ASPECTS ON THE USE OF WIND LIDAR MEASUREMENTS UP TO 600 METERS FOR WIND ENERGY STUDIES: WIND PROFILE, WEIBULL DISTRIBUTION AND BOUNDARY LAYER HEIGHT

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Summary One year of long range wind lidar measurements up to 600 meters above the ground has been analyzed and used to 1) validate the wind predictions by the WRF numerical model 2) estimate the vertical profile of the shape parameter k in the Weibull distribution and 3) to investigate (ongoing research) the ability to estimate the boundary layer height from turbulence profiles. It was found that WRF generally under-predict both the wind-speed and the Weibull shape parameter above 100 meters. Examples of well developed sigma-w profiles are shown.

Wind profile
We present and discuss some recent aspects and experimental data on the use of wind lidar measurements. The study is based on one-year pulsed lidar (Wind Cube 70) measurements of wind speed and direction from 100 to 600 meters with a vertical resolution of 50 meters and temporal resolution of 10 minutes at a coastal site on the West coast of Denmark. The wind profiles were predicted by using a real-time forecast system based on the WRF model developed at the National Center for Atmospheric Research, USA. Based on one year of measurements it was found that the scatter of observations to model results of the wind speed does not change significantly with height between 100 and 600 meters; and that WRF is generally under predicting the measured wind speed profile, Figure 1.

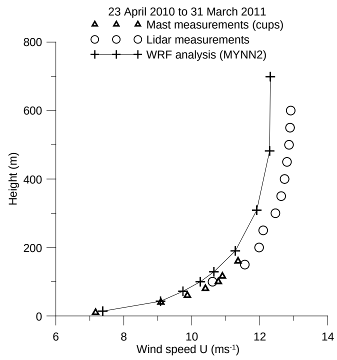

Fig. 1. *Measured and modelled mean wind speed profile averaged over one year.*

Profile of the Weibull Distribution.
The Weibull distribution is often used in applied models for wind energy assessment. The Weibull distribution has two parameters, the shape parameter k and the scale parameter A. The vertical profile of the k parameter is essential for wind energy assessments but largely unknown above meteorological tower heights (100 to 200 meters). Here we derived the A and k parameter profiles from the wind lidar measurements up to 600 meters. The k-profile increases, as expected, from the ground up to about 100 meters where it reaches a maximum and then decreases with increasing height. Comparing with the k profile that can be derived from the WRF model output reveals that the model k values above 100 meters are smaller than the measured ones, Figure 2.

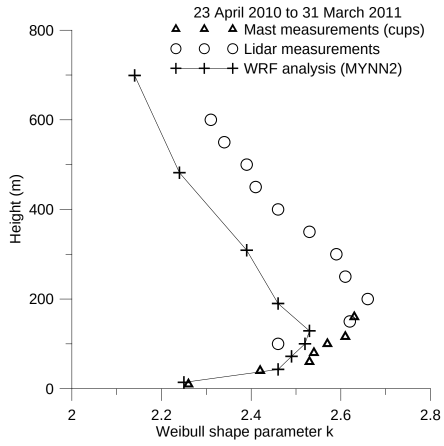

Fig. 2. *Measured and modeled profile of the shape parameter in the Weibull distribution.*

Height of the boundary layer

Additionally, the ability to estimate the height of the boundary-layer from the lidar measurements is currently being investigated. Profiles of the standard deviation of the vertical wind speed, sigma-w, derived from the wind lidar measurements under atmospheric unstable conditions are known to increase from the ground up to the middle of the boundary layer and then decrease towards the top of the boundary layer. Above the boundary layer sigma-w is small which marks the top of the boundary-layer.

Examples of a well developed sigma-w profiles is shown in Figure 3. At the 100 and 150 meter level it is possible to compare the sigma-w derived from the lidar with measurements performed with a sonic anemometer at a nearby meteorological mast. It can be seen, Figure 4, that sigma-w estimated from the lidar measurements is about 50% smaller than sigma-w from the sonic; this is in accordance with the volume filtering that is inherent when measuring with a lidar. Therefore the sigma-w profiles determined from the lidar do not constitute the real values but are reduced due to volume filtering, but they can still be used to provide the relative profile.

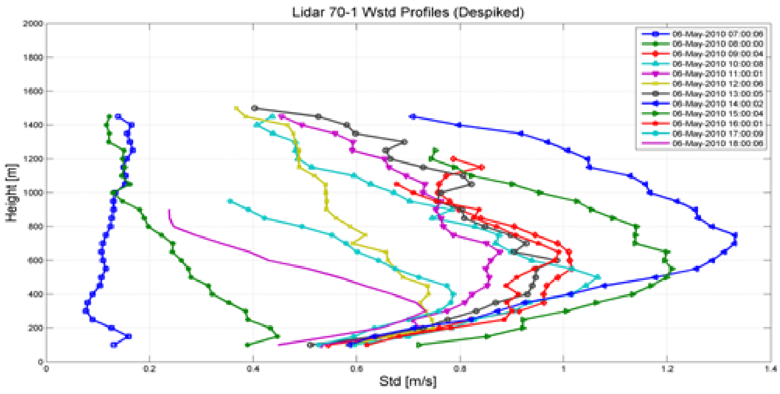

Fig. 3*. Lidar measurements of vertical profiles of sigma-w on 6 May 2010*

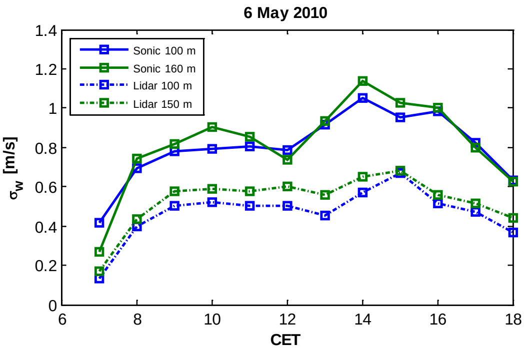

Fig. 4. *Comparison of sigma-w measured by lidar and sonic anemometers at the meteorological mast on 6 may 2010. The measurements are 100 and 150 meters for the lidar and 100 and 160 meters for the sonics.*

Conclusion

One year of long range wind lidar measurements up to 600 meters above the ground has been analyzed and used to 1) validate the wind predictions from a numerical model 2) estimate the profile of the shape parameter in the Weibull distribution and 3) discuss ongoing research on the ability to estimate the boundary layer height from turbulence profiles.

Acknowledgements.

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