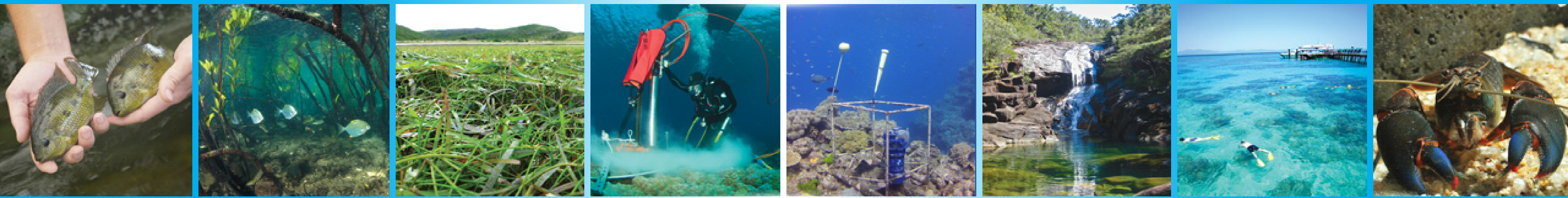


Water quality and river plume monitoring in the Great Barrier Reef: an overview of methods based on ocean colour satellite data

Michelle Devlin[1], Caroline Petus[1], Eduardo da Silva[1], Dieter Tracey[1]

TropWATER, James Cook University, Townsville

JAMES COOK UNIVERSITY AUSTRALIA

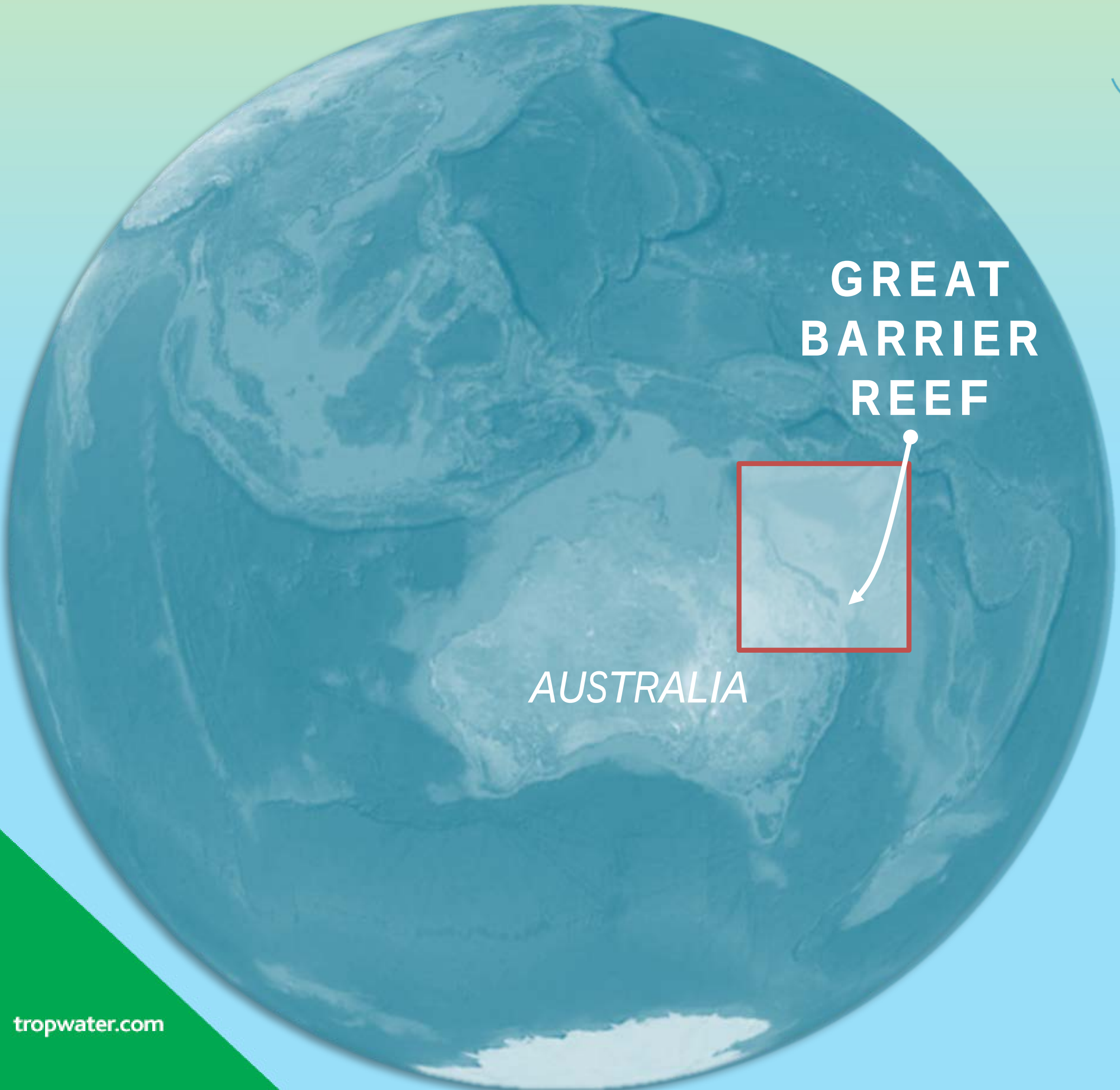
Why?

- The long-term goal of **Reef Plan** is to ensure that the quality of water entering the Great Barrier Reef from adjacent catchments has no detrimental impact on its ecosystem health and resilience
- Requires a monitoring and evaluation strategy that
  - evaluates the efficiency and effectiveness of implementation and
  - progress toward this goal.
- Monitoring activities under the Marine Monitoring Program include ambient and wet season water quality measurements, inshore coral and seagrass monitoring and herbicide detection.

Why

- Monitoring of river plumes and assessment of the influence of water quality events now forms an integral component of the MMP.
- Difficult to evaluate the complex responses to changing water quality based on in-situ water quality data only

WHAT?



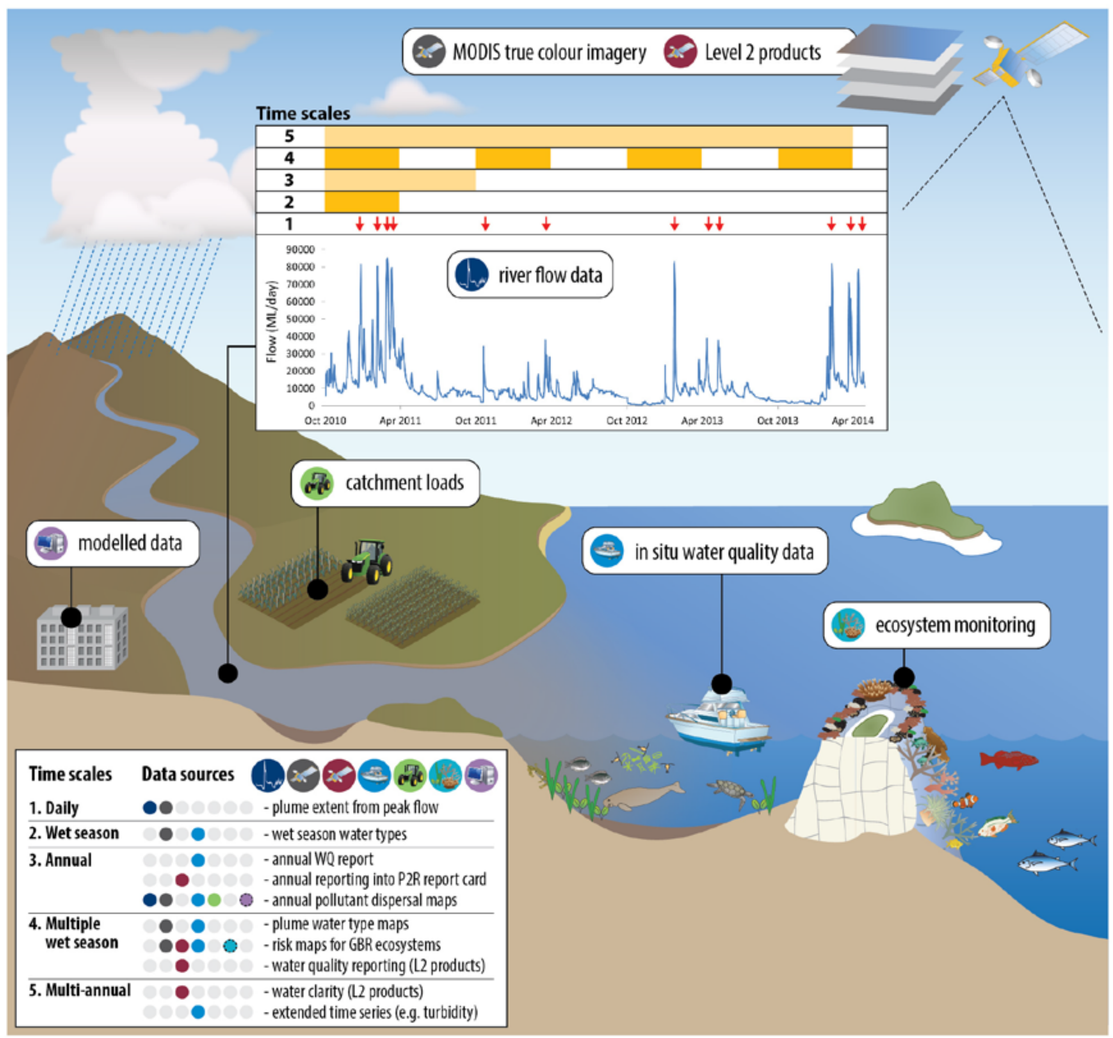
TropWATER

MODIS DATA:

- ✓ Key source of data
- ✓ Synoptic view of the ocean
- ✓ Daily observations from 2002
- ✓ Resolution: 250 - 1000 m

