Control of crest height statistics at a target position in a wave tank environment

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NH5.2 Extreme events in sea waves: physical mechanisms and mathematical models

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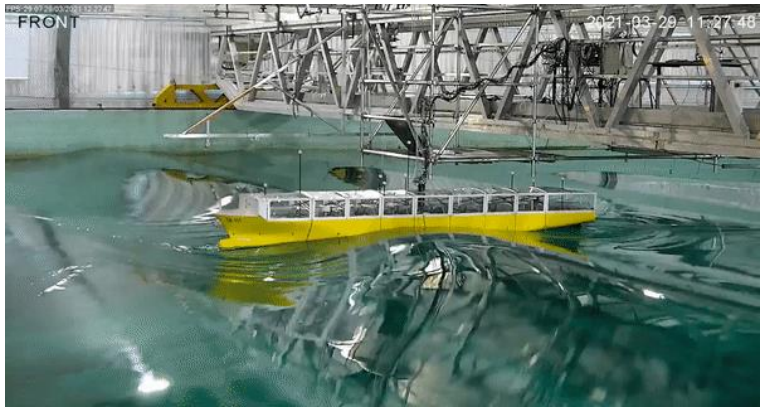
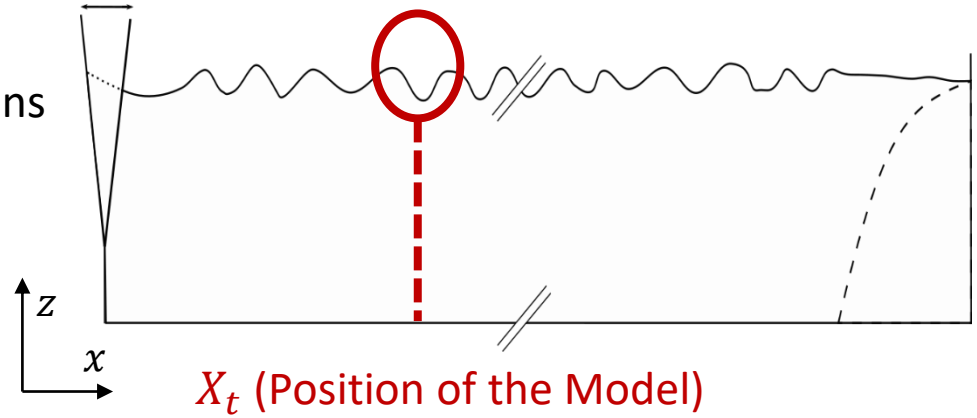
Context: Wave structure interaction tests in Experimental Or Numerical wave tanks

Offshore Structure / Ship Project

Structure / ship Model



Wave Conditions

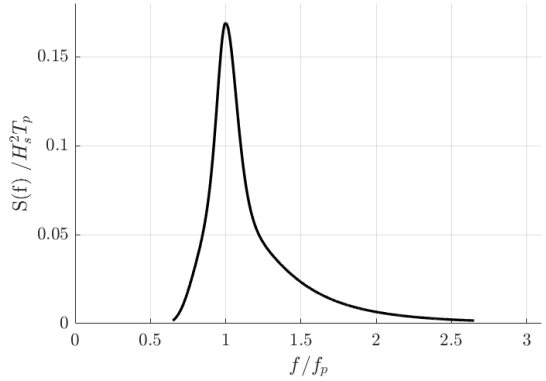


X_t (Position of the Model)

Context: Definition Of the Wave Conditions

In-Situ environmental wave conditions

Unidirectional Design sea states
(ex: JONSWAP power density spectrum)



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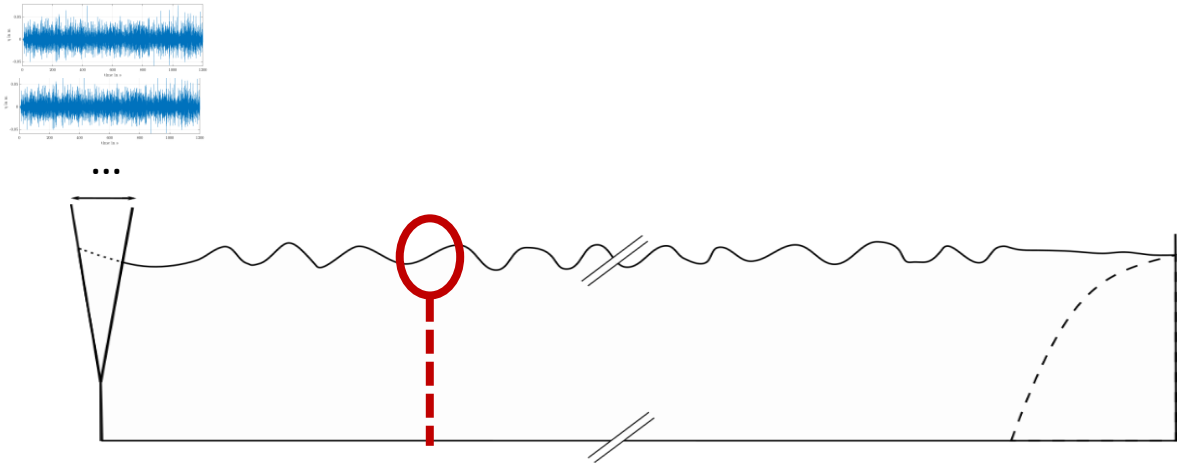
Typical storm duration of 3 hours (≈ 1000 waves)
=> $P_{design} \approx 1/1000$

Deterministic approach:
Reproduction of **1 particular event** (associated with P_{design})

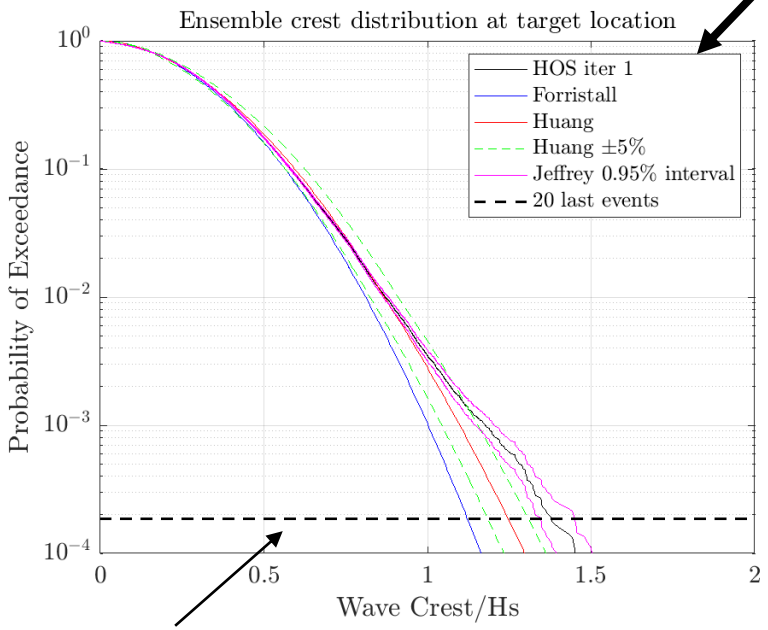
Stochastic approach:
Generation of **a long duration wave field** (until the events at P_{design} are statistically reliable)

