The Coastal Ocean Applications and Science Team (COAST): Science Support for a Geostationary Ocean Color Imager for Coastal Waters

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Relationship to NOAA Goals: The goal of COAST is to support NOAA to prepare to make optimal use of a Geostationary Ocean Color Imager (GOCI) for monitoring the coastal ocean. GOCI observations will help achieve NOAA's Ecosystem Mission (Strategic Goal 1) by providing data for monitoring, describing and assessing coastal environments and their complex ecosystems. These data will be used by the National Ocean Service (NOS), the National Marine Fisheries Service (NMFS) and state and local agencies to manage coastal resources. GOCI data will be used to identify, monitor and model Harmful Algal Blooms (HABs), river plumes, oil spills and other features that affect coastal water quality. The high frequency of GOCI measurements is essential to track these features which often move at several knots driven by tides and coastal currents. GOCI observations will also assist NOAA in meeting its Climate Mission (Strategic Goal 2) by providing appropriate observations to begin investigating the effect of increasing short-term, high intensity, events, e.g. the impacts of an increase in the yearly number of hurricanes, to more slowing varying, but equally damaging long-term changes, e.g. rising sea level on critical coastal environments. GOCI measurements will be used to develop estimates of the role of U.S. coastal waters as a source or sink of CO_2. Additionally, GOCI observations will provide the high resolution and high frequency measurements essential for the development and validation of coupled physical, bio-optical models of the coastal ocean.

Project Description: The Coastal Ocean Applications and Science Team (COAST) was formed in August 2004 to engage the broad oceanographic research and applications community to provide NOAA with support and technical expertise to optimize the design and utility of a geostationary ocean color imager to meet operational needs for the coastal ocean. A geostationary imager can provide the hourly sampling necessary to resolve the complex dynamics of the coastal environment.

The COAST activities became part of the GOES-R risk reduction activities in 2006. The proposed activities were presented at the GOES-R Risk Reduction meeting in Sliver Spring, MD, February 22 - 23, 2005. The presentation was well received and a proposal was submitted for the first two years of GOES-R Risk Reduction activities and was funded in July 2006. The focus of this initial two year effort is to develop the remote sensing and *in situ* data sets required to assess the utility of a GOCI and to use as the basis for recommending instrument performance parameters and developing an initial set of product algorithms. The participants in the risk reduction effort and their primary tasks are:

Oregon State University CIOSS Participants:

- Curtiss Davis, program management, calibration, atmospheric correction
- Mark Abbott, COAST Team Leader
- Ricardo Letelier, phytoplankton productivity and chlorophyll fluorescence, data management
- Peter Strutton, coastal carbon cycle, Harmful Algal Blooms (HABs)
- Ted Strub, CIOSS Director, coastal dynamics, links to IOOS

Other COAST Participants:

- Bob Arnone, NRL, optical products, calibration, atmospheric correction, data management
- Paul Bissett, FERI, optical products, data management
- Heidi Dierssen, U. Conn., benthic productivity
- Raphael Kudela, UCSC, HABs, IOOS
- Steve Lohrenz, USM, suspended sediments, HABs
- Oscar Schofield, Rutgers U., product validation, IOOS, coastal models
- Heidi Sosik, WHOI, productivity and optics
- Ken Voss, U. Miami, calibration, atmospheric correction, optics

The work is in close collaboration with NOAA, particularly:

- NOAA/STAR Menghua Wang, atmospheric correction
- NOAA/STAR Mike Ondrusek, calibration, MOBY
- NOAA/NOS Rick Stumpf, HABs
- NOAA/NMFS Cara Wilson, Ecosystem Management of Fisheries

The fourth COAST meeting was held June 28-29, 2006 in the Monterey Bay area. The meeting included planning for initiation of the risk reduction activities, and detailed specific planning for the first COAST data collection experiment in September, 2006 Monterey Bay. The Monterey Bay experiment plan was finalized and participants had a chance to view ship, ground support and laboratory facilities and make detailed plans for the experiment.

The first COAST experiment was conducted in Monterey Bay September3-15, 2006. There are no existing data sets that include all the key attributes of geostationary ocean color data, particularly the high frequency of sampling possible from geostationary orbit. The goal of this experiment was to collect data that exceeds all possible requirements for a geostationary ocean color imager so that the data may be binned spatially or spectrally to create a simulated data set for any possible set of requirements. For the Monterey Bay experiment we used the Florida Environmental Research Institute's (FERI) Spectroscopic Aerial Mapper with On-board Navigation (SAMSON; Figure 1), flown on a King Air aircraft at 30,000 ft. SAMSON collects a full hyperspectral dataset covering 256 bands in the VNIR (3.5 nm resolution over 380 to 970 nm range) at 75 frames per second. It is designed with a Signal-to-Noise Ratio (SNR), stability, dynamic range, and calibration sufficient for dark target spectroscopy. Monterey Bay was sampled at 5 m Ground Sample Distance (GSD) and for this study it will be binned to 300, 375 and 500 m to evaluate possible GSDs for a geostationary ocean color imager. The binned data will have SNR in excess of 1000:1. Noise can be added to simulate lower SNR data to understand what would be acceptable SNR for the satellite data.

