HICO Data User's Proposal

Title: Transformational approach to monitoring water quality sustainability of coastal ecosystems from satellite remote sensing.

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Abstract:

EPA's charge to protect human health and the environment requires a long-term commitment to creating sustainable solutions to environmental problems. The most direct way for EPA to ensure that management practices are achieving sustainability is to monitor the environment. The Hyperspectral Imager for the Coastal Ocean (HICO), currently flying on the International Space Station, is an experimental satellite remote sensing technology which will be the focus of this project. The primary objective is to develop a novel space-based environmental monitoring system that provides information appropriate for the sustainable management of coastal ecosystems. Proof of concept will occur through field calibration of HICO to develop water quality products from this instrument package. The second objective is to provide the foundation for a technology, which EPA can use in the future to report water quality conditions nationwide through media outlets and Smartphone applications. A Smartphone prototype product delivery component will be developed for data dissemination to the Regional Offices and Office of Water. We seek to create an EPA multi-Regional integration for what can become a national application. This proof of concept project will allow Regional Offices and Office of

Water to learn the full capabilities of satellite remote sensing, while ORD scientists will gain insight to the specific requirements of each Region.

Project Description:

EPA's charge to protect human health and the environment requires a long-term commitment to creating sustainable solutions to environmental problems. The most direct way for EPA to ensure that management practices are achieving sustainability is to monitor the environment. Sustainable practices are often restricted to a localized group of stakeholders. Sustainable practices have a significant impact, when widely implemented, thus relevant at a national scale. The technology being tested in this project has the potential to revolutionize how the United States and the EPA approach and develop water quality initiatives. Innovative use of an experimental satellite remote sensing technology will be employed, using a sensor pay load, currently flying on the International Space Station (ISS) for this project.

The Hyperspectral Imager for the Coastal Ocean (HICO) became operational on the ISS in October 2009. Remote sensing technologies, such as HICO, will allow national coverage of water quality conditions in all estuaries and coastal waters. This proof of concept project will position EPA to the forefront of a paradigm shift on how the nation responds socially and economically to water quality. Just as the public is accustomed to relying on weather condition reports from local and national daily news shows, satellite technology like HICO will allow for local and national daily water condition news reports or Smartphone application reports. These water quality news reports will change the social and economic dynamics for a nation to not only be aware of its water quality condition, but also support sustainable practices to improve those conditions.

Over the last several decades, satellite technology has allowed measurements on a global scale, but often has poor resolution at smaller estuarine scales, which is a more relevant to water quality managers. Remotely sensed water quality products were first developed for global ocean observations and are recently making progress in some coastal waters, large estuaries and lakes. Remotely sensed products can only resolve larger inland water bodies such as Albemarle-Pamlico Sound (Lunetta et al. 2009), Chesapeake Bay (Werdell et al. 2009), and the Great Lakes (Pozdnyakov et al. 2005; Witter et al. 2009). Additionally, approaches and methods to develop satellite water quality products for estuarine waters and coastal waters are more complex than in the open ocean. No current method can resolve water quality products across a continuum of spatial and temporal scales to include small reaches, bayous, estuaries, and the larger coastal ocean (defined as within 3 nautical miles from land). HICO is the first remote sensor designed specifically to image the coastal ocean and this is the first time ISS is used as a platform for scientific Earth observations (Fig. 1B). HICO spatial resolution is approximately 90 m with spectral coverage from 380 nm to 900nm with less than 6 nm resolution (Corson et al. 2006). The next remote sensing platform to have similar capabilities for water applications is the Geostationary Coastal and Air Pollution Events (Geo-CAPE) satellite, scheduled to launch within the next decade (National Research Council 2007).

The **primary objective** of this project is to develop a novel space-based environmental monitoring system that provides information appropriate for the sustainable management of coastal ecosystems. Proof of concept will occur through field calibration of HICO to develop water quality products from this instrument package. If successful, broad application of this approach would allow unprecedented means to monitor coastal systems across a range of spatial and temporal scales never before feasible with field-based monitoring. The environmental response variables include light attenuation (m^{-1}), chlorophyll (mg m^{-3}), suspended solids (NTU

or mg L^{-1}), and organic matter (m^{-1}). The **second objective** is to provide the foundation for a technology, which EPA can use in the future to report water quality conditions nationwide through media outlets and Smartphone applications. A Smartphone prototype product delivery component will be developed for data dissemination to the Regional Offices and Office of Water.

HICO was launched approximately 1 year ago (October 2009), with the goal of optimizing the HICO platform for future satellite applications. If successful, such satellites would provide unprecedented and comprehensive coverage of the US coastal zone. This project will assist in HICO implementation by using ground based observations for calibration and validation of water quality products. The results from this project will help EPA provide meaningful input into the future launch of a satellite-based system. This is also the first time EPA is using satellite imagery for water quality data transfer through wireless Smartphone applications. This is the first EPA research project proposing to use satellite products with the appropriate spatial resolution to resolve small estuaries and adjacent coastal waters. Thus, this project will serve an important role in advancing ORD's path forward towards creating sustainable solutions to environmental problems. Critical to achieving such sustainable solutions are cost effective and robust means of implementing sustained observation of the nation's coastal and estuarine waters over large temporal and spatial scales.

