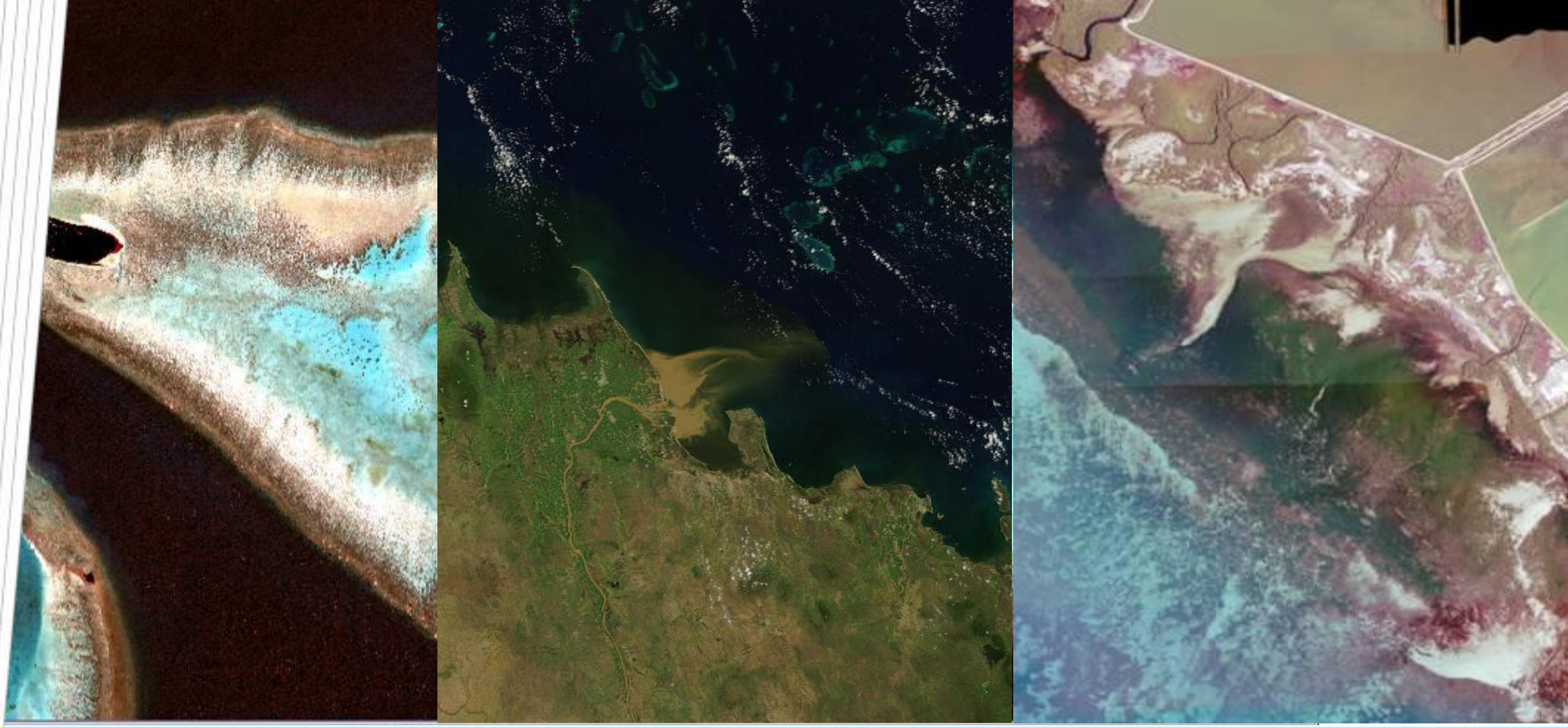


Developments in Operationalising Earth Observation of Coastal Waters in Australia using MERIS and MODIS

Arnold Dekker

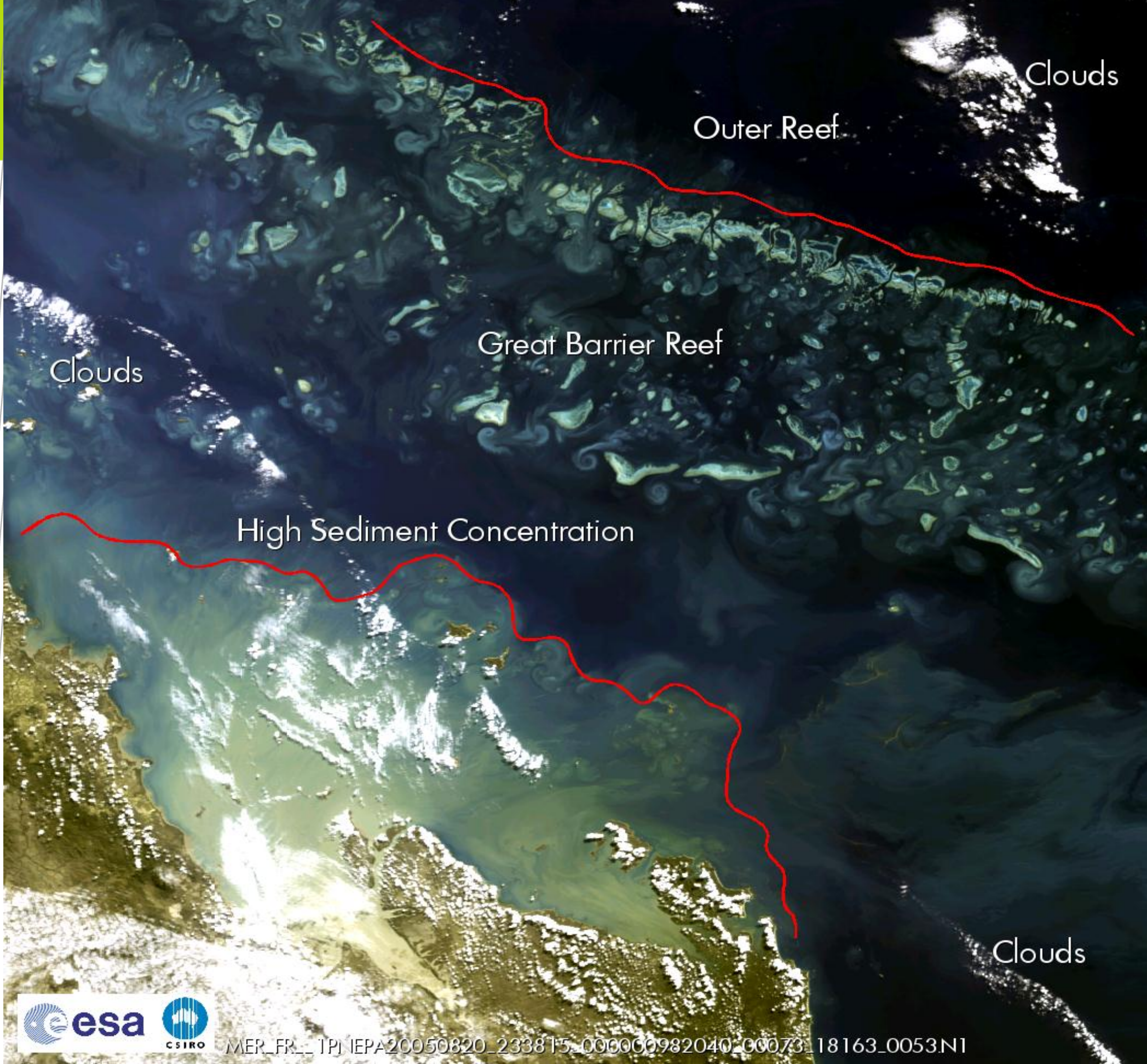
Based on work by: Vittorio Brando, Thomas Schroeder, Kadija Oubelkheir, Young Je Park, Nagur Cherukuru,, Hannelie Botha, Peter Dyce, Janet Anstee, Paul Daniel, David Blondeau-Patissier, Rebecca Edwards & Students and Visitors & *Collaboration with AIMS, JCU, CUT, UQ, UNSW, Geoscience Australia etc…*

www.csiro.au

CSIRO

What Information do Managers Need (from Optical Remote Sensing) in Aquatic Ecosystems?

- **Status, Condition and Trend & Anomalies:**
  - **Status (survey, classify and map**)
    - **what is where? (=99%of current remote sensing effort)**
      - **(is it absent when it should be present) or**
      - **(is it present when it should be absent?)**
  - **Condition:**
    - **is it healthy?, is it stable?**
    - **Is it stressed?**
  - **Trend:**
    - **Is it getting worse or is it improving?**
      - **Remote Sensing can do hind casting and now casting**
      - **Model data fusion needed for forecasting**
  - **Anomalies:**
    - **Normal (to be expected) or exceptional (indicating exceptional change from before? E.g. climate change indication?)**



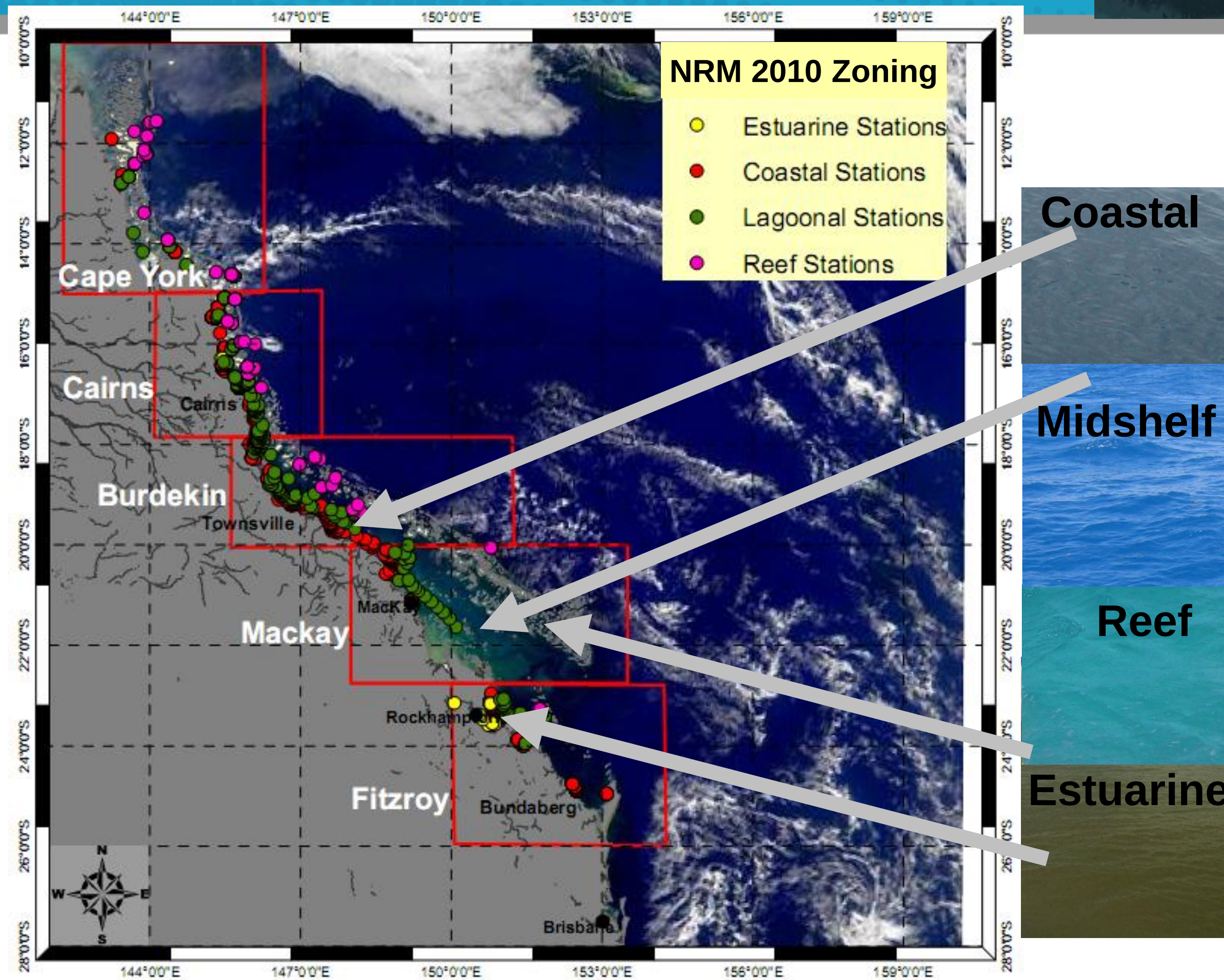
Clouds
Outer Reef
Great Barrier Reef
Clouds
High Sediment Concentration
Clouds
esa
CSIRO
MER_FR__1P NEPA20050820_233815_000000982040_00073_18163_0053.N1

