Data Processing and First Products from the Hyperspectral Imager for the Coastal Ocean (HICO) on the International Space Station

C.O. Davis[a*], R. A. Arnone[b], R. Gould[c], M.R. Corson[d], and M. Montes[e]

[a]Oregon State University, Corvallis, OR, USA - cdavis@coas.oregonstate.edu
[b]U.S. Naval Research Laboratory, Oceanography Division, Stennis Space Center, MS - arnone@nrlssc.navy.mil
[c]U.S. Naval Research Laboratory, Oceanography Division, Stennis Space Center, MS - gould@nrlssc.navy.mil
[d]U.S. Naval Research Laboratory, Washington, DC, USA – mike.corson@nrl.navy.mil
[e]U.S. Naval Research Laboratory, Washington, DC, USA – marcos.montes@nrl.navy.mil

Abstract – The Hyperspectral Imager for the Coastal Ocean (HICO) was installed on the International Space Station on September 24, 2009. HICO is the first spaceborne hyperspectral imager optimized for environmental characterization of the coastal zone. HICO data are collected and processed to produce maps including coastal bathymetry, bottom characteristics, and water column optical properties. Here we describe the HICO data processing system and give examples of HICO products.

Keywords: hyperspectral, coastal remote sensing, space

1. INTRODUCTION

The coastal ocean is a very complicated environment containing high levels of phytoplankton, suspended and dissolved organic matter, suspended sediments with various bottom types and depths, all of which can vary significantly on scales of tens to hundreds of meters. While multispectral ocean color imagers with 1 - 4 kilometer spatial resolution are excellent for imaging the open ocean the coastal ocean requires higher spatial sampling and multispectral data generally does not contain sufficient information to quantify and characterize the coastal environment (Davis et al. 2007). Over the past two decades, hyperspectral imaging from aircraft platforms has developed as a powerful method of characterizing the coastal environment. A hyperspectral imager records a contiguous spectrum of the light received from each pixel in the scene, and this extra spectral information is exploited to produce the desired maps of bathymetry, water constituents, and other coastal properties (Goetz, et al. 1985; Davis et al. 2006).

The Hyperspectral Imager for the Coastal Ocean (HICO) (Corson, et al. 2005) is the first spaceborne imaging spectrometer designed specifically to sample the coastal ocean. HICO will sample selected coastal regions at approximately 90 m with full spectral coverage (400 to 900 nm sampled at 5.7 nm) and a high signal-to-noise ratio to resolve the complexity of the coastal ocean. HICO is sponsored by the Office of Naval Research as an Innovative Naval Prototype (INP), and will demonstrate coastal products including water optical properties (absorption and scattering coefficients), bottom types, and bathymetry and on-shore vegetation maps. As an INP, HICO also demonstrates innovative ways to reduce the cost and schedule of this space mission including using Commercial Off-The-Shelf (COTS) components where possible. HICO was built in 16 months by the Naval Research Laboratory and was completed in July 2008 and integrated into the HICO and RAIDS Experimental Payload (HREP) in August 2008. HICO was integrated, launched and flown with support from and under the direction of the DoD Space Test Program. HREP was launched on the Japanese H-2 Transfer Vehicle (HTV) September 10, 2009. The HTV rendezvoused with the ISS on September 17, 2009. HREP was installed on September, 24, 2009 and the first HICO imagery was collected on September 25, 2009. HICO is operating normally and Image quality is excellent. A companion paper in this volume by Corson et al. discusses the HICO imager and its performance. Here we give an overview of the data handling and processing and we present example results for coastal regions and river mouth areas.

