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Laboratory Experiments Of Wave Overtopping Of Revetment Structures In Reef Environments

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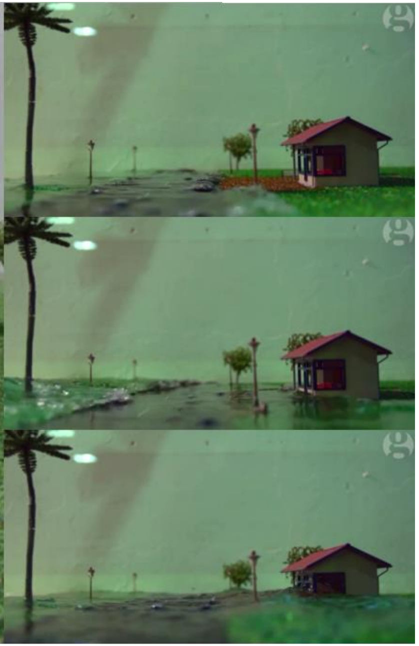

ACKNOWLEDGMENTS

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Wave Overtopping discharge on

smooth revetment with reef condition

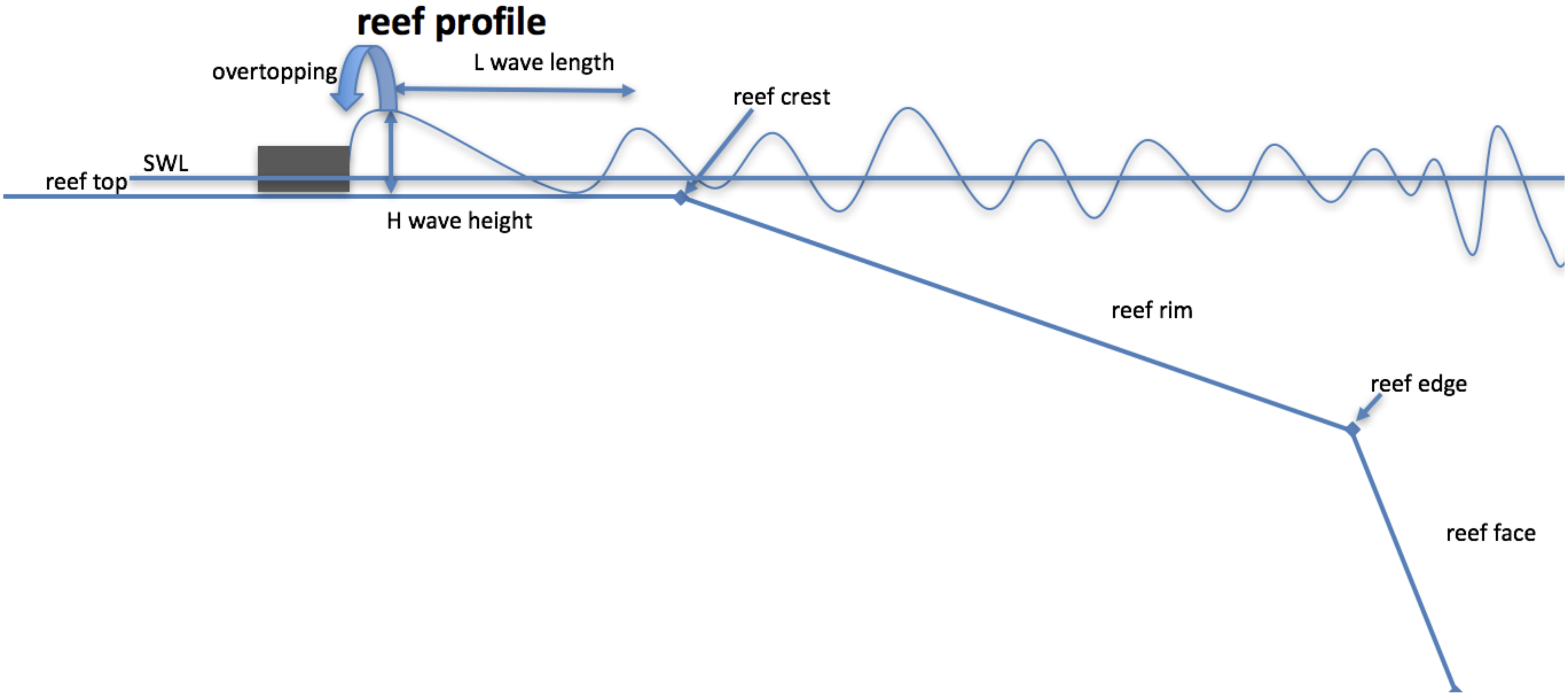
Supported by

The UNSW Sydney
Water Research Laboratory

Background

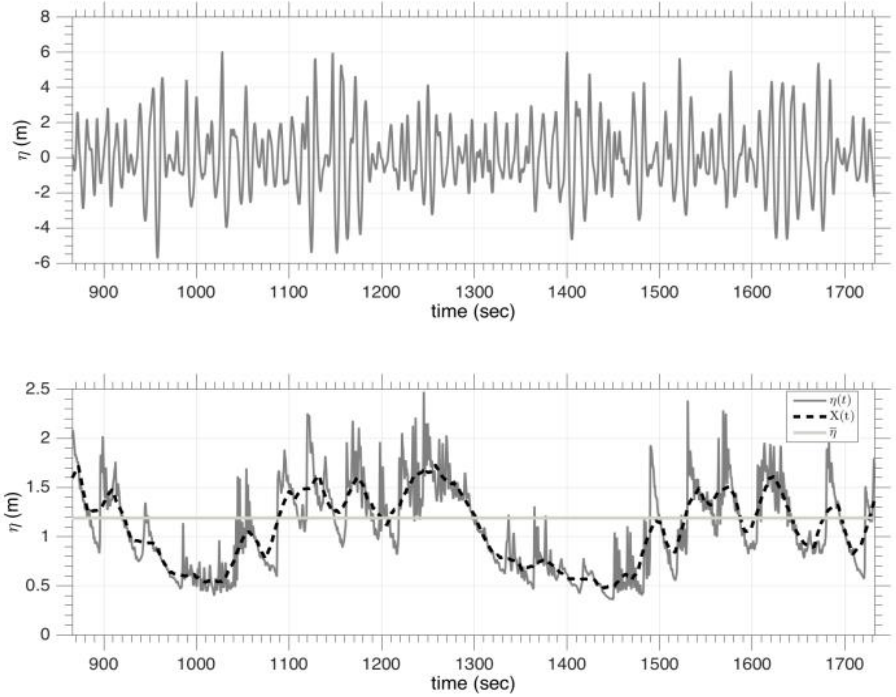
- Reef fronted islands are often protected from ocean swell during modal conditions
- During Tropical Cyclones
  - » Storm surge
  - » Large infragravity energy
  - » Inundation of low lying areas

THE REEF ENVIRONMENT



Wave Transformation on Reefs

- Offshore spectra shows groupiness of waves
- Reef top hydrodynamics
  - Incident waves dissipate much of their energy on the reef edge
  - Energy is transferred into low-frequency components – Surf beat
  - Incident band wave bores travel on top of this surf beat



PARAMETERS USED IN DESIGN EQUATIONS

$T_{M-1,0}$: For standard cases the ratio between Tp/Tm-1,0 equal to 1.1, but for the situation with shallow and **very shallow foreshore the ratio between these two parameters can be less than 0.3**(EurOtop,2016).

