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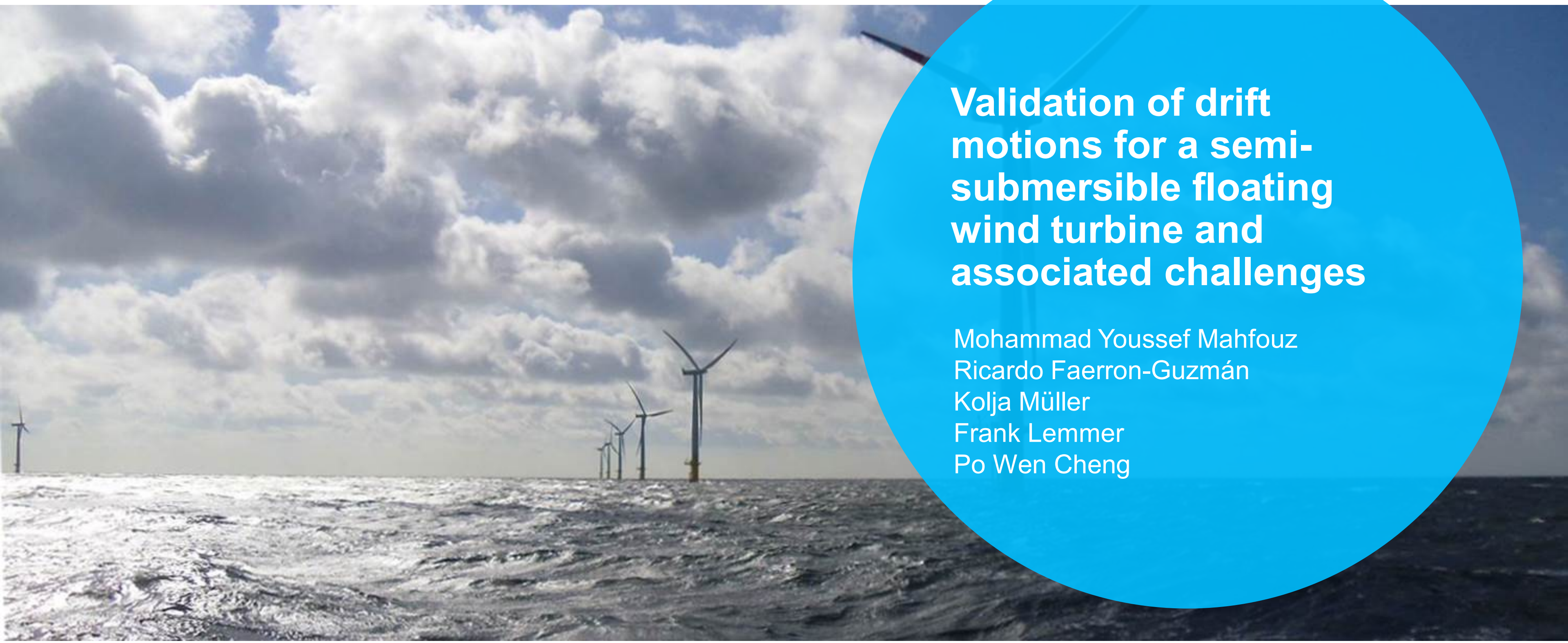

Validation of drift motions for a semi-submersible floating wind turbine and associated challenges

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Goal of this research

- Validation of the numerical simulations of a semi-submersible floater using wave tank test.
- Validation of the simulation tools capabilities to capture low frequency response.
- Identify the current challenges to capture the motion responses of floaters.

Work flow

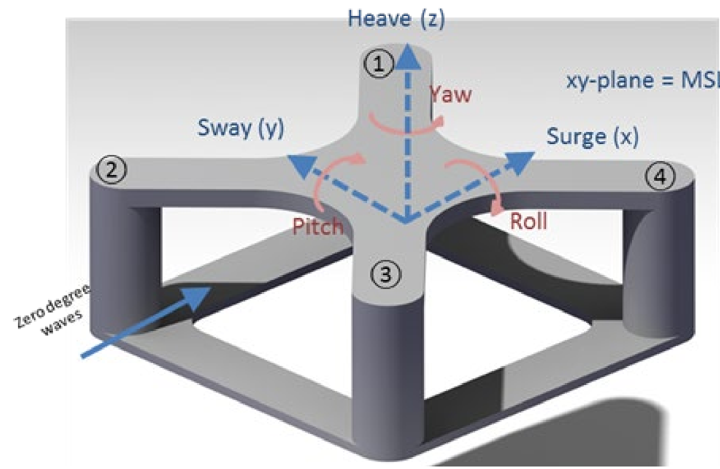
1. Choose relevant tests to achieve the research goals
2. Calibrate the FAST model to match the experiments
3. Damping properties for the platform
4. Identification tests (decay and pullout tests)
5. Load cases tests (pink wave and extreme irregular wave spectra)