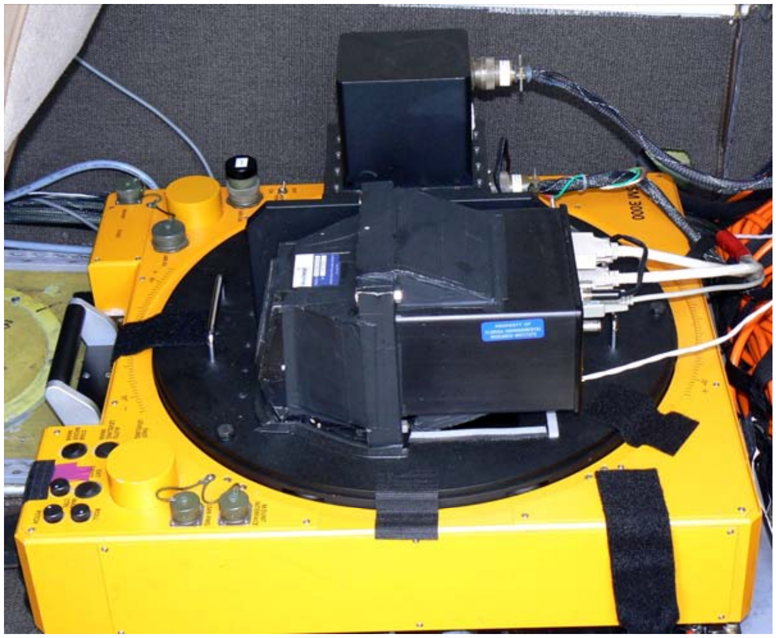

Figure 1. The Spectroscopic Aerial Mapper with On-board Navigation (SAMSON). The hyperspectral imager is black object in the foreground. The black box at the top of the image is the integrated inertial navigation system which sits atop a high resolution framing camera. The yellow frame is the motion compensation mounting system.

Two ships the R/V John H. Martin and the R/V Shana Rae were used during the experiment. A wide range of *in situ* measurements were made on the ships including:

absorption scattering, acdom (ac9, acs)
Backscattering (Hydroscat and Puck)
CDOM (fluorescence, waveguide)
CHL fluorescence
Remote sensing reflectance (above, in-water)
Diffuse attenuation coefficient – k(490,532)
Lu(+). Radiance, ED+ irradiance (HTSRB)
PAR (downwelling)
Volume Scattering Function (spectral) (ECO-VSF)
Radiance distribution – (NURADS)
Particle Size (LISST) (forward scattering) (green)
PC02 (underway)
Phytoplankton communities (underway)
Conductivity, temperature and Depth (CTD)
Aerosol optical depth –Microtops

At selected depths water samples were collected and returned to the laboratory for additional measurements:

a(detrital) filterpad absorption
a(cdom) (filterpad absorption)
POM Particulate - organic
PIM   Particulate - inorganic
SPM   Suspended
HPLC (pigments)
CHL (Fluorescence)
Nutrients
Primary Production
Fluorescence
PC02
Phytoplankton communities

Earlier measurements identified a Harmful Algal Bloom (HAB) in the northeast corner of Monterey Bay. Because of the interest in monitoring such blooms the experiment was focused in that part of the Bay. SAMSON was flown on grid covering that region that could be completed in 30 minutes. The grid was repeated every 30 minutes for up to 5 hours to simulate the time series of data that could be acquired from a geostationary ocean color imager. The data was calibrated, geolocated, and atmospherically corrected overnight to provide an initial product that was viewed the next day by the research team to plan the following day's experiments. Analysis of the spectra showed a prominent spectral peak at 709 nm that was indicative of the HAB. Figure 2 shows a map of the northeast corner of Monterey Bay using the 709 nm channel as an indicator of the HAB. Note that none of the planned or on orbit U.S. satellite ocean color sensors carry this channel. Those sensors were developed for mapping the global ocean chlorophyll content and productivity of phytoplankton and they have worked extremely well for that application. However, they are not necessarily suited for coastal waters where HABs, river runoff and other features may necessitate the selection of alternate or additional spectral channels to monitor those features. Our ability to identify 709 nm as an indicator of this large plankton bloom demonstrates the utility of collecting hyperspectral data for these studies.

All of the data was processed to an initial level during the experiment. Final reprocessing of the data is underway and all of the results are to be available in January on a web site at the Florida Environmental Research Institute (FERI) or via dynamic links from that web site.