Wave length $L_{m-1,0} = g\frac{{T_{m-1,0}}^2}{2\pi}$

Steepness ($S_{m-1,0}$): For shallow and very shallow foreshore condition the wave steepness is calculated by inputting the **wave length and wave height at toe of the structure**.

Breaker parameter (**ξ**): $\xi_{m-1,0} = \frac{tan\alpha}{\sqrt{S_{m-1,0}}}$, where slope defined by the structure typically

Rc = crest freeboard, measured from SWL

PARAMETERS USED IN DESIGN EQUATIONS

R2% (smooth impermeable surfaces and very shallow foreshores): (eq. 5.2 Eurotop 2016)

$$\frac{R_{2\%}}{Hm0} = 1.0 * \gamma_f * \gamma_\beta \left(4 - \frac{1.5}{\sqrt{\gamma_b * \xi_{m-1,0}}}\right)$$

γ_b is the influence factor for a berm [-], [in our case this will be 1]

γ_f is the influence factor for roughness elements on a slope [-], [in our case this will be 1]

γ_β is the influence factor for oblique wave attack [-] [in our case this will be 1]

γ_v is the influence factor for a wall at the end of a slope. [in our case this will be 1]

DESIGN EQUATIONS

General formula (eq. 5.10, Eurotop 2016)

$$\frac{q}{\sqrt{gH_{m0}^3}} = \frac{0.023}{\sqrt{\tan\alpha}}\gamma_b exp\left[-\left(b * \frac{R_c}{\xi_{m-1,0} * H_{m0} * \gamma_b * \gamma_f * \gamma_\beta * \gamma_v}\right)^{1.3}\right]$$

