A detailed analysis of ship-lidar measurements with comparison to FINO1

Research Alliance Wind Energy

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Summary

As part of the EERA-DTOC project, three ship-lidar measurement campaigns were performed. Main goal was the detection of wind turbine and wind farm wakes, but also the verification of the ship-lidar measurement itself. Therefore, within the third campaign, measurements under typical motion influences in proximity to FINO1 were executed. The influence of the motions, as well as different motion correction approaches, were compared.

Introduction

Within the EU-funded EERA-DTOC project, wind turbine wake and wind farm wake models were implemented. For the verification of these wake models, measurements in proximity to FINO1 and Alpha Ventus offshore wind farm were performed [1]. In order to verify the ship-based floating-lidar measurement and the motion correction itself, a calibration measurement in proximity to meteorological mast (met. mast) FINO1 was conducted. The conditions of the calibration measurement should be similar to the conditions during wake measurements.

Figure 1 and 2 show the used vessel and the ship-lidar measurement set-up.

Figure 1: Support vessel LEV Taifun. Ship-lidar position is marked.

Figure 2: Ship-lidar system comprising the lidar and additional measurement systems in a metal frame.

Motion effects on ship-lidar measurements, calibration

Influences of motions on floating-lidar systems were studied in [2,3]. For most lidar-buoy systems, averaging leads to minor effects on the 10-min-mean horizontal velocity, but a significant increase of the turbulence intensity. Wind direction has to be corrected by consideration of the platform yaw anyway.
For measurements from vessels with a non-neglectable translatory motion, the additional vectorial speed component will normally not disappear due to averaging. Therefor, motion correction is mandatory for all parameters.
Motion correction was already studied in the past. The implementation can be done on both the line of sight (LoS) radial velocities, or the resulting, calculated wind vector time series. Both methods will be applied within this work.
In contrast to lidar-buoy systems [4], there are no recommendations for ship-lidar calibration. Here we focus on the correlation of horizontal wind speeds between FINO1 reference data and measured data, both for 10-min means and 1-min means.

Measurement set-up and procedure

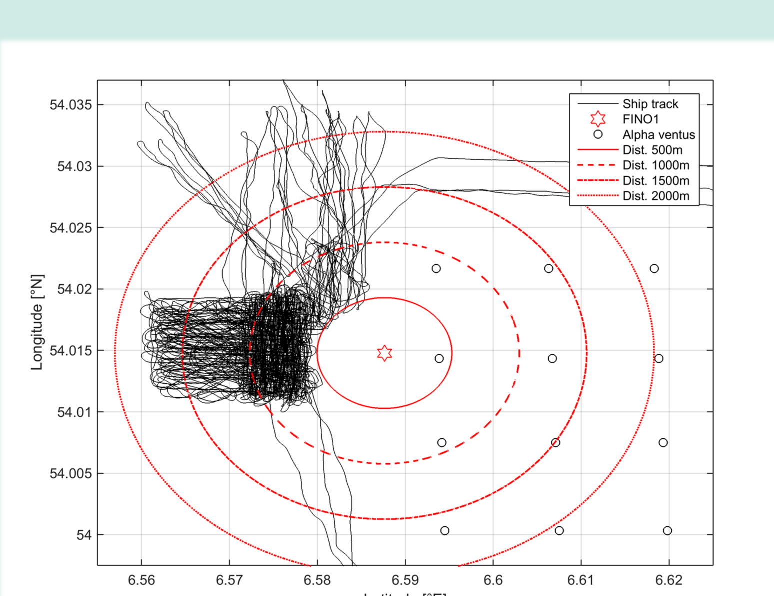

Figure 3: Ship track in proximity to FINO1

The Fraunhofer ship-lidar consists of a Leosphere V2 Windcube, motion sensors and data acquisition systems installed in a metal frame. The ship-lidar was installed on the support vessel LEV Taifun. The measurement were performed from 10-06-2014 until 15-06-2014. Similar to the performed wake measurements, the calibration measurement was performed with a mean vessel speed of 2m/s. The ship track in proximity to FINO1 is displayed in Figure 3.

Figure 4 and Figure 5 show the measurement time in hours, sorted for different distances to FINO1, reference wind speeds and vessel velocities.

