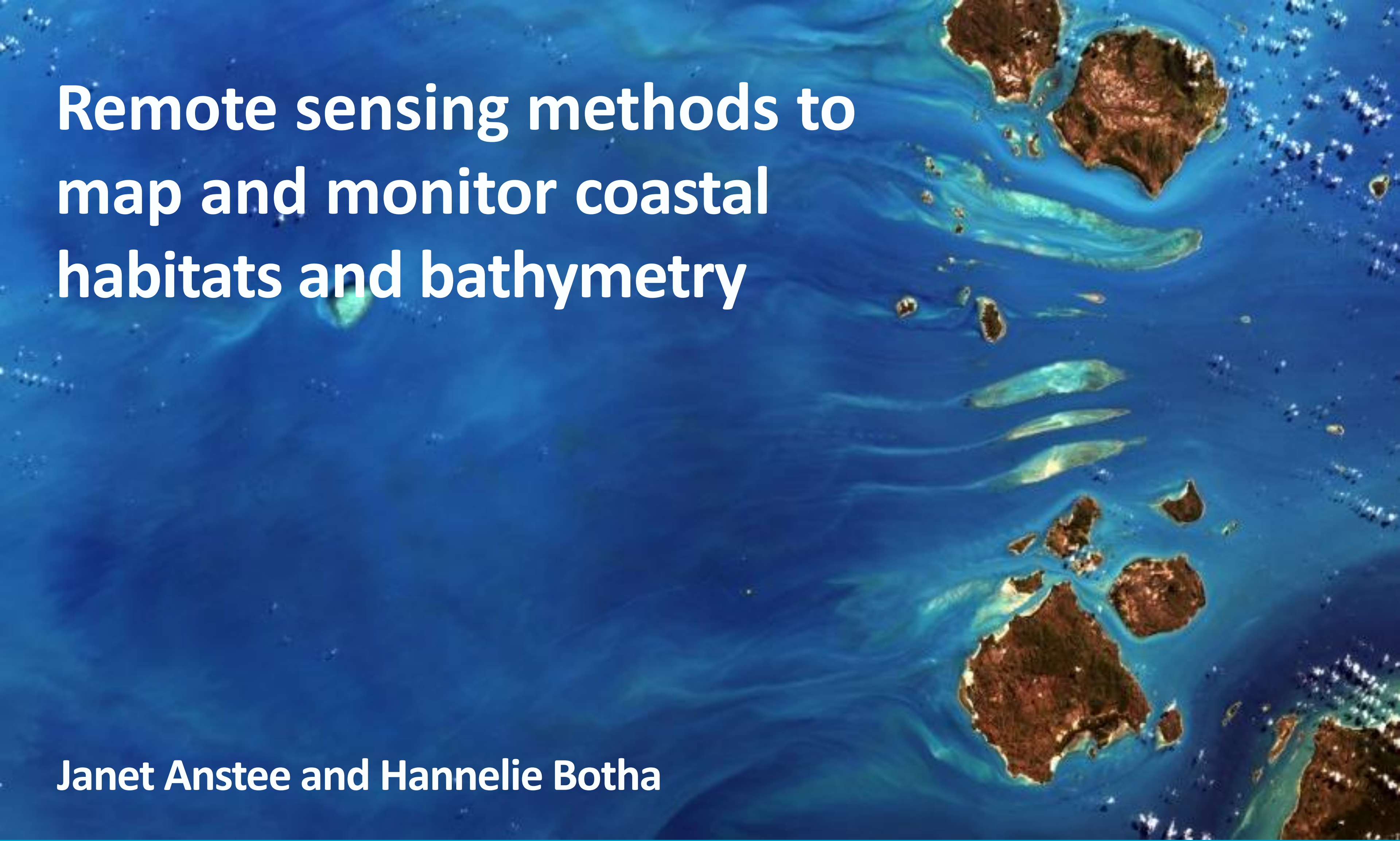

Remote sensing methods to map and monitor coastal habitats and bathymetry

Janet Anstee and Hannelie Botha

OCEANS AND ATMOSPHERE
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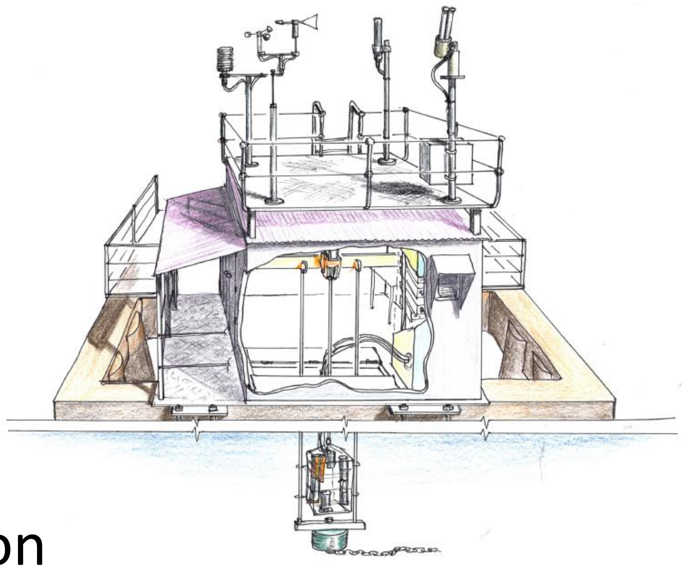
CSIRO

EOMAP SDB Day - 15 May 2019

Development of Earth observation methods for water quality and coastal habitat assessment

- Characterisation of aquatic bio-optics & substrates
- Calibration and validation facilities
- Algorithms
- Accuracy and uncertainty metrics
- Multi-sensor model-data integration



CSIRO - Optically Shallow and Optically Deep Water - Remote Sensing based on 3 methods

1. Atmospheric correction and air-water interface effects removal (RT physics-based and increasingly relying on ANN for fast processing)
2. For optically deep waters: adaptive linear matrix inversion method (aLMI) using variable sets of SIOPS (Specific Inherent Optical Properties) to allow for varying water types within one image
3. For optically shallow waters: enhancement of enhanced implementation of the inversion/optimization approach by Lee et al. (1999, 2001) by including multiple substratum types (SAMBUCA)

SAMBUCA: Semi Analytical Model for Bathymetry, Unmixing and Concentration Assessment

SAMBUCA is an enhancement (by Brando et al. 2009) of the inversion/optimization method by Lee *et al.* (1998; 1999; 2001) to enable:

- Retrieval of chlorophyll-a, CDOM and NAP concentrations in varying water types
- Pure and mixed substratum-type compositions
- Retrieval of vertical attenuation (for optically deep water)
- Retrieval of bathymetry
- Estimating the contribution of the substratum-type to the remote sensing signal (SDI)

Remote Sensing of Environment 113 (2009) 755–770

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Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse

ELSEVIER

A physics based retrieval and quality assessment of bathymetry from suboptimal hyperspectral data

Vittorio E. Brando [a,*], Janet M. Anstee [a], Magnus Wettle [a], Arnold G. Dekker [a], Stuart R. Phinn [b], Chris Roelfsema [b]

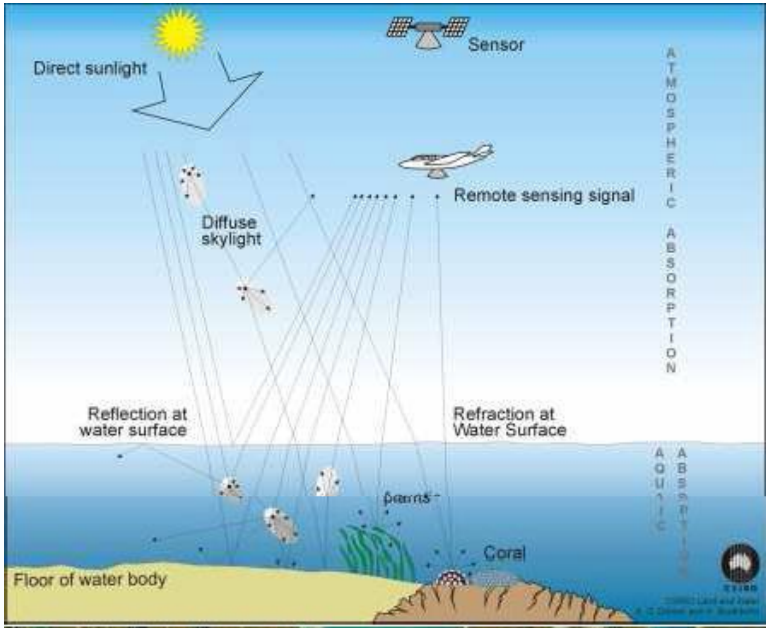
CSIRO

The challenge for water quality and coastal habitat assessment

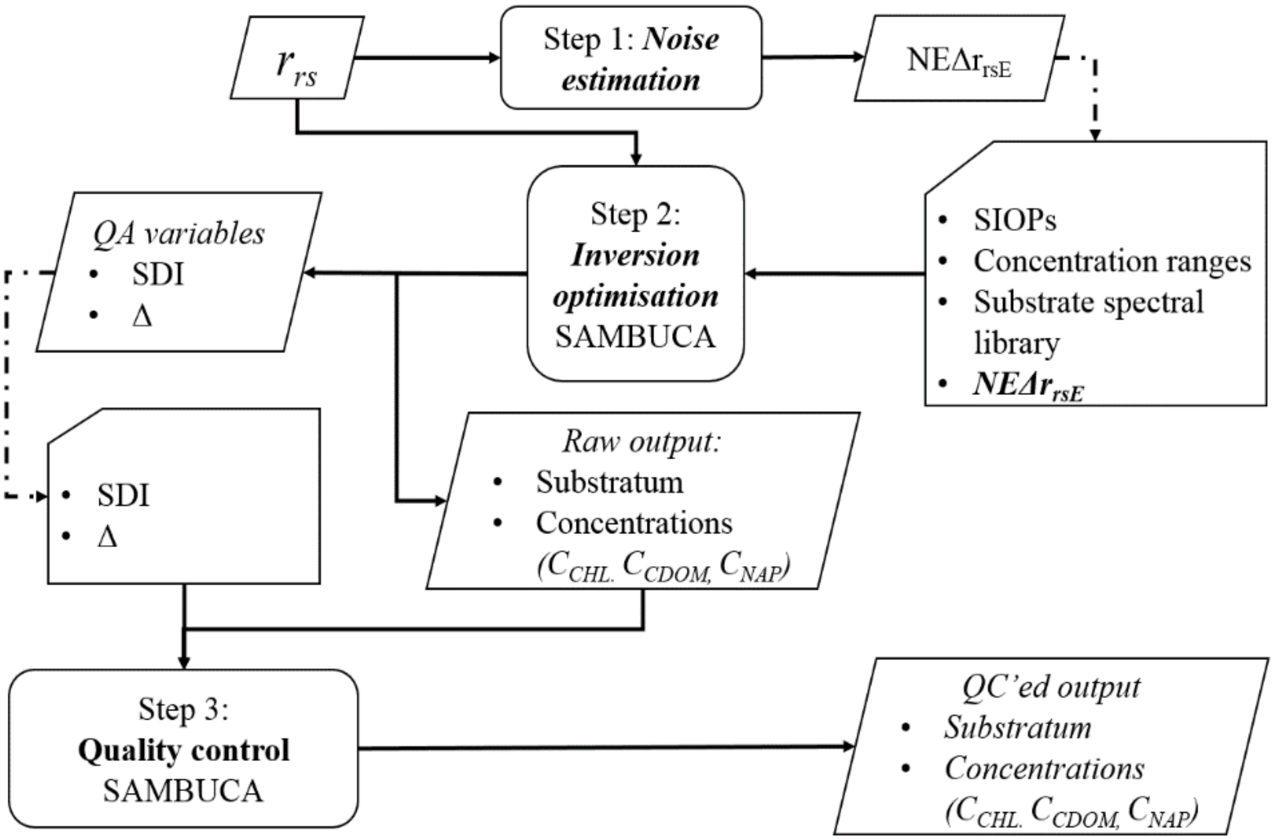
Coastal and coral reef water bodies are a mixture of:

- optically shallow,
- quasi optically deep
- and optically deep waters (gradients of clear to turbid waters & varying bottom visibility)
- substrate visibility and optical complexity affects water quality parameters model retrievals

- Previous approaches using empirical regression-based techniques cannot account for the complexity of these waters

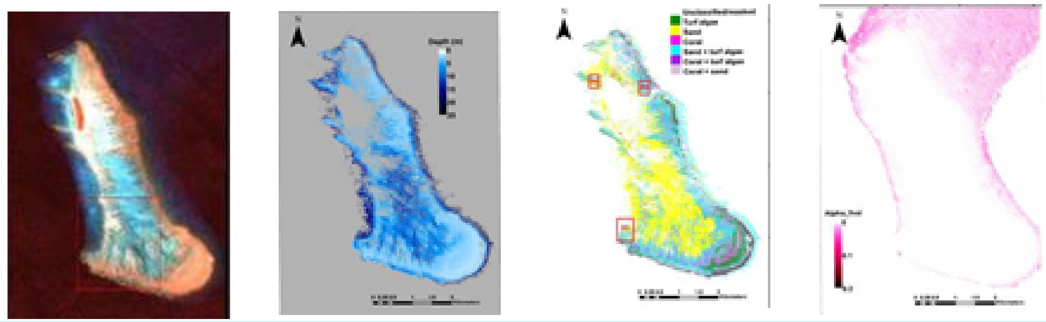


SAMBUCA: Semi Analytical Model for Bathymetry, Unmixing and Concentration Assessment



It is sensor agnostic: it works across multispectral to hyperspectral EO

Optically Shallow Waters Inversion Methods
SAMBUCA



- Implementing the Open Source code on the National Computational Infrastructure (NCI) facility at the Australian National University.
- This enables processing at higher resolution, within shorter periods of time and provide access to new tools and techniques (such as time-series analysis) when applied on the Digital Earth Australia DataCube.
- This research is currently being supported through a joint CSIRO-GA project.

Bathymetry

Submerged aquatic vegetation

Vertical attenuation of light

Chlorophyll

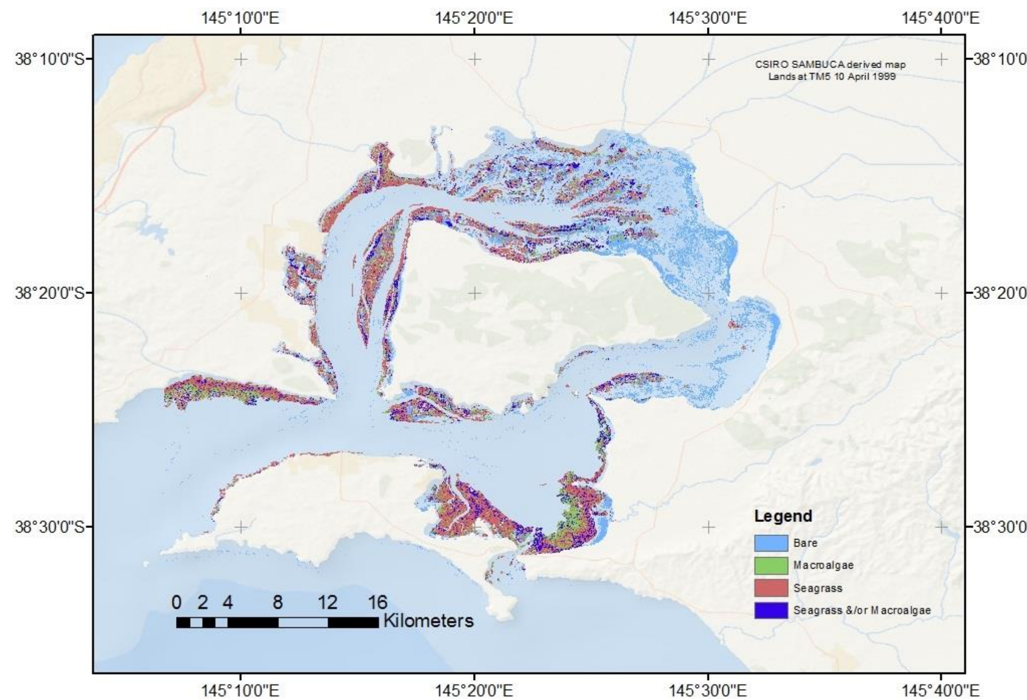
Total suspended matter

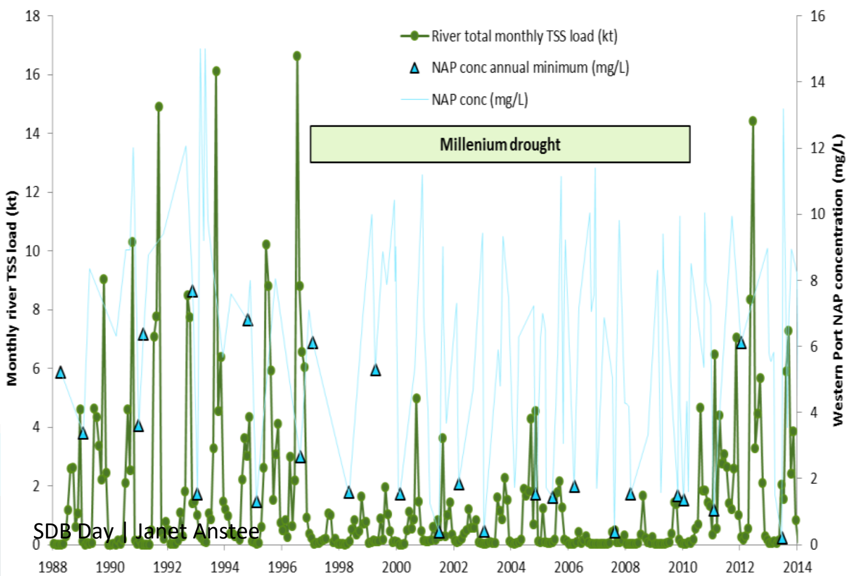
Coloured Dissolved organic matter

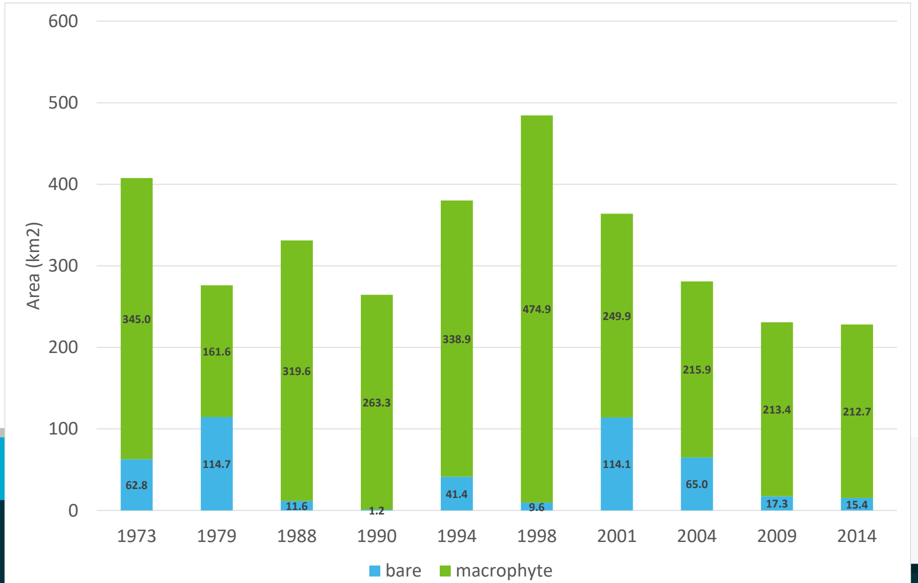
INVERSION

Western Port Bay

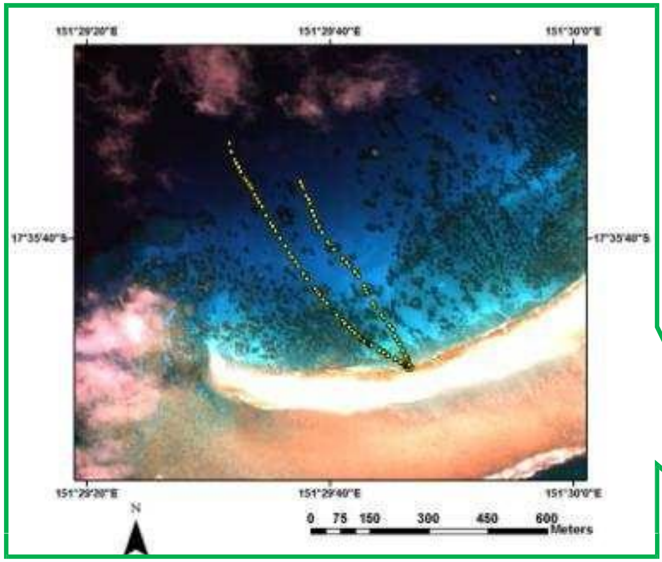
- Inversion retrievals of
- WQ information
- bathymetry
- substrate type
- Light Attenuation Kd(490)

