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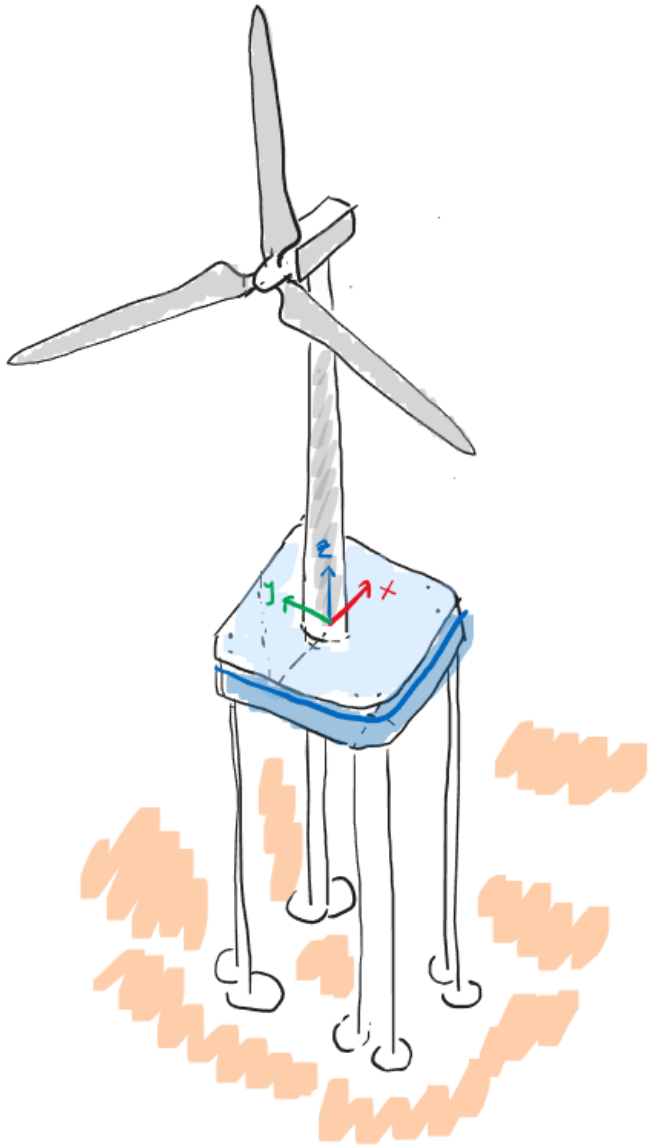
# NUMERICAL SIMULATIONS OF A 15 MW WIND TURBINE ON A CONCRETE TLP WITH RIGID PIPE TENDONS

# The concept: CT-bos floater

- Concrete TLP for 15MW wind turbine
- Cheap & robust
- Easy to build
- Adaptable to different depths
- Easy to deploy



# The Eurostars European project

(2021-2022)

Develop the CT-BOS floater

**Numerical modeling**

Tank testing

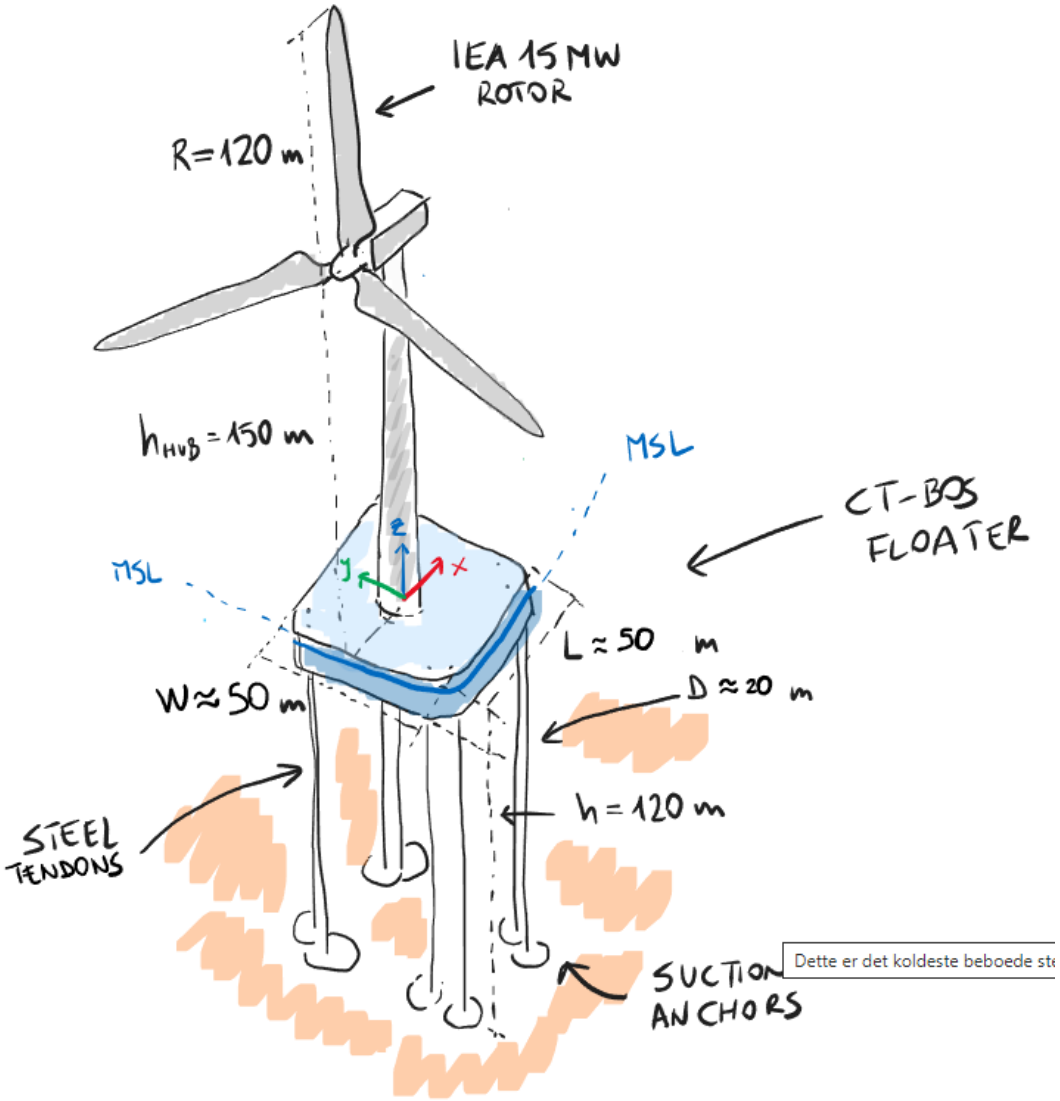
Building prototype of tendons connection

