Author's response to Anonymous Referee #1:

The authors thank the referee very much for the time and effort to review our manuscript and for the valuable comments. Please find our responses below. The original comments are stated in **bold** while our responses follow in plain text. Thank you very much.

Major comments:

P3, l10-11, Eq 5 : a space average is applied to the incoming flow measurements, arguing that "This approach is more appropriate to describe the wind speed affecting the rotor than a single point measurement". Please elaborate your argumentation.
There are two reasons to use the space averaged wind speed to describe the inflow conditions at the rotor's position.

1. Due to the rotor's rotation, the turbine is affected by the whole wind field across the rotor swept area. A single point measurement might therefore not capture important flow characteristics affecting the rotor on other positions within the rotor swept area. In numerous recent studies a rotor effective wind speed for inflow descriptions and advanced control strategies is used to capture the actual wind speed affecting the rotor [1, 2].
   Based on the data of the three hot wires, we investigated whether the space averaging shows different increment statistics compared to the single point measurements. As Fig. 1 of this reply shows, there is no significant difference regarding the intermittency of the increment PDF. The small deviations, especially of the center hot wire u_1, might be explained by the second reason for the space averaging, given below.

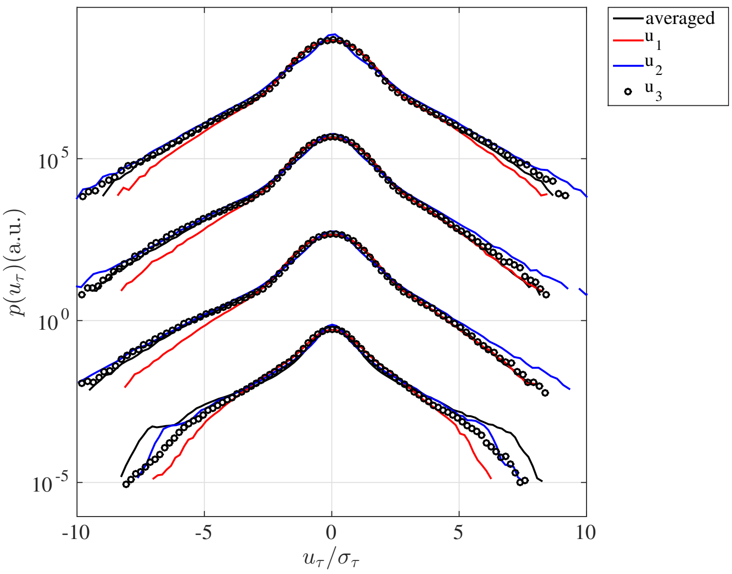

Figure 1: $p(u_\tau)$ for the three single point measurements and the respective space average.

2. As described by Reinke et al. [3] in detail, the active grid is made of numerous square metal flaps that are connected by joints equipped with streamlined support structures. Therefore, a single point measurement behind a joint is not as much affected by the movement of the flaps compared to a position behind a flap. Please refer to [3] for details. However, Fig. 1 shows that the intermittent character of the inflow is obvious for all single point measurements as well as the space average. Still, we believe that for inflow characterization a space averaging gives a more appropriate description of the flow affecting the whole rotor.

We clarified this aspect in the revised manuscript as follows:

Following the concept of a rotor effective wind speed used in [2], this approach is more appropriate to describe the wind speed affecting the rotor than a single point measurement. It should be noted that our results are hardly effected by using averaged measurements as opposed to data of the central hot wire. The distance...

If this approach is more appropriate, why is it not used in the following part of the study?

For inflow characterization we used space averaged data for reasons mentioned above. When comparing turbine data to wind speed data, single point hot wire measurements in front of the turbine were used so that *simultaneously* recorded data can be compared. As we mentioned above there is not a big difference between using averaged and non averaged wind speed. There is definitely another aspect, that each hot wire in front of the turbine will create a small perturbation of the inflow, especially when mounting multiple wire in one plane. Thus we prefer to work only with one hot wire for this comparison.

please show PSD for all signals and discuss them.
Please find the PSDs of the remaining three signals in the figures below. The PSD of the power data, Fig. 2 of this reply, clearly shows the mean rotational speed of the turbine, $\langle\omega\rangle \approx 25.2\,\mathrm{Hz}$, and the harmonics. Also the PSD of the thrust data (Fig. 3 of this reply) shows the rotation frequency along the the harmonics, although not as clearly as for the power data. More striking are the multiple peaks that we associate with the vibrations of the whole setup including the turbine and the support structures with ground mountings. We do not believe that adding all PSDs to the manuscript will improve quality and readability. We showed the PSD of the hot wire data because the filtered signal is the basis of the approach described in section 3.2. An explanation of the regular drops of the torque-PSD in given in the following aspect.

