**HICO Data User's Proposal**

# Detection and Mapping of Harmful Algal Blooms (HABs) using HICO Data in Four Large Inland Lakes in Mississippi and the Grand Bay, MS-AL Gulf Coast

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**Abstract/Project Summary**

Four large lakes- Sardis, Enid, Grenada, and the Ross Barnett Reservoir in Mississippi and the Grand Bay at the MS-AL gulf coast serve as important economic and recreational resources for the state of Mississippi and Alabama. The proposed project focuses on (1) testing our atmospheric correction procedure with HICO data over inland and coastal optically complex waters, (2) for making our existing cyanonbacteria algorithms applicable to HICO data over the four large Mississippi lakes, (3) developing new algorithms applicable to HICO data to quantify *K. Brevis* and *Pseudonitzia* blooms in the Grand Bay, and (4) developing HICO algorithms for estimating CDOM and suspended sediments by incorporating absorption and back-scattering components in a forward modeling setup. The current ocean color sensors, VIIRS and MODIS are not appropriate for detecting water quality constituents in small to moderate sized water bodies. Due to HICO's improved spatial and, more importantly, spectral resolution, HICO data has a great potential to accomplish the objectives of this project. Since these systems are similar in many ways to other water bodies, this research may be applicable to other lakes and bays around the world.

## 1. Statement of Work/Project Description

***1.1 Goal and Objectives:*** The overarching goal of this project is to test and develop algorithms to estimate cyanobacterial, *K. Brevis* and *Pseudonitzia* concentrations from HICO data. The project will involve quantification of the harmful cyanobacteria in four major lakes in Mississippi (lakes- Sardis, Enid, Grenada, and the Ross Barnett Reservoir) and *K. Brevis,* and *Pseudonitzia* blooms in the Grand Bay at the MS-AL coast of Gulf of Mexico (Fig. 1). The approach will start with two sampling trips to each of the four Mississippi lakes and the Grand Bay to improve our protocols to remove the atmospheric and in-water constituents' signal from composite upwelling signals from inland and coastal water bodies, based on our existing atmospheric and water correction algorithms that were developed using OCM data. The proposed improvements include: (1) application and testing of the atmospheric correction procedure to HICO data (2) adjustments of the developed cyanobacterial algorithms for making them applicable to HICO data over optically complex waters, (3) development of HICO based algorithms for *K. Brevis* and *Pseudonitzia* mapping, and (4) developing HICO algorithms for estimating CDOM and suspended sediments by improved atmospheric correction and in-water constituents signal detection in productive inland waters. Recently, a procedure was developed to estimate cyanobacterial concentrations by quantifying chlorophyll *a* and the primary cyanobacterial pigment phycocyanin using OCM satellite data (Dash et al., 2011). This required the development of an atmospheric correction and vicarious calibration methodology and subsequently the development of a set of bio-optical algorithms to estimate cyanobacterial pigments in inland and coastal waters from satellite data (Dash et al., 2012). The Co-Is have done extensive work on marine optics and satellite oceanography (D'Sa et al., 2006; 2007, 2011; D'Sa and DiMarco, 2009; Walker et al., 2005; 2011, Walker and Rabalais, 2006). The proposed project focuses on applying the developed techniques to quantify Harmful Algal Blooms (HABs) and to map the water column constituents in four lakes and a bay using HICO data.

