

Using SODAR measurements in the POWER project

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SYNOPSIS

Within the JOULE-project POWER (Predicting Offshore Wind Energy Resources) the main objective is to describe the wind climate over all European seas with regard to wind energy applications. One activity is the development of the Coastal Discontinuity Model. In order to validate this model wind profile measurements near the coast are carried out by using a mini-SODAR (SOUND Detecting And Ranging). The principle of SODAR will be explained, and the set-up of the first experiments. The results show a good comparison with data from a nearby mast with a cup anemometer. Wind speed profiles up to 170 m were measured, but the interpretation of the SODAR data is elaborate. Finally, the conclusions of the experiments and future plans will be outlined.

1. INTRODUCTION

Within the JOULE-project POWER the aim is to give a description of the wind climate over the European Seas for wind energy applications. An overview of the current state of affairs of the project is given at this conference by Watson *et al* (1999).

One of the specific objectives within POWER is the development of the Coastal Discontinuity Model (CDM). To validate the CDM measurements with a mini-SODAR are conducted near the coastline. This has been done at ECN in Petten (The Netherlands) during the period October 1998–May 1999. Experience has been gathered in setting up the system, carrying out the measurements and analysing the results. Some preliminary results are described by Van Dam and Werkhoven (1999).

In the paper first a brief introduction will be given of the technique employed by the SODAR to measure wind profiles. Then a summary of the experimental set up and some

of the results will be outlined. Finally some concluding remarks will be given about the use of the SODAR compared to a regular mast with anemometers and some future plans within the POWER project will be outlined.

2. SODAR TECHNIQUE

First we will give a brief summary of the working principle of the SODAR technique. Then the specifications of the AeroVironment 4000 SODAR used in our experiments will be outlined briefly.

A recent compilation of the results of several experiments conducted over a period of 20 years by different types and makes of SODAR systems can be found in Crescenti (1997).

2.1 General principle

The working principle that SODAR uses is that of acoustic backscattering. An acoustic pulse transmitted into the air experiences

backscattering from small temperature inhomogeneities (with a size in the order of the wave length). The travel time between emission and reception determines the height the signal represents. The Doppler shift in the frequency is proportional to the wind speed along the beam axis. The intensity of the received signal may be used to study the presence of inversion layers and stability conditions in general.

2.2 AeroVironment 4000 miniSODAR

The AeroVironment 4000 miniSODAR as used in this project is a phased-array type system. Its default operating frequency is 4500 Hz, corresponding to a wavelength of about 8 cm. According to the manufacturer's operating parameters the minimum height is 15 m, the maximum height 200 m, and the vertical resolution 5 m. The averaging time is user selectable between 1 minute and 1 hour.

The system consists of an acoustic antenna, an acoustic signal processor and a computer for data storage. It is installed in a plywood encasing, which is open at the top. Its dimensions are about 1.2 m by 1.2 m by 1.2 m. To shield the surroundings from noise hindrance and to improve the signal reception by shielding ambient noise the encasement can be doubled in height by hinging side plates (see Figure 1).



Figure 1: AeroVironment 4000 SODAR

The acoustic antenna consists of an array of 32 acoustic speakers for both transmission and reception of the acoustic signal.

Three independent beams of sound pulses are emitted by means of shifting the sequence of the transmitters. One beam is vertical, the other two have an angle of 16° with the vertical. The reflected signals are detected by the receivers and processed.

3. EXPERIMENTAL SET-UP

In the period October 1998—May 1999 the SODAR has been set up at the wind turbine test site of ECN in The Netherlands (within 1 km off the coast line).

During this period the SODAR has been run in ordinary operation, as well as in some specific tests, especially interesting for measurements near operating wind turbines. It became clear that setting up the SODAR to carry out measurements was quite easy.



Figure 2: SODAR at the ECN wind turbine test site

In operating the SODAR using the manufacturer's software it appeared that many

parameter settings can be changed manually to achieve certain objectives. However, it was not always clear what the optimum settings were in the case of our experiments. E.g., it is possible to impose a threshold to the signal-to-noise-ratio to exclude data from the analysis. Which threshold is the best has to follow from the analyses afterwards.