# A closer look

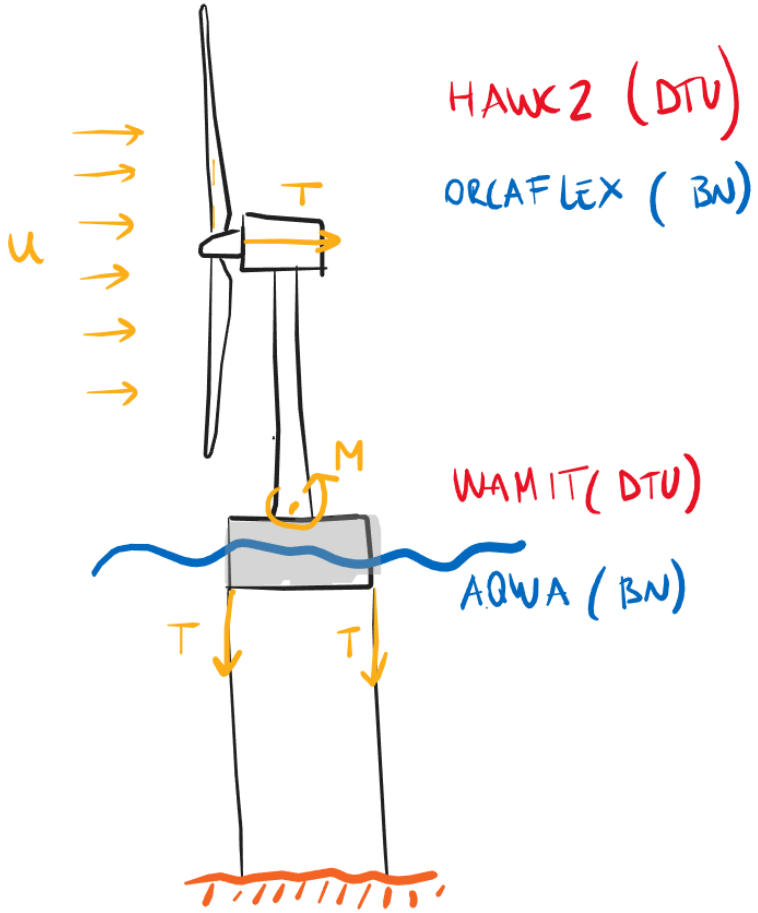
$$m_{RNA} \approx 1000\ [t]$$

$$m_{tower} \approx 1000\ [t]$$

$$m_{floater} \approx 20000[t]$$



# The two numerical models




**Current numerical model**

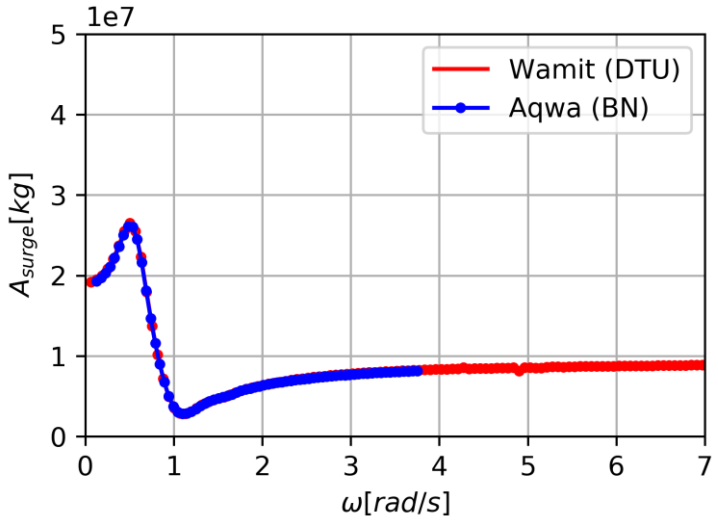
- Wave radiation damping ✓
- Hydro force tendons ✓
- Viscous damping platform ✗

- Flexible rotor
- Stiff lighter tower
- Structural damping

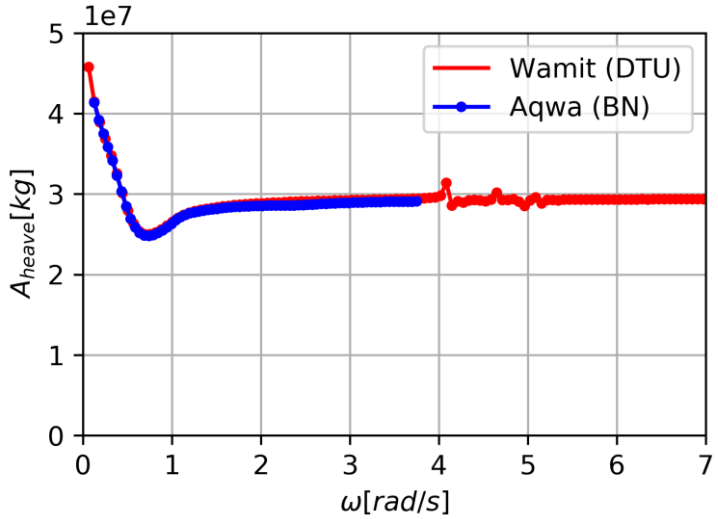
- Stiff rotor
- Stiff heavier tower (+20%)
- No structural damping

