Forum for Operational Oceanography

Modelling systems – research and operations

Peter Oke[1] and Gary Brassington[2]
[1]CSIRO [2]BoM

Talk outline

- Model resolution
  - Predictability
  - Modelling variability *vs* forecasting an event
  - Dependence on observations
- Overview of modelling systems within Australia

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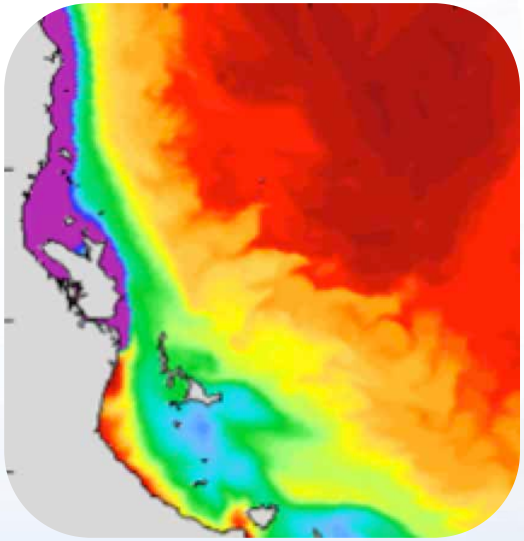
Model resolution and predictability

- Many operational applications demand high-resolution forecasts or hindcasts
- As scales become smaller … the variability becomes more chaotic and less predictable … consider:
  - Internal waves
  - Fronts
  - Filaments
  - Sub-mesoscale eddies



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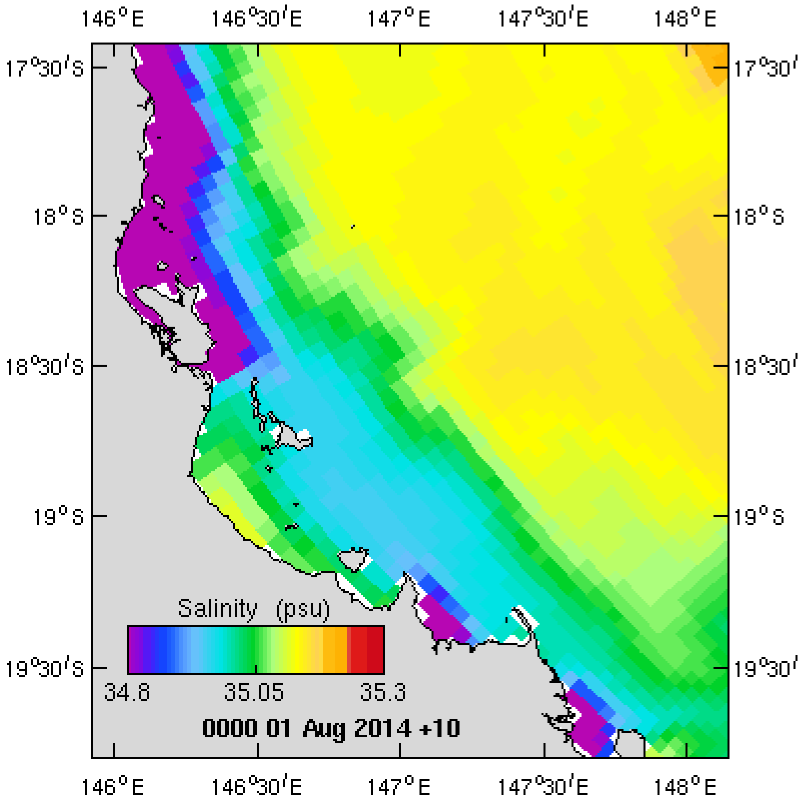
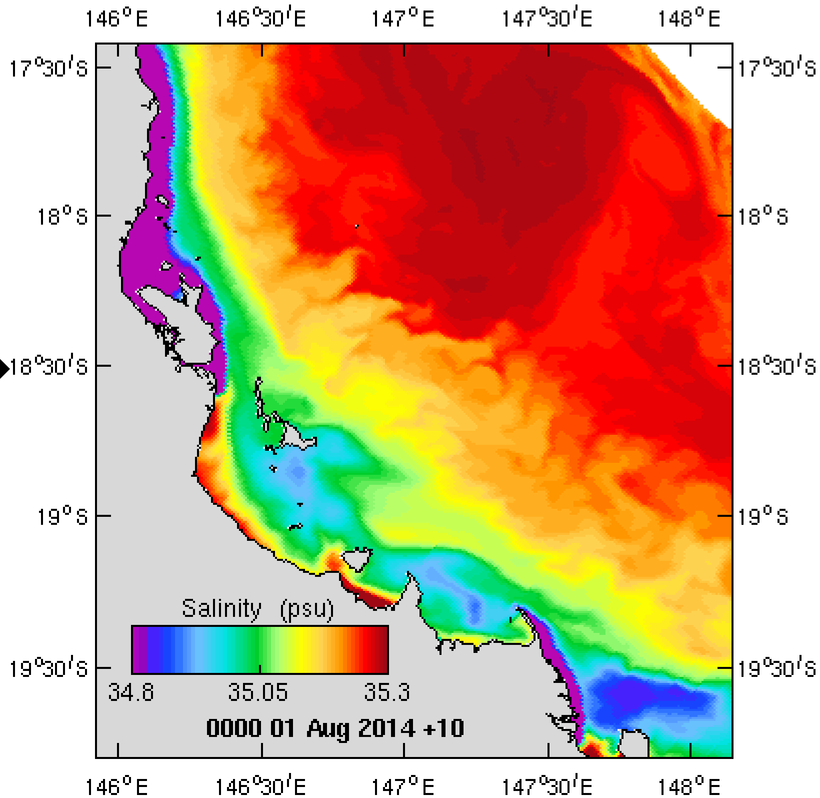
The lure of higher resolution





Credit: E. Jones, M. Baird, M. Herzfeld and M. Mongin

You can't observe coarse scales and hope to realistically reproduces fine scales

… can you?

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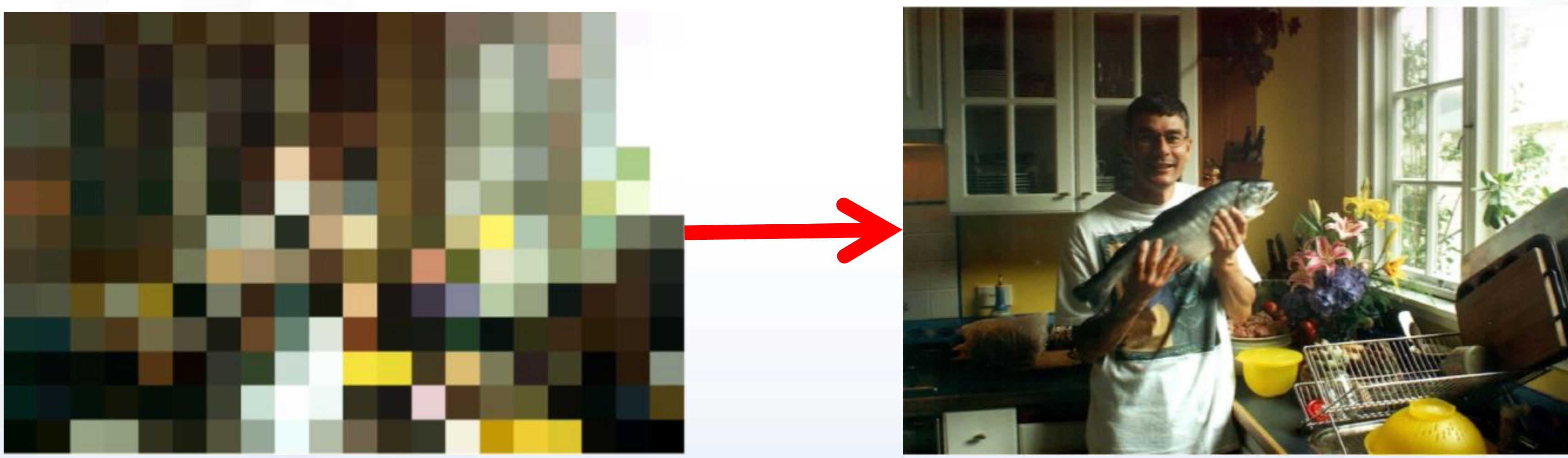
A proud Kiwi, ready for some fssh

Credit: http://marine.rutgers.edu/~wilkin/

You can’t observe coarse scales and hope to realistically reproduces fine scales

(for chaotic circulation features, like eddies, fronts, and filaments)



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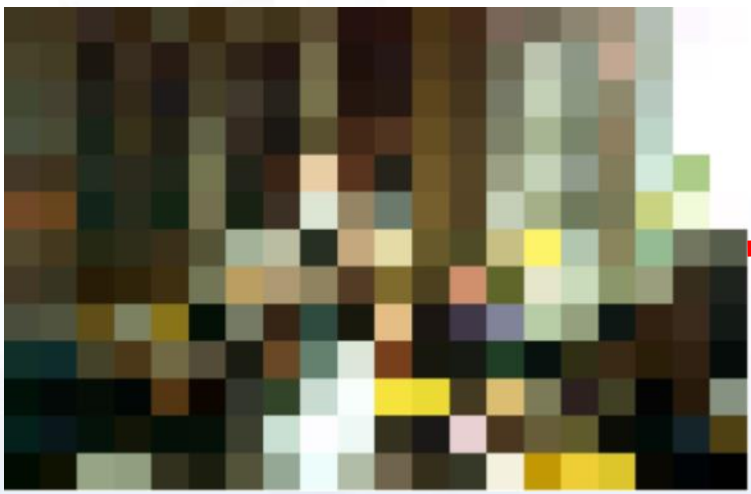
You can't observe coarse scales and hope to realistically reproduces fine scales

(for chaotic circulation features, like eddies, fronts, and filaments)

You may be able to realistically simulate variability at high-resolution … but predicting a specific feature or event often requires data assimilation



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Global Ocean Observations

- Satellite altimetry

  (~7 km along-track + ~100 km between tracks)
- Satellite Sea Surface Temperature

  (AVHRR: 1-4 km; Microwave: 25 km)
- In Situ profiling floats

  (Argo ~300 km spacing; XBT ~ 100 km spacing)
- Surface drifting buoys
- Regional observations
  - Moorings
  - HF radar
  - Gliders
  - Moorings

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Two options in regions with chaotic variability:

1. **Model resolution matches observed resolution**

   Initialise model state for each forecast and constrain the boundary forcing using observations

   … yields a single forecast

   4-10 km grid spacing

2. **Model resolution exceeds observed resolution**

   Perform an ensemble of forecasts with each ensemble member configured with different forcing, initial conditions and/or parameterizations

   … yields a probability forecast

   Finer than 4 km grid spacing

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Model systems in Australia

BoM + CSIRO + UTAS + AIMS + UNSW + UWA

Systems used for operations and research:

- Bluelink ReANalysis – BRAN
- OceanMAPS
- Relocatable Ocean Atmosphere Model – ROAM
- Marine Virtual Laboratory
- eReefs
- NSW 4dVar
- OzROMS

… other ??

