The Bureau of Meteorology

Recent Upgrade to the Bureau's Operational Wave Model

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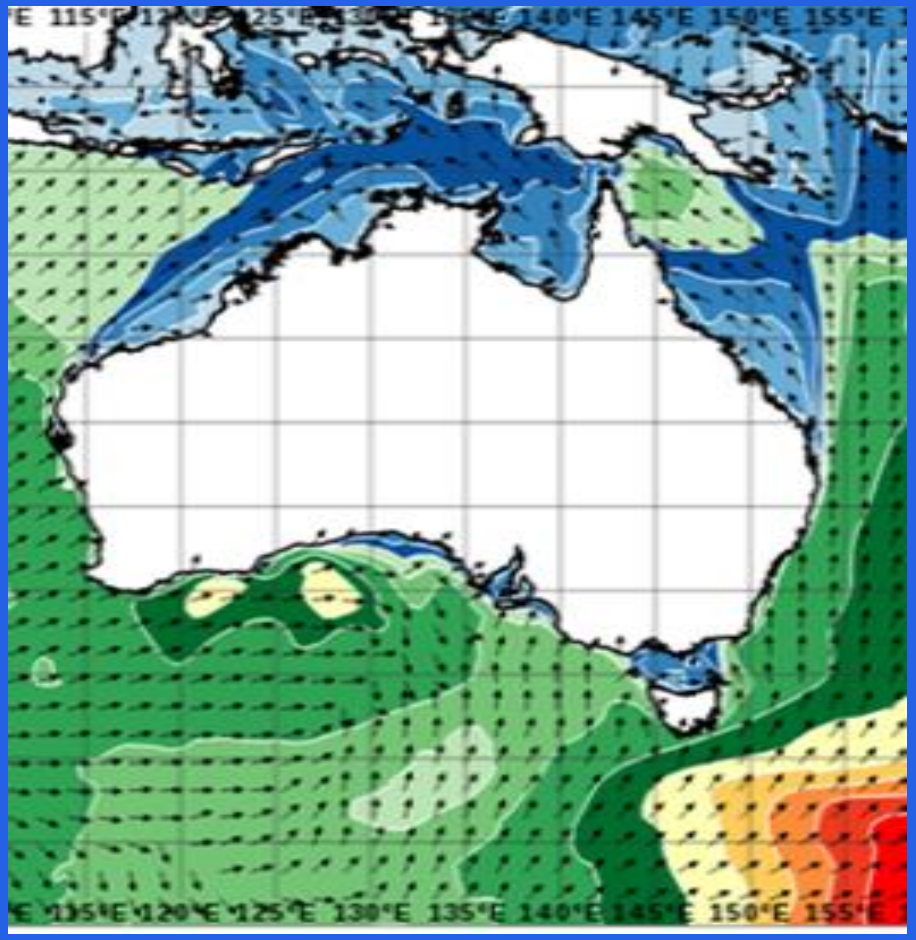
Research to Operation
Science and Innovation
Bureau of Meteorology



Acknowledgements: R2O Observation & Assimilation team

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Introduction

- Ocean waves affect a wide range of activities such as shipping, fishing, recreation & coastal and offshore industry.

- The Bureau of Meteorology has been running operational wave models since 1983.
  - ➡ Parameterisations based on empirical relationships for wind and swell wave height and period in 1983.
  - ➡ In 1986 First spectral wave model
  - ➡ In 1994 WAM became operational
  - ➡ In 2010 WW3 was implemented

- Numerical wave model guidance is used by the Bureau's marine forecasters to produce marine forecasts

National Meteorological Operations Centre (NMOC)

The following Analysis and Prediction Operations Bulletin provides a description of a major operational change at the National Meteorological Operations Centre, Melbourne, Australia.

NMC OPERATIONS BULLETIN NO 5.4 September1986

IMPLEMENTATION OF SPECTRAL SEASTATE MODELS

As from 4 September 1986 spectral wave forecast models have been introduced operationally in the NMC and replace the former TDL model for the production of the seastate prediction charts that are issued twice daily (Items M22, 23, 47 and M72, 73 and 93 on the Fax schedule).

The technical background and a description of the models and their performance is given in the Attachment, provided by the Public Weather and Marine Services Program Office.

ATTACHMENT

SEA STATE PROGNOSES

IMPLEMENTATION OF SPECTRAL WAVE MODELS

1. Introduction

Spectral wave forecast models for use in the prognosis of sea state for the oceans of the Southern Hemisphere and the Australian Region have been developed by the Bureau. The operational hemispheric model (Ocean Wave Model - OWM) and regional model (Australian Region Wave model ARWM) provide physically based prognosis of significant wave, wind wave and swell wave heights and periods, and swell wave direction, as guidance for Ocean and High seas forecasts in the Australian region. These models were constructed in the Research and Development Branch during the early 1980's by F. Trajer and P.Parker. Delays in implementation were partly due to limited computer resources. Similarly, implementation of more sophisticated models (see section 3) may have to await the next computer upgrade.

Any queries or comments concerning the new models or their performance should be directed to

Phil Parker

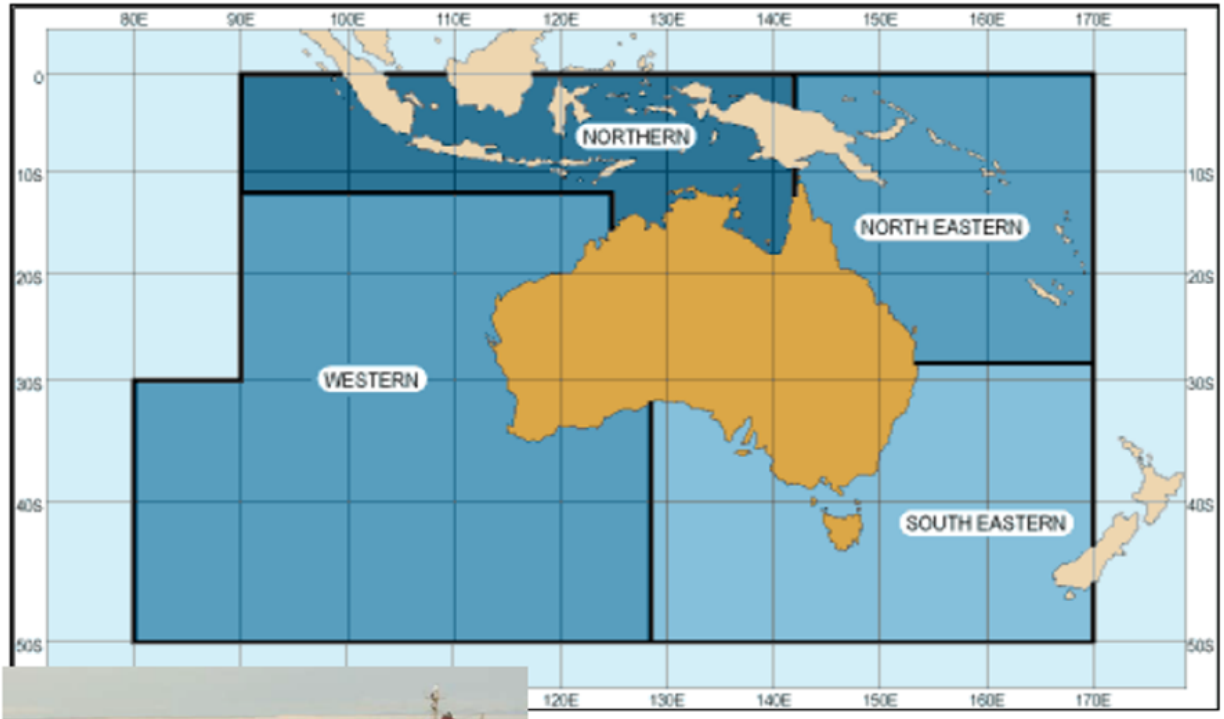
Public Weather and Marine Services Program Office

