

Comment on “Development and testing of the Active Temperature, Ozone and Moisture Microwave Spectrometer (ATOMMS) cm and mm wavelength occultation instrument” by E. R. Kursinski et al.

Anonymous Referee#2

The paper presents results from field experiments demonstrating a prototype of the ATOMMS instrument. The “high band” (around 183 GHz) and the “low band” portions of the instrument were tested under different conditions. Changes in water vapor were tracked from both bands, cloud liquid water content was tracked from the low band.

The paper is very interesting as it presents real data demonstrating some of the capabilities of the ATOMMS instrument, which is a very promising instrument regarding atmosphere and climate research.

I recommend publication of the paper after minor revisions according to the comments below.

General comments (GC)

- 1) It would be helpful to include some technical information (transmitter power, gains, etc.) on the instruments used for the experiment, since this information is interesting in view of the results. Also a graph showing the SNR would be interesting. What would be the minimum power needed to achieve reliable results?
- 2) I was wondering why slightly different procedures have been used to evaluate the high and low band measurements for water vapor resulting in water vapor pressure changes regarding the high band, and in specific humidity changes regarding the low band. Could you please comment on that? Comparison of the results would be easier if the results were harmonized.
- 3) Some symbols used in the equations are not explained in the text. It would be useful to explain every symbol once in the text (also when their meaning seems to be obvious; detailed notes in the TC section).
- 4) I recommend use of the NIST guidelines when specifying ranges of values; e.g. use 22 GHz to 183 GHz (instead of 22 to 183 GHz, or 22-183 GHz) (detailed notes in the TC section).
- 5) I recommend checking all equations and symbols as I assume a few errors have been introduced during typesetting by Copernicus (obvious errors are noted in the TC section).

Specific comments (SC)

- 1) p. 4668, lines 15 to 17: It is not exactly clear what you mean with the last sentence ("Ground truth is much harder to establish"). Please clarify this.
- 2) p. 4669, lines 1, 5, 13: I recommend to include one or more references containing further information on ATOMMS, RO and MLS, respectively
- 3) p. 4669, line 14: Are there any limitations regarding the all-weather capability?
- 4) p. 4669, lines 20 to 23 and/or p. 4671 lines 2 to 4: I recommend inclusion of one or more references about the differential absorption (DA) technique used by ATOMMS; if possible, these references should also contain quantitative information on how well noise sources can be reduced by using DA.
- 5) p. 4671, line 10: what means "... above the atmosphere..." in practice? Please include a note on that.
- 6) p. 4671 to 4672, lines 26 to 1; p. 4673, line 10: It is not clear here, if you use one or more reference/normalization times (even if it becomes clear when reading the following paragraphs). Maybe you can clarify this here already.
- 7) p. 4672, line 1 to 3: Could you please explain why the multipath effect remains constant? Will it really divide out or will there be a residual error? Please clarify this.
- 8) p. 4672, line 14 to 16: Could you please quantify to what degree the continuum cancels out? What is the maximum acceptable separation of f and f_{ref} so that this assumption is valid?
- 9) p. 4672, lines 22 to 23: How strong can pressure and temperature vary so that the relationship remains valid? It would be helpful to quantify this or at least to include a reference to section 2.2 where it is shown, that the assumption is valid for the experiment conditions.
- 10) p. 4673, line 18: in line with SC 9: please include a note that it is explained below, that Eq. 8 is valid for the experiment conditions.
- 11) p. 4674, line 9: "A series of these amplitude ratio spectra can be calculated..." Does this mean, that one $e_{\text{max}} - e_{\text{norm}}$ spectrum is calculated for every of the 27 tones? Or am I misinterpreting that. Please clarify it.
- 12) p. 4675, lines 6 to 7: "In contrast, ATOMMS...". This sentence can be skipped if you want, since this is clear.
- 13) p. 4675, lines 12 to 14: What exactly have been the reasons why the high band range could not be used entirely?
- 14) p. 4675, lines 17 to 18: What were the reasons and advantages of the test configuration run on this day?
- 15) p. 4675, lines 19 to 26: I don't understand this paragraph and in turn the red curve on Fig. 5. Could you please try to clarify it?
- 16) p. 4676, chapter 3.1: Could you please include some notes on the measurement cycle (frequencies, repetition time, etc.) used in the mountaintop observations (as you did it for the 183 GHz measurements?
- 17) p. 4677, lines 13 to 17: The last 2 sentences of this paragraph can be shortened as the issue with the calibration is the same as it was the case for the high band.
- 18) p. 4677, Eq. 11: Should this better be an "approximately equal" sign? What is typically the stability of the transmitter?
- 19) p. 4678, line 21 to 22: It would be interesting to see also graphs of the P and T conditions during the 22 GHz experiment.
- 20) p. 4681, line 14: Consider using "number of scattering elements per unit of volume and size" instead of "particle size distribution".
- 21) p. 4682, Eq. 15: Even if this is a basic relation, it would maybe be useful to include a reference for it.