=

SUBSTANTIAL BENEFITS IN ADDITION TO IN-SITU SAMPLING AND NUMERICAL MODELLING



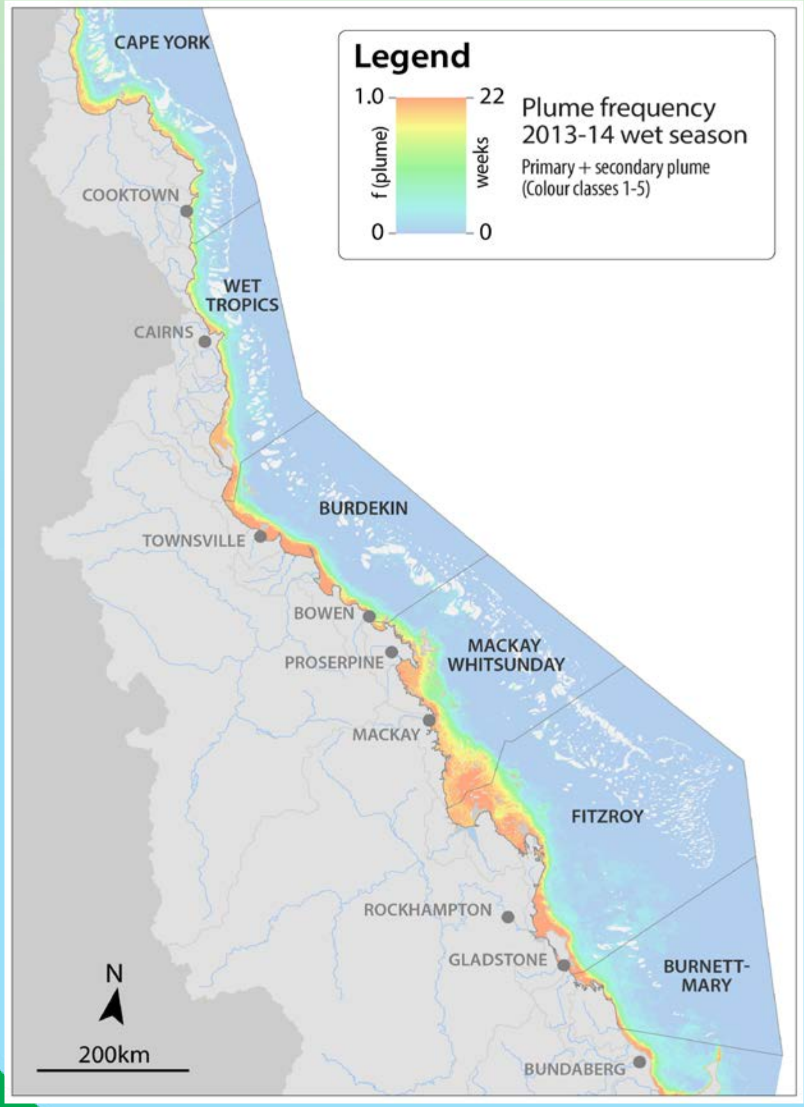
How? Where?

TropWATER

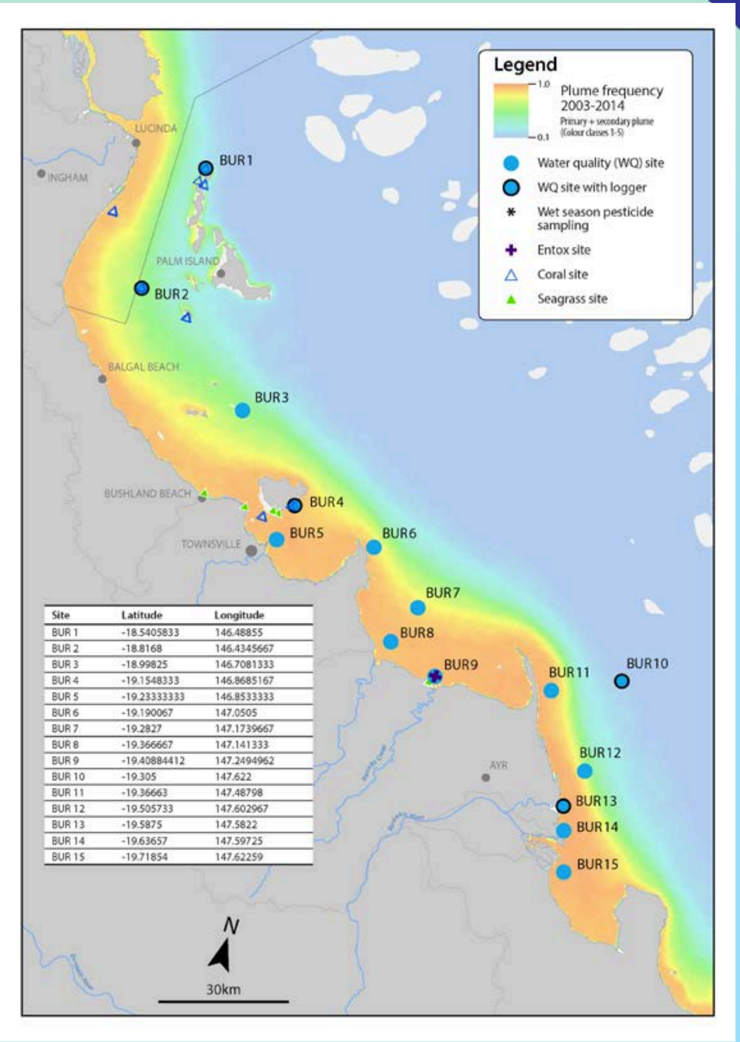
- RGB /true colour analysis – critical source of data for plume dynamics
- Correlation of true colour with in-situ water quality gradient can provide links to the GBR ecological systems

- Provides the information on relevant timescales associated with the variability associated with these transport processes
- Greater certainty of obtaining a complete spatial and temporal picture over wet season.

Where?



- To the end of the plumes and back



Site	Latitude	Longitude
BUR 1	-18.5405833	146.48855
BUR 2	-18.8168	146.4345667
BUR 3	-18.99825	146.7081333
BUR 4	-19.1548333	146.8685167
BUR 5	-19.23333333	146.8533333
BUR 6	-19.190067	147.0505
BUR 7	-19.2827	147.1739667
BUR 8	-19.366667	147.141333
BUR 9	-19.40884412	147.2494962
BUR 10	-19.305	147.622
BUR 11	-19.36663	147.48798
BUR 12	-19.505733	147.602967
BUR 13	-19.5875	147.5822
BUR 14	-19.63657	147.59725
BUR 15	-19.71854	147.62259

What products?

- **Wet Season monitoring part of the Marine Monitoring Program**

MAIN OBJECTIVES:

- **Mapping of flood plumes**
- **Modelling and summarizing land-sourced contaminants transport and light levels** within river plume waters, and;
- **Evaluation of the susceptibility of GBR key ecosystems** to river plume exposure

TropWATER

Australian Government
Great Barrier Reef Marine Park Authority

MAIN PROJECT: flood plume monitoring part of the Marine Monitoring Program

Australian Government
Great Barrier Reef Marine Park Authority

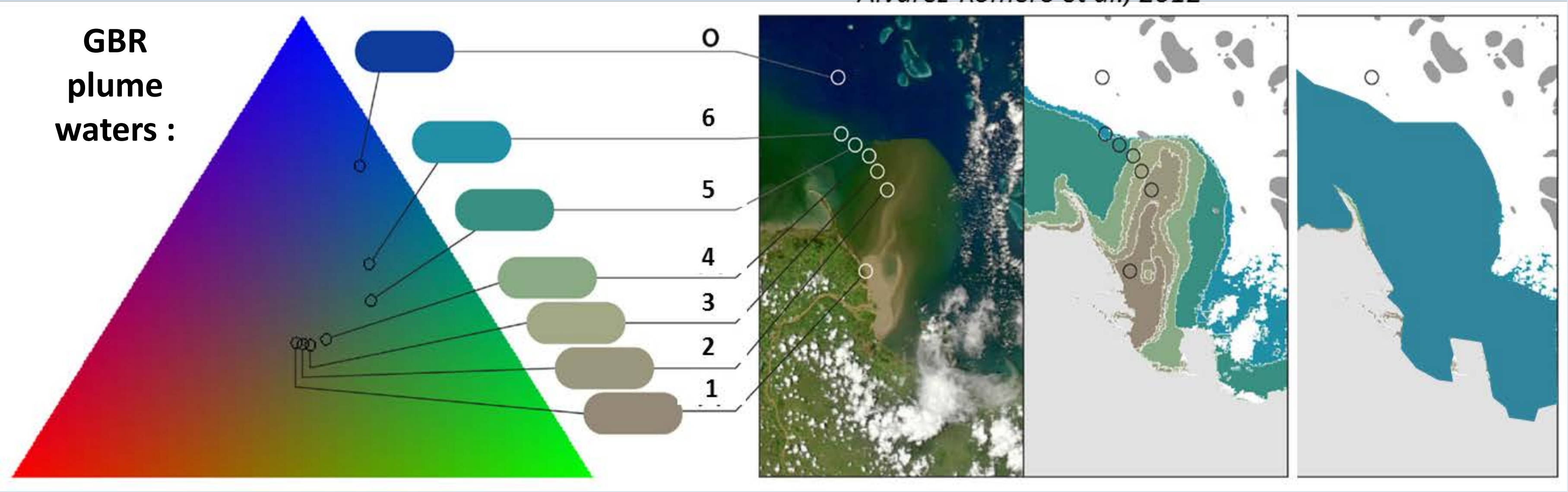
TropWATER

MAIN OBJECTIVES:

1. **Mapping of flood plumes**
2. **Modelling and summarizing land-sourced contaminants transport and light levels** within river plume waters, and;
3. **Evaluation of the susceptibility of GBR key ecosystems** to river plume exposure

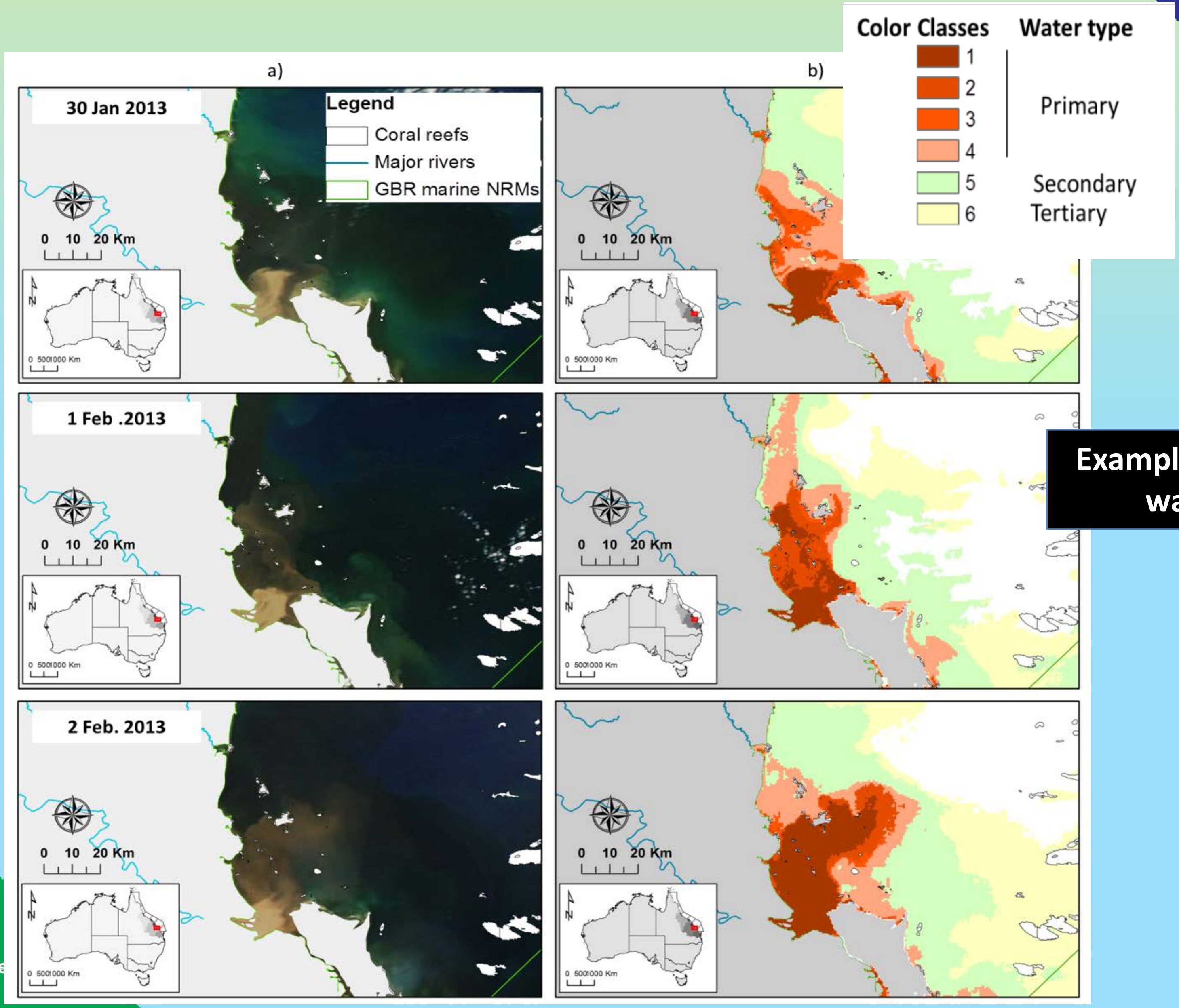
MAPPING OF GBR FLOOD PLUMES AND PLUME WATER MASSES: using a supervised classification of MODIS true colour images

