Responses to Comments from Anonymous Referee #2

We wish to thank this reviewer for their helpful review. We first copy the comments of the reviewer **(in bold)** with our response below. In cases where the text is modified, we show both the original text and the revised text, with the significant changes shown in blue.

General Comments:

The paper is a very interesting and indeed necessary contribution to investigate the atmosphere based on occultation measurement technique by exploiting the microwave capacity. It describes in detail the ground based experiment by detecting water vapour with microwave signals under clear too very turbulent conditions as pre-study to a microwave occultation satellite mission. Besides a detailed results description an error and validation discussion was done. The discussion in the appendix about the difficulty or even impossability to in-situ validate such an experiment rounds up the paper. I recommend the paper for publication with minor revisions.

In this paper the low band signal is only used to determine whether there are small water particles present or not but it apparently is not used for the retrieval of water vapor, which is done only for the high band signal (Fig. 2). It is though claimed that to derive the water vapor content under stormy conditions when the high band becomes opaque, the low band is needed but it is not done for this experiment.

Did you get results on the 8 fixed frequencies at the 22 GHz region to investigate the heavy rain situation at 15:30, since for such heavy weather situation sufficiant attenuation occured?

Unfortunately, we determined that the measurements taken at the 8 fixed frequencies near 22 GHz on this day could not be used to make accurate retrievals for water vapor. The main reason is that the path length (of only 5.4 km) is too short for accurate determination of water vapor using the weak 22 GHz line as the absorption is so small. While the liquid absorption was strong during the heavy rain period, the additional absorption due to water vapor is quite small across the 22 GHz band.

Specific Comments:

p. 2, line 16—20: Please give a reference to the RO technique including the specifications/limits of this remote technique. Please give references for other studies on microwave occultation technique pre-studies too.

To address this comment, we propose making some wording changes and adding additional references to the two consecutive paragraphs that begin on page 2, line 15.

Original text:

GPS radio occultation (RO) has become an important data source for numerical weather prediction (NWP), despite its relatively sparse coverage to date [e.g., Cardinali and Healy, 2014]. Its high impact comes from its unique combination of ~200 m vertical resolution, all weather sampling and very low random and absolute uncertainties via its direct connection to atomic frequency standards. GPS RO profiles atmospheric refractivity. Two limitations of GPS RO are

(1) its inability to separate the dry air and water vapor contributions to refractivity and (2) its insensitivity to water vapor in the colder regions of the troposphere and above.

In recognition of the strengths and weaknesses of GPS RO and radiance measurements and the need for better information about water vapor, in 1997 research groups at the University of Arizona and the NASA Jet Propulsion Laboratory (Herman et al., 1997 and Hajj et al., 1997) identified and began developing an RO system that is now called the Active Temperature, Ozone and Moisture Microwave Spectrometer (ATOMMS), which is designed to overcome these limitations by transmitting and receiving signals between satellites in low Earth orbit (LEO) near the 22 and 183 GHz water vapor absorption lines as well as nearby ozone absorption lines. Profiling both the speed of light like GPS RO as well as the absorption of light, which GPS RO does not measure, enables ATOMMS to precisely profile temperature, pressure and water vapor simultaneously from near the surface to the mesopause (Kursinski et al., 2002). It will also profile ozone from the upper troposphere into the mesosphere, scintillations produced by turbulence, slant path cloud liquid water and detect larger cloud ice particles, with approximately 100 m vertical resolution and corresponding 70 km horizontal resolution (Eq. 13, Kursinski et al., 1997). Kursinski et al. (2002) found that such a system could provide water vapor retrievals with a precision of 1 – 3% from near the surface well into the mesosphere. Kursinski et al. (2009) estimated the degradation in clouds would be less than a factor of 2.

Revised text, with changes shown in blue:

GPS radio occultation (RO) has become an important data source for numerical weather prediction (NWP), despite its relatively sparse coverage to date [e.g., Cardinali and Healy, 2014]. Its high impact comes from its unique combination of ~200 m vertical resolution, all weather sampling and very low random and absolute uncertainties via its direct connection to atomic frequency standards and relatively simple and direct retrieval method. GPS RO profiles atmospheric refractivity. Two limitations of GPS RO are (1) its inability to separate the dry air and water vapor contributions to refractivity and (2) its insensitivity to water vapor in the colder regions 20 of the troposphere and above (e.g., Kursinski et al., 1997; Kursinski and Gebhardt, 2014).

