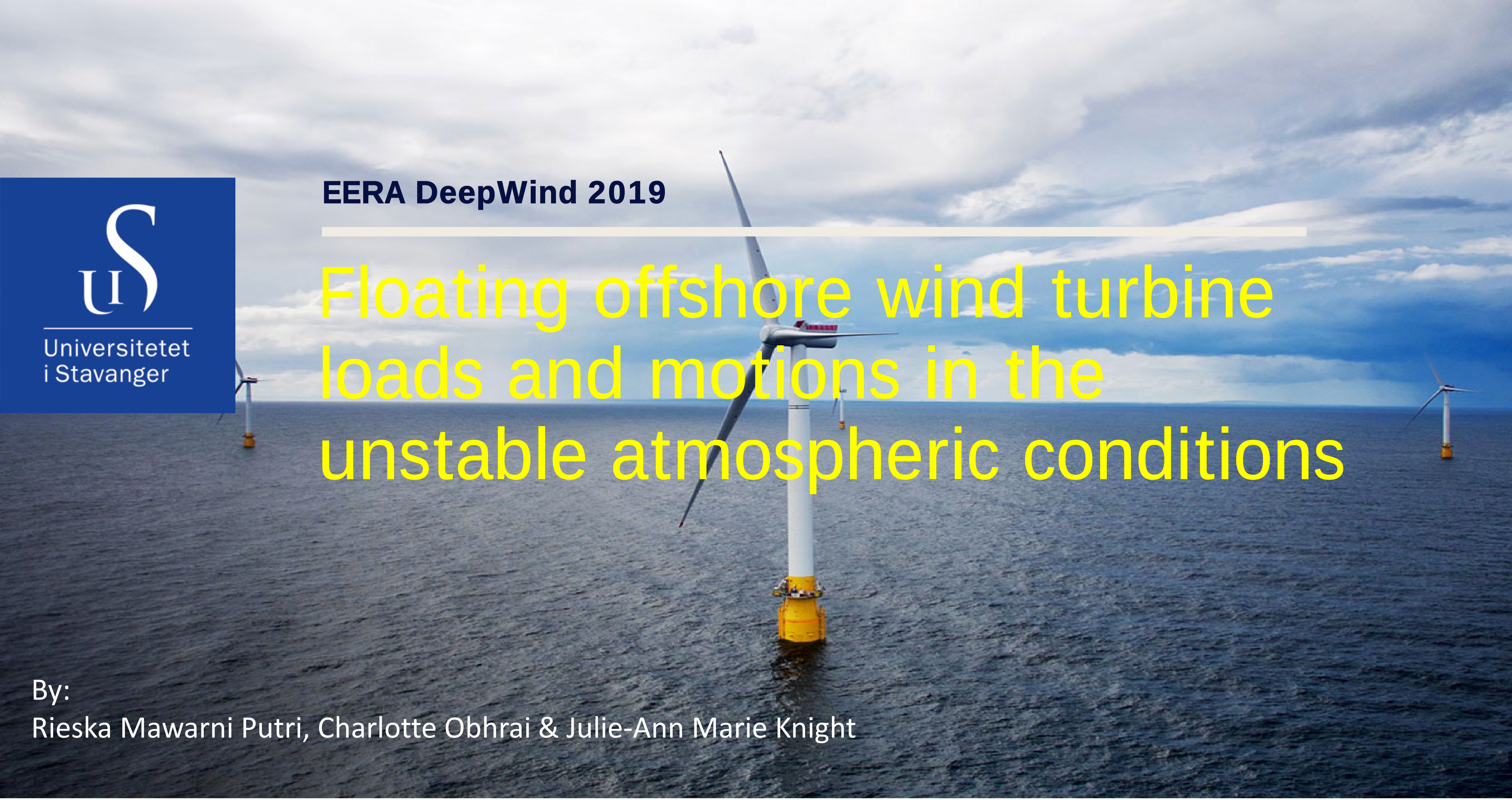

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EERA DeepWind 2019

Floating offshore wind turbine loads and motions in the unstable atmospheric conditions

