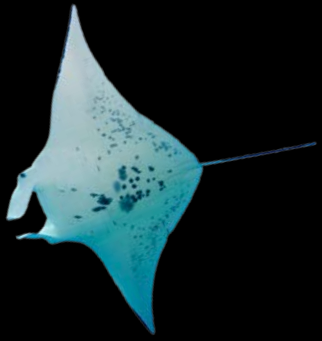
Applications of Ocean Colour to Biophysical Oceanography

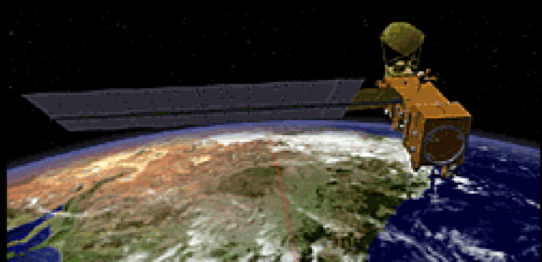
Dr. Scarla Weeks

Biophysical Oceanography Group

Remote Sensing Research Centre

University of Queensland





Primary applications

Teaching + Research

- Understanding the links between physical processes and the biological response
    - e.g. EAC/GBR, Mozambique/Agulhas, Peru/Humboldt - Ecuador

Primary satellite data

- Ocean colour, SST, altimetry
- Main sources: NASA OBPG & AVISO
- Ocean colour & SST @ 1km res: daily download & processing (L1A, L2, L3)
- Altimeter data: Delayed & Near Real Time
- Geophysical products:
    - SST → adjust flags & SST quality levels depending on application
    - Ocean colour: select flags & modify thresholds depending on region & application

Collaboration with NASA OBPG: develop & / or refine products

For example:

To understand exposure of the Great Barrier Reef to risk factors that cause stress & mortality

- → detect changes to the transparency of the water column
- → identify the dominant modes of variation in the spatio-temporal patterns of water clarity & physical dynamics involved

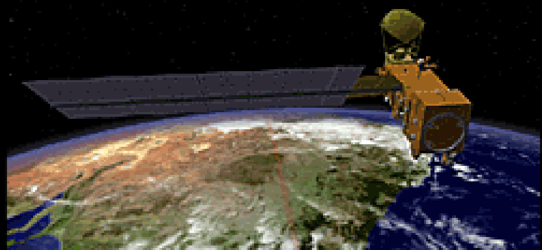
Algorithms for measuring geophysical parameters, such as chlorophyll concentration or water clarity, reliable over deep water but still limited in coral reef & coastal regions

→ Developed photic depth algorithm for GBR

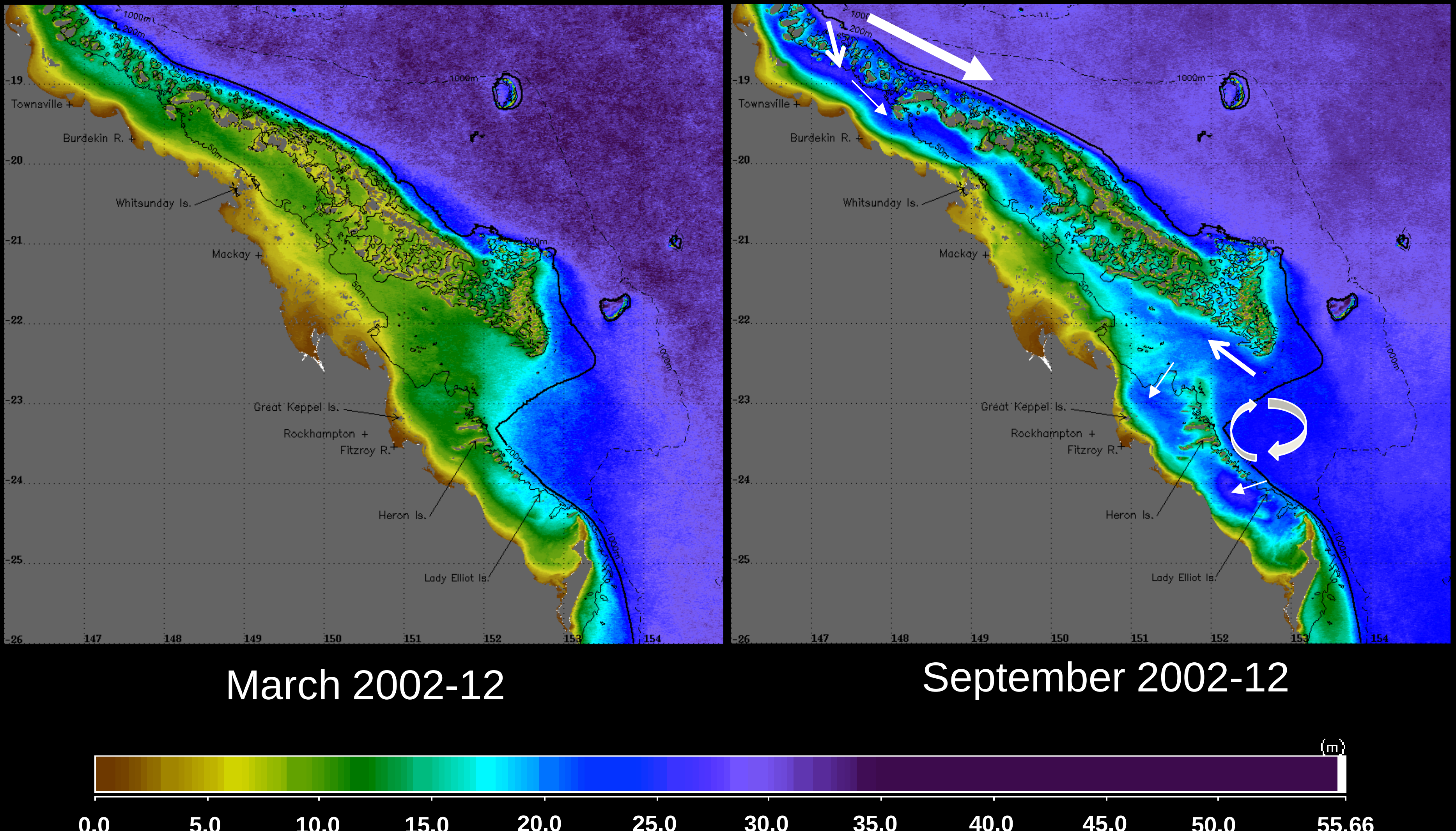
→ implemented into SeaDAS

→ applied to full regional time series of MODIS data

Weeks SJ, Werdell PJ, Schaffelke B, Canto M, Lee ZP, Wilding JG & GC Feldman. 2012. Satellite-derived photic depth on the Great Barrier Reef: Spatio-temporal patterns of water clarity. *Remote Sensing,* 4, 3781-3795



