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3D turbulence measurements using three intersecting Doppler LiDAR beams: validation against sonic anemometry

Fernando Carbajo Fuertes, Giacomo Valerio Iungo, and Fernando Porté-Agel

Wind Engineering and Renewable Energy Laboratory (WIRE). École Polytechnique Fédérale de Lausanne (EPFL), St. 2, CH-1015, Lausanne, Switzerland (fernando.carbajo@epfl.ch)

Nowadays communities of researchers and industry in the wind engineering and meteorology sectors demand extensive and accurate measurements of atmospheric boundary layer turbulence for a better understanding of its role in a wide range of onshore and offshore applications: wind resource evaluation, wind turbine wakes, meteorology forecast, pollution and urban climate studies, etc.

Atmospheric turbulence has been traditionally investigated through sonic anemometers installed on meteorological masts. However, the setup and maintenance of instrumented masts is generally very costly and the available location for the measurements is limited by the fixed position and height of the facility.

In order to overcome the above-mentioned shortcomings, a measurement technique is proposed, based on the reconstruction of the three-dimensional velocity vector from simultaneous measurements of three intersecting Doppler wind LiDARs. This measuring technique presents the main advantage of being able to measure the wind velocity at any point in space inside a very large volume, which can be set and optimized for each test. Furthermore, it is very flexible regarding its transportation, installation and operation in any type of terrain.
On the other hand, LiDAR measurements are strongly affected by the aerosol concentration in the air, precipitation, and the spatial and temporal resolution is poorer than that of a sonic anemometer. All this makes the comparison between these two kinds of measurements a complex task.

The accuracy of the technique has been assessed by this study against sonic anemometer measurements carried out at different heights on the KNMI's meteorological mast at Cabauw's experimental site for atmospheric research (CESAR) in the Netherlands.

An early uncertainty analysis shows that one of the most important parameters to be taken into account is the relative angles between the intersecting laser beams, i.e. the position of each LiDAR on the terrain and their elevation and azimuth angles. Following this analysis, different LiDAR layouts have been tested, e.g., one vertical beam and the other two almost horizontal, all three equidistant with the same elevation angle, etc.

Preliminary results show different degrees of agreement between the proposed technique and the sonic anemometers depending on the LiDARs layout, which is in agreement with the uncertainty analysis carried out. The best configurations show a good agreement for the three components of the velocity and turbulence spectra, thus proving the ability of the technique to measure accurately atmospheric turbulence, consolidating it as a very interesting alternative to meteorological masts for many different applications.