Operational Oceanography

Decision-Making Tools for Industry

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MetOcean Solutions

The New Zealand situation
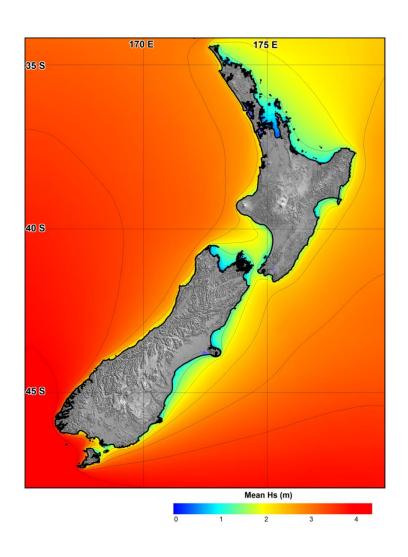

- Surrounded by an energetic ocean

- Many small ports with weather problems

- Surge, high winds, currents, sedimentation

- Sub-Tropical to sub-Antarctic weather

- Rapid changes in weather

- Small national economy

NZ needed accurate ways to monitor and predict marine conditions and the operational outcomes of weather.
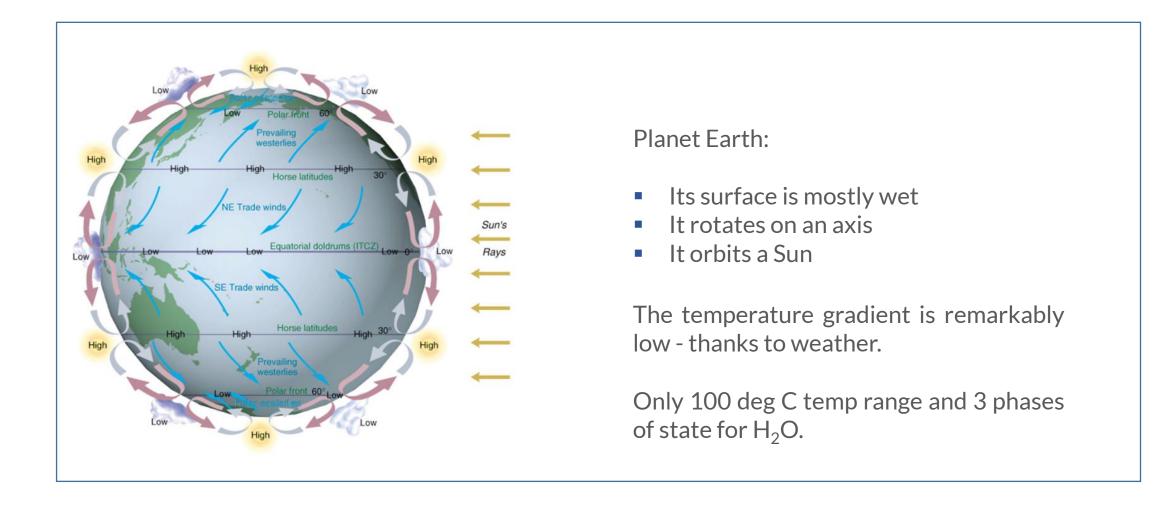
This ship did not need a wave height forecast

- it needed a vessel roll forecast

The New Zealand Solution

- Global and regional ocean models

- Latest open-source science code

- Nested hyper-local models for every port

- Real time measurements - winds, waves and currents

- Ensembles and derived products to aid decisions

- Sophisticated web tools to open access the data

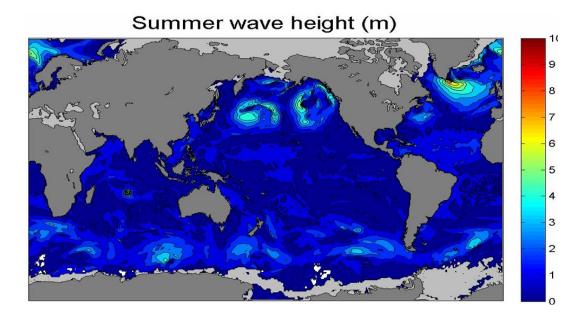- Education of the port industry for better decisions
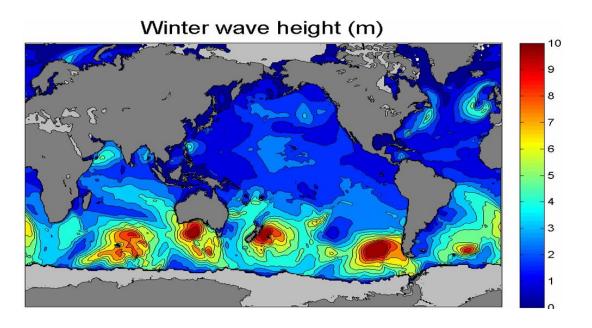
Creating knowledge from data!

The context

Planet Earth:

- Its surface is mostly wet
- It rotates on an axis
- It orbits a Sun

The temperature gradient is remarkably low - thanks to weather.

Only 100 deg C temp range and 3 phases of state for H_2O.

The context

Chile and New Zealand are exposed to Southern Oceans swells in summer and in winter

Summer wave height (m)

Winter wave height (m)

We can solve the equations of state perfectly if…
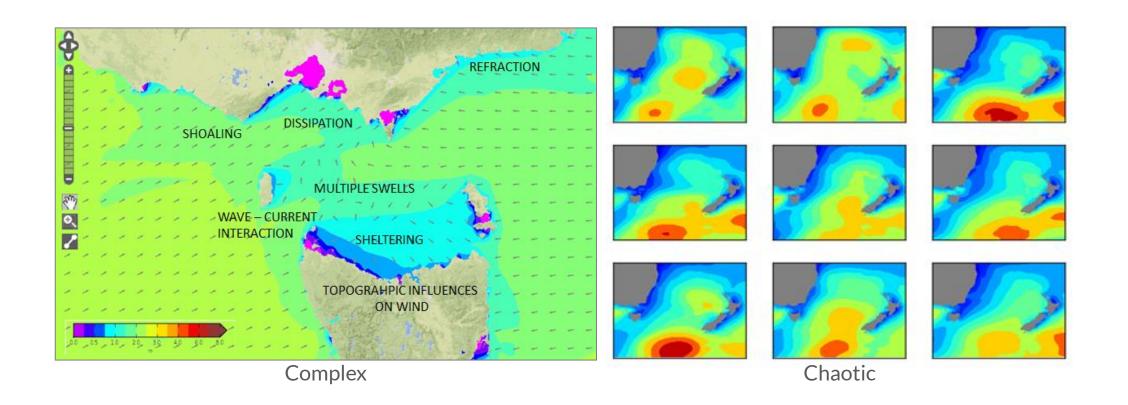
✓ Have lots of time and compute

