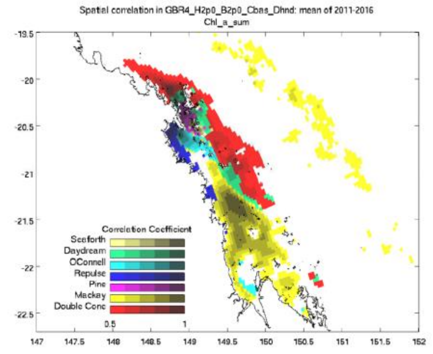
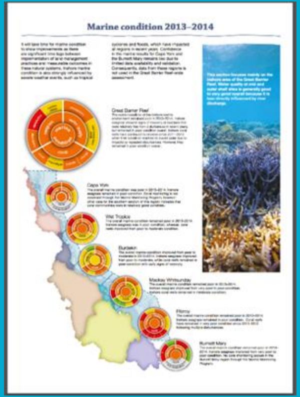
How models can direct science and data needs.

Mark Baird
Team Leader
Coastal Biogeochemical Modelling Team
CSIRO Oceans and Atmosphere

“What models can do is make the most of existing scientific knowledge, a major undertaking by any standards”

Charlie Veron (2008): A Reef in Time: The Great Barrier Reef from Beginning to End



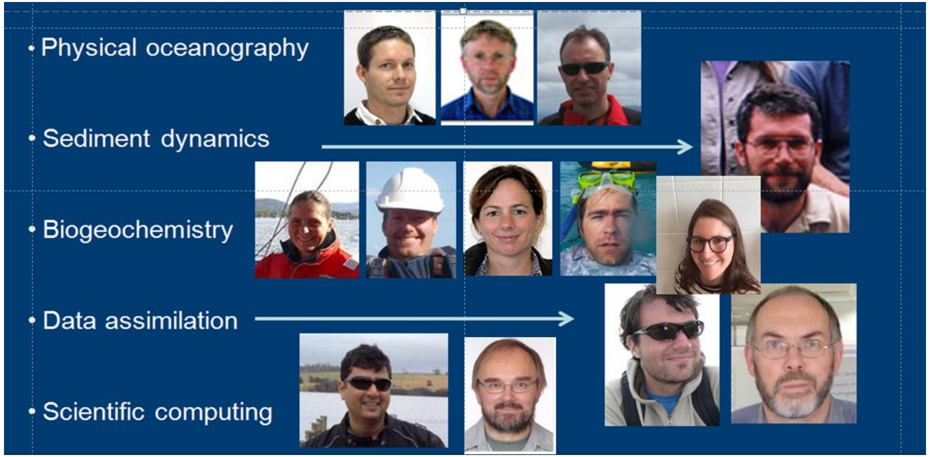

Marine condition 2013–2014

Outline

Three examples from the eReefs Project of science-driven modelling directing new science needs:

1. Design of observing systems on the GBR – where and what are the optimal observations.
2. Optimising catchment load reductions – where do we invest in catchment repair.
3. Coral bleaching modelling - what parts of the process of symbiont expulsion are not well quantified.

CSIRO team involved in eReefs Project.



Funding sources:

eReefs is a collaboration between

CSIRO

Australian Government

GREAT BARRIER REEF foundation

Australian Institute of Marine Science

Australian Government Bureau of Meteorology

eReefs is supported by

IMOS Integrated Marine Observing System

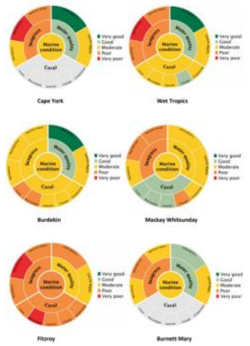
BMA

bhpbilliton

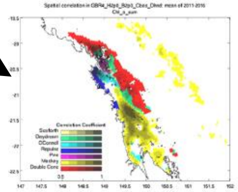
Caring for our Country

Queensland Government

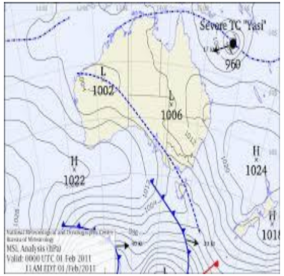
eReefs marine modelling system

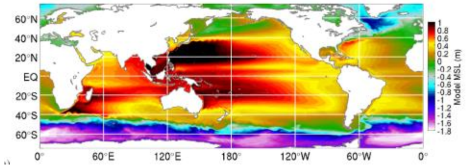


Applications.
- Optimising catchment repair
- Optimising reef interventions
- Estimating state of the GBR
- Optimising observation system design.

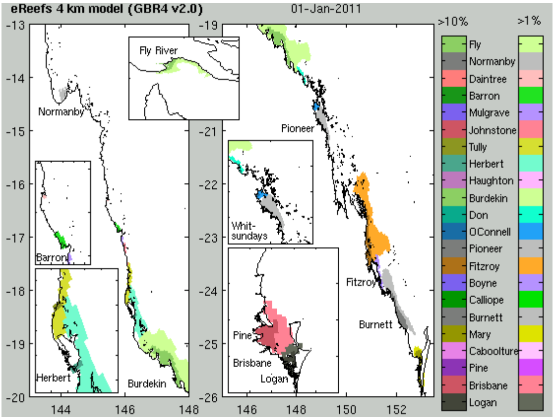


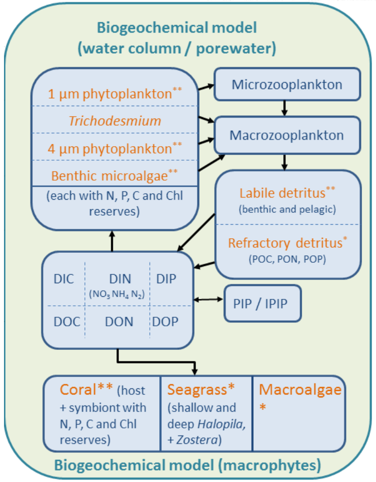
Catchment and marine models forced by BOM weather and CSIRO global ocean models

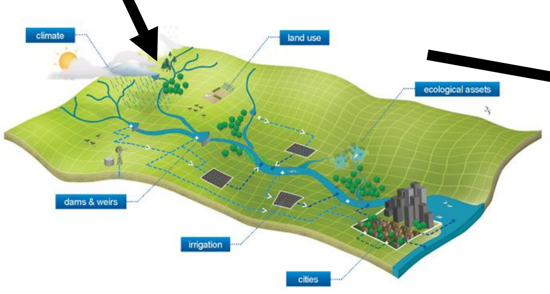




eReefs hydrodynamic modelling with river footprint estimation



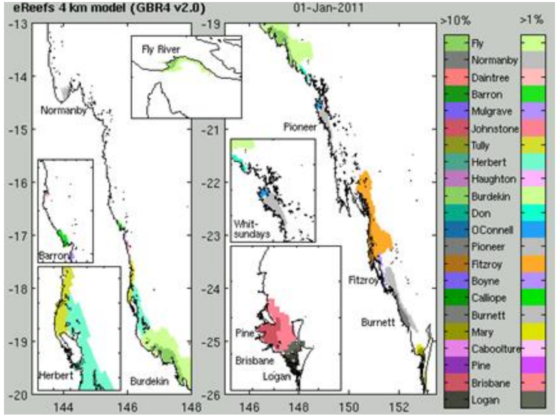




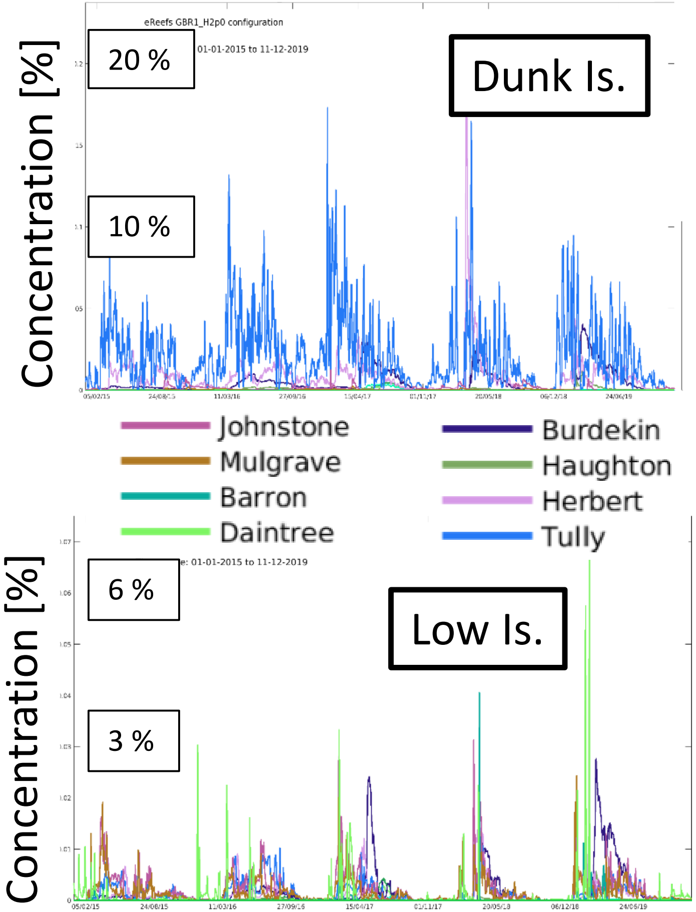
SOURCE Catchments loads of nutrient and sediments

Models directing science needs: How do I observe pesticides at reef sites?

