EERA DeepWind 2023

A Potential Flow Based Numerical Framework for Engineering Design of Floating Offshore Wind Turbine Foundations

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18 January 2023, Trondheim, Norway

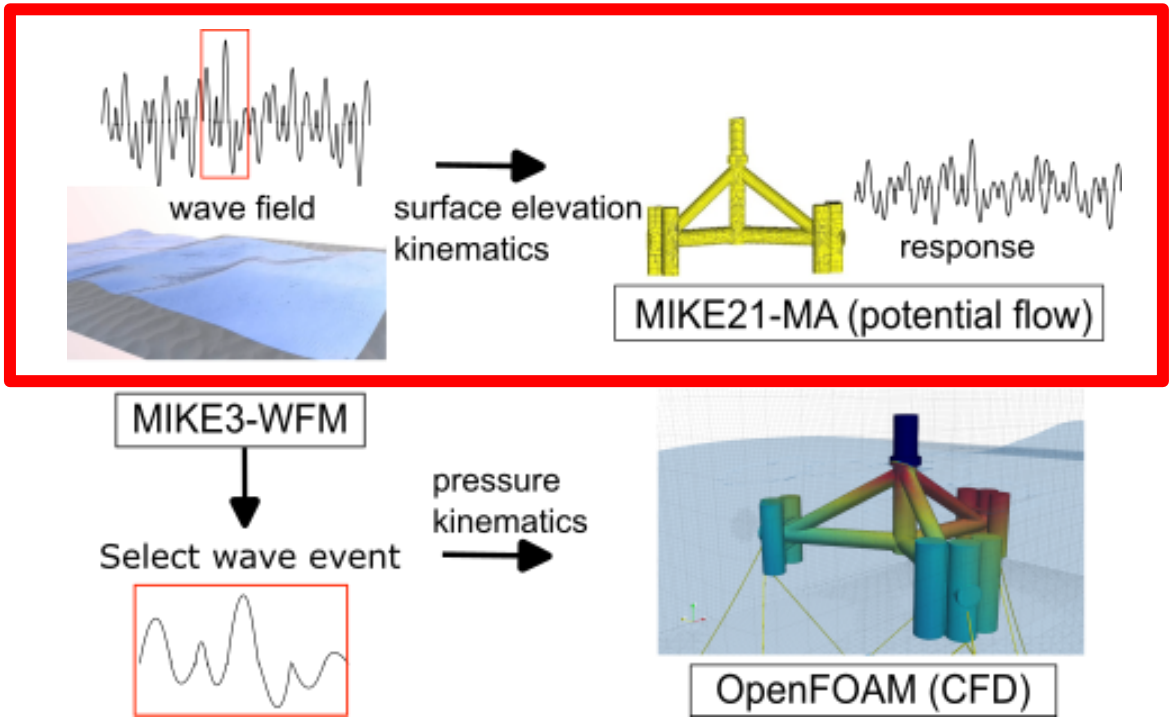
DHI

FloatStep research project

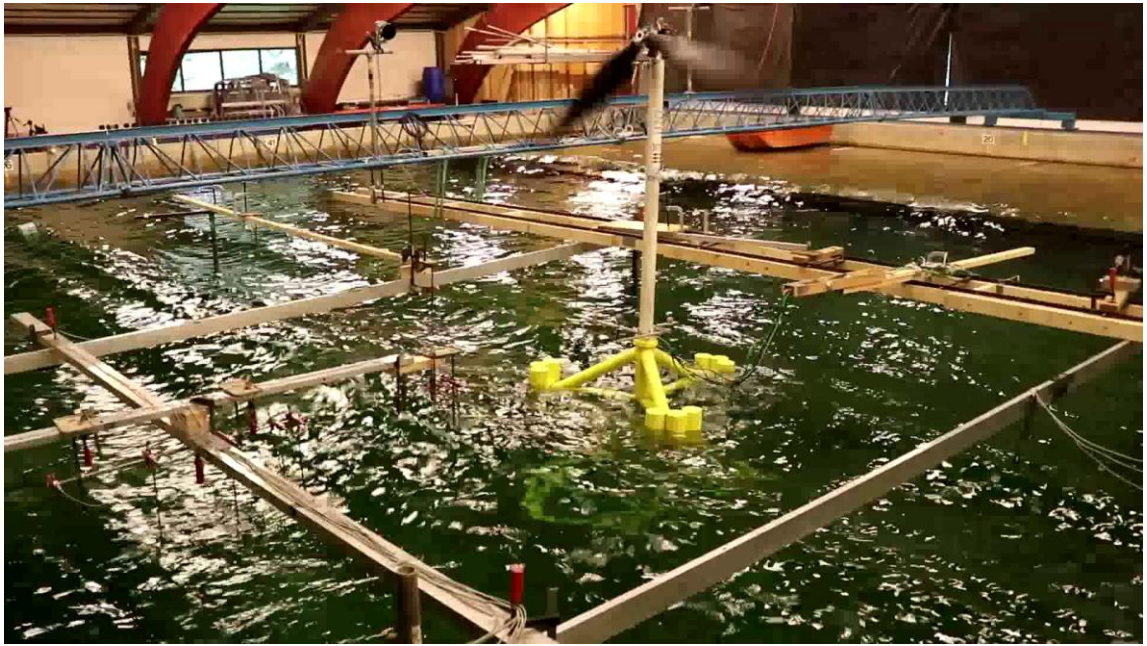
Support commercial breakthrough of Offshore Floating Wind technology by:

- Reducing cost by structural optimization
- Enabling accurate design by validated engineering tools
- Reducing risks from extreme waves by detailed flow simulations
- Reducing risks during installation and operation by lab tests and full-scale data

Hybrid numerical framework for FOWT foundation response



Experimental campaign at DHI laboratory (2017)



Team: DHI + DTU + Stiesdal OT

Floater: semi-sub configuration
spar configuration

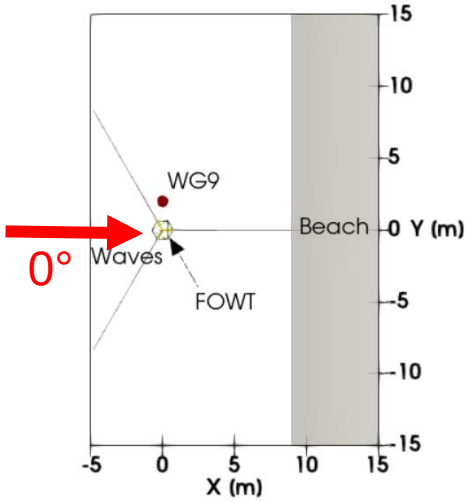
Turbine: DTU 10MW

Tests: decay tests,
only waves
waves+wind

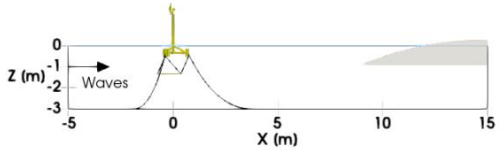
Data: water surface elevation,
floater 6DOF
nacelle 6DOF

Experimental tests for validation (wave-only, no wind)

Test ID	Sea state	Hs [m]	Tp [s]	Direction
T167	03	0.055	0.84	0°
T193	05	0.069	0.94	0°
T185	06	0.103	1.15	0°
T201	64	0.103	2.32	0°
T178	11	0.175	1.833	0°



