IMOS Integrated Marine Observing System

Australian Government

Australian Institute of Marine Science

The role of Sensor networks in monitoring and managing coastal systems including ecological monitoring of coral reefs

Scott Bainbridge

สวทช NSTDA สำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ
NATIONAL SCIENCE AND TECHNOLOGY DEVELOPMENT AGENCY

Overview

1. Sensor Networks – what, where, why – examples from the Great Barrier Reef, Australia

2. Applications:
   - Coastal monitoring and emergency response
   - Ecological monitoring of coral reefs

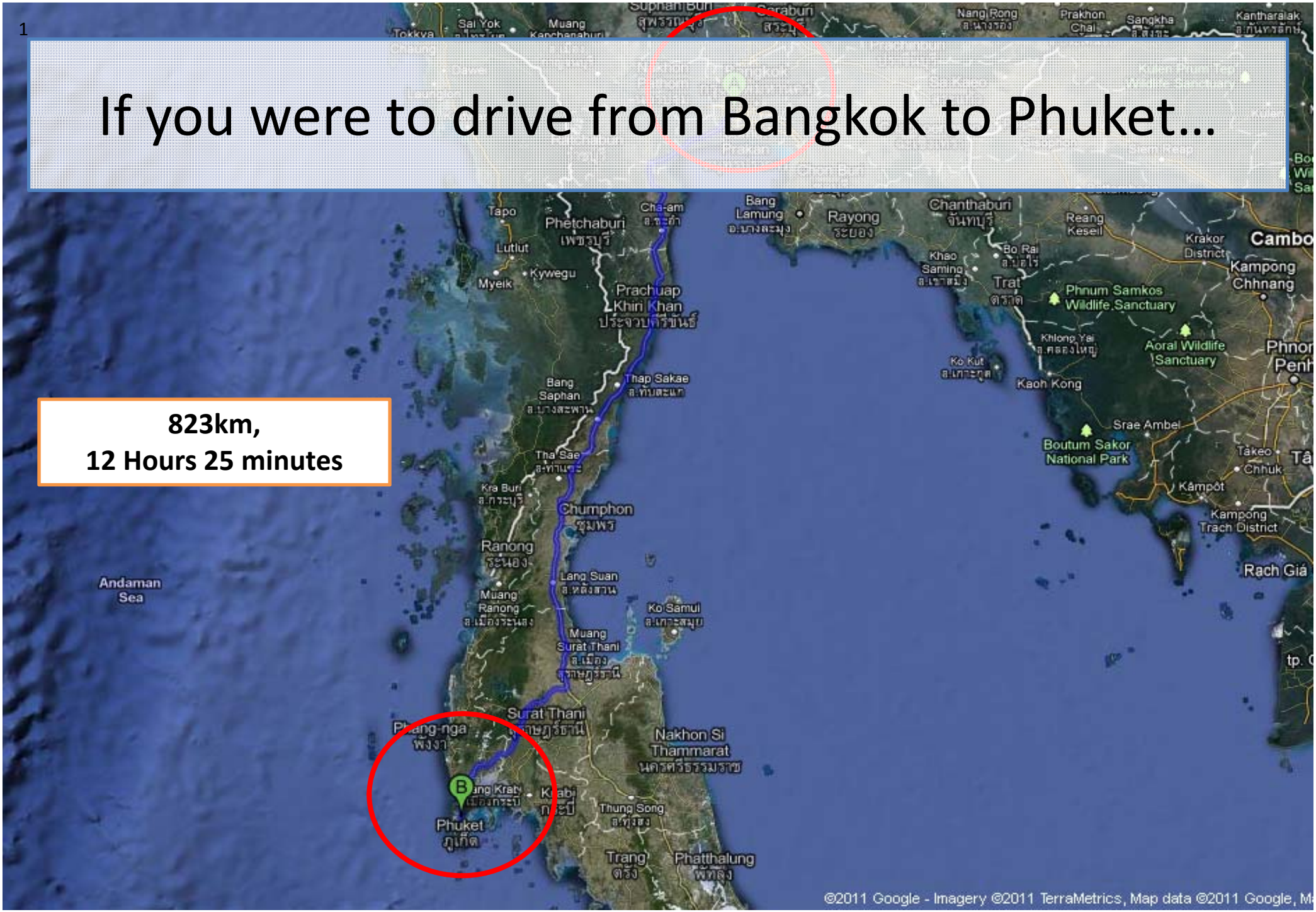
3. A Wired-World – a vision for the future

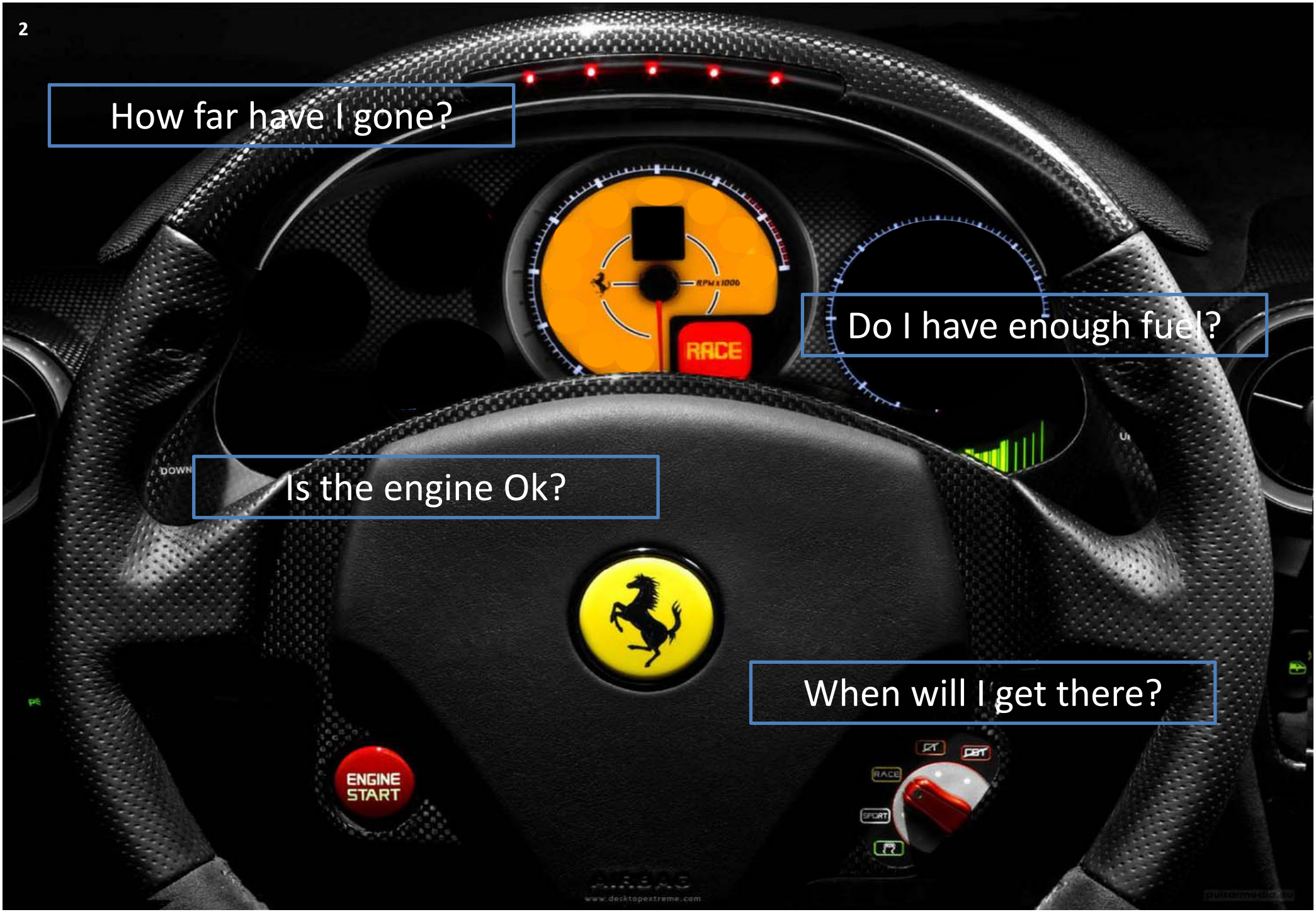
To **Manage** you need to **Know**…

To **Know** you need to **Monitor**…

To **Monitor** you need to **Measure**.

If you were to drive from Bangkok to Phuket…




How far have I gone?
Do I have enough fuel?
Is the engine Ok?
When will I get there?
RPM x 1000
RACE
ENGINE START
SPORT

The 21st century ‘dash-board’

- How can the world support **Nine Billion** people?
- How do we **manage Climate Change** both in the short term and long term?
- How do we **protect people and assets** in an increasingly chaotic world?
- How do we best use **the resources we have**?
- What do we need to do now to secure a more **sustainable future**?

To **Manage** these issues we need to **know** and to know we need to **measure**…

EARTHQUAKE DISASTER Ship and four trains are missing

Japan Earthquake Live

Japan Earthquake Live has updated. Click to see new entries

9:51 AM	Information about the disaster is coming thick and fast via social media and the web. Here are a few links to help you follow the Japan earthquake online. More »
9:15 AM	This animation produced by the NOAA shows the path of the tsunami generated by the magnitude 8.9 earthquake. More »
9:15 AM	This animation produced by the NOAA shows the path of the tsunami generated by the magnitude 8.9 earthquake. More »

More from Japan Earthquake Live

Times are AEDT (Sydney time)

It’s been a tough year…

Japan comes to terms

Top Stories | Video | Audio | Photos

Coral Reef ‘dash-board’

- The 2008 global census shows that worldwide **20% of reefs are already lost**, another 15% are under immediate threat and a further 20% are under longer term threat;
- **Massive coral bleaching** was observed in 1998, 2002 and to a lesser degree in 2006 – some areas had 70-80% coral loss;
- Coral Reefs are particularly **sensitive to climate change**, long term temperature changes of just 2°C can push corals into decline (lower calcification rates, higher bleaching rates);
- World wide some **300 million people**, mostly in the developing world, **depend on coral reefs** for their livelihood.

The Great Barrier Reef

NOAA NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE

NOAA: 2010 Tied For Warmest Year on Record

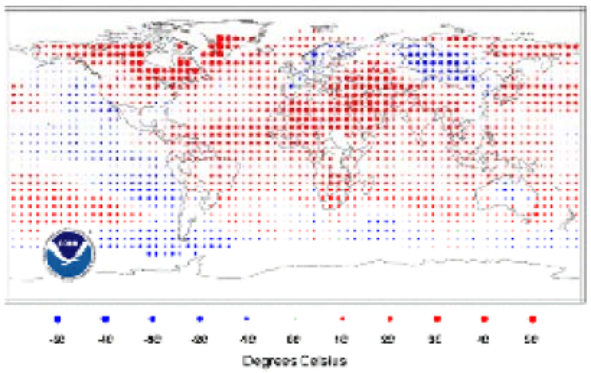
January 12, 2011

According to NOAA scientists, 2010 tied with 2005 as the warmest year of the global surface temperature record, beginning in 1880. This was the 34th consecutive year with global temperatures above the 20th century average. For the contiguous United States alone, the 2010 average annual temperature was above normal, resulting in the 23rd warmest year on record.

This preliminary analysis is prepared by scientists at NOAA's National Climatic Data Center in Asheville, N.C., and is part of the suite of climate services NOAA provides government, business and community leaders so they can make informed decisions.

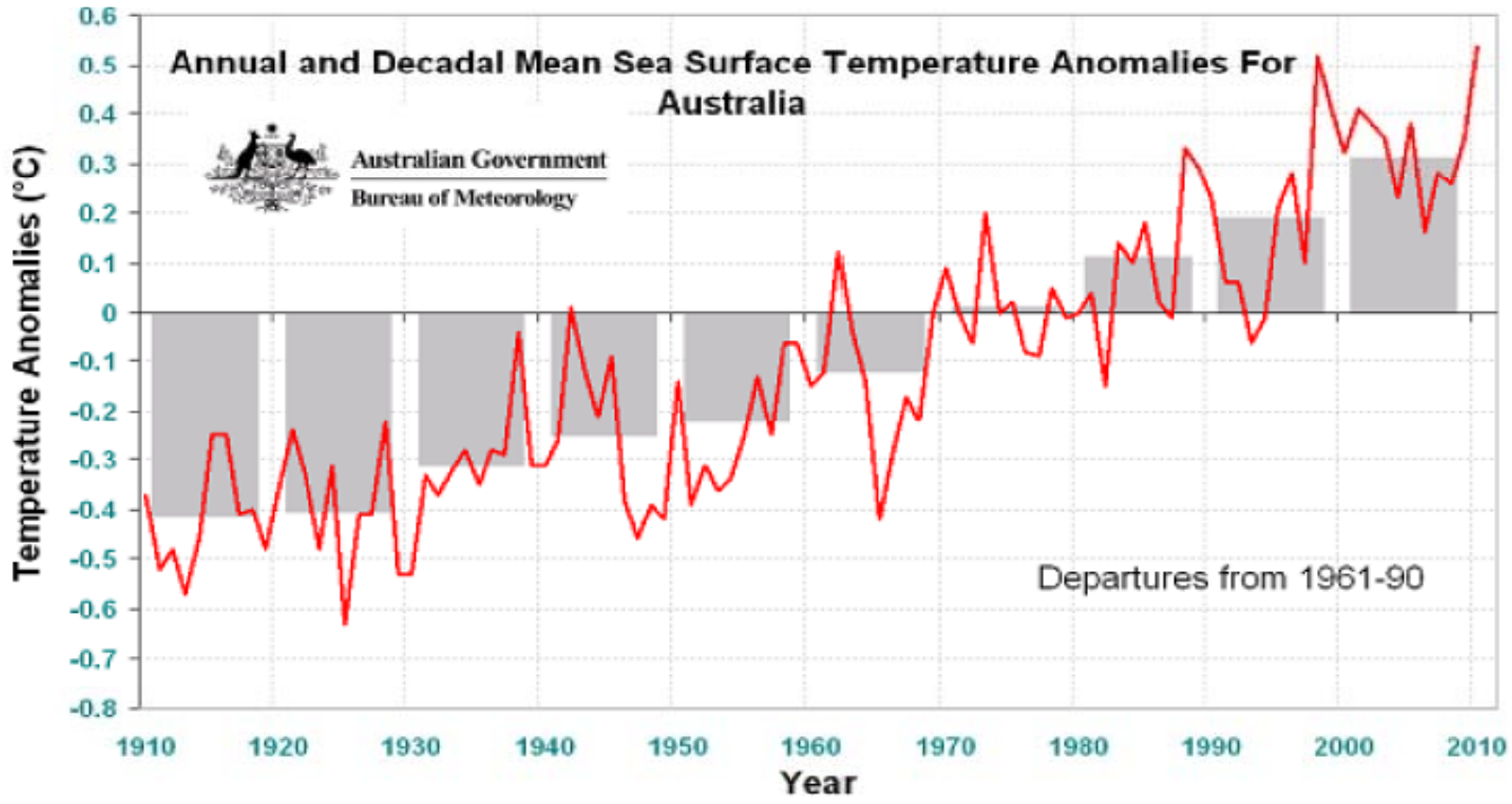
2010 Global Climate Highlights:

- Combined global land and ocean annual surface temperatures for 2010 tied with 2005 as the warmest such period on record at 1.12 F (0.62 C) above the 20th century average. The range of confidence (to the 95 percent level) associated with the combined surface temperature is +/- 0.13 F (+/- 0.07 C).*
- The global land surface temperatures for 2010 were tied for the second warmest on record at 1.73 F (0.96 C) above the 20th century average. The range of confidence associated with the land surface temperature is +/- 0.20 F (+/- 0.11 C).
- Global ocean surface temperatures for 2010 tied with 2005 as the third warmest on record, at 0.88 F (0.49 C) above the 20th century average. The range of confidence associated with the ocean surface temperature is +/- 0.11 F (+/- 0.06 C).



