Direct and fast probabilistic assessment of long term monopile load distribution from combined met-ocean data and fully nonlinear wave kinematics

EERA DeepWind 2021 Online Conference
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- Metocean data and JEVA
- DeRisk wave kinematics database
- Load and dynamic response
- Estimating short term distributions
- Long term load distribution
- Application in North Sea

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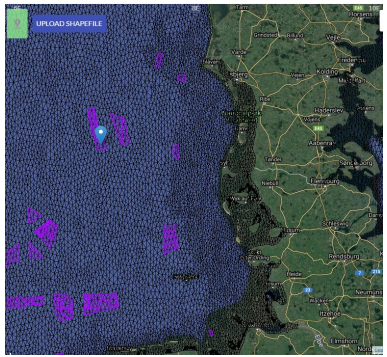
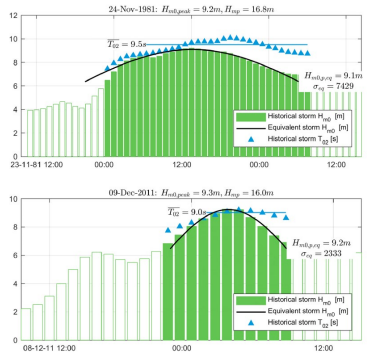
Joint Extreme Value Analysis (JEVA) key steps

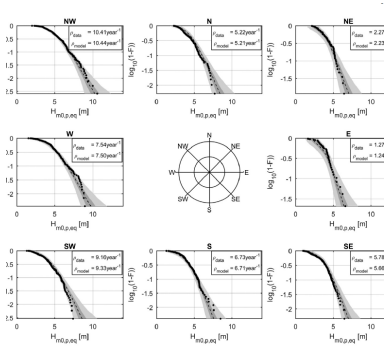
- 40 years of metocean data – H_{m0}, T_p, wind speed, water level, current speed etc.
- Use storm model when identifying events and estimate marginal and joint distributions with parameter uncertainty estimated
- Non-stationary seasonal and directional dependence
- Use Monte Carlo simulation to simulate large number of storms e.g. equivalent to 10,000 years and calculate design data for given return period from simulated non-exceedence probability



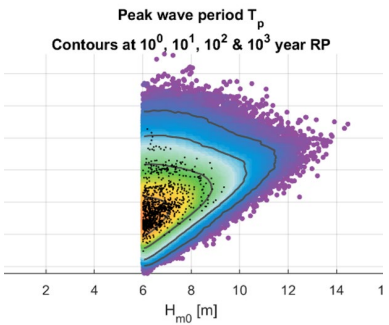
Validated Metocean Data



Storm Model based on Hm0,eq



Statistical fit of marginal and joint distributions with parameter uncertainty estimated



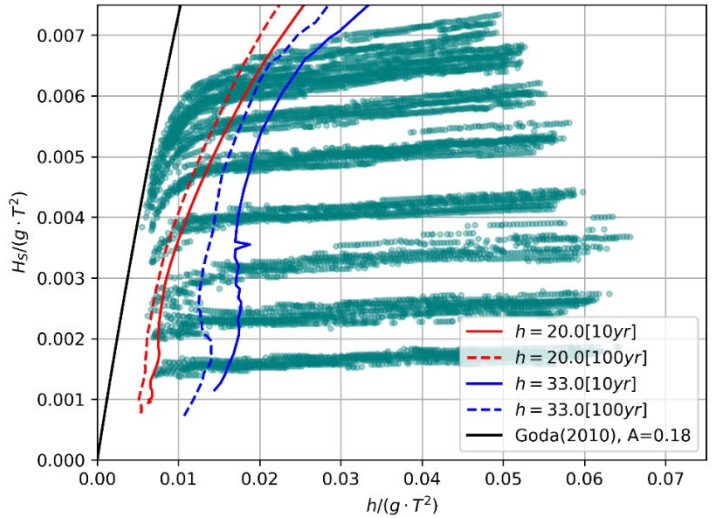
Monte Carlo simulation of events for very high number of years

https://www.sciencedirect.com/science/article/pii/S002980181930784X

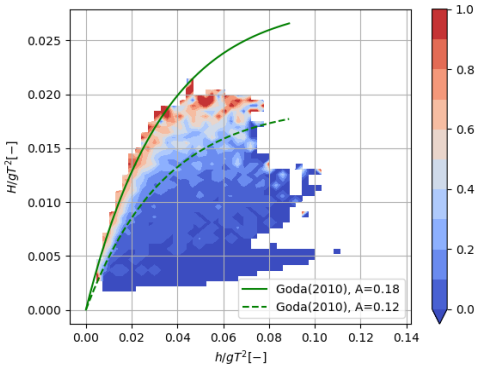
DeRisk fully nonlinear wave kinematics database
Load and response models