In recognition of the strengths and weaknesses of GPS RO and radiance measurements and the need for better information about water vapor, in 1997 research groups at the University of Arizona and the NASA Jet Propulsion Laboratory (Herman et al., 1997 and Hajj et al., 1997) identified and began developing an RO system that is now called the Active Temperature, Ozone and Moisture Microwave Spectrometer (ATOMMS), which is designed to overcome these limitations by transmitting and receiving signals between satellites in low Earth orbit (LEO) near the 22 and 183 GHz water vapor absorption lines as well as nearby ozone absorption lines. Profiling both the speed of light like GPS RO as well as the absorption of light, which GPS RO does not measure, enables ATOMMS to precisely profile temperature, pressure and water vapor simultaneously from near the surface to the mesopause (Kursinski et al., 2002). It will also profile ozone from the upper troposphere into the mesosphere, scintillations produced by turbulence, slant path cloud liquid water and detect 30 larger cloud ice particles, with approximately 100 m vertical resolution and corresponding 70 km horizontal resolution (Eq. 13, Kursinski et al., 1997). Kursinski et al. (2002) found that such a system could provide water vapor retrievals with a precision of 1 – 3% from near the surface well into the mesosphere. Kursinski et al. (2009) estimated the degradation in clouds would be less than a factor of 2. A summary of LEO to LEO occultation measurement concept studies and demonstrations to date at microwave and IR wavelengths is given in Liu et al. (2017).

The following two new references will be added to the reference list.

Kursinski, E.R., and T. Gebhardt (2014). A Method to Deconvolve Errors in GPS RO-Derived Water Vapor Histograms. *J. Atmos. Ocean. Technol.*, **31**(12):2606–2628, *https://doi.org/10.1175/JTECH-D-13-00233.1*

Liu, C.L., G. Kirchengast, S. Syndergaard, E. R. Kursinski, Y. O. Sun, W. H. Bai and Q. F. Du (2017), A review of LEO-LEO occultation techniques using microwave and infrared-laser signals[J]. *Advances in Space Research*.

p. 3, line 710: Please give a reference to this statement.

We will make a slight change to the text of the sentence in question and add a reference. The text update is more precise with respect to the information in the new reference. Changes are highlighted in blue.

Original text: The smaller than 1% discrepancies between the measured ATOMMS spectra and the forward modeled water vapor spectra, in clear, cloudy and rainy condition are unprecedented and one to two orders of magnitude smaller than present discrepancies between AIRS and ECMWF, which are limited to conditions of relatively low cloud opacity.

Revised text: The smaller than 1% discrepancies between the measured ATOMMS spectra and the forward modeled water vapor spectra, in clear, cloudy and rainy condition are unprecedented and more than on order of magnitude smaller than the 25% to 70% uncertainties in AIRS retrievals reported in Wong et al. (2015).

The following new reference will be added to the reference list.

Wong, S., E. J. Fetzer, M. Schreier, G. Manipon, E. F. Fishbein, B. H. Kahn, Q. Yue, and F. W. Irion (2015), Cloud-induced uncertainties in AIRS and ECMWF temperature and specific humidity, J. Geophys. Res. Atmos., 120, 1880–1901, doi:10.1002/2014JD022440.

p. 5, line 1—4: Did you do investigations in terms of distance of frequency to the calibration frequency and the remaining error if unwanted sources (scintillation, ..) of errors show a frequency dependency?

No formal (published) investigations have been done, though we have done internal simulations. The reference to Kursinski et al. (2016) that we suggest to add based on the next comment addresses this question for our ground-based retrievals.

p. 5, line 7: If the demonstration of these key aspects are published please give a reference.

In order to address this comment, we propose to add text and references to published work for our ground-based retrievals. The new text is rather long, but there is a lot to summarize. These references to past publications concerning ground-based retrievals probably should be contained in this paper.

We suggest to break the first paragraph in Section 3 after the second sentence and include a summary of our published findings from previous experiments using the ground-based ATOMMS system. The remaining sentences currently in the first paragraph will be moved to a new paragraph beginning after the suggested insertion given below.

Here is the revised beginning of Section 3. Again, only the first sentence is carried over.

