Reply to comments of Reviewer #2

We thank the reviewer for carefully reading the manuscript and his/ her constructive and helpful comments and suggestions. They helped us to improve the paper in several aspects. We considered them point by point as illustrated below. We like to remark that line numbers mentioned in the reviewers comments refer to the first submission of the paper. We re-run the retrieval code to simulate OH radiances as measured by SABER from SCIAMACHY spectra and corrected radiance contamination to the previous unfiltered 1.6 μm simulations from other band emission lines due to the selected wavelength range. This problem was found when we run the retrieval using Einstein coefficients obtained by van der Loo and Groenenboom [2007, 2008] as suggested by the reviewer #2. The abstract was rephrased to make it more clear. Following the reviewer #3, we also simulated the in-band data as measured by SABER without considering the filter transmission effect for comparison.

Specific Comments*:*

Abstract*: When reading the abstract for the first time, some parts are rather confusing. The meaning of the first three sentences is not clear and one needs to read the manuscript further for the abstract to make more sense. Somehow the references to the words "as measured" do not help and the second sentence "on the retrieval model to perform an inversion of OH(v) number densities in order to simulate OH ro-vibrational emission radiances using a non-linear regularized global fit technique" only complicates things further. The abstract needs to be well understood by itself and without referring to the rest of the manuscript. It must be clear to the readers that there are two sets of coincident / co-located measurements by these space-based instruments and one set is used to simulate the other and compare with it.*
It seems to me the abstract (and possibly the manuscript in general) understates the uncertainties of the Einstein coefficients and exaggerates the observed deviations between the SCHIAMACHY observations and SABER simulations. Additional comments will be discussed below.
Reply: Thank the reviewer for pointing out this issue. Most part of the abstract was rephrased to make it more clear to the readers. For details, please refer to the abstract. Following the reviewer's suggestion, Einstein coefficients calculated by van der Loo and Groenenboom [2007, 2008] were also considered in this work to estimate the uncertainties of the Einstein coefficients.

Main Manuscript*:*

1: *I am somewhat concerned that the truncation of the "overpopulated higher rotational levels" of the SCHIAMACHY spectra introduces systematic errors in this analysis. Non-local thermodynamic equilibrium conditions imply that we are dealing with a distribution that is not a true Boltzmann distribution. This applies to all rotational levels, including the ones with low rotational quantum numbers. For the lowest OH vibrational levels, it appears this effect is less significant and may be neglected in many cases, but the deviations become increasingly important for the highest vibrational levels and can, for example, lead to significant errors in the determination of the rotational temperatures. There is a sentence mentioning the authors performed a check of the effect of non-local thermodynamic equilibrium conditions and found it to be approximately 2%. It would be helpful to reconsider these checks and whether additional assessment is needed, and also provide some brief information on what these checks entailed. Moreover, it seems the SABER transmission windows include additional lines from other bands, e.g., there are a few lines of the 7-5 band in the 2.0-micron window. By neglecting these lines another systematic error is introduced, once again effectively "underestimating" the SCHIAMACHY measurements. Verifying that the above effects do not introduce significant bias in the simulation procedure and explicitly stating it would strengthen the manuscript.*

Reply: As said by the reviewer, non-LTE conditions affect all rotational levels deviating from a Boltzmann distribution with kinetic temperature. From the work of Oliva et al. [2015] and Kalogerakis et al. [2018], each vibrational state follows a Boltzmann distribution at low rotational levels, but with a different rotational temperature T_{cold}, which may differ from the kinetic temperature. Monthly zonal median OH airglow measurements from SCIAMACHY and monthly zonal mean temperature from SABER were used in the work. We can not use the SCIAMACHY measurements to investigate the non-LTE effect due to the low spectral resolution, as Oliva et al. [2015] and Kalogerakis et al. [2018] did based on cross-dispersed cryogenic spectrometer measurements in the spectral range of 0.97 μm to 2.4 μm. A theoretical study using the method of Oliva et al. [2015] has been performed. A weighted combination of two Boltzmann distribution equations with cold and hot OH rotational temperatures (T_{cold} and T_{hot}) was used to predict the observed intensities of OH emission lines. T_{cold} and T_{hot} were taken from the figure 2 of Oliva et al. [2015], as well as the fractions of the cold and hot molecules. Firstly, the calculated OH(9-7) band radiance is less than 1% larger than the one only considering the cold molecules. Secondly, the bandpass of the SABER interference filters capture the hot and the cold fractions of the rotational distribution. Therefore, this redistribution of energy is averaged out. Last but not least, Xu et al. [2012] investigated the temperature