Carol
Honchin
GBRMPA



5 years of river model data



Lessons:

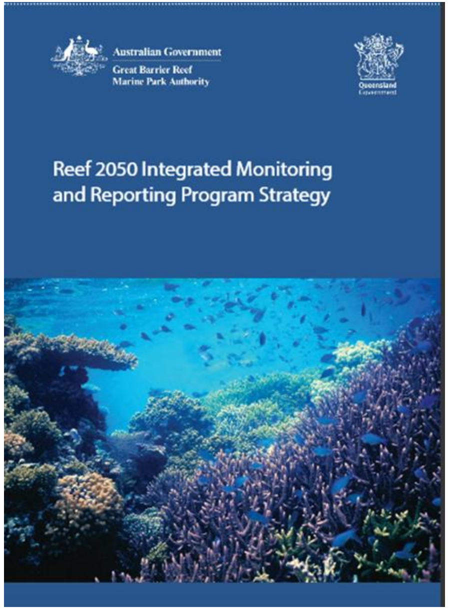
- Dunk dominated by Tully
- Tully signal lasts whole wet season and reaches 20 % of river mouth.
- Low Is. has lower concentrations but with more varied river sources.

Models directing science needs: How can we use models to optimise our observational networks?

Reef 2050 integrated monitoring and reporting program (RIMREP).

To establish a coordinated and integrated monitoring, modelling and reporting framework for the Great Barrier Reef and its catchment, explicitly linked to the outcomes in the Reef 2050 Plan.

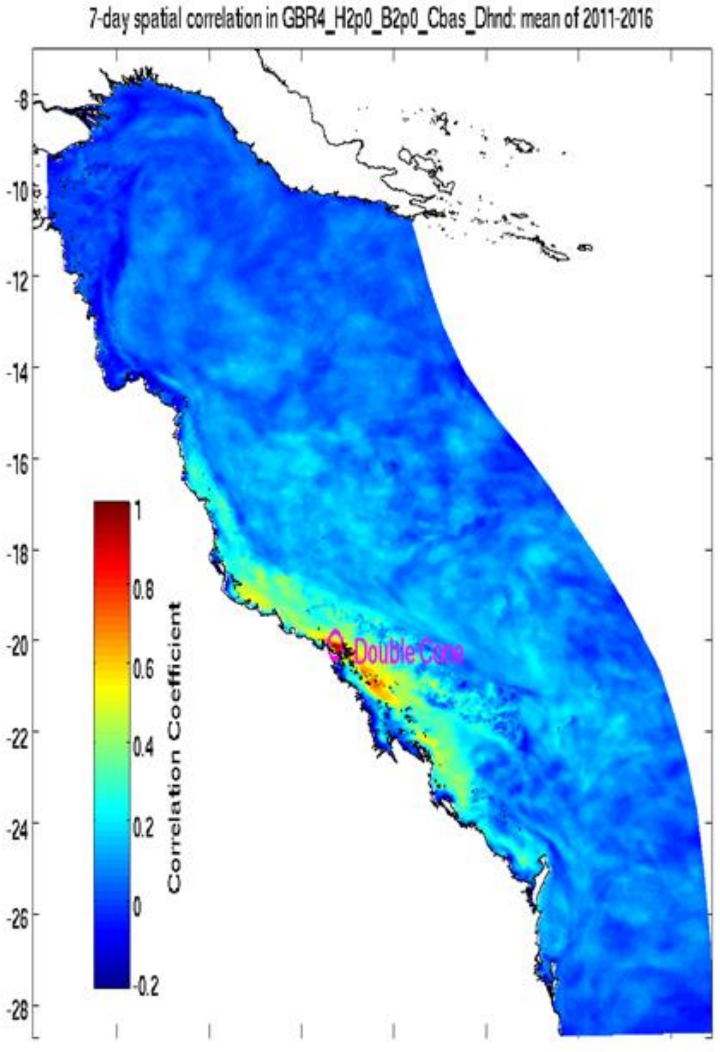
Richard Brinkman (AIMS)



Where should I put observation sites? → Observation System Simulation Experiments (OSSEs)

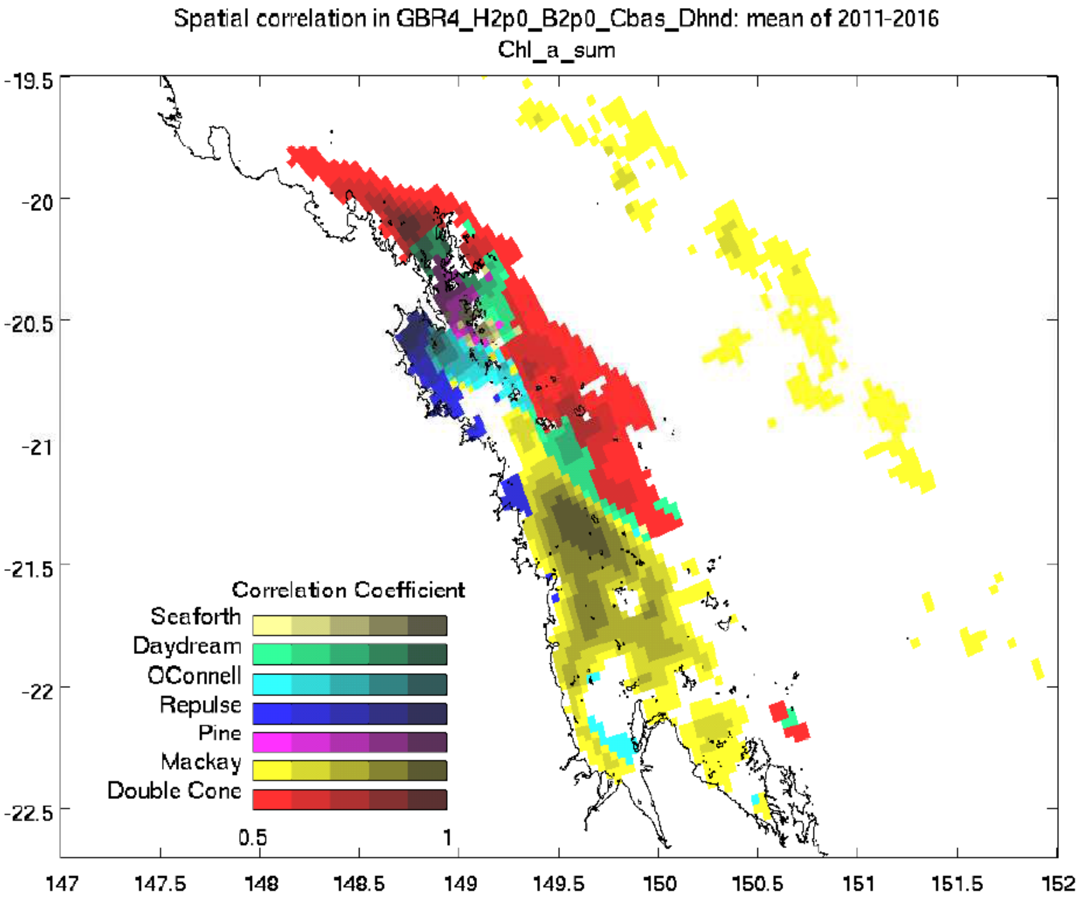
Observation System Simulation Experiments (OSSEs)

- eReefs model is run for 7 years, generating 3D temporally-varying fields of physical (T, S) and biogeochemical (nutrients, Chl, suspended sediments) variables.
- Mean spatial correlation of variables is generated from estimates of correlation over each successive 7-day period.

