THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

Deltares
Enabling Delta Life

THE UWA OCEANS INSTITUTE | SCHOOL OF EARTH AND ENVIRONMENT

A laboratory study of sediment transport in fringing reef environments

Sediment transport induced by low frequency motions

Andrew Pomeroy[1], Ryan Lowe[1], Mark Buckley[1], Ap Van Dongeren[2], Marco Ghisalberti[1], Willem Bodde[23]
[1]The University of Western Australia (corresponding author: andrew.pomeroy@uwa.edu.au)
[2]Deltares, The Netherlands
[3]TU Delft, The Netherlands

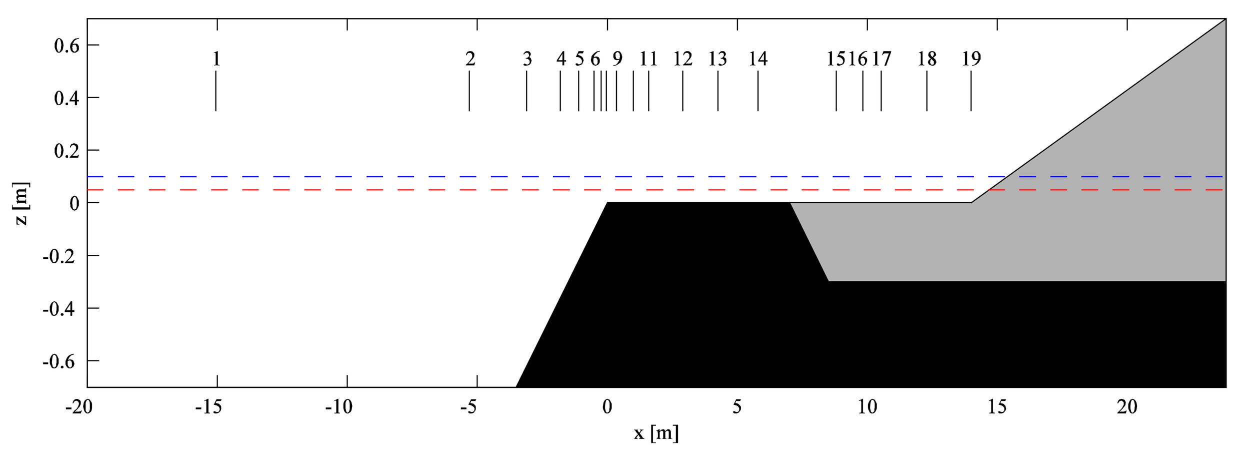
Motivation

- Suspended sediment distributions on reefs drive numerous ecological and morphodynamic processes.
- The hydrodynamics driving sediments on reefs are known to be distinct from sandy beaches.
- Shallow and wide coral reef flats induce wave breaking further from the shoreline than for beaches.
- This strongly affects the cross-shore distribution of high (sea and swell) and low (infragravity and very low) frequency wave motions.
- What does this mean for the transport of sediment and other particulate matter?

Experiment

Setup

- 55 m x 1.2 m x 1 m flume (Eastern Scheldt Flume at Deltares, The Netherlands)
- 1:15 scale with D_{50} = 110 μm sediment
- 18 wave height meters
- 6 velocity meters (electro magnetic sensors)
- 5 optical concentration meters on the reef
- A 5 intake pump sampler
- Roughness elements (18 mm³ at 40 mm spacing) were used on the fore-reef and reef flat as a proxy for bottom friction by coral roughness ($c_f \approx 0.1$)



Model design with instrument locations indicated by the numbered lines (7, 8 and 10 not shown). The fixed bathymetry is indicated by the solid black shading and the movable bed by the grey shading. The blue (red) dotted line indicates the deep (shallow) water case.