Tools used in the research

- FAST8 is used for numerical simulations.
  - First order radiation diffraction hydrodynamics using Cummins' equation.
  - RAOs are calculated using Ansys-AQWA.
  - Morison drag coefficients to capture viscous effects.
  - Second order difference frequency forces QTF.
- Mooring lines modelling
  - Static model using MAP++

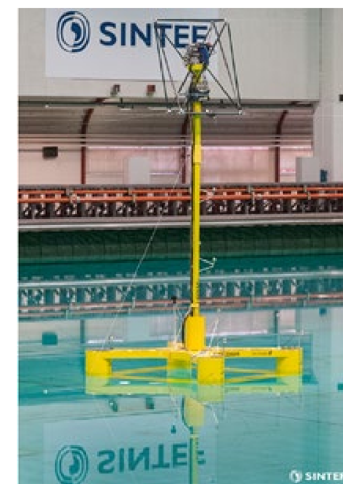
NAUTILUS semi-submersible floater

- NAUTILUS is a semi-submersible floater:
  - It has four columns connected together with pontoons (heave plates).
  - Active ballast platform.
  - Draft of 17.36m (zero wind speed).
  - Four mooring lines.



Wave tank test for 1:36 scaled model

- The wave tank test is done at SINTEF Ocean facilities as part of the LIFES50+ project.
- Incoming waves angle -15°.
- DTU 10 MW turbine is used on top of the floater.
- Active ballast is not modelled.

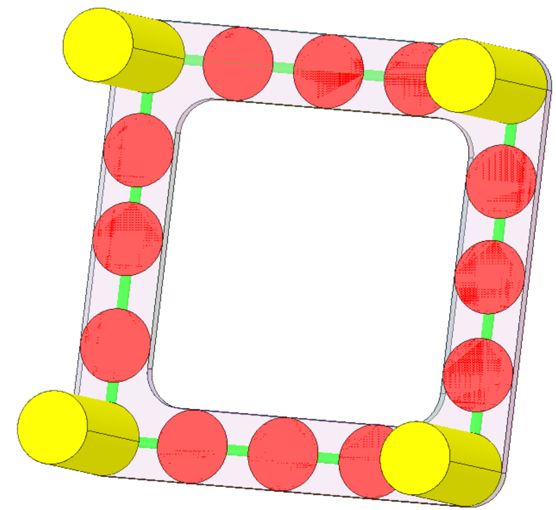


Tests used in this study

- All the test used are in the absence of wind. The main focus in this study is the hydrodynamic response of the floater.
- The tests used are:
  - Heave and pitch decay tests without mooring.
  - All platform’s degrees of freedom with mooring.
  - Pull out tests in the surge direction.
  - Pink noise wave spectra test (H_s=2m and T_p between 4.5-18.2 sec)
  - Extreme wave (Pierson-Moskowitz spectrum H_s=10.9 and T_p=15 sec)

