

## **Review of Liu et al.: Spatiotemporal patterns of the fossil-fuel CO<sub>2</sub> signal in central Europe: Results from a high-resolution atmospheric transport model**

General comments: the authors firstly presented the spatiotemporal patterns of the atmospheric fossil fuel CO<sub>2</sub> concentration over the central and southern Europe, and then conducted a sensitivity study on the impact of fossil fuel emission on the atmospheric CO<sub>2</sub> concentration varying with emission reduction and regions.

Overall, this study is interesting, fits the scope of ACP, and shows enough findings to be published. However, it is quite confusing to me sometimes that what the authors referring is fossil fuel emissions or fossil fuel CO<sub>2</sub> signals (concentration). One is a flux based concept, another is mixing ratio. The authors need to make it clear.

The authors conducted a reasonable amount of the statistics to support their findings, i.e., Table 1. However, based on their results, they used quite a few statements like “good agreement”, “agree well”, etc. These kinds of statements have no reference in the entire manuscript: no inter-comparison with other studies, and/or no significant test, which makes these statements are too vague and scientifically meaningless.

It will be very helpful if the authors list more information in the figure caption. For example, it’s not clear to me that which figure is based on the all time series, which based on the daytime afternoon. The bottom line is that readers can understand the figures without checking the text.

Overall, the authors did model evaluation (comparison to observations) based on the daytime values but did the annual mean based on the all time series. The models are struggled with simulating the nighttime CO<sub>2</sub> in general. The all time series will very likely bias the entire results of annual mean.

There are quite a lot details needed to be fixed and listed below as the specific comments. I would recommend the authors to work on the consistency of the statement and correct those comments before they resubmit the manuscript.

### Specific comments:

1. Line 22, what do you mean the last sentence of the abstract?
2. Line 50, Newmant et al., (2016, ACP) also studied the fossil fuel section based on the observation approach.
3. Line 63, it can’t be true that the model dynamic is fully resolved. The subgrid processes should be parameterized.
4. Line 87-93, the authors is explaining the possibility to detect the fossil fuel signal, which I was assuming that it referred CO<sub>2</sub> concentration. However, the two approaches – bottom-up and top-down – are used to quantify CO<sub>2</sub> fluxes in general. This confusion appeared a lot throughout the entire paper and needs to be fixed.

5. Line 132, in the model setup, the flux components are called surface flux and, can be considered as surface boundary condition. The prescribed global model output providing the advection on the boundaries of model domain is lateral boundary conditions. The statement regarding these drivers is not clear to me.
6. Line 170, the authors used time function to scale the monthly emission in time. I recommend the authors to make a figure that shows the time series of the scaled emission components and the total emission on top of Figure 2a. I also would like to see how the authors reconcile the discontinuity between weeks and between months.
7. Line 207, a table to describe all of the fossil fuel tracers will be very helpful for readers to follow.
8. Line 207 and 226 contradict each other. Please double check how many fossil fuel tracers used, and correct it if it's not.
9. Line 225, see item 5 above.
10. Line 235, does  $R > 0.7$  mean significant correlation?
11. Line 248, "underestimate" or overestimate? All of the bias values in Table 1 are positive but the one at Mace Head.
12. Line 248 – 259, I can't find those value in Tables. It's confusing.
13. Line 261, in Table 1 the STD for the model are  $\sim 4$  ppm and  $\sim 9$  ppm at Mace Head and Hungary, respectively. Please correct them and carefully check the values are stated in the manuscript.
14. Line 300, see item 10.
15. Line 314, what is the criteria for "the good to excellent evaluation"? Could the authors quantify them?
16. Line 317 – 319, "It is particularly ....". "The presence of an overall ..." These two sentence contradict each other.
17. Line 320, the statistics were made sometimes based on the daytime values sometimes based on the all time series. Overall, the authors did model evaluation (comparison to observations) based on the daytime values but did the annual mean based on the all time series. The models are struggled with simulating the nighttime CO<sub>2</sub> in general. The all time series will very likely bias the entire results of annual mean.
18. Line 333, more explanation needed on "suggesting a somewhat limited efficiency of atmospheric transport and mixing to disperse the signal laterally". More explanation needed.
19. Line 334, a map of terrain for the region of interest will be very helpful.
20. Line 360, "while the biospheric signal is stronger". Biospheric signal can be positive and negative, which will cause completely opposite effect on the total CO<sub>2</sub>. Please clarify it.
21. Line 369, the column averaged values are smaller than the surface ones, mainly because the signals are at surface and they are diluted in the column as averaged out. The statement is incorrect.
22. Line 400, what does lateral gradient mean specifically here?
23. Line 419-428, Figure 8 and the relevant statement doesn't make sense to me. I don't understand that why the contribution of each component (b-d) would be larger than the total (a).

24. Line 487-555, the authors made misleading statement regarding the relationship between meteorological matrix (such as PBL, etc.) and fossil fuel emission. Fossil fuel emission is strongly correlated to the anthropogenic activities. The increase and decrease of the fossil fuel emission is not affected by transport and/or mixing; the atmospheric CO<sub>2</sub> concentration is. At the beginning, I thought it (“emission”) is a typo, which is an easy fix. However, I realized that this relationship is not clear at all to the authors when I saw Figure 9b.
25. Line 670, the authors selected three location to do further analysis for Figure 15. Why these three? Please explain.
26. Line 700, yes, the authors were being optimistic as they admitted. All of the analyses were based on the model results. The cloud contamination was considered in the discussion. However, the more important errors are very likely caused by model transport errors and error estimate of biogenic flux. It will be great if the author can expand the discussion on the impact of those error on their findings.
27. Line 724, where does “110%” come from? Is it a new? The authors shouldn’t include any new results in the conclusions.
28. Figure 1, please put the labels on the color bars.
29. Figure 2, I would like to see the time series of the scaled emission components and the total emission.
30. Figure 4, 1) enlarge the font size. 2) what year is it? 3) night time model results included? If so, 10 m above ground is too late. Models are struggled at nighttime, especially for such low level. 4) Keep the color bars in the scale and same range for a and c, b and d.
31. Figure 5, the figure labels (a, b, c, d) are missing.
32. Figure 6, use the same color scale as Figure 4 does.
33. Figure 8 doesn’t make sense to me as I pointed out before. The contribution of each component can’t larger than the total.
34. Figure 9a, which minus which? Figure 9b doesn’t make sense to me. The fossil fuel emission is related to anthropogenic activities; it won’t be affected by transport and/or mixing. If it is concentration instead of emission. The correlation of the concentration and PBL height should be negative. It’s confusing.
35. Figure 11, what countries are they exactly included in SW?
36. Table 1, it’s a confusing statement that “the 3 hourly means between 12 – 18 PM”
37. Figure 13, enlarge the font size. Does it in percentage? Can the authors overlay the wind field on top?
38. Figure 14, it’s not clear to me to look at the standard deviation changes between two cases.
39. Figure 15, I can only find three green dots in Figure 14b, but Figure 15b shows four lines. Please make correction accordingly.