New text to begin section 3:

~~With funding from NSF~~, ~~w~~We designed and built a ground-based, prototype ATOMMS instrument and then used it to demonstrate some key aspects of ATOMMS capabilities and performance in several fixed geometries in southern Arizona with path lengths ranging from 800 m to 84 km. The prototype ATOMMS High-Band system transmits and receives two simultaneous continuous wave (CW) signals tunable from 181 to 206 GHz. The prototype Low-Band system consists of eight CW transmitters and receivers at fixed frequencies from 18.5 to 25.5 GHz spaced approximately one GHz apart, 10 centered approximately on the 22 GHz water vapor absorption line. Below we summarize the content of previous published work based on field experiments with the ATOMMS ground-based prototype.

In terms of ATOMMS water vapor retrievals, Kursinski et al. (2012) demonstrated agreement at the 2% level between water vapor measurements derived along an 820 m path using the ATOMMS High-Band instrument and a nearby, capacitive-type hygrometer. High-Band mountaintop measurements yielded the first detection by ATOMMS of $H_2{}^{18}O$ via its 203 GHz absorption line (Kursinski et al., 2016). Such measurements in the upper troposphere will determine isotopic ratios to constrain the hydrological cycle (Kursinski et al., 2004).

In terms of spectroscopy, ATOMMS measured lineshape across the 4 GHz interval above the 183 GHz line center agreed with the HITRAN line shape with a standard deviation of 0.3% (Kursinski et al. 2012), some 8 times better than the previously best estimate of Payne et al. (2008). ATOMMS mountaintop measurements between 5 and 25 GHz above the line center revealed discrepancies with the HITRAN line shape (Kursinski et al., 2016) which may help explain inconsistencies in 183 GHz derived water vapor estimates (Brogniez et al., 2016) and may be associated with atmospheric turbulence (Calbet et al., 2018). The ATOMMS measurements also revealed the shape of the 183 GHz line as represented in the Liebe et al., (1993) model is incorrect (Kursinski et al., 2012). The Liebe model is popular, having been referenced more than 600 times in the literature, and is still being used.

Kursinski et al. (2012) combined ATOMMS High-Band measurements with precipitation radar measurements to derive cloud liquid water content (LWC) along the ATOMMS signal path. Kursinski et al. (2016) demonstrated the ability to derive both cloud LWC and rainfall rates by combining the ATOMMS Low-Band and High-Band measurements.

Kursinski et al. (2016) derived the strength of atmospheric turbulence from scintillations of the ATOMMS signal amplitudes and demonstrated the ability to significantly reduce these turbulent amplitude variations via amplitude ratioing, in order to derive accurate water vapor estimates in turbulent conditions.

The last paragraph in the overview portion for Section 3 will be the end of the original paragraph:

On August 18, 2011, we collected approximately four hours of data with the instruments located on Mt. Lemmon Ridge (2752 m altitude) and Mt. Bigelow (2515 m altitude), separated by approximately 5.4 km. The observing geometry is shown in Fig. 1. The water vapor pressure derived from these ATOMMS measurements represents an average over the 5.4 km path which runs above a valley between the mountaintops on which the instruments sit.

This change also requires the following additional references to be added to the reference list:

Kursinski, E. R., D. Feng, D. Flittner, G. Hajj, B. Herman, F. Romberg, S. Syndergaard, D. Ward, and T. Yunck (2004), An Active Microwave Limb Sounder for Profiling Water Vapor, Ozone, Temperature, Geopotential, Clouds, Isotopes and Stratospheric Winds, in *Occultations for Probing Atmosphere and Climate* (OPAC-1), Springer-Verlag, Berlin, ISBN 978-3-540-22350-4, p. 173-188.

Calbet, X., N. Peinado-Galan, S. DeSouza-Machado, E.R. Kursinski, P. Oria, D. Ward, A. Otarola, P. Rípodas, and R Kivi (2018), Can turbulence within the field of view cause significant biases in radiative transfer modelling at the 183 GHz band? *Submitted to Atmos. Meas. Tech.*

Liebe, H.J., G.A. Hufford, and M.G. Cotton (1993), Propagation Modeling of Moist Air and Suspended Water/Ice Particles at Frequencies Below 1000 GHz. AGARD Conference Proc. 542, Atmospheric Propagation Effects through Natural and Man-Made Obscurants for Visible to MM-Wave Radiation, pp.3.1-3.10.

p. 5, line12: Please determine here already on wich of these locations the transmitter and receivers are located.

The following sentence will be added before the first sentence begins on page 5, line 13 of the originally submitted document. The paragraph that includes that sentence will be moved down in the introductory portion of section 3 as described in the previous response. It will begin after the sentence ending with “shown in Fig. 1.

