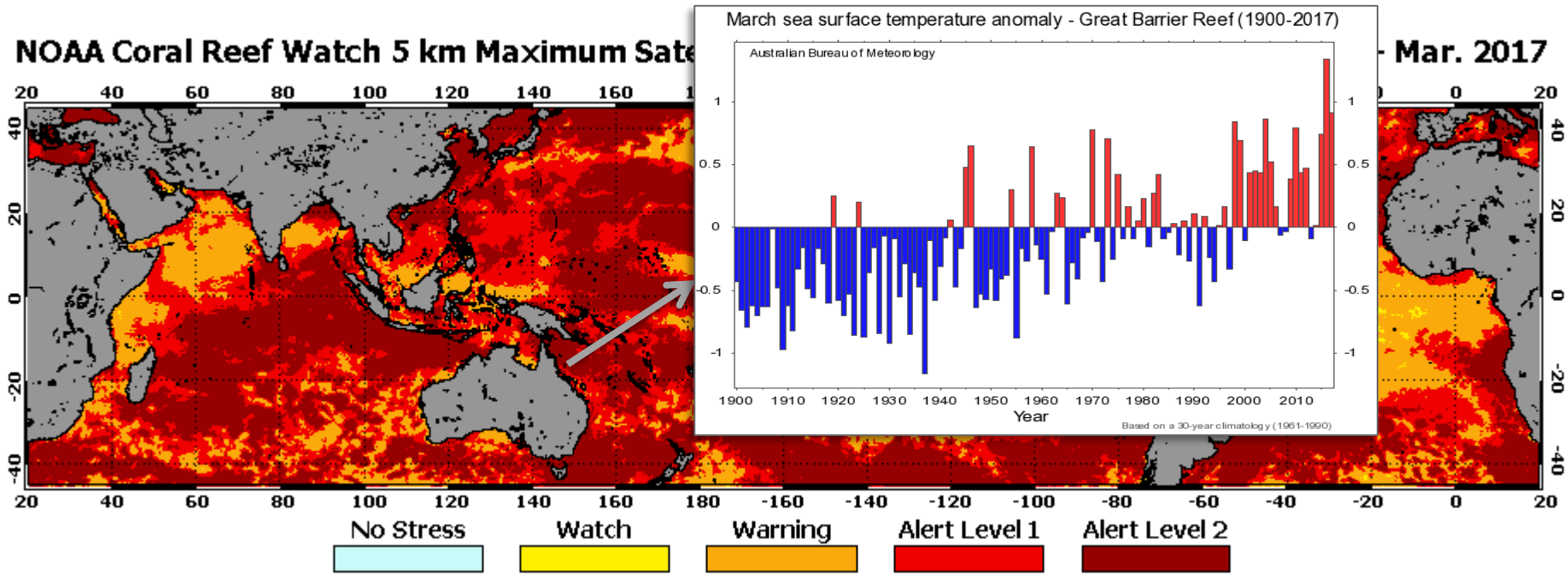
Responding to the 2016 and 2017 Mass Coral Bleaching events on the Great Barrier Reef: from Observations to Modelling

Craig Steinberg & Claire Spillman

N. Cantin, J. Benthuysen, H. Tonin, S. Bainbridge, F. McAllister, R. Brinkman, M. Herzfeld, M. Baird, C. Sun, W. Skirving, R. Pears, T. Simpson, C. Pattiaratchi E. Klein Salas

Australian Government
Bureau of Meteorology

Recent marine heatwave



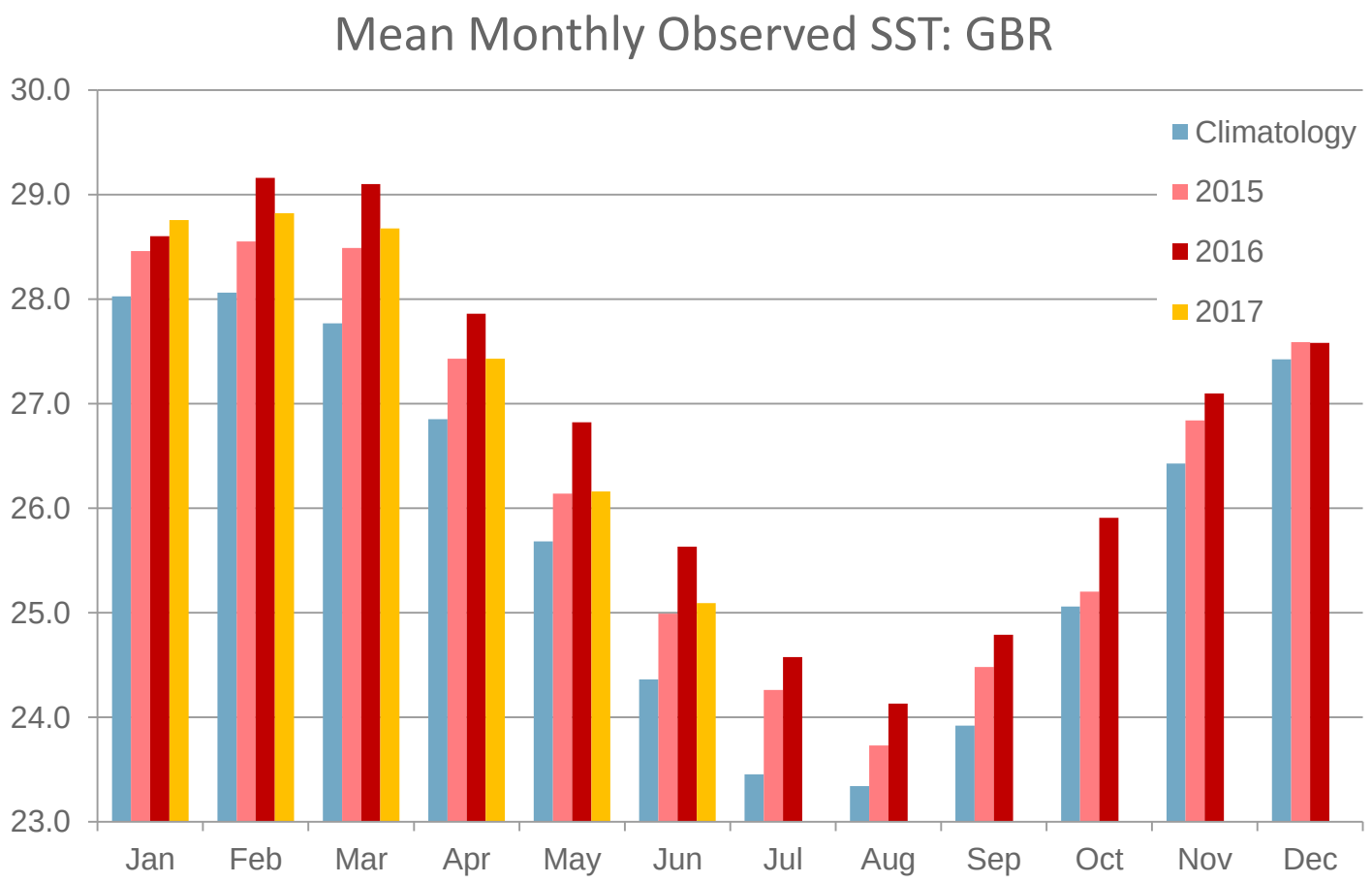
Alert Level 1: Significant coral bleaching
Alert Level 2: Widespread coral bleaching and significant mortality

More than 70% of coral reefs around the world have experienced heat stress that can cause bleaching and/or mortality since January 2014.

NOAA Coral Reef Watch; Liu et al 2014

Australian Government
Bureau of Meteorology

Monthly GBR SST



ERSSTv4 data set: 1961-1990 climatology

Australian Government
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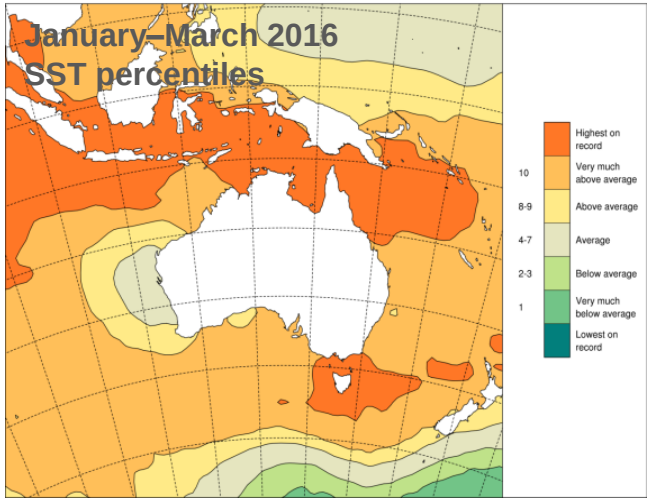
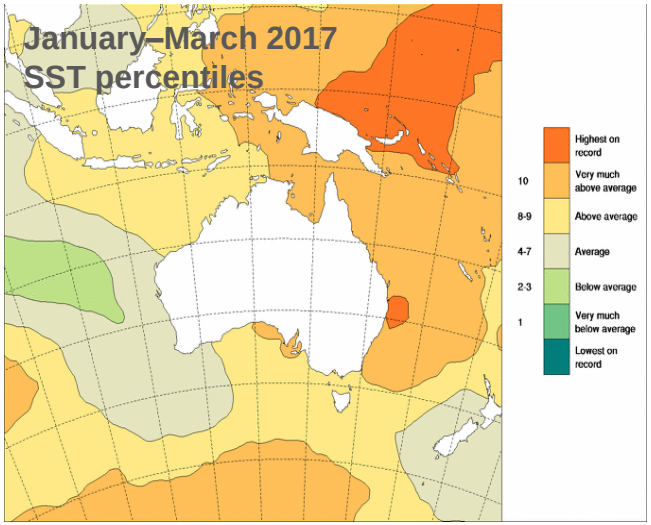
2016 vs 2017



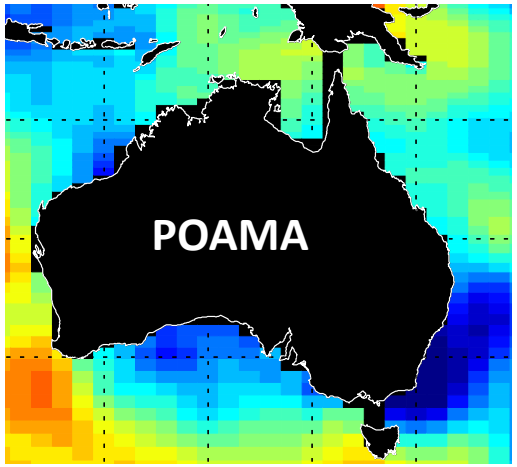


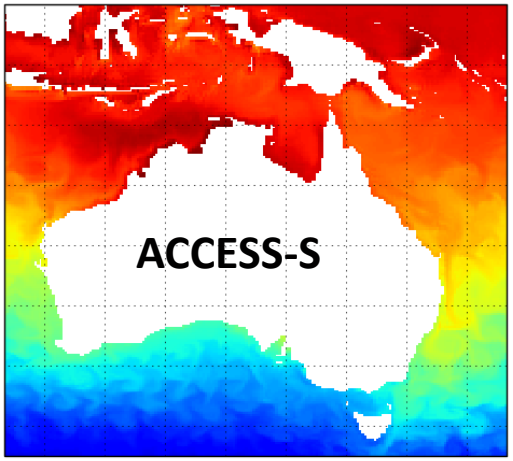
	2016	2017
ENSO	El Niño	Neutral
Cloudiness	Less cloudy than normal	Normal
SST	January, February, March and April hottest since 1900	March second hottest since 1900
Tropical cyclones	None over GBR (TCs Tatiana and Winston in Coral Sea)	Severe TC Debbie late March

Climate change a factor in both events through rising ocean temperatures

Australian Government
Bureau of Meteorology

Seasonal forecasting



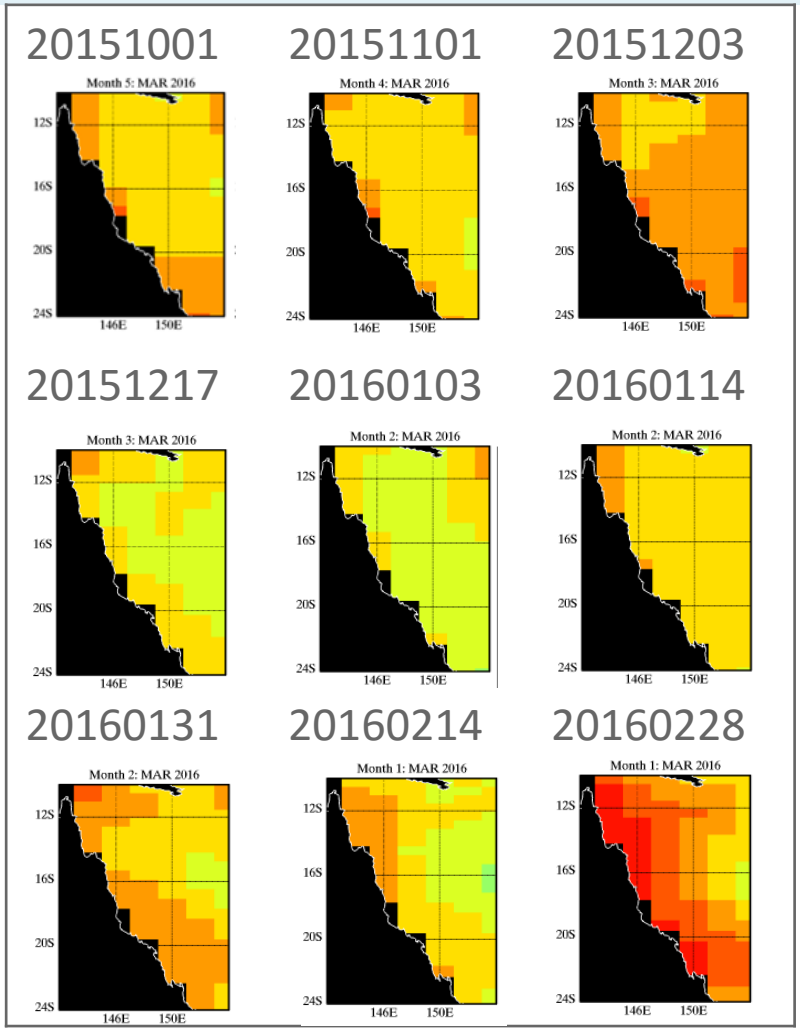


Ocean model grid resolutions

- POAMA current Bureau global operational dynamical seasonal forecast system
- POAMA assimilates Argo, XBT, buoy, satellite SST and altimetry data
- POAMA GBR forecasts first operational dynamical forecasts of coral bleaching risk in the world

- ACCESS-S1 to replace POAMA operationally in 2018
- UKMO collaboration
- ACCESS-S1 assimilates satellite & *in situ* SST, *in situ* T&S profiles, altimetry & satellite sea ice
- New operational seasonal GBR products March 2018
- New operational Australia-wide SST and thermal stress products June 2019

Did POAMA predict 2016?



