HICO Data Users Proposal

Spatial and Temporal Resolution Requirements for GEO-CAPE to Capture the Dispersion of Suspended Sediments and CDOM within River Plumes and continental margins

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Abtract
The goal of this activity is to study the dispersion of suspended particles, CDOM and organic carbon products within several river mouths and plume regions using data from GOCI, MODIS-Aqua high spatial resolution band, and HICO to determine what spatial and temporal resolution requirements are necessary for the GEO-CAPE high-resolution sensor to capture the variability of particle dispersion and organic carbon products. The focus will be on investigating the distributions of the suspended particulate matter (SPM), colored dissolved organic matter (CDOM) absorption coefficient (a_{CDOM}), and particulate (POC) and dissolved organic carbon (DOC). We will apply our empirical band-ratio algorithms (Mannino et al. 2008; in prep.) to derive HICO and GOCI products for a_{CDOM}, POC and DOC within the river plumes (Yangtze River/East China Sea, Mississippi River/Gulf of Mexico, Orinoco River/Caribbean Sea, Susquehanna River/Chesapeake Bay) and continental margins of our multiple study regions (entire GOCI viewing area, Middle Atlantic Bight and Gulf of Maine). The activity aims to provide recommendations on instrument requirements to meet the science requirements described in the GEO-CAPE Oceans Science Traceability Matrix.

Background

Rivers contribute significant amounts of suspended matter including sediments (4.6 x 10^{15} grams; Degens et al. 1991; Cauwet et al. 2002; McKee 2003) and organic carbon (0.43 x 10^{15} grams C; McKee 2003) into coastal waters. The concentration of suspended matter discharged by rivers into coastal waters determines the level of turbidity and thus light available for primary productivity in coastal ocean waters. Suspended sediments have strong light scattering properties, particularly within the red portion of the visible spectrum. This backscatter of red light within turbid waters provides a strong signal for ocean color retrievals of suspended sediments. Researchers have studied suspended sediment distributions using various satellite sensors including the AVHRR (Stump & Pennock 1989; Li et al. 1998; Myint & Walker 2002), SeaWiFS (Tassan 1994; Myint & Walker 2002; Binding et al. 2003), Landsat TM and ETM+ sensors (Tassan 1993; Keiner & Yan 1998), and MODIS (Li et al. 2003; Miller & McKee 2004). Furthermore, Neukermans et al. (2009) examined the feasibility of studying suspended matter distributions in the North Sea using the European SEVIRI meteorological geostationary sensor, which has a 15-minute scanning frequency and a 4km x 8km pixel resolution over the North Sea. Both band-ratio and single band algorithms have been applied to measure suspended sediments in coastal waters. The single band algorithms based on ocean remote sensing reflectance (Rrs) between 620-670 nm have been very successful at retrieval of total suspended matter from these satellite sensors (e.g., Binding et al. 2003; Miller & McKee 2004).

The potentially large fluxes of carbon, from production, sedimentation and export from the coastal ocean underscore the significance of the coastal ocean to the global carbon cycle. Continental margins account for >20% (~$9x10^{15}$ g C yr^{-1}) of the ocean's primary production (Knauer 1993). Furthermore, almost half of the global biological pump transfer of organic carbon to the deep ocean and >15% of the net air-sea transfer of CO_2 occurs on continental margins (Jahnke 2007). Recent global estimates of air-sea CO_2 fluxes suggest that ocean margins may be atmospheric CO_2 sinks (-$0.22x10^{15}$ g C yr^{-1}) with low latitude margins as sources and mid- to high latitude margins as sinks (Cai et al. 2006). Globally, rivers export an estimated $0.43x10^{15}$ g organic C yr^{-1} (Schlünz & Schneider 2000; Ludwig et al. 1996) and $0.4x10^{15}$ g inorganic C yr^{-1} to the ocean (McKee 2003 and refs therein). DOC alone comprises over 80-90% of the organic carbon found in the coastal ocean (e.g., Bates and Hansell 1999). Clearly, DOC represents a dynamic component of the ocean that may vary due to impacts of global change on ecosystems.

CDOM represents the optically active portion of DOM and is characterized as an exponential decrease in absorption from UV to visible wavelengths. Terrestrial plant matter is considered to be the primary source of CDOM to the coastal ocean (Del Castillo et al. 1999; Del Vecchio and Blough 2004). For example, Hernes and Benner (2003) found a strong correlation between dissolved lignin phenols (compounds derived from vascular plants) and $a_{CDOM}(350)$ within the Mississippi River plume. Such studies demonstrate that a_{CDOM} may be useful as a tracer of terrigenous DOM at least in the coastal ocean. However, biological processes such as grazing and microbial activity can contribute marine-derived CDOM to continental margins and pelagic ocean (Nelson et al. 2004; Steinberg et al. 2004). Moreover, CDOM can dominate the inherent light absorption at blue wavelengths in surface waters of the coastal (20-70% at 440nm; Del Vecchio and Subramaniam 2004; Pan et al. 2008) and pelagic ocean (>50% at 440nm; Siegel et al. 2002). The overlapping absorbance spectra of CDOM and chlorophyll *a* in the blue spectral region is one of the causes of poor satellite retrievals of chlorophyll in regions with high CDOM content.

