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Discussions

# *Interactive comment on* "IASI-derived $NH_3$ enhancement ratios relative to CO for the tropical biomass burning regions" *by* Simon Whitburn et al.

**Simon Whitburn et al.**

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We would like to thank the referee for his/her positive feedback on the paper and useful comments. All have been addressed. The point-by-point responses to each of the comments are provided below. A 'tracked changes' version of the manuscript is also appended.

We would also like to draw your attention to the following. After the initial submission of the manuscript, a major update in the IASI-NH3 retrieval product was introduced. This update is of importance especially since we identified in the previous version of the NH3 dataset sharp discontinuities in the NH3 time series related to inconsisten-



cies between the different versions of the operational Eumetsat IASI L2 algorithms for temperature and clouds (which are used as input in the neural network). To tackle this issue, we have developed a version of the IASI-NH3 Neural Network which relies on the ERA-Interim ECMWF meteorological input data (along with built-in surface temperature) rather than on the Eumetsat IASI L2 data. This provides a reanalyzed dataset which is coherent in time over the whole period covered by IASI (2008-today) and can therefore be used to investigate interannual variability. The reanalyzed dataset has been described in a paper recently published in AMTD:

Van Damme, M., Whitburn, S., Clarisse, L., Clerbaux, C., Hurtmans, D., and Coheur, P.-F.: Version 2 of the IASI NH3 neural network retrieval algorithm; near-real time and reanalysed datasets, Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2017-239, in review, 2017.

After careful analysis, we have judged that this new dataset should ideally be used also for the present manuscript. We have updated all the figures of the manuscript according to this new dataset. As you will see, the main conclusions of our paper remain unchanged, except for the comparison with the ERNH3/CO from the literature. The IASI derived ERNH3/CO are higher than in the manuscript initially submitted and this leads to a much better agreement with the values given in the literature. With these changes and the comments addressed, we are confident that the paper has been greatly improved.

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3_30: The expression 'fair' is only qualitative. Please describe the agreement in more quantitative terms.

We have changed the sentence in the manuscript to:

Two studies, based on a previous NH3 retrieval algorithm also using the HRI but relying on two-dimensional look-up tables for the conversion into a NH3 total column (molec.cm-2) (Van Damme et al., 2014), have shown a fair agreement between IASI-NH3 observations and other measurements (generally within the uncertainties of the IASI NH3 retrieved columns), with differences of about 60-80% reported in Van Damme et al. (2015) and of 30% on average in Dammers et al. (2016).

4_1: "We also have assumed a similar sensitivity for IASI to NH3 and CO in the lower layers of the atmosphere, which is not expected to introduce a significant bias in the studied regions due to a generally positive thermal contrast prevailing during daytime".
- Can you demonstrate this assumption e.g. by presenting typical averaging kernels showing such a similar sensitivity of the NH3 and CO retrievals at the lower altitudes?

The retrieval algorithm for NH3 does not provide averaging kernels. It is therefore difficult to compare quantitatively the sensitivity of NH3 and CO in the lower layers. However, the sensitivity of thermal nadir measurements near the surface is intimately related to the thermal contrast between the surface and the first layers of the atmosphere (Clerbaux et al., 2009). For NH3, Clarisse et al. (2010) have shown that, when the detection is possible (i.e. in case of good thermal contrast), the peak sensitivity for NH3 is in the boundary layer. For CO, Georges et al. (2009) and Bauduin et al. (2016) have also demonstrated the good sensitivity of IASI in the lower layers in case of high thermal contrast. Since we consider here only daytime measurements, in tropical regions and with a retrieval uncertainty on the NH3 column lower than 100% (i.e. a good sensitivity), the majority of the observations retained correspond to this situation of good thermal contrast.

George, M., Clerbaux, C., Hurtmans, D., Turquety, S., Coheur, P.-F., Pommier, M., Hadji-Lazaro, J., Edwards, D. P., Worden, H., Luo, M., Rinsland, C., and McMillan, W. (2009). Carbon monoxide distributions from the IASI/METOP mission: evaluation with other space-borne remote sensors. Atmos. Chem. Phys., 9(21):8317–8330. doi: 10.5194/acp-9-8317-2009.

Bauduin, S. and Clarisse, L. and Theunissen, M. and George, M. and Hurtmans, D. and



Clerbaux, C. and Coheur, P. F. (2016). IASI's sensitivity to near-surface carbon monoxide (CO): Theoretical analyses and retrievals on test cases. Journal of Quantitative Spectroscopy & Radiative Transfer, 189:428-440. doi: /10.1016/j.jqsrt.2016.12.022.

To clarify this, we have adapted the following sentence in the manuscript to:

We also have assumed a similar sensitivity for IASI to NH3 and CO in the lower layers of the atmosphere. This is not expected to introduce a significant bias since it has been shown for both CO and NH3 that the peak sensitivity was in the lower layers of the atmosphere in case of positive thermal contrast which is generally prevailing in the studied regions during daytime (George et al., 2009; Clarisse et al., 2010; Van Damme et al., 2014; Bauduin et al., 2016).

- Due to the different values of thermal contrast between surface and the lower atmosphere for different observations, an error could be introduced in the dataset which might partly be responsible for the overall variability of the ERs. Have you tried to correlate the temperature contrast with your dataset and can you exclude such an influence?

