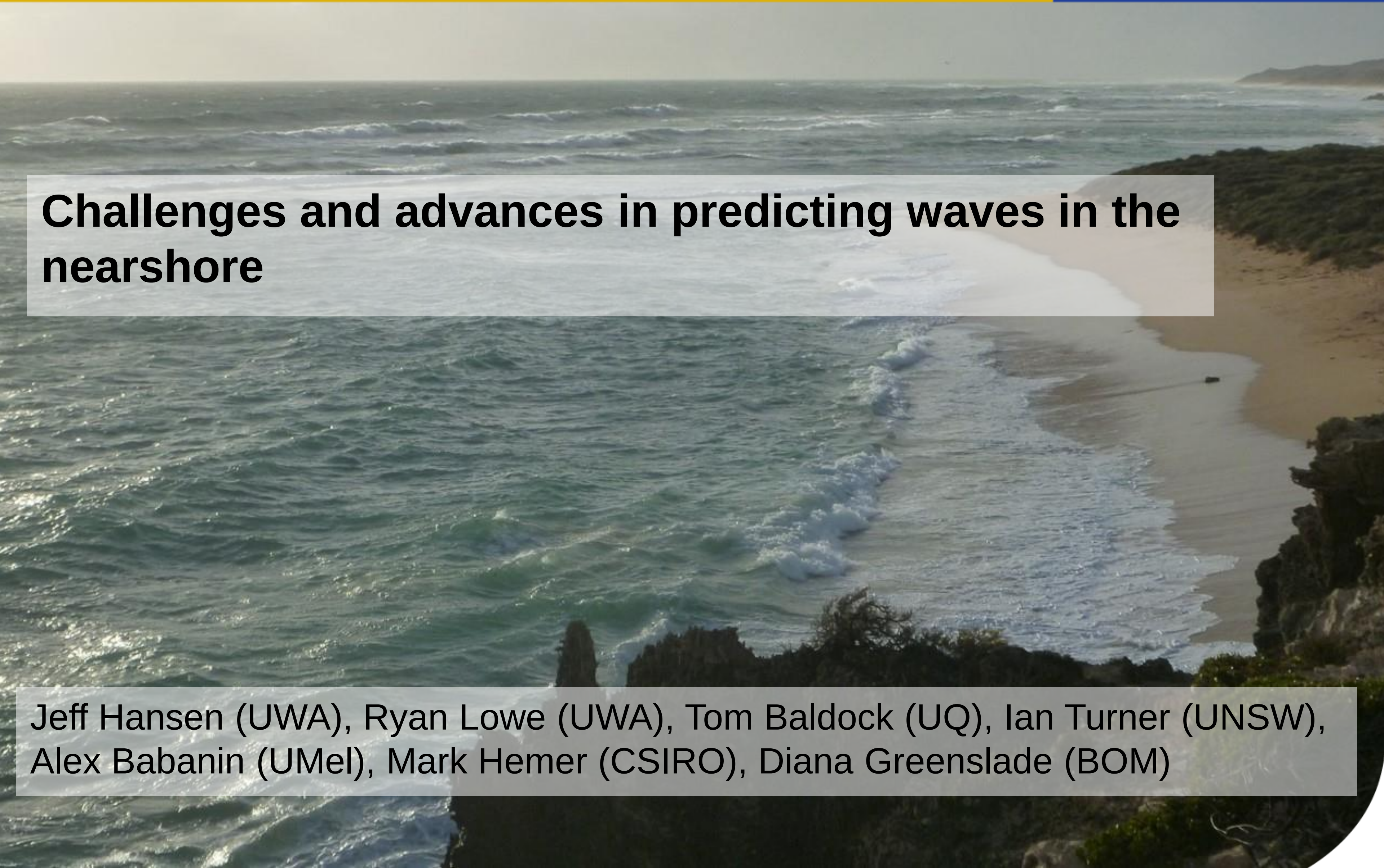

Challenges and advances in predicting waves in the nearshore

Jeff Hansen (UWA), Ryan Lowe (UWA), Tom Baldock (UQ), Ian Turner (UNSW), Alex Babanin (UMel), Mark Hemer (CSIRO), Diana Greenslade (BOM)

Characteristics and importance of the nearshore zone

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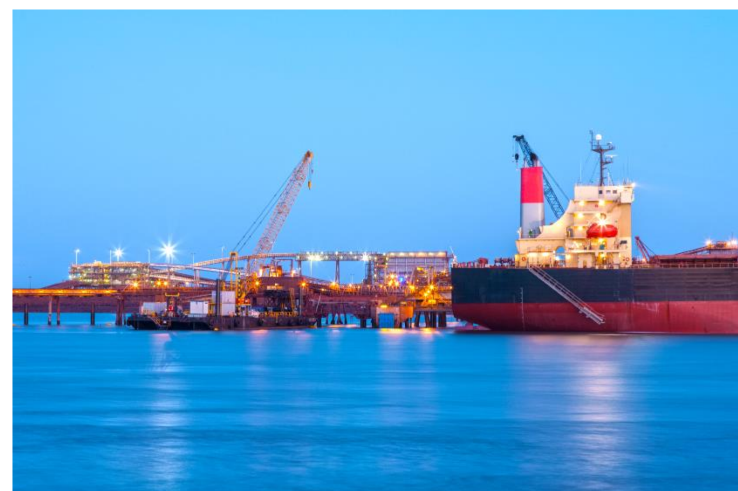
Characteristics

- <25 m depth (including surf zone)
- Abrupt wave transformation, nonlinear energy transfers, wave-driven circulation
- Rapid sediment transport & morphological changes

Importance

- The coastline is vital to Australia's livelihood (~90% of population lives <50 km from the coast)
- Vital for Australia's economy (e.g. tourism, ports).



Importance of accurate nearshore wave models

Coastal erosion

Coastal water quality and ecosystems

Port operations

Beach safety

Coastal planning

Defence

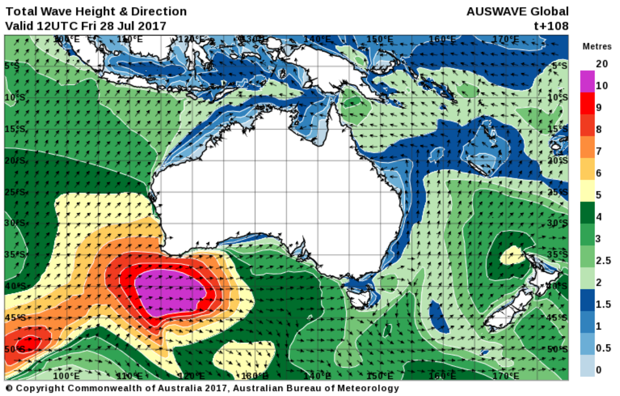
Background on wave models

Phase-averaged/spectral models

Scale
(wave periods/lengths)

$O(10-1000)$ Wave action balance

(e.g. SWAN, WAVEWATCH,WAM)



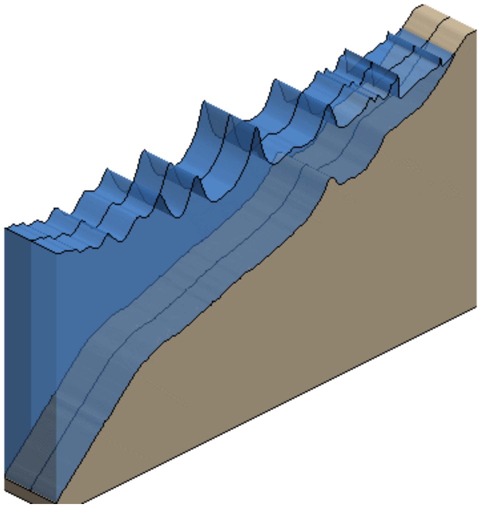
Phase-resolving wave-flow models

Scale
(wave periods/lengths)

$O(10-100)$ Mild slope equations (e.g. MILDwave)

$O(10)$ Boussinesq/non-hydrostatic models
(e.g. Funwave, Mike21 BW, HWAVE, SWASH, XBeach-NH)

$O(1)$ Computational Fluid Dynamics (e.g. OpenFOAM/ SPH)



Challenges of predicting waves in the nearshore: Wave breaking

- Dominant dissipation mechanism of wave energy.
- Drives wave-driven currents and setup/setdown.
- Poorly modelled by just about all classes of model (except maybe CFD/SPH).
- Presently parameterized even in phase resolving models.