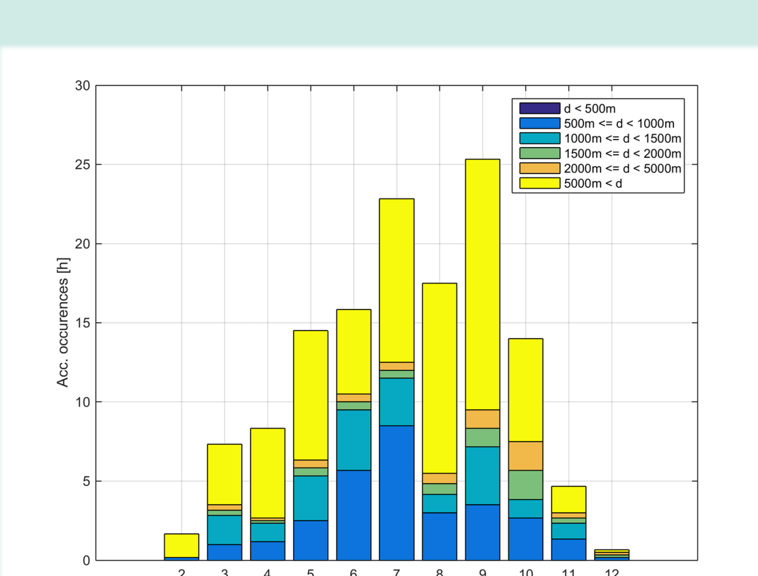

Figure 4: Distribution of reference wind speeds for different ship distances to FINO1.

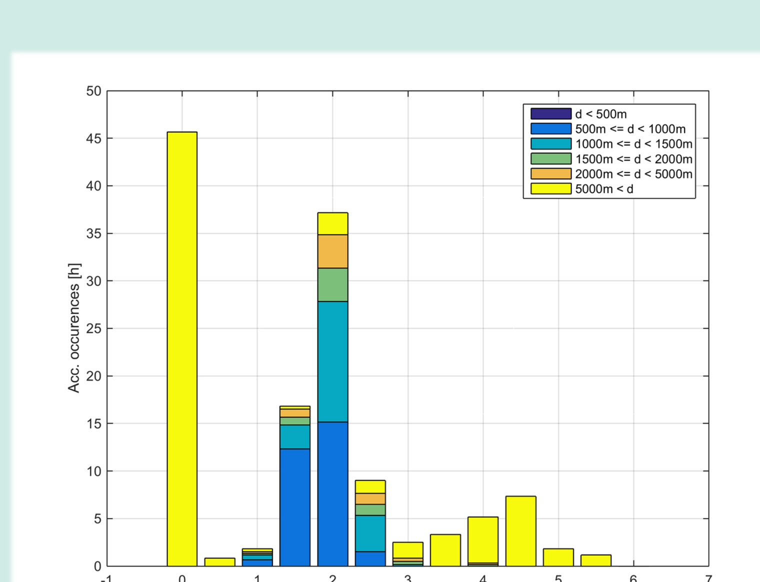

Figure 5: Distribution of vessel speeds for different ship distances to FINO1.

Measurement and motion correction results

The ship-lidar data was compared to FINO1 data measured on 100m altitude level. A linear fit through the origin with slope m was applied for each data set, compare [4]. The measurement data was filtered for reference wind speeds over 2m/s and distances to the reference met. mast. Measurement data for distances less then 2000m and 1500m were used for fitting.
Past wake measurements were analyzed for 1-min means, hence fitting will be applied on 1-min-mean data additional to 10-min-mean analysis. Measured and corrected data are evaluated by slope m and correlation coefficient r^2.
Figure 6-8 show the results for uncorrected, vectorial and line of sight corrected data. While the slope is slightly over one for uncorrected data, r^2 is under 0.62 and 0.83. After applying corrections, the slope exceed one by only 0.2%, while r^2 is better than 0.94 and 0.98. Therefor these values for best practice criteria for floating lidar are fulfilled, compare [4]. It must be noted that difference between both correction methods are negligible, at least for mean horizontal wind speed.

