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Two-beam lidar measurements in a non-homogeneous wind field

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Abstract

Nacelle based wind lidars are designed to sit atop a wind turbine structure and make measurements at given distances from it. Most times the lidar faces the turbine's upstream direction to sense oncoming wind.

Two lidars were set up looking upstream on two adjacent offshore turbines in Denmark. The case considered was for when the turbines were oriented such that one lidar was looking into the free stream while the other lidar had one beam in the first turbine's wake and the other beam in near free stream conditions. This enabled the possibility to look at horizontal wind speeds reconstructed inside homogeneous and non-homogeneous wind fields.

Data for the two lidars were processed and averaged over different intervals. Correlations of radial and horizontal wind speeds in different wind fields were performed. Results in this case show horizontal wind speeds reconstructed in non-homogeneous field similar to those reconstructed in a (assumed) homogeneous one.

Objectives

The Wind Iris (two beam) lidar is capable of resolving a 2-D horizontal wind vector under the assumption that the wind field it measures in is homogeneous in the range measured by the two line of site beams. In non-homogeneous conditions velocity vectors, $v_{inc,1}$ and $v_{inc,2}$, incident along the lines of sight (los) will, very likely, be unequal (see Fig. 1).

The objective of the test therefore is to look at the effect of non-homogeneous flow on the horizontal wind field as reported by the system. In this case the non-homogeneuos flow as seen offshore is generated by an upstream wind turbine.

The study will look at:

- Horizontal wind field output in wake induced flows
- Effect of averaging period on results

