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# Accurate load mapping for fatigue analysis of floating offshore wind turbine substructures



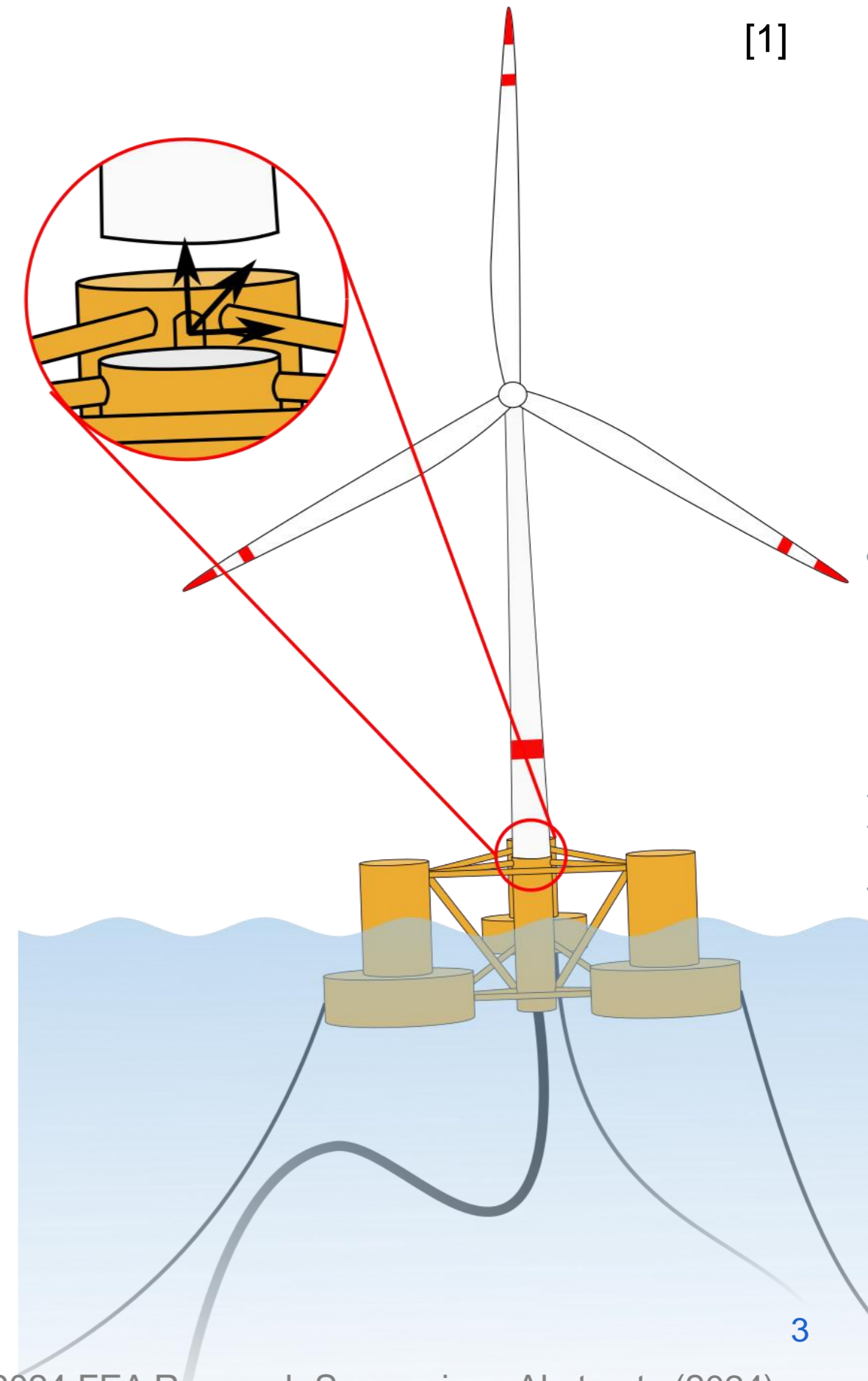
Ir. Victor Rappe<sup>a</sup>, Prof. Kris Hectors<sup>a</sup>, Prof. Muk Chen Ong<sup>b</sup>, Prof. Wim De Waele<sup>a</sup>

<sup>a</sup> Soete Laboratory, Ghent University

<sup>b</sup> OTICS, University of Stavanger

# Challenges in fatigue analysis

- Dynamic simulations
  - Rigid floater connected to rigid/flexible tower
  - Easy to extract loads at tower base
  - Result: focus on tower base fatigue in literature



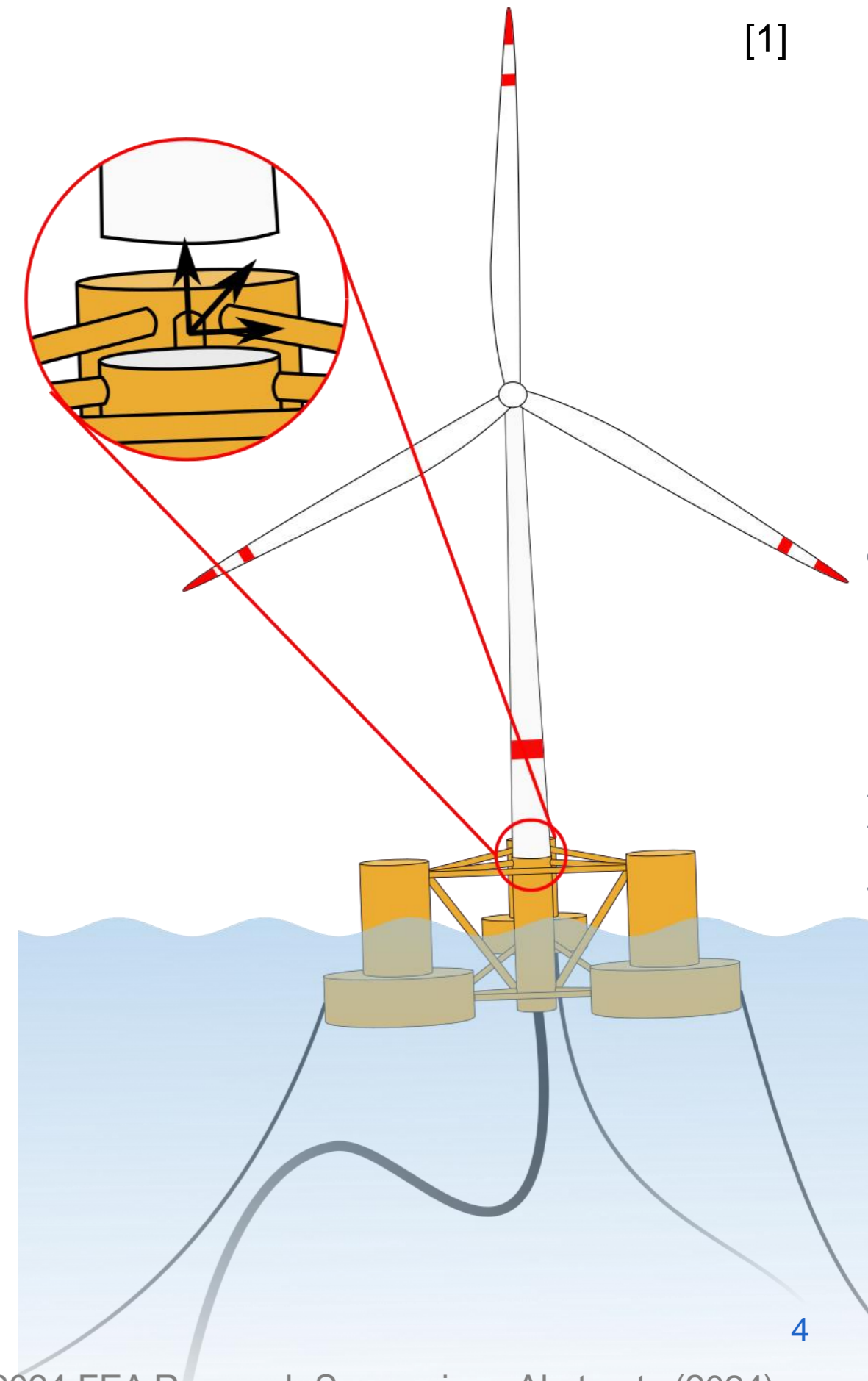
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# Challenges in fatigue analysis

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What about the welded joints?



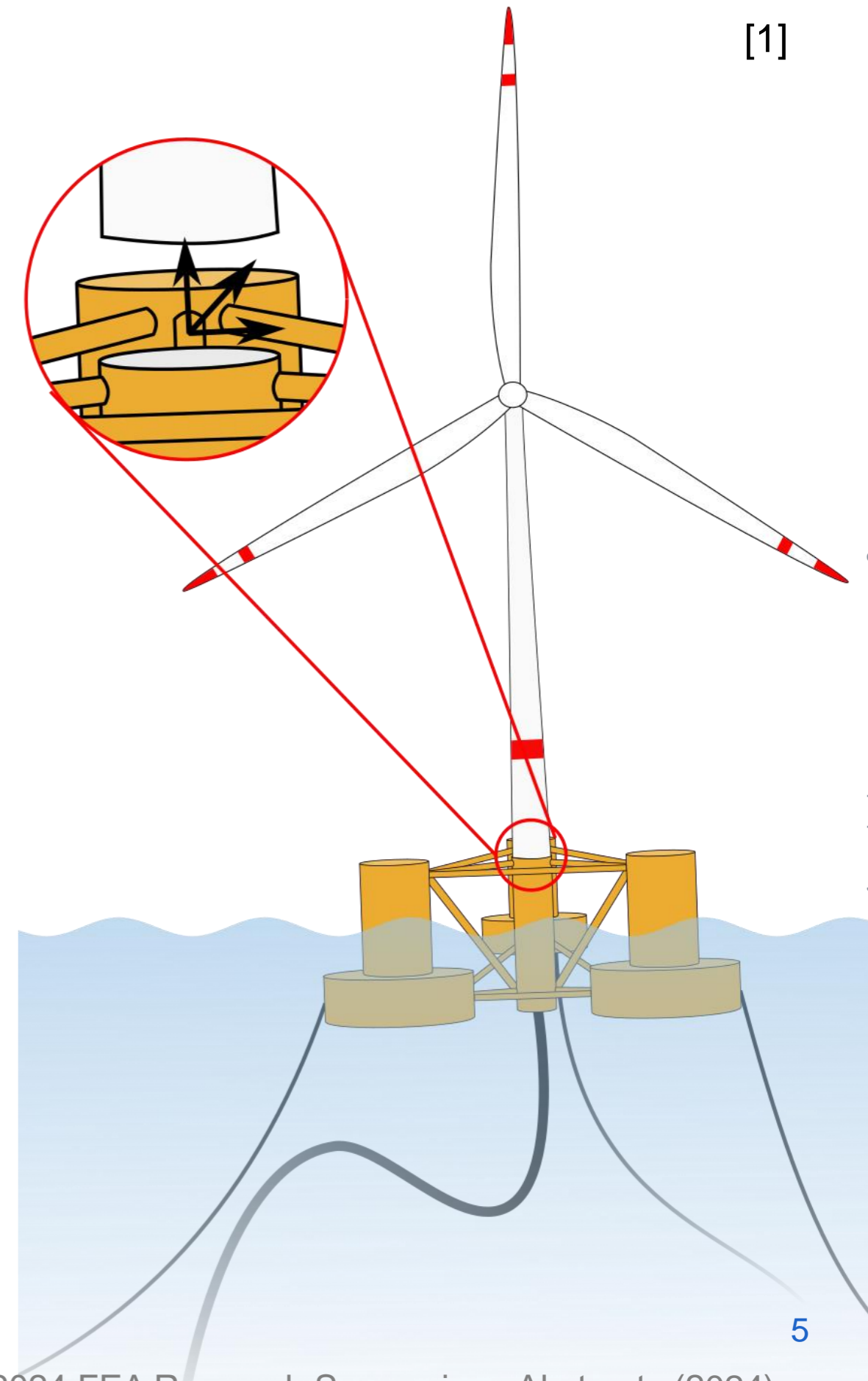
# Challenges in fatigue analysis

- Dynamic simulations
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What about the welded joints?