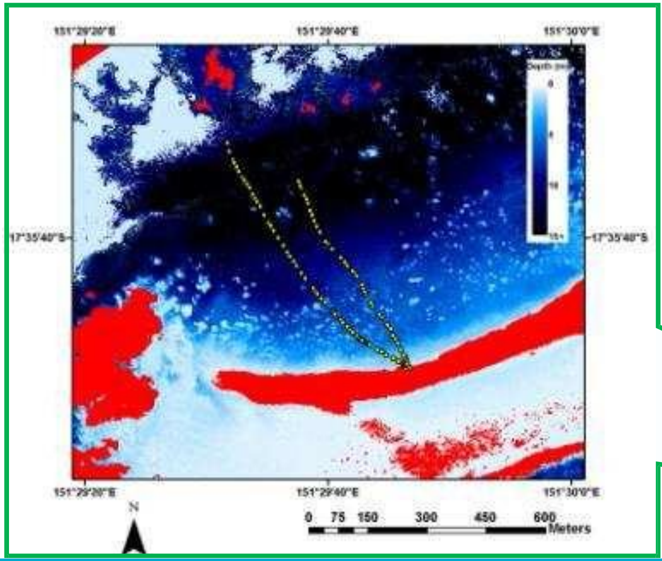




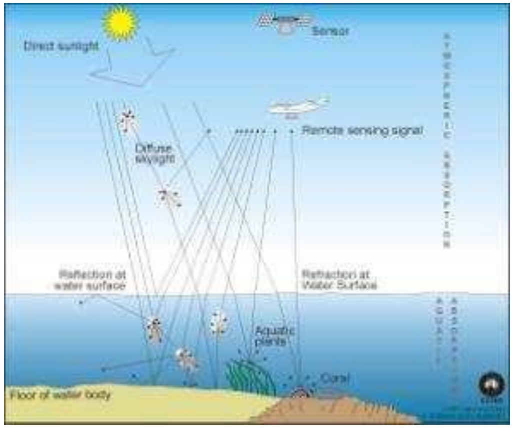


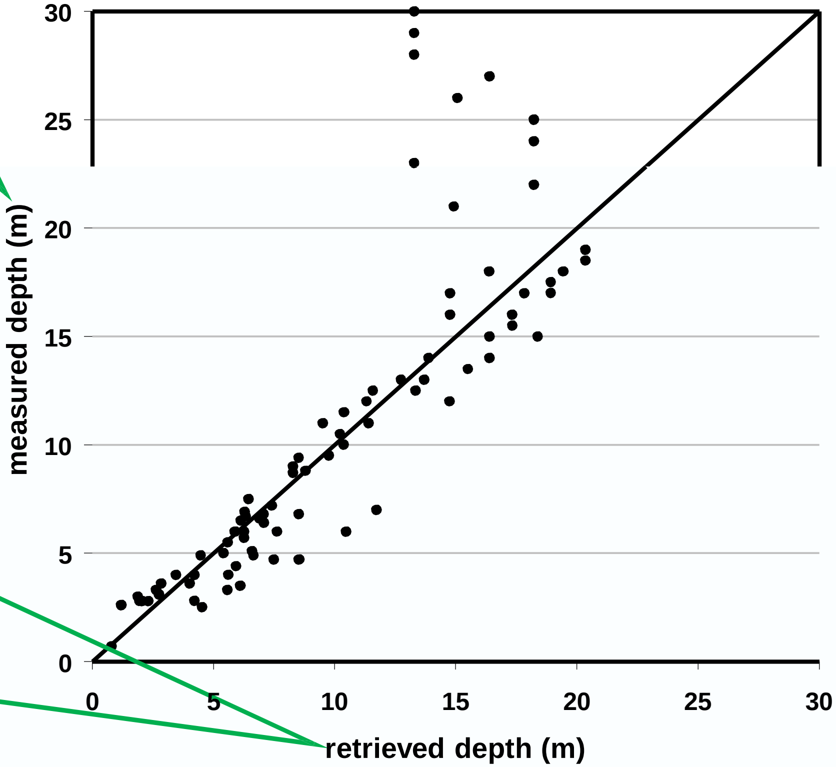
Example: Georgina Cay, Coral Sea



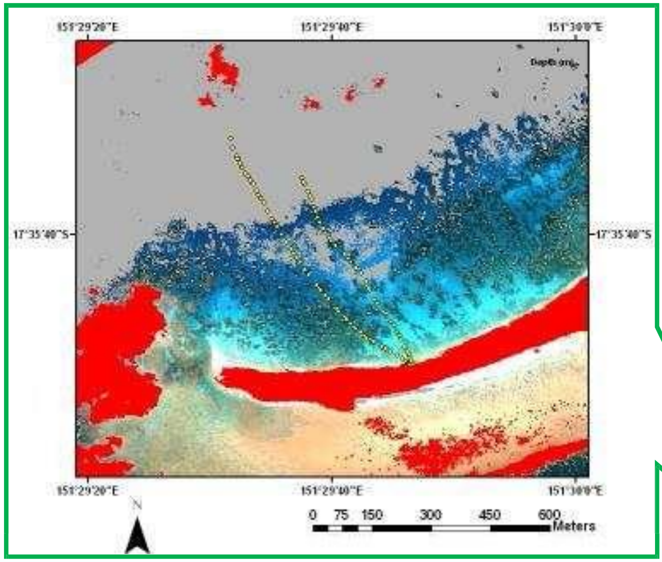


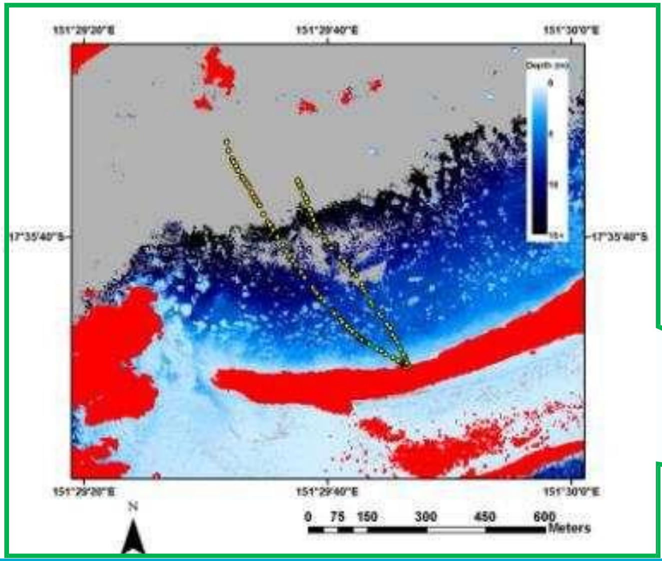
Land/clouds/sunglint

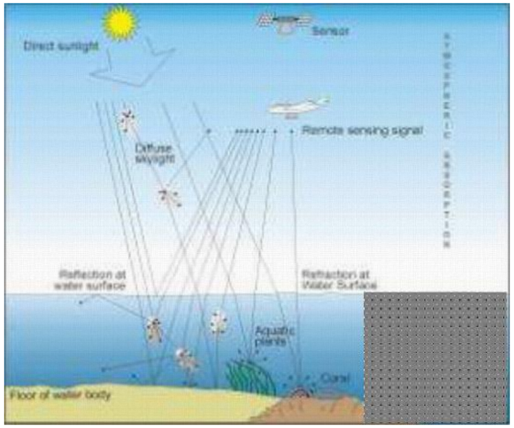




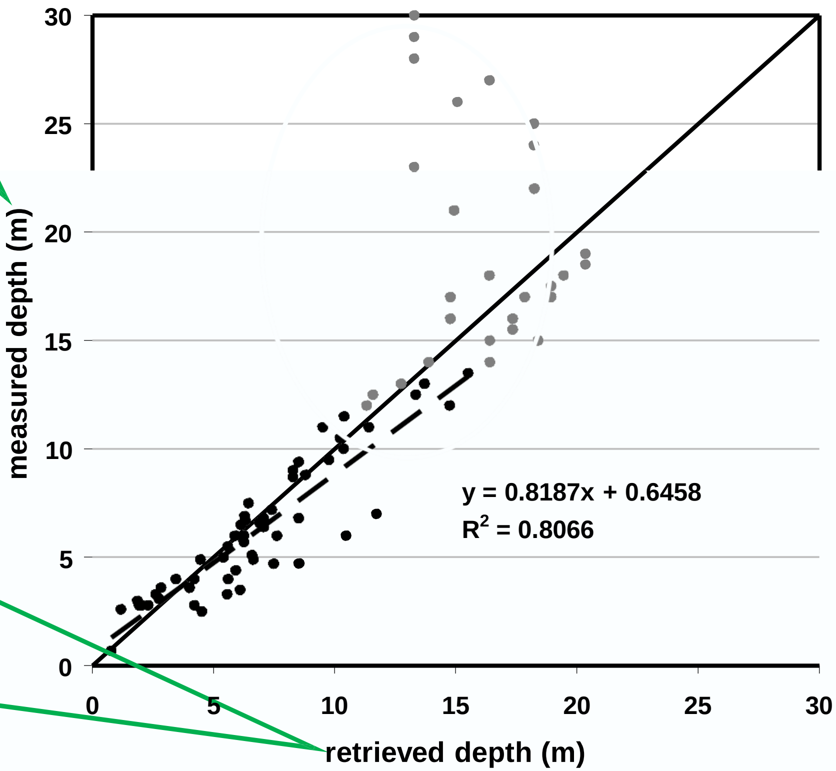
Example: Georgina Cay, Coral Sea



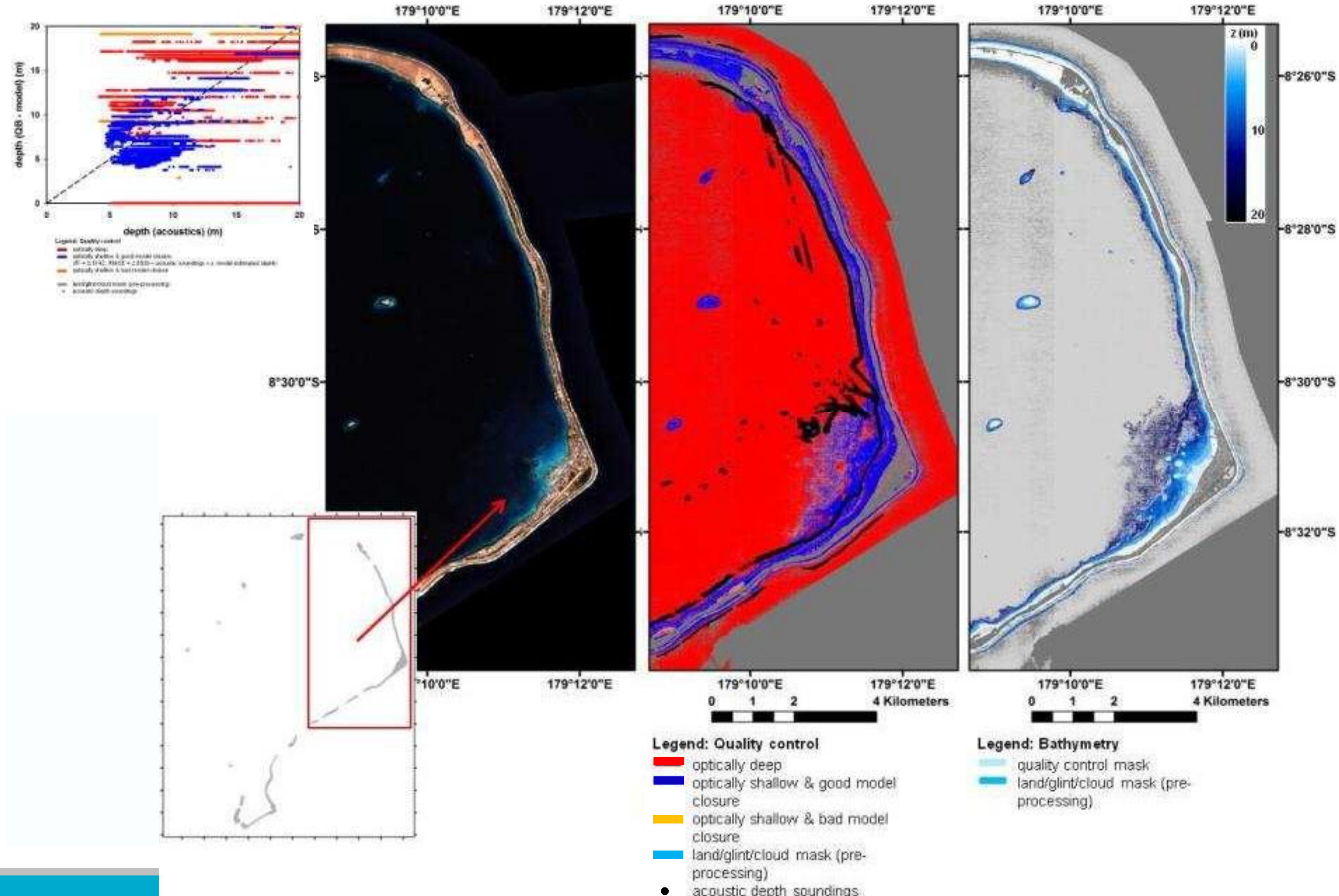




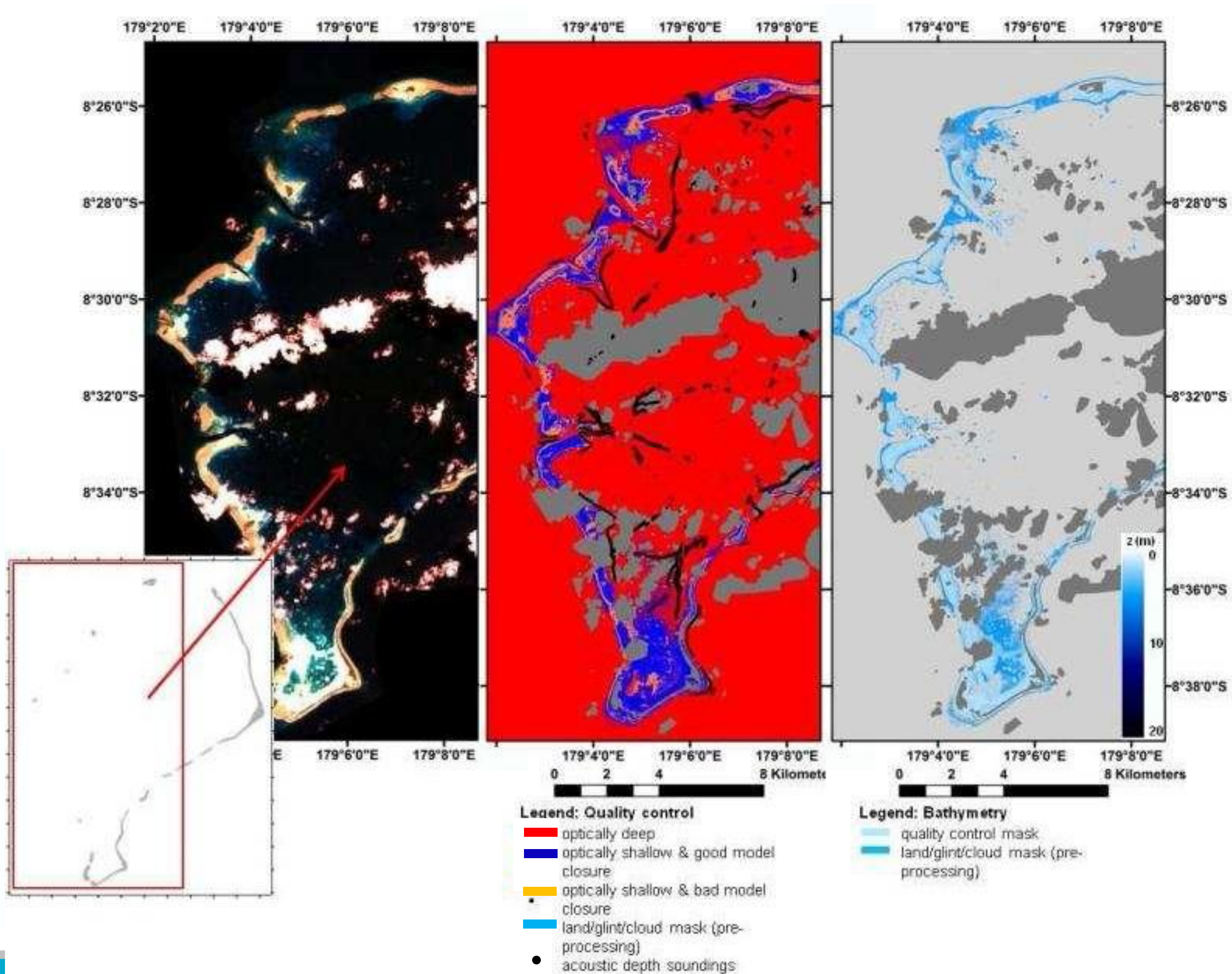
Land/clouds/sunglint
Quality control



Example: Funafuti, Tuvalu

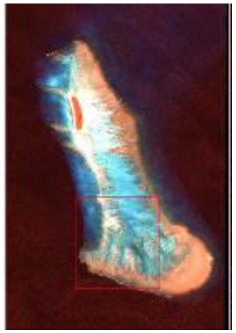


Example: Funafuti, Tuvalu



SAMBUCA approach

(applied on Quickbird imagery, Botha et al., 2010)



Quickbird image

Pre-processing:

1. **De-glinting**
2. **Atmospheric correction**

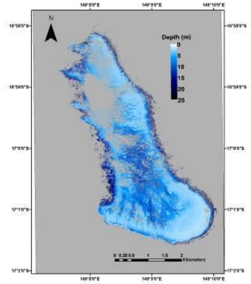
Substratum reflectance spectra

Aquatic

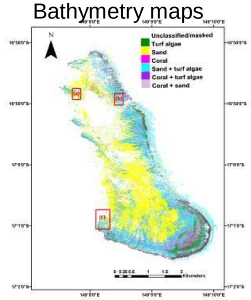
Physics-based inversion model (SAMBUCA Model)

water optical properties

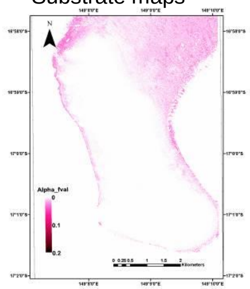