# The hydrodynamic properties of the platform

- WAMIT
  - ¼ platform modeled
  - N panels ~ 10000
- AQWA
  - Whole platform modeled
  - N panels ~ 7000

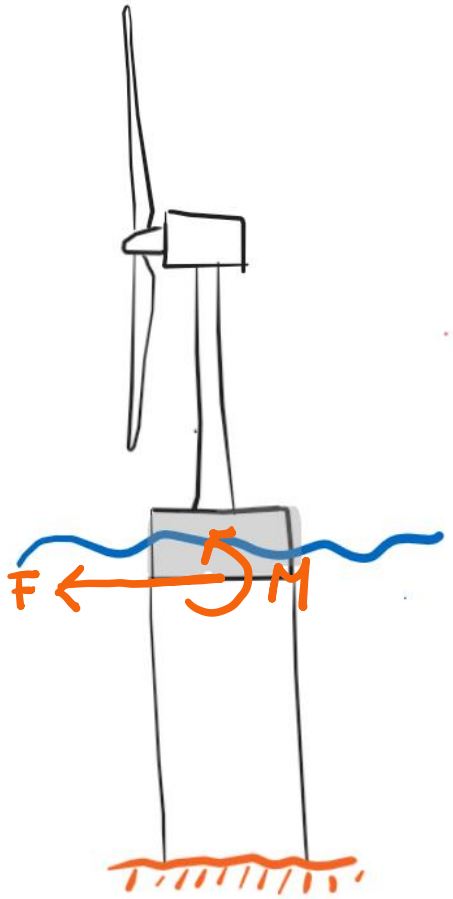



Added mass in surge




Added mass in heave

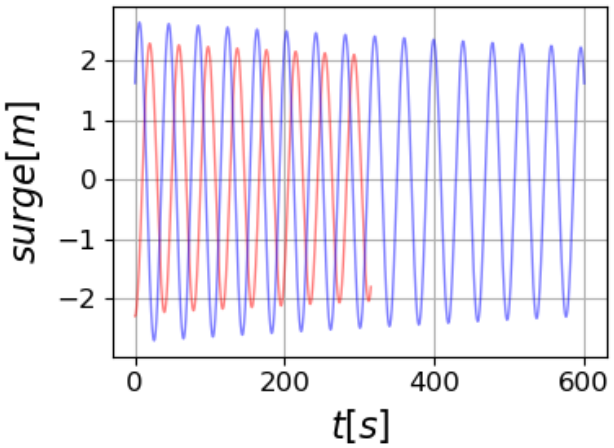
# The decay tests

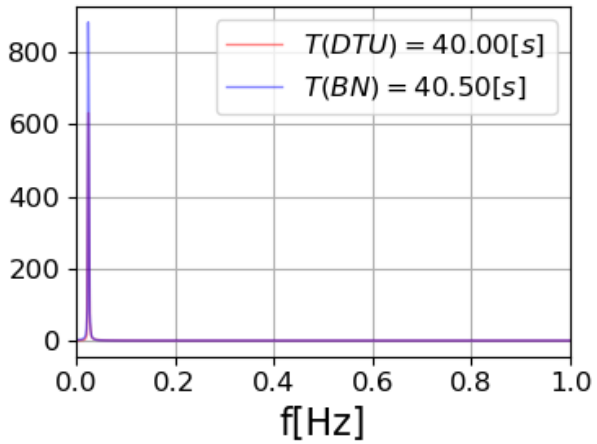


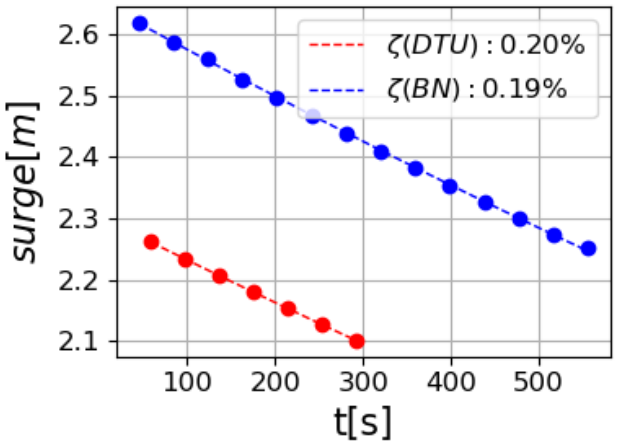

- Parked rotor ☑
- No wind ✕

- Forces and moments applied at keel line 🔄

# Decay test in surge

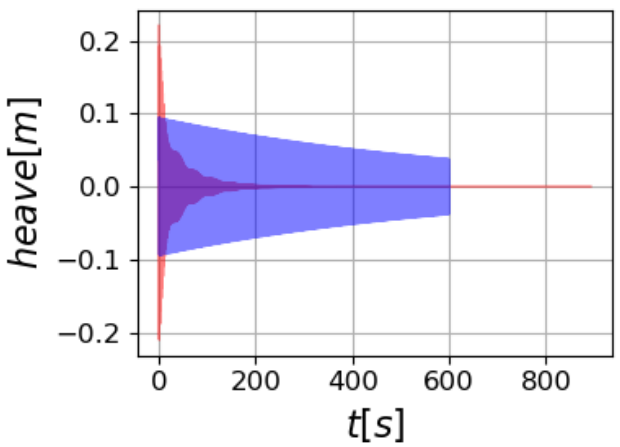


