STUDY OF WIND ENERGY AT GREAT HEIGHTS USING REMOTE SENSING TECHNIQUES LIDAR IN DOBROGEA

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În vara anului 2008 autorii au întreprins o campanie de evaluare a potenţialului eolian în Comuna Mihai Viteazu din Judeţul Constanţa, utilizând pentru prima dată în România un anemometru tridimensional cu laser (LIDAR) amplasat în paralel cu un anemometru clasic. Acest articol prezintă comparativ rezultatele celor două sisteme de măsură, ale căror indicaţii sunt foarte apropiate din punctul de vedere al valorilor medii ale vitezelor. Totuşi, sistemul LIDAR indică o atenuare a intensităţii longitudinale a turbulenţei faţă de cel clasic. Pe baza acestor rezultate autorii au extins prin continuitate profilele vericale de viteză medie în patru amplasamente apropiate şi au confirmt calitatea acestora până la înălţimea de 160 m în zone cu profil similar. Cercetările întreprinse permit integrarea tehnologiei LIDAR în procedura de predicţie a intensităţii vântului, necesară integrării fermelor eoliene de mari dimensiuni în piaţa de energie est-europeană.

During the summer of 2008, a LIDAR (Light Detection and Ranging) was installed for a wind assessment campaign by C-Tech in Mihai Viteazu, Constanta County in the close proximity of a 40 m wind measuring mast. This paper presents for the first time in Romania a set of results by comparison with data from two surrounding masts. Comparison between LIDAR and mast observation show a very good correlation for the mean speed on the free stream sectors. LIDAR observations of longitudinal turbulence intensity follow the behaviour of the cup anemometers with a degree of attenuation. The horizontal homogeneity of the site makes possible the extension of cup-mast profiles with LIDAR profile up to 160 m which results in a good match profile for four different free stream sectors. The results found in the paper encourage the use of ground based remote sensing techniques for wind resource assessment due to their good adaptability and performance.

Keywords: LIDAR, vertical wind profile, wind measurement.

1. Introduction

Knowledge of the shape of the vertical wind profile is an important issue particularly for site assessments and energy yield calculations. Strong efforts in the remote sensing technology yielded to state of the art wind measuring

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instruments like SODARs (SOund Detecting And Ranging) and LIDARs (LIght Detecting And Ranging) [1]...[11]. This study presents a wind measurement campaign carried out in Mihai Viteazu, Constanta County, where the terrain was medium complex and the winds were known to be some times very strong and turbulent. In Dobrogea area a number of 40/50/60 m wind measurement masts have been installed by C-TECH / NEK Umwelttechnik AG in order to record the wind conditions for wind power projects. To reduce the uncertainty of the vertical wind profile above 40 m, in particular around hub height, the developers are carrying out LIDAR campaigns alongside the installed masts. This report outlines the LIDAR measurements at Mihai Viteazu which have been carried out between the 11th of June and the 9th of July 2008.

2. The measurement site

The measurement site was located on a smooth hill northwest of the village of Mihai Viteazu at an altitude of 163 m above sea level. Tab. 1 lists the coordinates of the LIDAR and the 40 m mast 116 m apart from another. Fig. 1 shows an overview of the area.

Table 1

Coordinates of the LIDAR and 40 m mast Mihai Viteazu

Mihai Viteazu	coordinates (UTM WGS 84, zone 35)	altitude
LIDAR	628'660 / 4'946'693	163 masl
40 m mast	628'712 / 4'946'589	163 masl

Fig.1. Overview of the measurement area near Mihai Viteazu village.

3. The measurement campaign

3.1.   LIDAR configuration

The installed Lidar was of type ZephIR [4]. Table 2 shows the configuration of the LIDAR and Fig. 2 - the installed LIDAR at the Mihai Viteazu site.