The Mt. Lemmon instrument contained the 183 GHz transmitter and 22 GHz receiver and the Mt. Bigelow instrument contained the 22 GHz transmitter and 183 GHz receiver.

p. 7, line 8: What is the reference period exactly. For a faster understanding it would helpt too if the reference period is marked in Fig. 2.

See response to general comment #3 from anonymous reviewer #1. We originally submitted the wrong figure 2 without the annotations. Reference periods are marked with annotations in the correct figure.

p. 8, line 15: Please mark the second reference period in the Fig.2 too.

The second reference period is marked on the correct figure 2.

p. 8, line 22: Please give a clear acronym for your Atmospheric Model, version 7.2 e.g. AM7.2 and make the notation consistent in the entire document.

This was addressed in response to specific comment #18 from reviewer #1.

p. 9, line 5: Please give the color code in the text too you are using in the figures for a faster understanding. It is not explained in the text what „raw" in the figure label means? Why is the blue line not always higher then the black line? To my understanding the blue lines contains all atmospheric effects and the black line only the liquid optical depth part.

Figure 2 is introduced in the text beginning on page 6, line 32. We propose to make clarifying changes to the text at that point, rather than on page 9.

Original text: The observed variations in optical depth at 198.5 GHz and 24.4 GHz are shown in Fig. 2. 198.5 GHz was the frequency of the High Band calibration tone during this experiment. Also shown are the derived changes in liquid optical depth at 198.5 GHz, which was computed by subtracting the optical depth changes due to variations in the retrieved vapor 7 pressure and temperature from the total observed optical depth change.

Revised text: The measured changes in optical depth at 198.5 GHz (blue line, raw) and 24.4 GHz (red line, raw) are shown in Fig. 2. 198.5 GHz was the frequency of the High Band calibration tone during this experiment. Also shown are the derived changes in liquid optical depth at 198.5 GHz (black line) , which was computed by subtracting the optical depth changes due to variations in the retrieved vapor 7 pressure and temperature from the total observed optical depth change. The change in optical depth relative to reference period 1 will always be positive for liquid (rain and clouds), since there was no rain or clouds during the reference period. However, the change in optical depth due to changes in vapor pressure and temperature can be negative, which means that the overall change in optical depth relative to the reference period can be less than the optical depth change due to liquid alone.

p. 9, line 19: Please give a reference to this publications.

Reference will be added. This paper is already in our reference list. We also noticed a reference to the wrong section at the beginning of the sentence, which will also be changed.

Original Sentence: In Section 5 we note that similar advection of dry air following summertime thunderstorms in this region have been observed in previously published work and show that our estimation of the minimum vapor pressure was consistent with the nearby radiosonde observations from Tucson.

New Sentence: In Section 6 we note that similar advection of dry air following summertime thunderstorms in this region have been observed in previously published work (Kursinski et al., 2008*)* and show that our estimation of the minimum vapor pressure was consistent with the nearby radiosonde observations from Tucson.

p. 10, line 3: Why where the tempearature sensors so close to the ATOMMS instruments positioned? Why not in a seperate small tent, if protection due to heavy rainfall was needed, to avoide temperature bias due to lost heat by the ATOMMS instrument?

In retrospect, this was a mistake on our part. If we were to repeat this experiment, we would definitely position in-situ sensors slightly away from the operating instruments. However, as you say, these instruments would still have to be protected from the heavy rain and winds in a tent and therefore, not as tightly tied to the environmental conditions as one would like.

p. 10, line 19: Please use the color code of the graph when explaining the figures to gurantee no confusion with the graphs.

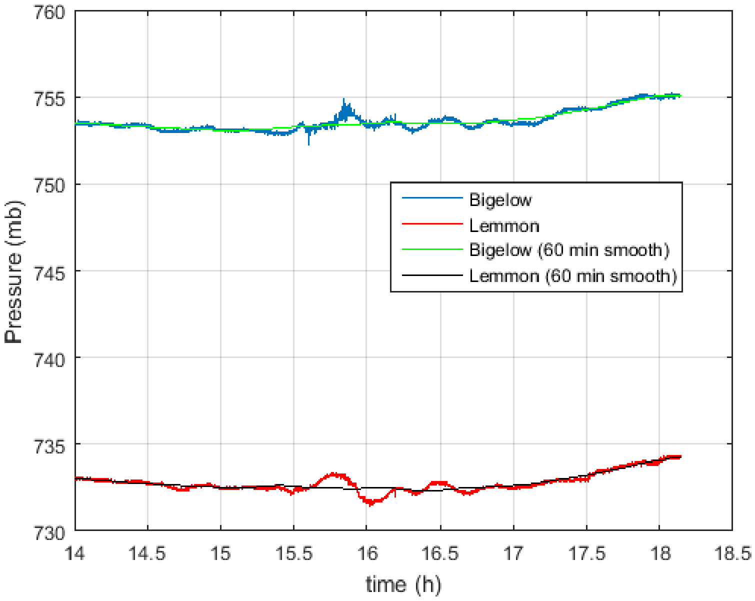
The following change will be made to the text.

