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.

Mark E. Baird, Nagur Cherukuru, Emlyn Jones, Nugzar Margvelashvili, Mathieu Mongin, Kadija Oubelkheir, Peter J. Ralph, Farhan Rizwi, Barbara J. Robson, Thomas Schroeder, Jennifer Skerratt, Andrew D.L. Steven, Karen A. Wild-Allen

Thank you to IMOS remote-sensing facility and the eReefs remote-sensing team.

Optical model

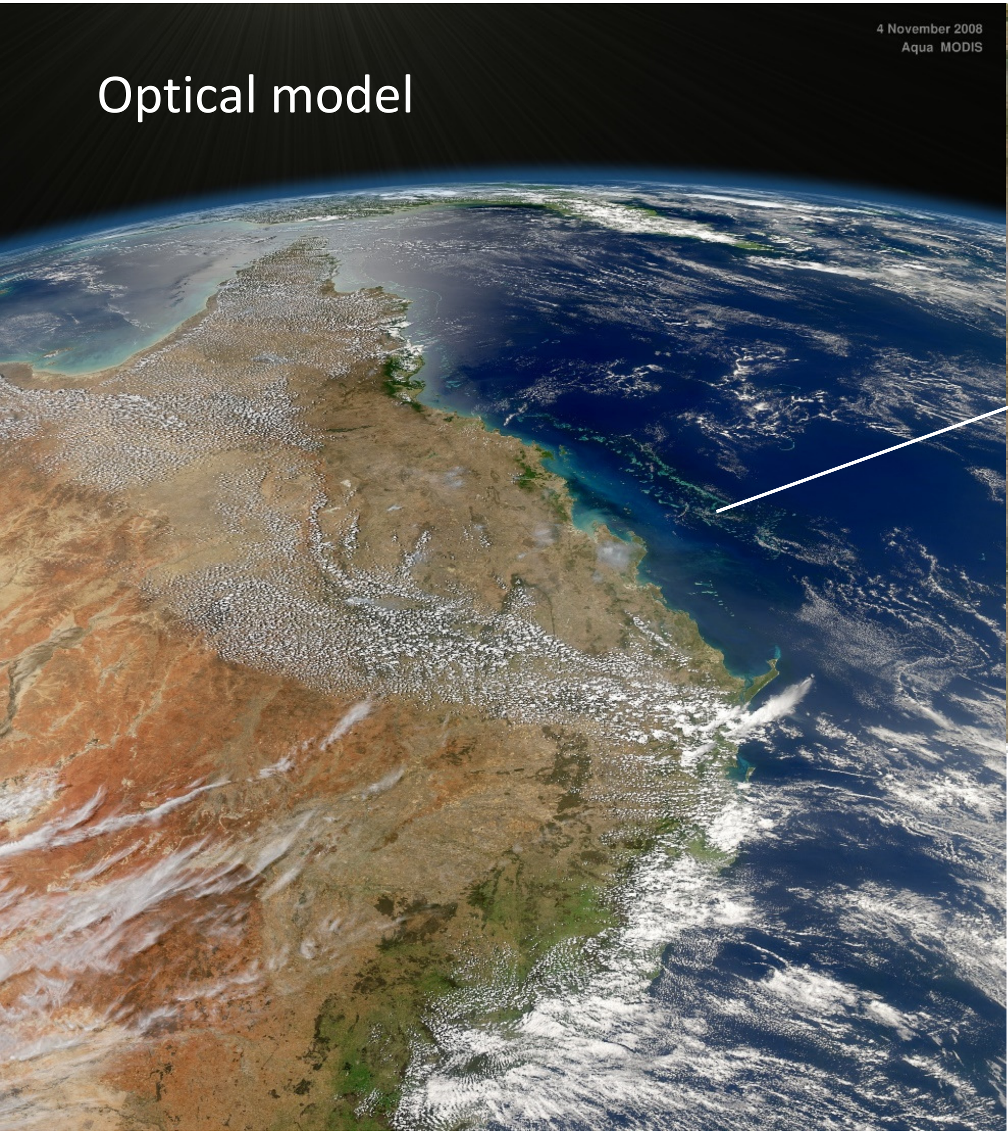
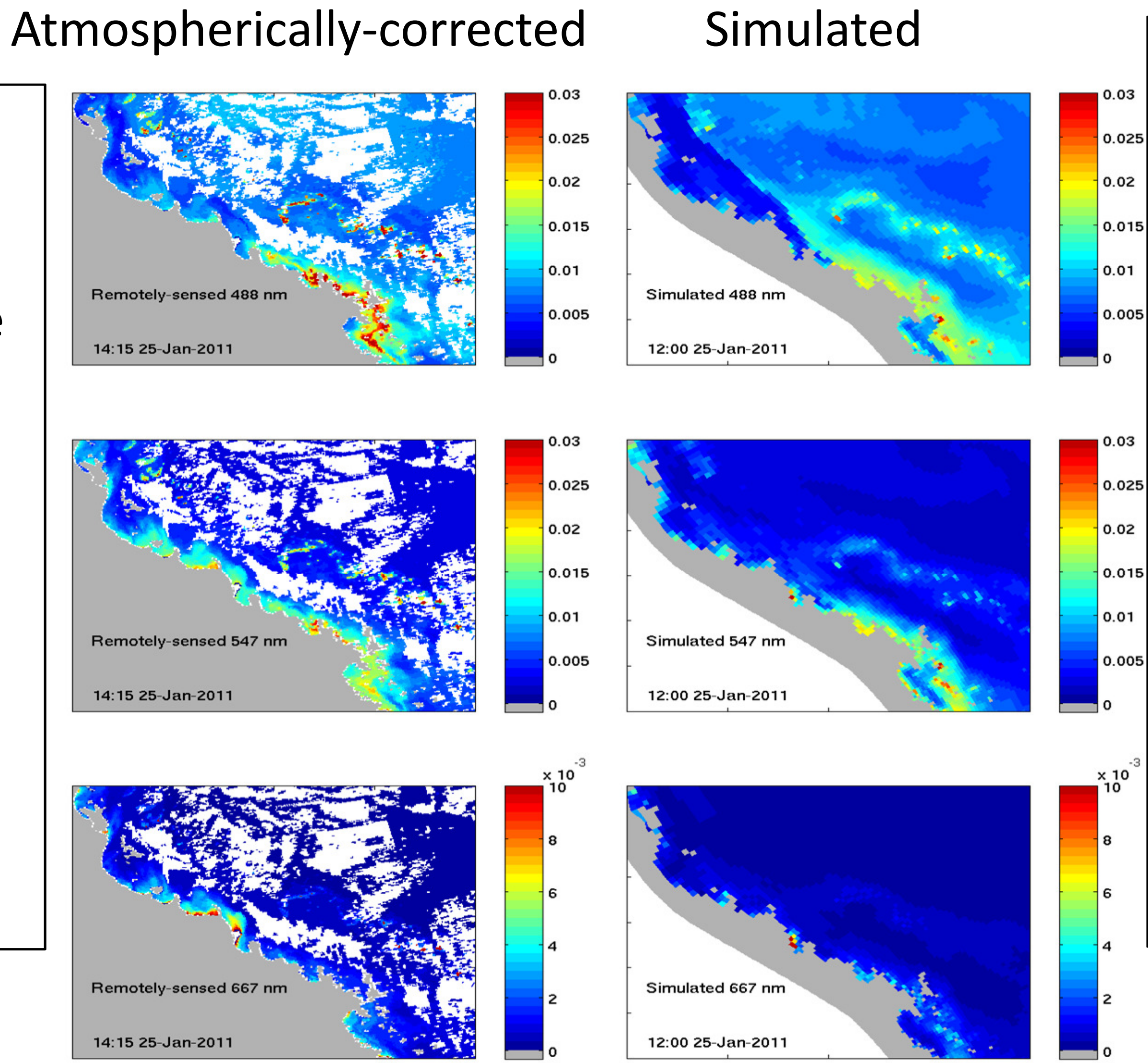
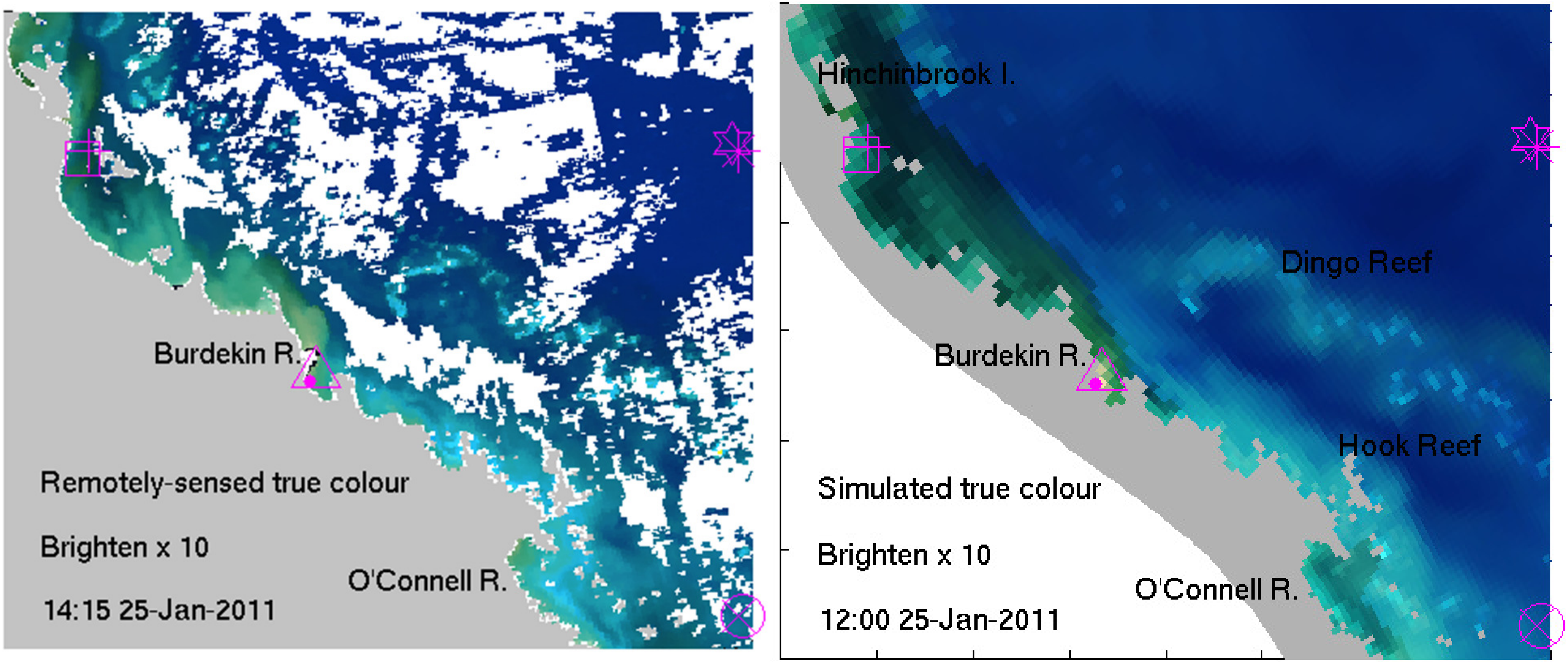


