Review of Atmos. Meas. Tech. Manuscript (#amt-2019-439) "Calibration of an airborne HOx instrument using the All Pressure Altitude based Calibrator for HO_X Experimentation (APACHE)" by D. Marno et al.

General Comments

In this work, a new airborne HOx calibration system was developed and evaluated to mimic the conditions (e.g., varying pressure, temperature, and humidity) during a typical flight. This kind of work is important to determine the response of HOx instruments for the accurate airborne measurements of OH and HO_2, which is the key to understand the atmospheric photochemistry. A computational fluid dynamics model (COMSOL) was used to simulate the fluid dynamics in the calibrator. Two actinometric methods based on the photolysis of ozone and N2O (used in ground-based calibrator) were used to determine the actinic flux of the mercury lamp that is used to generate OH and HO2. Overall I found this manuscript needs major revisions. The difference in actinic flux measurement using the two methods is quite large. I would suggest conducting the actinic flux measurement in APACHE using the photolysis of N2O to rule out any uncertainties in transferring the ground calibration to airborne calibration. Section 5 is particularly lean and not well organized. More details and discussion should be included in this section (see details below). I also found many errors in equations and units and tried to point most of them out. Please check out the entire manuscript. I would ask the authors to consider the following special comments in their revision.

Special Comments

1. L.18: For ground-based HOx instruments … (remove systems)
2. L.26: Define COMSOL at its first appearance.
3. L.47: "Other methods have also been … (Remove "However")
4. L.48: the CIMS work by C. Cantrell and L. Mauldin should also be cited here.
5. L.61-69: Start this with a new paragraph. At the end of this paragraph (or maybe start a third paragraph), you might want to mention what was done in this work (e.g. establishment and evaluation of the APACHE, etc.)
6. L.75: Define APACHE at its first appearance in the main text even though you have defined it in the abstract.
7. L.92: Figure 2 (capital F). Please check this throughout the manuscript.
8. Fig. 1: "Controlled humidity airflow of 300 sccm": is the 300 sccm of humidified air is enough to vary the humidity in the total flow of 200-900 sL/min mentioned in L.105?
9. Caption of Figure 1: Maybe change it to "Overview of the APACHE system and the pre-mixing setup. A picture at the bottom shows the perforated stainless steel plates with wool mesh."
10. L.107: The word "respectively" is used but the air speed changes by a factor of less than 2 (0.9 to 1.5 m/s) while the pressure changes by a factor of 4 (from 250 to 1000 mbar). I understand the total mass flow rate was adjusted accordingly. Please clarify this and

maybe remove respectively and say the pressure **from** 250 **to** 1000 mbar. Also because of ram effect during flight due to the installation of a choke point in the shroud (L.131) , the ambient air pressure can potentially more than 1000 mbar. Have the calibration system tested a little over 1000 mbar?

11. L.168, **where,** $W_{z1\ pwr}$ is …
12. Eq. (1) and (2): I would suggest using [OH] and [HO_2] for OH and HO_2 mixing ratios or concentrations. Please check this out for the entire manuscript. Also it seems to me that the last term ($C_{OH(2)}/C_{OH}*S_{OH}$) needs to take the laser power in the first and second axes into account (unless $Wz1_{\ power}$ and $Wz_{2\ power}$ are the same, which is unlikely) and assume there is little OH loss between the 2 axes. The OH signal in the second axis ($S_{OH(2)}$) should be:

    $S_{OH(2)} = [OH]*C_{OH(2)}*Wz_{2\ power} = S_{OH}/(C_{OH}*Wz_{1\ pwr}) *C_{OH(2)}*Wz_{2\ power}$