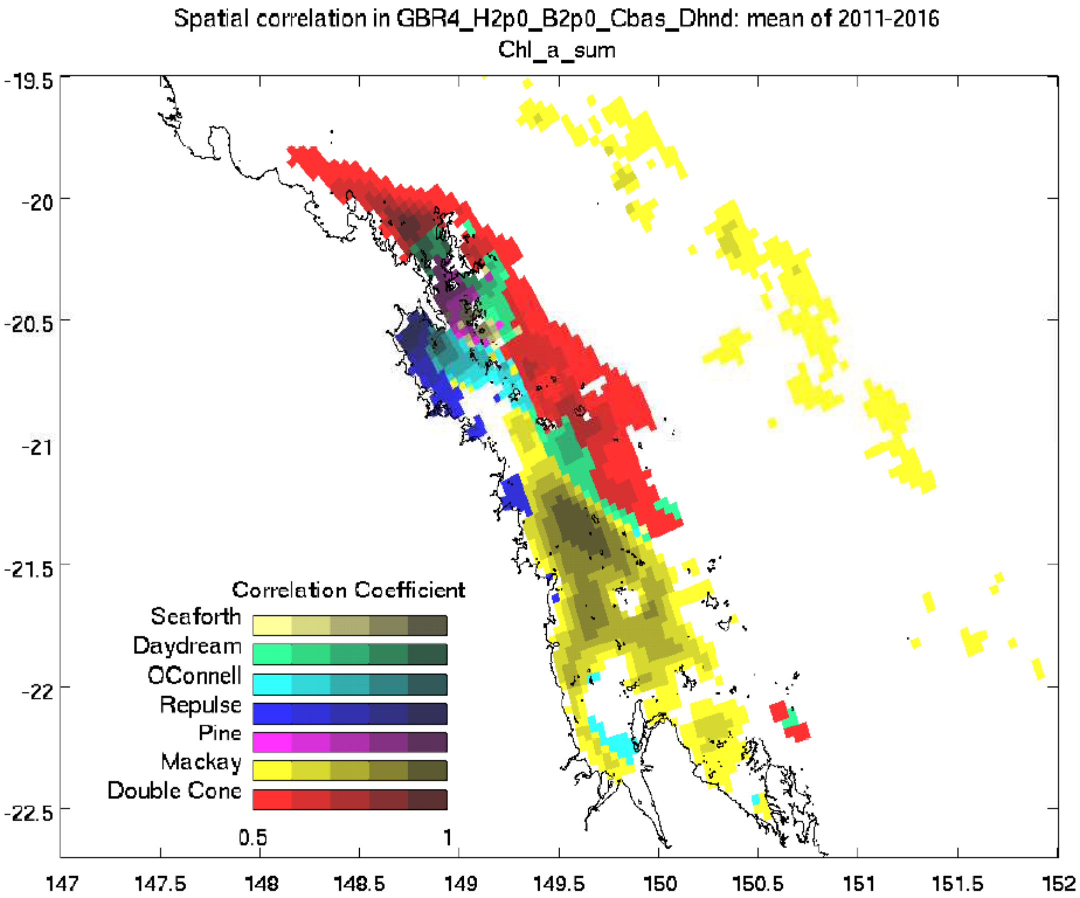


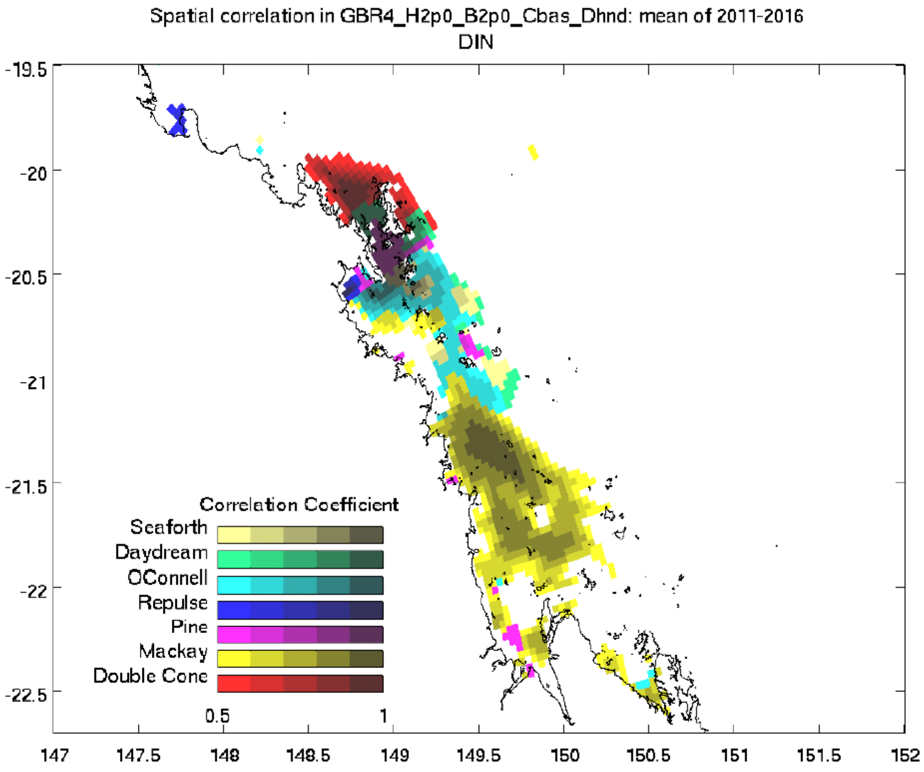
Can the model inform the best location for observations ?

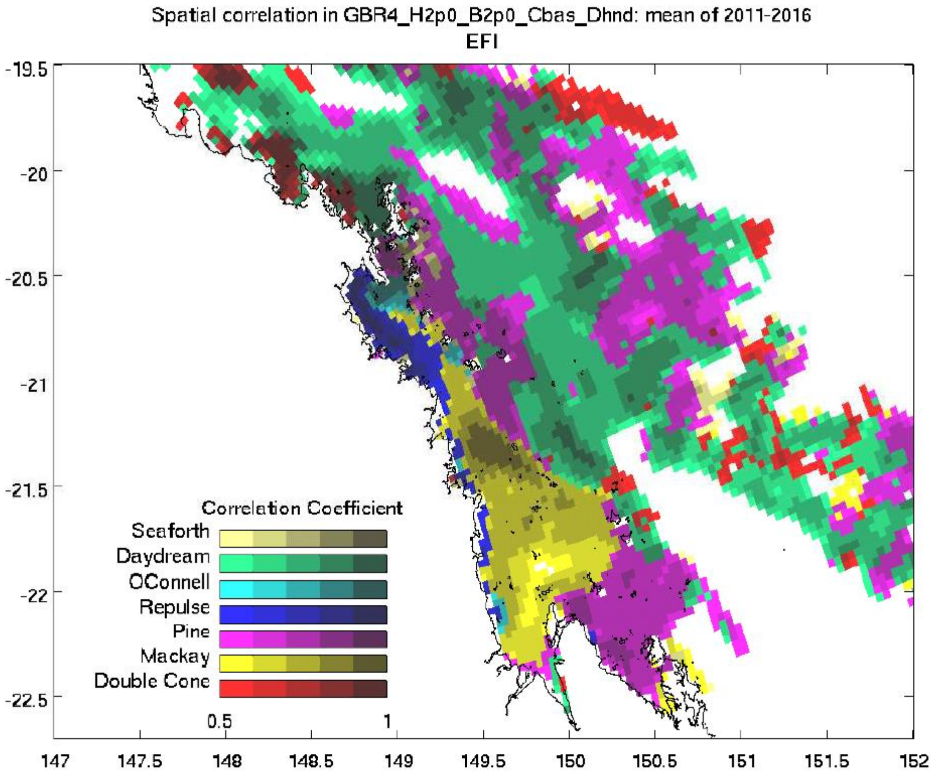
- Look at correlation between chlorophyll dynamics at the observation site and the surrounding water.
- If the correlation is greater than 0.5 (i.e. explains 50 % of variation), and greater than correlation with other sites, then it is part of the footprint.



- Double Cone captures processes at the inshore edge of the GBR lagoon.
- Daydream, Pine and Repulse, and Seaforth only capture local phenomena.
- A site off Mackay has the largest footprint, capturing processes in much of southern Repulse Bay.