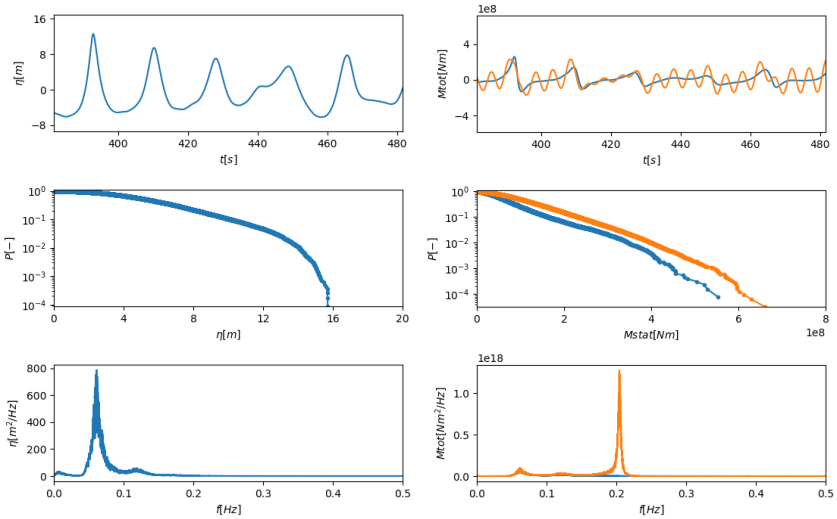
- Load model: Rainey: R. C. T. Rainey, "Slender-Body Expressions for the Wave Load on Offshore Structures," Proc. R. Soc. A Math. Phys. Eng. Sci., vol. 450, no. 1939, pp. 391–416, 1995
- Response model: QuLA: S. Schløer, L. Garcia Castillo, M. Fejerskov, E. Stroescu, and H. Bredmose, "A model for quick load analysis for monopile-type offshore wind turbine substructures," Wind Energy Sci., vol. 3, no. 1, pp. 57–73, Mar. 2018.

Properties of 88,000 1-hour wave kinematics plotted as non-dimensional depth (x-axis) versus non-dimentional significant wave height (y-axis)



Nondimensional water depth versus nondimensional wave height. In the color axis, the fraction of the largest waves registered in each 1hr sea state at h=33.0[m] that were breaking according to OW3D's breaking filter. The dashed line is the Goda (2010) breaking limit.



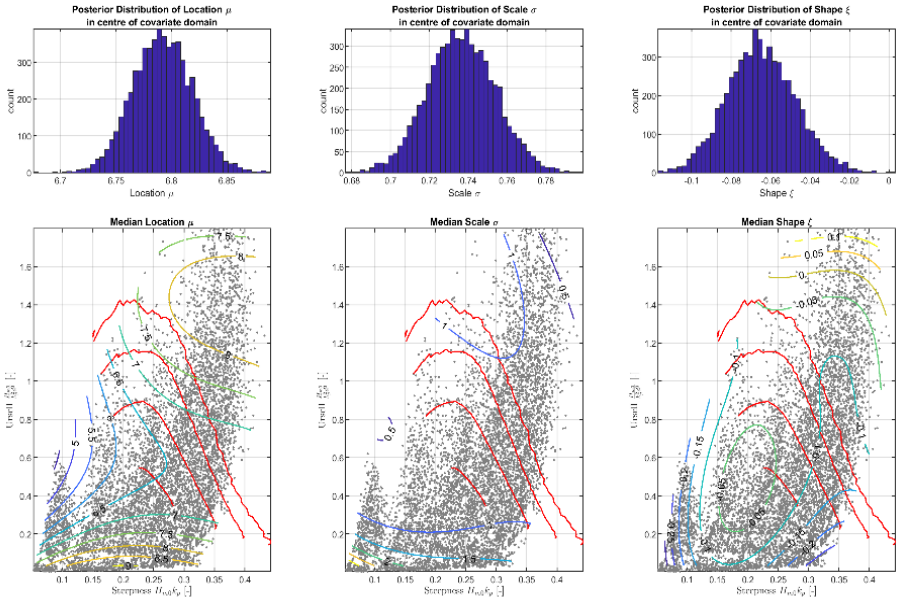


Free surface elevation and inline force for the h=33.0[m] case. On the left, the free surface elevation η is plotted. On the right, the total moment M_tot is plotted in orange and the static moment M_stat is plotted in blue

