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Nesting large-eddy simulations within mesoscale simulations for wind energy applications

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With increasing demand for more accurate atmospheric simulations for wind turbine micrositing, for operational wind power forecasting, and for more reliable turbine design, simulations of atmospheric flow with resolution of tens of meters or higher are required. These time-dependent large-eddy simulations (LES), which resolve individual atmospheric eddies on length scales smaller than turbine blades and account for complex terrain, are possible with a range of commercial and open-source software, including the Weather Research and Forecasting (WRF) model. In addition to "local" sources of turbulence within an LES domain, changing weather conditions outside the domain can also affect flow, suggesting that a mesoscale model provide boundary conditions to the large-eddy simulations. Nesting a large-eddy simulation within a mesoscale model requires nuanced representations of turbulence.

Our group has improved the Weather and Research Forecating model's (WRF) LES capability by implementing the Nonlinear Backscatter and Anisotropy (NBA) subfilter stress model following Kosović (1997) and an explicit filtering and reconstruction technique to compute the Resolvable Subfilter-Scale (RSFS) stresses (following Chow et al, 2005). We have also implemented an immersed boundary method (IBM) in WRF to accommodate complex terrain. These new models improve WRF's LES capabilities over complex terrain and in stable atmospheric conditions. We demonstrate approaches to nesting LES within a mesoscale simulation for farms of wind turbines in hilly regions. Results are sensitive to the nesting method, indicating that care must be taken to provide appropriate boundary conditions, and to allow adequate spin-up of turbulence in the LES domain.

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