eReefs is a collaboration between:

GREAT BARRIER REEF foundation · Australian Government Bureau of Meteorology · CSIRO · Australian Government Australian Institute of Marine Science · Queensland Government

Supported by funding from:

Caring for our Country · Queensland Government · Science and Industry Endowment Fund · bhpbilliton resourcing the future · BMA BHP Billiton Mitsubishi Alliance

eReefs Hydrodynamic Overview.

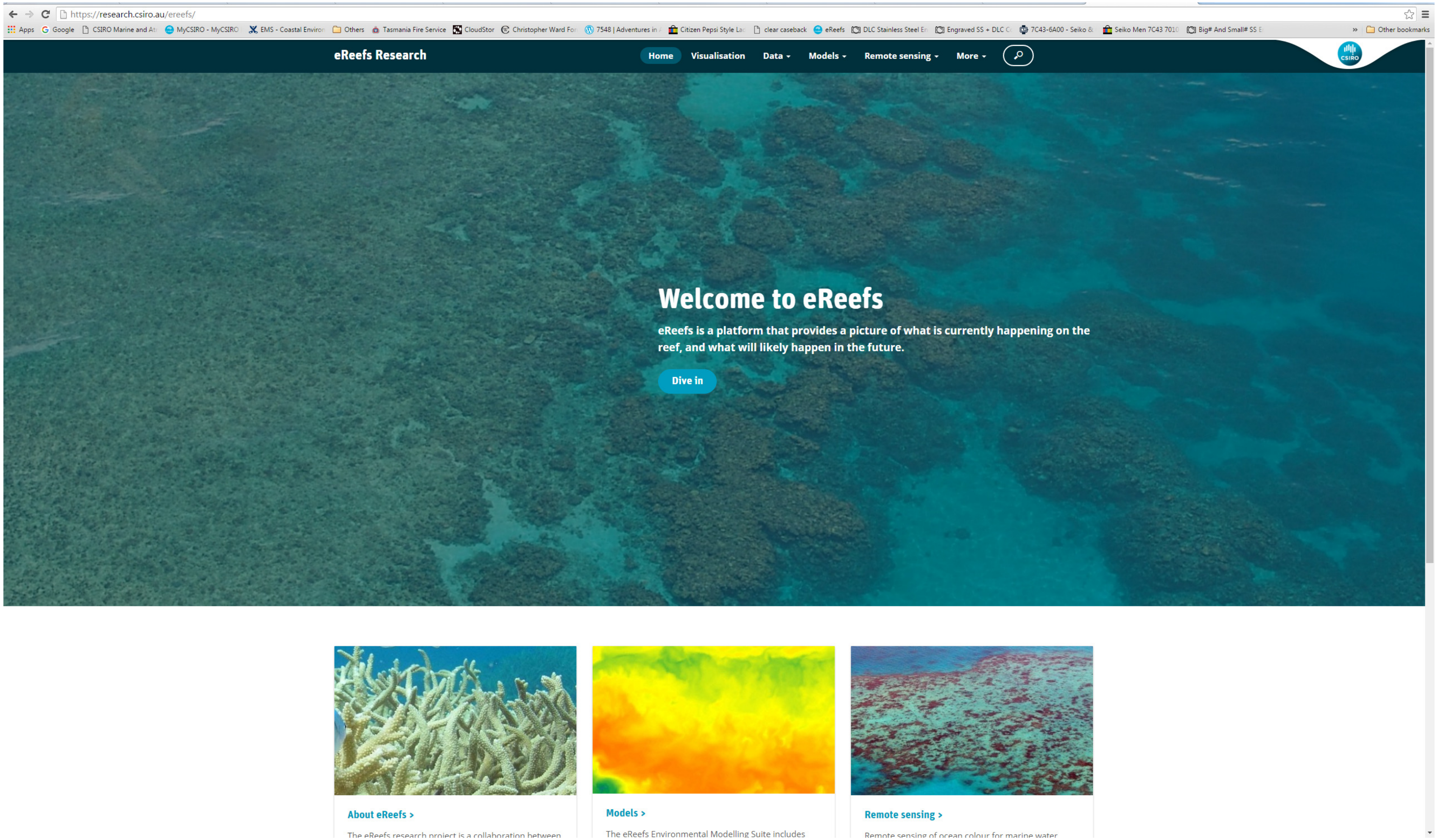
Mike Herzfeld

April 2016

O&A

www.csiro.au

eReefs website : https://research.csiro.au/ereefs/



Publications

ELSEVIER
Contents lists available at ScienceDirect
Ocean Modelling
journal homepage: www.elsevier.com/locate/ocemod

Active open boundary forcing using dual relaxation time-scales in downscaled ocean models

CrossMark

M. Herzfeld[a,*], P.A. Gillibrand[b]
[a] CSIRO Division of Marine and Atmospheric Research, GPO Box 1538, Hobart TAS 7001, Australia
[b] Environmental Research Institute, North Highland College, University of the Highlands and Islands, Thurso, Caithness KW14 7EE, UK

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Methods for freshwater riverine input into regional ocean models

CrossMark

M. Herzfeld[*]
CSIRO Division of Marine and Atmospheric Research, GPO Box 1538, Hobart, TAS 7001, Australia

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Contents lists available at ScienceDirect
Continental Shelf Research
journal homepage: www.elsevier.com/locate/csr

Research papers

Cross-shelf exchanges between the Coral Sea and the Great Barrier Reef lagoon determined from a regional-scale numerical model

CrossMark

Andreas Schiller[a,*], Mike Herzfeld[a], Richard Brinkman[b], Farhan Rizwi[a], John Andrewartha[a]
[a] CSIRO Oceans and Atmosphere, GPO Box 1538, Hobart, TAS 7001, Australia
[b] Australian Institute of Marine Science, PMB 3, Townsville, QLD 4810, Australia

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

A mass-conserving advection scheme for offline simulation of scalar transport in coastal ocean models

CrossMark

P.A. Gillibrand[a,*], M. Herzfeld[b]
[a] Environmental Research Institute, North Highland College, University of the Highlands and Islands, Thurso KW14 7EE, UK
[b] CSIRO Division of Marine and Atmospheric Research, GPO Box 1538, Hobart, Tas. 7001, Australia

Monitoring, Predicting, and Managing One of the Seven Natural Wonders of the World

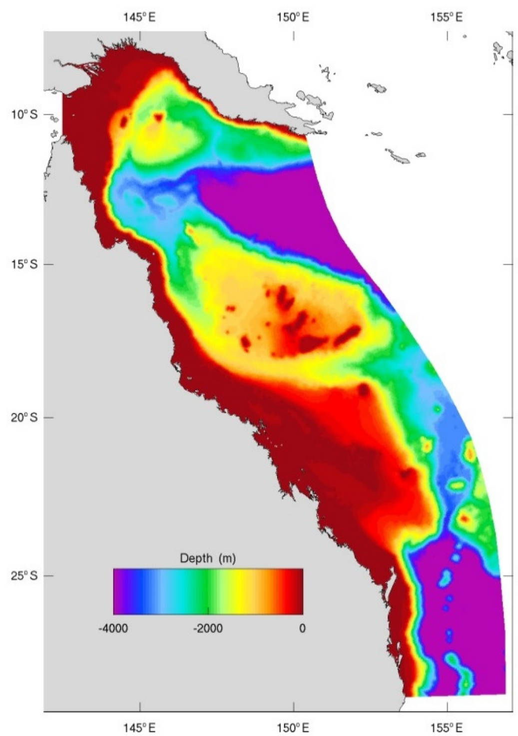
BY ANDREAS SCHILLER, MIKE HERZFELD, RICHARD BRINKMAN, AND GREG STUART

CSIRO

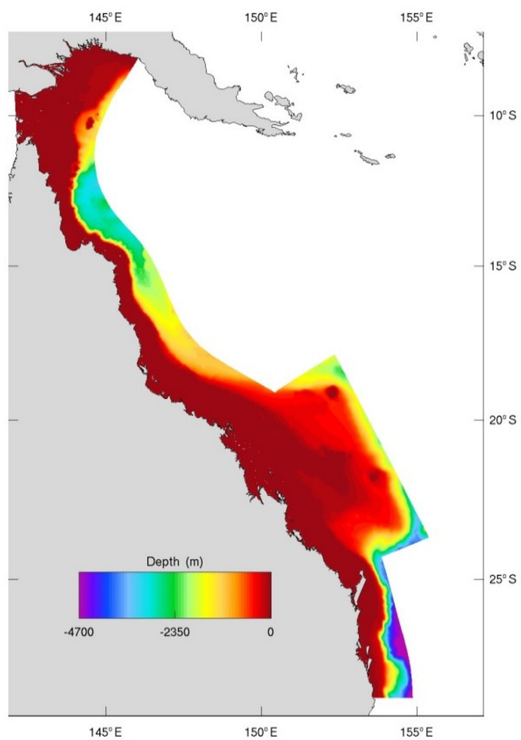
eReefs regional marine models

- Hydrodynamic models of 4 km and 1 km forced by OceanMAPS global model, ACCESS meteorology and 25 rivers.
- Hindcast from Sep 2010 – present day.
- Near real time.
- 4 km version resolves interaction of large rivers, reef matrix, shelf and open ocean.
  - Suitable for broad scale investigations,
  - Computationally efficient,
  - Bridging model for global model.
- 1 km resolves individual reefs, river plumes etc.
  - Suitable for more regional scale investigations,
  - Computationally inefficient.
- Supplies boundary and initial conditions to RECOM.

