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Enhanced storm surge forecasting services by the Bureau of Meteorology

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Acknowledgments

R&D team – *Diana Greenslade, Eric Schulz, Justin Freeman, Jeff Kepert, Holy Simms, Frank Colberg et al*

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Bureau's Queensland Regional Office – *Bruce Gunn*

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Drivers for Operational Storm Surge Service

- Government mandated warning service (Met Act 1955)
  - Safety of coastal communities
  - Protection of property and infrastructure
  - Economic prosperity
- Enhancements to address:
  - Identified user requirements
    - Past TC events
    - Extensive user/stakeholder consultation
  - Operational efficiencies and effectiveness for Bureau forecasters

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Bureau Warning Services

Moving towards **impacts based** messaging and risk based warnings

- Internationally
  - WMO;
  - UKMO;
  - CMA…….
- Nationally
  - AFAC
  - ANZEMC
    - ➢National Review of Warnings and Information

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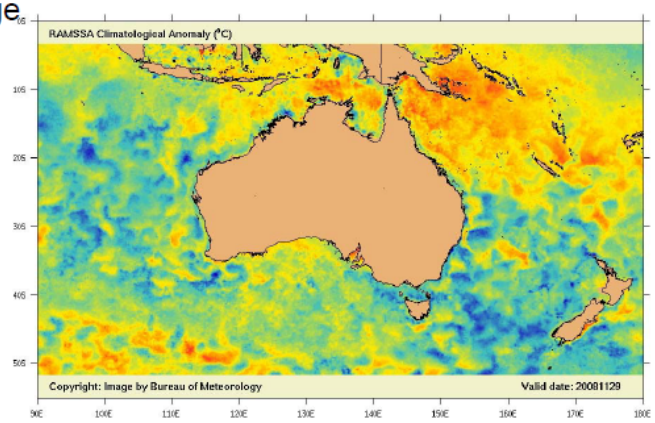
Map of Australia's sources – expected skill/risk

TC's, Trade winds
ENSO/ITF
MJO/Rossby waves
Large tidal range

TC's,
ENSO/SEC
Barrier Reef / Lagoon
Modest tides



Extra-TC's,
MJO/waves
Leeuwin Current
Low tidal range

Extra-TC's,
East coast Lows
ENSO/EAC
Coastal trapped
waves
Modest tidal range

Cold fronts/winter storm,
Forced coastal trapped waves
SA current

G.Brassington et al

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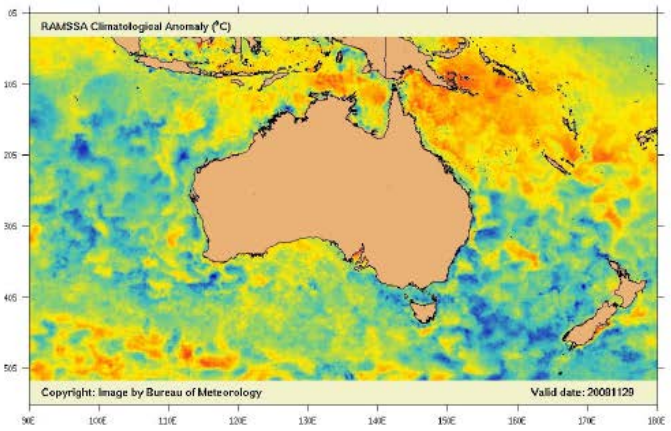
Map of Australia's sources – expected skill/risk

It's mostly winds and tides

It's mostly the winds



It's not just the winds

It's not just the winds

It's the not just the local winds but the time-history

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Storm Surge Project
(2013 - 2017)

<u>Objective:</u> To develop and implement a nationally consistent operational storm surge and aggregate sea level forecasting service:

- Enhancing the existing storm surge forecasting and warning capabilities and practices
- Based on solid science including the latest approaches to dynamical storm surge forecasting
- Utilising synergies with existing operational forecast systems available at the Bureau
- Integrated within existing tropical cyclone, severe weather, tide prediction, tsunami warning services
- Operational Service Implementation by 2017

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Forecast System Components

1. TC Storm Surge System

- Tropics (including offshore territories)
- Storm surge due TC events
- Probabilistic → uncertainty estimates
- Run specifically for TC events

2. National Storm Surge System

- Whole country (including offshore territories)
- Storm surge due synoptic scale storm events
- Deterministic
- Run routinely every 6/12/24 hours

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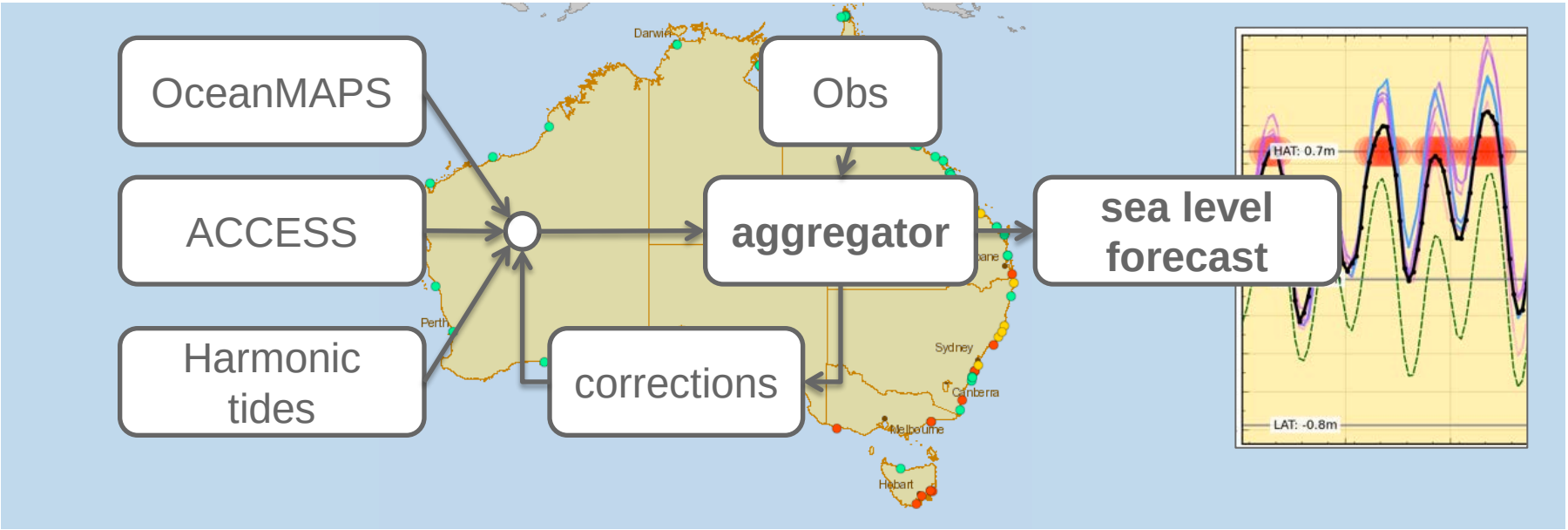
Experimental Aggregate Sea Level Alert and Monitoring System

Realisation of 'total sea level'

- Forecasts observable quantity
- National scope
- Tide gauge locations with R/T data
- User perspective