Van Gent (1999) for smooth sea dike with shallow/very shall foreshore

$$\frac{q}{\sqrt{gH_{m0}^3}} = 10^c exp\left[-\left(\frac{R_c}{(0.33 + 0.022 * \xi_{m-1,0}) * H_{m0} * \gamma_f * \gamma_\beta}\right)\right]$$

Where c = -0.92 +/- 1.64(0.24) – mean value approach

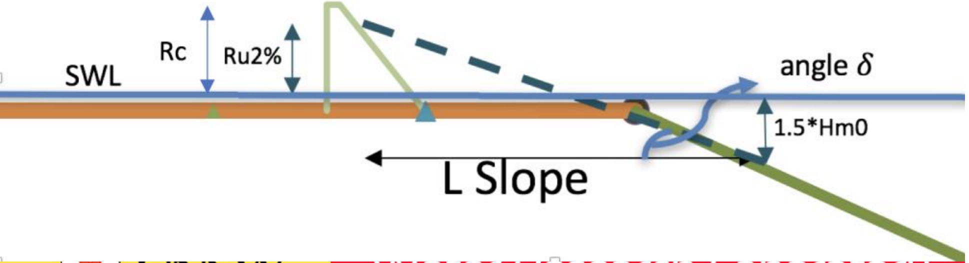
DESIGN EQUATIONS

Altomare (2016)

$$\frac{q}{\sqrt{gH_{m0}^{3}}} = 10^{c\_new} exp\left[-\left(\frac{R_c}{(0.33 + 0.022 * \xi_{m-1,0}) * H_{m0} * \gamma_f * \gamma_\beta}\right)\right]$$

Where c = -0.791 +/- 1.64(0.294) [mean value approach]; c = -0.5 (eq. 5.16 Eurotop) design and assessment

$$\xi_{m-1,0} = \frac{tan\alpha}{\sqrt{S_{m-1,0}}}$$

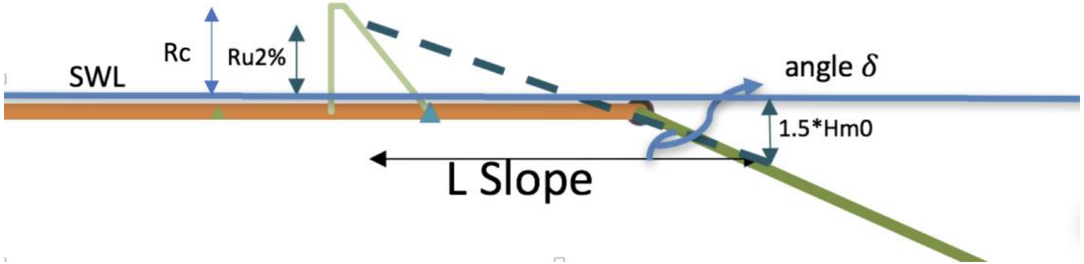


The equivalent slope $tan\alpha$ is defined as the average slope in the zone between still water level minus 1.5 significant incident wave height and still water level plus the wave run-up level exceeded by 2%of the incident wave.

DESIGN EQUATIONS

$$\tan \alpha_{sf} = \frac{1.5H_{m0}+R_{2\%}}{(1.5H_{m0}-h_t)*m+(h_t+R_{2\%}) \cot \alpha}$$ for ht/Hm0 <1.5 (eq. 5.14 eurotop)

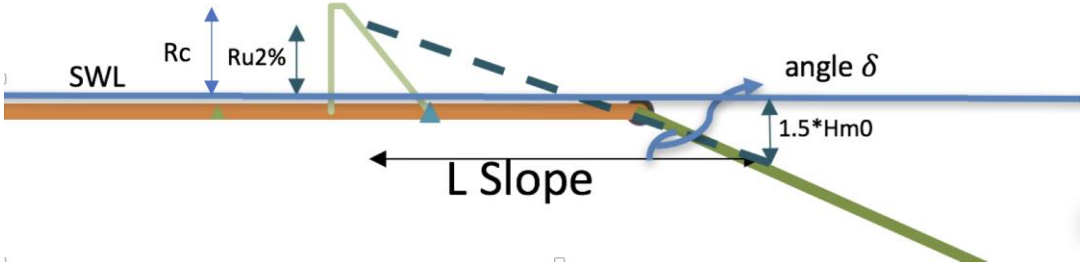
But what is ‘m’ on a flat reef with a steep slope at the rim?



DESIGN EQUATIONS

$$\tan\alpha_{sf} = \frac{1.5H_{m0}+R_{2\%}}{RW+(1.5H_{m0}-h_t)*mReef+(h_t+R_{2\%})\cot\alpha}$$ for ht/Hm0 <1.5

Modified equation for a flat reef with a steep slope at the rim?