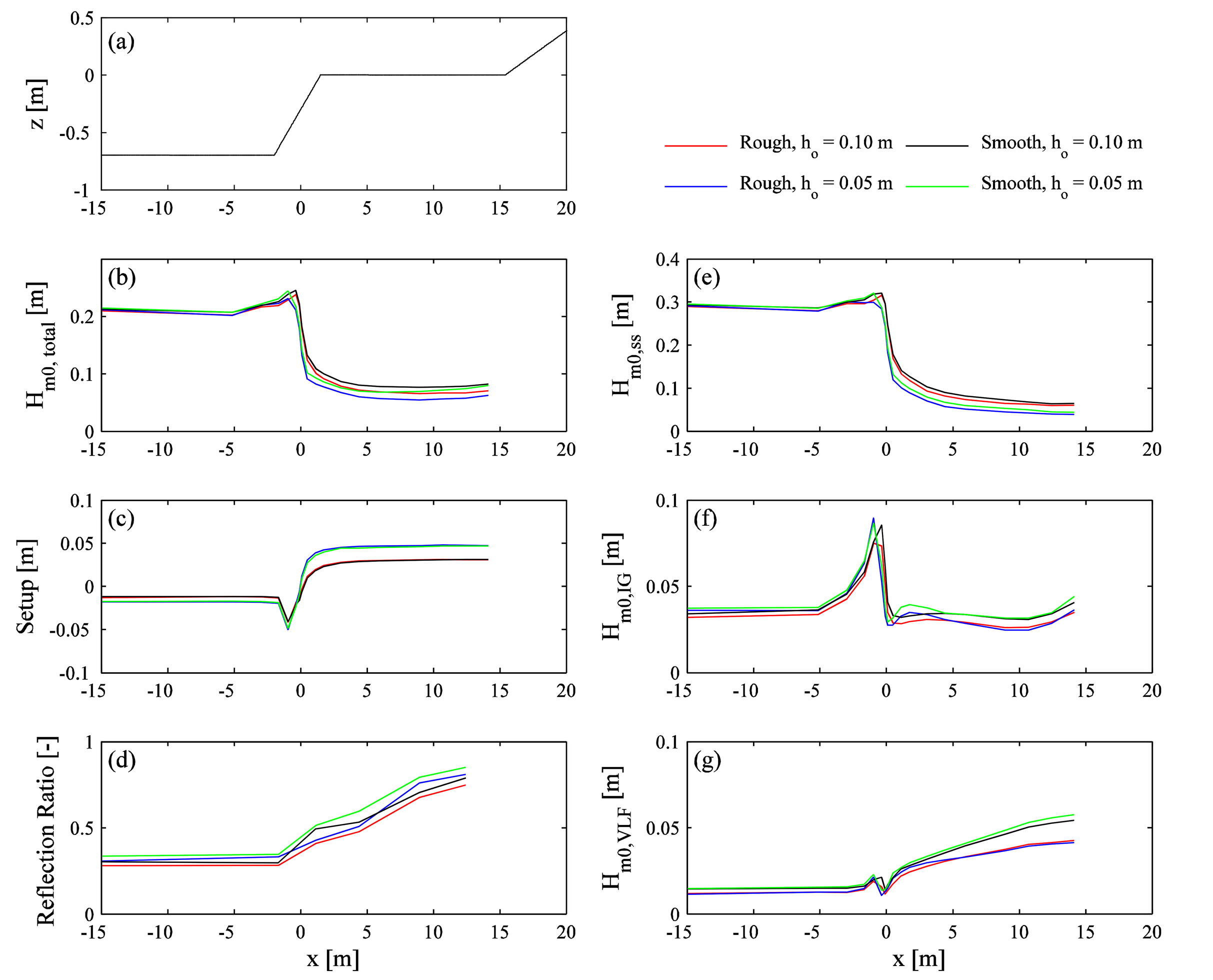
Simulation Cases

ID	H_{m0} [m]	T_p [s]	h_r [m]	Reef State
R1	0.20	3.20	0.10	Rough
R2	0.20	3.20	0.05	Rough
S1	0.20	3.20	0.10	Smooth
S2	0.20	3.20	0.05	Smooth