Exploit existing BoM systems

- Astronomical tide
- Sea level (OceanMAPS)
- Atmospheric pressure (NWP)
- Bias correction via observation



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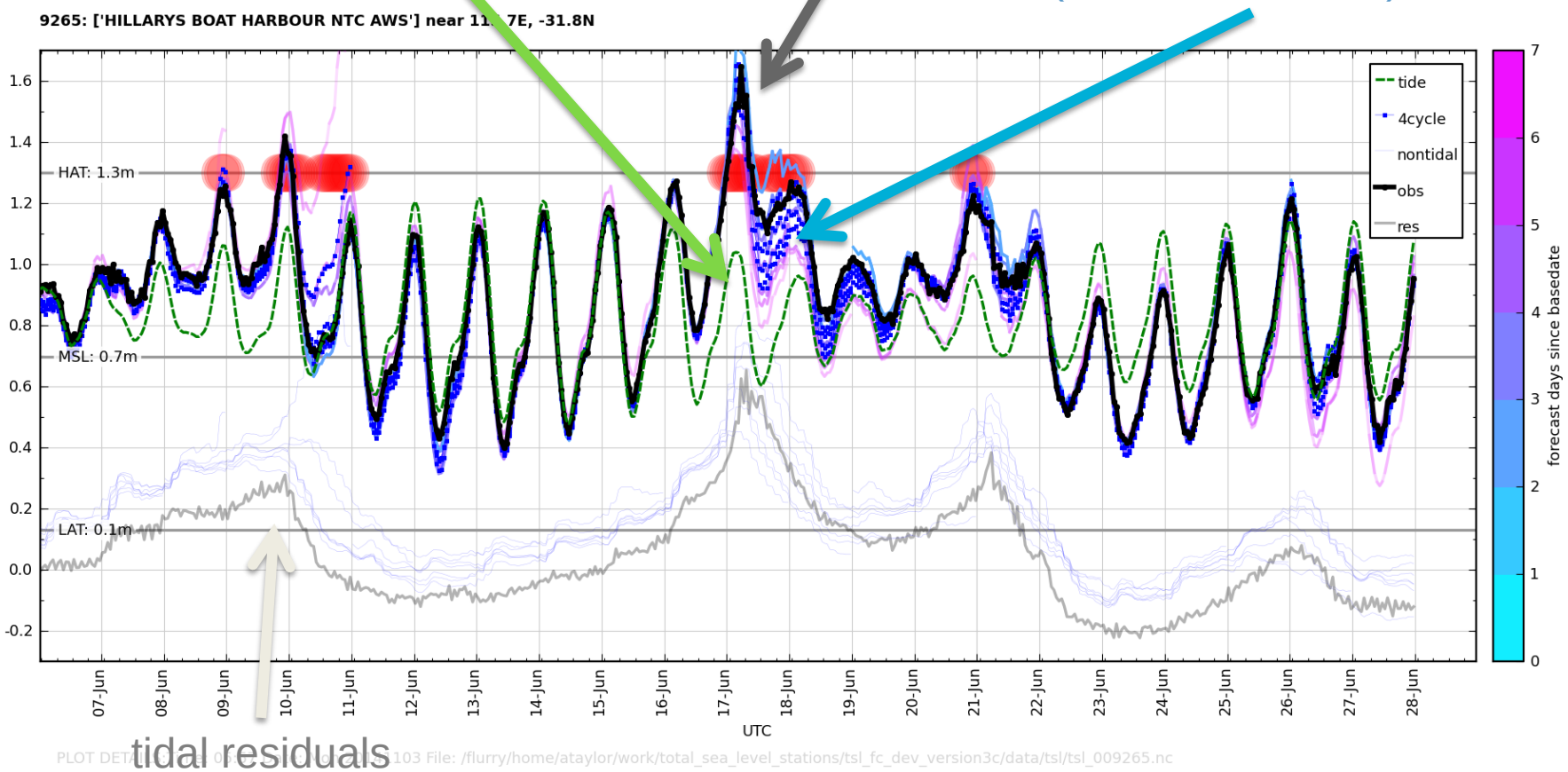
Perth June 2014 Event

astronomical tide

observed

aggregate forecasts
(colours lead time)



tidal residuals

PLOT DET 103 File: /flurry/home/ataylor/work/total_sea_level_stations/tsl_fc_dev_version3c/data/tsl/tsl_009265.nc

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Experimental Aggregate Sea Level System (cont)

Current and potential users:

- Forecasters from severe weather services – using as a guidance
- Bureau flood forecasting services (riverine flooding, HyFS)
- Under evaluation by several port authorities (ports management, under-keel clearance systems)
- Under evaluation by some government and commercial operators (environment protection agencies, fishery farms, …)
- Enhancing daily tidal predictions by providing daily anomalies up to 7 days ahead (under consideration by Bureau)

Dynamical forecast system

Forced by

- TC ensembles => Tropical probabilistic storm surge, event based
- Deterministic (NWP) events => National deterministic storm surge, routinely operating

Delivers

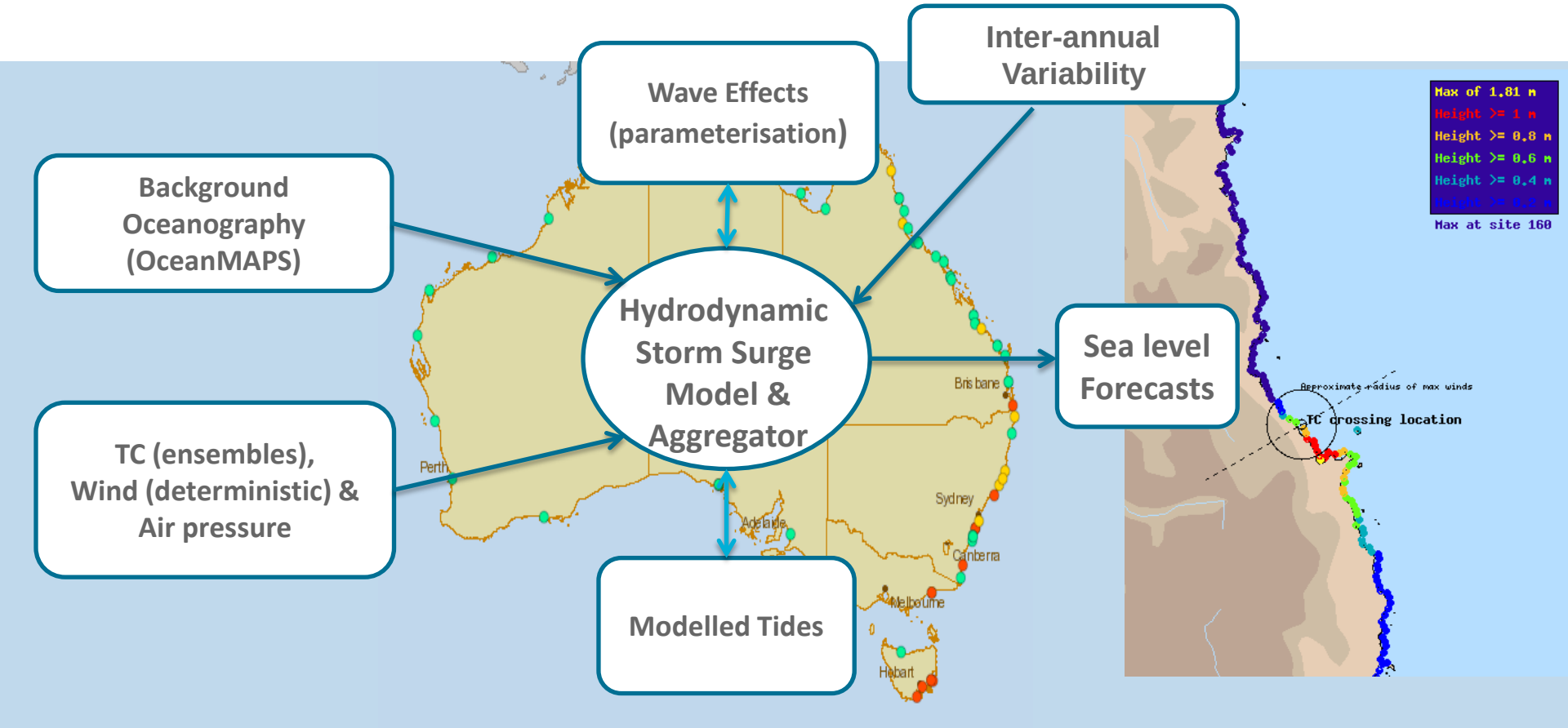
- Sea level predictions at all coastal locations

