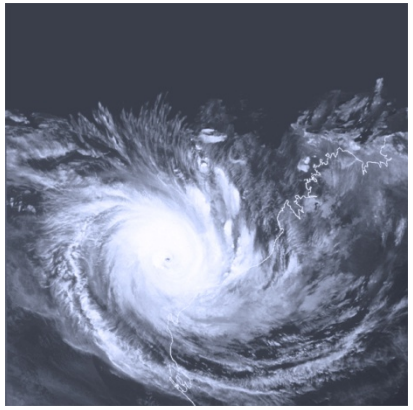
Advances in Swell Prediction for Australia's North West Shelf



Presented by:
Greg Williams and
Steve Buchan
RPS MetOcean Pty Ltd

Some Acknowledgements

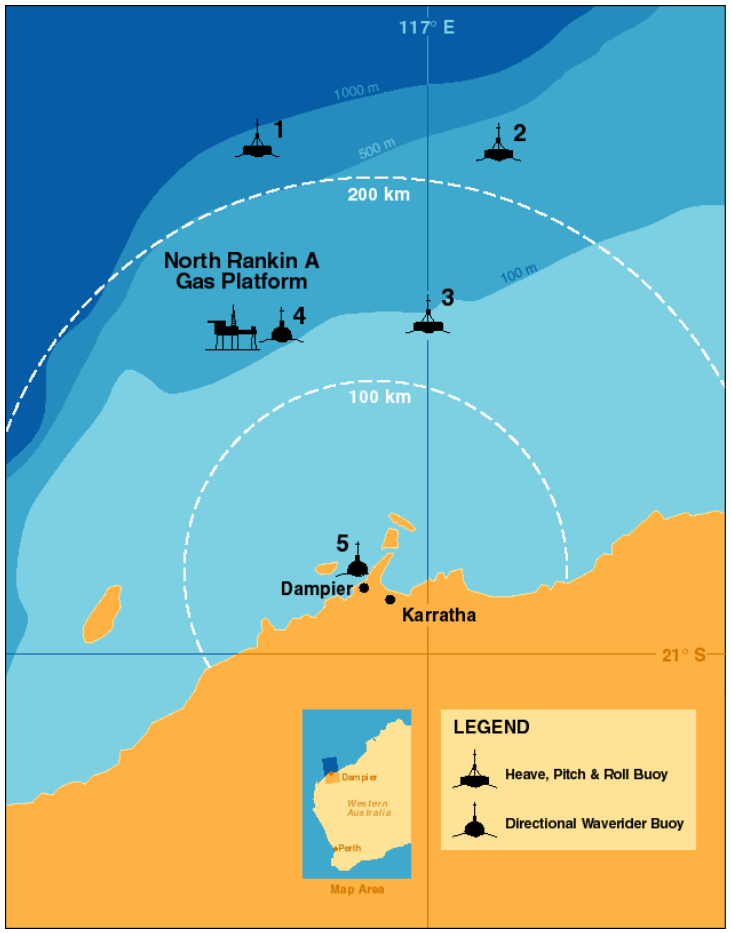
- Colleagues
  - Greg Williams – Doing it!
  - Emma Foster – TC wind field blending
  - Mark Szyszka – Making everything work
  - Matt McGowan – Keeping computers competent
- Ex-Colleagues
  - Henrique Alves – Concept grounding
  - Dave Duncalf – Holland 2010 !!
  - Jessica Sweeney – TC wind field parameterization

Presentation Outline

- The Prompt
- NWS Setting
- Swell Affected Operations
- Concept – Key Elements
- Performance
- Potential Products and Services

Remote Offshore Warning System

- Initiated in 1993 to provide tropical cyclone swell forecasts in Mermaid Sound for Woodside's LNG operations.
- Designed to give at least 4 hours forewarning of swell arrival (to allow termination of loading and safe exit of the shipping channel).
- Based on real-time swell measurements from an array of offshore buoys
- Measurements fed into a reverse ray wave refraction model to propagate swell energy into Mermaid Sound and the LNG loading berth.
- Planned new LNG carriers may need longer lead-times .



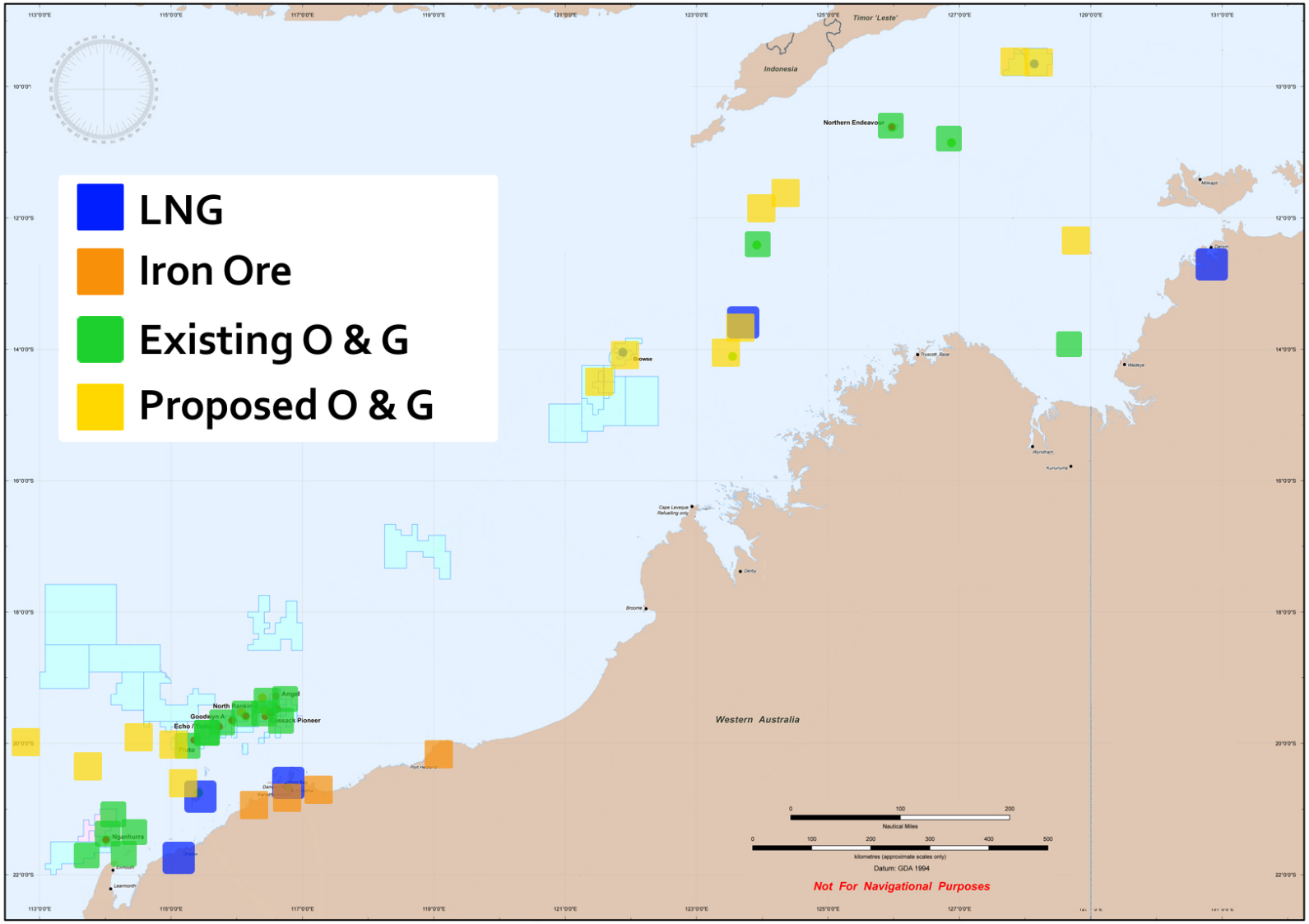
The Opportunity

- Longer lead times cannot be provided by measurements alone (buoys can be beyond region of cyclogenisis).
- Tropical cyclone track forecasting is improving
- Wave models are vastly improved.
- There is a burgeoning requirement for accurate, reliable, continuous swell forecasting over the entire North West Shelf region.
- Measurements remain key to sustained accuracy.

North West Shelf - Setting

- Industrial Setting
  - Global leader in Iron Ore export ($75B per annum)
  - Emerging leader in LNG ($25B per annum)
  - Globally remote
- Oceanographic Setting
  - Mega Tides
  - Severe tropical cyclones
  - Long-travelled (ultra long period) swell

North West Shelf – Industrial Setting



Spring Tide Range – Peter Harris , GA

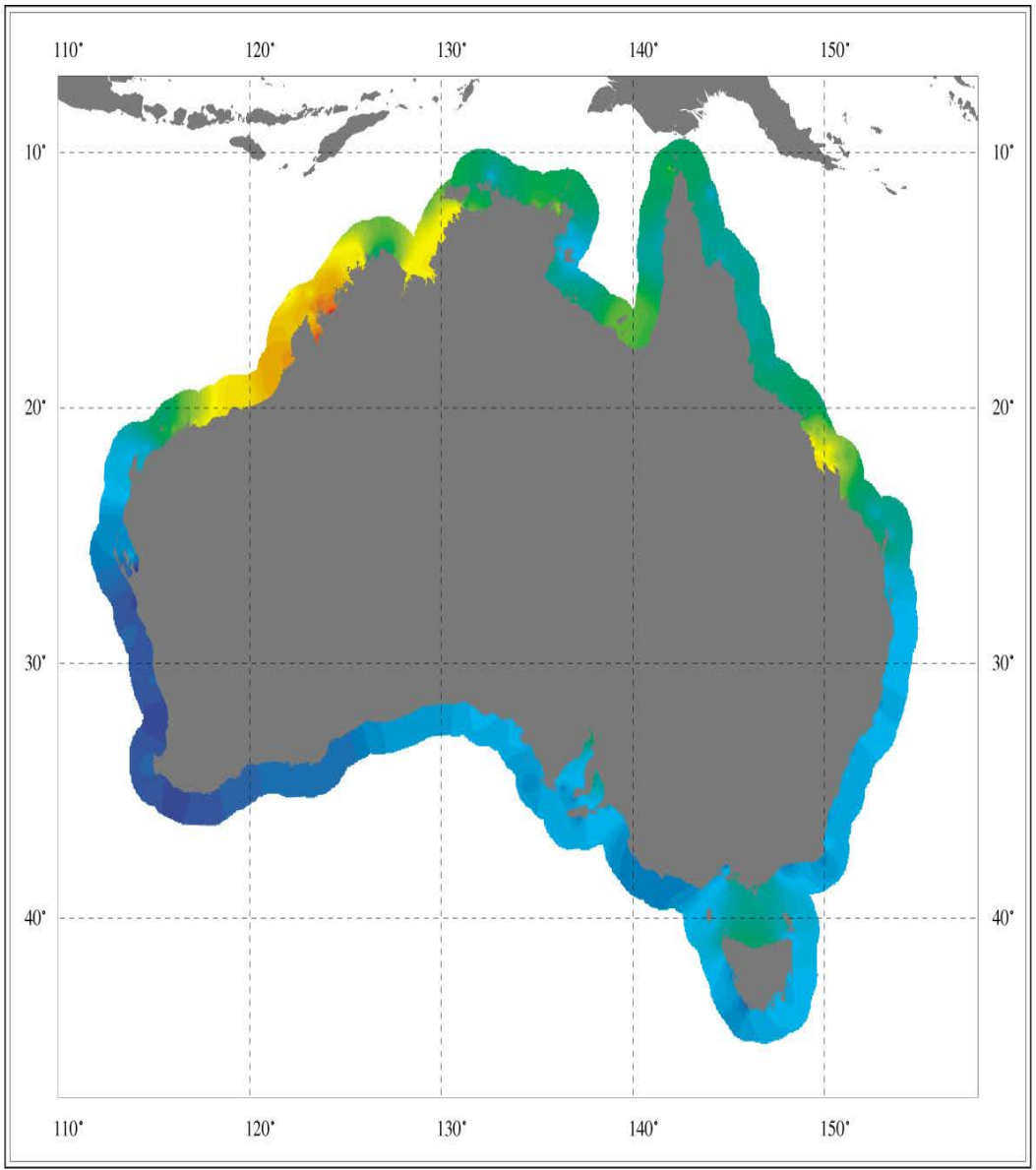
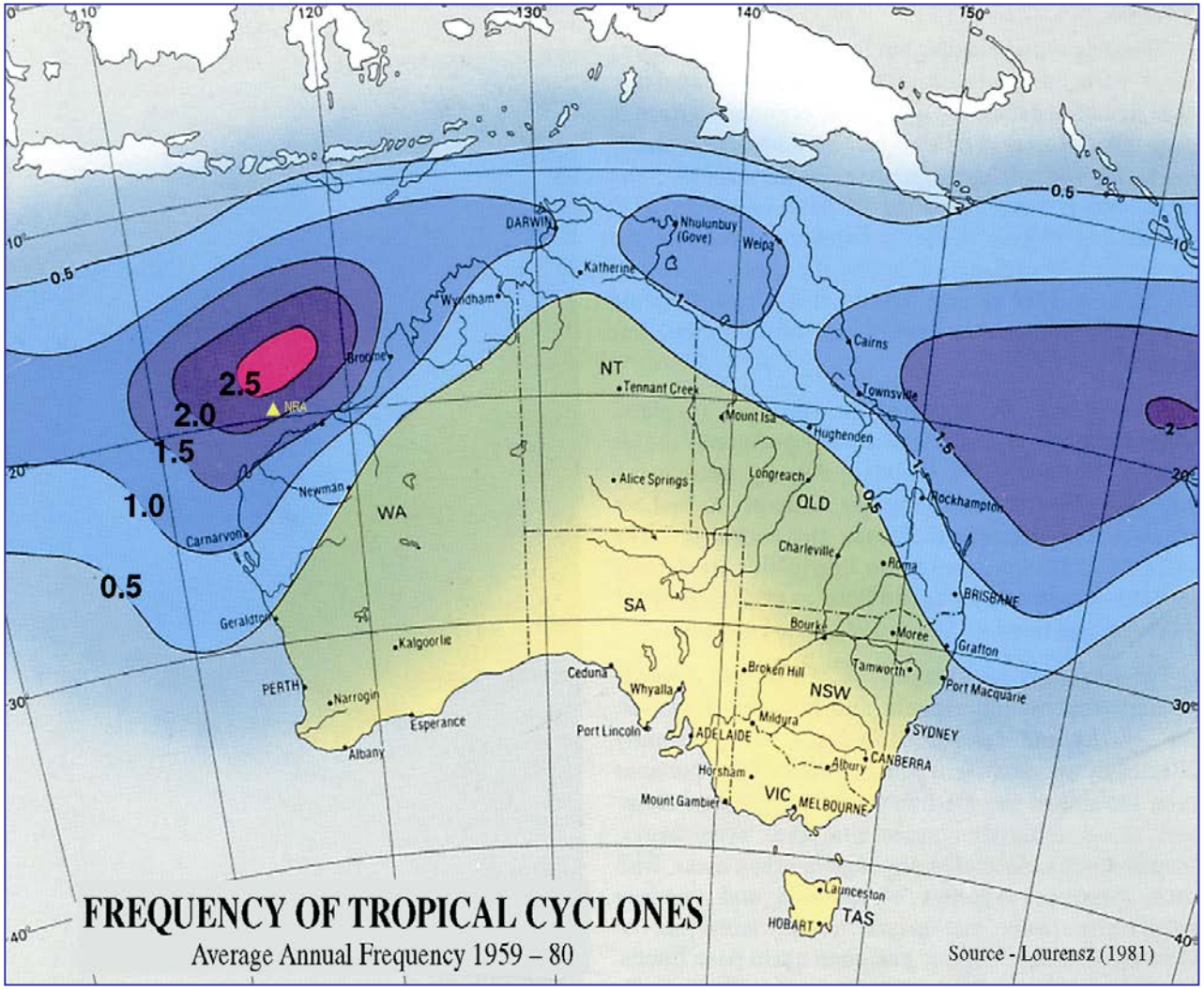


