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Towards Improved Performance of Operational Wave Models at Australian Coast

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Bureau of Meteorology, Australia

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This talk will cover

- **Introduction**
- **Operational Wave Models & products**
- **Evaluation of Wave Forecasts**
- **Wave Optimal Consensus Forecast**
- **Coastal Wave Modelling**
- **Conclusions**

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Introduction

- Ocean waves affect a wide range of activities such as shipping, fishing, recreation, coastal and offshore industry, coastal management and pollution control. They are also important in weather and climate processes.
- The Bureau is the primary provider of marine forecasts for the Australian region and has been running operational wave models for the past 25 years.
- Numerical wave model guidance is used by the Bureau's marine forecasters to produce marine forecasts and commercial weather services to produce tailored forecasts for commercial ports and offshore industry.
- The diverse range of wave conditions present in the Australian high seas forecast zones as well as along the Australian coastline creates a challenging forecasting environment, requiring models on a range of scales.

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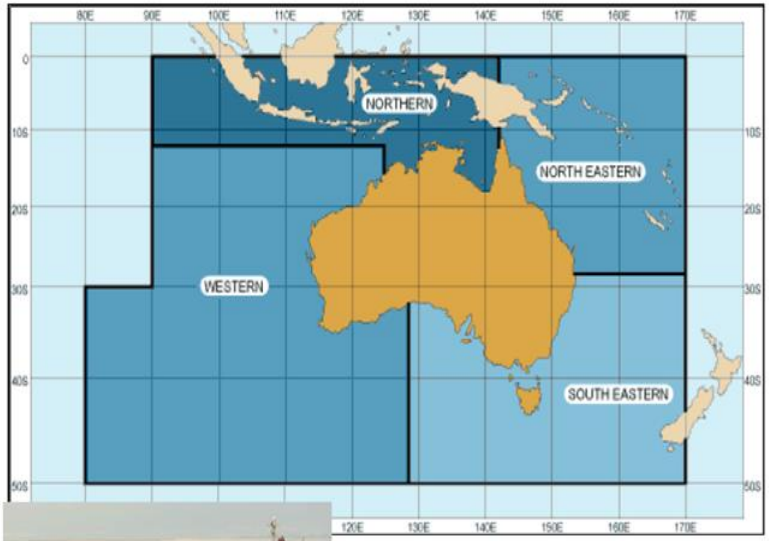
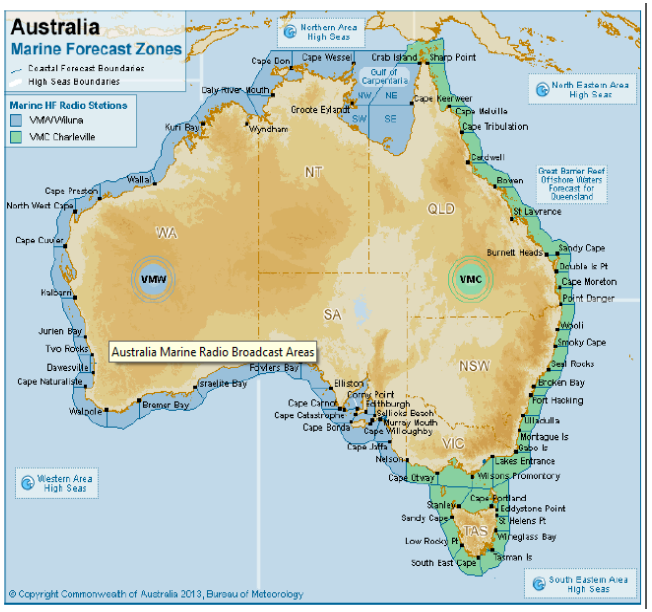
High Sea & Coastal Water Forecast and Warnings



Ocean areas for high seas forecasts

Within 60 Nautical Miles offshore

- 78 marine zones
- > 35000 km of coastline
- Warnings issued for same zones
  - strong wind,
  - gale,
  - storm force or
  - hurricane force winds



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Who are our external customers

- General Public
- Government Agencies
- AMSA
- RAN
- Ports Australia
- Commercial clients
- Research organisations & Universities

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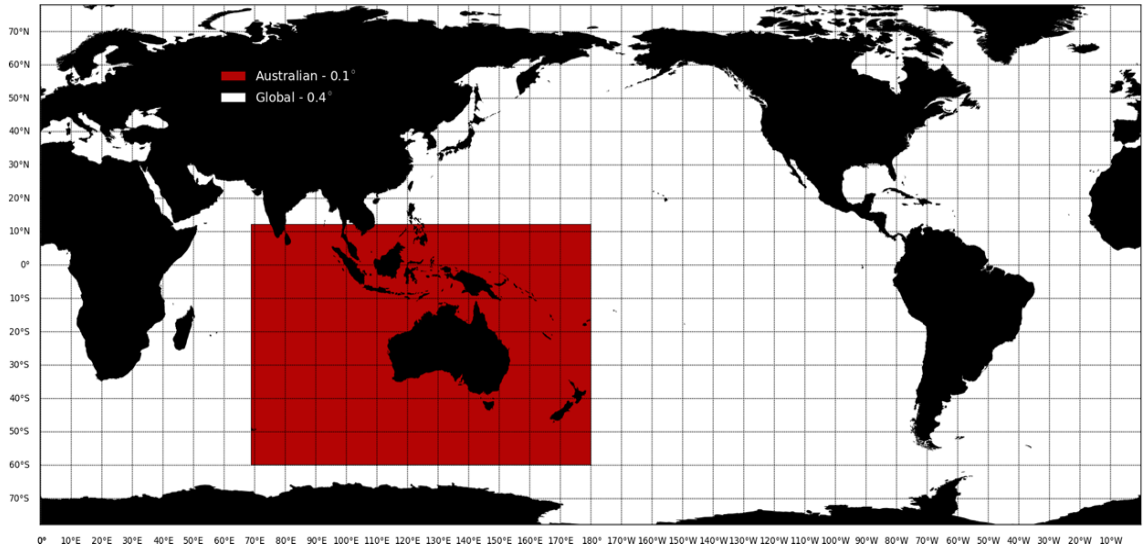
Operational Wave Model Configurations