Includes

- Tides
- Wave effects
- Background Oceanography

Builds on

- Aggregate sea level system



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Hydrodynamic model

- Regional Ocean Model System (ROMS), (Shchepetkin and McWilliams, 2005)
- 2-D (depth integrated) model
- Bathymetry: GA 500m national product
- Horizontal resolution around 2 km
- 72 hr forecasts
- Forced with wind stress and air pressure
- No nesting at boundaries (yet)
- No tide or wave coupling
- No inundation

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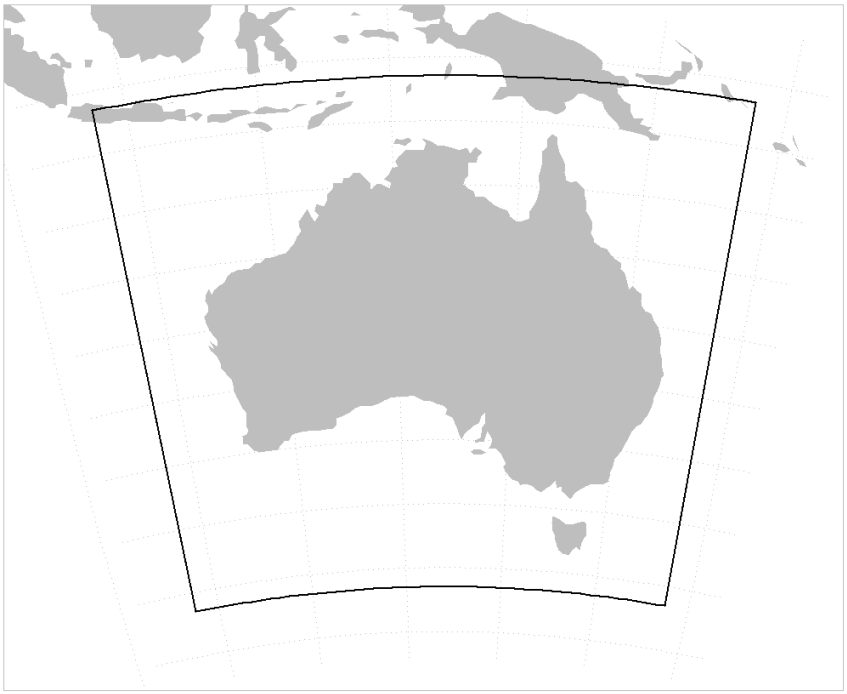
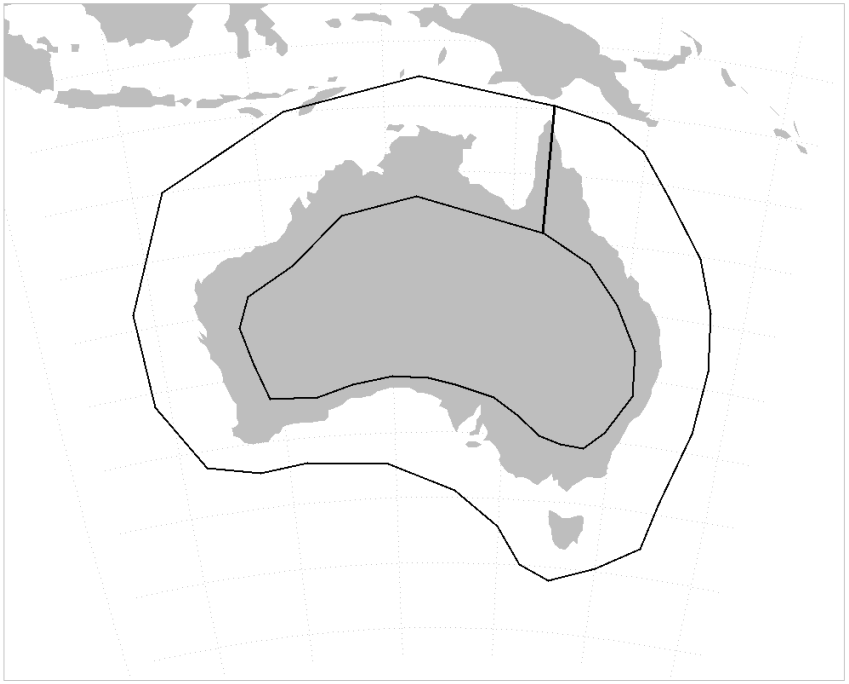
Possible grids for national system





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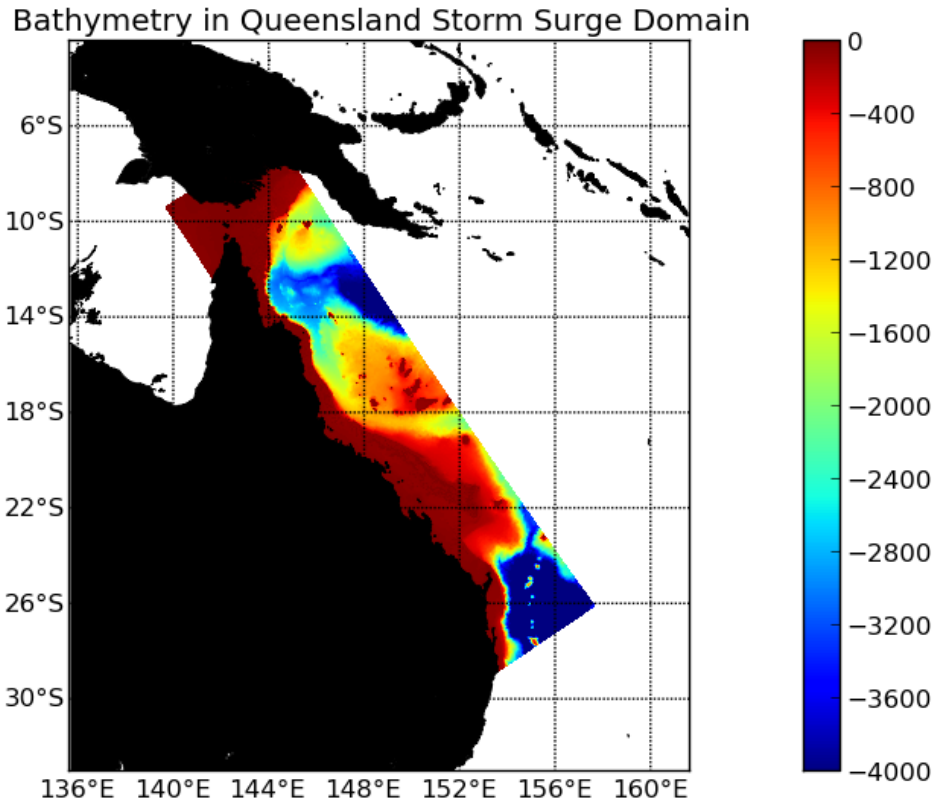
Initial (trial) system configuration for 2015/16 TC season

