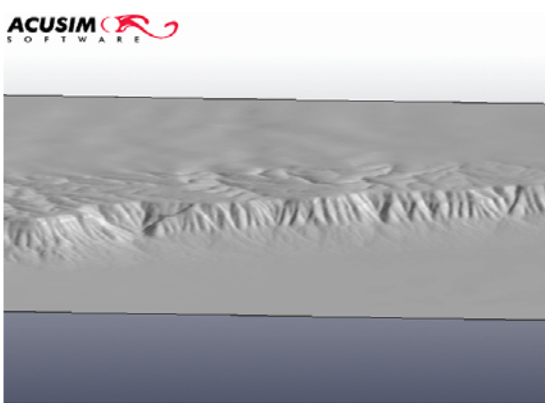
Wind Turbine Micro-siting and Wake Propagation

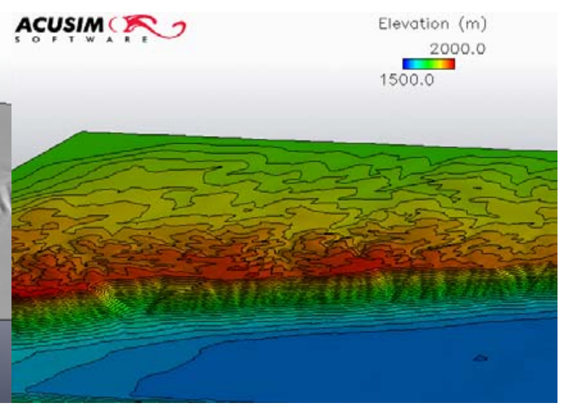
Optimization of wind turbine placement within a candidate wind farm location is a critical task in extracting as much energy as possible from the wind. By carefully analyzing the flow patterns over a plot of land and positioning the turbines carefully, wind farm designers can optimize the power production of a wind farm.

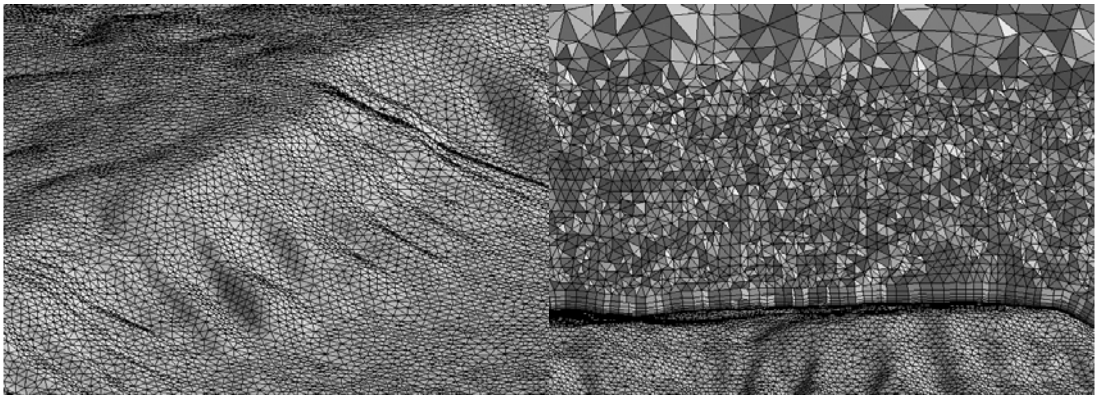
The ability to rapidly investigate flow patterns in the wakes of turbines and over complex terrain provides a unique advantage to wind farm designers. Using AcuSolve, designers can rapidly generate unstructured meshes over complex geometry without the need to spend days or weeks building block structured hexahedral meshes. AcuSolve's unique finite element formulation provides second order spatial accuracy for all element topologies and retains its speed and robustness on unstructured meshes.

To illustrate AcuSolve's capabilities in wind farm micro-siting, a representative terrain was meshed. The terrain model corresponds to the Aubrey Cliffs region in the Arizona desert, and encompasses a 14 x 12 km foot print. This region features a steep cliff that provides acceleration of the prevailing winds. The detailed profile of this accelerated flow can be exploited to position turbines with optimal location and hub height.

The terrain model was meshed using a combination of tetrahedral, prism, and pyramid elements. The elements near the terrain surface were clustered in the normal direction to provide a high level of boundary layer resolution. The first element spacing was approximately 10 cm. The volume mesh size in the domain is 100 m in most areas. Near the candidate turbine placement locations, the mesh size was reduced to 15 m. The terrain map and mesh sizing are shown in the following images.

