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Variability of the vertical profile of wind speed: characterization at various time scales and analytical approximation

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Wind measurements are key for the wind resource assessment. But as wind turbines get higher, wind measurement masts are often lower than the future wind turbine hub height. Therefore one of the first steps in the energy yield assessment is the vertical extrapolation of wind measurements. Such extrapolation is often done by approximating the vertical profile of wind speed with an analytical expression: either a logarithmic law which has a theoretical basis in Monin-Obukhov similarity theory; or a power law which is empirical. The present study analyzes the variability of the wind profile and how this variability affects the results of the vertical extrapolation methods.
The study is conducted with data from the SIRTA observatory, 20km south of Paris (France). A large set of instrumentation is available, including sonic anemometers at 10 and 30 meters, a LIDAR measuring wind speeds from 40 to 200 meters and a SODAR measuring wind speeds starting from 100m up to 1km. The comparison between the instruments enables to characterize the measurements uncertainties. The observations show that close to the ground the wind is stronger during daytime and weaker at night while higher, around 150 m, the wind is weaker during daytime and stronger at night. Indeed the wind shear has a pronounced diurnal cycle.
The vertical extrapolation methods currently used in the industry do not usually take into account the strong variability of the wind profile. The often fit the parameters of the extrapolation law, not on each time step, but on time-averaged profiles. The averaging period may be the whole measurement period or some part of it: there may be one constant parameter computed on the wind profile that was averaged on the whole year of measures, or the year of measures may be divided into a small number of cases (for example into night or daytime data, or into 4 seasons) and the parameter is adjusted for each case. The study analyzes thoroughly the errors generated by both extrapolation laws, and how the error decreases when dividing the data according to several conditions: the time of day, the months and the wind direction.