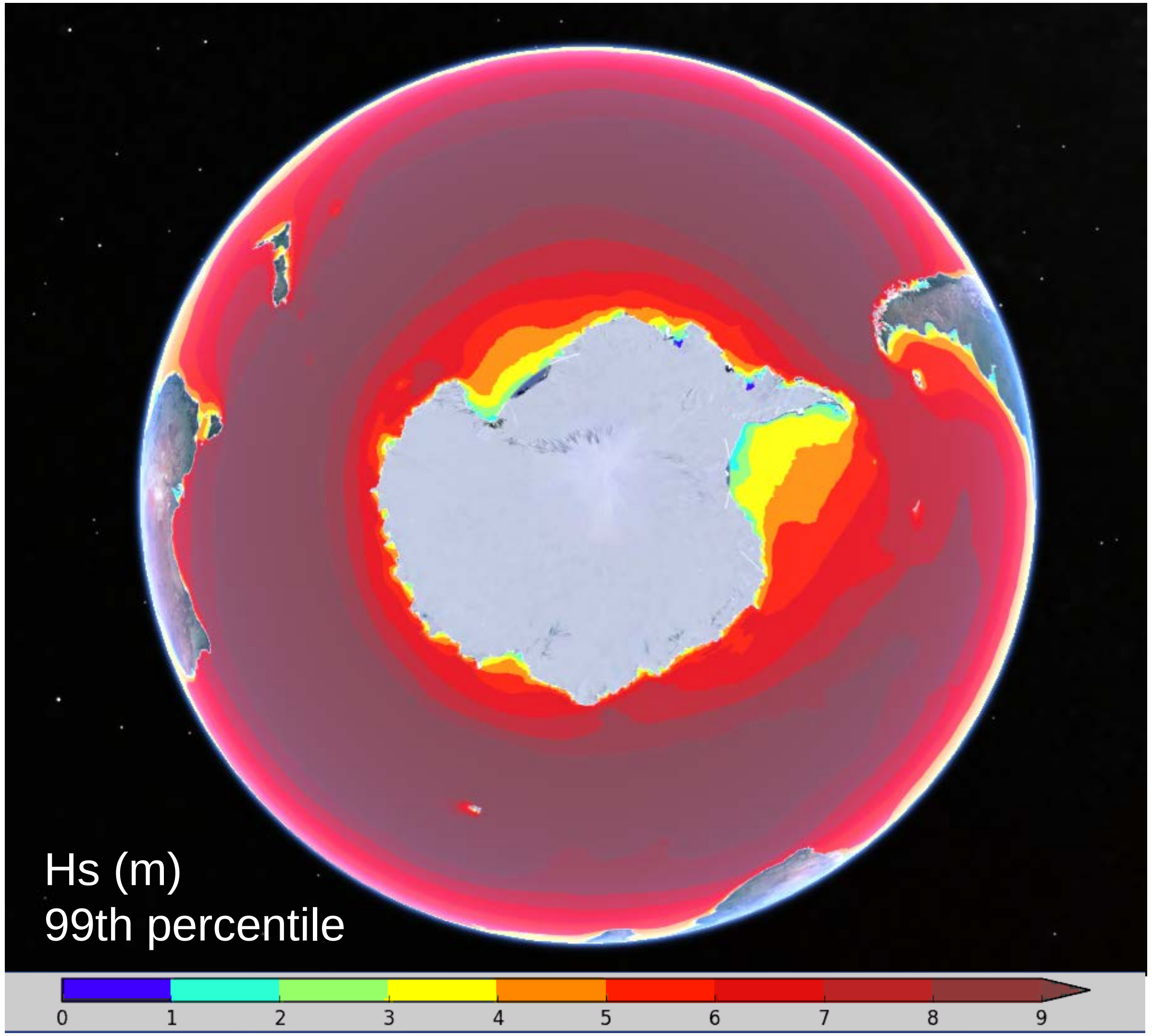
Long Period Waves

Peter McComb

Onda larga, long waves, IG, infragravity waves, LPW …

- What are LPW?
- How are LPW generated?
- What is the effect of LPW on moored ships?
- How do we measure LPW?
- Can we predict LPW and their effects?

NZ and Chile - we share the same ocean…



LPW cause ship motion

LPW cause ship motion

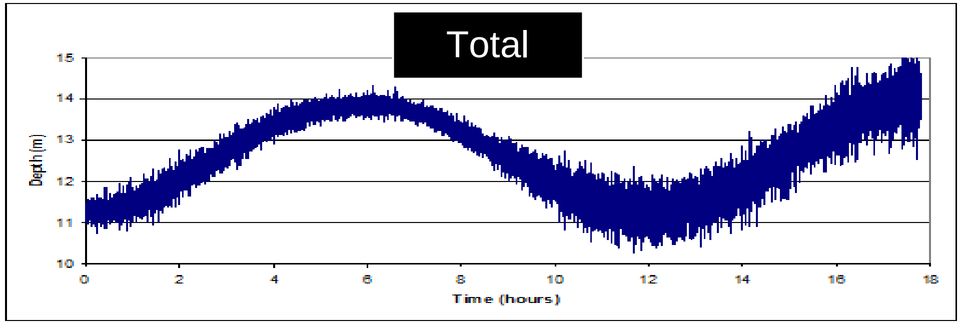
The effects can be catastrophic…

LPW dynamics in the 1990s…

Port Taranaki, New Zealand

Analysis of LPW

(a)



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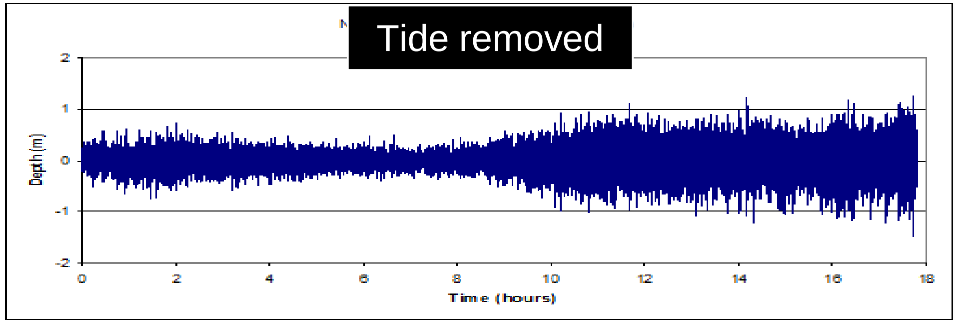

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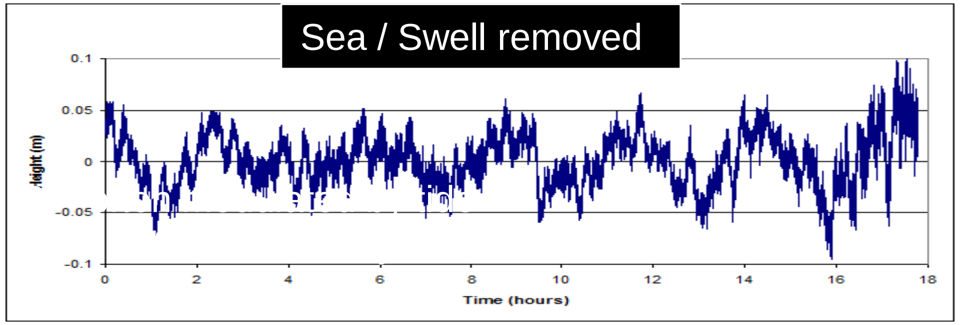

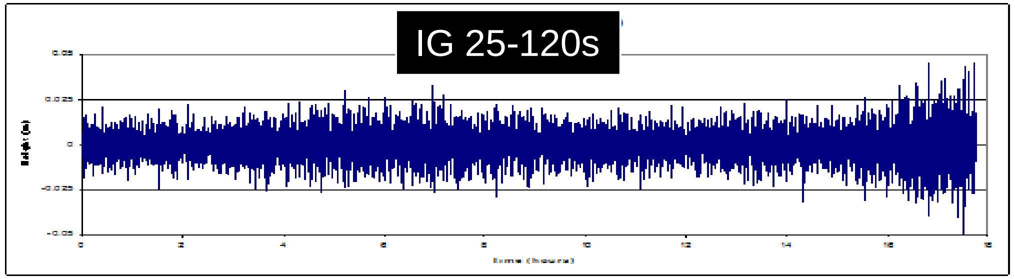

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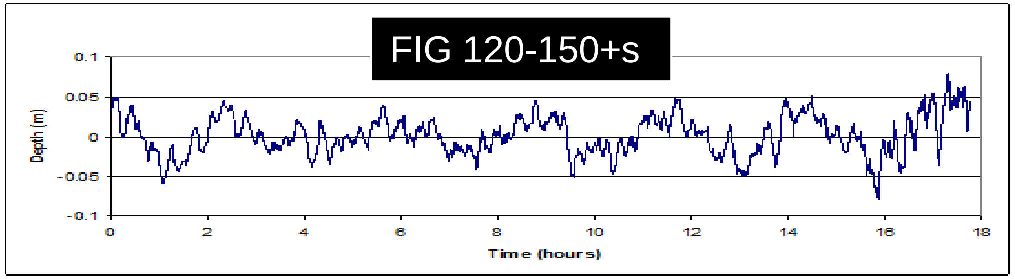

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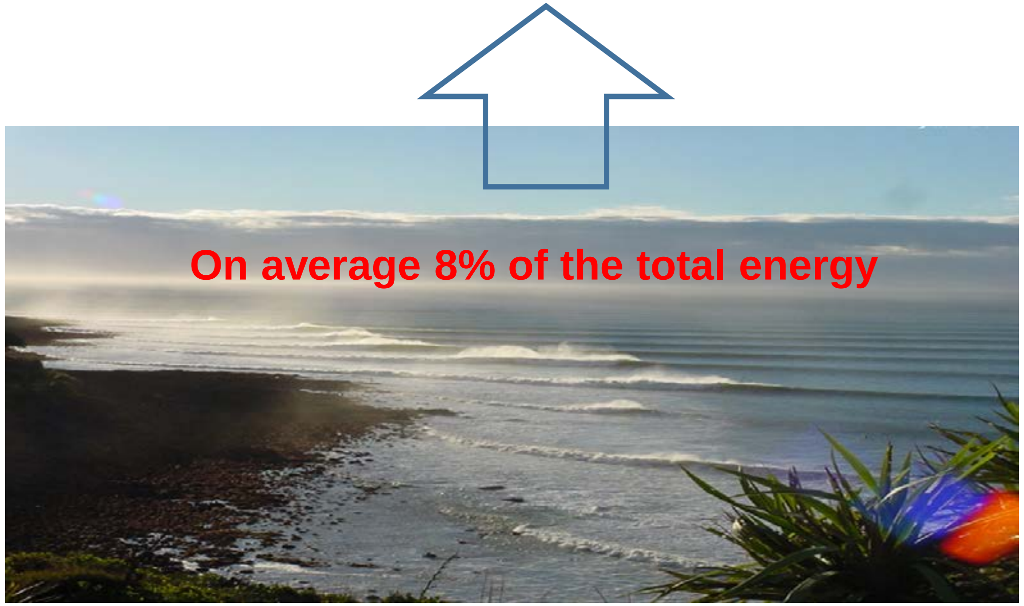
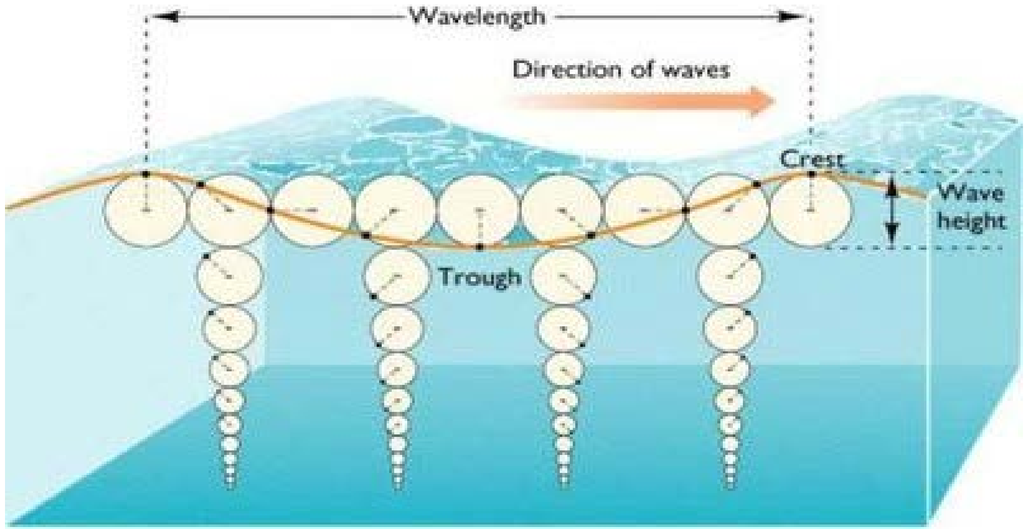


Analysis of LPW

$$E_p = \frac{1}{L}\int_0^L \int_0^\eta \rho g\, z\, dz\, dx$$

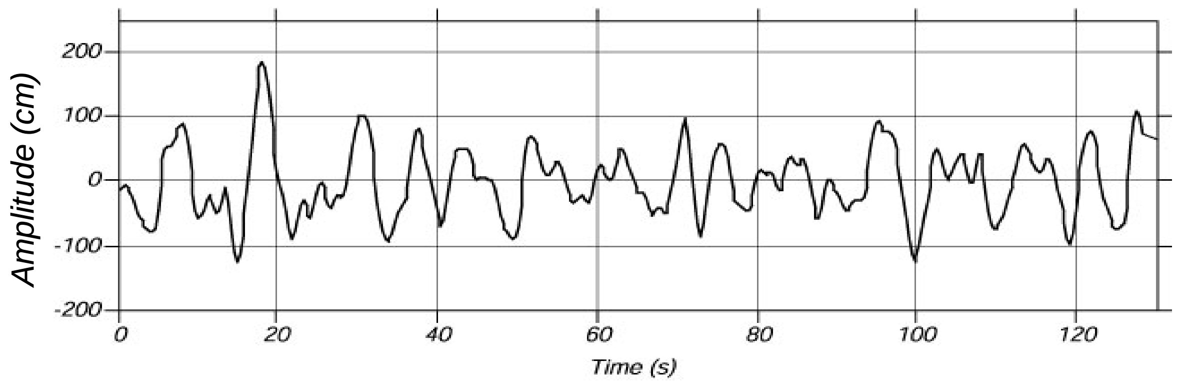
$$E_k = \frac{1}{L}\int_0^L \int_{-h}^\eta \frac{1}{2}\rho\left(w^2 + u^2\right) . dz\, dx$$

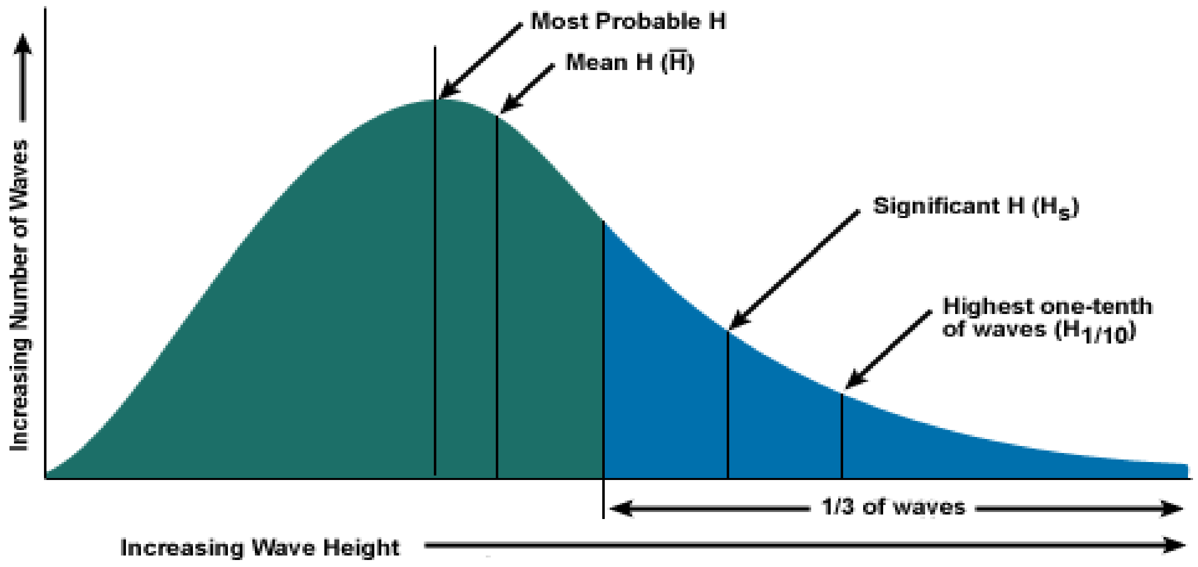
$$E_t = E_p + E_k = \frac{1}{8}\rho g H^2$$



Analysis of LPW

- Irregular ocean waves are usually well-represented by a Raleigh distribution.
- Need to sample ~100 waves to develop reliable statistics.
- Use time domain or frequency domain analysis.
- Is this appropriate for LPW?

