GISERA
Gas Industry
Social & Environmental
Research Alliance

An integrated study of the Gladstone Marine System

Gladstone Harbour biogeochemical and seagrass growth model

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11–12 August 2015

CSIRO | AUSTRALIA PACIFIC LNG | QGC A BG Group business

Biogeochemical modelling and seagrass.

Project began with a recognition that:

- Seagrass dynamics can only be understood if environmental conditions are well represented ➔ need for a coupled hydrodynamic biogeochemical model.

- Representing light-limitation is critical, and that it is desirable to consider light at multiple wavelengths ➔ spectrally-resolved optical model.

- Existing seagrass models miss processes that observational studies suggest are critical ➔ translocation of biomass between leaves and roots, uptake of nutrients from varying depths in the sediments, physiological differences between seagrass types.

- Model improvements in GISERA would be valuable for future applied studies in Gladstone (GHHP) and along the whole Queensland coast (eReefs).

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CSIRO Environmental Modelling Suite (EMS)
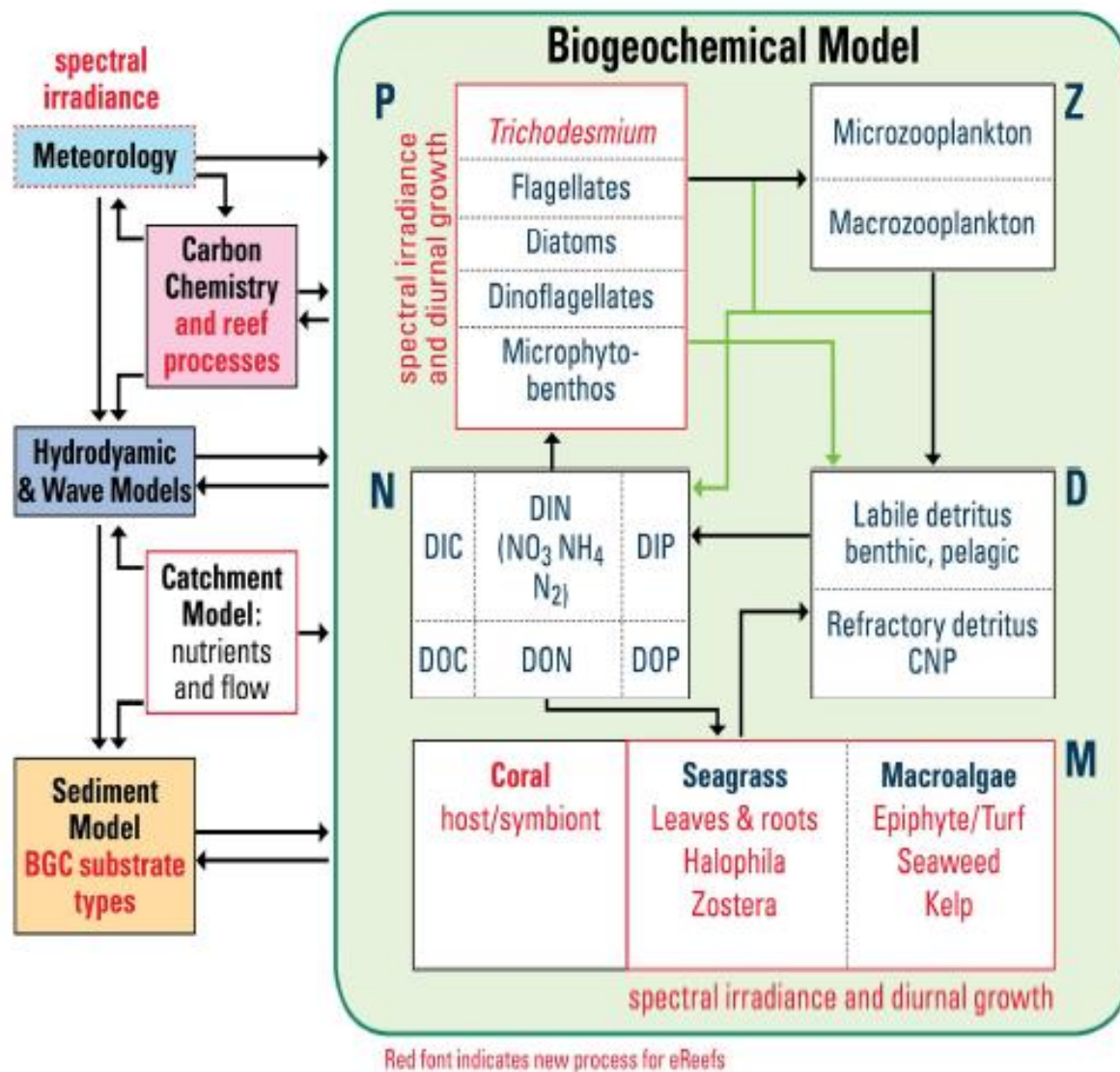
N – nutrients

P – phytoplankton

Z – Zooplankton

D – Detritus

M – Macrophytes.

In biogeochemical model:

Boxes – stores of nutrients

Arrows – fluxes of nutrients.

