Hydrodynamic / biogeochemical / optical modelling of algal blooms.

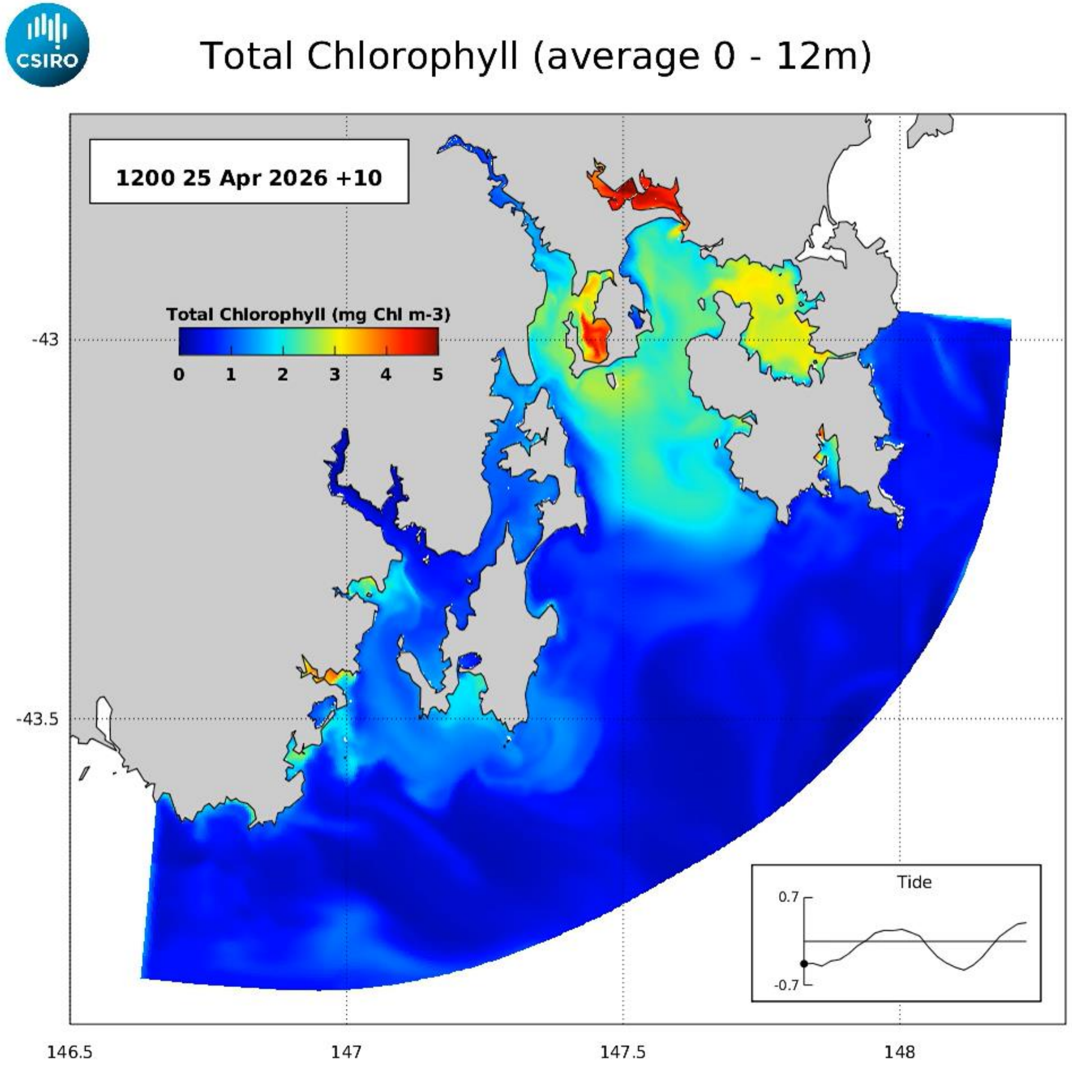
Mark Baird, Albertina Dias, Lachlan Phillips, Darren Engwirda, Chaojiao Sun, Jim Greenwood and Emlyn Jones | 2-June-2026

Acknowledgement of Country

Palawa and
Muwinina people of
Nipaluna / Hobart

Value of hydrodynamic / biogeochemical modelling for HAB blooms

- Hindcast to better understand environmental conditions that lead to algal blooms.
- Scenarios to understand impact of management strategies.
- Sensitivity analysis to understand limits to prediction of HABs.
- Climate downscaling projections to quantify future risk of algal blooms.



Coastal modelling platform - Environmental Modelling Suite EMS:

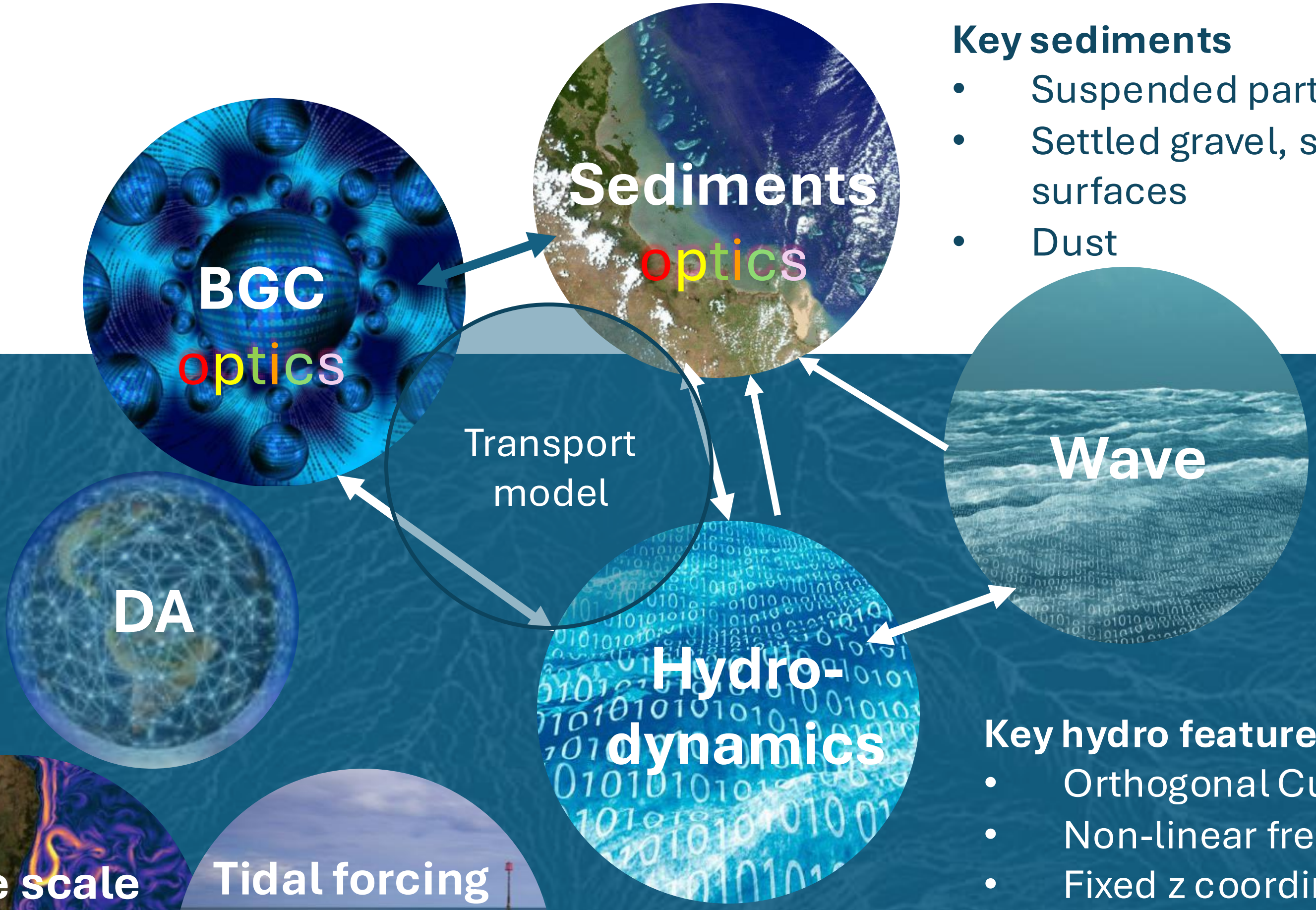
hydrodynamics, waves, sediment transport, biogeochemistry, ocean optics, plankton dynamics and data assimilation.