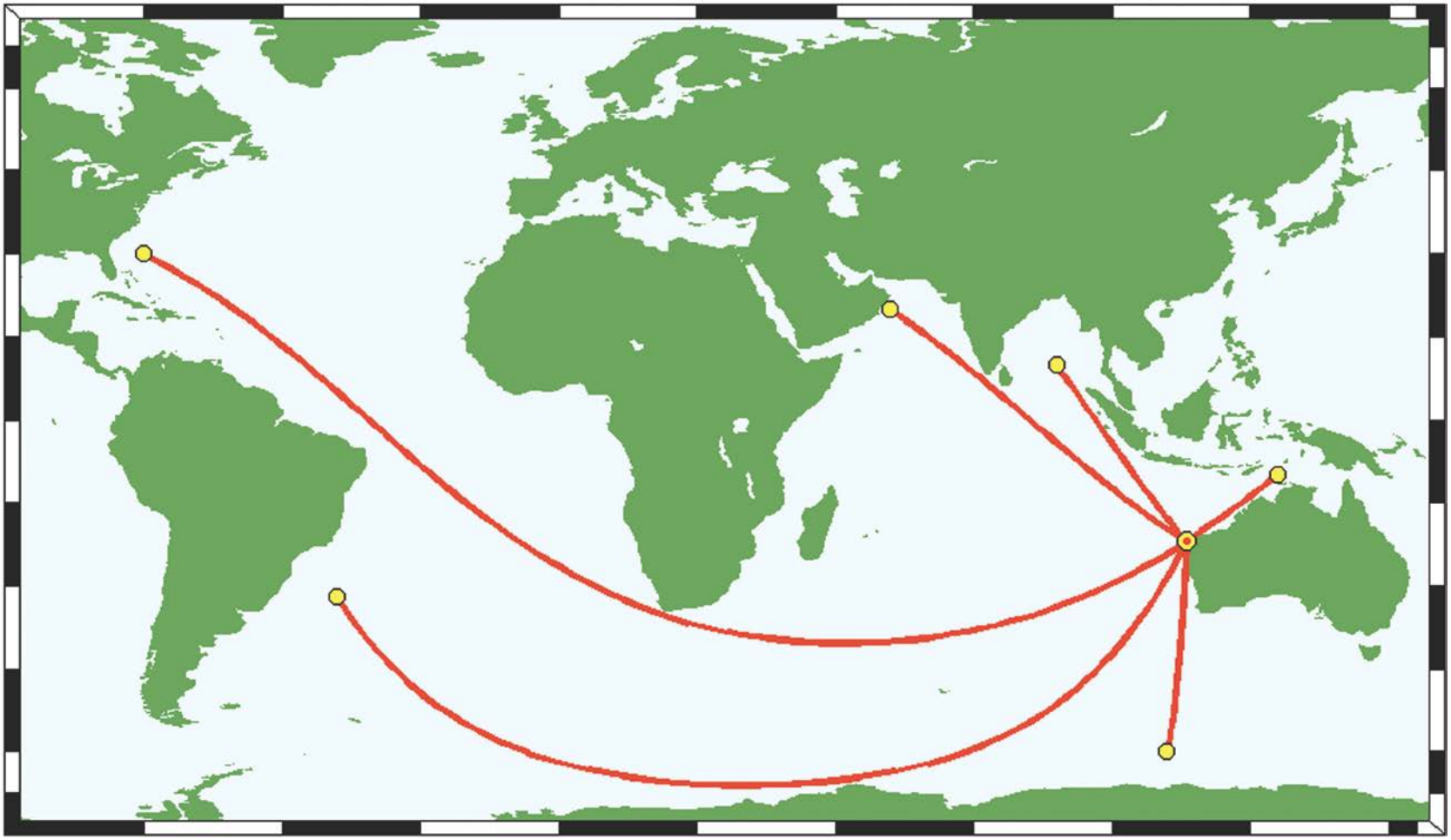
Figure 10.

Tidal Range

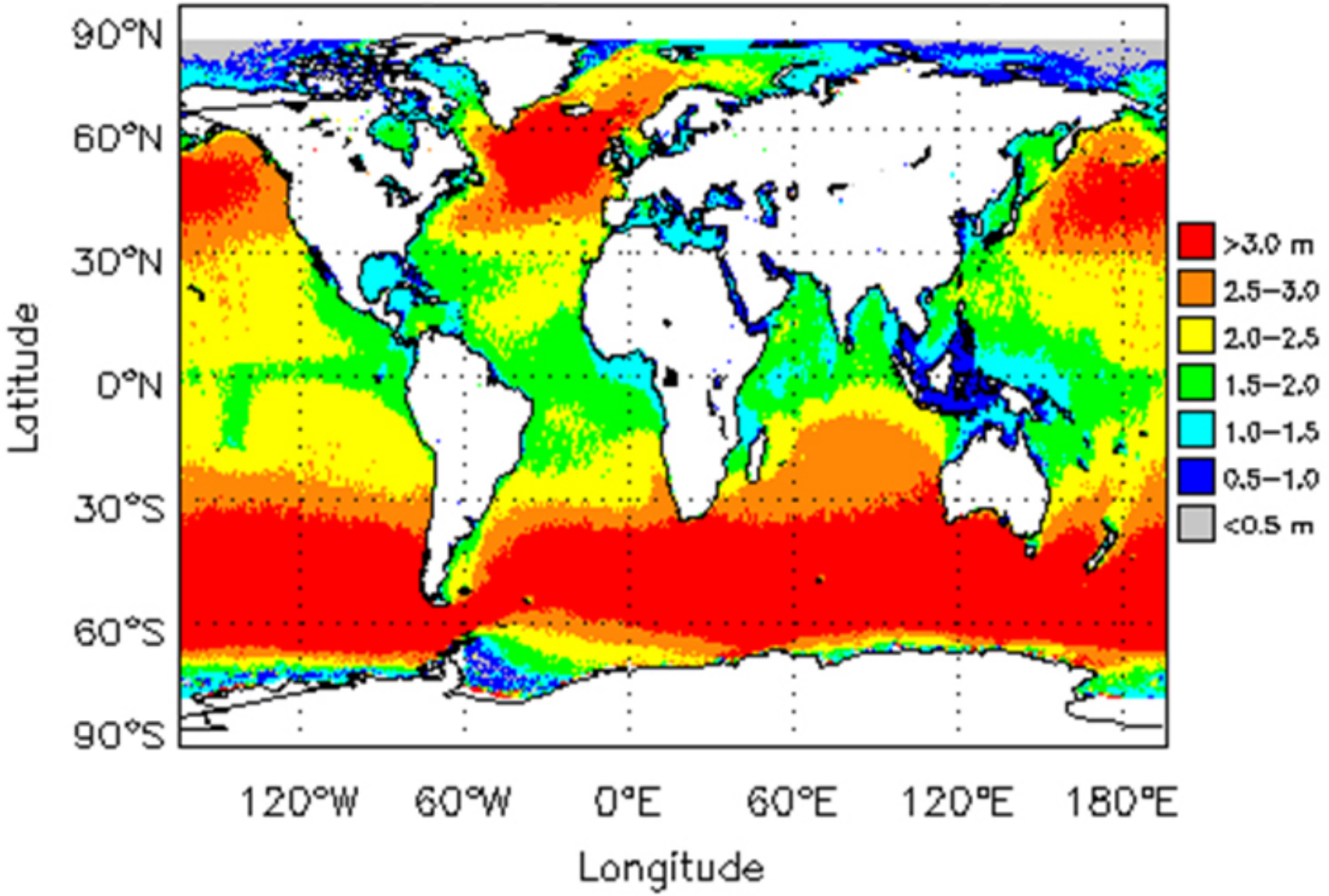
Australian TC Spatial Distribution



Swell Windows to the NWS



Global Mean Significant Wave Heights



Swell Affected Operations

- Coastal
  - LNG Loading
  - Iron Ore Shipping Channel Transit
  - Port Operability (infragravity waves)
- Offshore
  - Shipping
  - Drilling
  - Installation
  - Materials Transfer
  - Riser Disconnect/Reconnect
  - FLNG Unloading
  - Post-storm ROV Inspections

Iron Ore Loading

LNG Carrier Operations

Shipping

RPS

Oops!

Drilling

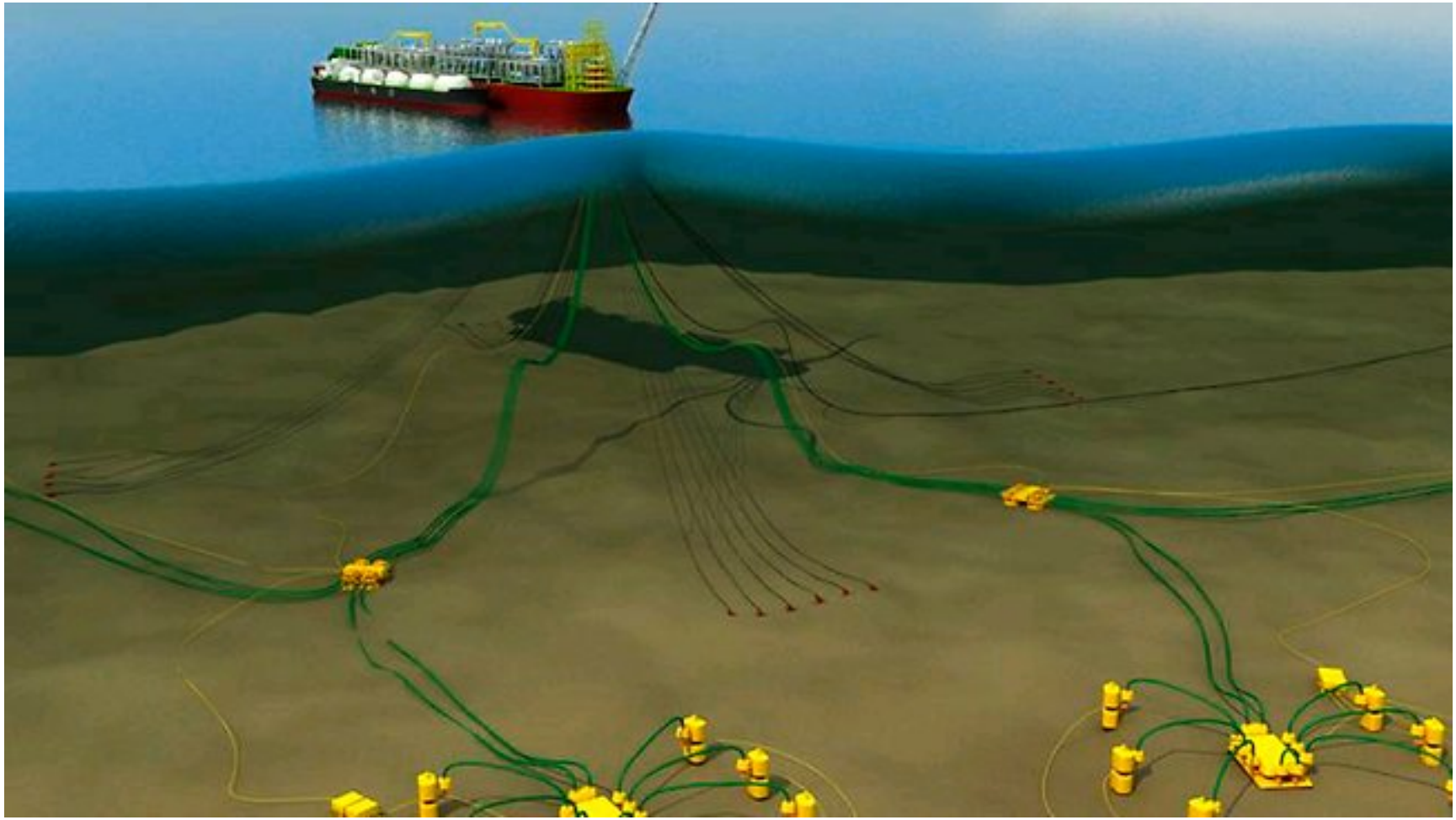
Installation

Materials Transfer (Deck Float-over)

Riser Disconnect/Reconnect

FLNG Unloading

Post Storm ROV Inspections



Why is RPS MetOcean doing this?

- We do not aspire to be weather forecasters, but..
  - we have (by far) the largest archive of measured NWS metocean data;
  - we have the most extensive suite of real-time metocean data gathering installations;
  - we are competent TC modellers in this (meteorologically) data sparse region;
  - we have established real-time delivery systems;
- „and we do understand Client needs.

The History

- Started with a ROWS review over a decade ago
- Originally conceived to:
  - assimilate satellite data to enhance wind fields
  - ingest measured data to improve wave modelling
  - collaborate with BoM to obtain TC forecasts
  - deploy an array of wave/met buoys
- But since then:
  - global wind field providers do all the assimilation (better than we could)
  - wave models generally do not benefit from wave data assimilation.

Present Focus

- Limited regional 'bulk correction' of global winds
- Localized adjustment of winds via RT measurements
- Automatic ingestion of BoM TC track forecasts
- Parametric TC wind field modelling
- Automated TC wind field blending
- Reliance on WaveWatchIII
- Post-calibration of swell predictions via measurements

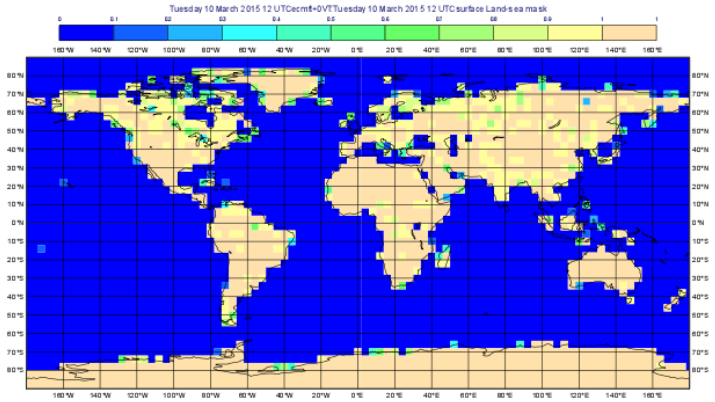
- Measurements remain the key to improved prediction.

Concept – Key Elements

- Winds
  - NCEP global model input
  - BoM tropical cyclone track forecasts
  - RPS storm vortex parameterization
  - RPS vortex blending into synoptic fields
- Waves
  - WaveWatchIII
- Measurements
  - Bulk windfield correction (nudging)
  - Wave model tuning
  - Forecast post-calibration
- Tailored Products

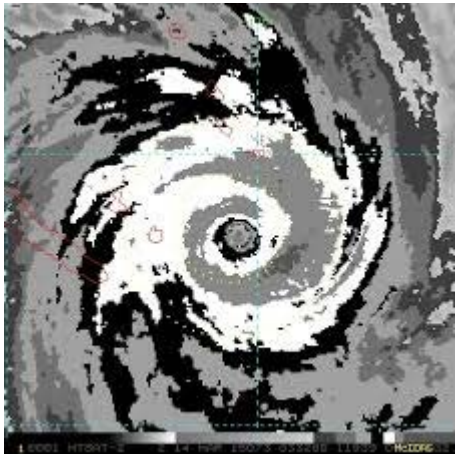
Global Wind Forecasts

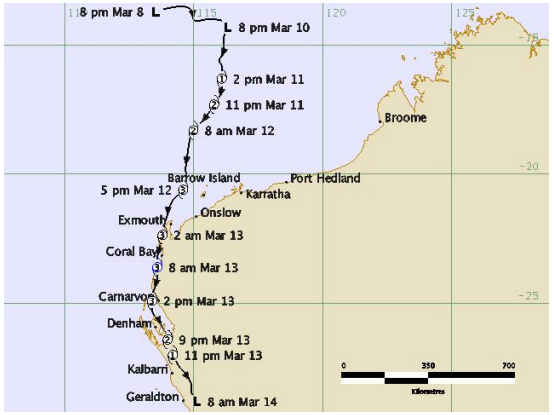
- New GFS (2015) – similar physics as the GFS (2010) component used in CFSR/CFSv2 but higher resolution.
- NCEP Global Data Assimilation System now T1534L64 (approx. 0.117-degree resolution), improved satellite sources essential for Southern Ocean, GDAS upgrades in collaboration with ECMWF.
- NCEP Global Forecast System 13km internal resolution with 0.25-degree outputs, resolves circulations and coastal processes better.
- In general GFS performs well 1-2 days ahead, event timing is good, with consistent and systematic (ie. correctable) bias in wind speeds.
- In contrast, ECMWF skill is better 4+ days ahead, magnitudes are good, but at the expense of timing (harder to correct). Low bias for extreme winds. Land-sea mask is still poor quality for Australia and Indonesia.