- Queensland east coast domain only
- Spatial resolution: 2 km
- Time step: 6 seconds
- Bathymetry dataset: Geoscience Australia 250m resolution south of 8°S, merged with GEBCO
- Run-time < 8 minutes for a 66-hour forecast on 32 processors



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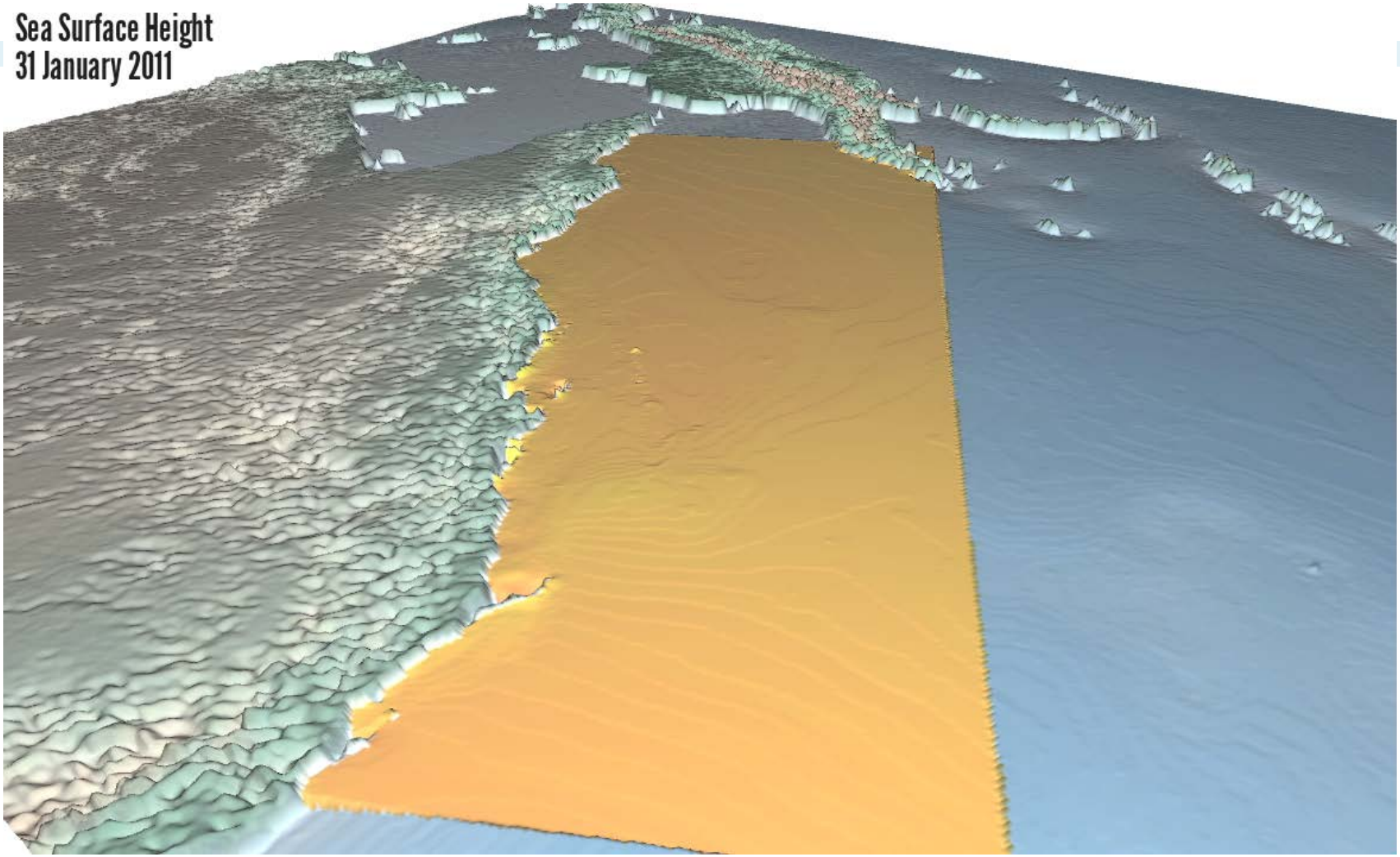
TC Yasi



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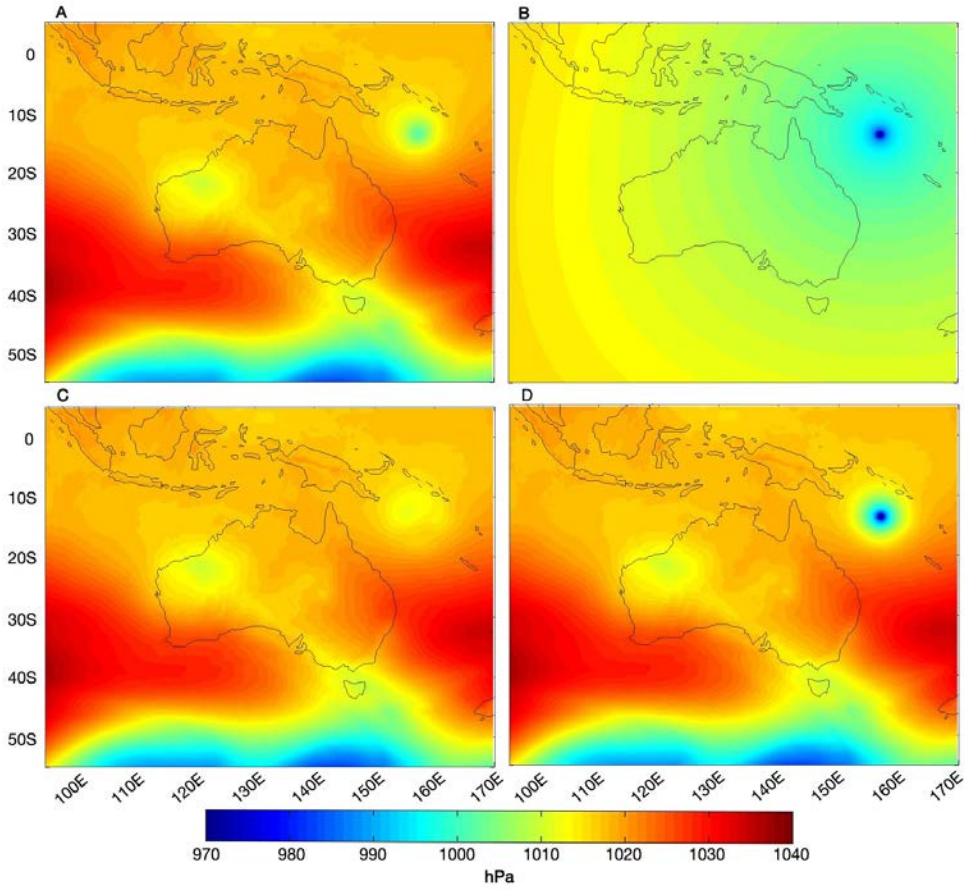
TC surface forcing

(A) Atmospheric pressure field from ACCESS-R

(B) Synthetic pressure field generated using input TC parameters

(C) ACCESS-R pressure field with the cyclone removed

(D) Merged pressure field between ACCESS-R with cyclone removed and synthetic (Rankine-type) vortex inserted.



