First verification test and wake measurement results using a Ship-LIDAR System

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Abstract

Measuring wind offshore in deep water depths will be a future challenge. Where the sea bed installation of foundations for fixed met masts is impossible, even the mooring of floating systems are more complicated. Ship-lidar systems are an alternative solution for a number of different applications.

In this poster we describe two motion-correction methods for motion-influenced lidar measurements. The ship-lidar system will be presented as well as the first measurements carried out as part of the EERA-DTOC project. Therefore a verification of one correction algorithm will be shown as well as first results from wake measurements behind the Alpha Ventus offshore wind farm.

Measuring set-up

The ship-lidar system comprises a Leosphere WindCube V2 device, different motion-sensors (AHRS, satellite compass), a computer for data acquisition as well as equipment for power supply and wireless communication. The system is combined in a frame in order to ensure a fixed geometry, compare [1].

For the presented measurements, the system was installed on the offshore support vessel LEV TAIFUN with a length of 41.45 m. The system was located approx. 7 m above the point of rotation, whereas the roll frequency is close to f=5 s with extreme roll angles up to 20°

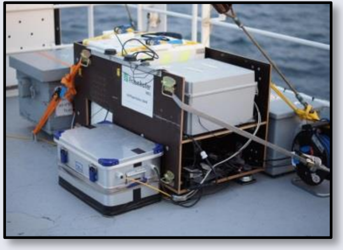

Figure 1: Ship-lidar installation on the LEV TAIFUN.

Figure 2: Ship-lidar measurement in proximity to offshore meteorological mast FINO1. Position of the lidar system is indicated by the red beam lines.

Motion correction algorithms

Wind-lidar measurements using line of sight (LoS) measurements in different beam orientations are solved under the assumption of homogeneity as well as constant wind velocity on each altitude, using a system of linear equations (SLE):

$$\begin{bmatrix} o_x(t_1) & \cdots & o_z(t_1) \\ \vdots & \ddots & \vdots \\ o_x(t_n) & \cdots & o_z(t_n) \end{bmatrix} \cdot \begin{pmatrix} u(h) \\ v(h) \\ w(h) \end{pmatrix} = \begin{pmatrix} v_{LoS}(t_1, h)) \\ \vdots \\ v_{LoS}(t_n, h) \end{pmatrix}$$

$$=> O \cdot \vec{u} = \vec{v}_{LoS}$$

In general, these measurements can be influenced by translatory and rotatory motions, that can be considered by modifying the SLE to

$$O_{tilt} \cdot \left(\vec{u} - \vec{v}^{sys.Velocity,lt}\right) = \vec{v}_{LoS}^{wind} + O_{tilt} \cdot V_{ko}^{sys.Velocity}$$

Under the assumption of constant orientation and motion during the time period covered by the system of SLE, a simplified motion correction can be applied on the resulting wind vector from the SLE.

$$\vec{u}_{wind} = R_{yaw}\left(\vec{u}_{measured}\right) - \vec{u}_{ship}$$

Especially periodical tilting motions in the frequency range of the lidar measurement frequency, combined with additional translatory motion due to the distance from lidar to center of rotation can lead to beating effects that are not considered by the simple motion correction.

Floating lidar corrections algorithms were studied in [2] and [3].

Measurement campaigns

For the EU FP7-funded EERA-DTOC project, two measurement campaigns were performed from 27-31 August 2013 and 04-09 October 2013 comprising approx. 7.5 days in proximity to Alpha Ventus wind farm.

Goal of the measurement was the survey of wind farm wakes in different distances. In order to verify the measurement principle, data was also acquired in free inflow in proximity to FINO1.

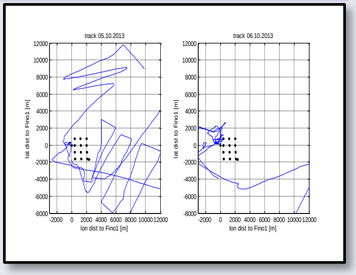

Figure 4: Plots of ship track for the second measurement campaign.

Verification of correction algorithm

For the first analysis, the simplified correction algorithm was applied on the measured data. Figure 5 shows results of uncorrected, yaw corrected (rotated) and fully corrected data for one-minute-mean values for the 5th of October 2013.

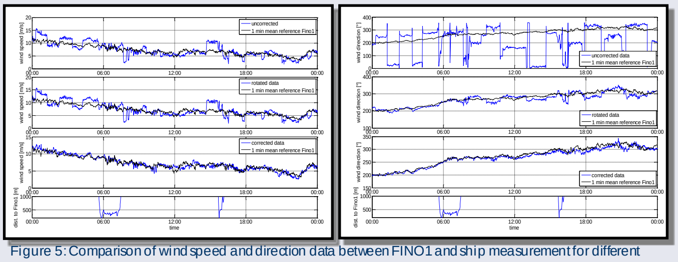

Figure 5: Comparison of wind speed and direction data between FINO1 and ship measurement for different levels of correction.

Scatter plots also show improvements between uncorrected and corrected data (see figure 6). Nevertheless the correlation of the data is not comparable to fixed lidar or lidar-buoy data [4].

A reason could be motion effects on the ship measurement that are not considered by the simplified motion correction.

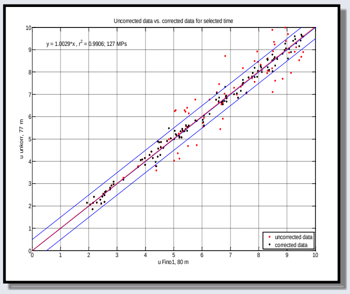

Figure 6: Scatter plot of 10-min-mean values, selected for wind direction and distance to FINO1.

Wake measurements

First wake measurements were performed with ship tracks perpendicular to the wakes, see figure 8. Results show distinct wakes for a distance of approx. 15D, see figure 7. These wakes can be identified by decreased wind speeds and increased turbulence.

For longer distances, reference wind data are necessary.

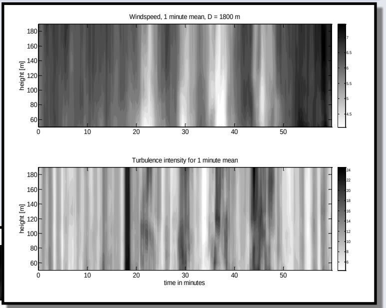

Figure 7: Plots of wind speed and turbulence intensity.

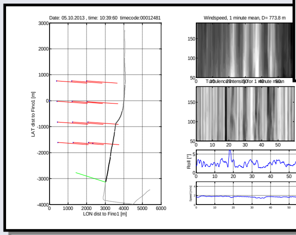

Figure 8: Overview of ship track and theoretical wind wakes.

Conclusions

First ship-based lidar measurements next to met masts FINO1 show good correlations for wind speed and direction using the simplified correction. Nevertheless it is assumed that the complete motion correction will improve the data.

Using the ship-lidar for wake measurements, wakes could be identified clearly for distances of approx. 15 rotor diameters. For longer distances, inflow reference data as well as a complete motion correction is necessary.

References

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