Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-369-RC2, 2018

Atmospheric Measurement Techniques Discussions

Interactive comment on "A UAV-based active AirCore system for accurate measurements of greenhouse gases" *by* Truls Andersen et al.

Anonymous Referee #2

Received and published: 3 January 2018

General comments

The paper reports on the development and on a field test of an UAV-based active AirCore system for measurements of greenhouse gases. The subject of the paper fits AMT perfectly; it describes a method that bears a lot of potential for future research on GHG fluxes on scales of 100's to 1000's of meters. It is an important contribution to this field of research and should thus be accepted for publication – but only if the comments below are adequately and fully addressed.

The presented tests, validation and field deployment are in my opinion sharp at the necessary minimum maturity for the paper to be accepted. The paper shows an interesting way forward, but fails to present a robust method/application for the time being. Only after additional work it will become clear for what applications and to what extent

an active AirCore can be used best. It is critical that this is clearly communicated in the Discussion and Conclusion parts of the paper.

I fully agree with Anonymous Referee #1 regarding the comment concerning Page 1/Introduction. Furthermore, writing style improvements are possible throughout the text; avoid using statements devoid of a clear meaning where they are not adding any information or the reader expects clear, often quantitative information. The resolution of the figures must be improved. Also, every figure must be readable also if printed on an A4 sheet of paper.

Specific comments and technical corrections

Note on Technical corrections: in some cases, I have marked a word or formatting only once, but make sure to apply the corrections throughout the text where relevant.

Page 1, Line 1 (1/1): the word "accurate" from the title is not backed up by the paper's content (see e.g. 1/24!) – acceptable title is:" A UAV-based active AirCore system for measurements of greenhouse gases"

1/10: in some places, you are describing too many detailed information for an abstract (e.g. tubing dimensions).

1/14: Replace "...sample atmospheric air in both vertical and horizontal planes." ...spatially sample atmospheric air."

1/16: delete "small" in "a small KNF micropump"

1/18: what is "... shortly after landing..."? for example use at least "not more than xx min after".

1/18: H2O should not be stated here; you are not calibrating for it, your sampled air is dried, it is not discussed in the text.

1/28: AirCore is not a platform – there are several platforms that would have access to locations you measure, but the question is what data and at what resolution it could

collect (and at what operational costs) – rephrase.

2/24: be clearer on the “vertical distribution” – I presume you are referring to the total column (as opposed to tall towers providing profiles, but only up to some 100’s of meters).

4/1: here some relevant references are missing (Khan et al. 2012, doi:10.3390/rs4051355 ; Kunz et al. 2017, doi: 10.5194/amt-2017-207; Watai et al. 2006, doi:10.1175/JTECH1866.1)

4/23: please define “lightweight”

4/29: be more explicit on the analyzer you have used

5/Table 1: is +- 1 g a meaningful information? Are the numbers after the comma for the vertical and horizontal resolution representative/funded in your calculations?

5/4: “inner diameter (ID)”, not “ID (inner diameter)”, same for 5/5

5/6: rather use “glue for ceramics”

5/11: unclear sentence – please rewrite. “in the laboratory.” implies that somewhere else, at another altitude this is different – clarify.

5/13: since you start describing the setup here, you should already here give details on the used hardware (e.g. pressure sensor type/model)

6/2: delete “product”

6/16: fox -> box

6/Fig 1: you can drop a and an before schematic and image. The photo should be cropped nearer to the box.

6/21: not necessarily true for H2O – delete this sentence; the relevant information on the analyzer’s precision is included in line 7/2

7/2: please clarify where you got the numbers for precision from.

7/4 and 7/6: how do you measure/monitor the flow rates?

7/8: There must be more details / figures related to laboratory tests in the paper as they are a corner stone for the validation of any method/measurement setup. You are testing a setup that later flies on an UAV, but have not done any tests where the pressure on the inlet side varies. How many experiments were there (several?)? How large was the variation of the measured trace gases? Also, the parameters measured during tests and flights (e.g. pressure) is nowhere shown – but should be.

7/27: quad copter -> quadcopter

7/31: how exactly was it attached/what was the position of the inlet? The position of the inlet is important as the sampled air is influenced by the rotors (also depending on the direction and speed of the movement – particularly at relatively low speeds as are 1.5-2.5 m/s that you discuss in connection with the resolution).

8/1: specify the hardware used (i.e., quick connects, rotary valve, solenoid valve,. . .).