*Bulk parameters used in the generation of the TMA spectrum

Hydrodynamic Setting

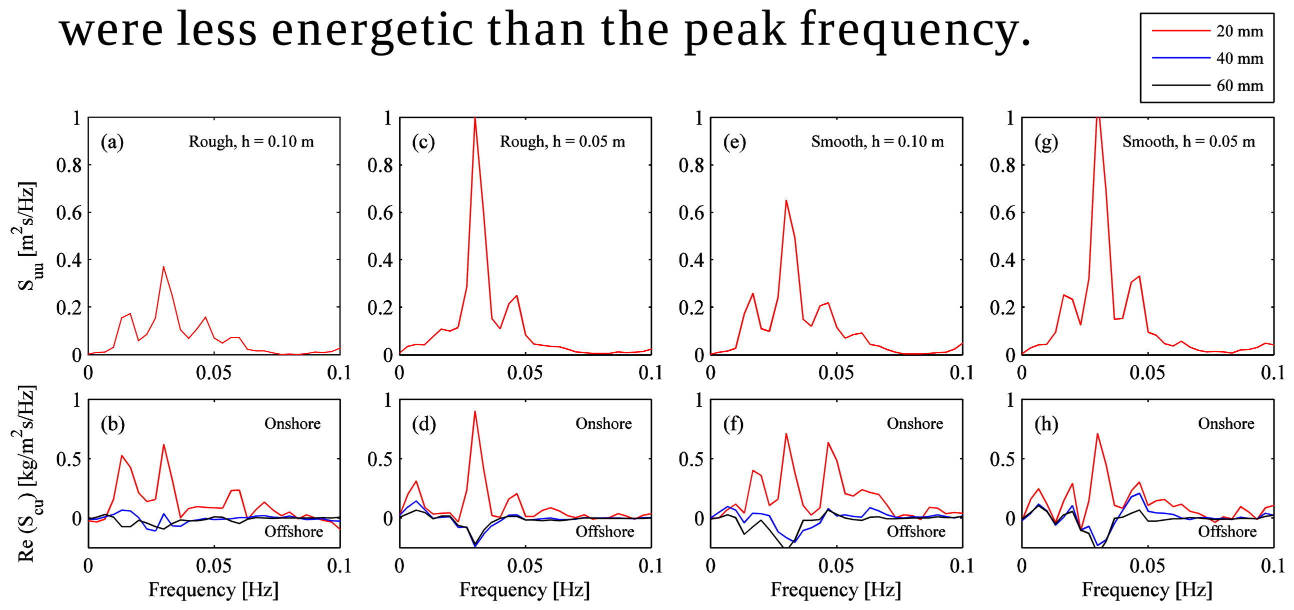
- Short waves (f > 0.15 Hz) dissipated rapidly near the reef crest.
- Infragravity (IG) motions (0.025 < $f \leq$ 0.15 Hz) initially increased in magnitude on the reef then dissipated over the back half of the reef before they increased in magnitude in the lagoon.
- Very low frequency (VLF) motions ($f \leq$ 0.025 Hz) increase in magnitude over the entire reef and lagoon.



Observed hydrodynamic conditions. (a) Model bathymetry, (b) Total wave height, (c) setup, (d) reflection ration $H_{m0,in}/H_{m0,out}$ (e-g) Decomposed incident wave motions

Sediment Flux

- Cross-spectral analysis of the concentration signal at different heights with the near-bed velocity signal show the variance and direction of sediment flux.
- A sediment flux peak occurred near f = 0.03 Hz for all simulations, falling within the IG wave band.
- Onshore flux was observed near the bed.
- Offshore flux was observed higher in the water column
- Higher and lower harmonics were also observed but were less energetic than the peak frequency.



Low frequency spectral observations. Spectral analysis of the velocity signal (top row) and cross-spectral analysis of the concentration and velocity signals (bottom row) . Analysis was conducted with the Welch approach with 50% overlapping Hanning windows.

Velocity moments

Significance

- The third order velocity moment $u^3 = (u_m + u_{IG} + u_{ss})^3$ represents a transport rate that is proportional to the dissipation energy near the bed (u^2) and a transport velocity (u).