By:
Rieska Mawarni Putri, Charlotte Obhrai & Julie-Ann Marie Knight

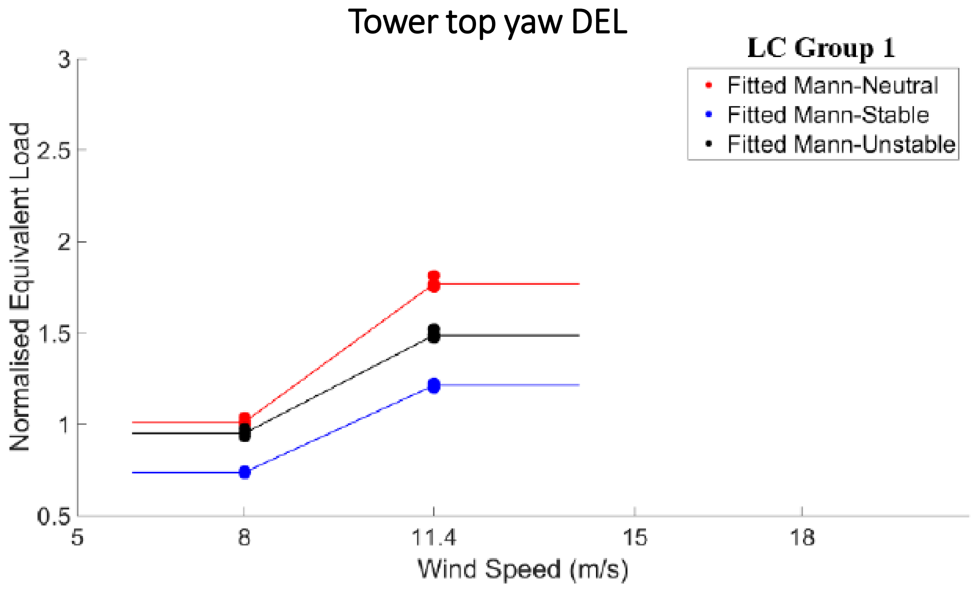
Picture retrieved from: https://windeurope.org/wp-content/uploads/hywind-scotland-first-floating-offshore-wind-farm.jpg

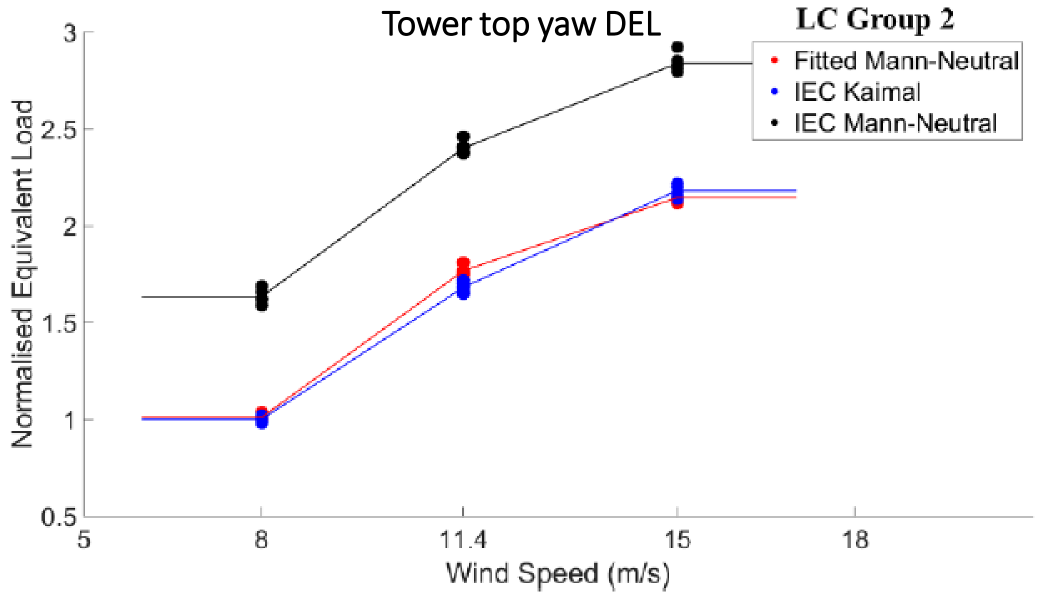
Outline

- Motivation
- Background
- Højstrup spectral model parametric study
- Results – coupled SIMO-RIFLEX on OC3-Hywind
- Conclusion
- Future work

