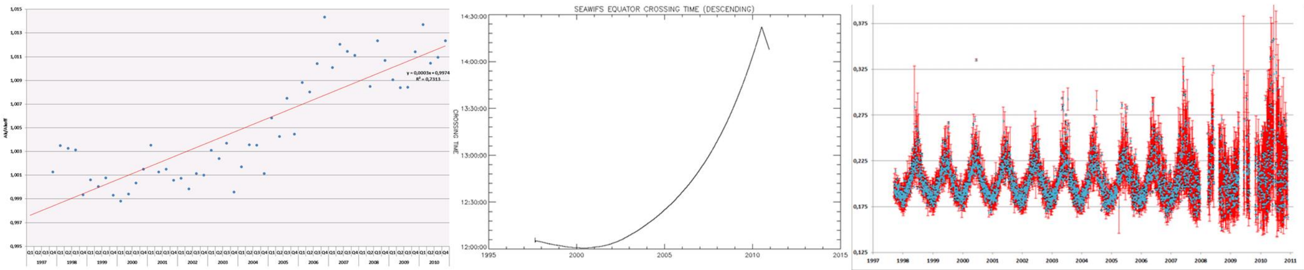
signal / simulated signal (called $\Delta A_k = A_k/A_{k\_ref}$), allows to estimate the absolute calibration difference from the reference one. The following general formula is used to calculate the TOA reflectance:

$$\rho_{TOA}(\theta_s,\theta_v,\Delta\varphi) = T_g(\theta_s,\theta_v).\left[\rho_{atm}(\theta_s,\theta_v,\Delta\varphi) + \rho_w(\theta_s,\theta_v,\Delta\varphi).\frac{T(\theta_s).T(\theta_v)}{(1 - s.\rho_w)}\right]$$

Absolute calibration results obtained for SeaWiFS have shown:

- A very high stability of the reference calibration: Quarterly absolute coefficients ratios ΔA_k are close to 1 for all spectral bands and throughout the SeaWiFS life;
- A very low scattering of the ΔA_k with a standard deviation always lower than 0.018;
- A decrease of the ΔA_k scattering with the increase of the spectral bands: standard deviation is lower in the red band than in the blue band;
- No correlation of ΔA_k vs. several analysed parameters: date, sun and viewing geometry, measured radiance, aerosol optical thickness, wave angle, wind speed, atmospheric pressure, ozone content, geographic location, et.

Concerning the ΔA_k temporal evolution we observe an averaged increase of 1 to 1.5% throughout the mission life and for all spectral bands. ΔA_k are particularly stable until 2004 and increase from 2005. This trend is all the more obvious that the spectral band increases.



(Left) Temporal evolution of $\Delta \boldsymbol{A_k}$ from top to bottom: 670 nm; (Centre) SeaWiFS equator crossing time drift; (Right) Temporal evolution of mean daily TOA reflectances at 412 nm over the PacSE area (selected observations)

The ΔA_k temporal increase is very close to the accuracy of the Rayleigh method and different contributors could explain such a small effect (aerosol, etc.). However, the impact of the orbit node drift is a potential lead to investigate. Indeed, the node-crossing time is stable and close to noon until 2004 and changes rapidly to reach ~14:30 in 2010. The viewing geometry change resulting from this orbit node drift leading to a larger scattering angle range, could impact absolute calibration results. Figure 8 shows the temporal evolution of mean daily TOA reflectances at 412 nm for SADE observations selected over South-East Pacific area. We note the regularity of the reflectances on the first half of the mission life time and the larger and larger scattering of the measurements from 2005, explained by the viewing geometry change. An accurate error budget study needs now to be carried out in order to identify the main impacting sources of errors.

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Comparison between MERIS and Regional High-Level Products in European Seas

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Summary

Standard ocean color data products from the Medium Resolution Imaging Spectrometer (MERIS) are compared with equivalent regional products determined for European seas exhibiting different bio-optical properties: the northern Adriatic Sea, the Baltic Sea and the Western Black Sea. Comparison results are consistent across the investigated European seas. Findings indicate the relevance of using regional bio-optical algorithms to evaluate standard products as a complement to match-up analysis relying on pairs of in situ and satellite data.

Introduction

In this poster, standard ocean color data products from the Medium Resolution Imaging Spectrometer (MERIS) are compared with equivalent regional products determined for European seas exhibiting different bio-optical properties: the northern Adriatic Sea, the Baltic Sea and the Western Black Sea (ADRS, BLTS and BLKS, respectively). Investigated quantities are those relevant to optically complex waters: 1) the algal-2 pigment index, alg2; 2) the composite absorption coefficient of yellow substance and non-pigmented particles at 442nm, a_{dg}; and 3) the concentration of Total Suspended Matter, TSM. Regional data products are created using Multi Layer Perceptron (MLP) neural nets [1] trained with field measurements from the Coastal Atmosphere and Sea Time Series (CoASTS) [2, 3] and Bio-Optical mapping of Marine Properties (BiOMaP) programs [4].

