From lidar scans to roughness maps for wind resource modelling in forested areas

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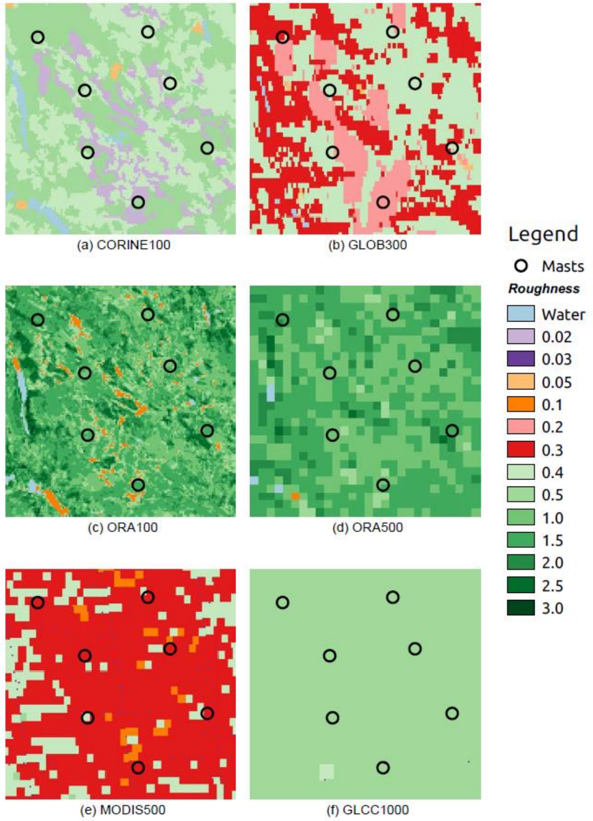
Abstract. Applying erroneous roughness lengths can have a large impact on the estimated performance of wind turbines, particularly in forested areas. In this study, a new method called the objective roughness approach (ORA), which converts tree height maps created using airborne lidar scans to roughness maps suitable for wind modelling, is evaluated via cross predictions among different anemometers at a complex forested site with seven tall meteorological masts using the Wind Atlas Analysis and Application Program (WAsP). The cross predictions were made using ORA maps created at four spatial resolutions and from four freely available roughness maps based on land use classifications. The validation showed that the use of ORA maps resulted in a closer agreement with observational data for all investigated resolutions compared to the land use maps. Further, when using the ORA maps, the risk of making large errors (> 25 %) in predicted power density was reduced by 40–50 % compared to satellite-based products with the same resolution. The results could be further improved for high-resolution ORA maps by adding the displacement height. The improvements when using the ORA maps were both due to a higher roughness length and due to the higher resolution.

We ran WAsP at a site with 7 met towers taking z_0 and d from different sources



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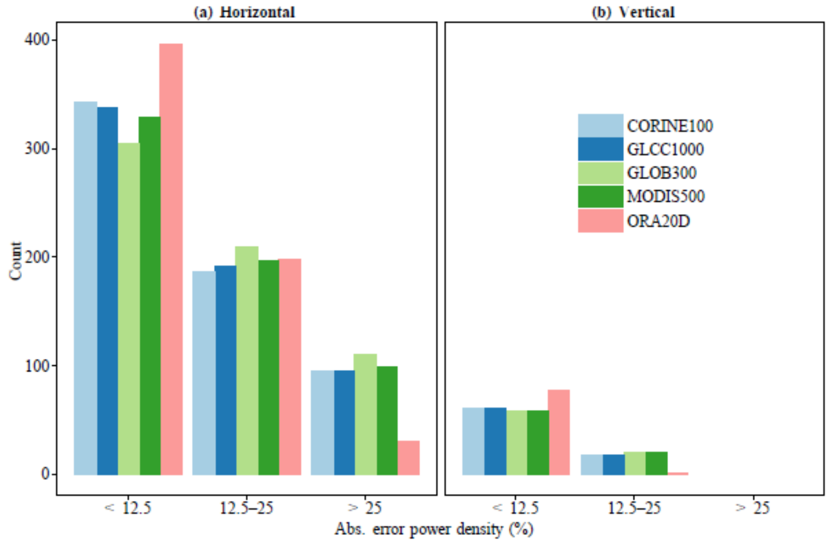
The results were clear, with z_0 and d from laser scans, errors were smaller, and the risk of large errors decreased