4. RESULTS

In the following figures several results will be shown. The analysis of the data is not yet finished due to some unclarities in the operating and analysis software of the SODAR. We expect to resolve this matter in consultation with the manufacturer and get more and better results out of the raw data.

4.1 Data availability

In Figure 3 the availability of data by height has been shown. These are 1 minute means of the month November 1998 (100% = 43,200 observations). Although a maximum height of 200 m is feasible according to the manufacturer's specifications, in this experiment 170 m was set to be the maximum.

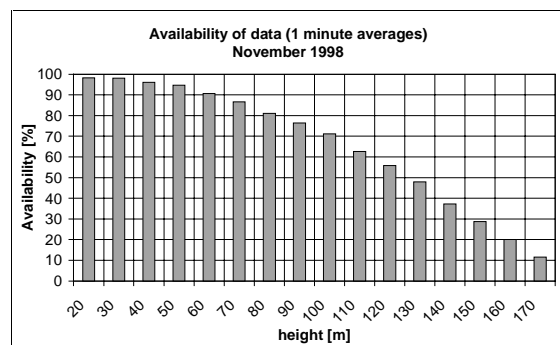


Figure 3: Data availability by height

Figure 3 shows a decrease in availability with height. The data availability depends on a number of factors, e.g. the atmospheric conditions, the site characteristics, the pulse frequency and the increasing attenuation of the signal with increasing travel distance (see e.g. Klein Baltink (1995)). Therefore the pattern of the availability shown in the figure is what could be expected beforehand.

4.2 Wind profiles

The horizontal wind speeds are shown in Figure 4 for the same period as the availability in the previous paragraph. Here, the line 'all available data' shows the mean wind speed for every observation at each specific height, and therefore with decreasing availability with height. For a better comparison the line 'only simultaneously available data' shows the mean wind profiles for those minutes when data were available at each height. For the latter the figure shows a logarithmic wind profile.

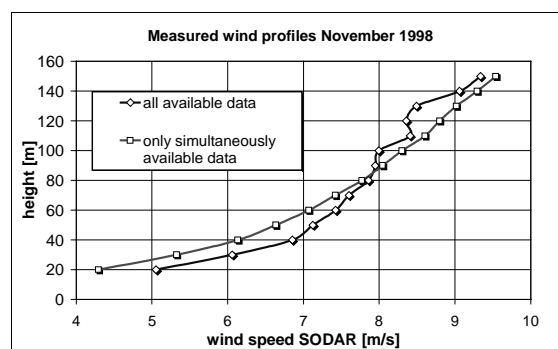


Figure 4: Wind profiles (1 minute means)

4.3 Comparison with mast data

One inherent problem of a SODAR in comparison to anemometers is the fact it cannot be calibrated in a similar fashion. Therefore it is always necessary to compare the SODAR data with 'ordinary' mast observations. For an overview see e.g. Crescenti (1997).

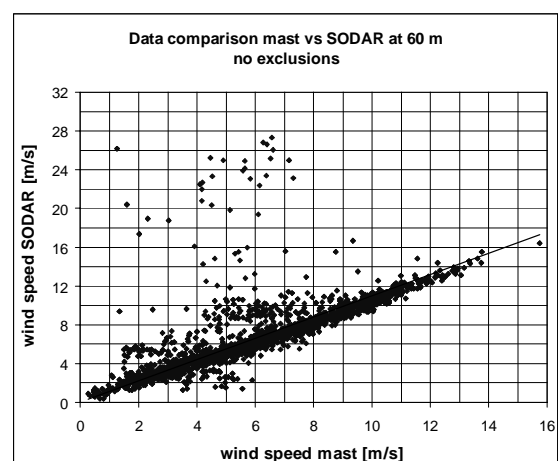


Figure 5: Scatter plot of mast data and SODAR data at 60 m without exclusions

At the ECN wind turbine test site a nearby mast with an anemometer at 60 m was present enabling us to compile several scatter plots with similar observations. In the first scatter plot all observations are shown for a period of 1 month without any selection.

It can be seen that the bulk of the data points are on a line as expected, however there are quite some deviant data points. In the next two scatter plots points are excluded for clear physical reasons.