Discussion

Case-2 water data products addressed in this study are MERIS alg2, a_{dg} and TSM values generated with MEGS 8.0. These quantities have been compared with equivalent regional products computed with MLPs trained using BiOMaP and CoASTS field measurements (e.g., Figure 1). Applied methods include the revision and integration of former schemes for the identification of the applicability of regional algorithms [5], the retrieval of pigment index values [6] and the assessment of data products [7]. Data product comparisons based on selected ROIs have shown consistent results in all investigated regions. Specifically, MERIS alg2 values overestimate the output of regional algorithms. An underestimate is instead observed for a_{dg}. MERIS TSM values are lower than MLP products in ADRS and BLKS, while a slight overestimate is reported for BLKS. The convergence between MERIS and regional products is hence significantly better for TSM than for alg2 and a_{dg}. These assessments are in agreement with independent findings exclusively based on match-ups of satellite and in situ data [8].

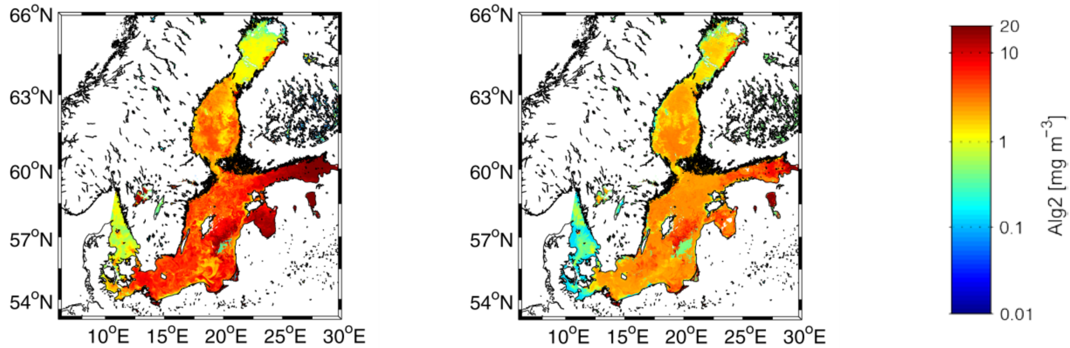

Figure 1 Example of alg2 product maps for the Baltic Sea. MERIS standard product and corresponding result from the application of the regional MLP are in the left and right column panel, respectively.

Conclusion

By presenting a comprehensive framework for the development, performance assessment, verification of applicability and products comparison, this poster intends to emphasize the feasibility and strategic importance of using regional algorithms to timely evaluate operational space mission results as a cost-effective complement to match-up analyses. Underpinning elements are the maintenance of programs to collect high-quality field measurements and the development of regional ocean color inversion schemes with defined ranges of applicability. The relevance of these recommendations is fully in line with accuracy requirements in optically complex waters of recent and forthcoming space sensors (e.g., VIIRS and OCLI).

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The Pre-Aerosol Clouds and ocean Ecosystems Mission – PACE

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The PACE mission relies on a combination of satellite remote sensing, field measurements (e.g. ship, mooring, and drifter), Earth system modeling, and synthesis efforts designed to address specific science questions. At the core of the PACE mission is a satellite-based optical sensors designed to provide the most advanced hyperspectral visible (VIS) and short-wave infrared (SWIR) observations ever collected of the world's pelagic and coastal ecosystems. This advanced Ocean Color Imager will provide scientific and societal benefits that cannot be achieved by any other satellite ocean sensor.

The PACE mission has been designed to address the following Ocean Ecology and Biogeochemistry questions. Table 1 shows measurements and mission requirements needed to address the science question.

SQ1: What are the standing stocks, compositions, and productivity of ocean ecosystems? How and why are they changing?

SQ2: How and why are ocean biogeochemical cycles changing? How do they influence the Earth system?

SQ3: What are the material exchanges between land and ocean? How do they influence coastal ecosystems and biogeochemistry? How are they changing?

SQ4: How do aerosols influence ocean ecosystems & biogeochemical cycles? How do ocean biological & photochemical processes affect the atmosphere?

SQ5: How do physical ocean processes affect ocean ecosystems & biogeochemistry? How do ocean biological processes influence ocean physics?

SQ6: What is the distribution of both harmful and beneficial algal blooms and how is their appearance and demise related to environmental forcing? How are these events changing?

SQ7: How do changes in critical ocean ecosystem services affect human health and welfare? How do human activities affect ocean ecosystems and the services they provide? What science-based management strategies need to be implemented to sustain our health and well-being?