EXPERIMENTAL STUDY

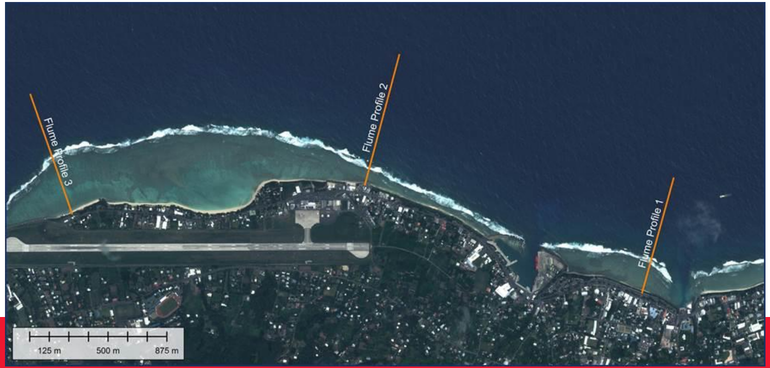
1:50 scale tests done on a reef representative of Cook Islands

Prototype Cyclone condition waves:

Wave condition	Wave height (m)	Peak wave period (s)	Still water level (m)
TC Sally	8m	11s, 13s, 15s	0.3m 1.0m
100 year ARI	12m	13s	1.5m 2.1m

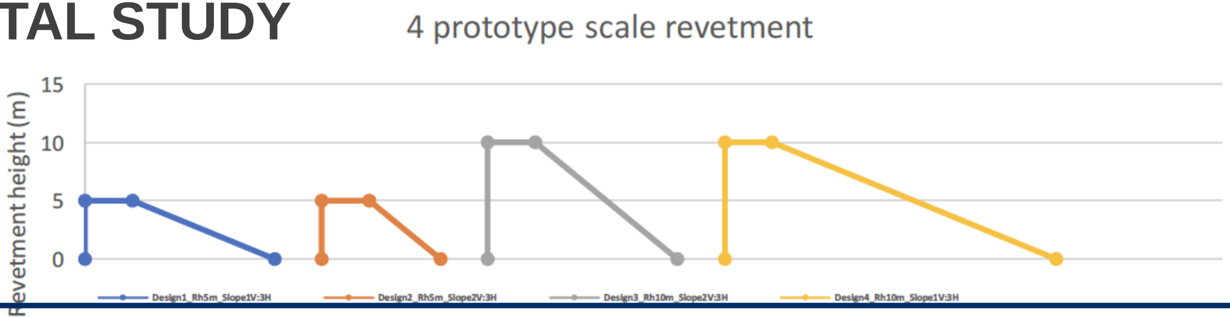
Reef widths:

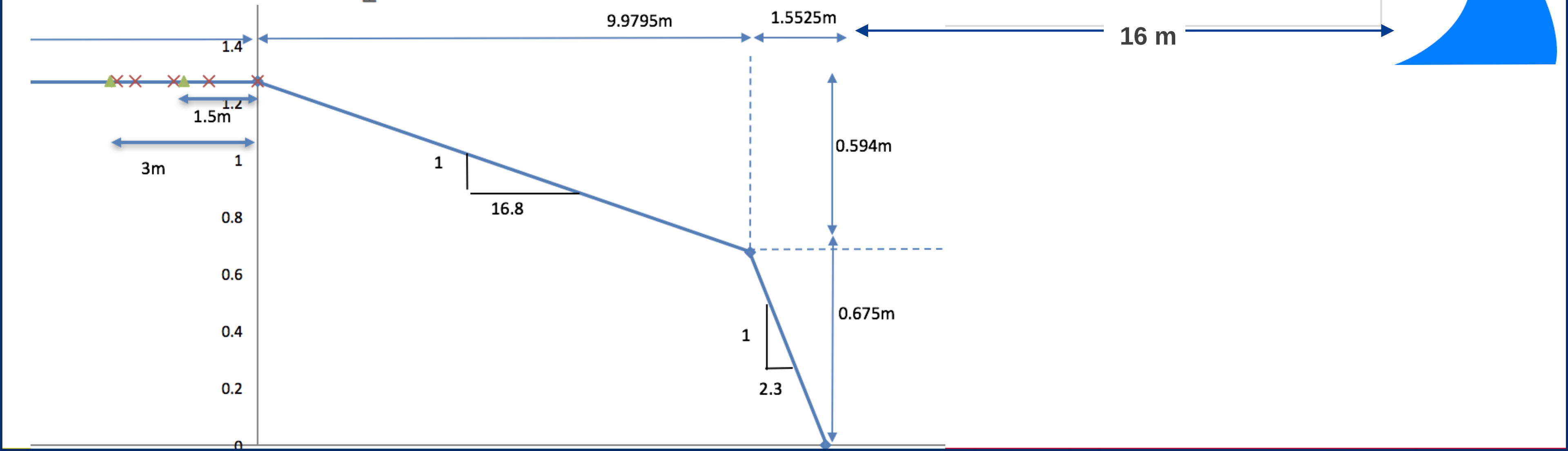
75 and 150 m



Each test was run for 1000 waves

EXPERIMENTAL STUDY

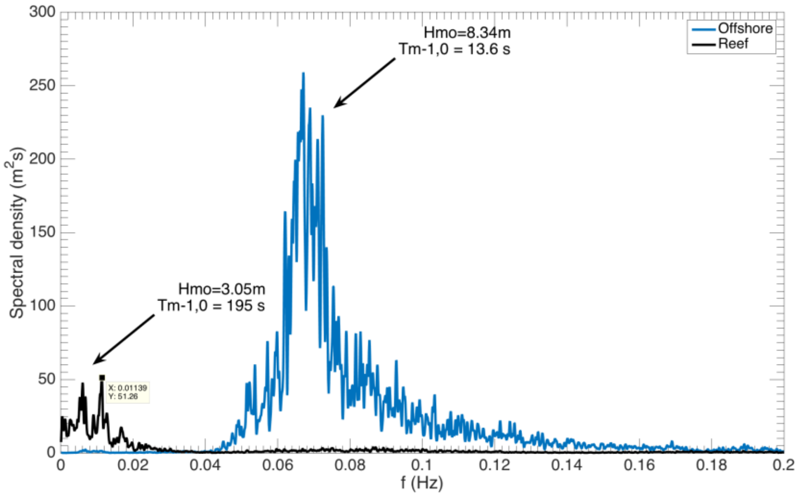


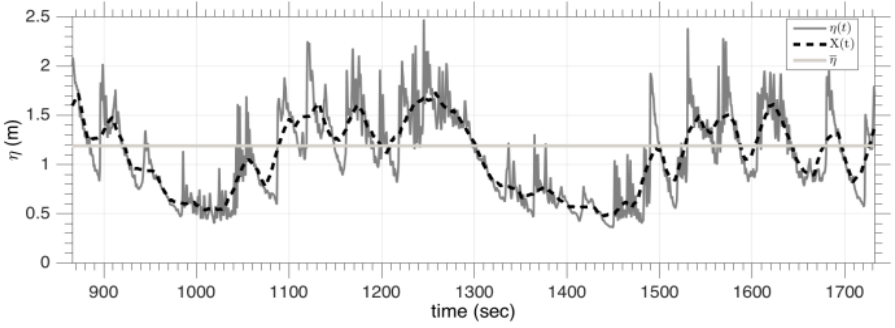


RESULTS – Example Spectral Transformation

Large change in Spectral characteristics

- Offshore
  - » Hm0 = ~8m
  - » Tm-1,0 = 13.6s
- Reef (post-breaking)
  - » Dominated by low-frequency motions caused by breaking on the reef rim
  - » Hm0 = 3m
  - » Tm-1,0 = 195s
    - Peaks at 100 and 166s
  - » Setup ~ 0(1m)
  - » Surf beat ~ 0(0.5m)





RESULTS – Comparison to Eurotop (2016) eq. 5.16

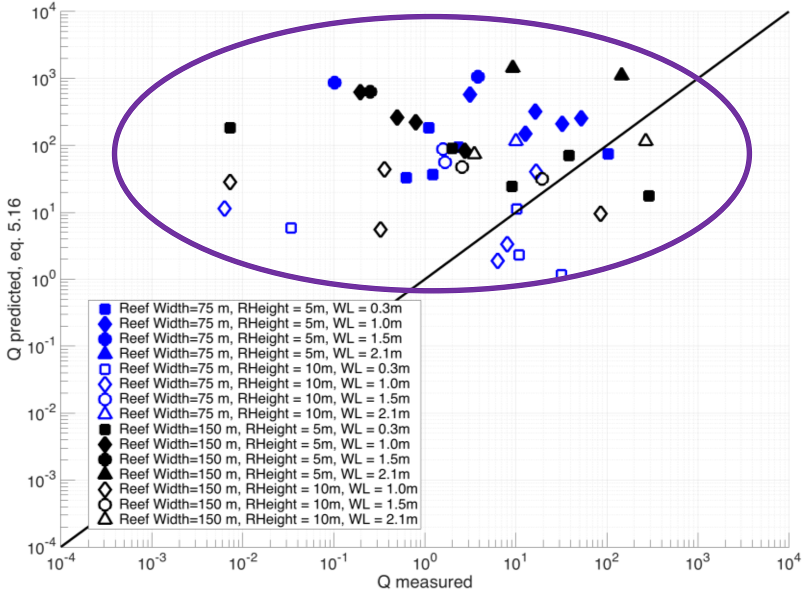
– Using **Hm0 and Tm-1,0** measured at toe of structure

