HICO Data User's Proposal

Impacts of Seagrasses and Ocean Acidification on Carbon Cycling and Sequestration at Dongsha National Marine Park, Republic of China (Taiwan)

Principal Investigator

Richard C. Zimmerman
Department of Ocean, Earth & Atmospheric Sciences
Old Dominion University
4600 Elkhorn Ave.
Norfolk, VA 23529
Tel: 757-683-5991
FAX: 757-683-5303
e-mail: rzimmerm@odu.edu

Co- Investigators

Victoria J. Hill, Dept. OEAS, Old Dominion University, vhill@odu.edu
David J. Burdige, Dept. OEAS, Old Dominion University, dburdige@odu.edu
Fred C. Dobbs, Dept. OEAS, Old Dominion University, fdobbs@odu.edu
Chin-Chang Hung, College of Marine Sciences, National Sun Yat-sen University, cchung@mail.nsysu.edu.tw

Signatures

Richard C. Zimmerman **Principal Investigator**	**H. Rodger Harvey** **Vice President for Research** **Old Dominion University**

Abstract/Project Summary

HICO imagery is requested to support our study of benthic biogeochemistry, carbon cycling and sequestration at Dongsha Marine National Park:

http://marine.cpami.gov.tw/english/index.php?option=com_efpublication&view=pdetailen&id=4&Itemid=79

The atoll is located at 20° 41’ 06.23”N 116° 48’ 43.98”E, approximately 420 km SE of the island of Formosa in the South China Sea. The Republic of China (Taiwan) will sponsor the research and cover all costs for travel and ground operations for the PIs, and provide access to the national park for this study during the period of 15 to 22 May 2014. Ground-based studies will provide a spectral library of benthic habitat types, a quantitative relationship between bottom reflectance and seagrass density, and various biogeochemical measures that will allow us to map seagrass density, sequestered organic (blue) carbon and rates of carbonate dissolution. HICO imagery will allow us to map these processes across the atoll and quantify their total impact on carbon dynamics in this unique system, testing the ability to apply algorithms and relationships we developed in previous studies to new locations in different ocean basins.

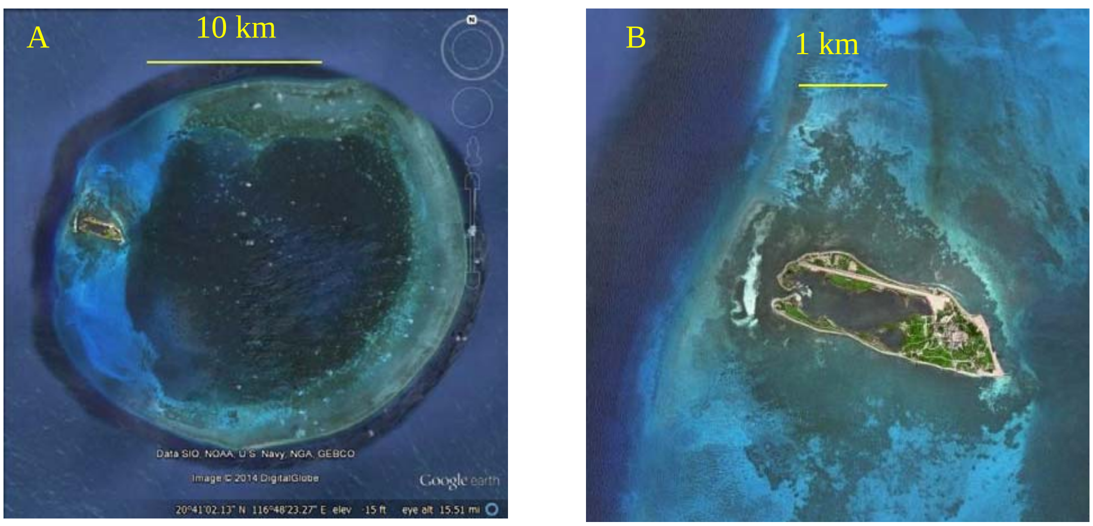

Figure 1. A. Google Earth image of Dongsha Atoll (20° 41N 116° 48’ E) showing the lagoon and barrier reef system. B. Close-up view of Pratas Island, on the eastern end of the atoll. The dark vegetated area around Pratas Island is mostly seagrass, and should be readily quantifiable with HICO 60 m imagery. Scale bars provided for reference.

1. Statement of work/project description

Dongsha Marine National Park is a circular coral atoll located approximately 420 km SE of the island of Formosa in the South China Sea (Fig. 1). It is approximately 23 km in diameter and ringed by a barrier reef that covers the western 70% of the perimeter. The eastern 30% the atoll consists of an extensive area of shallow (<3 m deep) habitat composed of carbonate sand vegetated by seven species of seagrasses, and Pratas Island which supports an airstrip, laboratory buildings and housing for the island staff and visiting scientists. The lagoon slopes to a central depth of 20 m and supports an extensive network of patch reefs, micro-atolls and sandy shoals vegetated to varying degrees with seagrasses and benthic algae.