Conclusions: The PACE mission will provide significant advancements in Ocean Ecology and Bigeochemistry research. In essence, the hyperspectral capabilities of PACE permits an unprecedented global spectroscopy from space that will open many opportunities for Earth Systems Science research that yield new discoveries and unique applications.

Table 1. List of threshold measurement requirements as specified by the PACE Science Definition Team Report[1]

Threshold Requirements

Orbit	• sun-synchronous polar orbit • equatorial crossing time between 11:00 and 1:00 • orbit maintenance to ±10 minutes over mission lifetime
Global Coverage	• 2-day global coverage to solar zenith angle of 75º • mitigation of sun glint • multiple daily observations at high latitudes • view zenith angles not exceeding ±60º • mission lifetime of 5 years
Navigation and Registration	• pointing accuracy of 2 IFOV and knowledge equivalent to 0.1 IFOV over the full range of viewing geometries (e.g., scan and tilt angles) • pointing jitter of 0.01 IFOV between adjacent scans or image rows • spatial band-to-band registration of 80% of one IFOV between any two bands, without resampling • simultaneity of 0.02 second
Instrument Performance Tracking	• characterization of all detectors and optical components through monthly lunar observations through Earth-viewing port • characterization of instrument performance changes to ±0.2% within the first 3 years and maintenance of this accuracy thereafter for the duration of the mission • monthly characterization of instrument spectral drift to an accuracy of 0.3 nm • daily measurement of dark current and observations of a calibration target/source, with knowledge of daily calibration source degradation to ~0.2%
Instrument Artifacts	• Prelaunch characterization of linearity, RVVA, polarization sensitivity, radiometric and spectral temperature sensitivity, high contrast resolution, saturation, saturation recovery, crosstalk, radiometric and band-to-band stability, bidirectional reflectance distribution, and relative spectral response • overall instrument artifact contribution to TOA radiance of <0.5% • initial image striping of < 0.5% & correction for image striping to noise levels or below • crosstalk contribution to radiance uncertainties 0.1% at L_{typ} • polarization sensitivity of ≤1% and knowledge of polarization sensitivity to ≤ 0.2% • no detector saturation for any science measurement bands at L_{max} • RVVA of <5% for the entire view angle range and by <0.5% for view angles that differ by less than 1º •Stray light contamination < 0.2% of L_{typ} 3 pixels away from a cloud • out-of-band contamination of <0.01 for all multispectral channels • radiance-to-counts relationship characterized to 0.1% over full dynamic range (from L_{typ} to L_{max})
Spatial Resolution	• Global spatial coverage of 1 km x 1 km (±0.1 km) along-track
Atmospheric Corrections	• retrieval of $[\rho_w(\lambda)]_N$ for open-ocean, clear-water conditions and standard marine atmospheres with an accuracy of the maximum of either 5% or 0.001 over the wavelength range 400 – 710 nm • two NIR atmospheric correction bands comparable to heritage, one of which is centered at 865 nm • NUV band centered near 350 • SWIR bands centered at 1240, 1640, and 2130 nm
Science Spectral Bands	• 5 nm spectral resolution from 355 to 800 nm • complete ground station downlink and archival of 5 nm data.
Signal-to-noise	• SNR at L_{typ} of 1000 from 360 to 710 nm; 300 @ 350 nm; 600 @ NIR bands; 250, 180, and 15 @ 1240, 1640, & 2130 nm
Data Reprocessing,	• full reprocessing capability of all PACE data at a minimum frequency of 1 – 2 times annually.

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1-NASA-PACE Science Definition Team Report - 2012
http://decadal.gsfc.nasa.gov/pace_documentation/PACE_SDT_Report_final.pdf

A remote sensing approach for linking the historic 2011 Mississippi River flood to wetland sedimentation on the Delta

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Summary

We use field calibrated satellite data to quantify differences in sediment-plume patterns between the Mississippi and Atchafalaya River, and to assess the impact of these extreme outflows on wetland sedimentation. We show that a focused, high-momentum jet emerged from the leveed Mississippi, and delivered sediment far offshore. In contrast, the plume from the Atchafalaya was more diffuse; diverted water inundated a large area, and sediment was trapped within the coastal current.

Introduction

Wetlands in the Mississippi River deltaic plain are deteriorating in part because levees and control structures starve them of sediment [1]. In spring 2011 a record-breaking flood brought discharge on the lower Mississippi River to dangerous levels. To relieve pressure on levees along the downstream portion of the Mississippi River in New Orleans, the Morganza Spillway was opened for the first time in almost 40 years. 3500m^3 s^{-1} of water was being diverted into the Atchafalaya Basin, flooding the swamps and marshes along the entire length of the Atchafalaya River. Although both the Mississippi River and Atchafalaya River channels had obvious sediment-laden plumes emanating from their mouths, the differences in plume patterns and extent of inundation were striking.