Model bathymetry



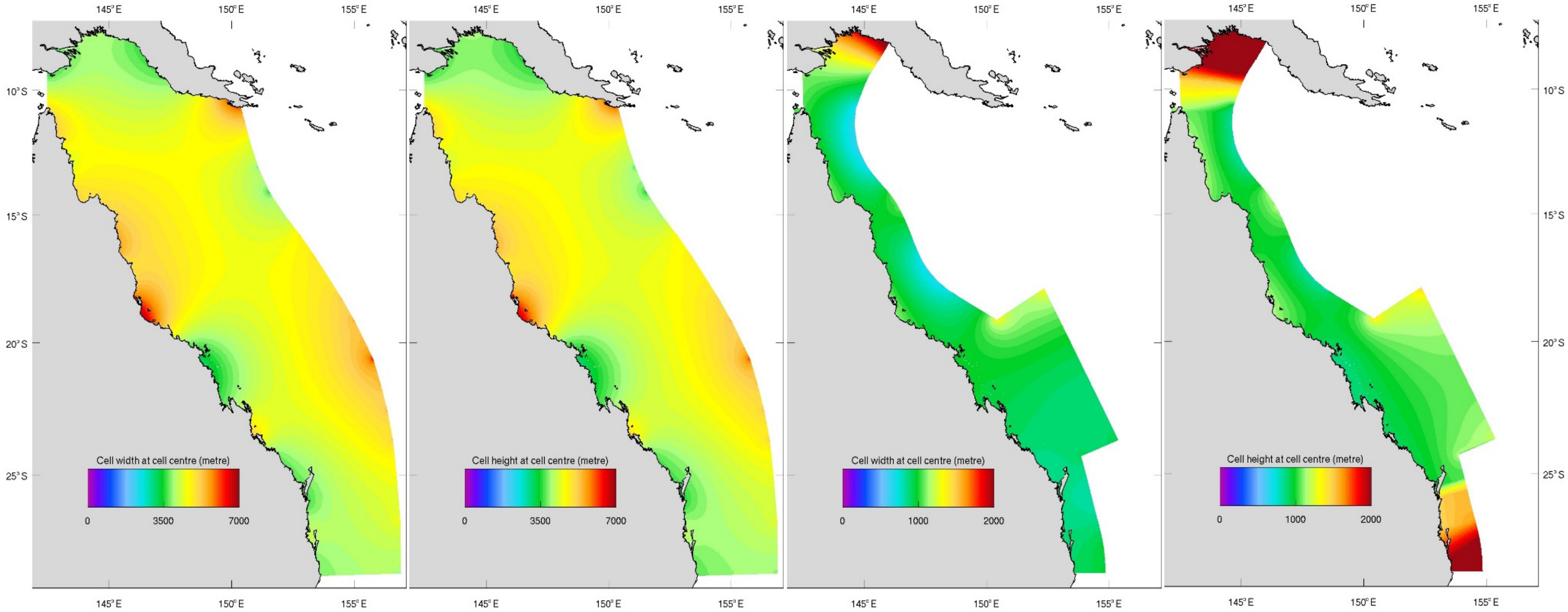
GBR4



GBR1

Bathymetry from Beaman (2010), http://www.deepreef.org/

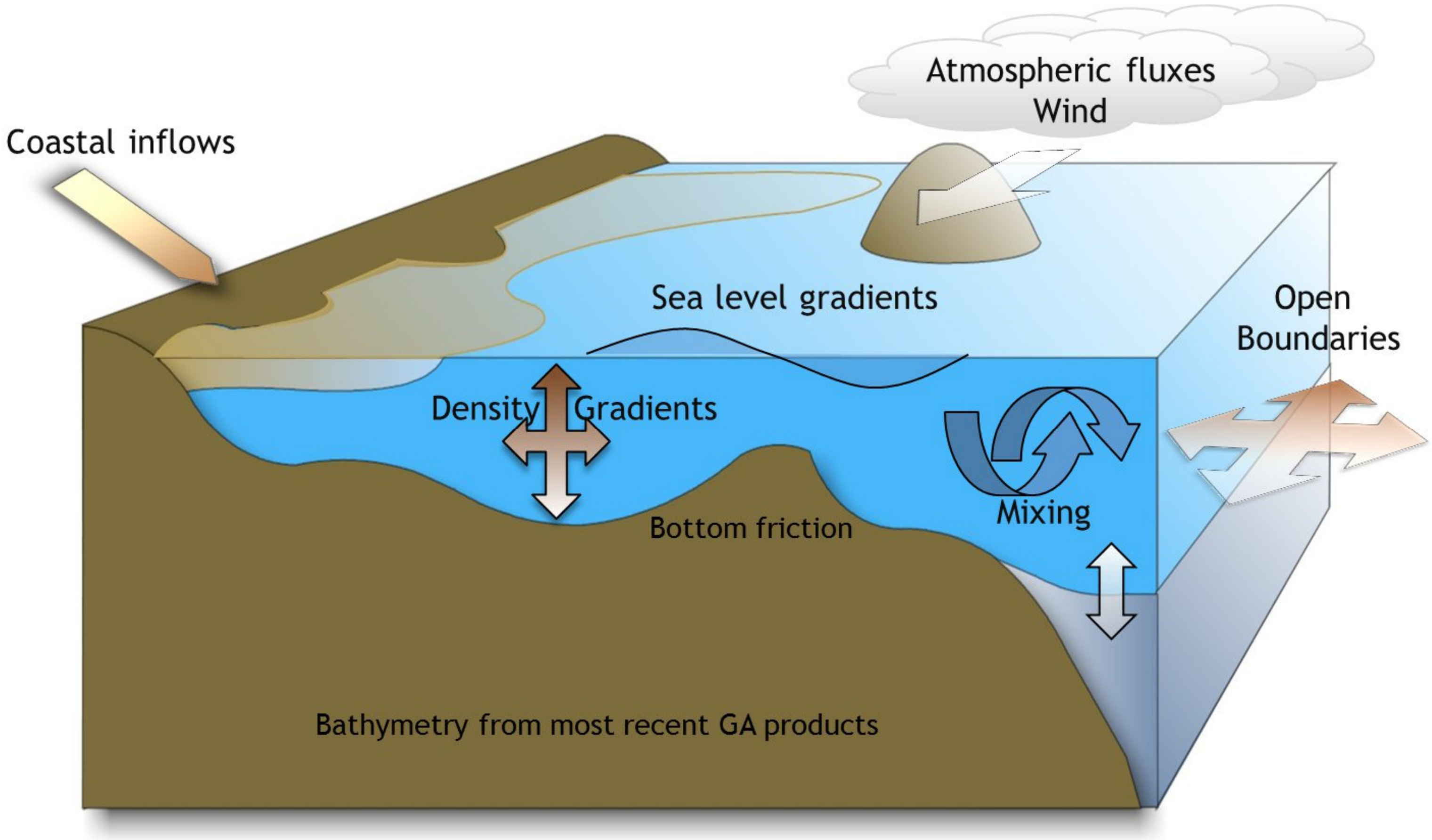
Model resolution



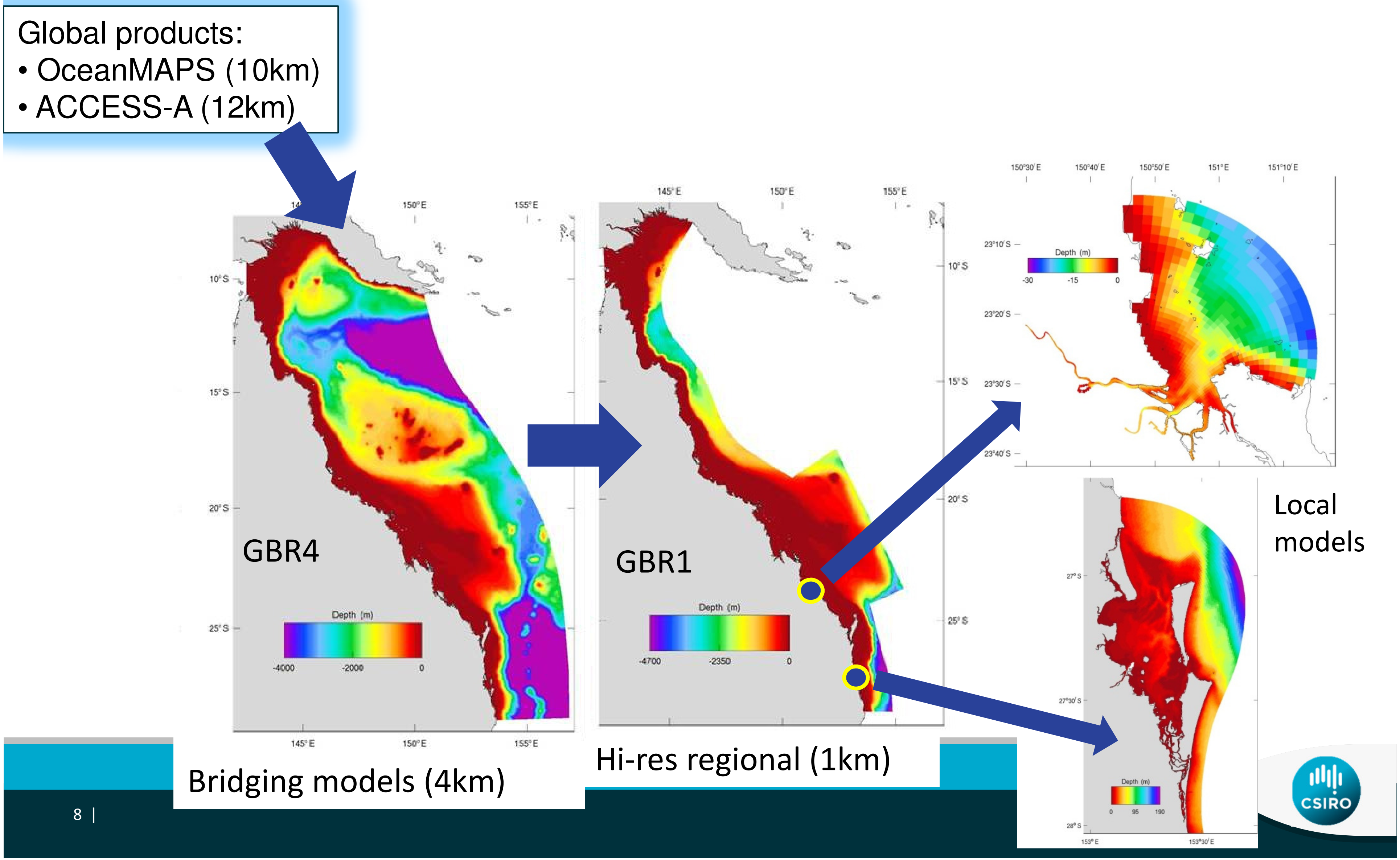
GBR4 : average ~4km

GBR1 : average ~1km

Conceptual hydrodynamic forcing



eReefs nested marine modelling suite



Prioritized freshwater inputs

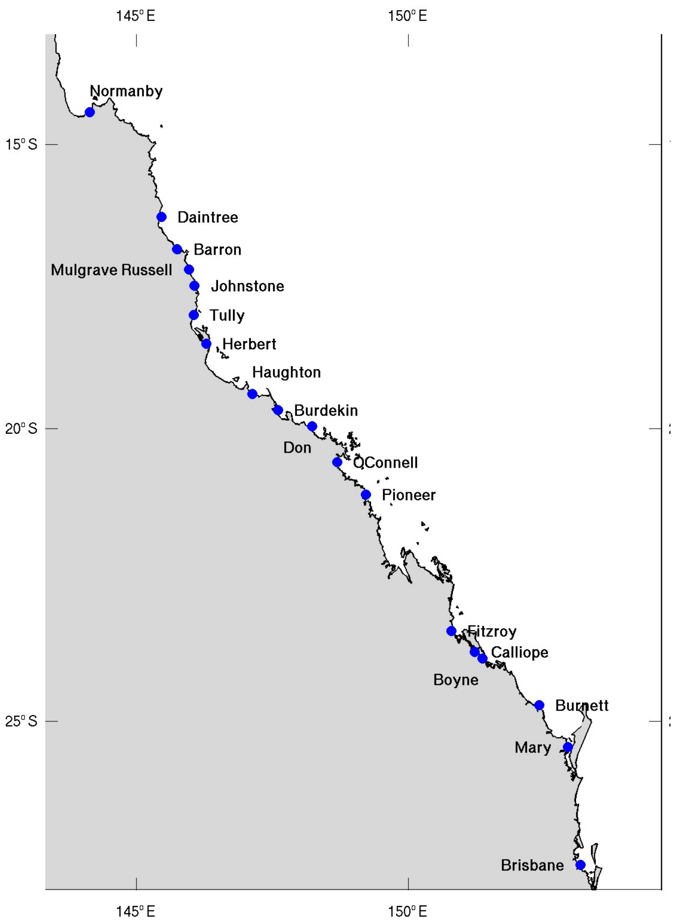
Table 4: Prioritised rivers in GBR province based on the load analysis in Appendix C of the top 6, 12 and 18 rivers. Asterisk (*) indicates that the system is not in *eReefs* models.

Rivers and Estuaries			
Top 6	Top 12	Top 18	Low Priority
Burdekin	*top 6 plus:*	*top 12 plus:*	*top 18 plus:*
Fitzroy	Herbert	Daintree	Don
Mary	Burnett	Endeavour*	Pioneer
Normanby	Plane Creek*	Proserpine*	Jeannie*
Mulgrave-Russell	O'Connell	Baffle*	Styx*
Johnstone	Olive-Pascoe*	Haughton	Lockhart*
	Tully	Jacky-Jacky*	Murray*
			Ross*
			Calliope
			Burrum*
			Stewart*
			Black*

Continuous Water Quality Monitoring on the Great Barrier Reef | 46

From: Steven, ADL, Hodge, J, Cannard, T, Carlin, G, Franklin, H, McJannet, D, Moeseneder, C, Searle, R, 2014. Continuous Water Quality Monitoring on the Great Barrier Reef. CSIRO Final Report to Great Barrier Reef Foundation, 1598pp.

Freshwater inputs



Name	Wet / dry	Annual Volume (km^3)	Monthly Mean (ML)
Cape York Region			
Normanby River	Wet	4.95	8229
Wet Tropics Region			
Barron River	Wet	0.81	1777
Daintree River	Wet	1.26	2418
Mulgrave-Russell Rivers	Wet	3.64	2186
Johnstone River	Wet	4.67	2229
Tully River	Wet	3.29	8571
Herbert River	Wet	4.01	6884
Burdekin Region			
Haughton River	Dry	0.74	1149
Burdekin River	Dry	10.29	24,539
Don River	Dry	0.75	494
Mackay Whitsunday Region			
O'Connell River	Dry	1.54	683
Pioneer River	Dry	1.19	3586
Fitzroy Region			
Fitzroy River	Dry	6.08	14,708
Calliope	Dry	0.3	456
Boyne	Dry	0.29	-
Burnett Mary Region			
Burnett River	Dry	1.15	3248
Mary River	Dry	2.72	4031
Other			
Brisbane River	-	-	-
Caboolture River	-	-	-
Pine River	-	-	-
Logan River	-	-	-
Fly River	-	-	-

(~70 inputs – not all turned on)

Surface fluxes

- ACCESS-A provides surface meteorological fluxes (wind, mean sea level pressure, cloud amount, air temperature and dew point temperature, precipitation)
  - Wind – converted to stress using bulk scheme of Large and Pond (1981)
  - Sensible and latent heat fluxes use the bulk scheme of Kondo (1975)
  - Cloud corrected short wave radiation (Reed, 1977)
  - Short wave radiation partitioned between surface and depth
  - Long wave radiation computed using Zillman (1972)
  - Evaporation estimated using latent heat fluxes

Boundary fluxes

- Initial and boundary ocean conditions supplied by OceanMAPS
  - Daily mean velocity, sea level, temperature and salinity
  - Tide added using the CSR tide model (Cartwright and Ray, 1990)
  - Open boundary condition uses the scheme of Herzfeld and Andrewartha
  - Conservative open boundary for temperature, salinity and sea level

Ocean Modelling 27 (2009) 18–32

Contents lists available at ScienceDirect

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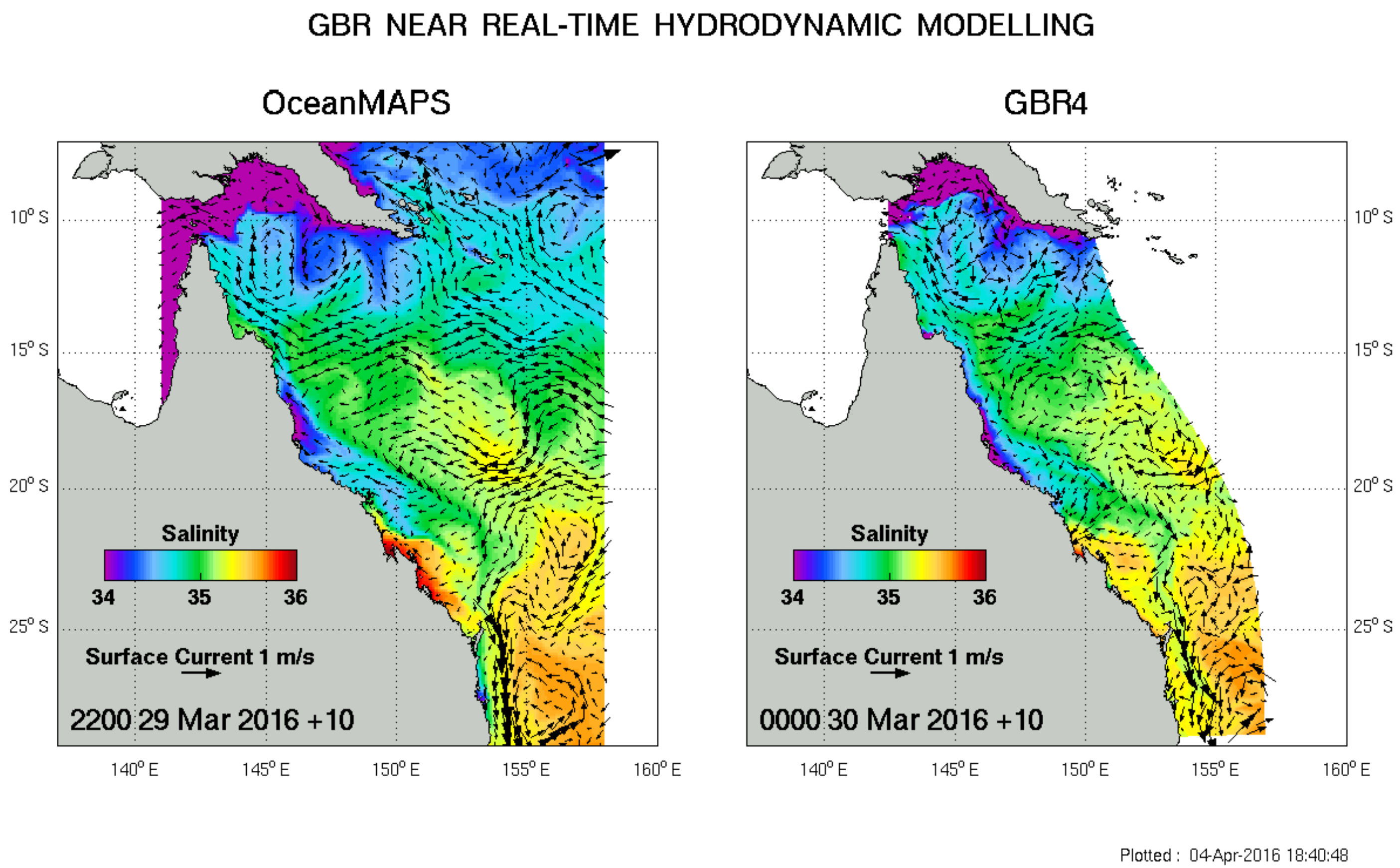
The role of numerical implementation on open boundary behaviour in limited area ocean models

