Analysis of the vertical wind profile at a BORA – dominated site in Bosnia based on SODAR and ZephIR LIDAR measurements

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INTRODUCTION

The goal of the project South East Europe Wind Energy Exploitation (SEEWIND) - embedded in the 6th framework program of the European Commission - is to gain experience in wind measurement, site development and operation of large scale wind turbines at sites in complex terrain and under harsh climatic conditions.

With remote sensing techniques such as SODAR (SOund Detecting and Ranging) and LIDAR (LIght Detection And Ranging) detailed analysis of the average vertical wind profiles and also of the temporal evolution of the vertical wind profile during Bora events were carried out.

A three-month measurement campaign with an Aerovironment 4000 miniSODAR was performed. In parallel, a three week campaign with a ZephIR LIDAR system was carried out. A 30 m mast provided long term data and also data for evaluating the remote sensing instruments.

SITE DESCRIPTION

The site called Maligrad (Fig. 1) is located on the high plateau Podvelez approximately 5 km east of the city of Mostar in Bosnia-Herzegovina. The instruments were installed at a height of 730 m asl. To the east there are two other hills reaching up to 880 m asl and 1'060 m asl, respectively. A mountain chain Velez (1'800 m asl) overshadows the site Maligrad further east. To the north north-west, west and south-west, the terrain lowers down to around 50 m asl in Mostar.
The prevailing wind directions are north north-east (Bora) and south. Wind speeds are very variable and can easily reach 20 m/s at 30 m height.

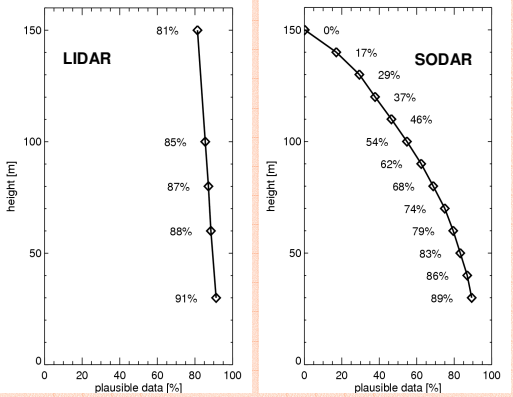
MEASUREMENT CONFIGURATION

The analyzed period for this study started November 22, 2007 and ended December 9, 2007.

	measurement height of wind speed	measurement height of wind direction	measurement period
30 m mast, cup anemometers: This Classic (uncal.)	12 m; 30 m	30 m	May 2005 – in course
SODAR (Aerovironment 4000 miniSODAR, ASC)	30 m to 150 m with 10 m resolution	30 m to 150 m with 10 m resolution	30 Oct 07 – 4 Feb 08
LIDAR (ZephIR, NaturalPower)	30 m; 60 m; 80 m; 100 m; 150 m	30 m; 60 m; 80 m; 100 m; 150 m	21 Nov 07 – 10 Dez 07

Fig. 1: The measurement site Maligrad with SODAR (left) and ZephIR-LIDAR (right).

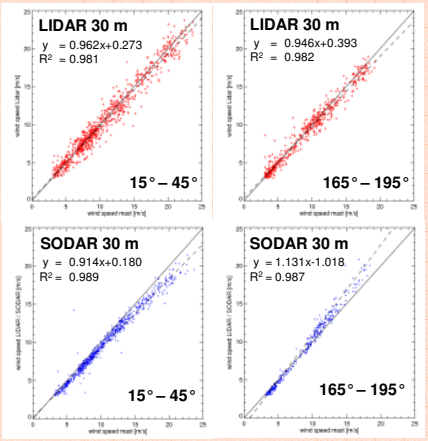
RESULTS: Data availability LIDAR - SODAR



LIDAR data are available only for five levels. At 100 m above ground the data availability is still 85%.
SODAR data are available at a vertical resolution of 10 m.
The data availability decreases rapidly with height. At 100 m above ground the data availability is only 54% considering the evaluated measurement period.

Fig. 2: Data availability as a function of the height for LIDAR (left) and SODAR (right).