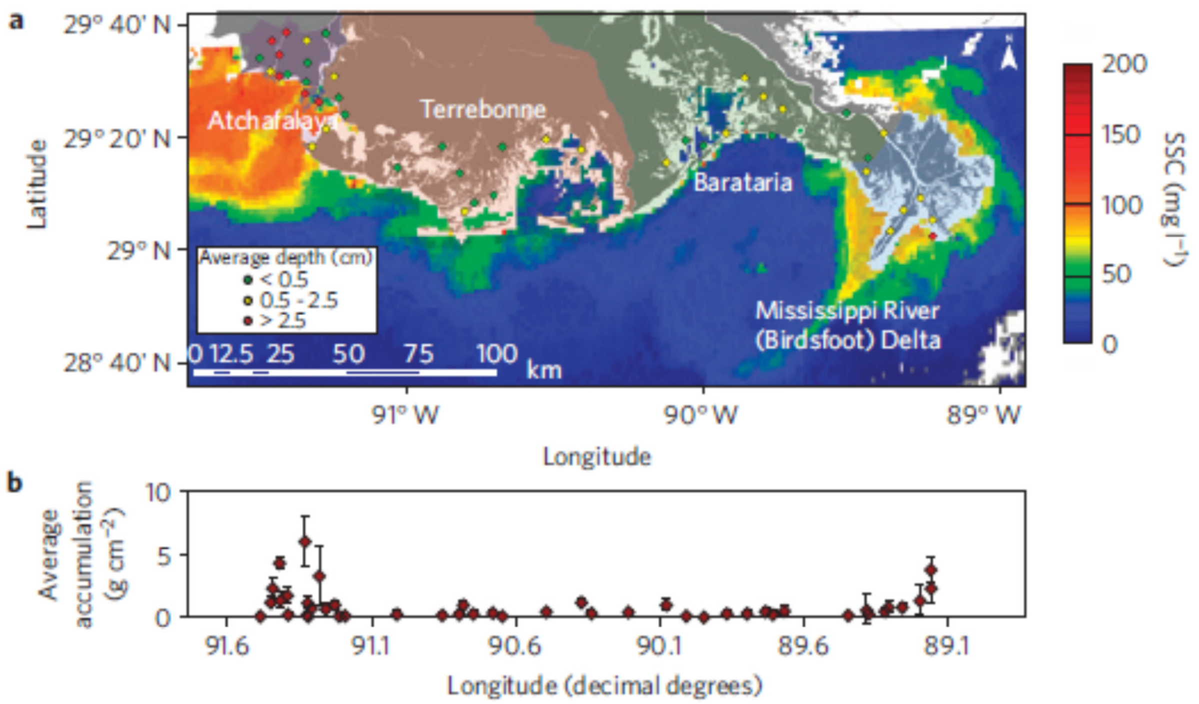
We performed time-series analysis of suspended sediment concentration (SSC) from MODIS satellite data, calibrated using field measurements. Satellite SSC data were obtained using processed Level-1A products by following a procedure for estimating suspended load from remote-sensing reflectance high-resolution band 1 at 645 nm [2]. To investigate the Mississippi River plume dynamics during this extraordinary event, and to calibrate satellite data, we also carried out oceanographic transects off the Mississippi Delta during the peak of the flood. Moreover, we conducted a sedimentation survey of 45 sites by helicopter across the Mississippi Birdsfoot, Barataria, Terrebonne and Atchafalaya basin wetlands.

Discussions

The Mississippi River, whose floodwaters upstream were completely contained within artificial levees, exhibited narrow and focused jets of sediment-laden water, especially from Southwest Pass, which penetrated the coastal current with limited mixing for the duration of the flood. The intentionally flooded Atchafalaya Basin inundated a ~100-km-wide coastal zone, and sediment from its broad plume seemed to be trapped in the nearshore zone for four weeks, where it thoroughly mixed with marine waters. The sedimentation survey confirmed a greater wetland sedimentation over a broad area in the Atchafalaya Basin, from both direct deposition by floodwaters and indirect deposition through coastal reworking of the plume. Our analysis suggests that river-mouth hydrodynamics influenced sediment deposition patterns during the spring 2011 flood.

Conclusions

The historic Morganza Spillway opening simulated a more natural flooding scenario in the Atchafalaya River: this diffuse plume-influenced by coastal currents and winds-delivered substantial sediment over a broad area, both directly to wetlands through inundation and to the nearshore zone where tides and currents could potentially carry it onshore. Although the Mississippi River carried a larger sediment load than the Atchafalaya River, it produced less sedimentation. Flow confinement promotes delivery of vast quantities of sediment far offshore, where it cannot build a land platform to support wetlands. If the Mississippi River plume was diffuse, its sediments would probably have been carried shoreward with the coastal current to produce substantial deposition at Barataria and Terrebonne. Our work shows how fine sediments carried in a flood and diverted to shallow marine settings could contribute substantially to marsh sedimentation.