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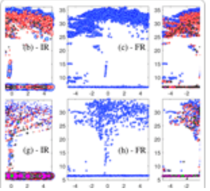
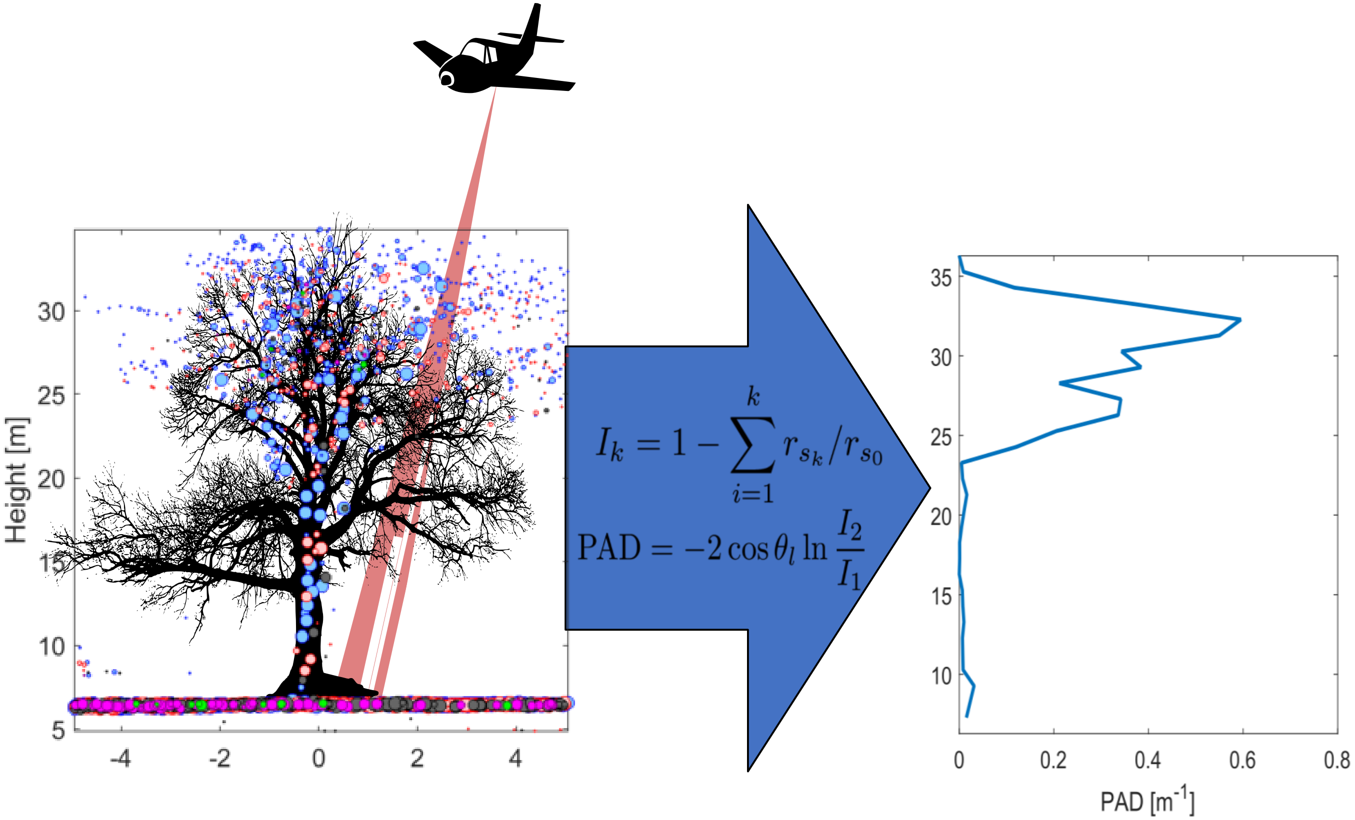
Robust processing of airborne laser scans to plant area density profiles

Johan Arnqvist, Julia Freier, and Ebba Dellwik



We developed robust a method to process airborne laser scans into plant area densities and published the code to do so in github



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Wind energy relevant characteristics of turbulence over boreal forests