Context: Stochastic Approach

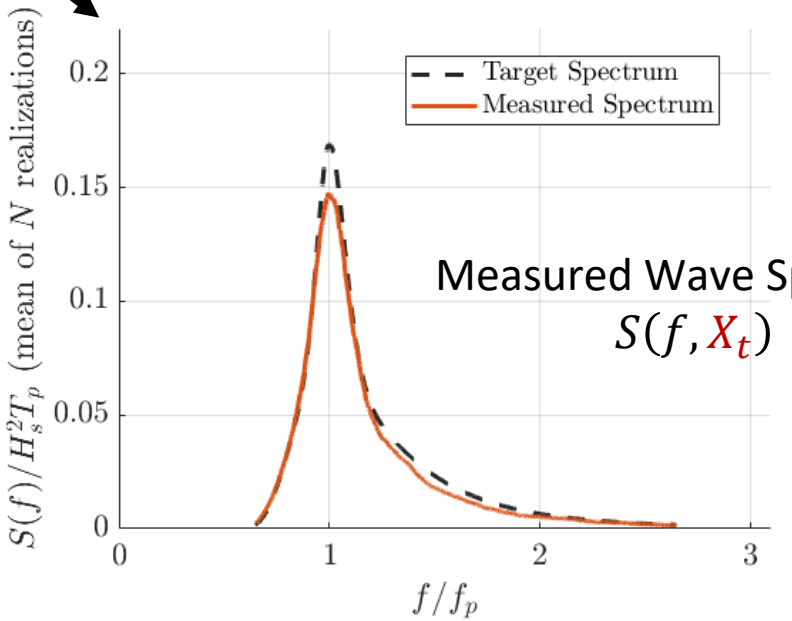
N Realizations based on input Fourier amplitudes $A_{input}(f)$ and random phases



Ensemble crest height distribution (PDER) at X_t



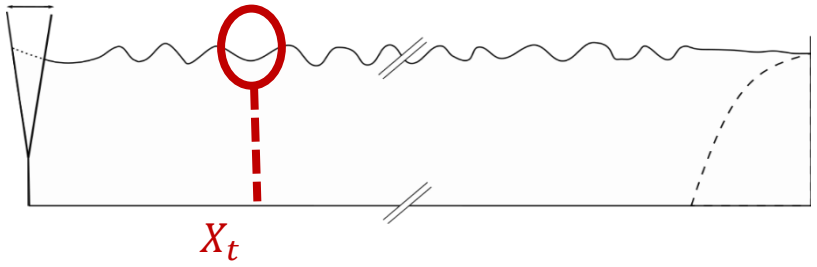
Reliability limit < P_{design}

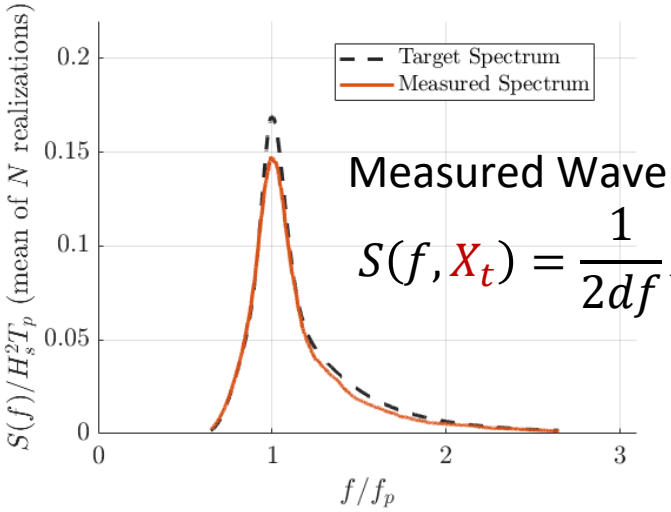


Measured Wave Spectrum $S(f, X_t)$

Context: Correction Of the Spectrum at X_t

N Realizations based on $A_{input}(f)$





Measured Wave Spectrum

$$S(f, X_t) = \frac{1}{2df} A(f, X_t)^2$$

Iterative correction of the wavemaker inputs **[1]**

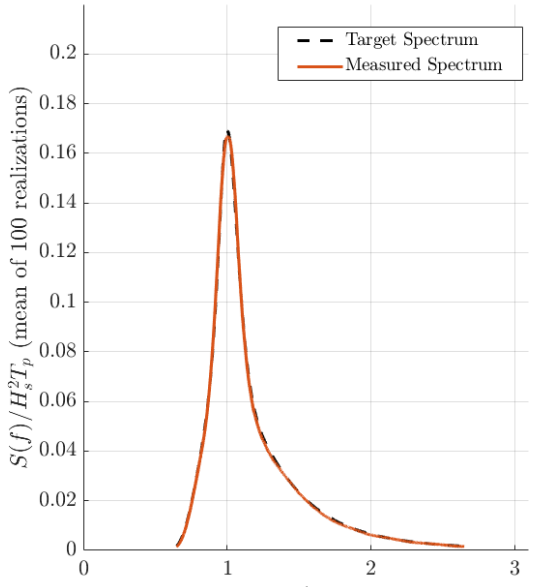
Iteration 0

$$A_{input(f)} = A_{design}(f)$$

Iteration 1

$$A^1_{input}(f) = A^0_{input}(f).\frac{A_{design}(f)}{A^0(f, X_t)}$$

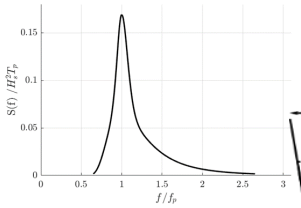
...



