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Wind modelling over complex terrain using CFD

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The present work deals with the numerical CFD modelling of onshore wind farms in the context of High Performance Computing (HPC). The CFD model involves the numerical solution of the Reynolds-Averaged Navier-Stokes (RANS) equations together with a κ-ε turbulence model and the energy equation, specially designed for Atmospheric Boundary Layer (ABL) flows. The aim is to predict the wind velocity distribution over complex terrain, using a model that includes meteorological data assimilation, thermal coupling, forested canopy and Coriolis effects.

The modelling strategy involves automatic mesh generation, terrain data assimilation and generation of boundary conditions for the inflow wind flow distribution up to the geostrophic height.

The CFD model has been implemented in Alya, a HPC multi physics parallel solver able to run with thousands of processors with an optimal scalability, developed in Barcelona Supercomputing Center. The implemented thermal stability and canopy physical model was developed by Sogachev in 2012.

The k-ε equations are of non-linear convection diffusion reaction type. The implemented numerical scheme consists on a stabilized finite element formulation based on the variational multiscale method, that is known to be stable for this kind of turbulence equations. We present a numerical formulation that stresses on the robustness of the solution method, tackling common problems that produce instability. The iterative strategy and linearization scheme is discussed. It intends to avoid the possibility of having negative values of diffusion during the iterative process, which may lead to divergence of the scheme. These problems are addressed by acting on the coefficients of the reaction and diffusion terms and on the turbulent variables themselves.

The k-ε equations are highly nonlinear. Complex terrain induces transient flow instabilities that may preclude the convergence of computer flow simulations based on steady state formulation of the fluid flow equations. A numerical strategy is discussed to obtain a steady solution with representative mean values of the wind velocity.

The CFD model is validated and tested against experimental measurements over wind farms obtained from industrial collaborators.