BoM Analysis and Forecast Tracks

- Manual analysis, forecasts, and 24x7 updates
- Predicts cyclone formation, position, and evolution
- Regional responsibility (official WMO TC Warning Centres)
- Focus on public safety, coastal impact, landfall – not industry, ports
- Continuous improvement and funding (eg. public, private, ITF)
- Automatic ingestion into RPS tropical wind blending model

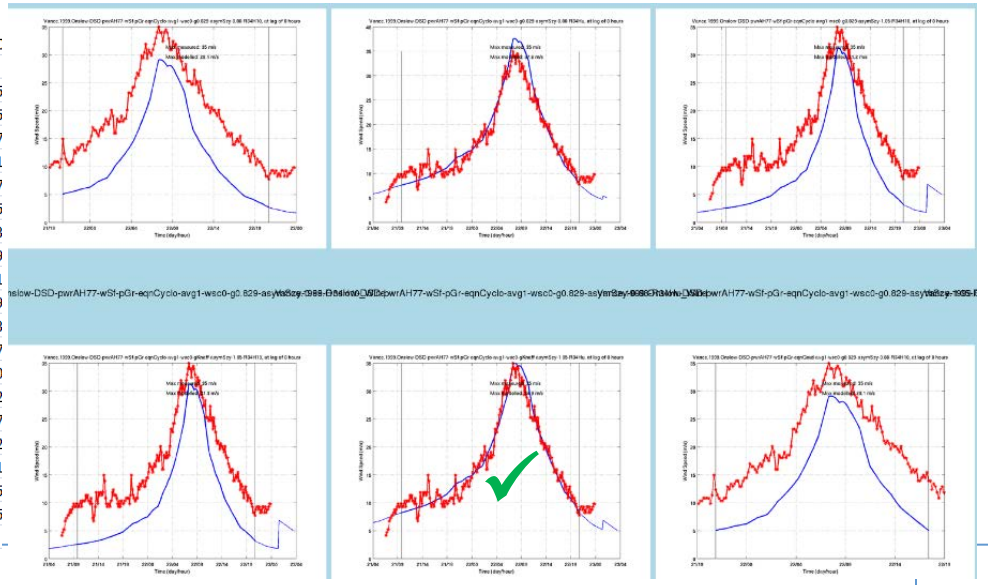




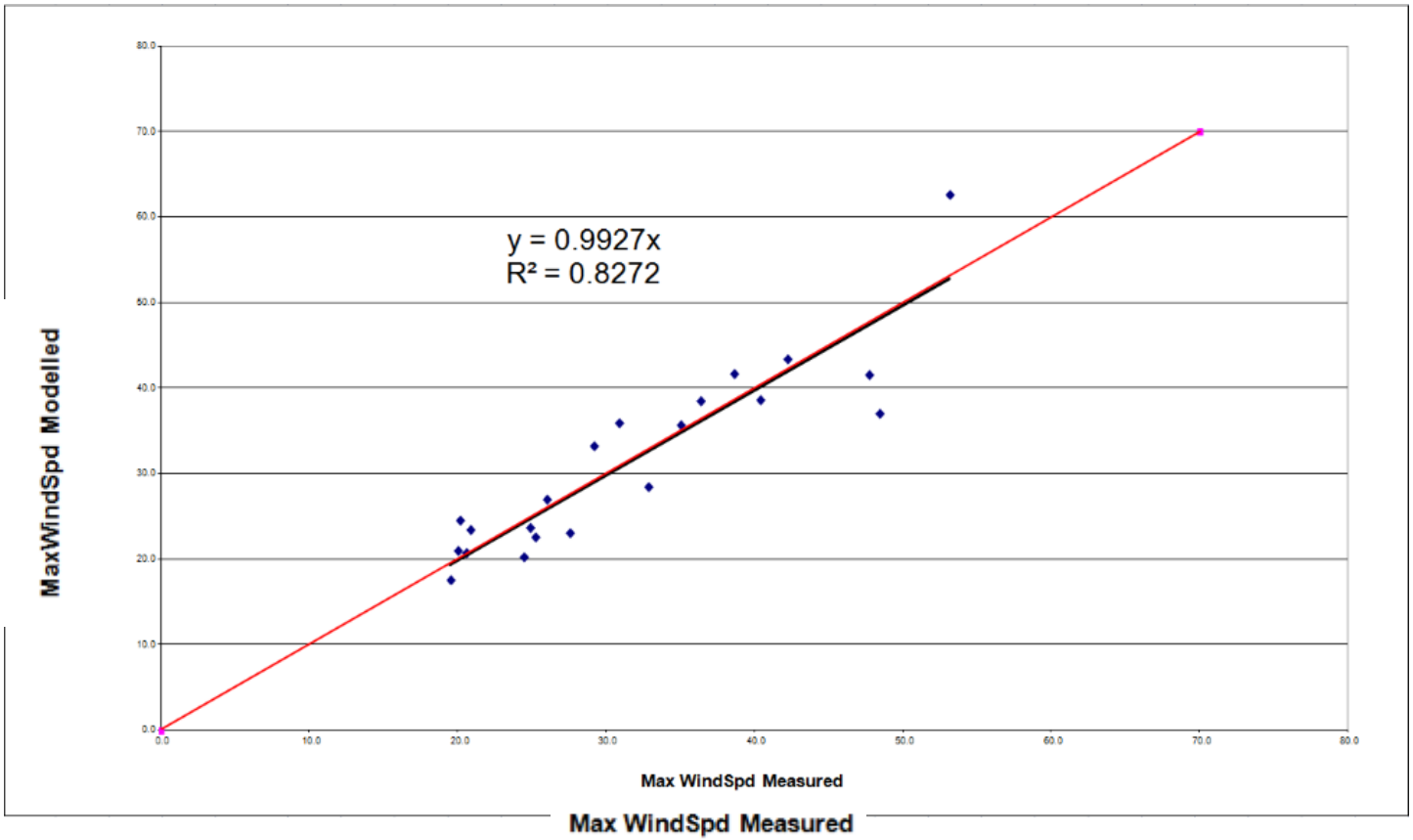
Tropical Cyclone Modelling

- RECENT REVIEW:
  - Parameterisation depends on choices of PWR, Vmax, Pc, Pe, Rmax, R34, Vt, θmax, B, profile, gust factors, …
  - We tested approximately 12,000 model combinations.
  - Validated against 30 years of offshore measurements on the NW Shelf.
  - A significant amount of work.

RANGE	GBV_Knaf	GBV_ISO_	GBV_Ocea	GBV_Ocea	GBV_Knaf	GBV_Ocea	GBV_ISO_	GBV_ISO_	GBV_Knaf	GBV_Ocea	GBV_ISC
-2.1 => -1.9	0	0	0	0	0	0	0	0	0	0	
-1.9 => -1.7	0	0	0	0.027925	0	0.027925	0.027925	0.027925	0	0.027925	0.01396
-1.7 => -1.5	0.027925	0.013963	0.013963	0.05585	0.069813	0.05585	0.05585	0.05585	0.069813	0.05585	0.01396
-1.5 => -1.3	0.237364	0.237364	0.237364	0.209439	0.195476	0.209439	0.209439	0.209439	0.195476	0.181514	0.08377
-1.3 => -1.1	0.153588	0.069813	0.097738	0.363027	0.37699	0.363027	0.363027	0.363027	0.37699	0.279252	0.18151
-1.1 => -0.9	0.43284	0.474728	0.446803	0.251326	0.223401	0.153588	0.251326	0.153588	0.209439	0.390952	0.41887
-0.9 => -0.7	0.530578	0.516615	0.530578	0.879643	0.684166	0.516615	0.893605	0.516615	0.48869	0.684166	0.34906
-0.7 => -0.5	2.41553	2.08042	2.06646	4.14689	3.30913	2.19213	4.17481	2.22005	2.68082	2.34571	1.7313
-0.5 => -0.3	7.91678	6.35297	6.10165	7.77716	8.61491	5.55711	8.02848	5.76655	7.24658	6.96733	5.5989
-0.3 => -0.1	17.8721	16.7691	16.2106	17.3834	18.5702	16.1128	17.7744	16.5317	18.5004	15.2192	13.571
-0.1 => 0.1	30.7875	30.7596	30.6758	29.9777	29.8939	29.7403	29.6565	29.5448	29.461	28.5535	28.399
0.1 => 0.3	22.396	23.7922	24.1273	22.0609	21.7397	24.4764	22.033	24.4345	22.6194	24.9232	25.73
0.3 => 0.5	10.444	11.1701	11.4772	10.4161	10.2066	12.2452	10.2904	11.9799	11.1142	12.1893	14.367
0.5 => 0.7	4.35633	5.18012	5.31974	4.13292	3.8816	5.40352	3.97934	5.36163	4.42614	5.51522	6.3250
0.7 => 0.9	1.13097	1.24267	1.34041	1.11701	1.00531	1.494	1.08908	1.3823	1.21474	1.36833	1.7732
0.9 => 1.1	0.460765	0.460765	0.474728	0.390952	0.363027	0.48869	0.349065	0.48869	0.446803	0.43284	0.53057
1.1 => 1.3	0.544541	0.572466	0.558503	0.530578	0.530578	0.572466	0.544541	0.572466	0.558503	0.628316	0.36302
1.3 => 1.5	0.181514	0.195476	0.209439	0.209439	0.251326	0.279252	0.209439	0.279252	0.279252	0.139626	0.29321
1.5 => 1.7	0.097738	0.097738	0.097738	0.05585	0.069813	0.083776	0.05585	0.083776	0.083776	0.083776	0.23736
1.7 => 1.9	0.013963	0.013963	0.013963	0.013963	0.013963	0.027925	0.013963	0.027925	0.027925	0.013963	0.01396
1.9 => 2.1	0	0	0	0	0	0	0	0	0	0	



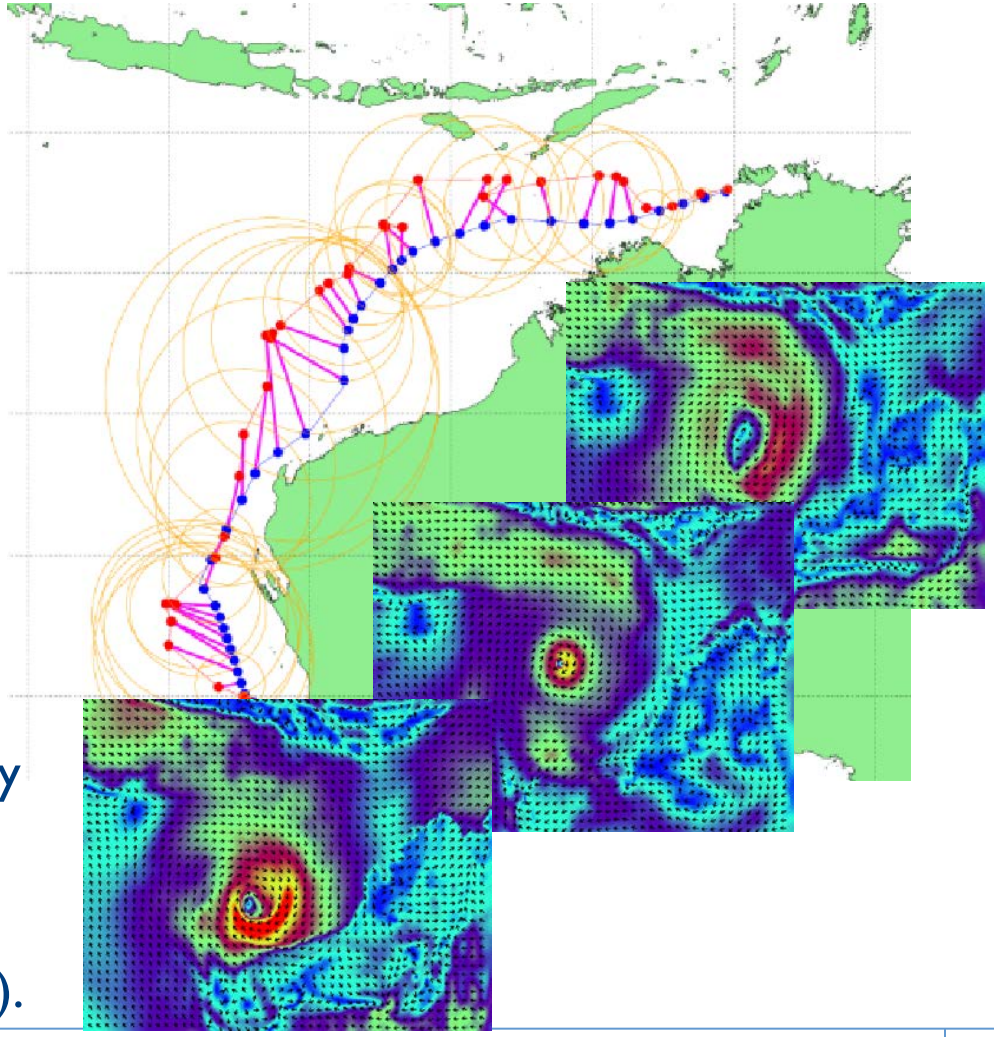
RPS Wind Model Performance



- RPS wind blending performance. Peak-to-peak comparisons against 30 years of Australian tropical cyclones. For fixed model configuration for all storms.

Need for Tropical Wind Blending

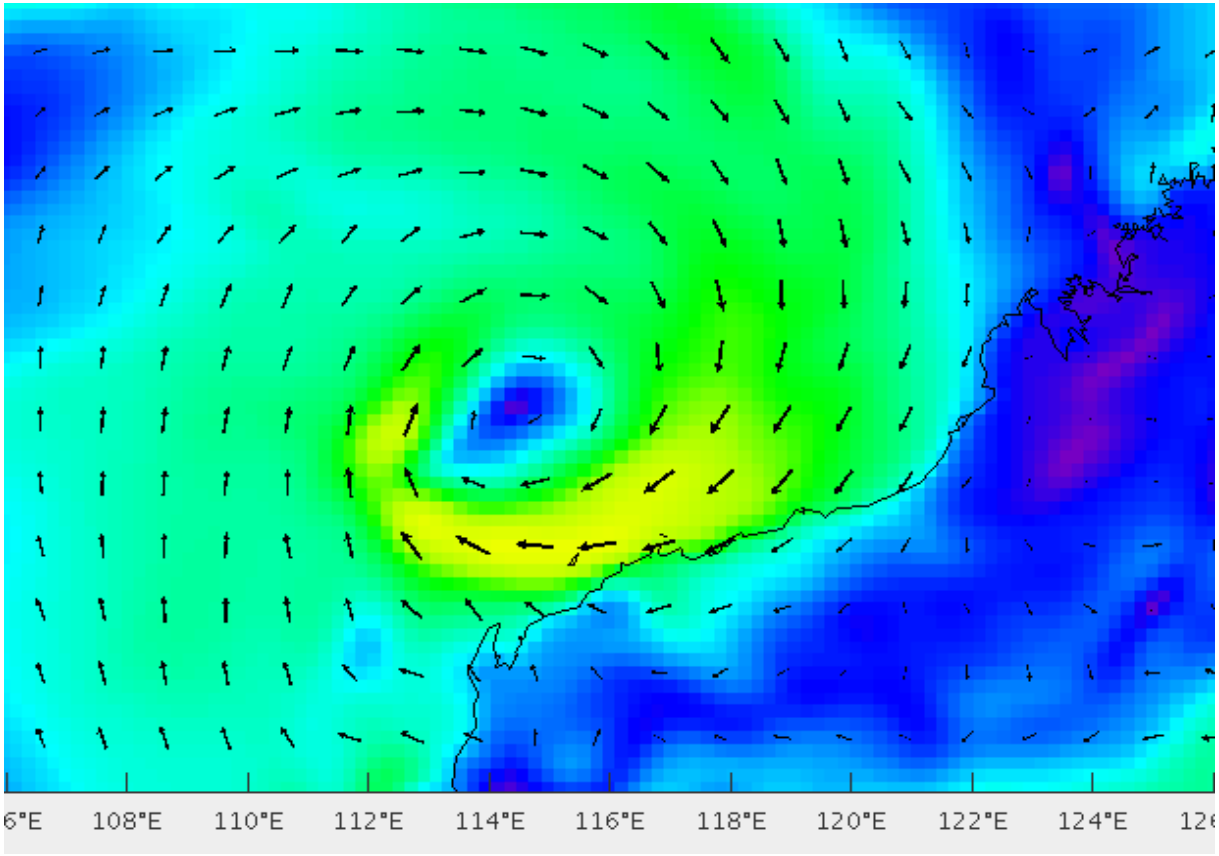
- Forecasting cyclone formation, position, and intensity is difficult for models. Experienced meteorologists can produce better results.
- Storm proximity and timing are key factors for coastal, port, and inshore operations affected by wind and swell.
- Wave model predictions are only as good as the wind inputs.
- Foster et al. 2009 (11th IWWHF).



