HICO Data User's Proposal

Determining inherent optical properties, bathymetry and benthic types using HICO imagery within northeast and western Australia

Principal Investigator:

Dr. Peter Fearns

Remote Sensing and Satellite Research Group
Department of Imaging and Applied Physics
Curtin University
Kent Street
Bentley, WA, 6102, Australia
Tel.: +61 9266 7450
Fax.: +61 9266 2377
e-mail: p.fearns@exchange.curtin.edu.au

Co investigators:

Dr. Lachlan McKinna, Curtin University, lachlan.mckinna@curtin.edu.au
Dr. Scarla Weeks, University of Queensland, s.weeks@uq.edu.au
Dr. Miles Furnas, Australian Institute of Marine Science, m.furnas@aims.gov.au
Mr. Mark Gray, Curtin University, markg@ivec.org
Mr Mark Broomhall, Curtin University, mark.broomhall@curtin.edu.au
Mr. Dan Marrable, Curtin University, d.marrable@curtin.edua.au
Mr. Rodrigo Garcia, Curtin University, rodrigo.garcia@student.curtin.edu.au

Determining inherent optical properties, bathymetry and benthic types using HICO imagery within northeast and western Australia

Abstract

Within Australia, information regarding light attenuation, bathymetry and benthic communities is of great importance for effective monitoring and management of aquatic ecosystems. Ocean colour remote sensing is a useful method for synoptic scale environmental monitoring of processes and change. However, many regions of interest such as coral reefs and seagrass meadows are located within optically complex, shallow regions. The increased spectral resolution of HICO makes the sensor an ideal candidate for remote sensing optically shallow ecosystems within Australia using the Bottom Reflectance Un-mixing Computation of the Environment model (BRUCE). Curtin University's BRUCE model is a hyperspectral inversion algorithm for deriving parameters of interest such as bathymetry, benthic types and IOPs. Focused airborne hyperspectral remote sensing surveys of Ningaloo Reef and Jurien Bay, Western Australia, have shown BRUCE to be an effective method.

Within this study we intend to use HICO data to complement present and planned field studies within north-eastern and western Australia. We aim to validate BRUCE-inverted HICO imagery with *in situ* radiometric, IOP and bathymetry data. These *in situ* data will also provide vicarious calibration opportunities for the HICO sensor. Additionally, comparisons between bathymetry derived from HICO and airborne imagery can be made.

1 Statement of Work

The main objectives of this project are to study shallow water ecosystems within Australia using *in situ*, airborne, and space-borne hyperspectral data. We propose to apply a shallow water inversion algorithm to HICO data to derive parameters of interest. Tasks undertaken within this research will include:

- Inversion of HICO data to retrieve inherent optical properties (IOPs), bathymetry and benthic habitat maps
- Validation of derived products using *in situ* data
- Collection of *in situ* hyperspectral radiometric data required for vicarious calibration of HICO

2 Background and Approach

2.1 Background

The Australian coastline is over 35,000 km in length. Presently, environmental concerns exist regarding the impacts of industrialisation, dredging, eutrophication, agricultural and urban runoff, and sea level rise in coastal zones. Consequently, numerous environmental agencies and research groups are undertaking water quality and benthic surveys within Australian to monitor change. At present, synoptic-scale ocean colour remote sensing using MODIS has been incorporated into water quality monitoring programs within the Great Barrier Reef, Australia (Schaffelke et al. 2010). However, the spectral resolution of MODIS is known to limit the retrieval of some parameters in optically shallow waters (Lee et al. 2002). In the situation of optically shallow waters, Lee et al. (2002) showed that a sensor with contiguous spectral bands spaced at least 10 nm apart is desirable.

For coral reefs and seagrass meadows, hyperspectral data have been used for deriving bathymetry and discriminating benthic communities (Dierssen et al. 2003; Mumby et al. 2004).