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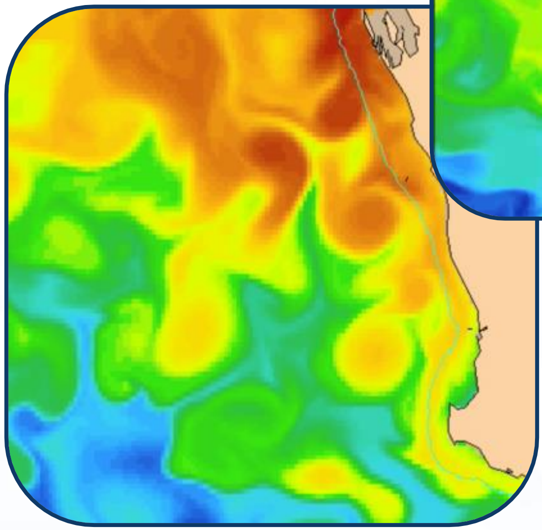
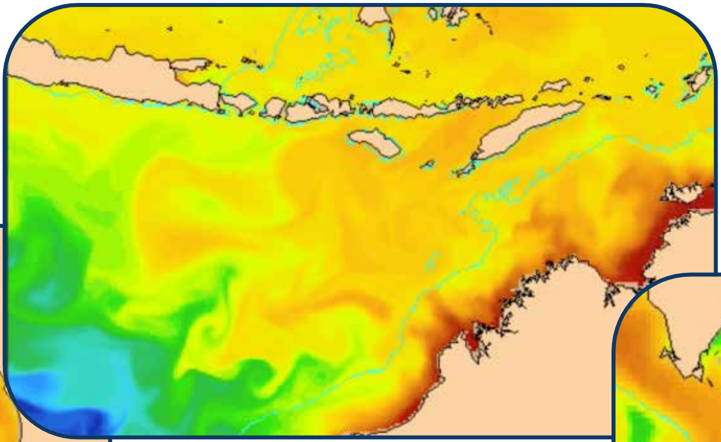
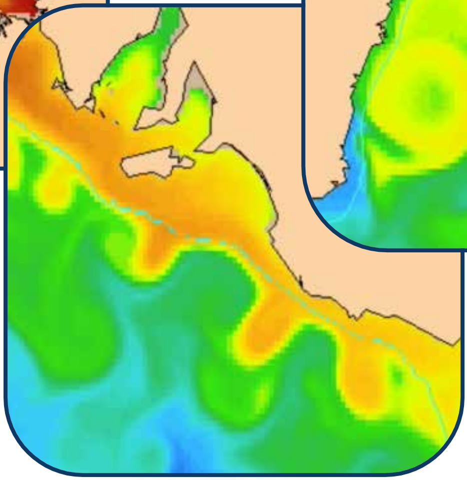
Bluelink ReANalysis

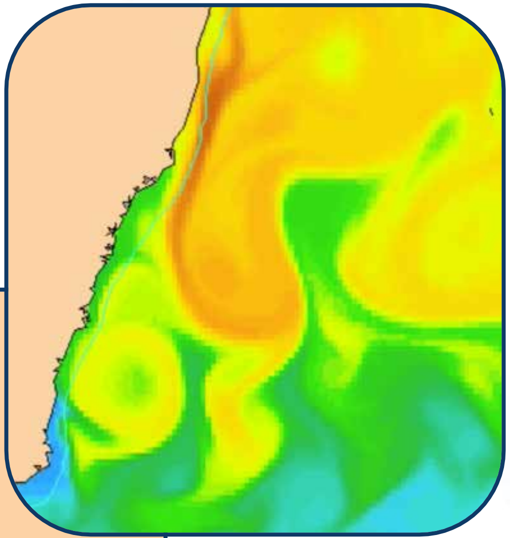
Peter Oke, Pavel Sakov, Paul Sandery, Russ Fiedler, et al.

- MOM: near-global 1/10º res. with 51 levels
- Forced with ERA-interim
- EnOI assimilating:
  - Argo + XBT + Tropical Moorings + Satellite SSH + Microwave & AVHRR SST
- 20+ year reanalysis (1993-present)
- 3-day cycle









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Bluelink ReANalysis

Peter Oke, Pavel Sakov, Paul Sandery, Russ Fiedler, et al.

BRAN history	
2005	BRAN1
2009	BRAN2p1
2013	BRAN3p5
2015	BRAN2015

BRAN2015 model-obs misfits:	
SLA	~7 cm
SST	~0.3 Dec C
T profiles	~0.4 Deg C
S profiles	~0.1 psu

BRAN2015 will soon be released to registered users for commercial and non-commercial use

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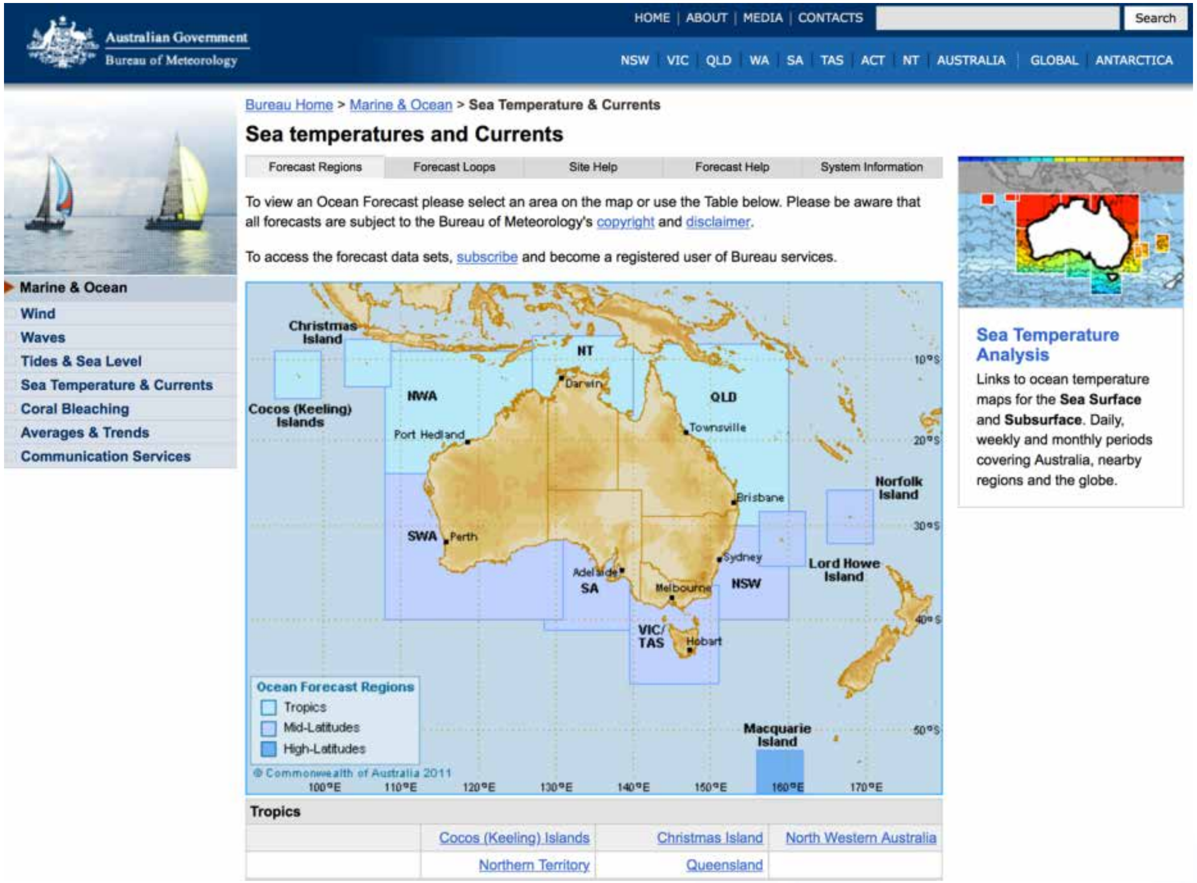
OceanMAPS

Gary Brassington, Justin Freeman, Pavel Sakov, Paul Sandery, et al.

- Operational implementation of BLUElink components with ACCESS-G forcing and NRT data-streams
- Same tools as BRAN, but NRT datastreams
- Four-cycle forecast system



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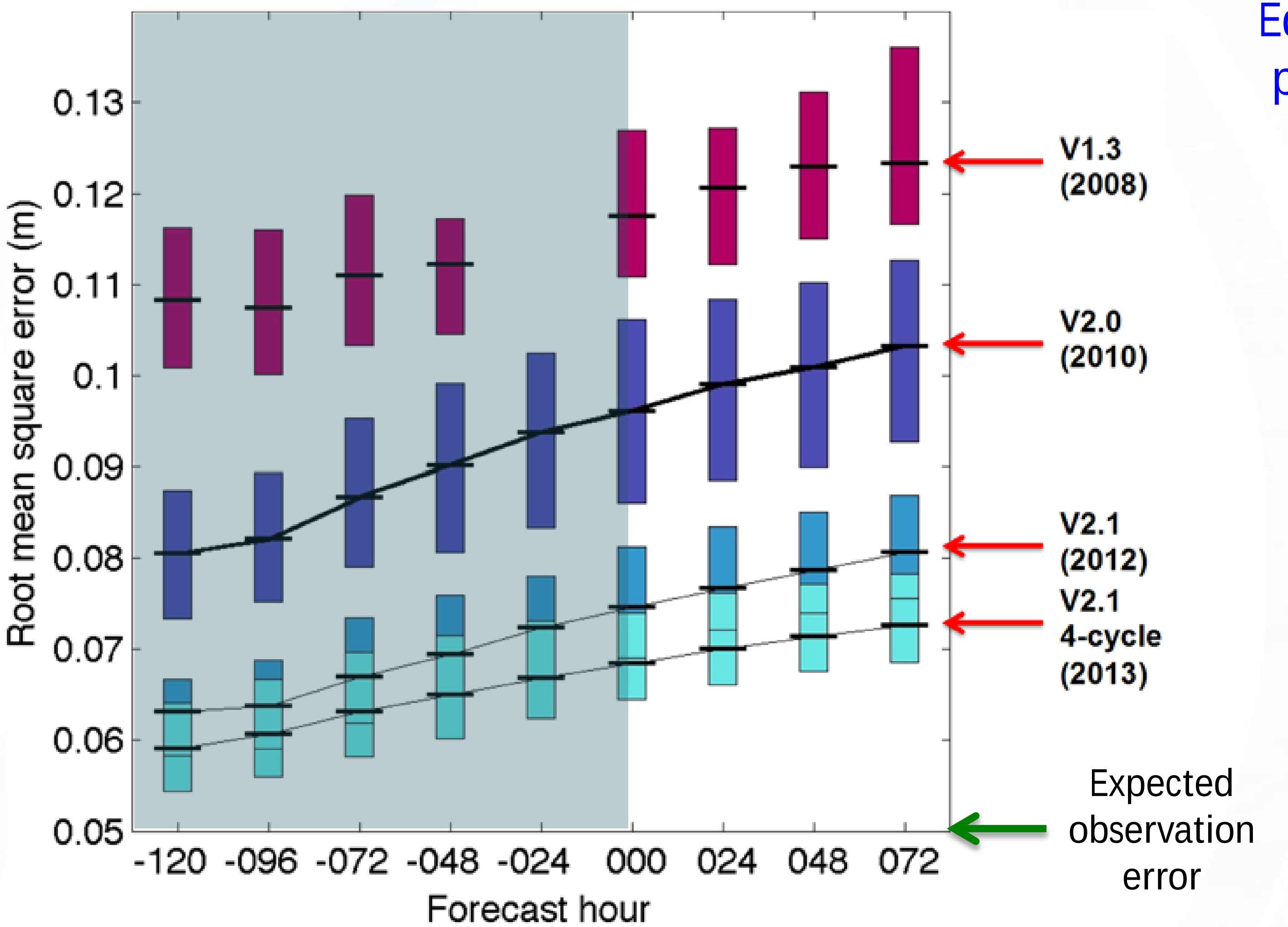
OceanMAPS – performance gains



