SAND2018-0425R

EXASCALE COMPUTING PROJECT

ECP-U-2017-XXX

ECP ALCC Quarterly Report (Oct-Dec 2017)

WBS 2.2.2.01 ExaWind

Michael A Sprague[1]

Stephen Thomas[1]

Jon Rood[1]

Jonathan Hu[2]

Jeremy Melvin[3]

[1]National Renewable Energy Laboratory

[2]Sandia National Laboratories

[3]University of Texas at Austin

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17 January 2018

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U.S. DEPARTMENT OF ENERGY | Office of Science

National Nuclear Security Administration

1. PROJECT DESCRIPTION

Project Title: Exascale Predictive Wind Plant Flow Physics Modeling

Project PI: Michael A. Sprague

Project Summary:

The scientific goal of ExaWind Exascale Computing Project (ECP) is to advance our fundamental understanding of the flow physics governing whole wind plant performance, including wake formation, complex terrain impacts, and turbine-turbine-interaction effects. Current methods for modeling wind plant performance fall short due to insufficient model fidelity and inadequate treatment of key phenomena, combined with a lack of computational power necessary to address the wide range of relevant length scales associated with wind plants. Thus, our ten-year exascale challenge is the predictive simulation of a wind plant composed of O(100) multi-MW wind turbines sited within a 100 km2 area with complex terrain, involving simulations with O(100) billion grid points. The project plan builds progressively from predictive petascale simulations of a single turbine, where the detailed blade geometry is resolved, meshes rotate and deform with blade motions, and atmospheric turbulence is realistically modeled, to a multi-turbine array in complex terrain.

The ALCC allocation will be used continually throughout the allocation period. In the first half of the allocation period, small (e.g., for testing Kokkos algorithms) and medium (e.g., 10K cores for highly resolved ABL simulations) sized jobs will be typical. In the second half of the allocation period, we will also have a number of large submittals for our resolved-turbine simulations. A challenge in the latter period is that small time step sizes will require long wall-clock times for statistically meaningful solutions. As such, we expect our allocation-hour burn rate to increase as we move through the allocation period.

Code Description and Characterization:

The ExaWind project utilizes the open-source CFD code Nalu (C++), for solving the low-Mach-number Navier-Stokes equations using an unstructured-grid discretization. Nalu leverages the open-source Trilinos solver library and the Sierra Toolkit (STK) for parallelization and I/O. Nalu has demonstrated scaling to over 500,000 cores on the Sequoia BG-Q platform, and was an acceptance test code for the NNSA system, Trinity. Nalu leverges Kokkos, a performance-portable shared-memory parallel-programming library, to achieve scalability on next-generation computing platforms. Turbine-coupled simulations be performed with Nalu coupled with the turbine simulation tool OpenFAST (Fortran), which is developed and maintained by the National Renewable Energy Laboratory. Recently, Nalu has been coupled to the Hypre AMG preconditoner/solver library and the TIOGA overset library.

Code Name	**Dense Linear Algebra**	**Sparce Linear Algebra**	**Monte Carlo**	**FFTs**	**Particles**	**Structured Grids**	**Unstructured Grids**	**AMR**
Nalu		X					X	

2. WHAT DID (WILL) YOU DO WITH THE ALLOCATION

Project Usage This Quarter:

In the last quarter (Oct-Dec 2017), we used 3.3M hours of our 5M hour allocation on Cori. It has been reported to ECP leadership that our needs in the ExaWind project exceed greatly the 5M hour allocation, and additional hours have been requested. Our largest simulations used 45K cores on Cori.

Future Project Usage:

At the end of Dec 2017, we have used a substantional fraction of our 5M hour allocation on Cori (as of writing this report, the full allocation was used in early January 2018). We have requested additional hours, and our compute-hour needs are expected to grow as we move to larger simulations with higher fidelity.

Report on Project Accomplishments:

The following is a list of simulation accomplishments in the last quarter:

- Direct-numerical simulations (DNS) of homogeneous stratified turbulence were performed in a regime where turbulent anisotropy would be similar to that found in the atmospheric boundary layer (ABL). This work is in support of the ADSE07-94. These simulations will be used for a priori and a posteriori testing of LES models being developed for wind farm simulations. On Cori we were able to run large enough DNS simulations using 64 KNL nodes to reach the strongly stratified regime, the minimum regime requirement for simulations applicable to the ABL.
- Cori was used to build and run Percept, which is a tool used for refining meshes. A particular mesh named “V27”, of a wind turbine, was refined to a target resolution of ~1 billion elements for testing on larger-scale runs of the Nalu application. This mesh was also further refined to ~4 billion elements for even larger scale investigation of scaling Nalu.
- A large part of our ECP exawind Cori allocation was dedicated to simulate turbulent flow and the formation of wake vortices around a Vestas V27 (225 kW) wind turbine. For the incompressible Navier-Stokes equations, the pressure-continuity solver has a large cost. The Nalu model has been interfaced to both the LLNL-CASC Hypre-BoomerAMG and Sandia Trilinos-Tpetra-MueLu solver stacks. These implement the classical C-AMG and aggregration SA-AMG algebraic multigrid preconditioners for a nonsymmetric GMRES solver, respectively. Strong scaling studies were performed with rotating blades in order to assess the costs of repeated matrix re-initialization and preconditioner set-up in addition to the overall time-to-solution. A sequence of finite element meshes was employed based on the V27 41 and V27 41a meshes. These consisted of refined meshes (R0 66M elements 18M DOFs, R1 541M element, 229M DOFs) and (R0 166 M elements, 45M DOFs, R1 1.3 Billion elements, 363 M DOFs, and R2 4.3 Billion elements, 1.8B DOFs). We ran Nalu+Hypre and Nalu+ MueLu simulations up to the maximum available 45K Haswell cores (1420 nodes x 32 cores). These simulations are in support of ECP Milestones; ADSE07-5, ADSE07-6, ADSE07-86, and ADSE07-92. With improvement to matrix re-initialization times these runs indicate that we could continue scaling out to 100K cores at 0.5 - 1.0 PetaFlops sustained with around 20K DOF’s per mpi rank (core).

3. FACILITY FEEDBACK

We have been satisfied in our interactions with the NERSC/Cori facility.

Acknowledgements

As a reminder to you and your team, please include appropriate acknowledgements for your work.

ECP: https://confluence.exascaleproject.org/display/KBPOL/ECP+Acknowledgment+Messaging

ALCF: https://www.alcf.anl.gov/user-guides/alcf-acknowledgment-policy

OLCF: https://www.olcf.ornl.gov/kb_articles/olcf-acknowledgement/

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