Distilling actionable information from earth observation in marine and freshwater ecosystems

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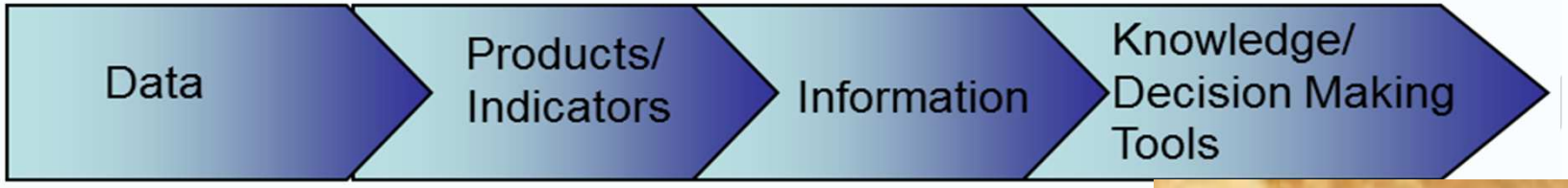
CNR Consiglio Nazionale delle Ricerche

irea istituto per il rilevamento elettromagnetico dell'ambiente

CSIRO



Actionable information (by stakeholders, policy makers, general public) from earth observation

Examples on “distilling information” for inland an coastal waters in Australia and Europe

Multi-temporal MERIS data to support the implementation of the Water Framework Directive

MERIS FR
Pixel size ~ 300 m

Data → Products/ Indicators → Information → Knowledge/ Decision Making Tools

SMILE
performe an irradiance to all bands
(BEAM-VISAT)

ICOL
correction for adjacency effects
(BEAM-VISAT)

Over 200 images
WFD

Atmospheric correction
(BEAM-VISAT)

Case2Regional Processor
(BEAM-VISAT)

Chl-a products

13 deep perialpine lakes

Bresciani et al., (2011). *Science of the Total Environment* 409: 3083–3091.

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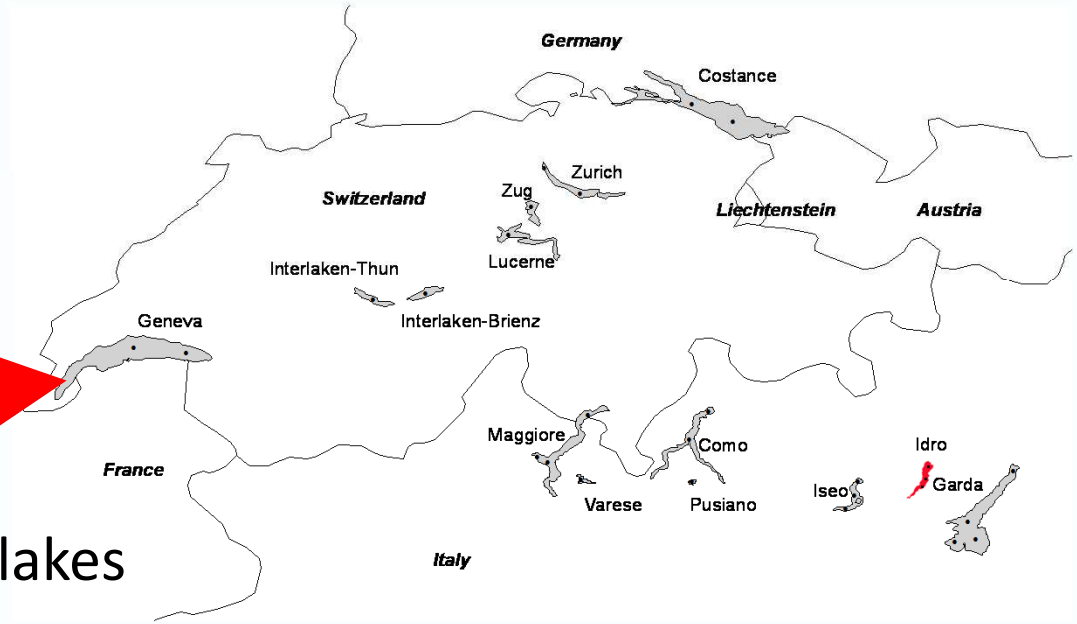

YOU ARE HERE !

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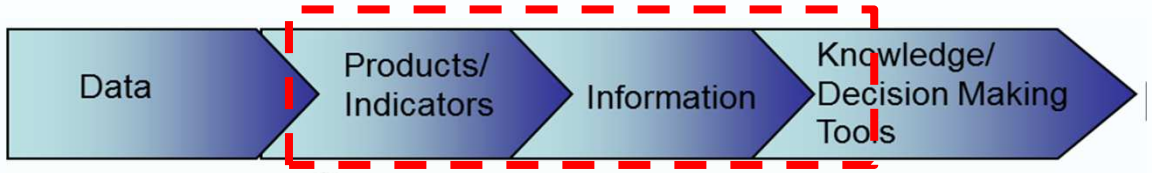
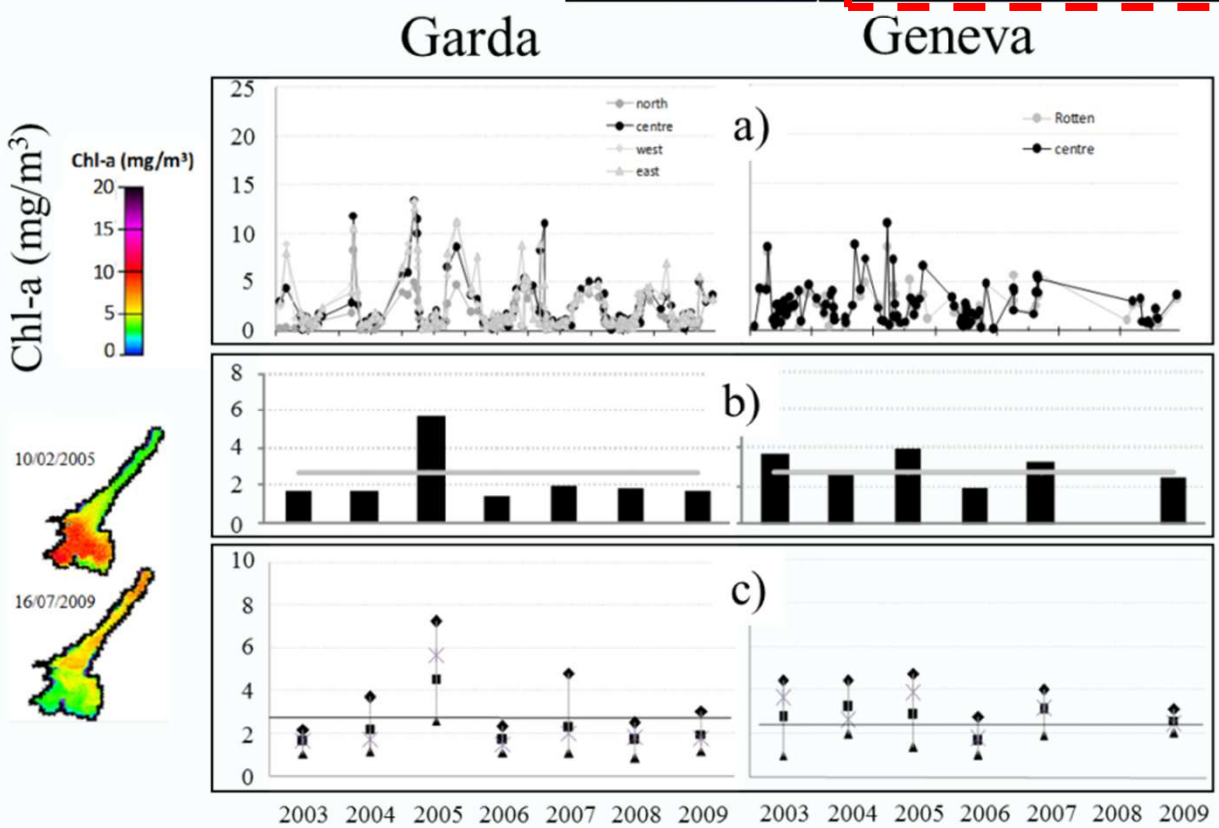
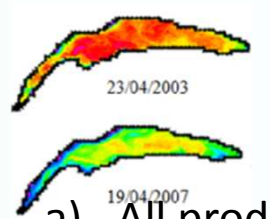




a) Trends of chl-a concentrations
b) Annual average value of Chl-a (one data for the six key periods of the year defined by WFD)



a) All product images available for the six key periods of the year (statistics analysis)

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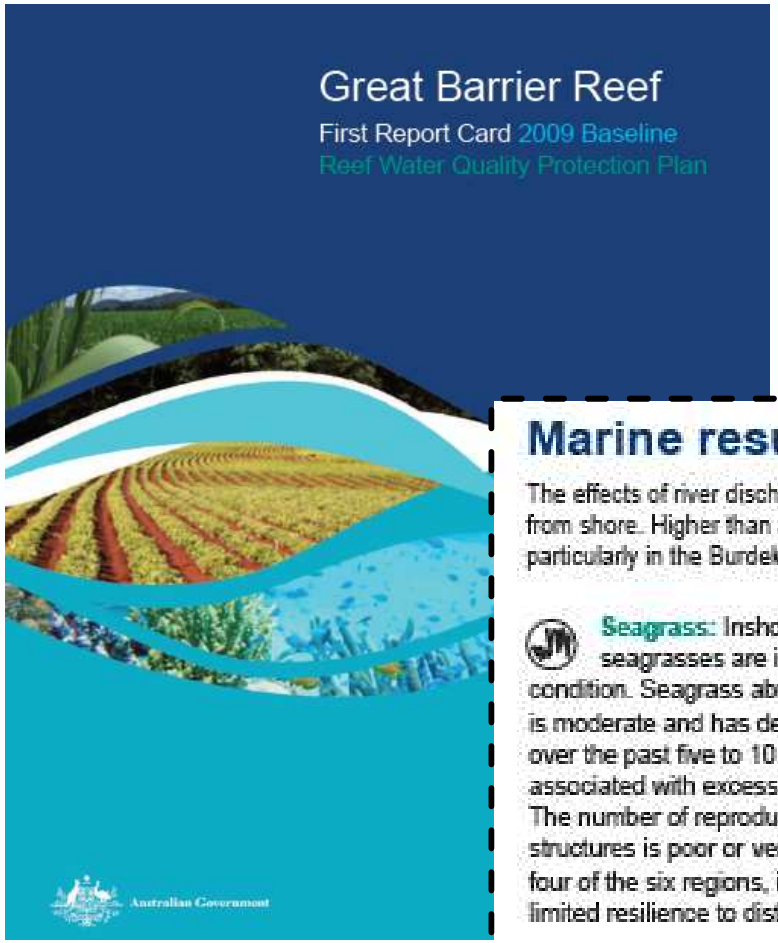
istituto per il rilevamento elettromagnetico dell'ambiente

GBR Report card

http://www.reefplan.qld.gov.au



Marine results

The effects of river discharge into the Great Barrier Reef are largely concentrated into inshore areas up to 20 kilometres from shore. Higher than average wet season rainfall in the Great Barrier Reef catchment occurred between 2007 and 2009, particularly in the Burdekin River catchment. Marine results for 2008–2009 are presented for seagrass, water quality and coral.

Seagrass: Inshore seagrasses are in moderate condition. Seagrass abundance is moderate and has declined over the past five to 10 years, associated with excess nutrients. The number of reproductive structures is poor or very poor in four of the six regions, indicating limited resilience to disturbance.

Waters within 20 kilometres of the shore are at highest risk of degraded water quality. These waters are only approximately eight per cent of the Great Barrier Reef Marine Park, but support significant ecosystems as well as recreation, tourism and fisheries.

Coral: Most inshore reefs are in good or moderate condition, based on coral cover, macroalgal abundance, settlement of larval corals and numbers of juvenile corals. Most inshore reefs have either high or increasing coral cover; however, corals in the Burdekin region are mostly in poor condition.

Water quality: Inshore water quality is moderate overall. Concentrations of total suspended solids range from poor (Burdekin and Mackay Whitsunday regions) to very good (Burnett Mary region).