Equivalent eddy position errors

~30 km

~15 km

~10 km

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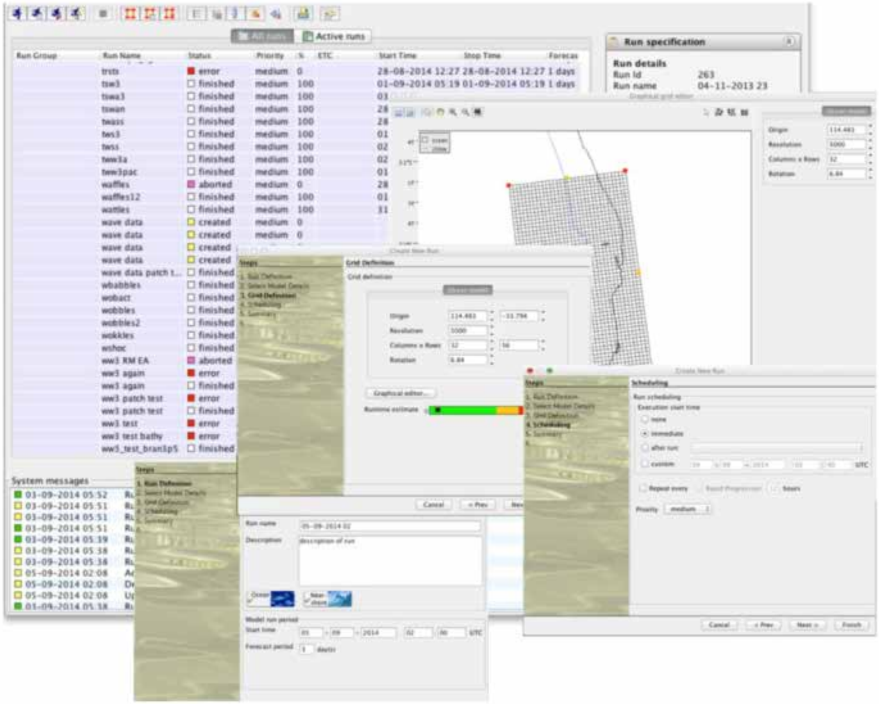
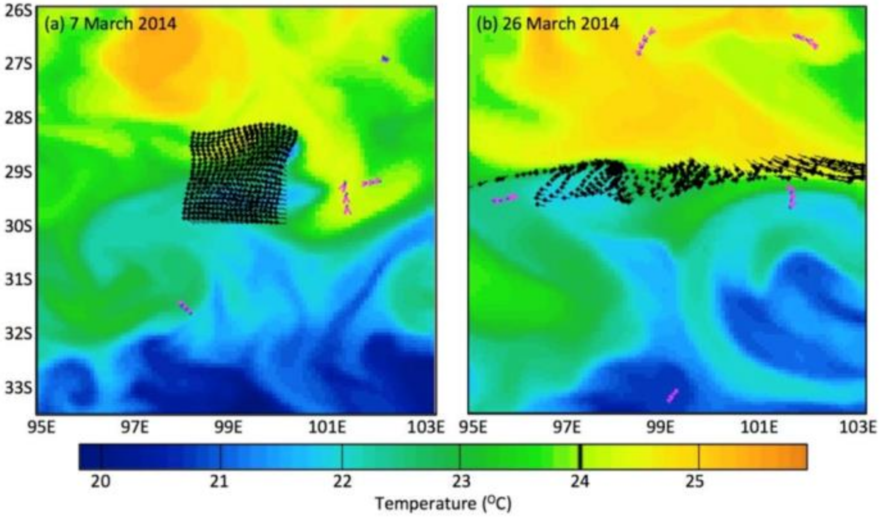
Relocatable Ocean Atmosphere Model (ROAM)

Uwe Rosebrock, Emlyn Jones, Mike Herzfeld, Peter Oke, et al.



Desktop application allowing a non-specialist to configure and execute a regional model forecast or hindcast



Model components:

- SHOC ocean model
- SWAN wave model
- RAMS atmosphere

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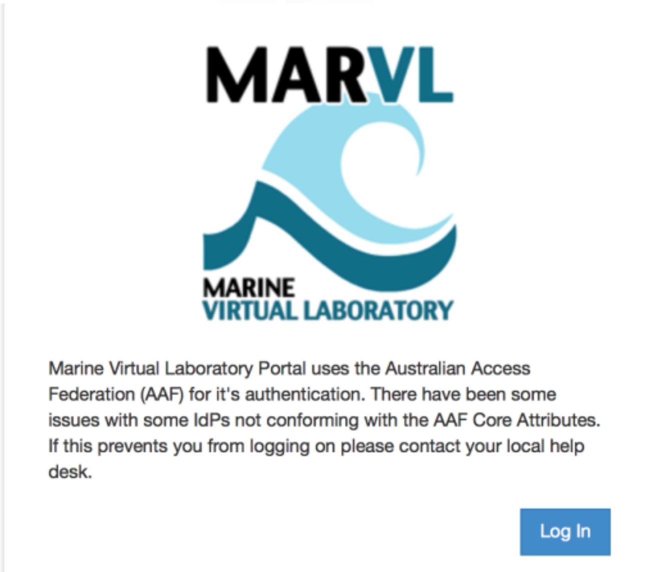
NRT applications include MH3570

Marine Virtual Laboratory (MARVL)

Roger Proctor, Peter Oke, Uwe Rosebrock, et al.



Web portal allowing a specialist to gather and format data needed for a regional ocean or wave model hindcast

Model options:

- SHOC, ROMS, MOM ocean model
- SWAN, WW3 wave model

Generates “take-away bundles” in model-specified formats.

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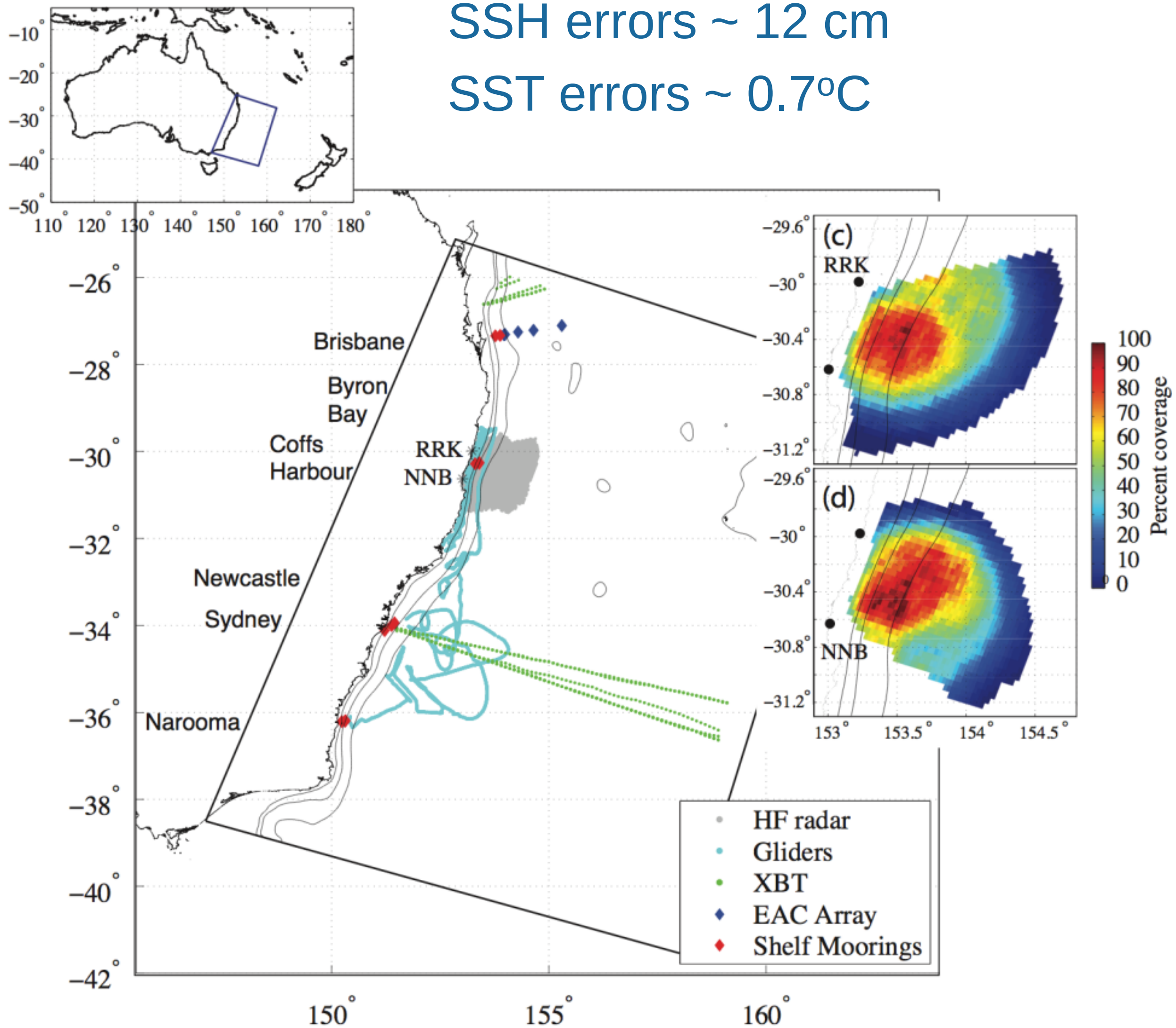
UNSW 4dVar

Colette Kerry, Moninya Roughan, Brian Powell, Peter Oke

- ROMS: 2.5 km res. with 30 layers
- Nested within OceanMAPS
- Forced with ACCESS_R
- 4dVar assimilating:
  - HF radar
  - Gliders
  - Argo + XBT
  - Moorings
  - Satellite SSH
  - AVHRR SST
- 2-year reanalysis (2012-2013)
- 4-day cycle

SSH errors ~ 12 cm

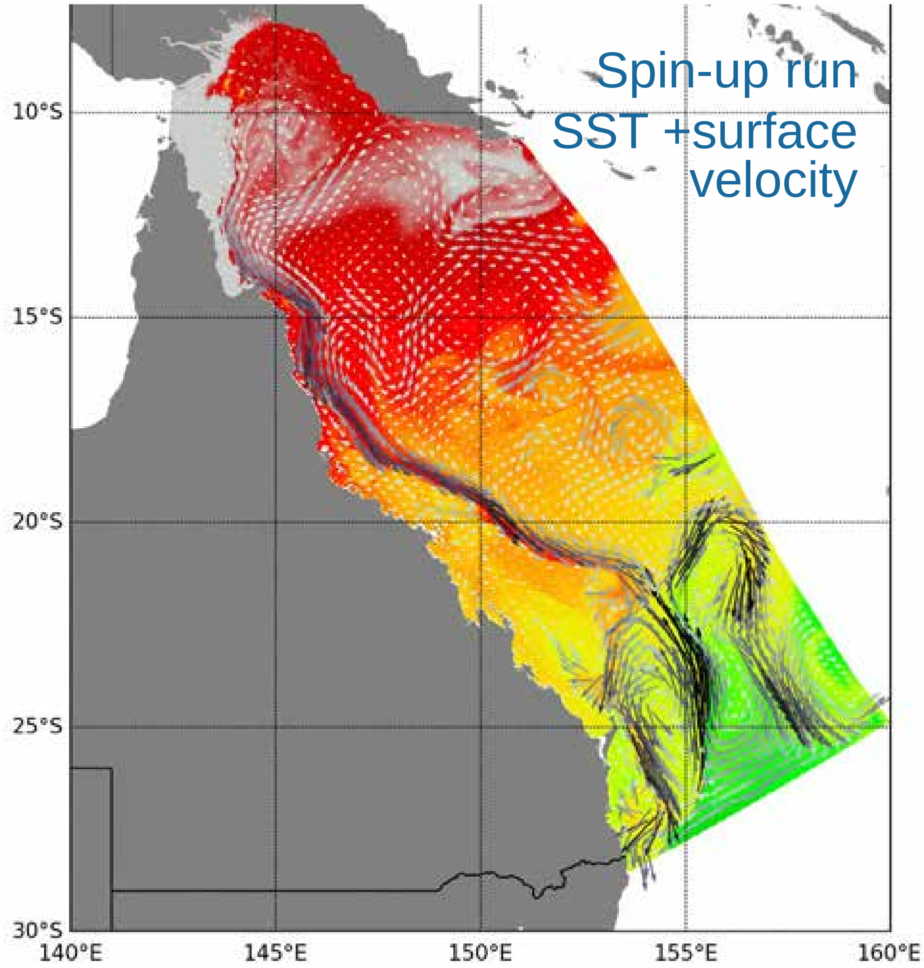
SST errors ~ 0.7^{o}C



eReefs

Gary Brassington, Mike Herzfeld, et al.