✓ Know the start conditions, perfectly

✓ Resolve the scale of the physics, correctly

$$\rho\left[\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z}\right] =$$

$$\rho g_x - \frac{\partial p}{\partial x} + \frac{\partial}{\partial x}\left[2\mu\frac{\partial u}{\partial x} + \lambda \nabla\cdot\mathbf{V}\right] + \frac{\partial}{\partial y}\left[\mu\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)\right] + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)\right]$$

$$\rho\left[\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}\right] =$$

$$\rho g_y - \frac{\partial p}{\partial y} + \frac{\partial}{\partial y}\left[2\mu\frac{\partial v}{\partial y} + \lambda \nabla\cdot\mathbf{V}\right] + \frac{\partial}{\partial z}\left[\mu\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)\right] + \frac{\partial}{\partial x}\left[\mu\left(\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}\right)\right]$$

$$\rho\left[\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}\right] =$$

$$\rho g_z - \frac{\partial p}{\partial z} + \frac{\partial}{\partial z}\left[2\mu\frac{\partial w}{\partial z} + \lambda \nabla\cdot\mathbf{V}\right] + \frac{\partial}{\partial x}\left[\mu\left(\frac{\partial w}{\partial x} + \frac{\partial u}{\partial z}\right)\right] + \frac{\partial}{\partial y}\left[\mu\left(\frac{\partial v}{\partial z} + \frac{\partial w}{\partial y}\right)\right]$$
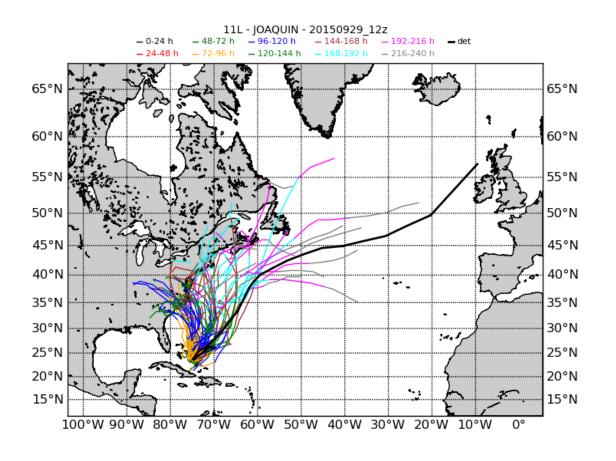
However, despite all that effort, chaos acts to unravel our attempts at accuracy over a forecast horizon.

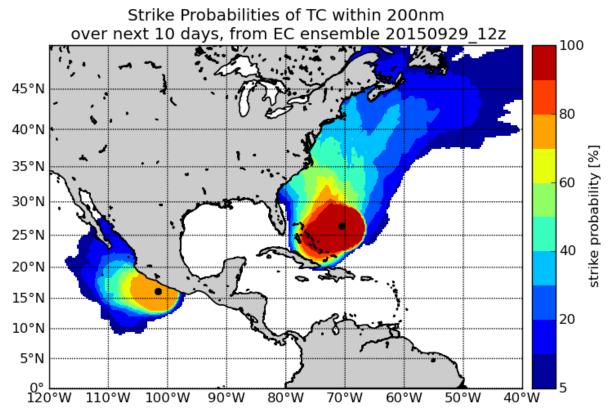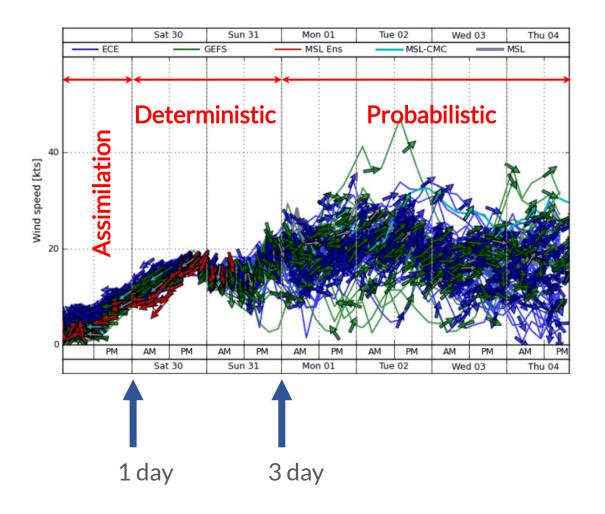# The technical challenge for marine weather forecasting

Complex

Chaotic

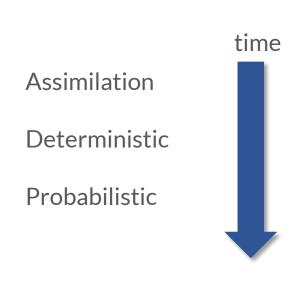The consequence of living on a wet, rotating planet is complex, chaotic weather.

But there is still good information within a chaotic system!

