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An operational coastal sea-level forecasting system

Diana Greenslade, Justin Freeman, Holly Sims, Stewart Allen, Frank Colberg, Eric Schulz, Mirko Velic, Prasanth Divakaran, Jeff Kepert, Andy Taylor, Andrew Donaldson, Rick Bailey, Mikhail Entel

Research and Development Branch

Bureau National Operations Centre

Information Systems and Services Division

Hazards Warnings and Forecasts Division

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Background

- Australian Bureau of Meteorology mandate (Met Act 1955) to provide warnings for extreme weather
- 2013 - 'Review of the Bureau of Meteorology's capacity to respond to future extreme weather and natural disaster events….'
- Additional funding to ….. *Implement an advanced storm tide prediction system*……
- Three year project: mid-2014 to mid-2017

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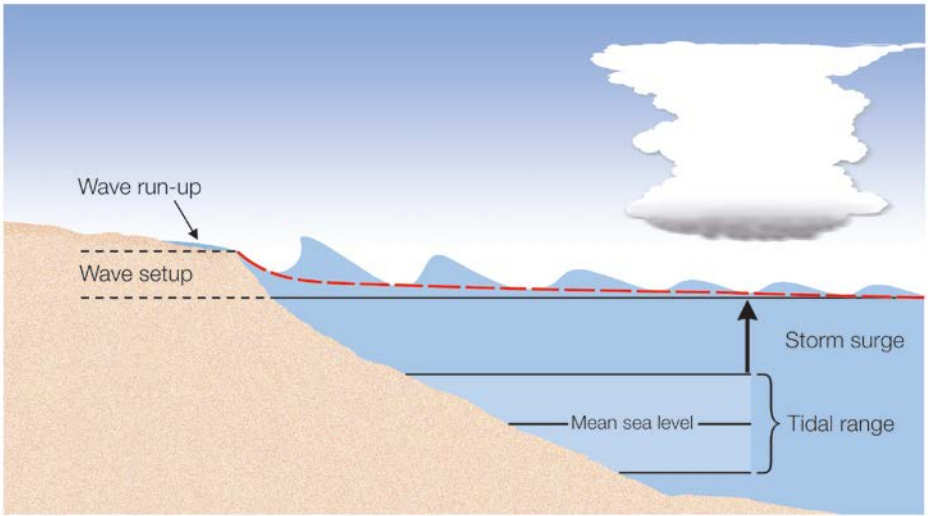
Storm tide



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Storm surge project

Two key modelling components

1. Operational Tropical Cyclone storm surge forecast system
   - Event-based
   - Tropical Australian region only
2. Operational national storm surge system
   - Mid-latitude storms
   - Run on regular basis

In addition – new and enhanced products and services, forecaster training, user engagement, etc.

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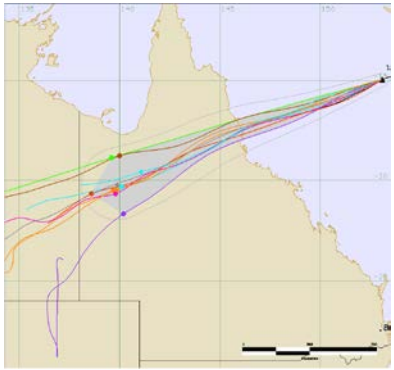
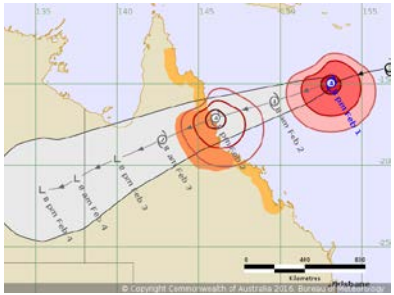
Tropical Cyclone storm surge system

- Ideal solution would be to drive storm surge model with surface forcing from Numerical Weather Prediction (NWP) model
- Standard NWP models generally do not predict Tropical Cyclones (TCs) sufficiently well
- Specialised TC models exist but are only one input into official TC forecast
- Challenge is to provide storm surge forecast consistent with official TC forecast track
- Given storm surge sensitivity to small errors in TC track, ensemble system has been developed