Services Policy Branch, Head Office (tel. (03) 96694510)

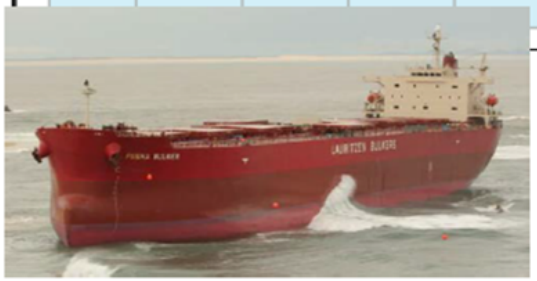
2. Basis of the models

High Seas Forecasts and Warnings

- Australia is responsible for 16 million square kilometres of ocean
- Approximately $200 billion worth of cargo is moved around our ports annually
- Ocean Wind Warnings
  - gale,
  - storm force,
  - hurricane force
  - Tropical Cyclones



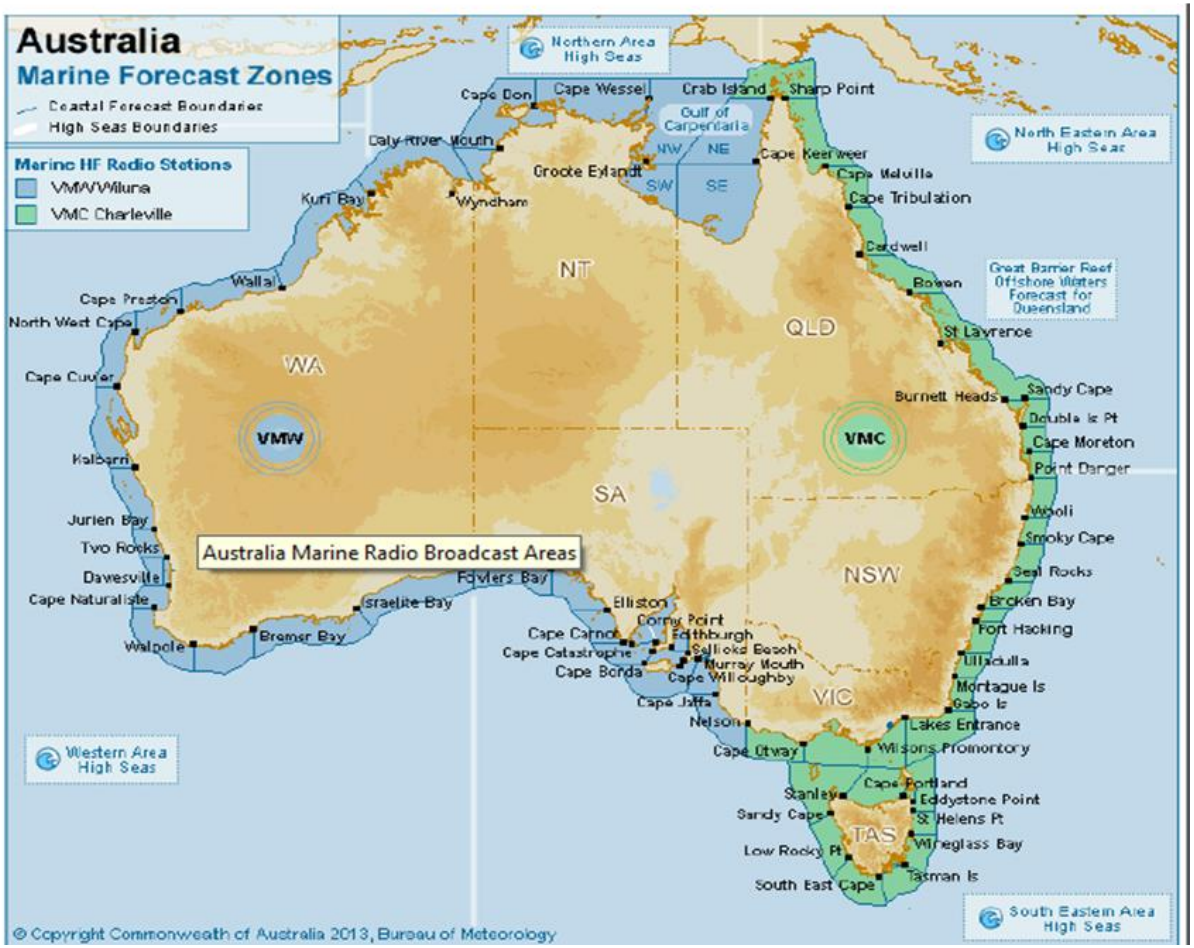
Ocean areas for high seas forecasts



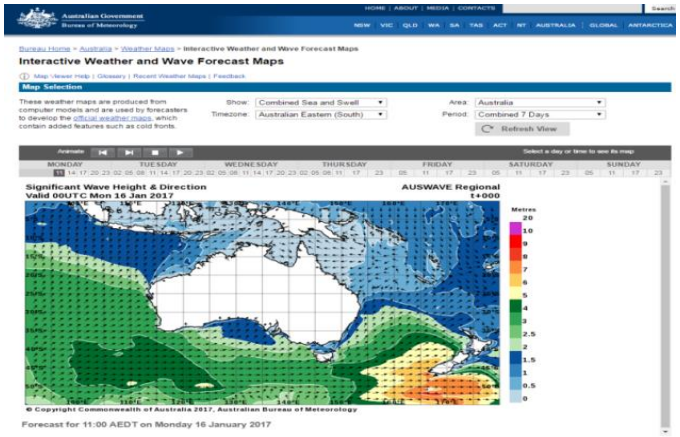
Coastal Water Forecast and Warnings

