Quantification of the error induced by floating lidar motions in wind vector and turbulence intensity estimation

Wind Energy Science Conference
Glasgow, UK
23-26 May, 2023

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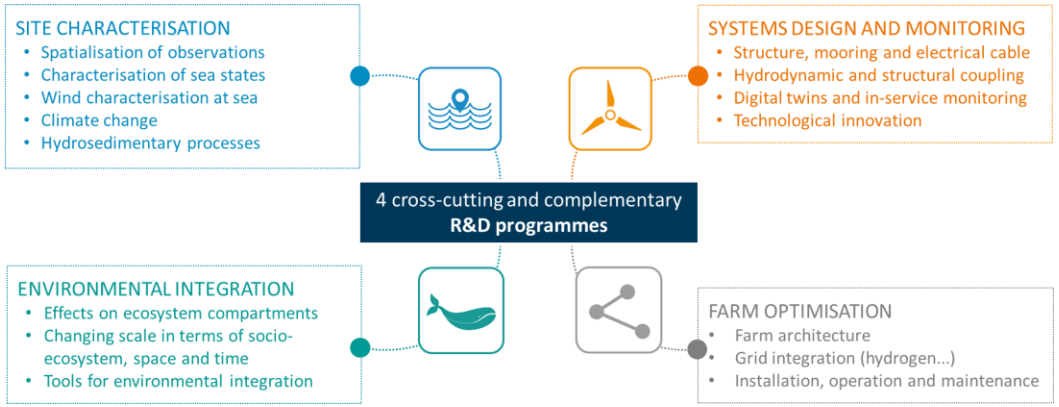
France Energies Marines in short

French National Research Institute fully dedicated to Offshore Renewable Energies

FRANCE ENERGIES MARINES

A public-private partnership



POWSEIDOM project

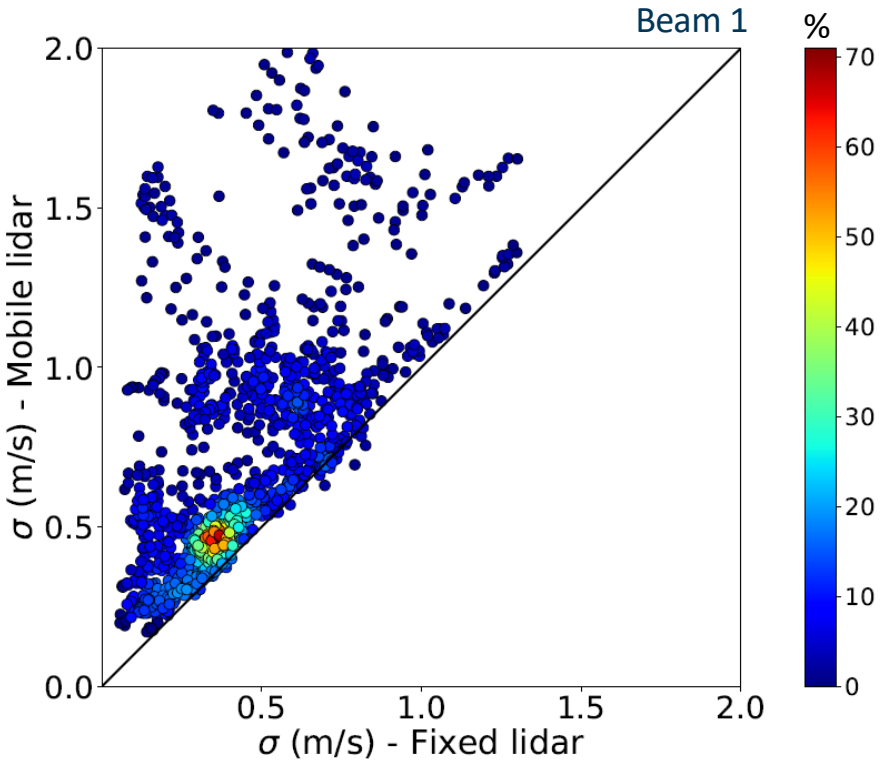
Objectives:

❖ Ground-based lidar
- Development of a new methodology for deriving TI from pulsed lidar profilers.
- Collecting long-term turbulence dataset in the Gulf of Lion (Mediterranean sea).