Key BGC features:

- Nutrient cycling, particles and water
- Phytoplankton and zooplankton
- Labile and refractory detritus

Key sediments

- Suspended particles (silt and mud)
- Settled gravel, silt, mud and sand surfaces
- Dust

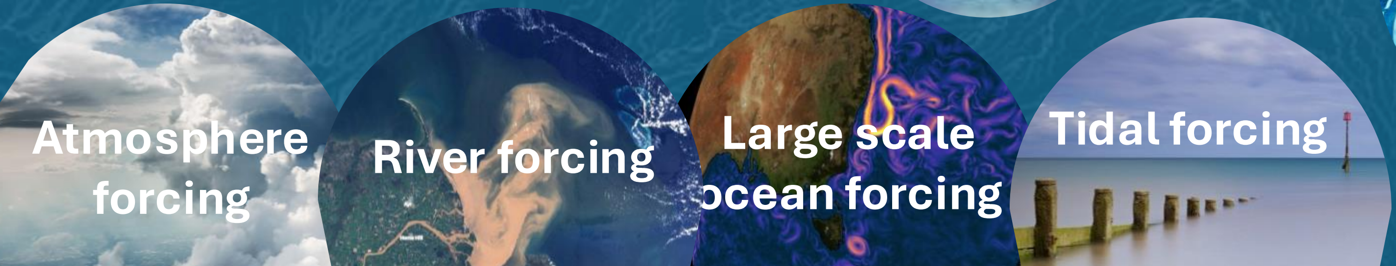


Unique features:

- seagrass, macroalgae and corals in sediment zone
- Spectrally resolved optics model, including remote-sensing reflectance

Key hydro features

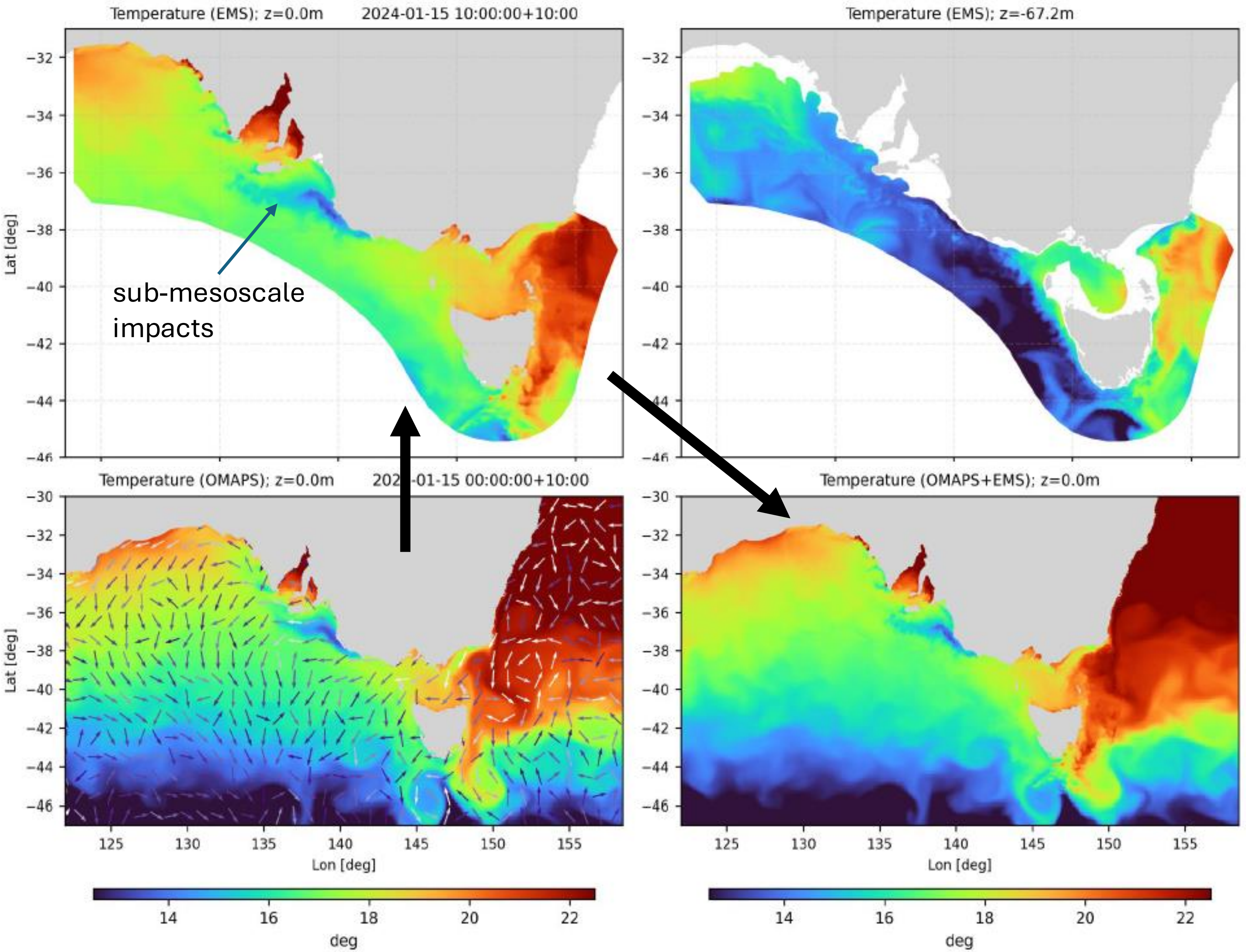
- Orthogonal Curvilinear grid
- Non-linear free surface - tides
- Fixed z coordinates + Wetting/drying



Shelf-scale hydrodynamic modelling

- Shelf-scale modelling that transitions from 10 km on a structured grid (OceanMaps) to a 2 km unstructured grid with coastal process (sub-mesoscale / shelf edge circulation, rivers, tides, wave-flow interaction).

- Enables further nesting to Gulf models, tracer simulations, climate downscaling etc.