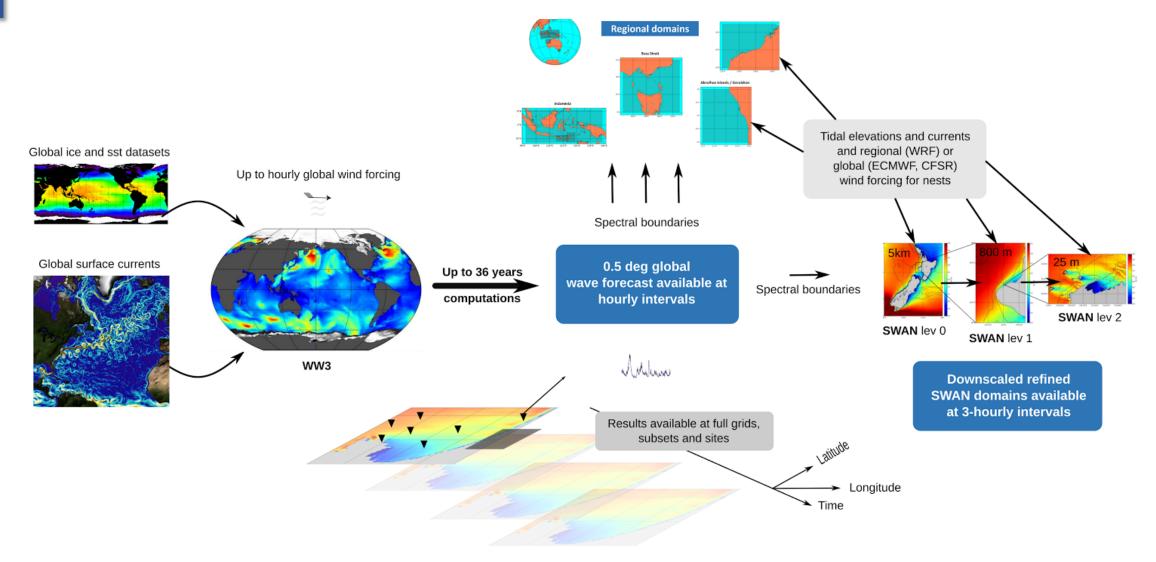www.metocean.co.nz

The challenge is finding the right balance

The New Zealand Solution

- System architecture

- Numerical models

- Example guidance for a port

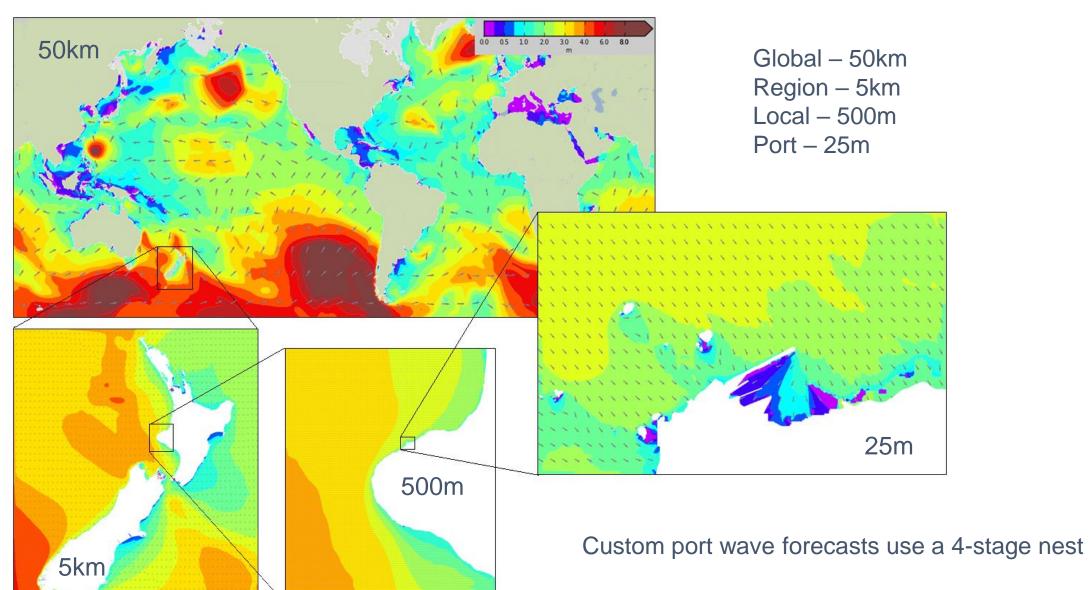- Example for long wave surge

- What's next?

System architecture

Establishing numerical domains

Global WW3 forced with ECMWF, NCEP, CMC
Regional and local SWAN
Regional and local WRF
Regional and local ROMS
Coupled waves and currents
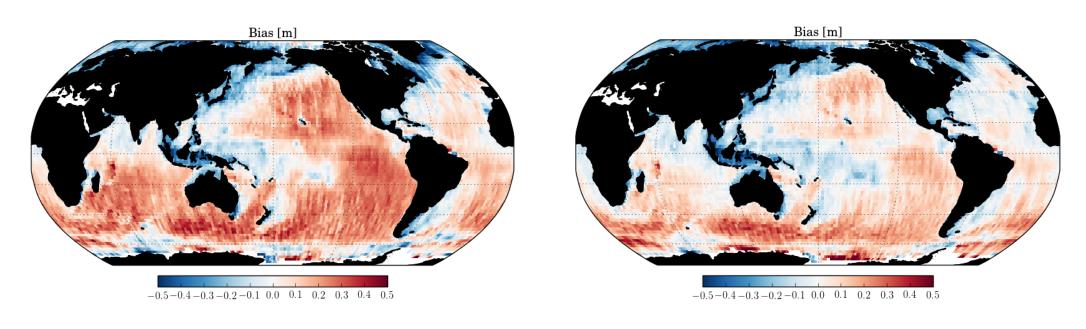
Hyper-local domains for ports

Global – 50km
Region – 5km
Local – 500m
Port – 25m

Custom port wave forecasts use a 4-stage nest

Model physics

Lower bias with improved model physics
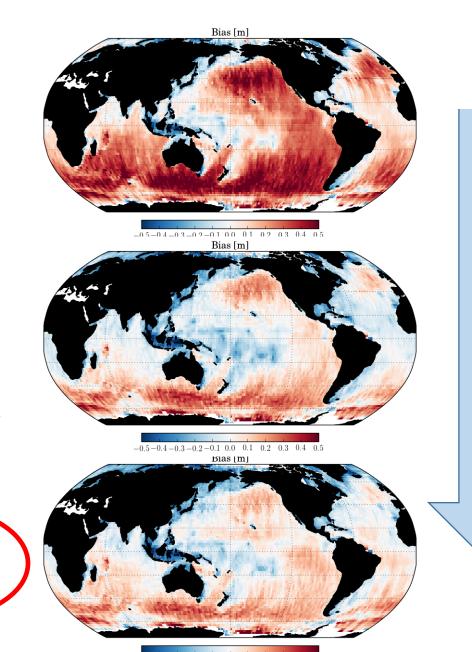
WW3 with TC physics → WW3 with Ardhuin 2010 physics
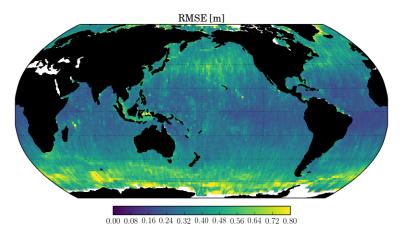
Model physics