- AUSWAVE based on version of 4.18 WaveWatchIII
- Source terms ECMWF WAM parameterisation ST4 (Ardhuin et al 2010)
- Driven by ACCESS-G2 and R2

AUSWAVE	Domain	Forcings	Horizontal Resolution	Directional Bins	Frequency bins	Domain (lat x lon)	Forcast Period (hours)
APS2-G	Global	ACCESS-G2	0.25º	24	25 (24 sec to 2.5 sec)	78ºS-78ºN 0-359ºE	+240
APS2-R	Regional	ACCESS-R2	0.1º	36	32 (28.8 sec to 1.5 sec)	60ºS-12ºN 69-180ºE	+72

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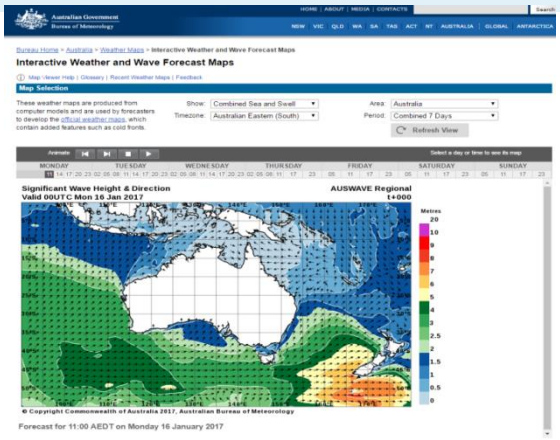
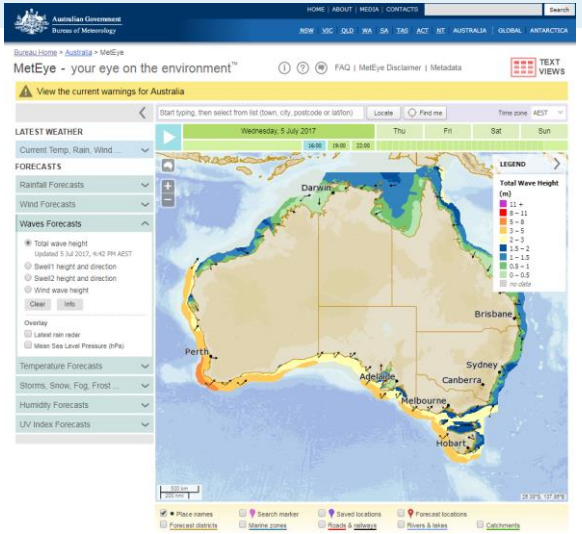
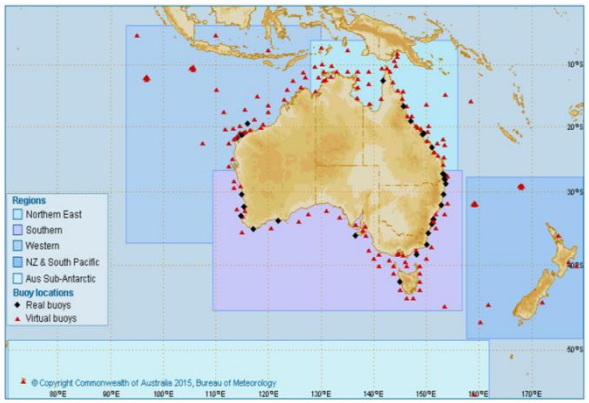
Wave Forecast Products

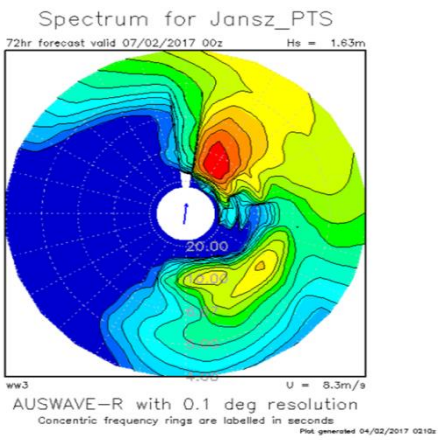




Plots of wave spectra at selected locations - AUSWAVE-R Model

To view AUSWAVE spectral loops for buoys, first click on a region to display a more detailed map. On this map, click on buoy locations to show the spectal loops for either global (AUSWAVE-G) or regional (AUSWAVE-R) model. Tables of Wave Partition and Time Series can also be viewed.





