Modeling mesoscale wind speed variations in large eddy simulations of wind farms

Yang Liu and Richard Stevens, Physics of Fluids group, University of Twente

Large eddy simulations (LES) of wind farms are typically performed for stationary geostrophic forcings, thus neglecting the effect of mesoscale flow phenomena on wind farm performance. As wind turbines and wind farms increase in size, it becomes crucial to consider the impact of mesoscale atmospheric effects, (such as dynamic wind speed and direction changes, and variations in thermal stability and moisture), on wind farm performance [1][2]. However, coupling mesoscale weather models with microscale wind farm simulations is non-trivial due to the different assumptions used in each model paradigm. For example, mesoscale models employ single-column models and parameterize the effects of turbulence implicitly [3]. In contrast, microscale models for wind farm simulations can resolve turbulence explicitly and simulate the time-varying, stochastic flow fields. Due to their increasing size, wind turbines and wind farms are increasingly expected to interact with atmospheric flow phenomena affected by mesoscale forcings, which are currently not incorporated in microscale wind farm simulations. Therefore, new techniques that can capture the effect of mesoscale forcings in microscale LES are urgently required to simulate wind farms under more realistic conditions.

Here we propose a new method to model mesoscale wind speed variations in microscale LES. This is achieved by combining a non-inertial moving reference frame with the concurrent precursor technique [4]. Figure 1 provides a sketch of the method, showing that we use a moving reference frame to simulate the dynamic wind speed variations compared to the average inflow. This allows us to model mesoscale wind speed changes in the microscale simulation domain. Through a set of test cases, we confirm that the proposed method can accurately model field-measured wind speed data in microscale wind farm simulations. This approach captures high-frequency variations, while the relatively low-frequency mesoscale wind speed variations are imposed using measurement data.

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