Wake meandering

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Meandering refers to the unsteady behaviour of the wind turbine wake that is characterised by random oscillation of the wake position in the horizontal plane. Although the phenomenon has been studied theoretically [1] and captured in field campaigns [2] and wind tunnel experiments [3], the source and effects of meandering are not fully understood and is a hot topic of today's research. In addition to higher frequency signatures as e.g. caused by periodic vortex shedding, also larger-scale turbulent eddies contained in the atmospheric boundary layer play an important role. These were included in the investigations during the Wind Turbine Wake Experiment in Wieringermeer (WINTWEX-W).

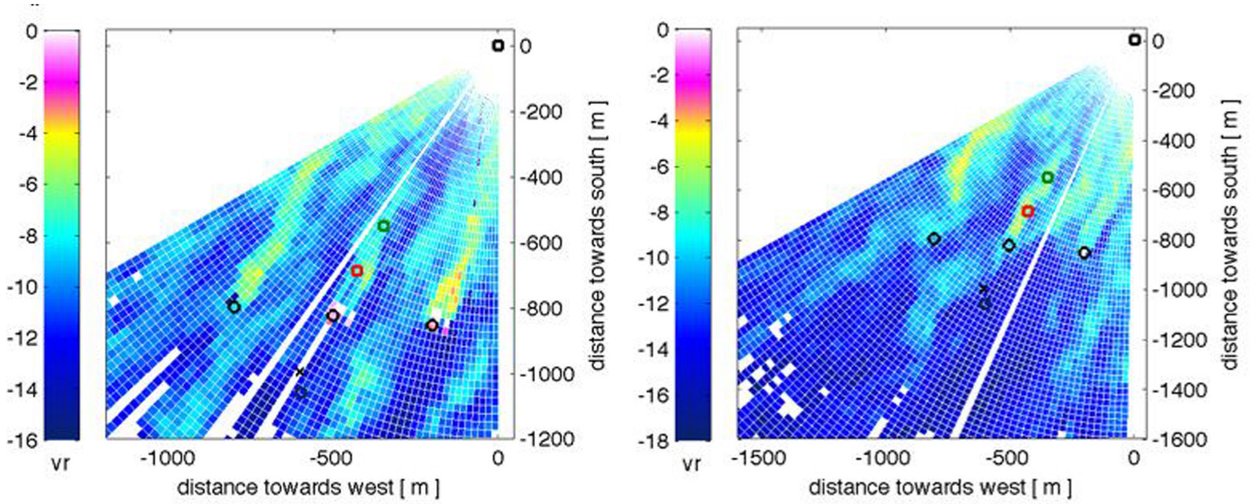

Figure 1: PPI scans on November 1st, 2013 with 4° (left) and 7° (right) elevation. Black circles locate the research turbines and, the black cross the met mast and the coloured squares the three Windcubes v1.

The random wavelike structures of meandering could be captured in LiDAR scans performed during WINTWEX-W and can be seen in Figure 1. The figure shows "small" displacements for three wakes of a research turbine row. In addition we can see wakes with longer wavelengths and amplitudes from upstream prototype turbines at ECN's wind turbine test facilities in Wieringermeer.

Exposing downstream turbines to a steady change between wake and wake-free conditions, meandering is clearly a challenge for wind park operations. These unsteady wind and turbulence conditions lead to unequal loads along the rotor disk and with that to an increase of fatigue. Additionally wakes of upstream turbines can interact with wakes of turbines positioned further downstream. Such multiple wake effects are rather complex and can even increase the power losses predicted by simpler wake models.

Another challenge, especially for offshore floating systems, could be that meandering can have a frequency signature, which is close to eigenfrequencies of the floating structure. The frequency-weighted power spectra obtained from three

