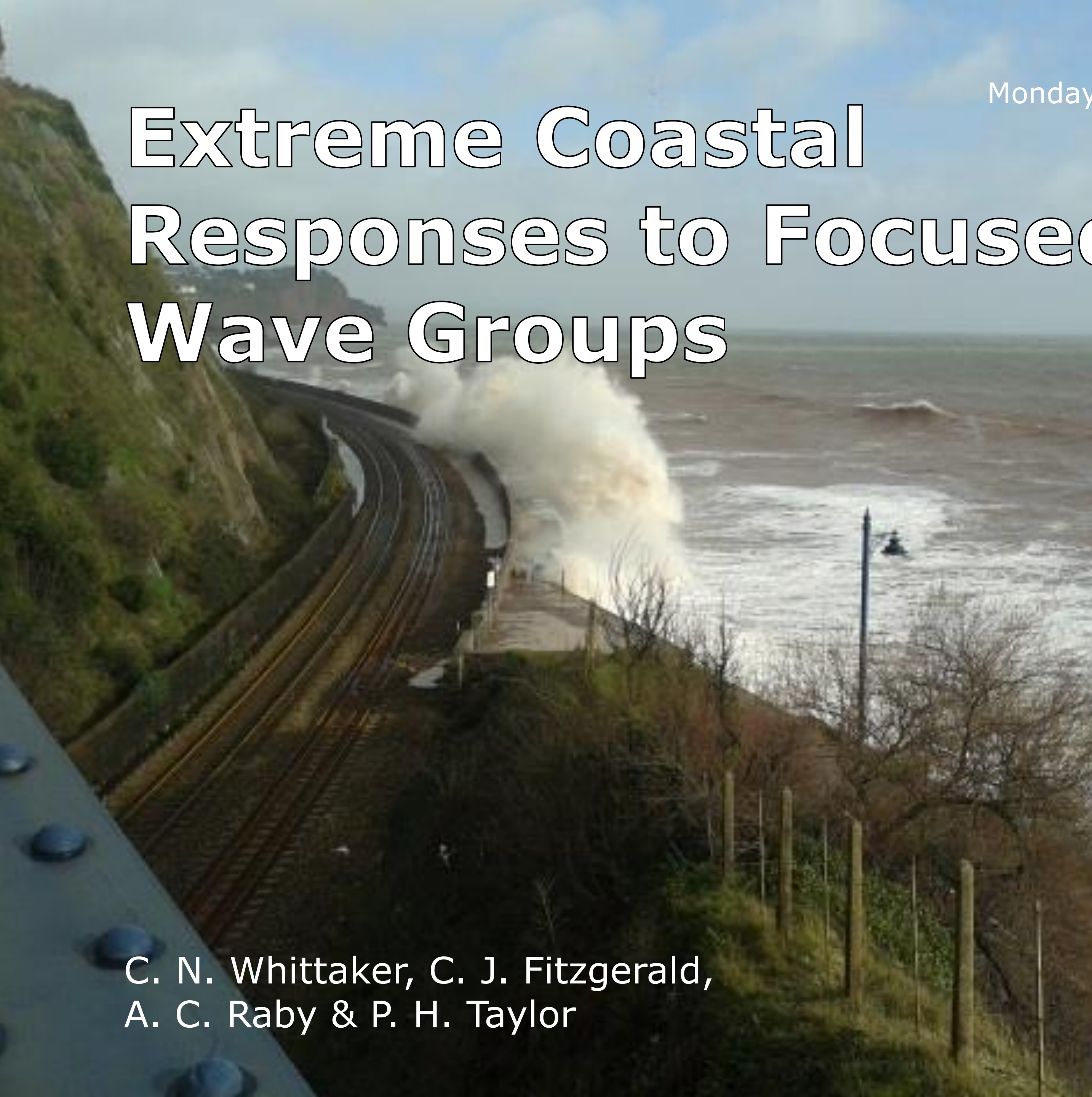

Monday, 18 November 2019

Extreme Coastal Responses to Focused Wave Groups

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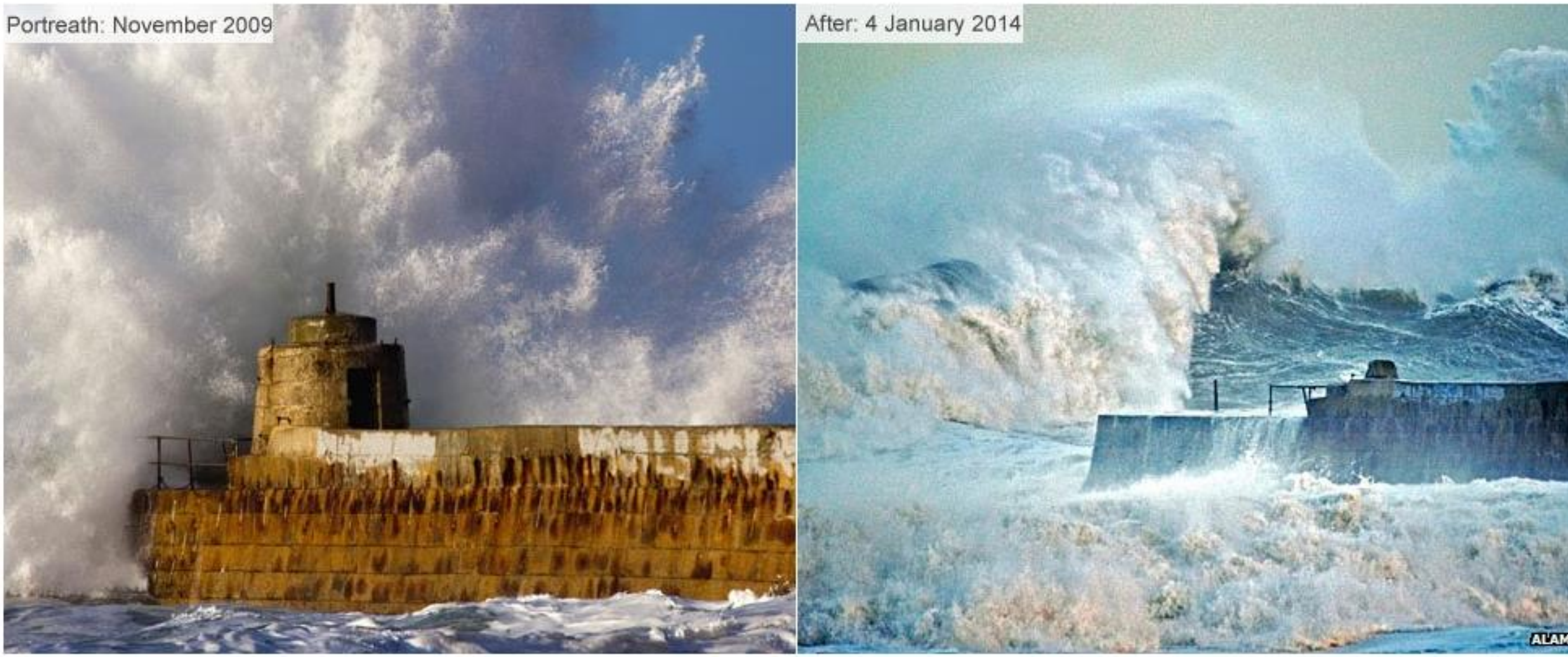
Introduction



BBC News
7 January 2014

The ENFORCE project

- Builds on wave statistics, physical and numerical work over a decade. 'NewWave' focused wave group

- Statistics of 'bulk' coastal extreme responses, such as run-up and overtopping

- Numerical and physical experimentation
  - Phase resolved - M&S extended Boussinesq equations coupled with NLSW equations
  - Wave group run-up and overtopping at the University of Plymouth

- Role of lab experiments and field data

NewWave background

The average shape around an extreme in a linear random Gaussian process is proportional to the auto-correlation function of the random process

The auto-correlation function is the Fourier transform of the power spectrum

The shape of ANY EXTREME is related to a bulk property of ALL the waves - large and small.