Motivation

- Initial study from the master thesis project ‘A study of the coherences of turbulent wind on a floating offshore wind turbine’





Background

- Højstrup spectral model: derived based on Kaimal spectral model, especially developed for unstable diabatic conditions:

$$S(n) = S_L(n) + S_M(n)$$

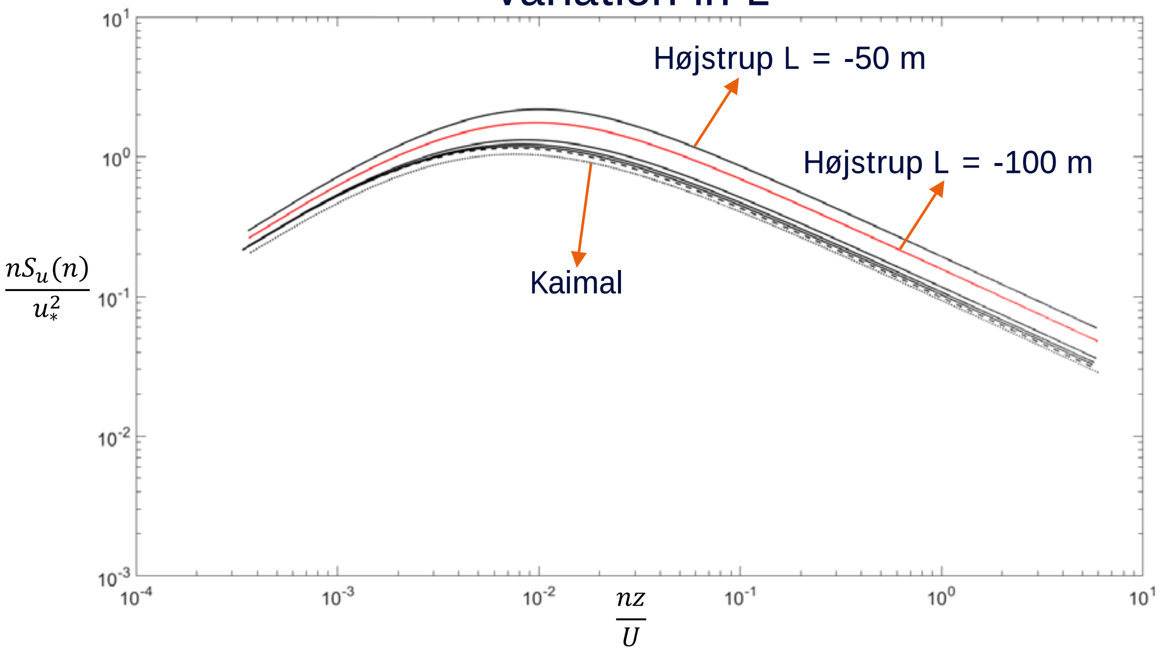
Low-frequency part High-frequency part

- Parameters: boundary layer height z_i, Obukhov-length L, height z
- In combination with Davenport coherence:

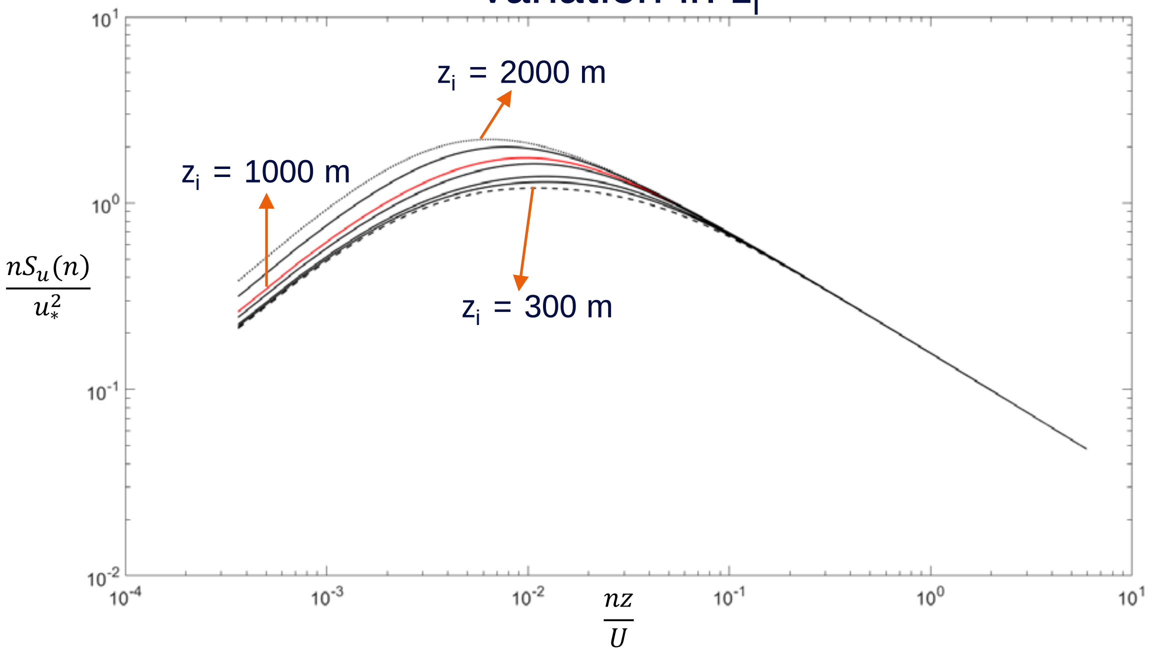
$$Coh_i(n) = \exp\left[-\frac{n}{\bar{u}}\sqrt{\left(C_i^y d_y\right)^2 + \left(C_i^z d_z\right)^2}\right]$$

Højstrup spectral model – parametric study

Variation in L



Variation in z_i



Benchmark: z_i=1000 m, L=-100 m

Simulations

- Turbulence box generation using MATLAB®

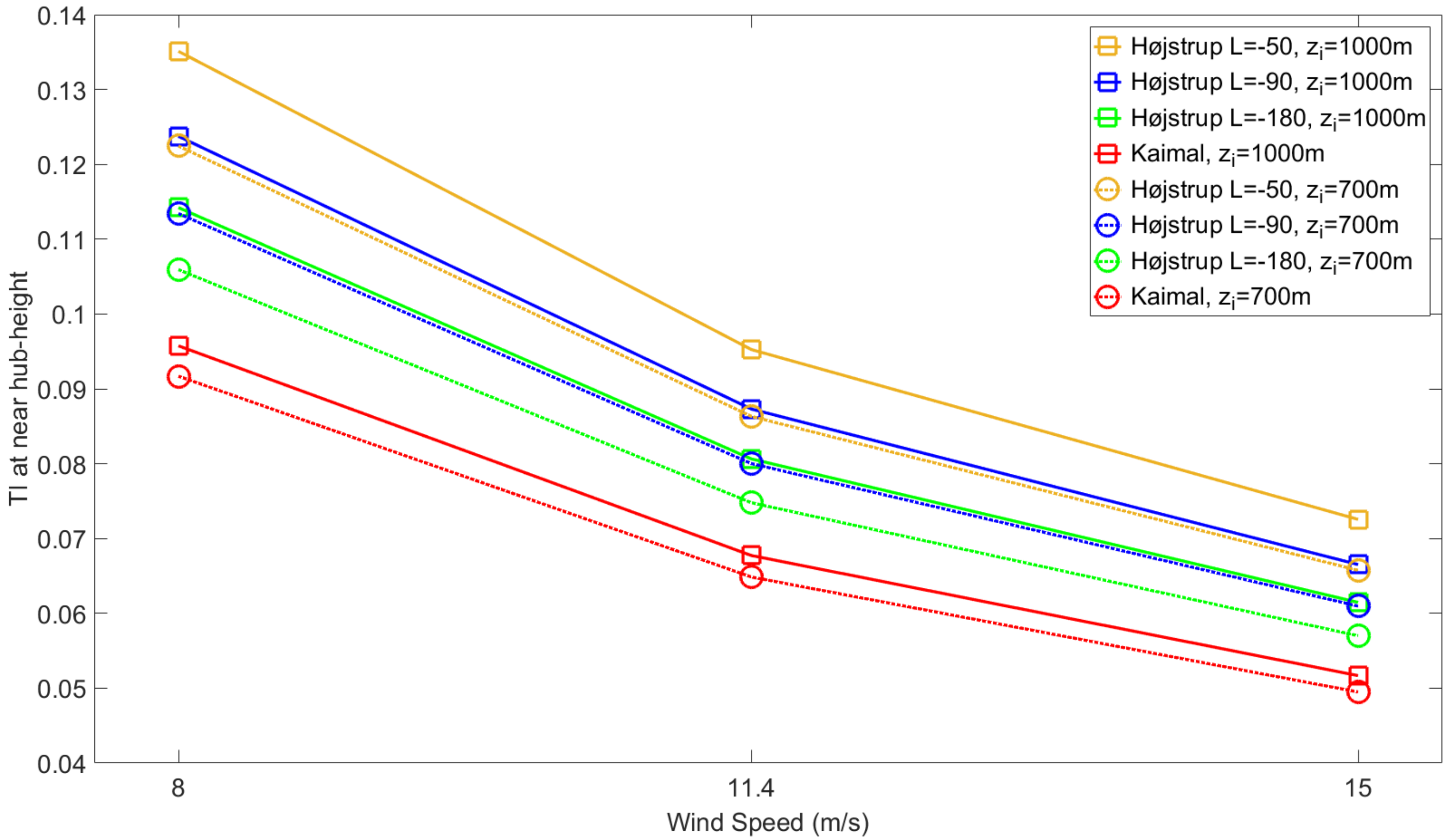
Load case		
Spectral model	z_i (m)	L (m)
Højstrup	700	-50
		-90
		-180
	1000	-50
		-90
		-180
Kaimal	700	∞
	1000	∞

