

Interactive comment on “Recent divergences in stratospheric water vapor measurements by frost point hygrometers and the Aura Microwave Limb Sounder” by Dale F. Hurst et al.

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The authors would like to thank the referees for their constructive comments, as these were helpful in improving this manuscript. Below, we provide reviewer’s comments, our detailed responses to each comment and any manuscript changes warranted by the reviewer’s comments.

1 Overview Reviewer Comment: This paper considers two very different sets of measurements of water vapour in the lower stratosphere. One set of measurements is made with a satellite instrument, MLS, the other is made with frost-point hygrometers carried on balloons.

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The paper notes that there are statistically significant differences between these two sets of data and that those differences have changed over time. This result needs to be reported in order to prevent over-interpretation either of the two datasets, so the paper should be accepted for publication, subject to some minor revisions. There are a few technical corrections to be made, but they are small; the paper is very clearly written and the figures are, for the most part, clear and easy to interpret.

Where the paper is lacking is in any explanation of the reported differences. Now, I recognise that:

(1) The authors can not produce an explanation out of thin air. (2) The publication of the observation should not be held up while we wait for an explanation to be forthcoming. (3) It is not valuable for the paper to include a lot of baseless speculation as a substitute for an explanation.

Author Comment: We agree with your opposition to adding speculative causes of the MLS drift (i.e., without hard evidence) to the manuscript, and your discouragement of a delay in the publication of this manuscript until the causes is discovered. We have added a short paragraph describing ongoing work by the MLS team to find the cause.

Author Revision: The following text has been added to the manuscript:

“The MLS team is actively exploring multiple avenues in their investigation of possible instrumental behaviors that might lead to water vapor measurement drifts of the magnitudes documented here. For example, the relationship between the MLS “standard” O3 product, measured in the 240 GHz region and shown to be very stable (Hubert et al., 2016), and a secondary MLS O3 product obtained from the same 190 GHz spectral region used for the water vapor measurements is being closely examined. At this stage it is premature to offer conclusions from these studies.”

Reviewer Comment: It would nevertheless be an improvement on the paper if it were possible to make any further factual statements on the possible causes of the differ-

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ences. Were there any secular changes in temperature over the measurement period, for example? If so, how clearly decoupled are the two water vapour measurements from the temperature? Is it possible to eliminate temperature changes as a potential cause of the differences observed in water vapour? It would be nice if the authors were able to address this kind of question rather than leaving it hanging. But if there is nothing to be said, then the paper should be left as it is.

Author Comment: Thank you for this suggestion. If there is one potential cause of the widening FP-MLS differences we can rule out, it is a change in atmospheric temperatures. The magnitude of drifts in MLS retrievals would require a very strong trend in atmospheric temperatures that is not observed by MLS or other instruments. We have added a short paragraph describing this.

Author Revision: The following text has been added to the manuscript:

“Given the known sensitivities of MLS retrievals to atmospheric temperature changes, an annual drift of 1% in water vapor retrievals would require a steep temperature trend of 2.5K/yr that is not observed in the temperature retrievals of MLS or other instruments. Such a temperature trend would also manifest itself as drifts in the MLS retrievals of other atmospheric constituents, like ozone, that are absent from the measurement records. Frost point hygrometers are stable over a wide range of atmospheric temperatures (-80° to 30°C) because their electronics are well insulated and their measurements are independent of atmospheric temperatures. It is therefore highly unlikely that atmospheric temperature changes are driving the observed drifts in MLS retrievals or FP measurements of water vapor.”

Reviewer Comment: A point which is worth my making here, and which should arguably be noted briefly in the paper, is that the ACE-FTS instrument provides a third set of data covering the same period. There are currently no ACE-FTS data available for dates after March 2013, but I am reliably informed that this is not because the instrument has ceased working. Rather, it is due to a software issue which has every

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prospect of being solved. The paper reviewed here does not need to wait for the updated ACE-FTS data. However, we may hope that the ACE-FTS data might allow a future paper to provide answers to some of the questions posed by the paper reviewed here.

Author Comment: We are in contact with the ACE-FTS team and eagerly await the release of the ACE-FTS data for dates after March 2013. From what we hear their goal is to make these data available by the end of 2016.

Author Revision: None required

2 Minor revision Reviewer Comment: The conclusions section should contain some conclusions on the rest of the paper. Currently, it contains only the point that both sets of measurements will come to an end soon and there are no firm plans in place to replace them. This point is extremely important and is not restricted to water vapour; measurements of many other chemical species in the upper troposphere and the middle atmosphere will come to an end with the forthcoming demises of the Aura and SciSat-1 (ACE) missions. However, the conclusions section of the paper should sum up the results of the paper as briefly as possible as well as making this point.

Author Comment: This is a reasonable point so we added text to the conclusions section to summarize the results of the paper.

Author Revision: The following text has been added to the manuscript:

“Recent, significant divergences in stratospheric water vapor measurements by balloon-borne frost point hygrometers (FPs) and the Aura Microwave Limb Sounder (MLS) are reported for 4 globally-distributed FP sites: Lindenberg, Germany, Boulder, Colorado, Hilo, Hawaii and Lauder, New Zealand. These sites employ two types of FPs with different manufacturers, calibration, frost control parameters and data processing. The rates of divergence from ~2010 to mid-2015 range from 0.03 to 0.07 ppmv yr⁻¹ (0.6 to 1.5% yr⁻¹), similar in magnitude to the ~1% yr⁻¹ average growth rate of strato-

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spheric water vapor observed over Boulder during 1980-2010 (Hurst et al., 2011). By mid-2015, the FP-MLS differences at some sites were large enough to exceed the 5-8% (1σ) combined accuracy estimates of the FP and MLS measurements.”

3 Technical corrections Reviewer Comment: In figures 3 and 4, the blue and green colours in the left-hand panel are rather hard for the eye to separate, especially on a paper copy read in artificial light.

Author Comment: We want the figures to be very clearly readable and therefore changed the color scheme of all figures to better separate the Boulder (blue) and Lindenberg (now red) data that appear in the same panel in Figures 3 and 4.

Author Revision: We now use red for Lindenberg data and green for Lauder data in all figures.

Reviewer Comment: In figure 5 I am not entirely convinced by the use of letters as data points. Well designed data points have an obvious centre which a plotting program will place at the right point. Letters do not have an obvious centre. The authors should at least consider replacing S, C, and E with something along the lines of a filled circle, an open circle and a square.

Author Comment: We agree that the use of letters as symbols in figure 5 is not visually exacting. Letters were used to aid the reader in remembering which symbols represent the “start”, “change point” and “end” values without having to consult the caption. These have been changed.

Author Revision: Symbols representing the “start”, “change point” and “end” values have been changed to open circles, asterisks and filled circles (i.e., increasing marker density with time) to improve the readability of the figure.

Reviewer Comment: In a number of places (Page 3 line 30, Page 4 line 32, Page 5 line 11) the word likely has been used as an adverb. The word likely, despite ending in the letters ‘ly’, is an adjective and is synonymous with probable. If you want the equivalent

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adverb, you have to use probably. The use of likely as an adverb is a common colloquialism but has, in my personal opinion, no place in good written English. (I accept that this is an issue on which I am fighting a losing, rear guard action.)

Author Comment: My grammatical “pet peeve” is the use of “data” as a singular noun (e.g., “the data is”), also a losing battle, so I sympathize with your comment.

Author Revision: Three instances of “likely” used as an adverb have been replaced with “probably” or “presumably”.

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2016-157, 2016.

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