

General comments

The study examines the changes in the atmospheric CO₂ seasonal cycle amplitude (SCA) at two Central-Eastern Europe stations, Kasprowy Wierch (KAS) and Hegyhatsal (HUN) since 1994. More specifically, the authors analyse seasonal minimum and maximum, and their trends and associations to the changes in climate conditions. Understanding the seasonal cycle of atmospheric CO₂ is important as it is affected by the seasonal cycle of both natural and anthropogenic fluxes, which can change due to climate change and mitigation actions.

They found that the atmospheric CO₂ SCAs at those sites have decreased since 1994, due to an increase in summer minimum and a decrease in winter maximum. These trends correlate well with CO₂ fluxes estimated from a model (CTE2016), where the European biospheric fluxes have increased and the European anthropogenic emissions have decreased. These results suggest that changes in biospheric activities and a reduction in fossil fuel emissions could be examined from the measurements. It also warns potential future changes; plants may be suffering from severe summers even more, and fertilization effect may be weakening, and thus there is an urgent need in faster reduction of anthropogenic emissions.

The two selected sites have high quality long-term records, which are suitable for examining such long trends. It is a slight concern that they only use two sites to conclude about regional CO₂ fluxes, but they have examined the trajectories of those sites, which support the appropriateness of those two sites for this study.

The manuscript is generally written carefully with considerations, but I would like to address a few points below, which the authors could further discuss more in depth.

- Major concern is that the authors conclude that the changes in the SCA have been driven only by increase in biospheric fluxes in summer and fossil fuel emissions in winter. Other causes, such as an extension of plants' growing seasons, effects of warm winter to biospheric fluxes or warm summer effects in anthropogenic emissions (see below) have not been discussed. The authors have examined exceptional years, but are there any sign of increasing trends of such years (e.g. mild winters and warm/dry summers)? In addition, if the increase in biospheric fluxes is a major cause in increase of summer minimum atmospheric CO₂, it is due to reduction of photosynthesis or increase in respiration? How about feedbacks, e.g. fertilization effects (only one sentence about fertilization in the conclusion)?
- The authors have concluded that the trends and events of the changes in the SCA is associated with climate conditions, but did not discuss in detail the effects of anthropogenic actions, such as land use change and policy or economical conditions. Also, references to show that fossil fuel emissions have decreased is missing (CTE and thus its prior is from a model). In addition, the seasonal cycle of anthropogenic emissions could have changed as well – warmer winter, and more severe summer could cause shift in fossil fuel emissions from winter heating to summer cooling.
- The evaluation with flux sources are done by comparing flux estimates from a model. As footprints of summer and winter are shown to dominate from Central-Western Europe, how much about Eastern Europe can you say? The CTE results are from whole Europe, so how do

you incorporate your arguments considering the trajectories? To be more precise, source contributions should be calculated by running trajectories or transport model for each source separately. This would require extra work, but increases the value of this study significantly.

- Using results from only one model in evaluation should be done with caution. Any models have their own features, and results may be biased. In addition, if those studied sites were assimilated in the CTE inversion (i.e. has influence on the flux results), the evaluation is not independent of the measurements. Please specify and justify the choice, and if possible, use other sources, such as results from Global Carbon Project for biospheric fluxes and UNFCCC reports for anthropogenic emissions as additional source of evaluation.

Specific comments

P2 L42-43: The advantage of GHG observations are useful not only for studying last decades, but also present and future. It is true that “currently available” observations can only see the past, but findings from those studies can be used for future predictions as well.

P2 L48-19: What was their main conclusion?

P2 L50-53: Please rephrase. It is not clear whether you wish to say that KAS is useful site and can represent Central-Eastern Europe, or rise problem about lack of observations. Please also be more specific about what you mean by “this” - you have not discussed this problem before.

P2 L54-55: Please add references to such studies.

Section 2: Please put information about the data gaps and gap-filling methods in this section for all sites. (Those of KAS is presented in capture of Figure 1, but please move it to this section). If there has been no gap in the data, please also notify.

P2 L61: Please add information about KAS data availability in this section.

P3 L94: Please specify which European network it belongs to.

P4 L122: Please be more specific about “periods of interest”. You probably did not run footprints of the whole study period, but part of it?

P4 L126: Please justify your choice of “96-hours”.

P5 L127, L137: You have used two different meteorological datasets (NCEP Reanalysis and ERA-Interim). Could you comment on those choices, how much differences there are, and whether the differences could possibly affect your analysis?

P5 L137: Please specify from which layers/level of air temperature data you have used (I could see that it is 2 m temperature from figures, but please also note in text). It could be good to specify it for soil humidity also in the beginning.

P5 L151-L152: Please explain what are included in the “biospheric fluxes” (biomass burning can also be considered as “biosphere” in some context).

P5 L152: The authors mention that ocean fluxes were negligible, but some (or actually quite many) MHD observations capture signals from ocean. Did you apply any specific filtering to such observations?

P6 L169: Please consider adding the following sentence before “It is apparent from Fig. 1b...”:
Therefore, seasonal cycle amplitude and annual level is much lower for KAS than HUN.

P7 L183-L185: How well do we know about seasonality of the anthropogenic emissions, and their contribution to the measured seasonal cycles at those sites? Please add references.

P8 L195: “uncertainty” → “standard error” (or deviation). In all the regression analysis, it was not very clear how you decide significances. For example, you mention that MHD peak-to-peak amplitude (0.05 ± 0.04) is not significant, but KAS summer min. (0.09 ± 0.04) is. If you have some additional quantitative values (e.g. p-value), that would help to better understand your arguments.

P9 L205-208: You already know the answer to this sentences. It would be better to go directly to the results, i.e. remove this sentence or rephrase.

Section 4.3: It seems that there are positive correlation between CO₂ amplitude and winter maximum, and negative correlation between CO₂ amplitude and summer minimum. Maybe you could consider starting discussion about those.

P13 L253: The authors meant to say that peak-to-peak amplitude is “low” in some years compared to average. Please rephrase the sentence to be more clear.

P14 L272-274: The authors explain that there is a clear differences in the direction of footprints, but I see strong influences from western Europe at both sites in Fig. 10. In addition, footprint of HUN show that the air is not coming much from northward directions. Could you explain these in a better way?

P20 L334-335: Please see my general comments about evaluation.

P20 L343-344: Please also rephrase “luck of strong biospheric signals”. The station captures biospheric signals, but mostly from western direction. Maybe you could say “luck of biospheric signals from eastwards”?

Conclusion: It would be good to add conclusion about our actions to be taken. Shall we be more urgent in reducing anthropogenic emissions, if plants are suffering more from sever summers, and fertilization effect may be weakening?

Figure 4 and 5: Please put each of them into one figure (i.e. without panels), and use same colour codes.

Figure 7: Why do you compare only with KAS?

Figure 8, 9, 11: Is it necessary to show the all years? You could consider showing only those important years.

Technical corrections

P2 L40: “except of” → “except for”, “Finish” → “Finnish”

P2 L56-59: Please use present tenses.

P5 L 137: “In order to calculate annual air temperature and...” → “In order to calculate annual regional air temperature and...” (It is good to specify in the beginning that you use these data for regional analysis, and not for site-level.)

P5 L150: “Wageningen University” → “Wageningen University and Research”

P20 L343: Please rephrase “...Hegyhatsal station because of larger footprint of Kasprowy Wierch and lack of” as “...Hegyhatsal station because of smaller footprint and...”, i.e. be consistent with the subject.