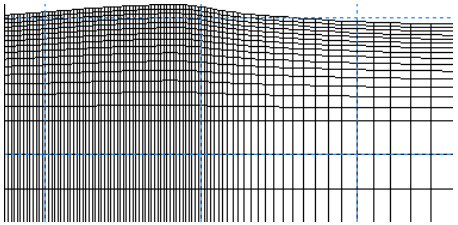
(a) Top view



The numerical model

DHI's MIKE3-WFM

Wave propagation

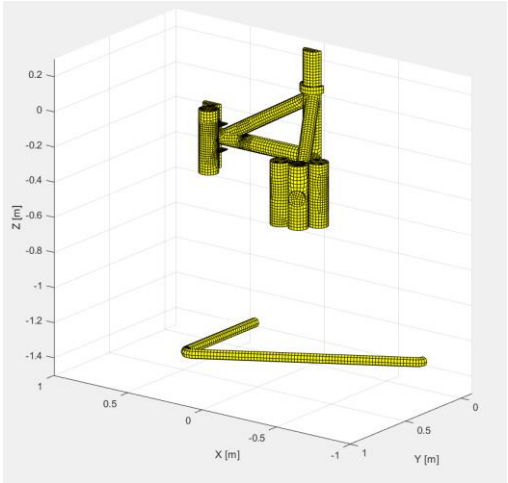


- CFD code
- Height function for free surface
- Sigma-layer system

Wave forcing coupling

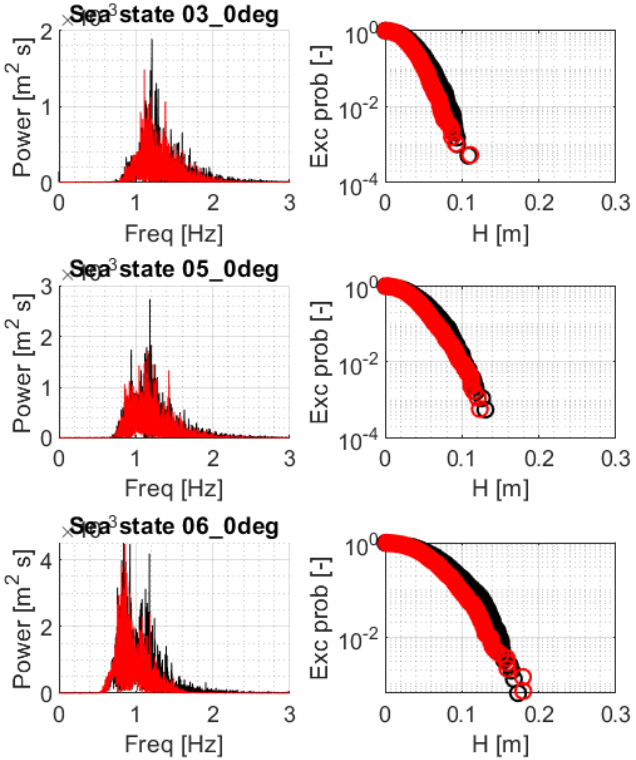
DHI's MIKE21-MA

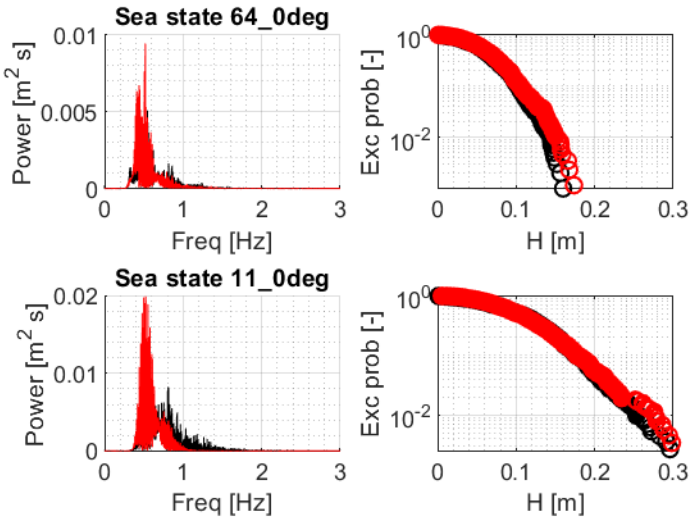
6DOF response

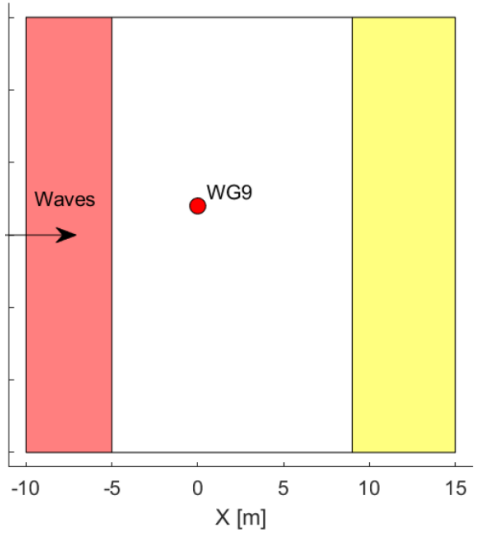


- Potential Flow Theory-based
- Radiation-diffraction in freq-domain
- Wave-response in time-domain