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TC ensemble generation (J.Kepert)

(A) An ensemble of N (50) perturbed tropical cyclone tracks generated using DeMaria et al (2009) system implemented by the Bureau to predict wind exceedance probabilities (blue).

Input track is shown in red

Ensemble mean is calculated from a much larger ensemble (shown in green)

(B) Individual tracks are smoothed while preserving ensemble PdF

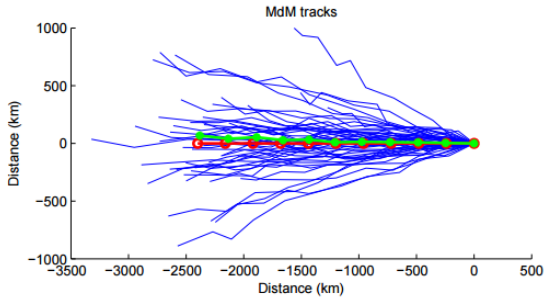

FIG. 1. An ensemble of 50 perturbed tropical cyclone tracks calculated by the method of DeMaria et al. (2009) (blue), together with the input track (red) and the ensemble mean calculated from a much larger ensemble (green).

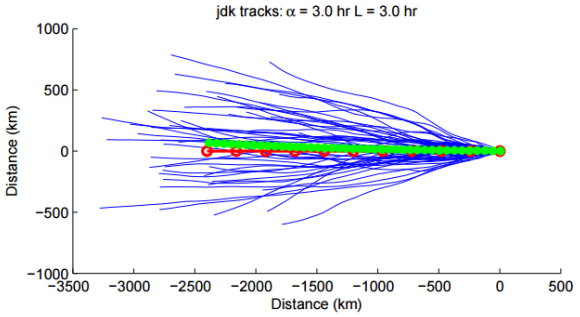

FIG. 5. As for Fig. 1, except calculated using the new method with $\alpha = 3\,\mathrm{hr}$, $L = 3\,\mathrm{hr}$.

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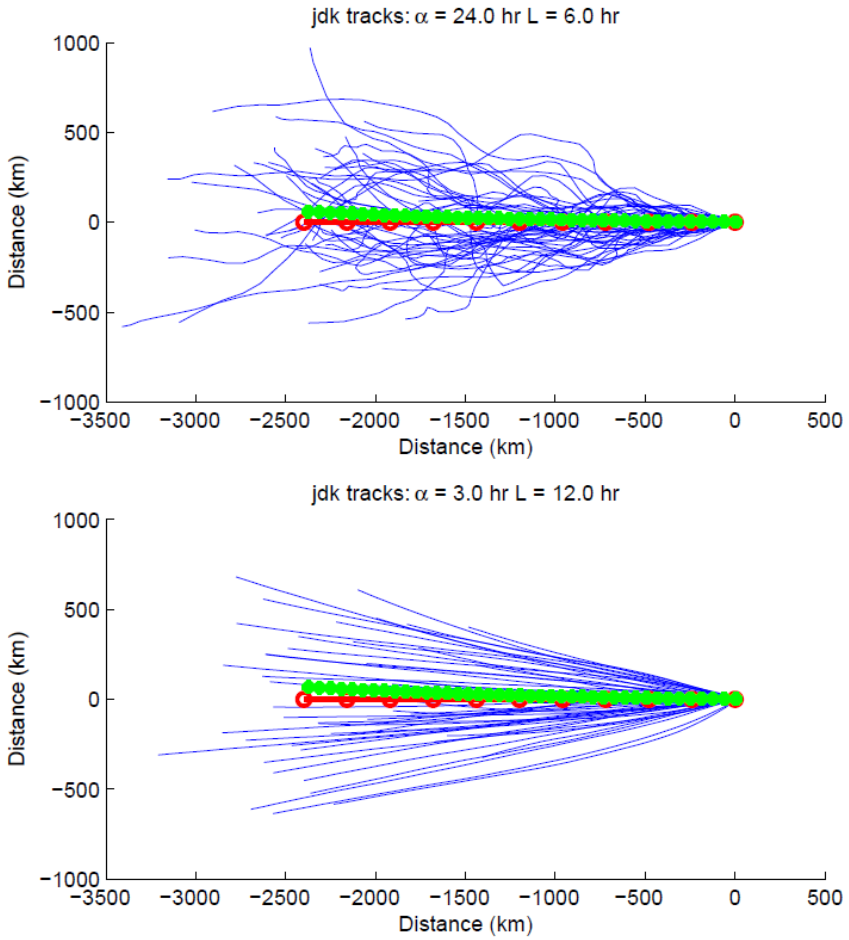
TC ensemble generation (cont)

(A) Top - weak temporal correlation leading to quite “wriggly” tracks

(B) Bottom: strong temporal correlation

(C) Similar sampling procedures for TC size and intensity



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100 member ensemble
72 hour forecast tracks for TC Yasi

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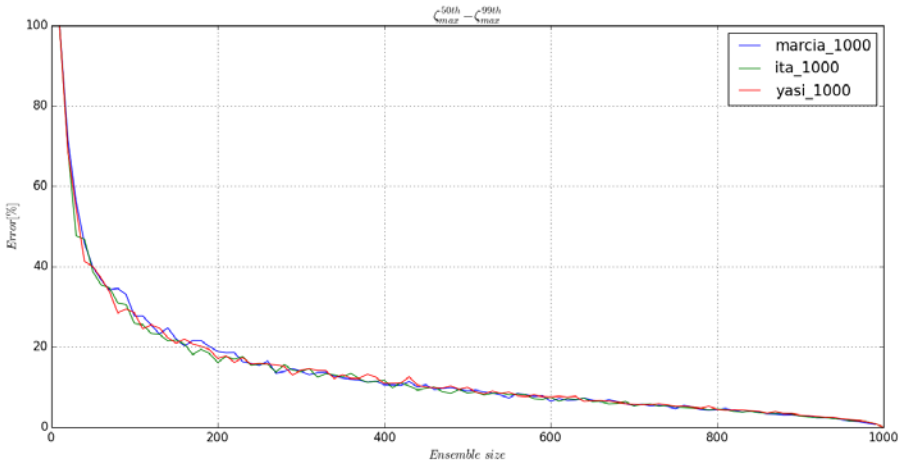
Determination of ensemble size