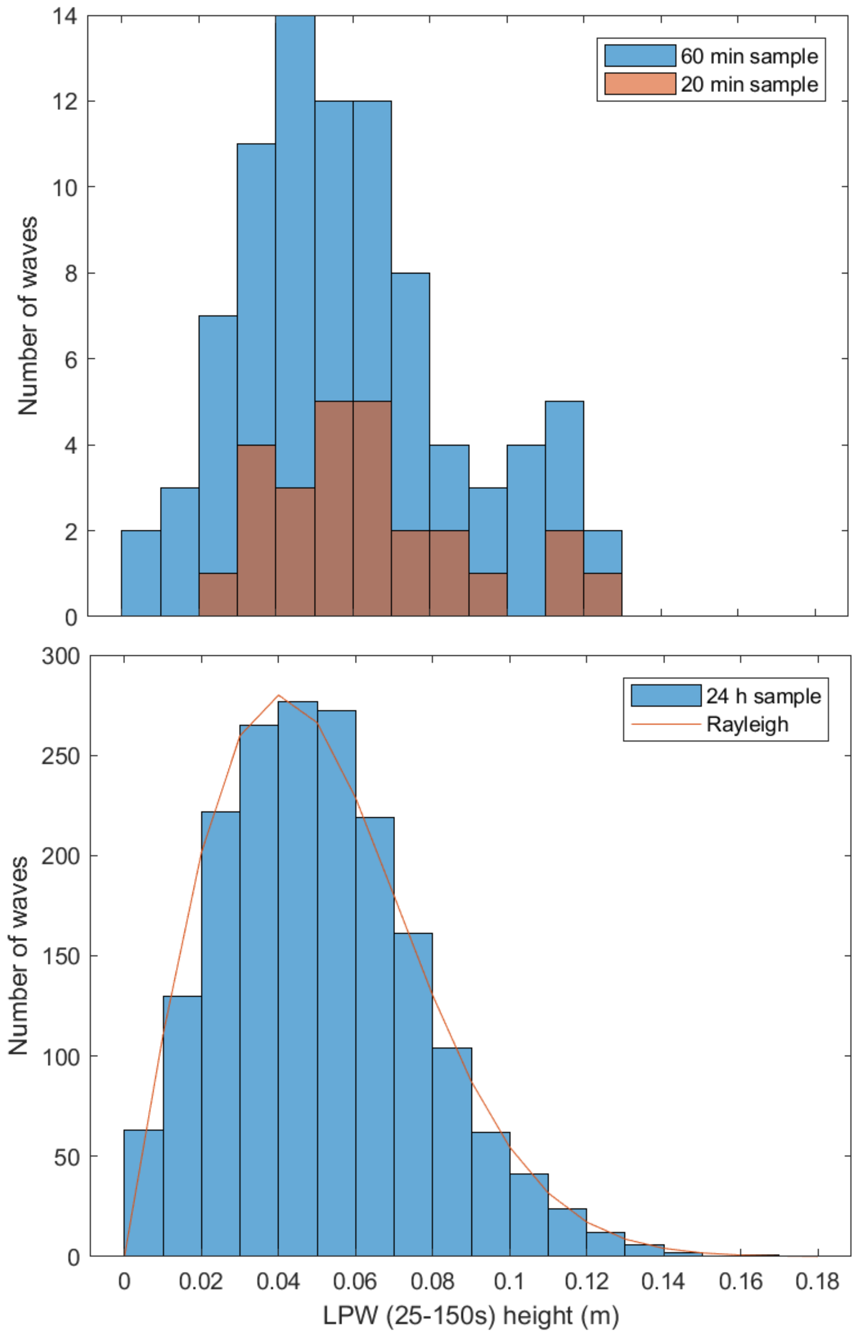




Analysis of LPW

Analysis of LPW

- Studied >35 locations worldwide.
- A 20 minute sample does not give reliable Hs.
- Hs is better resolved from 60 minute sample.
- Use zdc instead of spectral *m0* to derive Hs.



Two kinds of LPW – IG and FIG

IG waves – affect ships

- Are released in the surf zone
- Decay with distance offshore
- Have a broad range of periods (centre 40-50s)
- Often modulated by tide
- Correlate to Hs (T>8s)^{a} x Tp^{b}

IG <120s

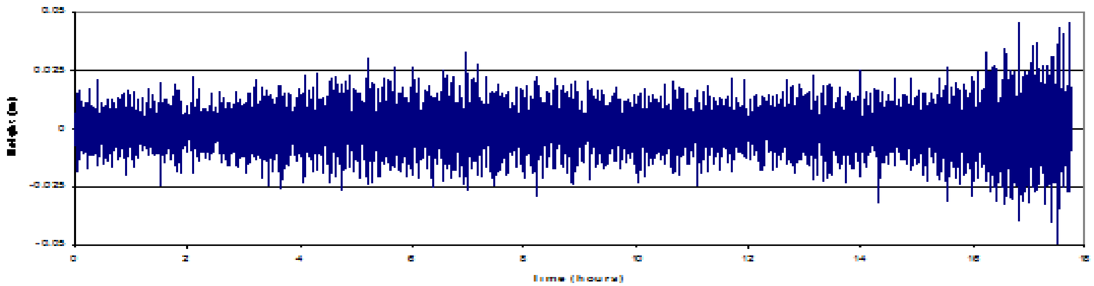


FIG waves – don't affect ships

- Initially bound to the wave group
- Found in swell-dominated climates
- No decay in ~20 m depth range
- No tidal modulation, highly variable periods
- Correlate to Hs (T>8s)^{a} x Sw^{b}

FIG >150s

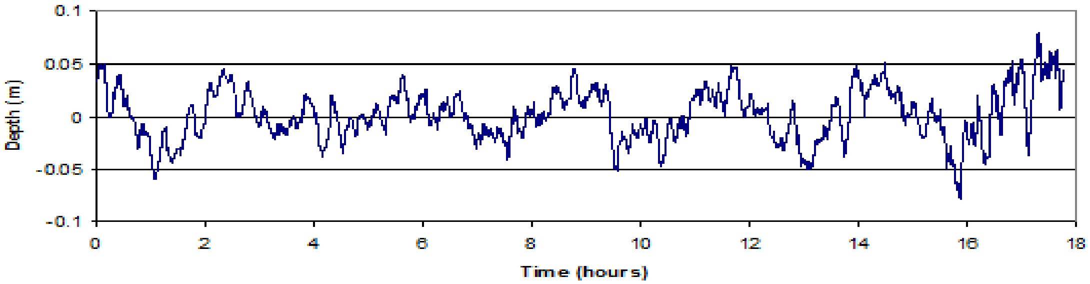
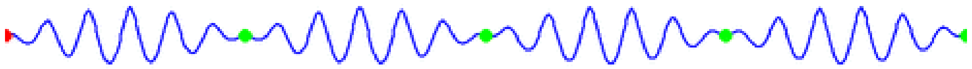


FIG and IG waves are not always co-linear with the swell wave direction.

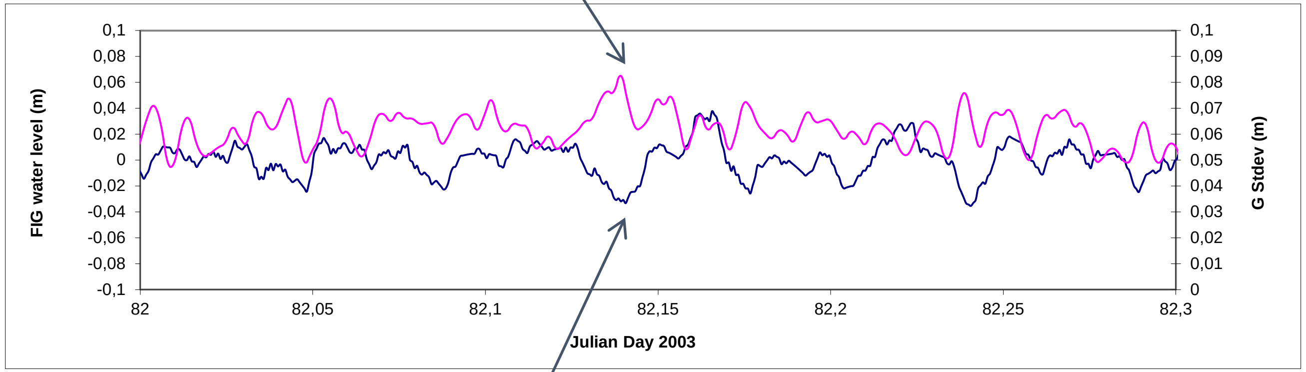
More about FIG

Swell wave groups generate FIG long waves



Time-series correlation of FIG to wave groups

Group of large waves



Trough of FIG wave

- FIG are created by the modulation of wave energy into ‘sets’.
- Can be correlated to swell wave spectral shape.

LPW that affect ships

IG waves – affect ships

- Periods of <150s
- Released in the surf zone by swell waves
- Decay with distance offshore
- Have a broad range of periods (centre 40-50s)
- Often modulated by tide
- Correlate to $Hs\ (T>8s)^a \times Tp^b$
- Can define the transformation from outside the port to a berth inside the port.

LPW transformation by a semi-empirical equation

Relationship of the offshore wave spectra to the port LPW heights (non-tidal).

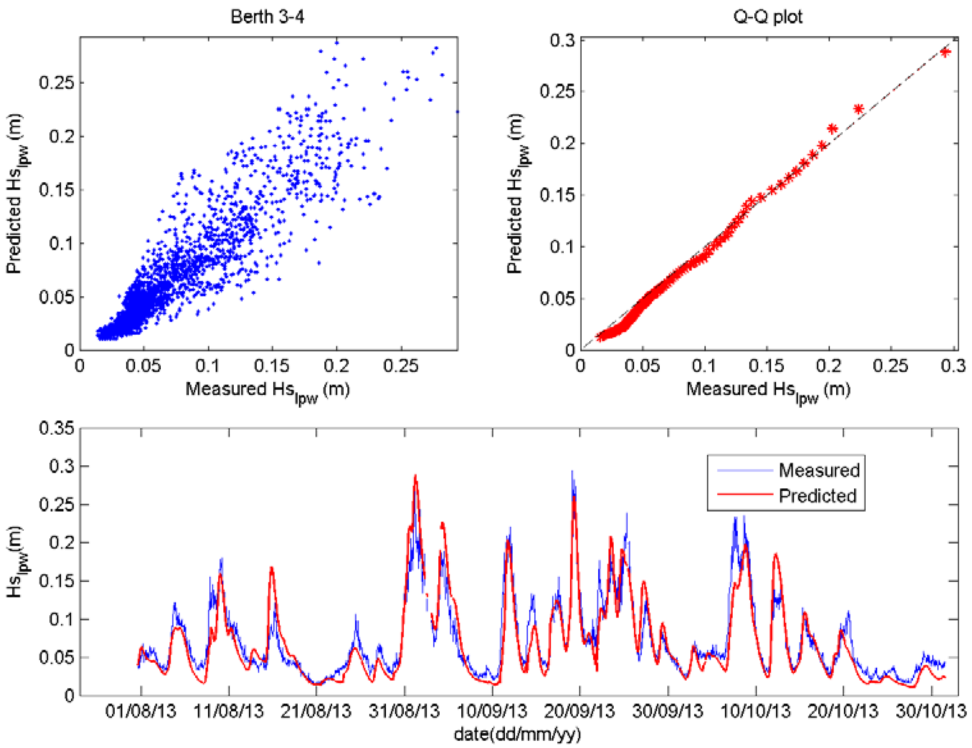
$$H_{s\ LPW(res)} = m\left[H_{s(swell)}{}^{\alpha}\ T_{p(swell)}{}^{\beta}\right] + C$$

with the effect of tidal modulation being expressed by:

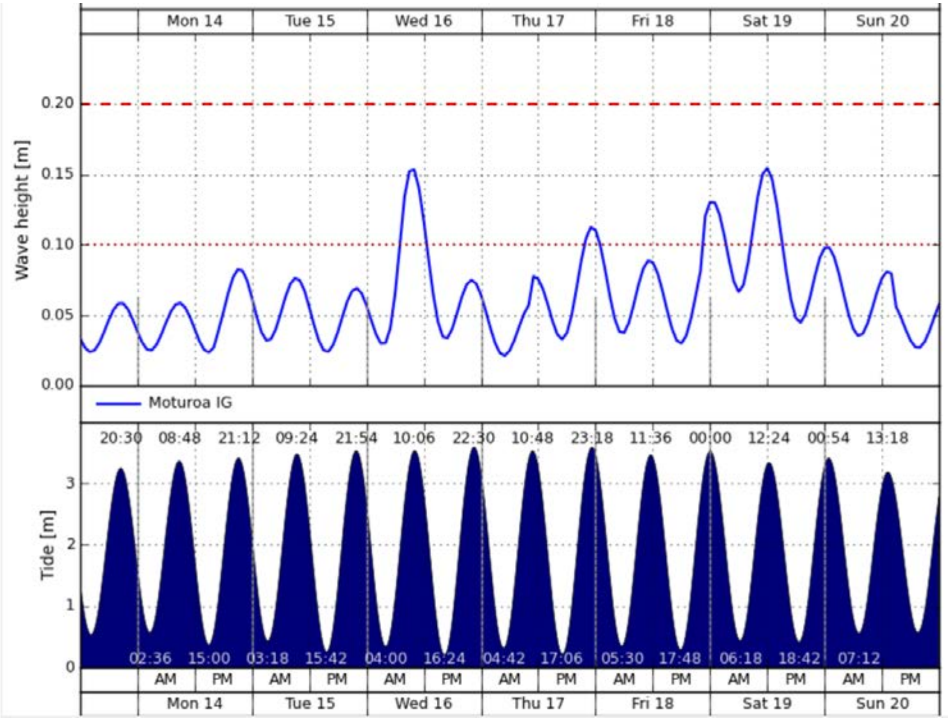
$$H_{s\ LPW} = H_{s\ LPW(res)}\,yh$$

A fitting regime is used to solve these 6 parameters.