Spatial distribution of sediment during the 2011 flood. ***a****, Locations, and measured recent sediment accumulation, from shallow cores along the delta shoreline (circles), merged with a map of remote sensing SSC on 1 June 2011.* ***b****, Recent sediment accumulation at each sampling site.*

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Overview of NASA's Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission

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The science objectives and technical requirements for the coastal ecosystems component of the Geostationary Coastal and Air Pollution Events (GEO-CAPE) mission will be presented. GEO-CAPE is a Tier 2 Earth Science Decadal Survey mission recommended by the U.S. National Research Council (NRC) in 2007 that focuses on measurements of tropospheric trace gases and aerosols and aquatic coastal biogeochemical properties from geostationary orbit (35,800 km altitude; Fishman et al. 2012). The main advantage afforded by an ocean color radiometer on a geostationary platform versus a low-earth polar orbit is the capability to image the same regions multiple times per day. Such a capability is necessary to study coastal oceans where the physical, biological and chemical processes react on short time scales from seconds to a few days. From a geostationary vantage point, a sensor can stare at an instantaneous field-of-view (iFOV) to gain sufficient signal-to-noise to retrieve ocean reflectance during low light conditions (early morning and late afternoon) and at high satellite view angles (e.g., high northern or southern latitudes). Compared to open oceans, satellite retrievals from coastal waters pose additional challenges including the need for increased signal-to-noise ratios (SNR), correcting for a more complex array of atmospheric constituents (absorbing and non-absorbing aerosols, ozone, nitrogen dioxide, etc.) and difficulties in calibration and validation efforts. Two sets of requirements are presented which represent the minimum (threshold) and fully capable (baseline) mission for achieving the stated science objectives. Current technological and financial realities weigh heavily on the requirement recommendations such that a mission with achievable science objectives and feasible sensor capabilities has been put forward.

A SATELLITE NET PRIMARY PRODUCTION (NPP) ALGORITHM FOR THE SOUTHERN OCEAN BASED ON A VARIANT OF THE VGPM FRAMEWORK - PERFORMANCE EVALUATION AND TIME-SERIES APPLICATIONS

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Summary

We present a synthesis and analysis of Southern Ocean in situ data for chlorophyll a (chl-a) and net primary production (NPP). Due to differentiation in the bio-optical properties of the Southern Ocean, we have developed the OC4ANT chl-a ocean color algorithm and the VGPMANT NPP algorithm. Implications for the quantitative differences between our approach based on a synthesis of data from more than 20 cruises to the Southern Ocean over 15 years, and the standard algorithms developed with low latitude data will be discussed.

Introduction

The Southern Ocean (SO) has bio-optical properties that are differentiated from lower latitudes, as first demonstrated by Mitchell and Holm-Hansen (1991). An alternative Southern Ocean chl-a algorithm has been developed by Mitchell and Kahru (2009; Figure 1A). Behrenfeld and Falkowski (1997) developed the Vertically Generalized Productivity Model (VGPM) for net primary production (NPP) that has proven relatively robust for much of the global oceans at lower latitudes. However, we find that some of the parameterizations of the VGPM NPP algorithm require tuning. Specifically our VGPMANT model differs in the estimate of Zeu from chl-a. We also optimized the estimate of Pbopt from SST. These new revisions were based on data from 12 SO cruises we carried out to diverse parts of the SO resulting in our modified model, VGPMANT. We evaluate VGPMANT using an in situ data set of 672 ship observations of NPP, PAR, chl-a and SST.

Discussion

The differences in bio-optical properties, in particular low concentrations of colored dissolved organic matter (CDOM) and larger phytoplankton with significant pigment packaging lead to differentiation in the reflectance vs chl-a relationship in the Southern Ocean. Backscattering differences are also noted but do not play a large role in the band ratio off sets which are dominated by absorption differences of the Southern Ocean compared to low latitude data sets. This also affects the penetration of PAR and hence the estimated depth of the euphotic zone, a parameter in the VGPM model framework for NPP. Figure 1A summarizes our data and algorithm for chl-a and Figure 1B shows the performance of VGPMANT with a large in situ validation data set we have synthesized.

Applying our algorithms to the Southern Ocean satellite time series reveals that the standard algorithms can underestimate chl-a and NPP by up to a factor of 2. OC4ANT performs better than the original VGPM and several other models we have tested. We apply OC4ANT and VGPMANT to time-series of the SO with a primary focus on the Drake Passage region. Major interannual variations in NPP will be discussed in relation to regional forcing including sea ice and bathymetry-steered circulation of the Drake Passage.