- De Maria process produces 1000 ensemble members
- Need to determine optimal storm surge ensemble size
- Consider max SSH and assess how the spread of this value (99th percentile – median) varies for different ensemble sizes
- Define the 'error' as the normalized difference between the spread of a set of ensembles of size N and an ensemble of size 1000
- Figure shows 'error' as function of N
- Preliminary recommendation: N=200



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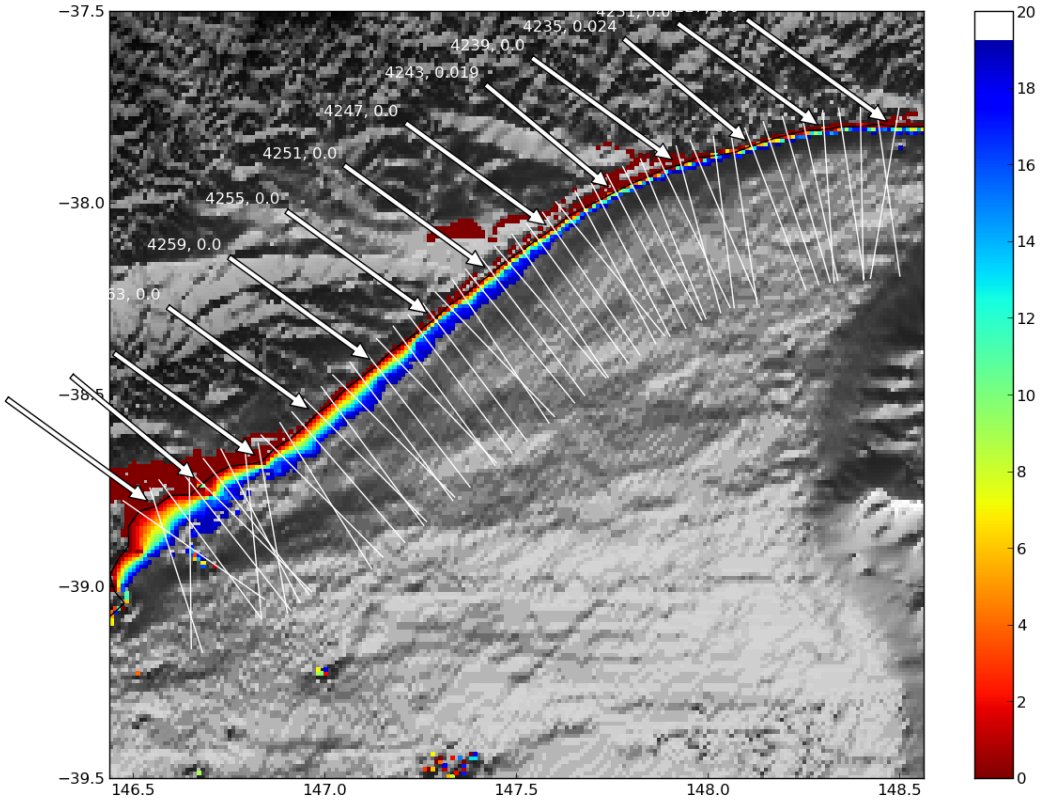
Wave Setup Prediction
(J. O'Grady, K. McInnes and R. Hoeke, CSIRO)

(A) SWAN wave model used

(B) Wave setup in 1D mode for ~ 4000 equally spaced bathymetry profiles around Australia

(C) 1m grid resolution



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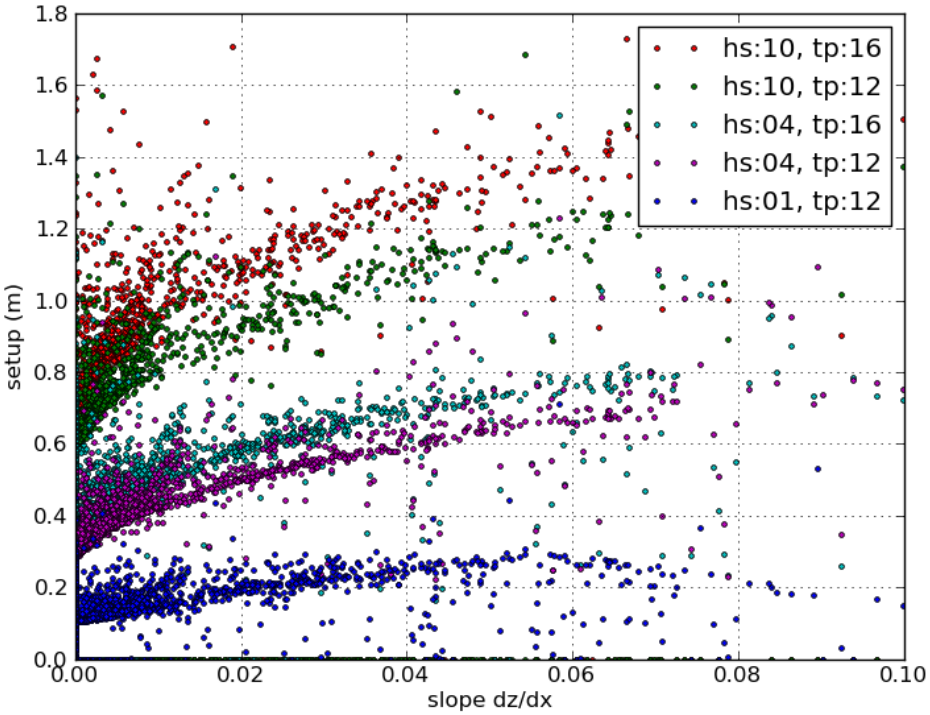
Example of ~4000 linear SWAN model results around the Australian Coastline



$$\bar{\eta} = 0.29(0.8)H_0[0.34S^{\frac{1}{7}}]\left(\frac{H_0}{L_0}\right)^{-\frac{1}{4}}$$