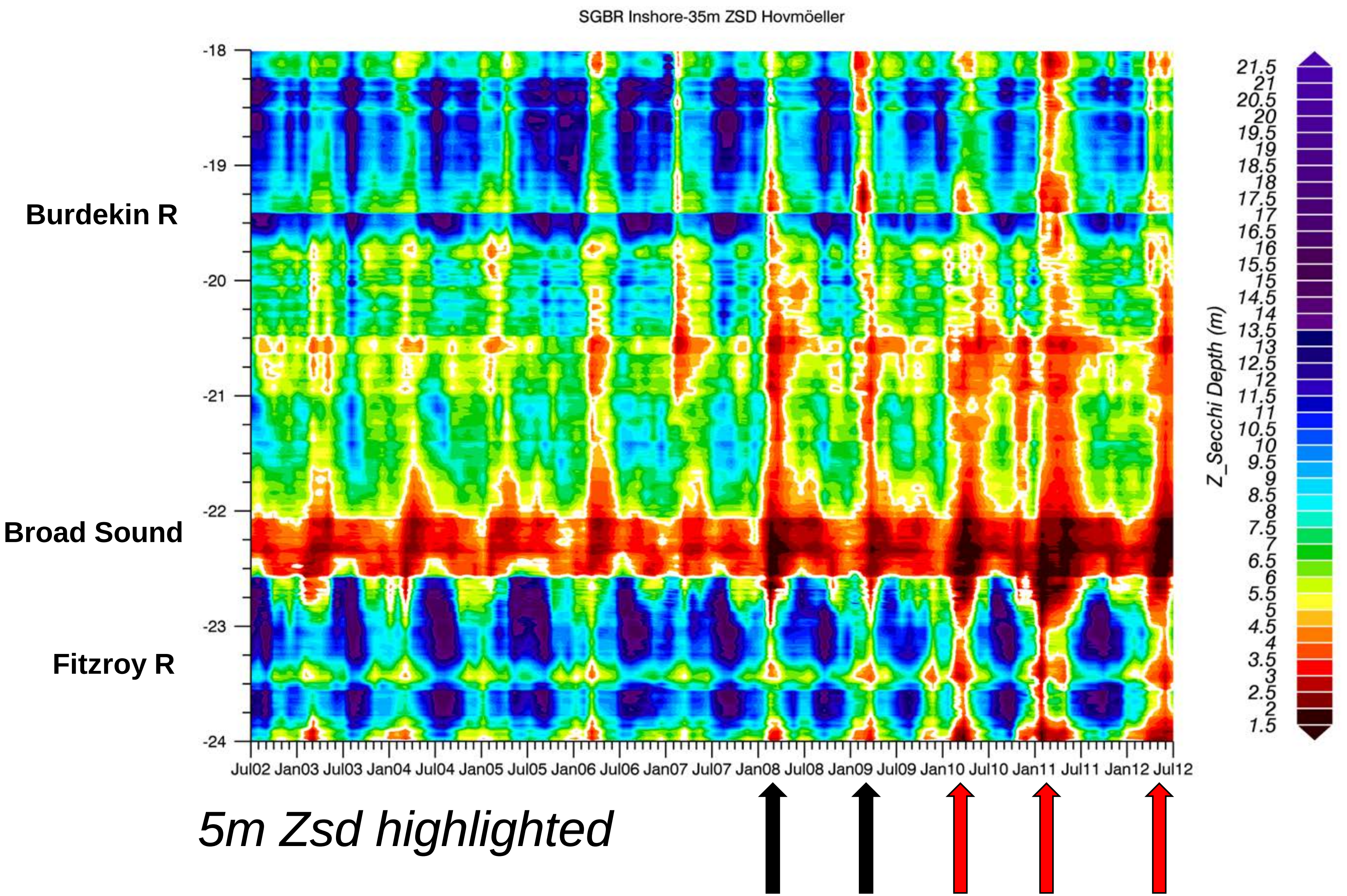
GBR Photic Depth climatology
MODIS @ 1km resolution for 2002 - 2012



March 2002-12

September 2002-12

Hovmöller plot – Inshore reefs
2002 Jul – 2012 Jun



5m Zsd highlighted

Assess inter- and intra-annual changes in water clarity in response to river run-off

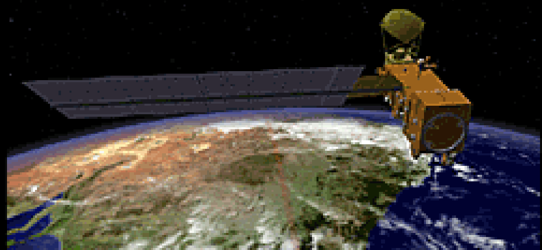
Magnitude of changes in water clarity related to river discharges

Fabricius KE, Logan L, Weeks SJ and J Brodie (2014). Assessing inter- and intra-annual changes in water clarity in response to river run-off on the central Great Barrier Reef from 10 years of MODIS-Aqua data. *Marine Ecology Progress Series*, doi:10.1016/j.marpolbul.2014.05.012

Logan M, Weeks SJ, Brodie J, Lewis SE and KE Fabricius (2015). Magnitude of changes in water clarity related to river discharges on the Great Barrier Reef continental shelf: 2002-*2013 Estuarine, Coastal and Shelf Science* (in press)

Current algorithms unable to correct for bottom reflectance in optically shallow regions

→ limits accuracy of satellite data in coastal & coral reef areas



ARC Linkage project with NASA OBPG: Improved tools for comprehensive monitoring of water-clarity and light availability in coral reef ecosystems

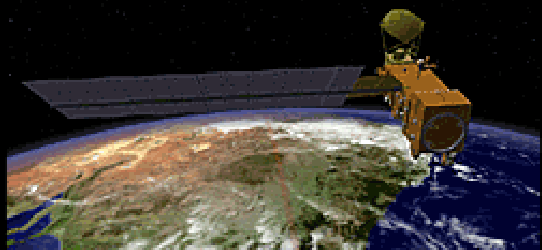
- Developed a shallow water algorithm: Shallow Water Inversion Model (SWIM)
- retrieves water column optical properties → using geometric water depth and benthic substrate reflectance as ancillary data fields

McKinna L, P Fearns, SJ Weeks, PJ Werdell, M Reichstetter, BA Franz, DM Shea and G Feldman (2015). A semianalytical ocean color inversion algorithm with explicit water-column depth and substrate reflectance parameterization. *Journal of Geophysical Research: Oceans*, 120, 1741-1770

Reichstetter M, McKinna L, Fearns P, Weeks SJ; Roelfsema CM, Furnas M (2014): Seafloor brightness map of the Great Barrier Reef, Australia, derived from biodiversity data. doi:10.1594/*PANGAEA* 835979.

Reichstetter M, Fearns P, Weeks SJ, McKinna L, Roelfsema CM, Furnas M (2015). Bottom reflectance in ocean colour satellite remote sensing for coral reef environments. *Remote Sensing* (accepted)

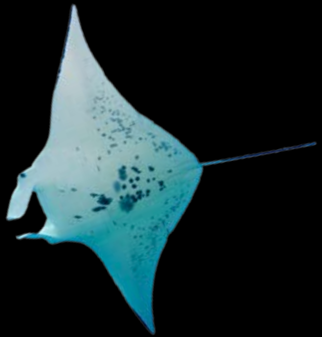
Implemented into SeaDAS → geophysical parameters for optically shallow waters

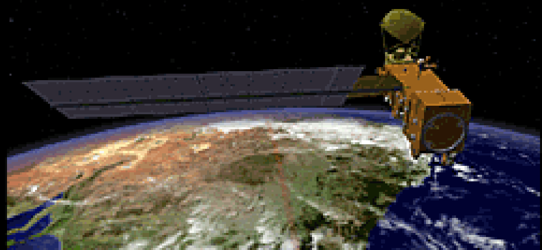


Application of satellite oceanography to understanding links between physical processes and the biological response