***1.2 Background and Project Significance:*** Four large Mississippi lakes- Sardis, Enid, Grenada, and the Ross Barnett Reservoir are the main drinking water source for more than 1 million citizens and serve as important economic and recreational resources for the state of Mississippi. Time-series of MODIS true color images from January 2010 to July 2012 clearly indicated the presence of algal blooms in all four lakes. Presence of algal blooms was also clearly indicated in the Grand Bay, MS-AL gulf coast by the time-series of MODIS true color images. Field data collected from the Grand Bay on October 18, 2012 also demonstrated higher levels of chlorophyll *a* and organic suspended sediments (Fig. 2). Field data collected from the four lakes during the summer of 2012 demonstrated the presence of numerous toxic species of cyanobacteria and the hepatotoxin microcystin that is produced by cyanobacteria (Fig. 3). The presence of cyanobacteria together with the toxins in all the four lakes and the high concentration of phytoplankton, potentially *K. Brevis* and *Pseudonitzia* warrant a thorough analysis of the water quality in these water bodies. However, the spatial and spectral resolution of currently available ocean color sensors limits this investigation. Hence, we propose to use data from the HICO sensor for the successful detection and mapping of the HABs in these four lakes and the Grand Bay.


Fig. 1. Location map of lakes Sardis, Enid, Grenada, Ross Barnett Reservoir and the Grand Bay with field sampling sites indicated.

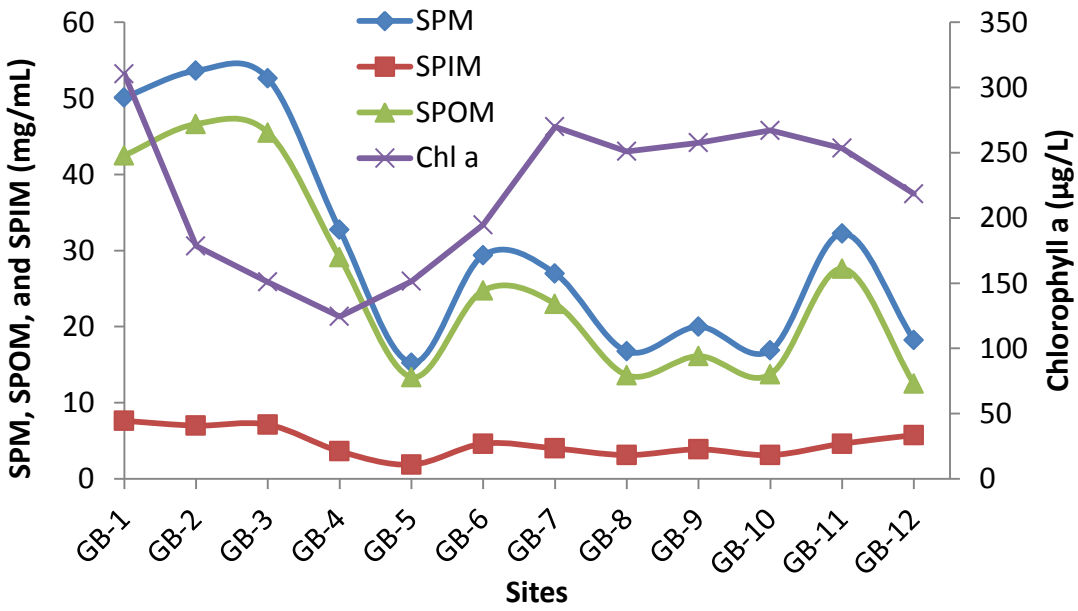


Fig. 2. Concentrations of Suspended Particulate Matter (SPM), Suspended Particulate Inorganic Matter (SPIM), Suspended Particulate Organic Matter (SPOM), and Chlorophyll a on 10/18/2012 at the 12 sites in the Grand Bay.

