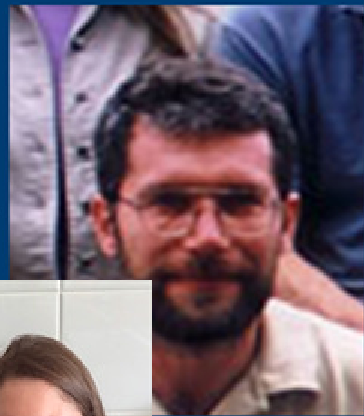
eReefs optical and biogeochemical model.

Coastal Environmental Modelling Team

- Physical oceanography

- Sediment dynamics



- Biogeochemistry

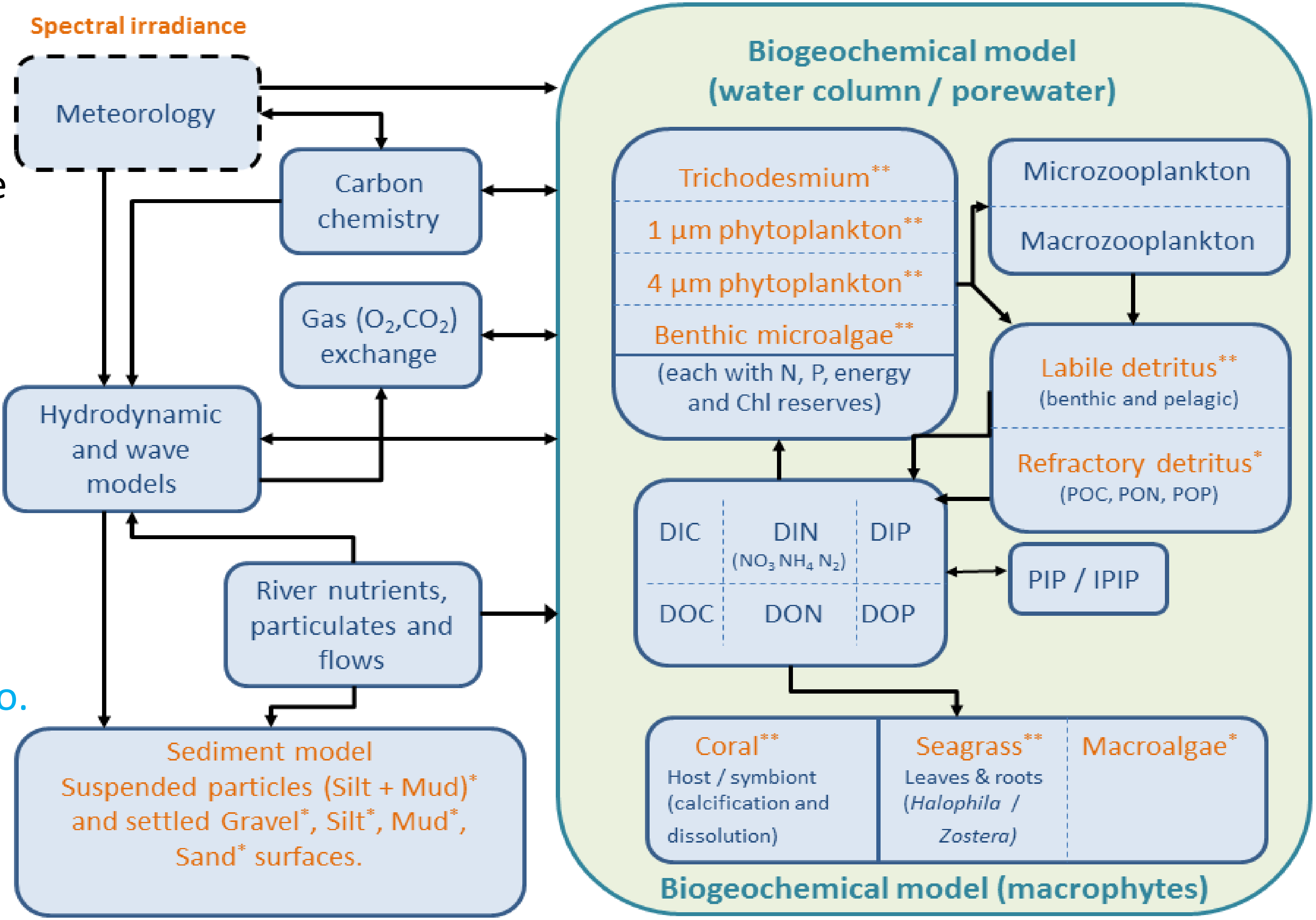
- Data assimilation

- Scientific computing

BGC state variables:
- 10 dissolved
- 22 living particulate
- 11 non-living part.
- 6 epibenthic.

Parameters:
- approx 100.

Full description:
https://research.csiro.au/ereefs/models/



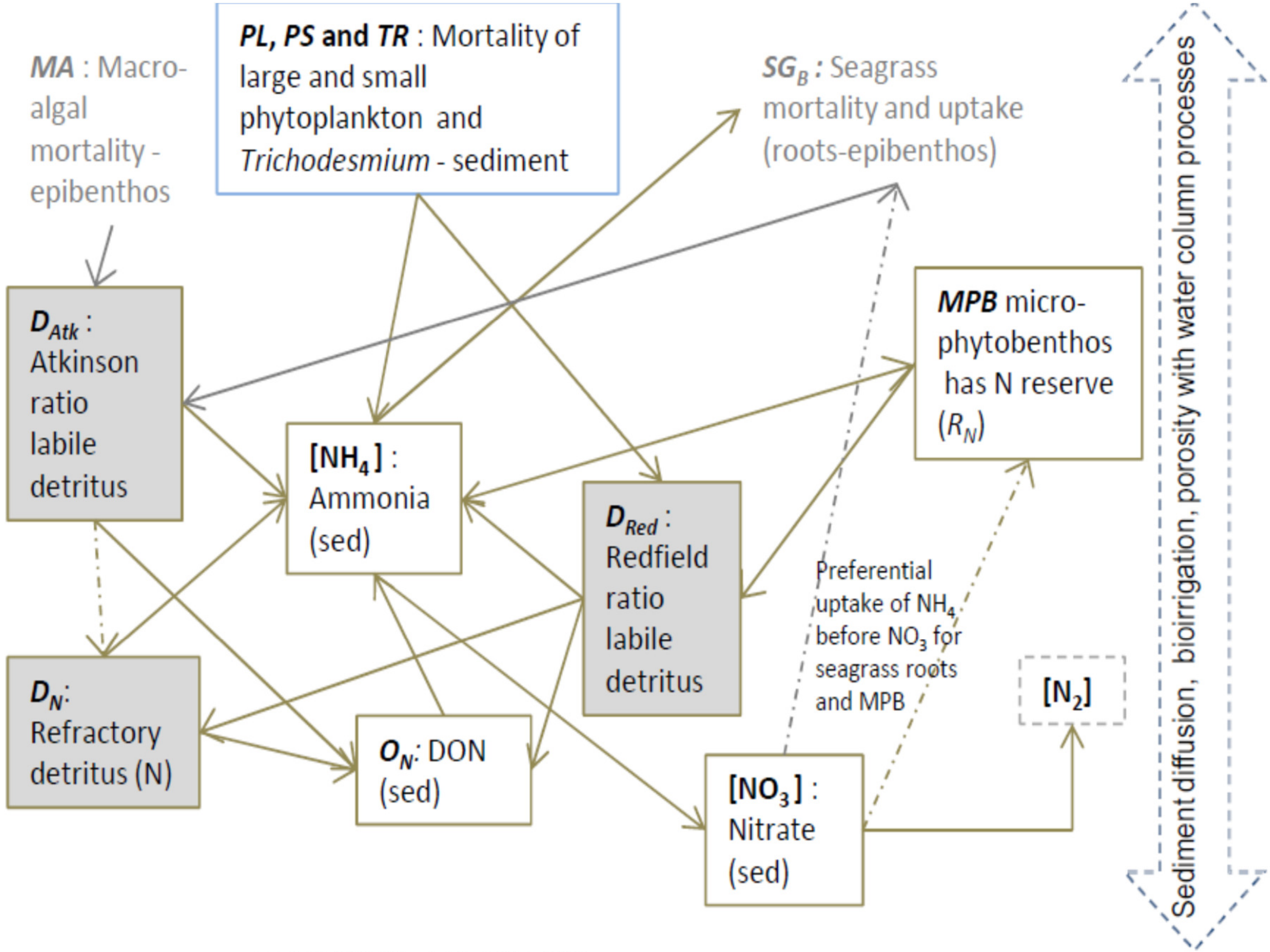
Organic nitrogen

Detrital processes include:

- Mortality
- Detrital decomposition
- Denitrification
- Nitrification

Other N processes

- Atmospheric deposition
- Preferential NH_4 uptake.
- N fixation.