Wave breaking

Challenges of predicting waves in the nearshore: Complex morphology

- Large changes in depth are difficult to account for.
- Morphology dictates rate of energy dissipation and thus setup, currents, energy transfers.
- Even the best model is useless without “good” bathymetry.

Complex morphology

Gnarabup Beach, WA

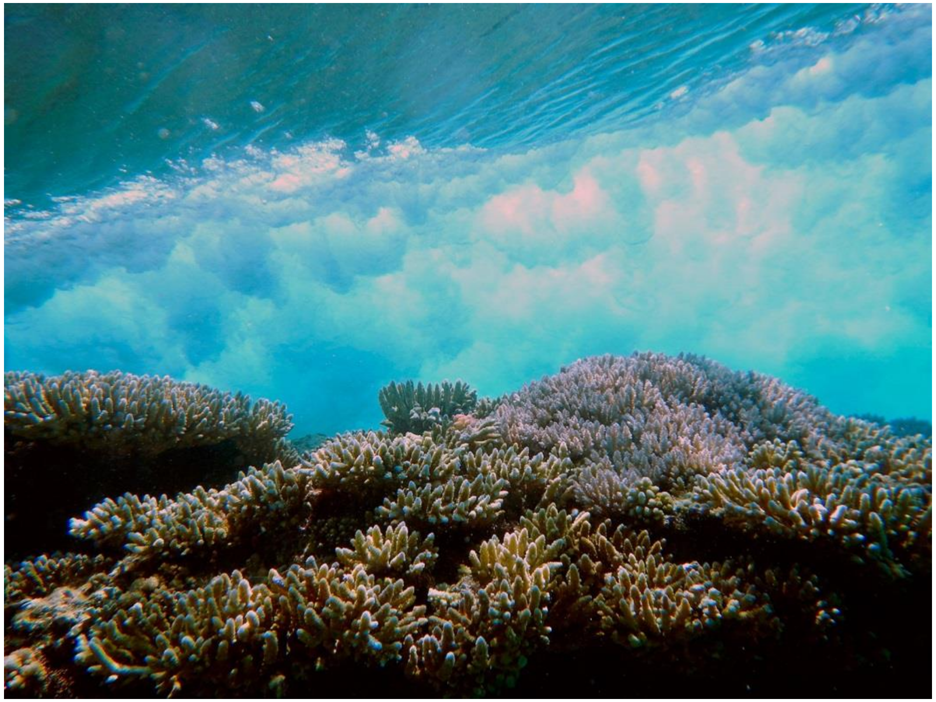
Challenges of predicting waves in the nearshore: Bottom roughness

- In environments with rough bottoms (e.g. reefs, sea grass, ripples), frictional dissipation can be significant (or dominate in some cases).

- Wave models crudely account for roughness, primarily with a catch all (empirical) wave friction factor.

- Phase-resolving models can do a bit better job (at very high resolutions) but still not great.

Bottom roughness



Challenges of predicting waves in the nearshore: Energy transfers

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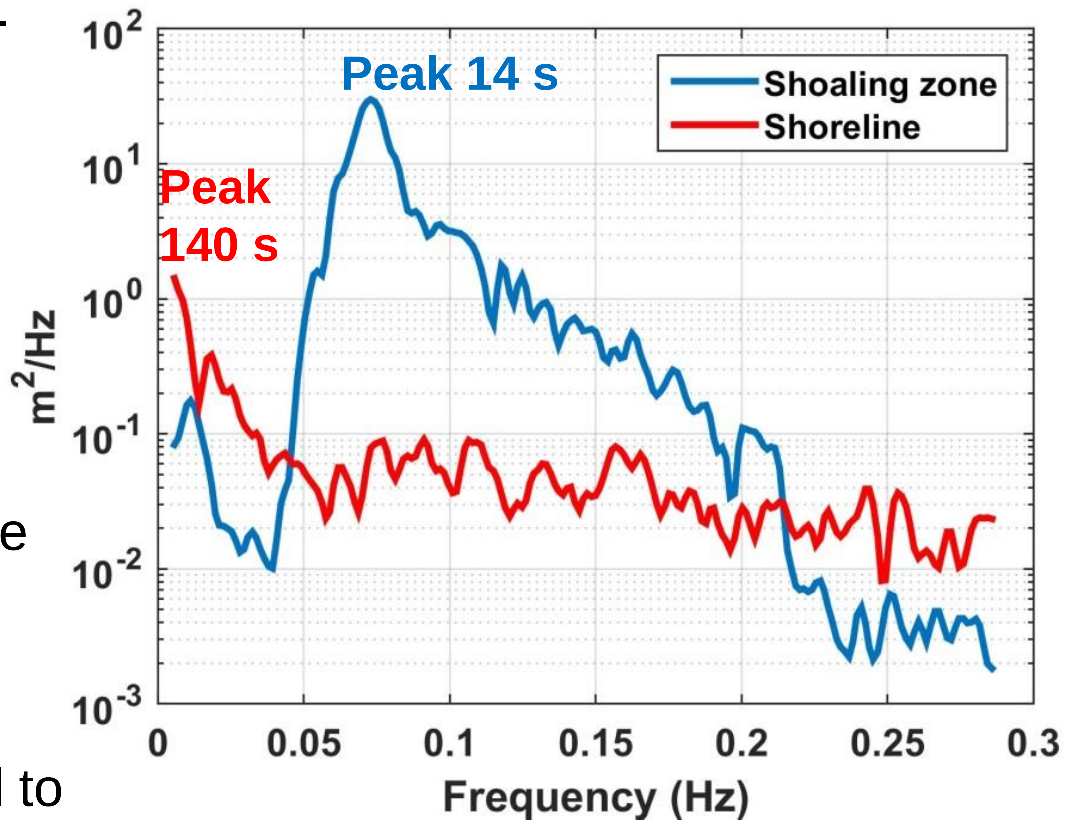
- The offshore incident wave spectrum is dominated by sea-swell (periods 5-25 s).
- At the shoreline the wave spectrum is dominated by infragravity (IG) waves (periods>25 s).
- IG wave dynamics dictate wave run up and have considerable influence on total water levels.
- Energy transfer from sea-swell to IG waves is not modelled at all in phase-averaged wave models.