Alvarez-Romero et al., 2012



Characteristic colour signatures of GBR plumes waters → MODIS true color → 6 Colour Classes → Plume full extent

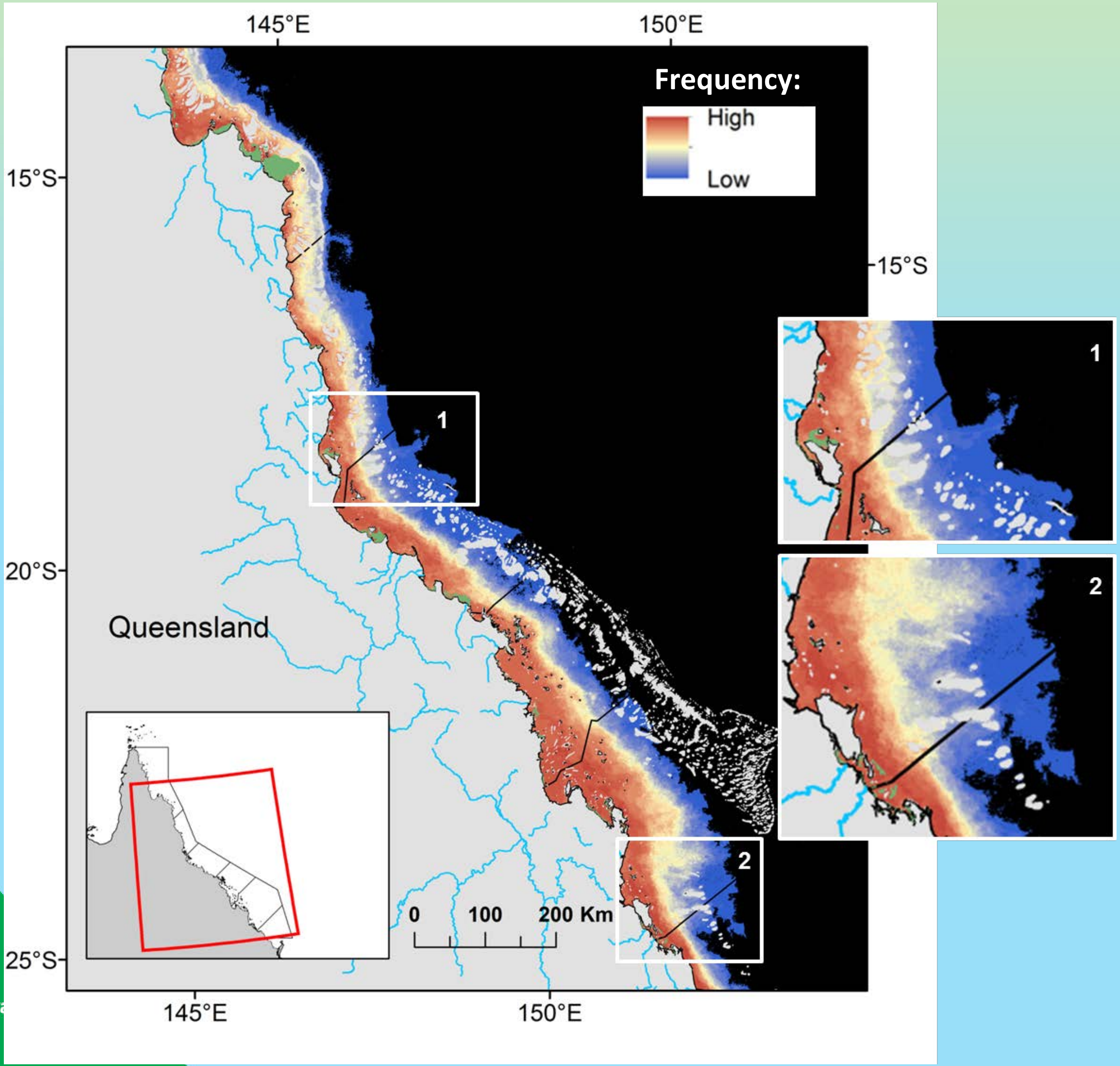
Map the MOVEMENTS of river plumes in the Great Barrier Reef



Example: Fitzroy plume water masses

Devlin et al., 2013

Map the FREQUENCY of river plumes during the wet season



MODIS ocean colour imagery

2011 plume frequency map

1. Tully-Herbert
2. Fitzroy

Alvarez-Romero et al., 2013
Devlin et al., 2013
Petus et al., 2014a

tropwa

Connecting land based pollutants with marine water quality

Australian Government
Great Barrier Reef Marine Park Authority

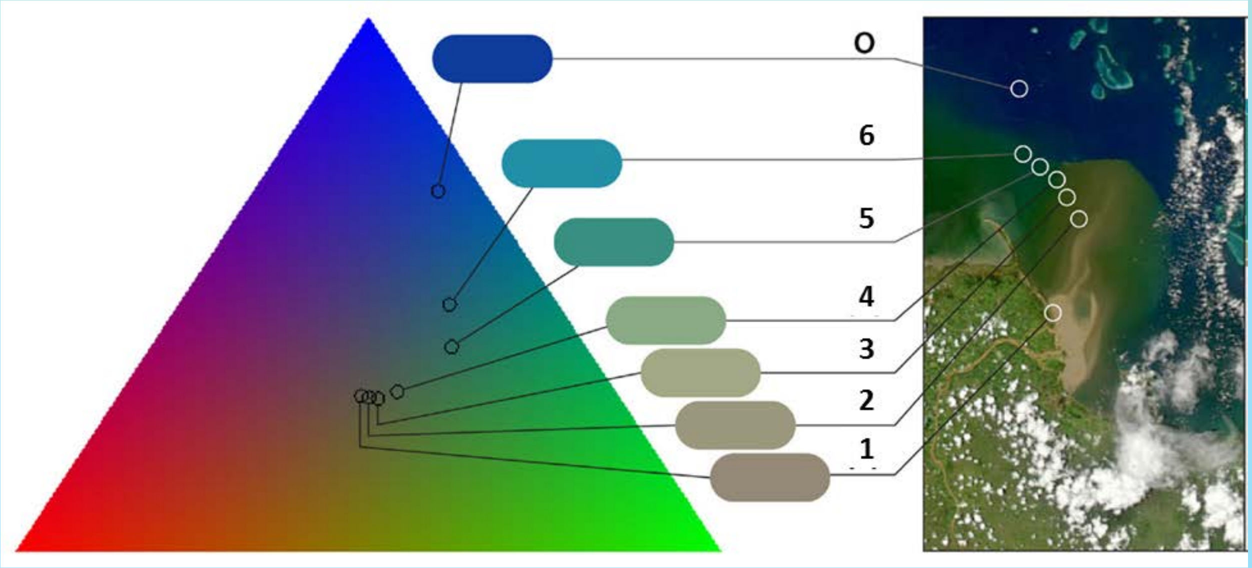
TropWATER

MAIN OBJECTIVES:

1. **Mapping of flood plumes**
2. **Modelling and summarizing land-sourced contaminants transport and light levels** within river plume waters.
3. **Evaluation of the susceptibility of GBR key ecosystems** to river plume exposure

Objective 2. Models summarizing land-sourced CONTAMINANTS TRANSPORT AND LIGHT LEVELS within river plume waters

WET SEASON WATER QUALITY MAPS

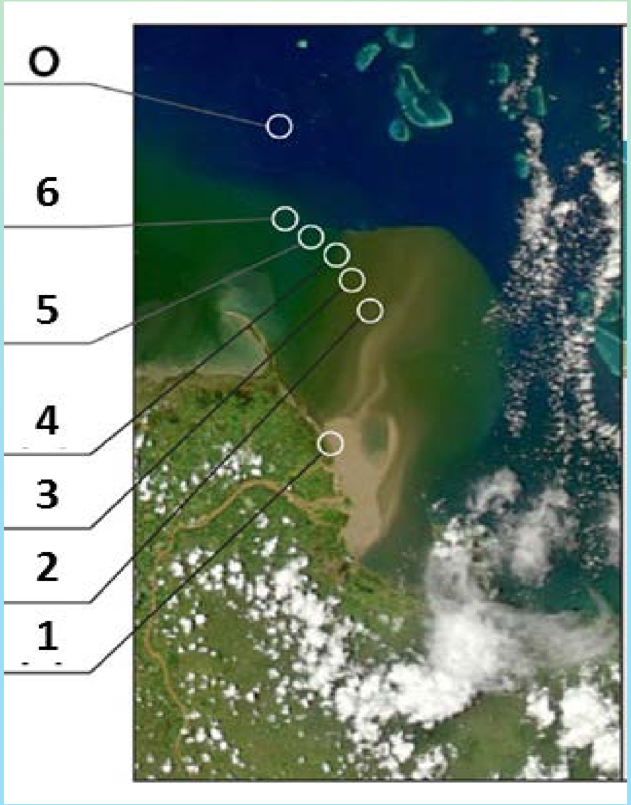


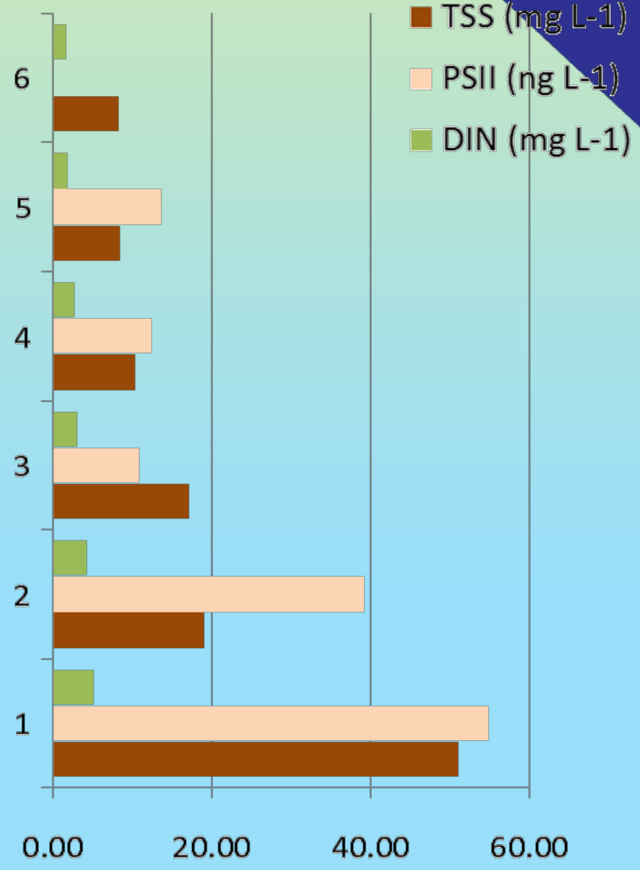
Plume water masses = different concentrations & proportions of :