M. Herzfeld *

CSIRO Division of Marine and Atmospheric Research, GPO Box 1538, Hobart TAS 7001, Australia

CSIRO

GBR4 and GBR1 operate routinely in real-time



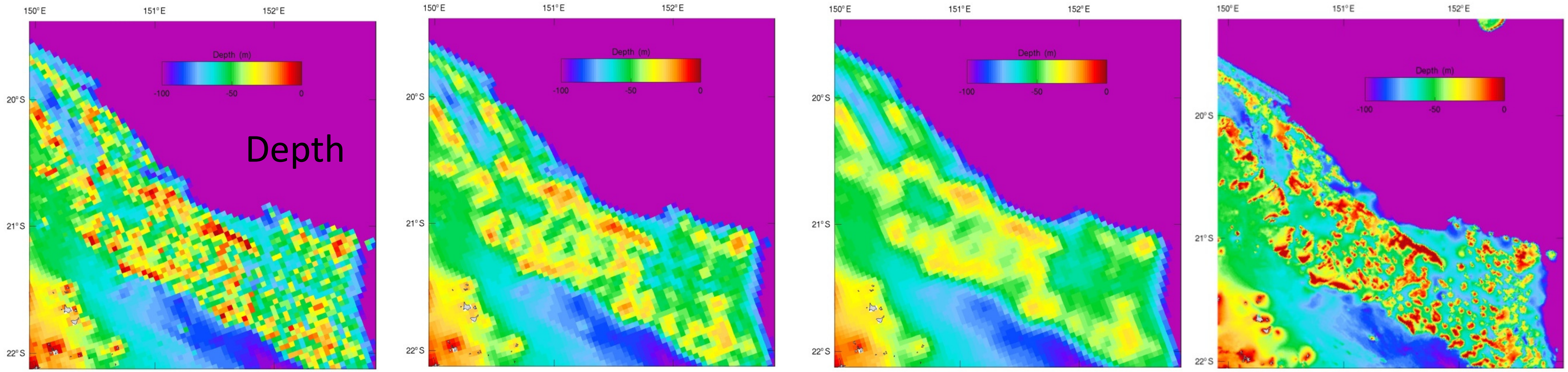
GBR4 : Model results archived since July 2010
GBR1: Model results archived since December 2014

Challenges

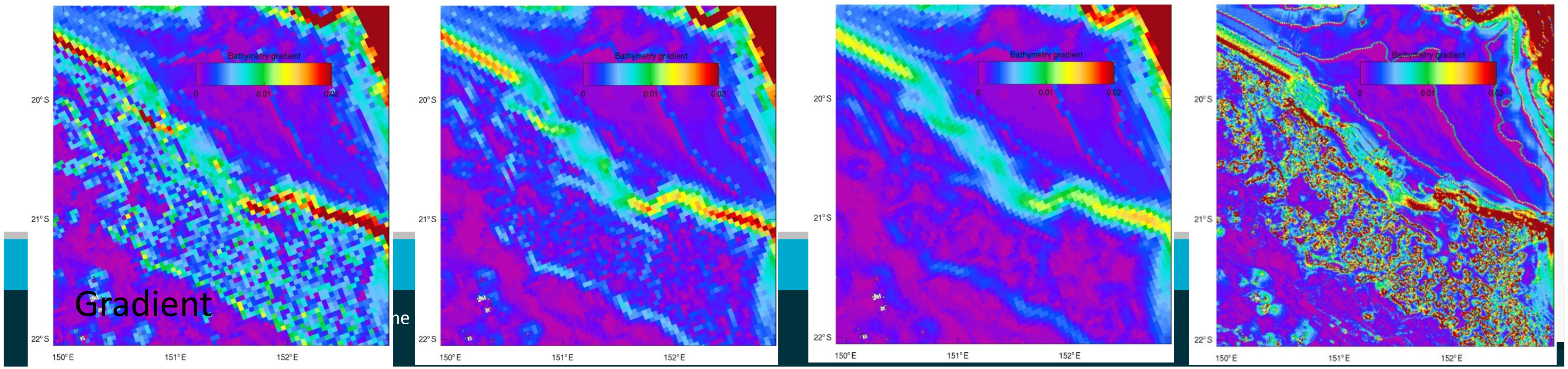
- Bathymetry
  - Wetting and drying,
  - Sub-grid reef parameterization.
- Open boundaries
  - Dirichlet method developed (Herzfeld & Andrewartha, 2012),
  - Dual relaxation in flux adjustment to account for low and tidal frequencies,
  - Conserves mass and volume in the boundary cell.
- River input
  - Based on the Dirichlet method,
  - Allows for brackish input at the coast,
  - Dynamic pycnocline adjustment.
- Short wave parameters
  - Uses bottom absorption,
  - Spatially varying using EnKF parameter estimation.
- 1km model throughput
  - Distributed processing cast for slave-slave transfers.

Capricorn Bunker Group Bathymetry

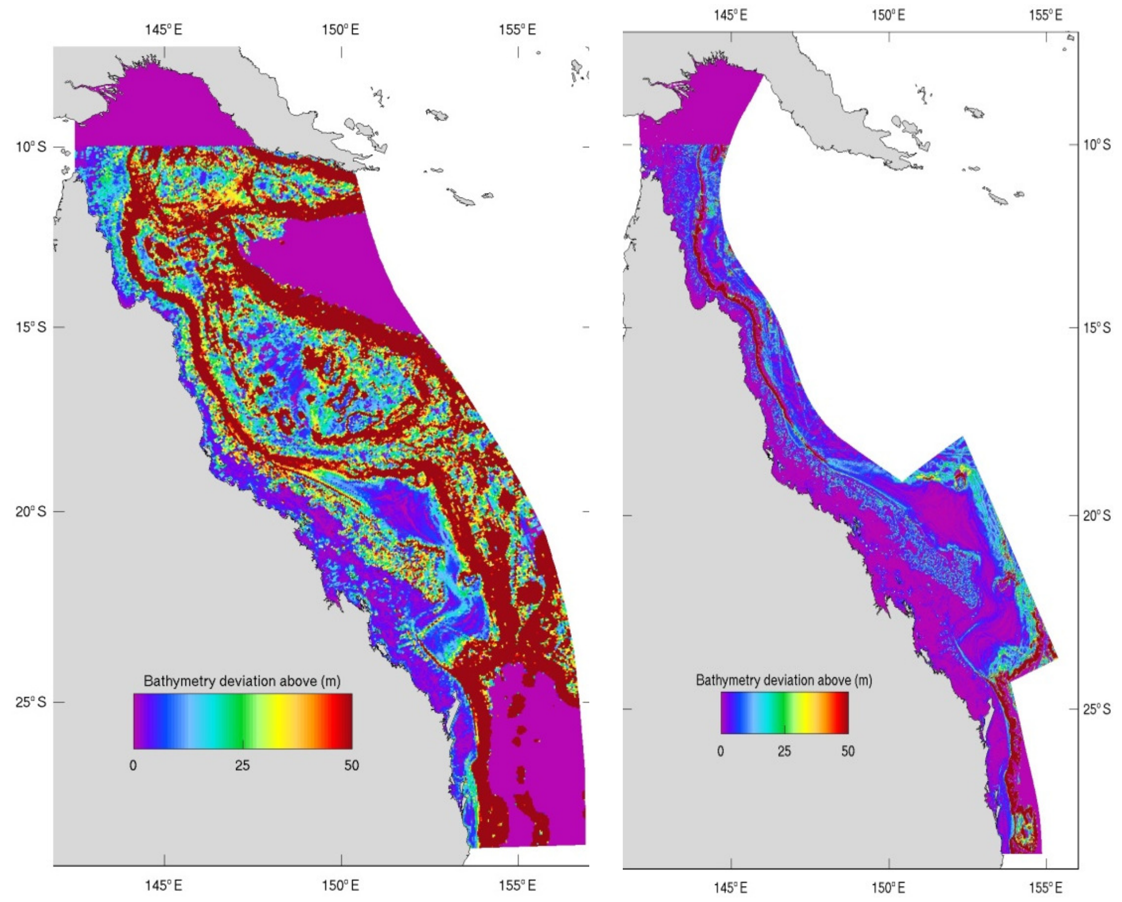
- Reef matrix generates small scale structure and deflects the large scale flow,
- Resolving the reef is critical to accurate dynamics in the lagoon.



GBR4: No smoothing 1 pass 3 passes GBR1: No smoothing



Bathymetry analysis

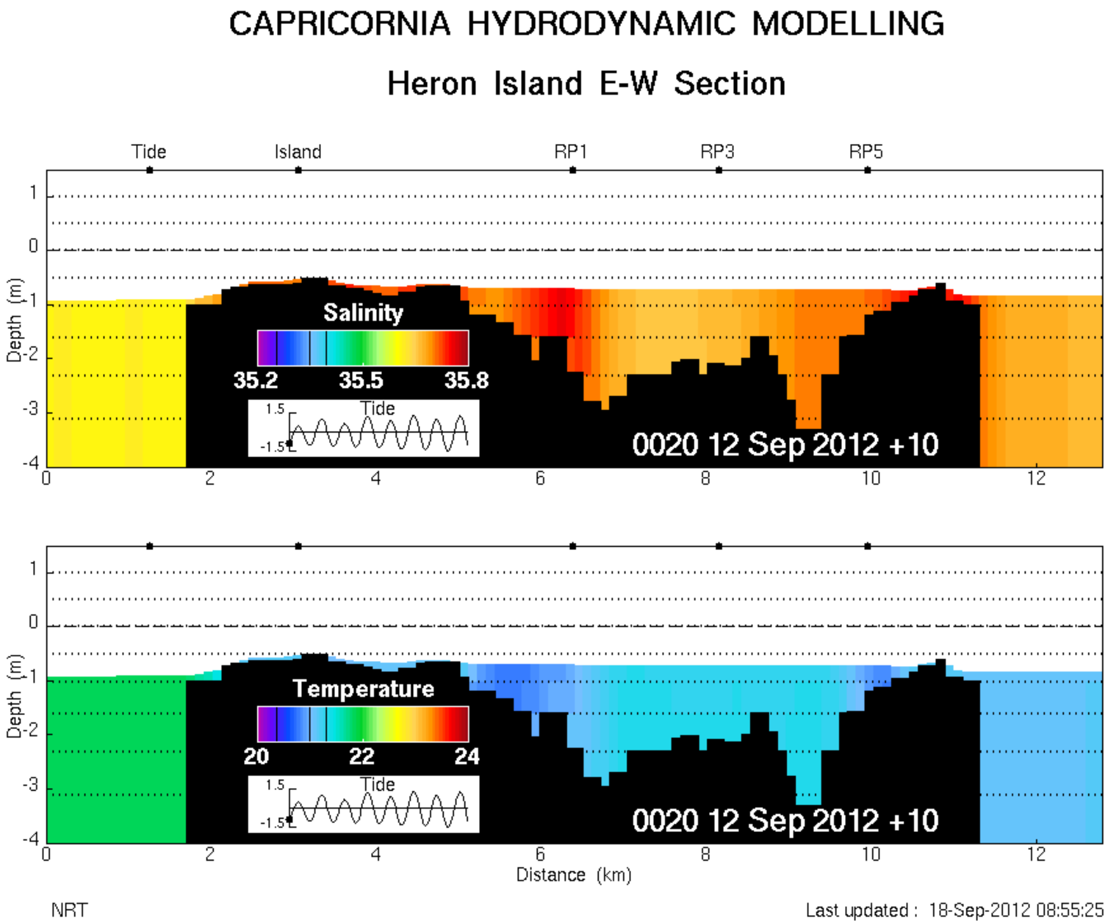


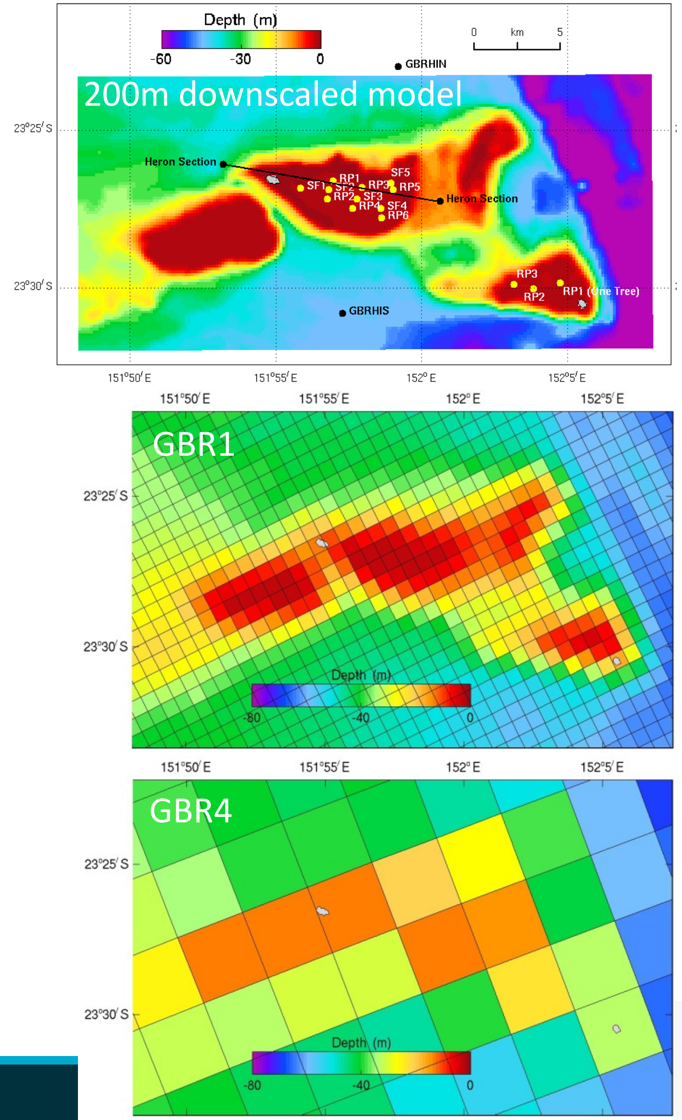
4km 1km

Difference between shallowest and gridded bathymetry

- Database used to average the bathymetry onto the model grid is 100m (i.e. reef resolving),
- Compute the maximum difference between model bathymetry (@4km/1km) and the shallowest depth in the database (@100m),
- GBR4 resolves the reef poorly.