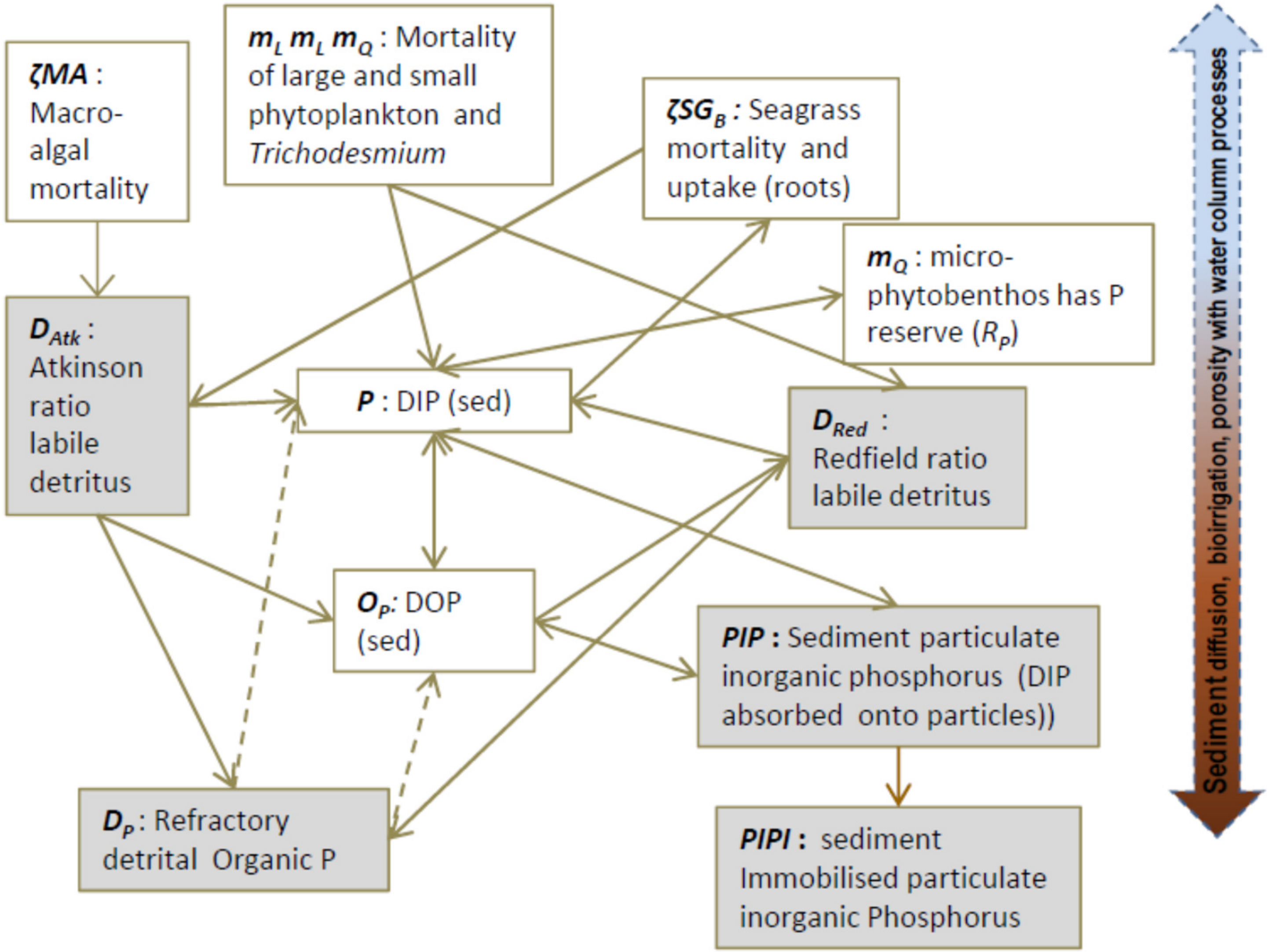
Organic phosphorus

Detrital processes include:

- Mortality
- Detrital decomposition

Other P processes

- Phosphorus adsorption / desorption.



Documentation of the biogeochemical model.

- Precise description of the model equations and parameter values are given in Appendix B. available on website.
- 132 pages, 50 Tables, 282 equations.
- New developments for eReefs published in Ecological modelling, Limnology and Oceanography, Environmental Modelling and Software:

Appendix B: CSIRO Environmental Modelling Suite: Scientific description of the optical, carbon chemistry and biogeochemical models

Mark E. Baird[1], Matthew P. Adams[2], John Andrewartha[1], Nagur Cherukuru[1], Malin Gustafsson[3], Scott Hadley[1], Mike Herzfeld[1], Emlyn Jones[1], Nugzar Margvelashvili[1], Mathieu Mongin[1], John Parlsow[1], Peter J. Ralph[3], Farhan Rizwi[1], Barbara Robson[4], Uwe Rosebrock[1], Pavel Sakov[1], Thomas Schroeder[1], Jenny Skerratt[1], Andrew D. L. Steven[1], and Karen A. Wild-Allen[1]

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[2]School of Chemical Engineering, The University of Queensland, Brisbane, Australia
[3]Plant Functional Biology and Climate Change Cluster, Faculty of Science, University of Technology Sydney, Sydney, Australia
[4]CSIRO, Land and Water, Canberra, Australia

January 28, 2016

A biophysical representation of seagrass growth for application in a complex shallow-water biogeochemical model *Ecol. Mod.* **325**: 13-27.
Remote-sensing reflectance and true colour produced by a coupled hydrodynamic, optical, sediment, biogeochemical model of the Great Barrier Reef, Australia: comparison with satellite data. *Env. Model. Software* **78**: 79-96.
The exposure of the Great Barrier Reef to ocean acidification. *Nature Communications* **7**, 10732.
The interacting effects of photosynthesis, calcification and water circulation on carbon chemistry variability on a coral reef flat *Ecol. Mod.* **284***,* 19-34*.*
A physiological model for the marine cyanobacteria, Trichodesmium. In Piantadosi, J., Anderssen, R.S. and Boland J. (eds) MODSIM2013, 20th International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2013, pp. 1652-1658.
A dynamic model of the cellular carbon to chlorophyll ratio applied to a batch culture and a continental shelf ecosystem. *Limnol. Oceanogr.* **58**, 1215-1226.
The interchangeability of autotrophic and heterotrophic nitrogen sources in Scleractinian coral symbiotic relationships. Ecol. Model. **250**, 183–194.

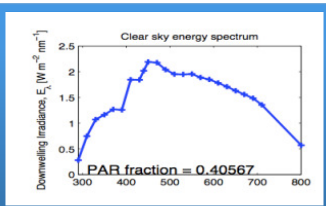
- Appendix B gives detail explanation of the parameters and state variables in easy to access tables (p108-134).

Description	Name in code	Symbol	Value	Units
Reference temperature	Tref	T_{ref}	20.000000	Deg C
Temperature coefficient for rate parameters	Q10	$Q10$	2.000000	none
Nominal rate of TKE dissipation in water column	TKEeps	ϵ	0.000001	$m^2\ s^{-3}$
Atmospheric CO2	xco2_in_air	pCO_2	396.480000	ppmv
Concentration of dissolved N2	N2	$[N_2]_{gas}$	2000.000000	$mg\ N\ m^{-3}$
DOC-specific absorption of CDOM 443 nm	acdom443star	$k_{CDOM,443}$	0.000130	$m^2\ mg\ C^{-1}$

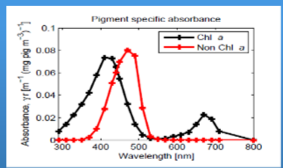
Phytoplankton chlorophyll	nc_iV [mg m^{-3}]	Concentration of the chlorophyll a pigment of the population. The four phytoplankton classes have two pigments, a chlorophyll a-based pigment and an accessory pigment. As the pigment concentration adjusts to optimise photosynthesis, including the presence of the accessory pigment, the intracellular content, c_iV, represents only the chlorophyll a-based pigment. As the model does not distinguish between mono-vinyl and di-vinyl forms of chlorophyll, this c_i represents either form, depending on the phytoplankton type.

