

Challenging wind and waves

Linking hydrodynamic research to the maritime industry

EERA DEEPWIND'2015

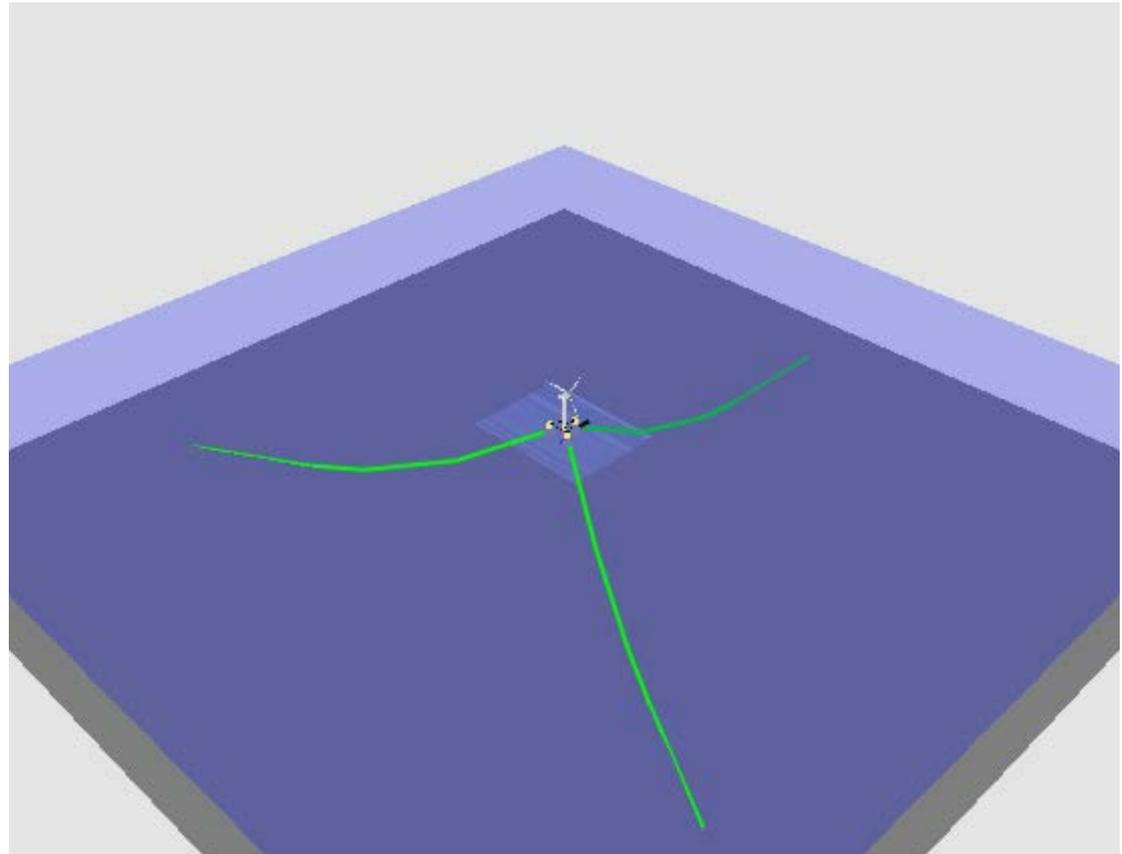
**VERIFICATION OF THE SECOND-ORDER WAVE LOADS
ON THE OC4-SEMISUBMERSIBLE**

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Maritime Research Institute of the Netherlands (MARIN)

BACKGROUND: FOLLOW-UP OMAE2014-23398

- OC4 (NREL)
- OC4-semi
- Rigid body
- LC2.2, only wave:
 - JONSWAP, $\gamma = 2.87$
 - $H_s = 6$ m, $T_p = 10$ s
- 2d order:
 - Excitation
 - Response
- Comparison of:
 - {DIFFRAC + aNySIM}
 - {WAMIT + FAST}



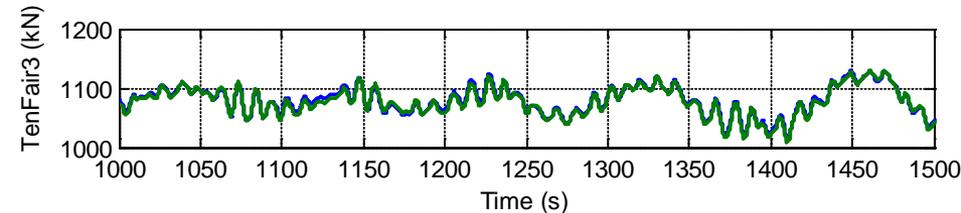
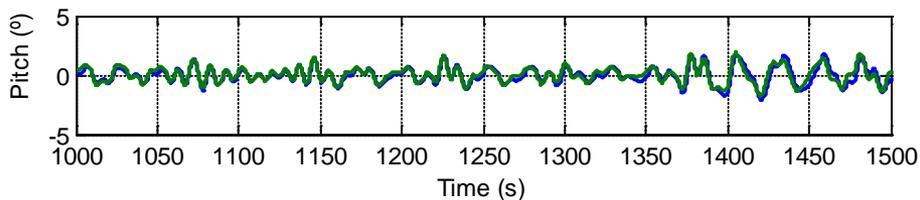
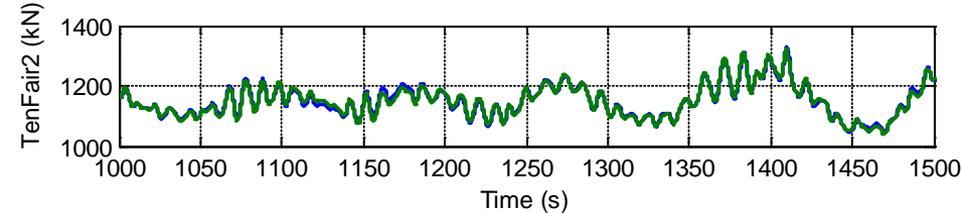
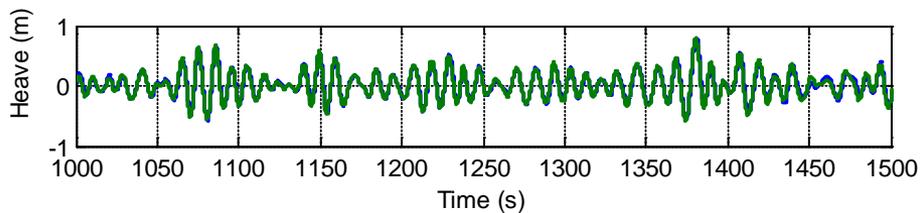
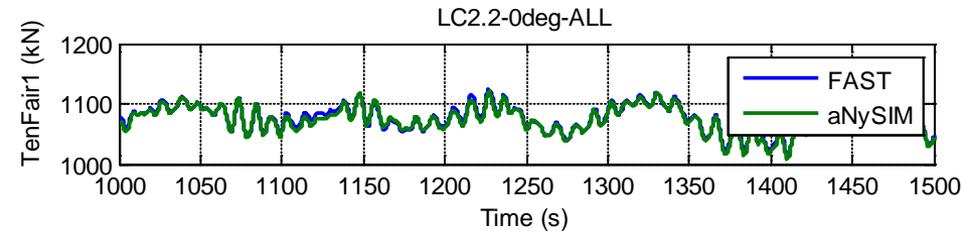
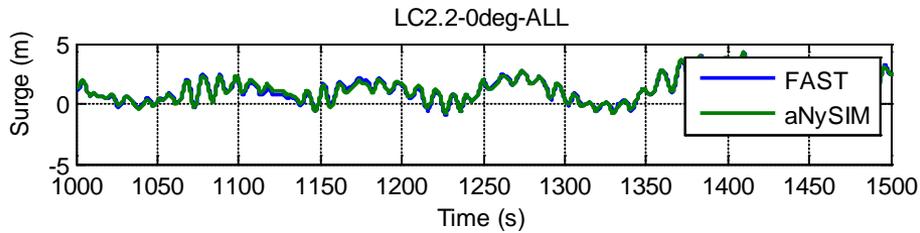
LC2.2 with 2d order excitation loads

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Dipartimento di Meccanica, Politecnico di Milano
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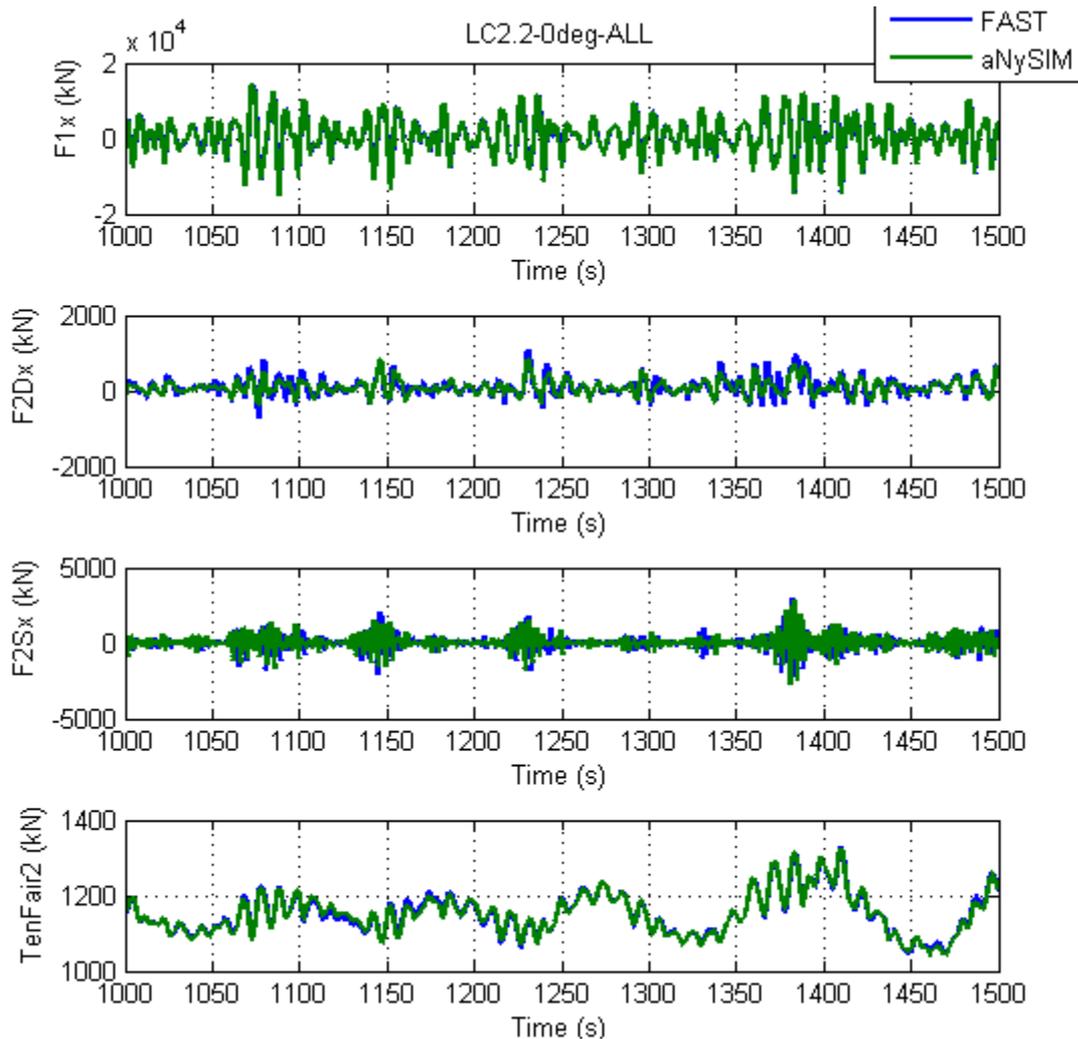
COMPARISON FOR 1ST & 2^D ORDER LOADS

