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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Two decades of water vapor measurements with the FISH fluorescence hygrometer: a review" *by* J. Meyer et al.

Anonymous Referee #3

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General Comments:

This paper provides a review and update of the measurement principle, calibration methodology, and laboratory and in-flight performance of the aircraft-borne Fast In-situ Stratospheric Hygrometer (FISH), which has been making measurements of upper tropospheric and lower stratospheric water vapor for nearly two decades. Over this period, FISH and the FISH team have a played a significant role in understanding the factors that control UT/LS water vapor concentrations, as well as to advancing measurement accuracy. This paper is the next in the line of valuable contributions from the FISH team.

Thorough documentation of measurement methodologies and calibration procedures

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in the peer reviewed literature is essential to establishing credibility within the scientific community. The advancements in the calibration procedure, i.e., the comparison of the commercial reference instrument to international standards, and the re-examination of, and improvements to the FISH calibration process, constitute significant steps in the community-wide effort to improve the accuracy and reliability of water vapor measurements.

The authors also revisit the accuracy of past measurements within the context of the recent modifications and utilize comparisons with other in situ and satellite instruments to demonstrate the general consistency and reliability of FISH over its decades-long history. As such, the manuscript is important for those that utilize in situ measurements for satellite validation, trend detection, model verification, etc.

The presentation of the manuscript is excellent. It is well organized and the analysis and results are clearly communicated and contextualized. Comparisons with other instruments are handled in an appropriate and balanced way.

Specific Comments/Questions

1) Just to make sure I understand: Eqn. 3 accounts for the outgassing component at low flow rates, and low humidities, and Eqn. 4 accounts for the time response of the PMT, which becomes an issue at high pressures and high humidities (i.e., high water vapor number densities = high count rates).

Figure 5a shows that for the outgassing correction, the data at all but the highest pressure setpoints are reduced with the correction. This makes mechanistic/physical sense, as outgassing within the FISH cell leads to a higher signal than that measured by the reference instrument.

At the highest pressure setpoint, however, the FISH data increase with the correction. Is there a physical explanation for the increase, i.e., P > Peq and you are correcting for water uptake on the walls? Or is this a result of the new calibration constant, fu?

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Similarly, I am confused by the results of Figure 5b. The largest DT (PMT count rate) correction is for the lowest water vapor number densities (i.e., lowest cell pressures) and the correction decreases with pressure. I would have expected the opposite pressure dependence since the fluorescence signal is correlated with the number of water molecules in the duct. NOTE that for an equivalent mixing ratio the number of water molecules will be greater at higher pressures. As the authors state on Page 7745, Line 5+: "Thus the time between subsequent counts detected by the PMT becomes shorter with a higher amount of water vapor molecules in the air."

Adding to my confusion is the statement on Page 7745, Line 16-17 that at UT/LS pressures, which are low, this DT effect on FISH is negligible. Again, Figure 5b shows the largest correction to the data at pressures in the UT/LS range. (Perhaps there is something else that I'm not understanding.)

2) You might (though it's not necessary) add a sentence in the text that provides an estimate of the percentage difference in VMR resulting from the temperature discrepancy discussion on page 7747. (You show % differences in Figure 6, but an additional sentence in the text on page 7747 might be helpful.)

3) The correction for outgassing in FISH during AquaVIT-1 (discussed at the bottom on Page 7756 and shown in Figure 11) is somewhat confusing. For the run shown in Figure 11b, which examined the lowest mixing ratios (i.e., $\sim$0.3 – 2 ppmv), the corrected FISH values are raised at every pressure/mixing ratio setpoint. One would expect that correcting for outgassing in FISH would lead to a reduction in the measured values, not an increase. That is, to match the values supplied by the chamber the outgassing contribution should be subtracted.

I'm guessing that the explanation is that the calibration factors for FISH changed, leading to a subsequent change in the measured values at low mixing ratios.

What were the flow rates through FISH during the AIDA experiments? Were they sufficient to ignore contributions from outgassing?

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4) The MLS documentation has a guide to comparing high resolution data sets with the retrieved satellite profiles. https://mls.jpl.nasa.gov/data/v3-3_data_quality_document.pdf Were MLS averaging kernels – or some other appropriate averaging technique – actually applied to the FISH data in the comparison? (There was a brief mention of averaging kernels on page 7757, but it's not clear if they were utilized in the following discussion or figures.) At the very least, the present analysis should consider this approach and see if it changes the results in any significant way.

Technical Corrections/Idiomatic Suggestions

1) The wording of the first sentence of the abstract is awkward.

2) Page 7737, line 7. Replace "for" with "of": "A crucial part of the FISH measurement. . ." (Alternative: Crucial for FISH measurement. . .)

3) Page 7737, line 12. Delete "also": ". . .stated in previous publications."