Optical model *Baird et al 2016. Environmental Modelling and Software* 78: 79-96

Atmospheric forcing uses spectrally-resolved energy distribution of sun light.



IOPs = adsorption ($a_{T,\lambda}$) and backscattering ($b_{T,\lambda}$) of plankton, CDOM, particles.



Vertical attenuation:

$$K_\lambda = \frac{a_{T,\lambda}}{\cos\theta_{sw}}\sqrt{1 + (g_i + g_{ii}\cos\theta_{sw})\frac{b_{T,\lambda}}{a_{T,\lambda}}}$$

Reflectance is the ratio of backscatter to attenuation:

$$u_\lambda = \int_0^z \frac{w_{\lambda,z'} b_{b,\lambda,z'}}{a_{\lambda,z'} + b_{b,\lambda,z'}} dz'$$

Where *w* is weighted by optical depth

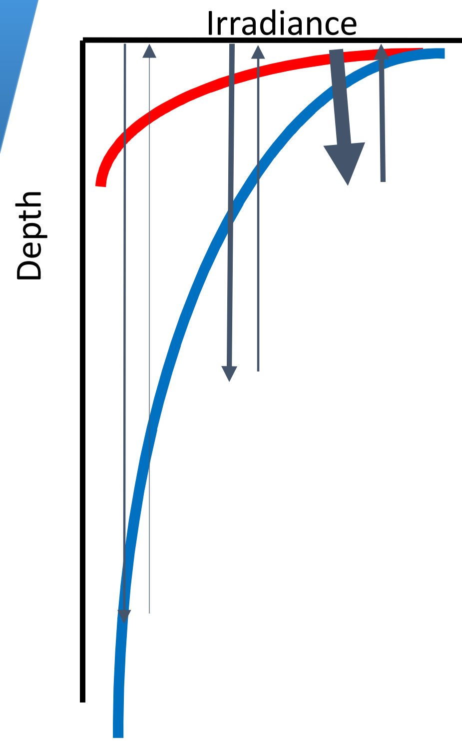
$$w_{\lambda,z} = \frac{1}{z_1 - z_0}\int_{z_0}^{z_1} \exp\left(-2K_{\lambda,z'}\right) dz'$$

Reflectance is function of

$$r_{rs,\lambda} = g_0 u_\lambda + g_1 u_\lambda^2$$

through the sea-air interface

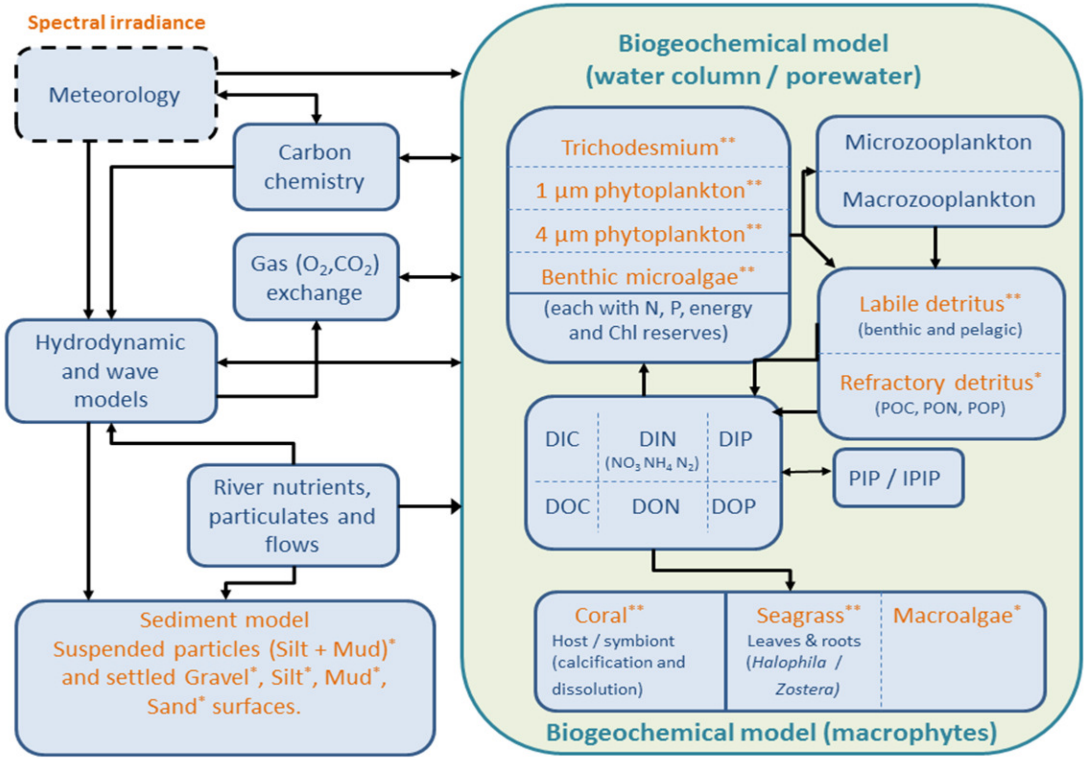
$$R_{rs,\lambda} = \frac{0.52 r_{rs,\lambda}}{1 - 1.7 r_{rs,\lambda}}$$

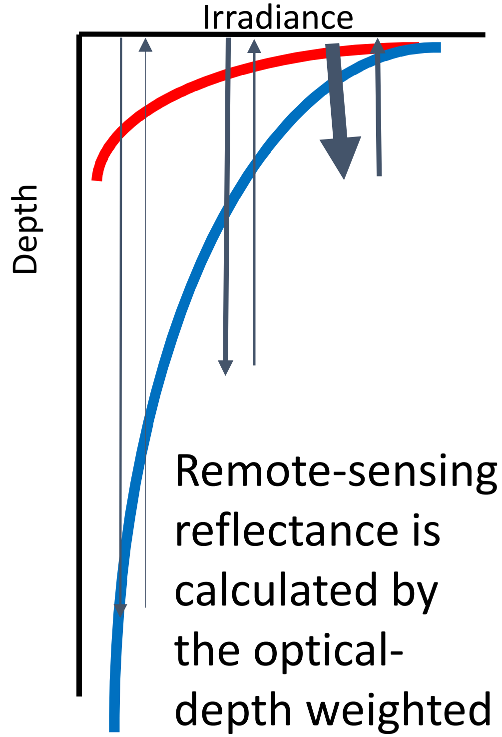


In other words:
Remote-sensing reflectance is calculated by the optical-depth weighted reflectance and bottom reflectance

24 optically – active components

- Clear water
- 4 types of phytoplankton with two pigment types each
- CDOM
- Macroalgae
- 2 types of seagrass
- Coral skeletons
- Zooxanthellae
- sediment x 6
- Detritus x 3

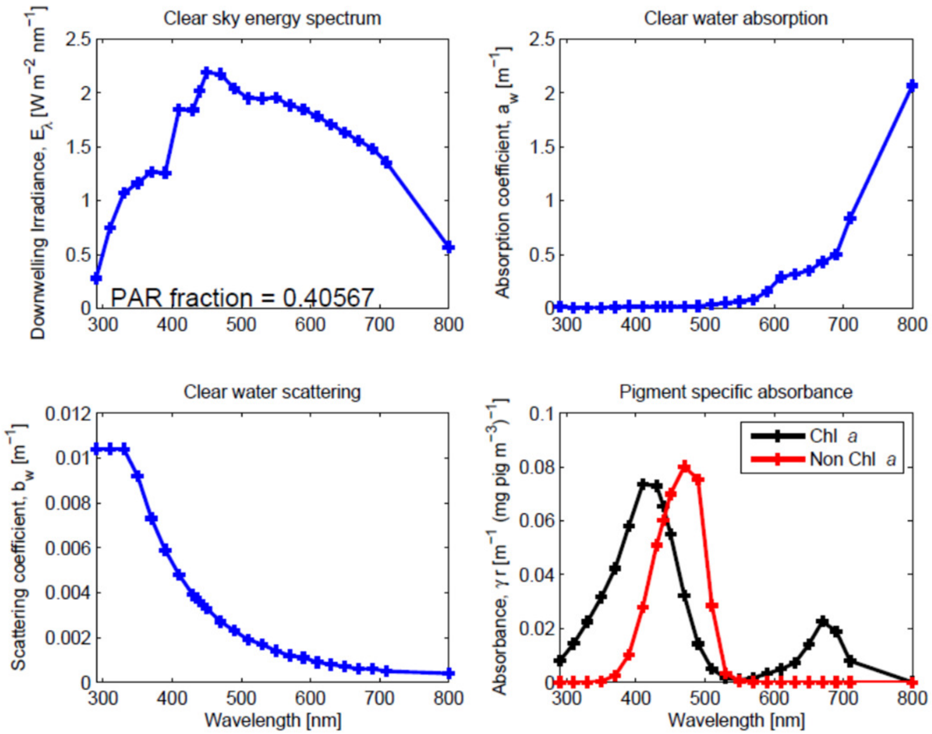




Remote-sensing reflectance is calculated by the optical-depth weighted reflectance and bottom reflectance