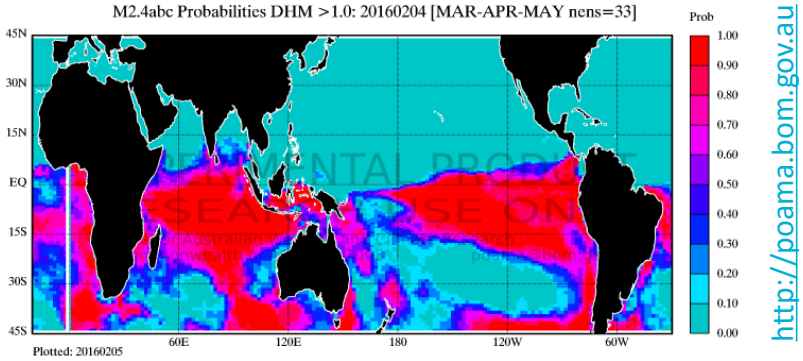
Forecasts for March 2016

Predictions in Oct/Nov 2015:

- Strong El Niño
- Warmer than normal summer SST
- 40% probability of DHM > 1 on GBR

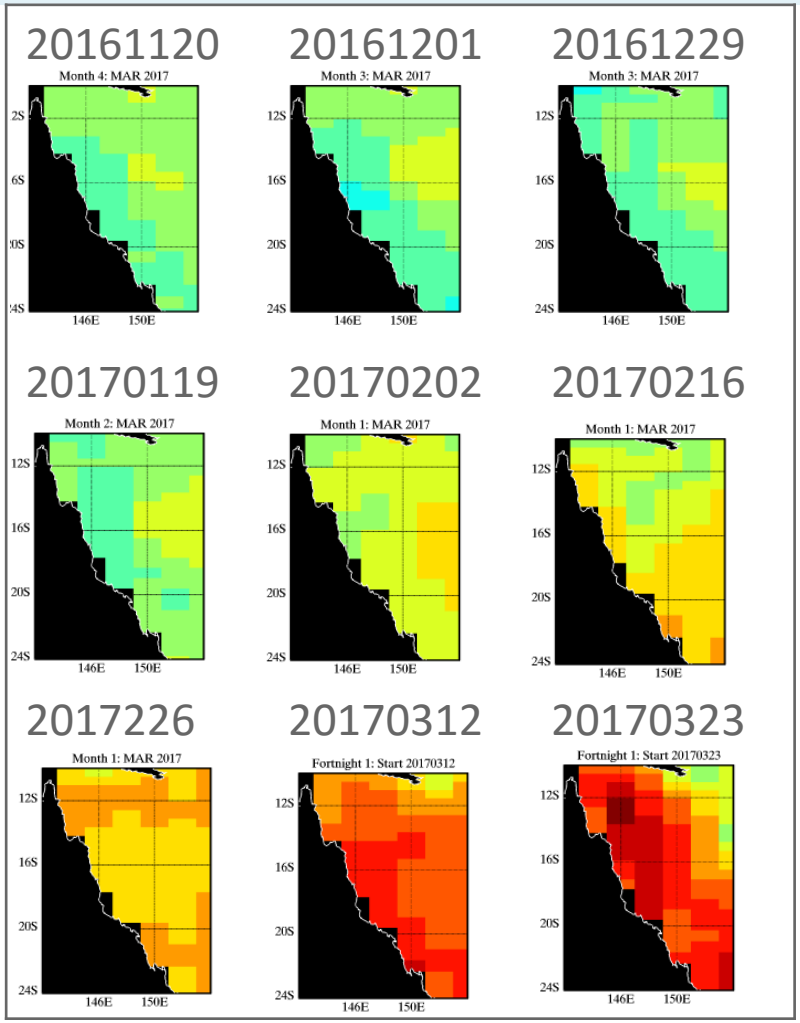
Predictions in Feb/March 2017:

- Local weather impacts in February increased SST predictions for March
- Warmer that average SST conditions predicted for GBR for March
- Very high probability of DHM > 1



http://poama.bom.gov.au

Did POAMA predict 2017?



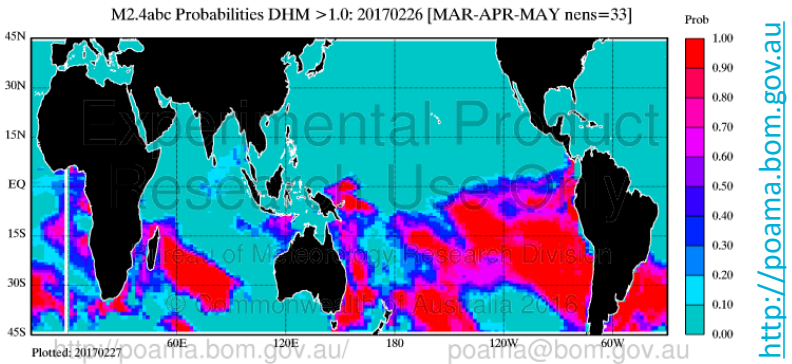
Forecasts for March 2017

Predictions in November 2016:

- La Niña WATCH status
- Near average SST conditions predicted for GBR for summer months
- Low probability of DHM > 1 over GBR

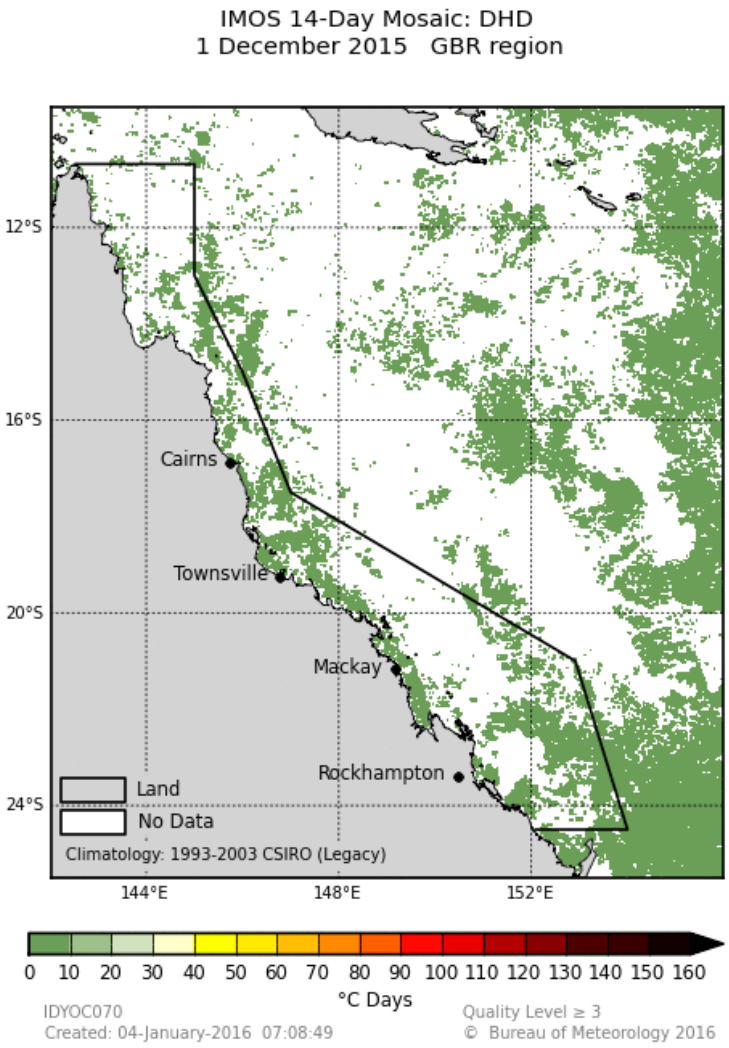
Predictions in February/March 2017:

- Warmer that average SST conditions predicted for GBR for March
- Very high probability of DHM > 1



Monitoring the events

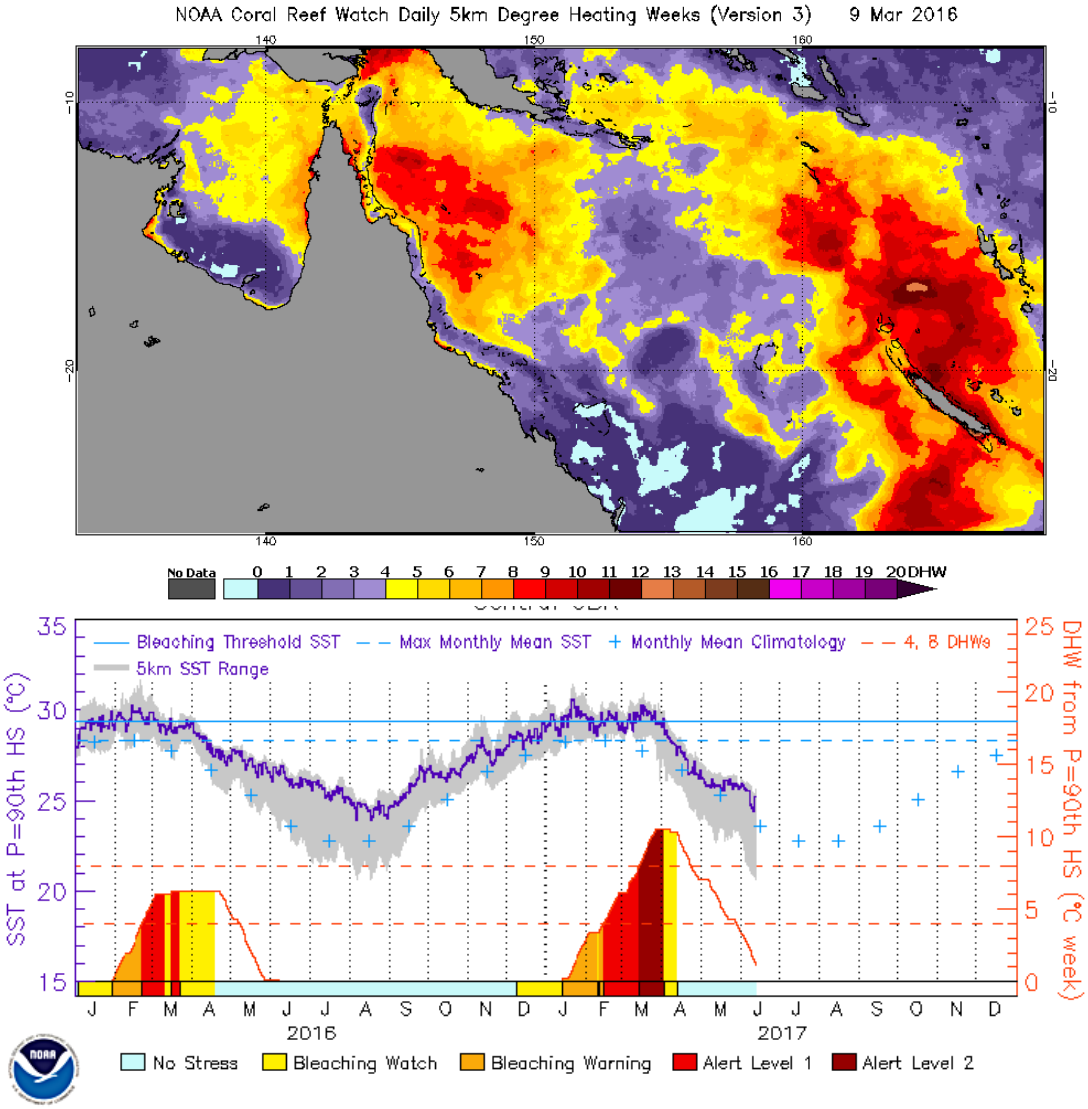
- ReefTemp Next Gen: Operational high resolution (2km x 2km) daily satellite SST monitoring tool
- IMOS L3S night-only daily SST
- Developed under eReefs
- Accumulation of daily thermal stress (Degree Heating Days):
  - Green = ok
  - Yellow = watch
  - Orange = worry
- Upgrade planned for 2018/19