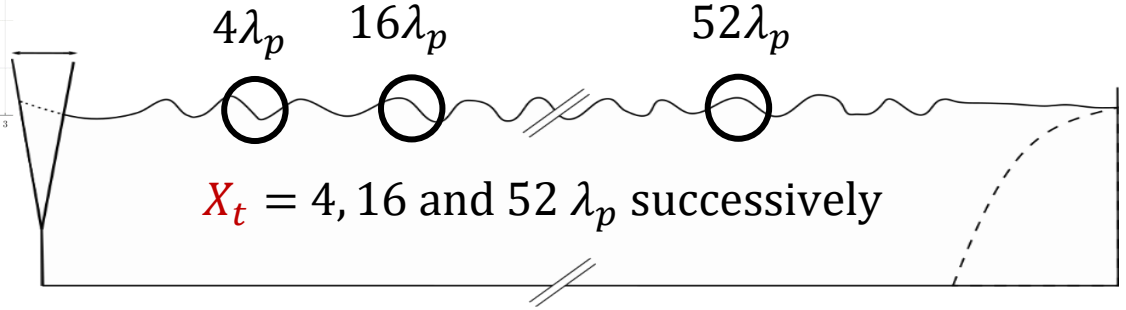
Context: Evolution of wave statistics depending on X_t

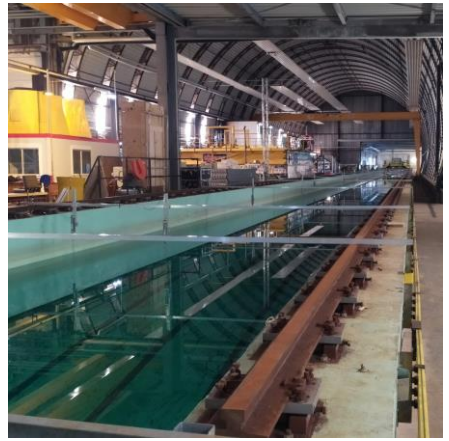
see **[1]** Canard, M., Ducrozet, G., & Bouscasse, B. (2022). Varying ocean wave statistics emerging from a single energy spectrum in an experimental wave tank. *Ocean Engineering*, *246*, 110375

$H_s = 5cm$
$\lambda_p = 2m$
$\gamma = 5$

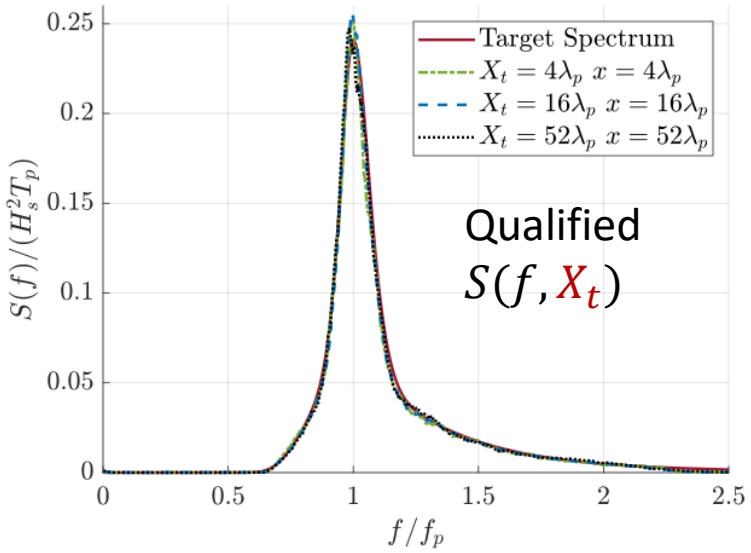


Unidirectional Jonswap

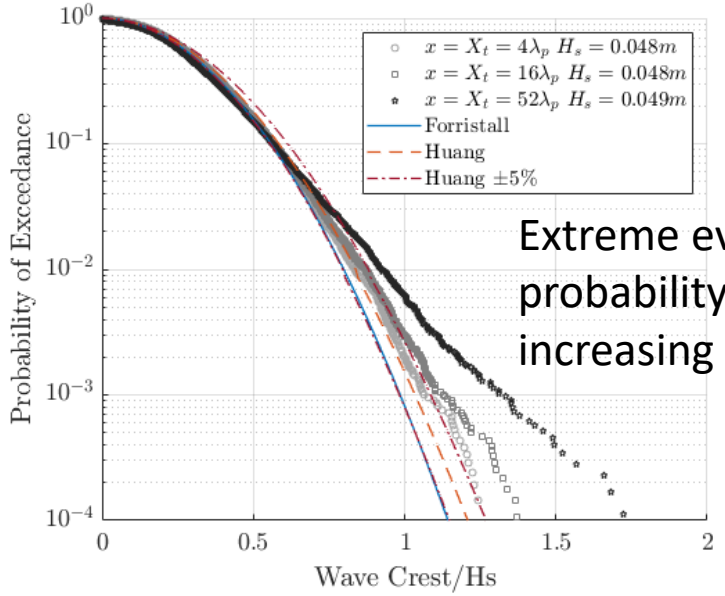




ECN Towing Tank with Resistive Wave Gauges



Qualified $S(f, X_t)$



Extreme events probability increasing with X_t

Context: Need to Control the Wave Statistics

Statistics are influenced by:

- The design spectrum nonlinearity ($BFI = \frac{steepness}{Spectrum\ width}$)
- The distance from the wavemaker X_t