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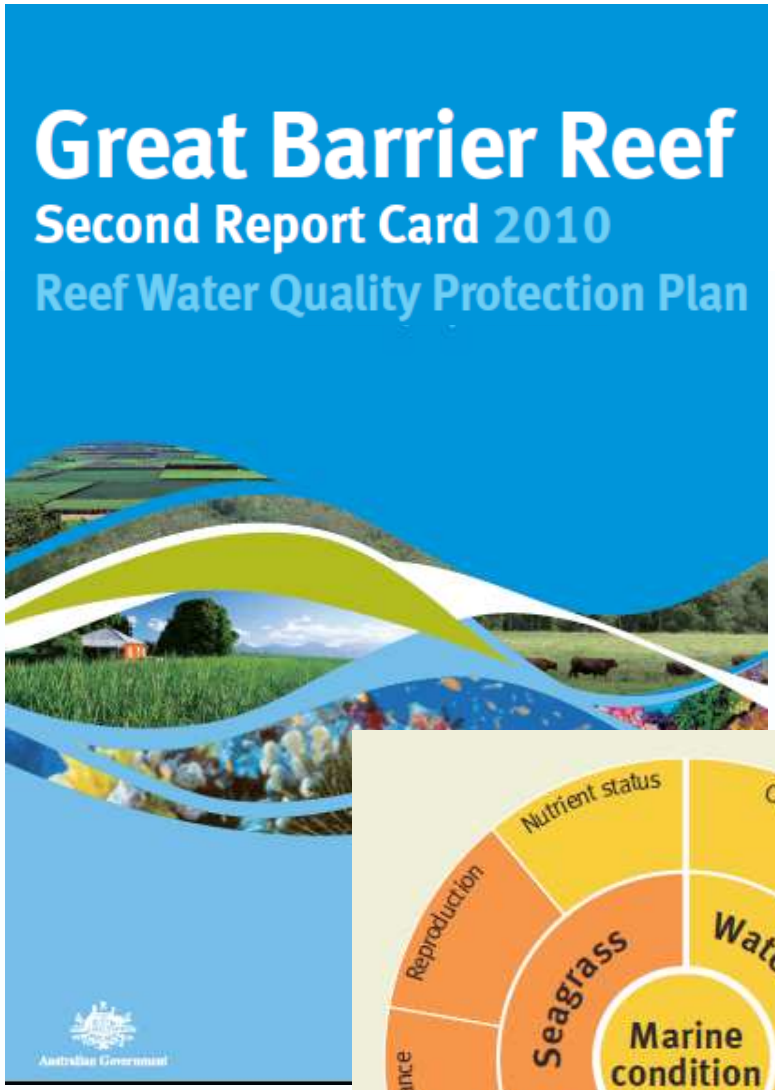
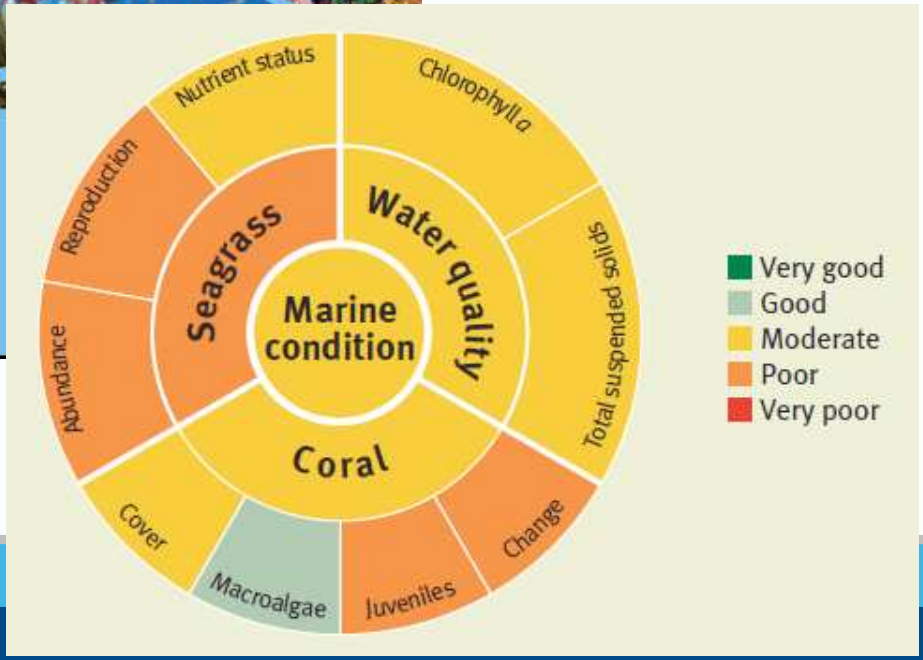
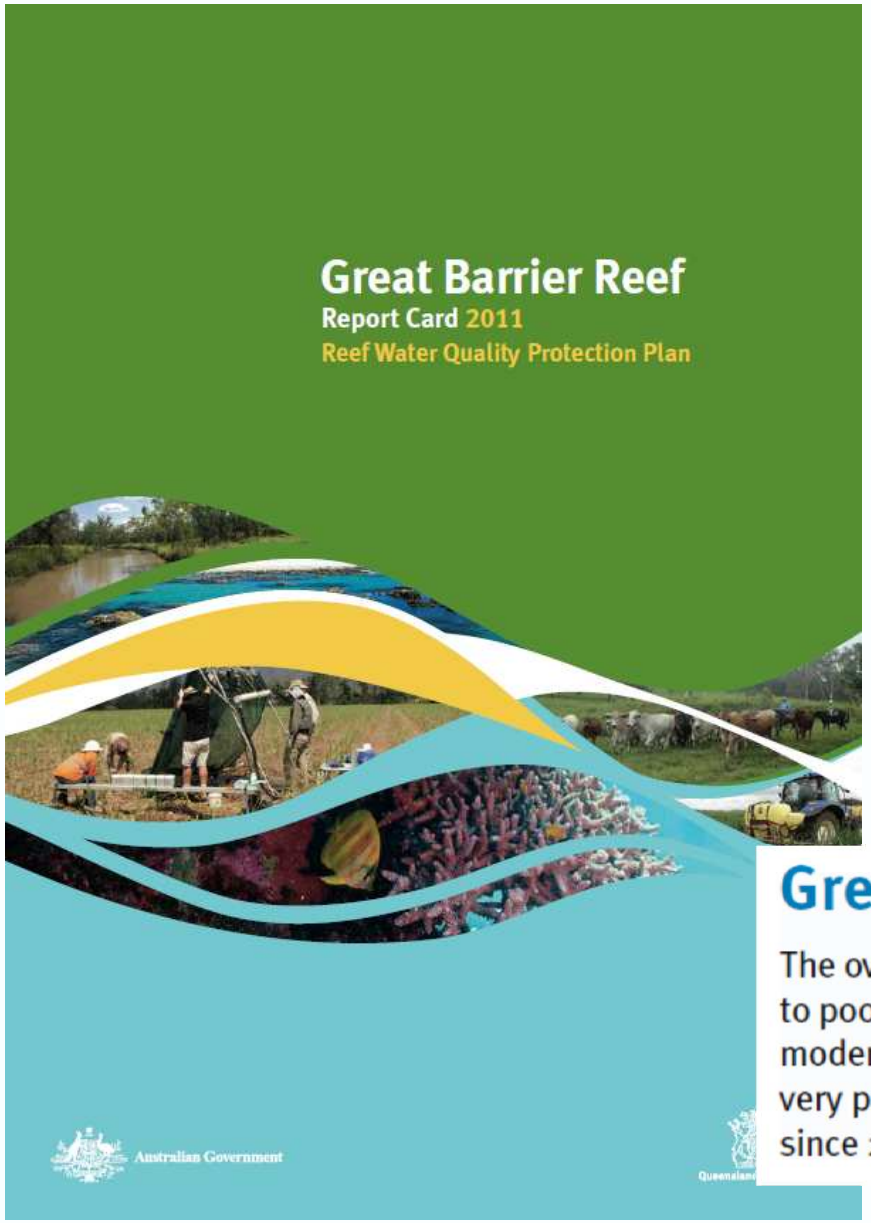
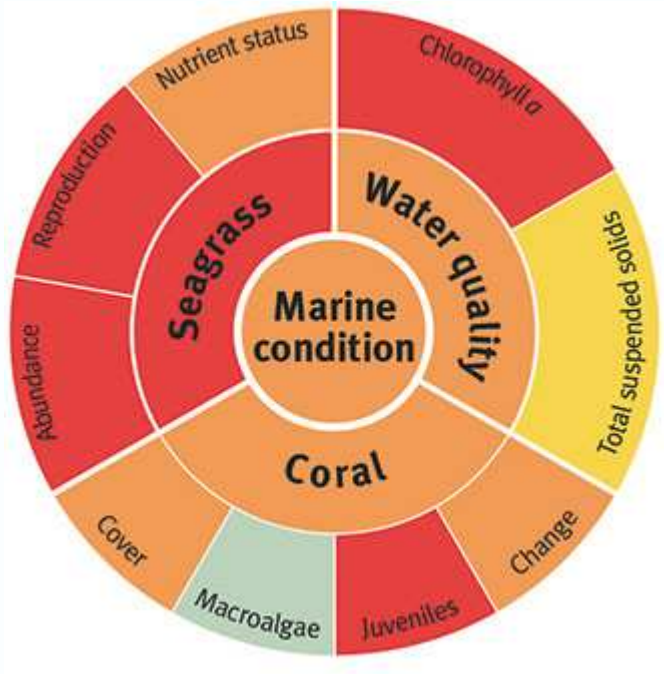


*"The condition of the marine environment remained moderate overall in 2009-2010. This ranking comprises **moderate scores for water quality** and coral and a poor score for seagrass, which has declined during the past four years."*







Great Barrier Reef-wide

The overall condition of the reef in 2010-2011 declined from moderate to poor. Inshore water quality was poor overall and varied from moderate to poor depending on the region. Inshore seagrass was in very poor condition overall, and its condition has continued to decline since 2006-2007. Inshore coral reefs were in poor condition overall.

Great Barrier Reef

Report Card 2012 and 2013

Reef Water Quality Protection Plan

Australian Government

Queensland Government

condition using the following categories:

Very good
Good
Moderate
Poor
Very poor

Marine condition 2012–2013

Improvements in land management practices will take time to translate into improved marine condition as there are significant time lags between implementation and measurable outcomes in these natural systems. Inshore marine condition is also strongly influenced by episodic events such as tropical cyclones and floods which have impacted all regions in recent years.

Confidence in the marine results for Cape York and the Burnett Mary remains low due to limited data availability and validation. Consequently, data from these regions are not used in the Great Barrier Reef-wide assessment.

Great Barrier Reef-wide

The overall condition of the inshore reef remained poor in 2012–2013. Inshore water quality was poor and varied from moderate to poor depending on the region. Inshore seagrass showed signs of recovery in some regions and improved from very poor to poor. Inshore coral reefs remained in poor condition.

CAPE YORK

Cape York

The overall marine condition adjacent to Cape York improved from poor to moderate. Inshore water quality also improved from poor to moderate. The one southern seagrass bed monitored was in poor condition.

WET TROPICS

Wet Tropics

The Wet Tropics' overall inshore marine condition remained poor. Inshore water quality remained poor and seagrass meadows declined from poor to very poor. Coral reefs were in poor condition having declined from moderate in 2011.

BURDEKIN

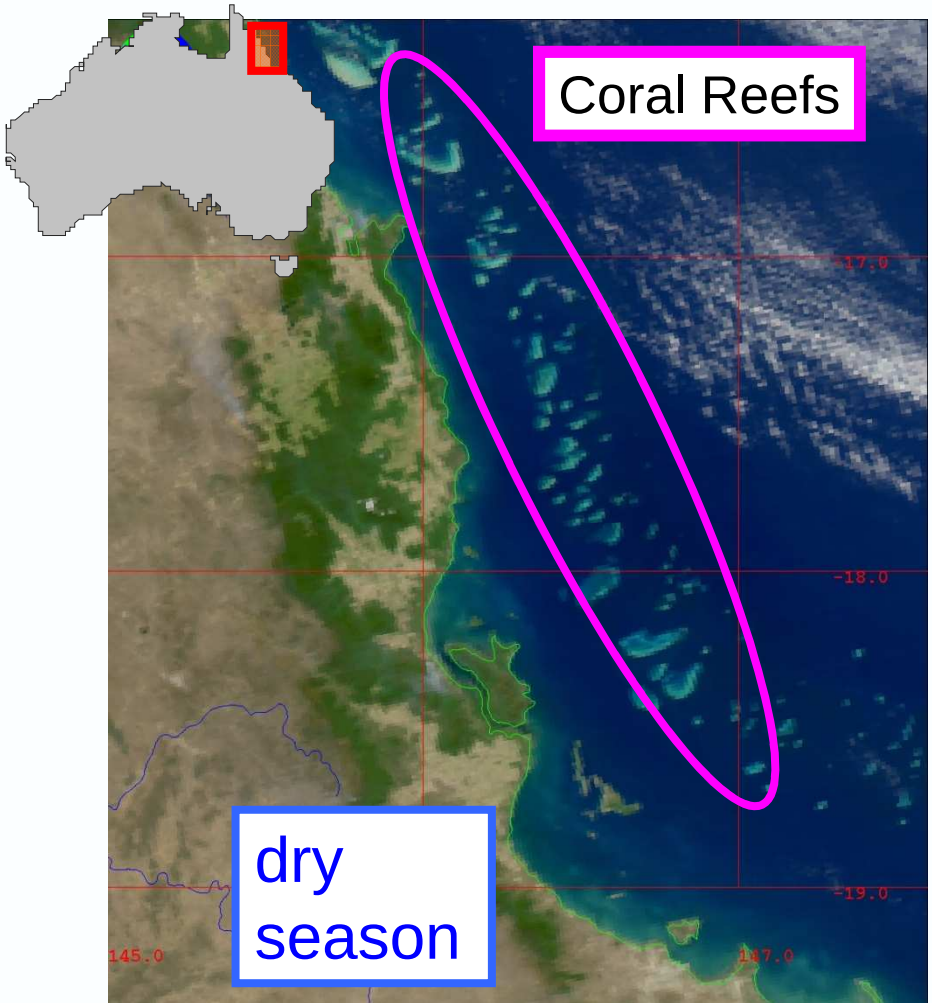
Burdekin

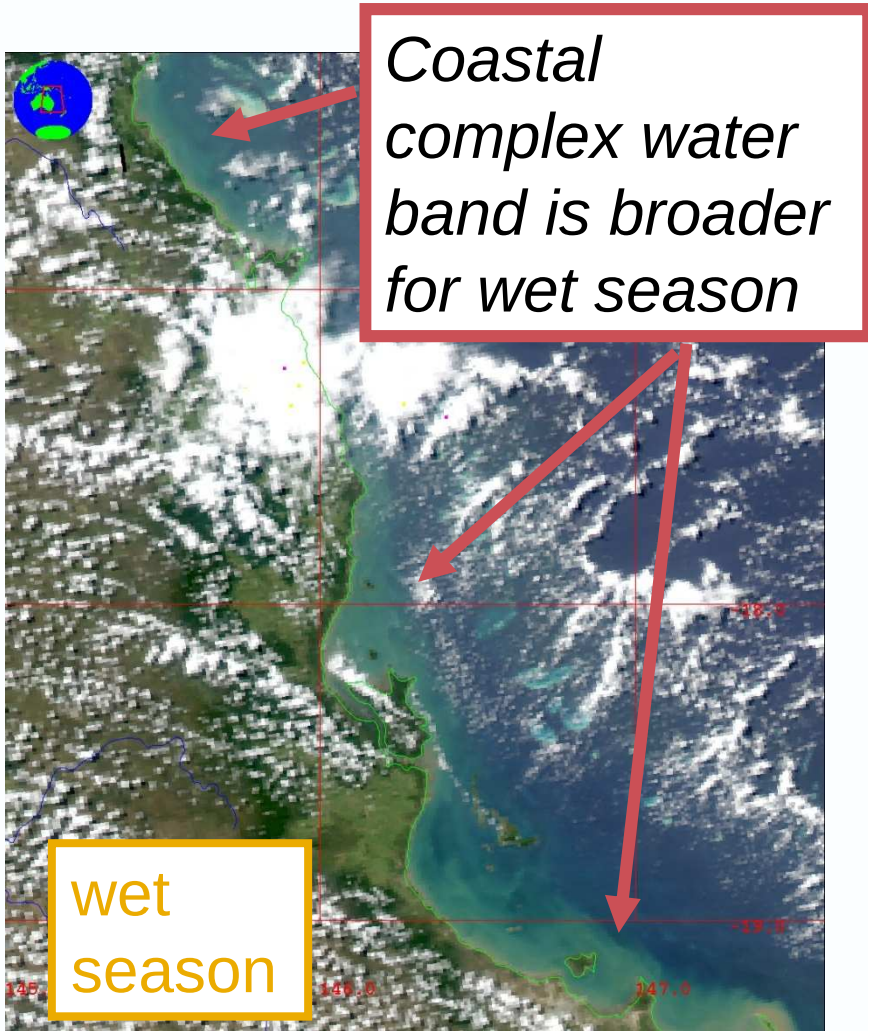
The Burdekin's overall inshore marine condition remained poor. Inshore water quality remained moderate, while inshore seagrass meadows improved from very poor in 2011–2012 to poor. Coral reefs remained in poor condition.