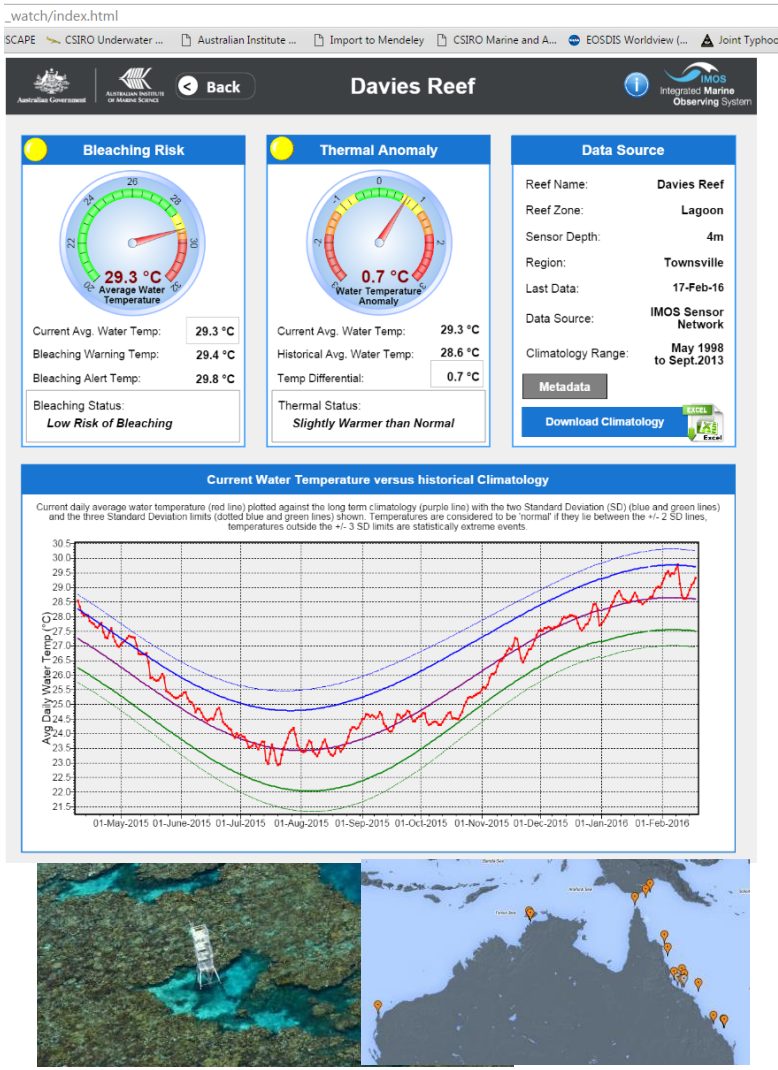
Garde et al (2014)

Monitoring Reef Weather

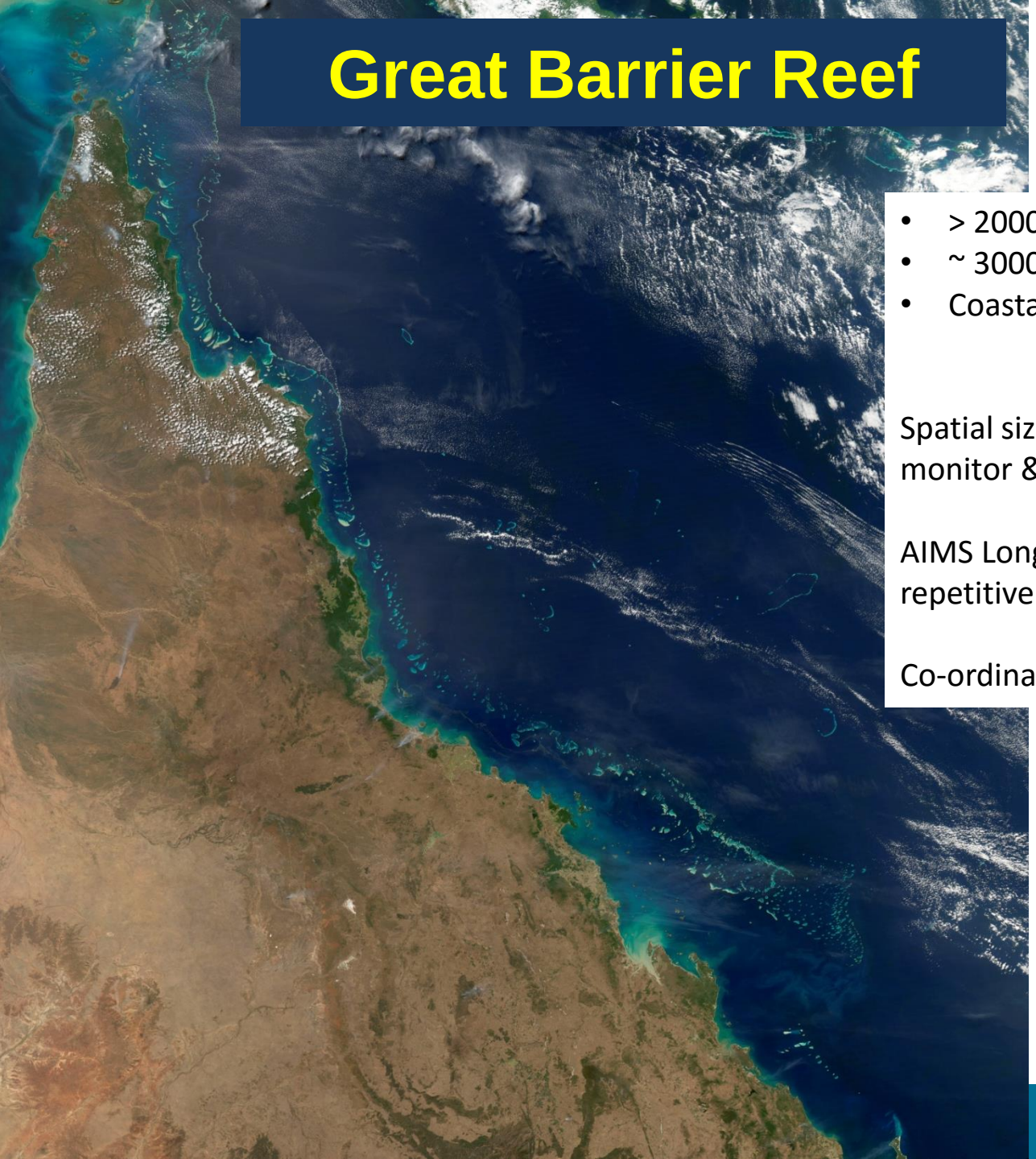
NOAA Degree Heating Weeks (DHW's)



AIMS reef weather stations & IMOS sensor networks



Great Barrier Reef



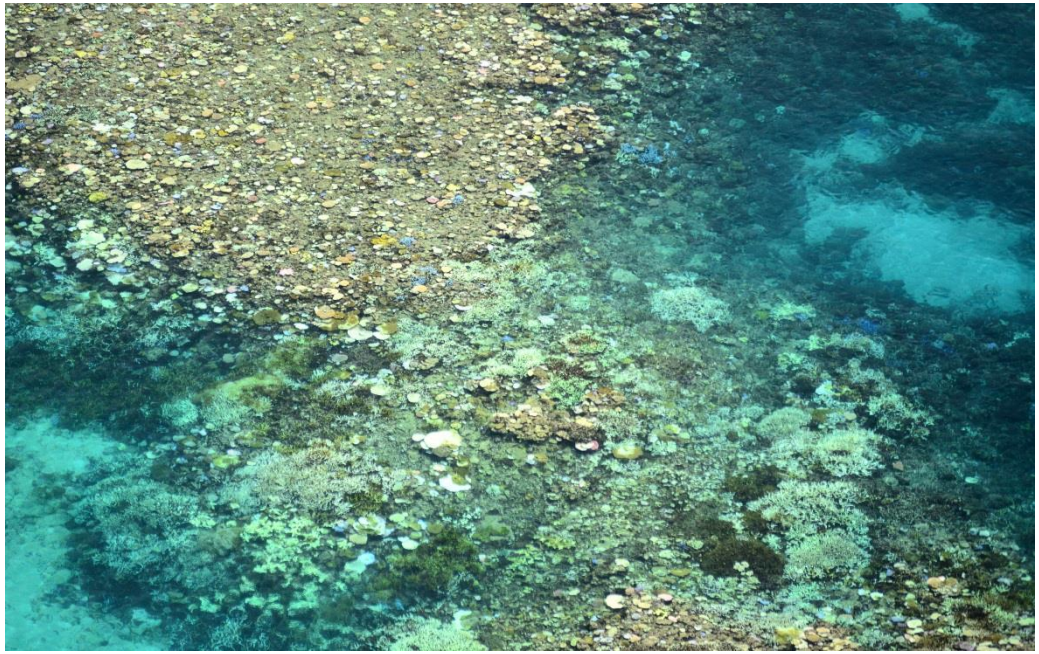
- > 2000km (1200miles) long
- ~ 3000 individual reefs and islands
- Coastal Barrier ecosystem

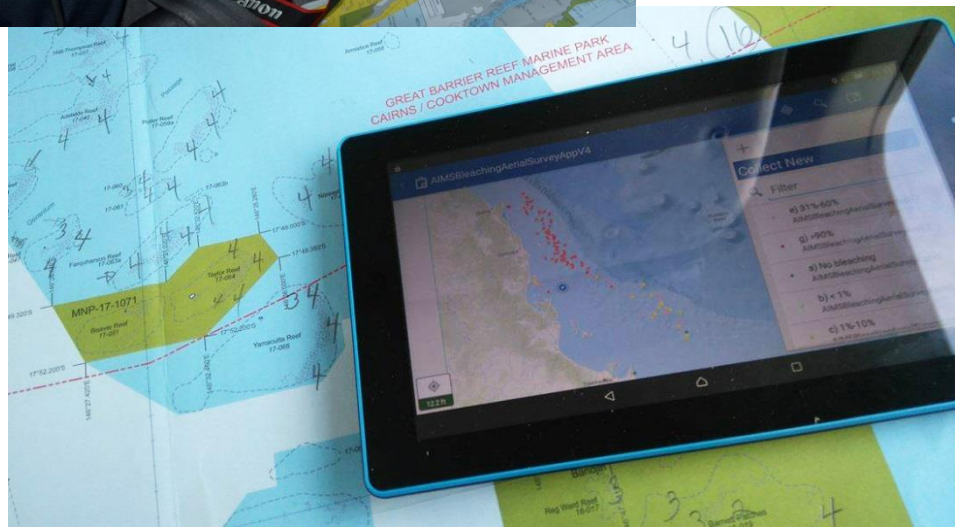
Spatial size = challenging ecosystem to monitor & fully document major change

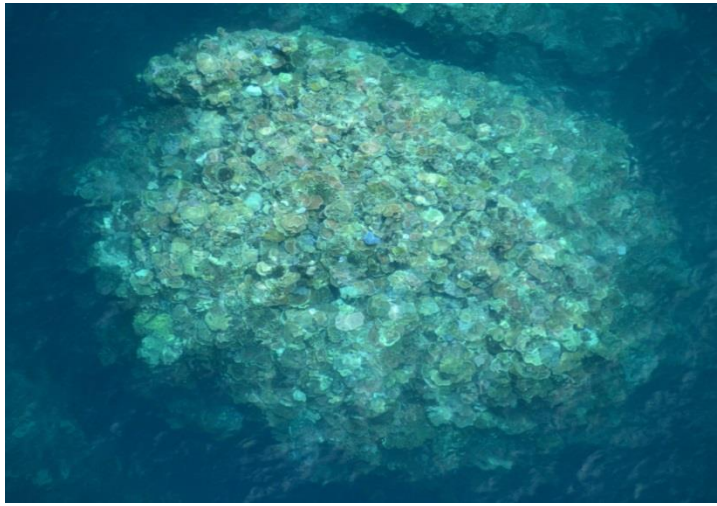
AIMS Long-term monitoring began systematic repetitive surveys between 1980-1992

