

## ***Interactive comment on “MIPAS level 2 operational analysis” by P. Raspollini et al.***

**P. Raspollini et al.**

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The authors would like to thank referee #2 for his/her thoughtful reading of the paper and his/her useful suggestions.

Below the answer to each individual comment is provided.

General comments:

- (1) The revised paper will be corrected to refer to the figures with the correct numbers.
- (2) More discussion on chi-square analysis is required.

Sect. 8 will be expanded with some further considerations that are reported below.

The histograms of Fig. 11 have been replotted using the same scale for all the plots and a constant box width for events with chi-square from 0.5 to 6. The last box on the right counts all the events with chi-square larger than 6. This explanation for the

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reading of the plots of the histograms of the chi-square has also been added. From inspection of the modified figure it is clear that the chi-square of all species, with the only exception of N<sub>2</sub>O (for which an error was proved to be present in the Level 2 processor), are distributed around a constant average value.

In the limit in which the amplitude of the residuals can be assumed to be a measurement of the amplitude of the retrieval error, a chi-square test equal to 2 implies that the amplitude of the forward model errors is equal to the amplitude of the random errors. However, in case that the different errors are not independent and/or forward model errors do not manifest themselves in an increased residual, the chi-square test can vary between 1 and 2, that is what is found for almost all species.

Finally, the fact that measured chi-square test is for almost all species smaller than the estimated one is an indication of a possible overestimation of the forward model errors, but this is not sufficient to reduce our error estimates.

(3) Stereographic maps of O<sub>3</sub> and HNO<sub>3</sub> will be added in Sect. 8. If this paper were presented as an isolated paper, further extra plots about the results would have been useful. However, since it is part of a special issue publication, in which several examples of MIPAS results will be given, we prefer to maintain the paper focused on the performances of the Level 2 analysis and limit the number of examples.

(4) Specific comments:

1. Pag 6526, lines 26-28. It is surely worthwhile to reduce the total retrieval error that is given by the square root of the quadratic sum of random and forward model errors:  $\text{total\_error} = \sqrt{\text{random}^2 + \text{forward\_model}^2}$ . If the two error components are approximately equal, then  $\text{total\_error} = \sqrt{2} * \text{forward\_model}$ . A significant decrease of the random error, with the forward model errors being unchanged, does not lead to a significant change in the total error. Since a reduction in the random error is obtained increasing the number of spectral data, and, accordingly, the computing time, the most effective choice in the optimisation of the trade-off computing time / reduction of the to-

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tal error is to have Random approximately equal to Forward\_model, as it is currently the case. In the abstract the concept can probably be made clearer by replacing 'useless' with 'not effective'.

2. Pag. 6527, lines 12-13. Actually what is written by the referee refers to the measurements beginning on the 9th of January 2005. MIPAS was switched off on the 26th of March 2004 to allow deeper analysis of all anomalies, it was then switched on again on the 9th of August 2004 and it operated with a reduced resolution mode until the 17th of September, when it was switched off again to understand the cause of the increasing frequency in the velocity of the Interferometer Drive Unit. MIPAS definitely restarted again on the 9th of January 2005, when measurements with a reduced resolution (40.99 % of the nominal resolution) and a new measurement scenario were performed with a duty-cycle of about 35%. In the text no mention is done to the August/September 2004 measurements. No change will be made in the text.

3. Pag 6528, lines 1-2. As written in the Introduction, this paper is dedicated to the analysis of the first two years of measurements, performed with the nominal high-resolution mode. Tests for assessing and quantifying changes in the performances of MIPAS due to the problems in the mirror driver of the interferometer are now in progress and results will be reported in a separated paper.

4. Line 22. The text will be changed as suggested.

5. Pag. 6529, line14. 'Extended range' refers to height. The text will be modified accordingly.

6. Pag. 6530, line 18. The text will be changed by removing the unnecessary qualification 'unknown profile'.

7. Pag. 6531, lines 1-3. Yes, we do. The text will be changed and reference will be made to the final iteration rather than to the convergence.

8. Line 8. The measure of the inversion being 'sufficiently well-conditioned' is given

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by the fact that regularisation and a-priori information are not necessary. The text will be modified as follows: 'The MIPAS inversion process resulted to be sufficiently well-conditioned to make a priori information and regularisation not necessary'.