Original Sentence: Figure 4 shows the derived air temperature between the instruments that was used in the retrievals, as well as the nearby, in-situ thermometer observations.

New Sentence: Figure 4 shows the derived air temperature between the instruments that was used in the retrievals in black, as well as the nearby, in-situ thermometer observations, which are shown in red, green, and blue.

p. 10, line 19: How do the aire pressure graphs look like including the one hour running mean of the air pressure?

The differences between the one hour running mean of air pressure and the higher time resolution observations of pressure are almost imperceptible when plotted on the same graph. Yet, these small variations over short time scales (relative to each other) do create noise in the hydrostatic temperature estimates when not using the time smoothed pressure. We have not made any changes to the text based on this comment. Below is a figure that shows both the high time resolution measurements of air pressure and the one hour running mean. We do not plan to include the figure in the final document.



p. 11, line 25: Did you estimate the residual error due to turbulences?

The largest peaks in Fig. 3B are near 14.6 hours. As stated in our revised text, these peaks are due to momentary noise in the calibration signal, and therefore not due to turbulence. Outside of those peaks, the maximum residual to the fit is about 1.8% between 16 and 16.5 hours based on Figure 3B. As stated in the text, we think this is mostly due to residual turbulence, and thus is an estimate of the residual error due to turbulence.

Therefore, we propose to modify the paragraph beginning on page 11, line 23. The original text is shown in black with modifications shown in blue. Please also note the change to the caption for Fig. 3B, which is shown below in response to a comment specifically concerning Fig. 3B.

Turbulence-induced amplitude scintillations (Category 2) were quite significant during the periods of strong convection. These were reduced by almost an order of magnitude via amplitude ratioing with the calibration signal (Kursinski et al., 2016). The strong peaks near 14.6 hours in Fig. 3B are caused by momentary noise in the calibration signal, which influences the frequency ratioing. Outside of this peak the largest fractional uncertainty is about 1.8% of the vapor pressure (green line). We attribute most of this to turbulent-induced scintillations that remain after the frequency ratioing. Thus, for the conditions of this field experiment, the upper bound for the random error in the vapor pressure retrieval due to turbulence is about 1.8% of the vapor pressure. ~~Residual amplitude scintillations may be the largest source of random error in the least square fits.~~

p. 12, line 8: How did you get the value of -0.17 hPa/C? Could you give a short explanation to this?

This was estimated by running forward simulations of the *am7.2* model for the approximate temperature and vapor pressure conditions observed during this experiment. This was partially addressed in one of the changes made to address comment 18 from Reviewer 1. We will add the additional underlined blue text to address this concern as well.

Page 12, line 6, original text. “For the conditions of this particular experiment, based on the AM7.2 model, the sensitivity of the change in derived water vapor due to a temperature change relative to the reference period temperature was approximately -0.17 hPa/°C.”

Revised text. “For the conditions of this particular experiment, based on forward calculations made with *am7.2* for the range of temperature and vapor pressure conditions observed during the experiment, the sensitivity of the change in derived water vapor due to a temperature change relative to the reference period temperature was approximately -0.17 hPa/°C.”

p. 13, line 11: Please give a reference to the Mie cloud model you where applying?

We will add the following citation at the end of the sentence … Mie cloud model (Bohren and Huffman, 1983).

And the following reference in our list of references.

Bohren, Craig F., and Donald R. Huffman. 1983. *Absorption and scattering of light by small particles*. New York: Wiley.

p. 14, line 22: Do you have information/graphs on the wind speeds correlating with the shift in time too e.g. by using the radar data?

Unfortunately we did not estimate wind speed. Our goal was simply to estimate wind direction in order to determine if the sign of the lags between the ATOMMS water vapor measurements and the *in situ* water vapor measurements on Mt. Bigelow made sense.

p. 15, line 2: Do you have a reference on the Tucson WSR-88 RADAR?