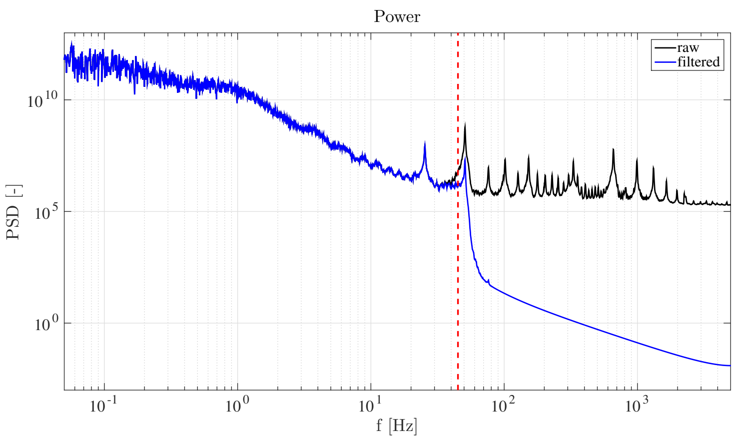

Figure 2: Power spectral density (PSD) of the intermittent power time series, raw (black) and filtered (blue).

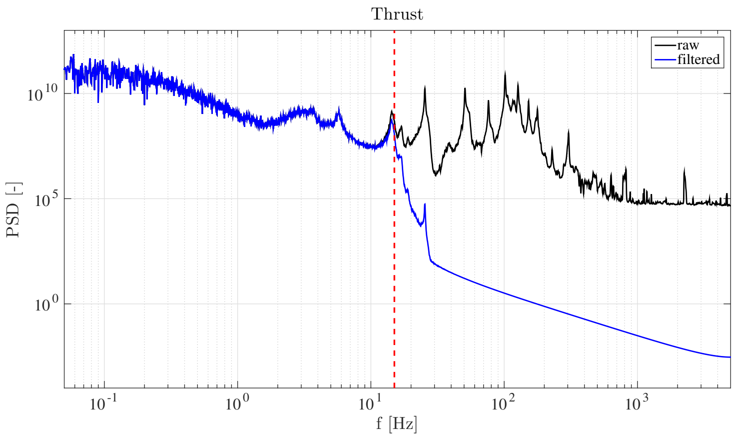

Figure 3: PSD for thrust data.

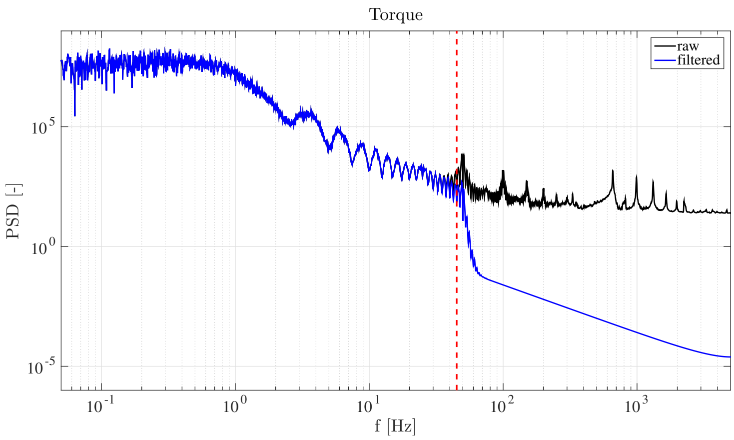

Figure 4: PSD for torque data.

Fig 5 : the coherence functions for power and torque are not continuous, but show regular peaks. Why? Don't we expect continuous functions? Please elaborate an explanation.

