

Interactive comment on “Gap-filling strategies for annual VOC flux data sets” by I. Bamberger et al.

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We thank Referee #2 for his/her thoughtful comments on how to improve the manuscript 'Gap-filling strategies for annual VOC flux data sets'.

This manuscript analyzes several different gap filling strategies for VOC flux data sets. VOC fluxes have significant effects on atmospheric chemistry and contribute to the net ecosystem carbon balance. In order to assess these impacts, flux information on seasonal to multi-annual time scales is needed. Long-term flux data sets are scarce, however, particularly for VOCs other than isoprene. Validated gap filling strategies can be useful in completing existing data sets so that cumulative fluxes and net exchange can be evaluated. The authors conclude that, for data obtained during the growing season, the mean diurnal value method has significantly lower errors and is therefore superior to the other tested methods. All tested gap filling methods were less effective

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(had greater associated errors) during winter periods, after cutting events, or for longer gaps. The authors call for more wintertime measurements to reduce uncertainties in the cumulative VOC flux during this time period. The methods for gap-filling VOC flux data sets presented in the paper are novel and important and warrant publication. I recommend the paper be accepted following minor revisions as indicated below.

We thank Referee #2 for his/her favorable assessment of our paper.

Comment 1: P 17791, lines 21-22: “Half-hourly VOC flux values passing the quality control were retained, while not quality approved flux values were termed as missing values.” Please revise this sentence for clarity. For example, “Half-hourly VOC flux values passing the quality control were retained, whereas flux values that did not pass were termed as missing values.”

Reply: Revised as suggested.

Comment 2: P 17799, lines 3-14: “Unlike the errors for individual VOCs, both, the absolute and relative error for the sum of the VOCs, which was introduced by the gap-filling, was lower in 2011 (root mean square errors between 2.8% and 6.0%) compared to 2009 (24.2%–60.7%). In addition to the continuous emission of methanol, monoterpenes showed considerable deposition fluxes only in 2009 (Bamberger et al., 2011) resulting in a lower VOC carbon sum in 2009 and a lower second main error source regarding the absolute error in 2011. Although the percentage of missing data was equal or, on a daily scale, even lower than during 2009, the composition of gaps was different with a tendency towards data gaps which span several days in 2011. The lower errors for the individual VOCs in 2009 show that the filling of several shorter gaps (with a larger number of measurements in between) introduces considerably lower errors than the filling of the same percentage of longer-lasting gaps.”

Suggest revising this paragraph. The first two sentences discuss errors in the sum of the VOCs, which had higher errors in 2009 than 2011. The last two sentences compare errors for individual VOCs, which in most cases were lower in 2009 than

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2011. Combining both of these ideas in the same paragraph is confusing. I would suggest dividing it into two separate paragraphs. It might also help to change the order (moving the paragraph containing the last two sentences before the one with the first two sentences), since errors in individual VOC fluxes are discussed earlier in the section.

Reply: We agree that combining the two statements in one paragraph might be confusing to the reader of the manuscript. Thus we revised the paragraph by adding the information on the individual VOC fluxes directly behind the paragraph on the individual VOC errors and lead over to the cumulative VOC fluxes within a separate paragraph. It now reads: 'Although in 2011 the percentage of missing data was equal to or, on a daily time scale, even lower than during 2009, the composition of gaps was different with a tendency towards data gaps spanning several days in 2011. The lower errors for the individual VOCs in 2009 show that the filling of several shorter gaps (with a larger number of measurements in between) introduces considerably lower errors than the filling of the same percentage of longer gaps.'

However, the influence of the monoterpene deposition in 2009 did result in a considerably lower net VOC carbon emission in 2009 compared to 2011. As a consequence, both, the absolute and relative error for the sum of the VOCs, which was introduced by the gap-filling, was lower in 2011 (root mean square errors between 2.8 % and 6.0 %) compared to 2009 (24.2 % - 60.7 %).'

Comment 3: P 17799, lines 16-18: "The time series of measurements exhibited no extended (> 2 h) data gaps during management actions of the grassland (cutting and fertilization) and this effect was also excluded from the gap-filling simulation for Table 1." I would suggest revising this sentence for clarity, for example, "The time series of measurements exhibited no extended (> 2 h) data gaps during management actions of the grassland (cutting and fertilization), HOWEVER, THESE PERIODS WERE excluded from the gap-filling simulation for Table 1."

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Reply: Revised as suggested.

Comment 4: P 17799, lines 20-21: ". . . was simulated exemplarily for the year 2009 and is presented in Table 3." Also used in the Table 3 caption and Fig 3 caption. 'Exemplarily' can mean 'as an example' but is more commonly used to mean of notable quality or commendable. To avoid the second meaning, which seems unintended in this case, I would suggest rephrasing, such as, ". . . was simulated for the year 2009 as an example and is presented in Table 3" (or similar) in the text and "Example shown for the year 2009" in the table caption.

Reply: This second meaning is indeed unintended. Thus we revised the statement in the text according to the Referees suggestions and rewrote the caption of the new Table 2. It reads now: 'Example how mean, root mean square and maximal errors introduced by the application of the four gap-filling routines change if management events on the meadow were included for the error simulation in 2009.'