Optical model

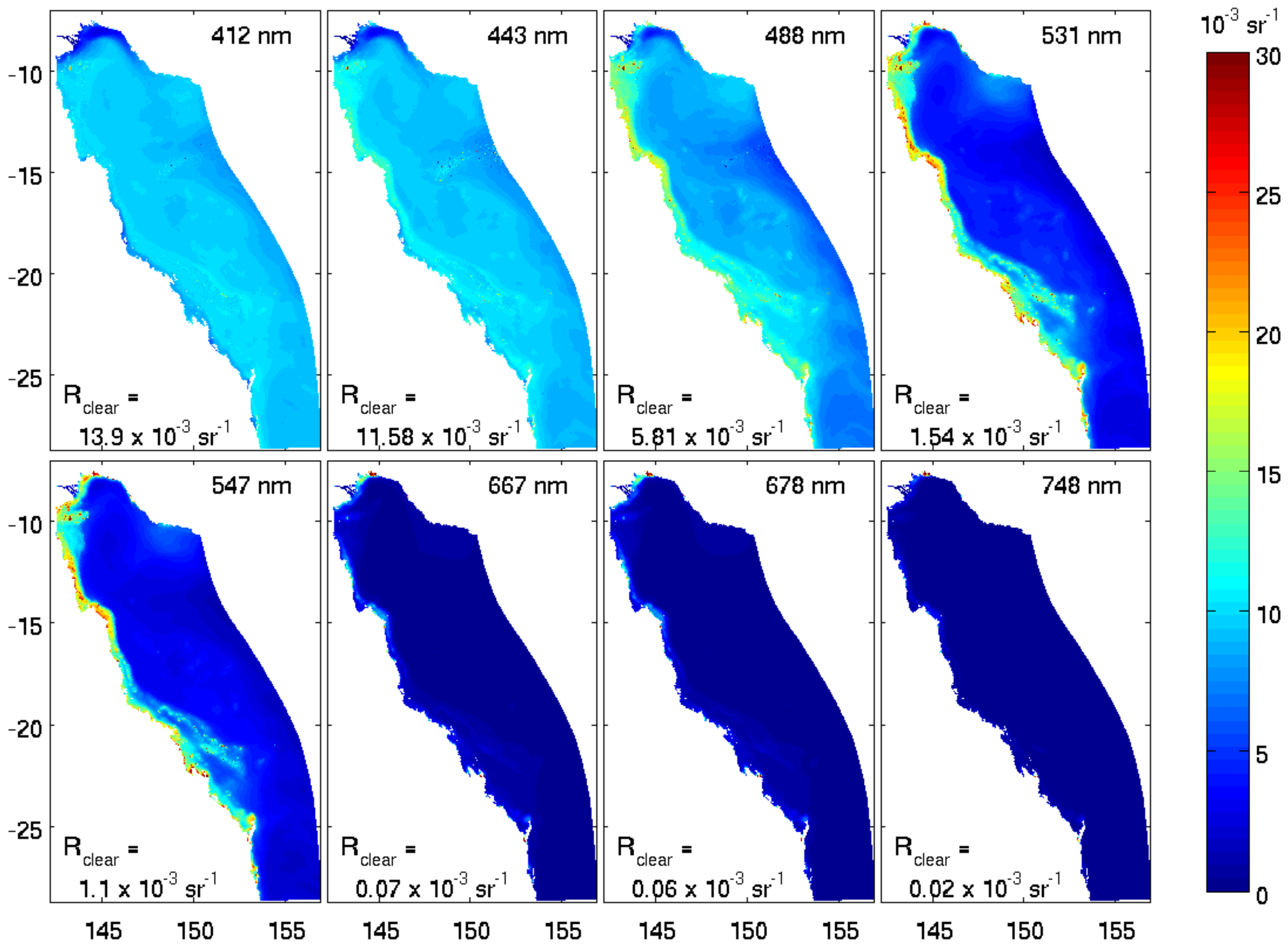
- During integration 23 wavelengths for the forcing of photosynthesis. Wavelength more resolved at pigment peak (430,440, 450 resolved).
- At output steps, light calculated at the MODIS 11 bands.
- Spectral-resolution is important because:
    - Photosynthetic plant response varies with spectral distribution.
    - Parameterisation of absorption characteristics more precise when done at a waveband.
    - Comparison with observation more direct if wavelength-specific.



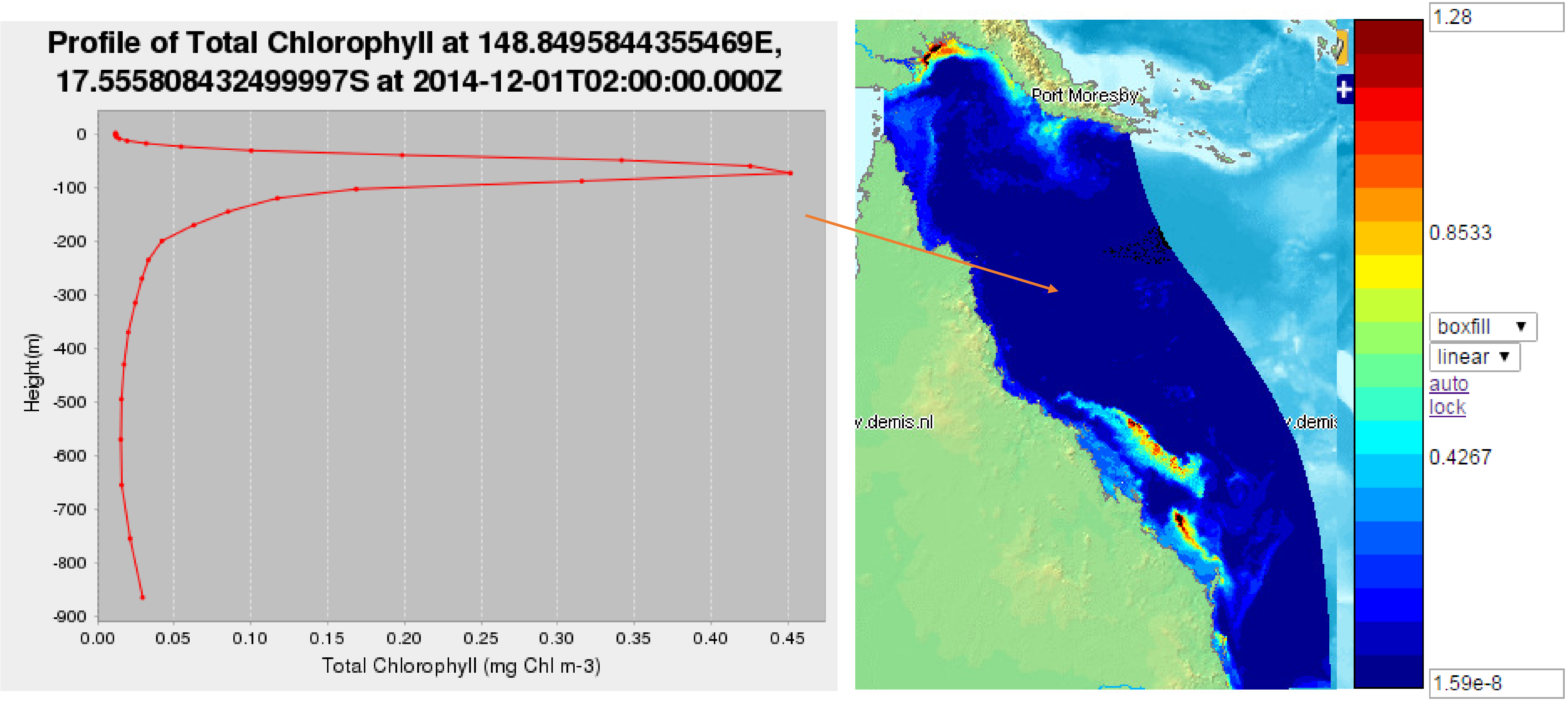
- Mean simulated remote-sensing reflectance for 2013 at the 8 MODIS ocean colour bands.