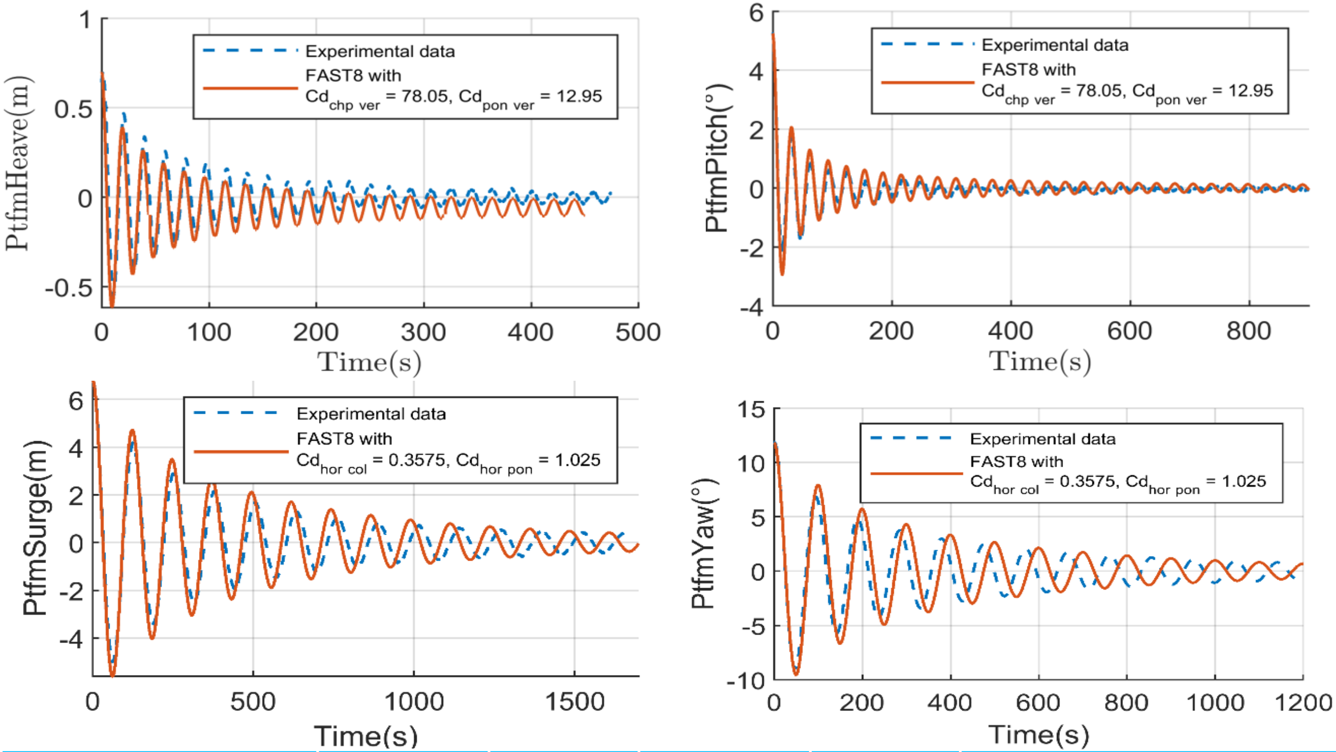
Platform's drag coefficients

- The damping discretization of the platform is done using four damping coefficients:
  - Vertical damping pontoon $Cd_{ver\ pon}$ (red circles)
  - Vertical drag coef. column $Cd_{ver\ col}$ (yellow)
  - Horizontal drag coef. column $Cd_{hor\ col}$ (yellow)
  - Horizontal drag coef. Pontoon $Cd_{hor\ pon}$ (green)



Decay tests

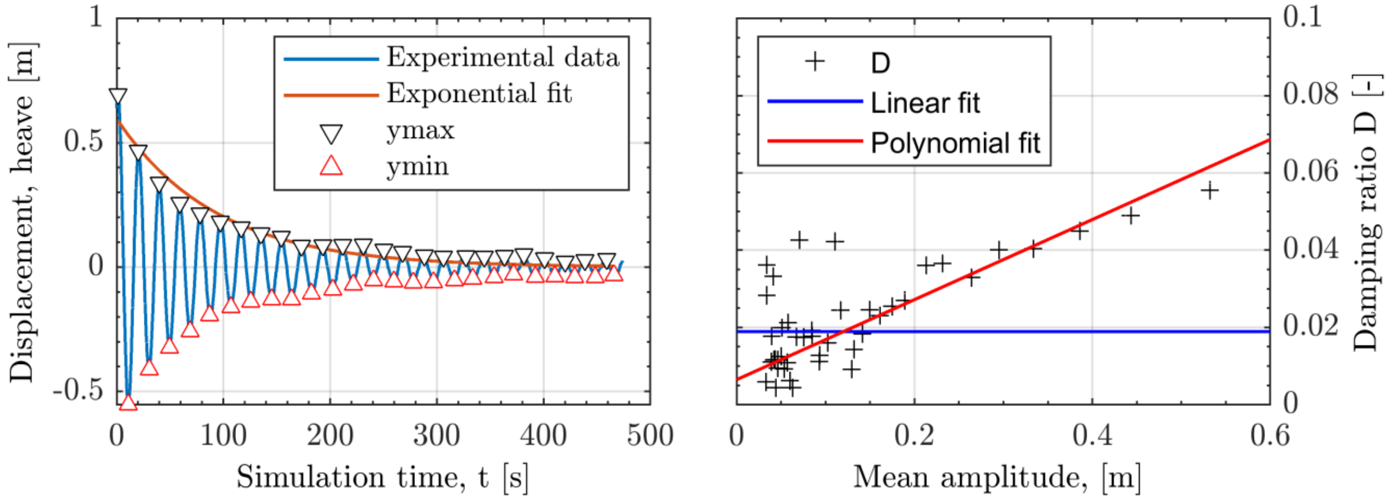
Heave, pitch, surge, and yaw decay tests with mooring



