International Ocean Colour Science Meeting 2013

Advancing Global Ocean Colour Observations

SUBMITTED ABSTRACTS

Topical Area

Applications, user services and tools

Applications, user services and tools

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Issues related to ocean colour in coastal zones and inland waters

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A review is presented of the principal challenges facing application of ocean colour radiometry to coastal and inland waters, focusing on the ecological, bio-optical and algorithmic aspects. Several example ecosystems are used as illustration: systems that encompass much of the ecological and optical complexity from global coastal and inland water bodies currently suitable for ocean colour application. These are the highly productive Benguela upwelling system, the tidally-dominated North Sea with variable sediment influence, the highly-stratified Baltic showing gelbstoff-rich waters and periodic cyanobacterial blooms, the large meso- to hyper-trophic Lake Erie, and the very small hypertrophic Hartbeespoort Dam in South Africa. A preliminary ecological review is conducted to determine the main temporal scales of variability concerning physical/biogeochemical drivers and biological response and impact. The range in optical complexity of the systems in time and space is also reviewed. The two analyses are used to provide a brief summary of the ocean colour user requirements needed to resolve ecological variability of the systems from the event scale upwards. Useful conceptual frameworks for harmful algal bloom observations, as a major application across coastal and inland water types, are discussed.

More detailed analyses are then used to spectrally characterise the range of water types seen across this diversity of systems - waters dominated by different eukaryotic and prokaryotic phytoplankton functional types at oligo-mesotrophic to hypertrophic biomass; and waters strongly influenced by both suspended sediment and gelbstoff at similar ranges of phytoplankton biomass. Spectral clustering and principal component analyses on hyper-spectral reflectance and associated inherent optical properties from recent publications and work in progress are used. These spectral signal analyses show how the main signal-carrying wavelengths shift to the green – NIR range at high biomass, the resultant importance of the fluorescence and 709 nm bands, and the need to consider the combined effects of reflectance shape and magnitude changes in waters with considerable scattering from both phytoplankton and non-algal particles.

Coupled inherent optical property/radiative transfer models, using optical models of equivalent algal populations and the Ecolight radiative transfer model, are then assessed and used to extend this study more systematically. Causal effects of IOPs on reflectance are considered across trophic ranges; phytoplankton functional types determined by assemblage size, pigment type and vacuole content; and effects of non-algal particles and gelbstoff. Model output is used to more systematically identify key spectral shifts in reflectance, isolate effects of IOP variability, and summarize the diversity in optical properties of coastal and inland waters. A brief summary is then made of the atmospheric

correction issues facing ocean colour use in coastal and inland waters: highly turbid waters, optically complex atmospheres and the need for alternative atmospheric corrections algorithms; and the problems of adjacency and geo-registration, particularly for small water bodies.

Focus is then shifted to community needs for more effective use of ocean colour radiometry in coastal and inland water types. There is a compelling need for more validation data, and standardized methods of data acquisition. Some of the major challenges confronting the acquisition of radiometric and other bio-optical data in turbid and hypertrophic waters are examined, such as significant sub-pixel variability, and instrument/ data processing issues in highly attenuating waters. The need for new bio-optical protocols for such water types, and perhaps new conceptual models for resolving spatial and temporal mismatch, is highlighted. The major advantages and potential disadvantages of synthetic data sets are also assessed, with particular regard to the need for adequate simulation of the natural covariance amongst primary constituents, and appropriate numerical simulation of phytoplankton biodiversity, succession and bio-volume related abundance.

Examples of algorithm options for coastal and inland waters are considered. Several algorithms that bypass the need for aerosol correction in hypertrophic waters are presented, and are used to discuss the advantages of phenological approaches to ocean colour based ecological analyses. Examples of other algorithm types are discussed: empirical, semi-analytical and coupled neural network approaches. The opportunities for system-transferable algorithms and algorithm structures are presented through spectral classification algorithms, with examples from both the global ocean and coastal/inland waters to demonstrate the scalable nature of this approach. The benefits of class- vs regionally-based approaches to algorithm selection and application are briefly discussed.

Finally, the sensor and programmatic outlook for ocean colour application in coastal and inland waters is summarised, with a focus on the user systems needed to maximize the value of forthcoming ocean colour constellations.

GMES-PURE:

SHAPING THE MARINE GMES/COPERNICUS USER REQUIREMENTS

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Summary

The Copernicus/GMES Marine Core Service (MCS) as currently implemented by MyOcean-2 will become operational in 2014. Recently, the European Commission (EC) has started the two-year project called GMES-PURE (Partnership for User Requirements Evaluation), to define and apply a structured process (see Figure 1) for the elaboration of the future MCS user requirements and their translation into service specifications, service data and technical requirements. While the focus for service data requirements is on space observations, high-level data requirements for in-situ observations will be captured and delivered as well. GMES-PURE constitutes a unique opportunity for MCS users to ensure that their current and emerging requirements are captured in time and to influence the future evolution of the MCS. The establishment and maintenance of long-term user driven operational services requirements and related coherent service specifications include a weighing of evolving user needs, scientific and technological capabilities, cost-effectiveness and affordability. This presentation will explain GMES-PURE approach and roadmap and how users can get and will be involved in the project.

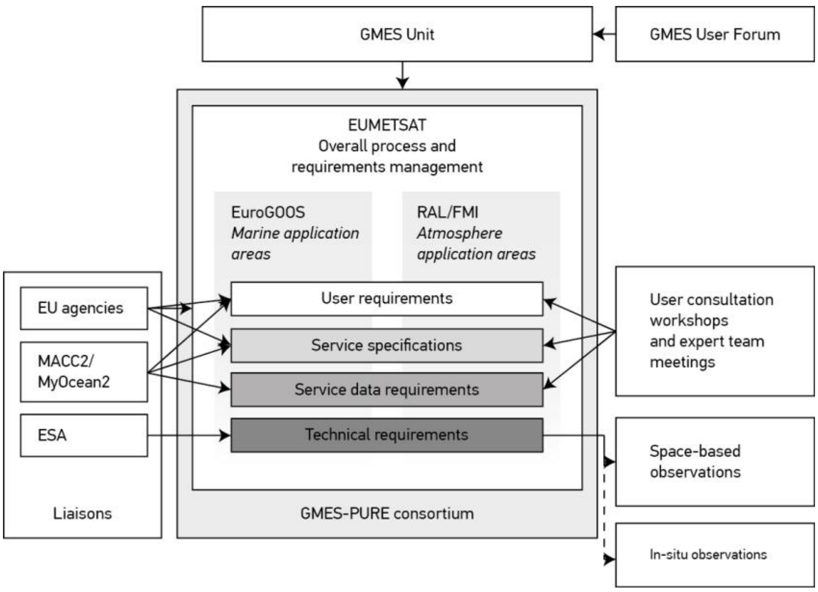

Figure 1 Overview of the GMES PURE project structure.

Use of Ocean Color Derived Products to Constrain and Optimize a Global Ocean Biogeochemistry Model as Part of NASA's Carbon Monitoring System Flux Project

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Summary

NASA's Carbon Monitoring System (CMS) Flux Project is characterizing the evolution of global carbon sources and sinks based on satellite and in situ observations and on numerical models. As part of the CMS Flux Project, the ECCO2-Darwin ocean carbon cycle model aims to estimate the spatiotemporal evolution of air-sea carbon fluxes. ECCO2-Darwin is based on a global, eddying, data-constrained estimate of the time-evolving physical ocean state provided by the Estimating the Circulation and Climate of the Ocean, Phase II (ECCO2) project and on the Massachusetts Institute of Technology (MIT) Darwin ecosystem model. Together, ECCO2 and Darwin provide a time-evolving physical and biological environment for carbon biogeochemistry, which is used to compute surface fluxes of carbon at high spatial and temporal resolution. We describe the ECCO2-Darwin ocean carbon cycle model and present preliminary results on the adjustment of initial biogeochemistry conditions and gas exchange coefficients using a Green's function approach. We carried out 11 model sensitivity experiments modifying initial fields of dissolved inorganic carbon, alkalinity, and oxygen, as well as gas exchange coefficients and other biogeochemical model parameters. Data constraints include primary production estimates derived from ocean color remote sensing data, in situ observations of carbon dioxide partial pressure (pCO_2), the Takahashi air-sea CO_2 flux atlas, and an estimate of the global mean air-sea CO_2 exchange. An optimized linear combination of the different initial conditions and exchange coefficients was obtained using a least-squares minimization. Integrating the model with this new set of initial conditions and exchange coefficients yields more realistic estimates of air-sea carbon fluxes. There remain, however, regions that require further improvement, for example, in the Southern Ocean.

Introduction / Model Description and the Initialization Problem

The components of the global carbon cycle interact through fluxes between the carbon reservoirs on our planet: atmosphere, land, oceans, and the geosphere. Understanding the exchange processes between these reservoirs requires knowledge about these fluxes. As there is no global scale observation network in place that could provide these flux estimates, we need to combine existing observations with models to compute them indirectly. To achieve the most realistic results, models can be constrained by observational data, especially global space-based observations that provide information about the physical and biological state of the land, atmosphere, or ocean. The goal of the NASA CMS Flux Project is to utilize the full suite of NASA data, models, and assimilation capabilities in order to attribute changes in the atmospheric accumulation of carbon dioxide to spatially resolved fluxes. The oceanic component of these fluxes is of critical importance as it is estimated that the oceans have absorbed 48±9% of the anthropogenic CO_2 emitted during 1880–1994 [1]. The current oceanic CO_2 uptake is estimated to be about a quarter of the anthropogenic emissions [2]. The ECCO2-Darwin model provides spatially resolved oceanic CO_2 fluxes constrained by observations of the physical ocean and ship-based CO_2 measurements for the CMS project. The ocean fluxes serve as a priori surface forcing for the ``top-down'' atmospheric flux estimates in the CMS project.

Model initialization is a difficult challenge when setting up high-resolution Ocean Biogeochemistry General Circulation Models like ECCO2-Darwin. Long integrations that reduce model drift are not practical because of computational cost. In the ocean, where circulation is slow compared to the atmosphere, it can take thousands of (model) years to reach an equilibrium state. Another problem associated with long spin-ups is model drift, that is, the increasing biases between the model simulation and nature. For short model integrations that circumvent these drift issues and allow high resolution and model complexity, choosing initial conditions therefore becomes a critical issue. The availability of oceanic data at any given point in time chosen to be the model's starting point is extremely limited. To solve this initialization problem for all biogeochemical quantities simultaneously and to avoid producing unrealistic air-sea carbon flux estimates, we use a simple, physically-consistent data assimilation approach based on model Green's functions, that is, on forward model sensitivity experiments [3].

Implementation and Results

Out of a large number of possible combinations of parameters and model sensitivity runs we choose seven runs that differed in their initial conditions, the piston velocity formulation used, and the ratio of particulate inorganic to particulate organic carbon. The data constraints we used for an initial optimization of our results included in situ surface pCO_2 data [4], the Takahashi air-sea CO_2 flux atlas, and an estimate of the global mean air-sea CO_2 exchange. The optimized model simulation yielded substantial cost (that is, data-model mismatch) reductions. In a second step we expanded our data constraints to observed full-depth profiles of dissolved inorganic carbon and alkalinity (see Fig.1) as well as ocean color derived primary production (Vertically Generalized Production Model, VGPM) [5]. Initial results indicate that these constraints improve our air-sea fluxes further. Still, some critical regions for improvement persist, for instance, regions of overly strong carbon uptake in the Southern Ocean and weak outgassing the Equatorial Pacific.

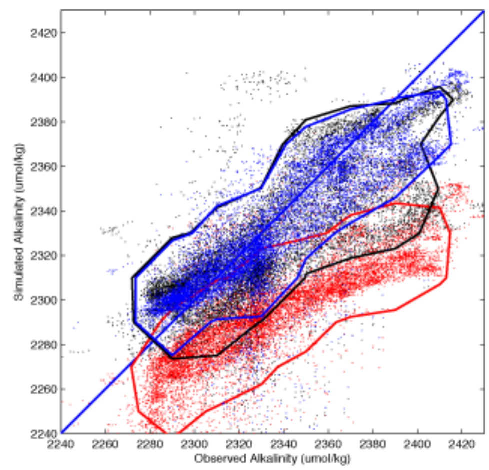

Fig. 1: Data-model comparison, initial run (red), using only pCO_2 (black), and pCO_2, DIC, and alkalinity (blue) as constraints. The contour lines denote regions where scatter plot density is greater than 0.5 points per ppm^2.

References

[1] Sabine, C.L., Feely, R.A., Gruber, N., Key, R.M., Lee, K., Bullister, J.L., Wanninkhof, R., Wong, C.S., Wallace, D.W.R., Tilbrook, B., Millero, F.J., Peng, T.H., Kozyr, A., Ono, T., Rios, A.F., 2004. The oceanic sink for anthropogenic CO2. Science 305, 367–371.

[2] Le Quéré, C., Takahashi, T., Buitenhuis, E.T., Rödenbeck, C., Sutherland, S.C., 2010. Impact of climate change and variability on the global oceanic sink of CO_2. Global Biogeochemical Cycles 24, GB4007, 10pp.

[3] Menemenlis, D., Fukumori, I., Lee, T., 2005a. Using green's functions to calibrate an ocean general circulation model. Monthly Weather Review 133, 1224–1240.

[4] Takahashi, T., Sutherland, S., Kozyr, A., 2011. Global Ocean Surface Water Partial Pressure of CO2 Database: Measurements Performed During 1957-2010 (Version 2010). Technical Report ORNL/CDIAC-159, NDP-088(V2010). Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy. Oak Ridge, Tennessee.

[5] Behrenfeld, M.J. and Falkowski, P.G., 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnology and Oceanography 42, 1-20.

Observed dominance of submesoscale features to subtropical chlorophyll

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Summary

We apply the surface quasi-geostrophic (SQG) to newly-available cloud-free high-resolution satellite sea surface temperature data and modeled interior state to show that sub-mesoscale physics have a strong impact on surface chlorophyll. In the oligotrophic North Atlantic Subtropical Gyre (NASG), as the resolution increasing from 25km to 10 to 1km leads to a factor of three of increase in the chlorophyll found in coherent vorticies, but a factor of five increase in the chlorophyll found in oceanic fronts. This enhancement is due to the revelation of small-scale frontal dynamics at high resolution. These dynamics are associated with density and vorticity gradients around and between vorticies. This is the first direct observational evidence that pervasive sub-mesoscale frontal structures that are associated with the bulk of chlorophyll in the oligotrophic subtropical oceans; and strong evidence that submesoscale frontal upwelling is the missing link that can close the nutrient budget of the NASG.

Introduction

Mesoscale eddies at O(10-100)km have received considerable attention in plankton patchiness studies after Jenkins [1] brought the relative importance of vertical flux of nutrients due to mesoscale eddies to the forefront. The strong influence of the currents is apparent in the eddy and filamental structures traced out by satellite ocean color. However, there is no agreement on mesoscale eddies' contribution to nutrient injection and many studies point to the issue of spatial resolution of numerical models [2-4]. Mahadevan and Archer[5] performed high-resolution modeling experiments. They reported up to a factor of three increase in primary productivity when model resolution was increased from 40km to 10km in an oligotrophic region. Increasing numerical resolution from 6 km to 2 km led to a doubling of the primary production in the model of Levy et al.[6]. This increase is due to the resolution of intense vertical velocities (typically 10-100 m/d compared to mesoscale eddies of 1-10 m/d), captured within filaments of strong vorticity gradients which surround eddies or which are ejected by the eddies.

Satellite altimeters do not resolve the sub-mesoscale of O(1-10) km and our knowledge of mesoscale and sub-mesoscale influence on phytoplankton ecology is almost exclusively derived from numerical simulations, which it is clearly not yet possible to provide effective eddy parameterizations. This study, different from previous approach using eddy-permitting numerical models, takes advantage of newly-available high-resolution satellite SST data and MODIS chlorophyll data, to directly estimate how much chlorophyll is found in mesoscale eddies as opposed to submesoscale fronts.

Results

In the North Atlantic study region (28^{o}N~38^{o}N, -75^o W~ -45^{o}W), 20-30% of the chlorophyll that is associated with mesoscale eddies when including the contribution from eddy edges (~20%). If surface chlorophyll is linearly related to primary production, this is an upper bound of mesoscale eddies' contribution to nutrient flux that ultimately drives that productivity and much less than the estimated contribution of eddies core from previous numerical modeling. As resolution increases from 25km to 1km, numerous fronts with a high temperature gradient (>0.6 C°/km) and vorticity gradient emerge at the center of subtropical gyre, mainly between the edges of submesoscale eddies, indicating that eddy-eddy interaction can generate intense fronts [7-8].

Frontal filaments are further parsed into warm and cold fronts based on resolved flow fields, as relative vorticity is negative on the warm side of the front and positive on the cold side. In the whole region, chlorophyll within positive-vorticity filaments are ~2.3 times higher than within negative-vorticity filaments at mesoscale, while comparable (~1.1) at submesoscale. This result suggests that regions of high phytoplankton are principally concentrated along the thin negative vorticity filaments as resolution increasing. This finding is largely consistent with results from the numerical simulations of Levy et al [6]. In their submesoscale experiment with no wind forcing, they found that strong injections of nutrients and high chlorophyll concentrations are concentrated on the negative vorticity side when density gradients along the front are growing. However, they also found high chlorophyll on the positive side when density gradients are decaying, a phenomena that we do not find in our analysis.

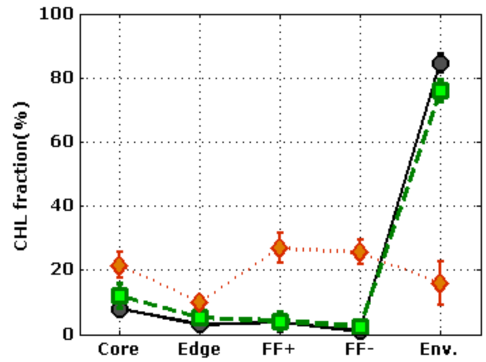

Figure 1. Additional contribution of eddies core, eddies edge, fronts of positive vorticity (FF+), fronts of negative vorticity (FF-) and the remaining environment to total chlorophyll field by increasing the flow resolution from 25km to 10km to 1km within the entire region. Mean and standard deviations are plotted, by repeating the experiments at four different random days with good satellite chlorophyll coverage: Jun 23,2010, Sep 1, 2010, Oct 12, 2010 and Mar 17, 2011.