MODIS Aqua Operational Water Quality System for GBR + Tasmania

MODIS 28 January 2005: Burdekin River (centre – muddy) and Mackay Whitsunday Rivers (lower, green) river flood plumes

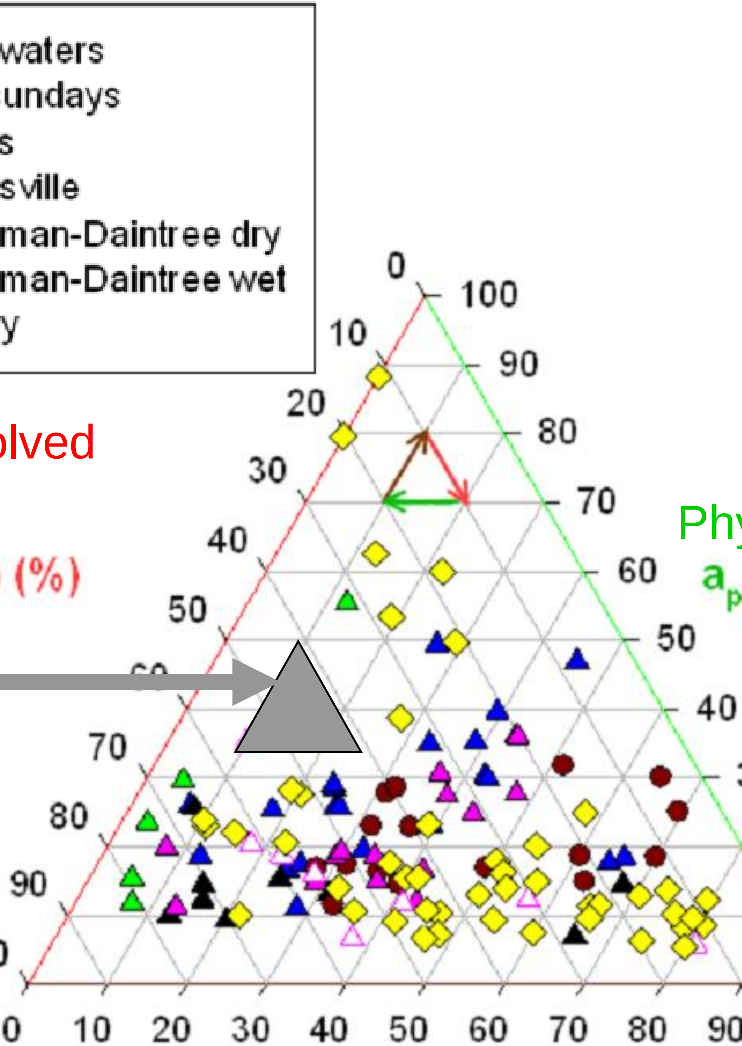
The Great Barrier Reef: A Complex System

- **Water types:**
  - ✓ Coastal
  - ✓ Estuarine
  - ✓ Reef waters



Blondeau-Patissier, Brando, Dekker et al. (2009), *Bio-optical variability of the absorption and scattering properties of the Queensland inshore and reef waters*, Australia, *JGR, 114*

The Great Barrier Reef – a complex system

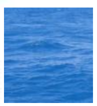


Coloured dissolved organic matter

$a_{CDOM}(440)$ (%)

Phytoplankton

$a_{ph}(440)$ (%)



Standard algorithms

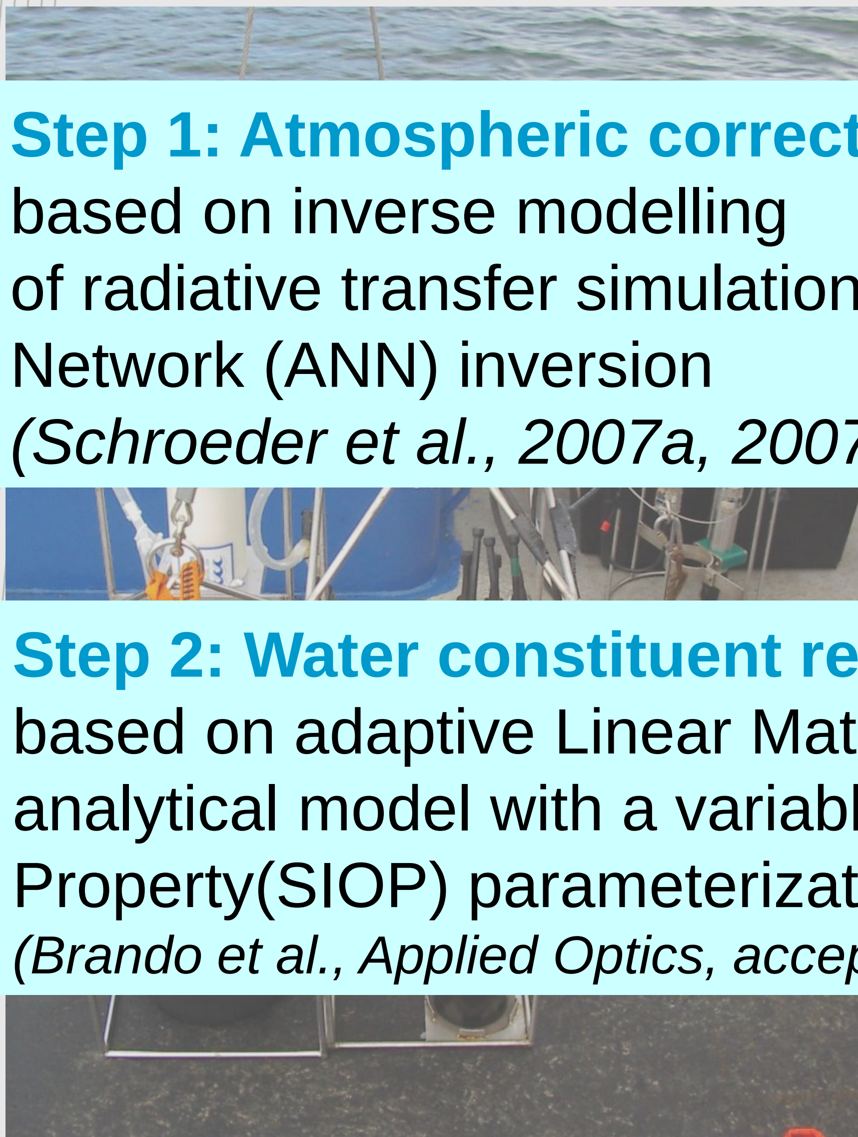
Non algal particulate

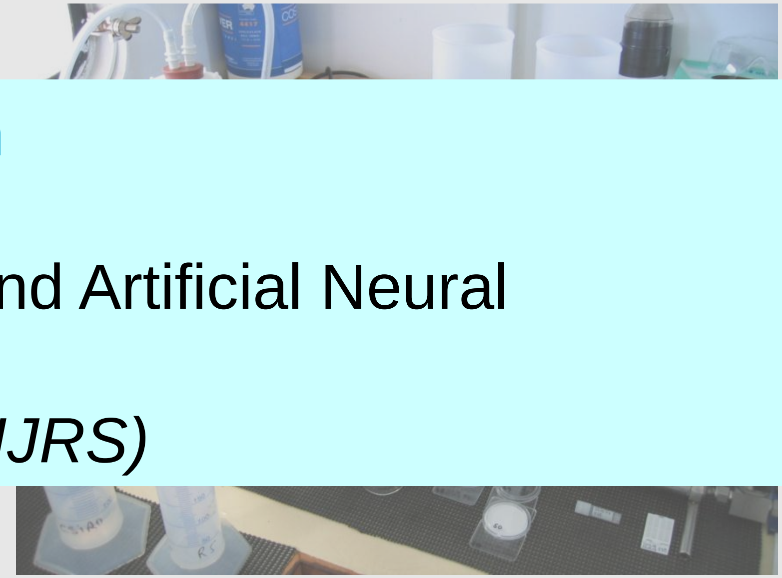
$a_{NAP}(440)$ (%)

N=129

David

CSIRO's algorithm for complex inland-coastal to ocean waters





Step 1: Atmospheric correction
based on inverse modelling
of radiative transfer simulations and Artificial Neural Network (ANN) inversion
(Schroeder et al., 2007a, 2007b, IJRS)

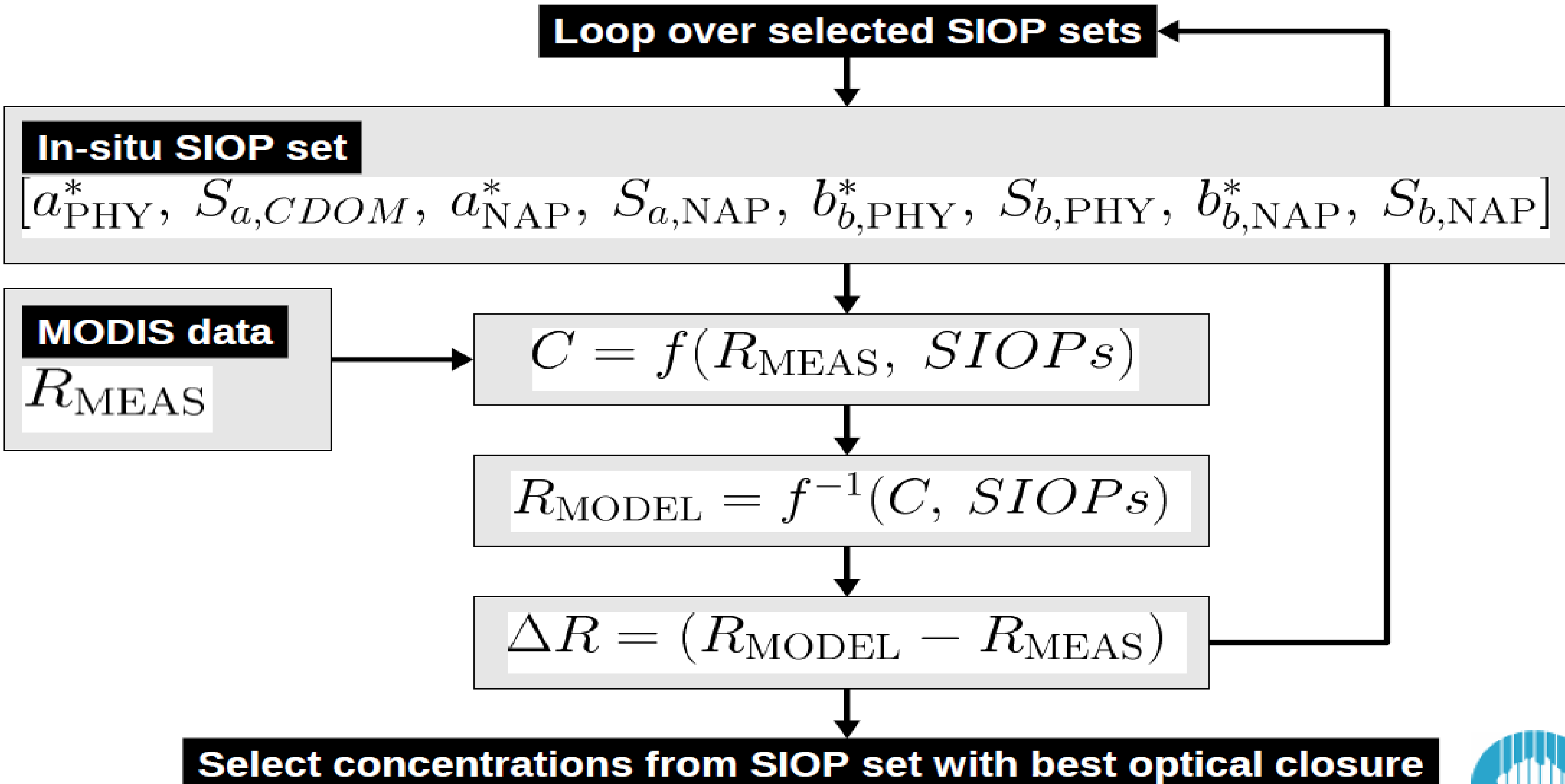
Step 2: Water constituent retrieval algorithm
based on adaptive Linear Matrix Inversion (aLMI) of a semi-analytical model with a variable Specific Inherent Optical Property(SIOP) parameterization
(Brando et al., Applied Optics, accepted pending revisions)

attenuation (AC-9)
Temperature, salinity (CTD)
Optics (RAMSES-Trios)