Proposed Karenia modelling – summary

Increasing sophistication:

1. Population dynamics based on environmental condition suitability.

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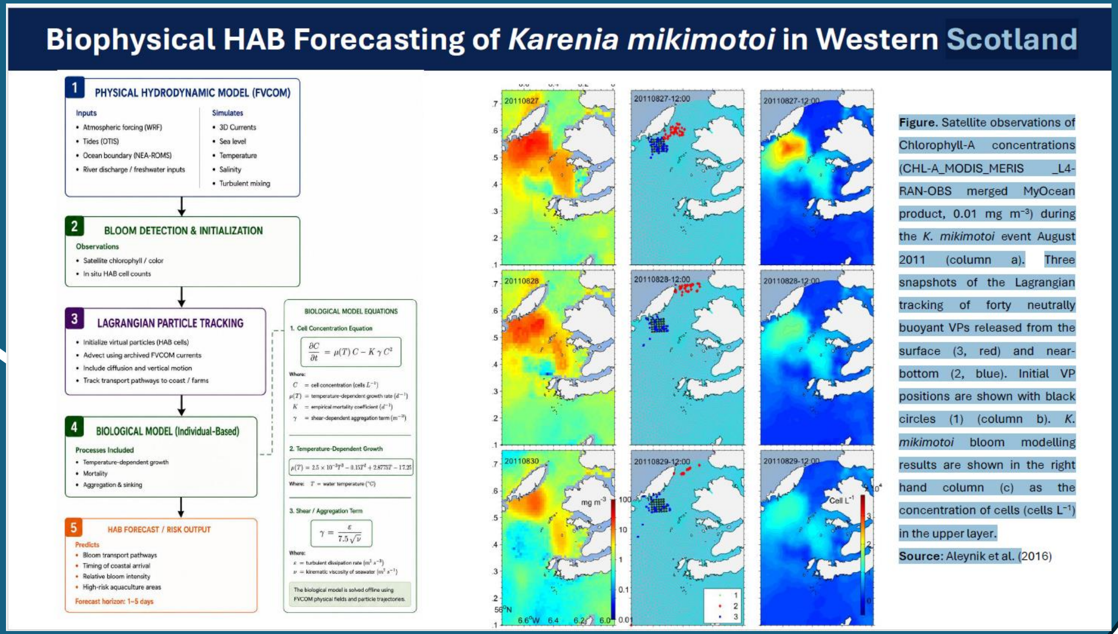
Example of single-species modelling.

- Species-specific temperature-dependence
- Shear stress modulated mortality.
- Transport using particle tracking.



Proposed Karenia modelling – summary

Increasing sophistication:

1. Environmental condition suitability.
2. Single-species population dynamics.
3. Simple biogeochemical (BGC) modelling (NPZD) + radiative transfer optical model (Rrs).
4. Complex BGC modelling + benthic communities, sediment processes.
5. BGC-modelling + species-specific behaviours such as life-cycles.

Example of single-species modelling.

- Species-specific temperature-dependence
- Shear stress modulated mortality.
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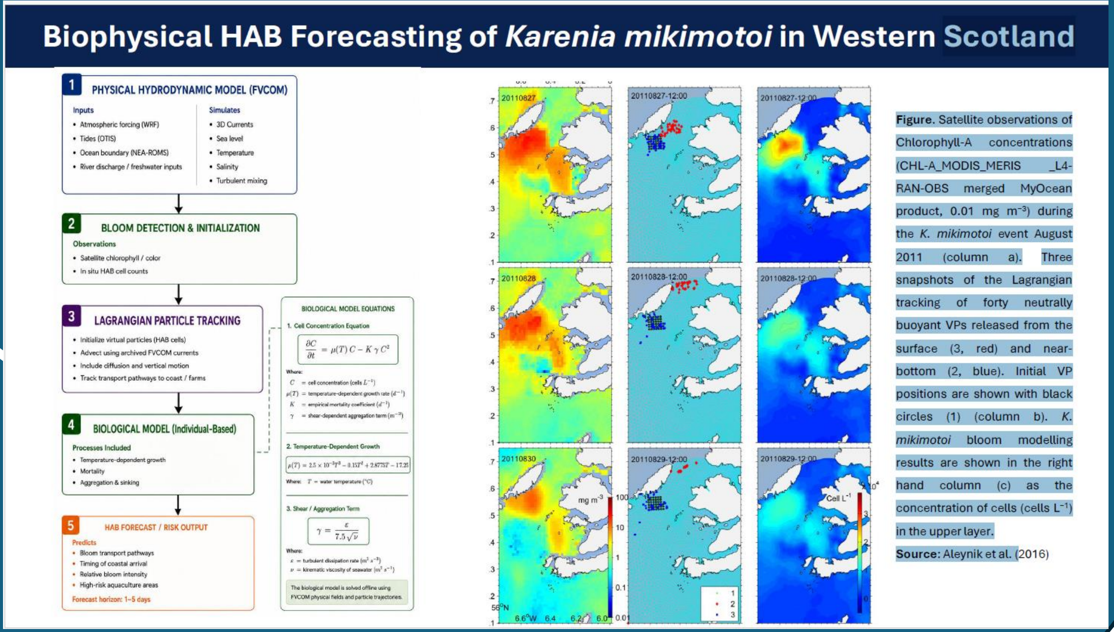
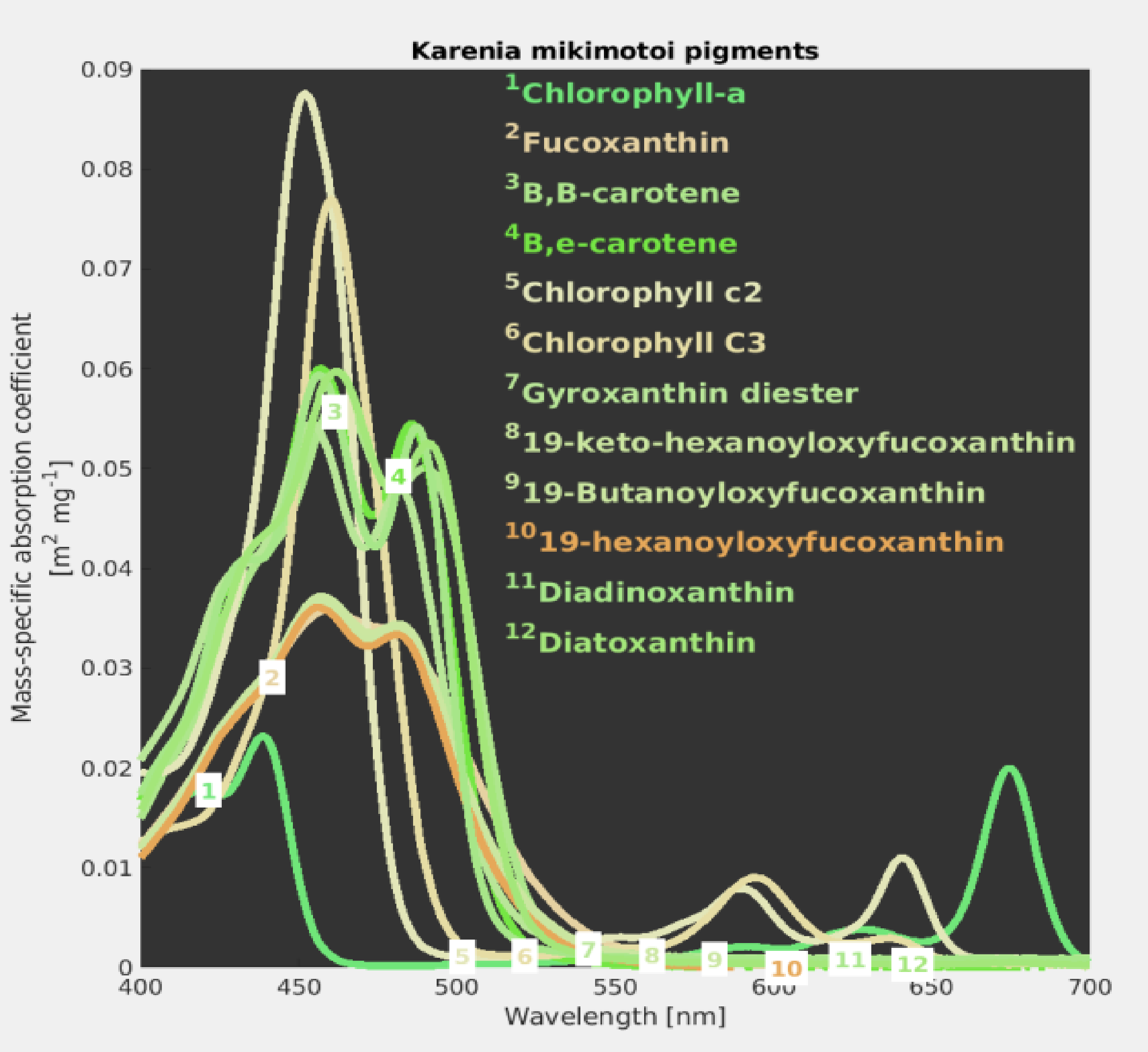


