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Directional Analysis of Turbulence Intensity over Forest and Open Land

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1. Introduction

The turbulence intensity, defined as the ratio of standard deviation to the mean wind speed is an important variable for the wind industry. As the roughness of the surface intensifies the development of turbulence it is important to know the influence of higher roughness on the performance of the wind turbine, since the planning of wind turbines in forest areas is increasing. Therefore information about the turbulence intensity over forest is of great interest. For this analysis lidar measurements were performed at two forest sites (S1 and S2 shown in Fig. 1) and at the same time on nearby fields. The turbulence intensity of this lidar data is compared for different height, directions and roughnesses.

2. Comparison of forest and field

The used lidar was validated with data from a met mast measurement with ultrasonic anemometers. In Figure 2 the wind roses of the 2 measurements and the number of the data points are shown in 3 heights. The turbulence intensity is evaluated here as a function of the wind direction (Fig. 3). At least in about 180 m a.g.l. the values converge over forest and open land. Especially in the generally used hub height of 140 m a.g.l. the differences may not be large, but higher turbulence intensities over forest lead to lower wind speeds. As in the formula for the calculation of the wind power the wind speed is considered in the third power the loss of the power production is quite large. This can be seen in Table 1. At the measurement sites in 140 m a.g.l. the energy production over forest is up to 8 % lower than over open land. In 180 m a.g.l. the energy production over forest and open land is almost balanced. Turbulence is an attribute of the air mass, which is locally enhanced by the roughness of the surface. This can be seen in Figure 3 in 60 m a.g.l. for both sites. Northwestern winds are more turbulent than eastern winds, but the turbulence intensities increases in both directions. This effect decreases by height.

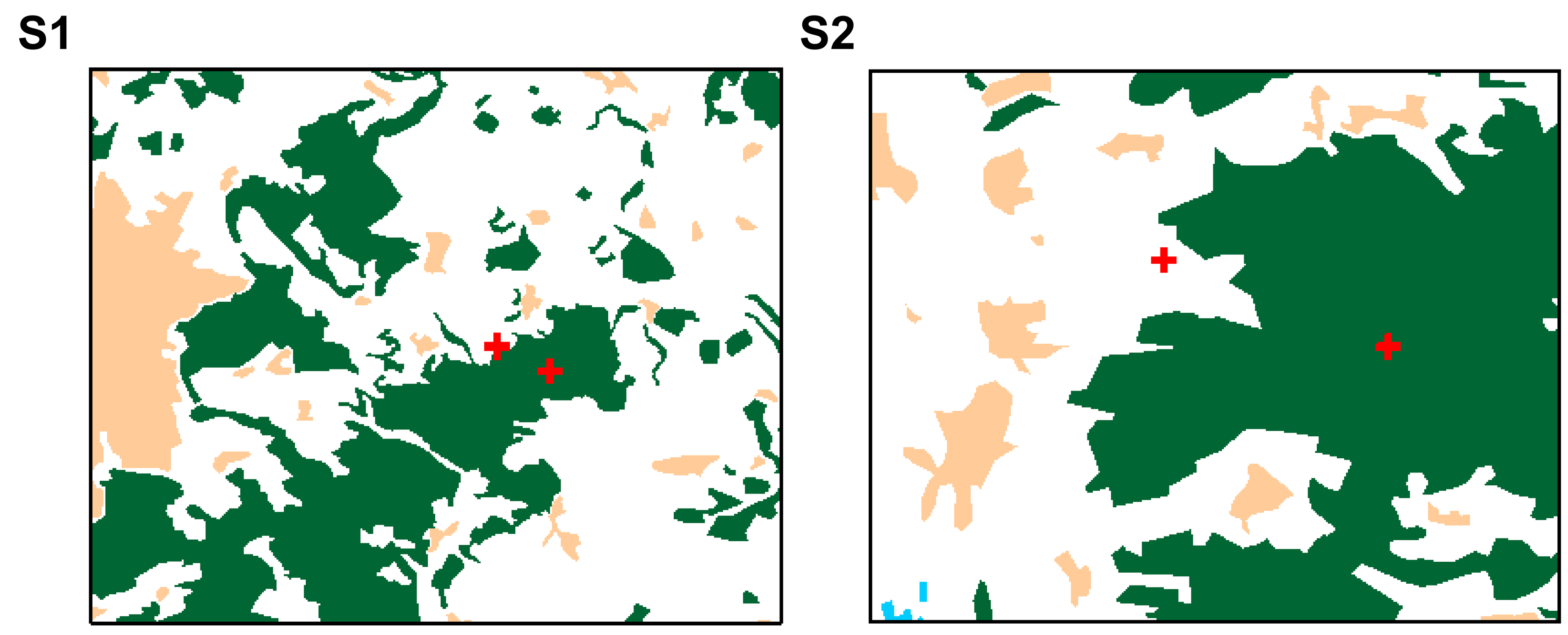

Figure 1: *Roughness layers of S1 (left) and S2 (right). Red crosses: measuring sites, green: forest, white: open land, orange: settlement, blue: water.*