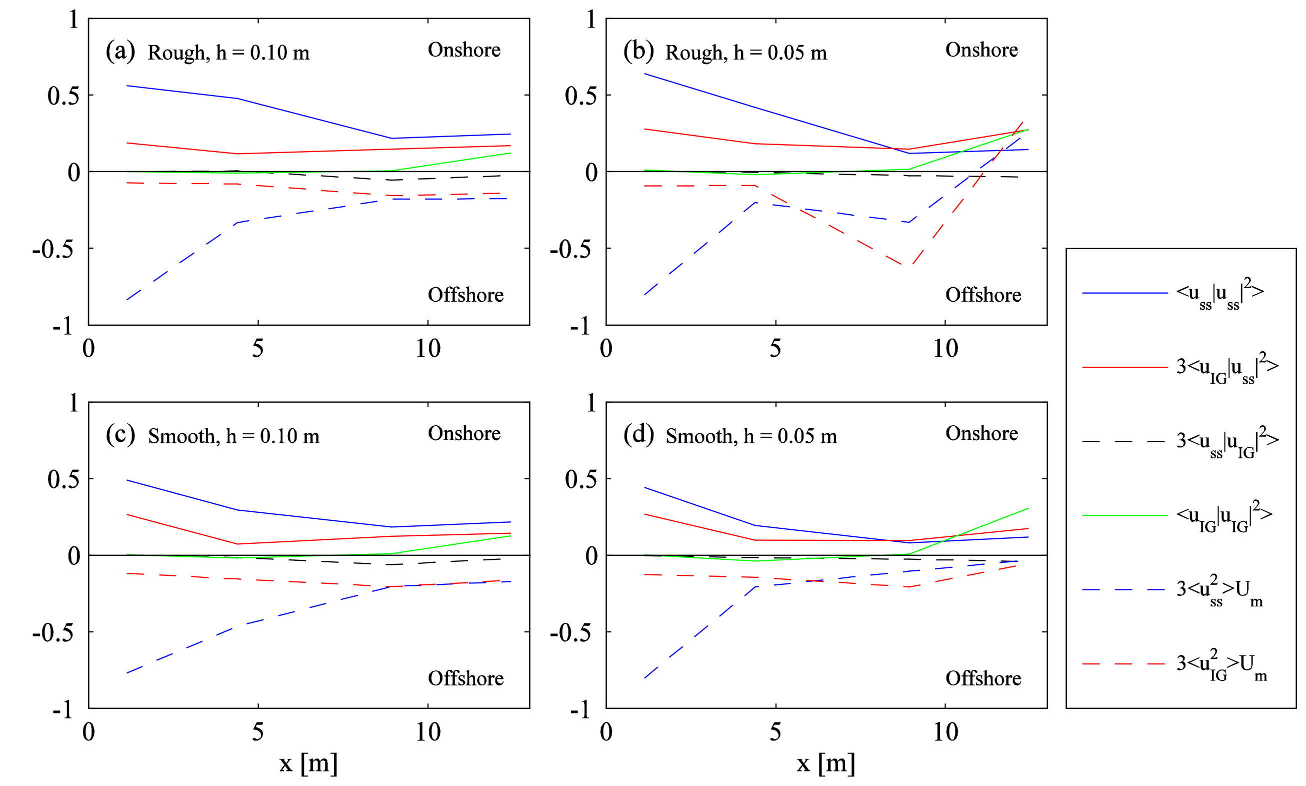
Dominant near-bed moments

Onshore transport

- Near the reef crest, short wave stirring and short wave transport ($\langle u_{ss}|u_{ss}|^2\rangle$).
- Across the reef, $\langle u_{ss}|u_{ss}|^2\rangle$ decreased and short wave stirring and long wave transport ($\langle u_{IG}|u_{ss}|^2\rangle$) increased.
- Long wave stirring and long wave transport ($\langle u_{IG}|u_{IG}|^2\rangle$) was small but became important near the beachface.

Offshore transport

- Near the reef crest, short wave stirring and mean flow transport ($3\langle u_{ss}^2\rangle u_m$).
- Small contribution by long wave stirring and mean flow transport ($3\langle u_{IG}^2\rangle u_m$).
- Across the reef, $3\langle u_{ss}^2\rangle u_m$ decreased and $3\langle u_{IG}^2\rangle u_m$ became more important.



Evolution of the terms of the decomposed third order velocity moment on the reef flat

Conclusions

- Infragravity motions become increasingly more important from offshore to onshore in the transportation of sediment across the reef flat and lagoon
- Water depth does not have a large affect on the magnitude of the near bed moments but does enhance nearbed sediment fluxes.
- Many sediment transport formulae rely on peak short wave motions. Over large parts of a reef the spectrum is bimodal (a mix of short and long waves) or long wave dominant. This makes modelling of sediment transport challenging.

This project forms part of a PhD study by A.Pomeroy at The University of Western Australia and is supported by Robert and Maude Gledden Postgraduate Scholarship and a Gowrie Trust Fund Grant (2013, 2014).
Additional support was provided by an ARC Future Fellowship Grant FT110100201(RL), a UWA Research Collaboration Award (AP, RL) and Deltares Strategic Research Funding in the "Event-driven hydro and morphodynamics" program (WB, AvD)