Research by Curtin University has found airborne hyperspectral imagery useful for these purposes (Klonowski et al. 2007; Fearns et al. 2011). Curtin University has developed the Bottom Reflectance Un-mixing Characterisation of Environment model (BRUCE) which can simultaneously retrieve IOPs, depth and benthic cover proportions via non-linear optimization (Klonowski et al. 2007). BRUCE is based on the Hyperspectral Optimization Process Exemplar model (HOPE) (Lee et al. 1998; Lee et al. 1999) with a modification to the bottom reflectance parameterisation. BRUCE presently handles three or more different benthic types, typically: coral, sediment and seagrass. However, these can be varied with adequate local knowledge of benthos within the study site. A focused study conducted at Jurien Bay, Western Australia using HyMap data showed the BRUCE algorithm's ability to retrieve bathymetry with a root mean square difference of 7% when compared to hydro-acoustic survey data. The Jurien Bay study also showed BRUCE could classify within-pixel relative proportions of three benthic types, which included sand, seagrass and brown algae.

Curtin University is currently partnered in several collaborative, multidisciplinary research projects (see Table 1). Within these projects Curtin University is tasked with providing a variety of geophysical products including IOPs, bathymetry, and benthic habitat maps from remote sensing imagery. An excellent opportunity exists to complement our existing research with HICO, a dedicated space-borne hyperspectral ocean colour sensor.

Table 1: Locations where Curtin University is planning or presently undertaking field surveys.

Site	***Region***	***Research Project Partners***	***Lat*** °S	***Lon*** °E
Heron Island	Great Barrier Reef	Australian Insitute of Marine Science (AIMS), University of Queensland (UQ)	23.44	151.92
Faure Sill	Shark Bay	West Australian Marine Science Institute (WAMSI)	25.96	114.05
Coral Bay	Ningaloo Reef	West Australian Marine Science Institute (WAMSI)	22.82	113.77
Barrow Island	Pilbara Coast	Department of Environment and Conservation (DEC)	20.80	115.40
Montgomery Reef	Kimberly Coast	Australian Museum	15.95	114.05
Swan River Estuary	Swan River	Swan River Trust	31.99	115.82
Darwin Harbor	Darwin	TBA	12.41	130.79
Esperance Archipelago	Esperance	TBA	34.12	122.17

2.2 Proposed Study Sites

Presently, Curtin University is actively collecting in situ hyperspectral radiometric data and IOPs within the north-eastern and western parts of Australia. Regions of recent, ongoing and planned field surveys include the Great Barrier Reef (GBR), Ningaloo Reef, Shark Bay, the Kimberly Coast, the Pilbara Coast and the Swan River Estuary, Darwin Harbour, and the Esperance Archipelago (see Figure 1). Of these eight regions, the GBR, Ningaloo Reef, and Shark Bay have been granted UNESCO World Heritage status.

Curtin University is conducting field sampling in optically shallow regions of the GBR from 2011 – 2013. These field surveys comprise both broad-scale and localised surveys. The broad-scale GBR surveys will be conducted from ships-of-opportunity approximately twice a year. Localised surveys will be conducted from small boats and focus on the coral reef surrounding Heron Island in the southern GBR. The next Heron Island research survery will be conducted from 1 – 7 December 2011.

Other planned and ongoing field studies during 2011 – 2012 include periodic sampling of the Swan River Estuary, and Barrow Island. An expedition to the Kimberly Coastline will take place in the latter part of 2011. Future studies of Darwin Harbour and the Esperance Archipelago are also being considered.