Technical Approach:

This proof of concept project will focus on collecting *in-situ* data from coastal and estuarine water along the northeastern Gulf of Mexico, specifically those of northwest Florida. Collection will occur via autonomous underwater vehicles (AUV) and small boat surveys.

Coastal waters

AUVs will be deployed in the coastal ocean within 3nm of the shoreline. These unmanned operations are run on ground controlled navigation systems. AUVs will be programmed to operate during the week of a scheduled ISS overpass to maximize sensor match-up potential. AUV tracks will follow the 15m and 20m bathymetric contours from Pensacola to Panama City, Florida. Payloads include instruments to measure temperature, salinity, depth, attenuation, and fluorescence pucks for chlorophyll-a, CDOM and turbidity.

Small boat surveys

A 25-ft EPA research vessel will be used to sample water quality in Pensacola, Choctawhatchee, St. Andrew, and St. Joseph Bays. The sampling design will be orientated around sampling gradients of suspended solids, chlorophyll, organic matter, and water-leaving radiance. The field effort is designed to get the most samples coincident with satellite overpass, while representing the spatial variability within an estuary. The vessel will be equipped with an existing Satlantic Hyperspectral Surface Acquisition System (HyperSAS) underway system and CDOM, chlorophyll/turbidity integrated flow-through system. The HyperSAS logs hyperspectral measurements (350–800 nm, resolution 1 nm) of above-water radiance ($Lt(\lambda)$), sky radiance ($Ls(\lambda)$), and downwelling irradiance ($Ed(\lambda)$). The HyperSAS collects and derives measures of water quality just like HICO, so it is used for validation. Existing HyperSAS and flow-through systems have already been calibrated using discrete water samples analyzed for chlorophyll, suspended solids, particulate absorbance, phytoplankton absorbance, and CDOM absorbance from previous field efforts. Field techniques will follow the recommended methods in Ocean Optics Protocols Volume IV (Mueller et al. 2003).

HICO remote sensing

HICO images will be processed through an automated processing system to radiometrically and atmospherically correct water quality products using spectral bands corresponding to features of light attenuation, chlorophyll, suspended solids, and organic matter. Satellite validation of the derived water quality products against field measurements are performed using the native resolution of the sensor. Satellite match-ups are evaluated with a Type II geometric mean linear regression between a 3x3 pixel extractions of satellite data centered at the corresponding *in-situ* measurement location. Satellite data are filtered for quality flags such as cloud contamination, land, and atmospheric correction failure (Bailey and Werdell 2006). Primary target locations will be Pensacola, Choctawhatchee, St. Andrew and St. Joseph Bays in Florida. Additional target estuaries may be included with availability of ISS overpasses and ground sampling resources to show proof of concept for multi-Regional and national application.

Biographical sketch and available facilities:

The principal investigator and most Gulf Ecology Division (GED) co-investigators were funded in 2009 by the NASA Applied Sciences Program: Decision Support through Earth Science Research Results. Additionally, in 2010 the GED team has developed an approach using satellite remote sensing that is being considered by EPA's Science Advisory Board for use in deriving numeric nutrient criteria for the State of Florida's coastal waters. During the Deepwater Horizon oil spill GED investigators assisted in ship-board monitoring at the wellhead. GED investigators further assisted Region 6 at Unified Command Center in Robert, LA on dispersant effectiveness, and served on the National Incident Command's Joint Analysis Group because of our expertise in bio-optics, remote sensing, and oceanography. Senior investigators routinely present current research at national and international conferences and publish research results in quality peer-reviewed journals. Finally, the principal investigator represents EPA on the NASA Geo-CAPE Science Working Group.

External collaboration will include AUV deployment, operation, and data processing since GED does not currently operate or maintain AUVs. The Naval Research Laboratory in Stennis, Mississippi has entered into an interagency agreement with GED to operate AUVs on this project. We seek to create an EPA multi-Regional integration for what can become a national application. The Regional Offices and Office of Water will provide review and technical support on this project. Regional integration will provide a national two-way dialog with ORD scientists. This proof of concept project will allow Regional Offices and Office of Water to learn the full capabilities of satellite remote sensing, while ORD scientists will gain insight to the specific requirements of each Region. Additional expertise in hyperspectral data and satellite remote sensing will be provided by the Atlantic Ecology Division and NERL Environmental Sciences Division. The application development and proof of concept for imagery data dissemination using Smartphone or other wireless technology to Regional and Office of Water participants will be provided by the Office of Environmental Information.

Output and deliverables

Within the first few months of funding external collaborations, a Quality Assurance Project Plan and refined cruise tracks will be established. The first half of the year will focus on field data collection and processing. HICO georeferencing, atmospheric corrections, data transfer and format issues will be resolved in the first six months. The third quarter of the year will still include field data collection and HICO processing, but will focus on approach review, technical guidance, and Smartphone application prototyping by Regional Offices, Office of Water, and Office of Environmental Information. The fourth quarter of the project will transition

from data acquisition to refinement of approaches and preparation of peer-reviewed publication. A peer-reviewed manuscript will be submitted after successful completion of the project.

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