ORIENTATION CORRECTION OF WIND DIRECTION MEASUREMENTS BY MEANS OF STARING LIDAR

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Abstract

For wind energy applications, concise wind direction information became important recently. We present a **method to reduce the azimuthal orientation error** of wind direction sensors **by** means of **Lidar** measurements, which is based on the line-of-sight wind speed comparison between a conventional sensor (i.e. wind vane, ultrasonic anemometer, …) and a distant long range Lidar pointing to it in staring mode. The **advantage** of this method compared to others **is having the line-of-sight as a precise reference**. We have applied this method in an measurement campaign in an offshore wind farm to a meteorological mast. The **alignment error** of an ultrasonic anemometer **was reduced to below ±1°**, consequently the **Lidar data quality has improved substantially.**

Objectives

The aim of this research is to **provide accurate wind direction** data **e.g. for** design of **wind farm layout**, or future **wind farm active wake control techniques**. Precise wind direction information is also needed to calculate **high quality Lidar wind speed data**, as the error of the projection – wind speed magnitude onto the line-of-sight – grows rapidly for unfavourable wind directions.

Staring velocity azimuth display method (SVAD)

A long range **Windcube 200S Lidar**, located on the substation of the offshore wind farm alpha ventus in the North Sea, was temporarily **staring to the Gill R3-50 ultrasonic anemometer** at 41.5m LAT height on met mast FINO 1 during a four week campaign in December 2013 and January 2014 (Fig.1).