The wave state is described by the full spectrum: low frequency at centre (long waves), high frequency at outside (short waves).

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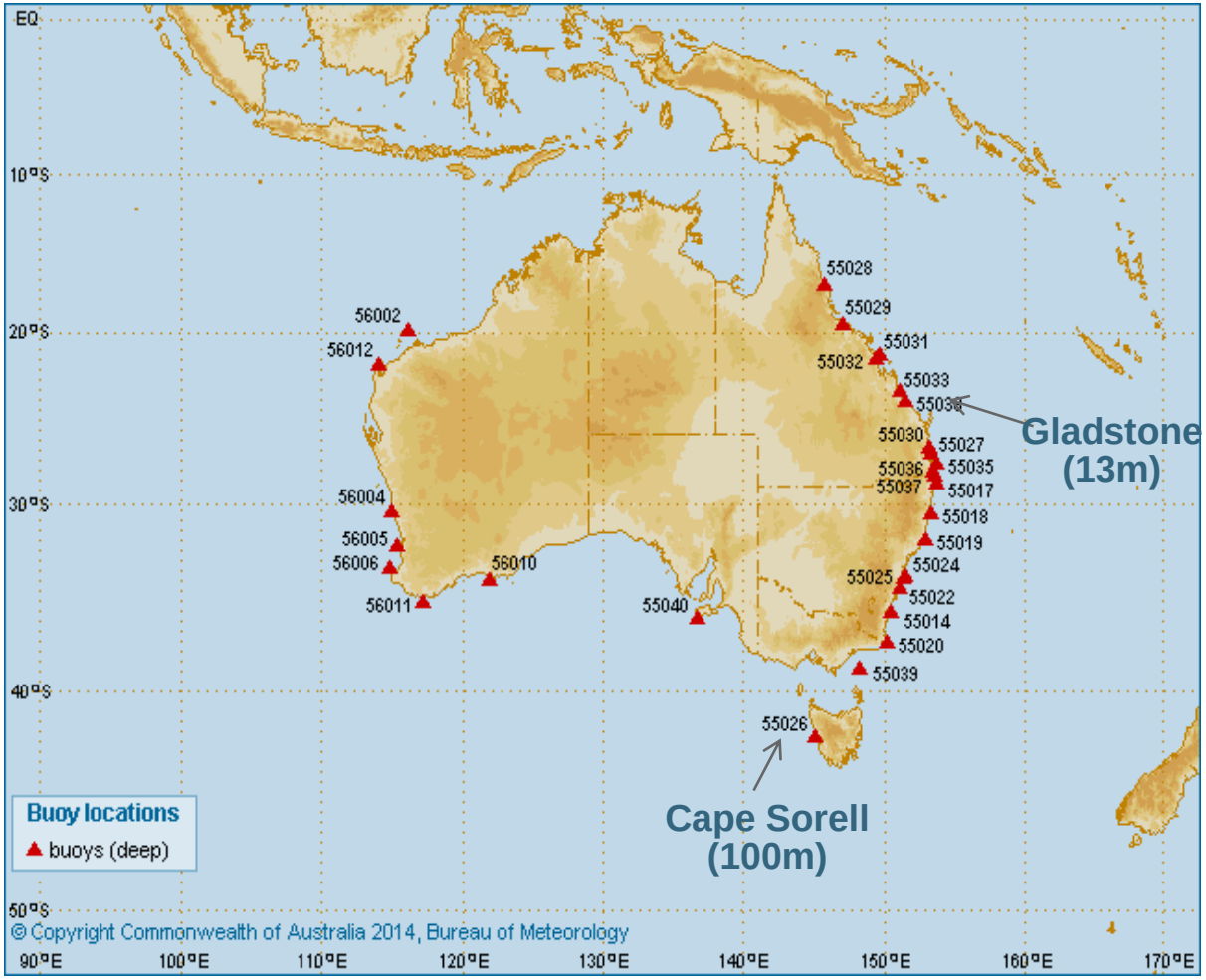
In-Situ Australian Wave Rider Buoys