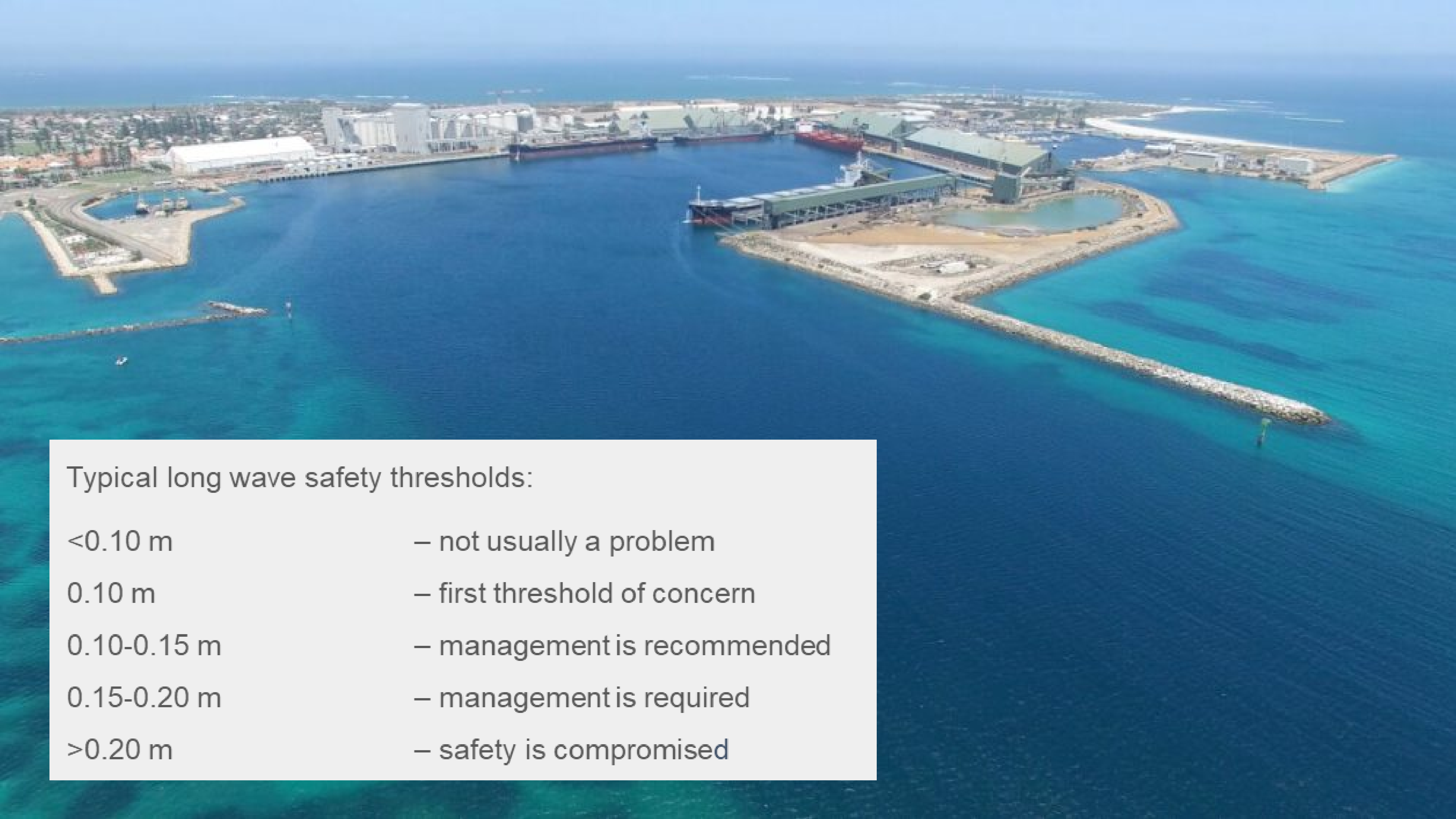
LPW berth forecasting for NZ and Australian ports since 2005



Step 1 - Collect some data and tune the equations



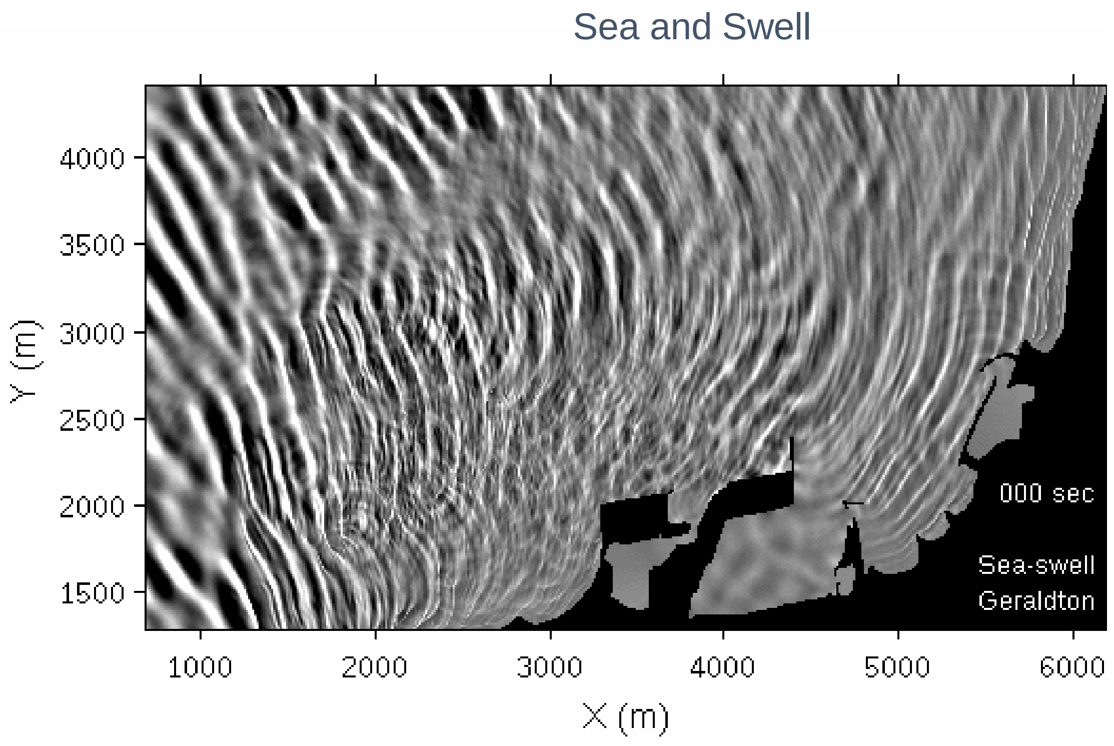
Step 2 - Produce operational forecasts for a berth



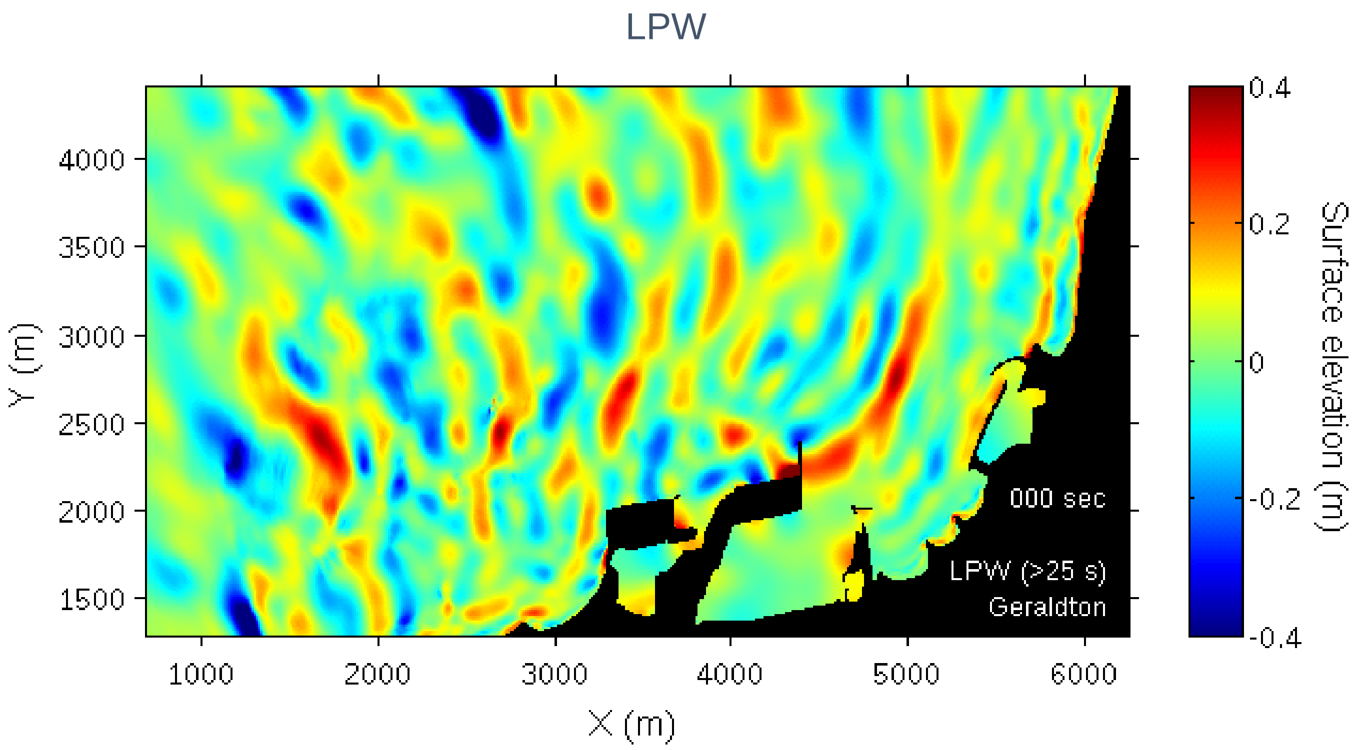
Typical long wave safety thresholds:

<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

What are LPW?

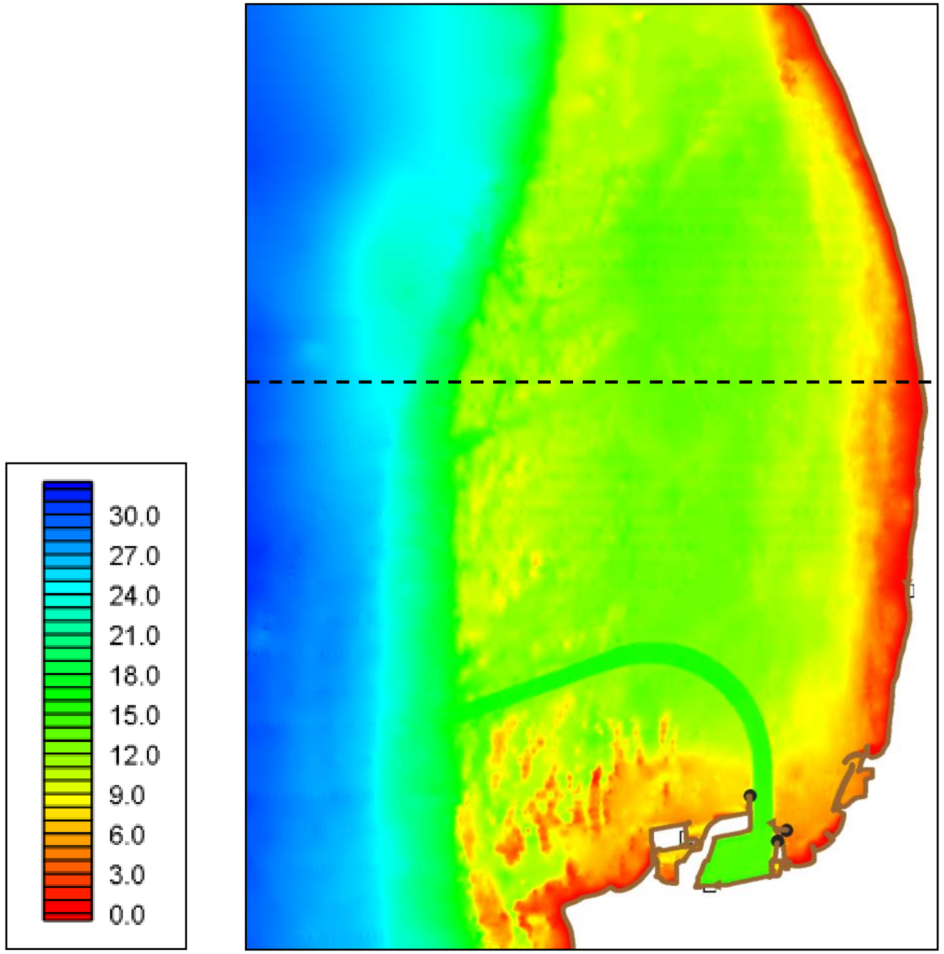


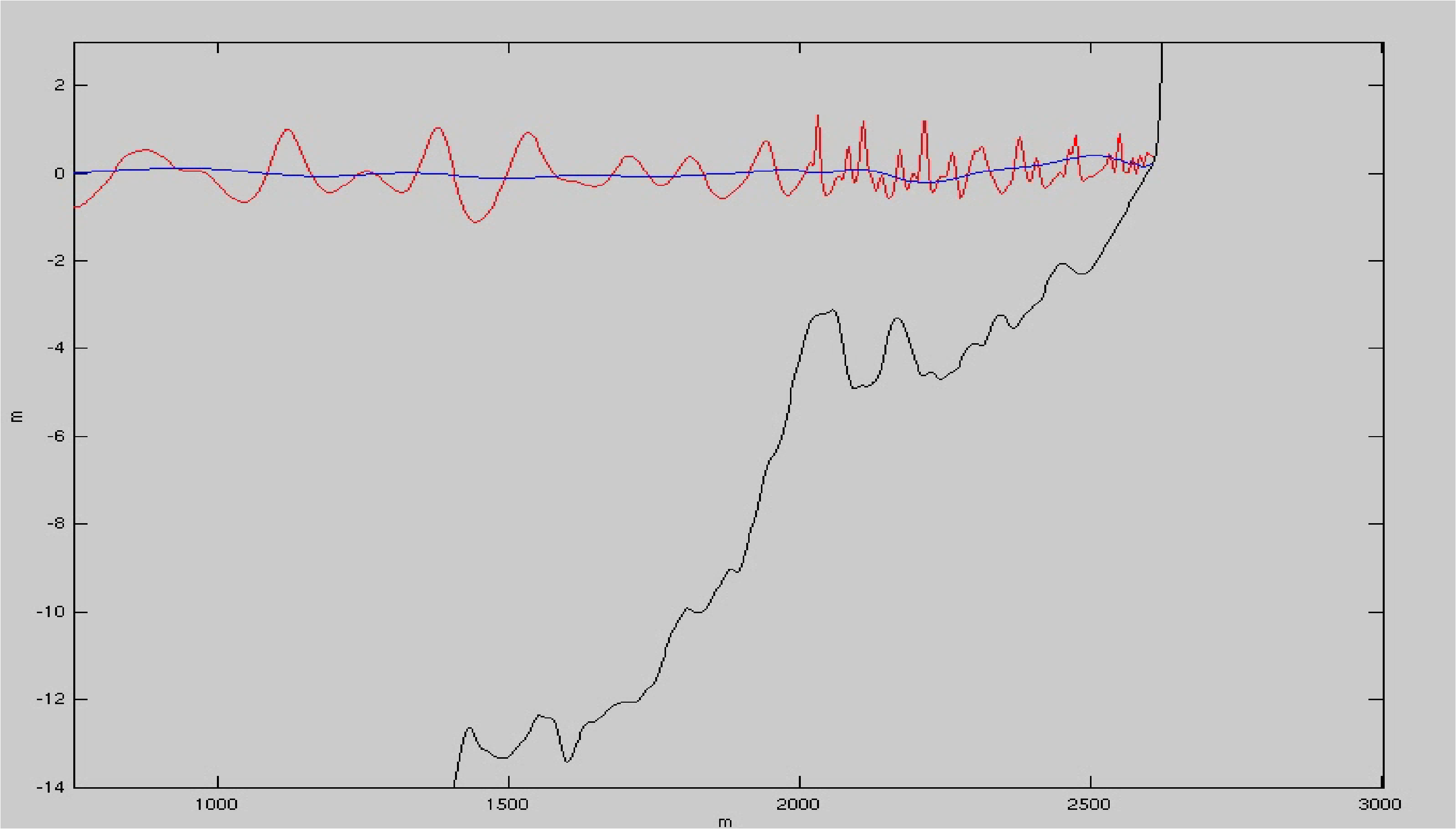
Sea and Swell
Y (m)
X (m)
000 sec
Sea-swell
Geraldton