Co-ordinated approaches are key

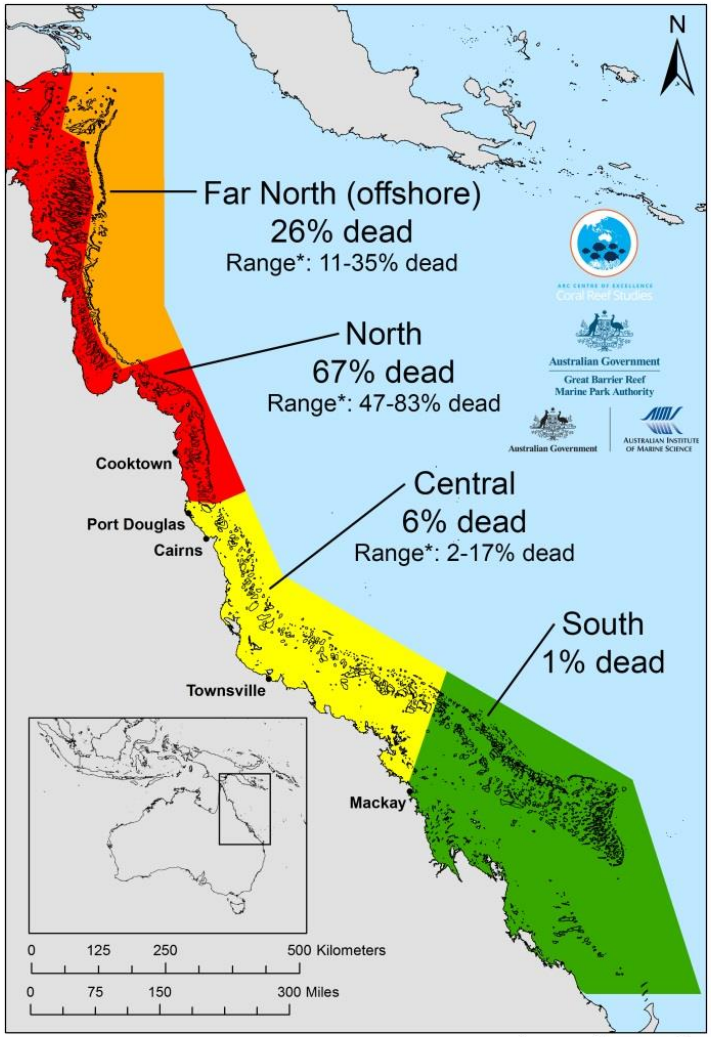
RESPONDING TO A CORAL BLEACHING EVENT







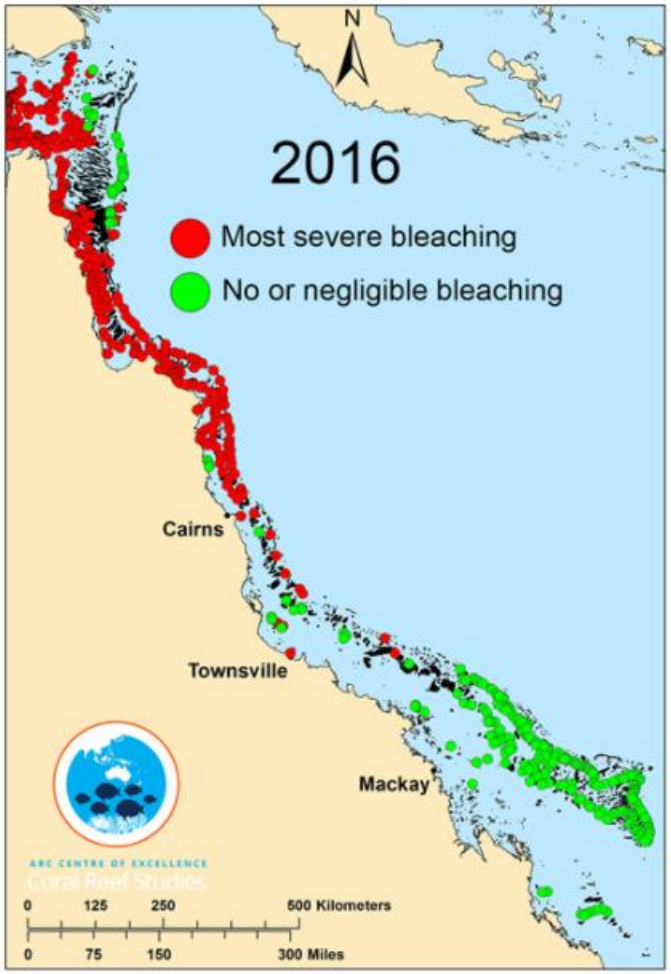
Coral mortality in 2016

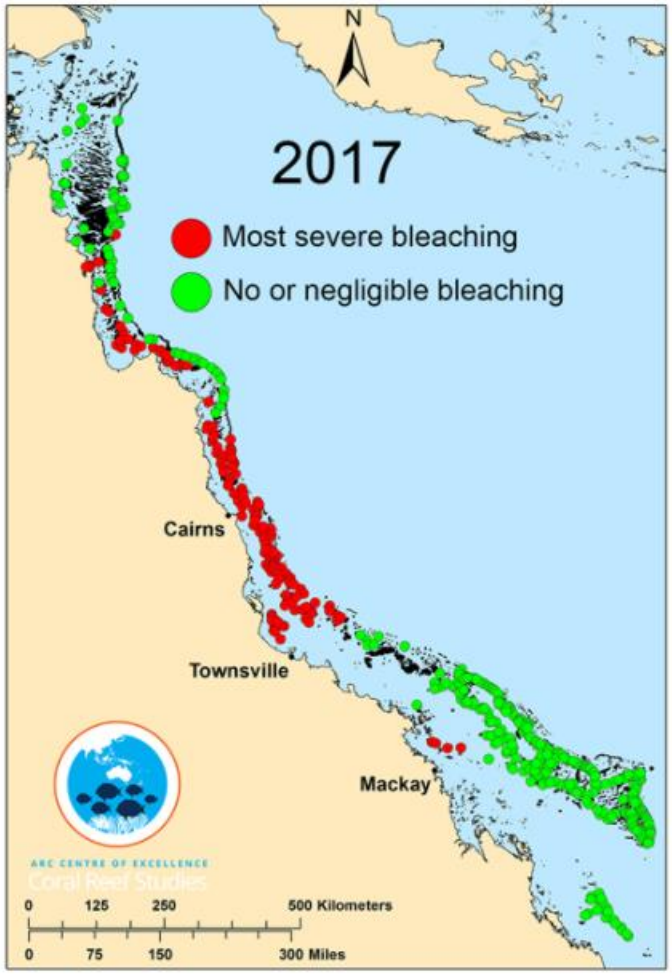


"Based on combined survey results so far, the overall mortality is 22% — and about 85% of that die-off has occurred in the far north between the tip of Cape York and just north of Lizard Island, 250 km north of Cairns."

Great Barrier Reef Marine Park Authority (GBRMPA), June 2016

A second successive bleaching in 2017



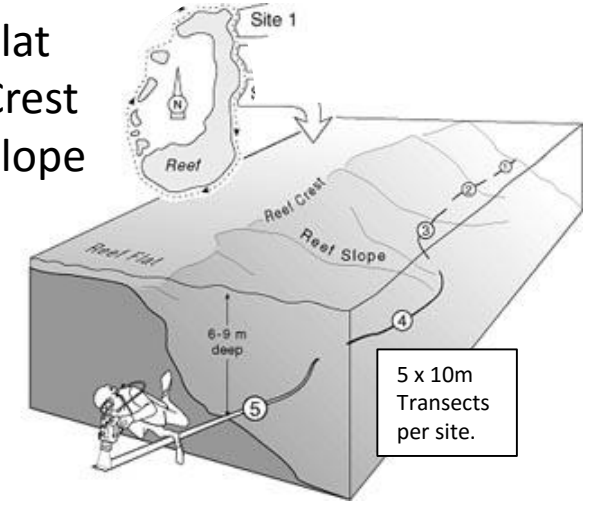


RESPONDING TO A CORAL BLEACHING EVENT

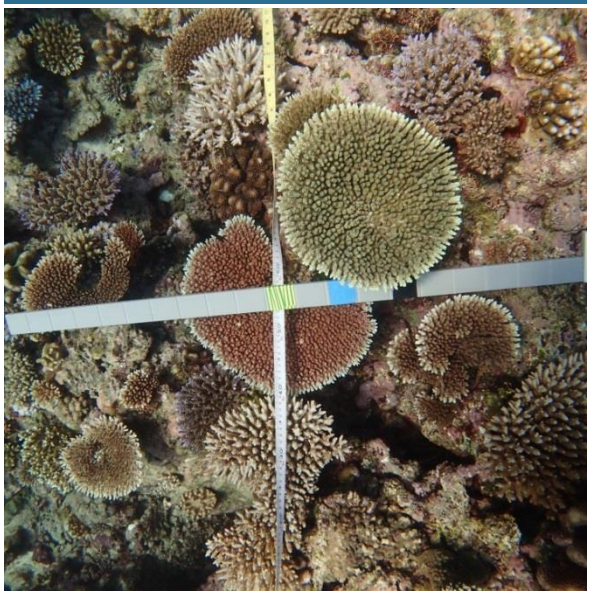
IN WATER SCUBA SURVEYS

- 50 m x 1m belt transects
- Bleaching severity of all corals within the 1m quadrat scored for bleaching severity
- Community bleaching severity (%)
- Live coral cover using Line Intercept methods