- LC2.2-ALL: All wave loads (1st and 2^d)

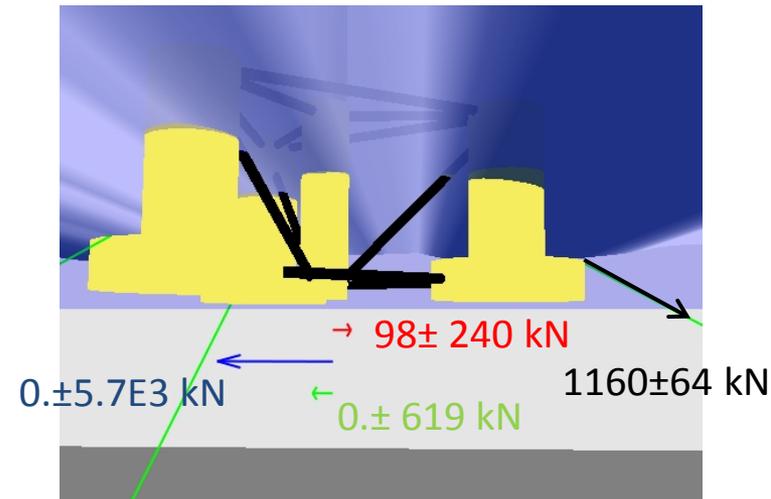


- aNySIM and FAST give very similar results

STUDY OF 1ST & 2^D ORDER LOADS

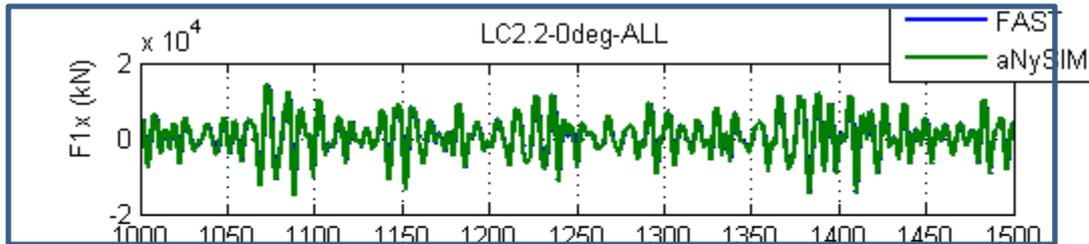


Effects of loads in surge on the tension

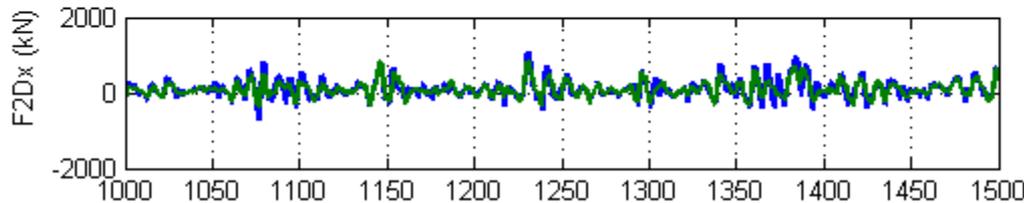


- All excitation forces in surge and tension in line 2

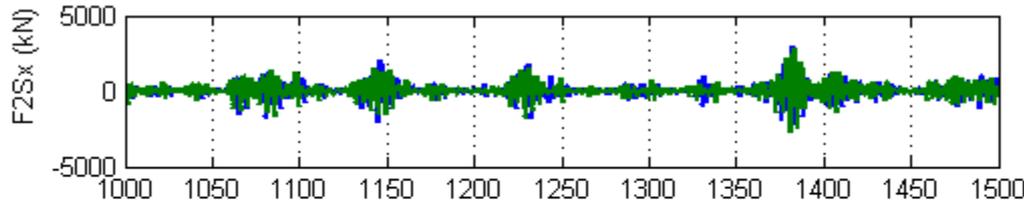
STUDY OF 1ST & 2^D ORDER LOADS



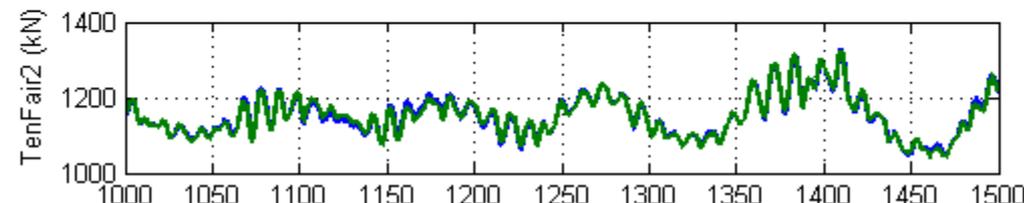
Time (s)



Time (s)

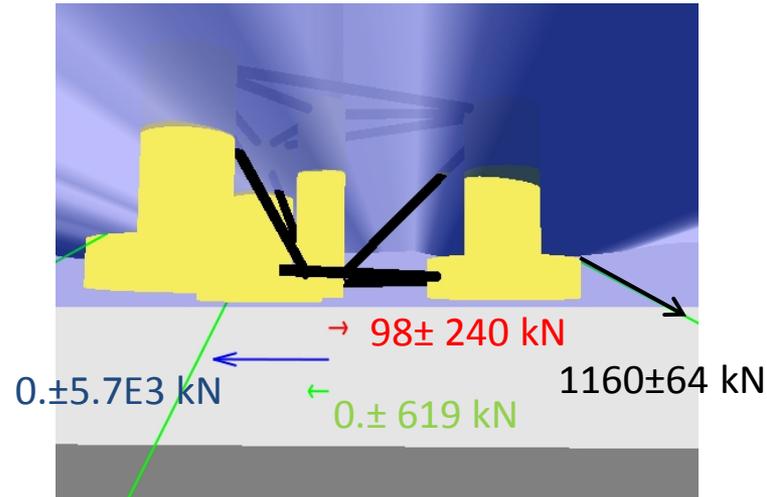


Time (s)



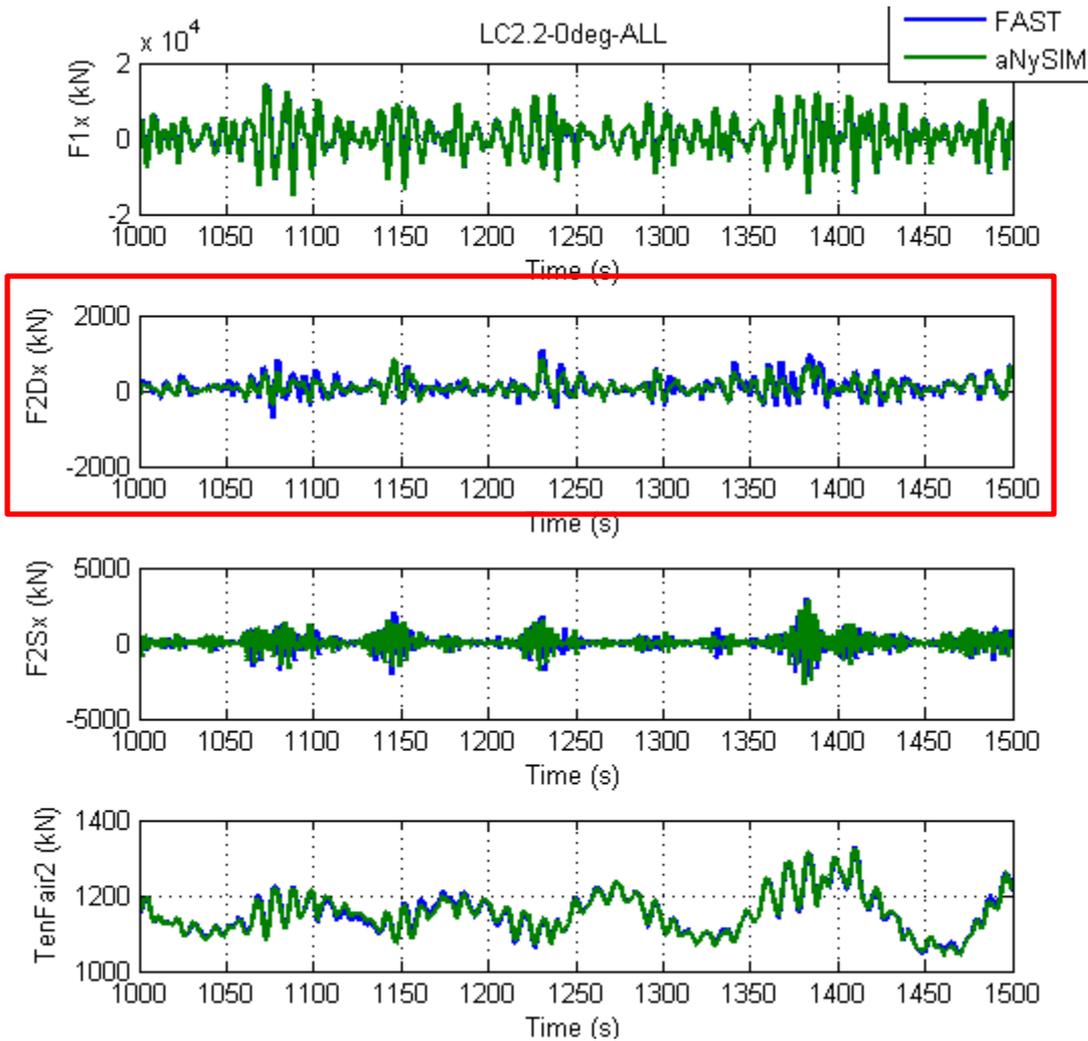
Time (s)