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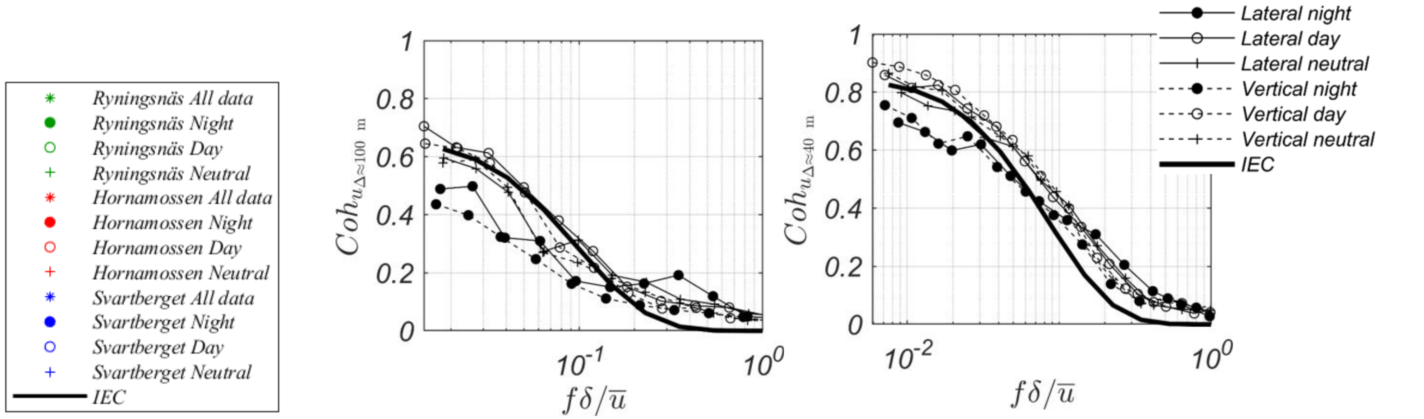
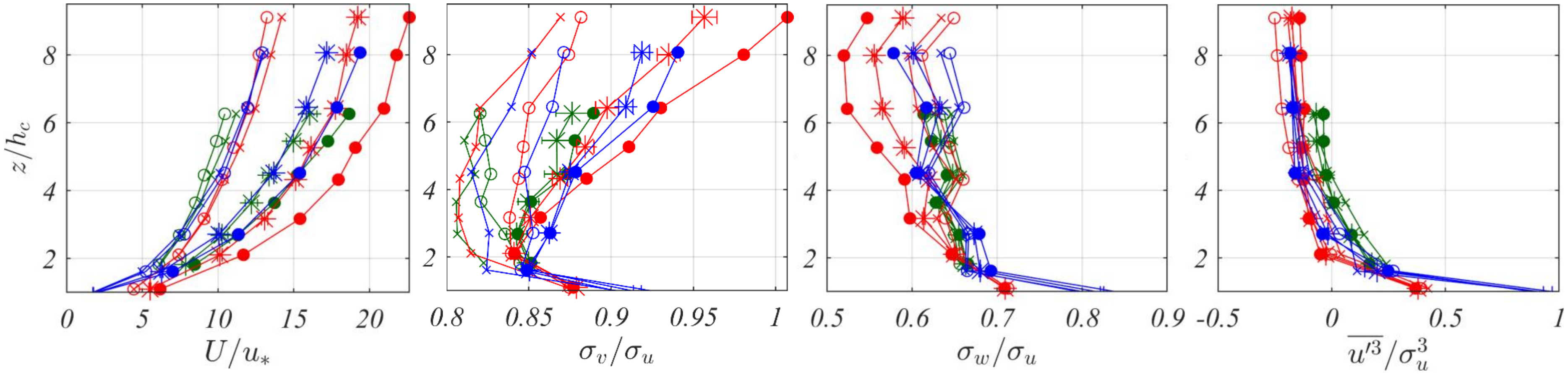
Abstract. Turbulence statistics from three tall meteorological masts and LES in forested landscapes are compared to standard turbulence models used for wind turbine design. The comparison is split into different atmospheric conditions to highlight the impact of stratification on the character of turbulence. The aim of the work is to clarify to which extent standard turbulence models are accurate over forested regions. To this end, different spectral measures such as power spectra and coherence are examined as well as vertical profiles of turbulence characteristics relevant to the design and siting of wind turbines. The measurements are used to investigate vertically separated 2-point statistics and the LES to investigate laterally separated statistics. The results show that in neutral stratification and for smaller separation distances, in the order of half a radius, the standard turbulence models apply, but in non-neutral stratification, particularly in stable conditions and for larger separations the disparity between observations and standard turbulence grow. This effect is mainly attributed to the effect of stratification, while features in the turbulence statistics specifically related to the forest cover is absent at heights relevant to wind energy. The results of the study are expected to be of interest for turbine design purposes as well as wind resource estimation and wind modelling in forested areas.

