High-Fidelity Blade-Resolved Wind Plant Modeling

Background and Importance
With rapid advances in high performance computing, high-fidelity models for complete wind farm simulation are becoming feasible. Current simulation technologies use only low fidelity models that do not incorporate the blade geometry directly. Using full rotor models for wind energy simulation has become a grand challenge problem for the DoE’s Exascale Computing Project (ECP). This work bridges the gap between current technologies and ECP’s ExaWind.

Impact
- Enable single turbine to complete wind farm control: power optimization and turbine longevity/reliability
- Accurate detailed loading, wake interactions and atmospheric turbulence effects
- Validate and improve effectiveness of lower fidelity models
- Tool for wind plant siting, environmental effects
- Straightforward path to incorporate additional effects: transition, roughness, icing, acoustics

Dual-Mesh Dual-Solver Paradigm
- Near-body solver: NS3ID
  - Implicit solver - Newton-Krylov and multigrid
  - DDES and ALE
  - Complex geometry
  - Scales up to 32k cores
- Off-body solver: dg4est
  - Explicit solver
  - High-order Cartesian DG solver
  - High Computational Efficiency
  - Dynamic h/p-AMR capabilities through p4est octree-based framework
  - Physics: Coriolis and Gravity
  - Scaling on Mira up to 1 million ranks

Related Work
- Link to atmospheric boundary layer LES simulations in complex terrain
  - One-way coupling to WRF-LES/SOWFA
  - Fluid-Structure Interface
  - Control model for wake steering
  - Acoustic design optimization
  - ONR research for ship wake interactions

Future Work:
- DoE Office of Science, Award DE-SC002671
- Numerical simulation of 48 wind turbines coupled with atmospheric inflow coupling using NCAR WRF
- Increase accuracy for improved blade loading
- Detailed blade design
- Structural response and control
- Better stall prediction
- Enable single turbine to complete wind farm control

Summary and Future Work
- Multiple flow solvers coupled by overset meshing
- Modular software interface written in C
- High-order dynamic h/p-AMR capabilities
- Successful wind farm simulation on 67,392 cores with 144 wind turbines
- Coupled in WRF-LES/SOWFA
- Simulate large scale wind farm for long run times
- Future work: Split form discontinuous Galerkin solver with turbulence modeling
- Future work: Couple NS3ID and FSI/CFD future work: Wind turbine control module

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