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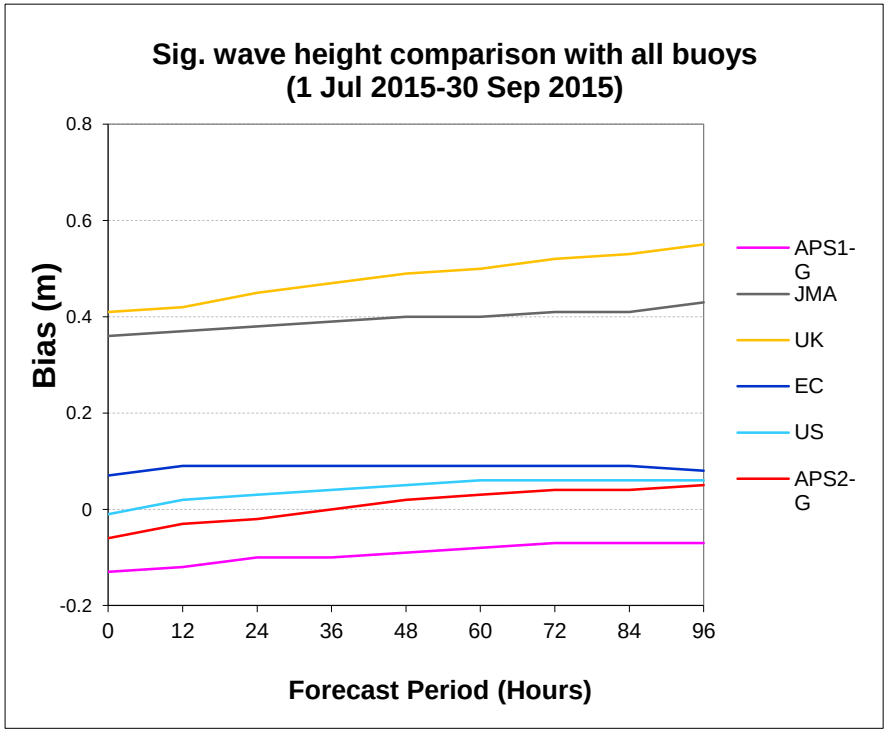
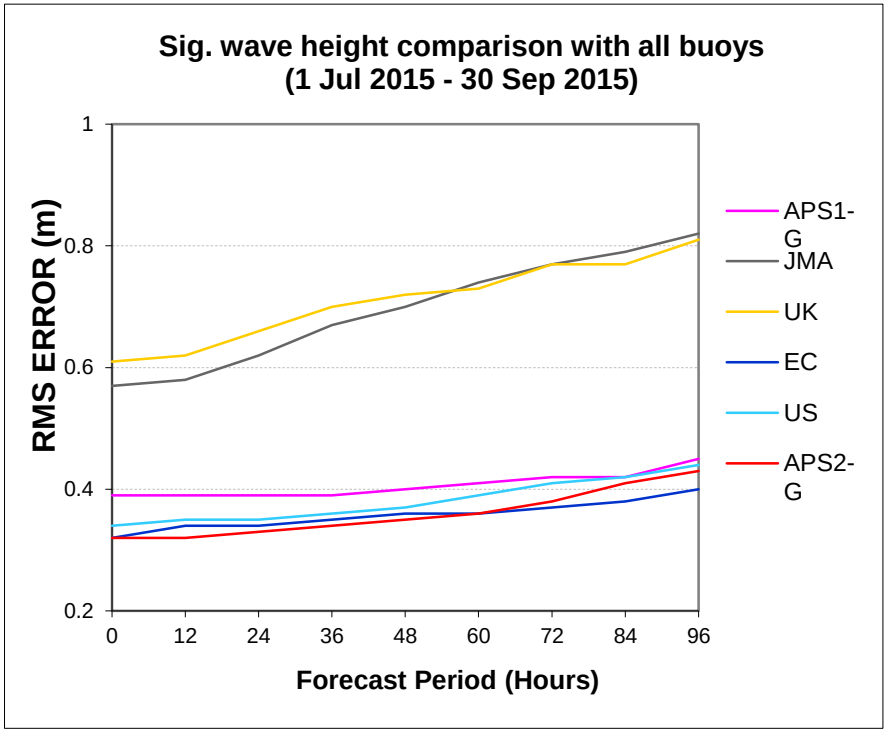
Model verification vs In-Situ Australian buoys





- **APS2 ACCESS-G provides wind forcing for the global wave model**
- **The global model skill over the Australian region is comparable to all the global wave models around the world**
- **The improvement in the wave model performance is mainly due to improved physical parameterization of source term and model resolution**

