Reply to reviewer # 2, egusphere-2026-4116

We thank the reviewer for their constructive and helpful comments that will improve the manuscript. Please find below in black the comments of the reviewer, and in blue our replies.

General Comments

The manuscript offers a very comprehensive overview and error analysis of the MIPAS nitrogen species. For each species previous validation work, the retrieval method, error analysis, and a light validation is presented. It is well written, thorough, and should be published. I have some comments and suggestions for the authors to consider.

The manuscript would benefit greatly from a little more "compartmentalizing" of the information presented. There seems to be a dual intent of providing an authoritative reference for the data version, but also serving as a guide for users. These two types of readers are often separate, information for both is provided in each section. As much as we would like every data user to read and understand a manuscript like this most of them just want to see a quick summary table with precision/accuracy/resolution and any usage recommendations. I would recommend the authors think about what the most important points they want a data user to take away, and place it together in one summary section.

Thank you for this recommendation. We will add a section including a table to the manuscript that summarizes the most important information for data users.

Specific Comments

l.71 "[MIPAS] on Envisat has been the only satellite so far that could measure all relevant NOy..." while true, for the reader it may be helpful to mention which nitrogen species have (and continue) to be measured by other instruments, especially since comparisons are performed later on

Thank you, we will add the NOy species measured by MIPAS. These are NO, NO_2, HNO_3, N_2O_5, HNO_4, $ClONO_2$, and $BrONO_2$. The latter, however, is only provided as a mean over 10^o latitude and 3 days, separated for sunlit and night conditions (Höpfner et al., 2021).

l.119: "radiance profiles" here is ambiguous since it has not yet been mentioned in this section that MIPAS vertically scans

The information about vertical scanning will be added to the manuscript.

l. 133 "Major changes refer to the nonlinearity correction", perhaps it is better to say something like "A major change in the most recent version was an improvement to the nonlinearity correction"

Thank you, we will change this accordingly.

l. 133. A better description of the data version numbering could be useful. The final appended numbers at the end are a mystery to me.

Thank you. We will add more explanations about the version numbering.

Section 2.2 is quite thorough, and a good summary of the performance of previous MIPAS data versions, but I'm left wondering what I am supposed to take away from this section. Most of the

data versions mentioned are V3-5, which might be a few revisions behind the currently presented V8. This is further complicated that the data versions may be quite old for the instruments being compared against. If the point is to motivate some of the improvements presented in this manuscript then I would encourage the authors to provide commentary on if the differences presented in this section are thought to be issues with the previous MIPAS processing to motivate the new developments. Related to this, unless I missed it, at this point the reader has not been told that V5 was the previous processing version.

Thank you! This has indeed not been made clear. We will add information to the revised version of the manuscript that we refer to the most recent data versions and validation efforts before the release of version 8.

l.243 "this spectroscopic dataset is identical to HITRAN2016" with HITRAN2024 now being out, this statement feels out of date

Indeed, the HITRAN data version used in these retrievals is not the most recent one. When we began the V8 trace gas retrievals, HITRAN2016 was the most recent version. For reasons of consistency, we did not want to change the spectroscopic information during the course of the data analysis. Further, for many species, we found that no changes were made in more recent HITRAN versions so that refering to a more recent HITRAN version would not have made a difference.

l.255 Related to the continuum emission… At these upper altitudes is it possible to distinguish a baseline offset versus something like aerosol? I thought the information came from the extra optical depth, but if the atmosphere is thin don't both terms look the same?

Yes, in principle you are right, in the linear case offset and continuum emission are almost impossible to distinguish. However, we have good information on the offset from the level-1b characterization of the data (Kleinert et al., 2018). We used this information as a priori under strong regularization.

l. 337 "This is a feature of all retrievals performed on retrieval grids finer than the tangent altitude spacing" I know what you are saying, but it's a little more complicated than just that because of the instantaneous field of view of the instrument.

Thank you, this is correct. We will introduce the field of view in this context as well.

Sec. 4.2 Perhaps it would be illustrative to show information displacement relative to the actual limb scan varying tangent point instead of a single reference to separate out the actual 2D effect and the geometry effect. I'm not sure what is included in the MIPAS L2 data, but some data providers will include the tangent point at multiple reference altitudes so the user can pick which one is most useful for their application.

We know that e.g. ACE-FTS provides the information on the geolocation of each tangent point, however, MIPAS does not. Instead, only the geolocation of the tangent point in the middle of the profile of each scan (near to 30 km altitude for NOM observations) is provided. The information displacement provides the horizontal distance to the vertical reference profile where the information at a specific altitude really comes from. All retrieved vmrs are rectified to the nominal geolocation; this, however, is relevant in cases only where horizontal gradients are also retrieved (which is not the case for the four species discussed in this paper for which horizontal homogeneity is assumed). For data users who – for example – compare to model simulations with high spatial

resolution, the information provided can be used to assess the relevance of the profile tilt for their comparisons.