Effects of loads in surge on the tension

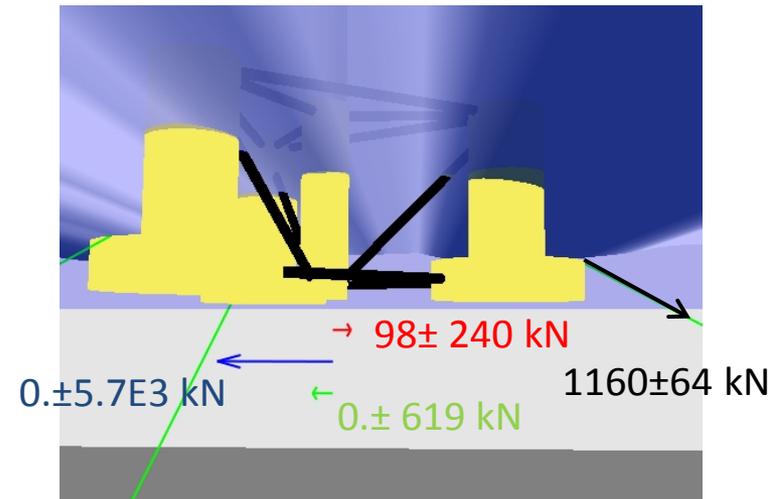


- Wave 1st order surge excitation

STUDY OF 1ST & 2^D ORDER LOADS

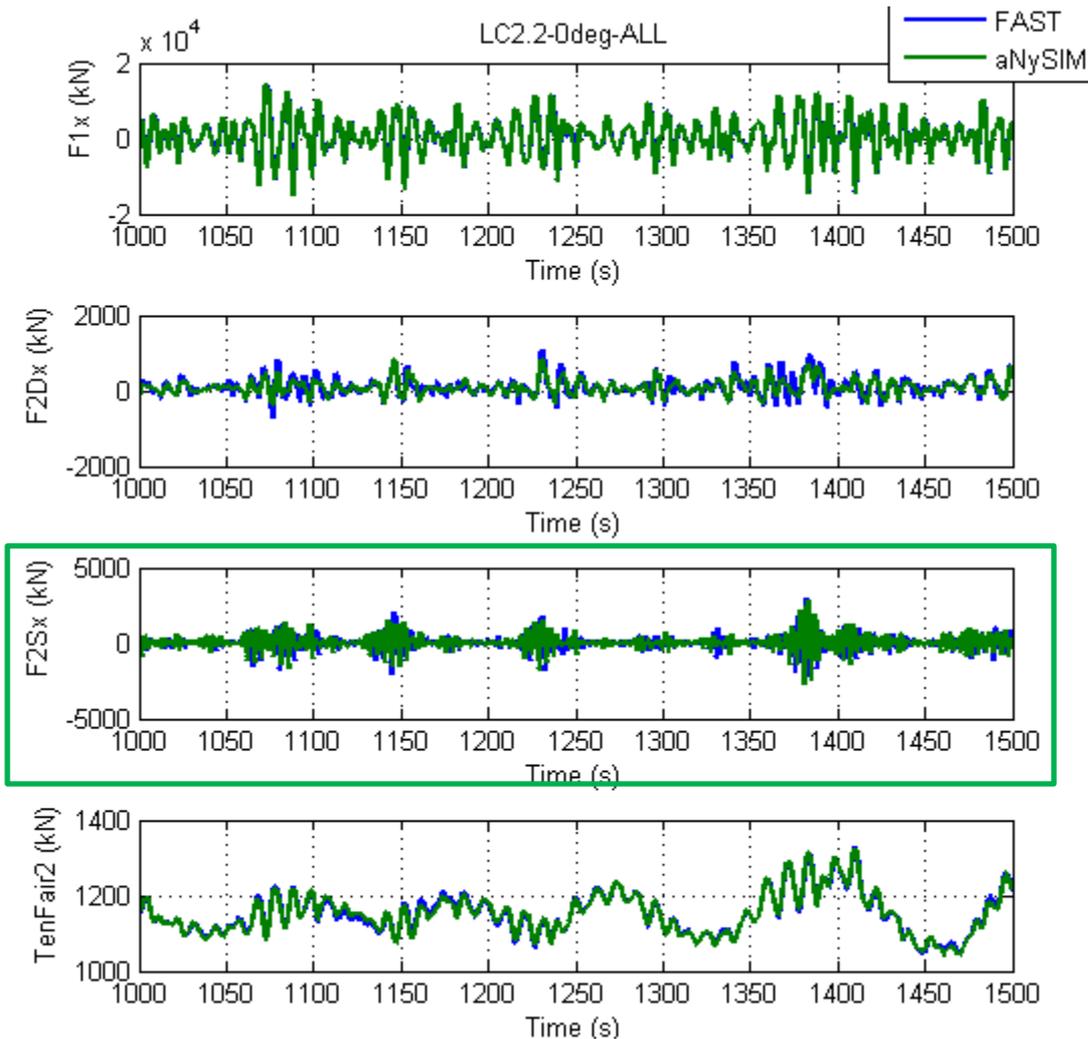


Effects of loads in surge on the tension

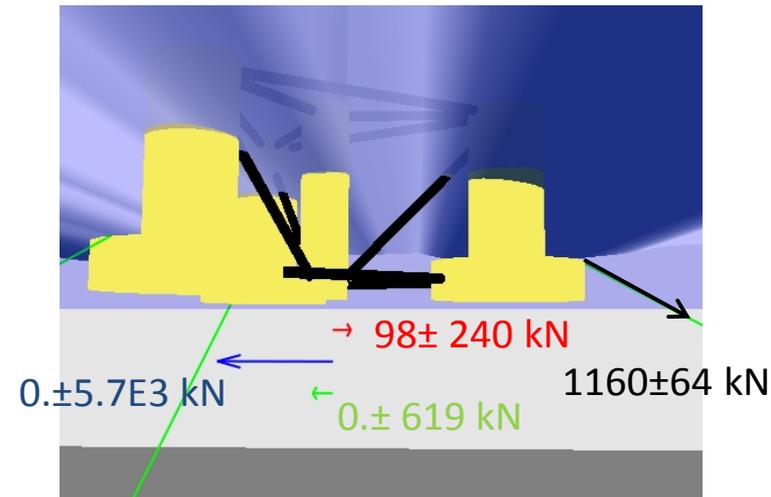


- Wave 2^d order difference frequency surge excitation

STUDY OF 1ST & 2^D ORDER LOADS

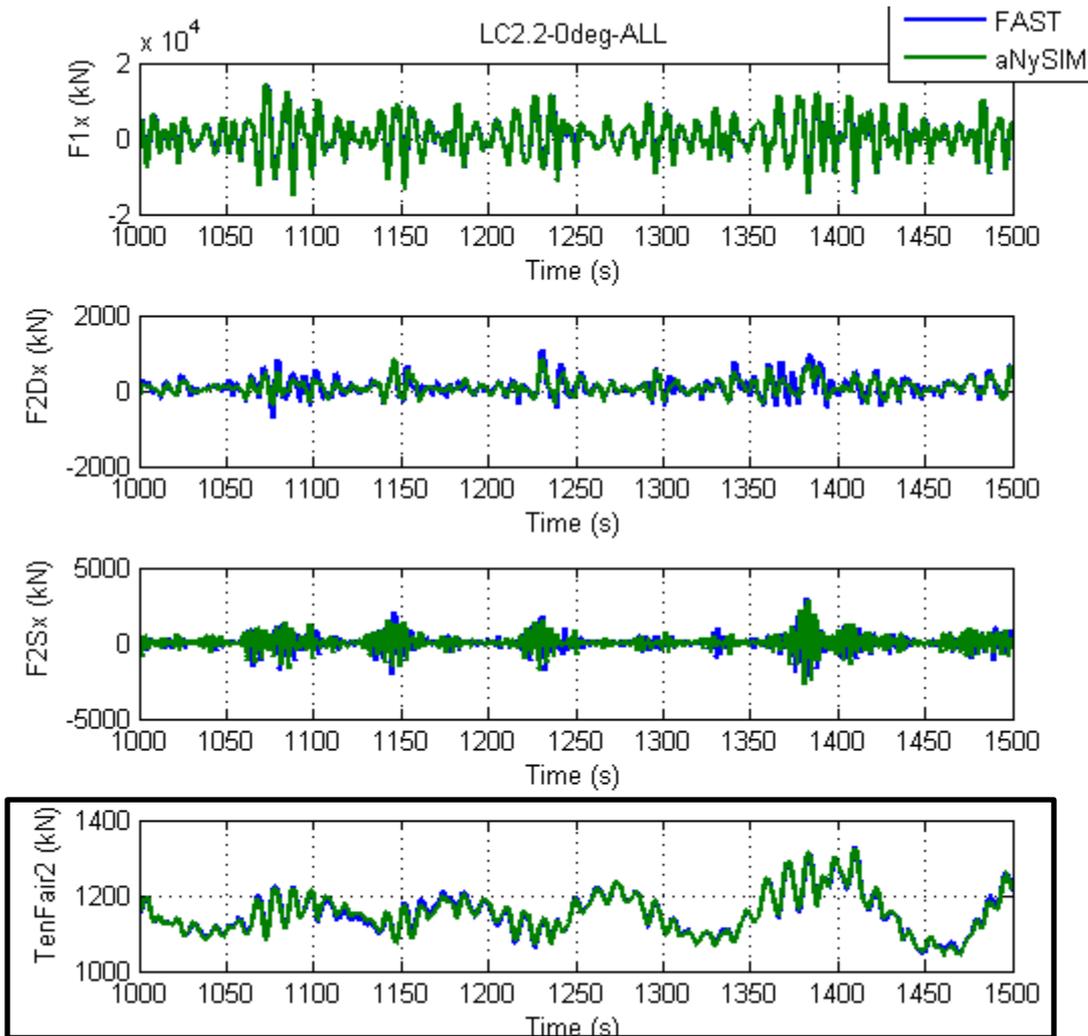


Effects of loads in surge on the tension

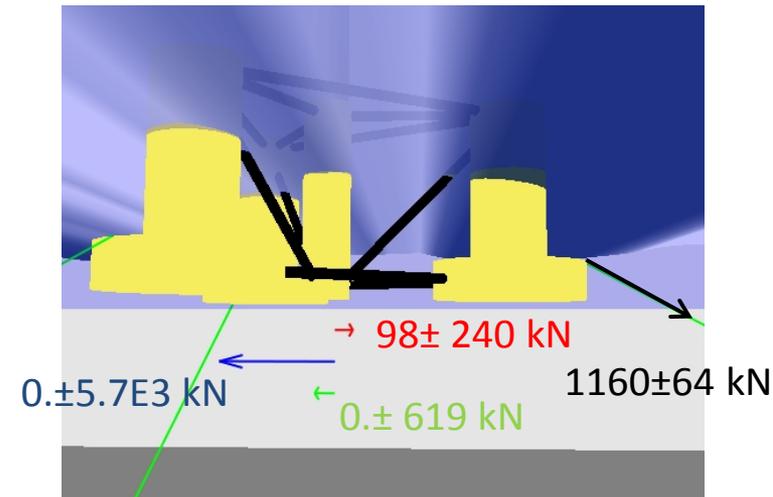


- Wave 2^d order sum frequency surge excitation

