Reply to reviewer # 1, 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 entitled "V*ersion 8 of IMK/IAA MIPAS reactive nitrogen reservoir gases"* by G. Stiller et al. presents a comprehensive description of Version 8 of the IMK/IAA MIPAS full-mission retrieval products for four reactive nitrogen reservoir gases, namely HNO_3, $ClONO_2$, HNO_4, and N_2O_5, together with the combined NOy product.

For each species, the manuscript provides a detailed description of the issues identified in previous versions, the changes introduced in the retrieval algorithm and auxiliary data, the quantities characterizing the products (including vertical and horizontal resolution and the error budget), the differences with respect to the previous version and discussion on the consequent possible impact on the quality of the products. Finally a discussion on the relative signature of processes in global distribution and time series is provided. The paper is a carefully documented reference to the released data product, in the tradition of previous IMK/IAA MIPAS species papers (e.g. Höpfner et al. 2021 for $BrONO_2$; Funke et al. 2023, 2026 for NO/NO_2).

Overall, I find the manuscript useful and potentially valuable for the atmospheric user community. Information of this type is essential for users who need to assess the quality and suitability of the products for their specific applications. For other satellite instruments, similar information is often provided in dedicated data-quality documents or readme files; for example, the MLS Version 5 Data Quality Document provides a detailed description of the corresponding products, which may have the advantage of containing all relevant information of the products in a consistent way in a unique document. Bringing the relevant information together in a peer-reviewed publication is nevertheless useful, as it provides a citable and comprehensive reference for the MIPAS IMK/IAA V8 products.

We thank the reviewer for their positive assessment. We decided for a publication in a peer-reviewed journal because by this, the documentation will receive a doi and will be traceable for a longer period of time. Internal documentation may tend to vanish after a few years because URLs change or servers are no longer maintained. Since the data version we describe here is most probably the final MIPAS data version, a close-to-permanent solution seemed most desirable to us.

Given the length and detailed nature of the manuscript, however, some of the information that is particularly relevant for data users is currently difficult to locate. Furthermore, some general concepts, which are likely described in more detail in other publications, are introduced here only at a rather general level. I therefore suggest a few minor additions and clarifications that, in my opinion, would further improve the manuscript's usefulness as a reference document for current and future users of the dataset.

We thank the reviewer for their thorough reading and their most helpful comments.

Specific comments

1. Sections 3 and 4: I strongly recommend adding a summary table reporting the altitude range over which the retrieval is actually performed for each species and measurement mode, together with the recommended altitude range for scientific use of each product. At

present, this information is provided at different locations in the text, but it is not straightforward to identify. Given the intended use of the manuscript as a reference for the datasets, having this information summarized in a single table would be very helpful.

Thank you, this is most helpful. We shall provide a table with the information of the altitude ranges, together with the most important other information for data users to take away, as requested by the other reviewer.

2. Page 19, line 370: The sentence is not very clear. Does the 'respective standard deviation' refer to the information displacement? In this case, are you using the same definition of von Clarmann et al., 2009a? Please clarify also that the factor (2\sqrt{2\ln 2}) converts the standard deviation of a Gaussian distribution into its full width at half maximum (FWHM).

   Yes, the standard deviation of the information displacement, evaluated from an ensemble of example profiles, is meant. And yes, we use the same definition as in von Clarmann et al., 2009a. In our opinion, the sentence "As long as the information distribution follows a normal distribution, this metric is equivalent with the full width at half maximum of the vertically integrated 2D averaging kernels" (l371/372) states that the standard deviation of a normal (= Gaussian) distribution is converted into its full width at half maximum by multiplying it with 2sqrt{2ln2}.

   Page 385: I suggest adding the corresponding horizontal sampling directly to Tables 4–6. At present, this information is provided only in the text, whereas including it in the tables would make the product characteristics easier to compare.

   Thank you for this suggestion; we will add the respective information to Tables 4 to 9.

3. Section 4.2: Could the authors clarify the purpose and practical use of the "information displacement"? In particular, can this quantity be used to determine the appropriate horizontal location of an individual retrieved profile at different altitudes? If so, this would be useful information for data users and could be explained more explicitly. Furthermore, is the information displacement provided for each individual profile, or is it primarily a diagnostic quantity intended to characterize the average behaviour of the retrieval?