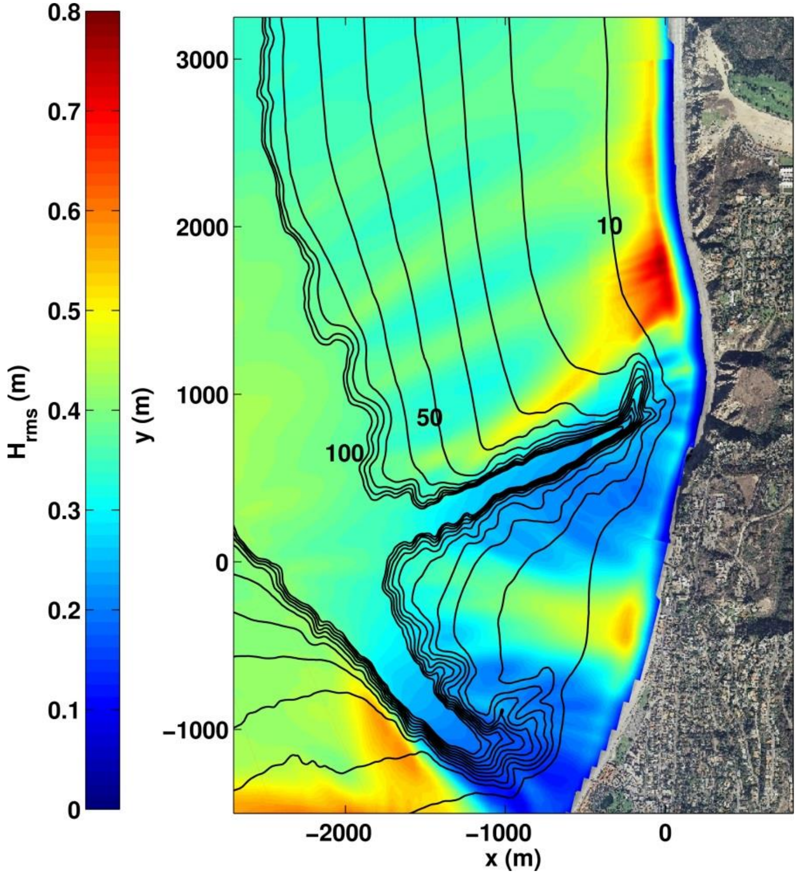
Spectral evolution: energy transfers



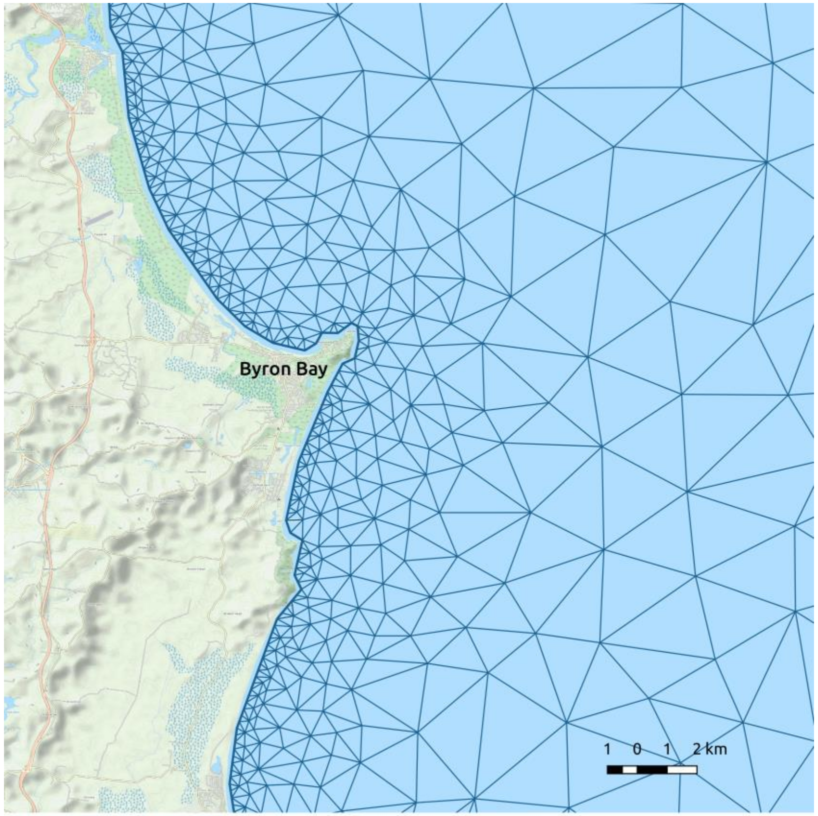
Phase averaged nearshore wave models

- Existing phase-averaged wave models (e.g. WW3 / SWAN / Mike21 SW) have proven extremely useful for both operational and research purposes.

- Generally do well in the nearshore (<25 m) for parametric statistics (Hs, Tp, Dp).



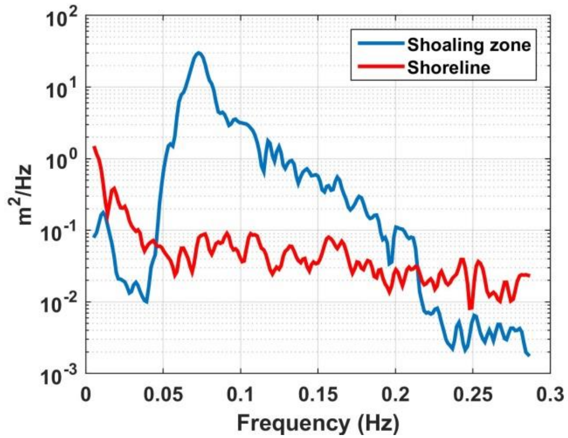
SWAN, Hansen et al. 2015



Unstructured WW3 from BOM

Disadvantages of phase averaged models in the nearshore

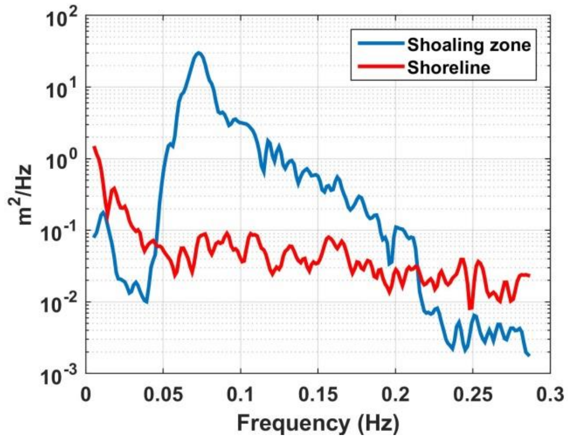
Infragravity waves



Run up

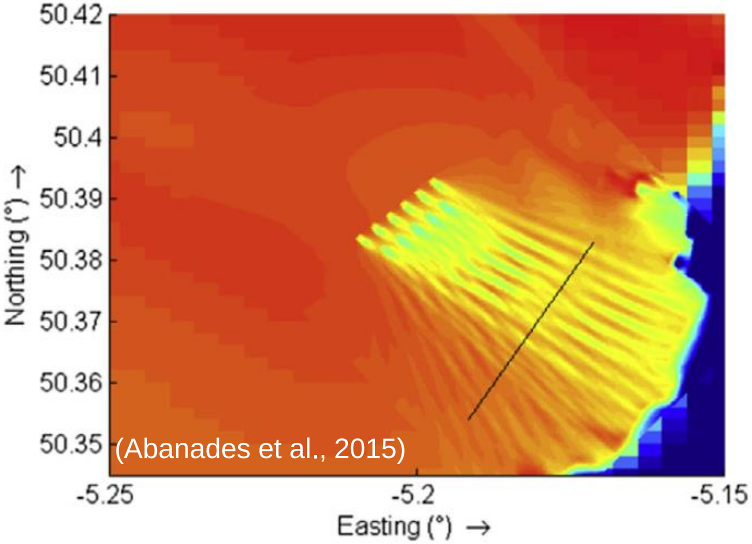
Disadvantages of phase averaged models in the nearshore