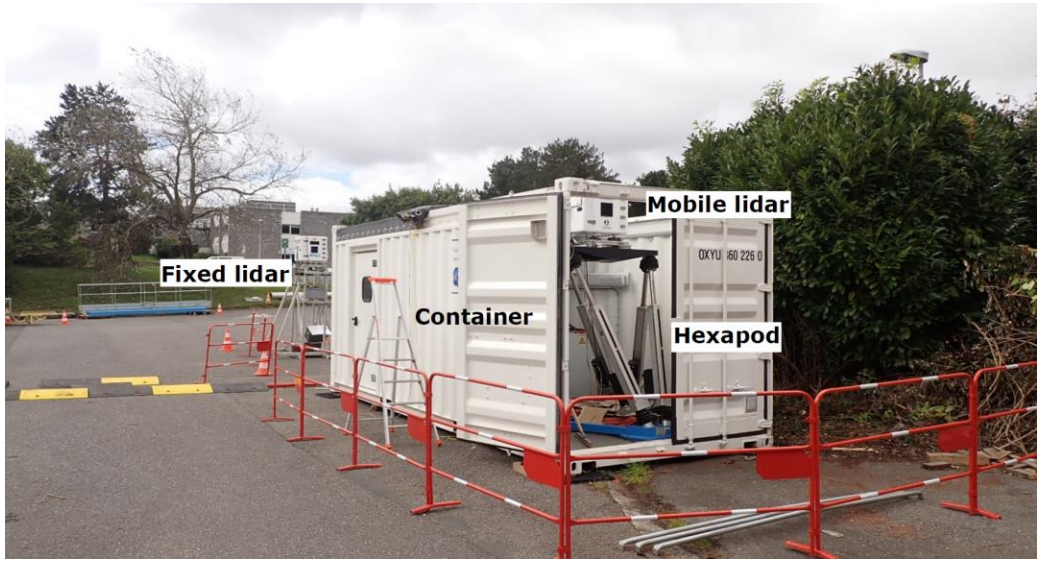
❖ Floating lidar
- **Experimental assessment of the motion-induced effect on turbulent fluctuations measurement of floating lidars.**
- Development of a preliminary motion-compensation algorithm for TI measurement.

Motivations

The motions of the floating platforms adds additional short-term wind fluctuations, σ, to the recorded wind data which generate overestimation of TI.



Experimental set-up



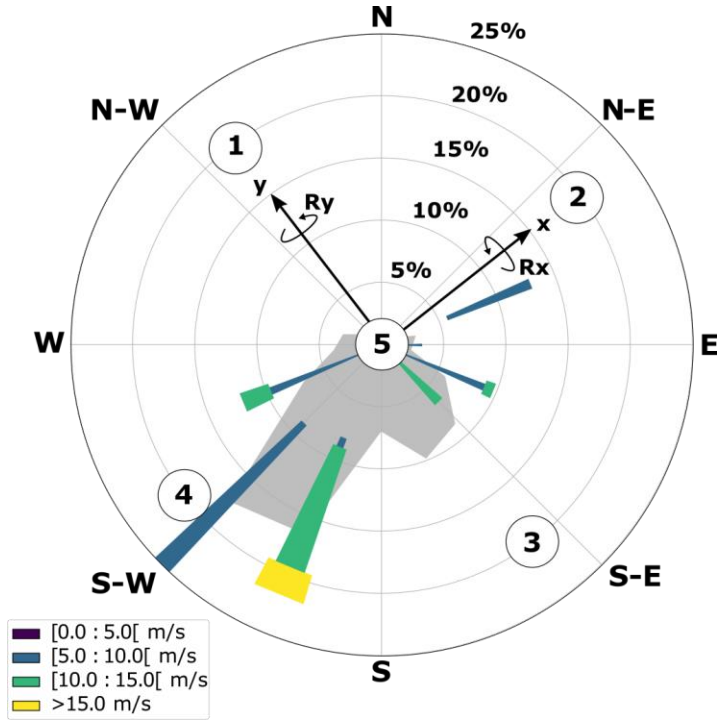
Test performed, onshore, at Ifremer Brest facilities.

Dataset

- 15 cycles of 3-hour long collected between October 6th, November 9th 2022.
- 1 cycle is composed of 12 sequences (regular and irregular motions).

Regular motions

Sequences (10-min)	Ry	Rx	Rz	
S1	T = 4s, A = 5°	NA	NA	Around 1 axis only
S2	T = 4s, A = 15°	NA	NA	
S3	T = 6s, A = 5°	NA	NA	
S4	T = 6s, A = 15°	NA	NA	
S5	T = 8s, A = 5°	NA	NA	
S6	T = 8s, A = 15°	NA	NA	
S7	T = 6s, A = 5°	T = 6s, A = 5°	NA	Coupling
S8	T = 6s, A = 5°	NA	T=6s, A=5°	
S9	T = 6s, A = 5°	T = 6s, A = 5°	T = 6s, A = 5°	