LPW
Y (m)
X (m)
000 sec
LPW (>25 s)
Geraldton
Surface elevation (m)

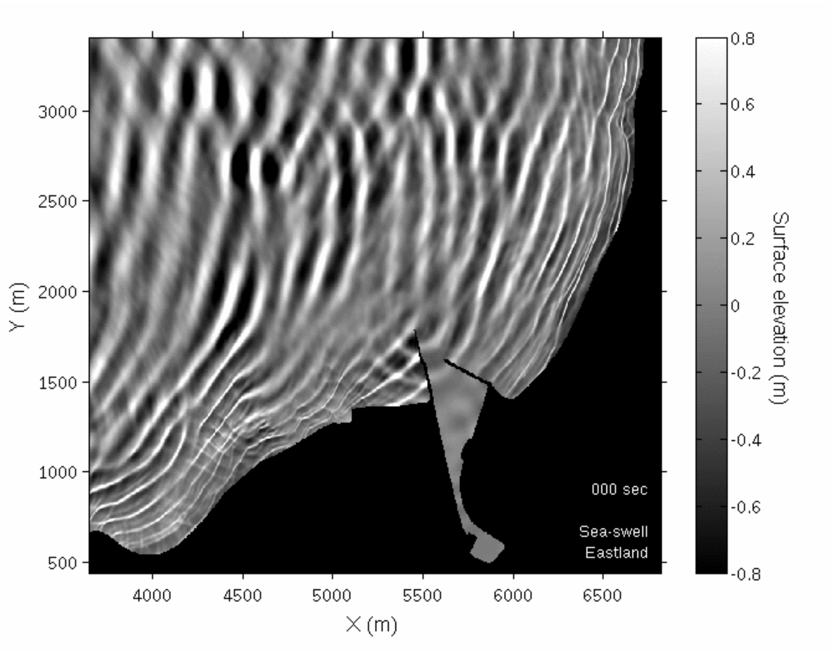
What are LPW?



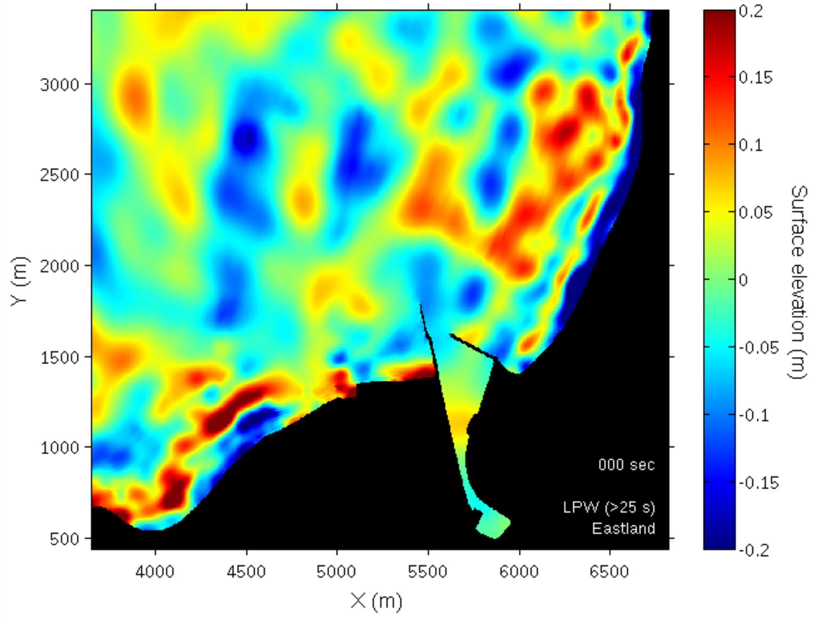


Red = swell
Blue = LPW

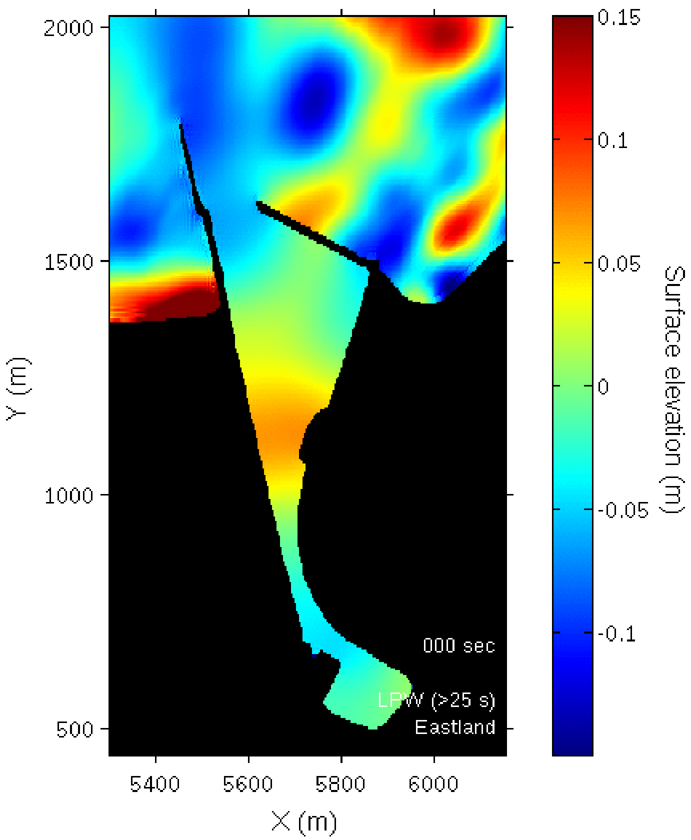
What are LPW?



Sea and Swell



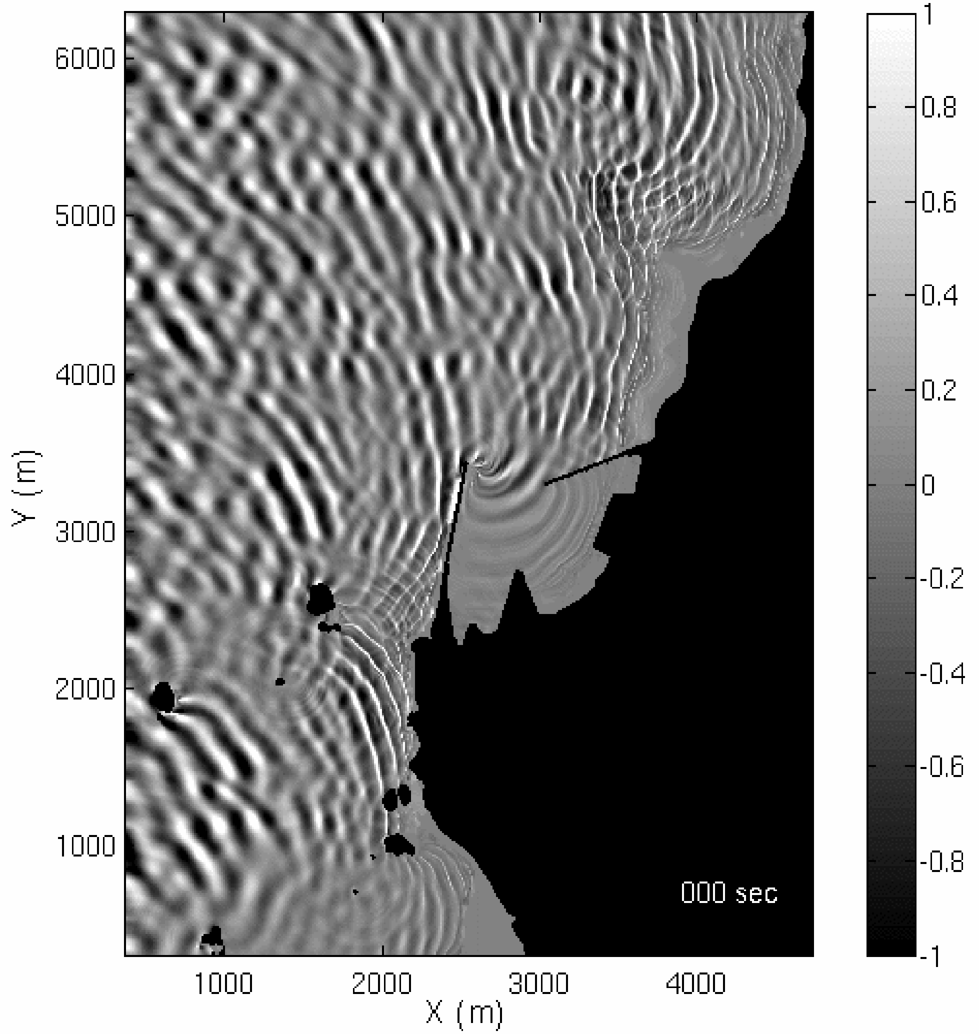
LPW



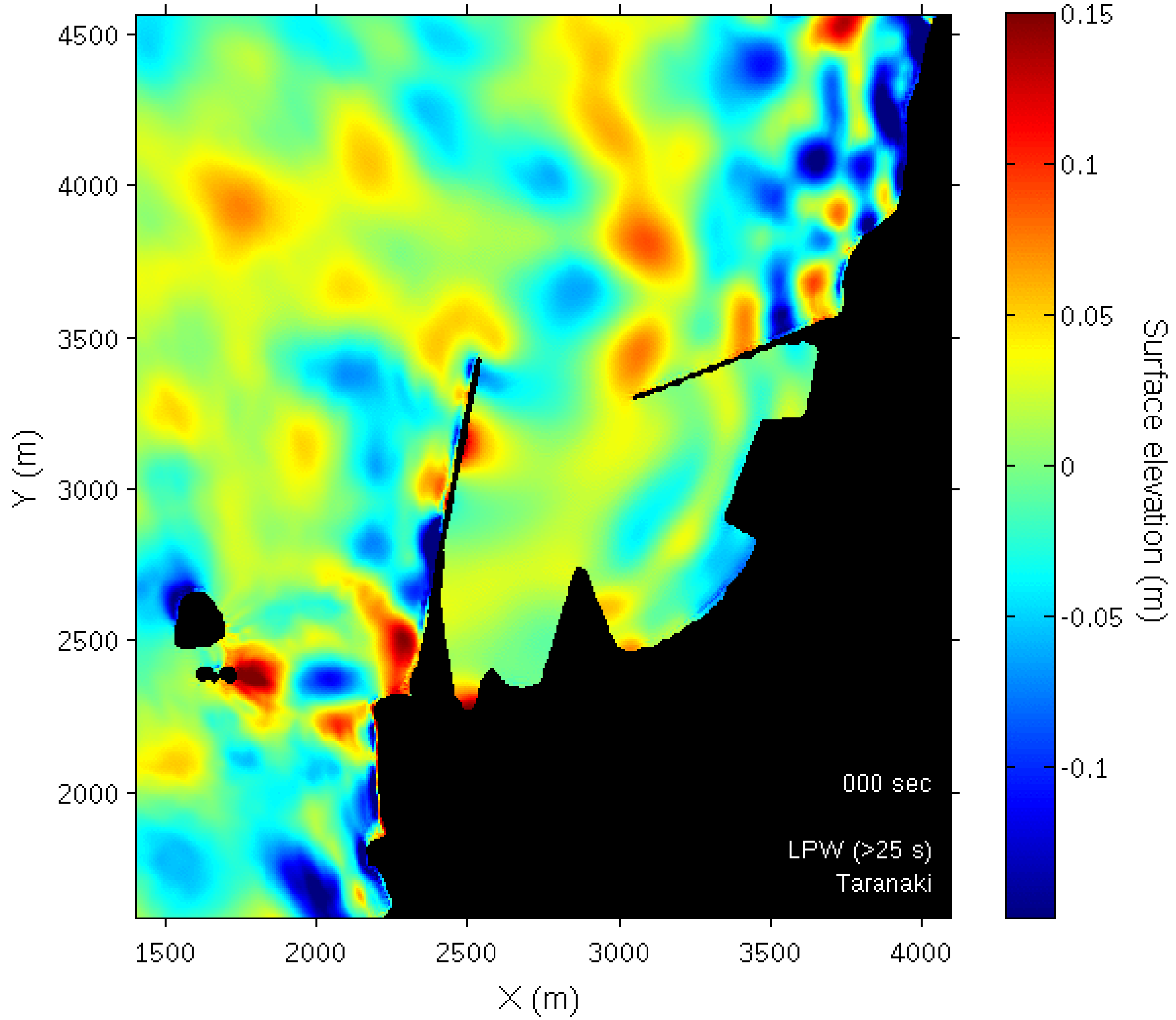
LPW

What are LPW?

