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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Comparisons between ground-based FTIR and MIPAS N_2O and HNO_3 profiles before and after assimilation in BASCOE" *by* C. Vigouroux et al.

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The authors thank the referees for their helpful and constructive comments and questions. The manuscript has been clarified in many points. Therefore, the referees have contributed to a substantial improvement of the paper.

Referee #2

1. Specific comments

1) Page 8338

Referee: "The manuscripts published in the ESA Special publication are not easy accessible. I therefore wonder on the usefulness of having as many references to this

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special publication".

The interest of giving individual references to the papers in the *ESA Special publication* is that they provide an indication of the persons working on the MIPAS validation for each species individually. The proceedings, and also the presentations, of ACVE-2 can be found at http://envisat.esa.int/workshops/acve2/.

But, following the referee's comment, we have limited, in the new manuscript, the specific references to the ones dealing with N2O and HNO3.

The reference Fricke et al. (2004), in the same ESA Special Publication, was the only source available at the time we have submitted the paper for the well-known problem of MIPAS altitude referencing, but the recent Raspollini et al (2006) paper provides a better reference.

Concerning the bias on HNO3 due to different spectroscopic databases, the reference Blumenstock (2004b) has been replaced by Flaud et al (2003a, b) and Raspollini et al (2006).

2) Page 8339

Referee: "Section 2 last sentence: "MIPAS data are valid over variable altitude range". What does "valid" refer to? Is it related to large errors; missing data?"

It refers to missing data, probably due to clouds (see answers to Referee 1). This clarification has been added in the manuscript.

In addition, we have also removed a few scans for which the MIPAS error was 2 times larger than the mean MIPAS error over all considered scans. This comment has been added in Section 5.3 of the manuscript.

3) Page 8340

Referee: "Section 2 last sentence: "Beyond the limits of MIPAS measurements, the MIPAS profiles are extrapolated using the MIPAS initial guess profile". It is not clear to

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me what have been done (what are the MIPAS limits), nor what impact this could have on the comparison."

The extrapolation is needed for calculating the smoothed profiles: the convolution with the averaging kernels requires extended MIPAS profiles on the grid of the FTIR profiles (which is the grid of the FTIR averaging kernels) covering the altitude range from the surface up to around 100 km. The MIPAS 'valid' grid (with no missing data) is different for each scan. For example, if a scan covers 10 km to 50 km, it will be extrapolated from the ground to 10 km, and from 50 km to 100 km using the MIPAS initial guess profile, which covers 0 to 120 km.

The impact of this extrapolation is minimal, since we are focusing on the (smoothed) partial columns above 12 km for N2O (and above 14 km for HNO3), i.e., in the altitude range where valid MIPAS data exist. Remember the statement in the manuscript that MIPAS scans with a lower altitude limit above 12 km for N2O and above 14 km for HNO3 are not included in the statistics (lines 1 to 3 on page 8340). For example, if the valid MIPAS range covers only the 16 to 50 km range, we don't use the scan in the statistics. So no extrapolated values are used in the partial columns limits. The horizontal bars in the figures showing profile comparisons (Figs. 8 and 11) are shown in order to avoid a discussion on comparisons outside the limits, where extrapolated values are used.

The lowest altitude observed in MIPAS data for N2O is 6 km. So it is a pity to compare FTIR (which has a better sensitivity in the troposphere for N2O) and MIPAS only for altitudes higher than 12 km. But we are forced to do so if we don't want to use extrapolated values in the comparisons, and keep a reasonable number of scans in the statistical data set.

Even if no 'pure' extrapolated values are used in partial columns and profiles comparisons (within the horizontal bars), one cannot avoid a slight impact of the extrapolation coming from the fact that the averaging kernels have a finite width and mix in some

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information from the extrapolated values (correlation between adjacent altitudes). The impact of that is supposed to be small and has been neglected. Especially at the high altitude boundary, there is at least 10 km difference between the upper limit of partial columns (chosen where the sensitivity of FTIR becomes lower than 0.5, so around 30 km) and the higher altitude covered by the MIPAS scans (around 43 km for HNO3 and 61 km for N2O). Above this sensitivity limit, the MIPAS smoothed profile is anyway becoming very close to the FTIR a priori (because the averaging kernels become close to zero values). The impact of the extrapolation may be somewhat larger at the lower altitude limit of the partial columns. We have evaluated the impact by using a different profile for the extrapolation and we have found that the variation of the relative partial column differences is less than 0.2% (in absolute units), which is anyway much smaller than the standard deviations.