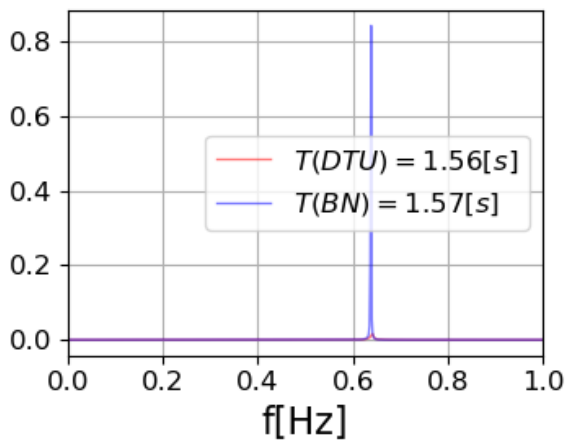



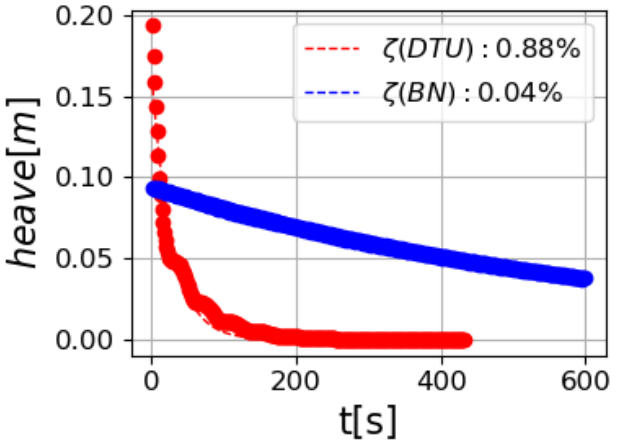




Good agreement

# Decay test in heave

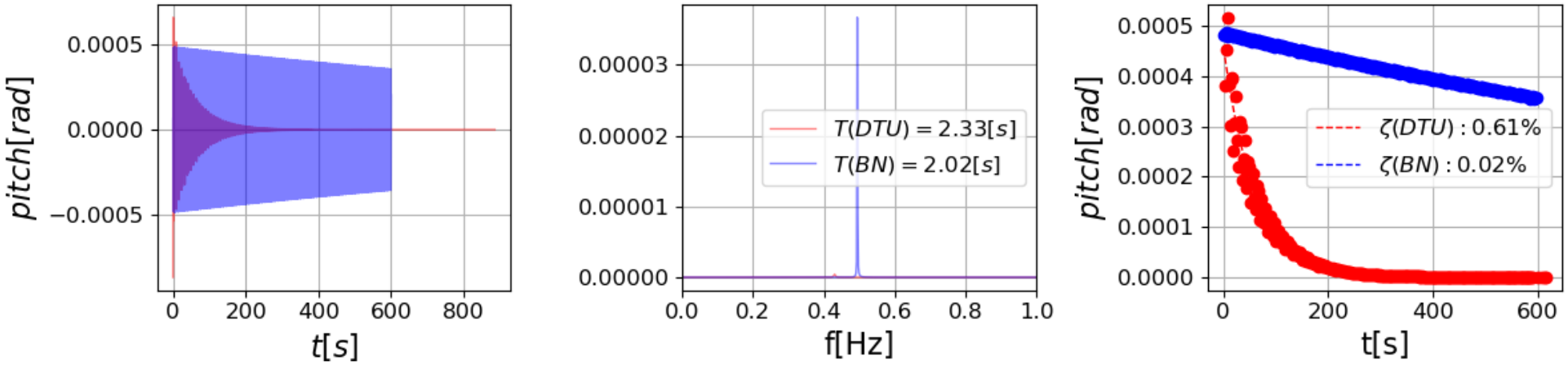


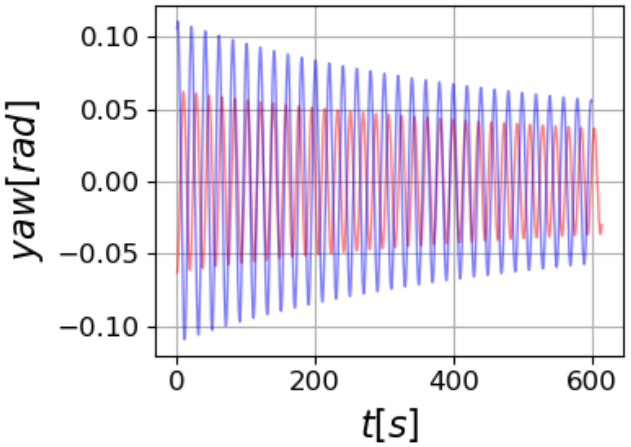

DTU: added structural damping in tendons ($\zeta = 0.1\%$)

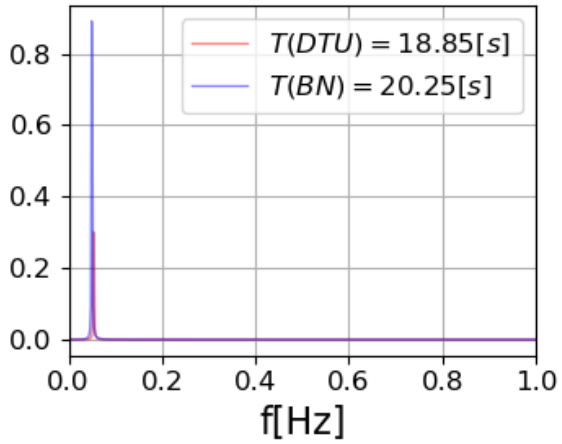
# Decay test in pitch

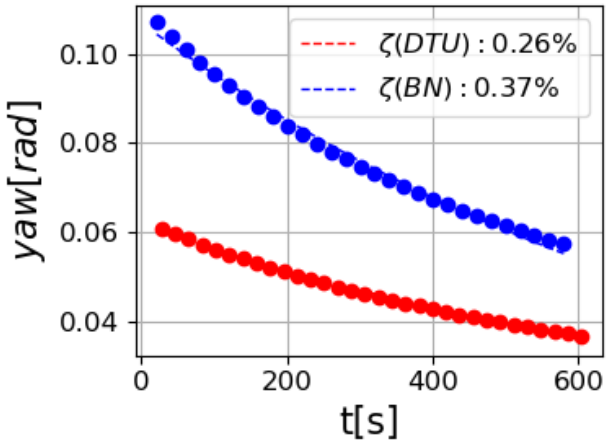



Slight difference in pitch period probably due to different tower mass & mass distribution

