**Review of AMTD-8-13525-2015**

**General Comments**

This paper clearly and concisely describes a new instrument, AIMS-H2O, for the in situ detection of water vapor in the upper troposphere and lower stratosphere (UTLS). The physical details, calibration procedure, detection methodology, data evaluation, sources of uncertainty, and flight performance are discussed in detail. Apart from a few comments/concerns enumerated below, the paper is well ordered, and well written. I recommend publication after revision.

**Specific Comments/Concerns**

1. The authors' correctly state that the largest percentage differences have been observed at the lowest mixing ratios encountered in the UTLS. The critical range is typically below 10 ppmv.
   **Suggestion:** If the performance at and below 10 ppmv is a point of emphasis, it would be worthwhile showing a second calibration curve that concentrates on values centered around 5 – 10 ppmv. The inset in Figure 6 of Thornberry et al., 2013, and the in-flight calibration cycle shown in Figure 9 of the same paper are good examples.
   Also, there is a significant degree of noise/variability (white and non-white) in the $Pt/H_2$ reference standard evident in Figure 6 (top panel). This is most evident at the lowest mixing ratios.
   **Question:** Does this variability in the reference – ~±1 ppmv at a mixing ratio of ~1.5 ppmv – limit the accuracy of the calibration at low mixing ratios?

2. The accuracy of the AIMS measurement is directly dependent upon the $Pt/H_2$ transfer standard, which in turn requires regular calibration with respect to a primary reference standard. In this case, an MBW 373-LX frost-point hygrometer.
   a. The authors do an excellent job identifying and discussing sources of measurement uncertainty and bias, in particular, discovering that ion transmission through the quadrupole is dependent upon the temperature of the aircraft cabin. This is an excellent demonstration of differences between the flight and laboratory that cannot be anticipated. It also emphasizes the necessity of in-flight calibration with respect to the $Pt/H_2$ source, as calibrations of AIMS performed on the ground are NOT valid in flight. Thus, it is absolutely essential that the accuracy of this source be established and shown.
      The authors provide a thorough description of the uncertainties and nonlinearities of the $Pt/H_2$ transfer standard, e.g., its dependence upon temperature, flow rate, exposure time, and history of use, but then do not provide sufficient quantitative analysis/evidence of its accuracy and performance with respect to the MBW.
      **Suggestion:** The paper would benefit greatly from the inclusion of a figure showing calibration data for the $H_2/Pt$ transfer standard along with the empirical fit, an indication of the stability of its calibration over time, and a discussion of accuracy that is more than "the total accuracy of the calibration source is around 6%."
      **Question:** Also, given that the stability of the catalyst is the largest source of uncertainty, how frequently is the $H_2/Pt$ source calibrated?
   b. **Suggestion:** Despite the fact that the calibration/performance of AIMS changes in flight, an end-to-end demonstration of its success in the laboratory would also help to validate the overall approach, e.g., showing:

i. empirical determination of $H_2$/Pt performance with respect to the MBW (as suggested above)
ii. calibration of AIMS on the ground with the $H_2$/Pt (could be combined with the low water suggestion earlier)
iii. verifying AIMS performance through simultaneous measurement by AIMS (using $H_2$/Pt calibration) and MBW (i.e., add a figure like Figure 8 of Thornberry et al., 2013)

c. **Question:** What is the direction of the error introduced by the temperature dependence?
**Question:** I presume the direction of desorption is predominantly a high bias?
**Question:** Is there evidence of desorption/hysteresis after takeoff?
**Question:** Is there evidence of hysteresis after thick cloud encounters?
**Question:** Is it possible to speculate why Thornberry et al., 2013, saw an effect with $CO_2$ and AIMS does not?
**Suggestion:** The paper would benefit by a table, similar to Table 2 of Thornberry et al., 2013, that summarizes and quantifies the different sources of uncertainty.

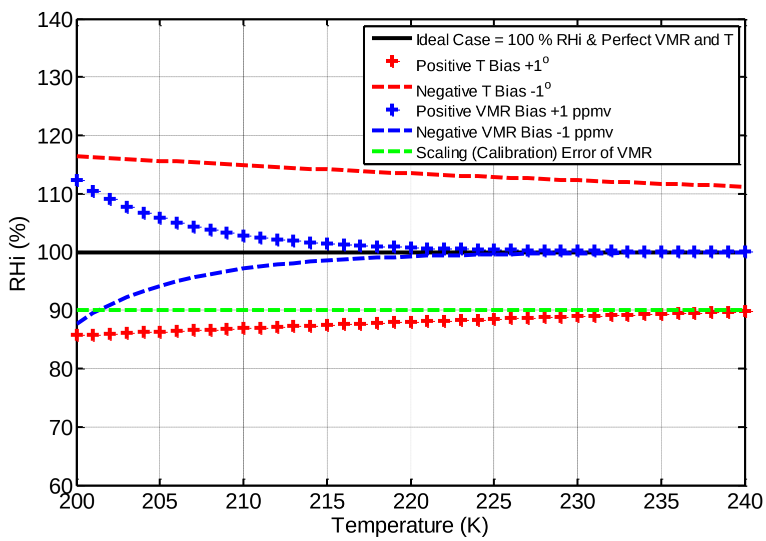
3. The use of dual methods of determining the water vapor mixing ratio is clever, particularly as the methods complement each other with different strengths in different mixing ratio ranges. (And it appears that differences between these two methods aided the discovery of the temperature dependence.) The requisite agreement between the two methods also provides a means of corroborating the accuracy of the measurement.
**Suggestion:** Would it be possible to show explicitly/quantitatively how well these methods agree in flight with a time series plot and/or a regression analysis?