4) Page 8342

Referee: "A priori information is crucial when trying to retrieve profile information from integrated measurements. The fact that this information varies from site to site may be subject to criticism if the authors do not at least clarify some issues. In particular, the Sa covariance matrix is not defined at any stage. Is it the same at the different sites? How much does it vary from site to site? Without this information it is very difficult to judge on the results (DOFS, sensitivity range) and also on the statistics relevance of the comparison. Also the impact of using different micro-windows (see Table 1) is unclear."

Here, the referee is questioning two points:

a) Importance of giving more details on the individual retrieval strategies in order to better understand the different DOFS and sensitivity range given in Table 1.

b) Importance of a homogeneity in the retrieval strategies for the "statistical relevance of the comparison", and "the fact that this information varies from site to site may be subject to criticism".

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The idea of the paper in general is not to judge and compare the FTIR results between them, but to show whether there is an agreement between MIPAS and *independent* FTIR data at different locations. The word independent is important here: we only prescribed the a priori profiles to be used in the FTIR retrievals, to avoid additional difficulties in the interpretation linked to different a priori profiles; all other retrieval parameters have been optimised by the FTIR PIs for their particular situation (site and spectral characteristics). What is important in the further comparisons is that we take into account the individual properties of the retrieval results, expressed in the averaging kernels and associated DOFS. This latter information is provided explicitly in the manuscript.

The characteristics of the retrieval results - expressed by the averaging kernels - are determined by the selection of microwindows, *all* the a priori information, as well as additional model parameters and retrieval parameter settings. So it seems to us that it does not make much sense to add e.g., the information about the a priori covariance matrix (Sa) only. Either we provide all details about the retrieval, or we provide only the elements that characterise the resulting retrieval results. We have opted for the latter choice – by providing Table 2 and examples of averaging kernels. (The first option would represent almost an additional paper or at least a significant annex). We have now also added explicit information about the averaging kernels for the partial columns (new Fig. 4 in the revised manuscript) and the associated DOFS (new columns in Table 2).

Table 2 therefore contains all necessary information to identify the limits between which partial column comparisons make sense, at each site, and to explain why they are different from station to station.

The reason for providing the information about the microwindows (Table 1) is to have better insight in possible biases coming from spectroscopic uncertainties, as is the case for HNO3, but not for N2O.

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The statistical relevance of the paper is to show that the agreement between MIPAS and FTIR data is good at all stations. And we believe that this conclusion is even more valid as it is obtained with independent choices of the FTIR retrieval strategy at each station (of course, each contributor's retrieval strategy is supposed to give robust results!). The statistics of the partial column comparisons show that clearly. This same conclusion could not have been made if the strategies would have been the same at each station. Of course, we have noticed, and this was mentioned in Sections 6.1.2 and 6.2.2 that for profiles comparisons, the results are influenced by the retrieval strategies. But as it was mentioned as well, the shapes of the profile differences (statistically spoken) mustn't be over-interpreted, because of the poor vertical resolution of the FTIR; the comparisons of partial columns are more relevant than the profiles ones.

Remark: We have removed a sentence in the conclusions that is misleading: "The consistency between the retrievals from the five stations has been optimised". Only the spectroscopic databases and the a priori profile information were chosen to be consistent.

5) Table 1:

Referee: "It is striking to note that same microwindows do not necessarily include the same interferers. Obviously, this had to do with the interfering species for which a column is simultaneously fitted. This should be at least stated but it also raises the question of the possible impact of the fixed model parameters on the retrievals."

A priori information could vary a lot if you are at mid- or high latitudes, for example water vapour could be more abundant in some sites. At each station, the impact on the retrievals of fitting additional interfering species could be more or less significant. As the choice of the a priori profiles for all the trace gases present in the microwindows (not only the fitted ones) is let to the judgment of each FTIR contributor, the necessity of retrieving or not an interfering species has to be tested individually for each case. Again the objective of the paper is not to compare FTIR results between them. We

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are interested in the averaging kernels and the DOFS for the target gases (HNO3 and N2O), which are used for the MIPAS comparisons. The impact on them of trace gases that are not fitted in the retrievals is negligible.

6) Page 8343

Referee: "It is not clear to me why the DOFS for N2O is larger at the Jungfraujoch. The altitude of the site is given as explanation but is it the physical reason? It is also the reverse for HNO3. Is it due to the fact that one is a typical tropospheric source and the other a stratospheric source?"