Karenia bio-optical modelling - pigments

Karenia will be uniquely parameterised by:

- Using the mass-specific absorption coefficients of the 12 pigments in the photosystems.
- Ratios of accessory pigments to Chl-a
- Considering cell size / volume and intracellular pigment concentrations to calculated absorption (see next slide).
- Individual cell growth and pigment synthesis rates.
- Spectrally-resolved passive fluorescence.

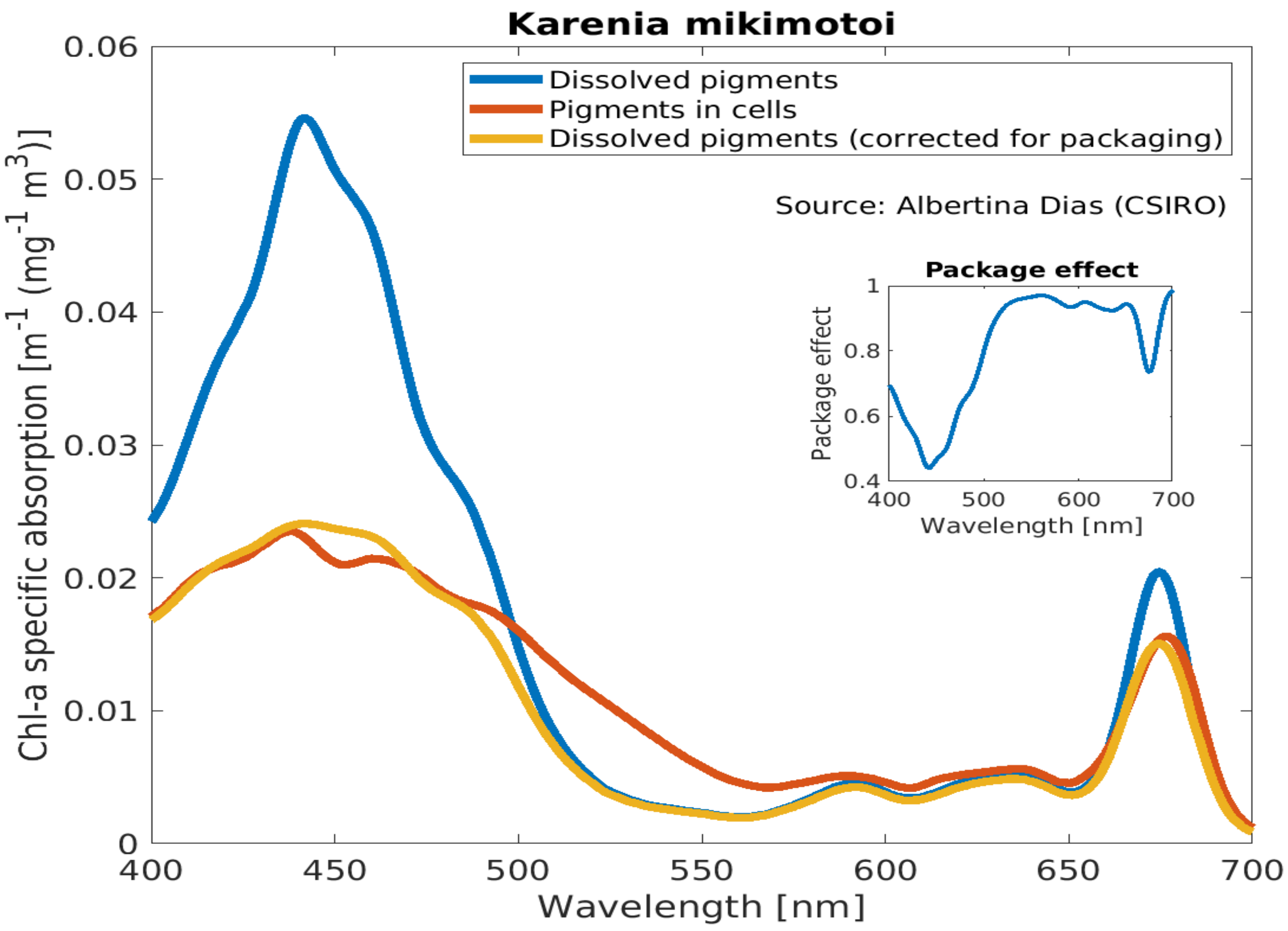


Albertina Dias (CSIRO)

Karenia bio-optical modelling – absorption

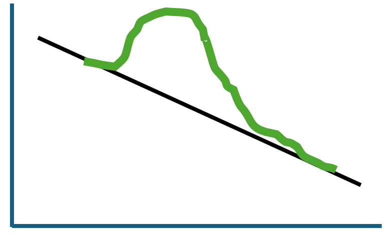
Chlorophyll-specific absorption (a^*_{Chl}) can be determined by:

- The sum of mass-specific coefficients pigments multiplied by their pig: Chl-a ratio (i.e. dissolved pigments).
- In-situ measurement of the absorption of a population of cells divided by the Chl-a conc.
- The sum of mass-specific coefficients pigments multiplied by their pig: Chl-a ratio, multiplied by the package effect.



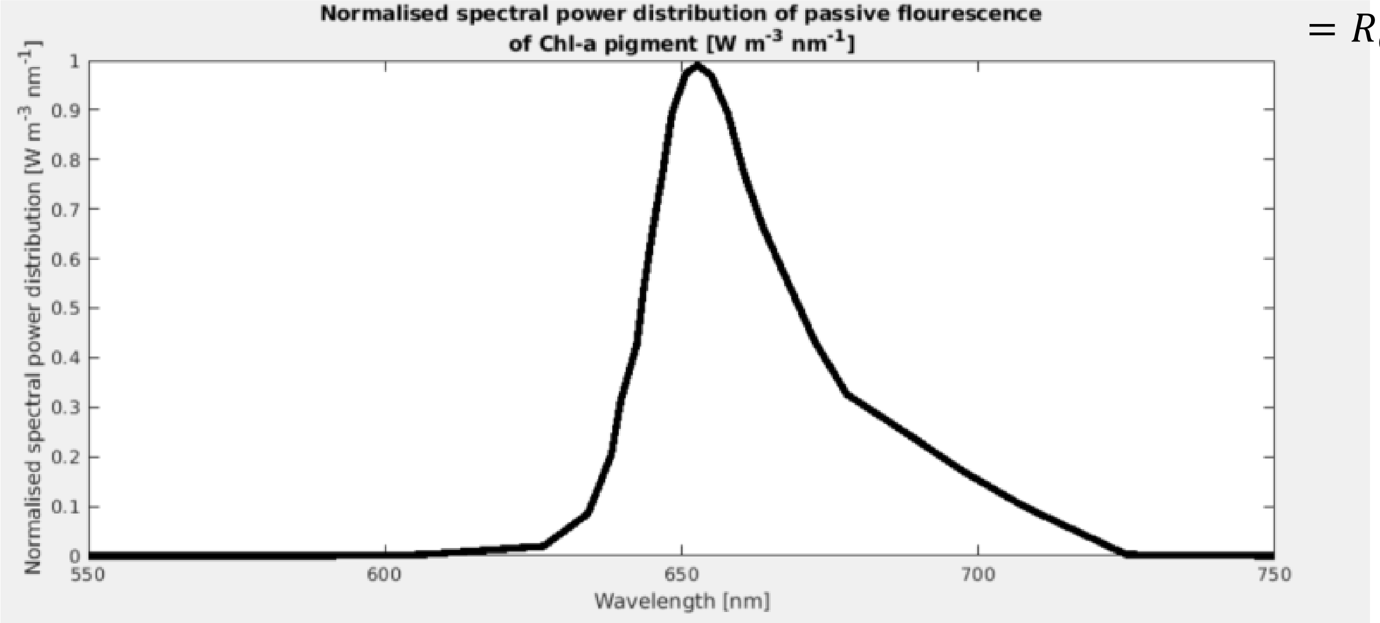
Karenia bio-optical – passive fluorescence

