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Modeling the Fluid Physics of Wind Farms

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Extended Abstract

The performance of large wind farms depends on the development of turbulent wind turbine wakes and the interaction between these wakes. Turbulence also plays a crucial role in transporting kinetic energy from the large-scale geostrophic winds in the atmospheric boundary layer towards heights where wind farms can harvest this energy. High-resolution large-eddy simulations (LES) are ideal for understanding these flow phenomena. Much has been learned from wind farm simulations, which initially focused on 'idealized' situations. The community increasingly focuses on modeling more complex situations, such as the effect of complex terrain and different atmospheric stability conditions. As wind farms become larger, the need to improve their design and develop control strategies to mitigate wake effects increases. However, due to the large separation of length scales and the number of cases, using LES for wind farm design is unfeasible. Therefore, LES is used to develop computationally more tractable modeling approaches ranging from Reynolds Average Navier Stokes (RANS) models to analytical modeling approaches. In this presentation, we will give particular attention to the challenges of modeling wind farm dynamics in large-eddy simulations and emerging challenges to account for the effect of mesoscale flow phenomena in these simulations.