Image shows:
- Bottom sediments / reefs
- Absorption by organic matter
- Phytoplankton blooms (+type)
- River plumes
- Circulation structure

Observation of top of atmosphere (TOA) remote-sensing reflectance corrected for atmospheric scattering and absorption to obtain, cloud permitting, surface reflectance as viewed at a solid angle, R_{rs} [sr^{-1}]

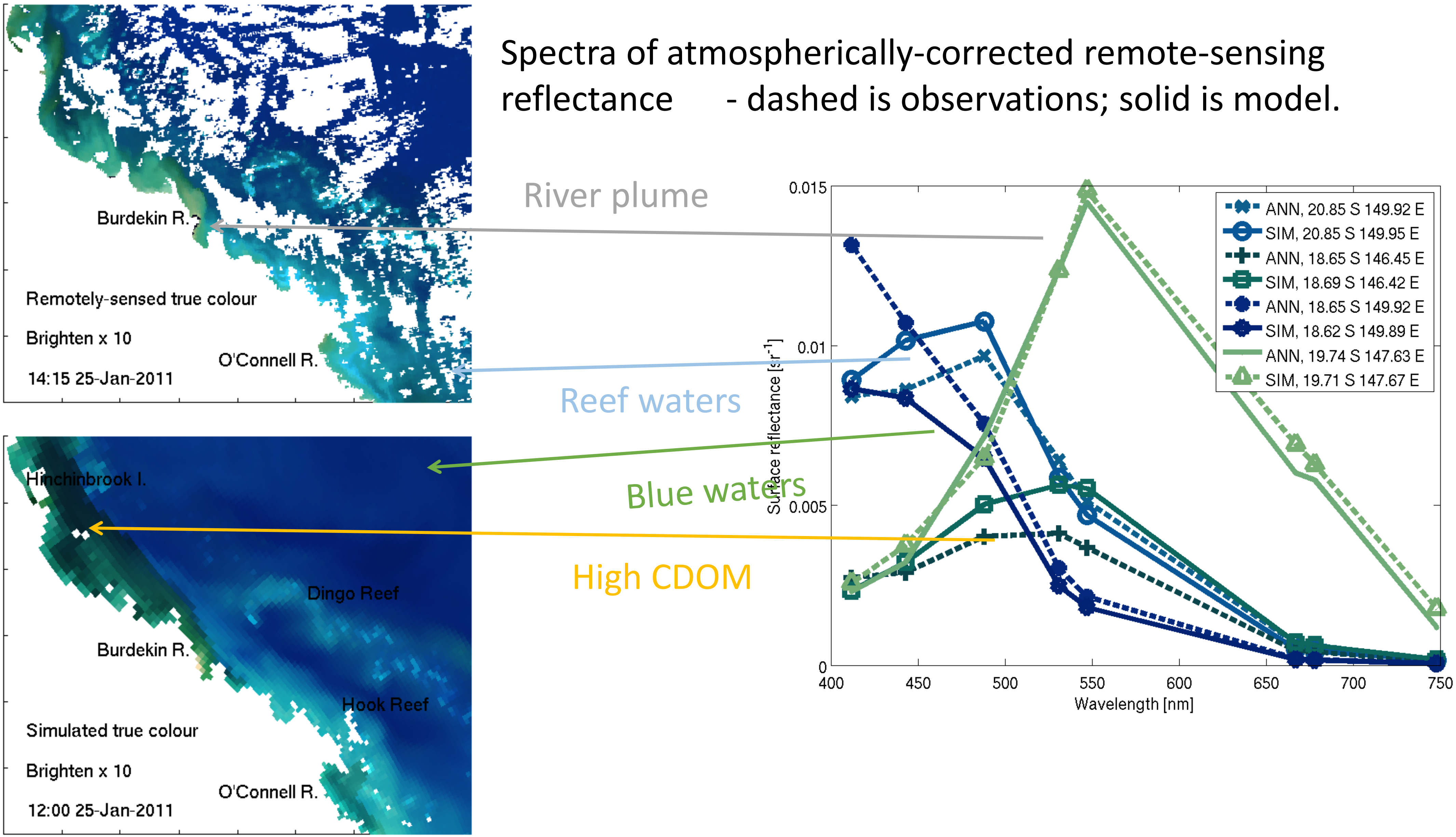


Optical-depth weighted remote-sensing reflectance as a result of 20 optically-active constituents initialised 100 days earlier, and transported, biogeochemically-transformed, flocculated and resuspended, to determine R_{rs} [sr^{-1}]

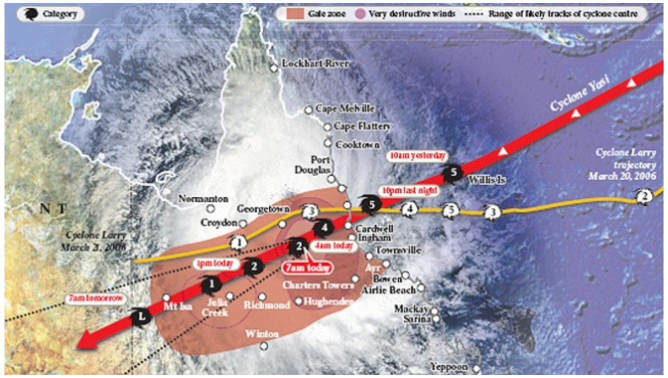


Burdekin R.
Remotely-sensed true colour
Brighten x 10
O'Connell R.
14:15 25-Jan-2011
Hinchinbrook I.
Dingo Reef
Burdekin R.
Hook Reef
Simulated true colour
Brighten x 10
O'Connell R.
12:00 25-Jan-2011

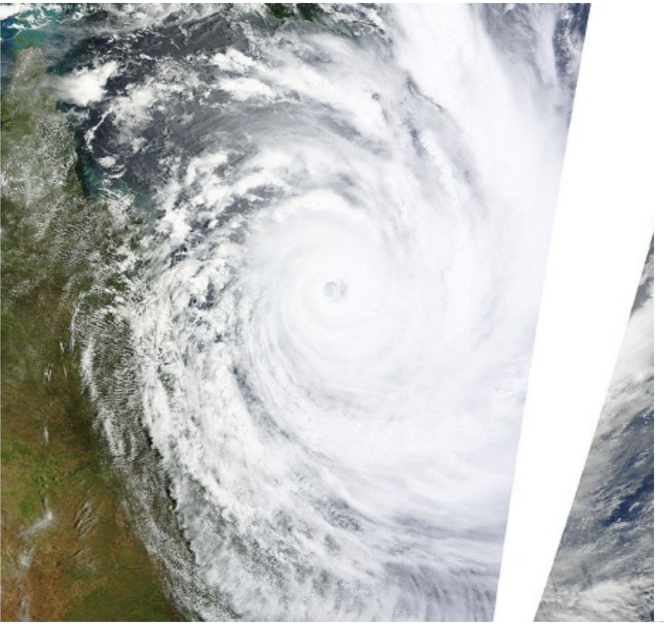
Spectra of atmospherically-corrected remote-sensing reflectance - dashed is observations; solid is model.