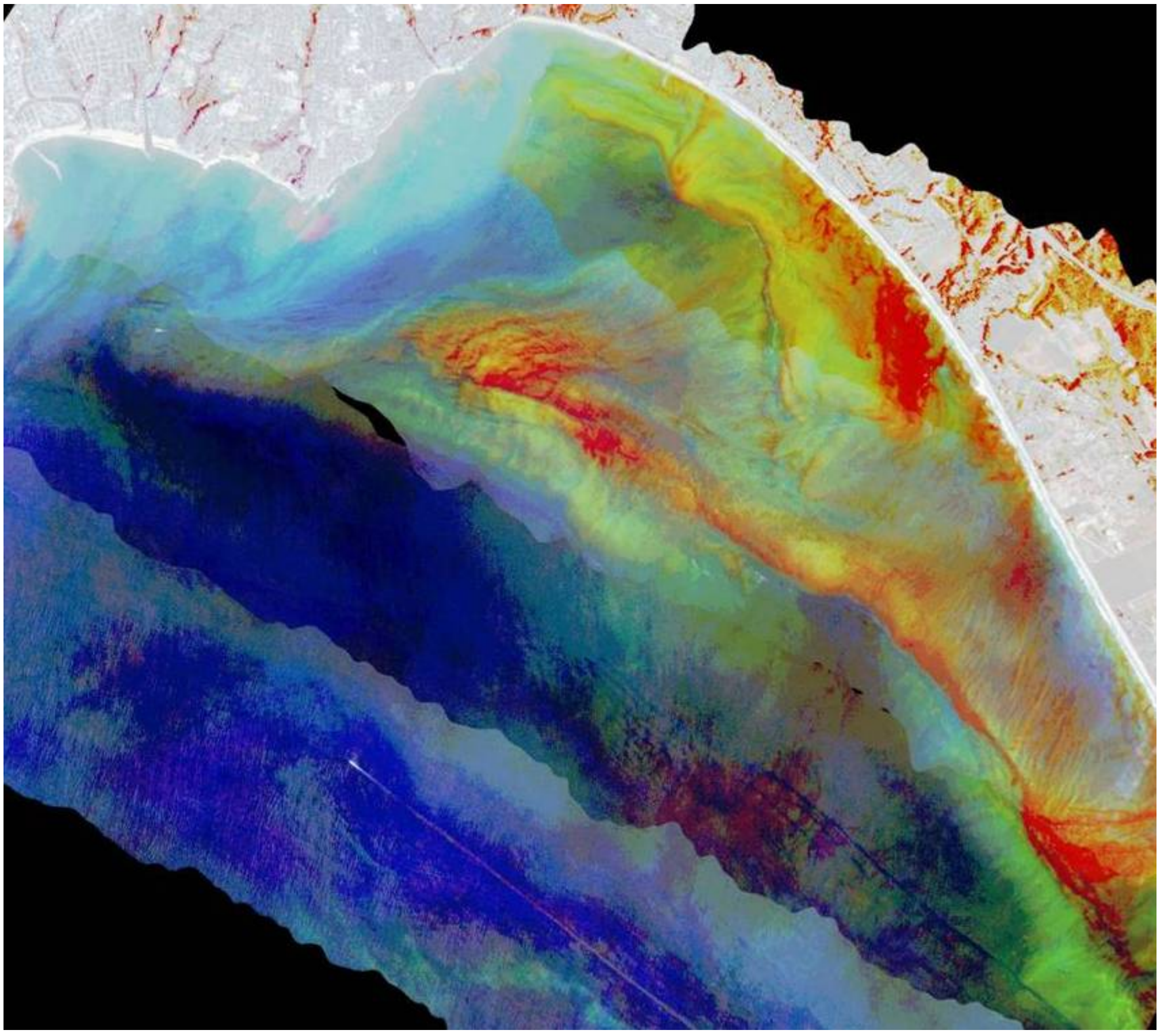

Figure 2. SAMSON image of the northeast corner of Monterey Bay. This is the third map collected on September 12, 2006. The bloom is identified using the 709 nm band and is indicated in red in the image. The adjacent regions in yellow also have high levels of phytoplankton. The bloom is a mix of species, but predominately the dinoflagellate *Akashiwo sanguinea*. Four flight lines are shown that have been geolocated to one pixel accuracy and mosaiced to produce the image.

During the experiment mid-summer foggy conditions persisted until the last day of the experiment limiting remote sensing opportunities. In spite of that we collected SAMSON Airborne hyperspectral data on Sept 5, 11, 12, and 15. Ship data was collected on those dates and additional measurements were made on cloudy days. Mooring and glider data were collected throughout the experiment. Overall we collected an exceptional data set for characterization of the HAB biology, optics and remote sensing characteristics. This data will be suitable for developing a West Coast HAB algorithm. On the last day of the experiment (September 15th) a dry cold front passed through the area thoroughly disrupting (ending?) the HAB; this dramatic change is documented in the remote sensing and in situ data.