

Interactive comment on “Line-averaging measurement methods to estimate the gap in the CO₂ balance closure – possibilities, challenges and uncertainties” by Astrid Ziemann et al.

Anonymous Referee #2

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General Summary and Comments: Overall the paper is well structured and detailed, specially through Sections 2-4. Combining some of the figures into one group of figures would be useful (e.g. Figures 8 and 9 or Figures 14 to 18) since they are often talked about concurrently. It would also be beneficial to combine or summarize the uncertainties shown in Tables 2-4 with respect to the temperature and wind values for better readability. The results sections are light on details why the CO₂ concentrations for the proposed approach are as different compared to the EC measurement (Specific Comments). Another sentence or two pointing toward the potential error sources and how it could be reduced would be useful for further studies. Overall well put together, but some minor revisions necessary.

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There are spots where the writing needs to be cleaned up and clarification but these do not impede the reading of the work (See Technical Comments below).

Specific Comments:

Pg. 5, Ln 5-7: Are there not effects from wind passing from behind the microphones on the sound collection or are the microphones directional so this is not a concern?

Pg. 9, Ln 17. What was the output power of the speakers?

Pg. 12, Ln 13-17: Can you provide more detail on the soil chamber measurement cycle? How long were the chambers closed for each interval and how was the concentration measured (see comment for Pg. 33, Figure 17).

Pg. 13, Ln 5: “growing sound frequencies”; what does this mean with respect to the 7-kHz frequency used?

Pg. 18, Ln 5-6: How much does the uncertainty decrease with the increased path lengths? If this is the case, why not use as long of a path length as possible instead of the “minimal path length of 50m”? What is the minimum path length that would generate usable data?

Pg 18. Ln 22: Section 3.2.1 didn't mention any amplifiers. Were amplifiers used and how did you generate the sound wave for the speakers?

Pg. 20, Ln 20-21: How stable was the frequency of the loudspeakers? How much of an error would this contribute to the results or was it negligible?

Table 2: Could the corresponding wind and temperature errors be added to this table and Tables 3 and 4?

Pg. 21, Ln 14-15: Overnight turbulence is not zero, there is still some minimal turbulence, but it may be negligible for this application. How much does turbulence negate the ground effects? Would this mean that daytime measurements are less error prone so better to validate the results of this method?

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Pg. 27, Ln 6-8: Are the sonic temperatures the virtual sonic temperature or converted to ambient air temperature? The text refers to T_{air} and sonic temperature (θv).

Pg. 28, Ln 3: Why was 20% chosen as the error level used?

Pg. 29, Ln 8: What constitutes “reasonable errors”?

Pg. 32, Figure 16: The FTIR CO₂ concentrations are high compared to the EC measurements (Figure 17); is this a product of the line averaging or error within the FTIR/EC measurement systems?

Pg. 33, Figure 17: Soil chambers and EC CO₂ measurements are not equivalent due to the height difference thus proximity to the source and the measurement style. At what point in the soil chamber cycle did the concentration measurement take place? Could you combine Figures 16 and 17 so the comparison between the concentration values were easier?

Pg. 33, Ln 7-8: Is the difference a product of the potential error within the measurement technique? In Ln 13-15 on Page 30 you state that the uncertainty was determined in studies based on with stronger temperature contrasts between the target gas and ambient air so couldn't the maximum uncertainty be even larger here? With only one point measurement of ambient CO₂ (EC station), I don't think it is reasonable to make a generalization like this without support from other works. There was a 100+ ppm difference in the line average (R72-R73) compared to the point measurement (EC), only approximately 10 m away; that large of a difference in the concentration needs to be explained.

Pg. 34, Ln 12: The range of uncertainty is very large and could change the sign of the horizontal advection values. Does the error range scale with the magnitude of the advection? How do we account for the uncertainty when comparing with EC-based advection?

Pg. 34, Ln 18: What was the wind direction for this period? Did it remain constant or

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did it change with time? The change in sign of the v component in Figure 14 implies a changing wind direction and does this change the upstream source region for CO₂ hence much larger advection?

Pg. 35, Ln 24-26: “It is expectable that...”. My understanding is the differences in concentration measurements is a product of measurement height and measurement principle, not just line versus point measurements. Some difference is expected from the line versus point measurement but there were points where the line average concentration (FTIR) doubled the point concentration (EC and SC) (Figures 16 and 17). This magnitude of difference in the concentration values doesn't seem to be just a difference in line versus point measurement averaging. I would expect the SC concentrations to be highest because of their proximity to the ground (CO₂ source). Under-sampling of fluxes is different than under- or over-sampling the concentration values and the resulting advection values.

Pg. 35, Ln 20: What is the error on the cited horizontal advection values; is the range you found similar to these studies?

Technical Comments

Pg. 1, Ln 22: “Thereby...”, “Additionally” may be a better word.