# Decay test in yaw

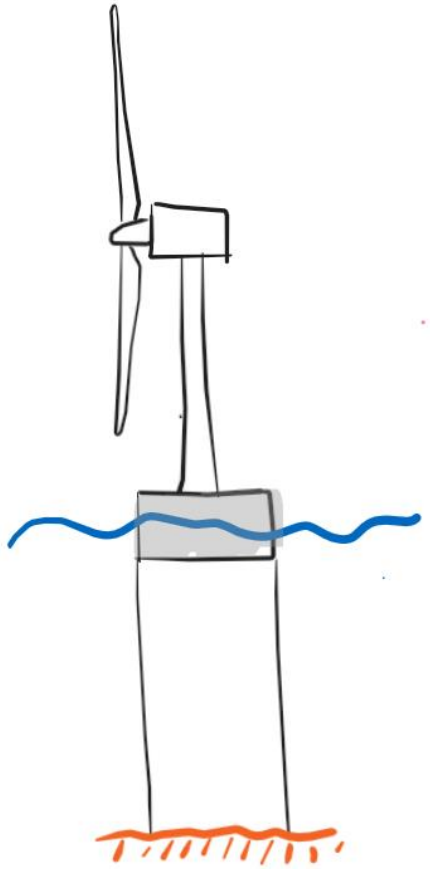


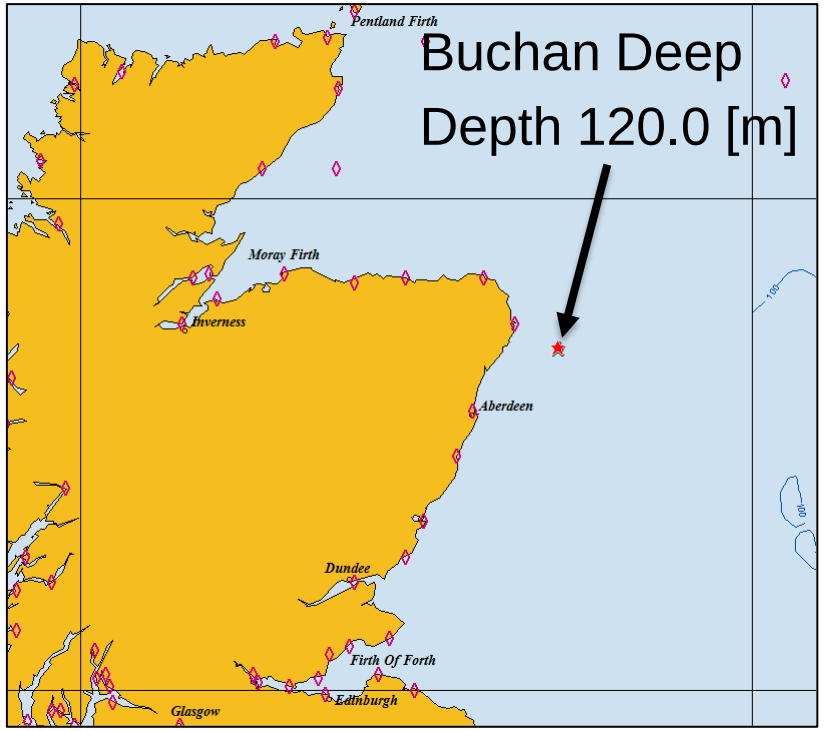



# Eigenfrequencies

- Surge: 40.0 [s]
- Yaw: 18.85[s]
- Pitch: 2.33[s]
- Heave: 1.56[s]
- Away from the main linear wave excitation range



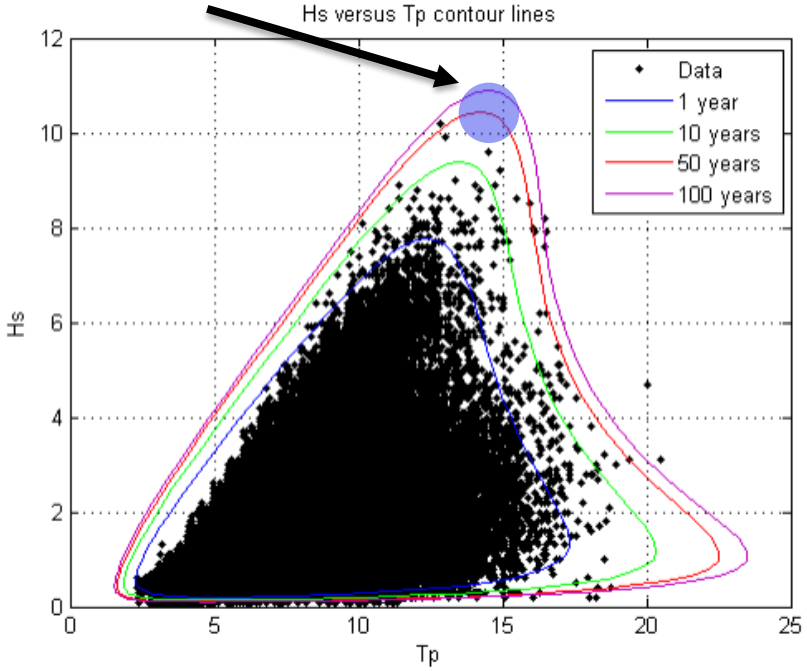
# Survival sea state (50-year storm)