- SHOC: 1 km res.
- SHOC 4 km res.
- ROMS 4 km res.
- Nested within OceanMAPS or BRAN
- Includes tides
- Forced with ACCESS_R
- EnOI assimilating:
  - Argo + XBT
  - Moorings
  - Satellite SSH
  - AVHRR SST
  - Satellite ocean colour
- Multiple reanalysis
- Routine forecasts systems running



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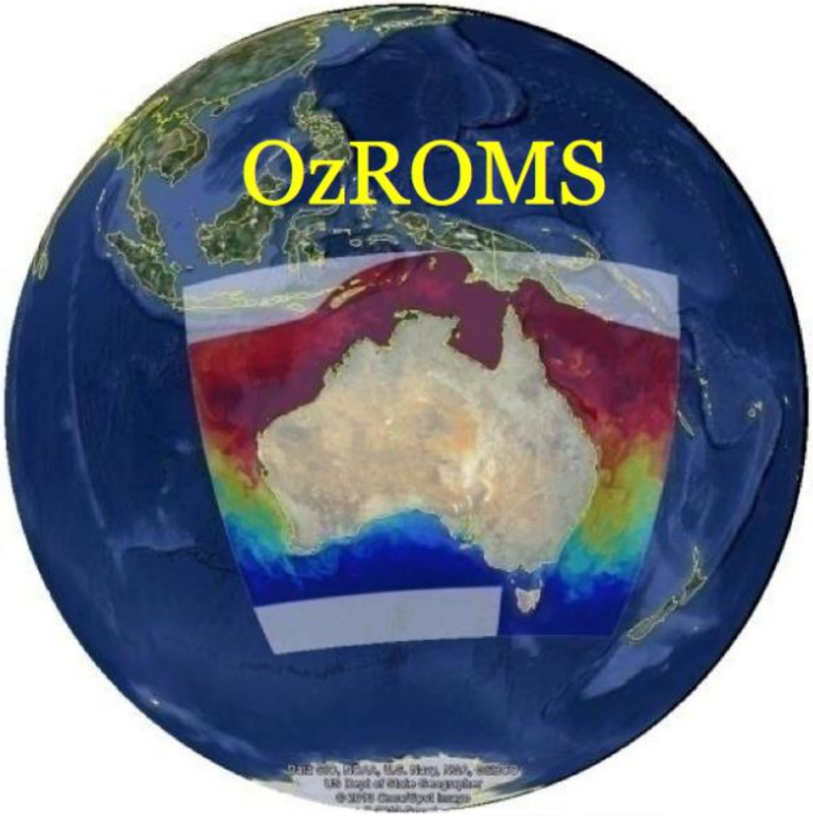
4km-res ROMS
Development version by BoM
Credit: F. Colberg

OzROMS

Chari Pattiaratchi, Sarath Wijeratne, et al.

- ROMS: 2-4 km res. with 30 layers
- Nested within HYCOM
- Forced with ERA-interim
- Includes tides
- No data assimilation
- Reports of “high skill” à realistic variability



Adapted from Wijeratne, Pattiaratchi, Proctor, 2014, ACOMO2014

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Summary

- Consider predictability … modelling variability vs forecasting … dependence on observations
- The Australian oceanography has established modelling and forecast systems suitable for research and operations
- Some systems are mature
- Some systems have been partially assessed
- Research systems have a role to play in operations:
  - Oil and gas planning and approval
  - Exploring different scenarios
  - Understanding extremes
  - …
- There's a difference between "operational" and "routine" forecasting

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Additional Slide

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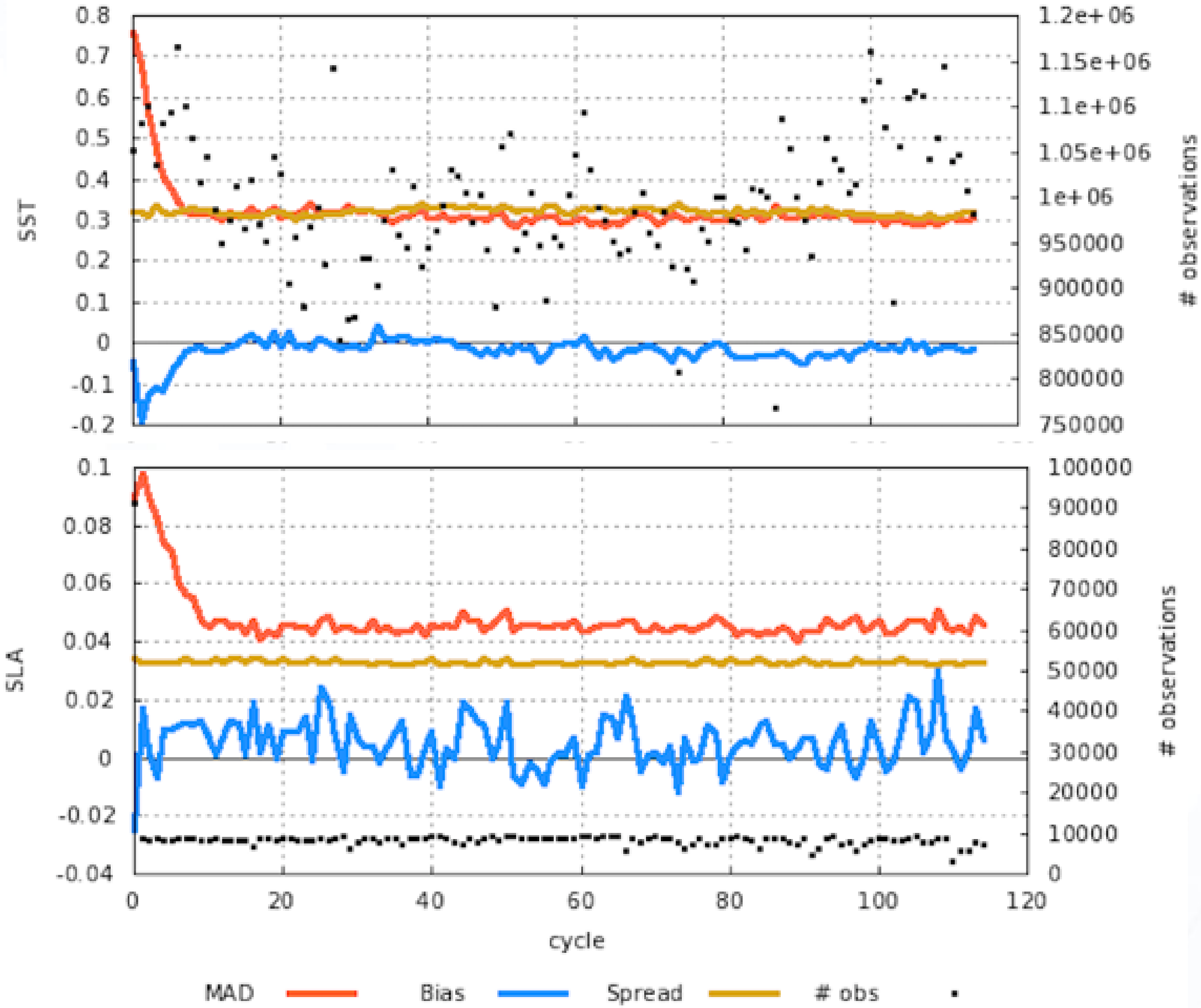
Bluelink ReANalysis

Peter Oke, Pavel Sakov, Paul Sandery, Russ Fiedler, et al.

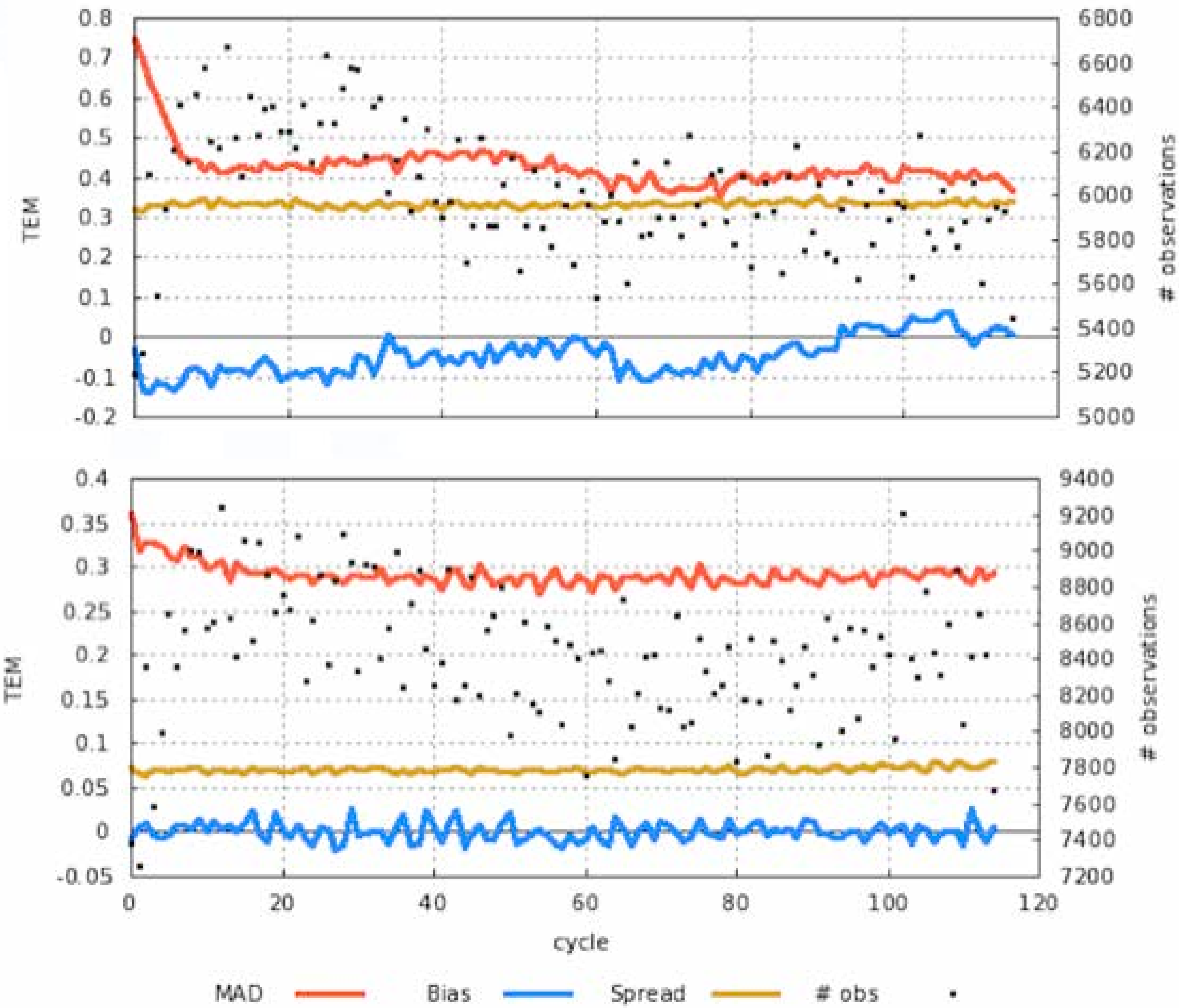


ß **SST**

ß **SLA**

Bluelink ReANalysis

Peter Oke, Pavel Sakov, Paul Sandery, Russ Fiedler, et al.