The Tucson radar type should have been specified as WSR-88D instead of WSR-88. We will add the following citation. However, reviewer #3 pointed out that we first reference radar data on page 7, so the citation will be placed there as well.

Original: "… Tucson WSR-88 RADAR"

Revised: "…Tucson WSR-88D radar (Crum and Alberty, 1993)."

And reference

Crum, T.D. and R.L. Alberty, 1993: The WSR-88D and the WSR-88D Operational Support Facility. *Bull. Amer. Meteor. Soc.*, **74**, 1669–1688, https://doi.org/10.1175/1520-0477(1993)074<1669:TWATWO>2.0.CO;2

p. 15, line 20: What was the horizontal distance of the radiosond to the actual microwave path, when passing through the mountain height levels of Mt. Bigelow and Mt. Lemmon? Was the radiosond actually passing the microwave path or was it very close or even far away from the microwave path?

The original text incorrectly states that the launch point for the radiosonde is about 20 km south of the observation path. The location of the radiosonde is estimated to be about 20 km south of the observation path during the time it crosses the observation path ascending through the altitudes of Mt. Bigelow and Mt. Lemmon. The sentence will be changed as indicated below.

Original Sentence: The sonde launched between 16:30 and 16:45 from a location about 20 km south of the experiment and ascended through the Mt. Bigelow to Mt. Lemmon altitude interval between 16:35 and 16:50.

Revised Sentence: The sonde launched between 16:30 and 16:45 from a location about 28 km southwest of the experiment and ascended through the Mt. Bigelow to Mt. Lemmon altitude interval between 16:35 and 16:50 at a location approximately 20 km south of the observation path.

p. 19, line 25. Please explaine shortly the other colored lines according to the altitude levels. It is not clear why e.g. the black and red lines show a less high ratio than the green and pink lines and they show even different linear dependencies within the length of the integration path.

We have decided to make a few changes based on this comment. One of the changes is to make some slight changes to Figure A1.

First, though, here is the response to the question based on the original figure, which is the last figure in the original document and incorrectly labeled as Figure A2.

The results are based on observations from aircraft observations. The black and red lines, referenced by the reviewer, are at the highest altitudes (lowest pressure) lines on the plot, which correspond with the driest part of the atmosphere. For these altitudes, there is a change in the slope of the ratio std(q)/mean(q) (<q-std>/<q-mean>) when the separation distance becomes smaller than about 10 km. This is likely because when the water vapor content is low, the observed ratio is more affected by instrumental effects. Under these dry conditions, we need separation distances larger than 10 km to be able to observe the effects of anisotropy in the absolute humidity field. Thus in the original figure, at separation distances between measurements longer than 10 km, we start to see the effects of anisotropy in the absolute humidity field for these highest altitude (lowest pressure) lines.

We have updated Figure A1 to show just the 447, 550 and 839 hPa pressure levels which are the only levels of relevance to us and the only levels shown and discussed in Otarola et al. (2011). This removes the odd behavior at the two lowest pressure levels that we believe is tied somehow to the performance of the aircraft hygrometer. We also cleaned up the figure so that the line that is interpolated to the ATOMMS horizontal distance separation does not extend beyond the y axis. The new figure and with an updated caption is shown below.

In carefully reproducing the figure, we also found that the original 13 m estimated length is actually 10 m. This requires that we change the document text references from 13 m to 10 m as listed below. The change to 10 is shown in blue.

Page 19, line 27: Given this power-law exponent and the requirement to keep uncertainties smaller than 1%, the path length required to achieve std(q)/mean(q) = 1% is approximately ~~13~~ 10 m.

Page 19, line 31: Thus, in situ sensors, accurate to 1% each, would need to be placed every ~~13~~ 10 m along a 5.4 km path to achieve an in situ-based path average consistent with the ATOMMS measurements to the 1% level.

Commented [k1]: Can you get rid of the blue background? I suspect AMT will not want that there.