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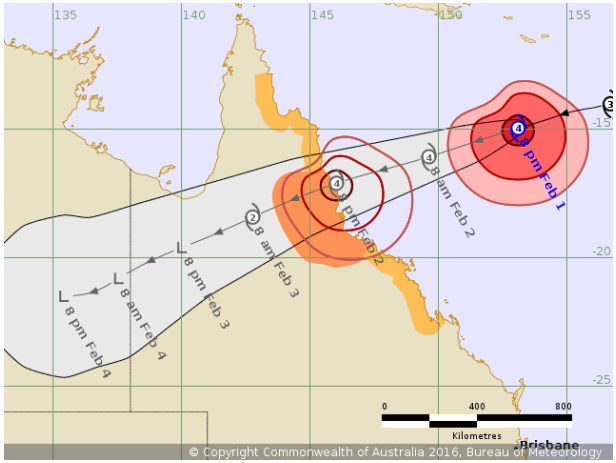
Tropical Cyclone storm surge system

- **Use BoM official forecast track**
- Derive ensemble of tracks (DeMaria et al., 2009)
  - Based on track errors over past 5 years
- Derive gridded forcing field from parametric TC vortex
  - Modified Rankine vortex including asymmetry due to storm forward motion
- Run ensemble of storm surge models



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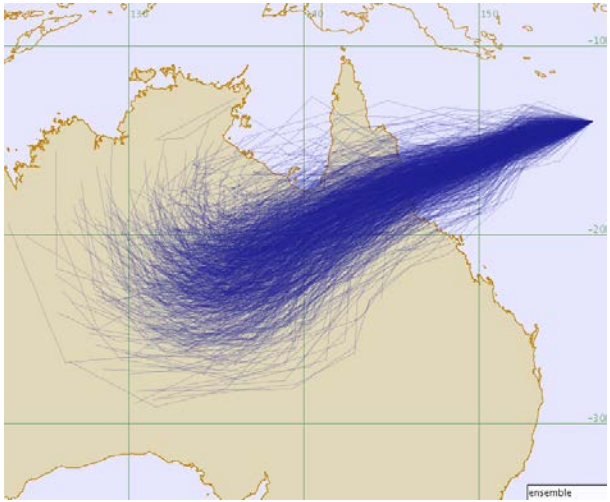

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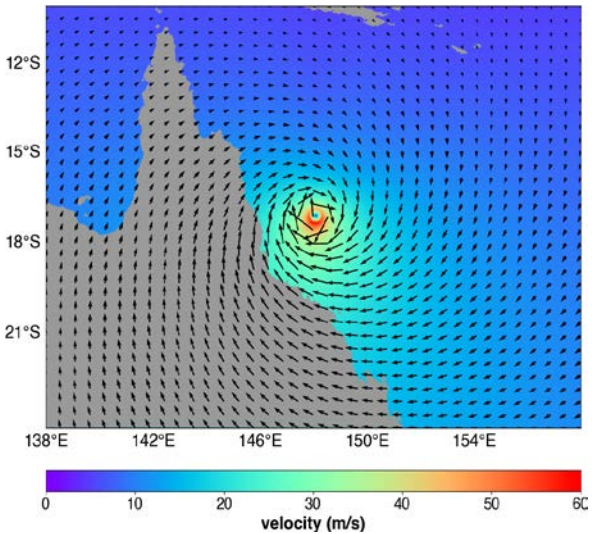

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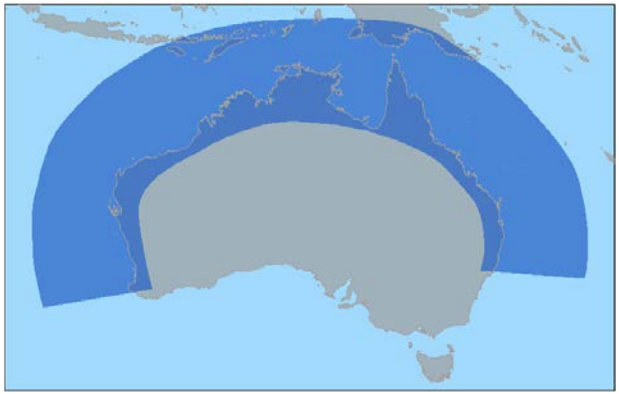