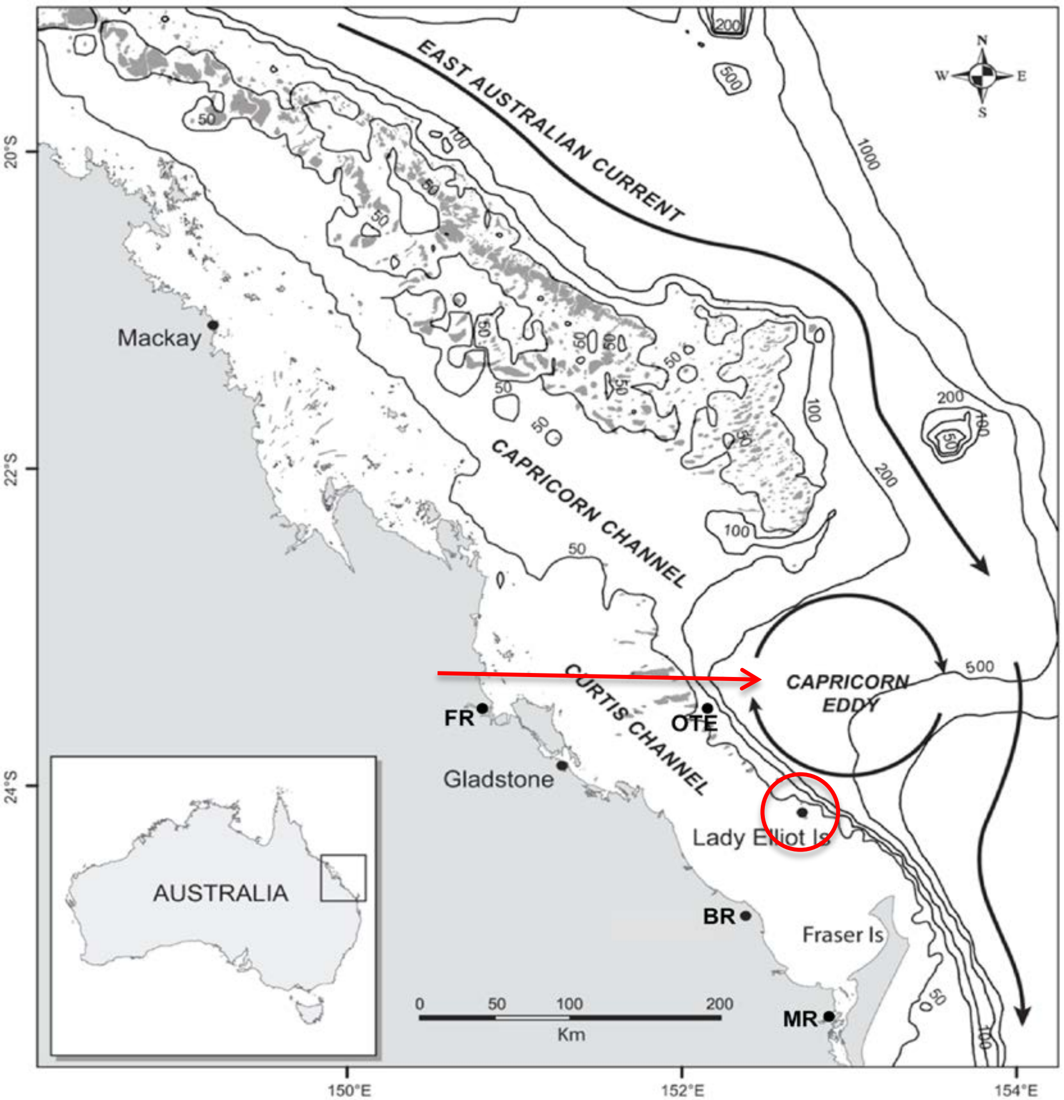
Unique sequence of oceanographic events triggers manta ray feeding frenzy in the southern Great Barrier Reef

Weeks SJ, Magno-Canto M, Jaine FR, Brodie J & Richardson AJ (2015). Unique sequence of events triggers manta ray feeding frenzy in the southern Great Barrier Reef, Australia. *Remote Sensing*, 7 (3). pp. 3138-3152





Background



Previous work: the Capricorn Eddy, in lee of shelf bathymetry

- linkages between large-scale oceanography (EAC) and mesoscale processes crucial to biologic responses
- effect of the eddy in upwelling of cool, nutrient-enriched oceanic subsurface water & bottom intrusions…

Eddy an important driver of manta ray abundance at Lady Elliot Island

- Jaine et al. (2012). When Giants Turn Up: Sighting Trends, Environmental Influences and Habitat Use of the Manta Ray Manta alfredi at a Coral Reef. PLoS ONE 7:e46170

Satellite telemetry – tagged manta rays → eddy to be important foraging ground for the species off eastern Australia

Jaine et al. (2014). Movements and habitat use of reef manta rays off eastern Australia: Off shore excursions, deep diving and eddy affinity revealed by satellite telemetry. *Marine Ecology Progress Series*, 510, 73-86. doi: 10.3354/meps10910.

Background

Manta rays

- Large & highly mobile plankton-feeding elasmobranchs
- Zooplankton - principal known food resource
- Occur at low population levels & for limited periods at inshore aggregation sites
- Vulnerable to Extinction on **IUCN** Red List

Eastern Australia

- Individuals **(***Manta alfredi*) observed to migrate seasonally between sites up to 750 km apart
- Key aggregation site - Lady Elliot Island

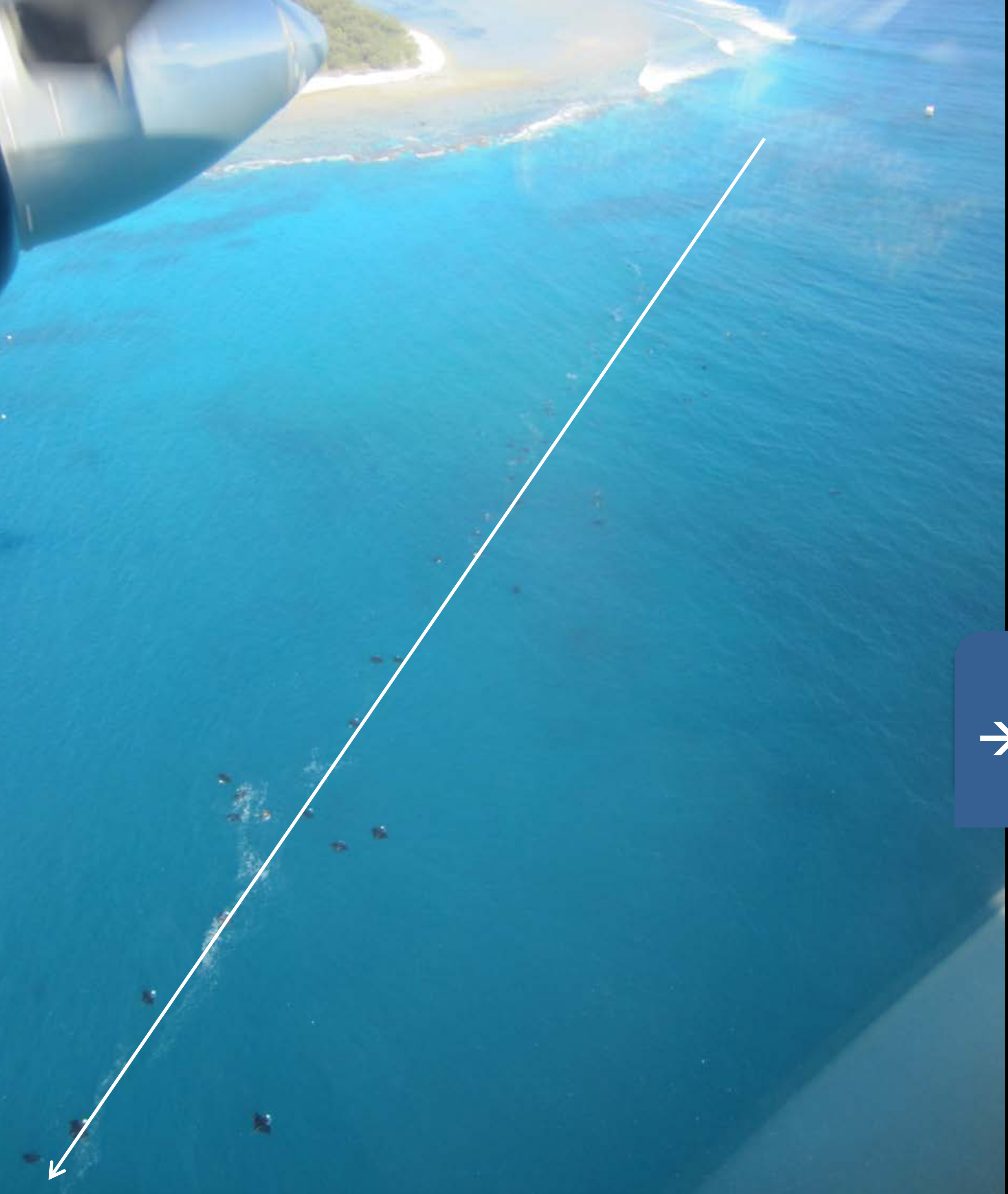
- Aggregations of foraging mantas peak during winter
- Drivers influencing seasonal variation unclear

  → enhanced food availability…

- During summer months, numbers sparse
- Until January 2013…

→ largest manta ray feeding aggregation observed off Australia

31 January 2013



- Feeding trains of +150 manta rays on 31 Jan & 1 Feb 2013 during spring ebb tide

Environmental processes → anomalous & unseasonal aggregation?

