Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2016-401-AC2, 2017

Atmospheric Measurement Techniques Discussions

Interactive comment on "Novel approaches to estimating turbulent kinetic energy dissipation rate from low and moderate resolution velocity fluctuation time series" *by* Marta Wacławczyk et al.

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Received and published: 6 June 2017

We would like to thank the Referee for the comments and suggestions. Below, we reply and discuss the issues raised up by the Referee and present the planned amendments of the manuscript.

1. *They do not perform a sensitivity study on the choice of dissipation range model. They use a specific exponential model from Pope (2000), but if they had read the discussion in that reference, they would have noted that Pope does not consider that model to be accurate. And as the authors point out, the dissipation range*

Fig. 1. Functions $E_{11}(k_1)$ and $k_1^2 E_{11}(k_1)$ calculated for the measured signal (black line), exponential f_η (dot-dashed blue line), Pope spectrum (dashed magenta line).

spectrum has a significant effect on the number of zero crossings.

In the cited reference [Pope, 2000] three different forms for the function f_η were considered, the exponential, the Pao and an improved form, which will be further referred to as the "Pope spectrum", see Eqs. (6.248), (6.249), (6.254) therein. All the three forms of the dissipative spectra integrate to ϵ i.e. they satisfy the requirement $\epsilon = 2\nu \int k^2 E(k) k$. According to the analysis of experimental data, the Pope spectrum provides the best fit in the dissipative range [Pope 2000].

In the revised manuscript we will compare results with both the exponential and the Pope forms of function f_η. We will show that the obtained ϵ estimates are very close to each other. To explain this we first note that in the proposed model (Eq. [22] in the manuscript) only the integral of the dissipative spectrum $k_1^2 E_{11}(k_1)$ is present. The spectral cut-off of the data considered in our work ($5Hz$) is in the inertial range, where $k_1^2 E_{11}(k_1)$ with both forms of f_η functions are almost indistinguishable, see the attached figures (dashed magenta lines are for the Pope spectrum, dot-dashed blue lines for exponential f_η). At the same time integrals of the remaining (recovered) parts of $k_1^2 E_{11}(k_1)$ are almost equal (as both dissipative spectra $2\nu k^2 E(k)$ integrate to ϵ). As a result, for the given spectral cut-off the ϵ estimates are almost the same, independently of the form of the f_η function. This might change for larger cut-off frequencies. We expect that in case the cut-off frequency is placed in a region influenced by the form of f_η function, the Pope spectrum will provide better estimates of the TKE dissipation rate. We will include the new results and the above discussion in the revised manuscript.

2. *Furthermore, they do not address practical issues inherent in digital signal processing: spectral bias due to finite temporal windows, aliasing due to temporal*

sampling, as well as sensor bias and noise. It seems that these artefacts might have a significant impact on a zero- crossing method. For example, it is not hard to see how sensor bias and noise, could significantly impact zero crossings, especially for low SNR data.

As suggested by the Referee we performed simulation analysis, [Frehlich et al. (2001), Sharman et al. (2014)], in order to address the issues of the influence of finite temporal windows and aliasing on ϵ estimates. In the revised manuscript we will present and discuss the obtained results. As far as the sensor bias is concerned, in fact both the variance of the noise as well as variance of its derivative influence the measured number of crossings. This issue was studied in detail by Sreenivasan et al. (1983), hence, we did not discussed it in the manuscript. Moreover, Poggi & Katul (2010) suggested to use the threshold- instead of the zero-crossings in case of low SNR signals. In our application the noise influences largely the higher frequencies (above $5Hz$) which are removed by the low-pass filter used in the proposed number of crossings method. Moreover, use of the threshold- instead of zero-crossings did not lead to any systematic change of our estimates. In the revised manuscript we will include a discussion concerning the sensor bias, referring to the two mentioned papers.

3. *So, they need to address the question of why one would want to use their method over more standard approaches (unless of course, one had data with significant content in the dissipation range), and how their method is susceptible/tolerant to signal processing artifacts. I feel strongly that they need to perform a simulation analysis to answer these questions in a statistical sense (see for example, Frehlich, et al. JAM 2001).*

Based on the results of the performed simulation analysis we will argue that the number of crossing method has certain advantages over standard methods. We created sets of artificial velocity signals with a prescribed form of the energy spectrum [Frehlich et al. (2001), Sharman et al. (2014)]. At least for these artificial

velocity signals, the obtained ϵ values were less sensitive to the aliasing error than the estimates from the power spectral method. Moreover, the bias due to the finite temporal windows was smaller for the number of crossing method, however, on the cost of larger uncertainty (larger standard deviations) of the estimated dissipation rate values.

These differences in errors of the number of crossing and the power spectral method can make the former an additional tool to improve ϵ estimates from the atmospheric measurements.

