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A canopy-type similarity model for wind farm optimization

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The atmospheric boundary layer (ABL) flow through and over wind farms has been found to be similar to canopy-type flows, with characteristic flow development and shear penetration length scales (Markfort et al., 2012). Wind farms capture momentum from the ABL both at the leading edge and from above. We examine this further with an analytical canopy-type model. Within the flow development region, momentum is advected into the wind farm and wake turbulence draws excess momentum in from between turbines. This spatial heterogeneity of momentum within the wind farm is characterized by large dispersive momentum fluxes. Once the flow within the farm is developed, the area-averaged velocity profile exhibits a characteristic inflection point near the top of the wind farm, similar to that of canopy-type flows. The inflected velocity profile is associated with the presence of a dominant characteristic turbulence scale, which may be responsible for a significant portion of the vertical momentum flux. Prediction of this scale is useful for determining the amount of available power for harvesting. The new model is tested with results from wind tunnel experiments, which were conducted to characterize the turbulent flow in and above model wind farms in aligned and staggered configurations. The model is useful for representing wind farms in regional scale models, for the optimization of wind farms considering wind turbine spacing and layout configuration, and for assessing the impacts of upwind wind farms on nearby wind resources.

Markfort CD, W Zhang and F Porté-Agel. 2012. Turbulent flow and scalar transport through and over aligned and staggered wind farms. Journal of Turbulence. 13(1) N33: 1-36. doi:10.1080/14685248.2012.709635.