dependence of the band-averaged Einstein coefficient. They found that the OH(9-7) band Einstein coefficient only changes by approx. 0.35% when the temperature increases from 200 K to 250 K. Therefore, the Non-LTE effect on the band-averaged radiance is less important than for rotational temperature retrieval. A detailed description of the checks are added in the text.
The low spectral resolution of SCIAMACHY spectra does not allow to estimate this effect from the measured data. Therefore, we performed model simulations using the same approach and parameter sets as Oliva et al. [2015] to quantify the effect of incomplete thermalization on the spectral ranges used in this study. We calculated OH 1.6 μm and 2.0 μm VERs by considering only the cold rotational temperature and then obtained them using cold and hot temperatures together as Oliva et al. [2015] and Kalogerakis et al. [2018] did. It was found that differences between them are less than 2% for both SABER channels.
The OH 1.6 μm and 2.0 μm channels include additional lines from OH(3-1) and OH(7-5), respectively. We assume two ideal filters for these two channels with upper cut-off wavenumbers at 5150 cm^{-1} for 2.0 μm channel and 6400 cm^{-1} for 1.6 μm channel. OH(7-4) and OH(3-1) nightglow emissions have been observed by SCIAMACHY channel 6 and the same retrieval procedure described in the main text applied to them to derive OH(7-5) and OH(3-1) emissions. The contributions of OH(7-5) and OH(3-1) to the two channels are about 3% and 1%, respectively. A statement is added in the main text as below:
The SABER 1.6 μm and 2.0 μm channels also observe emission lines from OH(3-1) and OH(7-5), respectively. We estimated their influence on spectrally integrated radiances by the derivation of the corresponding emissions using SCIAMACHY OH(3-1) and OH(7-4) nightglow measurements. These simulations show that the contributions of OH(7-5) and OH(3-1) to the two channels are about 3% and 1% on average, respectively.

2: *I find it rather difficult to accept the notion that the role of Einstein coefficients introducing bias is not significant. The fact that two rather similar sets of Einstein A coefficients were used provides some idea as to what differences can be expected, but the possibility of significant absolute systematic errors introduced by the coefficients cannot be excluded. The conversion of SCHIAMACHY observations to SABER simulations essentially depends on the ratio of the respective Einstein coefficients for the vibrational levels of interest, e.g., the ratios A(9-6)/A(9-7) and A(8-5)/A(8-6) for the SABER 2.0-micron channel. The values of these ratios for the HITRAN coefficient set* *are 13% larger than those of Brooke et al., but approximately 26% larger than the Einstein coefficient set of van der Loo and Groenenboom (2007, 2008). With older A coefficient sets, the discrepancies can be much larger, but it is quite reasonable to consider that these three most recent Einstein coefficient sets are the most appropriate choices available.*

Reply: Following the reviewer's suggestion, Einstein coefficients calculated by van der Loo and Groenenboom [2007, 2008] are also considered in the work. As said by the reviewer, the differences of the band-averaged Einstein coefficient ratios between HITRAN and those of van der Loo and Groenenboom (2007, 2008) are the largest by comparing the three Einstein coefficient datasets. The resultant differences of the retrieved VERs for 1.6-micron and 2.0-micron are 19% and 26%, respectively. The differences can potentially explain most of the deviations between SABER data and the simulations from SCIAMACHY data. The main text has been modified accordingly.

3: *Figure 1 displays the region of overlap between the two instruments (note: it is difficult to view the shaded area, please modify this figure to make it legible). Would it be meaningful to make another comparison by using the overlapping spectral region of the 4-2 band to simulate the SABER 1.6-micron channel? If the fraction of the 4-2 band that is covered is substantial, then such a comparison would be direct to some extent and would rely less on Einstein coefficients. Maybe testing one or two examples would clarify whether there is anything meaningful to be learned and any additional effort is warranted.*

Reply: As suggested by the reviewer, the shaded area in Figure 1 is highlighted to make it more legible. The overlapping spectral region by SCIAMACHY and SABER only covers about half of OH(4-2) emissions. In addition, there are a few OH(3-1) lines in the bandpass of SABER 1.6μm channel. In total, SCIAMACHY measurements cover only about 30% of the total radiances in the SABER 1.6μm channel directly. Therefore, the use of Einstein coefficients to transfer SCIAMACHY to SABER measurements cannot be avoided.

Technical Corrections:

Line 22: *"imaged" or "monitored" may be more appropriate verb choices rather than "captured"*

Reply: "monitored" is used.

Lines 112, 113, 114: *"inverse" or "inversion"?*

Reply: It is "inversion". Corrected.

Lines 162-163: *"It was also found the positive deviations of SABER in-band data from the simulated values, especially for OH 2.0 μm data." Something*

is missing in this phrase.
Reply: This sentence is deleted because a more detailed description is given: **Surprisingly, for the in-band data, the differences for the 1.6 μm and 2.0 μm channels are significantly smaller at most altitudes. They vary in a range of 8-28% (21-50%) and 8-60% (28-100%) from 83 km to 96 km at 0°-20°N (20°N-40°N).**

Line 167: *"than the corresponding" instead of "than corresponding"*
Reply: Corrected.

Figure 7: *"slope" instead of "slop" in the label for the y axis and "slop" instead of "slops" in the caption*
Reply: Corrected.

Line 211: *reference pages are missing*
Reply: Added.

Lines 244: *"Astrophys. J." This is the only journal that appears as an abbreviation (the preferred AMT format).*
Reply: We changed every journal's name to their abbreviation.

Line271 : *"Astrophysics" instead of "Atrophysics" (but still needs abbreviated title).*
Reply: The abbreviation of the journal is used.

References

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