Conclusion

This study has focused on the impact of meso and sub-mesoscale physics on surface phytoplankton patchiness, which is related with new production and an indications of nutrient fluxes in the oligotrophic oceans. Results from high-resolution satellite observations reveal that the sub-mesoscale physical features are associated with more than 1/2 of chlorophyll concentrations across the North Atlantic subtropical gyre. Consistent with the results of previous numerical studies, this is the first direct observational evidence of the significant impact of mesoscale physics on surface ocean productivity.

References

[1] Jenkins, W. J. and Goldman, J. C. (1985). Seasonal oxygen cycling and primary production in the Sargasso Sea. *J. Mar. Res.* **43,** 465

[2] Oschlies A. (2002a). Can eddies make ocean desert blooms? *Glob. Geochem. Cycles* **16,1830**

[3] Oschlies A. (2002b). Nutrient supply to the surface waters of the north atlantic: a model study. *J. Geophys.* Res.107:275

[4] McGillicuddy, D. J., Anderson, L. A., Doney, S. C. and Maltrud, M.E. (2003). Eddy-driven sources and sinks of nutrients in the upper ocean: Results from a 0.1 degree resolution model of the North Atlantic, *Global Biogeochem. Cycles,* **17(2),** 1035.

[5] Mahadevan, A. and Archer, D. (2000). Modeling the impact of fronts and mesoscale circulation on the nutrient supply and biogeochemistry of the upper ocean. *J. Geophys. Res.* **105,** 1209–1225

[6] Levy, M., Klein, P. and Treguier, A.M. (2001). Impact of submesoscale physics on production and subduction of phytoplankton in an oligotrophic regime, *J. Mar. Res.,* **59,** 535–565

[7] Levy, M., Ferrari, R., Franks, P.J.P, Martin, A.P. and Rivière, P. (2012). Bringing physics to life at the submesoscale, *GRL frontier article,* **39,**L14602

[8] Lima, I. D., Olson, D. B., and Doney, S. C. (2002). Biological response to frontal dynamics and mesoscale variability in oligotrophic environments: Biological production and community structure, *J. Geophys. Res.,* **107(C8),** 3111.

Development of the Next Geostationary Ocean Color Imager (GOCI-II) in Korea

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Summary

The development of GOCI-II, the successive mission of GOCI, was started in the late 2012. Major Enhanced performance requirements of GOCI-II are around 250m GSD(Ground Sampling Distance) with 13 spectral bands, and newly implemented Full Disk observation coverage. GOCI-II is expected to increase the applicability of ocean remote sensing products with increased data accuracy and addition of new products such as PFT.

Introduction

After the successful launch and operation of Geostationary Ocean Color Imager(GOCI) [1], necessity of succession of GOCI mission, ocean environment monitoring with ocean color, is highly increasing into ocean color remote sensing users in Korea as well as international users.

As a successor of GOCI mission, development of GOCI-II was started in 2012 and is planned to be launched in 2018.

Discussion

The mission and user requirements of GOCI-II are defined by Korea Institute of Ocean Science & Technology (KIOST) and domestic and international GOCI PI(Principal Investigator)s. GOCI-II has two nominal observation modes; FD (Full Disk) which can observe nearly full Earth disk area (East-West direction: inside 60 degrees at latitude, North-South direction: inside 60 degrees at longitude) on 128.2˚E longitude in Geostationary Earth Orbit (GEO), with 1km GSD (Ground Sampling Distance) at Nadir, and LA (Local Area) of which observation region can be freely definable by the user with 250m GSD at Nadir with 30 minutes imaging time and 1 hour interval. The scheduled LA observations are 10 times per day with 1 hour interval. The number of daily LA acquisition time is increased from 8 to 10 comparing with GOCI. The major enhancements of GOCI-II are around two time better GSD than GOCI's GSD and implementation of FD observation with 13 spectral bands. The comparison of performance requirements between GOCI and GOCI-II is summarized in Table 1. Additional 4 spectral bands and a dedicated wideband (presumably panchromatic band) for INR processing will be added to improve the accuracy of data products such as chlorophyll concentration, total suspended sediments, and dissolved organic matters, and to have a novel capability such as PFT(Phytoplankton Functional Type). GOCI-II has a plan to implement the user-definable local area observation mode to satisfy the user requests such as ocean observation over clear sky without clouds and special ocean event area. We are expecting this new capability will produce more applicable data products about special event area such as typhoon, oil spill, green algae bloom, and etc. These enhanced features will enable the monitoring and research of long-term ocean environment change with better image quality. For the research of long-term climate change in ocean, FD observation with one time per day is planned for nominal operation plan of GOCI-II.

Requirements	GOCI	GOCI-II

Mission life time	7.7 years	≥ 10 years
Reliability	≥ 0.85 @ EOL	≥ 0.85 @ EOL (7 years)
Duty Cycle (LA)	8 times / 1day	10 times / 1day
Duty Cycle (FD)	-	1 time / 1day
Observation Time	LA : ≤ 30 min	LA : ≤ 30 min FD : ≤ 240 min
Spatial Resolution	500m (LA)	effective GSD (LA) ≤ 250m (@ 130E, 0N) effective GSD (FD) ≤ 1,000m (@ 130E, 0N)
Spectral Range	400nm – 900nm	370nm – 900nm
# of Spectral Bands	8 (VIS/NIR)	13 (VIS/NIR, Wideband for INR)
SNR	> ~1,000 @ nominal radiance	≥ ~1,000 @ nominal radiance
MTF	> 0.3 (NS/EW) @ Nyquist frequency	> 0.25 (NS/EW) @ Nyquist frequency (Payload) > 0.10 (NS/EW) @ Nyquist frequency (System)
Inter-Slot Radiometric Discrepancy	-	≤ 0.2%
Band Center Wavelength Accuracy	± 0.5 nm	≤ ± 2.0 nm (≤ ± 0.5nm for band center at 680nm)
Radiometric Accuracy	≤ 4 % (over Saturation Radiance) ≤ 5 % (over Max. Cloud Radiance)	≤ 3 % (on ground before launch) ≤ 4 % (in orbit)
Out of band Response	≤ 1.0 %	≤ 1.0 %
Polarization	< 2 %	≤ 1.5 % (≤ 3.0 % for B1 (380nm))
Straylight	-	≤ 1.0 % (LA, ground processing)

Table 1 The summary of comparison of performance requirements between GOCI and GOCI-II

Conclusions

The international co-development of GOCI-II payload is planned to be started from June, 2013. Joint Development Team which consists of KARI (Korea Areospace Research Institute), KIOST and satellite development company outside Korea takes in charge of GOCI-II development. Dedicated ground station and data processing S/W for the operation of GOCI-II will be established or developed by 2018

Reference

[1] Joo-Hyung Ryu, Hee-Jeong Han, Seongick Cho, Young-Je Park, and Yu-Hwan Ahn (2012). Overview of Geostationary Ocean Color Imager(GOCI) and GOCI Data Processing System(GDPS). Ocean Sci. J. 47(3):223-233.

Application of Geostationary Satellite Images to the monitoring of dynamic variations

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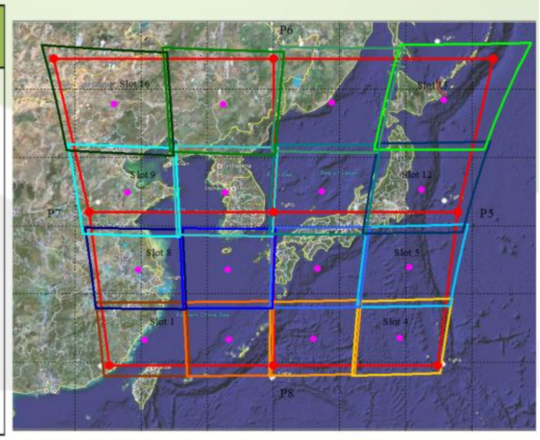
Summary

The primary advantage of the Geostationary Ocean Color Imager (GOCI), the world's first geostationary ocean color observation satellite, over other ocean color satellite imagers is that it can obtain data every hour during the daytime, allowing ocean monitoring in near real time. Here, we introduce and investigate various applications using GOCI to monitor the dynamic variations that are observed in the coverage of GOCI, in particular in the west coast of Korean peninsula along with land part applications.

Introduction

The Geostationary Ocean Color Imager (GOCI) is the world's first ocean color observation satellite placed in a geostationary orbit. GOCI was launched in June 2010 for near real-time monitoring of marine environments in northeast Asia with a 500-m spatial resolution. GOCI covers the 2,500 x 2,500 km square around Korean peninsula centered at 36°N and 130°E and is comprised of sixteen (4x4) slot images. GOCI has six visible bands with band center 412 nm, 443 nm, 490 nm, 555 nm, 660 nm and 680 nm, and two near-infrared bands with band center 745 nm and 865 nm [1]. Unlike the existing polar-orbit satellites, GOCI can gather data every hour from 10 a.m. to 5 p.m. local time (eight times per day) around the Korean Sea [2]. This temporal resolution of GOCI is very efficient for ocean environmental analysis. A more detailed time-series monitoring is possible for the spread and movement of a red tide, SS, DOM and other polluting materials. GOCI also has higher radiometric, spectral resolution and temporal resolution, so that more precise processing of the atmosphere for aerosol type analysis, yellow dust and cloud detection is feasible [3]. Moreover, some land applications including vegetation management, forest fire, heavy snowfall and inland flood detection and monitoring are also possible.

Band	*Central wavelengths*	*Band Width*	*Primary Application*
B1	412 nm	20 nm	Yellow substance and turbidity
B2	443 nm	20 nm	Chlorophyll absorption maximum
B3	490 nm	20 nm	Chlorophyll and other pigments
B4	555 nm	20 nm	Turbidity, suspended sediment
B5	660 nm	20 nm	Baseline of fluorescence signal, Chlorophyll, suspended sediment
B6	680 nm	10 nm	Atmospheric correction and fluorescence signal
B7	745 nm	20 nm	Atmospheric correction and baseline of fluorescence signal
B8	865 nm	40 nm	Aerosol optical thickness, vegetation, water vapor reference over the ocean



Spectral Bands Characteristics and primary applications of each band along with the target area of GOCI

Applications of GOCI

GOCI can be employed to investigate dynamic variations in the coastal water properties, in particular, in an environment affected by semi-diurnal tides such as the west coast of the Korean Peninsula. GOCI was effectively employed to the monitoring of coastal water turbidity variations based on the tidal cycle [1]. These hourly variations in coastal water properties can be basic dataset to develop an algorithm for catching the ocean current movement, i.e. velocity and direction which are crucial information for seawater circulations, fisheries, shipping control, military purpose, etc. in coastal area [4]. Another excellent application of GOCI in terms of the short-term variability is surveillance of waste disposal activity at sea. GOCI could even clearly trace the disposal activity of a sewage sludge disposal ship near-real time for several hours due to its great temporal resolution. Through that hourly-based traceable variability, the ship's cruising speed could also be estimated [5]. Although it is not the oceanic phenomena, sea fog movement can be clearly seen from 1-h interval GOCI images. GOCI-based near real-time monitoring of the sea fog can be greatly helpful for preventing safety accident and supporting fishery activities

Conclusions

The dynamics of ocean properties, especially near the coastal region can be successfully estimated using geostationary satellite images with high frequency like GOCI. To this end, algorithms for atmospheric correction, SSC, Chl and other parameters both in the open ocean and in high turbid water suited for GOCI with high accuracies are inevitable, which is still challenging. These accurate estimates of ocean parameters also make it possible to identify other various dynamic variability which have been impossible with polar-orbit satellite systems; differences in chlorophyll-a distribution before- and after-typhoon, which can be a clue to understand the transformation of ecological environment relating to the natural hazards, sea ice velocities along with its distribution, etc.

Reference

[1] Choi, J.-K., Park, Y.J., Ahn, J.H., Lim, H.-S., Eom, J., & Ryu, J.-H. (2012). GOCI, the world's first geostationary ocean color observation satellite, for the monitoring of temporal variability in coastal water turbidity, J. Geophys. Res., 117, C09004

[2] Cho, S.I., Ahn, Y.H., Ryu, J.H., Kang, G.S. and Youn, H.S. (2010). Development of Geostationary Ocean Color Iamger (GOCI) (Korean ed.). Korean Journal of Remote Sensing, 26(2), 157-165.

[3] Ryu, J. H., J. K. Choi, J. Eom, and J. H. Ahn (2011). Temporal and daily variation in the Korean coastal waters by using Geostationary Ocean Color Imager. Journal of Coastal Research, J Coastal Res, SI 64 (Proceedings of the 11th International Coastal Symposium), 1731-1735.

[4] Choi, J. K., Hyun Yang, H. J. Han, Ryu, J. H. and Park, Y.J. (2013). Quantitative estimation of the suspended sediment movements in the coastal region using GOCI, Proceedings 12th International Coastal Symposium (Plymouth, England), Journal of Coastal Research, Special Issue No. 65, ISSN 0749-0208.

[5] Hong, G. H., D. B. Yang, Hyun-Mi Lee, Sung Ryull Yang, Hee Woon Chung, Chang Joon Kim, Young-Il Kim, Chang Soo Chung, Yu-Hwan Ahn, Young-Je Park, and Jeong-Eon Moon (2012). Surveillance of Waste Disposal Activity at Sea using Satellite Ocean Color Imagers: GOCI and MODIS, Ocean Sci. J., 47(3), 387-394.

Optically black water in Lake Taihu

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Summary

In the summer of 2007, water quality problems associated with masses of "black" water in Lake Taihu, left more than 1 million people in the city of Wuxi without drinking water. Due to its intermittent nature and limited spatial extent, it has not been possible to identify the origin of these water masses. In May 2012, two black water masses were observed in the same area of the lake, allowing us to characterize their optical and biochemical properties and explore possible causes.

Introduction

Lake Taihu, the third largest freshwater lake in China, provides fundamental services to a large surrounding population. Yet it is one of the most severely polluted freshwater reservoirs in China. In the summer of 2007, water quality problems, initially associated with algal blooms, left more than 1 million people in the city of Wuxi without drinking water [1]. Further studies indicated that algal blooms were not the direct cause of problems for Wuxi. The apparent cause was the intrusion of a black water "agglomerate" of unknown origin into the main water intake of the city [2]. No successive black water masses were observed, either in *in-situ* surveys or in the daily satellite based monitoring program that is used to monitor lake water quality. In May 2012, black water masses were observed in the same area of the lake during regular *in-situ* bloom monitoring activities. Field measurements were made immediately to determine the optical and biochemical properties of two of these black water masses. These data provided an opportunity to gain a further understanding of: 1) their optical characteristics; 2) the possible causes of their intermittent occurrence; and 3) the possibilities for optical detection by remote sensors. To the best of our knowledge, this is the first study to address the occurrence of black water masses using optical methods.

Discussion

The color perceived by the human visual system depends largely on the total radiance incident

Role of optical constituents in setting in water and water leaving optical properties

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Summary

We present results from a global three-dimensional numerical model coupled to new irradiance module that captures the spectral absorption and scattering properties of water, phytoplankton, detritus and coloured dissolved organic matter (CDOM). We use the model as a tool to explore the sensitivity of the light field, and the feedbacks on the ecosystem and primary production, when we remove or modify the spectral properties of the optical constituents. For example, we show that higher absorption of CDOM strongly favouring some species, significantly altering community structure.

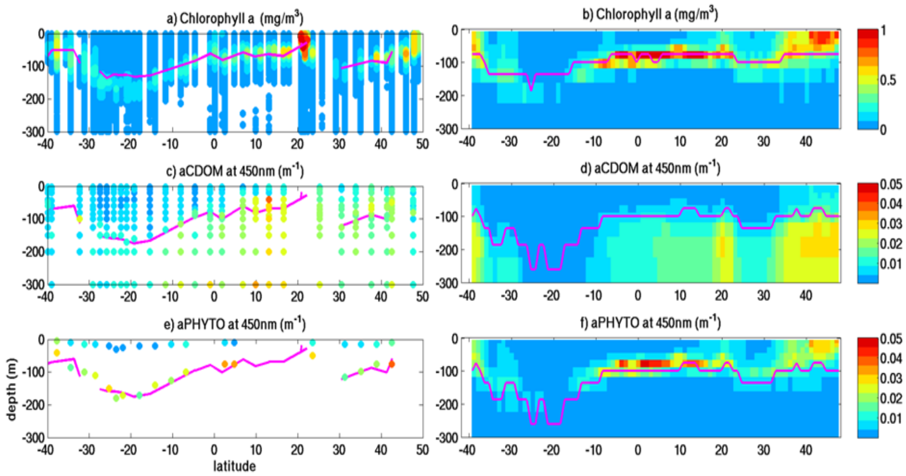
Introduction

Though crucial to understanding autotroph productivity, traditionally, marine ecosystem models have employed extremely simple models of downwelling, integrated photosynthetically available radiation (PAR). The resolution of radiative transfer in the water column and inherent optical properties of the particles (including phytoplankton) and dissolved matter will provide a more mechanistic representation of the light field and enables a closer connection between modeled and remotely measured properties. As a result, spectrally-resolving radiative transfer schemes have recently been implemented in some global ocean models [1,2]. Here we couple an irradiance model to our existing global biogeochemical/ecosystem model [3,4] and use the model to explore the consequences of different assumptions about the spectral properties of the optical water constituents for primary production, community structure and surface reflectance.

Model Description and Evaluation

The water-column radiative transfer model is based on the code of Ocean-Atmosphere Spectral Irradiance Model (OASIM [1]), but with an exact solver. PAR is represented as three streams (downward direct and diffuse, and upwelling irradiance) and in the default simulations is resolved in 25nm bands from 400nm to 700nm. Light is absorbed by water molecules, CDOM, phytoplankton (with pigment specific absorption spectra assigned to several different phytoplankton "functional" types), and non-algal particles. The model also includes forward and back-scattering by water molecules, phytoplankton (type specific spectra), and non algal particles. The specification of absorption spectra, and its ecological impact, is documented in [4]. The model qualitatively captures the distribution of chlorophyll-a, phytoplankton light absorption and spectral light penetration observed during the Atlantic Meridional

Transect Programme AMT15 cruise. Surface, spectrally-resolved, upwelling irradiance and reflectance are prognostic in the model, and capture the gradients observed in satellite derived reflectance data.



Atlantic Merdional Transect (AMT) observation and model comparison. (a,c,e) from AMT15 transect (Sep 2004); (b,d,f) current version of MIT ecosystem, biogeochemical, and optical model. (a,b) Chlorophyll a; (c,d) colored dissolved organic matter (CDOM) absorption at 450nm [5], in the model we represent an explicit CDOM-like tracer; (e,f) phytoplankton absorption at 450nm, in the model we resolve 8 phytoplankton types with different absorption spectra. Magenta line indicates 1% light level - in (a,b) for photosynthetically available radiation between 400-700nm; in (c,d,e,f) for 450nm wavelength. By capturing appropriate absorption (and scattering, not shown) in the model we obtain vertical distribution of light and chlorophyll seen in the observations.