Project Description

Objectives

1. To determine the spatial resolution required for the GEO-CAPE high-resolution sensor within the 100m to 1km trade space to resolve the dispersion of suspended particles, CDOM and organic matter between river mouths and coastal ocean regions.
2. To provide recommendations for the spatial resolution necessary to capture the dispersion and variability of SPM, CDOM, DOC and POC within continental margins.

The spatial resolution requirements necessary to capture the dispersion of suspended sediments, CDOM and organic carbon products between river mouths and the coastal ocean will be examined using satellite data from multiple platforms including GOCI (Geostationary Ocean Color Imager), HICO (Hyperspectral Imager for the Coastal Ocean), high resolution band on MODIS-Aqua. The regions of interest for the purposes of this study will include the following river mouths, plumes and coastal ocean regions: Yangtze River/East China Sea, the entire GOCI viewing area, Mississippi River/northern Gulf of Mexico, Orinoco River/Caribbean Sea, Susquehanna River/Chesapeake Bay, Middle Atlantic Bight (continental margin between Cape Hatteras and Cape Cod) and Gulf of Maine.

To study dispersion of suspended sediments, the approach here is to apply a broad single-band algorithm at ~645 nm depending on the specific sensor to retrieve suspended particulate matter (SPM) from the GOCI, HICO and MODIS sensors (Table 1). For the purposes of this work, the algorithm developed by Miller and McKee (2004) using MODIS Band 1 (645 ±25 nm) to retrieve SPM in the Mississippi River plume will be used for all study regions. The objective here is not to select the perfect algorithm to retrieve SPM, but rather to apply a consistent single-band algorithm to multiple sensors to study spatial and temporal variability in SPM distributions. Other appropriate SPM algorithms will also be considered. We will analyze MODIS data during variable river discharge conditions (low, moderate and high flow) for each of the River/Coastal regions. The GOCI and HICO data analysis will be limited to the data that are made available in 2010-2011.

Mannino has established a collaboration with scientists at the Korea Ocean and Research Development Institute (KORDI) to obtain field data of a_{CDOM}, POC/PN, SPM, and chlorophyll-a and samples for DOC and a_{CDOM} collected within the GOCI coverage. These datasets are essential for validating satellite algorithms using MODIS-Aqua, GOCI and HICO. Mannino and co-workers will integrate the *in situ* datasets with coincident GOCI, HICO, MODIS-Aqua remote sensing reflectances (Rrs) to refine and extend the range of existing band-ratio algorithms. The 3rd order polynomial for a_{CDOM} and the one-phase exponential decay for POC non-linear models versus remote-sensing reflectance (Rrs) band-ratios demonstrated strong curve-fits for our coastal ocean work for the products of interest (a_{CDOM} and POC; (Mannino et al. in prep.). These algorithms will be applied here. Our POC algorithm will be compared with another POC algorithm (Stramski et al. 2008) to determine which is more appropriate for the study region

To validate the band-ratio algorithms, the validation protocols described by Bailey and Werdell (2006) will be followed with the native sensor resolution products centered on the location of each field station (Mannino et al 2008). GOCI L1B data will be processed to L2 with the GOCI Data Processing System. The coincident satellite (GOCI, HICO and MODIS-Aqua) and field observation datasets will be randomly divided into two datasets, one for algorithm curve fitting and the other for the validation analysis. The MODIS-Aqua validation will help to confirm that HICO and GOCI yield comparable data products for coincident observations from the well-calibrated NASA sensor. The evaluation of algorithm performance is based on statistical parameters comparing the satellite-derived retrievals of products such as a_{CDOM}, DOC and POC with the field measurements, which are referred to here as validation match-ups. The statistical parameters applied include the mean and standard deviation of the absolute percent difference (APD), root mean square error, and the R^2 and slope values from linear regression analyses of the validation match-ups for each satellite sensor (Bailey and Werdell 2006; Mannino et al. 2008). MODIS-Aqua ocean color observations will be processed using the latest version of SeaDAS and IDL. For HICO, we will rely on atmospherically corrected radiances provided by the HICO team. Mannino was selected as a science PI on GOCI in 2008 and will have access to GOCI level 1B data that will be processed further to derive SPM, a_{CDOM}, DOC and POC using the GOCI Data Processing System software (GDPS).

Table 1: Instrument specifications relevant to this study.