WW3 TC
GFS wind
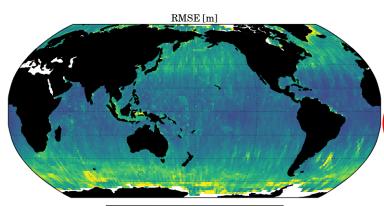
WW3 Arduin
GFS wind

WW3 Arduin
ECMWF wind
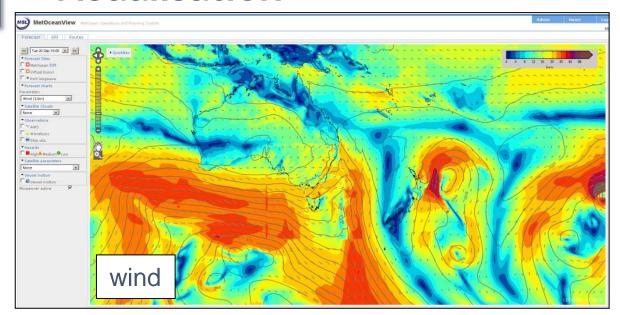
Lowering the global bias
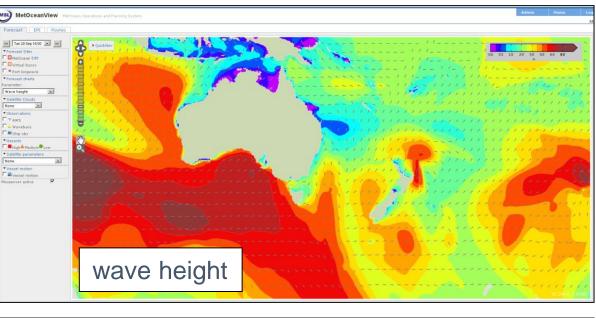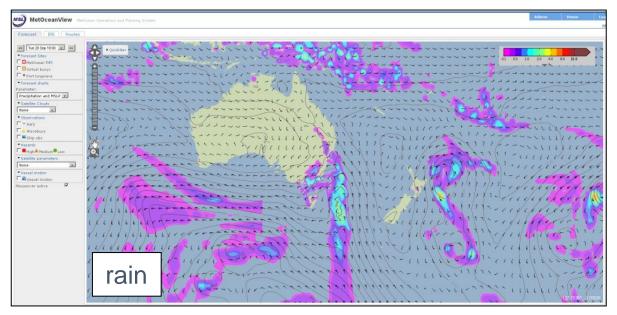
Visualisation

wind

wave height

rain

wave period

Port example
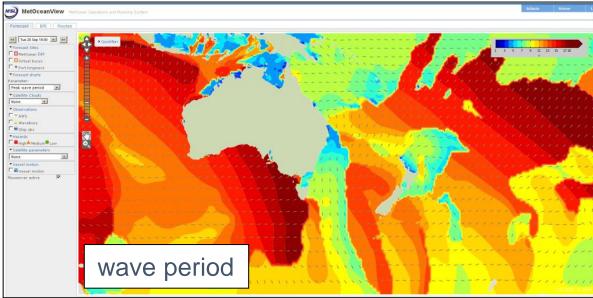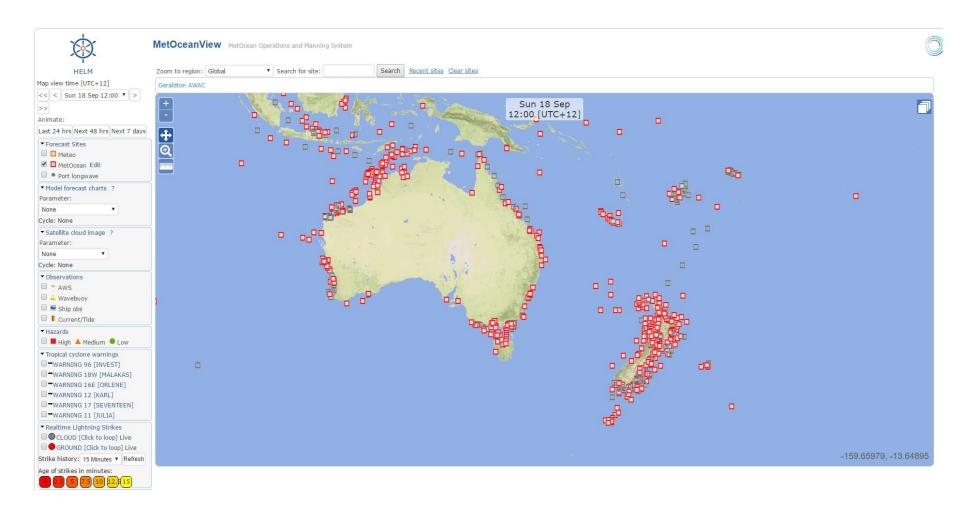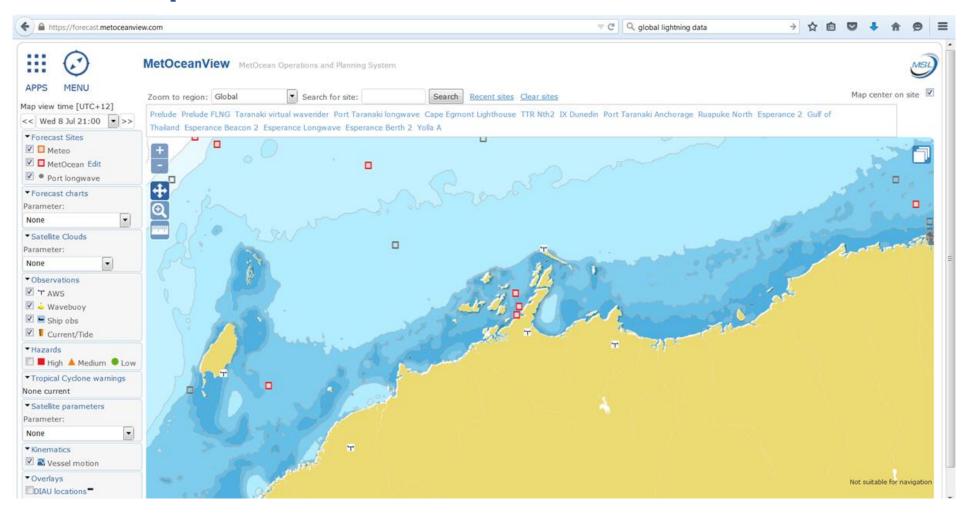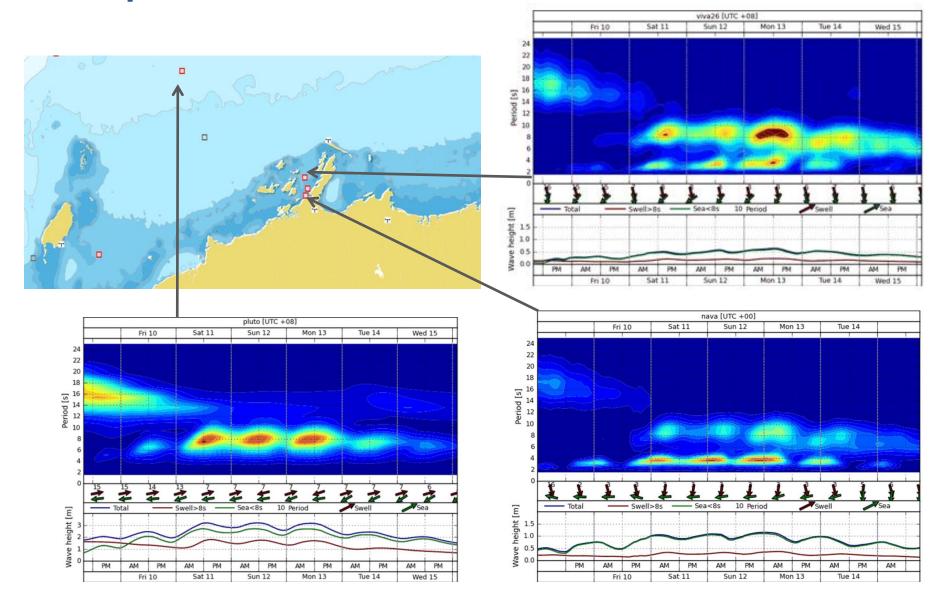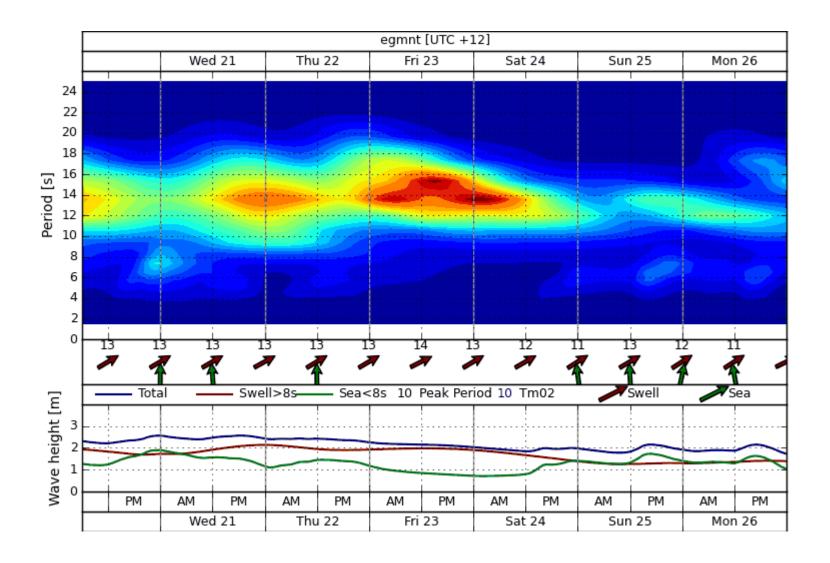
Forecast locations

