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LIDAR-BASED MAPS FOR FLOW MODELING IN COMPLEX FORESTED TERRAIN

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Abstract Tall roughness elements, like forest, affect the wind field strongly. Therefore, in order to assess flow model performance in forested terrain, a correct representation of the forest effect on the wind field is needed. In this work, we study the performance of a Reynolds Averaged Navier-Stokes (RANS) solver in a forested landscape. The effect of the forest on the flow is parameterized as a momentum source term S_i , which represents a distributed drag force that resolves the vertical shape and density of the forest:

$$S_i = -c_d |\mathbf{U}| U_i \cdot PAD, \quad (1)$$

where c_d is the drag coefficient, \mathbf{U} is the magnitude of the mean wind vector, U_i is the wind component in the i direction and PAD is the plant area density that varies in space. The turbulence is modeled by the modified k - ε model of Sogachev and Panferov [4], where a source term in both the k and ε transport equations is used to account for the influence of the vegetation on the turbulence. To characterize the shape and density of the trees via PAD , we use the raw data - the so-called point cloud - from aerial lidar scans of the land surface. We calculate the vertical profile of the forest for each grid point in the CFD domain following recent advances in forest canopy characterization [1]. Our test case area is an agricultural landscape with smaller forest patches on the island Falster, Denmark. In this area, DTU Wind Energy performed a full-scale forest edge wind experiment using 14 sonic anemometers in two towers near and inside a forest consisting mainly of beech trees [2] (Figure 1). The full-scale experiment ran from the winter to late summer, thus covering both the period when the forest is bare and when it is fully leafed. The sonic anemometer wind measurements showed a clear difference in how the wind field reacted to these two stages. In example, the higher porosity of the forest during the winter resulted in a smaller speed-up over the forest when the wind was towards the edge compared to the fully leafed summer period. To characterize the seasonality in the landscape, we process two point clouds: one from a helicopter scan from August 2014 and the second from an airplane scan taken during the winter of 2015. Near the two towers, the vertically integrated PAD from the ground to the top of the beech trees is approximately double the value during the summer compared to the bare winter scan level (Figure 1).

The in-house flow solver EllipSys3D is used [5, 3]. The model predictions are evaluated against the observational data near the forest edge for several wind directions. In Figure 2, the comparison for the summer (left) and winter (right) is shown for the case when the wind direction was perpendicular towards the edge, corresponding to the direction of the arrow in Figure 1. Whereas the simulated mean wind profiles show a close match with observations, the results for the turbulent kinetic energy are less perfect. We discuss the discrepancies and investigate some of the uncertainty sources in RANS simulations, the point-cloud based forest description and the observations.

References

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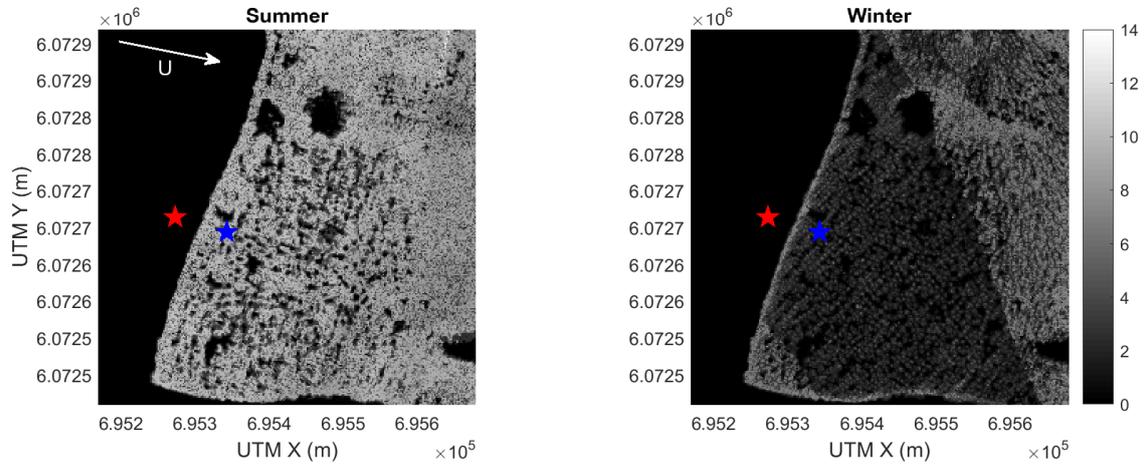


Figure 1. Vertically integrated forest density (m^2m^{-2}) of beech trees in forest edge wind experiment: the fully leafed summer case (left) and bare forest winter case (right). The locations of the towers with wind measurements are shown with a red (M1) or a blue star (M2), respectively. The arrow indicates the wind direction used for the RANS simulation in Figure 2.

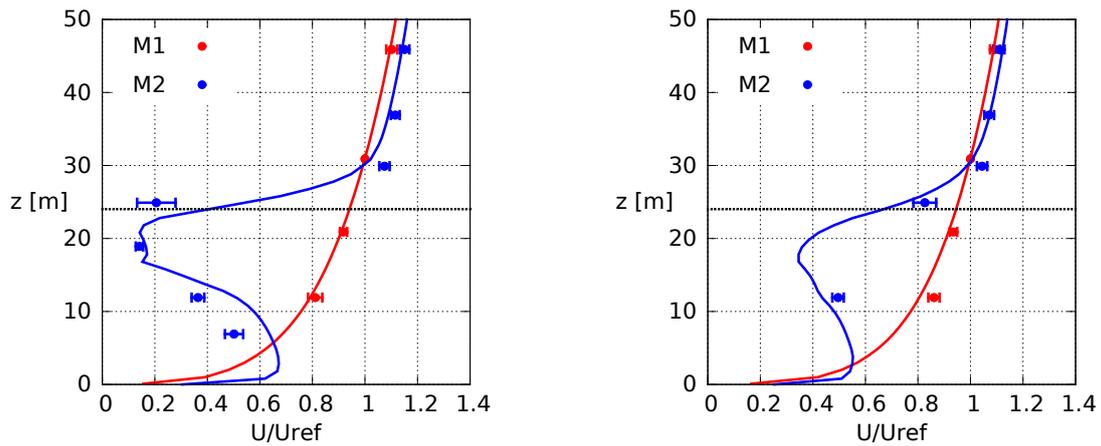


Figure 2. Simulated and measured stream-wise velocity profiles for the fully leafed summer case (left) and bare forest winter case (right). The locations of the towers with wind measurements are shown Figure 1. Results are normalized by the wind speed at 30.9 m, U_{ref} , taken at the location of the measurement tower outside the forest. The dotted horizontal line denotes the forest height at M2.