Northern Scotland

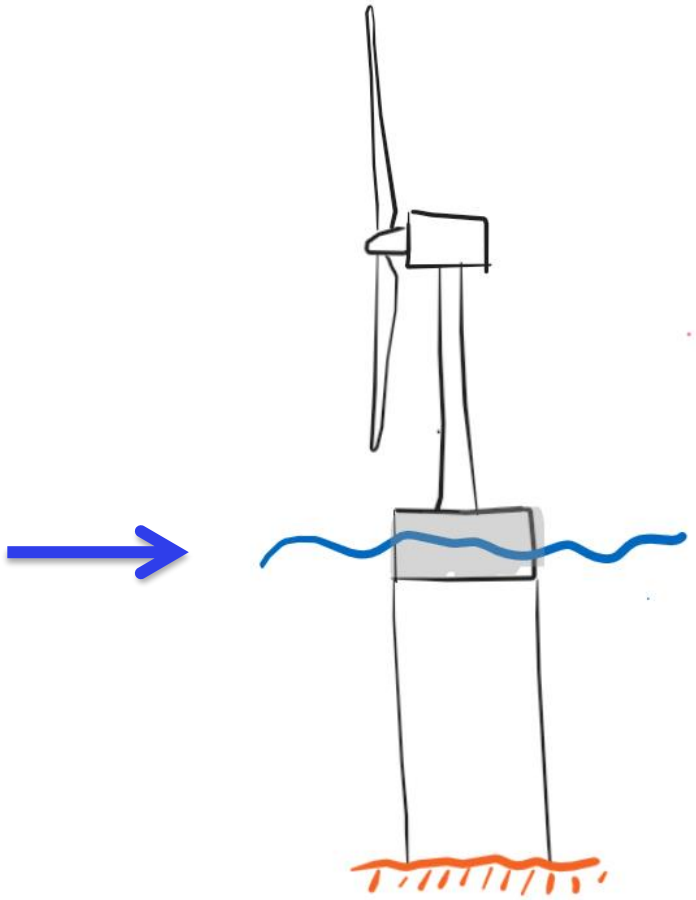
Sea state with 50-year return period

$H_S = 10.9[m], T_P = 14.6[s], \gamma = 1.9$



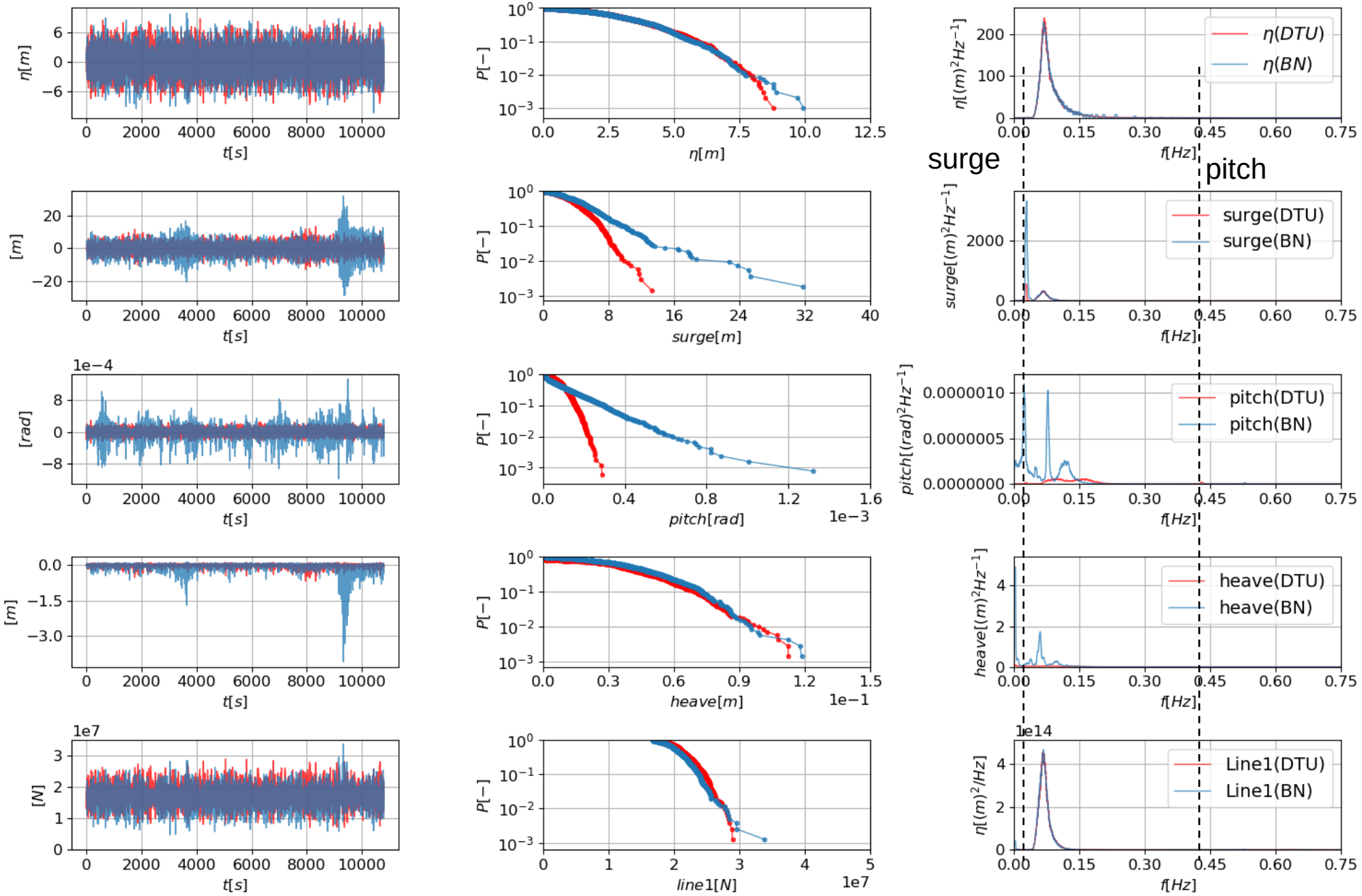

NORA10 hindcast dataset (1958-2010), reproduced from Buchan Deep Design basis (2014)