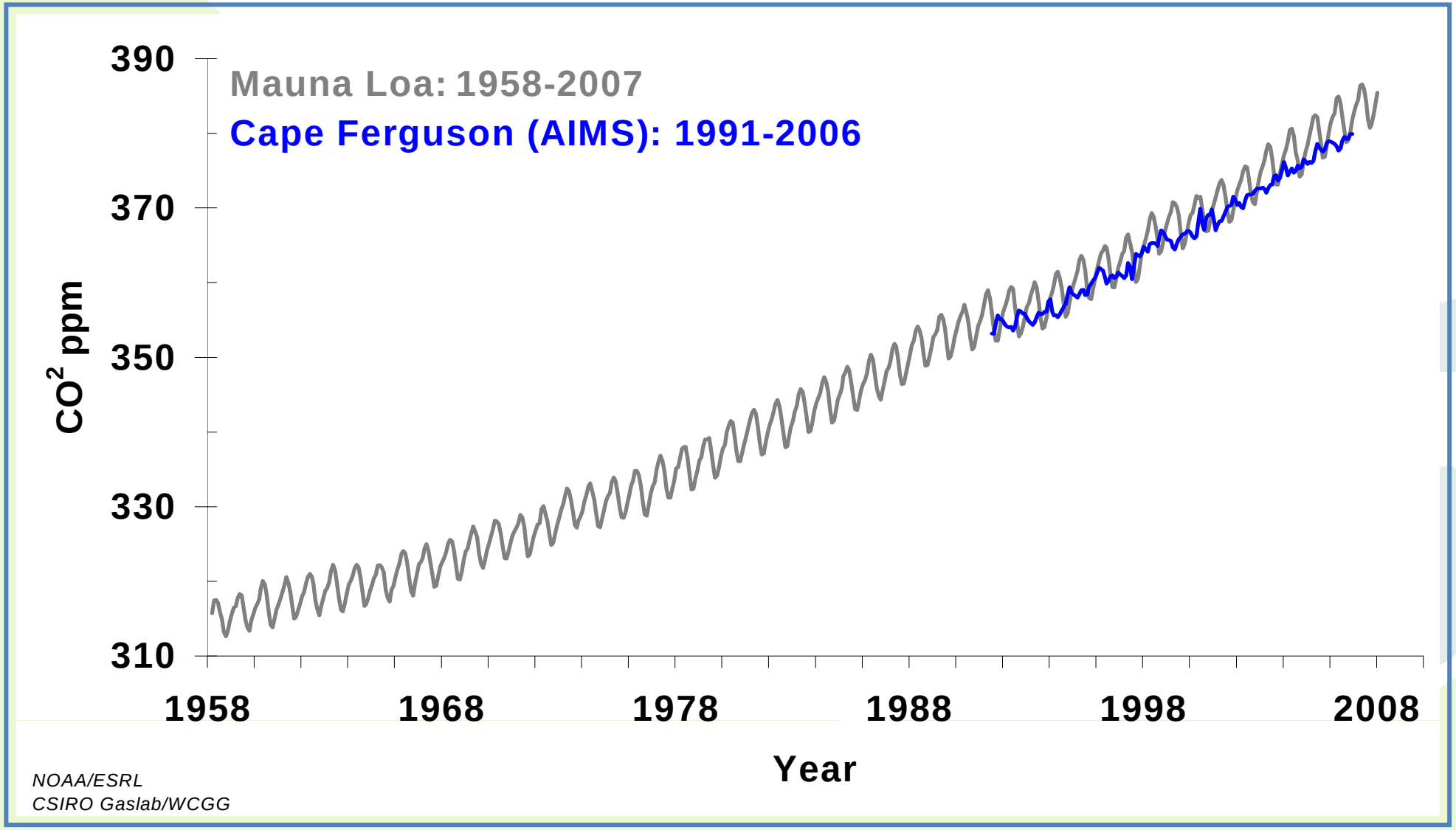
Global surface temperature anomalies for 2010.
High Resolution (Credit: NOAA)

Trends in ocean temperatures

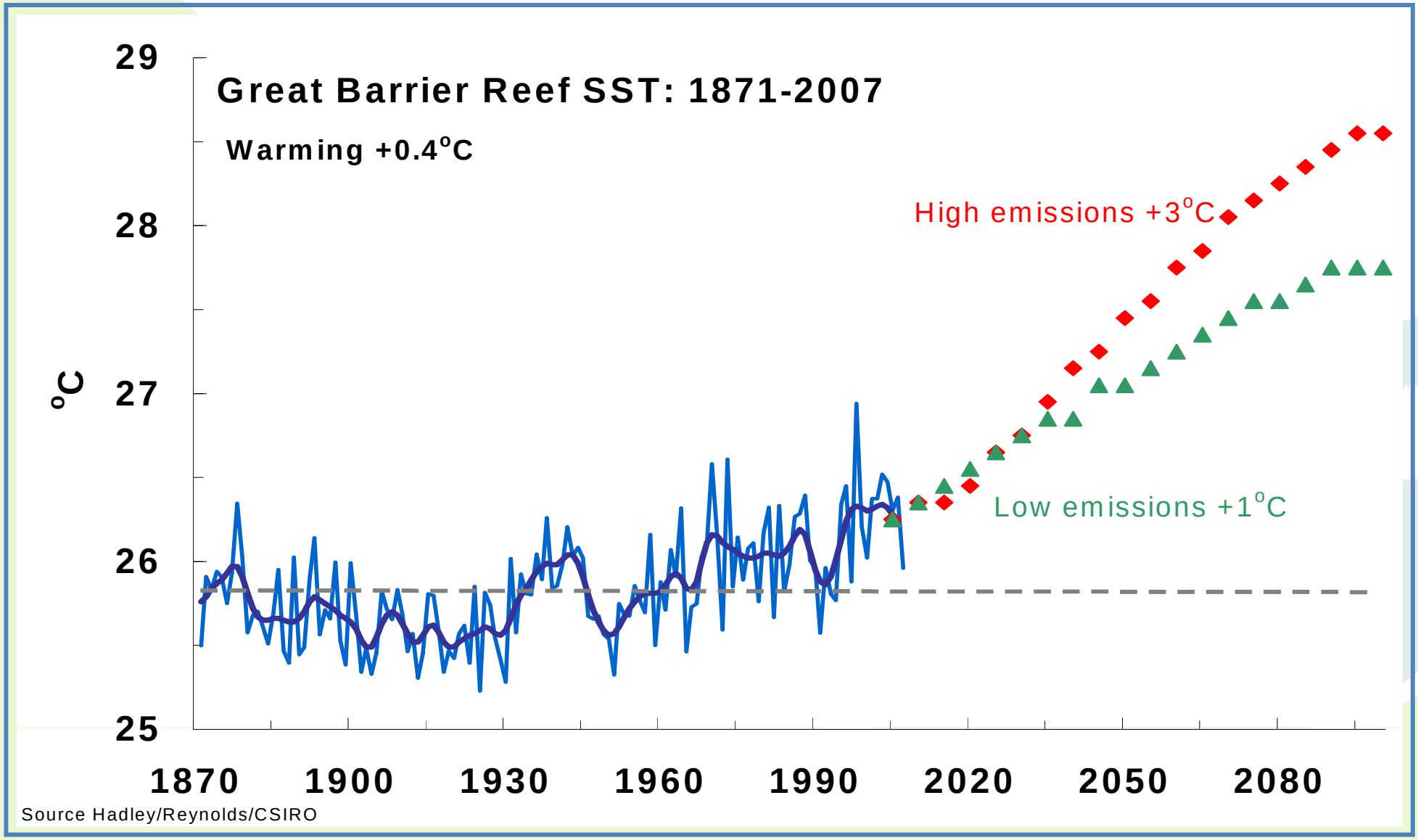


Annual and decadal mean sea surface temperature anomalies in the Australian region (compared with 1961 to 1990 average). The 2010 value is preliminary and does not include data for December 2010.

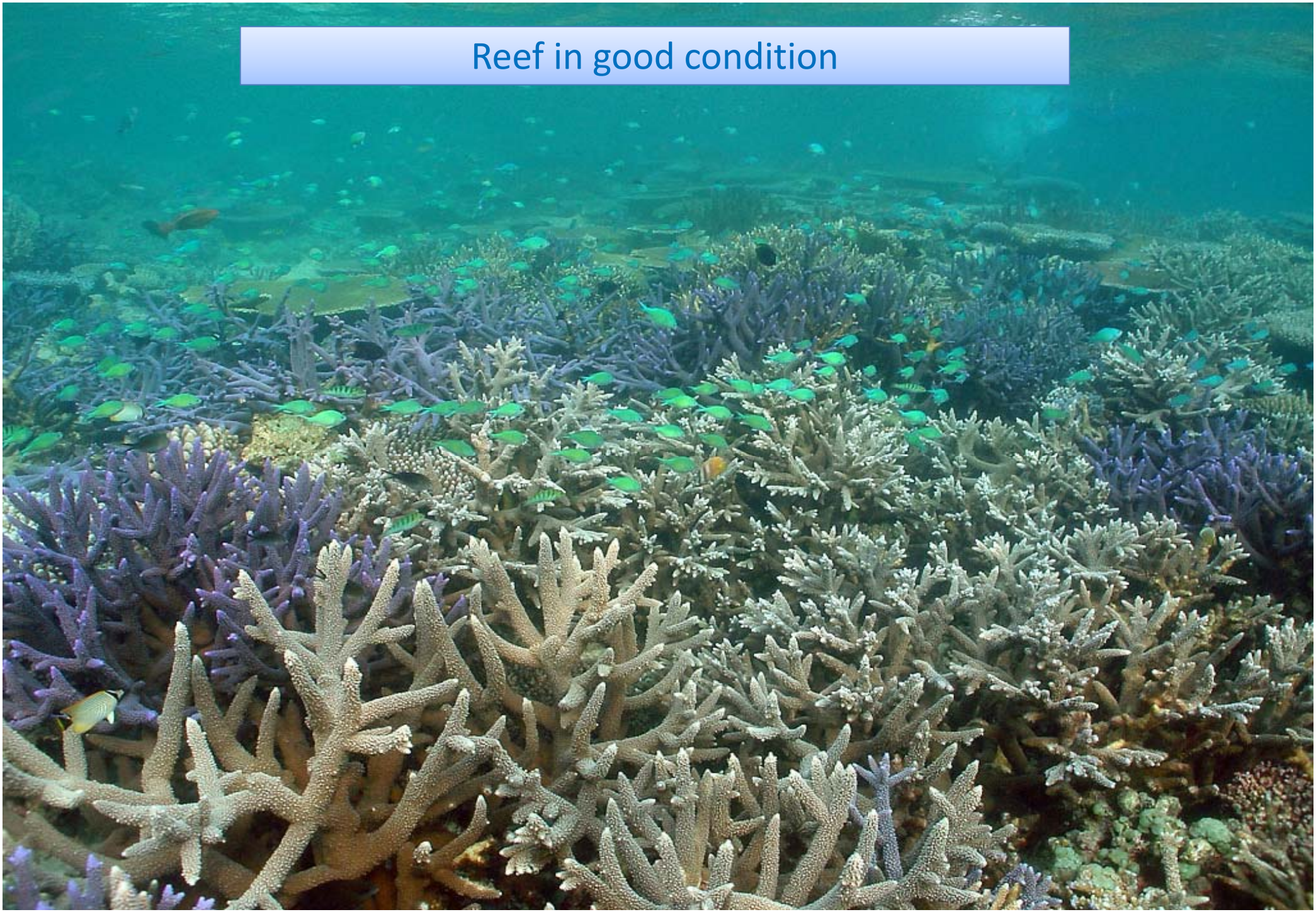
Evidence of increasing greenhouse gases



Warming of the Great Barrier Reef since 1960

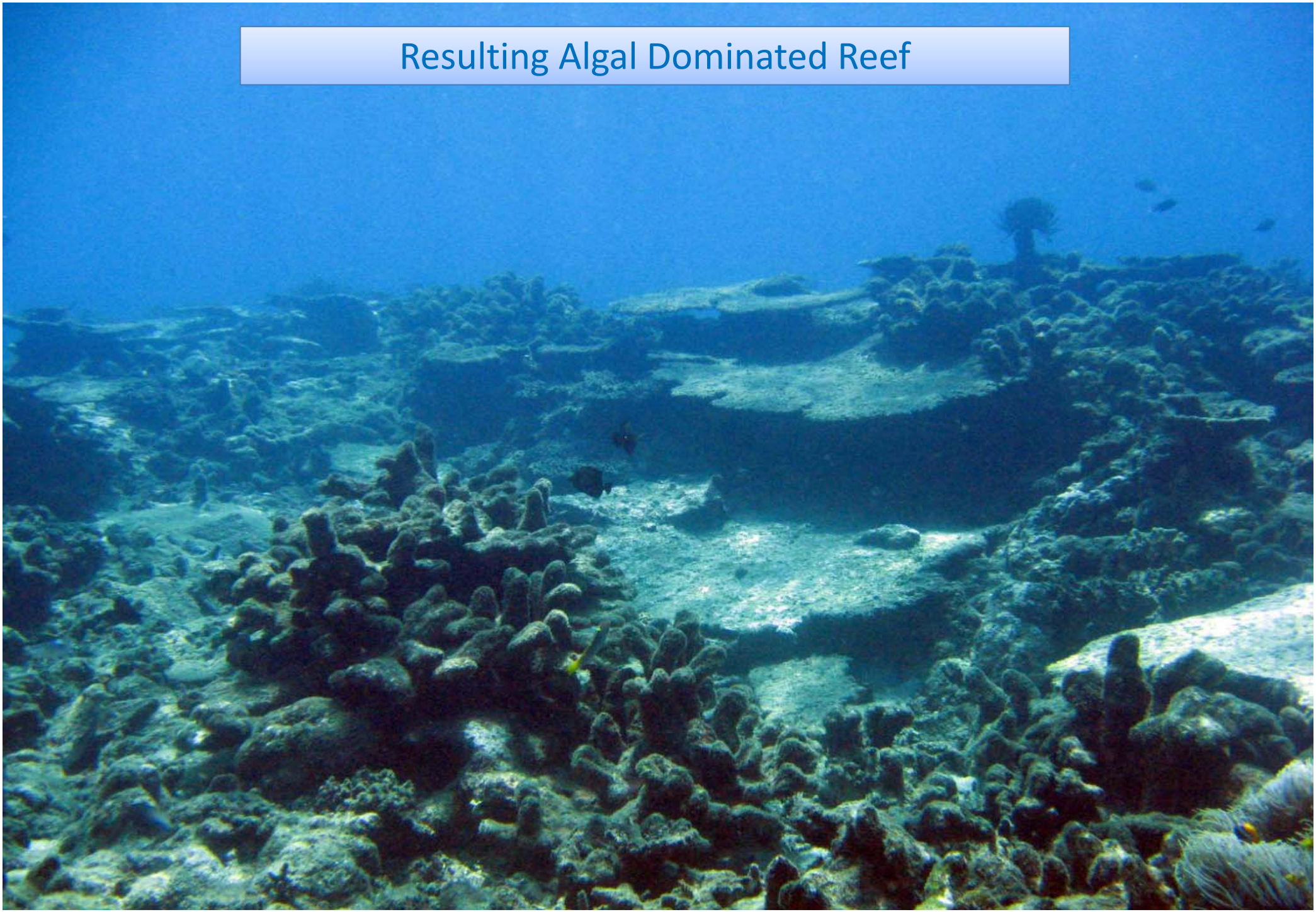


Reef in good condition



Bleached Reef

Resulting Algal Dominated Reef



Great Barrier Reef Ocean Observing System

- GBROOS is part of a larger Australian Integrated Marine Observing System (IMOS);
- Funded since 2008 to deploy a range of observing technologies along the Great Barrier Reef in Australia;
- Looks to understand **the impact of changes in the oceans on the coast**;
- Has developed a range of proven observing technologies suitable for coastal applications.

GBROOS Capabilities

- **Satellite Remote Sensing** – large scale daily images of sea surface temperature and ocean colour;
- **Ocean Moorings** – detailed water column measurements and currents, waves and tides;
- **Gliders & Drifters** – medium term (months) intensive measurements over large areas;
- **Sensor Networks** – coastal real time information about smaller scale processes and weather;
- **Ocean Radar** (with James Cook University), large area surface waves and currents.

Why Measure?

- Systems naturally **change with time**, to understand long term changes you need long term consistent measurements;
- Understanding change requires an understanding the **processes that force the system** (weather and the oceans) and how these impact at the species or habitat level;
- Evidence based Management requires high quality data to **drive decision making and planning**.

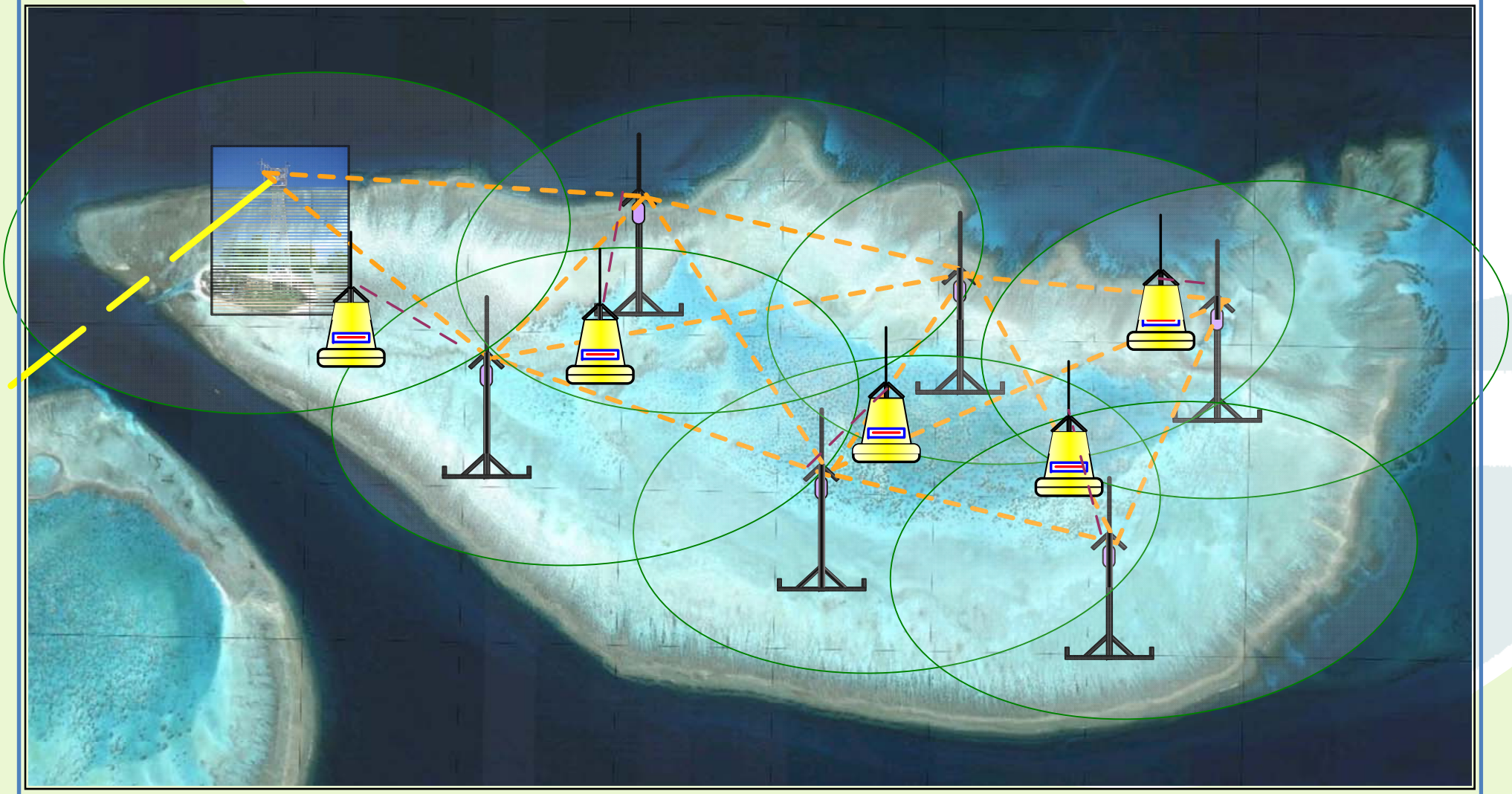
What are Sensor Networks?

