Parallel OpenFOAM - WRF Coupling Methodology and Comparison with Experimental Mast-Data

Engin Leblebici* and Prof. Dr. Ismail H. Tuncer†

RUZGEM/METU Aerospace Eng. Dept., ANKARA, CANKAYA, 06800, Turkey

1 Abstract

The main objective of this study is to obtain real-time atmospheric flow solutions using open source CFD solver OpenFOAM coupled with Numerical Weather Prediction (NWP) model: Weather Research Forecast (WRF). NWP can take moist convection, land surface parameterization, atmospheric boundary layer physics into account, but wind flow features finer than 1 km aren’t captured by the turbulence physics of such models. CFD simulations, however, have proved to be useful at capturing the details of smaller scales due to a finer scale topography. Moreover, using the WRF weather prediction data as unsteady and spatially varying BCs for the CFD solution may prove to be one of the most realistic representations for the atmospheric flow field, and also allows daily power production estimations. Coupling the mesoscale weather prediction model WRF (Weather Research and Forecast) with the open source CFD solver OpenFOAM is done via using low resolution WRF data as unsteady and spatially varying boundary conditions for the OpenFOAM domain. A basic schematic of the procedure is given in Figure 1.

For this purpose, a new unsteady and spatially varying boundary condition class (timeVaryingMixed) that switches between Neumann and Dirichlet depending on the flow is entering or exiting the domain to use the WRF data as boundary conditions without convergence issues for continuity, is developed.

Effects of coriolis acceleration and spatially varying roughness model that gets the data from Corine Roughness Data Set for any region of interest are implemented into the incompressible unsteady solver of choice 'pimpleFoam'.

Due to real-time prediction requirement, parallelization of the process is of utmost importance. But the developed boundary condition class 'timeVaryingMixed' cannot be run in parallel using OpenFOAM’s domain decomposition tool decomposePar as the indexes of cells change when the domain is decomposed. Parallelization of the process is done and made automatic using METIS to optimize the number of processor boundaries, even when all the cells that are in neighborhood of the developed boundary condition timeVary-

*Engin Leblebici, RUZGEM / METU Aerospace Eng., engin1@ae.metu.edu.tr.
†Ismail H. Tuncer Prof. Dr., RUZGEM / METU Aerospace Eng., tuncer@ae.metu.edu.tr.
ingMixed, are owned by 1 processor. Details about the methodology and parallelization of process will be given in the final paper.

Unsteady OpenFOAM solutions coupled with WRF are performed using the methodology on high resolution stretching structured grids seen in Figure 2. High resolution (1.5 arcsec) ASTER GDEM topographical data is used to create the topography in order to capture the viscous effects which dominates the flow characteristics at the surface layer of the atmosphere where majority of the wind turbines reside. Simulations in Alaiz Mountain (Spain) are carried out and validation studies using the met-mast data from the region are done at the met-mast location at 5 different heights (118, 102, 90, 78, 40 meters) above the ground. As a preliminary results, time-series wind speed data at 40 meters and 90 meters above ground is given in Figure 3 and Figure 4, respectively. Results show a drastic improvement over the WRF results especially in recent vicinity of the ground.

![Figure 3: Met-Mast data vs WRF and OpenFoam Solutions (118 m above ground)](image)

Unlike other methodologies, capability of time resolved energy prediction is attained in this study and also, observation data is not a must.

![Figure 4: Met-Mast data vs WRF and OpenFoam Solutions (40 m above ground)](image)