An SIOP-Adaptive Matrix Inversion Method
sensor agnostic-works across inland to estuarine and ocean waters

Principle water constituents retrieval

Linear Matrix Inversion (LMI)



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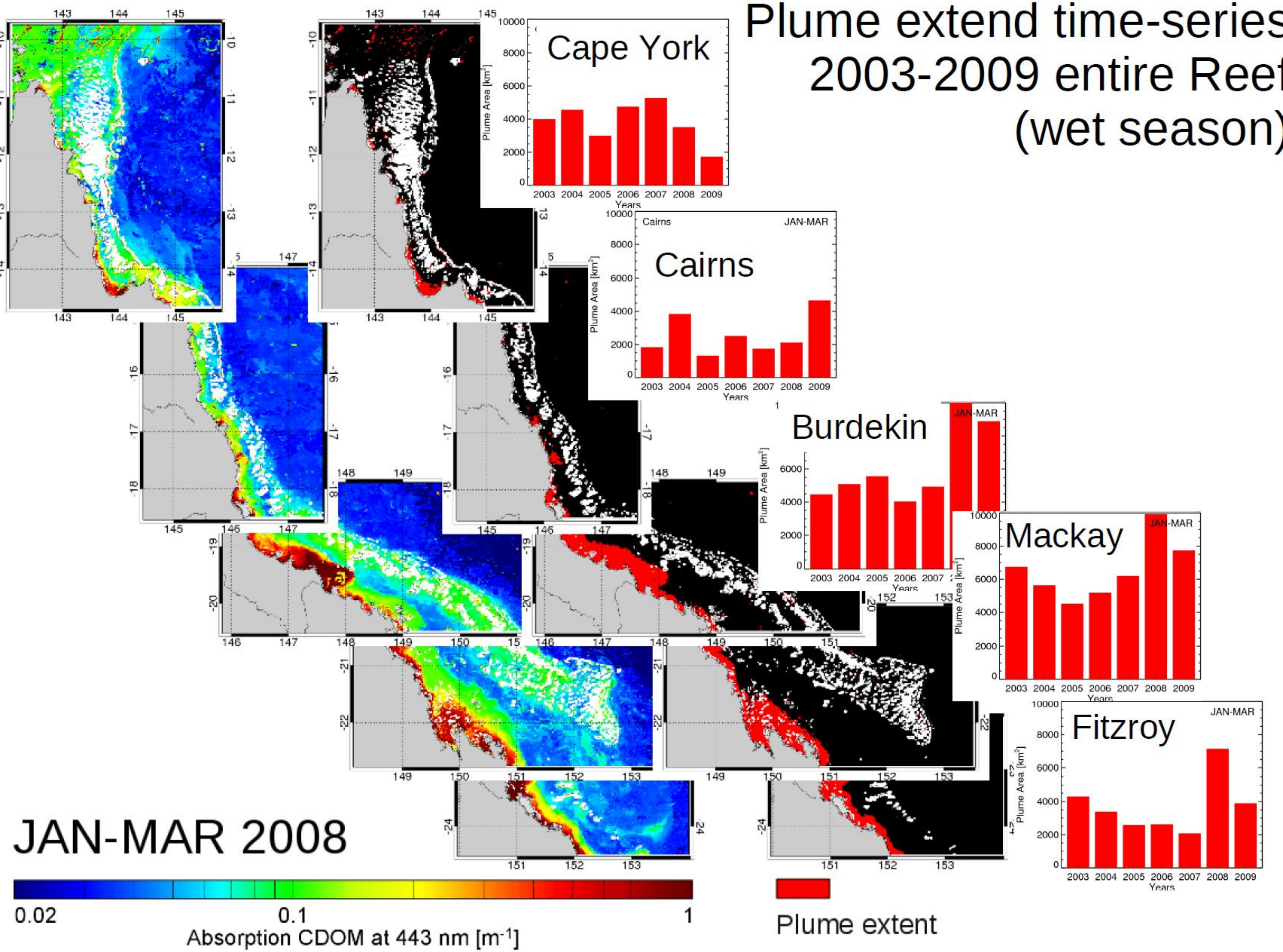
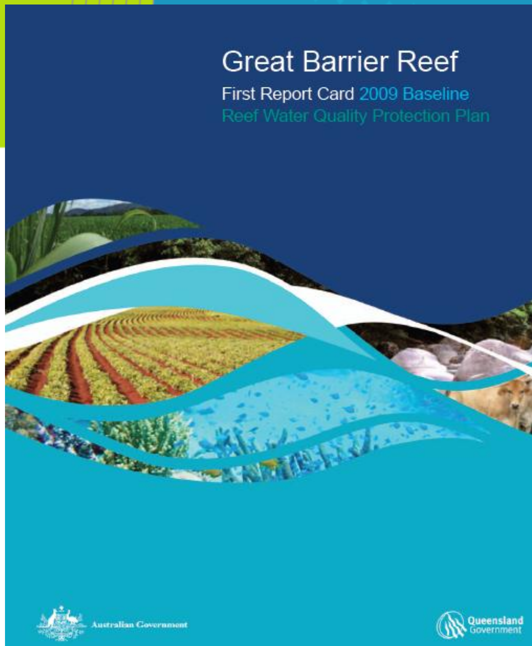
Plume extend time-series 2003-2009 entire Reef (wet season)



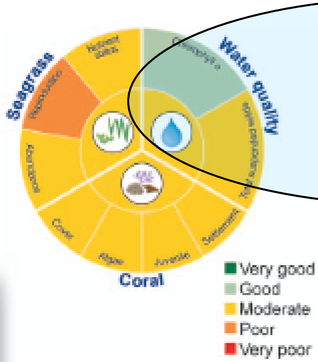
GBR Report card based on MODIS (CLW)
Brando V., Dekker A. et al.



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.



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).

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.

Pesticides: Pesticides, even at low concentrations, are a significant cause for concern. Of particular concern is the potential for compounding effects that these chemicals have on the health of the inshore reef ecosystem, especially when delivered with other water quality pollutants during flood events.

hytoplankton blooms

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 the 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

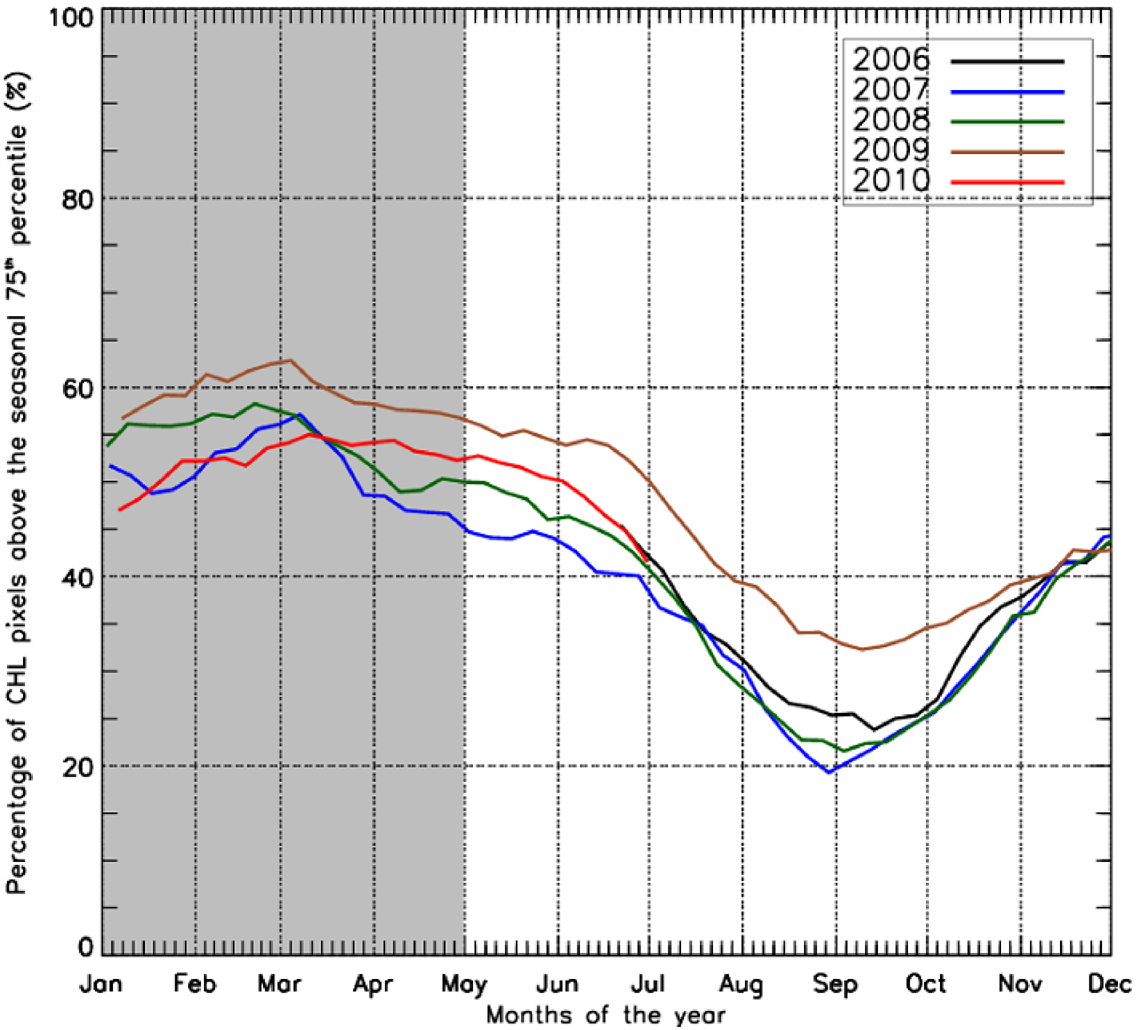
MERIS Applications [Proc .2]
(based on David Blondeau-Patissier's PhD thesis)

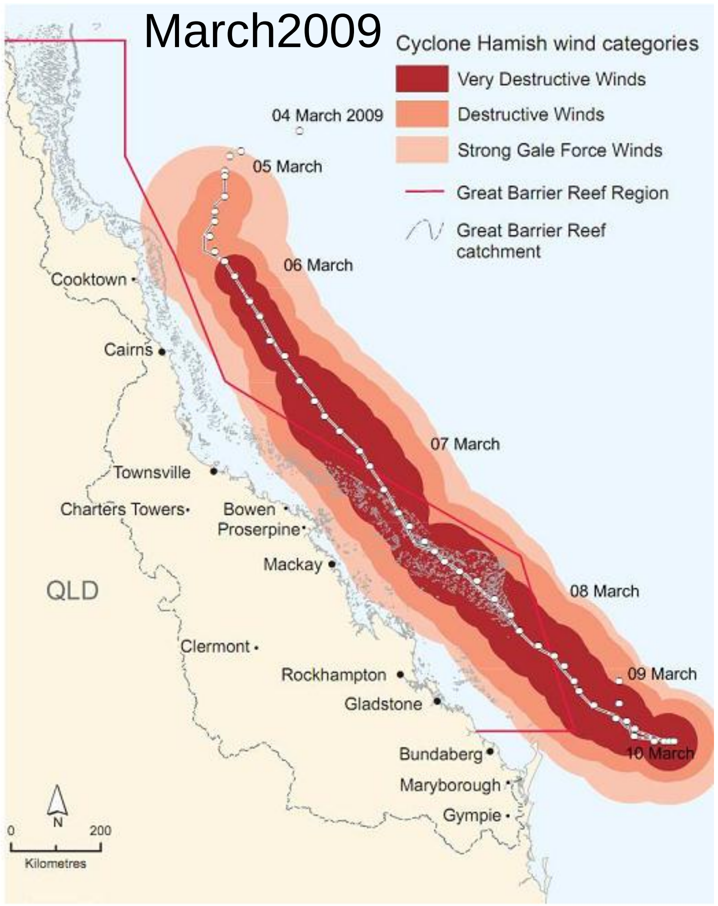
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

Detection and Quantification of Algal Blooms Dynamics in the Great Barrier Reef Lagoonal Waters Using Remote Sensing and Bio-Optics.