2. HICO DATA PROCESSING SYSTEM

HICO is a demonstration sensor and data is collected for particular study areas, from a target list compiled by NRL personnel with input from Navy, university, and international partners. The standard HICO scene is 42 x 192 km and a maximum of one scene is collected on each 90 minute orbit. Data requests are compiled by NRL and sent to the ISS by NASA for execution. Data is transmitted from the ISS to NASA Marshall Space Flight Center and then transferred to NRL in Washington DC (NRL-DC) for processing. The initial processing from level 0 (raw data) to level 1b (calibrated radiances with geolocation information) includes dark current subtraction, CCD smear correction, 2nd order correction, spectral calibration and radiance calibration (Fig. 1). The calibrated data are then sent to NRL Stennis Space Center (NRL-SSC) for further processing using the NRL SSC Automated Processing System (APS). APS was developed for processing SeaWiFS, MODIS and other multispectral ocean color data. It ingests level 1b data and produces a wide range of standard products. APS was modified in two fundamental ways to process HICO data: the capability to ingest full hyperspectral data cubes was added, along with the capability to apply hyperspectral algorithms to make a variety of products from that data. Thus, APS HICO has two processing lines: one for making standard APS products from HICO data convolved to multispectral bands and one for exploiting the full hyperspectral data. Using the multispectral line HICO data is binned spectrally to

* Corresponding author. Postal address: Oregon State University, 104 COAS Administration Building, Corvallis, OR, 97331, USA. Telephone: (541)737-5707. FAX: (541) 737-2064.

Proceedings Oceans from Space Symposium, Scoula Grande di San Giovanni Evangelista, Venice, Italy, 26-30 April 2010, JRC European Commission, EUR24324 EN-2010, pp 73-74.

simulate MODIS data and then processed to produce all the standard MODIS products but at 90 m ground sample distance (GSD) instead of the MODIS 1 km GSD. This is important in coastal areas were the tides, diurnal winds, river outflow and bottom features create complex patterns in the coastal ocean (Fig. 2).

The Hyperspectral processing is more experimental. As HICO is the first ocean color hyperspectral sensor in space we have not previously developed automated processing for hyperspectral ocean color data. The hyperspectral processing branch includes several options for atmospheric correction and product production. Additionally, the calibrated hyperspectral image cube is available and that data is being used at NRL, OSU and other universities and laboratories for developing new hyperspectral algorithms.