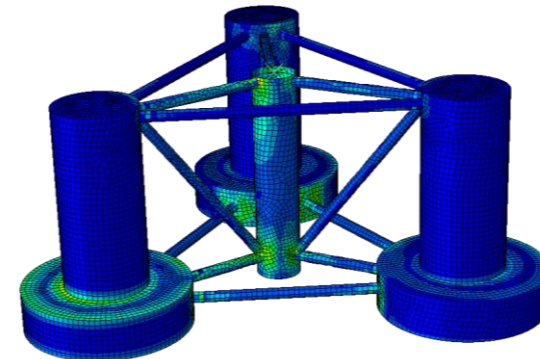
- Detailed fatigue analysis
  - Need knowledge of local stresses
  - Solution: development of multi-dimensional modelling strategy
  - Reference turbine: OC4 DeepCWind



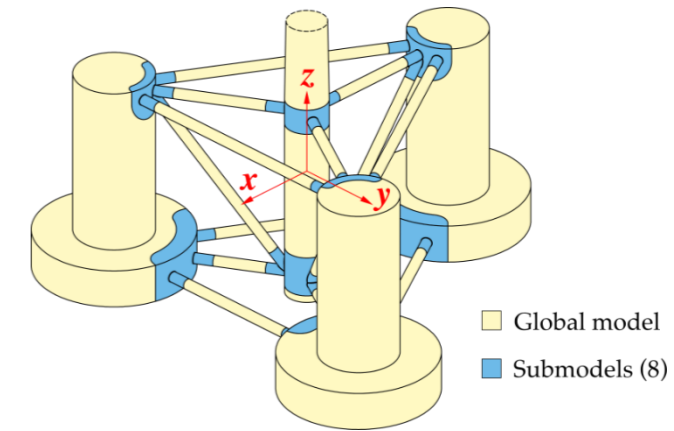
# Multi-dimensional modelling strategy



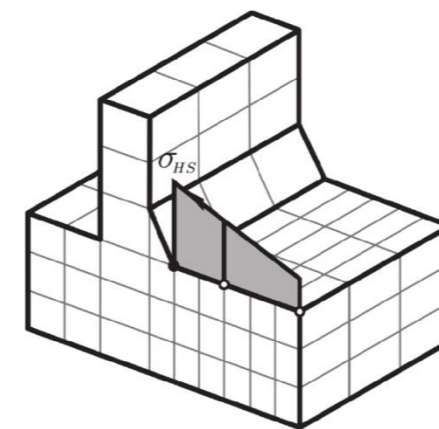
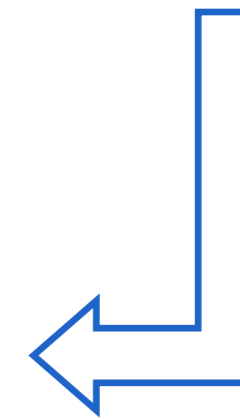
Global hydrodynamic analysis



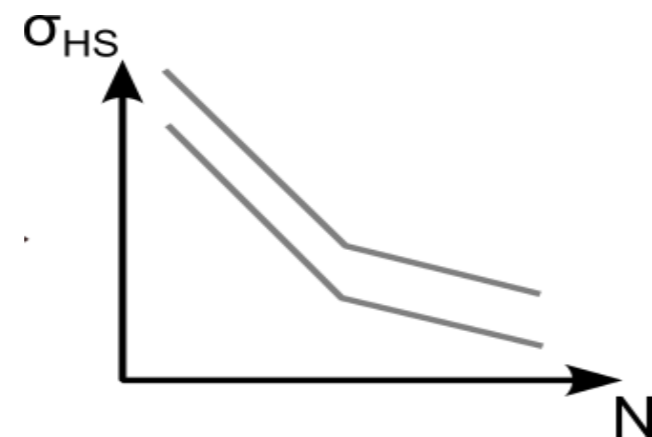
Shell-based FE analysis



Solid-element submodels



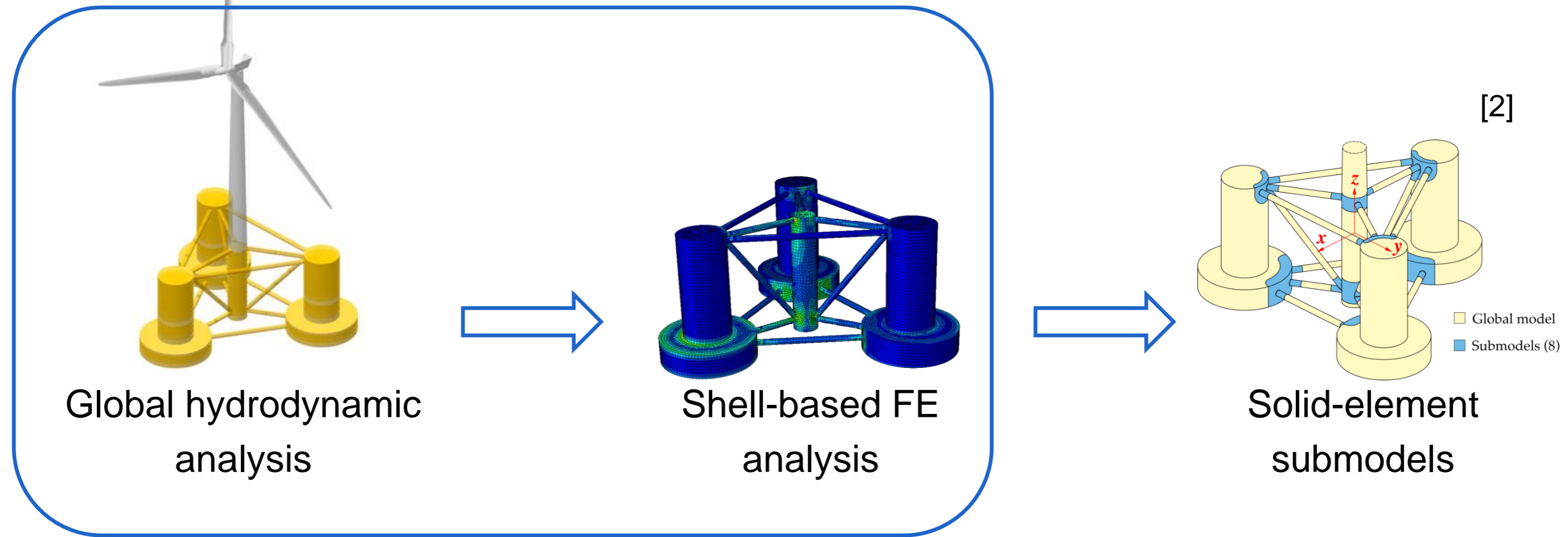
Hot spot stress approach



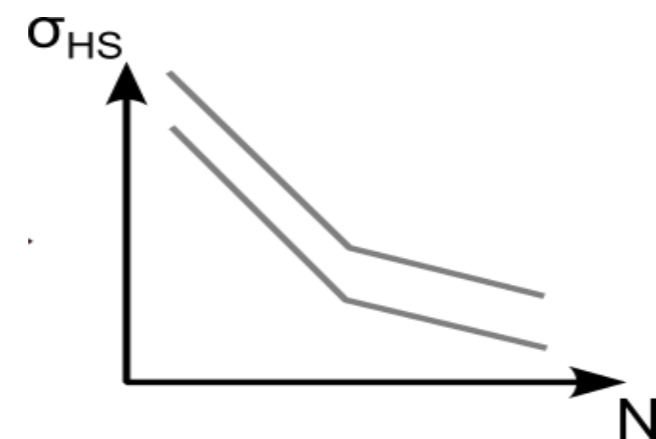
Local fatigue damage

[2] Rosario Dias, D., Extended abstract: "Analysis of the Structural Integrity of a Floating Semisubmersible Foundation for Offshore Wind", Universidade de Lisboa (2020).

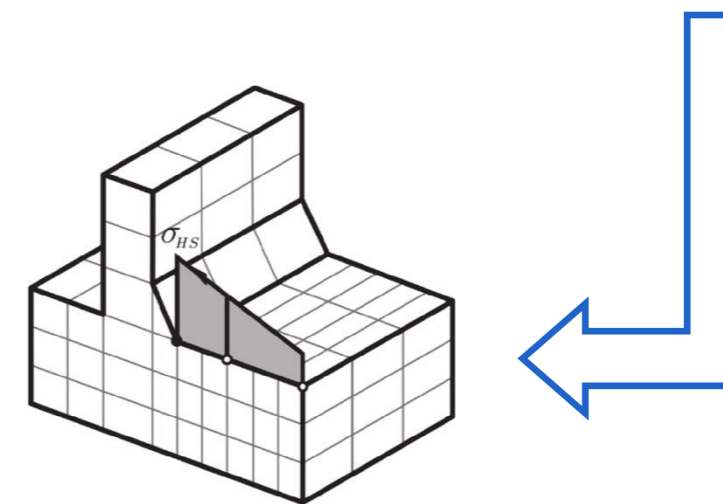
# Multi-dimensional modelling strategy



## Load mapping method



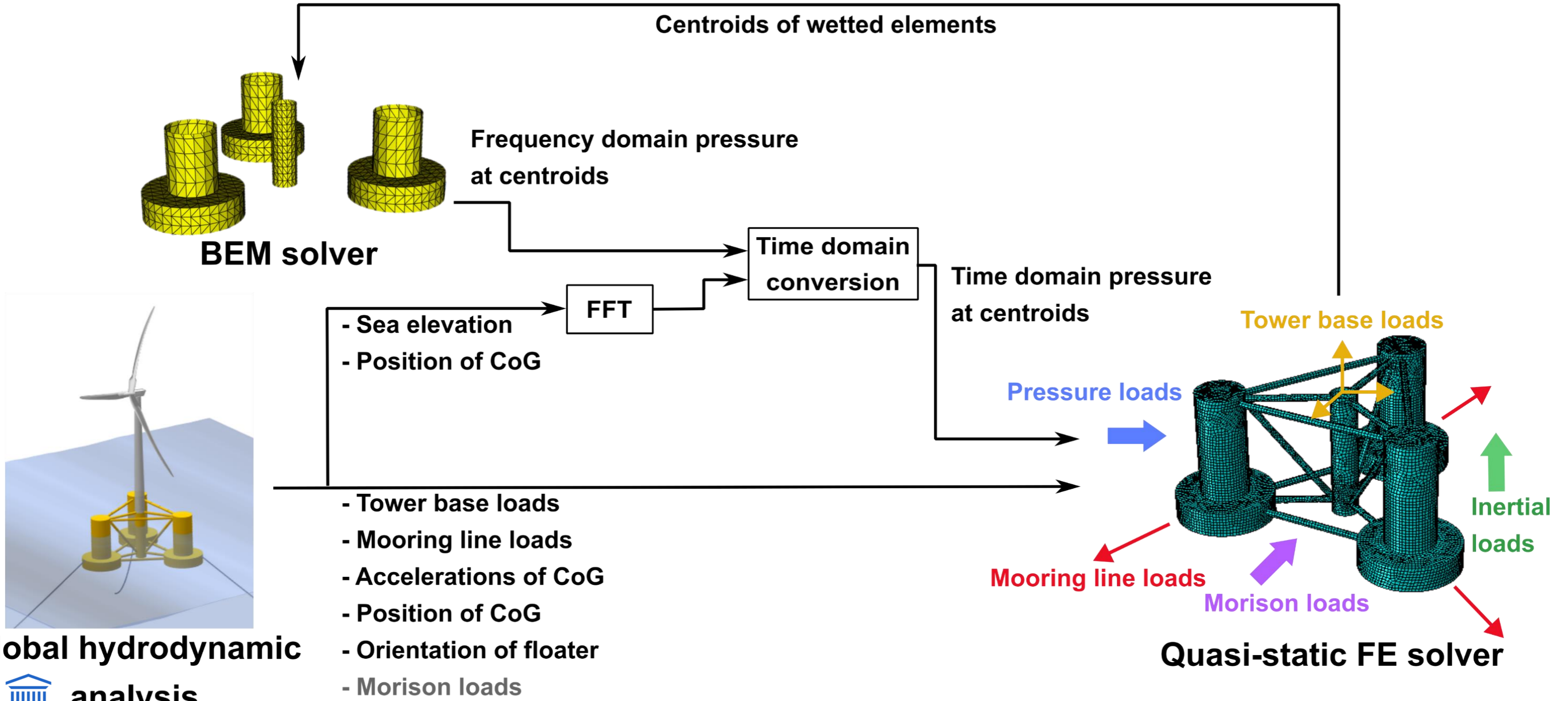
Local fatigue damage



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# Load mapping method

[1]



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OpenFAST simulation without wind or Morison loads, wave height = 10m, wave period = 9s