Decay coefficient (Davenport Coherence)						
	C_u^y	C_v^y	C_w^y	C_u^z	C_v^z	C_w^z
Value	7	7	6.5	10	10	3

Wind speed	8, 11.4, 15 ms^{-1}
#seed	6
Wave	JONSWAP
	H_S = 6 m
	T_p = 12 s
	γ = 3.3

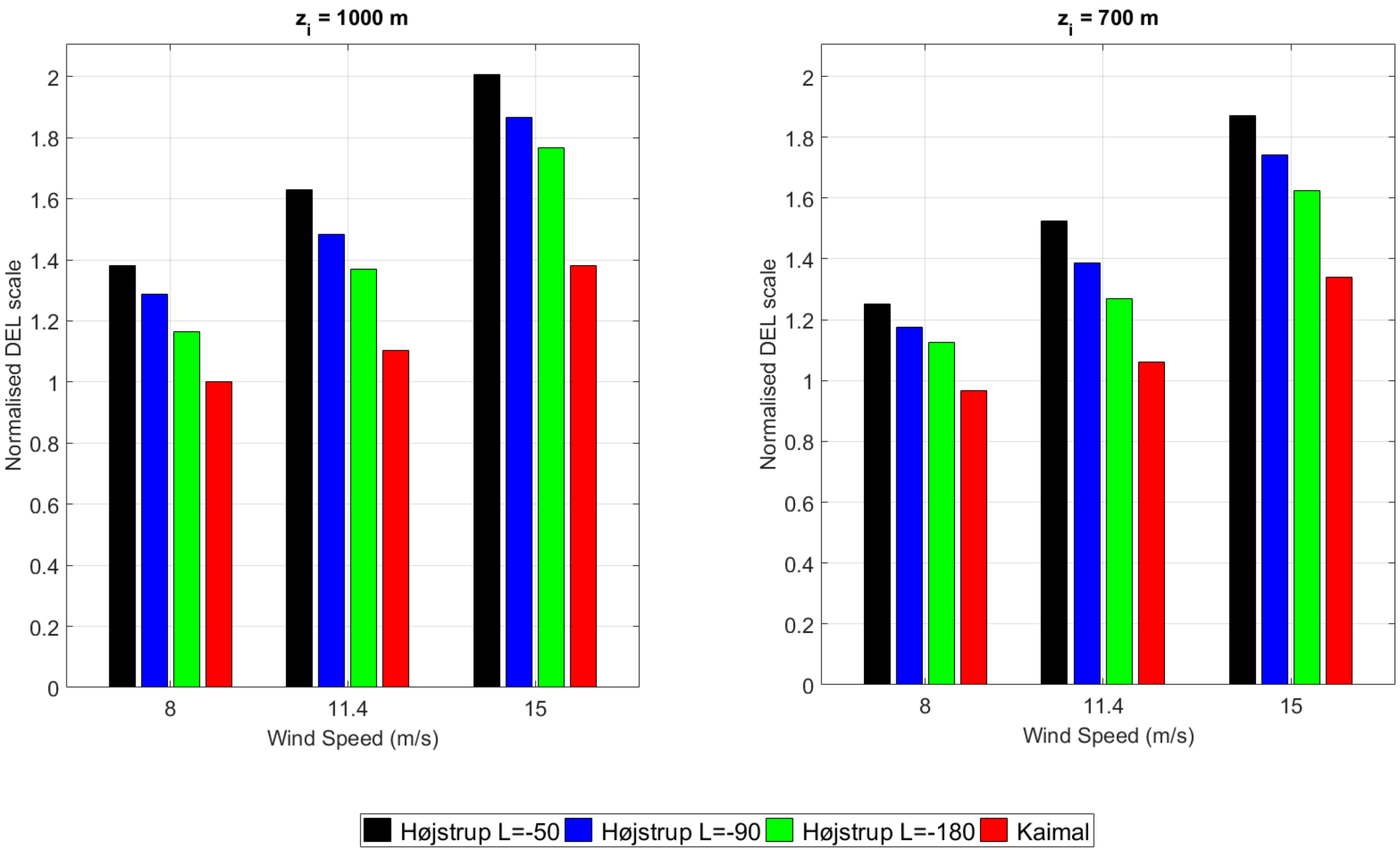
- Coupled SIMO-RIFLEX® simulations on the OC3-Hywind

