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FINITE ELEMENT AND SPECTRAL ELEMENT SCALE RESOLVING SIMULATIONS FOR WIND FARM AND AERODYNAMIC APPLICATIONS.

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Abstract. While wind energy is a relatively mature technology, plant-level energy losses are still estimated at around 20% in typical settings, with even higher losses in complex terrain. To reduce these inefficiencies, a deeper understanding of atmospheric flow is essential. The immense computational power of exascale computers now enables scale-resolving simulations that offer unprecedented insights into these flows.

For over a decade, we have been leveraging our in-house multiphysics finite element code, Alya, to analyze industrial wind farms in collaboration with Iberdrola. These advanced simulations incorporate canopy models to account for forested areas, actuator disc models to simulate wind turbine wakes, and thermal coupling to model varying stability regimes throughout the diurnal cycle. Recently, we have also integrated mesoscale forcing from weather simulations to enhance accuracy.

In pursuit of greater precision, we have encouraged our industrial partners to transition from Reynolds-Averaged Navier-Stokes (RANS) models to Large Eddy Simulations (LES). To make these more computationally feasible, we are porting code to GPUs and employing external Algebraic Multigrid linear solvers.

Over the past two years, we have also been developing a new Spectral Element code, SOD2D, which operates entirely on GPUs. This code has demonstrated superior accuracy at a reduced computational cost. While not all the physics required for wind energy applications have been fully transferred from Alya to SOD2D, initial applications to wind energy and aerodynamics problems will be presented.

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