Large wind farm power and variability: insights from turbulent boundary layer fundamentals

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In this presentation we examine the question of wind energy power density and variability from the viewpoint of basic turbulent boundary layer physics. We restrict attention to near-neutral atmospheric conditions and consider the limit of very large wind farms on flat terrains or off-shore. We first review the generalization of the constant flux, logarithmic layer concept for application to the wind turbine array boundary layer. In this type of boundary layer two logarithmic regions arise, one above and another below the turbine height. We show how such generalized logarithmic velocity profiles (or Monin-Obukhov similarity) can be used to enhance our understanding of wind power density. We also consider the question of wind farm power fluctuation characteristics, specifically its frequency spectrum. We show how basic knowledge about spatio-temporal spectra in wall-bounded turbulence can be used under some simplifying assumptions to develop a tractable model of wind farm frequency spectra that can take into account any turbine layouts (e.g., aligned or staggered). Where needed, we refer to results from Large Eddy Simulations using actuator-disk parameterizations of wind turbines, as well as from some wind tunnel experiments.

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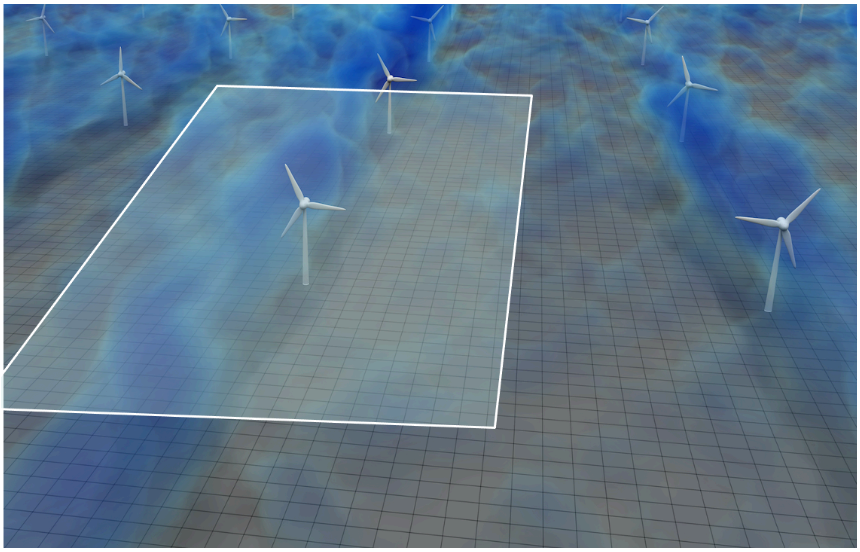

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