Tropical Cyclone Modelling

TC Olwyn 2015

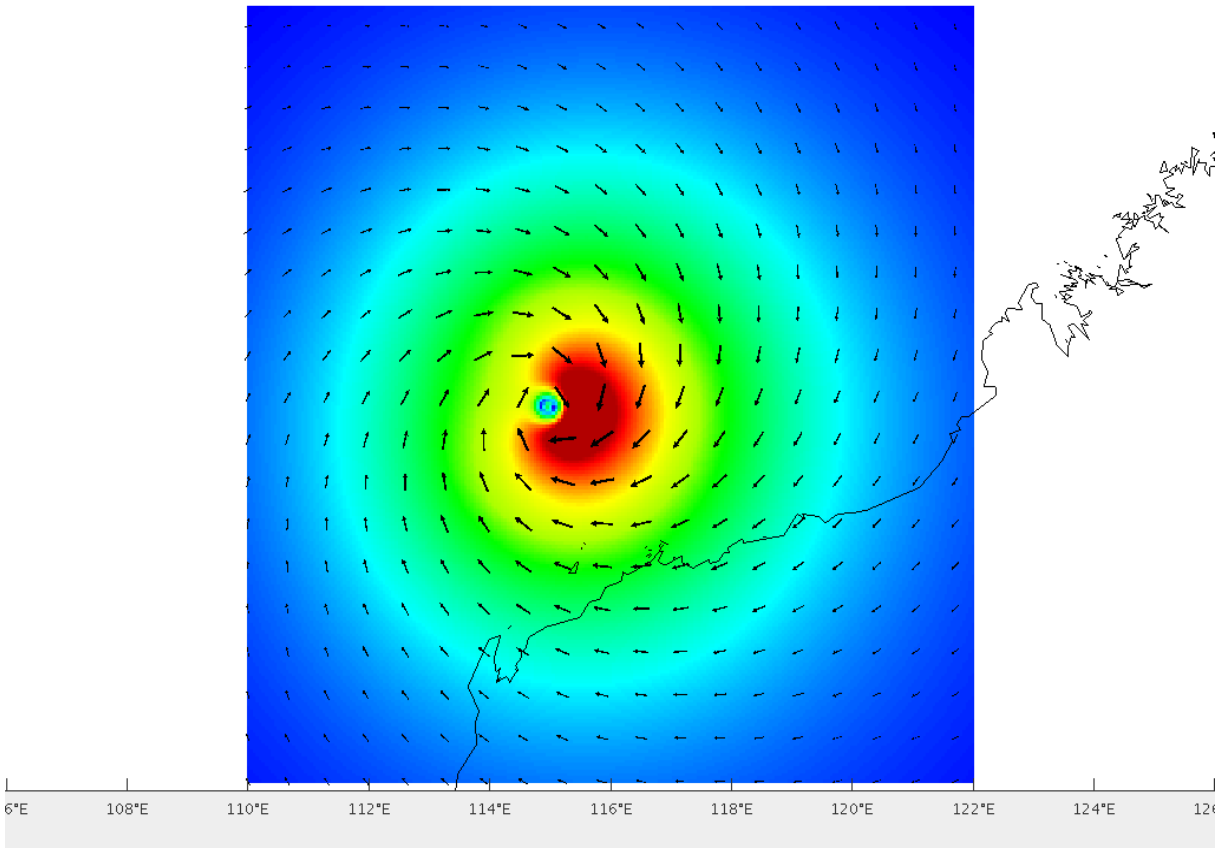
Global wind field



Tropical Cyclone Modelling

TC Olwyn 2015

High resolution parameterized vortex



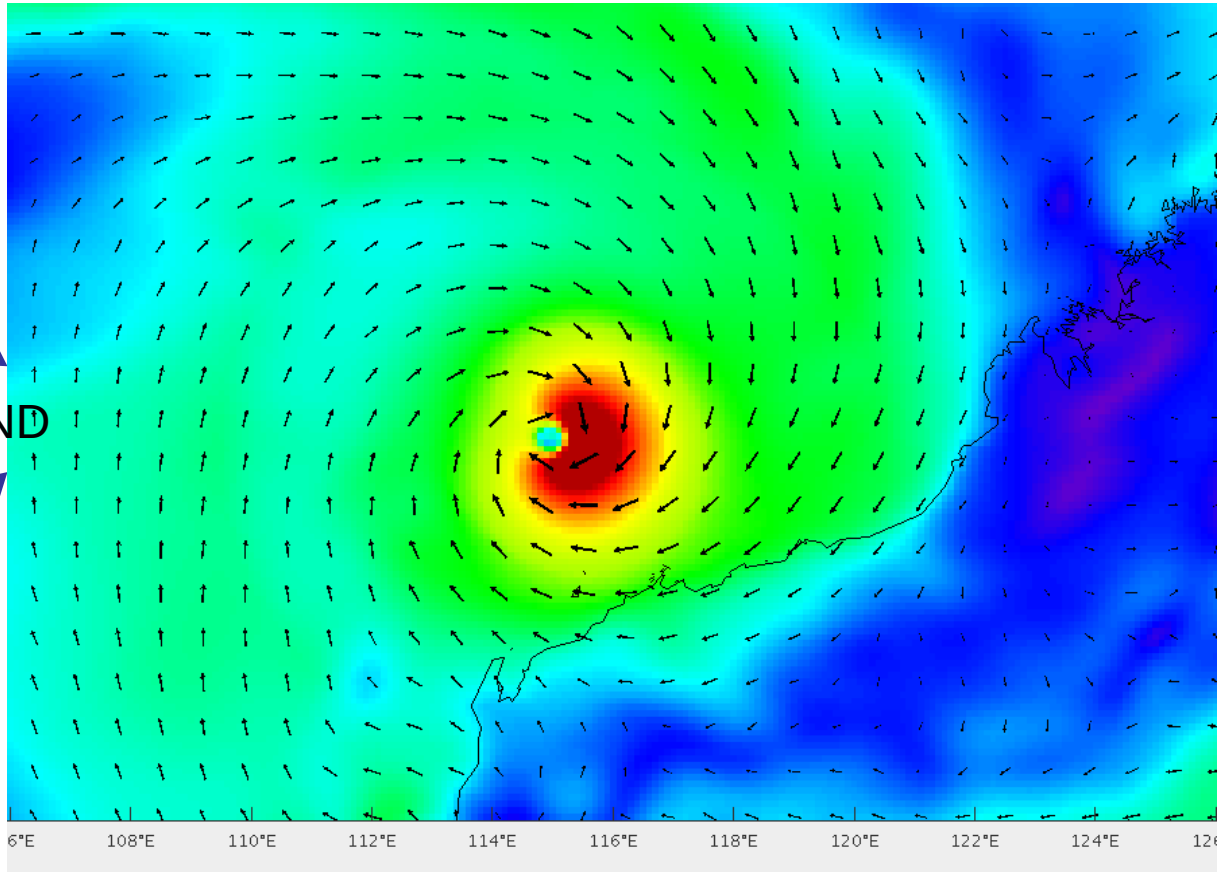
Tropical Cyclone Modelling

TC Olwyn 2015

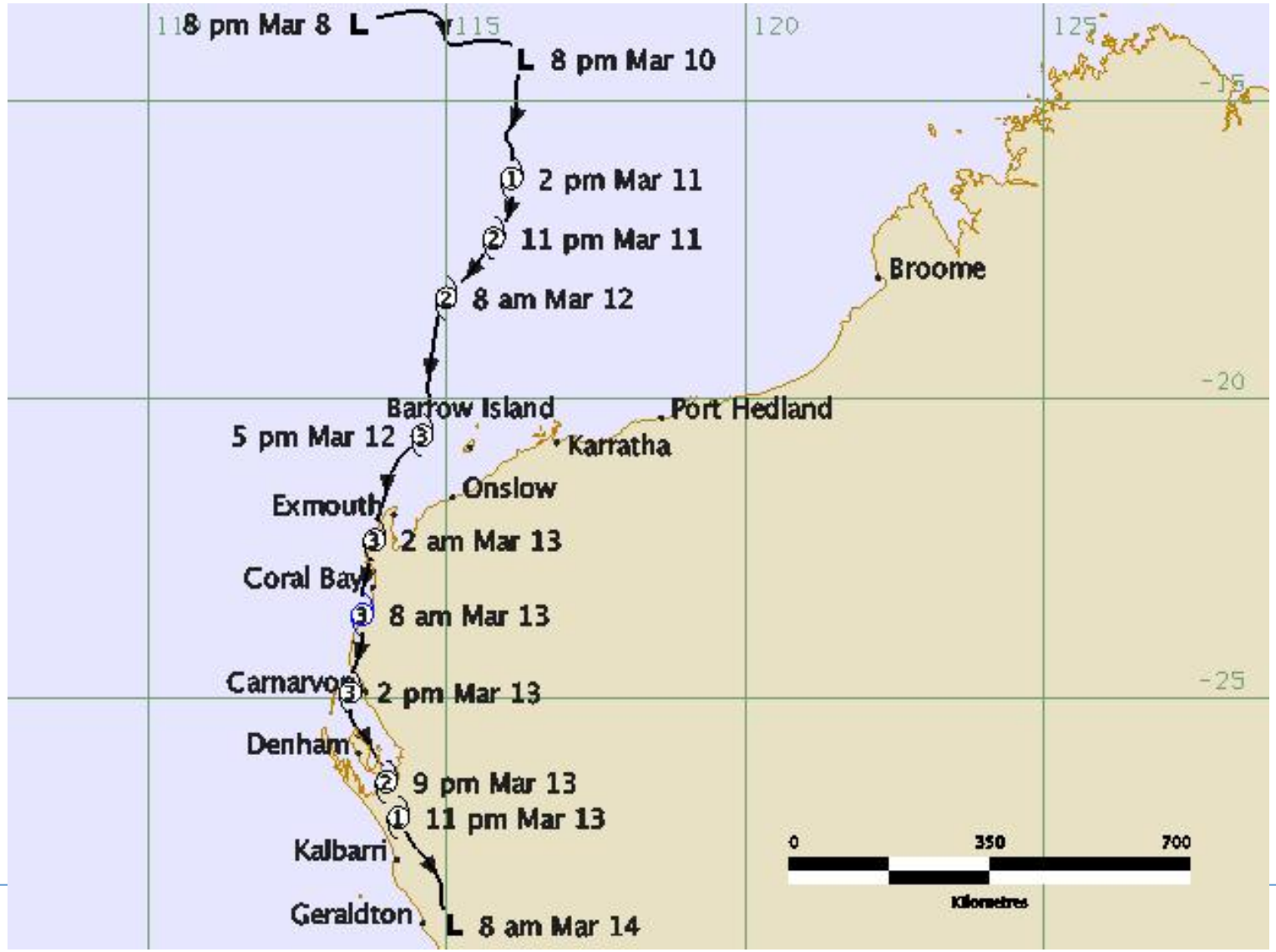
High resolution parameterized vortex

Global wind field

BLEND



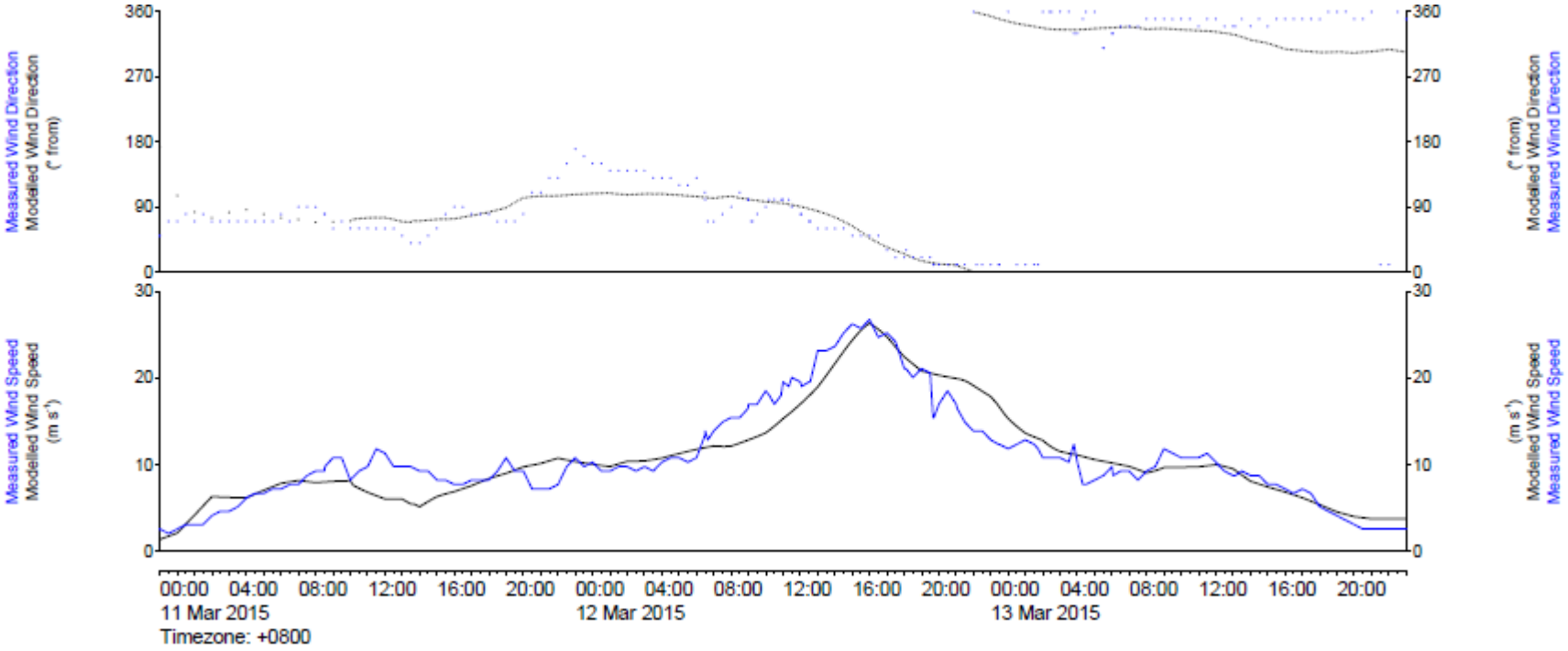
TC Olwyn BoM Track



Tropical Cyclone Modelling

TC Olwyn 2015

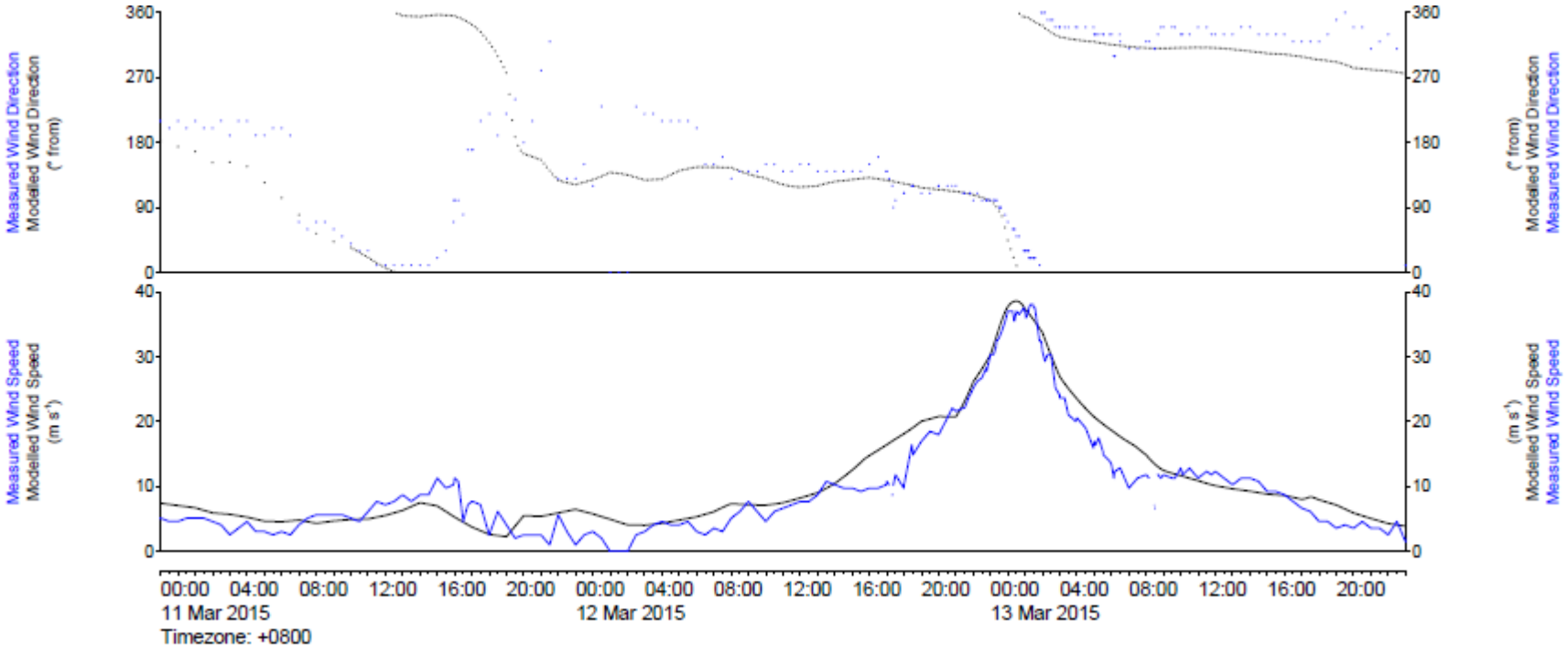
- Comparisons with measurements are good
- eg. Barrow Island



