WorldWideWind

NUMERICAL INVESTIGATION ON TLP PLATFORMS FOR WIND TURBINES UNDER EXTREME ACTIONS USING THE SPH METHOD

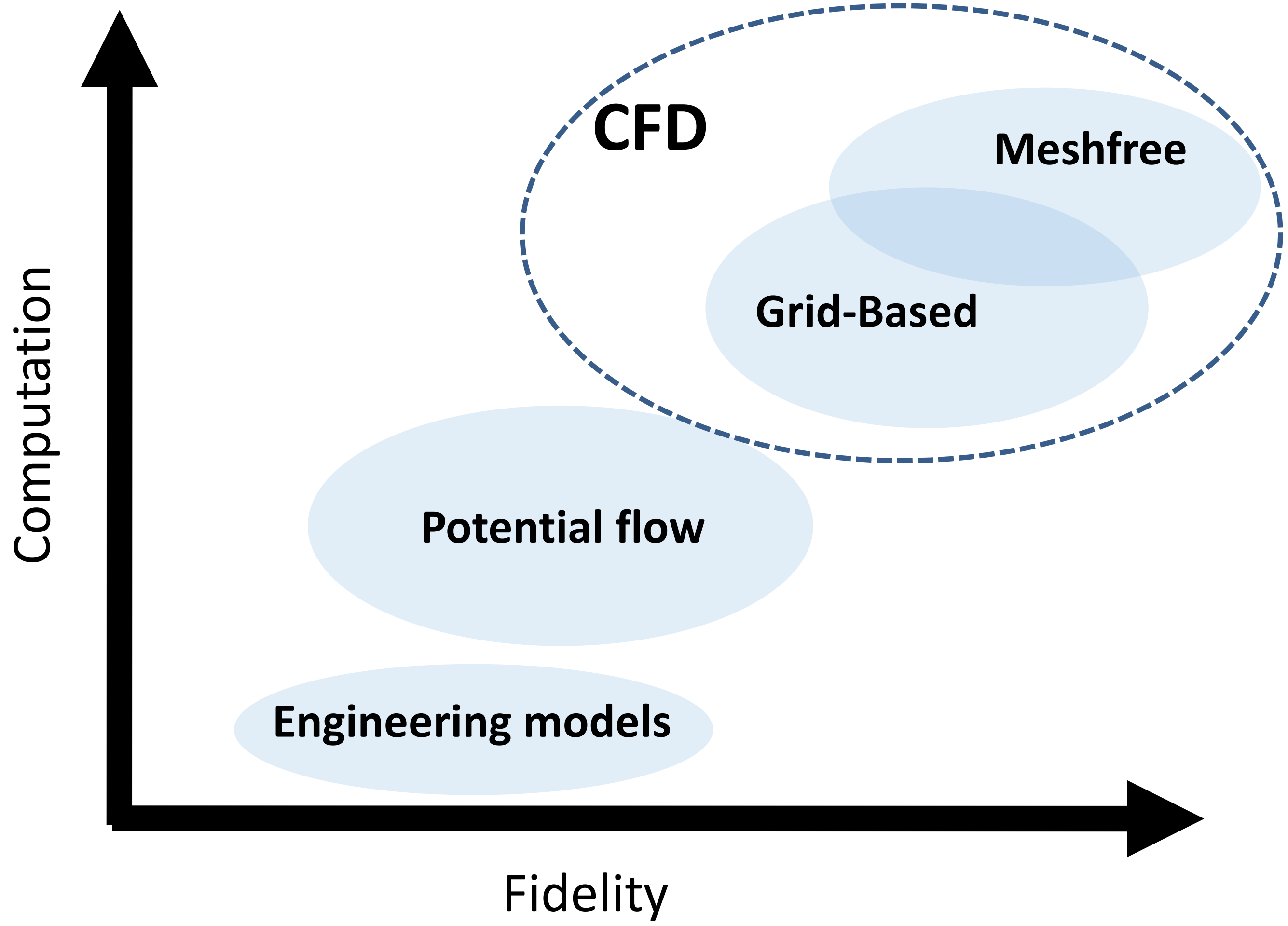
B. Tagliafierro, M. Karimirad, M. Göteman, H. Bernhoff, I. Martínez-estévez, S. Capasso, JM. Domínguez, C. Altomare, G. Viccione, M. Gómez-gesteira, AJC. Crespo

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

QUEEN'S UNIVERSITY BELFAST

UNIVERSIDADE DE VIGO

MARINE RENEWABLE ENERGY DEVICES



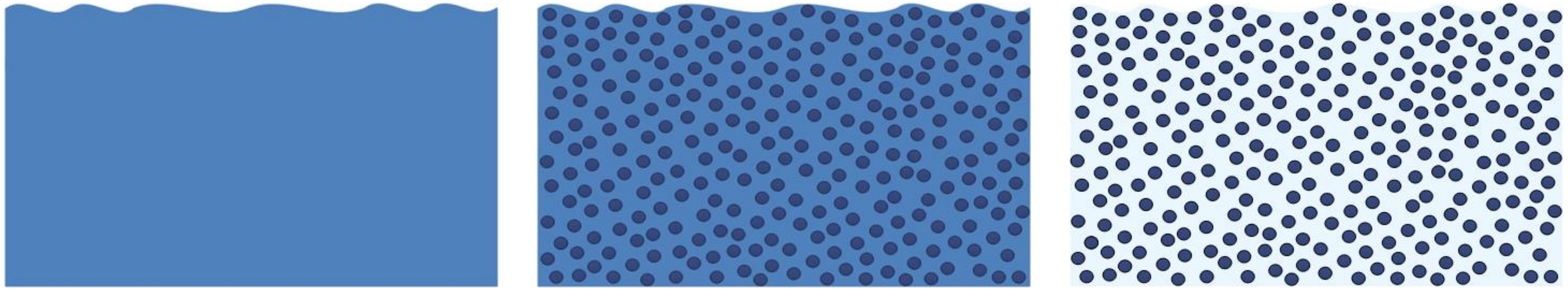
(after Penalba et al. 2017)

FSI problems play prominent roles in many scientific and engineering fields but strong nonlinearity and multidisciplinary nature pose a great challenge

↓

Balance between computational effort and fidelity of the simulation

SMOOTHED PARTICLE HYDRODYNAMICS



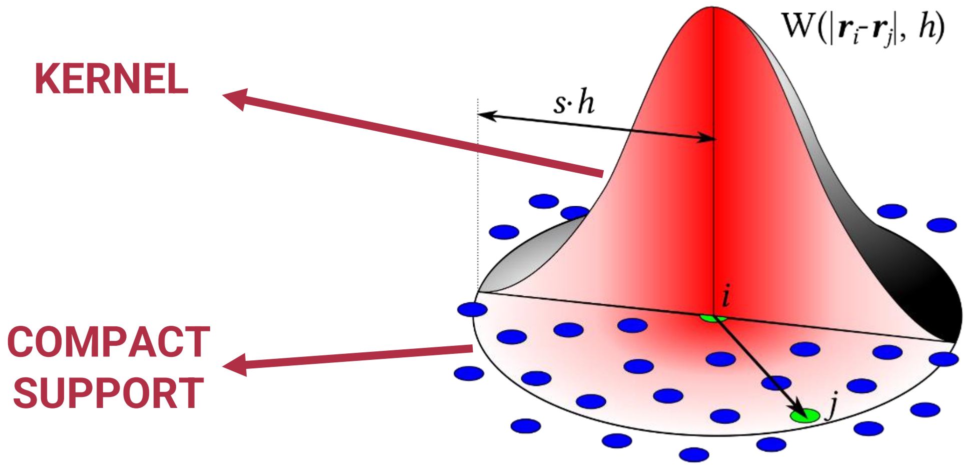
Continuos fluid — Set of particles

Each of these particles is a **nodal point** where **physical quantities** are computed as an **interpolation** of the values of the **neighboring particles** solving the N-S equations and using **summations.**

Generic properties

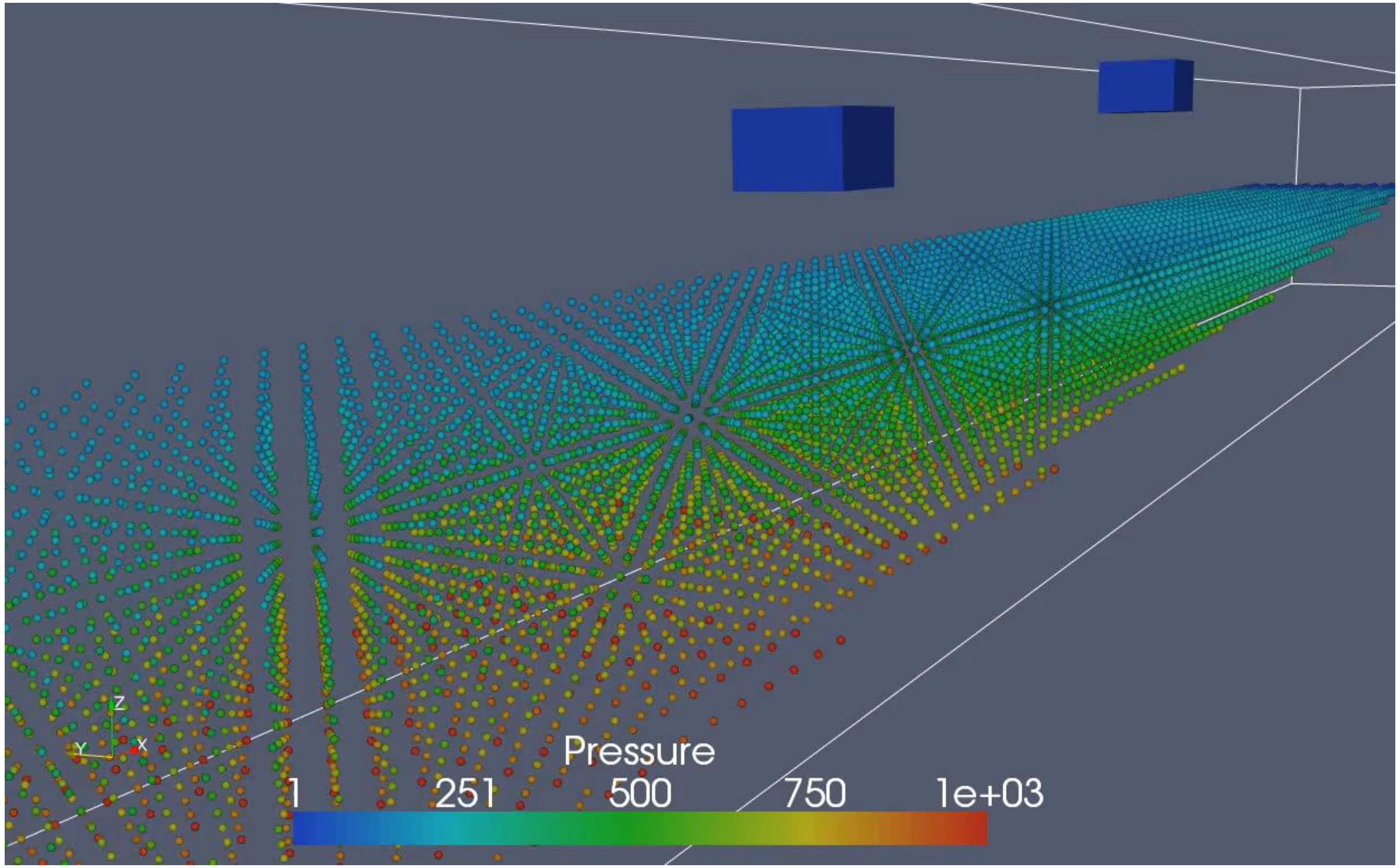
$$A_i = \sum_{j=1}^{N} A_j W(r_i - r_j, h) \frac{m_j}{\rho_j}$$

KERNEL FUNCTION



Schematic view of a SPH convolution (Wikipedia CC BY-SA 4.0)

SMOOTHED PARTICLE HYDRODYNAMICS

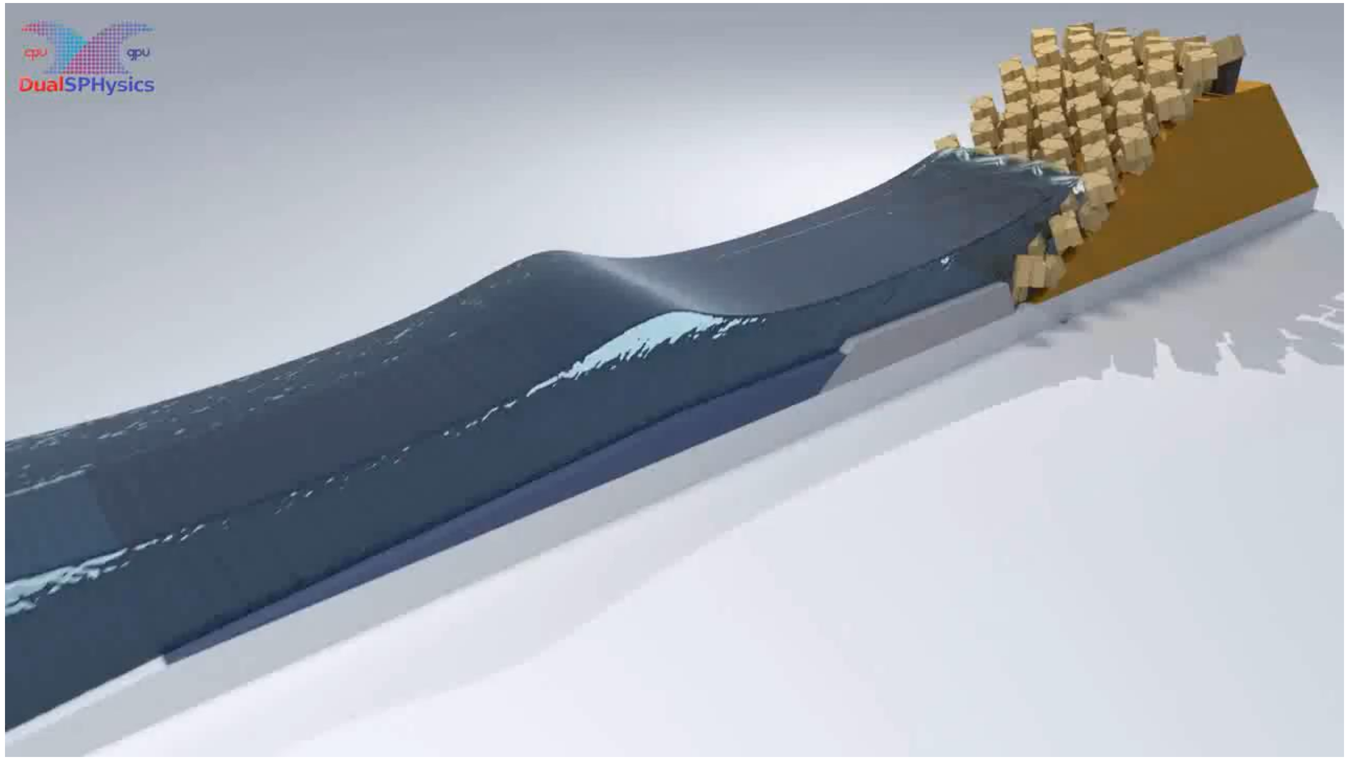


SPHERIC YouTube: https://youtu.be/huXY-rhwMJA

DualSPHysics

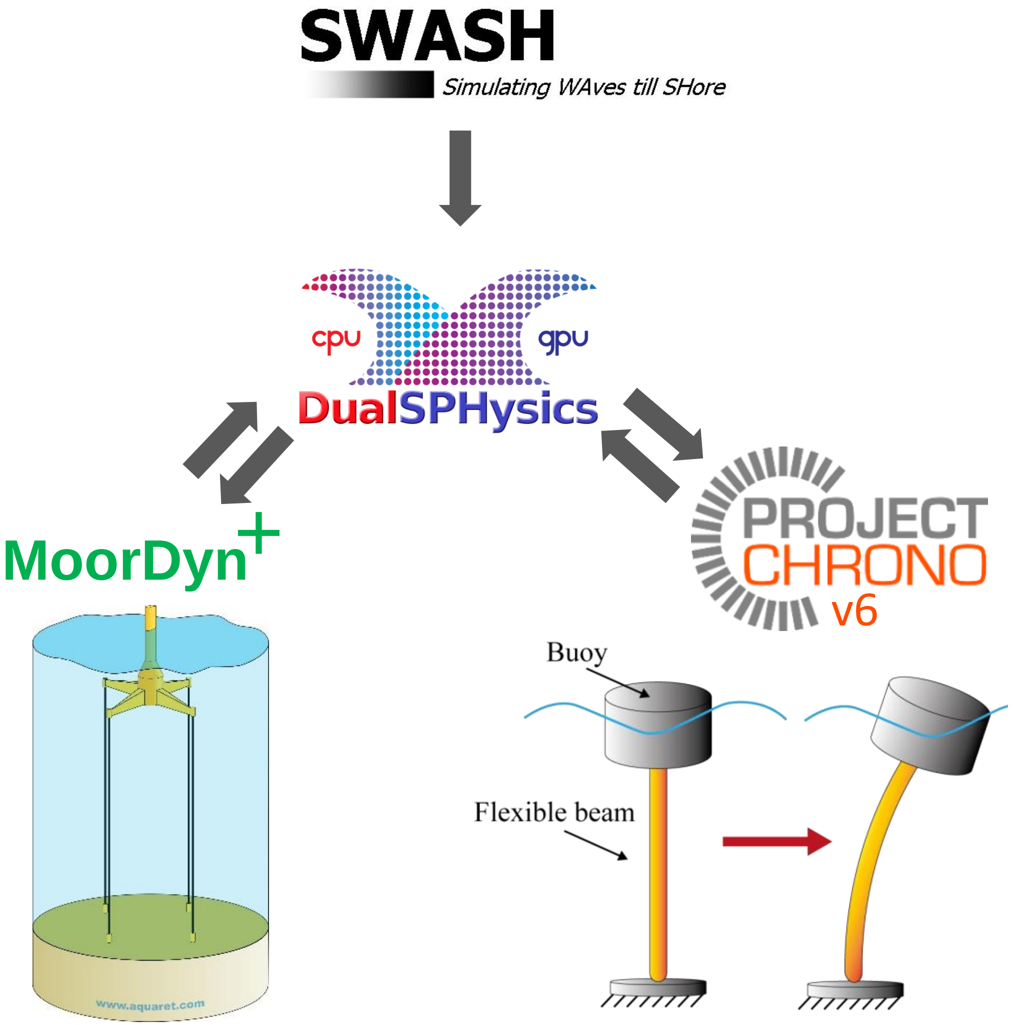
is based on the Smoothed Particle Hydrodynamics method, and it is developed to study free-surface flow phenomena where Eulerian methods can be difficult to apply