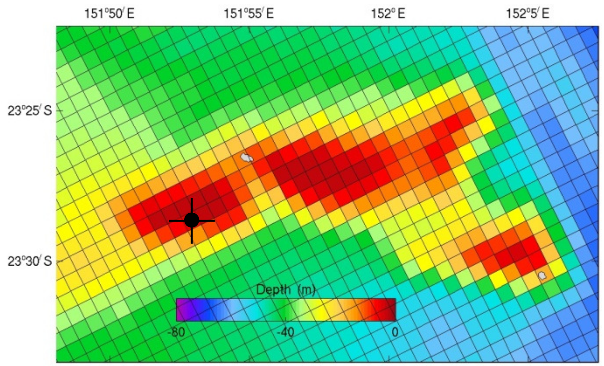
Water properties on drying reefs



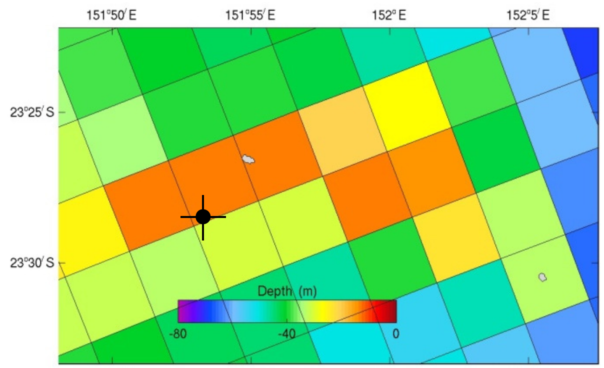


Diurnal temperature change

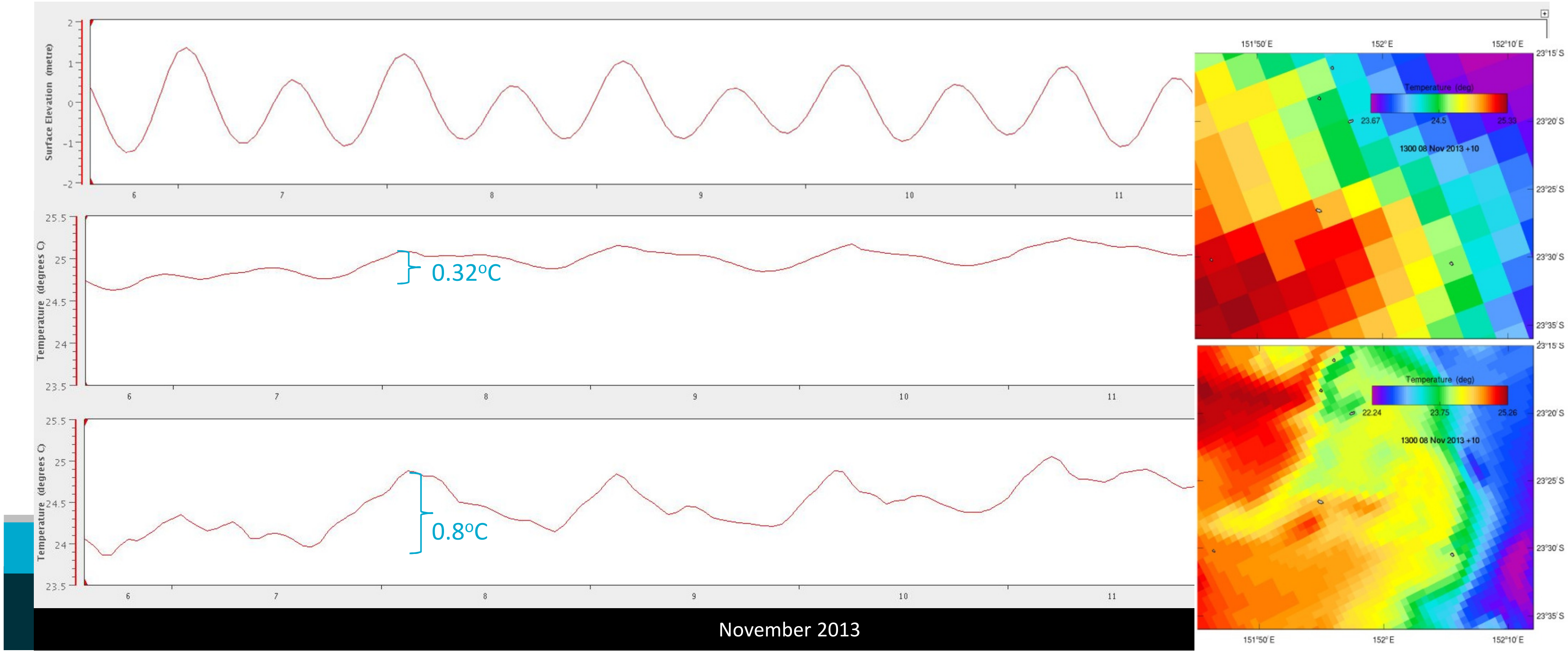
Wistari Reef;
Heron Island



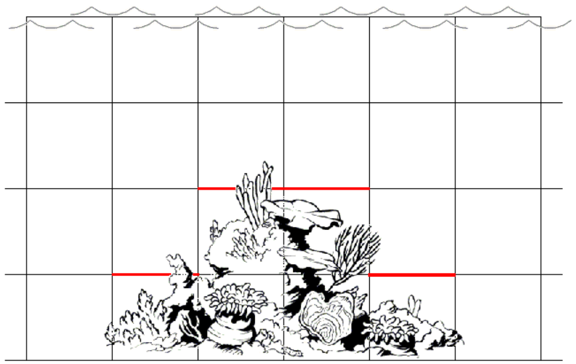
GBR1: depth = 3.7m



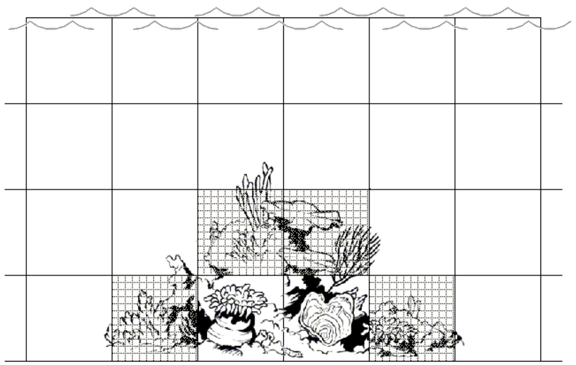
GBR4: depth = 13.4m



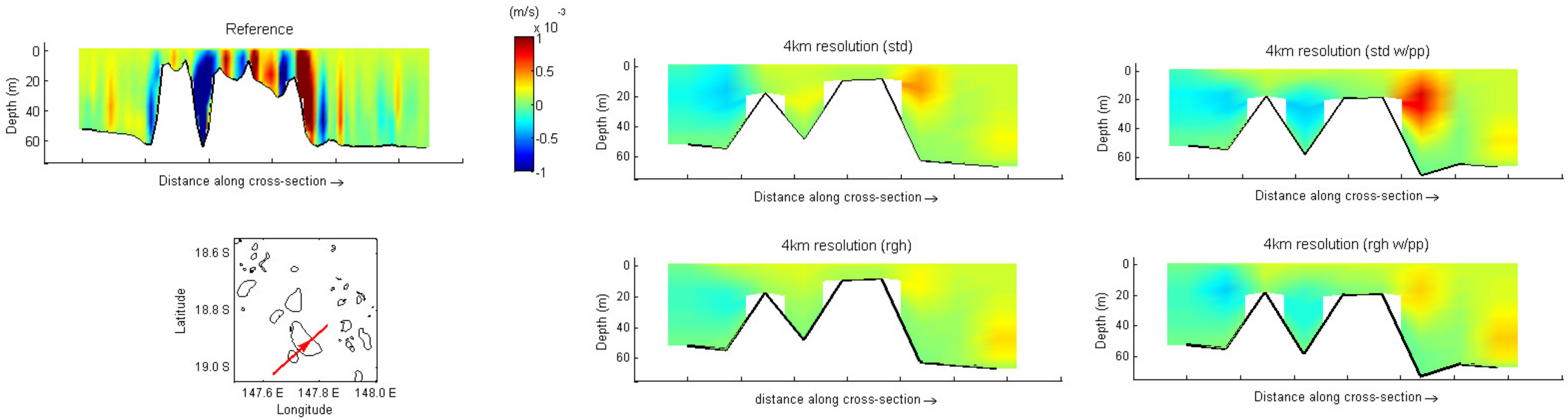
Sub-gridscale reef parameterization



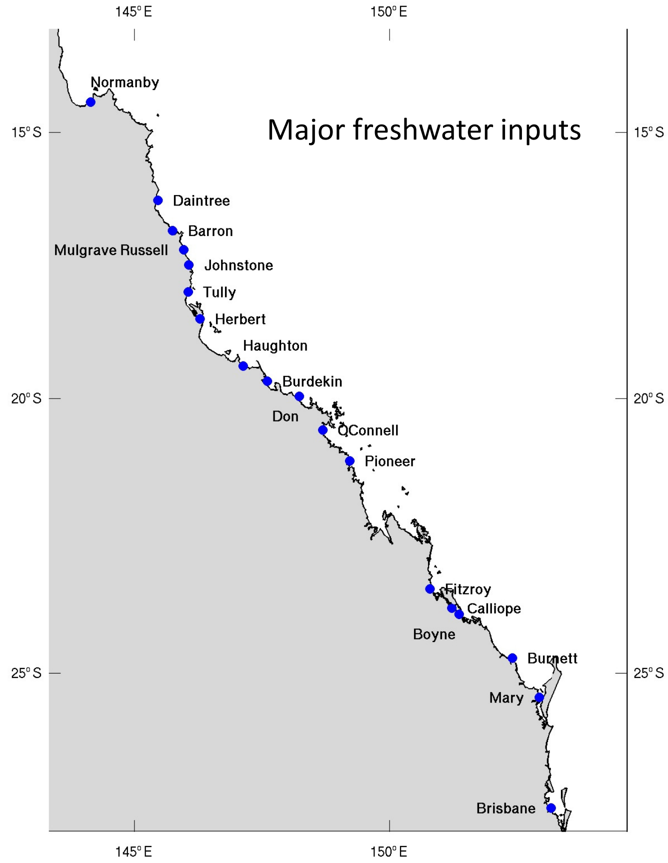
Modified drag coefficient (rgh)

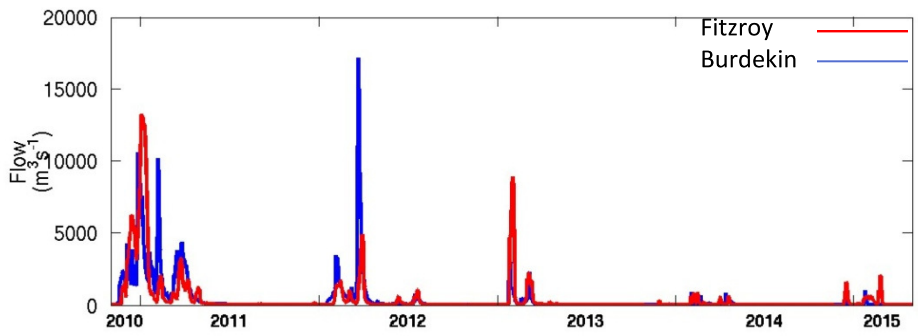


Porus plate (w/pp)



Freshwater input - GBR model has 22 river inputs



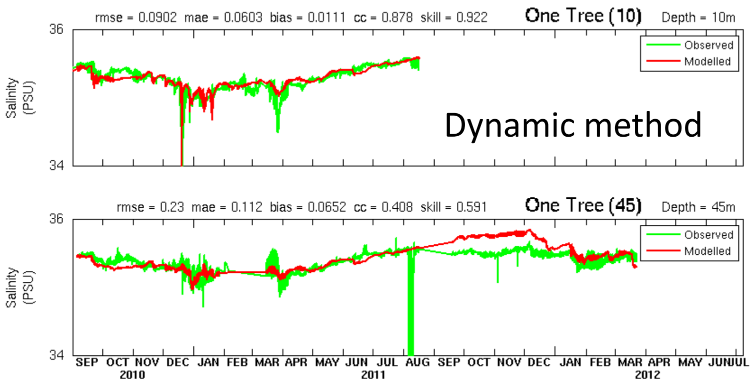


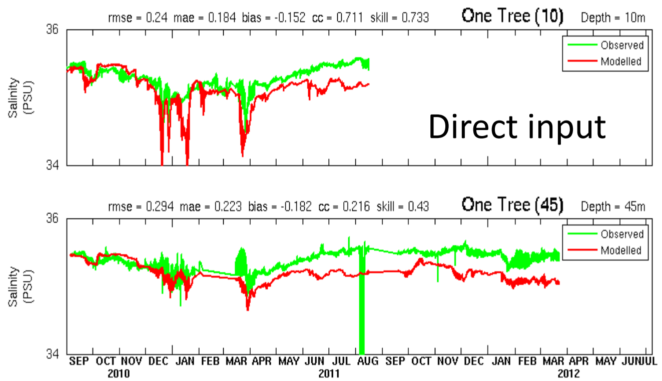
- Seasonal flow regime
- Wet season flows can be large
- Extreme flows when tropical cyclones make landfall
- Need to quantify freshwater fluxes accurately
- Use simple inlets in regional models (estuary not resolved)

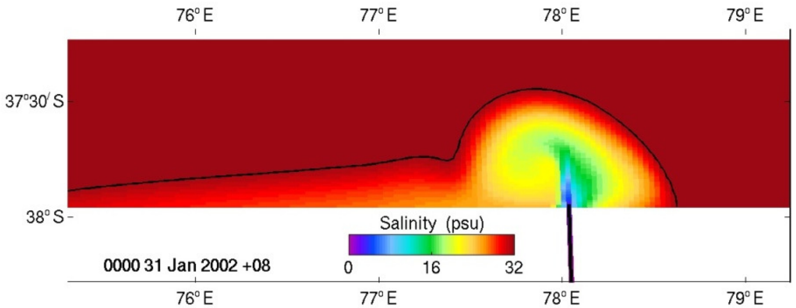
River inflow : 3 issues

- Fresh (S = 0) input at the coast results in the lagoon becoming too fresh.
- A simple inlet at the coast generates a numerical response,
  - Type 1 plume: steady state with small offshore bulge, downstream coastal current and no upstream intrusion,
  - Type 2 plume: non-steady upstream intrusion with anticyclonic circulation into the downstream coastal current,
  - Type 3 plume: non-steady growing offshore bulge with negligible coastal current.
- Point source and flow inputs require a predefined depth distribution.