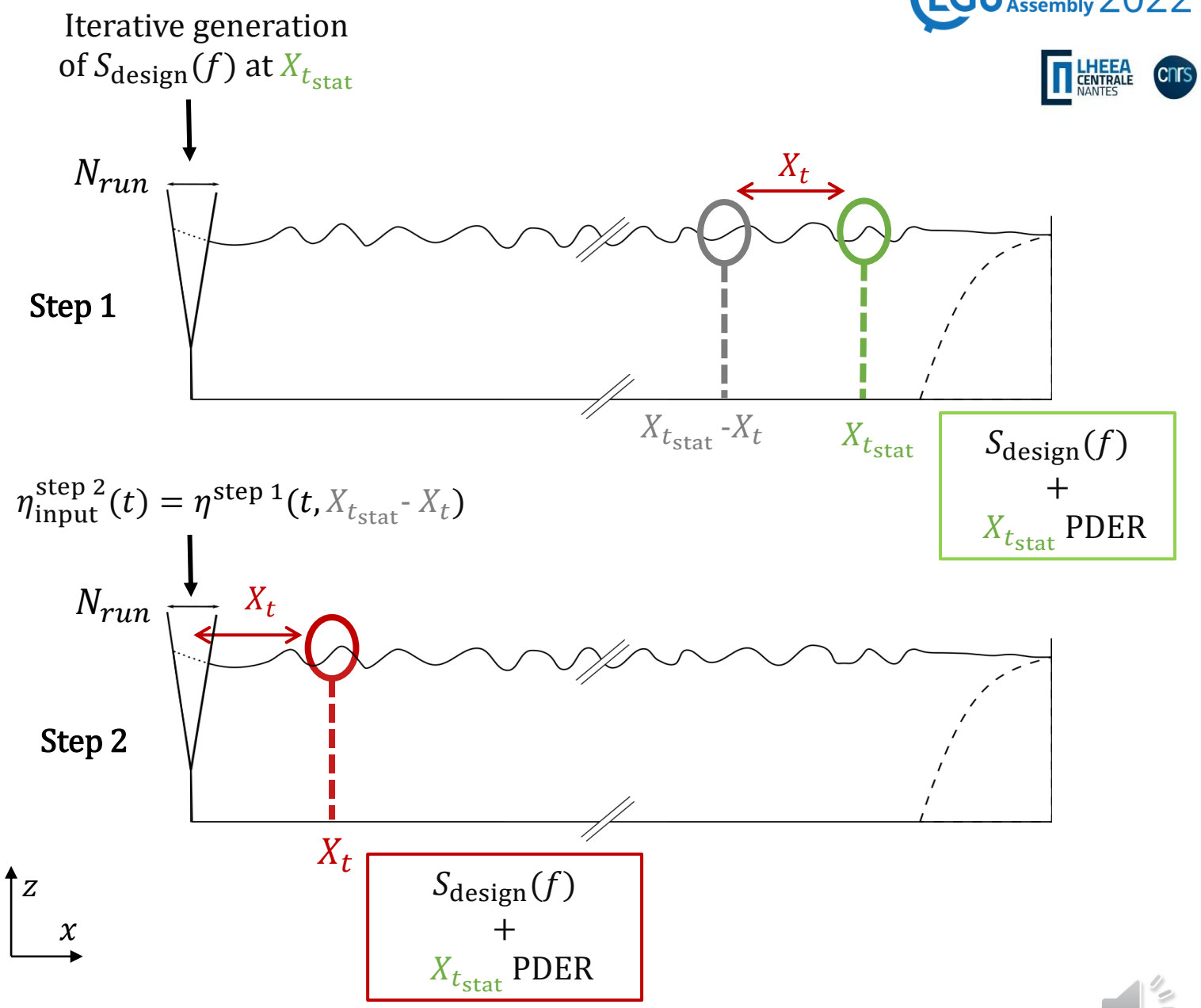
Objective of the present study:

Development of a method to control the wave statistics at X_t
(to improve the wave generation procedures for wave structure interaction tests)

Method to control crest height statistics

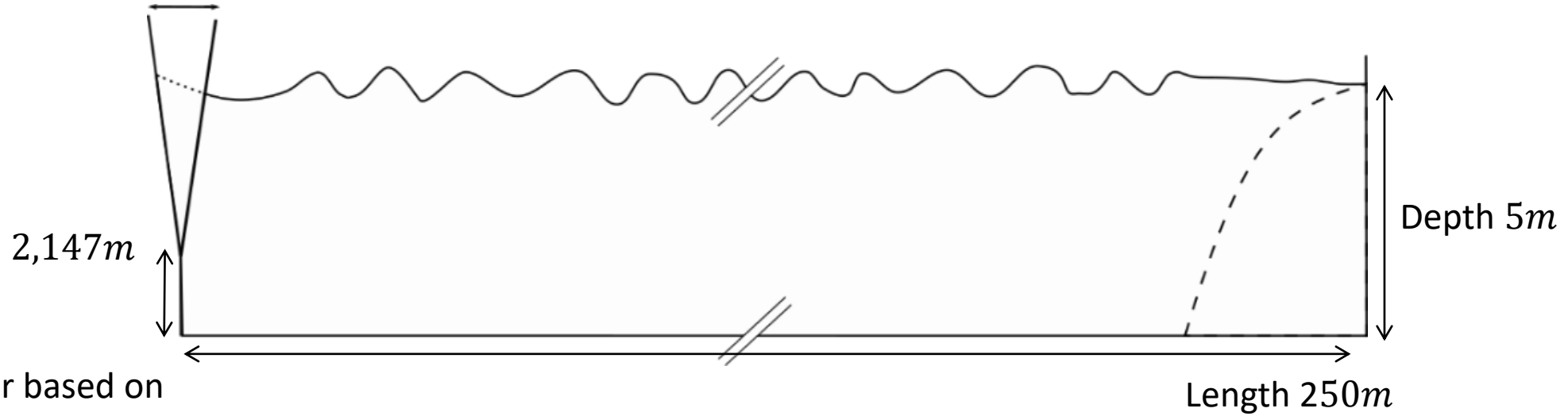
Objectives:

- Generate $S_{target}(f)$ at X_t
- Generate $X_{t_{stat}}$ statistics at X_t



Set-up of the numerical study

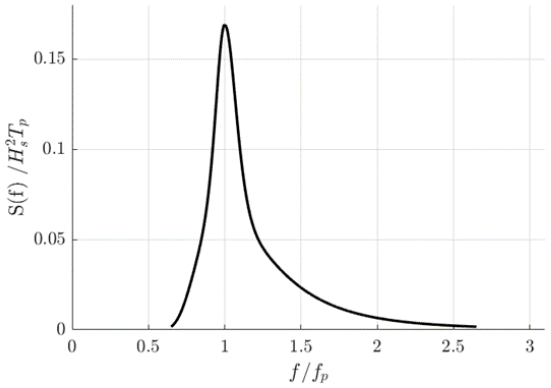
- Nonlinear potential wave solver HOS-NWT (see **[2]**)
- Domain: 2D numerical wave tank (wavemker at $x = 0$; absorbing beach at the end)
- Converged numerical set-up
  Spatial Discretization: $N_x = 3130$ (i.e. $k_{max} = 25k_p$)
  Order of nonlinearity: 5