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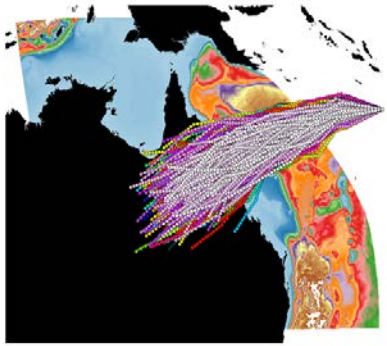
Tropical Cyclone storm surge system

- ROMS (Regional Ocean Modelling System)
  - 2D barotropic mode
  - Open boundary conditions
  - Ribbon domain
  - Coastal spatial resolution ~2.5km
- Re-locatable domain (subset of full grid) to reduce computational time
- 200 ensemble members (randomly chosen from 1000 possible tracks)
- 72 hour forecast
- Wave set-up (from AUSWAVE-R) and tides linearly added to surge



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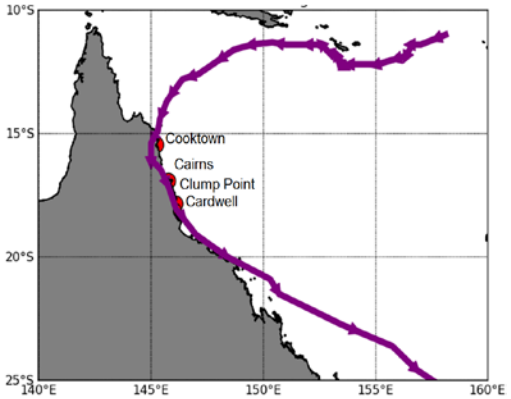
Tropical Cyclone storm surge system

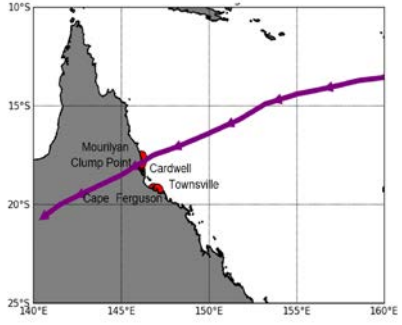
- Verification
  - 'Best track' hindcast runs for 7 recent TCs
  - 28 tide gauge time series
  - Mean observed surge ~1m
  - Assess amplitude and timing of peak surge

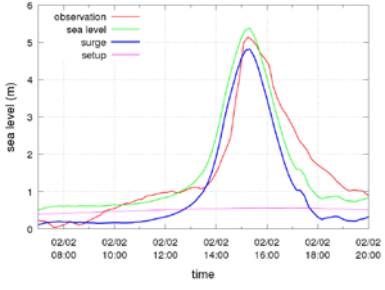


TC Ita 'Best Track'

