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Flow adjustment inside large finite-size wind farms approaching the infinite wind farm regime

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Due to the increasing number and the growing size of wind farms, the distance among them continues to decrease. Thus, it is necessary to understand how these large finite-size wind farms and their wakes could interfere the atmospheric boundary layer (ABL) dynamics and adjacent wind farms. Fully-developed flow inside wind farms has been extensively studied through numerical simulations of infinite wind farms. The transportation of momentum and energy is only vertical and the advection of them is neglected in these infinite wind farms. However, less attention has been paid to examine the length of wind farms required to reach such asymptotic regime and the ABL dynamics in the leading and trailing edges of the large finite-size wind farms. Large eddy simulations are performed in this study to investigate the flow adjustment inside large finite-size wind farms in conventionally-neutral boundary layer with the effect of Coriolis force and free-atmosphere stratification from 1 to 5 K/km. For the large finite-size wind farms considered in the present work, when the potential temperature lapse rate is 5 K/km, the wind farms exceed the height of the ABL by two orders of magnitude for the incoming flow inside the farms to approach the fully-developed regime. An entrance fetch of approximately 40 times of the ABL height is also required for such flow adjustment. At the fully-developed flow regime of the large finite-size wind farms, the flow characteristics match those of infinite wind farms even though they have different adjustment length scales. The role of advection at the entrance and exit regions of the large finite-size wind farms is also examined. The interaction between the internal boundary layer developed above the large finite-size wind farms and the ABL under different potential temperature lapse rates are compared. It is shown that the potential temperature lapse rate plays a role in whether the flow inside the large finite-size wind farms adjusts to the fully-developed flow regime. The flow characteristics of the wake of these large finite-size wind farms are reported to forecast the effect of large finite-size wind farms on adjacent wind farms. A power deficit as large as 8% is found at a distance of 10 km downwind from the large finite-size wind farms.