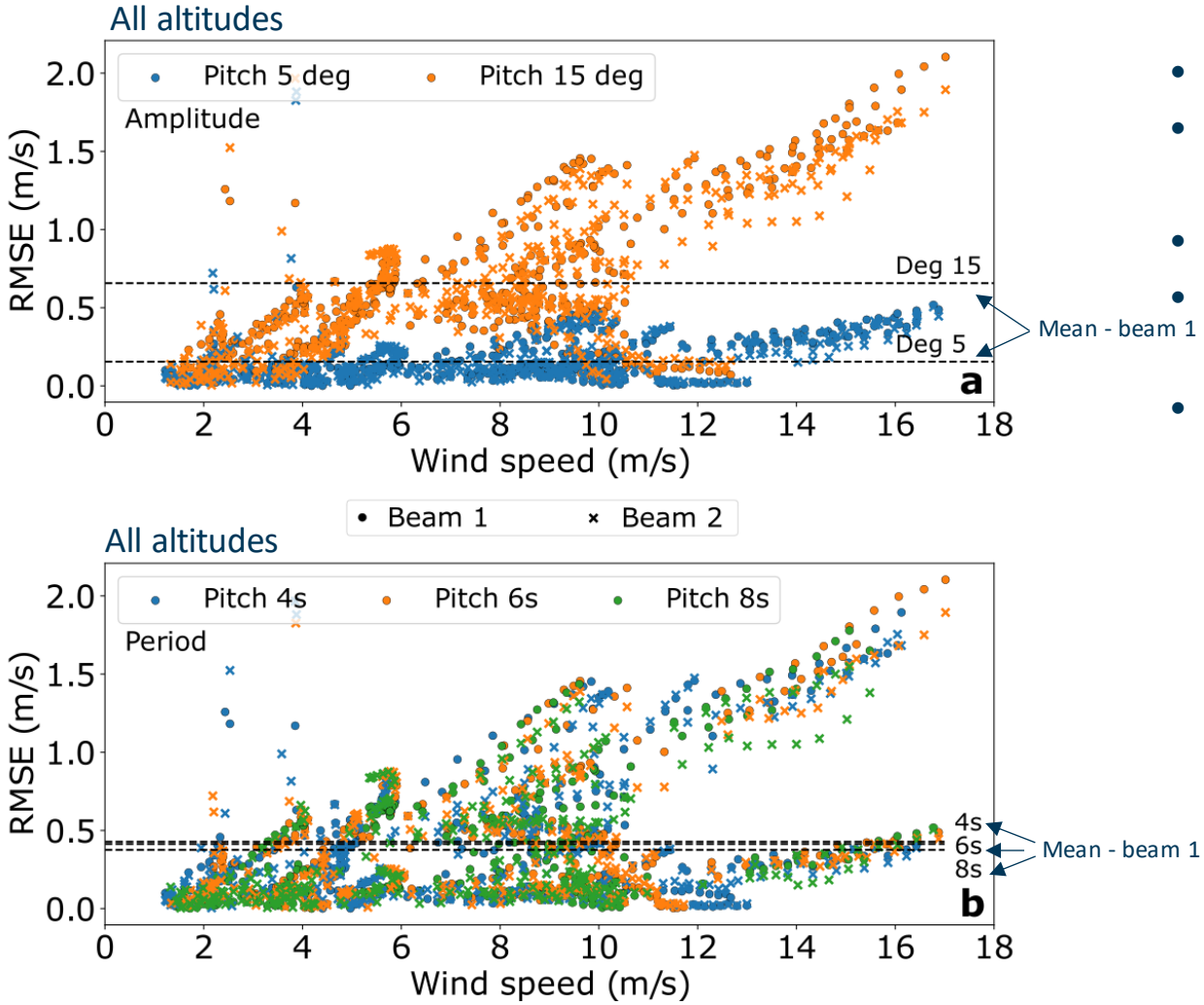


Metrics

- Focus on the LOS turbulent fluctuations, σ, given by the standard deviation of the detrended signal.

- Metric of error: RMSE between σ_{fixed} (reference) and σ_{mobile}.

