Operational products supporting the future management of the Great Barrier Reef

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[1]Australian Institute Of Marine Science, [2]Bureau of Meteorology, [3]Great Barrier Reef Marine Park Authority, [4]NOAA,

Australian Institute of Marine Science

Australian Government
Bureau of Meteorology

Australian Government
Great Barrier Reef
Marine Park Authority

National Oceanic and Atmospheric Administration
NOAA
U.S. Department of Commerce

Great Barrier Reef Marine Park

AREA
344,400 km²

LENGTH
2300 km long

70 million
football fields

Roughly the
same area as…


ITALY


JAPAN


GERMANY


MALAYSIA

3000 coral reefs

600 continental islands

1625 types of fish

133 varieties of
sharks and rays

600 types of soft
and hard corals

Great Barrier Reef Marine Park

AREA
344,400 km²

LENGTH
2300 km long

70 million
football fields

Roughly the
same area as…


ITALY

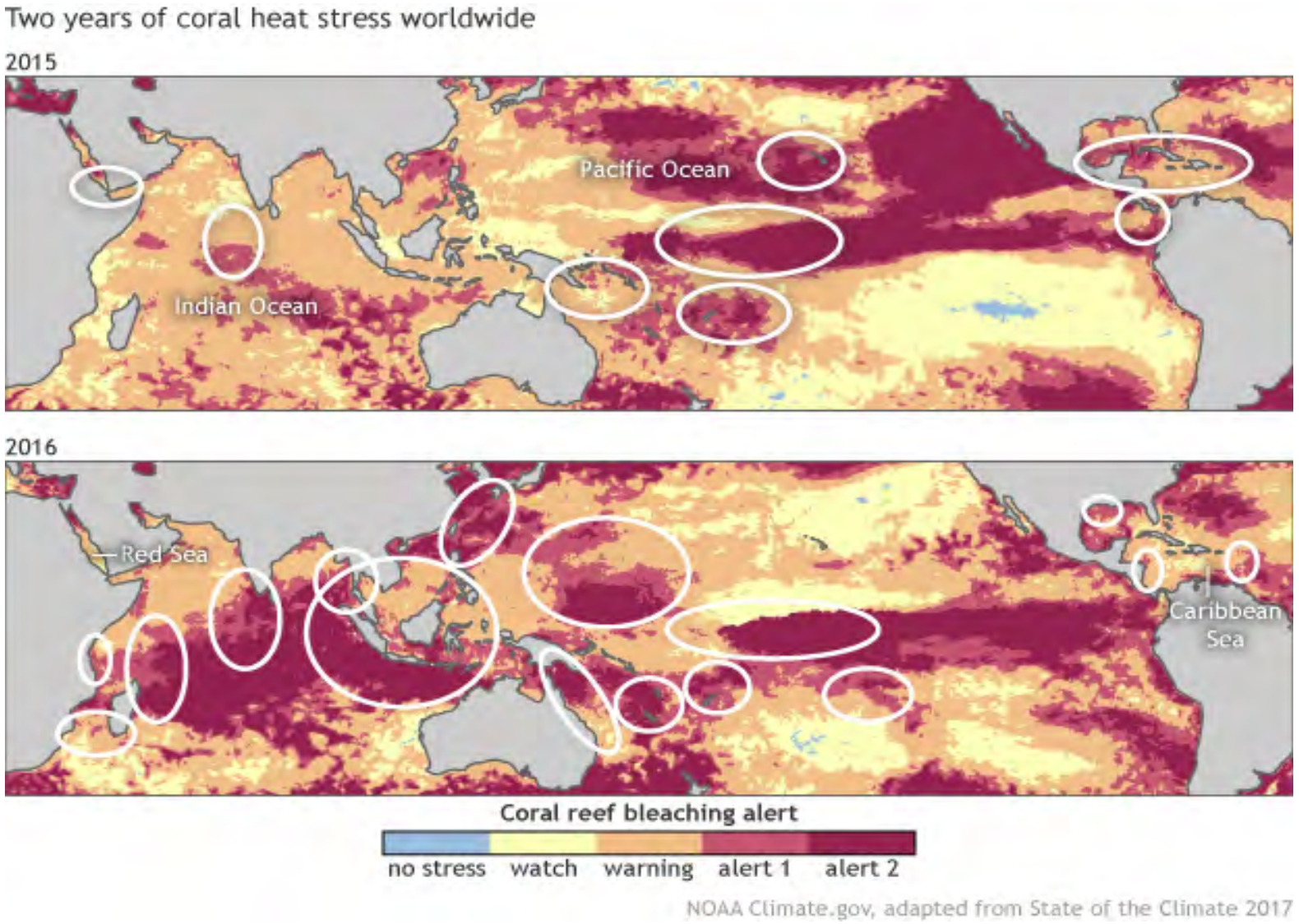

JAPAN


GERMANY

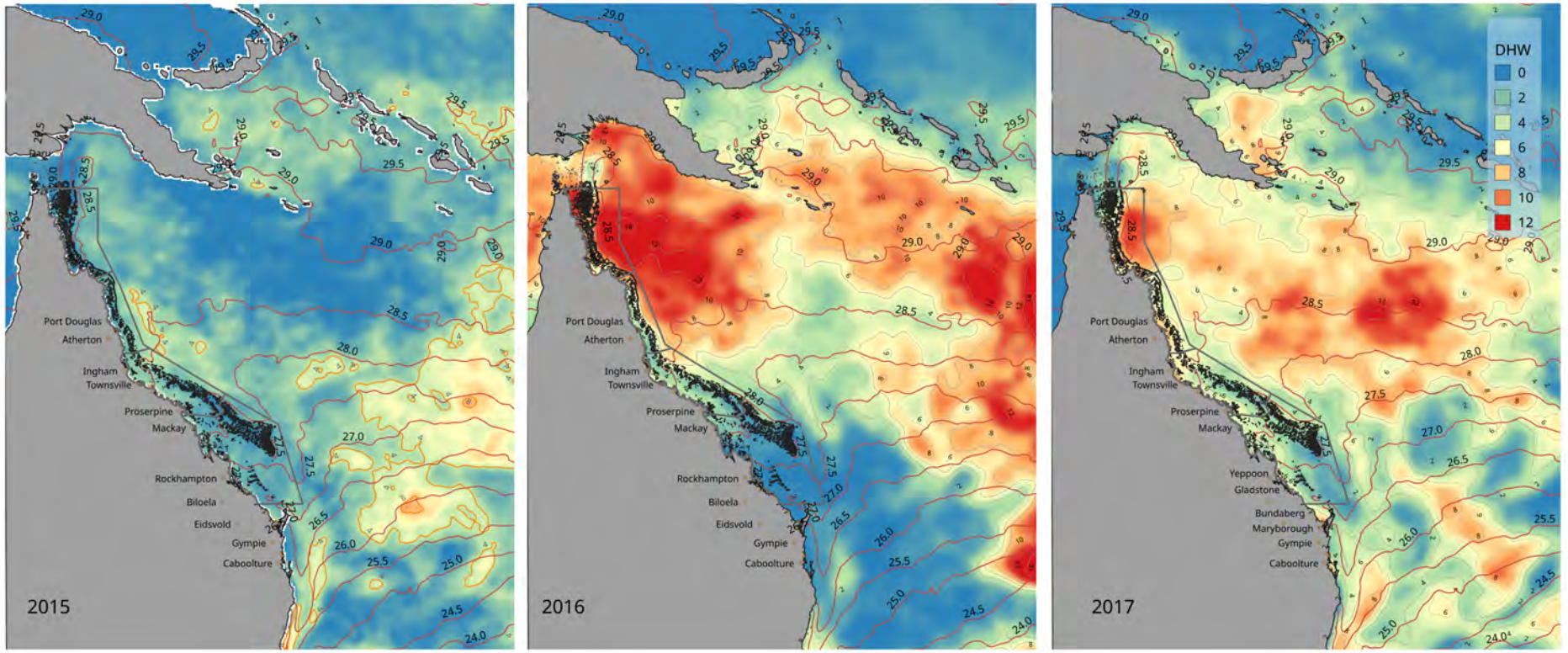

MALAYSIA

- Economic, social and icon asset value of $56 billion.
- Supports 64,000 jobs
- Contributes $6.4 billion to the Australian economy.

Global Marine Heatwave Event 2014-17



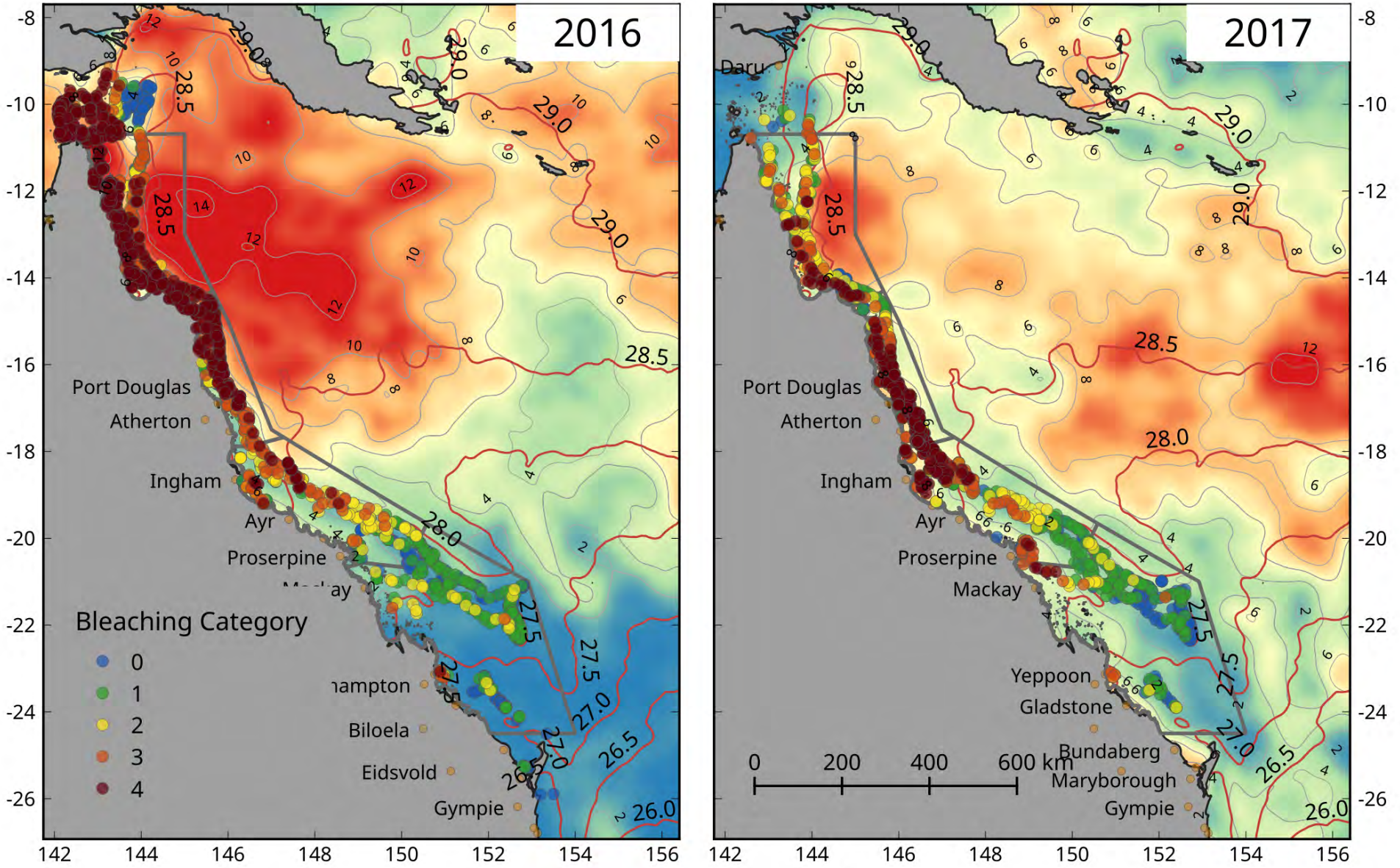
2016 – 2017 Heat wave



Contours – temp climatology
Colours – degree heating weeks

2-3 months above historical summer maximum

Mass Coral Bleaching



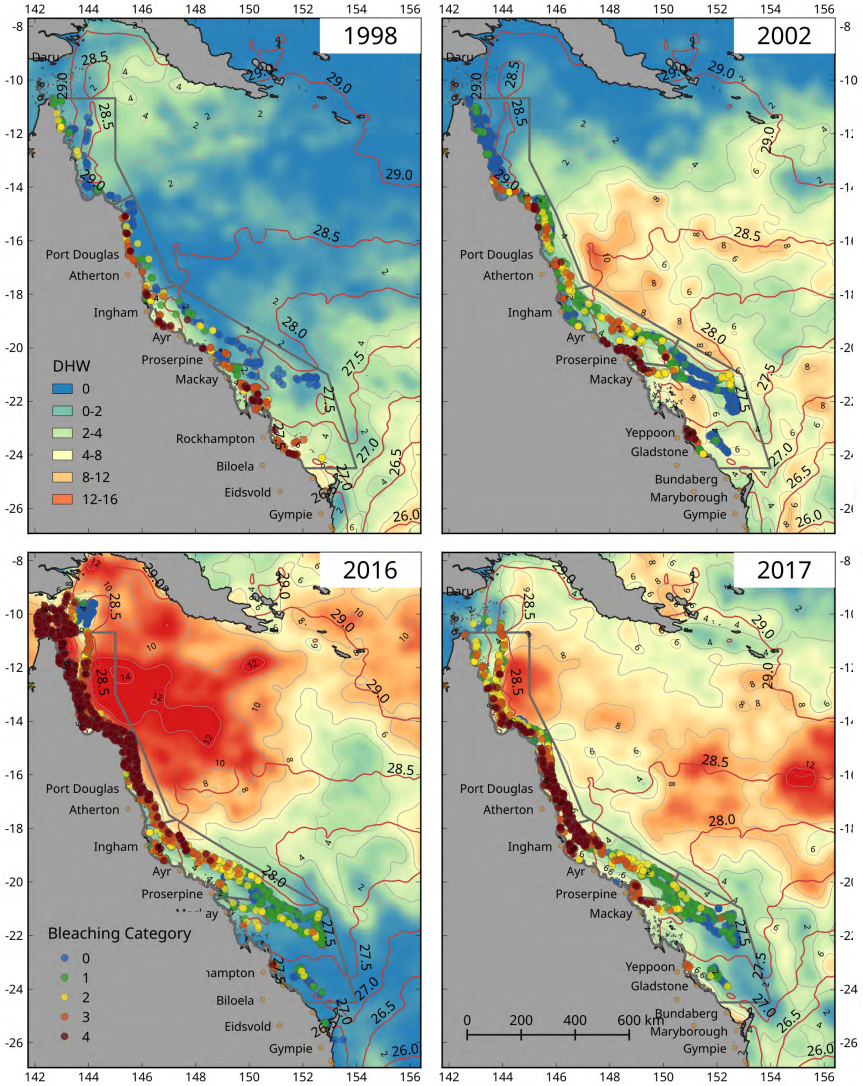
Australian Institute of Marine Science

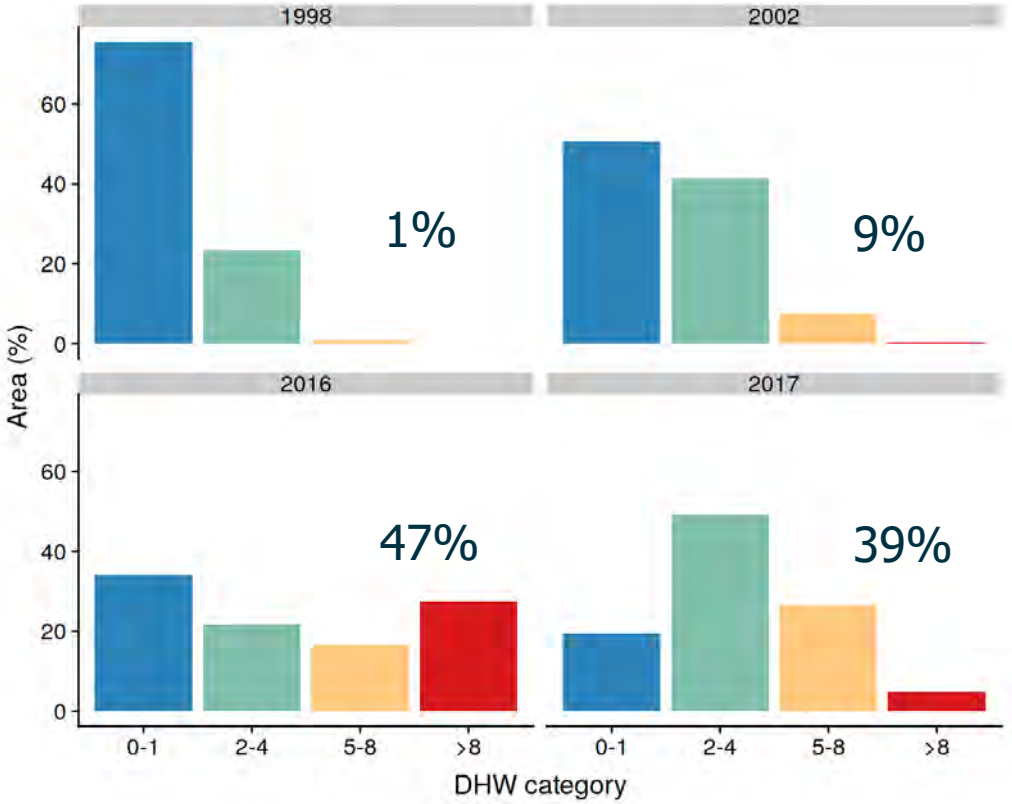
ARC Centre of Excellence Coral Reef Studies