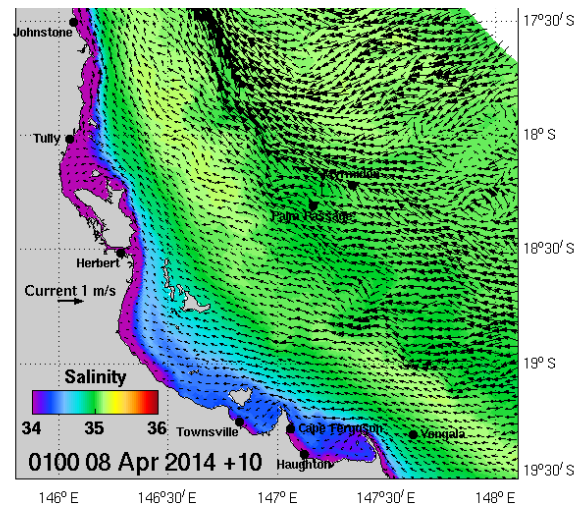# Regional hydrodynamic models

• Hydrodynamic models of 4 km and 1 km forced by global model and 22 rivers.
• Hindcast from Sep 2010 – present day.
• Near real time.
• 4 km version resolves interaction of large rivers, reef matrix, shelf and open ocean.
• 1 km resolves individual reefs, river plumes etc.
• 200 m resolution models forced by GBR4 and GBR1 resolves reef crest / reef lagoon / river entrances.
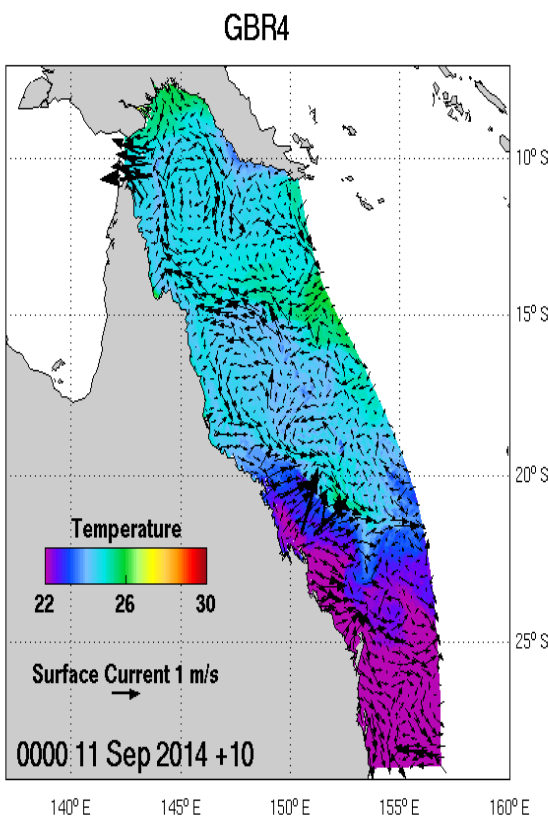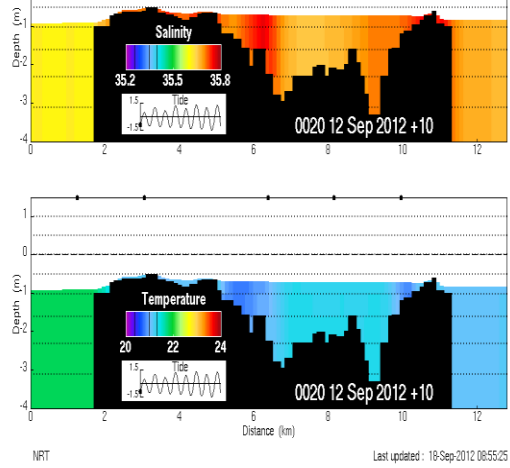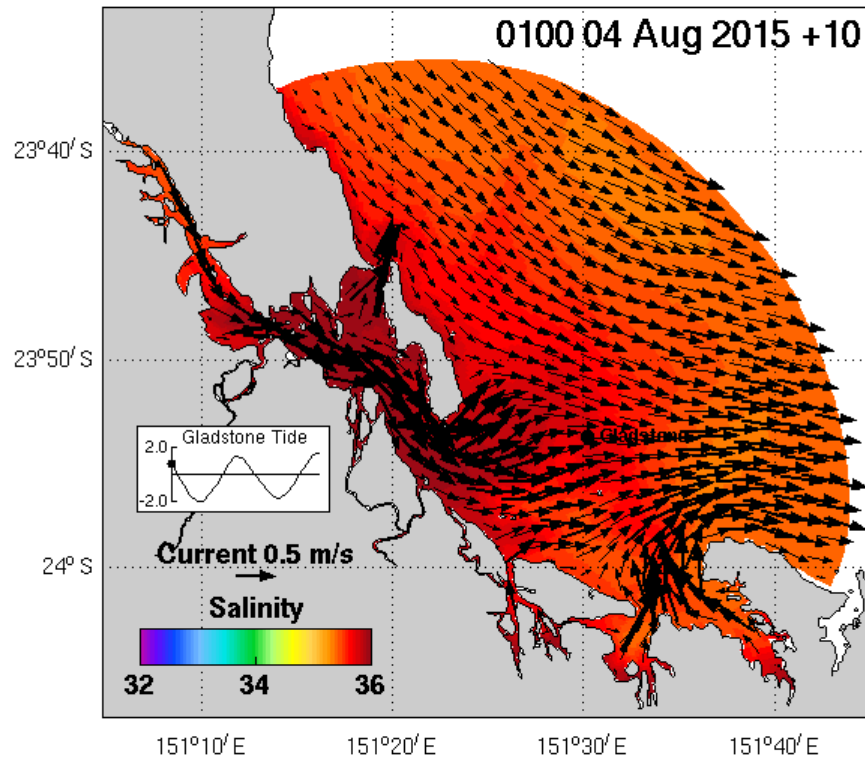

200 m regional models

PORT CURTIS

NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity — 0100 04 Aug 2015 +10

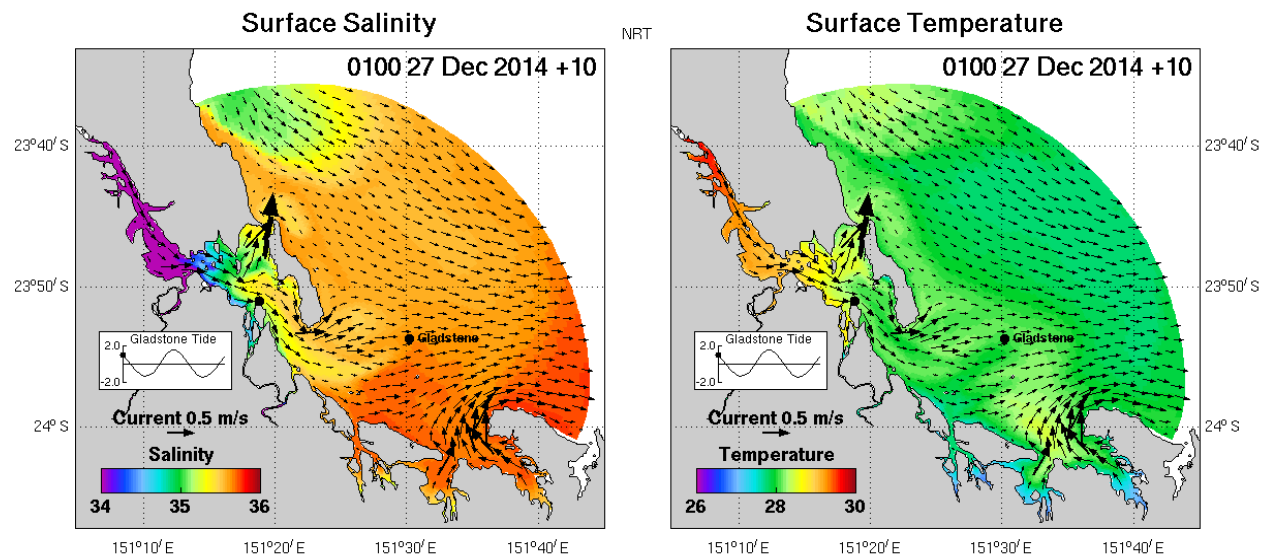Surface Temperature — 0100 04 Aug 2015 +10
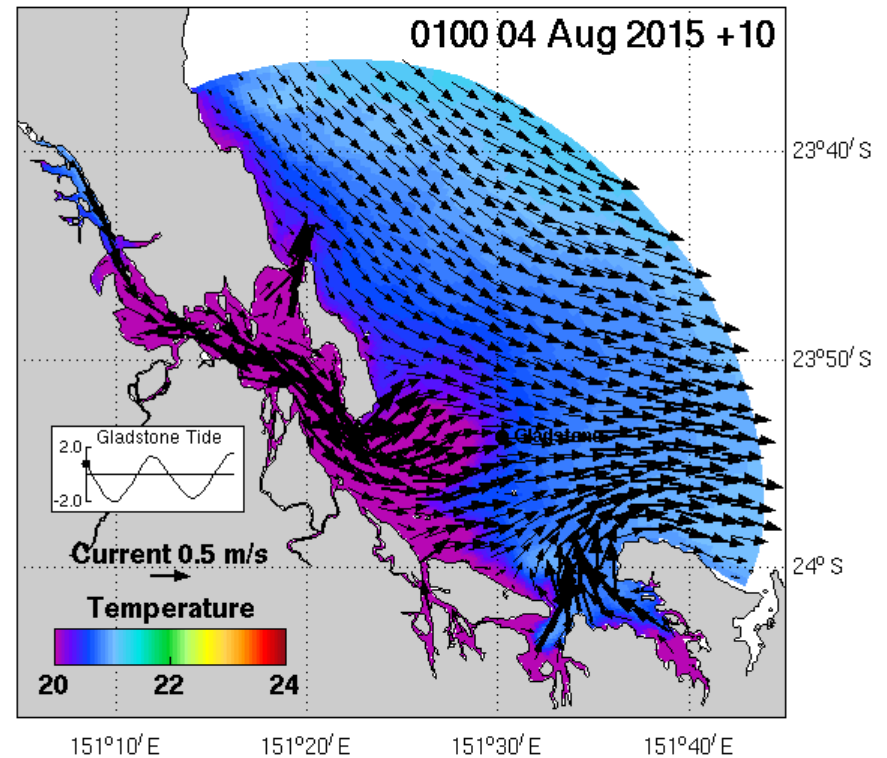
Last updated : 09-Aug-2015 02:11:21