9. Lines 10-11. The text has been misunderstood. The three listed 'choices' (sequential retrieval of the species, use of microwindows, global fit analysis of the limb sequence) identify the main features the retrieval is based on. Each of these features was obtained as the result of a choice among different possible options. In the text the word 'choices' will be replaced with the words 'corner stones'.

10. Pag. 6532, line 20. The text will be modified as follows: 'Features that are taken into account IN THE OFM are: '

11. Pag. 6533, line 1-2. The reason of not including non-LTE operationally is mainly the cost of computational time. This issue is already further discussed in Sect. 4.3.3 and no change will be made to the text.

12. Line 8. In other words, the sequence is appropriate for the objectives described in the subordinated sentences. This expression can be confusing, and the word 'appropriate', which is indeed redundant, will be removed.

13. Pag. 6534, lines 6-8. The conclusions of the AMIL2DA study were that the results of the forward and the retrieval model agree, within the predicted error margins, with the results provided by the other processors considered in the AMIL2DA project. Moreover, the blind test retrieval experiment highlighted that the retrieval code is capable of producing reliable results, in the sense that the discrepancies between retrieved and true (assumed) profiles are statistically consistent with the profile error bars determined on the basis of analytical error propagation. The text will be expanded reporting these results.

14. Pag. 6535, lines 16-17. The terms used are standard. Some confusion was caused by the fact that day and night were not explicitly noted in the text. We will use

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capital letters to denote the conditions as: typical mean yearly profiles for Tropical ( $0^\circ$ ), Mid-latitude Day ( $45^\circ$ ) and Mid-latitude Night ( $45^\circ$ ), and typical mean seasonal profiles for Polar Winter ( $>70^\circ$  in winter vortex, nighttime conditions), Polar Summer ( $>70^\circ$  in summer sunlit conditions).

15. Pag. 6537, line 9. The "best microwindows" were chosen according to an ad-hoc criterion, which attempted to retrieve the maximum information on the target species with the minimum CPU cost. In practice, the effect of including the CPU cost mostly just limited the total number of microwindows, which were used, rather than affecting the actual microwindows, which were selected. The text will be expanded.

16. Line 27. As described at line 23, 'Auxiliary data' are both retrieval settings and databases (spectroscopic database, microwindow database, climatological profiles)

17. Pag 6539, line 4-9. Forward model calculations using the 5 standard atmospheres were used to assess where cloud index values at 12 km (the original lower end of the MIPAS retrieval range) could identify clouds as distinct to "clear sky" conditions. The cloud indices were tested against CRISTA spectra, prior to the launch of MIPAS, to verify that the thresholds were indeed reasonable. The text will be expanded in the revised paper.

18. Pag. 6542, line10. We have empirically verified that 10 are a 'sufficiently large number of iterations' for the retrieved values not to change any more. The text will be changed with this clarification.

19. Line 16. The meaning of 'more active' is already explained at line 17. Since convergence is reached when one of the two criteria is fulfilled, the threshold relative to the linear chi-square was set to a very small value in order to make improbable its fulfilment. As a consequence, convergence is reached when the threshold relative to variation of profiles is reached.

20. Line 23. Yes, they do. The text will be changed.

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21. Pag. 6543, lines 22-23. Reference to figure numbers will be corrected.

22. Pag. 6544, lines 1-3. The implications of the total error being larger than the proposed objective of the mission, (and larger than what can be potentially obtained by MIPAS) are that more work has to be done to investigate on the forward model errors, for example for a better characterisation of the instrument and for a reduction of the spectroscopic errors. This shortcoming is partially due to the complexity of the problem, but is also aggravated by the data analysis investments, which are very small when compared with the cost of the instrument development. These implications probably do not need to be stated explicitly in a scientific paper.

23. Lines 12-15. If two retrieved quantities are completely correlated it is not possible to extract information on both from the measurements. For the specific case, if retrievals of temperature and radiometric calibration are performed simultaneously, retrieval cannot distinguish between increasing the temperature and reducing the calibration parameter or vice versa. Two correlated variables can be retrieved simultaneously when there is a subset of measurements that mainly depends on one of the two variables.