Australian Government
Great Barrier Reef Marine Park Authority

National Environmental Science Programme
Tropical Water Quality Hub

More Severe mass bleaching than ever before…





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Australian Government
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National Environmental Science Programme
TROPICAL WATER QUALITY HUB

…and widespread ecological impacts

Coral bleaching

% of corals bleached:

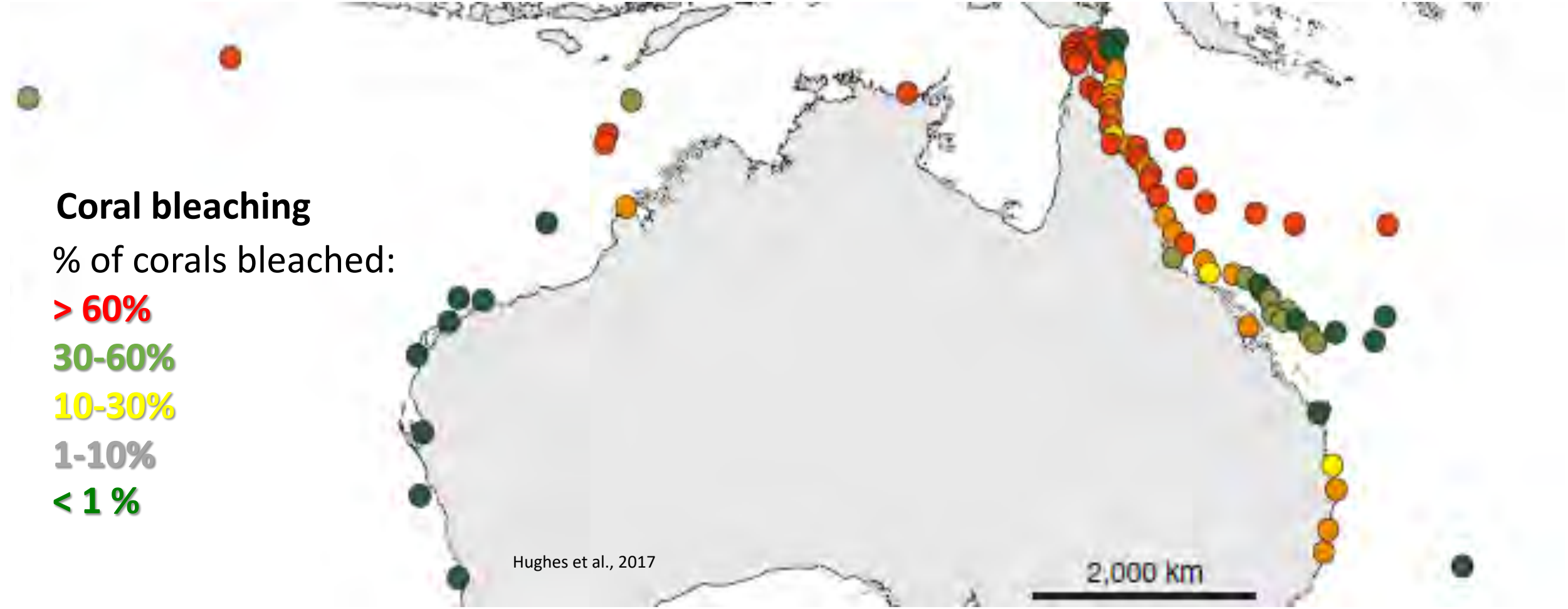
> 60%

30-60%

10-30%

1-10%

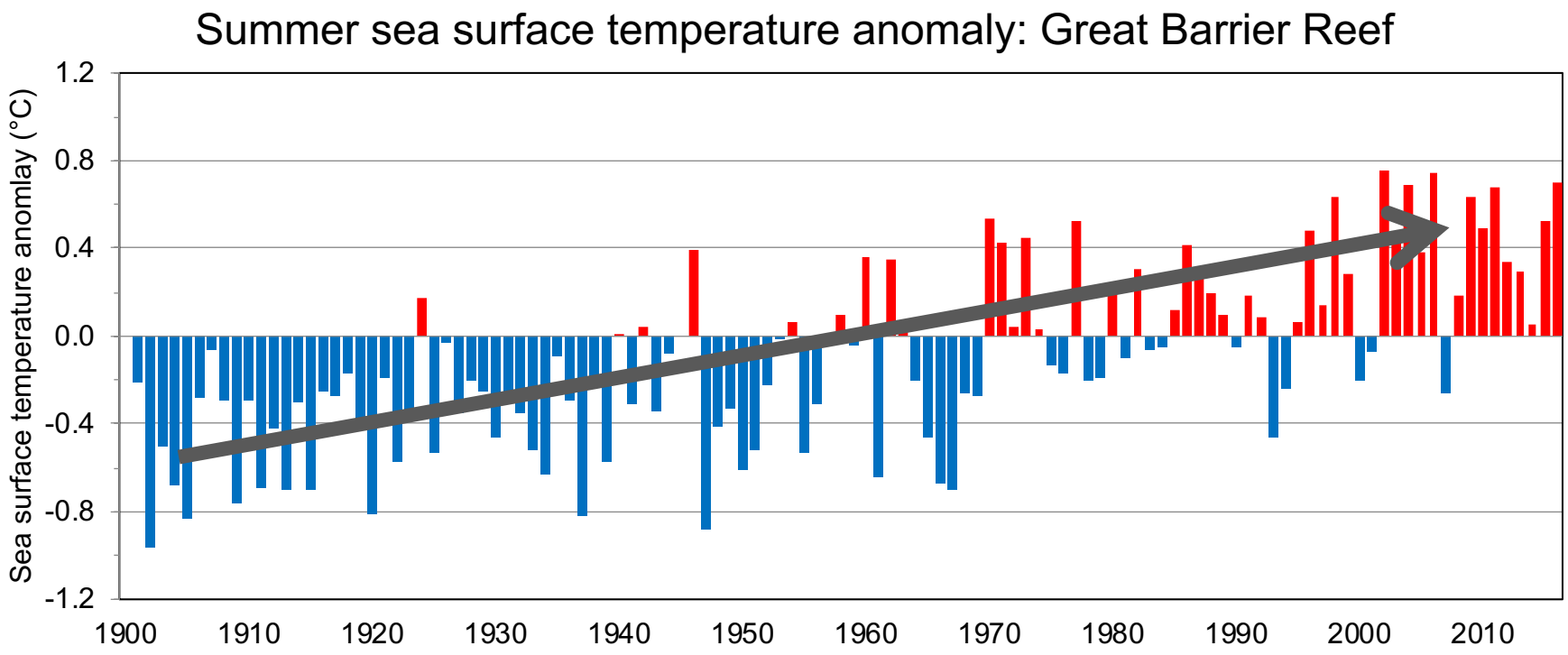
< 1 %



Hughes et al., 2017

So what caused it?
Increasing summer SST

Summer ocean temperatures have risen dramatically on the GBR over the last century



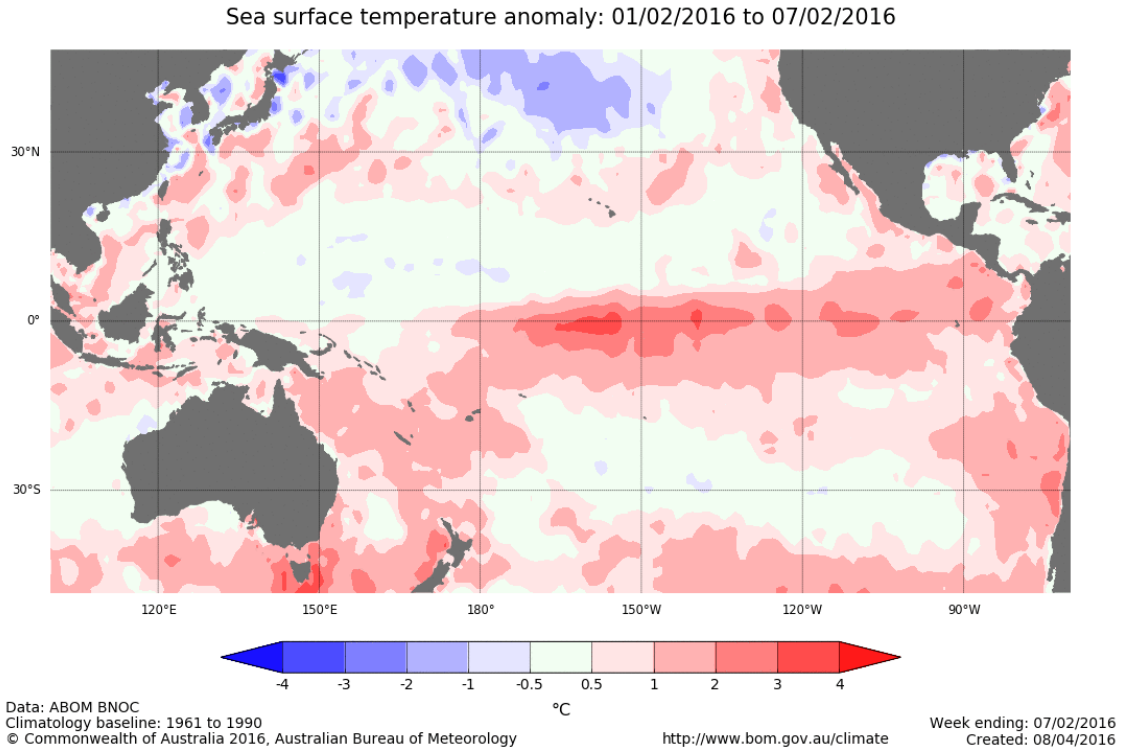
- Annual SST warmed by **0.54°C** (1998-2015 vs 1871-1900)

1964: +0.34
1981: +0.3
1998: **+0.83**
2002: +0.35
2016: **+0.88**

Anomalies against a 30 year climatology 1961-1990. Data from ERSSTv4.

Australian Government
Bureau of Meteorology

So what caused it?
The 2015/16 El Nino



- One of the top three strongest El Niño events in past 50 years
- El Niño delayed the monsoon, reducing cloud cover & weakening winds
- As El Niño started to break down in late summer, warmer waters in the central equatorial Pacific were brought towards Australia

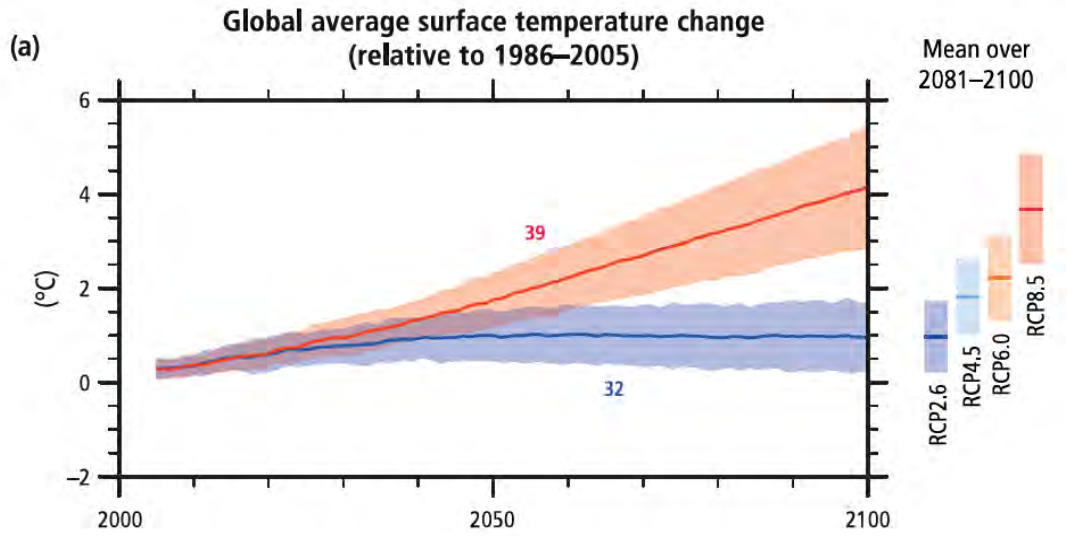
Australian Government
Bureau of Meteorology

The Risk

Climate change is <u>the</u> most significant threat to reefs around the world:

- more frequent and severe coral bleaching
- more frequent and severe weather events, such as cyclones and floods
- ocean acidification.

Based on current emissions trajectory, world's reefs predicted to be catastrophically declined by 2050



How is the Reef currently managed?