The publication presents wind energy statistics and comparison between field observations and IEC-standards





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WIND ENERGY SCIENCE

Micro-scale model comparison (benchmark) at the moderately complex forested site Ryningsnäs

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Abstract. This article describes a study in which modellers were challenged to compute the wind field at a forested site with moderately complex topography. The task was to model the wind field in stationary conditions with neutral stratification by using the wind velocity measured at 100 m at a metmast as the only reference. Detailed maps of terrain elevation and forest densities were provided as the only inputs, derived from airborne laser scans (ALSs) with a resolution of 10 m × 10 m covering an area of 50 km × 50 km, that closely match the actual forest and elevation of the site. The participants were free to apply their best practices for the simulation to decide the size of the domain, the value of the geostrophic wind, and every other modelling parameter. The comparison of the results with the measurements is shown for the vertical profiles of wind speed, shear, wind direction, and turbulent kinetic energy. The ALS-based data resulted in reasonable agreement of the wind profile and turbulence magnitude. The best performance was found to be that of large-eddy simulations using a very large domain. For the Reynolds-averaged Navier–Stokes type of models, the constants in the turbulence closure were shown to have a great influence on the yielded turbulence level, but were of much less importance for the wind speed profile. Of the variety of closure constants used by the participating modellers, the closure constants from Sogachev and Panferov (2006) proved to agree best with the measurements. Particularly the use of $C_\mu \approx 0.03$ in the k–ε model obtained better agreement with turbulence level measurements. All except two participating models used the full detailed ground and forest information to model the forest, which is considered significant progress compared to previous conventional approaches. Overall, the article gives an overview of how well different types of models are able to capture the flow physics at a moderately complex forested site.

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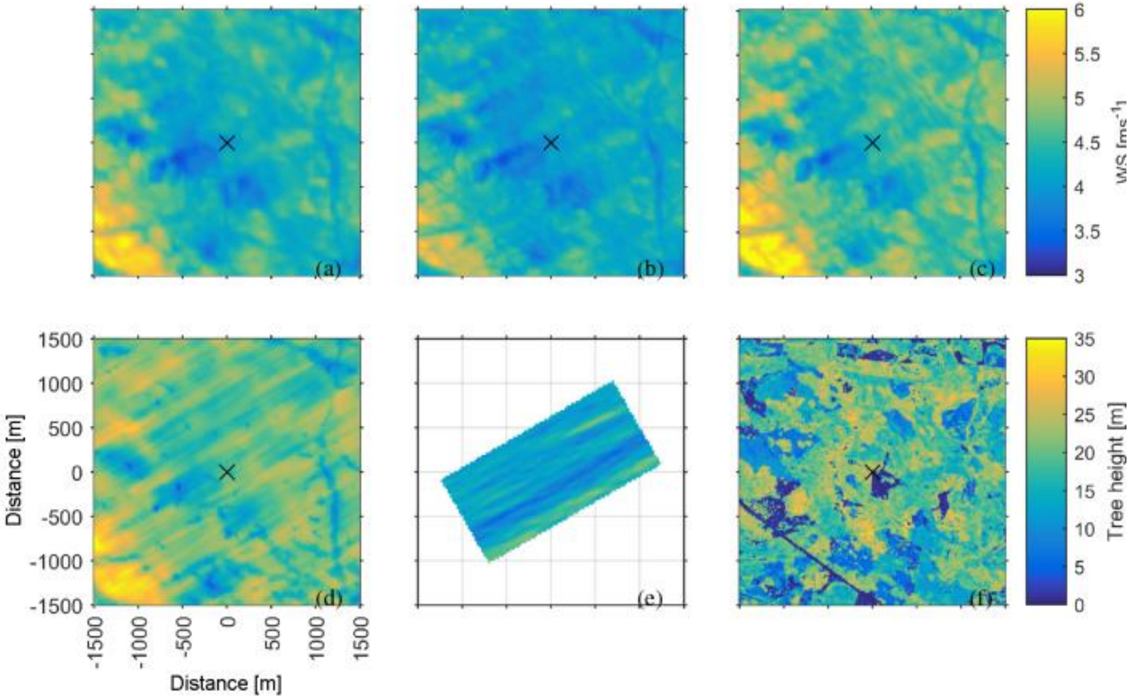
The publication presents a modelling benchmark and recommends best practice for CFD modelling over forested areas



