A controlled-motion lidar experiment: Comparison of measurements by fixed and moving lidar wind profilers

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Train2Wind – A Marie Curie Network on Offshore Wind, EU no. 861291

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Outline

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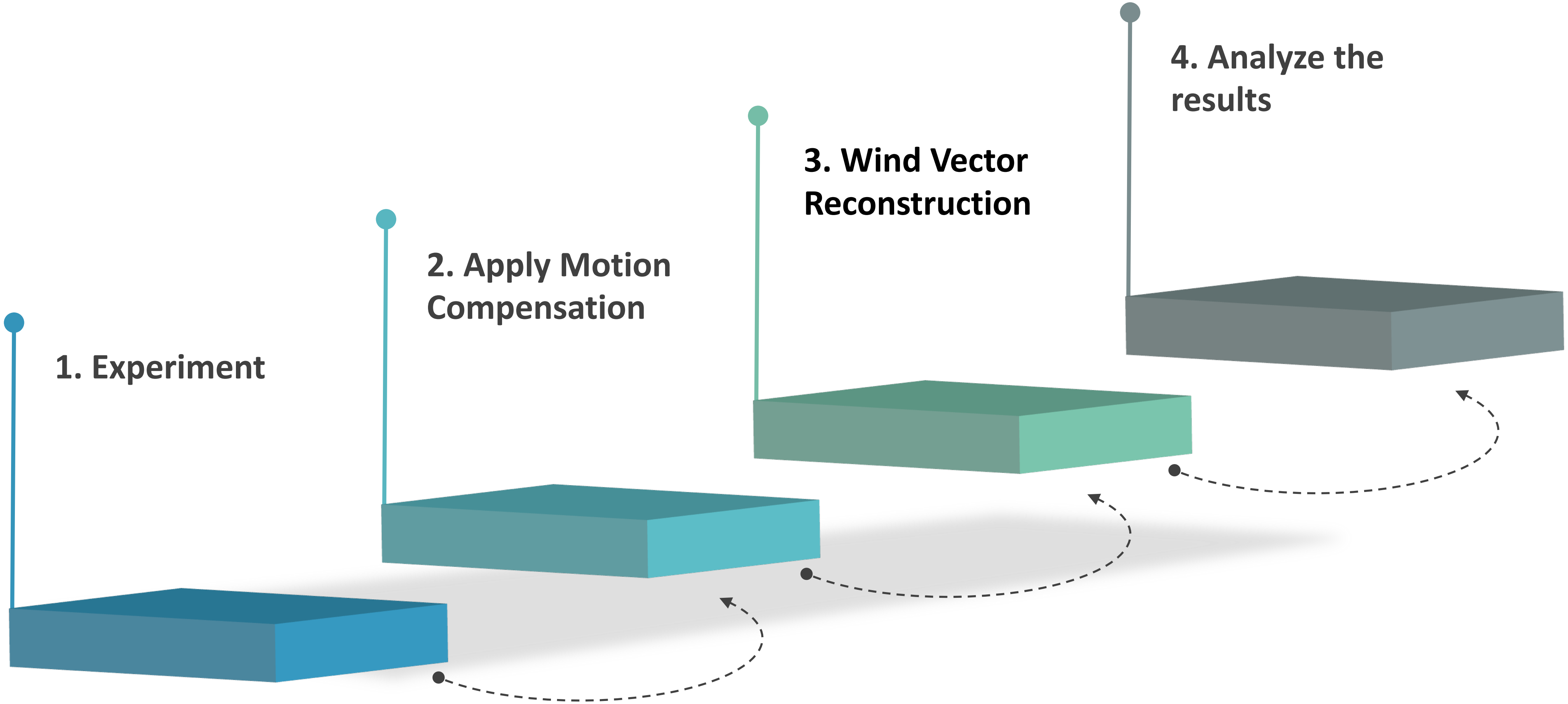
Introduction

- ✓ An economic approach for wind measurement in offshore wind farm is using Floating lidars
- ✓ The movement of the ship or floating buoy induces error on measured wind
- ✓ Error induced my motion should be compensated
- ✓ Reference data for validating motion compensation is sparse
- ✓ Comparing with Met-Masts installed offshore, it would be hard to distinguish between motion induced error and general lidar error due to larger spatial separation in lidars
- ✓ Comprehending isolated error induced by motion on lidar measurements (by conducting controlled experiments) is required

Research Question to be addressed:

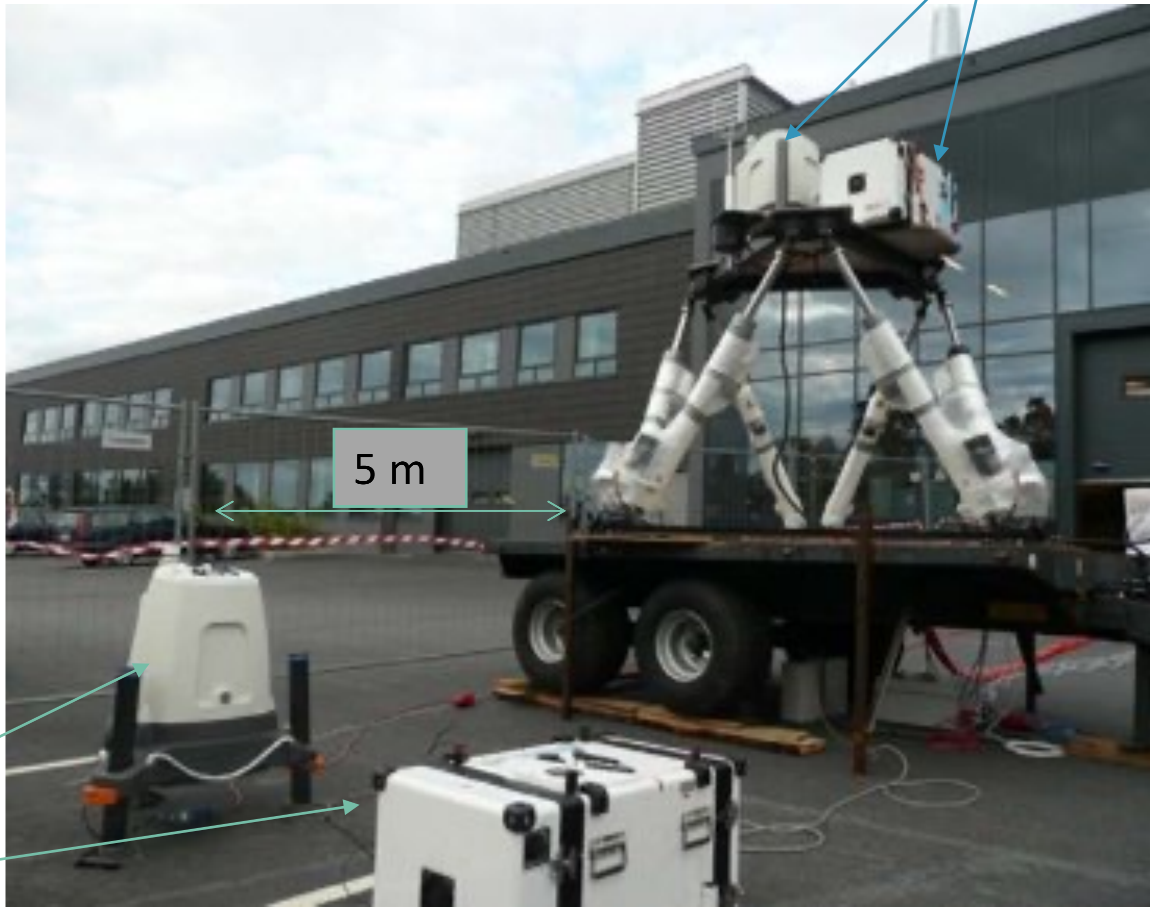
- ✓ **What is the error induced by motion on lidar measurements and how to evaluate it?**

Methodology



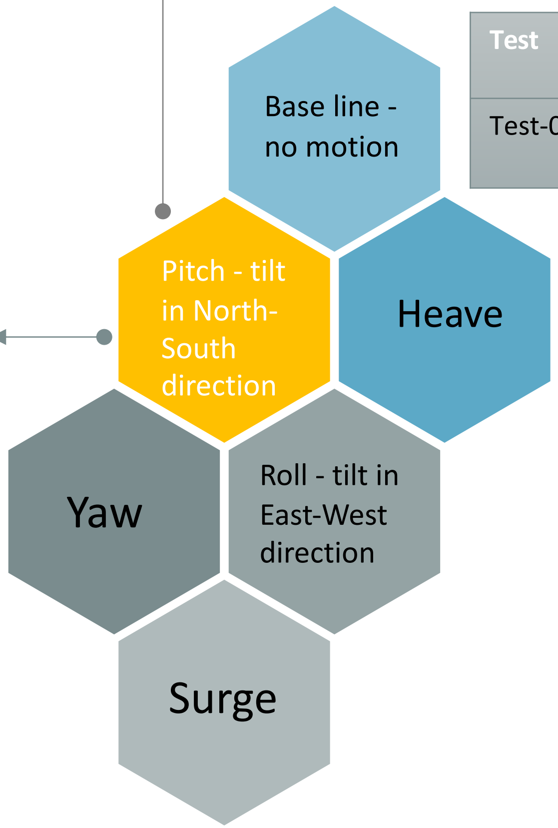
Experimental setup

- ✓ Experiment conducted in Grimstad, Norway from 16th to 26th August 2011
- ✓ Two lidar systems (ZephIR 300 and WindCube V1) exposed to controlled motions on a hexapod platform
- ✓ Two fixed reference lidars located at 5 m from the platform
- ✓ Wind speed was measured at approximately 80m above the surface



Test cases in the Experiment

- ✓ 54 different test cases were conducted: motions along the principal axis (roll, pitch, yaw, heave and surge) in addition to the combined motions
- ✓ Test case number 11 with the most consistent data and large amplitude was chosen for this study
- ✓ Sinusoidal motion in one single degree of freedom with constant amplitude and frequency



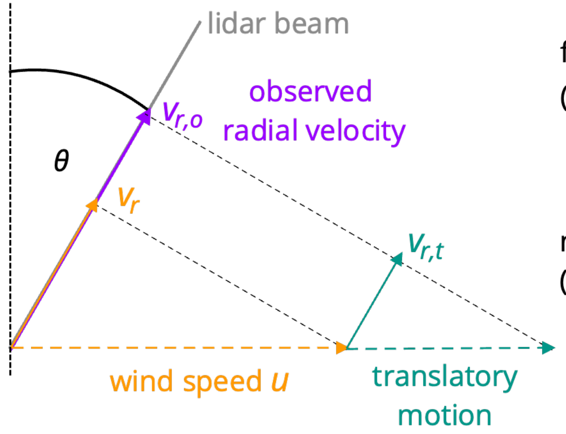
Test	Start time	End time	Motion	Amplitude	Frequency
Test-011	2011/08/18 14:34	2011/08/18 18:00	Pitch- Tilt N-S	15 Degrees	0.2 Hz