GHHP Harbour Receiving Water Quality Model

• Approx 200 m resolution model hydrodynamic model run for Sep 2010 to present.
• Calliope and Boyne Rivers resolved past the tidal limit.
• Atmospheric forcing from BoM, Calliope and Boyne rivers from QLD govt.
• Assessed against PCIMP sediment and biogeochemical and JCU seagrass observations, but produced without a dedicated observational program.
• Biogeochemical and sediment model ocean boundary conditions provided by eReefs 4 km 2010 hindcast.
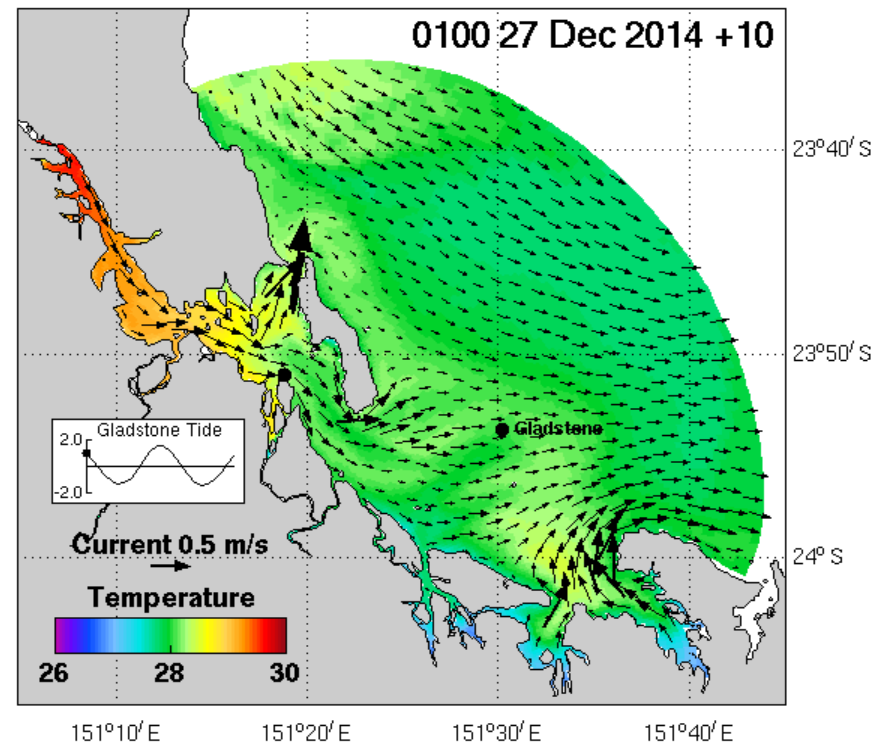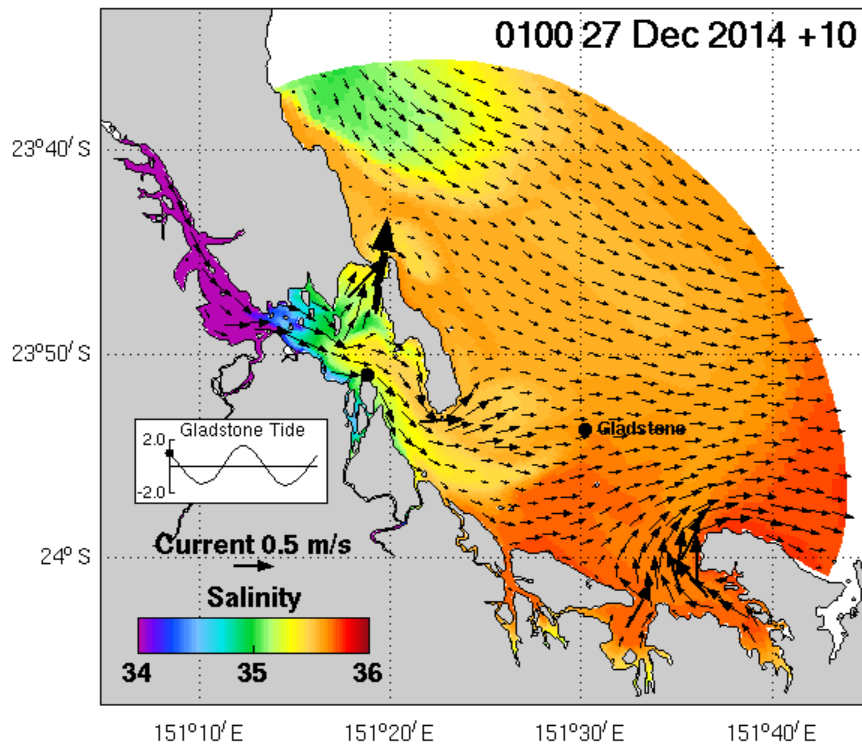
PORT CURTIS

NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity

0100 27 Dec 2014 +10

NRT

Surface Temperature

0100 27 Dec 2014 +10

Gladstone Tide

Current 0.5 m/s

Salinity

34   35   36

Gladstone Tide

Current 0.5 m/s

Temperature

26   28   30

Last updated : 12-Jan-2015 02:02:28

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PORT CURTIS

NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity — 0100 27 Dec 2014 +10

Surface Temperature — 0100 27 Dec 2014 +10

NRT

Last updated : 12-Jan-2015 02:02:28

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Sediment transport model

- Simulates sinking, deposition and resuspension of suspended sediment

- Adds a multilayer sediment bed to the EMS grid

- Is driven by 3-D hydrodynamics and wave data

- Provides physical settings to simulate biogeochemical model

WATER COLUMN

Advection Diffusion   Settling   Flocculation

Resuspension
Deposition
Bioturbation

Consolidation   Bioturbation

SEDIMENT BED
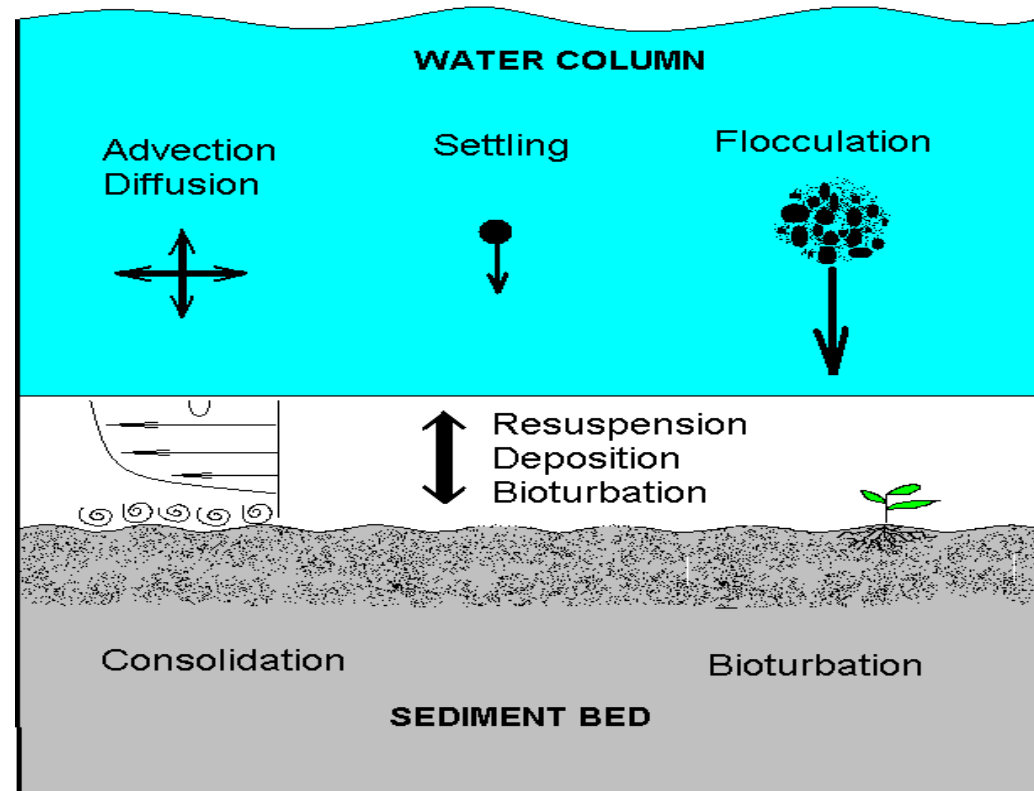
Optical model

Spectrally-resolved vertical attenuation of light due to scattering and absorption of (19 optically-active components in total):
• 4 phytoplankton classes with two pigments
• Coloured dissolved organic matter
• Suspended inorganic particles and detritus
• water molecules
• Bottom substrates – seagrass, macroalgae, benthic microalgae, corals (skeletons and symbionts).
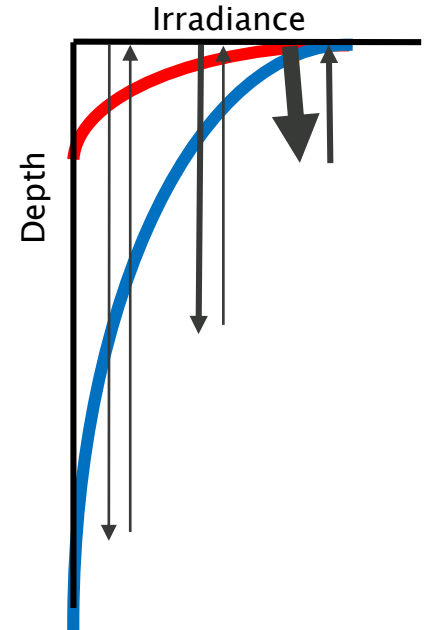
Remote-sensing reflectance seen at surface (i.e. viewed by a satellite) comes from reflectance all depths ~ weighted by optical depth

Irradiance

Depth

Only about 3 % of light returns

Optical model – Inherent Optical Properties (IOPs) from model state.

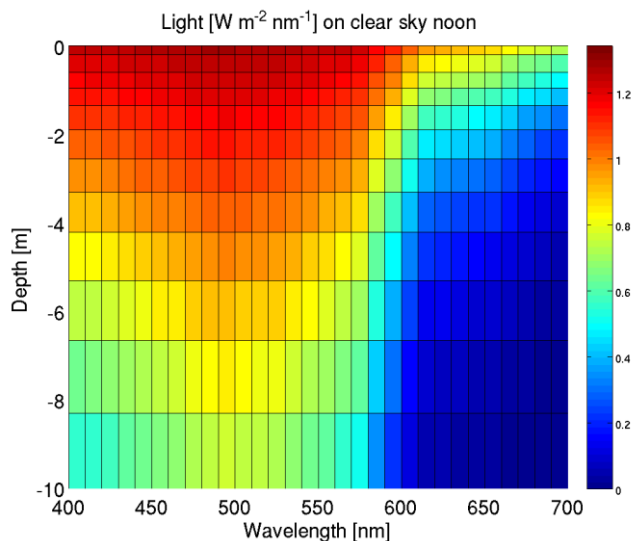Suspended sediment properties – scattering / attenuation observations from an acs.
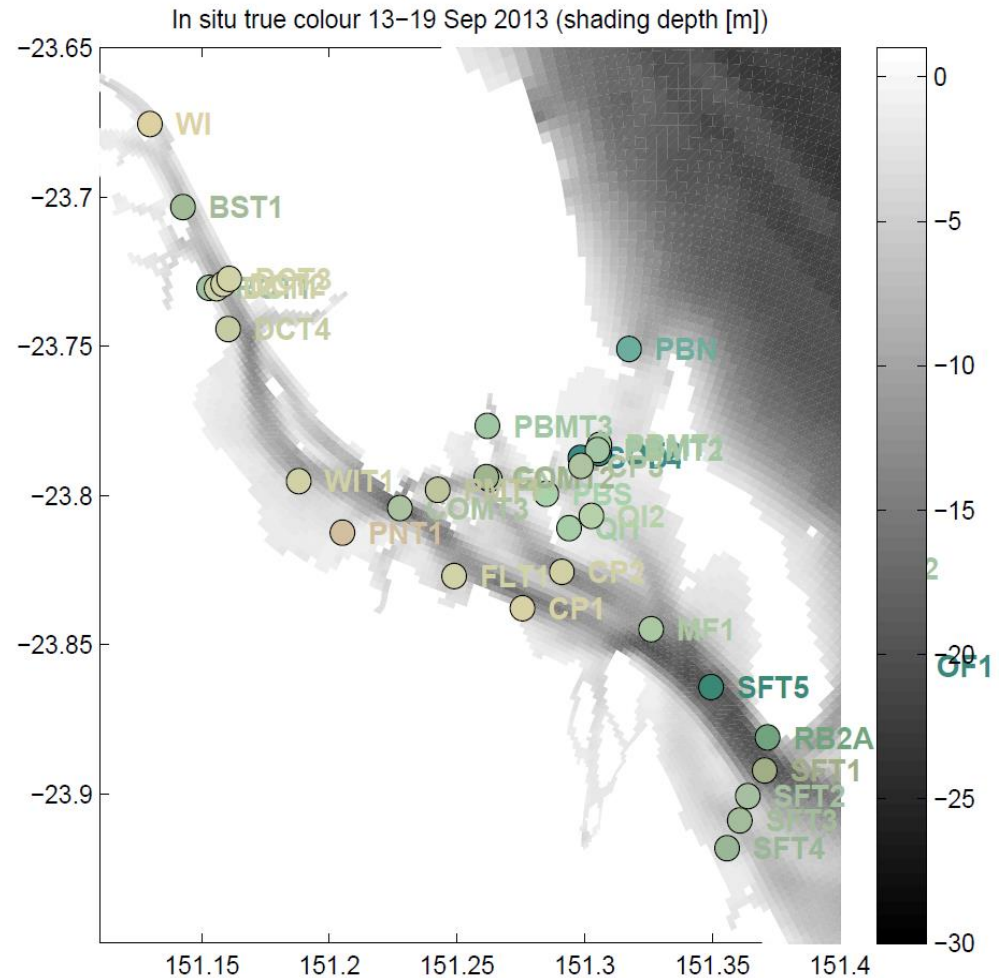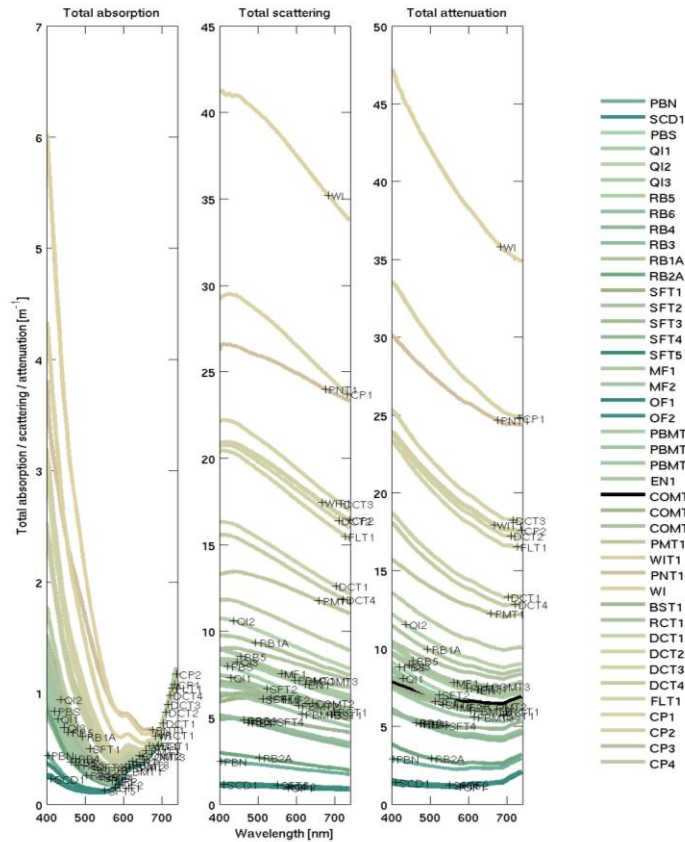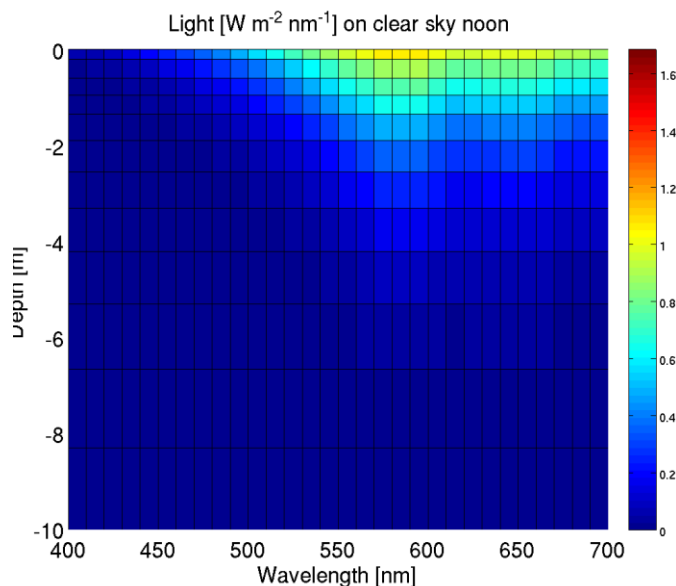
Results from optical model