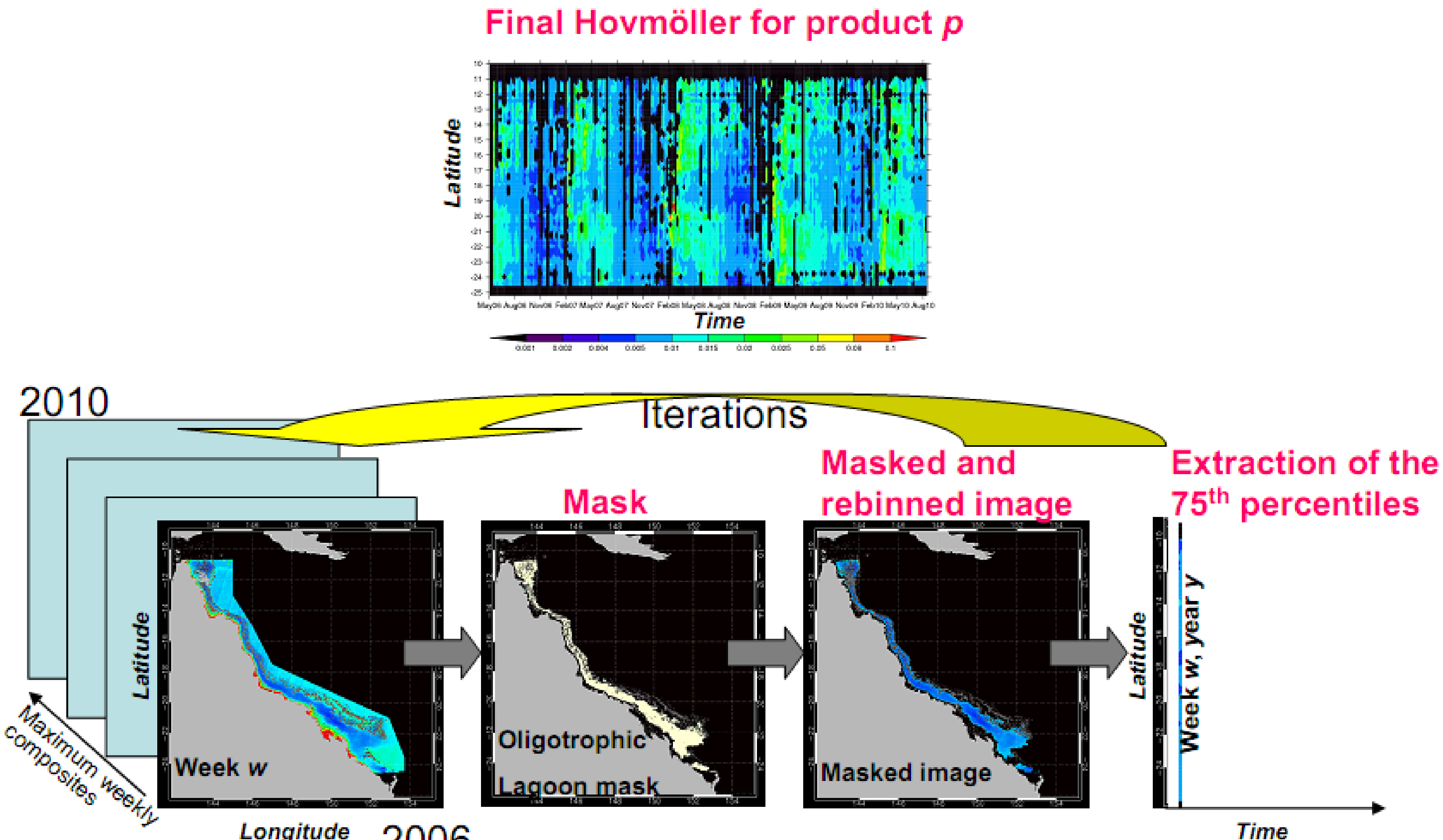
David M. BLONDEAU-PATISSIER

Multi-annual monthly Chlorophyll (MERIS) FUB

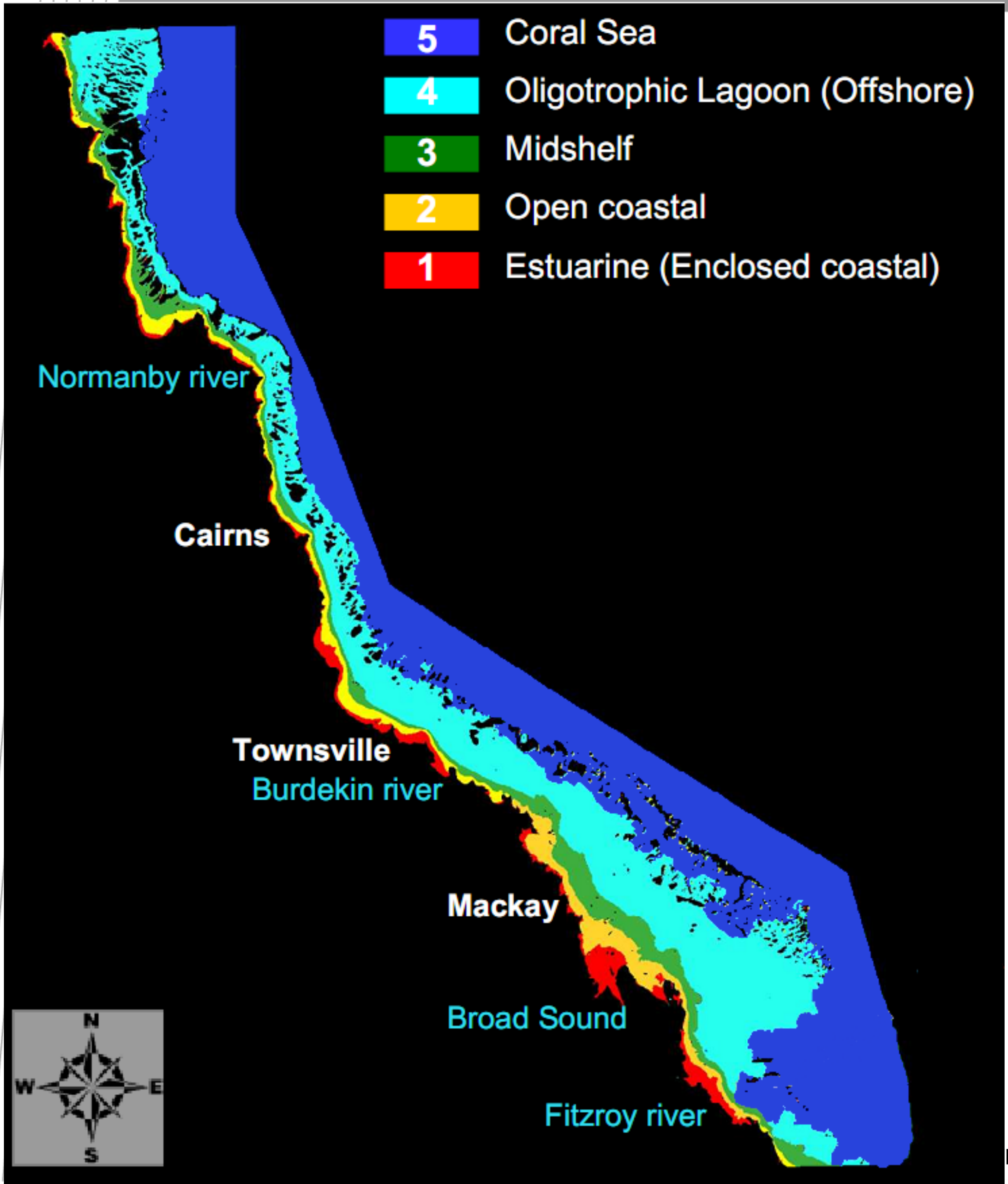




Latitude-time plots

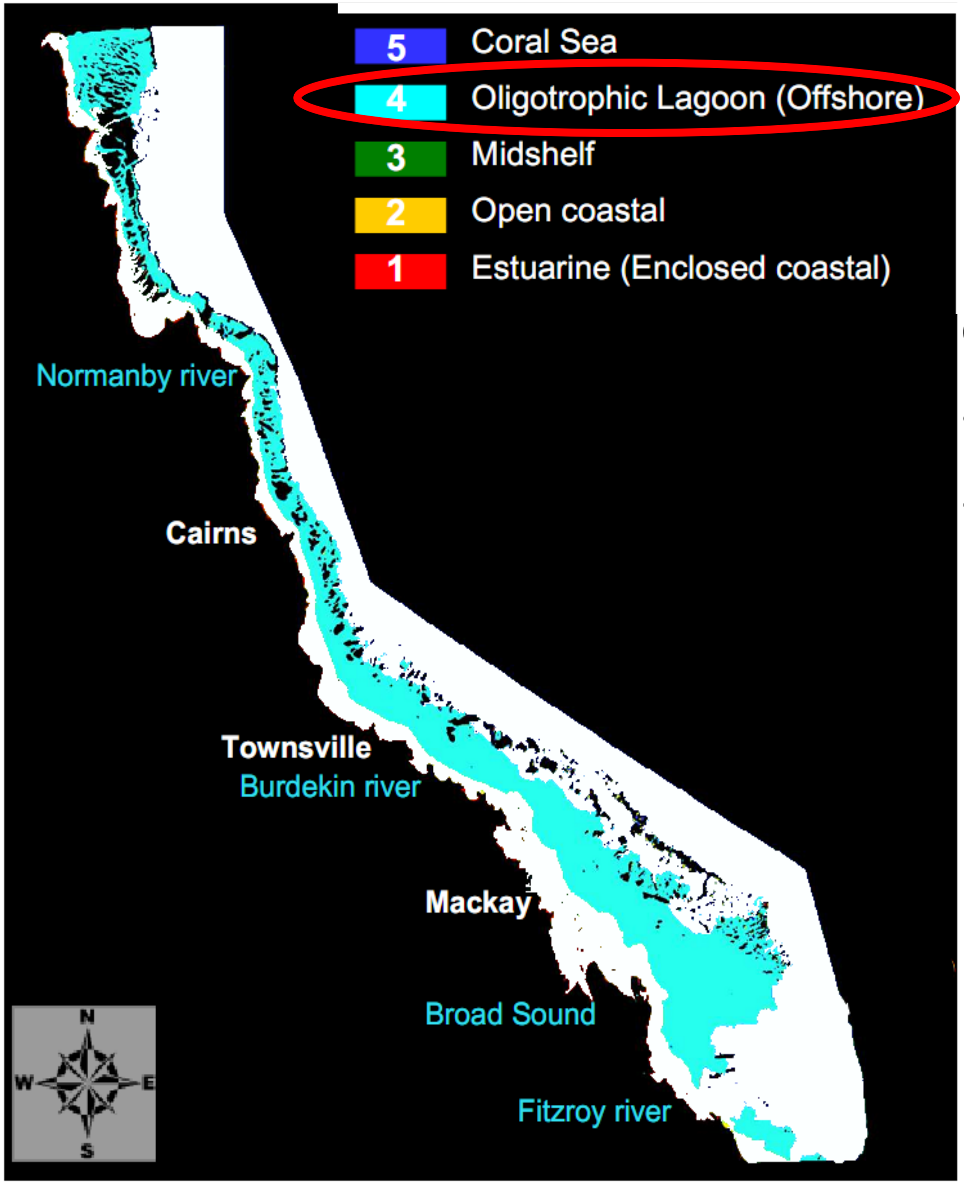


Clustering the Great Barrier Reef waters



K-means clustering results based on 12 monthly-means Chlorophyll-a maps.