L_0 - deep water wave length

H_0 - deep water wave height

S - bathymetric slope

Options for graphical products for TC track, intensity and storm surge forecasts

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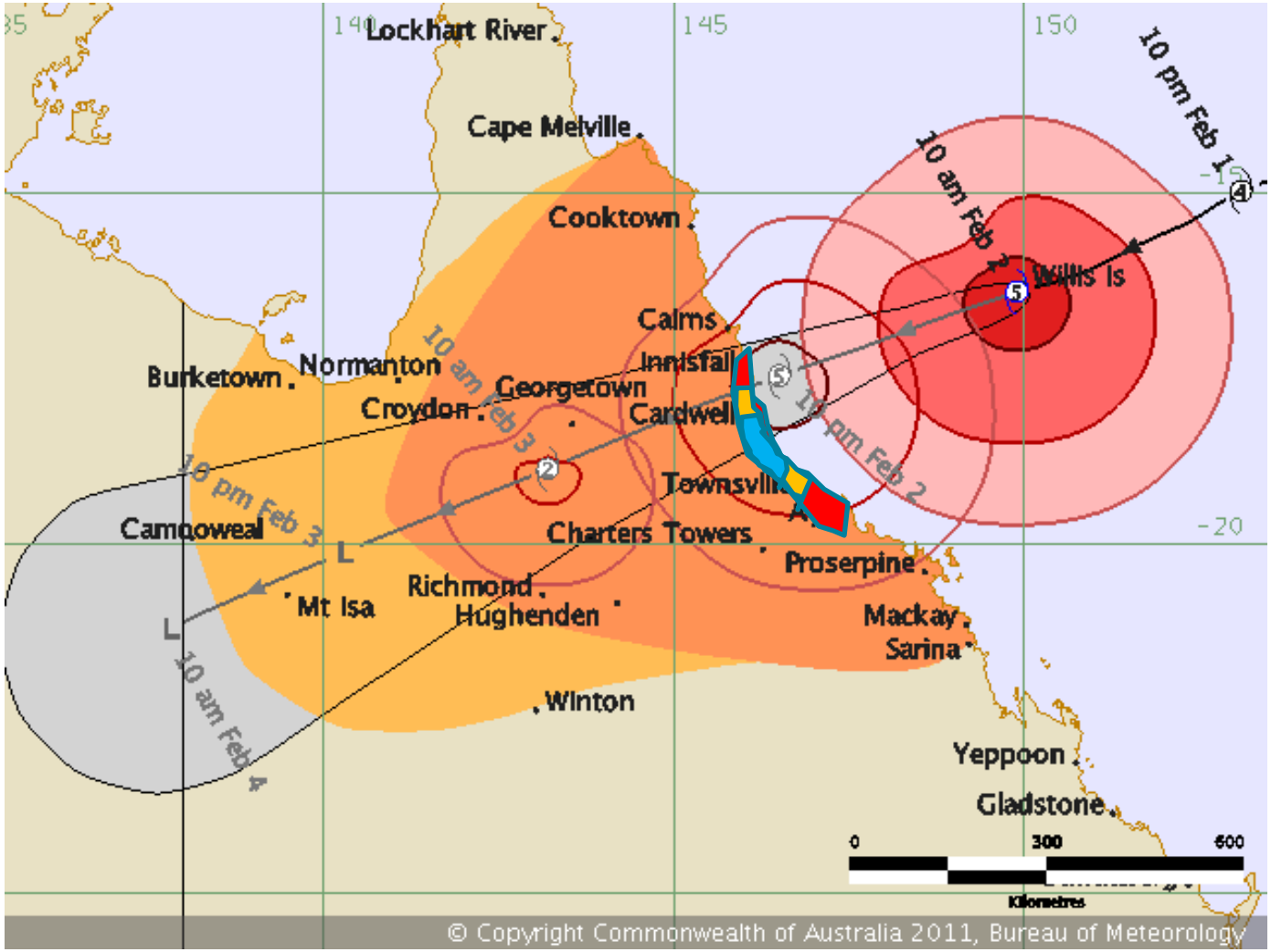
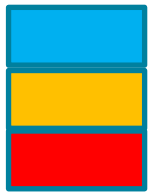


Dangerous storm tide possible



Colours consistent with Qld Evacuation zones

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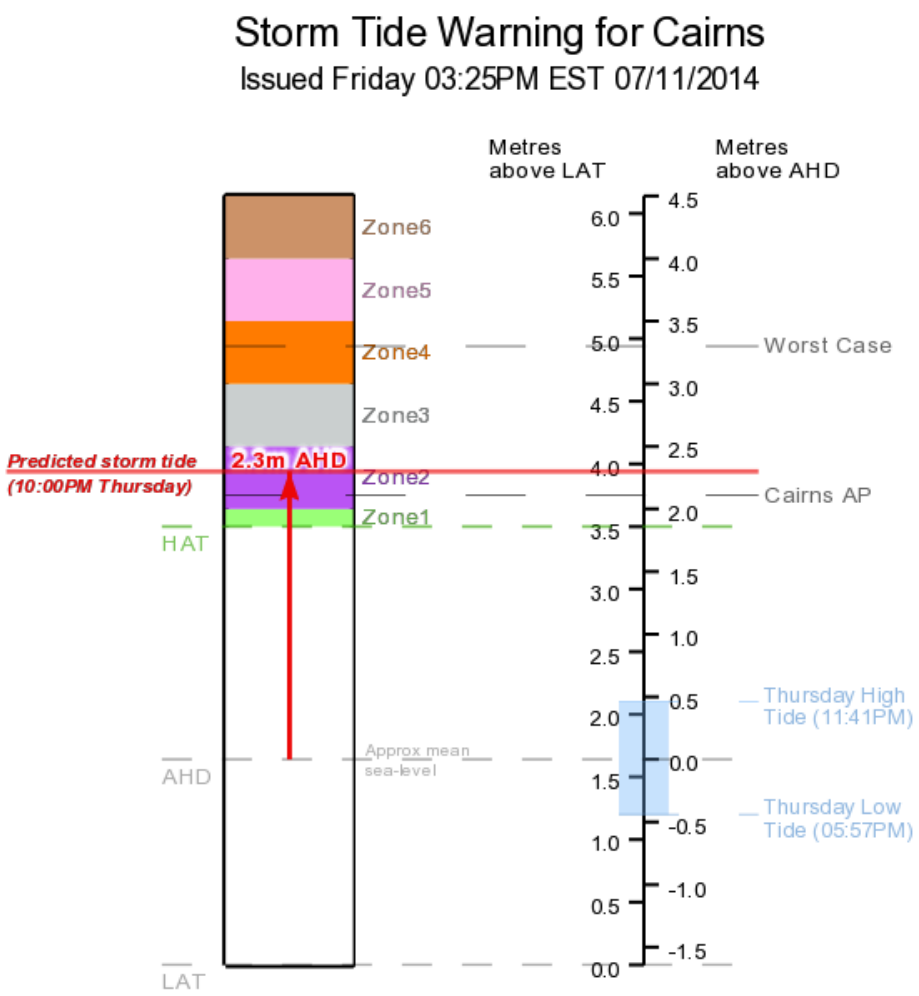
"Totem poles"



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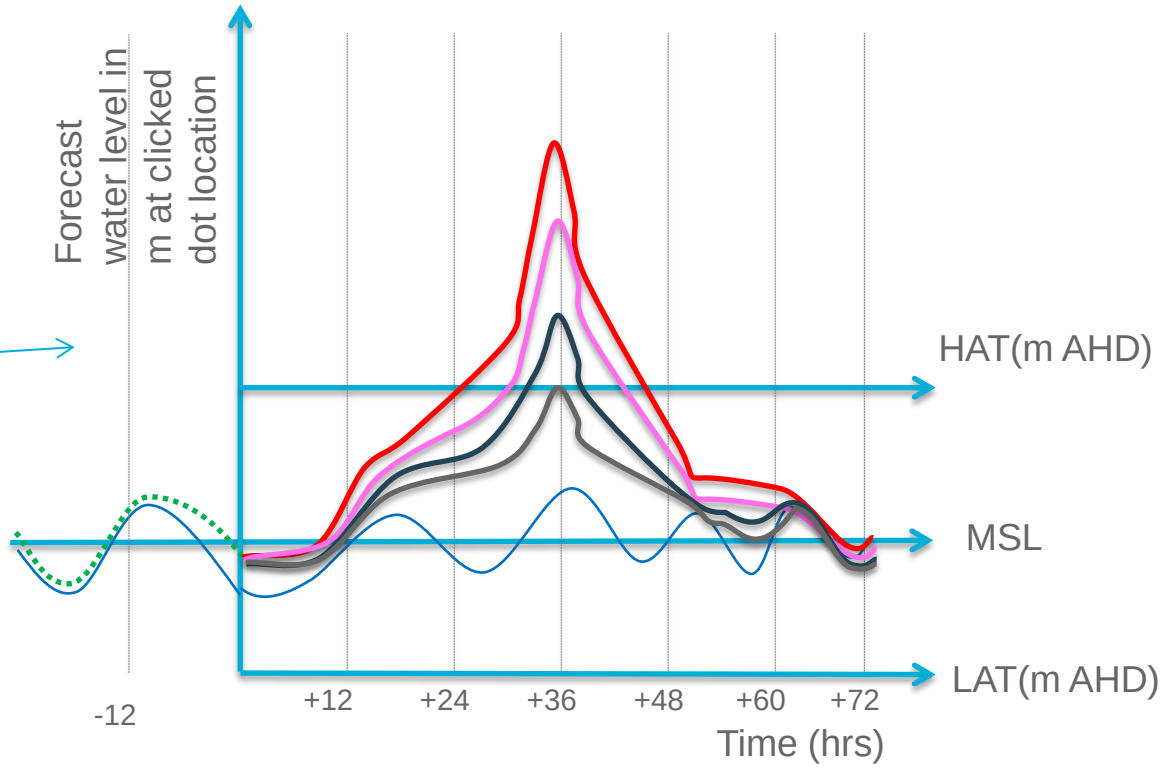
Storm Tide-grams