MACKAY WHITSUNDAY

Mackay Whitsunday

Coastal waters of the Great Barrier Reef: Optical complexity and seasonal differences

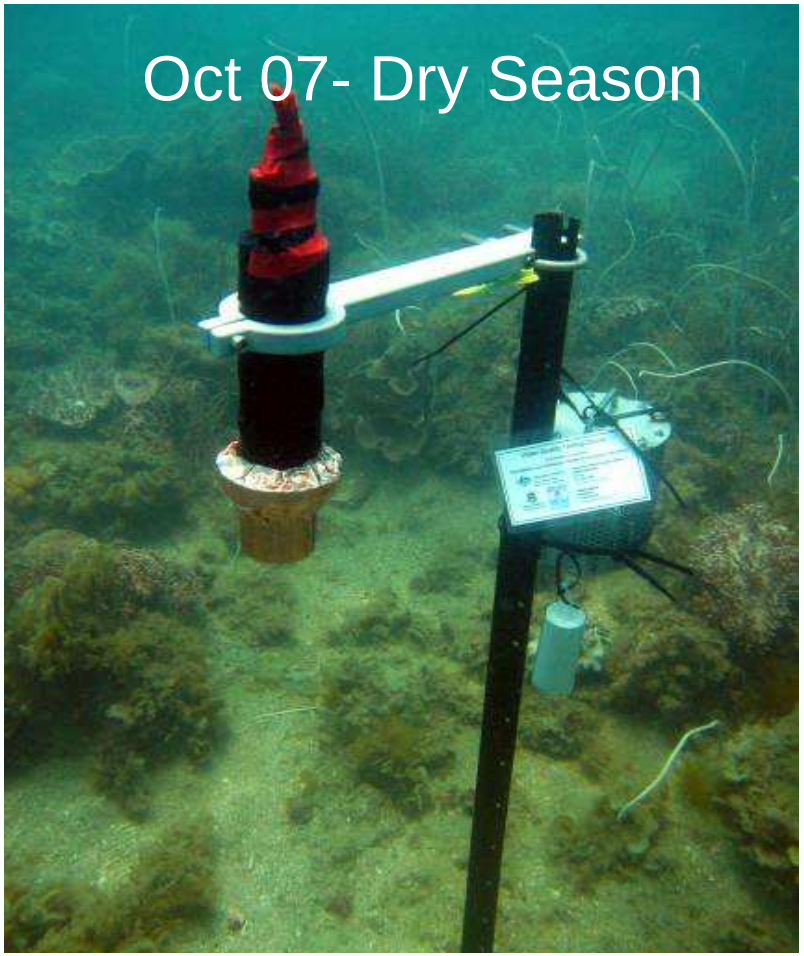




MODIS AQUA
20 September 2007

19 April 2008

Coastal waters of the Great Barrier Reef: Optical complexity and seasonal differences



WET Labs Eco FLNTU (Fluorometer and Turbidity Sensor) at Barren Island

Photos courtesy of Britta Schaffelke, AIMS

Australian Government

Australian Institute of Marine Science

CSIRO

Remote sensing in coastal waters: dealing with optical complexity

Retrieval algorithms exploit the relationship between water-leaving radiances (i.e. the “ocean colour”) and other biological or optical parameters

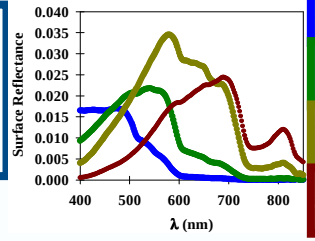
Optically Active Constituents
- Phytoplankton
- Suspended matter
- Coloured dissolved organic matter
- Water itself

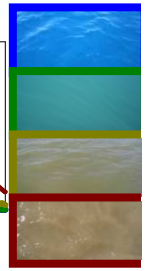
Empirical approaches

(statistical methods)

Physics-based approaches

(model inversions)



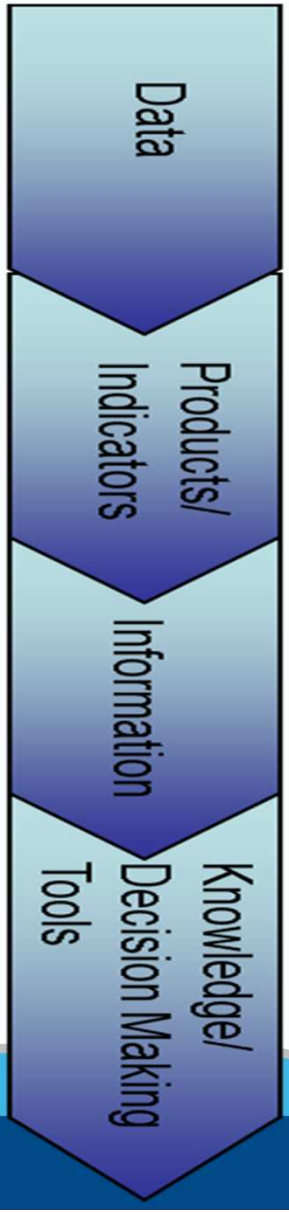


Inherent optical properties
- Absorption (a)
- Scattering (b)
- Beam attenuation (c)
- Volume scattering [β(0)]

Apparent optical properties
- Colour
- Reflectance [$R(0\text{-})$]
- Attenuation (K_d)
- Transparency (Z_{SD})

Environmental reporting of water quality retrieval for complex waters for the Great Barrier Reef

- A physics based approach
  - Characterize the optical properties of GBR coastal waters
  - Assess validity of NASA's global algorithms
  - Develop regionally valid algorithm
- Translation into management relevant information
  - Engage with stakeholders to understand end-user needs
  - Process 11 years of daily images at 1 km resolution
  - Deliver water quality data to GBR monitoring programs
  - Operational processing system



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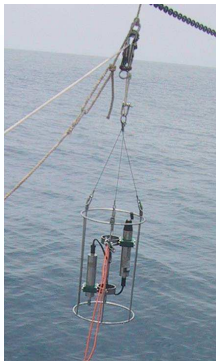
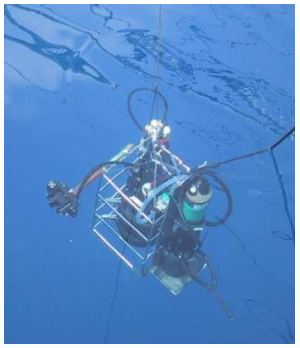
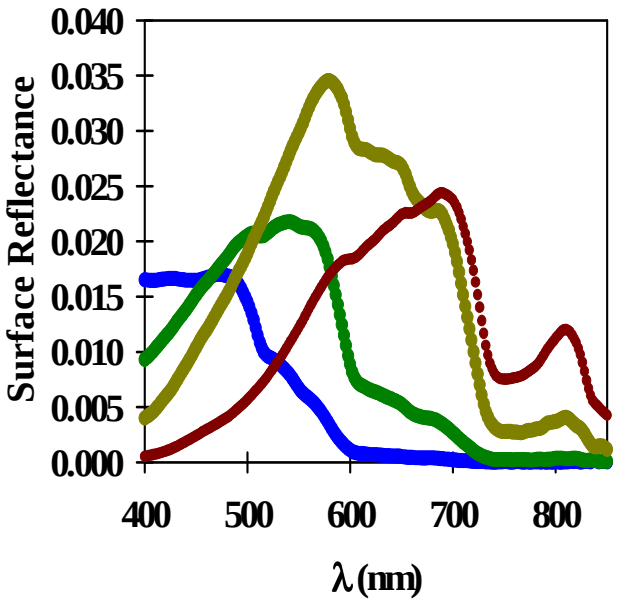
- 250 stations during 2002-2008







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- "Changes in particle concentration, size and chemical composition lead to large variability in the associated optical properties"

  (Oubelkheir et al., 2006, JGR)

- "The characteristics of these tropical water types fall outside the predefined ranges used in the MODIS algorithms".

  (Blondeau-Patissier et al., 2009, JGR)

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- Sensitivity analysis of retrieval uncertainty for MODIS algorithms
  - In this region, the variability in optical properties leads to poor performance of MODIS standard algorithms for chlorophyll and bulk IOP retrieval

(Qin et al., 2007, GRL)

- Need to develop a regionally valid algorithm that incorporates regional and seasonal knowledge of optical properties

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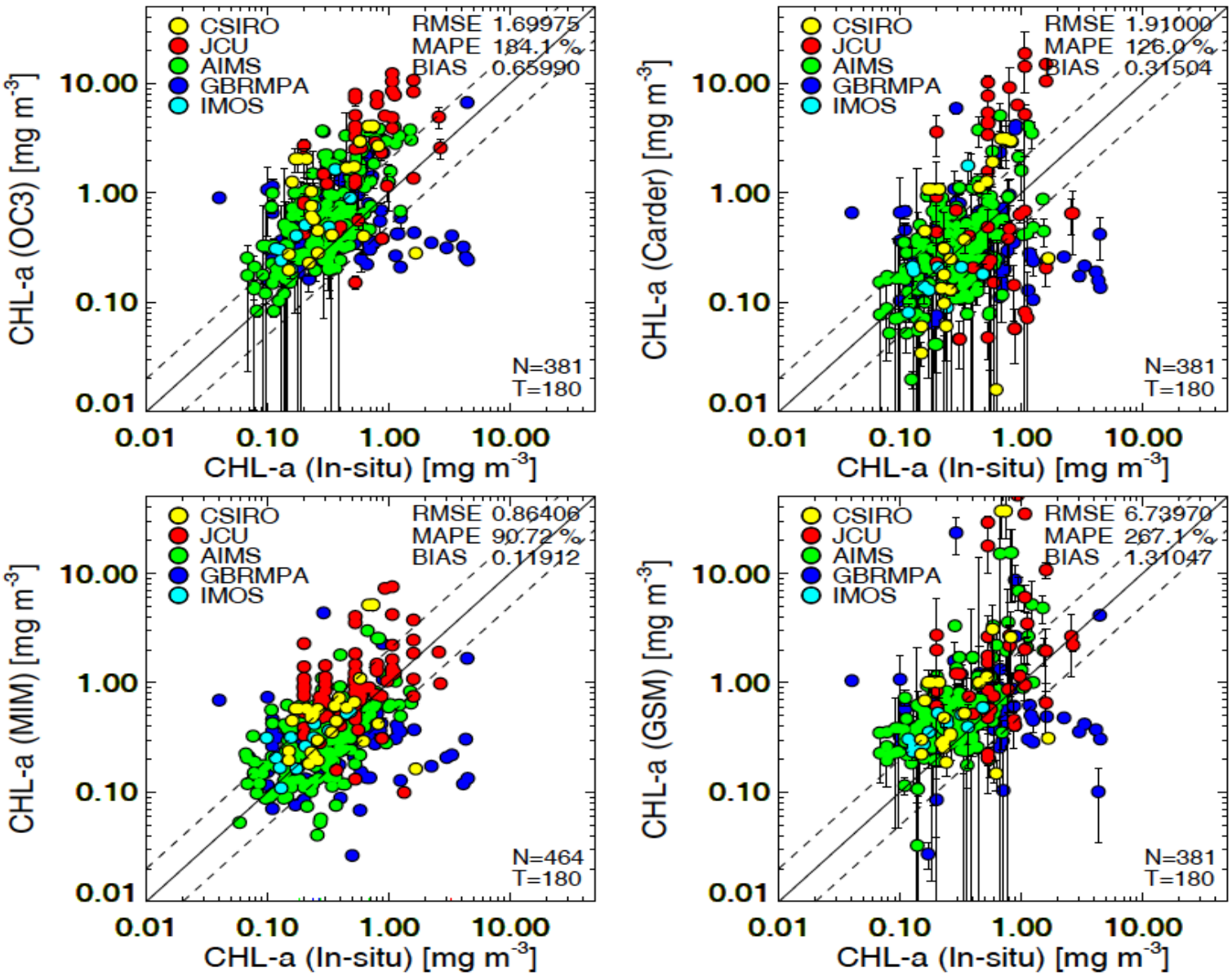
Two physics-based inversion algorithms were coupled to improve the accuracy of retrievals from MODIS data

1. Artificial Neural Network based atmospheric correction
   (Schroeder et al., 2012, MPB)
2. The optically active constituents were retrieved using an algorithm that incorporates regional and seasonal knowledge of optical properties
   (Brando et al., 2012, AO)

Retrieval of Chlorophyll-a: Validation results for Great Barrier Reef Waters



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The coupled physics-based inversion algorithms perform better compared to NASA standard products

BUT … there is a need for ongoing calibration and validation

King, E.A., T. Schroeder, V.E. Brando, and K. Suber, *A Pre-operational System for Satellite Monitoring of Great Barrier Reef Marine Water Quality. eReefs Remote Sensing, Phase 1*, *Wealth from Oceans Flagship report.*2013.

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- From remote sensing imagery archives, it is possible to derive products suited to:
  - the specific needs of end-users or
  - particular geographic regions
- in a number of outputs:
  - maps,
  - animations,
  - statistical compliance assessments and
  - alert / anomaly systems.

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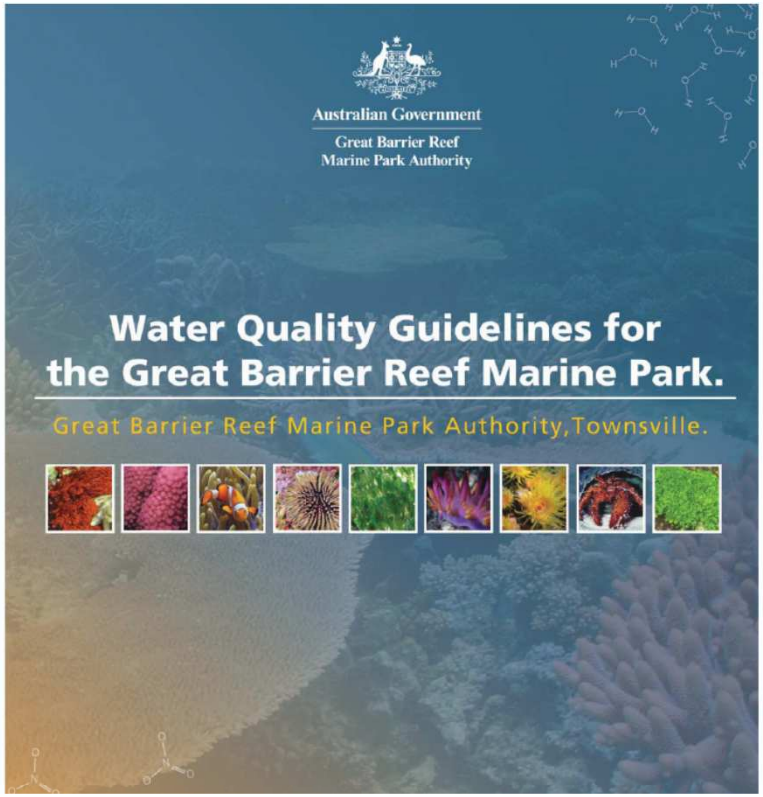
- Compliance with the water quality guideline released in 2009 for the entire GBRWHA for chlorophyll and total suspended solids.