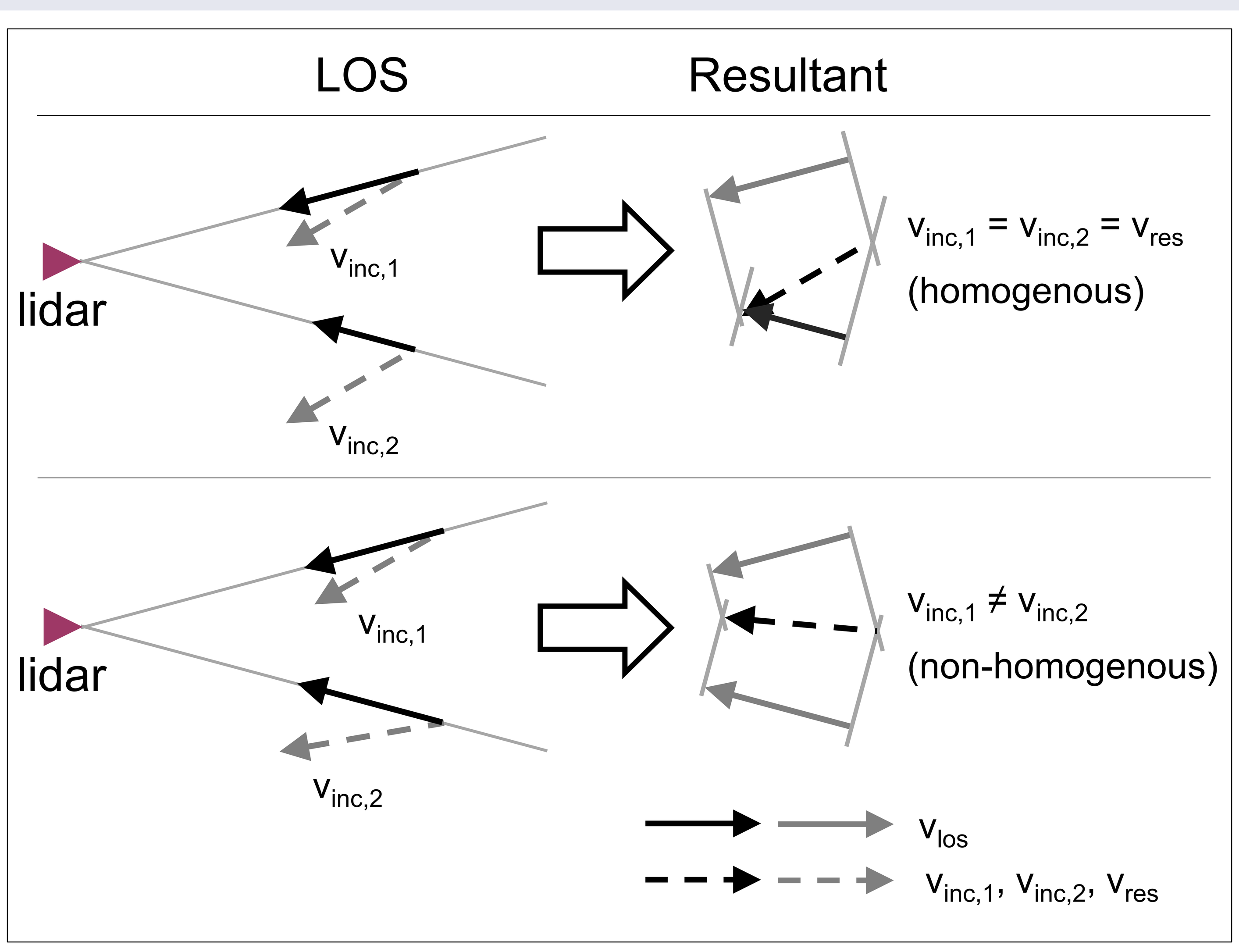

Fig. 1 – Representation of los measurements and wind vector reconstruction

Method

Instances of data were looked at for when one lidar (atop turbine T1) looked at free stream conditions while the adjacent turbine (T2) was oriented in such a way that the second lidar had its two beams in different wind conditions - one in wake conditions downstream from T1 and the other in near free stream (see Fig. 2). Turbine yaw angles were selected such that both turbines had more or less the same heading, with an orientation of +9° relative to when they were back-to-front with turbine T1 pointing in the free stream direction.

The yaw data was available as 10 minute averages whereas the lidar data had a temporal resolution of 1 second (1Hz radial wind speed, 2Hz resolved wind vector). Data from the lidars that fell within the periods that satisfied the yaw angle criteria were picked out from the rest of the data. It was assumed that the turbines kept a constant heading for each 10 minute interval. The wind was then required to head directly onto T1, with a tolerance of ±5° .

Method (cont'd)

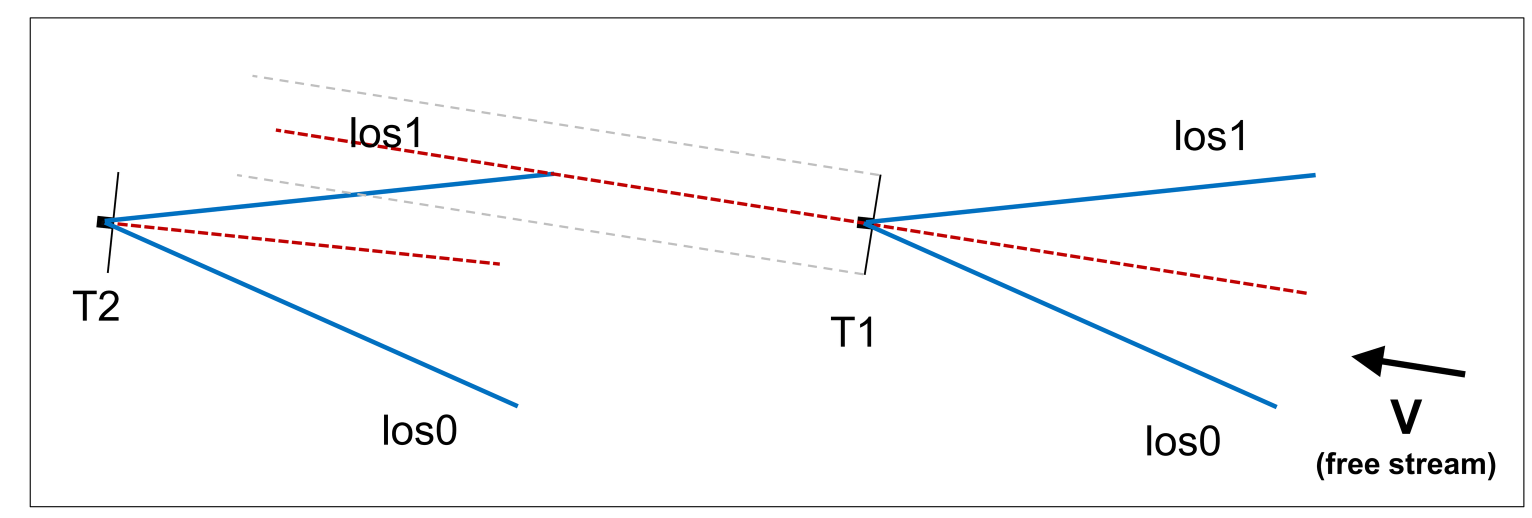

Fig. 2 – Lidar los oriented for the case when both turbines were each off alignment by +9°