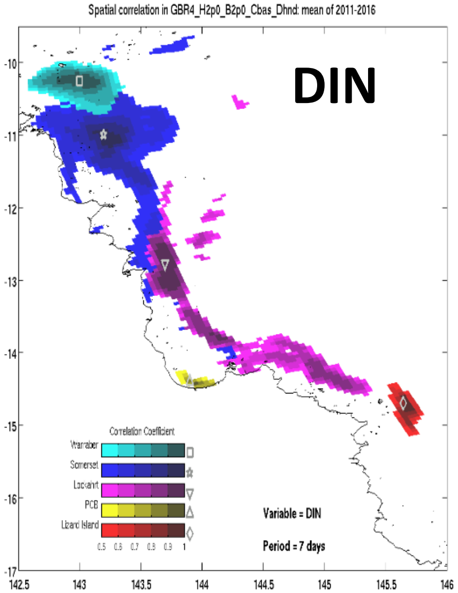
DIN a lot like chlorophyll, although Double Cone much smaller footprint.

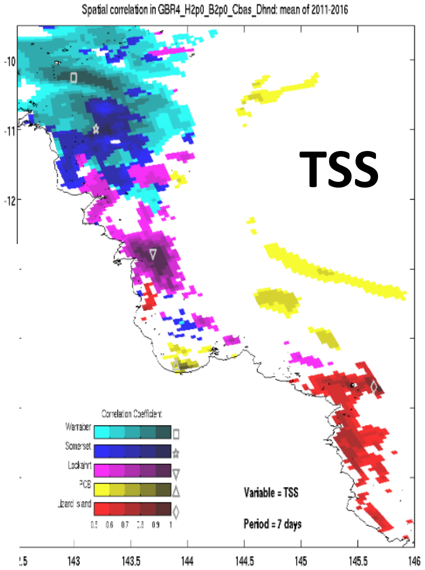
Suspended sediments has more distant correlations as it is driven by tidal resuspension with tides synchronised.

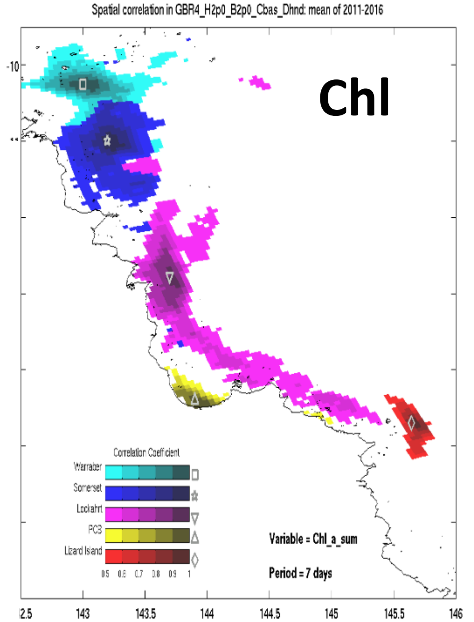
Where would be the best spot in Cape York?

Lockhart River has the largest spatial extent.

Princes Charlotte Bay and Lizard Island have limited spatial scales.



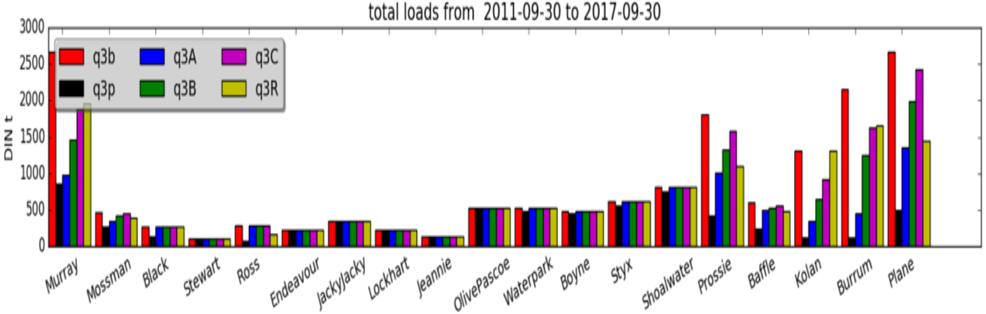




Models directing science needs: Which rivers do we need to reduce pollutant and sediment loads most?

SOURCE Catchments provides the nutrient and sediment loads to the eReefs marine model.

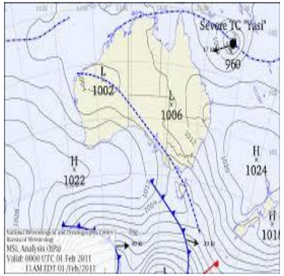
Dave Waters / Robin Ellis
(QLD Govt. Department of Natural Resources and Mines, DES)

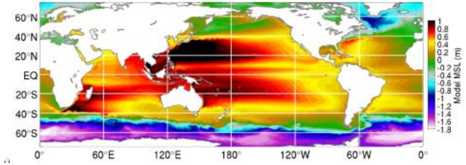


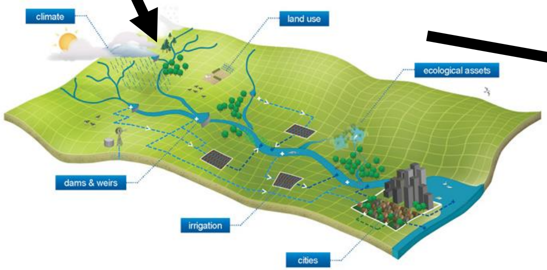
Carl Mitchell, Nyssa Henry and Paulina Kaniewska (OGBR)

Catchment and marine water modelling to support load reduction targets.

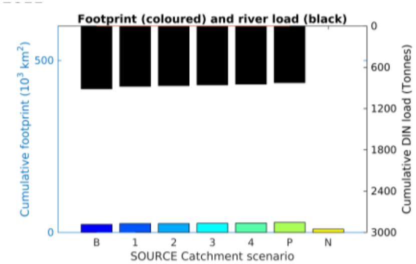
Catchment and marine models forced by BOM weather and CSIRO global ocean models





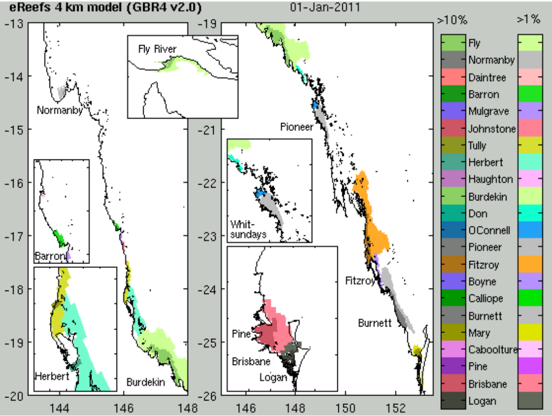


SOURCE Catchments loads of nutrient and sediments

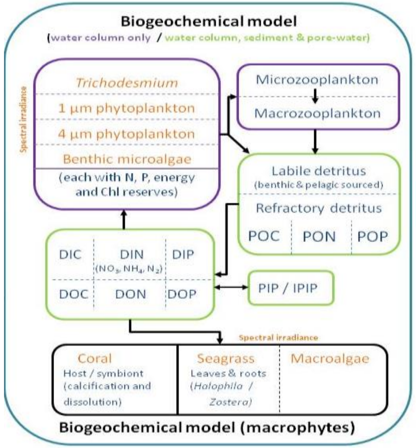


Load reduction using water quality outputs / ecological targets and catchment loads.

eReefs hydrodynamic modelling with river footprint estimation



eReefs water quality modelling for Chl, TSS and water clarity



- Quantify impact of anthropogenic loads on water quality.
- Use the river tracers to determine which river was responsible for the water quality condition at a point in time.
- Determine what reduction in load would be required at each river to improve water quality to the condition required.

