Optimization of combined Mast and Lidar Measurement Concepts aided by Maps of Terrain Complexity based on IEC 61400-1

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INTRODUCTION

Sophisticated measurement concepts with a combination of mast and flexible remote sensing devices can significantly reduce effort and duration of on-site measurements and minimize uncertainty especially in complex terrain. The precondition for a successful measurement campaign is an accurate design and planning of measurement positions taking the representativeness and other factors into account. An integrated approach is demonstrated which is well-proven for European projects and international projects.

MEASUREMENT CONCEPT

Complex terrain, i.e. structured orography or a mix of open land and forest, results in complex flow leading to strong horizontal gradients in wind speed, high turbulence intensity and high wind shear. The spatial representativeness of wind measurements in such cases is limited (up to 2 km according to MEASNET [1]) and wind flow modelling requires elaborated 3D models. In non-complex terrain the representativeness of measurement positions is limited too. Usually 10 km are assumed as upper limit. Choice of an inappropriate measurement location can reduce the representativeness significantly.

Different measures are common to assess the terrain complexity e.g. slope, ruggedness index (RIX) or the modelled lidar error [2]. The lidar error is modelled with high-fidelity, three dimension meteorological models, e.g. FITNAH-3D [3]. Another measure is the topographical complexity defined in IEC 61400-1 [4]. To compute a complexity index the terrain around a position is divided in directional sectors with extent depending on the planned hub height. These sectors are approximated by plains and the slope and height deviations from these plains are calculated (see Figure 1).

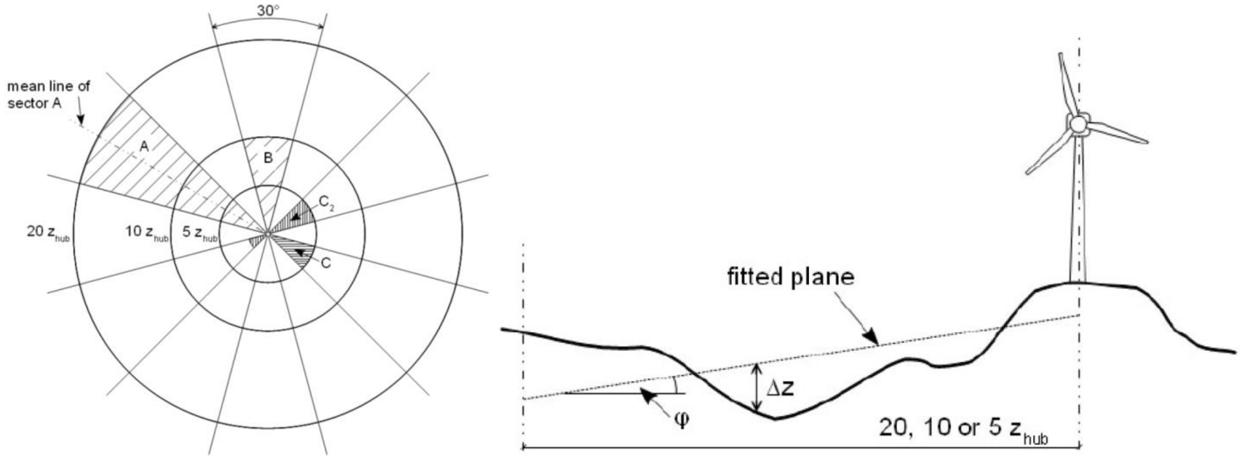

Figure 1 – IEC 61400-1 complexity test.

To create a map of terrain complexity the algorithm is applied to each cell of a regular grid (Figure 2). The terrain complexity index can be taken as an objective measure for the occurrence and intensity of complex flow.