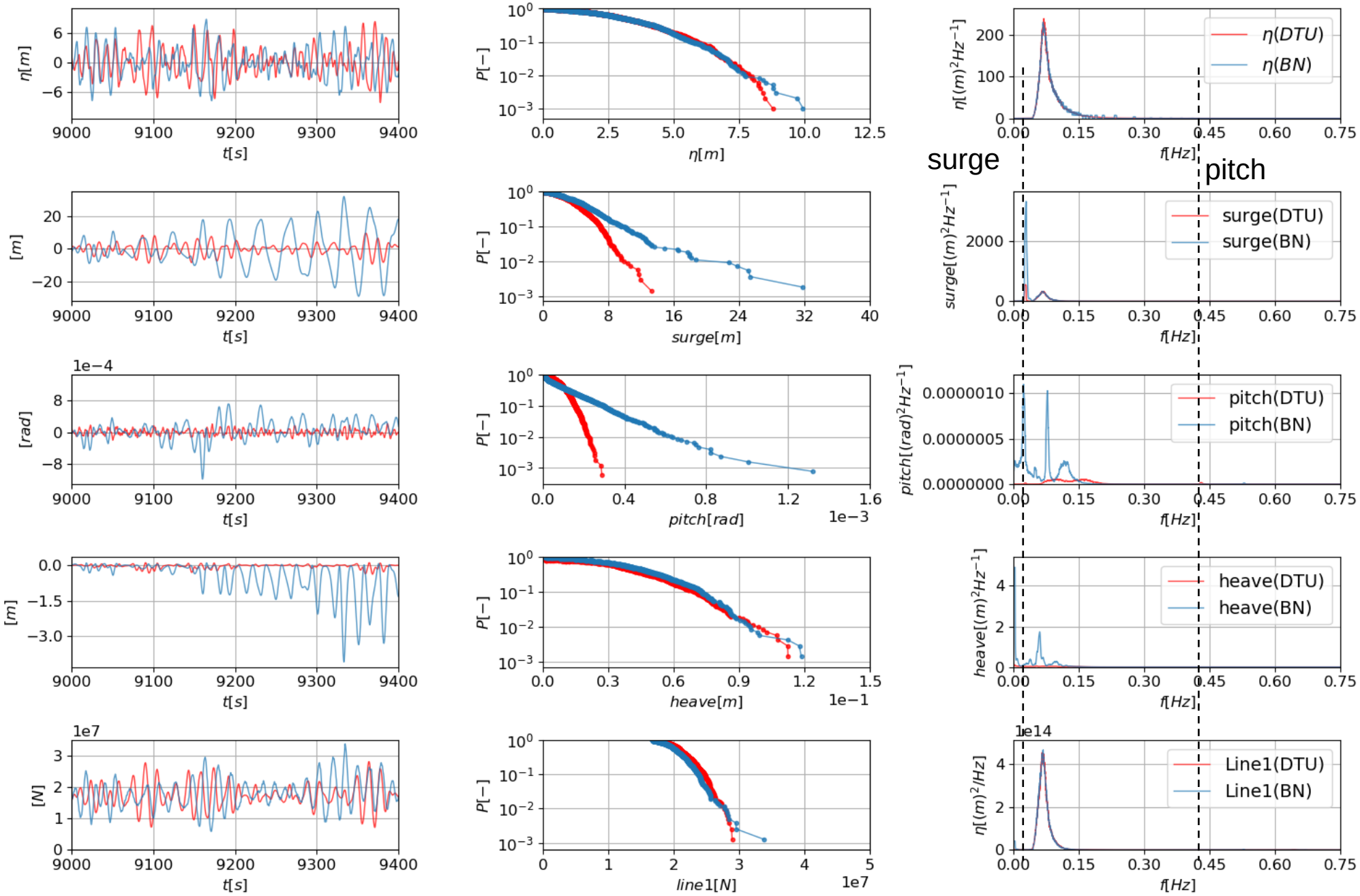
# The survival sea state



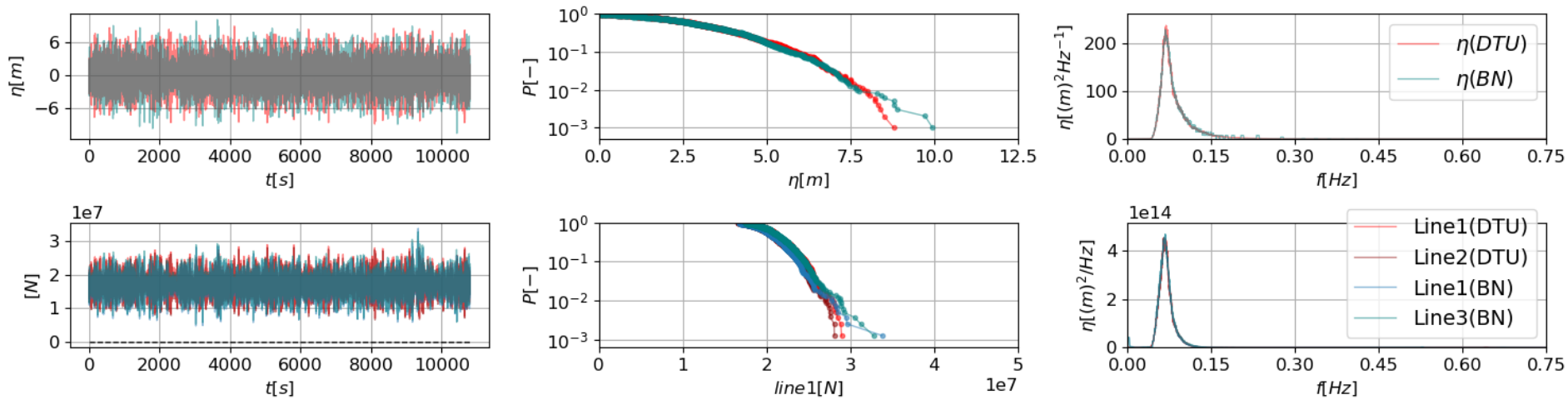
- Parked rotor ☑
- No wind ✕

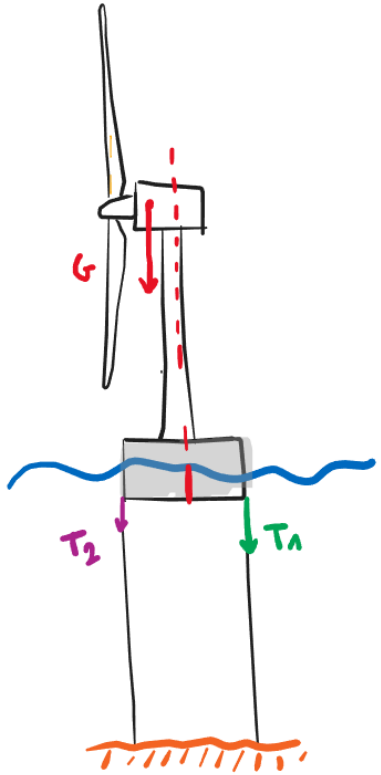
- First Order excitation (DTU)
- First+Second order excitation (BN)


surge
pitch
η[m]
t[s]
P[−]
η[m]
η(DTU)
η(BN)
η[(m)²Hz⁻¹]
f[Hz]
[m]
surge[m]
surge(DTU)
surge(BN)
surge[(m)²Hz⁻¹]
1e−4
[rad]
pitch[rad]
1e−3
pitch(DTU)
pitch(BN)
pitch[(rad)²Hz⁻¹]
heave[m]
1e−1
heave(DTU)
heave(BN)
heave[(m)²Hz⁻¹]
1e7
[N]
line1[N]
1e14
Line1(DTU)
Line1(BN)
η[(m)²/Hz]


surge
pitch
η[m]
t[s]
P[−]
η[m]
η(DTU)
η(BN)
η[(m)²Hz⁻¹]
f[Hz]
[m]
surge[m]
surge(DTU)
surge(BN)
surge[(m)²Hz⁻¹]
[rad]
pitch[rad]
1e−4
1e−3
pitch(DTU)