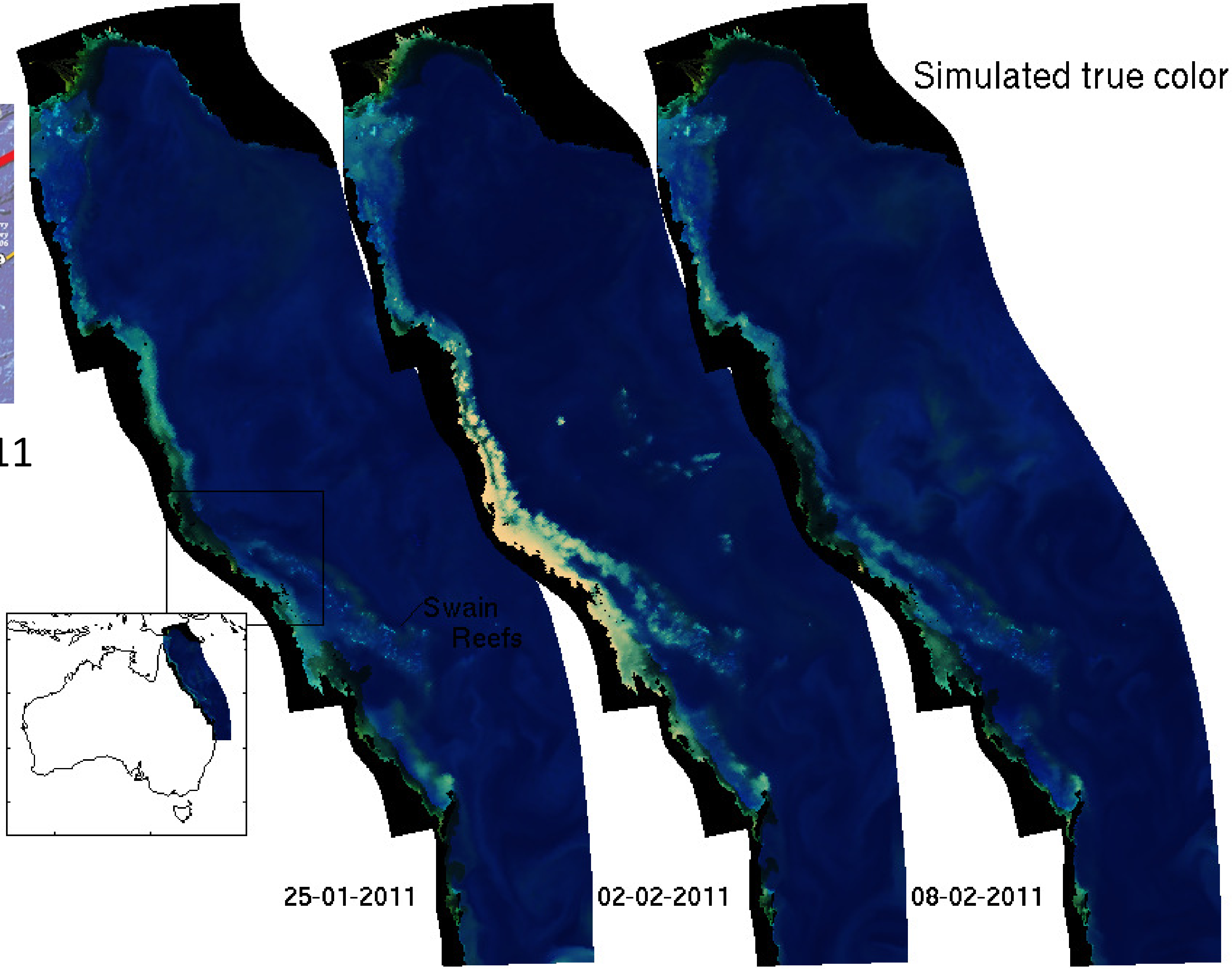


Tropical cyclone Yasi 2011



MODIS true color, 2 Feb 2011





Key points:

1. First time observed remote-sensing reflectance from 8 MODIS ocean colour bands has been compared to that calculated by a coastal biogeochemical model.

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CrossMark

Mark E. Baird [a,*], Nagur Cherukuru [a], Emlyn Jones [a], Nugzar Margvelashvili [a], Mathieu Mongin [a], Kadija Oubelkheir [a], Peter J. Ralph [c], Farhan Rizwi [a], Barbara J. Robson [b], Thomas Schroeder [a], Jennifer Skerratt [a], Andrew D.L. Steven [a], Karen A. Wild-Allen [a]

2. Errors were primarily due to the distribution of optically-active constituents, thus the errors are useful for biogeochemical model assessment.

3. Simulated true colour, generated using remote-sensing reflectance at the red, green and blue bands, is a powerful visualisation tool.

The exposure of the Great Barrier Reef to ocean acidification

Mongin, M., M. E. Baird, B. Tilbrook, R. J. Matear, A. Lenton, M. Herzfeld, K. A. Wild-Allen, J. Skerratt, N. Margvelashvili, B. J. Robson, C. M. Duarte, M. S. M. Gustafsson, P. J. Ralph, A. D. L. Steven

Thanks to Sven Uthicke et al. for a high quality data set made freely available.

eReefs carbon chemistry has small errors.

The mean (and range) of the errors across the 22 sites were:

A_T: 39.90 (8.5, 91.5) mmol m^{-3}

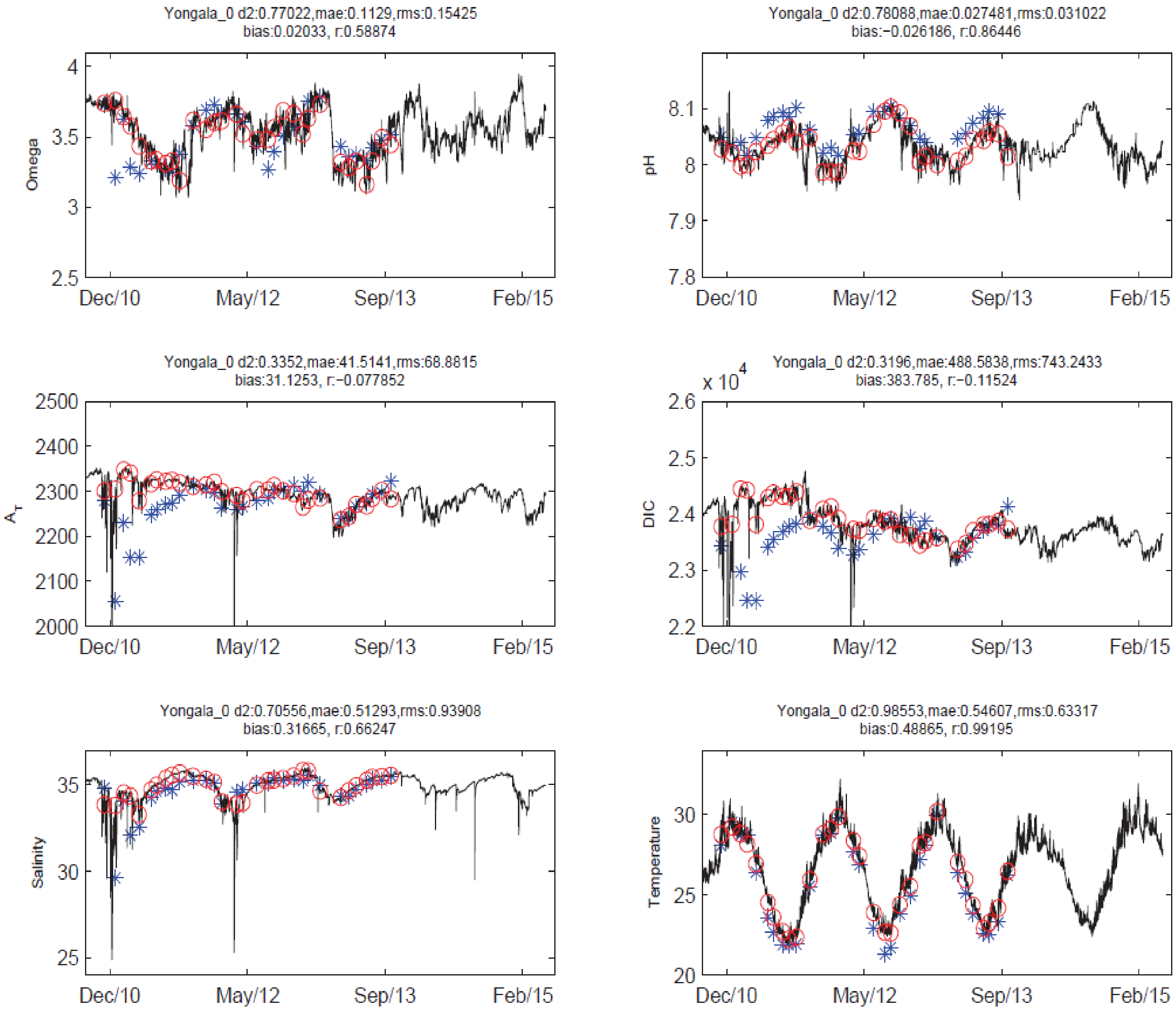
C_T: 35.9 (12.5, 63.97) mmol m^{-3}

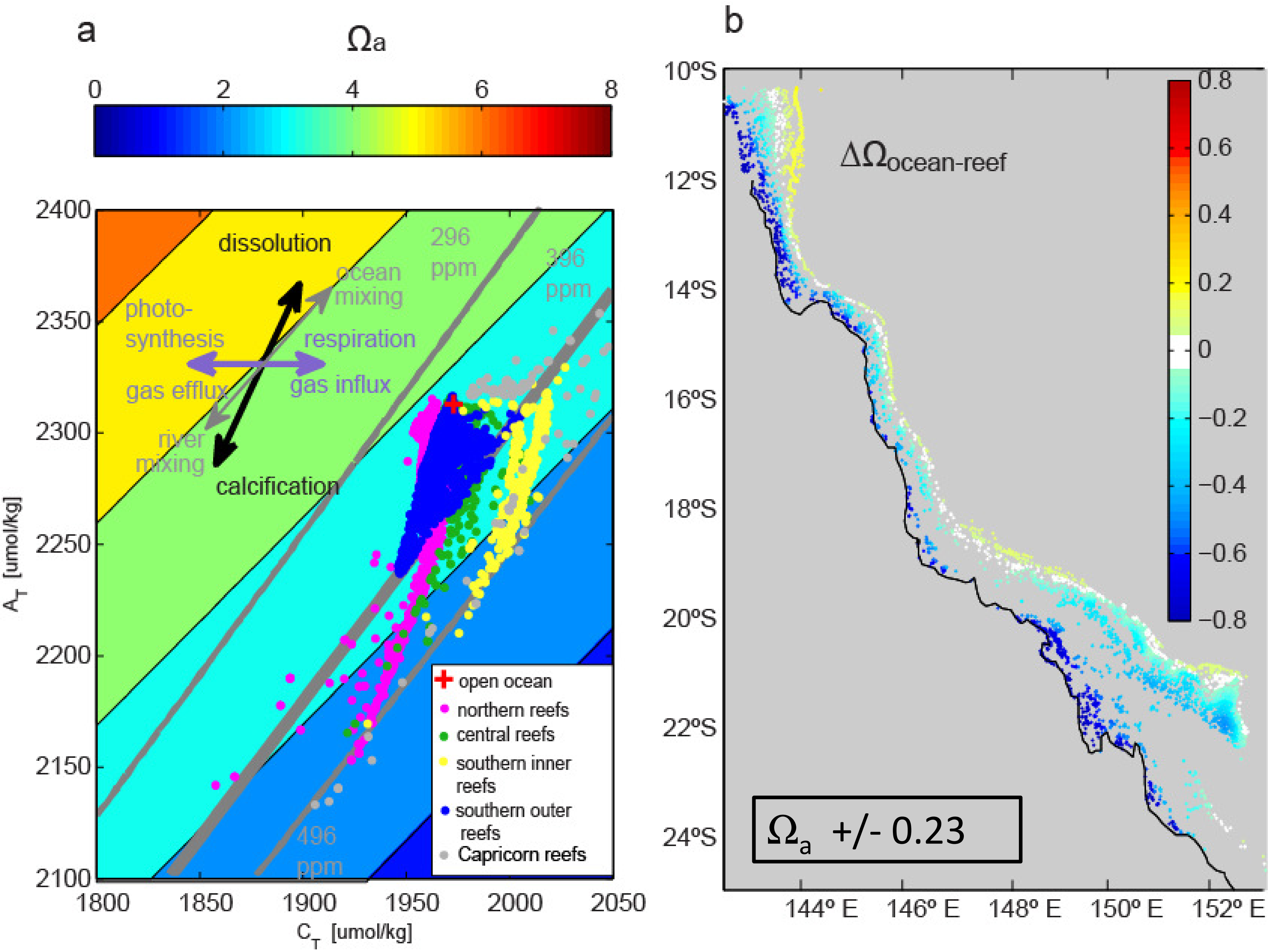
S: 0.47 (0.15, 0.93)

T: 0.87 (0.63,1.24) °C

resulting in an error in the calculated

Ω_a of 0.23 (0.09, 0.54)





It is impossible to observe Ω_a at all reefs, but critical for optimal management.