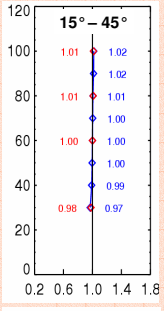
RESULTS: Scatter plots of the wind speed 30 m: cup – LIDAR / cup – SODAR

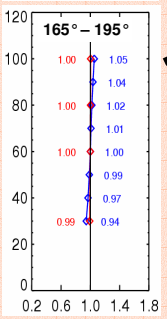


A comparison of the measured wind speeds at 30 m is shown in Figure 3. The data is displayed for two prevailing wind direction sectors.
Plausible LIDAR data are available for wind speeds well above 20 m/s and show a good correlation to the cup anemometer data.
The quality of SODAR data decreases rapidly for wind speeds > 15 m/s and the correlation with the cup anemometer data shows pronounced differences depending on the considered wind sector.

Fig. 3: Scatterplot of 30 m wind speed: cup – LIDAR (red) and cup – SODAR (blue), for the wind sectors 15-45° (left) and 165-195° (right).

RESULTS: Vertical profiles LIDAR - SODAR





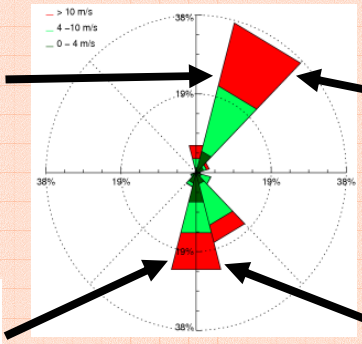


Fig. 4: Wind rose at 30 m measured at the mast.

The wind rose on figure 4 shows the two prevailing wind directions at Maligrad for the period 22nd November 2008 to 9th December 2008.
The constant vertical wind profiles of LIDAR and SODAR agree very well for the sector 15°-- 45° (figure 5, top). However, in the south sector 165° -- 195° (figure 5, bottom) the SODAR shows a stronger increase with height than the LIDAR data.

Fig. 5: Vertical wind profiles normalized to 60 m of LIDAR data (red) and SODAR data (blue) for the prevailing wind directions.

RESULTS: Turbulence intensity cup - LIDAR - SODAR

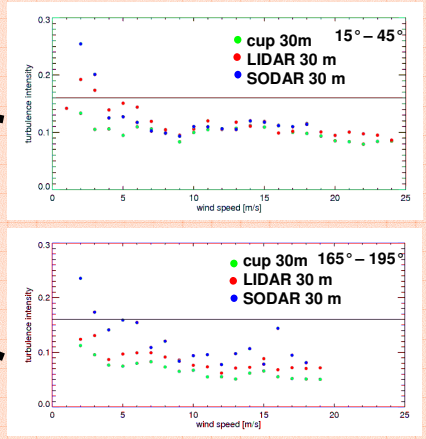


Fig. 6: Turbulence intensity of cup data (green), LIDAR data (red) and SODAR data (blue) at the height of 30 m for the sector 15°- 45° (top) and 165°-195°(bottom).

The calculated turbulence intensity of cup, LIDAR, and SODAR in the sector 15°-- 45° agree very well (figure 6, top). For the sector 165°--195° (figure 6, bottom) a bias can be seen for the comparison of the cup anemometer data to the LIDAR data. Turbulence intensity from SODAR data show strong discrepancies to LIDAR and cup anemometer data in the south sector.

CONCLUSIONS

- The LIDAR and the SODAR system showed both a good performance under the extreme climatic conditions at Maligrad.
- The LIDAR has a remarkably higher data availability compared to the SODAR.
- The quality of SODAR data decreases rapidly at wind speeds >15 m/s.
- At the measuring site the increase of wind speed with height is very small.
- Turbulence intensities are higher for the sector 15°-- 45° than for the sector 165°-195°. However, the turbulence intensities for both prevailing wind directions are still below class A and B of the IEC considering LIDAR and SODAR also at 80 m above ground (not shown here).

ACKNOWLEDGEMENT

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