As discussed in von Clarmann et al. (2009a), the major part of the information displacement is due to the geometry effect, i.e. the change of tangent point geolocation with the pointing elevation in combination with the movement of the satellite during the scan. Due to MIPAS looking rearward and scanning from top to bottom, the two effects almost compensate each other resulting in a profile tilt with a horizontal distance of less than ± 150 km at the top and bottom of a profile (see Fig. R2-1). Radiative transfer effects, e.g. saturation effects, provide a displacement in the order of ±10 km.

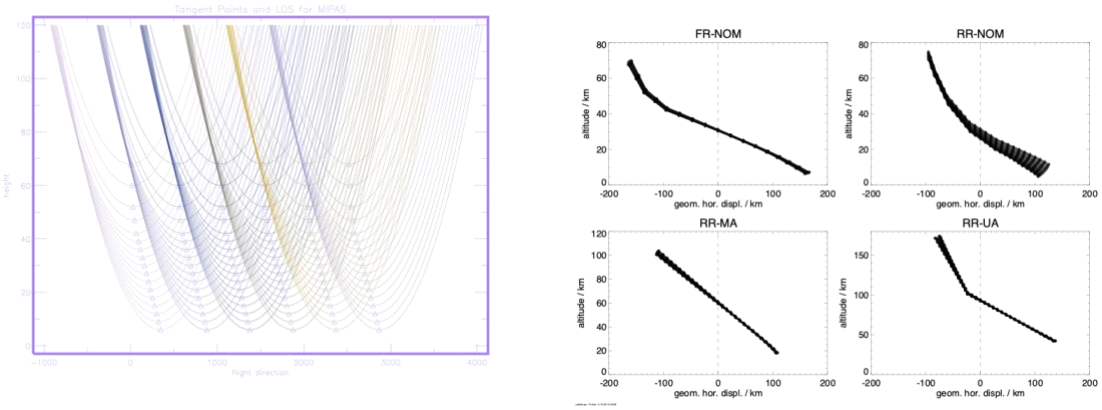


Figure R2-1. Left panel: MIPAS ray paths through the atmosphere for 6 consecutive scans provided as altitudes along the orbit in satellite flight direction. The tangent altitudes for each measured spectrum of a scan are indicated as diamonds. Right panel: Geometric displacement of the tangent points of scans along an orbit relative to the nominal geolocation (tangent point nearest to 30 km for NOM mode). The variation along the orbit results from the oblateness of the Earth, and, in case of RR-NOM, from the variation of the lowest tangent altitude with latitude.

We will add some explanation following the sentences above to the revised version of the manuscript, and additionally provide the average information displacement due to the pure geometry effect in Tables 4 to 6.

Fig. 10. From the figure it looks like the spectroscopy error is greater than the total systematic error? Is that right?

This is correct. As described in von Clarmann et al. (2022), we consider also contributions of spectroscopic uncertainties to random errors. These occur if systematic errors like spectroscopic data uncertainties modulate randomly over time and/or space, e.g. due to varying temperatures in connection with the non-linear relation of spectroscopic parameters to temperature. The bias (i.e. systematic) part of the error due to spectroscopic uncertainties is determined from the mean estimated error of an ensemble representing a certain latitude/season/illumination (one of the 36 representative atmospheres), while the random part is determined from its standard deviation.

In our figure we sum up systematic variances for the total systematic error, which in this specific case is almost completely given by the systematic spectroscopic uncertainties (bias). The random part of the spectroscopic error added into the total spectroscopic error provides the surplus to the total systematic error. We will explain this procedure in more detail in the revised version of the

manuscript. Further, as requested by reviewer #1, we will add a table indicating the random and systematic errors shown in the Figures.

In the following Figure (Fig. R2-2) the error components are shown separated into random (Fig. R2-2, bottom left) and systematic (Fig. R2-2, bottom right) errors. In the upper part of the profile, the random and systematic parts of the spectroscopic error are almost comparable. For this reason, the total spectroscopic error, summed up from the random and systematic parts, is considerably larger than the systematic part alone, which, in turn, accounts for almost the entire systematic error.