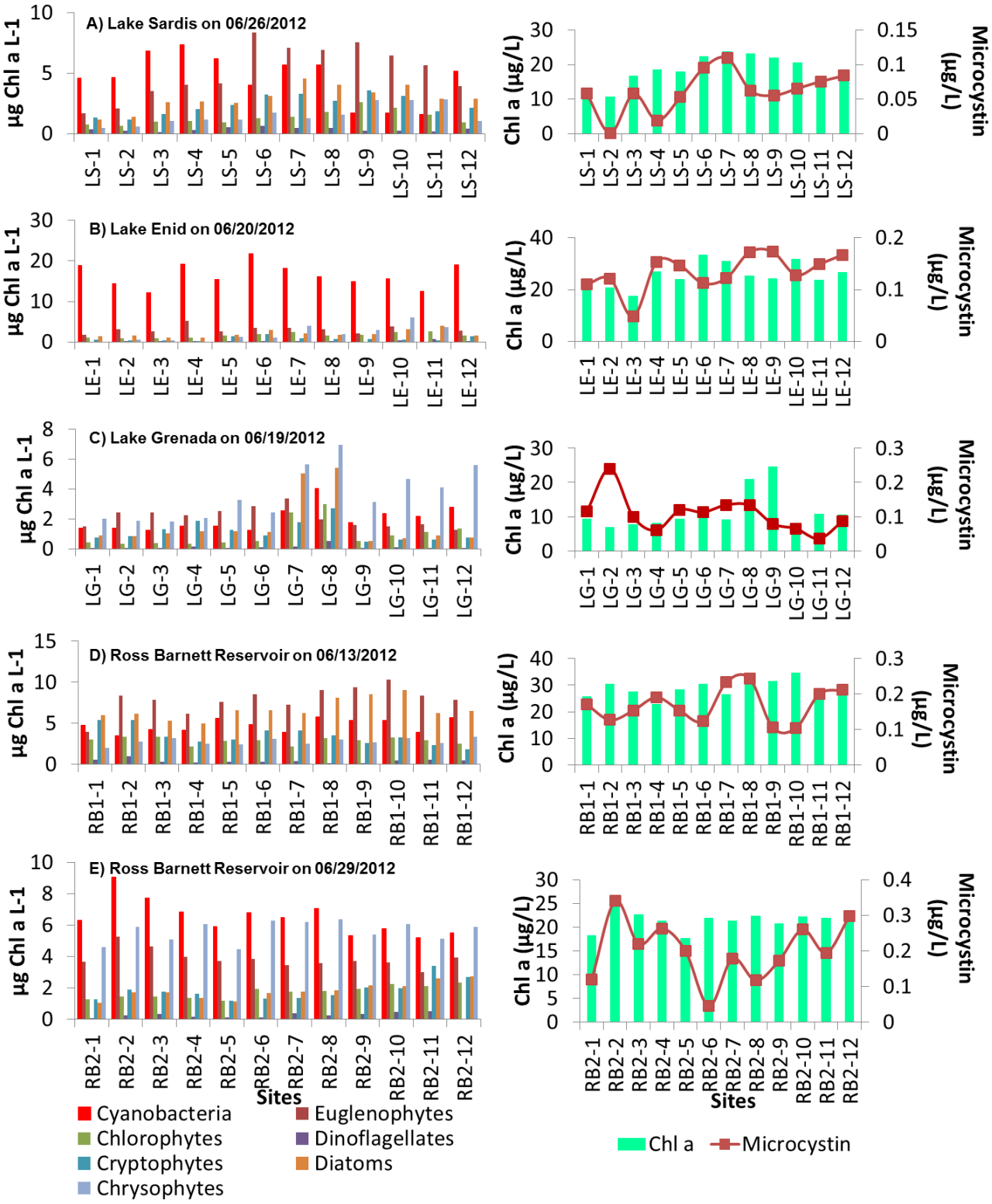


Fig. 3. Left panel shows the relative abundance of algal groups determined using HPLC pigment data and the right panel shows the concentration of chlorophyll a and cellular microcystin in water for lakes Sardis, Enid, Grenada and the Ross Barnett Reservoir from top to bottom.