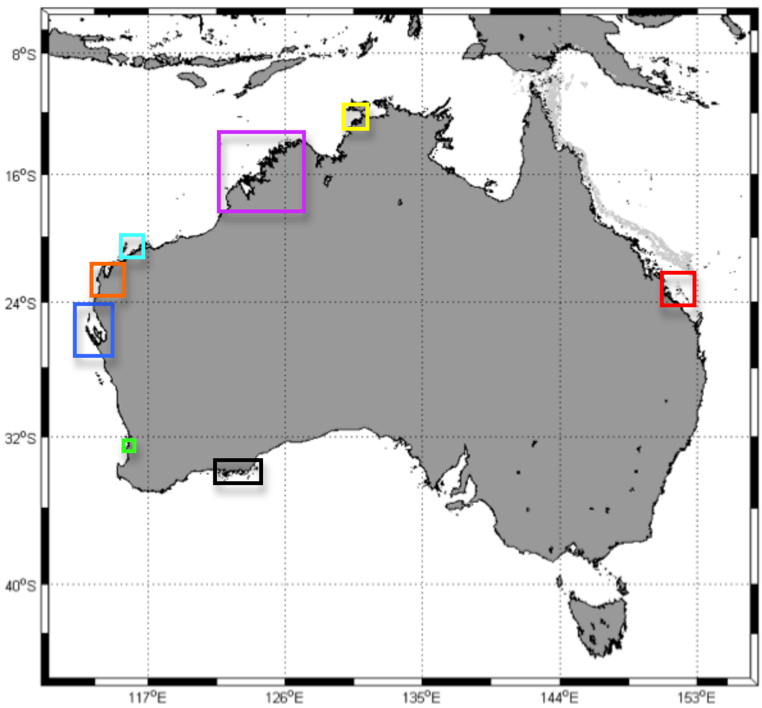

Figure 1: Present and planned field study locations within Australia: Heron Island, the Great Barrier Reef (red box), Darwin Harbour (yellow box), the Kimberly Coast (purple box), Pilbara Coast (light blue box) Ningaloo Reef, (orange box), Shark Bay (dark blue box), the Swan River (green box) and the Esperance Archipelago (black box).

2.3 Sampling Approach

Curtin University is experienced in conducting focused field campaigns for the purpose of algorithm development and validation in optically shallow waters. Typically, a three-channel, hyperspectral radiometer is used to measure above-water remote sensing reflectance, $R_{rs}(\lambda)$, from a small boat. Co-incident measurements of acoustic depth, IOPs and water quality parameters such as chlorophyll-a concentration and total suspended solids are also made. Representative samples of benthos such as sediment, coral and seagrass are collected for each region and their irradiance reflectance spectra, $R(\lambda)$, are measured. This approach allows the BRUCE model to be regionally tuned with appropriate benthic reflectance inputs. The *in situ* IOPs and bathymetry information provide a validation data set which is essential for verifying algorithm performance. Our approach also provides under-atmosphere radiometric data that is useful for assessment and tuning of atmospheric corrections, and further refinement of the BRUCE algorithm.

3 Biographical Sketch

3.1 Biographical sketch of PI

Dr. Fearns has over 15 years experience in physics and remote sensing science. His work has recently focussed on ocean colour remote sensing and in-water optical processes. He is a member of the Curtin University of Technology's Remote Sensing and Satellite Research Group. The group has expertise in field-based collection of optical and biogeochemical validation data, processing and analysis of aircraft and space-based remotely sensed data, reception and management of direct broadcast data, and processing of very large data sets using High Performance Computing facilities. The group has a long history of modelling and algorithm development in atmospheric, land and ocean remote sensing. Dr. Fearns has been involved in all aspects of the Group's research.

4 Available Resources and Facilities

4.1 Computing Infrastructure

Curtin University presently has the facilities to process and archive hyperspectral imagery using the iVec high performance computing infrastructure (http://www.ivec.org). The iVec facility presently has over 10,000 processing cores and a petabyte storage system.

4.2 Radiometric Calibration

To ensure radiometric data collected in the field is the highest quality, Curtin University has established a calibration facility. The facility ensures that radiometric instruments are frequently calibrated using a NIST-traceable FEL lamp and precision current source following Volume II of the Ocean Optics Protocols for Satellite Ocean Color Sensor Validation (Mueller et al. 2003).