- Heave, pitch and roll responses are affected by vertical drag
- Surge, sway and yaw responses are affected by horizontal drag

	$Cd_{ver\ col}$	$Cd_{ver\ pon}$	$Cd_{hor\ col}$	$Cd_{hor\ pon}$	Specific weight mooring line (kg/m)
FAST8 decay tuned	78.05	12.95	0.3575	1.025	157.172

Experimental behavior of damping



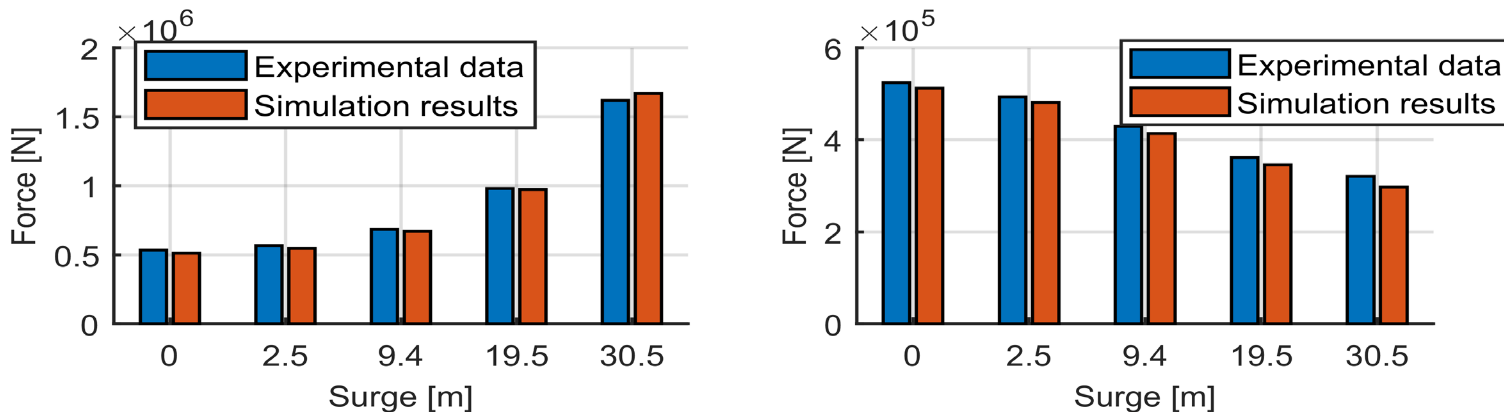
- Nonlinear damping behaviour.
- Dependency on both Keulegan-Carpenter (KC) number and Reynolds number.
- Hard to fit in a simple model.

Decay results discussions

- This good match was only reached after decreasing the mooring lines specific mass.
- Pull out tests are simulated later to make sure that the mooring lines of the model are representative.

	Surge Moored	Heave Moored	Pitch Moored	Yaw Moored
Test (Hz)	0.0079	0.0527	0.0314	0.0110
FAST8 decay tuned (Hz)	0.0082	0.0533	0.0322	0.0100