STUDY OF 1ST & 2^D ORDER LOADS

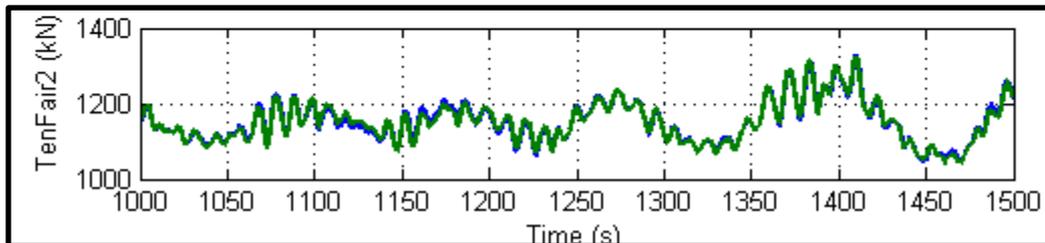
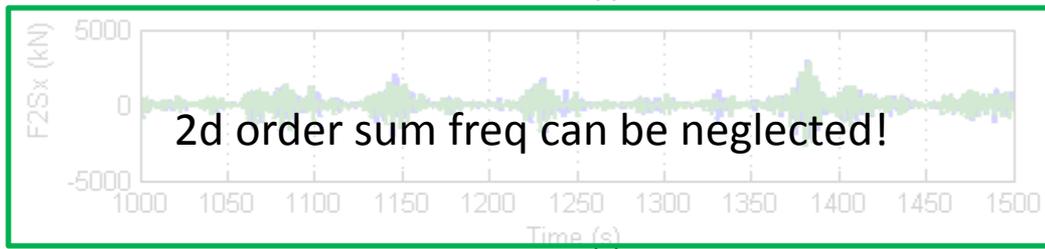
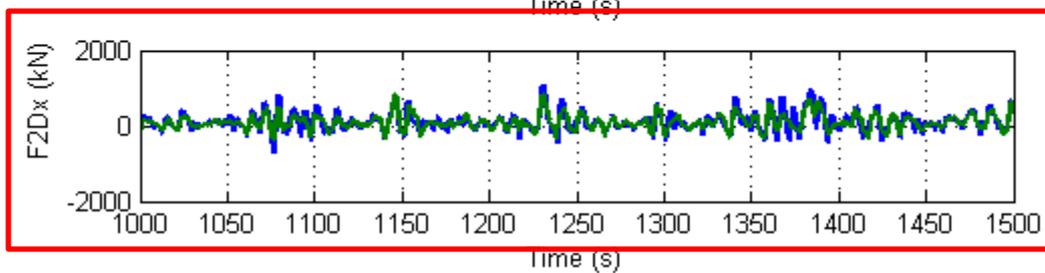
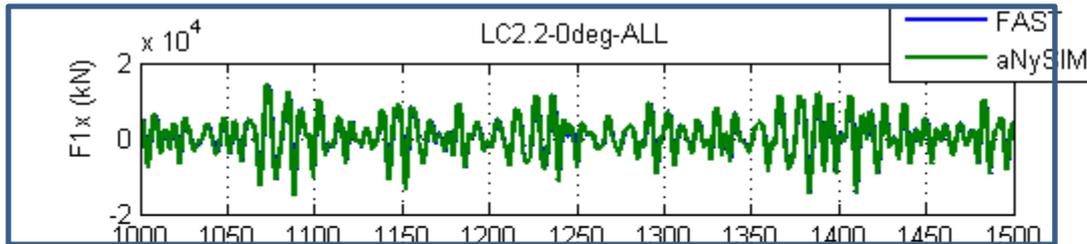


Effects of loads in surge on the tension

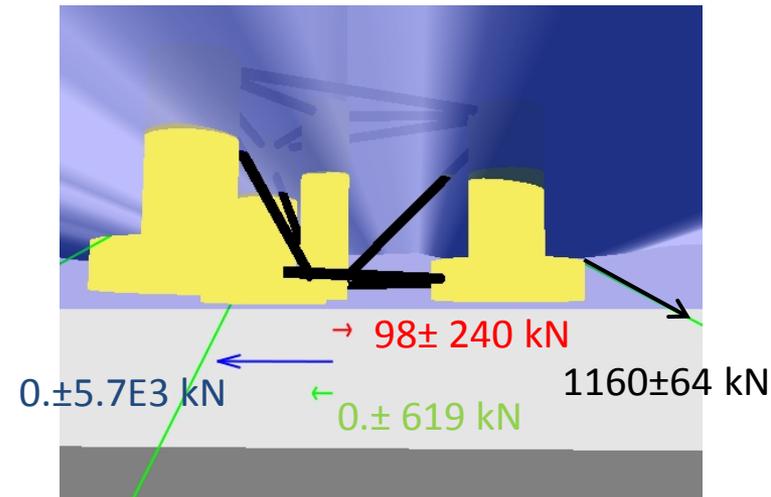


- Tensions follow the drift motion + wave motion

STUDY OF 1ST & 2^D ORDER LOADS

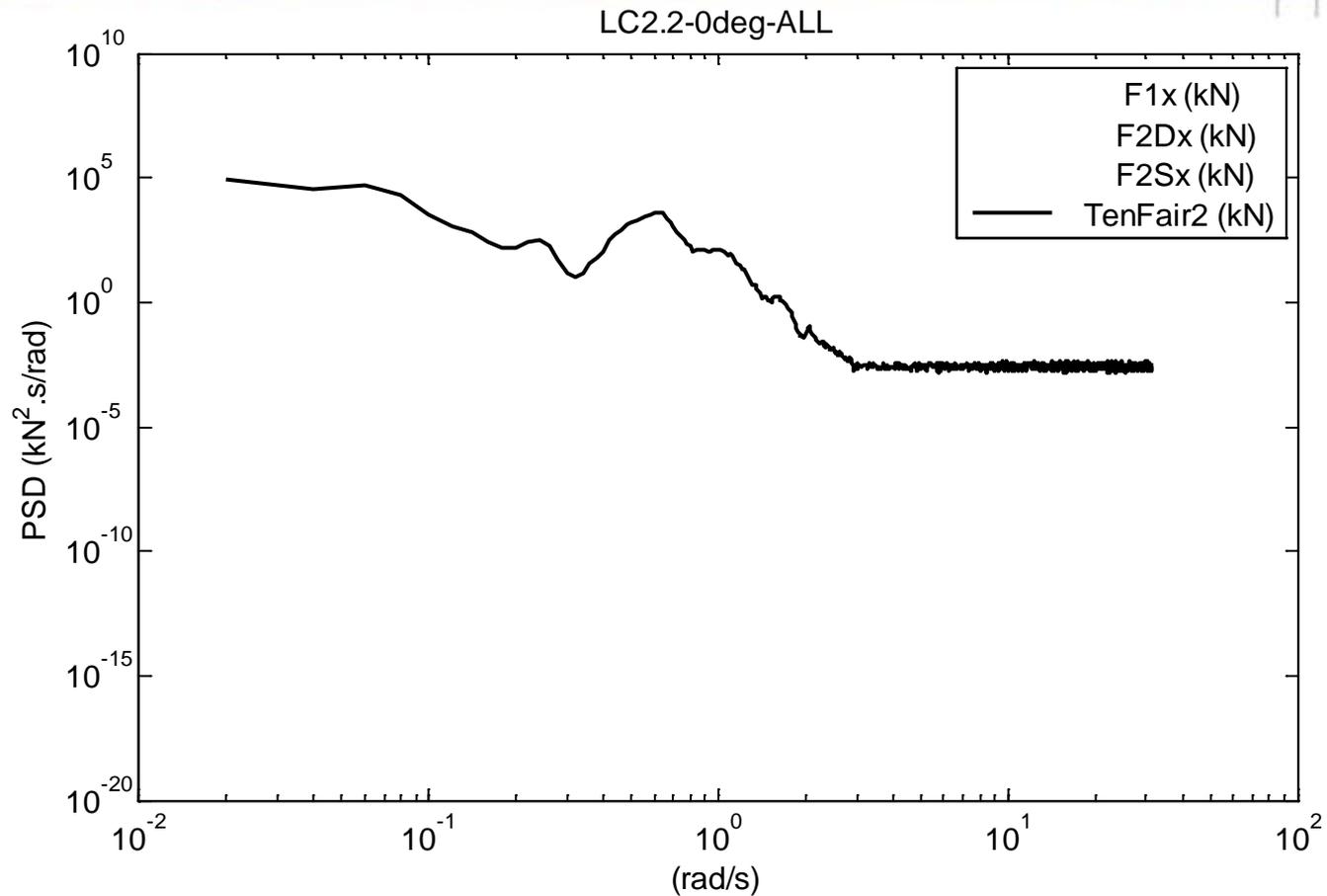


Effects of loads in surge on the tension

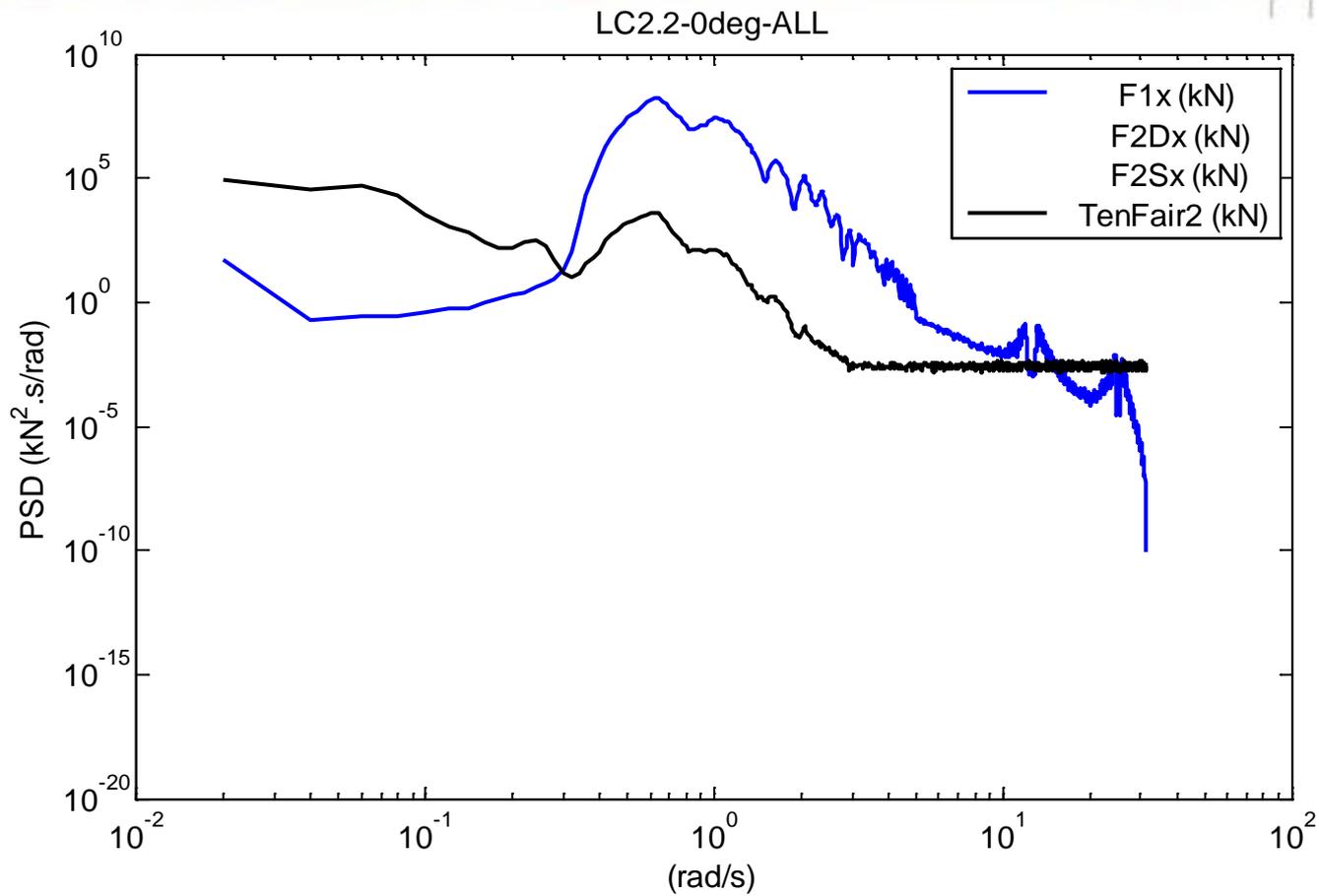


- Tensions follow the drift motion + wave motion (little effects of sum freq.)