8/3: What do you mean by “contamination of room air”?

8/17:”reference gas”? In Fig. 2 you have Cal and Fill gases, only – please clarify.

8/18: replace “chase” (with “push” or “ force”)

8/21: This leads to a well-defined sample between the two reference gas mole fraction values.

9/14: This cannot be correct – see GAW Report No. 229 (2016; on p. 6: ” The current scales are (as of June 2016): WMO CO2 X2007, WMO CH4 X2004A, WMO CO X2014A,. . .”) and edit accordingly.

9/Table 2: the WMO CO calibration range is currently 30-500 ppb; see also 9/14

9/8: please explain what you mean with “. . .to correct for the small nonlinearity if there

is any,...".

9/12: "$\frac{3}{4}$ ways" – why? (and it is a rise, not a dip). In general, explain the starting and ending point choices.

10/Fig.3: "H2O [%%]"?

11/9: a map shoving the station and enough surroundings to meaningfully support the description of the station/the field experiment described later in the text is missing here.

11/12 "situated directly behind" is unclear – how far is "directly"? (see previous comment)

11/13 unclear/wrong sentence - rephrase sentence.

12/3: "The observatory itself is surrounded by insignificant shrubs and grass." – what exactly are "insignificant shrubs"?

12/8: I guess you mean 60 m a.g.l.? Any references describing the Lutjewad station measurement setup that you could cite here?

12/18: replace "happened" with "took place"

12/19: instead of "right before sunrise", better state the exact time of sunrise on that day.

13/Table 3: mean speeds are misleading as there was also some hovering involved in some flights (see also 7/31).

14/Fig.5: zooming into area / time of interest (all graphs) and adding measurement points from Aircore would largely increase the usefulness of these plots.

15/Fig.6: same as for comment above .

15/4: Is the time lag due to the long inlet lines at the tower taken into account in your calculations?

16/Fig.7: The titles above the graphs are not necessary. What are the fine dots in 7.c? As the five flights were so few and different it is difficult to say anything concrete on the quality or interpretation of the flights (particularly on flight #1). I therefore strongly suggest avoiding highly speculative interpretation attempts (as in 18/6-9). Some retro trajectories might help (even if a trajectory does not explicitly give information of the fluxes), but that might be already beyond the scope of this paper. 7 a and b are so much zoomed out that we can only poorly evaluate the performance of AirCore vs. tower – Table 4 is more helpful – some discussion is needed on why flight #3 seems to be giving the "best fit" profile, judging from Table 4 (even if there was no data recorded on the SD card).

18/10: "Both the descending and ascending mole fraction profiles during all the flights compare well with the continuous measurements of CO2, CH4, and CO at 60 m and 7 m, indicating that the features seen during the first flight's CO2 profile is indeed real.": I cannot agree with this statement – the unexplained features of flight #1 are above the 60 m level. The fact that the measurements agree somewhat (not well) at 60 and 7 m does not imply that one knows what happened above 60 m – please rephrase.

18/19: from where did you obtain the information on the wind speed and direction (as the instrument on the tower was not recording this information)? For which altitude are the 2.5 – 3.0 m/s?

18/21: with what std.dev. for the mean mole fractions? And, you should state at first mention of "mole fraction" in the text that you are referring to "dry air mole fractions" (c.f. GAW Report No. 229, p.2)

18/30-31: mentioned already in 18/19-20

19/Fig.8: using the rainbow scale is not recommended (see e.g. https://www.climate-lab-book.ac.uk/2016/why-rainbow-colour-scales-can-be-misleading/ , https://www.poynter.org/news/why-rainbow-colors-arent-best-option-data-visualizations,etc.)

19/4: Chapter 3.5 is actually an attempt of validating the active Aircore measurements and could thus be part of Chapter 3.3.1. It is important to note that this “verification” is informative, but that it has only limited informative value for active flights, where the position of the UAV is changing (rapidly).

20/Fig.9e: there seems to be a clear trend – any ideas how to explain it? Could there be a systematic bias introduced during data processing?

20/7: do you mean transport delay and time constant?

21/20: how different are the uncertainties for CO2 and CH4 (having in mind their different molecular diffusivity)?

22/29: “This study shows the active AirCore’s ability to capture both vertical and horizontal trace gas profiles with high precision and accuracy.” I strongly disagree with this statement. Unless you find a definition of high precision and accuracy that fits your results, this sentence should be deleted/rephrased.

23/25: only cite what is published at time of writing

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