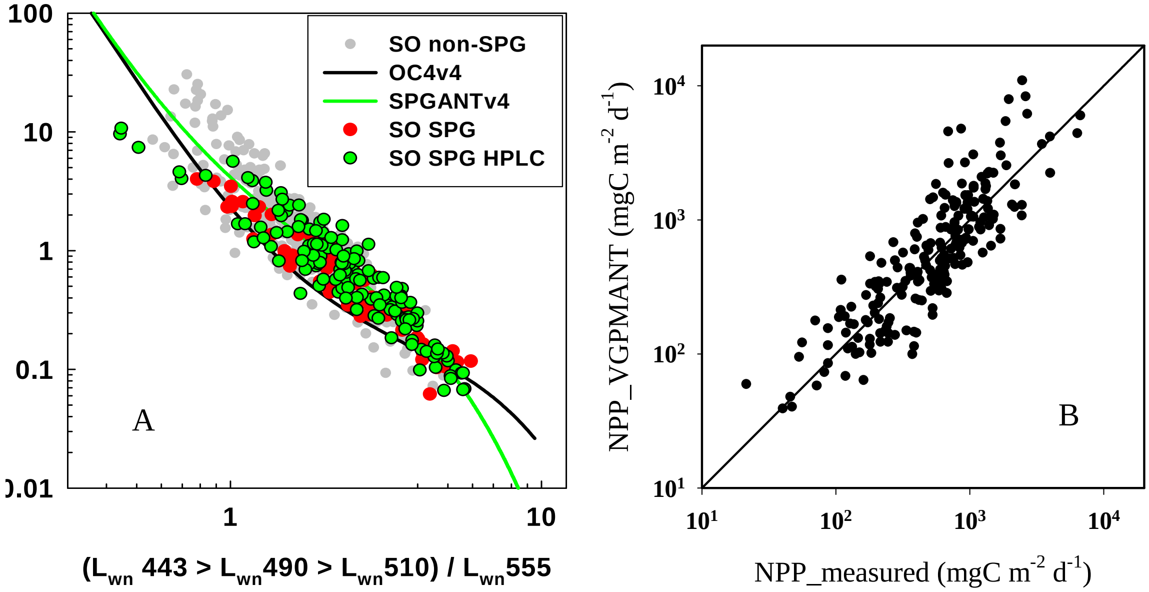

Figure 1. **A.** Chlorophyll plotted vs an OC4 Maximum Band Ratio for our Southern Ocean data (red fluorometric chl-a, green HPLC chl-a) and NOMAD Southern Ocean data from other groups (gray). The black line is NASA standard OC4v4 fit and the green line is our OC4ANT fit to our data sets. There is large divergence with the NASA standard underestimating chl-a by up to 2-3x for chl-a values in the range 0.5-5 mg m^3. **B**. Net primary production (NPP) measured at sea using 14C bicarbonate methods (our data merged with data of Saba et al. 2012) compared to the estimate using our VGPMANT algorithm. Our VGPMANT has slope of 1 and almost no bias compared to in situ data and agreed better than the standard VGPM or other models we tested with our merged in situ validation data set.

Conclusions

Using a synthesis of optics, chl-a and NPP data from more than 20 cruises over 15 years, we validate the original concepts of bio-optical differentiation in the Southern Ocean reported first by Mitchell and Holm-Hansen (1991) . The data are used to develop OC4ANT and VGPMANT, Antarctic variants of the classic maximum band ratio approach for chl-a (OC4) and VGPM for NPP. There is a need to explore how best to implement these Southern Ocean algorithms in global processing of ocean color data.

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GCOM-C SGLI calibration and characterization

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Summary

Evaluation tests of the Engineering Model (EM) of the Second-generation Global Imager (SGLI) on the Global Change Observation Mission (GCOM) is being reviewed in this winter-spring. The tests included radiometric gain, linearity, spectral response, stray light, polarization sensitivity, geometric characterization and so on. Manufacturing of the Pre-Flight Model (PFM) reflects the results of EM design and its evaluation. SGLI has multiple on-board calibration methods using a solar diffuser, LED lamps, a thermal black body, and monthly pitch-maneuver operation for the lunar observation at the same phase angle.

1. SGLI sensor system and onboard calibration system

The Second-generation Global Imager (SGLI) on the Global Change Observation Mission -Climate (GCOM-C) is a multi-band optical imaging radiometer in the wavelength range from 380nm to 12000nm. It consists of two main components, the Visible and Near Infrared Radiometer (SGLI VNR) and the Infrared Scanning Radiometer (SGLI IRS) [1].