(Lindgren 1970, Boccotti 1983, Tromans et al. 1991)

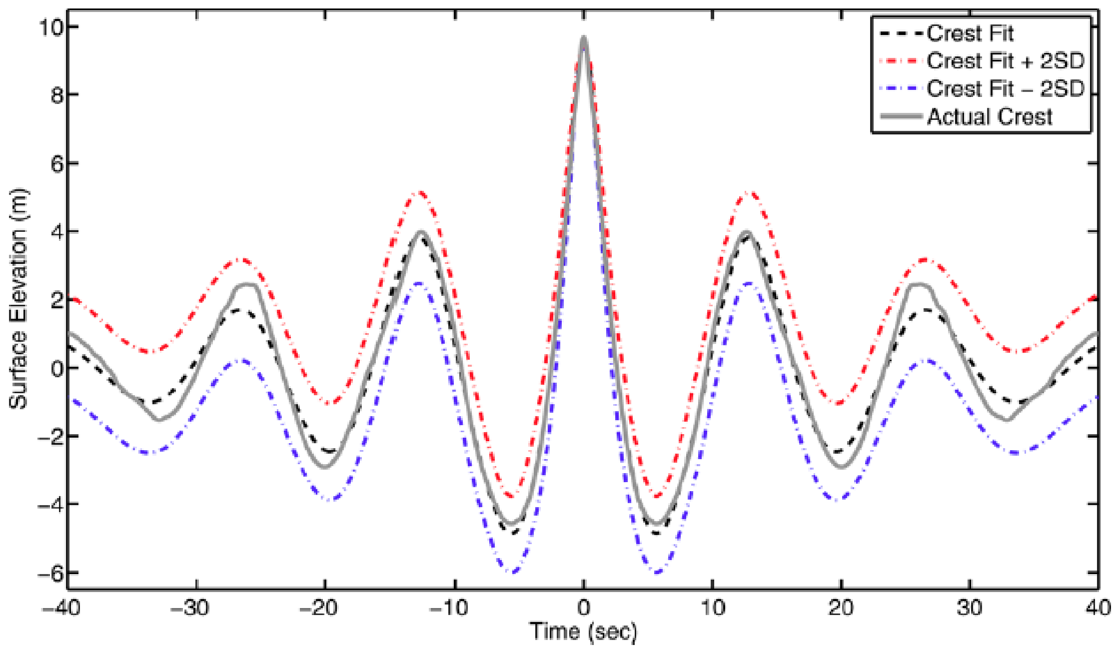
NewWave background

The linear focus amplitude may be linked to the number of waves in a given sea state by assuming the following Rayleigh distribution:

$$A_N = \sqrt{2\sigma^2 \ln N},$$

This may allow us to move from simulating (e.g.) 1000 irregular waves to simulating the coastal response to the “1 in 1000” wave.

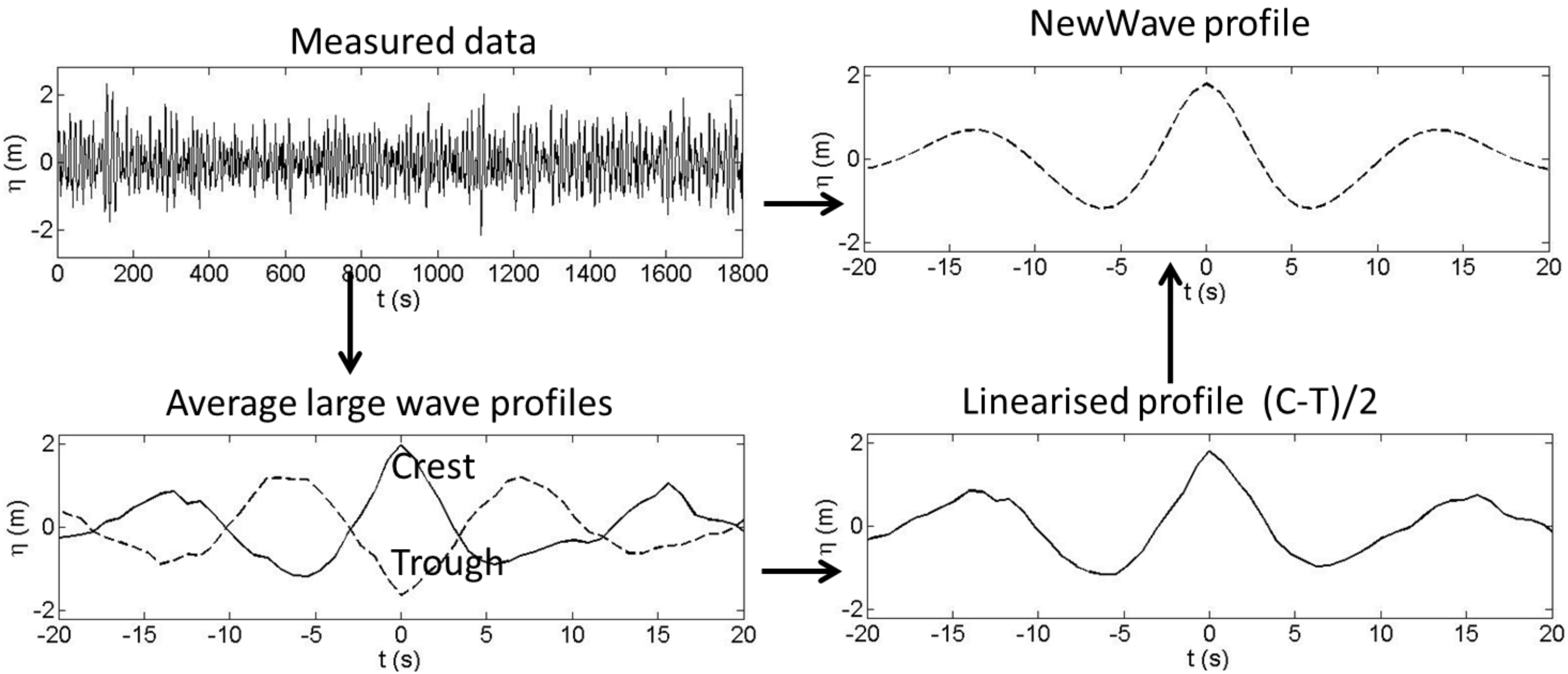
Validated against the average shape of large waves in field data for kD between 1.6 and 3.5 – intermediate or deep water



Time history of the mean of largest crests

Jonathan, P., and Taylor, P. H. (February 1, 1997). "On Irregular, Nonlinear Waves in a Spread Sea." ASME. *J. Offshore Mech. Arct. Eng*. February 1997; 119(1): 37–41. https://doi-org.ezproxy.auckland.ac.nz/10.1115/1.2829043