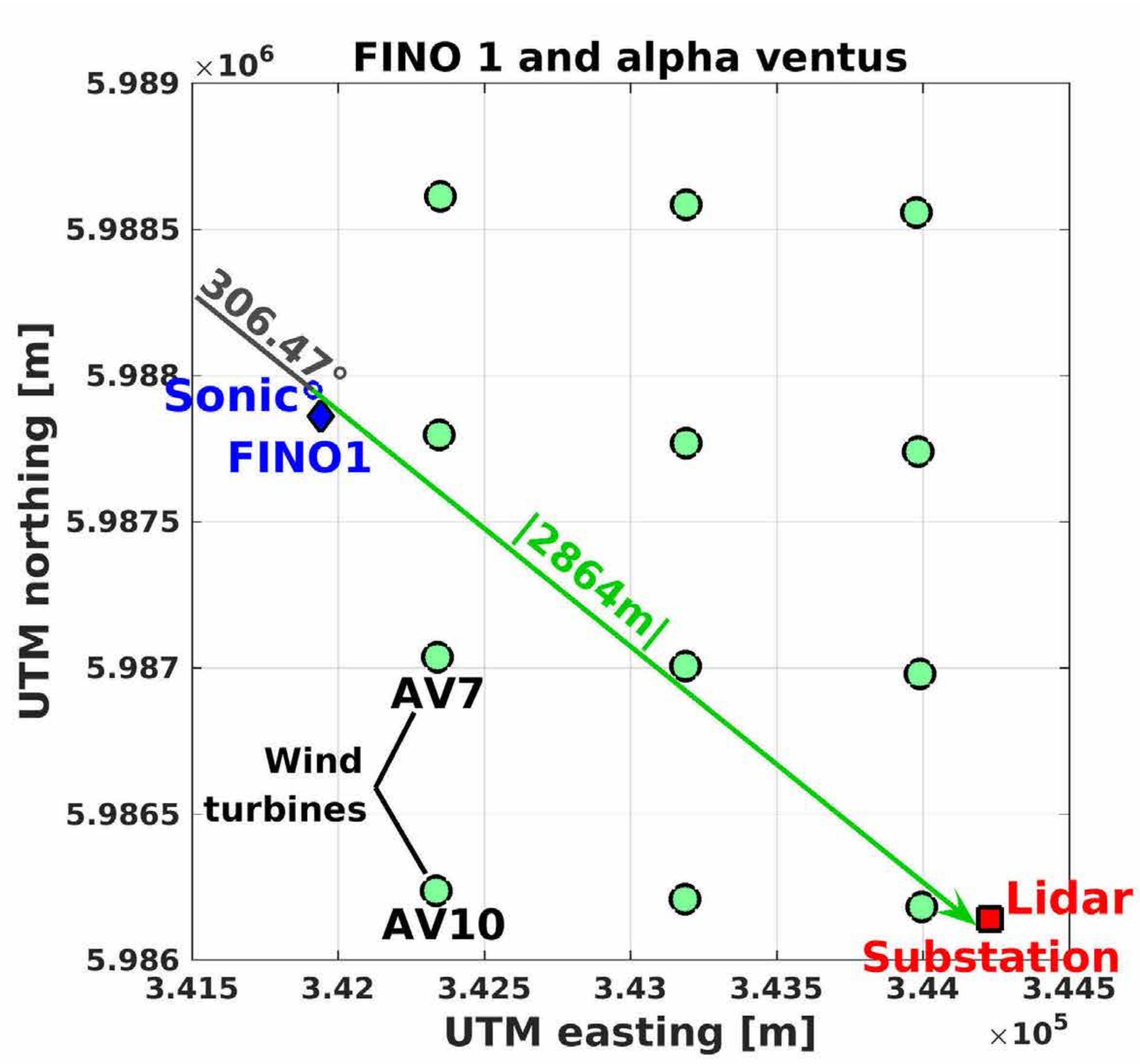

Fig.1: Layout of measurements in wind farm alpha ventus. The distance between lidar range gate 2864m and Sonic was smaller than 8m.

The **Lidar's line-of-sight**, recognized **as reference** for the direction evaluation here, was at 306.47°±0.28°(compass system). The Sonic wind speed is projected onto this **direction** to get the line-of-sight speed $V_{los,Sonic}$. Classification of V_{los}-data by wind speed magnitude necessarily arrange them on sinusoidal curves with maximum at the line-of-sight direction. **Different alignments** of two sensors **introduce a phase shift** between the curves, as shown for the Lidar and the Sonic by Fig. 2 for the wind speed range 12.5-13.5m/s.

The explanation for the **phase shift** of the $V_{los,Lidar}$ curve **is** found in **the Sonic's misalignment**. It's size is calculated by fitting the $V_{los,Lidar}$ data to the function

$$V_{los,\ lidar} = \overline{V_{los}} \cdot \cos\left(\alpha + \Phi + \gamma\right),$$

wherein $\overline{V_{los}}$ is the center of the wind speed bin, α is the wind direction, Φ transfers the Cartesian to the compass system and rotates this to the line-of-sight, γ is the phase shift, identified as misalignment angle.

Due to statistical uncertainty, γ slightly differs for the wind speed bins. The average is $\bar{\gamma} = 3.69°$. The resulting error, including GPS location errors of Lidar and Sonic (0.28°), the Lidar's orientation error (0.1°, checked by hard targeting experiments), and the γ's standard deviation (0.34°), is ±0.45°. So, the **Sonic's misalignment is found to be $\bar{\gamma}$=3.69°±0.45°.**