Wavemaker based on
ECN Ocean Engineering
Tank geometry

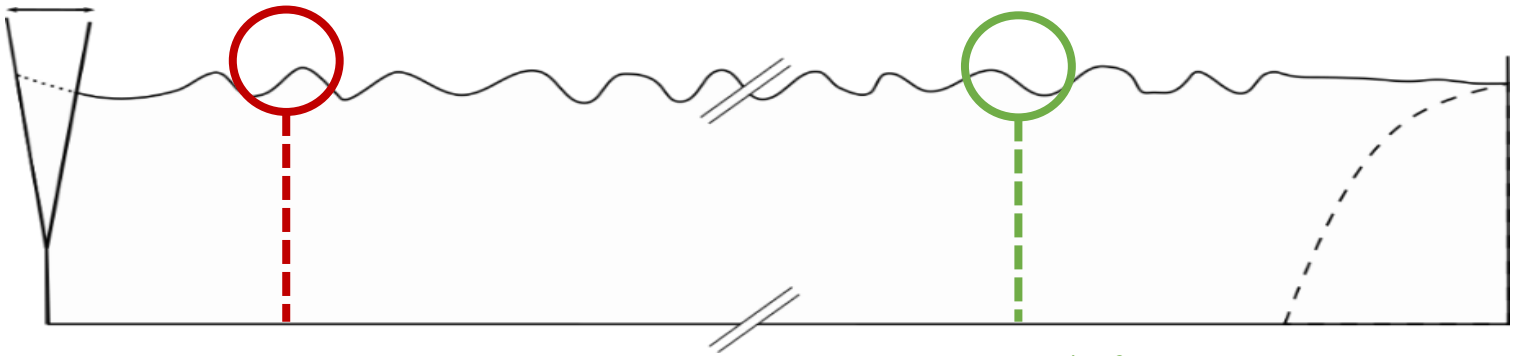
Set-up of the numerical study

- Non breaking JONSWAP sea state

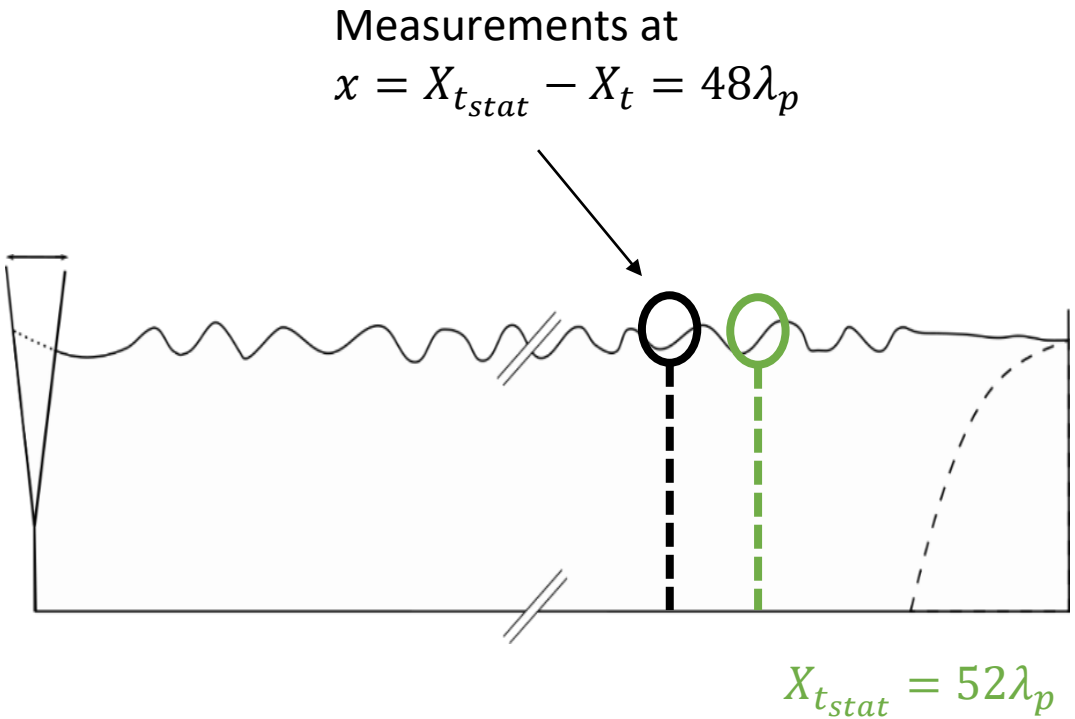


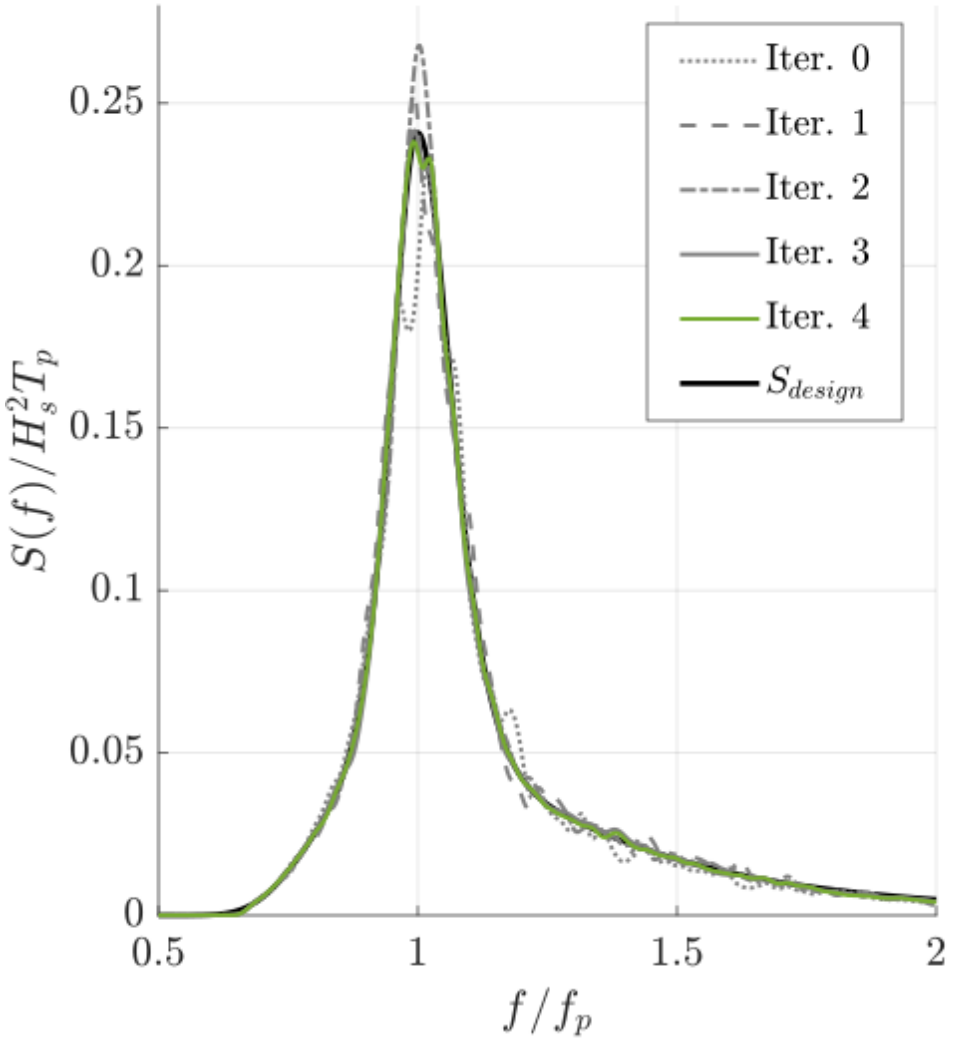
Name	Ss6g5 (scale 60)
γ	5
H_s	0,10m
T_p	$1{,}6s$
λ_p	$4m$
H_s/λ_p	2.5%
BFI	0.3