Port example
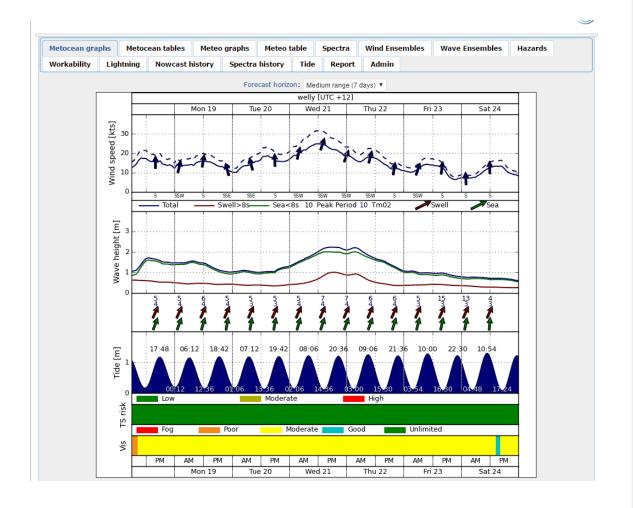
Fully nested wave, wind and current models
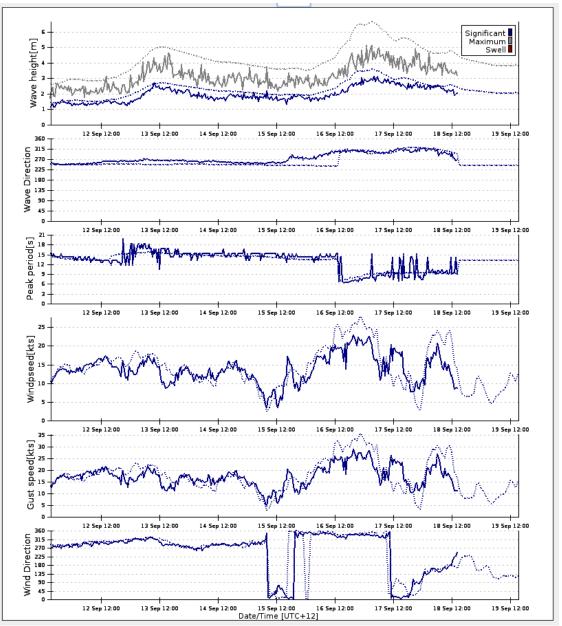
Port example