Results – Turbulence Intensity



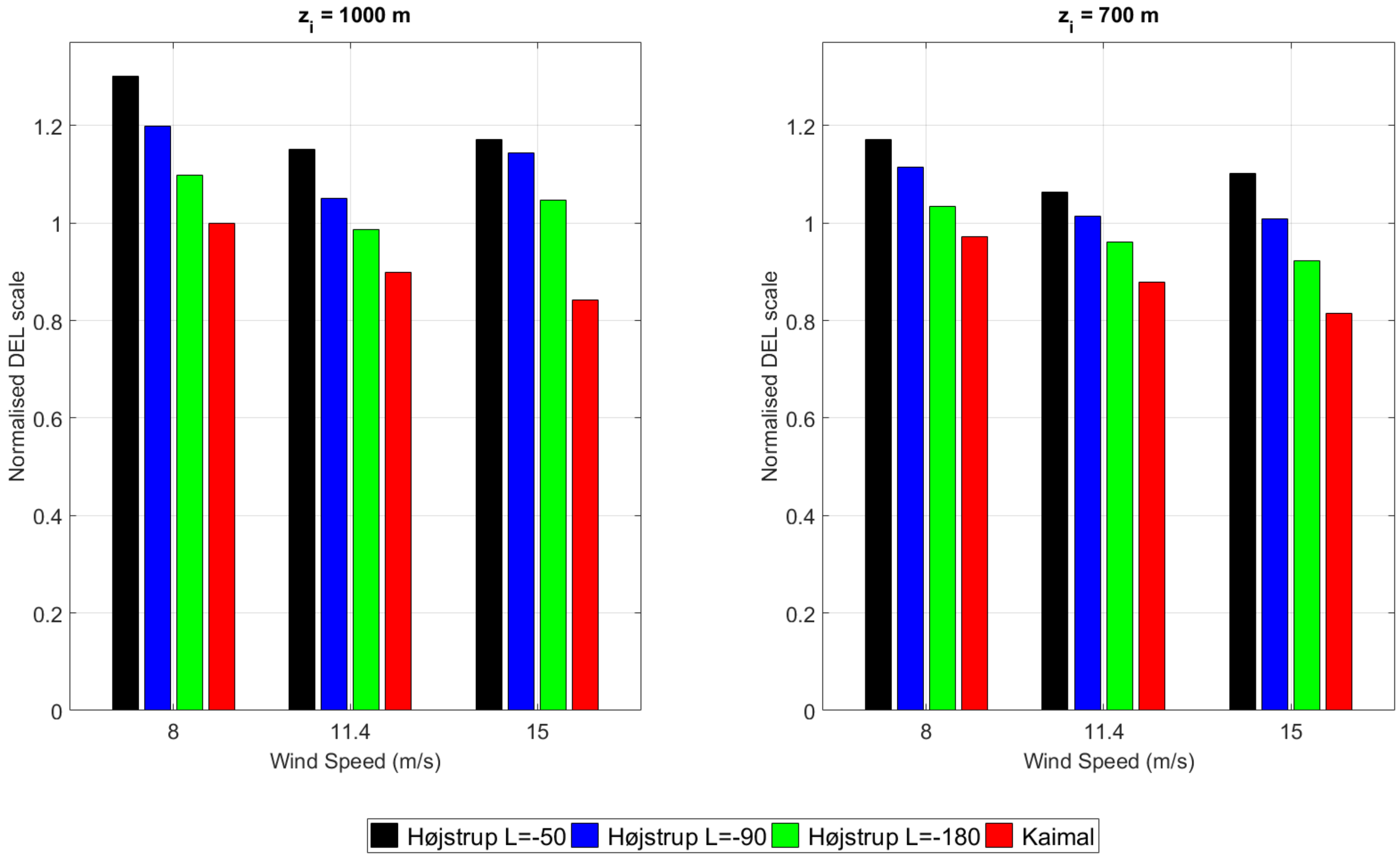
- 40% TI difference between neutral (Kaimal) and very unstable (Højstrup L=-50 m), considering the same z_i
- 14% TI difference between z_i = 700 m and z_i = 1000 m, considering the same L