Table 2

Configuration of the LIDAR

Parameter	Value
Measurement heights above ground	40 m, 60 m, 80 m, 100 m, 120 m
Sampling interval	3 seconds
Averaging interval	10 minutes
Alignment of instrument, offset from geographic north	-4°

Fig. 2: The installed LIDAR at Mihai Viteazu with the 40 m mast in the background.

3.2. Measurement protocol

The measurement campaign started on the 11th of June 2008 and ended on the 9th of July 2008.

4. Data availability

Fig. 3 shows the time series of the data availability at each measurement

level for the entire measurement campaign at Mihai Viteazu. Less than one percent of the data have been rejected at each level (see Tab. 3). Data are rejected if an insufficient number of data points are collected at a certain level and time, respectively. This happens in particular when the air is very dry.
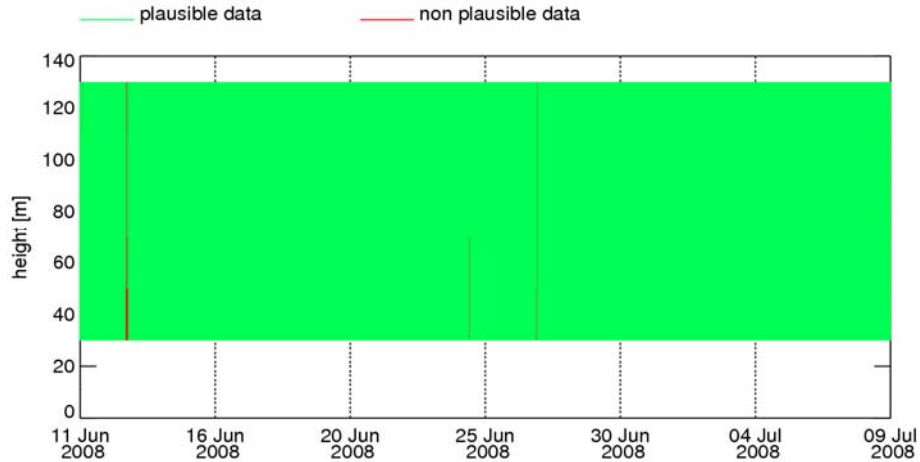

Fig. 3: Time series of the data availability of the LIDAR measurements at Mihai Viteazu for each measurement level. Plausible data are displayed in green, rejected values in red.

Table 3

Amount of available data of the LIDAR measurements at each level at Mihai Viteazu

Measurement level	Available data
120 m	99.83%
100 m	99.88%
80 m	99.88%
60 m	99.78%
40 m	99.65%

5.   Results

5.1.   Wind speed

Fig. 4 shows the 10 minute wind speed values of the LIDAR measurements at the Mihai Viteazu site for each measurement level. In Fig. 5, the calculated daily means at each level are displayed.

Fig. 6 shows the ratio of the measured wind speed (daily means) at 40 m to the wind speed at 60, 80, 100 and 120 m respectively.
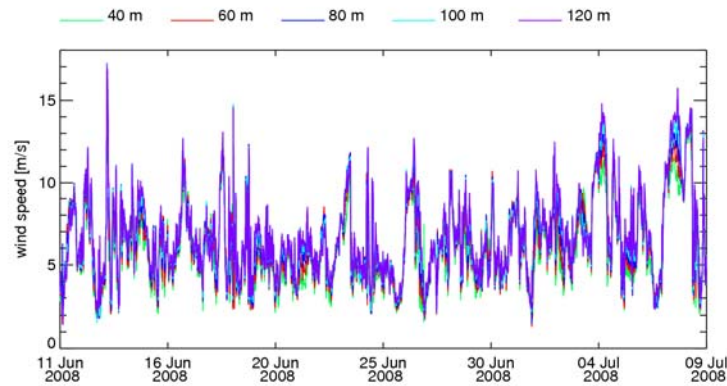
Fig. 4: The 10 minute wind speed of the LIDAR measurements at Mihai Viteazu at 40, 60, 80, 100 and 120 m above ground.
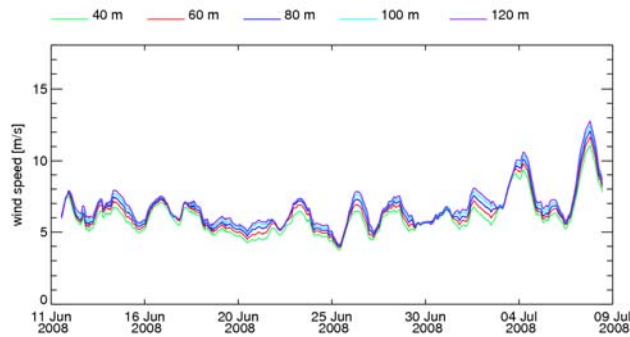