- **land-sourced pollutants**
- **Optically Active Components**

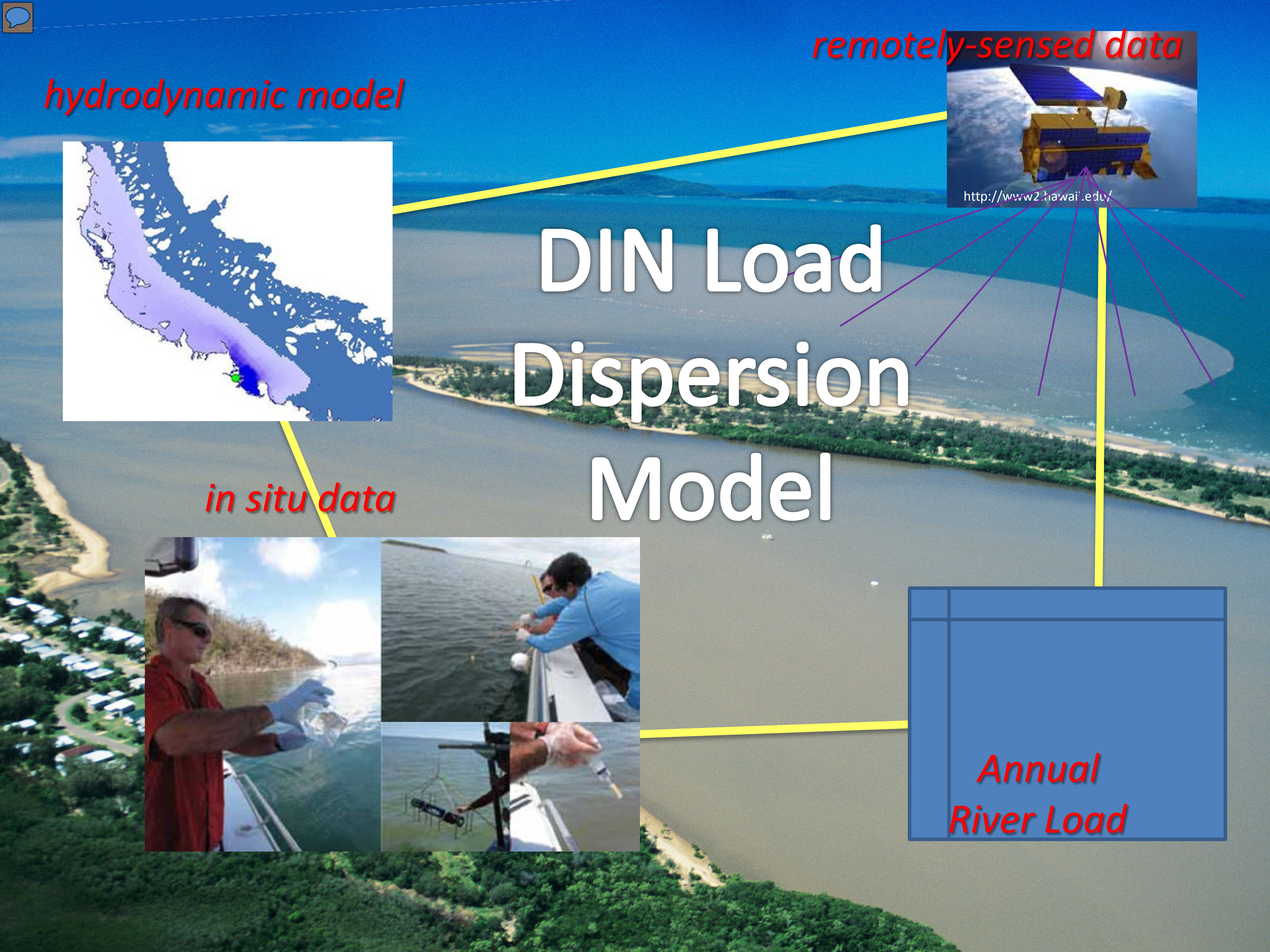
LAND-SOURCED CONTAMINATION MAPS

Petus et al., in Prep.

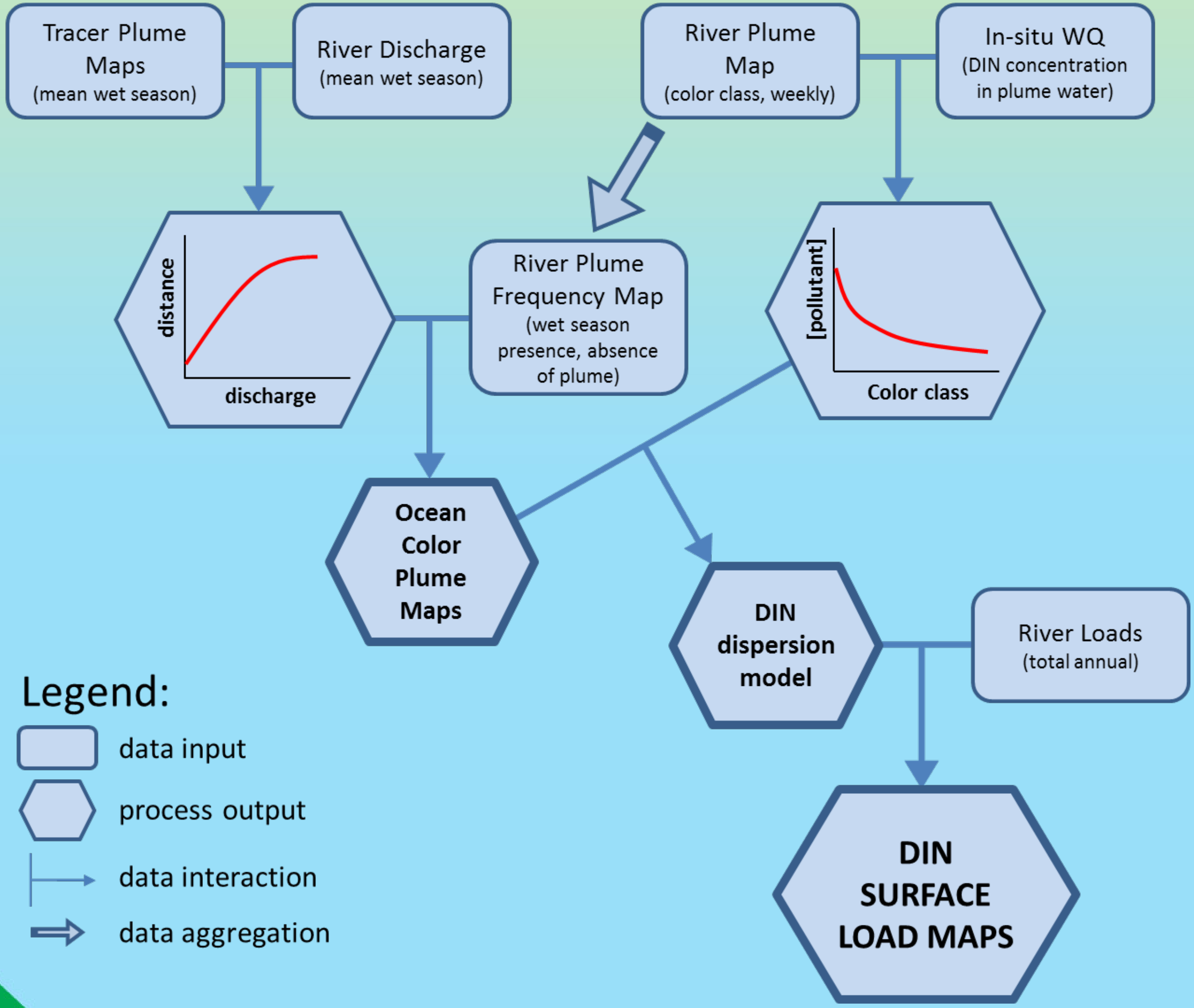




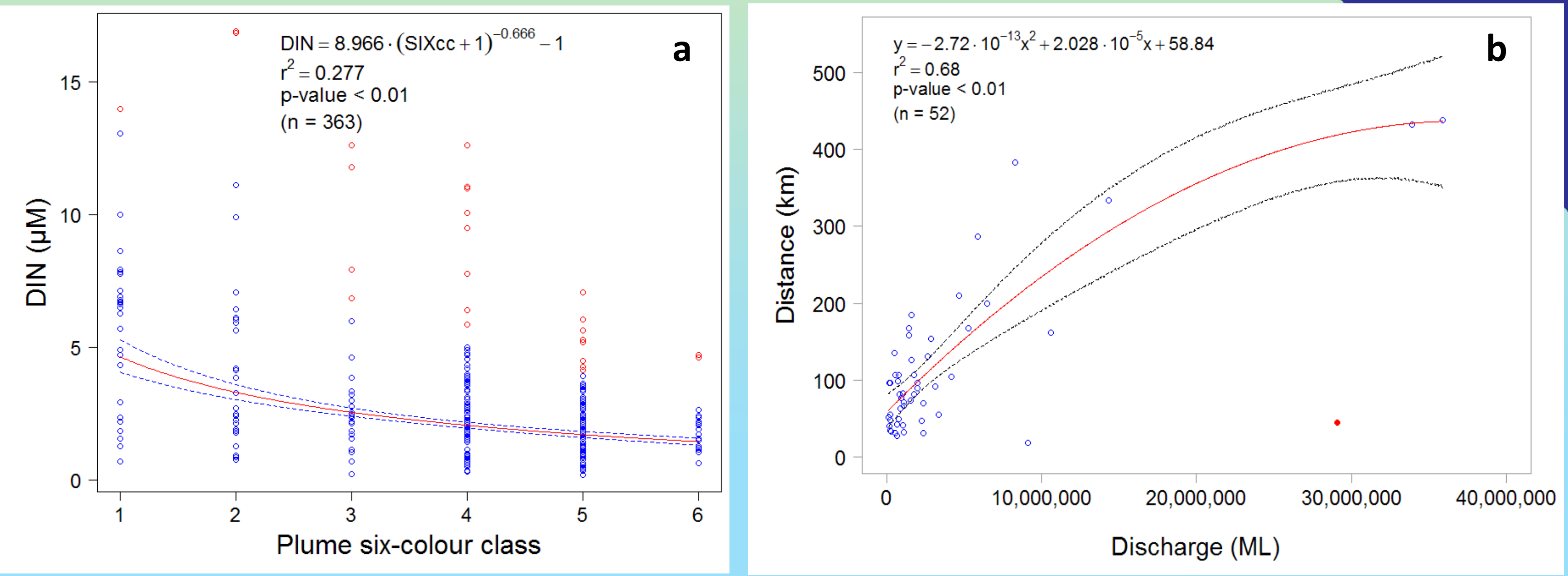
Broad scale approach to reporting contaminant concentrations in the GBR marine environment


remotely-sensed data
http://www2.hawaii.edu/
hydrodynamic model
DIN Load Dispersion Model
in situ data
Annual River Load