Sea and Swell



LPW



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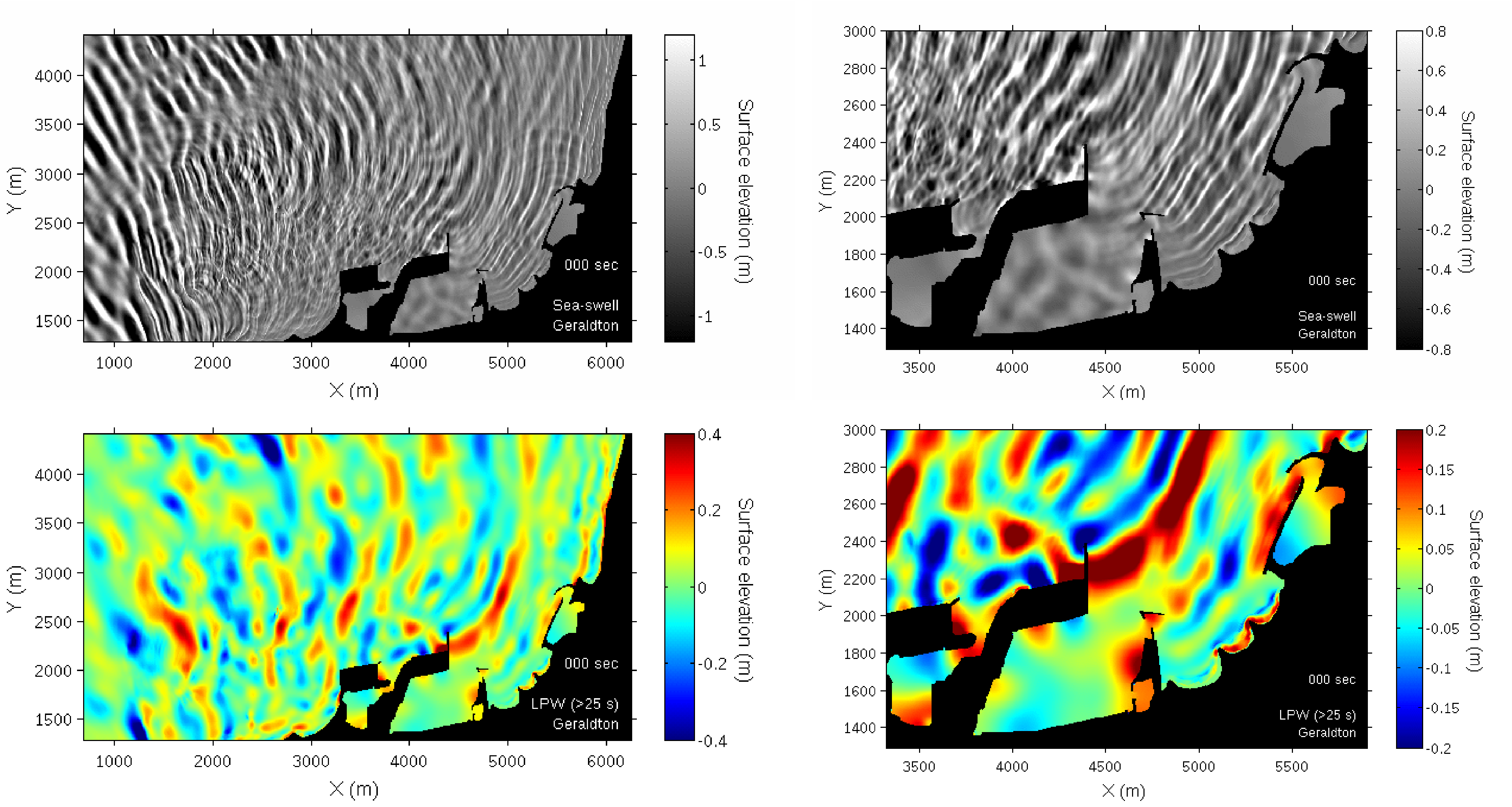
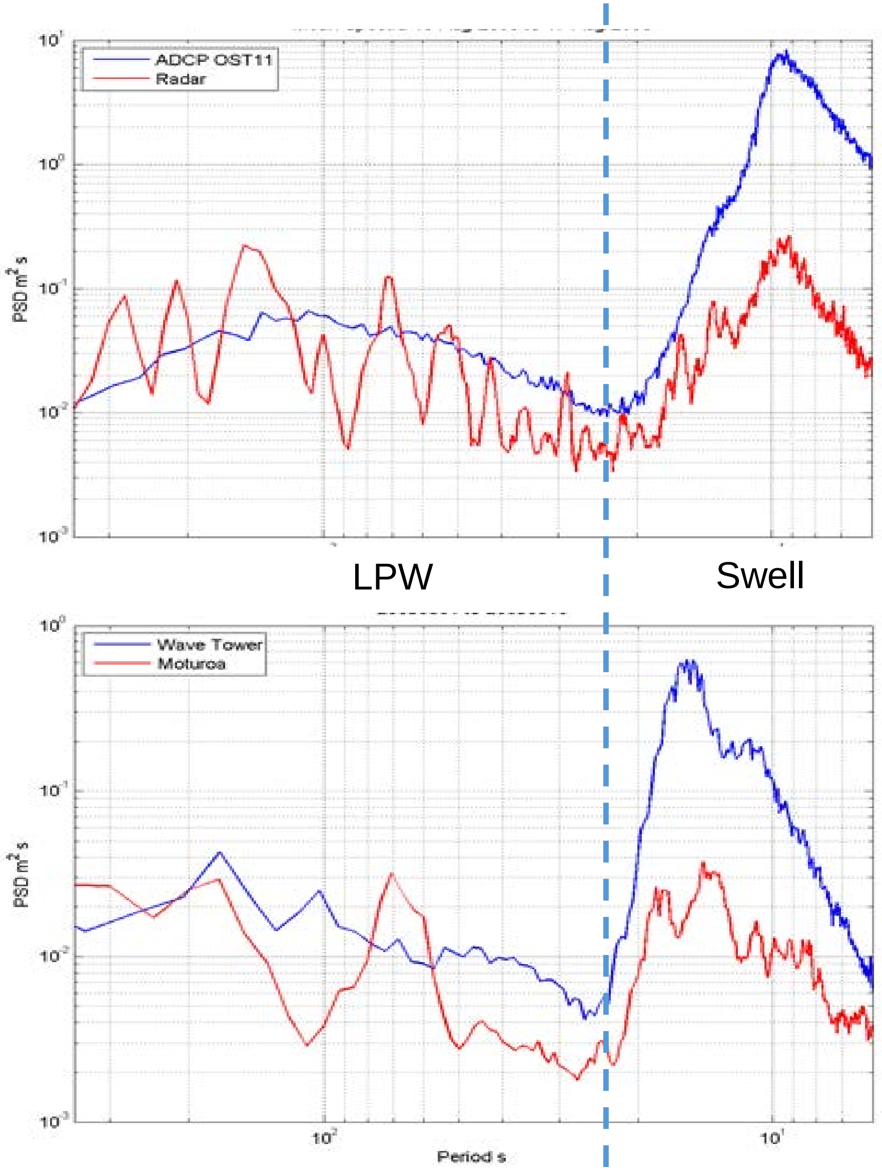