- One approach to remote-sensing Karenia is using normalised Fluorescence Line Height.
- Predict energy of passive fluorescence by cells as a function of photosystem state and incident light.
- Spectral distribution determined by pigments.



NASA Karenia algorithm looks for an anomalously high R_{685} due to passive fluorescence:

$$Chl_{Karenia} = R_{686} - \left(685 - \left(670 - \left(\frac{41}{R_{711} - R_{670}}\right) R_{670}\right) / \left(\frac{41}{R_{711} - R_{670}}\right)\right)$$



Using the Red Band Difference Algorithm to Detect and Monitor a *Karenia* spp. Bloom Off the South Coast of Ireland, June 2019

Catherine Jordan[1,2], Caroline Cusack[2], Michelle C. Tomlinson[3], Andrew Meredith[4], Ryan McGeady[2,5], Rafael Salas[2], Clynton Gregory[1] and Peter L. Croot[1]*

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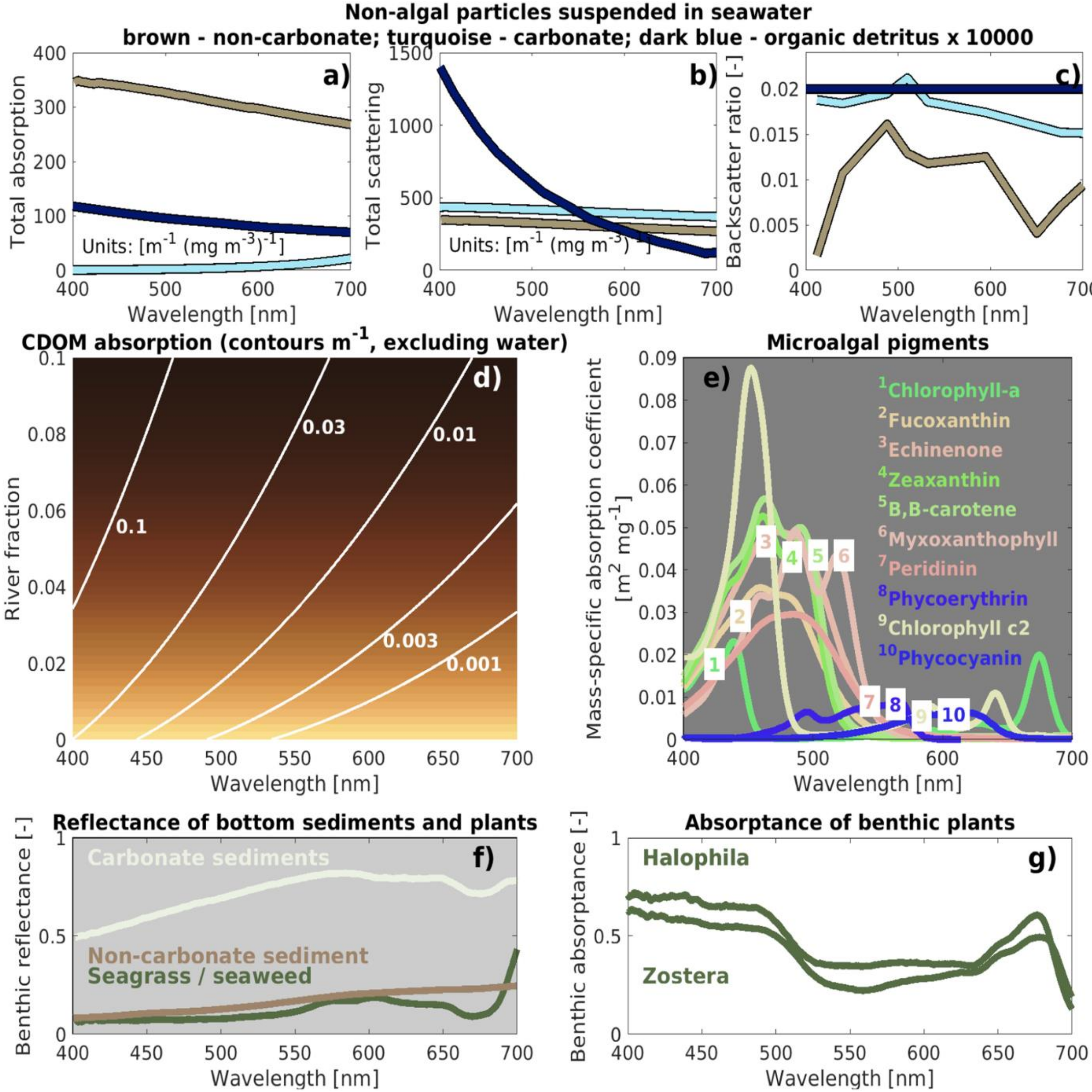
Optical modelling

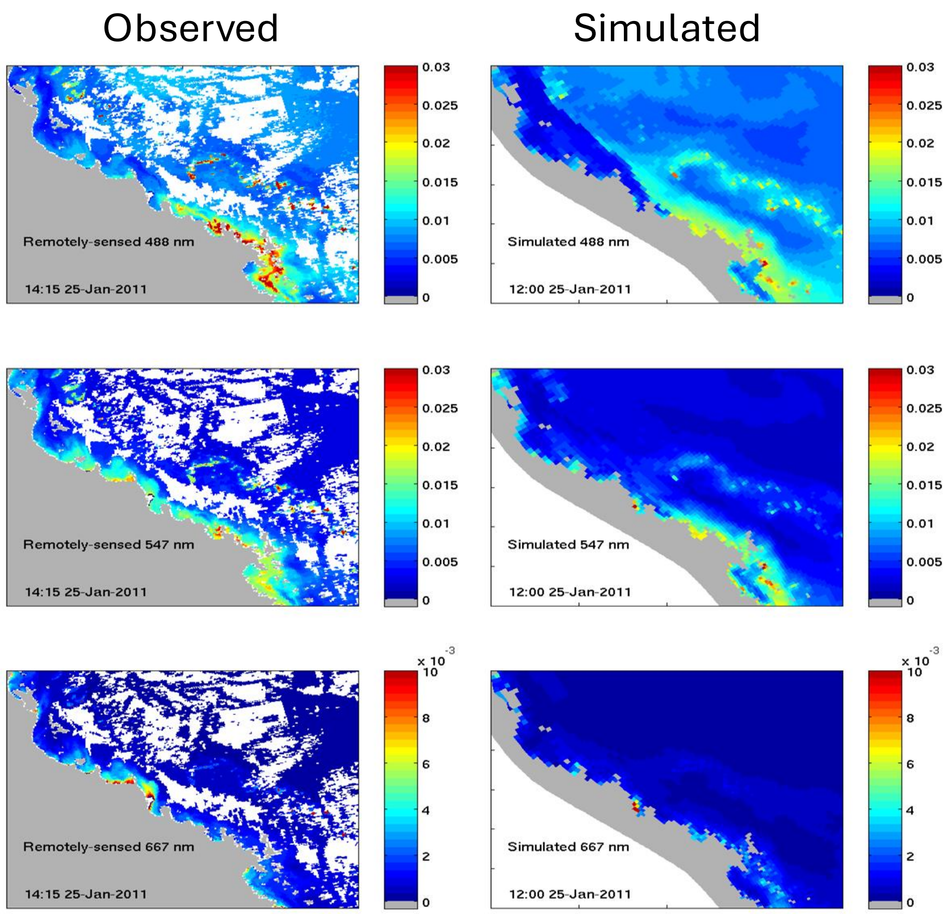
- Represents spectrally-resolved scattering and absorption of water, CDOM, plankton, detritus, inorganic particles and benthic substrates.