Note: all loads in the local frame of reference

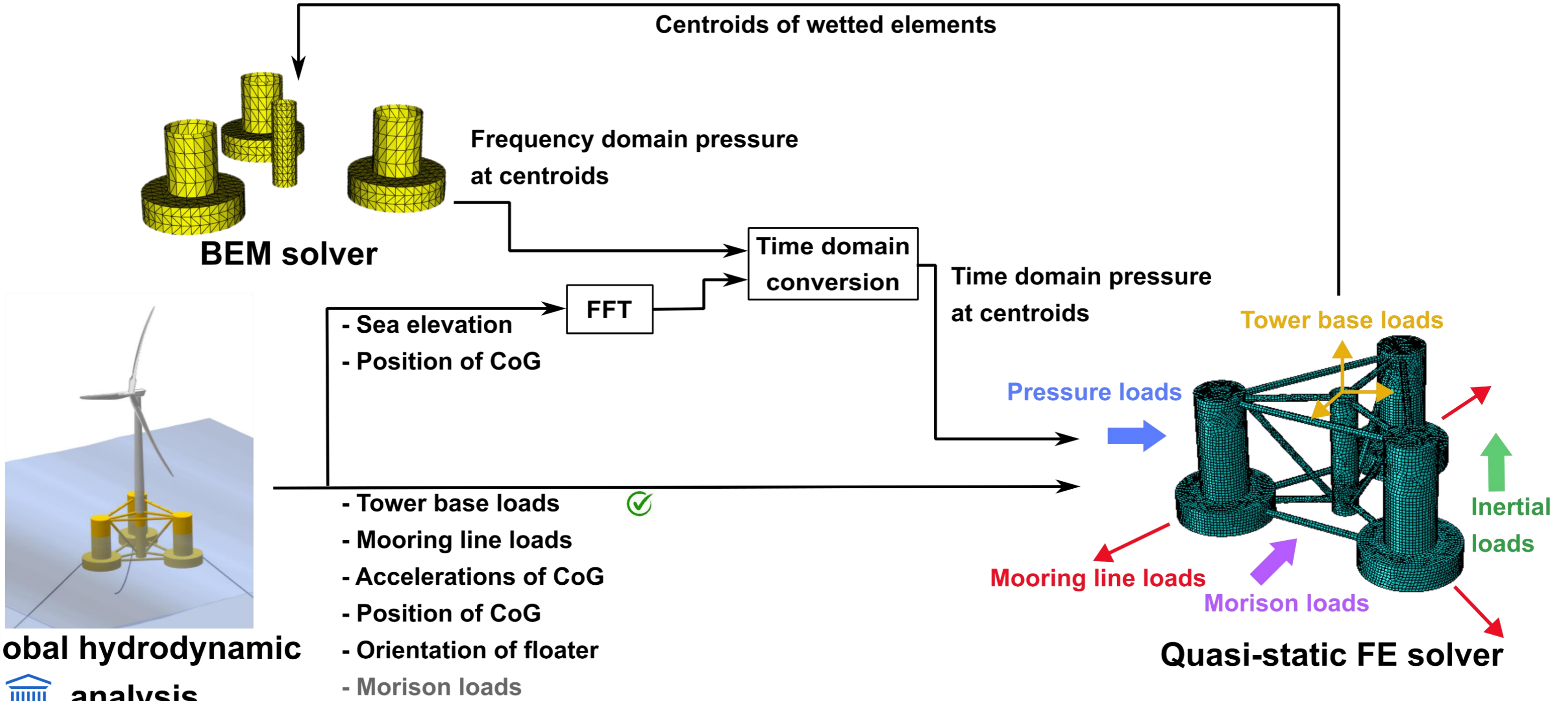
Global hydrodynamic analysis





# Load mapping method

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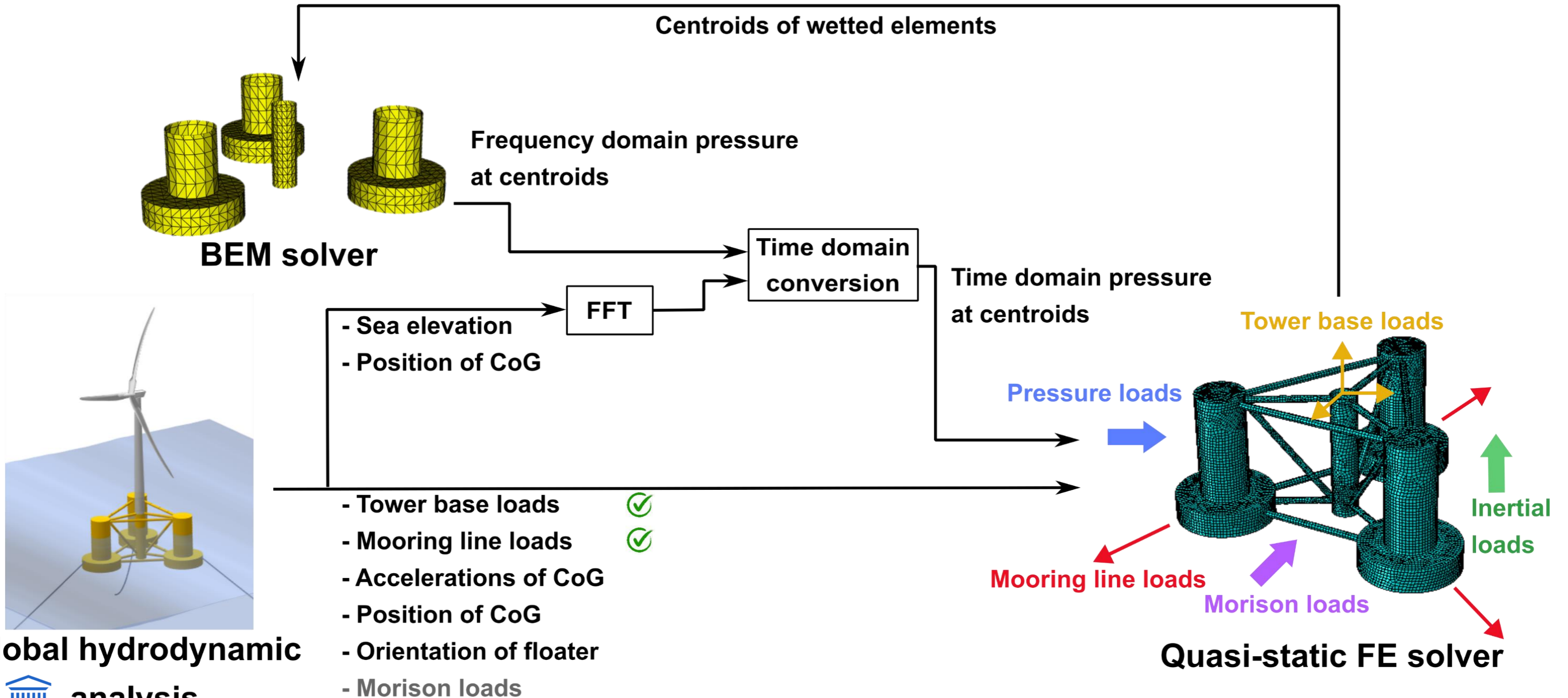
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Global hydrodynamic analysis



# Load mapping method

[1]



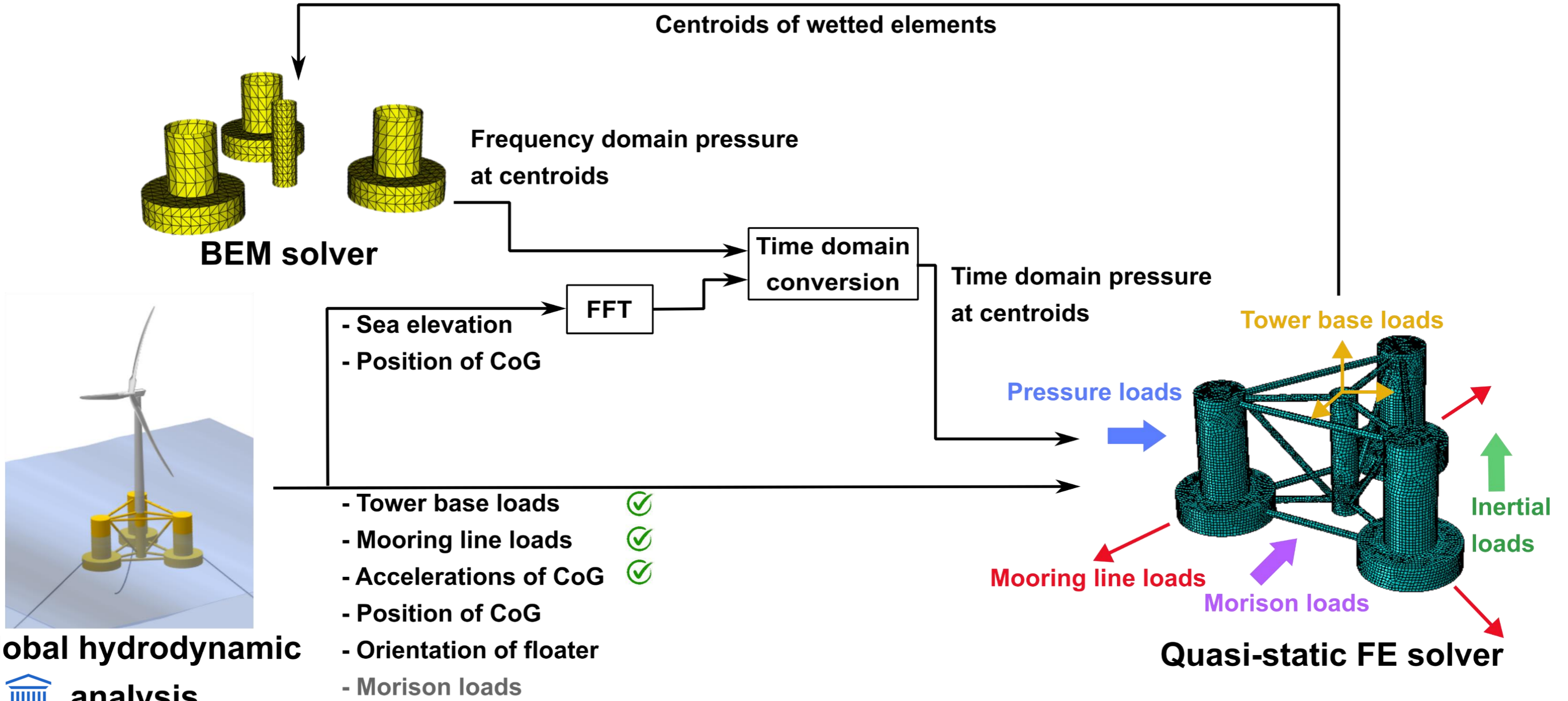
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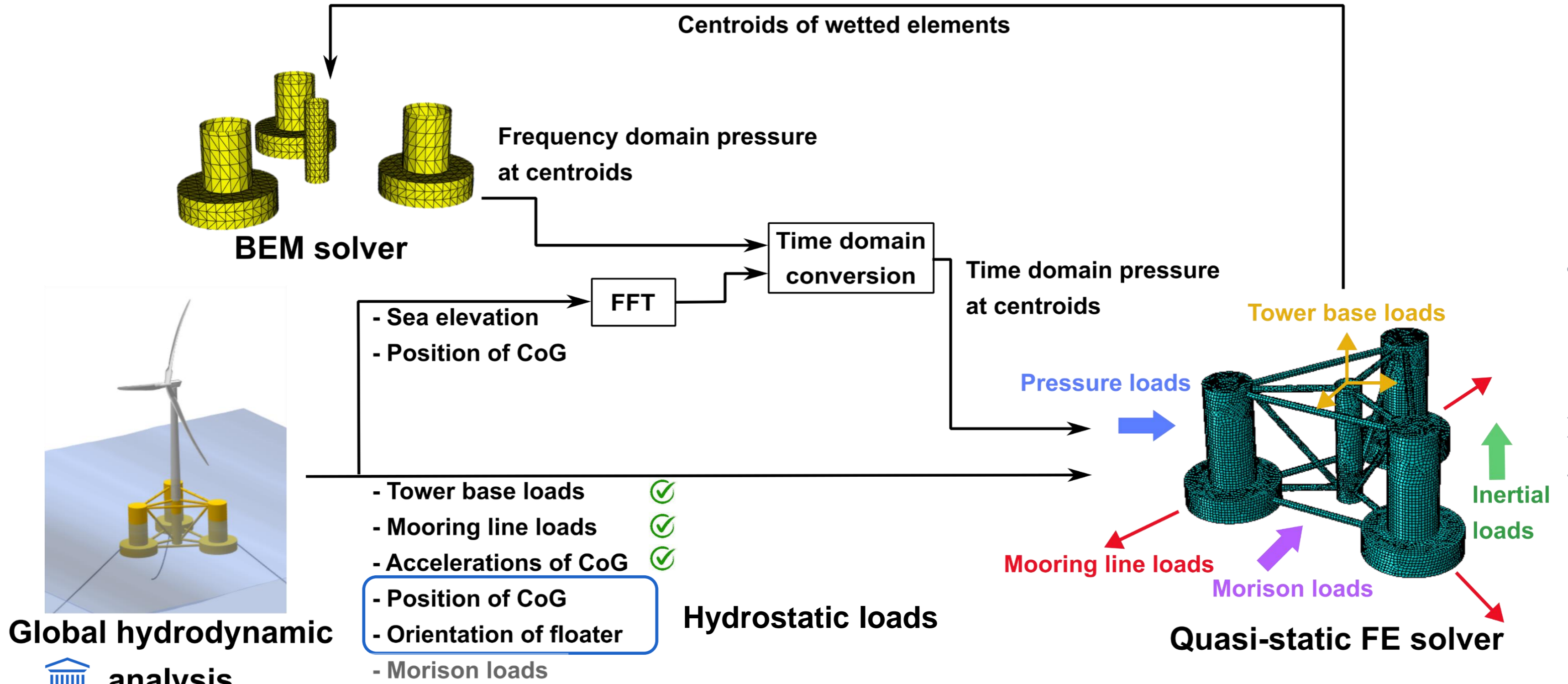
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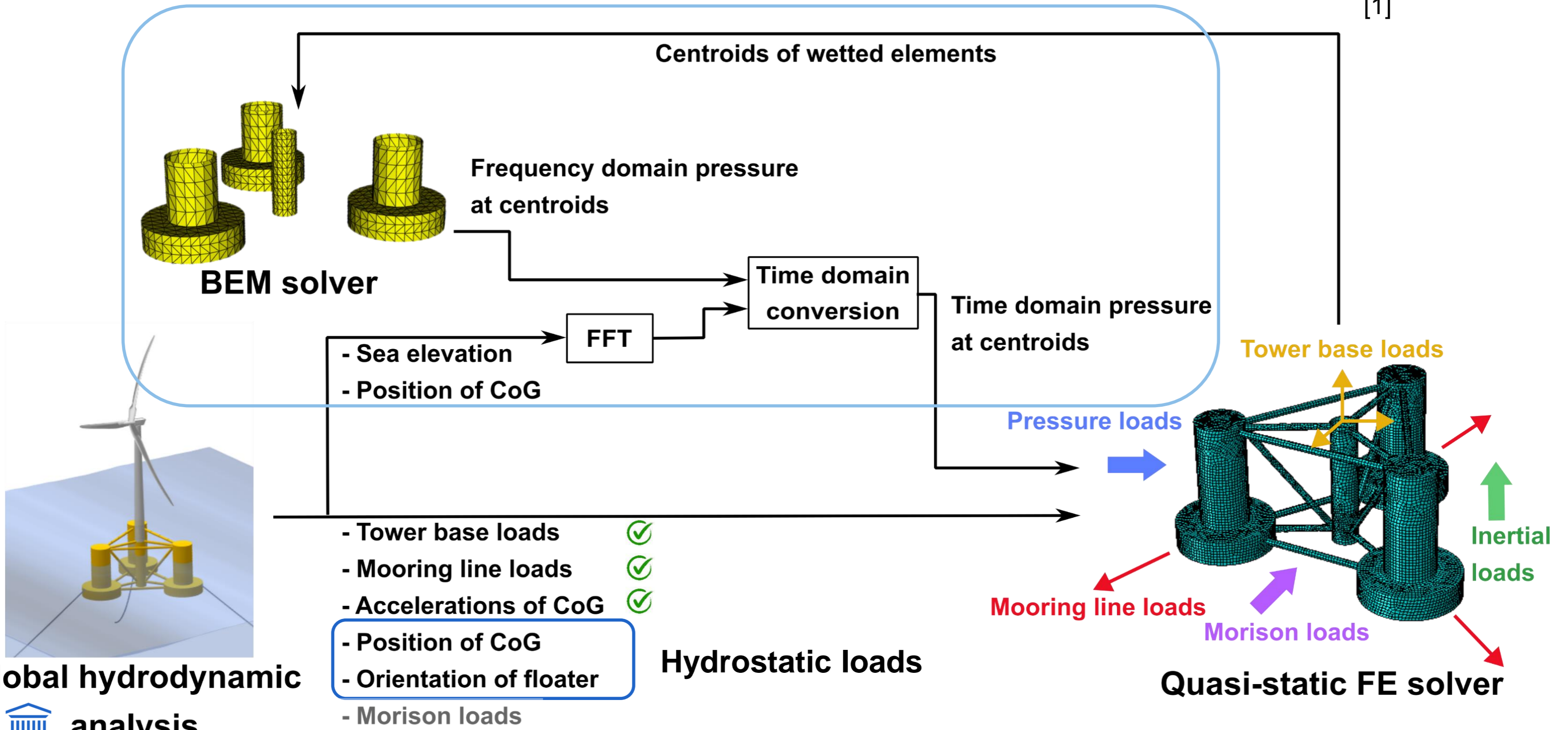