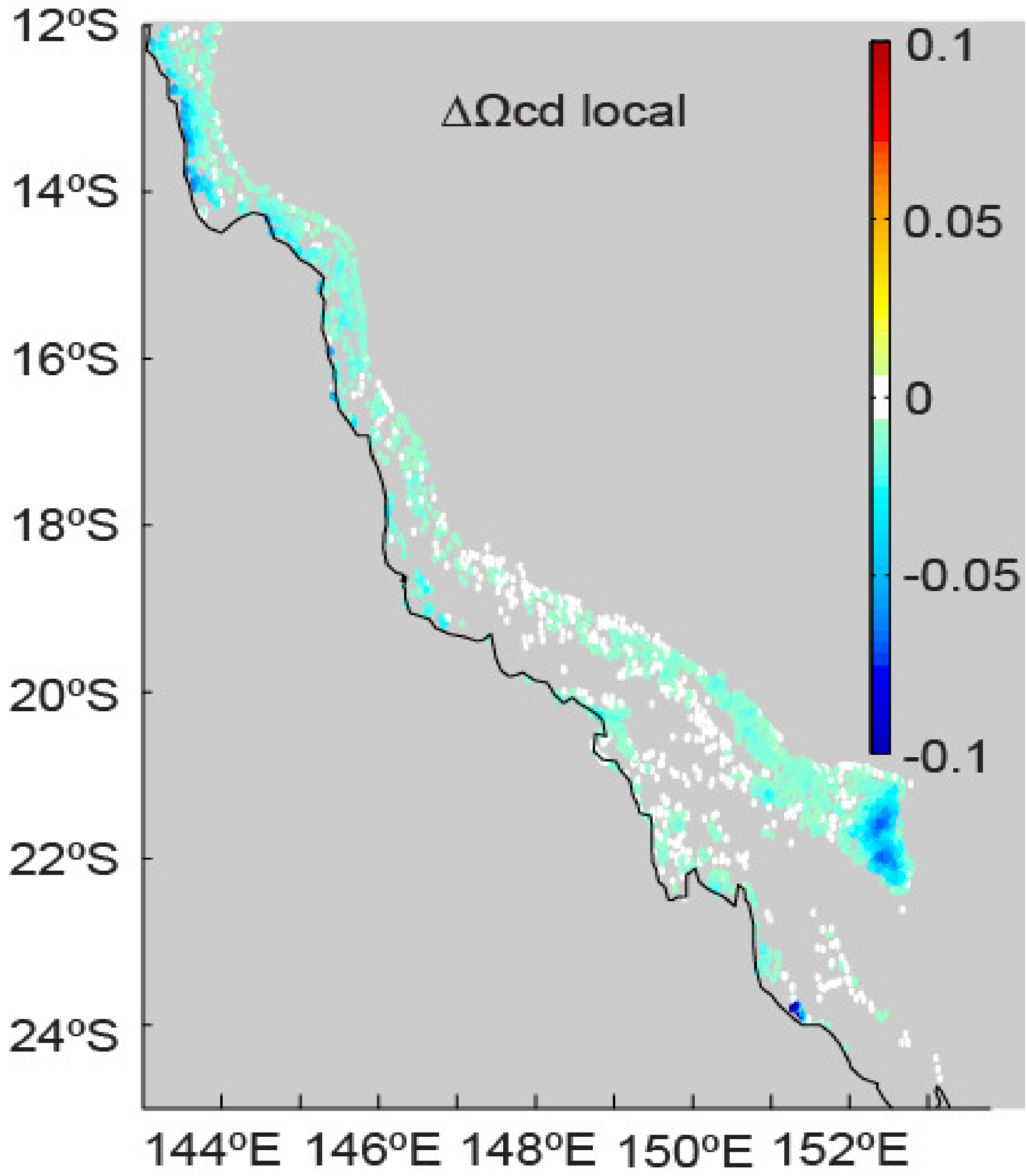
Model – generated map of the aragonite saturation in the vicinity of 3,581 reefs of the GBR.

What is driving OA?

Should be easy, just pull out all terms changing total carbon (C_T) or total alkalinity (A_T) in the model (i.e. Calcification / dissolution, production, respiration, air-sea flux).

No. It is not local, but primarily cumulative, upstream processes, that are change aragonite saturation above individual reefs

How can we untangle multiple upstream processes, and their mixing and advection etc?



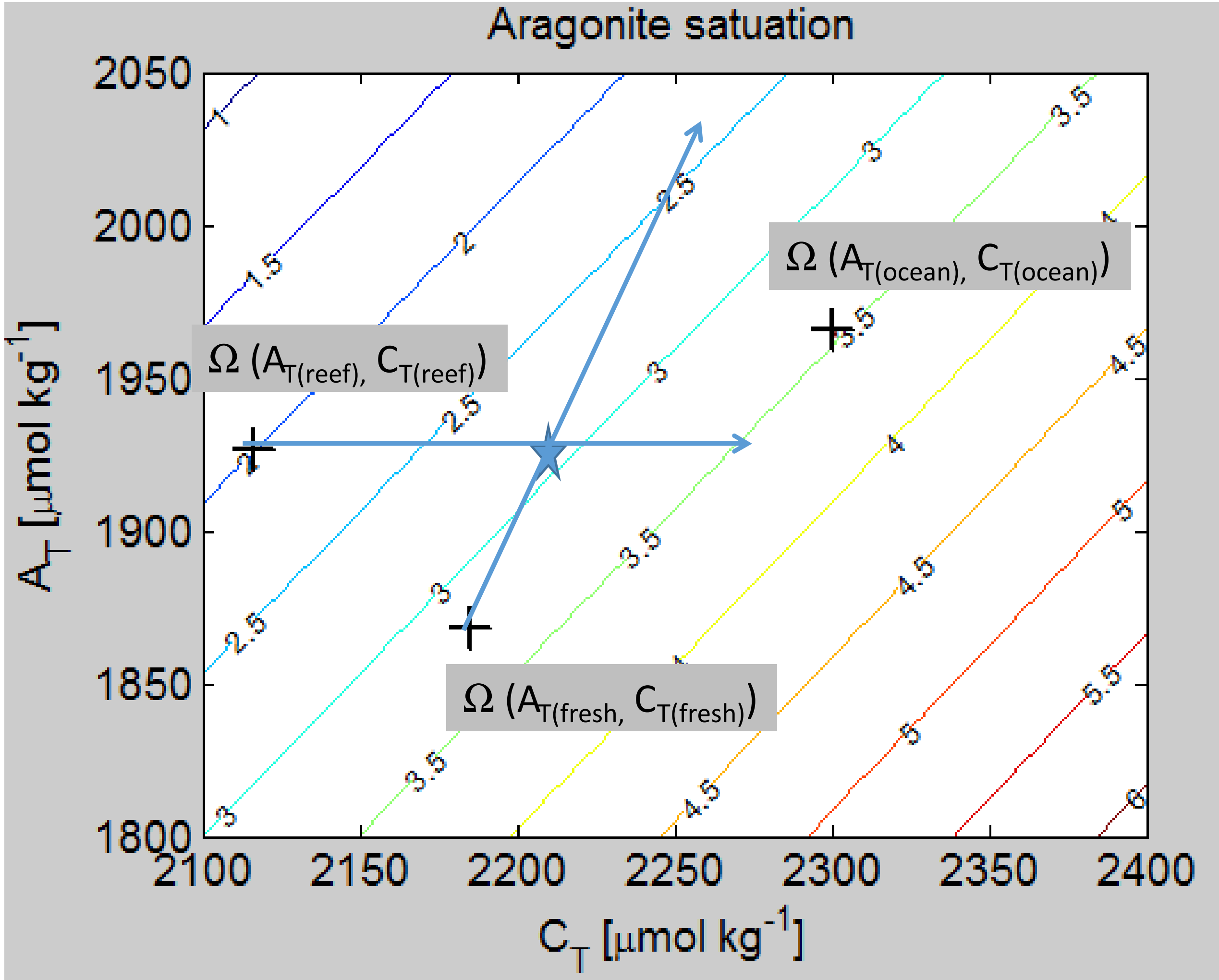
Our new idea : use unique impact of processes on A_T and C_T to isolate processes.

$\Delta\Omega$reef-ocean = 2.0 - 3.4 = -1.4

Hydrological cycle:

$\Delta\Omega_{fresh}$ = $\Omega(A_T(fresh),C_T(fresh))$ - $\Omega(A_T(ocean),C_T(ocean))$ = 3.2 – 3.4 = - 0.2

Where A_T(fresh) are C_T(fresh) determined from conservative mixing using model salinity – biggest when river flows have an influence.



