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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Technical Note: Novel method for water vapor monitoring using wireless communication networks measurements" *by* N. David et al.

N. David et al.

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We would like to thank the reviewer for the very constructive remarks. The material for the article was reviewed and thanks to the reviewer's attention several parts will be modified. In our response we have grouped reviewer comments that had common relevance.

Comment: "Another interesting parameter to study would be the signal delay (and its variations) of the used communication links. An advantage of using the delay, which is caused by the real part of the refractive index, is that it is in practice insensitive to fog, clouds, and rain along the propagation path. A fact which is used in the application of inferring the atmospheric water vapour content from the signals from the GPS satellites.

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Although the presently available link data probably not provide any time delay values this option could be mentioned in the introductory material."

Response: This is indeed an interesting point. Our general approach, however, is one where the communication system's data are obtained from the cellular providers without addition or change. Therefore, we are interested in applications that rely on existing data. Other potential applications of this system are possible of course. This important comment is noted, and will be added to the opening paragraph of the article, as suggested.

Comment: "Given that the presented method is restricted to weather conditions excluding rain and clouds containing liquid water (along the propagation path) I think that ought to be mentioned already in the abstract".

Response: It is true that at this stage the method is limited to periods where there is no rain, and no clouds in the links line of sight. In the revised article, this point will also be mentioned in the abstract.

Comment: "The reader may also want to know: how representative are the results from the four weeks of data? It is indeed important if the presented results are typical or if they are examples of cases demonstrating some kind of best agreements?"

Response: The results presented are from two links that provided humidity measurements relatively well. Overall, for the two links mentioned in the article, as well as links from other locations measured at other times, correlation vary between 0.5 and 0.9 was found (please also see the comment given to Referee #1 where additional results are presented). During the research we noticed that some links are better for monitoring humidity than others. One of the questions we are dealing with at this time is understanding how these type of links can be distinguished from other links.

Comment: "Abstract, line 17, page 11679 line 15, and page 11680 line 20: Avoid using subjective measures such as "excellent", "very good" and "good". They contain no

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extra information in addition to the correlation coefficients. (In fact you use these three different grades to describe the same results. Why are they "excellent" in the Abstract and only "good" in the Conclusions?)"

Response: We shall amend the phrasing.

Comments:

"Abstract, line 10: the phrase "... can provide moisture observations at high temporal and spatial resolution" is not supported by the results presented in the manuscript. What do you mean?"

"Page 11681, line 1: It is unclear what you mean by "high resolution data". If it is the temporal resolution you are referring to why present only one data point per 24 hours?"

Response: The microwave links are distributed over wide areas, and further, provide a humidity average over a link that spans several kilometers, unlike conventional spot humidity gauges. Thus, they can, in principle, provide measurements with high spatial resolution. To more precisely explain the temporal resolution issue - the communication system we used provides attenuation data every few seconds, but only stores one data point per 24 hours. The system can be configured to store data at shorter intervals, it is a matter of technical definition by the cellular companies.

Comments:

"Abstract, lines 21 and 22: The acronym RMSE is not explained here and it is not clear which parameter the percentages are calculated for."

"Page 11679, line 1: The expression RMSE is misleading since the two methods are measuring different volumes of air. I think RMS Difference (RMSD) would be more appropriate."

Response: The term RMSE is explained quantitatively and verbally in the theoretical part of the article (page 11679). It is definitely possible to add the explanation of the

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acronym to the abstract and to call it RMSD.

The following points were raised regarding the uncertainty in the quantitative values mentioned in the article:

Comments:

"I miss a quantitative analysis of the uncertainties. In order to make it more quantitative there is a need for an uncertainty analysis of the attenuation measurements, the ITU relations between attenuation and humidity, the local point measurements of the absolute humidity, and the impact of using different averaging periods"

"Page 11676, line 18: A resolution of 0.1 dB for the attenuation measurements seems a bit high. Using the facts given in the manuscript for the typical attenuation of 0,2 dB/km and a 4 km link indicates that the resolution is as large as 12.5%. This number cannot be neglected compared to the observed RMS differences of 20-30%."

"Page 11677, lines 22-23: I miss the expression for N" (which I think is much more relevant than are the present Equations (4)-(7) on how to calculate the absolute humidity from the relative humidity and temperature). Furthermore, the uncertainty for the expression of N" are of fundamental importance and shall be compared to the other uncertainties."

Response: The calculation of absolute humidity is based on the model detailed in the ITU recommendation (Rec. ITU-R P.676-6, 2005). It did not seem fit, in this particular framework, to elaborate all of the formulas and functions that appeared in the aforementioned reference. The expression for N" is long and cumbersome and so we preferred to point the readers to the proper reference where they can find additional details. The humidity measurements taken via the microwave link were calculated from a signal instantaneously sampled at 03:00 AM. Humidity measurements with the regular humidity gauge were taken at the surface stations every half hour, and from these measurements, the ones relating to the same hour were selected. The uncertainty in

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measuring temperature and pressure are of the magnitude 0.1 degrees Celsius, and 1 mb, respectively. But changes of this magnitude in pressure or temperature do not create a change in the absolute humidity calculation based on this model. Hence, the model is not sensitive to such changes in temperature and pressure. The dominant uncertainty affecting the absolute humidity calculation is that of the attenuation. For a 3.86 km link the uncertainty in evaluating attenuation is +- 0.026 dB/km. As a result we get that the error in calculating absolute humidity in this case is of the magnitude of +- 1 g/mˆ3. In the case of an 11.05 km link the uncertainty in evaluating the attenuation is +- 0.01 dB/km, hence the corresponding error in calculating the absolute humidity is of the magnitude of +- 0.5 g/mˆ3. The estimated uncertainty in measuring humidity with regular humidity gauges is about 0.2 to 0.5 g/mˆ3 (depending on the relative humidity and the temperature), while the error in measuring relative humidity was taken to be 3%. A section dealing with the aforementioned uncertainties will be added in the revised manuscript.

Comment: "Page 11677, lines 16-17: It is assumed that the contribution from oxygen to the attenuation can be ignored compared the water vapour. The oxygen attenuation varies with both temperature and pressure. It would be interesting to learn a specific a value for these variations given the typical temperature and pressure variations observed in the relevant area(s). This value can then be compared with the other uncertainties."

Response: Oxygen's effect on attenuation is two orders of magnitude lower than that of water vapour in this case. Quantitatively it is 0.001 dB/km for Oxygen and 0.2 dB/km as a result of humidity (for a link operating near 22 GHz, temperature of 15C, humidity of 7.5 g/mˆ3 and a sea level pressure). However, we should note that the algorithm takes into account the effects of Oxygen, and corrects for them, although, as we mentioned, the effect is negligible in relation to the effect of water vapour around frequencies of 22 GHz.

Comment: page 11679, line 18: it is not clear to me what the "p value" refers to?

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Response: We investigated the correlation between absolute humidity values calculated using the method described, and those which were measured using a regular humidity gauge. For this we used Matlab to perform a Pearson correlation test. This test also calculates the p-values. The p-values test the hypothesis of no correlation. Each p-value is the probability of getting a correlation as large as the observed value by random chance, when the true correlation is zero. If p is less than 0.05, then the correlation is significant.

We wish to thank the reviewer for the rest of the comments and remarks - they are gratefully accepted.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 11673, 2008.