- Free, open-source code
- Collaborative project
- LGPL license
- Highly parallelised



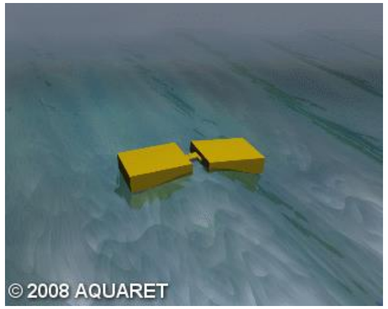
Domínguez et al. (2022). DualSPHysics: From fluid dynamics to multiphysics problems. **Computational Particle Mechanics**. Link

COUPLING TO OTHER MODELS

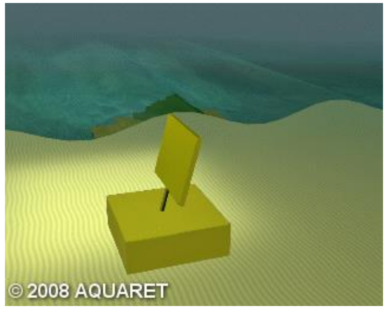


Numerical modelling to study the efficiency and survival of WECs

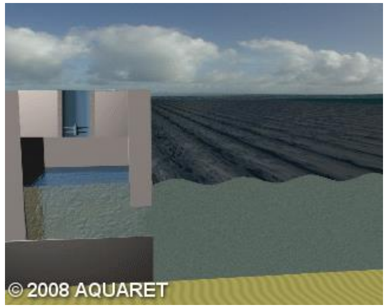
Point absorber



Attenuator



Oscillating wave surge converter (OWSC)



Oscillating water column (OWC)

Universidade de Vigo

EPhysLab

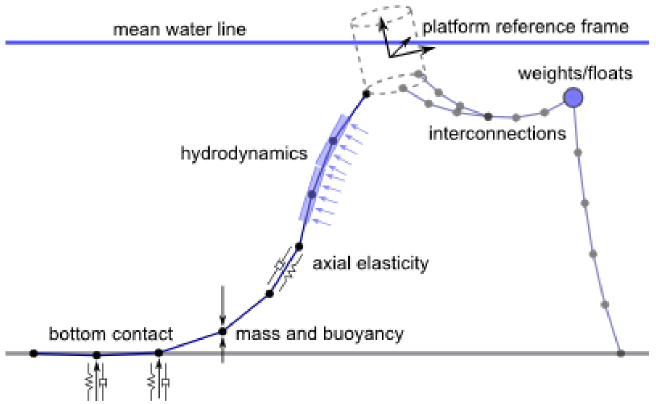
MoorDyn

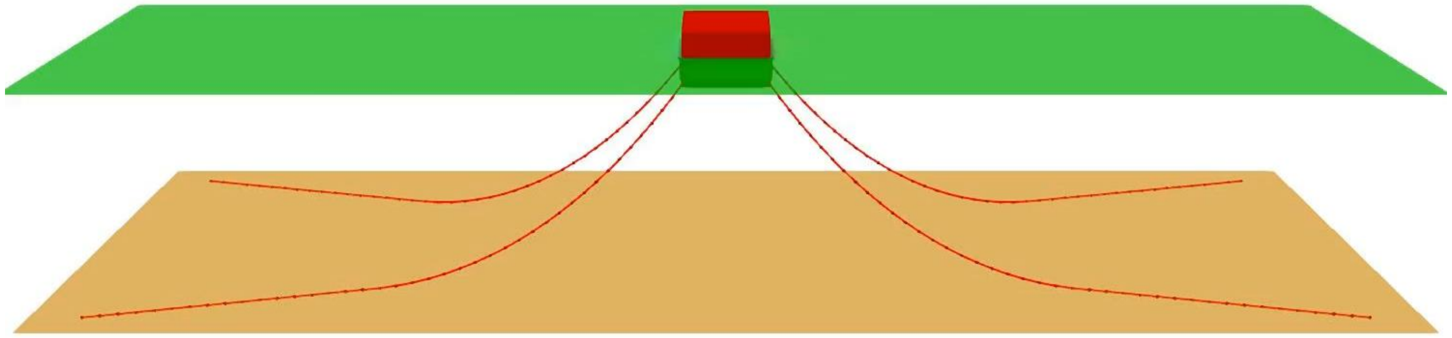
Reimplement

MoorDyn+

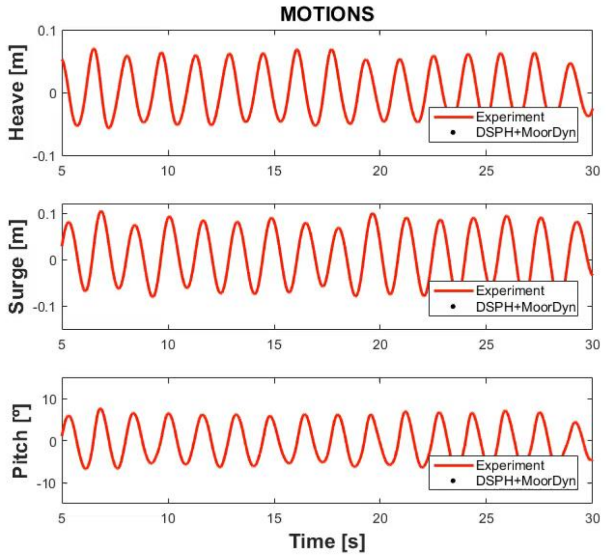
http://www.matt-hall.ca/moordyn/

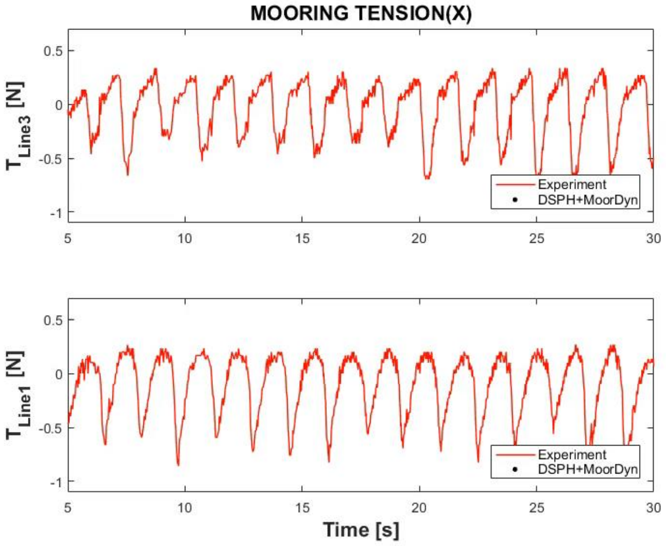
https://github.com/imestevez/MoorDynPlus





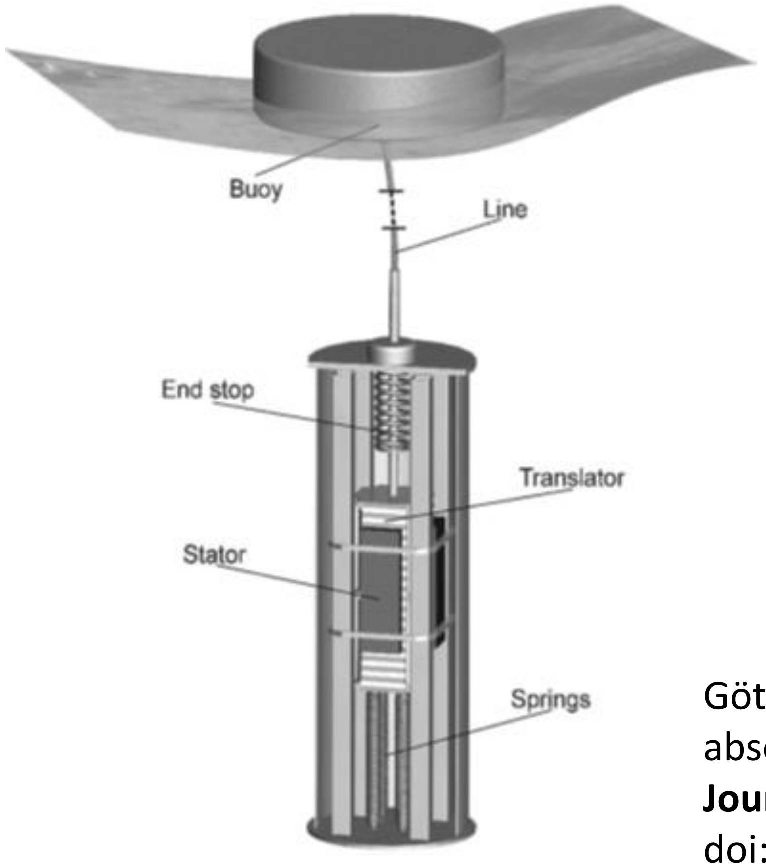
- C++ implementation
- Bugs in MoorDyn are solved
- Robust control of exceptions
- Different water depths
- More than one moored floating object
- Mooring connected to more than one floating object
- Define a maximum value of tension for the mooring lines





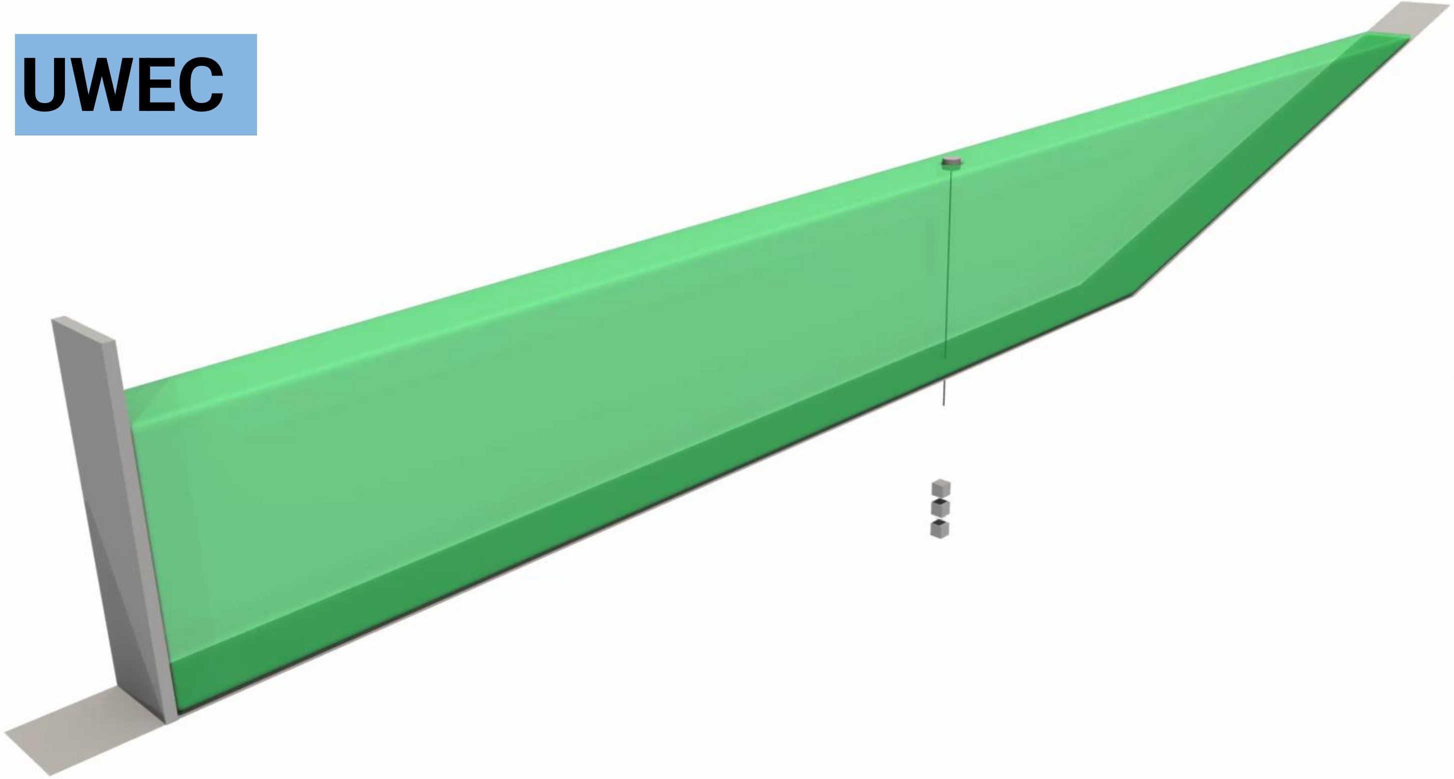
Uppsala WEC

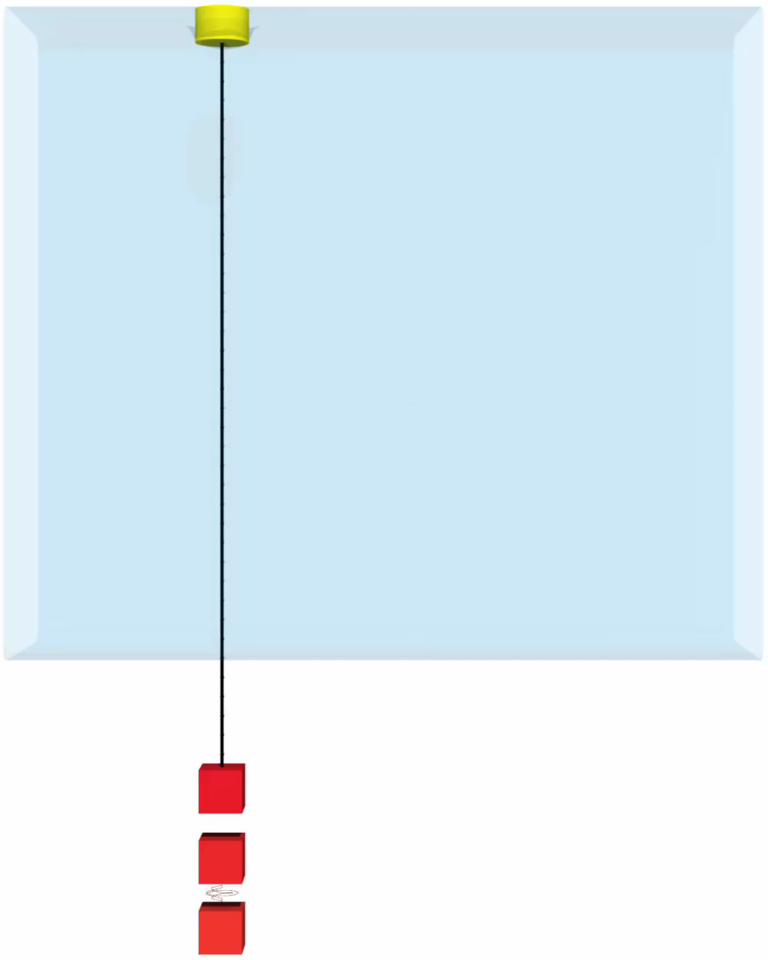
UPPSALA UNIVERSITET



Göteman, M. et al. (2015). Wave loads on a point-absorbing wave energy device in extreme waves. **Journal of Ocean and Wind Energy**, 2(3), 176-181. doi:10.17736/jowe.2015.mkr03

