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Atmospheric Measurement Techniques Discussions

Interactive comment on "Methane emissions from an oil sands tailings pond: A quantitative comparison of fluxes derived by different methods" *by* Yuan You et al.

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Article "Methane emissions from an oil sands tailings pond: A quantitative comparison of fluxes derived by different methods" by You et al. introduces a flux measurement method comparison from methane flux measurements over an oil sands tailings pond. Their analysis includes three micrometeorological flux measurements methods including eddy covariance, floating chamber and gradient flux measurements. In addition, they include in their analysis another method called inversed dispersion fluxes. High methane emissions of the tailings pond are interesting by themselves and allow for a proper flux measurement method comparison, making a good addition to the existing

literature of flux measurement method comparions studies over waterbodies. However, the methods and analysis used in the study require recalculations and corrections for drawing proper conclusions, than what has been done in the present form of the manuscript. The overall presentation of the manuscript is not all the time well structured, and for example the analysis is jumping from only the pond area measurements to fluxes from all different wind directions. Thus, I cannot recommend publication before major revisions are made to the analysis.

General comments:

Measurement methods in general require more description:

- Eddy covariance flux calculation description is lacking relevant information. The authors list as correction methods axis rotation, time lag compensation, WPL correction and storage term correction. Which axis rotation method was used? WPL correction should actually not be applied for this gas analyzer (Picarro G2311-f) as it is already included in the instrument itself. Spectral corrections are not mentioned in the text. Spectral corrections (especially high frequency spectral correction) are essential in EC flux processing and can affect even the sign (direction) of the flux measurement. Recommended spectral correction methods are introduced in e.g. Aubinet et al., (2000) and Mammarella et al., (2009). Was u* filtering applied? If yes, what was the threshold and how was it determined? How about storage change fluxes, how were they calculated? Fluxes from different wind directions are presented in this study, but it is not clear wether all these fluxes were processed in similar way. If all wind sectors are covered with different types of roughness elements (such as pond, buildings, trees), the different sectors should be processed (and fluxes calculated) individually. Environmental data required for the flux calculation (air pressure, temperature and humidity) are not described.

- Gradient flux method has defeciencies. Eddy diffusivity is calculated from CH4 EC flux, so gradient flux is not totally independent from EC CH4 flux measurements. I

understand the eddy diffusivity is not taken directly based on EC measurements, but from a fit of Schmidt number against stability parameter. Even though making this fit makes gradient fluxes not directly dependent from EC, it should still be discussed how the usage of EC measurements in eddy diffusivity calculations affect the comparison between these methods, as it has not been currently discussed at all. The authors refer to a study by Bolinius et al., 2016 where the eddy diffusivity is calculated from the heat flux measurements of the EC system instead of the gas flux. This is a well established method and I recommend the authors to study it more carefully and implement in their study as well. I suggest the authors at least compare this method to their original gradient flux calculations. Another study worth taking a look at is Rantala et al., (2014), where eddy diffusivity is calculated from the Monin-Obukhov similarity theory. Heat flux is independent from the gas flux, so calculating eddy diffusivity from the heat flux measurements will allow more reliable comparison between EC and gradient CH4 fluxes.

- Chamber measurements are currently not described at all but a proper method description is needed (what kind of chamber design was used, dimensions, how long enclosure time was after reaching equilibrium with carrier gas flow and inside air, how was the air flow implemented, how was the flux calculated, what kind of data selection methods were used etc.).

Comparison of fluxes is highly misleading and fundamentally flawed. The authors have included in the flux averages all data available, which are then compared with each other. What the authors should do instead is to select only those timeperiods/data points when all the measured fluxes are available, and then calculate averages that are comparable. If this is not done, it easily happens so that one of the methods is measuring e.g. more fluxes from one wind direction or time of the day than the other, which is causing a clear bias in the comparison.

Conclusion section is currently an additional discussion section that should have been implemented in the section “Results and discussion” already. Proper conclusions - with

no new information given but rather a summary with a perspective to future studies - is totally missing and should be included.

Specific comments:

Table 1: This comparison does not make sense if the fluxes are not averaged from simultaneous measurements. You should only include the datapoints in averaging when you have a datapoint from all the methods. What does it mean that fluxes are “relatively steady”? The uncertainty estimation in footnote c is unclear.