Tropical Cyclone Modelling

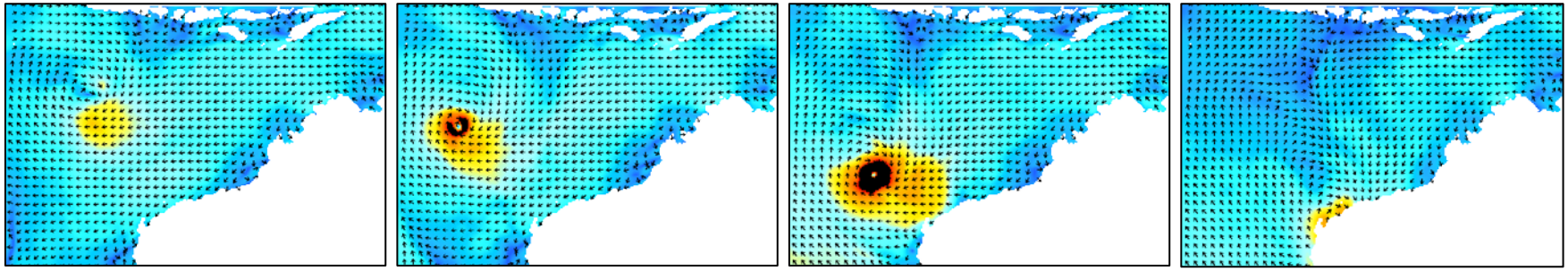
TC Olwyn 2015

- Comparisons with measurements are good
- eg. Learmonth



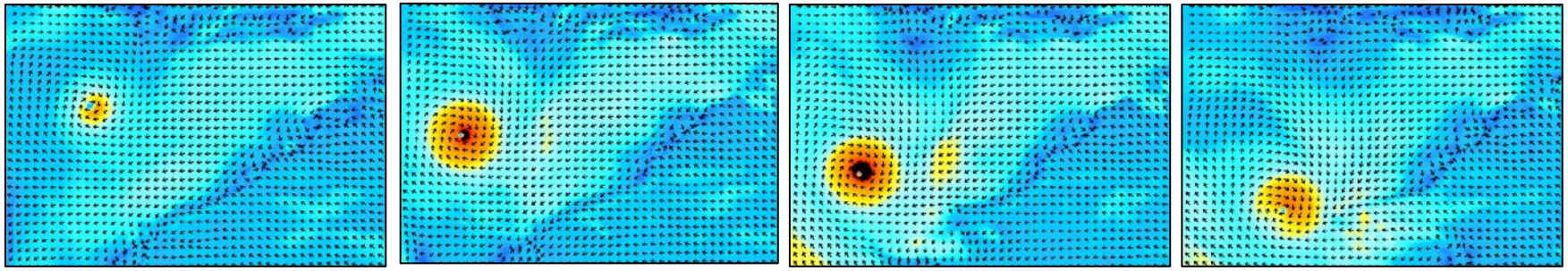
Wind Blending – TC Quang

NCEP GFS:



2015/04/28 12Z | 2015/04/29 12Z | 2015/04/30 12Z | 2015/05/01 12Z

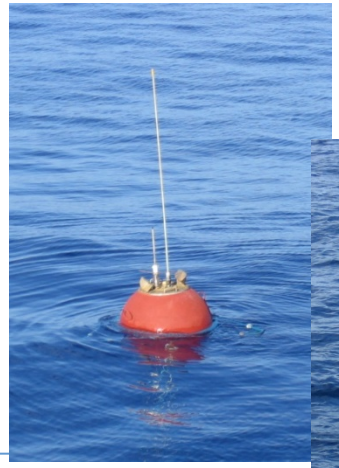
RPS WPS:

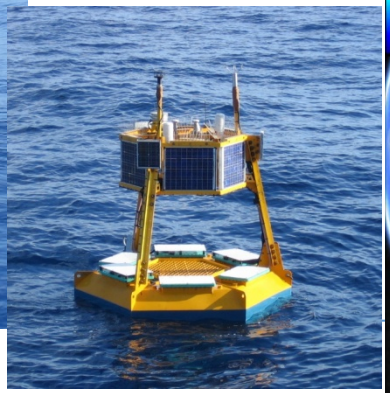


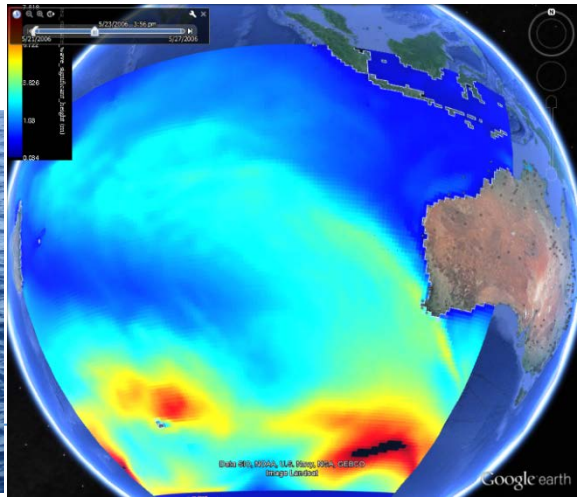
2015/04/28 12Z | 2015/04/29 12Z | 2015/04/30 12Z | 2015/05/01 12Z

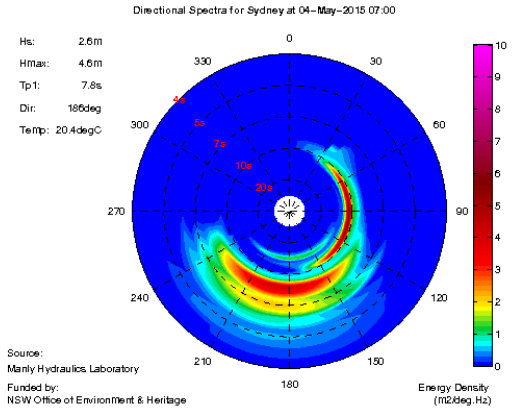
Wave Modelling

- Based on latest WW3 release with features relevant to NWS
- Comprehensive calibration and tuning options
- Driven by RPS modified wind fields.
- Able to ingest spectral measurement data (eg. buoy and satellite)
- Supports data assimilation of measurements and coefficients
- Support for moving TC nests and wave-system tracking
- Output spectra suitable for vessel motion/response/port systems

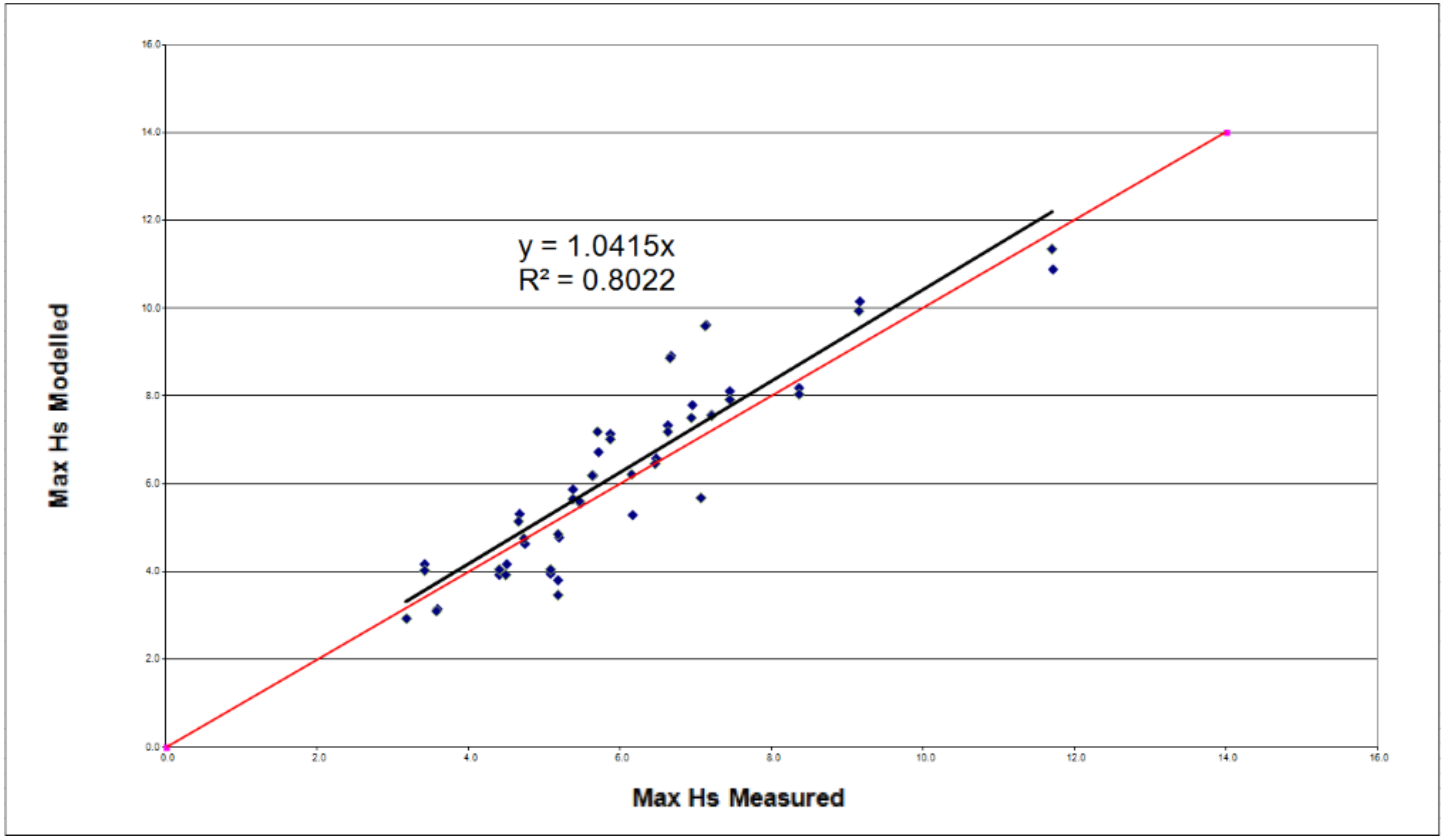








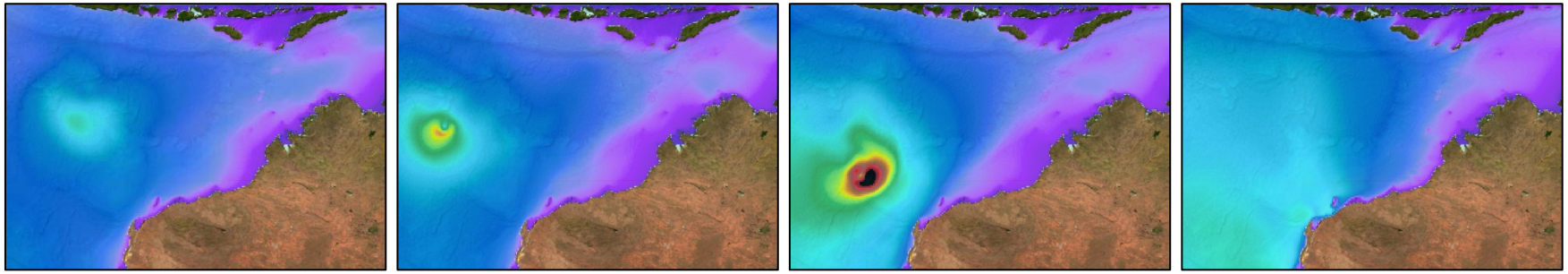
Wave Model Results – Tropical Cyclones



- RPS wave model performance. Wave height comparisons against 30 years of Australian tropical cyclones. For fixed model configuration.

Swell Prediction - TC Quang

NCEP GFS forcings:



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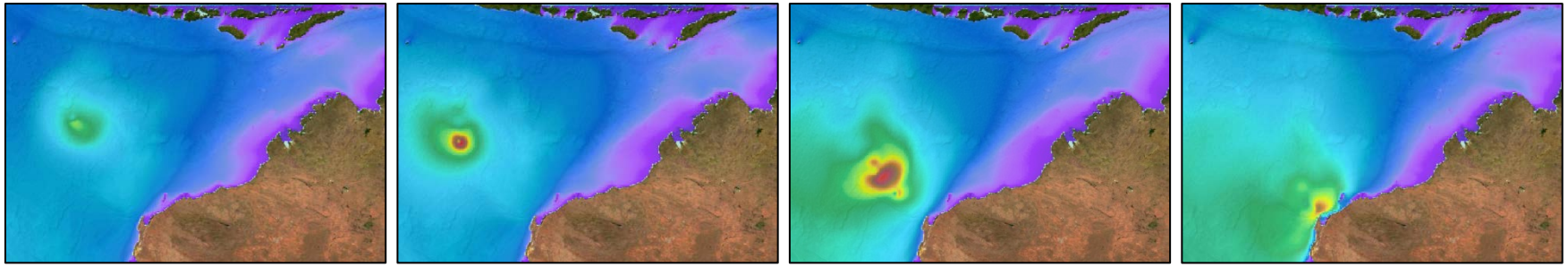
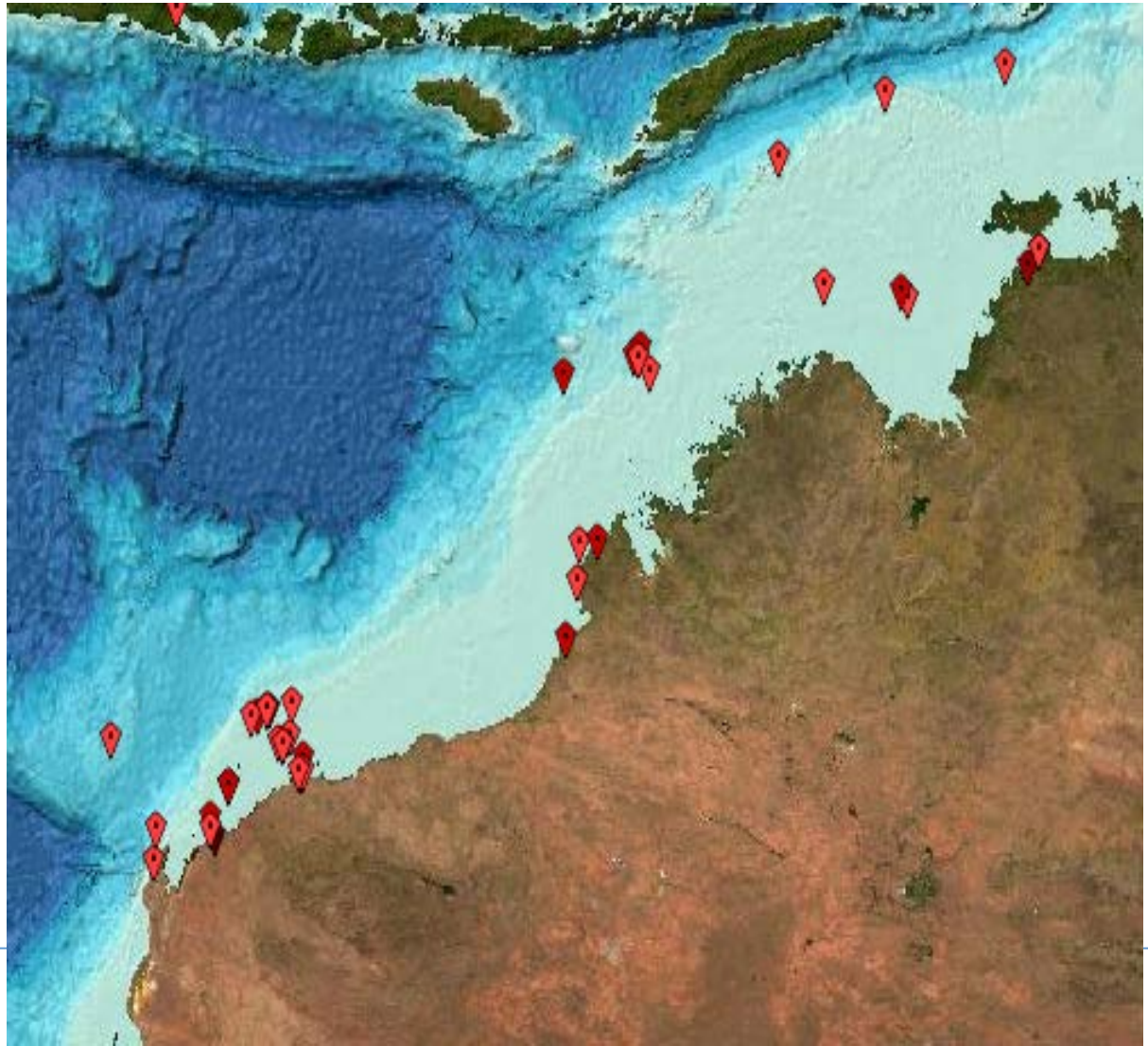
RPS SPS:



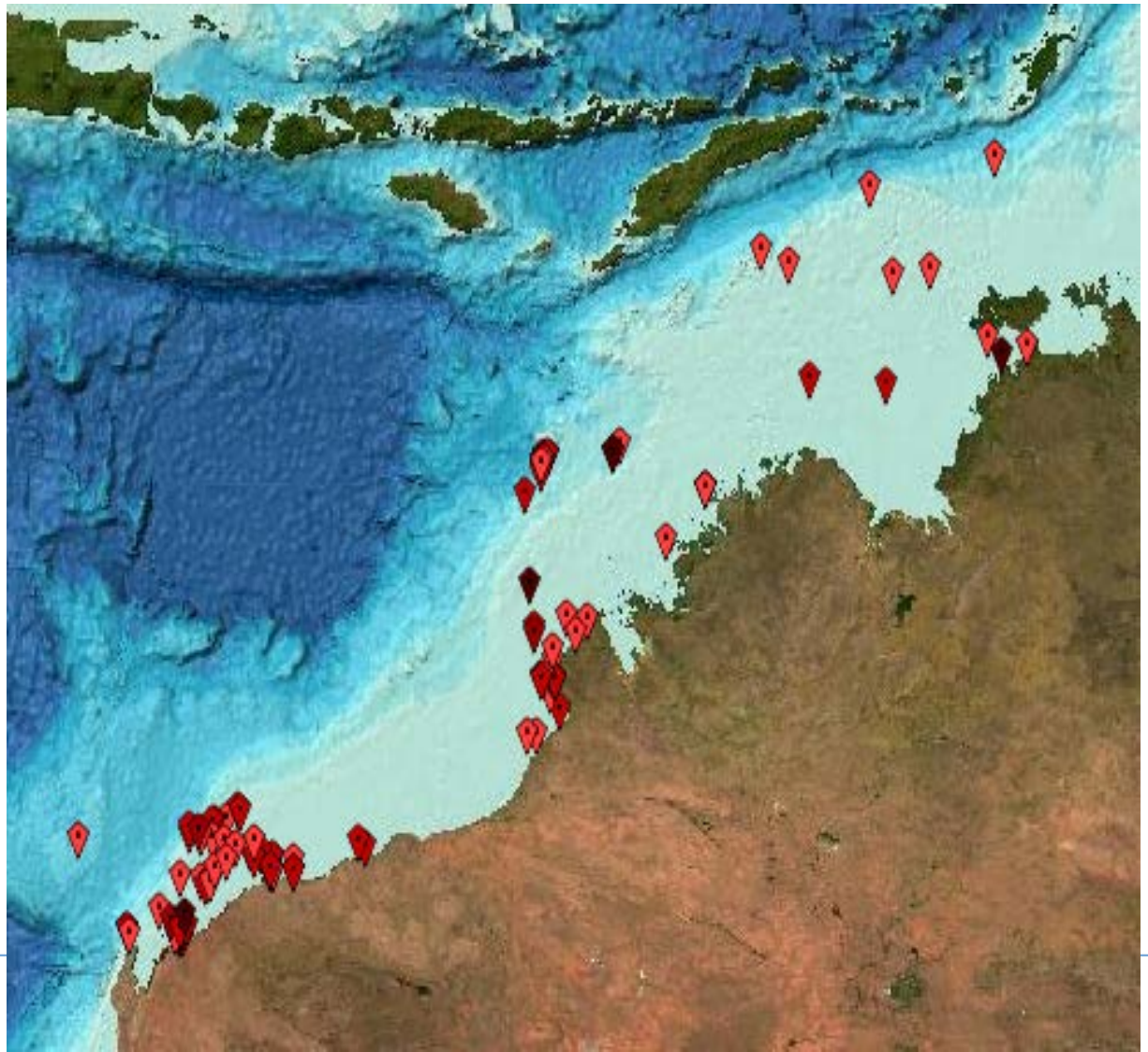
2015/04/28 12Z | 2015/04/29 12Z | 2015/04/30 12Z | 2015/05/01 12Z