Optical model produces spectrally-resolved depth profile:
- Distinguish between impact of
  - sediment plume (scattering)
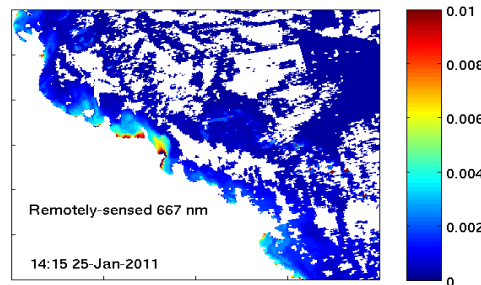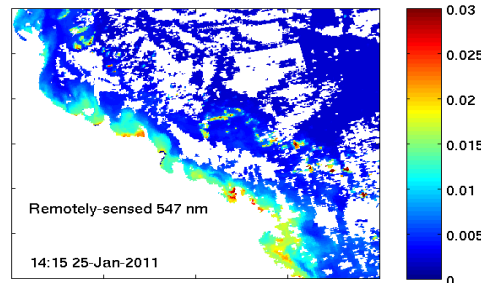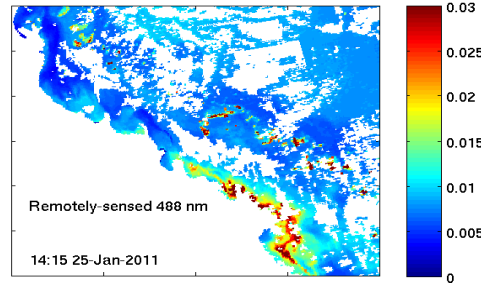 - Phtyoplankton bloom (absorption at chl. pigment maximum

Offshore

Narrows
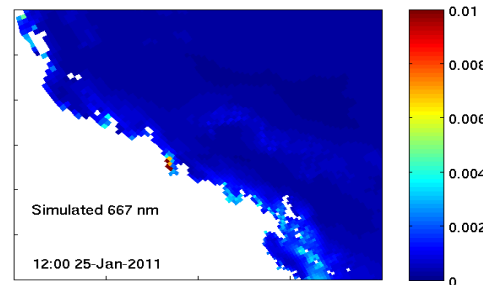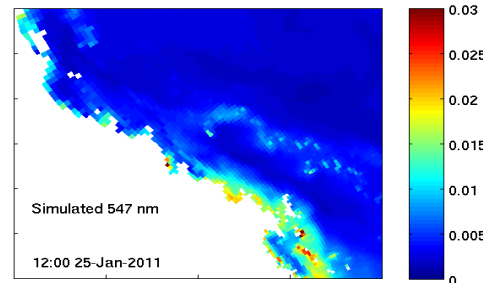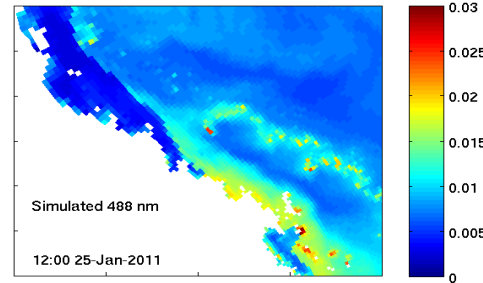
Atmospherically-corrected   Simulated