The coherence function of power and torque show regular drops at multiples of 2.5 Hz. Both the power and torque depend on the electric current in the circuit, please see equations (6) and (8) in the manuscript. The same drops at multiples of 2.5Hz in the PSD can be found in the PSD of the torque data, see Figure 4 and therewith in the current data itself. The reason for this is a moving average function implemented in the control algorithm of the turbine controller. In Figure 5 we show the PSD of the voltage U_{FET} applied to the field effect transistor for controlling the electrical load.

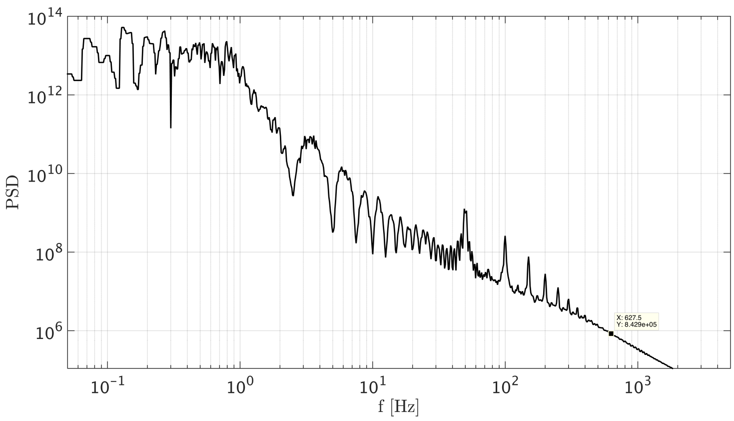

Figure 5: PSD of the voltage signal applied to the field effect transistor, U_{FET} (extract of 1E6 samples).

The update rate of 50Hz shows up in the PSD along with the same drops at multiples of 2.5Hz as in the PSD of the electric current. The tip speed ratio is the controller input, which is smoothed using a moving average filter of 20 samples before being passed to a PI controller within the 50Hz control loop, resulting in the regular drops at multiples of 50Hz/20 = 2.5Hz. To further show, Figure 6 shows the PSD of laboratory turbulence data (hot wire data, sampled at 8kHz) used in [4]. The raw data (black) and the same data set smoothed by a 100 samples moving average filter (red) are shown. As can be seen, periodic drops at multiples 8000Hz/100 = 80Hz in the PSD are the result of the moving average filter. Due to the definition of the magnitude coherence squared (eq. 10 in the manuscript, see [5] for details.), the drops in the PSD are found in the coherence as well.

It should be stressed that this is a pure signal problem but does not change in principle our findings of this paper. To clarify this point we added the following explanation to the caption of Fig. 5 of the manuscript:

Magnitude-squared coherence of filtered hot wire data and thrust (a) as well as power and torque (b) respectively. 500 Hanning windows with 50 % overlap were used here, as suggested by [5].Graph (b) shows regular drops of γ^2 which are caused by a filter function within the control algorithm of the model turbine. As the controller affects the electric circuit, there is a direct connects to the electric current and therewith to the power and torque. Consequently, the effect of the filter is clearly visible in this graph.

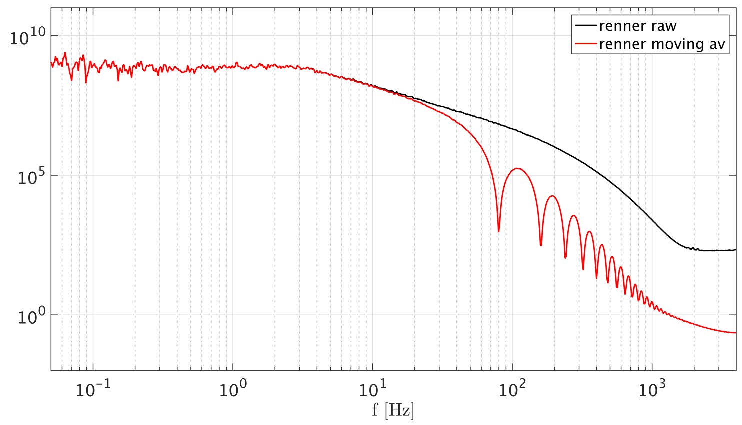

Figure 6: PSD of laboratory turbulence data used in [4] based on raw (black) and smoothed (red) hot wire data.