Information Products



Bathymetry maps



Substrate maps



Accuracy maps

National Research
FLAGSHIPS
Wealth from Oceans

CSIRO

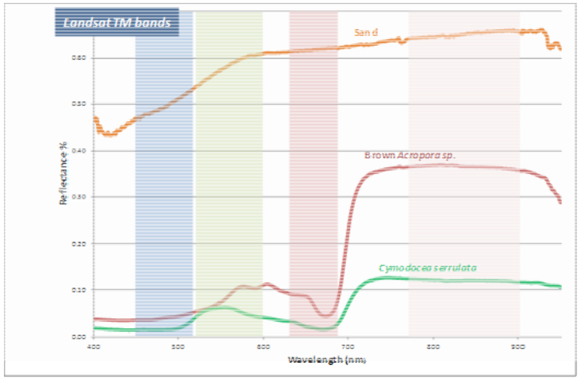
Remote sensing for habitat mapping and change detection in tropical Commonwealth marine protected areas – phase 2

E.J. Botha, A.G. Dekker, Y.J. Park, J.M. Anstee, N. Cherukuru, L. Clementson

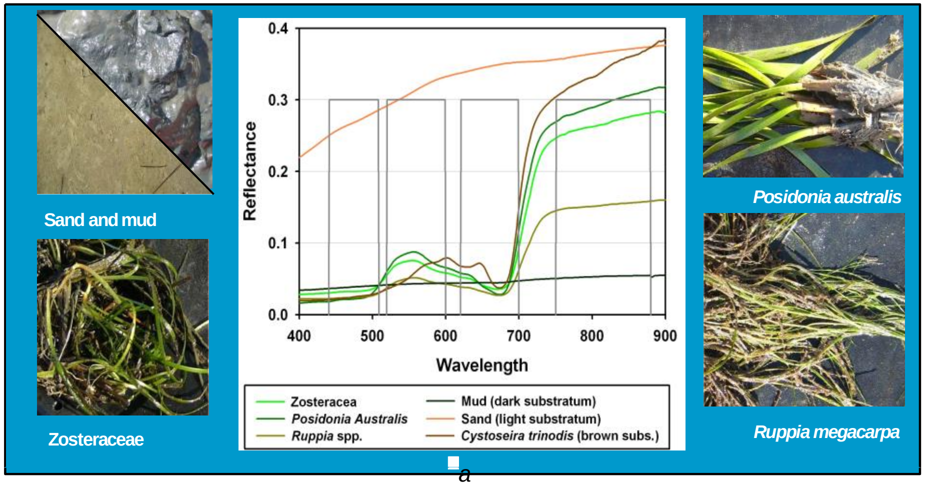
June 2010

Parameterizing SAMBUCA: Substrates

Spectral sensitivity of satellite data:



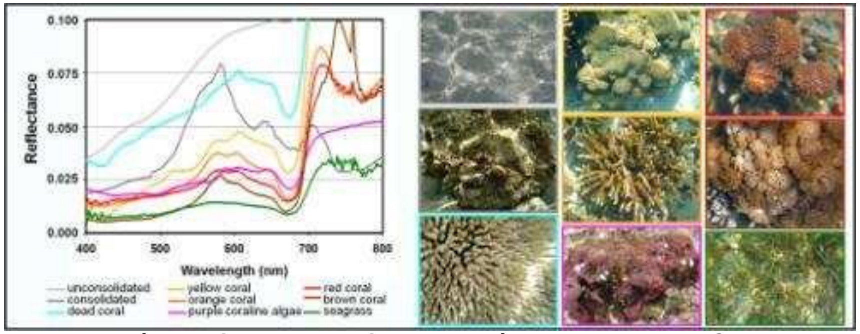
	Sand	*Cymodocea serrulata*
Acropora sp	0.913	0.492
Sand		1.010



a

Data prepared from:

Archival spectral library derived from historical in situ measurements.

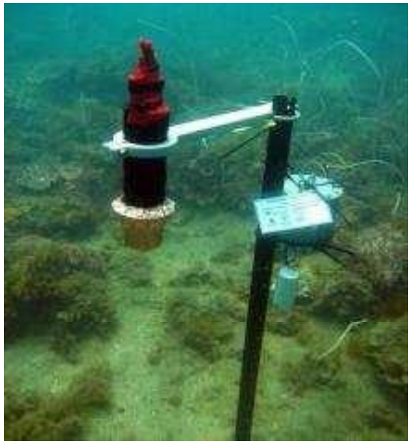


normalized Spectral Separability Metric, nSSM (**Botha, et al. 2013**) accounts for spectral shape and magnitude features in multispectral datasets by combining the Spectral Angle Mapper (SAM), metric with an Euclidian Minimum Distance metric.