- Sensor Networks **are arrays of small, wirelessly interconnected sensors** that together work to collect data back to a central data centre;
- The sensors are ‘smart’ in that they can **adaptively sample** – changing how and what they sample based on current conditions;
- Sensors are **internet connected**, using IP communication protocols, and so are able to push their data to the internet or receive programs and commends from the data centre – the communications is always on and fully two way;
- The sensors have **some on-board processing power** and so can convert raw data to derive values, do some image analysis and so on – more and more the technology will push data management, access and processing down to the sensor node.

Sensor Networks – new ways of measuring

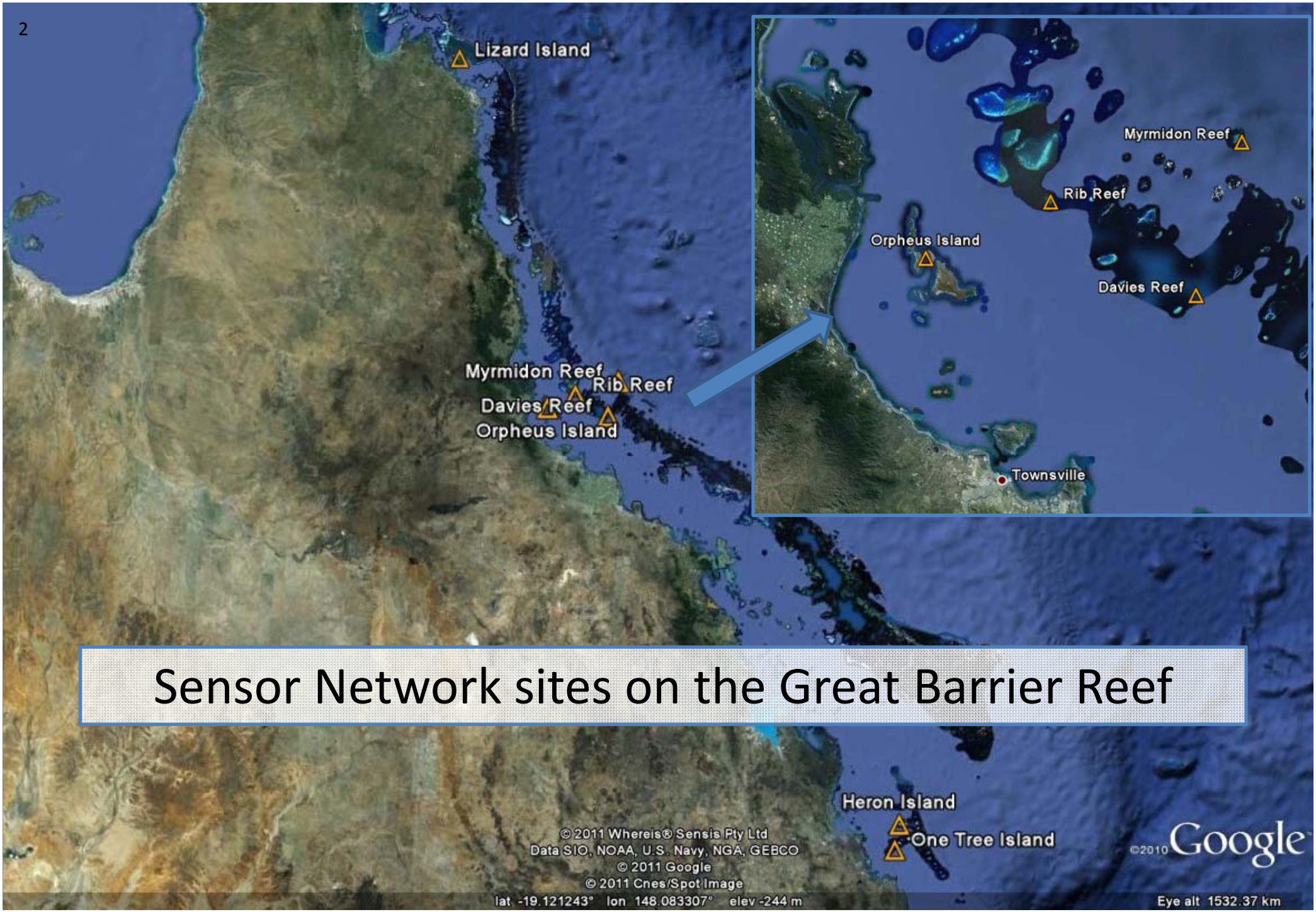
Sensor Networks	Traditional Sensors
✓ Real Time Data	✘ Delayed or logged data
✓ Two ways communications	✘ No communications
✓ Intelligent controllers	✘ ‘Dumb’ controllers
✓ Adaptive sampling	✘ Fixed sampling
✓ On-node data processing	✘ Raw or simple processing
✓ Self organising	✘ Fixed topography
✓ Internet connected	✘ Stand alone
✓ Wide range of sensors	✘ Limited sensors
✓ Scalable	✘ Limited scalability
✓ Cost effective	✘ Expensive

How they work…



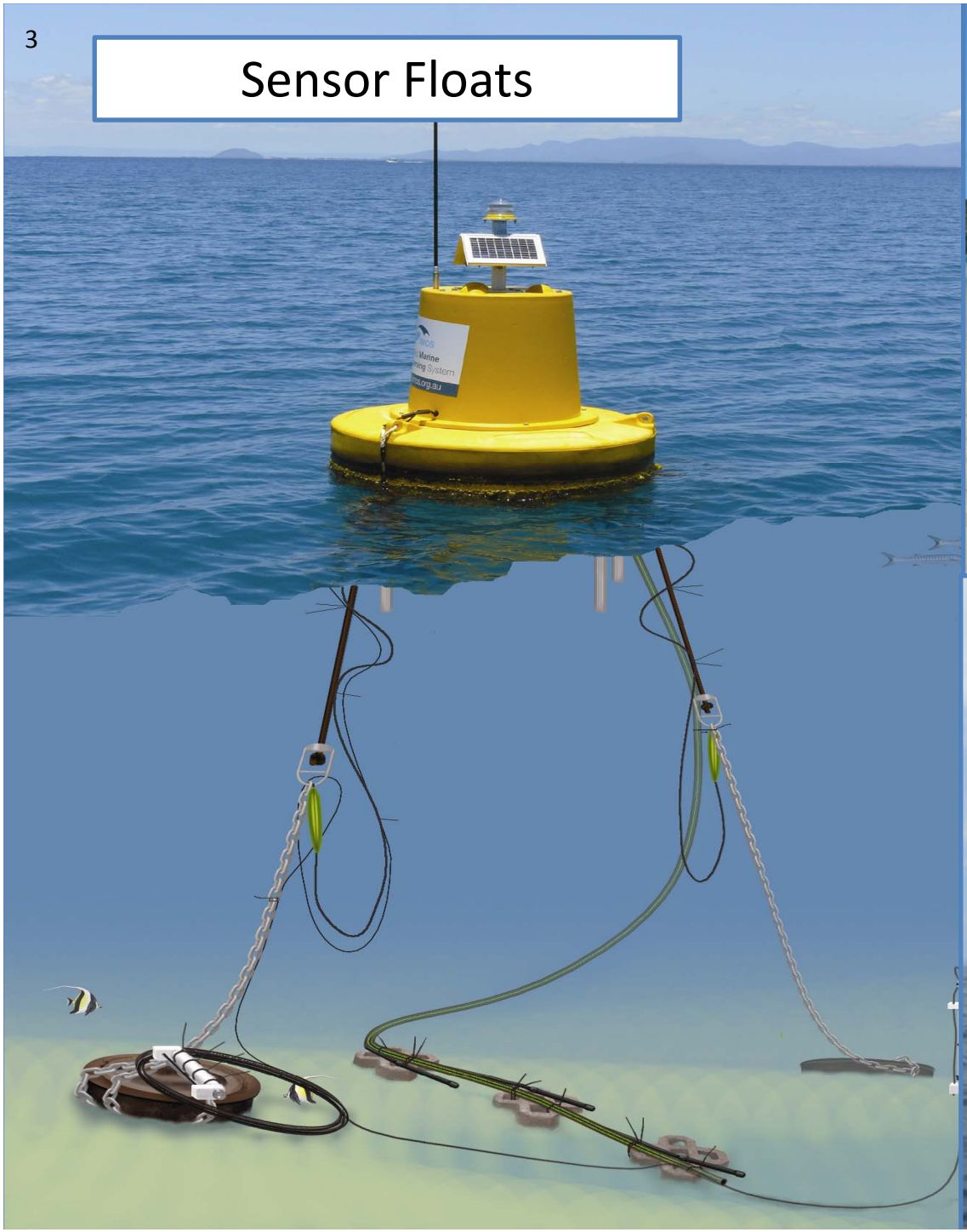
What they provide…

- **Fine scale real-time environmental observations** for weather, temperature, salinity, turbidity, chlorophyll, light and even still images and video;
- Provide an **adaptive platform** for sampling controlled over two-way IP based high speed communications;
- Propagate an **on-reef 802.11 wireless Internet network** to which platforms and sensors communicate;
- Support the deployment of sensors and instruments from other organisations and agencies, becomes a **platform on which other work can be done**.