pitch(BN)
pitch[(rad)²Hz⁻¹]
heave[m]
1e−1
heave(DTU)
heave(BN)
heave[(m)²Hz⁻¹]
[N]
line1[N]
1e7
1e14
Line1(DTU)
Line1(BN)
η[(m)²/Hz]

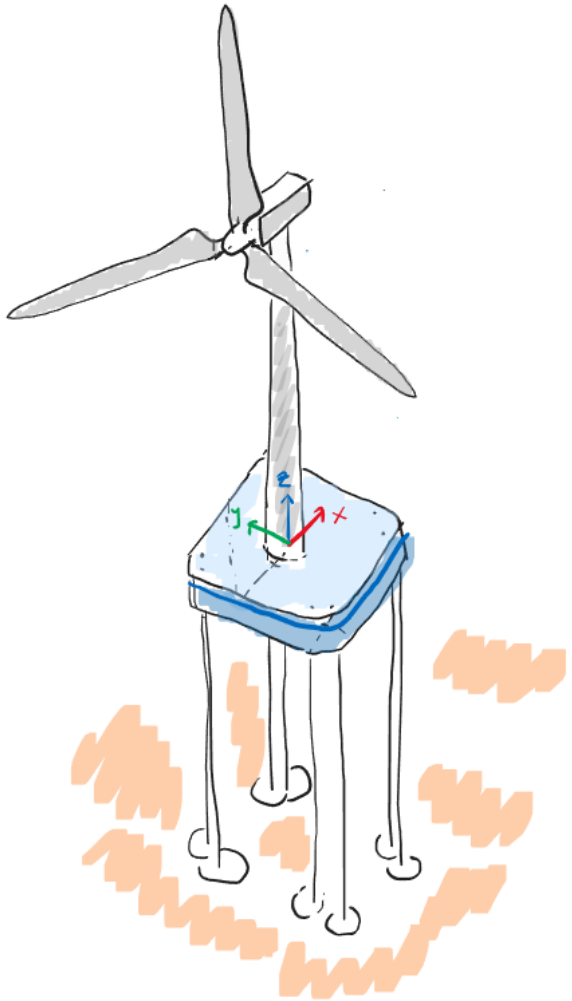
# Tension in the tendons



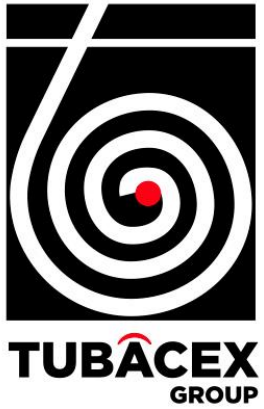
# Conclusions and future work

- Decay tests
  - Agreement BN vs. DTU
  - Frequencies sufficiently far from wave excitation spectrum
- Survival sea state
  - Second-Order excitation of surge due to low overall damping (BN)
  - Far from the tendon compression, despite the severe sea state
- FLS + ULS computation in advanced status in Orcaflex
- DTU to perform more benchmarking simulations in HAWC2



# Thank you for your attention





DTU