Global hydrodynamic analysis

# Load mapping method

Hydrodynamic loads

[1]

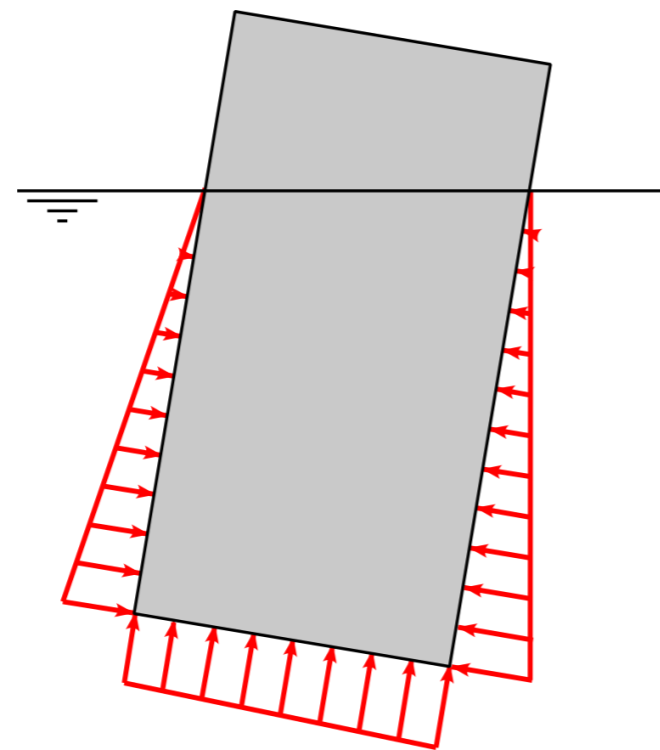


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OpenFAST simulation without wind or Morison loads, wave height = 10m, wave period = 9s

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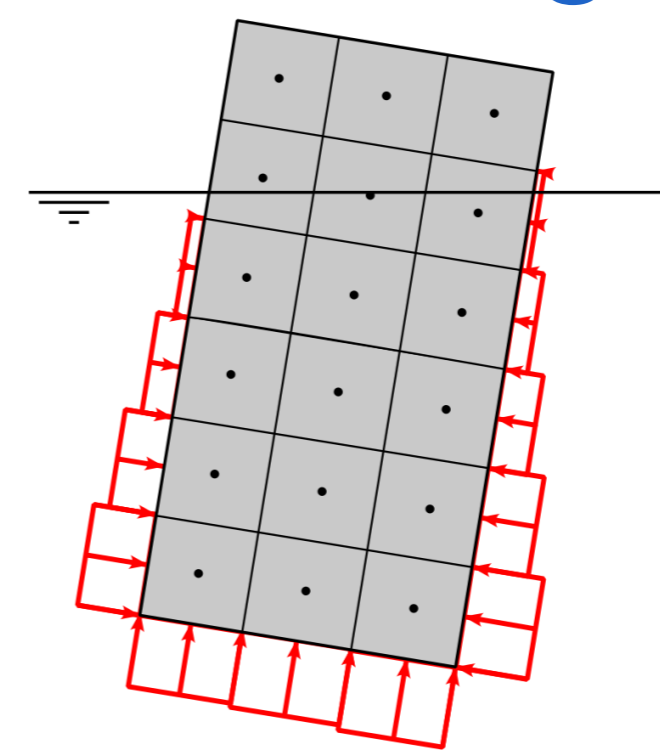
# Hydrostatic loads – Impact of modelling decisions



Analytical

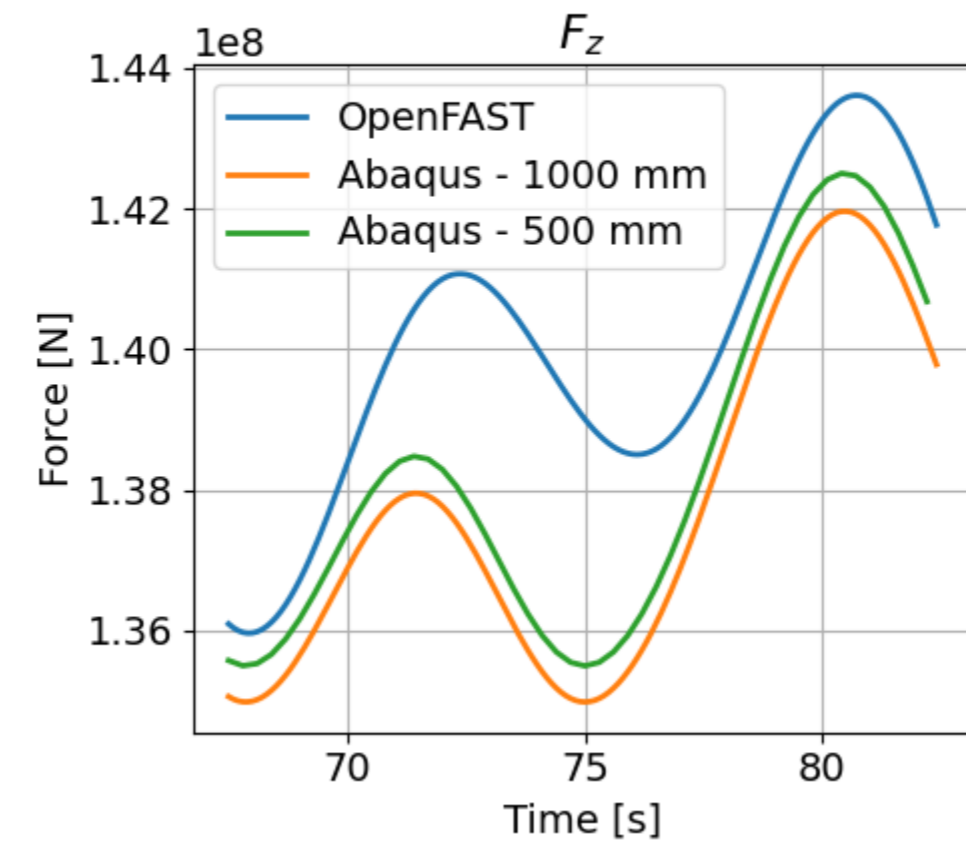
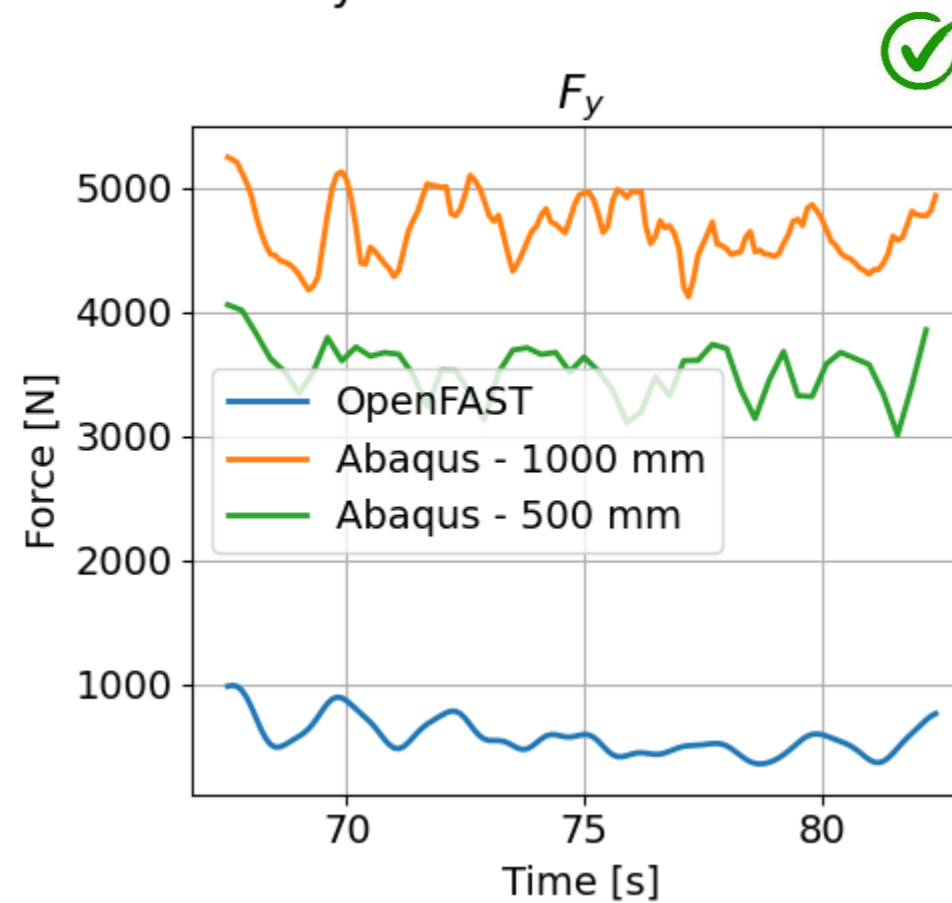
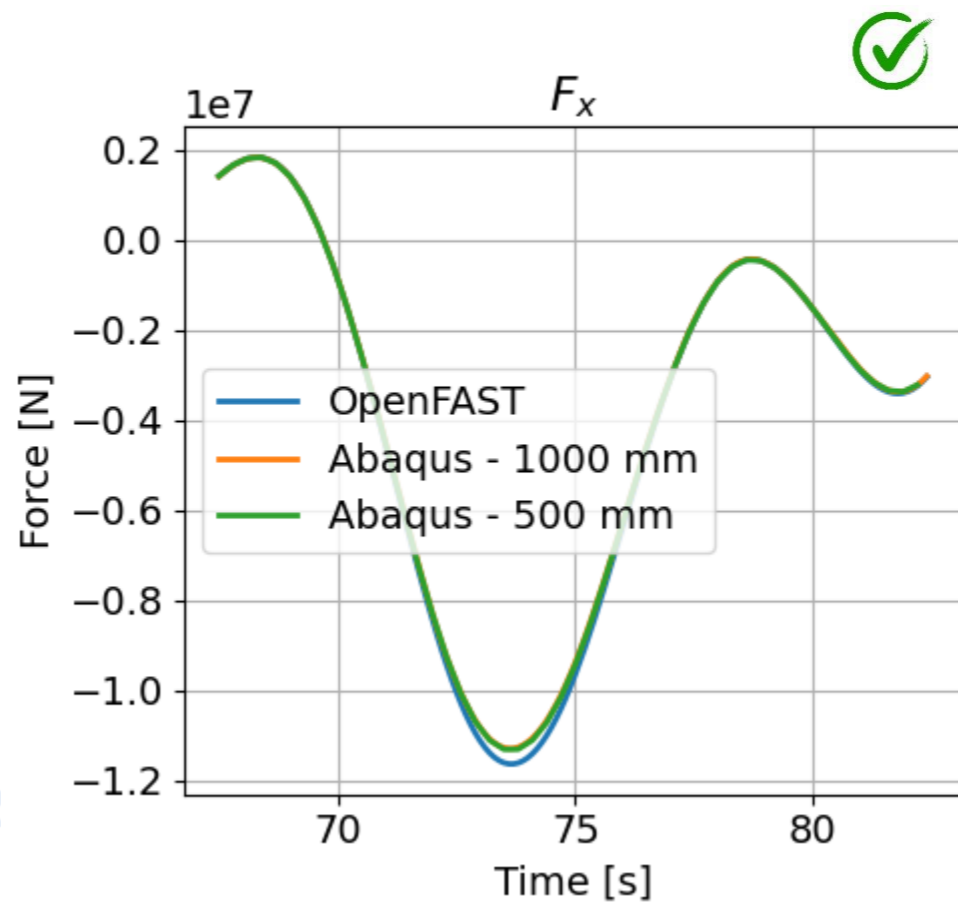
$$C_{HS} = \begin{bmatrix} c_{11} & \dots & c_{16} \\ \vdots & \ddots & \vdots \\ c_{61} & \dots & c_{66} \end{bmatrix}$$

