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GBROOS – An Ocean Observing System for the Great Barrier Reef

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Abstract. The Great Barrier Reef Ocean Observing System (GBROOS), a geographic node of the Australian Integrated Marine Observing System (IMOS), is an observation network deployed along the Great Barrier Reef (GBR) in Northern Australia. The project aims to quantify and monitor the impact of the Coral Sea, in particular cool and warm water intrusions, on the GBR and to provide the real-time data required to understand the impact of climate change and other environmental factors on coral reef ecosystems. The project has five components. Sets of paired deep (200 m) and shallow (30-70 m) oceanographic moorings will be deployed to detect water moving onto and along the GBR from the pole-ward East Australian and the equatorial Hiri western boundary currents. Upgraded Remote Sensing capacity, coupled with underway validation data, will give large-scale information about the GBR. A set of reference moorings will provide long-term baseline data on water parameters supplemented by detailed monthly water samples. Sensor networks located at seven sites will provide real-time information about small-scale phenomena. The observational data will have significant impact on our understanding of global change, its potential impact on the physical and chemical conditions and the associated changes to the biology and structure of the GBR.

Keywords: GBR, Ocean, Observing, Sensor networks, Climate change, Great Barrier Reef

Introduction

GBROOS is an observation network that seeks to understand the influence of the Coral Sea on continental shelf ecosystems in north-east Queensland including the GBR Marine Park.

The South Equatorial Current (SEC) is the dominant flow in the Coral Sea. On reaching the Australian coast, the SEC bifurcates into northern and southern boundary currents. The northern arm is responsible for driving a clockwise gyre in the Gulf of Papua that is a nursery for tropical rock lobster; a major resource for indigenous communities in the Torres Strait. The southern arm becomes the East Australian Current (EAC), which flows down the eastern seaboard and affects coastal climate and ecosystem performance from southern Queensland to Tasmania (Ridgeway and Dunn 2003).

The SEC is dynamic on annual and decadal time scales. Variations in flow of the EAC associated with the Southern Oscillation Cycle (El-Niño/La-Niña) affect the thermal and carbonate chemistry regimes on the outer barrier reef, and the replenishment of commercial fish stocks along the eastern seaboard (Harris et al. 1988; Oke and Middleton 2001).

In the central GBR, the slope bathymetry favours intrusion of Coral Sea water onto the continental shelf and flushing of the outer Lagoon while also suppressing cross-shelf exchange. Many of these intrusions draw cool nutrient-rich water from the deeper Coral Sea onto the shelf (Andrews and Gentien 1982).

The Coral Sea has a direct impact on the water that is delivered to outer-shelf reef systems and to in-shore areas where intrusions are able to penetrate through the reef matrix. These incursions play a critical part in determining the water that forms the lagoon of the GBR (Steinberg 2007). The large scale circulation and characteristics of oceanic water influences local factors and circulation to determine the thermal and other characteristics of the water that the corals experience. In order to understand how corals respond to changes in their environment we must first measure that environment, and for the GBR, this means understanding the impact and functioning of the oceanic water processes.

Material and Methods

There are five components to GBROOS that together provide information at a range of scales from synoptic remote sensing data to fine scale sensor network data.

The remote sensing component involves the installation of an L and X band receiving station in Townsville for the collection of the older AVHRR data and new higher resolution data such as MODIS. This compliments an existing L-Band receiving station that has been operating since the mid 1980's.

To compliment the remotely sensed data a number of vessel-based systems are deployed to collect daily validation data. A radiometer mounted on a commercial ferry that transits between Shute Harbour and Hardy Reef collects radiance data to validate the AVHRR SST data. An Ocean Colour reference station is being established near Lucinda in North Queensland to validate the MODIS ocean colour data.

Underway water quality data is being collected from two AIMS research vessels (the *R.V. Cape Ferguson* and the *R.V. Solander*) and a commercial ferry operating between Gladstone and Heron Island in the southern part of the Great Barrier Reef. The instruments consist of a Sea-Bird thermo-salinograph (temperature and salinity) and a WetLabs FLNTU (chlorophyll and turbidity) as well as position from the vessel GPS. The data is downloaded nightly and will be used to validate other data, such as remote sensing data, and to build up a long-term data series. For the commercial ferry this will be for the same transect, for the research vessels this will be for their area of operation over northern Australia.