Results – DEL tower top yaw torsion



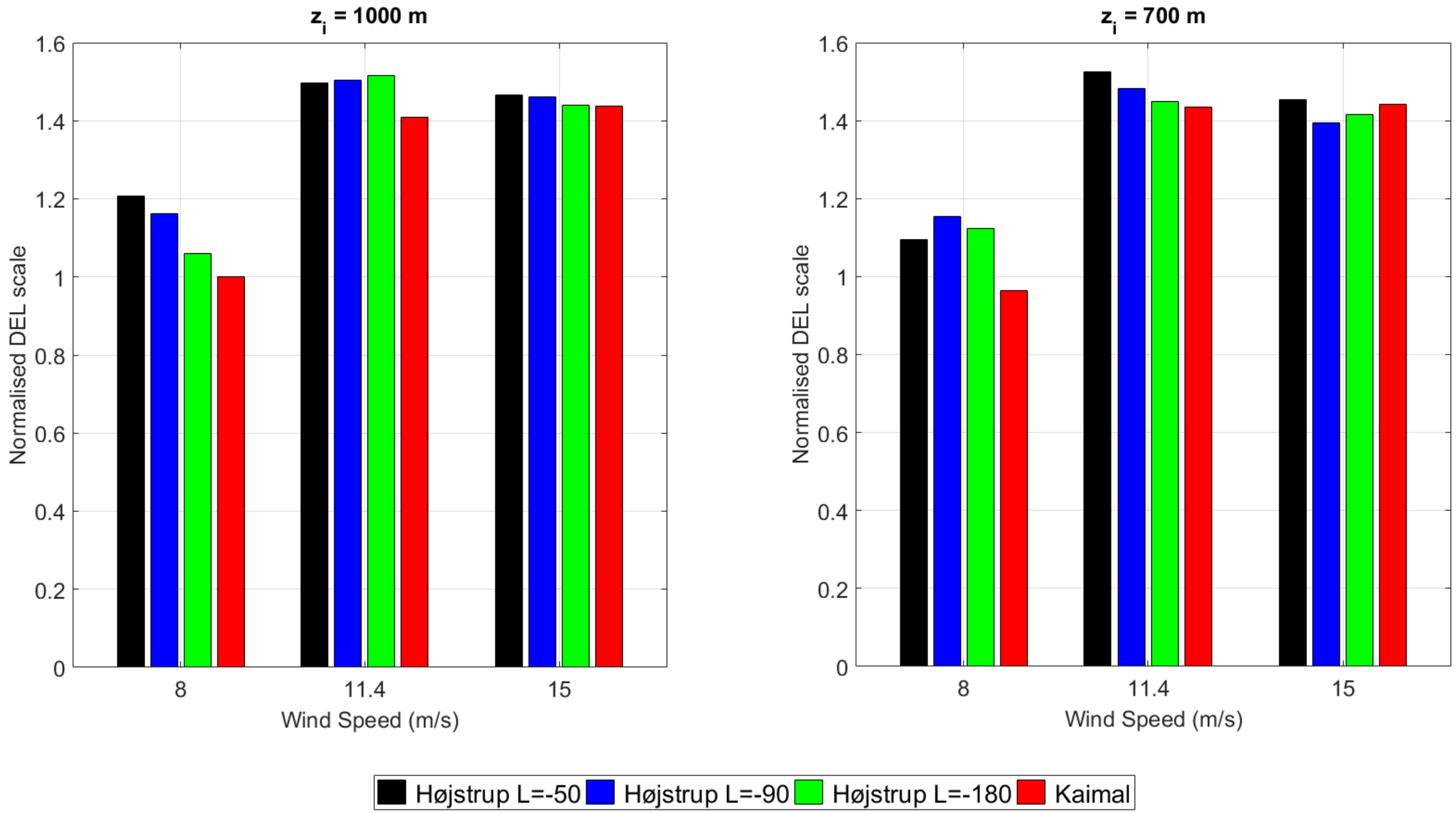
65% difference between neutral (Kaimal) and very unstable (Højstrup L=-50m)