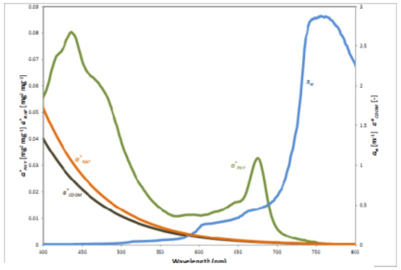
Parameterizing SAMBUCA: Water Column

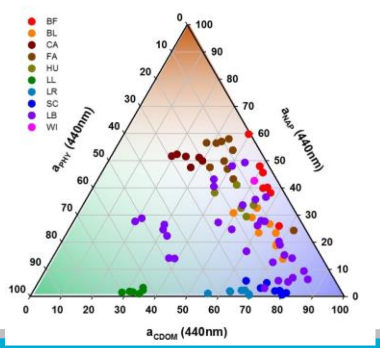
Optical complexity and seasonal differences:

Oct 07- Dry Season



Feb 08 – Wet Season





Data prepared from:

- Archival spectral library derived from historical in situ measurements
- Field campaign measurements over a range of seasons would improve the accuracy of the SAMBUCA retrievals

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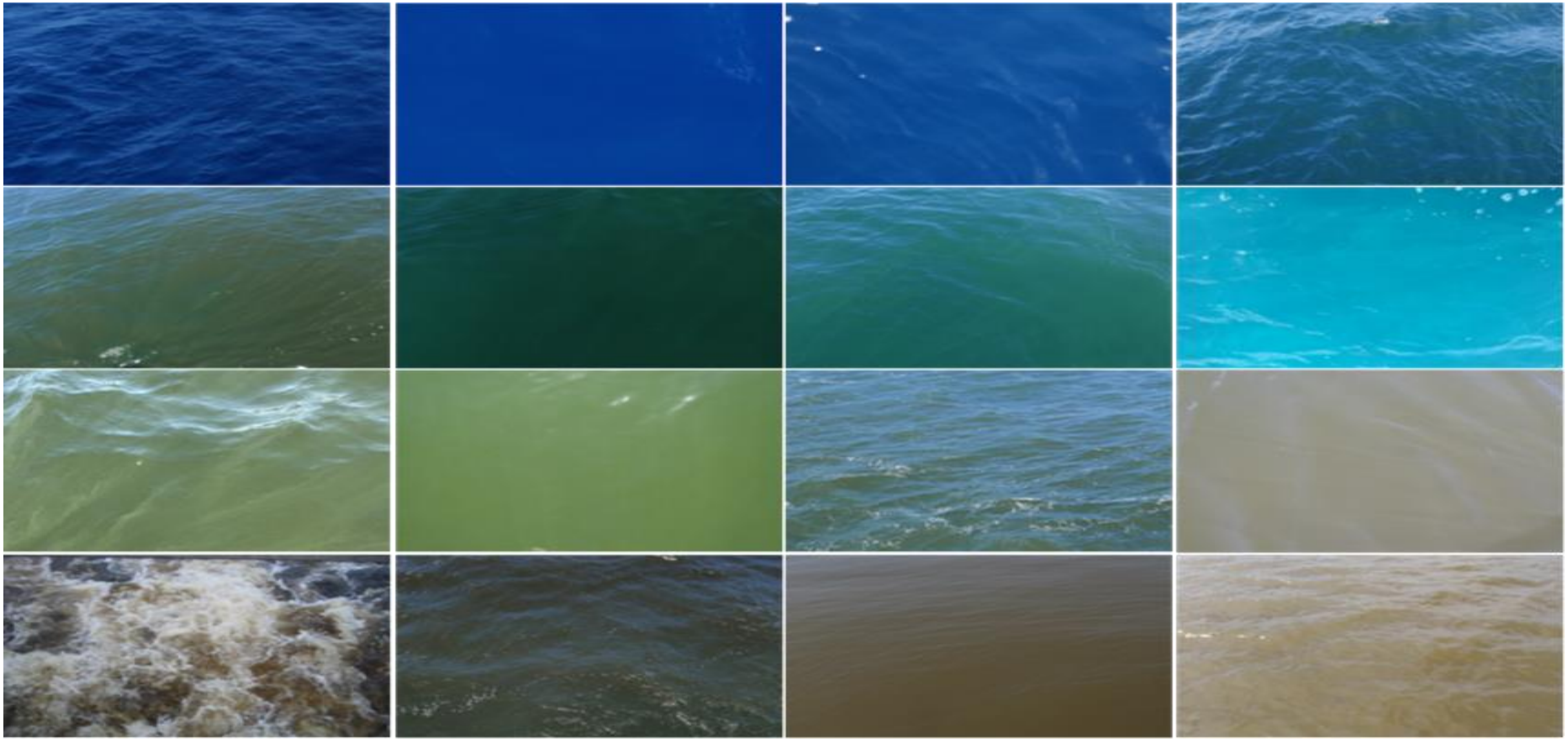
Parameterising a semi-analytical model



- Operational continental scale water quality
- OWT classification reduce optical complexity of water bodies

Workflow

Measured SIOPs:
- CHL (µg L^{-1})
- NAP (mg L^{-1})
- $aCDOM_{440nm}$
- γ_{aCDOM}
- a*PHY
- a^*NAP_{440nm}
- γ_{aNAP}
- bb^*NAP_{555nm}
- γ_{bbNAP}

- Solar zenith = 30°
- Depth = 20m (optically deep)
- Wind speed = 0 m s^{-1}
- Salinity = 35
- Temperature = 20°C

Ecolight model

R_{rs}

Normalization:
- $(R_{rs}-\mu)/\sigma$

Hierarchical clustering:
- Metric: Euclidian distance
- Linkage criteria: Centroid

Spectral clusters

Transfer spectral clusters to input SIOP matrix for analysis

Input SIOPs grouped by spectral clusters

ANOVA
- Each input factor by spectral groups

Factors significantly different between groupings

Tukey HSD test
- All possible grouping pairs
- Each input factor

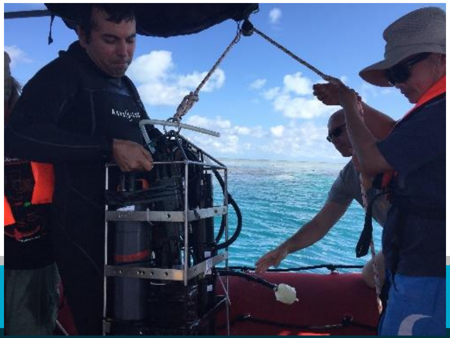
Clusters significantly different for all significant factors

yes

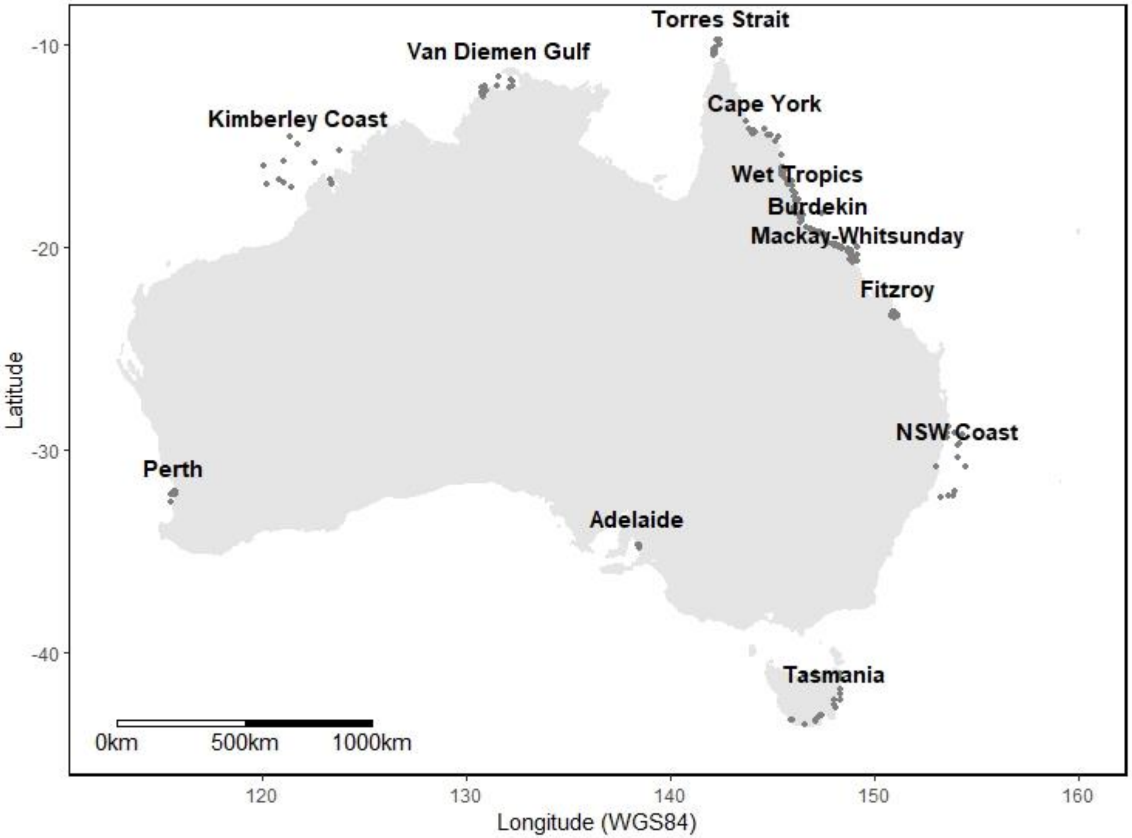
no

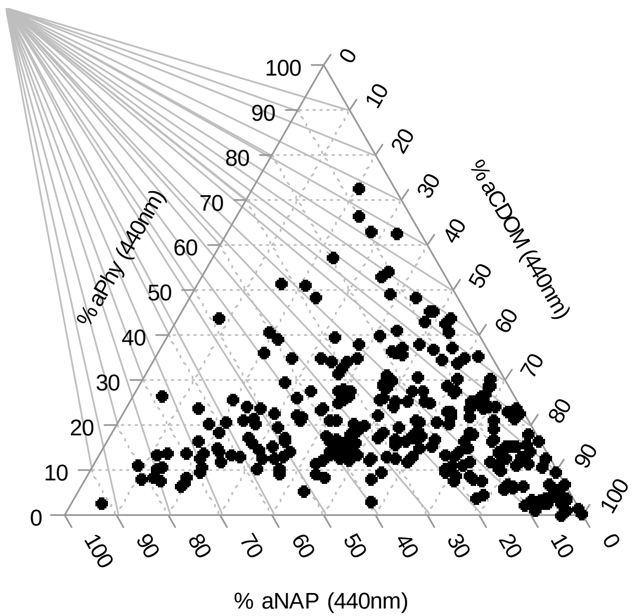
Merge similar clusters

Median SIOPs for each cluster



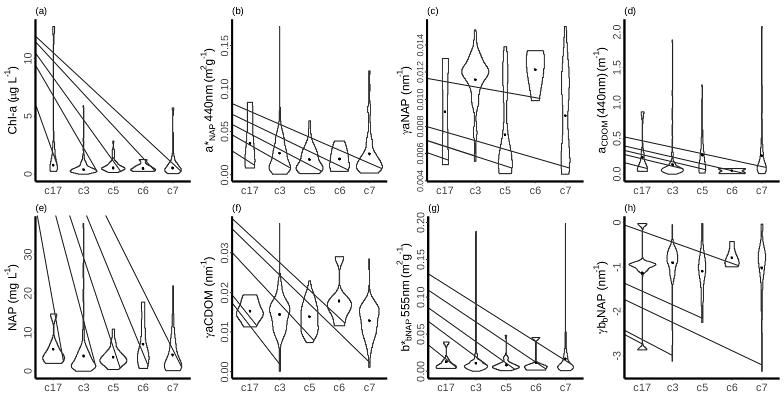
Coastal SIOPs
(2001 – 2017, 286 observations)