Port example

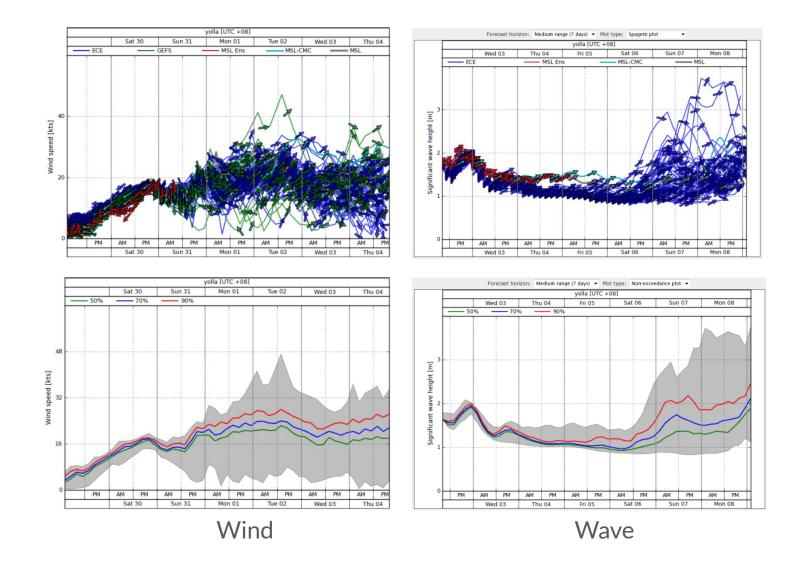Wave spectra

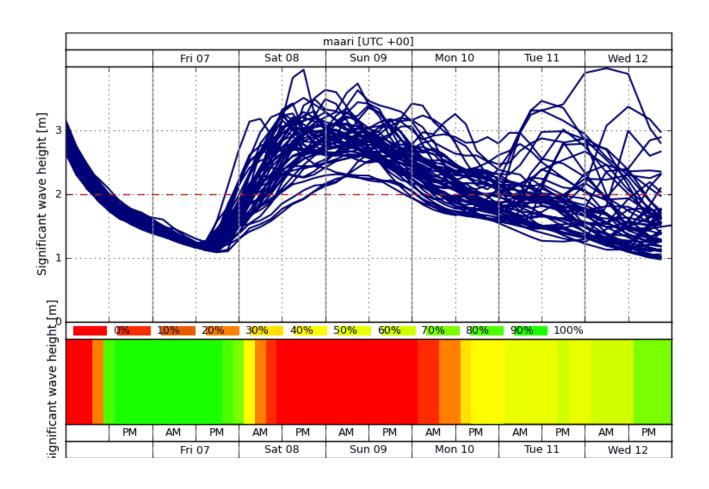# Port example

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Port example
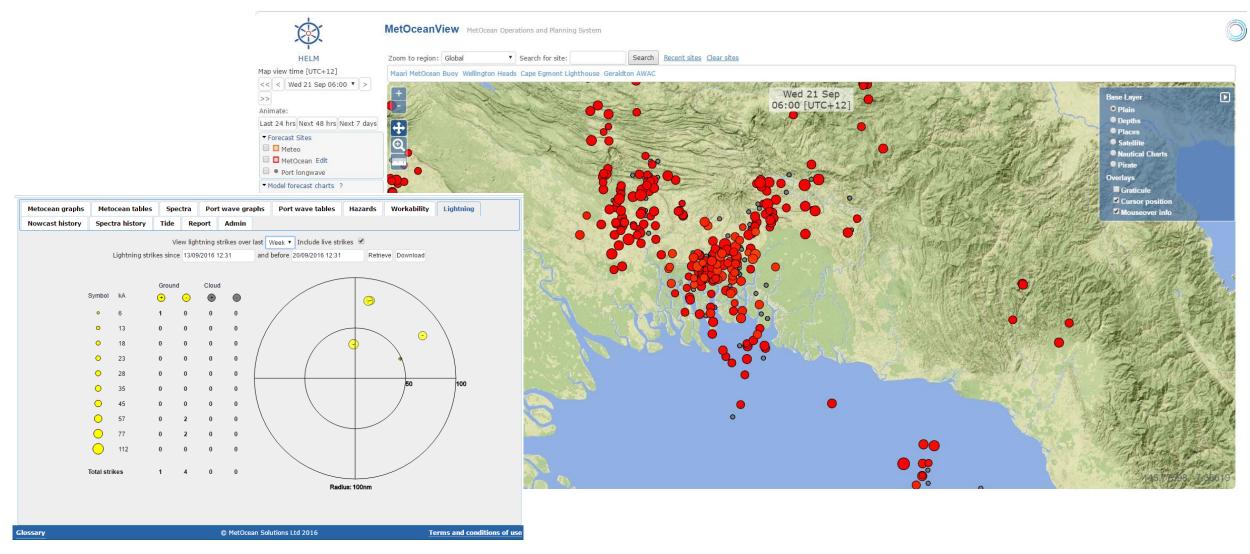
Real time lightning