Infragravity waves



Run up

Diffraction



Phase resolving models

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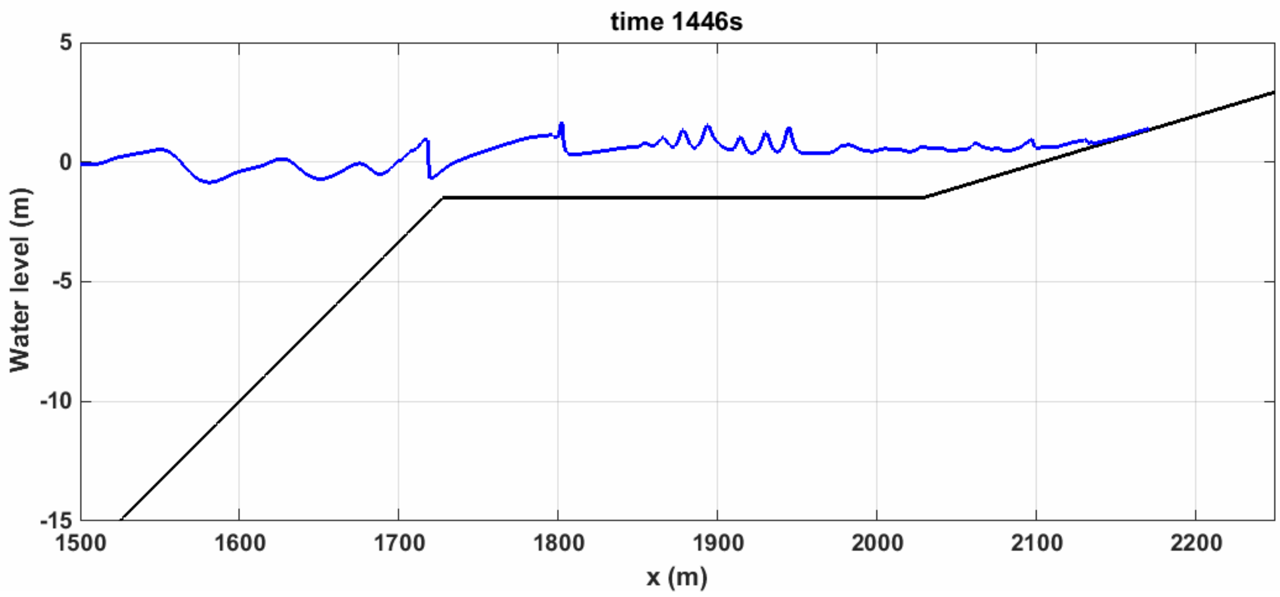
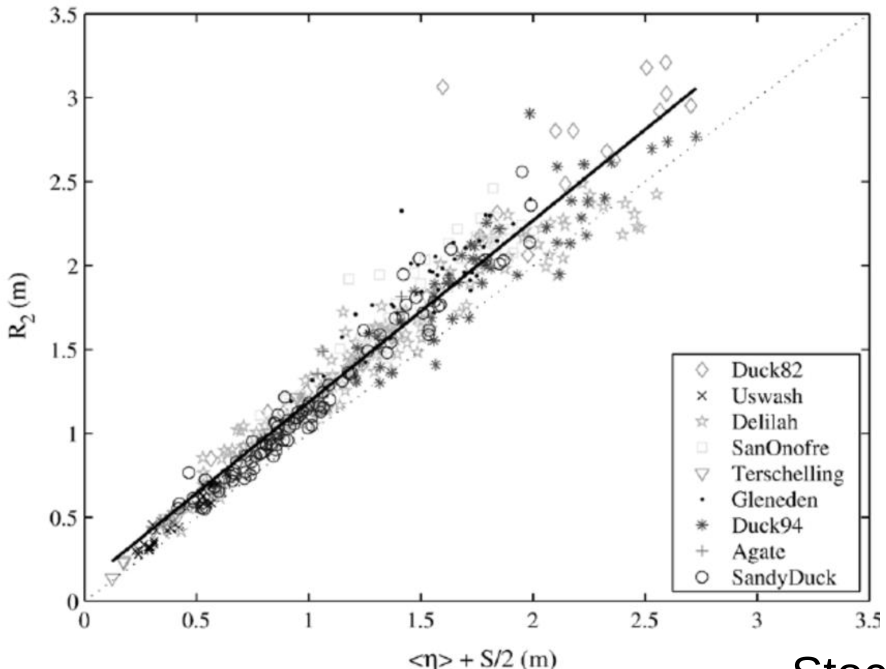
- Remain computationally expensive, but continually getting better.
- Have the advantage of intrinsically including nonlinear energy transfers (i.e. IG wave generation).
- Will result in improved predictions of run up and thus potential for coastal flooding/infrastructure damage.
- Include non-stationarity associated with waves and wave groups.



Example: Predictions of run up elevation

- Wave run up elevation, which determines if dune/structure overtopping occurs is often determined via empirical relationships (e.g. Stockdon et al., 2006)
- However, these formulations have been developed and tested in a narrow range of conditions at mostly mild sloping beaches.

$$R_2 = 1.1\left(0.35\beta_f(H_0L_0)^{1/2} + \frac{[H_0L_0(0.563\beta_f^2 + 0.004)]^{1/2}}{2}\right).$$

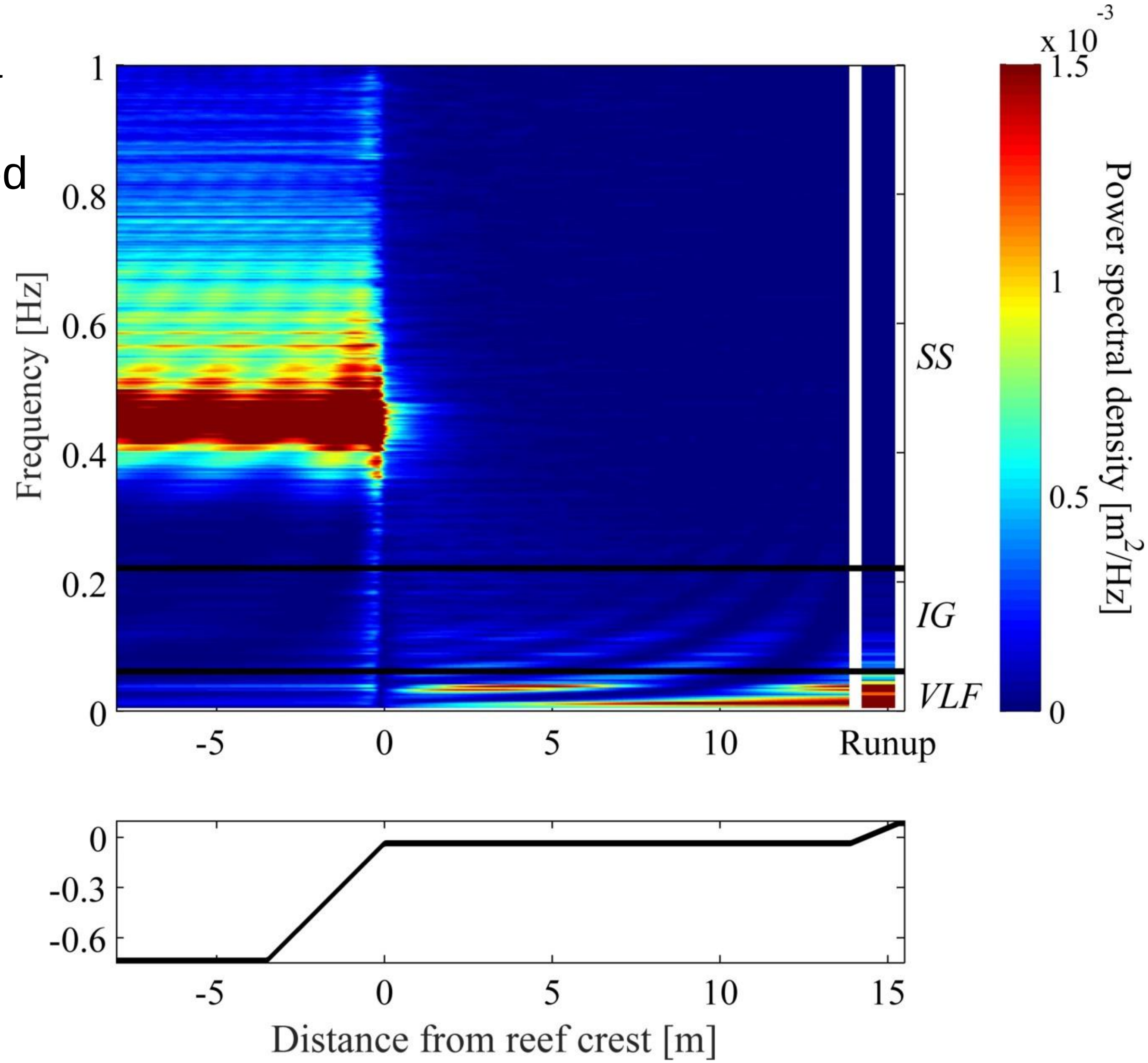


Stockdon et al. 2006

Run up predictions from a phase-resolving model

• A variety of field and lab data sets indicate resonance can occur in fringing/shore attached reef environments.

•In these cases runup at the shoreline is strongly impacted by the geometry of the reef-beach system, and can be dominated by very-low frequency (VLF) motions.