4. **Question:** When calibrating in flight I presume the calibration flow is sufficient to halt any sample flow from the atmosphere?
**Suggestion:** If so, you might add a sentence or two about this.

5. Figure 10 shows the good broad-scale linear agreement between the two instruments.
**Question:** Was the linear fit done on the raw data or on the log of the data? In other words, do the slope and intercept shown on the figure mean that AIMS = 0.99961xSHARC+0.001, or that log(AIMS) = 0.99961xlog(SHARC)+0.01?
   a. The biggest concern here is that log-log plots hide detail that can matter when evaluating the agreement between a pair of instruments. Indeed there are some significant trends/differences evident at both the high and low ends of the scatter plot that suggest that the agreement at any given time during a flight can be significantly greater than the implied agreement of ~1% and 0.01 ppmv. (See also the data shown in the time series of Figure 9.) The combination of Figures 2 and 3 of Rollins et al., demonstrates the degree to which significant systematic differences between pairs of instruments can be buried in a log-log plot and composite fit.
   **Suggestion:** A figure like that of Rollins et al., 2014, Figure 3, would provide a more detailed exposition of the agreement between SHARC and AIMS.
   b. Additionally, it is informative to quantify the uncertainty of the fit. Certain linear fitting algorithms have the capability of estimating uncertainty in the fit parameters that arises due to uncertainties in both the x and y datasets. This might constrain the number of significant figures you report for the fitted slope.
   c. **Question:** What is the stated accuracy of SHARC?

**Suggestion:** This number should be cited, since you conclude that the disagreement between AIMS and SHARC during the first segment of the 7 April 2015 flight is within their combined uncertainty.

6. **Question:** Despite being within the uncertainty limits, is the fact that the RHi is consistently 90% during the dense homogenous cloud segment cause for concern? Could this sustained difference from thermodynamic equilibrium suggest the presence of a systematic error, i.e., calibration error of the water measurements, or (maybe more likely) bias in the temperature measurement?
A plot of RHi as a function of cloud IWC, as well as a plot of RHi as a function of temperature would be interesting. These figures aren't necessary for the publication, but might provide evidence for the discrepancies, i.e., 1) the difference between SHARC & AIMS during the heterogeneous cloud encounter; and 2) the difference between the measured RHi and the expected value of 100%. (The figure below illustrates how different measurement errors can impact observed RHi.)




**Technical Corrections:**

1. page 13526, line 5, suggested wording: "…the role of $H_2O$ in the UTLS energy budget…"
2. page 13527, line 14, insert "the": "In Part 2… the setup…"
3. page 13527, line 21, suggested wording: "…greenhouse gas and engages in a positive feedback with changes in long-lived…"
4. page 13526, line 27, change "in" to "on": …offsets on the order of…
5. page 13528, line 9, suggested wording: "…radiation budget including the effect of clouds…"
6. page 13528, line 15, remove "partly": "…but still above…"
7. page 13528, line 24, replace upper troposphere and lower stratosphere with UTLS: "…mixing ratios of the UTLS."
8. page 13529, line 4, suggested new paragraph starting with "In this work…"
9. page 13529, line 7, suggested wording: "Second, we present the in-flight calibration setup that is used to assure accurate and reliable airborne measurements, and evaluate its performance."

10. page 13530, line 14, suggested wording: "The one directly at the TGI is used to add calibration gas, and the second one is used for optional dilution of the flow with dry synthetic air."
11. page 13530, line 6, suggested wording: "The dilution flow is added…"
12. page 13536, line 1, typo: "…is shown in Fig. 4."
13. page 13538, line 21, replace "already" with "is": …(R1-R4) is completed"
14. page 13542, line 16, add comma: "…around 5 ppmv, which…"
15. page 13545, line 4, suggested wording: "AIMS-$H_2O$ flew on the DLR Falcon…"
16. page 13547, line 8, replace "sucked in" with "drawn in" or "sampled"?
17. page 13547, line 14, remove "a": "…established by regular in-flight calibration…"
18. page 13547, line 18, remove "directly" and add comma: "…15 ppmv, we use the count rate…"
19. page 13547, line 20, remove "a", and "other": "…provides better data quality. Major contributors to…"
20. page 13547, line 26, remove "a" and add commas: "…showed reasonable agreement, within ±10 %, for most of the data."
21. Page 13548, line 1, suggested wording: "…proved to be well-suited to contrail and…"
22. Figure 2. Suggested wording, add "through": "…inlet and passes through a pressure regulation…"
23. Figure 4. Suggested wording, change "the" to "a" and change "ist" to "is": "A resistance of 500 MOhm is…"
24. Figure 7. The y-axis label does not match the text or the units of ES. Should it be $ppmv^{-1}$?