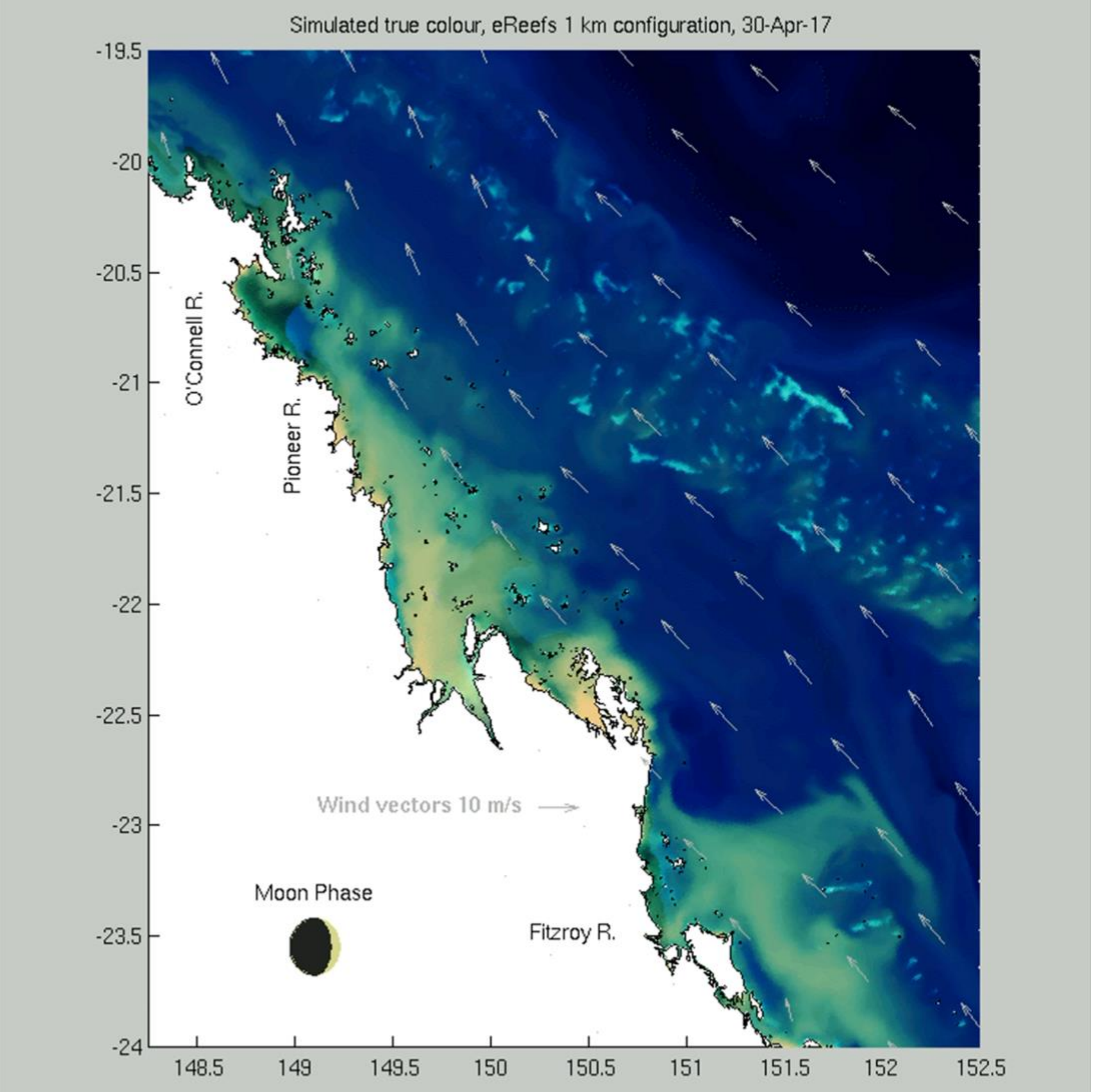
Corbett et al. Remote Sens. 2025, 17, 1711.



Optical modelling

- Calculates light field and remote-sensing reflectance using a 3-stream radiative transfer model (direct and diffuse downwelling and diffuse upwelling).