Sea and Swell

LPW

LPW reflected wave dynamics

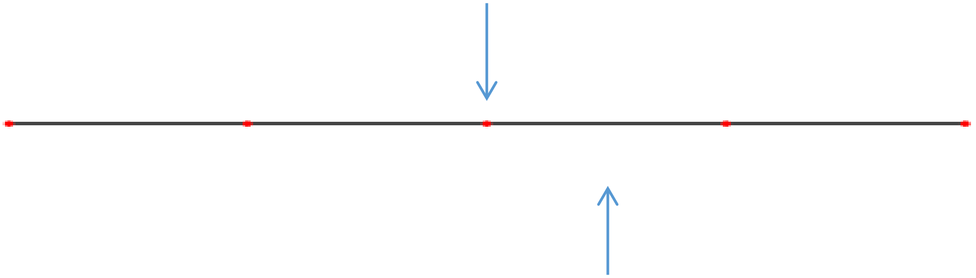
Red = inside
Blue = outside



Port Salalah, Oman

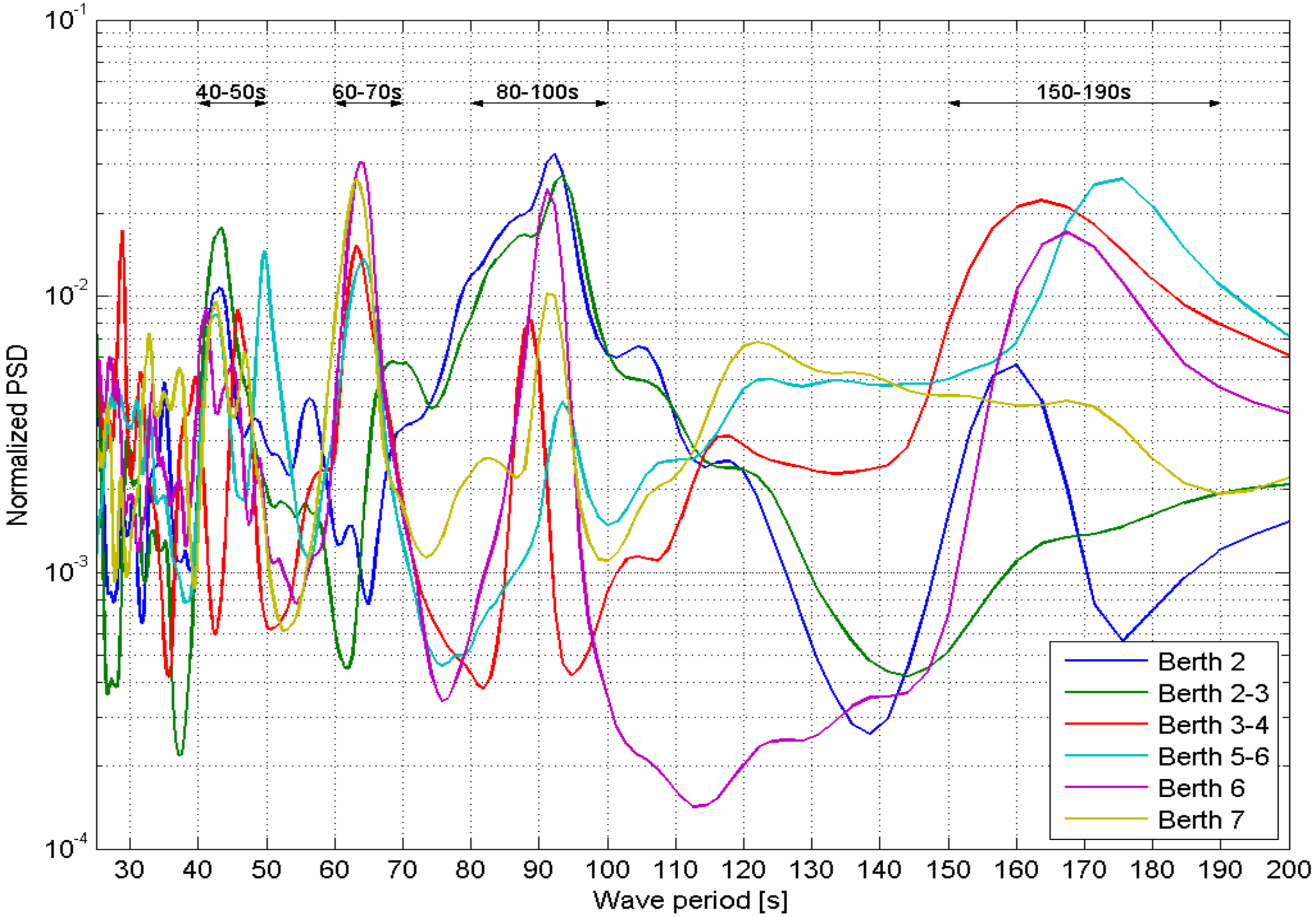
Port Taranaki, New Zealand

LPW reflected wave dynamics

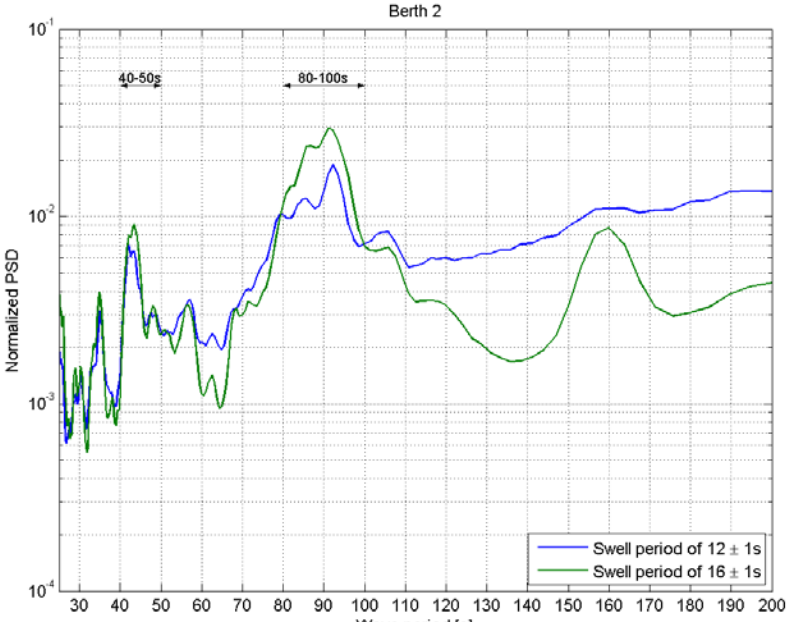


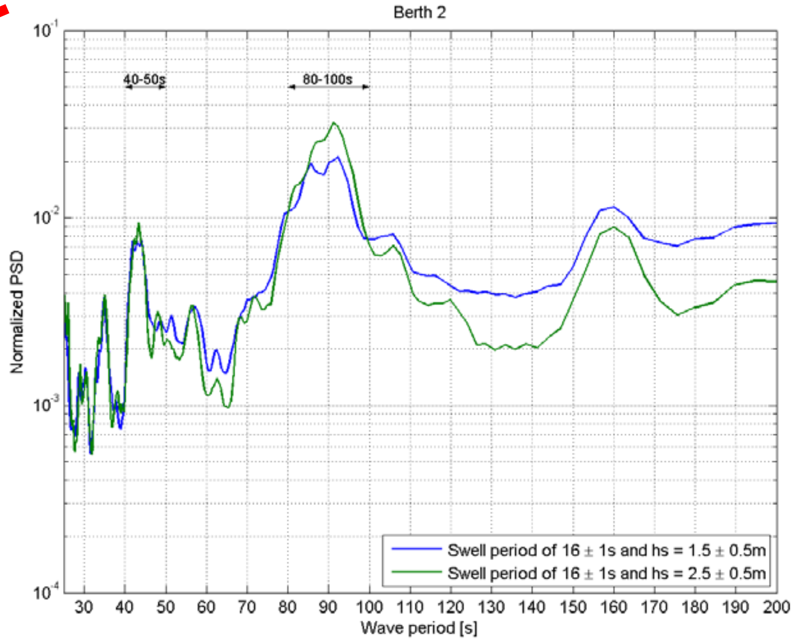
Where you measure LPW is very important

LPW reflected wave dynamics

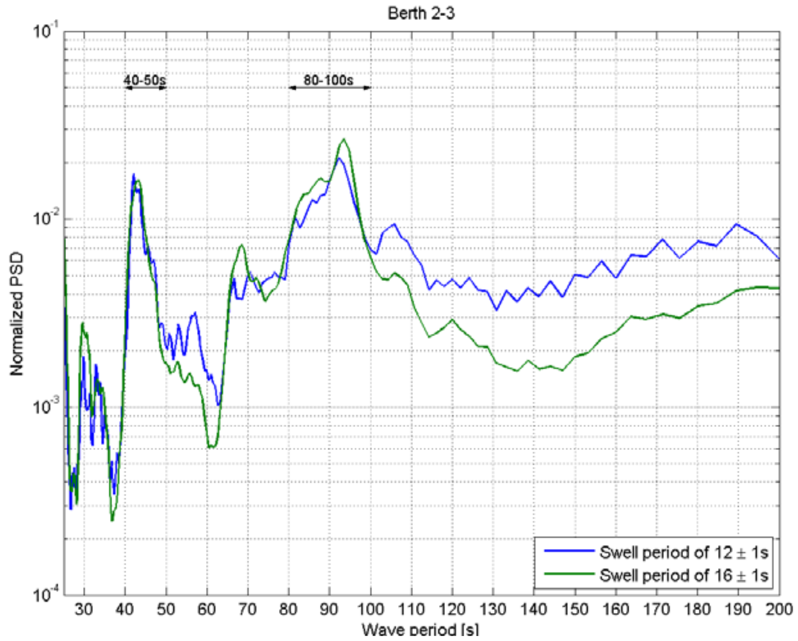


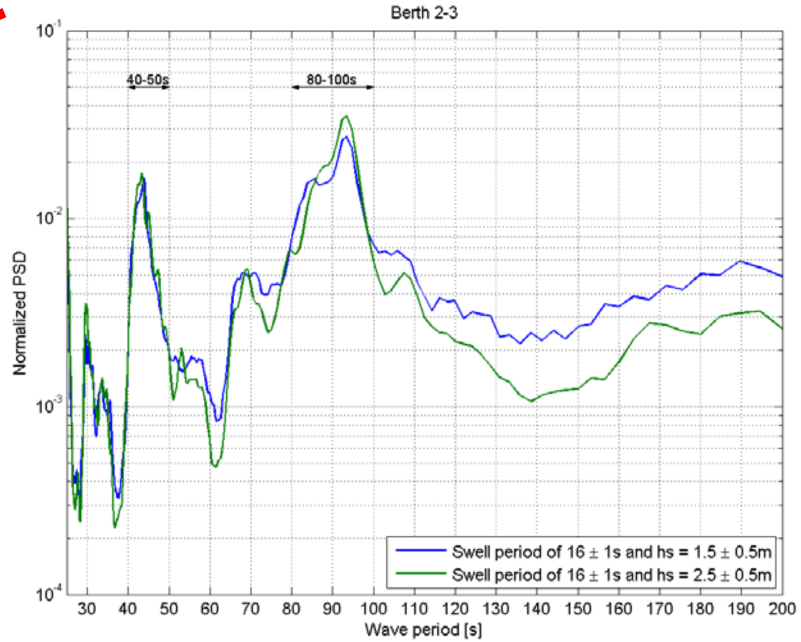
LPW reflected wave dynamics



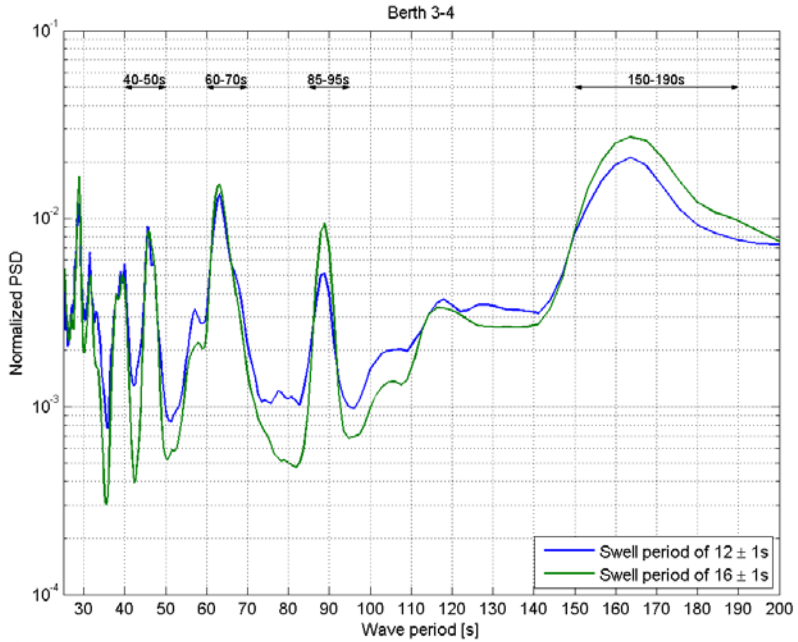


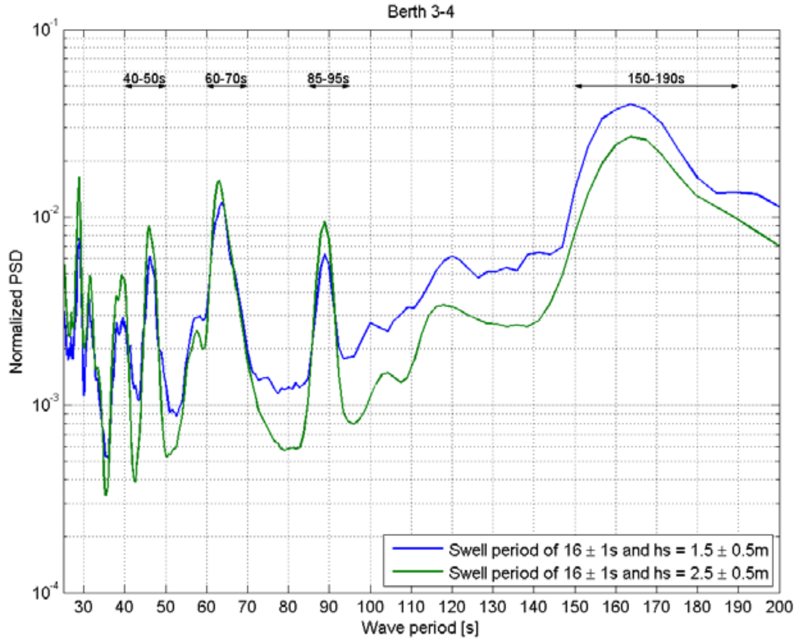
LPW reflected wave dynamics



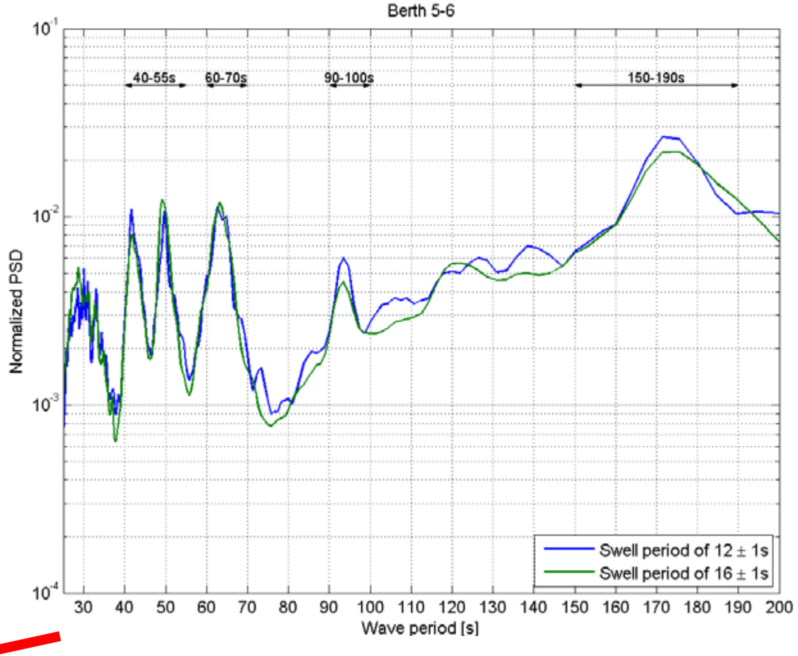


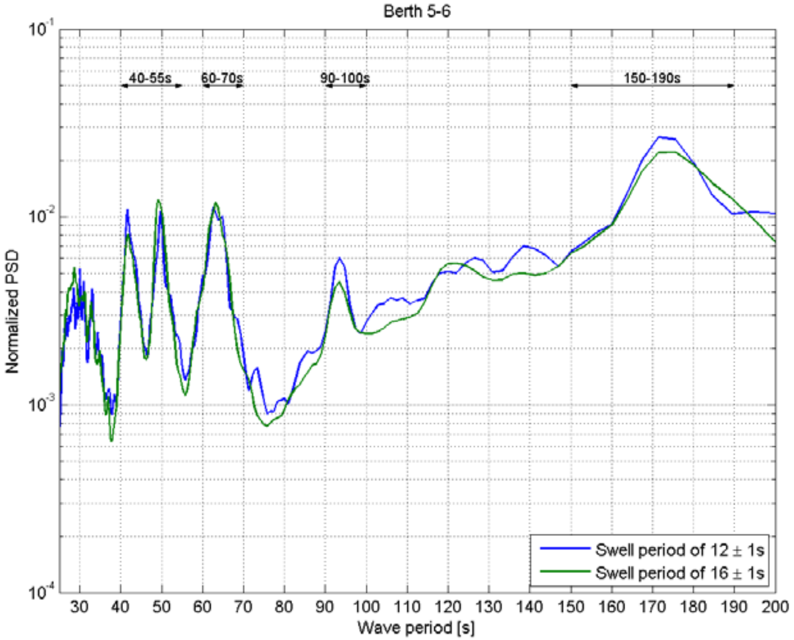
LPW reflected wave dynamics