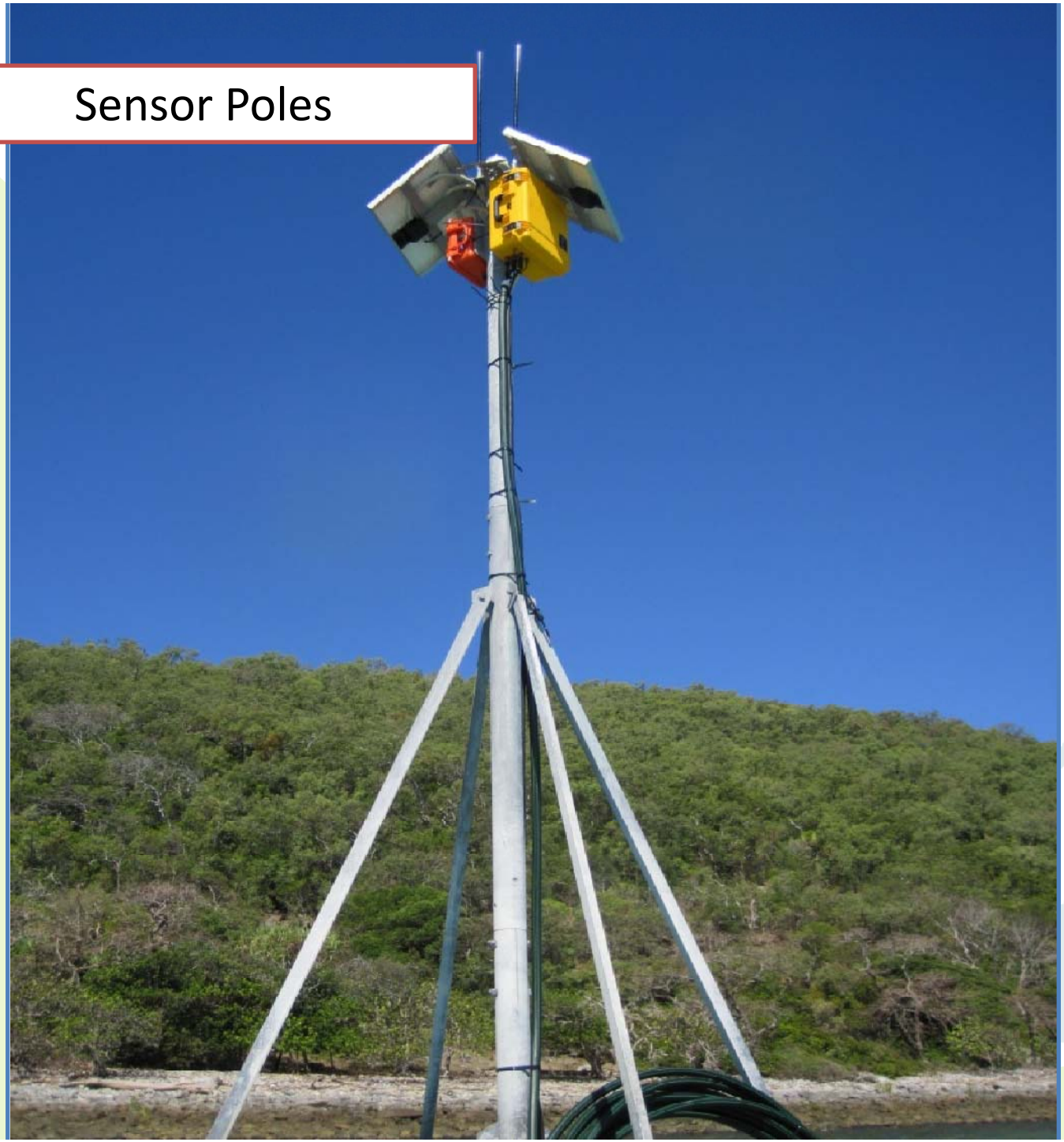


Sensor Network sites on the Great Barrier Reef

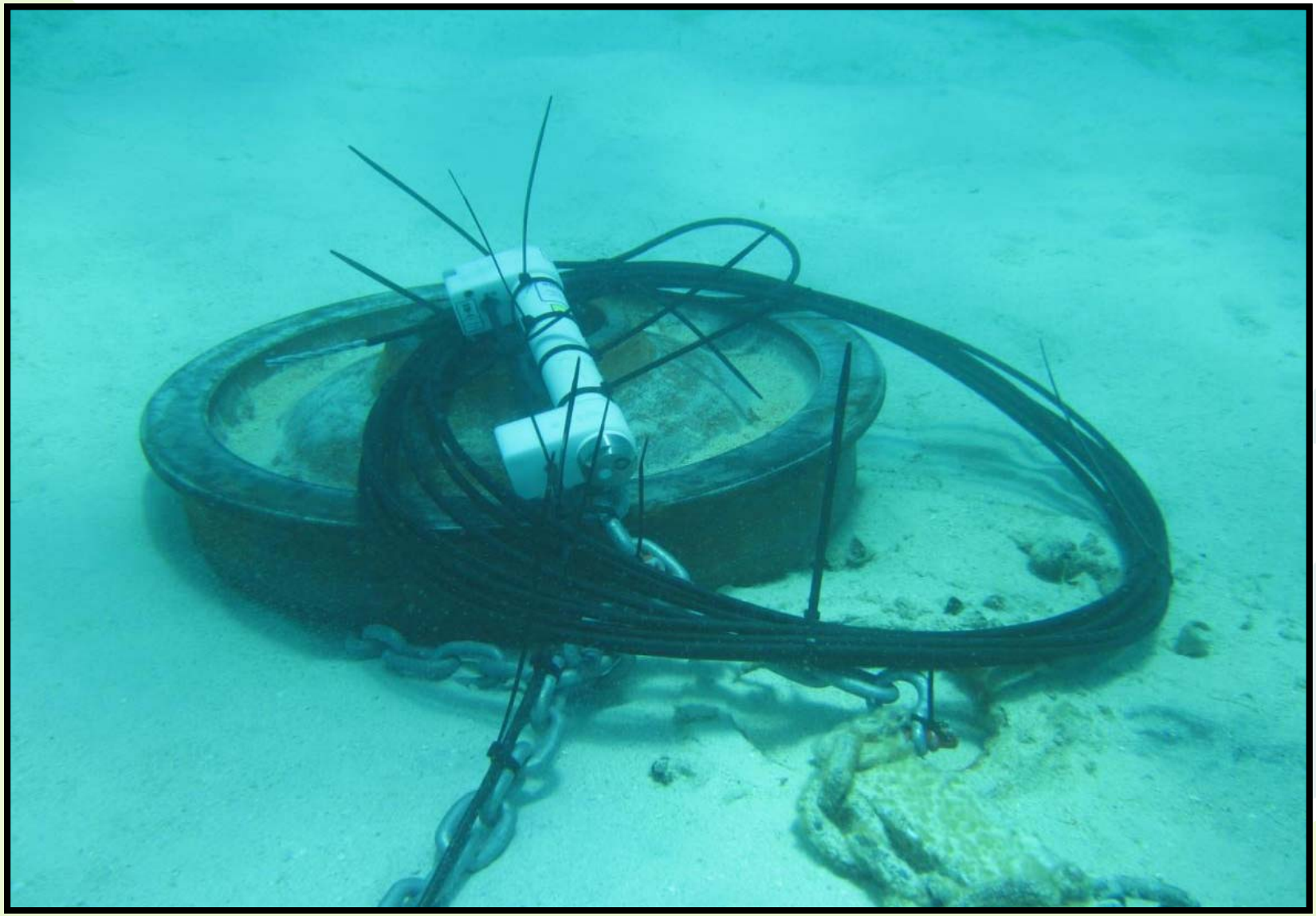
Sensor Floats



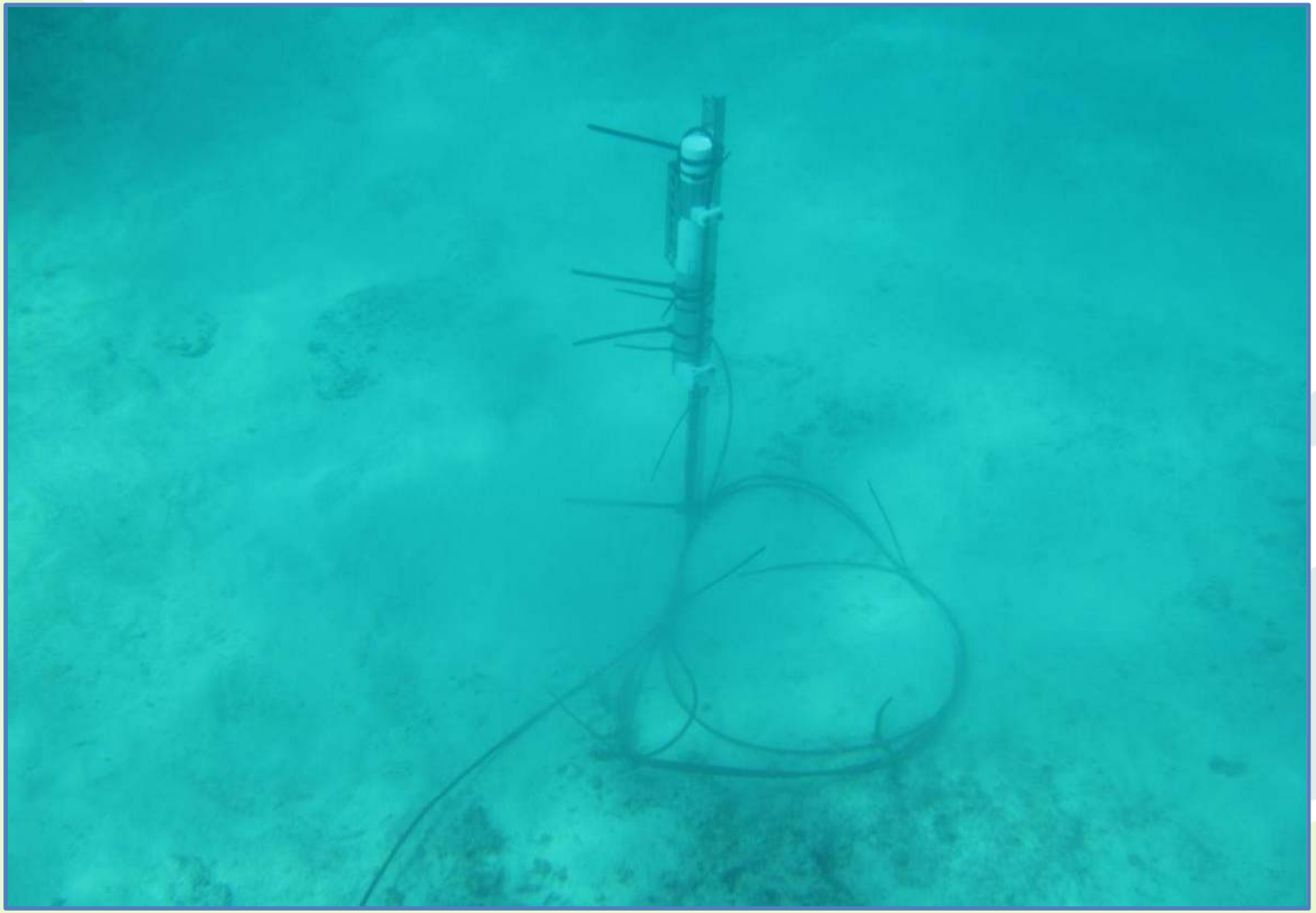
Sensor Poles



Sensors



IM based SBE37 – Conductivity, Temp and Pressure




IMOS

Data Management

- Managing the data collected is as important as collecting it in the first place – **if you can't manage it don't bother collecting it**;
- Data Management is **not easy** but worthwhile;
- Future use of the data we collect may be for very different use so by describing and storing the data correctly we **give this data to future** generations;
- Data Management should account for **10-15% of the budget** for any data collection project.

Metadata

- Metadata is **'data about data'** or a description of the data being collected;
- It allows for data to be **found by search engines** and for all of the **ancillary information** about a dataset to be located or referenced from the one point;
- It **adds value to the data** and allows the data to be used by people who didn't collected it for reasons it wasn't collected for – it gives it life!
- **ISO 19115** is the metadata standard for spatial data.

Data Outputs

- The GBROOS project looks to make its data available in a number of ways:
  - Dedicated web sites
  - iPhone Apps
  - Web Services (REST based along with WMS/WFS)
  - Ocean Data ‘Portals’
  - Social Networking (Twitter)

Dedicated web page

IMOS Integrated Marine Observing System

GBROOS DATA

GBROOS GREAT BARRIER REEF OCEAN OBSERVING SYSTEM

AIMS DATA CENTRE

GBROOSData - Observing the Great Barrier Reef

- Home
- Science Rationale
- About/Contact Us
- Accessing the data
- Today On the Reef
- Sensor Deployments
- Search Metadata
- Sensor Network
- Mooring Deployments
- Remote Sensing
- Underway Sampling
- Knowledge Pages

Welcome to the GBROOS-Data web site! This site gives access to the data collected by the Great Barrier Reef Ocean Observing System (**GBROOS**) Project which is part of the Australian Integrated Marine Observing System or IMOS. GBROOS is run by the Australian Institute of Marine Science (AIMS) on behalf of a consortium of Universities and research agencies.

GBROOS is an observing system that looks to document the impact of the Coral Sea on the Great Barrier Reef and in particular to provide the observational data to understand long term change and the impact this will have on the Great Barrier Reef.

There are five components to GBROOS, the data from each of these can be accessed via this site.
They include:

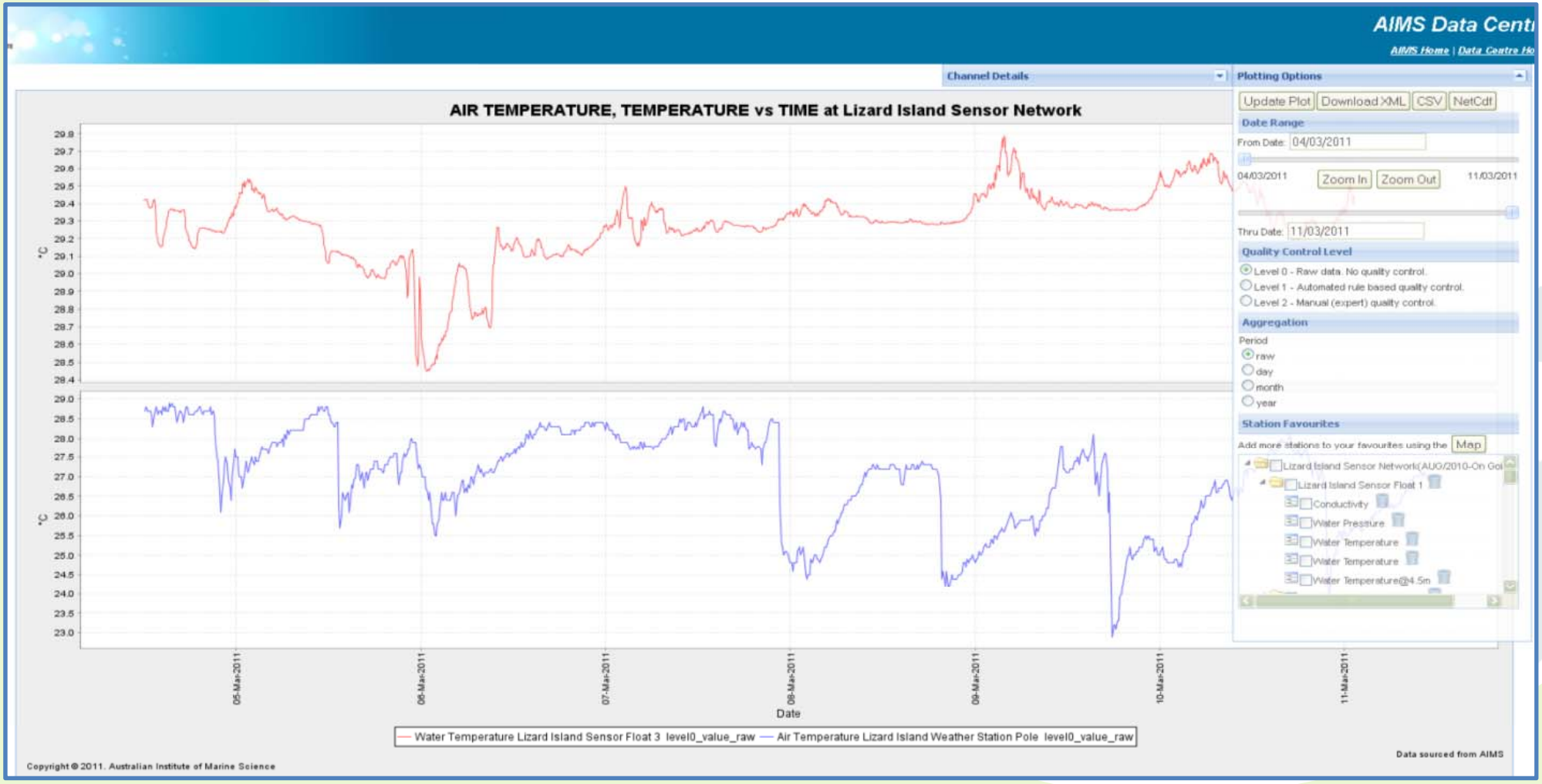
- Nine long term moorings, data includes temperature and salinity profiles, waves and currents;
- Two reference mooring stations – basic oceanographic parameters;
- Sensor networks located on a number of reefs, data includes temperature profiles and weather data (with more to be added over time);
- Remote sensing satellite data (sea surface temperature and ocean colour data)
- Underway sampling (temperature, salinity, chlorophyll)

Use the links below to directly access the information you require or use the navigating bar to the left to navigate around the site. Finally of you would like to leave feedback or contact us please go to the About / Contact Us page.

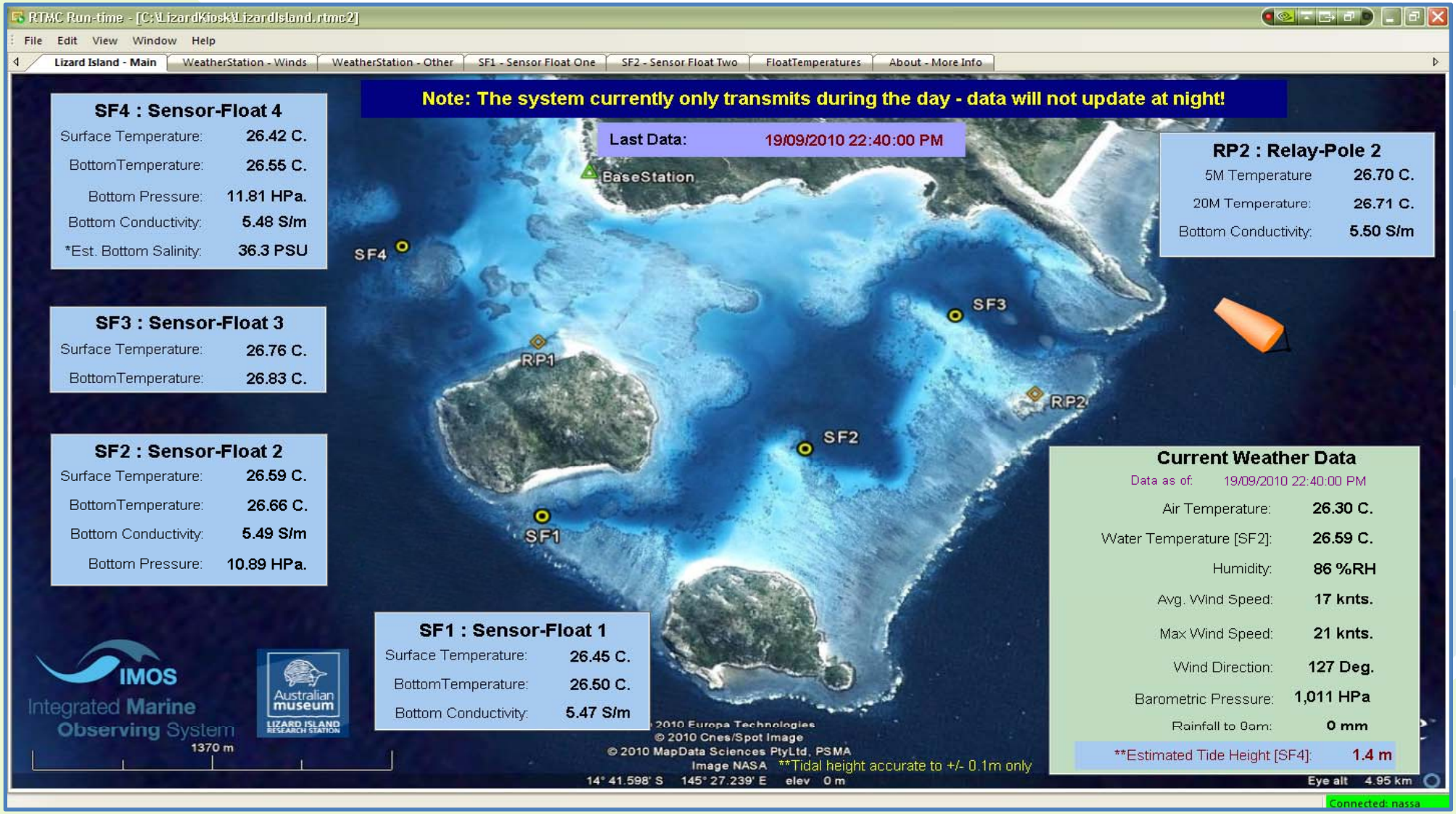
Quick Links:

- Click for information about the GBROOS project in general
- Click for information about the IMOS project
- Click to see the latest data from the reef
- Click to explore and graph the sensor network data from the project
- Click to see what sensor network equipment is deployed and where
- Click to see mooring deployments
- Click to contact us or to leave feedback
- Click to go to the AIMS web site