Observation of top of atmosphere (TOA) reflectance corrected for atmospheric scattering and absorption to obtain, cloud permitting, reflectance as viewed at a solid angle, R_{rs} [sr^{-1}]
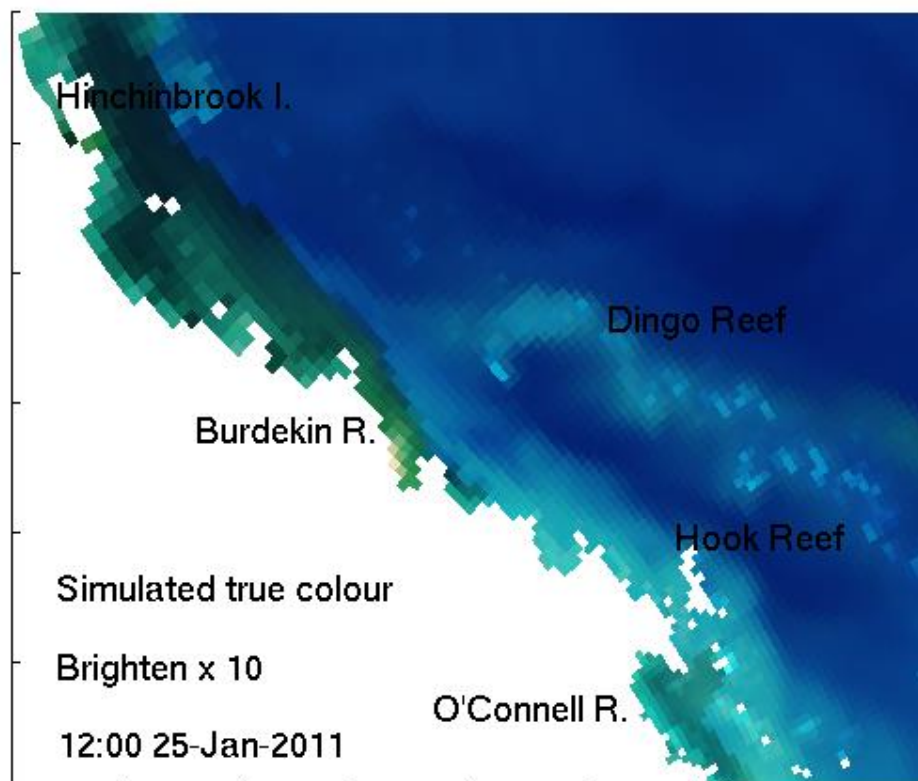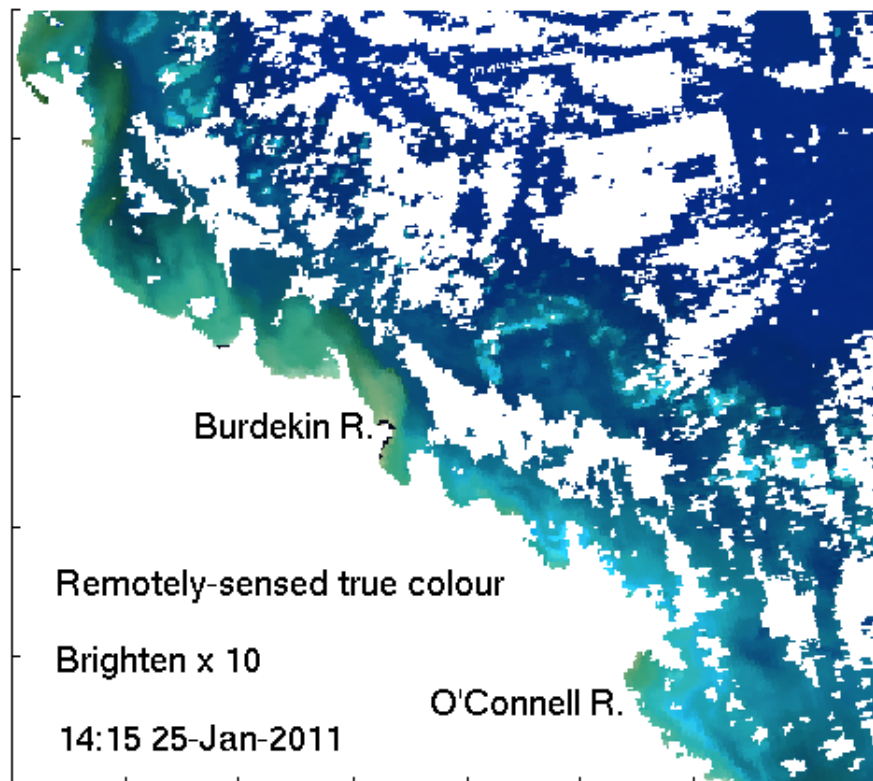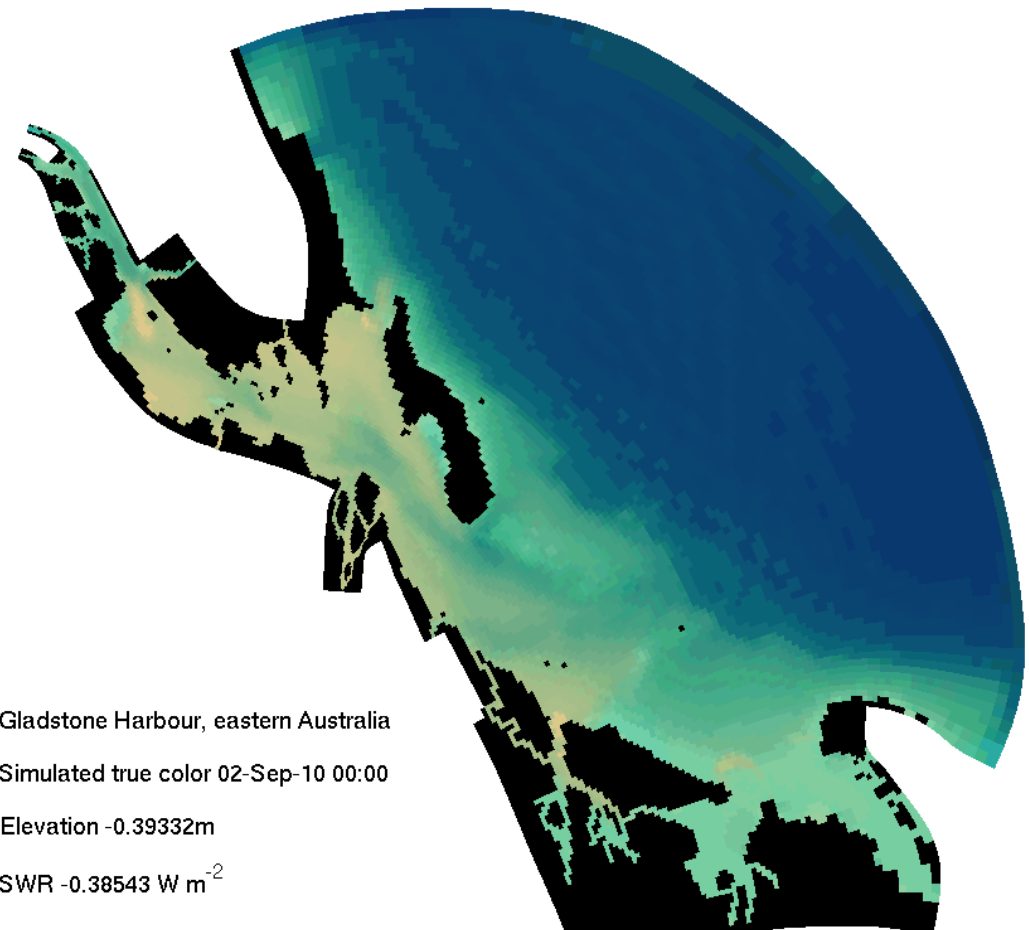
Optical-depth weighted reflectance as a result of 20 optically-active constituents initialised 100 days earlier, and transported, biogeochemically-transformed, flocculated and resuspended, to determine reflectance at any time, viewed at a solid angle, R_{rs} [sr^{-1}]

Remotely-sensed 488 nm
14:15 25-Jan-2011

Simulated 488 nm
12:00 25-Jan-2011

Remotely-sensed 547 nm
14:15 25-Jan-2011

Simulated 547 nm
12:00 25-Jan-2011

Remotely-sensed 667 nm
14:15 25-Jan-2011

Simulated 667 nm
12:00 25-Jan-2011

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Remotely-sensed true colour

Brighten x 10

14:15 25-Jan-2011

Burdekin R.

O'Connell R.

Hinchinbrook I.

Dingo Reef

Burdekin R.

Hook Reef

Simulated true colour

Brighten x 10

12:00 25-Jan-2011

O'Connell R.