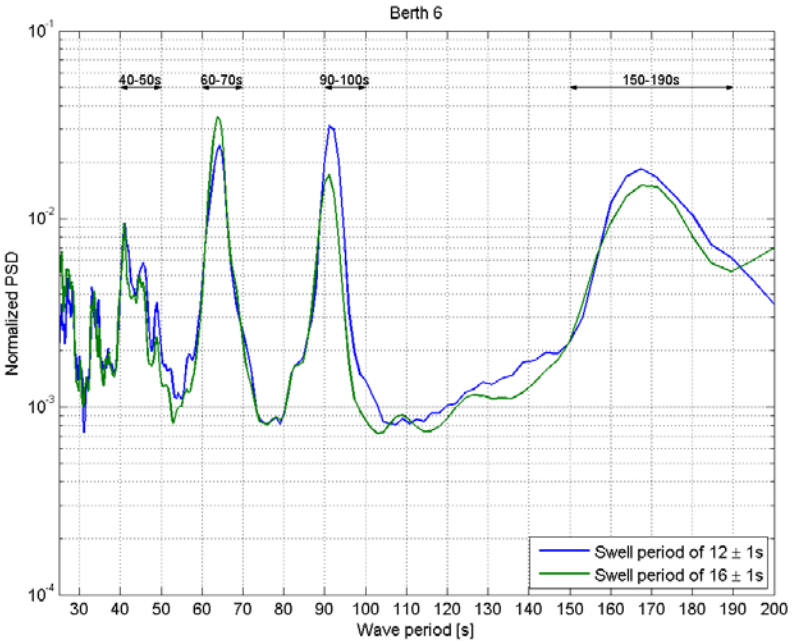


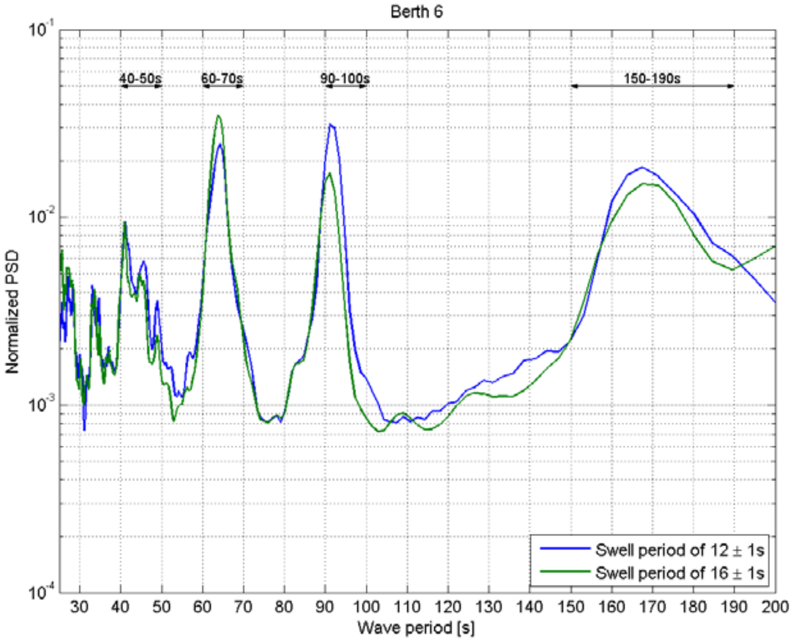
LPW reflected wave dynamics



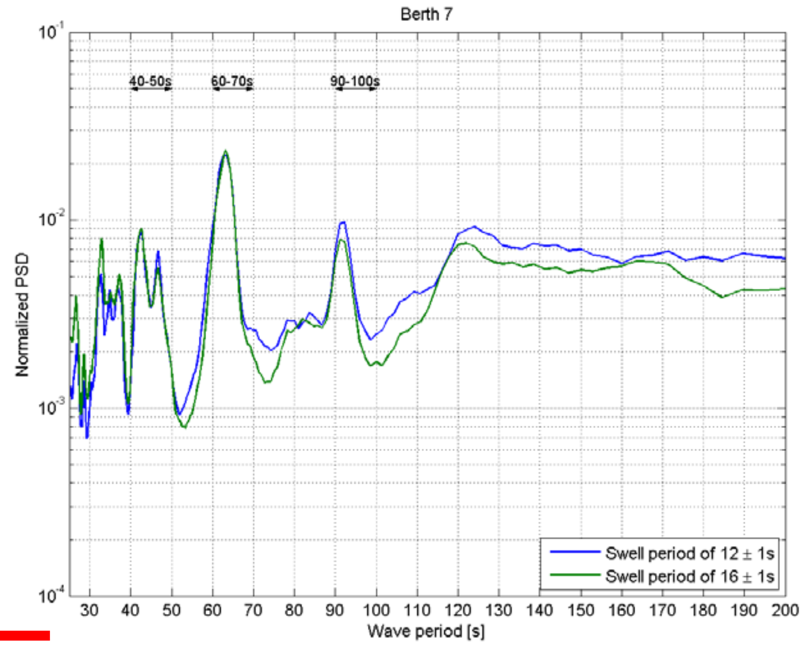


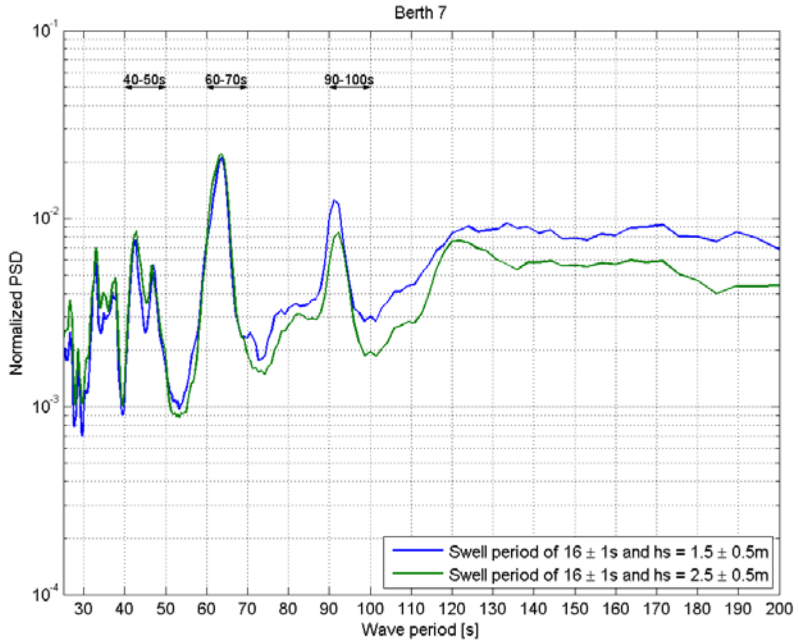
LPW reflected wave dynamics





LPW reflected wave dynamics





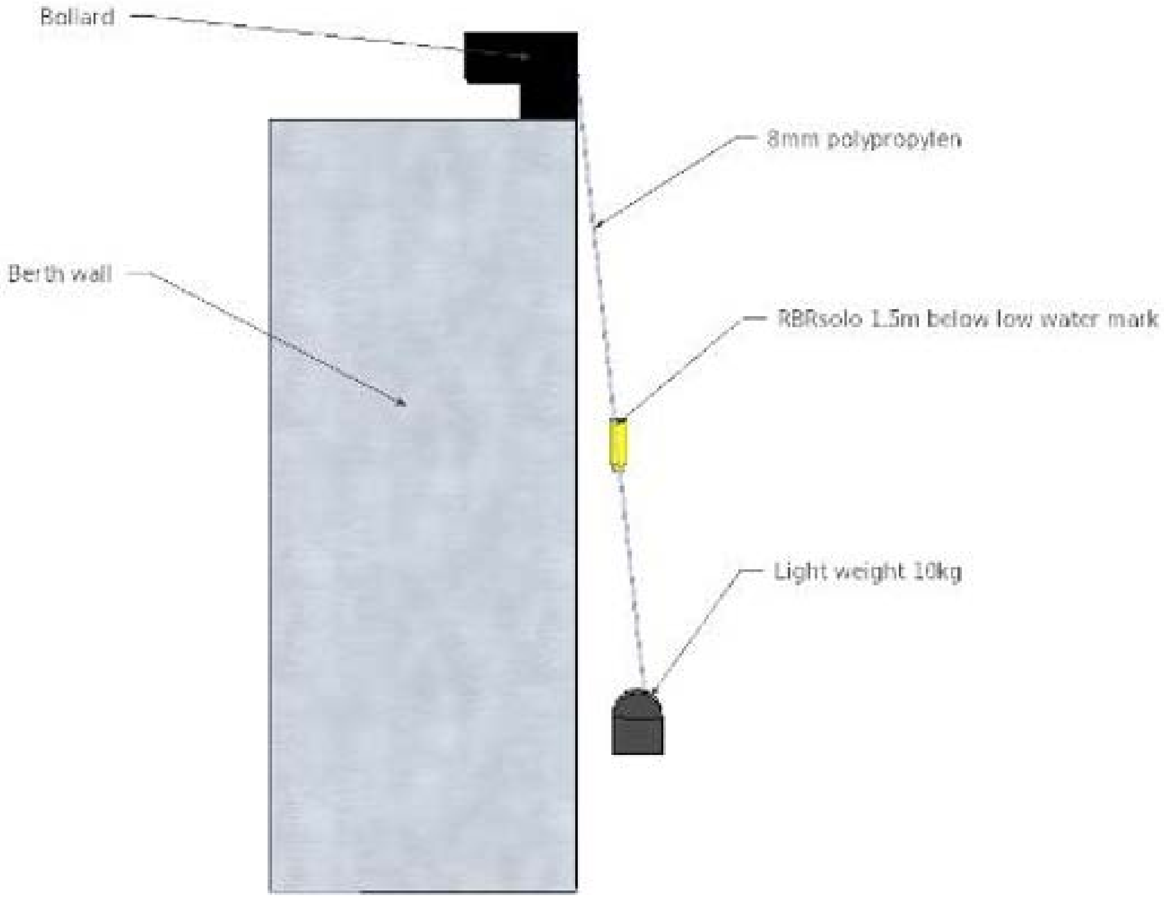
LPW dynamics

- LPW outside the port have a broad range of periods (peak 40-50s).
- Once LPW are inside a port they reflect off the internal walls.
- This creates energy peaks at certain frequencies.
- These energy peaks change with location and along each berth.
- However, the energy peaks don’t change with different swell conditions.
- This means we can create a robust characterisation and prediction system.