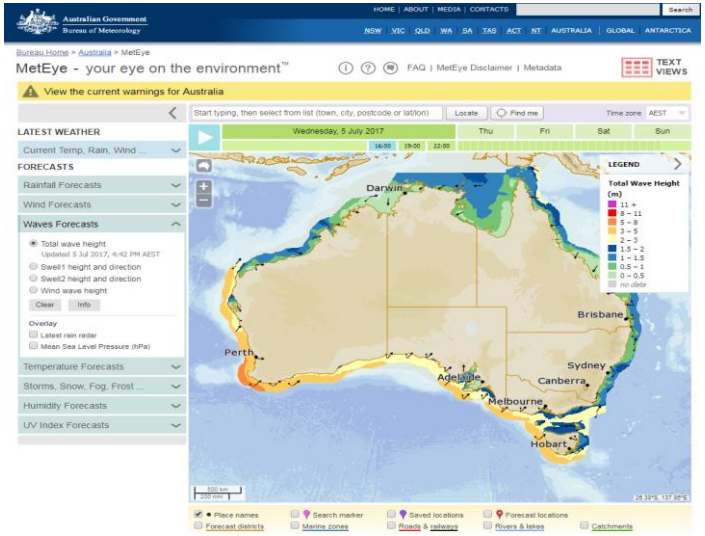
Within 60 Nautical Miles offshore

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



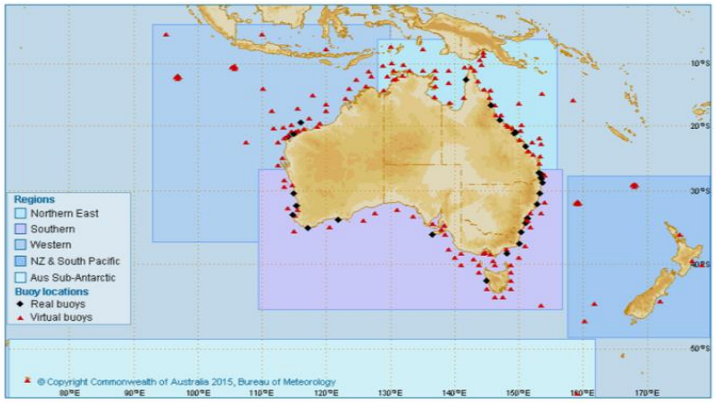
Public Wave Forecast Products





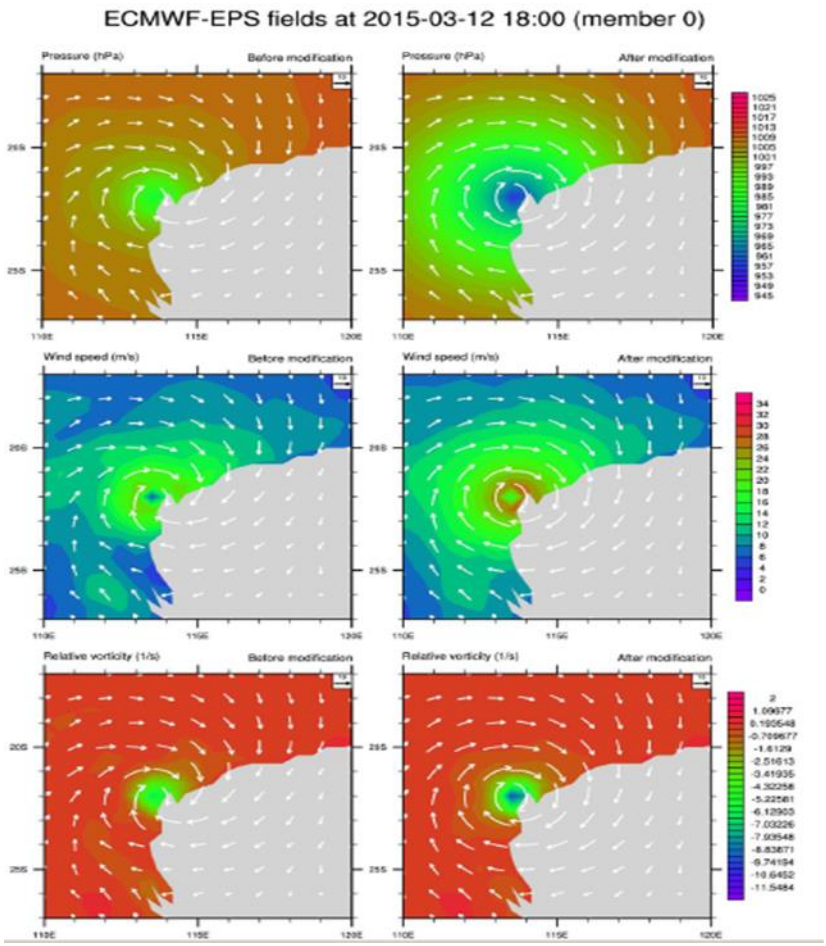
Plots of wave spectra at selected locations - AUSWAVE-R Model

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.



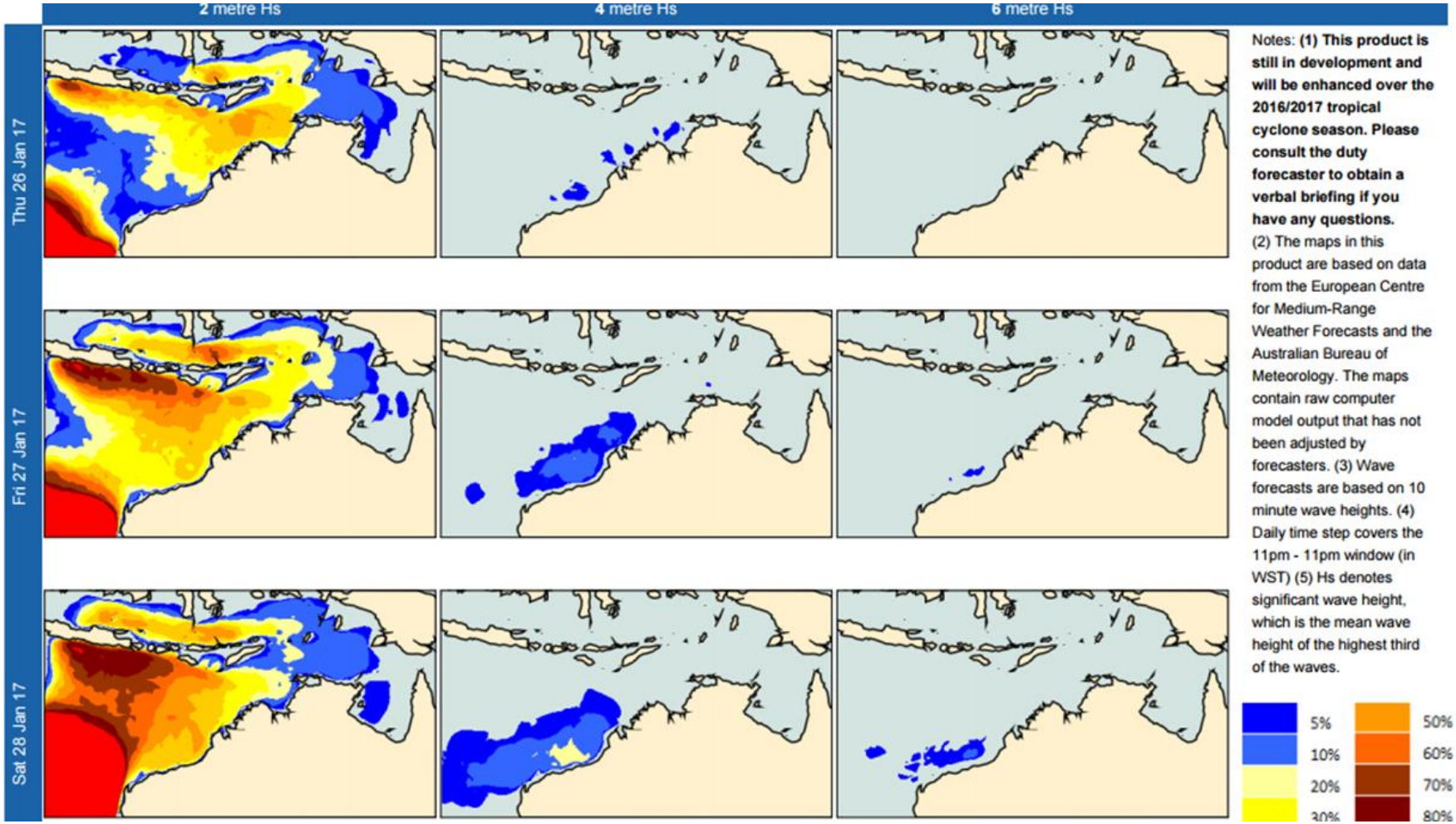
The wave state is described by the full spectrum: low frequency at centre (long waves), high frequency at outside (short waves).

