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Validation of Taylor's Hypothesis under offshore conditions. An experimental study using a nacelle-based 'two-beam' Lidar.

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Knowledge of the incoming wind into a rotor plane of a wind turbine could be used to maximize its power production and minimize structural loads due to wind gusts. Nowadays wind turbines are equipped with a nacelle based wind measurement system (cup or ultra-sonic) with the purpose to give basic information of the approaching wind. However, this measured wind is not a good representative of the real wind in the rotor plane as it is strongly disturbed by the rotor itself.
In the last years wind lidar (light detection and ranging) systems are becoming a promising alternative to cup or ultra-sonic wind sensors and can also be installed on a wind turbine nacelle measuring the incoming wind. With the information about upcoming short-term wind variations, such as gusts, changes in wind direction and shears could e.g. be used to improve the turbine control. However, an estimation of the wind within the rotor plane from a wind measurement before the rotor plane is only valid with the assumption of Taylor's "frozen flow" hypothesis. The Taylor's hypothesis states that, in certain circumstances, the advection contributions by turbulent fluctuations measured at one point in the space can be considered small and that therefore the turbulent eddies move forward with the mean wind speed.
From July to November 2010, a nacelle mounted lidar prototype, developed by Leosphere Upwind, was located on a 5 MW offshore wind turbine (116 m rotor diameter) at about 95.2m height at the Alpha Ventus wind farm. This system, by pointing a laser beam in two directions upwind and making some assumptions it is possible to measure the horizontal wind speed and direction at different distances perpendicular in front the rotor plane (from 80m to 300m).
This campaign gives a unique opportunity to examine the Taylor hypothesis especially for the fundamental question until which frequency/wave number this hypothesis holds and, if those frequencies are relevant for the wind turbine control. Therefore, we are analyzing the behavior of both the correlation and the spectrum functions for those values which provide information associated with the smaller eddies sizes. At first, this is carried out between wind speed time series measured at the spatial points that are provided by the lidar and in a second step the lidar data will be analyzed with the rotor effective wind speed estimated from the wind turbine data.
Another advantage of the experiment is that we were able to check the Taylor hypothesis for the undisturbed wind flow and also in the wake of neighboring wind turbines. Therefore this study will be carried out for a free flow sector and a sector where the incoming wind is disturbed by the wake of adjacent wind turbines.