Measurements

Archived Long-Term Wind Measurements

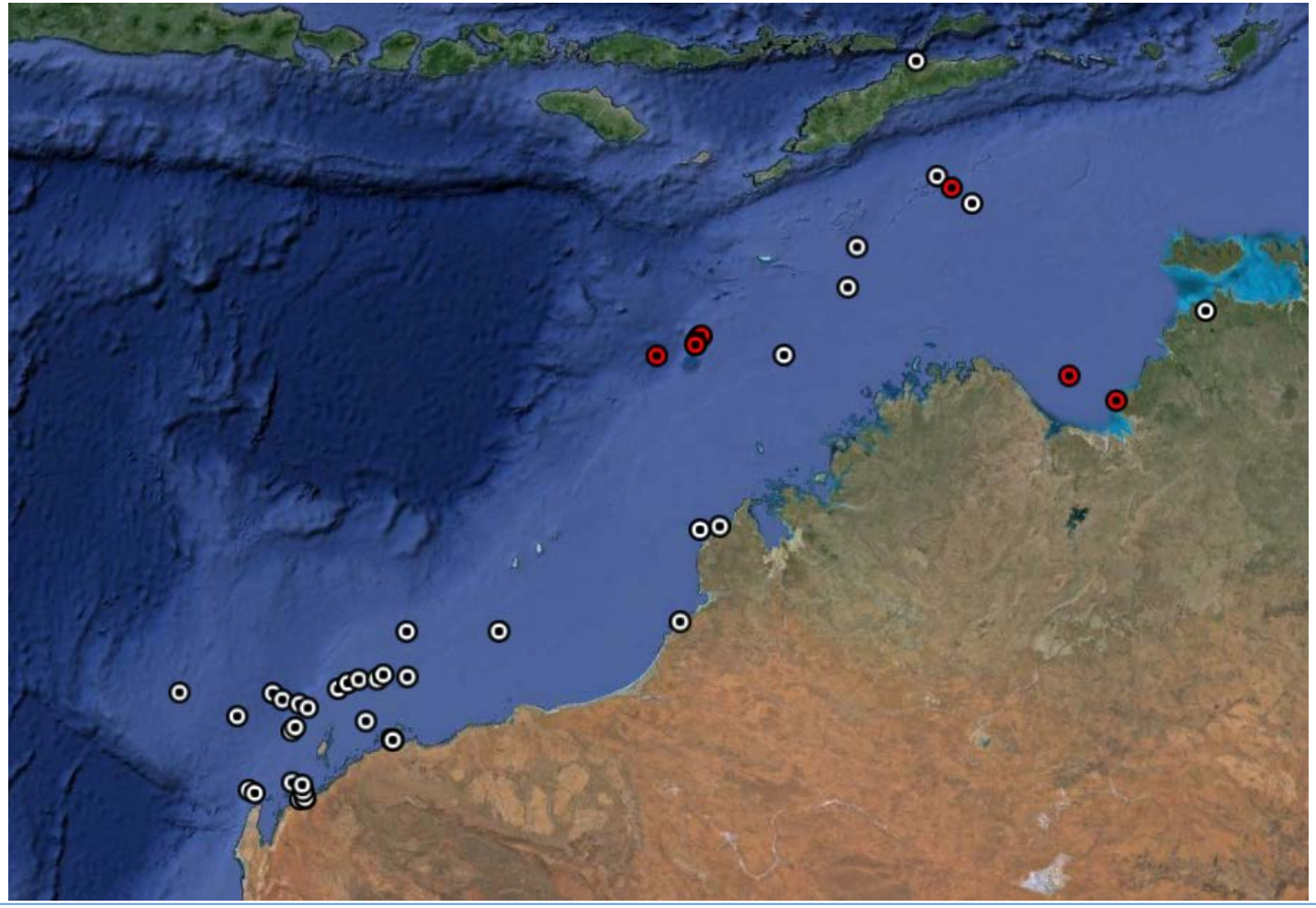


Archived Long-Term Wave Measurements

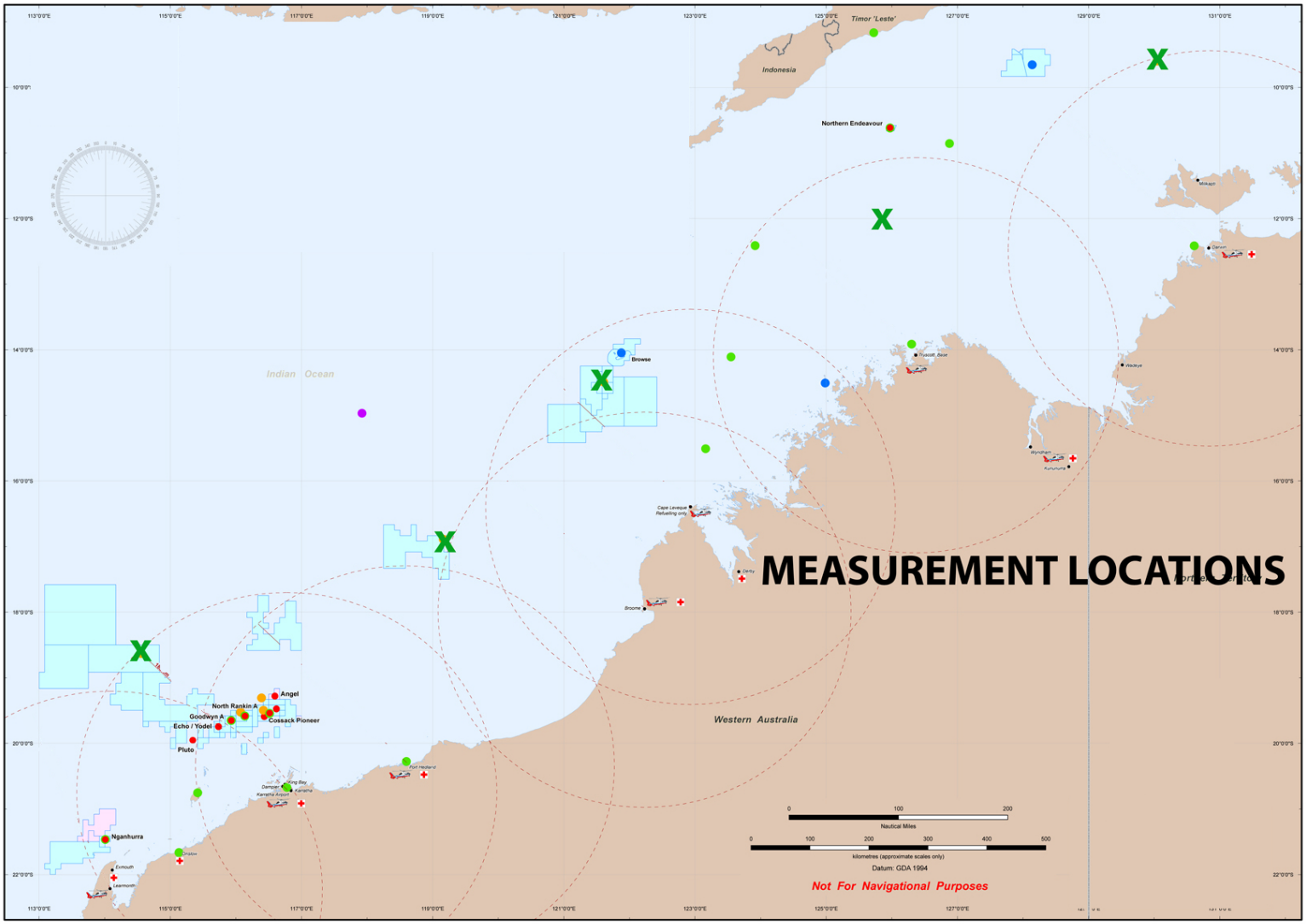


Purpose-built RPS Wave & Met. Buoy

Available Real-time Data Ingestion Sites

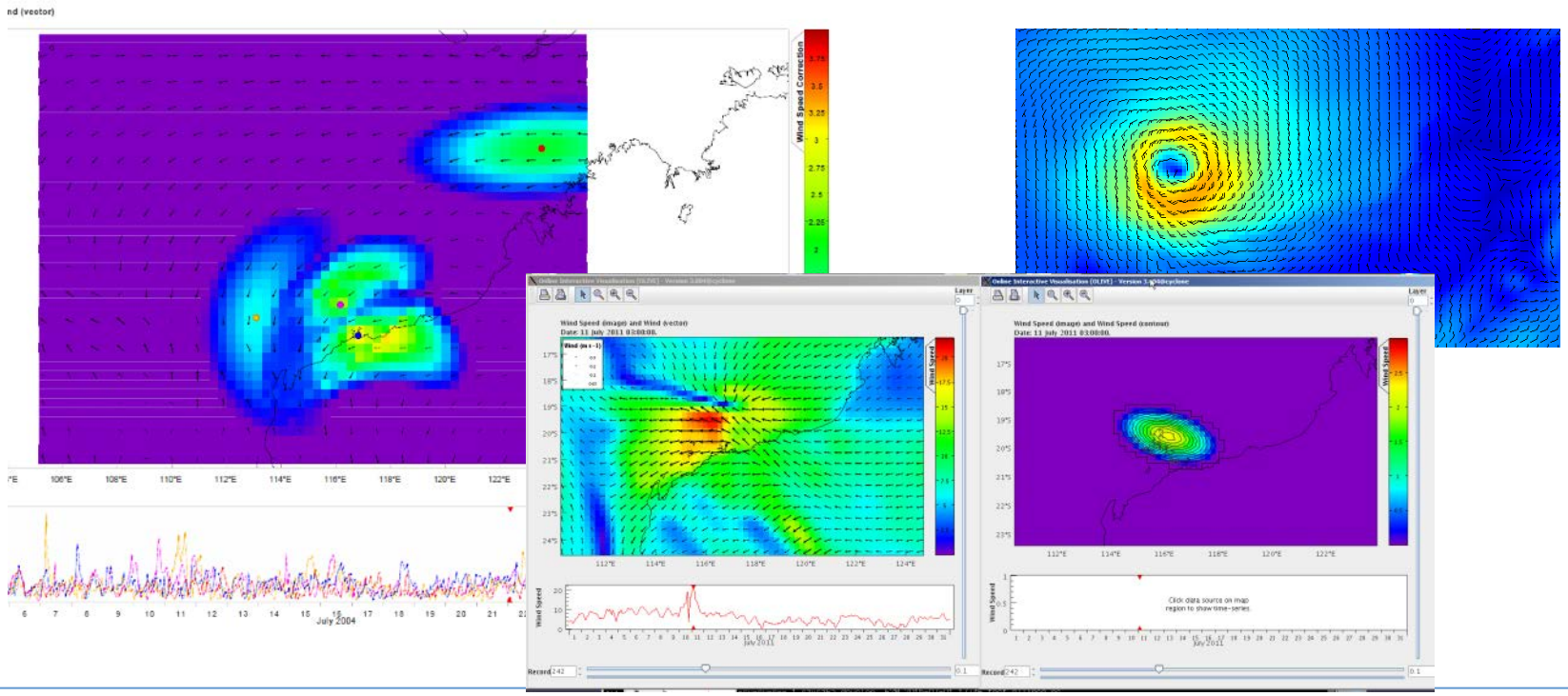


Prospective Measurement Locations

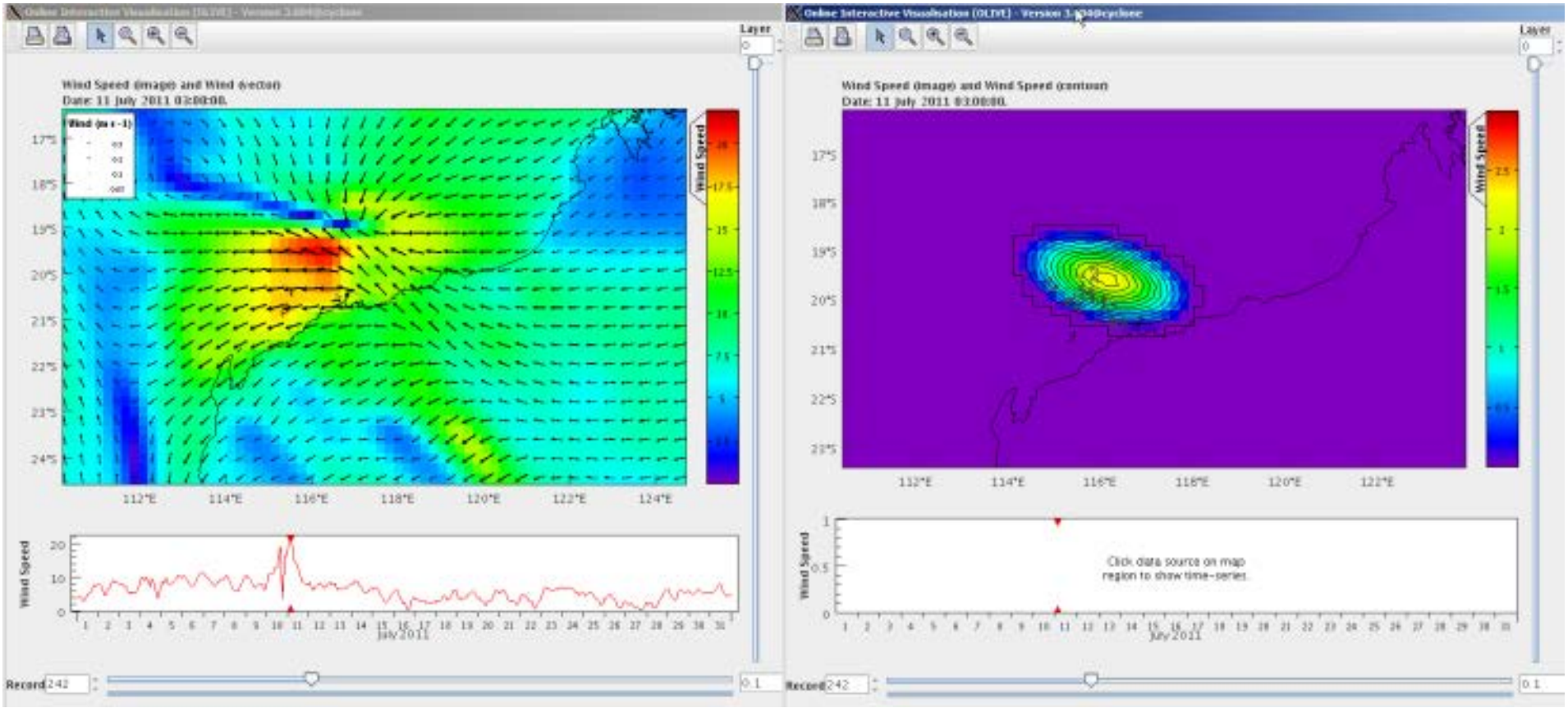


Windfield Improvement Systems

- RPS obswind – based on Objective Analysis concepts introduced by Cressman (1959)
- Uses marine and terrestrial met observations to create improved wind fields and predictions.

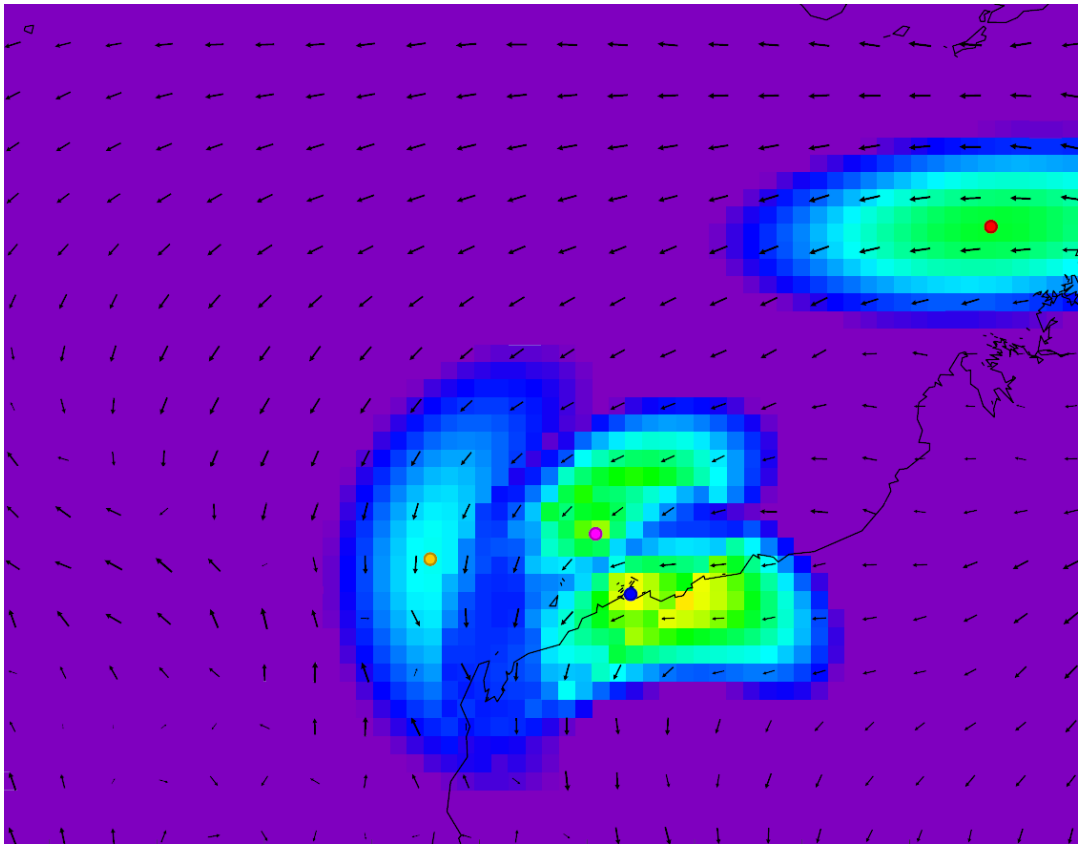


Effect of a single wind measurement



Using an objective analysis technique, the influence of a single site measurement (right) into a gridded wind field (left) used in model forcing improves local wind-sea and swell propagating to adjacent sites.

Multiple wind measurements



Multiple measurement sites improve the nearshore wind field over a larger area, support automated quality-control of realtime data, and limit the influence of coastal effects from onshore measurements.

Wave Data Assimilation Systems

- RPS ww3da – can use remote wave heights derived from satellite altimeters to adjust swell fields during model data-assimilation, improving long-period swell arriving on the NWS of Australia.

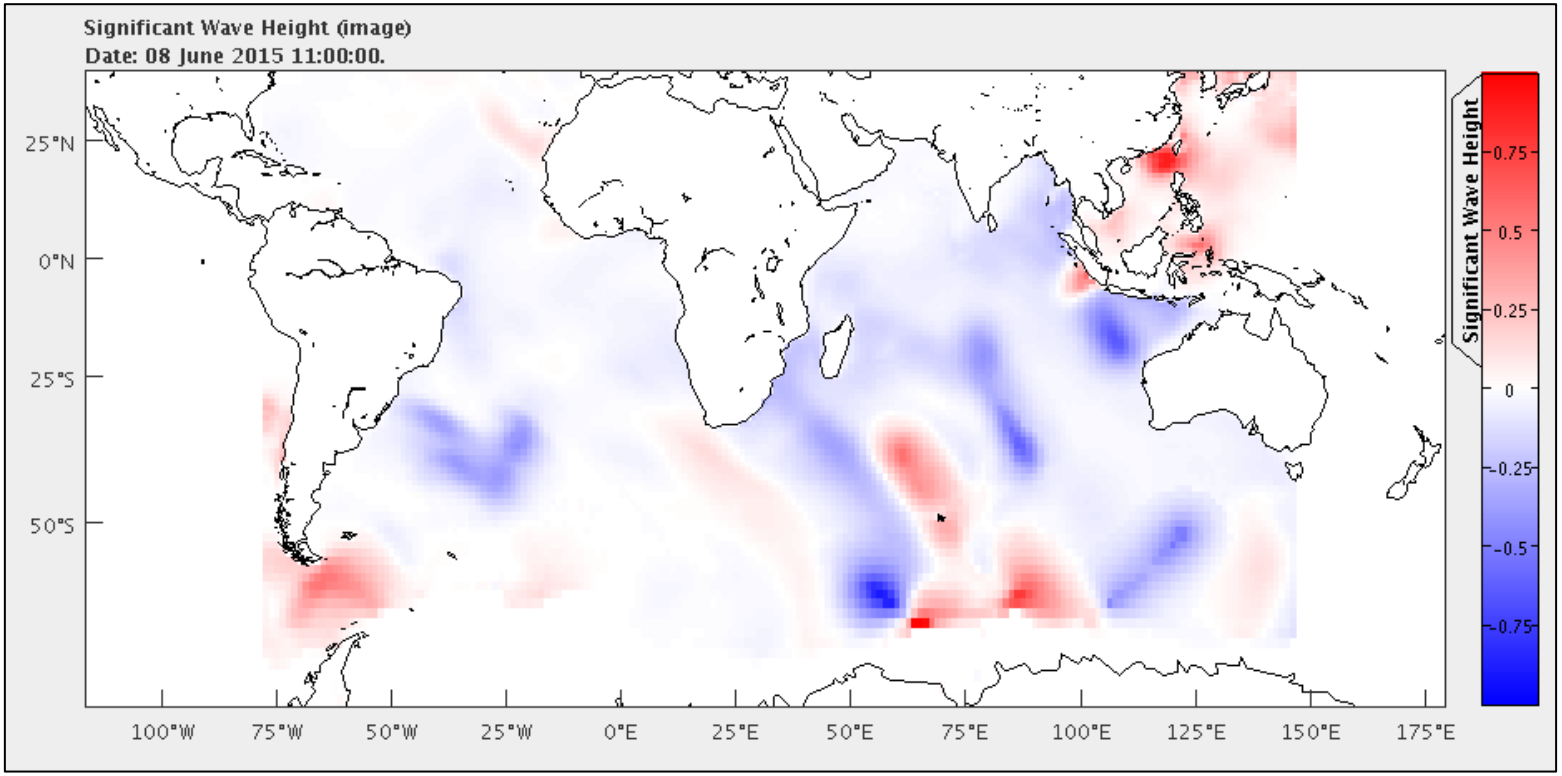
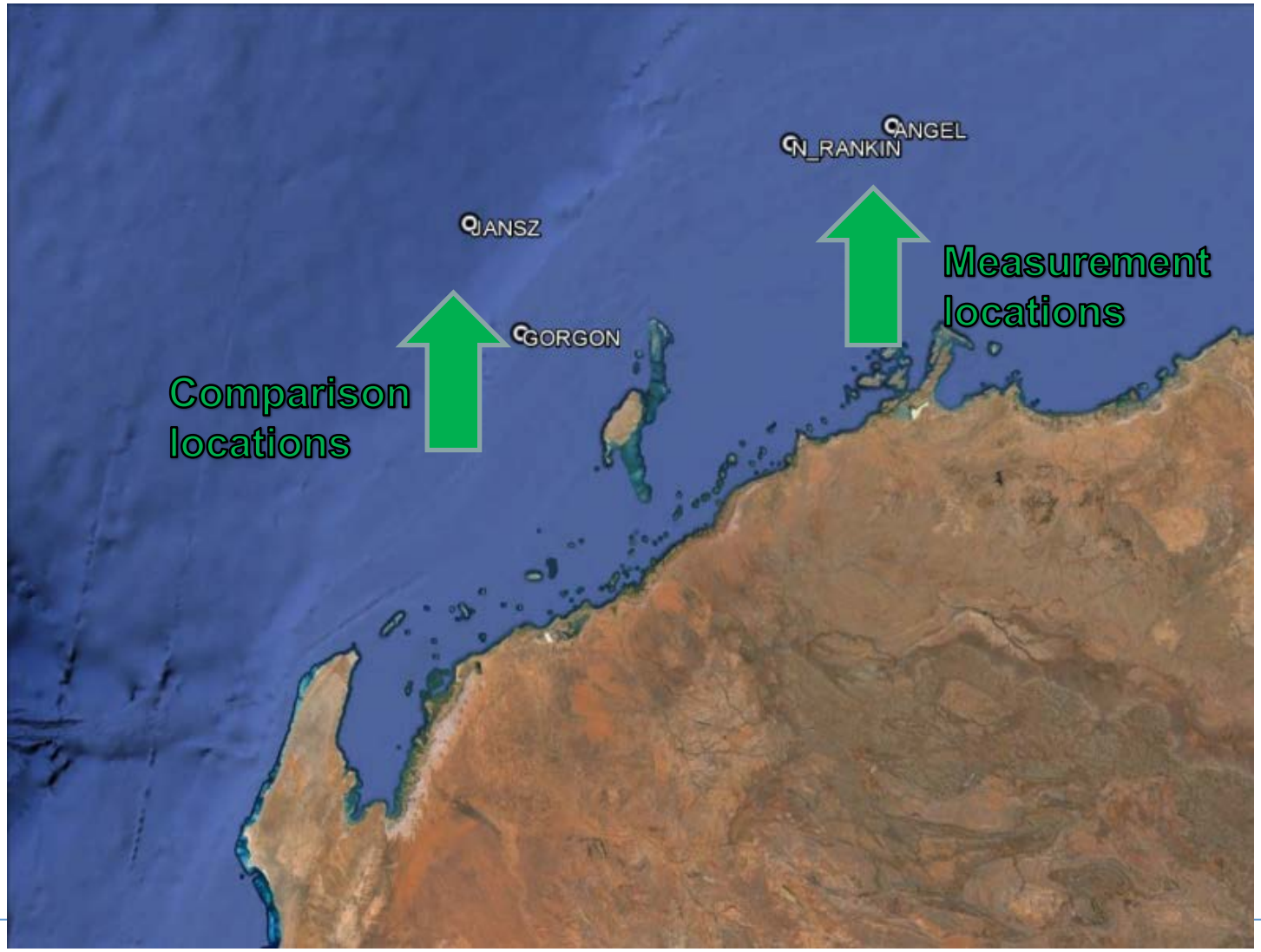


Illustration of Swell Prediction Improvement

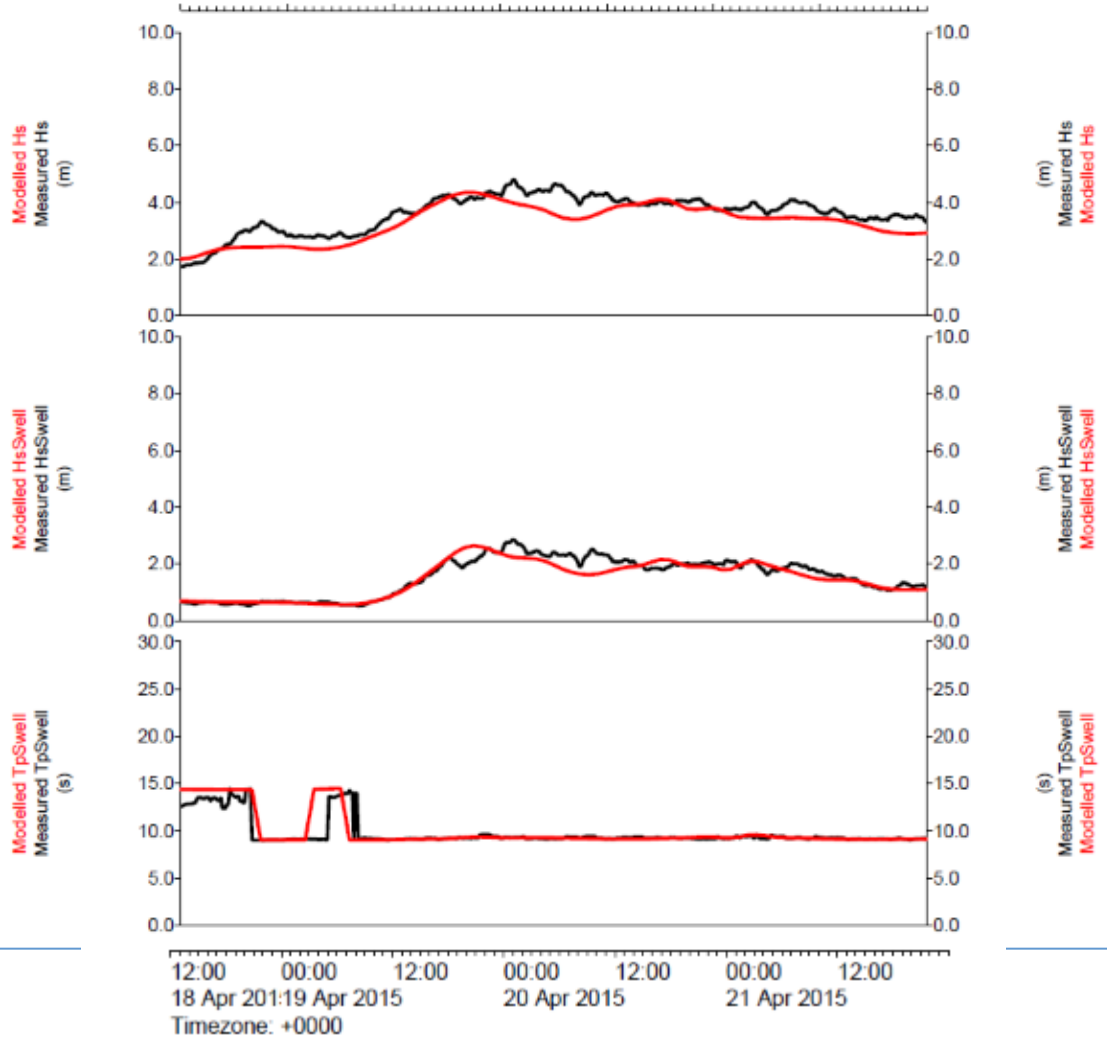
- Onset of strong ESE Gales over Pilbara coast
- Gales not strong enough in global winds.