   The information displacement provides the horizontal distance to the vertical reference profile where the information at a specific altitude really comes from. The nominal geolocation of a profile is given as the latitude and longitude of the tangent point nearest to 30 km (for nominal mode observations; 60 km for MA/UA/NLC observations), and the profile is assumed to be vertical. All retrieved vmrs are rectified to this 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; we assume horizontal homogeneity for them. For comparisons with an atmospheric model with very high spatial resolution it could be of relevance to understand where exactly the retrieved vmr was measured. Strictly speaking, the model would need to be convolved with the horizontal averaging kernel of the MIPAS observation. Unfortunately, neither the horizontal averaging kernels nor the information displacement is provided for each individual profile in the data set. It is a diagnostic quantity for the behaviour of the average retrieval that, however, does not change severely for similar latitudes. If necessary, we can provide this information to the data user for an example orbit. See also our reply to reviewer #2 wrt this issue.

4. Section 5, Eq. (1) – vertical resolution of NOy. What is the impact of the change in the equation of vertical resolution and mainly, what is the vertical resolution of NOy?

The formulation for vertical resolution was updated because vertical resolution is fundamentally inversely proportional to information content. Because the total information content of NOy is given by the volume mixing ratio (VMR)-weighted sum of the information contents of its individual constituent species, the combined vertical resolution of NOy cannot be derived via a simple linear average. Instead, it must be calculated as the inverse of the VMR-weighted average of the inverse individual vertical resolutions. This change ensures a physically consistent representation of the retrieved NOy vertical smoothing characteristics, preventing high-concentration species from artificially dominating or masking the informational contributions of minor individual NOy families.

The vertical resolution of NOy is provided with each individual profile in the MIPAS NOy data set. We will show an example of the vertical resolution of NOy in the revised version of the manuscript.

5. Section 4.3.1: Please clarify which contributions are included in the reported random error. If possible, I suggest adding this information to the relevant tables, so that users can more readily understand the components of the reported error budget.

   We will provide a table with random and systematic errors as reported in the respective figures. Within our error assessment we follow strictly the method layed out in von Clarmann et al., 2020 and von Clarmann et al., 2022. In the latter, the problem of error sources causing systematic as well as random errors is discussed under the term 'headache errors'. We follow this concept, too, and therefore include random errors also for error sources that have usually been considered purely systematic, such as spectroscopic uncertainties.

6. Data screening and recommended usage: Since one of the main purposes of the manuscript is to provide users with information needed to work with the V8 products, I suggest adding a short subsection describing the recommended data screening procedure. In particular, it would be useful to specify which quality flags, error thresholds, altitude restrictions, or other criteria should be applied when selecting profiles for scientific analysis.

   Thank you for this comment; indeed, such a section would be most useful. We will include it in the revised version of the manuscript.

7. N_2O_5/H_2SO_4 joint retrieval and consequences: Did interference of H_2SO4 in the N_2O_5 retrieval (Sect. 3.4) appeared in the retrieval residuals or was it completely compensated by the increase of N2O5 in previous version? In the first case probably a residual comparison with/without H_2SO_4 included would be of value.

   Comparison of the residuals with and without H_2SO_4 as joint fit parameter (i.e. comparing V5 and V8 retrievals) demonstrates that the rms becomes smaller with H_2SO_4 included, and the N_2O_5 signature cannot fully compensate for the H_2SO_4 contribution to the spectrum, in particular around 1240 cm^{-1} (see Fig. R1-1). We shall add a short discussion of the impact of joint-fitting H_2SO_4 on the spectral resisuals to the revised version of the paper.

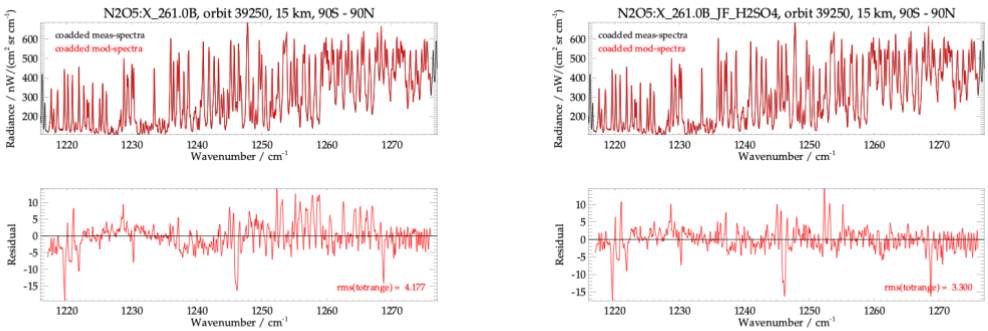


Figure R1-1. Measured (black) and modelled (red) spectra at 15 km tangent altitude covering the N_2O_5 signature coadded over one orbit are shown in the upper part of the panels. The lower parts show the residuals between measured and modelled spectra. In the left panel, the retrieval without the joint-fit of H_2SO_4 (version 5 retrieval) is shown. The right panel shows the version 8 retrieval result with H_2SO_4 as joint fit parameter.