Lidar data was processed and radial wind speeds from each lidar beam (los0 and los1) and horizontal wind speeds were averaged over periods of 1 minute, 5 minutes and 10 minutes, following some qualitative data filtering. Correlations were made between v_{los} values at 240m along los0 from T1 and v_{los} values at all range gates along los0 from T2. The same was done for beams los1. This was done since both beams los0 had roughly the same orientation, as did both beams los1. Horizontal wind speed values from the lidar at T2 were compared to those at 240m upstream from T1.

Regression coefficients (slope) and R^2 values for the correlations against distance from T2 are presented in the results section for each of the averaging periods.

Results

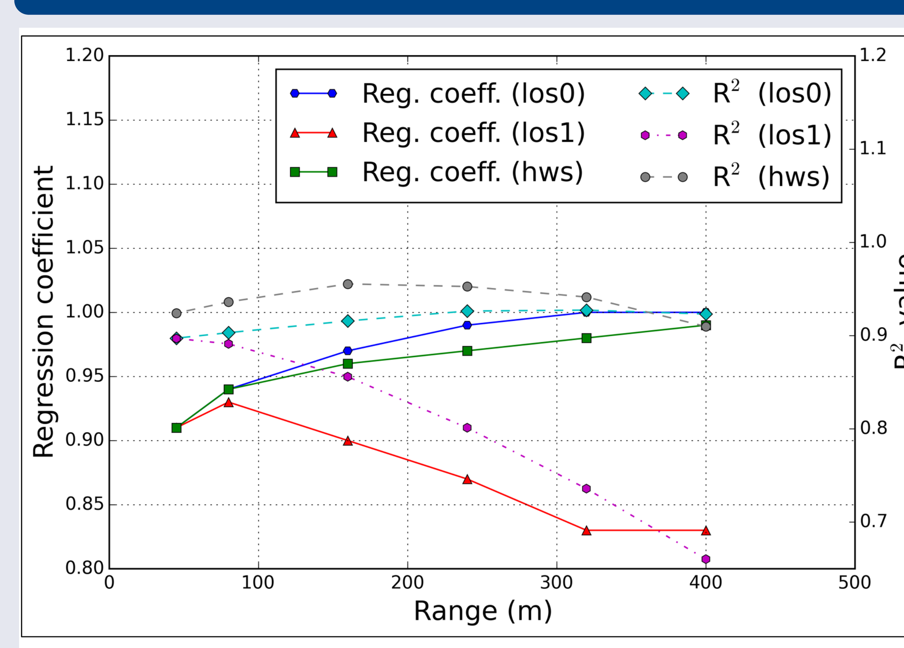

Fig. 3 – Statistics from correlations for data averaged over 1 minute intervals

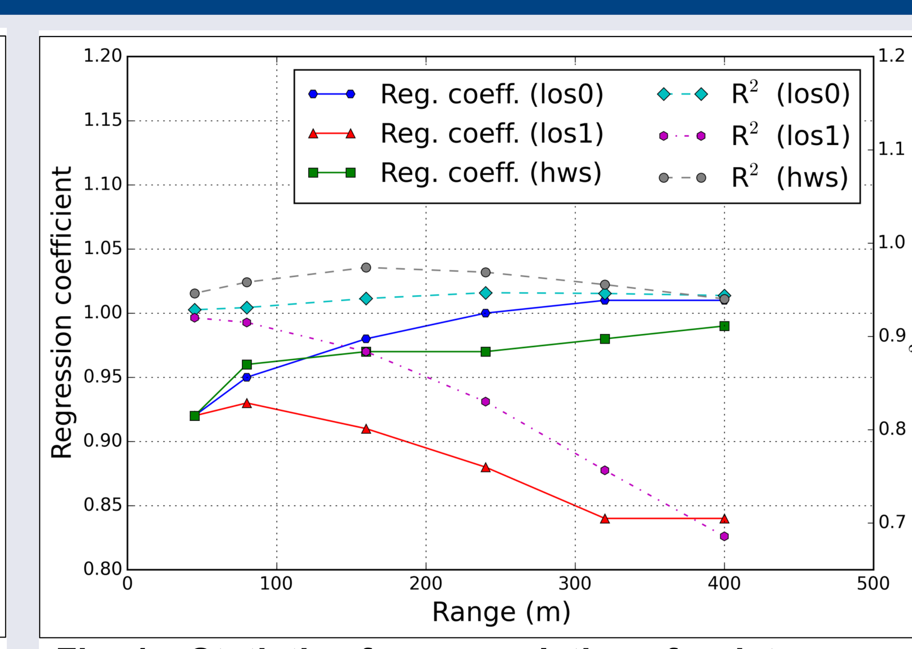

Fig. 4 – Statistics from correlations for data averaged over 5 minute intervals

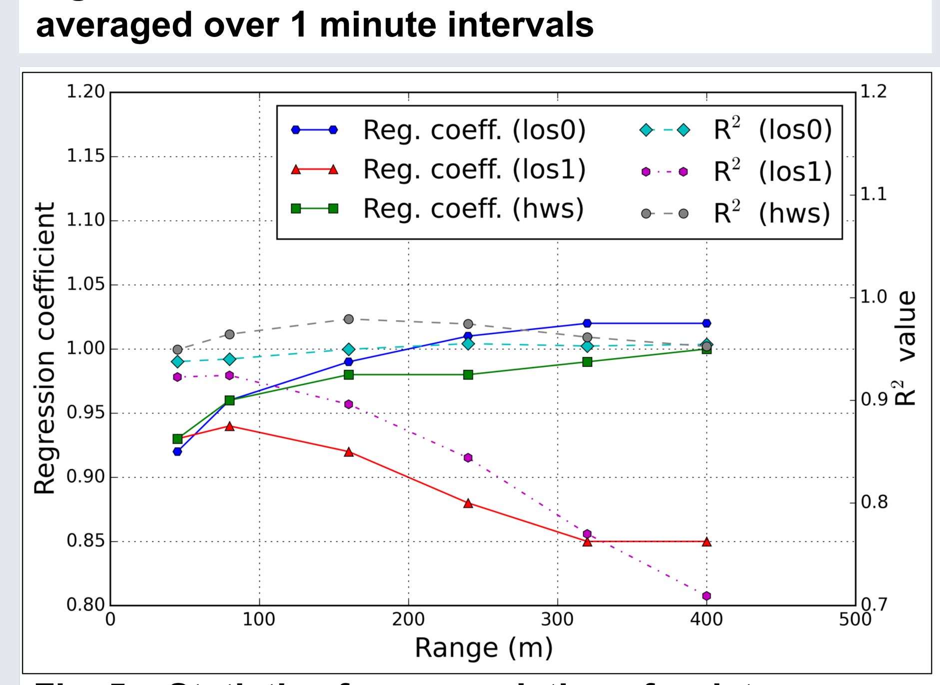

Fig. 5 – Statistics from correlations for data averaged over 10 minute intervals

Correlations for v_{res} from the lidar on T2 (in partial wake) with v_{res} at 240m upstream of T1 gave relatively high reg. coeffs. even with most of los1 from T2 inside wake conditions. All R^2 values less than 0.98.