Wind turbine data sets are low-pass filtered with a cut-off frequency of 15Hz for thrust and 45Hz for power and torque data. These cut-off frequencies are very close to the frequencies related to the time scales of interest, 13 and 40Hz.One can therefore expect that the signal distortion due to filtering (magnitude damping and phase shift) affects the wind turbine signals at the frequencies of interest, and so their unsteady properties, including intermittency. In other words, how confident can one be in the increment PDFs obtained for the thrust with tau = 0.067s, whereas the signal is lowpass filtered at 15Hz; and for the power and torque with tau = 0.025s, whereas the signals are low-pass filtered at 45Hz?

The reason for filtering the data is the presence of noise disturbances as described in Section 3.2. Therefore, the data is not really suitable for testing the effect of shifting the filter frequency and/or the time scale analyzed since it is not possible to distinguish the effect of the filter from the effect resulting from the noise. Because of that we use laboratory turbulence used by Renner et al. [4]. Figure 7 shows the PSD, which does not show any noise peaks which allows us do isolate the effect of low pass filters on the increment PDF.

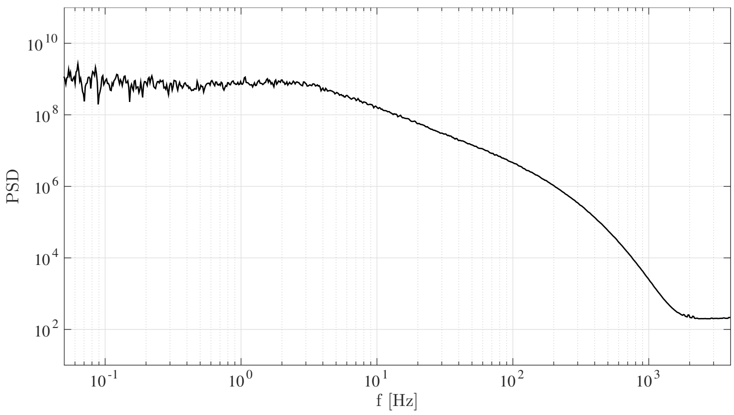

Figure 7: PSD for the lab data used in [4].

We fix the time scale to $\tau = 0.01\,\mathrm{s}$, which corresponds to a frequency of 100 Hz. We use the same 6th order butterworth low pass filter as in our study to filter the turbulence data exacly at 100Hz (corresponding to the time scale τ) as well as at larger (120Hz) and smaller frequencies (80Hz). Figure 8 shows the increment PDF for the raw data and the filtered version. The same approach is carried out for filter frequencies closer to 100Hz, being 98Hz and 102 Hz, please see Figure 9.

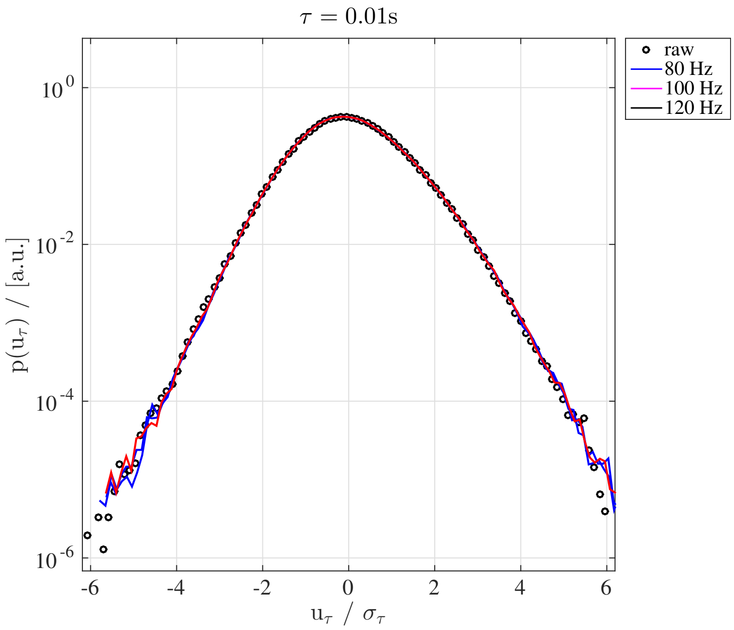

Figure 8: Fixed $\tau = 0.01\,s$, butterworth low pass filter at the frequencies shown in legend.