Fig. 5: The daily mean wind speed of the LIDAR measurements at Mihai Viteazu at 40, 60, 80, 100 and 120 m above ground.
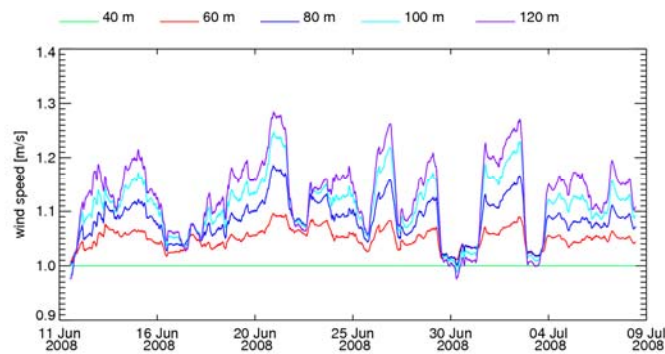

Fig. 6: The ratio of the daily mean wind speed at 40 m above ground to the wind speed at 60, 80, 100 and 120 m respectively.

5.2. Wind roses / turbulence roses

Fig. 7 shows wind roses and turbulence roses for each measurement

level. During the measurement campaign, winds from north-northwest and south-southeast were prevailing.
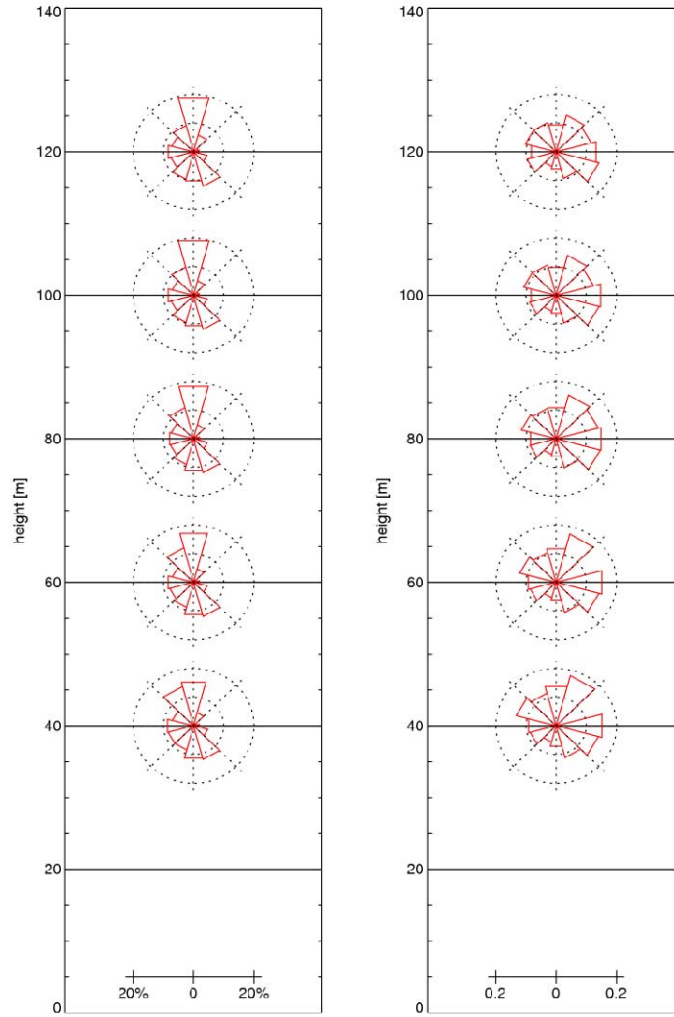