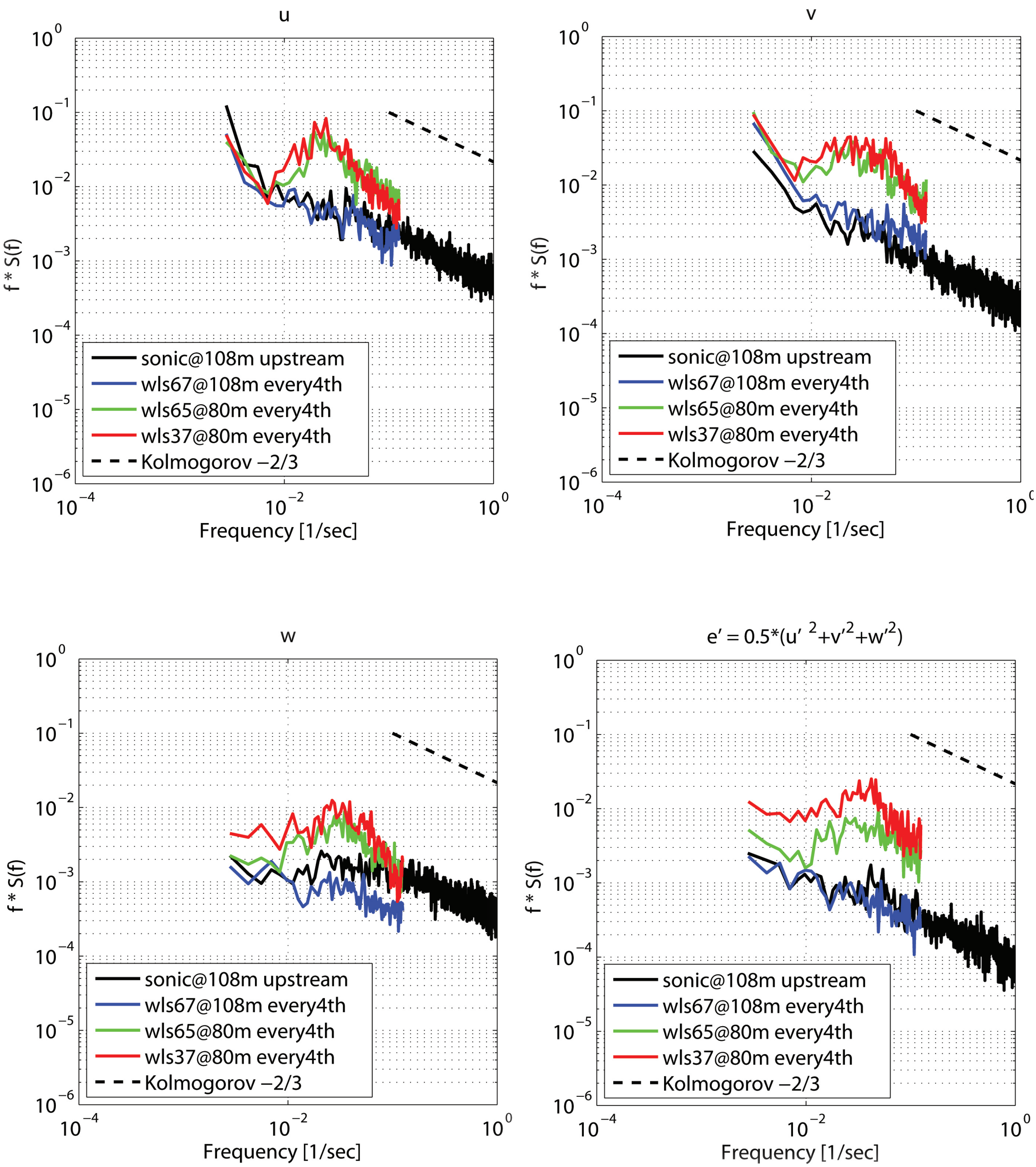

Figure 2: Frequency weighted spectral energy density plots of the three wind components and the turbulent kinetic energy. Colours denote the upstream Windcube in blue and the sonic anemometer in black, and the downstream Windcubes in green and red. The dashed line indicates the Kolmogorov slope.

Windcubes v1 (one upstream, two downstream) in Wieringermeer show enhanced wind speed fluctuations downstream of one research turbine for frequencies of around 0.03 Hz (Figure 2).

If we normalise this frequency signal by the ratio between the rotor diameter D and the average upstream wind speed u_{mean} (fD/u_{mean}=0.48) we find a very good agreement to the frequency signal (fD/u_{mean}=0.5) obtained in wind speed and wake position time series collected in wind tunnel experiments by Muller et al [4]. They found significant correlations between upstream transversal velocities and wake positions. Moreover, they also found significant correlations between the wake position and the lateral force as well as the yaw torque of downstream turbines.

These correlations highlight again the importance of a better understanding of meandering and the need for improvements in wind turbine and wind park control systems. In our future work we will focus on the stability dependency of the frequency signature related to meandering.

References:

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