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Multiple-LiDAR measurements of wind turbine wakes: effect of the atmospheric stability

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Aerodynamic design and optimization of a wind farm layout are mainly based on the evaluation of wind turbine wake recovery by moving downstream, and on the characterization of wake interactions within a wind farm. Indeed, the power production of downstream wind turbine rows is strictly affected by the cumulative wake produced by the turbines deployed upstream. Wind turbine wakes are dependent on their aerodynamic features, and being immersed in the atmospheric boundary layer (ABL), they are also affected by surface heterogeneity, e.g. site topography and surface coverage, and atmospheric stability. The ABL stability is typically classified as neutral, convective or stable. In a neutral ABL the mechanical turbulent production is the dominating phenomenon. Conversely, for a convective ABL the turbulent kinetic energy and vertical transport phenomena are enhanced by positive buoyancy. Finally, for a stable ABL, a lower turbulence level is typically observed with an increased wind shear. For the present campaign convective ABL was typically observed during day-time, and neutral ABL for early morning and sunset periods. The aim of the present work is the evaluation of the influence of the ABL stability on downstream evolution of wind turbine wakes, which is mainly controlled by different ABL turbulence characteristics. Field measurements of the wake produced from a 2 MW Enercon E-70 wind turbine were performed with three scanning Doppler wind LiDARs. The wind and atmospheric conditions were characterized through a sonic anemometer deployed in proximity of the wind turbine. One LiDAR was placed at a distance about 12 rotor diameters upstream of the turbine in order to characterize the incoming wind. Two additional LiDARs were typically used to perform wake measurements. Tests were performed over the wake vertical symmetry plane in order to characterize wake recovery. Measurements were also carried out over conical surfaces in order to investigate the wind turbine wake with varying wind direction, thus different turbine yaw angles. Moreover, a 3D characterization of the wind turbine wake was performed by scanning the LiDAR over a 3D measurement volume. However, the large sampling period required for the 3D scans does not allow the investigation of wake dynamics. The LiDAR measurements show that wake evolution is significantly affected by the stability conditions of the ABL, thus by the different turbulence characteristics of the incoming wind. In particular, a faster wake recovery is observed in the presence of an increased turbulence of the incoming wind and for more convective atmospheric flows.