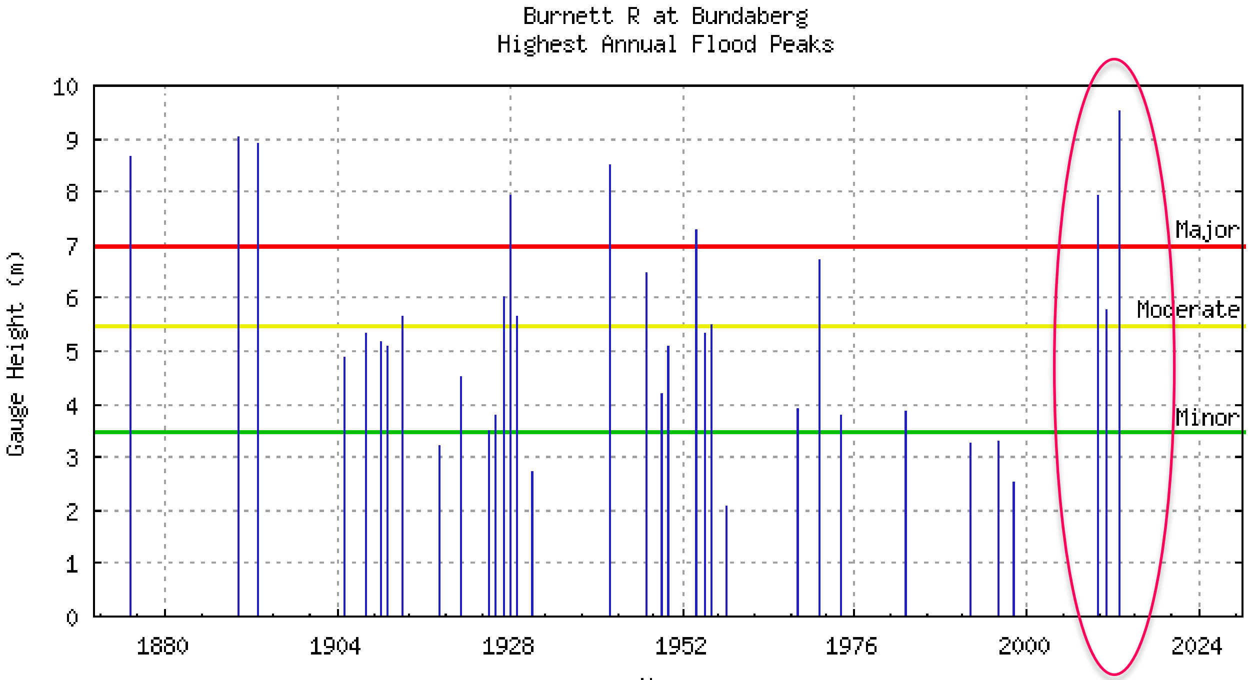
Primary mesoscale features?

Tropical Cyclone Oswald over the Cape York Peninsula, NE Australia on 21 Jan 2013 (MODIS)

Last week of January 2013

- Tropical Cyclone Oswald impacted NE coast of Australia → very heavy rainfall
- Anomalously high river discharges from 3 rivers → highest gauge height on historic record

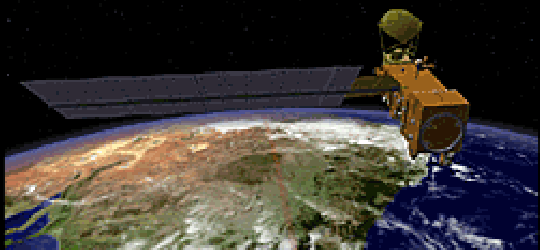
- → extensive river plumes onto the S-GBR shelf & phytoplankton blooms with *in situ* chlorophyll-a conc 6-18 µg/L
- discharges enriched with nitrogen and phosphorus



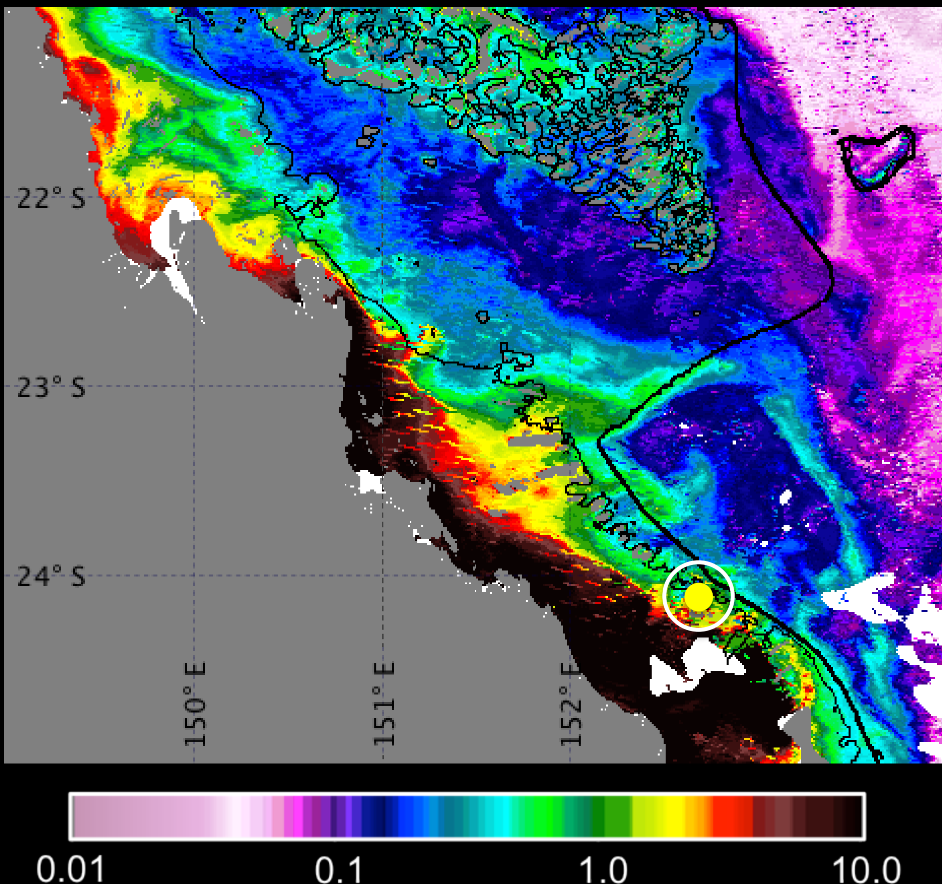
Mesoscale Ocean Features

- Daily MODIS SST, chlorophyll-a concentration & photic depth @ 1 km spatial resolution
- Decadal (2002-2012) monthly climatologies @ 1 km resolution - baseline for comparison
- Photic Depth provided a measure of water clarity → GBR-validated photic depth algorithm