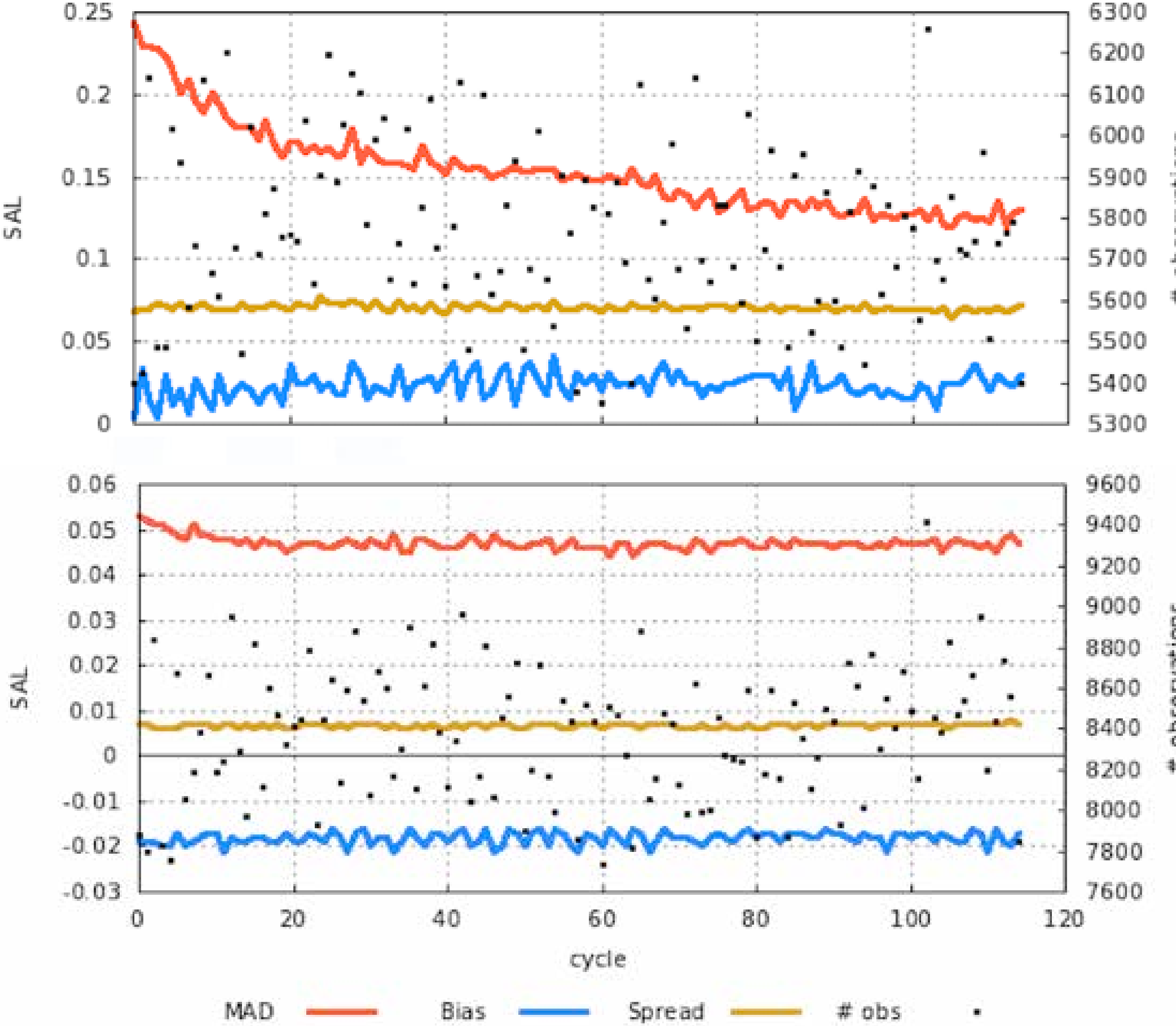


ß Temp (0-50 m)

ß Temp (> 500 m)

Bluelink ReANalysis

Peter Oke, Pavel Sakov, Paul Sandery, Russ Fiedler, et al.



ß Salt (0-50 m)

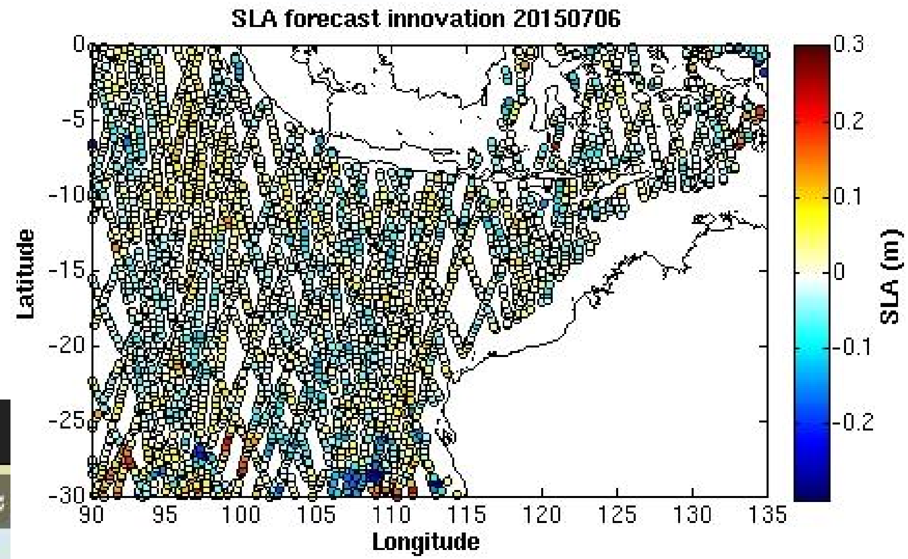
ß Salt (> 500 m)