Motion Compensation

Compensation of **each line-of-sight** measurement for:

✓ Translatory Motion

Subtracting relative velocity component from radial velocities that changed by rigid body motion of lidar window



for retrieval without motion:
(simplified: no v, no w)

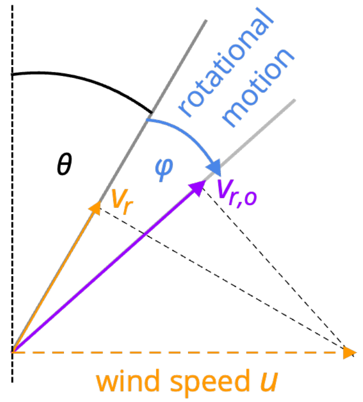
$$v_r = u \sin(\theta)$$

motion compensation
(simplified, translatory)

$$v_r = v_{r,o} - v_{r,t}$$

✓ Rotational Motion:

Compensation by matrix operation due to the changing scanning geometry



for retrieval and
motion compensation
(simplified, rotational)

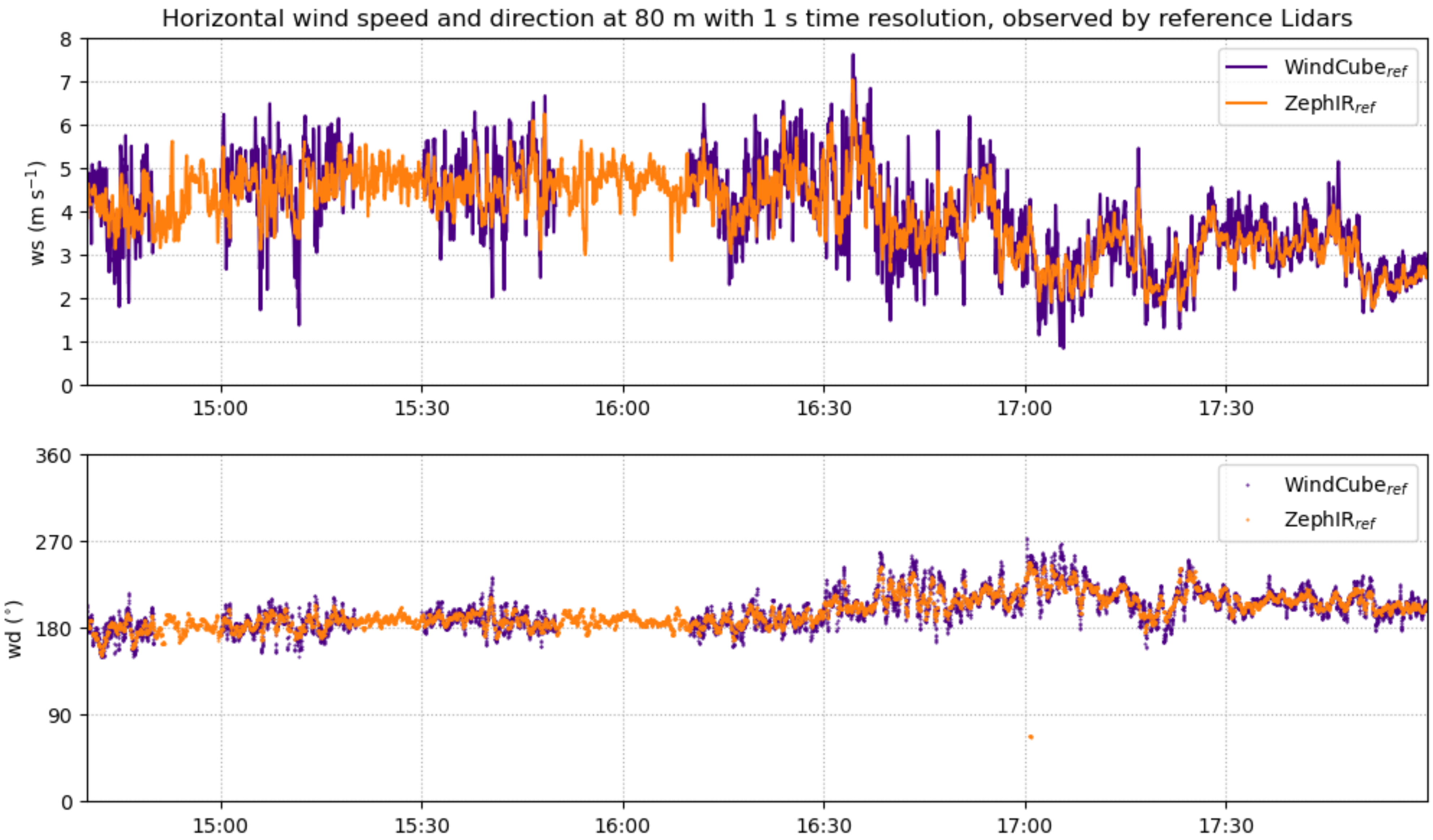
$$v_{r,o} = u \sin(\theta+\varphi)$$

…using time-synchronized synthetic motion data.

