Full-Scale Spectrum of Boundary-Layer Winds

Extensive mean meteorological data and high frequency sonic anemometer data from two sites in Denmark, one coastal onshore and one offshore, have been used to study the full-scale spectrum of boundary-layer winds, over frequencies $f$ from about 1 yr$^{-1}$ to 10 Hz. 10-min cup anemometer data are used to estimate the spectrum from about 1 yr$^{-1}$ to 0.05 min$^{-1}$; in addition, using 20-Hz sonic anemometer data, an ensemble of 1-day spectra covering the range 1 day$^{-1}$ to 10 Hz has been calculated. The overlapping region in these two measured spectra is in good agreement. Classical topics regarding the various spectral ranges, including the spectral gap, are revisited. Following the seasonal peak at 1 yr$^{-1}$, the frequency spectrum $S(f)$ increases with $f + 1$ and gradually reaches a peak at about 0.2 day$^{-1}$. From this peak to about 1 hr$^{-1}$, the spectrum $S(f)$ decreases with frequency with a $-2$ slope, followed by a $-2/3$ slope, which can be described by $S(f) = a_1 f^{-2/3} + a_2 f^{-2}$, ending in the frequency range for which the debate on the spectral gap is ongoing. It is shown here that the spectral gap exists and can be modelled. The linear composition of the horizontal wind variation from the mesoscale and microscale gives the observed spectrum in the gap range, leading to a suggestion that mesoscale and microscale processes are uncorrelated. Depending on the relative strength of the two processes, the gap may be deep or shallow, visible or invisible. Generally, the depth of the gap decreases with height. In the low frequency region of the gap, the mesoscale spectrum shows a two-dimensional isotropic nature; in the high frequency region, the classical three-dimensional boundary-layer turbulence is evident. We also provide the cospectrum of the horizontal and vertical components, and the power spectra of the three velocity components over a wide range from 1 day$^{-1}$ to 10 Hz, which is useful in determining the necessary sample duration when measuring turbulence statistics in the boundary layer.