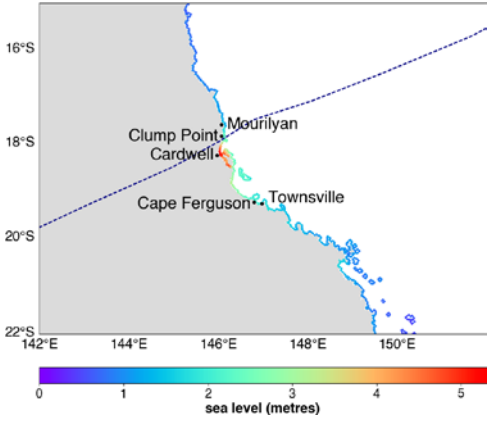
TC Yasi – Best track

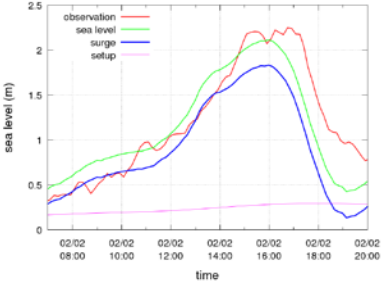
Jan/Feb 2011





Cardwell





Townsville

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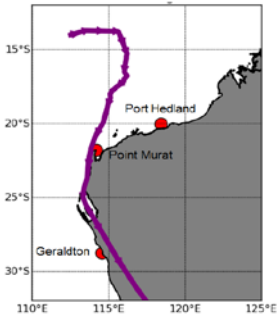
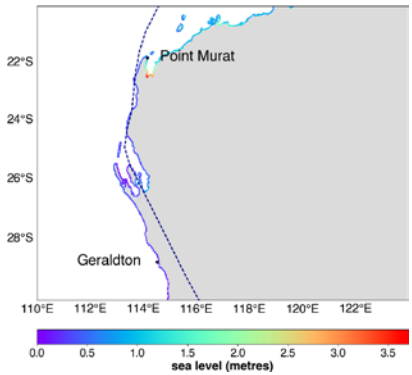
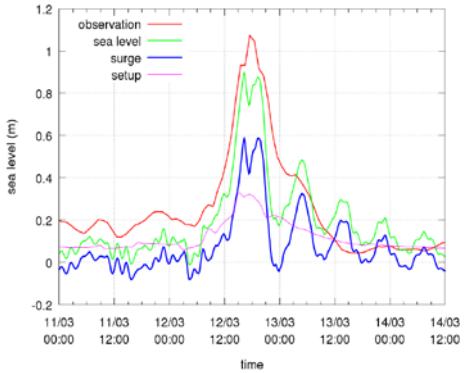
TC Olwyn – Best Track
March 2015







Point Murat

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Verifications

- Overall peak amplitude accuracy:
  - Bias = 0.19 cm (model > obs)
  - MAE = 0.31 cm
- Overall peak timing accuracy:
  - Bias = 29 minutes (model early)
  - MAE = 64 minutes
- Slight improvement over Bureau's existing operational system

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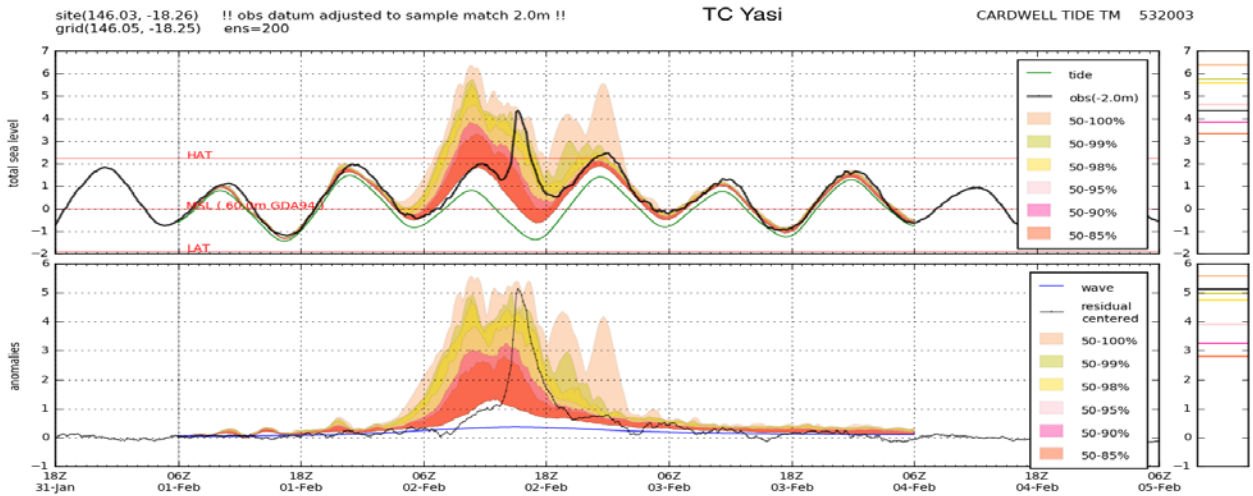
Ensembles



