Kimberley Marine Research Program

WAMSI Project 1.4

Remote sensing in support of marine environmental monitoring

Remote sensing technologies offer a cost-effective method to monitor change in the marine environment which can then be used to inform ongoing management of the coastal region. In order to determine the most reliable technologies that can be widely applied as marine management tools, a team of researchers has been assessing remote sensing technologies for monitoring turbidity levels in coastal areas of the Kimberley.

Background

The Kimberley region is vast, remote and both difficult and expensive to access. It's also an area that is noted for its exceptional conservation values, with 1.8 million hectares for inclusion into the proposed North Kimberley Marine Park, one of three that comprise the Great Kimberley Marine Park. As with any marine park, there will be a need to manage this these areas to achieve the desired conservation outcomes.

Remote sensing is the acquisition of data from a distance and usually involves a device such as an aircraft, satellite or ship to obtain the information.

Remote sensing data has increasingly been used to monitor the natural environment. It offers a cost effective method to gather historical and baseline data at synoptic (large) scales as well as near-real-time observations from metre to kilometre resolution.

Its use in the Kimberley is particularly beneficial, as its removes the need for large scale fieldwork, which can be both costly and hazardous.

Figure 1. True Colour Satellite Image of the Kimberley Region. Solander Vessel in Kings Sound (inset) highlighting the high turbidity levels observed.

Remote sensing tools have the potential to enable scientists to monitor change in the marine environment which can then be used to inform ongoing management of this coastal region.

For example, visible spectrum and near-infrared (NIR) sensors on Earth observing satellites can provide estimates of total suspended solids concentration (TSS) and diffuse attenuation of light (K_d). Knowledge of light attenuation and water depth allows estimates of light levels at the substrate. This is important for assessing the impact of turbidity on biological processes such as primary production.

Before such technologies can be widely applied as marine management tools, there is a need to understand the uncertainties inherent in utilising remotely sensed products.

Research Objectives

The core goal of the project was to develop a well-considered strategic plan for the long-term, cost-effective and efficient use of remote sensing technologies to monitor environmental assets and their conditions in the Kimberley region of Western Australia (WA).

This four year project was divided into two phases.

Phase 1 of the project focussed on gathering information to understand the current state of remote sensing science in the context of Condition, Pressure, Response assessments undertaken in the Kimberley by the WA Department of Parks and Wildlife (Parks and Wildlife).

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A review of remote sensing work and procedures with respect to the development of remote sensing methods was completed in 2014.

From the review, a second phase of research commenced focussing on quantifying the reliability of remotely sensed turbidity products for application in the Kimberley region. The key objectives of the research were to:

- Assess uncertainties of remotely sensed turbidity products; and
- Analyse time series of remotely sensed turbidity data to provide first-stage pilot products that may be applicable for future use as marine management tools.

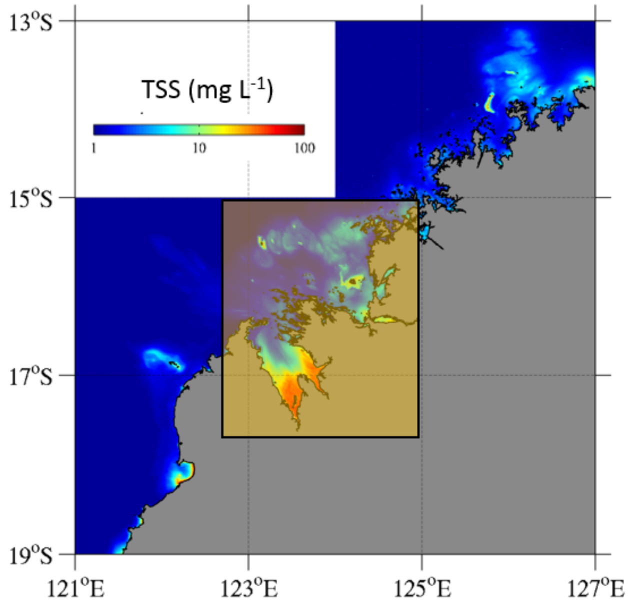

Figure 2. Mean concentration of satellite derived total suspended solids (mg L^{-1}) observed between 2000 and 2015. The yellow box defines the King Sound and Collier Bay region where the highest concentrations were observed.

What we've found

Phase 1

The review of remote sensing (Phase 1), in the context of the Kimberley, involved interviews with Parks and Wildlife staff to understand management needs that could potentially be delivered by remote sensing data.