Altomare (2016)

$$\frac{q}{\sqrt{gH_{m0}^3}} = 10^{-0.5} exp\left[-\left(\frac{R_c}{(0.33+0.022*\xi_{m-1,0})*H_{m0}*\gamma_f*\gamma_\beta}\right)\right]$$

– Modified $\xi_{m-1,0} = \frac{tan\alpha_{sf}}{\sqrt{s_{m-1,0}}}$

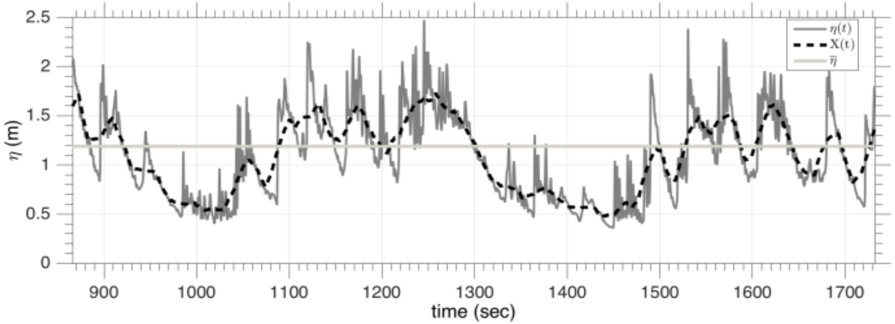
– $\tan\alpha_{sf} = \frac{1.5H_{m0}+R_{2\%}}{RW+(1.5H_{m0}-h_t)*mReef+(h_t+R_{2\%})\cot\alpha}$



$$Q = \frac{q}{\sqrt{gH_{m0}^3}} * \sqrt{gH_{m0}^3}$$

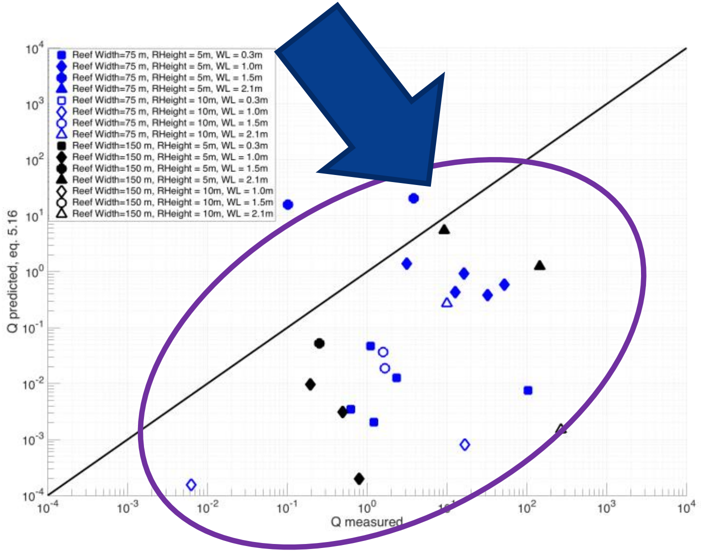
RESULTS – Comparison to Eurotop (2016) eq. 5.16

– Recalling that this is what the free surface timeseries looks like are Hm0 and Tm-1,0 the best values?