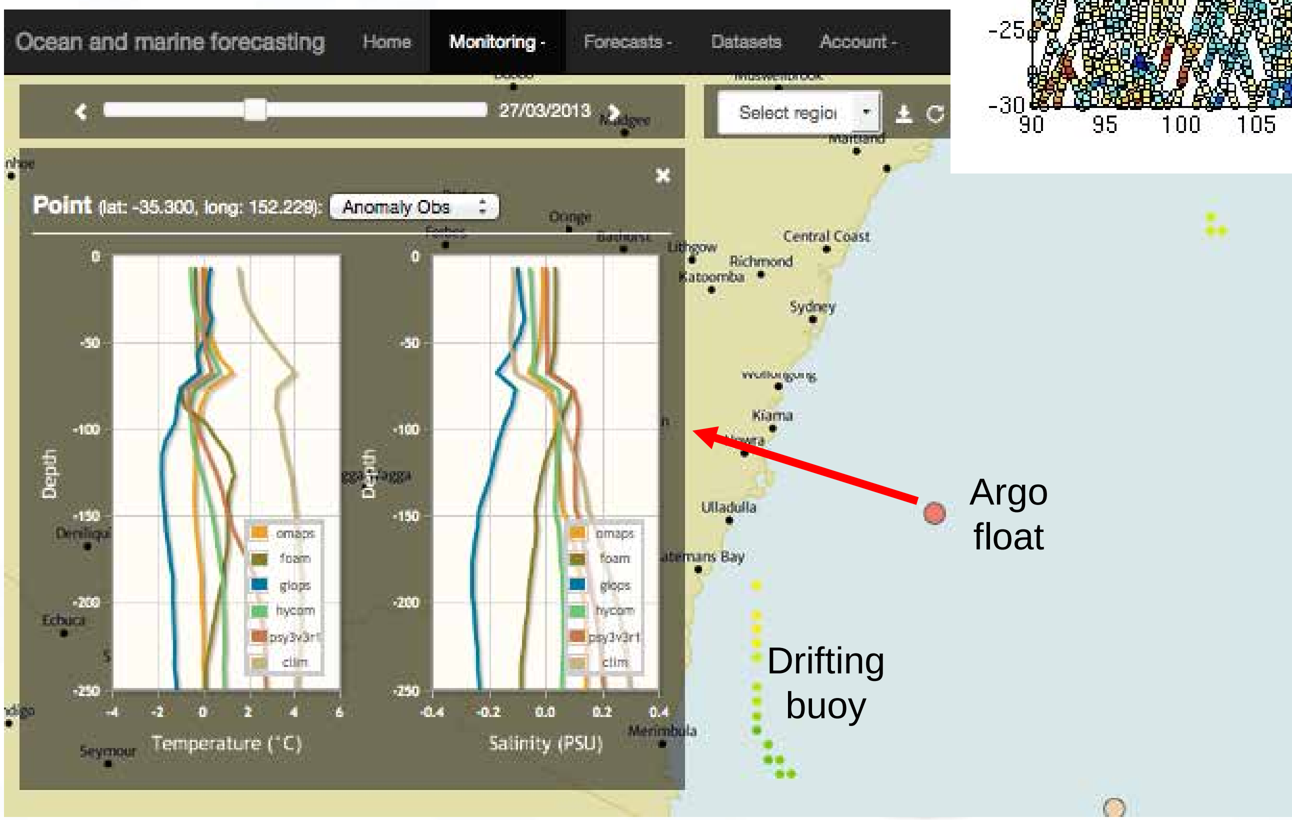
OceanMAPS – routine verification

Verification is critical to operations

System and inter-comparison metrics

Smart tools to improve relevance





Australia

UK

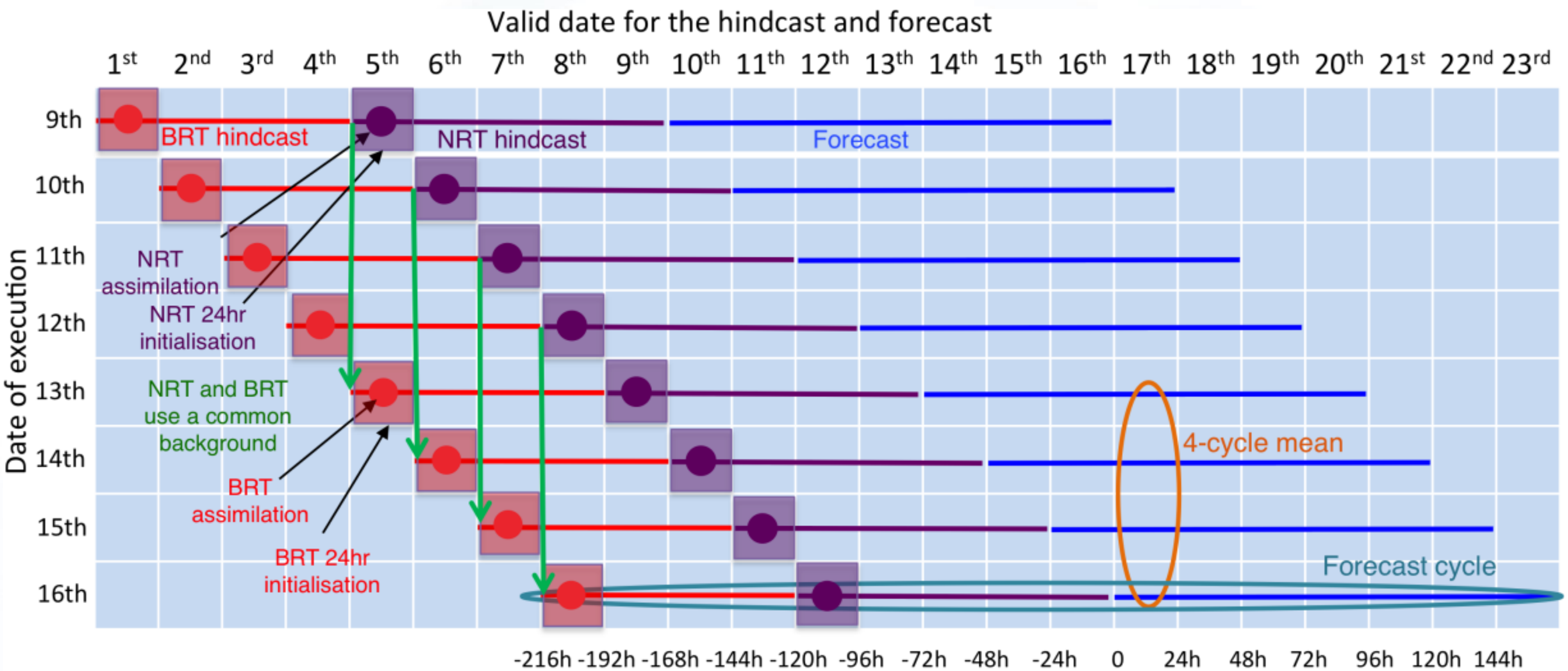
Canada

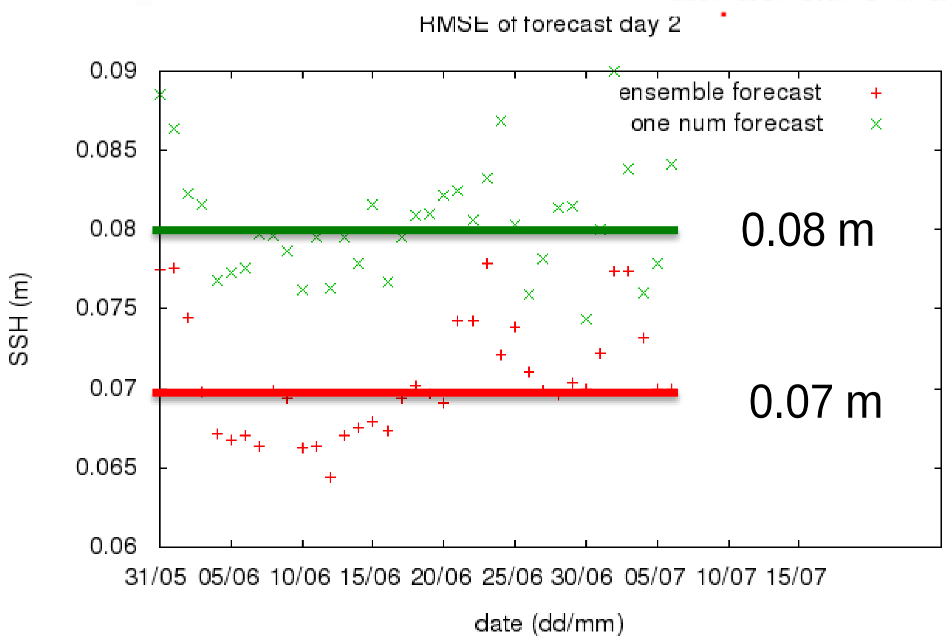
USA(NOAA)

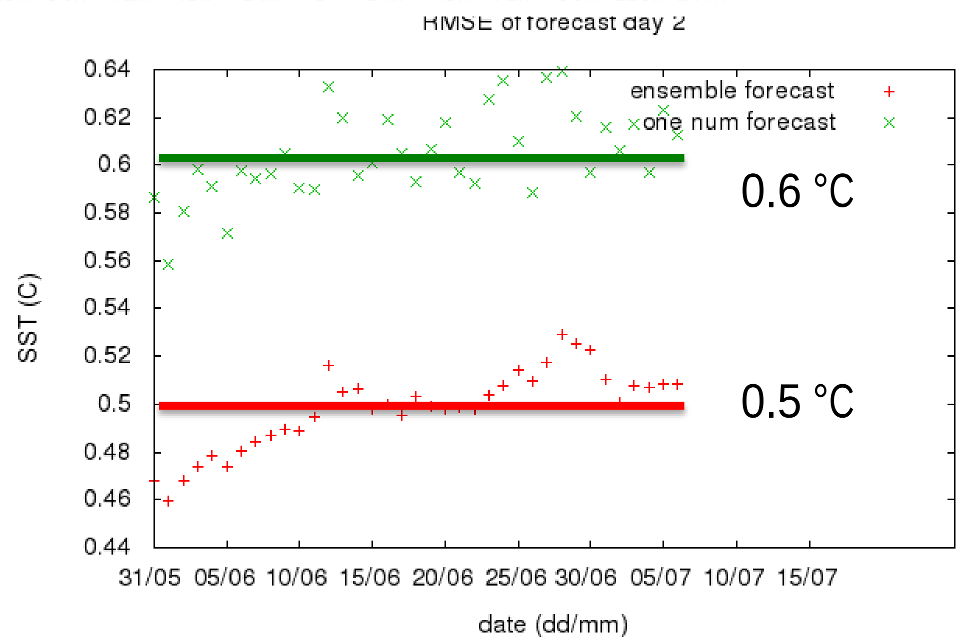
France

Climatology

OceanMAPS – four-cycles reducing uncertainty

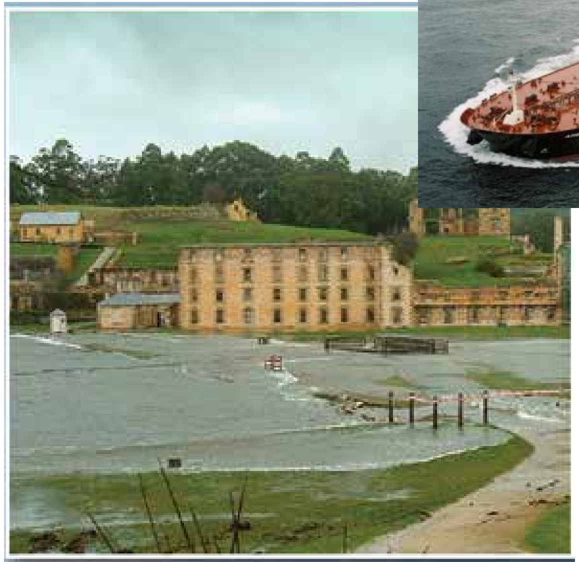






OceanMAPS – impact

- RAN operations
- Montara Oil Spill response
- SAR and MH370
- Aggregate sea level
- Coastal downscaling
- Heat stress