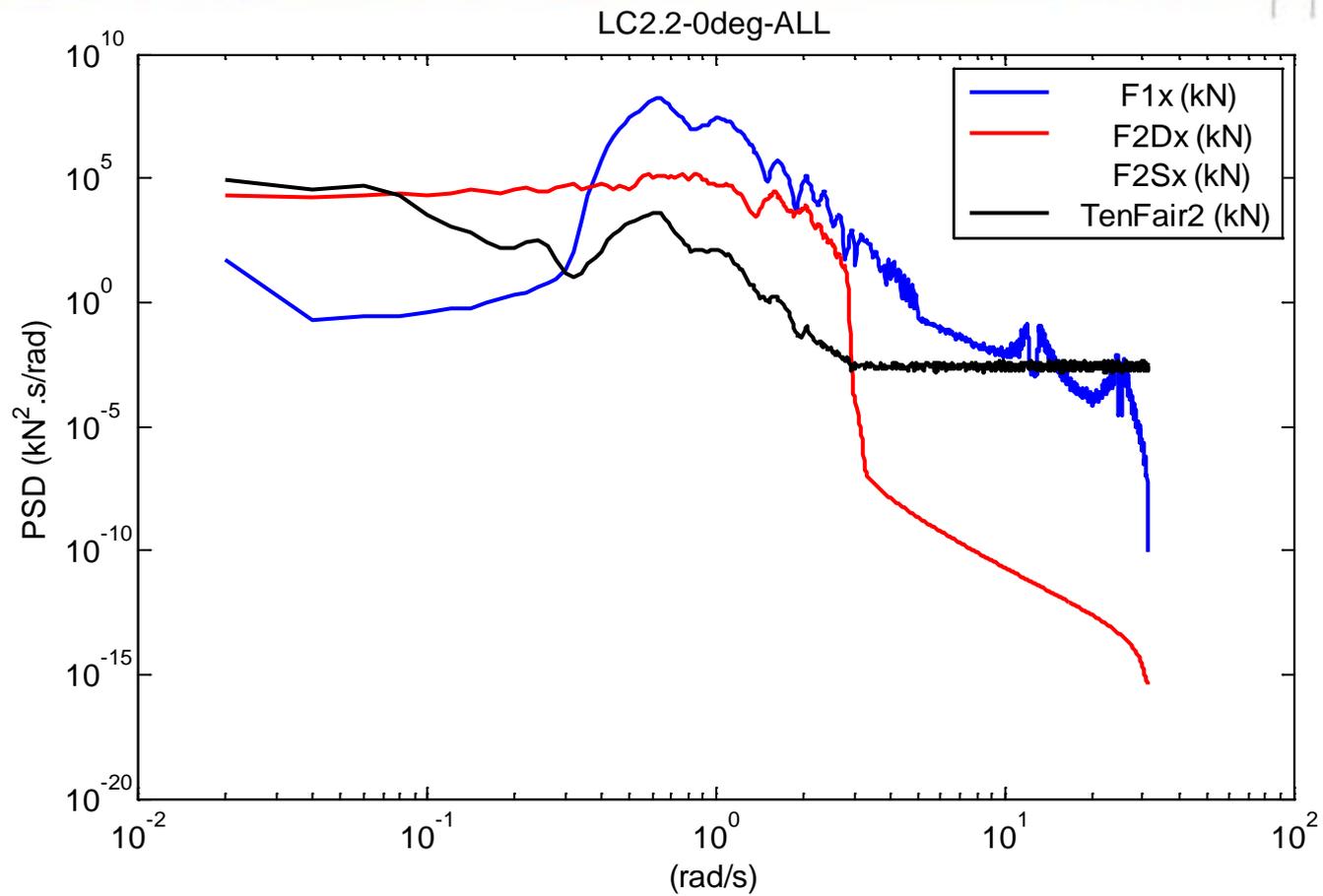
SPECTRAL ANALYSIS OF LC2.2 WITH 2^D ORDER LOADS



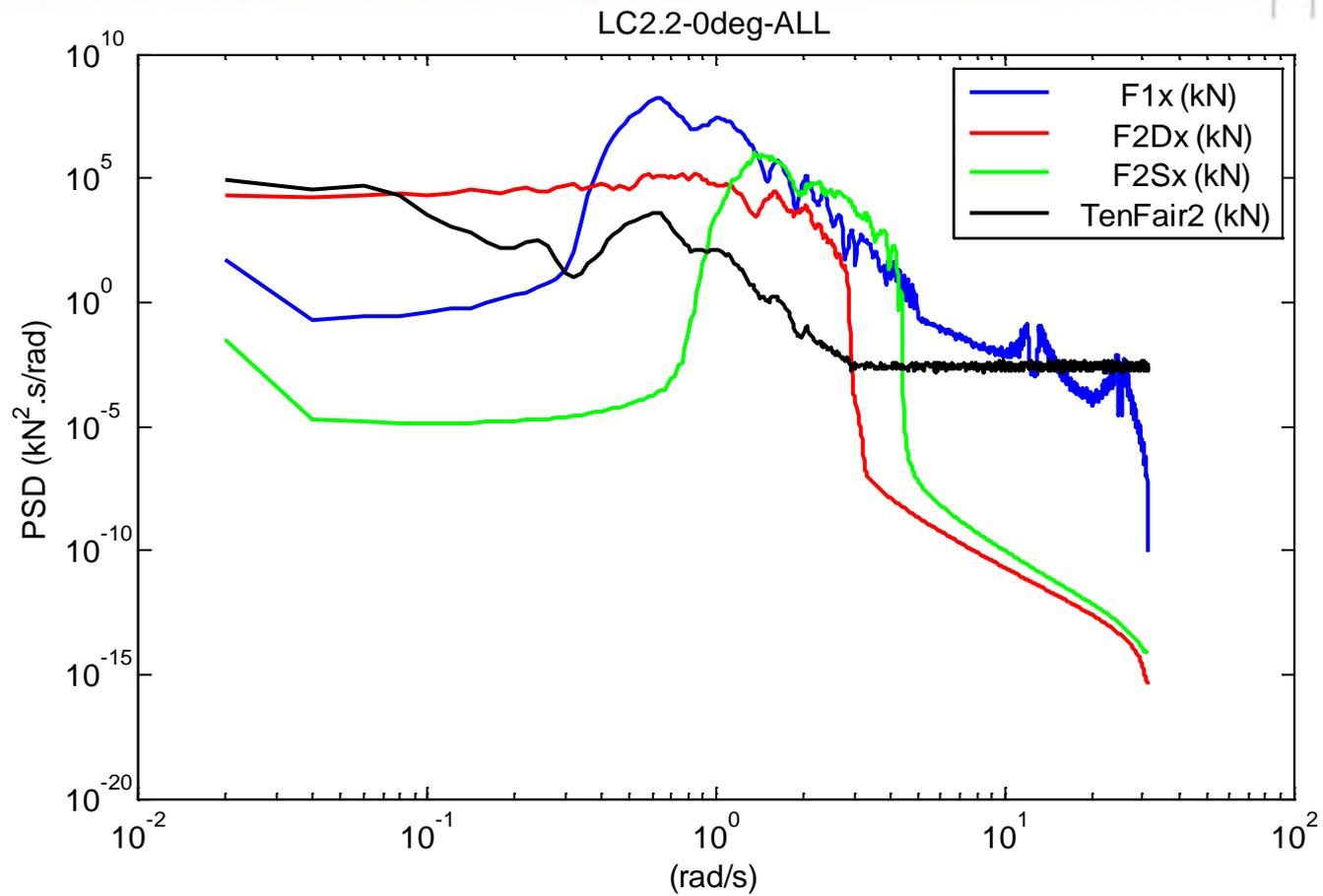
- Tension in mooring line 2 at fairlead (Power Spectral Density)



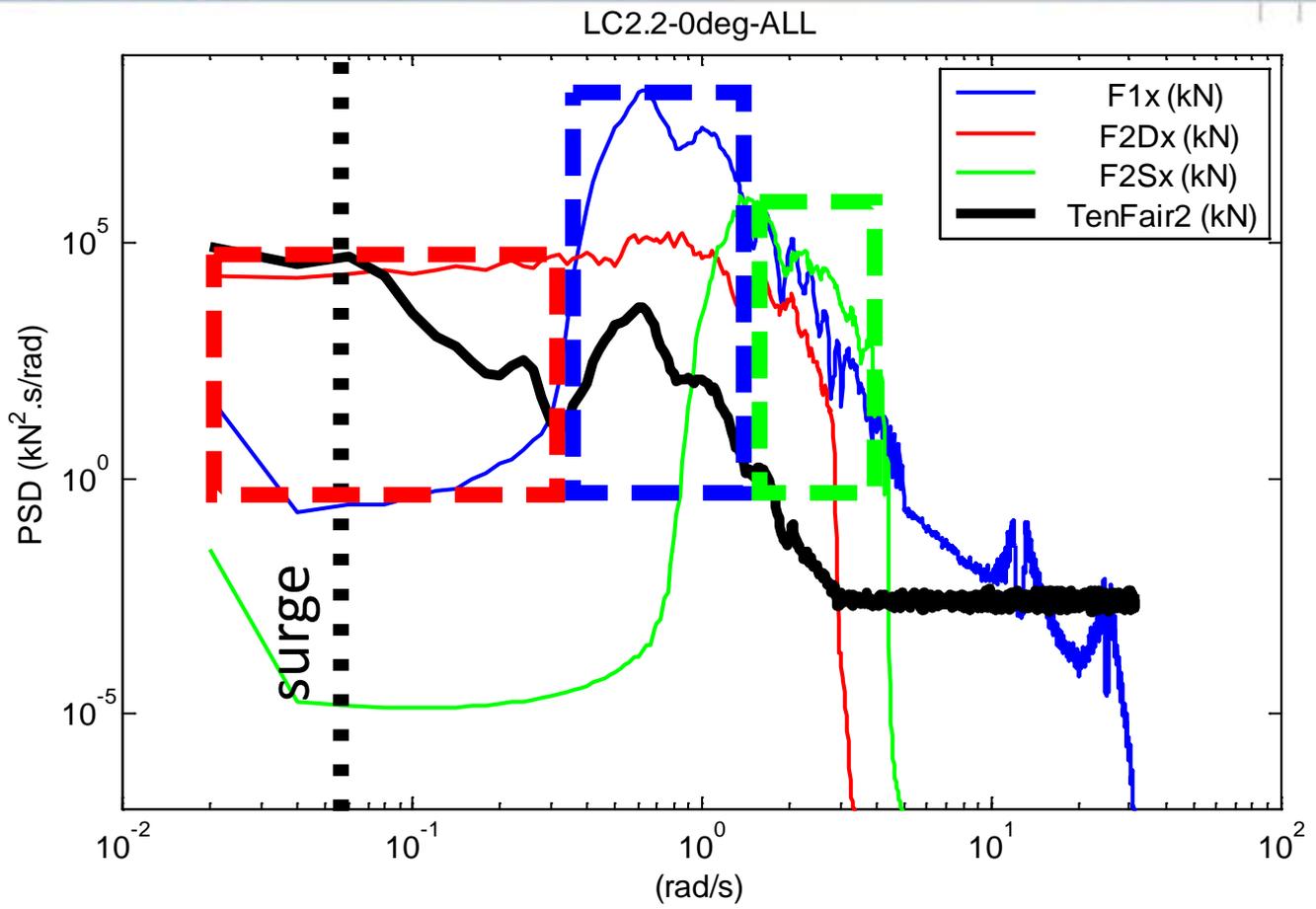
- + 1st order wave loads in surge (PSD)