Comment 5: Section 3.2.4 and Table 2 It's unclear to me what time period the cumulative fluxes for the winter data (shown in Table 2) are summed over. Is it the number of snow-covered days in the sample? If so, then the number of days in the sum is quite different for the two years and the cumulative values are not comparable. I would suggest adding a column for the daily average total C flux or the cumulative flux over all winter days. This would facilitate evaluation of the estimated flux for the full winter season and comparison of the predicted flux and associated errors with the values for the growing season. This is particularly needed so that the reader can reconcile the cumulative fluxes given in the tables (in which the winter period seems like it could be a significant contributor, depending on the time period the cumulative flux represents) with the annual budget presented in Figure 4 (in which the wintertime fluxes seem to be quite small.) (It's possible the cumulative flux given in the table is summed over all winter days of the year, which would lead to a very different interpretation of the values presented in Table 2. A more thorough explanation is needed.)

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Reply: The values given in the (old) Table 2 are indeed cumulative values for the whole winter period estimated by the methods given in Section 2.3.3. To make that clear we revised the lower part in section 2.3.3 which reads now: 'For the gap-filling of the winter period we used available VOC-flux data during days with full snow cover in 2009 and 2011 and evaluated possible flux values for the corresponding winter periods by calculating a) average values/average diurnal cycles and b) median values/median diurnal cycles of the available days with snow cover during 2009 and 2011, respectively. These values were used to fill each winter day/half hour without corresponding measurements and to calculate the estimates for cumulative wintertime fluxes, accordingly. A third approach, leading to zero winter time fluxes, would be the padding of snow cover days with zeros, assuming that there is no exchange of volatiles between the meadow and the atmosphere when the vegetation is covered by snow.'

We further revised the caption of the new Table 3: 'Table 3. Cumulative VOC fluxes for the winter periods not covered by measurements (96 days in 2009 and 95 days in 2011) including corresponding errors calculated on a daily/half-hourly base for the years 2009 and 2011. The winter fluxes were estimated using mean daily/mean diurnal cycles and median daily/median diurnal cycles (calculated from measurements during days with snow cover). In addition the estimated values for the maximum and minimum cumulative fluxes for the winter data are stated.', and reworded some sentences in the paragraph 'Gap filling for the winter period'

We also revised the second sentence in Figure caption two which reads now: 'The cumulative fluxes for the winter period calculated after gap-filling the complete number of missing winter measurement days on a half hourly base using median diurnal cycles (WP MDV) and on a daily base using median daily values (WP diurnal), which were obtained from the measurements during days with snow cover (2009 and 2011), are shown as additional information.'

Concerning the total number of days with missing winter fluxes the cumulative sum over missing winter days was obtained for 96 days in 2009 and 95 days in 2011, respectively.

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This information is now given in new Table 3 and its caption.

Comment 6:

Section 3.4. Annual VOC Budget Along the same lines as the previous comment, it is not clear how the wintertime data was filled for the annual budget estimate. Section 2.3.3 discusses 3 approaches for winter gap filling, but it is not stated which was used in the annual budget calculations shown in figure 4. Section 3.4 says the MDV method was used for the annual budget estimate – does that apply to the wintertime period as well? More detail on this aspect of the analysis would be helpful.

Reply: We agree with Referee #2 that this information should be given in Section 3.4. and therefore added the statement: 'The wintertime fluxes were estimated by filling the missing days in the winter period with median diurnal cycles (which are less susceptible to outliers than mean values) as calculated from the measurements during days with snow cover.'

Comment 7: P 17804, lines 19-21: "...a lot lower than the complete annual exchange of carbon (between 6.2–12.5 g C m⁻²) estimated above a ponderosa pine plantation (Bouvier-Brown et al., 2012)." I believe the authors mean that this is the observed annual exchange of carbon in the form of VOCs (not the complete exchange of carbon, which would include CO₂). I would suggest rewording to clarify this point.

Reply: The statement was reworded accordingly.

Comment 8: Fig 2 (bottom panel) axis label: C₁₂H₁₆ should be changed to C₁₀H₁₆ for monoterpenes.

Reply: We assume Referee #2 refers to Figure 1 (rather than Figure 2) with this comment. Indeed this should be C₁₀H₁₆ (monoterpenes) and was changed accordingly in a revised version of Figure 1.

Comment 9: Table 3 is presented and discussed before Table 2 in the text. Suggest reversing the order of the tables.

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Reply: Done as suggested by Referee #2.

Comment 10: Fig 4: Is it possible to include an error estimate for the cumulative flux due to gap-filling in the figure for illustration purposes?

Reply: The error estimates given in Table 1 are only meaningful on the annual time scale therefore it is not possible to include them to the time series of the cumulative fluxes in Fig 4. The differences between the different gap-filling methods, however, are discussed in Figure 2 (and the corresponding paragraph) and it would be confusing to add the cumulative time series for the other methods to Figure 4. Therefore we decided to stay with the original Figure 4.

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