Yes, indeed the effect of the altitude site is stronger for a tropospheric source species. The effect of the altitude on HNO3 on the DOFS should be very small because there is almost no information at low altitude (see Table 2, for the sensitivity range: the sensitivity becomes larger to 0.5 only at 8 km). On the contrary, the sensitivity of a tropospheric species as N2O is higher near the ground. The test was made to calculate the DOFS at Jungfraujoch with a 'fictive' altitude site of 0 km, all retrieval parameters remaining the same, and the DOFS was then comparable to the other stations: we obtained a DOFS=3.8.

For HNO3 the DOFS is even lower than for the other stations: it is partly due to the fact that only a single micro-window is used, and partly due to stronger constraints in the a priori covariance matrix.

Referee: "Table 2: It is not clear at this stage how the sensitivity range is defined. Reference to the text should be made."

We have added it in the revised manuscript.

Referee: "Also, as stated above, it is hard if not impossible to compare the results without information on the a priori variability".

Again, as stated above, the aim of the paper was not to compare the retrieval characteristics at the different ground-based stations between them. Table 2 is given to

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indicate that we have selected the sensitivity ranges for the comparisons with MIPAS in a consistent way, accounting for the different retrieval characteristics. The fact that the DOFS are different just explains to the readers why the comparisons will be made between different limits. We have verified that for all stations the DOFS for the partial columns is greater than one, and the averaging kernels of partial columns peak at the right altitude.

But, you are right if one considers the profiles comparisons shapes in detail, as stated above and in the previous manuscript. For example, the fact that the N2O upper limit at the Jungfraujoch is so high compared to the other stations is partly due to the fact that at high altitudes the a priori variances (diagonal elements of the Sa matrix) are larger than at other stations. This has an impact if one wants to discuss in details Fig. 8 (number in initial version of the manuscript) at high altitude: the standard deviation for the MIPAS-FTIR comparison is very high, and we could conclude that, if the high variability was chosen to be close to the reality, the FTIR retrievals do not seem to reproduce the reality. But the impact on partial columns comparisons is small because there is almost no N2O at high altitude.

Referee: "Figure 3: For HNO3, the analysis of the averaging kernels is not straightforward. Table 2 reports a mean DOFS of 2.8 but one can hardly see where these informations are located, especially as there are important anti-correlations."

Yes, it is right. We have added a figure with the relevant partial columns averaging kernels, to show where the information is for the partial columns that will be compared with MIPAS. Also, we have added in Table 2 the DOFS for the partial columns that are used in the comparisons. They were already given in the text in Sections 6.1.2 and 6.2.2, but it will now be clearer also in the table.

7) Page 8344

Referee: "The partial columns are not defined on the same altitude ranges for the different station: does that not impact at all on the statistics?

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Again, we do not compare the results of different stations between them. The idea is to show whether there is an agreement with MIPAS, in the altitude ranges where the FTIR has some sensitivity. The error budget evaluations have taken the different altitude limits into account. For example, as the FTIR has a low vertical resolution, we can expect that a very small partial column would show more variability than the 'physical' one, thus the standard deviations of the comparisons with MIPAS would be larger. But, the FTIR error in this case would also be larger. As we compare the standard deviations to the corresponding random error budgets, there is no problem.

Referee: "Indeed the ranges have been defined in terms of sensitivity without considerations of the possible error profiles".

As the FTIR has a low vertical resolution, it is important to compare with MIPAS in altitude ranges where the a priori information has a small contribution to the FTIR retrieval results, even if the FTIR error is larger at these altitudes. Because the error budget is taken into account anyway to judge the comparisons, we do not see the point here.

Referee: "Figure 5: For N2O, is it correct that the errors of the FTIR are close to 10% in the troposphere? If yes, how does that compare to the prior uncertainty? Is a smaller variability for N2O not expected?"

Yes, it is correct. In the troposphere, one expects a variability that is at least one order of magnitude smaller.

Anyway, we do not make the comparisons in the troposphere because there are too few MIPAS scans that cover low altitude ranges (6-12 km).

8) Page 8356-8357

Referee: "The bias observed for HNO3 is explained in terms of different spectroscopy. The differences in intensities are pointed out but the most recent databases also differ, at least, from the point of view of the number of lines. Does this not affect the

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retrievals?"

See answer to Referee 1.

2. Technical corrections

All suggested corrections have been taken in to account in the revised version of the manuscript.

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