Table 2: Not clear what are the time periods for these flux estimates, should they even be comparable? Annual averages are different from summertime measurements. It would be interesting to see a comparison to natural waters or reservoirs as well, to see the high magnitude of the methane emissions.

Figure 1: It would be very helpful for the reader to include in the map the EC footprint lines and/or lines for approved wind directions. It is not very clear from the closeup image where exactly are the pond edges. Maybe this could be highlighted somehow? Add chamber measurement locations to this map.

Figure 2: What is the correlation coefficient of the linear fit? How does it change if you use the original datapoints instead of binned averages for fitting? It does seem that data are very scattered with higher Km and Kc, how does this affect the fitting? What do the boxplots represent (what are the box limits, whiskers, center line etc)?

Figure 3: “Best fit” - determined by what criterion? The bins are not of equal size and I believe this is also affecting the fit. What do the boxplots represent (what are the box limits, whiskers, center line etc)?

Figure 4: Fig 4b is not discussed anywhere and is a bit pointless without water temperature. In 4a, u* is missing interquartile ranges and 10% and 90% percentiles. In 4e sensible heat flux is missing quartiles off-pond and 10% and 90% percentiles on pond. Mark in the diurnal plots the times of sunset and sunrise to help the reader.

Figure 5: Scale seems quite arbitrary, how was it defined? Directions are missing, where is north?

Figure 6: You should add a, b and c to subplots. Colors of EC and gradient fluxes are too similar in the printed version and in the lowest panel red and green are used which is not color-blind friendly. You can check colorblind and printer friendly color choises e.g. from here: https://colorbrewer2.org

Figure 7: Shade the pond area also here, similar to Fig. S6. What do the boxplots represent (what are the box limits, whiskers, center line etc)?

Figure 8: What is the offset of the fit? It does not seem to be crossing y=0 at x=0 in neither of the plots.

Figure S2: What do the confidence intervals represent?

Figure S3: "...countours of the EC footprint area". It would be very helpful for the reader to get S3 b on top of a map, to see where the contours are crossing pond edges.

Figure S4: It is not mentioned here which EC flux this is. Methane? Mention in each subplot which wind direction it is representing (in legend/title/xlabel/ylabel) to help the reader. What do the boxplots represent (what are the box limits, whiskers, center line etc)? Mention in the caption what is in each wind sector (pond, buildings, trees, etc).

Figure S5: Mention in the ylabel that this is methane flux. Mention in the caption what is the r2 representing (least squares linear fit?).

Figure S6: What do the boxplots represent (what are the box limits, whiskers, center line etc)?

Figure S7: What do the boxplots represent (what are the box limits, whiskers, center line etc)?

Table S1: Are the fluxes compared here from exact same time periods? Same comment as for Table 1 about the uncertainty estimate and "relatively steady".

L10: "develop" is a little bit misleading here since the authors don't really develop any new method, rather compare already existing ones.

L11-12: Mention briefly which are these three flux methods in one sentence.

L15: inverse dispersion model comes here from out of the blue. Describe it briefly before writing about the results.

L18-19: This sentence is a bit misleading. In one perspective it is quite obvious that a larger footprint represents a larger area. On the other hand if the EC tower is placed so that it is measuring only e.g. shallow area while actually the pond is deeper from a much larger area, then would EC be representative of the whole pond emissions? Then on the other hand nobody can know what is the real flux. It might as well be closer to the chamber flux than EC.

L21: Abbreviation AOSR is not used anywhere in the text

L23: "Oil Sands" or "oil sands"? Throughout the manuscript.

L48: "eddy covariance (EC)" and then use EC after this throughout the manuscript instead of eddy covariance

L49: "area sources" or "source areas"?

L53: So only emissions can be measured with this method, not uptake?

L56: What is meant by "relatively well-defined spatially"? If the fluxes are well-defined, why do you measure them?

L59: "Field study" is not a very descriptive title. Maybe "Site and measurement description"?

L62: Trees are not part of natural landscapes? What is? How far were the other facilities? In the catchment area or further away? How large is the cathment area?

L65: What is meant by "mobile tower"? How high were the measurements above water

(which is more relevant than ground in the case of pond fluxes)?

L69: Is this the diameter or radius? Inner or outer diameter?

L71-72: I am not sure it can be said that turbulent flow is ensured. Reynolds number is ∼1300 according to my calculations, so it is possible that the flow is turbulent, but I wouldn't call it "ensured".