As the experiments took place at the ECN wind turbine test site a wind turbine with a hub height of 60 m, and a rotor diameter of 46 m was located nearby. To eliminate the influence of the wind turbine the data points from the sector 100° – 230° were excluded from the data. The results are shown in Figure 6. The number of deviant data points is reduced significantly.

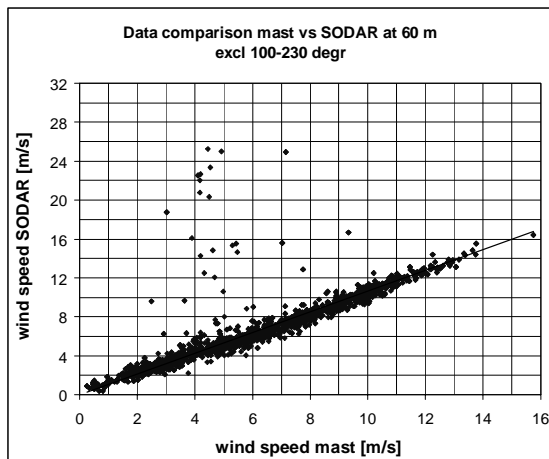


Figure 6: Scatter plot of mast data and SODAR data at 60 m excluding the wind directions 100° – 230°

A known fact that limits the use of a SODAR slightly is that precipitation reduces the signal-to-noise-ratio in a way that no wind speeds can be observed. Therefore it is standard practice to install a rain detecting device in order to be able to identify these erroneous values. In the final scatter plot all the ‘rain’ data have also been excluded, see Figure 7. It is shown that this leads to a quite good comparison between the data from the mast and the SODAR. The SODAR wind speed is on average 4% less than the mast.

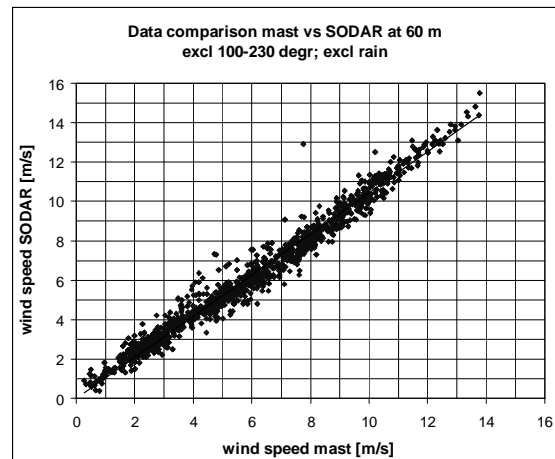


Figure 7: Scatter plot of mast data and SODAR data at 60 m excluding the wind directions 100° – 230° and the rain data

5. CONCLUSIONS

Setting up the measurement equipment is relatively easy. So long the SODAR is set up level and with aid of a compass only power and a telephone line for remote operation are needed. However, the data processing, the interpretation and analysis of the measurements are very time consuming. Although a miniSODAR is of-the-shelf technology, it is not so straightforward to operate the system with optimum settings. Data interpretation and data analysis also are time consuming for the best results.

The experiments at ECN show that comparison of the SODAR data with mast data using an anemometer at 60 m compare well. This provided that data from the directions 100° – 230° are excluded because of the presence of a wind turbine, and also data during spells of rain.

6. FUTURE WORK

The measured data will be analyzed in more detail with different settings of various parameters. After consultation with the manufacturer the conclusion that the percentage of usable data may be enhanced in this way. Parameters that can be changed are e.g., the level of the signal-to-noise-ratio and the averaging time.

In order to do the validation of the Coastal Discontinuity Model the data are processed

into a suitable format. The validation will be carried out in the next few months.

Finally it is expected that SODAR measurements will be conducted at an offshore platform (Measuring Post Noordwijk) starting in September 1999. This platform is located 9 km off the coast, and has been used for research purposes and for synoptic observations (also wind speed) for many years. These measurements will provide an excellent opportunity to study the various effects the Coastal Discontinuity Model should be able to account for.



Figure 8: Measuring Post Noordwijk located 9 km off the Dutch coast

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