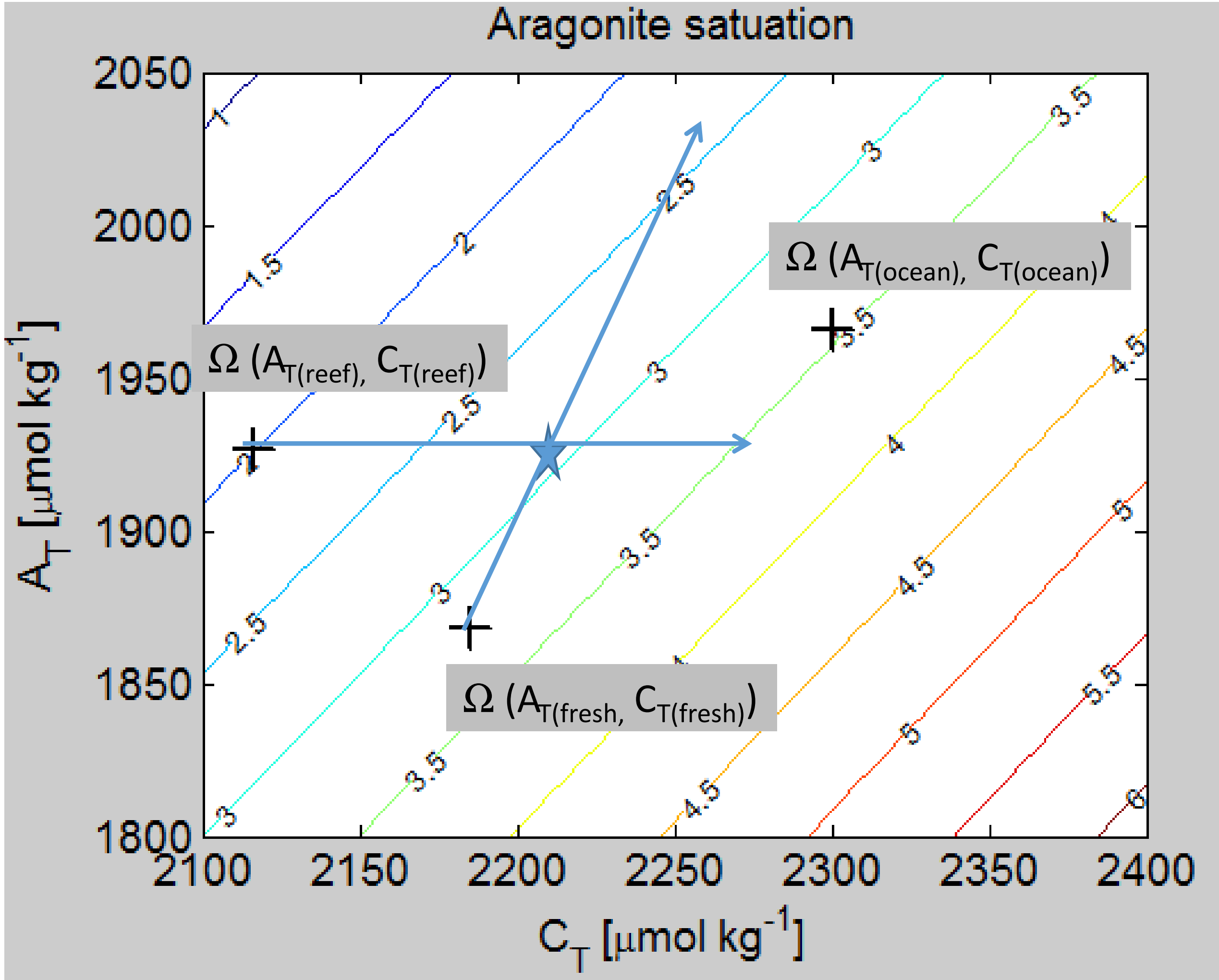
Only processes remain that changes A_T are calcification and dissolution:

$$\Delta\Omega cd = \Omega(A_T(\text{reef}), [C_T(\text{fresh}) + (A_T(\text{reef}) - A_T(\text{fresh}))/2]) - \Omega(A_T(\text{fresh}), C_T(\text{fresh}))$$
$$= 2.9 - 3.2 = -0.3$$

Where calcification, dissolution change C_T by half the change in A_T

All the rest of the processes are lumped together, and the change calculated:

$$\Delta\Omega pra = \Delta\Omega\text{reef-ocean} - \Delta\Omega\text{fresh} - \Delta\Omega cd$$
$$= -1.4 - (-0.2) - (-0.3)$$
$$= -0.9$$



Thus the breakdown of drivers becomes:

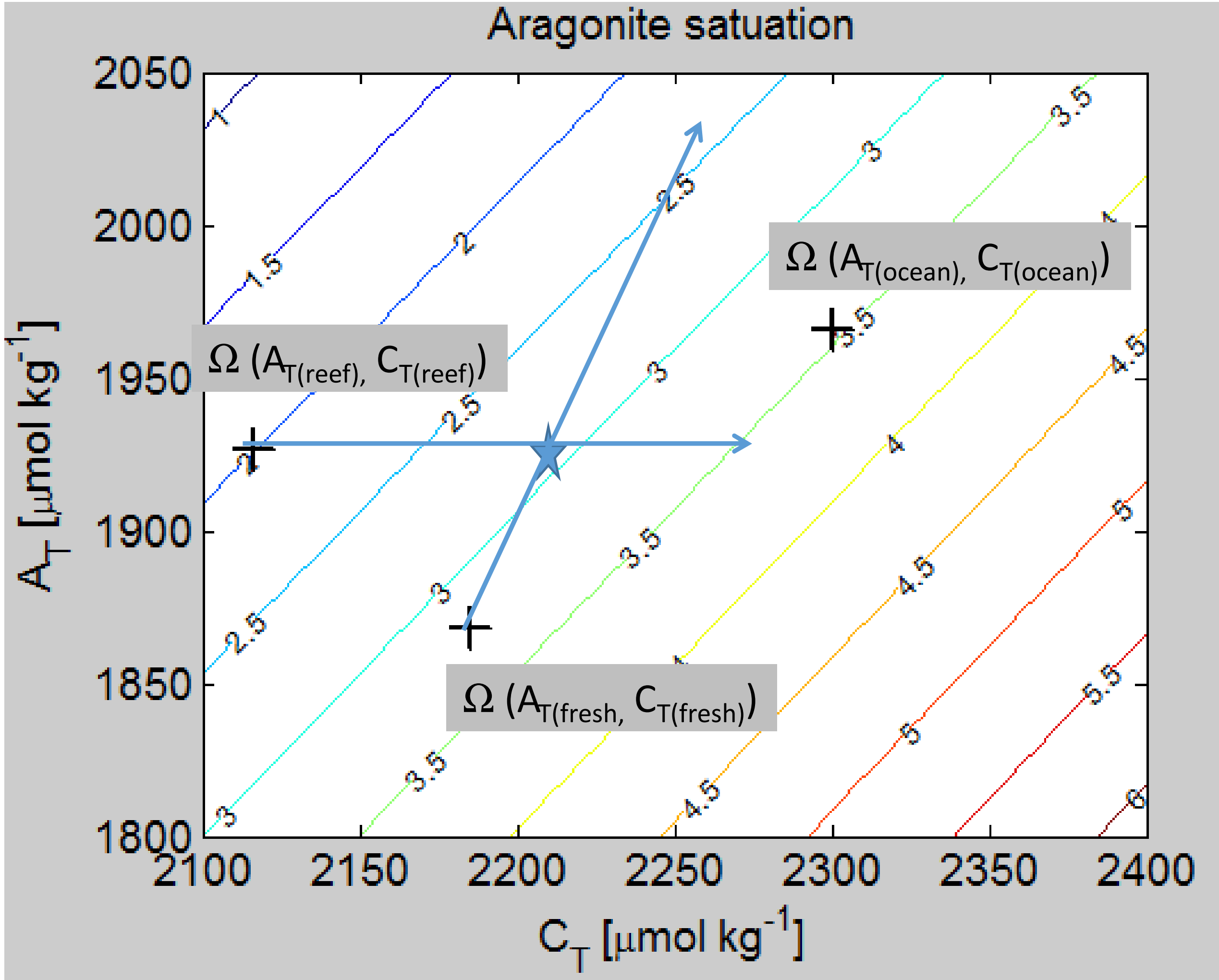
Net calcification: $\Delta\Omega cd$ = - 0.3

Hydrological cycle: $\Delta\Omega_{fresh}$ = - 0.2

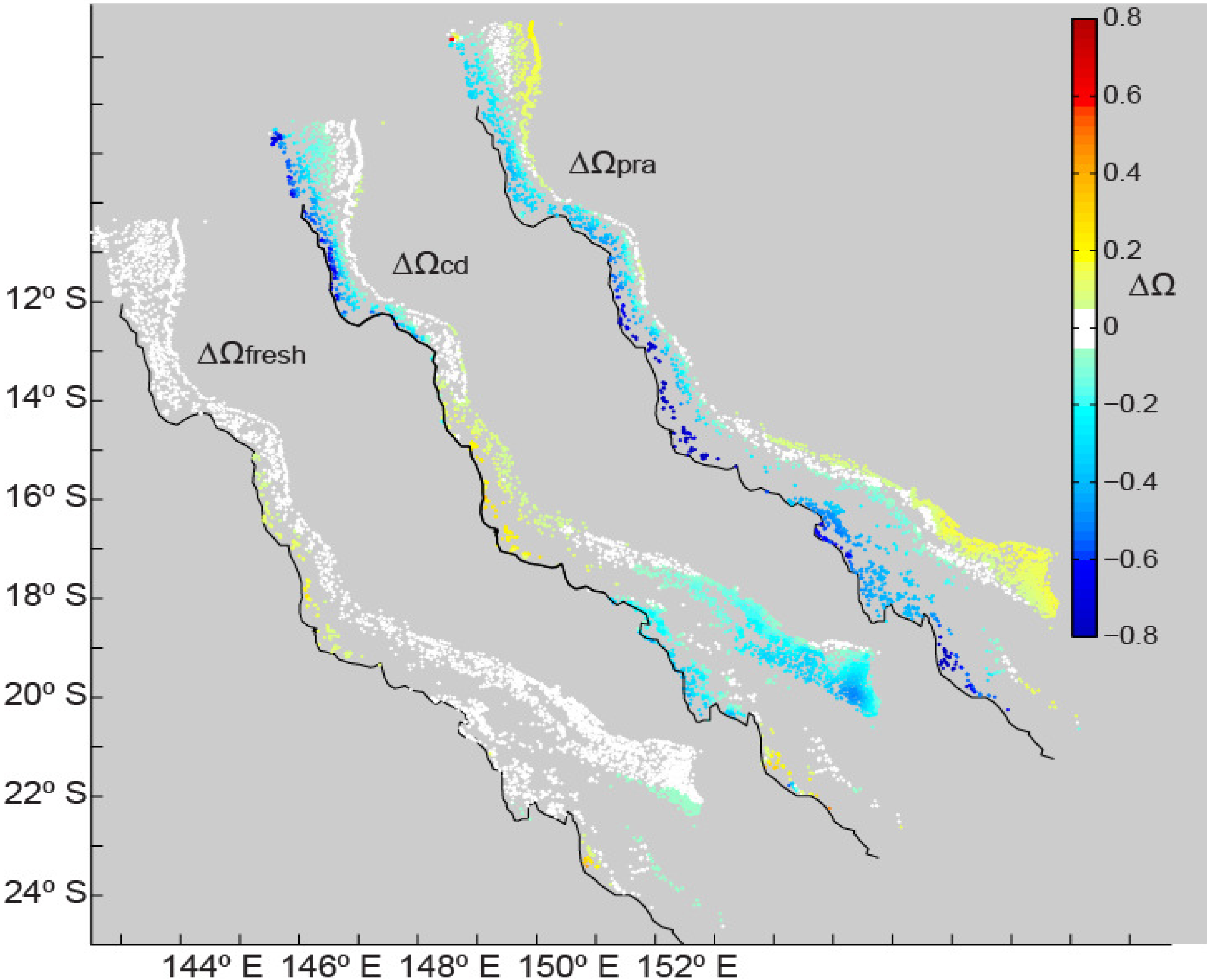
Photosynthesis / respiration / air-sea flux