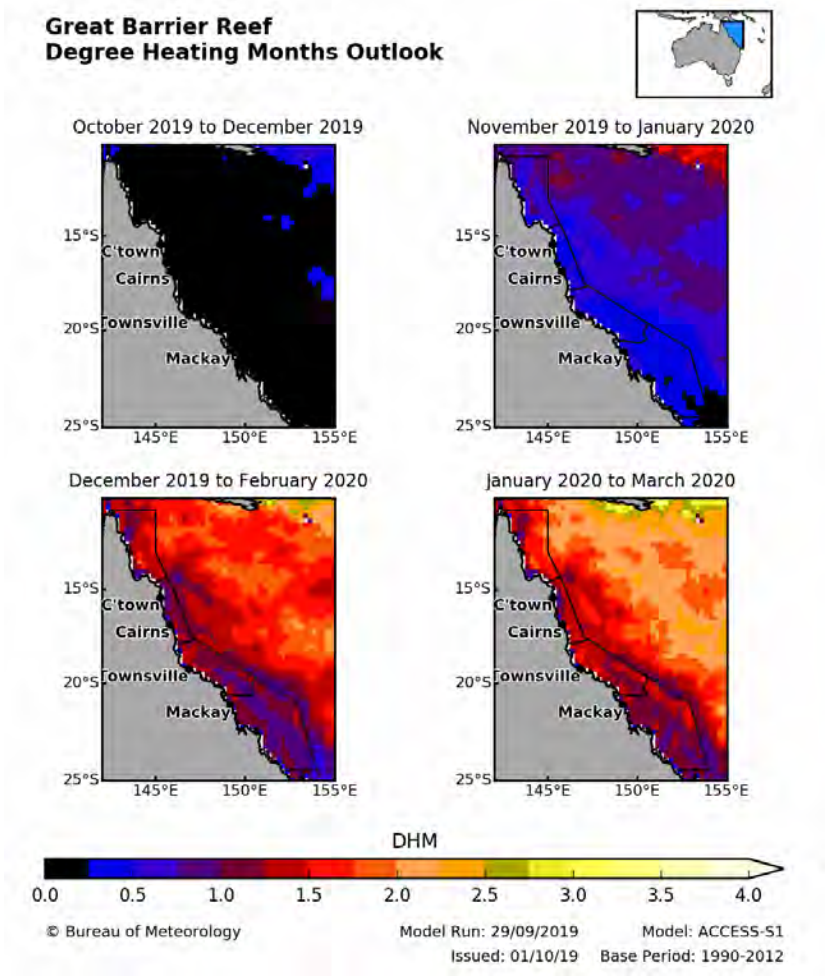
Conventional management practices to reduce environmental stressors including:

- improving water quality
- managing predatory crown-of-thorns starfish
- zoning of the Great Barrier Reef Marine Park.
- Small scale/temporary interventions

Photographer: D. Shultz, Copyright: Commonwealth of Australia (GBRMPA)

What do Reef managers use?
Seasonal forecasts for coral bleaching risk

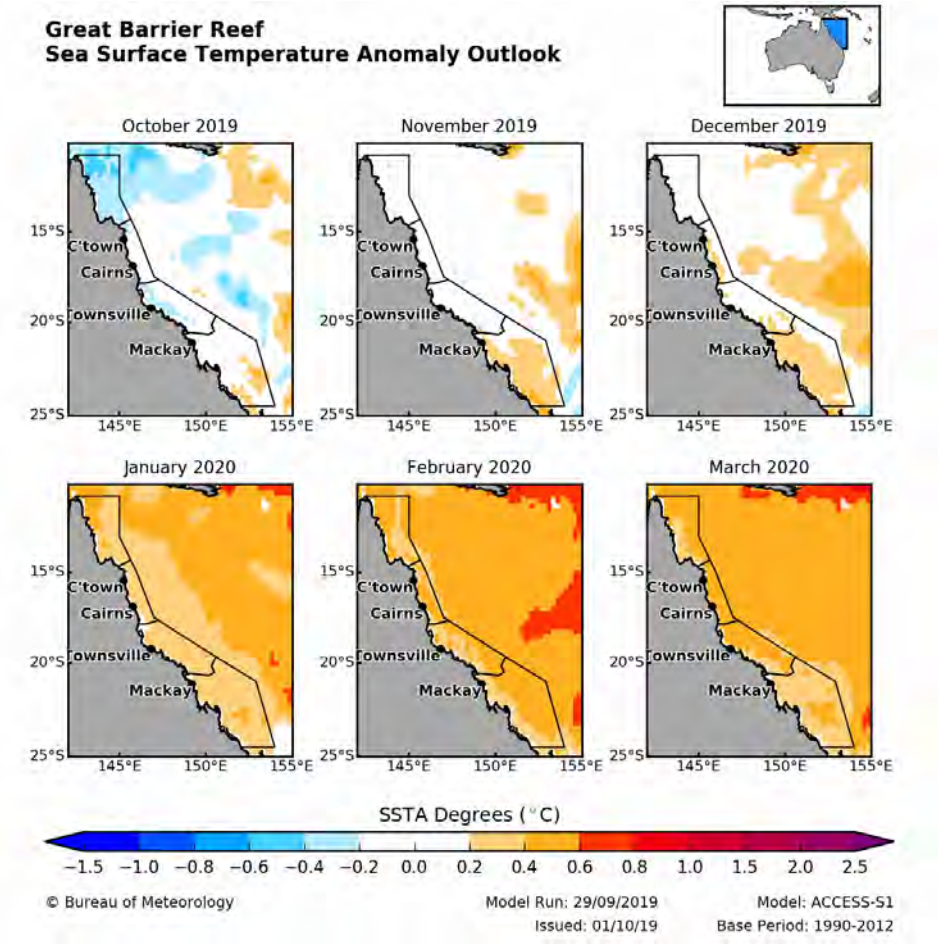
- **ACCESS-S1:** New Bureau global seasonal prediction system
- Operational seasonal forecasts of thermal stress out to 6 months
  - SST & SST anomalies
  - Regional SST indices for reef regions
  - Hotspots & Degree Heating Months
  - Probability of exceedance
- 25 km x 25 km resolution
- 1990-2012 climatology
- Updated twice weekly in realtime



http://www.bom.gov.au/oceanography/oceantemp/sst-outlook-map.shtml

Australian Government
Bureau of Meteorology

Seasonal forecasts in reef management



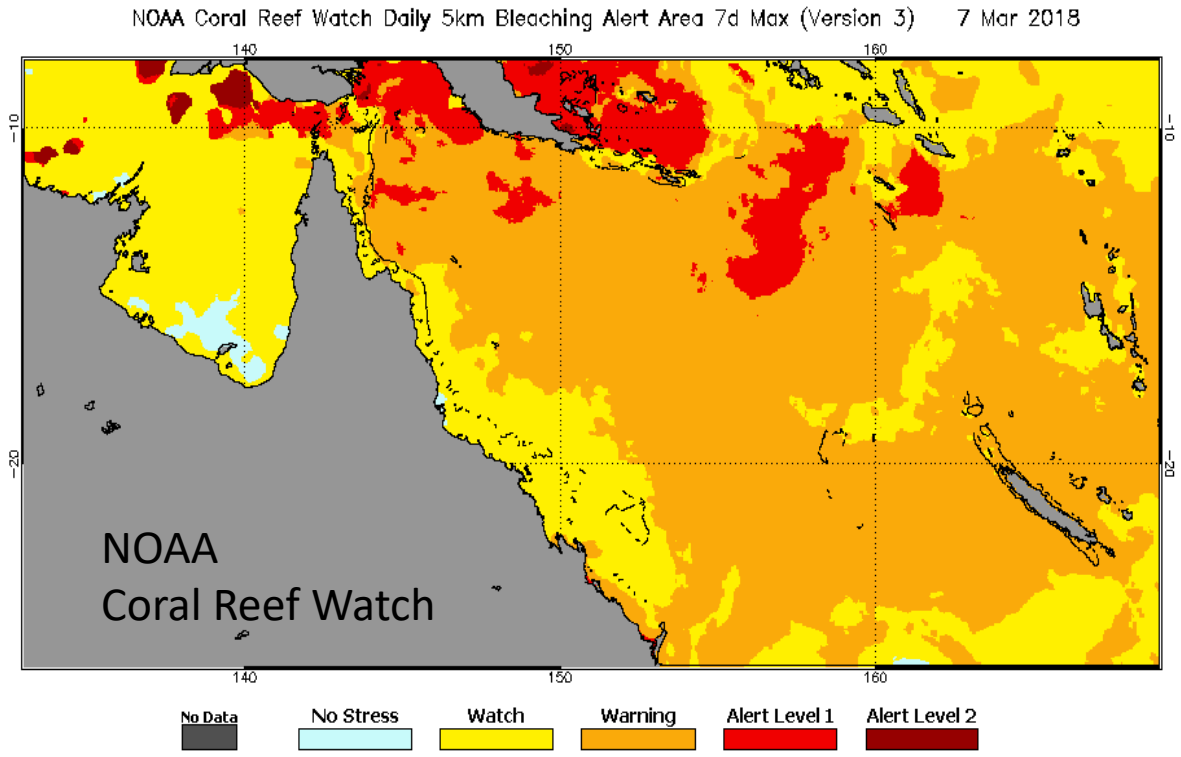
- Reef managers use seasonal forecasts to plan operational activities for the upcoming summer
- Provide an early window to implement management strategies to minimise impacts
- Integral part of GBRMPA Early Warning System for coral bleaching
- Brief government, tourist operators, general public
- First operational dynamical seasonal forecasts for coral bleaching risk – service coverage now Australia wide

Spillman et al 2009, 2011, 2012, Smith & Spillman 2019

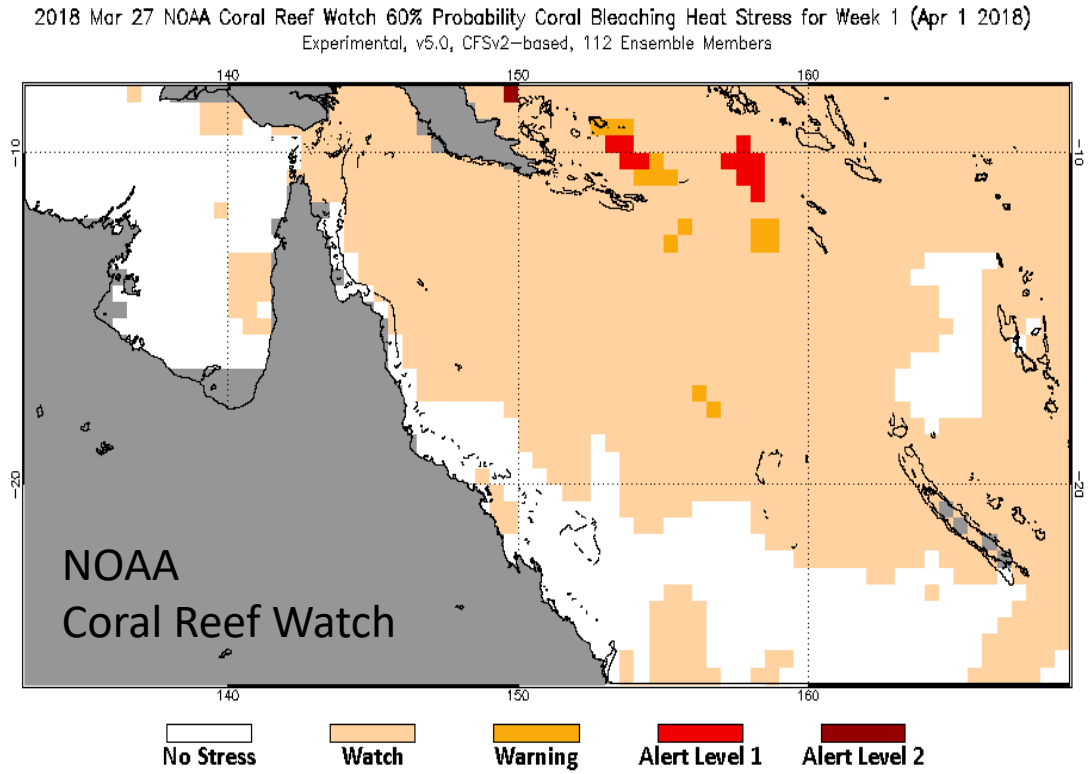
Australian Government
Bureau of Meteorology

….and similar forecast from NOAA

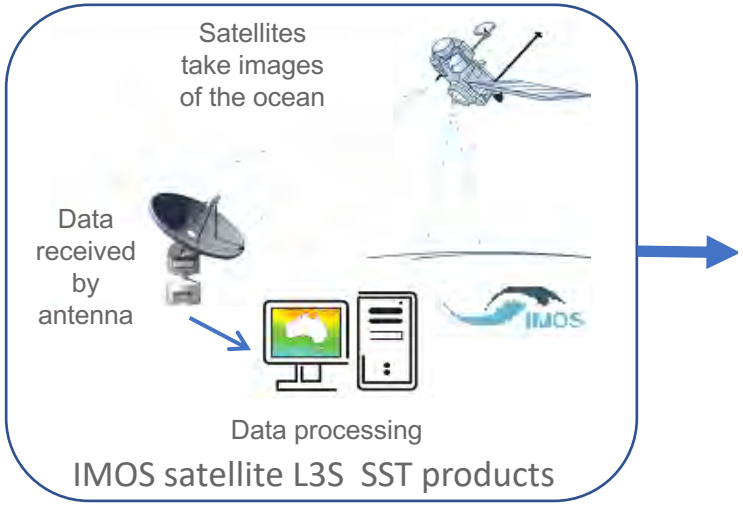
Modelled outlooks –
Daily 5km Bleaching Alert

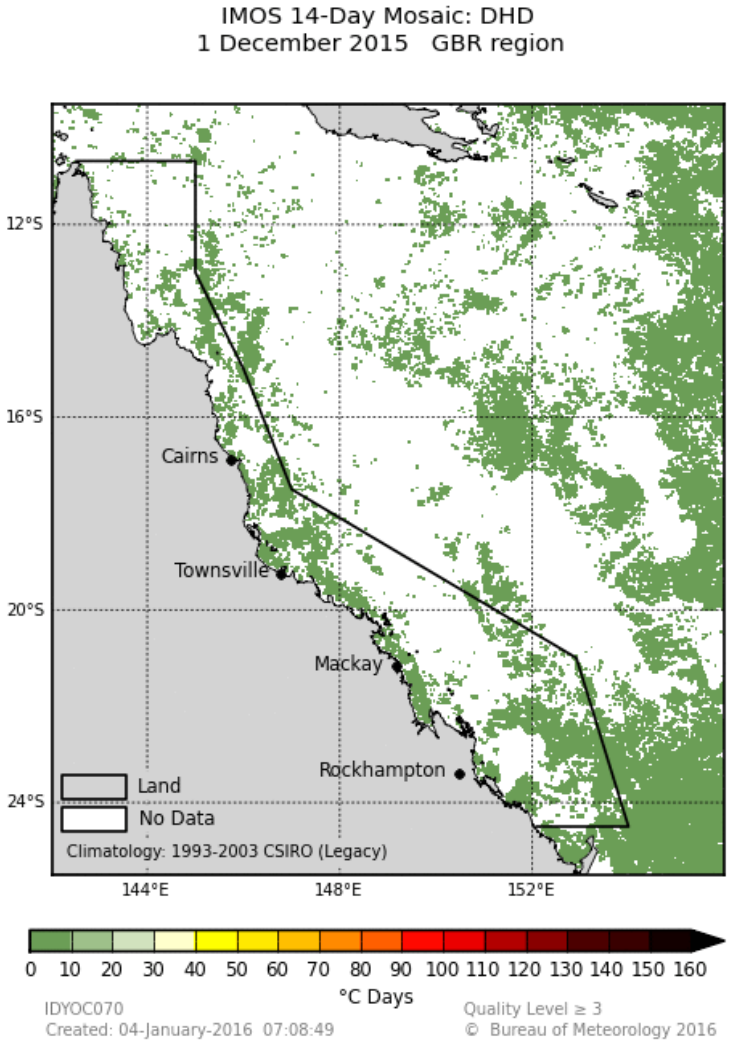


Modelled outlooks –
Four-month coral bleaching outlook



ReefTemp
Next Generation





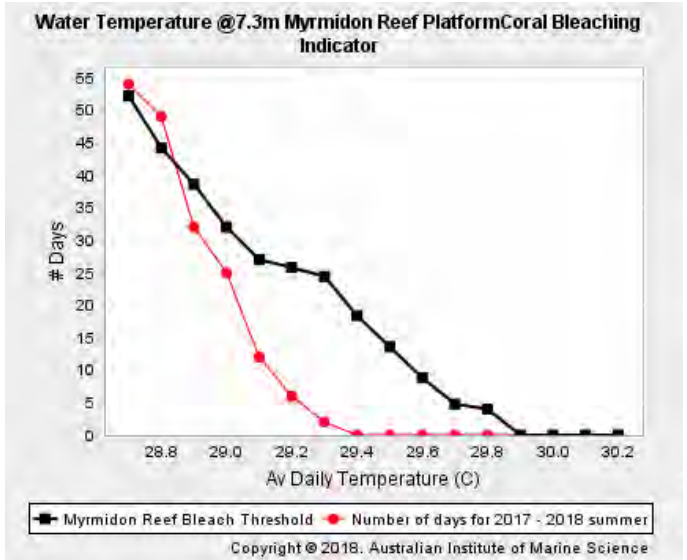
Thermal stress accumulation
(Degree Heating Days)
for the summer 2015/2016