OpenFAST



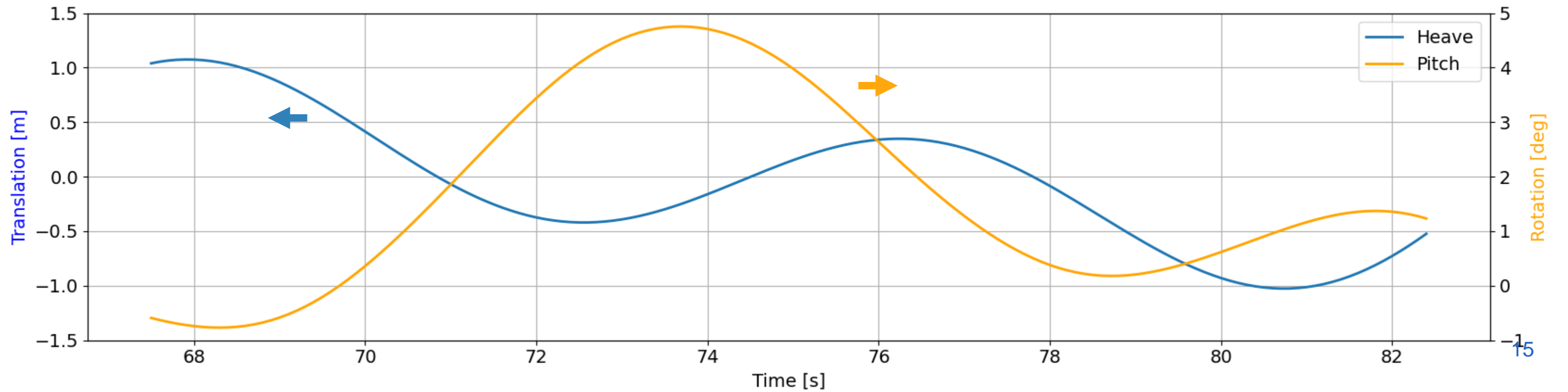
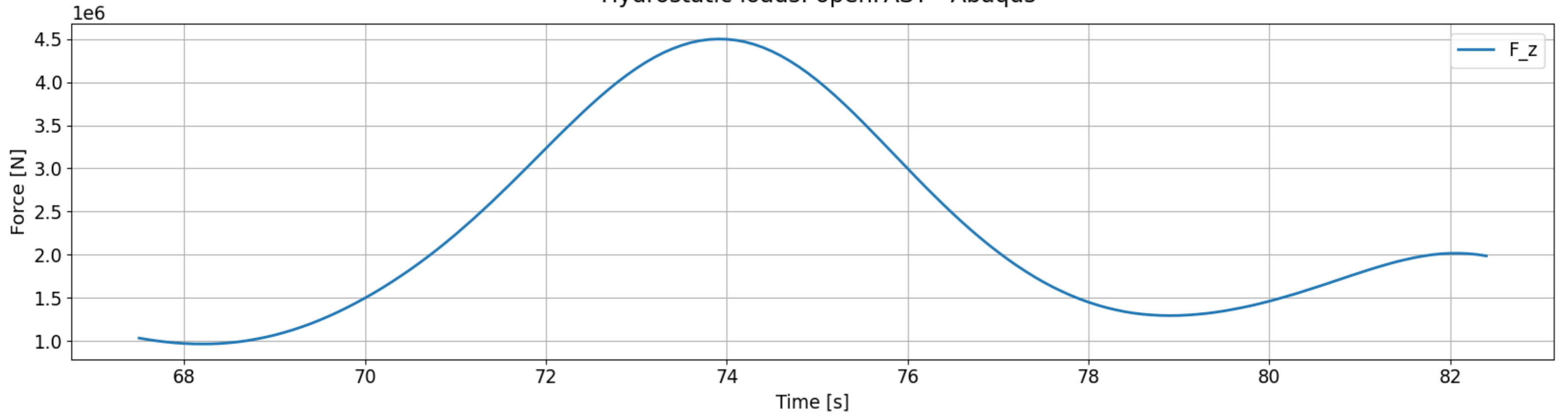
Abaqus

Hydrostatic loads



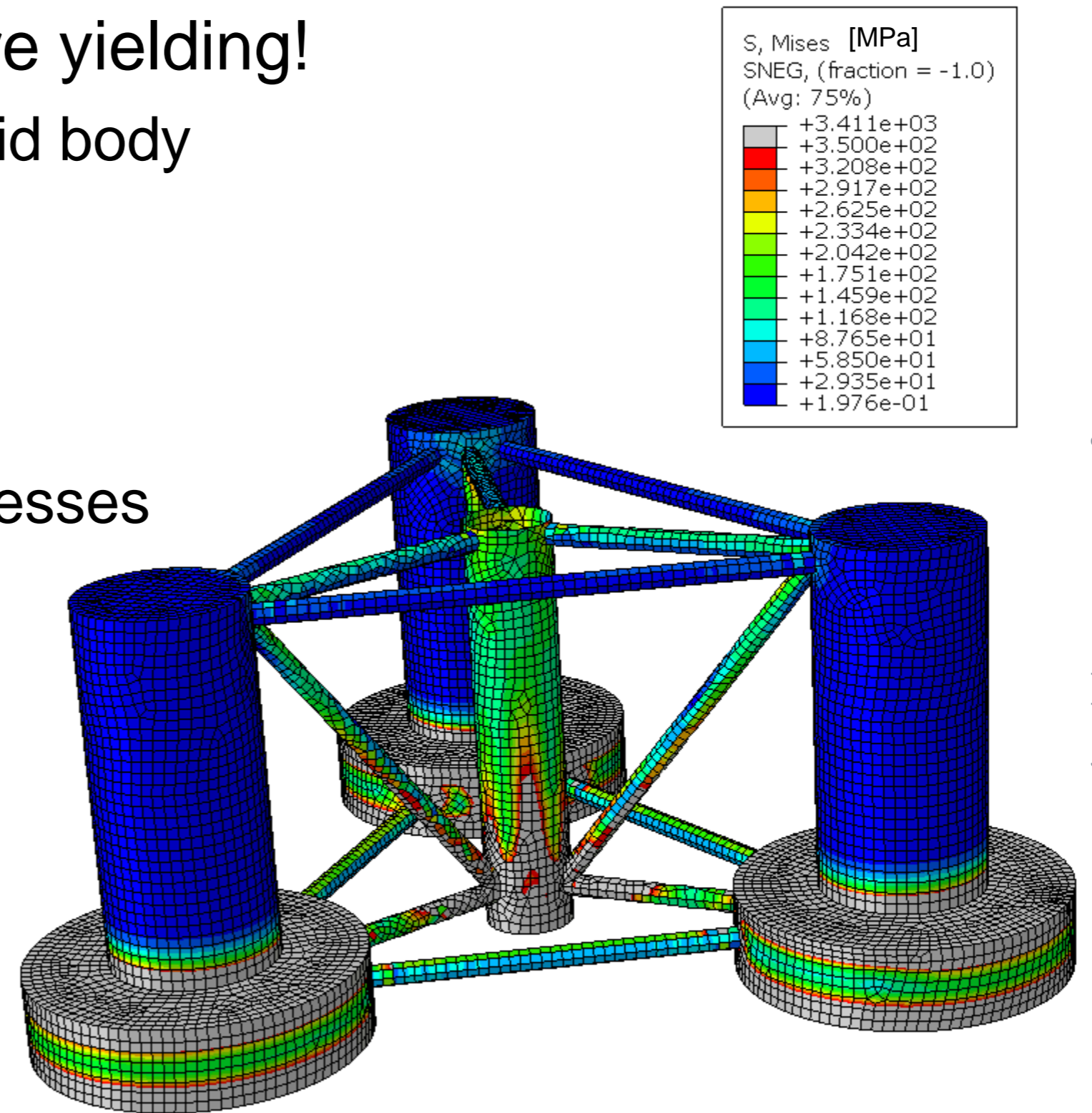
# Hydrostatic loads – Effect of pitch on $F_z$

Hydrostatic loads: openFAST - Abaqus



# Design challenges for the OC4 DeepCWind

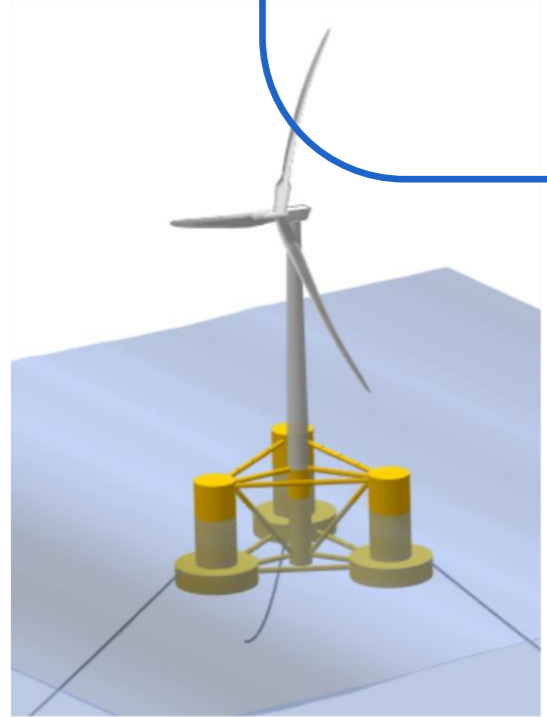
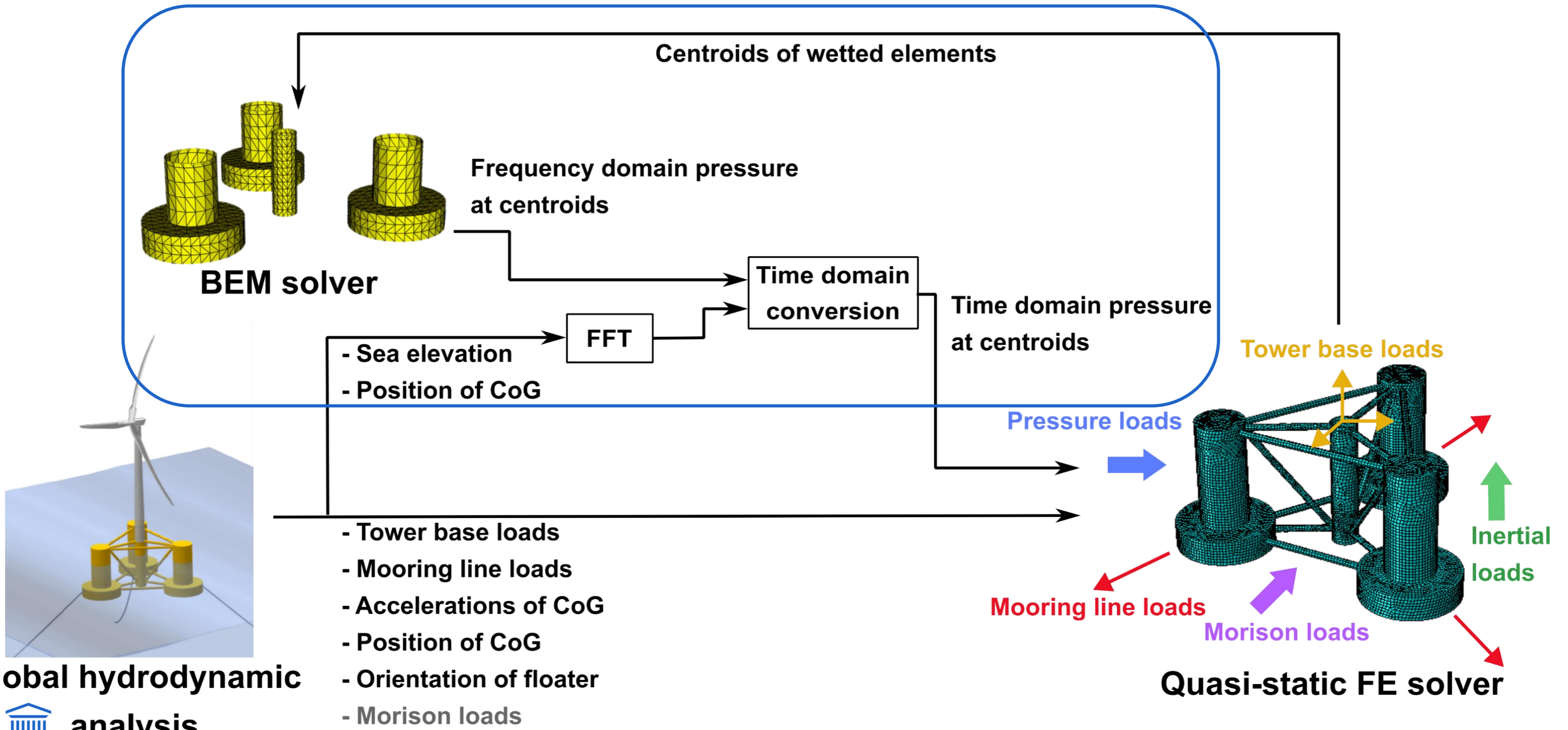
- Hydrostatic pressure is enough to ensure yielding!
  - Floater is only designed to be used as rigid body
  - Hollow cylinders + ballast
- Redesigned the OC4 DeepCWind
  - Added stiffeners and changed wall thicknesses
  - Based on work of Vasconcelos et al. [2]
  - Value as reference turbine is lost