- More reflectance at shorter wavelengths.

- On a relatively clear day 1 million plus data points per wavelength, up to twice a day

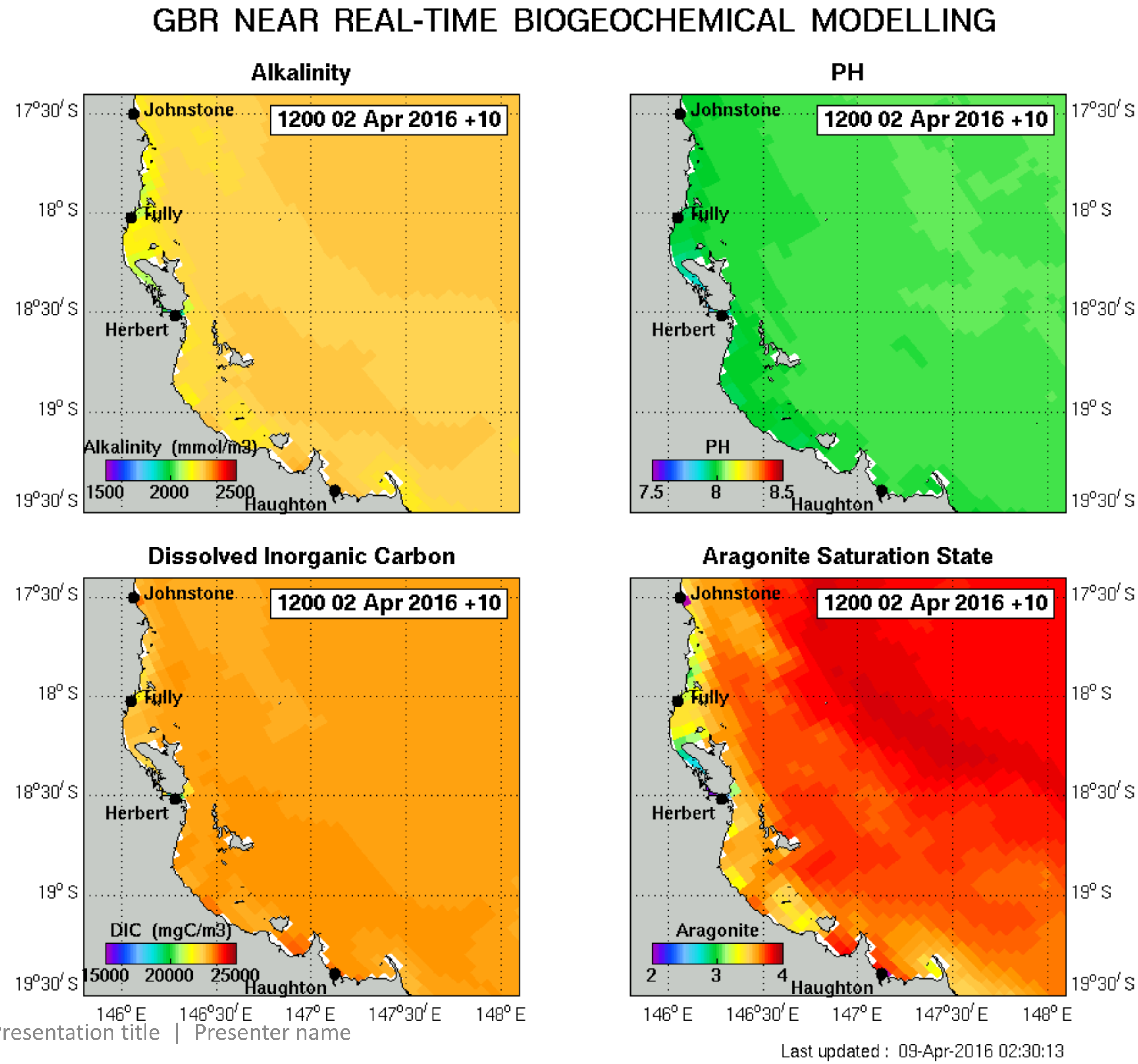


Lets look at chlorophyll through on-line data.



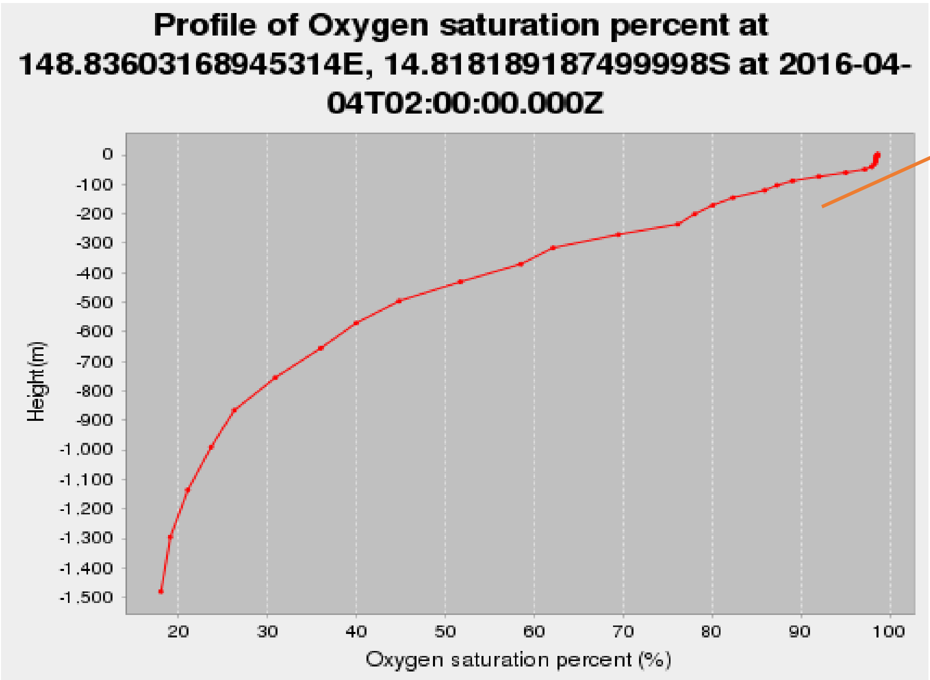
Carbon chemistry.