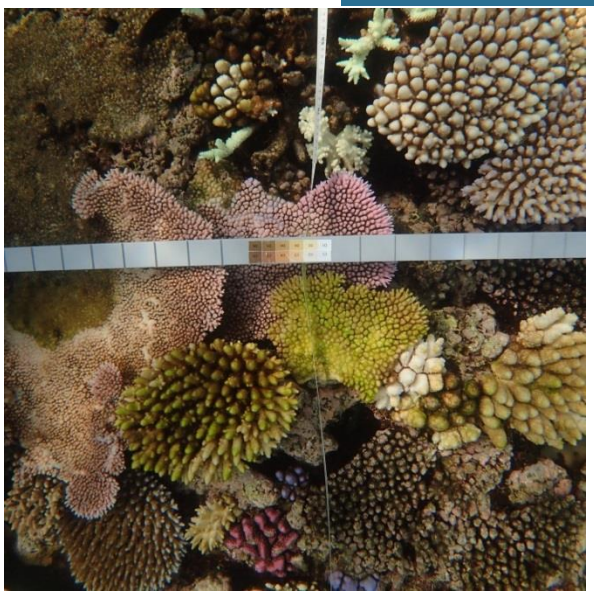
- Flat
- Crest
- Slope

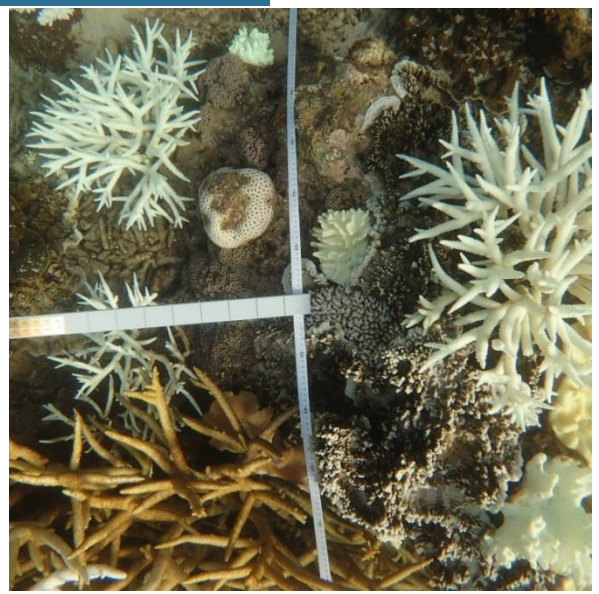


NO/MINOR BLEACHING



SEVERELY BLEACHED AND DEAD



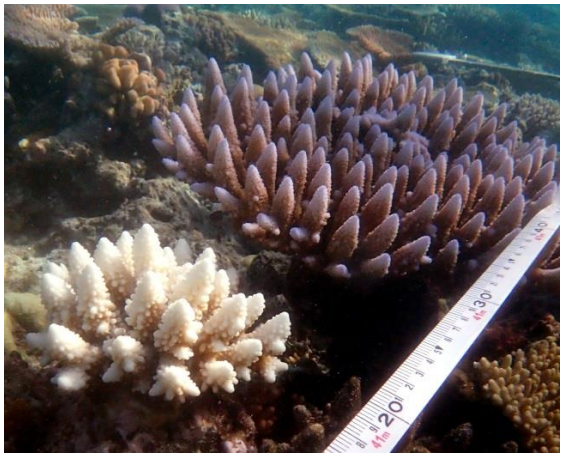


BLEACHING SEVERITY

NO BLEACHING

MINOR:
1 - 50%

MAJOR:
50-95%

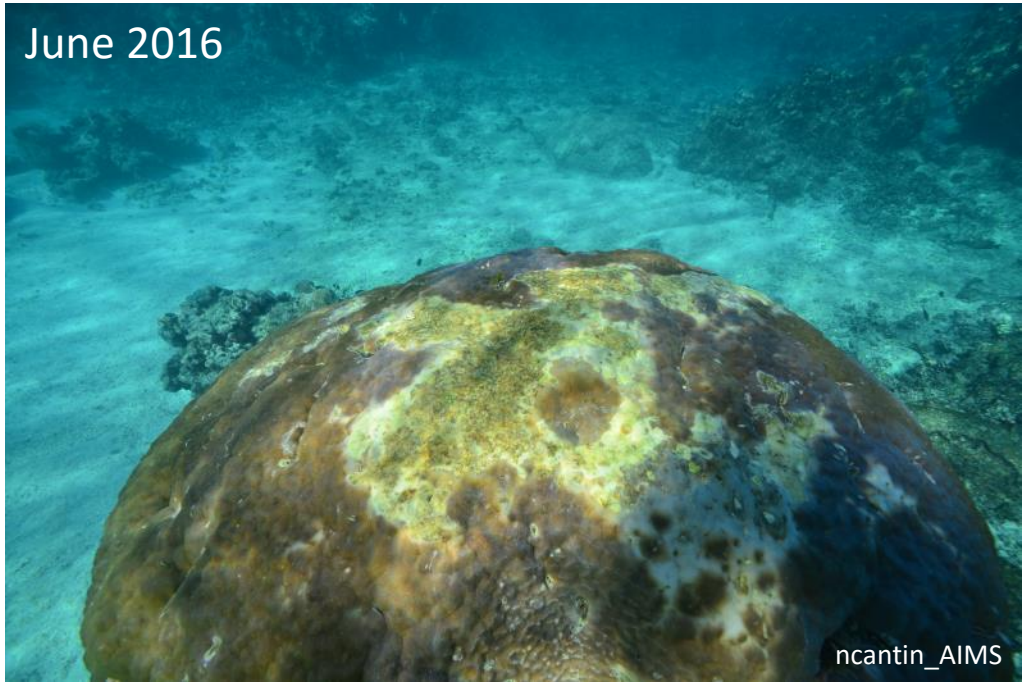


SEVERE:
95-100% white & fluorescent

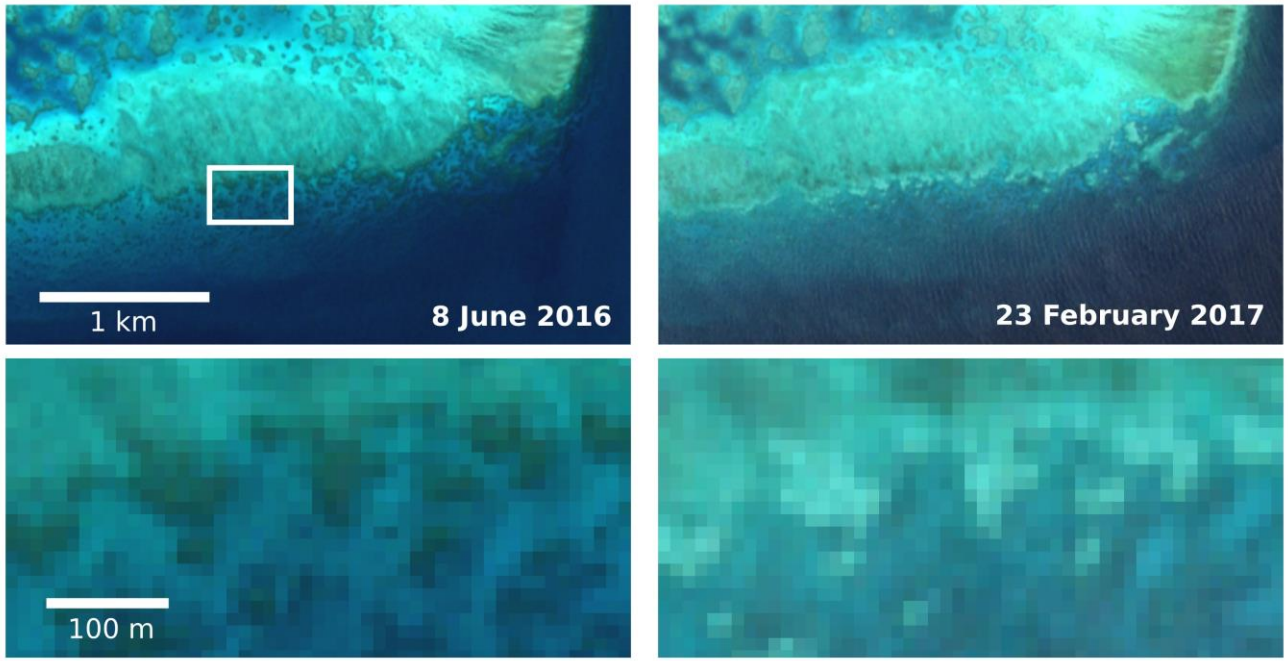
RECENT MORTALITY

Bleached Porites

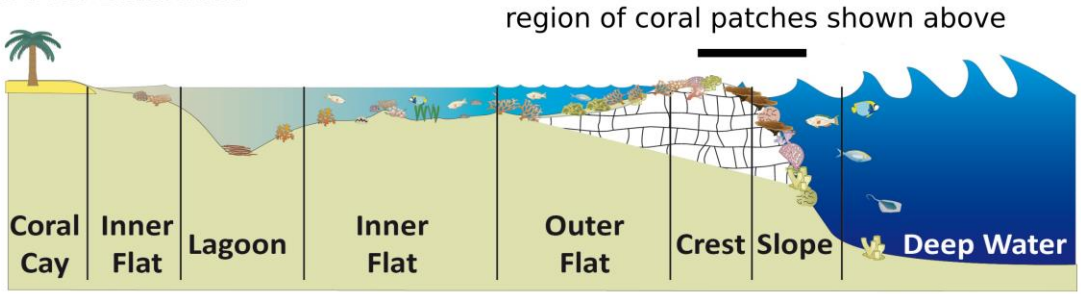
- Long-lived, old individuals 100-400 yrs
- Tolerant coral species
- **Bleached** and **Partial mortality** of tissue
- Surviving tissue overgrows sections of partial mortality



Sentinel-2 captures coral bleaching

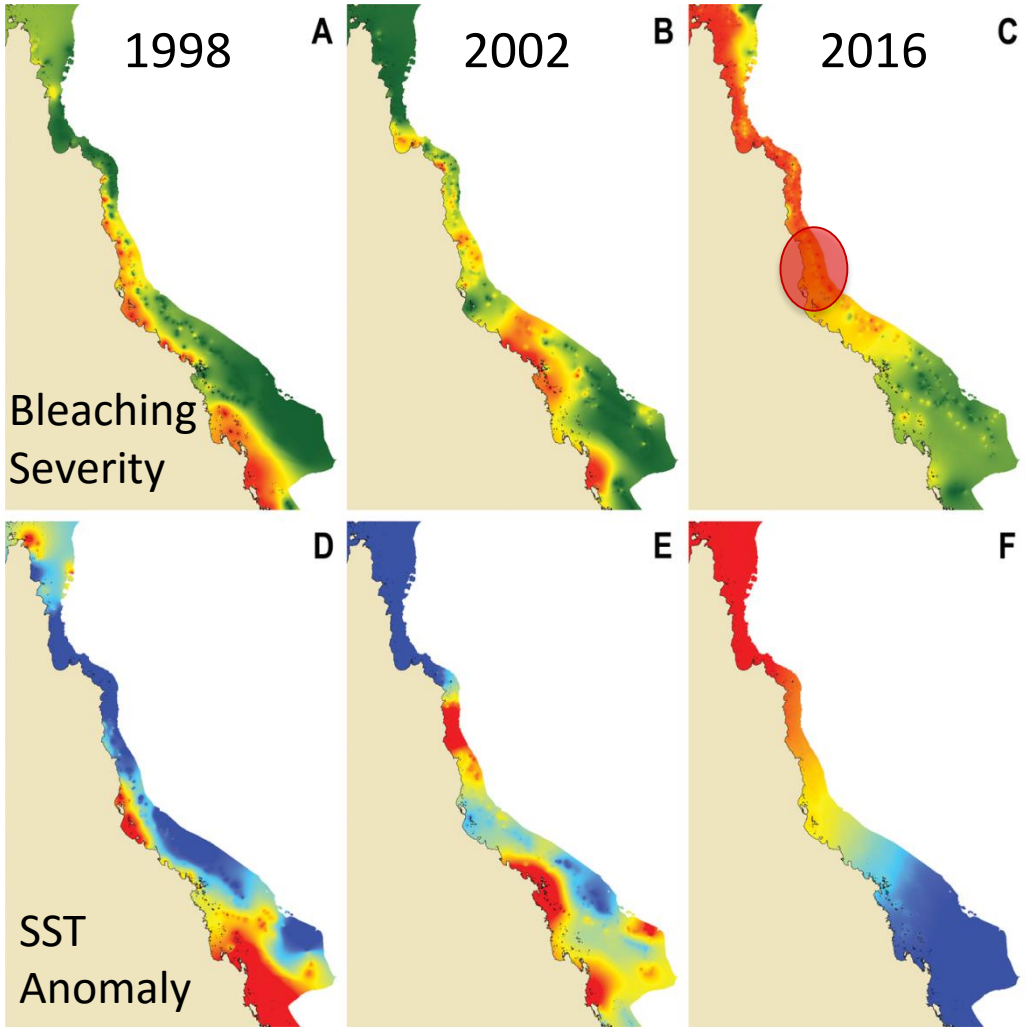


Typical reef zonation:

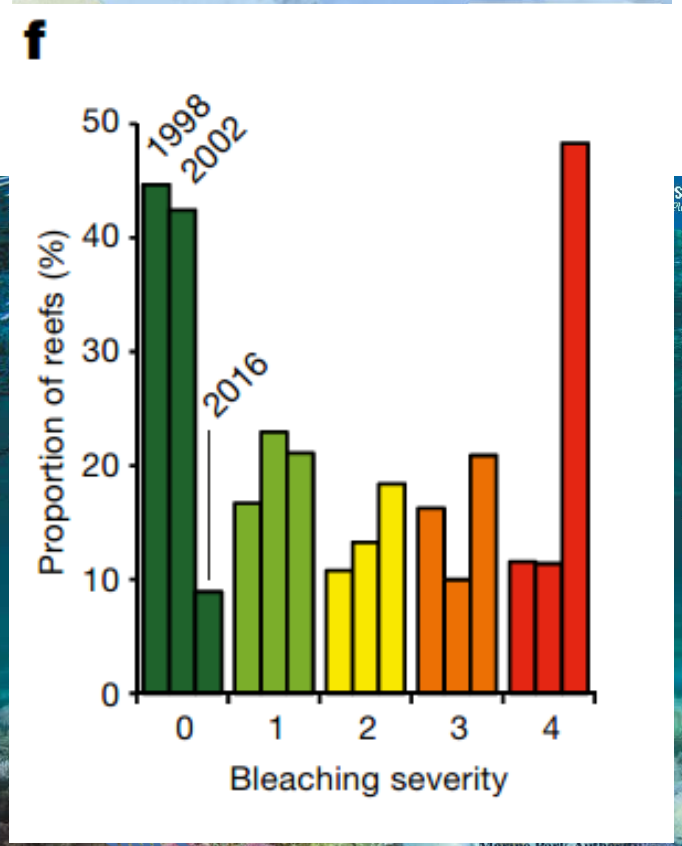


processed by J. Hedley; conceptual model by C. Roelfsema
Images from the Copernicus Sentinel-2A satellite captured on 8 June 2016 and 23 February 2017 for Adelaide Reef, Central GBR.