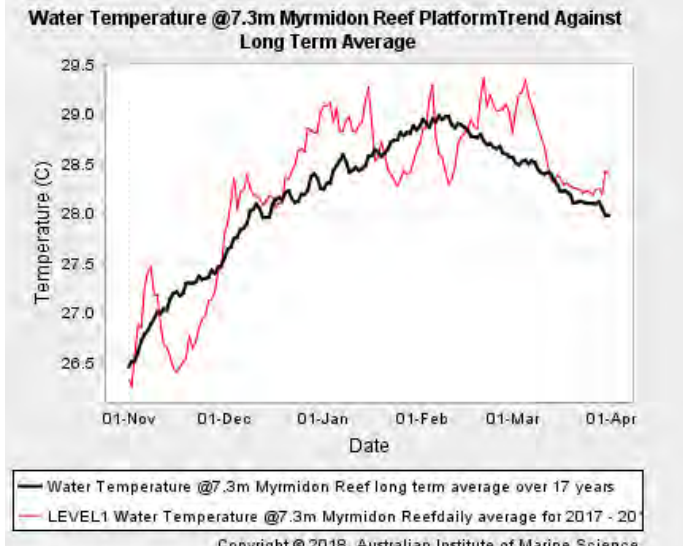
Contact: Dr Claire Spillman

Australian Government
Bureau of Meteorology

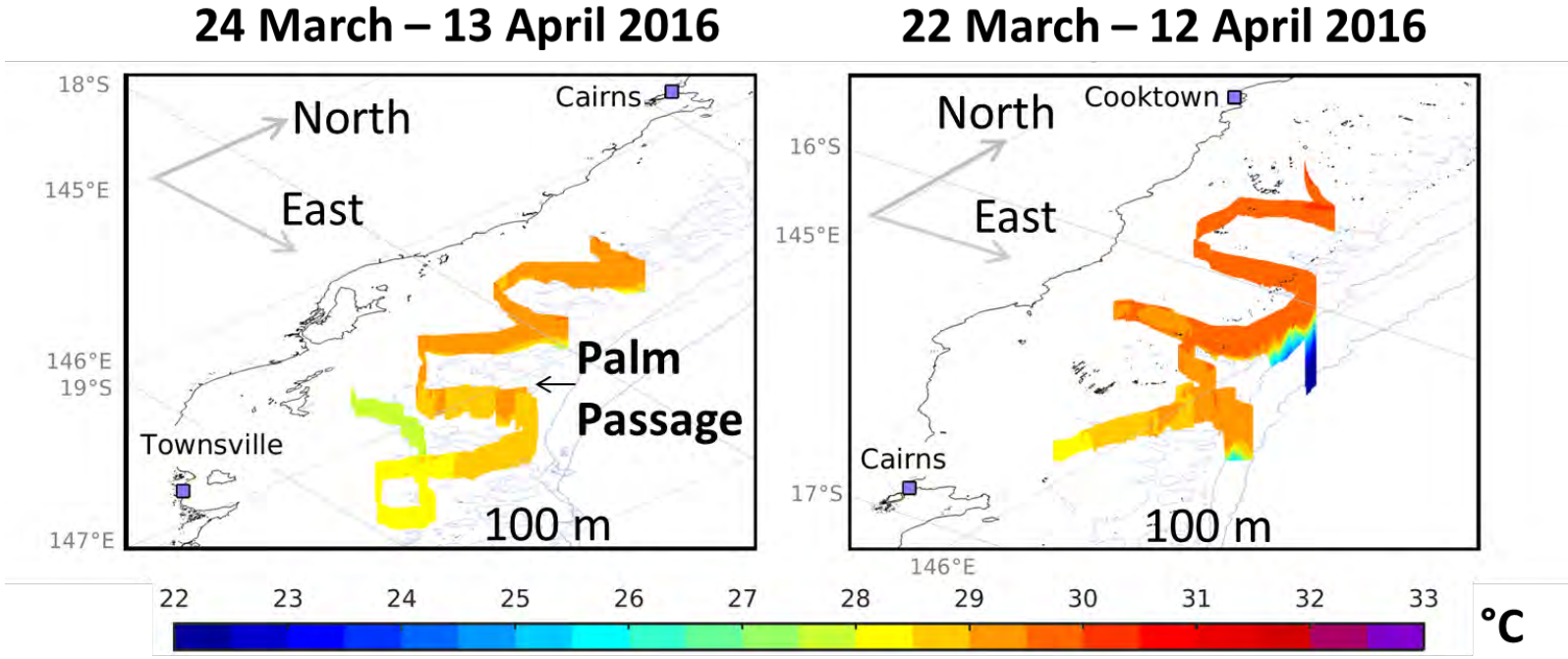
NRT in situ sea water temperatures

Coral bleaching risk indicators



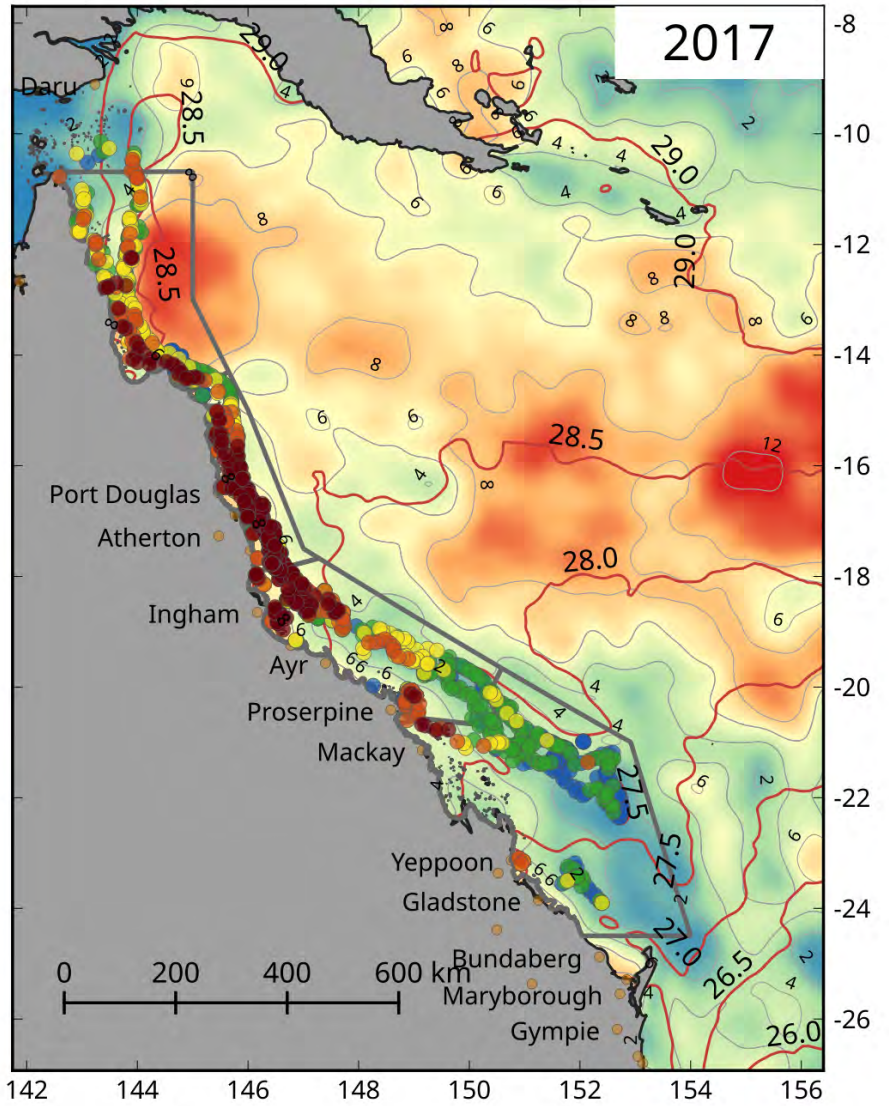


Event Based Sampling for Marine Heatwaves – delivered through the Ocean Glider Facility

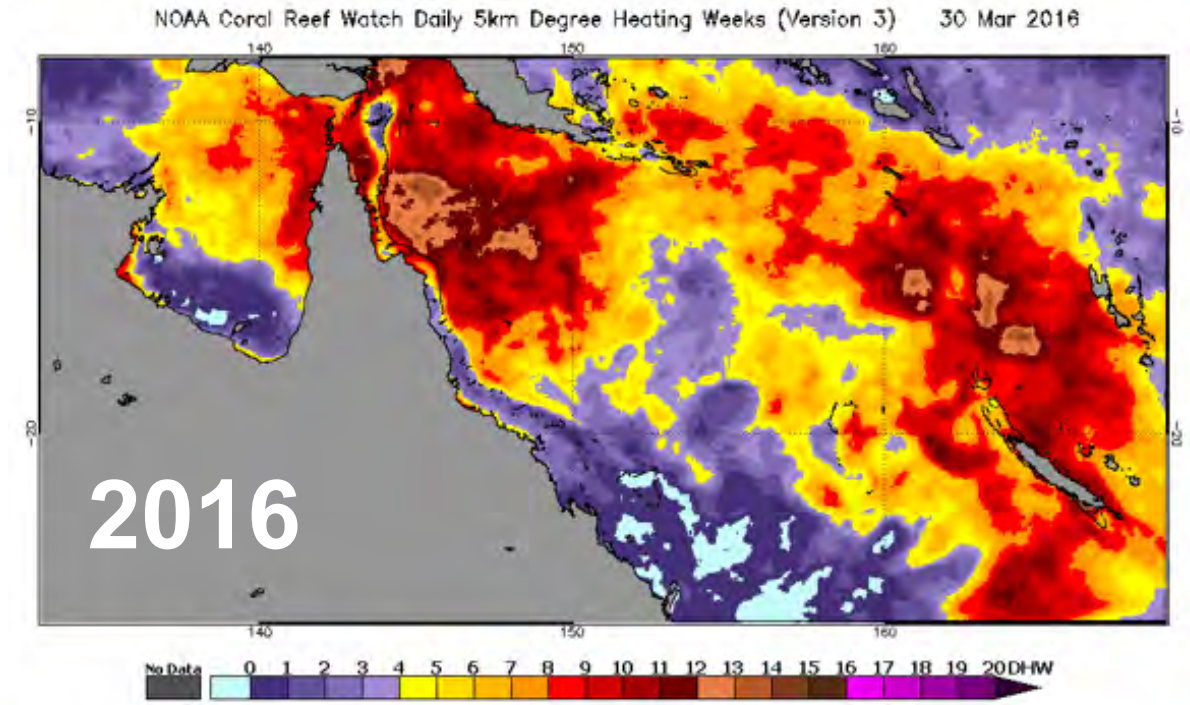


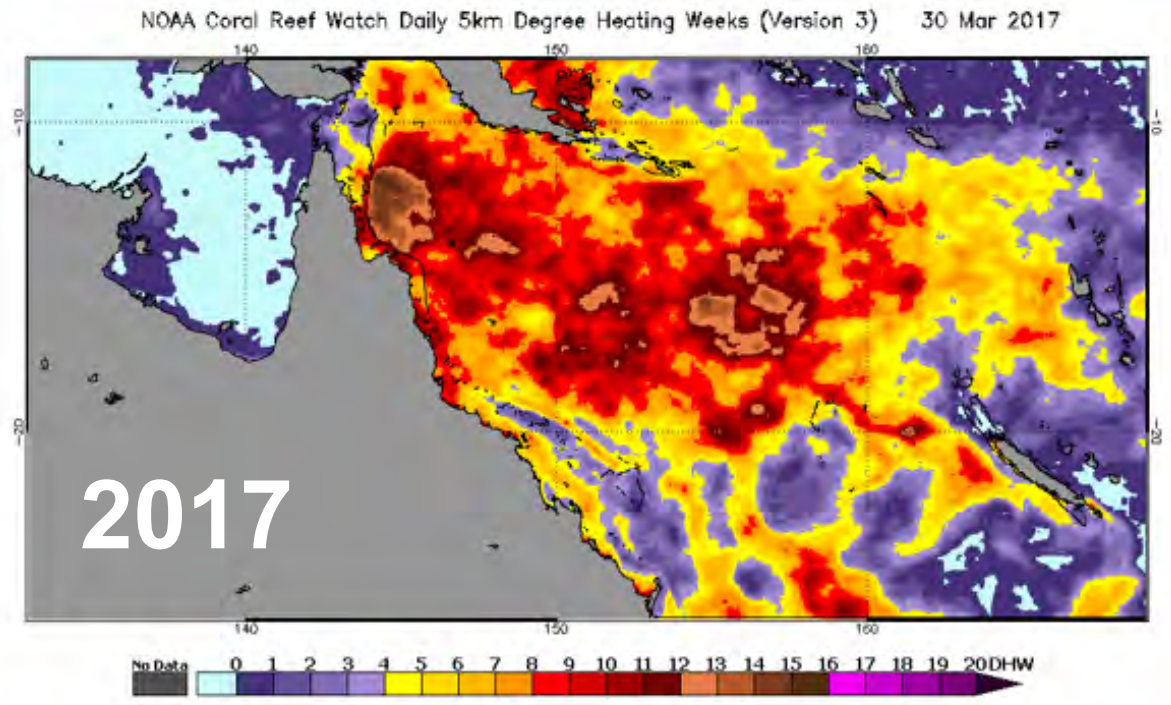
Benthuysen et al. 2018, Extreme marine warming across tropical Australia during austral summer 2015-2016. Journal of Geophysical Research: Oceans.

But not all of the GBR bleached…



What caused spatial variability of Temperature?



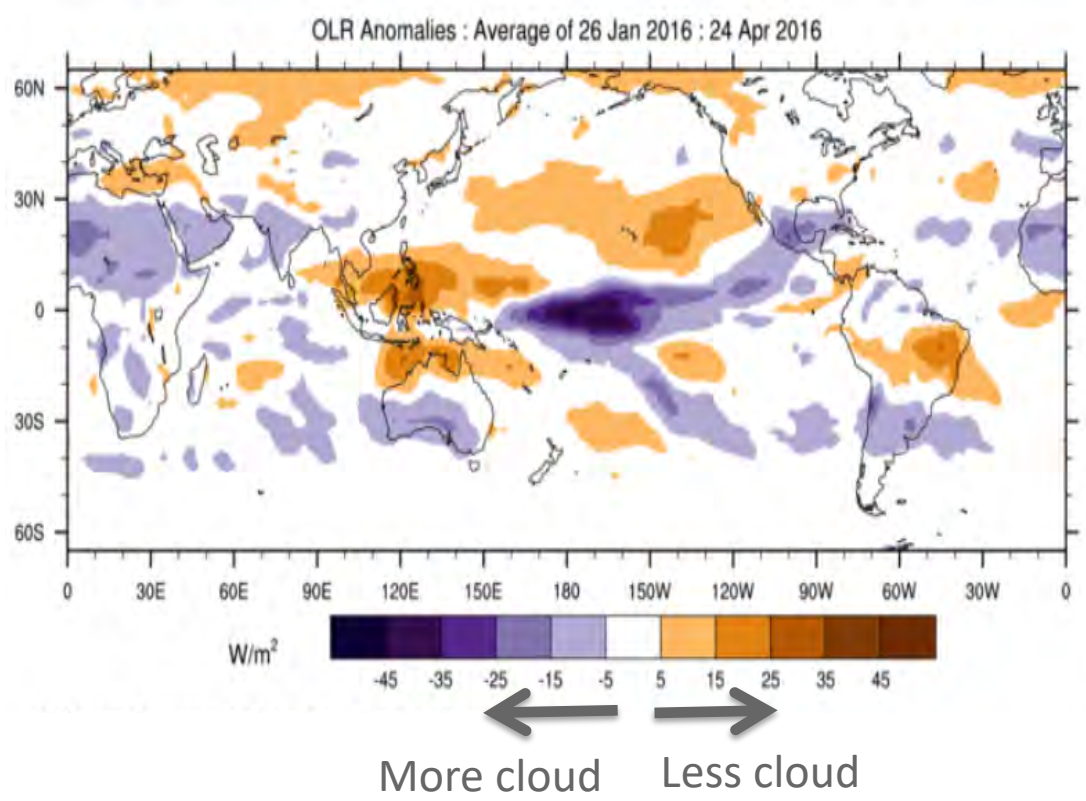


Satellite derived heat accumulation (Degree Heating Week) observed in the Coral Sea for as at March 30 for 2016 (left) and 2017 (right) summers.