As part of the larger IMOS project a number of identical reference moorings are being located around Australia to provide equivalent long-term records of basic water parameters. GBROOS is responsible for two of these moorings; one off Townsville in North Queensland and one near Darwin in the Northern Territory. The instruments deployed include a near-surface (around 10 m depth) and near-bottom (around 5 m from the bottom) WetLabs WQM (temperature, salinity, depth, turbidity, chlorophyll), a series of temperature sensors (Sea-Bird SBE39's) along the mooring wire, a surface buoy mounted weather station (Vaisala WXT-510/520 – air temperature, wind speed and direction, relative humidity, rain duration and amount, barometric pressure) and waves and currents (via a bottom mounted Nortek AWAC). The design is shown in Fig. 1.

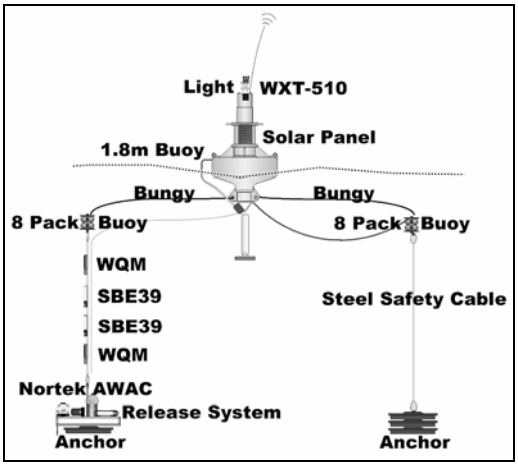

Figure 1: The basic design of the Reference Station moorings.

Water samples will be collected from the Reference Stations monthly. The parameters investigated include hydrochemistry (nitrate, nitrite, phosphate, etc), carbonate chemistry, suspended matter, zooplankton, phytoplankton pigments, as well as a CTD cast and validation samples for the instrument data.

The fourth component of GBROOS is the GBR Mooring Array. This consists of four pairs of moorings located along the GBR with one of the pair located on the continental slope in relatively deep water (70-200 m) and the other of the pair located on the continental shelf in shallower water (30-70 m).

The design looks to detect the movement of oceanic water up the continental slope and onto the shelf and so give information about upwelling events and about the strength and direction of the oceanic currents as they impinge on the reef matrix. The locations of the moorings and the main current flows, as measured by surface flows, are shown in Fig. 2.

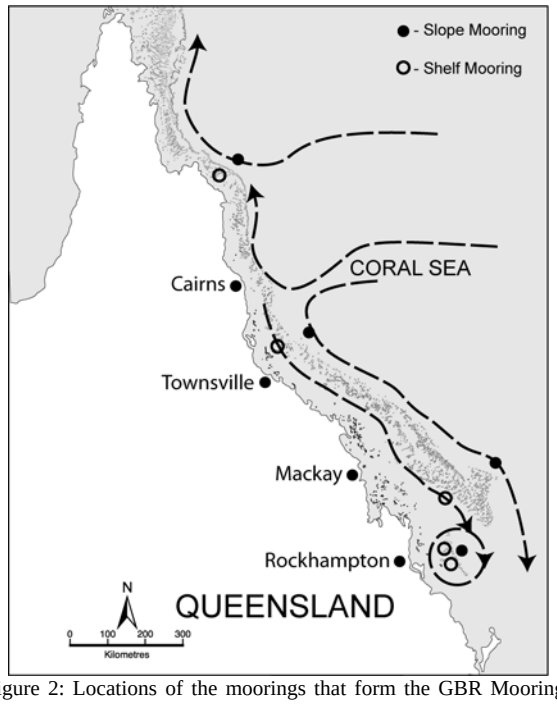

Figure 2: Locations of the moorings that form the GBR Mooring Array, slope moorings are shown as solid markers, shelf moorings as open markers. The major currents are shown as dashed lines based on current surface flows (from Steinberg 2007).