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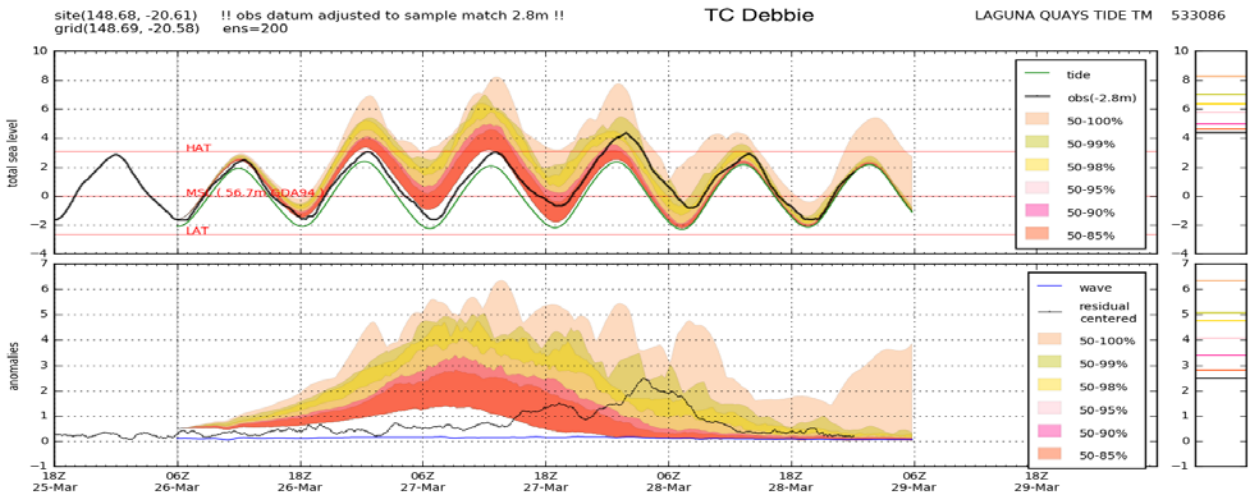
Ensembles



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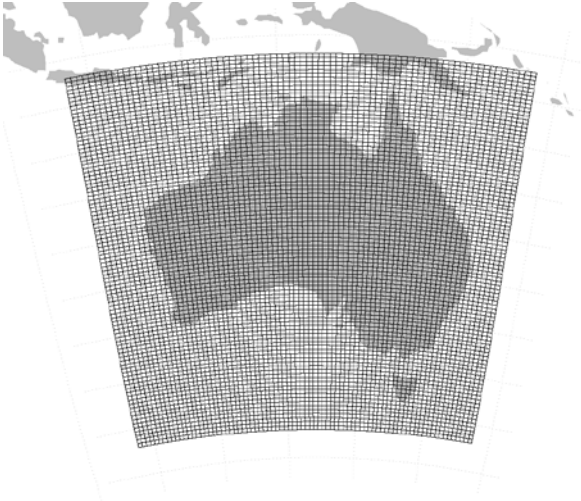
National Storm Surge system

- Run routinely
- Forced with ACCESS-R MSLP and wind stress
- 72-hour forecast every 6 hours
- Forecasts for entire Australian coastline
- ROMS
  - 2D barotropic mode
  - Open boundary conditions
  - Coastal resolution ~2.5km
- Wave set-up (AUSWAVE-R) and tides linearly added to surge



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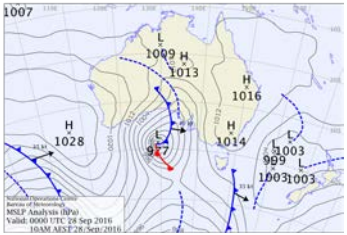
National Storm Surge system

- Two approaches to validation
  - 2.5 year hindcast to assess long term performance
    - Average rms error ~10cm
  - 7 case studies of significant storms

Case study
South Australia, September 2016

10am 28 Sep 2016



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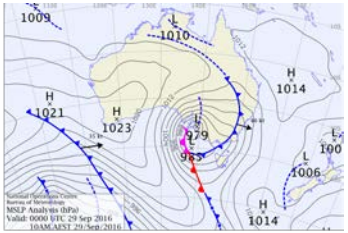

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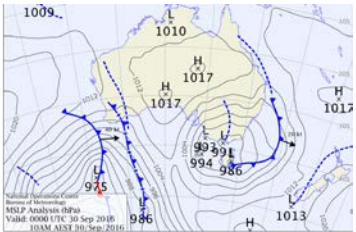
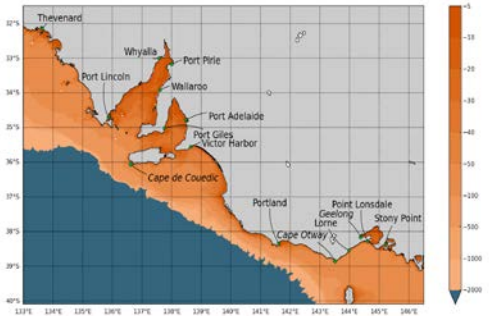