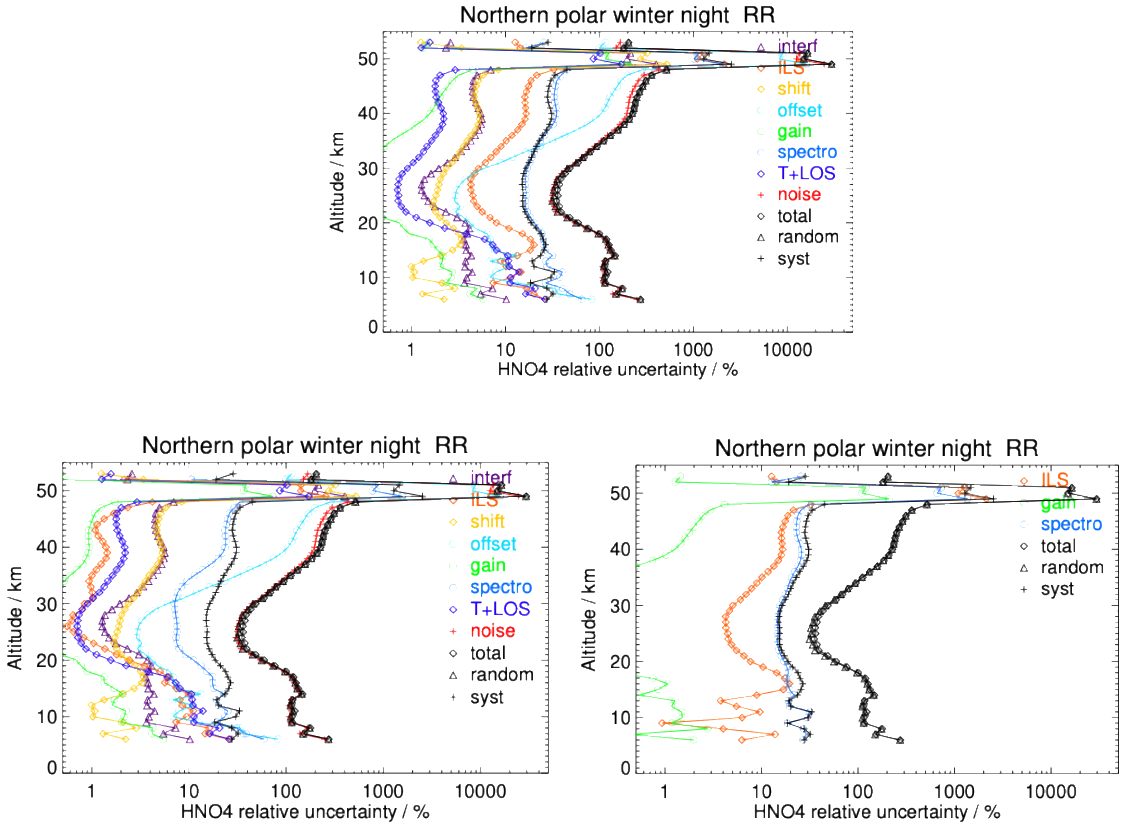


Figure R2-2. Error components for HNO_4, Northern winter polar night conditions. The upper panel shows all error components summed up along the error sources. The lower left panel shows the random components of all error sources, while the lower right panel shows the systematic components. In all panels, errors due to uncertainties in spectroscopy are depicted as open light blue circles.

Section 5. The systematic error on NOy is a little harder to interpret than the other species. A single species spectroscopic error is going to be pretty close to perfectly correlated, but different spectroscopic error in each species going into NOy will cause different errors depending on the partitioning and be pseudo-random.

The systematic errors of the individual species within one geolocation are considered to be fully uncorrelated. Looking at many profiles, it is correct that varying partitioning causes varying total systematic errors of NOy. However, we attempt to tackle this problem by assessing error budgets for our set of 36 representative atmospheres that cover the expected varying partitionings. For each individual NOy profile, the individual error profiles (random, systematic, and total) are calculated by scaling the error components that are relative by nature with the individual vmr profile. It is inevitable that for this individual NOy profile, the partitioning of the six species may be different

than for the related representative atmosphere. In this sense, there is a remaining unassessed pseudo-random component in the error assessment, and you are correct. We will add a discussion of this issue to the manuscript.

Section 8: I'm a little confused about the pressure grid. The regular MIPAS retrieval is done on an altitude grid correct? So in the coarse grid retrieval you would have a different altitude grid for each scan? Or is the retrieval done on a fixed altitude grid then converted to pressure layer means?

Yes, in the coarse grid retrieval we have a different altitude grid for each scan, while the pressure grid is constant. Before starting the coarse grid retrieval, the regular profiles are converted onto a pressure grid by using the retrieved temperature and pressure for each altitude grid point, and then interpolated to a fixed pressure grid. The coarse grid retrieval is then performed on the fixed pressure grid.

l.735 Maybe this is on my end but the link doesn't work for me.

Thank you. We have checked the link and found a typo which will be corrected in the revised version.

References:

Höpfner, M., Kirner, O., Wetzel, G., Sinnhuber, B.-M., Haenel, F., Johansson, S., Orphal, J., Ruhnke, R., Stiller, G., and von Clarmann, T.: The Michelson Interferometer for Passive Atmospheric Sounding global climatology of $BrONO_2$ 2002–2012: a test for stratospheric bromine chemistry, Atmos. Chem. Phys., 21, 18433–18464, https://doi.org/10.5194/acp-21-18433-2021, 2021.