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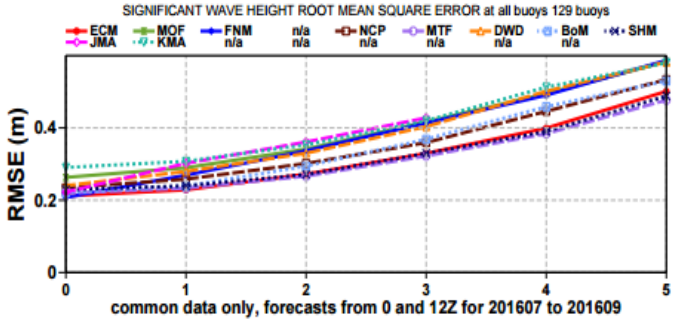
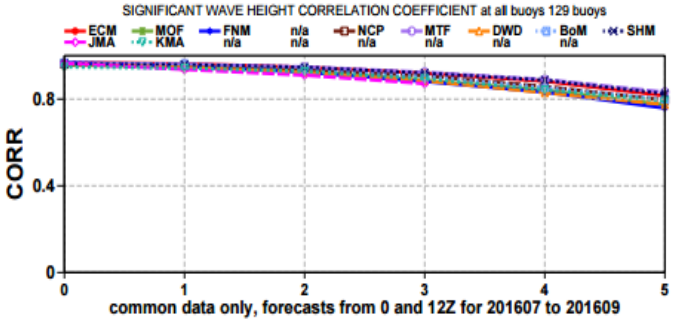
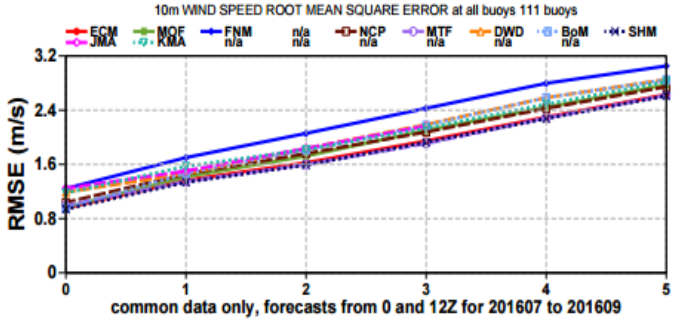
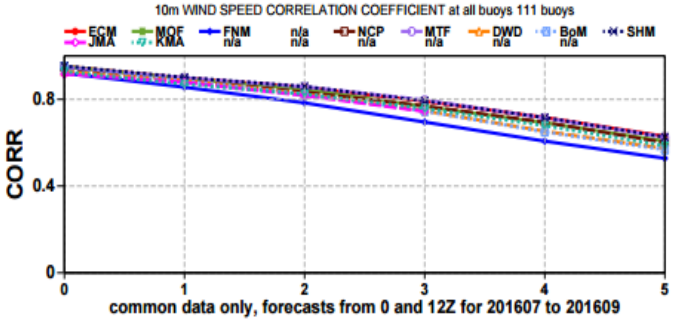
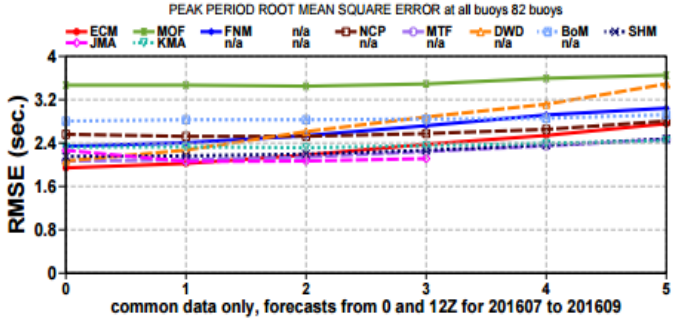
Inter-comparison of wave forecasting systems against global in-situ observations, Jul – Sep 2016

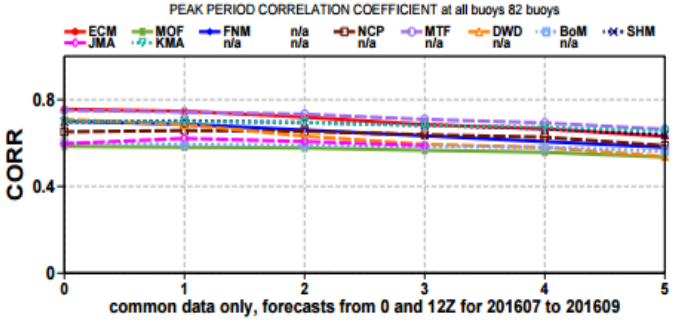












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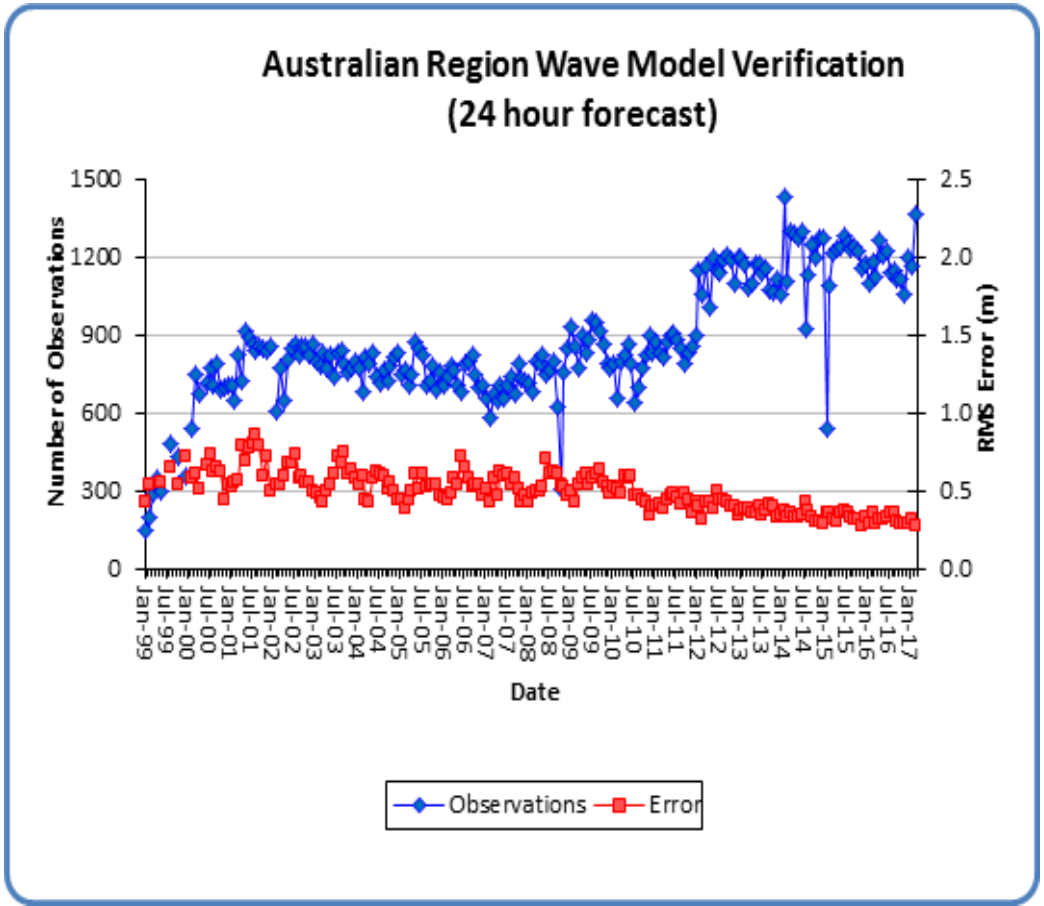
Regional Wave Model Verification