***1.3 HICO Data Requested and Utility to the Proposers:*** We request Level 1 and Level 2 images that cover the four lakes and the Grand Bay during two different times per year for two years. Both Level 1 and Level 2 images are requested so that the results of the atmospheric correction on the Level 1 data can be compared with the Level 2 data. Two overpasses are requested to use the first overpass for algorithm calibration and the second overpass for algorithm validation. The center latitude and longitude of the four lakes and the Grand Bay are as follows (Fig. 1):

| | | |
|---|---|---|
| Lake Sardis: | Latitude: 34.46712 | Longitude: -89.68529 |
| Lake Enid: | Latitude: 34.15228 | Longitude: -89.82150 |
| Lake Grenada: | Latitude: 33.82909 | Longitude: -89.75355 |
| Ross Barnett Reservoir: | Latitude: 32.45520 | Longitude: -90.02848 |
| Grand Bay: | Latitude: 30.25595 | Longitude: -88.31093 |

HICO data will be of immense use to this project as the spatial and spectral resolution of the data from current satellite sensors such as VIIRS and MODIS are insufficient over the study areas of this project. HICO provides the necessary hyperspectral bands with much higher spatial resolution than the currently available ocean color sensors, which will be appropriate and will prove to be instrumental in detecting the HAB forming phytoplankton in the four largest lakes in Mississippi and the Grand Bay.

## 2. Biographical Sketch and Available Facilities

***2.1 Biographical Sketch of Investigators:*** **Dash (PI)** received his Ph.D. in Oceanography and Coastal Sciences from Louisiana State University (LSU), Baton Rouge, LA in December 2011 and has been employed with Jackson State University (JSU), Jackson, MS as an Assistant Professor in Biology and Environmental Science since February 2012. He specializes in remote sensing, harmful algal blooms, biological oceanography, environmental remote sensing, ocean color remote sensing, water quality, limnology, biological and physical oceanography and coastal & oceanic biogeochemical processes. He has authored and co-authored five papers in peer reviewed journals such as Remote Sensing of Environment, Remote Sensing, and Harmful Algae, given more than 20 professional presentations, and is supervising one Ph.D., one M.S., and nine undergraduate students at JSU. Now, he has two ongoing projects, one is funded by NOAA-NCCOS which is based on quantification of HABs in the Grand Bay, and another is being partially funded by MS INBRE which is based on a systems level approach to the water quality of the four largest lakes in Mississippi. **Walker (Co-I)** has over 30 years of experience in the application of satellite data to the study of coastal and deep ocean physical and biological processes. She has been funded as a co-PI by the NOAA NGOMEX hypoxia program, having worked with Dr. Nancy Rabalais (LUMCON), Dr. Eugene Turner (LSU), Dr. Steven DiMarco (TAMU) and Dr. Piers Chapman (TAMU) for the past decade. Her interests include the contribution of physical and biological factors to the development of hypoxia on the Louisiana shelf. She has studied the relationship between satellite-derived Chl a, nutrients and river discharge, and oxygen concentrations on the Louisana shelf. She has also studied hurricane-induced upwelling and the enhancement of Chl a in Gulf of Mexico cyclonic eddies and impacts of loop current frontal eddy cyclones and wind forcings on the 2010 gulf of mexico oil spill. **D'sa (Co-I)** is an Associate Professor in the Dept. of Oceanography and Coastal Sciences and he is interested in the field of marine optics and ocean color remote sensing. Specifically, his research interests have focused on understanding the optical properties of colored dissolved and particulate matter in the coastal waters and its interaction with the light field. D'Sa has used regional ocean color algorithms and hydrodynamic modeling in collaboration with NRL researchers to study physical influences on suspended particulate matter distribution in the Gulf of Mexico. Previously, D'Sa has collaborated with NASA researchers to develop ocean color algorithms for the optically-complex river-dominated waters of the northern Gulf of Mexico.

