FY19 Q3: High-order methods for wind turbine simulations and moving to next-generation platforms

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Scope and objectives

- ExaWind Objective: Create a computational fluid and structural dynamics platform for exascale predictive simulations of wind farms.
- Challenge Problem: Predictive simulation of a wind farm composed of O(100) wind turbines sited over O(100) km^2 with complex terrain.
- FY19 milestone activities are focused on establishing a full set of baseline physics modeling capabilities in Nalu-Wind, establishing a pathway to high-order discretization, and establishing a new turbulence modeling capability.
- Additional FY19 activities include preparing the software stack for assembly and solve on next-generation platforms.

Highlight results: High-order efficiency

- Tested new matrix-free scheme on an intentionally under-resolved turbulent flow. Time-to-solution is roughly independent of polynomial order and only marginally slower than the production edge-base vertex centered finite volume scheme (EBVC)

Impact

- The new high-order spatial discretization provides a promising pathway to accurately propagating turbine wakes over long distances, which is critical for predicting and understanding turbine-turbine wake interactions.
- The new discretization may constitute the best path for an unstructured-grid background solver (interfaced to low-order near-turbine models through overset meshes), especially for complex-terrain problems.
- The new discretization, with its Kokkos-implementation underpinnings and operation intensity, is especially promising for next-generation architectures.

Project accomplishment

- Developed, implemented, and tested a new matrix-free algorithm for high-order spatial discretization for unstructured grids for the control-volume finite element method (CVFEM), including (1) an efficient tensor-product scheme for matrix-vector products, (2) a new efficient quadrature scheme, (3) a new preconditioning scheme based on low-order connectivity.
- Tested the method on Taylor-Green vortex-breakdown benchmark problem and showed that for a fixed number of degrees of freedom, high-order discretization can outperform low-order discretization.

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EXASCALE COMPUTING PROJECT