Dynamic input performance

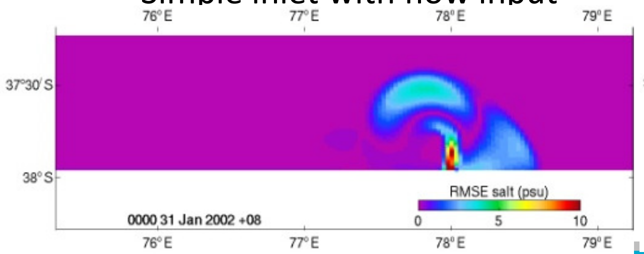




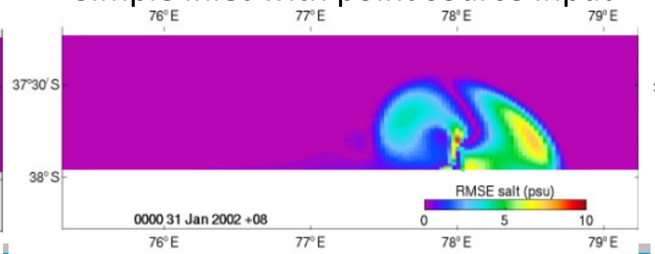


Baseline response where the estuary is resolved to beyond salt wedge propagation

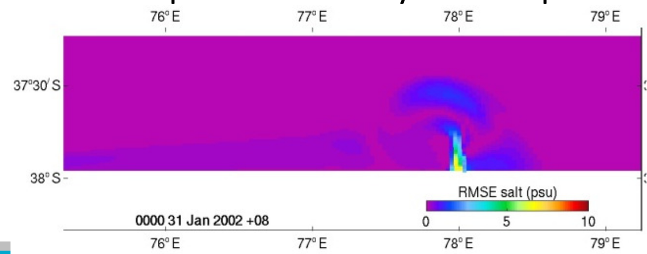
Simple inlet with flow input



Simple inlet with point source input



Simple inlet with dynamic input

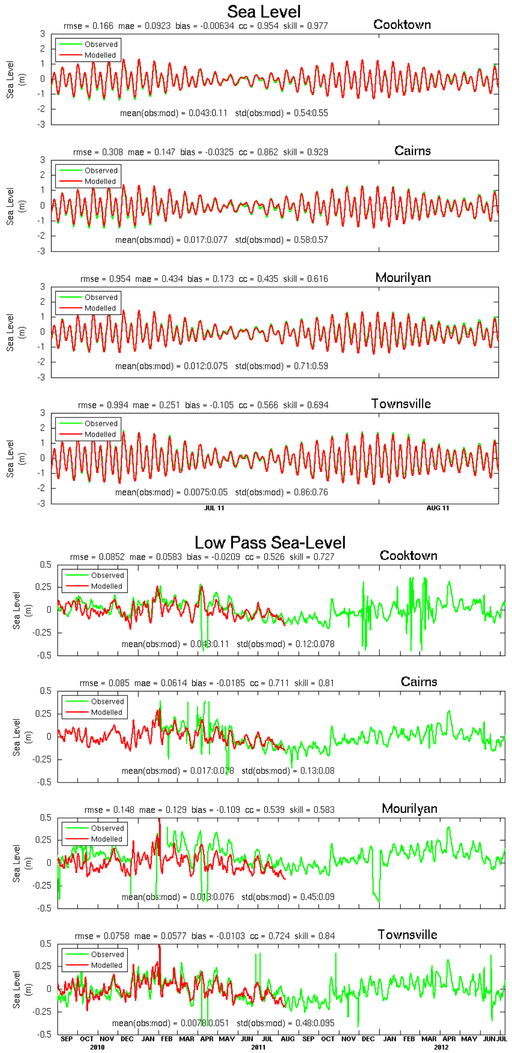


RMS errors

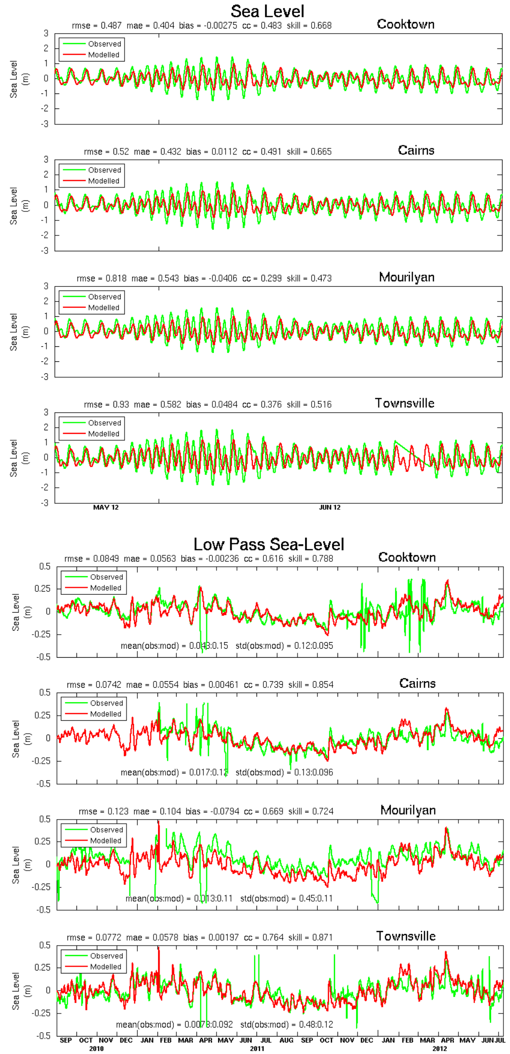
Open boundary issues

- Open boundaries must supply information to drive the tides,
  - This implies an 'active' open boundary, where the model interior responds to the boundary specification.
- Southeast trade winds (Jan – Aug) drive northward flow in the lagoon,
  - This implies a 'passive' open boundary, where the boundary responds to the interior forcing.
- Difficult to reconcile these conflicting requirements,
  - Active or passive nature of boundaries usually controlled by unique relaxation time-scales,
  - A 'dual relaxation' boundary scheme was developed to cope with this situation.

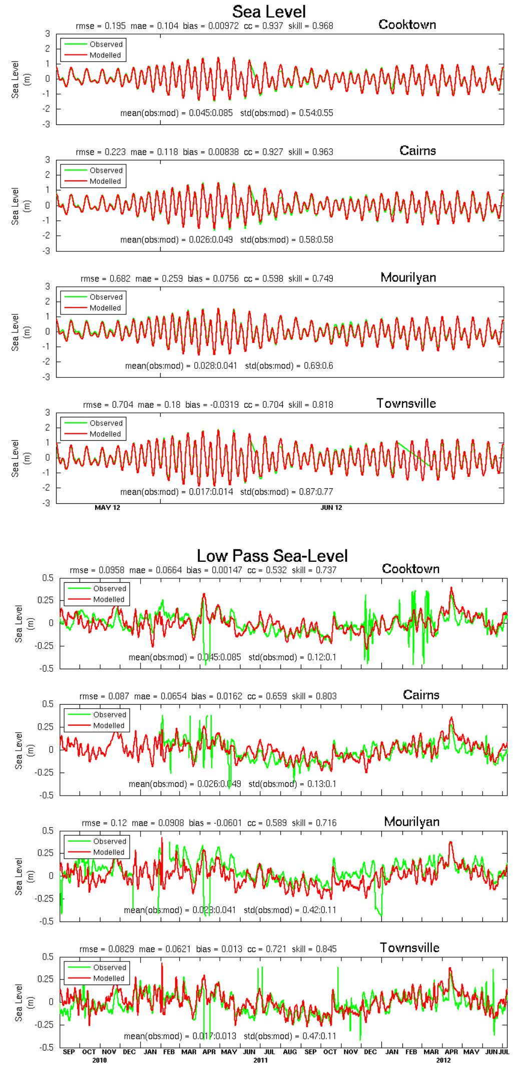
Optimum sea level achieved with dual relaxation



Hard relaxation (unstable)
OBC over-specification

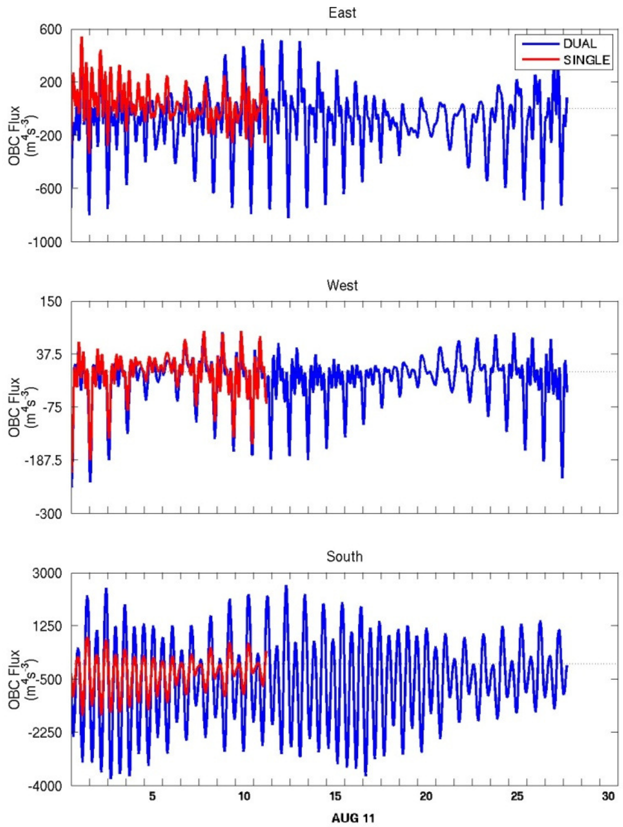


'default' relaxation (tide suffers)
OBC under-specification

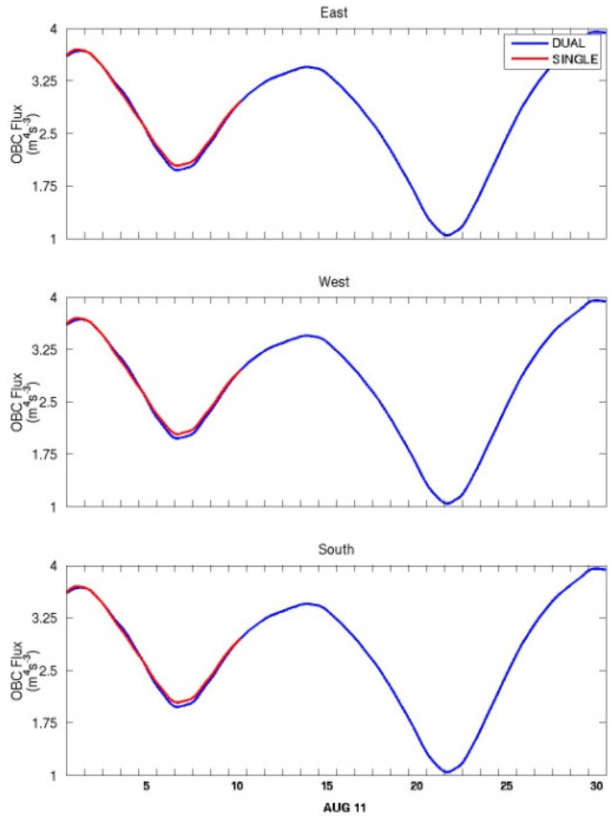


Dual relaxation (optimum)