Assessing compliance with the water quality guideline for the GBRWHA based on daily MODIS water quality data

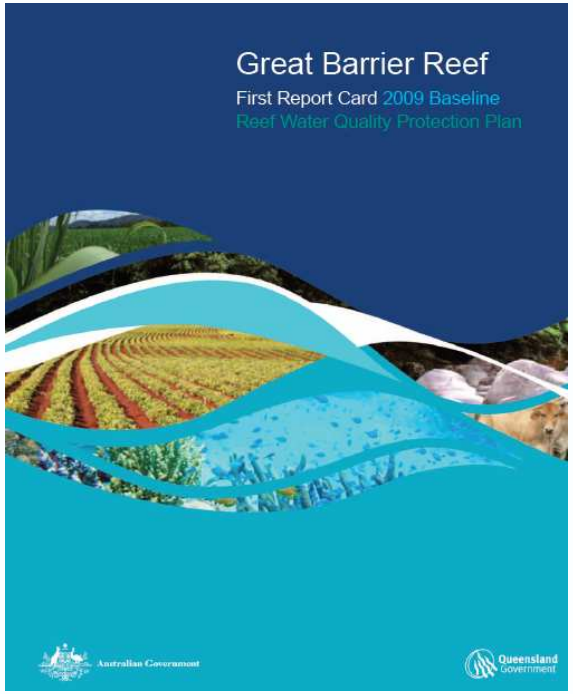


The guidelines provide triggers for management action where exceedance occurs

Satellite retrievals of Chlorophyll, Secchi depth and Total Suspended Solids and can be used for the assessment of compliance to these guidelines in the GBRWHA.

Parameter\Water Body	Enclosed coastal (Wet Tropics/Central Coast)	Open coastal	Midshelf	Offshore
Secchi (m) (minimum mean annual water clarity) [1]	1.0/1.5	10	10	17
Chl *a* (µg/L)[2]	2.0	0.45	0.45	0.4
SS (mg/L)	5.0[2]/15	2.0	2.0	0.7

GBR Report card



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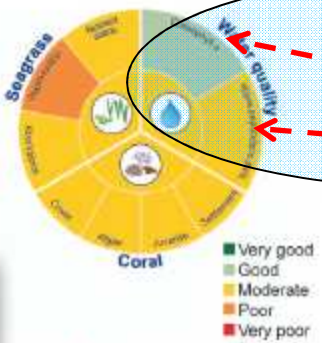

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Water quality: chlorophyll *a* and suspended solids

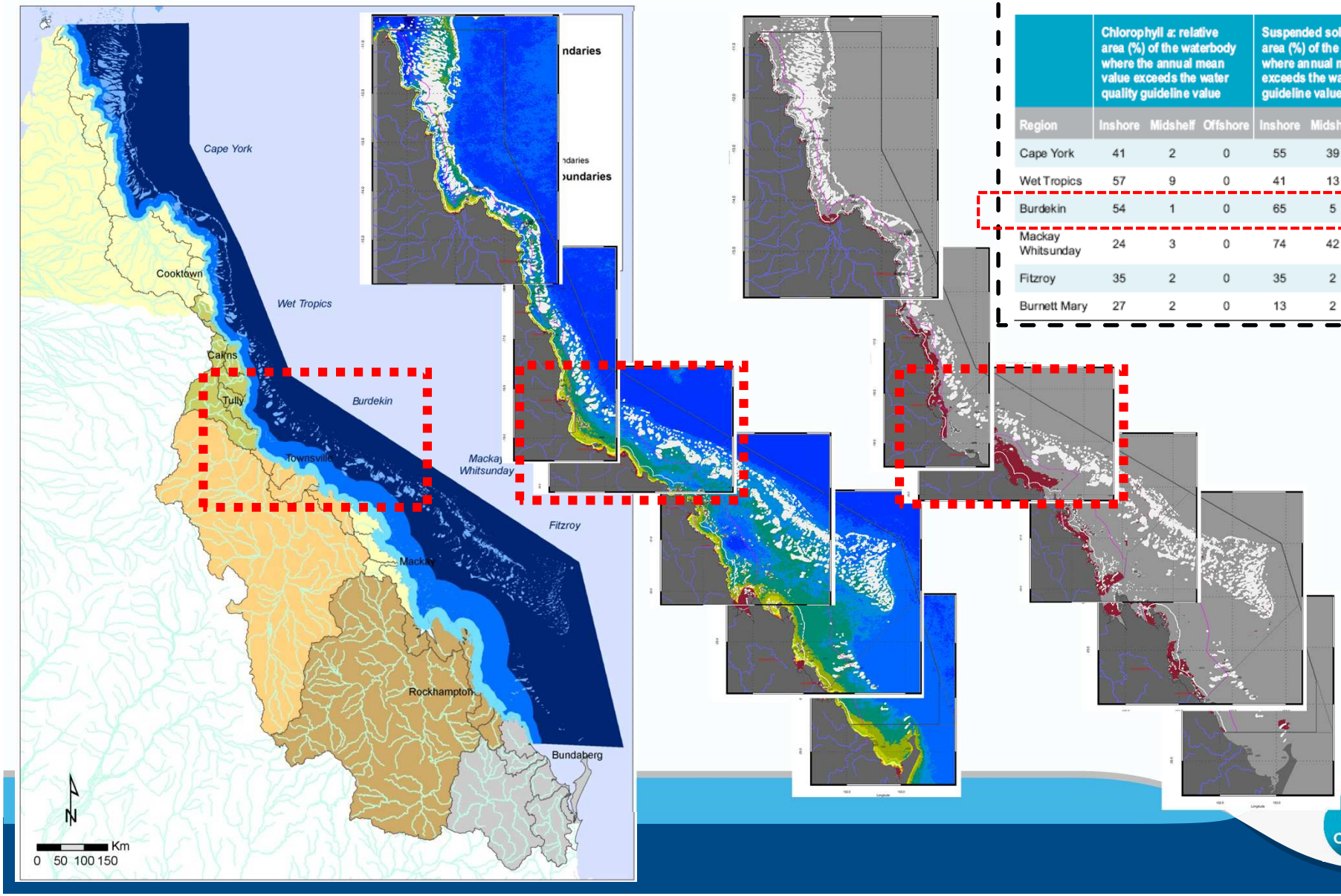
Chlorophyll *a* is used as an indicator of nutrient loads in the marine system. Data analysed from satellite imagery showed that inshore waters in the Wet Tropics and Burdekin regions had elevated concentrations of chlorophyll *a* over the monitoring period (Table 5.9).

The satellite data also showed that highest concentrations of suspended solids were recorded at inshore areas of the Cape York, Burdekin and Mackay Whitsunday regions. High concentrations of suspended solids were also recorded in midshelf and offshore waters in the Mackay Whitsunday region. It should be noted that the Cape York remote sensed water quality data requires further validation.

Table 5.9 – Summary of the exceedance of mean annual chlorophyll *a* and non-algal particulate matter as a measure of suspended solids using remote sensing data (retrieved from MODIS AQUA) for the inshore, midshelf and offshore waterbodies (1 May 2008–30 April 2009).

	Chlorophyll *a*: relative area (%) of the waterbody where the annual mean value exceeds the water quality guideline value			Suspended solids: relative area (%) of the waterbody where annual mean value exceeds the water quality guideline value		
Region	Inshore	Midshelf	Offshore	Inshore	Midshelf	Offshore
Cape York	41	2	0	55	39	13
Wet Tropics	57	9	0	41	13	12
Burdekin	54	1	0	65	5	3
Mackay Whitsunday	24	3	0	74	42	50
Fitzroy	35	2	0	35	2	0
Burnett Mary	27	2	0	13	2	3

Implementing the guidelines



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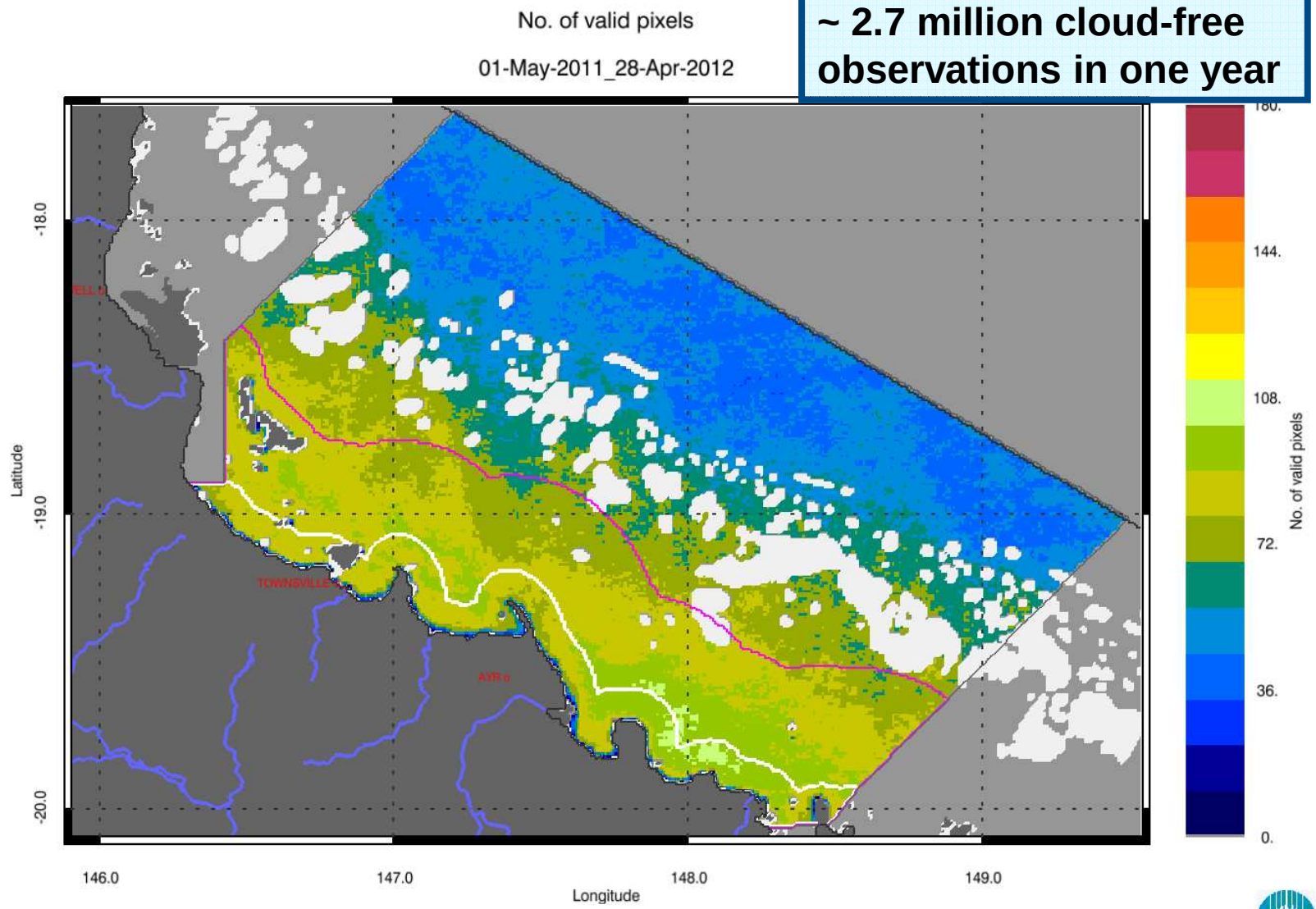
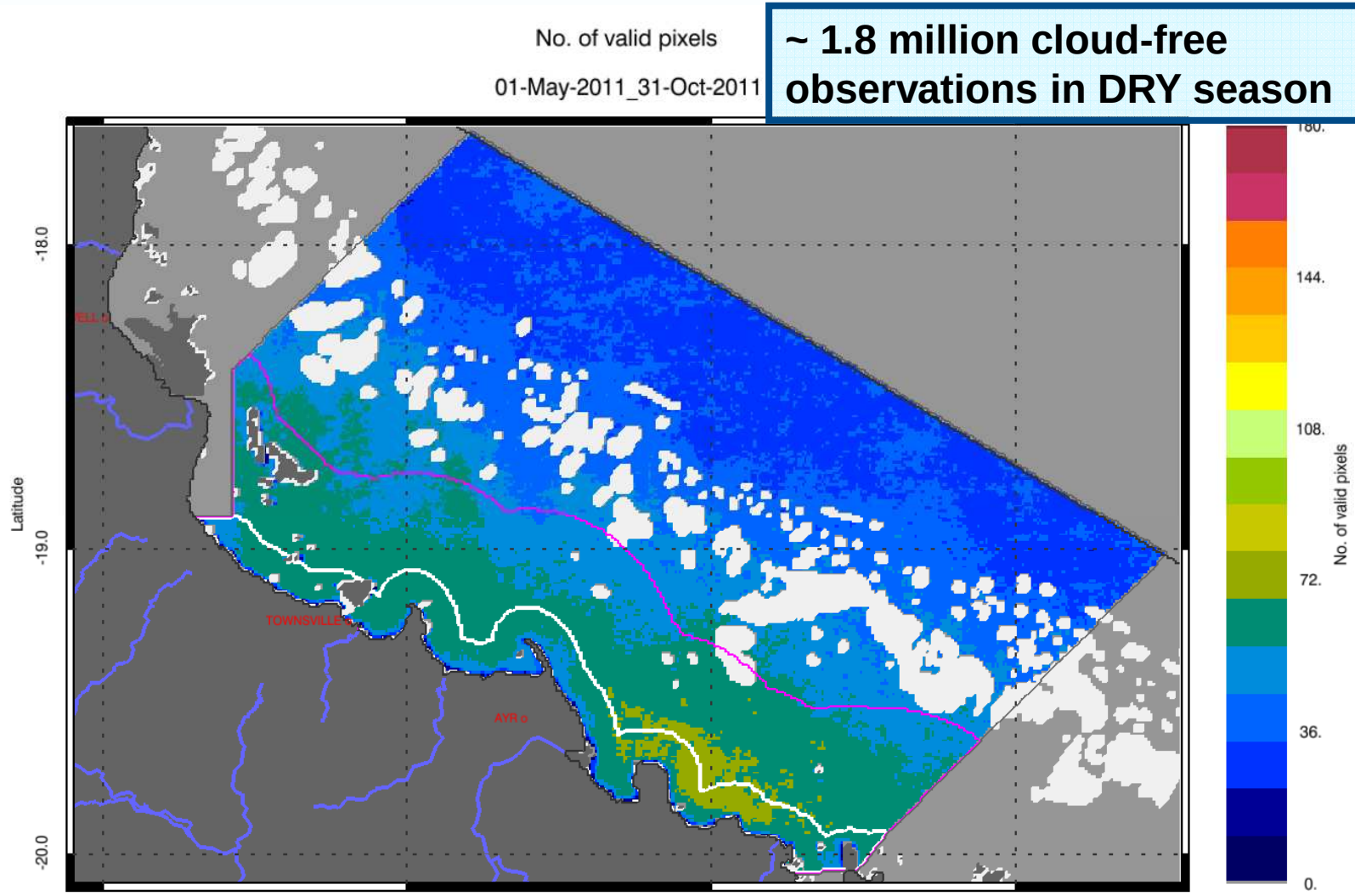
Reporting year 2011/12 - Burdekin region: satellite observations