Example: the oligotrophic lagoon cluster



Oligotrophic cluster

•More responsive to environmental forcings

•Hypothesis was that the blooms were short lived.

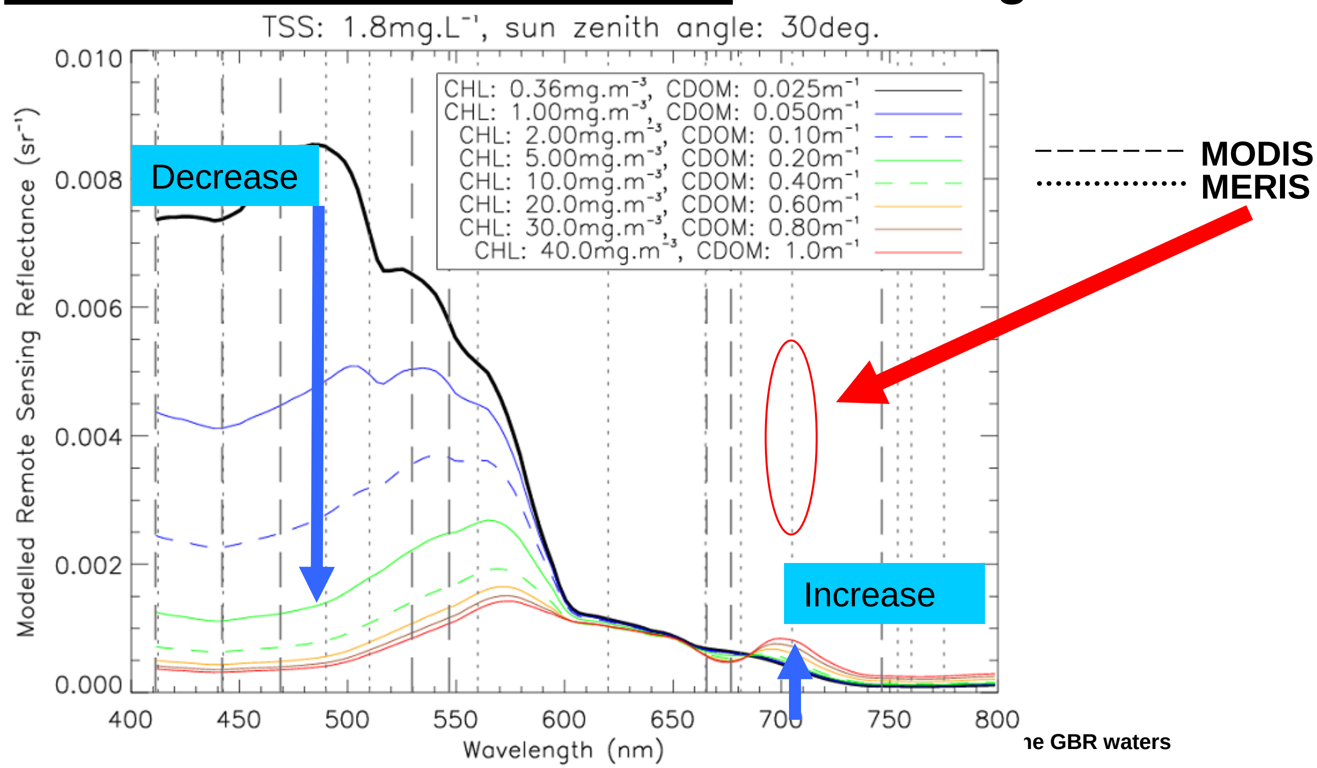
toplankton blooms in the GBR waters

Three MERIS algorithms for algal blooms

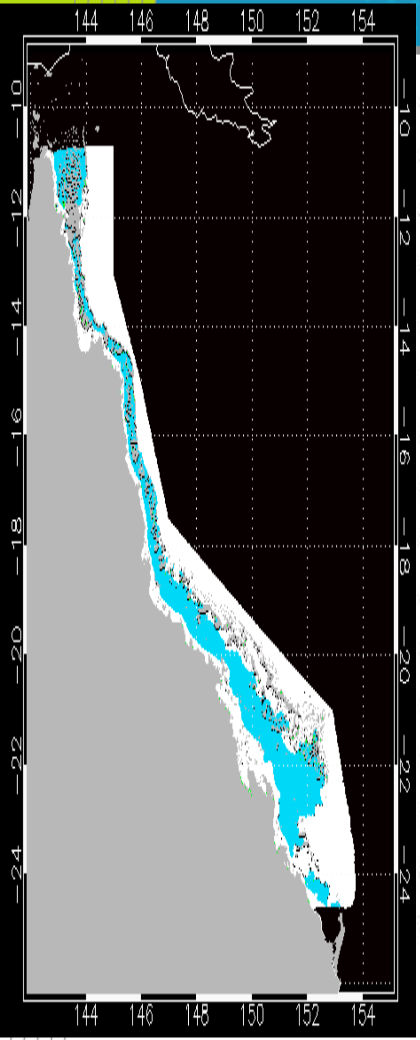
1. **Chlorophyll –a**: in-water algal blooms, up to ~50 mg.L^{-1}

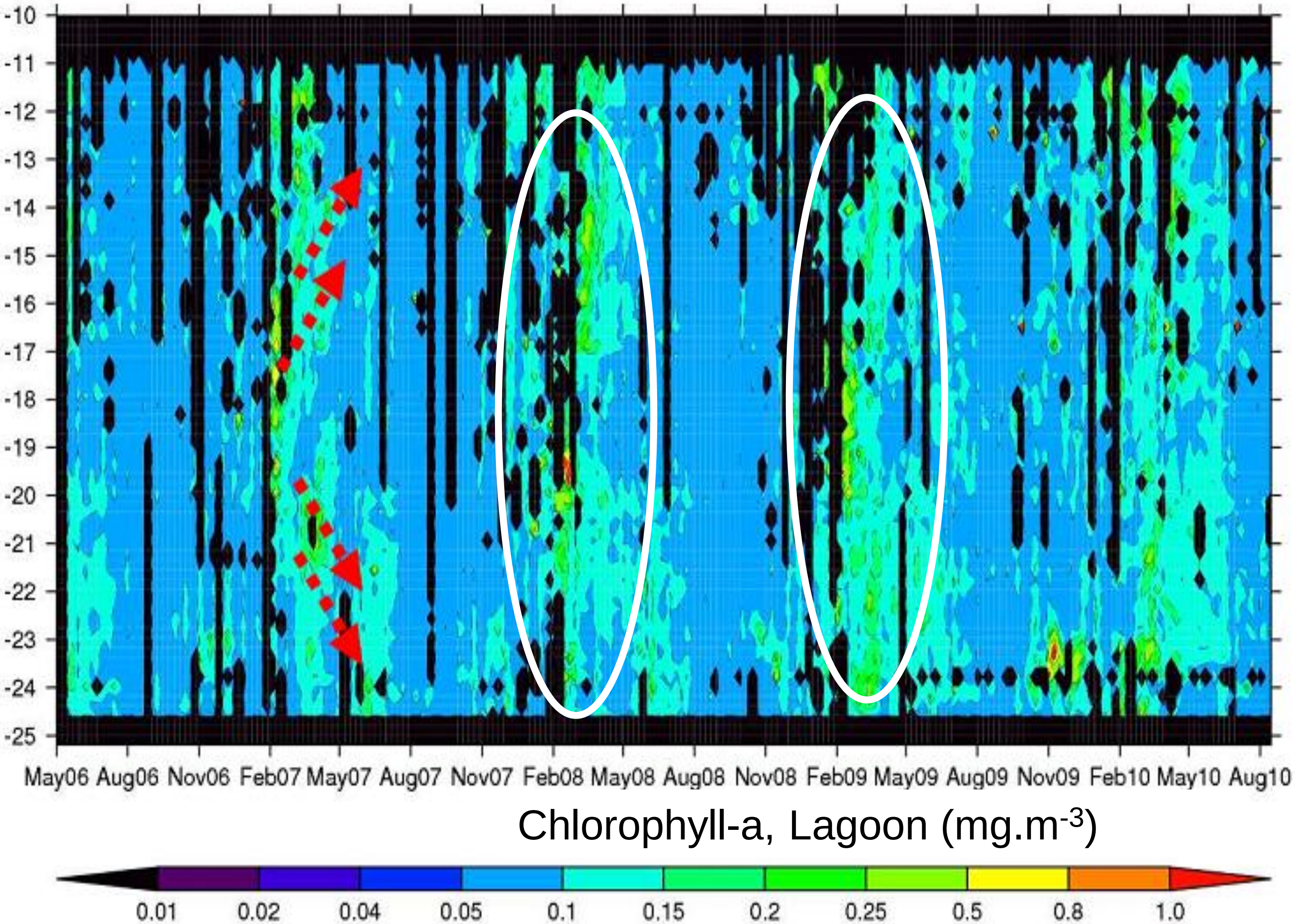
2. **Fluorescence Line Height:** in-water algal blooms, up to ~5 mg.L^{-1}