– Using **Hm0SS and Tm-1,0SS** measured at toe of structure

– Data shifts down but may now have a similar slope



RESULTS – Comparison to Eurotop (2016) eq. 5.16

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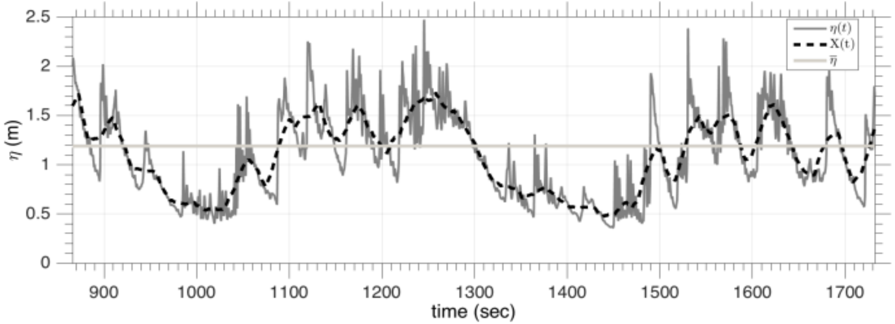
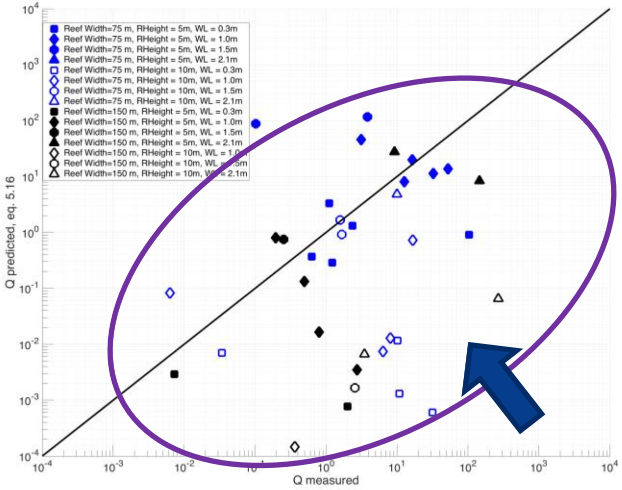


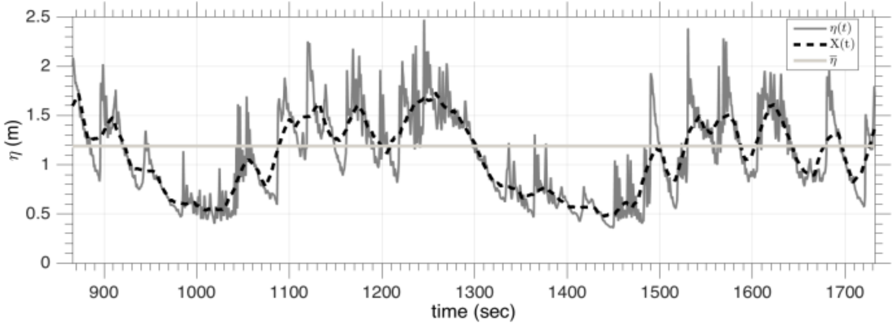


– Using **Hm0SS and Tm-1,0** measured at toe of structure (**focussing on infragravity modulation**)

– Data shifts slightly up from previous and may still have a similar slope

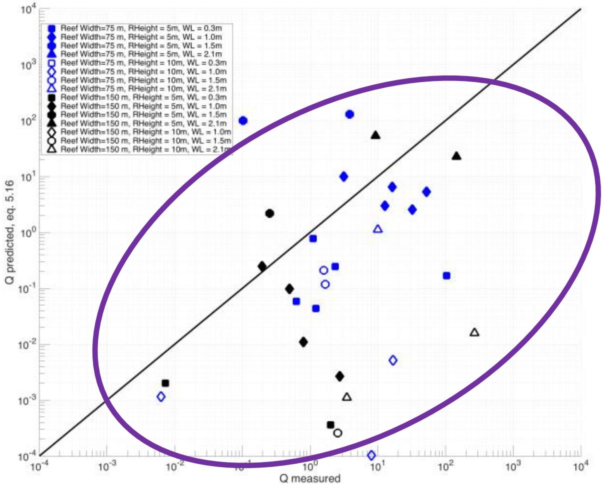
RESULTS – Comparison to Eurotop (2016) eq. 5.16

– Recalling that this is what the free surface timeseries looks like are Hm0 and Tm-1,0 the best values?



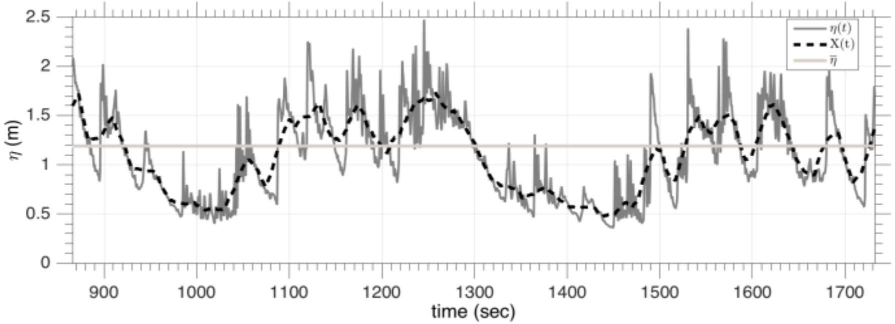
– Using **Hm0SS and Tm-1,0SS** measured at toe of structure (**including wave setup**)