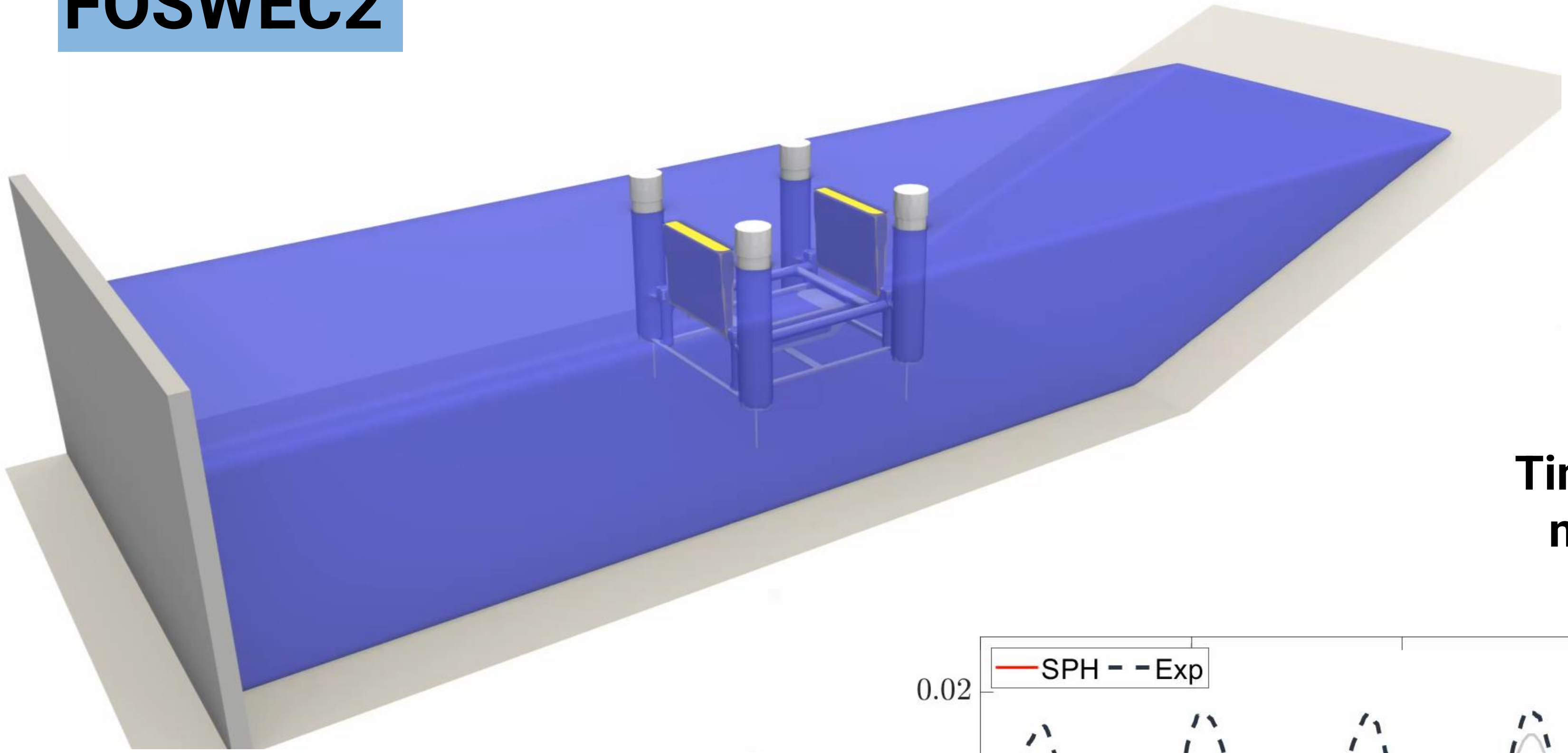
UWEC





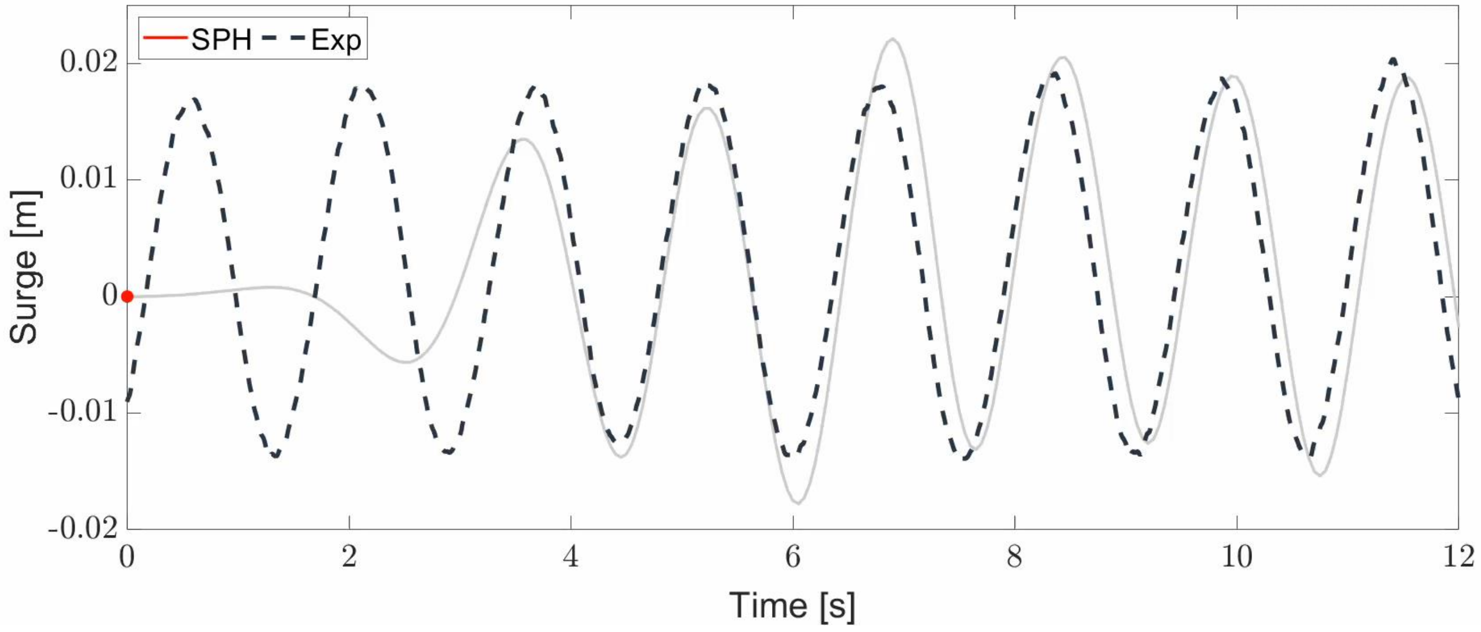
Tagliafierro, B., Martínez-Estévez, I., Domínguez J.M., Crespo, A.J.C., Göteman, M., Engström, J., Gómez-Gesteira, M. **(2022)**. *A numerical study of a taut-moored point-absorber wave energy converter with a linear power take-off system under extreme wave conditions*. **Applied Energy**, 311 https://doi.org/10.1016/j.apenergy.2022.118629

FOSWEC2



Tagliafierro et al. 2022 *Numerical modelling of moored floating platforms for wave energy converters using DualSPHysics: preliminary tests under extreme waves*. 41st OMAE2022, 6-9 Jun 2022, Hamburg, Germany.

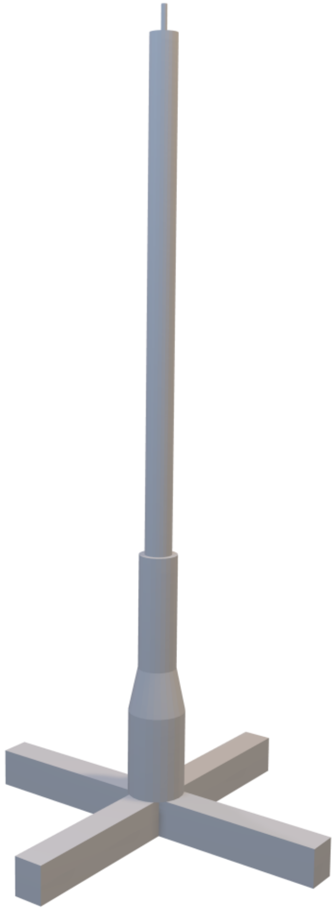
Time series of experimental and numerical angles of the flaps



Sandia National Laboratories

TENSION-LEG PLATFORM

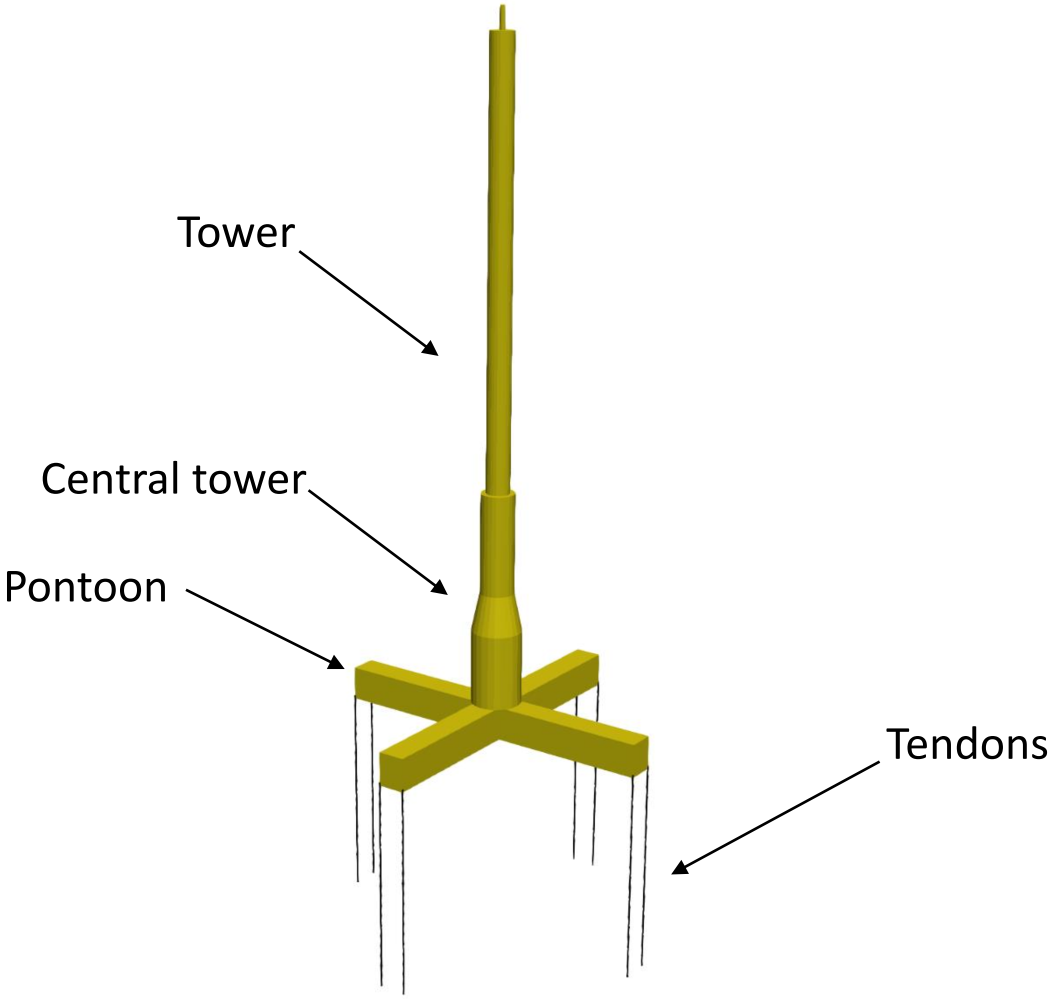
A Tool for Multiphysics Simulations of Floating Offshore Wind Turbines



500k core*hour
(20k GPU*hour)

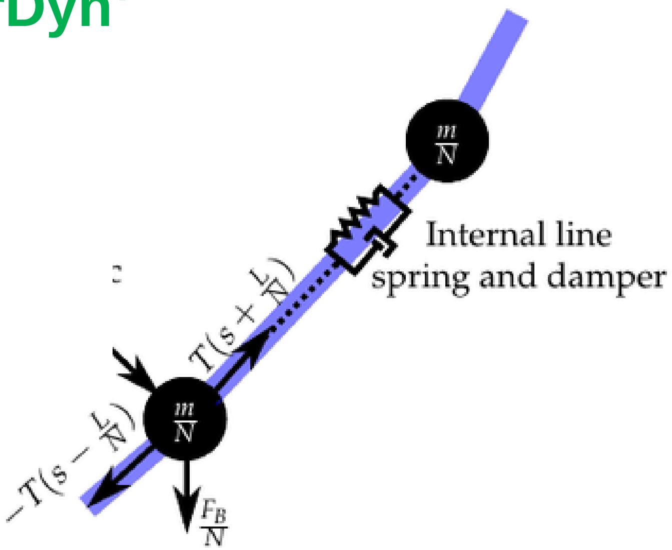
36 GPU nodes each housing 4 NVIDIA V100s (16 GB RAM)

INITIAL SETUP



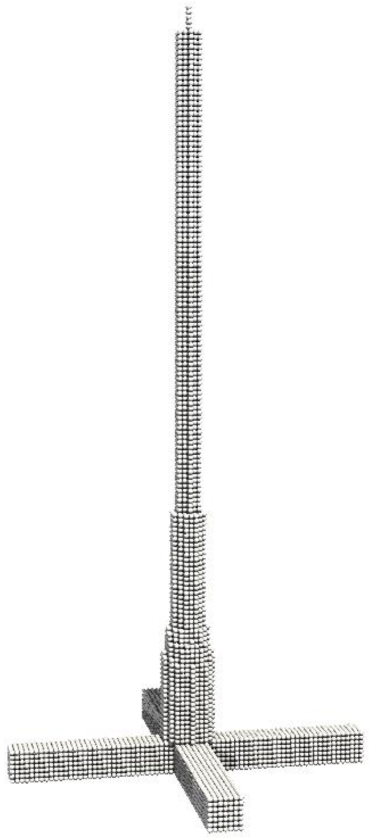
Element	Symbol	Quantity	Unit
Cross sectional stiffness	EA_l	93.3	kN
Equivalent stiffness	EA_{mod}	31.1	kN
Nominal diameter	D_N	2.50	mm
Segments	N	10	-
Density in air	ρ_l	7500	kg/m^3
Weight in fluid	W_l	0.40	N
Natural frequency (Eq. (11))		3.00	MHz
Model time step	dt_M	3.35e-06	s