Moreover, we argue that the number of crossings method applied to the fully-resolved signals has become a fairly standard tool for ϵ estimates, used also in the atmospheric measurements, see e.g. Poggi & Katul (2010). Therein, the discussed advantages of the method are that no gradient measurements are required (to estimate the Taylor microscale λ), no assumptions about scaling laws in structure functions (and power spectra) are needed and no simplifications in the TKE budget are adopted (for which ϵ is computed as residual). The method proposed in the current manuscript, in particular, the second approach based on the recovered part of the spectrum, generalises number of crossing method and makes it applicable also for signals with spectral cut-off. Off course, an additional cost is that certain form of the energy spectrum must be assumed. The method can be interesting in particular for data with cut-offs reaching the dissipation range, but still with part of this range missing (or contaminated with noise). In such case, using only the inertial-range estimates may lead to a significant loss of information, as the data from the dissipation range are not taken into account.

References

Frehlich, R., Cornman, L., and Sharman R.: Simulation of Three-Dimensional Turbulent Velocity Fields, Journal of Applied Meteorology, 40, 246-258, 2001.

Poggi, D. and Katul, G. G.: Evaluation of the Turbulent Kinetic Energy Dissipation Rate Inside Canopies by Zero- and Level-Crossing Density Methods, Boundary-Layer Meteorol., 136, 219–233, 2010

Pope, S. B. , *Turbulent flows*, Cambridge, 2000.

Sharman, R. D., Cornman, L. B., Meymaris, G., Pearson, J. P., and Farrar, T.: Description and Derived Climatologies of Automated In Situ Eddy-Dissipation-Rate Reports of Atmospheric Turbulence, Journal of Applied Meteorology and Climatology, 53, 1416-1432.

Sreenivasan, K., Prabhu, A. and Narasimha, R.: Zero-crossings in turbulent signals, Journal of Fluid Mechanics, 137, 251–272, 1983.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-401, 2017.

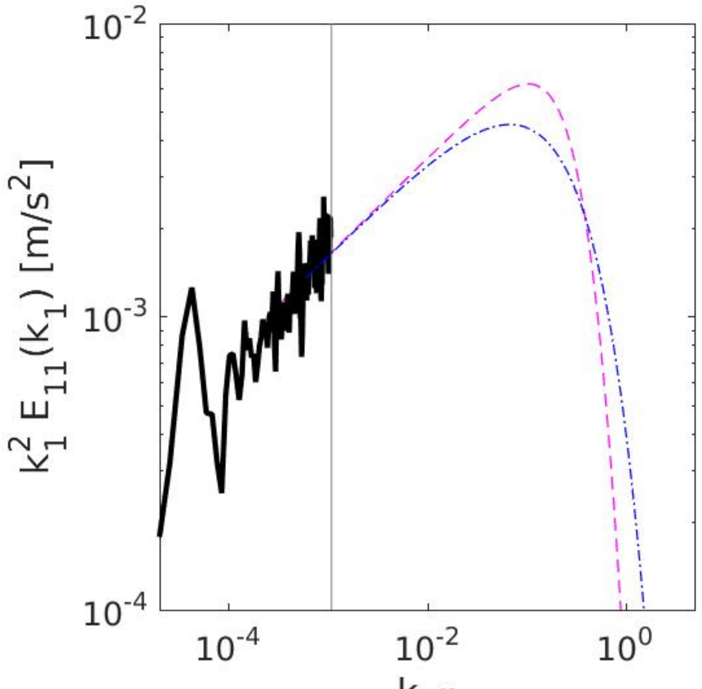

Fig. 2.

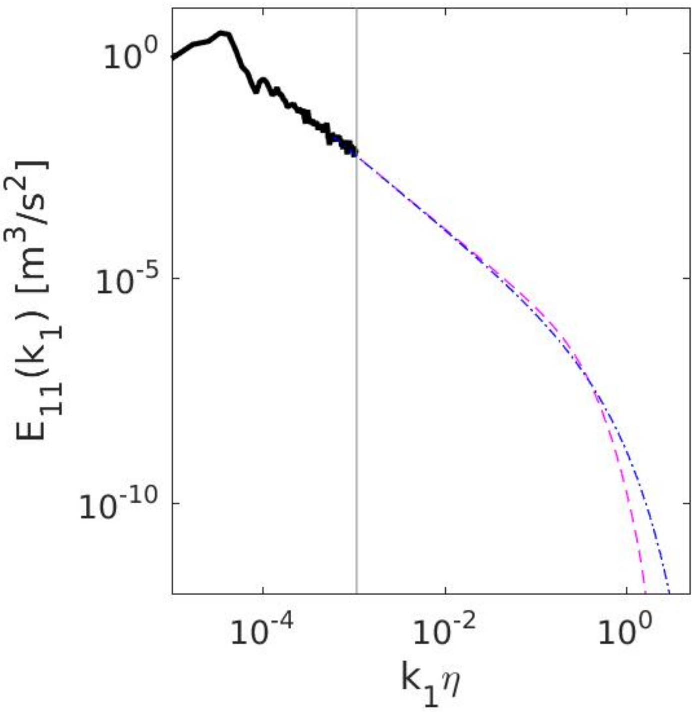

Fig. 3.