Extreme responses in coastal problems: Experimental and numerical modelling with wave groups

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EXTREME RESPONSES USING NEWWAVE FORCES, OVERTOPPING AND RUNUP IN COASTAL ENGINEERING

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1. Context

- Extreme wave runup poses a significant threat to coastal communities.
- A design focused wave group may provide time and cost savings compared to lengthy irregular wave simulations.
- The ENFORCE project will assess the applicability of NewWave to coastal problems.
- The maximum runup generated by a NewWave group will be compared to the extreme runup observed within irregular wave simulations.

2. NewWave

$A_N = \sqrt{2\sigma^2 \ln N}$ Amplitude from Rayleigh statistics

$$\eta(x,t) = A_f r_t = \frac{A_f}{\sigma^2} \sum_{i=1}^{M} S_{\eta\eta}(\omega_i) \cos\left(k_i(x - x_f) - \omega_i(t - t_f)\right) \Delta\omega$$

$$\sigma^2 = \sum_{i=1}^{N} S_{\eta\eta}(\omega_i)\,\Delta\omega = H_s^2/16$$

Variance of sea state

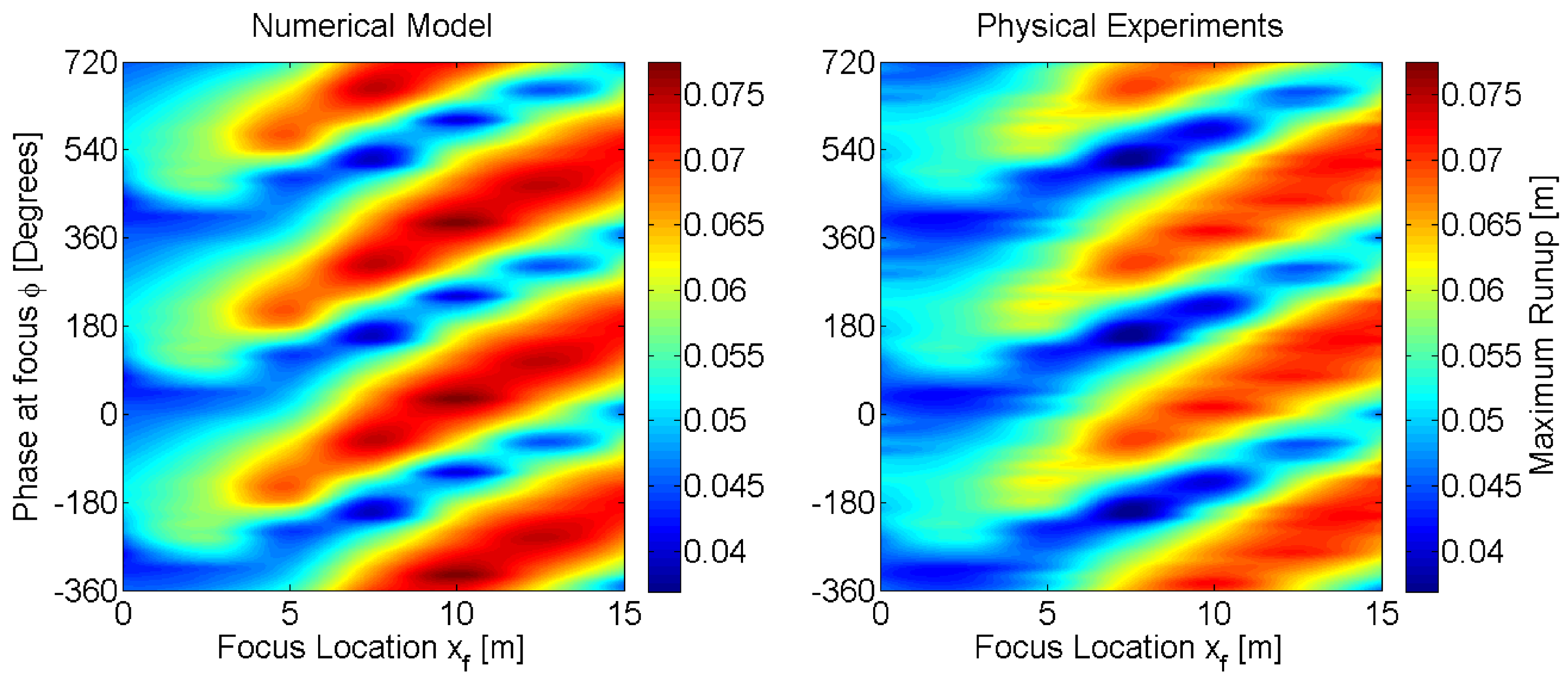
Linear focus event with all components in phase at location x_f and time t_f