Sensitivity Studies

We use the model as a tool to explore the sensitivity of the light field, and the feedbacks on the ecosystem and primary production. We perform a series of sensitivity experiments where we remove or modify the absorption and scattering spectral properties of the optical constituents (water, CDOM, detritus, phytoplankton). First we consider how each component affects PAR penetration and surface reflectance given the same distribution of the various constituents. We then explore how these different experiments evolve in time and feedback on the system. For example, very strong absorption by CDOM favours cyanobacteria over other phytoplankton. Additionally, we assess the difference in ecosystem, productivity, and light penetration with different resolutions of the spectral light field (e.g. broadband versus 25nm bandwidths). These sensitivities are considered both with depth along the AMT-like transect in the model and on the model derived surface reflectance.

References

[1] Gregg, W.W. and N.W. Casey (2007), Modeling Coccolithophores in the Global Oceans. *Deep- Sea Res. II,* 54, 447-477.

[2] Fujii, M., E. Boss, and F. Chai (2007). The value of adding optics to ecosystem models: a case study. *Biogeosciences*, 4, 817-835.

[3] Dutkiewicz, S., B. A. Ward, F. Monteiro, and M. J. Follows (2012). Interconnection of nitrogen fixers and iron in the Pacific Ocean: Theory and numerical simulations, *Global Biogeochem. Cycles,* 26, GB1012, doi:10.1029/2011GB004039.

[4] Hickman, A.E., S. Dutkiewicz, R.G. Williams, and M.J. Follows (2010), Modelling the effects of chromatic adaptation on phytoplankton community structure in the oligotrophic ocean. *Mar. Ecol. Prog. Ser.,* 406, 1-17, doi:10.3354/meps08588

[5] Stubbins, A., G. Uher, C.S. Law, K. Mopper, C. Robinson, R.C. Upstill-Goddard (2006), Open-ocean carbon monoxide photoproduction. *Deep- Sea Res. II,* 53, 1695-1705.

The role of sea surface processes in anchovy larvae distribution in the Strait of Sicily (Central Mediterranean).

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Summary

We present a comparison between anchovy larval survey data and remote sensing data in the Strait of Sicily. We analyze larvae distribution in the Strait with respect to sea surface currents and hydrographic/biogeochemical patterns. We find a strong correlation between the satellite date set, which in turn marks ocean and wind dynamics in the Strait, and the larvae distribution. Our analysis allows for the investigation of cross-shore transport processes of anchovy larvae.

Introduction

The European Anchovy (Engraulis encrasicolus, Linnaeus, 1758) is one of the most important resources of the Mediterranean Sea. The anchovy population off the Mediterranean coasts exhibits a patchy distribution which is not well understood. Moreover, the influence of the environment on such a distribution, and its variability, is poorly known. [1]

The Strait of Sicily, where a robust ichthyoplankton data set is available, represents a particularly appropriate region for investigating the relation among ocean dynamics and anchovy distribution. The Strait is characterized by upwelling regions, fronts, vortices, and filaments. The mean surface circulation is given by the Atlantic Ionian Stream (AIS), a meandering current of Atlantic origin [2]. The AIS climatologically encircles two cyclonic vortices: the Adventure Bank Vortex (ABV) and the Ionian Shelf Break Vortex (IBV), and describes a pronounced anticyclonic meander in between (Maltese Channel Crest, MCC) [2]. The AIS path and variability have consequences for anchovy spawning and larvae distribution [3].

To analyze such a distribution we use ichthyoplankton measurements collected in the Strait during the peak spawning season. These measurements are then paired to remote sensing data such as sea surface temperature (SST), chlorophyll (Chl), primary production, surface wind speed as well as light attenuation, absorption, and particle backscattering coefficients (e.g., K490).

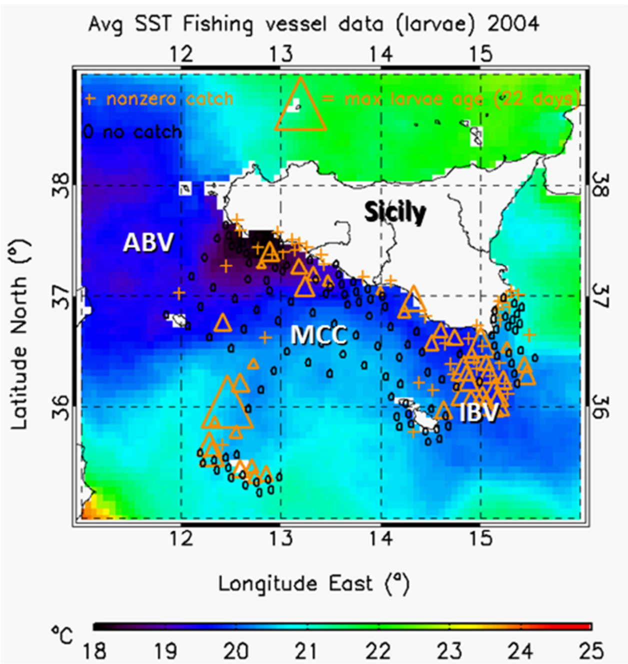
Discussions

All oceanographic patterns that characterize the Strait of Sicily are identified by the cruise averaged SST map: the cyclonic vortices by their cold surface signature and the MCC by the intrusion of warm water to the shore in between ABV and IBV. Both the ABV and the IBV well mark a high presence of larvae, while the higher distribution of samples in the IBV confirms the retention of larvae in the frontal structure originated from the AIS and Ionian Sea water masses interface [3]. In the southern part of the

Channel, we also observe that anchovy larvae laid along a cold belt, a feature that may indicate the important role of mesoscale activity, such as filaments, in delivering larvae cross-shore. Samples were approximately collected in areas characterized by medium values of both Chl and K490. The spawning habitat was generally confined to shelf edges of the Channel. Larvae whose age is greater than 8 days are mostly collected around the south-east end of the coast, confirming that larvae are mainly transported along the Sicilian shelf. However, the presence of 6-8 days old larvae offshore, in the central portion of the Strait, also shows that cross-shore transport processes plays an important role.

Conclusions

The development of environmental indicators that give support to fishery sustainability are becoming an important goal in the marine science community. Our investigation seek to recognize those multidisciplinary data that play a physical based role in building such indicators. Our analysis on the European Anchovy shows and quantifies how the AIS path and variability, as well as the upwelling-induced south Sicilian coastal current, have consequences for anchovy spawning and larvae distribution. Surface currents transport anchovy larvae towards the Sicilian coast's south-eastern tip. However, significant cross-shore transport events due to mesoscale and/or wind-induced activity were also observed. All these dynamics are fairly well recognized by the remote sensing data we used.



Cruise-averaged SST (°C) map, superimposed to ichthyoplankton survey data of anchovy larvae (18 June to 7 July, 2004); triangles are proportional to larvae age; o = no catch, ***+*** *= catch with no larvae size/age measurement*

References

[1] Cuttitta, A., Carini, V., Patti, B., Bonanno, A., Basilone, G., Mazzola, S., Garcia Lafuente, J., Garcia, A. Buscaino, G., Aguzzi, L., Rollandi, L., Morizzo, G. and Cavalcante, C. (2003). Anchovy egg and larval distribution in relation to biological and physical oceanography in the Strait of Sicily. Hydrobiologia 503: 117–120.

[2] Lermusiaux, P.F.J. and Robinson, A.R. (2001). Features of dominant mesoscale variability, circulation patterns and dynamics in the Strait of Sicily. Deep-Sea Res I 48: 1953–1997.

[3] García-Lafuente, J., García, A., Mazzola, S., Quintanilla, L., Delgado, A., Cuttita, A. and Patti, B. (2002). Hydrographic phenomena influencing early life stages of the Sicilian Channel anchovy. Fish. Oceanogr. 11: 31–44.

Ecosystem disruption in the Arabian Sea linked to climate change and the spread of hypoxia

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Summary

The northern Arabian Sea has been witnessing unprecedented blooms of a green mixotrophic dinoflagellate *Noctiluca scintillans* during the winter monsoon. First seen in smaller numbers off Oman, *Noctiluca* blooms have now become more pervasive and widespread throughout the northern Arabian Sea replacing diatoms as the dominant winter-time bloom forming phytoplankton. Here we have used shipboard and ocean color satellite observations to show that the unprecedented appearance of *Noctiluca* blooms may be tied to the influx of oxygen deficient waters into the upper euphotic column and the extraordinary ability of its endosymbiont *Pedinomonas noctilucae* to photosynthesize more efficiently over other phytoplankton under reduced oxygen conditions. We also present examples that demonstrate the promise and potential of ocean color imagery for identifying the origin and dynamics of this unusual bloom, and the long-term implications of these recurrent blooms for carbon cycling in the Arabian Sea.

Introduction

Between 1994 and 1996, the Arabian Sea became the focus of a multinational effort directed at studying ocean biological and physical processes and their links to the global carbon cycle [1,2]. The results of this comprehensive, multi-disciplinary effort known as the Joint Global Flux Study (JGOFS) program provided important indications of the role of the reversal of the monsoons and extremes in wind forcing in causing the greatest seasonal variability of primary production and vertical flux of carbon observed in any of the world's oceans. Since the end of the JGOFS program large-scale field ocean biogeochemical studies in the Arabian Sea have been few. Most contemporary investigations of primary productivity and biogeochemical possesses in the region have based on data collected during small programmatically focused shipboard cruises which have been largely regional in scope [3]. Over the past few years, large basin-scale studies have relied largely on coupled physical-biological models [4] and on satellite based observations [5,6]. Several of these studies have suggested that biological productivity within the Arabian may be on the rise.

In our satellite based study focused on the Arabian Sea using SeaWiFS data alone [5], we were able to conclude that the increase in chlorophyll in the Arabian Sea between 1998 and 2003 was largely the result of a year-on-year increase in summer-time phytoplankton blooms in the western Arabian Sea. With the aid of other satellite data products, we were able to demonstrate that the increase in summer-time phytoplankton blooms was not occurring in isolation but was part of a systematic response to the warming trend over Eurasia. Over the period of nine years of SeaWiFS observations, we were able to observe that the decline in winter and spring time snow over the Himalayan-Tibetan Plateau region associated with the warming trend, was causing a secular increase in the intensity of the SWM winds and upwelling along the coasts of Somalia, Yemen and Oman. We showed that an increase in nutrients resulting from enhanced upwelling was fuelling the year-on-year increase in phytoplankton biomass.

In the present study, we have used satellite data to show that the warming trend is undermining winter cooling in the Arabian Sea. Despite the weakening of convective mixing, satellite data sets reveal that chlorophyll (Chl *a*) concentrations have been on the rise. We have used data from several shipboard studies undertaken in collaboration with colleagues in India that show that the increase in Chl *a* during the winter monsoon is being caused by unprecedented blooms of a mixotrophic dinoflagellate, *Noctiluca.* The presence of a large population of an endosymbiotic prasinophyte *Pedinomonas noctilucae* affords the Arabian Sea *Noctiluca* its green color which making *Noctiluca* easily visible from space. We present some examples that demonstrate the promise and potential of ocean color imagery to provide the necessary temporal and spatial resolution required to identify the origin and dynamics of this unusual bloom.

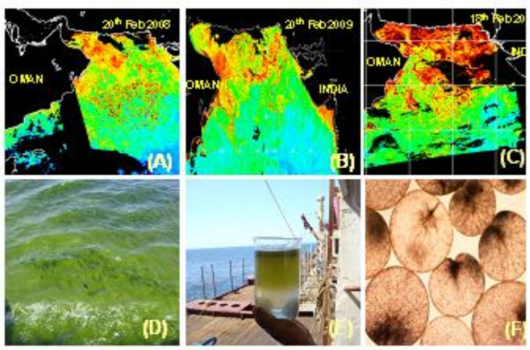

Fig. 1. Spatial extent of Noctiluca bloom as seen in Aqua-MODIS daily chlorophyll images of Feb. A) 2008, B) 2009 & C 2010. D) Blooms as seen from the ship-deck. E) Bucket sample transferred to a glass beaker shows thickness of bloom F) Bloom sample under a microscope showing individual Noctiluca cells.

Conclusions

Shipboard bio-optical measurements have been utilized to show that the large expanse of high Chl *a* seen in ocean color imagery is due to thick, surface dwelling blooms of *Noctiluca*. Large blooms of *Noctiluca* have become a regular feature of the Arabian Sea during the winter monsoon replacing diatoms as the dominant winter-bloom forming phytoplankton. Shipboard ecophysiological studies suggest that the growth of *Noctiluca* to bloom proportions in the open Arabian Sea is being facilitated by an unprecedented influx of oxygen deficient waters into the upper euphotic column. The extraordinary ability of its endosymbiont to photosynthesize more efficiently than other phytoplankton under reduced oxygen conditions also appears to offer *Noctiluca* a competitive growth advantage over other phytoplankton in a region of the world's oceans that appears to becoming increasingly hypoxic. Our observations also suggest that *Noctiluca* blooms may be causing a substantial loss of phytoplankton biodiversity, disrupting the traditional food chain of the Arabian Sea and effecting substantive shifts in carbon export.

References

[1] Burkill, P.H., (1999) ARABESQUE: an overview. *Deep-Sea Research II*, 46, 529-548. *Smith, 2001)*
[2] Goes, J.I., Thoppil, P.G., Gomes, H.do R., Fasullo, J.T., (2005) Warming of the Eurasian landmass is making the Arabian Sea more productive. *Science*, 308, 545-547.
[3] Kahru, M., and B. G. Mitchell, (2008) Ocean Color Reveals Increased Blooms in Various Parts of the World. *Eos Trans., AGU,* 89(18), doi:10.1029/2008EO180002. *Kahru and Mitchell, 2008*
[4] Parab, S., Matondkar, S.G.P., Gomes, H.d.R., Goes, J.I., (2006) Monsoon driven changes in phytoplankton populations in the eastern Arabian Sea as revealed by microscopy and HPLC pigment analysis. *Continental Shelf Research*, 26(20), 2538-2558.
[5] Smith, S.L., (2005) The Arabian Sea of the 1990s: New biogeochemical understanding. *Progress in Oceanography*, 65, 113-115.
[6] Wiggert, J.D., Hood, R.R., Banse, K., Kindle, J.C., (2005) Monsoon-driven biogeochemical processes in the Arabian Sea. *Progress in Oceanography*, 65, 176-213.

Useful tools for geostationary ocean color satellite data processing: GDPS

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Summary

GOCI Data Processing System (GDPS) which is the standard data processing software for GOCI [1] has been improved with its products algorithms and user interfaces following the requests from ocean color colleagues. This software can support 64 bit windows operating system as well as 32 bit. It generates almost GOCI level 2/3 products including the Rayleigh corrected reflectance which is applied into land application and disaster monitoring. Image display/analysis functions are improved and GDPS batch processing functions are introduced for user convenience. GDPS new version install file is provided on the KOSC (Korea Ocean Satellite Center) website. For more reliable GOCI operation and data accuracy enhancements, the atmospheric correction algorithm and each products algorithms in GDPS will be improved continuously.

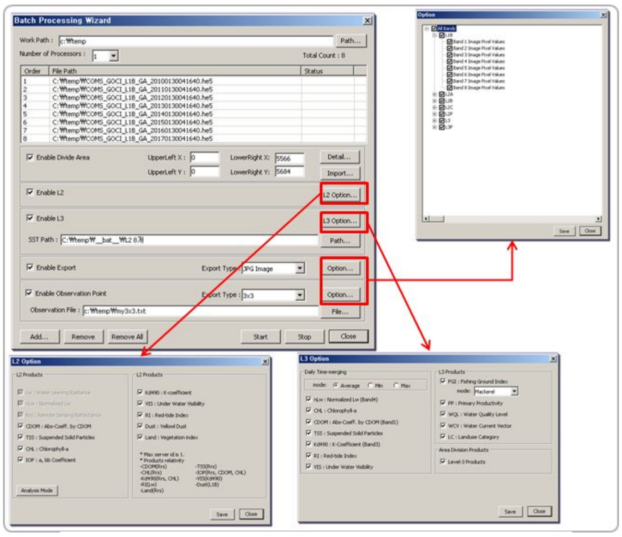
Introduction

GOCI is the world-first satellite to monitor the ocean environmental phenomena on geostationary orbits. For the data processing of GOCI, KOSC provides the GDPS as basic tools including atmospheric correction, L2/ L3 products generation, display, analysis like spectral profile, band math, etc since Sep. 2011. Band new version of GDPS is version 1.2 released in Mar. 2013.
New features of GDPS ver. 1.2 are composed to a. 64bit OS supported GDPS b. new products c. batch processing d. user-friendly interface. 64bit GDPS has improved processing speed and stability and has increasing number of opening windows because of extending memory available. This software can generate GOCI Level 2/3 products not only standard products as water leaving radiance, chlorophyll concentration, total suspended sediments, colored dissolved organic matter but also additional products like red-tide index, primary productivity, water current vector, fishing ground index, yellow dust over ocean, vegetation index, daily composite products, etc. It generates also the Rayleigh corrected reflectance which is applied into land application and disaster monitoring, for example, like green algal spread, oil spill movement. GDPS batch processing function can do various simultaneous works like to subset image, to generate L2, to generate L3, to export other format, to extract pixel information matching to *in-situ* measurement points from several GOCI input files. Improvement of the navigation window which treats displayed area size/location is syncing opening windows. The mouse point information window add the draw point button to show the red cross sign(+) for selected point on display window and arrow button(up, down, left, right) to move the draw point one pixel toward each direction. In data analysis field, spectral profile can overlay 20 points spectrum with conversion option to excel file and image file. Water current vector result can be shown on image display, also.

Discussion

GOCI has high temporal resolution to observe short-term ocean phenomena. Syncing and draw point function is very useful to detect the movement of interested something in time-series images. Draw point works as ground control point for all images opened in GDPS.

For GOCI products algorithm validation, it is necessary to generate match up information for comparison between in-situ measurement data and satellite derived data. If user uses the GDPS batch processing function, he can get match up result text files from all GOCI Level 1B files during in-situ observation periods and observation point information. If someone need to process fishery ground index or primary productivity in L3 processing, he should prepare the sea surface temperature (SST) like GHRSST from NASA Ocean Color web and photosynthetic active radiation (PAR) like MODIS PAR using Import L3 Aux of File menu beforehand. All result of match up point can be extracted with surrounding values by 3x3 or 5x5 and statistical information as minimum value, maximum value, average, standard deviation.