- RMS error has decreased from 0.5m in August 2010 to its current value of ~0.3m due to implementation of the new wave model and upgrade of ACCESS NWP system
- There is an annual cycle of higher RMS error in winter associated with more severe synoptic systems: low RMS error in Summer
- A significant increase of wave buoys along the Queensland coast contributes to the large increase of the total buoys number from 2012

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Optimal Consensus Forecast (OCF)

***Consensus*: it is beneficial to combine forecasts from several models**

•Averaging forecasts from more than one model results in more accurate predictions than from the individual models
•It reduces the amount of information the forecaster needs to combine in his or her head.

Methodology for sites OCF:

•Use direct model outputs from all models and bilinearly interpolate gridded to observation site locations
•Bias correct each model individually for each location using a fixed 30-day window
•Take weighted average of forecasts: weight each component using the inverse of the mean absolute error

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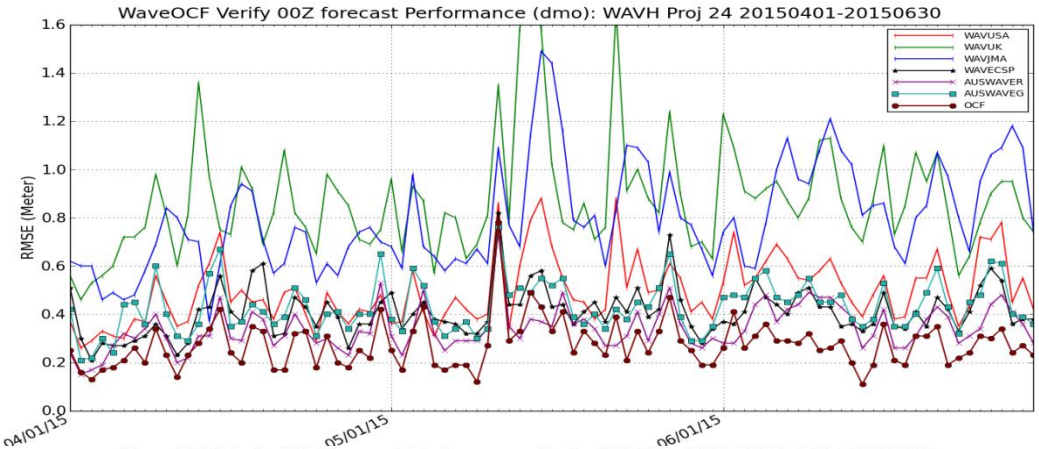
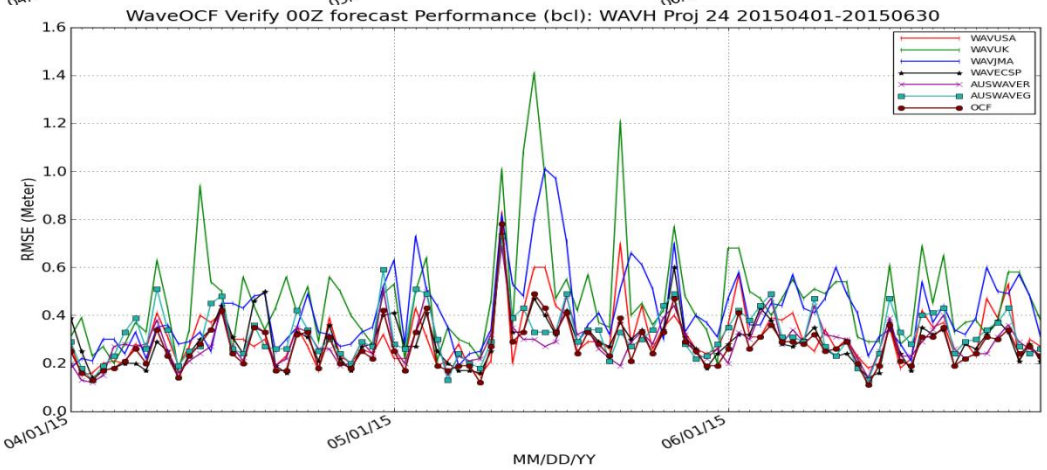
Wave Optimal Consensus Forecast (OCF)

- Combine forecasts from six wave models and remove models' biases to produce forecasts of significant wave height, peak wave period, wind direction and wind speed up to 5 days ahead at 30 selected sites.