~ 2.7 million cloud-free observations in one year



Reporting year 2011/12 - Burdekin region: satellite observations

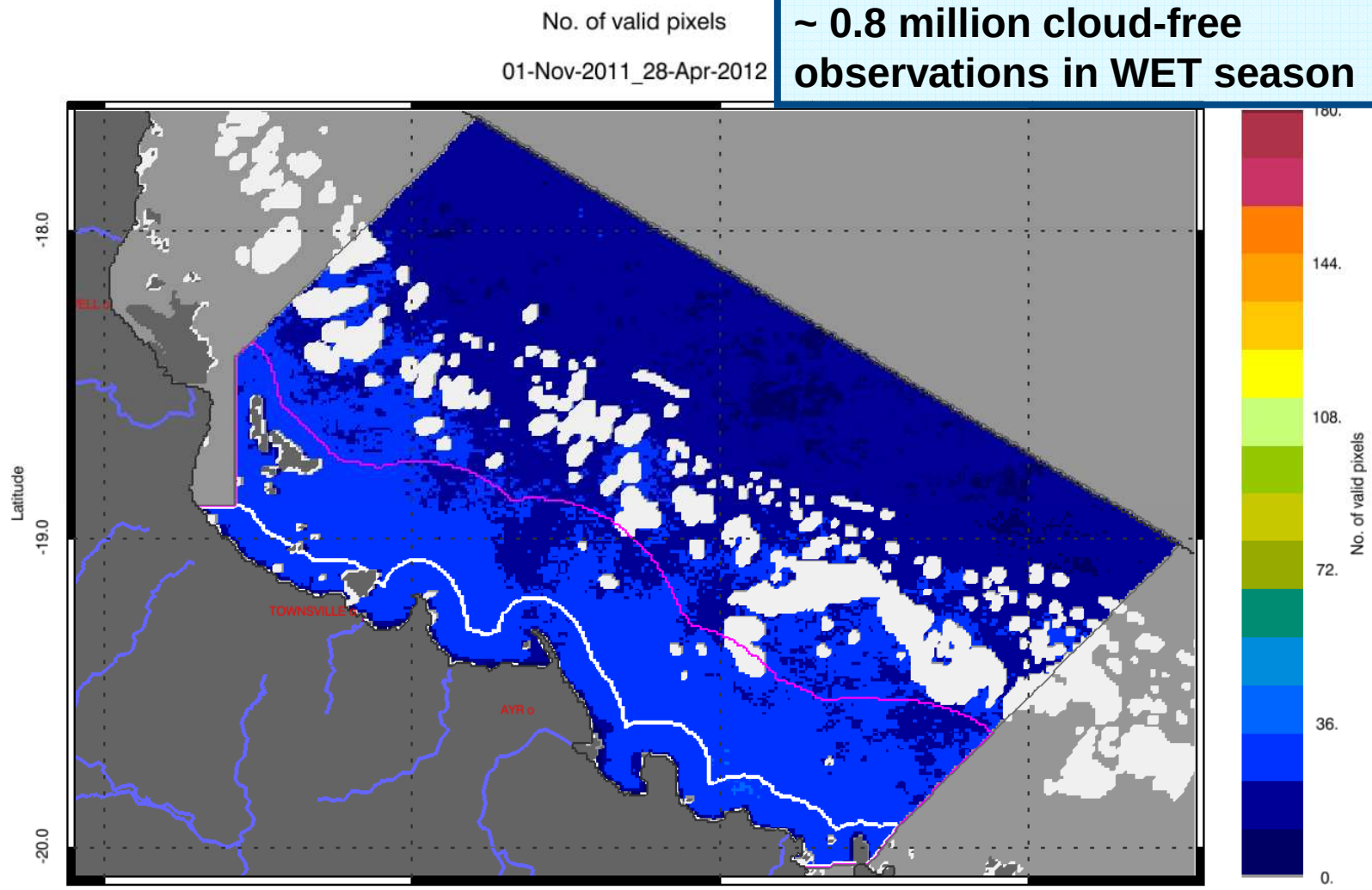
~ 1.8 million cloud-free observations in DRY season



30-80 observation per pixel in the DRY season

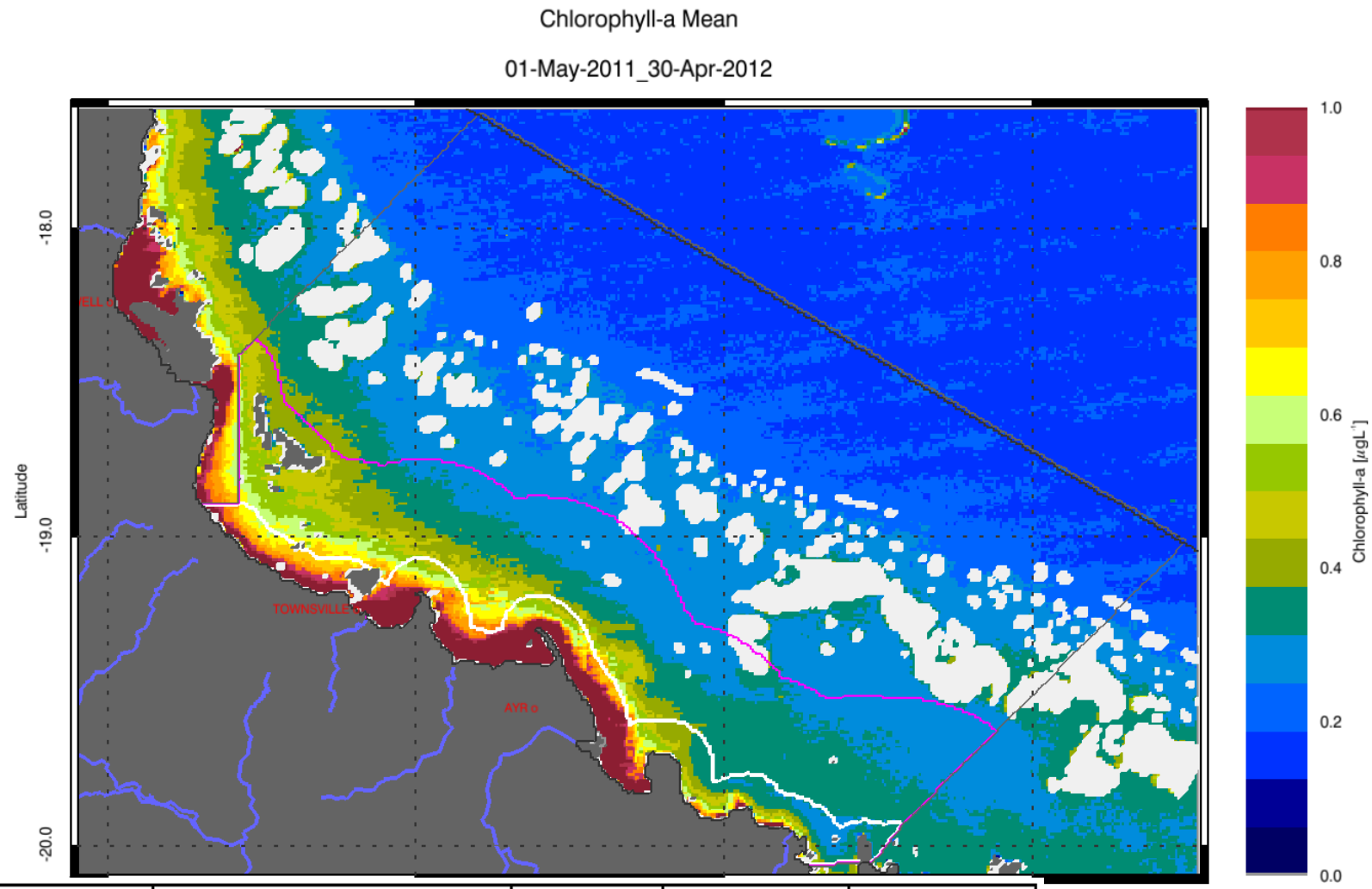
Reporting year 2011/12 - Burdekin region: satellite observations

~ 0.8 million cloud-free observations in WET season



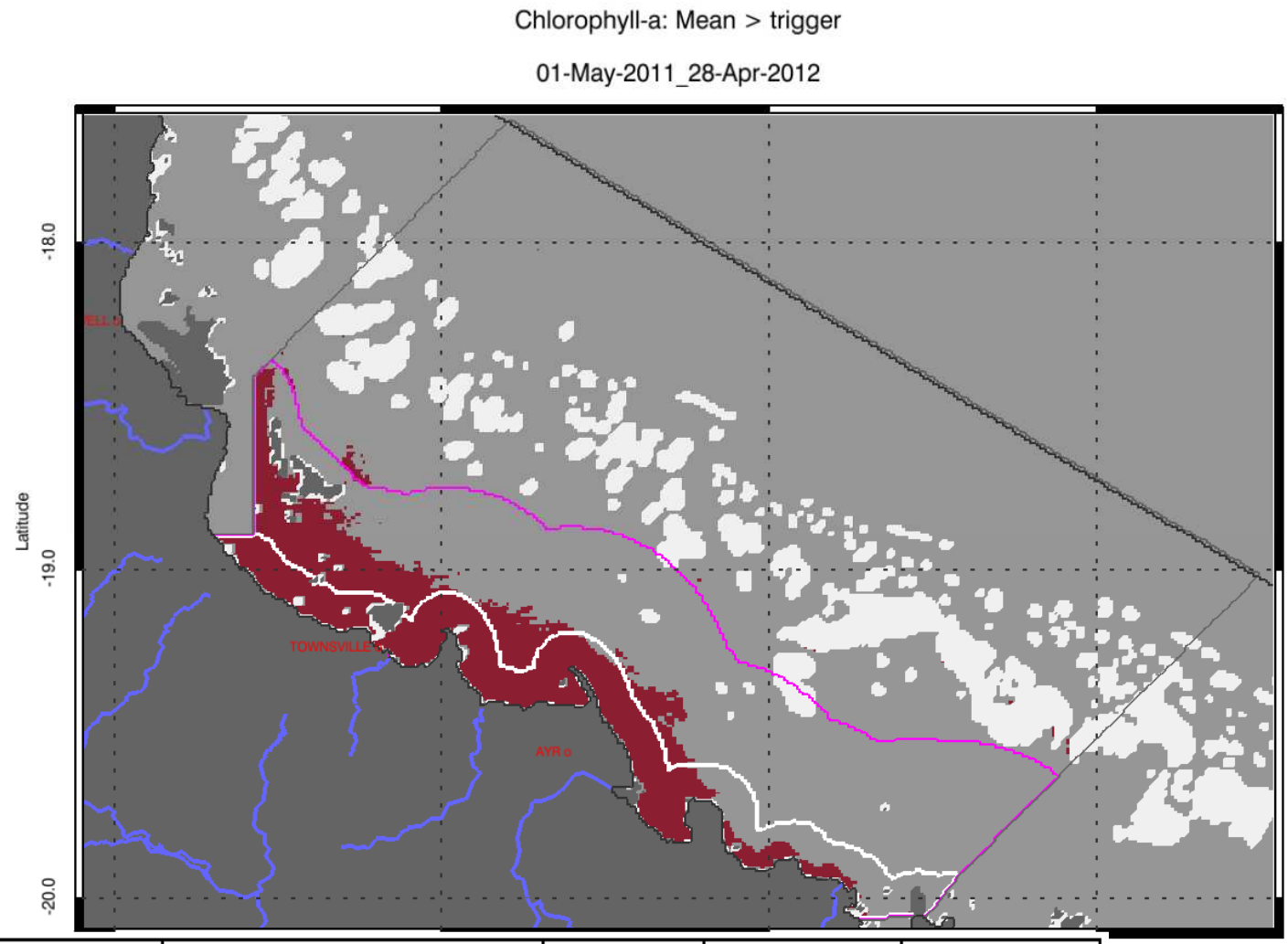
20-50 observation per pixel in the WET season

Reporting year 2011/12 - Burdekin region: CHL mean



Parameter\Water Body	Enclosed coastal (Wet Tropics/Central Coast)	Open coastal	Midshelf	Offshore
Chl *a* (µg/L)[2]	2.0	0.45	0.45	0.4

Reporting year 2011/12 - Burdekin region: non-compliant CHL mean



Parameter\Water Body	Enclosed coastal (Wet Tropics/Central Coast)	Open coastal	Midshelf	Offshore
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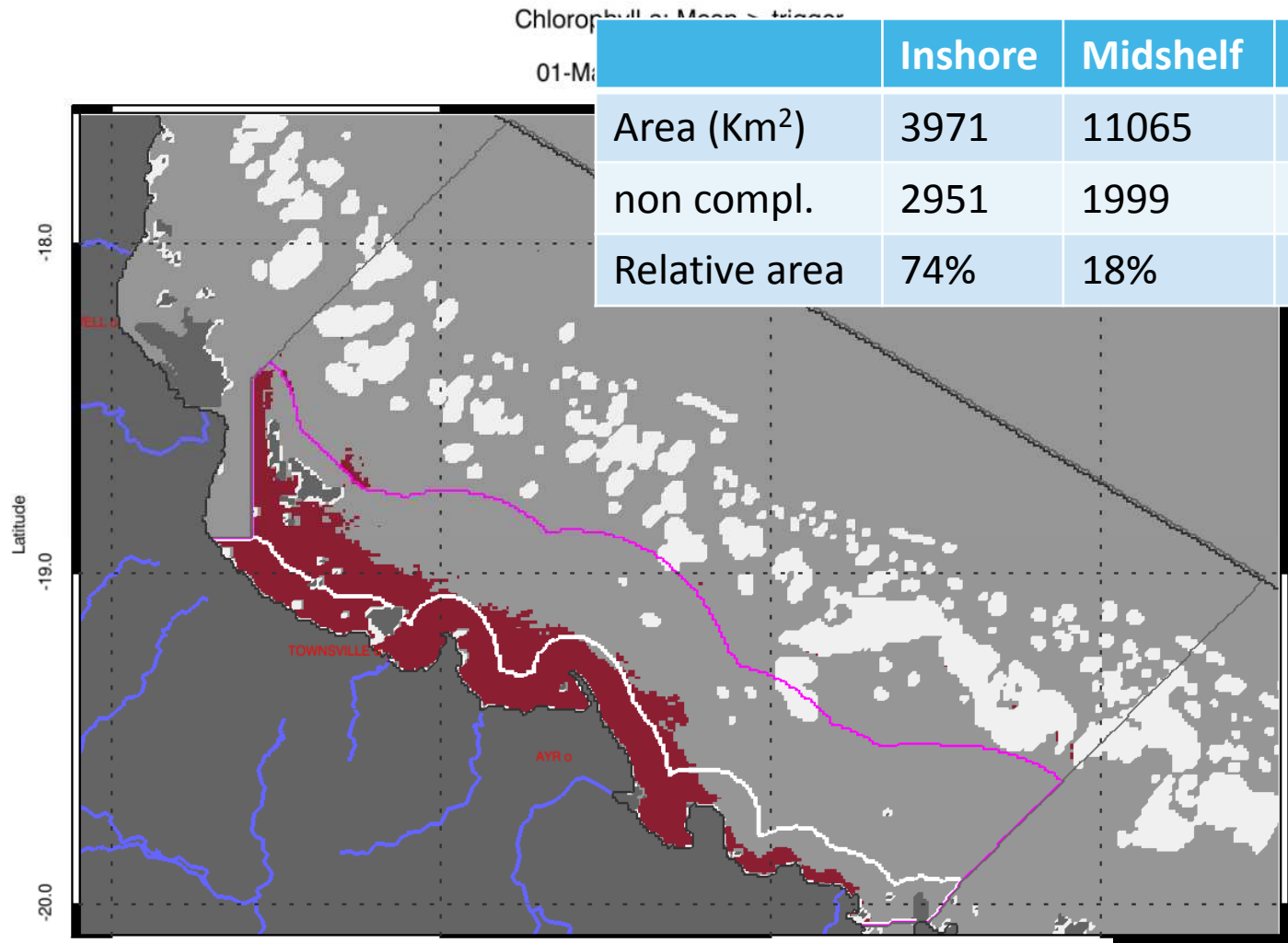