GDPS Batch Processing Wizard

Conclusions

GDPS new version can generates all L2 data. But it still remains many correction and validation work for data accuracy enhancements. This software will be improved consistently in processing algorithms and user interfaces. GDPS will have the functionality to open NOAA SST, MODIS SST, PAR, COMS MI SST to compare with GOCI at once. Also, KOSC will establish GOCI data reprocessing system for composite data generation applied new algorithms.

Reference

[1] Joo-Hyung Ryu, Hee-Jeong Han, Seongick Cho, Young-Je Park, and Yu-Hwan Ahn (2012). Overview of Geostationary Ocean Color Imager(GOCI) and GOCI Data Processing System(GDPS). Ocean Sci. J. 47(3):223-233.

Role of pigments in setting phytoplankton community structure and resulting effects on water leaving radiance

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Summary

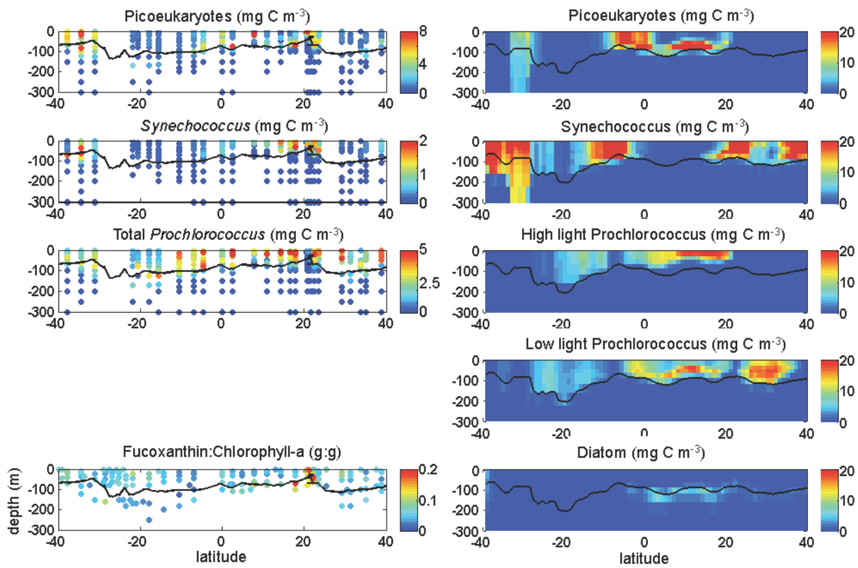
We use a three-dimensional numerical model to explore how the species-specific pigment compositions of marine phytoplankton contribute to setting the observed horizontal and vertical phytoplankton distributions in the global ocean. The optical properties of each of several different phytoplankton "functional" types are prescribed from a representative species in culture [1,2]. We perform a series of sensitivity experiments where we impose uniform absorption spectra, uniform scattering spectra, as well as uniform growth parameters for the different phytoplankton. We find that the specific absorption spectra are very important in determining the competiveness of the different phytoplankton types, the ecosystem structure, and the feedback to biogeochemistry. We also explore the difference in model derived surface reflectance between these sensitivity experiments.

Introduction

Phytoplankton are a key part of the marine microbial community; the primary producers of organic carbon in the ocean, they mediate biogeochemical pathways including the export of organic matter to the deep ocean and ocean carbon storage. Their functional diversity has important biogeochemical implications. Motivated by these factors, recent efforts to observe the biogeography of marine phytoplankton from space, and to model these populations and their biogeochemical activity, have placed emphasis on resolving aspects of this diversity. Intracellular pigments are a key functional trait that differs between plankton types. Here we expand on an earlier study [1] to explore how the chromatic adaptation helps set the global biogeography of different species and assess the impact of the ecosystem optical characteristics on surface reflectance.

Model Description and Evaluation

The model resolves a three-stream radiative transfer of photosynthetically available radiation (PAR, 400-700nm), which is dependent on the spectral absorption and scattering properties of water, phytoplankton, detritus and coloured dissolved organic matter (CDOM). The model is described in more depth in companion abstract "Role of optical constituents in setting in water and water leaving optical properties". The optical properties for each phytoplankton type is prescribed from a representative species in culture [1,2]. Other traits such as growth rate and nutrient requirements are derived from relative size of the different species and from the literature. The phytoplankton types include *Prochlorococcus* (high and low light), *Synechococcus*, a generic pico-autotroph, coccolithophores, diatoms and *diazotrophs*. We evaluate the model against data from the Atlantic Meridional Transect Programme AMT15 cruise. We capture the broad patterns of Chlorophyll-a, the 1% light level and the community structure distribution. In particular we find a well defined vertical distribution of the phytoplankton types. On a global scale the model also compares well to satellite derived products such as Chl-a, PIC, POC as well as the patterns of surface reflectance within the different spectral wavebands.



Atlantic Meridional Transect (AMT) community structure: (left) observation from AMT15 transect (Sep 2004) and (right) from MIT ecosystem, biogeochemical, and optical model. Black line indicates 1% light level for photosynthetically available radiation between 400-700. Flow cytometry data on Prochlorococcus, Synechococcus and a mixed group of picoeukaryotes courtesy of Jane Heywood and Mike Zubkov.

Sensitivity Experiments

We perform a series of sensitivity experiments to assess the role of pigments against other traits in setting community structure. We use the model to explore the mechanisms by which species selection takes place, the feedbacks on biogeochemistry and the impact on surface leaving irradiances. We sequentially impose uniform absorption spectra, uniform scattering spectra, and uniform growth parameters for the different phytoplankton types. When absorption spectra are the only trait that differs between functional groups we find that coccolithophores dominate the ecosystem. When all functional groups have the same optical properties, low light *Prochlorococcus* and pico-eukaryotes dominate. Thus, though important, the chromatic adaptation between species has co-evolved (or is energetically determined) along with their other traits. We find that while the scattering characteristics of the different phytoplankton types are of minimal importance for setting the community structure, they do impact the water leaving irradiances.

References

[1] Hickman, A.E., S. Dutkiewicz, R.G. Williams, and M.J. Follows (2010). Modelling the effects of chromatic adaptation on phytoplankton community structure in the oligotrophic ocean. *Mar. Ecol. Prog. Ser.,* 406, 1-17, doi:10.3354/meps08588

[2] Stramski D., A. Bricaud, A. Morel (2001). Modeling inherent optical properties of the ocean based on the detailed composition of the planktonic community. Appl. Optics, 40, 2929-2945

Multi-sensor ocean color in Greenlandic waters

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Summary

This study spans five years and examine the spring phytoplankton dynamics in relation to break up of sea ice in Disko Bay, West Greenland using Chlorophyll *a* concentrations from satellite and in situ measurements. The in situ data were collected at a monitoring station 1 Nmile south of Qeqertarsuaq from February to June for the years 2008-2012. The satellite data used are Meris data from ENVISAT until April 2012 and Modis data from AQUA for the entire period.

Introduction

Disko Bay is located on the western coast of Greenland at the southern border of sea ice. This makes the bay an ideal test site for investigation of climate impacted changes of the ice plankton dynamics. In a period of five years in situ measurements of chlorophyll *a* have been collected during the spring bloom together with sea ice coverage. It is well documented that spring bloom in ice covered seas is impacted by advection and ice conditions.

These data are compared with satellite chlorophyll a values to extrapolate from point measurements off Disko Bay to the bay proper and thereby get an indication on how the blooms is impacted on bay scale by the changes in ice cover.

The satellite data used are from the medium-spectral resolution imaging spectrometer (Meris) onboard the ENVISAT satellite and the Moderate resolution imaging spectroradiometer (Modis) onboard the AQUA satellite. Both data sets have a resolution of approximately 1 km. The data sets cover the period February – June 2008 – 2012 except for Meris which stopped sending data on April 2012. The satellite data are from the operational setup at DMI covering several areas round Greenland.

Discussion

The sea ice cover is changing due to climate impact. This effects the primary production of phytoplankton. In situ measurements capture the spring bloom very precise but only in points. The spring bloom is intense and lasts for only a few weeks between April and June. After this interval the nutrients has been depleted. The satellites are able to see the spring bloom over a larger area and keep track of the spatial and temporal distribution regardless of the timing of the spring bloom, see Figure 1.

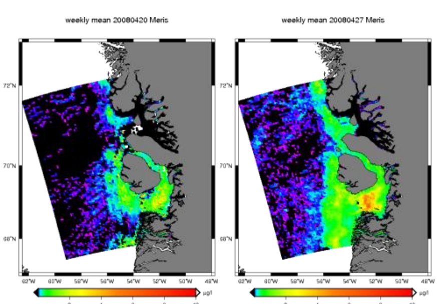

Figure 1Weekly means of satellite data from end April 2008 showing the spatial distribution of primary production

Data Assimilation and Numerical Simulation of Storm Surges Along Bay of Bengal and Bangladesh Coast

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Summary

Bangladesh is situated at the northern tip of the funneling Bay of Bengal (BoB). The long continental shelf, shallow bathymetry, and complex coastal geometry with many kinks and islands with the overall funneling shape of the Bay of Bengal are well-known features of the highest storm surge of the longest duration. IIT Kharagpur Model (2002) for storm surge is used for numerical simulation of storm surges near Orissa, West Bengal, and Bangladesh coasts. High resolution (Δx = 3.7 km, Δy = 3.5 km, Δt = 60 sec) IIT Model has been used for the simulation. Three or six hourly positional data of several severe storms that hit Bangladesh and West Bengal coasts have been used for making gradual changes in the storm surge scenario. A Generic Mapping Tool (GMT) has been employed with a view to imaging surges. 3D view of the peak surges during landfall has also been made by incorporating geo-referenced peak surge data into WinSurfer. Doppler Weather Radar (DWR) Data are used to study the BoB cyclone through 3-dimensional variational (3DVAR) data assimilation technique within the WRF-ARW modeling system. The mean track error at the time of landfall of the cyclone is 66.6 km. The distribution and intensity of rainfall are well simulated by the model as well and were comparable with the TRMM estimates. Using this model, numerical experiments are performed to simulate the storm surge heights associated with past severe cyclonic storms which struck the coastal regions of Bangladesh. The model results are in agreement with the limited available surge estimates and observations.

Introduction

Cyclone Aila-2009 was of moderate intensity it ravaged southwestern part of Bangladesh badly. Alongside it ravaged West Bengal of India, eastern Nepal and southern Bhutan. Due torrential rain these four countries had flooding effects. Advanced Research WRF (ARW) Model with horizontal resolution of 9 km x 9 km, 50s time step and 27 vertical levels has been used to simulate the nature of cyclone Aila and its associated wind, rainfall etc.

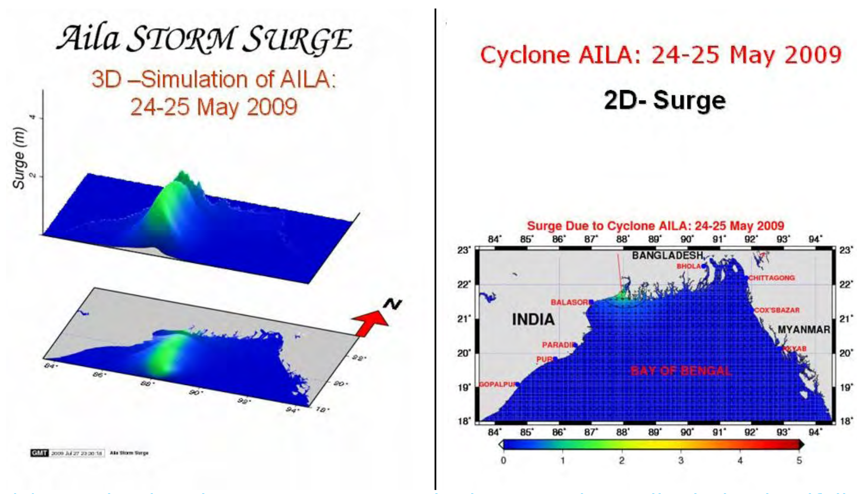
Hydro-dynamical/ Numerical Storm Surge Model with Air Bubble Entrainment is a vertically integrated semi-implicit forward with time, centred with space numerical/ Hydro-dynamical storm surge model based on Indian Institute of Technology (IIT) Model [1]. Entrainment of air-bubble is made in the Model. The required meteorological and hydrological inputs are (1) three hourly storm centres of Cyclone Aila, (2) three hourly radii of maximum winds, (3) three hourly pressure drop and (4) topographic and bathymetric data (USGS ETOPO2). Domain of the Storm surge model is model is 18 - 23°N, 83.5 - 94.5°E with horizontal resolution of 3.7 km x 3.5

km, and time step of 60s. Generic Mapping Tool (GMT) is used for visualization of surge.

Discussion

The strong low level heating and a cooperative positive vorticity in the wind field acts as a triggering mechanism for the initial rise and growth of the thermal energy [2]. Vorticity field moved more or less northwards with the movement of the cyclone and is distorted when the cyclone approached the hilly areas of Nepal, Bhutan and northeast India.

3-D and 2-D storm surge scenarios of Aila during landfall are shown in Fig. (a) and Fig. (b) respectively.



(a) 3-D simulated storm surge scenario due to cyclone Aila during landfall,
(b) 2-D simulated storm surge scenario due to cyclone Aila during landfall.

Conclusions

The tropical cyclone (Aila), developed over the North Indian Ocean, is selected to simulate the characteristics such as structure, intensity and movement. Model simulated rainfall is over estimated over hilly region like Bhutan and neighbourhood and also over West Bengal and Bangladesh except for Chittagong region where it was under estimated. Simulated lowest ECP, before the landfall is 7 hPa higher than observed or satellite derived observations and the maximum simulated wind is 4 m/s lower than the satellite estimated wind. SYNOP, AWS and TEMP data of STORM Field Exp. 2009 and Khepupara DWR Radial Wind have been used in 3DVAR DA (Cold and Warm start). There is some spatio-temporal shift in rainfall which is minimized by 3DVAR DA. Very high resolution topographic data is needed for making better predictions.

References

[1] Debsarma, Sujit Kumar, (2009). Simulations of Storm Surges in the Bay of Bengal, *Marine Geodesy*, 32:2, 178-198.
[2] Mohanty, U.C., M. Mandal and S. Raman, (2004). Simulation of Orissa super cyclone (1999) using PSU/NCAR meoscale model, *Natural Hazards*, 31, 373-390.

Interannual variation of Phytoplankton Production in the southern Benguela upwelling system

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Summary

Satellite-derived SST, Chl*a* and primary production (PP) was investigated in order to describe the large scale spatial and temporal variability in phytoplankton biomass and production rates in the southern Benguela at seasonal and interannual timescales, and to explore the relationship between PP and environmental variability. In general, above-average biomass and PP corresponded to negative SST anomalies that tended to be associated with La Niña conditions. In contrast, positive SST anomalies associated with El Niño conditions generally coincided with below-average biomass and PP.

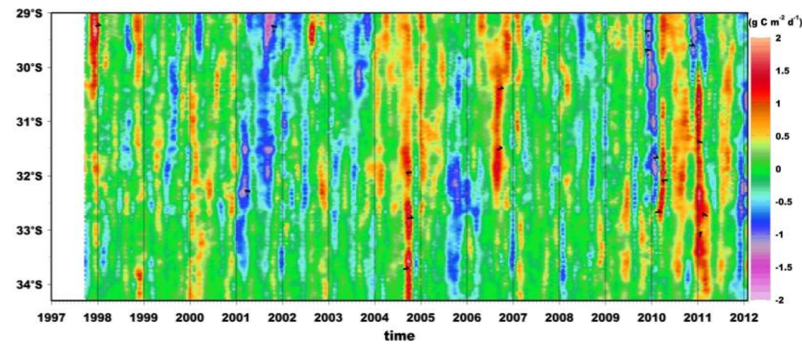
Introduction

The southern Benguela upwelling system is a highly dynamic environment with significant seasonal and interannual variability in oceanography and meteorology which drives the variability in PP. This environment supports a rich pelagic ecosystem, as well as numerous top predators such as seals, gannets and penguins [1]. Understanding the spatial and temporal patterns and trends in PP in the southern Benguela is important for the effective management of the economically and ecologically significant pelagic ecosystem. Warming trends observed in most LME's [2] have resulted in large spatial changes in phytoplankton distribution and a reduction of global PP since the early 1980s [3]. The predicted decrease in global PP has important consequences for the sustainability of fisheries ecosystems like the southern Benguela. The primary aim of this study was to investigate the large scale spatial and temporal variability in phytoplankton biomass and production at seasonal and interannual timescales, and to explore the relationship between PP and environmental variability.

Discussion

Standard monthly-averaged ocean colour data from SeaWiFS and MODIS-Aqua, with a spatial resolution of 9.26 km, was obtained from the OBGP at NASA's GSFC. SeaWiFS data covered the period from September 1997 to June 2002, while MODIS-Aqua data covered the period from July 2002 to February 2012. The VGPM model was applied to the SeaWiFS and MODIS-Aqua data in order to obtain PP estimates [4]. Monthly-averaged SST from AVHRR Pathfinder and MODIS-Aqua, with a spatial resolution of 4 km, was used to explore the relationship between PP and environmental variability. Monthly time series of latitudinally-averaged SST, Chl*a* and PP were constructed along the coast between 29 °S and 34.3 °S, and used to investigate temporal patterns and latitudinal differences. Anomalies were computed by subtracting the monthly climatic mean from each month in the time series.

The seasonal variation in SST was described by higher temperatures during spring and summer, and lower temperatures in autumn and winter. The seasonality in chlorophyll *a* concentrations and PP was generally in phase with periods of maximum upwelling during spring and summer. Throughout the time series, SST varied between 13-21°C and PP typically ranged from 0.5-6 g C m^{-2} d^{-1}. Considerable interannual variations were evident, with the highest summer temperatures being observed during 2002 and 2003, while the lowest were noted in 2006. A clear decreasing trend in the summer maxima is evident for the period from 2003 to 2006. Although the exact timing did not always coincide on a month to month basis, above-average SSTs generally corresponded to El Niño events, while negative SST anomalies were associated with La Niña events. A clear decreasing trend in the maximum summer PP was observed from 1997 to 2003 and again from 2007 to 2010, while PP during 2004 and 2005 was typically above-average and was associated with higher than normal biomass and SST, and also corresponded to a prolonged period of El Niño conditions.



PP anomalies in the Southern Benguela

Conclusions

Over the long term, temporal variations in PP were observed to be larger than the spatial differences. This was opposite to the findings of [5], who showed that spatial variations were generally greater. Similar to the findings of [3], the long term variations in SST, Chl*a* and PP were linked to variations in climate, with increasing temperatures related to a decrease in phytoplankton biomass and PP, and vice versa. These variations are likely to have a significant impact on ecosystem functioning by driving changes in the physiological state of phytoplankton, taxonomic composition of zooplankton populations, and ultimately influencing the trophic structure of pelagic food webs [3]. In the southern Benguela, this pattern is not straight-forward and is complicated by regionally-driven events.