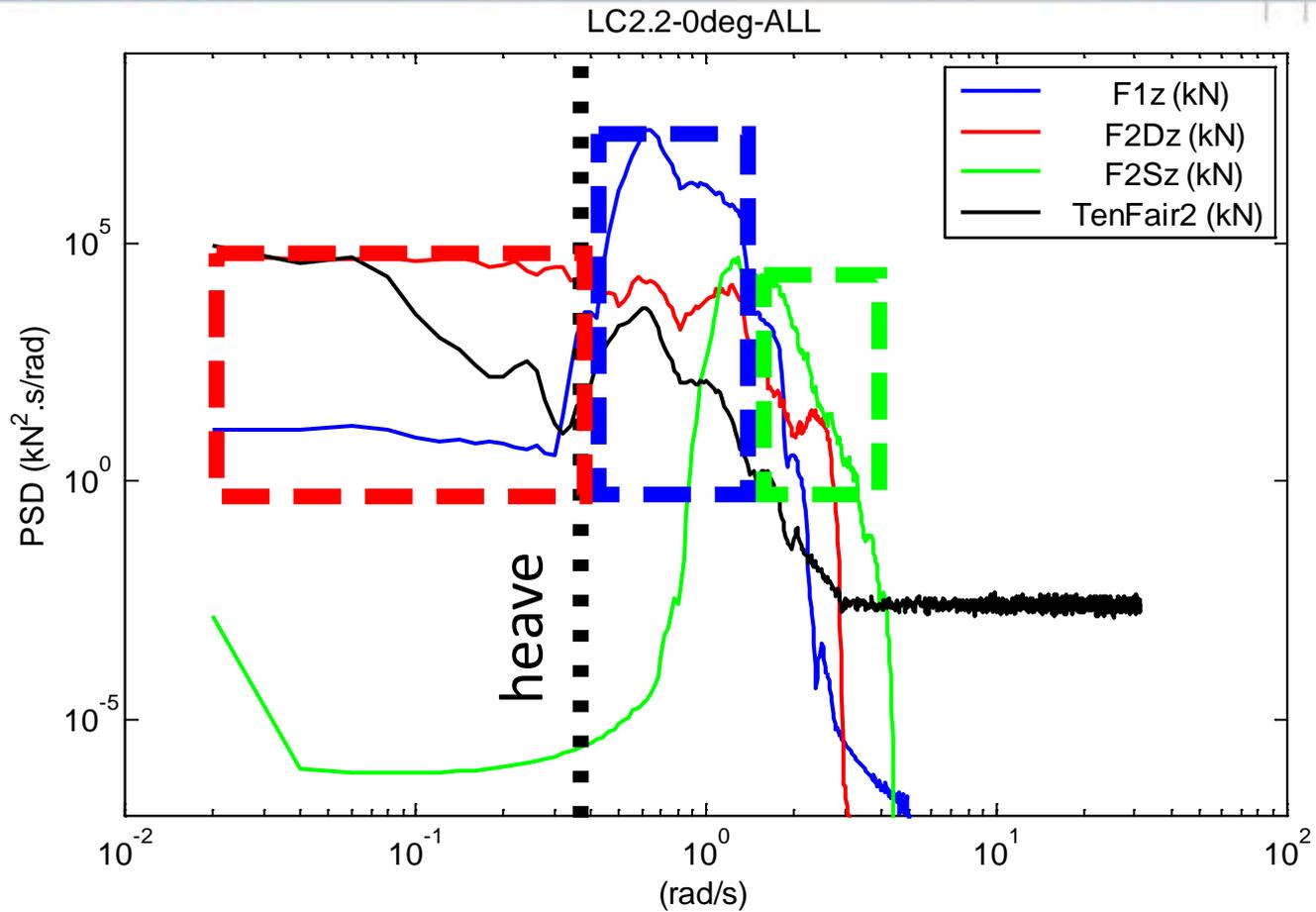
- + 2^d order difference frequency wave loads in surge (PSD)



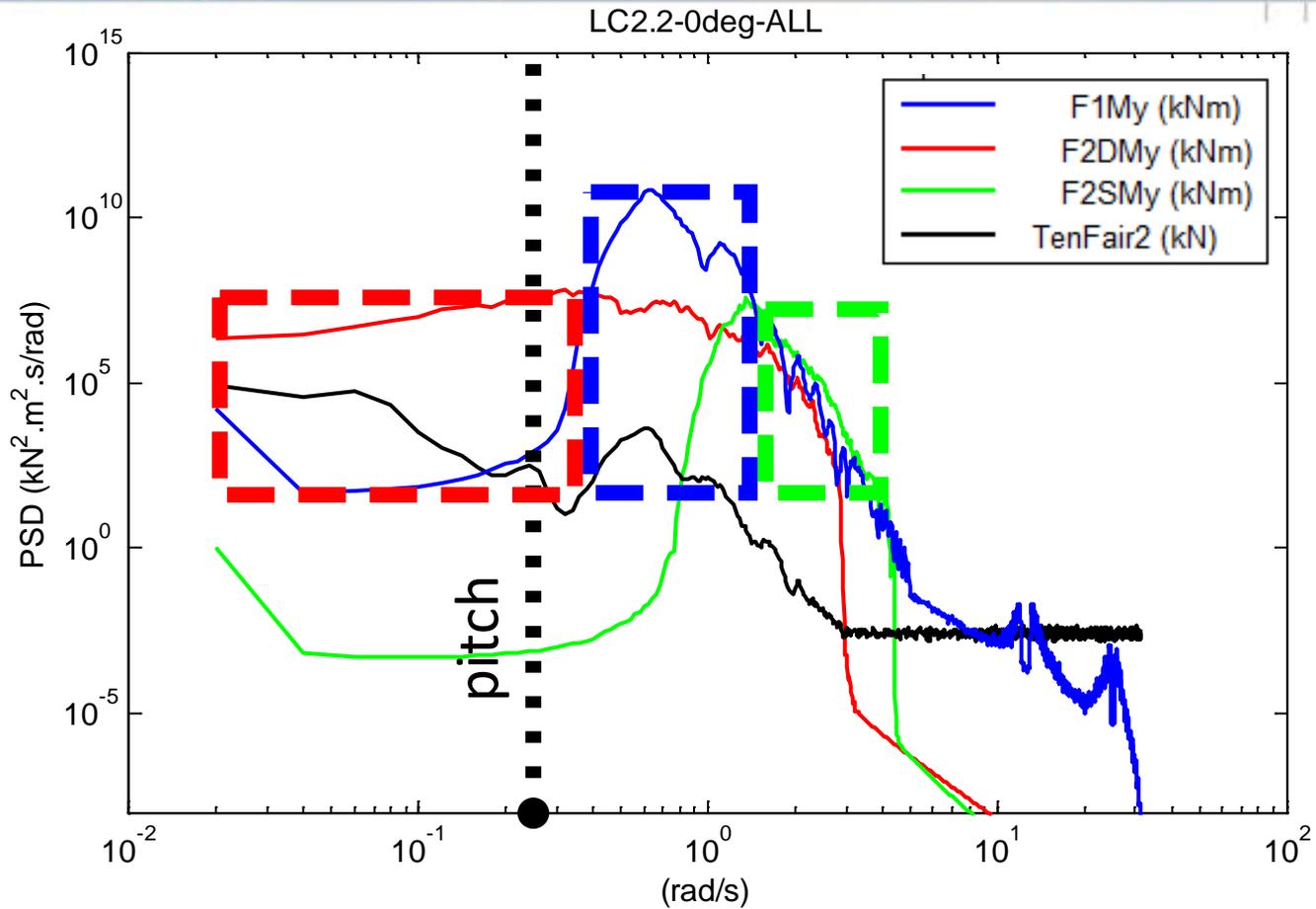
- + 2^d order sum frequency wave loads in surge (PSD)



- + eigen frequency in surge



- Same graphic for heave => influence of 2^d order diff freq



- Same graphic for pitch => influence of 2^d order diff freq

Code comparison:

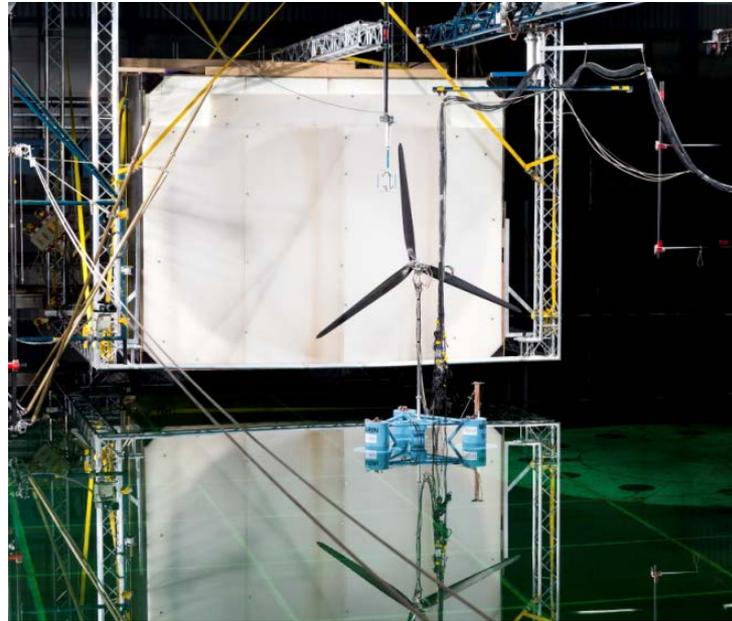
- Approach to compare the 2^d order load (ex: OC4-semi, rigid)
- {WAMIT+FAST} \approx {DIFFRAC+aNySIM} for 1st & 2^d order loads.

For the OC4-semi (rigid, WD=200 m, spread-moored):

- Sum-frequency 2^d order loads can be neglected.
- Difference-frequency 2^d order loads cause mooring line tension variations.
- Difference-frequency 2^d order loads have an effect on the heave and **pitch** motion (when a full QTF is used).

Check against measurements:

- OC5 model-tests of UMaine & NREL at MARIN in 2013



- Do we see:
 - Surge drift?
 - Second-order response in heave and pitch?

DIFFERENCES BETWEEN OC4 & OC5 (MT)

	OC4	OC5 as built
Nacelle	<<	
Total mass	14072 t	14040
Pitch radius of inertia /G	28.27 m	33.38
Surge natural period	113.2 s	105.3 s
Heave natural period	17.0 s	17.3s
Pitch natural period	25.1 s	32.2 s

