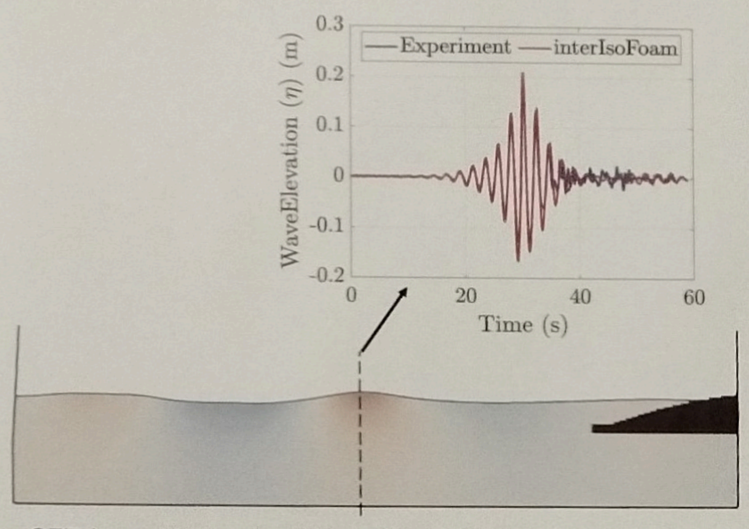
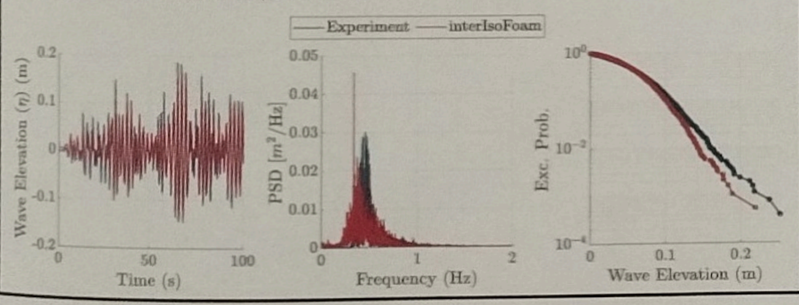
Long term lab wave reproduction in CFD based Numerical Wave Tank with Domain Decomposition

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Can we generate long term sea states in general CFD based Numerical wave tank ?

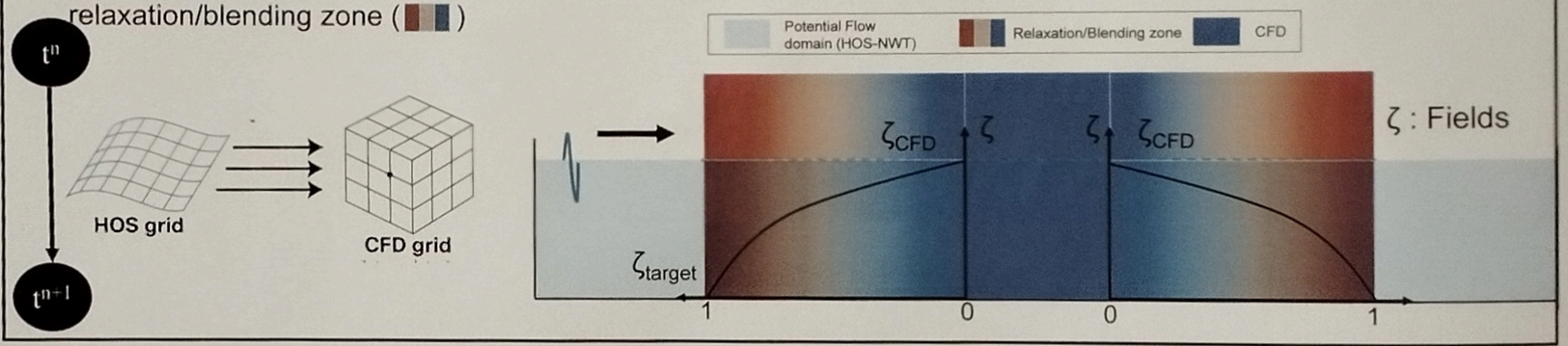


- CFD-based Numerical Wave Tanks (NWTs) effectively simulate short-term sea states and extreme wave events
- Extreme focusing waves are well reproduced using active wavemakers and and porous beach absorbers, closely matching experiments.
- However, simulating long-term sea states presents challenges due to **accumulating numerical errors** (e.g., phase shifts, interface smearing) and **high computational cost**.
- Even with 400 cells per wavelength, CFD struggles to retain key wave events and energy content, as shown in the comparison of a JONSWAP-based long-term extreme sea state with experiments