Energy flux through open boundaries



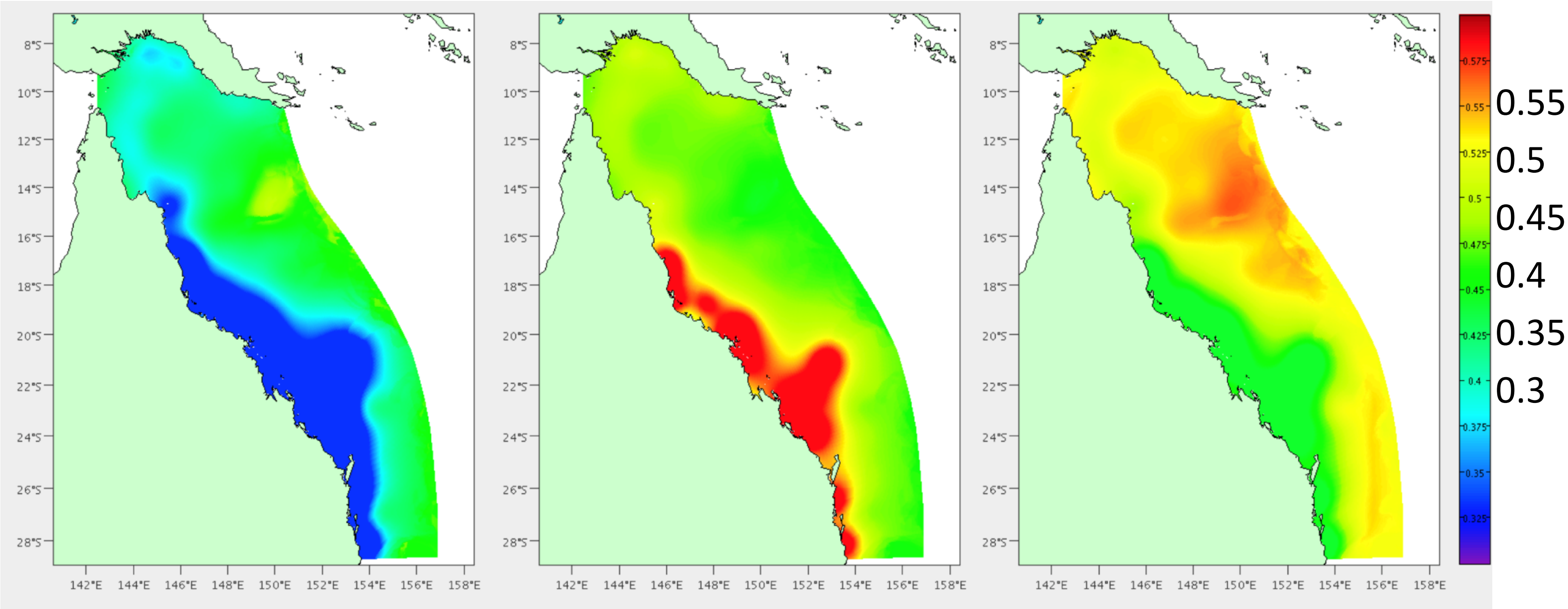
Tidal frequency



Low frequency

Shortwave Parameter Estimation using a DEnKF

Transmission Attenuation Bottom absorption



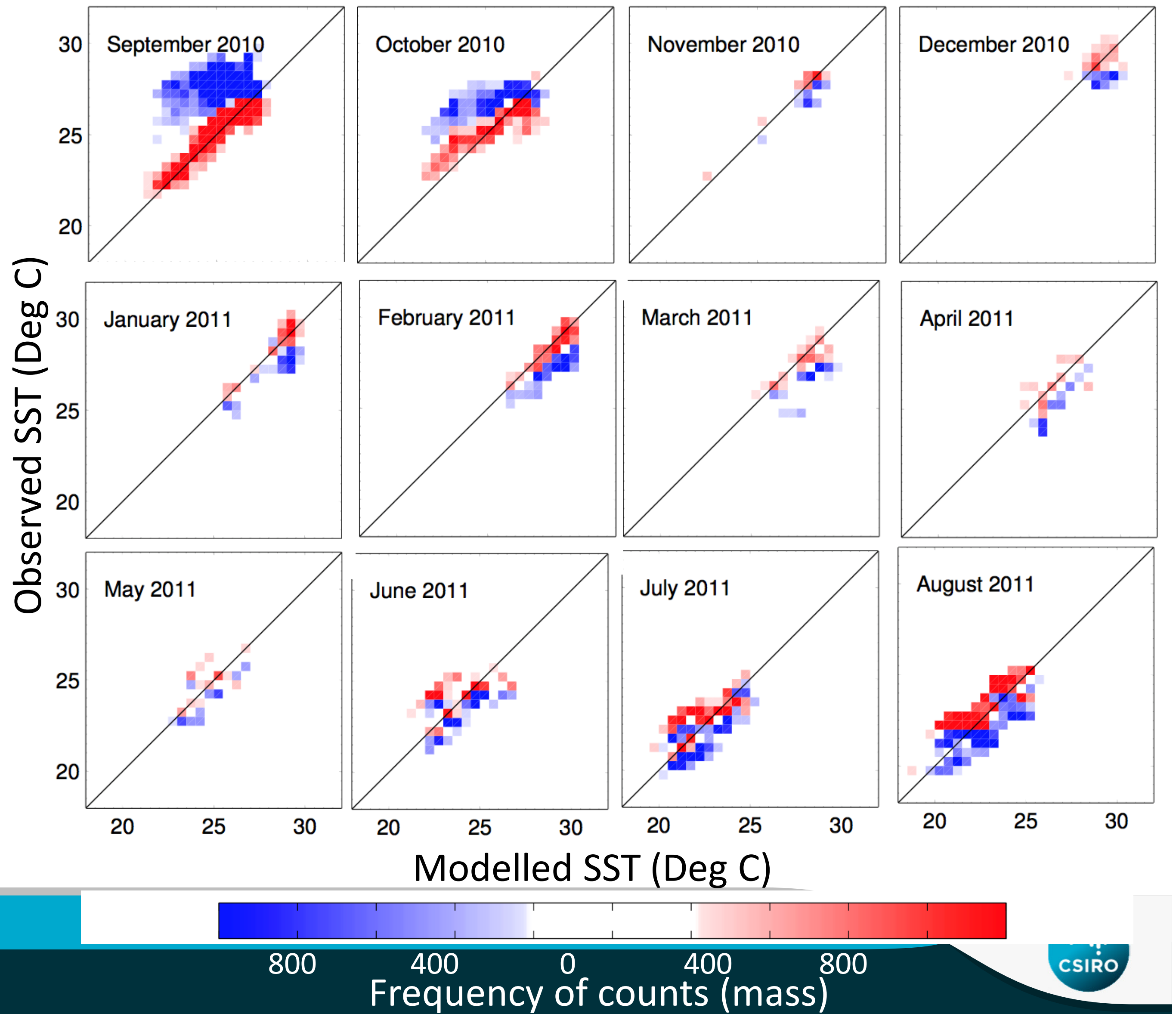
- Less transmission, attenuation and bottom absorption than the prior estimate
  … less heat goes in; *and more heat is distributed nearer the surface*
- Relatively clear offshore water with high transmission and low attenuation
- Turbid inshore waters due to river discharge, tidal mixing, and mixing due to waves

Parameter Estimation using a DEnKF

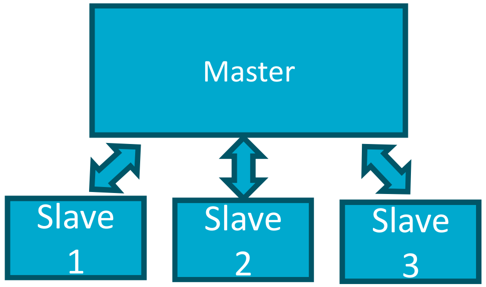
2D histograms comparing modelled and observed SST

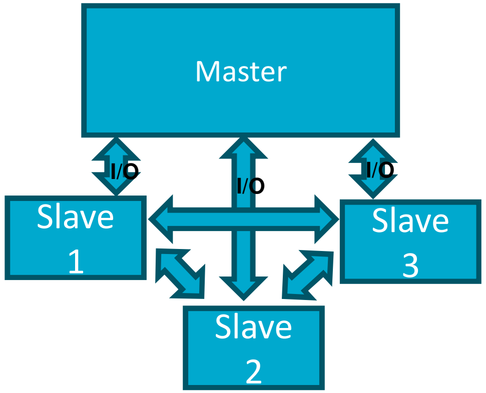
Blue = with original parameters … constant in time and space

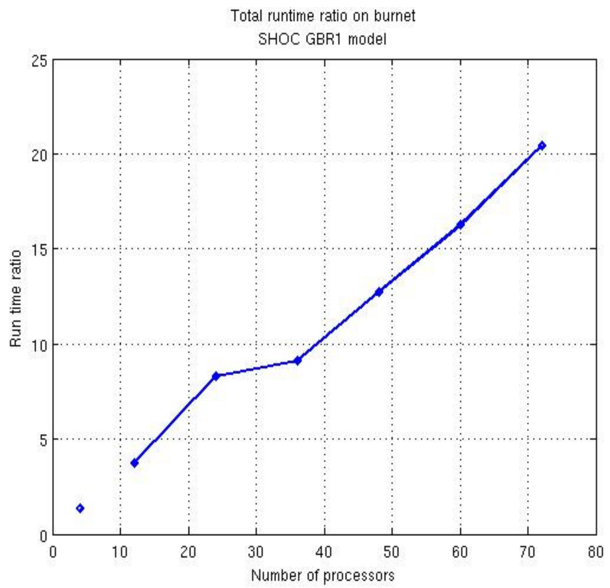
Red = with optimised parameters … spatially varying



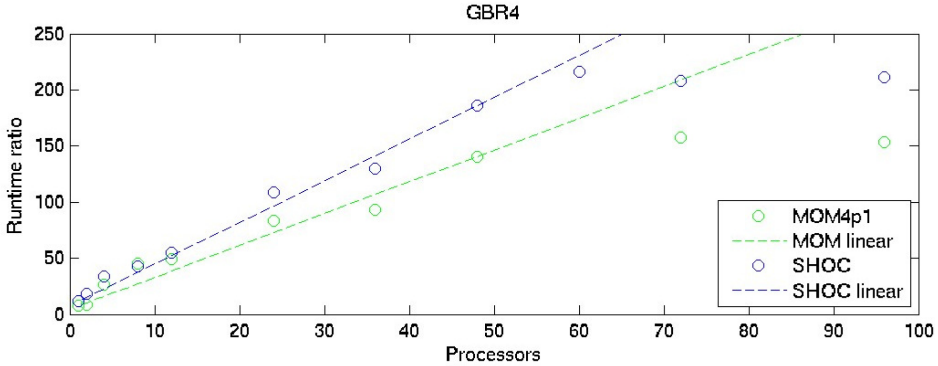
1 km model is computationally expensive







Distributed processing based on slave-slave communication increases efficiency.



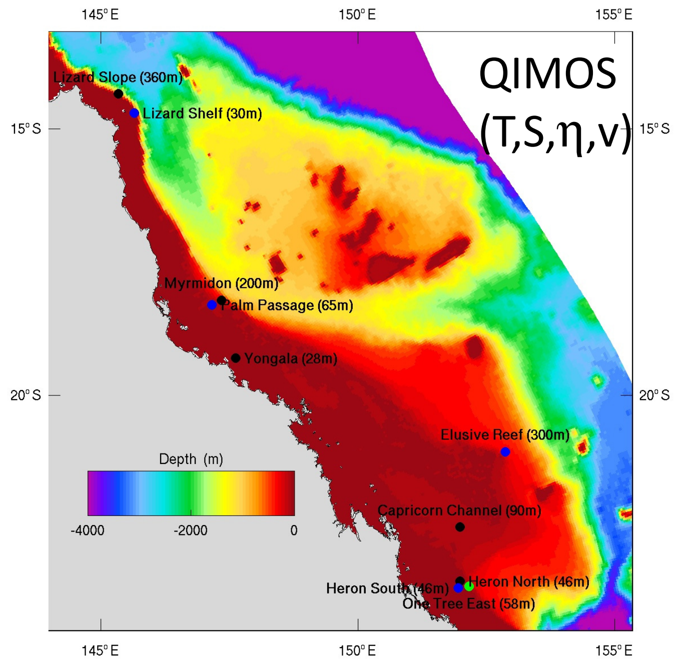
Transport model

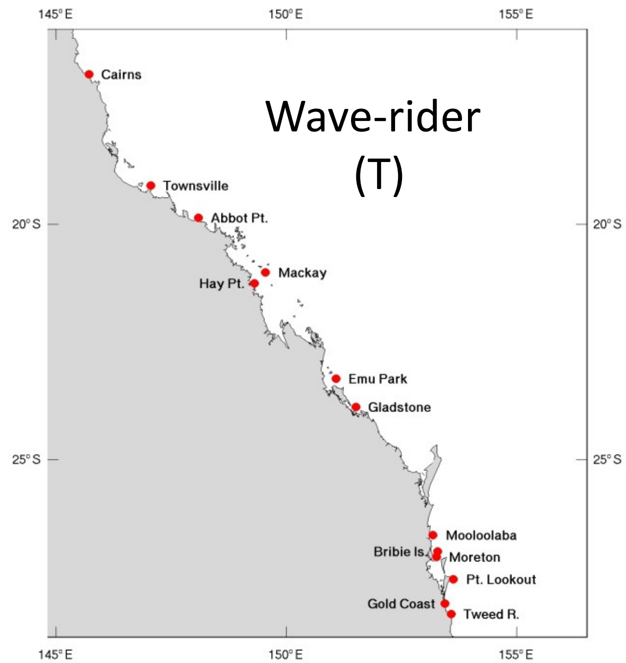
- Sediments and BGC are too computationally expensive to run coupled to the hydrodynamic model,
- Use a transport model driven by offline flow fields,
- Run time can be decreased using large time-step with semi-Lagrangain advection scheme,
  - These schemes are not conservative.
- Flux-form semi-Lagrange methodology has been implemented to produce a conservative result using a long time-step.
- Run times are reduced by orders of magnitude.