JIP TC: Bias Correction to ECMWF winds



- The Joint Industry Project for Tropical Cyclones aims to provide accurate operational forecasts specifically around tropical cyclone events affecting the North West Shelf of Western Australia (3°S to 25°S and 106°E to 144°E).
- ***AUSWAVE-EPS*** – **new operational service**: a 51-member ensemble wave forecast system driven by surface winds from bias-corrected ECMWF ensemble forecasts.
- Designed file structures to store cyclone structure parameters from the observations.
- Insert the bias-corrected TC structure back into the original ECMWF-EPS wind fields.
- At time steps or ensemble members where there is no TC detected, it simply retains the original wind fields.

Ensemble probabilistic forecasts - wave PDF



Motivation of the Model Upgrade

- Improve parametrisation of wind input and swell dissipation terms from the latest WAVEWATCH III® (WW3) model release

- Simplify the model framework: a single AUSWAVE multiple-resolution global wave prediction system (AUSWAVE-G3) to replace two model configurations (AUSWAVE-G & AUSWAVE-R)

- Improve model resolution: the new wave model features ~12.5 km spatial resolution globally to match with ACCESS-G3 horizontal resolution with refinement around sub-grid scale feature ~6.25 km over shallow/coastal regions.

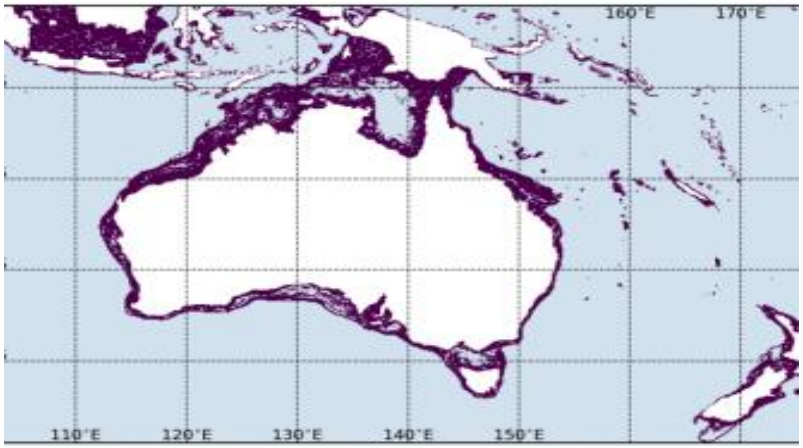
- Allow for ocean current effects on the wave field. The ocean current field is taken from real-time Ocean Model Analysis and Prediction System (OceanMAPS).

Model Configuration

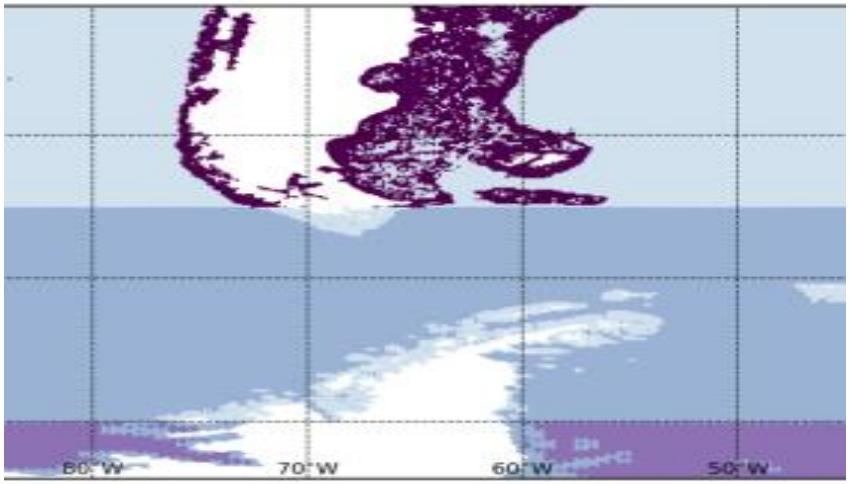
AUSWAVE	Horizontal Resolution	Directional Bins	Frequency Bins	Domains	Forecast Hours
AUSWAVE-G	0.25°	24	25 (24 sec to 2.5 sec)	78°S-78°N 0-359°E	+240
AUSWAVE-R	0.10°	36	32 (28.8 sec to 1.5 sec)	60°S-12°N 69-180°E	+72
AUSWAVE-G3	**0.0625~ 0.125°**	**30**	**28**	**75°S-75°N 0-359°E**	**+72(06Z, 18Z) +240(00Z,12Z)**

AUSWAVE-G3 With Spherical Multiple Cell Grid (Li 2011)

- 2 tier refinement (~12km and ~6km)
- 2 tier refinement at high latitudes



Grid resolutions with 1/8°x 1/8° in pale blue & 1/16°x 1/16° in purple less than 350m water depth.



Four grid resolutions:

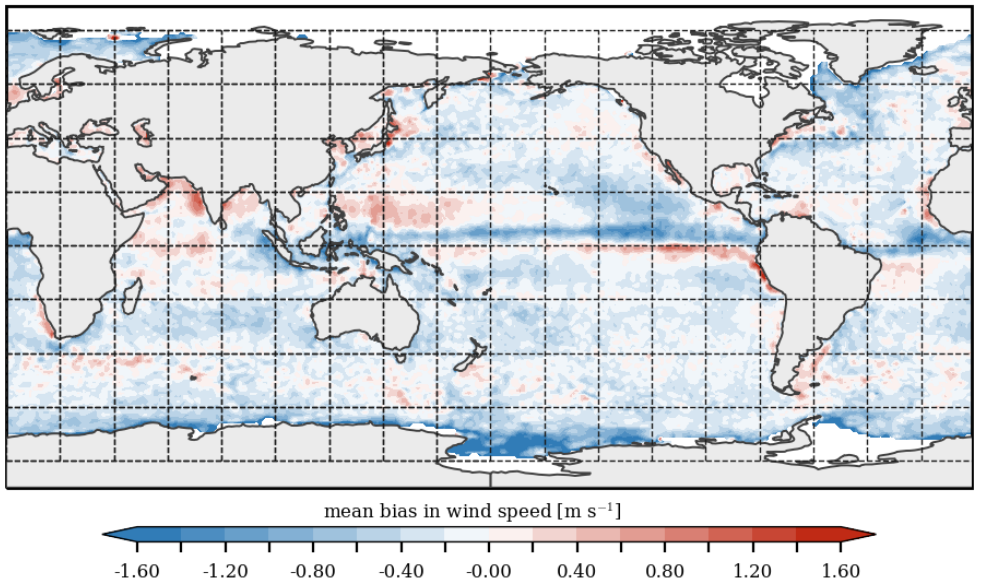
- 1/8° in pale blue and 1/16°in purple up to 55° latitude
- 1/8°x1/4° between 55°~ 70°latitude in blue
- 1/8°x1/2° beyond 70°latitude in dark blue.