Wave modelling results

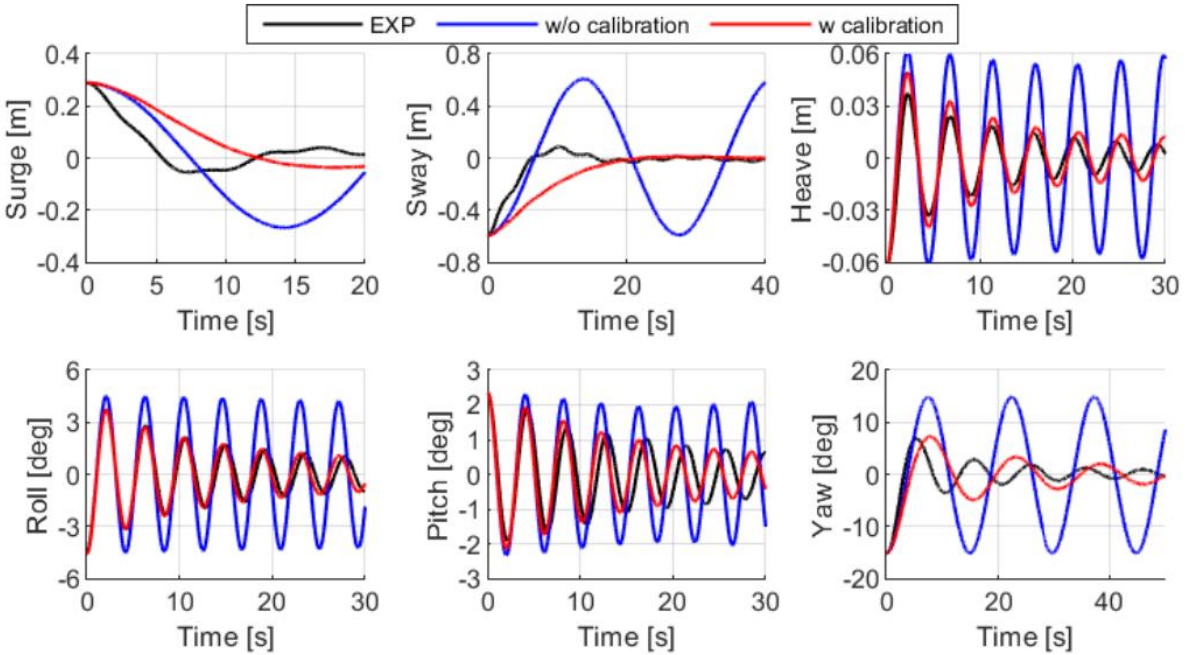






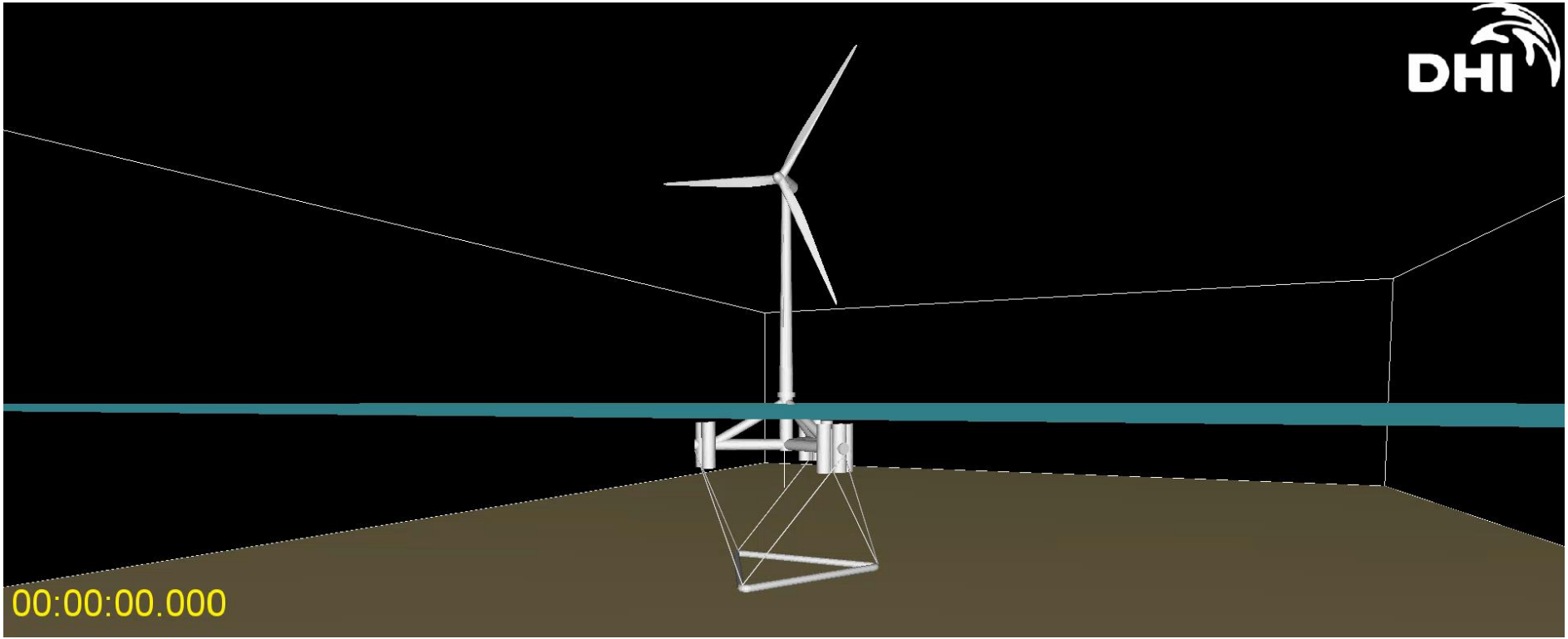
Exp, model

Damping calibration through experimental decay tests



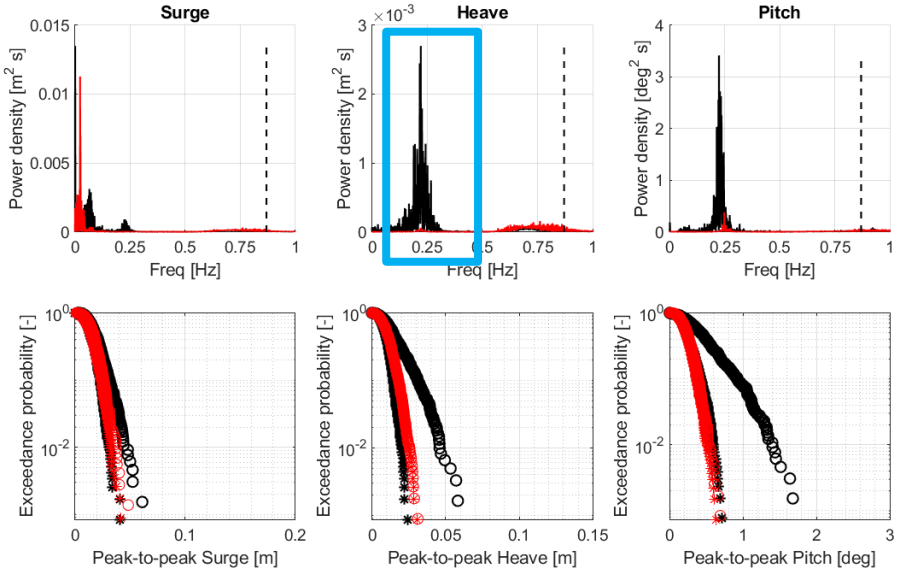
$$F_{j,visc}(t) = B_{0,j} + \sum_{k=1}^{6} \left\{ B_{1\_jk}\dot{x}_k(t) + B_{2\_jk}\dot{x}_k(t)\left|\dot{x}_k(t)\right| + B_{3,jk}\dot{x}_k^3 \right\}$$

An animation from one of the cases...



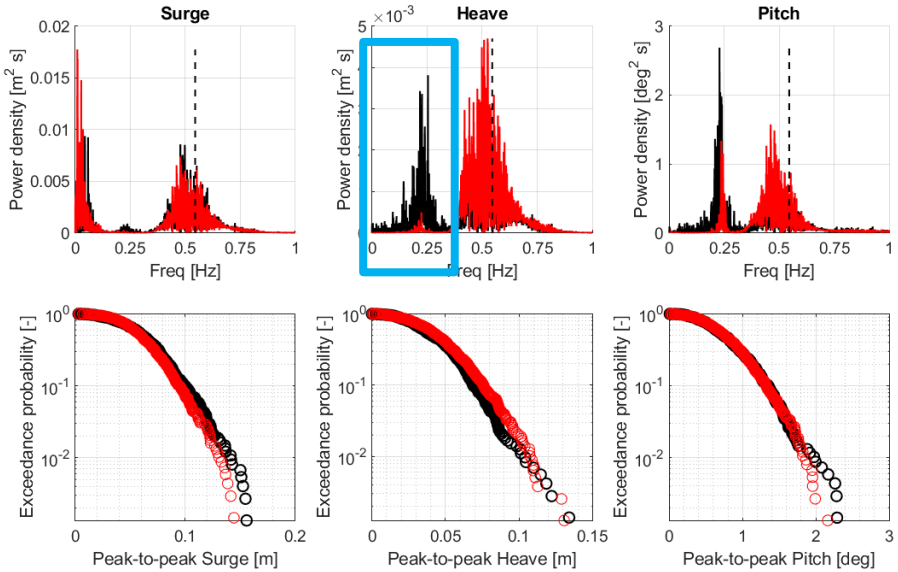
6DOF-response analysis results

Sea state 06 (Hs = 0.1 m, Tp = 1.15 s)