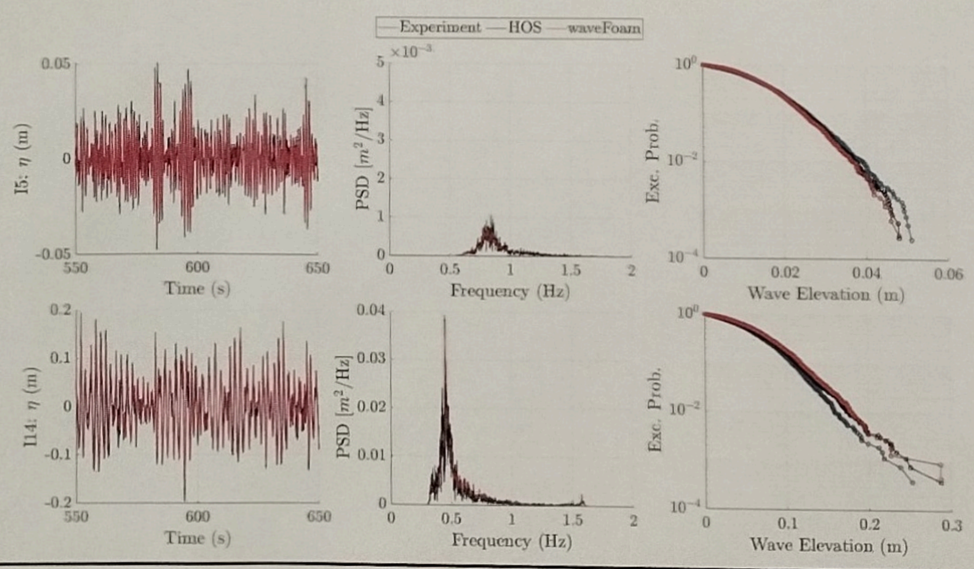


What is this domain decomposition strategy?

- **Domain Decomposition**[1]: Splits the computational domain into parts, applying the appropriate solver for each. In our approach, a viscous CFD solver is used for the inner sub-domain ( ), while a potential flow solver is applied to the inviscid outer sub-domain ( )
- **Similarity to Waves2Foam**: The ideology mirrors the famous Waves2Foam, but we leverage Grid2Grid[3] with the Higher Order Spectral Method (HOS-NWT[2]) for the potential solver and OpenFOAM for the viscous domain.
- **Grid2Grid**[3]: Reconstructs wave fields of HOS using inverse Fast Fourier Transforms (FFTs) and a quick spline module, enabling fast reconstruction of nonlinear wave fields for any given simulation time and space in the relaxation/blending zone ( )

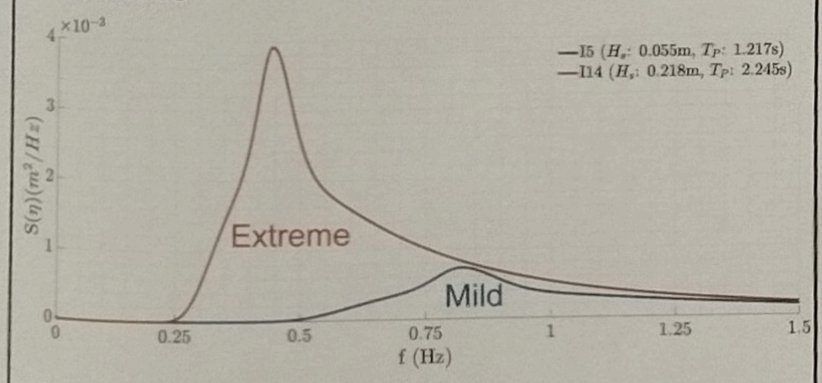


So Yes, we can reproduce long-term sea states similar to the experiment



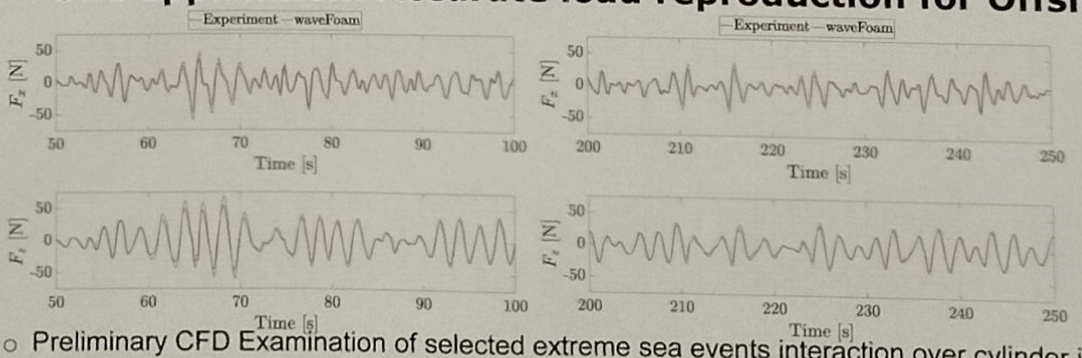
- Coupling methodology validated[4] for both mild and extreme sea states to assess wave reproduction accuracy
- 200 cells per wavelength with a Courant number (Co) of 0.25 accurately reproduces long-term sea states, matching experiments and the potential solver HOS
- Minor over-predictions were observed in some extreme events (I14) stem from HOS limitations in breaking events and experimental uncertainties
- Results confirms robustness and reliability of the approach