Average v_{los} in near free stream conditions (T2, los0) compared well to v_{los} in free stream conditions (T1, los0 @ 240m). Reg. coeffs. and R^2 values for los1 were lower at ranges in wake conditions downstream of T1.

Reg. coeffs. for los2 and hws were lower at ranges close to turbine T2 due to the localised blockage effect in the induction zone.

Conclusions

v_{los} values along a (nacelle mounted) lidar beam in near free stream conditions were very similar to those along a beam with the same orientation from a neighbouring lidar in free stream conditions. The second beam from one of the lidars was mostly inside a wake affected region. v_{res} values from the lidar on T2 with one beam in a wake and the other in near free stream compared well to the ones from the lidar on T1 entirely in free stream conditions. The effect of the induction zone was seen close to T2 as correlation values were low. Different time averaging did not affect the results much.

References

1. Albers, A., Franke, K., Wagner, R. et al. (2012). Ground-based remote sensor uncertainty – a case study for a wind lidar. *Proceeding of EWEA 2012, Copenhagen*.
2. Gottschall, J., Courtney, M., Wagner, R. et al. (2012). Lidar profilers in the context of wind energy – a verification procedure for traceable measurements. *Wind Energy*, *15*(1), 147-159.
3. Wagner, R., Pedersen, T. F., Courtney, M. et al. (2014). Power curve measurement with a nacelle mounted lidar. *Wind Energy*, *17*(9), 1441-1453.