Australian Government
Department of the Environment, Water, Heritage and the Arts

Marine and Tropical Sciences Research Facility Milestone Report, 31 January 2009

Program 5i: Climate change: Great Barrier Reef

Project 2.5i.2: Early warning and assessment system for thermal stress on the Great Barrier Reef – Extension (b) *Implementation of Kd[par], the attenuation of photosynthetically available radiation, to the Great Barrier Reef ecosystem*

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Report Summary

Collaboration with the NASA Ocean Biology Processing Group (OBPG) and Dr. ZhongPing Lee of the US Naval Research Laboratory to develop a process for generating maps of euphotic depth in space and time for Great Barrier Reef (GBR) waters has been advanced considerably. Euphotic zone depth reflects the depth where the photosynthetic available radiation (PAR) is one percent of its surface value, providing a measure of water clarity. ZhongPing Lee's "Case-2" IOP (Inherent Optical Properties)-based algorithm is currently considered the optimal operational water-clarity algorithm to determine euphotic depth in eutrophic waters.

An international Inherent Optical Properties Algorithm Workshop, *Ocean Optics XIX*, took place in Italy in October 2008 – the workshop goal being to achieve international consensus on the most effective algorithmic approach for producing remotely-sensed semi-analytical IOP products. The optimal algorithms to retrieve IOPs of the water column were selected from the international scientific community, analysed and tested. A consensus algorithm was determined based on Lee's remote sensing reflectance ratios. The NASA is currently in the process of implementing the consensus IOP algorithm into the NASA SeaDAS software and will begin producing global time-series of IOPs for all ocean colour missions (MODIS, MERIS and SeaWiFS) over the next several months.

Further to this, the NASA OBPG has now incorporated Lee's "Case-2" IOP-based algorithm into the SeaDAS software. Collaboration between ZhongPing Lee, Scarla Weeks and the OBPG has led to the initiation of an effective approach to the application of this algorithm to MODIS satellite data for waters of the GBR. Specific algorithm validation and further refinement of the water-quality algorithm for optically shallow GBR waters (where the sensor can 'see' the substratum or bottom) requires GBR in situ data. However, the availability of GBR in situ data to both regional scientists and to the international Bio-Optical Marine Algorithm Data set (NOMAD) housed at NASA remains an unresolved issue. Dr. ZhongPing Lee will travel to Australia in February 2009 and Scarla Weeks will convene a meeting at the University of Queensland, to which Australian ocean colour scientists are invited to participate and discuss a potential resolution.

As the recently (2008) elected committee member to the panel of the International Ocean Colour Co-Coordinating Group, Scarla Weeks has been invited to attend the 14th IOCCG

Committee meeting in China in April 2009. The main objectives of the meeting will be to develop international consensus and synthesis of satellite ocean colour and decide on specialised scientific working groups to investigate various aspects of ocean-colour technology and its applications.

Project Milestones to be Reported Against

Milestones
Project 2.5i.2 Extension (b) **Description:** The objective of this project is to detect changes to the transparency of the water column which is critical for understanding the exposure of the Great Barrier Reef to risk factors that cause coral bleaching, or are involved in nutrient/flood dynamics. This partnership with the NASA Ocean Biology Processing Group (OBPG) will deliver maps of water clarity in space and time based on the optimal, available algorithm for light attenuation through the water column. These will form an integral layer to the Risk Resilience and Response Atlas (MTSRF Project 1.1.5), hence allowing the detection and monitoring of the two most important environmental impacts on the Great Barrier Reef – thermal stress and turbidity change. **Milestones:** 1. Acquire relevant MODIS Aqua satellite data at one-kilometre resolution from the NASA OBPG for the period mid-2002 to present. 2. Develop a process to generate maps of euphotic depth in space and time, using ZhongPing Lee's "Case-2" IOP-based algorithm, to cover the entire GBR regional waters, extending from 10°S-30°S; 142°E-158°E at two-kilometre spatial resolution, and further selected regions at one-kilometre resolution. 3. Work with NASA and Lee to develop an effective approach to remove the impacts of bottom on the retrieval of water properties in coral reef ecosystems, using available in situ optical data. 4. Liaise with regional RS scientists to incorporate GBR in situ data to the extent possible into the development of these optical products. 5. Collaborate with Reef Atlas participants in selection of sub-regions and optimal temporal periods and temporal resolution of required outputs (daily/weekly/monthly).

Project Results

1. Acquire relevant MODIS Aqua satellite data at one-kilometre resolution from the NASA OBPG for the period mid-2002 to present.

MODIS Aqua satellite data has been acquired at one-kilometre resolution for the GBR regional waters extending from 10°S-30°S; 142°E-158°E for the full Aqua period: mid 2002 to present. Testing of Lee's euphotic depth algorithm has been applied to the more recent data, from January 2007 onwards.

2. Develop a process to generate maps of euphotic depth in space and time, suing ZhongPing Lee's "Case-2" IOP-based algorithm.