Fig. 7: Left: Wind roses of the LIDAR measurement at Mihai Viteazu at 40, 60, 80, 100 and 120 m above ground.
Right: Turbulence roses at 40, 60, 80, 100 and 120 m above ground.

The calculation of the turbulence intensity has only been carried out for wind speeds greater than 4 m/s. Sectors with less than 50 valid values are not considered.

5.3. Vertical profiles of wind speed

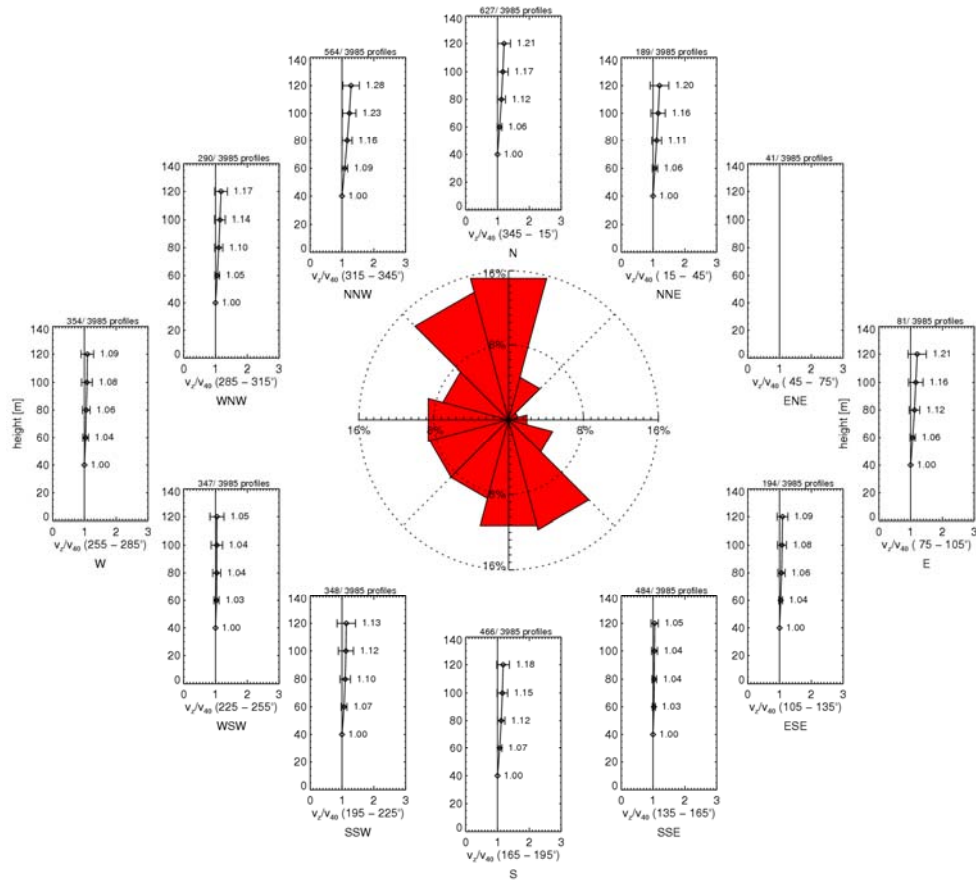Fig. 8 shows the vertical profiles of wind speed scaled to 40 m in 30° wind direction sectors.