***2.2 Facilities:*** The laboratories of the three investigators are outfitted with the necessary computer resources. The PI's lab has three computers for image processing with IDL/ENVI, Erdas Imagine, and SeaDAS that will be used in this project. The PI's lab is also equipped with a portable GER 1500 radiometer and a Hanna instrument for use in this project. He has four filtration apparatuses, which will be used for the filtration of the water samples. The lab also has all the necessary equipment for SPM analysis. In addition, he has a plate reader for toxin anlaysis, an

Evolution 600 spectrophotometer for absorption measurements, and a Trilogy fluorometer for PC and Chl a concentration measurement among other standard laboratory resources. Additionally, the Plant Science Building, where the lab is located, has a -80° C Freezer, a centrifuge and a Shimatzu Fluorometer. He also has access to additional laboratory resources of the department (RCMI Core Labs). The Environmental Toxicology Core Laboratory maintains a well-equipped flow cytometry facility, where the imaging can be performed that will be required for the project for delineating the phytoplankton community structure. Walker is the Director of Earth Scan Laboratory (ESL) and Interim Director of Coastal Studies Institute (CSI) within the School of the Coast and Environment at LSU. The ESL, through a series of Louisiana state grants, has built extensive capabilities for capturing and processing satellite measurements from six unique satellite systems in real-time. The ESL is well-equipped with the computer resources. Walker's wet lab has a filtering apparatus. She has a GER 1500 radiometer and an YSI 6600 instrument. LSU CSI's Field Support Group has extensive expertise in working in the field and houses several boats and trucks. The D'Sa lab at LSU is equipped with equipment such as a Horiba Jobin Yvon Fluoromax© 4 fluorometer, a Perkin Elmer Lambda 850 spectrophotometer and a multiple path-length aqueous capillary waveguide. In addition, D'Sa lab has equipment including a Wetlabs ac-s, Wetlabs ECO triplet VSF-3 sensor and Satlantic Hyper-OCR Hyperspectral Radiometer.

***2.3 In Situ Data:*** Through the NOAA-NCCOS and MS INBRE projects the PI has collected extensive *in situ* data from all the four lakes and Grand Bay since summer 2012. The field data includes collection of water samples in clean Nalgene bottles, *in situ* remote sensing reflectance (*Rrs*) measurements using a GER 1500 spectro-radiometer (Spectravista Inc., NY), *in situ* backscattering measurements using a BB-3 instrument (Wetlabs Inc., OR ), and in situ water quality data using a Hanna multiparameter probe (HI769828, Hanna Instruments, RI). The water samples were collected for high performance liquid chromatography (HPLC) photopigments, the cyanobacteria unique pigment PC, colored dissolved organic matter (CDOM), suspended particulate matter (SPM), cyanotoxins, micro-organisms, toxic metals, and microscopy analyses. Additionally, the absorption and back-scattering coefficients were measured in the laboratory for characterizing the non-algal particulate and phytoplankton absorption and back-scattering properties. He plans to conduct at least 9 sampling trips this summer to collect additional data. Further, concurrent with HICO overpass dates, additional *in situ* data will be collected. All these *in situ* data will be used for this project.

**3. Output and Deliverables**

***3.1 Products:*** The output products of the project will be as follows:
(1) An atmospheric correction procedure for HICO data over inland and coastal optically complex waters
(2) A set of HICO algorithms for the estimation of cyanobacterial pigments
(3) A set of HICO algorithms for the estimation of *K. Brevis* and *Pseudonitzia* blooms
(4) A set of algorithms for CDOM and suspended sediments by incorporating absorption and back-scattering components in a forward modeling setup
(5) Presentations at the annual HICO, local and national meetings and publications of results in peer reviewed journals.

***3.2 Advancing the HICO Mission:*** This project will help advancing the HICO mission by testing, calibrating, and validating algorithms for cyanobacterial, *K. Brevis*, and *Pseudonitzia* blooms. Our substantial experiences with ocean color remote sensing in optically complex waters and measurements in this region will provide an opportunity to exploit the optimal utility of the improved spectral and spatial resolution presented by HICO data. The proposed project will possibly utilize the spectral regions not yet explored for estimation of HABs by other satellite sensors.

***3.3 Annual HICO Team Meeting:*** One of the investigators (possibly Dash and the involved students) will attend the annual meeting to present the project results and join in the discussions about uses and applications of HICO data.

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