Toward the integration of atmospheric flow prediction and wind plant simulation: An overview of the DOE A2e Mesoscale-Microscale Coupling project

Jeffrey D. Mirocha[a] **and Sue Ellen Haupt**[b]
[a]Lawrence Livermore National Laboratory, Livermore, CA, USA, jmirocha@llnl.gov
[b]National Center for Atmospheric Research. Boulder, CO, USA

Abstract

The Mesoscale-Microscale Coupling project is a coordinated, multi-institutional effort to integrate mesoscale atmospheric flow prediction with microscale wind plant simulation, the goal being to enable wind plant optimization over the full range of meteorological conditions experienced over a lifetime of operation. Herein, we describe the challenges to this integration, including i) coupling strategies for various environments and flow conditions, ii) turbulence generation and equilibration at mesh refinement interfaces, and iii) improved surface layer dynamics for turbulence resolving simulations. We describe how these challenges are being addressed by project team, highlight successes so far, and discuss remaining challenges.

Keywords: *Mesoscale-Microscale Coupling, Large-Eddy Simulation*

Summary

The absence of high-fidelity atmospheric boundary layer (ABL) inflow and its representation within microscale wind plant simulations remains a key contributor to uncertainties in wind plant performance, reliability, and optimization. For this reason, development of robust and well characterized mesoscale-microscale coupling methods to incorporate the numerous atmospheric and environmental factors impacting flow characteristics that affect power generation and turbine component reliability has been identified as a crucial industry need. The Mesoscale-Microscale Coupling (MMC) project, within the Department of Energy's Atmosphere to electrons (A2e) program, is addressing this need by creating new simulation capabilities that are able to represent the full range of atmospheric flow conditions impacting wind plant operations in diverse landscapes and flow conditions.

Development of robust MMC techniques presents many challenges, both theoretical and practical. The MMC team is currently investigating the following four key challenges identified as most critical to enabling a general MMC methodology; 1) methods to incorporate mesoscale information into microscale simulations for different applications, 2) methods for turbulence generation at the inflow boundaries of turbulence-resolving large-eddy simulation (LES) domains using mesoscale inflow, 3) accelerating flow equilibration under subsequent mesh refinement, and 4) methods for higher-fidelity representations of surface layer dynamics in LESs.

These MMC activities are proceeding in coordination with other projects under the A2e umbrella, including the related topics of simulating turbulent flow across multiple scales using new techniques for turbulence closure in the "terra-incognita", and development of the Nalu microscale code to efficiently utilize emerging high-performance computer (HPC) resources to meet the growing computational requirements of modern MMC simulations. Herein the team is working mainly with the WRF and SOWFA codes, with the best performing MMC approaches developed within those codes being subsequently implemented and tested within Nalu.