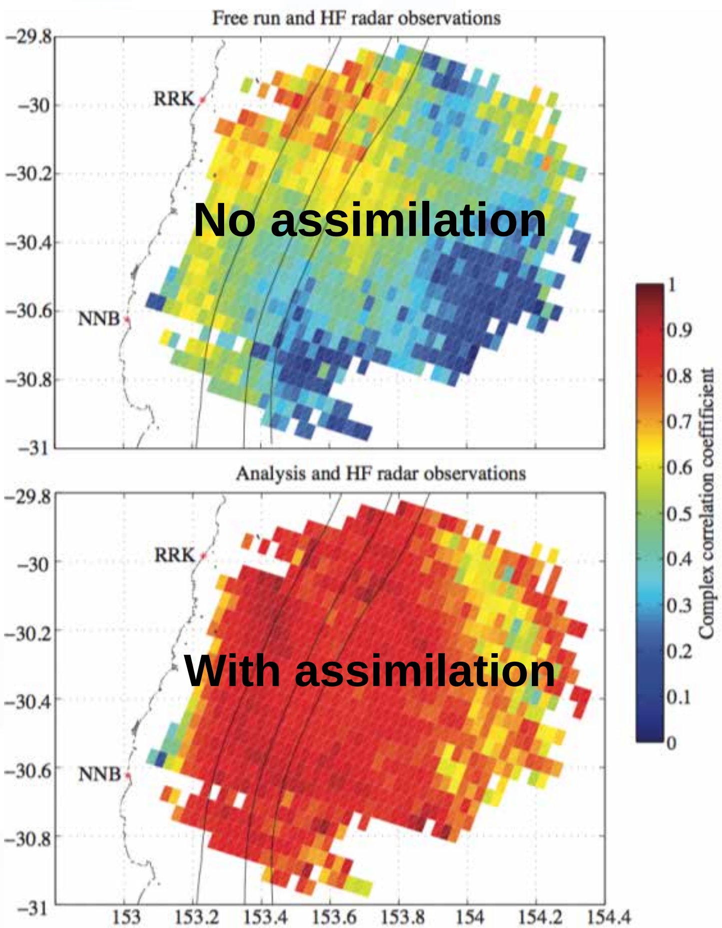


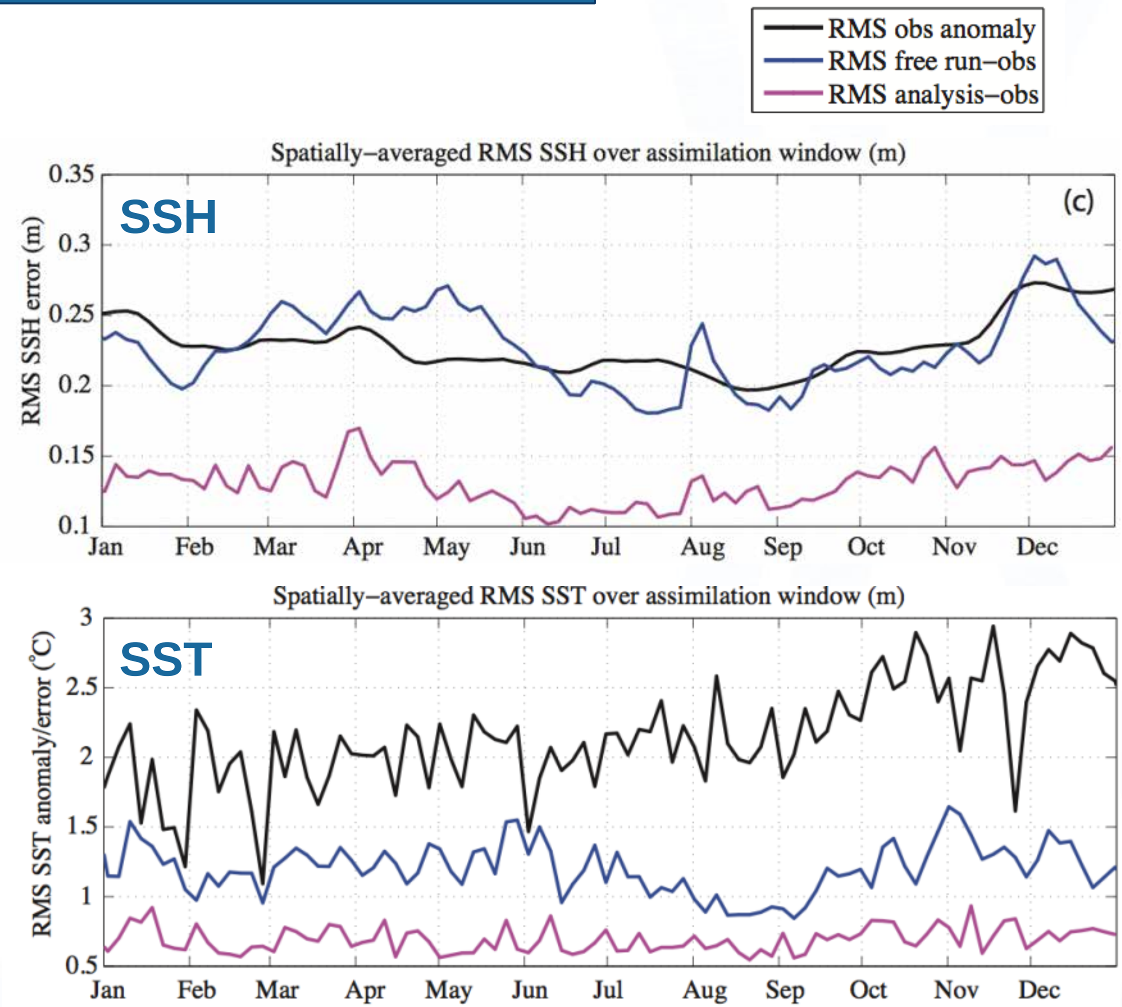
UNSW 4dVar

Colette Kerry, Moninya Roughan, Brian Powell, Peter Oke

The reanalysis provides a dynamically-consistent synthesis of the 3d ocean circulation

HF radar





eReefs

Gary Brassington, Mike Herzfeld, et al.

- SHOC: 1 km res.
- SHOC 4 km res.
- ROMS 4 km res.
- Nested within OceanMAPS or BRAN
- Includes tides
- Forced with ACCESS_R
- EnOI assimilating:
  - Argo + XBT
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- Multiple reanalysis
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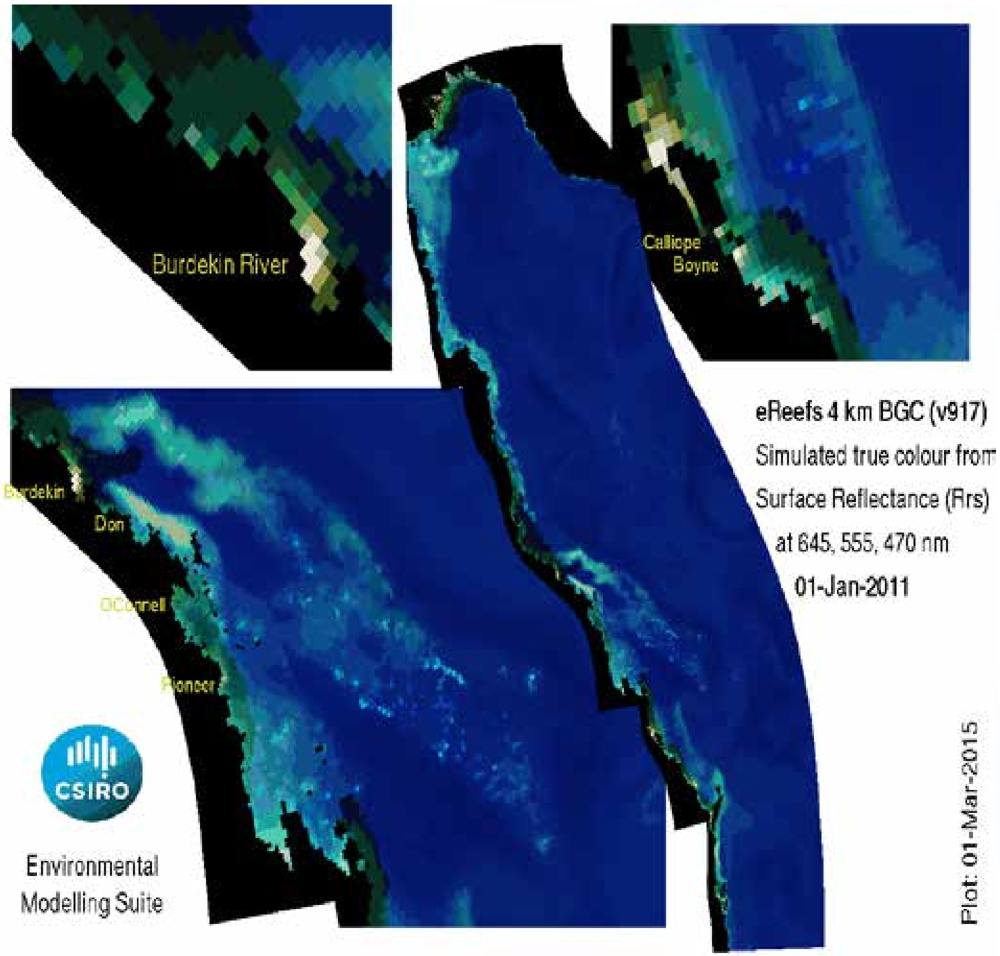

Credit: M. Baird

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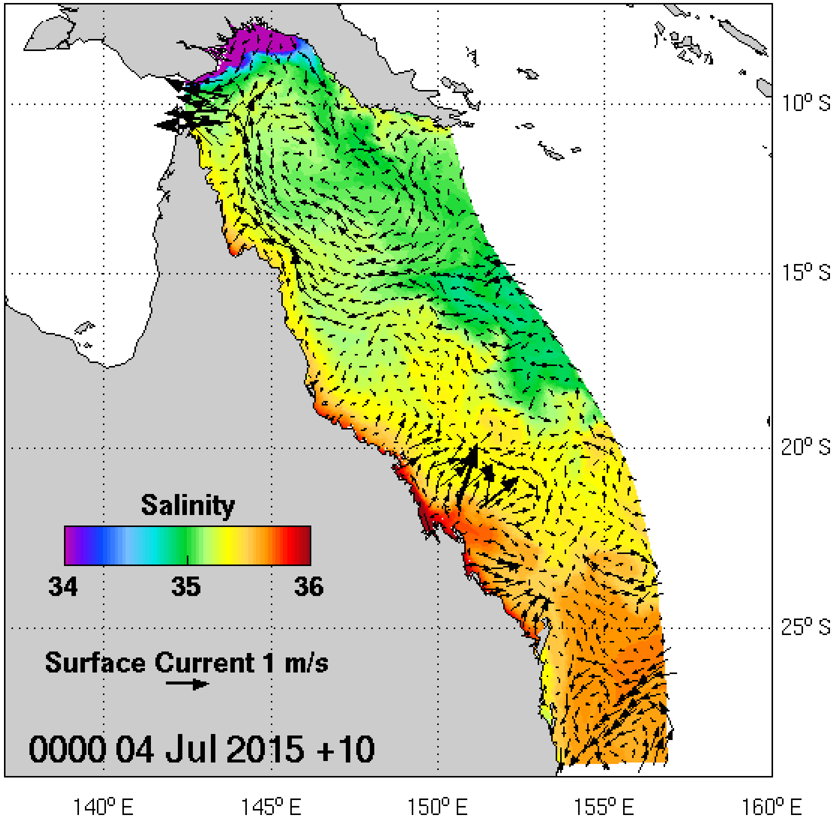

GBR4, SHOC
Showing results for 4-8 July 2015
Run "routinely" by CSIRO
Accessed on 14 July 2015
Credit: J. Andrewartha

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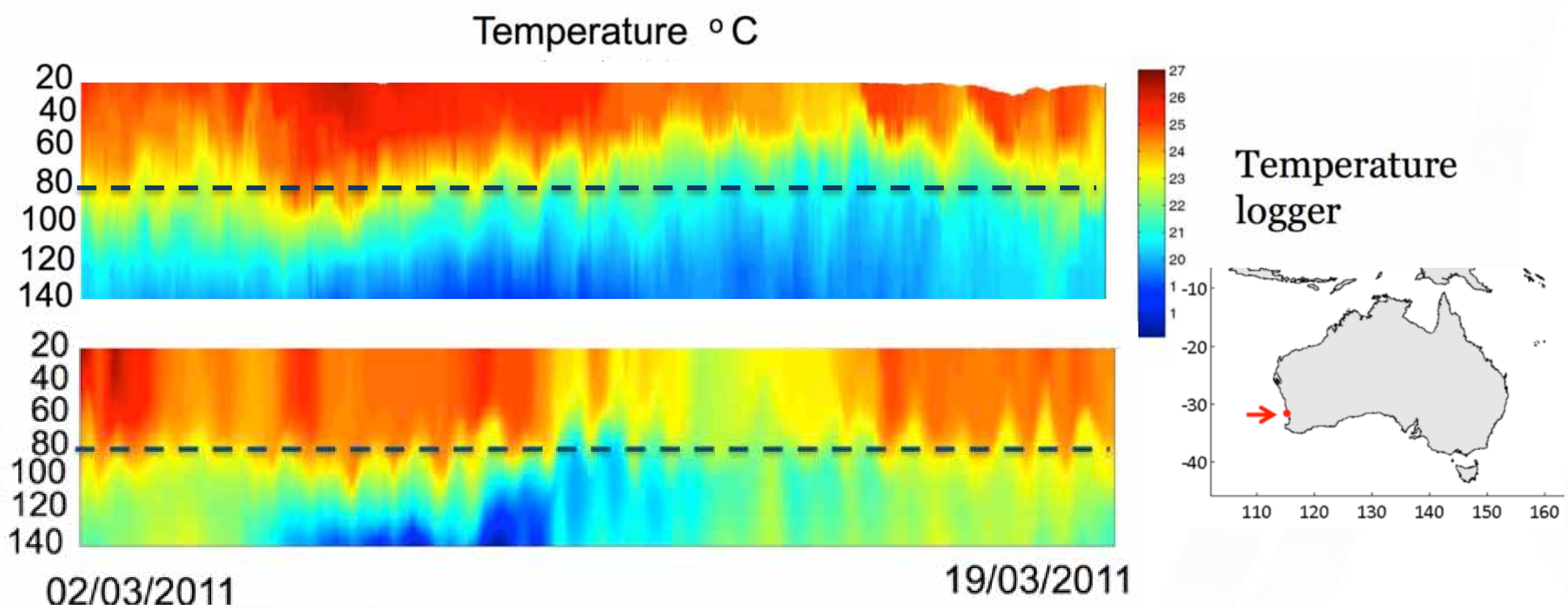
OzROMS

Chari Pattiaratchi, Sarath Wijeratne, et al.