16 & 17 dramatic increase in both heat stress and bleaching severity



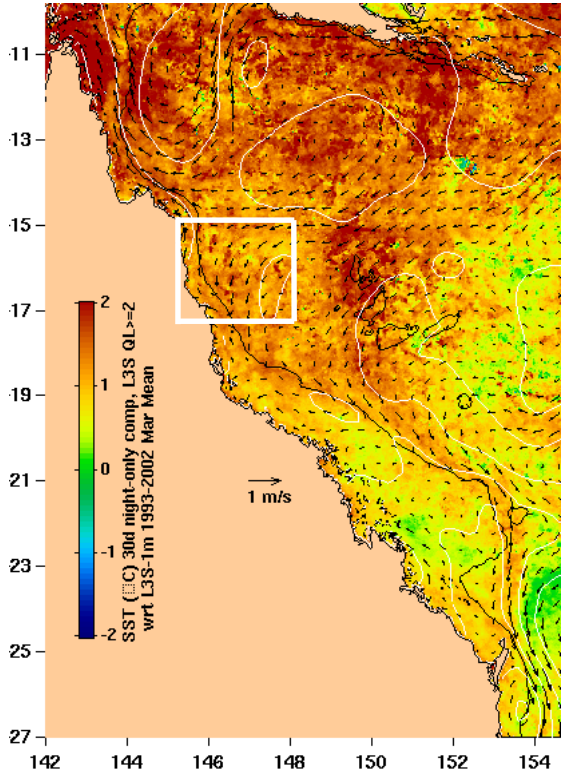
2017

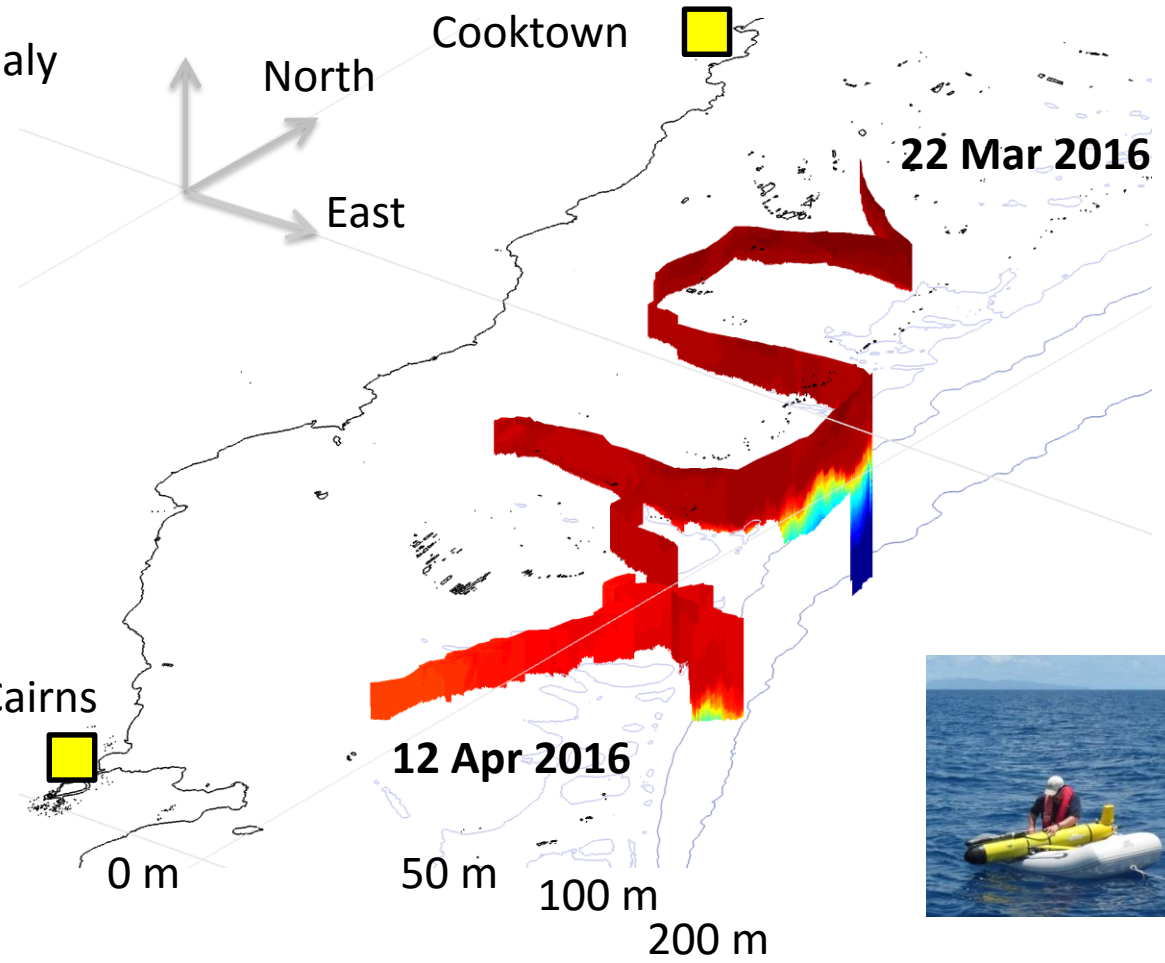


Hughes *et al.*, 2017; Berkelmans et al. 2004

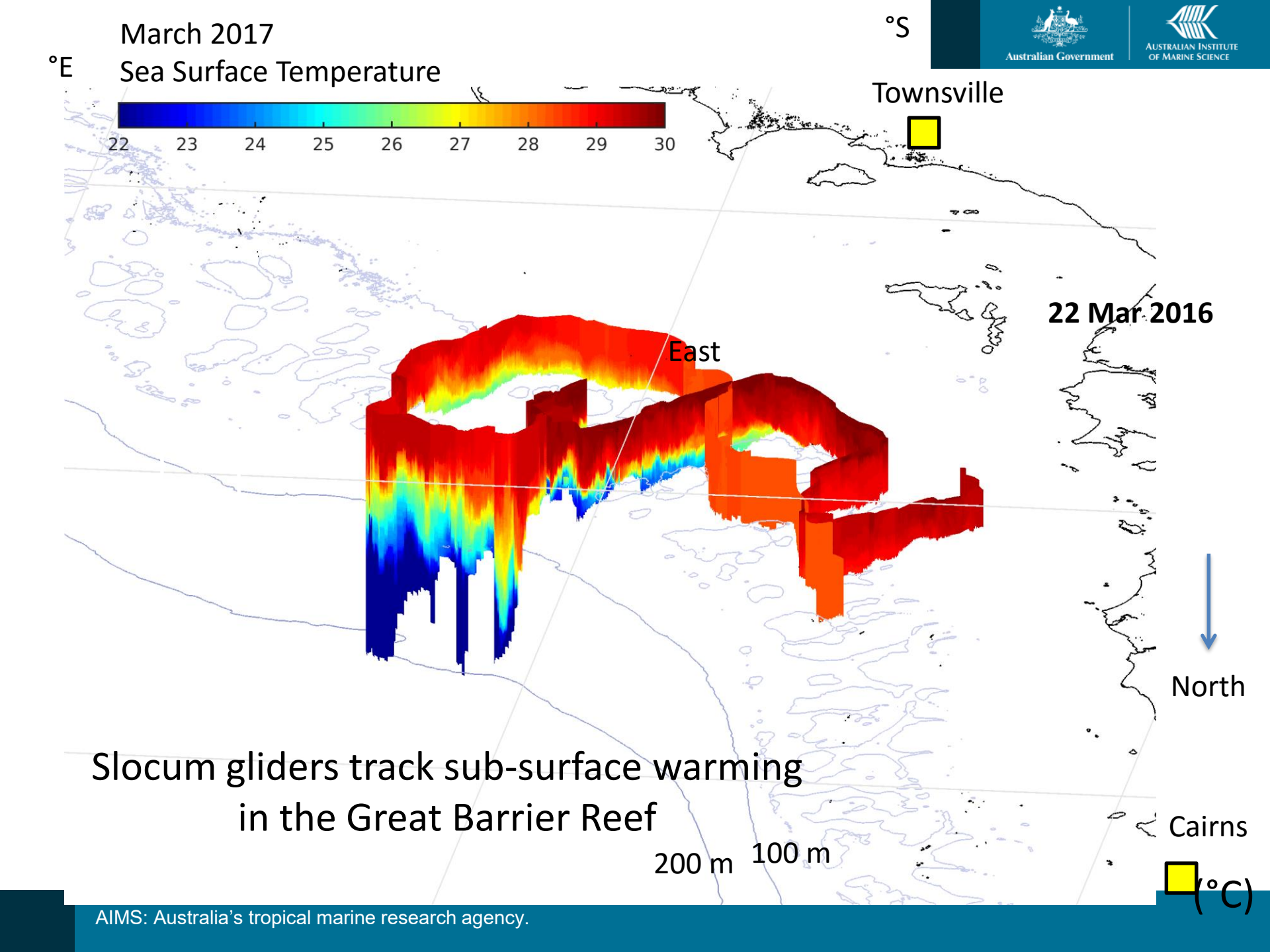
Slocum gliders track sub-surface warming in the Great Barrier Reef