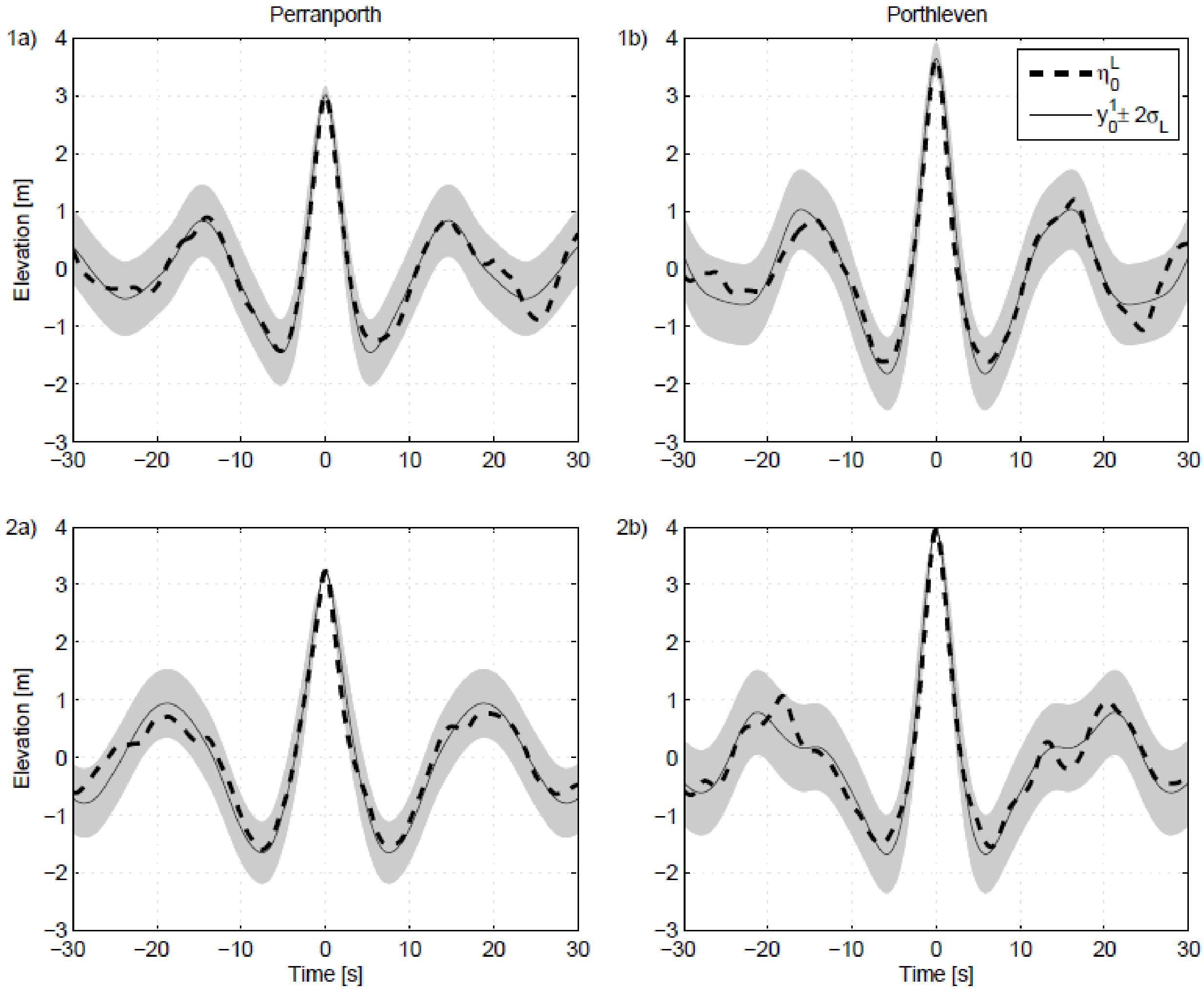
Shallow-water field data



$$y_0^1(t) = \alpha r_t = \frac{\alpha}{\sigma^2}\sum_{i=1}^{N} S_{\eta\eta}(\omega_i)\cos(\omega_i t)\Delta\omega,$$

$$\sigma^2 = \sum S_{\eta\eta}(\omega_i)\Delta\omega.$$

NewWave replication of linearised average large wave profiles

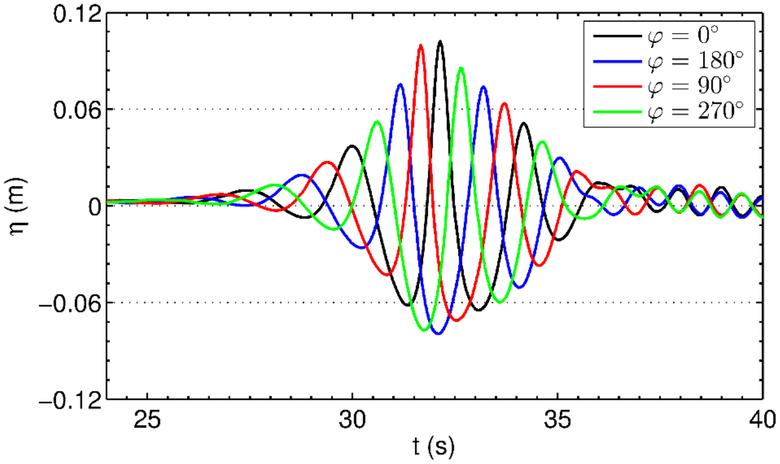


Whittaker, C. N., Raby, A. C., Fitzgerald, C. J., & Taylor, P. H. (2016). The average shape of large waves in the coastal zone. *Coastal Engineering*, *114*, 253-264.

Physical experiments

- Comprehensive experimental investigation into influence of focused wave parameters (A, x_f, ϕ) on:
    - Runup on a plane beach
    - Overtopping and horizontal forces exerted on an idealised seawall

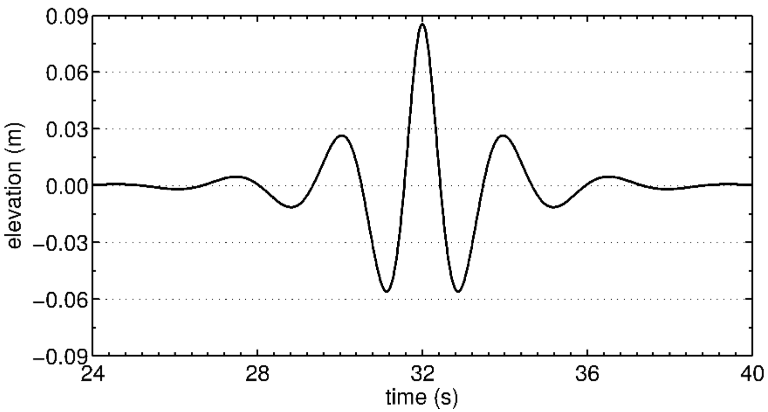
- Investigate influence of wave generation technique



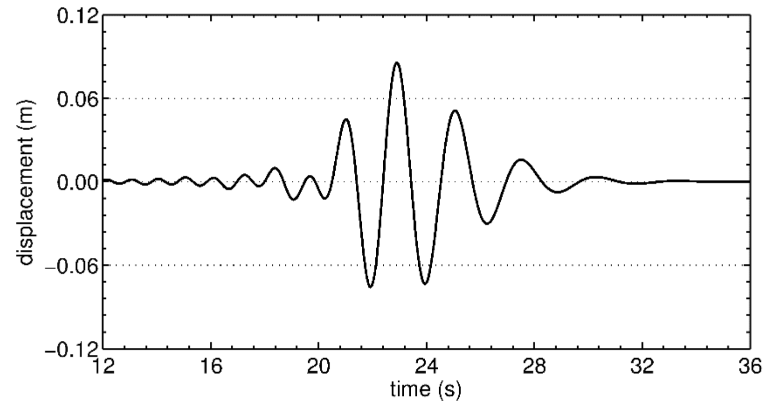
$$\eta(x,t) = \frac{A_f}{\sum S_{\eta\eta}\Delta\omega}\sum_{i=1}^{M} S_{\eta\eta}(\omega_i)\,\Delta\omega\,\cos\left(k_i\left(x - x_f\right) - \omega_i\left(t - t_f\right) + \phi_f\right)$$