MoorDyn+

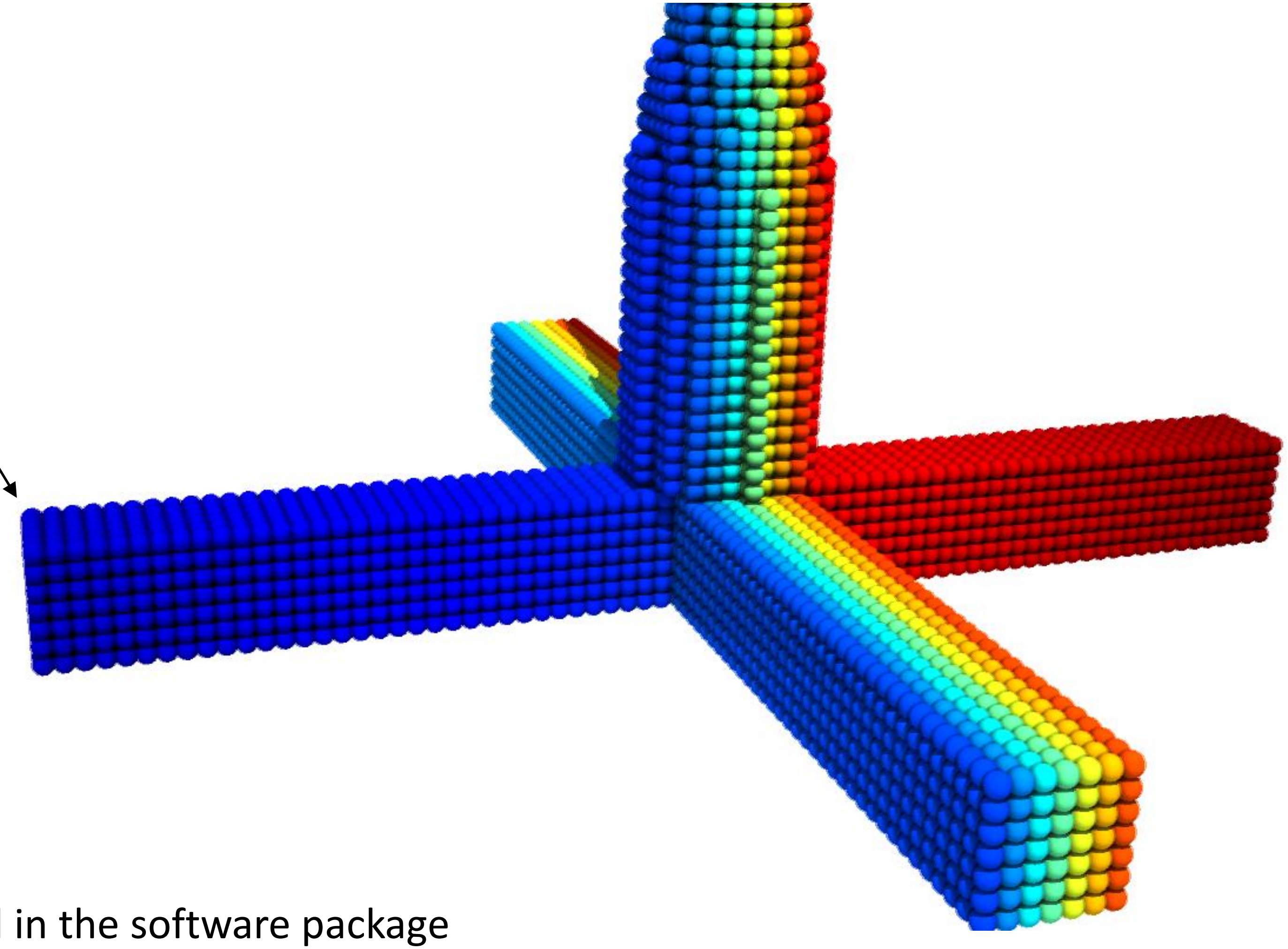


Oguz et al. (2018). *Experimental and numerical analysis of a TLP floating offshore wind turbine*. **Ocean Engineering**

PARTICLE DISCRETIZATION



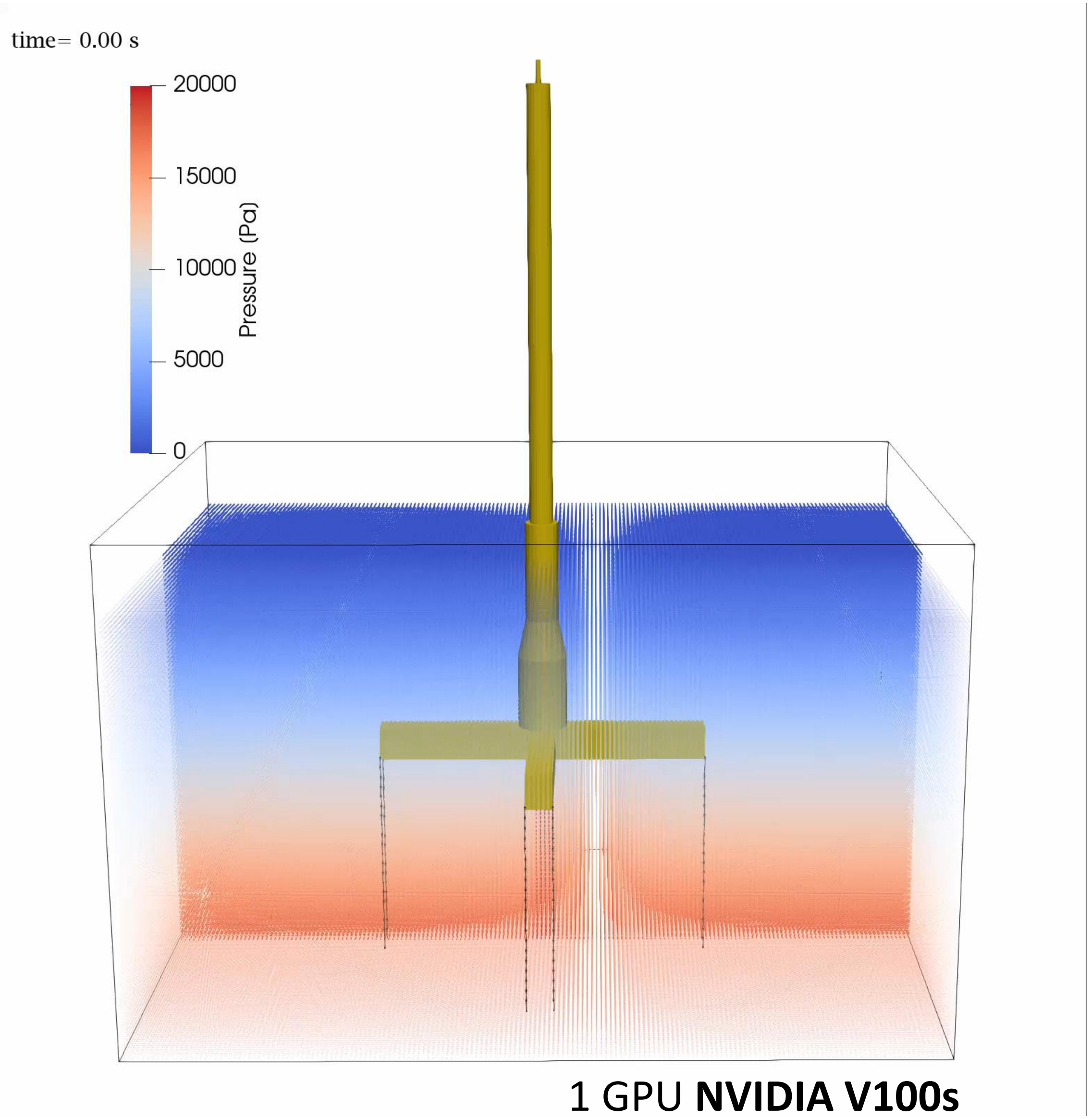
Nodal point
(or *particle*)



Pre-processing tool comes bundled in the software package

SURGE DECAY TEST

$$T_{exp} = 4.05\ s$$



1 GPU **NVIDIA V100s**

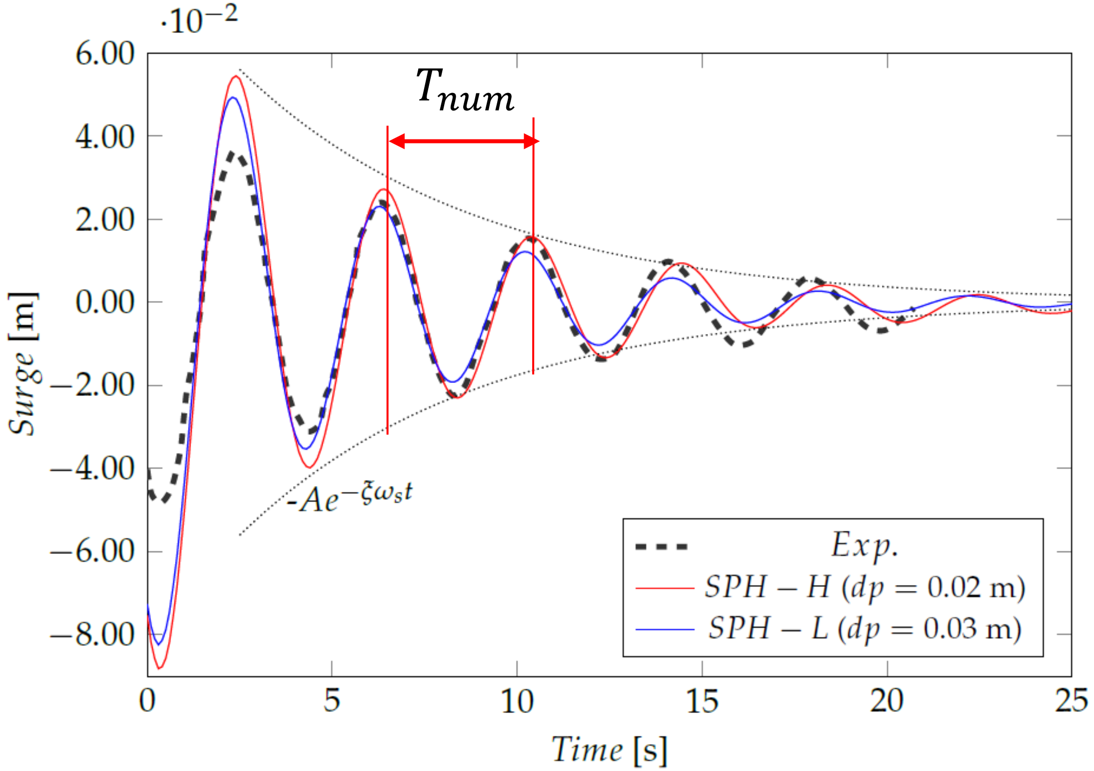
35 s Physical time

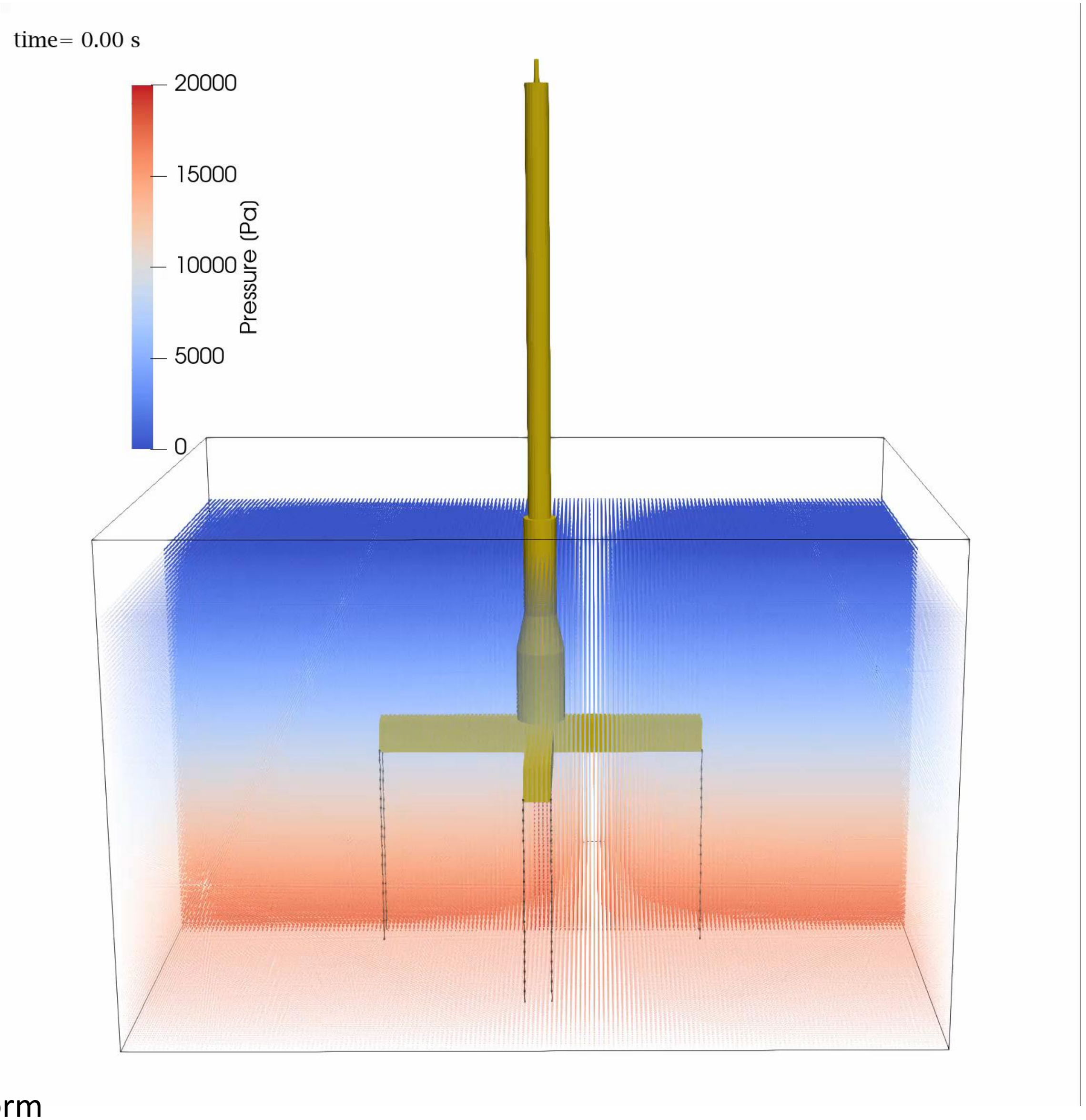
2.65 M particles

23 h Runtime

SURGE DECAY TEST

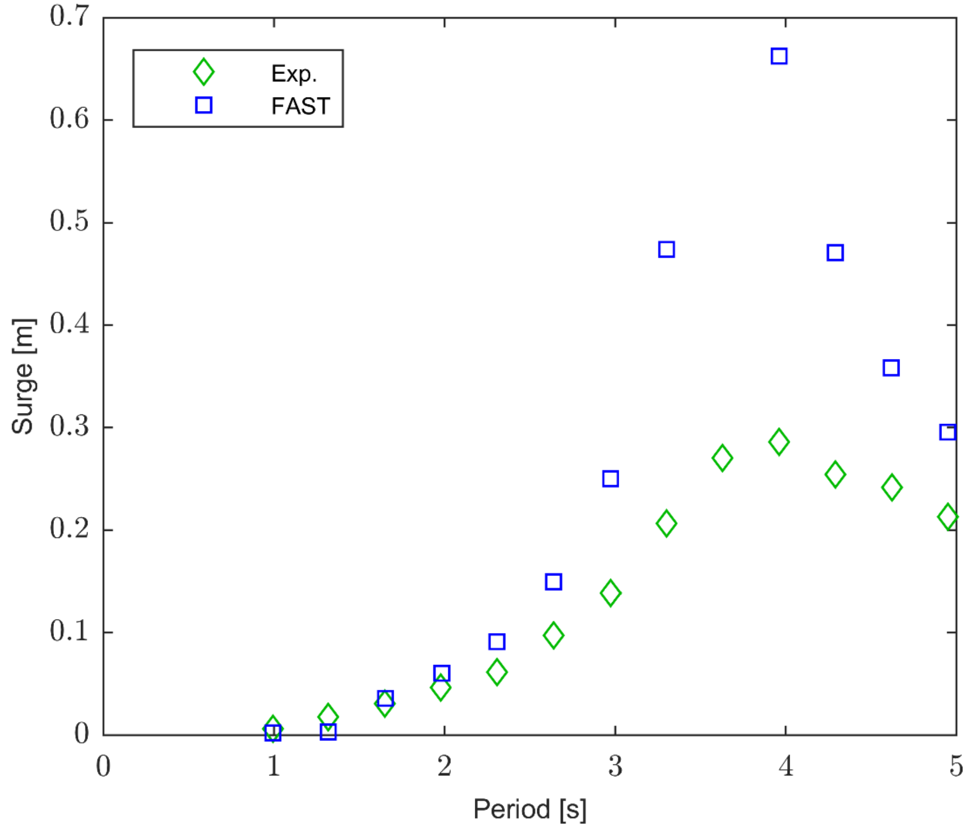
$$T_{exp} = 4.05\ s$$
$$T_{num} \approx 4.02\ s$$