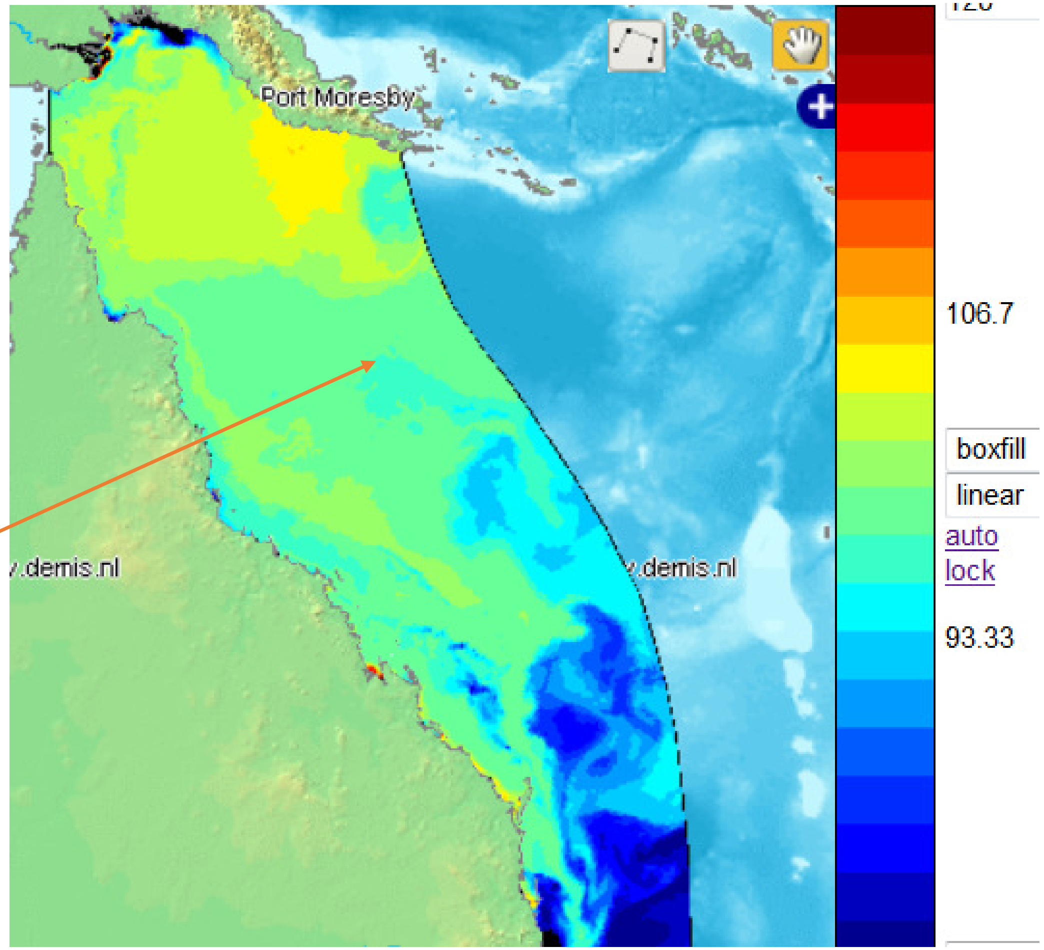
- Model uses OCMIP carbon chemistry routines to calculate pH, aragonite saturation, and air-sea fluxes from the total alkalinity, A_T, and dissolved inorganic carbon concentration, C_T, as well as temperature, salinity and wind speed.



Oxygen dynamics.

- Model uses saturation state calculations as well as wind speed to determine oxygen concentrations, and percent saturation.





Seagrass model

- Two species model – *Zostera*-like and *Halophila*–like.
- Nutrient uptake from multiple layers of sediments.
- New formulation of relationship between % cover and benthic biomass.
- Translocation between roots and leaves.

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

A biophysical representation of seagrass growth for application in a complex shallow-water biogeochemical model

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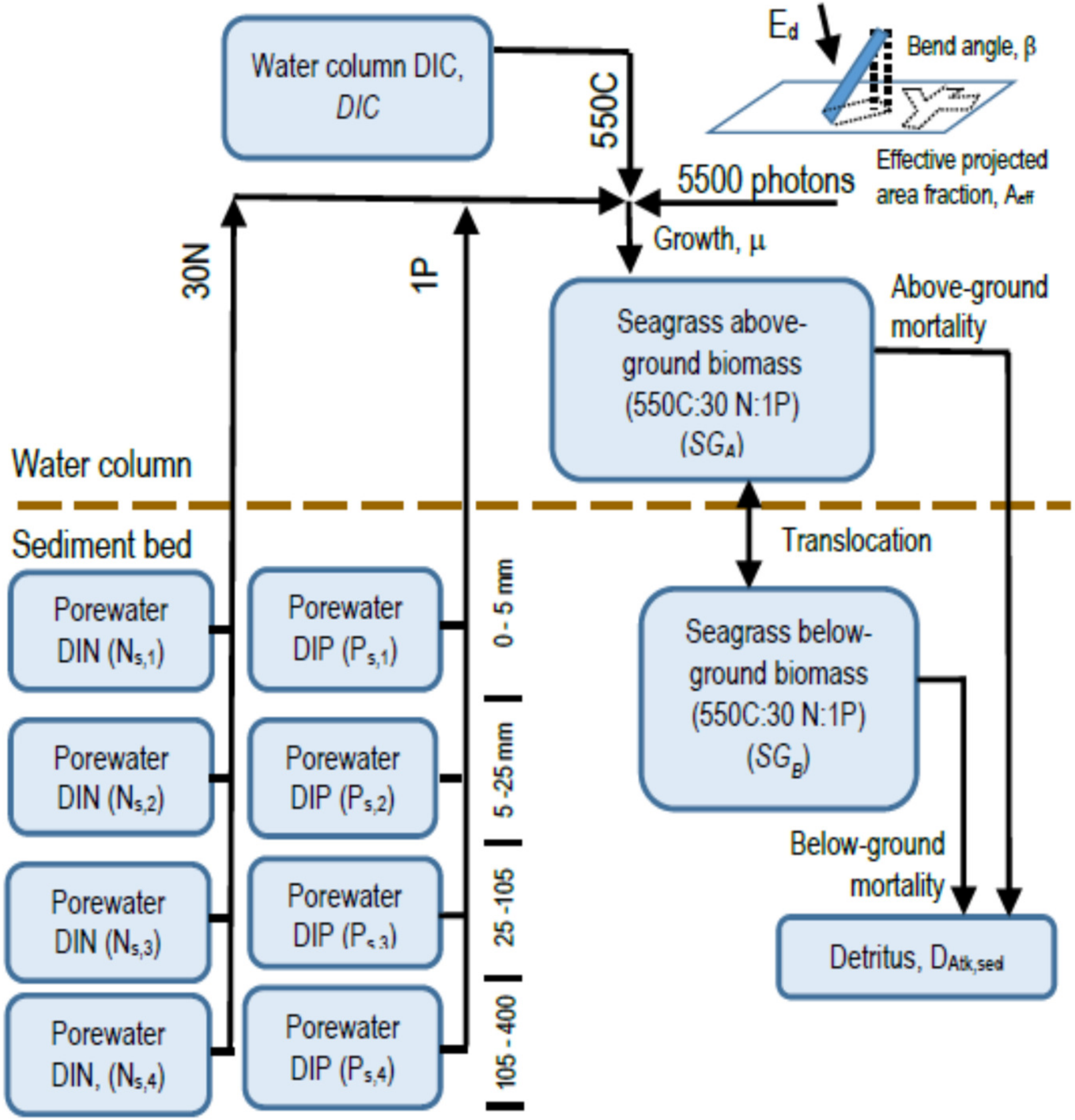
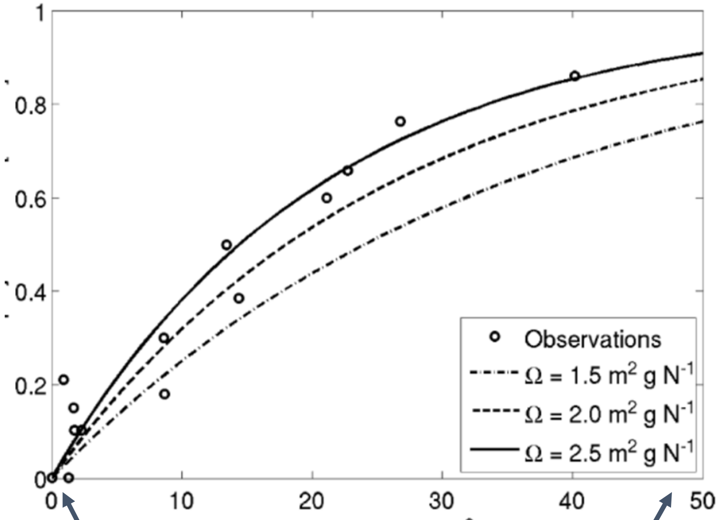
[e] Centre for Tropical Water & Aquatic Ecosystem Research, James Cook University, Cairns, Australia