Water level at coastline during forecast period

- observed water level (tide gauge data, where applicable)
- astronomical tide
- most likely storm tide (consensus track)
- 50th % exceedance prob storm tide
- 10th % exceedance prob storm tide
- 0th % exceedance prob storm tide

HAT: highest astronomical tide
MSL: mean sea level (0 m AHD approx)



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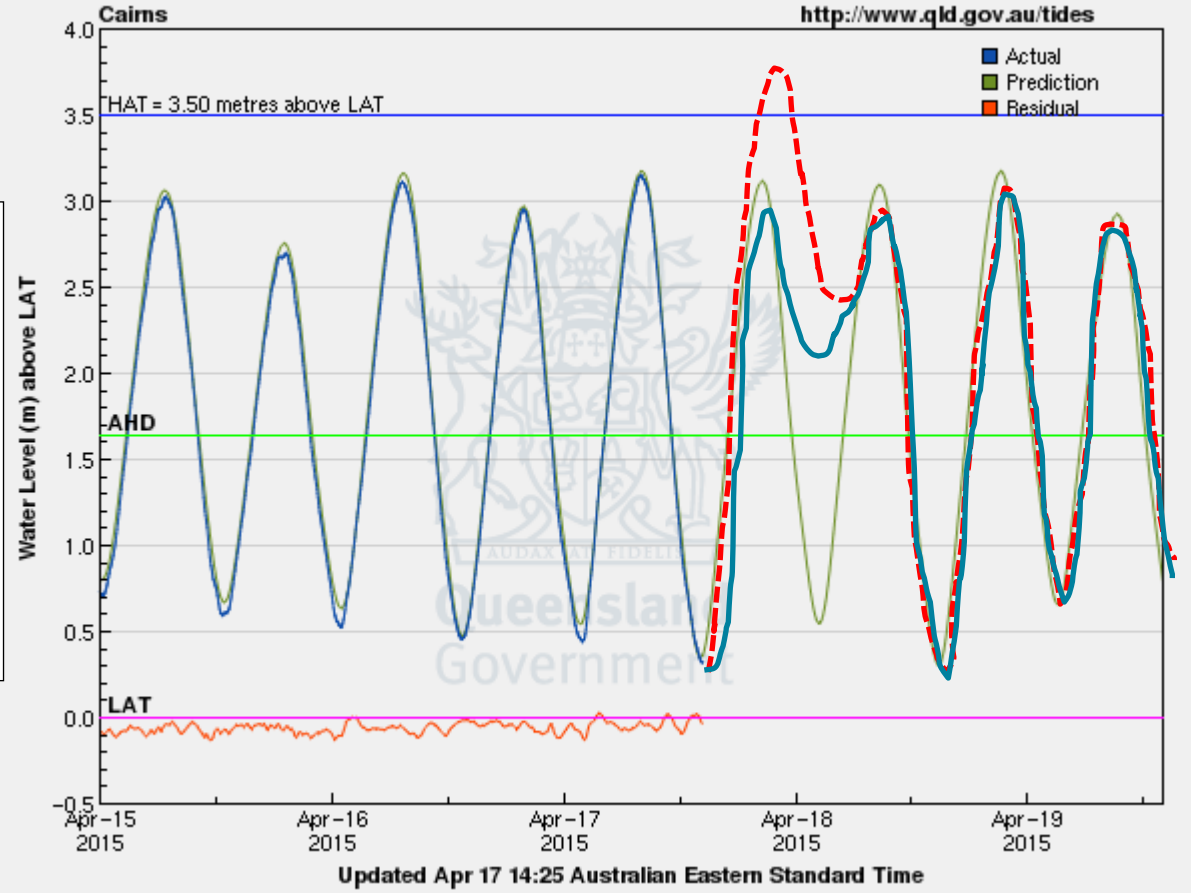
Storm surge time series:

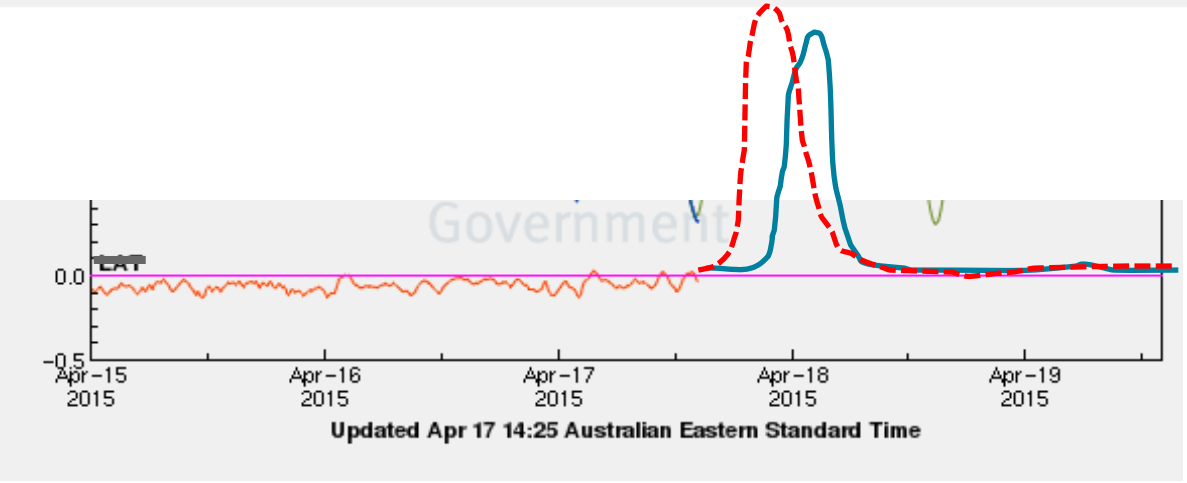
Most likely vs worst case

Storm surge plus setup plus tide



Forecast track scenario
Worst case scenario

Storm surge plus setup



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THANK YOU!