	Inshore	Midshelf	Offshore
Area (Km^2)	3971	11065	25560
non compl.	2951	1999	74
Relative area	74%	18%	0

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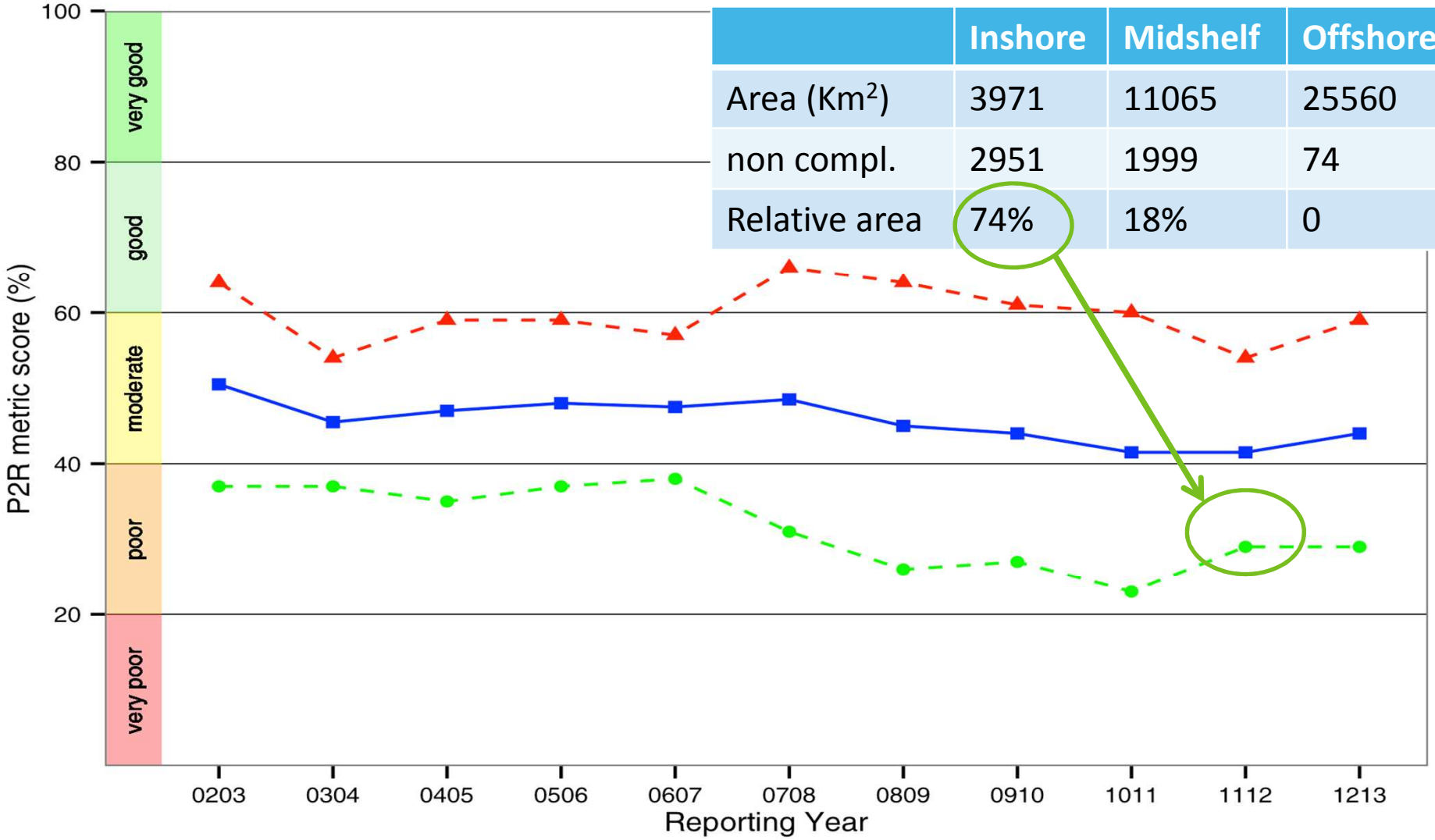
Paddock to Reef Water Quality index Burdekin region 2002/03-2012/13



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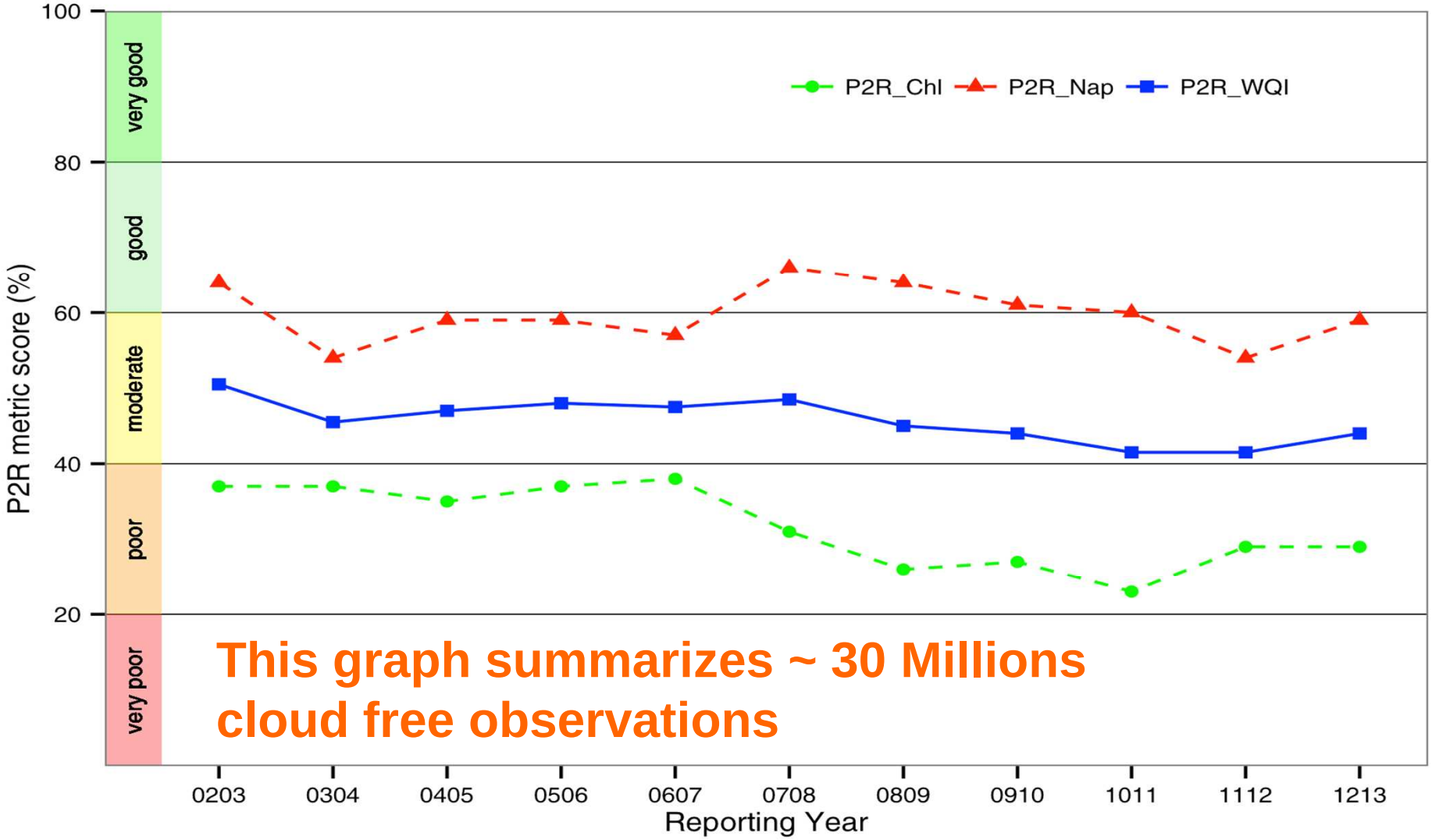
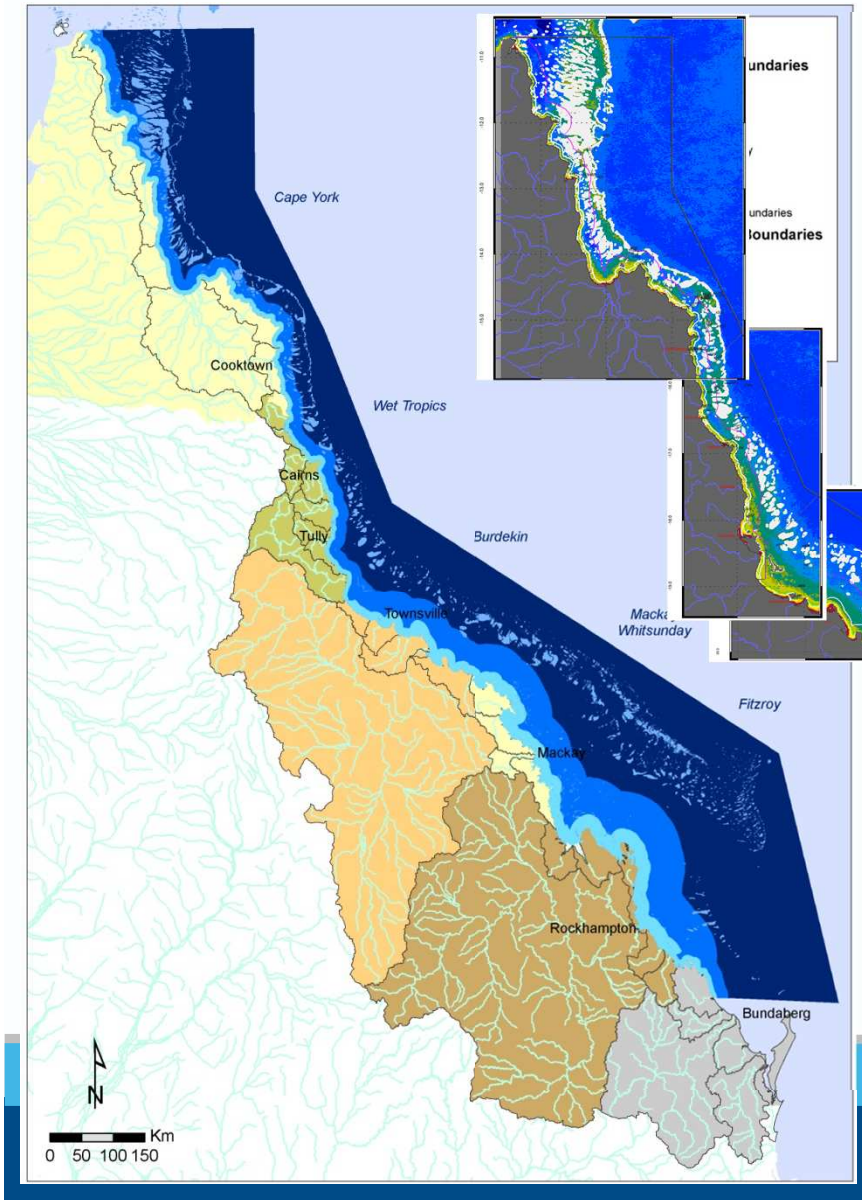
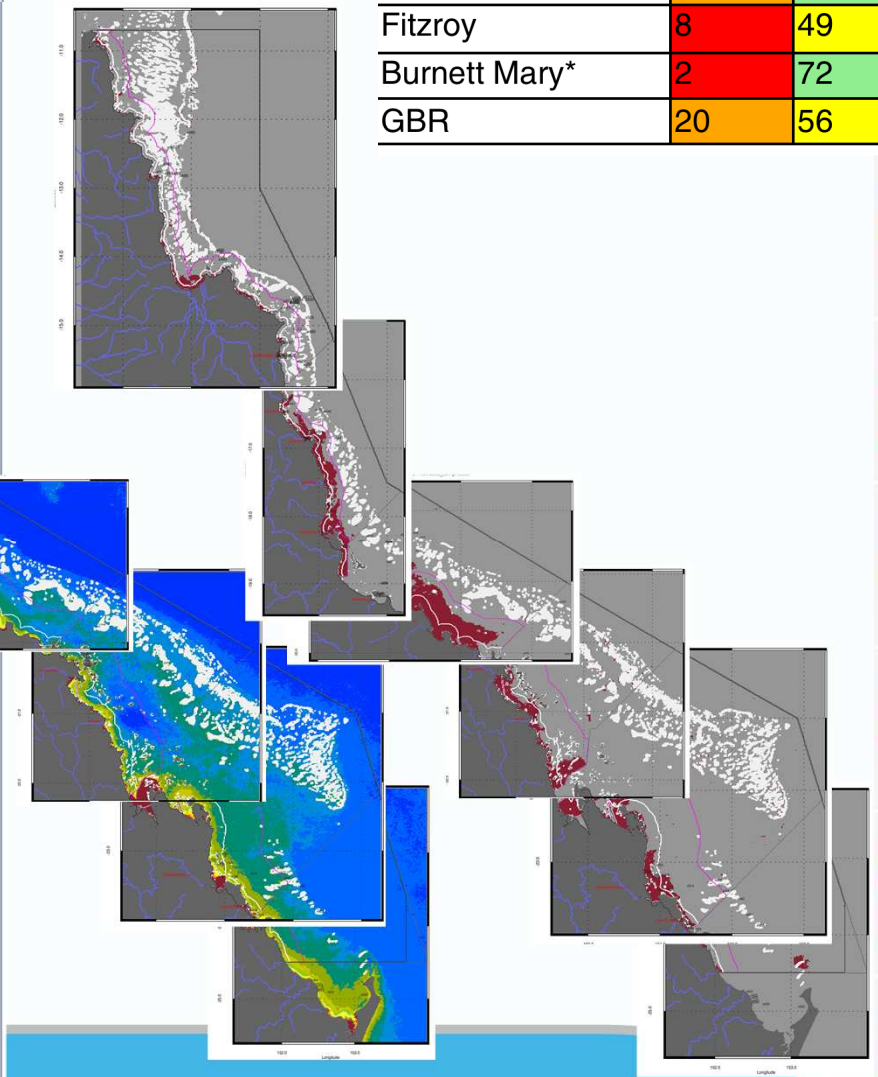