References

[1] van der Lingen, C.D., Shannon, L.J., Cury, P., Kreiner, A., Moloney, C.L., Roux, J-P., Vaz-Velho, F. (2006) Resource and ecosystem variability, including regime shifts in the Benguela Current System, In: Benguela: Predicting a Large Marine Ecosystem, Large Marine Ecosystems 14, Shannon, V., Hempel, G., Malanotte-Rizzoli, P., Moloney, C.L., Woods, J. (Eds), Elsevier, Amsterdam.
[2] Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems. Prog Oceanogr 81: 207-213.
[3] Behrenfeld, M.J., O'Malley, R.T., Siegal, D.A., McClain, C.R., Sarmiento, J.L., Feldman, G.C., Milligan, A.J., Falkowski, P.G., Letelier, R.M., Boss, E.S. (2006) Climate-driven trends in contemporary ocean productivity. Nature 444: 752-755.
[4] Behrenfeld, M.J., Falkowski, P.G. (1997) A consumer's guide to phytoplankton primary productivity models. Limnol Oceanogr 42: 1479-1491.
[5] Chassot, E., Bonhommeau, S., Dulvy, N.K., Mélin, F., Watson, R., Gascuel, D., Le Pape, O. (2010) Global marine primary production constrains fisheries catches. Ecol Lett 13, 4: 495-505.

Climate and Human Influences on Land-Ocean Fluxes in a Large River System

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Changing climate and land use practices have the potential to dramatically alter coupled hydrologic-biogeochemical processes and associated movement of water, carbon and nutrients through various terrestrial reservoirs into rivers, estuaries, and coastal ocean waters. Consequences of climate– and land use–related changes will be particularly evident in large river basins and their associated coastal outflow regions. Here, we describe a NASA Interdisciplinary Science project and complementary Carbon Monitoring System project that employ an integrated suite of models (Figure 1) in conjunction with remotely sensed as well as targeted in situ observations with the objectives of describing processes controlling fluxes on land and their coupling to riverine, estuarine and ocean ecosystems. The objectives of these efforts are to 1) assemble and evaluate long term datasets for the assessment of impacts of climate variability, extreme weather events, and land use practices on transport of water, carbon and nitrogen within terrestrial systems and the delivery of materials to waterways and rivers; 2) using the Mississippi River as a testbed, develop and evaluate an integrated suite of models to describe linkages between terrestrial and riverine systems, transport of carbon and nutrients in the Mississippi and Atchafalaya rivers and tributaries, and associated cycling of carbon and nutrients in coastal ocean waters; 3) evaluate uncertainty in model products and parameters and identify areas where improved model performance is needed through model refinement and data assimilation; and 4) establish and populate geospatial portals for sharing and analysis of carbon datasets and products. This research will provide information that will contribute to determining an overall carbon balance in North America. Results would also benefit efforts to describe and predict how land use and land cover changes impact coastal water quality including possible effects of coastal eutrophication and hypoxia.

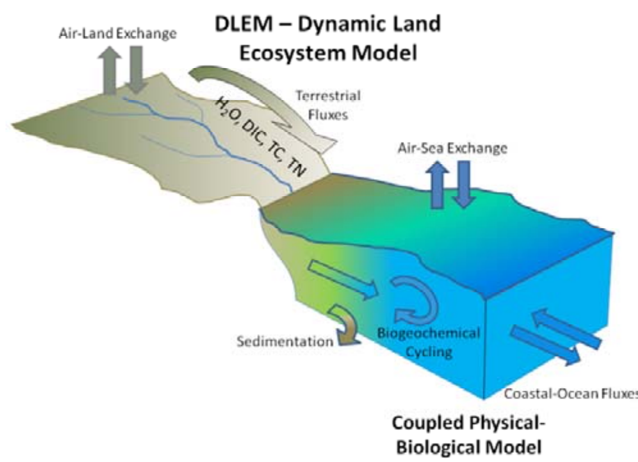

Figure 1. Integrated land-ocean modeling suite.

Examining dissolved organic carbon transport by rivers using satellite imagery: the Orinoco River case study

by

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Summary

We examined the seasonal transport of dissolved organic carbon by the Orinoco River into the eastern Caribbean using the conservative relationship of colored dissolved organic matter (CDOM) and dissolved organic carbon (DOC) in low salinity coastal waters influenced by river plumes. In situ measurements of CDOM absorption, DOC, and salinity were used to develop an empirical model for DOC concentration at the Orinoco River Plume. Satellite remote sensing reflectances were used with empirical models to determine DOC river transport. Our estimates of CDOM and DOC significantly correlated with in situ measurements and were within the expected ranges for the river. Average DOC transport by the Orinoco River during the period of 1998 to 2010 was 5.29 Tg C y^{-1} of DOC, a ~ 6% increase to previous published estimates.

Introduction

The Orinoco River is the fourth largest in the world in terms of water discharge and organic carbon export to the ocean. River export of organic carbon is a key component of the carbon cycle and the global carbon budget. Dissolved organic carbon (DOC) is a major component of terrestrial carbon transported by rivers, comprises most of the organic carbon found in the coastal ocean, and is one of the largest global carbon pools [1].

Accurate assessments of the global ocean carbon concentration and understanding of ocean carbon cycle dynamics is limited in large-part by the availability of in situ data. In contrast, the easily accessible, large sets of ocean color data obtained from satellite instruments such as the Sea-Viewing Wide Field-of-View Sensor (SeaWiFS) and the Moderate Resolution Imaging Spectroradiometer (MODIS) may provide a means to obtain global estimates of land-ocean carbon fluxes of DOC.

DOC concentration cannot be measured directly using ocean color sensors because not all the organic carbon is colored. However, colored dissolved organic matter (CDOM) is a major component of the total dissolved organic carbon pool in coastal waters influenced by rivers. CDOM is often the major absorber and provides a direct approach to determining DOC concentration in coastal waters particularly those environments influenced by rivers [2]

In this study we hypothesize that the conservative behavior of CDOM and DOC in river plume influenced coastal waters, along with the possibility of detecting CDOM with Ocean Color remote sensing allows for a globalize approach in the estimation of organic carbon export by large rivers. A general goal was to expand and generalize the previous approach of Del Castillo and Miller [*3*] by incorporating the use of the QAA semi-analytical algorithm to estimate CDOM and to estimate river discharge using hydrological models and data from NASA's Tropical Rainfall Measuring Mission (TRMM). Unlike the Mississippi River system which is instrumented and there exists a large set of field measurements, the Orinoco River is not instrumented. Therefore, as a large river, the Orinoco River is an ideal system in which to develop a remote sensing approach to estimate terrestrially derived flux and dynamics of DOC coastal waters.

Results and Conclusions

The distribution of CDOM determined by surface patterns of a_g443 indicates that CDOM concentration changes as the ORP mixes with oceanic waters throughout the eastern Caribbean. The direct relationship of DOC and a_g443 in this region and constant spectral slope throughout the Gulf of Paria suggests that CDOM and DOC concentration is governed in large-part by the concentration and mixing of river waters indicating a conservative behavior throughout the plume[2,4]. An empirical model to estimate DOC was then developed based on the relationship between measured in situ CDOM, salinity and DOC, from samples of the Orinoco River Plume (ORP) and Mississippi River Plume (MRP). This model is defined by:

$$\text{Salinity} = 36.65 - 26.1 * a_g443 \quad (1)$$

$$DOC_P = 5.3 - 0.12 * \text{Salinity} \quad (2)$$

Subsequently, using a two end-member mixing model *Del Castillo and Miller* [3] we extrapolated DOC_P these modeled concentrations to the expected concentrations at the river itself. These estimates were then multiplied by the modeled river flow to obtain the DOC transport per day, with an average of 0.0143 Tg C day^{-1}. These estimates correlated those calculated using in situ DOC concentrations measured in situ[1], and integrated to yearly transports rates of 5.29 Tg C y^{-1} of DOC for the 1998 to 2010 period. Reflecting a 6.1 % increase in DOC transport over the previous estimates.

Despite image variability and methodology biases, our analysis captured the dynamics of organic carbon in the Orinoco River plume. The variability in organic carbon fluxes responded mostly to the seasonality of the river flow, and not to variations in the DOC concentrations within the river waters. The collection of ORP and MRP into a single data set favored a decrease in the variability and into conservative DOC estimates.

In conclusion our results corroborates the possibility of estimating organic carbon transport by large rivers, using remote sensing data and hydrological models. We propose that, because river flow is the dominant term in organic transport, a global CDOM-DOC relationship can be used to estimate carbon export in rivers with sparse or no field data. Our methodology here applies only to river plumes where there is a conservative behavior between salinity, CDOM, and DOC. At global scales the transport by large rivers such as the Orinoco River outweigh the impact of these areas to the global carbon cycle, our estimates of total organic carbon flow into the eastern Caribbean by the Orinoco River represent a 3.1 % of the total continental discharge.

References

[1] Hedges, J. I. 2002. Why Dissolved Organics Matter, p. 1-33. *In* A. H. Dennis and A. C. Craig [eds.], Biogeochemistry of Marine Dissolved Organic Matter. Academic Press.

[2] Del Castillo, C. E., P. G. Coble, J. M. Morell, J. M. Lopez, and J. E. Corredor (1999), Analysis of the optical properties of the Orinoco River plume by absorption and fluorescence spectroscopy, *Marine Chemistry*, *66*(1-2), 35-51.

[3] Del Castillo, C. E., and R. L. Miller (2008), On the use of ocean color remote sensing to measure the transport of dissolved organic carbon by the Mississippi River Plume, *Remote Sensing of Environment*, *112*(3), 836-844.

[4] Blough, N. V., O. C. Zafiriou, and J. Bonilla. 1993. Optical Absorption Spectra of Waters From the Orinoco River Outflow: Terrestrial Input of Colored Organic Matter to the Caribbean. J. Geophys. Res. **98:** 2271-2278.

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[1] By the Environmental Research Observatory (ORE) HYBAM (http://www.ore-hybam.org/)

OSS2015 - Ocean Strategic Service beyond 2015

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OSS2015 Objectives

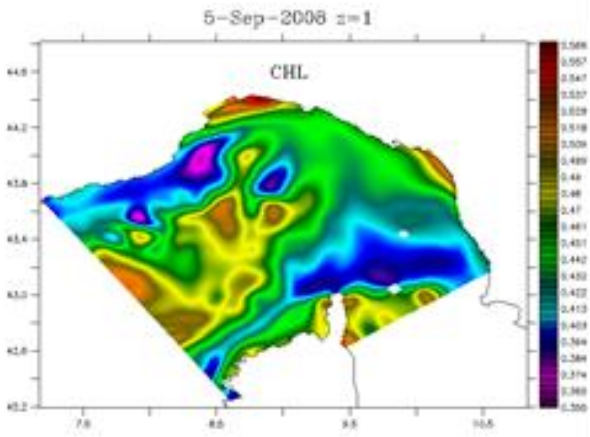
OSS2015 is a FP7 R&D project focused on nowcast, forecast and climatology of the biogeochemical properties of the ocean mixed layer. OSS2015 addresses the fusion of satellite ocean colour data (multispectral radiance of the sea surface) and in situ measurements from autonomous platforms (buoys, drifters, gliders, …) through assimilation into biogeophysical models.

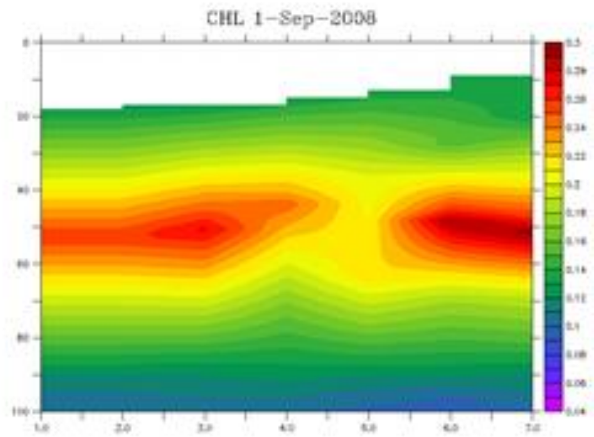
R&D activities are performed in order to improve the nowcast, the forecast and the estimation of the spatial and temporal variability of biogeochemical variables in the ocean mixed layer, the development and validation of new tools for integration and assimilation of EO and in situ data into biogeochemical models as well as of new products relevant to the biogeochemistry of the ocean. Development and demonstration of new prototype service lines towards scientific and operational users are also in the scope of OSS2015 activities.

The OSS2015 project aims to carry out R&D activities for the development of marine biogeochemistry products and services not currently available through the precursor service of the operational forecast and analysis component of the European Marine Core Service (MCS)- the upstream marine service of GMES/Copernicus.

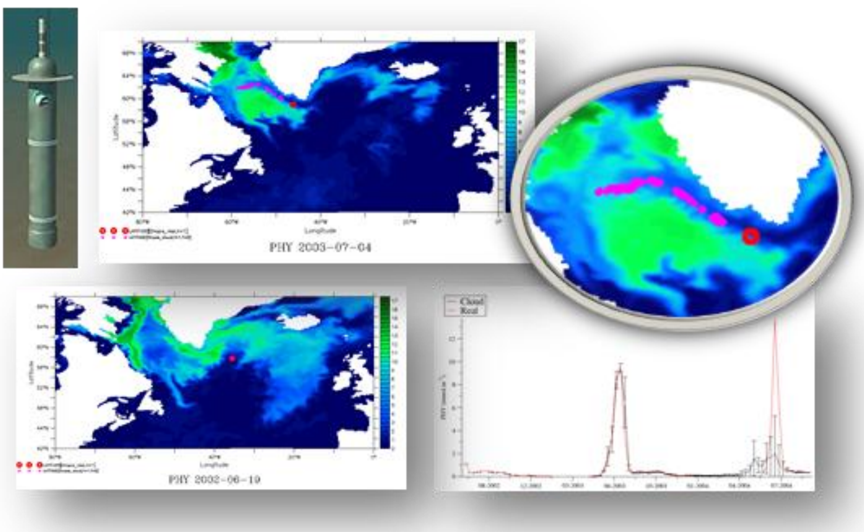
Main scientific topics of the project

1. Exploitation of in-situ and satellite data in bio-geochemical and bio-optical models:
   - For **direct assimilation** of bio-optical parameters in the Ligurian sea (and in parallel assimilation of EO-Chl-a in a pilot site in the North-Atlantic)

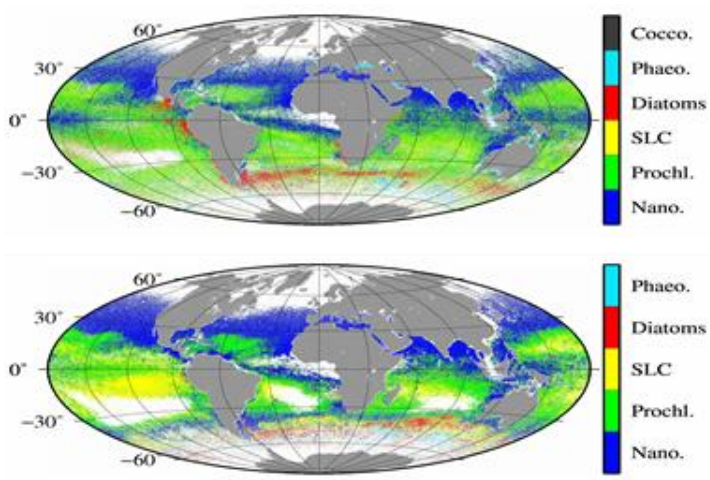




❖ For **optimisation** of deployment of bio-argo profilers in North Atlantic



2. Definition and test **production of bio-geochemical information** (POC, NPP, PFT, PSD) relevant to Climate Science and Ecosystem Health assessment



3. Prototyping **"on-demand" services of data processing**, information formatting and delivery

Present project results

The project has started in November 2011 and will last until October 2014. Latest results obtained at the time of the meeting IOCS will be presented.

Acknowledgment

The research leading to these results is receiving funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n° FP7-SPA.2011.1.5-03 / Collaborative project N° 282723 (OSS2015)

KALICOTIER: A DEMONSTRATION DATA SERVER TOWARD DEDICATED EARTH OBSERVATION SERVICES IN THE COASTAL ZONE

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Around 44% of the world's population lives within 150km of the coast. Therefore, an important part of economic activities take place in the coastal zone: marine related activities (fisheries, fish farming, shipping, mining, leisure …) as well as terrestrial activities concentrated around urban centres. Being at the interface between land and ocean, the coastal zones are under the influence of a complex mixture of natural and anthropogenic phenomena originating from both oceans and lands. For the latest, river discharge which carries pollution originating from agricultural, industrial and domestic activities of the entire river basin is a major contributor on coastal environment. As a consequence, the coastal zone is the major place of interest for environmental and safety monitoring. This complexity leads to an important need of integrated coastal management in which remote sensing can play an important part from long term monitoring to fast analysis and response to natural or industrial hazards.

In order to address these needs, the Kalicotier demonstration data server has been funded by CNES as part of the GIS COOC data portal (French Scientific group in Ocean colour). This portal, dedicated to coastal satellite data and available at http://kalicotier.gis-cooc.org is an ocean colour data server providing extensive remote-sensing datasets for the study of coastal regions of major oceanographic interest. Kalicotier so far provides an easy and fast access to MERIS Full Resolution data (300m) on five coastal sites: Ligurian Sea, English Channel, Bay of Biscay, New Caledonia and Vanuatu Islands and the South Vietnam region. Each site is managed in partnership with a researcher of the scientific community locally involved in the region, who insures relevance and update of the information. The objective of Kalicotier is to demonstrate on a limited number of coastal sites the utility of providing comprehensive satellite time series. If relevant, data from other sensors will be added to the data portal. This could include other ocean colour sensors (SeaWiFS, MODIS, VIIRS, OLCI) as well as other data type (SST, SSH, wind speed, broad band high resolution radiometric sensors). Ultimately, the concept would be extended and integrated in operational services with a focus on NRT and RT data dissemination.