Buckley et al. (in prep)

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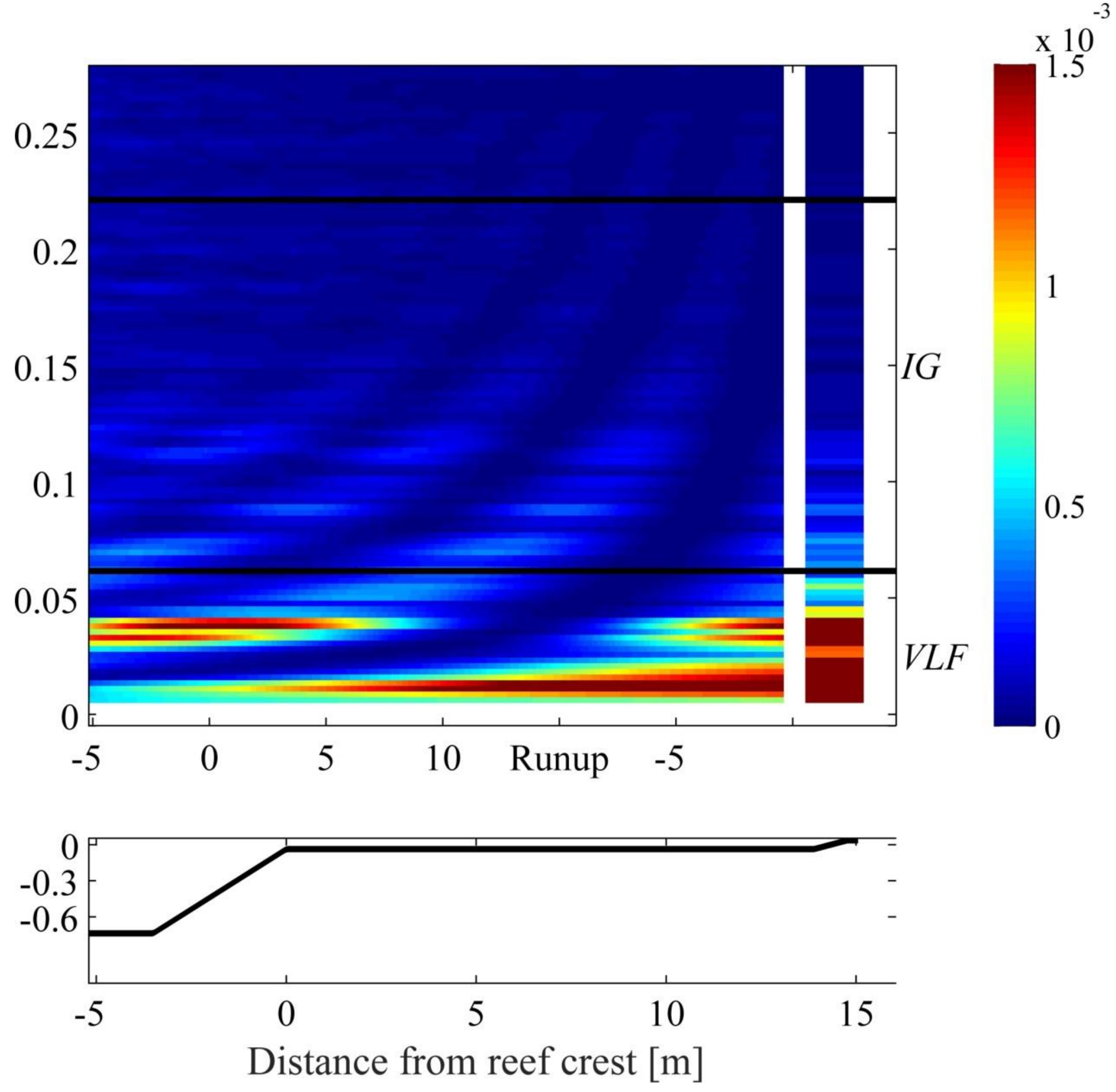
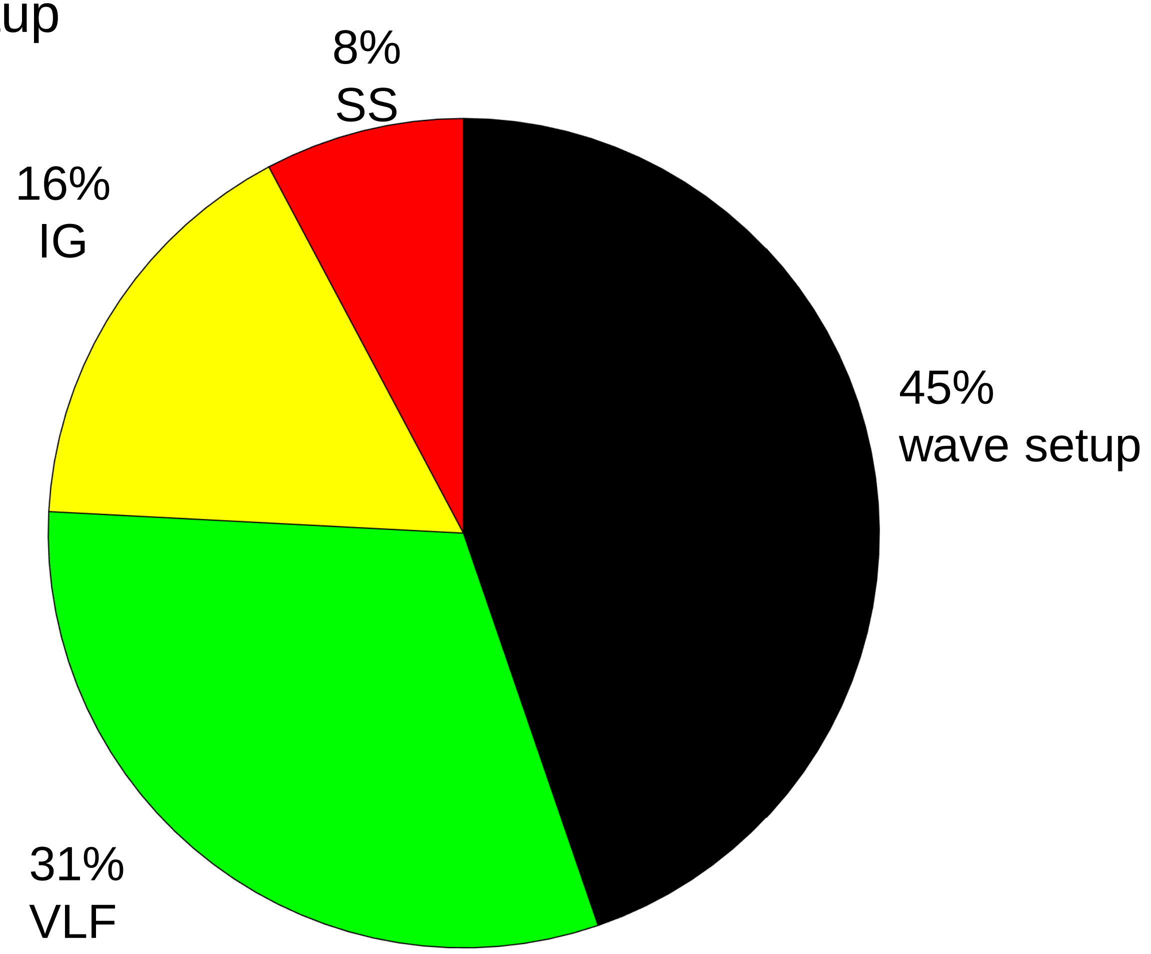


Buckley et al. (in prep)