Forecasting uncertainty
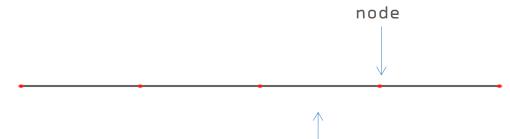

Wind

Wave

Forecasting uncertainty - visualisation

Long - the cause of harbour surge and line breakage

Swell waves

Long waves

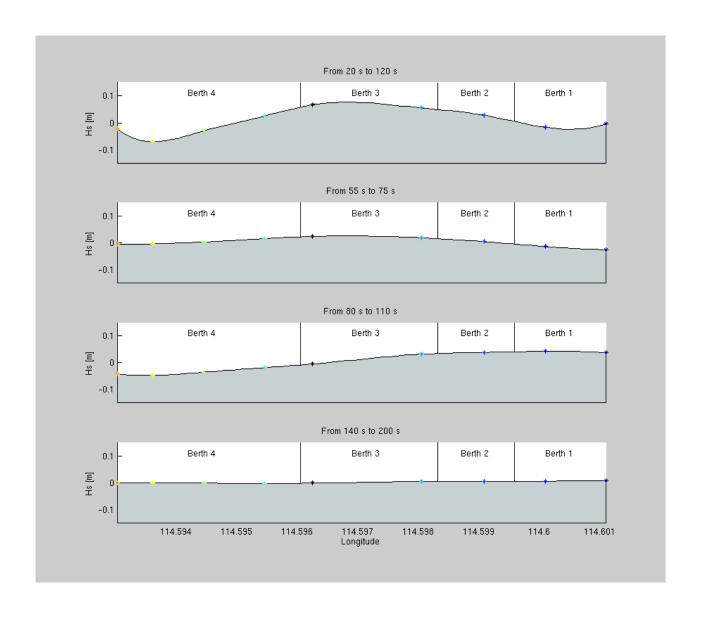Swell wave groups generate long waves

Measuring long waves

node

anti-node

In a complex location one measurement site may not be enough
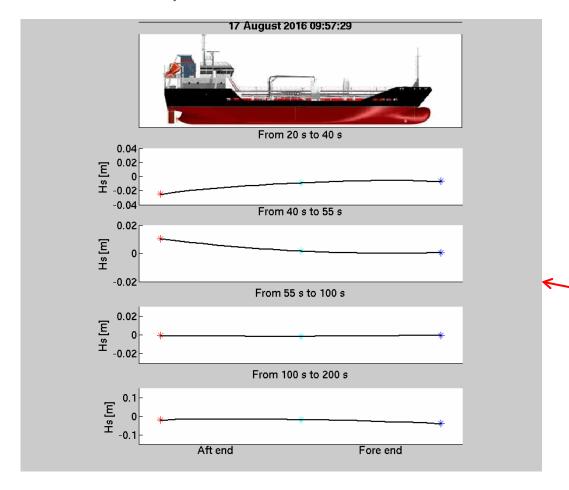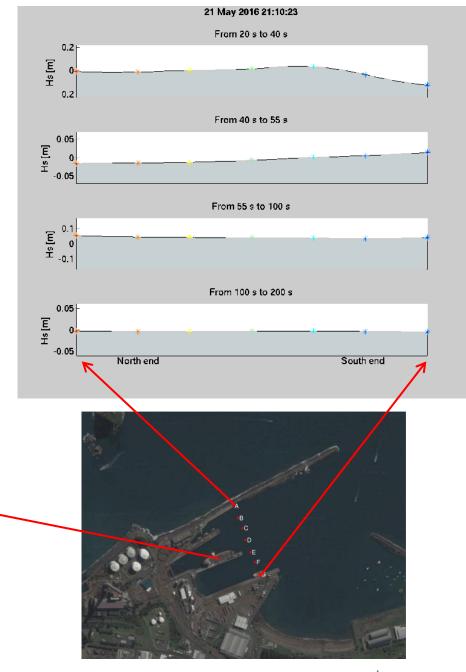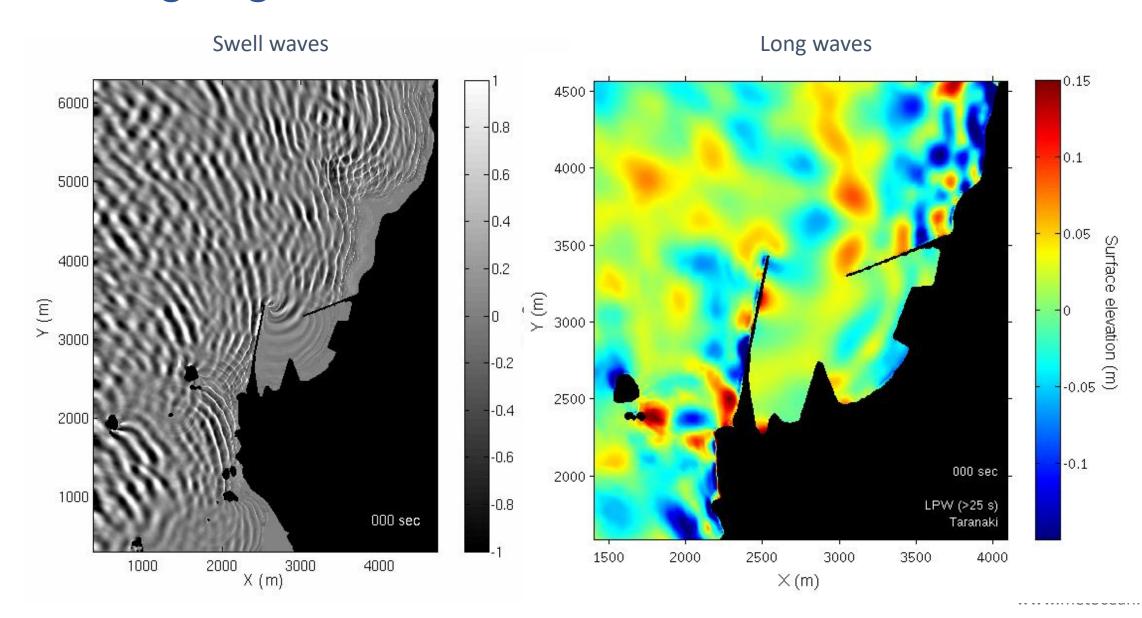
Measuring long waves
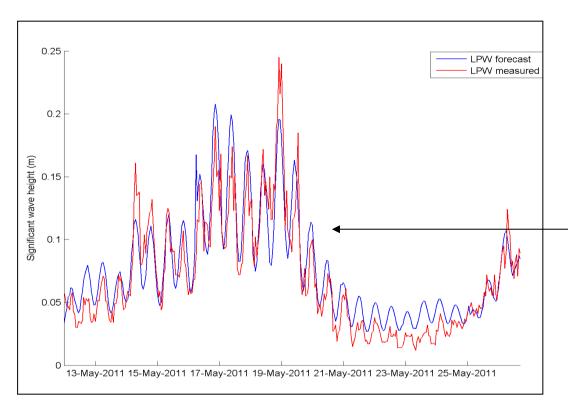
Measuring long waves

Co-temporal measurements

Modeling long waves

Swell waves

Long waves

Forecasting long waves

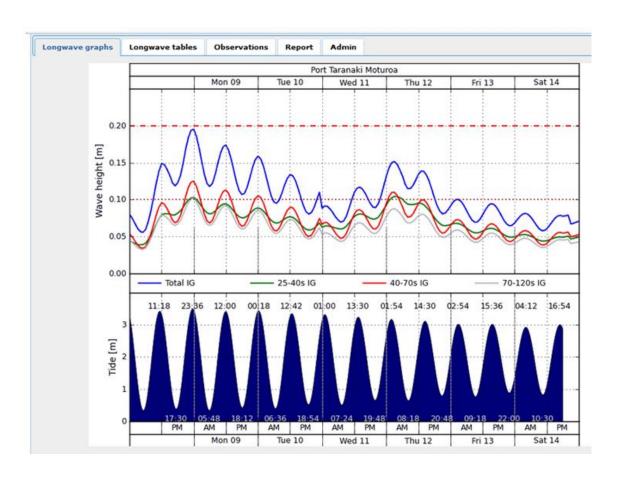Spectral wave forecasts are used to predict LPW height for specific berths:

- 1-3 months berth LPW data required for calibration
- Warning levels can be provided
- Forecast accuracy is similar to swell (5-7 days)
- Semi-empirical technique
- Includes tidal modulation

