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Wind Resource Assessment in Complex Terrain with a High-Resolution Numerical Weather Prediction Model

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A crucial step in planning new wind farms is the estimation of the amount of wind energy that can be harvested in possible target sites. Wind resource assessment traditionally entails deployment of masts equipped for wind speed measurements at several heights for a reasonably long period of time. Simplified linear models of atmospheric flow are then used for a spatial extrapolation of point measurements to a wide area. While linear models have been successfully applied in the wind resource assessment in plains and offshore, their reliability in complex terrain is generally poor. This represents a major limitation to wind resource assessment in Austria, where high-altitude locations are being considered for new plant sites, given the higher frequency of sustained winds at such sites. The limitations of linear models stem from two key assumptions in their formulation, the neutral stratification and attached boundary-layer flow, both of which often break down in complex terrain. Consequently, an accurate modeling of near-surface flow over mountains requires the adoption of a NWP model with high horizontal and vertical resolution.

This study explores the wind potential of a site in Styria in the North-Eastern Alps. The WRF model is used for simulations with a maximum horizontal resolution of 800 m. Three nested computational domains are defined, with the innermost one encompassing a stretch of the relatively broad Enns Valley, flanked by the main crest of the Alps in the south and the Nördliche Kalkalpen of similar height in the north. In addition to the simulation results, we use data from fourteen 10-m wind measurement sites (of which 7 are located within valleys and 5 near mountain tops) and from 2 masts with anemometers at several heights (at hillside locations) in an area of 1600 km2 around the target site.

The potential for wind energy production is assessed using the mean wind speed and turbulence intensity at hub height. The capacity factor is also evaluated, considering the frequency of wind speed between cut-in and cut-out speed and of winds with a low vertical velocity component only. Wind turbines do not turn on at wind speeds below cut-in speed. Wind turbines are taken off from the generator in the case of wind speeds higher than cut-out speed and inclination angles of the wind vector greater than 8o. All of these parameters were computed at each model grid point in the innermost domain in order to map their spatial variability. The results show that in complex terrain the annual mean wind speed at hub height is not sufficient to predict the capacity factor of a turbine; vertical wind speed and the frequency of horizontal wind speed out of the range of cut-in and cut-out speed contribute substantially to a reduction of the energy harvest and locally high turbulence may considerably raise the building costs.