CONCEPTUAL MODEL OF THE DIN LOAD DISPERSION MAPS: DATA SOURCES AND MAIN PROCESSES

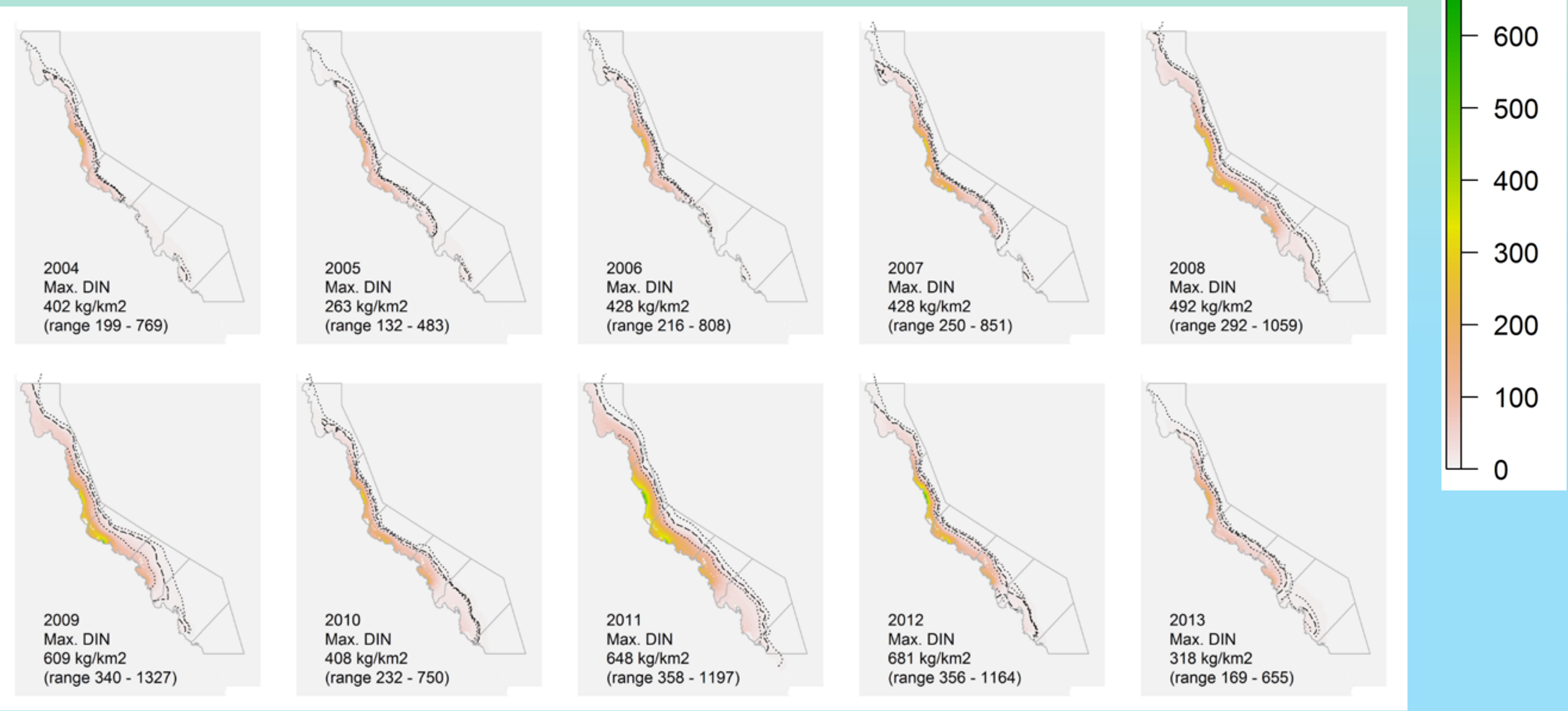


DIN DISTRIBUTION & PLUME DISTANCE MODELS



Regression models adjusted to (**a**) in-situ DIN and plume color class (1 – 6) sampled from 2003 to 2013, under flow conditions > 75th percentile, and (**b**) plume distance and river discharge from the hydrodynamic model. Dashed lines stand for CI 95%. Red dots stand for outliers.

DIN (Mass/Area)



DIN load and its contribution to the marine NRM regions

TropWATER

NRM region	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Burdekin	644	718	1510	1127	3488	7899	9256	2820	10348	5171	1197
	731	920	1465	1385	3074	5138	5761	3055	8957	4196	1687
	(13%)	(28%)	(-3%)	(23%)	(-12%)	(-35%)	(-38%)	(8%)	(-13%)	(-19%)	(41%)
Wet Tropics	1380	3706	2298	4530	4046	3770	5914	3648	9697	5144	3299
	1302	3004	2143	3742	3769	4709	5983	3565	9748	5151	2909
	(-6%)	(-19%)	(-7%)	(-17%)	(-7%)	(25%)	(1%)	(-2%)	(1%)	(0%)	(-12%)
Mackay-Whitsunday	305	117	531	274	1477	2482	1807	2502	5466	2604	1656
	433	176	493	186	1278	2971	2380	2580	4641	2548	1525
	(42%)	(50%)	(-7%)	(-32%)	(-13%)	(20%)	(32%)	(3%)	(-15%)	(-2%)	(-8%)
Fitzroy	674	382	363	135	176	1580	367	2061	3900	947	920
	412	257	257	103	121	834	354	1088	1738	517	502
	(-39%)	(-33%)	(-29%)	(-24%)	(-31%)	(-47%)	(-3%)	(-47%)	(-55%)	(-45%)	(-45%)

RIVER LOAD (TON): DIN MASS DISCHARGED BY THE RIVER

NRM MASS (TON): DIN MASS THAT REMAINS AT THE NRM RIVER BELONGS TO

DIFFERENCE (%): (NRM MASS - RIVER LOAD)/RIVER LOAD * 100

Grey > 10% increase

MAIN PROJECT: flood plume monitoring part of the Marine Monitoring Program

Australian Government

Great Barrier Reef Marine Park Authority

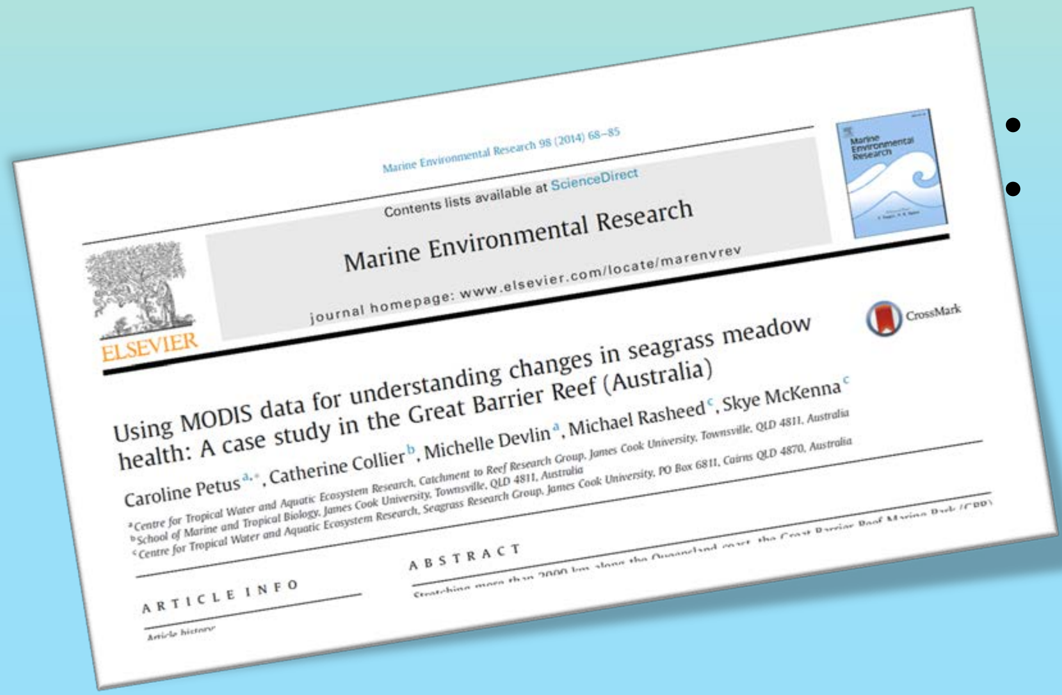
TropWATER

MAIN OBJECTIVES:

1. **Mapping of flood plumes**
2. **Modelling and summarizing land-sourced contaminants transport and light levels** within river plume waters, and;
3. **Evaluation of the susceptibility of GBR key ecosystems** to the river plume exposure

Evaluation of the SUSCEPTIBILITY OF GBR KEY ECOSYSTEMS to river plume exposure

- **Using MODIS data for understanding changes in seagrass meadow health.**


Marine Environmental Research 98 (2014) 68–85
Contents lists available at ScienceDirect
Marine Environmental Research
journal homepage: www.elsevier.com/locate/marenvrev
ELSEVIER
CrossMark

Using MODIS data for understanding changes in seagrass meadow health: A case study in the Great Barrier Reef (Australia)

Caroline Petus[a,*], Catherine Collier[b], Michelle Devlin[a], Michael Rasheed[c], Skye McKenna[c]