Estimating short term GEV distributions for load as function of wave steepness and wave non-linearity (Ursell number)

ID	Formulation
Constant	$f(\boldsymbol{\chi}, \boldsymbol{\beta}) = \beta_0$
Linear	$f(\boldsymbol{\chi}, \boldsymbol{\beta}) = \beta_0 + \beta_1\chi_1 + \beta_2\chi_2$
Order 2	$f(\boldsymbol{\chi}, \boldsymbol{\beta}) = \beta_0 + \beta_1\chi_1 + \beta_2\chi_1^2 + \beta_3\chi_2 + \beta_4\chi_2^2$
Order 2CT	$f(\boldsymbol{\chi}, \boldsymbol{\beta}) = \beta_0 + \beta_1\chi_1 + \beta_2\chi_1^2 + \beta_3\chi_2 + \beta_4\chi_2^2 + \beta_5\chi_1\chi_2$
Order 3CT2	$f(\boldsymbol{\chi}, \boldsymbol{\beta}) = \beta_0 + \beta_1\chi_1 + \beta_2\chi_1^2 + \beta_3\chi_1^3 + \beta_4\chi_2 + \beta_5\chi_2^2 + \beta_6\chi_2^3 + \beta_7\chi_1\chi_2 + \beta_8\chi_1^2\chi_2^2$

Polynomial covariate expansions tested for the location, scale and shape parameters in the GEV distribution of 1-hour maximum waves. χ_1 is wave steepness and χ_2 is the Ursell number based on H_{m0} and T_p of the corresponding sea state.

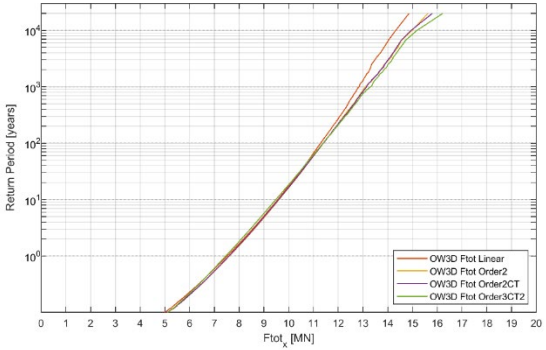


Site: Dogger Bank (20m). Fitted GEV parameters (rainbow contour lines), location, scale and shape (left to right) and JEVA joint probability lines (red contours going from 1 year to 1000 year return period inside-out) for inline force considering dynamic response as function of wave steepness (x-axis) and Ursell number (y-axis). Order3CT2 covariates.

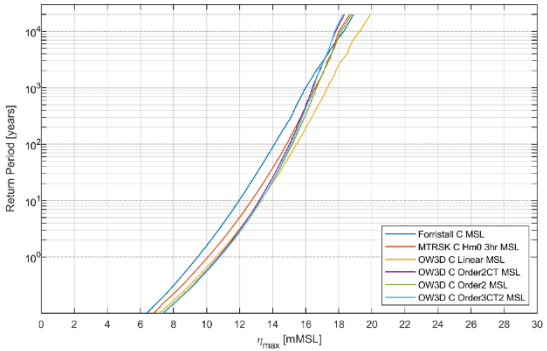
Application for long term load distribution in North Sea

- Direct and fast estimates of long term loads on turbine substructures is achieved
- Compared to Forristall, max crest heights are initially larger due to non-linearity then becomes smaller due to wave breaking

German Bight (33m). Response considered is one-hour maximum of inline force considering dynamic response, Ftot_X.



German Bight (33m). Response considered is one-hour maximum crest height with respect to mean water level, Cmax, MSL



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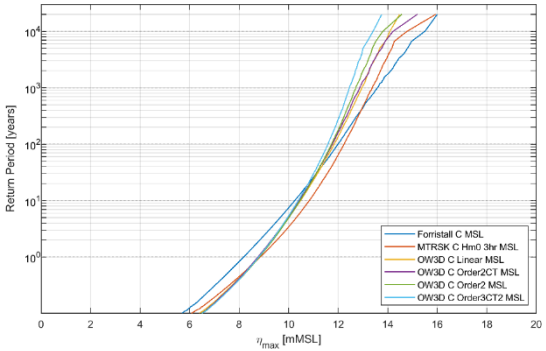

Dogger Bank (20m). Response considered is one-hour maximum of inline force considering dynamic response, Ftot_X