Sources of coastal flooding: Laboratory (physical model) example

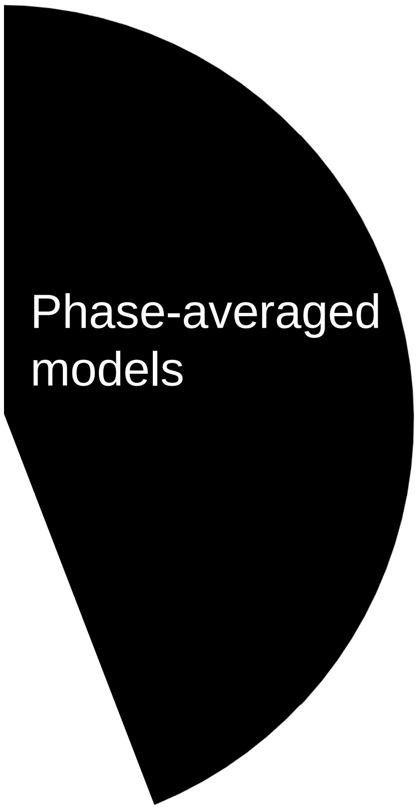
- Sea-swell waves (SS)
- Low frequency waves (IG and VLF)
- Wave setup



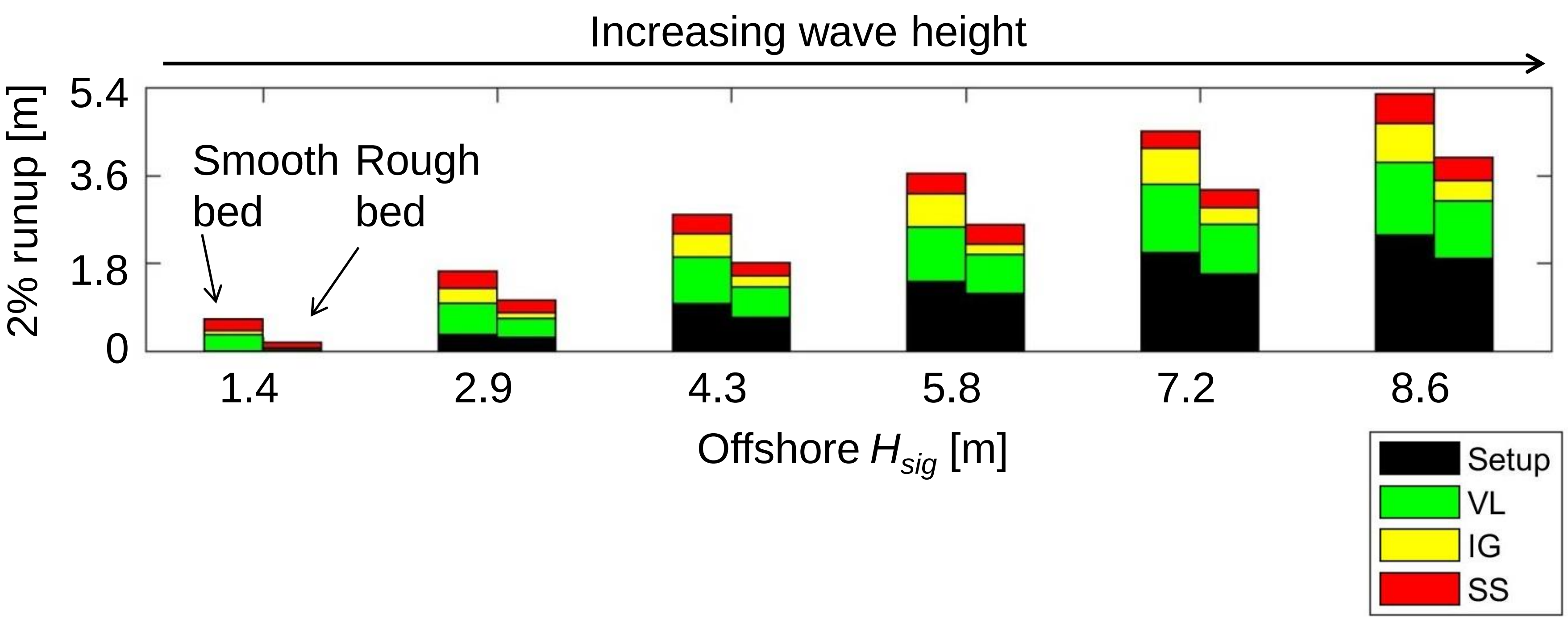
Example: H_{rms} = 2.1 m, T_p = 19 s, h_r = 1.5 m

Sources of coastal flooding: Laboratory (physical model) example

- Sea-swell waves (SS)
- Low frequency waves (IG and VLF)
- Wave setup



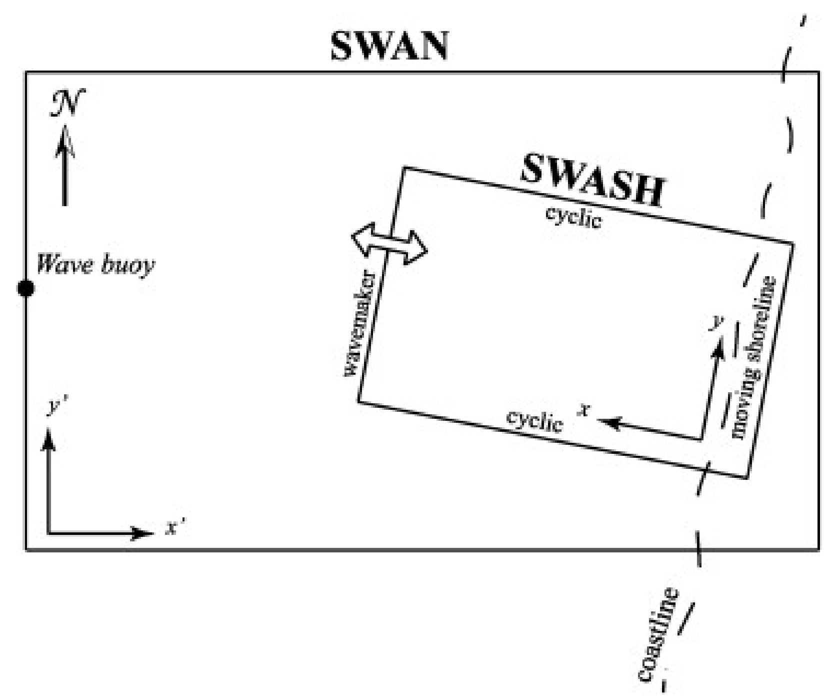
Contributions to run up elevation
Varying wave height and bottom roughness

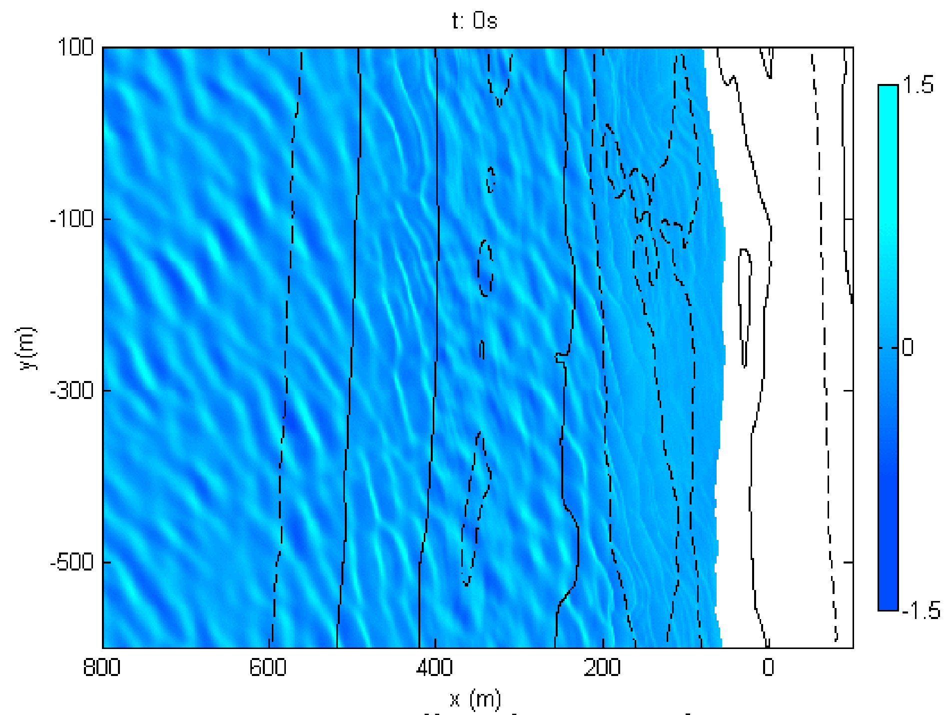


Can phase-resolving models be made "operational"

• Phase-averaged and resolving models can be coupled.