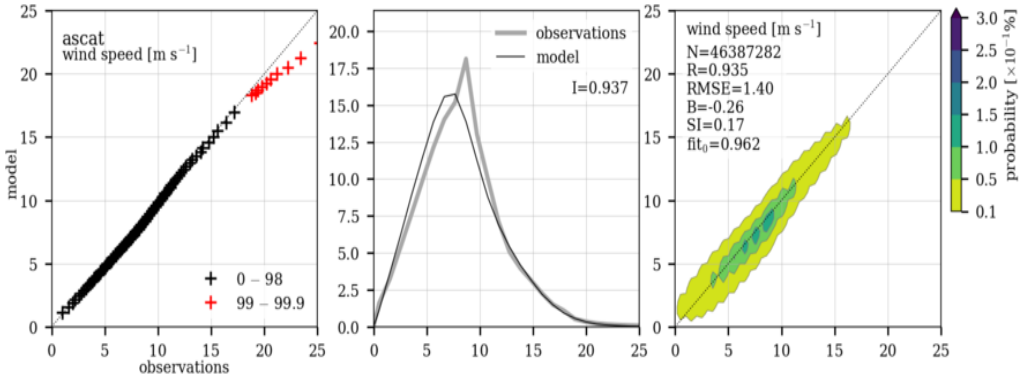
Li, J.-G., 2011. Global Transport on a Spherical Multiple-Cell Grid. Mon. Weather Rev. 139, 1536–1555. doi:10.1175/2010MWR3196.1

ACCESS-G3 Marine Surface Wind

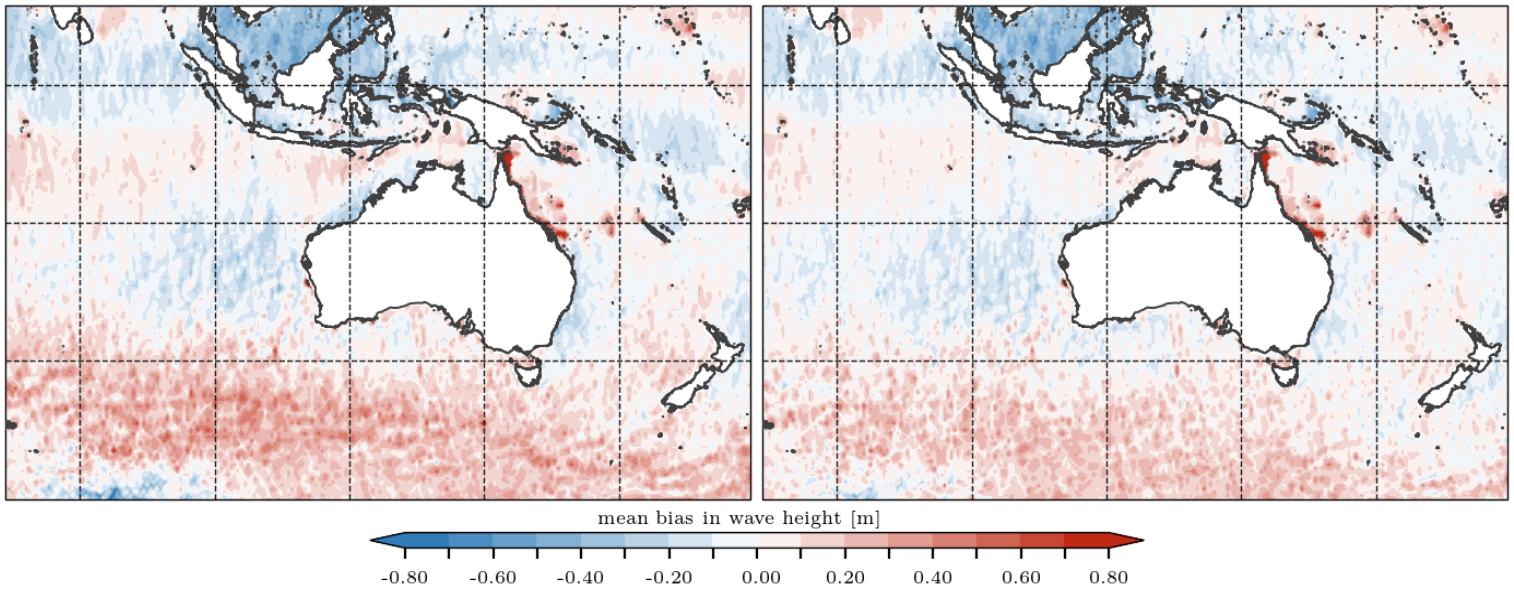
- Wave model accuracy depends strongly on the accuracy of the surface winds.
- ACCESS-G3 surface winds vs satellite winds from Advanced Scatterometer (ASCAT)
- Large mean bias over the ITCZ and othe regions corresponding to major currents e.g Gulf Stream & Antarctic Circumpolar Current
- RMSE at 1.40 m/s is small and close to the observational error ~0.98 m/s for scatterometers

Period 1/3/22 – 31/5/22





Impacts of Ocean Surface Currents on Sig Wave Height



Errors of Sig Wave Height w/o currents

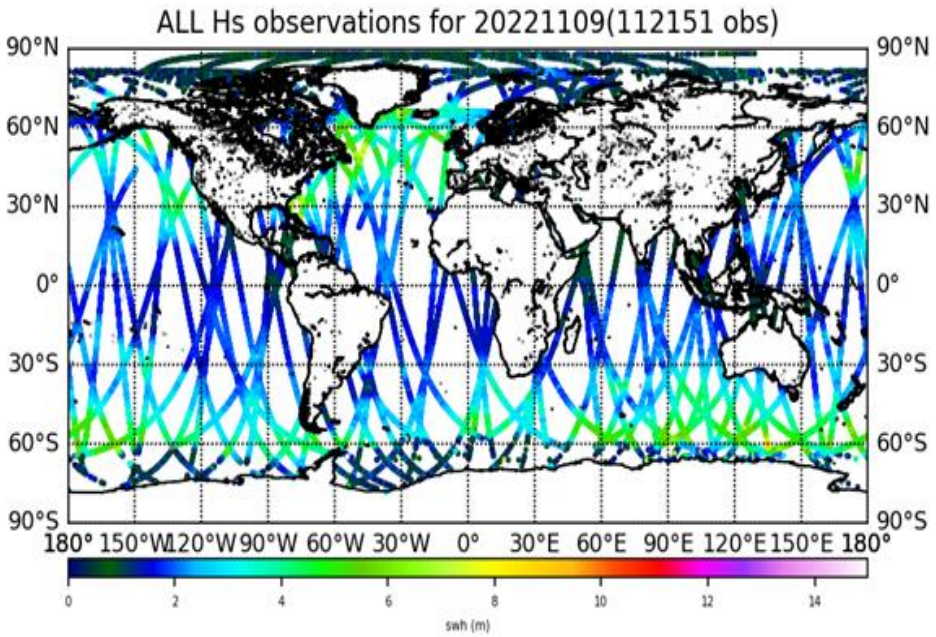
Errors of Sig Wave Height with currents

→Enable linear wave effects over slowly varying currents:

- Adjust for group velocity of waves
- Change in wave direction
- Change in wave steepness
- Change in surface roughness length

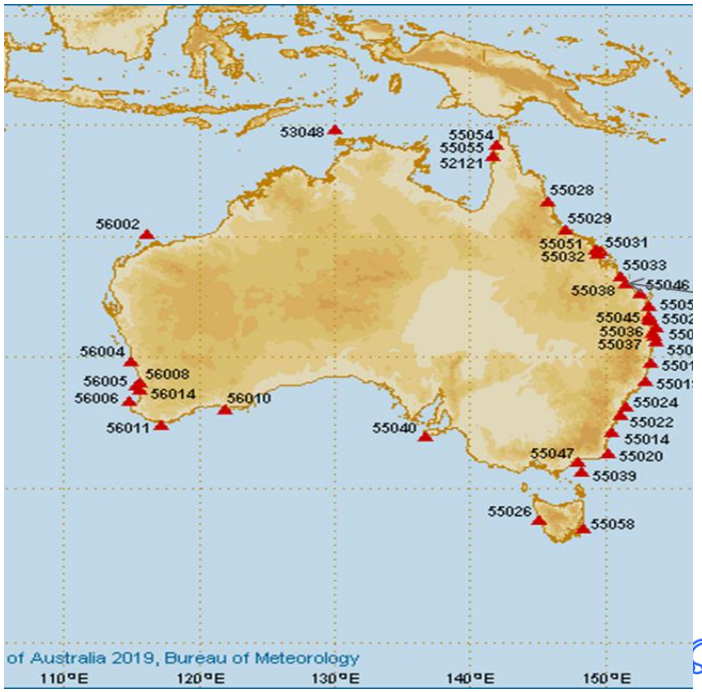
→Improved significant wave height Hs error around Australia and the Indian Ocean.