Mean absolute error of SWH from direct model outputs



Mean absolute error of SWH from model outputs after bias correction



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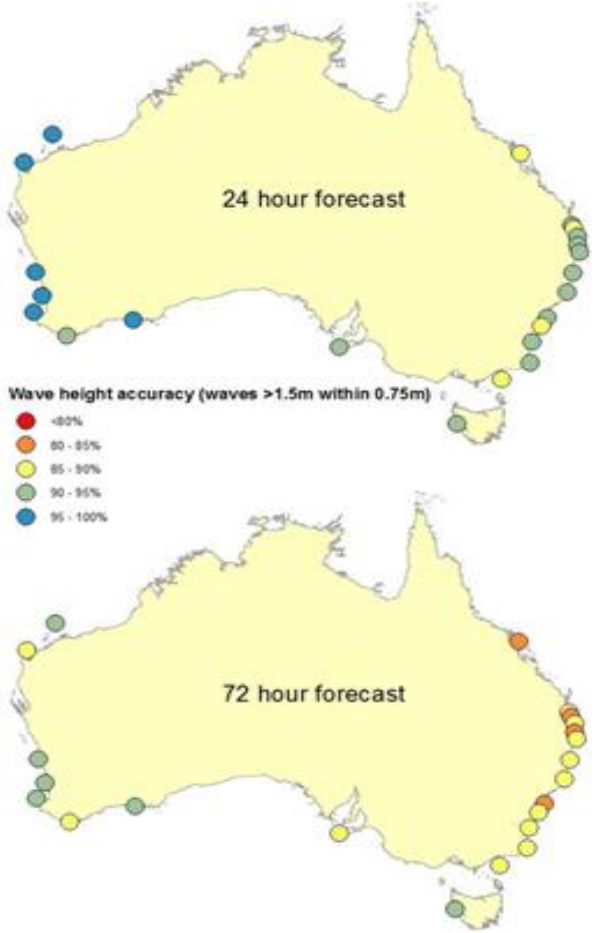
Wave OCF verification (2012-2013)



Overall wave height forecast reliability and wave period reliability for periods of >=12 seconds

	Wave height (all obs)		Wave period (>=12sec)	
	OCF	Auswave-R	OCF	Auswave-R
+24hrs	94%	92%	90%	87%
+72hrs	89%	88%	89%	86%

- **3% improvement from the AUSWAVE-R model to the OCF at both +24 and +72 hrs.**

Forecast challenges exist primarily along the East Coast likely due to complex wave generating systems such as East Coast Lows

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Northwest Shelf Wave Forecast Systems

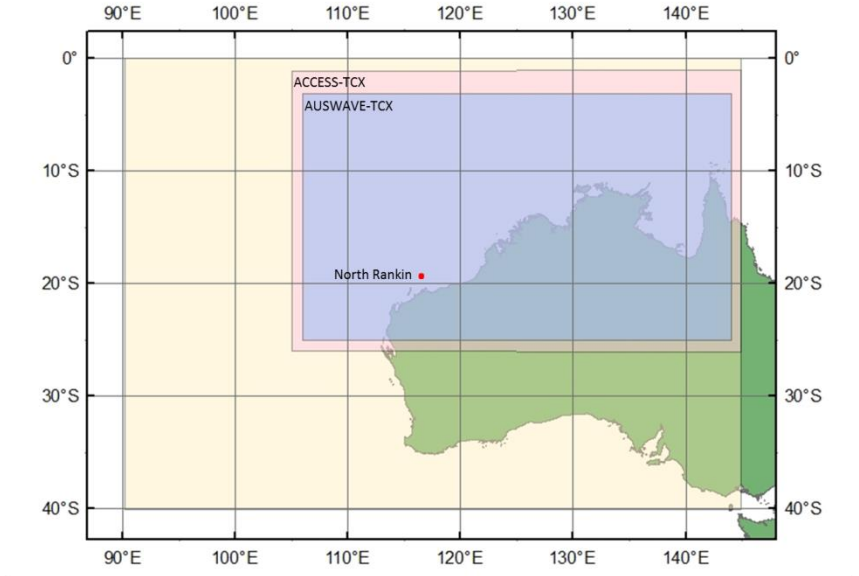
AUSWAVE-EPS

- Ensemble wave prediction system
- Operational in December 2016
- 51 members
- Forced by surface winds from bias-corrected ECMWF atmospheric ensemble

AUSWAVE-TCX

- Deterministic wave prediction system
- Due to be operational in October 2017
- Forced by surface winds from ACCESS-TCX

-see Jeff Kepert's talk



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Coastal wave forecasting

- Small R+D project funded through Surf Life Saving NSW under Australian Government's Beach Drowning Black Spot Reduction Fund
- Surf Life Saving NSW identified that AUSWAVE-R at 10 km resolution does not meet their needs
- Aim of project is to enhance the Bureau's surf warning framework and improve nearshore wave forecasts