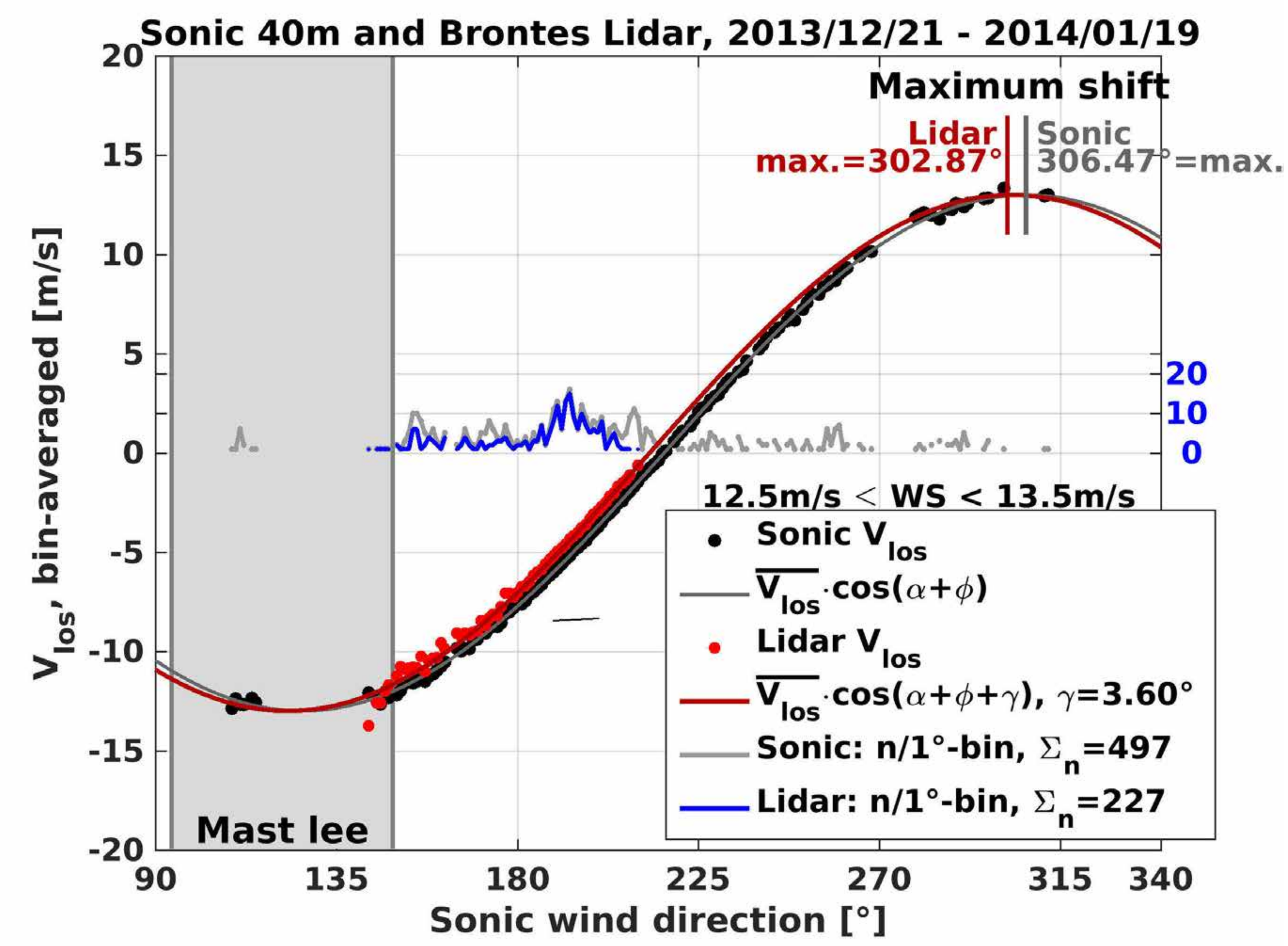

Fig.2: Fitting the $V_{los,Lidar}$ data in wind speed bin 12.5-13.5m/s to a sinusoidal function yields γ=3.60°, identified as misalignment of the Sonic wind direction.

For the analogy to the well-known VAD-Lidar technique, we propose to call this new alignment method "Staring Velocity Azimuth Display" (SVAD).

Evaluation of the method

The recalculation of the Lidar wind speed using the correctly aligned Sonic wind direction data clears the Lidar to Sonic wind speed bias (Fig.3).