$\Delta\Omega pra$ = - 0.9

Sum of three: $\Delta\Omega$reef-ocean = -1.4



So the drivers of change in aragonite saturation:



ARTICLE

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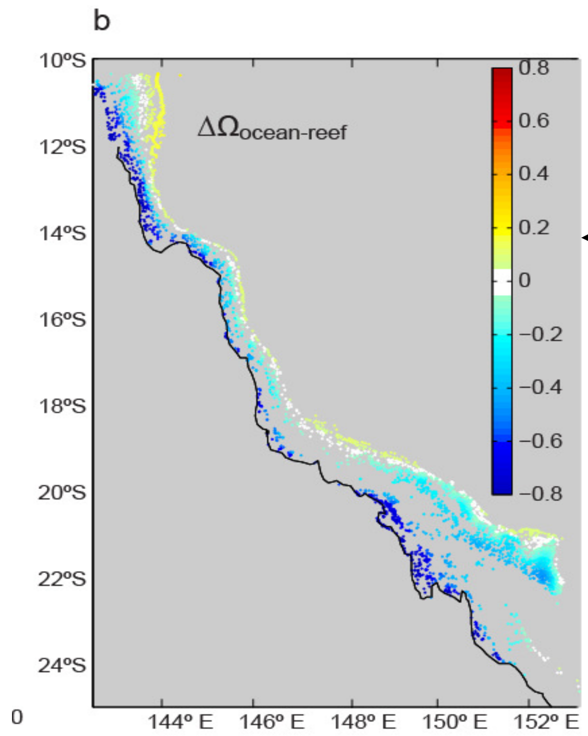
OPEN

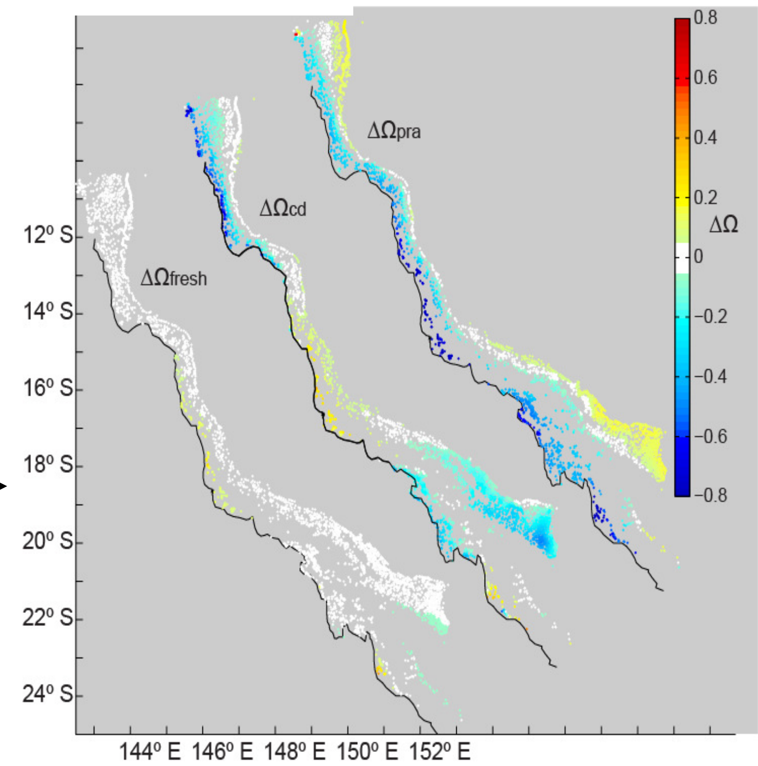
The exposure of the Great Barrier Reef to ocean acidification

Mathieu Mongin[1], Mark E. Baird[1], Bronte Tilbrook[1,2], Richard J. Matear[1], Andrew Lenton[1], Mike Herzfeld[1], Karen Wild-Allen[1], Jenny Skerratt[1], Nugzar Margvelashvili[1], Barbara J. Robson[3], Carlos M. Duarte[4], Malin S.M. Gustafsson[5], Peter J. Ralph[5] & Andrew D.L. Steven[1]



New map of aragonite saturation

First quantification of relative drivers of Ω



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

Baird, M. E., M. P. Adams, R. C. Babcock, K. Oubelkheir, M. Mongin, K. A. Wild-Allen, J. Skerratt, B. J. Robson, K. Petrou, P. J. Ralph, K. R. O'Brien, A. B. Carter, J. C. Jarvis, M. A. Rasheed

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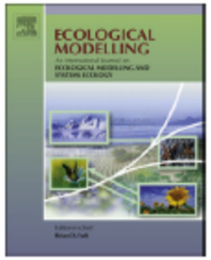

A biophysical representation of seagrass growth for application in a complex shallow-water biogeochemical model

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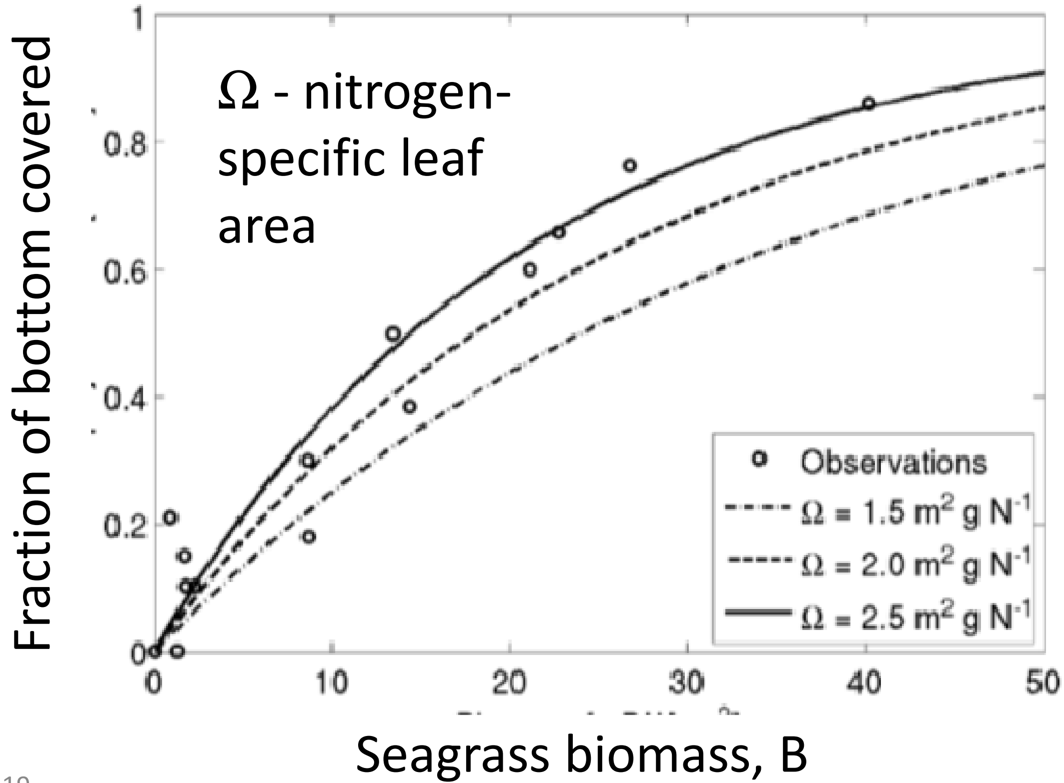
Mark E. Baird[a,*], Matthew P. Adams[b], Russell C. Babcock[a], Kadija Oubelkheir[a], Mathieu Mongin[a], Karen A. Wild-Allen[a], Jennifer Skerratt[a], Barbara J. Robson[c], Katherina Petrou[d], Peter J. Ralph[d], Katherine R. O'Brien[b], Alex B. Carter[e], Jessie C. Jarvis[e], Michael A. Rasheed[e]

New relationship between % cover and biomass for benthic plants.