March 2016
Sea Surface Temperature Anomaly





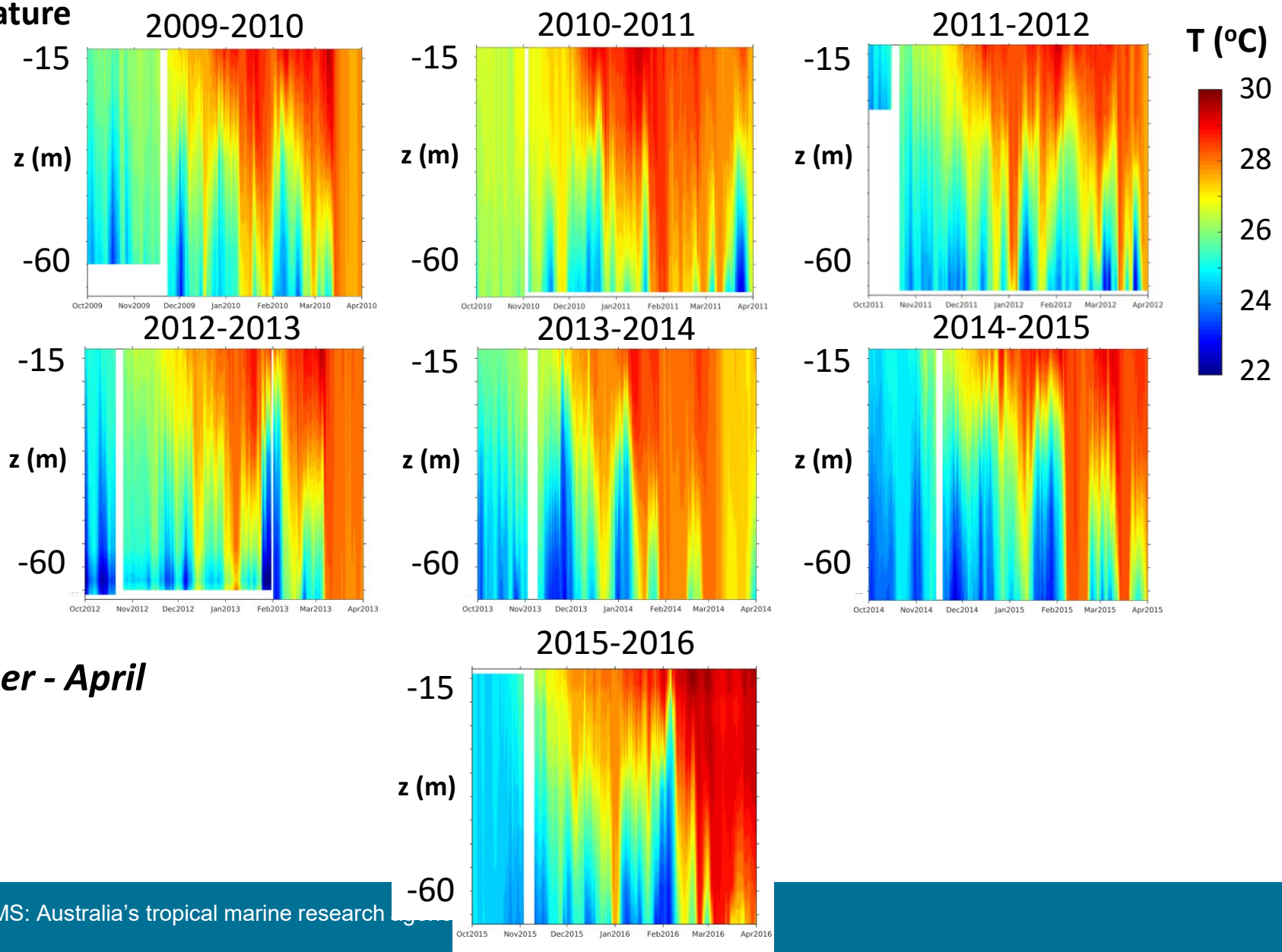
IMOS OceanCurrent News, 24 May 2016



Slocum gliders track sub-surface warming in the Great Barrier Reef

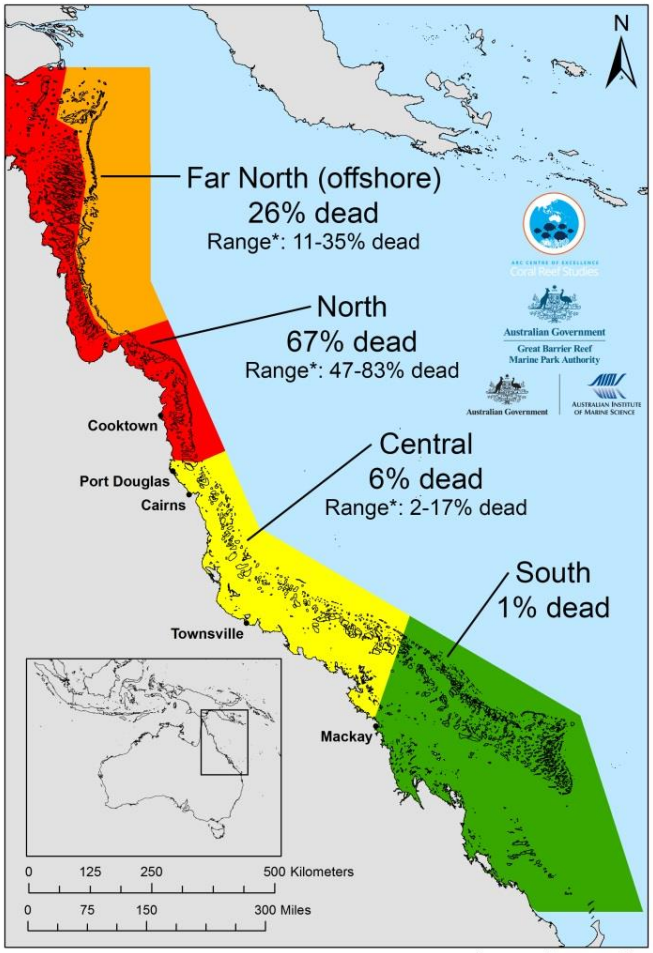
Palm Passage mooring: bottom intrusions

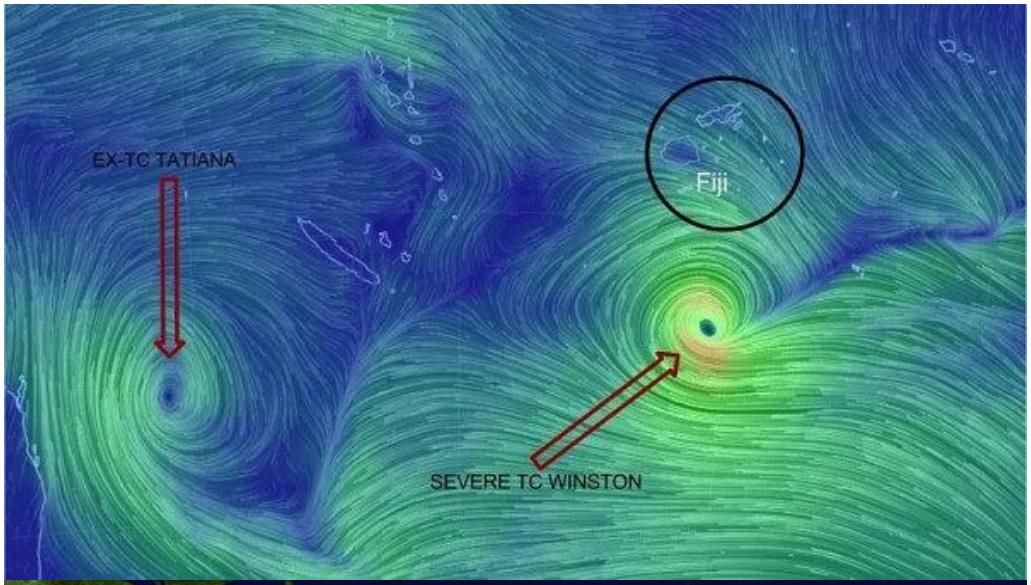
Temperature

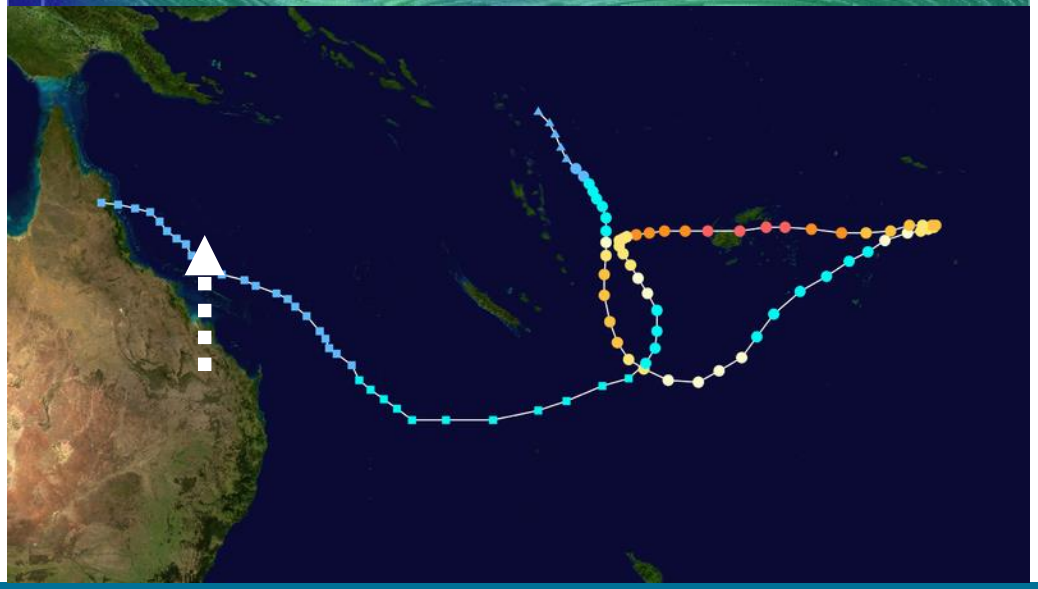


October - April

ex TC Tatiana and TC Winston in 2016

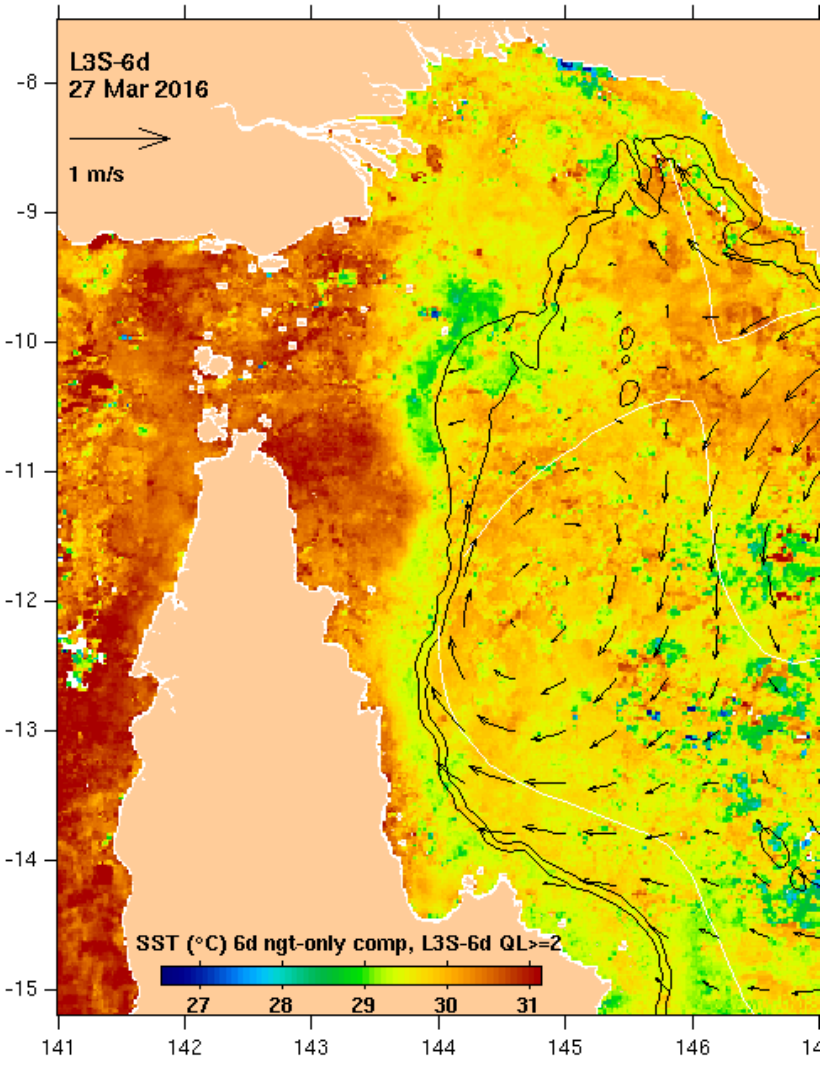


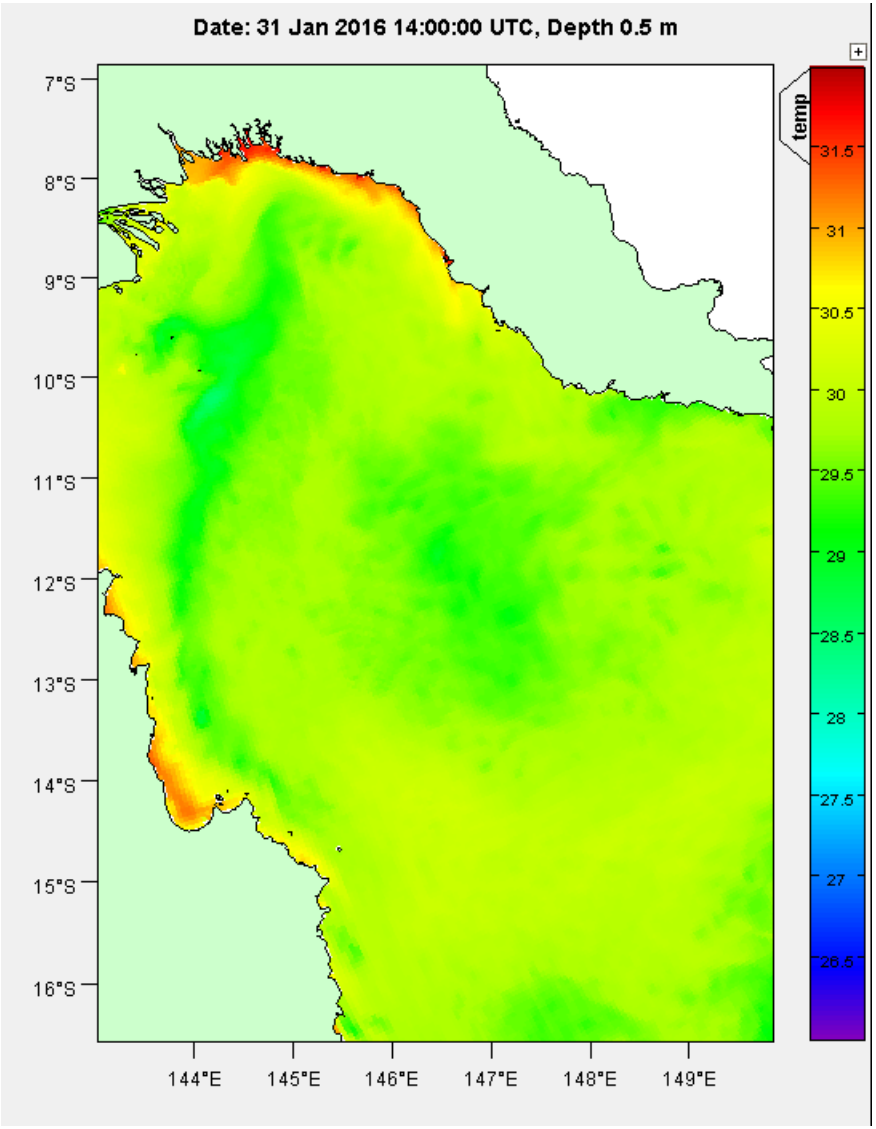




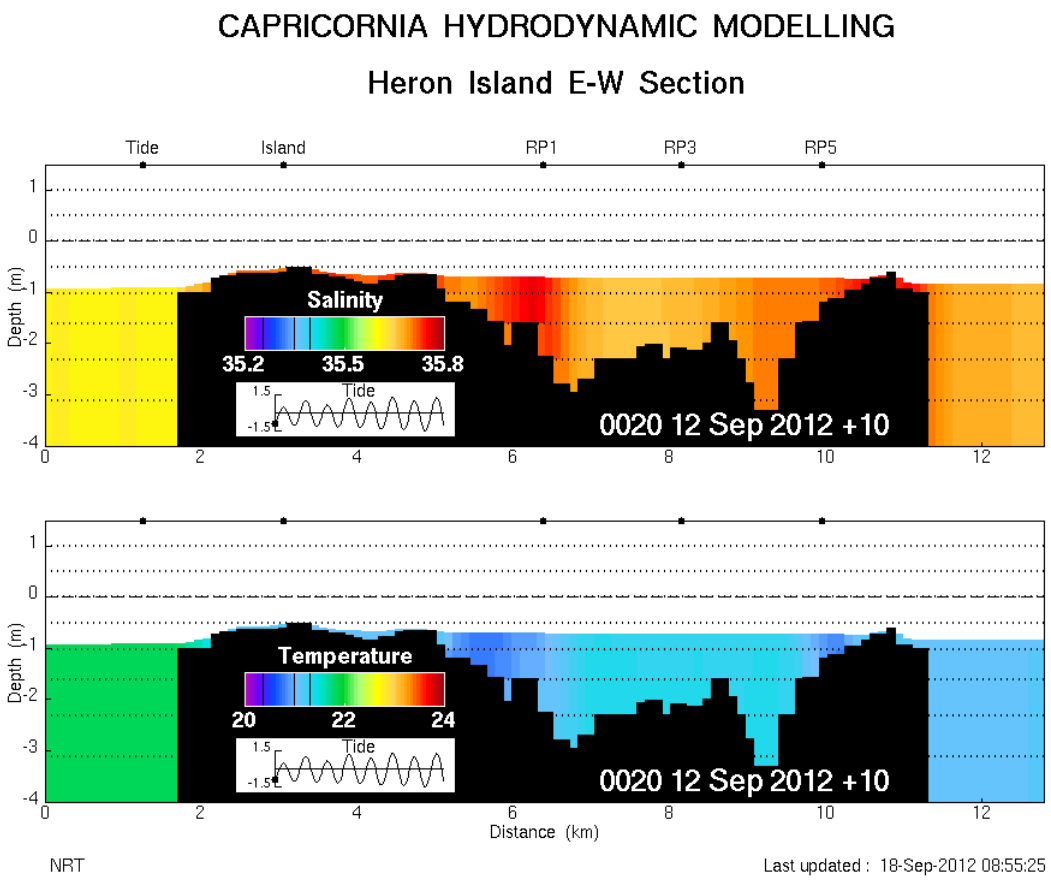
Distant or low end tropical cyclones can have a silver lining