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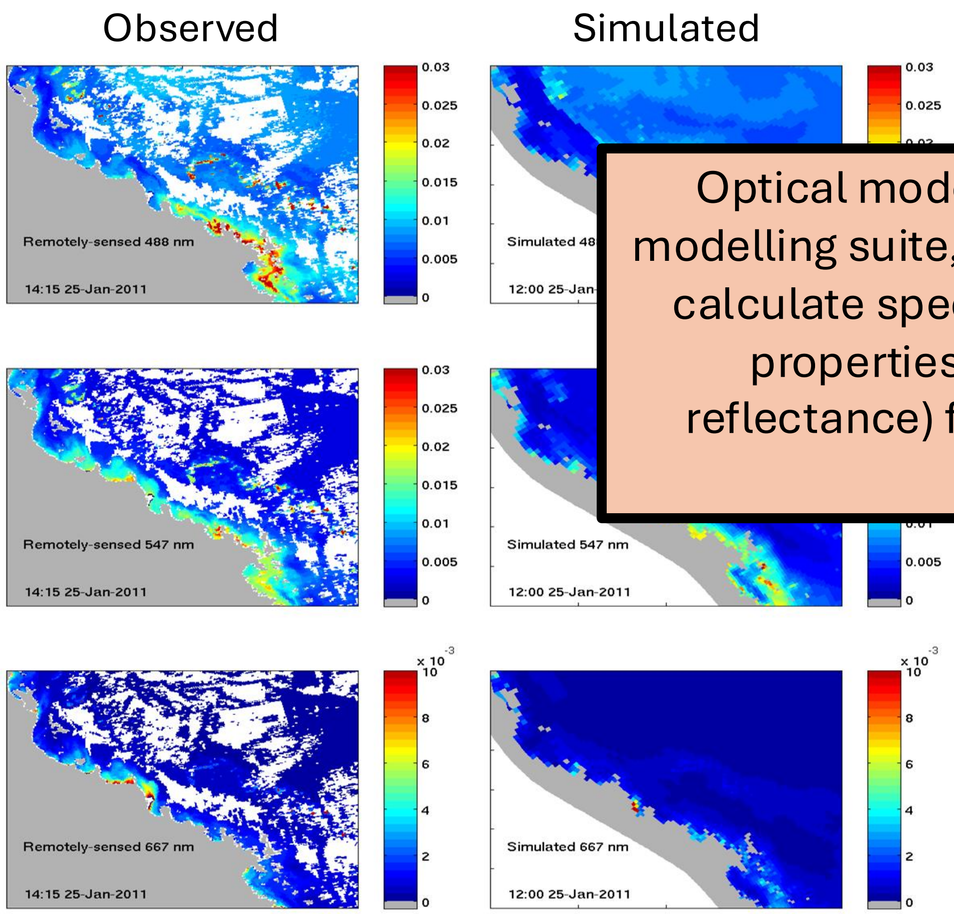
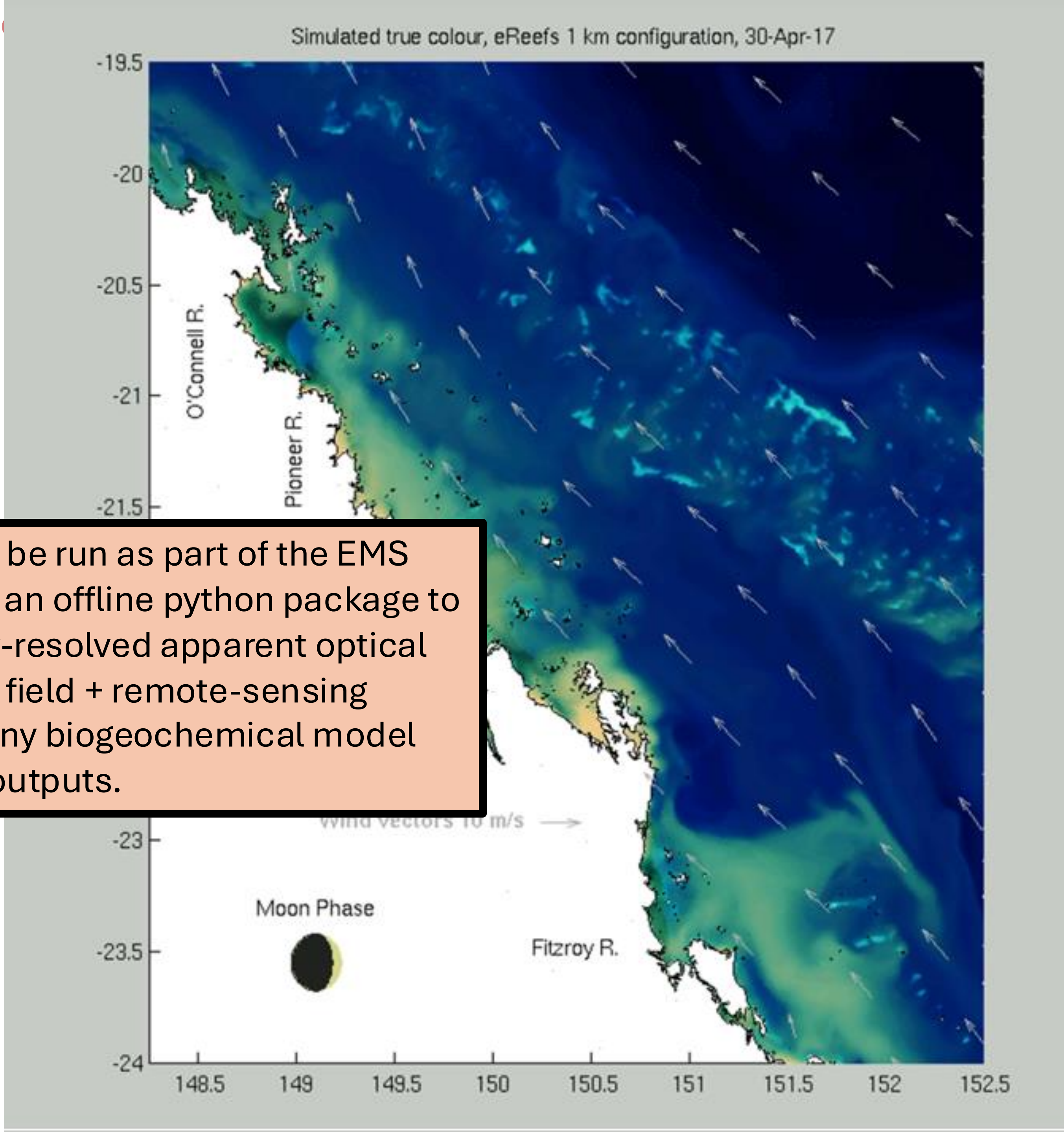
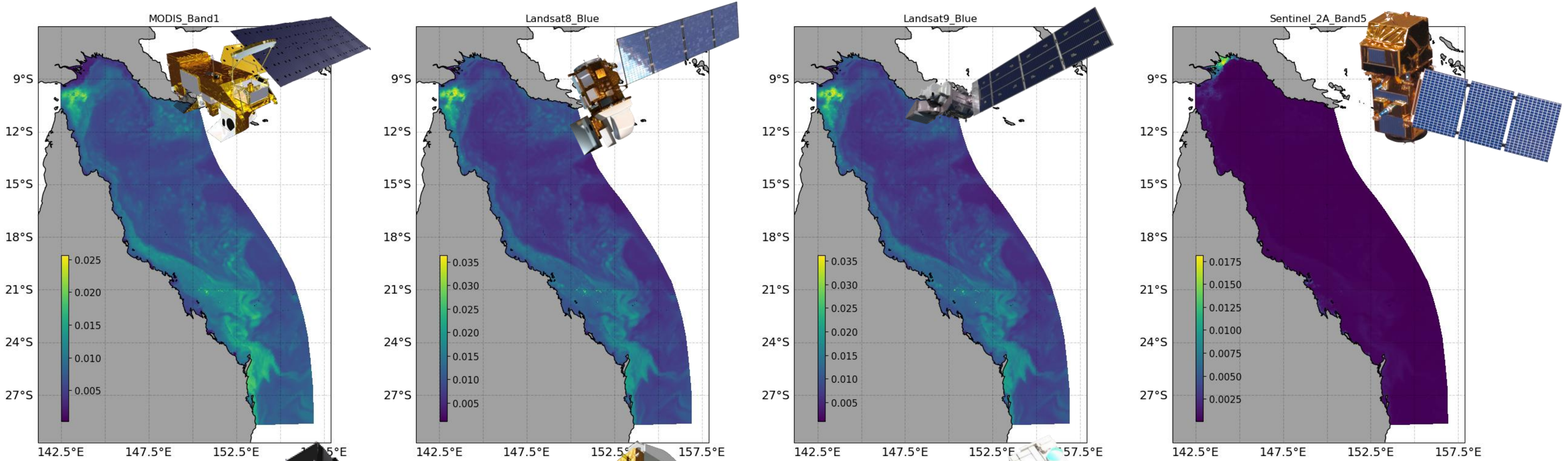
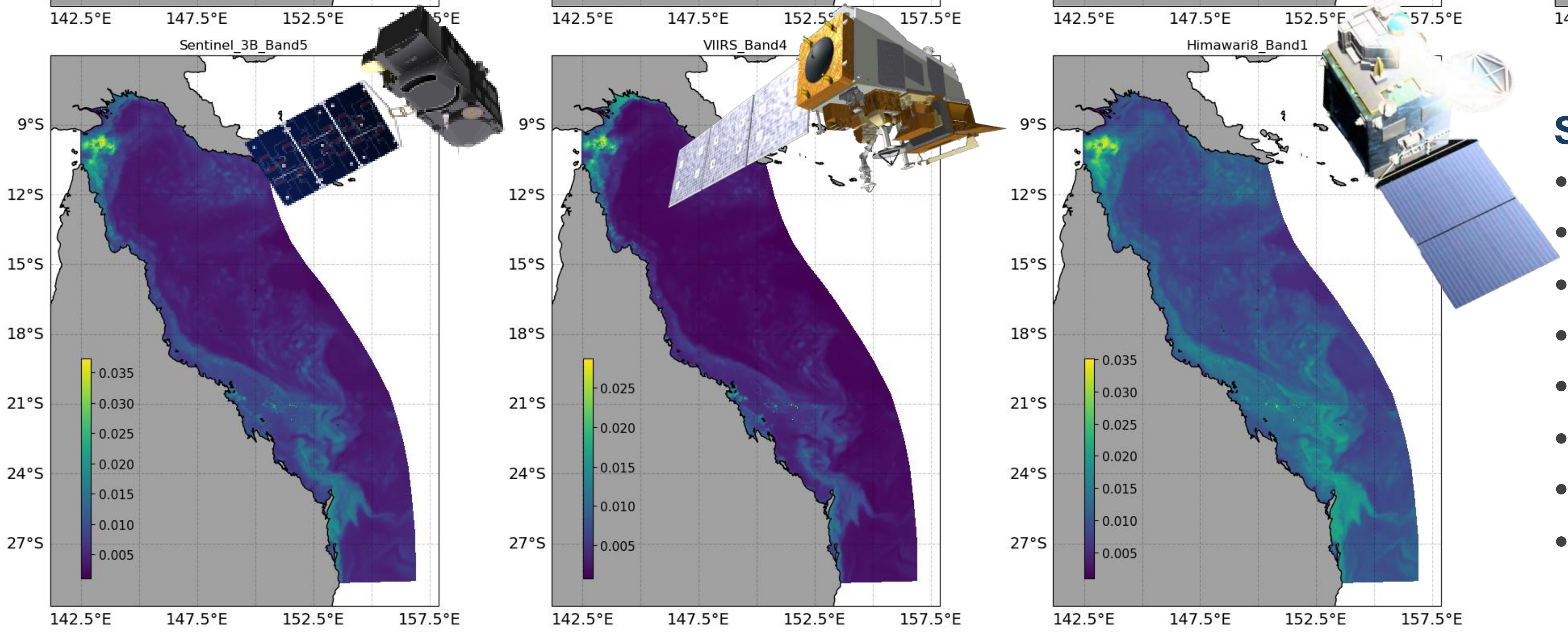