Comparisons with observations show some systematics errors, plus some qualitative agreement



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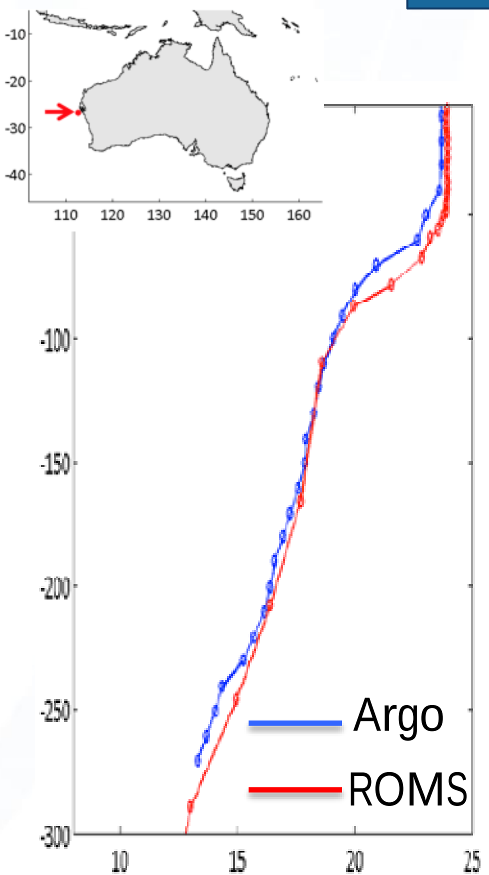
Adapted from Wijeratne, Pattiaratchi, Proctor, 2014, ACOMO2014

OzROMS

Chari Pattiaratchi, Sarath Wijeratne, et al.

Comparisons with observations show realistic variability – but a comprehensive assessment hasn't been done … has it?



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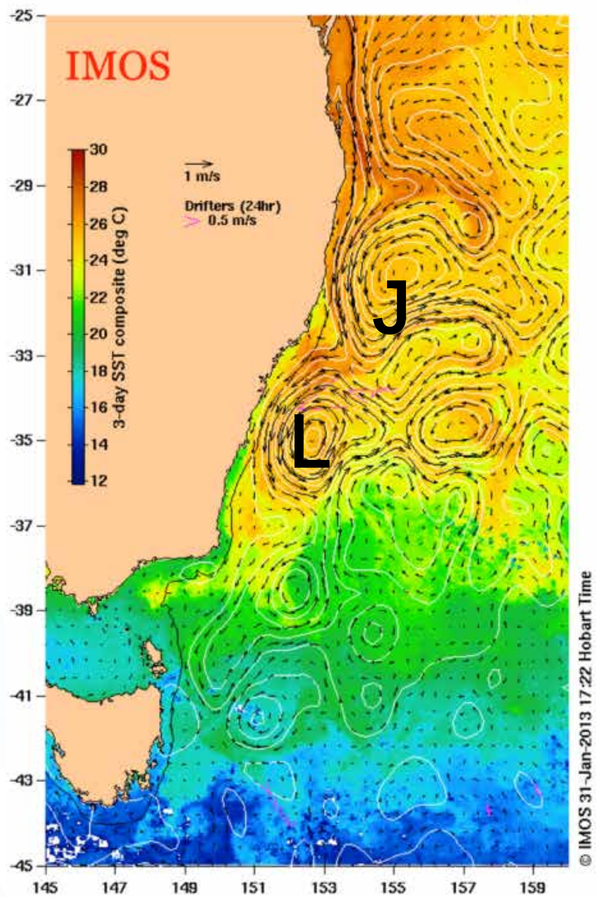
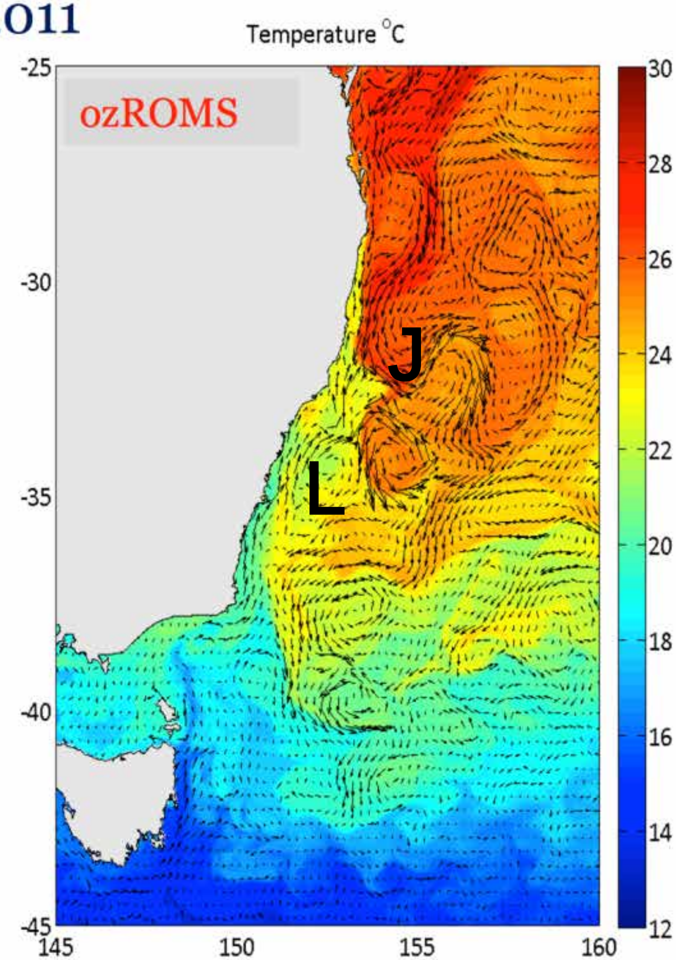
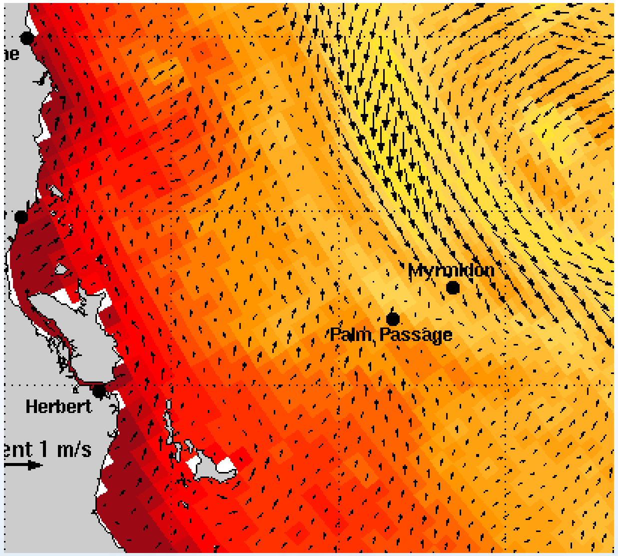
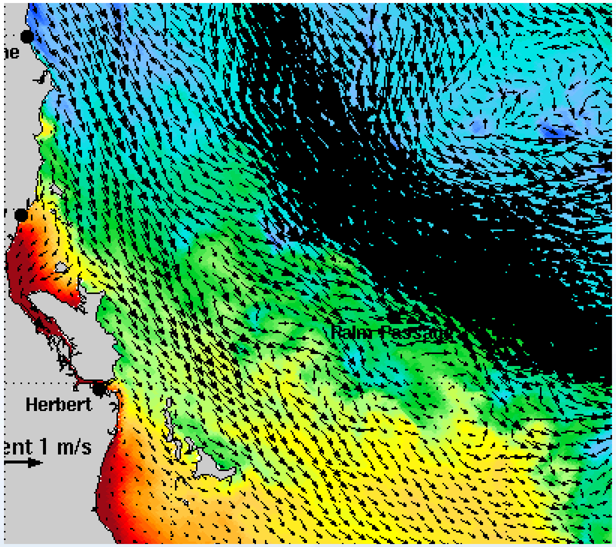
24 Jan 2011





The lure of higher resolution





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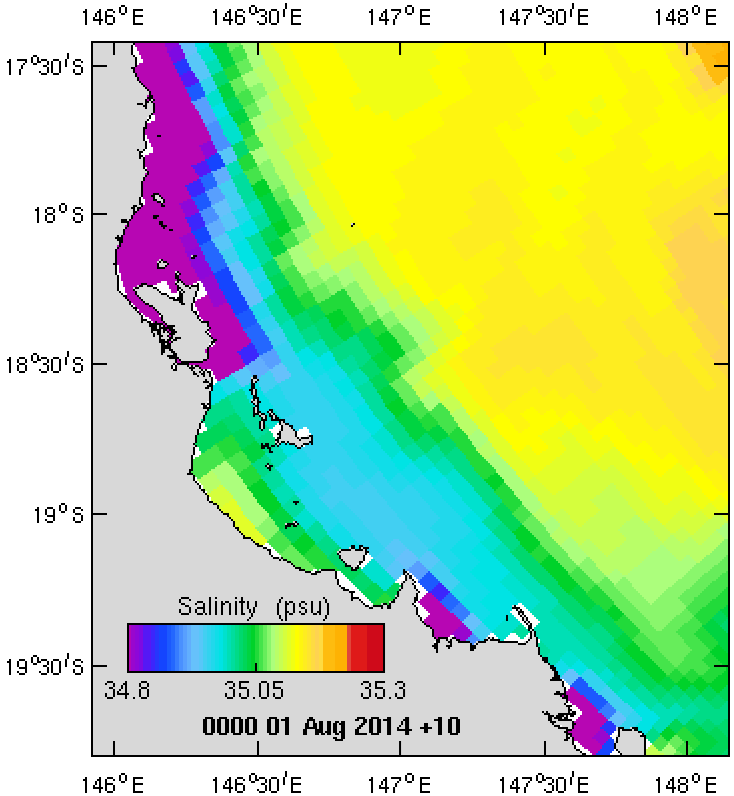
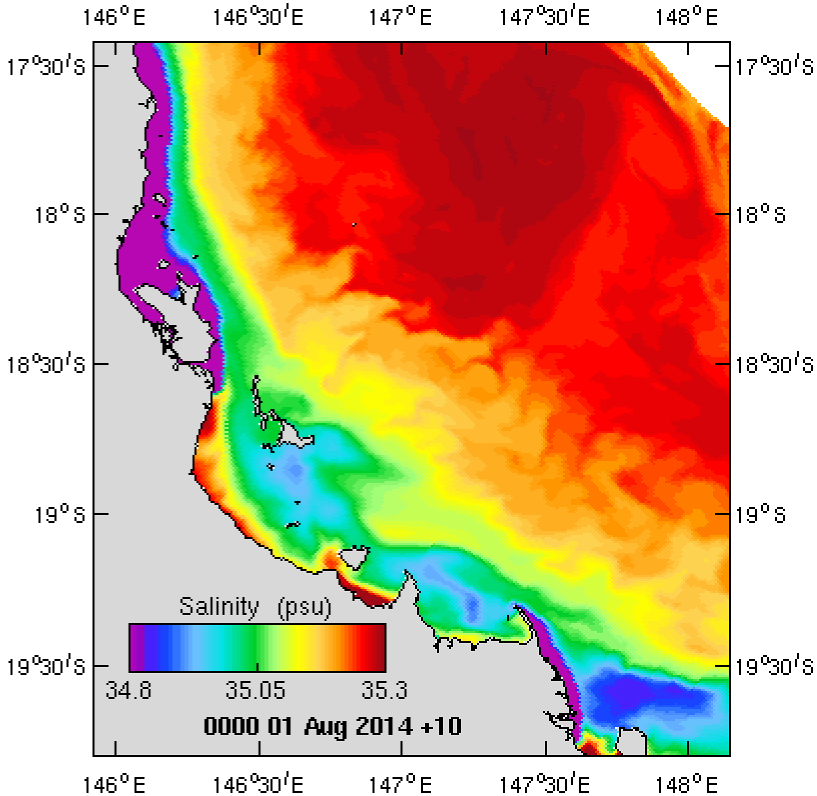
Ocean Modellers love to increase the model's resolution ...



4 km grid



1 km grid

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Credit: E. Jones, M. Baird, M. Herzfeld and M. Mongin