This graph summarizes ~ 30 Millions cloud free observations

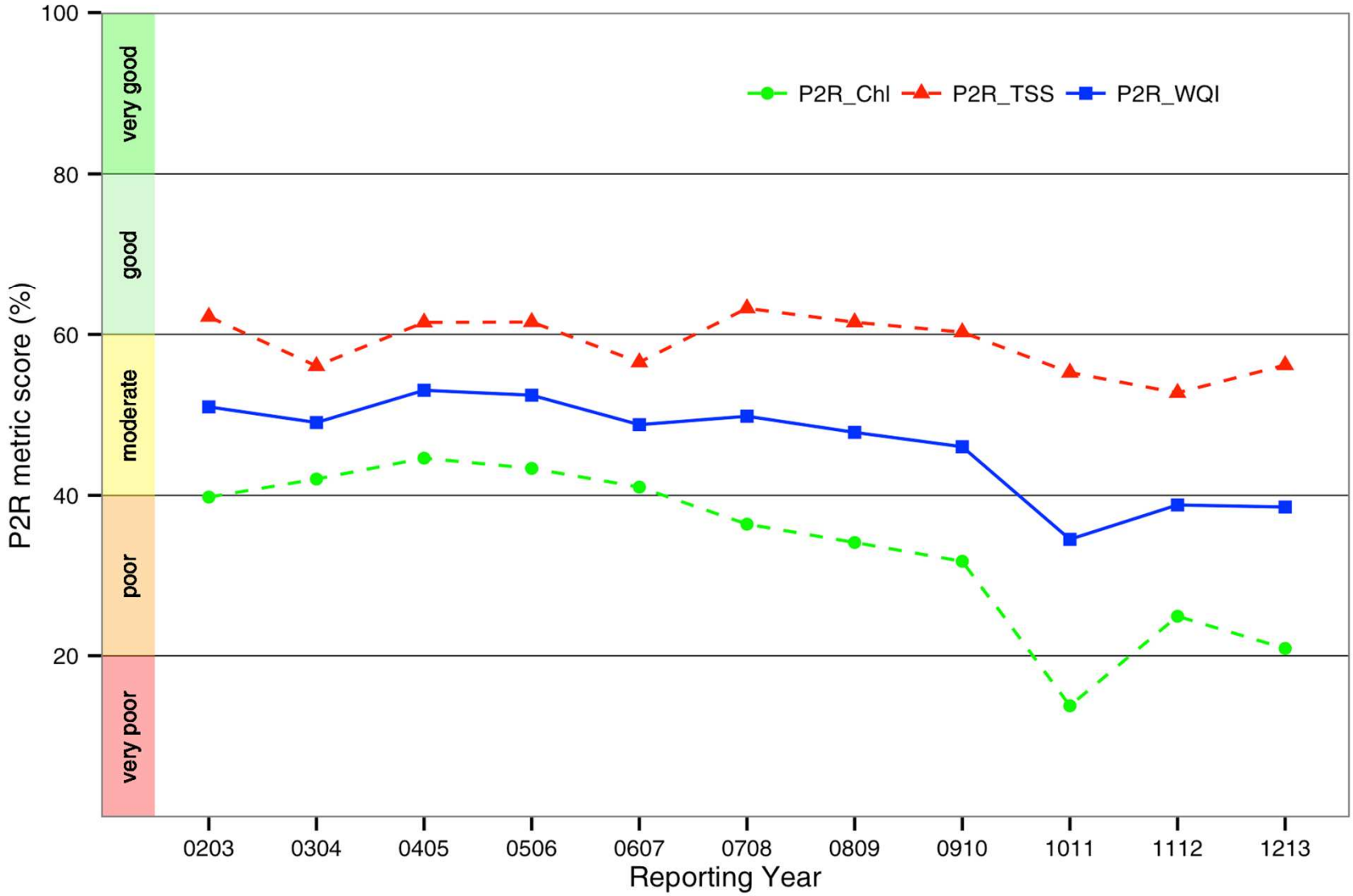
Whole GBRWHA

Location	P2R_Chl	P2R_TSS	P2R_WQI
Cape York*	25	66	45
Wet Tropics	14	63	38
Burdekin	29	59	44
Mackay Whitsunday	36	61	48
Fitzroy	8	49	28
Burnett Mary*	2	72	37
GBR	20	56	38

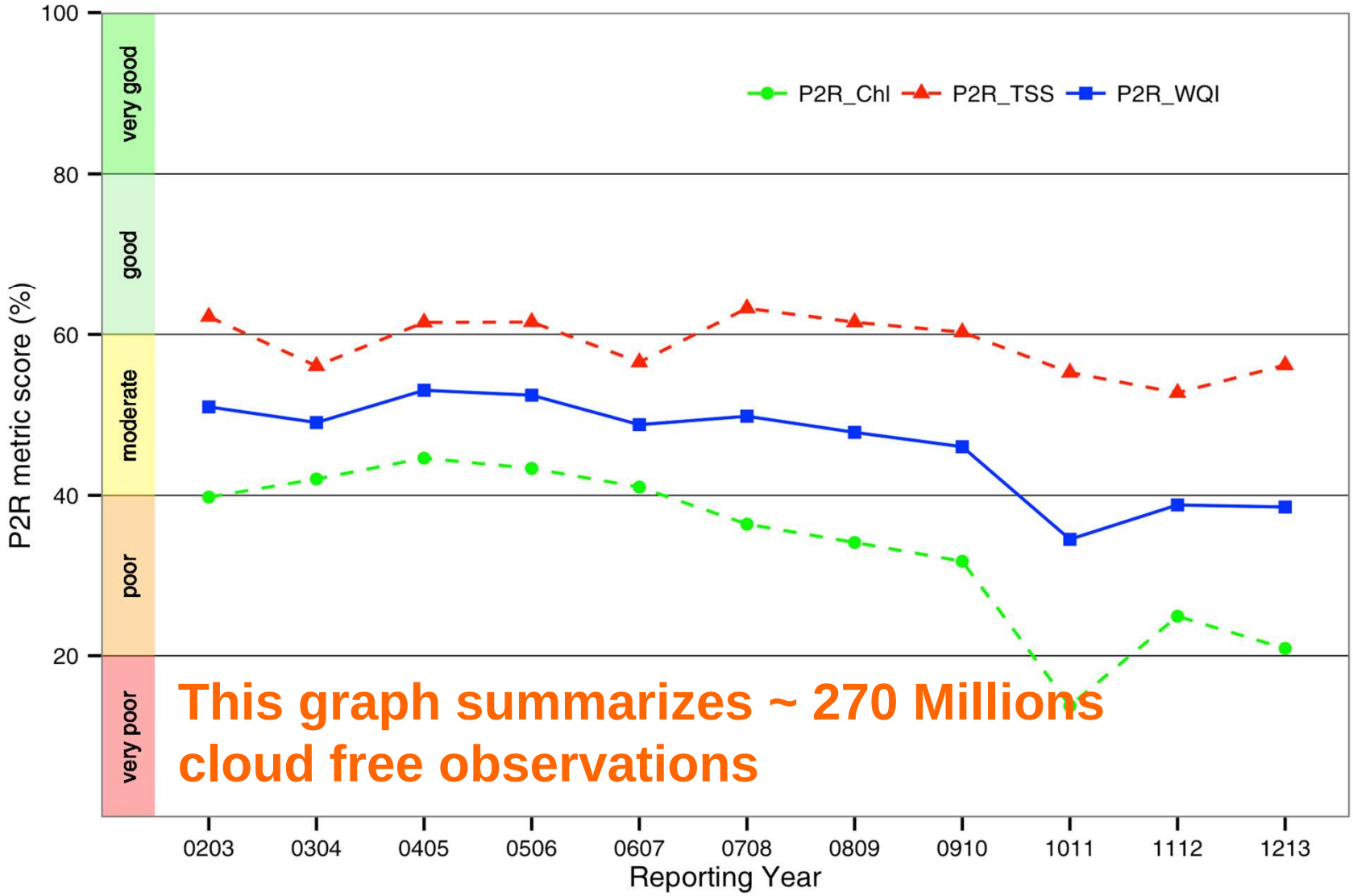




Paddock to Reef Water Quality index Whole GBRWHA 2002/03-2012/13



Paddock to Reef Water Quality index Whole GBRWHA 2002/03-2012/13



This graph summarizes ~ 270 Millions cloud free observations

Paddock to Reef Wate
Whole GBRWHA 2002

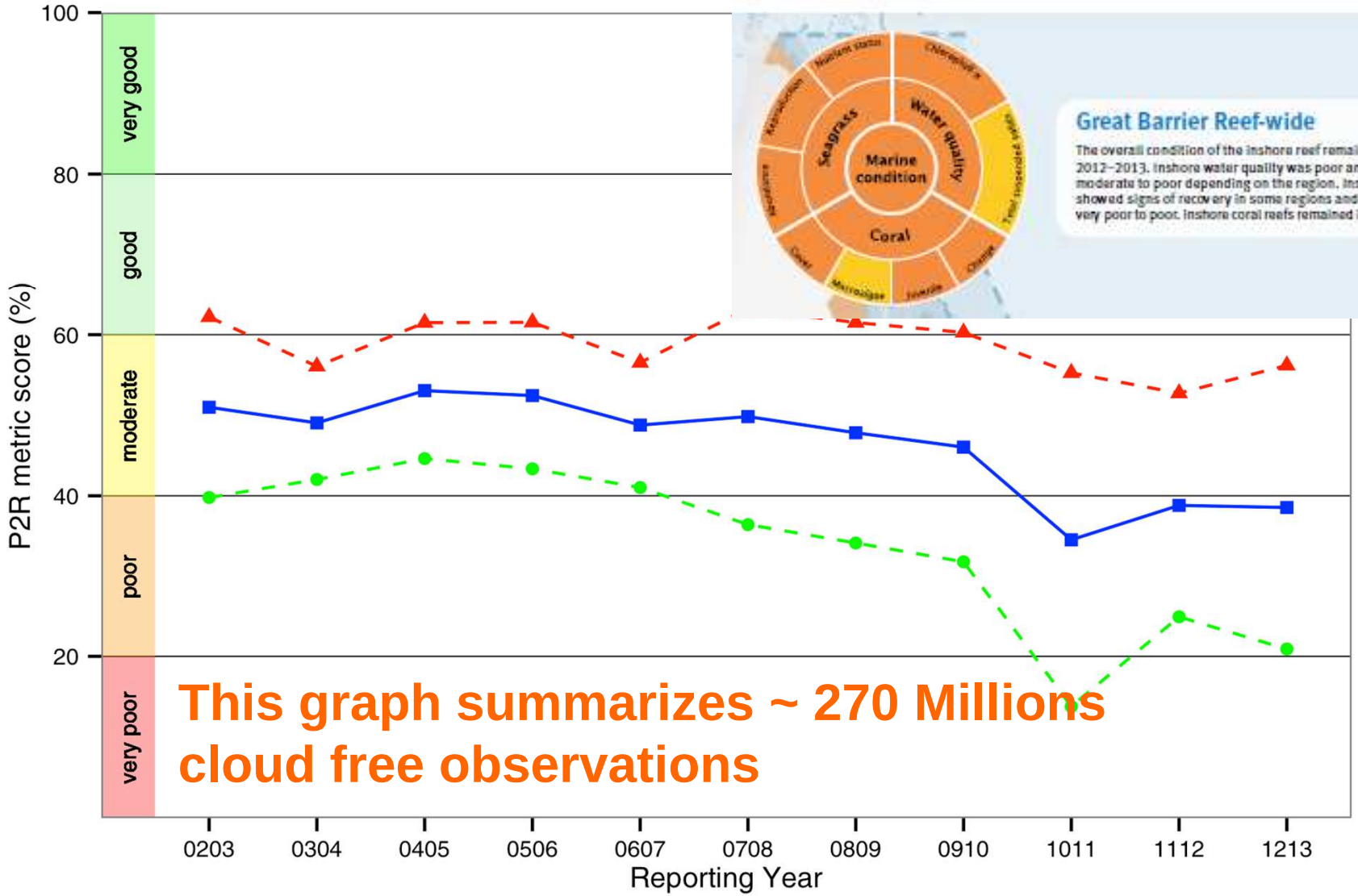
Marine condition 2012–2013

Improvements in land management practices will take time to translate into improved marine condition as there are significant time lags between implementation and measurable outcomes in these natural systems. Inshore marine condition is also strongly influenced by episodic events such as tropical cyclones and floods which have impacted all regions in recent years.

Confidence in the marine results for Cape York and the Burnett Mary remains low due to limited data availability and validation. Consequently, data from these regions are not used in the Great Barrier Reef-wide assessment.

Great Barrier Reef-wide

The overall condition of the inshore reef remained poor in 2012–2013. Inshore water quality was poor and varied from moderate to poor depending on the region. Inshore seagrass showed signs of recovery in some regions and improved from very poor to poor. Inshore coral reefs remained in poor condition.



