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Wind tunnel investigation on wind turbine wakes and wind farms

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The interaction between atmospheric boundary layer and wind farms leads to flow modifications, which need to be deeply characterized in order to relate them to wind farm performance. The wake flow produced from a wind farm is the result of a strong interaction between multiple turbine wakes, so that the wind farm configuration turns out to be one of the dominant features to enhance power production. For the present work a wind tunnel investigation was carried out with hot-wire anemometry and velocity measurements performed with multi-hole pressure probes. The tested wind farms consist of miniature three-bladed wind turbine models. Preliminarily, the wake flow generated from a single wind turbine is surveyed, which is characterized by a strong velocity defect lying in proximity of the wind turbine hub height. The wake gradually recovers by moving downstream; the characteristics of the incoming boundary layer and wind turbulence intensity can strongly affect the wake recovery, and thus performance of following wind turbines. An increased turbulence level is typically detected downstream of each wind turbine for heights comparable to the wind turbine blade top-tip. These wake flow fluctuations produce increased fatigue loads on the following wind turbines within a wind farm, which could represent a significant hazard for real wind turbines. Dynamics of vorticity structures present in wind turbine wakes are also investigated; particular attention is paid to the downstream evolution of the tip helicoidal vortices and to oscillations of the hub vortex. The effect of wind farm layout on power production is deeply investigated. Particular emphasis is placed on studying how the flow adjusts as it moves inside the wind farm and can affect the power production. Aligned and staggered wind farm configurations are analysed, also with varying separation distances in the streamwise and spanwise directions. The present experimental results are being used to test and guide the development of improved parameterizations of wind turbines in high-resolution numerical models, such as large-eddy simulations (LES).