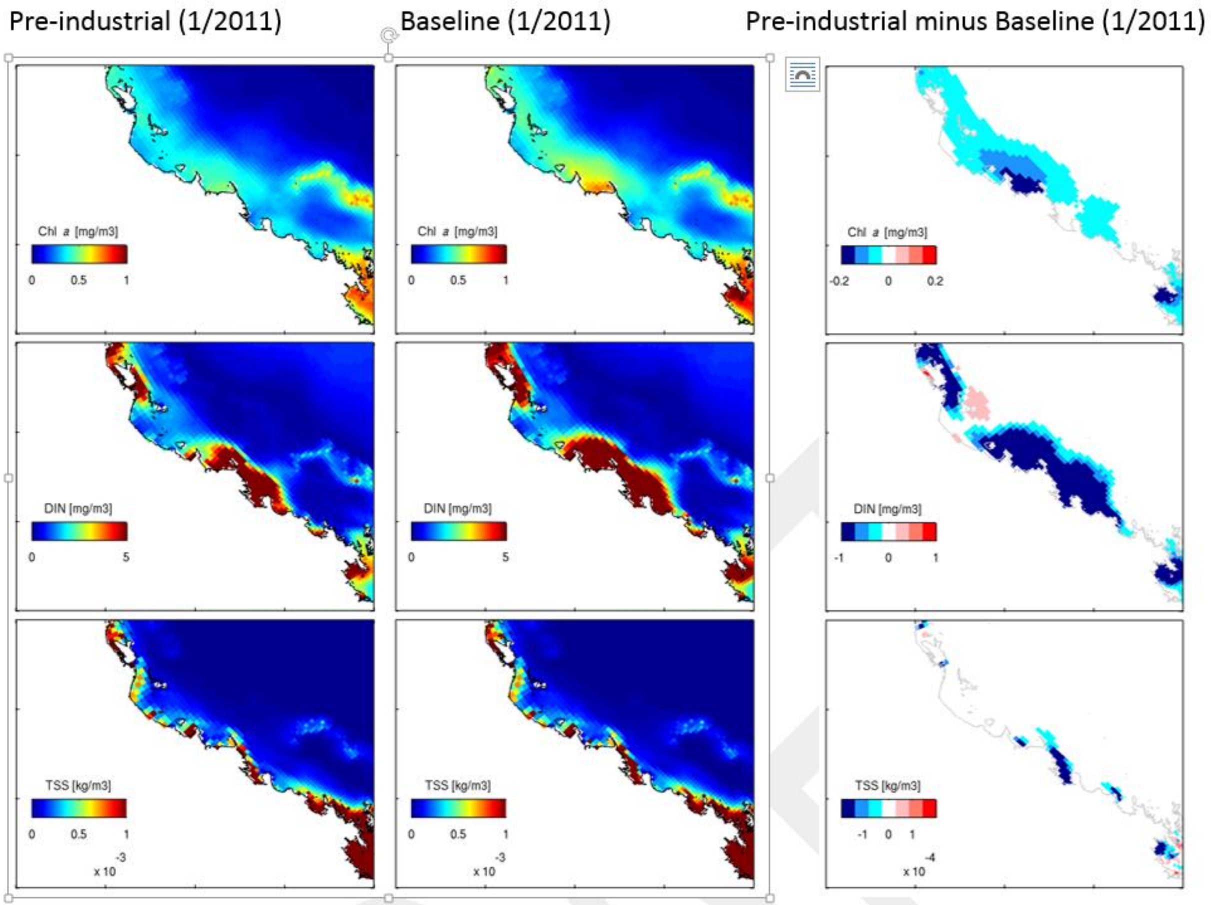
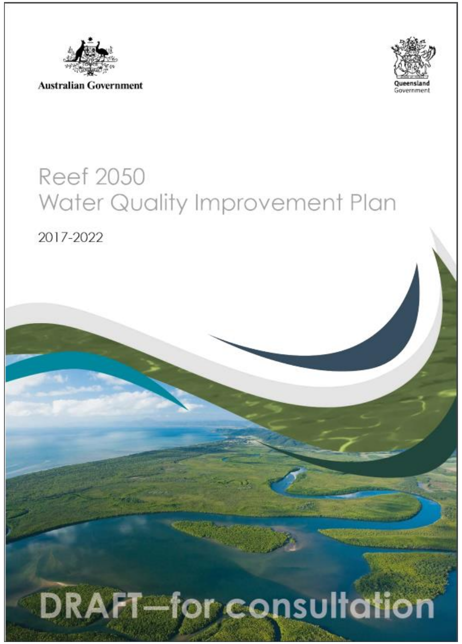
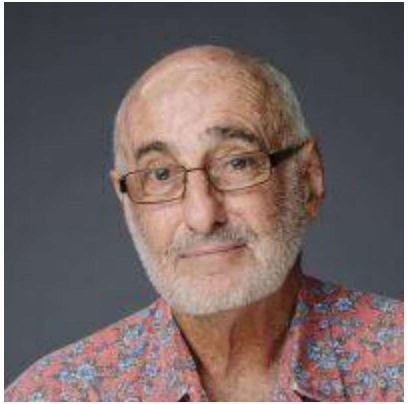


Figure 5 Monthly mean Chl *a*, DIN and TSS for the Burdekin region in January 2011. First column is the Pre-industrial scenario, second column Baseline scenario and third column is Pre-industrial minus Baseline scenario. Blue shading is a decrease in the scenarios compared with the Baseline and red is an increase.





Jon Brodie
(JCU)

- Joint release from Federal and QLD governments.
- Replaces nominal targets (80 % DIN, 50 % SS) with scientifically-determined, outcome based targets.
- This determines which catchments should have highest priorities for improved understanding, data collection and ultimately on-ground works.

Table 9. End-of-catchment anthropogenic water quality targets for the Great Barrier Reef catchments by 2025 and relative priorities for water quality improvement (t= tonnes; ND= not determined)

NRM region	Catchment/ Basin	Area (ha)	Dissolved inorganic nitrogen target		Fine sediment target		Particulate phosphorus target		Particulate nitrogen target		Pesticide (priority only)
			%	t	%	kilo-t	%	t	%	t	
Cape York	Jacky Jacky Creek	296,330	0	0	0	0	0	0	0	0	
	Olive Pascoe River	417,950	0	0	0	0	0	0	0	0	
	Lockhart River	288,330	0	0	2	1	2	2	2	5	
	Stewart River	274,280	0	0	6	2	6	2	6	7	
	Normanby River	2,439,490	0	0	10	15	10	5	10	15	
	Jeannie River	363,750	0	0	6	2	6	2	6	9	
	Endeavour River	218,240	0	0	10	3	10	3	10	11	
Wet Tropics	Daintree River	210,670	0	0	0	0	0	0	0	0	
	Mossman River	47,240	50	52	0	0	0	0	0	0	
	Barron River	218,880	60	52	0	0	0	0	0	0	
	Mulgrave-Russell River	194,400	70	300	10	16	10	19	10	53	
	Johnstone River	232,390	70	350	40	100	40	250	40	490	
	Tully River	168,350	50	190	20	17	20	23	20	68	
	Murray River	110,840	50	120	20	8	20	11	20	32	
	Herbert River	984,590	70	620	30	99	30	57	30	200	
Burdekin	Black River	105,970	ND	ND	ND	ND	ND	ND	ND	ND	
	Ross River	170,820	60	74	ND	ND	ND	ND	ND	ND	
	Haughton River	405,080	70	640	0	0	0	0	0	0	
	Burdekin River	10,310,940	60	100	30	840	30	440	30	720	
	Don River	373,620	0	0	30	55	30	43	30	75	
Mackay Whitsunday	Proserpine River	249,440	70	110	0	0	0	0	0	0	
	O'Connell River	238,760	70	130	40	96	40	120	40	250	
	Pioneer River	157,360	70	140	20	35	20	23	20	61	
	Plane Creek	253,870	70	260	0	0	0	0	0	0	
Fitzroy	Styx River	301,340	0	0	0	0	0	0	0	0	
	Shoalwater Creek	360,180	0	0	0	0	0	0	0	0	
	Waterpark Creek	183,650	0	0	0	0	0	0	0	0	
	Fitzroy River	14,254,470	0	0	30	390	30	380	30	640	
	Calliope River	224,060	0	0	30	15	30	54	30	107	
	Boyne River	249,630	0	0	40	6	40	5	40	9	
Burnett Mary	Baffle Creek	408,470	50	16	20	11	20	15	20	33	
	Kolan River	290,450	50	34	20	6	20	5	20	14	
	Burnett River	3,319,540	70	150	20	85	20	29	20	68	
	Burrum River	337,170	50	93	20	3	20	3	20	8	
	Mary River	946,580	50	180	20	130	20	160	20	470	

Models directing science needs: Knowledge gaps in coral bleaching physiology?