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Simulated true colour
animation in September
2010

Gladstone Harbour, eastern Australia

Simulated true color 02-Sep-10 00:00

Elevation -0.39332m

SWR -0.38543 W m^{-2}

Seagrass model.

• Two seagrass types: Zostera and Halophila.
• Resolve above and below ground biomass.
• Spectrally-resolved absorption
• At low biomass, absorption is a linear function of biomass
• At high biomass independent of biomass.
• Curve follows a cumulative Poisson dist of probability of leaves covering each other as shown by the '+'.

Seagrass spectral absorbance [K. Petrou, UTS]

$$\% \text{ cover} = 1-\exp(-\Omega B)$$

Thanks to Matthew Adams, UQ
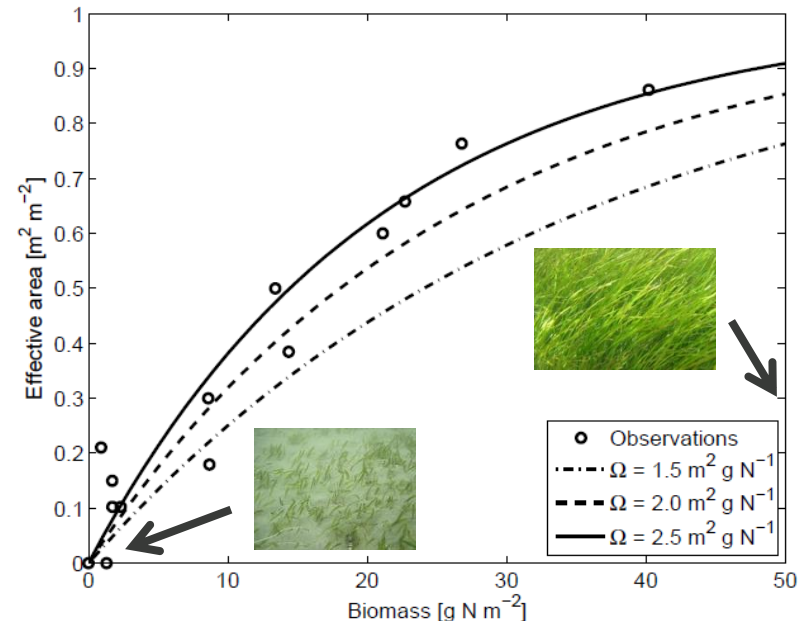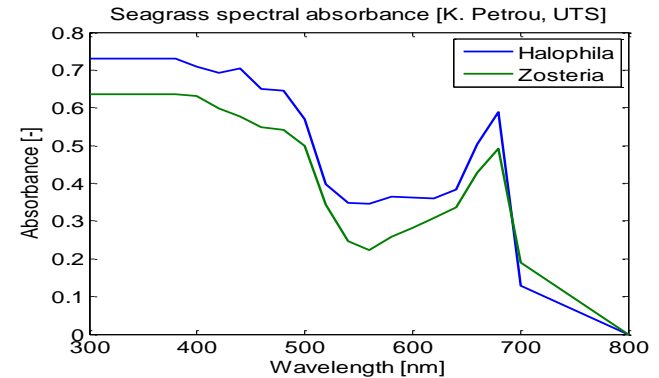
Results

**What determines the light available to seagrass communities?**

- Solar radiation (clouds etc.)

- Depth of water (varies with site, and point in tide)

- Vertical attenuation coefficient (K_d) that varies with suspended solids, chlorophyll concentration.

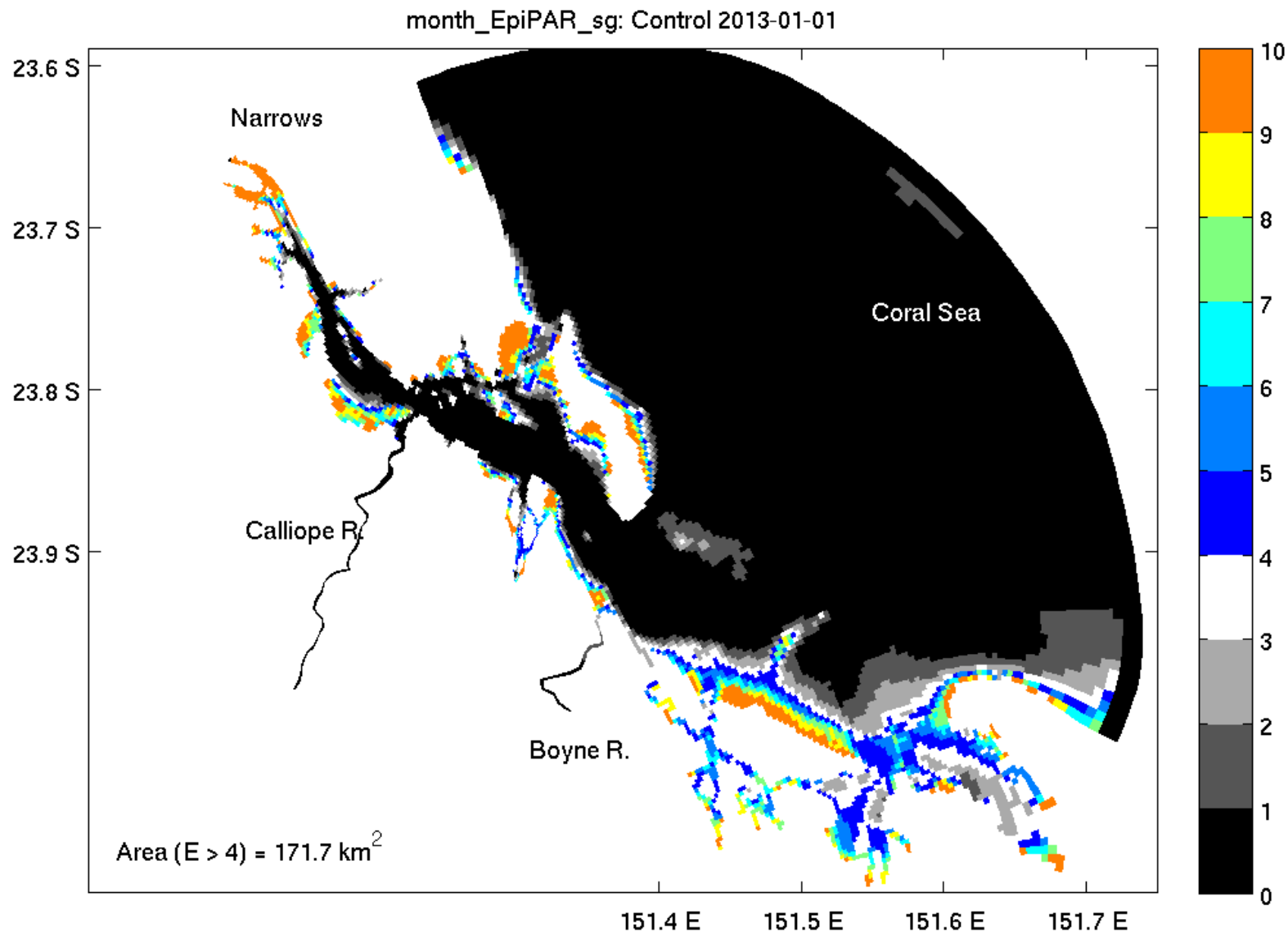- Seagrass growth depends on the recent light history (see production).
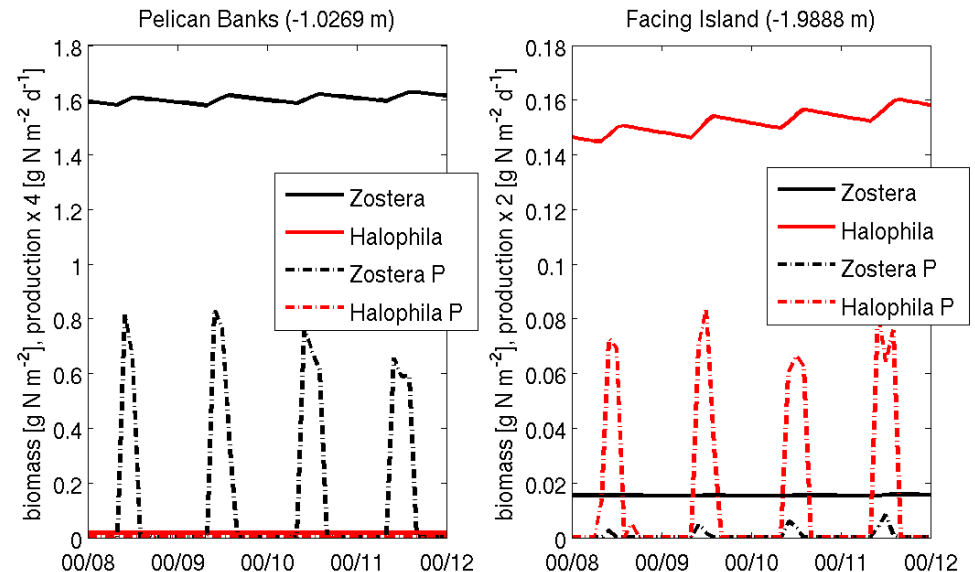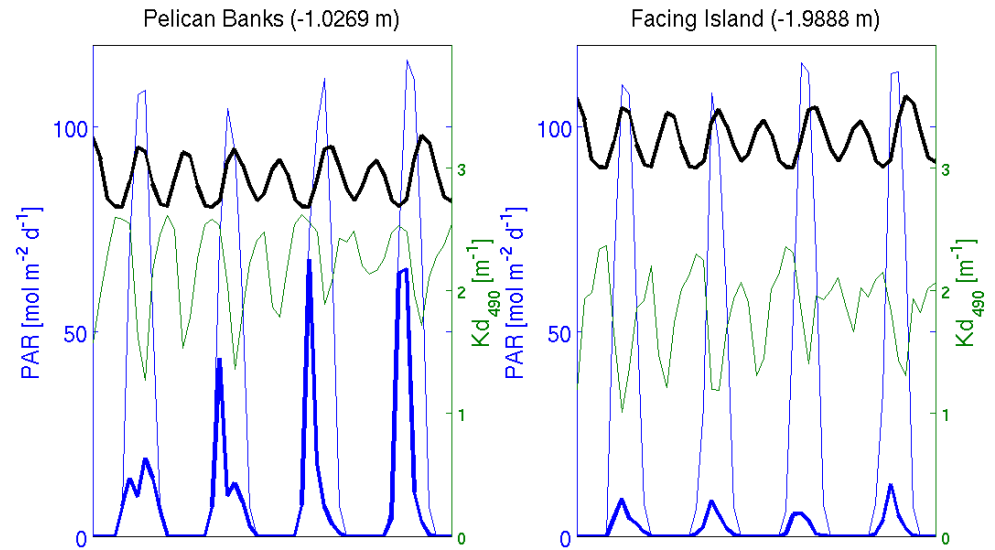
Comparison of GHHP
configuration multi-species
seagrass distribution after 2
year simulation with
observed mean distribution
over 2002-2012.