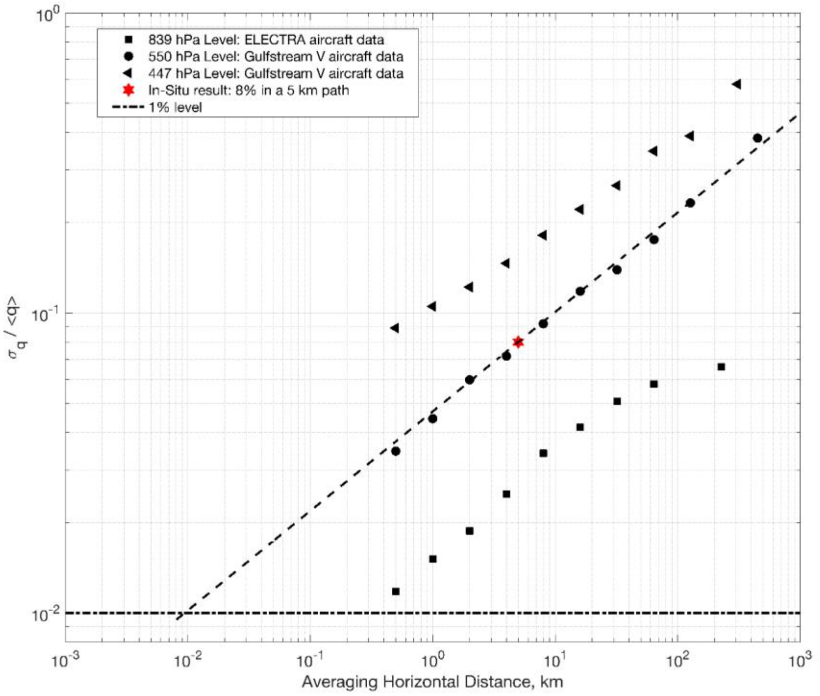


Figure A1: Ratio of the standard deviation of absolute humidity to the mean absolute humidity based on aircraft data taken at different altitudes, which is indicated by the air pressure along different flight paths. The red star on the dashed line constructed for the 550 hPa altitude observations corresponds with the value calculated from the three in-situ sensors operating during the experiment (ratio of 8% 5 for a 5 km path). The slope of the dashed line corresponds with a power law exponent of 0.35 for the dependence of std(q)/mean(q) with the length of the path, which is consistent with Kolomogorov turbulence. Extrapolation of this line to std(q)/mean(q) equal to 1% would indicate that in-situ observations are required every 10 m in order to validate the 1% accuracy of the ATOMMS retrievals. Adapted from Otarola et al. (2011).

Fig. 1: Is it possible to mark the position of the radiosond when passing through the altitude level of the two mountains?

Unfortunately, this is not possible. Figure 1 is about 3 km by 5 km, which zooms on the instrument locations. The sonde was approximately 20 km to the south of the observation path.

Typo Comments:

p. 2, line 9--10: I would recommend to be consistence with the entire paper to write everything in hPa than in mb.

We will search for all remaining instances of ‘mb’ and change it to ‘hPa’ for consistency.

p. 4, line 30: Please change hydrometers to hydrometeors.

This typo is actually on line 13 of page 4. Change will be made.

p. 7, line 21: Please make the notation for the time consistence in the entire document and figures. Sometime 4:30, then 4,5 or even the 12 hour notation is used.

This was addressed in comment 14 from reviewer 1. We will use 24 hour notation, e.g., 16:30 for all such references to time.

p. 10, line 25: The +-1% signe is underlined. Please remove the underline.

The underline will be removed.

p. 14, line 24 – 27: Please make the time consistent. They do not agree with the given times in the legend of Fig. 8B.

The text providing the time ranges on page 14 will be changed to be consistent with the figure and a 24 hour clock time that will be used throughout.

p. 15, line 19: Please make the notation of the Tucson radiosond consistent with legend in Fig. 7.

The text on line 19 will be changed to match the text in the figure caption

Original text: 00Z Tucson radiosonde

Revised text: 00 UTC Tucson radiosonde

Fig. 3A: Please use the consisten units e.g. hPa instead of mb and h instead of hours (in Fig 3A and 3B)

The axis labels will be changed to always use hPa (instead of mb) and h (instead of hours). Below is the updated Fig. 3A. The updated Fig. 3B is included below to address the next comment regarding the right axis labeling of Fig. 3B.