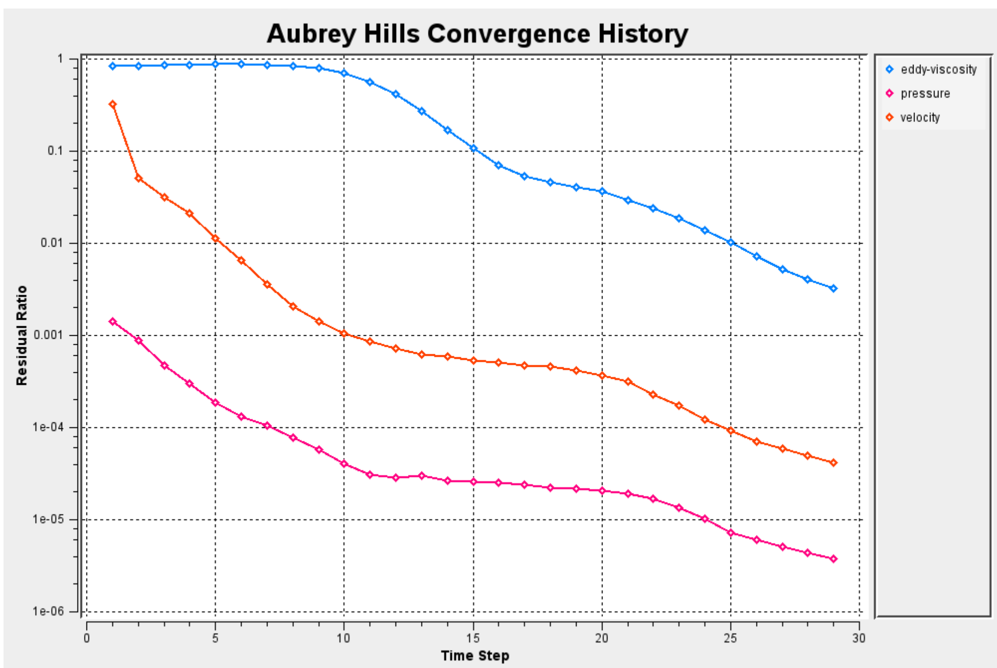




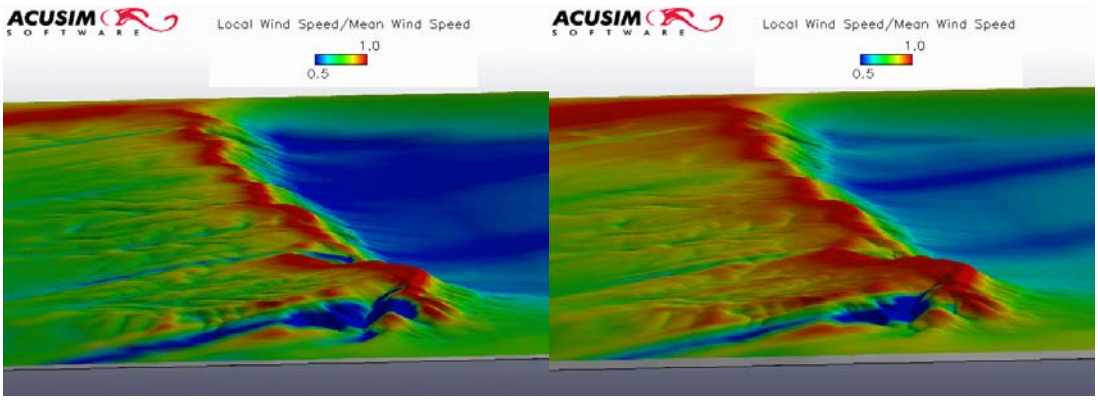


The steady state flow field was simulated using the Spalart-Allmaras turbulence model. A velocity profile was set at the inlet to the model based on a standard boundary layer profile under neutrally stable atmospheric conditions. The speed and direction of the flow was set based on the prevailing wind conditions at the site.

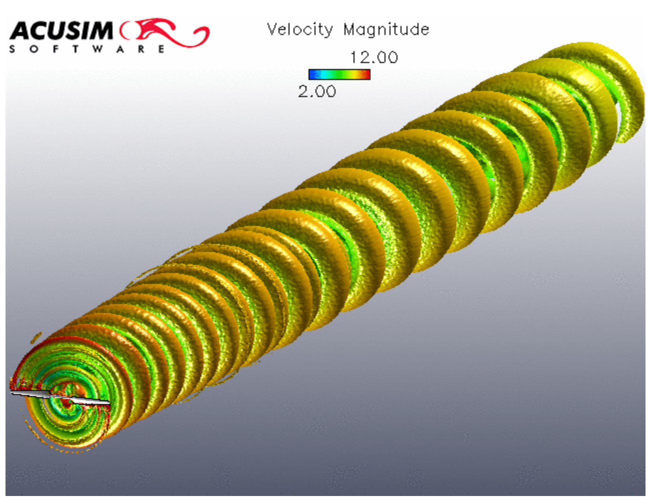
AcuSolve's efficient coupled solution algorithm converged the simulation to a steady state in 29 iterations. The following residual plot illustrates the convergence behavior of AcuSolve.



The 3-d CFD solution provides a detailed wind speed/direction map within the simulation domain. The local wind speed can be visualized in terms of a speed-up factor (local wind speed/mean wind speed). This quantity reveals high velocity regions that would be good candidates for wind turbines. The following images show the speed-up factors at different elevations above the terrain surface.



In addition to being a powerful tool for micro-siting applications, AcuSolve has been successfully used to simulate the propagation of wind turbine wakes. AcuSolve's non-diffusive numerical methods permit accurate calculation of wake aerodynamics. For example, the following image shows the wake behind a 2-bladed rotor that is visualized for the entire length of the simulation domain (a total of 12 diameters downstream of the turbine).



AcuSolve continues to prove its utility in the wind power arena by combining ease of use, speed, and accuracy to provide engineers with a highly capable CFD simulation tool.