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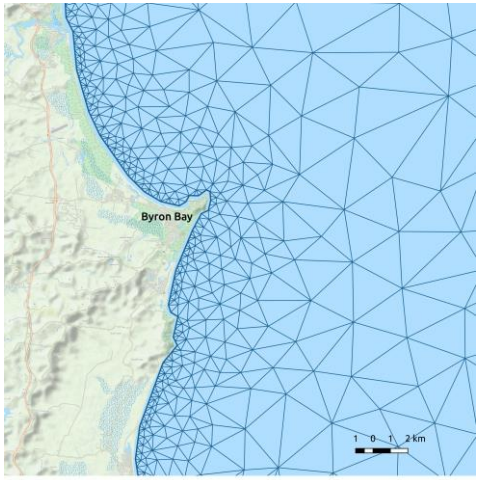
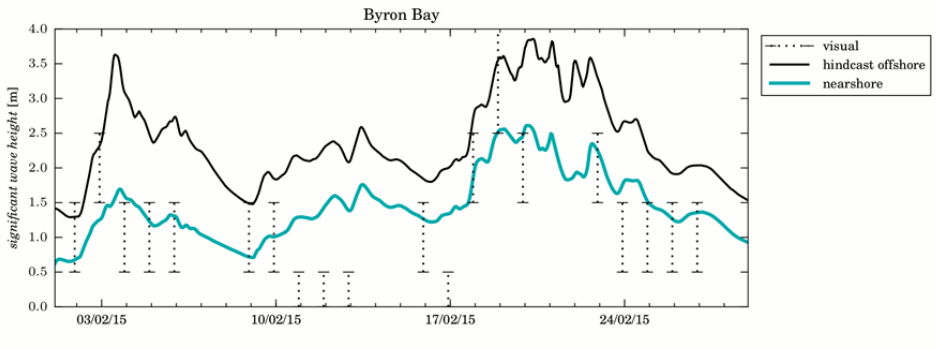
Coastal wave forecasting

- Set up a high resolution wave model
  - WAVEWATCH III
  - Unstructured grid
  - Highest resolution ~250m nearshore
  - Deepreef bathymetry (100m)
  - 72-hour forecast takes a couple of minutes on the National Computational Infrastructure (ANU)





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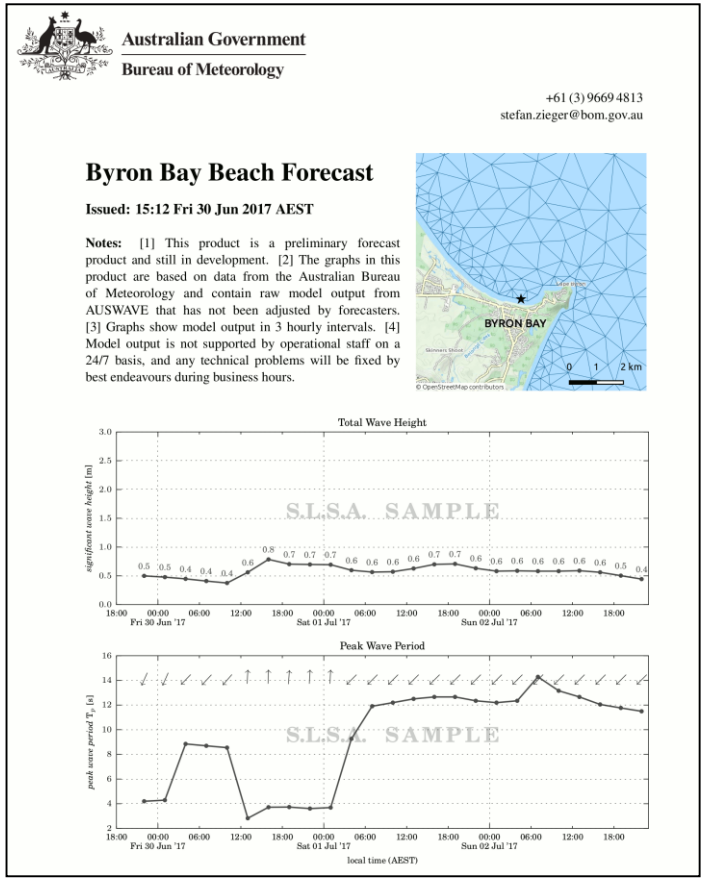
Coastal wave forecasting

- Pilot real-time system running on NCI (non-operational)
- Forecast e-mailed each day at @ 9am
- Significant wave height, peak period and peak direction
- Verifies well against visual obs
- Potential to improve with ongoing research into shallow water waves
  - see Jeff Hansen's talk
- Potential to extend to other locations around Australia
- Potential to extend to entire Australian coastline
  - Bathymetry limitations



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Byron Bay Beach Forecast

Issued: 15:12 Fri 30 Jun 2017 AEST

Notes: [1] This product is a preliminary forecast product and still in development. [2] The graphs in this product are based on data from the Australian Bureau of Meteorology and contain raw model output from AUSWAVE that has not been adjusted by forecasters. [3] Graphs show model output in 3 hourly intervals. [4] Model output is not supported by operational staff on a 24/7 basis, and any technical problems will be fixed by best endeavours during business hours.

Total Wave Height

Peak Wave Period

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Summary

- Both global and regional AUSWAVE models provide useful model guidance to the marine forecasters and users including general public and commercial clients
- The global model skill is comparable to all the global wave models around the world and the regional system performs the best over the Australian Domain
- Wave OCF combines forecasts from several models, removes the model's biases and produces more accurate wave predictions around the Australian coast than from any individual models
- Future development of
  - operational coastal wave model for Australia
  - global ensemble wave prediction capability in 2018 - 2020