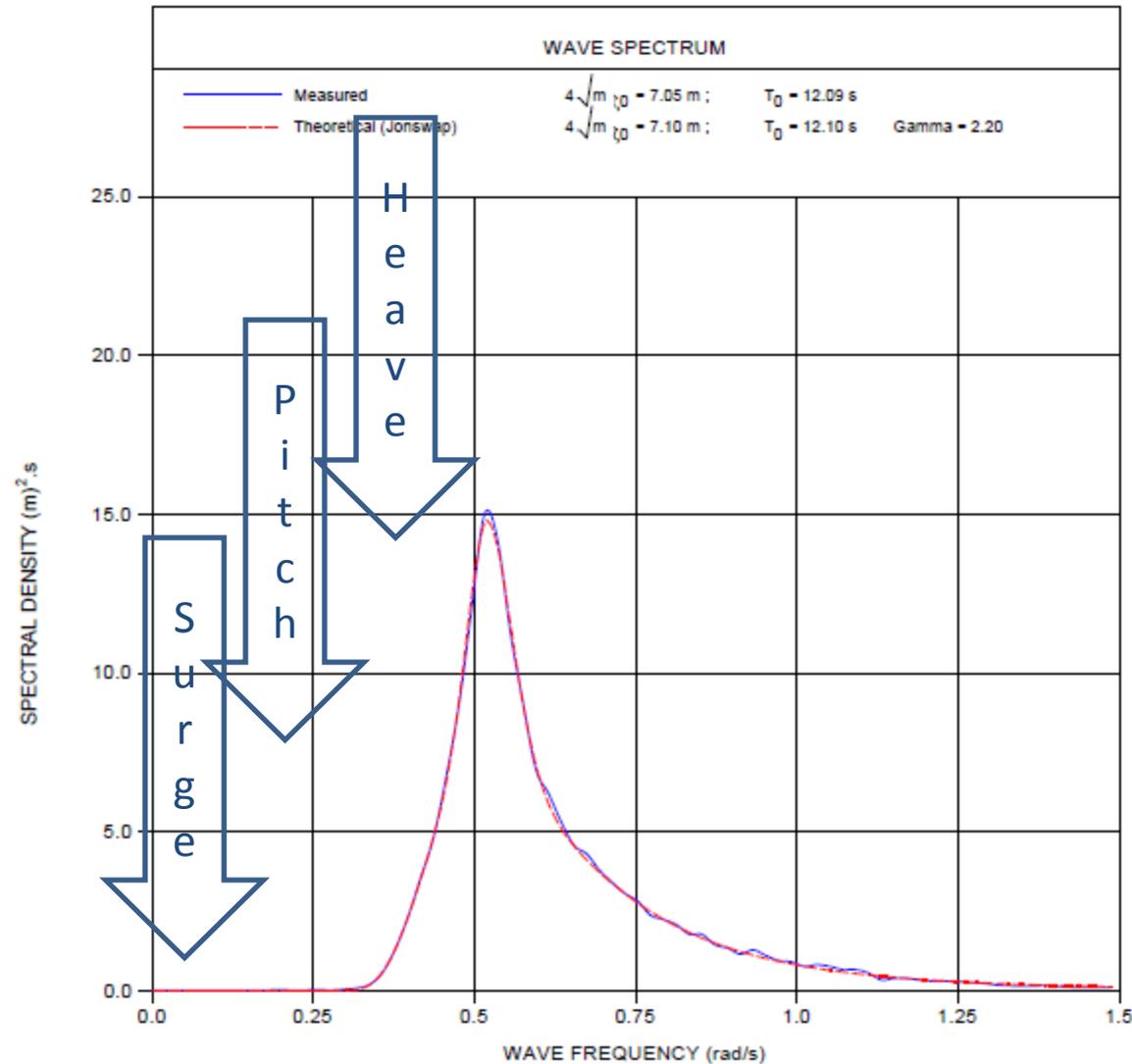
Eigen frequencies (rad/s)	OC4	OC5 as built
Surge	0.05	0.06
Heave	0.37	0.36
Pitch	0.25	0.20

MODEL TEST

Operational wave

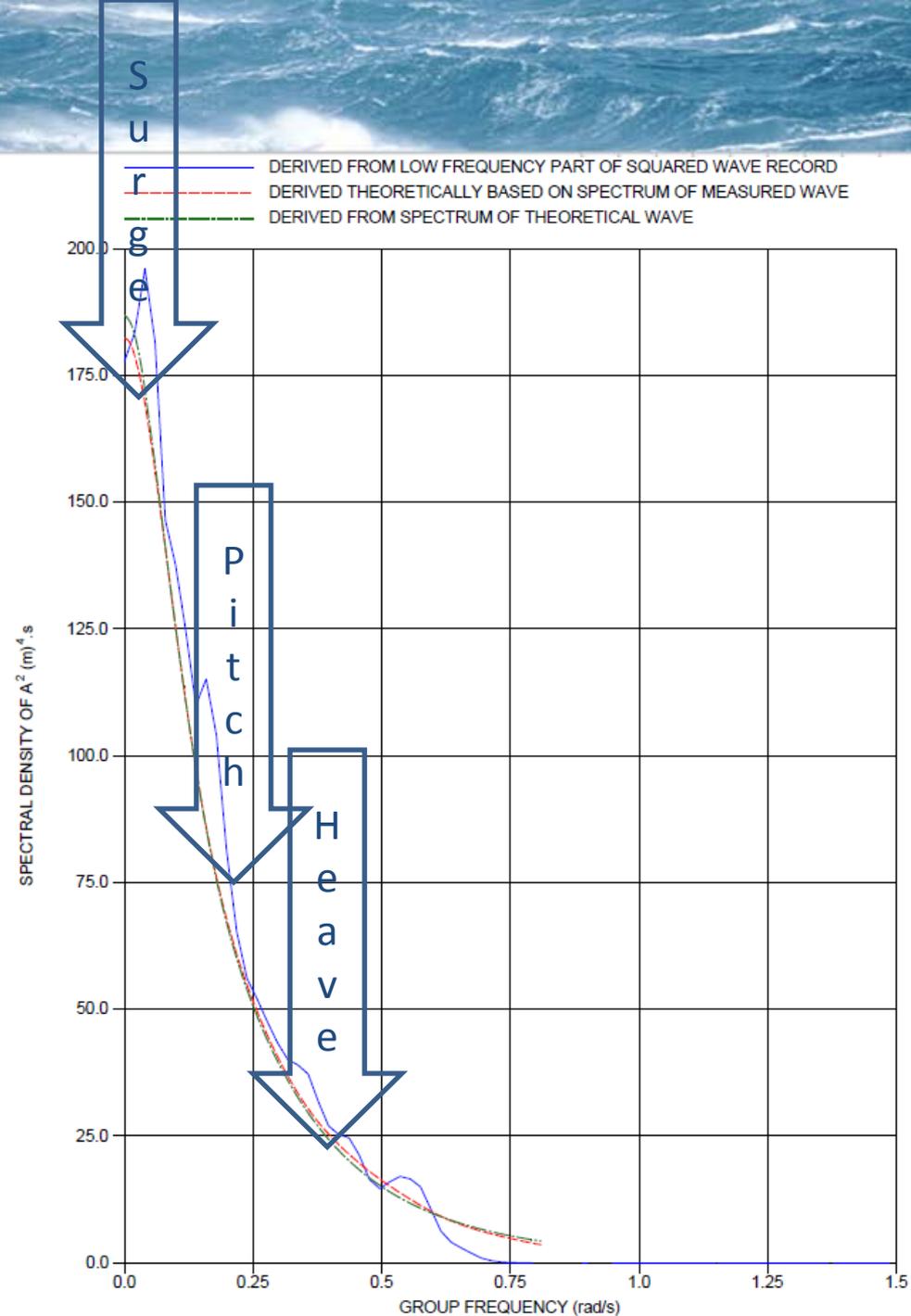
- JONSWAP
- $H_s = 7.1$ m
- $T_p = 12.1$ s
- $\Gamma = 2.2$

No wind



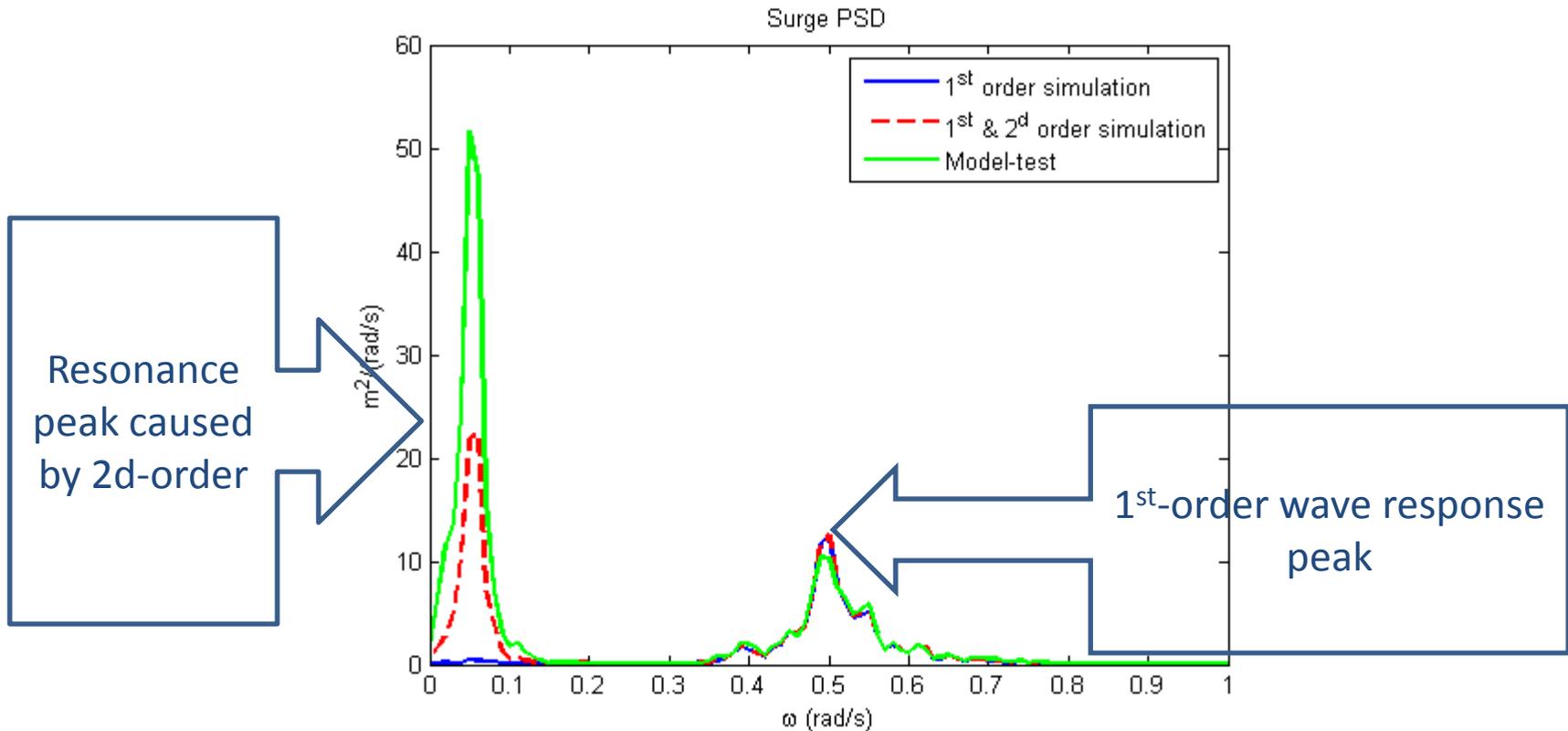
MODEL TEST

- Focus on low-frequent wave excitation
- Interested in frequencies below 0.35 (rad/s)