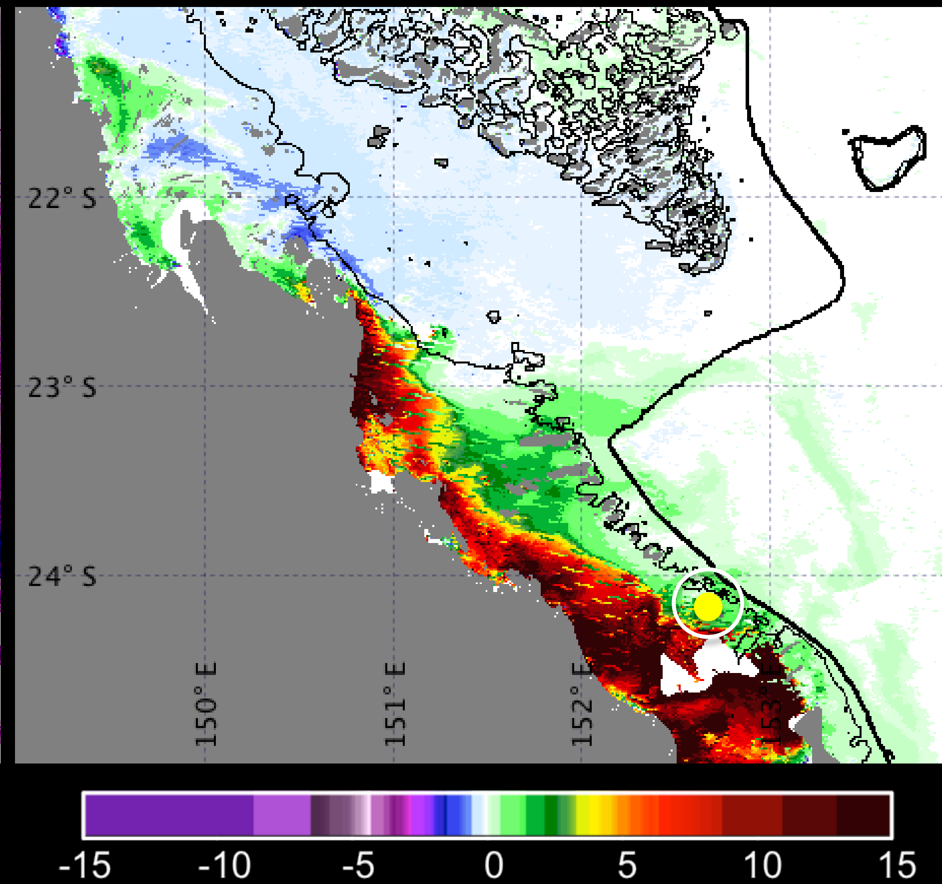
- Severely impacted cloud contamination…



MODIS chlorophyll-a concentration



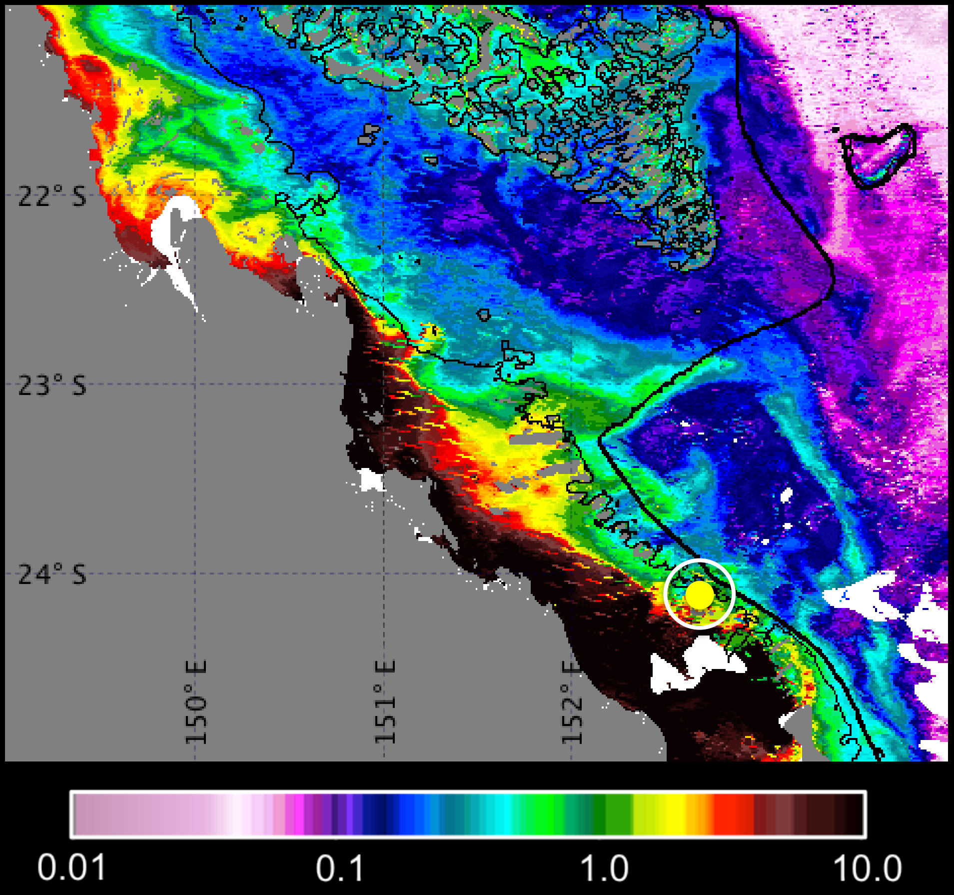
Chlorophyll-a concentration (mg.m^{-3})
2 – 4 February 2013

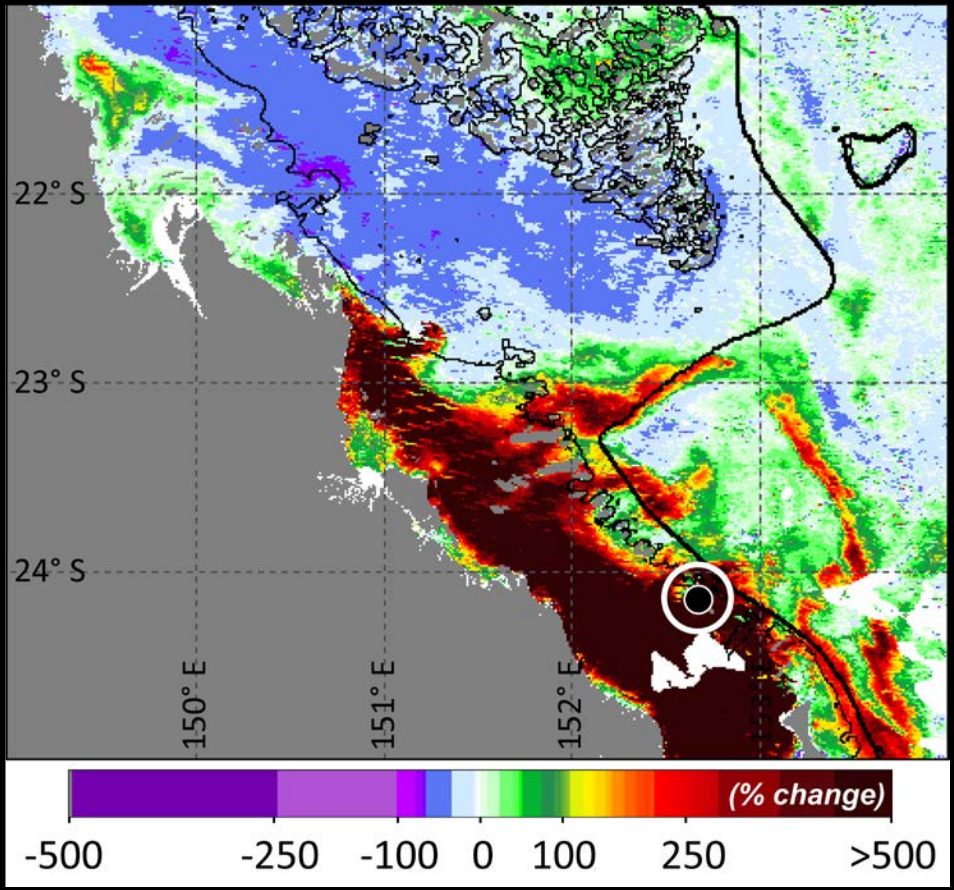


Chlorophyll anomalies (mg.m^{-3})
2 – 4 February 2013

Strong positive chlorophyll anomalies (10-15 mg.m^{-3}) extend across width of continental shelf

