HICO Data User's Proposal

Utilization of HICO Data for Great Lakes Water Quality Investigation

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Abstract/project summary:

Michigan Tech Research Institute (MTRI) proposes to use HICO imagery to aid in the study of water quality and water related environmental and climate change problems in the Laurentian Great Lakes. We will address three research topics using HICO imagery as well as exploring many follow-on questions to each main research topic. First, we will evaluate various existing atmospheric correction models for hyperspectral imagery to determine which models prove most effective over land and water. Proper atmospheric correction techniques are important when analyzing radiometric satellite data, especially over atmospherically dynamic areas like the Great Lakes. Finding an optimal atmospheric correction routine will allow MTRI to explore its next two related research topics. The exploitation of hyperspectral imagery could allow for both an increased accuracy in mapping existing water quality parameters, along with mapping more specific water quality parameters. These specific parameters include, but are not limited to, the differentiation of algal species, the separation of sediment based on both particle size and sediment type. MTRI proposes to evaluate re-sampled HICO imagery against concurrent MODIS imagery for existing water quality parameters, and also modify existing water quality algorithms to analyze full hyperspectral data such as HICO.

1. Statement of work/project description

As space borne sensors move towards hyperspectral capabilities (NASA Website), it is important to develop preliminary algorithms capable of processing hyperspectral imagery. The first step in this process is validating or modifying existing hyperspectral atmospheric correction models so they are accurate over the Great Lakes Region. Once an accurate atmospheric correction model is chose, existing water quality algorithms that are optimized for multispectral sensors can be applied to HICO imagery. This process works in two steps, first modifying HICO imagery to mimic existing multispectral imagery and assessing the accuracy of water quality algorithms. The second step involves modifying the existing algorithms to analyze hyperspectral imagery. The water quality algorithms that will be used in the initial analysis include the CPA-A algorithm designed to detect chlorophyll, suspended mineral, and CDOM absorption in the water column (Shuchman et. al., 2005, Shuchman et al., 2013), the Primary Production Algorithm, designed to calculate the primary production of a pixel based on chlorophyll concentration, location, and Julian day (Shuchman et al., 2013), and the HABs algorithm designed to quantify extent of Harmful Algal Blooms in the Great Lakes (Sayers et al., in prep). Hyperspectral imagery like HICO also provides scientist with the ability to explore problems and use analysis techniques that are not possible with conventional multi-spectral sensors. For example, the use of derivative analysis as well as spectral feature fitting can be used with HICO imagery due to the regularity of its band centers and increased spectral resolution (Williams et al., 2003; Becker et al., 2005). These techniques will hopefully prove useful when trying to differentiate different algal species in a harmful algal bloom, or identifying different sediment particle sizes/types from river outflow.

MTRI will use HICO imagery to atmospheric correction methods to establish an optimal routine for the Great Lakes. Secondly, HICO imagery will be used to model water quality constituents, and the accuracy of those models will be assessed. Finally the use of HICO and existing hyperspectral analysis techniques to identify different algal species and sediment particle sizes/types will be explored.

Establishing an optimal atmospheric correction routine for Great Lakes HICO imagery is important due to the dynamic nature of the atmosphere over the Great Lakes. The large inland water bodies can create different atmospheric properties than exist over the coastal ocean or land, and it is important to account for these differences when performing radiometric analyzes of HICO data. While algorithms like the CPA-A (Shuchman, 2012), PP (Shuchman -2013) and HABs (Shuchman- 2014) have been supported in literature using MODIS imagery, it is important to evaluate HICO's ability to monitor these same parameters against MODIS imagery.

MTRI will also use HICO to evaluate the MERIS based CI index, and index used for mapping cyanobacterium related to Harmful Algal Blooms (Wynne et al., 2010). Once HICO has proven to have acceptable accuracy, the additional utility of hyperspectral imagery in sensing water quality parameters will be assessed. The ability to map multiple species of algae found in Lake Erie can go a long way in directly determining whether an algal bloom is harmful. Furthermore, if species identification proves possible, the mapping of harmful toxins produced by different algal species found in Harmful Algal Blooms would also be possible. Another important aspect of mapping HABs is the identification of floating algal mats. These algal mats are erratic in nature, because many environmental factors (wind, temperature, chlorophyll residence time) have to align for the mats to occur. The patchy nature of these floating algal mats also makes it difficult for low spatial resolution sensors like MODIS to fully characterize this part of the Harmful Algal Bloom. HICO provides an opportunity both spectrally and spatially, to further analyze the spectral identification technique as well as help quantify the 'mixed pixel problem' for floating algal mats. The ability to identify sediment particle size/type could prove extremely useful in calculating incoming nutrient load from major rivers. Different particle sizes or types could transport different amounts or types of nutrients, which could in turn have effect on the severity of Harmful Algal Blooms in a given year.