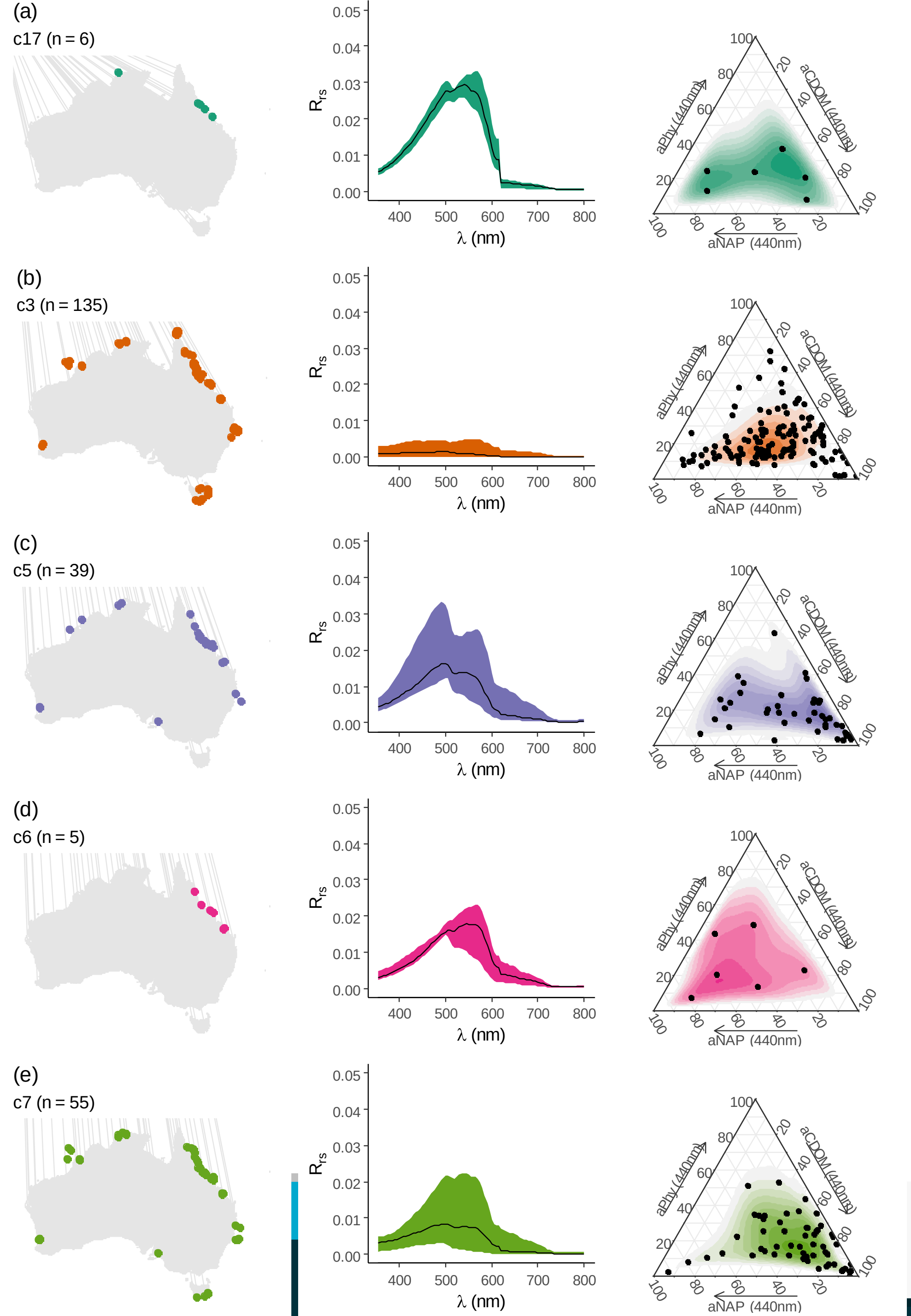




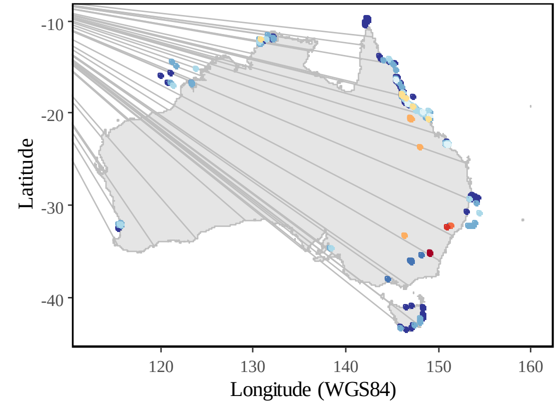
Coastal Clusters

Cluster	n	Description
C17	6	Turbid tropical wet season
C3	135	Clear coastal dominated by CDOM absorption
C5	39	Coastal waters with a strong estuarine influence
C6	6	Turbid tropical dry season
C7	55	Open coastal waters with higher amounts of suspended organic material than c3.





Final clusters

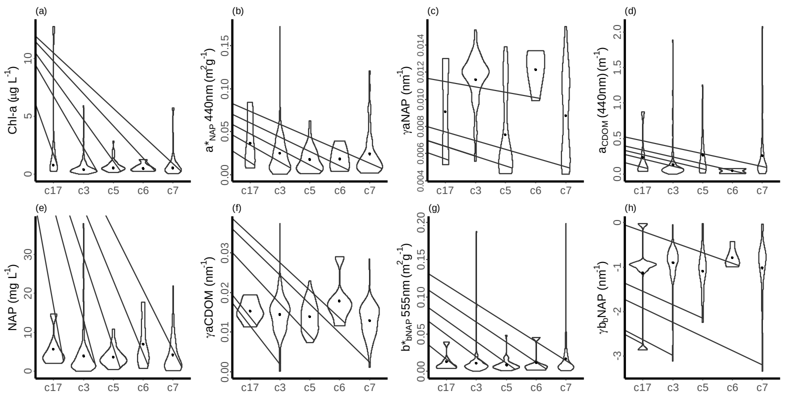


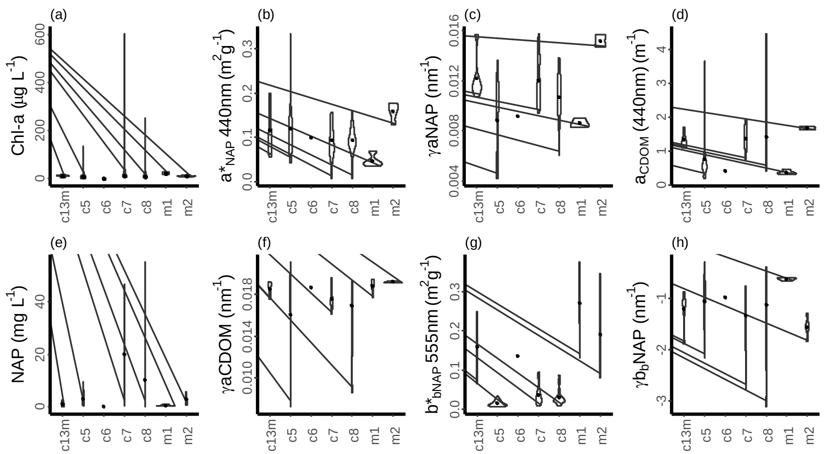
Coastal (5)

Cluster	n	Description	
C17	6	Turbid tropical wet season	
C3	135	Clear dominated by CDOM absorption	
C5	39	Strong estuarine influence	
C6	6	Turbid tropical dry season	
C7	55	Open coastal waters with higher amounts of suspended organic material than c3.	

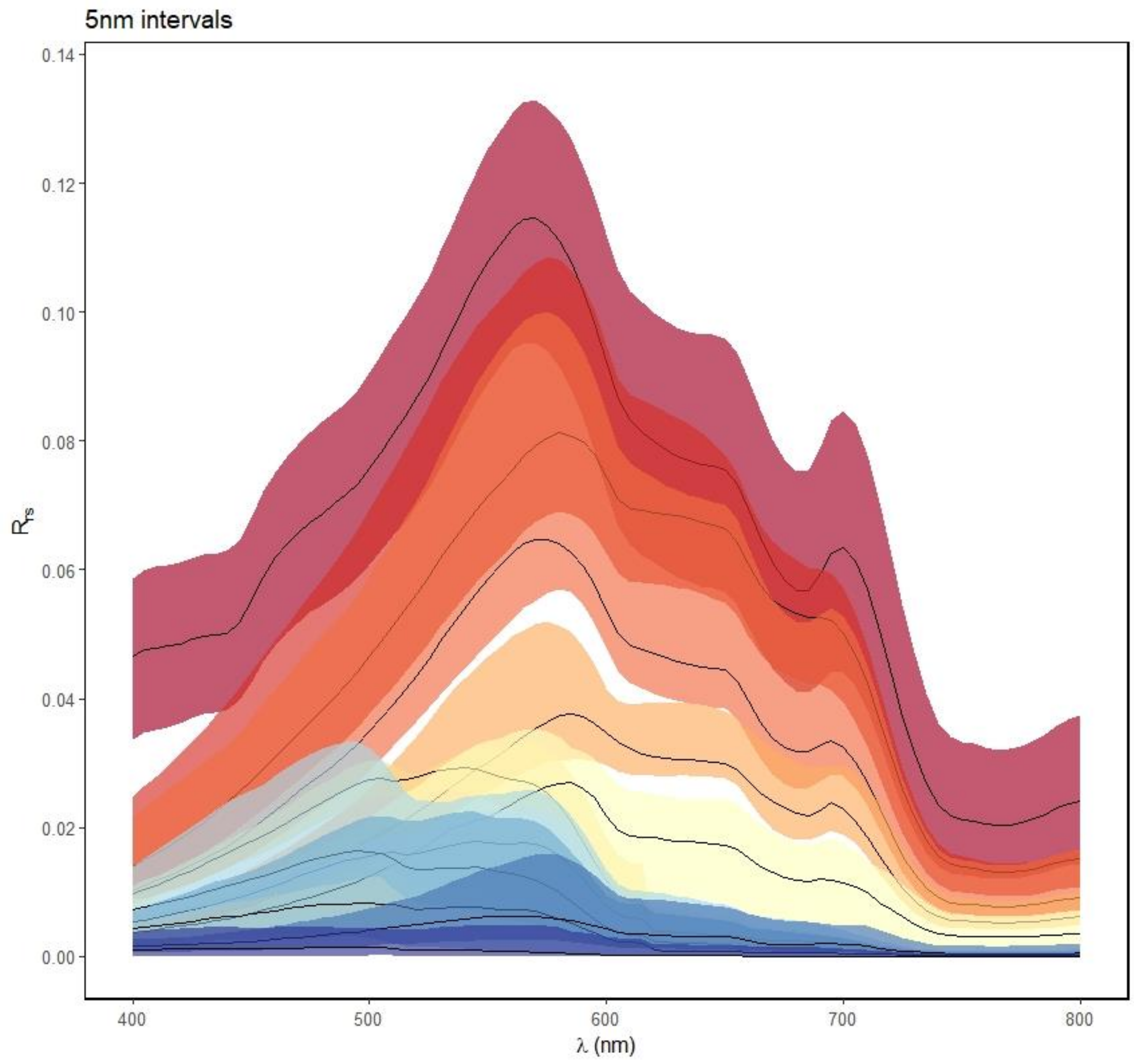
Inland (6)

