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Multi-component wind measurements of wind turbine wakes performed with three LiDARs

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Field measurements of the wake flow produced from the interaction between atmospheric boundary layer and a wind turbine are performed with three wind LiDARs. The tested wind turbine is a 2 MW Enercon E-70 located in Collonges, Switzerland. First, accuracy of mean values and frequency resolution of the wind measurements are surveyed as a function of the number of laser rays emitted for each measurement. Indeed, measurements performed with one single ray allow maximizing sampling frequency, thus characterizing wake turbulence. On the other hand, if the number of emitted rays is increased accuracy of mean wind is increased due to the longer sampling period. Subsequently, two-dimensional measurements with a single LiDAR are carried out over vertical sections of the wind turbine wake and mean wake flow is obtained by averaging 2D measurements consecutively performed. The high spatial resolution of the used LiDAR allows characterizing in details velocity defect present in the central part of the wake and its downstream recovery. Single LiDAR measurements are also performed by staring the laser beam at fixed directions for a sampling period of about ten minutes and maximizing the sampling frequency in order to characterize wake turbulence. From these tests wind fluctuation peaks are detected in the wind turbine wake at blade top-tip height for different downstream locations. The magnitude of these turbulence peaks is generally reduced by moving downstream. This increased turbulence level at blade top-tip height observed for a real wind turbine has been already detected from previous wind tunnel tests and Large Eddy simulations, thus confirming the presence of a source of dangerous fatigue loads for following wind turbines within a wind farm. Furthermore, the proper characterization of wind fluctuations through LiDAR measurements is proved by the detection of the inertial subrange from spectral analysis of these velocity signals. Finally, simultaneous measurements with two LiDARs are performed over the mean vertical symmetry plane of the wind turbine wake, while a third LiDAR measures the incoming wind over a vertical plane parallel to the mean wind direction and lying outside of the wake. One LiDAR is placed in proximity of the wind turbine location and measures pointing downstream, whereas a second LiDAR is located along the mean wind direction at a downstream distance of 6.5 diameters and measures pointing upstream. For these measurements axial and vertical velocity components are retrieved only for measurement points where the two laser beams result to be roughly orthogonal. Statistics of the two velocity components show in the near wake at hub height strong flow fluctuations with magnitudes about 30% of the mean value, and a gradual reduction for downstream distances larger than three rotor diameters.