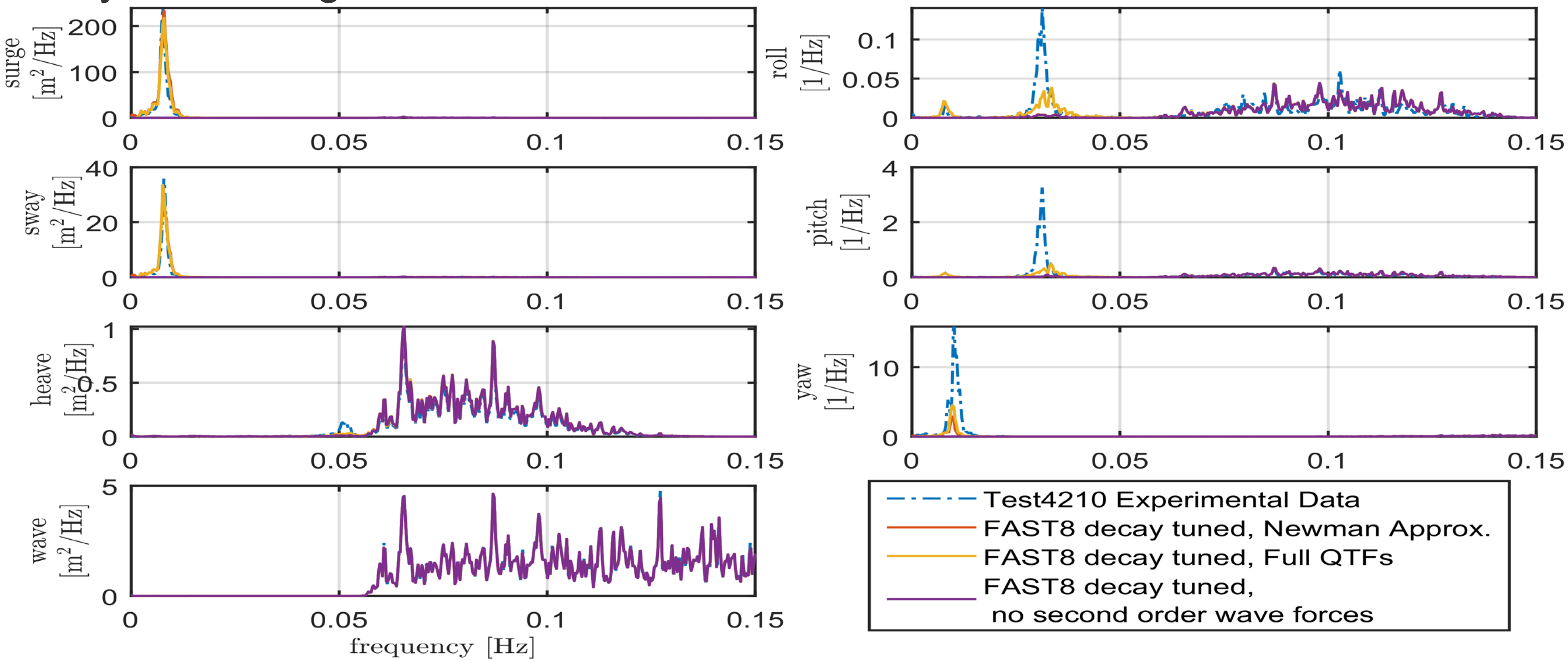
Pull-out test



- Pull-out tests to check if the mooring lines used in the simulation model are representative to the wave test model.
- The tension of two different lines show that the model is representative.
- The changes in the mooring lines specific mass is acceptable.