Transport model speed-ups

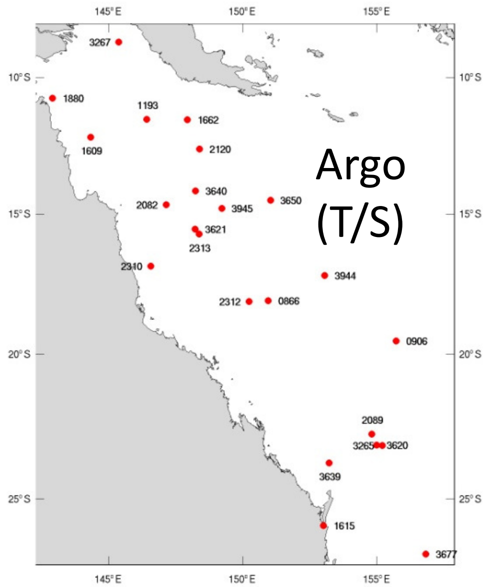
	Model Speed (Time ratio)			
Test Case	No. Cores for HD	HD model	FFSL Scheme	Lagrange scheme
Closed Estuary	1	5300	72000	57600
Open Estuary	1	5877	66461	61714
GBR4	12	34	367	319

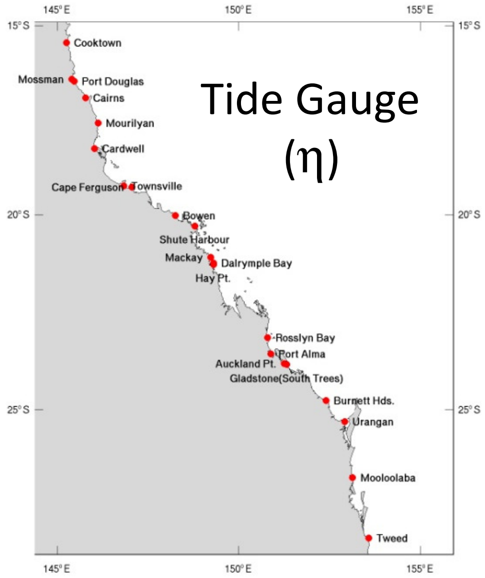
GBR Observation sites



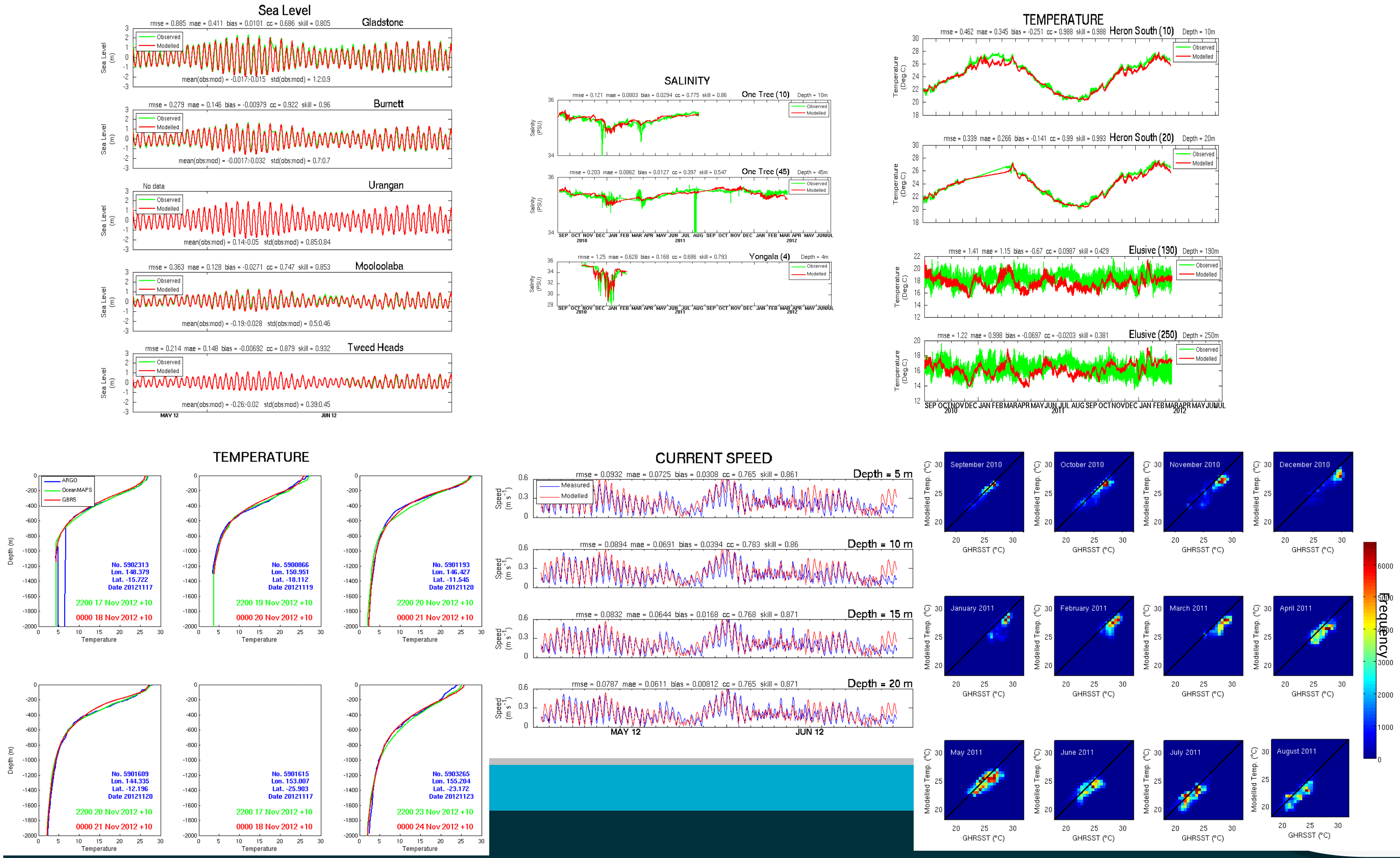


+ GHRSST

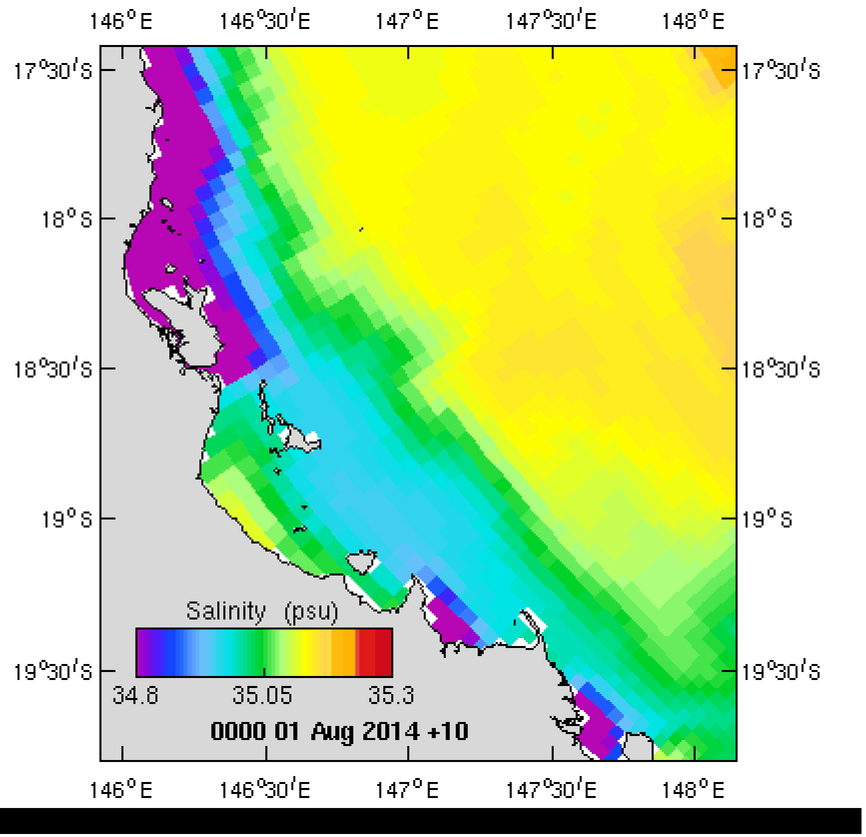




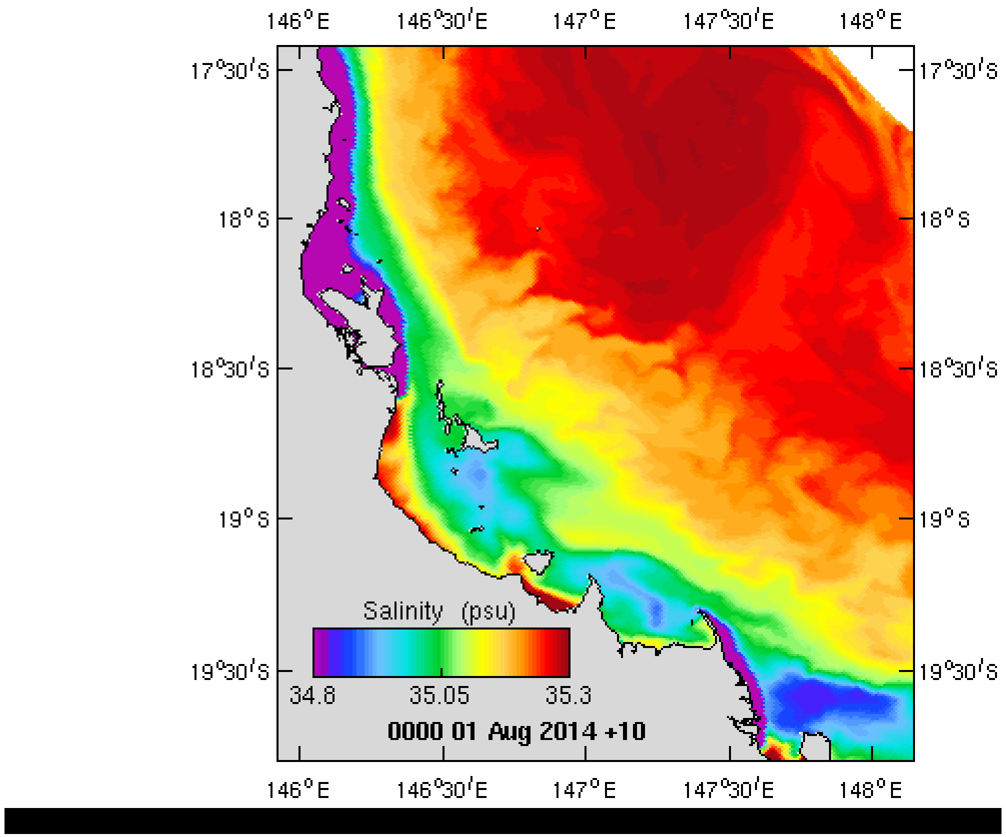
Calibration – free running model



Increased process resolution in the 1km model

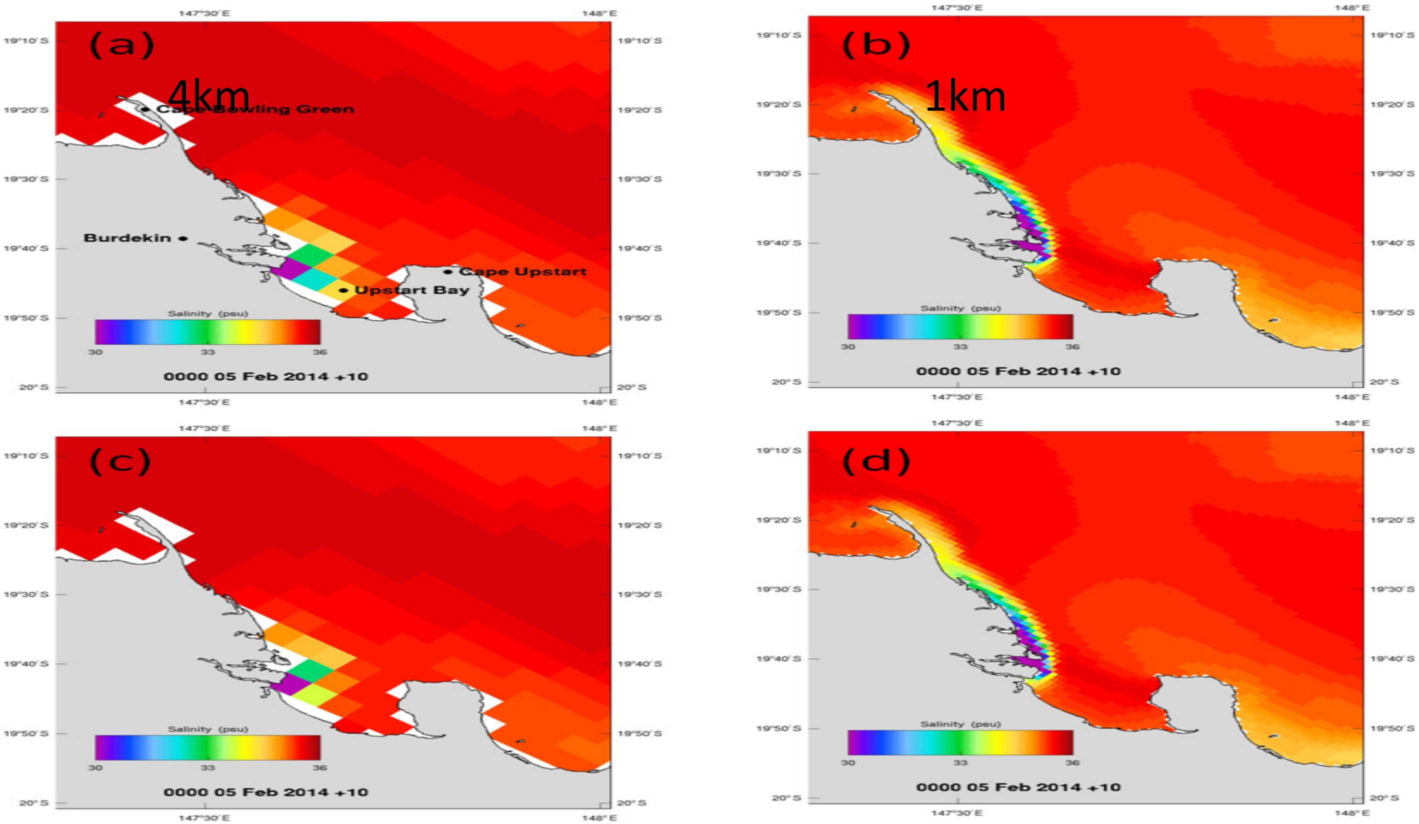


GBR4

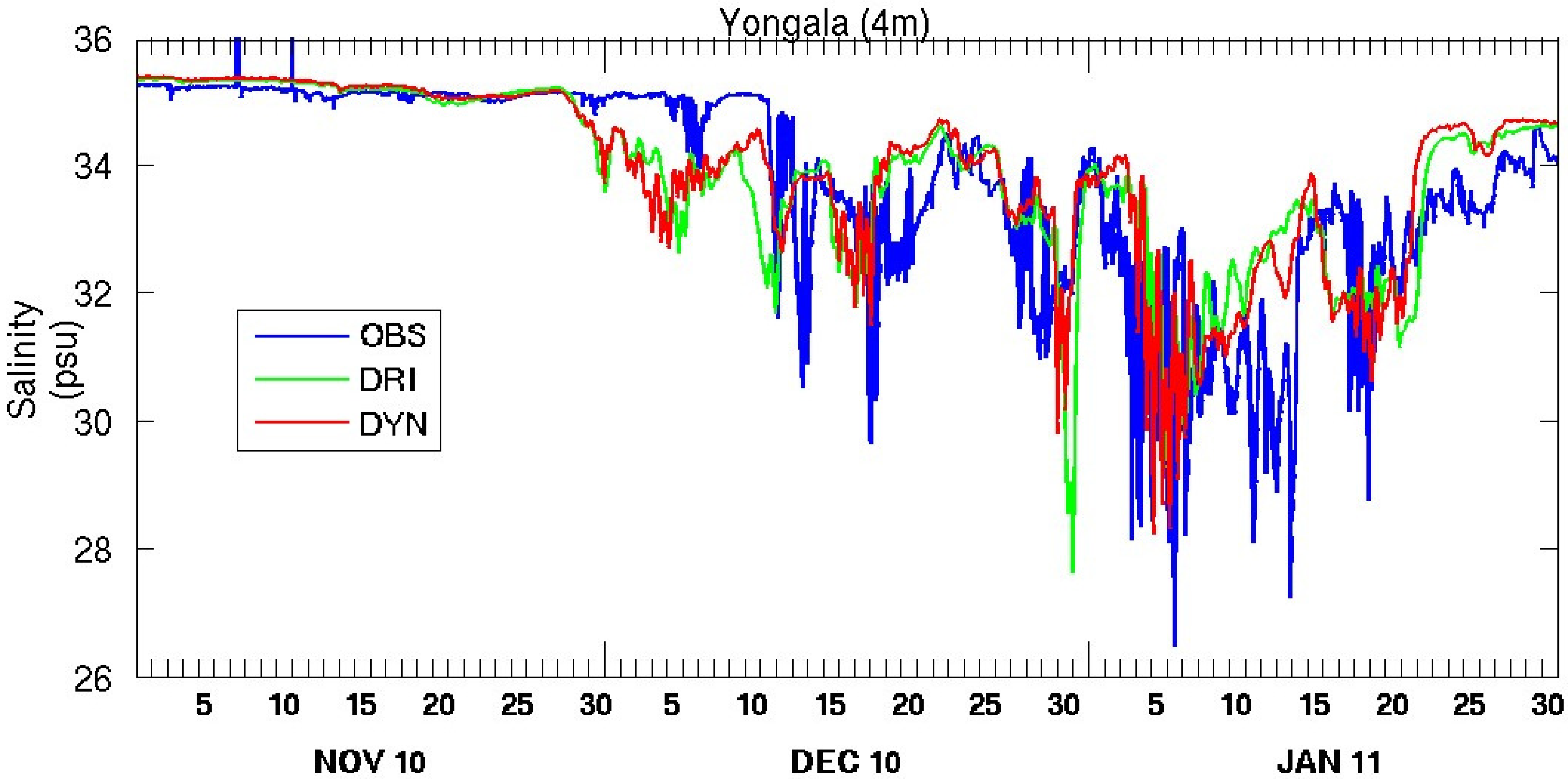