Model is spatially more
homogenous, but generally
produces realistic biomass
and distribution of shallow
and deeper water seagrass.

Thank you to the JCU
TropWATER for providing
the raw observations.

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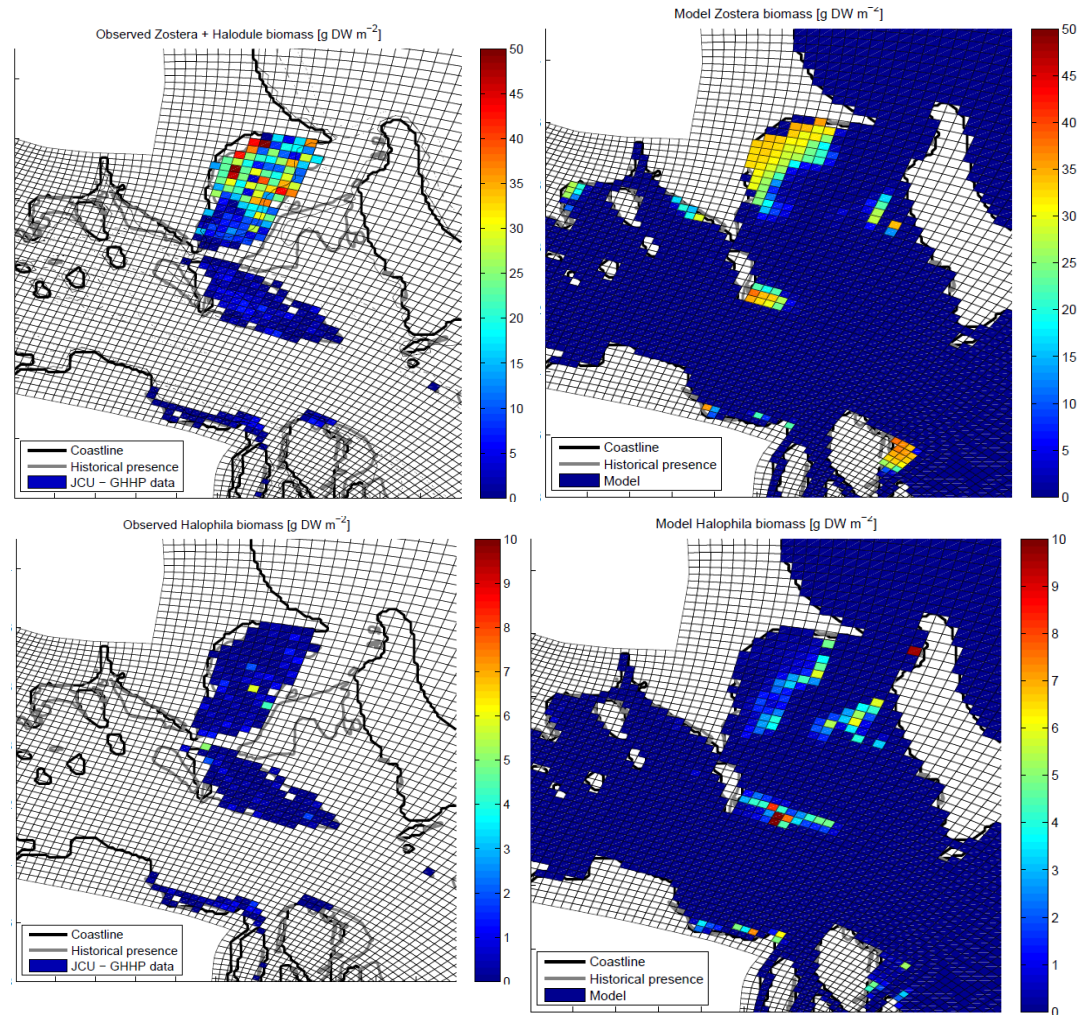
Running average monthly light above seagrass.

month_EpiPAR_sg: Control 2013-01-01

Thank you

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Gladstone Harbour, eastern Australia

Simulated true color 02-Sep-10 00:00

Elevation -0.39332m

SWR -0.38543 W m^{-2}