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A new spectrum model for the atmospheric crosswind component applicable from mesoscales to microscales

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A crosswind spectrum model $S_v(f)$ is proposed that covers both the meso and the microscale, ranging in frequency $1/5 \text{ day}^{-1}$ to the turbulence inertial subrange. The purpose is to improve the calculation of flow meandering effect over areas of the sizes of offshore wind farms and clusters.

The development is based on measurement (from Høvsøre) analysis over this broad frequency range for cases where wind direction does not change much during a day. The model reads:

$$\begin{aligned} fS_v(f) &= \text{Boundary-layer model} && \text{for } f > f_1, \\ &= \text{Constant} && \text{for } f_2 < f < f_1, \\ &= a_1 f^{-2/3} + a_2 f^{-2} && \text{for } f < f_2 \end{aligned}$$

Here, the frequency range f_2 to f_1 defines the gap region, and the constant in this subrange is determined by the spectra on both sides of this range; the boundary-layer model used here is either the Kaimal model or the Mikkelsen-Tchen model; a_1 and a_2 are climatological coefficients. The credibility of the model is evaluated against with measurements from another wind test site Østerild, with measurements ranging in height from surface layer to a height of 241 m.

The model is used together with a similar model for the longitudinal wind component u to obtain time series $u(t)$ and $v(t)$, from which direction statistics are obtained and compared with those from measurements. It was found that the boundary-layer models could only describe stationary time series for wind vectors. The new v-spectral model improves significantly the statistics of wind direction variation over scales that correspond to offshore wind farms and clusters.