Map of Locations



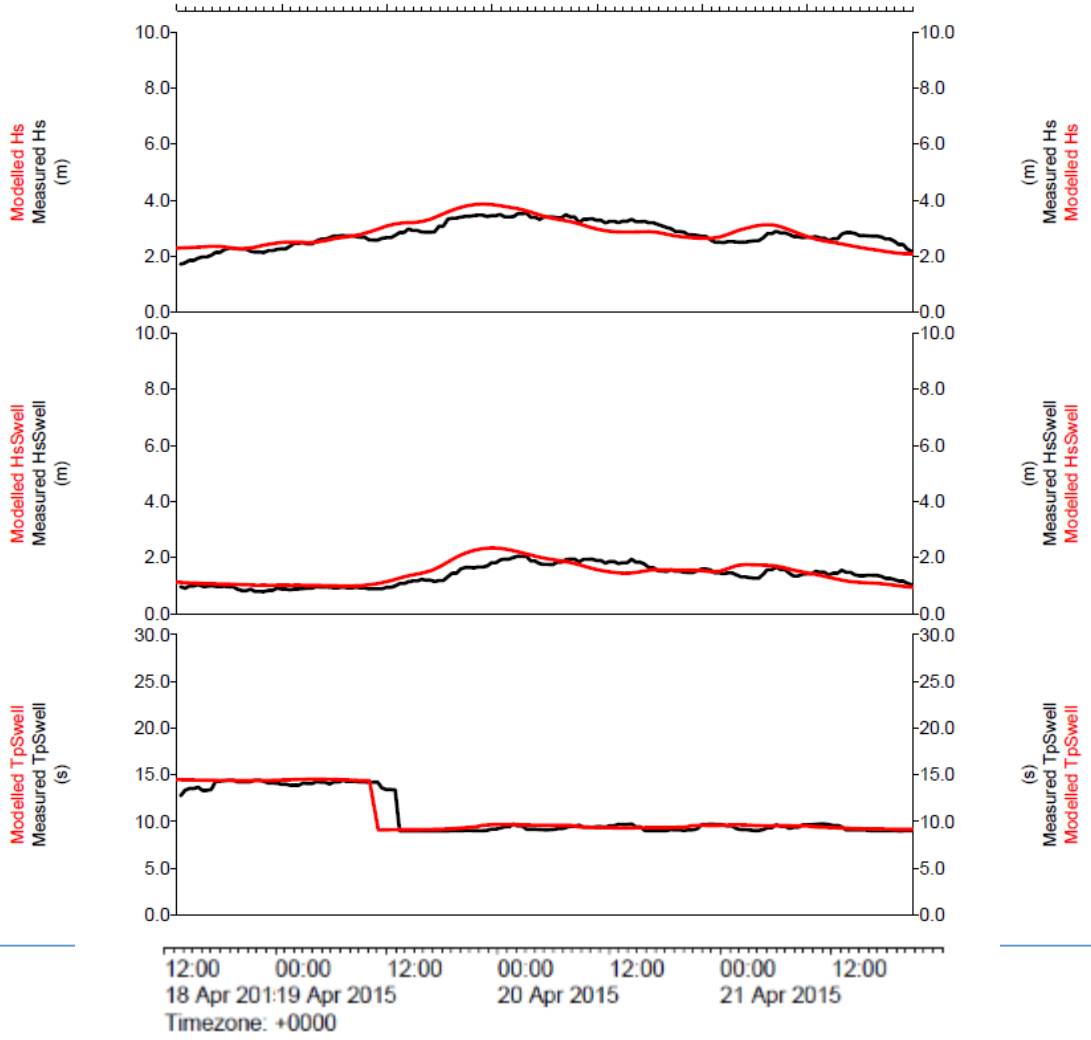
Model Tuning – TEST451f performance

- eg. North Rankin = Fairly good



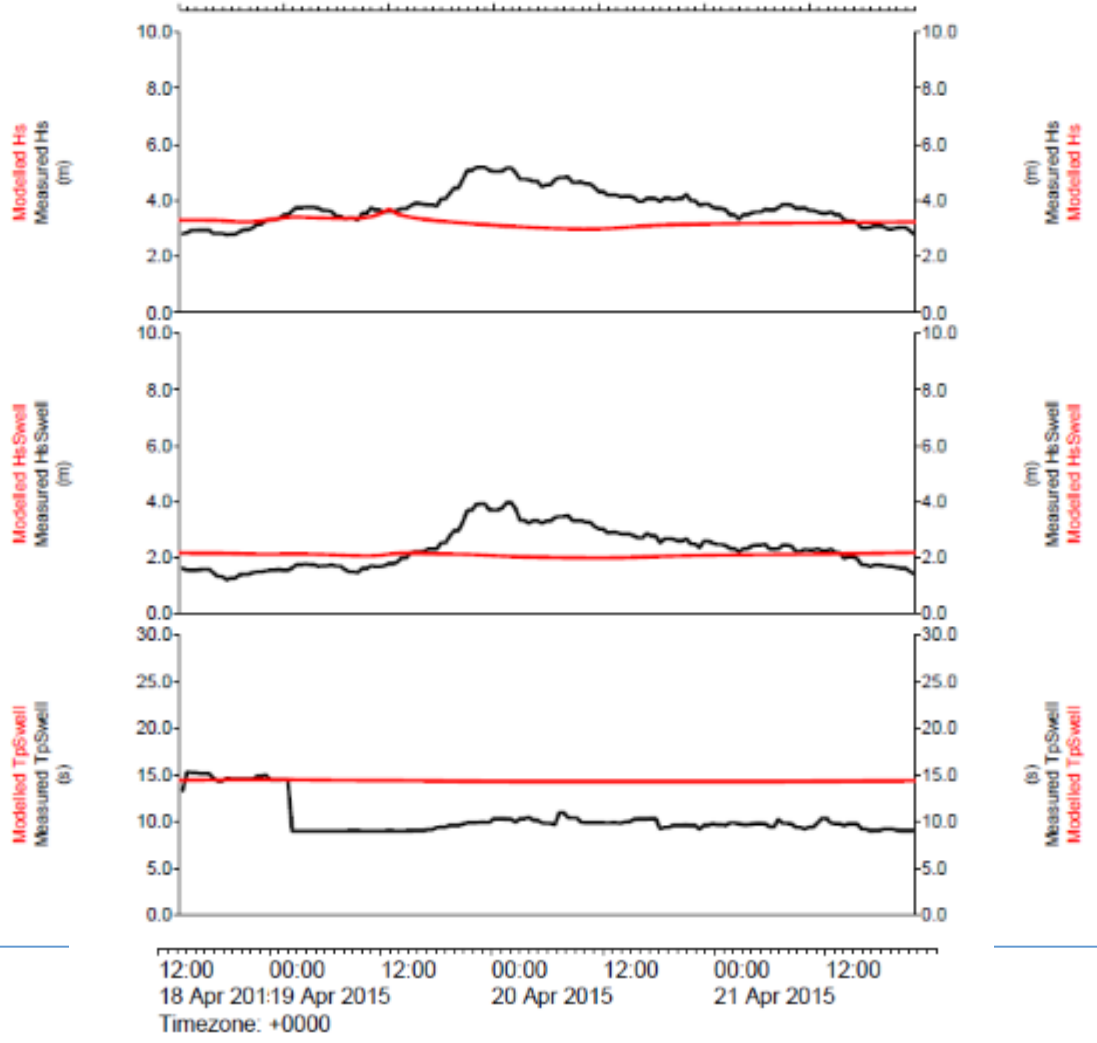
Model Tuning – TEST451f performance

- eg. Gorgon Location = Good



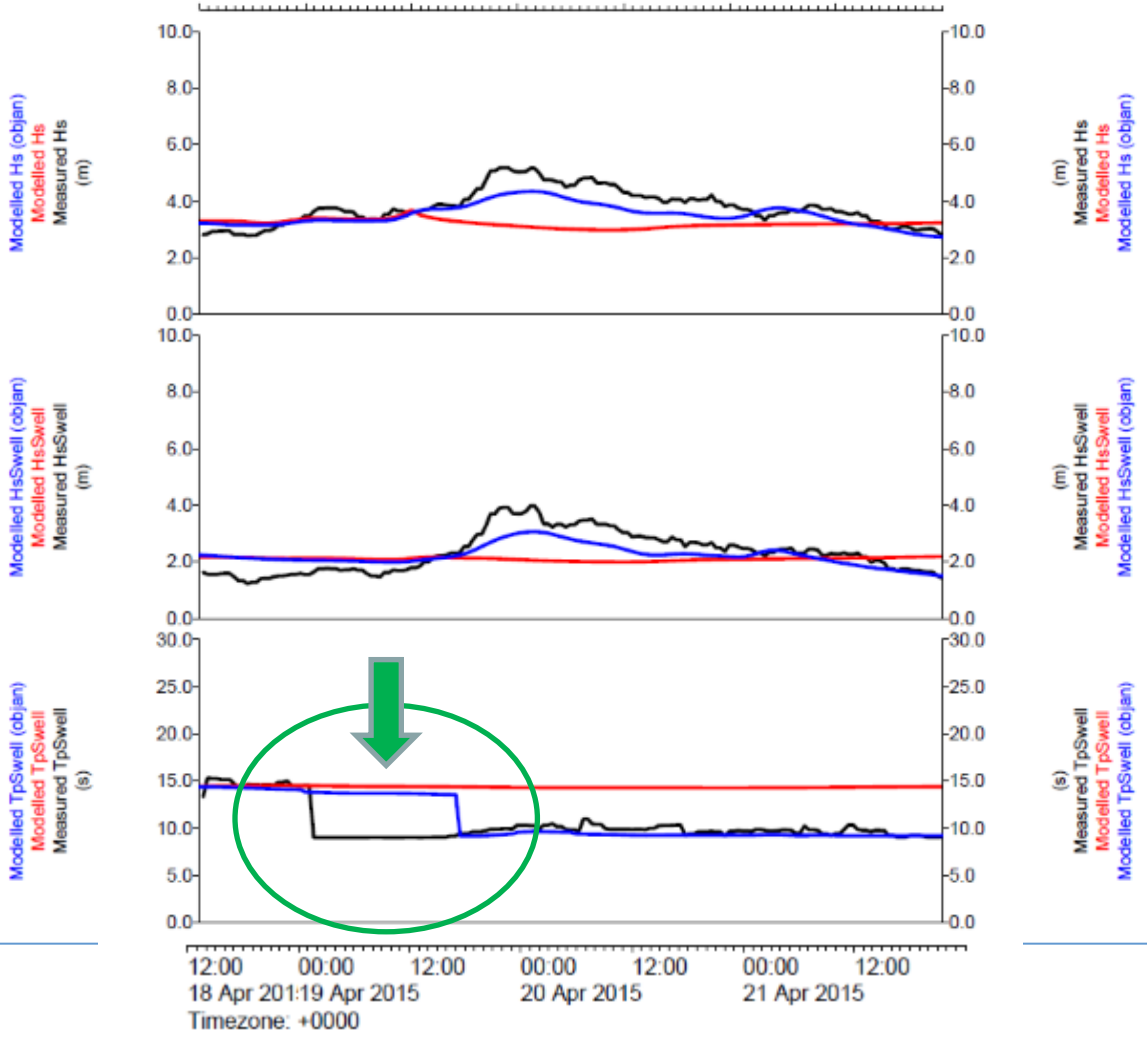
Model Tuning – TEST451f performance

- eg. Jansz = Poor



Model + Measurement

- eg. Jansz = Better (hourly winds from Angel, NRA)

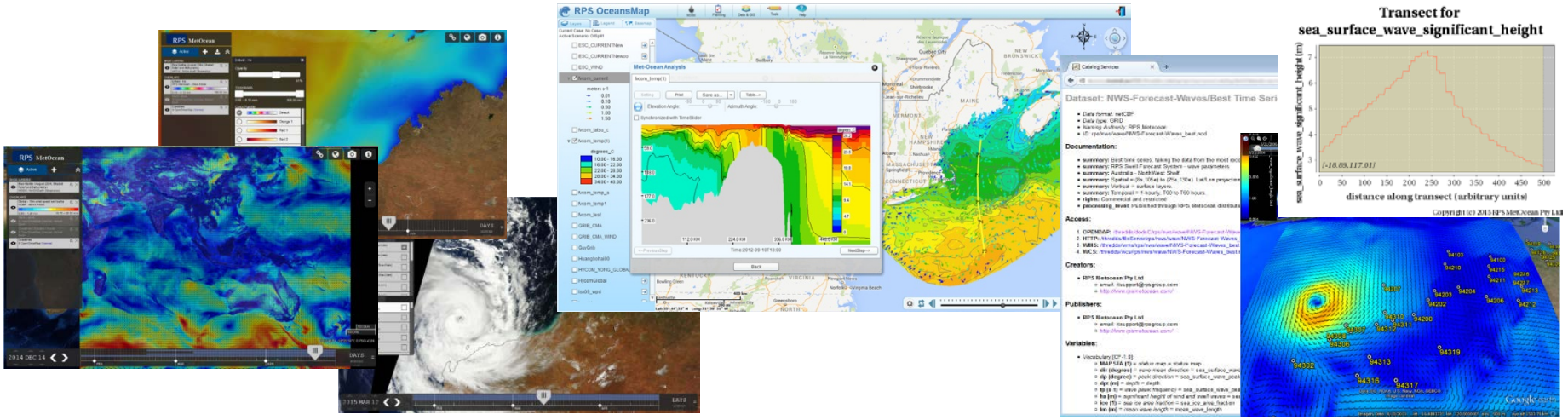


Products and Services

- Tropical cyclone swell alerts
- Berth operability assessments
- Swell input to Under Keel Clearance predictions
- Vessel motion forecasts (via RAOs)
- Installation and Materials Transfer operability
- FPSO riser disconnect/reconnect forecasting
- FLNG side-by-side operability forecasting
- Fatigue monitoring and ROV inspection assessments

Data Interfaces – Client Integration

- A consistent view of forecast data will be available via a number of data interfaces to enhance Client Integration:
- In-situ systems – ROWS, REMS, on-board port/vessel systems
- ‘Traditional’ interfaces – simple HTTP, FTP, Email, SMS
- Enhanced interfaces – OPeNDAP, RESTful (web-query)
- GIS/desktop integration – ESRI, OGC WMS/WCS/WFS/KML
- Interactive interfaces – CoastMap, EDS, web browser/tablet/etc




THE END