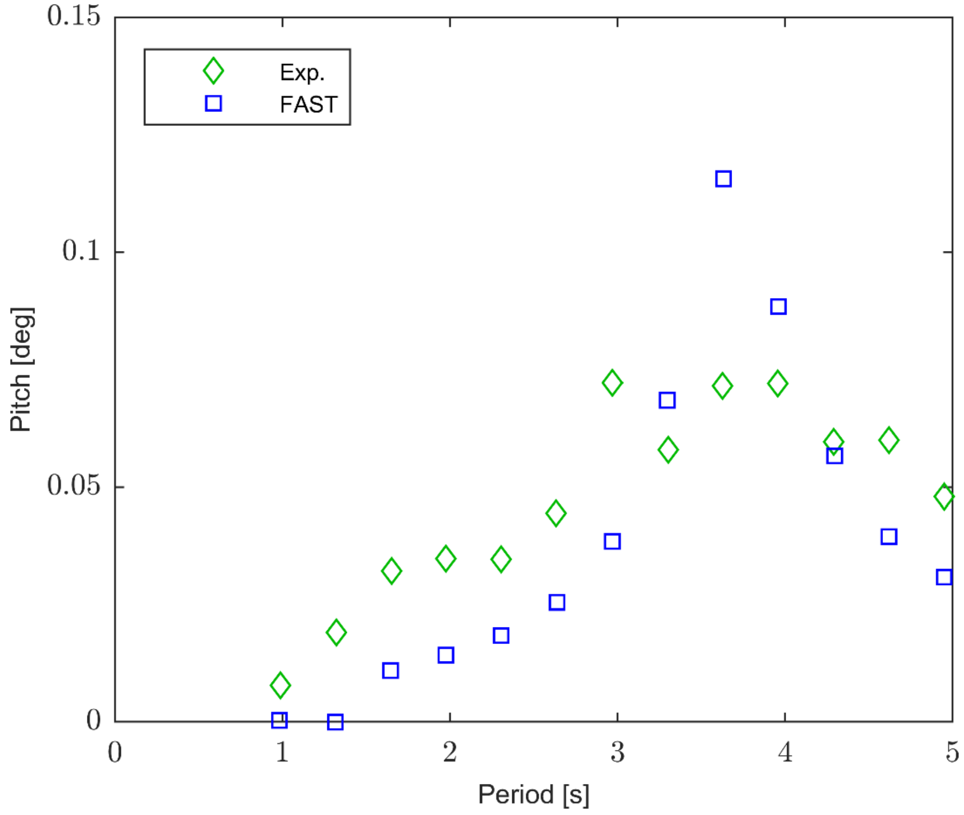




Tagliafierro, B.; Karimirad, M., et al. Numerical Assessment of a Tension-Leg Platform Wind Turbine in Intermediate Water Using the Smoothed Particle Hydrodynamics Method. *Energies* **2022**, *15*, 3993.

Response Amplitude Operator (RAO)





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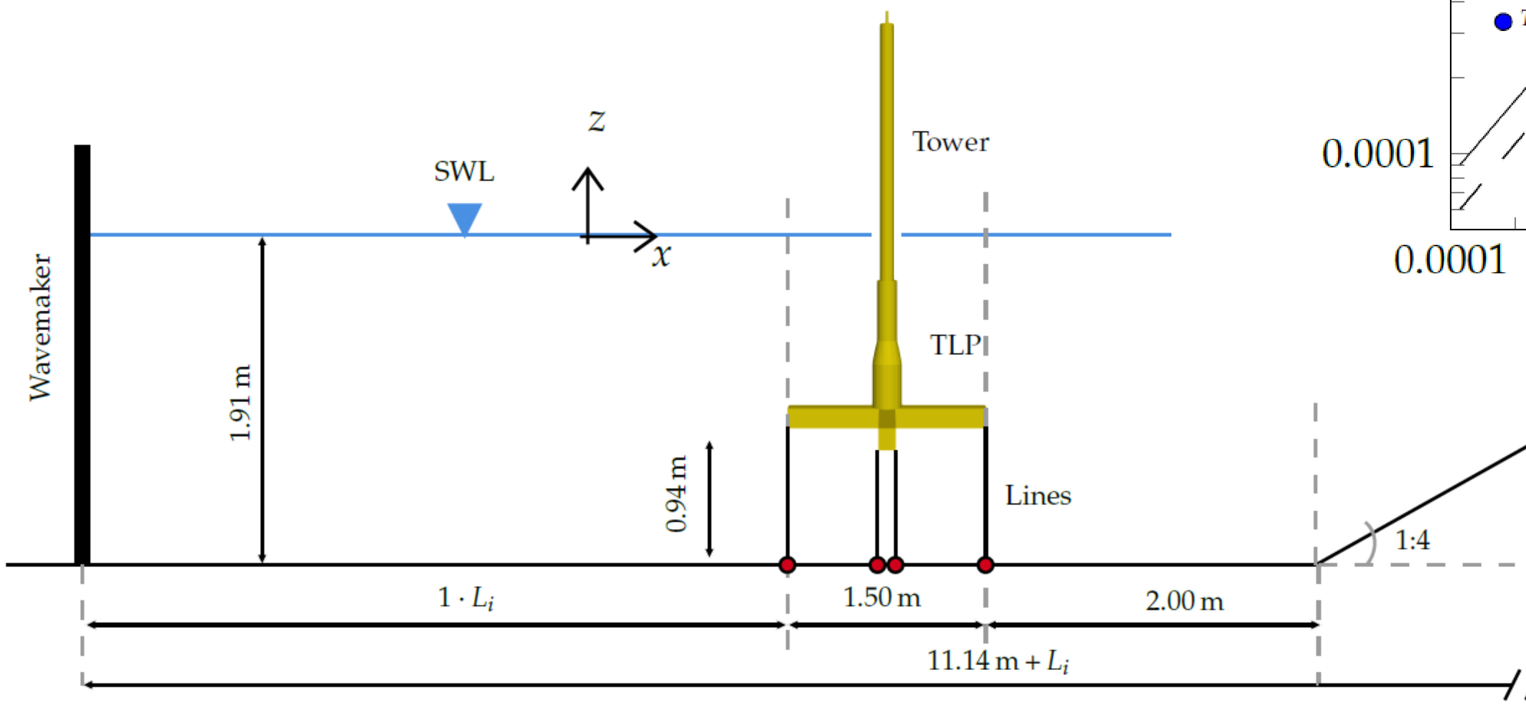
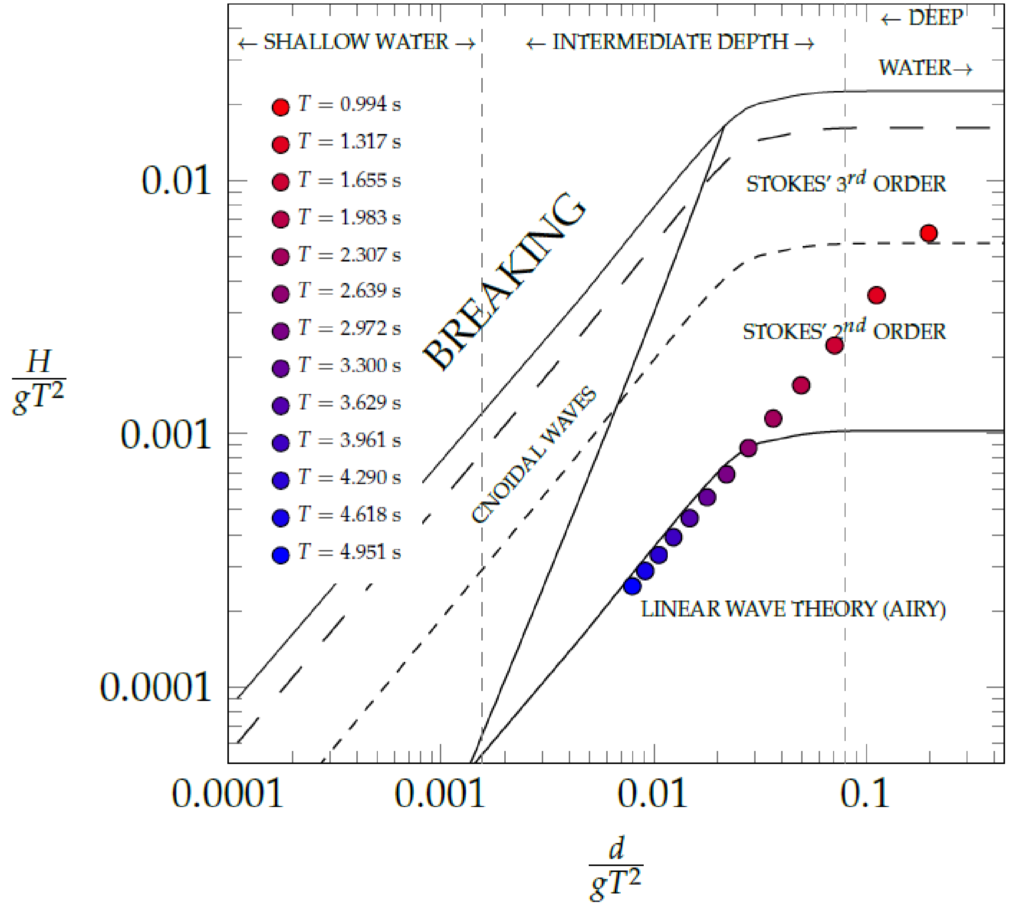
WAVE GENERATION AND PROPAGATION

$$wave\ period = [1.00\ - 5.00]\ s$$

$$wave\ height = 0.06\ \text{m}$$

$$water\ depth = 1.91\ \text{m}$$





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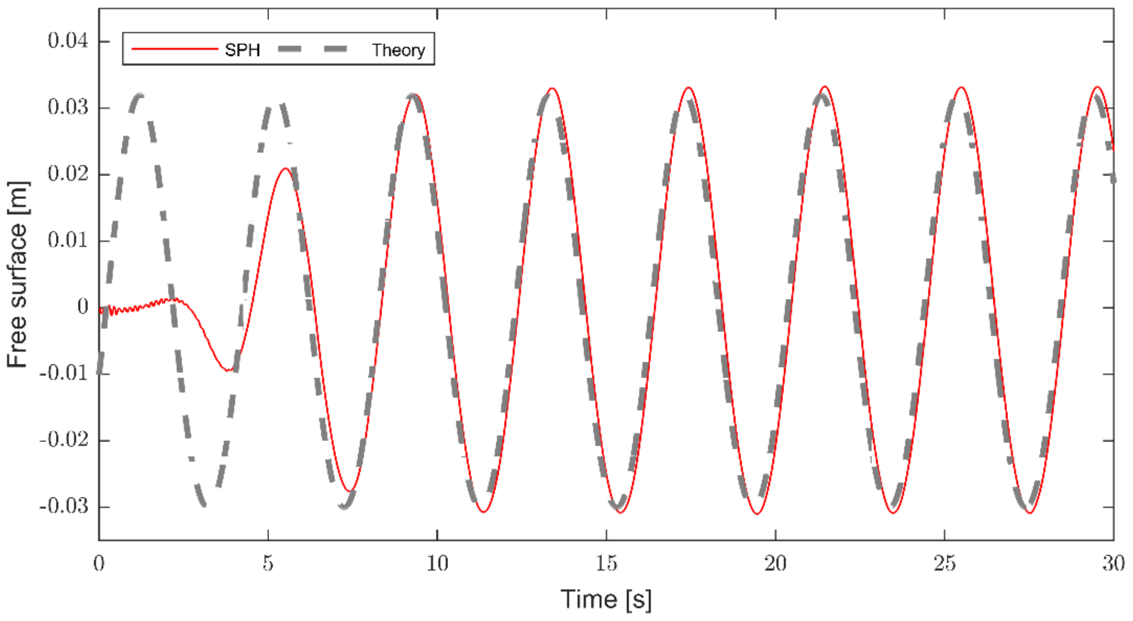
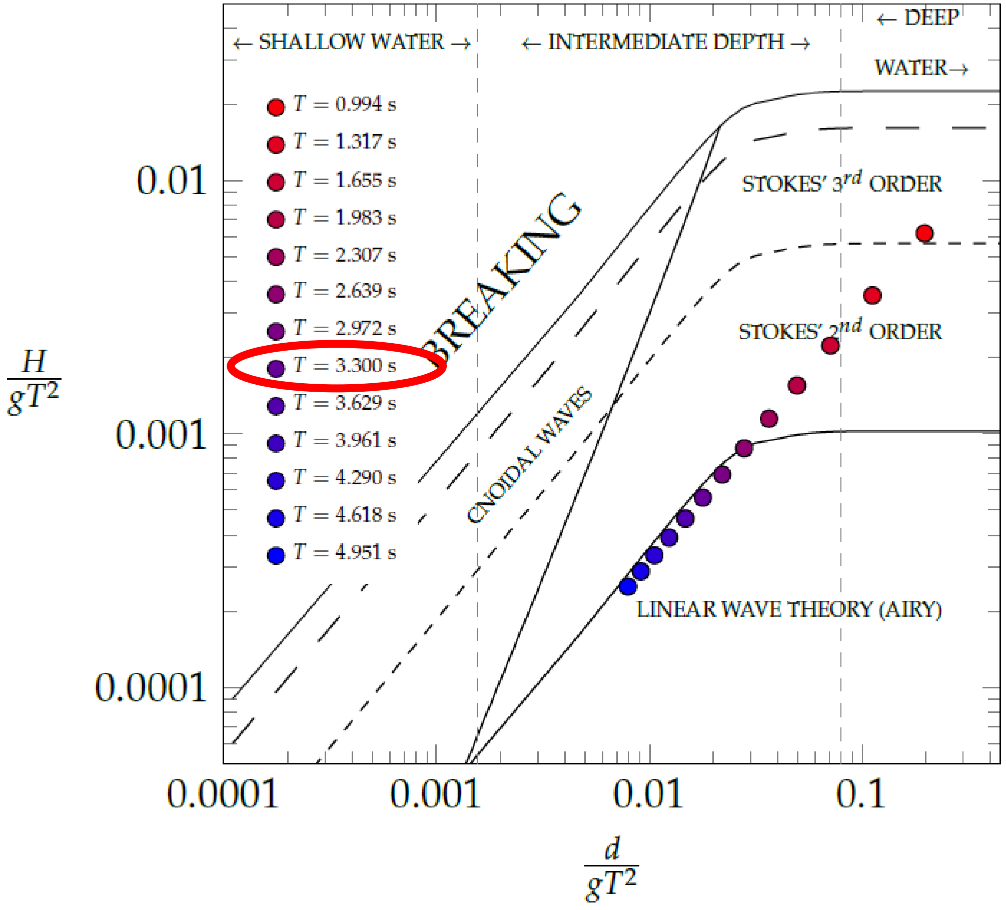
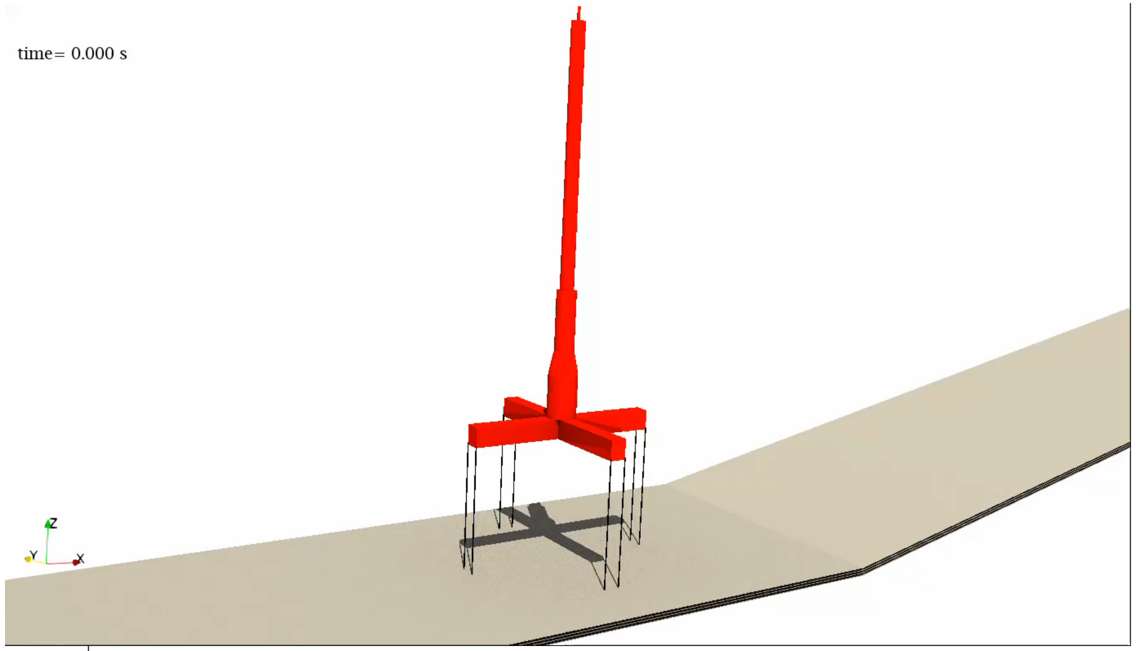
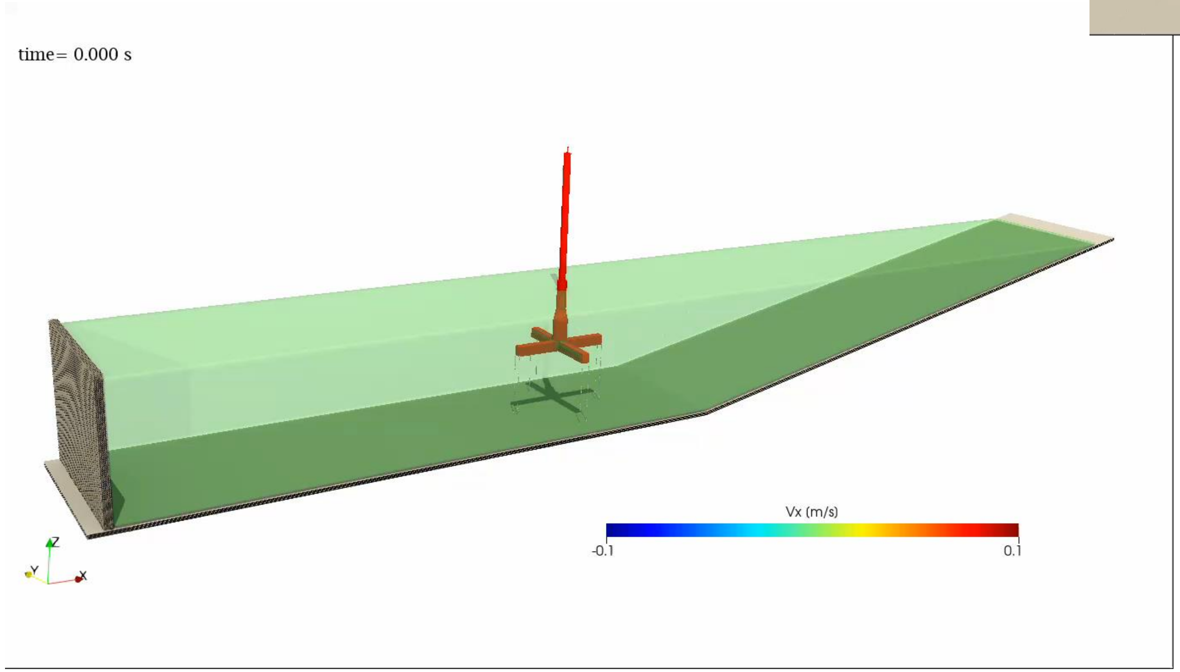




