Authors' response to Reviewer#2

First of all, we would like to thank the Reviewer for his/her positive evaluation of our manuscript and would like to thank him/her for the comments and suggestions, which help us to improve the manuscript. Below you will find our detailed point-by-point response to the comments and suggestions.

Comment 1: *The first point concerns the possibility of generalizing these results to other sites, by determining a relationship between the hourly aggregation uncertainty and the variability of the CO_2 signal over the periods available.*

Response: The Reviewer is right, there is a certain relation between the signal variability and the uncertainty of the estimated hourly average concentrations. The signal variability within an hour consists of two terms: the variance caused by the trend and the variance of the detrended signal (VAR). The trend can be characterized by the slope of the regression line fitted to the raw data (REG). A few random tests proved that a bivariate (REG, VAR) regression model can estimate the absolute deviation of the calculated hourly averages from the true values with reasonable reliability. The coefficients of the model depend on the number of intakes and the sampling period. Under our conditions, the intra-hour trend is the dominant term, and it might also be true for other sites. The reason is fairly obvious: in the case of a significant trend within the hour, the start time of the first measurement period significantly determines the calculated hourly average. Depending on the start time, the highest/lowest values at the beginning/end of the hour are missed from the averaging. Unfortunately, at the operative tall-tower sites neither the intra-hour trend nor the variance of the detrended data series can be calculated because the measurement is non-continuous. Therefore, a regression model like mentioned above cannot help the generalization of our results. Where continuous measurements are available, our calculations can be repeated locally. Unfortunately, high-resolution data are not available in the databases, therefore, we could not perform any test calculations of this kind. In the revised manuscript, we will mention the importance of the intra-hour trend governing the uncertainty of the estimated hourly average concentration values, and give information on the typical diurnal variation of the concentration at our monitoring site. It might give a clue for the station operators to guess whether the uncertainty might be higher or lower at their sites

Comment 2: *The second point concerns the discussion of the importance of hourly aggregation uncertainties for atmospheric inversions. It is essential to discuss more about random errors vs systematic errors, and to remember that atmospheric inversions currently only use measurements made when the atmosphere is well mixed, and therefore with minimal aggregation errors (according to your analysis).*

Response: In the revised manuscript, we will clearly distinguish between systematic error, which is not discussed in the study, and may cause bias in the model results, and random errors caused – among others - by the non-continuous sampling, and may increase the uncertainty of the model results. We, the authors of the paper, are experimentalists having limited information on the ongoing model developments; therefore, we should be careful with our statements. Traditionally, the atmospheric inverse models used only the early afternoon measurements of the continental sites because the atmosphere is the best mixed in these hours, and the spatial representativeness of the measurements is the highest under continental conditions. It meant that >80 % of the measurements were useless for the models. The progress in the representation of atmospheric dynamics in the models may make it possible to

use data from a wider time-window, making more measurement data useful. However, the wider time-window also means that data with higher uncertainty also penetrate the model. We think, the uncertainties of these data, and their temporal variations are important background information for the modelers in the evaluation of the model results.

Comment 3: *Line 43: "which adds to the common instrument noise and scale uncertainty": I think there should be a clear distinction between random and systematic errors. Please specify that the latter are more critical in the context of atmospheric inversions, and those discussed in the paper are random errors.*

Response: Agreeing with the Reviewer, we will complete the paragraph in the revised manuscript with a few sentences making a clear distinction between random and systematic errors, and emphasizing their different effects and importance on the modeling results.

Comment 4: *Line 106-112: "we selected only those periods when the measurement elevation (82 m above the ground) was well within the planetary boundary layer" : I do not see the point of excluding those periods from the analysis. I would recommend to keep them and provide the results as a separate dataset.*

Response: The top of the planetary boundary layer (PBL) drops below the measurement elevation almost exclusively during nights. The variability of the concentration in and above the planetary boundary layer is quite different. Mixing of the uncertainty values for these quite different regimes would lead to hardly interpretable results. They may not be characteristic for either those cases when the measurements represent the conditions in the PBL or those cases when they represent the conditions in the nighttime residual layer/free troposphere. In the study, the PBL height data from ERA5 reanalysis dataset were used, which also have their own uncertainty. To be sure that the measurements certainly represent the boundary layer conditions we set a lower limit for the PBL height (120 m) safely above the measurement elevation (82 m).

Comment 5: *Figure 4: please clarify the period considered in this figure Line 180: "the shorter the sampling period the lower the uncertainty of the calculated hourly averages": I would rephrase this sentence to make it clear that the more injections of short duration, the lower the uncertainty.*

Response: Thank you for calling our attention to missing a piece of important information from Figure 4. The figure shows the median and the 90-percentile values of the absolute deviation from the true hourly averages based on all data (whole year). The sentence in Line 180 of the original manuscript will be rephrased in the revised version according to the suggestion.

Comment 6: *Line 221-223: "It should be emphasized that the numerical results presented here may be highly site-specific..." The question that the paper does not answer is whether the uncertainty is site dependent or a function of signal variability. Would it be possible to establish a relationship between the estimated uncertainty and the variability of the observed signal? With such a relation would it be possible to generalize the estimation of uncertainties?*

Response: While the uncertainty directly depends on the signal variability, the signal variability is basically site-dependent. It depends on the geographical environment of the

monitoring site (seashore, mountain top, low elevation mid-continental site, etc.), climate conditions, and the elevation of the measurements above the ground. The land-cover may also influence the signal variability through local turbulence. As it is discussed in detail in Response to Comment 1, a few random tests proved that a bivariate regression model based on the intra-hour trend and variance of the detrended data can estimate the absolute deviation of the calculated hourly averages from the true values with reasonable reliability. Unfortunately, at the operative tall-tower sites neither the intra-hour trend nor the variance of the detrended data series can be calculated because the measurement is non-continuous, the measurement elevations are sampled sequentially. As the uncertainty is dominated by the intra-hour trend, at least at our site, we will add information on the diurnal variation of the concentration. It might give a clue to the station operators whether the uncertainty at their sites may be higher or lower than at our one.

Comment 7: *Line 235: "Our analysis has shown that the uncertainty derived from the noncontinuous sampling at the tall tower sites may be significantly higher than the other terms of the measurement uncertainty": It seems to me that this conclusion deserves to be weighed. First of all, it is necessary to differentiate between random errors, such as the one discussed in this paper, from systematic errors such as those related to calibration scales. The latter is clearly more detrimental to the calculations of CO2 fluxes by the inverse methods. In addition, it should also be noted that most of atmospheric inversions only use data from tall towers during the afternoon, due to their difficulty in correctly reproducing the atmospheric dynamic the rest of the time. As a result, the data used in inversions correspond to those where the uncertainty of hourly aggregation is the lowest as shown by your analysis.*

Response: Here we would repeat our response to Comment 2. In the revised manuscript we will make a distinction between the systematic errors (not discussed in the paper) and the random errors among which the uncertainty caused by the non-continuous sampling is studied. We believe that with the development of the atmospheric inverse models more measurement data could be used, and we would like to call the modelers' attention that data with higher uncertainty will appear as input what has to be taken into consideration when the model results are discussed.

Comment 8: *Line 242: "Metadata on sampling frequency and integration time, as well as more uncertainty studies, may help their work": Fully agree. One's could also considered to provide users with minute average concentrations rather than hourly average.*

Response: We will add a sentence to the paragraph suggesting the submission of minute data. It would allow the users to perform their own statistical evaluations on the uncertainty of the aggregated data.