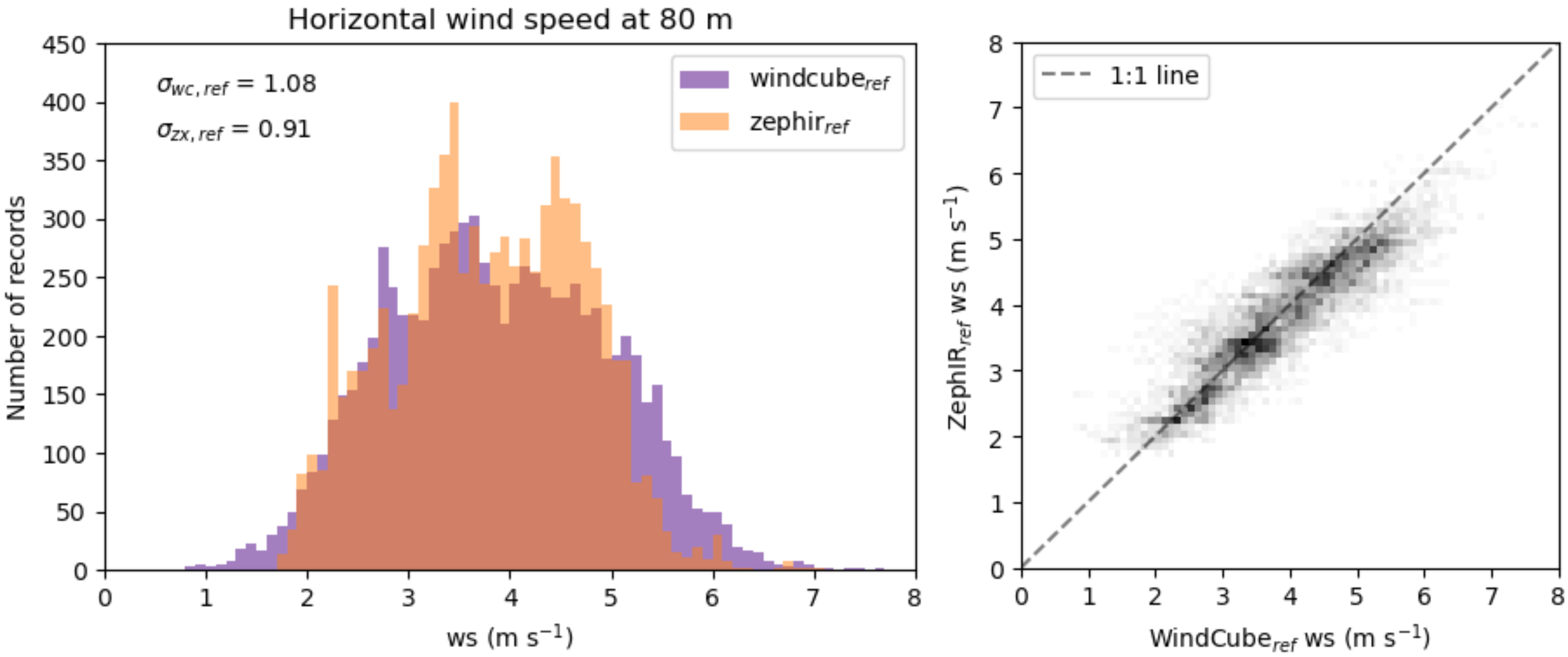
Details in: Kelberlau et al. (2020)

Results

Comparison of the Reference Lidars test-011



Horizontal wind speed statistics for reference lidars



Motion Compensation Evaluation for moving lidars

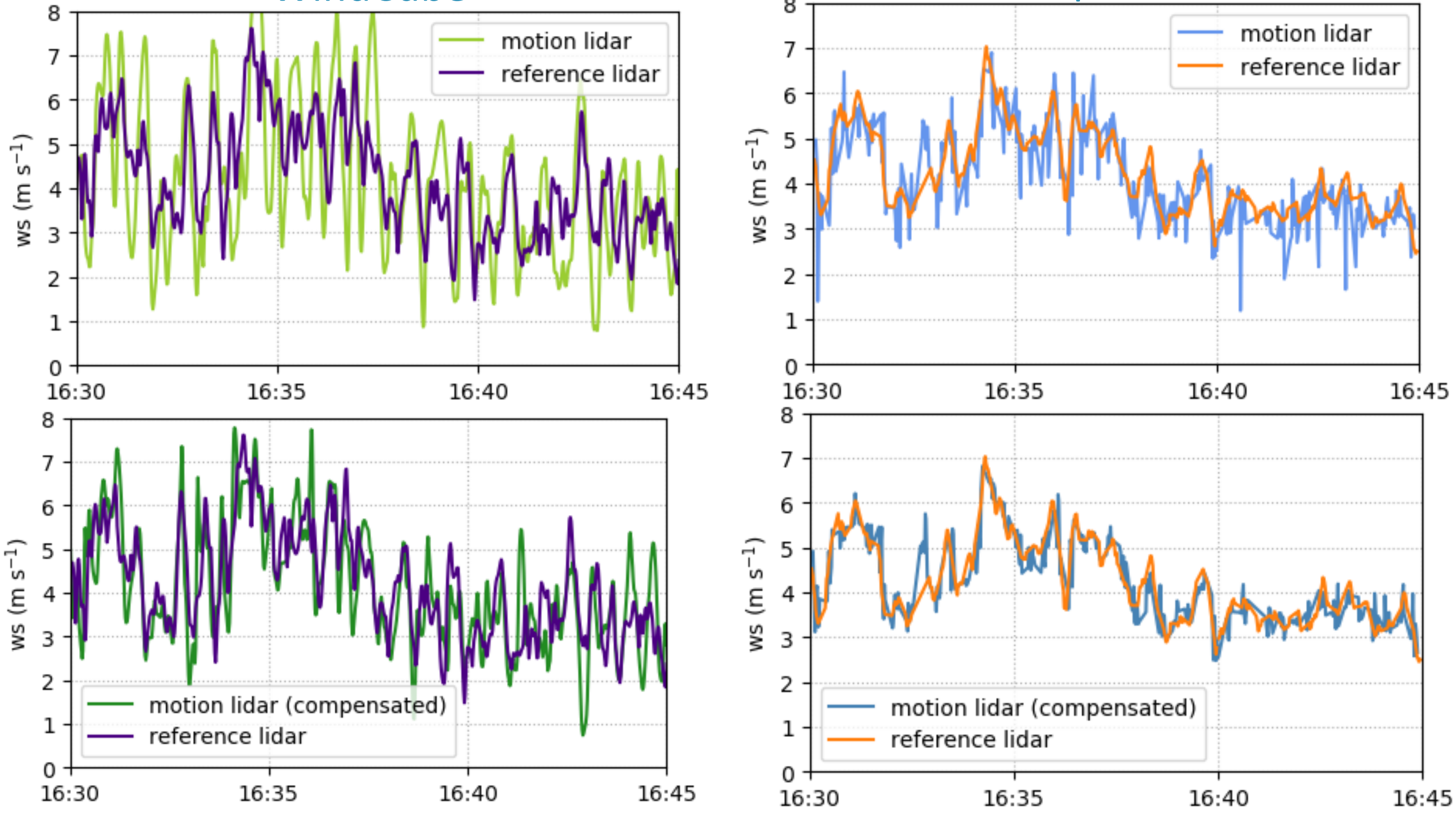
15-minute example time slice (uncorrected vs corrected)