RAO VALIDATION

Tests under regular waves





1 GPU **NVIDIA V100s**

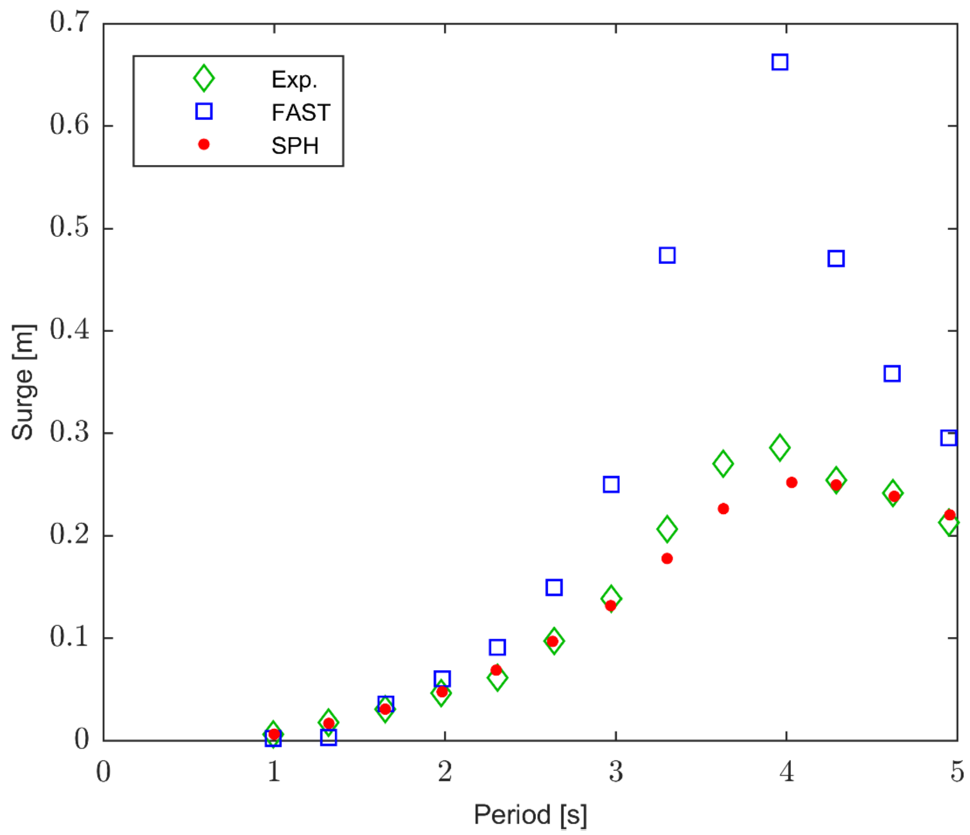
48 s Physical time

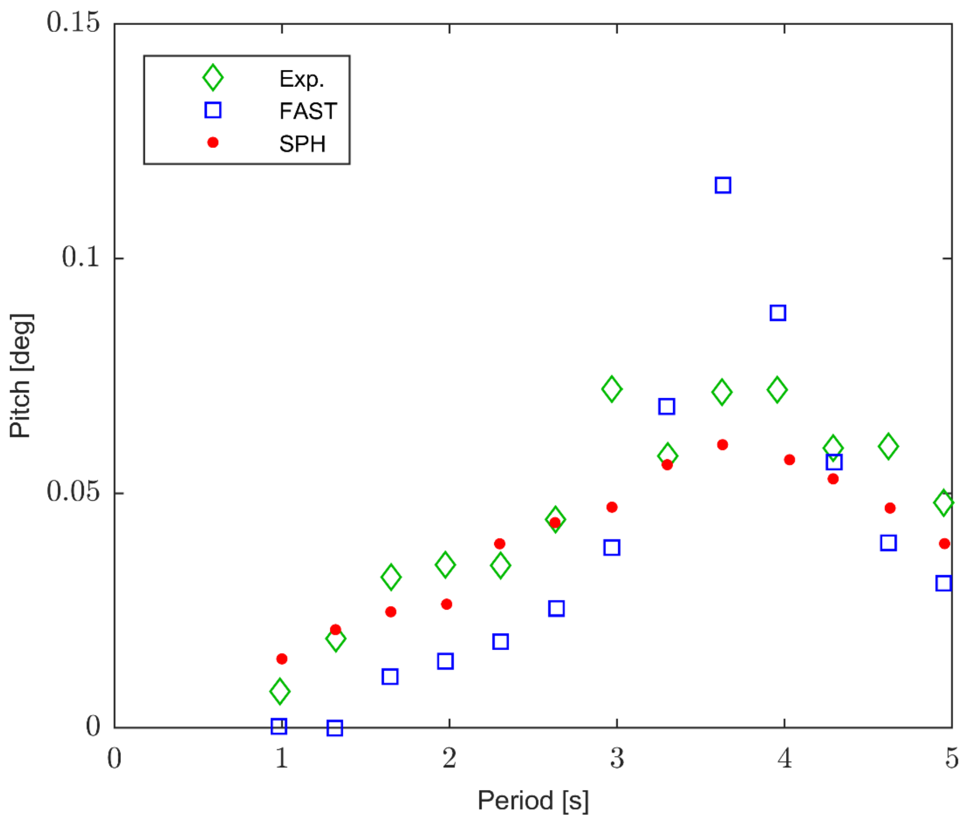
5.82 M Particles

79 h Runtime

RAO VALIDATION

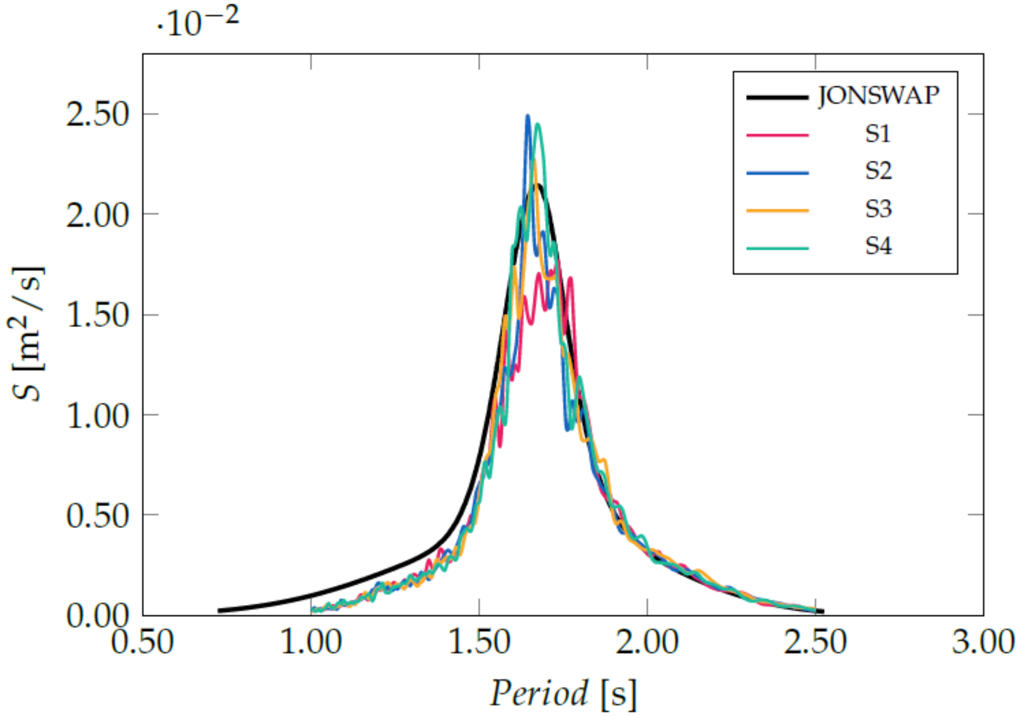
"[…] it is presumed that this lack of **viscous effects** leads to the overestimation of the surge response at the peak of the RAO."



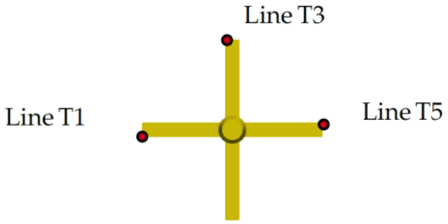


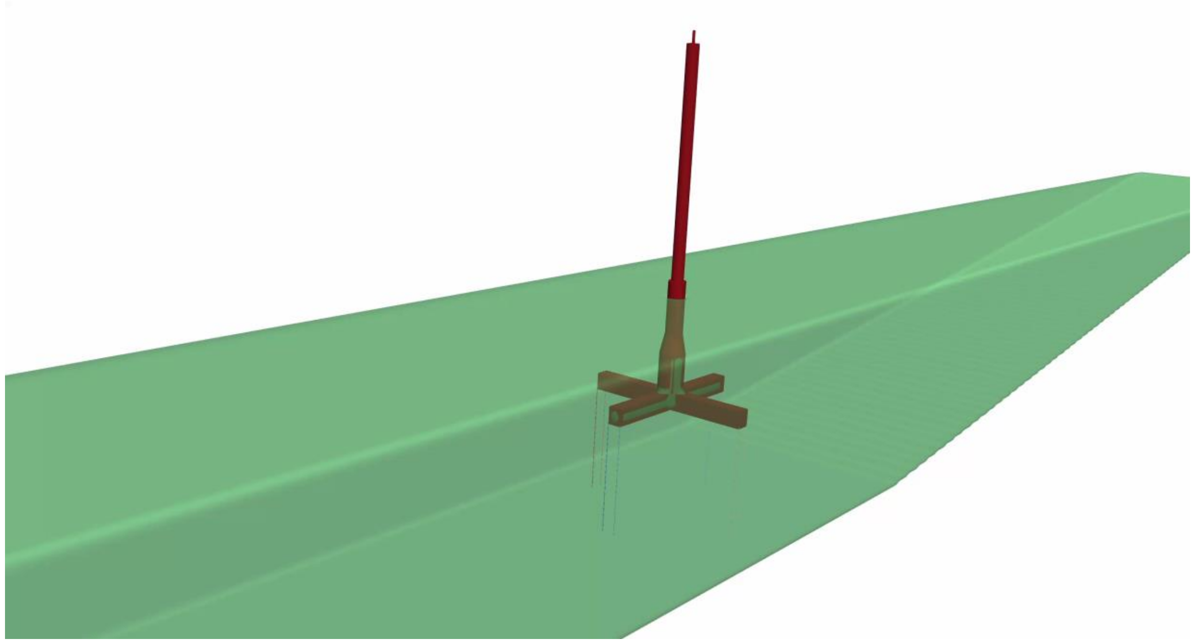
Tagliafierro, B.; Karimirad, M., et al. Numerical Assessment of a Tension-Leg Platform Wind Turbine in Intermediate Water Using the Smoothed Particle Hydrodynamics Method. *Energies* **2022**, *15*, 3993.

IRREGULAR SEA-STATES



Comparison of analytical spectral density (JONSWAP) of the surface elevation in the generation of irregular waves for the four realizations S1-4.