GBR1

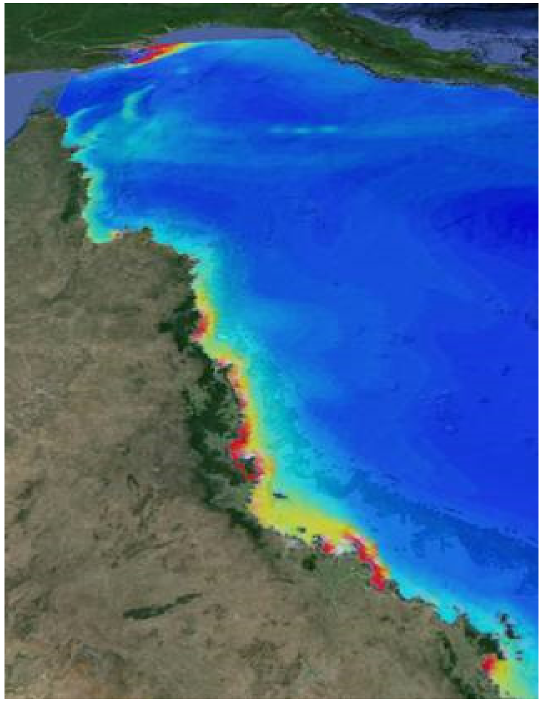
River plume representation (moderate flow)



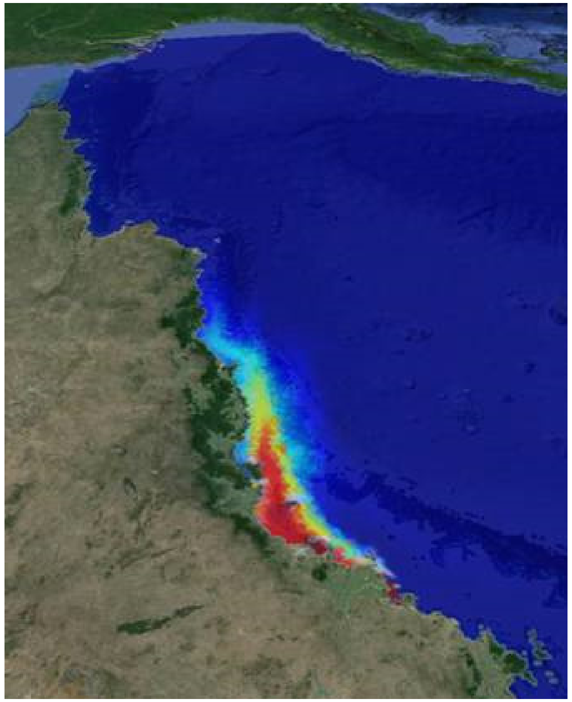
High flow salinity response - Yongala



Outputs – catchment connectivity

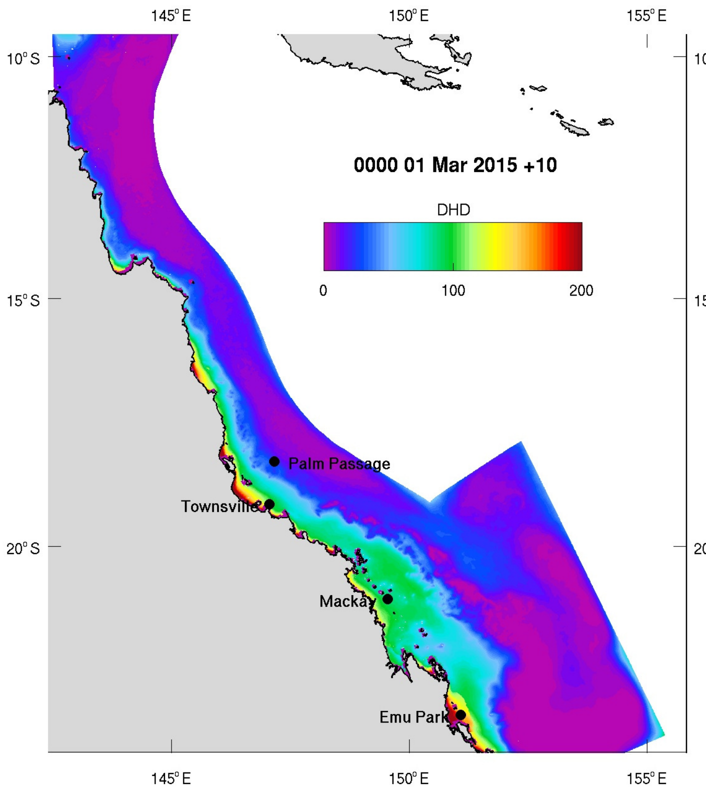


Salinity distribution

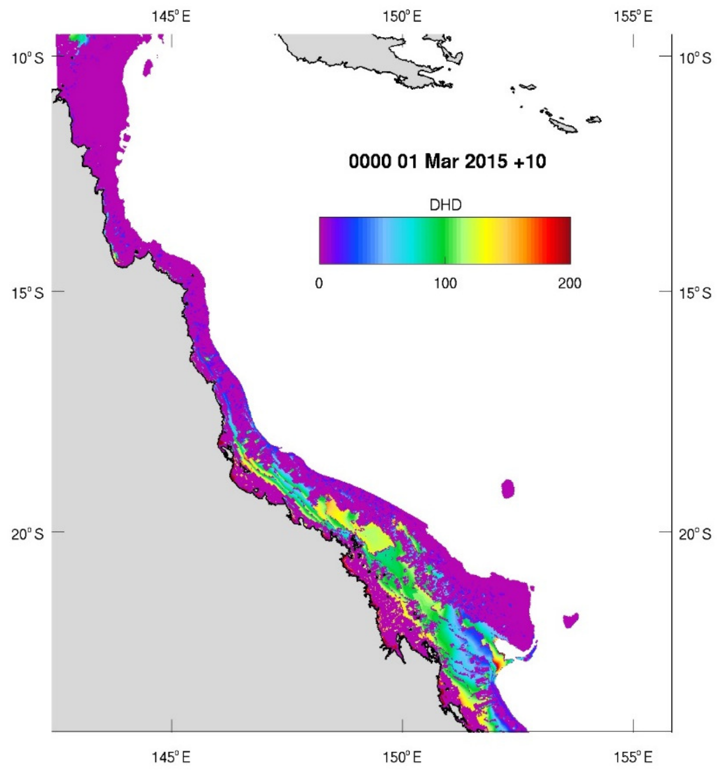


Passive tracer

Temperature exposure

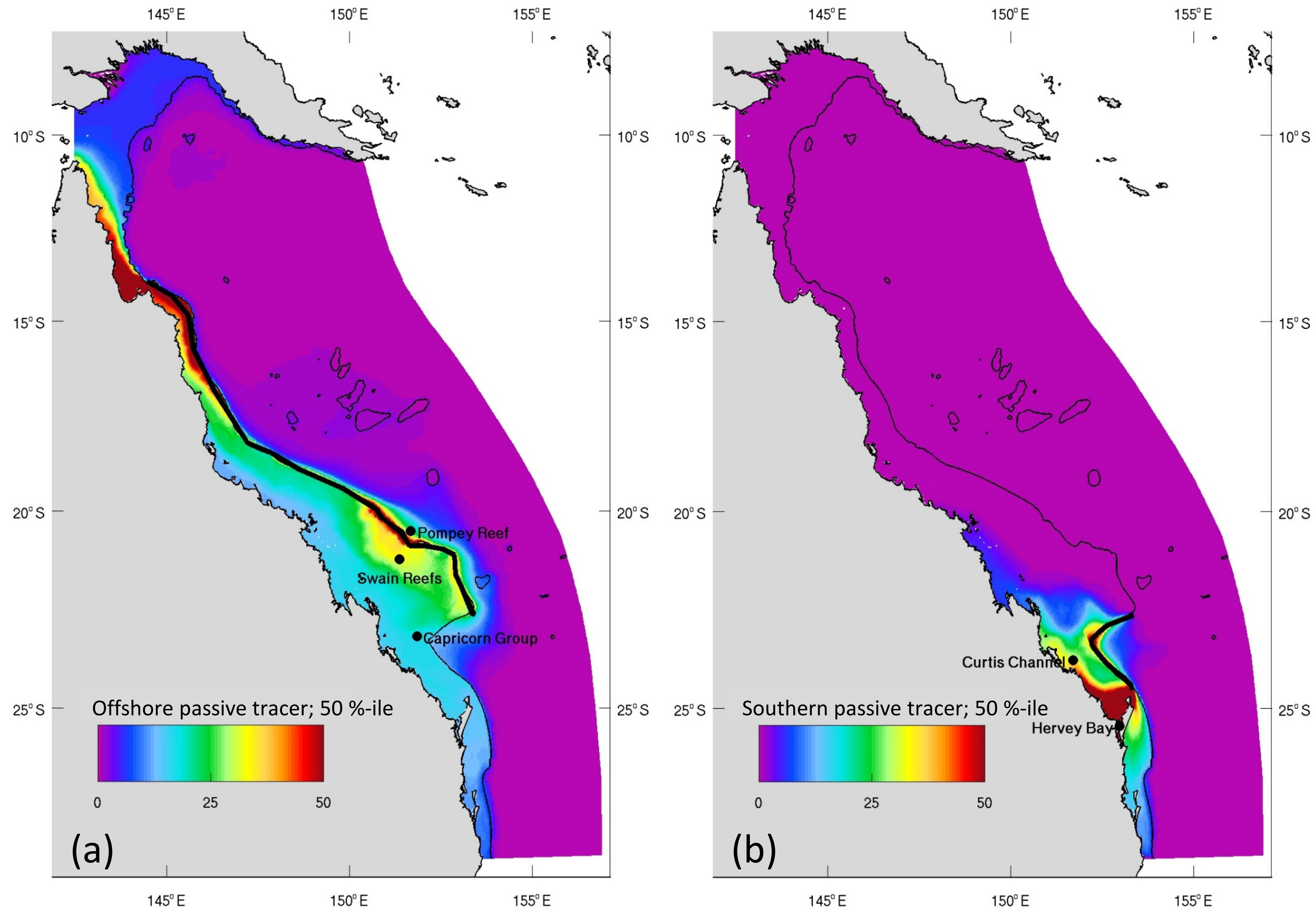


Surface exposure



Bottom exposure

Shelf exchange analysis



Thank you

Coastal Development and Management
Mike Herzfeld

t +61 3 6232 5167
e mike.herzfelde@csiro.au
w http://www.emg.cmar.csiro.au/www/en/emg.html