Image: Port Pirie Recorder



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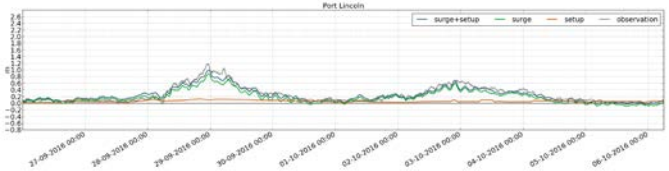

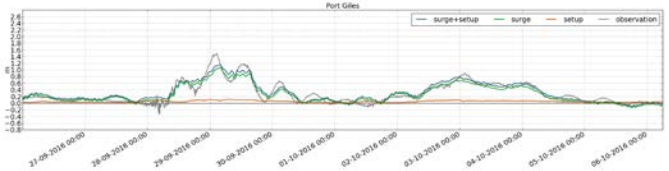

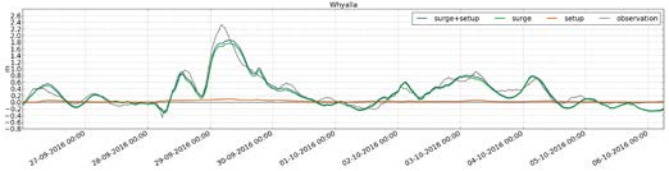

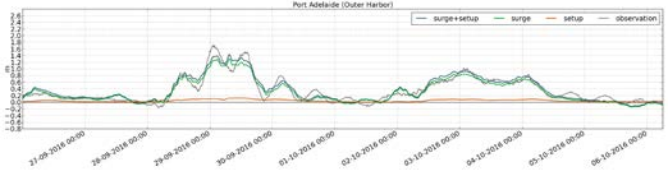

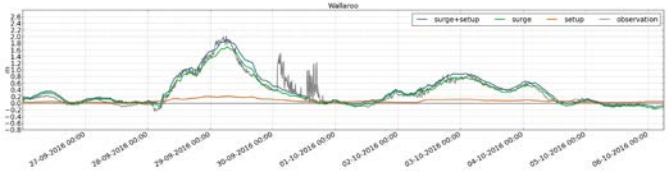

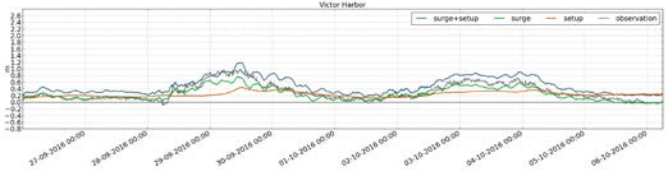

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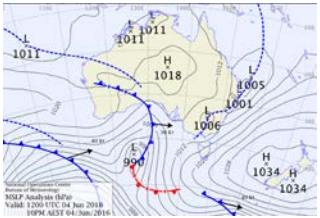
Case study
New South Wales, June 2016

10pm 4 June 2016



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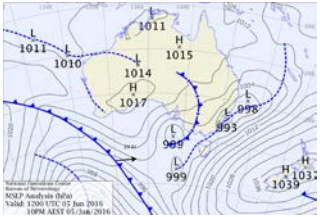

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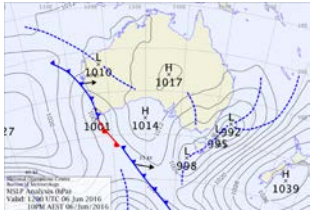

Image: John Grainger

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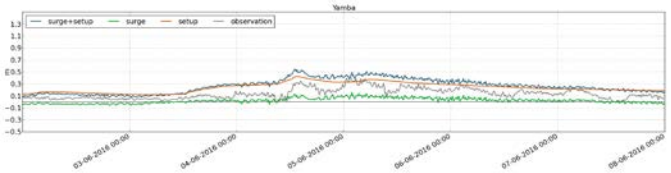