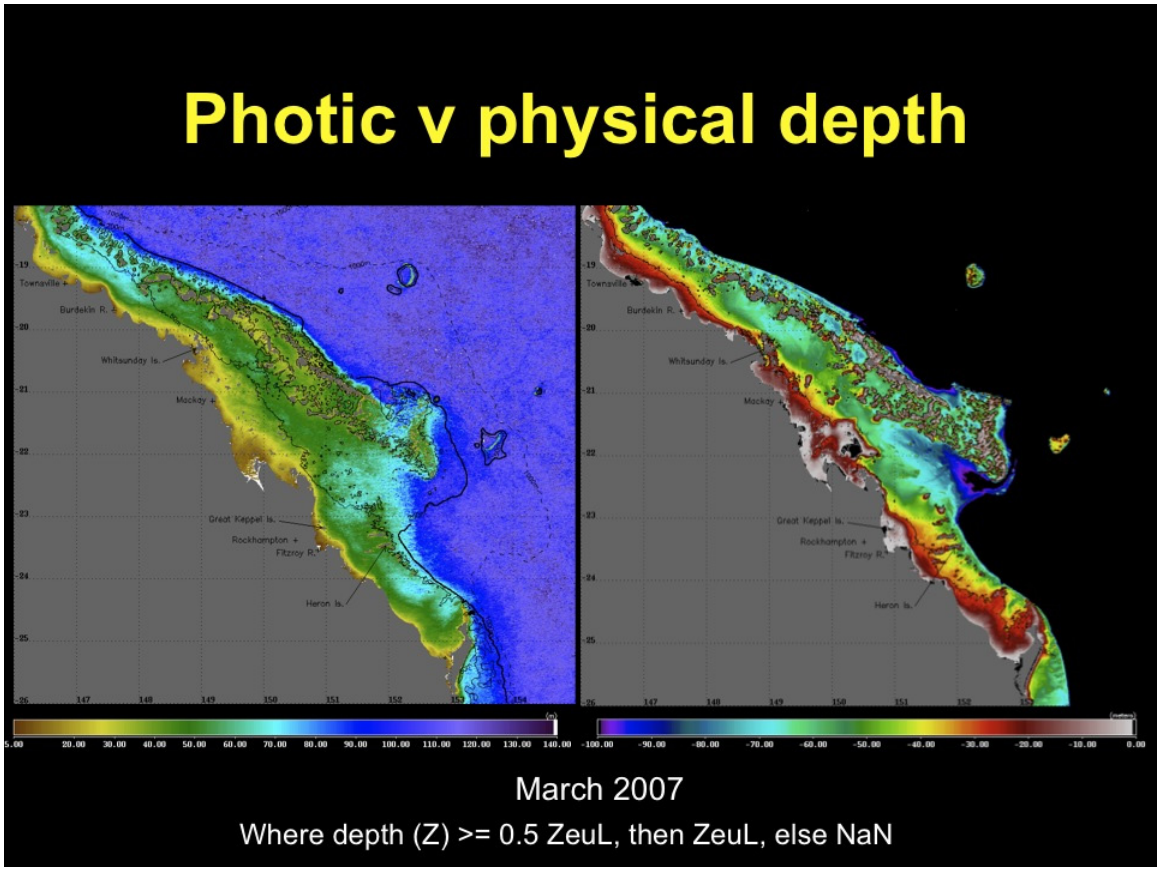
Lee's Euphotic Depth algorithm has now been implemented into SeaDAS, the NASA ocean colour software. Euphotic zone depth, the depth where photosynthetic available radiation (PAR) is one percent of its surface value, measures water clarity much more rigorously than Secchi depth and provides much more reliable results (Lee *et al.* 2007;

Preisendorfer 1986)[1]. Lee's algorithm is a quasi-analytical (QAA) algorithm based on the Inherent Optical Properties of the water column, and developed for "Case 2" (eutrophic) waters. The algorithm has now been tested and validated for oceanic and coastal waters, including the Arabian Sea, Gulf of Mexico, Monterey Bay, Yellow Sea, China, and in different seasons. It will be validated for GBR specific waters as soon as regional in situ data is made available for validation purposes.

Collaboration between ZhongPing Lee, Scarla Weeks and the OBPG has led to the initiation of an effective interim approach to the application of the Euphotic Depth algorithm to MODIS satellite data for GBR waters. The satellite data are processed with SeaDAS, applying the Euphotic Depth algorithm to GBR regional waters. Further processing is then applied to the output parameter, *ZeuL*, whereby the following criteria are tested and implemented for each data pixel:

Using Geoscience Australia 250m bathymetric data:
For waters deeper than 30m, use *ZeuL*
For waters shallower than 30m,
if the depth is greater than 0.5 *ZeuL,* use *ZeuL*
if the depth is less than 0.5 *ZeuL,* apply a mask to the pixel.

The figure below shows, (i) the mean euphotic depth for the southern GBR for March 2007 prior to application of the above criteria (left panel), and (ii) the 250m resolution bathymetry mapped to the identical region (right panel).