Target specifications - A hyperspectral image from HICO is requested to support our study of benthic biogeochemistry, carbon cycling and sequestration at Dongsha Marine National Park. The central coordinate for the requested rectangle is

20° 41’ N Latitude
116° 48’ E Longitude

Target orientation (ascending vs. descending orbital path) is not critical, but the target should be imaged using an off-nadir view angle to minimize sun glint. The optimum dates for target acquisition are from 15 to 22 May 2014, during which time we will be conducting field work at the site (see below). However, precise concurrency with our field work is not absolutely critical, and any image collected during the month of May 2014 would be adequate.

Field measurements - This project will investigate the combined impacts of seagrass metabolism and ocean acidification on carbon cycling and sequestration on Dongsha Marine National Park, a coral atoll ecosystem administered by the Republic of China (Taiwan). Ocean acidification (OA) is likely to have dramatic consequences for carbon cycling throughout the ocean through its effects on carbonate solubility and on the provision of dissolved inorganic carbon (DIC) for photosynthesis. As with all climate change impacts, there will be ecological losers and ecological winners. Coral reef ecosystems, in particular, are likely to experience negative impacts because OA increases the solubility of biogenic limestone that forms the basis of the reef ecosystem (Fabry et al. 2008). In contrast, seagrasses (marine angiosperms) are projected to benefit from OA because photosynthesis is stimulated by increased concentrations of dissolved aqueous CO_2 (Zimmerman et al. 1997, Invers et al. 2001, Palacios and Zimmerman 2007). They are also an important source of blue carbon, and one of the few coastal ecosystems that can be demonstrably shown to promote the burial of organic carbon in marine sediments.(McLeod et al. 2011).

The field team of Co-I’s. Zimmerman, Burdige, Dobbs and Hung will be working at Dongsha Atoll from 15 – 22 May to measure seagrass density *in situ* using quadrats and transects at various locations throughout the atoll but particularly in proximity to Pratas Island. We will measure benthic spectral reflectance [$R_b(\lambda)$]of seagrass meadows across a range of densities from bare sand to extremely dense vegetation, as well as coral and macroalgae throughout the reef system, using our Diver-Operated Benthic Bio-Optical Spectrometer, a 3-channel HydroRad specially modified for measuring $R_b(\lambda)$ and the diffuse attenuation coefficient [$K_d(\lambda)$] that we have employed successfully in seagrass meadows throughout the Bahamas, Gulf of Mexico and California (Dierssen et al. 2003, Zimmerman 2003, Dierssen et al. 2009, Dierssen et al. 2010, Hill et al. 2014). Optical properties of seagrass leaves and leaf epiphytes will be determined as per (Drake et al. 2003). In addition to developing a reference library of spectra for quantifying benthic type for all habitats (coral, algae, seagrass, sand), we will quantify the relationship between $R_b(\lambda)$ and seagrass density that will allow us to map seagrass density and biogeochemical processes across the atoll from HICO imagery (Dierssen et al. 2003, Hill et al.

2014) and explore our ability to identify epiphyte loads in seagrass meadows from the hyperspectral HICO imagery.

We will analyze the chemistry of carbonate sediments and their porewaters to determine rates of organic matter deposition and carbonate dissolution as a function of seagrass density (Burdige and Zimmerman 2002, Burdige et al. 2008), both of which can serve as vehicles for the sequestration of atmospheric CO_2 in these shallow water ecosystems (McLeod et al. 2011). In addition, we will conduct an ocean acidification manipulative experiment in which compressed CO2 is bubbled into a patch of seagrass. The increased availability of CO_2 substrate should instantaneously stimulate seagrass photosynthesis (Zimmerman et al. 1997, Invers et al. 2001), below-ground O_2 transport (Bodensteiner 2006) and respiratory dissolution of carbonate sediment (Burdige and Zimmerman 2002), which we will follow by analysis of porewater chemistry.

Simultaneous with bio-optical and sediment geochemical measurements, we will collect sediment and seagrass biofilms for determination of domain Bacteria community structure. The samples' genomic DNA will be extracted and sent to a commercial facility for pyrosequencing of the hypervariable V1-V3 region of the 16S rRNA gene (Dowd et al. 2008). Sequence data will be analyzed using the mothur pipeline v.1.32.1 (Schloss et al. 2009). Taxonomy will be assigned (domain to genus level) using the Ribosomal Database Project Naïve Bayesian Classifier (Wang et al. 2007). DNA distance matrices will be calculated and sequences clustered into operational taxonomic units via the average neighbor algorithm (Schloss and Westcott 2011). Diversity richness will be calculated using rarefaction curves and invsimpson and Shannon indices, species richness with ACE and Chao 1 nonparametric estimators. Given these metrics of Bacteria community structure, we will test the hypothesis that there exist spatial- and niche-related differences among bacterial communities in the sediments and on leaf biofilms.