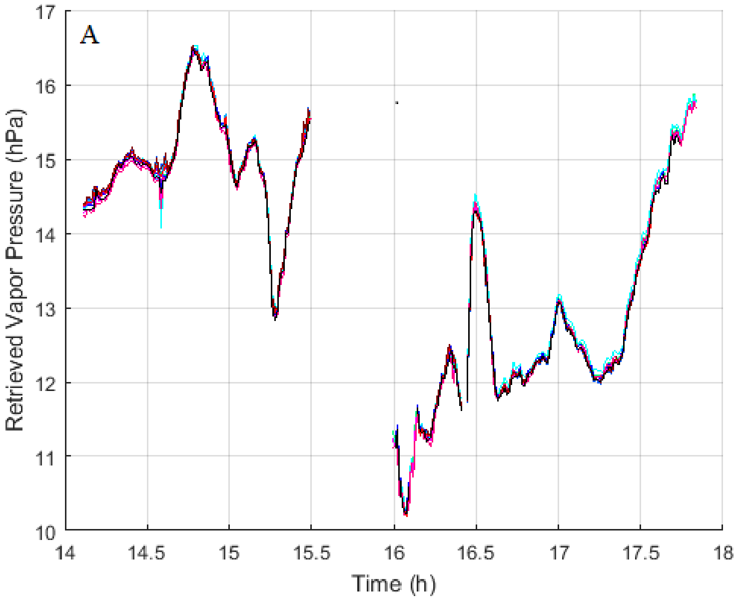


Fig. 3B: What is the strong peak at about 14.6? In the text % is used but in the figure you use fraction for the right y-axes. Please make it consistent.

Below is the updated Fig. 3B in which the right axis has been labeled in percent. We added text to the caption for Fig 3B in two places for clarification. One change is to clarify that the right axis is expressed in percent. The other change is to address the comment related to page 11, line 25 above. The added text is shown in blue.

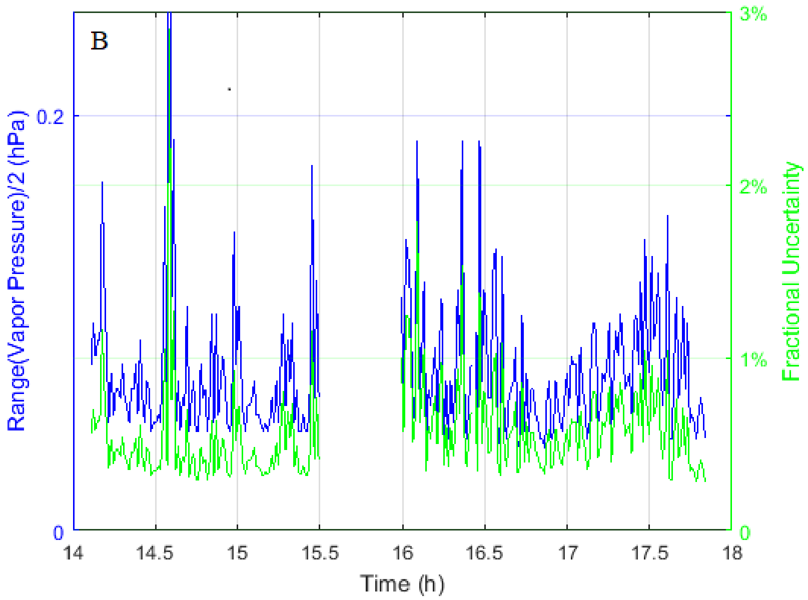


Figure 3: A. Retrieved vapor pressure for the 12 retrieval test cases described in the text. Each line is a different color. B. Blue line and left axis indicate the half range, which is one half of the maximum minus minimum vapor pressure from the 12 retrieval cases; green line and right axis is the half range divided by the absolute vapor pressure at each retrieval point expressed in percent. The strong peaks near 14.6 hours are due to momentary noise in the calibration signal.

Fig. 8B: Please make the time in the label, legend and text consistent. Please give units?

The text in the caption referring to the time will be changed to a 24 hour clock formation as shown in the figure legend. Original caption shown with changes highlighted in blue.

Figure 8: A. Vapor pressure derived from ATOMMS observations (blue) and measured with an in-situ sensor on Mt. Bigelow (red). Also shown in other colors are four time segments of the in-situ observations shifted in time (as described in text) to highlight correlation between the two vapor pressure data sets. The time shift for each colored line is indicated in panel (B). B. 5 **Cross-correlation coefficients as a function of sample lags between the ATOMMS-derived vapor pressure and in-situ measurements of water vapor taken on Mt. Bigelow. The four lines correspond with the four time segments described in the text: green (14:03 – 14.47 hours), black (14:59 to 15:30 hours), cyan (16:00 to 16:25 hours), and magenta (16:45 to 17:23 hours).**

Fig. A1: Please remove the title of the plot or make the symbols for standard deviation and mean value consistent. Please correct the x-axes label.

These issues have been fixed with our changes to figure A1 as described in our response to the comments related to page 19, line 25 above.