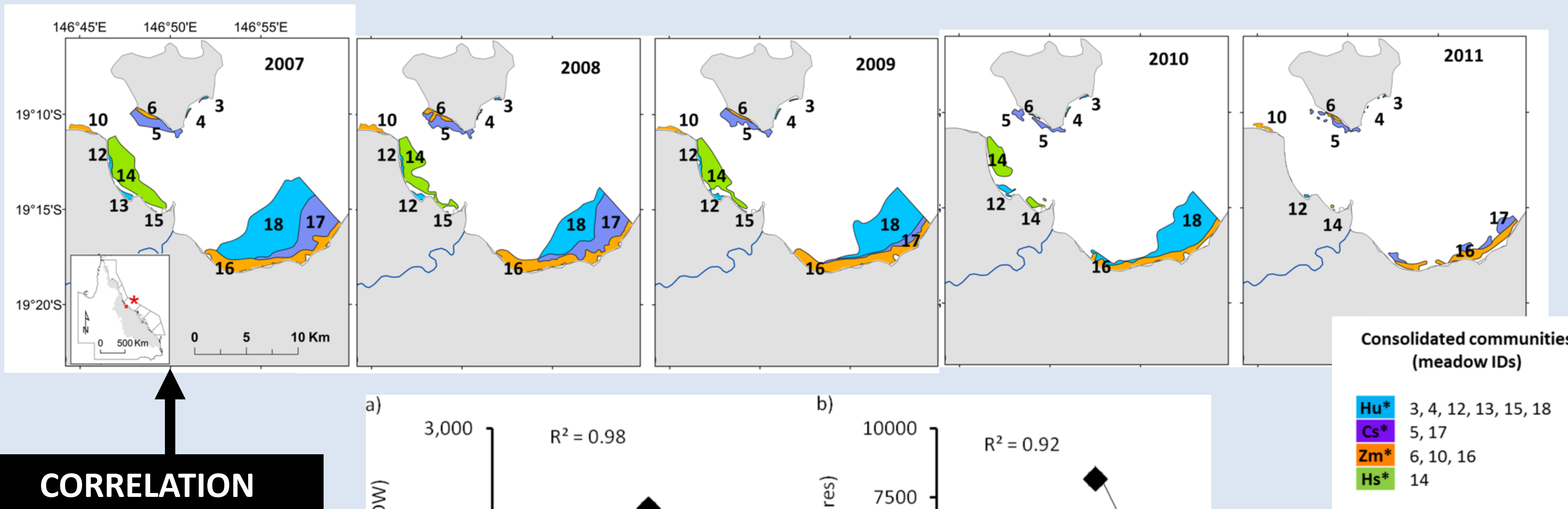
[a] Centre for Tropical Water and Aquatic Ecosystem Research, Catchment to Reef Research Group, James Cook University, Townsville, QLD 4811, Australia
[b] School of Marine and Tropical Biology, James Cook University, Townsville, QLD 4811, Australia
[c] Centre for Tropical Water and Aquatic Ecosystem Research, Seagrass Research Group, James Cook University, PO Box 6811, Cairns QLD 4870, Australia

ARTICLE INFO

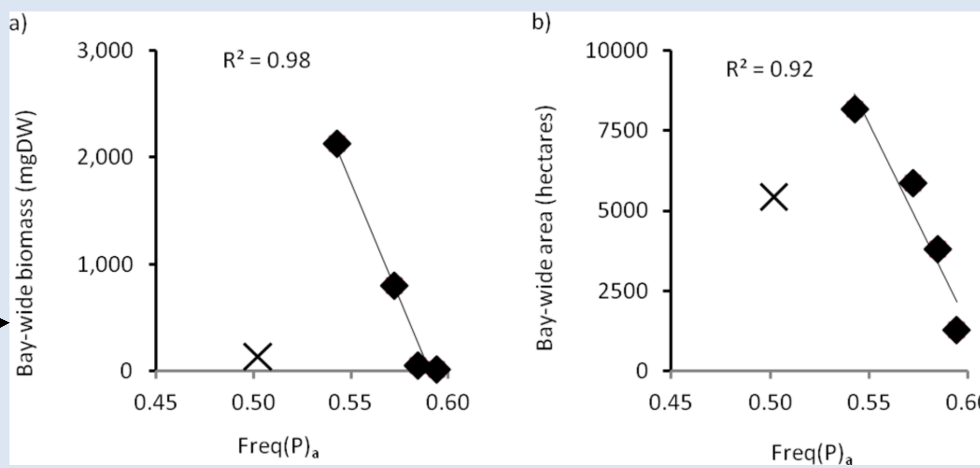
ABSTRACT

- **Critical for management**
- **Strong application of the true colour data over annual and multi-annual time scales**

Evaluation of the SUSCEPTIBILITY OF GBR KEY ECOSYSTEMS to river plume exposure



CORRELATION SEAGRASS HEALTH & Fp (turbid waters)

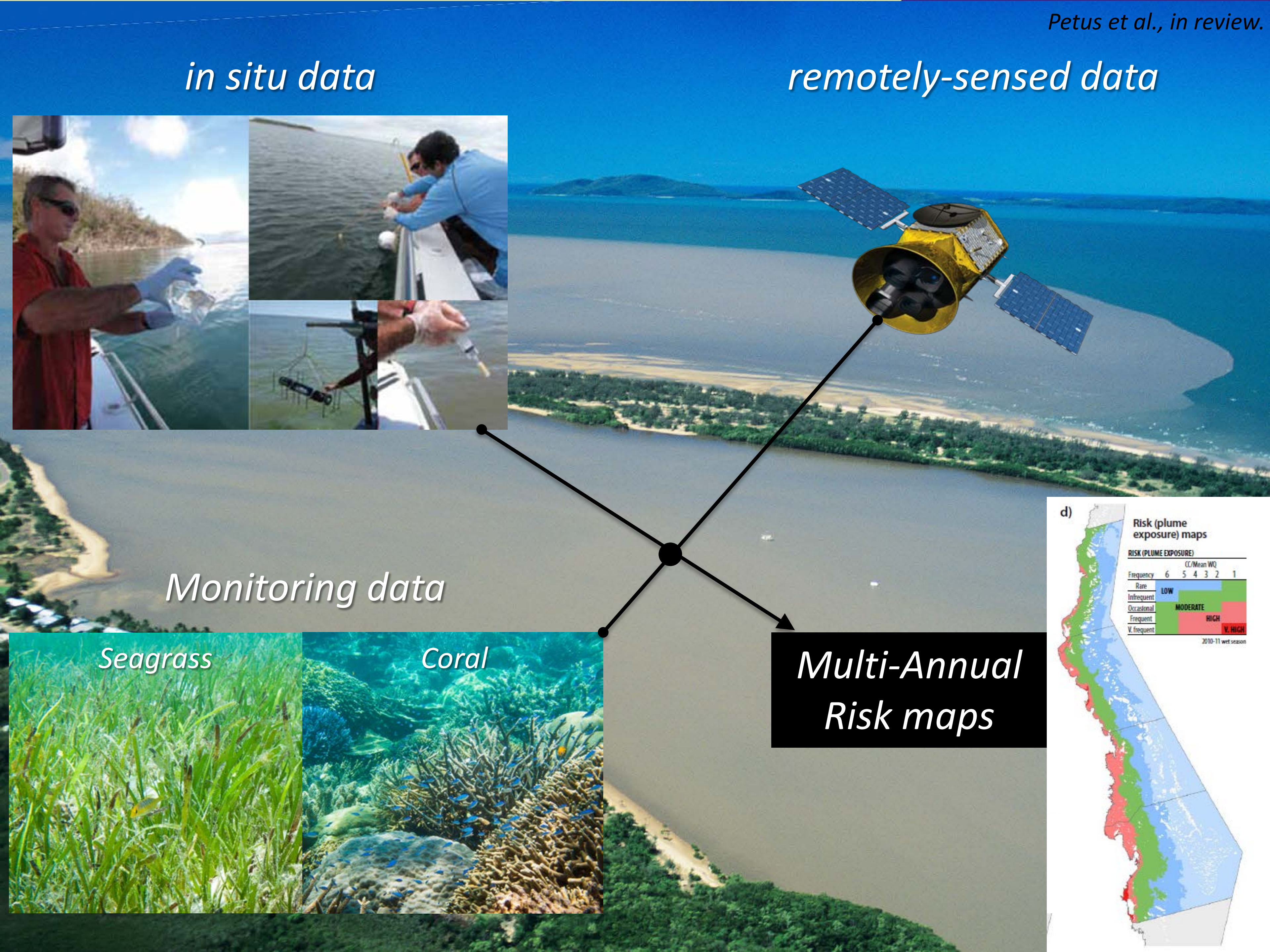


tropwa

Petus et al., 2014b

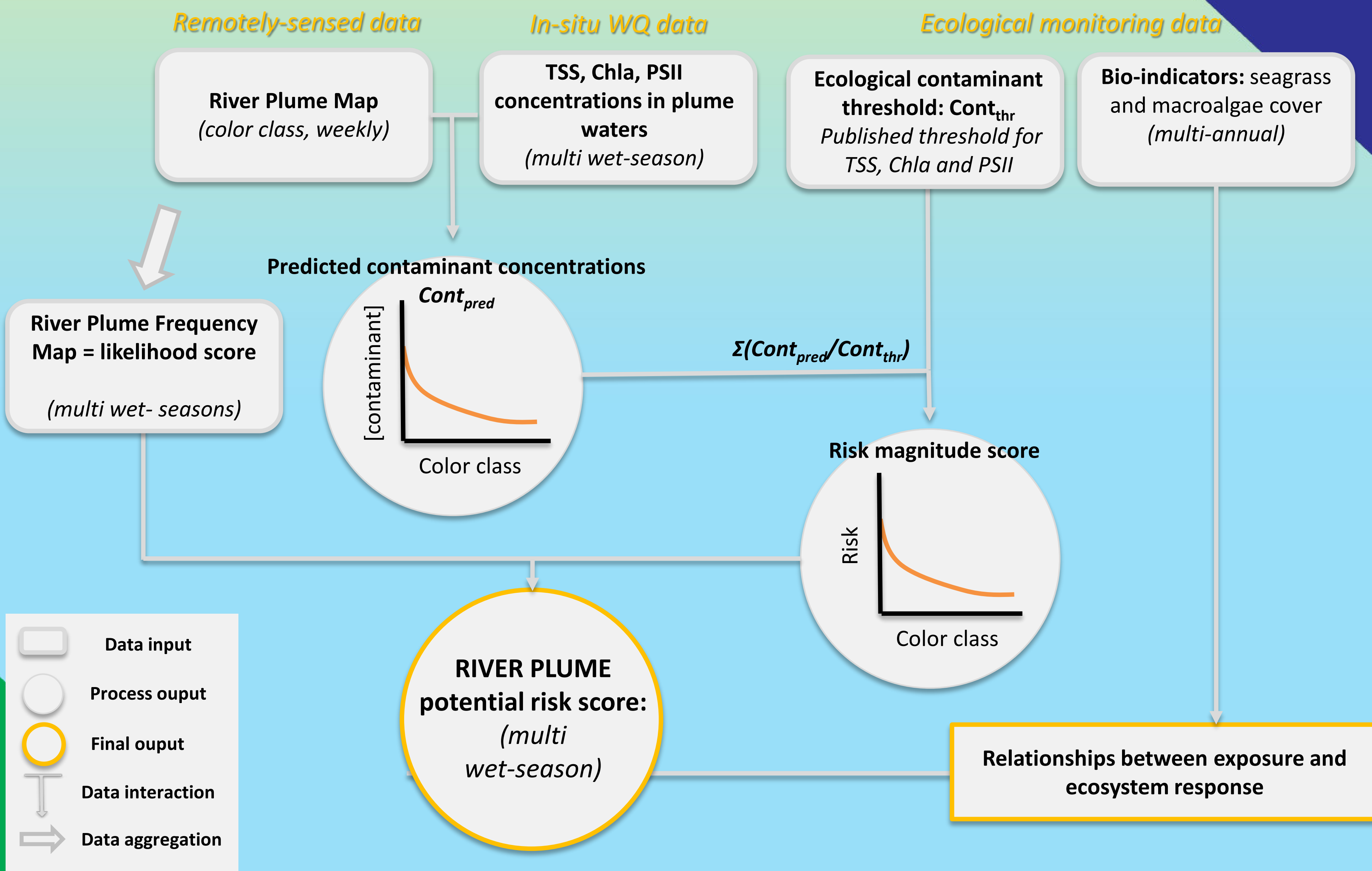
Develop satellite risk framework and river plume risk maps

s et al., in review, Devlin et al., 2015.