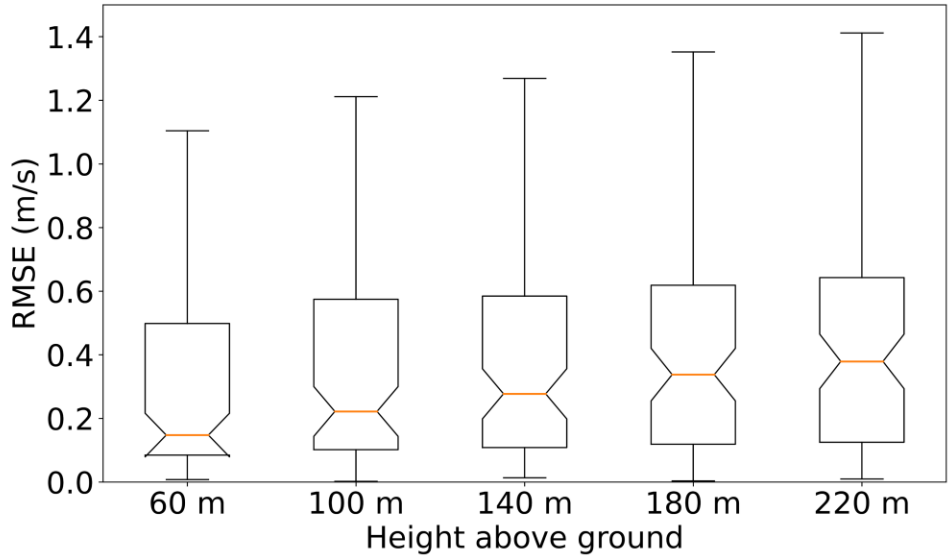
One single rotation - Ry



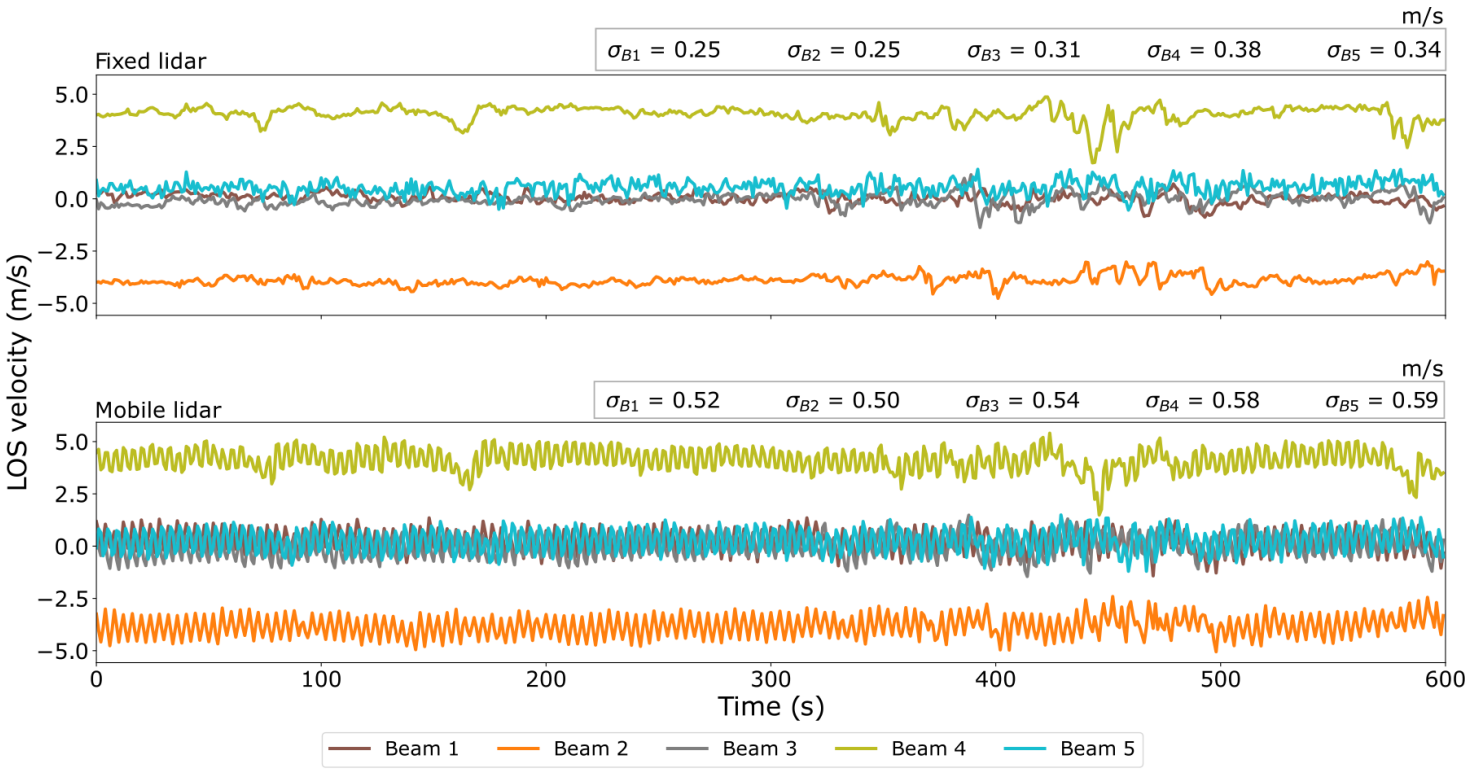
- The amplitude impacts considerably the RMSE.
- Amplitude ↗ RMSE ↗