A key outcome identified by interviewees was the need to monitor significant changes to marine assets (biodiversity and social values in the marine park).

To reliably quantify change and the sensitivity to change, the researchers needed to determine the accuracy of results provided by remote sensing technologies.

From the interview survey data understanding turbidity, specifically in terms of its effect on the light environment within the water column (from the surface to the seabed) and at the substrate (surface where organisms live), was found to be the most frequently occurring metric needed for the monitoring and management of assets by Parks and Wildlife. This was based on the strong relationship between the presence of light and its effect on primary producer habitat (e.g. seagrass, algae, coral).

Phase 2

Based on the Phase 1 review outcomes, Phase 2 focussed on turbidity, including whether remote sensing technologies could be employed to monitor total suspended solid (TSS) concentration (an indicator of turbidity), and what methods and temporal and spatial scales would be most appropriate.

Estimates of TSS concentrations in marine waters in the Kimberley were made using 15 years of measurements collected by NASA's MODIS sensor on its Aqua and Terra satellites.

Satellite estimates of TSS were compared with data obtained from a number of recent expeditions along the Kimberley and Pilbara coastline. The satellite estimates were considered reliable up to a concentration of approximately 100 mg L^{-1}.

Highest concentrations of TSS were found in King Sound and Collier Bay in the vicinity of major rivers such as Fitzroy River (Figures 1 and 2).

Patches of relatively high TSS were also observed further from shore (Figures 1 and 2).

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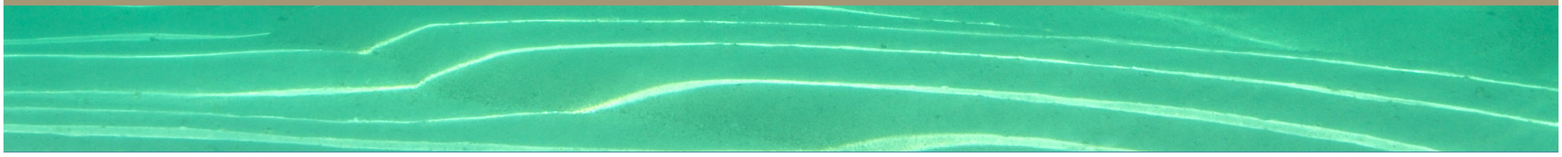

Time series analysis showed two seasonal peaks in TSS concentration in the water column; one in the early part of the year (February to March) coinciding with peak river discharge in the wet season (November to April), and a second larger one during the months of June and July (Figure 3a).

Closer examination reveals that TSS also fluctuates on a fortnightly time-scale consistent with the spring-neap tidal cycle (Figure 3b).

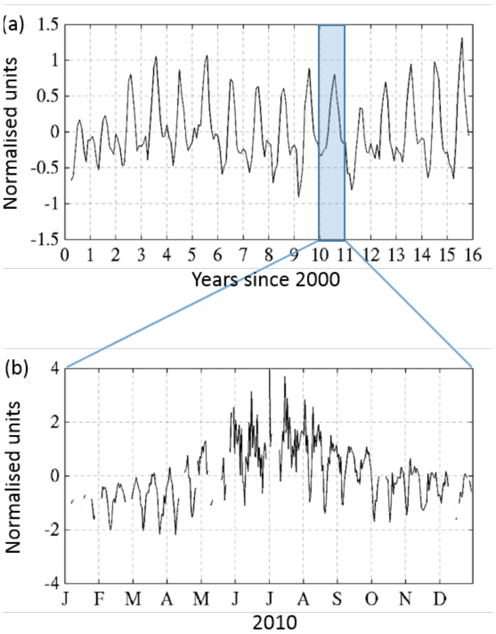

Figure 3. Time series of expansion coefficients of the dominant modes of variability in TSS observed in the King Sound and Collier Bay region with cycles evident at (a) seasonal, and (b) fortnightly, timescales.