Optical model can be run as part of the EMS modelling suite, or as an offline python package to calculate spectrally-resolved apparent optical properties (light field + remote-sensing reflectance) from any biogeochemical model outputs.



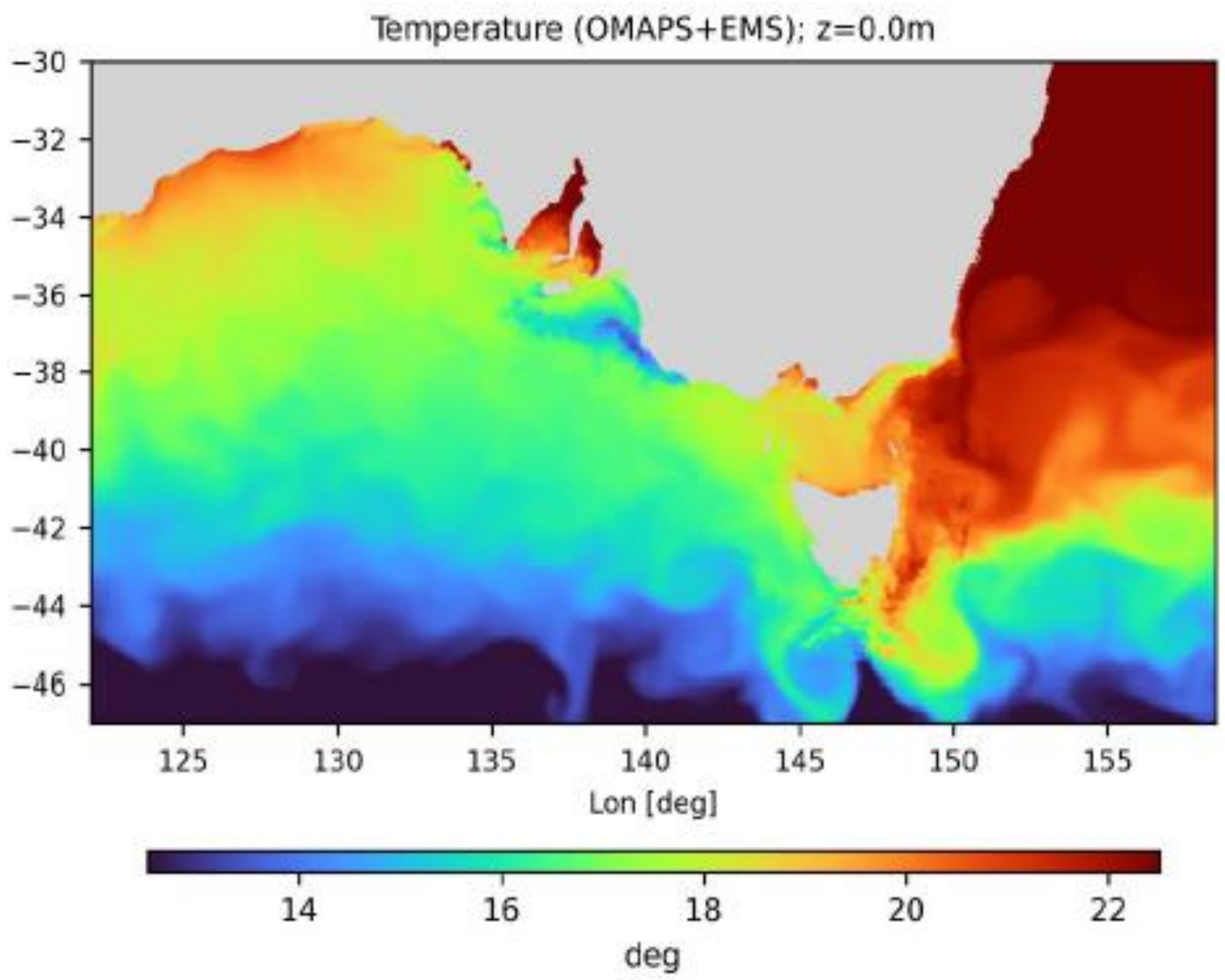


Simulated Satellites

- MODIS
- Landsat 8
- Landsat 9
- Sentinel 2
- Sentinel 3
- VIIRS
- Himawari 8
- PACE

Summary

- CSIRO / SARDI coupled hydrodynamic - biogeochemical modelling will provide a nesting capability between large scale oceanography / climate and gulf scale.
- Biogeochemical / Karenia modelling will focus on bloom attribution and prediction capabilities.
- Emphasis in optical modelling will be model assessment against satellite products and improve synergy with remote-sensing based machine learning modelling systems.



Particulate Backscattering Ratio as an Indicator of Changing Particle Composition in Coastal Waters: Observations From Great Barrier Reef Waters

Monika Soja-Woźniak[1], Mark Baird[1], Thomas Schroeder[2], Yi Qin[3], Lesley Clementson[1], Brett Baker[4], David Boadle[4], Vittorio Brando[5], and Andy D. L. Steven[2]