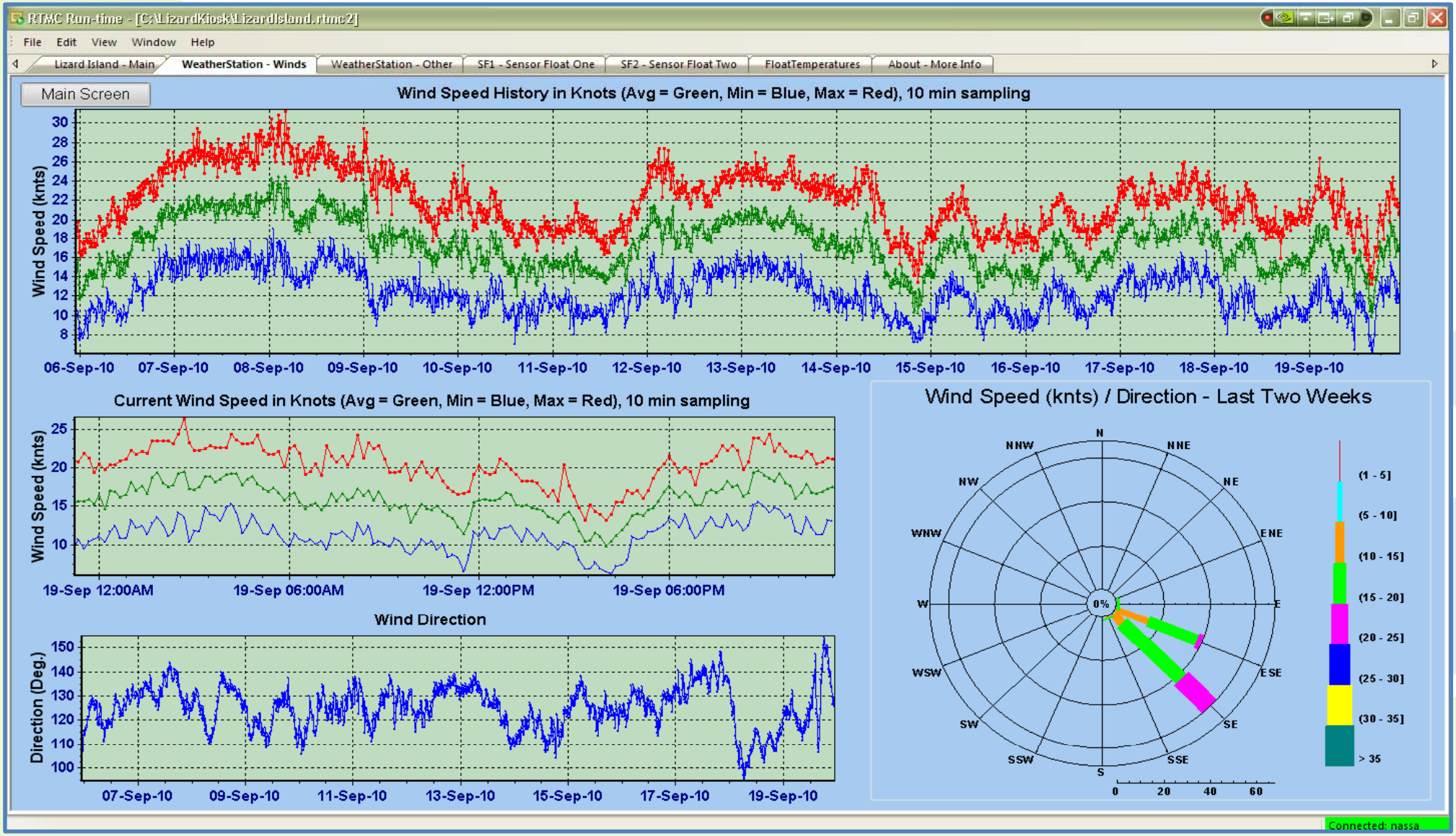
Web plotting and access



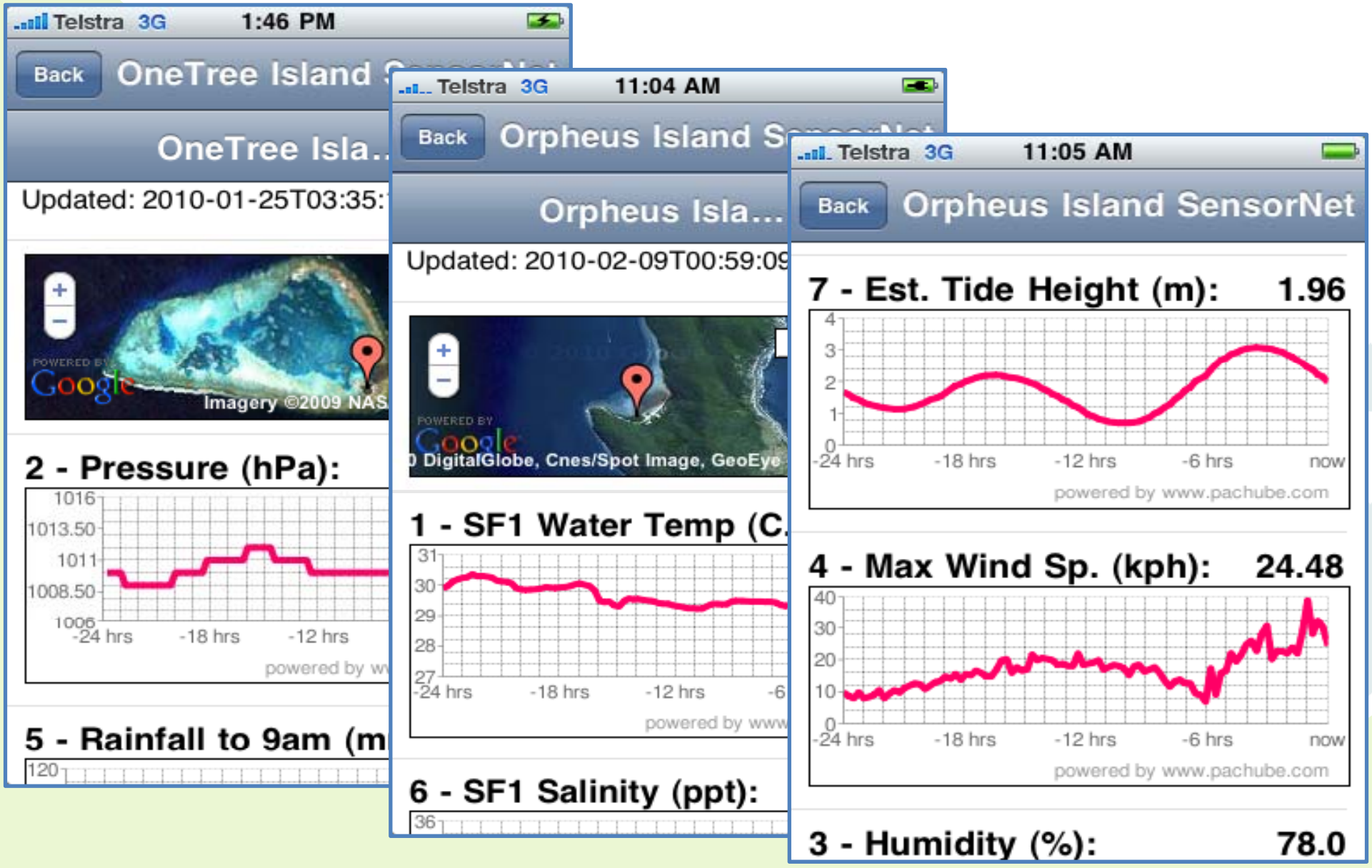
Data ‘Kiosks’ for public on-site access



Current Winds



iPhone Application



Applications of Sensor Networks

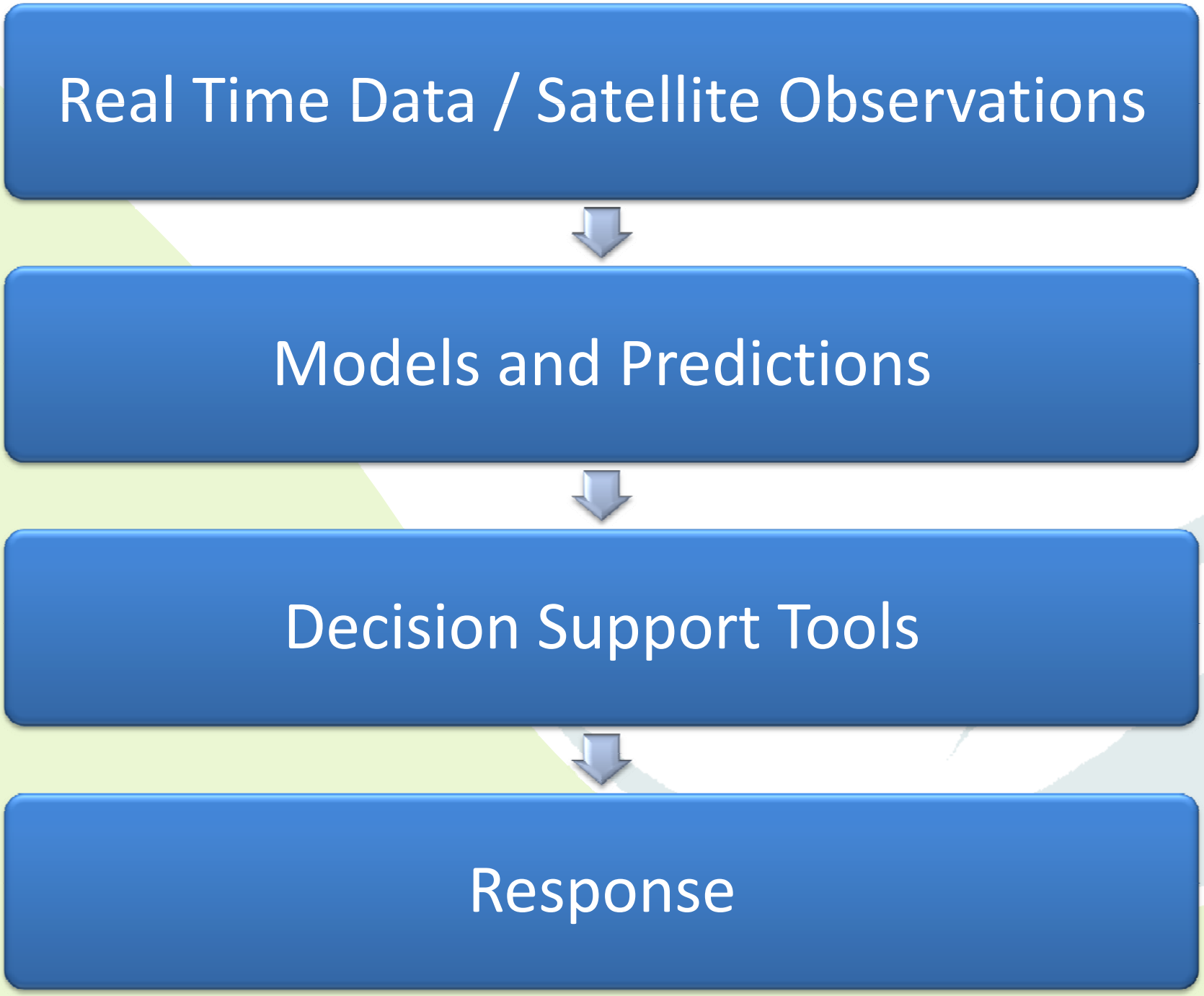
1. Emergency Response
2. Ecological Monitoring

Why Manage Coastal Systems?

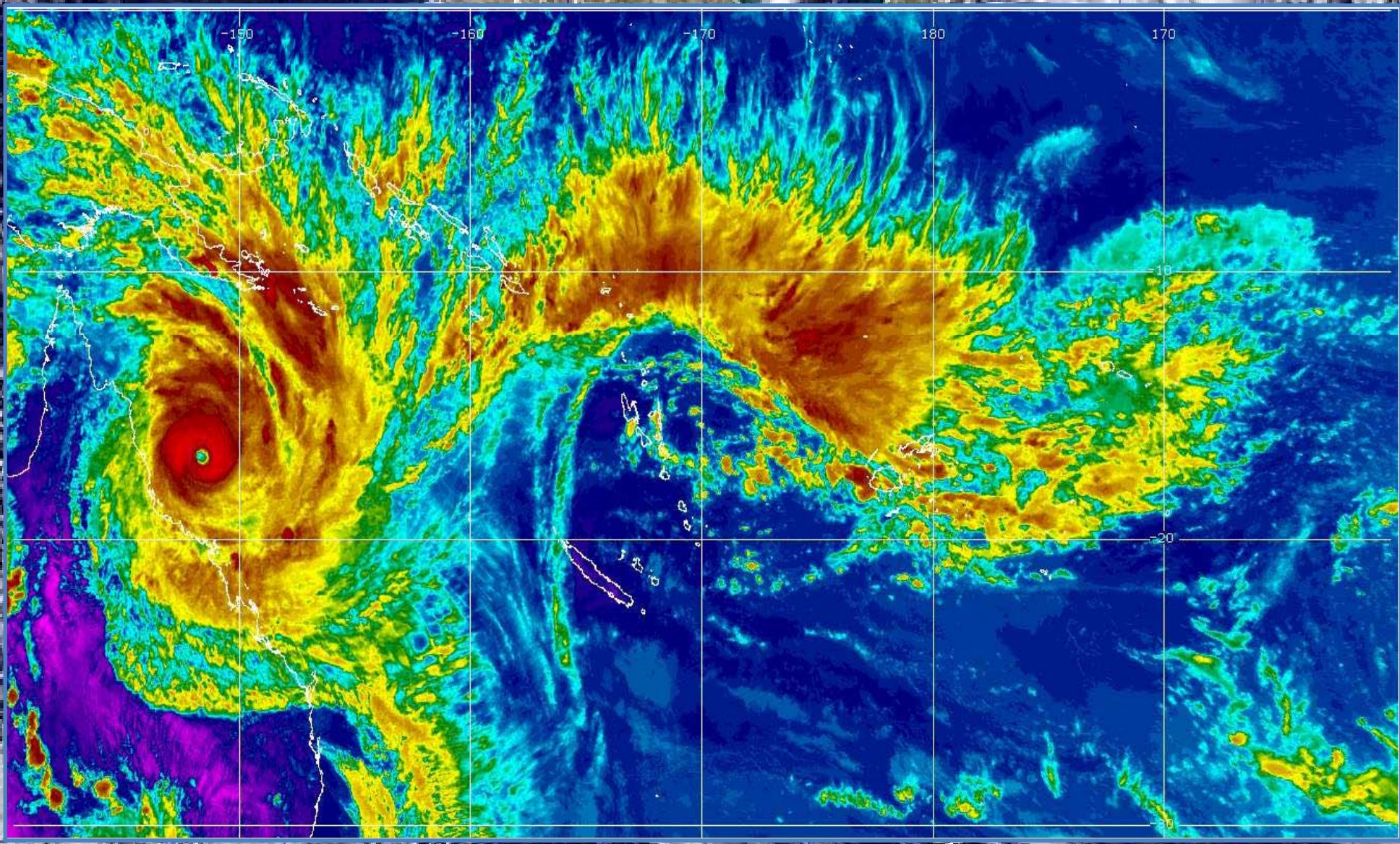
- Understand and deal with **Climate Change**
  - Complex and long term
  - Occurs within other levels of change such as El-Nino events
- To **manage emergency events** such as floods, cyclones / typhoons, tsunami's, earthquakes;
- To **manage human activities** such as pollution, run-off, impact of human activities, regulation of resources, etc;
- To deliver a **more sustainable future** to the people that live and rely on coastal systems.

1. Emergency Response: Tropical Cyclone ‘Yasi’

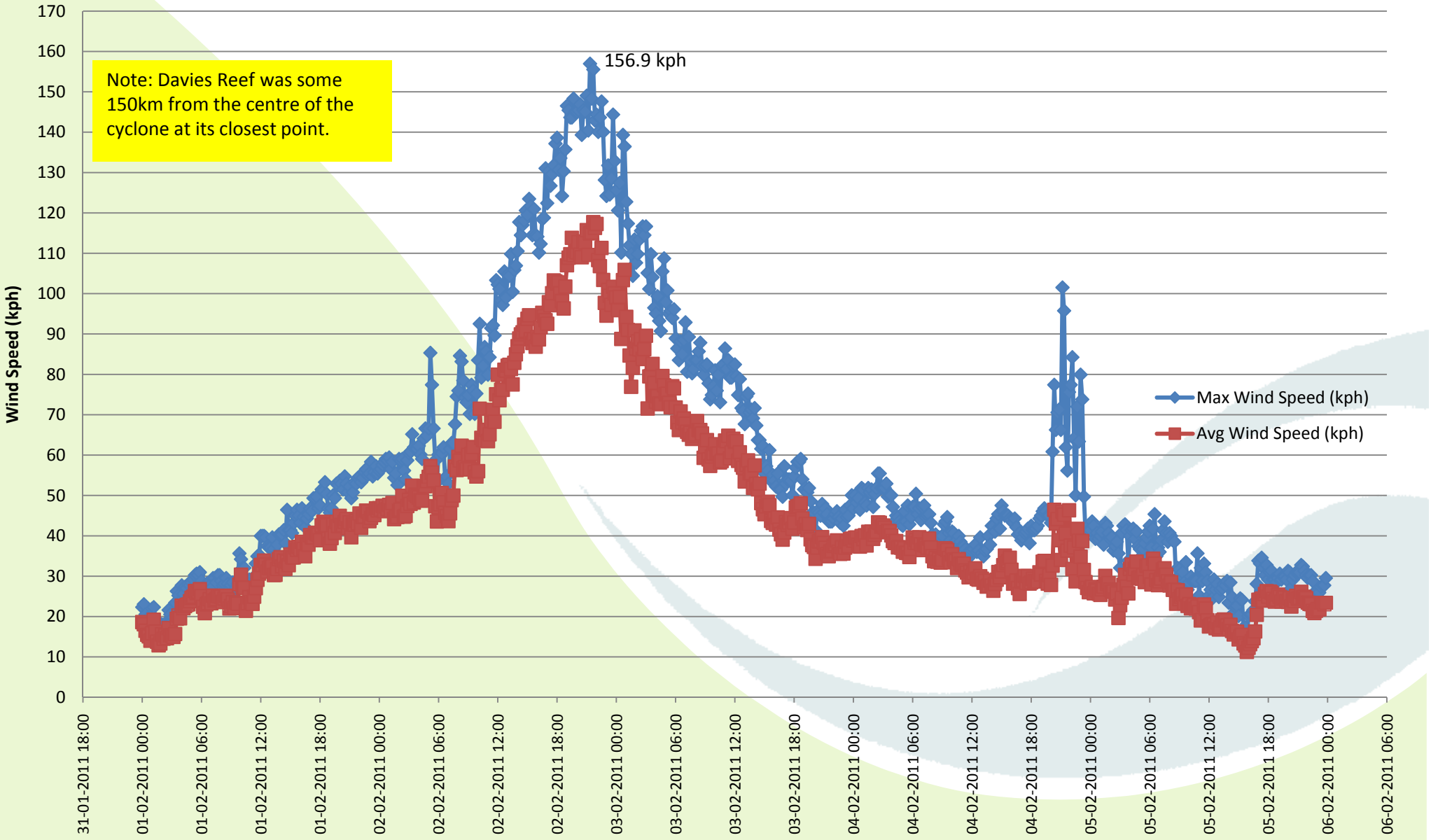
- Category-5 Tropical Cyclone ‘Yasi’ came through the central Great Barrier Reef in February 2011 causing damage in a number of coastal communities;
- Advanced notice was given including weather predictions, SMS and Voice Mail alerts leading to the evacuation of some towns;
- The GBROOS data gave important information on the progress and impact of the cyclone;
- Gave a unique opportunity to study the impact of the cyclone and correlate this to the observations collected.