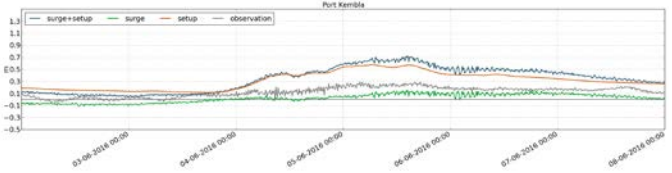

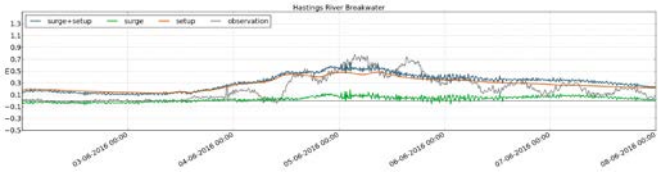

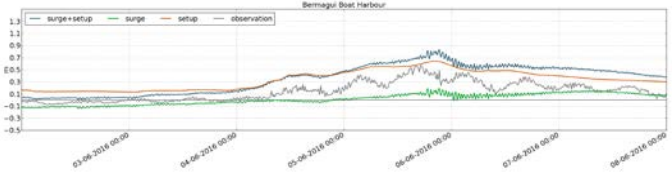

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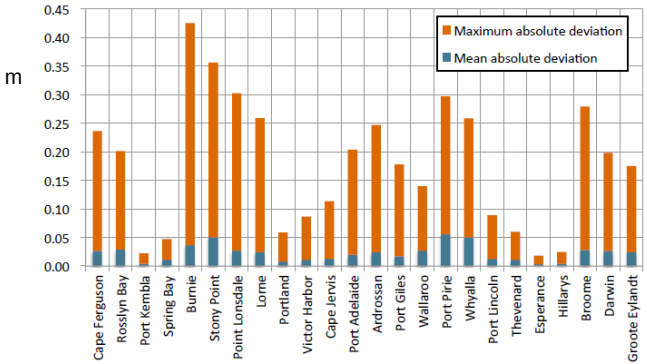
Non-linear tide-surge interactions

- Adding tides to surge after model run assumes no interaction between tides and surge
- Three model runs
  1. Atmospheric forcing only
  2. Tidal forcing only
  3. Both atmospheric forcing and tidal forcing
- Does 1+2 = 3?
- Examine difference between 3 and (1+2)



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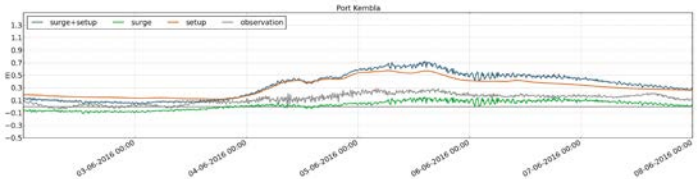
Further work

- Ongoing assessment as events occur
- Analysis of tide gauge locations for representativeness
- Improve wave set-up for ensemble TC system
- Incorporation of non-linear tide-surge interactions



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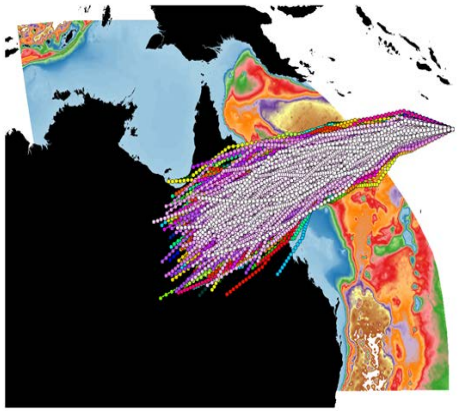

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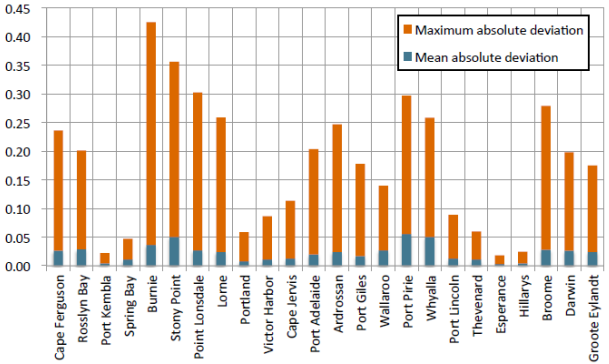

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Summary

- Two new operational storm surge systems implemented at the Bureau of Meteorology
  - Event-based ensemble system for TCs
  - Routine national deterministic system
- TC system performs slightly better than existing operational BoM systems
- Considerable scope for further improvement

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Thank you