- 22) p. 4685, lines 19 to 20: "Since the signals (note: 0.5 micron and 1.5mm) at both wavelength bands propagate through the same atmosphere and particles". I don't agree with that as the MW refractivity (Smith-Weintraub) and the VIS refractivity (Edlen) differ especially in moist conditions. Also the Fresnel zones are different. However, assuming the same propagation path is probably a good approximation for this rather short path.
- 23) p. 4687, lines 19 to 20: The last sentence of this paragraph can be skipped/shortened, as this was already mentioned.
- 24) p. 4690, lines 13 to 16: It is right, that long wavelengths have many advantages regarding penetration of water vapor and clouds. But also other wavelengths can provide useful measurements regarding climate and weather forecasting. You should consider to rephrase the sentence (to weak the absoluteness of this statement).

Technical corrections (TC)

- 1) p. 4668, line 7: 22 GHz and 183 GHz (in line with GC 4)
- 2) p. 4668, line 15: unit is missing (5.4 km path)
- 3) p. 4670, line 8: 182 GHz to 205 GHz (GC 4)
- 4) p. 4670, line 10: include also the acronym for the AME building
- 5) p. 4670, line 16: I mean it should be "... measures the attenuation of the signal due to WATER VAPOR along ITS propagation path."
- 6) p. 4672, line 20, Eqs. 7 and 8: The usage of the symbols is not uniform: Delta-tau(...,e_norm...) or Delta-tau_norm(...e(t_0)...); e(t_0) or e_norm ?
- 7) p. 4672, Eq. 5: tau_dry is not explained in the text (in line with GC 3)
- 8) p. 4672, Eq. 6: e_norm is not explained in the text (GC 3)
- 9) p. 4673, line 4: the year in the date is missing (13 March 2010)
- 10) p. 4673, line 6: you could mention in brackets, that the range described comprises 27 tones
- 11) p. 4673, line 12: maybe more correct "... measured DURING this test..."
- 12) p. 4673, Eq. 9: Can the time index be specified for P and T on the right hand side of Eq. 9? And should the time index for e_max and e_norm be added, too?
- 13) p. 4675, line 5: probably better "The PAS HYGROMETER changes in capacitance ..." (instead of "The first...")
- 14) p. 4675, line 14: 128 GHz to 205 GHz (GC 4)
- 15) p. 4676, lines 7,8,11,14,16: please use m or km instead of ft.
- 16) p. 4676, lines 9, 17: There are no "a" "b" labels in Fig. 8
- 17) p. 4676, line 9: 20 to 21 August (GC 4)
- 18) p. 4677, line 2: isolateS (?)
- 19) p. 4677, line 5: no comma in between "...hygrometeors track..."
- 20) p. 4677, line 7: no "a" "b" labels in Fig. 9
- 21) p. 4677, line 19: maybe better "...relative to the specific humidity AT THE BEGINNING of the test..."
- 22) p. 4678, line 3 to 4: I recommend writing simply "Using the AM 6.2 model or the MPM 93 model..." as both models have already been mentioned before.
- 23) p. 4678, line 7: comma missing after "K"
- 24) p. 4678, line 19: 22.6 GHz and 23.5 GHz (GC 4)
- 25) p. 4679, line 2: 22.6 GHz (red) and 23.5 GHz (blue) (GC 4)
- 26) p. 4679, line 7: no "a" "b" labels in Fig. 10
- 27) p. 4679, line 9: 22 GHz (not GHZ)