4.3 Software

Curtin University has access to a series of useful software packages and computer code for processing hyperspectral remote sensing including:

- ENVI and IDL software for processing hyperspectral airborne imagery.
- TAFKAA atmospheric correction
- Hydrolight-Ecolight radiative transfer software
- SeaDAS ocean colour processing software

4.4 Instruments

For field validation purposes, Curtin University presently has access to, and experience with, the following instruments:

- WET Labs ac9 meter
- WET Labs bb9 meter
- HOBI Labs Hydroscat 6 meter
- WET Labs c-star transmissomter
- Wet Labs chlorophyll-a fluorometer
- A DALEC hyperspectral above-water radiometer
- HOBI Labs HydroRad profiling radiometer

4.5 Data Archive

4.5.1 Hyperspectral Airborne Data

Curtin University is actively collecting and processing hyperspectral imagery using an airborne AISA Eagle II sensor. These data have been georectified, aerosol and glint corrected and inverted with BRUCE to retrieve bathymetry, benthic cover and IOPs for Ningaloo Reef, Jurien Bay, and most recently Shark Bay (Klonowski et al. 2007; Fearns et al. 2011).

4.5.2 Spectral Reflectance Library

Curtin University is compiling a spectral library of bottom reflectance spectra for each region where field studies are conducted. These spectra include a variety of corals, seagrasses, sediments and algae.

5 Deliverables

Outputs and deliverables from this research will include:

- BRUCE model evaluation, improvement and recommendations
- Inherent optical properties
- Bathymetry mapping
- Benthic habitat maps
- Vicarious calibration data

References

Dierssen, H. M., R. C. Zimmerman, R. A. Leathers, T. V. Downes and C. O. Daviss (2003). "Ocean Color remote sensing of seagrass and bathymetry in th Bahamas Bands by high-resolution airborne imagery." Limnology and Oceanography **48**: 444-455.

Fearns, P. R. C., W. Klonowski, R. C. Babcock, P. England and J. Phillips (2011). "Shallow water substrate mapping using hyperspectral remote sensing." Continental Shelf Research **31**(12): 1249-1259.

Klonowski, W. M., P. R. Fearns and M. J. Lynch (2007). Retrieving key benthic cover journal articles and bathymetry from hyperspectral imagery, SPIE.

Lee, Z., K. L. Carder, C. D. Mobley, R. G. Steward and J. S. Patch (1998). "Hyperspectral Remote Sensing for Shallow Waters. I. A Semianalytical Model." Appl. Opt. **37**(27): 6329-6338.

Lee, Z., K. L. Carder, C. D. Mobley, R. G. Steward and J. S. Patch (1999). "Hyperspectral Remote Sensing for Shallow Waters. 2. Deriving Bottom Depths and Water Properties by Optimization." Appl. Opt. **38**(18): 3831-3843.

Lee, Z. P. and K. Carder (2002). "Effect of spectral band numbers on the retrieval of water column and bottom properties from ocean color data." Applied Optics **41**(12): 2191-2201.

Mueller, J. L. and R. Austin (2003). Characterization of Oceanographic and Atmospheric Radiometers. Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 4. J. L. Mueller, G. S. Fargion and C. R. McClain. Greenbelt, NASA Goddard Space Flight Center. **Volume II**.

Mumby, P. J., W. Skirving, A. Strong, J. T. Hardy, E. LeDrew, E. H. Hochberg, R. P. Stumpf and L. T. Davind (2004). "Remote sensing coral reefs and their physical environment." Marine Pollution Bulletin **48**: 219-228.

Schaffelke, B., M. Furnas, M. Skuza, J. L. Mueller, K. Kennedy, J. O'Brien, C. Bentley, A. Heffernan, A. Dunn, S. Carter, M. Hodge, V. E. Brando, A. G. Dekker and T. Schroeder (2010). Inshore marine water quality monitoring. Reef Rescue Marine Monitoring Program: Quality Assurance / Quality Control Methods and Procedures. Townsville, Reef and Rainforest Research Centre.