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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Quantification of CO_2 and CH_4 emissions over Sacramento, California based on divergence theorem using aircraft measurements" *by* Ju-Mee Ryoo et al.

Anonymous Referee #1

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Summary

This paper presents a methodology that estimates CO2 and CH4 fluxes using cylindrical flight patterns combined with kriging and Gauss divergence theorem over Sacramento, California and quantifies the corresponding uncertainty. The study finds that fluxes vary as a function of wind pattern, seasonality, background assumption, flight path, and flux estimation approach by a factor of 1.5 to 8. Total flux estimations using the entire circumference are larger than if just downwind region is used. It is stated in the article that using entire circumference to estimate GHGs fluxes allows for accounting of unknown sources that otherwise could be missed.

General Comments (Major Revisions)

Although the paper does make a lot of important and useful points regarding estimation of GHGs emissions with an aircraft, there are many places that are unclear and need to be elucidated before I can accept this article for publication.

First, I am not exactly clear on how the used methodology is different from a traditional mass balance. I see the explanation, but I am not convinced that it provides any information that is not obtained from the standard method. I would like to see the comparison. Please perform standard mass balance and compare it to your method.

Another issue that I find in this article is that the actual plane data is not carefully presented. First it is important to present data for all of the 3 cases in an equal manner. There are different plots for different days and it becomes confusing. For example, finding exact local time of all the flights is difficult (including just take off time is not enough in this case). This information needs to be easily accessible. I could not locate wind measurements for all of the days. Figure S2 (d) is misleading and actually leads to a flawed assumption regarding steady state for November 17, 2015 (more on that later). The paper needs to be reorganized and improve its clarity of presentation.

The explanation of background is very confusing. Given the method presented, background should be everything that flows into the cylinder. I am not following the justification for different background assumptions (you would not want to pick a minimum value in this case). Also the concept of raw and mass-balanced mean wind needs to be better explained. Why averaging winds horizontally achieves mass balance? And if plume is not well mixed, how can you do that? Plume is transported differently at each level. You cannot just assume that all of the levels move at the same rate.

Specific Comments

Line 170: It says, "The background level is derived from the lowest flight measurement." When using kriging method, do you apply kriging to all of the data including the background?

Line 191: How do you know that kriging approach captures better plume features? Kriging method interpolates data, meaning that it basically guesses it. It has no knowledge of the actual plume dispersion mechanism. The Figure S4 is misleading as it has different color bar scales for different plots. Please make sure that all of the color bars are the same. In actuality you don't know how the plume is changing below your lowest measurement point. Anything that you assume below that point is highly uncertain. It could be almost constant for all we know. It really depends on the location of source. That's why ideally you want to sample well-mixed layer and not partially mixed layer with an aircraft when estimating flux.

Section 2.4: See the comment about the raw wind vs. mass-balanced mean wind in the general comments section.

Figure 1c: I am confused about the following sentence in the caption, "The shading represents the pressure ... normal to the cylinder." What shading? I am not sure I see any shading. Please explain what do you mean here. Also, here you say that blue is inflow and red is outflow. It seems that everything that is in blue should be a background for everything that is in red assuming steady state. Please comment.

Lines 265-270: I do not understand your choice of background. Given your set up you should be using inflow as background. The definitions you describe here are used in regular mass balance because sometimes there is just not enough sampling, but generally they are flawed. Please explain why you are not using inflow. You need to justify your choices with relevant physical processes.

Another important point that you do not mention is an uptake of CO_2 by vegetation. That also can affect background and your fluxes quite a bit. I know it is November in two of your cases, but you need to comment on your assumptions. Your case in July could be more problematic with regard to CO_2, although there you concentrate on CH_4 so it may not matter as much.

Line 306: How come highways and airports are indicative of CH_4 emissions? It is not common for these sources to emit any significant CH_4. Please explain.

I think using kriging when you do not understand your sources is a risky endeavor. It is better to solve for everything without kriging first and then see how kriging may affect your results. But in your situation you definitely do not want to trust kriging. Using kriging in regular mass balance is also dangerous if you do not have a good understanding of what you are measuring. Unfortunately it is often used without much thought.

For example, see Figure 6 in Conley et al. (2017), the paper also uses the divergence methodology that you apply here, but they are careful to note that you want an optimal number of loops around your source before you can get a stabilized estimate of emissions. They estimated an optimal number of loops to be about 15 to 25. That is the case because turbulent conditions tend to increase the magnitude of random error. I am afraid your sampling here is just too small for a good application of divergence theorem. It is important to acknowledge it. Solve without kriging and see what you can get.

Figure 2S (b and d): You will have to eliminate November 17, 2015 case from your article. You cannot assume steady state conditions on a day with calm to variable winds near the surface. The wind rose is misleading as you mainly show free tropospheric winds, which should not be used for boundary layer flux calculation. Your boundary layer winds have no consistent direction. The data from a local weather station in Sacramento, CA supports that (and actually if you look carefully at your wind data you will see it too in your Figure). This comes back to the point I made earlier, where you need to show your actual wind data from every case. You cannot just pick and choose what you show. It is no surprise that your flux estimations did not work well on that day. None of the aircraft methods would work on that day. It is very important to have a good forecast before you go and fly a mission of this type. I am not sure who designed this flight and for what, but it does not work here for your purpose. Perhaps you can find another flight that works better.

Please make sure you address all of my comments.

References

Conley, S., Faloona, I., Mebrotra, S., Suard, M., Lenschow, D.H., Sweeney, C., Herndon, S., Schwietzke, S., Pétron, G., Pifer, J. and Kort, E.A., 2017. Application of Gauss's theorem to quantify localized surface emissions from airborne measurements of wind and trace gases. Atmospheric Measurement Techniques, 10(9).

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