2. Biographical sketch and available facilities

<u>PI Biographical Sketch:</u>

Dr. Shuchman is presently Co-Director of the Michigan Tech Research Institute (MTRI), and Adjunct Professor in the Department of Geological and Mining Engineering and Sciences at Michigan Technological University (MTU). Dr. Shuchman received his Ph.D. in Oceanic Sciences and Natural Resources from the University of Michigan in 1982. His dissertation included development of a combined hydrodynamic/electromagnetic model that correctly predicted the observed backscatter values of subsurface ocean bottom features imaged by the NASA Seasat Synthetic Aperture Radar (SAR). His publications include contributions to 5 books, over 50 refereed technical papers, over 75 technical reports and have presented over 100 papers at technical society meetings. Dr. Shuchman is the co-editor of the GSA Monograph entitled "Bering Glacier: Interdisciplinary Studies of Earth's Largest Temperate Surging Glacier". In recent years, he has been researching applications of advanced color producing agent algorithms to assessing Great Lakes water quality via remote sensing as well as the mapping of bottom cover types in the region for the US EPA under the Great Lakes Restoration Initiative (GLRI), the Great Lakes Observation System (GLOS), and NASA. He was PI for the 2009-2011 NASA ROSES Feasibility study on "Determining the Feasibility of Mapping and Monitoring the Extent of Cladophora in the Laurentian Great Lakes with Multi-Scale Remote Sensing" and is currently PI for the NASA ROSES Energy and Water Cycle study on "Multi-Scale Assessment of Water Quality using a Refined Chlorophyll, Dissolved Organic Carbon, and Suspended Minerals Algorithm for the Great Lakes.

<u>Facilities:</u>

A particular strength of the proposal team is the existing MTRI Spatial Analysis Lab infrastructure that has been successfully applied to previous related projects. Because the infrastructure is already in place, tested, and available for this project, we are not requesting any funding to cover new equipment, software, or other similar direct costs. The remote sensing and GIS software will be applied to solve complex spatial problems in this study. MTRI's fully-equipped Spatial Analysis Laboratory (SAL) is the primary source of hardware and software resources for geospatial projects at the Institute, and also helps main campus faculty and staff with geospatial components of research projects. The SAL includes a full suite of GIS and remote sensing software, a large and scalable storage system, and large-format printing capabilities. Remote sensing software includes ERDAS Imagine, ENVI with IDL, Feature Analyst, LiDAR Analyst, Trimble eCognition, and Imagemanip. GIS software includes ESRI's Desktop ArcGIS, Quantum GIS, ArcGIS Server, ArcSDE, ArcPad, Spatial Analyst, and the Geostatistical Analyst. Other relevant available software includes GeoServer, OpenLayers, GeoDjango implementations, PostGIS, Google Earth Professional and Trimble Pathfinder Office. The SAL data storage system holds 63 terabytes of spatial data, and has a comprehensive collection of GIS layers for study areas including the Great Lakes region and Alaska. MTRI operates two ArcGIS Servers, a GeoServer-based web server, a relational database servers (running Microsoft SQL Server and PostgreSQL), an Image Web Server, a remote access GIS processing server, six high-speed GIS workstations, and two sub-meter capable Trimble GPS units. MTRI owns and operates a portable ASD Field Spec 3 Spectroradiometer, which operates from 350 – 2500 nm. Multiple UAV platforms and a 17' Boston Whaler are also part of MTRI's field ready equipment.

3. Output and deliverables

The aim of this project is to present results in both scientific journals and conference proceedings as necessary. Specifically, MTRI will produce a validation paper detailing the results of the atmospheric correction model evaluation. Publications will also follow the evaluation of HICO with existing water quality parameter algorithms and separate publications for each the exploration of using HICO to differentiate algal species and sediment particle size/type. To more broadly distribute the HICO produced data products, MTRI will develop and publish example maps of the aforementioned parameters.

4. References

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