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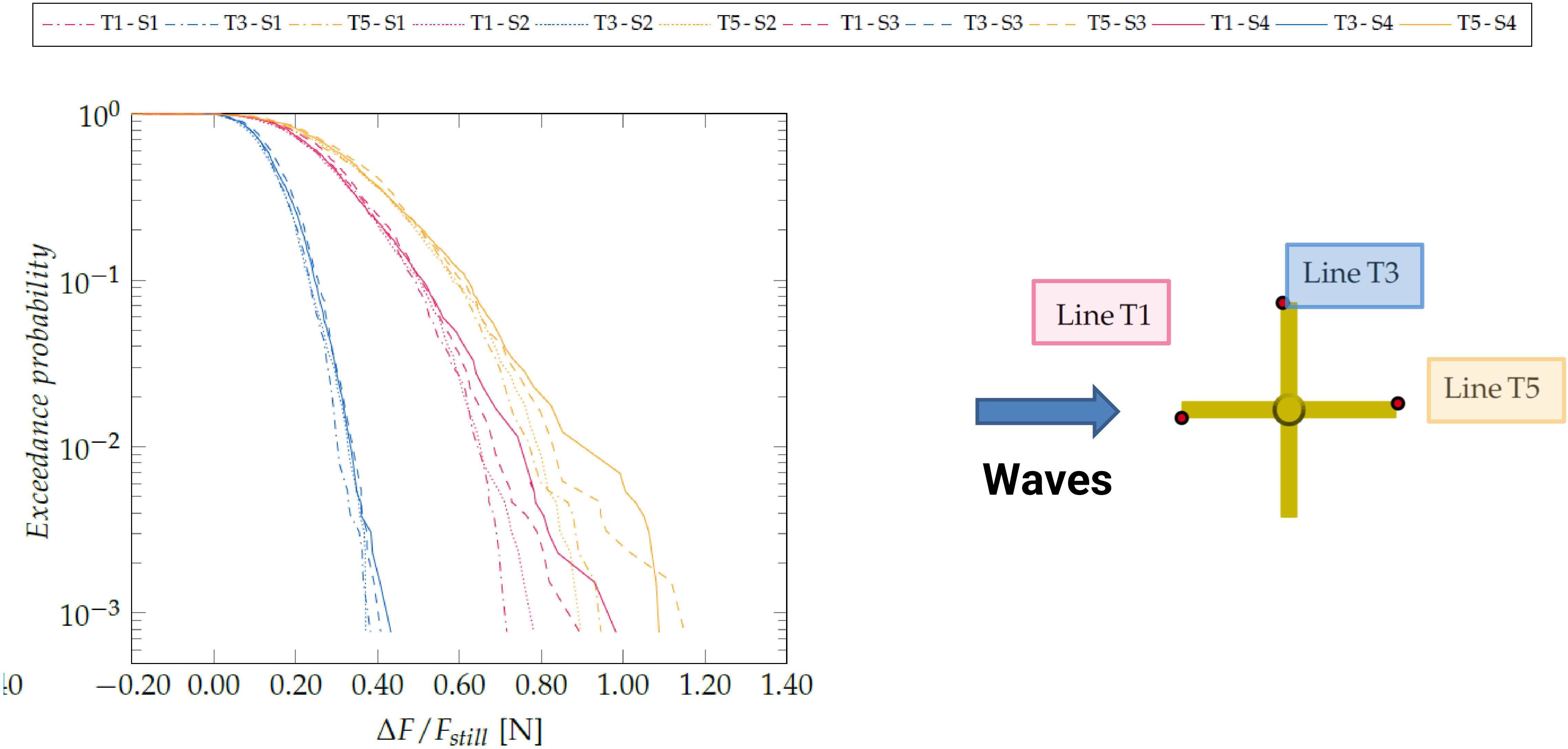
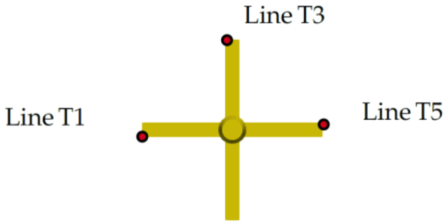
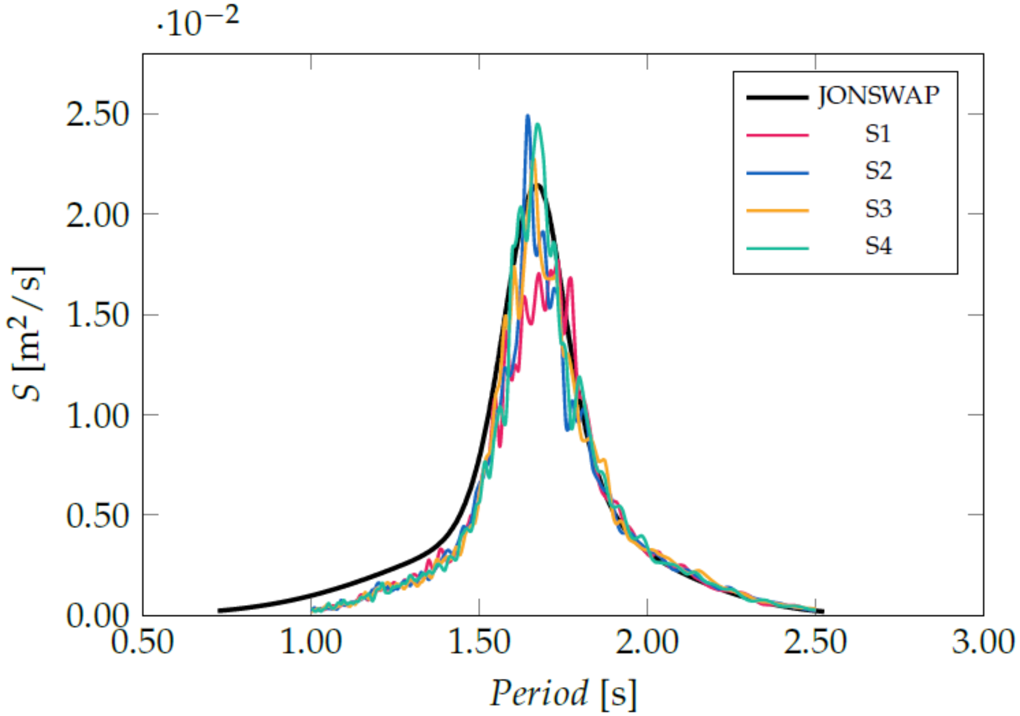
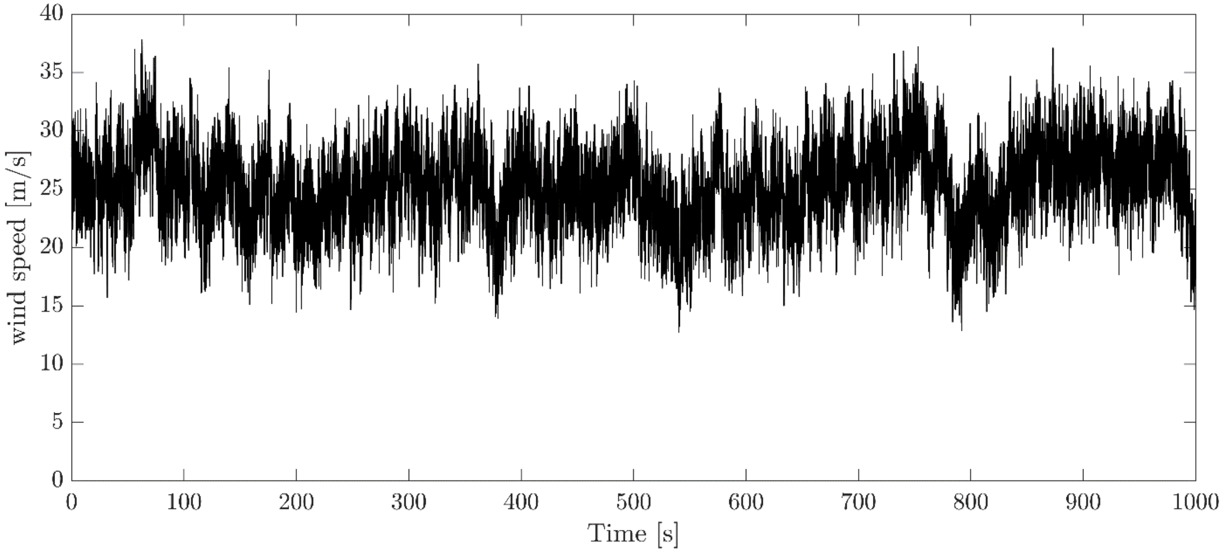
IRREGULAR SEA-STATES



IRREGULAR SEA-STATES+WIND







Comparison of the experimental and analytical spectral density (JONSWAP) of the surface elevation in the generation of irregular waves for the four realizations S1-4. The waves are measured at a TLP side location.

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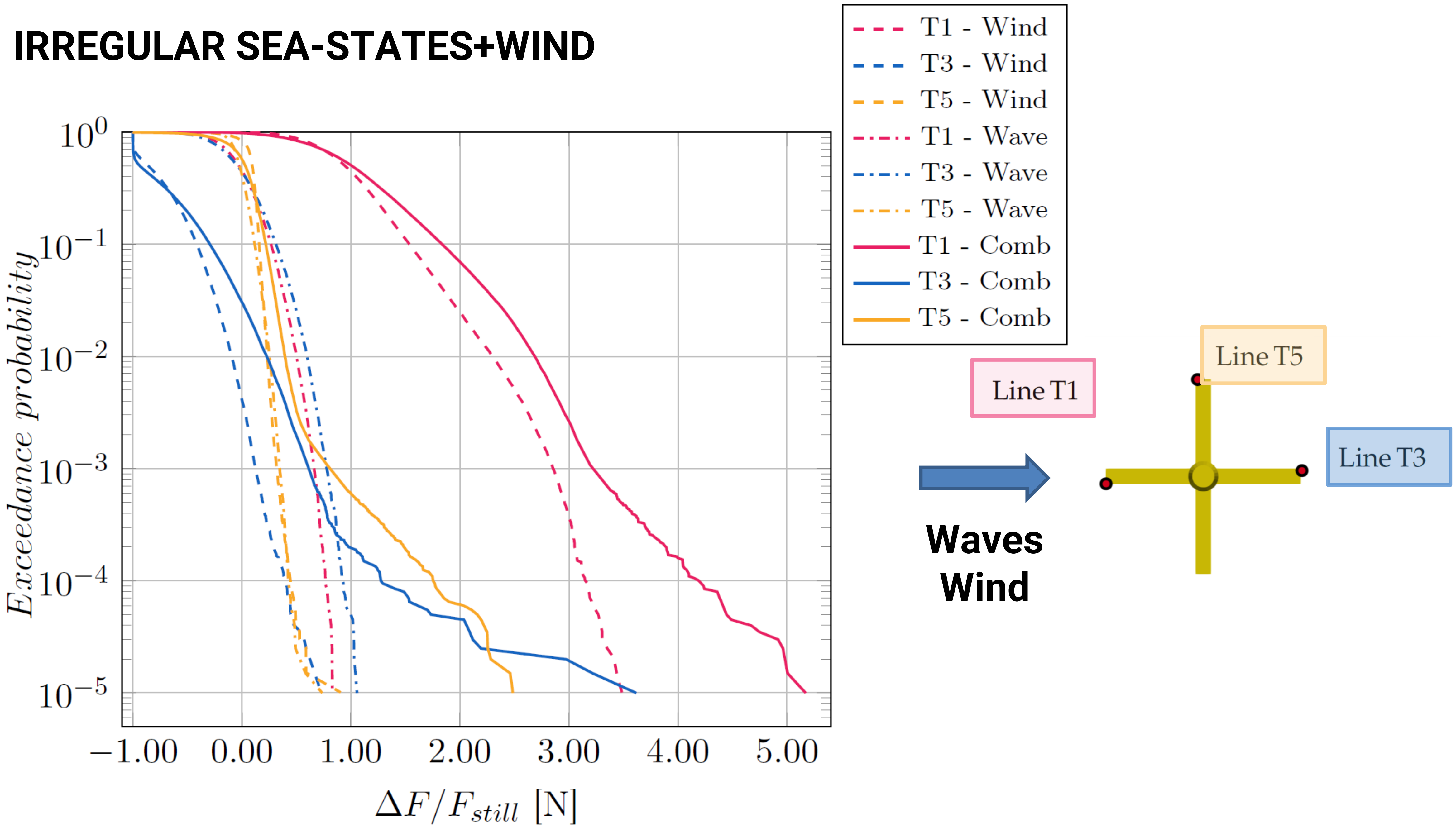
IRREGULAR SEA-STATES+WIND

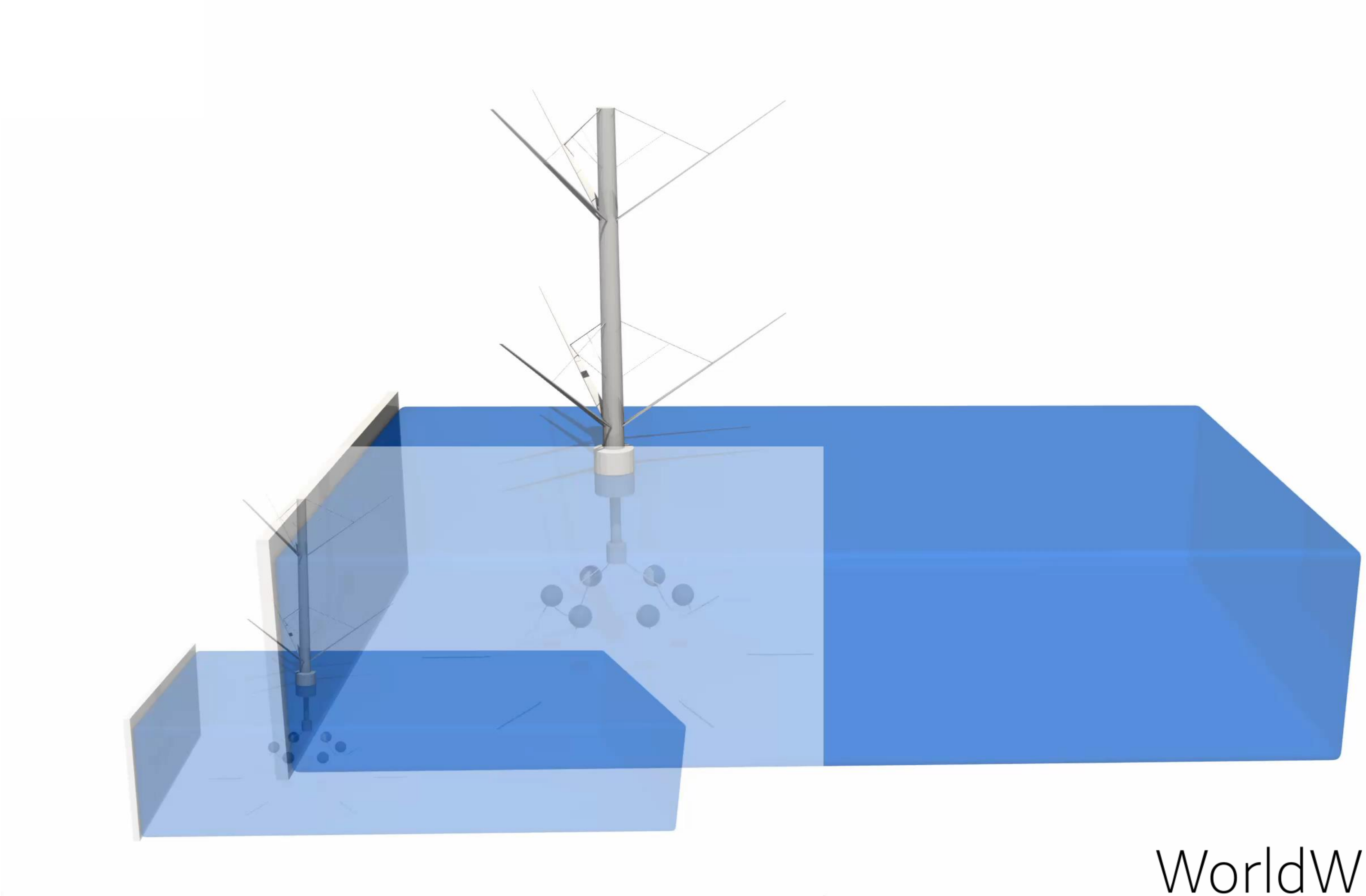


A NOVEL APPLICATION

CRAFT: a Counter-Rotating vertical-Axis Floating Tilting wind turbine

WorldWideWind

CRAFT: a Counter-Rotating vertical-Axis Floating Tilting wind turbine



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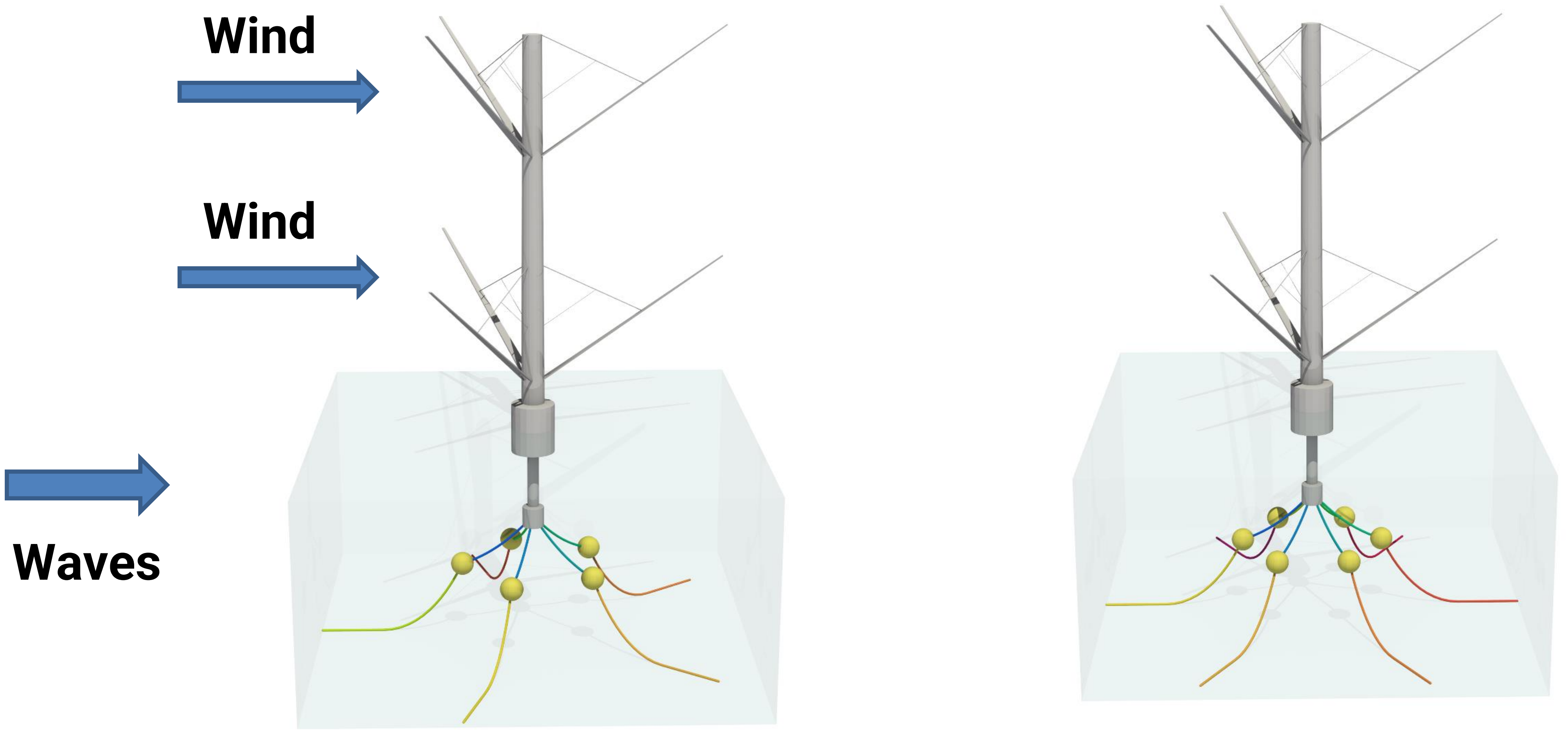
CRAFT: mooring configuration