Wave Verification Assessment



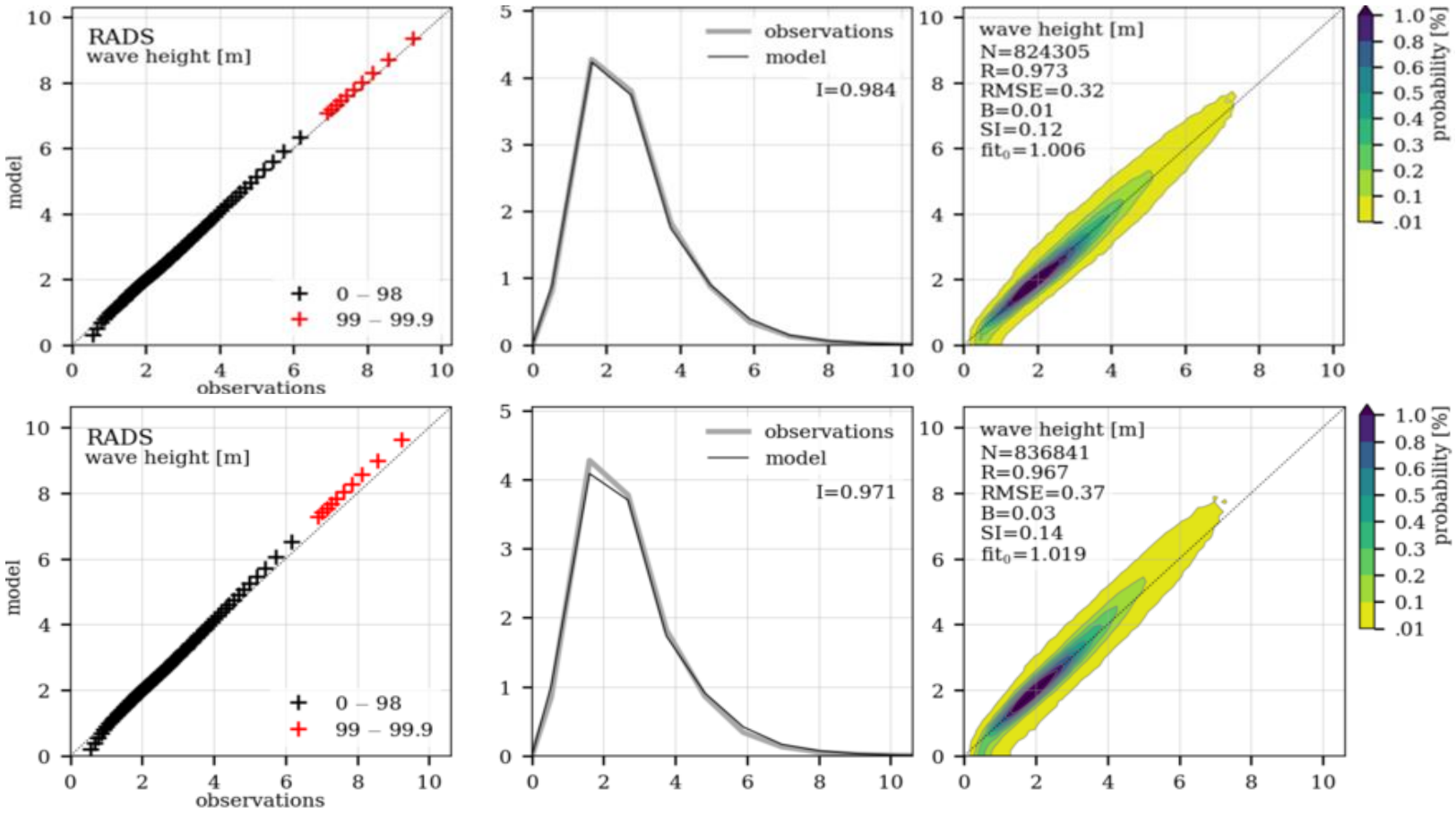
Radar Altimeter Database System (RADS)

In-situ wave buoys



Comparison with satellite altimeters

AUSWAVE-G3 (Mar- May 2022)

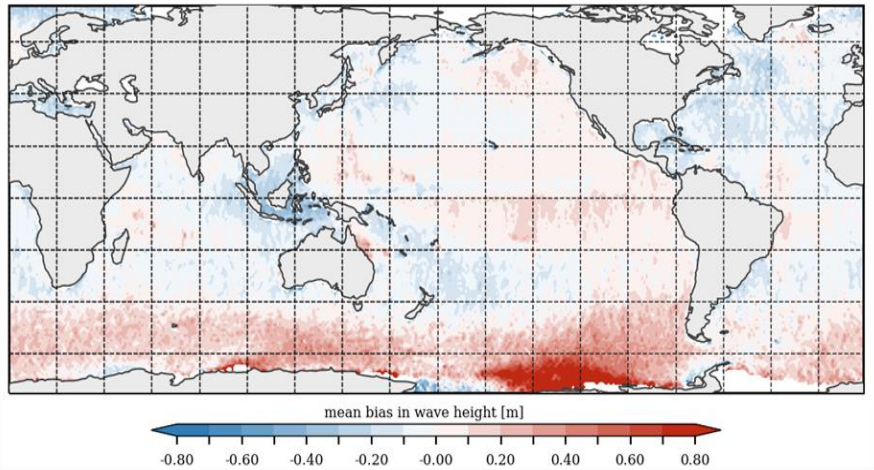


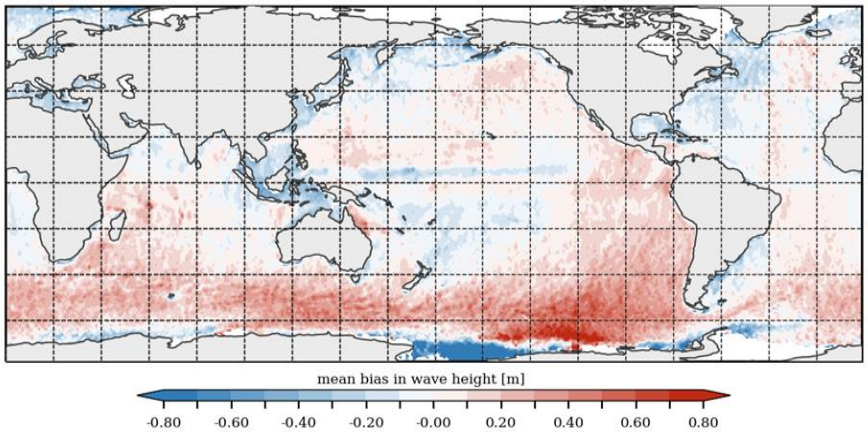
AUSWAVE-G

Scatter comparison of +24h forecasts of Sig wave height. Left: quantile-quantile (QQ plot); Middle: probability density plot; Right: scatter statistics