Fig. 8: Vertical profiles of wind speed for 30° wind direction sectors, scaled to 40 m at the LIDAR measurement site Mihai Viteazu.

The bars indicate the standard deviation. In the center the wind rose at 40 m is displayed. Sectors with less than 50 valid values are not considered. Fig. 9, Fig. 10 and Fig. 11 show the vertical profiles of wind speed scaled to 40 m for the main wind directions north, west and south for different wind speeds as well as the statistical mean errors of the profiles. Due to rare occurrence of Easter winds, those vertical profiles of the wind speed are not shown.
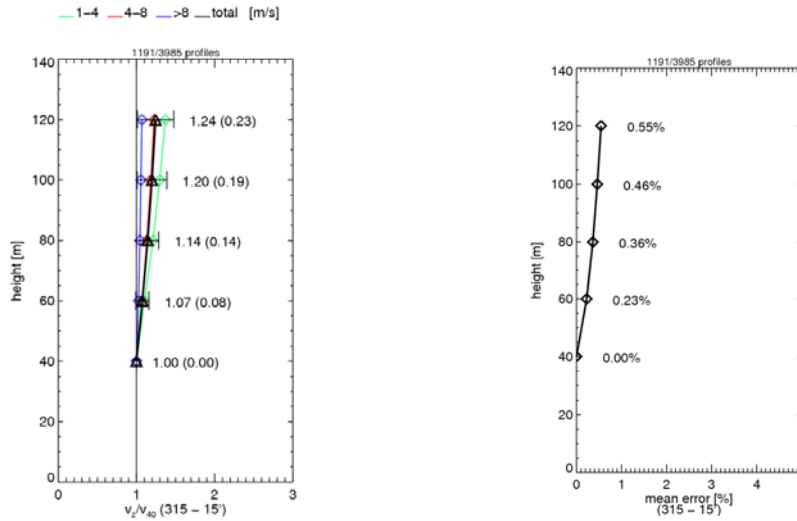
Fig. 9:   Vertical profile of the wind speed for the main wind directions north for different wind speeds (left) and the mean error of the profile (right).
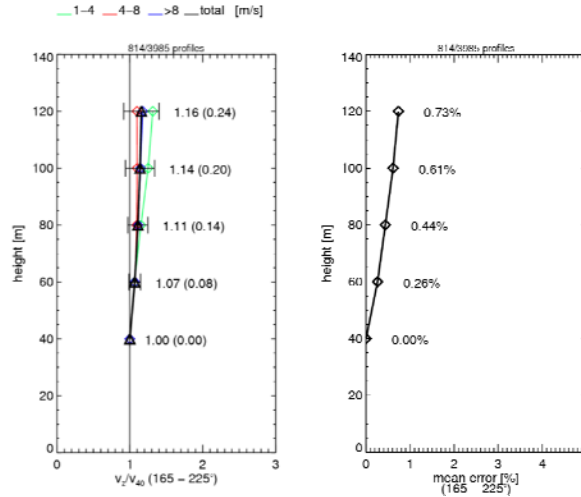

Fig. 10: Vertical profile of wind speed for the main wind direction south for different wind speeds (left) and the mean error of the profile (right).

