Response to Reviewers’ Comments on the preprint amt-2024-108

Dear Reviewers,

We greatly appreciate your valuable and insightful comments. We have carefully considered your suggestions and revised the manuscript to address the points raised. Your feedback has significantly improved the clarity and rigor of our work.

We have provided our responses below. Your comments are enclosed in boxes, and our corresponding responses are written below each box. The line numbers of the revisions have been indicated for both the revised manuscript (RM) and the tracked changes file (TCF).

RC1: 'Comment on amt-2024-108', Anonymous Referee #2, 24 Sep 2024

> This manuscript describes a microwave radiometer that has been measuring ozone profiles from Seoul since 2016. The authors do a nice job addressing details of the measurements that are extremely important in obtaining accurate retrievals (e.g. tropospheric opacity and pointing). Understanding such details is important for any group attempting to make such measurements. I thank the authors for addressing my concerns in the initial review.
>
> 1) Figure 8, line 287, and conclusion – Are the tropospheric opacities shown in Figure 8 for KLAPS and SORAS calculated at precisely the same time? It is not clear whether the higher summer opacity of the KLAPS results come from periods when SORAS opacity measurements are not possible because of the high opacity. In the conclusion the authors say that the O3 bias relative to MLS is different during the summer than during other seasons, but in order to establish this a clear plot showing the difference in tropospheric opacity biases is needed.

[in RM: Line 403 and Fig. 16 // in TCF: Line 431 and Fig. 16]

The opacity shown in Figure 8 for SORAS and KLAPS represents the data available for the same period. SORAS spectra were averaged at 10-minute intervals plotted accordingly, while KLAPS data were provided at a 1-hour interval. To compare the two datasets, SORAS data corresponding to the KLAPS time were extracted, and a plot showing the differences between the two datasets is provided below. This plot is intended to be added as Figure 16 in the manuscript. The opacity of SORAS during summer is lower than that of KLAPS, as shown in Fig. 16. The low calculated opacity affected the intensity by overestimating the contribution of $T_{b,O3}$ in the observed spectrum T_b. As a result, the comparison between SORAS and MLS led to a different bias during the summer compared to other seasons.

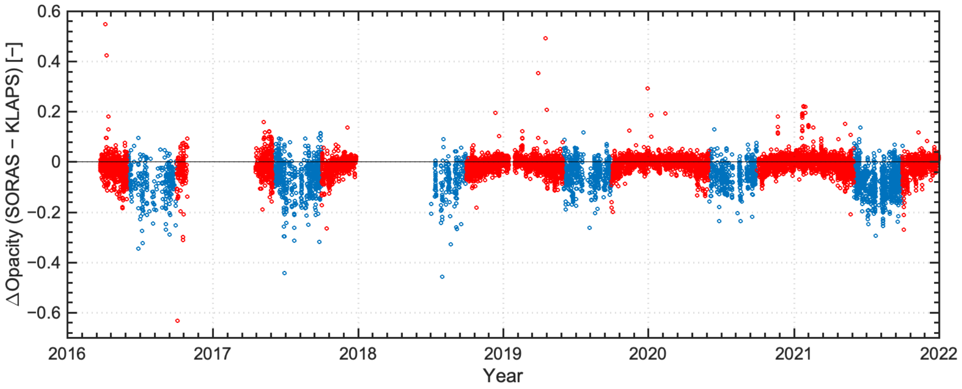

Figure 1. Difference in opacity between SORAS and KLAPS (see Fig. 8). Only SORAS data matching the time of the KLAPS data were used. The red marks are indicated as described in Fig. 15.

2) Paragraph starting on line 382 and conclusion - While the authors are correct in attributing a portion of the observed negative bias to the use of an AC240 spectrometer, this is not thought to cause an altitude dependence in the bias. Just as for the instrument presented here, the Sauvegeat study does show an altitude dependence in the bias between that ground-based instrument and MLS. But, as for the instrument discussed in the Sauvegeat study, the altitude dependence of that bias is only weakly, if at all, caused by the AC240 (their Table II, last column). This should be noted in the text.

[in RM: Line 410 and 436 // in TCF: Line 439 and 468]

We addressed it to the manuscript.

3) Lines 305 and 409 – What velocity does a 55 kHz doppler shift imply? Is this physically realistic? Is the 55 kHz smaller than the expected error of the local oscillators used in the instrument?

[in RM: Section 4.1 Spectrum setup and 5. Conclusions]

The 55 kHz Doppler shift corresponds to a velocity of 149 m/s, which is significantly higher than the known wind speeds. Another reviewer raised a similar concern regarding this issue, prompting us to re-examine the matter carefully. Upon recalculating, we discovered that the frequency error increased to –86 kHz due to incorrect mapping between the spectrometer channels and frequencies. Additionally, we identified that the local oscillator within the baseband converter has a –6 kHz offset.