The specificity of the coastal zone regarding atmospheric correction has put forward the need to provide to users an improved algorithm SAABIO (Semi Analytical Atmospheric and BIO-optical processor), described hereafter. Together with the satellite data, Kalicotier provides validation plots for each selected area thanks to long term in situ acquisition systems (notably BOUSSOLE, AERONET-OC and SOMLIT) and oceanographic cruises provided by institutional partners. Main features of Kalicotier portal are (figure 1):

1. Access to full time series of MERIS FR Level 1 and Level2 products (NetCDF format) over five coastal regions.

2. Access to two processing version (MERIS 3rd reprocessing and an experimental processor, SAABIO, described hereafter)
3. Extraction capability of single Level 2 products from NetCDF files to reduce storage volume in users facilities
4. Fast and easy visualization of all MERIS products
5. Visualization tool to select none cloudy images
6. Validation plots of satellite data against in situ measurements
7. Data are restricted to research and educational

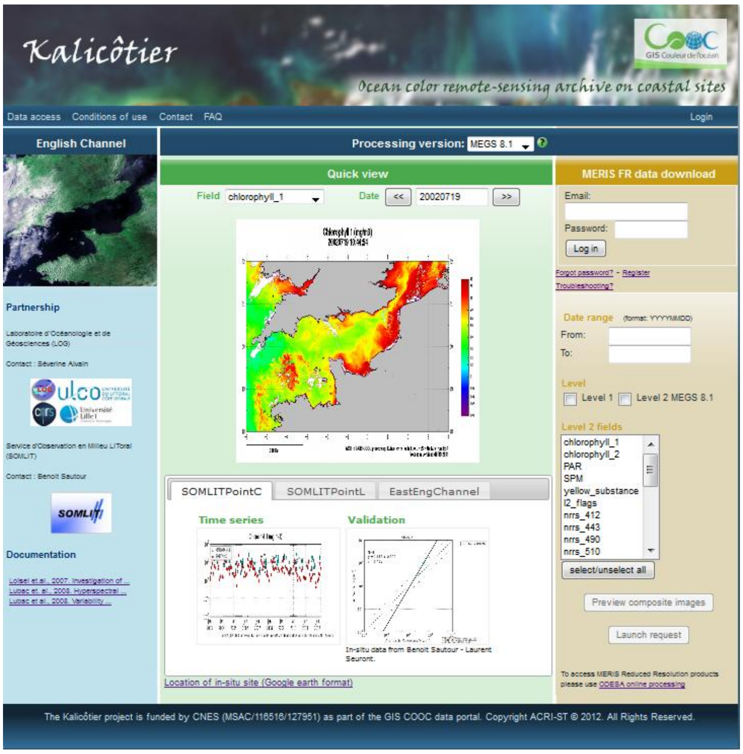

Figure 1 Kalicotier web page, http://kalicotier.gis-cooc.org

SAABIO is an experimental processor developed by CNES and ACRI-ST, alternative to the Case 2 neural network of the MERIS 3rd reprocessing. It is based on:

1. An alternative Bright Pixel Atmospheric Correction, using a semi-analytical approach to retrieve residual marine reflectance in the red and near-infrared;
2. The GSM, semi-analytical bio-optical model to retrieve Chl, bbp and cdm;

Kalicotier is foreseen to evolve in the near future and users are invited to express their needs for evolution, providing other alternative algorithms, requiring for other EO data as well as suggesting evolution of the data portal itself. The purpose of the presentation is the description of the SAABIO algorithms and the main outcomes of the reprocessing as well as the usages carried out from the Kalicotier datasets.

ODESA, A TOOL FOR THE IMPLEMENTION AND VALIDATION OF OCEAN COLOUR ALGORITHMS

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Summary

ODESA is the Optical Data processor of the European Space Agency. Its main feature is ODESA software (*Figure 1*) which has been developed to provide the scientific community with a complete level 2 processing environment for MERIS data. Three additional and complementary facilities are also available through ODESA system: ODESA online processing facility, a validation and qualification tool linked to MERMAID facility and a dedicated forum to help and foster ESA optical sensor community. All ODESA features are accessible through a single web page: http://earth.eo.esa.int/odesa/.

ODESA software provides users with the binary codes and the source codes of MERIS level 2 Ground Segment prototype processor (MEGS) in a user friendly environment (Java GUI). ODESA software basic feature allow users to process level 1 to level 2 images, access all intermediate variables of MERIS level 2 processing chain, select region of interest, able or disable land, cloud or water branches, modify Auxiliary Data File (ADF) configuration. Alternative products like fully normalized water leaving reflectance or GSM products are already implemented in ODESA software. Level 2 outputs can be generated either in native ENVISAT or NetCDF format, readable in BEAM. Advanced features allow users to implement custom product in the processing chain. MEGS is written in C language but any routine developed in a compiled language like C++ or Fortran can be implemented in the processing chain. A quick start guide and a detailed tutorial are available to beginners on ODESA webpage. Training sessions are regularly proposed to users in addition to support provided on ODESA forum. An essential feature of the software is it capacity to process text file and notably MERMAID level 1 data files. It is unique and fundamental aspect of ODESA since it provides users with the capacity to validate a remote sensing product against a representative among of consolidated in situ measurements. In situ measurements available include AOPS, IOPs and biogeochemical measurements. Last but not the least, ODESA software is evolving to offer the capacity to process next generation of ESA optical sensors, namely OLCI and SLSTR on-board sentinel-3.

ODESA online is as a web based facility that provided MERIS level 1 and level 2 products on user selected regions. Data are available in 2nd and 3rd reprocessing versions.

The validation and qualification tools allow users to access MERMAID database and assess the performance of new algorithms against in situ measurements. Qualified algorithms can be implemented on a dedicated cluster for mass processing and comparison against nominal ESA processing.

Finally ODESA forum provide users with a tool to resolve any issue related to ODESA, MERIS data and MERIS data processing.

ODESA system therefore provide comprehensive tools to process, implement, analyse and validation remote sensing optical data.

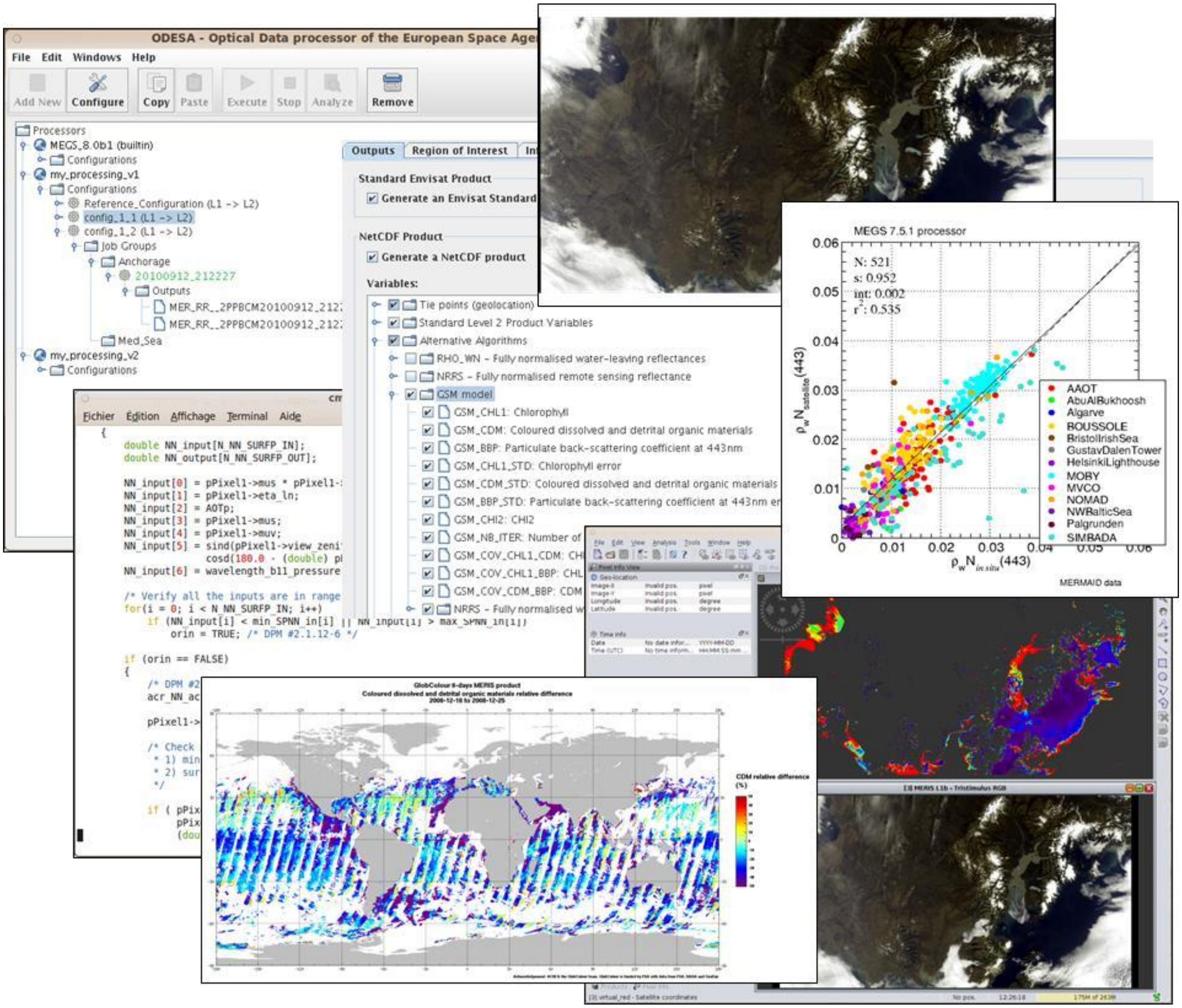

Figure 1: Screenshot from ODESA facility

Past Observations and Future Challenges for Ocean Color Remote Sensing

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Summary

About 40 years ago, an ocean color sensor to be flown on the NASA Nimbus-7 earth observation satellite was proposed and approved. The sensor was called the Coastal Zone Color Scanner (CZCS). The CZCS was a technology demonstration as the only previous remote sensing measurements had used simple airborne sensors, e.g., nadir viewing only. The CZCS proved much more successful than ever anticipated, particularly over the open ocean ironically, in providing quantitative estimates of pigment concentrations (chlorophyll-a + phaeophytin) and diffuse attenuation coefficients. As a result of this success, a variety of sensors with ocean color measurement capabilities have been launched by a number of space agencies. Those providing global observations include the Sea-viewing Wide Field-of-View Sensor (SeaWiFS, US), the Ocean Color and Temperature Scanner (OCTS, Japan), the Moderate Resolution Imaging Spectroradiometer (MODIS, US), the Medium Resolution Imaging Spectrometer (MERIS, Europe), the Global Imager (GLI, Japan), and the Visible and Infrared Imaging Suite (VIIRS, US). A number of future global ocean color missions are in the planning or development phases, e.g., the Second Generation Global Imager (SGLI, Japan), the Ocean and Land Colour Imager (OLCI, Europe), and the Ocean Ecology Sensor (OES, US). As requested by the IOCS planning committee, this presentation focuses on a “top ten” list of specific projects, events, and developments that this presenter feels played a major role in advancing the field of ocean colour remote sensing. The selections emphasize activities initiated and lead by members of the research community that reflect outstanding team work, initiative, and vision. An “honorable mention” list is also included, but not discussed in any detail, because of the numerous noteworthy contributions. Certain publications are highlighted as related to the particular entries in the top ten list, but no single publication is listed as a “top ten” entry because of the huge volume of outstanding research.

Selecting the “top ten” accomplishments is indeed challenging and the presenter spent much time deliberating on the list and will discuss the rationale for the selections, identifying key individuals involved in each as best possible. The order is intended to be chronological rather than a ranking of importance so as to “tell the story” of satellite ocean color remote sensing to date.

The conveners also asked for a perspective on the challenges that lay ahead for our community. There are a number of political, financial, and technical hurdles before us and the presenter will outline a number of these.

Analysis of recent dust storm over the Indian region using real time multi-satellite observations from direct broadcast receiving system at IMD

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Summary

In this study, observations from microwave satellites, visible and infrared instruments have been analyzed to detect dust storm over north and north-west part of India during 18 to 23 March 2012. This study investigated the approaches to utilize the multi satellite data of Moderate Resolution Imaging Spectroradiometer (MODIS) onboard Terra and Aqua satellite and the Advanced Microwave Sounding Unit (AMSU) onboard NOAA satellite to study the characteristics of dust storms from real time direct broadcast (DB) receiving system installed at three places of India Meteorological Department (IMD). Microwave measurements are used to detect the dust storm underneath clouds and ice clouds, while visible and infrared measurements are utilized for delineating the cloud-free dust systems. The dust storm detection is based on infrared brightness temperature (BT) difference between channels at 11 and 12 µm and polarized BT difference between two channels of 89 GHz and 23.8 GHz. It is found that the significant differences between the BT of channel 89 and channel 23.8 can be used as a discriminator of identifying dust storm. Finally, the occurrence of dust outbreaks has also been validated with skyradiometer of IMD, which confirms the presence of a dust storm over the Indian region.

Introduction

Dust storms are common in the northwest part of the Indian sub-continent covered by Thar Desert, which is a primary source of dust storms in south Asia. The dust outflow over the region exhibits a marked seasonality with higher frequency and intensity during dry pre-monsoon season between March to May. As a consequence, dust strongly affects the aerosol characteristics over these regions as it is mixed with local anthropogenic pollution. Several techniques have been proposed for detecting dust and volcanic ash using thermal–infrared observations (Ackerman, 1997; Singh et al.,2008). Ackerman (1997) suggested in his study that a combination of three IR channels near the 8, 11, and 12 µm band is likely to provide a more robust way to identify dust. He also outlined the usefulness of BT differences either in two or three channels for detecting the dust storms. However, the most common dust storms are those caused by strong winds behind a cold front and generally coexist with cirrus. Because the visible–infrared radiance is primarily sensitive to the upper cirrus cloud layer, especially when the upper-layer cirrus is thick, the temperature difference approach is not very useful to detect dust under cirrus areas whereas the microwave radiation is not significantly scattered or absorbed by ice clouds.

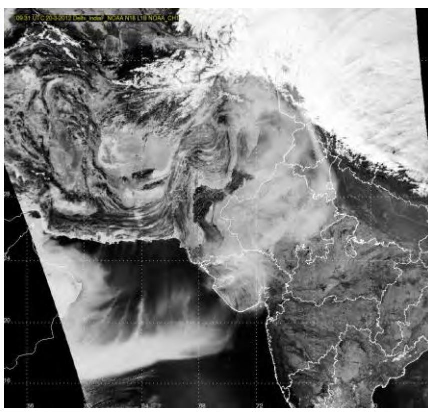
Discussion

Dust screening using AMSU channel 23.8 and 89 GHz BT from NOAA satellite

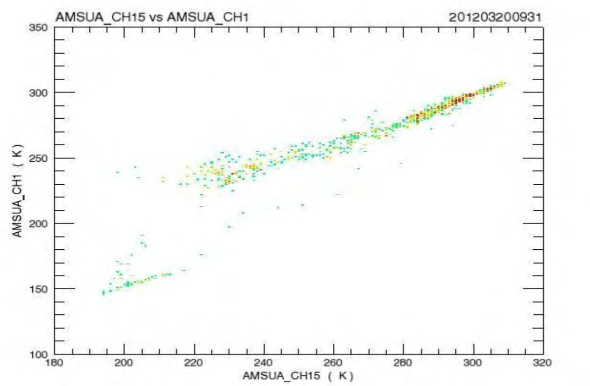
The microwave region of the electromagnetic spectrum has longer wavelengths compared to the visible and ultraviolet regions. However, the dimension of dust particles is larger than that of the normal aerosol particulates, but is similar to the incident wavelength of microwave radiation. Therefore, Mie scattering is dominant when sand particles are about the same size as the radiation wavelength. This type of scattering takes place in the lower atmosphere less than 4.5 km, where larger particles are more abundant. The shorter the wavelength of the incident radiation in the microwave range, the greater the scattering and hence the BT is lower (El-Askary et al., 2003). AMSU-A on-board the NOAA satellite is primarily a temperature sounder operating in 15 frequency channels ranging from 23.8 to 89 GHz and has 40 kms horizontal spatial resolution at Nadir. The first and last channels, 23.8 and 89 GHz respectively, provide the surface information. In the present study, we have used the 23.8 GHz and 89 GHz frequency channel (vertically polarized - horizontal polarized) from AMSU-A. The difference between polarized channels of 23.8 and 89 GHz could represent the scattering signature of dust aerosols because the scattering in Mie regime tends to depolarize the surface polarization. Huang et al., (2007) have shown that the difference (ΔBT) between lower frequency (23.8 GHz) and higher frequency (89 GHz) can be used as a benchmark to detect dust regions. Figure-6 (a, b, c) shows the polarized difference of scatter plot of Tb89 GHz (AMSU Channel 15) and Tb23.8 GHz (AMSU Channel 15) for three dust storm cases during March, April and June 2012. It can be seen from the figures that the Tb of channel 89 and channel 23.8 is much larger in the dusty region (shown in the red color) but for other than dust such as cloud, water cloud and precipitation particles the difference is much lower (<273K, shown in the yellow and off blue color). This large difference arises due to the presence of clouds since microwave radiation emanates from much lower dust layers than the top ice cloud radiance. These results suggest that significant differences between the Tb of channel 89 and channel 23.8 can be used as a discriminator of identifying dust storm.

Conclusions

This paper investigated the integrated approach to use the multi satellite data of thermal IR bands from MODIS on-board Terra and Aqua satellite and the microwave data of AMSU on-board NOAA satellite to study the characteristics of dust storms over the Indian region from real time direct broadcast (DB) receiving systems at IMD during March to June 2012. It is found that the thermal IR band difference between channels at 11 and 12 µm, can discriminate against pure dust regions with appropriate thresholds, but it is not so useful for the dust covered by the clouds or water droplets because sometime the BT of the pixels over the water and ice cloud may also scatter emitted radiance with the same peak as dust and complicate the discrimination process. Since microwave radiation can penetrate the ice and clouds, the polarized BT difference between two channels of 89 and 23.8 GHz from NOAA satellite has been analyzed and found that the significant differences between the BT of channel 89 and 23.8 GHz can be used as a discriminator for identifying the dust storm.



NOAA Channel-1 (1 Km resolution) at 09:31 UTC



The microwave brightness temperature difference (in K) between BT 89 − BT23.8 on 20/03/2012. The red color represents the cloud free dust region.