	GOCI	HICO	MODIS	GOES imager
Spatial Resolution at nadir (m)	500	100	250	1000
Scanning Frequency (hour)	1	infrequent	Daily	0.5
Sediment band (± half-width) (nm)	660 (±10 nm)	645 (±5 nm) hyperspectral	645 (±25 nm)	650 (±100 nm)

The spatial dispersion of suspended sediments and CDOM will be examined at multiple spatial scales to determine the optimal pixel resolution for GEO-CAPE between 100 to 1000 m for this application. The study will begin with MODIS-Aqua since over 8 years of data is already available. The data analysis will involve analyzing relative percent differences (RPD) in SPM retrieved from MODIS-Aqua, HICO and GOCI between adjacent pixels and for adjacent pixel arrays of increasing dimensions (2x2, 3x3, 4x4 and 5x5). Frequency distributions will be generated to determine at what pixel dimensions do TSM concentrations exceed RPD of >10% from each reference pixel or pixel array. Uncertainties in water-leaving radiances for MODIS-Aqua are on the order of 5-10%, therefore, spatial or temporal RPD of 5-15% would be the threshold signifying greater dispersion of suspended sediments. We will also apply another statistical approach used to analyze spatial data called the variogram, which is a graphical representation depicting the variances between each pair of pixels as a function of distance between the pixels. Separate variograms will be calculated for different directions in the datasets to account for sediment dispersion in multiple directions from the river mouth. The range of the variogram will represent the distance at which SPM values for each pair of pixels are no longer correlated, representing the edge of the river plume.

Biographical Sketch for Antonio Mannino

I. Professional Preparation

University of Virginia, Charlottesville	Environmental Science	B.A., 1992
University of Texas at Austin	Marine Science	M.A., 1994
University of Maryland at College Park	Marine-Estuarine-Environmental Sciences	Ph.D., 2000

II. Appointments

2002-present Oceanographer, NASA Goddard Space Flight Center, Greenbelt, MD.

2001-2002 Research Chemist/Mendenhall Postdoctoral Fellow, U.S.G.S, Reston, VA.

2000-2001 Assistant Research Scientist, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD.

1994-2000 Graduate Research Assistant, Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, MD.

III. Recent Relevant Publications

Hofmann, E.E., B. Cahill, K. Fennel, M.A.M. Friedrichs, K. Hyde, C. Lee, **A. Mannino**, R.G. Najjar, J.J. O'Reilly, J. Wilkin and J. Xue. 2011. Modeling the Dynamics of Continental Shelf Carbon. *Annual Review of Marine Science*, 3, 93–122.

Druon, J-N, **A. Mannino**, S. Signorini, C. McClain, M. Friedrichs, J. Wilkin and K. Fennel. 2010. Modeling the dynamics and export of dissolved organic matter in the northeastern U.S. continental shelf. *Estuarine, Coastal and Shelf Science*, 88, 488-507.

Pan, X., **A. Mannino**, M. Russ, S. Hooker, and L. W. Harding, Jr. 2010. Remote sensing of phytoplankton pigment distribution in the United States northeast coast. *Remote Sensing of Environment,* 114, 2403–2416.

Mannino, A., M.E. Russ and S.B. Hooker. 2008. Algorithm development for satellite-derived distributions of DOC and CDOM in the U.S. Middle Atlantic Bight. *Journal of Geophysical Research – Oceans*, C07051, doi:10.1029/2007JC004493.

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IV. Relevant Current Research Efforts

Through current support from NASA OBB (PI) and Interdisciplinary Science (co-I) grants, the impact of climate variability on primary productivity and organic carbon distributions is under investigation along the northeastern U.S. continental margin. Algorithms for retrieval of CDOM, DOC, POC and pigments from MODIS and SeaWiFS have been validated. Using these algorithms, we can quantify the inventories of DOC, POC and CDOM, net ecosystem production of DOC and the loss of CDOM through photooxidation. As part of the NASA USECoS team, Mannino has contributed to the development and evaluation of the biogeochemical model.

V. Synergistic activities

NASA GEO-CAPE Oceans Science Working Group co-lead (2009-present)

NASA ACE Oceans Science Working Group member (2010-present)

Existing Facilities

The facilities and equipment to carry out the proposed research are available at NASA/Goddard Space Flight Center. Computing equipment for satellite data analysis includes a Mac Pro-Intel dual quad-core workstation (>20 TB hard drive), Linux dual core workstation, and a Macbook-Pro with both SeaDAS and IDL as well as three MATLAB software licenses.

Output and Deliverables:

Date	**Output and Deliverables**
February 2012	Presentation at Ocean Sciences Meeting
Spring 2012	Presentation at GEO-CAPE workshop with recommendations on spatial resolution.
May 2012	Validation of HICO and GOCI CDOM and organic carbon products
June 2012	Final report with recommendations to NASA
2012	Attend and present findings at HICO annual meeting

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