Power spectral density of sea state

4. Focused wave results

Parameter	Values
$A_f(m)$	0.0285, 0.0570, 0.0855, 0.1140
$x_f(m)$ relative to wavemaker relative to beach toe	$15.176 - 30.176$ $0.0 - 15.0$
ϕ_f(degrees)	$0° - 360°$

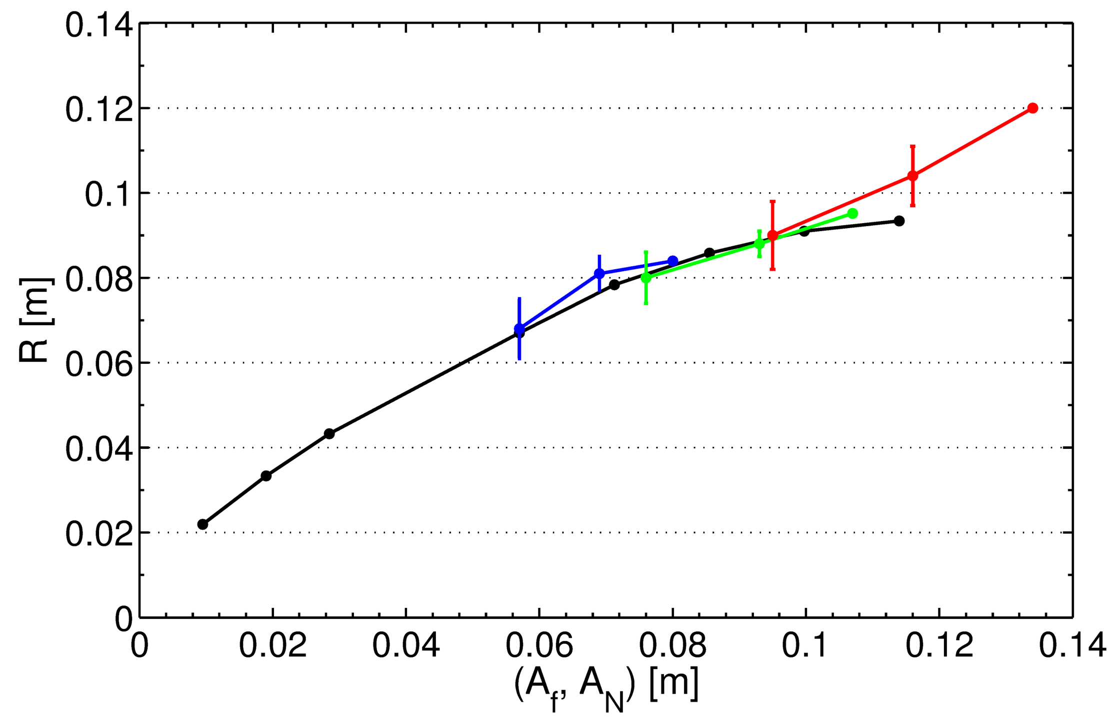
- Results show clear dependence on the amplitude, focus location and phase at focus.
- Optimal 'bands' of phase-focus location combinations exist within the parameter space (red stripes in figure).
- Excellent agreement between the numerical model and experiments over the parameter space.



Maximum runup elevation at each focused wave amplitude

5. Irregular wave results and conclusions

- Irregular wave simulations were conducted within the numerical model.
- 100 realisations of 100 incident waves were tested at three significant wave heights (0.075 m, 0.100 m and 0.125 m).
- The maximum runup generated by N incident waves may be compared to the runup generated by a '1 in N' incident wave using Rayleigh statistics.
- The agreement between the two methods indicates that extreme incident waves may be used to (at least approximately) predict extreme irregular wave runup.
- Future applications include overtopping and forces.



3. Experimental/numerical modelling

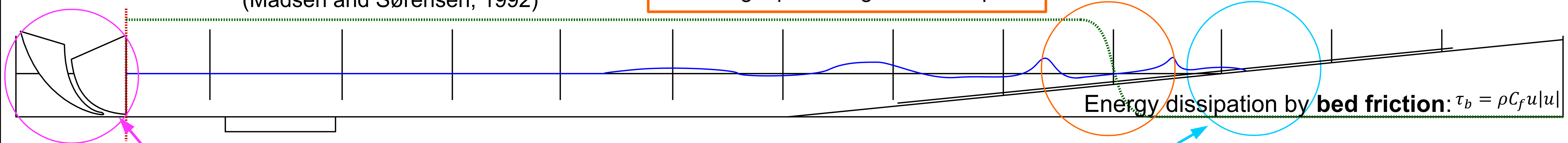
Pre-breaking wave propagation: Enhanced Boussinesq equations (Madsen and Sørensen, 1992)

Breaking occurs when the free surface slope exceeds the limiting value:

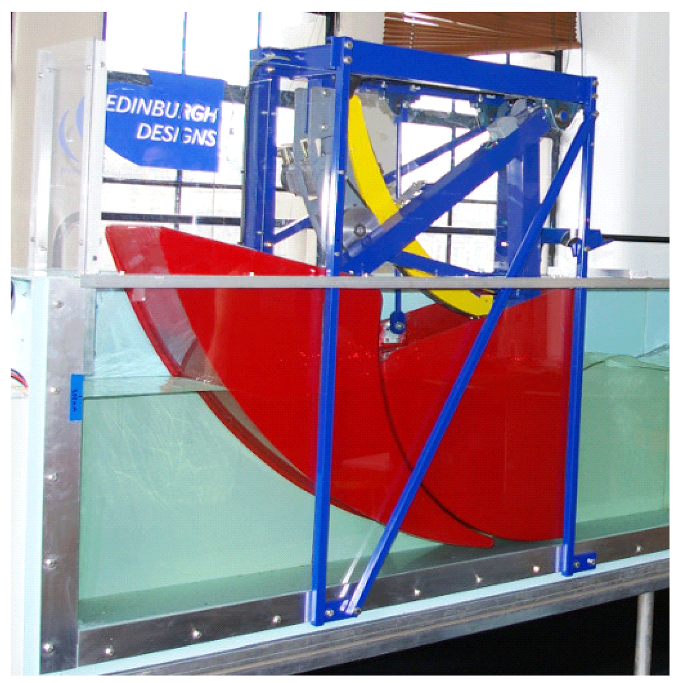
$$-\eta_x \geq 0.4$$

The dispersive terms (green line) are ramped down to zero over half a wavelength preceding the switch point.

Post-breaking wave propagation: Nonlinear shallow water equations



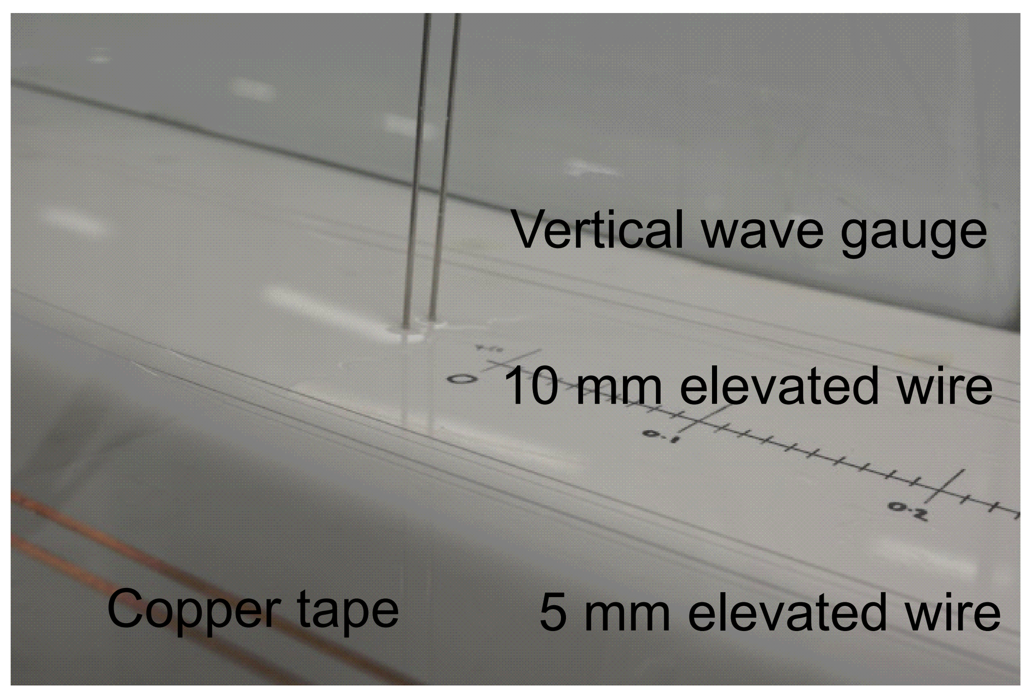
Second-order wave generation (Schäffer, 1996)



$$x_p(t) = \varepsilon x_p^{(1)}(t) + \varepsilon^2 x_p^{(2)}(t)$$

- Elimination of subharmonic error waves is vital for robust modelling of coastal responses such as runup (Orszaghova et al., 2014).
- The second-order wavemaker theory of Schäffer (1996) is used to eliminate spurious error waves in the experiments and numerical simulations.

Wave runup, shoreline motions



- Wetting and drying is treated in the numerical model using the algorithm of Liang and Borthwick (2009)
- The moving shoreline location is included as part of the solution of the nonlinear shallow water equations using a finite volume method.
- The shoreline is measured experimentally using vertical and inclined wires, and the maximum runup using strips of copper tape attached to the surface of the beach.

Agreement between experiments (red line) and model (black line)