# Load mapping method

Hydrodynamic loads



Global hydrodynamic



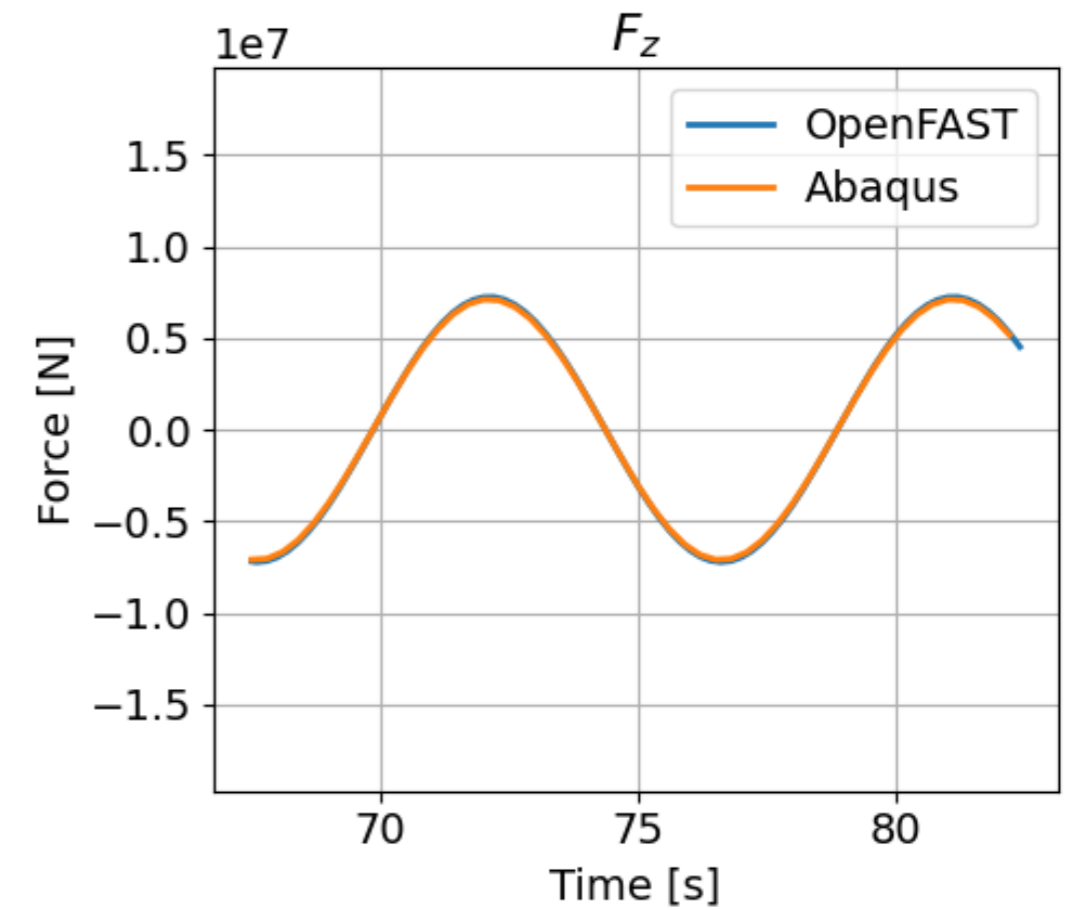
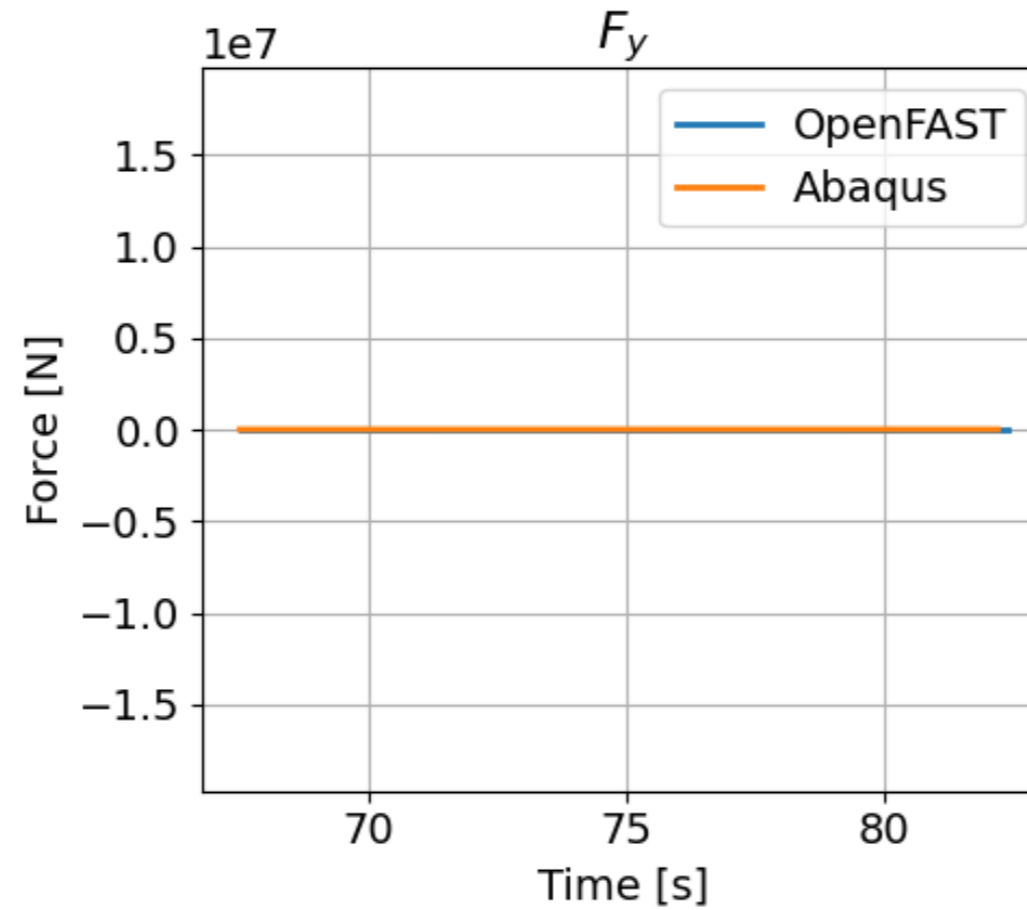
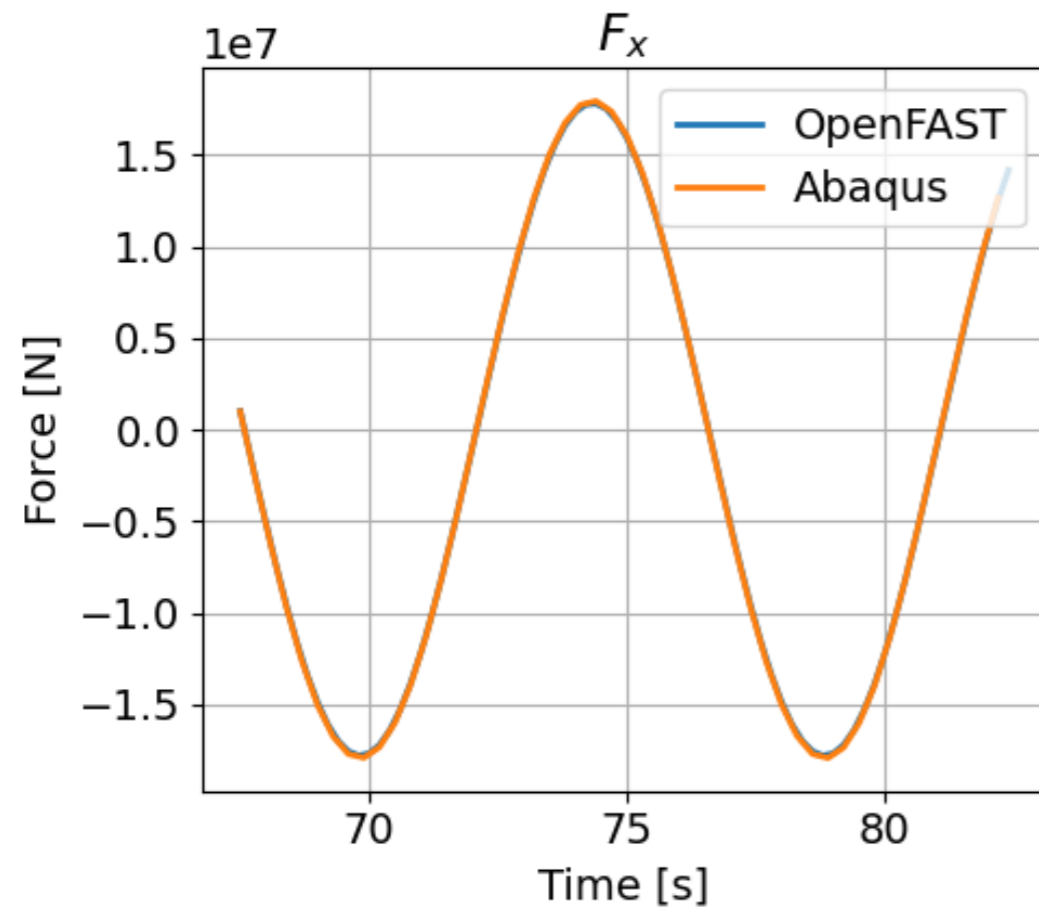
OpenFAST simulation without wind loads, wave height = 10m, wave period = 9s

Note: all loads in the local frame of reference

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# Hydrodynamic loads – Diffraction and Froude-Krylov

