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Instability of outer tip vortices for a 2.5 MW wind turbine: integrating snow PIV with LES[1] FOTIS SOTIROPOULOS, XIAOLEI YANG, JIARONG HONG, University of Minnesota, MATTHEW BARONE, Sandia National Laboratories — Recent field experiments conducted around a 2.5 MW wind turbine using super-large-scale PIV (SLPIV) using natural snow particles have revealed tip vortex cores (visualized as areas devoid of snowflakes) of complex shape, consisting of both round and elongated void patterns. Here we employ large-eddy simulation to elucidate the structure and dynamics of the complex tip vortices identified experimentally. The LES is shown to reproduce vortex cores in remarkable agreement with the SLPIV results, essentially capturing all vortex core patterns observed in the field in the tip shear layer. We show that the stretched elongated vortex cores observed in 2D planes are the footprints of a second set of counter-rotating spiral vortices that emanates along the tip shear layer immediately downwind of the blades and is intertwined with the tip vortices. We argue that this large-scale instability is of centrifugal type since the mean flow characteristics in the outer tip shear layer resemble those of the Taylor-Couette flow. This study highlights the feasibility of employing snow voids to visualize tip vortices and demonstrates the enormous potential of integrating SLPIV with LES as a powerful tool for gaining novel insights into the wakes of utility scale wind turbines.

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Fotis Sotiropoulos
University of Minnesota

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