## Abstract

# Applying turbulent boundary layer concepts to flows in wind farms

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In this presentation we provide several examples of application of basic turbulent boundary layer concepts to improve our understanding of the mean and fluctuating flow structure in wind farms. Specifically, we consider the flow structure and turbulence in the wind turbine array boundary layer[1,2,3] (the WTABL), also distinguishing between developing and fully developed WTABLs. We perform a series of Large Eddy Simulations that represent the turbines as actuator disks or actuator lines. Salient LES results are then synthesized in order to develop simplified analytical models needed for wind farm design and optimization. There one encounters the dichotomy of modeling individual turbine wakes or to model the wind farm flow as a boundary layer over a roughened surface whose properties depend upon the wind farm array. The coupled wake boundary layer model[4] attempts to match these two approaches iteratively. Ultimately, such models can lead to improved estimation of optimal wind turbine spacing including costs associated with covered surface, cabling and operation & maintenance[5]. We also present new results on the temporal variability of wind power as measured in a wind tunnel experiment[6] and its relationship to the spatio-temporal properties of turbulent boundary layers[7]. It turns out that as a first approximation, for situations without thermal stratification effects, one may consider the sum of turbine power to be a discrete sampling of the wavenumber-frequency spectrum of turbulent boundary layers. This model thus enables us to connect wind farm design parameters (turbine spacing, positioning, etc.) to fundamental properties of turbulent boundary layers.

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