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Atmospheric Measurement Techniques Discussions
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Interactive comment on "Flux calculation of short turbulent events – comparison of three methods" *by* Carsten Schaller et al.

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Answer to Anonymous Referee 2

We thank the reviewer for his constructive comments and will revise the manuscript accordingly.

1) We will include in the manuscript the explicit form of the applied mother wavelets.

2) Thank you for this important comment. We were aware of this problem, but assumed that for the Mexican Hat wavelet, which is capable of detecting events very accurately in the time domain, for a period of about 32 minutes a dilation scale of 8 minutes is enough. We agree with the reviewer that an exact comparison with the Morlet wavelet (period 34 min, scale 32 min) is not possible. This is not relevant for

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Discussion paper

our purpose, i.e. the detection of turbulent events and the calculation of fluxes with a time resolution of about 1 minute, but for the comparison shown in Figs. 2 – 5 this may have an influence. Therefore we followed the reviewer's recommendation and multiplied the scale of the Morlet wavelet by a factor of three to have a similar frequency band for both wavelets. To do so, we first calculated the 1-minute and the 30-minute averaged fluxes, focusing on the time period from 19 July 18:00 to 07. August 11:00. Within this test period, we found minor but systematic differences between the original Morlet fluxes (i.e. calculated as described in the first manuscript version) and the modified Morlet fluxes (i.e. using a Morlet period multiplied by 3, as suggested by the reviewer). This differences were identical for both 10-minute and 30-minute averaging periods, and resulted in shifts of 0.004 nmol mol^{-1} m s^{-1} for the median and 0.007 nmol mol^{-1} m s^{-1} for the mean flux value. This difference is significant (Wilcoxon signed rank test), but amounts to just about 1 % of the typical flux rate, therefore stays within the uncertainty range of the observed fluxes. We have not revised Figs. 2 and 3, but discussed the problem in the text. The comparison for the steady-state case shown in Fig. 4 for 23 July 13:00 – 17:00 provides an interesting example on the effect of the wavelet method setup on calculated fluxes. We have executed three different calculation versions, using the following setup:

1. Case A: Morlet wavelet as used in the original paper
2. Case B: Morlet wavelet with a period multiplied by 3
3. Case C: Morlet and Mexican wavelet, each with a reduced window and identical scale range of 1.4 to 8.1 min (additional test case, as recommended by the reviewer). This scale range refers to a Morlet period of 1.4 to 8.4 min and a Mexican hat period of 5.7 to 32.3 min.

Results for this method intercomparison are summarized in the table below. The flux differences in the table are given in nmol mol^{-1} m s^{-1}.

Case	Scale	Period Mexican hat (MH)	Period Morlet (Mo)	Flux difference Mo – MH median	mean
A	10 ms – 8.1 min MH 10 ms – 32.4 min Mo	39 ms – 32.3 min	10 ms – 33.5 min	0.038	0.025
B	10 ms – 8.1 min MH 0.3 ms – 9.7 min Mo	39 ms – 32.3 min	10 ms – 29.9 min	0.033	0.018
C	1.4 min – 8.1 min	5.7 min – 32.3 min	1.5 min – 8.4 min	0.025	0.009

The difference between the original calculation (Case A) and the corrected Morlet period (Case B) is 0.005 nmol mol^{-1} m s^{-1} for the median and 0.006 nmol mol^{-1} m s^{-1} for the mean value. This is about 1 % of the measured flux, and thus within the accuracy of the method. Accordingly, no correction of Figs. 4 and 5 will be necessary. Even the difference between the calculation based on the Morlet and Mexican Hat wavelets, respectively, is with about 10 % of the fluxes still in the accuracy limit of the eddy-covariance method (the relevant references are given in the paper). Based on these test runs, we decided that there is no need to change our conclusions. Still, we believe that these additional calculations support our method with differences in the range of periods of the wavelets.

3. We assume that this comment is related to comment 2, because in our calculation the lowest period limit is 10 ms for the Morlet wavelet, and 39 ms for the Mexican Hat wavelet. We do not consider this a relevant problem, because of limitations of the measuring technique for these high frequencies. Some fluxes for periods < 1 seconds are missing due to the sampling time, the path length of the sensors and the separation of the sensors; however, it is straightforward to correct these very small losses with the usual tools in eddy-covariance software (Moore, 1986). As mentioned in the text, this correction was not used for the comparison of the methods because it is identical for both methods.

Regarding potential spectral losses for low frequencies, please refer to our answer to the comments by the first reviewer. To clarify our position on this issue in the manuscript, we will include this sentence: "If the Morlet wavelet shows large flux contributions in the low frequency range, the necessity of a correction should be tested with the ogive test (Desjardins et al., 1989; Oncley et al., 1990). According to own investigations (Foken et al., 2006; Charuchittipan et al., 2014), flux contributions of periods exceeding 30 minutes are very small, and usually only become relevant in the transition time from day to night and reverse, when all fluxes are very low."

Specific remarks:

p.3, l.17: We will include the reference by Hoaglin et al. (2000), which describes the mathematical background.

p.4, l.5: We will correct this.

Paragraph 2.4: We agree that both statements the reviewer referred to are not clear in the current version of the manuscript. We will therefore include in line 25 the following sentence: "Because <w> according to Eq.(5) was nearly exactly 0 in the flat terrain, no coordinate rotation was necessary to fulfill the conditions for Eq. (4)."

p.5, l.5: We agree that our simplification in Eqs. (8) and (10) can be misinterpreted. Therefore we have included in both equations also the summation over the time, which was previously given only in Eqs. (7) and (9).

p.6, l.5 and p.8, l.19: Will be added, the unit is second.

p.6, l.21: The steady state test was performed for covariances (lines 22–23) with reference to Foken and Wichura (1996). The test was necessary for the comparison of all three methods. Therefore a steady state time series with well-developed turbulence was selected. We will include in line 21 a sentence: "This was done to ensure that the comparison of the three methods is based on steady-state data with well-developed turbulence, which is recommended for the eddy-covariance method."

p.7, l.1: We will correct this.

p.7, l.28: The Fourier wavelength, i.e., the period or inverse frequency, is related to the scale of the wavelet (see Table 1 in Torrence and Compo, 1998). It describes the range of time in the frequency domain for which the wavelet was applied.

p.8, l.12: We will correct this.

p.8, l.22: We will add the unit nmol mol^{-1} m s^{-1}.

p.8, l23: We will add the unit nmol mol^{-1} m s^{-1}.

p.11, l.4–5: Please refer to our answer regarding general comment 3. We will add in line 6 an additional sentence: "If the Morlet wavelets indicates large flux contributions for low frequencies, these time series should be controlled or even corrected with the ogive method."

Figs. 4 and 5: We will improve the layout of symbols to improve the differentiation of methods in the figures.

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