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Computational modelling of an operational wind turbine and validation with LIDAR

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We present a computationally efficient method to model the interaction of wind turbines with the surrounding flow, where the interaction provides information on the power generation of the turbine and the generated wake behind the turbine. The turbine representation is based on the principle of an actuator volume, whereby the energy extraction and balancing forces on the fluids are formulated as body forces which avoids the extremely high computational costs of boundary conditions and forces. Depending on the turbine information available, those forces can be derived either from published turbine performance specifications or from their rotor and blade design. This turbine representation is then coupled to a Computational Fluid Dynamics package, in this case the hr-adaptive Finite-Element code Fluidity from Imperial College, London.

Here we present a simulation of an operational 950kW NEG Micon NM54 wind turbine installed in the west of Scotland. The calculated wind is compared with LIDAR measurements using a Galion LIDAR from SgurrEnergy.

The computational domain extends over an area of 6km by 6km and a height of 750m, centred on the turbine. The lower boundary includes the orography of the terrain and surface roughness values representing the vegetation – some forested areas and some grassland. The boundary conditions on the sides are relaxed Dirichlet conditions, relaxed to an observed prevailing wind speed and direction.

Within instrumental errors and model limitations, the overall flow field in general and the wake behind the turbine in particular, show a very high degree of agreement, demonstrating the validity and value of this approach.

The computational costs of this approach are such that it is possible to extend this single-turbine example to a full wind farm, as the number of required mesh nodes is given by the domain and then increases only linearly with the number of turbines