Real Time Data / Satellite Observations
Models and Predictions
Decision Support Tools
Response

Real Time Data – Satellite Images

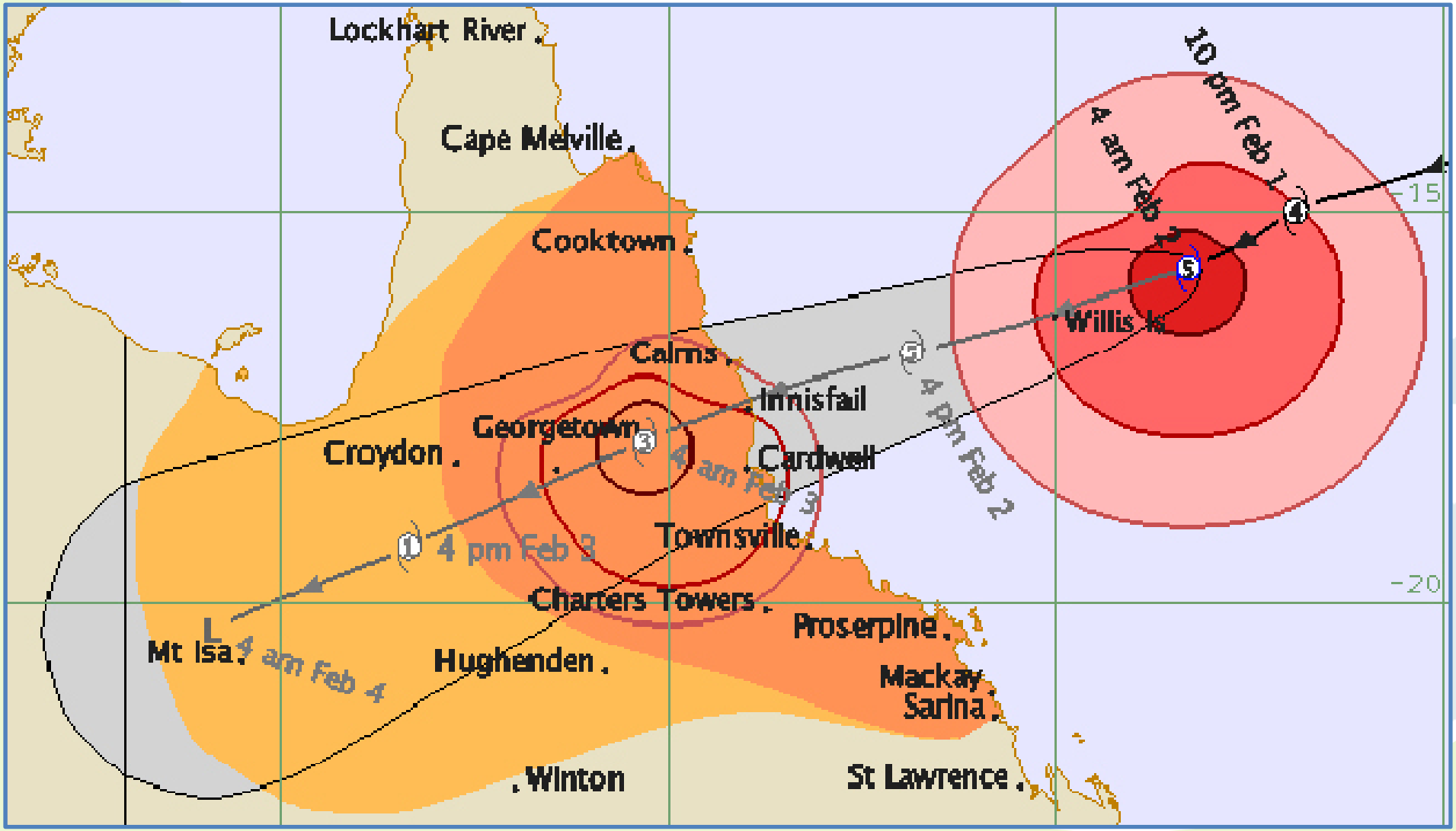


Real Time Data – Sensors and Sensor Networks




Australian Institute of Marine Science - Bowling Green Bay Wed 02 Feb 2011 18:51 (UTC+1000)

Models and Predictions



Response

Cardwell a ghost town ahead of Cyclone Yasi

By Petrina Berry | The Daily Telegraph | February 02, 2011 3:45PM

Video | Image | Flash

Anne Reid and daughters Grace, 13, and Emma, 11, sandbag their take away store in Cardwell. Picture: Tran Jack *Source:* The Daily Telegraph

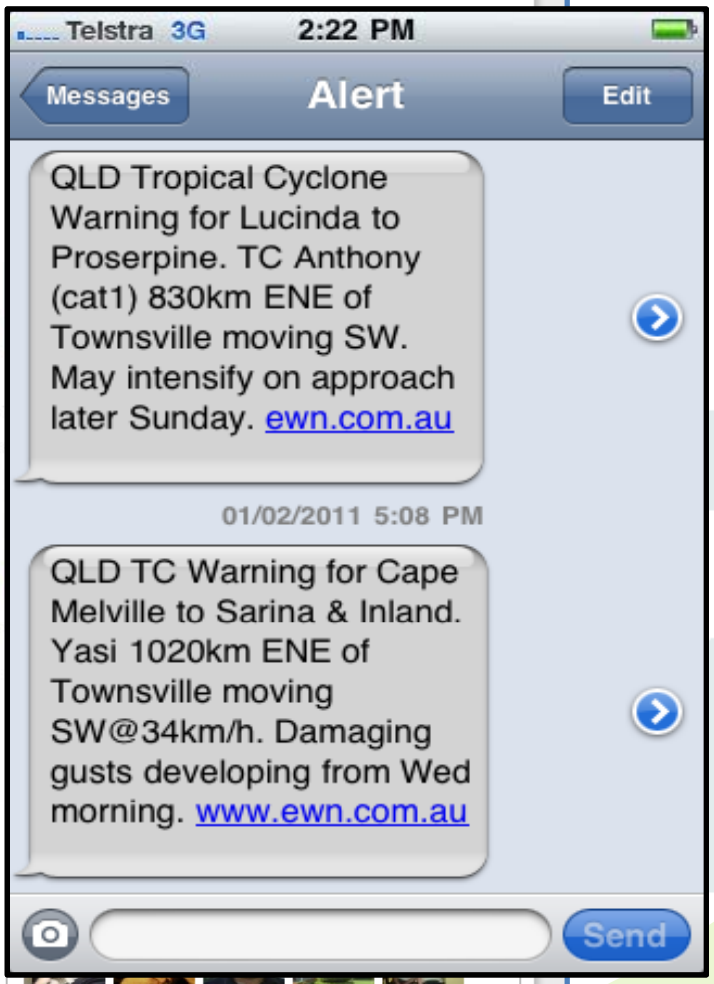
THE small north Queensland town of Cardwell is a ghost town ahead of Cyclone Yasi.

No one's been stupid enough to hang around to see what devastation category five Cyclone Yasi will do to the seaside tourist town.

No wonder really.

The only thing that separates the beach from the main drag, and the town's homes, is the Bruce Highway.

There's simply nothing to stop the up to seven-metre storm surge Yasi's expected to send into the town.



Role of Sensor Networks in Emergencies

- **Real time measurements** of events as they occur, often from areas that are no longer safe for people;
- Data directly **linked into event detection systems** and models to predict likely outcomes;
- Multi-use systems – data used by a number of systems for various usage;
- **Image and video data** useful for public awareness;
- Historical data important for post-event analysis.

2. Ecological Applications – Coral Bleaching

- Corals are animals with single cell algae embedded in their tissues;
- Normally the algae provide up to 70% of the food for the coral, the coral provides a home;
- Under conditions of high light and temperature the relationship breaks down and the coral expel the algae = bleaching;
- Without its food source the coral will die unless conditions allow it to re-establish the relationship with the algae.

Mass Coral Bleaching

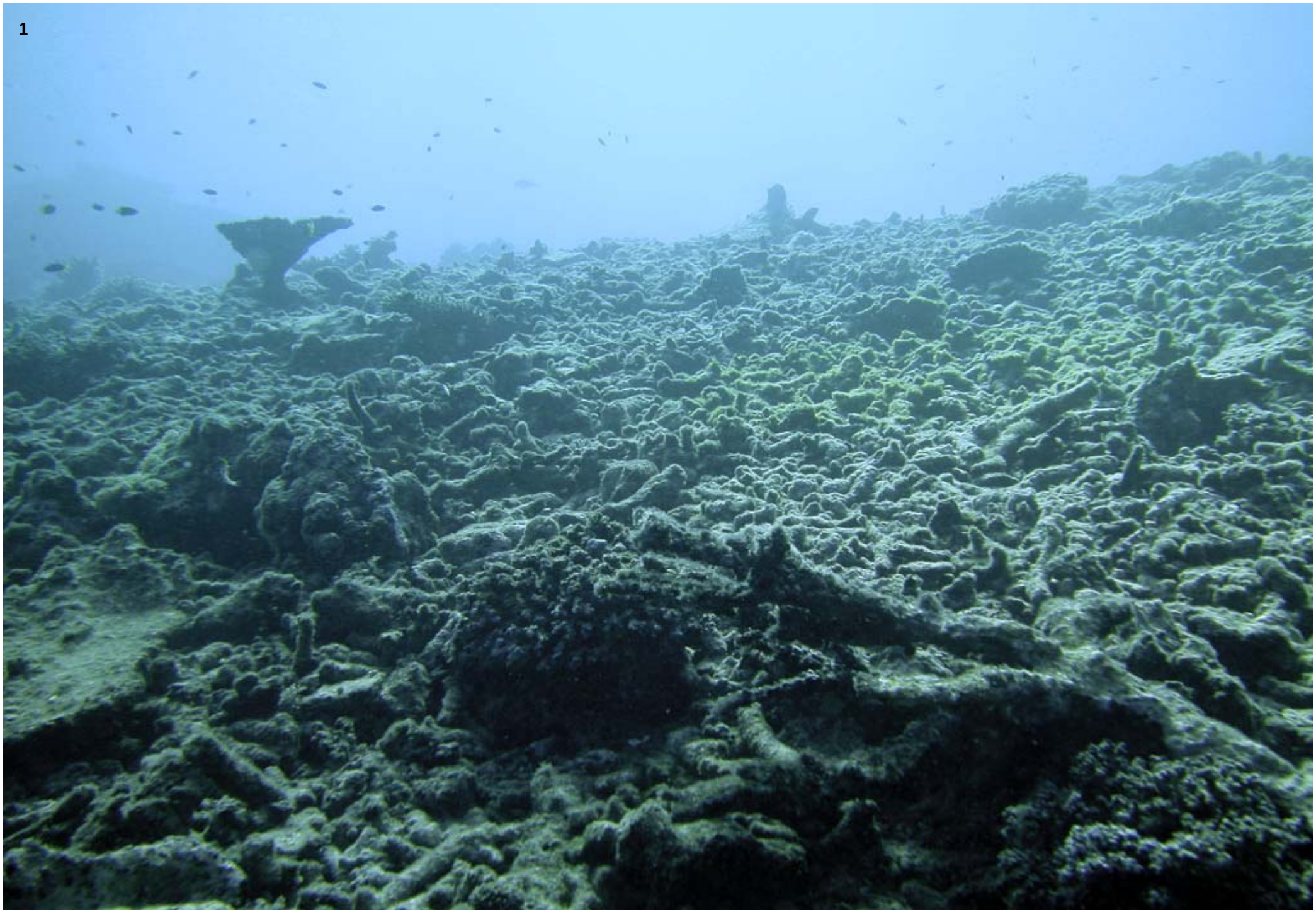
Distribution of Coral Bleaching Events, 1998

Severity of bleaching
- 0
- 1
- 2
- 3
- Coral

Data Sources
NOAA
GCRMN
CORDIO

Map compiled by Rachel Donnelly

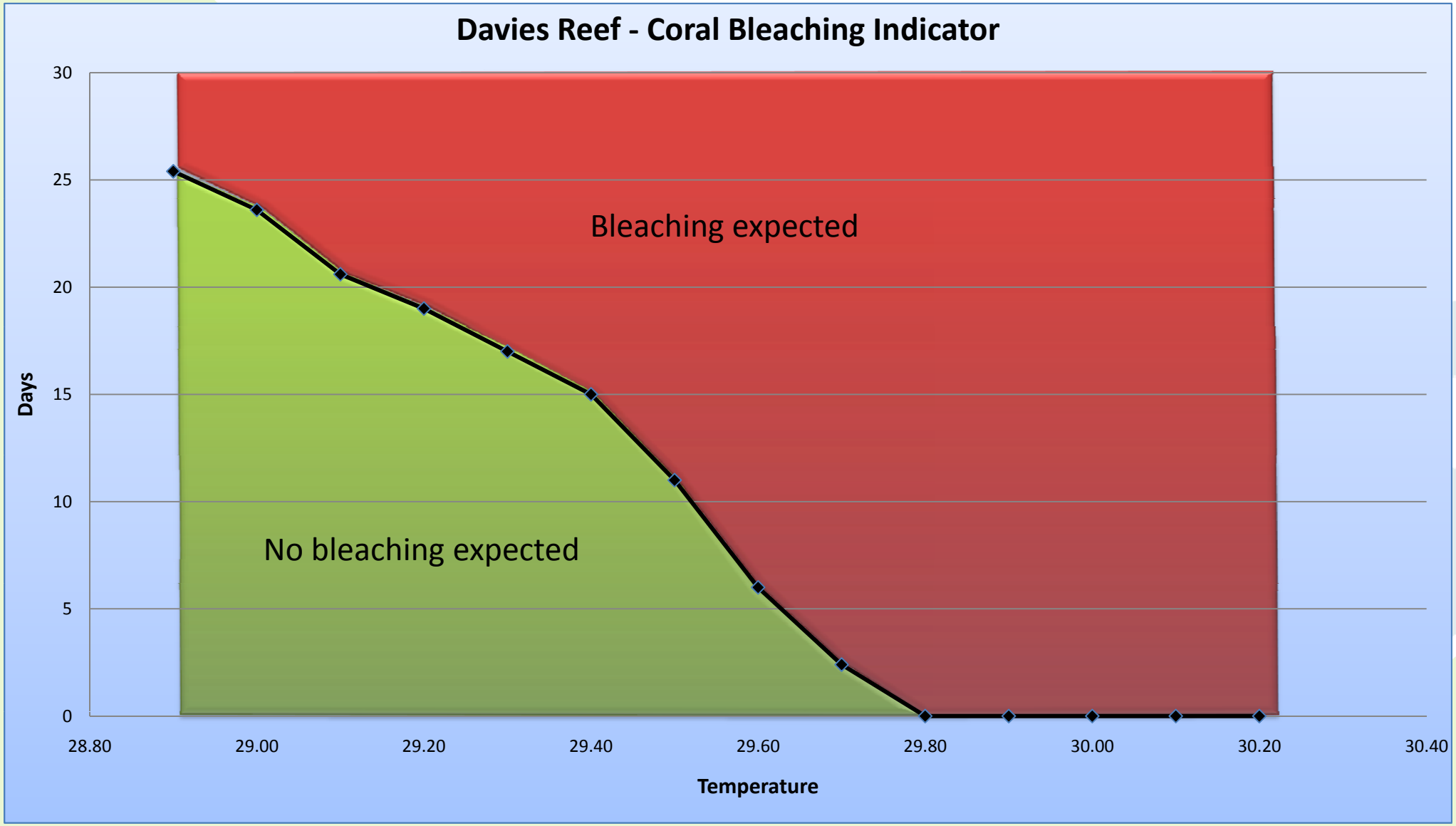
WCMC


1

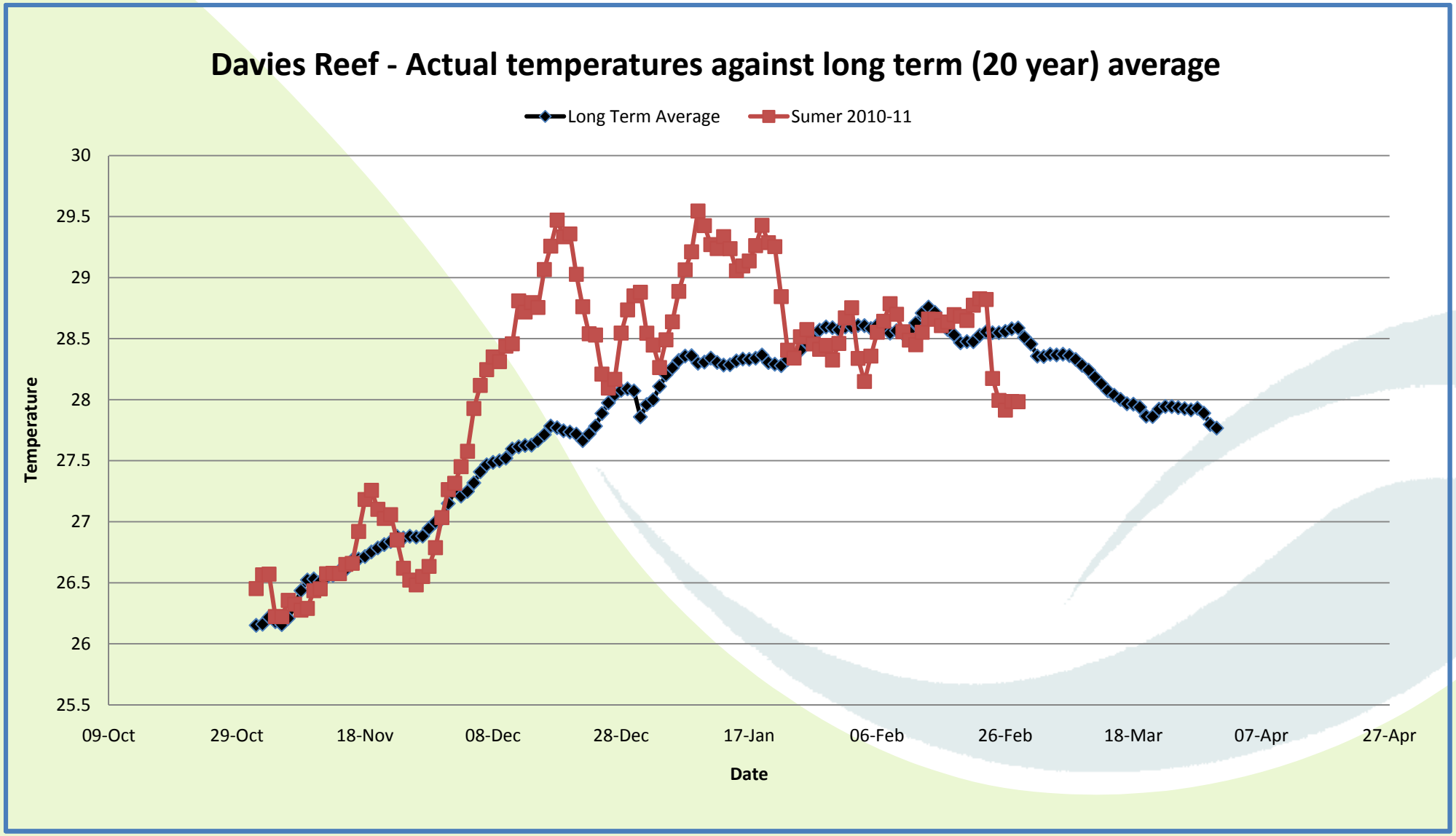
Coral Bleaching Alerts

- We now know what conditions **lead corals to bleach**, we have detailed measurements for some reefs.
- The sensor network observing systems can be used to **predict places and times of potential bleaching**;
- Using the real time measurements with simple models of bleaching we can produce **bleaching threats maps** for local reef managers.