4) Page 7738, lines 20-23. Eliminate "As a side note": "Krämer et al. (2009) investigated this "supersaturation puzzle" with the FISH measurements. They applied a quality check procedure to the in-cloud supersaturation measurements and were able to explain all valid supersaturations with established microphysics."

5) Page 7739, line 8. Replace "percents" with "percent", etc. : ". . .differences may be on the order of several tens of percent (Fahey et al., 2014; Weinstock et al., 2009), thus exceeding. . ."

6) Page 7740, line 22. Replace "a" with "an": ". . .water molecules are split into an excited OH. . ."

7) Page 7741, line 21. Replace "factors" with "factor": "The pressure dependent Kf factor considers non-radiative. . ."

8) Page 7743, line 1. Replace "with" with "of": "Since in the field the supply of dry air. . ."

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9) Page 7744, line 9. Eliminate “is”: “. . .flow rate through the cell and the smaller. . .”

10) Page 7744, line 13. Replace “vanish” with “vanishes”: “. . .where the partical pressure difference vanishes.”

11) Page 7744, line 17. Add “by”: “. . .can be accounted for by including. . .”

12) Page 7745, Line 25+. You might add a little more text: “When the calibration data are evaluated with the two additional correction factors, the calibration factor ck changes very little. . .”

13) Page 7746, Line 20. Replace “Firstly” with “First”: “First, the. . .”

14) Page 7746, Line 21. Eliminate “from time to time”: “. . .manufacturer to be recalibrated. . .”

15) Page 7748, Line 7. Replace “inputn” with “input”: “. . .to depend on the pressure at its input (pre-pressure).”

16) Page 7748, Line 13. Replace “depict” with “depicts” or alternative “illustrates”: “This illustrates the lower and upper uncertainty. . .”

17) Page 7749, Line 22. Add “measured”: “. . .the uncertainty of the measured WVMR. . .”

18) Page 7750, Line 27. Change wording. “. . .the Lyman-α radiation is more strongly absorbed. . .”

19) Page 7751, Line 10. Change H2Otot to WMR for consistency with the rest of the text: “Thus, these high WMR in thick cirrus. . .”

20) Page 7751, Line 18. Replace “distinct” with “distinguish”: “. . .is to clearly distinguish. . .”

21) Page 7754, Line 20. Replace “were” with “was”: “. . .humidity or temperature) was found.”

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22) Page 7756, Line 8+. Wording changes: “The value of these sub 1 ppmv AIDA measurements is questionable when considering the atmospheric measurements, since mixing ratios this low at the high pressures used in AIDA never occur in the atmosphere, and as such are outside the design parameters for the in situ instrumentation.”

23) Page 7756, Line 18. Add “absolute”: “. . .where the largest absolute discrepancies occur. . .” Actually, I have a question about this. . . are these also the largest relative, i.e., percentage differences as well? If so, you could instead say: “. . .where the percentage differences occur. . .”

24) Page 7757, Line 17. Remove “exemplarily”: “Figure 13 demonstrates. . .”

25) Page 7757, Line 22. Remove “for”: “Because of the MLS averaging kernel, . . .”

26) Page 7757, Line 25+. Wording: “Differences are between $\pm$2 ppmv at the low water vapor concentrations found in the stratosphere (typically less than 10 ppmv).”

27) Page 7757, Line 28. I suggest rephrasing this sentence: “. . .and are therefore approximately $\leq$ 10% at the. . .”

28) Page 7758, Lines 2-3. Wording: “This slightly higher value was observed at high latitudes during the Reconcile campaign, and appears to be a MLS retrieval artifact. . . .Similar deviations of -0.2 to -0.7 ppmv are found for all campaigns at the 100 hPa MLS level (not shown). Overall, Fig. 13 demonstrates the excellent agreement between FISH and MLS water vapor measurements over six-year period from 2005 to 2011.”

29) Page 7758, Lines 11-12. Wording: “. . .during numerous campaigns. The large dataset, compiled over this decades-long interval, affords a unique perspective from which to evaluate the performance of FISH. We have now reassessed. . . “

30) Page 7758, Line 18. Eliminate also: “. . .evaluation which now accounts for high. . .”

31) Page 7758, Line 26-27. Wording: “During the last two decades, FISH has had many opportunities to compare with other in-situ hygrometers. In fact, some cam-

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paigns were partly dedicated to assess hygrometer performance, like the MACPEX campaign. . .”

32) Page 7759, Line 14. Wording: “. . .in-flight and remote sensing instrumentation demonstrate the ability of FISH to precisely and reliably measure water vapor in the UT/LS.”

33) Page 7759, Line 20+. Wording: “He devoted all his efforts towards improving the FISH (see Fig. 1) instrument making it one of the leading instruments for measuring the low water vapor content of the stratosphere. His efforts contributed to developing a better understanding of the transport mechanisms and variability of water vapor in the UT/LS.”

Interactive comment on Atmos. Chem. Phys. Discuss., 15, 7735, 2015.