WindCube

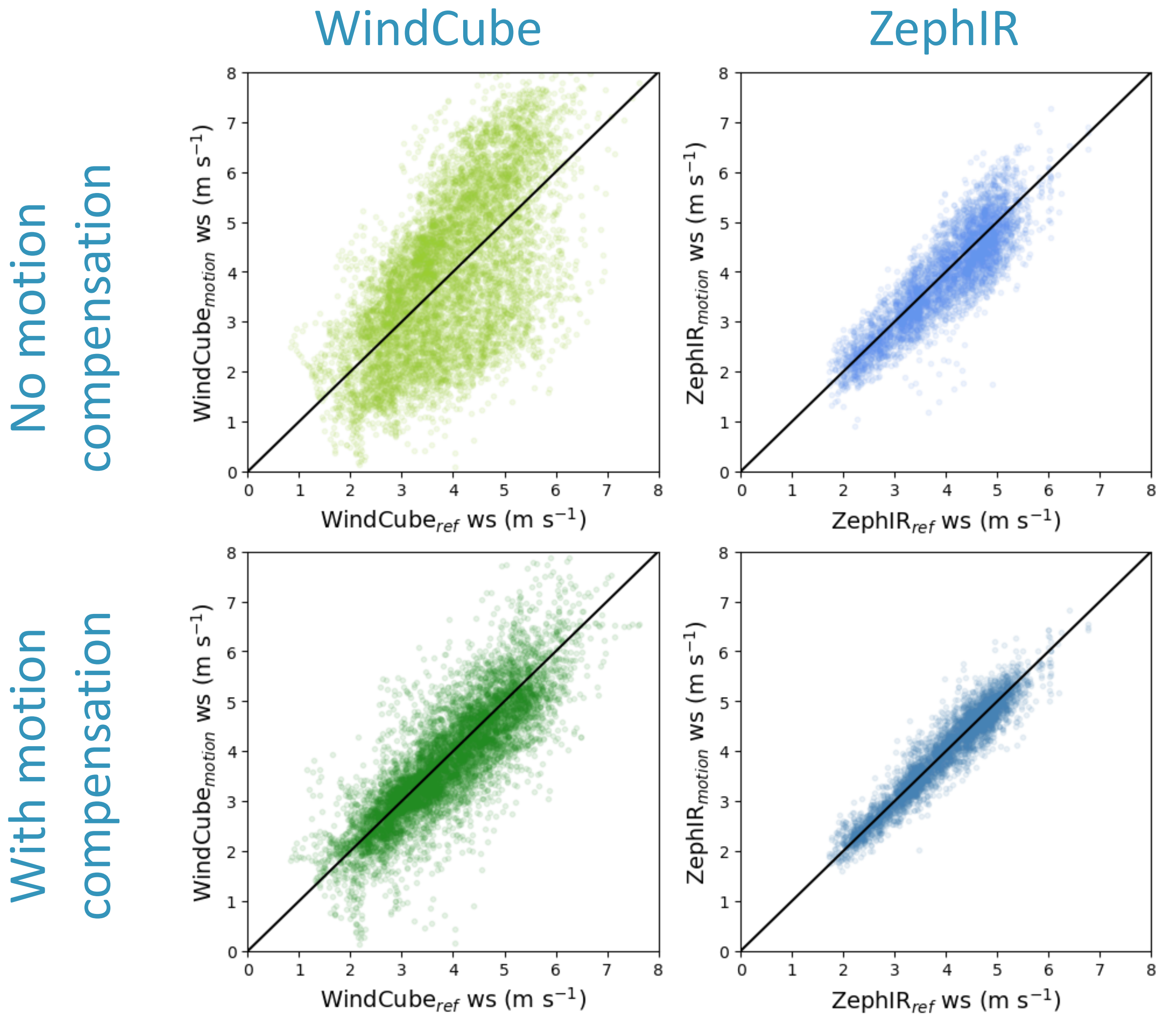
ZephIR

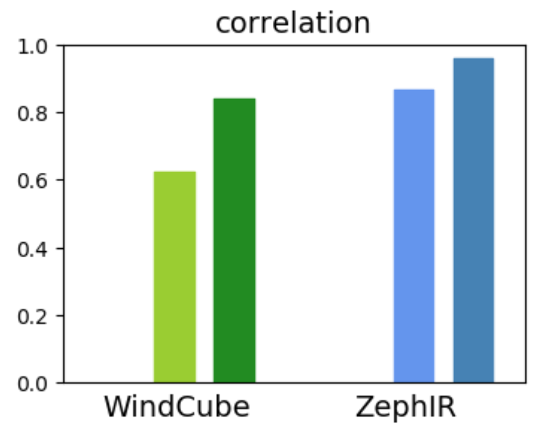
No motion compensation

With motion compensation



Horizontal wind speed improvement





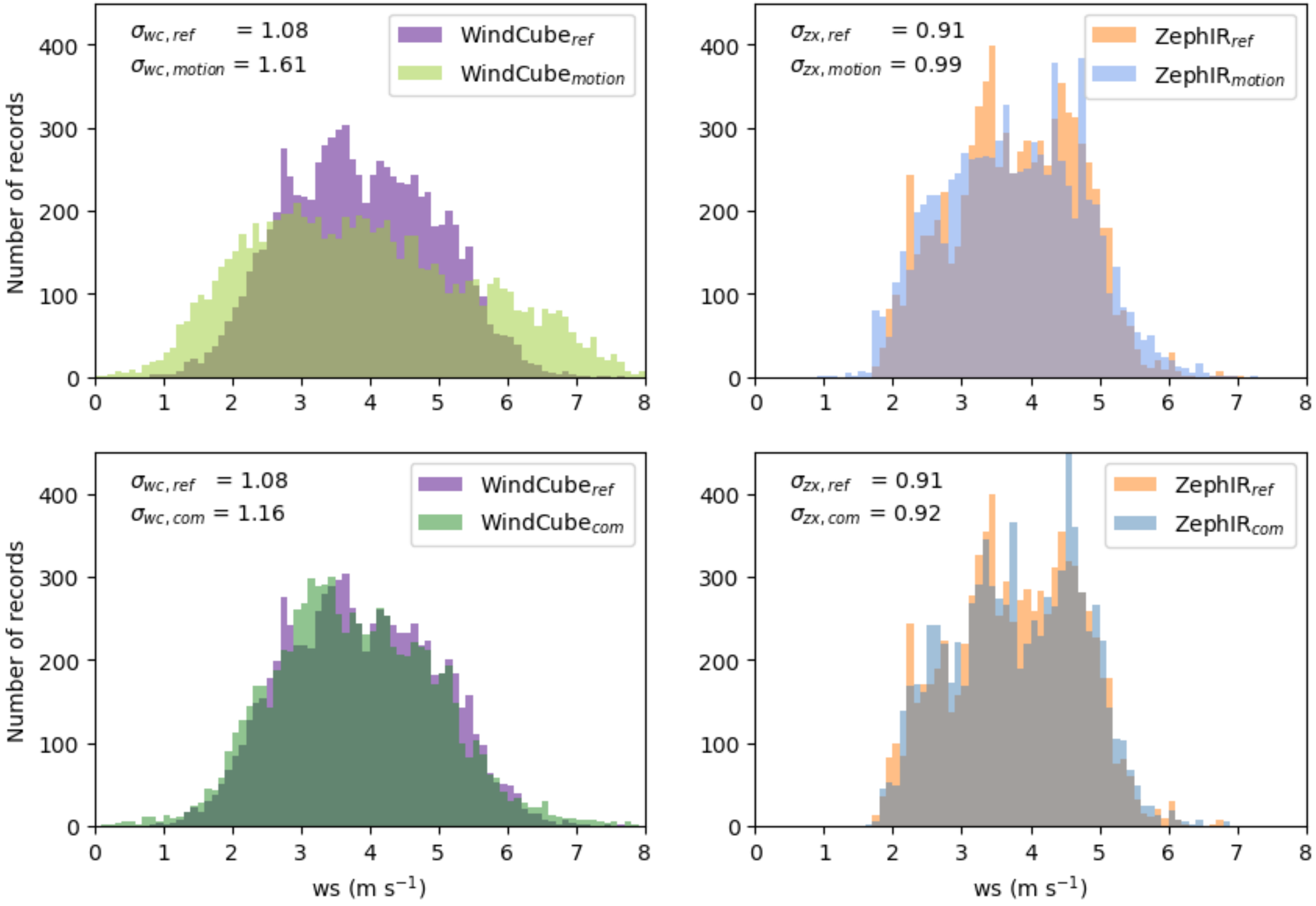
Horizontal wind speed improvement

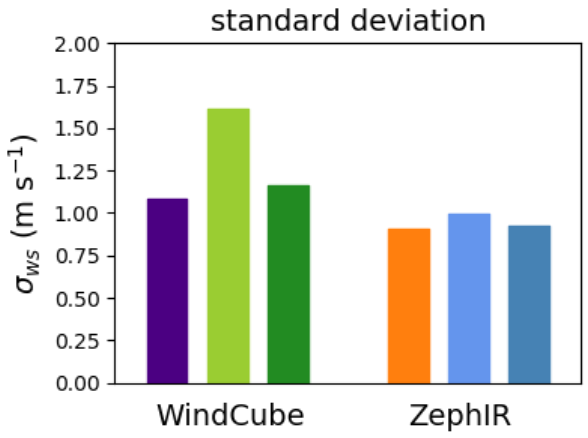
WindCube

ZephIR

No motion compensation

With motion compensation



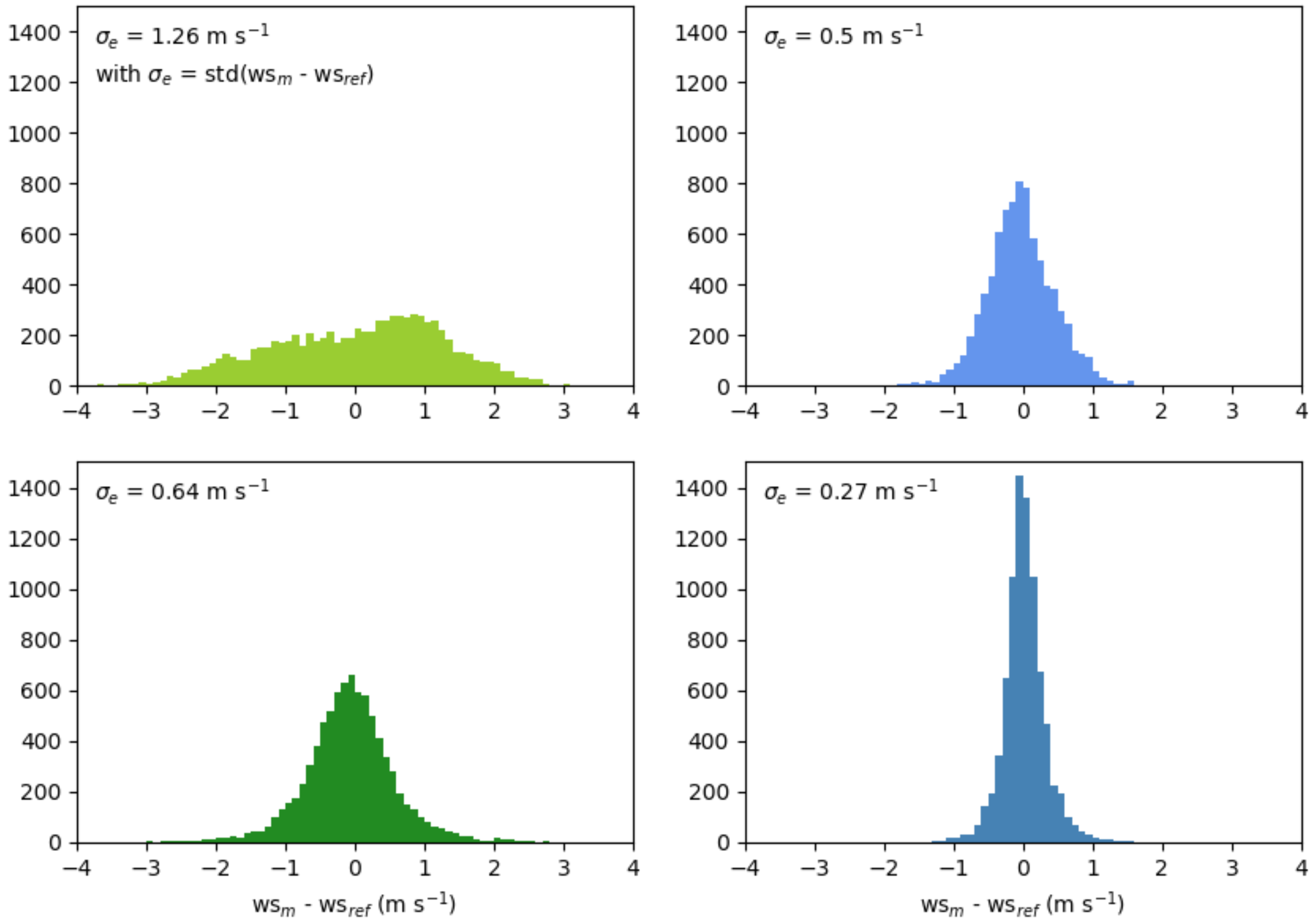