MODIS chlorophyll-a concentration

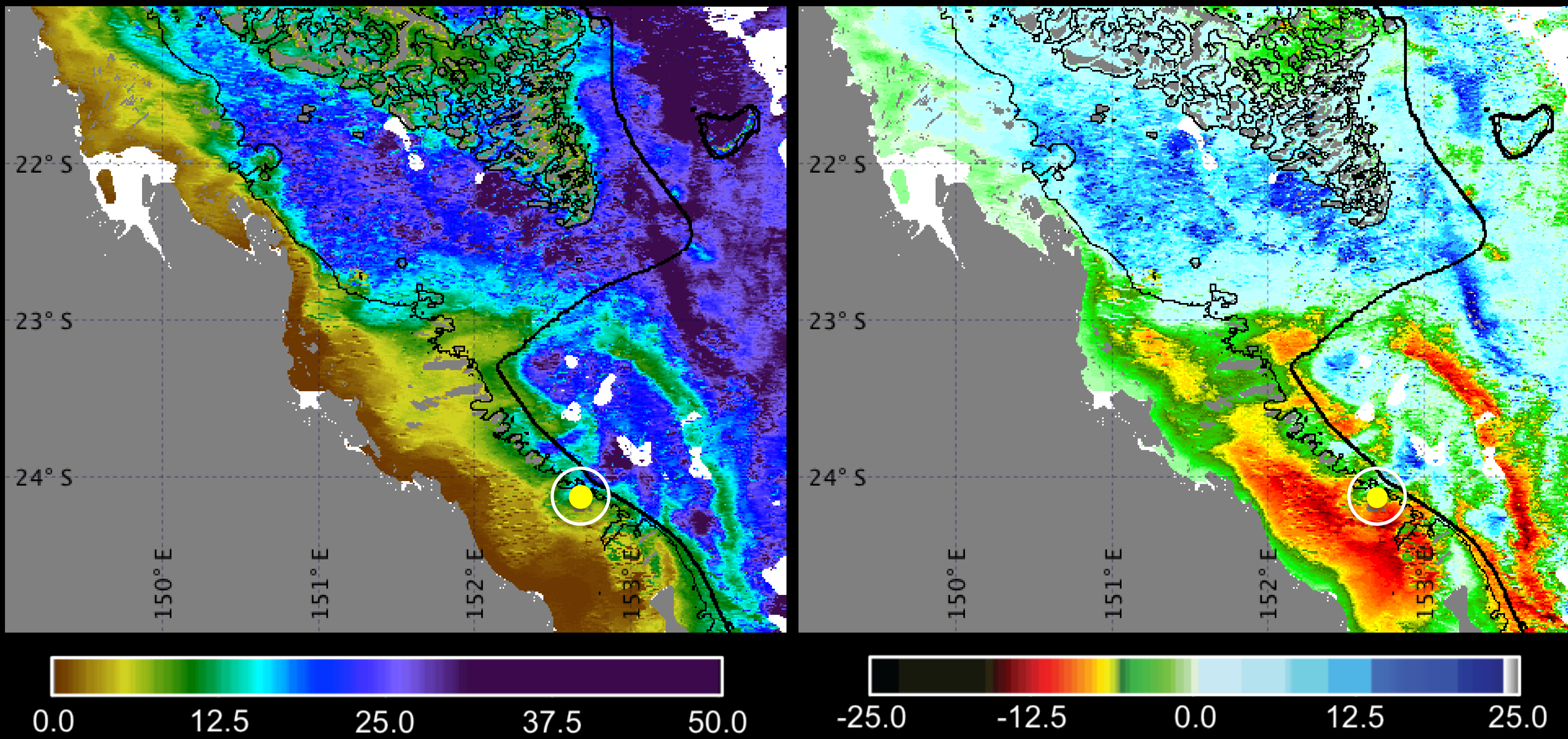




Transformed chlorophyll anomalies (% change)
2 – 4 February 2013

Capricorn Eddy particularly evident when chlorophyll anomalies expressed in terms of % change