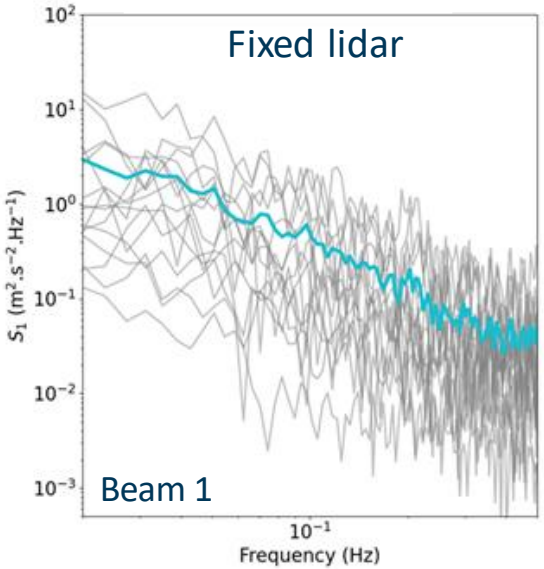
- The period has a relatively low impact.
- Period ↘ RMSE ↗

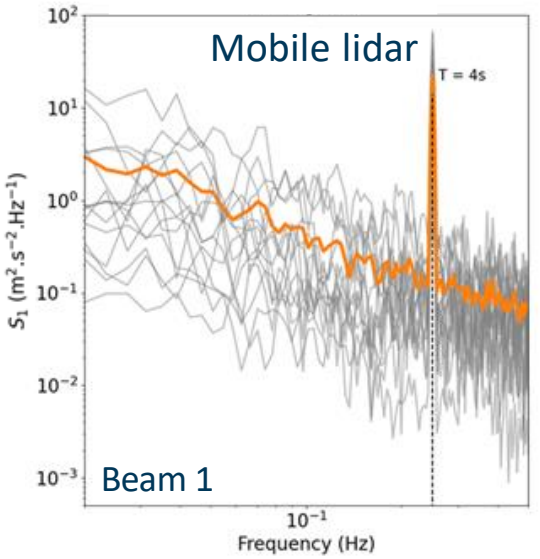
- Altitude ↗ RMSE ↗



One single rotation - Ry

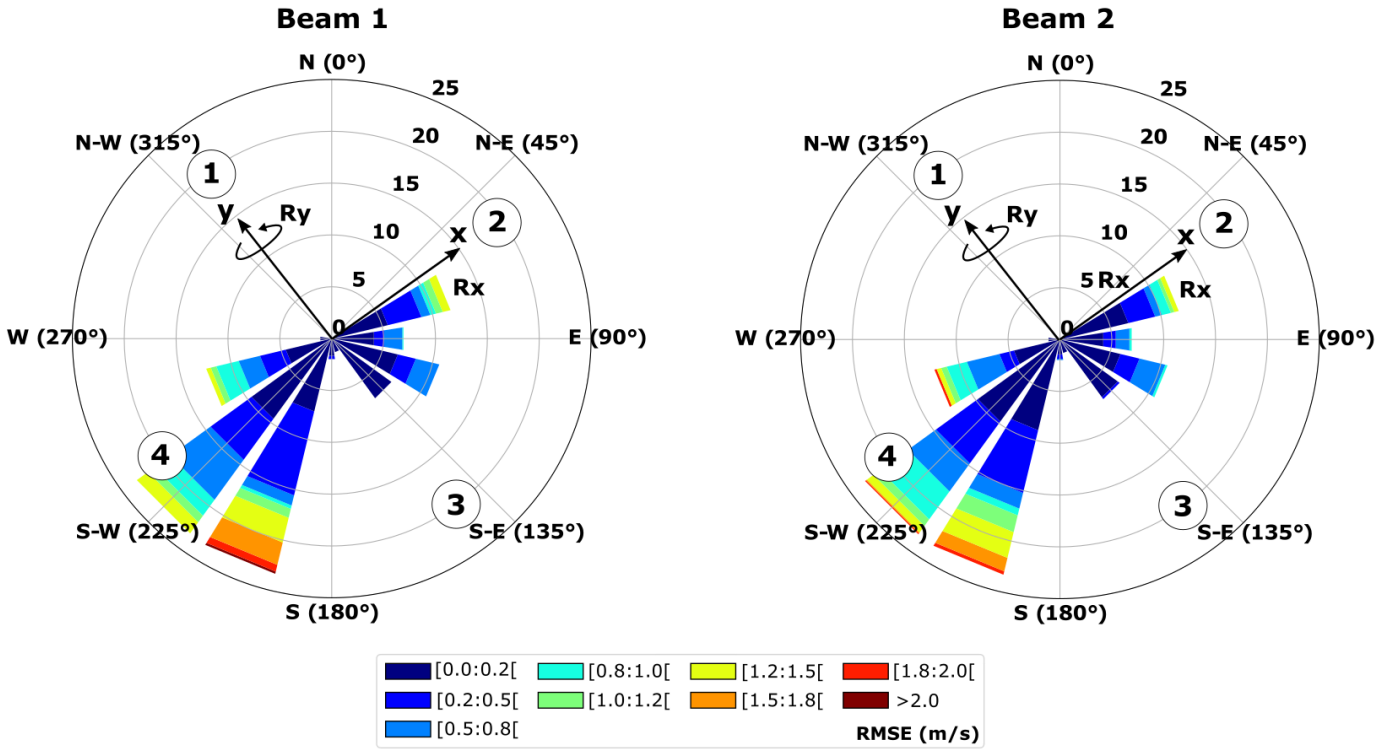




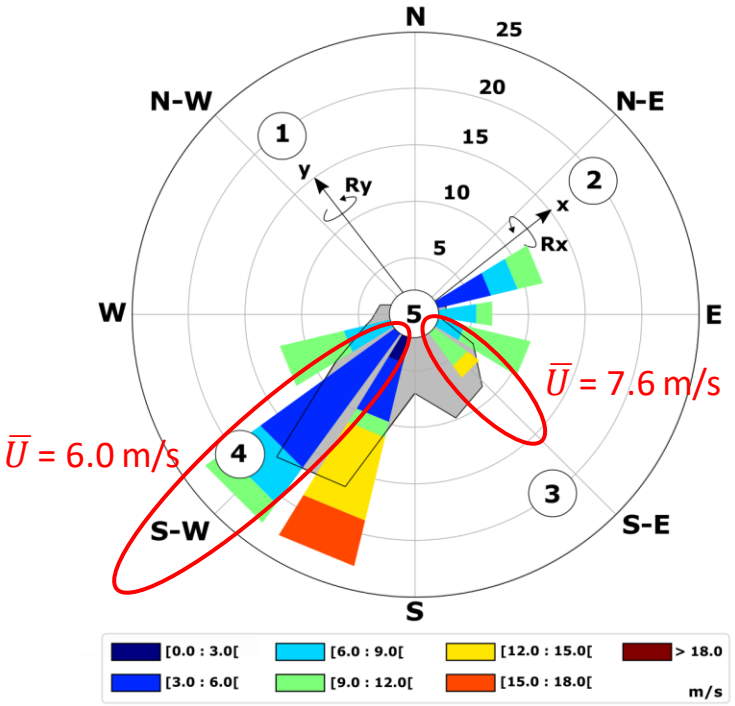


One single rotation - Ry