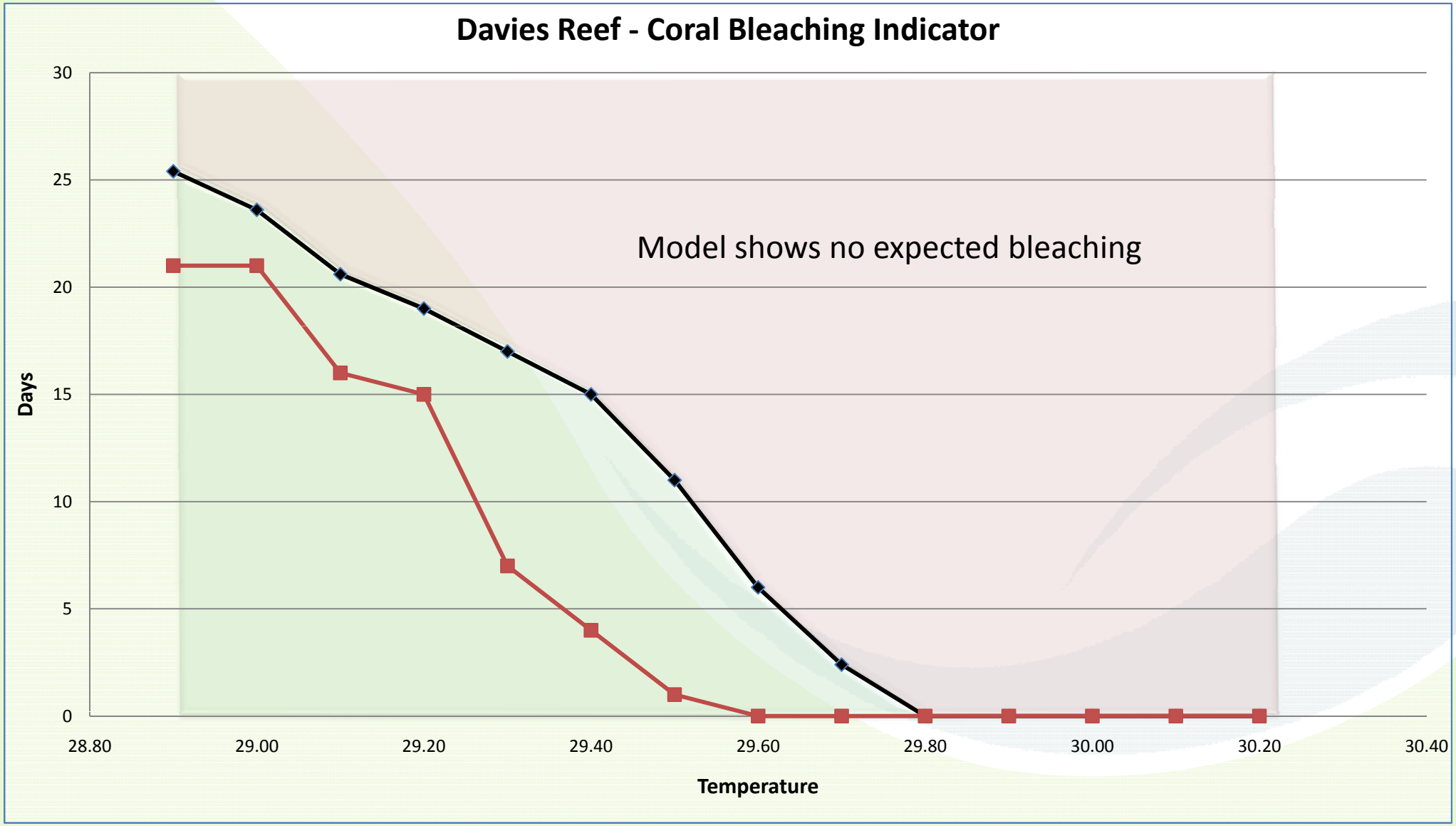
Coral Bleaching Indicator – Davies Reef



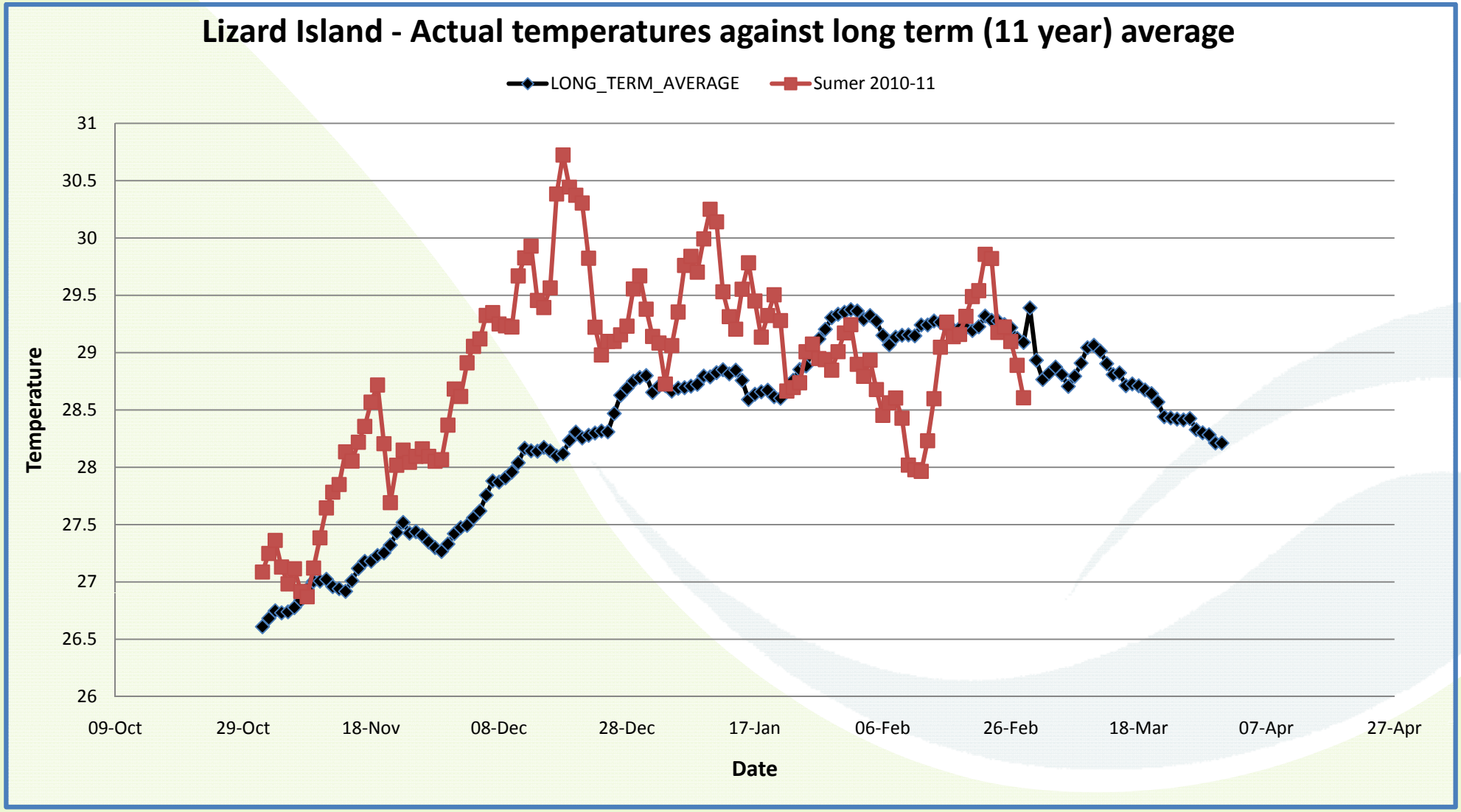
Davies Reef – Measured temperatures



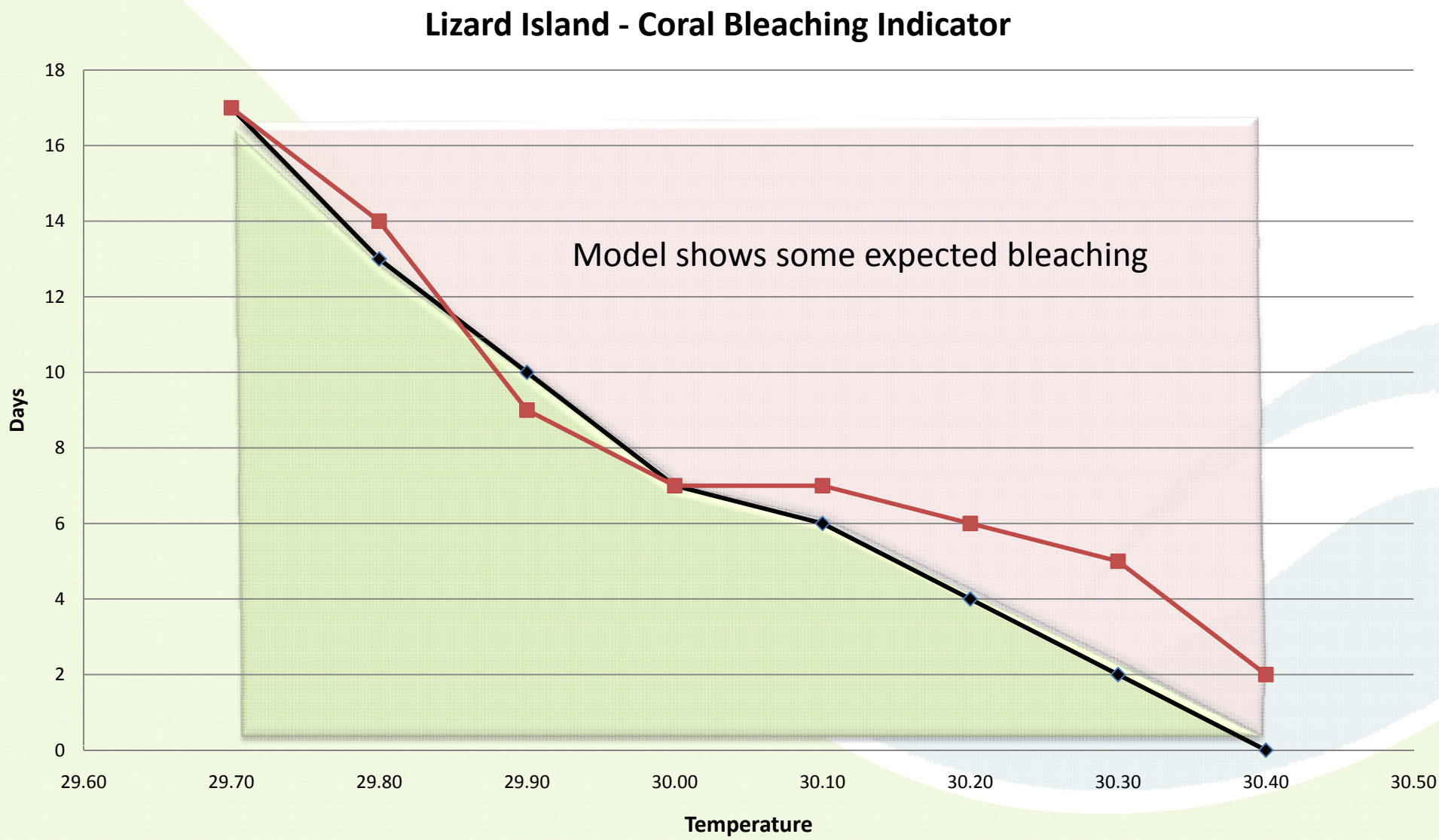
Davies Reef Bleaching Indicator



Lizard Island – Measured Temperatures



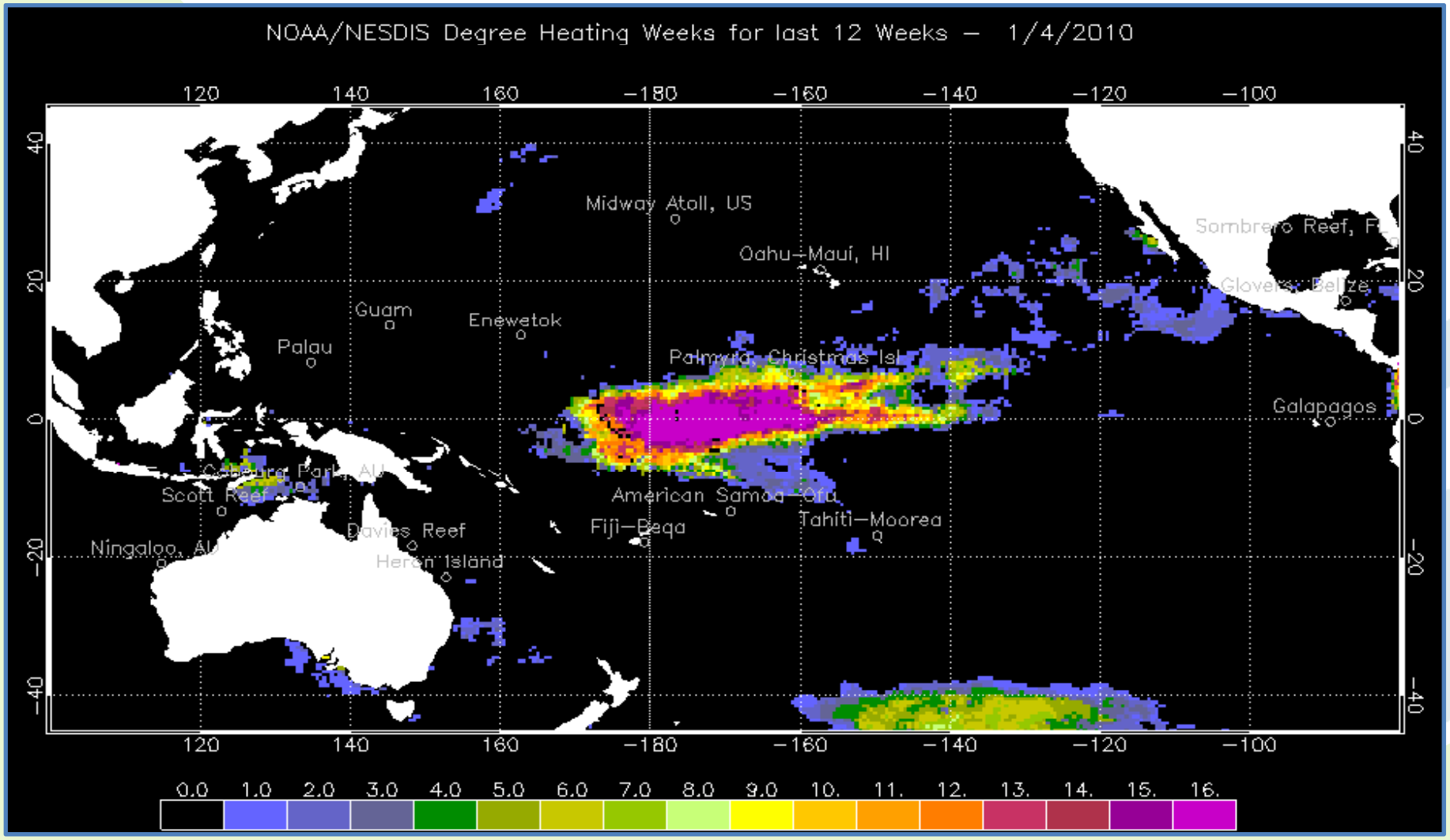
Lizard Island Bleaching Indicator



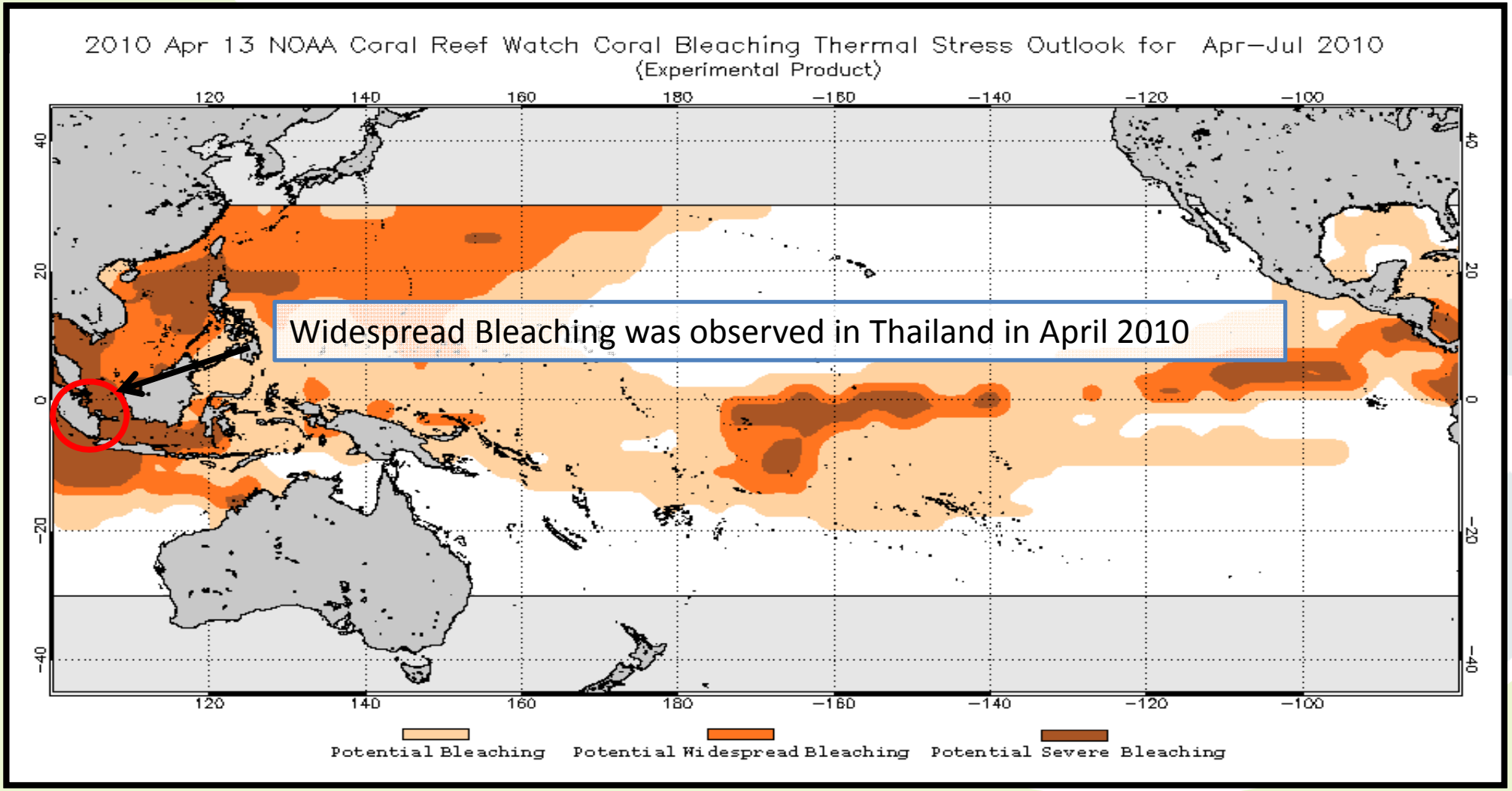
NOAA / AIMS Coral Reef Bleaching alerts

- NOAA, using satellite data and data from observing systems, such as GBROOS, identifies areas of the ocean that are **hotter than their long term mean**;
- They use a measure of how much hotter than normal and how long the temperature has been above the average to develop a **bleaching indicator**;
- The GBROOS data is used to correct the satellite data and to help in the models that produce the indicator maps.