Table 1: *Loss of the energy production over forest compared to open land in the corresponding measuring heights.*

Height a.g.l.	S1	S2
40 m	63 %	76 %
60 m	38 %	54 %
80 m	23 %	37 %
100 m	15 %	25 %
120 m	10 %	15 %
140 m	7 %	8 %
160 m	5 %	4 %
180 m	3 %	0 %

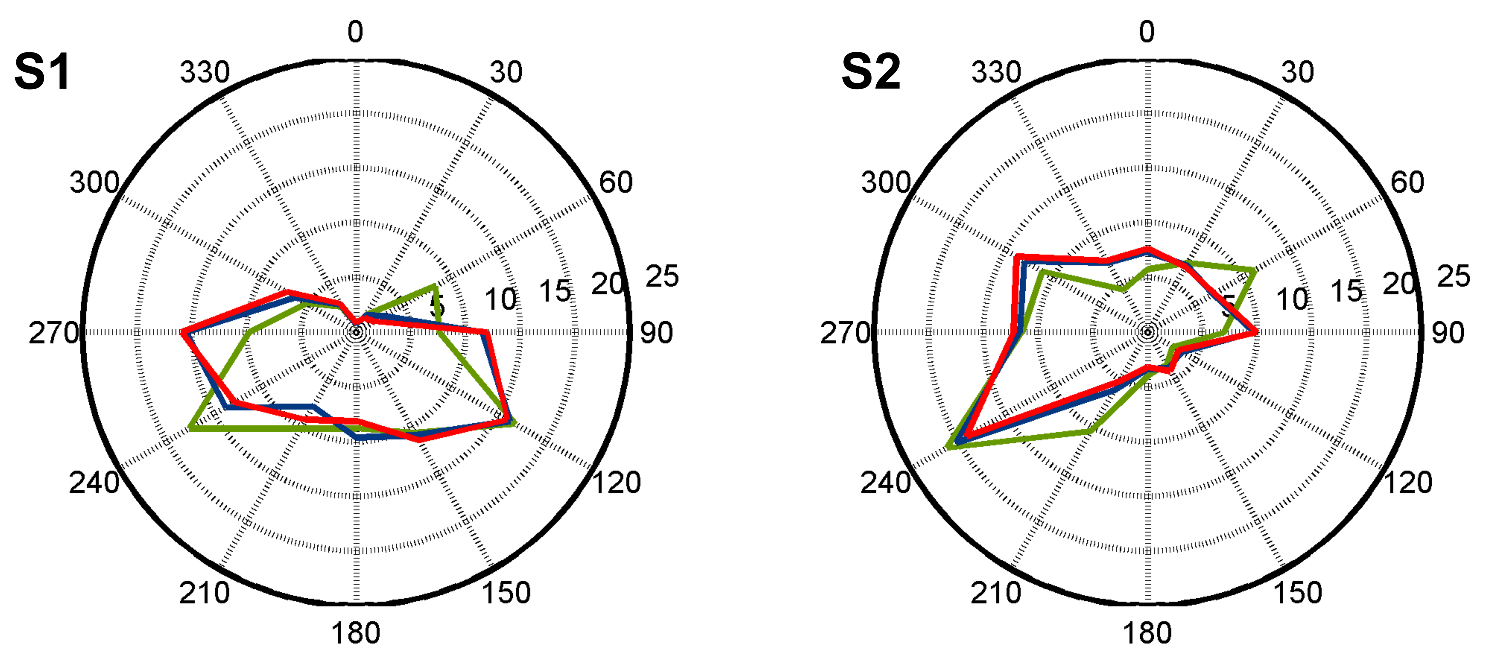

Figure 2: *Frequency distribution in percentage terms of 2 sites at 3 levels. Green: 60 m a.g.l, blue: 140 m a.g.l., red: 180 m a.g.l.. Number of data points: 727 (S1) and 3012 (S2).*