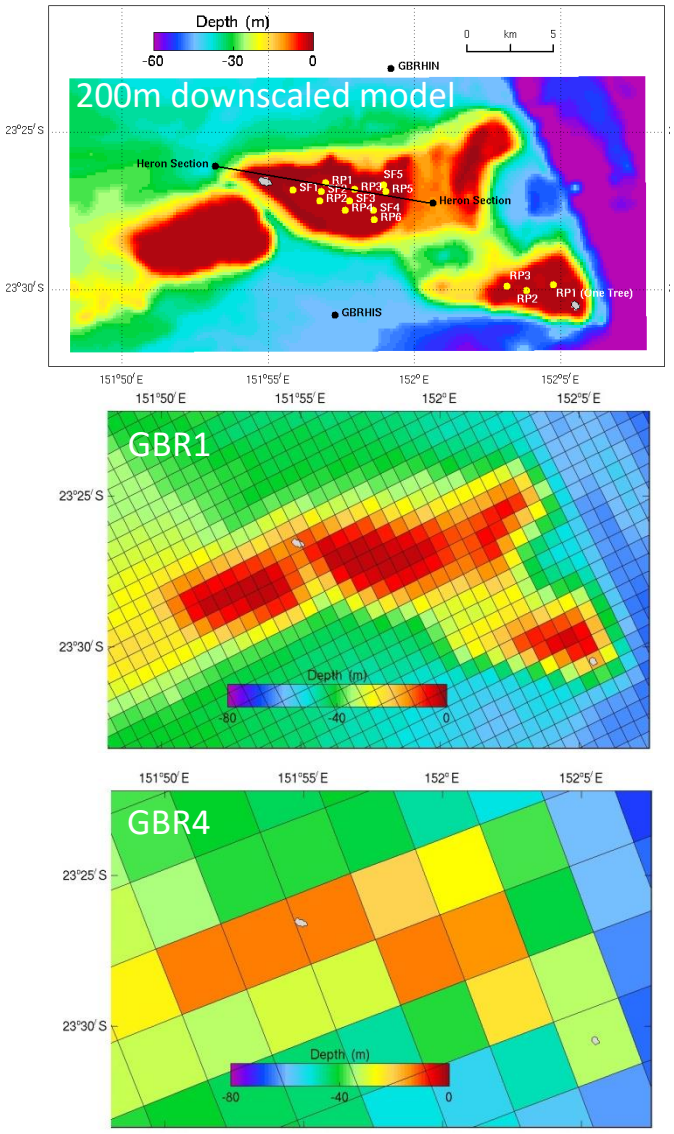
eReefs 3D captures cooling mechanisms





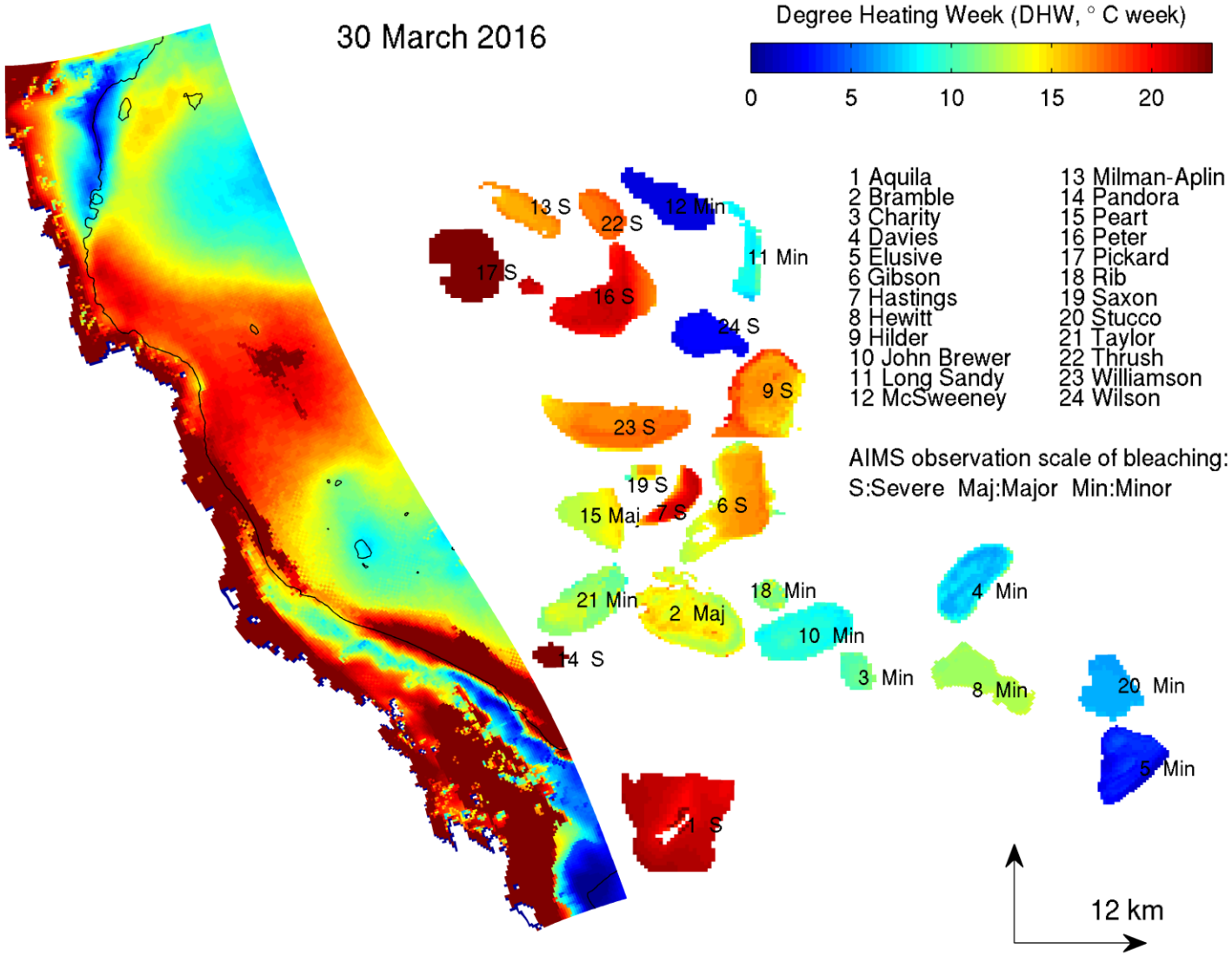
Differential heating on drying reefs





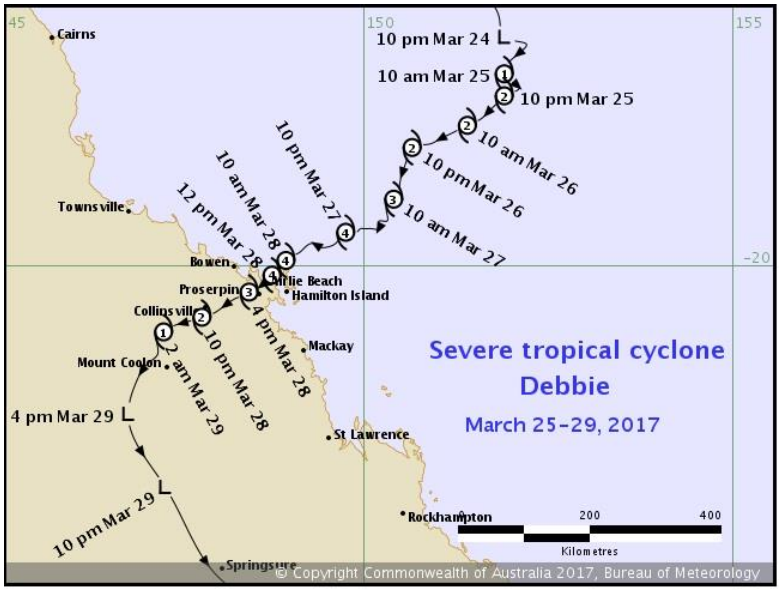
Mongin, CSIRO

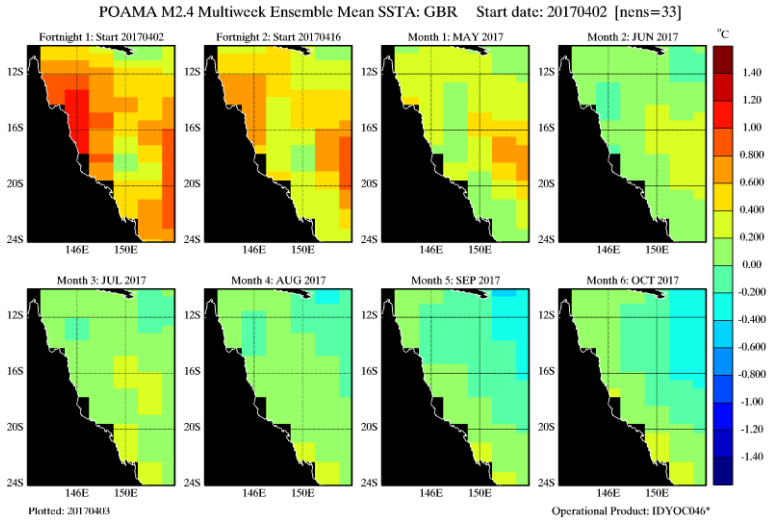
eReefs RECOM DHW



Elofer & Baird, CSIRO & Cantin AIMS

TC Debbie





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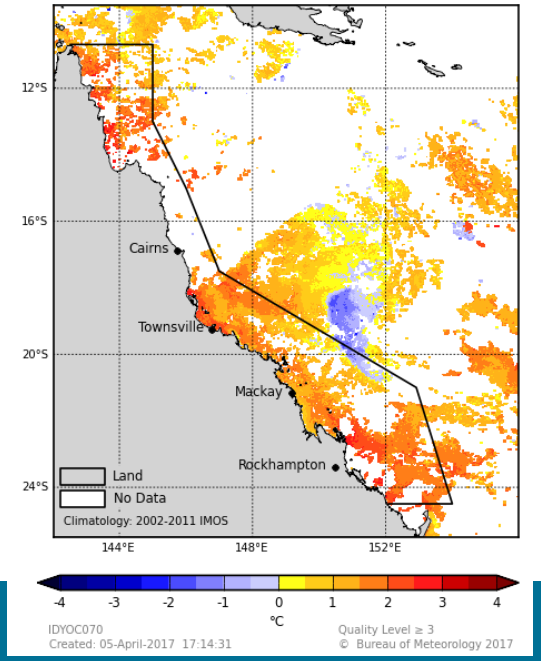
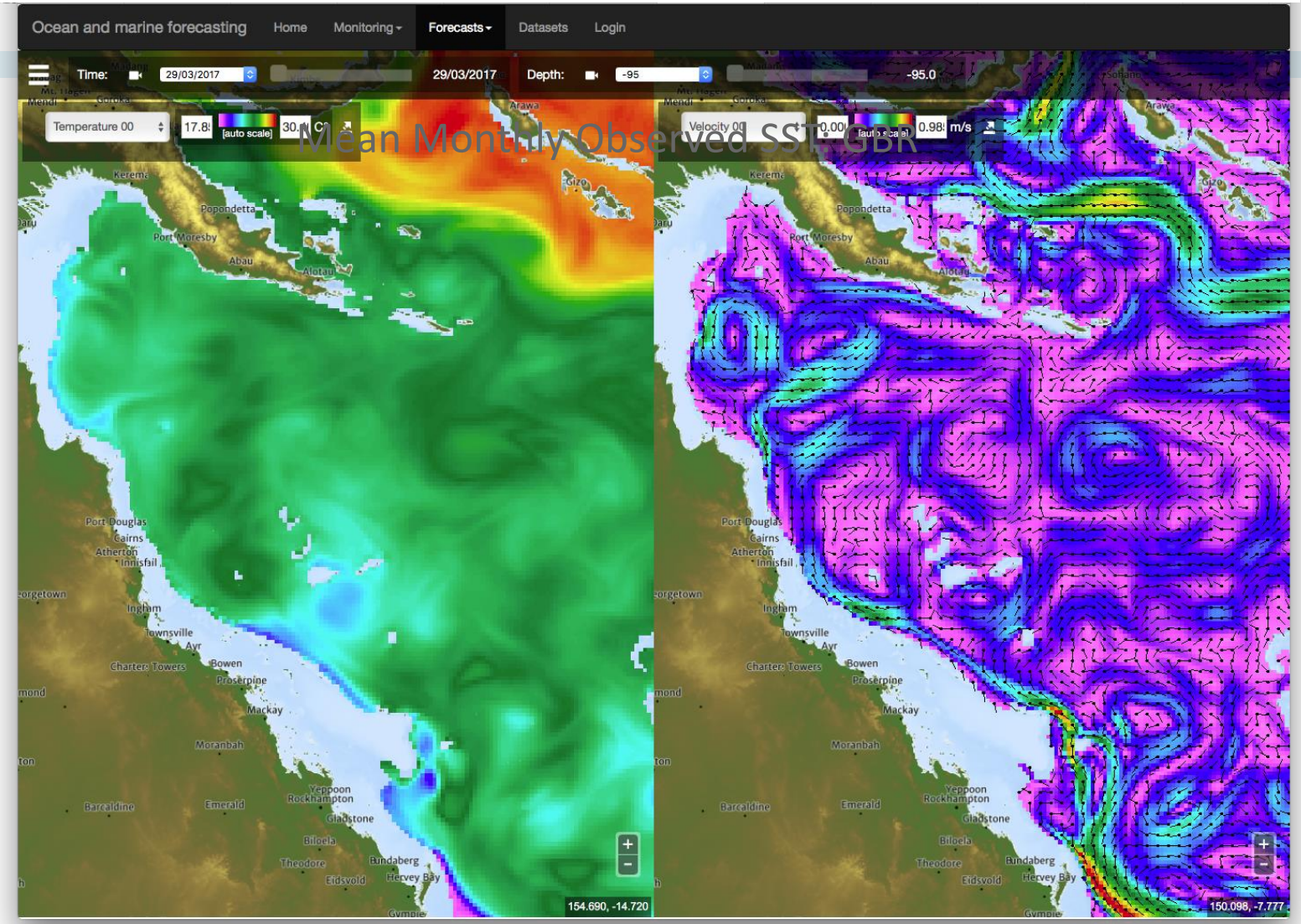


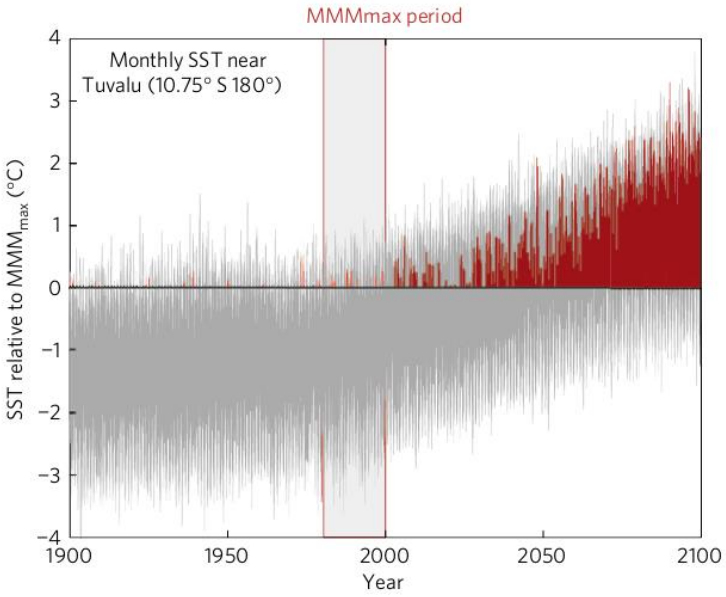
TC Debbie led to cooling of surface waters over the mid and southern GBR in late March. This is reflected in cooler mean observed SST for April 2017 as well as seasonal outlooks for April.

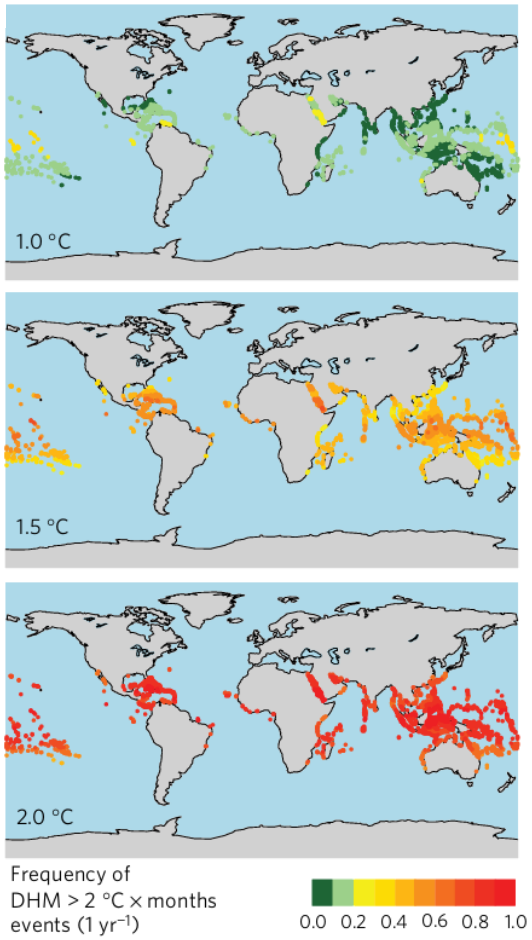
Oceancurrent 95m below the surface
TC Debbie March 29, 2007



Courtesy Gary Brassington, BoM

Bleaching Thresholds in a warming ocean





- Increased frequency of extreme thermal anomalies influence bleaching thresholds?
- Can corals adapt and keep pace with the rising trend in temperature?

Frieler et al. 2012, Nature Climate Change

Thank you

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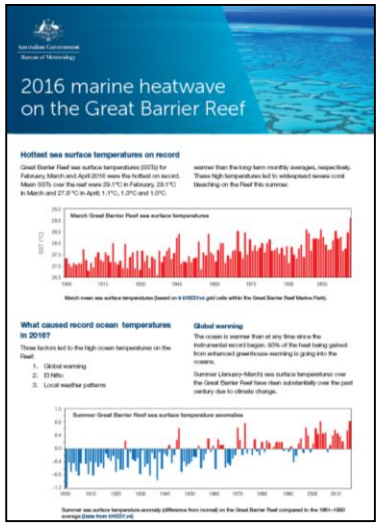
- **OceanCurrent**
  http://oceancurrent.imos.org.au
- **ReefTemp Next Generation:**
  http://www.bom.gov.au/environment/activities/reeftemp/reeftemp.shtml
- **POAMA seasonal forecasts**
  http://poama.bom.gov.au
- **eReefs**
  http://ereefs.org.au/ereefs
- **AIMS Weather**
  http://weather.aims.gov.au/



http://www.bom.gov.au/environment/doc/marine-heatwave-2016.pdf