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Wind Gusts at Heights of Wind Turbines

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The increasing trend in the size of wind turbines has revised the needs for turbulence and wind gust data. While the hub heights can reach up to 100 m or more, the blade diameters can also be as large as 100 meters. Therefore, it is not enough to study gusts at a single height, but information on the vertical profile of gusts is also needed. Here, we define a gust, following WMO practices, as a maximum of average wind speeds of short duration during a longer time interval. Typically, at synoptic weather stations a 3 s gust is recorded during each 10 minute interval, and in climatological studies, hourly gusts are often used instead.

In this study, we analysed long time series of high-resolution wind data from a 100-m-high meteorological tower located on flat grassland in Høvsøre, close to the western coast of Denmark. We excluded cases of weak winds (less than 5 m s-1) as during such conditions the gusts vary the most relative to the mean wind speed and weak winds are not as important in wind energy production. The data covers various stability conditions. We further compare the Høvsøre results with those from two coastal/archipelago sites in the Baltic Sea with different surface conditions, and evaluate which features of gusts are related to observation practices (gust duration / averaging period length), surface roughness, height above the surface and, above all, meteorological conditions.

In meteorological applications gusts are often considered together with the mean wind speed using the concept of a gust factor, which is the ratio of gust wind speed to the mean wind speed. In engineering applications, gusts are more often related to the standard deviation of wind speed rather than to the mean wind speed. A peak factor describes the ratio of the maximum deviation (gust wind speed - mean wind speed) and the standard deviation. We combined these two approaches to derive a new gust parametrization, and have applied it to heights relevant for wind energy using the mast observations. The new parametrization makes use of the surface friction velocity, Obukhov length, height above the surface, and the boundary-layer height and provides a height-dependent estimate for the gust. Further, using observations, we compared the method with two earlier methods originally developed for the surface layer with reference height of 10 metres. It was found that the new method outperformed the two older methods: the effects of surface roughness, stability and the height above surface were well represented by the new method.