Physical experiments

Target free-surface elevation at focus

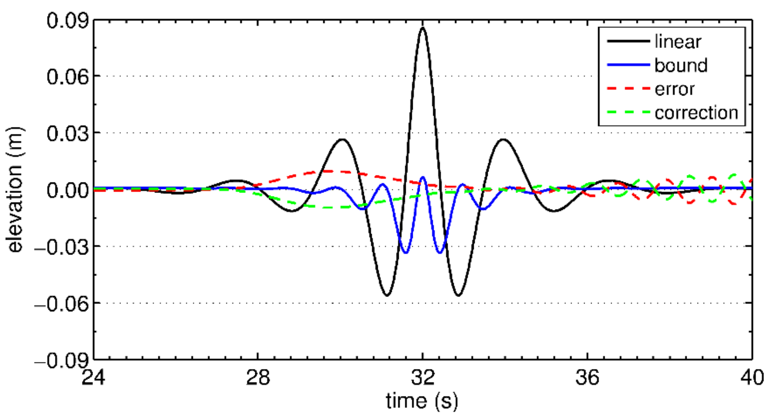


Piston paddle motion

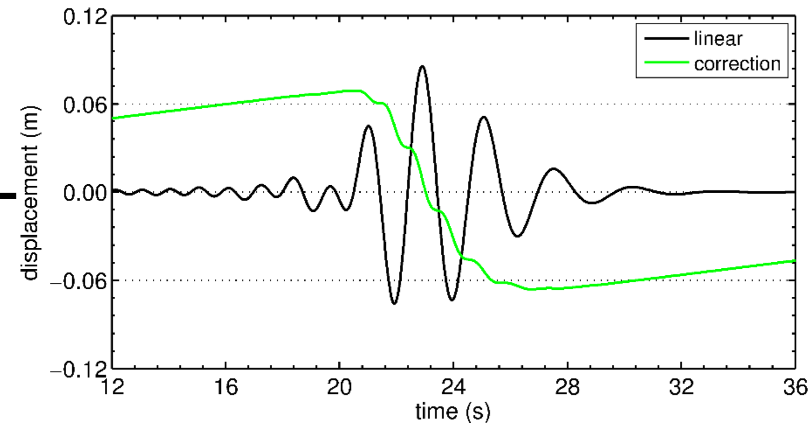


Second order theory

Actual free-surface elevation at focus



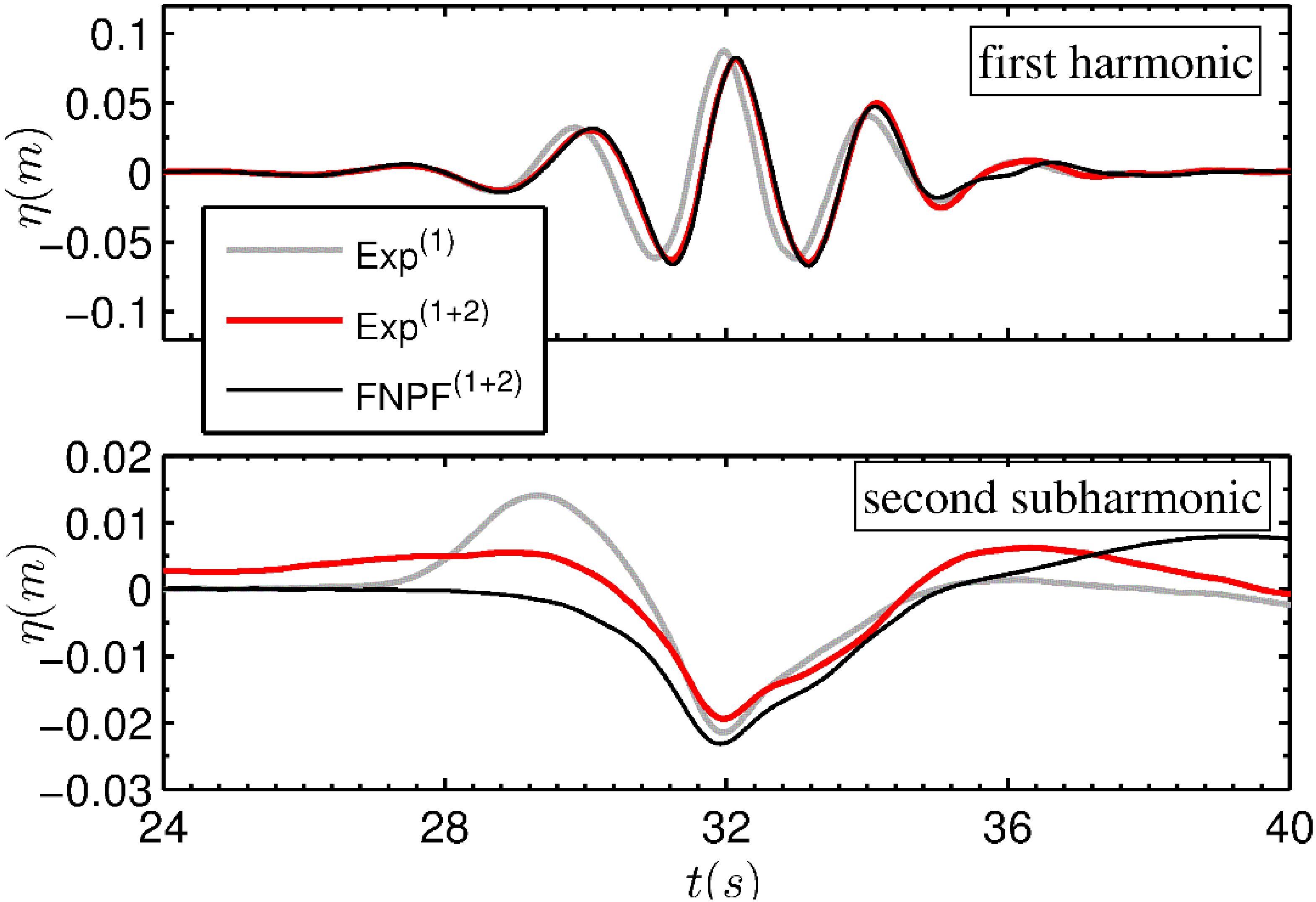
Second order corrected paddle motion



Orszaghova, J., Taylor, P. H., Borthwick, A. G., & Raby, A. C. (2014). Importance of second-order wave generation for focused wave group run-up and overtopping. *Coastal Engineering*, *94*, 63-79.

Schäffer, H. A. (1996). Second-order wavemaker theory for irregular waves. *Ocean Engineering*, *23*(1), 47-88.