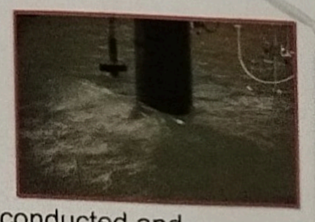
Mild and Extreme long term sea States

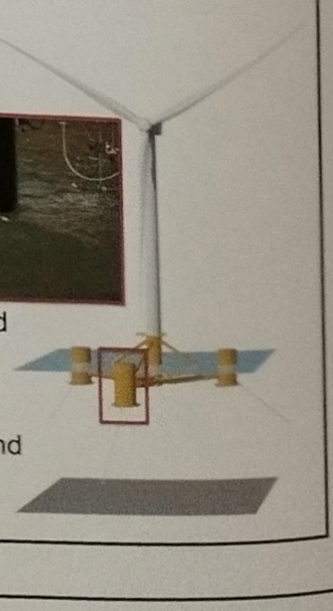


Validation: Present work is validated using two sea states: **I5 mild** and **I14 extreme sea state,** both of which were experimentally evaluated at the DHI experimental facilities in Denmark as part of the Floatlab project campaign

Where we can apply this?
One application: Accurate load reproduction for Offshore Structures

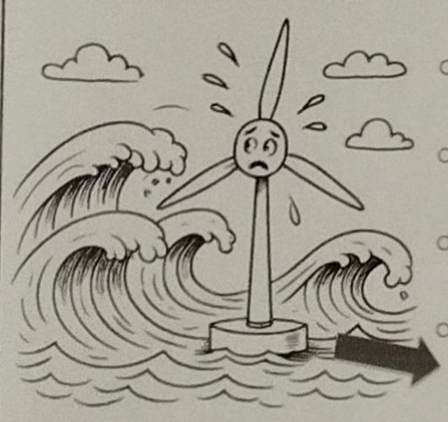




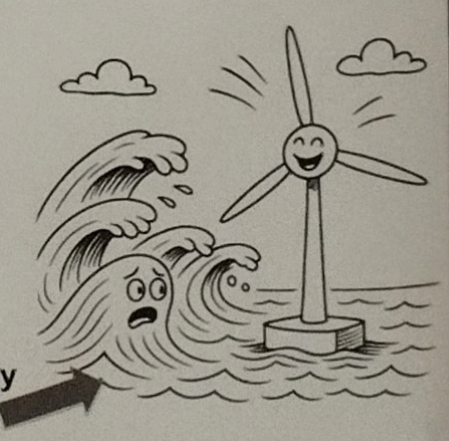


- Preliminary CFD Examination of selected extreme sea events interaction over cylinder is conducted and CFD results are validated against Floatlab experiment of similar situation
- Force comparisons (horizontal (F_x) and vertical (F_z) forces) are closely matching
- Wave generation and propagation are now accurate and fast, no longer limiting the simulation speed and main bottleneck is now the FSI, requiring very small cells and smaller time steps
- Future optimization should target the mesh strategy and solver coupling near solid boundaries

Food for Thought (To Go)



- HOS-OpenFOAM coupling methodology discussed here will soon be released as opensource solver namd '**FoamWaveTank**' after finalizing parametric studies
- Key setup: 200 cells per wavelength, an aspect ratio (AR) of 1, and a Courant number (Co) of 0.25 ensures accurate wave reproduction.
- The isoAdvector-based solver, '**waveIsoFoam**' performs slightly better than the traditional waveFoam, maintaining sharper interfaces and delivering results approximately 20% faster.
- With such precise wave reproduction methodology, **load calculations** become more accurate, offering better and quicker support for understanding nonlinearities. Our group is also working on **functional decomposition strategy** to further accelerate CFD solvers to get a quicker solution—stay tuned for future conferences and papers ☺.



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