The basic current flows (Steinberg 2007) show the main south equatorial current impinging on the GBR in the Cairns area with one flow going north as the Hiri current and one going south to form the East Australian Current. The southward flow includes components that go down the outside of the reef matrix and those that flow through the larger GBR lagoon. The two flows meet in the southern part of the GBR where a complex series of eddies occurs before the main southward flow becomes coherent.

The pair of moorings off Townsville looks to measure water intruding from the deeper slope onto the shelf or reef matrix so supplying coastal reefs with oceanic water. In this area the reef matrix is open and so water is able to move up and across the shelf. The moorings around Lizard Island are designed to measure the northward current flow outside the reef matrix and the inflow of that water through the ribbon reefs into the reef matrix. The moorings south of Mackay are positioned to measure the southward current flow outside the reef matrix via the deep water mooring and through the main reef lagoon using the inshore mooring.

Around Heron and One Tree Islands three moorings have been deployed, two shelf and one slope, to capture the complex nature of the currents in this area.

The deeper moorings do not have a surface float and so log their data, the shallower shelf moorings will be converted to a surface buoy and will have real-time communications installed. This will allow for summary real-time data to be communicated; the instruments will continue to log the full data set which is retrieved on servicing. The moorings are serviced every six months.

The moorings typically contain a sub-surface float at 10 m, a series of Sea-Bird SBE39 temperature and pressure sensors down the mooring giving surface (10 m), middle and bottom measurements with five minute sampling. These are complimented by two WetLabs WQM's deployed to give upper and lower water column temperature, salinity, turbidity and fluorescence also sampling at five minutes. Currents are measured with a near-bottom mounted Acoustic Doppler Current Profiler (ADCP). For shallow moorings (< 100 m) an RDI 300kHz ADCP is deployed with a sampling of 30 minutes at 25 four-metre 'bins' or intervals, for deeper moorings a Nortek 600kHz ADCP is used with 50 four-metre bins. Some moorings have a Nortek AWAC for waves and currents. At the start and end of each deployment a CTD cast is done with a Sea-Bird SBE19+ to give validation data for the deployed instruments as well as giving start and end profiles.

The final component is the wireless sensor network. Sensor networks will be deployed at seven sites, four island research stations (Heron and One Tree Islands in the southern GBR, Orpheus Island in the central GBR and Lizard Island in the northern GBR) and three reefs (Davies, Rib and Myrmidon Reefs, all in the central GBR). The locations are shown in Fig. 3.

At each site a high speed data link is installed using microwave links or 3G phone technologies. An on-water wireless network is then created using a series of network repeater poles located around the reef and a 900 MHz spread-spectrum radio system.

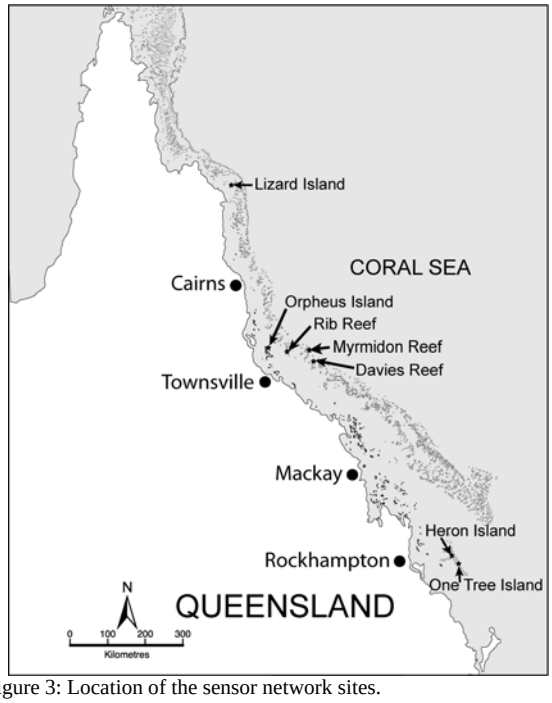

Figure 3: Location of the sensor network sites.

Into this network are located the sensor floats onto which the actual sensors are attached. The floats contain a logger and radio that transmit the data back to the base station and then, via the data link, back to AIMS. The data is relayed in real-time and made available via streaming sensor middleware.