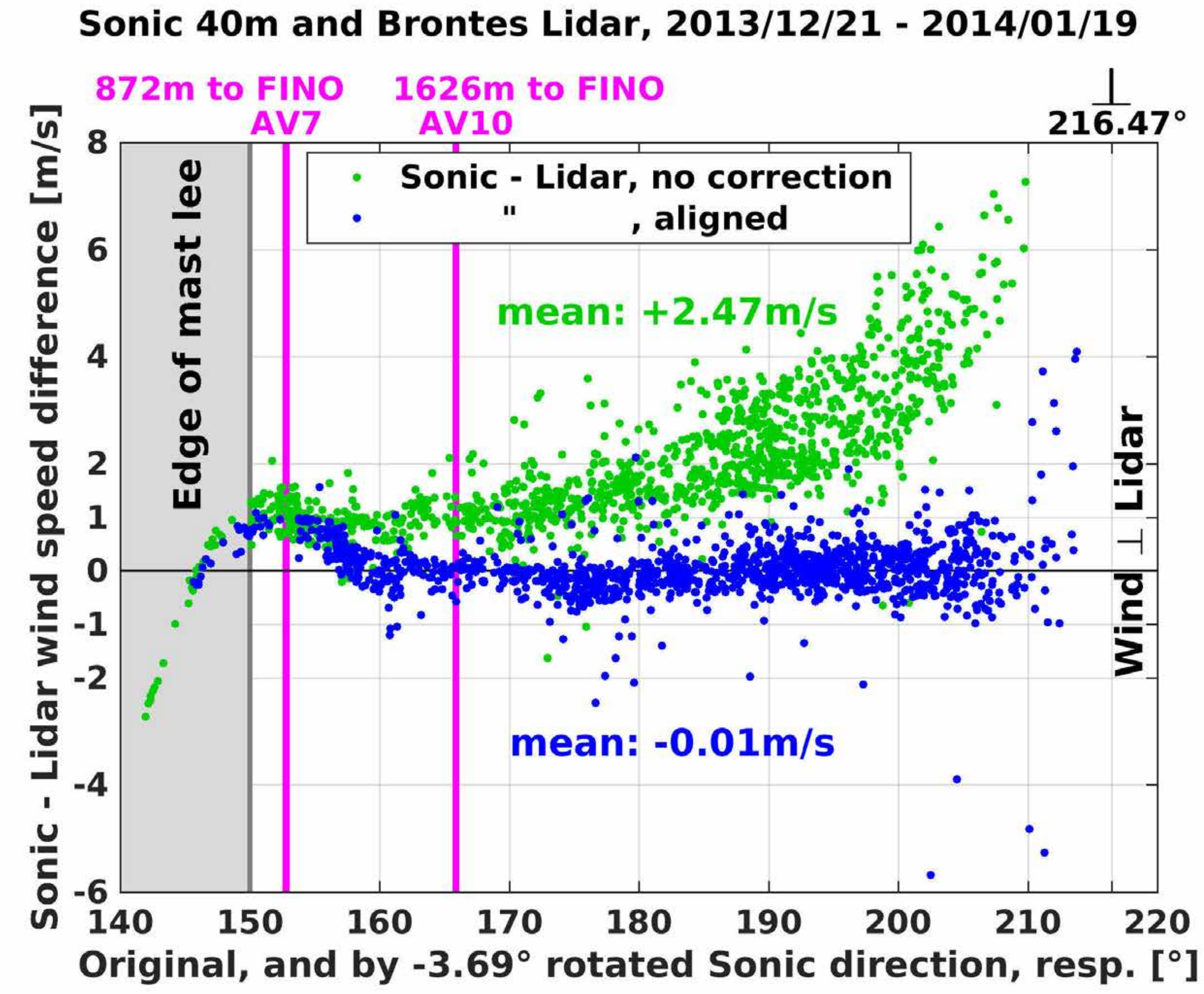

Fig.3: Turbine AV7 wakes (145°- 160°) do stronger affect Lidar than Sonic measurements. Perpendicular to line-of-sight, the Lidar error is still big, but vanish in sector 160°-210°.

Conclusions

The SVAD method achieves **direction information with previously unknown accuracy**, and **increases considerably the value of** both, **wind measurements at a mast and Lidar measurements**. It can be applied without access to the sensor or the mast. We expect this method to be useful also for aligning wind vane or VAD-Lidar data.

References

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