Pink noise wave spectra test

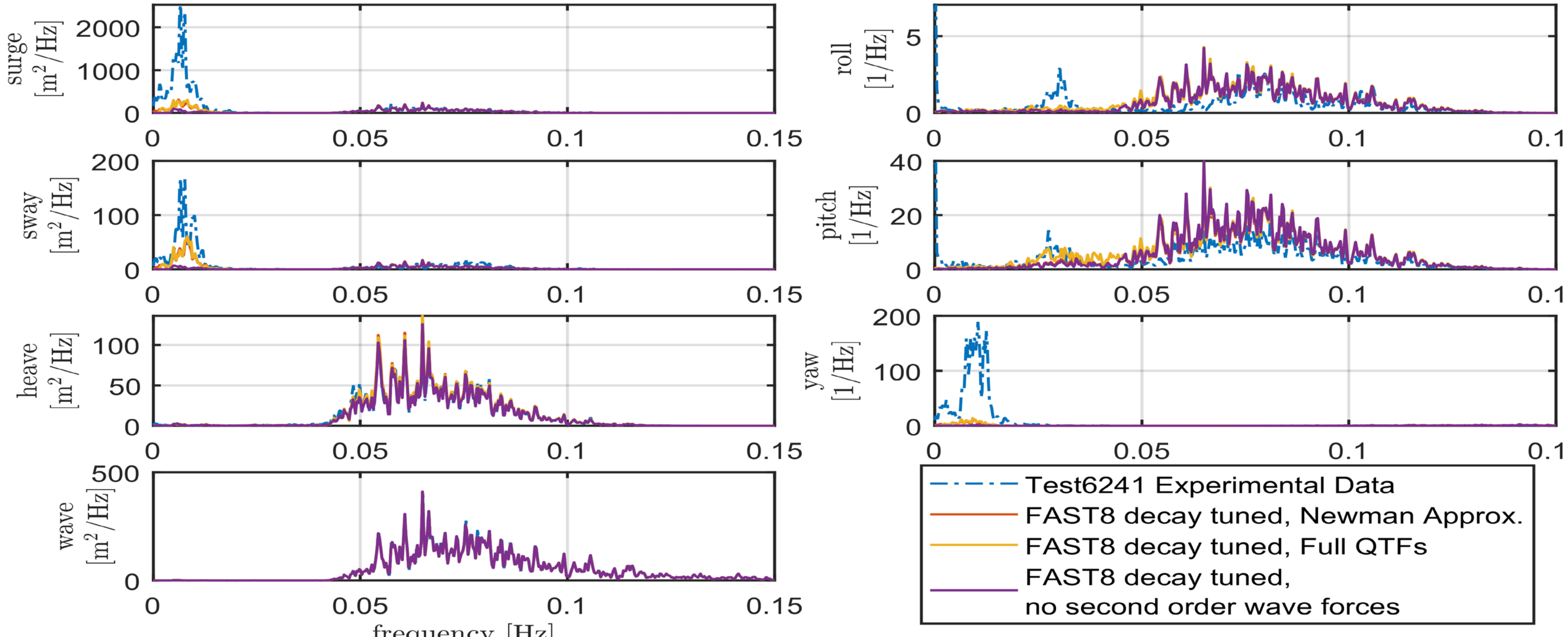
Decay tuned drag coefficient



- Without the second order QTF the simulation cannot capture the low frequency responses.
- Heave, pitch, roll and yaw responses are under estimated.
- The model is over damped.

Extreme irregular wave test

Decay tuned drag coefficient



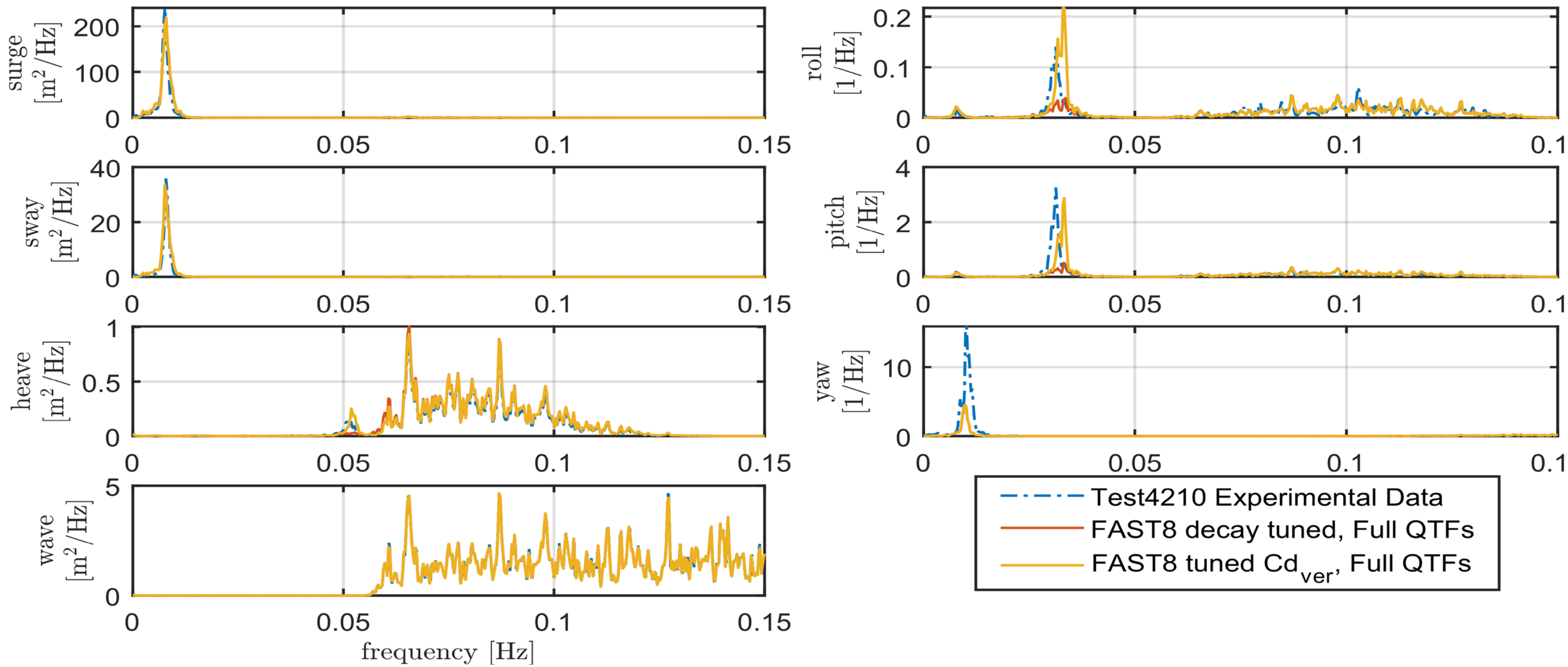
- All DOFs except heave are under estimated.
- The model is again over damped for low frequencies.
- At wave frequency the model over estimates the pitch response.