The design allows for areas to be intensively wired up and monitored, much of the equipment is relocatable and can be deployed around individual coral heads and bommies giving real time information about the conditions around the corals themselves. The initial sensors include temperature, salinity and depth but the infrastructure is suitable for other sensors, such as video, partial pressure of CO_2 (pCO_2) and photosynthetically active radiation (PAR). The involvement of the island research stations that form the Tropical Marine Network (TMN) allows for cleaning and maintenance of equipment and the specific deployment of equipment for short-term experiments.

Affiliated with the GBROOS Node is the Australia Coastal Ocean Radar Network (ACORN) facility that is installing WERA based HF coastal radar systems. A system will be based in the southern GBR to give coverage over most of the southern GBR area including the moorings and sensor network sites in the Heron Island area. The coastal radar will therefore provide additional information about waves and surface currents in this area.

All of the data will be made freely available as soon as possible via a dedicated GBROOS data web site or via the IMOS web site (www.imos.org.au).

Results

The project has been operational since mid 2007 with significant deployments already undertaken and the remaining due to be completed by 2009. The first data from most of the components is now being collected and the data management systems are being built to make the data available.

The remote sensing station was commissioned in May 2008 and is sending data to the Bureau of Meteorology for inclusion in their processed products along with some of the vessel based validation data.

The underway systems have been installed on two research vessels with the commercial ferry to be completed by mid-2009. Some initial data has been collected; this is currently being processed and will be available from the final data web site.

The Townsville reference mooring has been deployed in a reduced mode without the surface float and so the data is currently being logged. The station will go to real time in the first half of 2009. The Darwin station is due to be installed in mid-2009 as a real-time buoy with the data available soon after.

The mooring array has been operational since mid 2007 with service/data download visits being performed every six months. The initial data is being analysed and the data management systems are being built so that this data can be made available on the web. There has been a delay in doing this as there is a need to first develop some underlying data standards within the IMOS community and this is taking time.

The initial data from the southern GBR moorings shows periods of distinct stratification of the water column inter-dispersed with mixing events that mix the water down to 40 or more metres. This data is being analysed against the remote sensing and coastal radar data to identify the source and cause of these mixing events and to link these into movements of the currents in this area and events such as upwelling.

Three of the seven sensor network sites have been deployed; these are Heron and One Tree Islands in the southern GBR and Davies Reef in the central GBR. The deployments at One Tree Island consist of three sensor poles, one in each of the smaller lagoons within the main One Tree Island lagoon. The sensor poles have a series of thermistors going from reef flat down into the deeper water of the lagoon. At Heron Island five sensor floats have been deployed around the lagoon each with a surface thermistor, as well the six network relay poles have a single bottom thermistor attached. At Davies Reef the sensors currently deployed include a weather station and a number of sensor floats with surface thermistors. Additional sensors will be added to the existing deployments by mid 2009, these will include depth (pressure) and salinity.

Initial results from One Tree Island Lagoon from the sensor network component for late September 2008 (see Fig. 4) show a series of daily cycles in temperature with increasing temperatures as the days go by and then a series of events that re-set the temperatures. This may be caused by periodic mixing of colder oceanic water into the relatively protected lagoon or by a series of cold-water events pushing colder water into the lagoon. This pattern is also seen at nearby Heron Island indicating that larger scale processes may be at work such as cold water moving onto the reef or through weather events that reduce the surface temperature of the water. A reef-based weather station is due to be installed that may shed some light on the cause of these events. This result shows that there are processes operating at a weekly scale that have the ability to alter water temperatures by four to five degrees in rapid periods of time.