Physical experiments

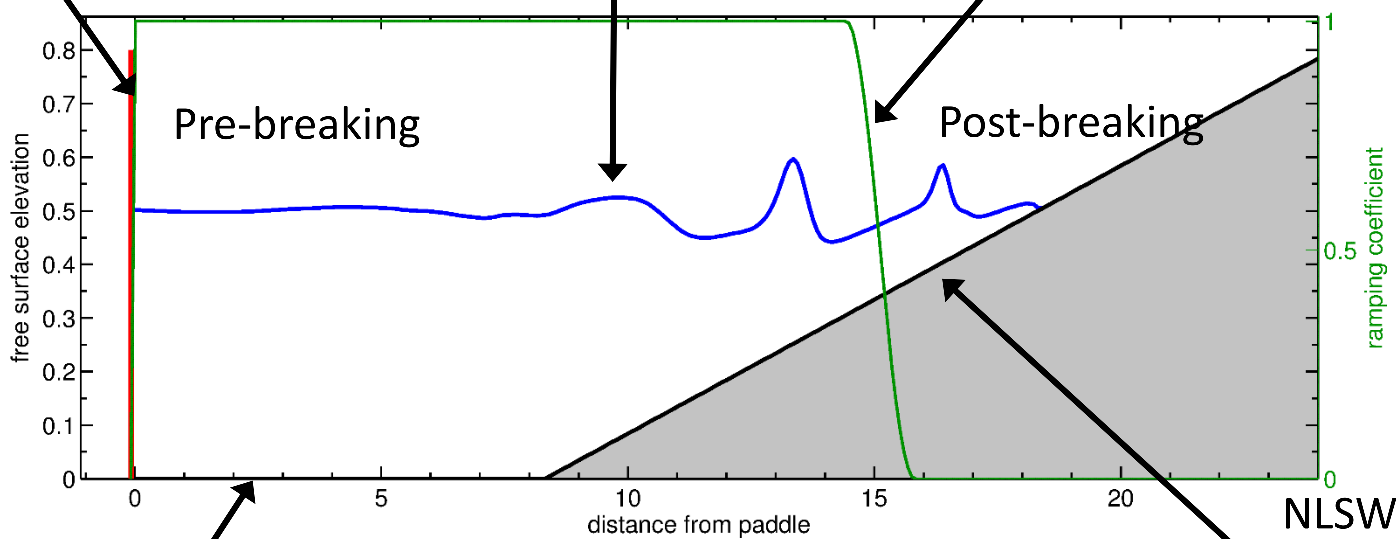


OXBOU model

Inbuilt piston wavemaker

Boussinesq equations (M&S, 1992): FD solver

Boussinesq-NLSW equation switch determined by local water surface slope



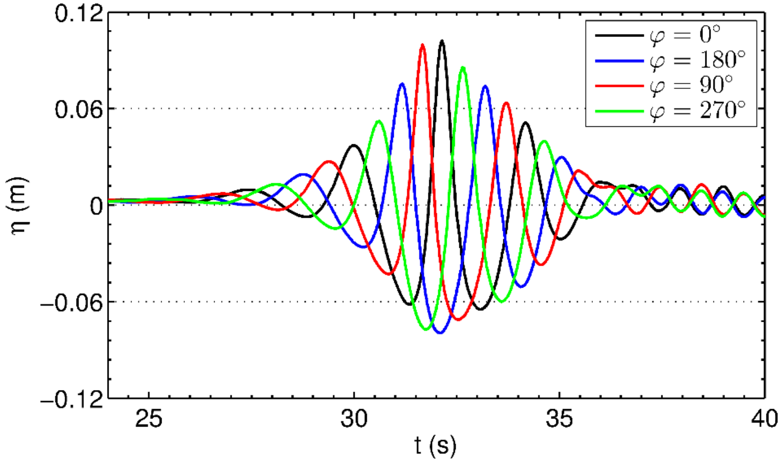
Active absorption of reflected waves

NLSW equations: FV scheme (with wetting and drying)

Fitzgerald, C. J., Taylor, P. H., Orszaghova, J., Borthwick, A. G., Whittaker, C., & Raby, A. C. (2016). Irregular wave runup statistics on plane beaches: Application of a Boussinesq-type model incorporating a generating–absorbing sponge layer and second-order wave generation. *Coastal Engineering*, *114*, 309-324.

Orszaghova, J., Borthwick, A. G., & Taylor, P. H. (2012). From the paddle to the beach–A Boussinesq shallow water numerical wave tank based on Madsen and Sørensen's equations. *Journal of Computational Physics*, *231*(2), 328-344.

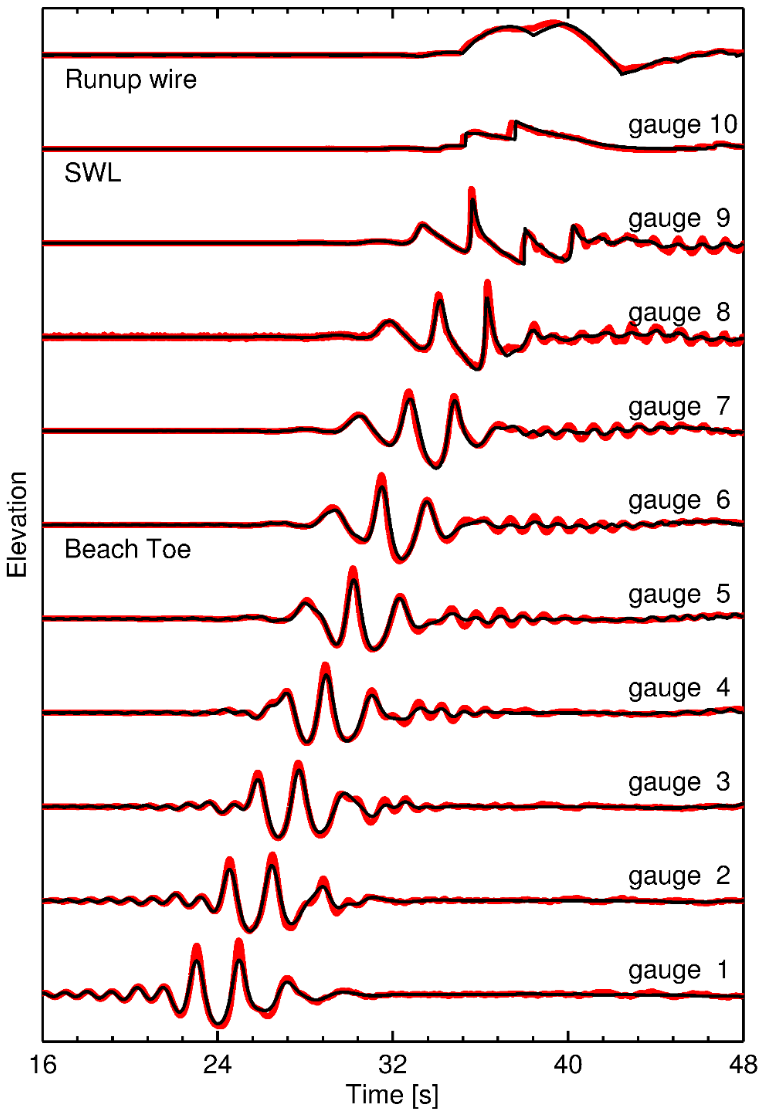
Runup on a plane beach



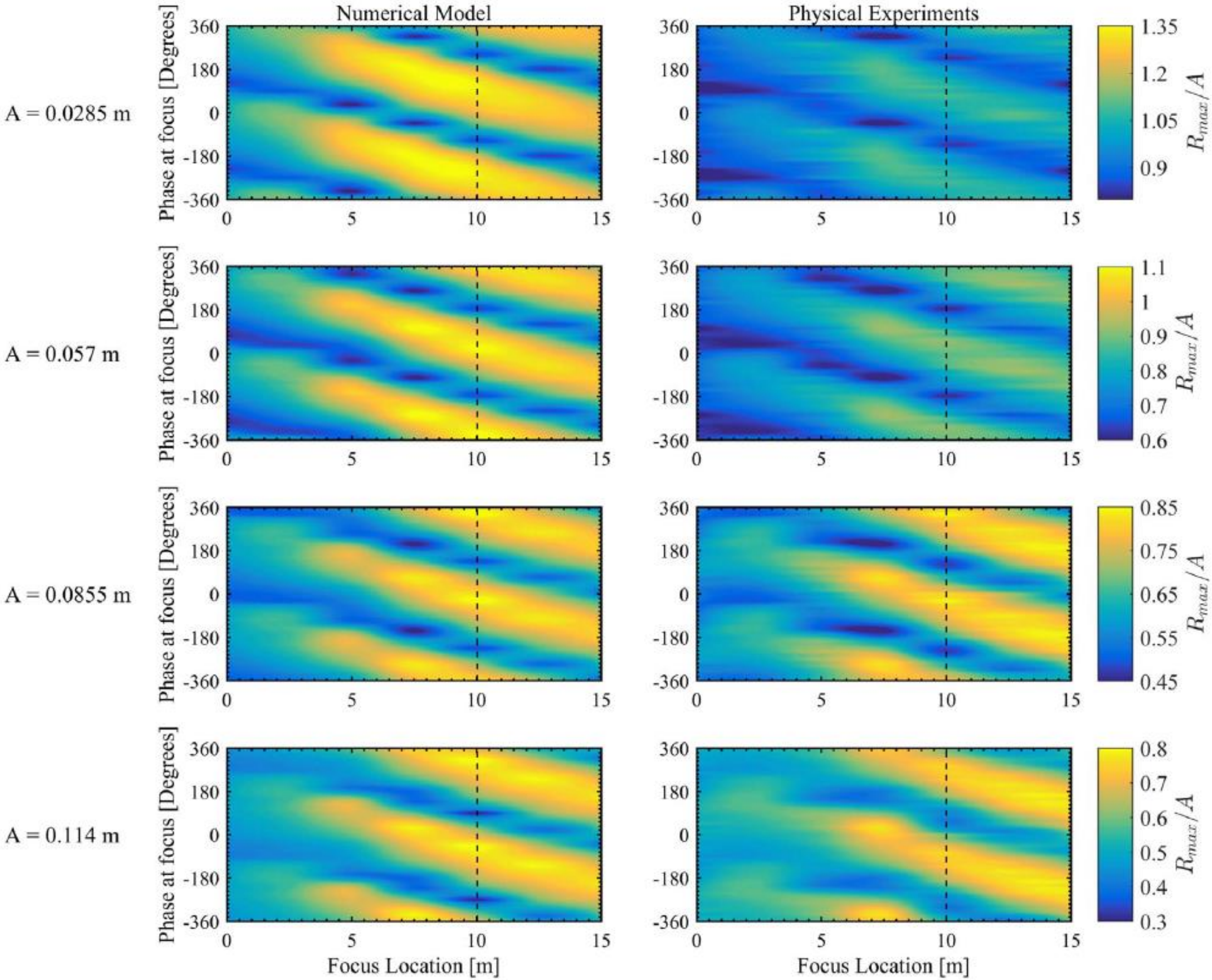
1:20 beach slope, fixed bed.