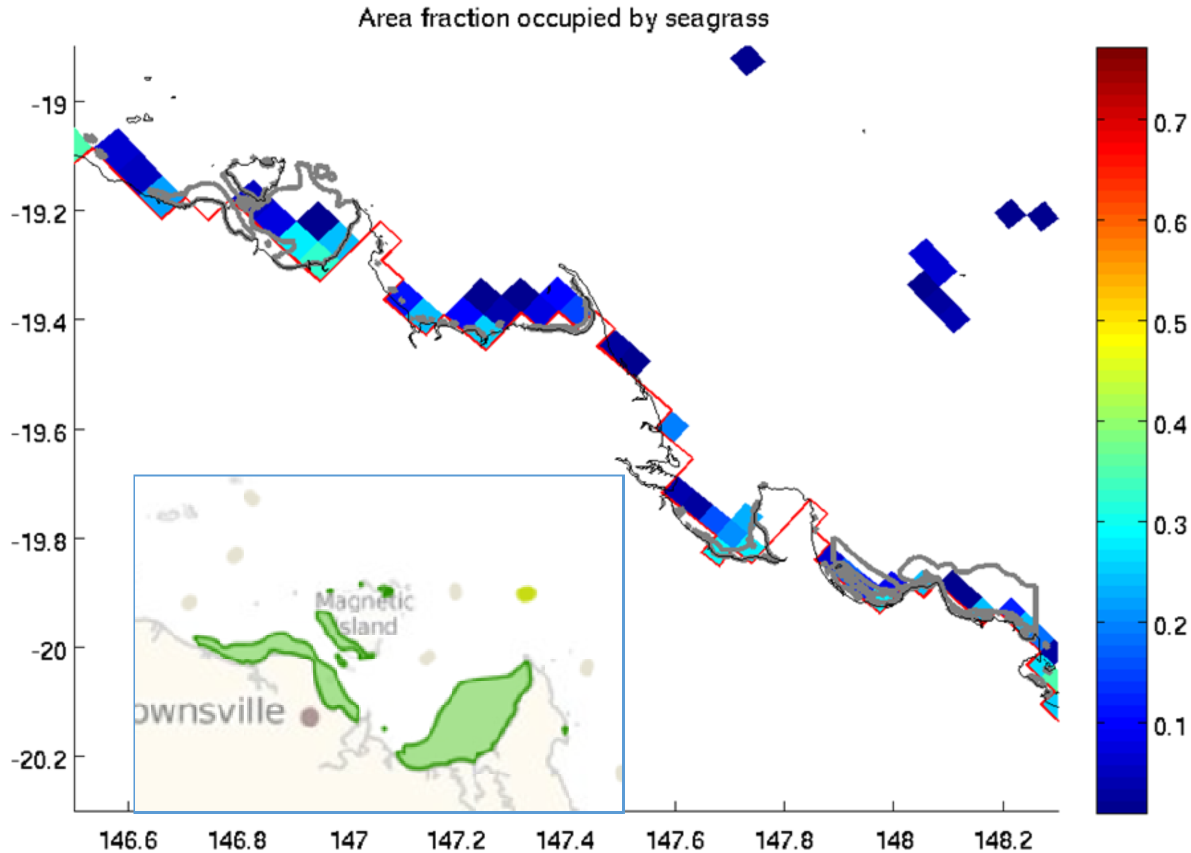
Seagrass behaviour - % of the bottom covered.

Ω - nitrogen-specific leaf area

Fraction of bottom covered



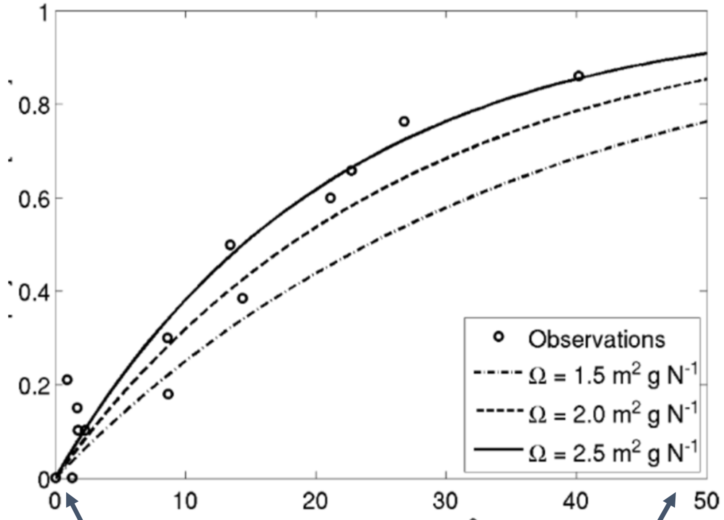
Seagrass biomass, B



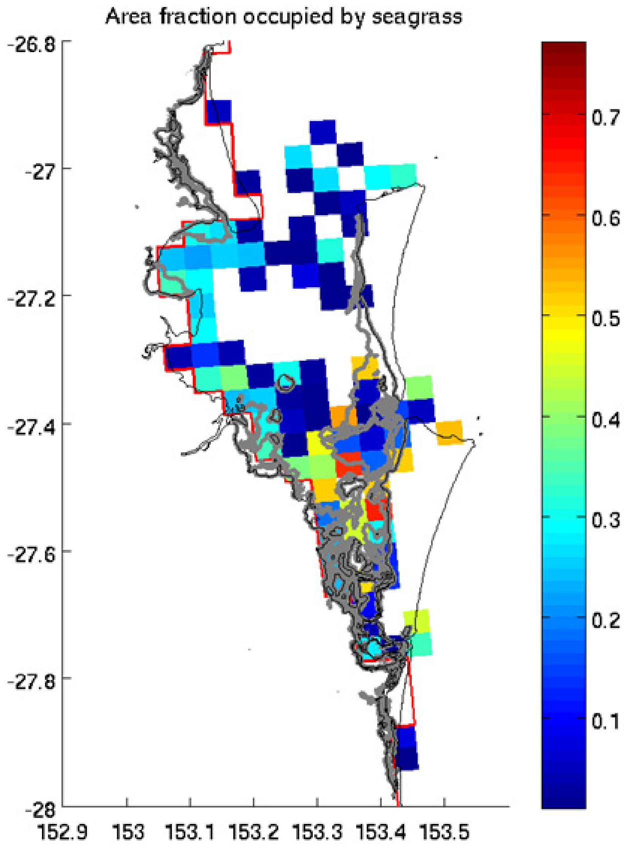
Seagrass behaviour - % of the bottom covered.

Ω - nitrogen-specific leaf area

Fraction of bottom covered



Seagrass biomass, B



Seagrass behaviour in Gladstone Harbour.

- Spectrally-resolved daily-varying light surface light field
- Seagrass depth varies with changing tides.
- Application of laboratory and field observation of compensation scale irradiance to determine respiration rates.

Thank you to JCU team for obs.