- Target Positions



Results: iterative generation of the S_{design} at $x = X_{t_{stat}}$ (step 1)





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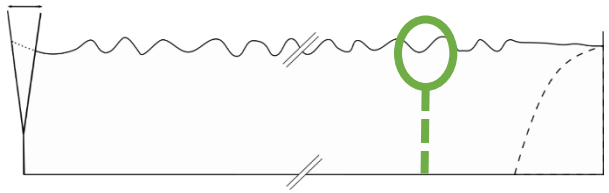
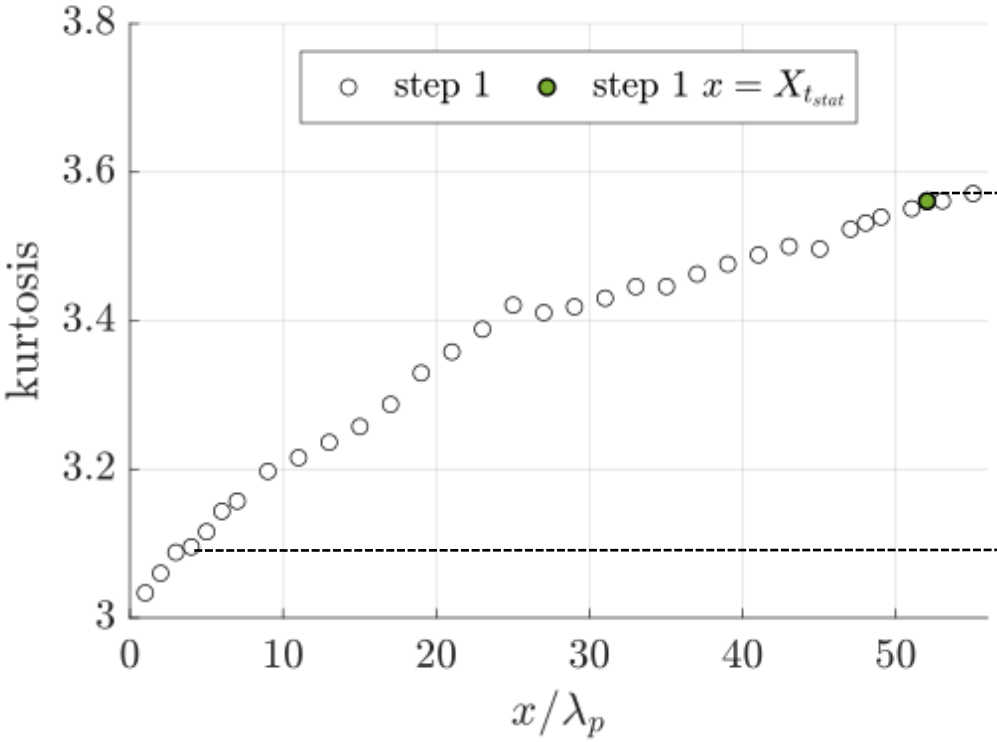
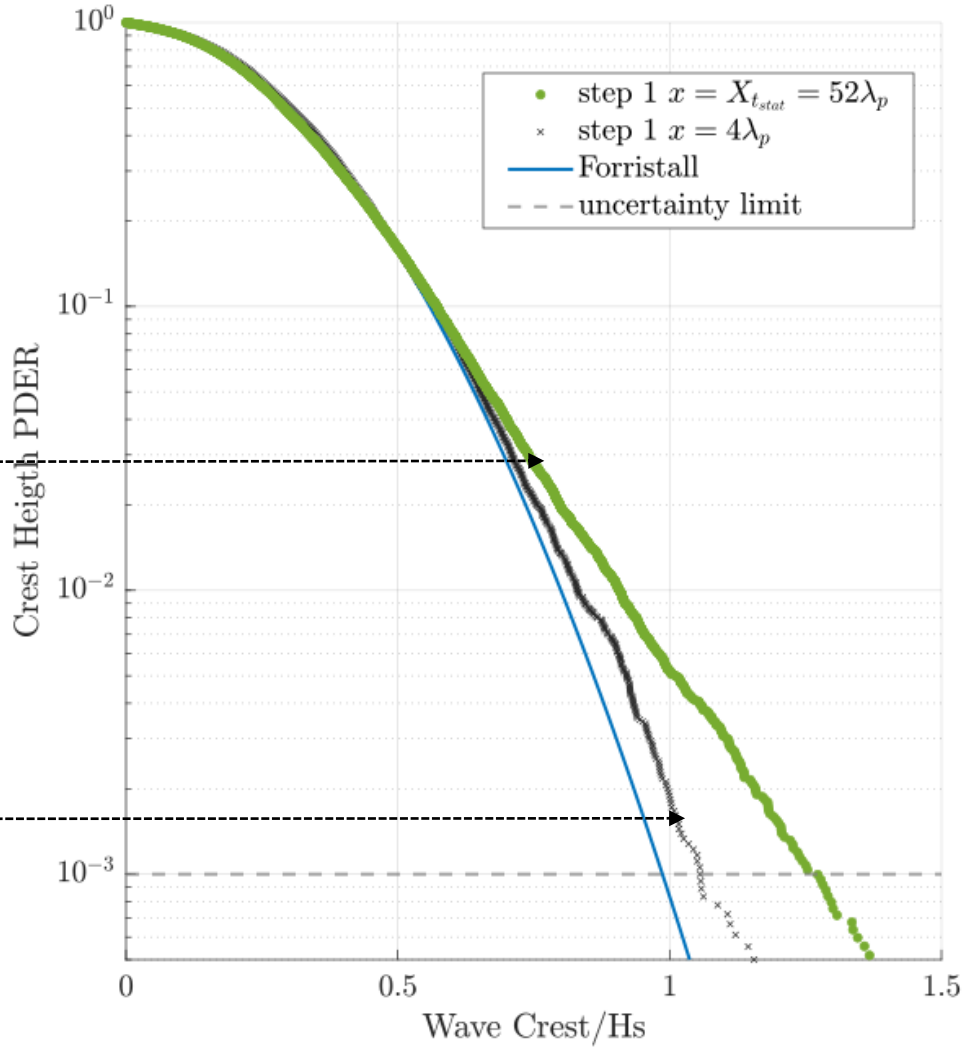