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DISCUSSIONS

- Model verification & validation
- Turbulence assessment
- Forest footprint

Modelling of wind flows over realistic forests with LES

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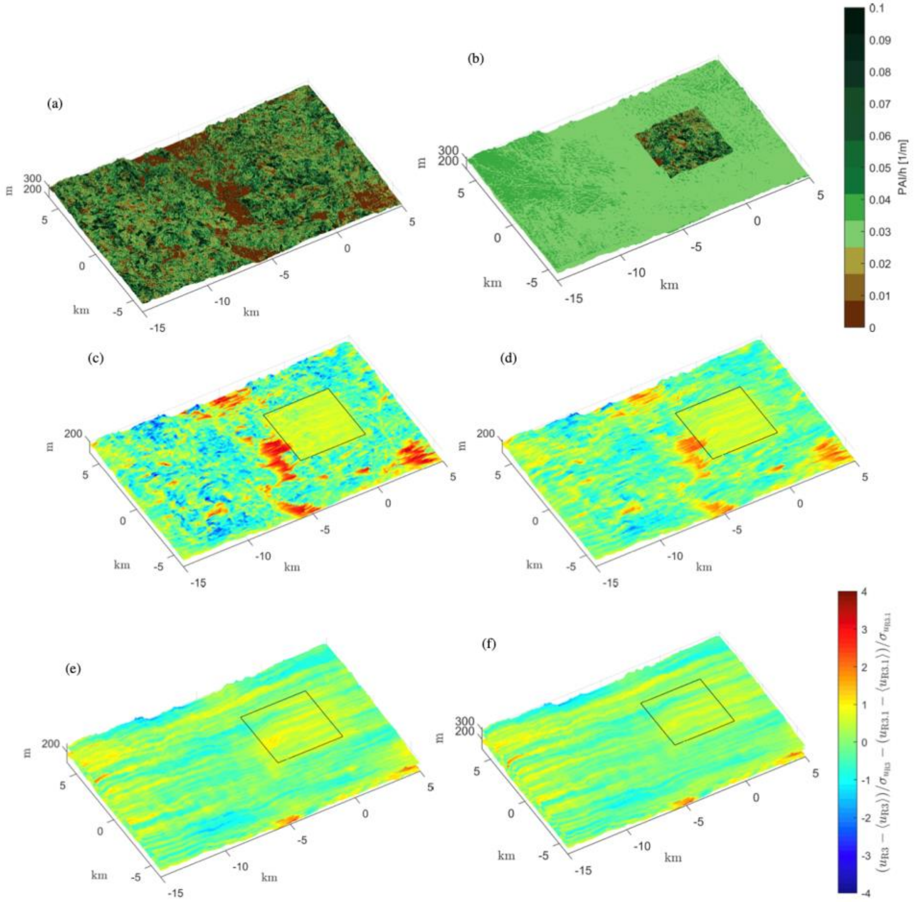
Abstract.
An LES based model for the simulation of wind flows over realistic forests and topography is presented. Terrain elevation as well as forest density maps from airborne laser scans are employed to investigate the importance of specific model choices related to capturing upstream terrain effects on the wind resource. The study is divided in three parts. Firstly, an extended verification process over idealized conditions is carried out. Secondly, a validation where the model is compared to field measurements acquired in the south-east of Sweden and finally an assessment of the forest and terrain footprint based on variations of the surface representation. The results show an agreement of turbulence statistics compared to the literature when forest is



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