Co-I Hung will providing a digital elevation model of atoll bathymetry based on their airborne LIDAR surveys and acoustic soundings performed by the Republic of China (Taiwan), which will provide essential bathymetric data for quantifying the distribution of benthic vegetation and corals across the submarine landscape from HICO imagery, as reliable optical retrieval of water depth from remote sensing imagery has proven elusive. Although the very clear waters of this atoll may permit optical retrieval of bathymetry, the DEM will provide a firm basis for evaluating our retrievals and guide algorithm development in this area.

Maps of seagrass distribution and density across the atoll will be generated from HICO imagery using the spectral algorithm approach we developed for extremely clear waters of the Bahamas (Dierssen et al. 2003) and subsequently applied to more the more optically complex waters of St. Josephs Bay, Florida, in the Gulf of Mexico (Hill et al. 2014), after appropriate local calibration for leaf optical properties and sand reflectances.

2. Biographical sketches and available facilities

Richard C. Zimmerman is a Professor of Ocean, Earth & Atmospheric Sciences and directs the Bio-Optical Research Group at Old Dominion University. He will conduct the bio-optical measurements and quantify seagrass abundances needed at the field site needed for development of the quantitative maps from HICO imagery. Dr. Zimmerman has extensive experience with eco-physiology, bio-optics and remote sensing of seagrass ecosystems in temperate and tropical environments, and published more than 80 scholarly articles. He has been working with hyperspectral imagery since the mid-1990s, and was a principal developer of the seagrass bio-optical algorithm to be used in the analysis of the HICO imagery requested here.

Victoria J. Hill is a Research Assistant Professor of Ocean, Earth and Atmospheric Sciences and co-directs the Bio-Optical Research Group at Old Dominion University. Extensively trained in marine bio-optics, Dr. Hill has led our seagrass mapping efforts in the Gulf of Mexico using both hyperspectral (SAMSON) and multi-spectral (World View 2) imagery. Dr. Hill has published more than 15 papers on bio-optics and remote sensing of pelagic and coastal marine ecosystems and has been working with SAMSON hyperspectral imagery since 2005.

David J. Burdige is a Professor and Eminent Scholar of Ocean, Earth & Atmospheric Sciences at Old Dominion University. He will conduct the sediment geochemistry studies described above. He is an internationally-known expert in marine geochemistry, and he has spent much of his career studying biogeochemical processes in marine and estuarine sediments and their resulting effects on the cycling of carbon, nitrogen, and trace metals such as iron, manganese and copper. He has published more than 60 peer-reviewed papers, and in 2006 authored the book *Geochemistry of Marine Sediments*, published by Princeton Univ. Press.

Fred C. Dobbs is a Professor of Ocean, Earth & Atmospheric Sciences at Old Dominion University. A marine microbial ecologist, he will perform the 16S rRNA metagenomic studies described above. He has previously worked with Profs. Zimmerman and Burdige in research focused on carbonate sediments and seagrass biofilms. He has authored or co-authored more than 50 peer-reviewed publications.

Chin-Chang Hung is a Professor in the Department of Oceanography at National Sun Yat-sen University, Kaohsiung, Republic of China (Taiwan). Dr. Hung has been working on particulate organic flux since the mid-2000s. His current research interests are to study processes affecting marine carbon cycling and nutrient dynamics in the Dongsha Atoll and the South China Sea. His lab will provide necessary sampling equipment in this collaborative research between USA and Taiwan.

All equipment, laboratory instrumentation, and supplies necessary to perform the proposed field measurements will be provided by the PI's. The Republic of China (Taiwan) will provide funds for travel, shipping expenses, accommodations and laboratory facilities during the course of the field campaign. No support is requested from the HICO program except to provide a radiometrically calibrated, orthogonally registered hyperspectral image of the target.

3. Outputs and deliverables

The proposed study will quantify the relationship between seagrass abundance and the biogeochemical processes that control carbon cycling and sequestration at Dongsha Marine National Park, and the optical signatures of shallow water environments detectable by HICO imagery. All results of our benthic surveys, optical measurements, biogeochemical process studies and maps generated from HICO imagery will be provided to the HICO project as per the HICO data distribution policy. A signed data-user agreement was submitted with this proposal.

4. Literature cited

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