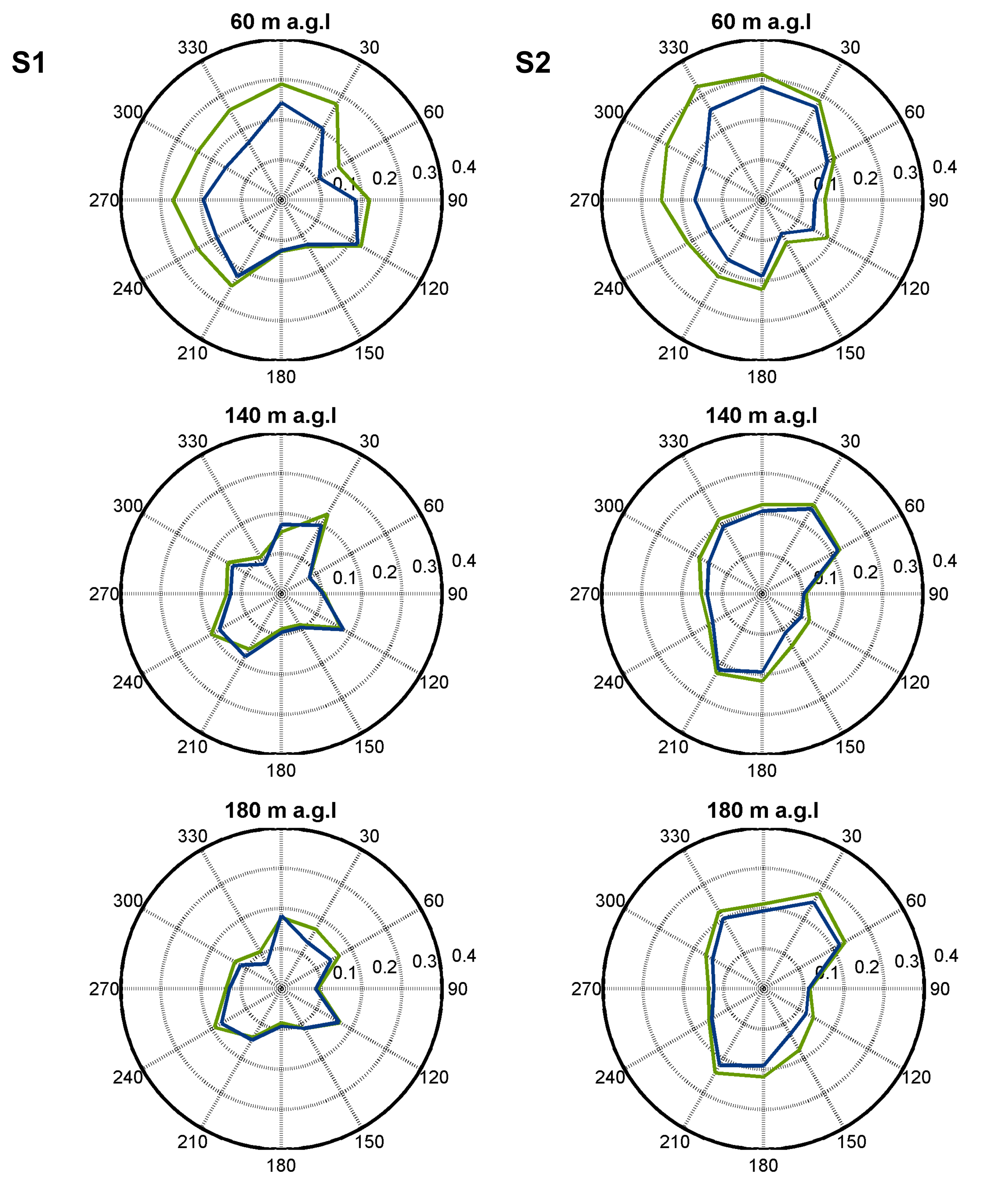

Figure 3: *Turbulence intensities in relation to the wind direction, measured at different heights for two locations (left column: S1, right column: S2). Green: forest, blue: open land.*

3. Summary and outlook

The comparison of these two measurements is a first attempt to demonstrate the differences between wind conditions over forest and open land. However, it must be observed that the measurement periods were too short to allow more precise conclusions. Furthermore, is it necessary to have information about the stability of the atmosphere during the measurements to validate and specify the results. The current hub height of wind turbines are 140 m. As seen in this poster at this height the performance and the machine fatigue of a wind turbine is influenced by the increased turbulence intensity over forests. This has to be considered during the planning.

Sources:
Measurement data, own preparation