Petus et al., in review.
in situ data
remotely-sensed data
Monitoring data
Seagrass
Coral
Multi-Annual
Risk maps
d)
Risk (plume
exposure) maps
RISK (PLUME EXPOSURE)
CC/Mean WQ
Frequency 6 5 4 3 2 1
Rare
Infrequent
Occasional
Frequent
V. frequent
LOW
MODERATE
HIGH
V. HIGH
2010-11 wet season

CONCEPTUAL MODEL OF RIVER PLUME RISK MAPS: DATA SOURCES (2005 TO 2014) AND MAIN PROCESSES

TropWATER



River plume risk score

TropWATER

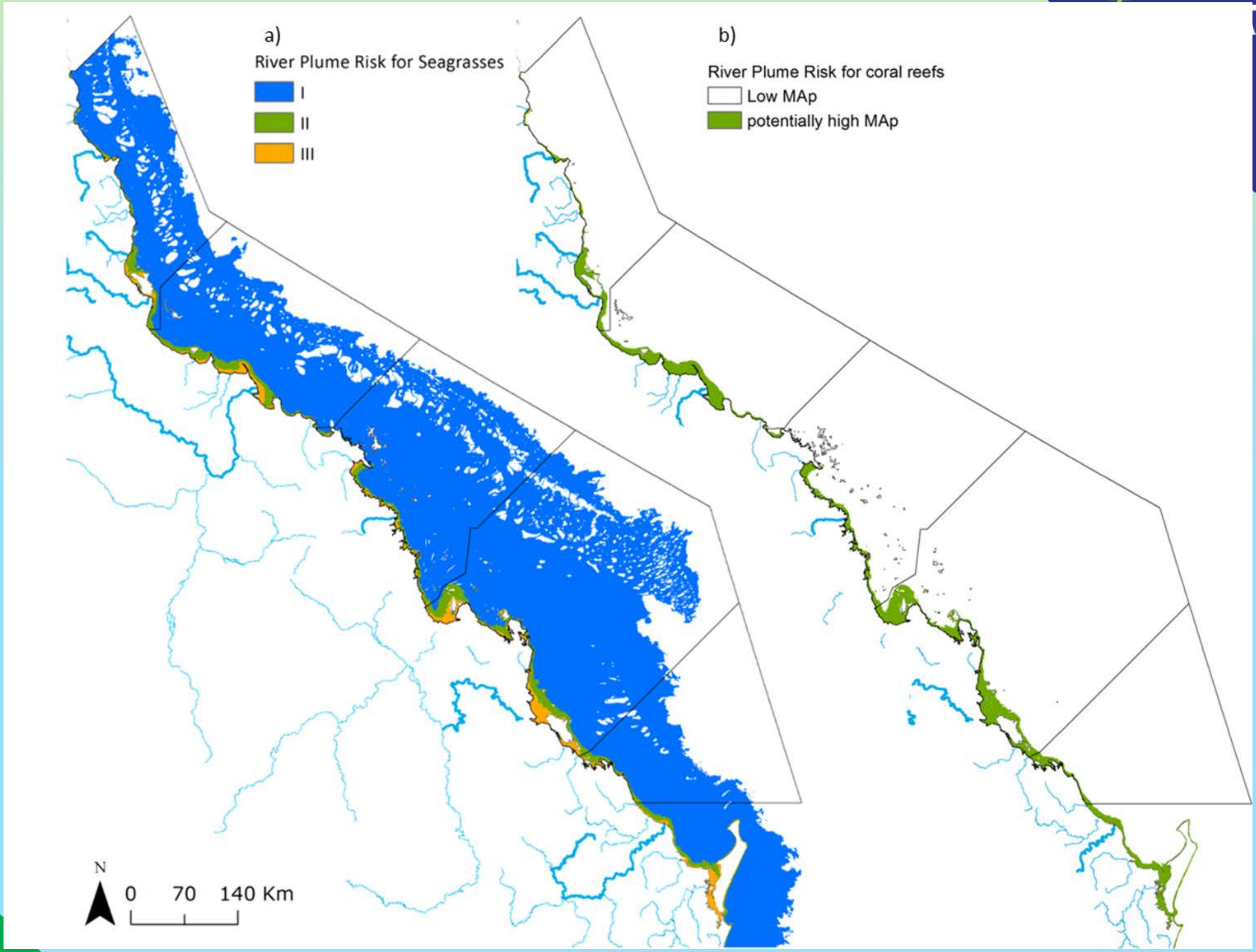
Land-sourced contaminant	TSS	Chl-a	PSII-Heq	ΣR_{CC} *1	MAGNITUDE MScc (0-10)	×	LIKELIHOOD Fcc (0-1)
CC1	51.00	2.90	0.04	13.7	10	×	0.4
CC2	19.0	2.1	0.03	7.4	4	×	0.4
CC3	17.2	2.3	0.03	7.6	5	×	0.5
CC4	10.5	1.5	0.02	4.8	2	×	0.2
CC5	8.4	0.9	0.01	3.2	1	×	0.2
CC6	8.4	0.5	0.01	2.3	0	×	0.1
CONSEQUENCES: *Ecological threshold: Cont.$_{thr}$*	*7 mg L^{-1}*	*0.45 µg L^{-1}*	*0.1 µg L^{-1}*				

Concentration in plume waters Cont.$_{CC}$ (mean 2005-2015)

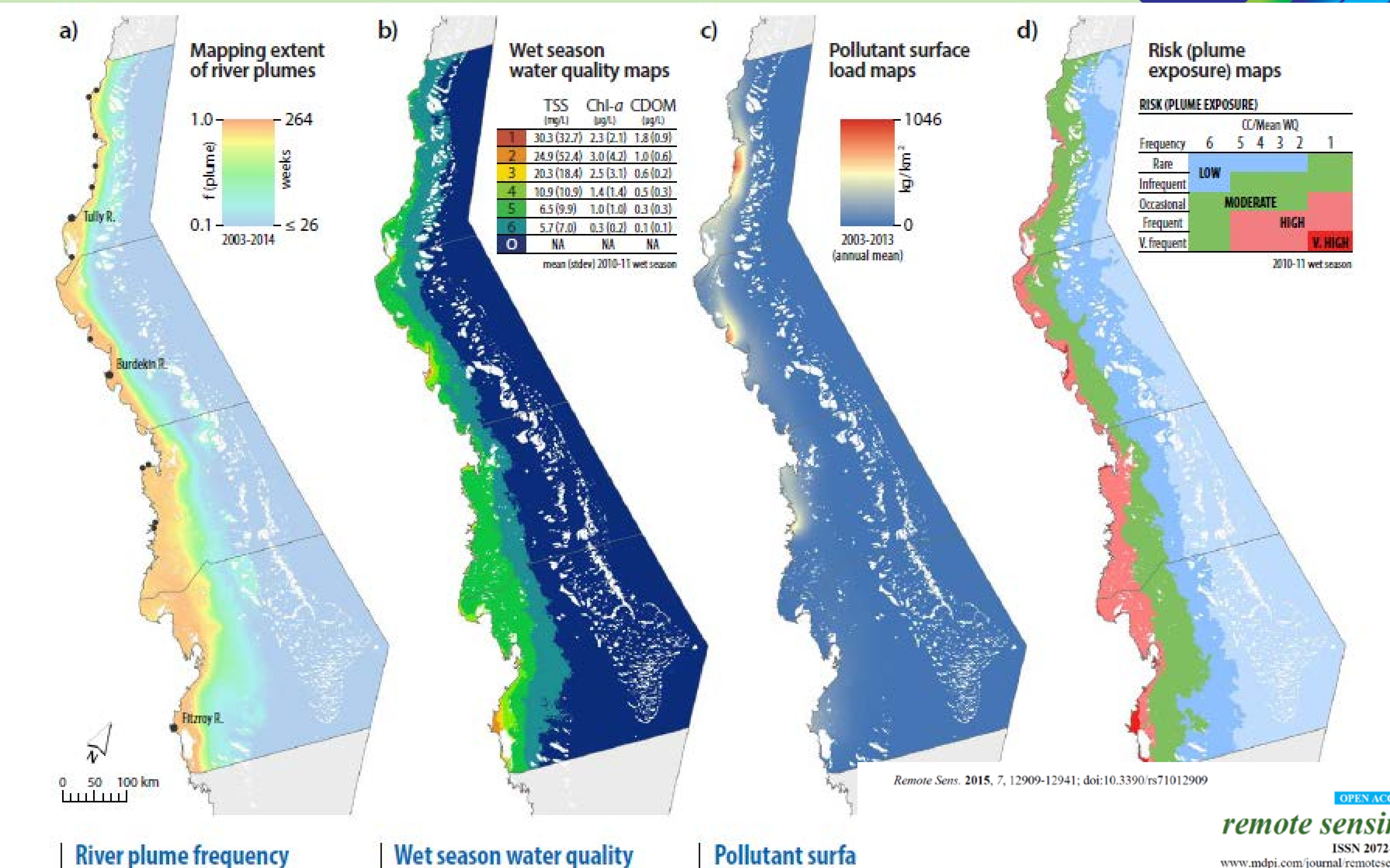
SCORES (/area):

MSarea : *2
RIVER PLUME RISK SCORE

Multi-annual risk map for GBR seagrass ecosystems from river plume exposure



RS data provides - multiple products for wet season, plume monitoring and risk assessment