RMSE of LOS velocity fluctuations

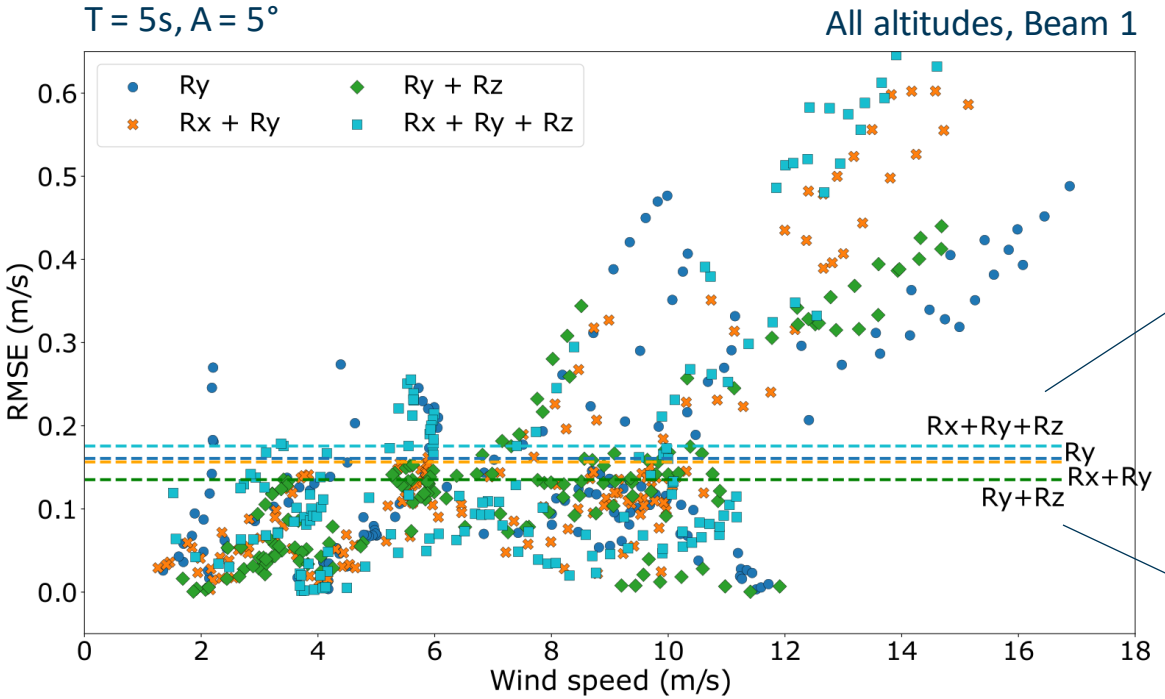


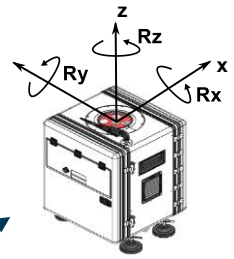
Wind Speed



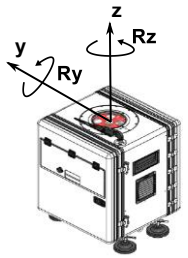
- Wind speed **orthogonal** to the axis of rotation gives **higher** RMSE.
- Wind speed **aligned** with the axis of rotation gives **lower** RMSE.