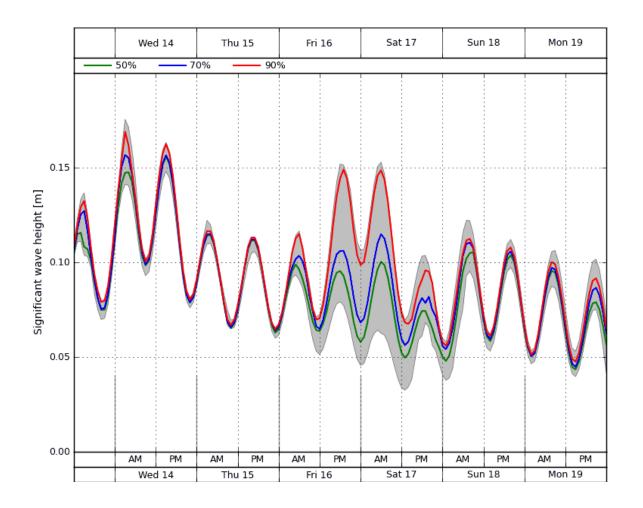Comparison of measured and forecast LPW

Forecasting long waves

Typical Long Wave safety thresholds:

<0.10 m — not usually a problem

0.10 m — first threshold of concern

0.10-0.15 m — management is recommended

0.15-0.20 m — management is required

>0.20 m — safety is compromised
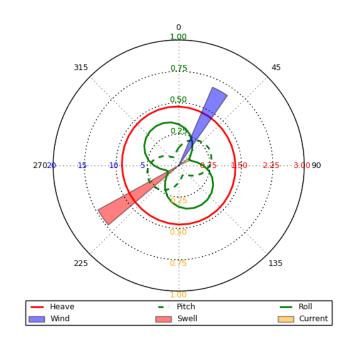

7-day forecast of Long waves
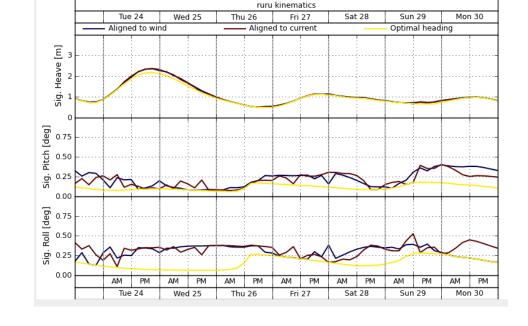
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Forecasting long wave uncertainty

Forecast of the long period waves inducing surge at a berth inside a harbour.

Forecasting complex things – vessel motion

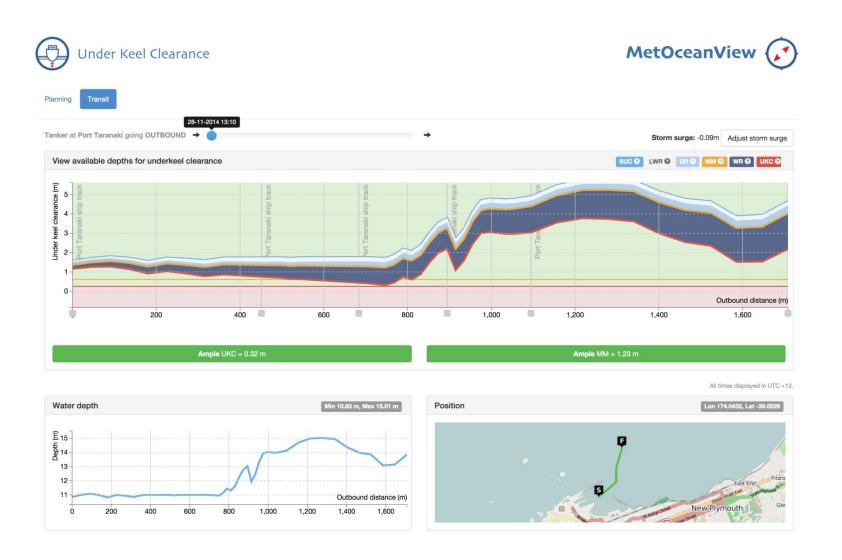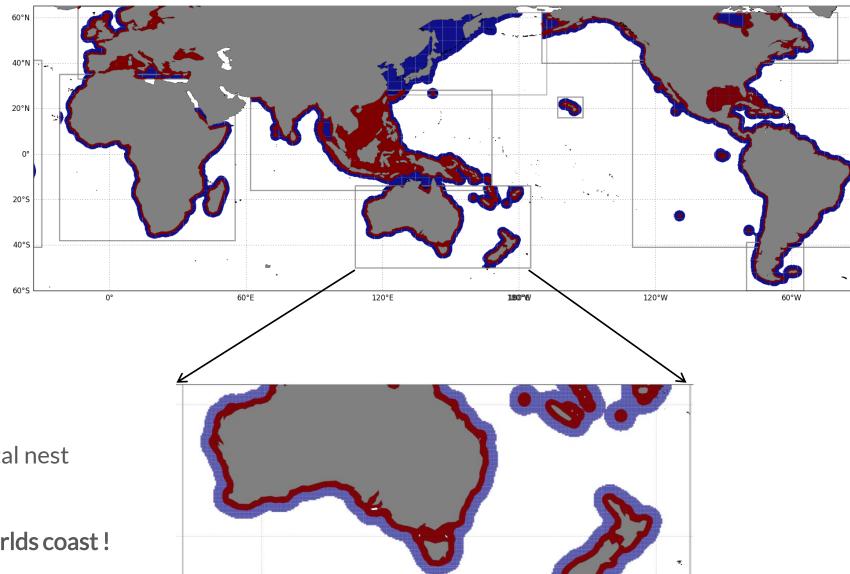Forecast 2D wave spectra convolved with RAO = motion forecast solutions

Heave/roll/pitch amplitude as a function of heading

Time series forecast of vessel motion

Forecasting something complex and making it simple
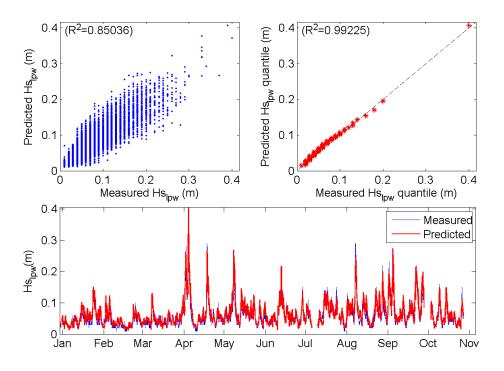

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The future ?

Multi-nested WW3 -

0.2 deg with a 0.05 deg coastal nest

5 km resolution for all the worlds coast !

The future ?

Port long waves predicted 330 minutes ahead from real time wave buoy data located 390 km away.

In summary

- Understand the governing physical processes

- Measure and monitor waves, winds, currents and tides

- Publish the data in real time to everyone

- Forecast the wave, winds and currents exactly where it is needed

- Educate the marine industry and give them tools

- **Create knowledge from data!**

Gracias