References

[1] Ackerman, S. A. Remote sensing aerosols using satellite infrared observations. *Journal of Geophysical Research*, 102(D14), 17,069−17,080. 1997

[2] Singh, RP; Prasad, AK; Kayetha, VK, et al., Enhancement of oceanic parameters associated with dust storms using satellite data, JOURNAL OF GEOPHYSICAL RESEARCHOCEANS Volume: 113 Issue: C11 Article Number: C11008

[3] El-Askary, H., Gautam, R., Singh, R. P., & Kafatos, M. Dust storms detection over the Indo-Gangetic basin using multi sensor data. Advances in Space Research Journal, 37, 728−733. 2006

Challenges and Opportunities for the operational use of Ocean Colour for Fisheries

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Satellite remote sensing affords monitoring of large spatial areas at very high temporal scales. The availability of food, feeding habits and environmental conditions play a key role in the distribution of fishery resources. The congregation of food on surface, water column and sea bed habitats, control the abundance, type and distribution of fish. The chlorophyll images from ocean colour data provide information on productivity and on oceanographic features such as colour boundaries, fronts, eddies, rings, gyres, meanders and upwelling regions. The next important aspect is physiologically suitable environment for fishery resource. Satellite-derived sea surface temperature (SST) partially explains suitability of fish to a habitat.

The SST images when used along with ocean colour images allowed identification of various oceanographic feathers as well as gradient in magnitude in productivity and temperature. This coincidence of chlorophyll and SST features indicate close coupling of the physical and biological processes. Sea surface wind provide information on the movement of oceanographic features and thus on circulation. The synergistic analysis of time series measurements of chlorophyll, SST and surface wind vector allows to understand the formation of productive grounds and its dynamics. Attempts are being made to assess fishery potential using ocean color data as the productivity is linked to physical processes. It has been now realized that sardine fishery is closely linked to onset of monsoon. The use of ocean colour in ecosystem modelling has been taken up. The prediction of seasonal productivity will help assessment of fishery resources.

Changing trend of Arabian Sea Productivity

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Summary

Analysis of 13 year (1997-2010) record of satellite ocean color showed that summer monsoon chlorophyll concentration in the south-western Arabian Sea has been decline after 2003. Based on the analysis of possible physical parameter (wind, sea surface temperature (SST), Sea Level Anomaly (SLA) and thermocline depth), we attributed the declining chlorophyll concentration during summer monsoon to increasing SLA. This led to deepening of thermoclione and subsequently limits the supply of nutrients to the euphotic zone. This result suggests that changes are occurring in the biology of the south-western Arabian Sea not only due to local wind but also due to remotes forcings.

Introduction

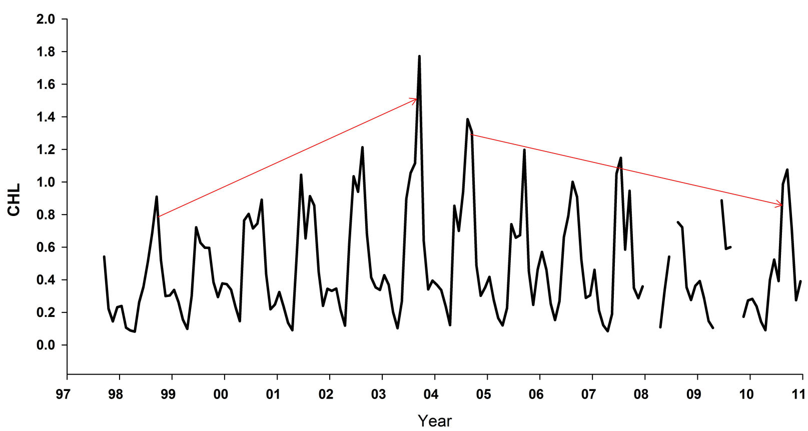

Figure 1 Figure 1Area averaged monthly time series of Chlorophyll -a for south-western Arabian Sea (47-55°E&5-10°N). The trend lines shown depict the increasing and decreasing trends during 1998–2003 and 2004–2010, respectively

South-western Arabian Sea is the most productive region in the Indian Ocean. The biogeochemistry of the Arabian Sea is mainly driven by seasonally reversing monsoons: Southwest (summer) and Northeast (winter) monsoons. Both the monsoons trigger high biological production but the underlying mechanisms are different: during summer south westerly monsoon wind causes an intense coastal and open ocean upwelling in Somalia and Oman coasts convective mixing during the northeast monsoon bring ample nutrient into the upper layer and triggers high biological production. Some of the recent observations on the basis of ocean color data have shown contradicting trends in ocean productivity for the Arabian Sea; it has increased by more than 350% over the last 6 years in the western Arabian Sea due to strengthening of the monsoonal winds [1] whereas no such trend is seen in the eastern Arabian Sea [2].The present study analyses satellite derived surface chlorophyll data for the past 13 years to investigate the long term changes in the in the south-western Arabians Sea (area identified by [1]) and delineates mechanism that explains the observed change.

Discussion

Our analysis of Satellite derived (9-km spatial resolution SeaWIFS) Level-3 monthly chlorophyll-*a* concentration data for the period of 1997-2010 shows a decreasing trend in the summer chlorophyll-*a* for the south-western Arabian Sea (Somali Coast,47-55°E & 5-10°N) after 2003. The trend analysis revealed that there was an increase in the summer peak chlorophyll-*a* concentration from 1998 to 2003 (slope: 0.24 ± 0.06; r^2 = 0.85; p = 0.02) but decreased after that (slope: -0.06± 0.03; r^2 = 0.44; p = 0.10). In order to understand the responsible mechanism for the observed Chlorophyll-*a* change in the region, we analysed wind, sea surface temperature (SST), Sea Level Anomaly (SLA) and thermocline depth data. Analysis of winds (Cross Calibrated Multiplatform wind and QuickSCAT) strength and wind stress curl from 1997 to 2003 and from 2004 to 2009 does not show any appreciable change. During the period 1997 to 2003 Satellite derive SLA along the Somalia coast shows a decreasing trend (Slope = -0.06 cm/month, P-value = 0.02) while in between 2004 to 2010 the SLA increases (slope = 0.07 cm/month, P-value = 0.03). The sea level change generally reflects thermocline variation. Increase

(decrease) in sea level associated with deepening (shallow) of thermocline. We also choose to show the depth of the 23°C (D23) isotherm, which is a proxy for thermocline depth. Summer (June to September) average of D23 during 1997 was 130 meter which gradually decreases and shoaled upto 85 meter in 2003 and then reached 71 meter in 2004, but after 2004 it again gradually increases and deepens up to 109 meter in 2010. As the nutricline and thermocline are closely associated in the Arabian Sea there for change of thermocline directly affects the supply of nutrient to the surface layer. Thus the deepening of the thermocline during 2003 to 2010 reduced the supply of nutrients to the euphotic zone and thus causing a decrease in surface chlorophyll-*a*.

Conclusions

Our analysis reveals a remarkable change in trend in the chlorophyll concentration of the South-western Arabian Sea after the year 2003. Our finding raises the possibility that the south-western Arabian Sea could witness increase/decrees in bloom of phytoplankton not only due to the strengthening/weakening of local wind but sea level anomaly also play a crucial role in strength of bloom. So the bloom in the south-western Arabian Sea is not only due to atmospheric effect but it is the manifestation of oceanic effects. The observed variability in productivity is not an effect of the global warming but may be a part of the decadal oscillation. The changes observed in the SLA may be due to the local or remote forcing.

Reference

[1]Goes, J. I., P. G. Thoppil, H. do R Gomes, and J. T. Fasullo (2005), Warming of the Eurasian landmass is making the Arabian Sea more productive, Science, 308, 545–547, doi:10.1126/science.1106610.

[2] Prakash, S., and R. Ramesh (2007), Is the Arabian Sea getting more productive?,Curr. Sci., 92, 667– 671.

Ocean Diurnal Variations Measured by the Korean Geostationary Ocean Color Imager (GOCI)

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ABSTRACT

The first geostationary ocean color satellite sensor, Geostationary Ocean Color Imager (GOCI) onboard South Korean Communication, Ocean, and Meteorological Satellite (COMS), which was launched in June of 2010 and has eight spectral bands from the blue to the near-infrared (NIR) wavelengths in 412-865 nm, can monitor and measure ocean phenomenon over a local area of the western Pacific region centered at 36°N and 130°E and covering ~2500 × 2500 km^2. Hourly measurements during daytime (i.e., eight images per day from local 9:00 to 16:00) are a unique capability of GOCI to be used for the short- and long-term regional ocean environmental monitoring.

A recent study from a collaboration between NOAA Center for Satellite Applications and Research (STAR) and Korean Institute of Ocean Science and Technology (KIOST) 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 [1] were significantly improved compared with the original GOCI data products and have a comparable data quality as MODIS-Aqua in this region [2]. It is also shown that the GOCI-derived ocean color data can be used to effectively monitor ocean phenomenon in the region such as tide-induced re-suspension of sediments, diurnal variations of ocean optical and biogeochemical properties, and horizontal advection of river discharge.

In this presentation, we show some more results of GOCI-measured ocean diurnal variations in various coastal regions of the Bohai Sea, Yellow Sea, and East China Sea. With possibly eight-time measurements daily, GOCI provides a unique capability to monitor the ocean environments in near real-time, and GOCI data can be used to address the diurnal variability in the ecosystem of the GOCI coverage region. In addition, more in situ data measured around the Korean coastal regions are used to validate the GOCI ocean color data quality, including evaluation of ocean diurnal variations in the region. The GOCI results demonstrate that GOCI can effectively provide real-time monitoring of water optical, biological, and biogeochemical variability of the ocean ecosystem in the region. Finally, two-year GOCI ocean color data are used to characterize seasonal and interannual variations in water optical, biological, and biogeochemical properties in the western Pacific region.

References

[1] Wang, M., Shi, W., and Jiang, L. (2012). Atmospheric correction using near-infrared bands for satellite ocean color data processing in the turbid western Pacific region. *Opt. Express*, 20(2), 741-753.
[2] Wang, M., Ahn, J., Jiang, L., Shi, W., Son, S., Park, Y., and Ryu, J. (2013). Ocean color products from the Korean Geostationary Ocean Color Imager (GOCI). *Opt. Express*, 21(3), 3835-3849.

The Black Sea Color Website

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Launched in the late 70's and early 80's satellite instruments (CZCS and MKS-BS) were the first ones which allowed to retrieve a quantitative information about the water-leaving radiances from the measurements of the spectral radiances of the ocean-atmosphere system with acceptable level of signal/noise [1, 2]. In the late 90's and early 2000's, the next generation of color scanners (OCTS, SeaWiFS, MERIS, MODIS-Terra/Aqua and etc.) began to accumulate to the daily global records of bio-optical products which is still going on [1]. However, as it has been shown in [3], the results of comparison between a global model processing and field measurements are unsatisfactory in different ocean areas. This stimulated the development of regional bio-optical algorithms and, accordingly, of regional websites where these results can be found, in particular, to the Black Sea color website [4]. The feature of this website is that web products were received with the use of regional bio-optical algorithms for the different color scanners during their lifetime period [5-8]. Some examples of presented on the website products are shown in Fig. 1 and 2.

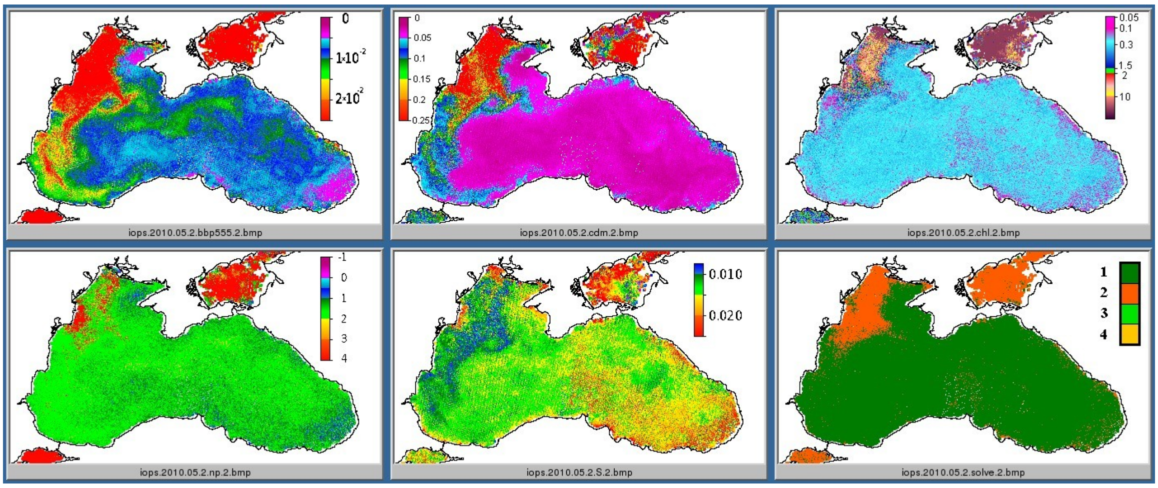

Fig. 1. Example of $IOPs$ *maps for second half of May, 2010.*

Top: (left) particle backscattering coefficient at 555 nm, $b_{bp}(555)$ *, m*$^{-1}$*, (center) absorption coefficient of sum of colored dissolved organic matter and non-algal particles (CDM) at 490 nm,* $a_{CDM}(490)$ *m*$^{-1}$ *, and (right) chlorophyll a concentration,* C_a *, mg m*$^{-3}$
Bottom: (left) spectral slope of particle backscattering coefficient, n_p *dimensionless, (center) spectral slope of CDM absorption coefficient* S *, nm*$^{-1}$ *, and (right) class of decision, dimensionless*

In addition, it is permanently updated (approximately once a month) in process of receipt and processing/reprocessing of data set from existing scanners color.

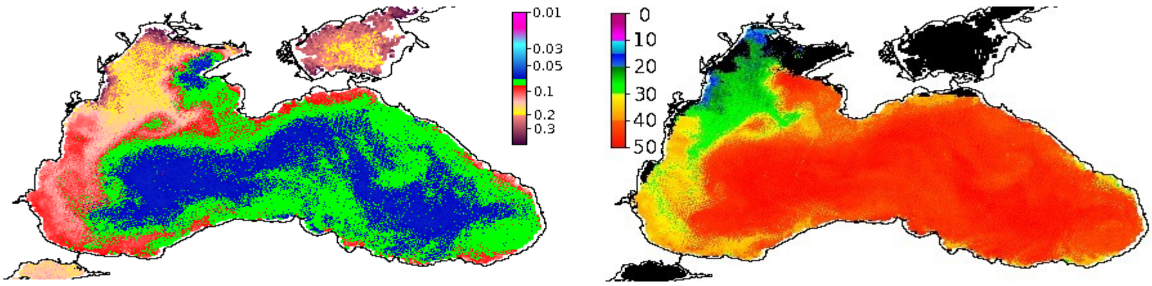

Fig. 2. Example of downwelling diffuse attenuation coefficient at 490 nm, $K_d(490)$ *, and depth of the euphotic zone,* Z_{eu} *,maps for 2nd half of May, 2010: (left)* $K_d(490)$ *is in m*$^{-1}$ *and (right)* Z_{eu} *is in m*

Acknowledgments

Source Data Credit: NASA/GSFC/OBPG, projects ODEMM, MyOcean-2, PERSEUS, DEVOTES, Russian-Ukrainian project "The Black Sea as a simulation model of the Ocean", "Fundamental problem of operative oceanography" and "Riski" of National Academy of Sciences of Ukraine.

References

[1] Feldman, G. C., C. R. McClain, Level 1 and 2 Browser, Ocean Color Web, Eds. Kuring, N., Bailey, S. W., Thomas, D., Franz, B. F., Meister, G., Werdell, P. J., Eplee, R. E., MacDonald, M., Rubens, M. 28 January 2013. NASA Goddard Space Flight Center. 28 January 2013. http://oceancolor.gsfc.nasa.gov/cgi/browse.pl?sen=am
[2] Bischoff K., Orlicek E., Schmelovsky K, Zimmermann G. (1983) First results of the Interkosmos satellite IK21// Acta Astronaut., Vol. 10, 3135.
[3] Gregg, W., Casey N. (2004). Global and Regional Evaluation of the SeaWiFS Chlorophyll Data Set. Rem. Sens. Environ., 93: (4) 463—479
[4] Black Sea Color Website: http://blackseacolor.com
[5] Suslin V., Churilova T., Ivanchik M., Pryahina S., Golovko N. (2011) A simple approach for modeling of downwelling irradiance in the Black Sea based on satellite data // *Proc. of VI International Conference «Current problems in optics of natural waters» (ONW'2011)*, St-Petersburg. Russia, September 6-9, 2011, Saint-Petersburg, Publishing house of «Nauka» of RAS, 199-203.
[6] Suslin V., Churilova T., Sosik H. The SeaWiFS algorithm of chlorophyll a in the Black Sea // Marine Ecological J., 2008, Vol. VII, No. 2, p. 24-42, (in Russian)
[7] Churilova T., Suslin V., Sosik H. Bio-optical spectral modelling of underwater irradiance and primary production in the Black Sea // Proceeding of XIX Ocean Optics conference, 6-10 October 2008, Tuscany, Italy, CD.
[8] Churilova T.Ya., Suslin V.V. Seasonal and inter-annual variability in waters transparency, chlorophyll a content and primary production in the Black Sea simulated by spectral bio-optical models based on satellite data (*SeaWiFS*) // Ocean Optics XXI, Glasgow, Scotland, October 8-12, 2012, 13 p.

The Felyx High Resolution Diagnostic Dataset System (HR-DDS)

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Felyx is currently under development and is the latest evolution of a generalised High Resolution Diagnostic Data Set system funded by ESA. It draws on previous prototype developments and experience in the GHRSST, Medspiration, GlobColour and GlobWave projects.

Felyx is fundamentally a tool to facilitate the analysis of EO data: it is being developed by IFREMER, PML and Pelamis. It will be free open software written in python and javascript. The aim is to provide Earth Observation data producers and users with an open-source, flexible and reusable tool to allow the quality and performance of data streams from satellite, in situ and model sources to be easily monitored and studied. New to this project, is the ability to establish and incorporate multi-sensor match-up database capabilities. The systems will be deployable anywhere and even include interaction mechanisms between the deployed instances.

The primary concept of Felyx is to work as an extraction tool. It allows for the extraction of subsets of source data over predefined target areas(which can be static or moving). These data subsets, and associated metrics, can then be accessed by users or client applications either as raw files or through automatic alerts. These data can then be used to generate periodic reports or be used for statistical analysis and visualisation through a flexible web interface.

Felyx enables:

* subsetting - large local or remote collections of Earth Observation data over predefined sites (geographical boxes) or moving targets (ship, buoy, hurricane), storing locally the extracted data (reffered as miniProds). These miniProds constitute a much smaller representative subset of the original collection on which one can perform any kind of processing or assessment without having to cope with heavy volumes of data.
* generation of statistics - computing statistical metrics over these miniProds using for instance a set of usual statistical operators (mean, median, rmse), which is fully extensible and applicable to any variable of a dataset. These metrics are stored in a fast search engine which can be interrogated by humans and automated applications.
* generate reports or warnings/alerts - based on user-defined inference rules, through various media (emails, twitter feeds,..) and devices (phones, tablets).
* analysing – analysis of miniProds and metrics through a web interface allowing the data to be

explored and extracting useful knowledge through multidimensional interactive display functions (time series, scatterplots, histograms, maps).