..and can new products improve it's observation and prediction ?

Local weather

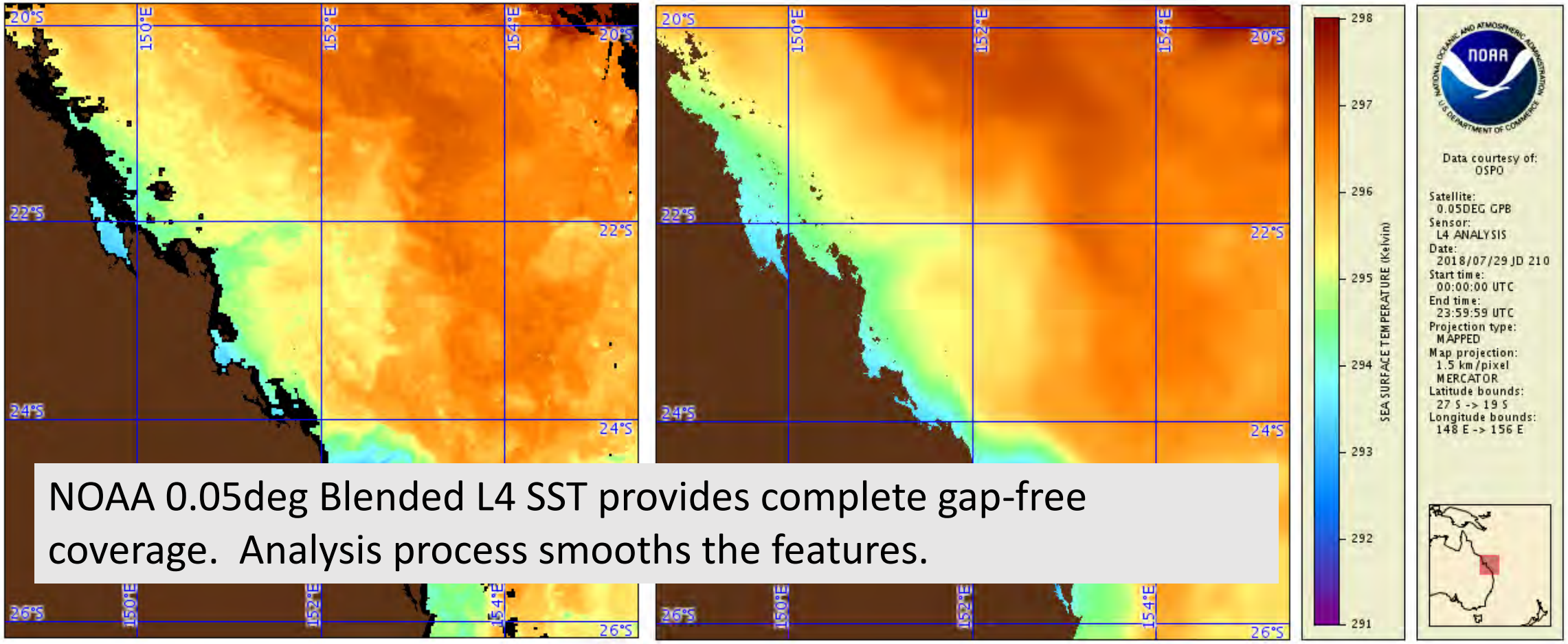
- Reduced cloud cover led to increased solar radiation loading
- Weaker winds reduced lagoon over-turning
- A less active tropical cyclone season & fewer storms
- EAC kept warm waters near the coast



New blended products

29 July 2018 – BoM AVHRR 0.02deg L3S NOAA 0.05deg Geo-Polar Blend L4

Helen Beggs, BoM

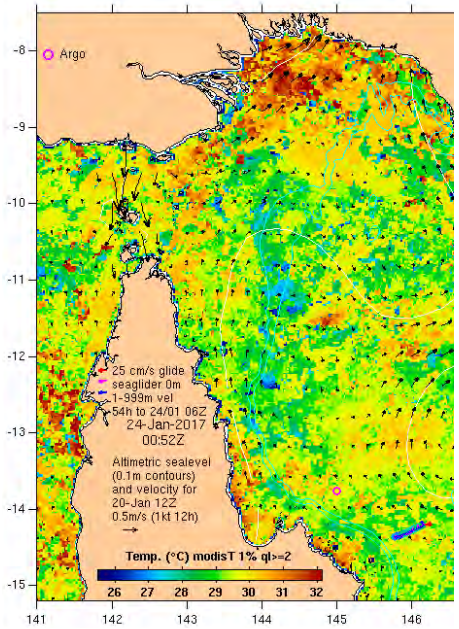


NOAA 0.05deg Blended L4 SST provides complete gap-free coverage. Analysis process smooths the features.

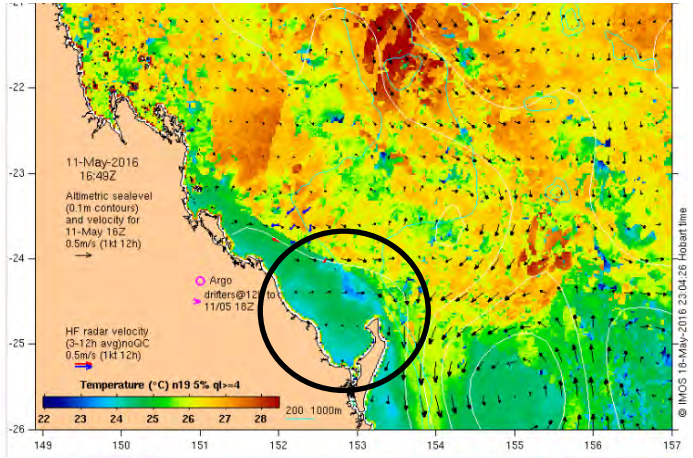
BoM collates IMOS HRPT AVHRR SSTs from NOAA-18/19 and VIIRS SST a into night-only L3S, multisensory. Testing as input for ReefTemp NextGen Coral Bleaching Nowcasting System.

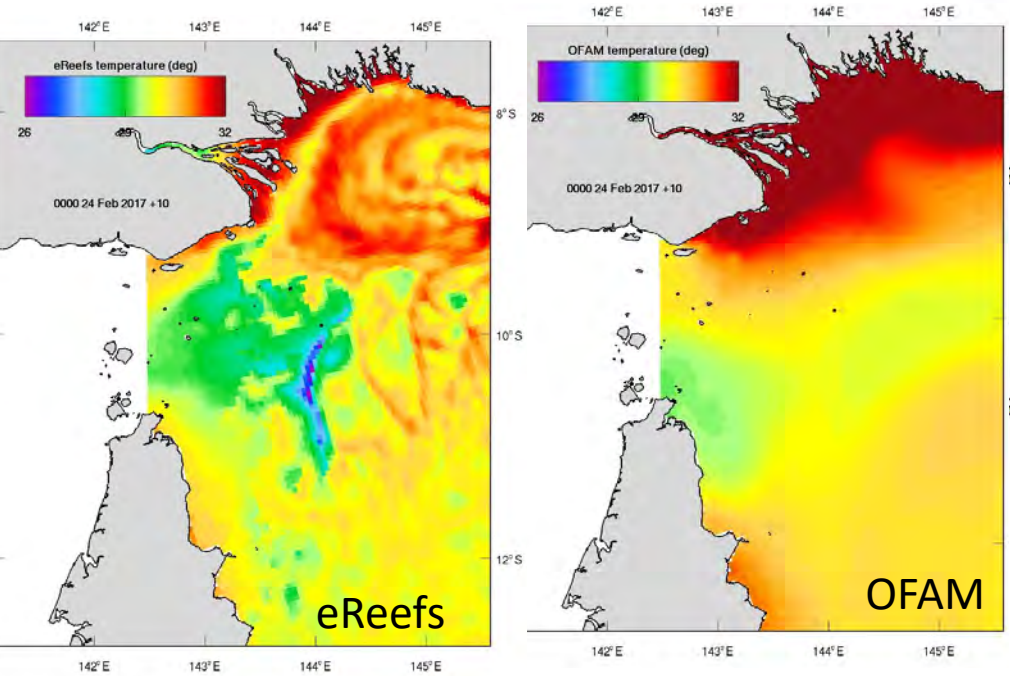
Local processes
Upwelling

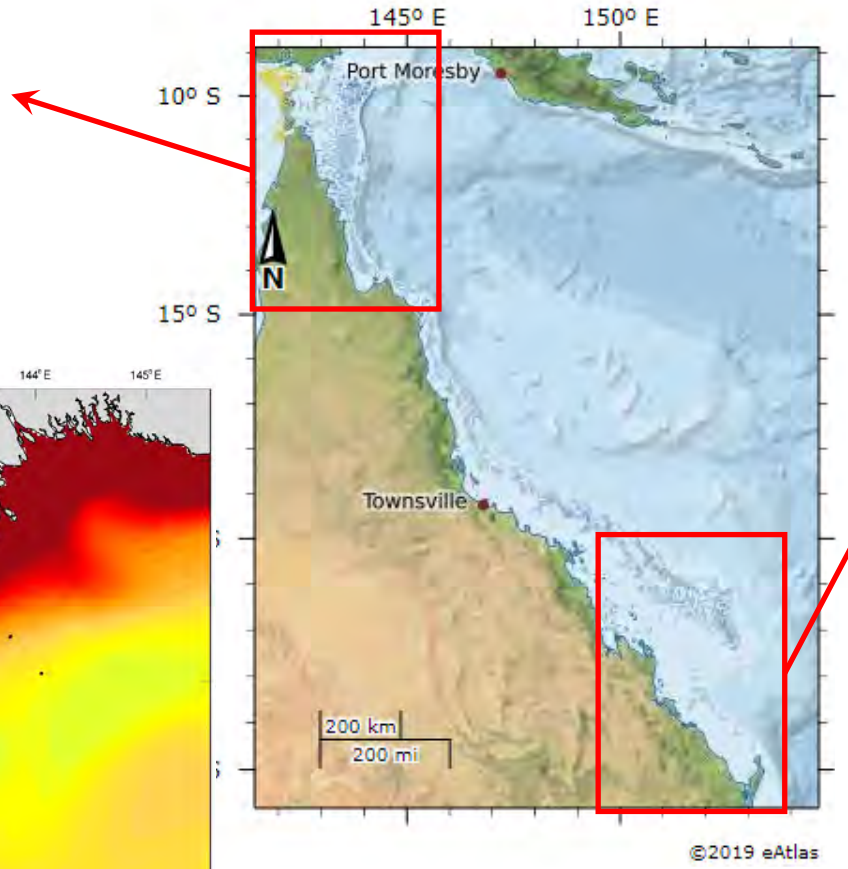
IMOS SST

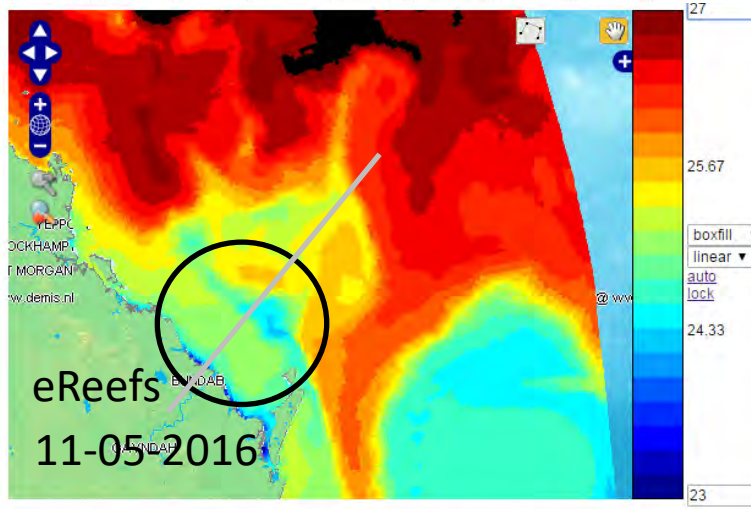


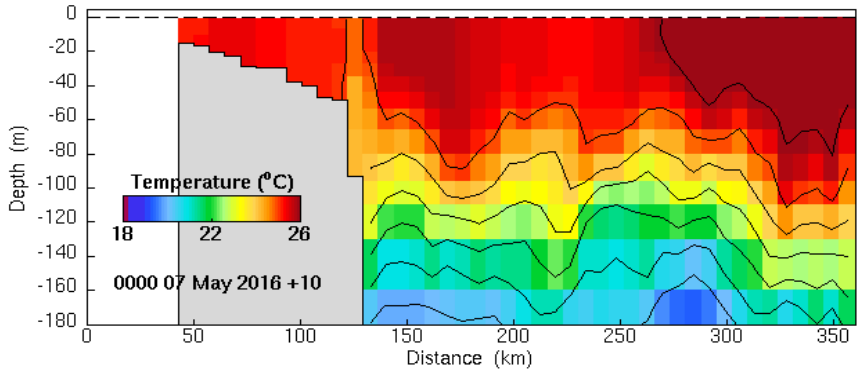
IMOS SST http://oceancurrent.imos.org.au/sst.php