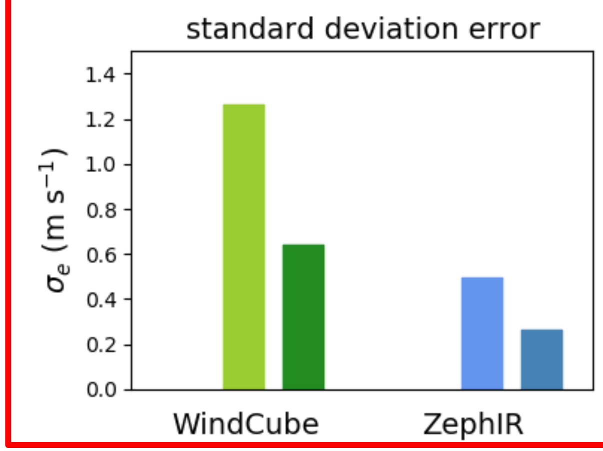
Horizontal wind speed improvement

WindCube ZephIR

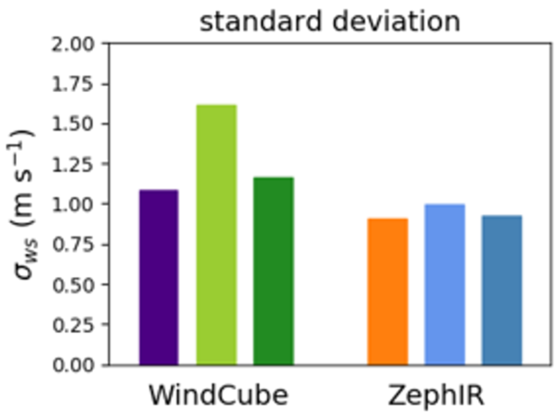
No motion compensation

With motion compensation





Error Reduction by Motion Compensation



Horizontal wind speed

WindCube: 85.1 %

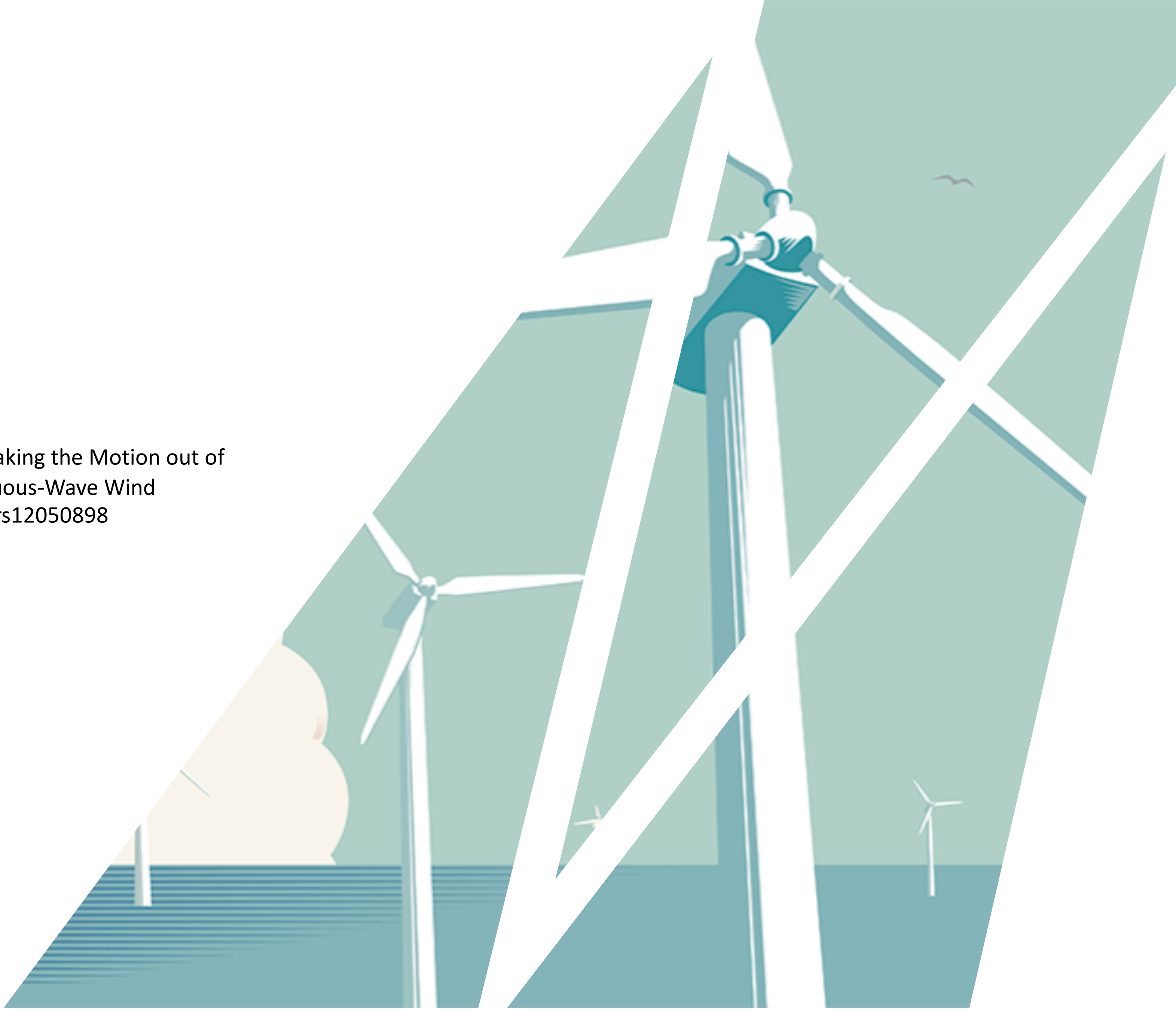
ZephIR: 82.5 %

Conclusion

- ✓ The impact of pitch motion with the frequency of 0.2 Hz on estimates of the horizontal wind speed is larger for the WindCube than for the ZephIR
- ✓ The WindCube shows larger random error before and after motion compensation
- ✓ The applied motion compensation is effective for both lidars
- ✓ The error was reduced by 85% and 82% after motion compensation for WindCube and ZephIR respectively

Reference:

1. Kelberlau, F.; Neshaug, V.; Lønseth, L.; Bracchi, T.; Mann, J. Taking the Motion out of Floating Lidar: Turbulence Intensity Estimates with a Continuous-Wave Wind Lidar. *Remote Sens. 2020*, *12*, 898. https://doi.org/10.3390/rs12050898



Next Steps

- ✓ Improve experiment setup
- ✓ More realistic motion
- ✓ Have longer measurements over different wind conditions
- ✓ Two reference Lidars to isolate the random error
- ✓ Conduct the experiment in a more representative site

Acknowledgment:

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