Nevertheless, we observed notable frequency offsets of –80 kHz, as well as high occurrences at –245 kHz and –60 kHz. These offsets appear to result from instabilities in the local oscillator, although the exact cause remains unclear. We have updated the manuscript to include these findings, and texts to the Doppler shift and JPL frequency error has been revised.

Our response about this issue overlaps with the points addressed in item 12 of Referee #3's comments. The content has been provided below.

We identified that the offset is not caused by the Doppler effect but instead originates from an incorrect channel definition in the AC240 spectrometer and a frequency offset in the local oscillator.

According to Benz et al. (2005), the AC240 spectrometer analyzes a 1 GHz bandwidth using 16384 channels. As stated in Eq. (2) of the reference, the center frequency (ν) corresponding to a channel is calculated as:

$$\nu_{AC240} = \frac{m}{16384} + \frac{0.5}{16384} \qquad (m = 0, 1, 2, \dots, 16383)$$

where m represents the channels for positive frequencies and ranges from 0 to 16383. As the frequency in Eq. (2) was defined as the lower edge of channel m, 0.5/16384 was added to represent the center frequency of the channel. However, in this study, the first channel of the spectrometer was incorrectly defined as 1 instead of 0, and the frequency was calculated by dividing the channel number, k, by 16384. Therefore, the corrected frequency at the spectrometer of SORAS should be calculated as follows:

$$\nu_{soras} = \frac{k-1}{16384} + \frac{0.5}{16384} = \frac{k-0.5}{16384} \qquad (k = 1, 2, 3, \dots, 16384)$$

The corrected frequency is 30.5 kHz, smaller than the incorrectly defined frequency, and Fig. 9 and Fig. 10 have been revised to reflect the new frequency.

This adjustment further increased the offset from −55.1 kHz to −85.6 kHz.

Following your suggestion, we also plotted a histogram of the offsets. The histogram shows symmetry around the mean offset of −86 kHz. However, there is a significant frequency of offsets at −245 kHz and 60 kHz. As you mentioned, this appears to result from frequency shifts to specific levels caused by instability in the local oscillator, although it is unclear at which stage of the frequency conversion this occurs. Additionally, as you pointed out, such LO frequency shifts are likely to have a significant impact when averaging long-term observation data.

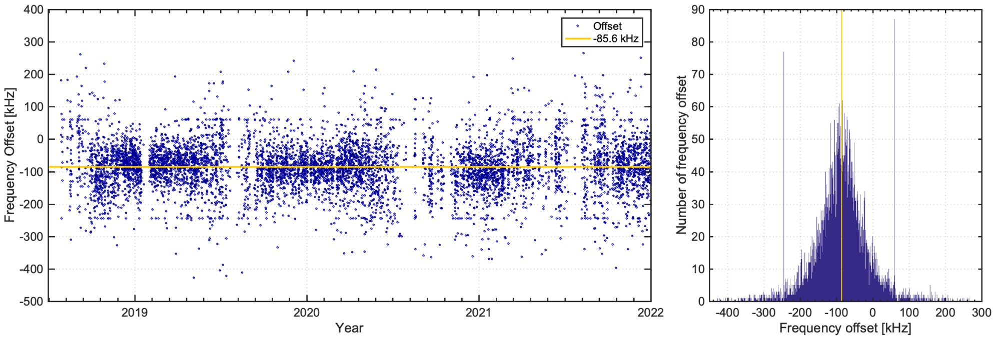

Figure 2. (Left) The individual frequency offset is determined by the curve fitting method. On average, the center frequency of the measurement is shifted by −85.6 kHz from 110.836 GHz. (Right) The frequency offset distribution is presented as a histogram, showing high occurrences of frequency shifts at −245 kHz and 60 kHz.

We examined the local oscillator of the baseband converter. The LO frequency has a frequency offset of −6 kHz from 2 GHz. The −6 kHz LO offset contributes to a −85.6 kHz shift.

We have incorporated it into the manuscript.

The content in the manuscript referring to the Doppler effect has been removed, and the text was revised to prevent further misunderstanding. Unlike previous studies investigating the Doppler effect with radiometers, such as Rufenacht et al. (2012) (6.1 kHz) and Hagen et al. (2018) (12.2 kHz), the frequency resolution in this study is 5 to 10 times larger. Additionally, due to the lack of opposite-direction observation corrections, the observation conditions in this study are insufficient to evaluate the Doppler effect.

---

4) Line 343 – ‘bacause’ should be ‘because’

[in RM: Line 360 // in TCF: Line 388]

We corrected it.