Wave group runup dependence on:

- amplitude A_f
- focus location x_f
- phase at focus ϕ_f

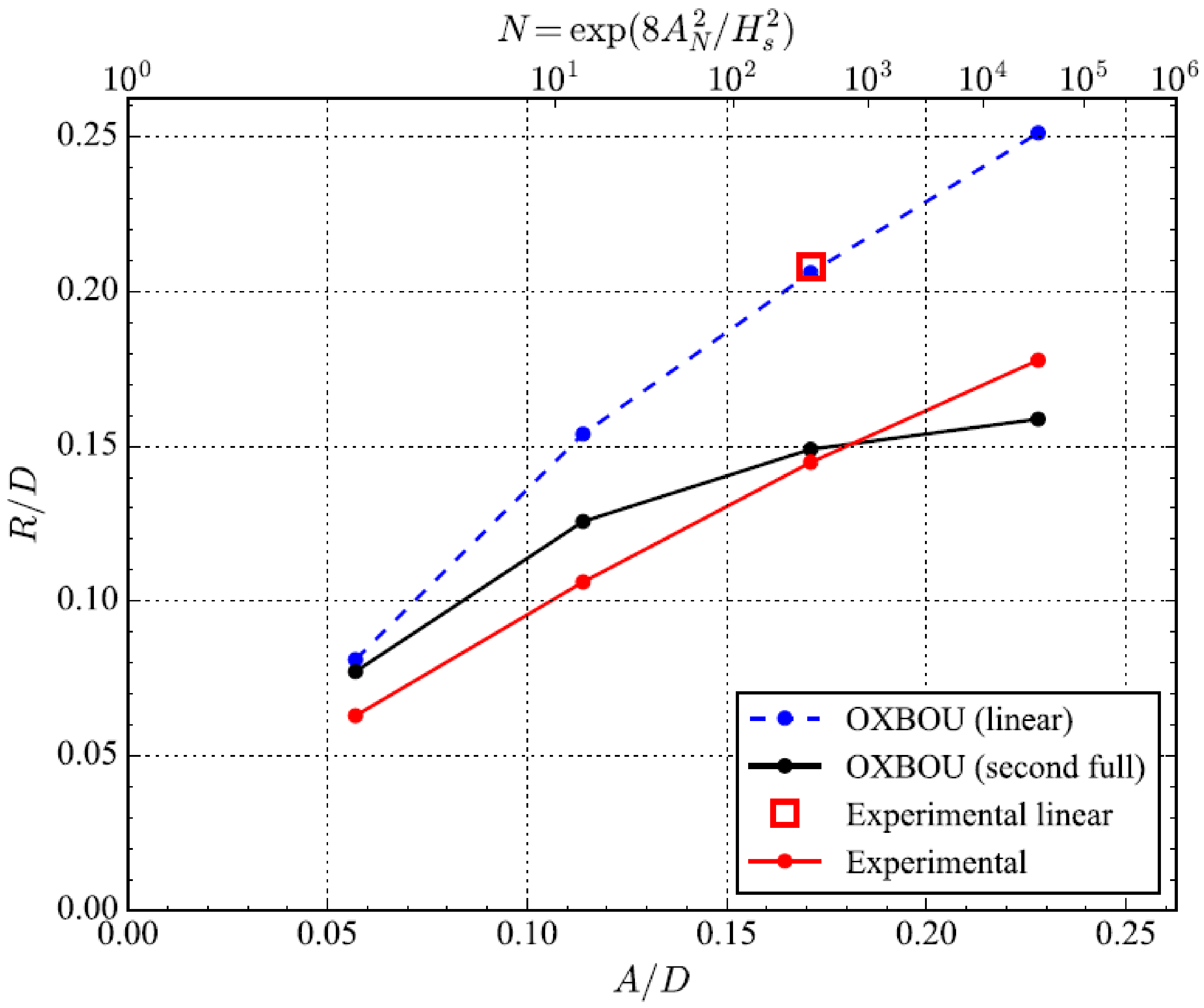


Whittaker, C. N., Fitzgerald, C. J., Raby, A. C., Taylor, P. H., Orszaghova, J., & Borthwick, A. G. L. (2017). Optimisation of focused wave group runup on a plane beach. *Coastal Engineering*, *121*, 44-55.