Load case specific drag coefficient

- The decay tuning is over damping the simulation.
- Load case tuning for different tests is required.
- Vertical drag coefficient tuning is done for pink noise wave spectra test.
- Both vertical and horizontal drag coefficient tuning for extreme irregular wave test.

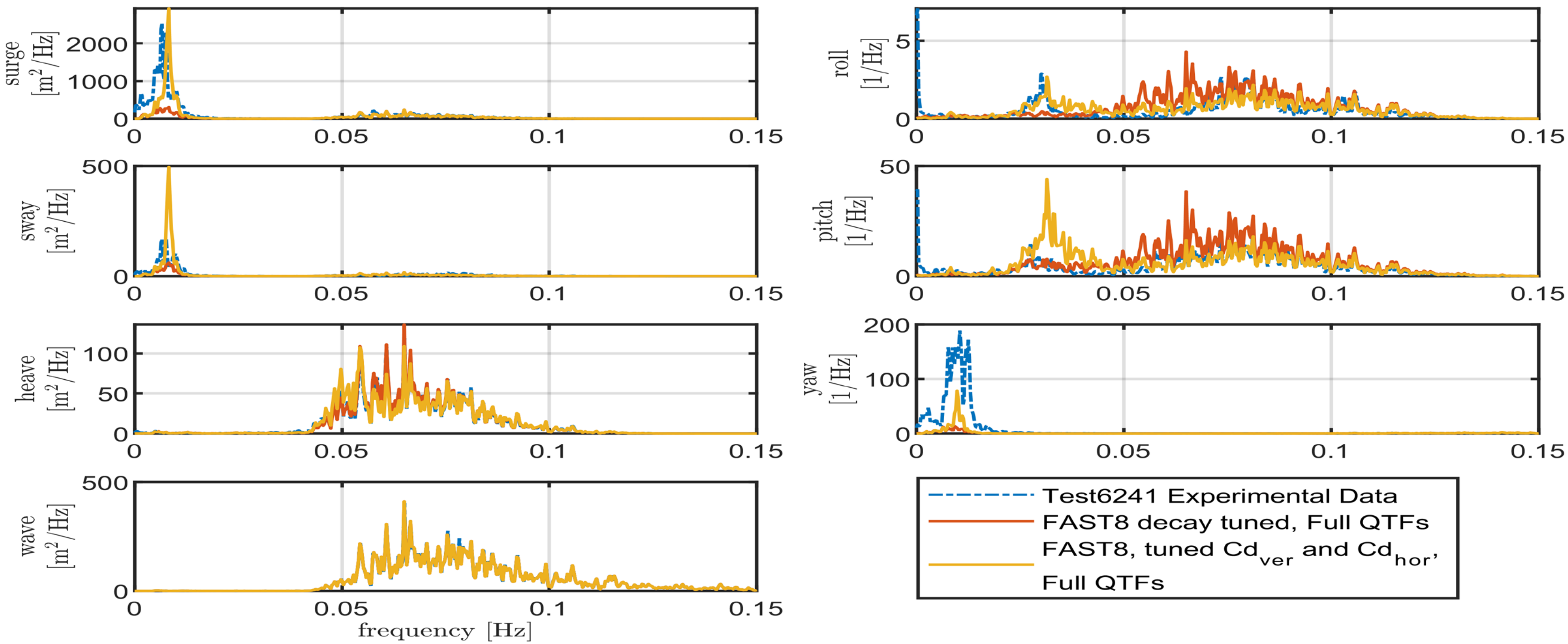
Model	$Cd_{ver\ col}$	$Cd_{ver\ pon}$	$Cd_{hor\ col}$	$Cd_{hor\ pon}$
Decay tuned (Combination of all decay tests)	78.05	12.95	0.715	2.05
Pink noise tuned Cds	23.415	3.885	0.715	2.05
Extreme irregular wave tuned Cds	31.22	5.18	0.5125	0.1787