Project 3.3.1 Quantifying the linkages between water quality and the thermal tolerance of GBR coral reefs

Tropical Water Quality Hub

National Environmental Science Programme

Most of the model equations based on sophisticated labs studies …

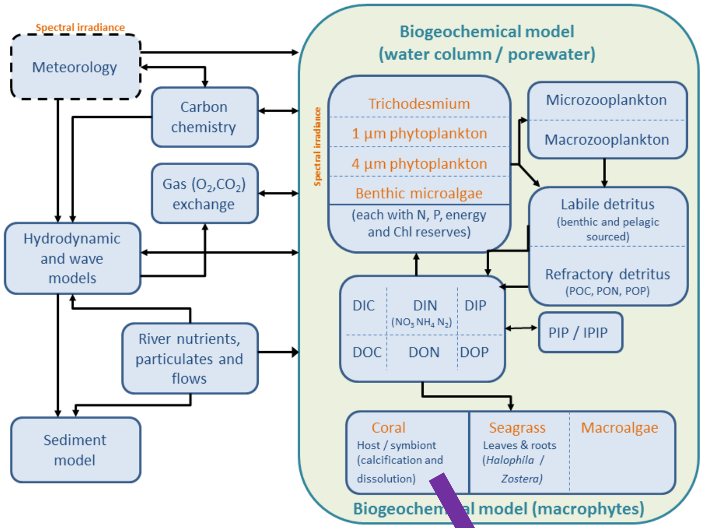
Neal Cantin (AIMS)

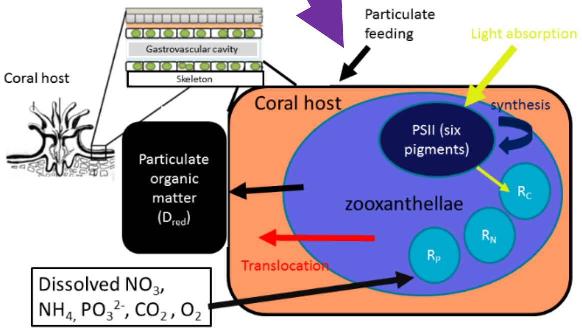
Line Bay (AIMS)

Peter Ralph (UTS)

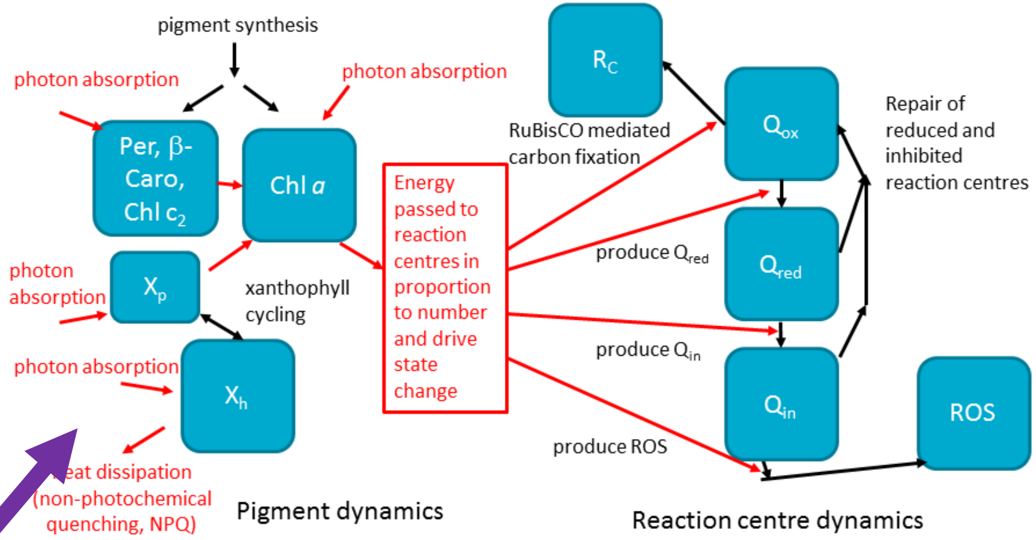
Malin Gustafsson (UTS)