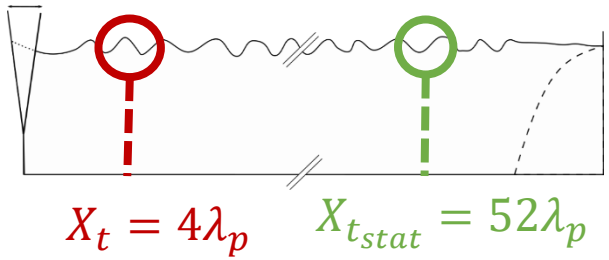
$X_{t_{stat}} = 52\lambda_p$

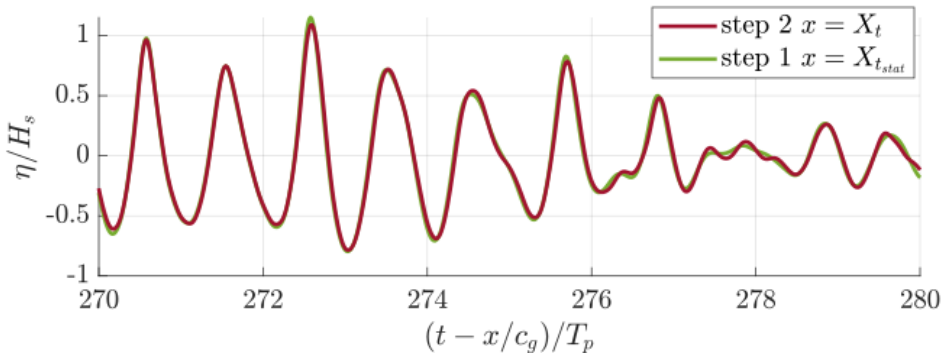


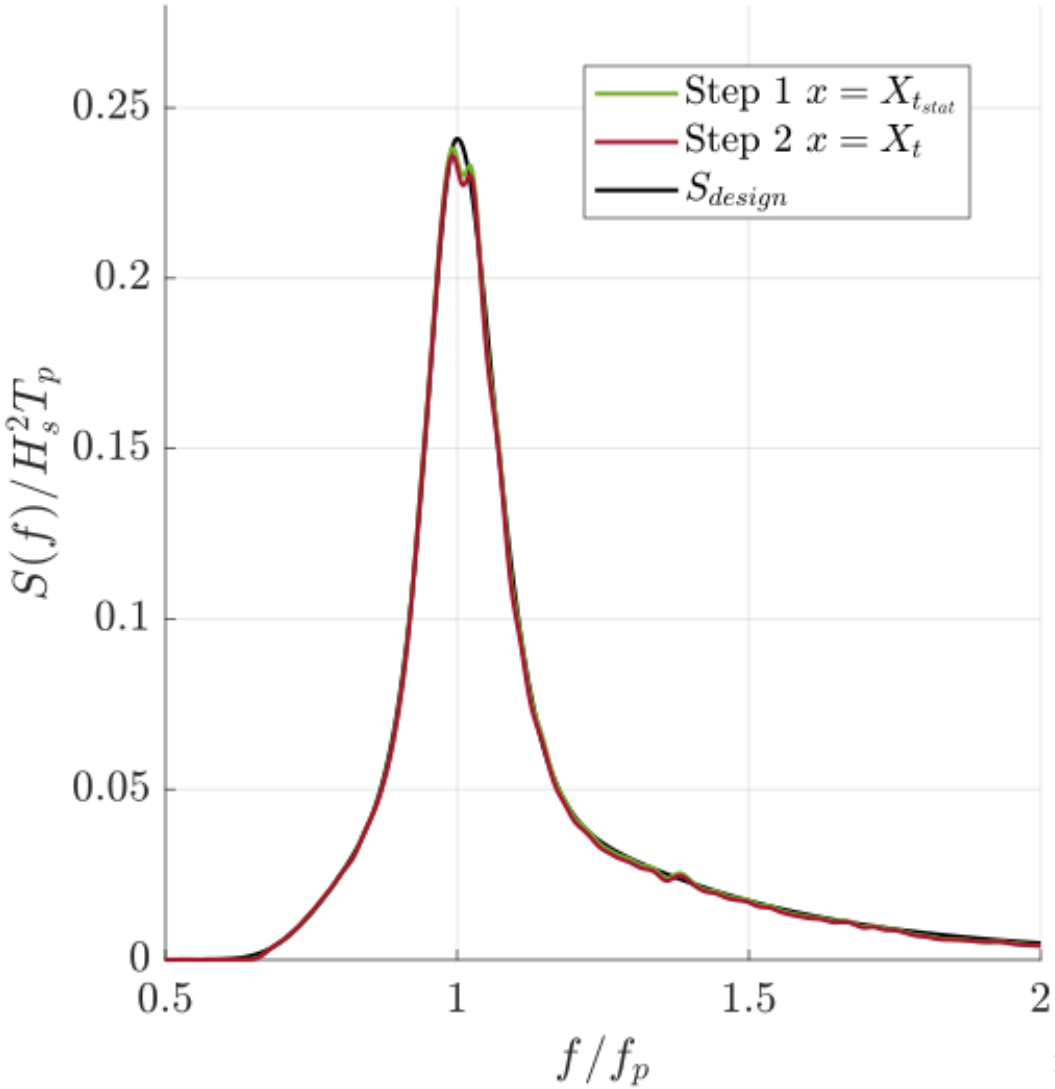


Kurtosis of the free surface elevation (linked to the probability of the extreme events)

Results: step 1 Measurements at $x = X_{t_{stat}} - X_t$ used as wavemaker inputs (step 2)