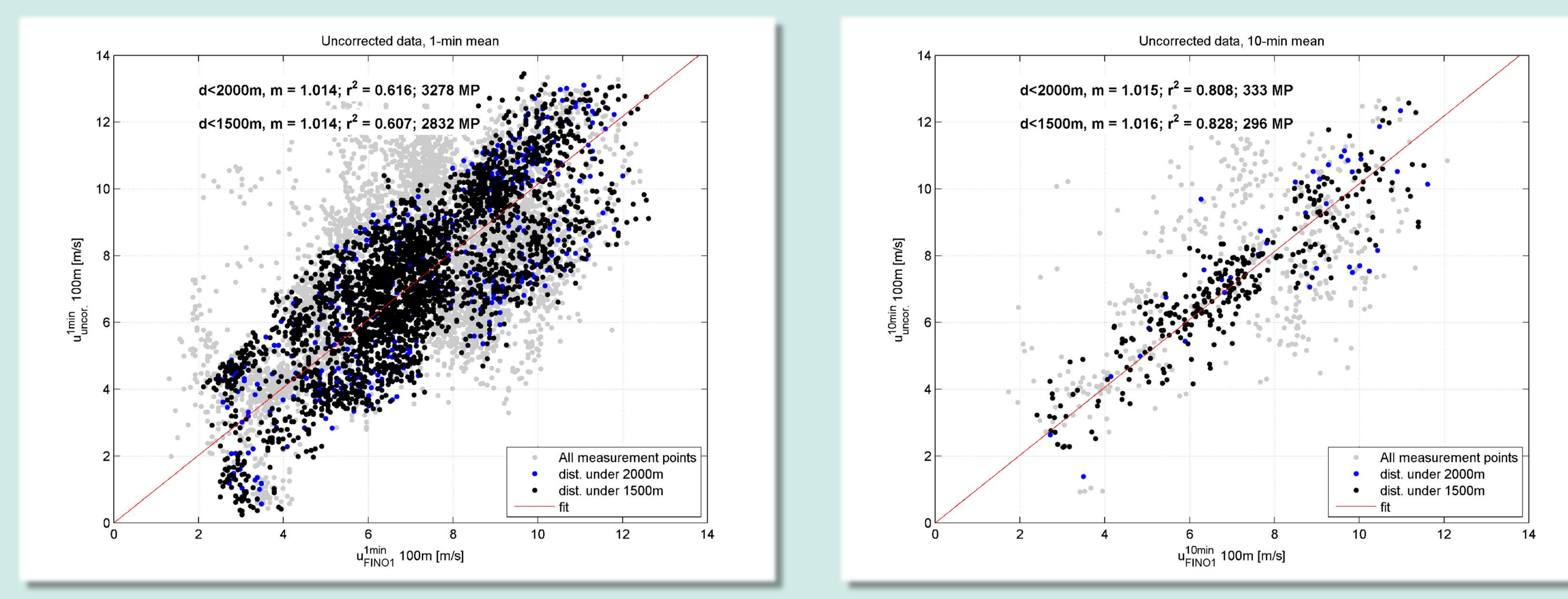

Figure 6: Correlation between uncorrected data for 1-min means (left) and 10-min-means (right) and FINO1.