Coral bleaching model

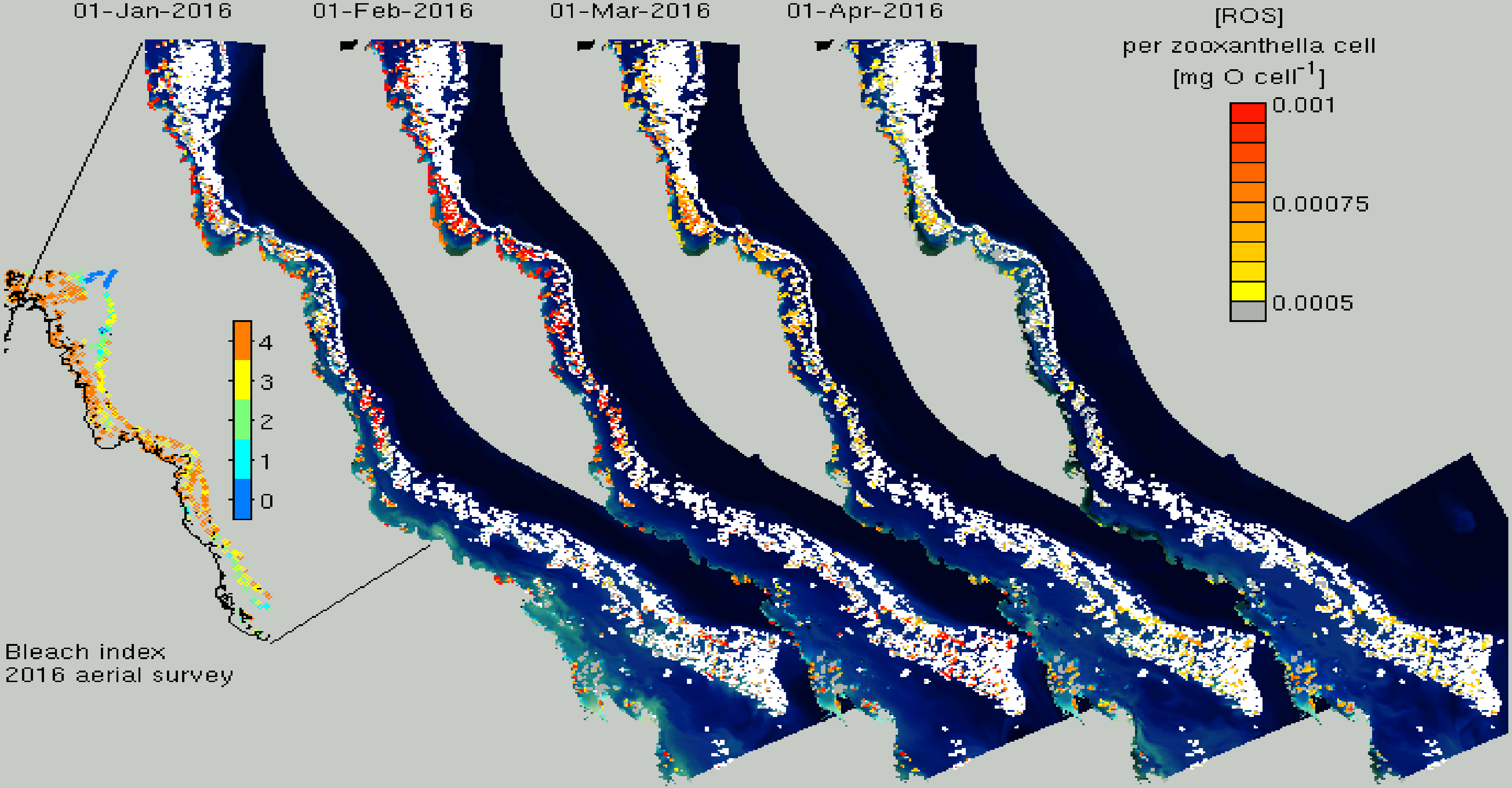


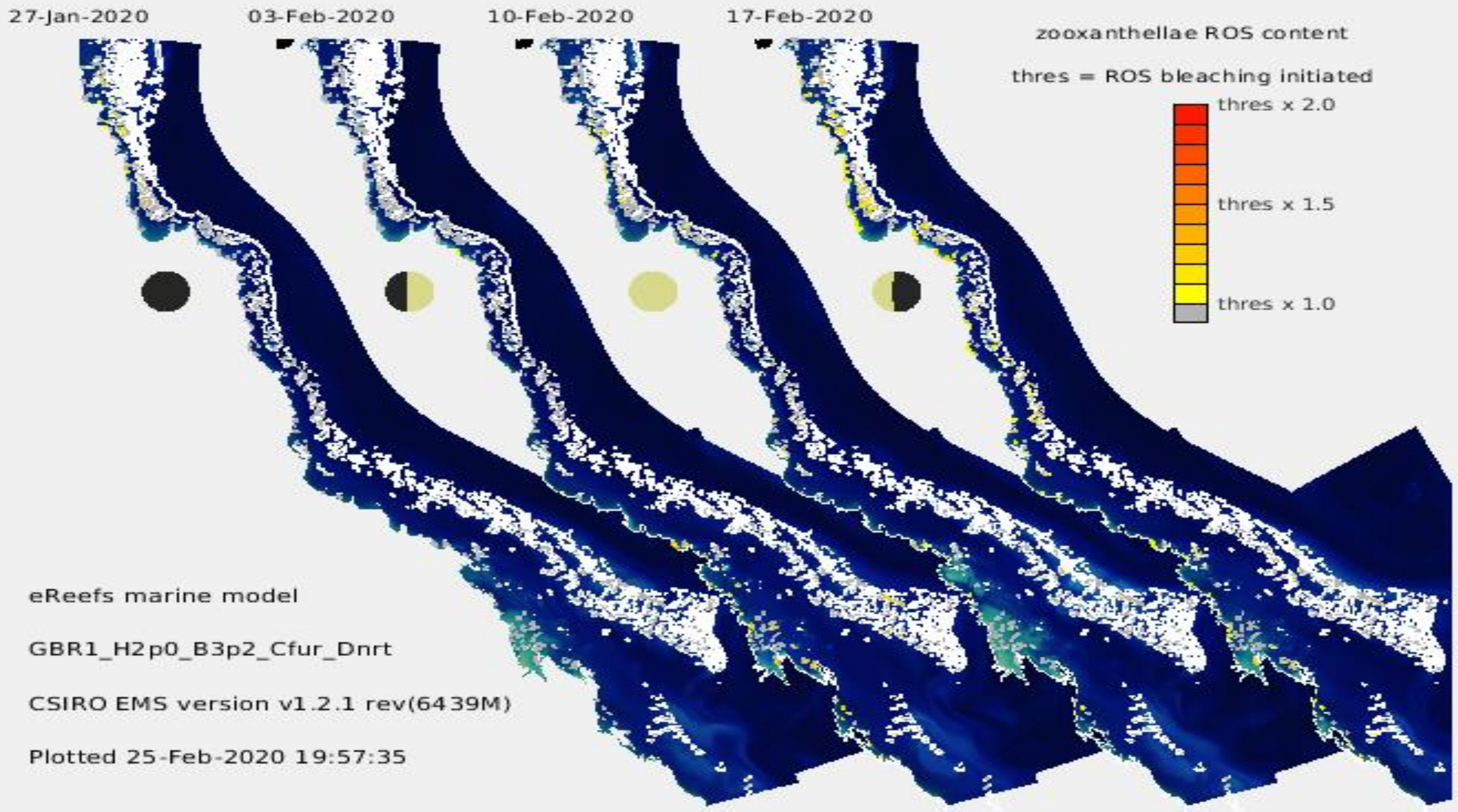


Photon / energy pathways through the model photosystem



To capture the process of reactive oxygen build-up, a model explicitly represents coral host biomass, as well as zooxanthellae biomass, intracellular pigment concentration, nutrient status, and the state of reaction centres and the xanthophyll cycle. Photophysiological processes represented include photoadaptation, xanthophyll cycle dynamics, and reaction centre state transitions.


01-Jan-2016
01-Feb-2016
01-Mar-2016
01-Apr-2016
[ROS]
per zooxanthella cell
[mg O cell^{-1}]
0.001
0.00075
0.0005
4
3
2
1
0
Bleach index
2016 aerial survey


27-Jan-2020
03-Feb-2020
10-Feb-2020
17-Feb-2020
zooxanthellae ROS content
thres = ROS bleaching initiated
thres x 2.0
thres x 1.5
thres x 1.0
eReefs marine model
GBR1_H2p0_B3p2_Cfur_Dnrt
CSIRO EMS version v1.2.1 rev(6439M)
Plotted 25-Feb-2020 19:57:35

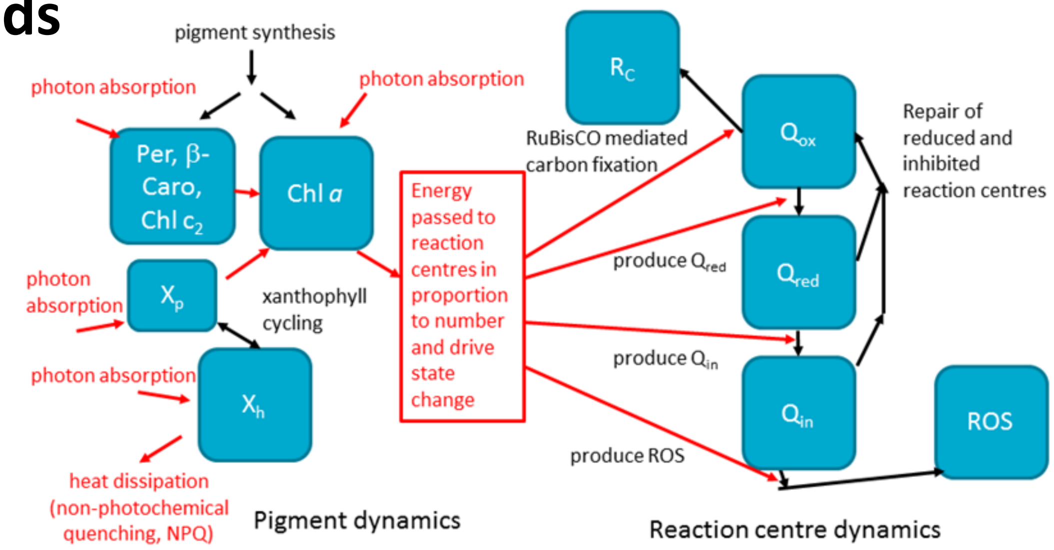
Models directing science needs Knowledge gaps in coral bleaching physiology?

Some processes were poorly-constrained by existing lab studies:

- rates of detoxification of ROS
- ROS toxicity
- ROS threshold for expulsion.

Underlying science challenge is to measure ROS directly in cells – this has proved very difficult.

Photon / energy pathways through the model photosystem



An insight from modelling:

- A zooxanthellae that adapts to warming through better temperature tolerance of Rubisco will have to keep adapting as climate changes
- One that detoxifies better will be a one-off adaptation because solar radiation is not increasing.

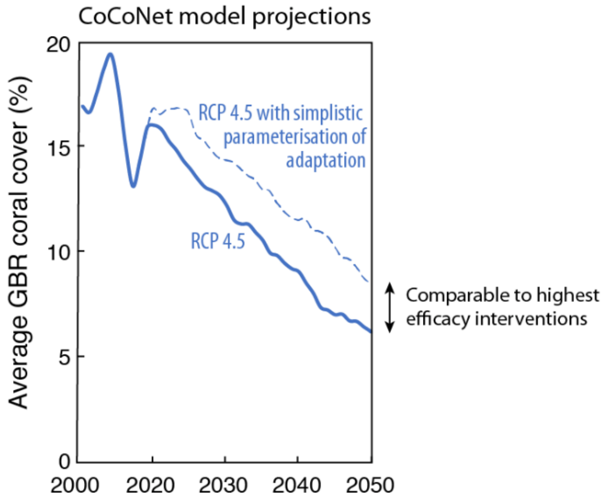
Models directing science needs: Knowledge gaps in coral bleaching ecology?

Pete Mumby UQ

Yves-Marie Bozec (UQ)

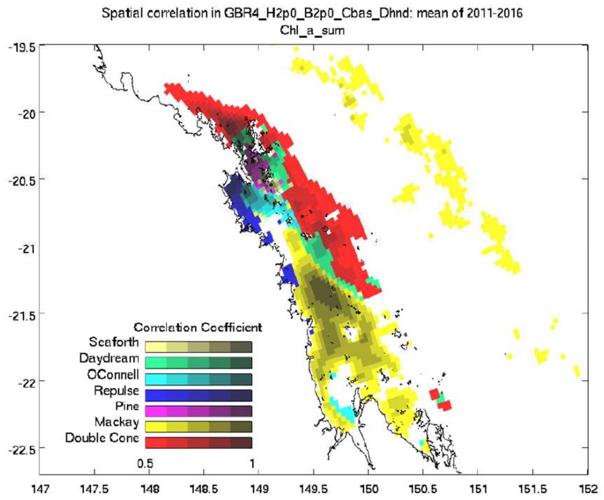
Scott Condie (CSIRO)

- The Reef Restoration Adaptation Program (RRAP) modelled the survival of corals to 2100, and whether interventions (cloud brightening etc.) will improve outcomes.
- RRAP modelling studies showed the key importance of natural adaptation to higher temperatures in determining future coral cover.
- RRAP has proposed a sub-program (EcoRRAP) to pursue uncertainties, many identified by modelling, that will investigate uncertainties.