24. Pag. 6549, line 26. Decimation is a data compression technique used to lower the size of the measured interferogram in the ground data transmission. In the text the word 'un-decimated' will be replaced with the expression 'raw full size'.

25. line 27. Ghosts are fake lines due to a modulation in the interferogram signal, such as the one caused by a pointing jitter. A sentence will be added to help the reader.

26. Pag. 6550, line 7.  $E$  is a rectangular matrix with dimension  $N \times 2N$  (with  $N$  equal to the number of limb views in a scan), characterised by significant values along the two lines correlating the  $i$ th element of the VMR profile with the  $i$ th element of temperature and pressure profile respectively. However, non-negligible values are found also in correspondence of the adjacent elements. The whole matrix  $E$  is provided and taken into account in the computation of the  $p$ ,  $T$  induced error on VMR profile. This information has not been added in the text, since matrices  $E$  are available at the web

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page <http://www.ifac.cnr.it/retrieval/auxiliary.html> as written at pag. 6556, line 9. Only a reference to Sect. 5 will be added.

27. Pag. 6553, line 5. The answer is affirmative. The text will be changed accordingly.

28. Pag. 6556, line 11-13. Errors such as the propagation of the random  $p$ ,  $T$  error into VMR retrievals will be "systematic" if considering, for example, the sum of  $2 \cdot \text{CH}_4 + \text{H}_2\text{O}$  at one altitude within one scan since both the  $\text{CH}_4$  and  $\text{H}_2\text{O}$  retrievals share the same error in temperature retrieval for that altitude. However, when comparing  $\text{CH}_4$  retrievals for 2 successive scans, the contributions of the temperature errors will be uncorrelated. So the  $p$ ,  $T$  error can be regarded as random for time/length scales beyond 1 scan (75seconds/500km). Contaminating species, such as CFC-11, are modelled assuming a zonal mean climatology. The actual atmospheric CFC-11 distribution is likely to depart from the climatology in a correlated manner with, say, a 30 degree latitude bin on a particular day but not within the same latitude bin when combining data from different months. So this error can be regarded as random for time/length scales beyond 1 month/3000km. This issue is important if the reviewer asked for a clarification and this explanation will be added in the text.

29. Pag. 6558, line 15: 'seed' is the starting number used to generate a random vector. 'Seed' replaced with 'starting number'.

30. Pag. 6559, lines 8-9: The high value of  $p, T$  chi-square is a graphical effect since in the box on the right all events having chi-square larger than 3.75 were counted. In  $pT$  retrieval the tail of the distribution is a bit larger than in the other cases due to the fact that the average chi-square is larger. The figure will be modified using the same scale for all histograms and a constant box width for events with chi-square from 0.5 to 6, while the number of events with chi-square values larger than 6 will be counted in the last box on the right.

31. Line 15: Numbers are provided in the Table. Therefore, we believe that the reviewer is asking about the implications rather than about the quantifications. The discussion

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will be modified and statements will be added about the implications (see answer to the general comment).

32. Lines 18-19. A comment about CH<sub>4</sub> will be added.

33. Also considering the previous three points, Sect. 7 contains now considerably more discussion.

34. Pag. 6560, lines 17-18. Polar stereographic plots will be added.

35. Line 23. Text will be expanded with a clarification that the minima in HNO<sub>3</sub> concentration is a well-known climatological feature of the Antarctic vortex at this time of the year (September) which has been shown to be due to denitrification, i.e. irreversible removal of nitrogen to lower levels through sedimentation of polar stratospheric clouds. A reference will be made to published literature on the denitrification effect.

36. Pag. 6570, Table 3: The lack of specific numbers for these errors is a deliberate decision due to the nature of the errors and the complexity with which they are modelled. Similarly the spectroscopic errors are too variable to be listed. The assumed climatological SD is different for each of the (22 unretrieved species) \* (5 reference atmospheres), as described at the end of section 2.2 (Reference atmosphere database) so actual values cannot be listed in the table. The pT error covariance is a matrix of 34\*34 elements (actually 5 different matrices - one for each atmosphere). The non-LTE and CO<sub>2</sub> line mixing errors are modelled by differencing spectra calculated with and without these effects so, if there is a numerical value assigned to these particular errors, it would be 100%.

37. Pag. 6572, Fig.1. The caption will be modified indicating that A, AB, B, C are the MIPAS bands.

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