[1] Lee, Z., Weidemann, A., Kindle, J., Arnone, R., Carder, K. L. and Davis, C. (2007) Euphotic zone depth: Its derivation and implication to ocean-color remote sensing. *J. Geophys. Res.* 112, C03009 [doi:10.1029/2006JC003802]
Preisendorfer, R. W. (1986) Secchi disk science: Visual optics of natural waters. *Limnol. Oceanogr.* 31(5): 909-926.

Based on this approach, selected monthly mean images of Euphotic Depth have already been generated for, (i) the GBR region (10°S-30°S; 142°E-158°E), and (ii) the southern GBR (18°S-26°S; 146°E-155°E), at one-kilometre resolution retrospectively to January 2007. This approach is considered suitable as a general quality index of euphotic depth in GBR regional waters. However, optically shallow water pixels (where the sensor can 'see' the substratum or bottom) are masked. This essentially impacts clear shallow waters, such as inshore coastal waters in non-monsoonal winter months and shallow waters around the outer coral reefs.

3. **Work with NASA and Lee to develop and effective approach to remove the impacts of bottom on the retrieval of water properties in coral reef ecosystems, using available in situ optical data.**

Lee's euphotic depth algorithm functions very well for optically deep waters, i.e. waters where the sensor cannot 'see' the substratum. This may be a confusing point for some as river plume waters are optically deep waters, as are any waters where constituents are such that visible light does not reach the physical bottom. The approach outlined above deals effectively with this data.

However for water pixels classified as optically shallow, specific algorithm validation and further refinement of the water-quality algorithm is required, requiring GBR-specific in situ data. The above approach masks pixels considered as optically shallow. Further studies of real or simulated cases need to be undertaken to determine ZeuL for these pixels. To this end, a proposal was submitted to NASA in 2008 to: "Develop an operational water-clarity algorithm for optically-shallow waters: A support for coral reef studies", as a collaboration between ZhongPing, the NASA OBPG and Australian RS scientists. UQ, CSIRO and AIMS colleagues were included as co-PIs on this proposed work, in an attempt to advance regional collaboration. The proposal was unfortunately not funded. Scarla is presently exploring alternative options for funding to achieve this necessary collaboration. ZhongPing Lee will travel to Australia in February 2009 and Scarla is convening a meeting at the University of Queensland inviting Australian colleagues to participate and discuss the optimal way forward.

4. **Liaise with regional RS scientists to incorporate GBR in situ data to the extent possible into the development of these optical products.**

The availability of GBR in situ data in particular to the international Bio-Optical Marine Algorithm Data set (NOMAD) housed at NASA remains an unresolved issue. To date, NOMAD includes coincident (satellite and in situ) radiometric spectra data from over 4000 global stations – but not a single data point from Australian regional waters. These are the data used by the international scientific community in the development and validation of remote-sensing algorithms; hence GBR waters are currently not included in the algorithm development.

GBR in situ data currently resides primarily with CSIRO, with limited data at Curtin University and AIMS. The relevant colleagues at these institutions were included in the proposal submitted to NASA in 2008, not funded though. As mentioned above, Dr. ZhongPing Lee will travel to Australia in February 2009 and Scarla Weeks is convening a meeting at University of Queensland February 2009, inviting regional RS scientists. The primary objective of this meeting will be to find an optimal collaborative framework which will allow incorporation of GBR in situ data to determine the euphotic depth in optically shallow waters of the GBR.

5. **Collaborate with Reef Atlas participants in selection of sub-regions and optimal temporal periods and temporal resolution of required outputs (daily/weekly/monthly).**

   A discussion with Reef Atlas development personnel has been undertaken regarding the formats of data and imagery for import into the Atlas. Currently, the Atlas is unable to import HDF data – the common format for satellite data (along with netCDF). An example of an HDF data file has now been provided to the Atlas developers, along with associated PNG files, showing the region of interest. In order to incorporate satellite data, it will be fairly important for the Atlas to be able to import both HDF and netCDF, and perhaps interchange between these formats. The software generally used by satellite RS scientist is IDL and/or MatLab. The NASA software package, SeaDAS, is built on top of IDL – ref http://oceancolor.gsfc.nasa.gov/seadas/.

Problems and Opportunities

Achieving agreement on participation and collaboration of the NASA proposal to develop an operational water-clarity algorithm for optically-shallow waters encompassed much time and effort. Hence, the lack of funding is disappointing, particularly as the project offered an incredible opportunity for Australian scientists to collaborate not only with one another, but with of the best algorithm folk internationally. However, the planned meeting in February 2009 should allow opportunity to find an alternative approach to achieving the goal.

Communications, Major Activities and Events

- Scarla Weeks attended and presented at the Asia-Pacific Remote Sensing conference in Noumea, New Caledonia, in November 2008.

- Discussion with French scientists from the Institute of Research Development (IRD), France, has led to their interest in collaborating on the application of satellite ocean colour to coral reef waters. (Scarla collaborated actively with IRD colleagues prior to moving to Australia).