Remote Sens. **2015**, *7*, 12909-12941; doi:10.3390/rs71012909

OPEN ACCESS

remote sensing

ISSN 2072-4292

www.mdpi.com/journal/remotesensing

Article

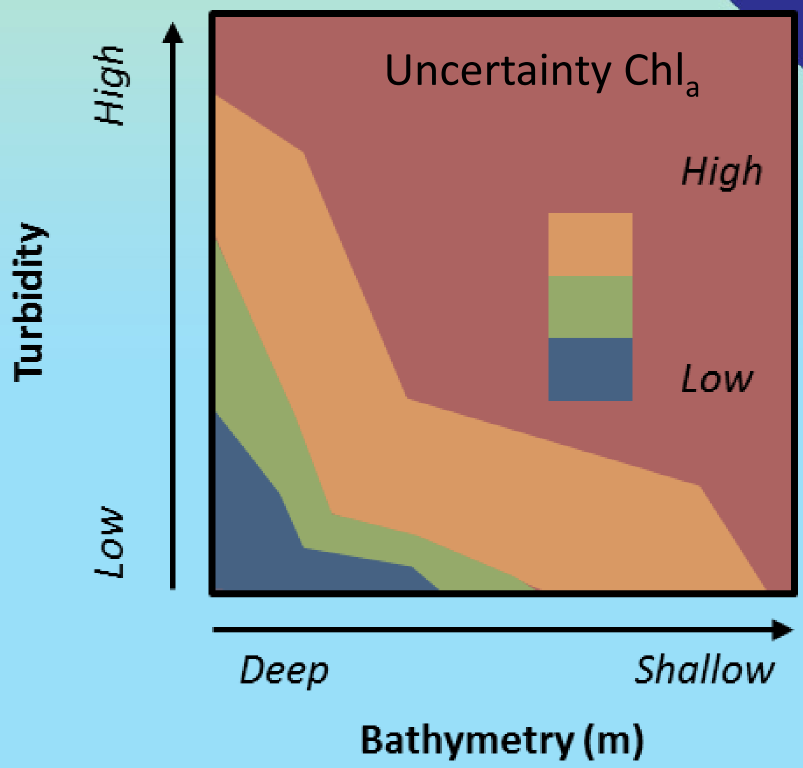
Water Quality and River Plume Monitoring in the Great Barrier Reef: An Overview of Methods Based on Ocean Colour Satellite Data

Michelle J. Devlin [1,*], Caroline Petus [1], Eduardo da Silva [1], Dieter Tracey [1], Nicholas H. Wolff [2], Jane Waterhouse [1] and Jon Brodie [1]

Understand uncertainty in chlorophyll a assessments from remote sensing (for WQIP's)

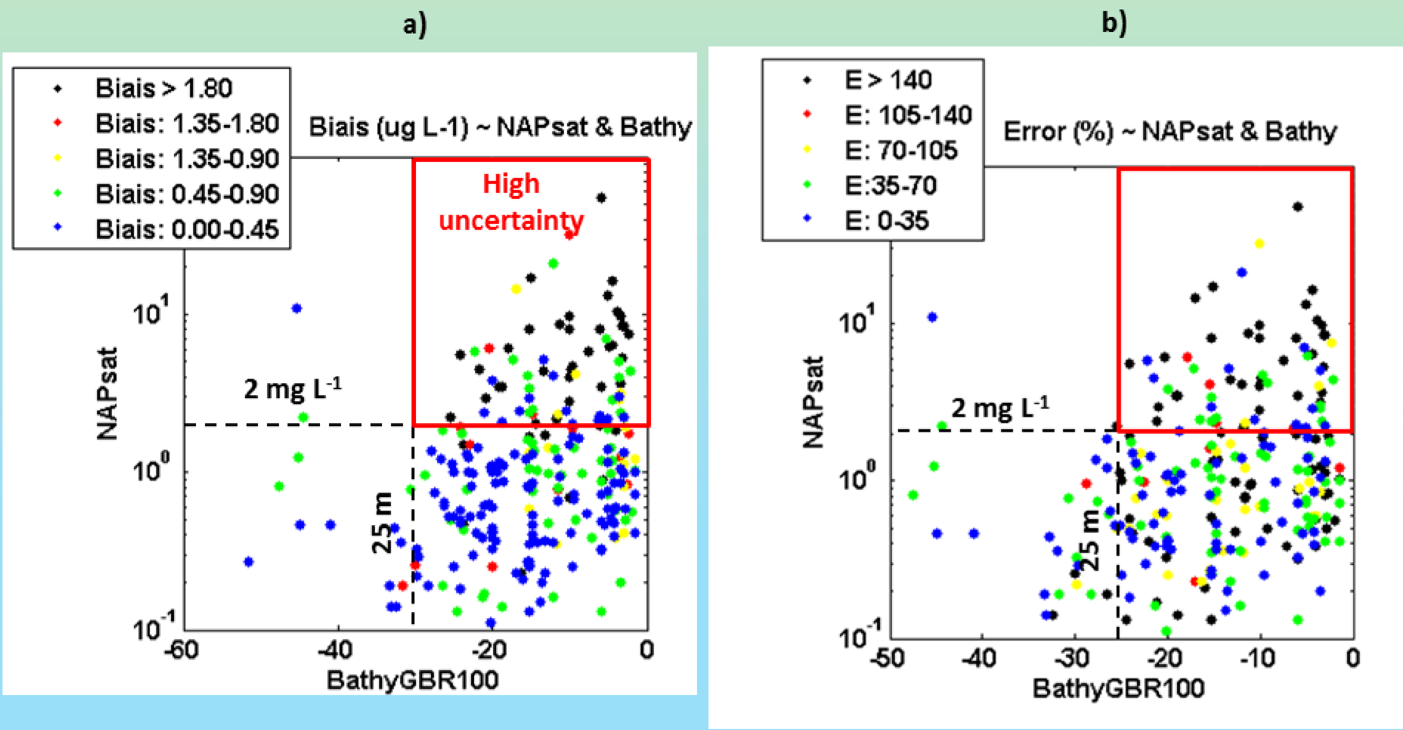
- Is the uncertainty increasing as a function of the bathymetry or/and turbidity of the water?
- In-situ vs. satellite Chl_a match-ups
- Using in-situ Chl_a data collected through the Marine Monitoring Program

Conceptual model



Petus et al., in Prep.

- Plotted |Bias| and % error against several TSS in-situ and satellite NAP concentrations and bathymetry levels



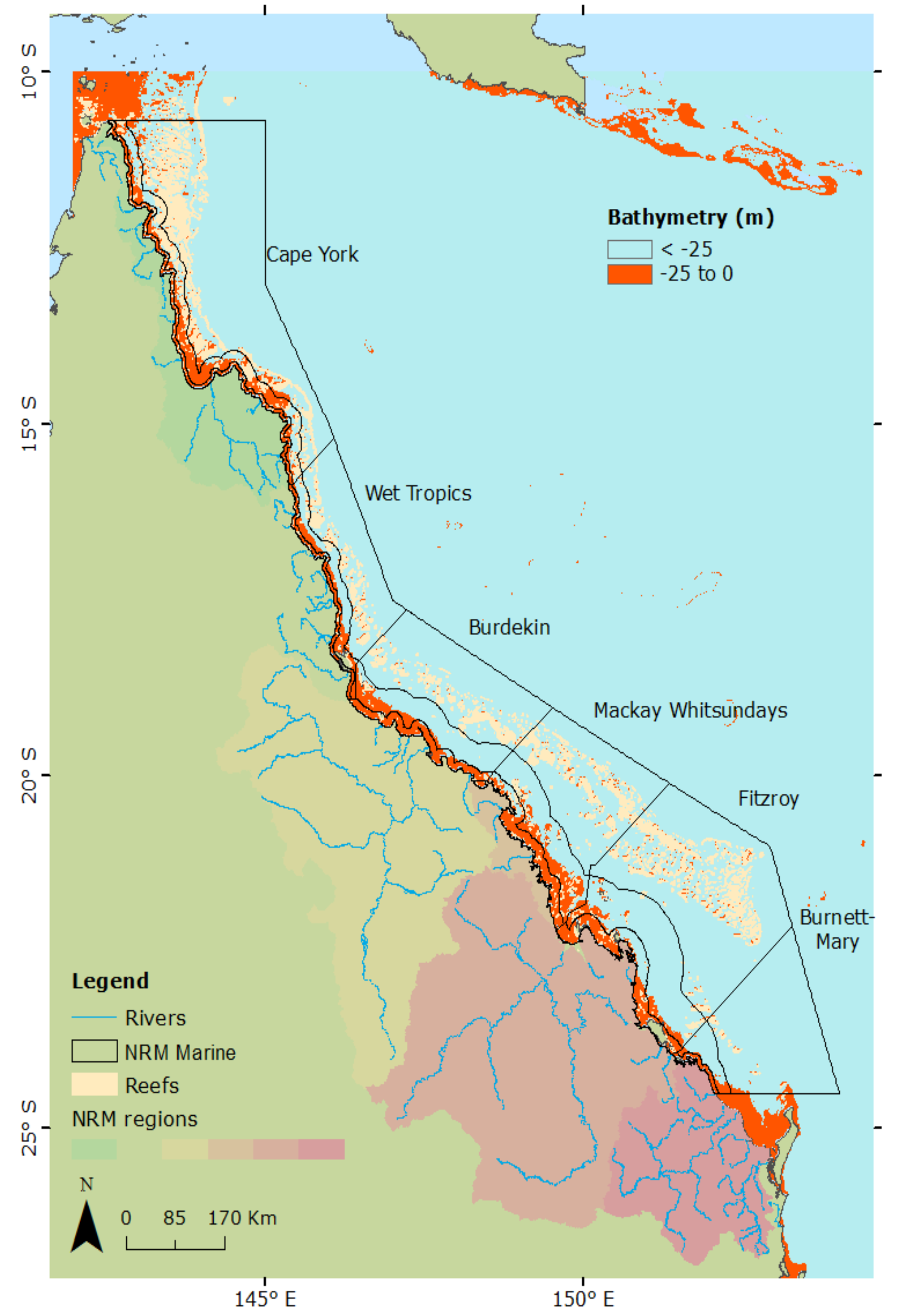
A trend toward an increase of uncertainties observed when the satellite NAP concentration increases and the bottom depth decreases; with thresholds values estimated around **satellite NAP = 2 mg L^{-1} and depth= 25 metres**.

The errors and bias reported in this study are performance statistic for the wet seasons and for flood plume waters only.

Validation of the remote sensing Chl-a retrievals based on in-situ Chl-a samples collected mainly during the dry season have been presented in King et al., 2014 with stronger validation statistics i.e., E% = 89%.

Uncertainty map – draft!!

Preliminary indication of a Chl-a satellite confidence map based on the 25 metre bathymetry contour



Uncertainty

- Becoming a major issue due to the use of RS data in the WQ metric for GBR reporting
- Uncertainty not included in the first 3 years of Paddock to Reef Reporting. Only RS data included in metric
- High uncertainty in coastal areas.
- Higher uncertainty in Cape York, wet season
- Requires incorporating/understanding uncertainty when aggregating data into a WQ metric
- Still a balance
  - between the utility of large scale RS data adding to knowledge/assessment of state and
  - Recognition and incorporation of uncertainty into end products
  - Communication an issue when dealing with the requirements of managers and management agencies

Conclusions

TropWATER

- Ocean colour – despite limitations – has provided a valuable source of data in GBR monitoring
- Extended our knowledge of water quality gradients
- Improved risk assessment
- Integration of data – in-situ, remote sensing, modelled – increases the individual value of each different data set.

THANK YOU!