Modelling infragravity waves across the Ningaloo (Western Australia) fringing reef

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Introduction

- Coral reef systems are present along large parts of tropical coastlines.
- Wave transformation (breaking) and wave-induced motions across the reef destroy and pick-up reef material, drive material and nutrient transport, as well as transport and dispersal of larval fish and other organisms.
- However, time-varying hydrodynamics across reefs are still little studied compared to sandy coasts.
- Recent field studies show dominance of infragravity wave motions over the reef.

Research questions

- What is the skill of a hydrodynamical model (derived for mildly-sloping beaches) on a coral reef?
- What effect do infragravity waves have on particle motions and currents?

XBeach model

- Solves the coupled time-dependent 2DH equations of wave action propagation and dissipation, the 2DH equations of conservation of mass and momentum of flow (surface elevation and currents), sediment transport and bottom changes using varying (spectral) wave and flow boundary conditions.
- Includes non-stationary wave driver with directional spreading on the time scale of wave groups which forces infragravity wave motions.

Model calibration

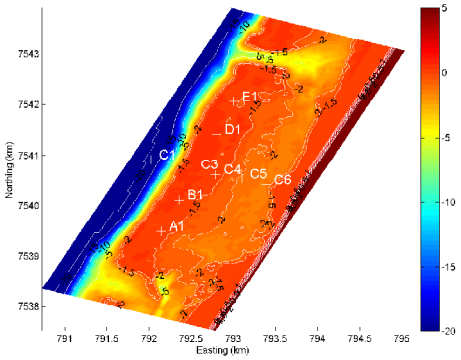
Relative to the default version, the wave action balance is extended with a term for bottom friction dissipation which is significant on rough bathymetries.

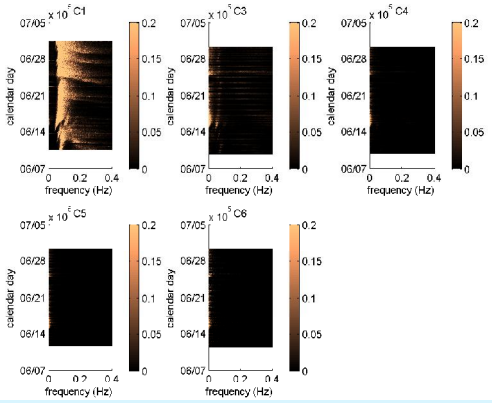
$$D_f = \frac{2}{3}\rho\pi f_w \left(\frac{\pi H}{T_{rep}\sinh kh}\right)^3$$

where free parameter f_w is tuned to 0.6 for conditions at peak of storm.

Ningaloo Reef, W. Australia – setup and data

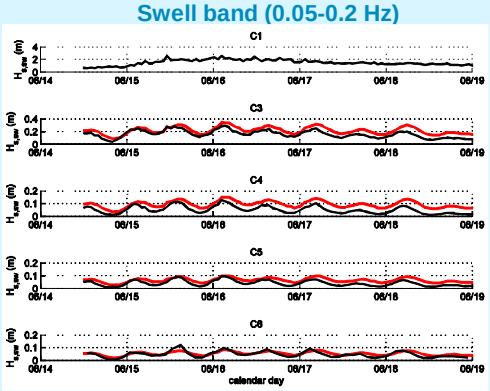
The reef extends 250 km along the North-West Cape of Australia and comprises about hundred individual reef-lagoon-channel circulation systems with gaps (channels) occurring in the reef every few kilometers, through which a majority of the water exchange between the lagoons and ocean occurs. The system is subject to swells from the South-West (roaring 40's). The data shows that swell wave energy (0.05-0.2 Hz) decays over the reef from C1 to C3, and that large storms excite IG (0.004-0.05 Hz) response. Data courtesy R. Lowe.





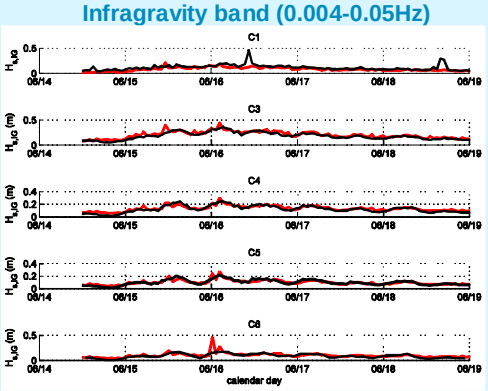
Model (blue) - data (red) comparison

Swell band (0.05-0.2 Hz)



- rapid swell wave height decay from C1 to C3 and swell variance on reef well predicted.
- small phase delay due to bottom friction.

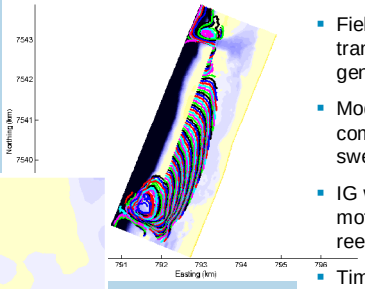
Infragravity band (0.004-0.05Hz)

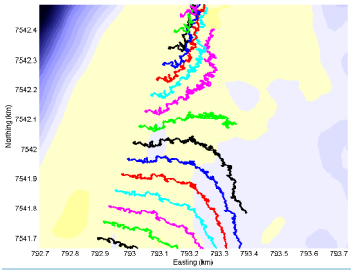


- IG wave height response well predicted across the reef.
- IG wave heights are larger than swell wave heights.

Particle motions

Particles are driven over the reef, into the lagoon and out through the channels.



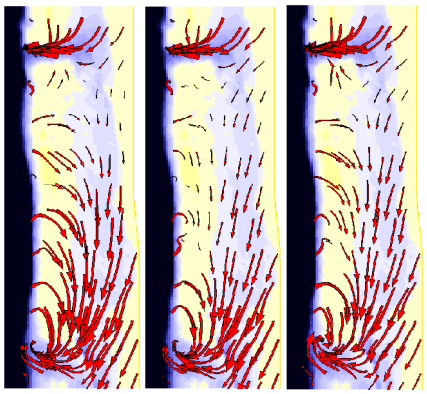


In detail, the IG waves force oscillations in the motion, ie. extra shear stress on the reef

Conclusions

- Field campaign captured significant swell transformation and infragravity wave generation events over a fringing reef.
- Model results for swell and IG wave heights compare well to data for the duration of a swell event.
- IG waves force oscillations in the particle motion and thus extra shear stresses on the reef.
- Time-varying forcing causes oscillations in the currents through the lagoon and through the channels.
- Next up: detailed analysis of shear stresses and comparison to measured current data.

Time-varying currents



XBeach available for free and open-source via *xbeach.org*

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