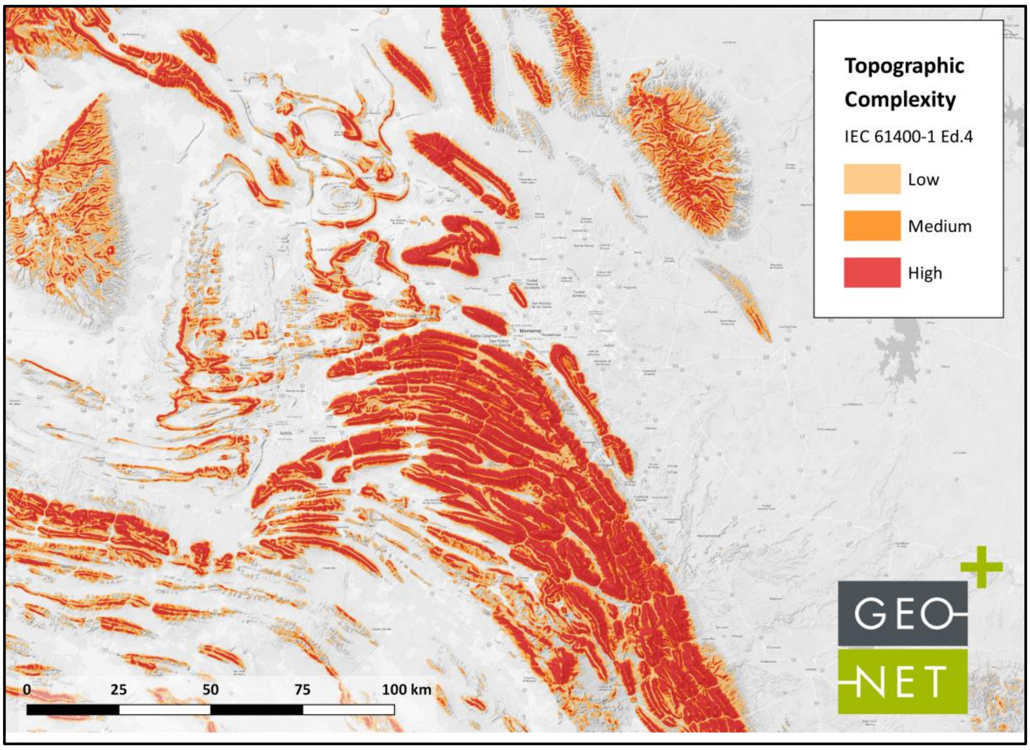

Figure 2 – Example of a large scale map of terrain complexity.

Combining maps of topographic complexity, topography and LiDAR error respectively, yields a substantial basis for determination of a measurement concept and measurement positions. It is possible to avoid areas with low representativeness and therefore minimize the uncertainty of horizontal extrapolation of wind conditions. In case of applying remote sensing devices and moving them to different locations the coverage of the whole wind farm area can be maximized. The lidar error map (see Figure 5) helps to find locations with low influence on the measurement and therefore lower measurement uncertainty.

EXAMPLE PROJECT

The following example shows a typical site in a European low mountain range. The areal extent and the number of planned wind turbines is low compared to Brazilian conditions, but it is well suited to demonstrate the approach and the benefits of a detailed planning of the measurement campaign.

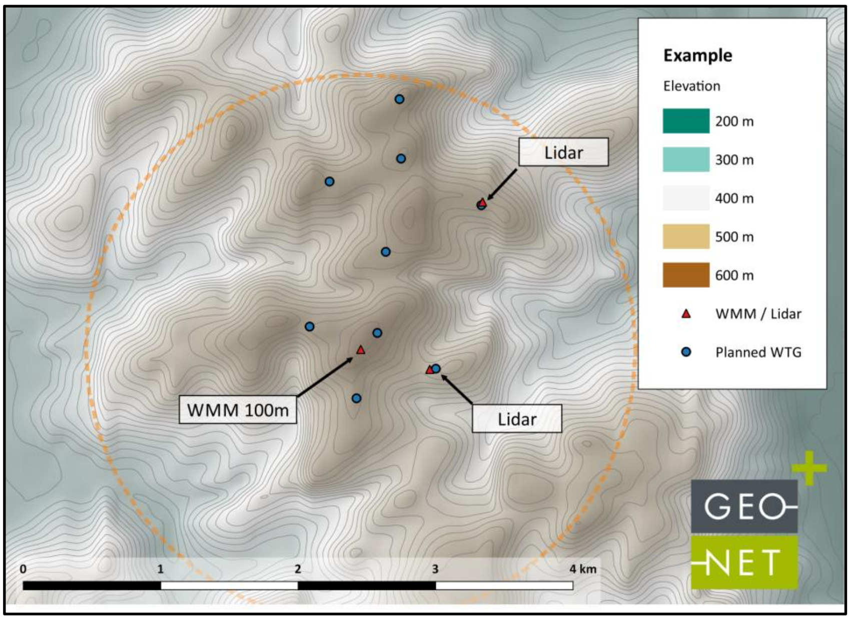

Figure 3 – Topography of example project site.

Figure 3 shows the topographic conditions at the planned site. The positioning of the turbines is quite constricted due to existing roads, forest areas and legal restrictions. The challenge is to find the optimum position for the measurement equipment. A 100 m measurement mast was deployed, supplemented by one lidar device that measured for three months at each position and was placed directly at the mast at the beginning and at the end of the campaign.