- 28) p. 4679, line 11: 22.6 GHz (GC 4)
- 29) p. 4679, line 20: "... estimates of the water vapor CHANGE..."
- 30) p. 4679, line 21: 22.6 GHz and 23.5 GHz (not 23.5 Hz)
- 31) p. 4679, line 24: 5.3 g kg⁻¹ to 6.3 g kg⁻¹ (CG 4)
- 32) p. 4679, line 28: "... ATOMMS instrumentS..."
- 33) p. 4680, line 13: "Figure 12 (LEFT HAND SIDE) shows the temperature and..."
- 34) p. 4681, Eq. 14: D is not explained in the text.
- 35) p. 4681, line 24: maybe "... measured by ATOMMS at 197 GHz SHOWN in Fig. 14
- 36) p. 4682, line 5: consider including a reference to Fig. 15 "... radar derived estimates (Fig. 15)..."
- 37) p. 4862, Eq. 15: r and lambda are not described (GC 3)
- 38) p. 4682, line 17: n₀ (m⁻³) and alpha(m⁻¹) are not described (GC 3)
- 39) p. 4862, Eq. 16: the r in the exponent must not be superscript
- 40) p. 4683, line 3: include the symbol R: "and rain R is in mm h⁻¹" (GC 3)
- 41) p. 4683, Eq. 18: Typo? To the power of 0.71 > why not 0.7?
- 42) p. 4683, lines 7, 8: symbols r and R are explained here; explanation can be removed if they were already explained before (see TC 37 and 40)
- 43) p. 4683, Eq. 20: rho is not explained (GC 3)
- 44) p. 4684, line 2: Fig 16 (not Fig. 15)
- 45) p. 4684, Eq. 23: n_{rain} is not explained (GC 3)
- 46) p. 4684, Eq. 25: t₁₉₇ and z are not explained (GC 3)
- 47) p. 4684, lines 22 to 23: "The distances are... 0.010 km, 0.30 km and 0.78 km" (GC 4)
- 48) p. 4685, lines 5, 13: Eq. 26 (not Eq. 25)
- 49) p. 4685, line 19: Eq. 15 (not Eq. 16)
- 50) p. 4686, line 5: symbol x was not explained
- 51) P. 4686, Eq. 27: I assume the symbol p in the equation should be a rho. Please check the equation!
Explain symbol k_{cloud} in the text (GC 3)
- 52) p. 4686, Eq. 28: overbar(k_{cloud}), L are not explained in the text (GC 3)
- 53) p. 4686, Eqs. 28 and 29: again the p instead of the rho
- 54) p. 4687, line 6: maybe better "... that make the radar data noisy as VISIBLE in..."
- 55) p. 4687, line 11: 15.6 hPa to 17.5 hPa (C4)
- 56) p. 4687, line 16: Fig 14 (not Fig. 17)
- 57) p. 4690, line 13: 60 % to 70 % (GC 4)
- 58) p. 4692, Eq. 20: one bracket in the lowest row of the first term is wrong
- 59) p. 4692, line 22: "calculate the tau" (instead of the "r")?
"relative" (instead of "celative")?

Comments on the tables and figures:

General comments:

- Please label all axes and/or add their dimensions (also dimensionless; time axes e.g. like in Fig. 11). Especially Figs. 4, 5, 6, 7, 13 to 17, 19.
- Depending on the final figure size consider to increase the font size of the individual figures.

Specific comments:

Table 1: - Either describe the abbreviations “Avg-“, “Avg” and “Avg+” in a footnote or in the caption of the table, or use the full terms (average optical depth) directly in the table.

- Also K is a mean value.

Fig. 1: Could be optimized using a vector graphics program (e.g. Inkscape).

Fig. 2: - As the vertical axis shown in the figure is altitude, you could consider including approximate altitude levels additionally in the caption (esp. supplementing the “230 K altitude”, “240 K” and the “~ 10 mb level”).

- I think the arrow indicating the GPS H2O profiling should not extend up to the Earth’s surface.

Fig. 3: Left hand: You could consider including symbols indicating the transmitter and receiver on the figure or simply use an arrow to display the measurement direction.

Fig. 5: In line with SC 15: the last sentence of the caption is not clear to me.

Fig. 8: The labels in the left hand figure should have a readable font size (also the arrow end).

Fig. 10: Caption: consider including something like: “Left hand panel showS results of conversion OF ATOMMS MEASURED AMPLITUDES to specific humidity...”

Fig. 11: Caption: Consider including something like: “The ATOMMS 22.6 GHz and 23.5 GHZ channel AMPLITUDES have been converted...”

Fig. 12: Correct typos in dimension of specific humidity: g/kg (not gr/Kg)

Fig. 14: Caption: No figure labels “a” “b” ;
0.88 degree and 1.28 degree (GC 4)

Fig. 15: Caption: You could consider including the name of the radar.