Modeling and Validation across Scales: Parametrizing the effect of the forested landscape

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Abstract
When validating the performance of a flow model in forested areas, it is important that the model accurately represents the forest effects. This presentation concerns the use of remote-sensing technology for describing forest effects, and more specifically, how positioning lidar data can be transferred into a parametrization of forests in wind models. The presentation covers three scales: the single tree, the forest edges and clearings, and the large-scale forested landscape in which the forest effects are parameterized with a roughness length. Flow modeling results and validation against observations are presented along with the different forest presentations for each of the cases. In a new research project called InnoWind, the use of satellite-based alternatives to airborne lidar campaigns are investigated, and examples of satellite products in wind power modeling are discussed.

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Introduction

Trees are complex multi-scale structures, which makes them challenging to describe in modern flow models. Given how effective the trees are in absorbing the momentum of the wind, their effect is important to take into account for wind power modelling at several scales. Single-trees and rows of trees add to the roughness in an open landscape [1], and in the predominantly forested landscape the forest parametrization has a large impact on the flow modelling results [2]. For a small wind turbine, a single upwind tree could significantly reduce the power production. Wind turbines in the forested landscape are subjected to high levels of turbulence and shear [3] and an accurate site-specific assessment is needed to make sure that a project is economically viable. This presentation covers three examples, in which trees or forests are resolved with different levels of detail in flow models.

Single tree

The first full-scale experiment on how a single tree affects the wind field is currently taking place at DTU Wind Energy in Denmark. The experiment is centered around an open-grown six meter tall oak tree. Two masts with sonic anemometers measure the wind field upwind and downwind of the tree, and in parallel, the short-rage wind scanning technique is deployed. These wind observations will be used for validation of both a Reynolds' Averaged Navier Stokes (RANS) and a Large Eddy Simulation (LES) approaches, in which the tree structure is either resolved or parameterized. To create the necessary tree models, the tree was scanned with a Leica Total Station (Leica Geosystems AG) with 0.01 m resolution, and the resulting point cloud was used to make tree models suitable for the flow models.

Forest effects in canopy resolving micro-scale models

In the spring of 2016, two long-range wind-scanner lidars were mounted 50 m above ground on the two masts at the Østerild test site in Denmark. The site is located in and near old plantations of coniferous trees. The goal of the experiment was to measure the wind field plane over the complex forested landscape and to compare this dataset with RANS model output. In the RANS model, the forest effects are parameterized as a distributed drag force [4], varying in three dimensions [5]. We use the plant area density (PAD) profiles to quantify the influence of the forest effects. The PAD profile, in turn, was estimated using data from an airborne lidar campaign [5]. The modeled wind field at 50 m above the ground clearly shows the influence of the forest input (Fig. 1), where tall vegetation leads to low wind speeds and vice versa.

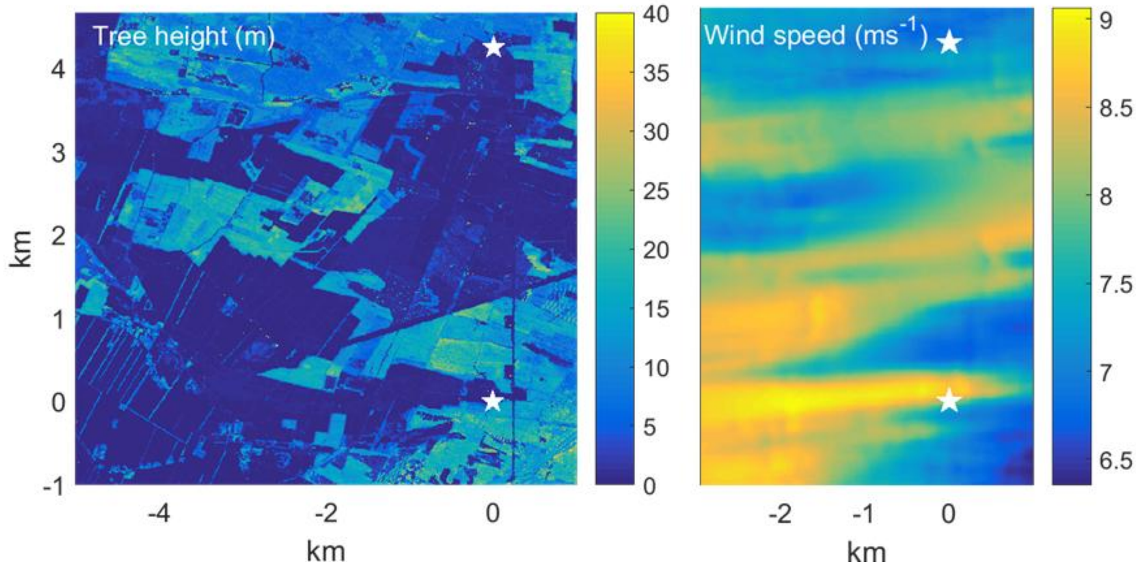

Fig. 1 Tree height map derived from air-borne lidar at the Østerild site (left) and simulated wind speeds using RANS at 50 m height (right). The blue low-wind-speed areas reflect the influence of green-yellow tall vegetation. The two white starts show the location of the Østerild towers, in which the long-range wind scanners were placed during the 2016 campaign.

The forested landscape in roughness models

In most land surface models used in the meso-scale models, forested areas are parameterized through tabular values associated with land use class. For wind simulations, the value of the aerodynamic roughness lengths associated with the forest classes affect the results both in term of wind resource and turbulence intensity. Also, many micro-scale models, including the WAsP siting tool and several CFD models, use standard conversions from land use to roughness values. Although few – if any – experimental studies support the low roughness values typically associated with forested areas in these conversions, they persist in the modelling chain [2,6]. This part of the talk focuses on both the resolution and roughness value of commonly used land use products for forested areas and example tall masts experiment are used to show what adjustments are needed for an accurate prediction of wind climate.

Finally, new remote-sensing products from satellites are demonstrated and opportunities in relation to these products are discussed.

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