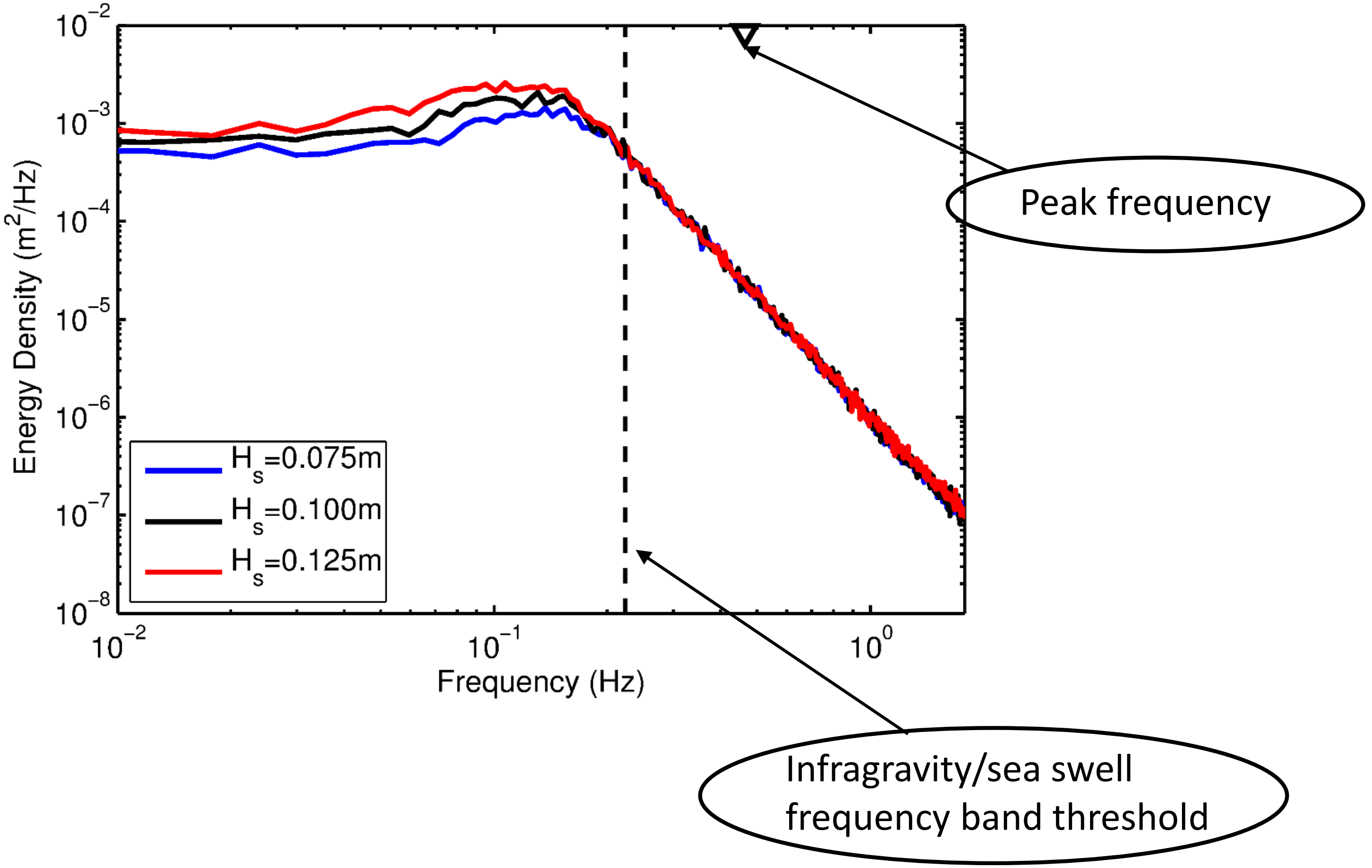


Numerical Model
Physical Experiments
A = 0.0285 m
A = 0.057 m
A = 0.0855 m
A = 0.114 m
Phase at focus [Degrees]
360
180
0
-180
-360
0
5
10
15
Focus Location [m]
R_{max}/A
1.35
1.2
1.05
0.9
1.1
1
0.9
0.8
0.7
0.6
0.85
0.75
0.65
0.55
0.45
0.8
0.7
0.6
0.5
0.4
0.3