MODIS GBR 10% photic depth

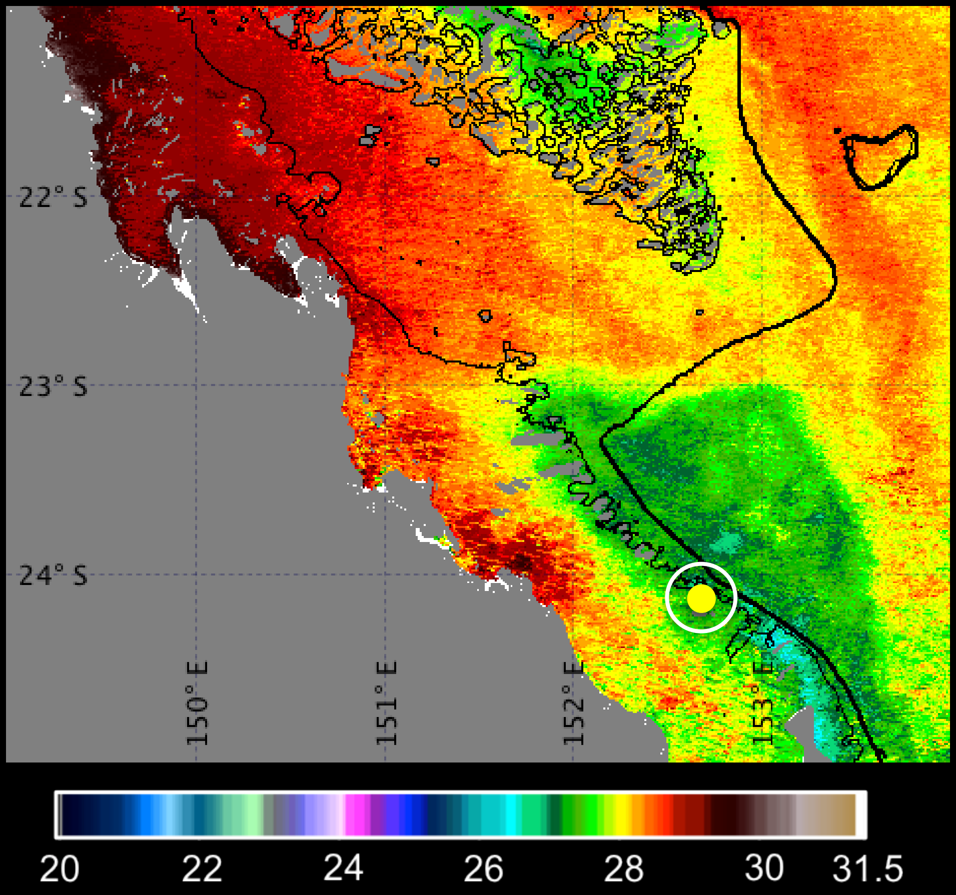


Photic depth (m^{-1})
2 – 4 February 2013

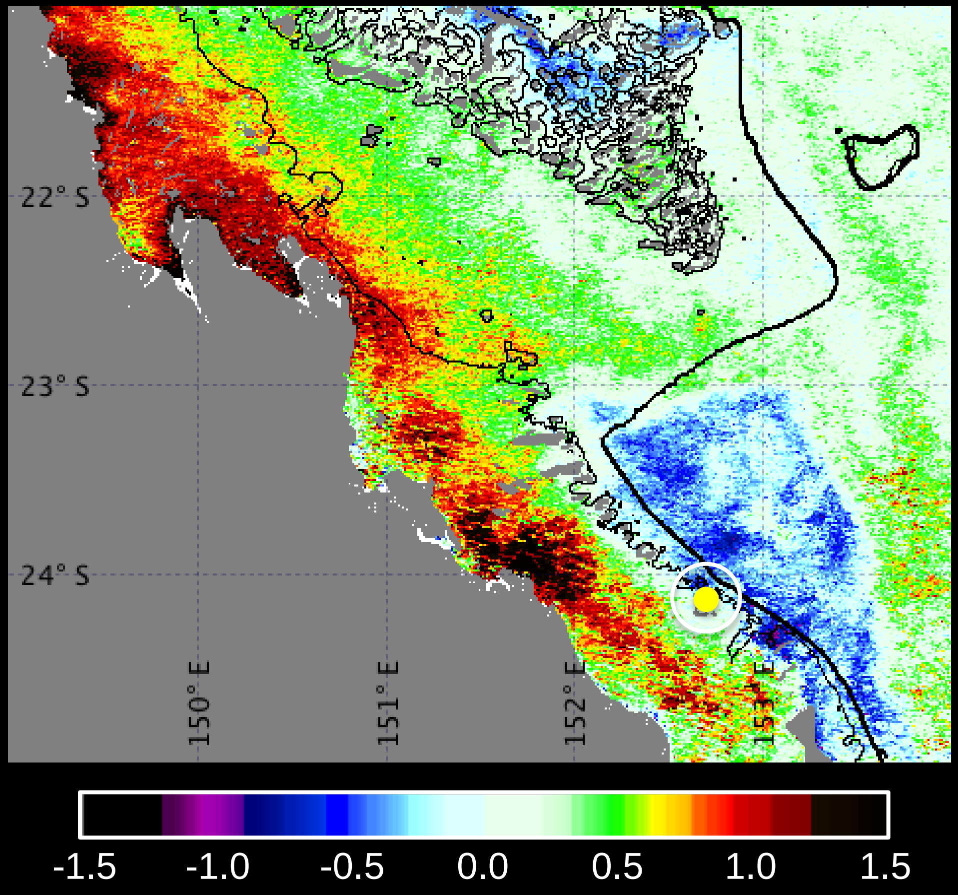
Photic depth anomalies (m^{-1})
2 – 4 February 2013

Intensely anomalous decrease in water clarity of up to -15m as far out as LEI

MODIS Sea Surface Temperature



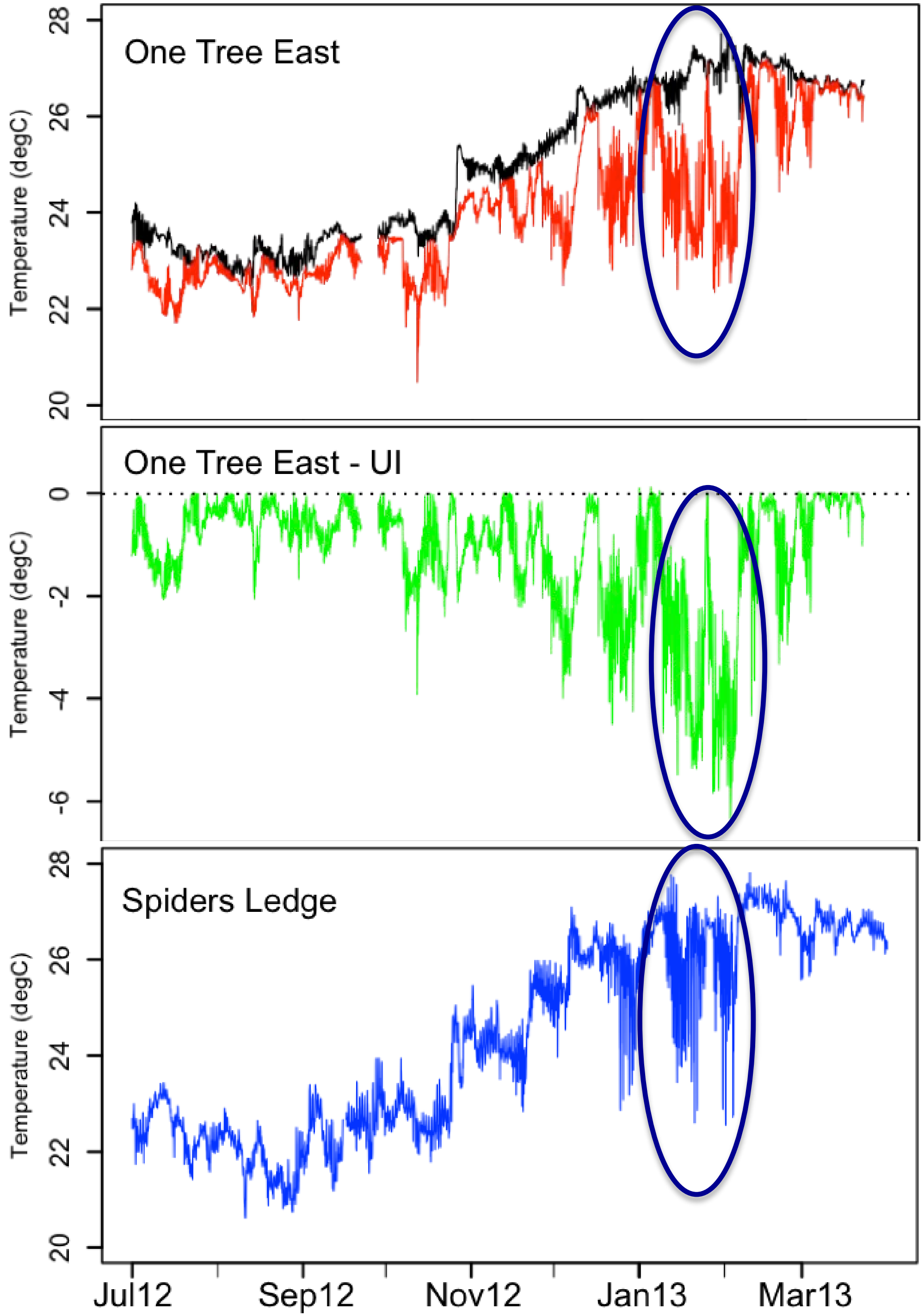
Sea surface temperature (° C)
2 – 4 February 2013

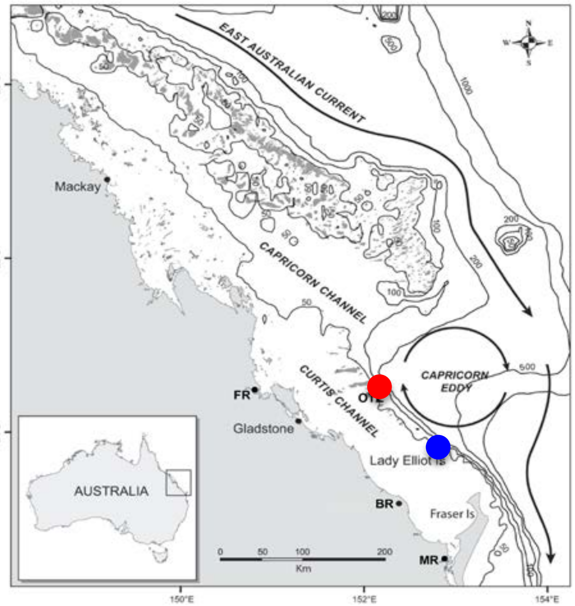


SST anomalies (° C)
2 – 4 February 2013

SST anomaly data highlighted two opposing bodies of water

In situ data





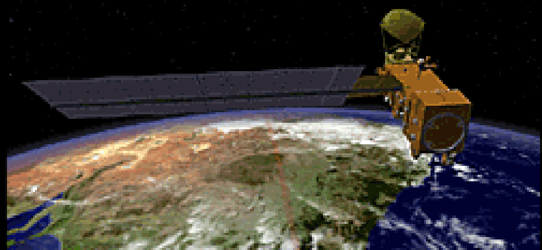
IMOS mooring east of One Tree Is: → ns temperature data (-9m) & at 55m depth July 2012 - March 2013