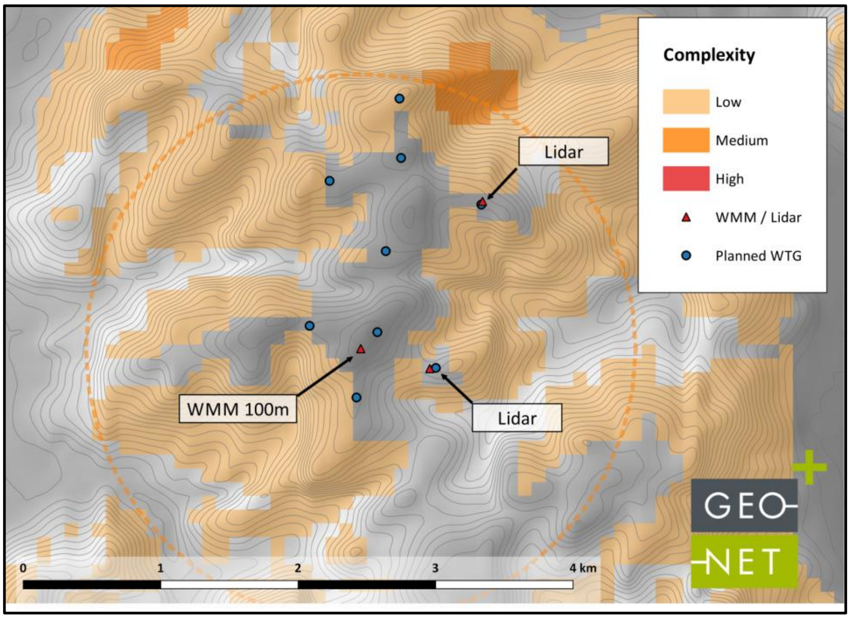

Figure 4 – Terrain complexity map.

The terrain complexity criterion given in IEC 61400-1 is intended to evaluate the turbulence and flow inclination conditions at the site. These conditions are closely related to the expectable error in flow field modelling. Regions with complex areas should always be modelled with a 3D-model, even if met masts and turbine sites are formally non-complex. The influence of complex terrain features like escarpments or ridges can have effects on remote positions.

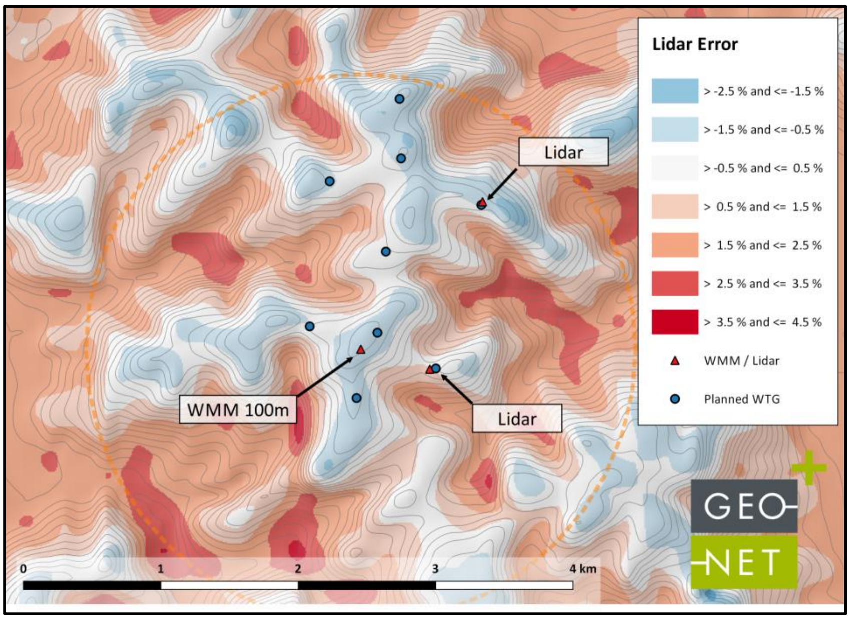

Figure 5 – Lidar error map.

The lidar error map is produced by modelling the flow inclination (i.e. the deviation from horizontal flow which is assumed by lidar processing algorithms) at the points of the lidar's laser beams. The error in measurement can be corrected, but it is favorable to keep that correction small as it is an uncertainty component. In the example it was possible to place the lidar in area with low error. That means away from areas with high curvature (e.g. hill tops).

In this example using only the measurement mast would have complied with current guidelines, assuming that hub height not larger than 150 m were planned. The additional lidar measurement which covered one year in total yielded a reduction in uncertainty of about 3,5 percentage points.

CONCLUSION

The application of the described measures can help maximizing the area covered with a minimum of equipment and reduce the overall uncertainty of the energy yield assessment. The application of a number of objective parameters for the assessment of the representativeness makes a dependable calculation of uncertainties possible.

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BIOGRAPHIES

Co-author: Henrique Ferreira – Electrical Engineer by the Federal University of Santa Catarina/Brazil in 2005. He established GEO-NET in Brazil in 2016. Henrique has experience of more than 10 years in services and products sales in power distribution, transmission and generation markets.

Author: Christian Wetzel – Studied at the University of Hamburg, Germany and earned a diploma in Meteorology in 2007. After working as a research associate in the field of Polar Meteorology and as freelance Data Scientist, he joined GEO-NET in 2011. Christian works on the advancement of methodologies and the development of innovative products. His focus lies on microscale/CFD flow modelling and wind farm performance analysis.