COMPARISON WITH MODEL-TESTS

Power Spectrum Density of the surge motion

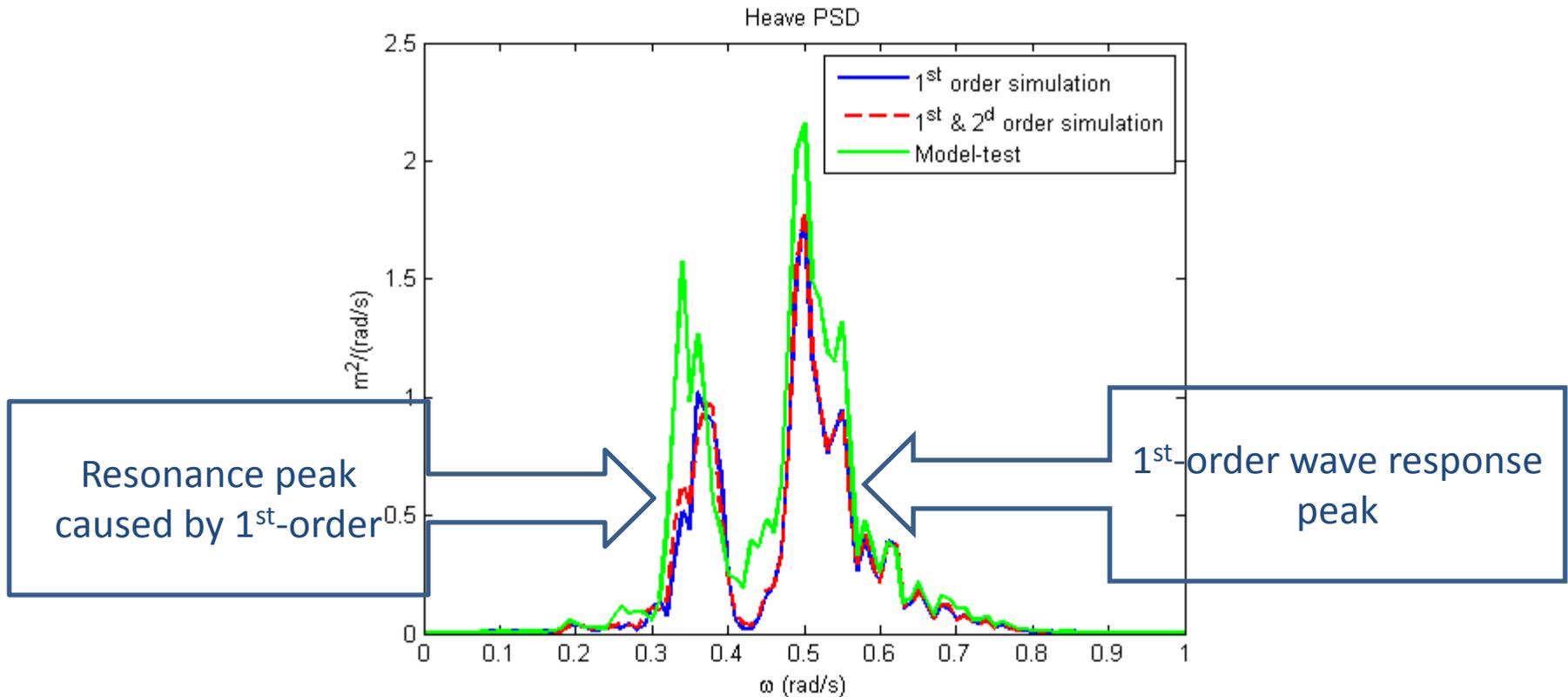


⇒ Low frequent (resonance) peak, underestimated in the simulation

⇒ Wave response is very similar

COMPARISON WITH MODEL-TESTS

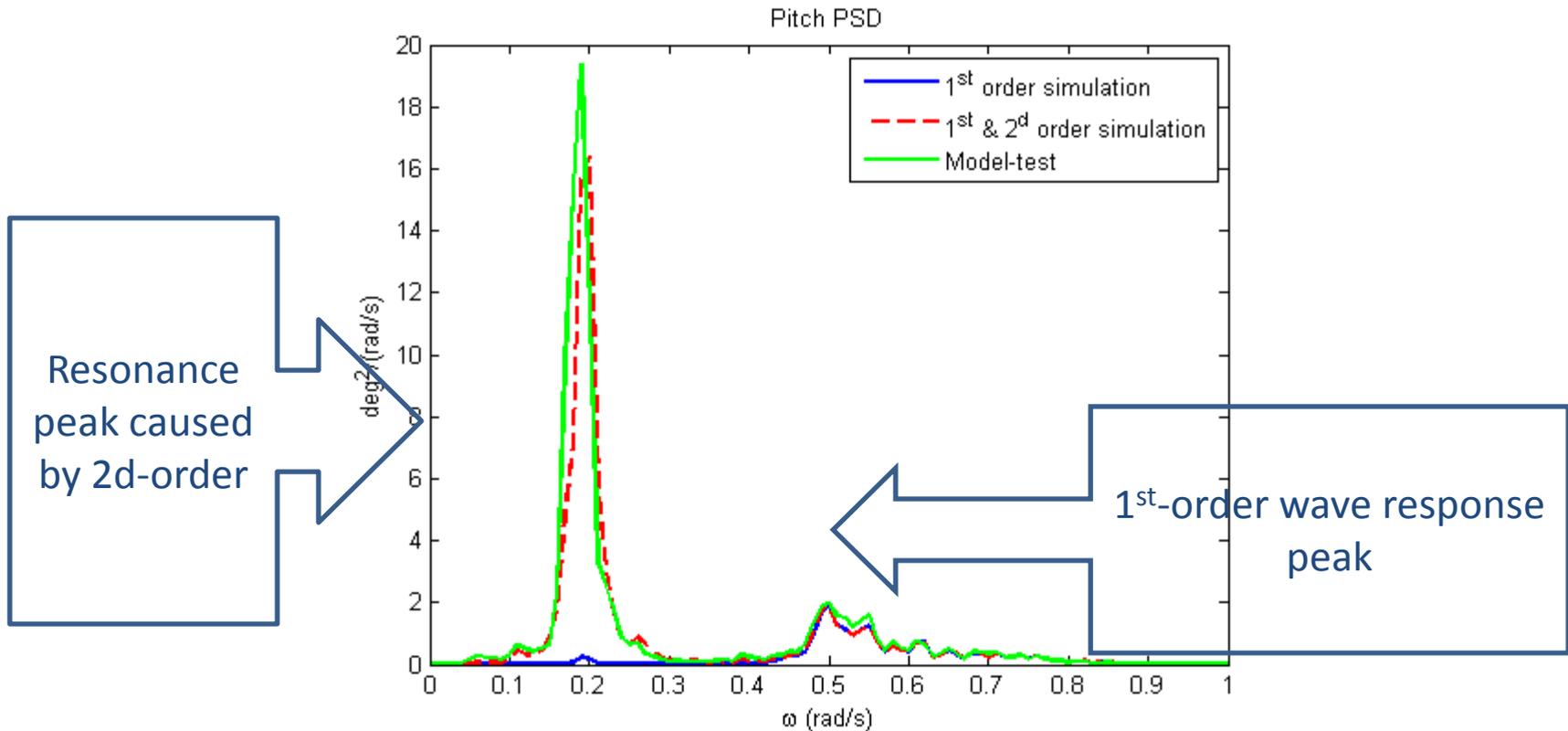
Power Spectrum Density of the heave motion



- ⇒ Resonance peak caused mainly by 1st order wave excitation
- ⇒ Wave response and resonance peak slightly underestimated

COMPARISON WITH MODEL-TESTS

Power Spectrum Density of the pitch rotation



- ⇒ Low frequent (resonance) peak is present in the measurements, and reproduced well by the simulation.
- ⇒ Wave response is very similar

CONCLUSIONS

- What's observed in the simulation corresponds to model tests
 - Resonance response to second-order wave loads in:
 - Surge
 - Pitch

Recommendations for OC4-semi:

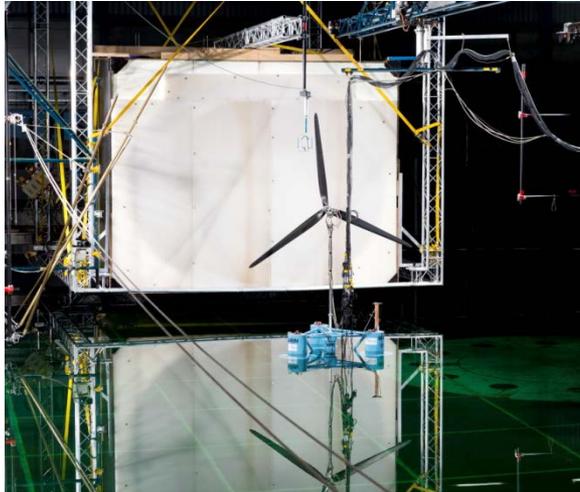
- Full QTF
- 2d order wave loads:
 - Horizontal
 - Vertical



Surge resonance
response to 2d order
wave loads
(mooring)

Pitch resonance
response to 2d order
wave loads

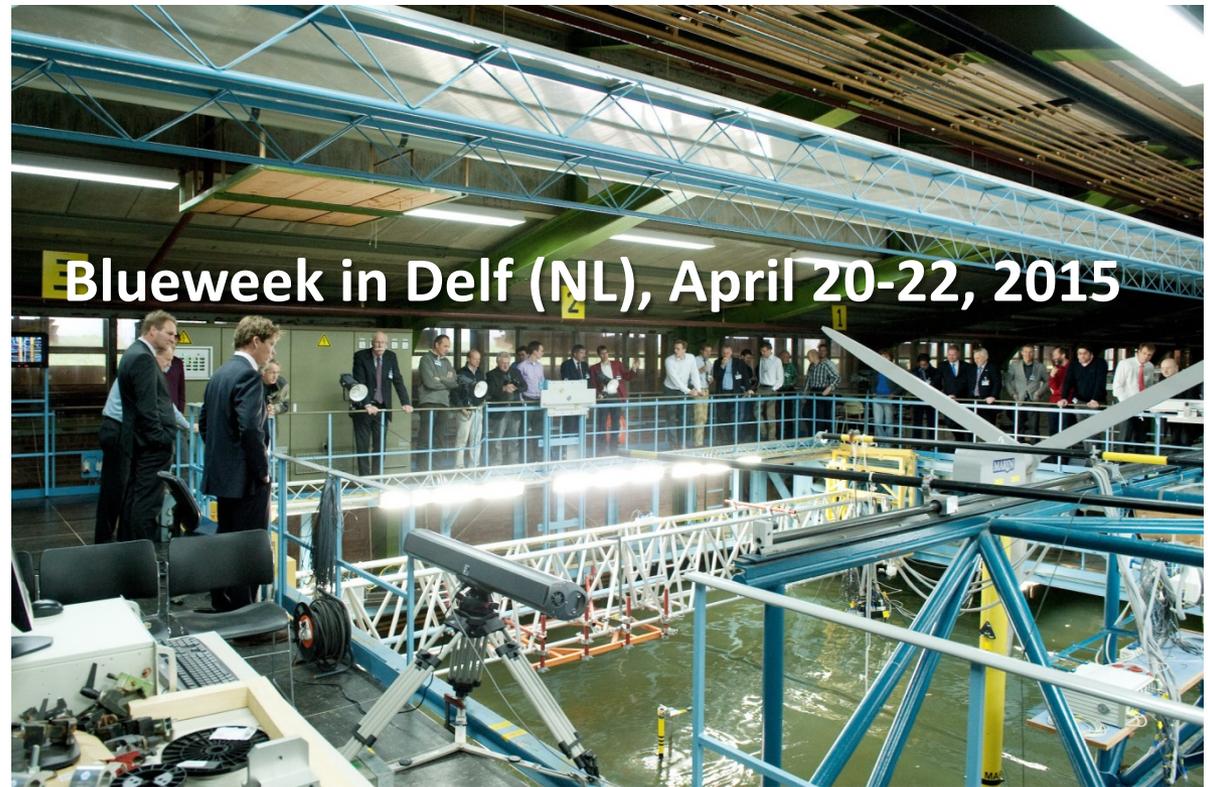
THANK YOU!



Acknowledgment to UMaine and DoE for making these model-tests possible.

www.marin.nl

DE ZEE IS BLAUW LA MER EST BLEUE LA MAR ES AZUL
THE SEA IS BLUE 海是蓝色的 DAS MEER IST BLAU
IL MARE E'BLU LA MAR ES BLAVA O MAR É AZUL



Blueweek in Delf (NL), April 20-22, 2015