Temperature logger at 'Spiders Ledge' at LEI (-22m) → nb temperature data at 20.5m depth

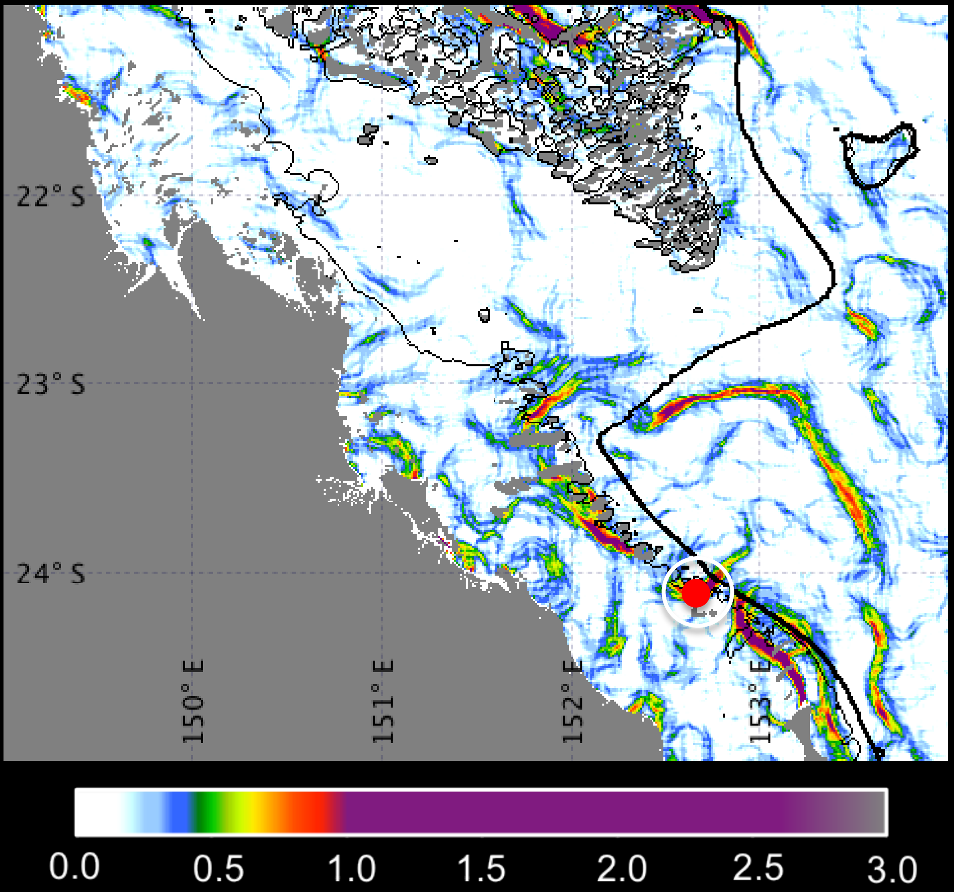
Ocean Fronts

To investigate the convergence of the two opposing bodies of water - warmer, turbid shelf waters with the cooler, oceanic sub-surface waters raised by the eddy dynamics:

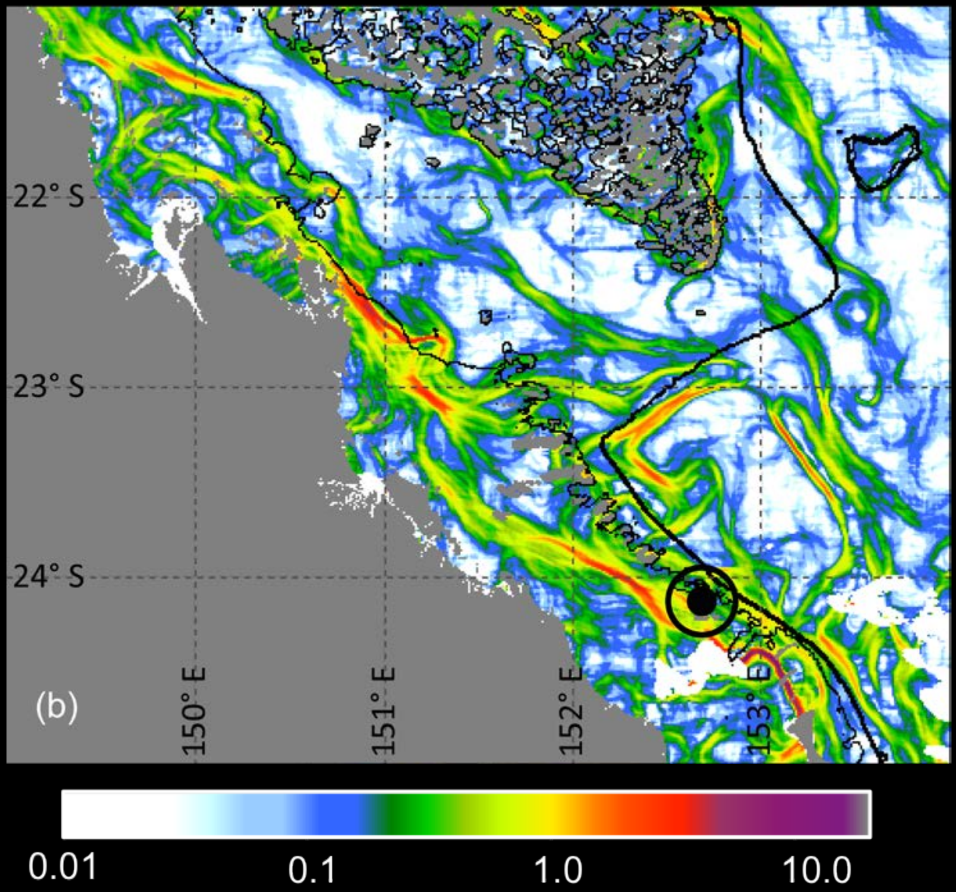
- → images of frontal gradient intensity were generated
- → show magnitude and rate of horizontal change



MODIS frontal gradient intensity

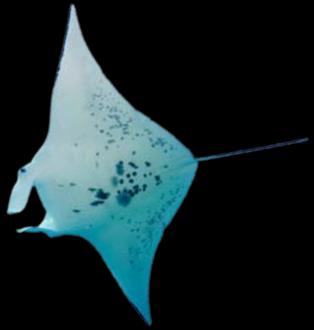


SST gradients (° C.km⁻¹)
2 – 4 February 2013



Chlorophyll gradients (mg.m⁻³.km⁻¹)
2 – 4 February 2013

Strongest SST gradients at boundary between shelf and eddy-influenced waters, overlying LEI



Concluding remarks

Largest manta ray feeding aggregation yet observed off eastern Australia, and first report of reef manta rays exploiting an oceanographic front

Ocean fronts concentrate & retain biological productivity, attracting & shaping aggregation patterns of planktivores & other species

Many marine vertebrates target oceanic fronts for foraging & migration
→ frontal zones important sites for conservation*

Future work: mapping probability & persistence of fronts from RS data to aid management & conservation of marine species

Altimetry data – mesoscale features?