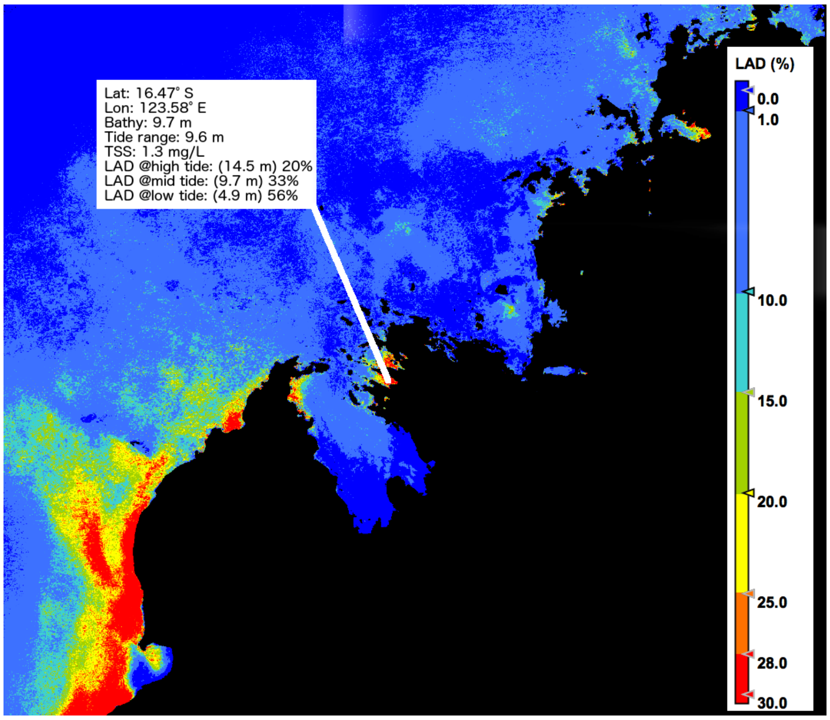

Figure 4. An example of an average monthly LAD product at mid-tide for February 2010. Light at depth (as % of surface light), derived from MODIS Aqua TSS, bathymetry and tidal range.

Light at Depth

A new value-added product, light at depth (LAD), was derived after incorporating TSS, bathymetry and modelled tidal range. The LAD product is an example of a preliminary test product that can highlight changes in the marine light environment. The LAD is expressed as a percentage of the 'at-surface light' that reaches the depth of the substrate.

Field measurements taken near Onslow (in the Pilbara region of WA) were used in determining a relationship between TSS and spectral attenuation coefficients (K_d). Through the application of Beer's Law, the attenuation coefficients along with a calculated depth below the water surface were used to determine the proportion of surface light reaching that depth in the water column.

Determining the water column depth at a particular location involves knowing the bathymetry and relevant tidal levels for that location. Tides in the Kimberley region range between one and two metres during a neap tide and between nine and 10 metres during a spring tide. This variation in water column depth affects the amount of light that can reach the seabed.

Tidal ranges were generated using the Regional Ocean Modelling System (ROMS). The water column depth data was then combined with light attenuation to predict LAD (Figure 4).

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The LAD product is useful for determining regions where the impact of TSS decreases the light levels to such an extent that the potential for photosynthesis is decreased. Regions that experience extended periods of high TSS, identified through the time series analysis, also experience significantly reduced light levels.

The analysis of the variability between different remote sensing TSS algorithms has highlighted the potential accuracy under different water column conditions as well as for different spatial resolutions. This will enable considerations around the scale at which those responsible for managing the Kimberley can use the products.

The time series analysis of TSS data has also highlighted regions experiencing high and low TSS variability and provided clues to the mechanisms responsible for driving these observations.

Who will use this information?

It's expected that the project will deliver remote sensing products for use by Parks and Wildlife and other organisations involved in natural resource management of the Kimberley region.

An understanding of the uncertainty around their use will also help to identify where and what applications are most appropriate.

Information collected as part of this research will be of particular relevance to the Kimberley Science and Conservation Strategy, to inform ongoing management of the proposed Great Kimberley Marine Park network.

Type of data collected

In situ validation data used in this project were obtained from a number of cruises prior to the project, along the Kimberley coastline including Collier Bay, Walcott Inlet, outer King Sound, Koolama Bay, Lesueur Islands and Van Diemen Gulf.

Data parameters collected include TSS, chlorophyll a pigment (Chl), downward PAR attenuation rate (K_d), inherent optical properties (IOPs), SST, and salinity.

Data available in:

The metadata associated with this project can be viewed via the CSIRO and AODN metadata catalogues. Data will not become available until completion of the embargo period for the project (June 2018).

Project Team

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The $30 million Kimberley Marine Research Program is funded through major investment supported by $12 million from the Western Australian government's Kimberley Science and Conservation Strategy co-invested by the WAMSI partners and supported by the Traditional Owners of the Kimberley.