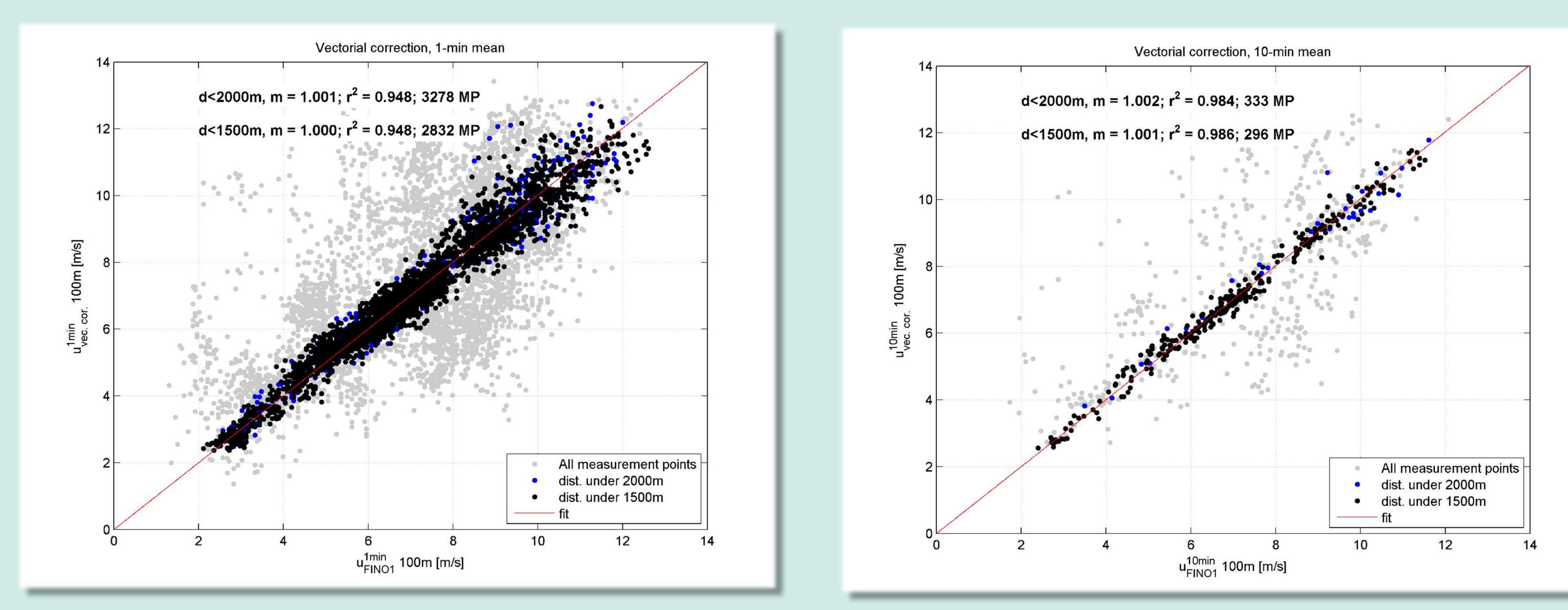

Figure 7: Correlation between vectorial corrected data for 1-min means (left) and 10-min means (right) and FINO1.

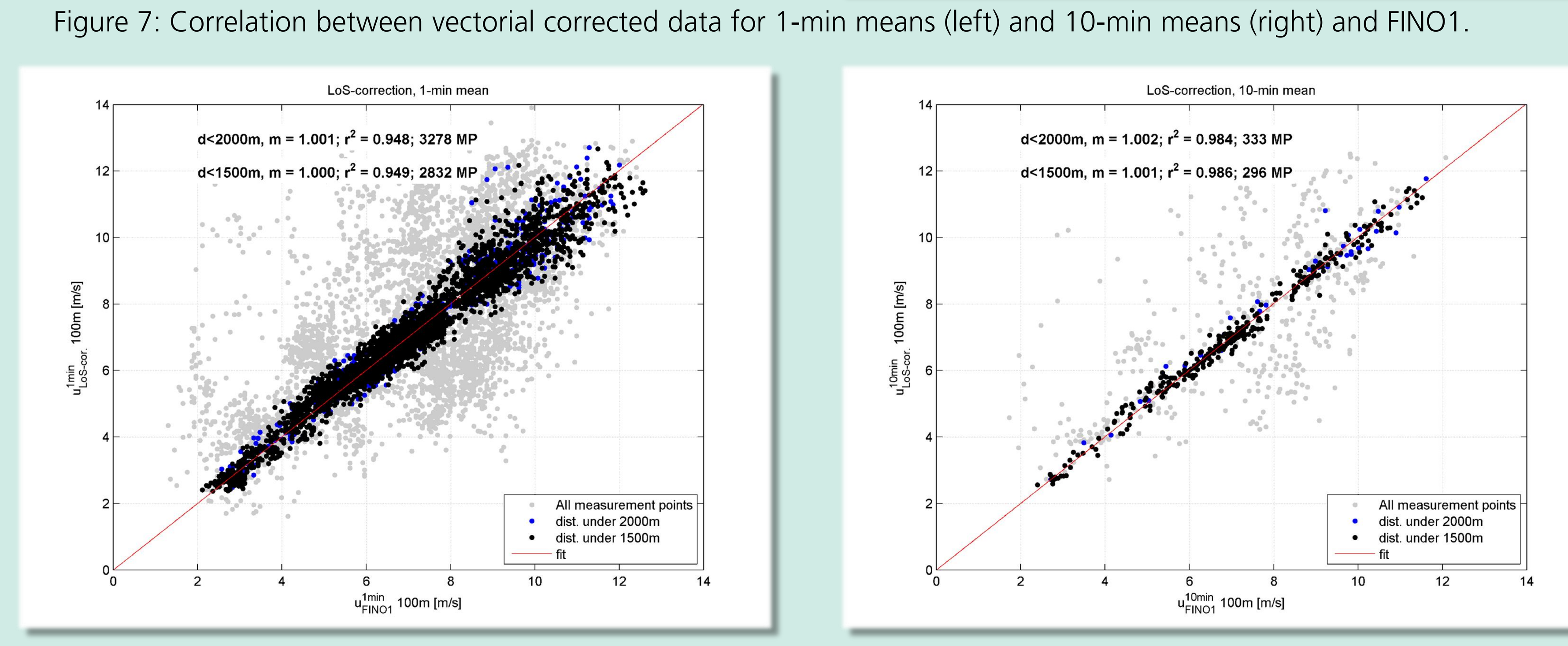

Figure 8: Correlation between line of sight corrected data for 1-min means (left) and 10-min means (right) and FINO1.

Conclusions

The results show a significant influence from motion on ship-lidar measurements for the horizontal wind speed. Hence, motion correction is mandatory. Both vectorial and line of sight correction lead to a significant data improvement, while the difference between the correction methods is insignificant, at least for the wind speed.

The ship-lidar is a measurement device for special purposes, e.g. like wake measurements or for the installation on service vessels, considering the vessel velocity.

Acknowledgements

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