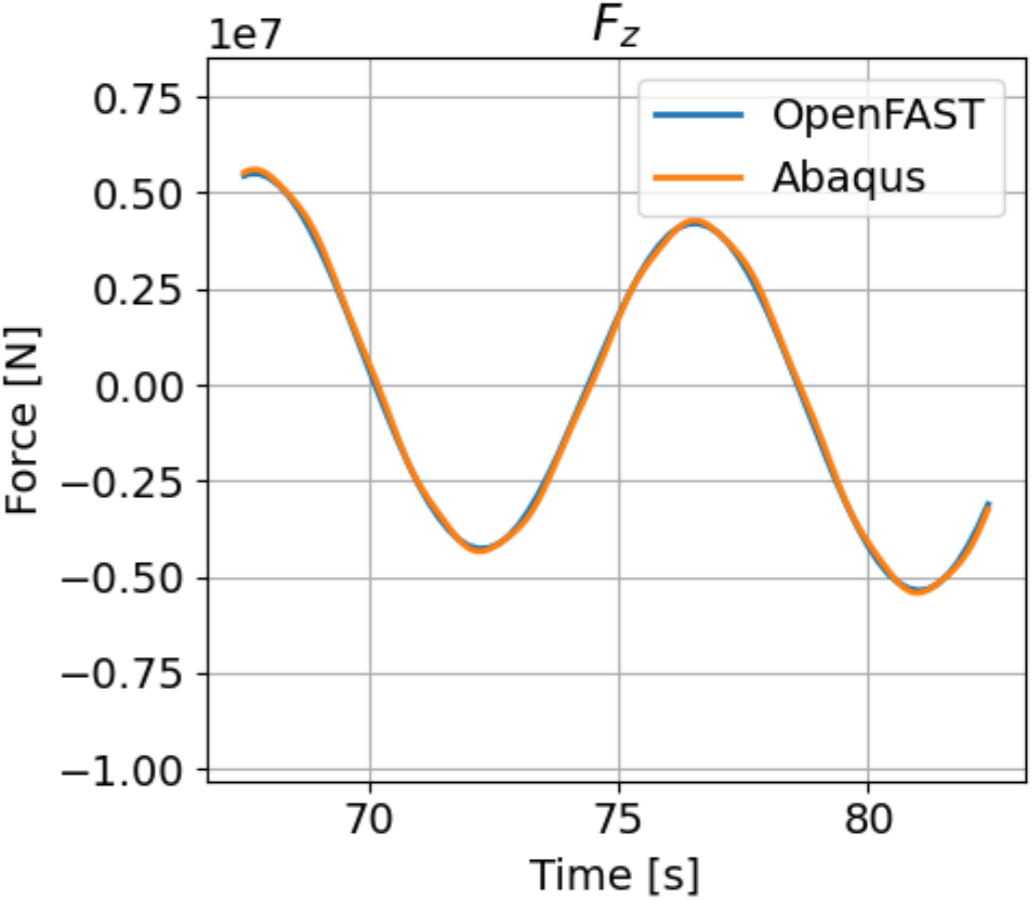
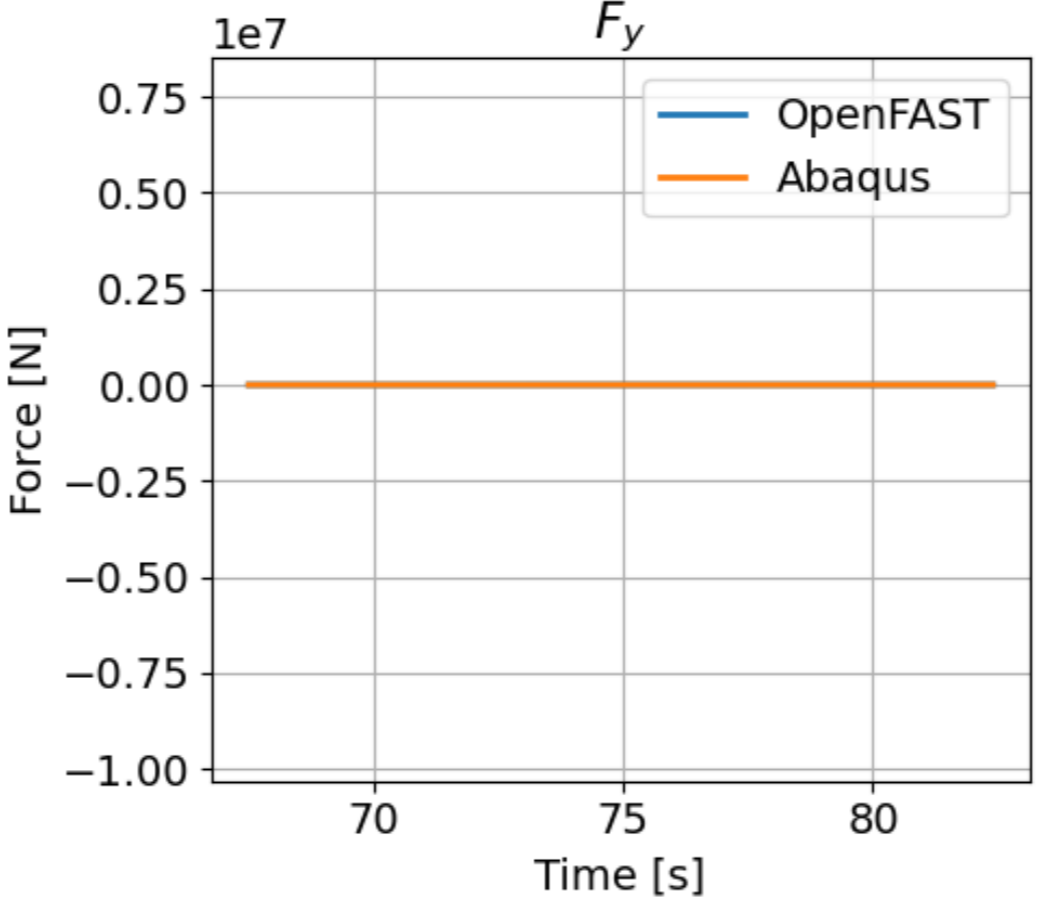
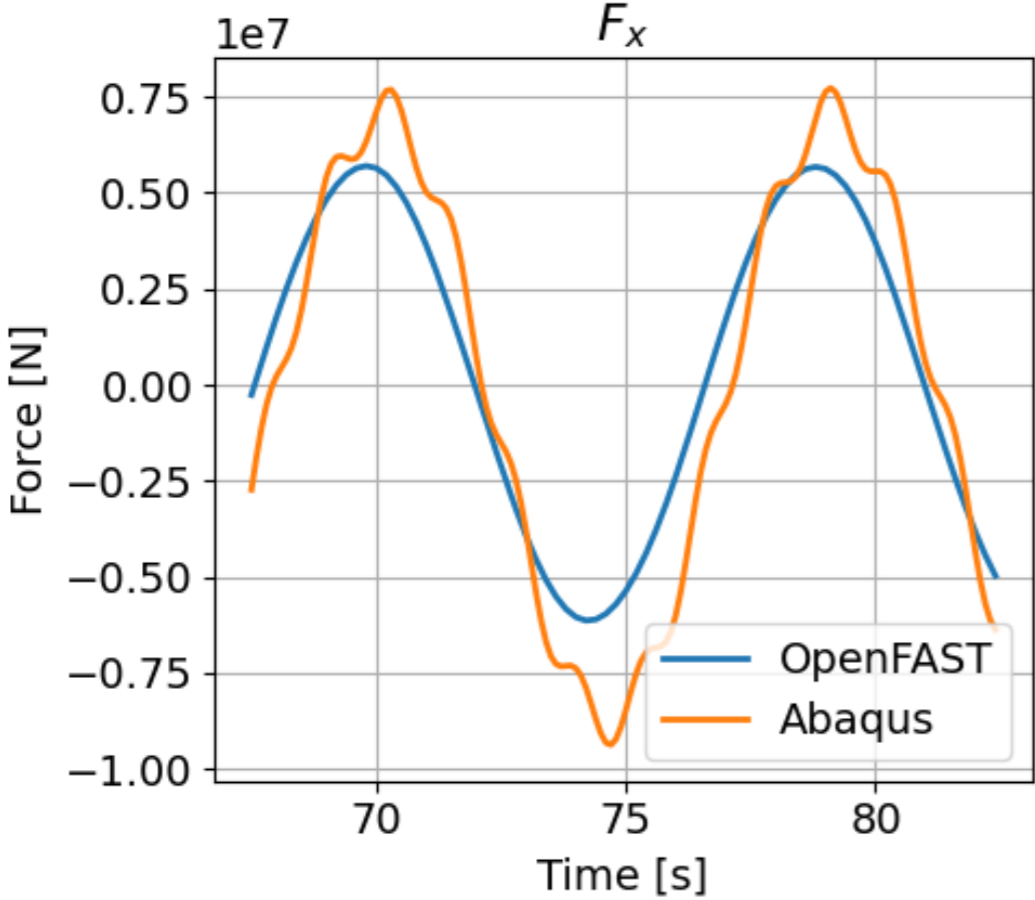
Diffraction and Froude-Krylov loads



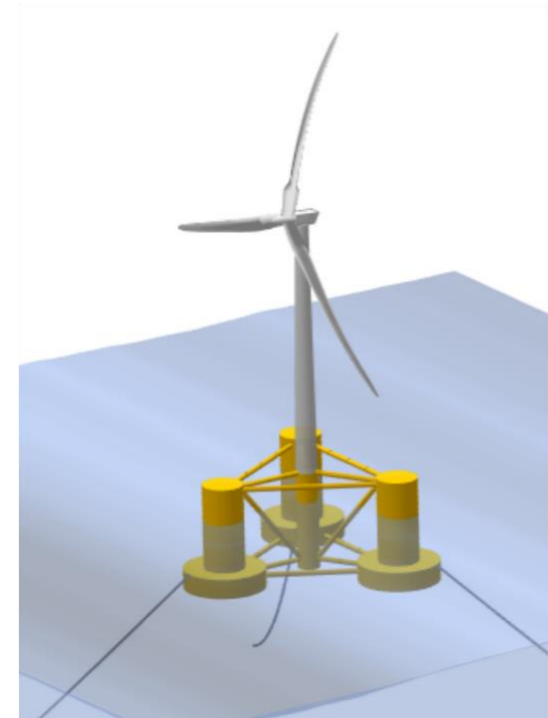
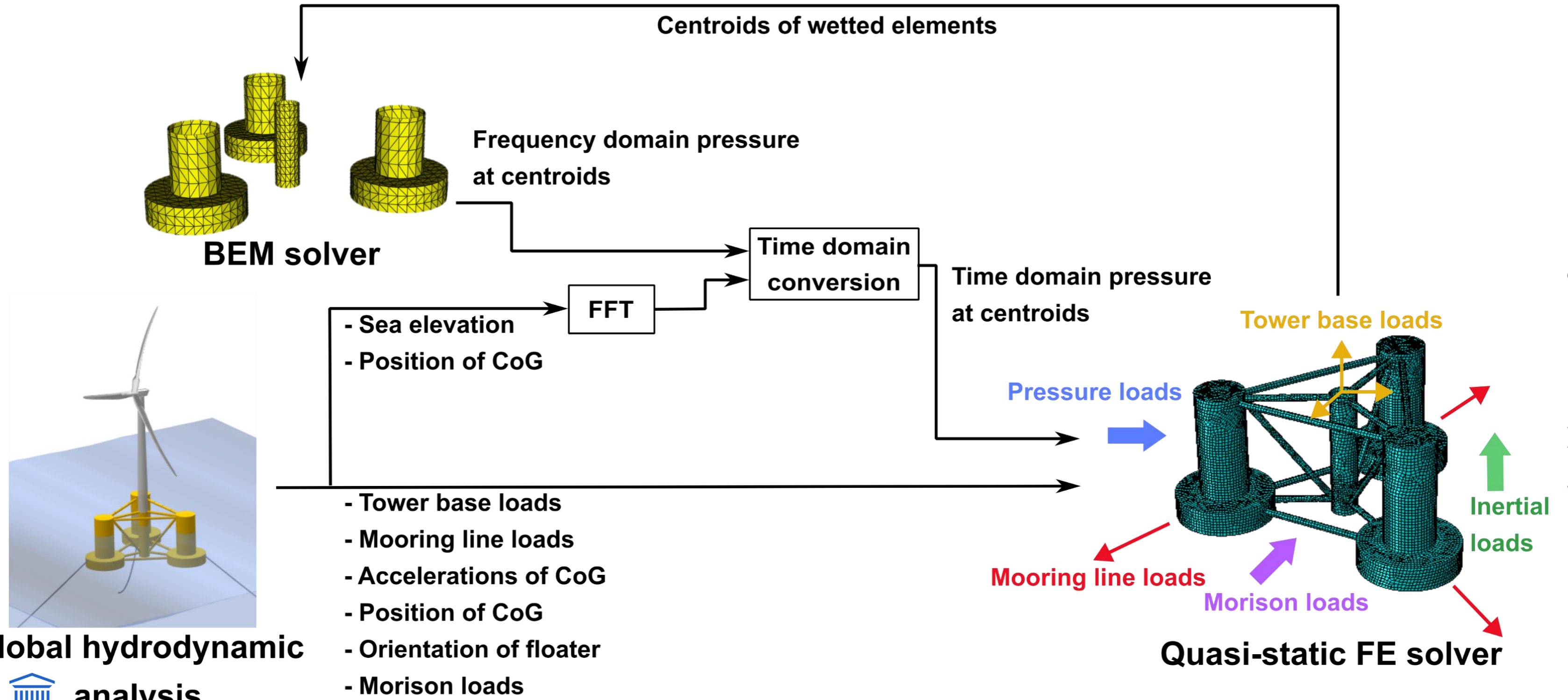
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# Hydrodynamic loads – Radiation