% cover = 1 – exp(- Ω B)



$$\frac{dA_{eff}}{dB} = k(1 - A_{eff}) \tag{B.1}$$

where k is a constant. Rearranging, and integrating both sides:

$$\int \frac{dA_{eff}}{1 - A_{eff}} = \int k dB \tag{B.2}$$

Solving the integration terms gives:

$$-\ln(1 - A_{eff}) = kB + C \tag{B.3}$$

where C is the integration constant. Taking the exponential of both sides, and rearranging, gives:

$$A_{eff} = 1 - \exp(-kB - C) \tag{B.4}$$

At zero biomass, there is zero effective surface area, thus $0 = 1 - \exp(-0 - C)$. Rearranging, $\exp(-C) = 1$, thus $C = 0$. So Eq. (B.4) becomes:

$$A_{eff} = 1 - \exp(-kB) \tag{B.5}$$

To show that the constant k is the nitrogen-specific leaf area, Ω, differentiate Eq. (B.5) with respect to biomass:

$$\frac{dA_{eff}}{dB} = k\exp(-kB) \tag{B.6}$$

At zero biomass, when the surface is completely uncovered, placing a leaf of biomass B on the surface covers an area of ΩB. Thus at zero biomass,

$$\frac{dA_{eff}}{dB}|_{B=0} = \Omega = k\exp(-k0) = k \tag{B.7}$$

So $k = \Omega$, and we reach, as required:

$$A_{eff} = 1 - \exp(-\Omega B) \tag{B.8}$$

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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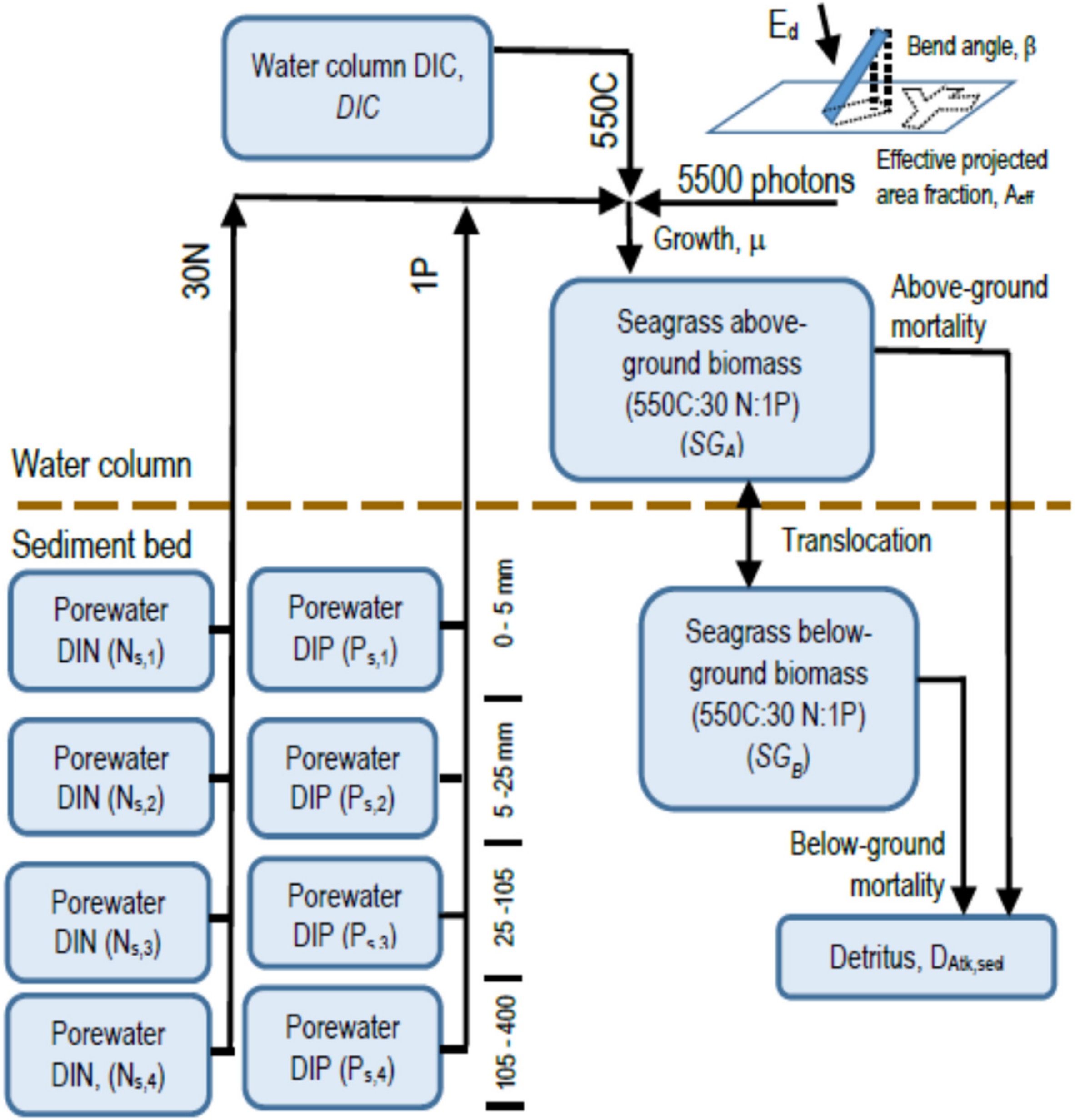
[a] CSIRO, Oceans and Atmosphere, Hobart, Australia
[b] School of Chemical Engineering, The University of Queensland, Brisbane, Australia
[c] CSIRO, Land and Water, Canberra, Australia
[d] Plant Functional Biology and Climate Change Cluster, Faculty of Science, University of Technology Sydney, Sydney, Australia



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.

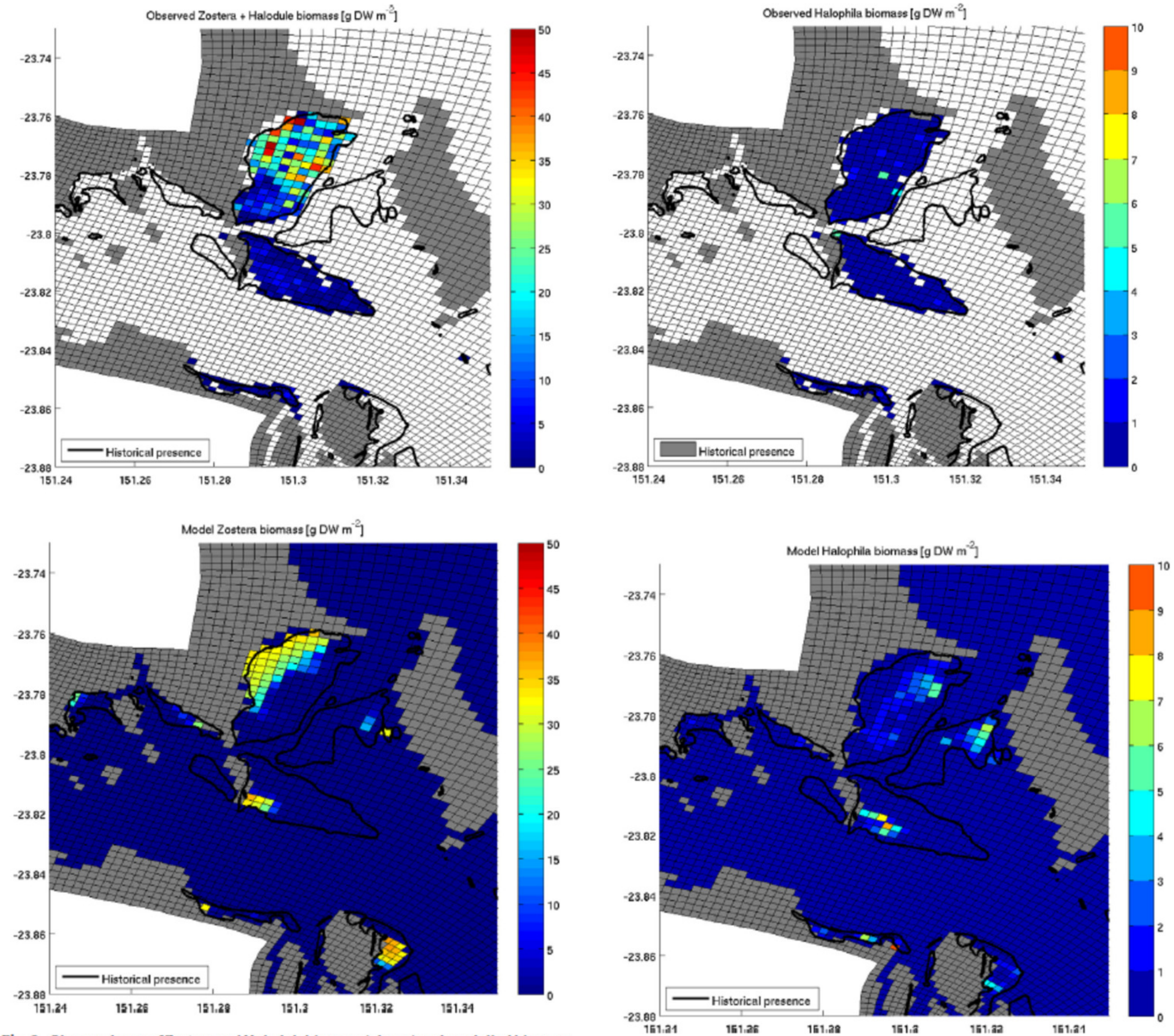
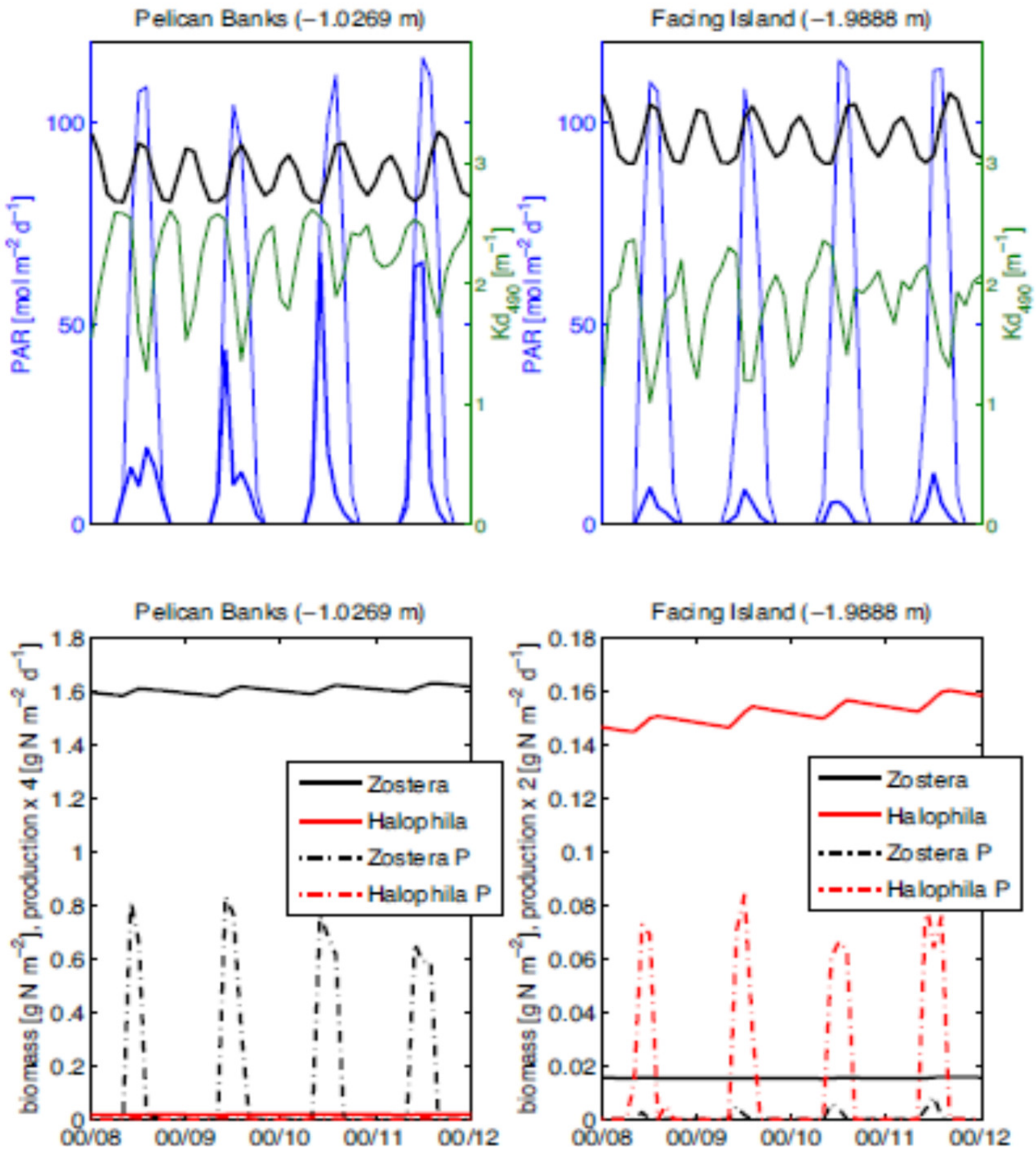