Mean Bias of Sig Wave Height (Mar-May 2022)

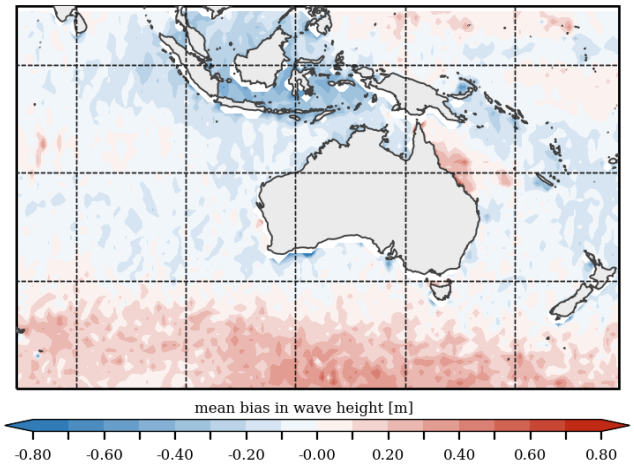
AUSWAVE-G3

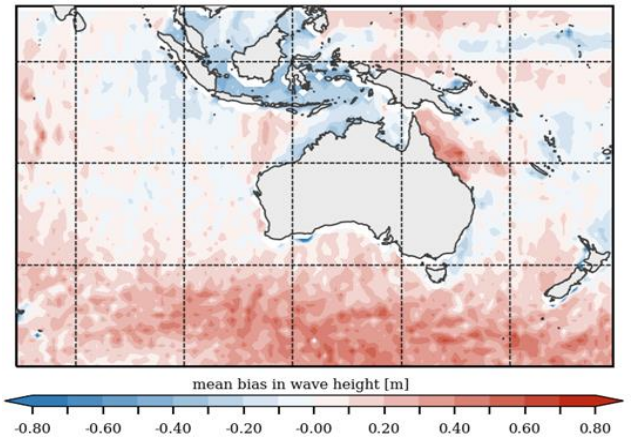




Legacy AUSWAVE-G

AUSWAVE-G3



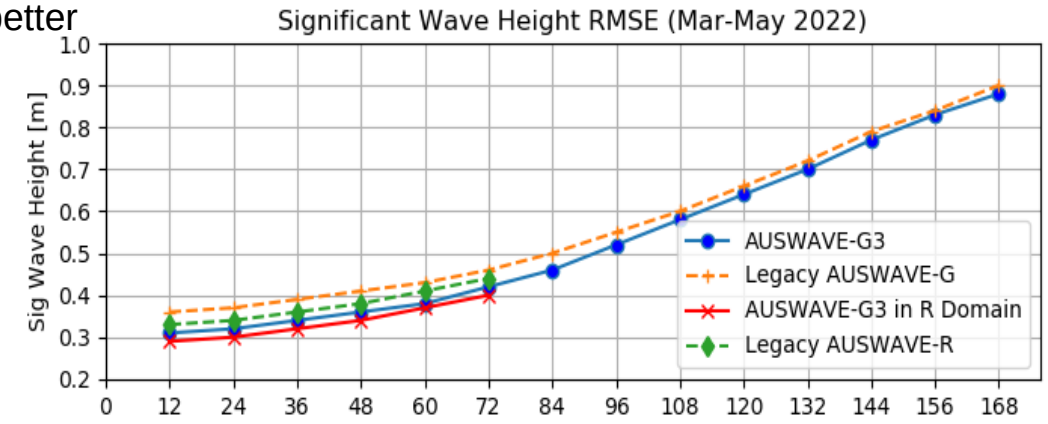


Legacy AUSWAVE-R

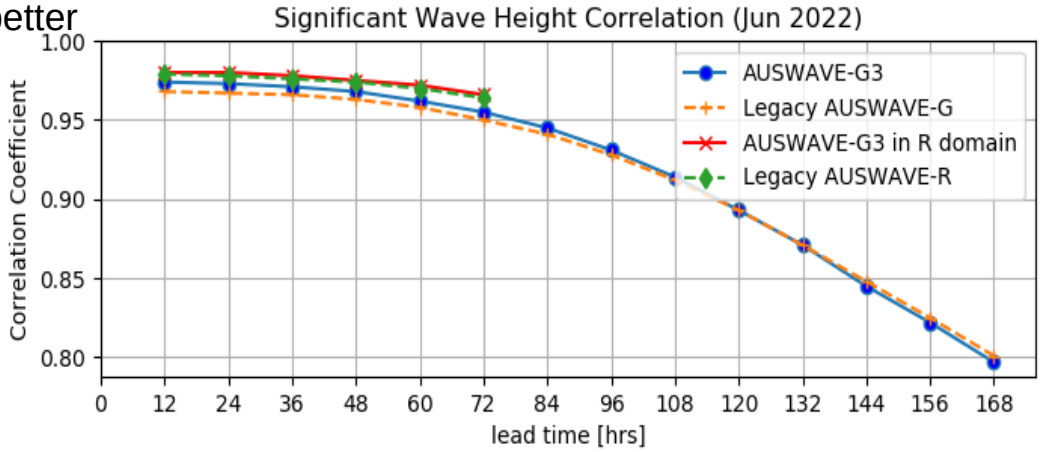
- AUSWAVE-G3 shows a reduction in bias in the Southern Ocean, Arctic Ocean, Pacific Ocean (east and south), Indian Ocean, and generally around Australia