This graph summarizes ~ 270 Millions cloud free observations

Environmental reporting of water quality retrieval for complex waters for the Great Barrier Reef

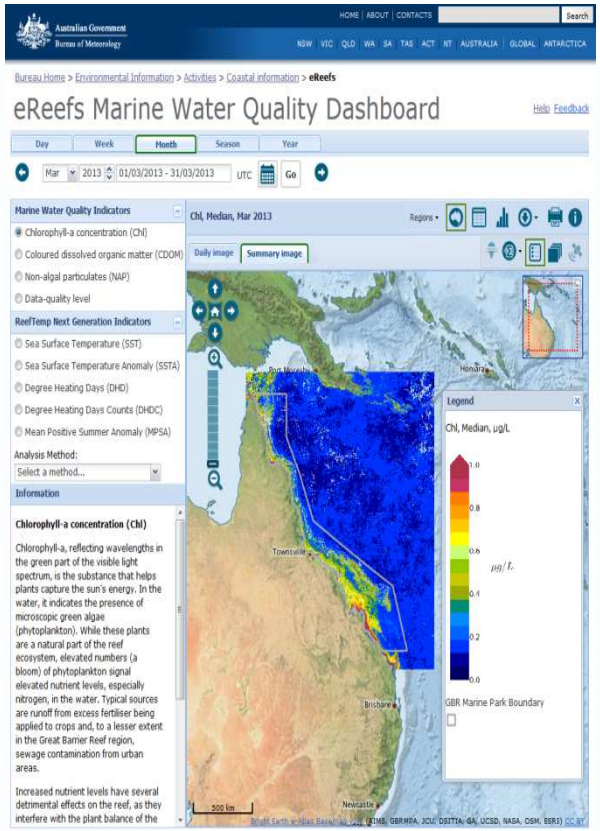
- A physics based approach
  - Characterize the optical properties of GBR coastal waters
  - Assess validity of NASA's global algorithms
  - Develop regionally valid algorithm
- Translation into management relevant information
  - Engage with stakeholders to understand end-user needs
  - Process 11 years of daily images at 1 km resolution
  - Deliver water quality data to GBR monitoring programs
  - Operational processing system

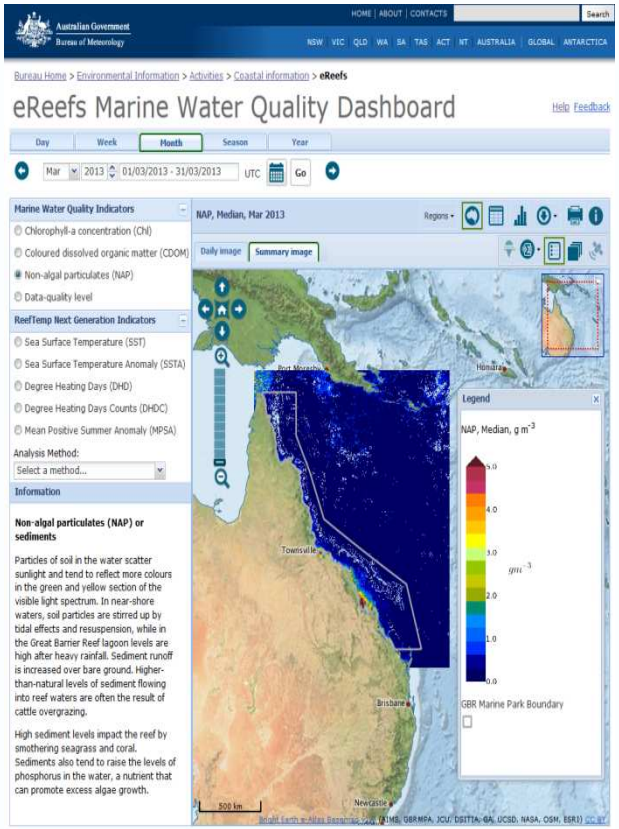
- eReefs partnership: (2012-2017)
  - near real-time production of marine water quality from satellite data
  - routinely operating 4km and 1km hydrodynamic models
  - sediment transport models and BGC process models.
  - re-locatable coastal modelling packages.
  - Near real-time model outputs publically available via the web

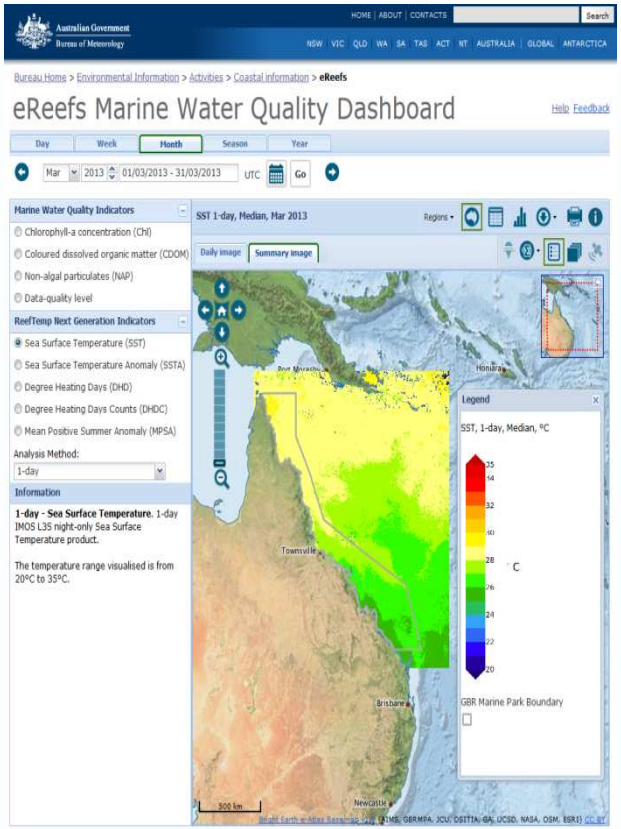
ereefs.org.au

eReefs Marine Water Quality Dashboard

http://www.bom.gov.au/marinewaterquality/







eReefs is a collaboration between:

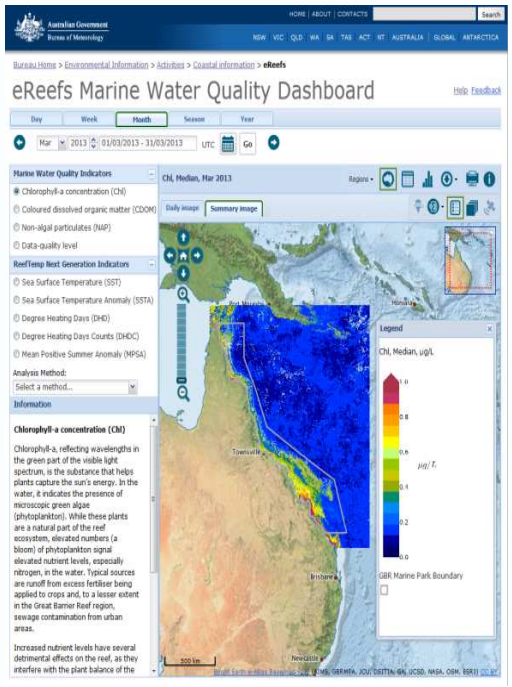
GREAT BARRIER REEF foundation · Australian Government Bureau of Meteorology · CSIRO · Australian Government · Australian Institute of Marine Science · Queensland Government

Supported by funding from:

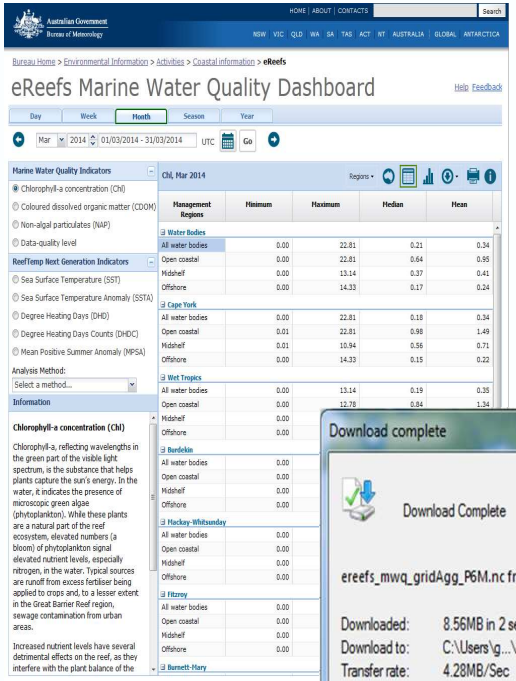
Australian Government · Queensland Government · Science and Industry Endowment Fund · bhpbilliton resourcing the future · BMA BHP Billiton Mitsubishi Alliance

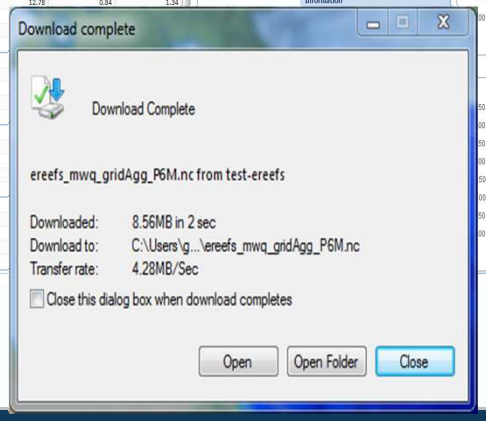
Key Features of the Dashboard

Maps

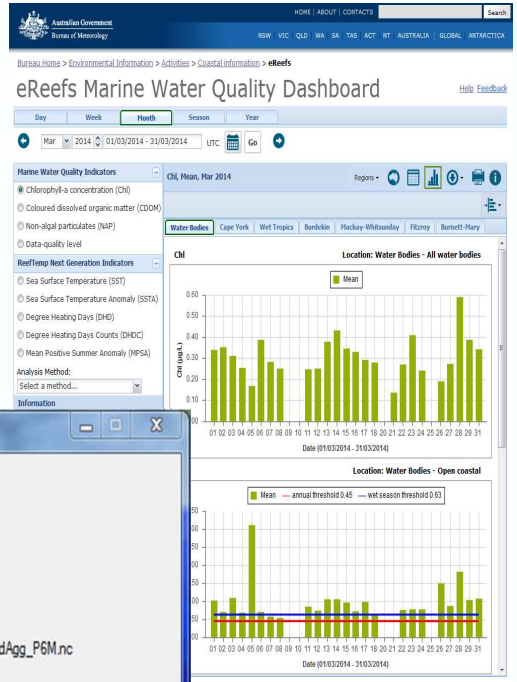


Tables





Charts



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Future Work

integration of water quality data at various spatial and temporal scales

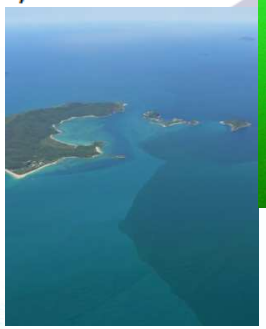
In situ sampling (ambient)

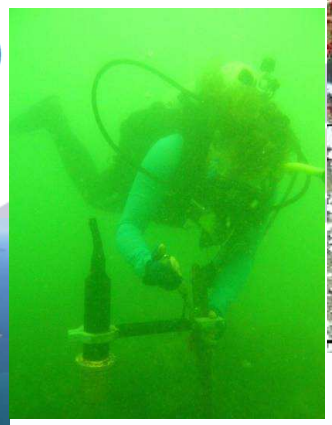
In situ sampling (event driven)

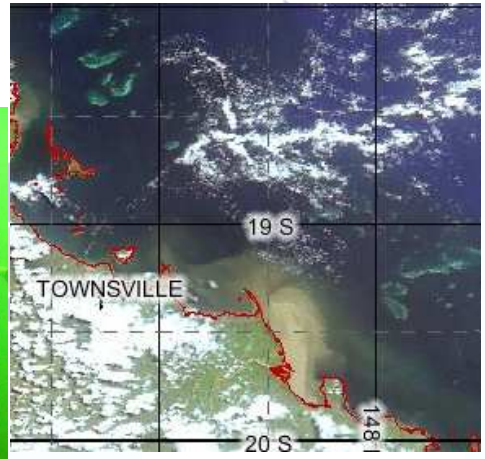
High frequency sampling (data loggers)

Remote sensing techniques

Synthesis and intercalibration of different data formats





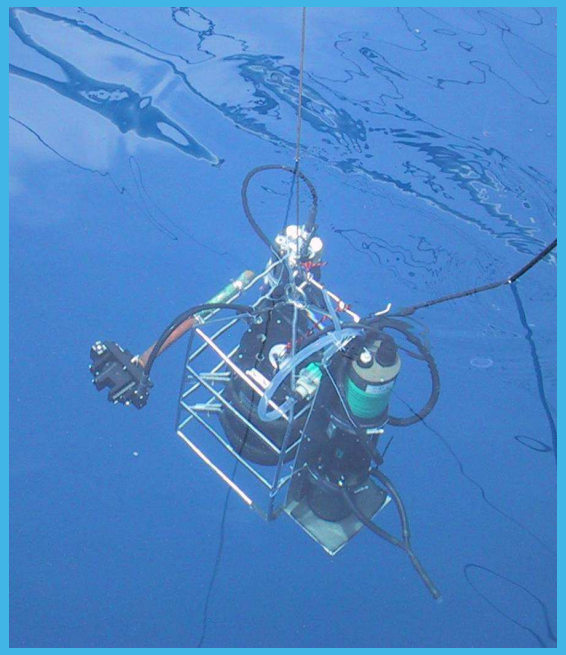


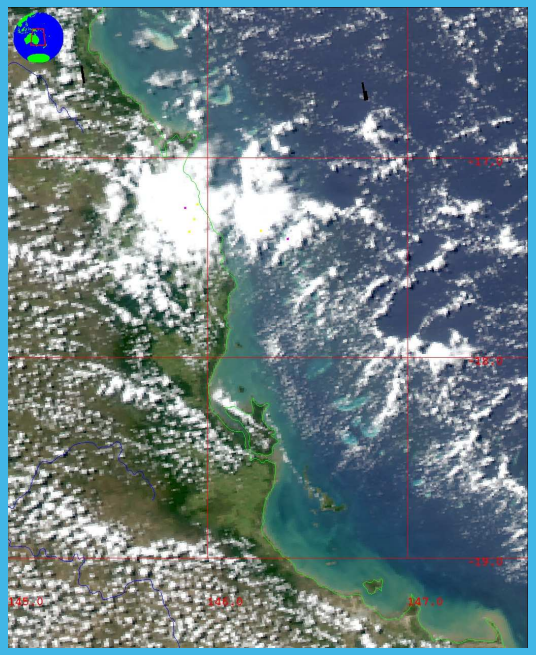
Complementary approaches and techniques

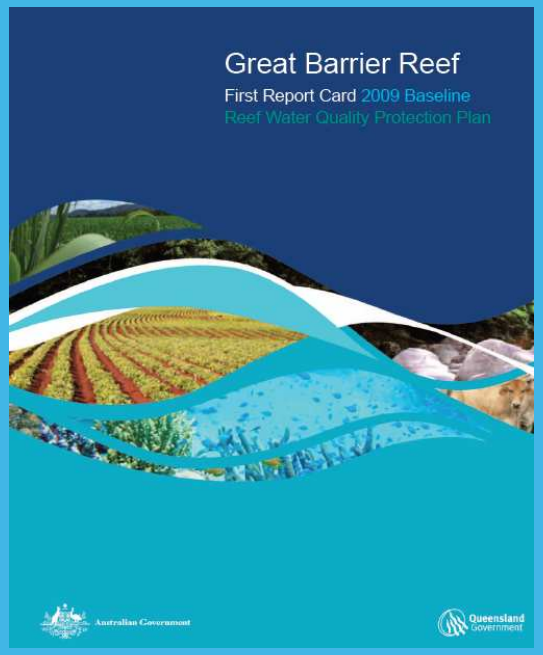
Distilling actionable information from earth observation

Summary (i.e. Issues and food for thought):

- Actionable information is function of policy drivers
- User engagement on “distilling information” is very important
- Communicating accuracy and uncertainties
- Communicating change in the system (i.e. reprocessing, sensors …)
- Need to keep in mind proxies and non EO-observable variables
- Need to integrate data sets from different techniques to get larger spatial & better temporal coverage:
  - Geospatial techniques
  - Coupled HBCG modelling







Collaborators:

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Acknowledgments:

- CSIRO Wealth from Oceans Flagship
- Reef Rescue Reef Water Quality Marine Monitoring Program
- Great Barrier Reef Marine Park Authority
- Department of Sustainability, Environment, Water, Population and Communities
- eReefs
- IMOS Satellite Remote Sensing Facility
- National Computing Infrastructure
- European Union (FP7-People Co-funding of Regional, National and International Programmes, GA n. 600407)
- CNR RITMARE Flagship Project

Thank you!

Dr. Vittorio E Brando

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