It is true that the thermal contrast greatly influence the sensitivity of IASI to near-surface measurements. However, as mentioned here above, for the observation considered, we are generally in a situation of high positive thermal contrast where NH3 (and CO) can generally be retrieved with a good accuracy. Moreover, the sensitivity of the retrieved column to the atmospheric parameters (including the thermal contrast) is included in the uncertainty.

4_5: "Whitburn et al. (2016b) have calculated that the use of an alternative profile could affect the retrieved column up to 50%" It would be very helpful if one could try to derive a quantitative error assessment for the NH3/CO ratios combining estimated errors of NH3 and CO, taking into account such effect as described. At least it would be very helpful to put together a table where specific uncertainties and their source are listed for NH3 and CO separately.

Since the $ER_{NH3/CO}$ are calculated from the slope of the linear regression of $NH_3$ versus CO total columns, they do not rely on the individual uncertainties of each $NH_3$ and CO observation. It is therefore very difficult to estimate a quantitative error assessment for the $NH_3$/CO ratios. As explained in the next comment, the total uncertainty on the $NH_3$ retrieved columns depend on the atmospheric conditions and on the amount of $NH_3$. Examples of the relative importance of the different atmospheric parameters on the total uncertainty are given in Whitburn et al. (2016b). The observations considered in this study correspond generally to a situation of high thermal contrast and a relatively high $NH_3$ column. In the case of high thermal contrast and high $NH_3$ column, Whitburn et al. (2016b) have shown that the contribution to the total uncertainty was well distributed on the different parameters while, for high thermal contrast but lower columns, the major contribution to the total uncertainty was on the HRI (mainly instrumental noise). Note that Whitburn et al. (2016b) have shown that, despite a possible high uncertainty, the average bias on the columns is close to zero. For CO, the uncertainty is generally lower (of about 5-10% and up to 20% for the observations considered here). The uncertainty on the calculated $ER_{NH3/CO}$ is therefore mainly driven by the uncertainty on the $NH_3$ column (which is lower than 100% due to the pre-filtering applied).

5_26: "With a relative error lower than 100% for NH3": Which kind of error is this? Only due to spectral noise?

The error associated with the $NH_3$ retrieved columns includes a full uncertainty analysis and depend on the atmospheric conditions and the amount of $NH_3$. The uncertainty analysis is performed by perturbing the input parameters (Temperature profile, $NH_3$ a priori vertical profile, HRI, etc.) of the neural network and evaluates for each retrieved column how the uncertainty of the input parameters propagates to the final result. We have added the following sentence in the manuscript to make it more clear for the reader (3_21):

The retrieval also includes a full uncertainty analysis, performed by perturbing the input



parameters (temperature profile, HRI, $NH_3$ a priori profile, etc.) of the neural network.

8_5: "The agreement would become even better if we consider in addition a possible bias due to the use of a non-representative NH3 vertical profile." What is the reason that the agreement would improve and not becoming worse when using another a-priori NH3 profile?

Thank you for pointing this out. It is indeed very hard to evaluate whether the 'real' $NH_3$ profiles would increase or decrease the retrieved columns because of the large variety of $NH_3$ profiles associated with transported fire plumes. As mentioned above, Clarisse et al. (2010) have shown that in case of favorable thermal contrast, the peak sensitivity of IASI for $NH_3$ is in the boundary layer (below 1 km). For the fire plumes, Val Martin et al. (2010) have shown that, for tropical forests and grasslands/croplands fires, the plume height was generally below the boundary layer height while only a small fraction peaked above 1.5 km. Due to a lack of available information on plume height for each individual fires, it is hard to determine the impact of the true profile on the retrieved columns (and therefore on the ratio $NH_3$/CO).

M. Val Martin, J. A. Logan, R. A. Kahn, F.-Y. Leung, D. L. Nelson, and D. J. Diner. Smoke injection heights from fires in North America: analysis of 5 years of satellite observations. Atmospheric Chemistry and Physics, 10(4):1491-1510, 2010. doi: 10.5194/acp-10-1491-2010.

We have adapted the following sentence to clarify this:

Finally, as we mentioned in section 2.1, the retrieval of $NH_3$ could be biased by the use of a constant $NH_3$ vertical profile not representative of the variety of profiles observed above biomass burning plumes.

10_8: "These differences may be explained by various factors including…": In the list, possible errors regarding the NH3 (and CO) IASI retrievals is missing though it has been mentioned before.

We have modified the following sentence to take this into account:

This may be explained by various factors including 1) the parametrization (pre- and post-filtering of the data) considered for the calculation of the ERNH3/CO, 2) a bias towards the flaming phase due to the selection of IASI observations close to MODIS active fires (less sensitive to the smoldering phase) and 3) a possible accumulation of CO in the region during the fire season, introducing a low-bias in the IASI-derived ERNH3/CO. Another possible explanation might lie in the use of a unique vertical profile shape in the retrieval scheme of NH3 while biomass burning plumes exhibit a large variety of plume injection heights.

23_Table1: It would be very helpful if you could list, e.g. after each number, the result from the actual analysis for a similar biome and geographic region.

This is indeed a good suggestion. We have added to table 1 two rows including the results from the actual analysis (one on a regional level and one for a biome level).

Technical comments have been taken into account.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2017-331/acp-2017-331-AC1-supplement.pdf

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