• For example, ~30 min SWASH simulations (a few minutes to run on a supercomputer) using input from BOM's AUSWAVE-R + water levels model as a boundary condition could be run for vulnerable sites to generate total water level forecast.





Rijnsdorp et al., 2015

What is needed to continually improve nearshore wave predictions in Australia?

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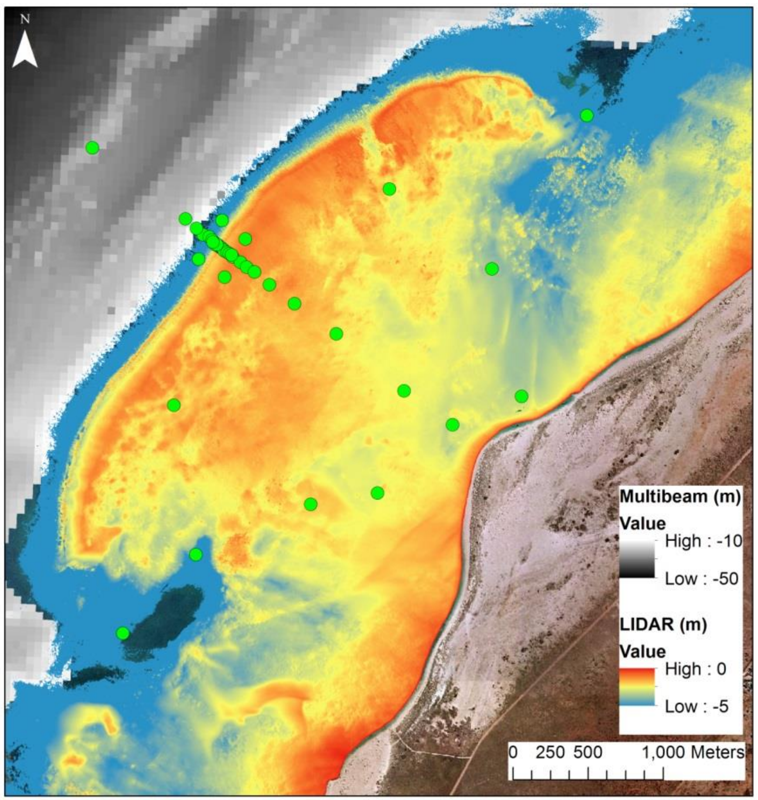
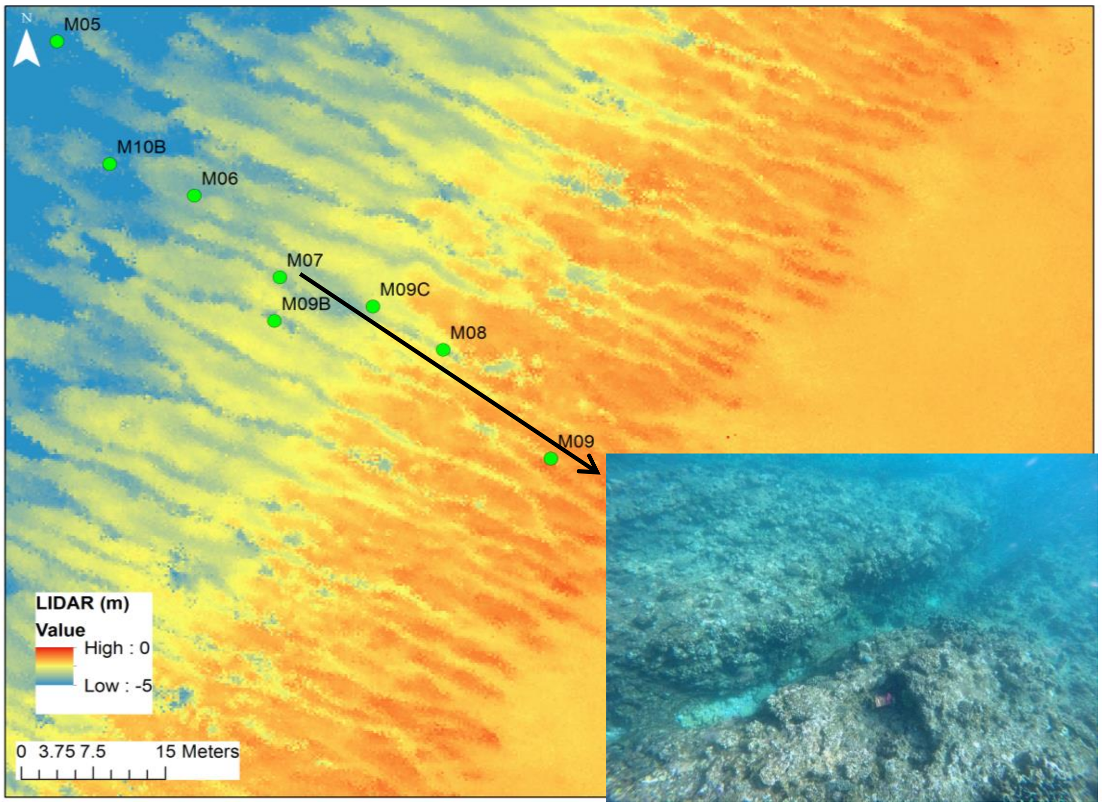
Bathymetry

- Without good bathymetry nearshore wave models are of limited use.