SGLI VNR is a push-broom scanning type radiometer (Fig. 1). VNR Non-Polarized observation sub unit (VNR-NP) has 11 bands in the wavelength range from 380nm to 865nm [2] with 250-m spatial resolution and 1150-km cross-track swath covered by three telescopes. Other two telescopes are mounted on the tilting bench (+/-45 degrees along track) and dedicated for the polarized light observation at two bands of red and NIR (VNR-PL). SGLI IRS is a whisk broom type scanner with a 45deg-folded scanning mirror rotating for 1400-km swath.

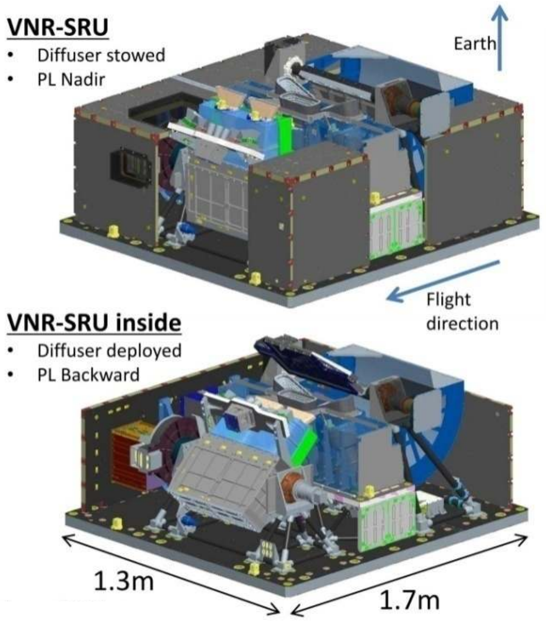

Figure 1 SGLI VNR sensor design. The calibration diffuser is deployed in the lower figure. Cited from [3].

SGLI-VNR has multiple on-board calibration functions, diffuser for solar irradiance and lamp (LED) calibration. SGLI-IRS also has a diffuser illuminated by the sun and lamps (LED and halogen), black body (for thermal infrared bands), and deep space window. Maneuver observation is planned for evaluating BRDF of the solar diffuser after the launch. SGLI is planned to see the moon at a constant phase angle monthly by pitch maneuver of GCOM-C satellite [3].

2. Pre-launch calibration and characterization

Sensor characterization (development of a sensor model) and radiometric gain calibration will be conducted by the similar way that has been done for the evaluation tests of EM [4].

(1) Gain calibration
Radiometric gain including non-linearity at each pixel (VNR and IRS) and scan angle (IRS) by using the integration sphere which have to be traceable to the national standard through transfer instruments, e.g., spectro-radiometer and blackbody radiators.

(2) Signal to noise ratio (SNR)
SNR at the standard radiance level (depend on application targets) is evaluated in the optical tests. Noise of the dark target is also evaluated. SNR and dark noise will be monitored by the lamp calibration data both before and after launch.

(3) Spectral response
Spectral response of band-pass filters and the total optical system will be measured. Field-Of-View (FOV) dependence of the line filters are carefully measured and characterized [2].

(4) Polarization sensitivity
Polarization sensitivity is measured at several points in the FOV for each band and sensor components, IRS and each telescope of VNR.

(5) Stray-light
Stray-light is often to be one of the serious problem for the imager. It can be caused by scatterings in the telescope and around the focal plane. Quantitative characterization and correction model will be investigated.

(6) Geometric model
The geometric model depends on the sensor geometric design and optical characteristics. It will be measured in the pre-launch tests and revised after launch by the GCP matching analysis. The GPS receiver and the star-tracker will be used for the geometric (position and angle) correction on orbit.

3. Calibration strategy integrating the calibration functions/methods

Multiple ways are planned for the SGLI calibration after launch. SGLI calibration team will use the solar-diffuser as the main calibrator, and lamp data for checking the launch shift, and moon observation for monitoring long-term change [3]. Vicarious adjustment will be conducted over both the land and the ocean, and the results will be compared to the on-board calibration methods and other satellite sensors in cooperation with international community and CEOS Cal/Val groups.

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NASA Science Team Assessment of S-NPP VIIRS Ocean Color Products

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Summary

Following the picture perfect launch of the Visible Infrared Imaging Radiometer Suite (VIIRS) aboard the Suomi National Polar-orbiting Partnership (S-NPP) spacecraft, the NASA S-NPP Science Team began an evaluation of the mission's ocean color data products to determine whether they could continue the existing NASA ocean color climate data record (CDR). To support this evaluation, evaluation products were generated using existing computation infrastructure at Goddard Space Flight Center and also at NOAA, the former having independent calibration and full, mission-level reprocessing capabilities. Members of the science team also investigated the use of algorithms for VIIRS that were not being applied operationally, including those that generated standard products for the Earth Observing System (EOS). Now, with over a year's worth of data, we present our assessment of both the operational ocean color data products and the NASA and NOAA evaluation data.