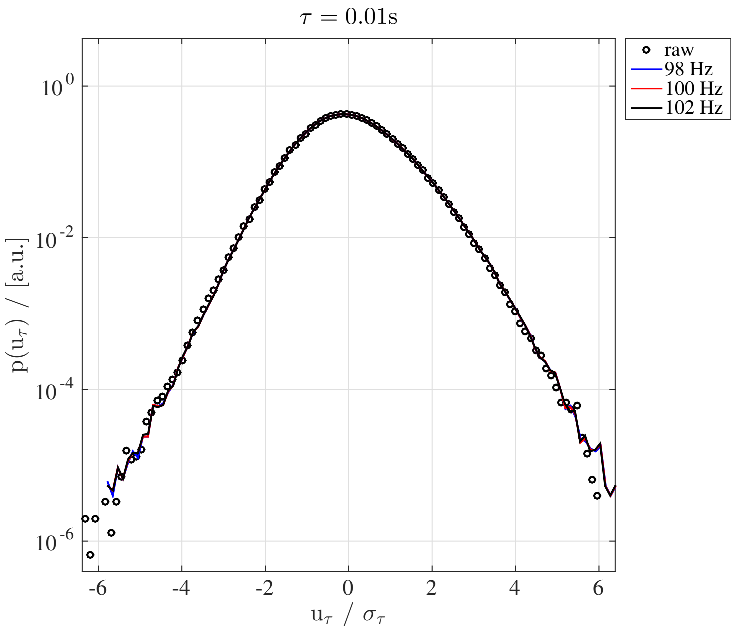

Figure 9: Fixed $\tau = 0.01\,s$, butterworth low pass filter at the frequencies shown in legend.

Herewith we show that the low pass filter does not change the shape of the increment PDF the lab turbulence. As the magnitude is damped by the filter in frequency space and we consider distributions *normalized* to the standard deviation of the increment time series (cf. Section 2 of the manuscript), the shape of the distribution is not significantly affected.
To clarify, we added the following text to the revised manuscript (p. 17. lines 12 ff.):
...a cutoff frequency of 15 Hz *was chosen in order to include a scale between the rotor diameter and the blade length. From the analysis of other intermittent data, it can be shown that our filtering used here is not effecting the intermittency effects in an significant way. Thus, the filtering only suppresses noise effects.*

Minor comments:

if I compute the frequency related to the time scale 0.08s, I obtain 12 instead of 13Hz.
$1/0.08\,\mathrm{s} = 12.5\,\mathrm{Hz}$. This will be corrected in the updated manuscript.

Fig. 11: use solid lines for the inflow for both plots.

When showing increment PDF throughout this paper, lines were used for wind speed data and symbols for turbine data. To distinguish between Gaussian and intermittent wind speed data, solid lines were used for intermittent and dashed lines for Gaussian data as in p5,Fig.1, p13,Fig.9, p14,Fig.10. Therefore, we would rather not change the line style in Fig.11 for consistency, although Fig. 11(a) shows only one type of inflow. We think that the shape of the distribution is clearly visible.

We agree with all other minor comments and will correct them in the updated manuscript.

References

[1] Soltani, M. N., Knudsen, T., Svenstrup, M., Wisniewski, R., Brath, P., Ortega, R., and Johnson, K., "Estimation of rotor effective wind speed: A comparison," *IEEE Transactions on Control Systems Technology*, Vol. 21, No. 4, 2013, pp. 1155–1167.

[2] Schlipf, D., Schlipf, D. J., and Kühn, M., "Nonlinear model predictive control of wind turbines using LIDAR," *Wind Energy*, Vol. 16, No. 7, oct 2013, pp. 1107–1129.

[3] Reinke, N., Homeyer, T., Hölling, M., and Peinke, J., "Flow Modulation by an Active Grid," *Experiments in Fluids*, 2016, submitted.

[4] Renner, C., Peinke, J., and Friedrich, R., "Experimental indications for Markov properties of small-scale turbulence," *Journal of Fluid Mechanics*, Vol. 433, 2001, pp. 383–409.

[5] Carter, G. C., Knapp, C. H., and Nuttall, A. H., "Estimation of the Magnitude-Squared Coherence Function Via Overlapped Fast Fourier Transform Processing," *IEEE Transactions on Audio and Electroacoustics*, Vol. 21, No. 4, 1973, pp. 337–344.