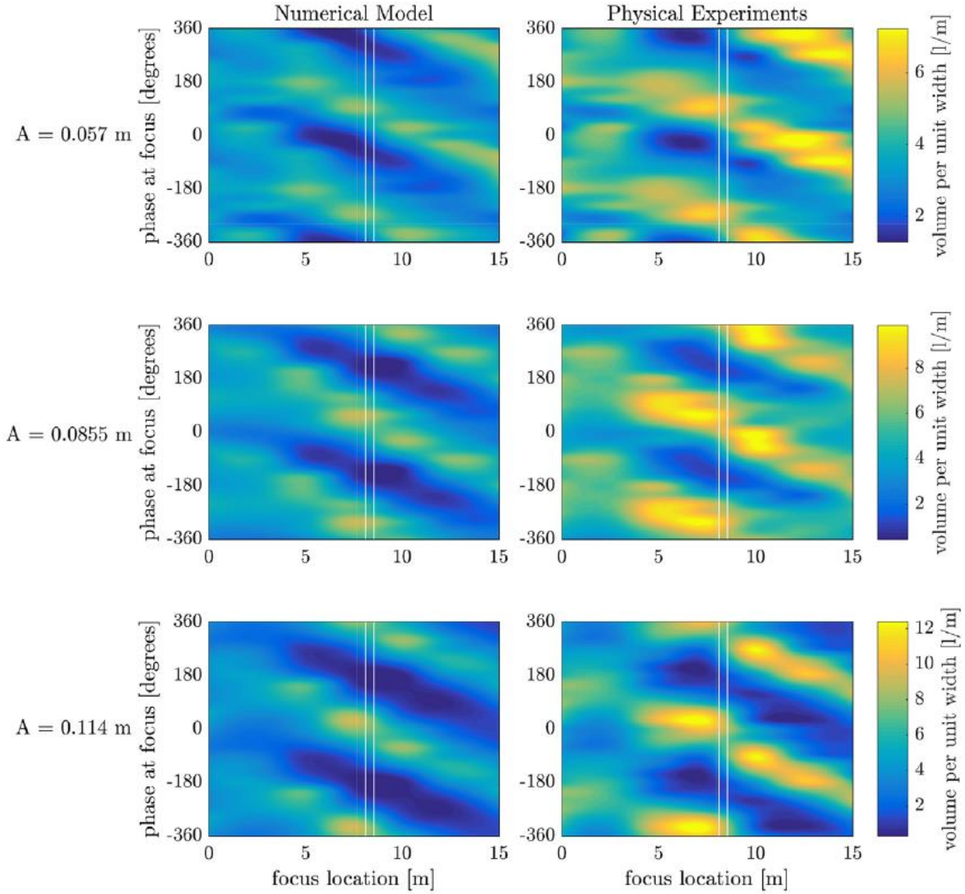
Extreme responses

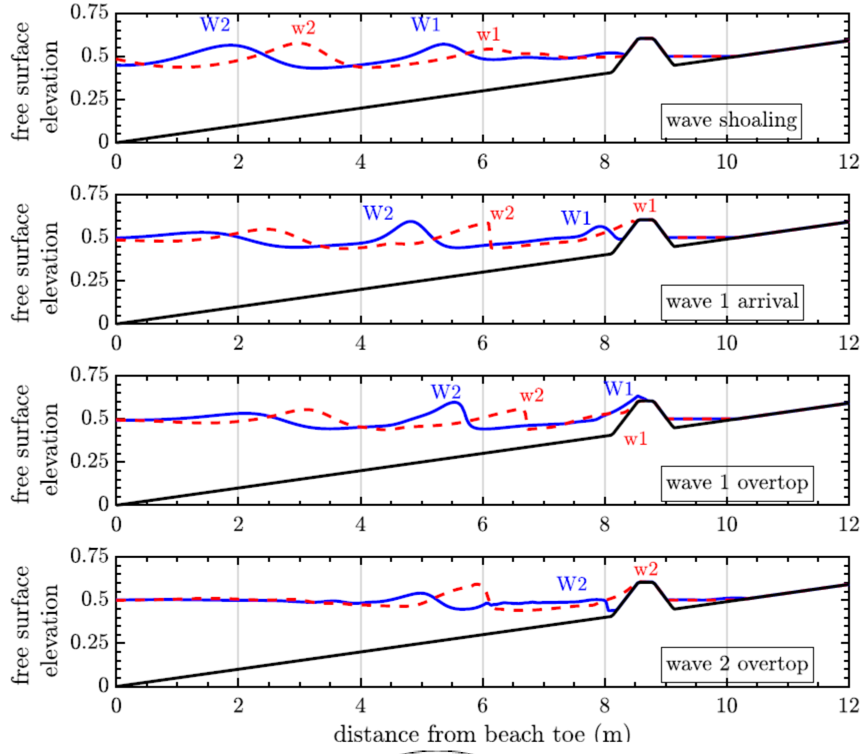


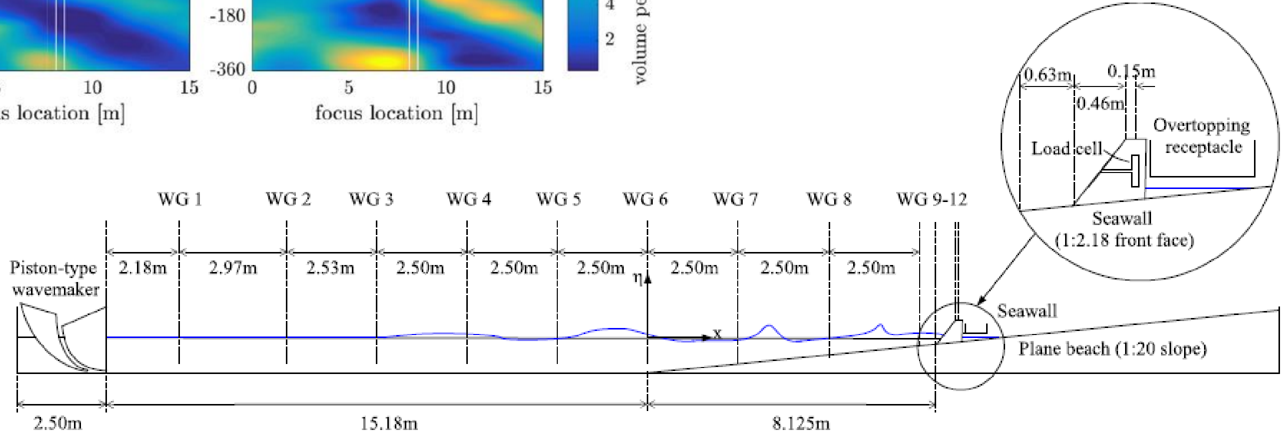
Saturation of swash spectra



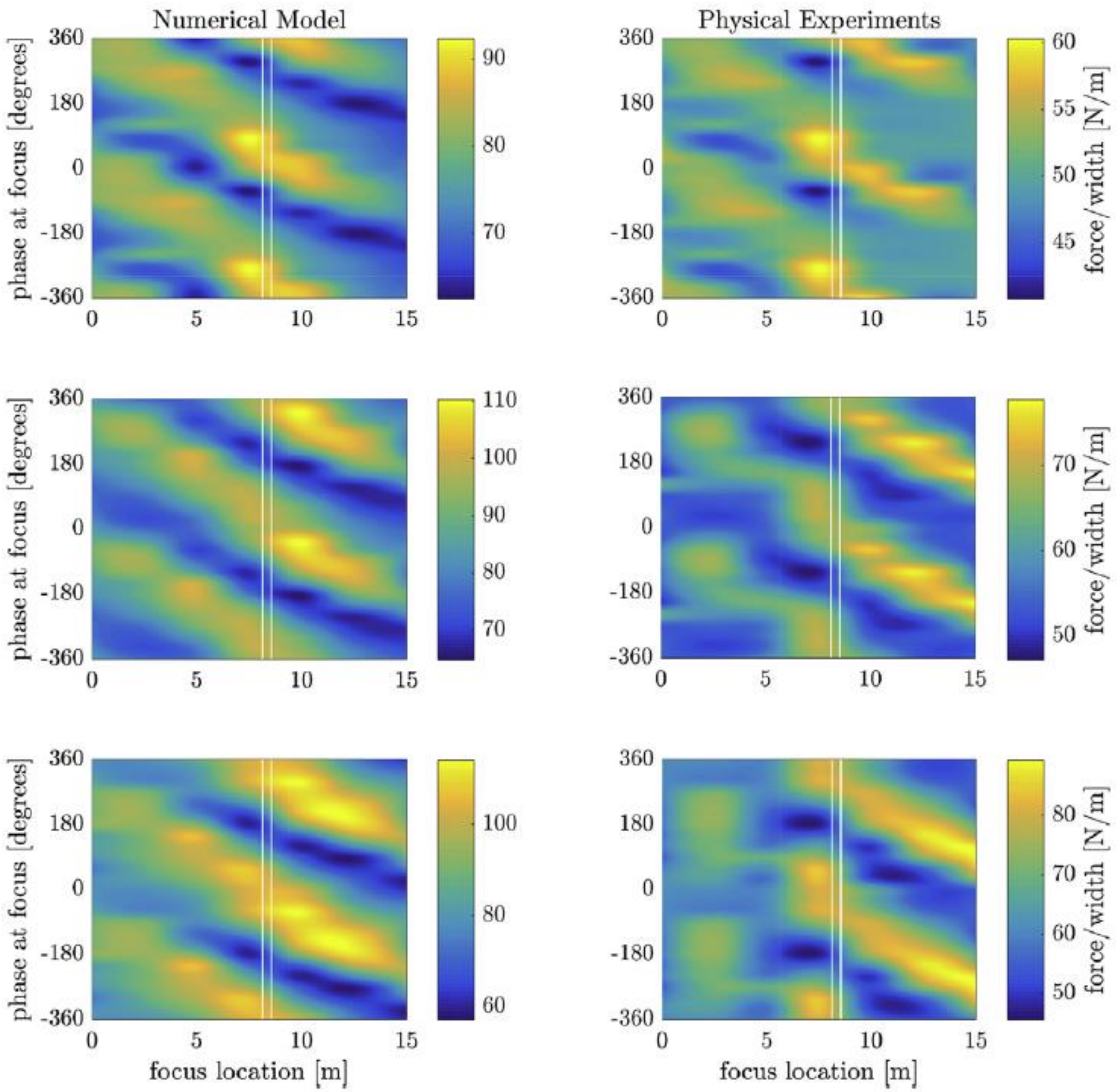
Overtopping







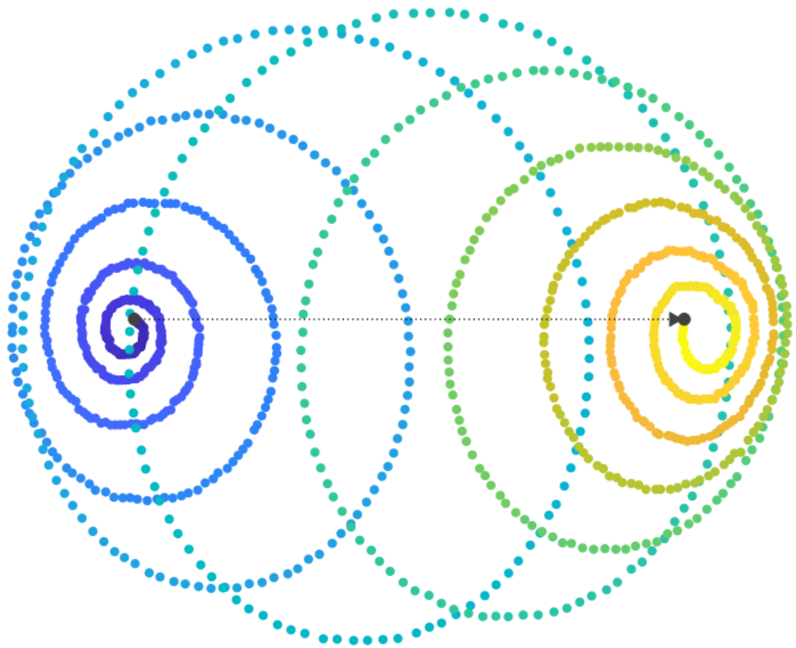
Forces



Whittaker, C. N., Fitzgerald, C. J., Raby, A. C., Taylor, P. H., & Borthwick, A. G. L. (2018). Extreme coastal responses using focused wave groups: Overtopping and horizontal forces exerted on an inclined seawall. *Coastal Engineering*, *140*, 292-305.

Conclusions

- NewWave captures the average profile of large waves even in relatively shallow water
- Second-order generation is crucial when assessing coastal responses to extreme wave attack
- Phase, focus location and amplitude dependence of runup, overtopping and horizontal forces
- Link to irregular wave attack, challenges and opportunities



Thank you