Pg. 1, Ln 27: Considering averaging... does not need “Considering” and is missing a comma: “Averaging over a period of 30 minutes, the standard error”.

Pg. 2, Ln 2: “A closing gap for balance...” would be better as “Closing the gap for...”

Pg. 2, Ln 4: “measurement of flows” awkward phrasing

Pg. 2, Ln 31: “considered advective fluxes” Vertical or horizontal advection?

Pg. 3, Ln 1: This sentence is misleading since substantial advection can occur in any land-cover type, the only requirement is a CO₂ gradient to exist (e.g. Feigenwinter et al., 2008). I believe what the authors are attempting to convey is advection is commonly

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the largest error source in complex terrains.

Pg. 3, Ln 5-6: How much reduction in annual CO₂ uptake? And in which forest?

Pg. 3, Ln 27: Remove extra parenthesis

Pg. 5, Ln 19: Replace “several” with “two”.

Pg. 6, Ln 25: Don’t need “Then,”.

Pg. 6, Ln 29: Not a complete sentence; rewrite.

Pg. 7, Ln 18-19: Combine “The permanent EC...” and “Meanwhile is it...” into one sentence. Define “ICOS-D (C3 station)”.

Pg. 8, Ln 10: “class-a-pan” should be “Class A pan”.

Pg. 9, Ln 17: “speakers for frequencies” should be “speakers with frequencies”.

Pg. 14, Figure 6: Could you add the sent signal as well to illustrate the time shift?

Pg. 17, Ln 26: Need a comma between “50 m” and “a maximal”.

Pg. 18, Ln 4: Remove “For”, so “A minimal path length...”.

Pg. 19, Ln 16: “The latter is influenced...”, don’t need “one”.

Pg. 21, Ln 5-10: This paragraph feels out of place. Some of this information was presented earlier in the section.

Pg. 21, Ln 16-17: “It was proven, whether...”, which of the two were proven, that you can separate the two sound wave parts or it wasn’t possible to separate the two parts?

Pg. 22, Ln 9-10: Repeat from earlier.

Pg. 22, Ln 22-23: “...vertical wind and temperature gradients...”; vertical gradient of the horizontal wind? And what “horizontal ones”? Horizontal temperature gradient or wind gradient? Which wind components in the horizontal? Be specific.

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Pg. 23, Ln 12: “solves”, not “is solving”.

Pg. 23, Ln 14: “were”, not “was”.

Pg. 23, Ln 15: “...their vertical gradients...”, vertical gradient of which component?

Pg. 23, Ln 16-18: Which gradient is being referred to in these sentences, wind speed, temperature, and/or speed of sound?

Pg. 23, Ln 20-25: Why not talk about this when Figure 7 was introduced earlier?

Pg. 24, Ln 19: “controlled”, does this mean measured?

Pg. 25, Ln 7-8: “Actually, no signal is receiving...” What is this sentence trying to say, it makes no sense.

Pg. 25, Ln 9: What percent is “mostly possible” to measure an upwind-directed signal?

Pg. 25, Ln 10: “if the wind speed and therewith...” what is a “moderate gradient?” This sentence is awkward and needs to be clarified.

Pg. 25, Ln 23-24: “imply the main important inherent...” what influence is this referring to?

Pg. 35, Ln 23: “our results...maybe worth looking into.” How else should the results be viewed and why weren’t these ideas presented? It’s possible a unique event occurred this night to produce a large advection value since the EC flux was large as well; this appears to be a case for analysis of more nights under various conditions to better vet the methodology.

Pg. 35, Ln 23: “Thereby, the different measurement volumes...” To what is this sentence referring? Feels out of place.

Pg. 35, Ln 24-26: “It is expectable that...”. “Expected”, not “expectable”.

Pg. 35, Ln 26 and 28: Two Siebicke et al. papers are cited (2011 and 2012) but only one is present in the reference list.

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Pg. 36, Ln 3: “to be on a safe side” should be “to be on the safe side”.

Pg. 36, Ln 9: “will allow enhancing the security” could be “will enhance the security. . .”

Pg. 36, Ln 16: “has to take into account” should be “has to be taken into account”.

Pg. 36; Ln 21-23: “Thus a highly. . .”, This sentence would read better as “The results from a high number of optical and acoustic paths can be used. . .”

References: Feigenwinter, C., Bernhofer, C., Eichelmann, U., Heinesch, B., Hertel, M., Janous, D., Kolle, O., Lagergren, F., Lindroth, A., Minerbi, S., Moderow, U., Mölder, M., Montagnani, L., Queck, R., Rebmann, C., Vestin, P., Yernaux, M., Zeri, M., Ziegler, W., Aubinet, M., 2008. Comparison of horizontal and vertical advective CO₂ fluxes at three forest sites. *Agric. For. Meteorol.* 148, 12–24. doi:10.1016/j.agrformet.2007.08.013

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