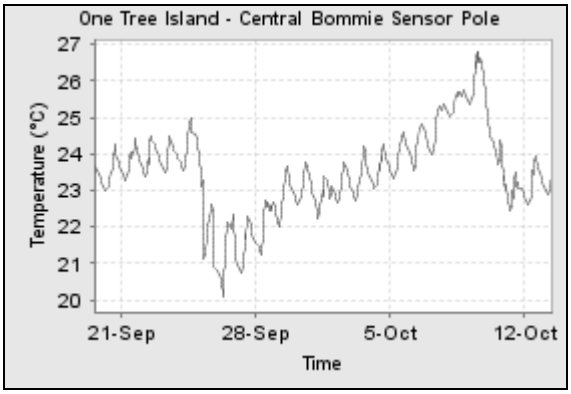

Figure 4. Plot of temperature over time for the bottom (lagoonal) sensor on the sensor pole located in Central Bommie, One Tree Island lagoon, southern Great Barrier Reef for late September 2008.

The project is committing resources to develop data management systems for all of the data being collected. The systems include data archiving of files, quality control of the data, production of metadata (to ISO 19115 standard) and the ingestion of data into a common database schema.

The work includes the development of service based data access routines where access to data and data products (such as Google Earth files, GIS files) is done automatically via user or client submitted URL's. This will allow web sites to be built around the data and for other users to tap into the data using their client of choice, from Matlab, Excel to simple text editors.

For the mooring data the project will help develop a 'toolbox' of routines for processing the raw instrument data as well as an agreed to final file format. With the sensor network data the project is deploying specialised streaming data middle-ware (such as the Data Turbine software) to give users access to real-time data with minimal or no delay.

Discussion

Coral reefs face a range of threats and globally the outlook for coral reef systems is not good. Wilkinson (2004) estimates that some 20% of reefs globally have been effectively destroyed with another 24% under immediate threat and a further 26% under longer term threat. Issues such as climate change are more insidious as the impacts cannot always be dealt with by local management activities and so even reefs that are well managed can be impacted. This disconnect between the impacts that are causing declines in coral reef systems and the local management of the reefs represents a dramatic new turn for the conservation and sustainability of coral reef systems worldwide.

The need is to better understand how each system is exposed to, and impacted upon, the ocean systems that provide much of the water that feeds into the reef and how changes in currents, in upwelling and circulation, impact the long term sustainability of these reefs. Critical to this understanding is the ability to monitor these systems and in particular the interactions with the main oceanic water systems. Observing systems such as GBROOS are designed to help understand and monitor these processes.

GBROOS provides data at range of scales; from synoptic remote sensed imagery of sea surface temperature and ocean colour to underway sampling that gives surface water information across regular transects to the fixed mooring sites that provide long term detailed profile data at key locations. The sensor networks provide re-locatable fine scale information at the level of individual coral heads. Being able to link data from the scale of tens of kilometres down to tens of centimetres is unique and hopefully will provide the connectivity information required to fully understand the impact of large scale oceanic events on the microclimate and biological responses of individual corals.

Future work will look at the linkages between the various observing components and in particular to investigate the linkage between large scale ocean processes and small scale within reef processes and subsequent biological responses. A series of experiments are planned for 2009/10 at Heron and One Tree Islands to develop and validate models that better express the linkage between processes operating at differing scales.

In the northern sites the work will focus on tying biological processes, such as spawning, into the physical parameters and to again develop models of behaviour and responses that are driven or impacted by physical water conditions. The aim is to better understand these processes and the potential and real impacts of change on the fundamental biological systems.

Under the governance model of the project all data will be made freely available as soon as possible with much of it being in real-time. The infrastructure of moorings, communications systems, data management and logistical support will be made available to the marine science community via a competitive bidding system managed by IMOS. This means that the GBROOS data and infrastructure are open to all and that as such GBROOS belongs to the science community not to a few agencies.

GBROOS looks to provide the data, through a range of real-time and delayed mode data streams that will facilitate the development of new models and understandings of how oceanic processes impact and drive coral reef systems and how changes in these large-scale systems are related to smaller scale events such as the bleaching of an individual coral. Being able to measure the entire thermal history of a coral head will give much better understanding as to why some corals bleach and others don't.

Observing systems will not replace divers or field work but as they are able to provide real-time, long-term and *in-situ* data they are an important part of understanding how these systems function and how the biological responses observed in the field link to the fundamental oceanic forces that drive reef systems. GBROOS is a first step in a systematic attempt to provide the information required to support modelling and visualisation work and to support a range of fundamental and applied science.

Acknowledgement

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