Radiation loads



# Load mapping method – All together



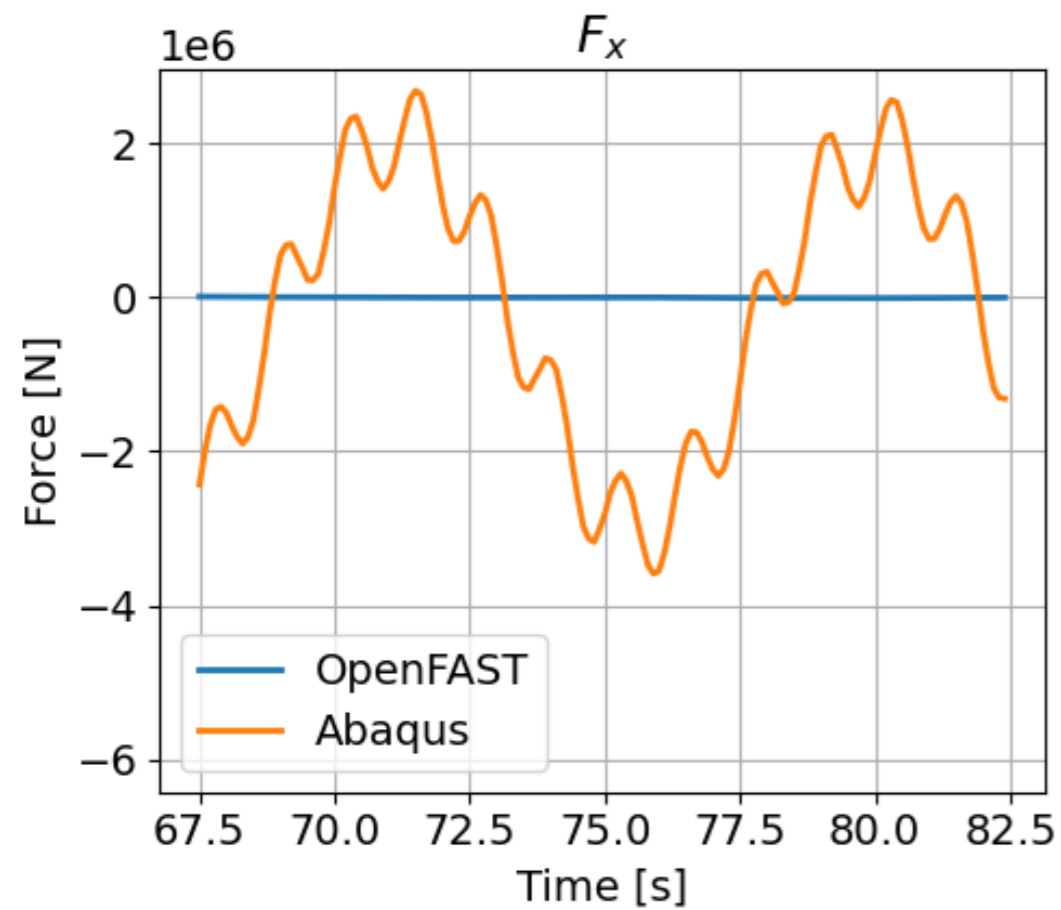
Global hydrodynamic



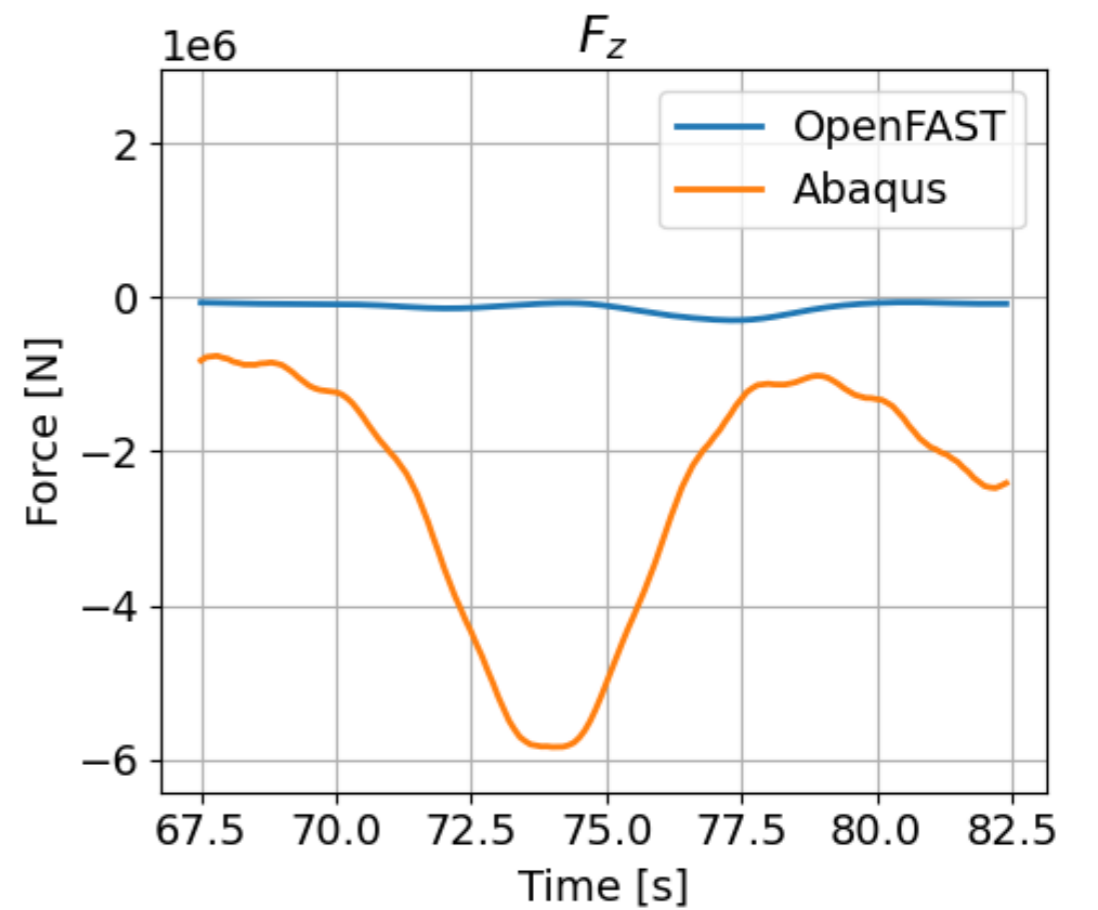
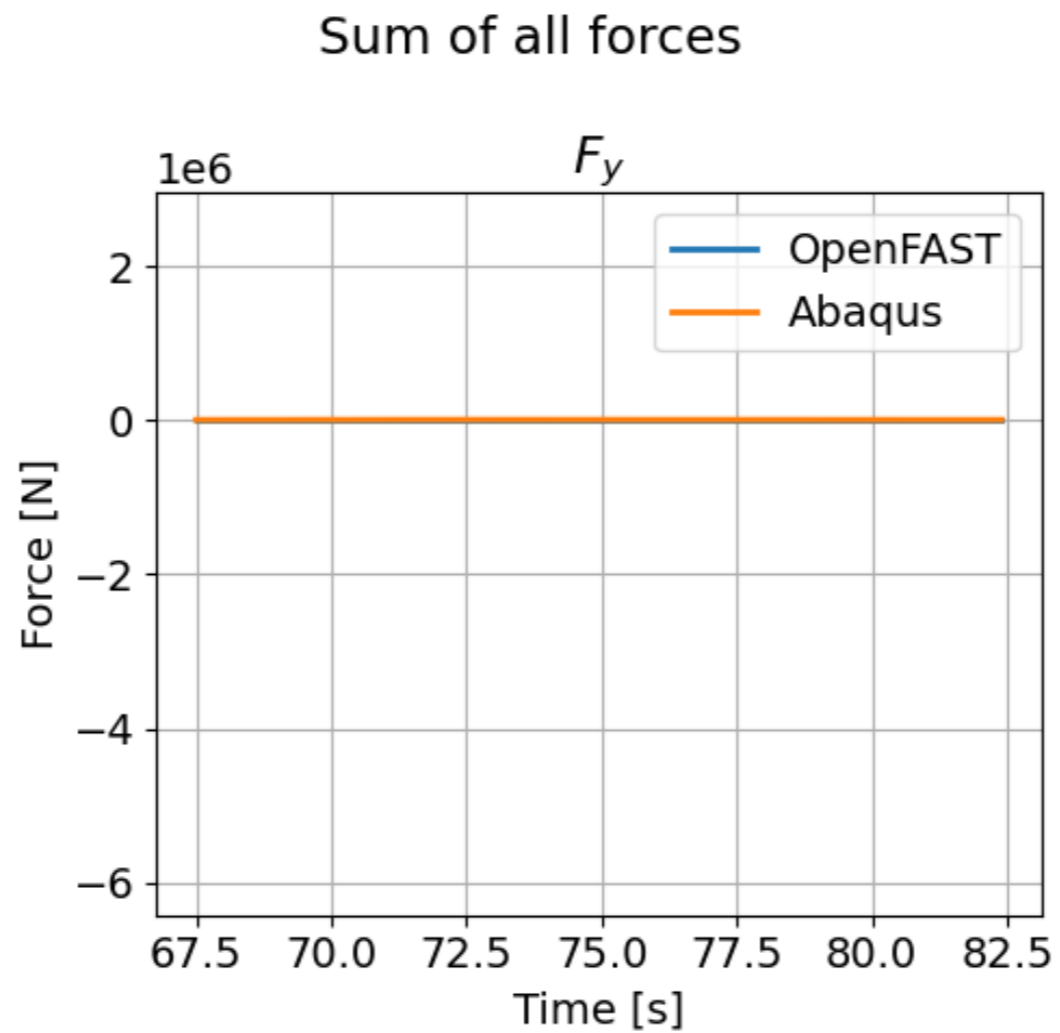
OpenFAST simulation without wind loads, wave height = 10m, wave period = 9s

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# Sum of all forces



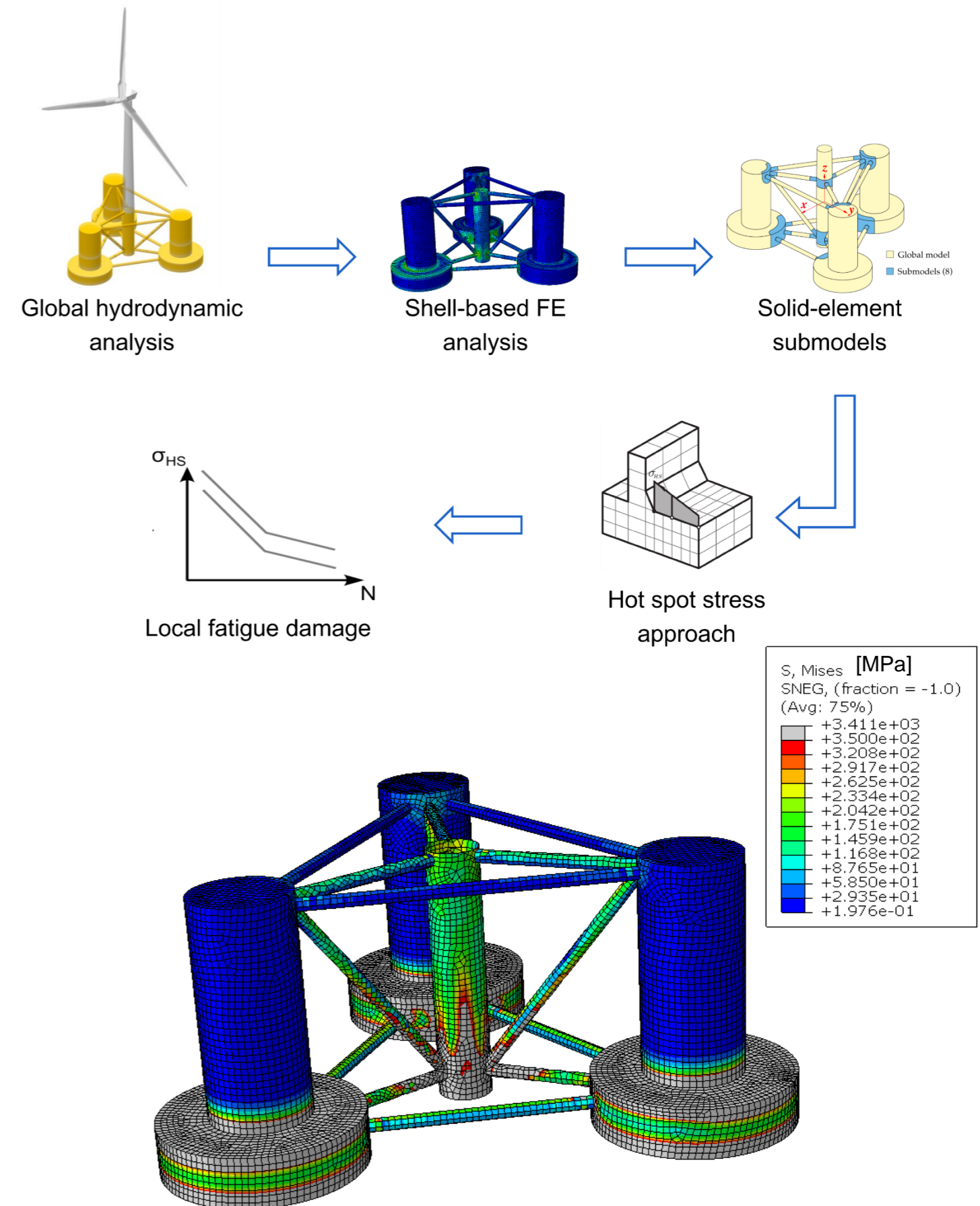
**Effect of radiation**



**Effect of hydrostatic modelling**

# Summary

- Load mapping method
  - Part of a multi-dimensional modelling strategy
  - Impact of hydrostatic modelling
  - Distributed hydrodynamic loads
- OC4 DeepCWind
  - Updated version no longer useful as “reference turbine”
  - Use modelling strategy to strengthen substructure without changing hydrodynamical parameters



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