‘Hot-Spots’ Map – Jan 2010



Forecast – April to July 2010, predicts observed bleaching in S.E. Asia.



3. Video and Image Monitoring

- Sensor networks support image and video analysis through high speed IP communications, web cameras and on-node image processing;
- Potential uses include:
  - Jelly fish monitoring
  - Crocodile monitoring
  - Fish behaviour
  - Surveillance
  - Beach monitoring

Jellyfish monitored using remote cameras

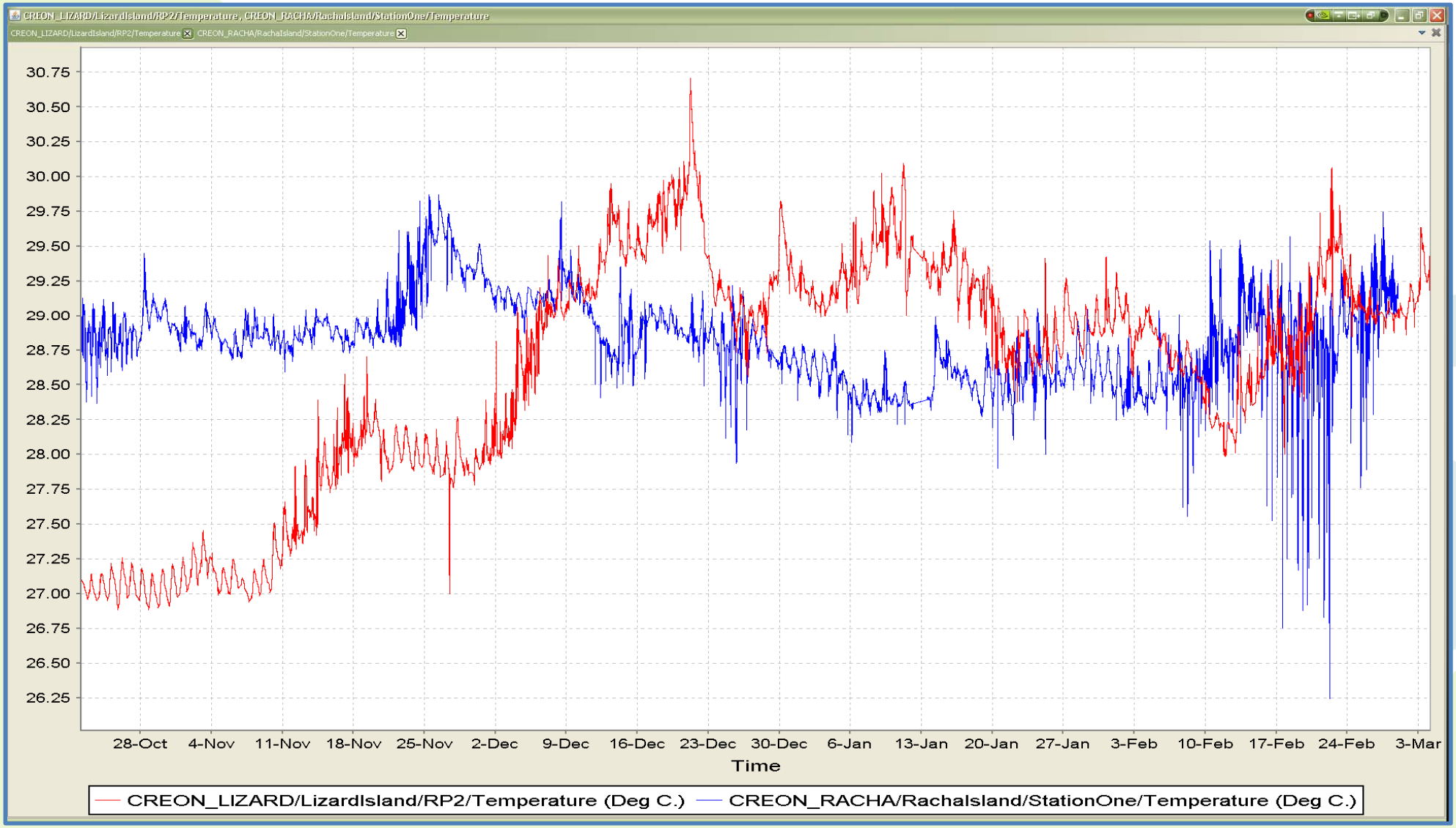
- CREON is an international group looking at the development of coral reef sensor networks;
- Current sites include the Great Barrier Reef in Australia, Kenting and Orchid Island in Taiwan, Moorea in French Polynesia and **Racha Island** in Thailand;
- The group looks to help groups establish sensor networks and then develop information systems to identify patterns in conditions across the sites.

CREON

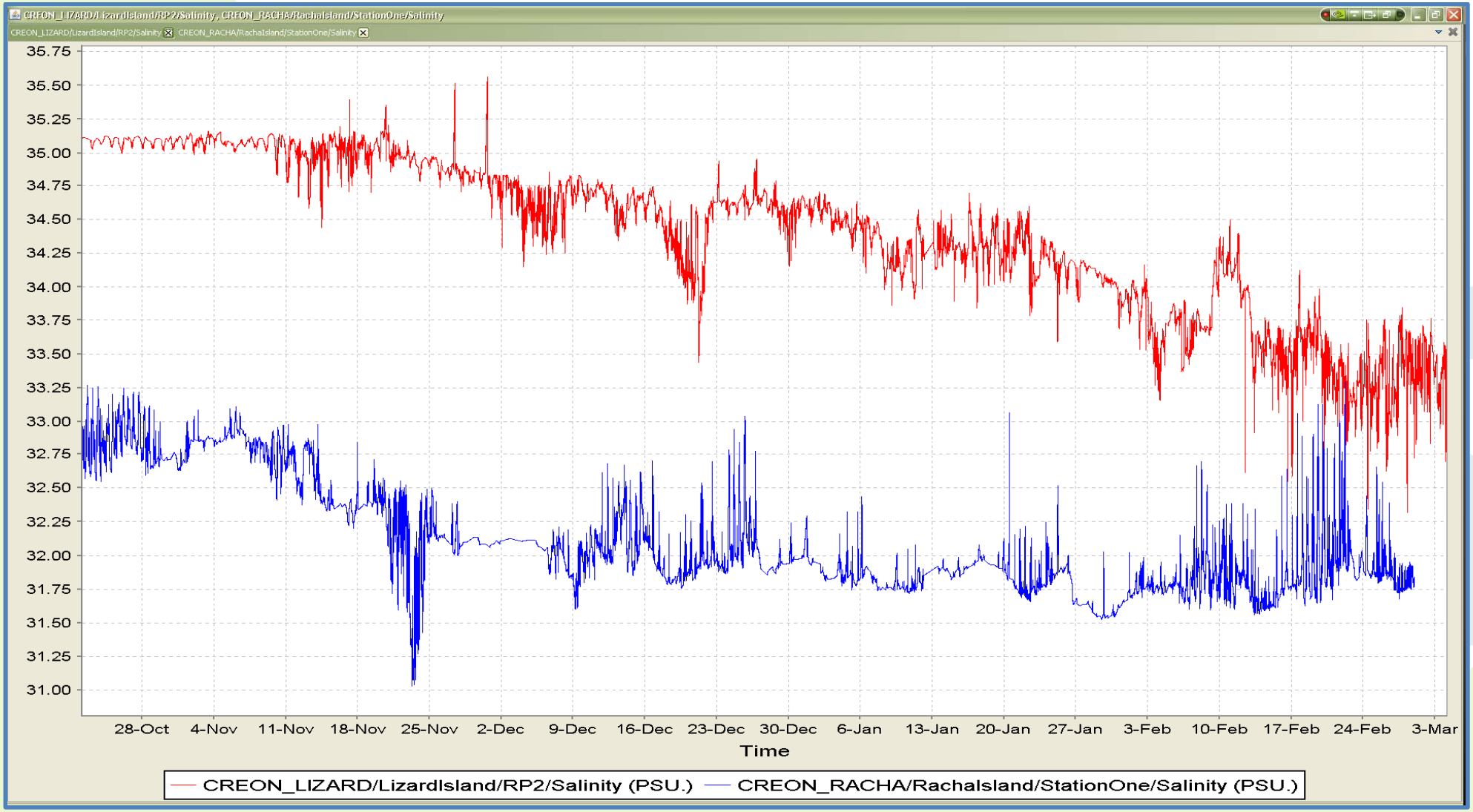
Coral Reef Environmental Observatory Network

- In September 2010 a joint CREON project was organised with scientists from Walailak University Thailand, University of California San-Diego and the Australian Institute of Marine Science;
- The project put in place a sensor network connecting existing weather stations, temperature loggers and video cameras to a new CTD instrument;
- The aim was to document environmental conditions over the coming summer to identify if coral bleaching conditions occurred.

Temperature Data from Racha Island, Thailand (blue) and Lizard Island, Australia (red)



Salinity Data from Racha Island, Thailand (blue) and Lizard Island, Australia (red)



3. A wired world – the vision

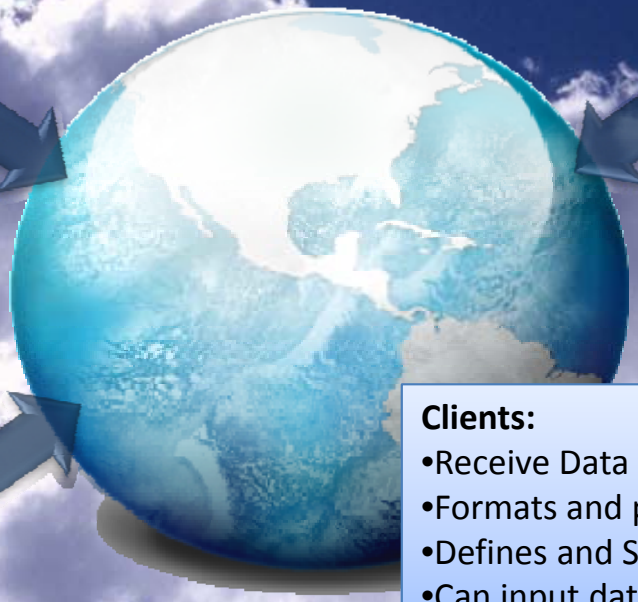
- **Technology has a part to play** in helping to deal with the issues of the 21st Century;
- **Informing decision makers**, whether in times of emergency or in making longer term plans, is a critical role for new technologies such as sensor networks;
- Environmental Sensor Networks are uniquely able to provide real time data often when it is **not possible to collect data in other ways** such as during storms or cyclones.

Internet of Things (IoT)

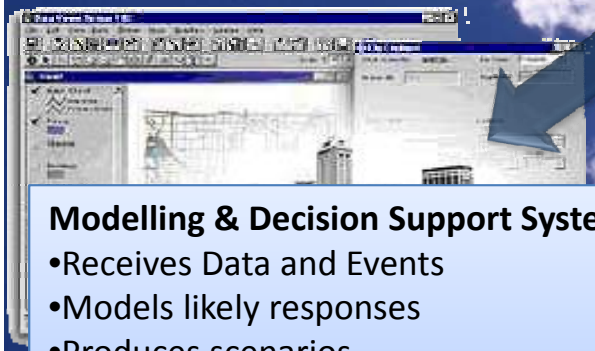
- Currently the Internet is used to connect people (via browsers) to machines (servers) to information;
- In the future most connections will be machine to machine – a machine talking to another machine via web-services to get and process information;
- Using this model we can build a new way of building sensor systems and how they deliver data and information products.

Cloud Computing:
- Receives Data, Processes Data (QC, formats)
- Detects Events from range of Data
- Send Events Notification
- Sends Control Commands
- Sends Data to Modelling and Decision systems

Sensor:
- Collects and Processes Data
- Sends Data to Cloud
- Sends Event Notifications
- Receives Control Commands
- Receives Events from other Systems



Clients:
- Receive Data and Event Notifications
- Formats and presents Data and Notifications
- Defines and Subscribes to events
- Can input data back into the system (user feedback)



Modelling & Decision Support Systems:
- Receives Data and Events
- Models likely responses
- Produces scenarios
- Generates model outputs
- Sends Control Commands to sensors to obtain required data
- Sends Alerts based on events and scenarios

pachube

Store, share & discover realtime sensor, energy and environment data from objects, devices & buildings around the world.
Pachube is a convenient, secure & scalable platform that helps you connect to & build the 'internet of things'.

OUTPUT • Use a Feed

Racha Island CTD

http://api.pachube.com/v2/feeds/19558.xml

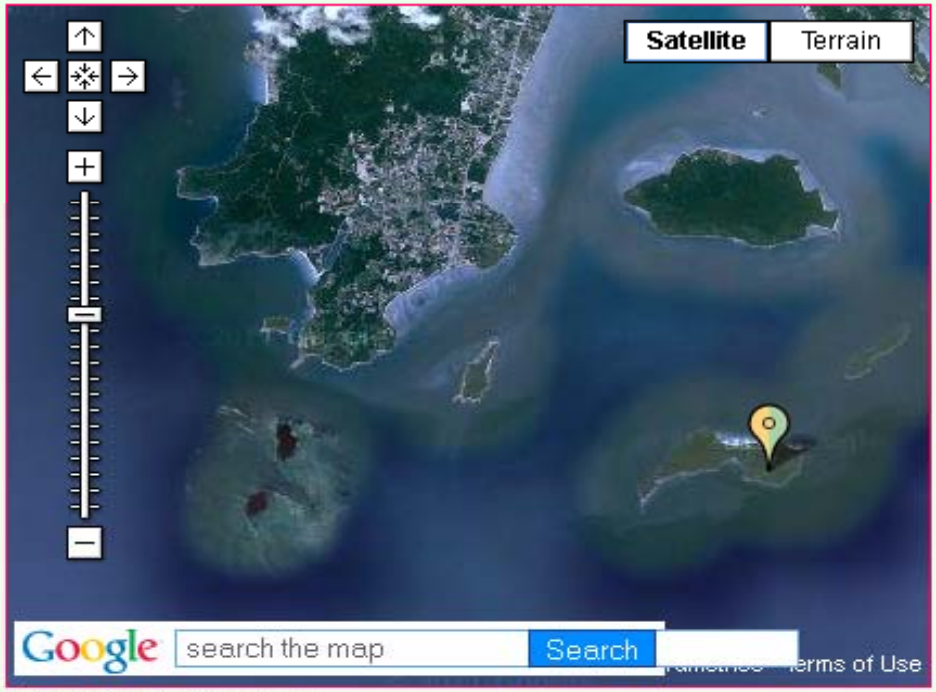
http://api.pachube.com/v2/feeds/19558.csv
http://api.pachube.com/v2/feeds/19558.json
Yet to receive data, currently: frozen.
Published by creon PRO.

CTD Located at Racha Island, Thailand

Contact: scottjbainbridge@gmail.com
Website: http://www.corelreefeon.org
Tags: creon:instrument:SBE37, creon:platform:buoy_1, creon:site:Racha Island

Edit Feed Delete Feed Add to Favourites

Share / Save



Right click for additional options.

Location name: ***Racha Island***
Elevation: ***-10***.
Domain: ***physical*** , *Exposure:* ***outdoor*** , *Disposition:* ***fixed***

ID Tags Value Units Embeddable graphs & tools

Sensors on ‘Twitter’

Conclusion

- Technology has a vital part to play in helping us deal with the issues facing us including climate change, emergency events and human impacts;
- Our ability to deal with emergencies, to safeguard our people and environments will need to include new ways of collecting and using information;
- Sensor Networks represent an exciting new set of technologies to deliver new capacity and with this new capacity new outcomes.

- Better Data → Better Understanding
- Better Understanding → Better Decisions
- Better Decisions → Better Outcomes
- Better Outcomes → Sustainable Future


I know how far I have gone
I have enough fuel
The engine is fine
I will be there soon
RACE
ENGINE START
RPM x 1000
bar
km/h

Thanks!