Wave Model Skill Assessment

Skill better



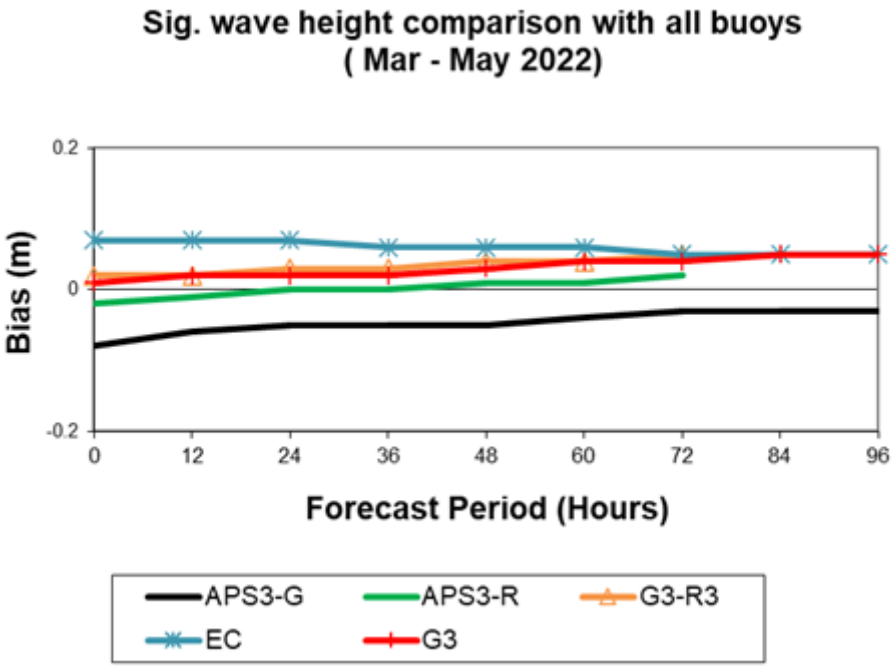
Skill better

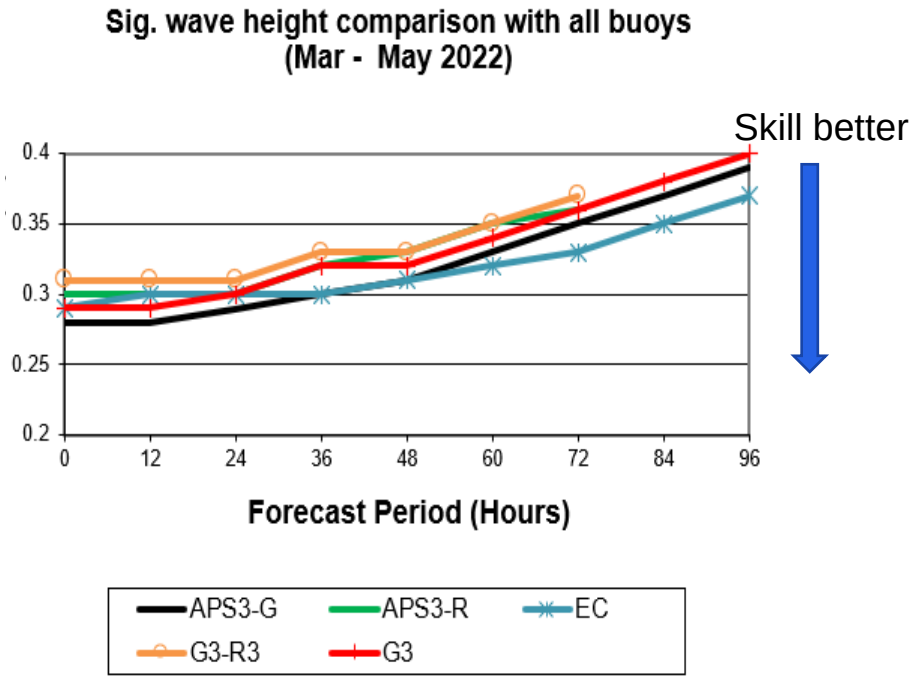


- RMSE does not change significantly over the first 2-3 days, but grows at a higher rate after 3 days
- AUSWAVE-G3 in R domain shows greater model forecast skill
- AUSWAVE-G3 configuration outperforms the legacy global and regional systems .

Wave height (Hs) plotted as a function of lead time. Panels show (top): RMSE & (bottom) Pearson's correlation coefficient

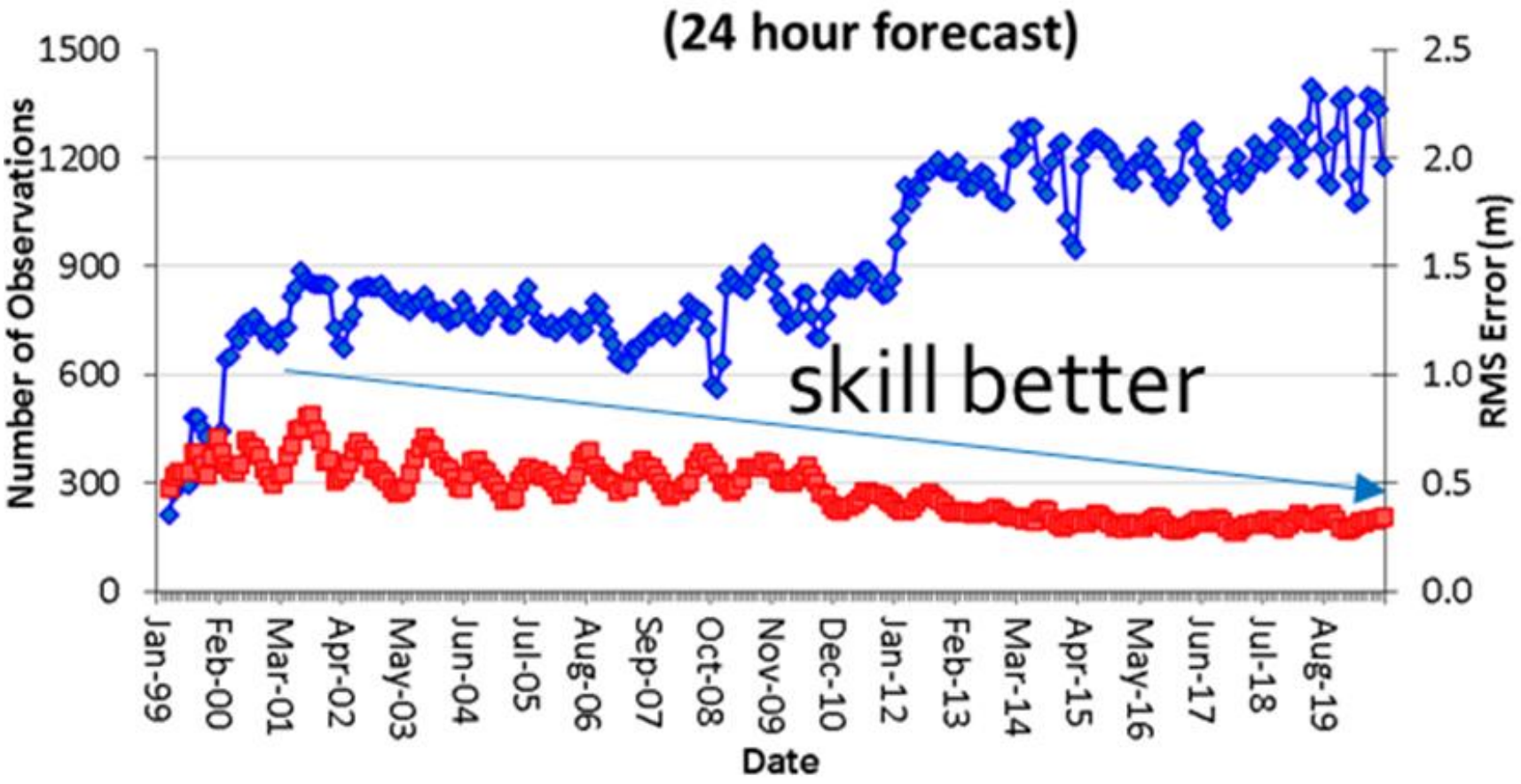
Comparing with In-Situ Wave Observations





- AUSWAVE-G3 shows significantly less bias than the legacy AUSWAVE-G and AUSWAVE-R at all lead times.
- Legacy AUSWAVE-G shows slightly better RMSE than the new AUSWAVE-G3.
- ECMWF is the best performance model overall especially over longer lead time
- No wave observations are available from northwest shelf of West Australia where our commercial clients operate

Regional Forecast Model Skill



Summary

- Develop single AUSWAVE-G3 global system to replace the Bureau of Meteorology's global and national wave models.
- Increase the global wave model resolution and deliver seamless regional wave forecast around Australia up to +10 days vs previously +3 days
- Satellite verification results show AUSWAVE–G3 model outperforms the previous global system for a large number of verification metrics e.g an improvement of +24H forecasts of RMSE of significant wave height of 13.5% for the global domain.
- In-situ verification results show AUSWAVE-G3 has less bias than the legacy AUSWAVE-G. However, the legacy system shows slightly better RMSE than AUSWAVE-G3.
- More future work to improve the model performance near the coast. Next generation of national coastal model provides great opportunity and a tool to explore possible model improvement near the coastal area

The Bureau of Meteorology

Thank you

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