3. **Maximum Chlorophyll index:** surface algal blooms or >30 mg.L^{-1}



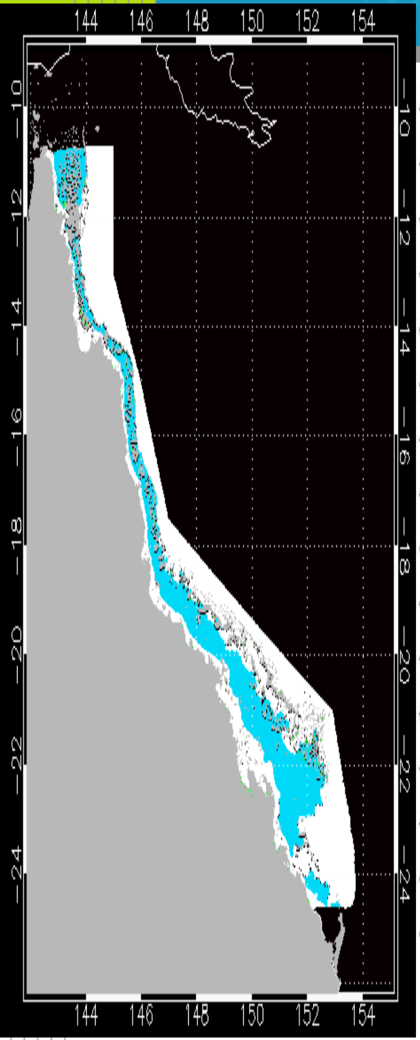
Latitude-time plots of Chlorophyll

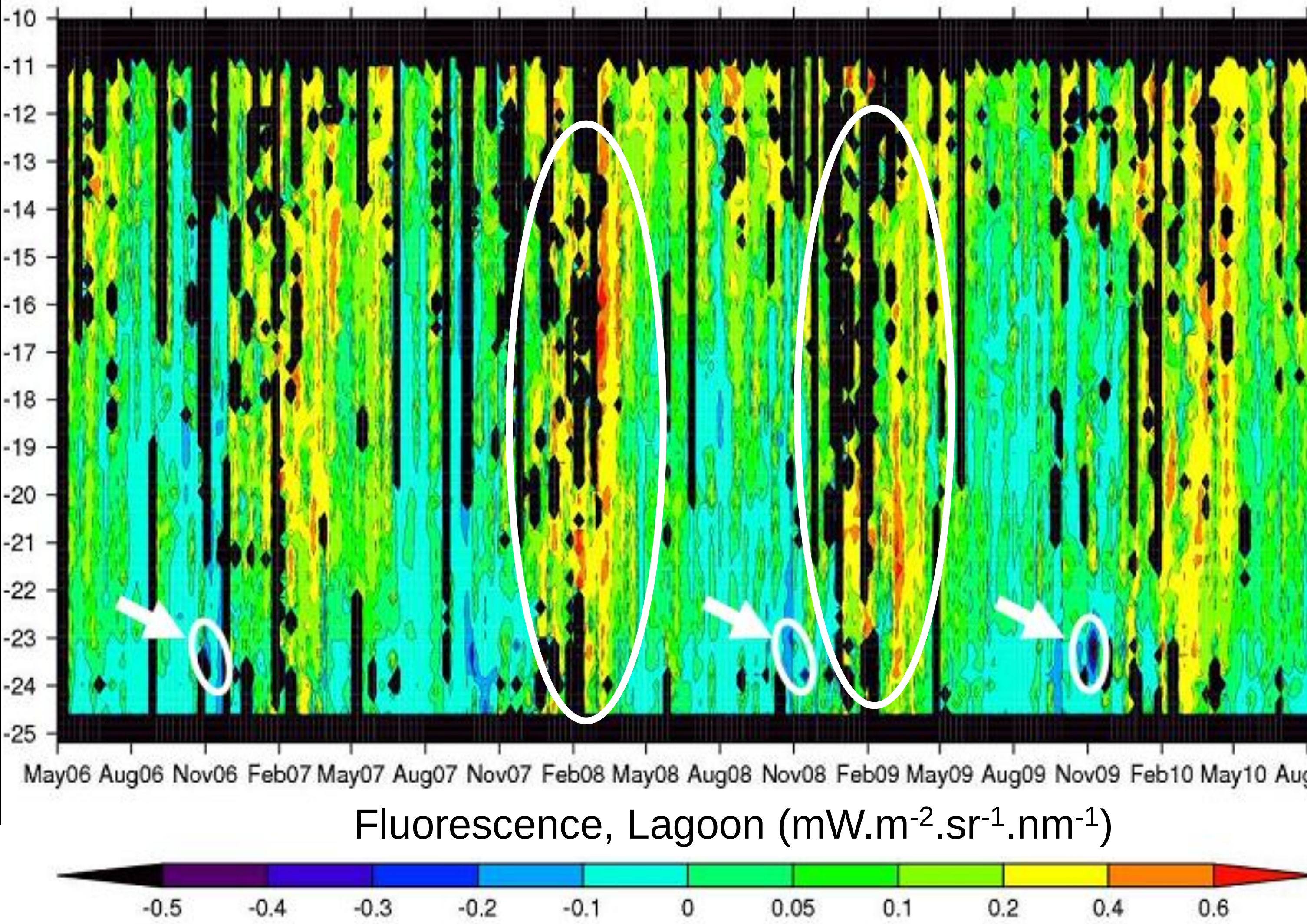




1. Chlorophyll-a: in-water algal blooms, up to ~50 $mg.L^{-1}$

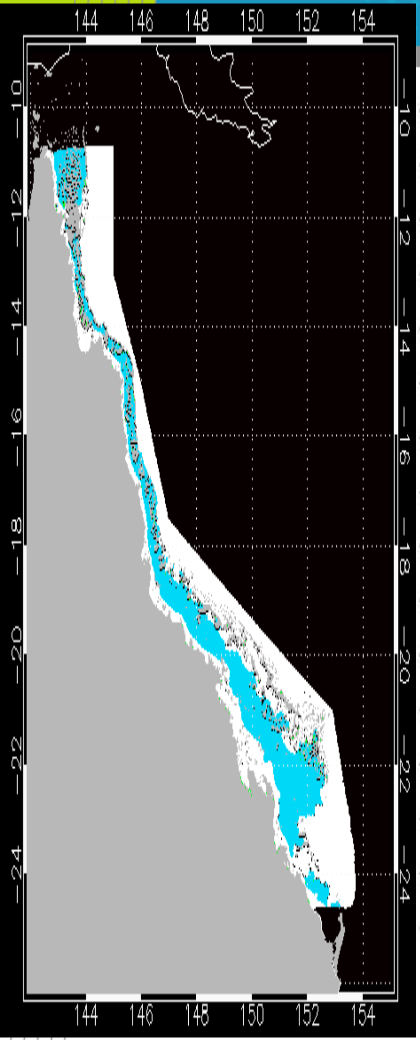
Latitude-time plots of Fluorescence

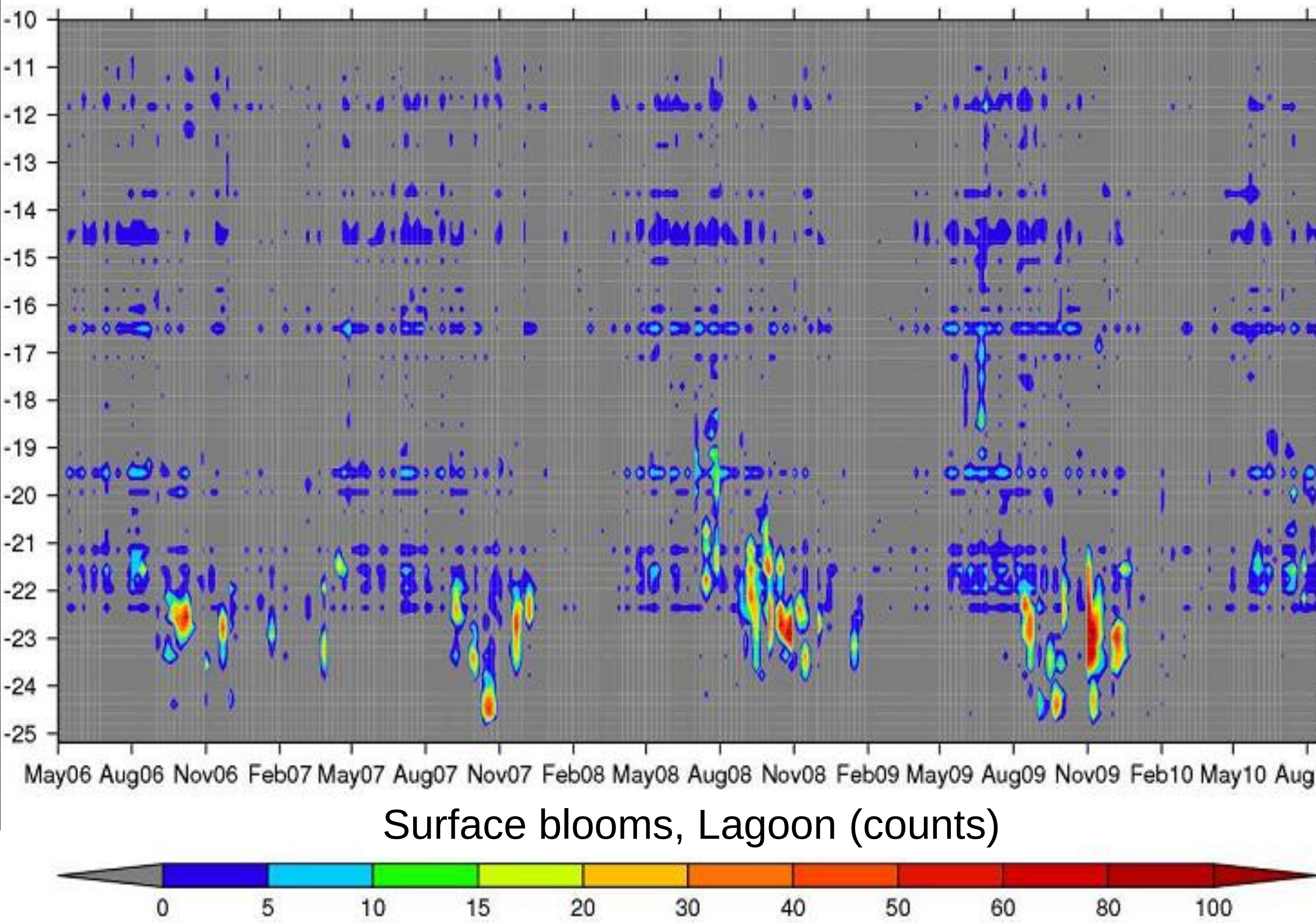




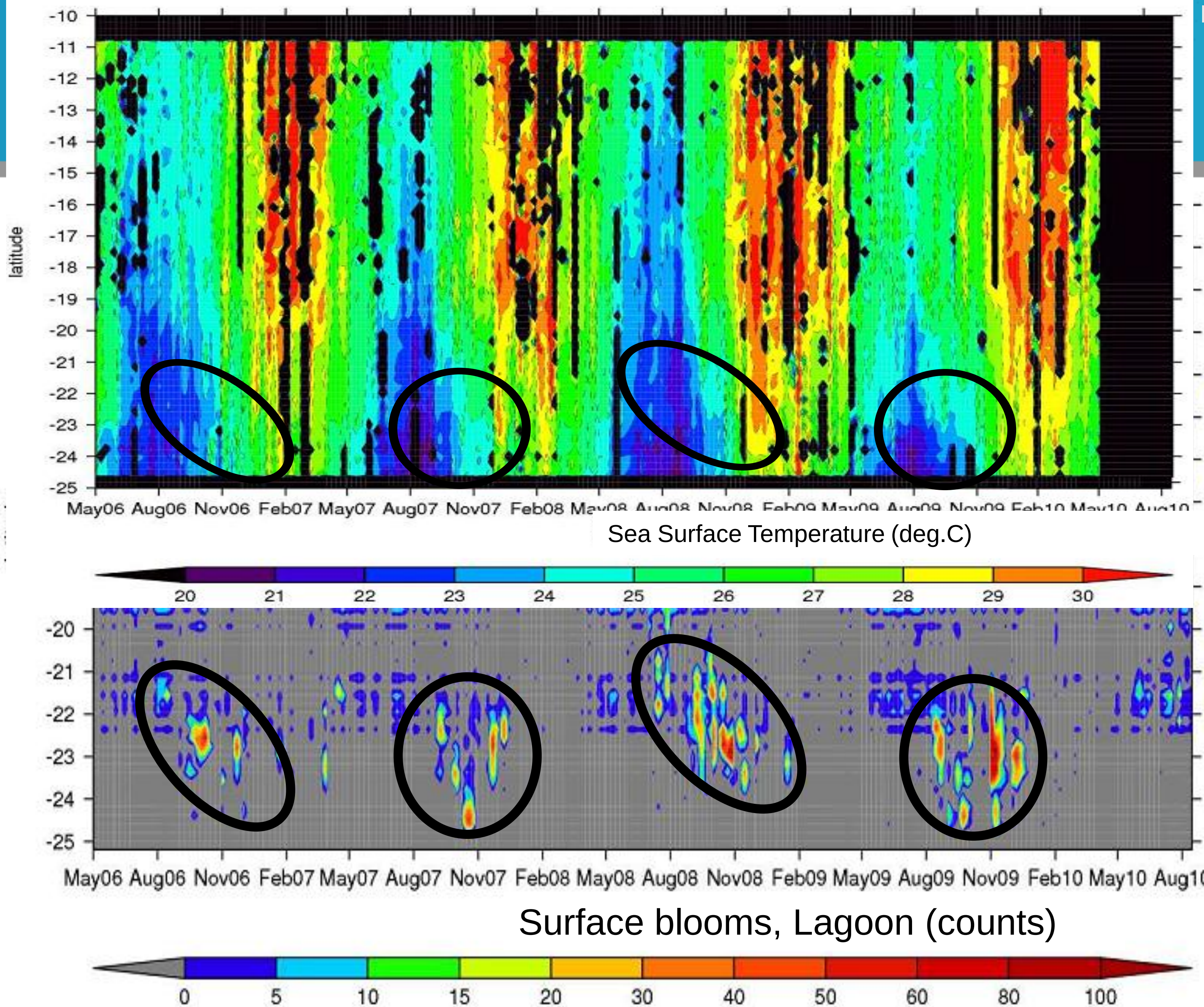
2. Fluorescence: in-water algal blooms, up to ~5 $mg.L^{-1}$

