

# Diurnal variations in middle atmospheric water vapor by ground-based microwave radiometry

D. Scheiben, A. Schanz, B. Tschanz, N. Kämpfer

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## Response to the comments from Referee #1 on the manuscript acpd-13-3859-2013:

We thank Referee #1 for the comments on our manuscript. In the following, we answer these comments point-by-point. The Referee's comments are given in *green and italic* font, our answer in black.

General comment:

- Review of Scheiben et al., Diurnal variations in middle atmospheric water vapor by ground-based microwave radiometry This paper shows comparisons between observed diurnal variations of water vapor, and variations seen in WACCM. The paper is generally well written, and the WACCM analysis is good. I do have some major concerns with the presentation of the comparisons, and, particularly, with the error estimates presented for the ground-based measurements. Only near the end of the paper is it admitted that “The discrepancy between modelled and observed diurnal cycle below 1 hPa could be attributed to instrumental effects.” This is an admirably honest statement which must be made (I think it should extend to the 1 hPa data as well), but it is clearly inconsistent with the error bars on Figures 2 and 4. A casual reader would look at the Figures, see the error bars, and conclude that there must be a serious problem with the model – a conclusion which is never drawn in the paper. A more thorough reader will conclude that the authors wrote the study and at the end realized that the original error bars were too small. I understand the difficulty of accurately calculating error bars, particularly in cases where the causes of the error are not all clearly understood. Before publication at least two changes should be made regarding the error bars. First, take the discussion of errors from Section 4 and move it to so that it is together with the error discussion. Secondly, edit the captions to Figures 2 and 4 so that they clearly state terms are included in these error bars.*

The error bars are calculated as described within the manuscript. However, it is obviously very important to mention that these are random errors and that systematic errors are not included within the error bars because we cannot quantify them. The discussion of errors that is following the results of Figs. 2 and 4 tries to determine the source of the systematic errors, i.e., we try to explain the discrepancy between the observations with their error bars and the model data.

In the revised manuscript, we clearly state what is included in the error bar calculation. We also tried to unify the discussion of the cause of the errors. In addition, we changed the manuscript according to your further comments below.

Specific comments:

- 3863, line 25+: Apparently all of the data shown here has been taken with upgraded instruments which provide more profiles per day. The implication is that it would not be possible to perform this study without this upgrade and that therefore only the upgraded data is used (is this true?). But the Haefele et al. study was clearly performed before the upgrade, showing that it is not necessary to use the upgraded instruments. Please clarify.*

We do not say that a study on diurnal variations in water vapor was not possible before the upgrade. However, the study by Haefele et al. was using retrievals from an acousto-optical spectrometer (AOS) with a much coarser spectral resolution than the current Fast Fourier-Transform spectrometer (FFTS). The coarse resolution of the AOS resulted in a lower noise level compared to the FFTS but did not allow to retrieve water vapor above 0.1 hPa. On the other hand, the lower noise level allowed to obtain a temporal resolution in the order of hours even before the upgrade. With the new FFTS we retrieve water vapor up to 0.02 hPa and for these altitudes, a temporal resolution in the order of hours was not possible before the instrument upgrade.

- 3864, line 10: *“To reduce these baseline artifacts, a polynomial fit of order 3 and a sine-fit with 6 periods are applied to the measurement. This leads to a loss of measurement sensitivity on lower altitudes and is the main reason why the instruments are not sensitive below 35 km altitude.” This is a modification of a ground-based microwave retrieval which can have important consequences for the retrieved vertical profile in the stratosphere, yet there is very little detail and no reference given. Is it fit as part of the optimal estimation procedure? The Tschanz manuscript referenced here suggests so, but it gives a somewhat different description of the baseline, and also mentions that the two instruments use different fits. How have the investigators determined the altitude sensitivity for the results shown here? Is it different for the two instruments? How large are the fitted waves and polynomials and how does this compare to the signal?*

In our revised manuscript, we provide more details on the baseline fit addressing your comments and the comments from Referee #2. The baseline fit is part of the optimal estimation and is done within QPack. We use a dedicated retrieval version for this study which is the same for both instruments. The measurement sensitivity of the two instruments only differs due to the different spectral resolution of the spectrometers (30.5 kHz for MIAWARA-C and 60 kHz for MIAWARA). The fitted sinewaves are at least one order of magnitude smaller than the signal.

- *Presumably there is a diurnal variation in the tropospheric optical depth. What efforts have been made to ensure that these are not affecting the data? How is this accounted for in the error estimates? Do diurnal variations in rain have any significant affect on the data?*

There are diurnal variations in the tropospheric optical depth. The tropospheric correction that we apply to the balanced spectrum take into account the optical depth, which is determined every 15 minutes. Since the tropospheric correction is a scalar value, a tropospheric correction with a faulty diurnal cycle would result in a diurnal cycle in the retrieved water vapor profile which would be independent on altitude. We made test runs for such a faulty diurnal cycle in the tropospheric correction and found that for such a case, the diurnal variations in water vapor are indeed independent on altitude. Since the observed diurnal variations are changing with altitude, we conclude that the diurnal variations are not originating from a faulty tropospheric correction. Our radiometers do not operate during times of precipitation, hence a diurnal variation in precipitation could only lead to diurnally varying errorbars since the number of measurements would change during the day.

- 3869, line4+: *“The sharp phase shift in the WACCM data from December to April . . .”. This makes it sound as if the phase shift is from December to April. Please rewrite as, perhaps, “The December to April WACCM data shows a sharp phase shift . . .”.*

We rewrote that sentence.

- 3870, line 14: *“In the mesosphere, the observations and the model data agree well with each other.” The authors simply cannot make this statement. Based on Figure 5, the agreement breaks down at 0.2 hPa in the December to April data, while the amplitude for the June to October data in Figure 5 looks to be about an order-of-magnitude larger throughout almost the whole of the mesosphere in the measurements when compared to the model. None of this is consistent with “agree well”.*

You are right. In the revised manuscript, we rewrote the first part of the discussion section such that we state that good agreement between model and observations are only found in the December to April data above 0.2 hPa and in the June to October data above 0.03 hPa. The discrepancies between the model and the observations at lower altitudes are then discussed during the rest of the section.

- 3871, line 28: *“The previous study by Haeferle et al. (2008) ...”. The lack of comparison with this previous study is troubling, since one would hope for some consistency between these results and those. How does this study compare with the Haeferle study at lower altitudes? “However, the amplitude in the current study is approximately twice as large.” – Are the authors saying that they have 100% measurement contribution, and the previous study had only 50%? This would only*

*possibly be true, if at all, over a very small altitude range.*

The previous study showed diurnal variations in water vapor on 0.1 and 3.14 hPa. The comparison in the revised version of our manuscript is now also considering the lower pressure level (3.14 hPa). The results between the two studies are consistent regarding phase. The amplitude on 0.1 hPa is smaller in the previous study compared to our study. This is attributed to the fact that the measurement sensitivity at 0.1 hPa was lower in the previous study due to an older spectrometer.