Cluster	n	Description	
i5	42	Clear NAP dominated	
i7	21	Clear CDOM dominated	
i8	27	Turbid	
i13	6	Highly turbid NAP dominated	
im1	5	Green – phytoplankton dominated	
im2	4	Turbid – highly reflective	

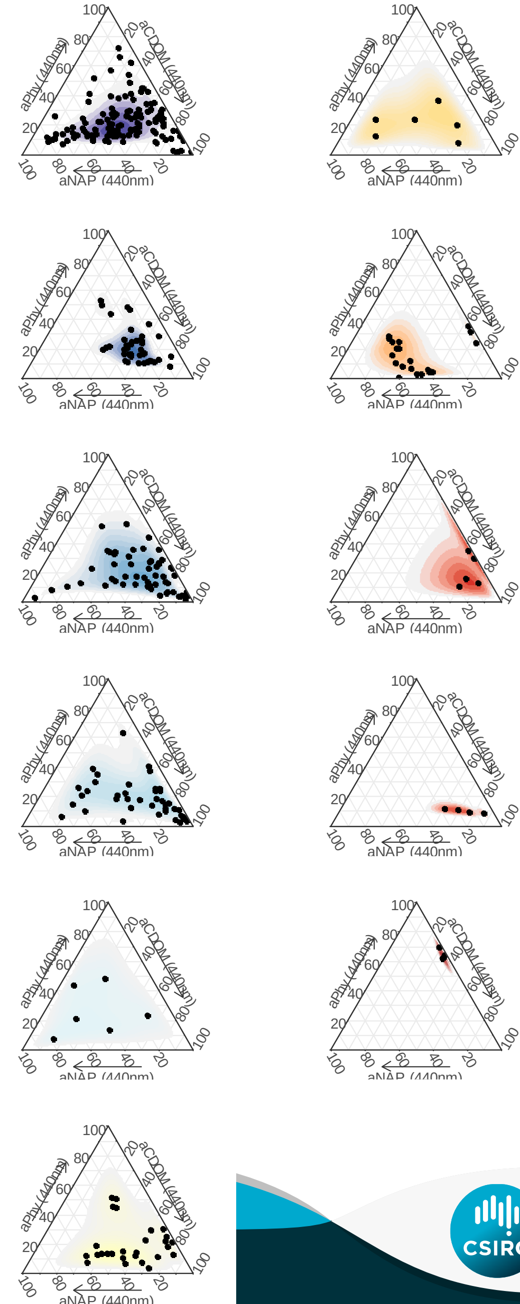




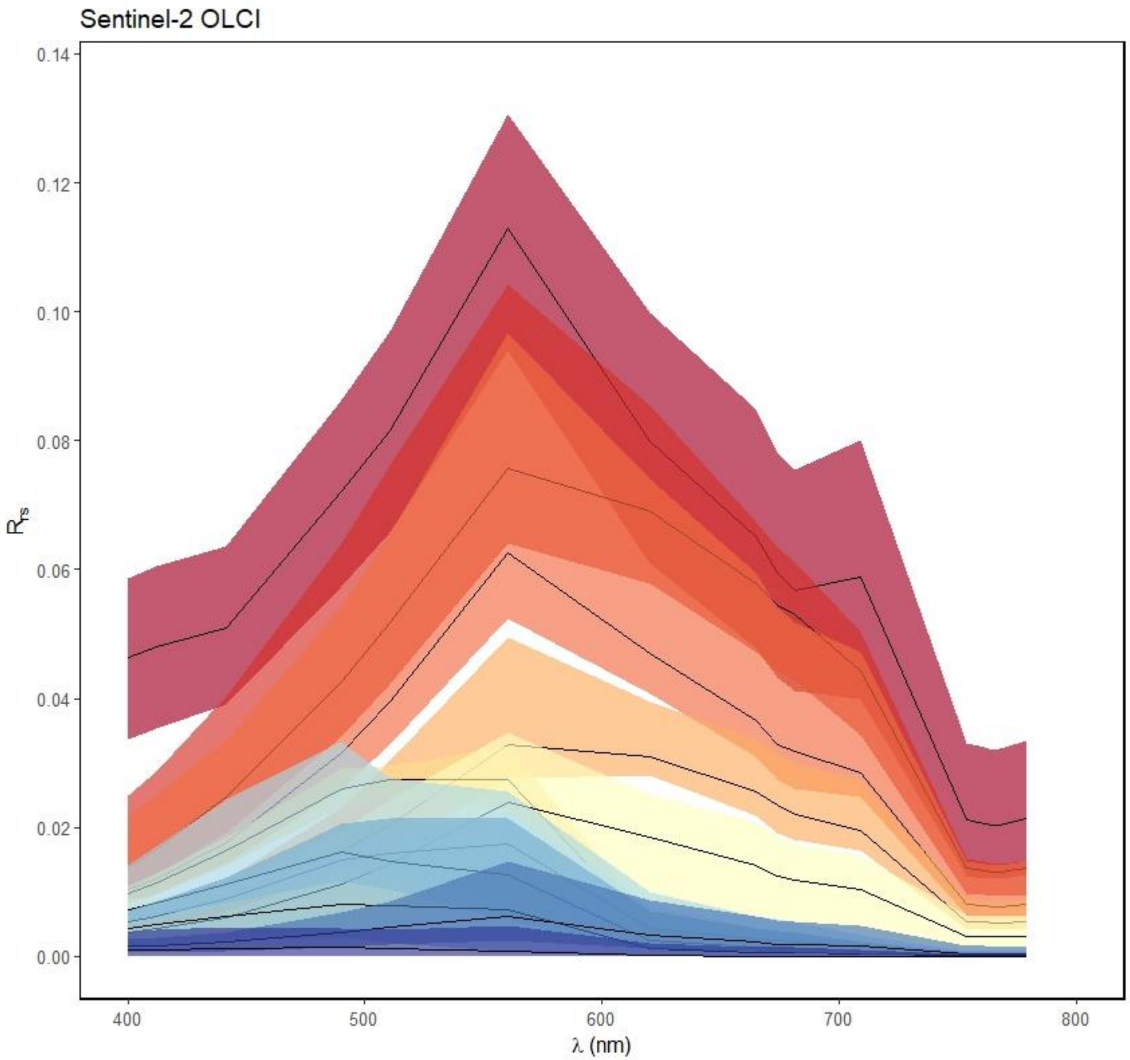
Final clusters



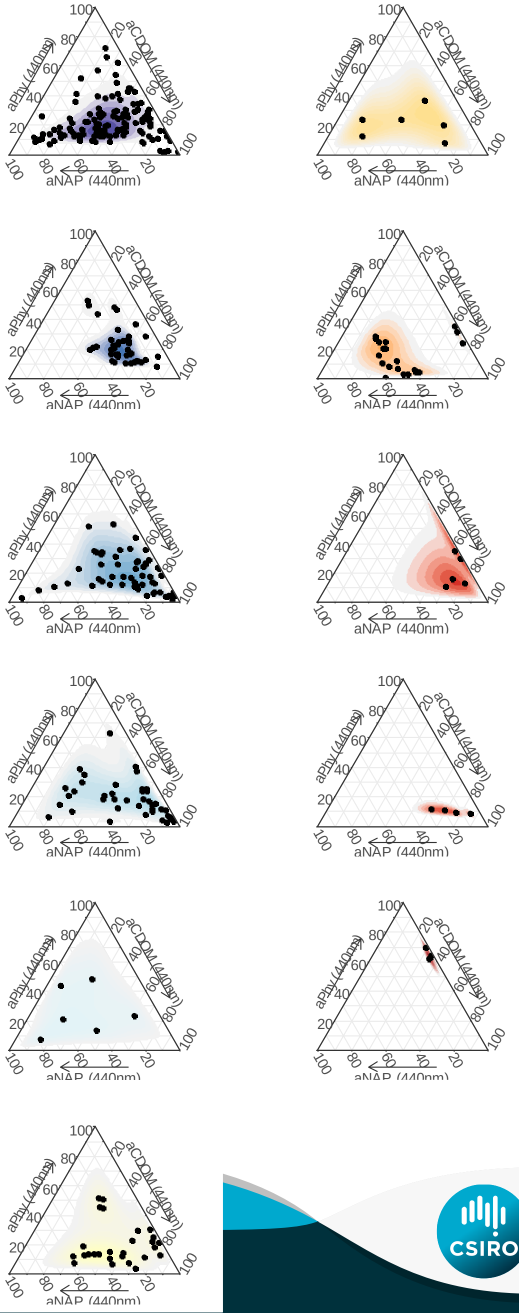
Absorption budget



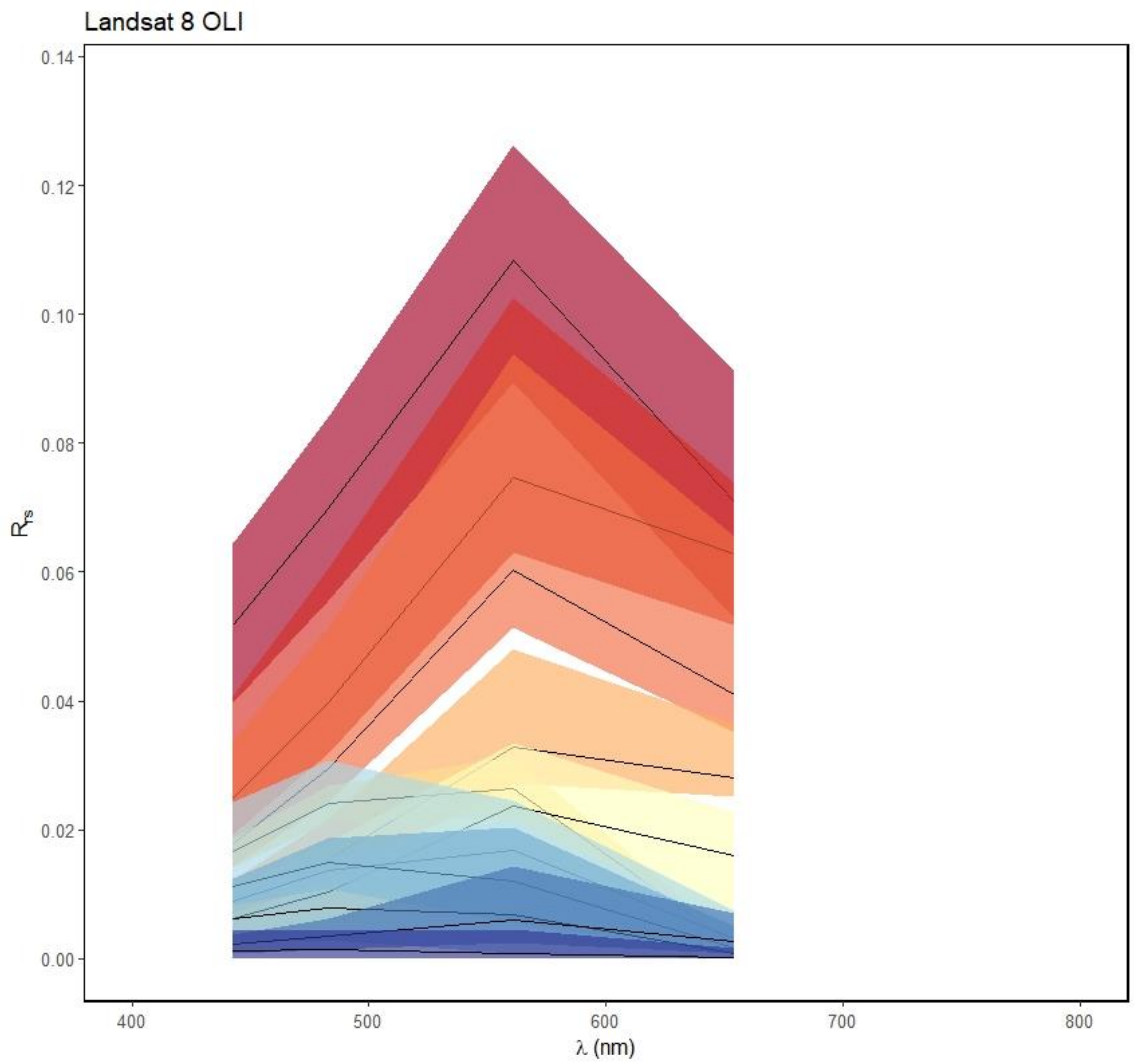
Final clusters



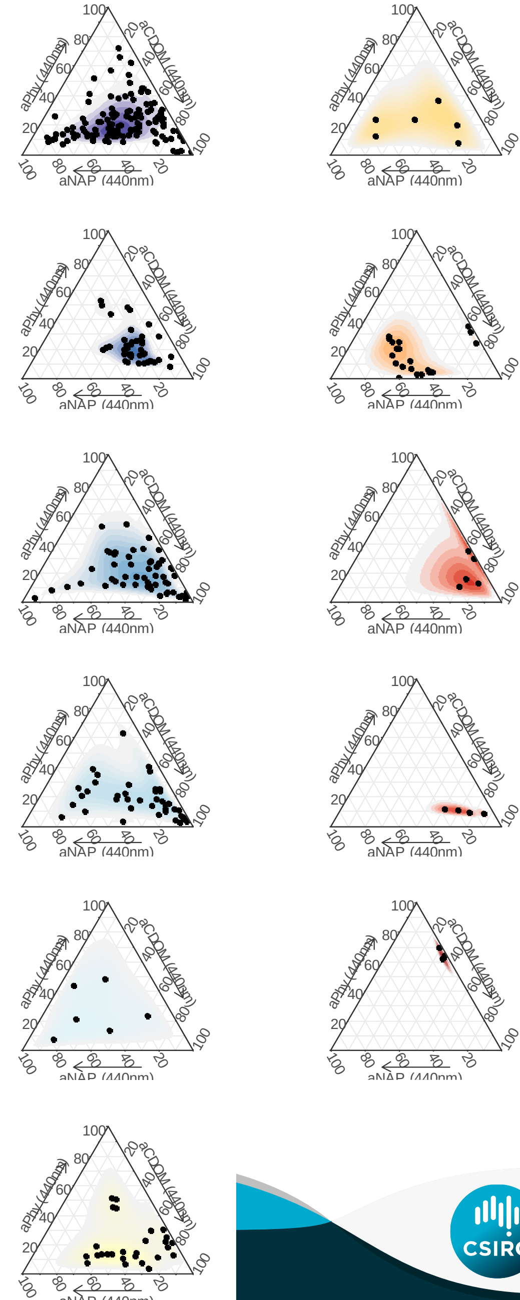
Absorption budget



Final clusters



Absorption budget



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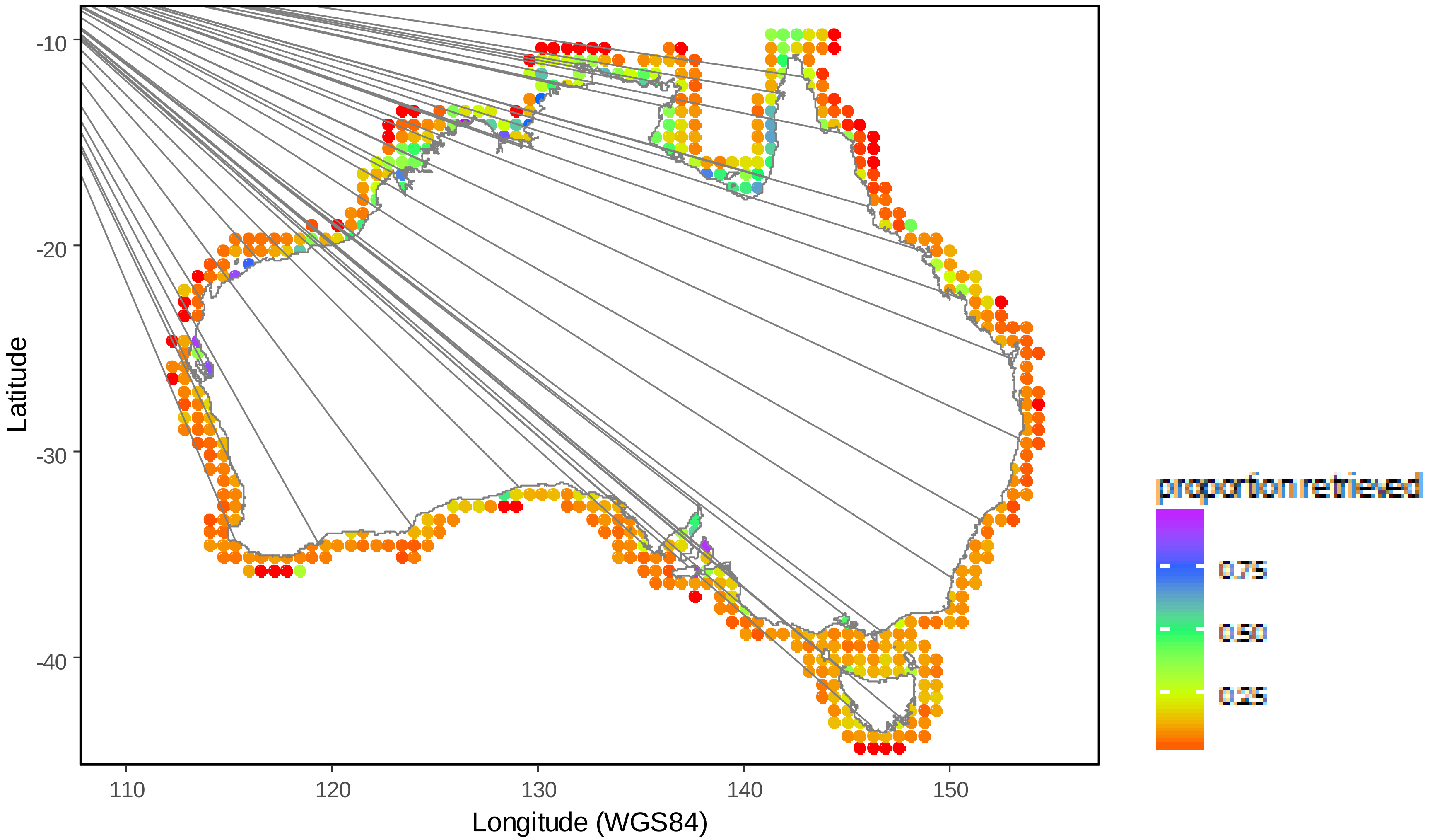
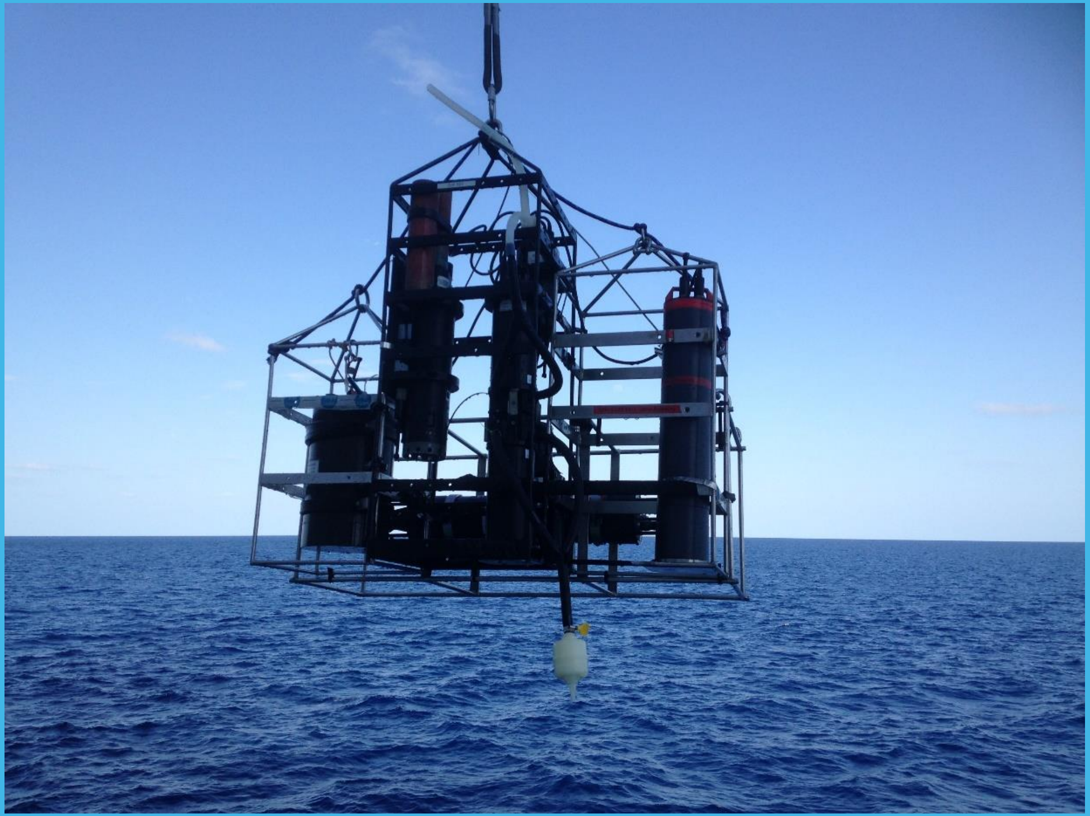
Potential applications
gap analysis using an EO Data Cube



Conclusions

- First steps towards a spatial and spectral gap analysis method for SIOP data.
- Despite obvious gaps in the datasets, there are distinct similarities of coastal and estuarine water properties in eastern, southern and western Australia.
- There is a lack of temporal data to understand the variability associated with seasons.
- The cluster analysis returned several small clusters that were both spectrally and bio-optically unique but did not have enough observations to be statistically sound.
- Further surveys (especially in nice places) are required to capture unique end-members before a full continental-scale model can be implemented for all waters in Australia.

Thank you



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