Proactive monitoring of Wind Farm Performance through Wind LiDAR Data and a Reduced Order Model

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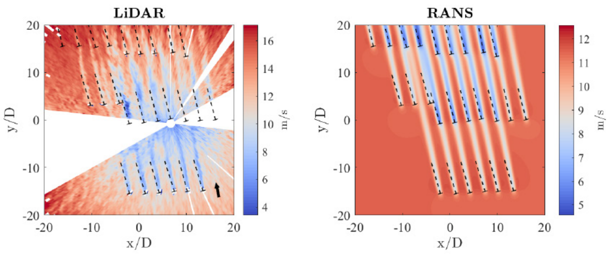
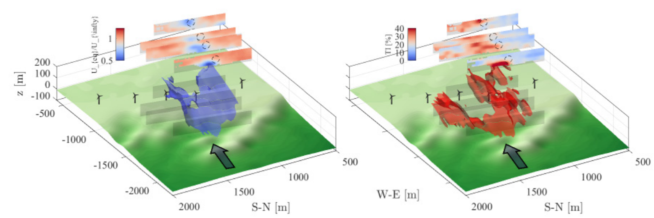
This project aims to develop a CFD tool for accurate predictions of wind turbine wakes and power capture at the turbine level by reproducing the typical variability during the daily cycle of the atmospheric stability. This CFD tool is based on the Reynolds-averaged Navier-Stokes (RANS) equations, which are solved parabolically in order to reduce the computational costs. The model has been validated against real data of a flat terrain farm with 10-minute time resolution. The latest upgrade of the CFD tool showed an accuracy of 12% with a confidence level of 90% for estimates of power capture from individual turbines. Among different features, the CFD tool provides a data-driven calibration of the turbulence closure in order to mimic variability in wake recovery due to different regimes of the atmospheric stability. Furthermore, the thrust force over the turbine blades is experimentally estimated by coupling LiDAR data and RANS simulations.



LiDAR data compared to the 2D RANS numeric field in the Panhandle Phase II wind farm.



3D reconstruction of the velocity field induced by the topographic wake impacting a Mitsubishi turbine at the Cedar Creek wind farm.

In order to extend the range of applicability of this CFD tool to wind farms on complex terrain, a new LiDAR field campaign was carried out for the Cedar Creek wind farm in Colorado. Massive topography-induced wakes were detected by our LiDAR station and their effect on the power or the nearby turbines was quantified. Losses in power up to 33% were observed in particularly unfavorable conditions, along with enhanced power fluctuations increased by 115% compared to the baseline case. Statistical analysis of 3 years of SCADA data allowed to quantify the yearly energy losses due to this kind of phenomena that amounts to 4% for the turbines installed by the escarpment. Furthermore, the LiDAR capability for resource assessment in complex terrain were explored ad reveal an outstanding accuracy. Finally, the 2D RANS model has been adapted for the Cedar Creek I wind farm. The large inhomogeneity in the flow induced by the complex orography has been taken into account by adding a data driven pressure field able to mimic the action of topography no the wind speed.