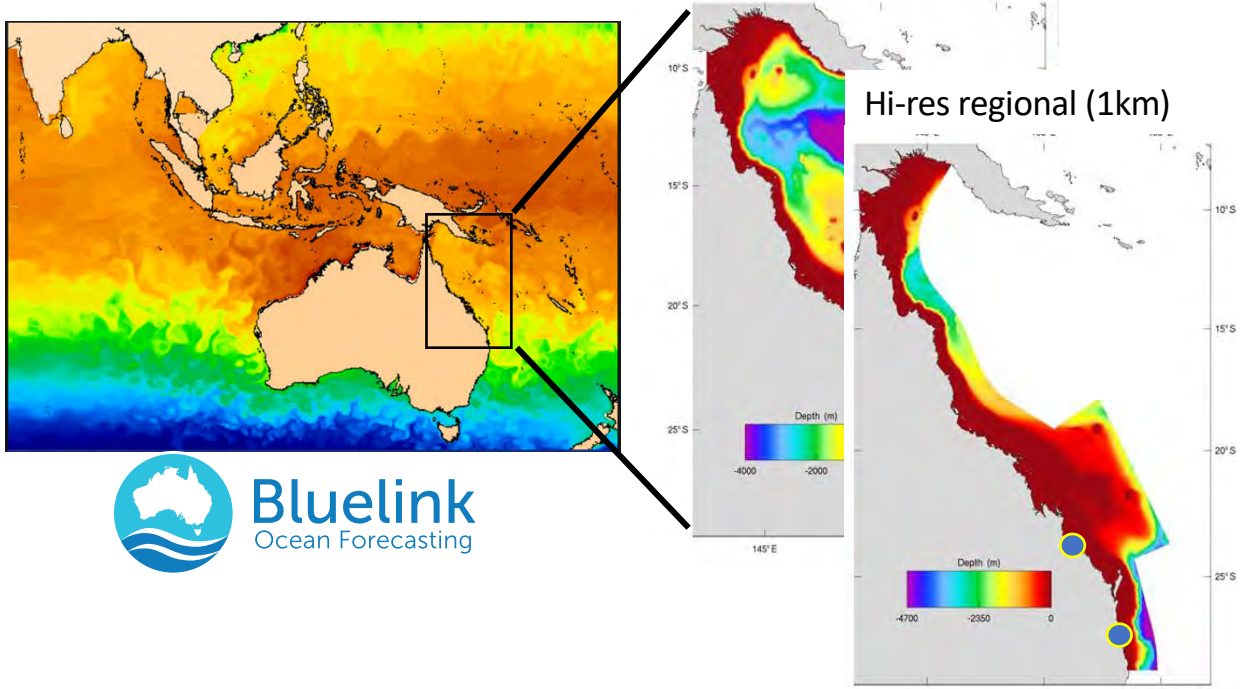


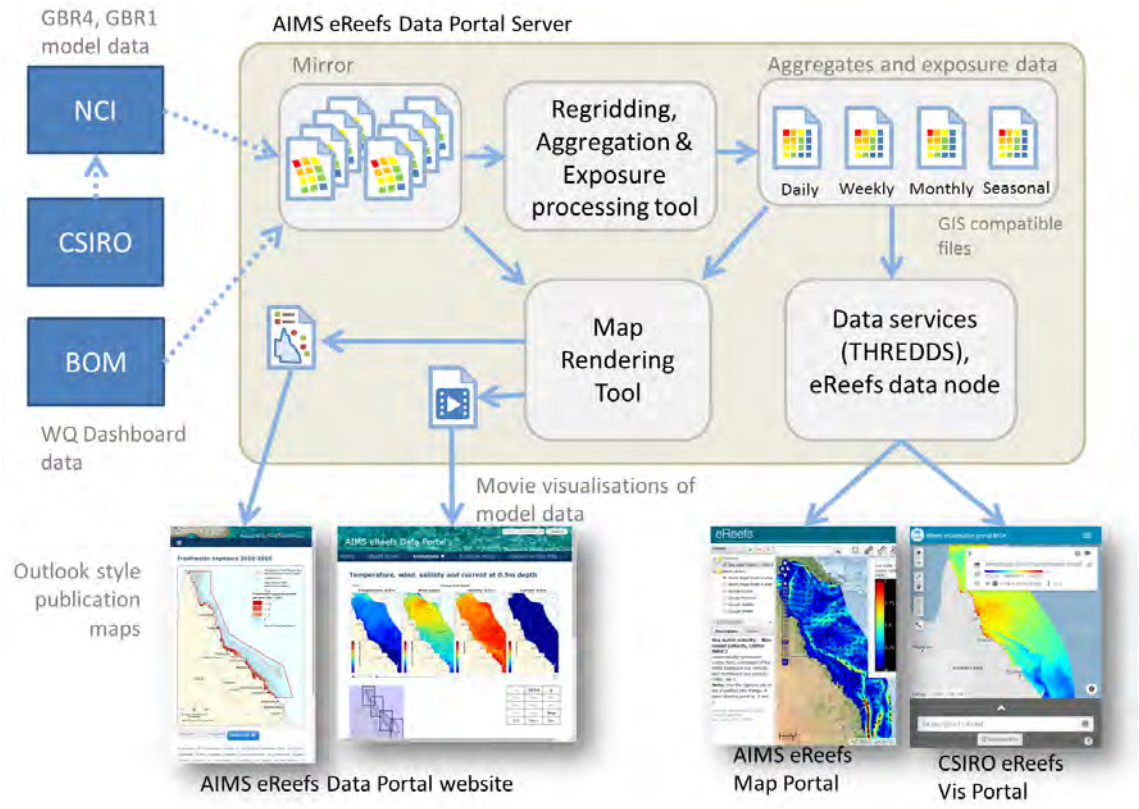


Downscaled models – a new dimension

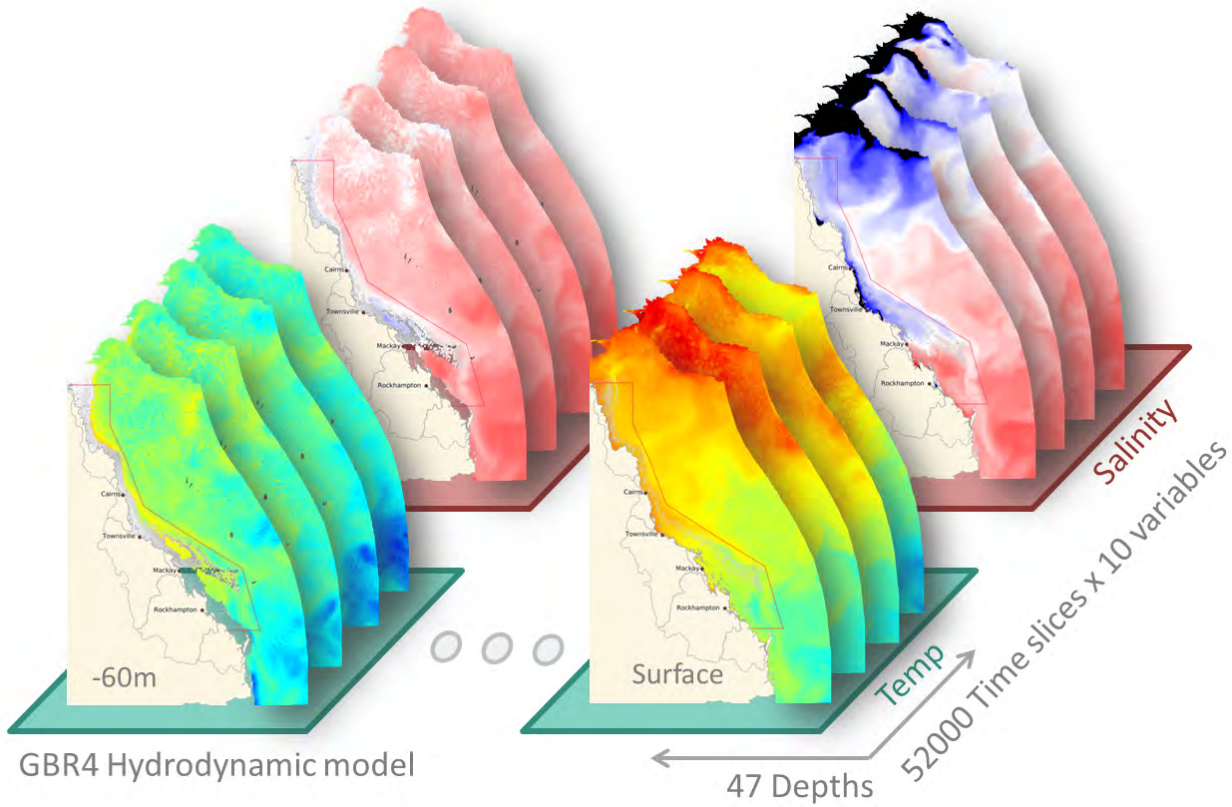
A (multiple) nested modelling approach

- **Multiple nests are required to achieve boundary ratios not exceeding 5:1**
- **SHOC and Orthogonal curvilinear grid**



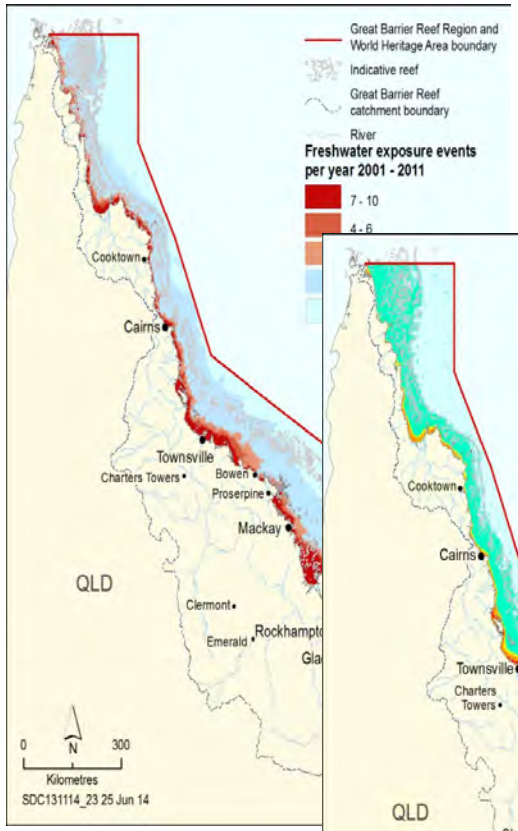


New, useful data outputs

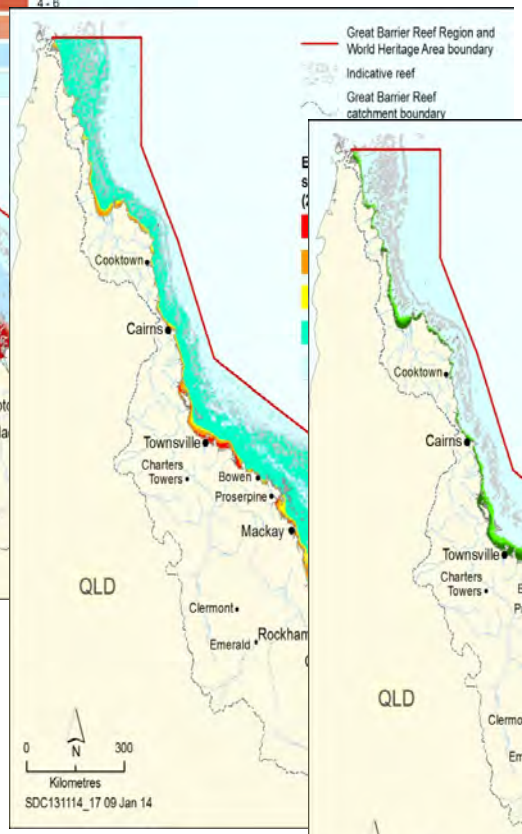


GBR4 Hydrodynamic model

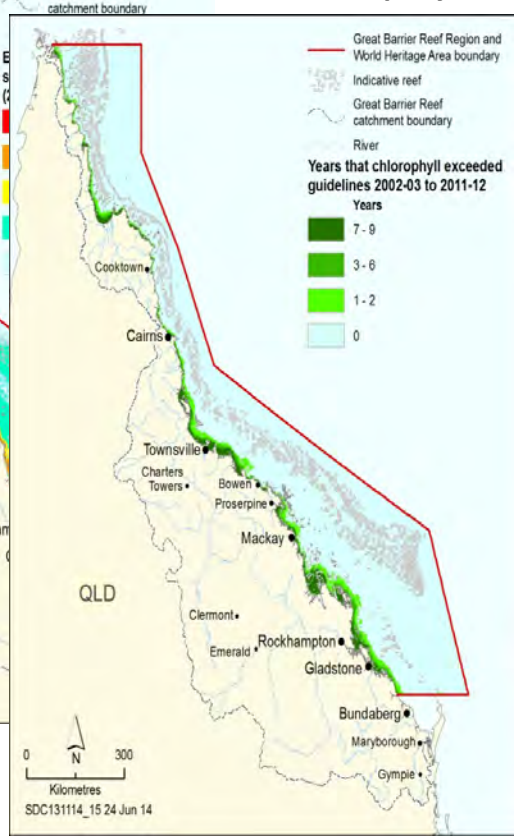
Freshwater exposure



Benthic Light



Chlorophyll



SSTs Over and Around Reefs (SOAR) Workshop

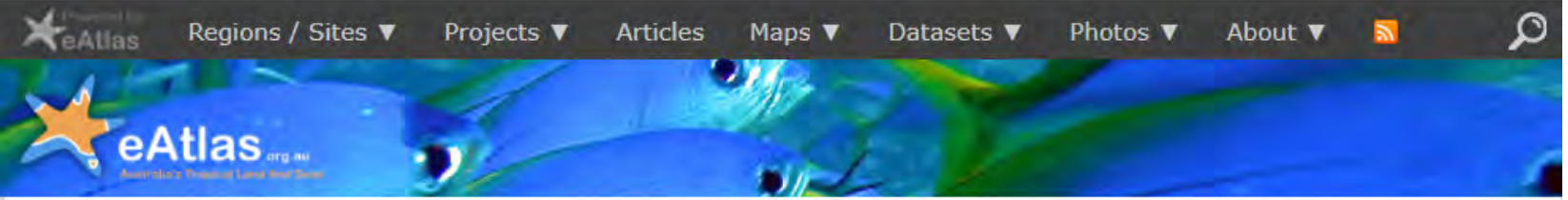
Recommendations from Managers:

The most urgent unmet requirements and potential improvements to cater for them were identified:

- Compatibility between multiple sources of data, e.g. standard climatologies
- Higher temporal and spatial resolution of data
- Estimates of diurnal and vertical temperature variations
- Uncertainty information

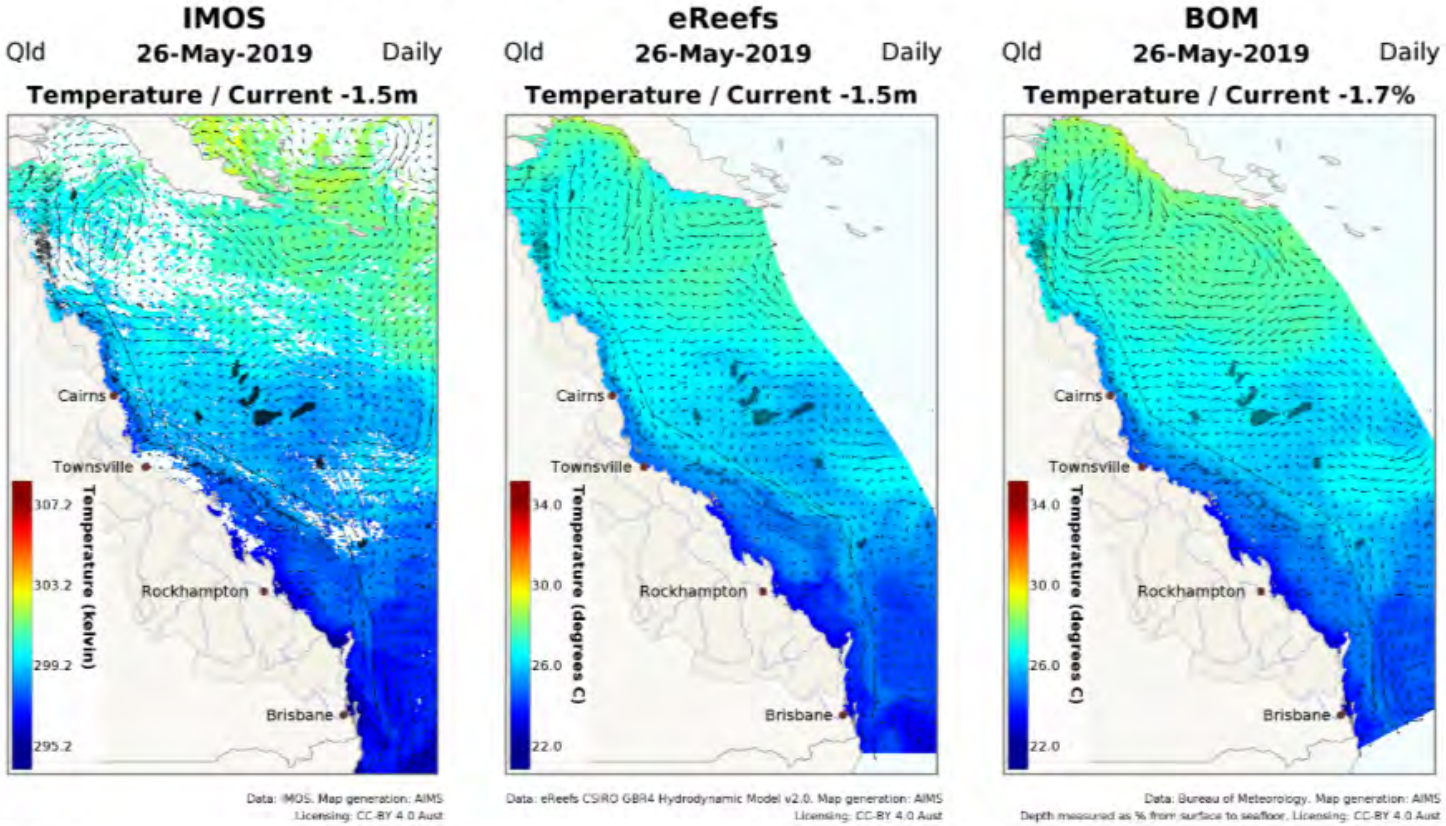
GBR Marine Park Authority Priorities:

- Consistent maintenance of products
- Consistent frequency of information updates
- Importance of three dimensionality of the reef system considered and incorporated
- Any new products should have an option for GBR (or other regions) specific view/query
- Simple explanations of product strengths, weaknesses and limitations



Gateway to environmental data on the GBR - Temperature

Temperatures



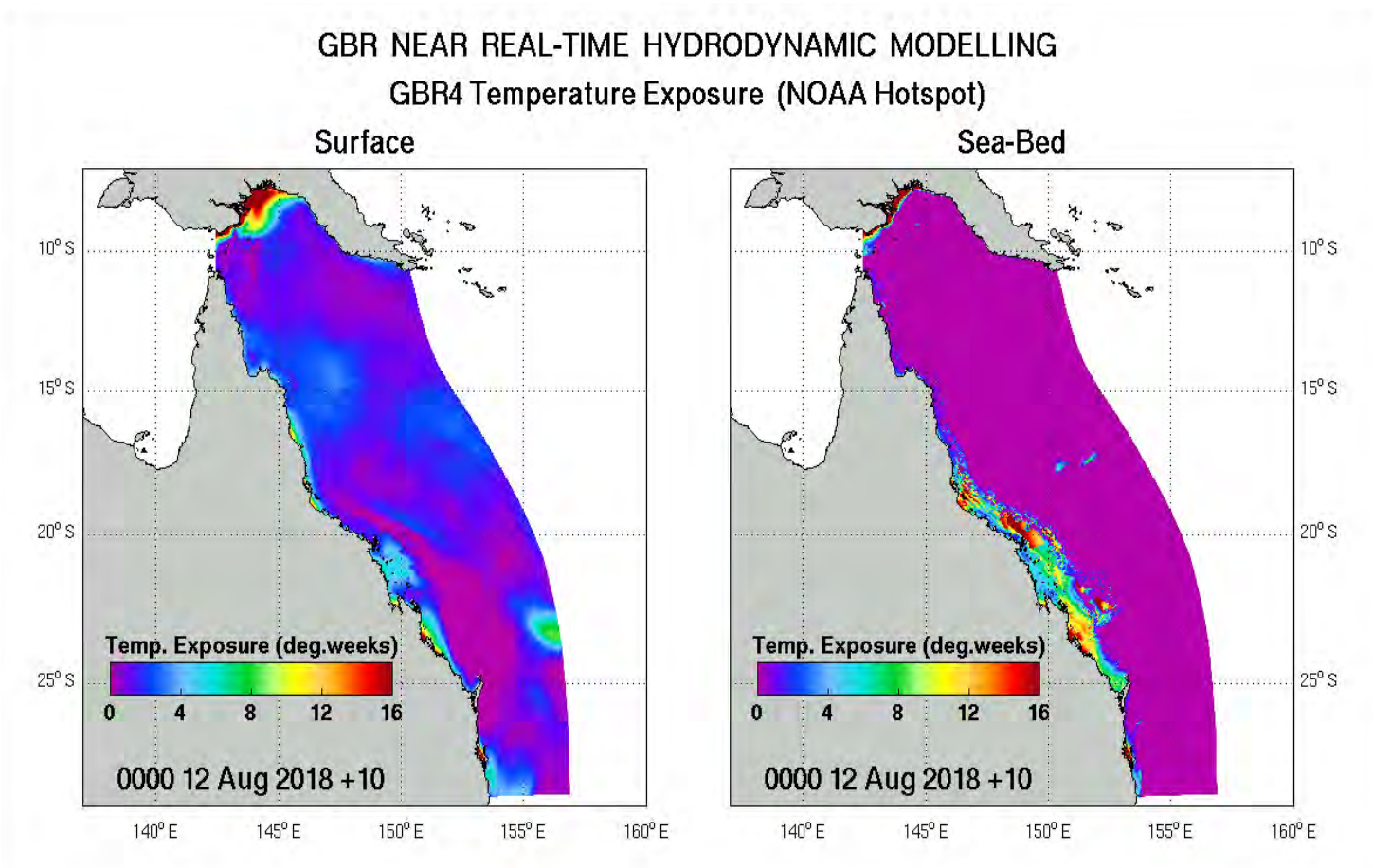
Today -9

Observations and Model intercomparisons:

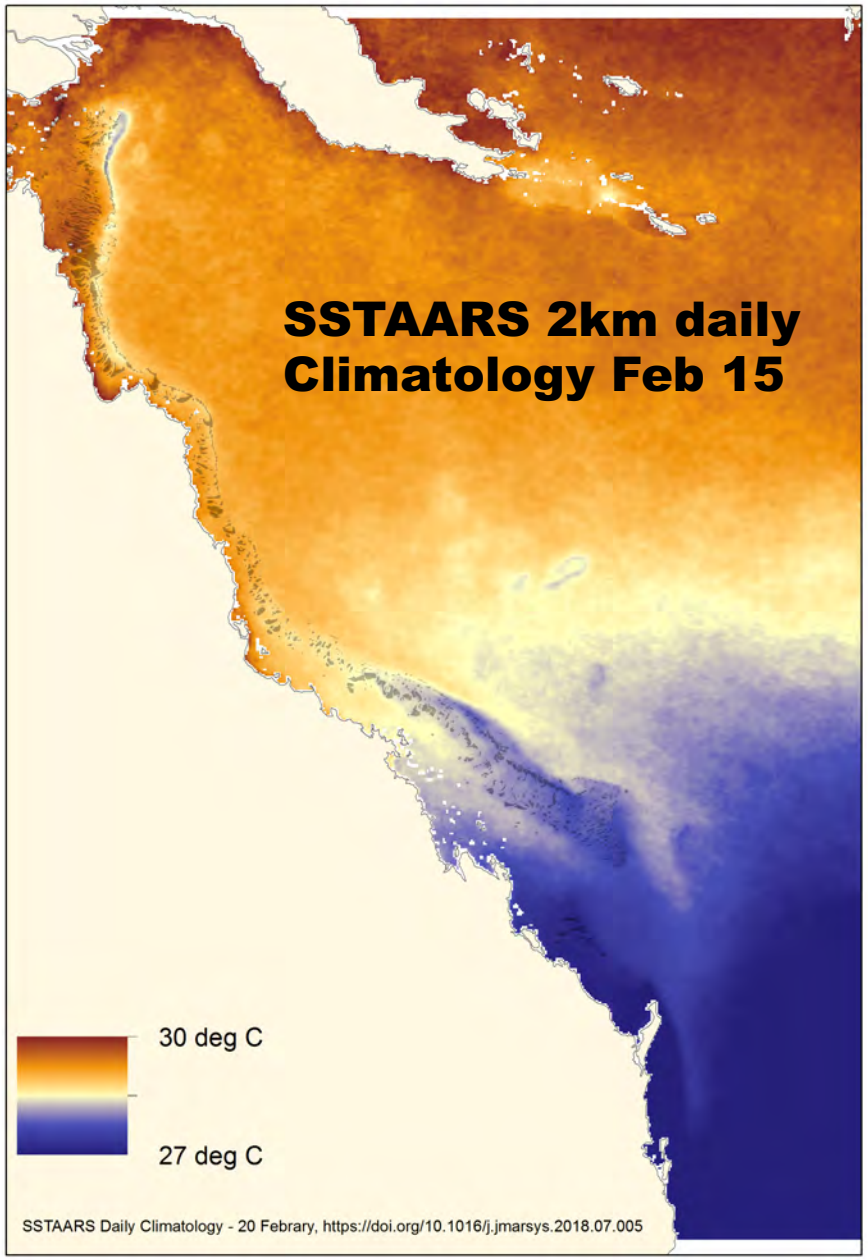
Products are often found on different locations with different ranges and colourbars

New Products:

- Replicating accepted products using models
- Hybrid model – observation products
- Fill gaps – add depth

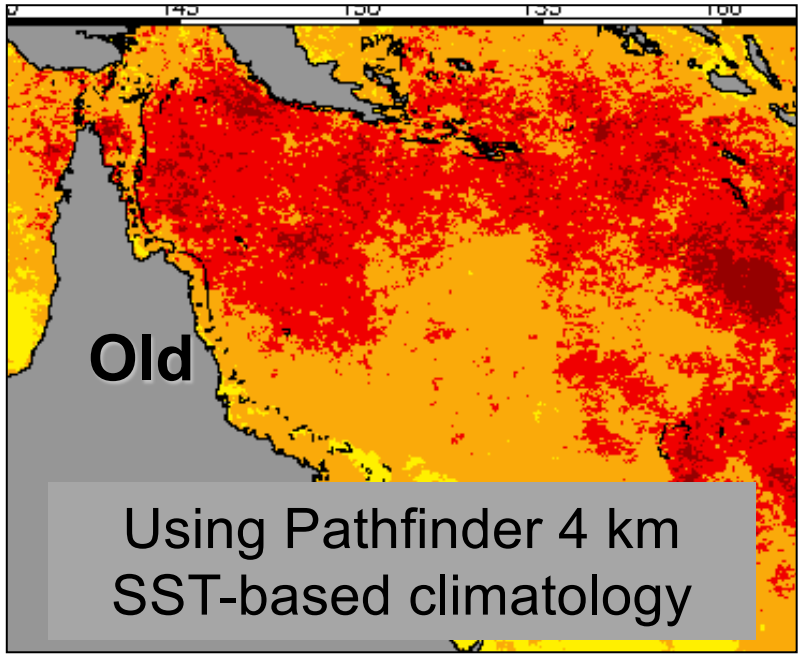


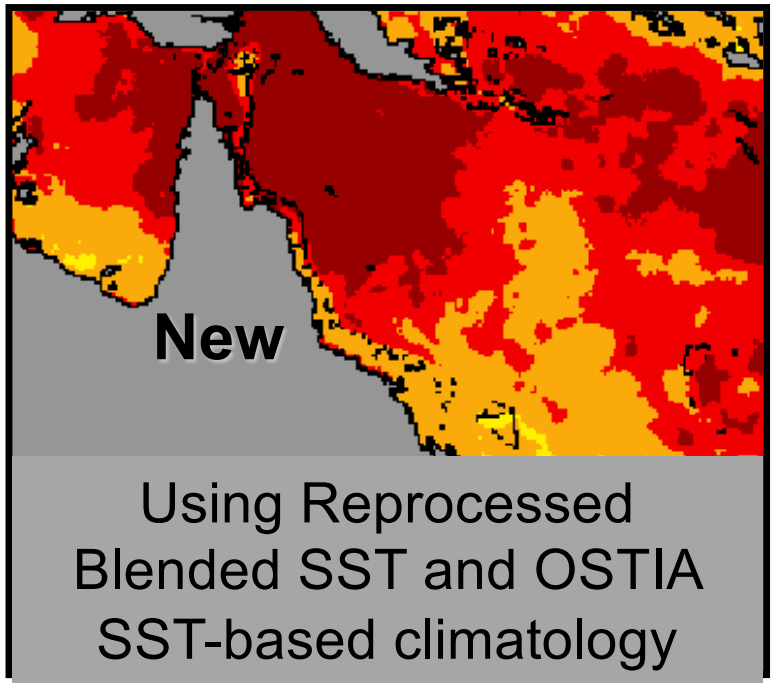
National Environmental Science Programme
TROPICAL WATER QUALITY HUB



Improved Climatology

improved products



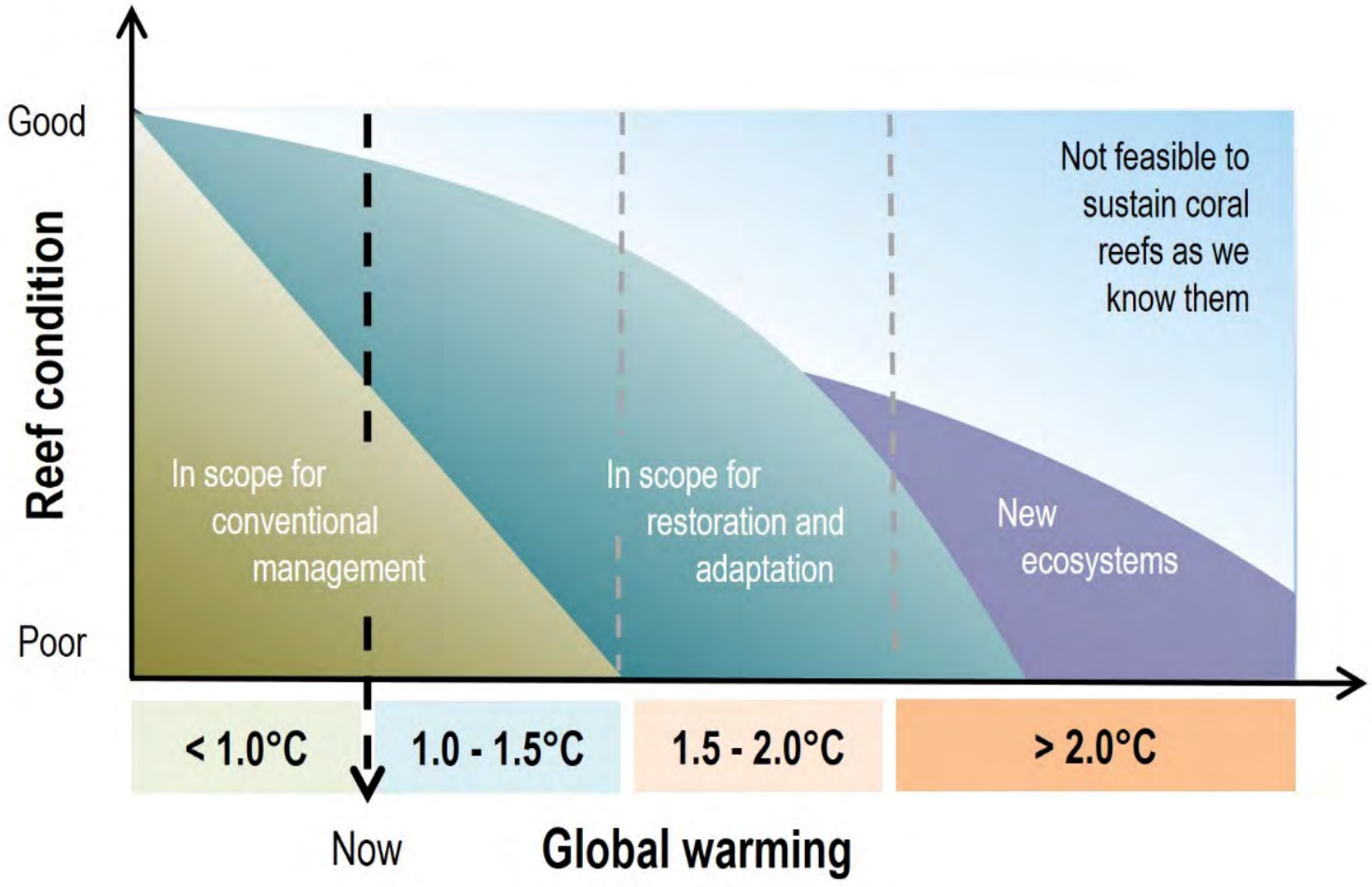


Moving to Interventions - At-scale restoration and adaptation

Modelling shows restoration and adaptation interventions needed in addition to reducing emissions and continued best-practice Reef management.

The longer we wait:

- the more expensive and difficult to successfully intervene at any scale
- the greater the risk the window of opportunity will close.