8. Section 6: It would be useful to provide some discussion of the origin of the differences between V8 and V5. To what extent can these differences be attributed to changes in the retrieval algorithm, changes in the auxiliary data, changes in the L1? For example, for HNO_3, a new version of the spectroscopic database has been used. Could the authors comment on whether, and to what extent, the observed differences may be related to this change?

   Where possible, we will add such a discussion to the revised version. In general, we expect an impact of the improved calibration (i.e. Level-1b improvement) on the trends of time series, since the major calibration improvements dealt with better adjustment to the detector aging. Another observed major impact had the extension of a continuum fit up to the upper stratosphere instead to an altitude of 30 km only, together with a strongly constrained offset fit. Changes in spectroscopy always have a strong immediate impact on the resulting trace gas profiles.

9. Section 6: The authors are transparent that Section 6 is just a discussion on possible consequences of delta differences between V8 and V5 products on the results of previous validation. However, in several places (e.g., Sect. 6.2 $ClONO_2$, Sect. 6.4 N_2O_5) the changes in the new version indicate an increase of the discrepancies wrt ACE-FTS rather than a decrease of V8 wrt V5, in some cases substantially (e.g., $ClONO_2$ at 40 km, up to 100% increase in polar summer; N_2O_5 negative changes in the lower stratosphere "further worsen the discrepancy"). While the authors correctly point out that a proper reassessment needs an updated ACE-FTS version, I recommend the paper state more explicitly this in the conclusions for $ClONO_2$ and N_2O_5 specifically.

   This will be done in the revised version.

10. HNO_4 post-2004 interruption issue (Sect. 6.3, Fig. 16). The authors highlight an artifact caused by detector noise between the 2004 interruption and May 2005, and state this is "fully covered by the increased uncertainties during this time." Probably a map of the increased noise should be of help.

Here we refer to Fig. 4 of Kleinert et al., 2018 which we have reproduced below as Fig. R1-2. The increase of spectral noise during 2004 and the first half of 2005 is obvious. In our revised version, we will refer to this Figure and the paper of Kleinert et al. (2018) to provide more evidence for the increased detector noise.

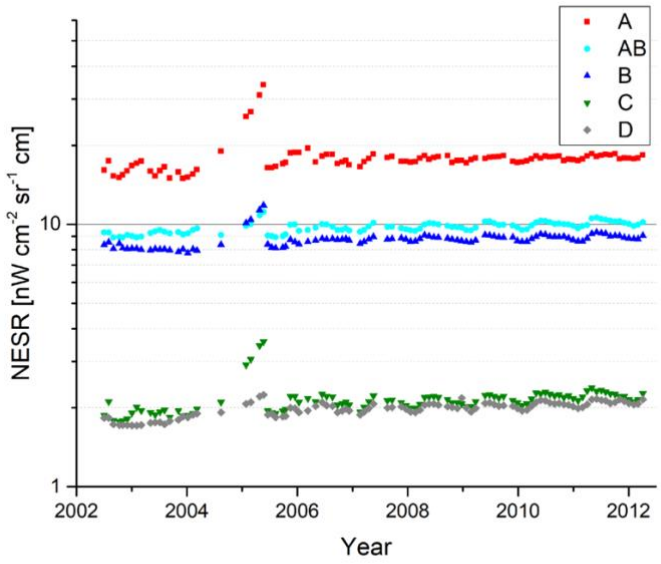


Figure 4. NESR values in the middle of each band throughout the mission. Again, the values measured in FR mode (2002 to 2004) have been scaled to the spectral resolution of the OR mode.

Figure R1-2. Reproduction of Fig. 4 of Kleinert et al., 2018, presenting the increase of noise (in terms of NESR) during end of 2004 and first half of 2005.

11. Section 8 coarse-grid/maximum-likelihood product: Does the steps of the coarser vertical grid approximately correspond to the vertical resolution declared in Sect. 4? I think that this should be discussed in the paper.

    Yes, this is the case. The coarser vertical grid was set up with the vertical resolution of the original retrieval used as first guess. However, in order to provide averaging-kernel free information for all atmospheric scenarios, the worst case vertical resolution (i.e. the worst vertical resolution achieved in the complete 10-year data record) had to be used. We will add this information to the revised version of the paper.

Technical corrections

1. Page 5, line 127: In the sentence “Here we refer to …”, FR NOM appears to be missing. Please check.
2. Page 11, line 270: Please check the wording of “... is retrieved up to AND altitude.”
3. Page 26, line 424: A closing parenthesis appears to be missing.

    Thank you. We will correct the manuscript accordingly.

    References:

Kleinert, A., Birk, M., Perron, G., and Wagner, G.: Level 1b error budget for MIPAS on ENVISAT, Atmos. Meas. Tech., 11, 5657–5672, https://doi.org/10.5194/amt-11-5657-2018, 2018.