5 *Anchors* 6 *Anchors*

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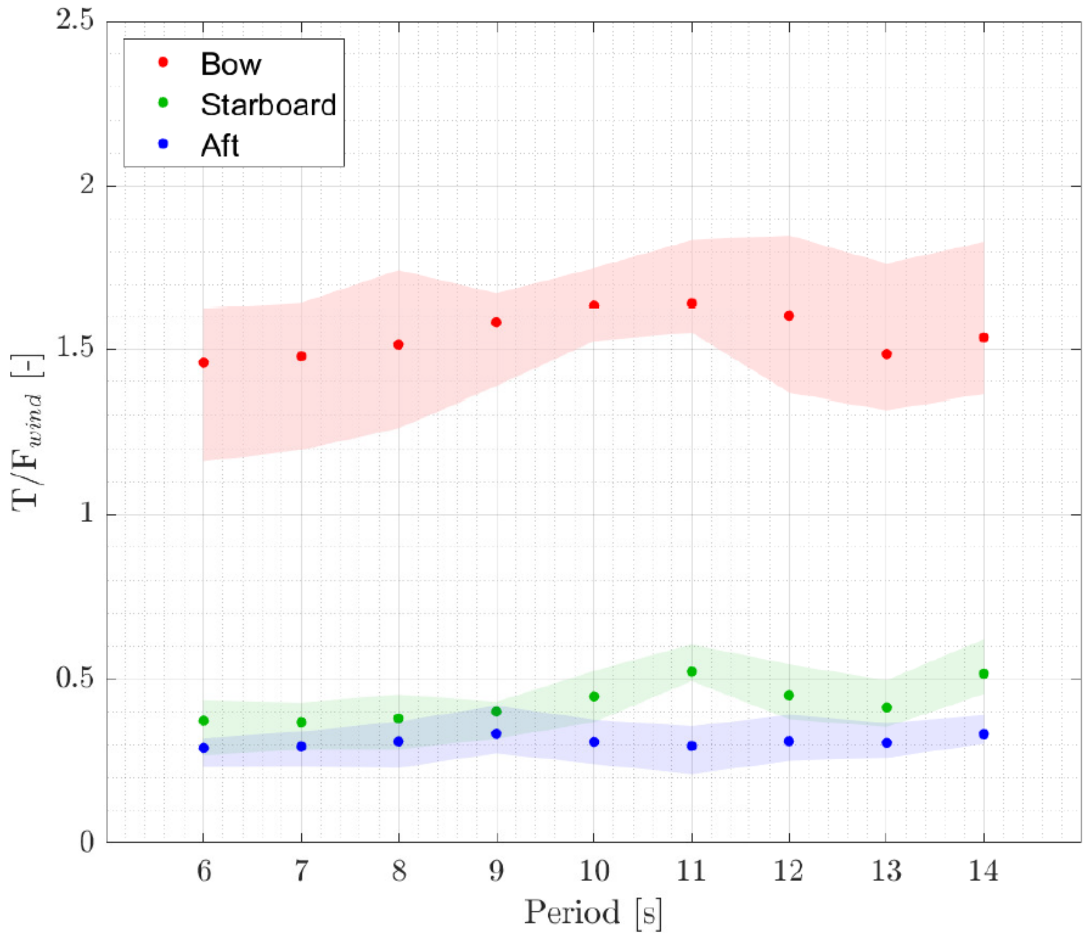
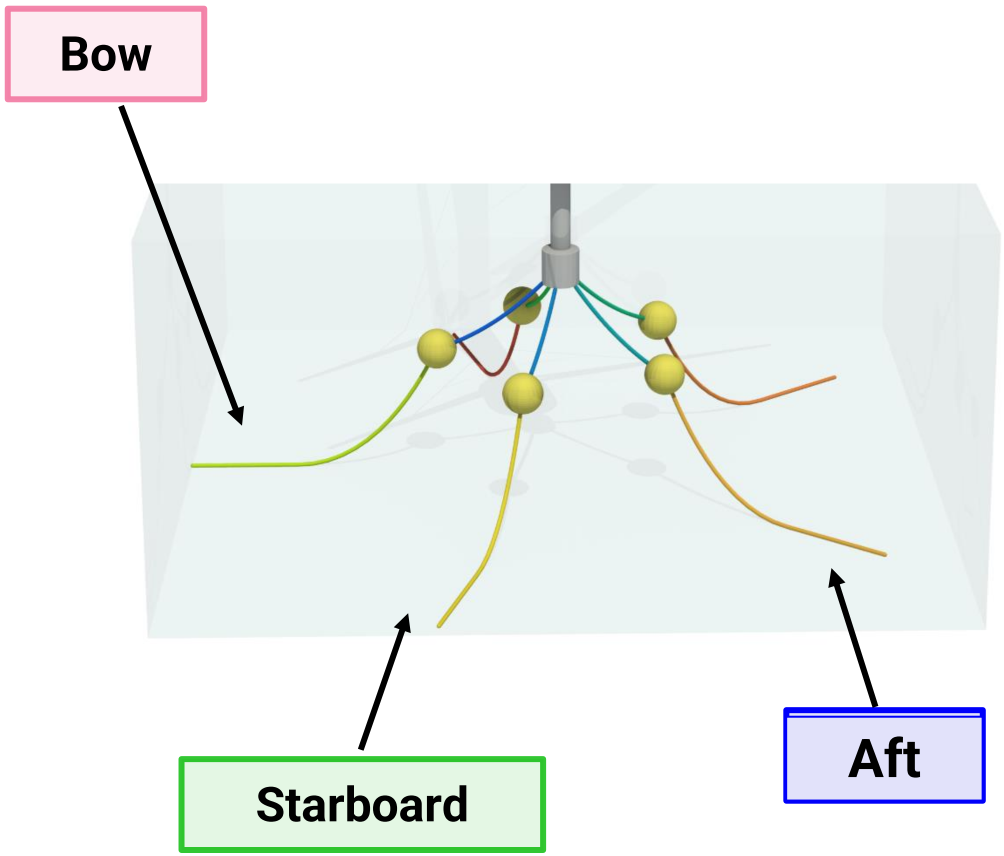
Line Tension

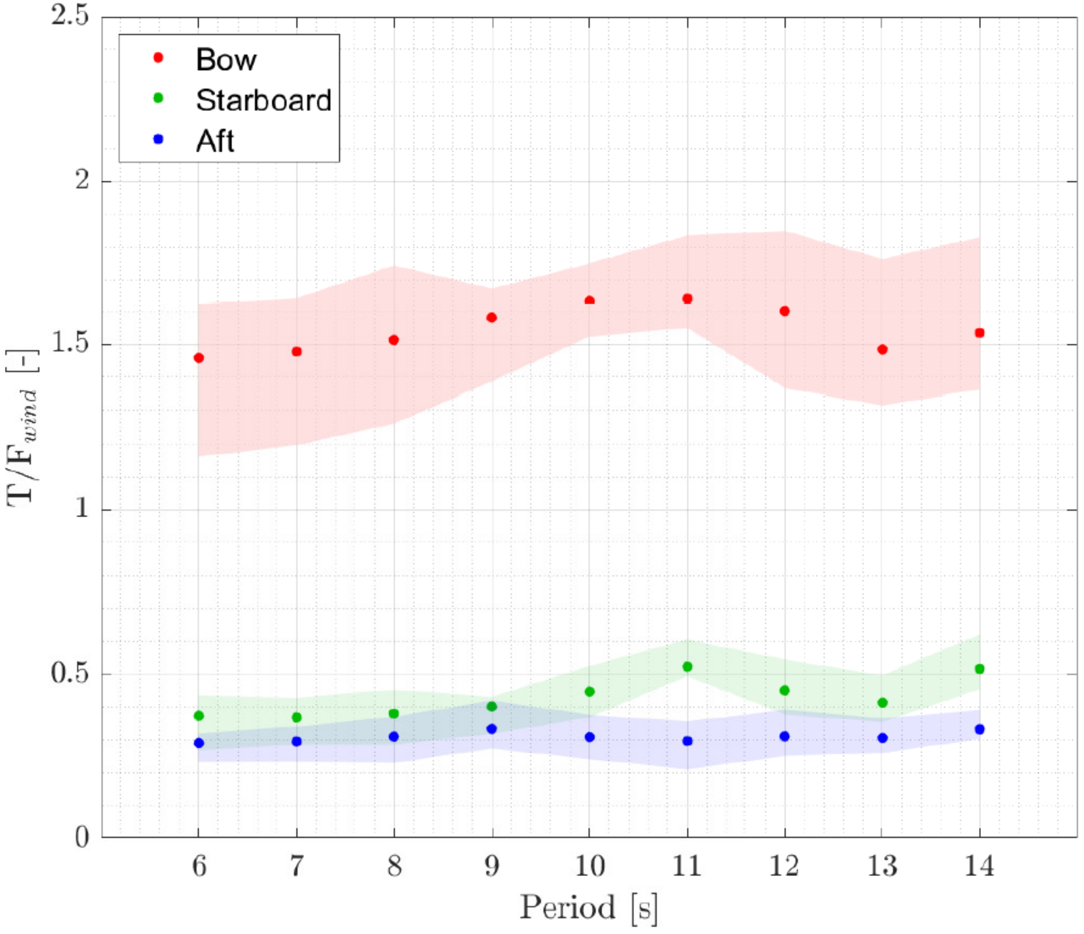


$5\ Anchors$

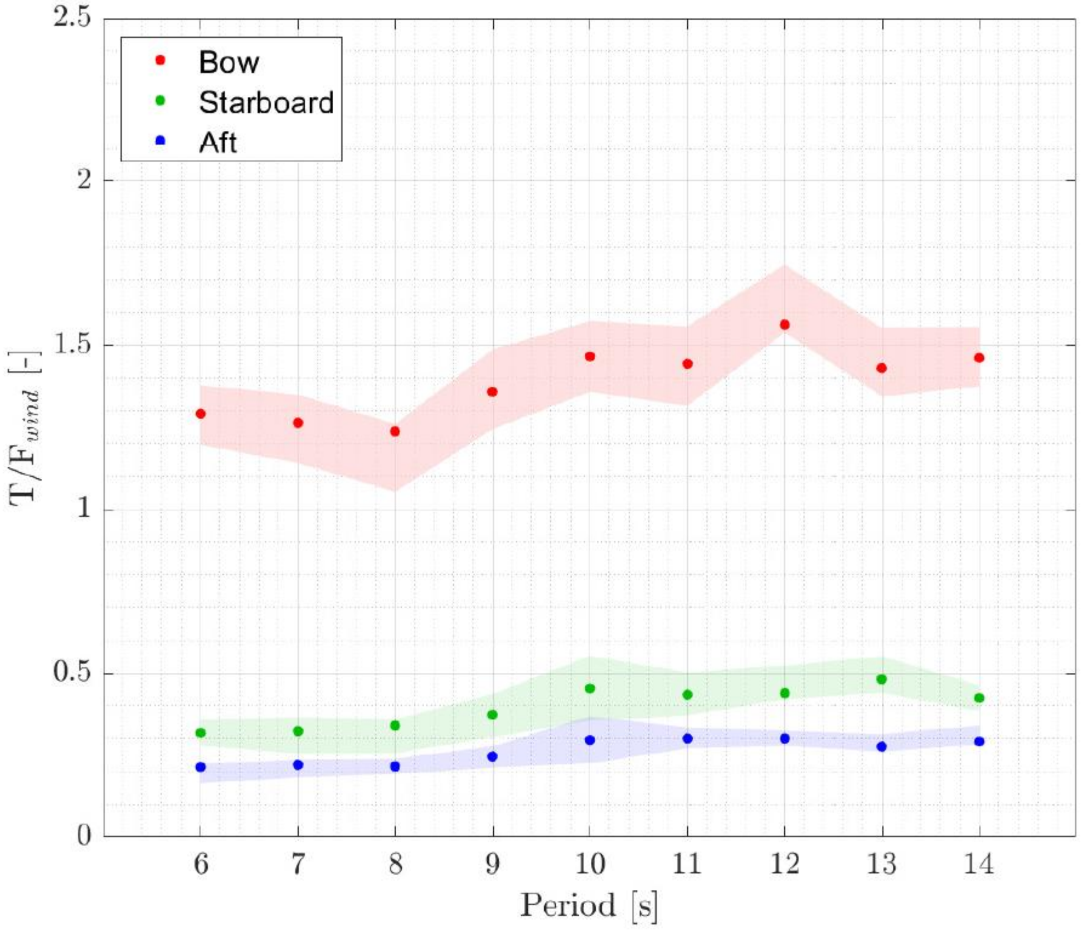


Line Tension

WorldWideWind



5 *Anchors*



6 *Anchors*

CONCLUSIONS

- An SPH framework can be as accurate as other CFD solvers;
- It is suitable for FOWTs;
- Coupling with external libraries;
- GPU-accelerated hardware.

WorldWideWind

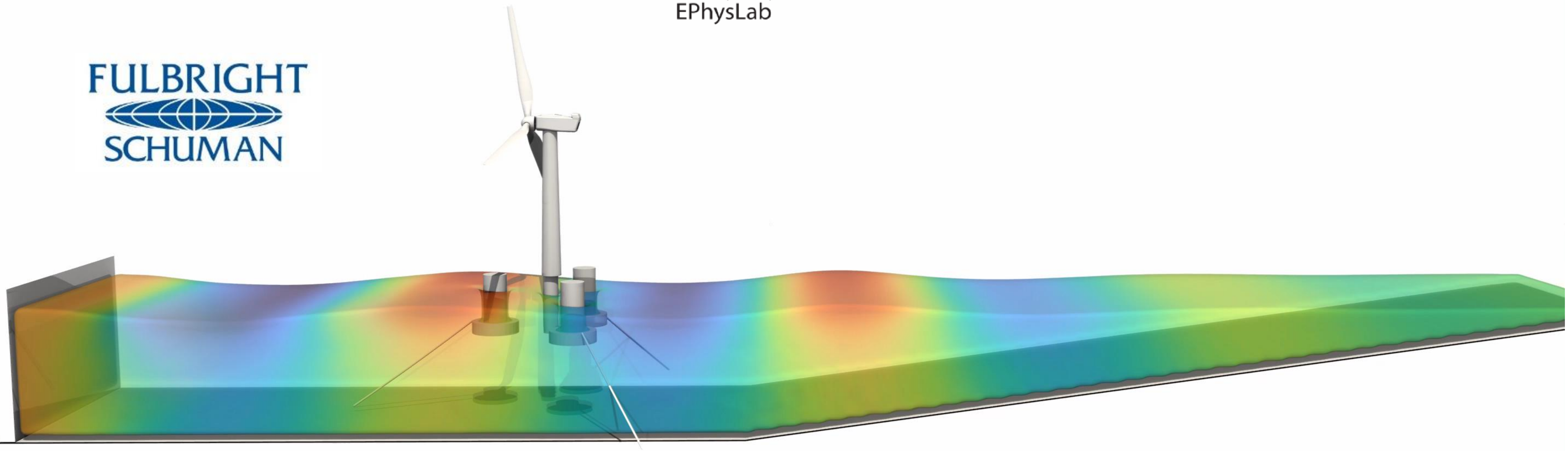
XUNTA DE GALICIA

FEDER - FONDO EUROPEO DE DESENVOLVEMENTO REXIONAL
"Unha maneira de facer Europa"
UNIÓN EUROPEA

FULBRIGHT

Environmental | Physics | Laboratory
EPhysLab

FULBRIGHT SCHUMAN



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