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LARGE-EDDY SIMULATION OF CANOPY FLOW UNDER THERMAL STRATIFICATION

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There is a strong incentive for placing wind turbines in forest regions, motivated by, for example, easier maintenance compared with off-shore wind turbines. Since larger wind turbine towers are used, wind turbines can operate efficiently even in the fairly low wind speeds encountered above forests. However, the wind in forest regions is characterized by strong wind shear and increased turbulence levels. As a consequence of that, wind turbines in forest regions are exposed to strong fluctuating aerodynamic loads, which will affect their fatigue life and maintenance requirements. Numerical simulations of canopy flow can be used to both gain a deeper understanding of the special characteristics of forest turbulence and also to investigate the encountered aerodynamic wind turbine loads. This can help to optimize wind turbine siting within forests and hence to mitigate the maintenance requirements.

For that reason, the atmospheric boundary layer under the influence of a forest canopy is investigated using large-eddy simulation. Instead of accounting for the forest in terms of a rough surface wall function, the forest is included explicitly in the simulations. The resistance effect of the forest on the flow is represented with help of drag force terms added to the momentum equations. Such a forest model was used in LES first by Shaw and Schumann [1] and has been widely used since [2, 3, 4].

The simulations have been made for both neutral and unstable stratification. In the latter case, a distributed heat source is placed in the forest.

For validation, comprehensive measurement data from the Ryningsnäs test site in southern Sweden is available. The forest at the test site consists mainly of scots pine trees and the average tree height is about 23 m. The measurements are made on a 140 m high meteorological mast, with equipment installed each 20 m. Detailed information concerning the measurements can be found in [5].

In Fig. 1(a), the horizontal wind speed profile, $M = \sqrt{u^2 + w^2}$, is presented for the case of neutral stratification. Good agreement with the measurement data can be observed. The slight overprediction might be an artefact of a too narrow domain size. Figure 1(b) shows that also the vertical shear stress component, $\overline{u'v'}$, is in good agreement with the measurements. Moreover, other first and second order statistics are found to agree well with both measurements and expectations from literature.

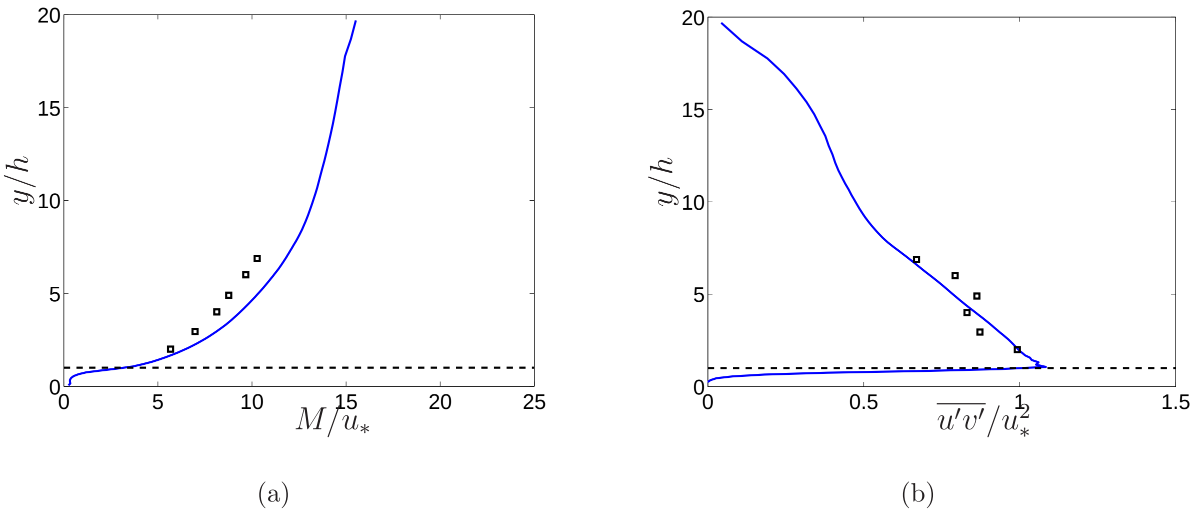

Figure 1: Neutral stratification: (a) normalized horizontal wind speed and (b) normalized shear stress. ——: LES, □: Measurement

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