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Proper Orthogonal Decomposition analysis of kinetic energy entrainment in LES of very large wind farms

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Wind turbines are being installed across the world in large arrays. As the number of wind-turbines in a wind farm grows, so does the importance of the dynamic interactions between neighboring turbines and with the turbulent atmospheric boundary layer (ABL). If the array is an order of magnitude longer than the height of the ABL, then a fully-developed flow regime is established and the entrainment of kinetic energy from above becomes a limiting factor for array performance. This phenomenon has previously been studied numerically and experimentally, but the following question remains: are there large-scale coherent structures that are involved in this kinetic energy entrainment? In this study we use Proper Orthogonal Decomposition (POD) to identify coherent structures, the strongest of which were found to be streamwise counter-rotating vortices located above the wind turbines. The contribution by each structure to the entrainment of kinetic energy is measured and found to converge more quickly than their contribution to the kinetic energy, for which the POD analysis is optimal. The LES domains considered here are infinite arrays of aligned and staggered turbines and ABL flow without wind turbines. While the POD flow structures are found to be quite robust, their contributions to kinetic energy entrainment are found to depend on the design of the wind turbine array. This research is supported by NSF Graduate Fellowship, NSF-CBET-113380 and NSF-OISE-1243482.