Latitude-time plots of Surface blooms



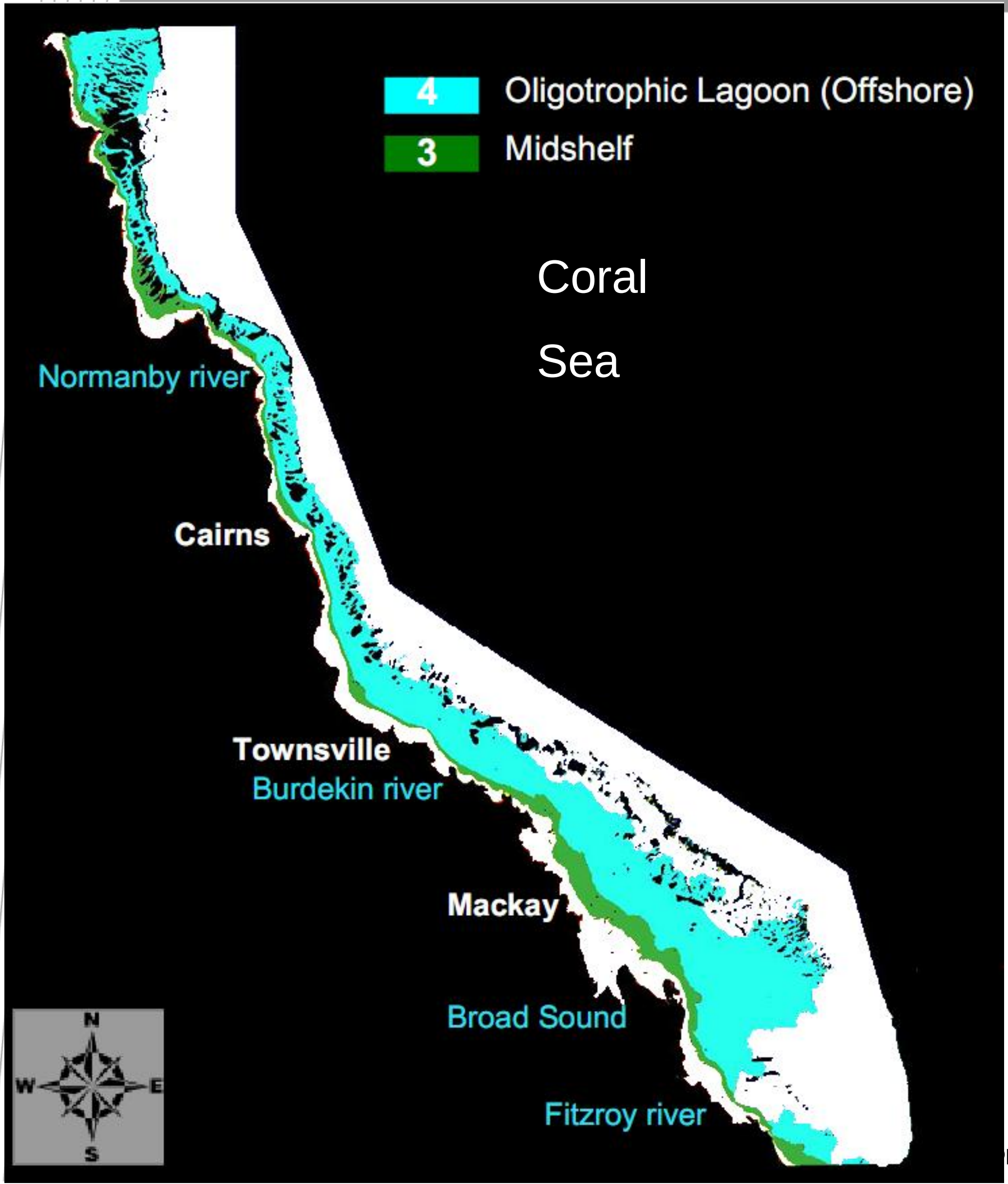


3. Maximum Chl. Index: surface algal blooms >30 mg.L^{-1}



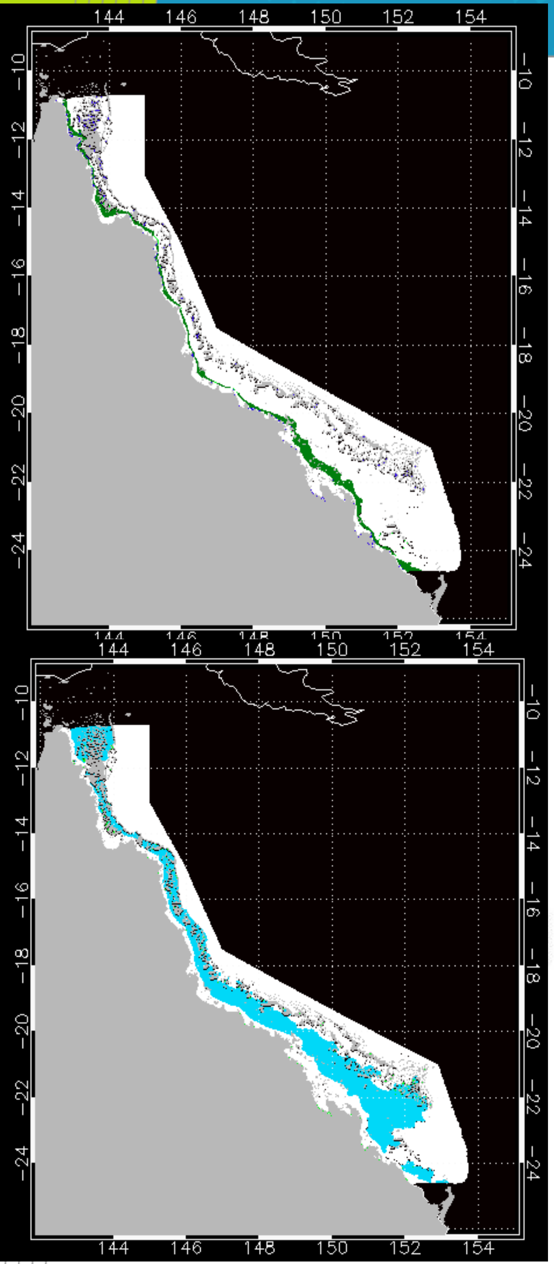
3. Maximum Chl. Index: surface algal blooms >30 mg.L-1

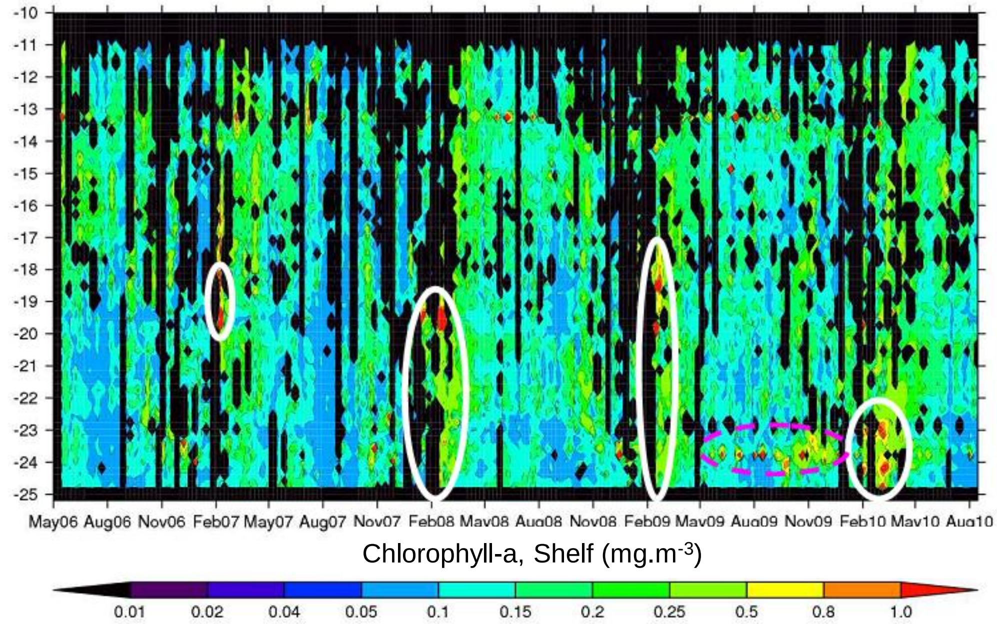
Clustering the Great Barrier Reef waters



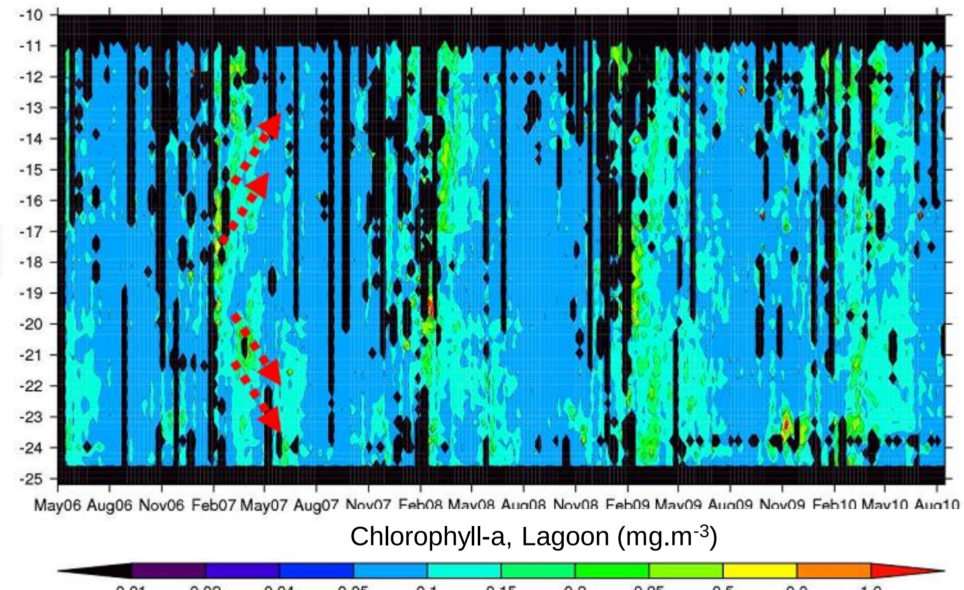
The oligotrophic waters cluster vs. Mids
waters cluster.