L72-74: All kinds of measurements are presented that are not used in the analysis or shown anywhere in the manuscript. I suggest to leave out the description of those gas measurements not used in this particular study. Why is a 40 m long tubing required for 18 m height measurements? This will cause quite long lag time for EC. What are the three and four levels mentioned here?

L74: There must be some flush time of the tubings and analyzer between the different height measurements. How long is the flush time? One level cannot be measured 2.5 min during 10 min period if you take into account the flush time.

L76-77: Was there any drift of the instruments between calibrations? Did they compare well with each other?

L80-82: This is well known EC theory and does not need to be explained.

L88-89: Was the infrared sensor calibrated somehow?

L92: How were the suitable wind directions determined?

L104: EC also has its limitations, "benchmark" seems a bit exaggerated

L106: Response time and sampling frequency are not the same. Response time should be given in seconds, sampling frequency in hertz. EC measurements require both fast response times and high sampling frequency.

L107: "CO2 and CH4 fluxes"

L108-109: Reformulate the sentence. EC does not calculate anything, and in this case

you are talking about gas fluxes explicitly (not e.g. heat flux since you mention mole fraction)

L113-114: Repetition from above

L115: "storage change flux". Out of curiosity, how large was the storage change flux? Often in lake studies they have been neglected but might be important as well.

L118-122: More description is needed on the processing methods used. How long was the lag time on average?

L122: What do the different flags mean (what are the criterion)?

L123: "Gradient flux method"

L130: units?

L135: How do you define the gradient method footprint?

L168: Shifting winds are also a problem for EC measurements!

L177-180: What are the units of these variables?

L181: Why are L and u* used as inputs, since u* is already used in calculating L?

L185: How close is "right beside"?

L188-195: More description needed

L196-199: Not understood where this is used (which methods) and why. More description please.

L202: "wind coming from" or "wind that came from"

L214: Sunsets and sunrises are not directly seen from Fig 4d.

L215-216: The same wind direction/ source area applies to gas fluxes. Why different wind direction analysis is applied to sensible heat fluxes and not the others?

L229: You can only see this from Fig 4c. What is meant by “species”? Methane?

L225-230: This is done for wind direction filtered data I assume? Should be clarified since all wind directions are analyzed in some way or another in this manuscript.

L230: This is not seen from Fig S3 (b), since you cannot see pond edges in the figure.

L231: “gradient flux”

L234: delete “however”

L235-240: But there is much more data from off-pond direction than from pond direction. How does influence the analysis?

L245-253: It is not clear why fluxes off-pond are reported since this is a study concentrated on pond emissions. Are these sectors processed in flux calculation individually or not?

L253-258: Are these now results from pond direction? Wind and turbulence are still driving the turbulent/diffusive transport of gases from pond to the atmosphere (e.g. Tedford et al., 2014).

L263-265: How do medians correlate? Take into account my earlier comments about representativeness as well.

L270-272: This is quite far taken conclusion. Based on the results here you can only say that EC fluxes were used to calculate Kc, which of course then correlates well with EC. . .

L272-274: And what were the outcomes of these studies? How do they compare to this study?

L278-281: Medians are actually not that different and means are within confidence intervals. Perhaps different time periods were used to calculate the averages of the two Sc’s?

L292: Above it is mentioned that the footprints are similar but here that they are different? How would the different footprint of the concentration measurement influence the flux?

L297: “Results of IDM fluxes..”

L297-298: Where is this shown?

L300: What are bubbling zones and where are they located? It comes as a surprise here that the chambers are not measured on the footprint of EC. If you measure bubbling zones with lots of ebullition, how is the chamber flux calculated? Don’t the bubbles bring sudden bursts of methane, invalidating the normal flux calculation methods?

L300-305: How are large the medians compared to average fluxes?

L332: replace “a month” with “five weeks”

L336: Lower than what?

L344: These are not comparable if not taken from same time periods and same footprints

L365: Excatly, different time periods are compared with each other making the method comparison useless in this form.

L383-386: In the equation there should be FCO2 and FCH4 instead of CO2 and CH4? These are results rather than conclusions. Abbreviation CO2eq is not defined and there are too many significant numbers in the result.

Reference list: Two references are not peer reviewed yet, and there are quite many non-peer reviewed reports included.

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