Conclusion:

- Models are generally created to test an idea, or to produce a prediction, as a means to add value to existing scientific understanding and observations.
- But models can also highlight deficiency in scientific understanding that motivate more studies in the laboratory, or observations in the field, and eventually better models …



- The pipeline from science to models and back again takes time and resources, but can be the most professionally rewarding dimensions of a modeller’s career …

eReefs is a collaboration between

GREAT BARRIER REEF foundation

CSIRO

Australian Government

AUSTRALIAN INSTITUTE OF MARINE SCIENCE

Australian Government

Bureau of Meteorology

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IMOS Integrated Marine Observing System

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BHP Billiton Mitsubishi Alliance

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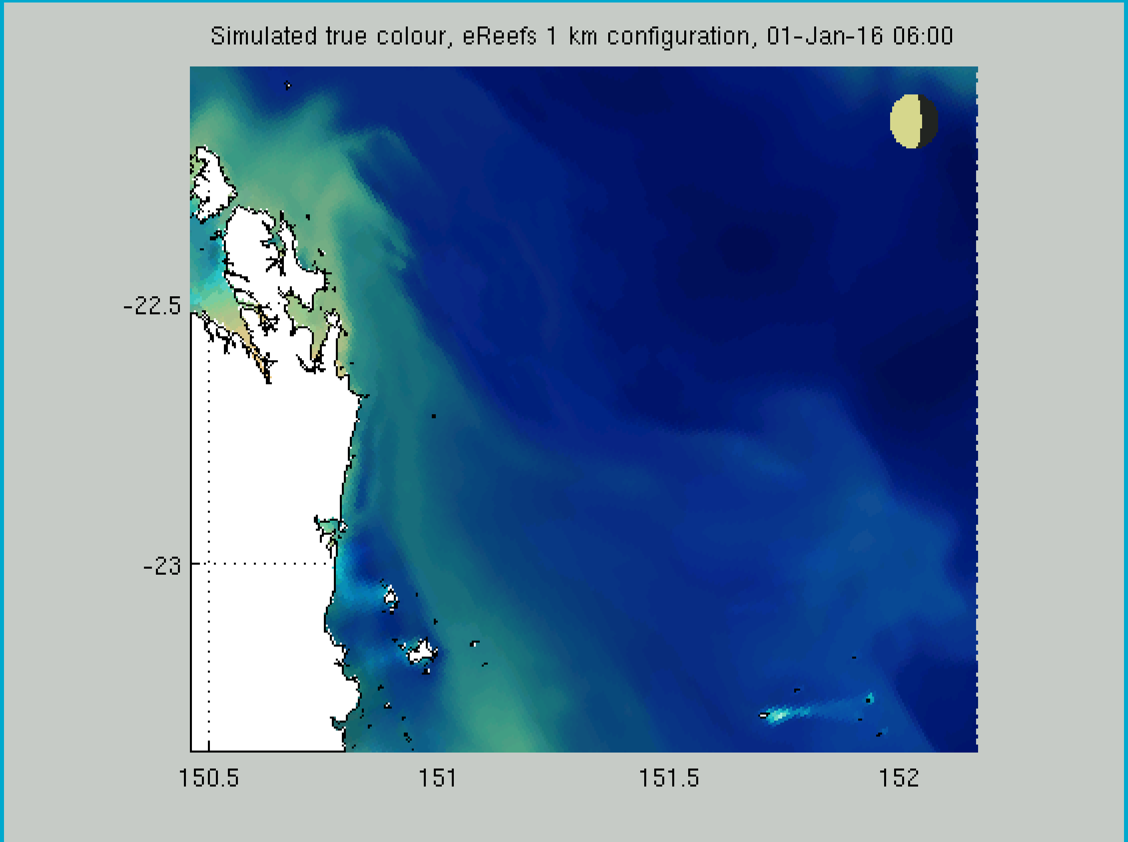
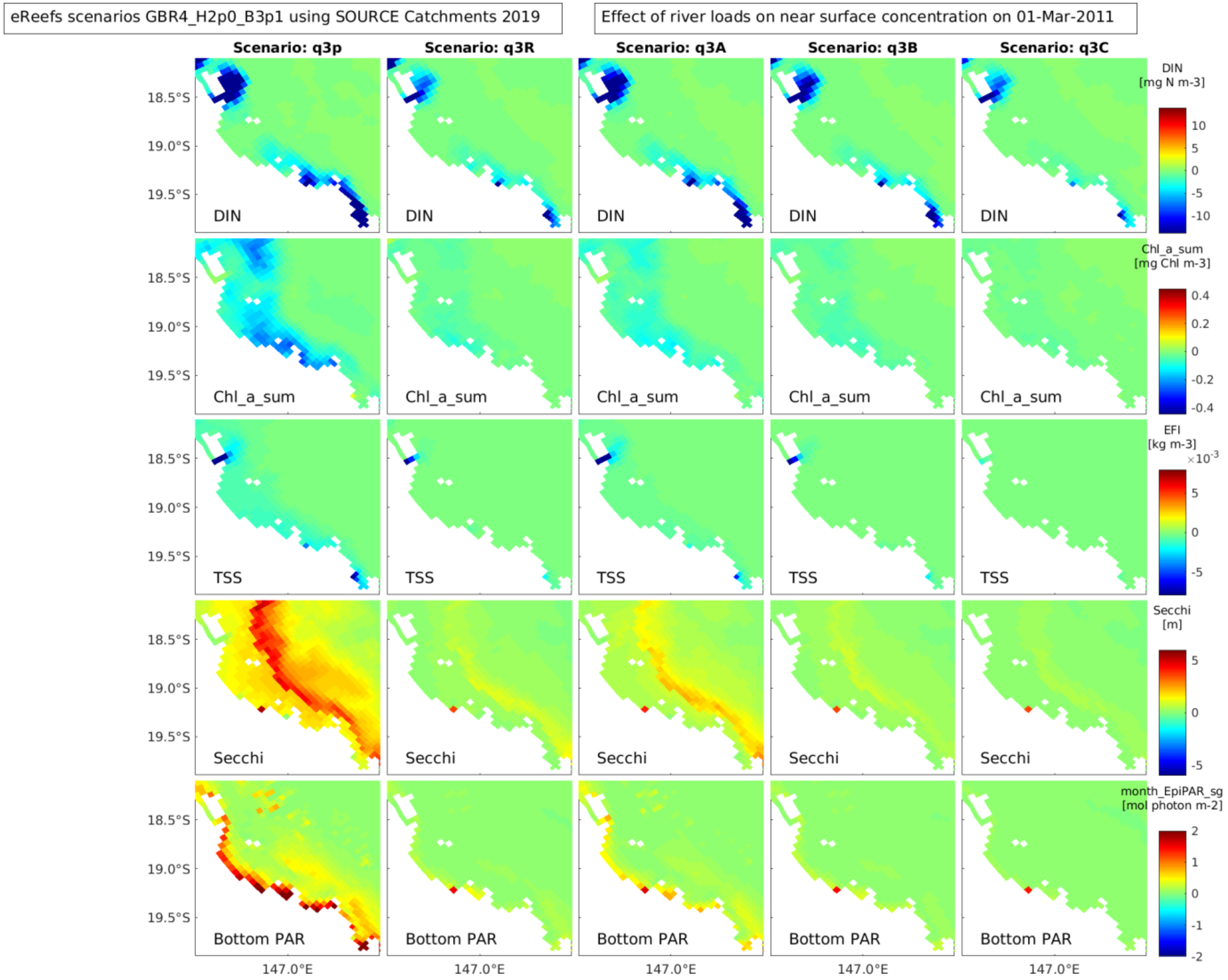


Thank you
Mark Baird


eReefs scenarios GBR4_H2p0_B3p1 using SOURCE Catchments 2019
Effect of river loads on near surface concentration on 01-Mar-2011
Scenario: q3p
Scenario: q3R
Scenario: q3A
Scenario: q3B
Scenario: q3C
DIN
Chl_a_sum
TSS
Secchi
Bottom PAR
18.5°S
19.0°S
19.5°S
147.0°E
DIN [mg N m-3]
Chl_a_sum [mg Chl m-3]
EFI [kg m-3]
×10-3
Secchi [m]
month_EpiPAR_sg [mol photon m-2]