– Minor differences from using Tm-1,0

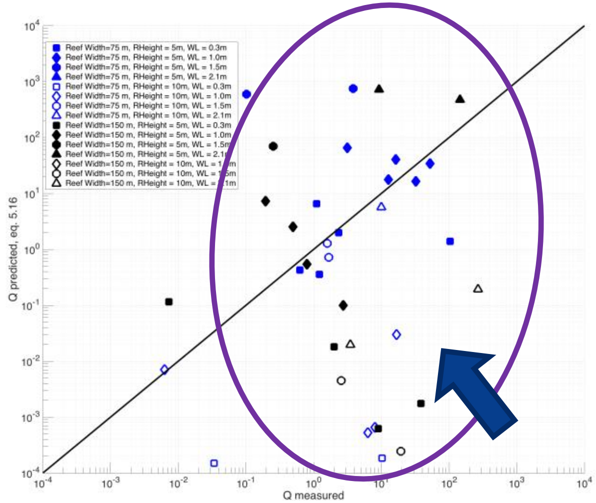


RESULTS – Comparison to Eurotop (2016) eq. 5.16

- Recalling that this is what the free surface timeseries looks like are Hm0 and Tm-1,0 the best values?



- Using **Hm0SS and Tm-1,0SS** measured at toe of structure (**including wave setup and 2*surfbeat**)
- Slight shift up and more vertical spread from wave setup alone



CLOSING THOUGHTS

- It appears from these preliminary tests that we may be missing key processes that determine over-topping of revetments in reef environments during extreme events
- These are AVERAGE Q values. Are these the best to be designing for in environments with high temporal modulation of overtopping where the mean does not represent the true over-topping rate which will flood houses, sweep people off their feet and cause structural damage ???
- We welcome your thoughts/comments and advice, from you the experts in this field.

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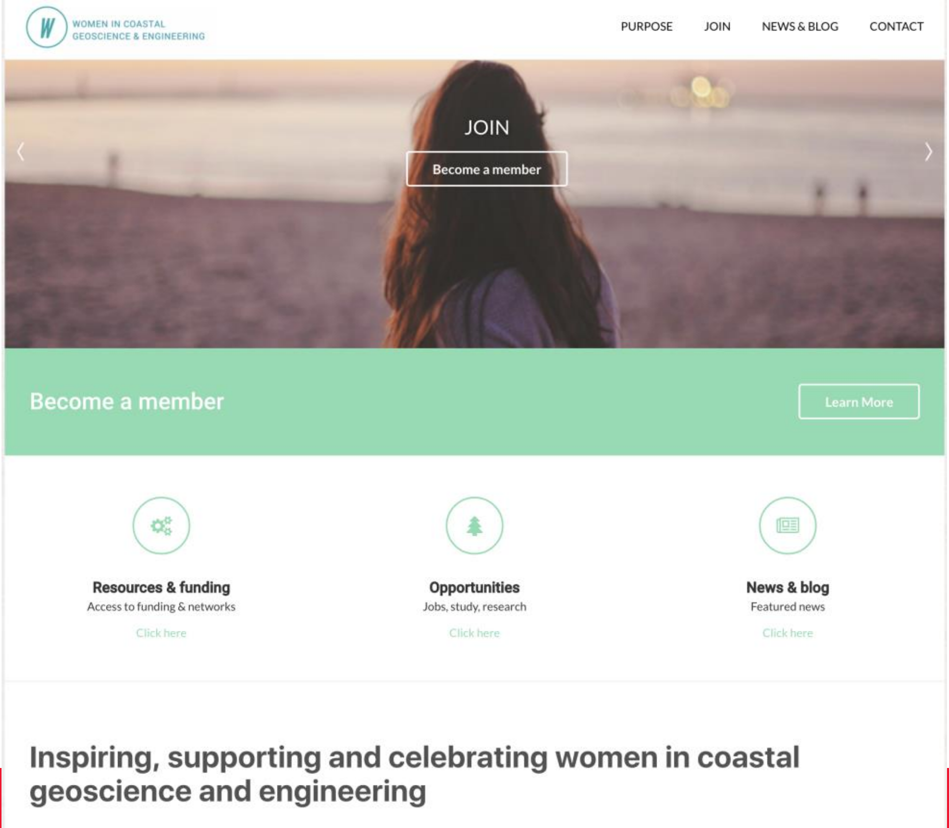

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KEY DATES

Abstract Submissions Open	1 Apr 2019
Abstract Submissions Close	15 Sep 2019
Registration Opens	13 Apr 2020
Earlybird Registration Closes	3 Jul 2020

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