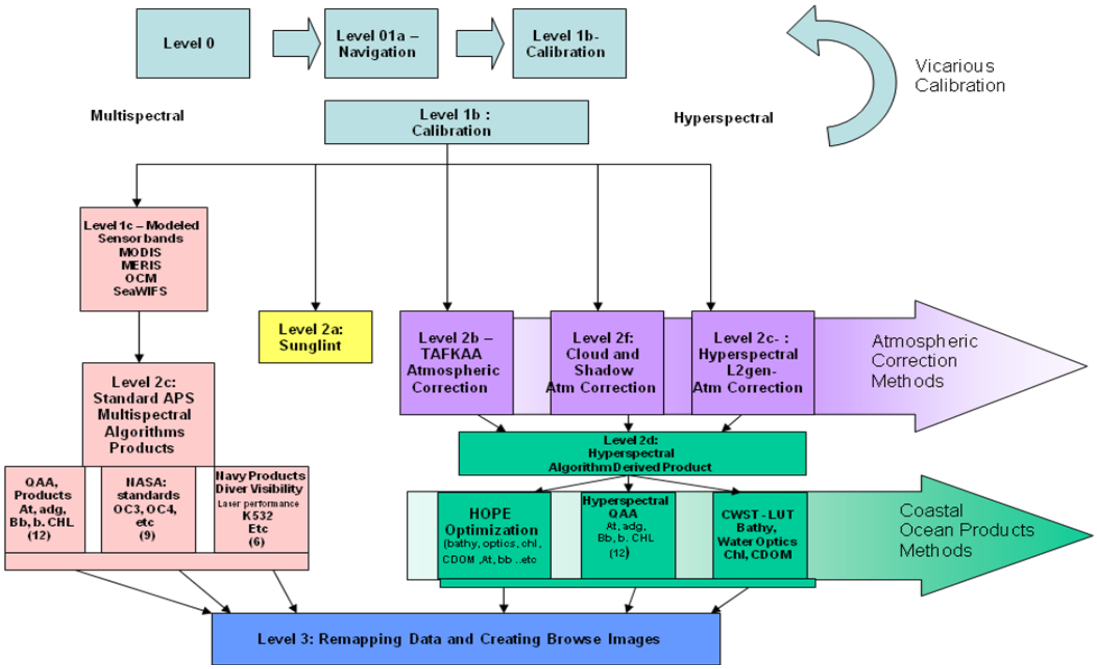

Fig. 1. Flow diagram for the HICO data processing system. The initial processing from Level 0 to 1b (blue boxes) is done at NRL-DC. The remaining processing is done in APS at NRL-SSC. The multispectral processing line (pink boxes) is used to produce MODIS like products at 90 m GSD. The Hyperspectral processing line (purple and green boxes) uses multiple approaches for atmospheric correction and product production to test and evaluate new approaches to take advantage of the full spectral data. Level three and higher processing (geolocation, binning, remapping, etc.) is then done to both data types.

3. EXAMPLE HICO PRODUCTS

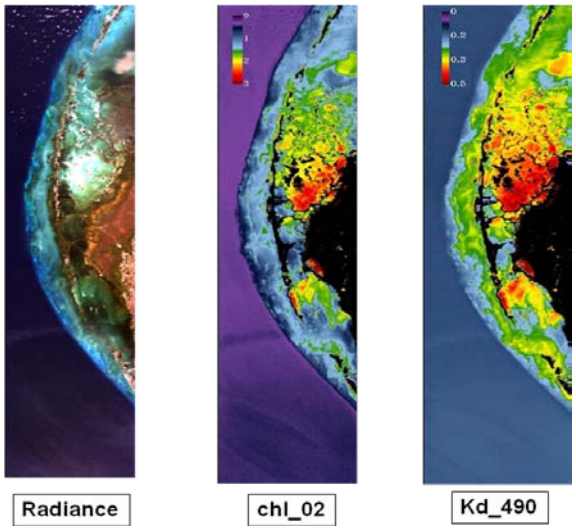

Fig. 2. Example APS products from a HICO image of the Florida Keys near Key Largo. Orientation is from southwest at the top to northeast at the bottom.

Figure 2 is an image of the Florida Keys near Key Largo showing some of the products produced with the multispectral HICO processing in APS. We continue to test and validate new products from HICO particularly for the full hyperspectral data.

4. CONCLUSION

The Hyperspectral Imager for the Coastal Ocean demonstrates the ability to produce coastal environmental products from spaceborne imagery. HICO and its products are pathfinders for future operational systems.

REFERENCES

Davis C.O., K.L. Carder, B.-C. Gao, Z.P. Lee, and W.P. Bissett (2006). “The development of imaging spectrometry of the coastal ocean”. IEEE Proceedings of the International Geoscience and Remote Sensing Symposium, 4, pp. 1982-1985.

Davis, C. O., M. Kavanaugh, R. Letelier, W. P. Bissett, and D. Kohler, (2007). “Spatial and spectral resolution considerations for imaging coastal waters”. Coastal Ocean Remote Sensing, edited by R. J. Frouin and Z. P. Lee, Proc. of. SPIE vol. 6680, 66800P, pp. 1-12.

Goetz, A. F. H., Vane G., Solomon J., and Rock B. N., (1985). “Imaging spectrometry for Earth remote sensing”. Science, vol. 228, pp. 1147−1153.

Corson, M. R., D. R. Korwan, R. L. Lucke, W. A. Snyder and C. O. Davis (2008). “The Hyperspectral Imager For The Coastal Ocean (HICO) On The International Space Station”. IEEE Proceedings of the International Geoscience and Remote Sensing Symposium, 978-1-4244-2808-3/08.