Orientation correction of wind direction measurements by means of staring lidar

Michael Schmidt, Hauke Beck, Juan-José Trujillo and Martin Kühn

ForWind – University of Oldenburg, Institute of Physics,
Ammerländer Heerstraße 136, 26129 Oldenburg, Germany

Friday 22nd April, 2016

1 Introduction

At present the wind community is experiencing a strong need for very accurate orientation of wind direction sensors; e.g. for precise design of wind farm layout, or test of new wind farm control techniques with active wake control. In spite of the efforts made at the time of installation of wind vanes or ultrasonic anemometers, there is always a remaining uncertainty of several degrees in the absolute north of such sensors. In this research we present a method to reduce the azimuthal orientation error of wind direction sensors by means of Doppler lidar measurements operated in staring mode. Our method is applied in an offshore measurement campaign where we are able to reduce the maximum alignment error to below $\pm 1°$.

2 Approach

The method is based on targeting the wind sensor with a lidar installed at a far distance and comparing the wind speed in the line of sight u_{los} from both sensors. For this the wind speed from the sensor is projected onto the lidar beam direction, which is obtained from the geographical positions of both sensors. Hard targeting of the mast is used to assure the accurate orientation of the lidar. The orientation error of the sensor is assessed by comparing the directional position of the maximum u_{los} obtained by both systems.

3 Main body

The aligning of a sensor's orientation in relation to the lidar beam direction is performed by analysis of u_{los} with respect to the wind direction for fixed wind speed magnitudes.

We applied this technique on measurements performed at the offshore research platform FINO1 and at the neighbouring wind farm alpha ventus. During a four week measurement campaign we set up a long-range lidar in the wind farm to measure closely to the FINO1 ultrasonic anemometer at 40 m height above mean sea level (a.m.s.l.). The lidar is located at 22 m a.m.s.l., and it's distance to the ultrasonic is around 3 km. The lidar data collected amount – after quality filtering – to 1243 ten-minute averages. This number is sufficient to classify them by wind direction and speed. The ultrasonic sensor's data projection onto the lidar beam direction to gain it's u_{los} is done directly from the data.

Classified u_{los} data show a direction-dependent sinusoidal characteristic for both, the sensor and the lidar measurements (Fig. 1). Keeping in mind, that the lidar beam direction is "locked", we see, that an orientation error in the sensor's frame of reference will cause a shift γ of the sinusoidal functions. This shift is identified as the misalignment angle of the ultrasonic sensor. We use this angle to correct the sensor's orientation.

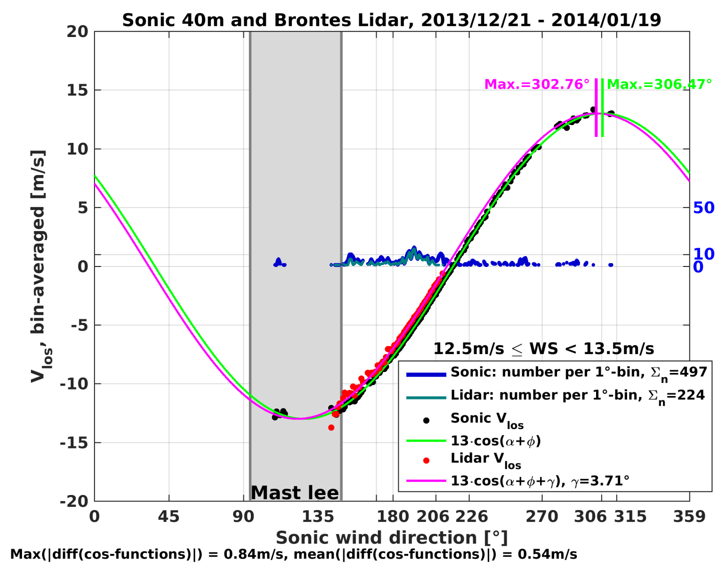

Figure 1: The shift between the sinusoidal functions for the ultrasonic anemometer and the lidar is $\gamma = 3.71°$. This has to be repealed by re-calculation of the ultrasonic's wind direction after aligning the data by rotation with angle γ.

The results show that we can align the ultrasonic anemometer to north, the remaining error is estimated to be smaller than $\pm 1°$. We validate this conclusion by comparing u_{los} from the lidar and the ultrasonic anemometer with corrected orientation. The bias between both systems diminishes considerably after correction.

4 Conclusion

This research shows that the staring mode technique can be applied to improve the estimation of the absolute orientation of ultrasonic sensors. The technique is applied in-situ to correct data after installation of the measurement system. Moreover, it can be applied from the ground without need for access to the sensor or the meteorological mast. We expect this method to be useful also for aligning wind vane data, and to correct nacelle anemometer data as well.

5 Learning objectives

- We demonstrate a new method for wind sensor direction data correction by means of a long-range lidar to achieve direction information with previously unknown accuracy, and
- we present the application of this method for reliable comparisons of lidar and ultrasonic anemometer measurements.