5.4.   Vertical profiles of turbulence

Fig. 11 shows vertical profiles of the turbulence intensity at Mihai Viteazu. Turbulence intensity was calculated only for wind speed greater than 4 m/s. No turbulence was calculated for sectors/levels with less than ten valid 10 minute values.
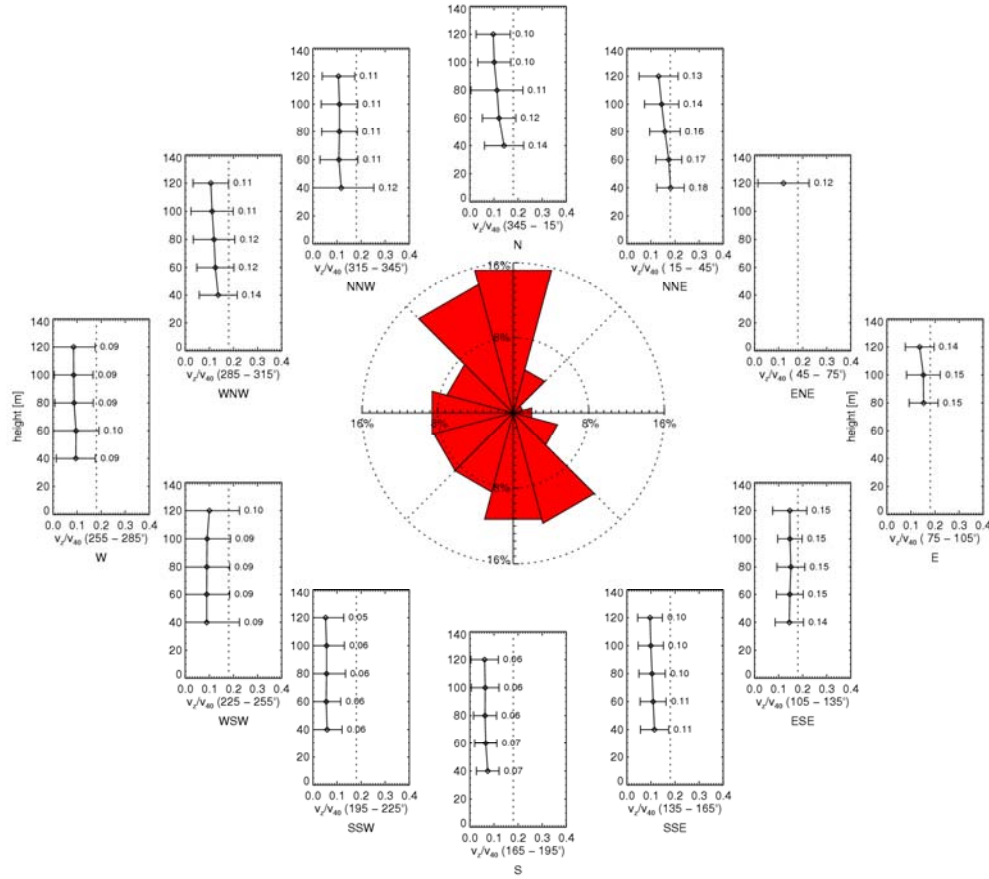
Fig. 11: Vertical profiles of turbulence intensity for 30° wind direction sectors
at the LIDAR measurement site Mihai Viteazu.
(bars indicate the standard deviation; in the center the wind rose at 40 m is displayed)

6.   Conclusions

The vertical wind gradient varied over the course of the year. Large scale weather systems are more pronounced in winter than in summer, and henceforth the geotropic wind is weaker during summer compared to winter. Consequently, the low-level winds are higher during winter, resulting in a stronger vertical wind shear in winter.

The LIDAR measurement period (11.06.08 - 09.07.08) coincided with a period of low wind speed, and therefore probably lead to an underestimation of the vertical gradient. So are, for example, the vertical (standard) gradients

modelled by WindSim and WAsP stronger than the ones obtained with the LIDAR measurements. We therefore expect that the use of the profiles presented in this Section tends to underestimate the actual annual average wind speed at hub height and subsequently the energy yield of the park. On the contrary, turbulence can be expected to be lower in times with slow wind speeds, so that turbulence intensity might be underestimated in our calculations.

The measurement campaign with ZephIR LIDAR came up with a remarkable data availability of better then demanded value of 90%. The deviations between LIDAR wind speeds and cup anemometers wind speed were less than 3%. The results returned from this study have shown that the QuinetiQ LIDAR system is capable of returning good quality results, useful in the energy market predictions [12].

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