Pink noise wave spectra test



- Results are better with load case tuning.
- The model is able to capture all DOFs within acceptable range except for the yaw motion.

Extreme irregular wave test



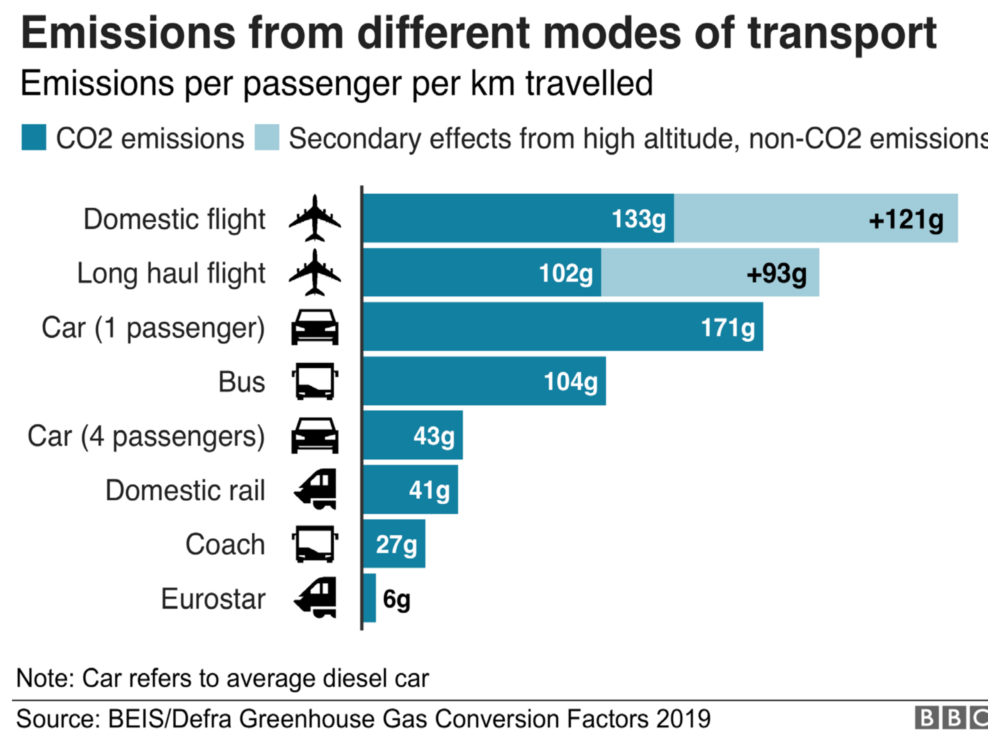
- The model is unable to capture the responses with acceptable precision.
- Surge, sway and pitch motions are over estimated.
- Yaw motion is under estimated.
- The model shows better response for pitch at wave frequency.

Conclusion

- The use of difference frequency full QTF increased the response of the platform for the low frequency region.
- The load case dependent tuning process, gave good results for the pink noise wave spectra test. However, it didn’t work for the extreme irregular wave test.
- The decrease of the Morison drag coefficients, lead to an increase of the response at low frequencies. On the other hand, it decreased the response at wave frequency. This is due to the fact that Morison equation has both damping and forcing effects.
- For future work the validation with the aerodynamics included will be done.

Lets cut carbs

- Voluntary commitment to refrain from short-haul business flights “I won’t do it under 1,000 km”
- https://unter1000.scientists4future.org/



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LIFES50+

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