Measuring LPW

Co-temporal

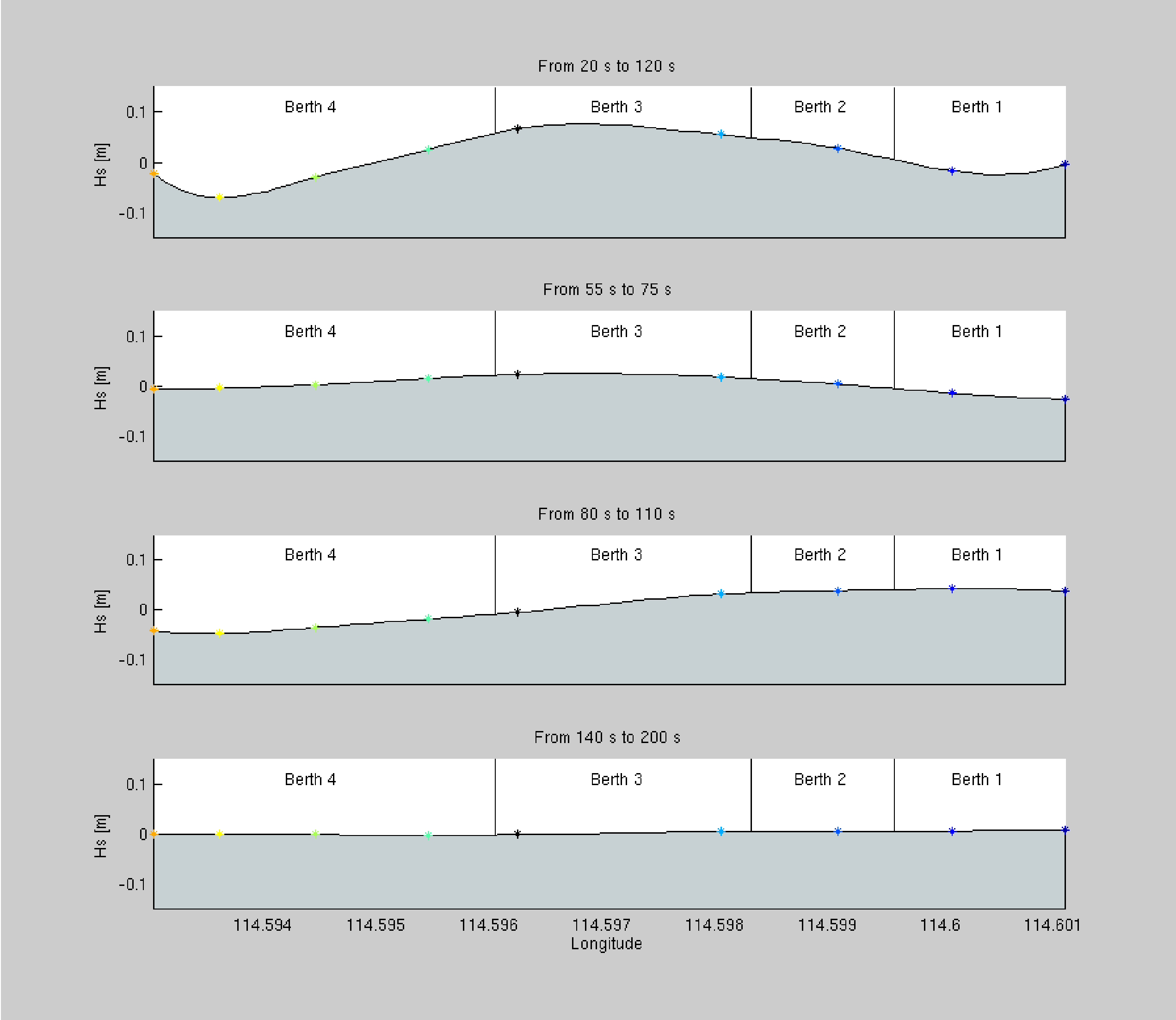
measurements



Measuring LPW

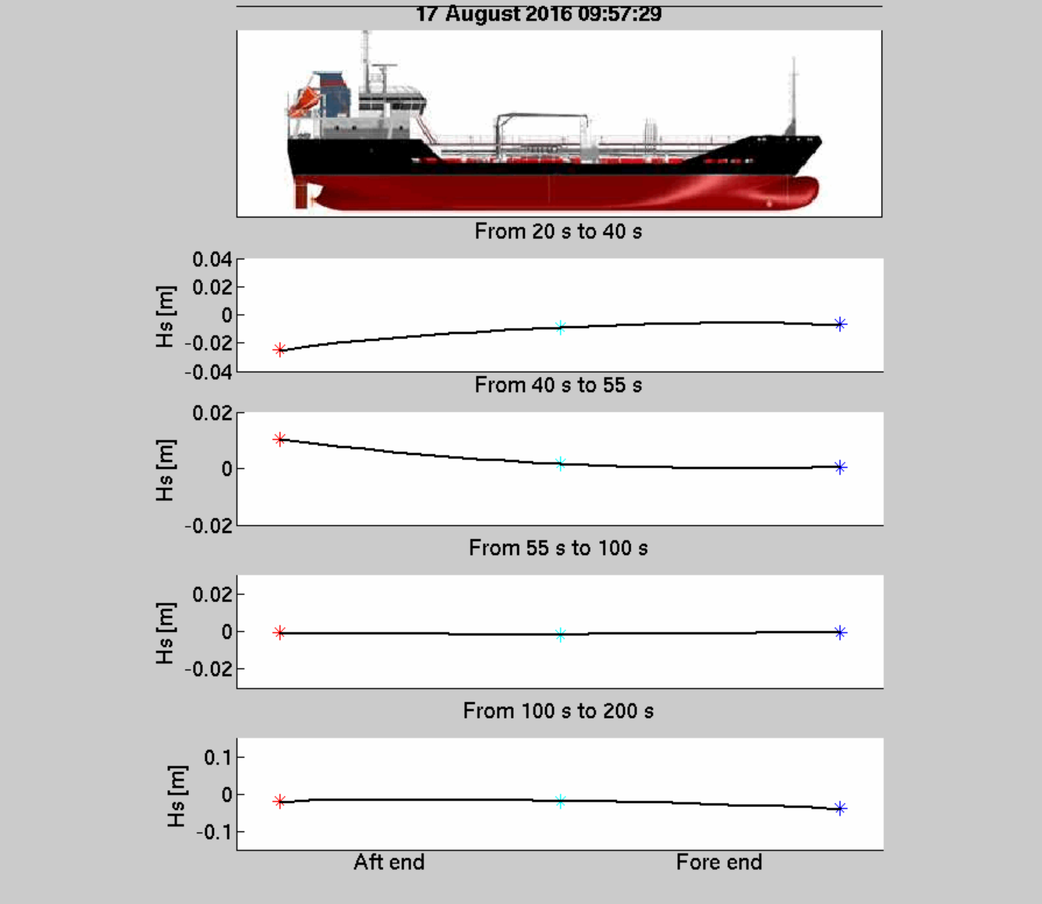
Co-temporal

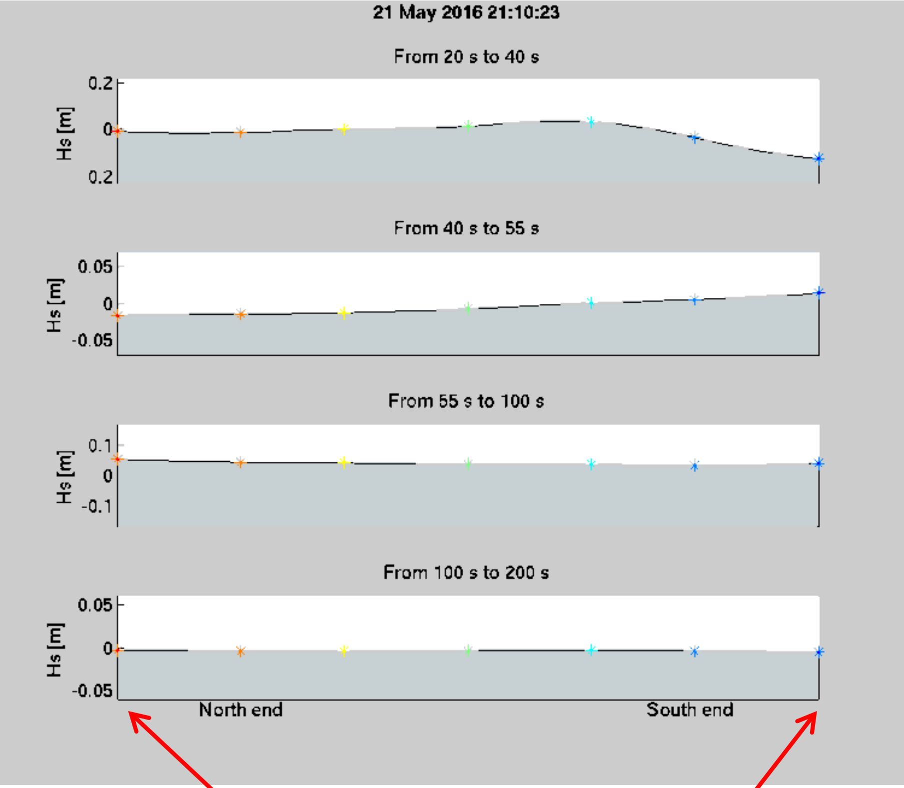
measurements



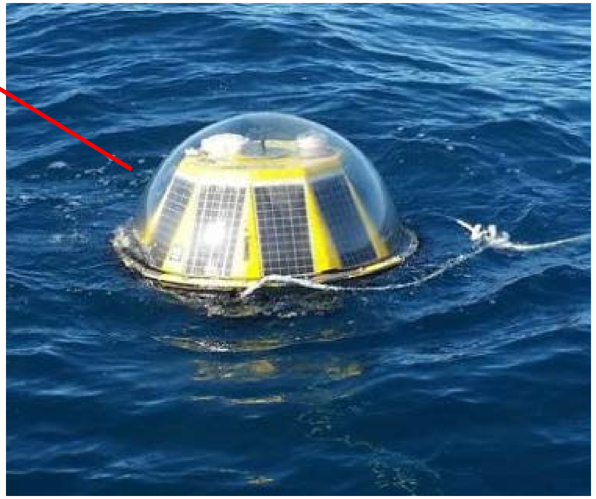
Measuring LPW

Co-temporal measurements





Measuring LPW



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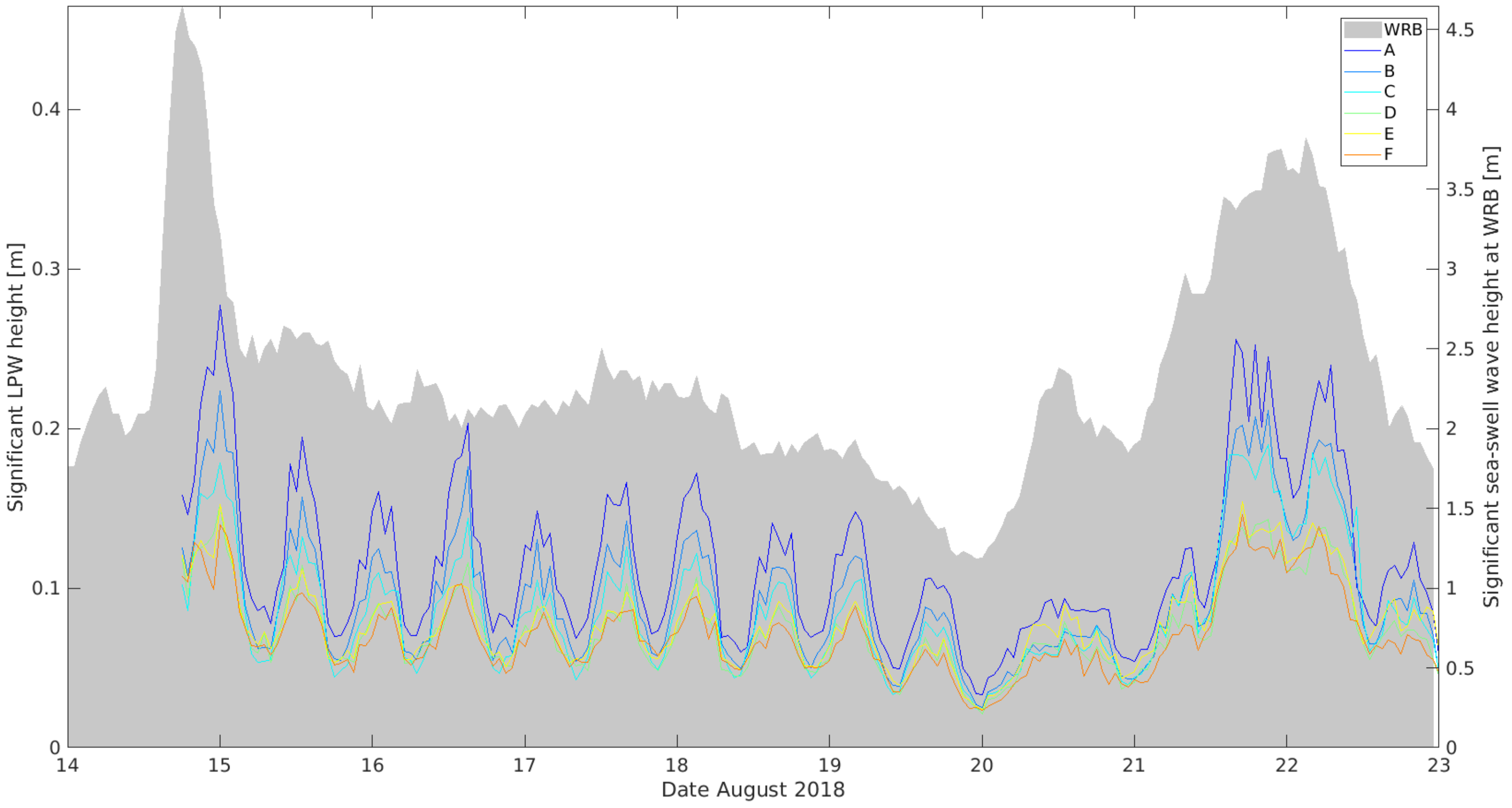
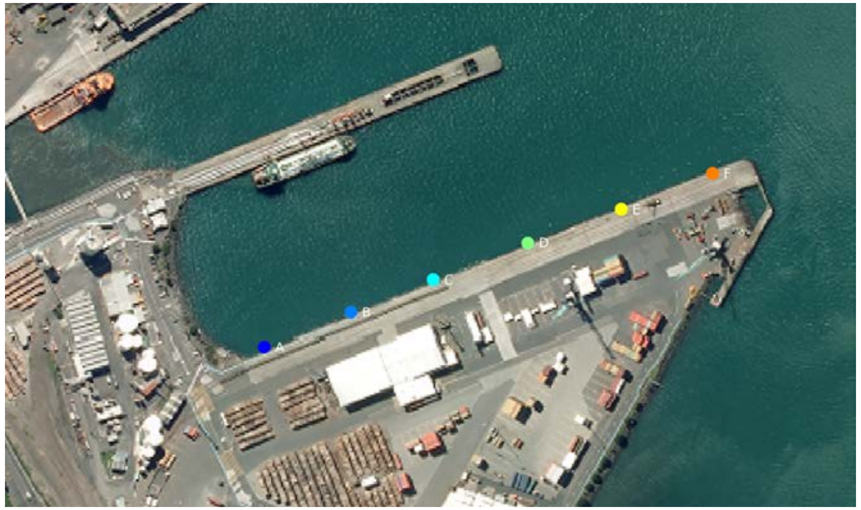
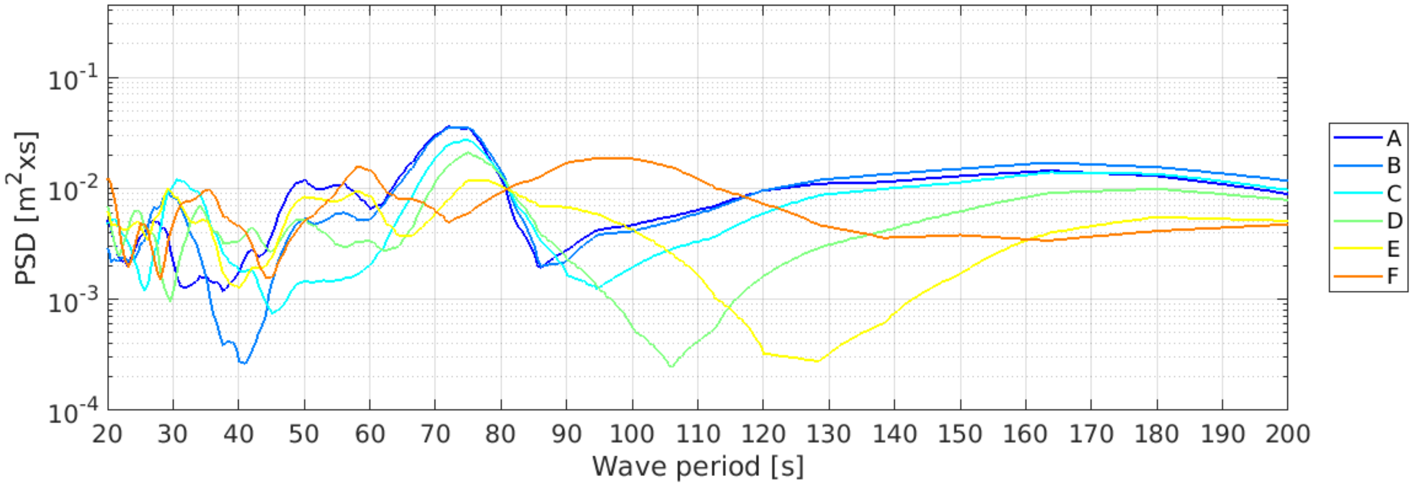
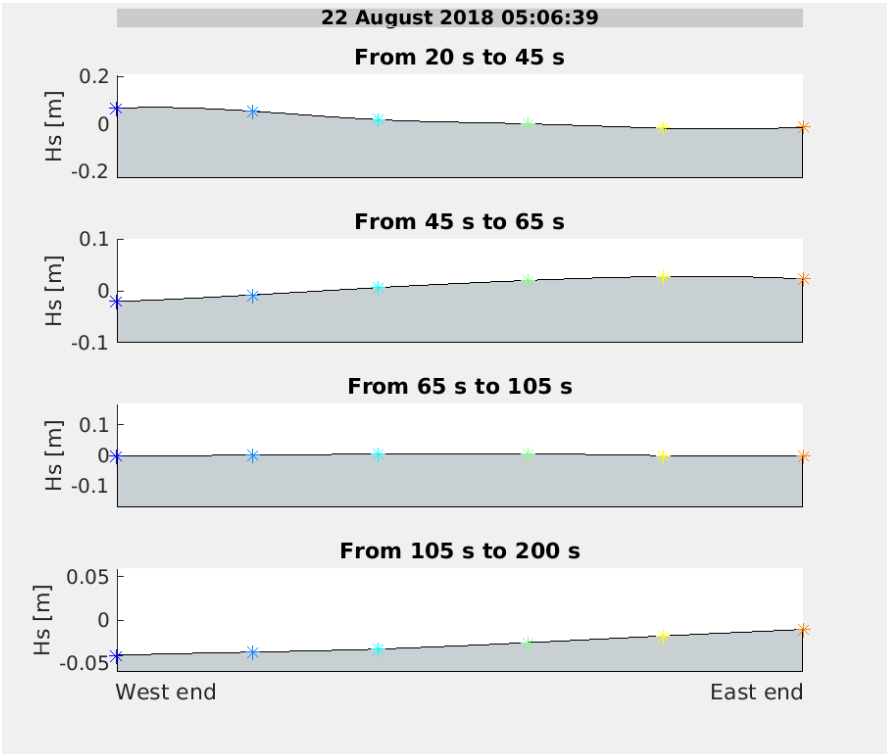




Measuring LPW





Summary

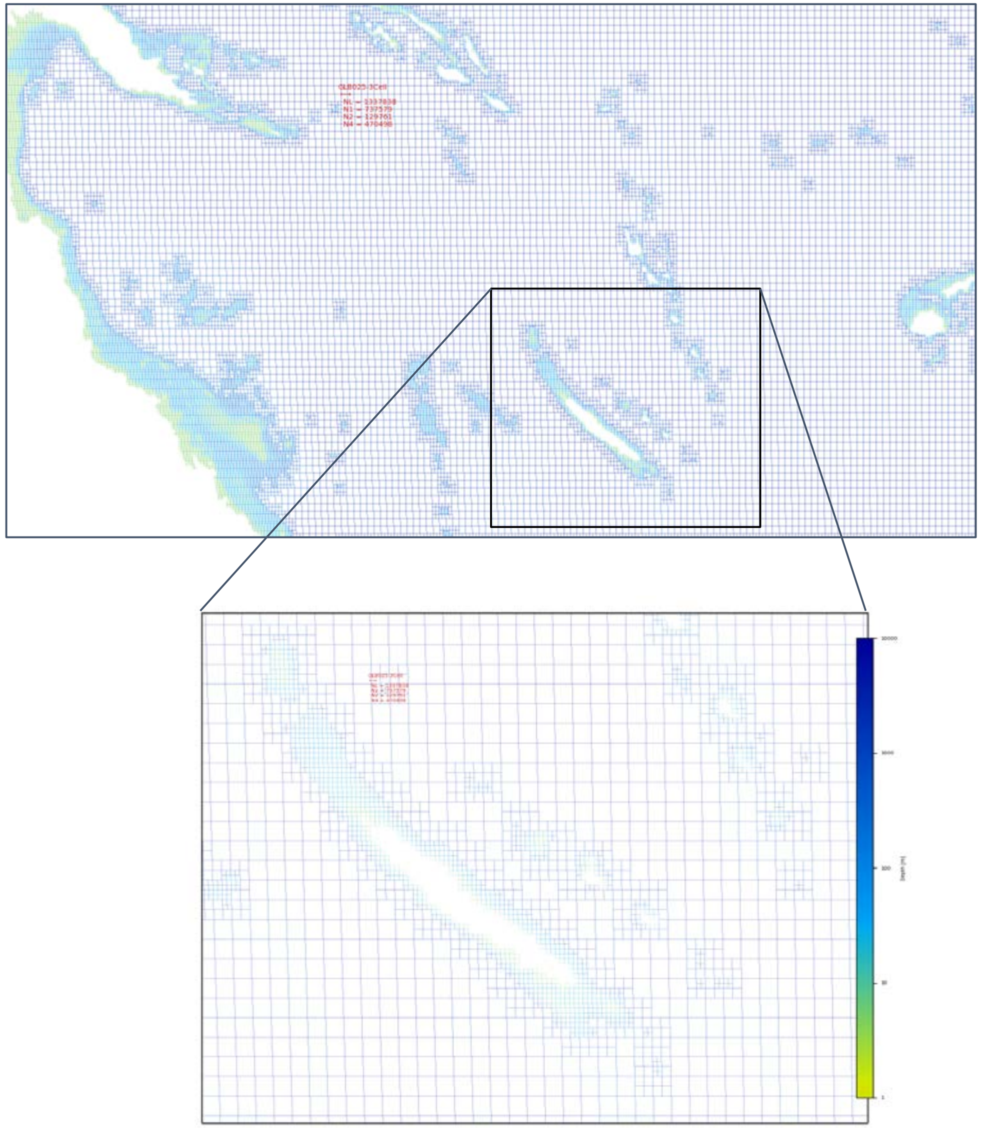
- Moored ships are energised by specific LPW periods.
- There is often a strong gradient in period and magnitude along a berth.
- Need to measure along each berth to fully capture the LPW dynamics.
- LPW magnitude is a very good predictor for effects.
- The water level slope at the ship scale is another good predictor.
- Measuring LPW is much easier than modelling.

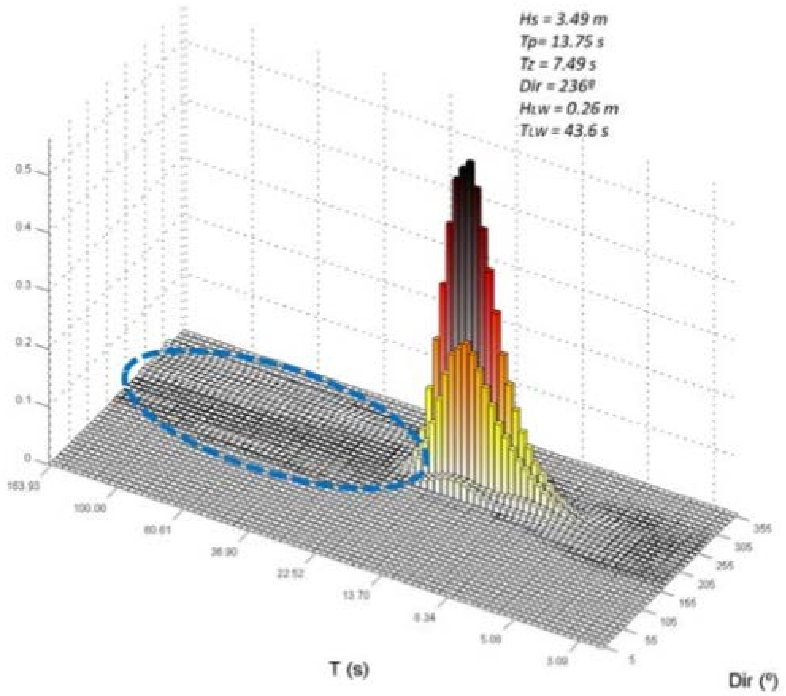
LPW forecasting – what is next?

- Produce nearshore (20m) LPW energy directly from WW3.
- Replace the Hs –Tp equations.
- Forecast additional parameters on the berth
- E.g. sea level gradients, ship specific values.
- Seasonal forecasting of LPW for operational downtime estimates.
- Collaborating in Spanish ports with GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO Puertos del Estado

LPW forecasting – what is next?

See Diaz, Lara & Losada (2016)





Goal – use SMC gridding and upgrade WW3 to produce a nearshore boundary LPW forecast for all the coast of Planet Earth at 5 km resolution.

Gracias por su tiempo

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