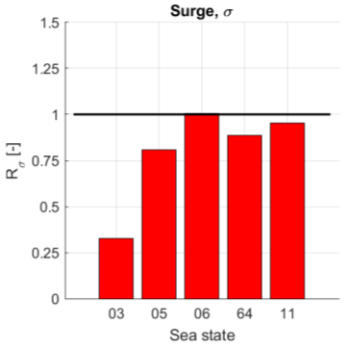
Exp, model

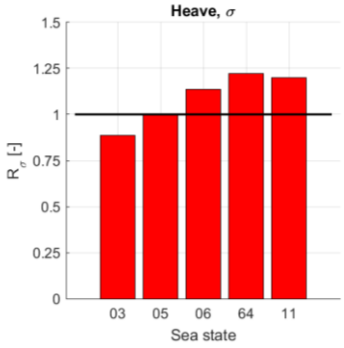
Sea state 11 (Hs = 0.17 m, Tp = 1.83 s)

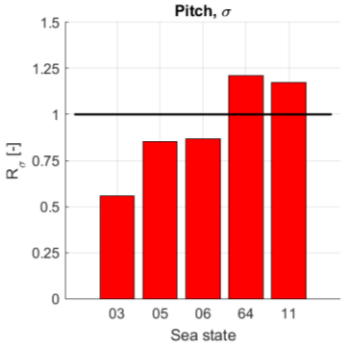


Exp, model

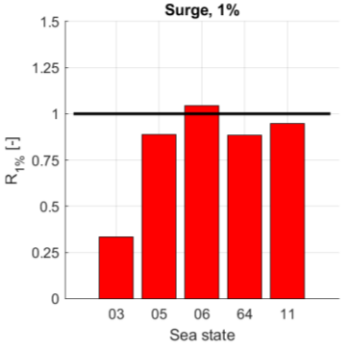
Wave-induced 6DOF response (overview for 0°-waves)

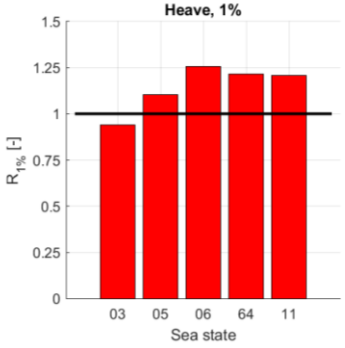


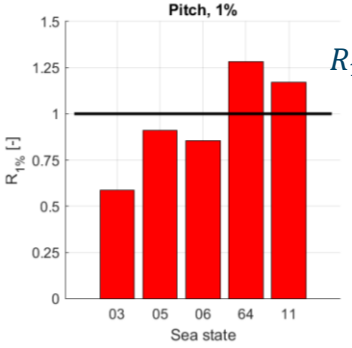




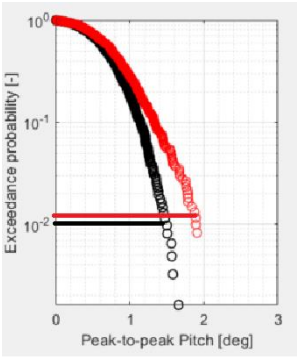
$$R_\sigma = \frac{\sigma_j\,(model,filt)}{\sigma_j(experiments,filt)},\ \sigma_j \text{ is st. dev. of } j\text{-DOF}$$







$$R_{1\%} = \frac{m_{j,1\%(model,filt)}}{m_{j,1\%(experiment,filt)}},\ m_{j,1\%} \text{ is the } j\text{-DOF with 1\%-occurrence}$$



Conclusions & Future work

- Wave modelling validation was satisfactory overall
- Response validation indicated good results within the wave forcing frequency range. The model did not fully reproduce the (second-order) subharmonic motions

- Extend validation to cases with 30°-incident wave direction
- Investigate more the 2nd-order drift force modelling
- Finalize the framework with including the CFD module for highly-nonlinear responses
- Include wind forcing

Thank you, dto@dhigroup.com

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