Hacker, Hansen, Lowe

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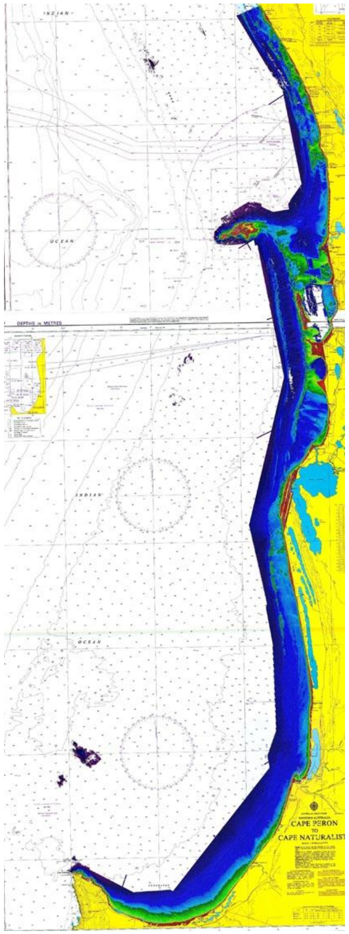
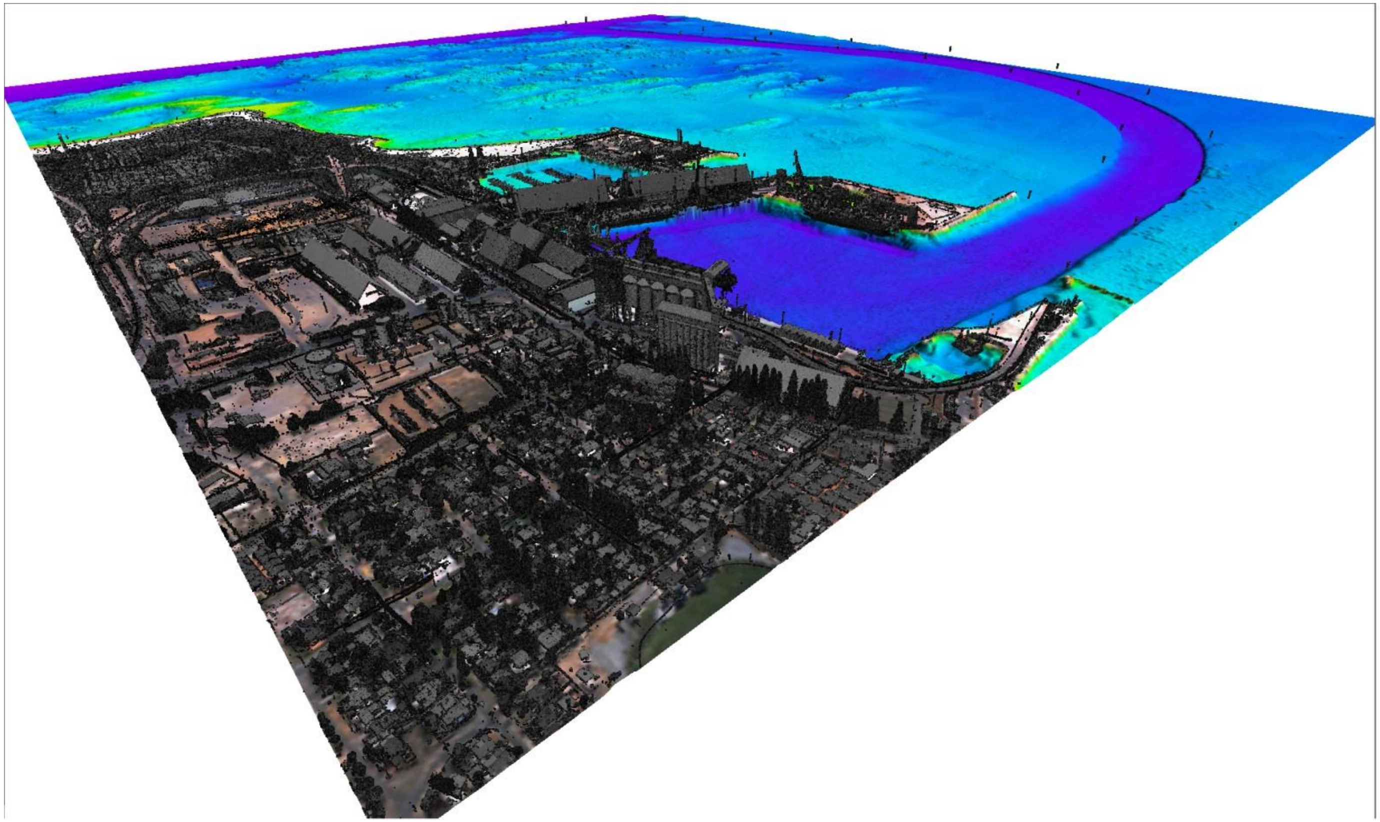


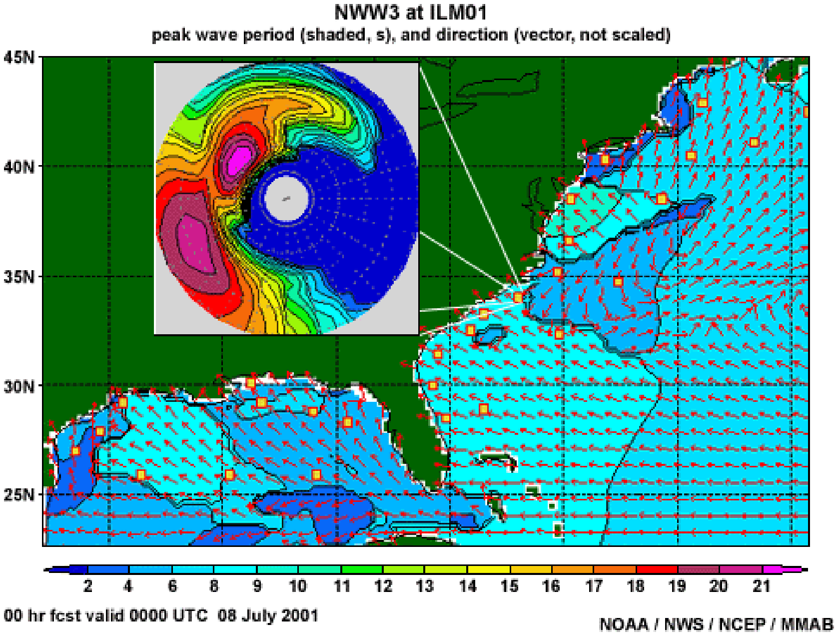


Geraldton Port, WA DOT/Planning

What is needed to continually improve nearshore wave predictions in Australia?

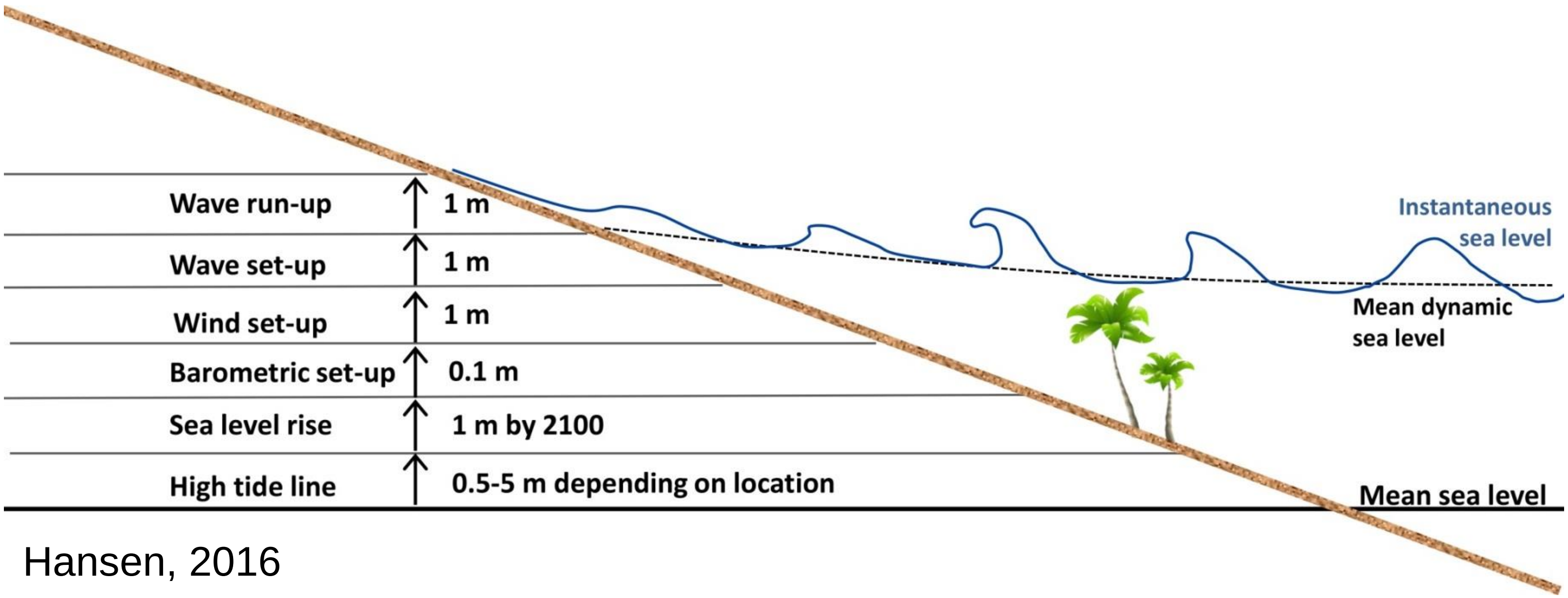
Boundary conditions

- Spectral (rather than parametric) wave data, from buoys and regional wave models.
- The cost of wave buoys is decreasing rapidly.



Concluding remarks

- Given modest computing resources, phase-resolving models can be used to accurately predict waves and currents in the nearshore.
- Coupling phase-resolving models with regional wave/circulation models can improve prediction/forecast of total water levels, coastal hazards/flooding, sediment transport, and port conditions.
- Nearshore wave models will continue to improve, but will always need good boundary conditions and bathymetry as inputs.



Hansen, 2016


Thanks!