Results – DEL tower base side-side bending



37% difference between neutral (Kaimal) and very unstable (Højstrup L=-50m)

Results – DEL blade root flap-wise bending



24% difference between neutral (Kaimal) and very unstable (Højstrup L=-50m)

Results – platform yaw motions

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Results – other DEL and motions

- Tower base fore-aft bending DEL: 7% difference between neutral (Kaimal) and very unstable (Højstrup L=-50) conditions
- Blade root edge-wise bending DEL: 3% difference between neutral (Kaimal) and very unstable (Højstrup L=-50) conditions
- Other platform motions mode variations were not noticable (except for roll, despite its small magnitude of -0.3^{o} to 0.6^{o})

Limitations – Davenport decay coeffients

- A modified Davenport coherence by Cheynet et. al (2018) for vertical coherence:

$$Coh_i(d_z, n) = \exp\left[-\sqrt{\left(\frac{c_1^i f d_z}{\bar{u}}\right)^2 + \left(\frac{d_z}{l_2}\right)^2}\right]$$

- $l_2 = \bar{u}/c_2^i$, proportional to a typical length scale of turbulence
- Decay coefficient depending on stability conditions $(-2 < z/L < -0.2)$ derived from FINO1 data:

Decay coefficient			
c_1^u	c_1^v	c_1^w	c_2^w
$11+1.8\exp(4.5\,z/L)$	$7.1+3.4\exp(6.8\,z/L)$	$3.5+0.7\exp(2.5\,z/L)$	$0.05+0.13\exp(5\,z/L)$

Conclusions

- The addition of low-frequency component in Højstrup model increases the spectral energy and TI
  - L and z_i are the parameters driving the TI
  - OC3-Hywind DELs for tower top yaw torsion showed a variation up to 65% for the different load cases. Also up to 37% for tower base side-side bending
- Højstrup spectral model was developed based on onshore measurement
- The importance of selecting a proper wind model representative for offshore environment in the OWT simulations, particularly for unstable conditions

Future work

- Simulations using spectral & coherence model as derived in the study of (Cheynet et al., 2018) using data from FINO1 measurement platform. This is only verified for vertical separations
- New measurements from the COTUR project will hopefully provide new information on coherence for horizontal separations
- Simulations using modified Mann spectral tensor model (Chougule et al., 2018) – with the possibility of deriving parameters from offshore data into the models
- Comparing various floater models and rotor sizes (Bachynski & Eliassen, 2018)

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