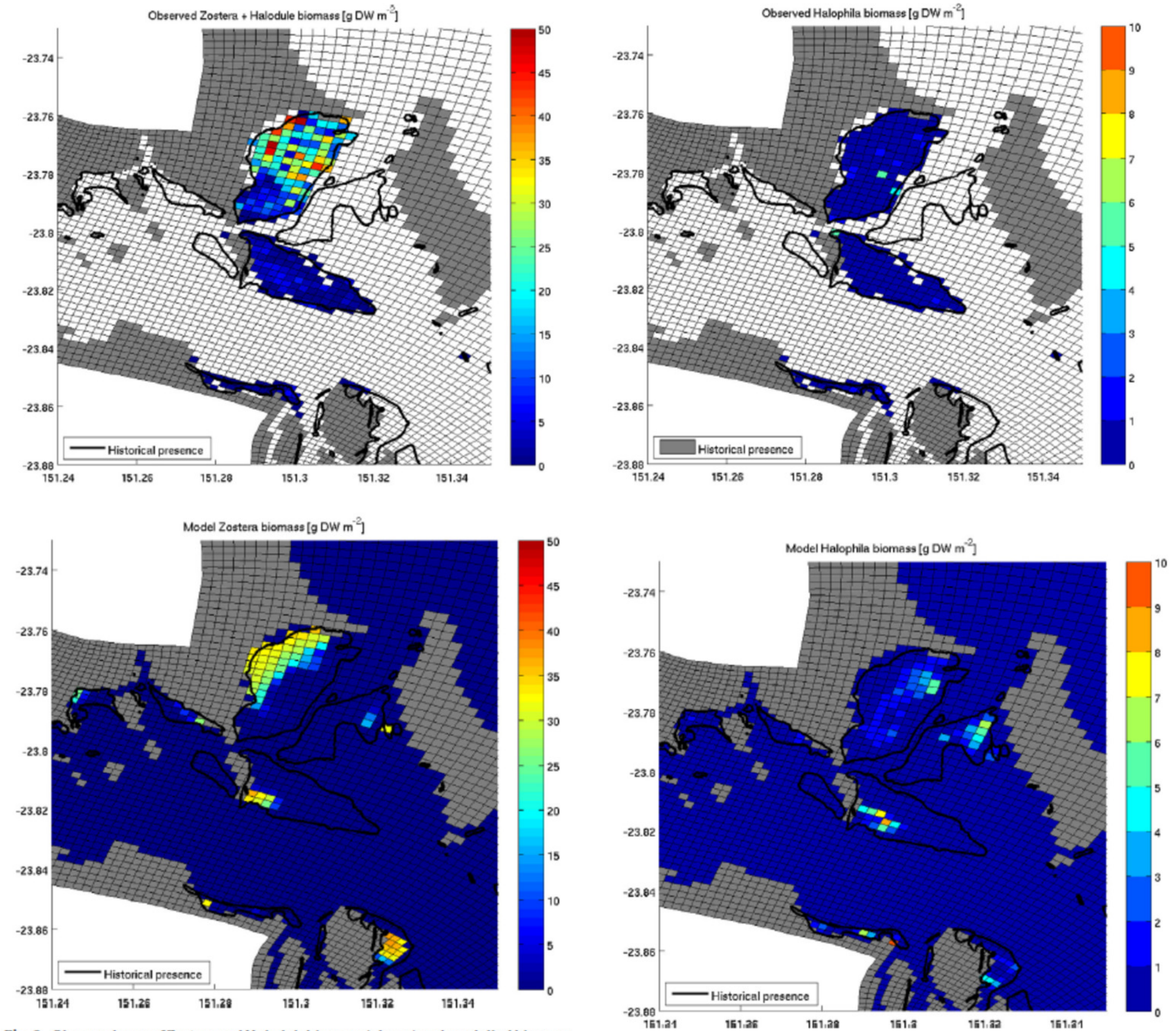
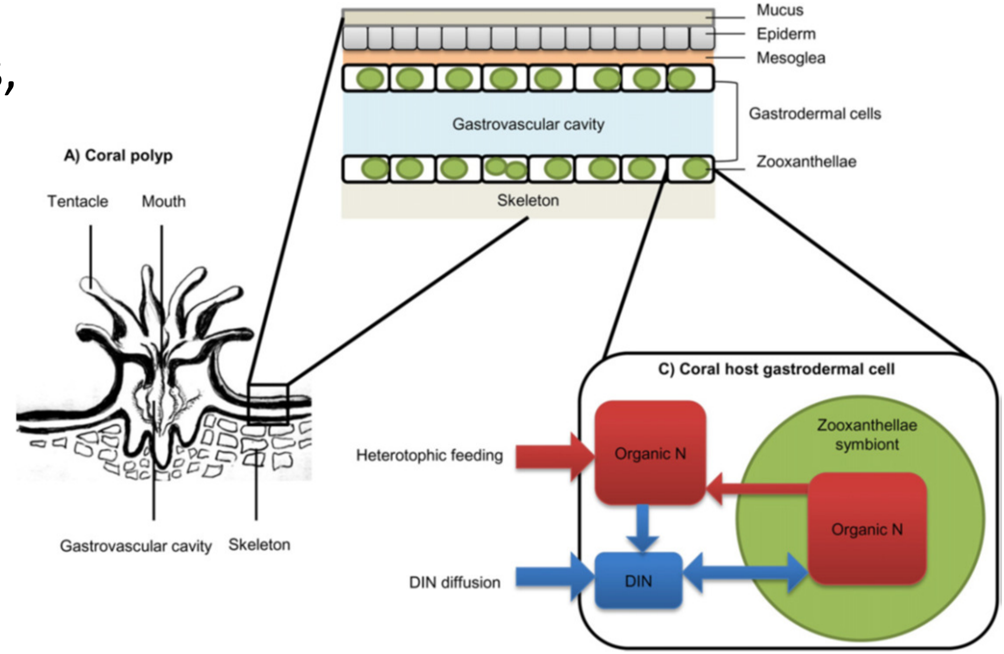
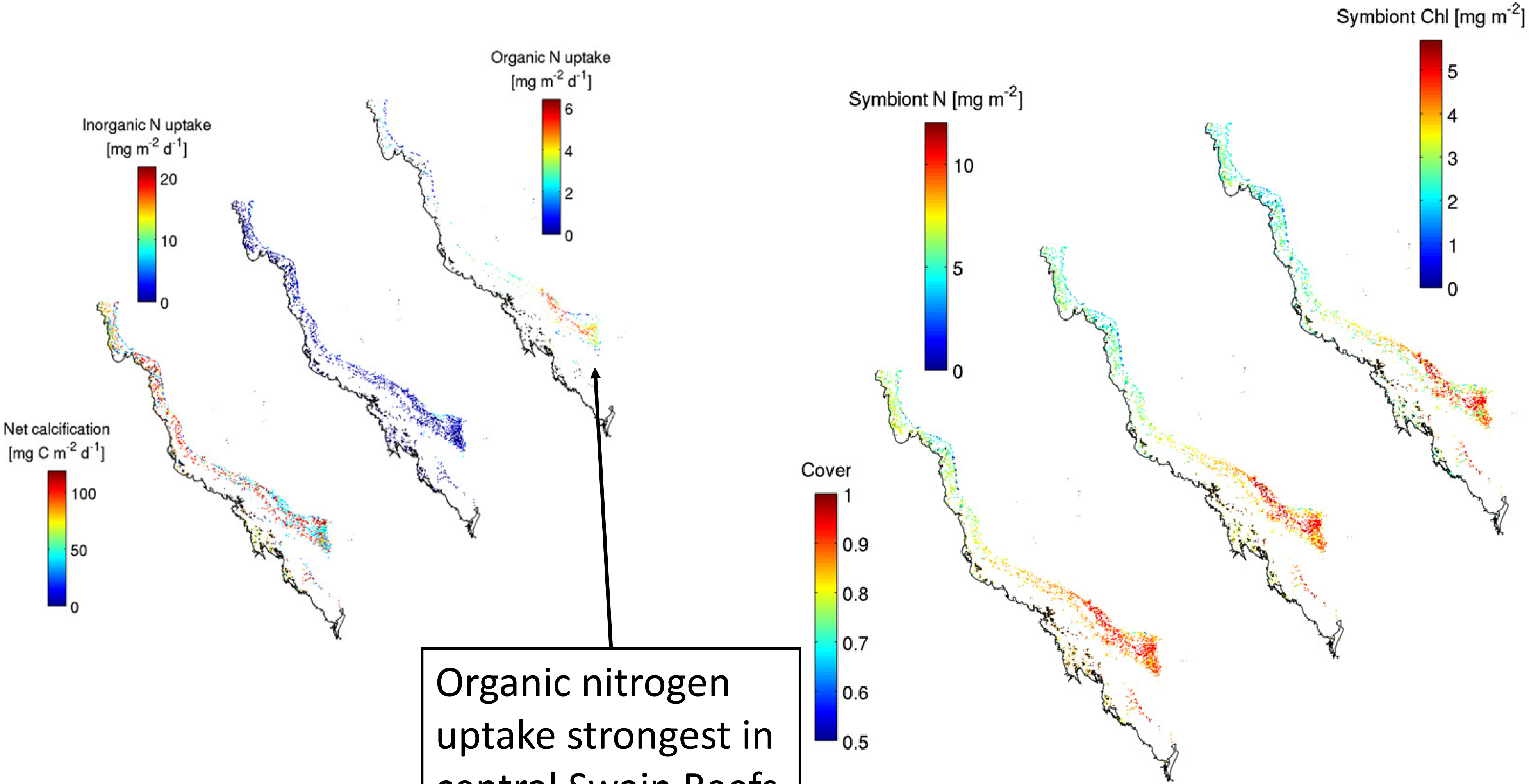


Fig 6. Observed sum of *Zostera* and *Halodule* biomass (above) and modelled biomass

Coral model

- Coral biomass represented by three variables, host biomass, zooxanthellae biomass and chlorophyll content of zooxanthellae.
- Processes include:
  - coral host growth
  - zooxanthellae growth
  - zooxanthellae chlorophyll synthesis and photosynthesis
  - organic matter uptake (host)
  - inorganic matter uptake (zooxanthellae),
  - translocation of organic matter from zooxanthellae to host.
  - calcification (alkalinity and DIC uptake).





Organic nitrogen uptake strongest in central Swain Reefs – does this provide bleaching resilience?