There are many potential applications but important uses foreseen are :

* monitoring and assessing the quality of Earth observations (e.g. satellite products and time series) through statistical analysis and/or comparison with other data sources
* assessing and inter-comparing geophysical inversion algorithms
* observing a given phenomenon, collecting and cumulating various parameters over a defined area
* crossing different sources of data for synergy applications

The services provided by felyx will be generic, deployable at users own premises, and flexible allowing the integration and development of any kind of parameters. Users will be able to operate their own felyx instance at any location, on datasets and parameters of their own interest, and the various instances will be able to interact with each other, creating a web of felyx systems enabling aggregation and cross comparison of miniProds and metrics from multiple sources.

Initially two instances will be operated simultaneously during a 6 months demonstration phase, at IFREMER - on sea surface temperature and ocean waves datasets - and PML - on ocean colour.

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Monitoring eutrophication in the North Sea: an operational CHL-P90 tool

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Summary

The satellite-based chlorophyll a 90 percentile product (CHL-P90) is an important indicator used to monitor for the eutrophication state of the North Sea. The accuracy of the CHL-P90 is impacted by the irregular availability of satellite chlorophyll a (CHL) observations both in space and time due to cloudiness, quality flagging, sensor malfunction, etc. A detailed simulation study enabled the development of advanced methodologies to generate CHL-P90 products taking into account the quality of the considered CHL time series and correct for possible sampling irregularities.

Introduction

The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) are important drivers for monitoring the coastal and offshore waters in Europe with the objective of reaching a 'good environmental status' [1]. Human-induced eutrophication is one of the considered criteria of the good environmental status and is assessed monitoring the chlorophyll a concentration (CHL) as it is a proxy of phytoplankton biomass. More specifically, for countries such as Belgium, the CHL-P90 over the phytoplankton growing season (i.e. March – November incl.) is the parameter of choice as it describes the intensity of the algal blooms during the year. A satellite-based CHL-P90 tool was developed in the framework of the Aquamar project (EU-FP7) which is available in the open-source toolbox and development platform BEAM (VISAT, Brockmann Consult, Germany). This tool allows for an optimal analysis of satellite-based CHL time series taking into account the irregular sampling by satellites during the growing season.

Discussion

Ocean color satellite data enables the calculation of CHL-P90 pixel-by-pixel resulting in a map product which is expected to provide more accurate CHL-P90 estimates compared to the *in situ* data due to an increased temporal and spatial resolution. However, satellite remote sensing is subject to one major limitation: cloud presence can totally or partially cover the area of interest [2]. For the North Sea this generally results in a high percentage of missing data in the daily images. This missing data is not evenly distributed over the year, and thus impacts the standard percentile calculation. This impact is two-fold and dependent on (1) the availability of observations during the actual phytoplankton bloom and (2) a proportional distribution of observations in the bloom and non-bloom periods.

This study has focused on the additional errors generated in multi-temporal products. A detailed sensitivity analysis was performed using simulations techniques (e.g. MIRO&CO-3D ecosystem model) to generate realistic CHL time series for the Belgian part of the North Sea with high temporal resolution ensuring the availability of sufficient reference data for a variety of algal bloom dynamics (i.e. bloom intensity and timing). These CHL time series were subsequently sub sampled using actual pixel specific MERIS sampling frequencies during the growing season 2003 to 2011 and used for the standard CHL-P90 product generation. A direct comparison of these CHL-P90 products with the reference data showed that with the current observation density of the MERIS satellite relative errors of up to 30% on Chl-P90 estimation due to the effects of irregular sampling are not uncommon. The results of this study were used to improve the CHL-P90 algorithms by the use of an interpolation procedure taking into account the CHL time series quality. The interpolation method was used to compensate for sampling irregularities by filling the gaps in the CHL time series. Both methods were compared to the standard CHL-P90 products and reduced the relative errors caused by the irregular availability of MERIS data to 10%-15%.

Conclusions

The proposed interpolation approach provides a method to take into account sampling issues resolving a significant part of this problem without the need for additional data. This method was translated to an operational BEAM-tool. The open source software BEAM is both a toolbox supporting a wide range of optical sensors for Earth Observation and a development platform that allows users to easily create their own visual and data processing tools. The BEAM Graph Processing Framework (GPF) allows users to create EO data processors, and thus facilitates evolutionary processor development. In combination with a number of analysis tools, BEAM supports the full circle of creating and updating an algorithm, (re-)processing data products, validating the results, and deriving new requirements that in turn affect the algorithm's design.

The gap-filling strategies have been made accessible in BEAM by means of the Temporal Percentile Operator, which has been implemented as operator based on the GPF. Its purpose is to compute the 90th percentile threshold for a time series of EO data products. For a given input set of EO data products, the operator produces a new data product which contains a band containing the respective percentile thresholds for each pixel of the input time series. See figure 1 for an example displayed and analyzed in BEAM VISAT. Additionally, the operator creates a per-pixel time series from the daily means of the input products. This time series can be visualized and analyzed in VISAT using the dedicated Time Series Tool extension.

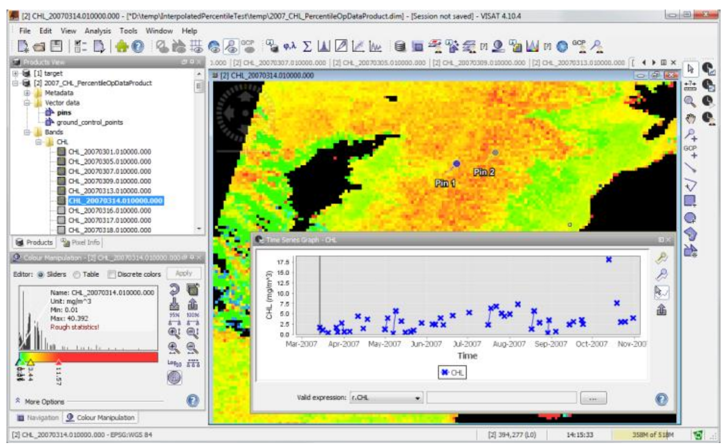

Fig 1. Screenshot of VISAT showing interpolated percentile product

References

[1] Sorensen K, Severinsen GG, Aertebjerg G, Barale V, Schiller C (2002), Remote Sensing's contribution to evaluating eutrophication in marine and coastal waters. European Environment Agency, 41p.

[2] Sirjacobs D., Alvera-Azcarate A., Barth A., Lacroix G., Park Y., Nechad B., Ruddick K., Beckers J.-M. (2011). Cloud filling of ocean color and sea surface temperature remote sensing products over the Southern North Sea by the Data Interpolating Empirical Orthogonal Functions methodology. Journal of Sea Research, Vol. 65, pp. 114–130.

VIIRS data accessible via ERDDAP and with ArcGIS: Facilitating access for marine resource managers

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Summary

Since March 2013 global fields of VIIRS (Visible Infrared Imager Radiometer Suite) chlorophyll data have been available through the THREDDS Data Server and ERDDAP server at the NOAA/SWFSC Environmental Research Division (ERD) (See Figure 1). ERDDAP (the Environmental Research Division's Data Access Program) is a data server that gives users (and machines) a simple, consistent way to download subsets of scientific datasets in a variety of common file formats and to make graphs and maps. Our specific intent with making VIIRS data available on THREDDS and ERDDAP servers was to target marine resource managers, and more specifically, two broad classes of users: ArcGIS users, and marine biologists who work with tagged animal data.

Introduction

Ocean color data is a critical for oceanographers and marine resource managers, and given the demise of the SeaWiFS satellite, and the beyond-design life age of both the MODIS and MERIS sensors there has been concern about the future availability of ocean color data. Because of this, ocean color data from VIIRS has been eagerly anticipated by the oceanographic community. Marine resource researchers and managers usually only require data from a small region of the global dataset, and require the data in that region over time. When the data are available only as individual global HDF (or other format) files, the user must download a very large amount of data and then try to figure out how to perform the necessary extracts from many files. There are two user groups who are particularly affected by this - the large community of ArcGIS users, and marine biologists who work with tagged animal data. ArcGIS is a mapping and spatial analysis software that is used widely within both NMFS and NOS. Traditionally, importing satellite data into ArcGIS had been challenging, since importing multiple HDF files into ArcGIS

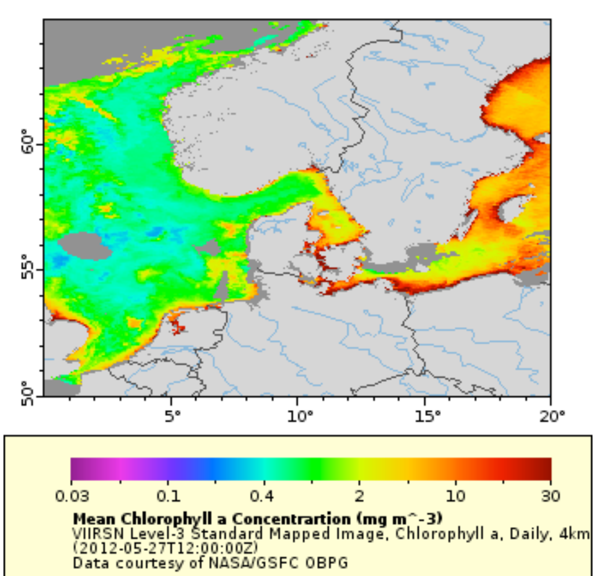

Figure 1. VIIRS image of the North Sea for May 27, 2012, generated from the ERDDAP server at ERD.

the input of longitude, latitude, time, and a chosen variable (SSH, SST, chlorophyll, etc). There are a number of advantages to making VIIRS data available on THREDDS and ERDDAP:

- These services create a "virtual file" that is aggregated through time and allows for simple temporal and spatial subsetting.
- The ERD servers are an established repository, handling on average one million data requests a day. Having the VIIRS data on the ERDDAP server therefore exposes it, and makes it accessible to, any user coming in to the ERDDAP server. Additionally, by virtue of being on the ERDDAP server at ERD, the VIIRS data is now available through the combined NOAA Unified Access Framework (UAF) catalog as well as for search through the GeoPortal being developed for the UAF.
- The ERDDAP servers at ERD serve an extensive suite of oceanographic datasets, not just satellite data. This enables "one-stop" shopping, where users can get a variety of other relevant environmental data at the same time, in the same format.
- The data is available in a large variety of formats, including .asc, .csv, .mat, .nc, .kml, .esri, .odv.
- Using the EDC (Environmental Data Connector), data on these servers can be directly imported into ArcGIS. This is particularly valuable for ArcGIS users as traditionally importing satellite datasets into ArcGIS has been very cumbersome.
- Using scripts developed at ERD, data on these servers can be "extracted" along a moving x-y-t track to obtain environmental informational along a tagged animal track.

Conclusions

The VIIRS chlorophyll data is available on the ERDDAP server at ERD:
http://coastwatch.pfeg.noaa.gov/erddap

The VIIRS chlorophyll data is available on the THREEDS server at ERD:
http://oceanwatch.pfeg.noaa.gov/thredds/catalog.html

The EDC tool is available at: http://www.pfeg.noaa.gov/products/edc/

The xtractomatic routines are available at: http://coastwatch.pfel.noaa.gov/xtracto/

Status and Prospective of Operational Ocean Color Products from the NOAA CoastWatch Okeanos System

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The status and future of the NOAA CoastWatch Okeanos operational ocean color product system are summarized in this paper. In recent years, the NOAA CoastWatch Okeanos system has been providing a series of high quality ocean color operational products for our user communities, e.g., 1 km daily and bi-monthly mean chlorophyll concentrations, and chlorophyll concentration anomaly compared to 61-day averages from MODIS/AQUA. The 1 km daily, bi-monthly, and anomaly products of remote sensing reflectance at 667 nm are also available for MODIS/AQUA. The products are generated respectively using the NASA NIR and the NOAA NIR-SWIR algorithms. Figure 1 displays examples of operational ocean color products generated in the CoastWatch Okeanos operational system by using the NASA NIR algorithm (http://oceancolor.gsfc.nasa.gov/). The products have been beneficial in assessing water quality and tracking potentially harmful algal blooms in order to protect public health. For example, the chlorophyll concentration product has been used to understand and predict the harmful algal blooms in the Gulf of Mexico by the NOAA Center for Operational Oceanographic Products and Services (CO-OPS). Recent efforts also continue to provide more MODIS/AQUA ocean color products to user community. The chlorophyll frontal operational products are expected to be available in June 2013. Operational products of Global *Emiliania huxleyi* (Ehux) bloom distribution may be available in 2013 if any NOAA operational users are identified. Figure 2 shows example of NOAA NIR-SWIR chlorophyll-a product and upcoming chlorophyll frontal and Ehux products. More importantly, all existing operational products will be extended to NPP Visible/Infrared Imager Radiometer Suite (VIIRS) and other upcoming ocean color sensors in the next few years. Therefore, it is expected that our future operational ocean color product system offers more valuable information for federal, state, and local marine scientists, as well as coastal resource managers and fisheries managers.

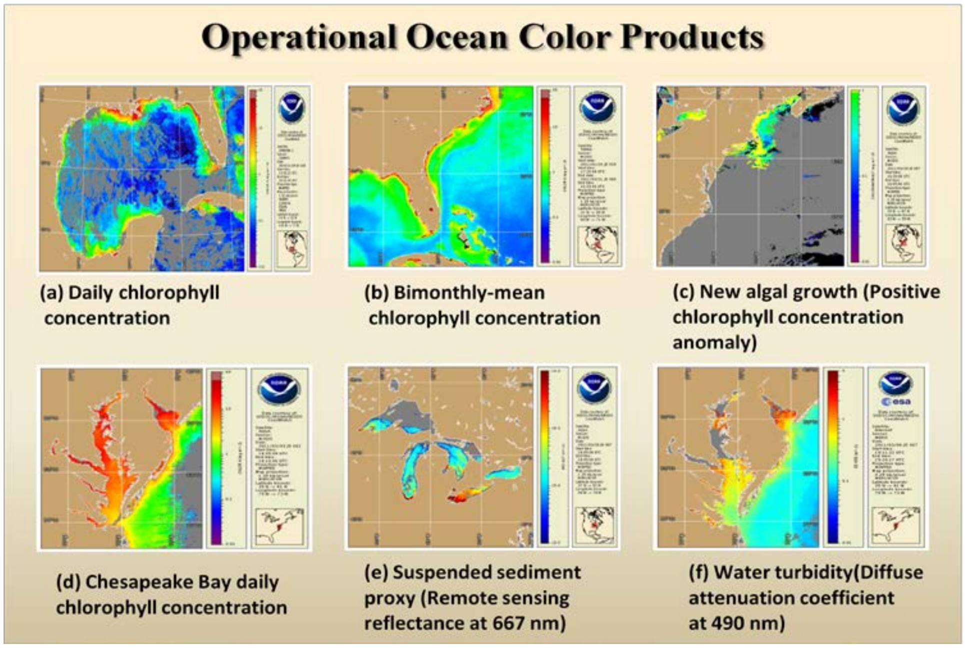

Figure 1 NOAA operational ocean color products retrieved from MODIS/Aqua satellite observations, generated in the CoastWatch Okeanos operational system by using the NASA l2gen NIR algorithm (http://oceancolor.gsfc.nasa.gov/). (a) Daily chlorophyll concentration. (b) Bimonthly-mean chlorophyll concentration. (c) New algal growth (positive chlorophyll concentration anomaly). (d) Chesapeake Bay daily chlorophyll concentration. (e) Suspended sediment proxy (remote sensing reflectance at 667 nm). (f) Water turbidity (diffuse attenuation coefficient at 490 nm).

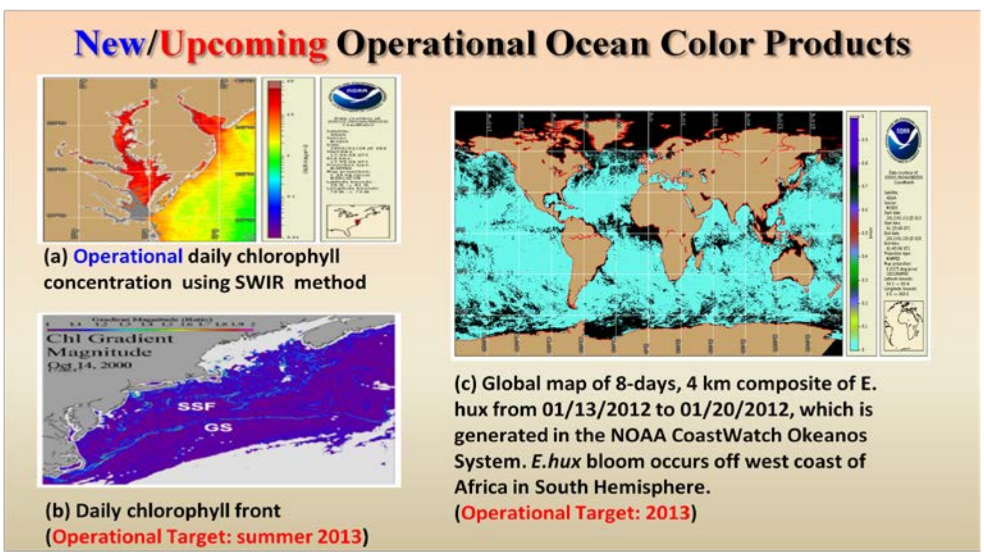

Figure 2 New operational and pre-operational ocean color products retrieved from MODIS/Aqua satellite observations in the CoastWatch Okeanos system. (a) Operational daily chlorophyll concentration by using the NIR SWIR method (Wang *et al*., 2009). (b) Pre-operational daily chlorophyll frontal products by using the BOA-SNRA algorithm (Belkin and O'Reilly, 2009; Belkin *et al.* 2013). (c) Pre-operational global map of 8-days, 4 km composite of E. hux by using the Ehux algorithm (Brown and Yoder, 1994).

References:

Belkin, I., O'Reilly, J.E., 2009: An algorithm for oceanic front detection in chlorophyll and SST satellite imagery, *J. Mar. Syst.*, doi:10.1016/j.jmarsys.2008.11.018

Brown, C. W., and Yoder, J. A., 1994: Coccolithophorid blooms in the global ocean, *J. Geophys. Res*. **99**, pp.7467-7482.

Wang, M., S. Son, W. Shi, 2009: Evaluation of MODIS SWIR and NIR-SWIR atmospheric correction algorithms using SeaBASS data, *Remote Sen. Environ*., **113**, *pp*. 635-644.