Introduction

VIIRS is being used by NOAA to routinely generate measurements of the Earth's surface and atmosphere, which are referred to as Environment Data Records (EDR). The ocean color EDR includes normalized water-leaving radiance, inherent optical properties (absorption and phytoplankton backscatter coefficients, *a* and b_b, at five wavelengths) based on an algorithm developed by Carder et al. [1], and chlorophyll *a* concentration using the three channel version of the empirical algorithm developed by O'Reilly et al. [2]. The science team needed to determine whether the NOAA ocean color EDR products would meet NASA science objectives, including continuity of the existing climate data record (CDR) established with earlier NASA ocean color missions, including the Sea-viewing Wide Field of view Sensor (SeaWiFS) and the MODerate resolution Imaging Spectroradiometer (MODIS) aboard the EOS satellite Aqua. Team members at the NASA/Goddard Space Flight Center (GSFC) evaluated the EDR products against NASA evaluation products, which were based on standard NASA ocean color algorithms, an independent calibration, and were generated with existing computational infrastructure with a full, mission-level reprocessing capability. Meanwhile, another team member (Wang) also compared the EDR products against those generate with NOAA research algorithms, based on the same standard NASA algorithms and the operational calibration. That investigation also looked at estimation of the diffuse attenuation coefficient at 490nm (i.e., $K_d(490)$), which is not part of the EDR suite, and the potential use of the VIIRS Shortwave Infrared (SWIR) bands to improve atmospheric correction over coastal waters.

Other members of the science team pursued data collection for product validation and for parameterization of other algorithms not currently in the operational processing stream. Data products considered that are part of NASA data record included an estimate of Particulate Inorganic Carbon (PIC) by Balch and an estimate of Photosynthetically Available Radiation (PAR), by Frouin. Experimental algorithms were also explored using *in situ* data. Gregg investigated a novel application that looked to improve the consistency of the chlorophyll *a* record using data assimilation. Siegel compared performance of the Garver, Siegel, Maritorena (GSM) semi-analytic model for VIIRS and MODIS in optically complex waters.

Discussion

The independent evaluation processing at GSFC demonstrated that a consistent, high quality color data could potentially be generated from S-NPP VIIRS using evaluation reprocessing. Indeed, the NASA evaluation chlorophyll *a* concentration from VIIRS agrees remarkably well with MODIS Aqua (see Figure 1). Likewise, VIIRS shows promise in supporting EOS standard products, such as PIC, PAR, and K_d(490). Validation analysis showed that operational and research evaluation surface reflectance showed relatively good comparisons with *in situ* data matching spatial and temporal criteria. However, biases in the radiometry, which a smaller than the uncertainty of the *in situ* regression analysis, are still sufficiently large to negatively impact the quality of the operational chlorophyll *a*.

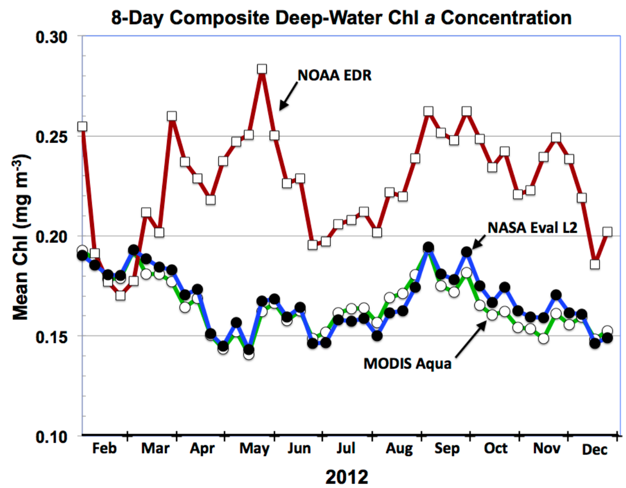

Figure 1 Comparison of Chlorophyll *a* Times Series - Averages were taken from 8-day global composites where depth was >1000m and bins existed for VIIRS EDR, evaluation products and for MODIS Aqua.

Conclusions

Operational and NASA evaluation surface reflectance are reasonable when compared with *in situ* data, however closer investigation indicates the significant biases still exist for the operational product and that this adversely affects derived product quality. Evaluation products show traditional EOS products currently not operationally carried by S-NPP can be generated can be continued with S-NPP at a quality level that is comparable to the NASA CDR. The first year of operational data demonstrates that reprocessing is critical to producing consistent and highly accurate VIIRS ocean color products required for continuity of the NASA CDR.

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