    Please check and correct this.
13. L.179: I believe the term Wz_{pwr} the should be a denominator in Eq.(4) as the units for C_{OH} should be cts cm^3 $molecule^{-1}$ s^{-1} mW^{-1}. Also here cm^3 $molecule^{-1}$ is used, while in L.170 $pptv^{-1}$ is used. Please be consistent and check this out for the entire manuscript.
14. L.189: White cell (capital W)
15. L.199: again the units in the denominator are not correct because C0 has units of cts cm^3 $molecule^{-1}$ s^{-1} as mentioned in L.183, assuming S_{OH} has units of cts s^{-1}.
16. L.206: see the above comment for the issue of units.
17. Caption of Figure 3: **dash-dotted** blue line and **dashed** red line.
18. L.211: Table 1 (capital T)
19. L.213: change pure to purified.
20. L.241: the units for $F_{184.9\ nm}$ should be photons **cm^{-2}** s^{-1}.
21. L.288-289: were the air flow speed profiles measured at different pressures, e.g., such as pressures lower than 920 mb to simulate conditions at high altitudes during flight?
22. L.297: Spell out COMSOL.
23. L.309-315: the disagreement could also be due to the uncertainty in the COMSOL model simulation.
24. Figure 6: the air flow speed within APACHE is really unified, even close to the wall. This is good.
25. L.316: do you mean discrete instead of discreet?
26. Caption of Figure 7: “The black arrows depict the flow direction.” It is hard for me to see those arrows. Maybe include a big arrow on each plot to show the flow direction instead?
27. L.361: Please add “In Table 2” at the beginning of this sentence.
28. L.362: streamline (remove s or use streamlines in other places)

29. L.366: **F**igure 8 and **T**able 2
30. L.368: **On** the APACHE walls.
31. L.377: "between **the lamp** and a quartz wall" to be clear.
32. L.392-392: Martinez et al., 2010 is referred here, but I think at least a brief description of the ground-based calibration system should be given, especially the method to determine the actinic flux of the Hg lamp using the photolysis of N2O to provide the context for Table 3. Otherwise readers may have no idea why NO monitor/N2O cross section are suddenly mentioned in Table 3.
33. Later I found the difference of the two methods is quite large (~20%). I wonder if it is possible to conduct the actinic flux measurement in APACHE using the photolysis of N2O directly so that any uncertainties in transferring the ground calibration to airborne calibration will not affect this difference.
34. L.397: "…when the smaller 0.8 mm critical **orifice** was used."
35. L.418: Do these OH and HO_2 occur inside APACHE during the transport of air flow from the UV radiation zone and HORUS inlet? Please specify.
36. L.426: Duplicate definition as this has been defined in L.235.
37. L.457: units for F_β should be photons cm^{-2} s^{-1}.
38. L.458: Table 3 should be referred here.
39. L.459-460: Martinez et al., 2010 should be referred here.
40. Section 5: Results and Discussion: this section is very lean. Some results in Section 4 could go into this section (e.g., the results for the two methods to determine the Hg lamp actinic flux). There is also no mention how the individual measurements of overall sensitivity (1^{st} row of Figure 10) are used to calculate OH and HO2 mixing ratios in the real airborne measurements. For example, the HO_2 sensitivity in the 2^{nd} axis varied by a factor of 2 (20 vs. 10 cts/s/pptv/mW) at the internal density of 1.5E17 cm^{-3}. What sensitivity to use for the real measurements with internal densities between these two calibration points? Also any plan/future work to conduct more calibrations to get a better statistics and possibly to draw a smooth calibration fitted line as a function of internal pressure as shown in Figure 3?
41. L.489: Table 6 is mentioned before the appearance of Table 5.
42. L.495: "…resulting in **the transmission** for both OH and HO_2 to be…"
43. L.498: ".. the time it takes **for** air to flow…"
44. L.522-526: this paragraph is out of the context of this section. I would suggest moving this paragraph and some actinometric results in Section 4 to a new subsection of 5.2.
45. L.524-526: Again units for F_β should be photons cm^{-2} s^{-1} or cm^{-2} s^{-1}.
46. Again I would suggest conducting the actinic flux measurement in APACHE using the photolysis of N_2O directly.
47. Section 5.2. Absolute Calibration Uncertainty: this section is very lean and more discussion can be included

48. L.531: **T**ables 5 to 8.
49. Table 5: units for F_β should be photons cm^{-2} s^{-1} or cm^{-2} s^{-1}. Also a temperature range of 282-302 K is given but no mention in the text how it was varied within APACHE.
50. Table 7: this should go Section 5.1 where transmissions are discussed.
51. Table 6 and the 3rd row in Figure 10: details about how the term cN* internal density is calculated/measured should be given.
52. L.559, and 562: the actinic flux of the mercury lamp should be photons cm^{-2} s^{-1}.
53. Figure 10: the 1st row: the units should be cts $\mathbf{s^{-1}}$ $pptv^{-1}$ mW^{-1}.
54. Figure 10: "Row C is (C) is internal density and cN". Do you mean "Row C is the product of internal density and cN"? I don't understand how cN is calculated.