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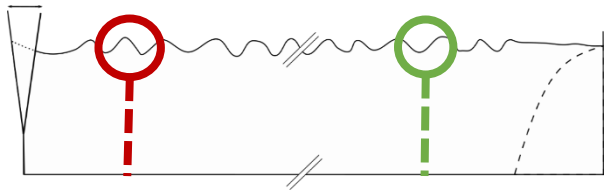
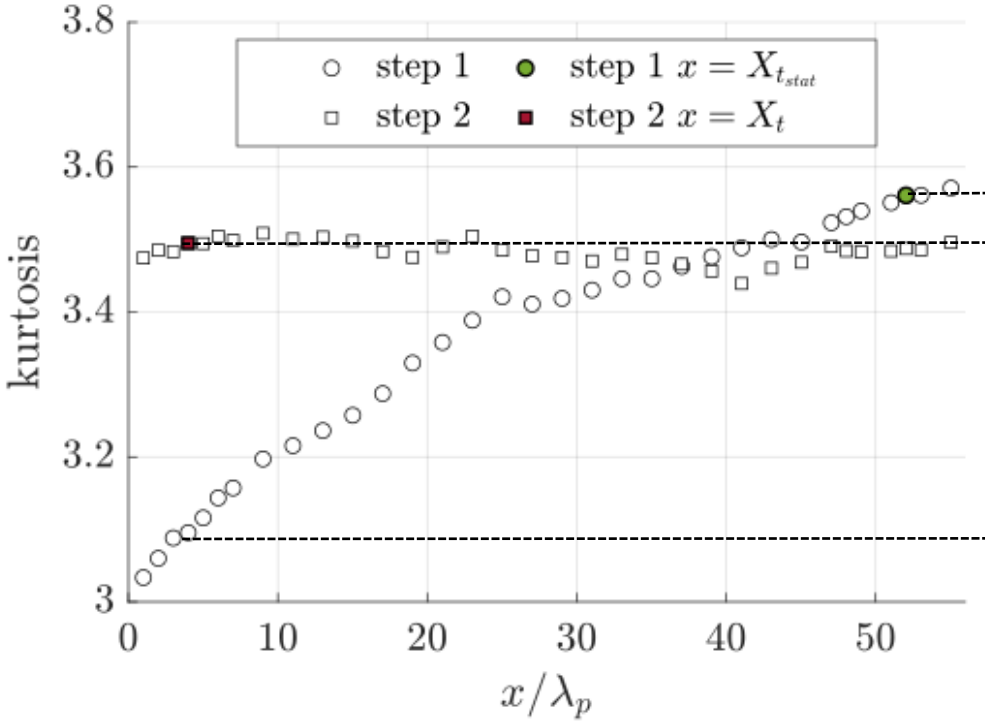
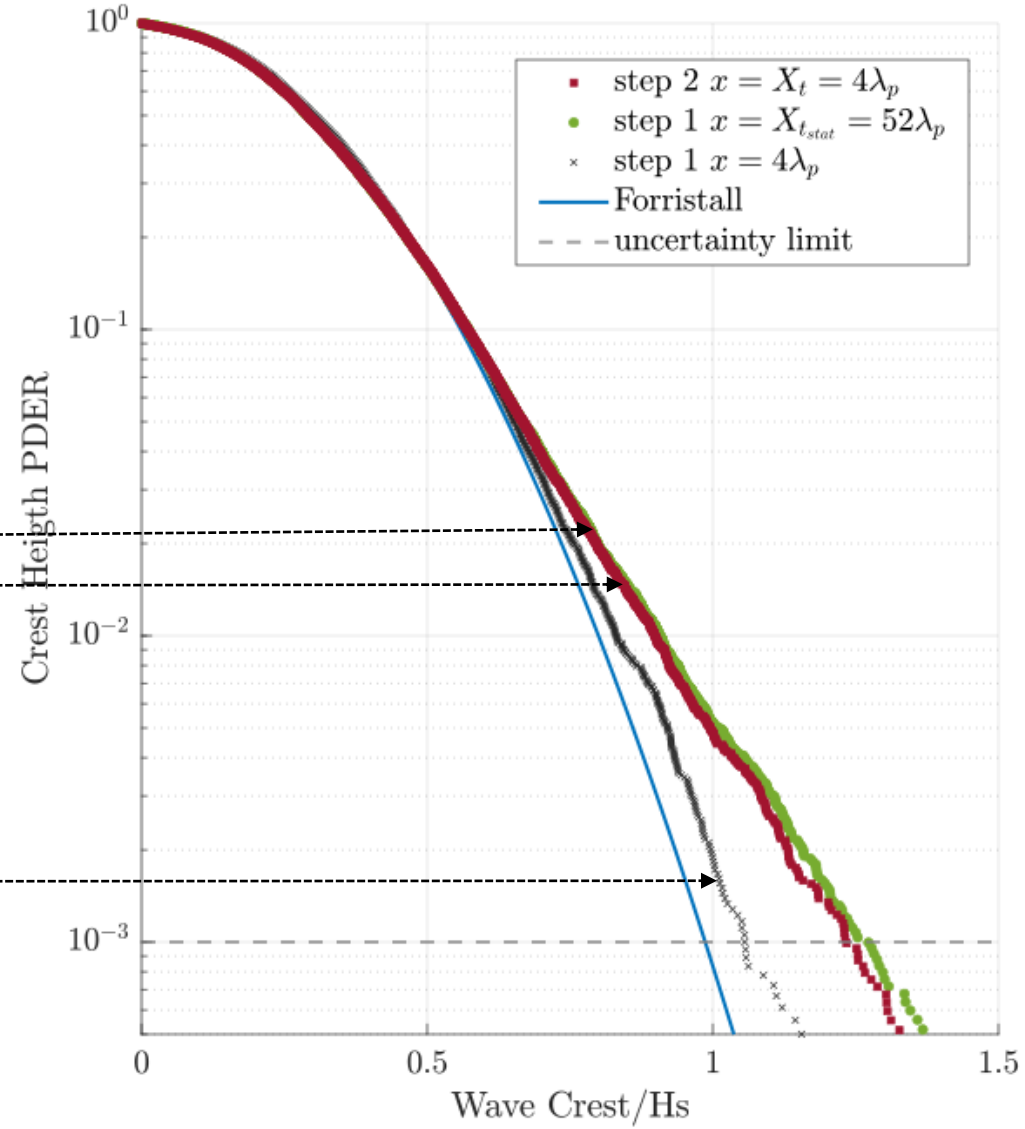


$X_t = 4\lambda_p$ $X_{t_{stat}} = 52\lambda_p$





Conclusion

- A procedure has been developed to control the statistics of the waves generated in a wave tank environment
- The procedure is numerically validated
- Extreme statistics appearing naturally end of the tank are successfully reproduced close to wavemaker
- Experimental validation is needed (work in progress)

References

[1] Canard, M., Ducrozet, G., & Bouscasse, B. (2022). Varying ocean wave statistics emerging from a single energy spectrum in an experimental wave tank. *Ocean Engineering*, *246*, 110375

[2] Ducrozet, G., Bonnefoy, F., Le Touzé, D., & Ferrant, P. (2012). A modified high-order spectral method for wavemaker modeling in a numerical wave tank. *European Journal of Mechanics-B/Fluids*, *34*, 19-34.