Fig 6. Observed sum of *Zostera* and *Halodule* biomass (above) and modelled biomass

- Thin blue - PAR above the surface.
- Black - sea level.
- Green – vertical attenuation.
- **Thick blue – light at bottom**

- **Model captures that bottom light is a function of vertical attenuation, and to a lesser extent at these sites of sea level and vertical attenuation.**

- **Seagrass production responds to the bottom light.**



Prese

Two studies of coral physiological response to varying nutrient sources and temperature stress.

Gustafsson, M.S.M, M. E. Baird and P. J. Ralph

eReefs coral model has been extended version, applied only to a single polyp, of photo-inhibition-driven bleaching.

Ecological Modelling 250 (2013) 183–194

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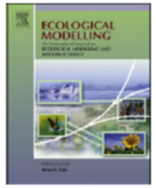


The interchangeability of autotrophic and heterotrophic nitrogen sources in Scleractinian coral symbiotic relationships: A numerical study

Malin S.M. Gustafsson*, Mark E. Baird, Peter J. Ralph

Plant Functional Biology and Climate Change Cluster, Faculty of Science, University of Technology, Sydney, NSW, Australia

Limnol. Oceanogr., 59(2), 2014, 603–622

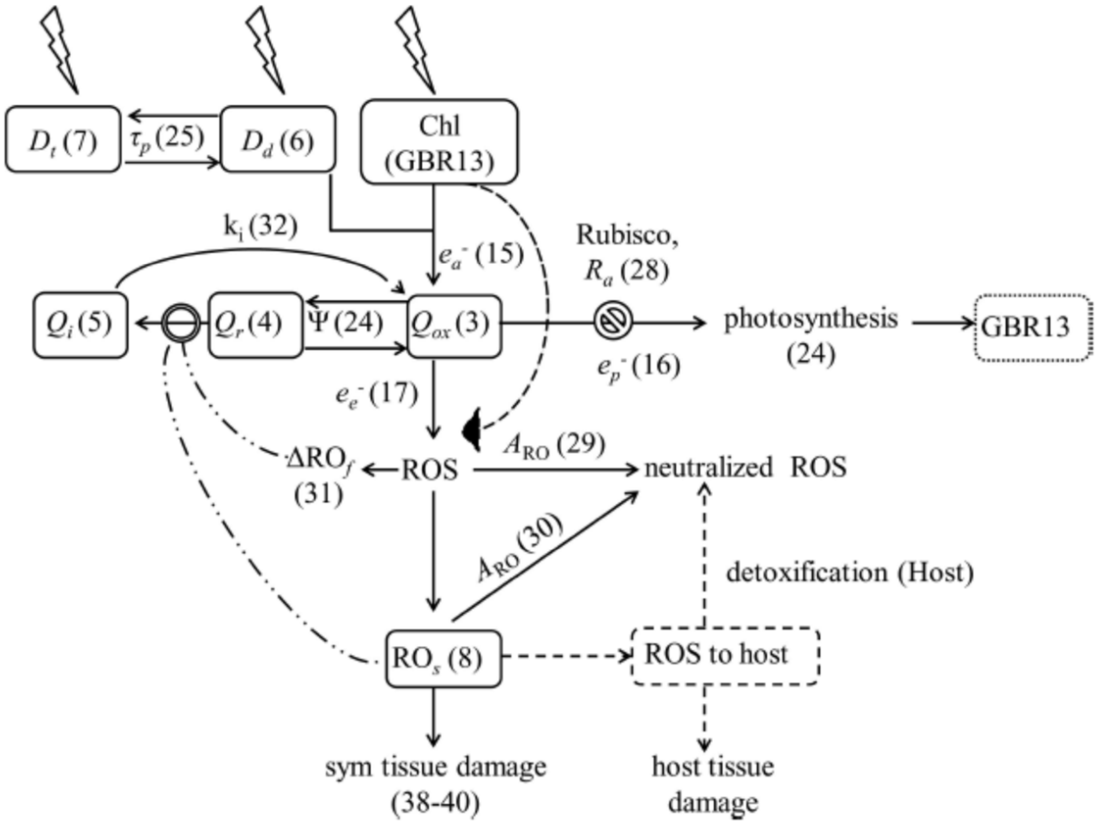
doi:10.4319/lo.2014.59.2.0603

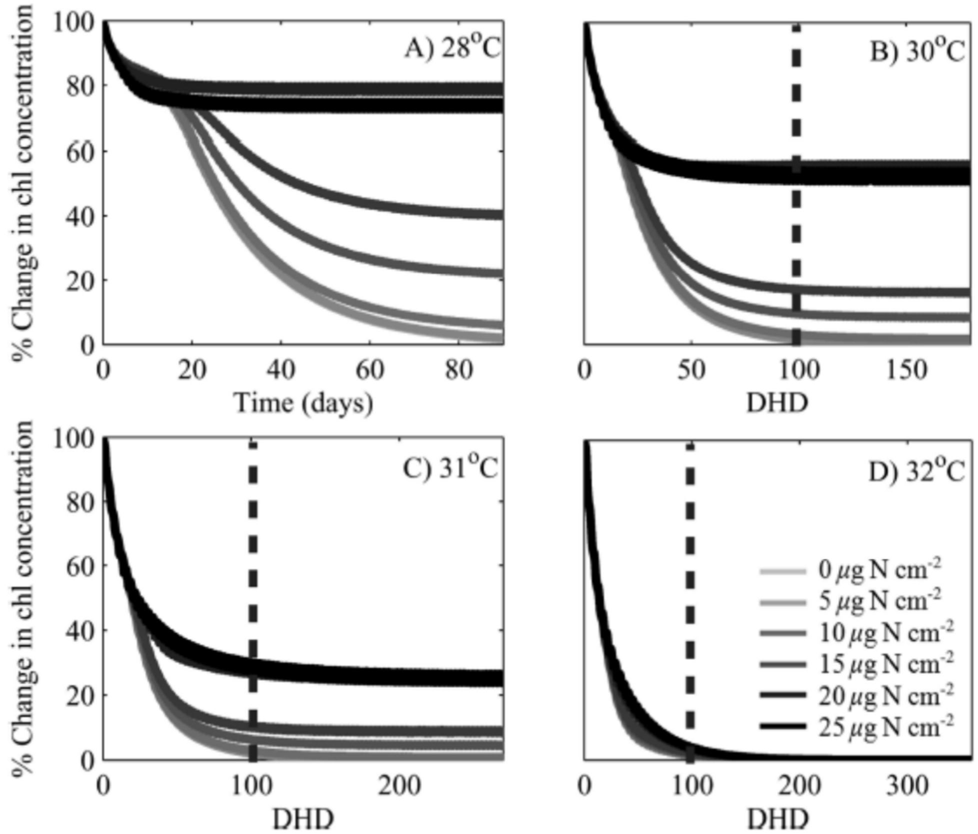
Modeling photoinhibition-driven bleaching in Scleractinian coral as a function of light, temperature, and heterotrophy

Malin S. M. Gustafsson,[1,*] Mark E. Baird,[2] and Peter J. Ralph [1]

[1] Plant Functional Biology and Climate Change Cluster, Faculty of Science, University of Technology, Sydney, Sydney, New South Wales, Australia

[2] Commonwealth Scientific and Industrial Research Organisation, Marine and Atmospheric Research, Hobart, Australia





Complex model including photoadaptation, non-photochemical quenching, production of free oxygen radicals, and a temperature-dependent repair rate of the D1 protein.

Model captured the rate of bleaching against DHD, and showed a reduced bleaching under organic nutrient supply vs inorganic nutrient supply.