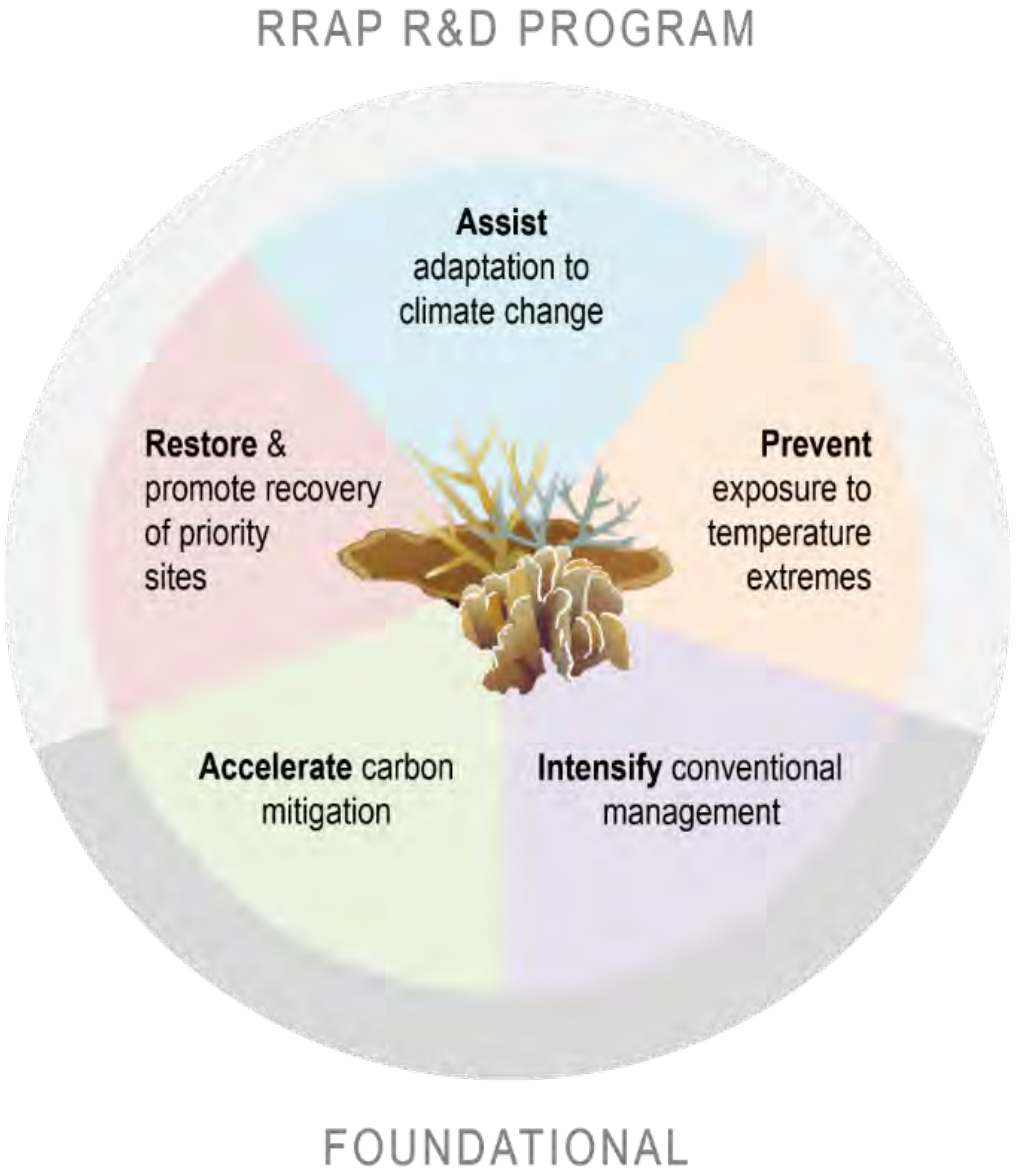


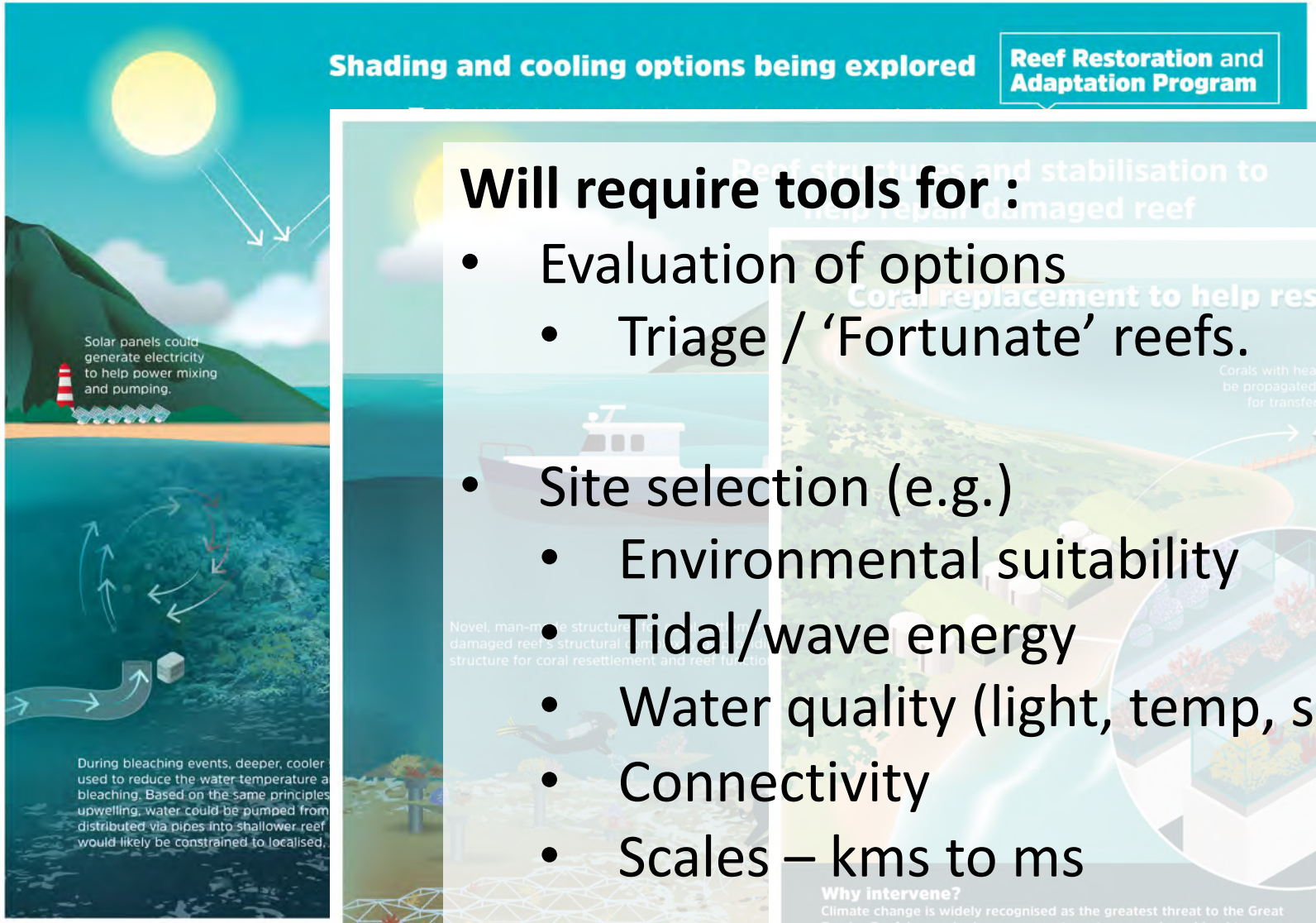
Source: modified from Anthony (2016)

Multiple approaches

Interventions to be implemented in an integrated three-point approach:

1. cooling and shading the Reef to help **protect** it
2. **restoring** damaged and degraded reefs
3. assisting Reef species to **adapt** to the changing environment → minimise need for ongoing intervention





Will require tools for :

- Evaluation of options
  - Triage / ‘Fortunate’ reefs.
- Site selection (e.g.)
  - Environmental suitability
  - Tidal/wave energy
  - Water quality (light, temp, salinity etc)
  - Connectivity
  - Scales – kms to ms
- Logistics of operations and deployments

Requirements for Reef Management

Needs:

Tactical – response

- Bleaching, flooding, TC tracks and damage zones,
- Maritime operations

Strategic – Planning and intervening

- Management, planning usage, zoning
- RRAP

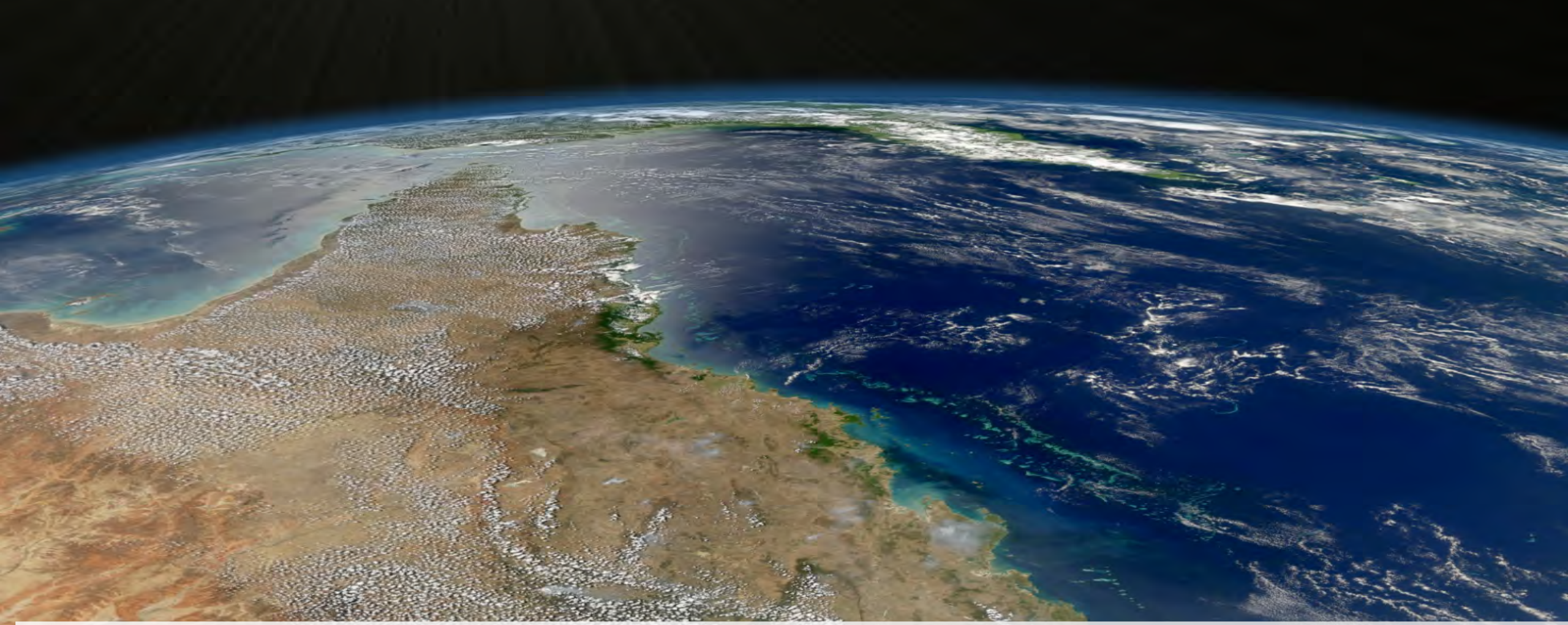
Tools need to be able to integrate obs and models –

- Fill gaps/dimensions
- Understand current state and assess future state, predictions of impacts.
- fortunate reefs – triage

Priority:

- Consistent maintenance of products
- Consistent frequency of information updates
- Importance of three dimensionality of the reef system considered and incorporated
- new products should be agnostic of data source (observations versus models)

- Higher resolution – capture scales of most relevant variability
- Higher frequency of information updates



Australian Institute of Marine Science

Australian Government
Bureau of Meteorology

Australian Government
Great Barrier Reef Marine Park Authority

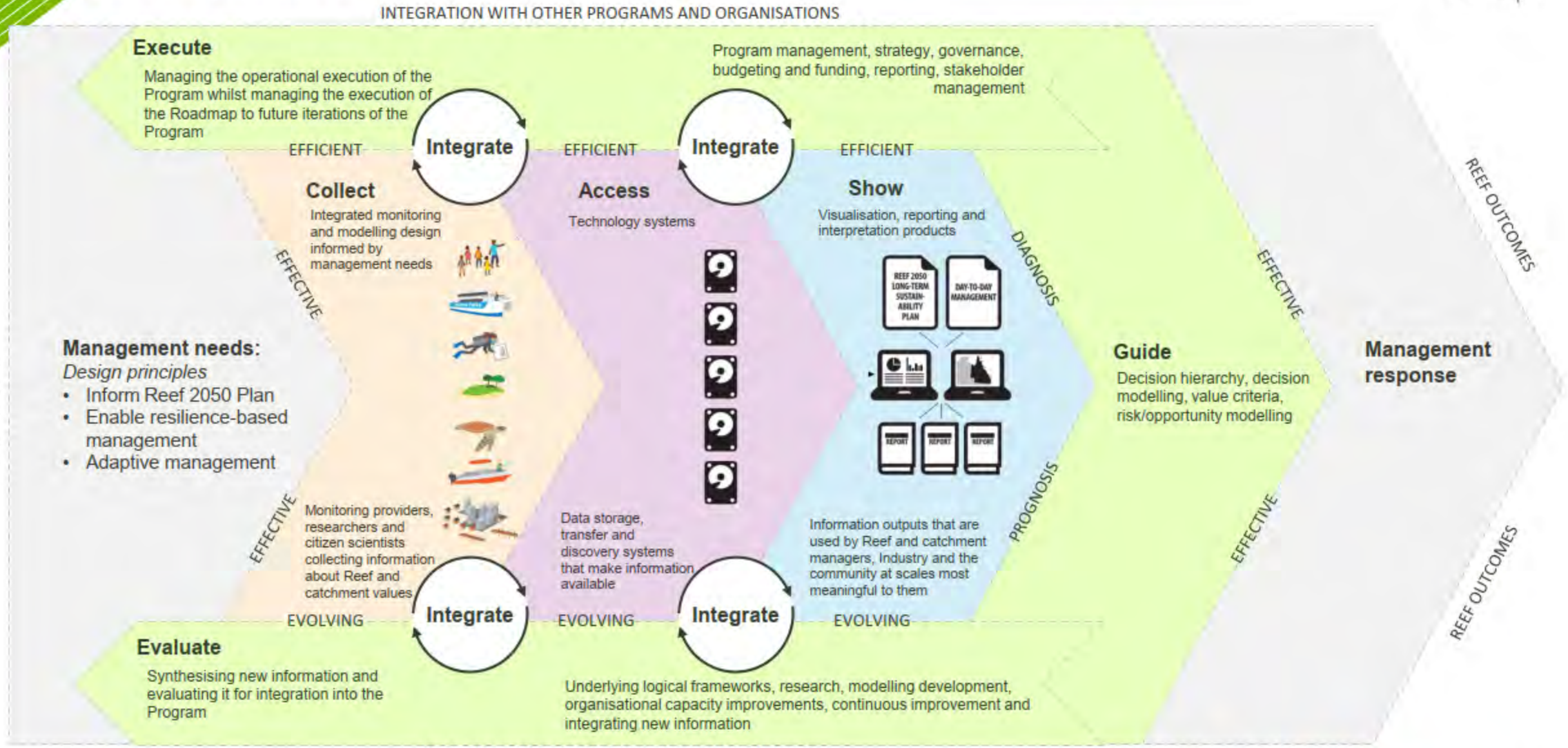
ARC Centre of Excellence
Coral Reef Studies

National Oceanic and Atmospheric Administration
U.S. Department of Commerce
NOAA

National Environmental Science Programme
Tropical Water Quality Hub

Proposed RIMReP Program Design

Bringing ideas to life



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