Phytoplankton dynamics: Lagoon vs shelf





Shelf

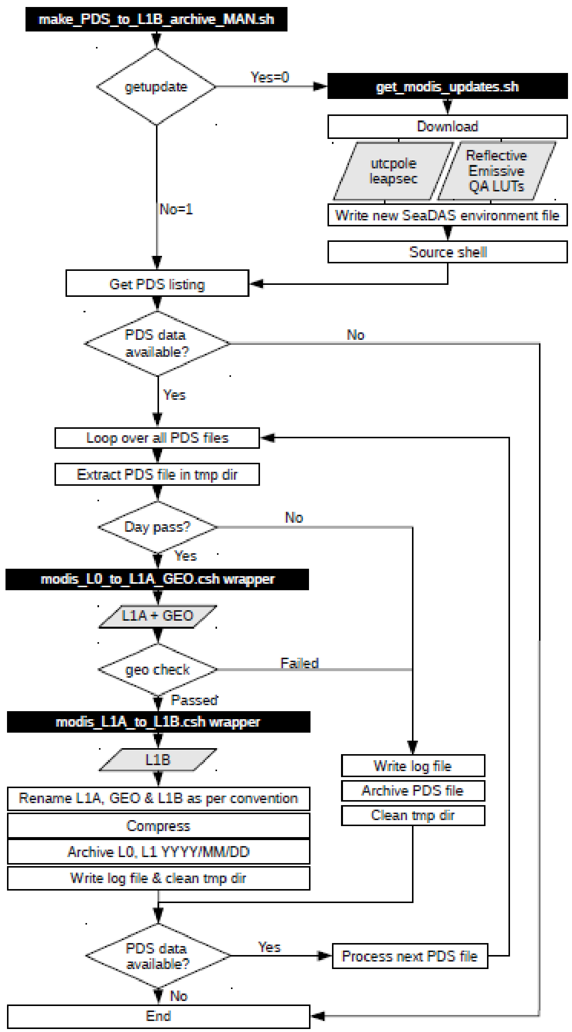


Lagoon

Algorithm Specific Requirements Effective Operationalisation EO-

- **Robust algorithms for primary information products:**
  - Chlorophyll, Phaeophytin (&CP-Cyanin & CP-Erythrin)
  - *Phytoplankton Functional Types?*
  - Suspended matter
  - *Particle Size Distributions?*
  - Coloured dissolved organic matter
  - Transparency & turbidity as vertical attenuation of light (k_d)
  - *Corrections for bottom effects?*
- **Robust methods for assimilating this data into information products:**
  - Eutrophication/compliance
  - Sediment loads/compliance
  - Primary Productivity
  - Flood Plume
  - Algal Bloom
  - ??Coral Bleaching?? (needs 3-D water column and substratum analysis = more complex)

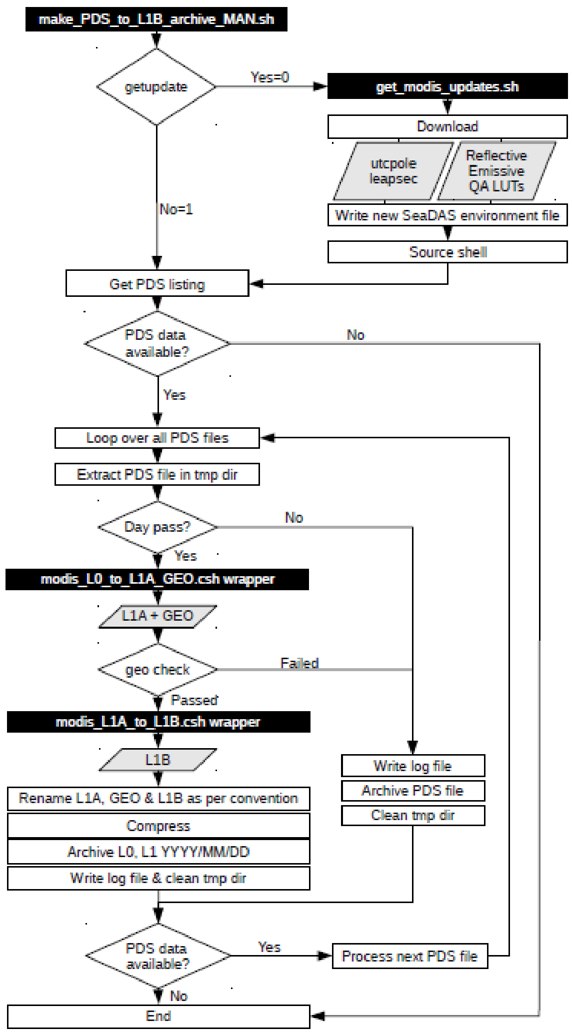
Processing Transfer – Nationally Consistent Archive
National Computational Infrastructure (NOAA-AVHRR-SeaWiFS,MODIS-*MERIS*)



- 1492 nodes in Sun X6275 blades, each containing:
  Two quad-core 2.93GHz Intel Nehalem CPUs
  24-48 GBytes DDR-1333 memory
- Peak theoretical performance of ~140 TFlops
- Total of 37 TBytes of RAM on compute nodes
- Approx 800 TBytes of usable global storage

NCI National Facility
nf.nci.org.au
National Computational Infrastructure

Australia's (scientific) end user requirement
MERIS: L1P full archive (on disk) and then update via ftp
SENTINEL-3: DB?



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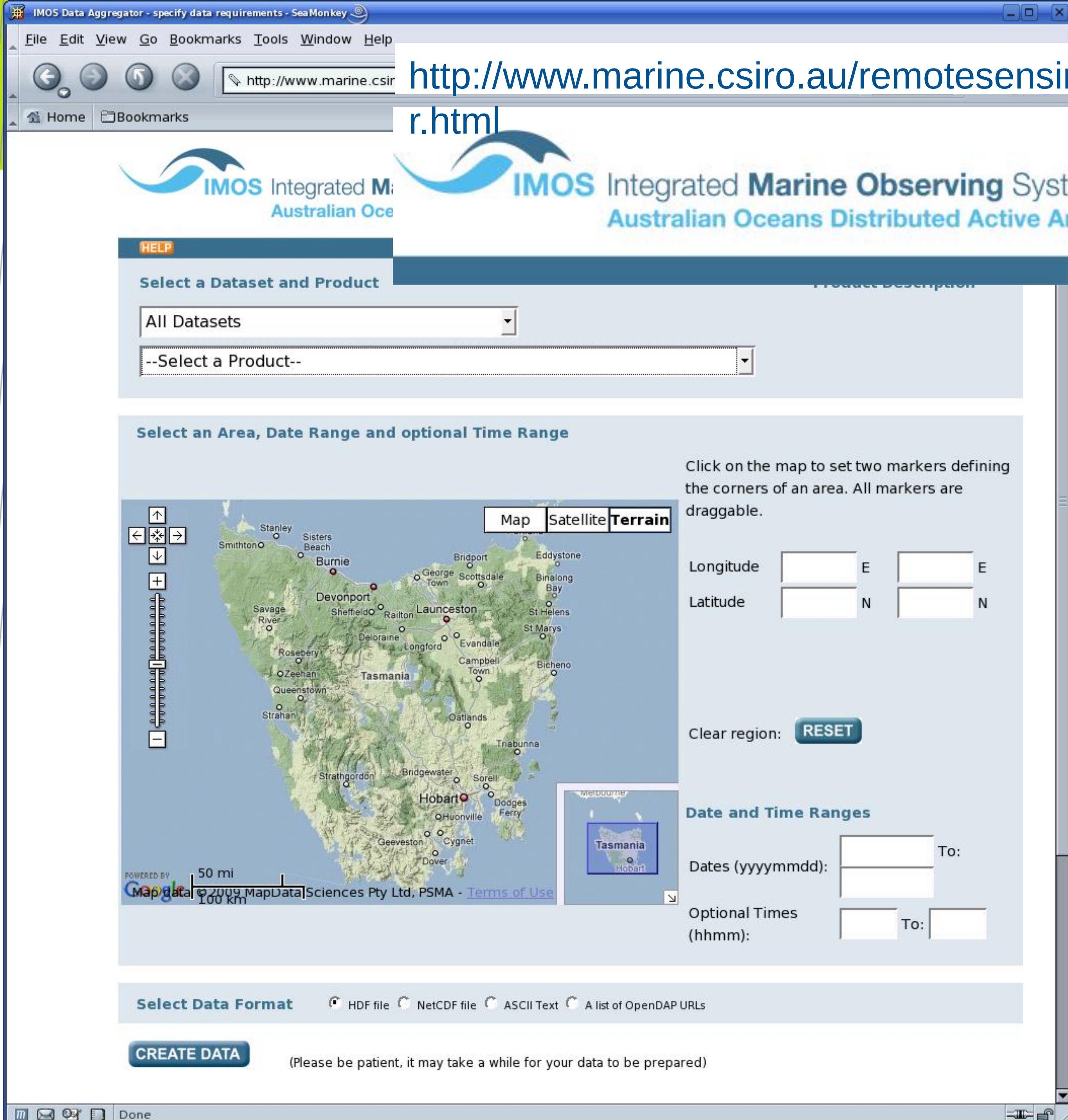
NCI National Facility nf.nci.org.au National Computational Infrastructure http://www.marine.csiro.au/remotesensing/imos/aggregator.html

IMOS Integrated Marine Observing System
Australian Oceans Distributed Active Archive Centre



Australia: towards an aquatic ecosystems Earth Observation System: Water Quality

- **For (actual) end-users (= not ESA UCM community) water quality information needs to be packaged into manageable format before it shall be adopted**
- **SoE in Australia was knowledgeable about earth observation of coastal and marine systems –**
- **Hovmoller plot made it feasible to incorporate 5 years of trends and anomalies into total of 5 pages of SoE discussion for coasts and oceans Australia.**
- **Continuity of data and information provision crucial! (requires smooth transition MODIS to VIIRS; MERIS – SENTINEL-3 OLCI)**

Australia: towards an aquatic ecosystems Earth Observation System: All applications:

Using MODIS now & MERIS (when proc.3 archive is available), VIIRS and Sentinel-2 and 3 in future as core missions (augmented by high spatial res sensors)

- **Shoreline erosion and flooding**
  - Supratidal (from the mangrove and saltmarsh via the intertidal to the subtidal)
  - Intertidal zone extent (HAT to LAT)
  - Bathymetry
- **Emergency management**
  - Oil & Chemical Spill Response Atlas
- **Erosion Budgets**
  - Effect of land-use changes on run-off
- **Eutrophication- Nutrients Fluxes & Budgets**
  - Inland waters, bays and estuaries to coral reefs
  - Bathymetry, habitat, water quality
- **Carbon Fluxes & Budgets**
  - Land to sea fluxes and reservoirs (coastal wetlands)
  - Hydrodynamics, salinity tracer
- **National Environmental Accounts**
  - State of Environment reporting
  - National Environmental Accounting
- **Fisheries**

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- **National Environmental Accounts**
  - State of Environment Reporting
  - National Environmental Accounting

Wrap-Up

Sincere thanks to ESA CoastColour for being "global".

Keep this Coastal COP going! Add inland waters!

Arnold.Dekker@csiro.au

Thomas.Schroeder@csiro.au

Some recent publications of interest to ESA-CC community:

Bouma, J., Kuik, O. and Dekker, A.G. (2011) *Assessing the value of Earth Observation for managing coral reefs: An example from the Great Barrier* Reef; *Science of the Total Environment*, Vol. 409, Issue 21, pp 4497-4503. DOI 10.1016/j.scitotenv.2011.07.023.

Dekker A.G., Phinn S.R., Anstee J.M., Bissett P. Brando V.E., Casey B. Fearns P., Hedley J., Klonowski, W., Lee Z.P., Lynch M., Lyons M., Mobley C. and Roelfsema C. (2011) Intercomparison of shallow water bathymetry, hydro-optics and benthos mapping techniques in Australian and Caribbean coastal environments; *Limnology & Oceanography Methods.* Vol 9:pp 396-425