Coupling





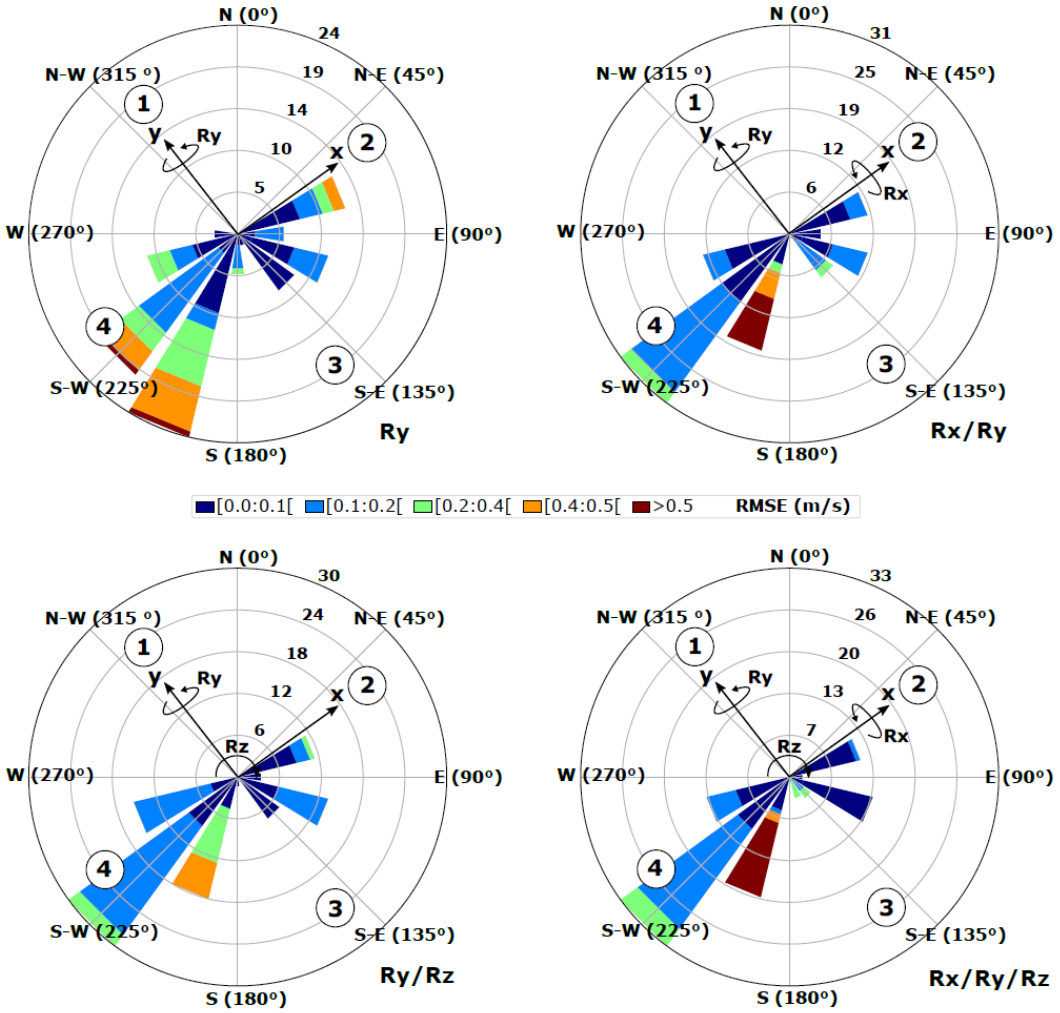
Higher RMSE



Lower RMSE

- For similar wind speed:
- Coupling of Rx/Ry/Rz has the most impact
- Followed by Rx/Ry.
- Followed Ry alone
- Followed by Ry/Rz. Does it mean that a rotation around the z-axis generate low RMSE?

Coupling



When coupling motions, there is no clear impact of wind direction on RMSE.

Conclusions

What has the biggest impact on turbulent fluctuations measured by floating lidars?

High impact	Low impact
• Amplitude of the motion. • Wind speed. • Wind direction in comparison to the axis of rotation • Beam position orthogonal to the axis of rotation.	• Period of the motion. • Rotation around the vertical axis ?

For rotations around one single axis.

- These are only hypothesis resulting from our observations.
- They need to be confirmed by a (numerical – virtual lidars?) study covering exhaustive wind directions associated with wider wind speed ranges.

Future work : NEMO project

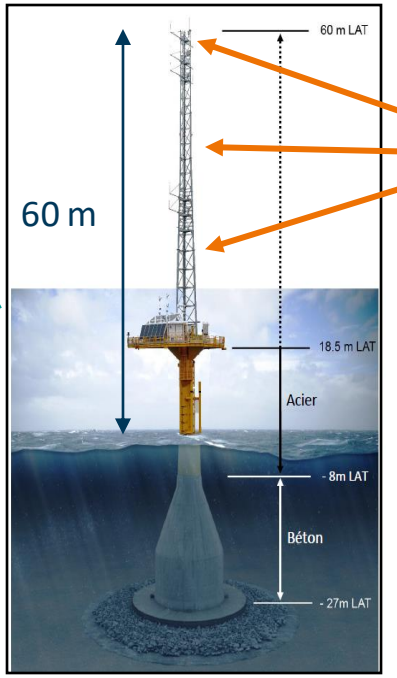
(New methods for turbulence measurements and models in offshore wind)

Collaborative project going to start end of 2023 with the following objectives :

- Collect a comprehensive set of in-situ. measurements to challenge the capabilities of different instruments
- Compare turbulence intensity information collected by different means (measurements and modelling, onshore vs offshore, punctual vs volume averaged)
- Development of innovative methodologies to assess turbulence from complementary measurements and numerical modelling
- Advance the characterization of offshore wind turbulence beyond the current state-of-the art

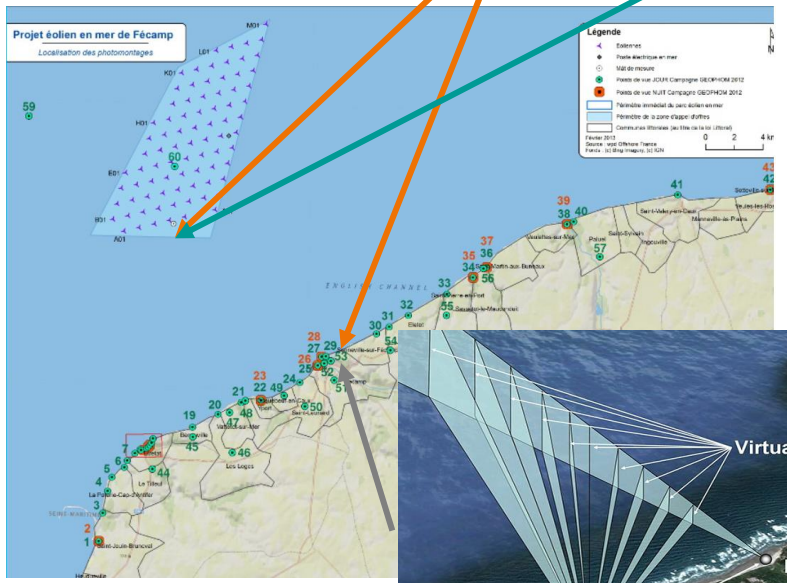
Collaborative project expected in 2024 on wake characterization based on new measurement campaigns from the met mast.

Feel free to reach out if you want to know more about these projects.



3D sonic anemometers

WindCube
Onshore & offshore



WindCube Scan
(Dual-Doppler configuration)

Fraunhofer IWES

France Energies Marines

Thank you !