SUMMARY OF THE MIPAS VALIDATION RESULTS

H. Fischer & H. Oelhaf

Institut für Meteorologie und Klimaforschung, Universität and Forschungszentrum Karlsruhe, P.O.Box 3640, D-76021 Karlsruhe, Germany, Email: herbert.fischer@imk.fzk.de

ABSTRACT

One objective of the ENVISAT workshop in May 2004 (ACVE-2) was the validation of the MIPAS operational data products, namely profiles of temperature, O_3, H_2O, CH_4, N_2O, HNO_3, and NO_2. In general, the quality of these data products is already good but there exist still some problem areas which have to be treated in the near future. This statement, however, is based on a very limited statistics since only a small subset of data processed with the latest processor version (v4.61) has been available so far. Further improvements in the data processing and labeling of data for special measurement conditions are possible and necessary. Also, the data basis for intercomparisons between MIPAS results and measurements of various other instruments will be enlarged as soon as all MIPAS Version 4.61 data will be available.

1. INTRODUCTION

During ACVE-2 in May 2004 only the validation of operational products of MIPAS has been discussed, even if some results of scientific processors of expert laboratories have been taken into account. The MIPAS operational data products are temperature, O_3, H_2O, CH_4, N_2O, HNO_3, and NO_2 profiles on a global scale during day and night.

Furthermore, it has to be pointed out that the MIPAS spectra contain a tremendous amount of information on the composition of the atmosphere [1], [2]. It has already been shown by expert support laboratories and by the processing of MIPAS balloon data by IMK/FZK that a larger number of additional scientific data products can be derived (e.g. [3]). Profiles of ClONO_2, N_2O_5, NO as well as CO and Polar Stratospheric Cloud (PSC) properties have been partly validated already. Further scientific data products of which first results are available, are HNO_3, CFC-11, CFC-12, SF_6 as well as upper atmosphere CO, NO, NO_2, H_2O, O_3, and non-LTE parameters. Indeed, the scientific potential of MIPAS data products is enormous.

After two years of nominal operation the MIPAS instrument onboard the ENVISAT satellite has been switched off on March 26, 2004 because of problems with the movement of the two retro-reflectors of the Michelson interferometer. A considerable number of test measurements have been performed in the meantime in order to define and characterize a new measurement mode. It is very likely that the instrument will be operated at reduced spectral resolution (about 40% of the previous one) from summer 2004 on. Regular data release is planned for the beginning of fall 2004.

This summary is based on the presentations of various speakers during the workshop. More detailed information on special aspects can be found in corresponding papers in this volume.

2. SUMMARY OF LEVEL 1 DATA PROCESSING

Different versions of processing software have already been generated for the operational data products. The latest version (v 4.61) was activated in mid of March 2004 for the Near Real Time data processing and for the off-line reprocessing. Main improvements in comparison to previous versions are the first-order correction of Spectra Oscillation Anomalies, the suppression of aliasing spikes, a better NESRT reporting and flagging of the ADC saturation. In addition, a number of changes have been carried out in the Auxiliary Data File (ADF). As a consequence,
essential improvements have been accomplished by significantly reducing the Forward/Reverse oscillations in non-linear channels and the spectral calibration variation along the orbit. Fig. 1 shows an example of significant reduction of these oscillations in series of forward/reverse interferometer scans in the case of a N₂O retrieval as performed by IFAC/CNR.

Since the beginning of the MIPAS measurements ice has accumulated on the detectors every time until the instrument was warmed up again. The rate of ice accumulation decreased in the meantime to 0.9%/week in maximum gain change. Anyhow, the ice layer on the detectors is only a small problem because it is taken into account in the calibration procedure. The frequency of the laser of the interferometer has been monitored and yielded a very small drift of 6.10⁻⁶ per year. Before January 2004, the line-of-sight (LOS) pointing showed a considerable drift as a function of time (about 0.01 degree per 500 orbits). After the improvement of the Satellite Attitude Control in January 2004 the MIPAS pointing has been very stable within the requirement of ± 1km.

It is intended to further develop the level 1 data processing in the Second Improvement Cycle. For example, the ILS Retrieval and the Spectral Calibration Approach will be improved. The Residual Phase Error after calibration of forward and reverse scans will be investigated and corrected. The non-linearity of the detectors will be better characterized and the calibration scenario will be optimized. Also, more housekeeping data will be provided (e.g. instrument temperature) and the presentation of these data will be improved (e.g. pointing angles in topocentric coordinates).

3. SUMMARY OF LEVEL 2 DATA PROCESSING

All major modifications of the level 2 data processing [4] have been made by changing the Auxiliary Data Files (ADF) up to now. At 23 July 2003 the spectroscopic data base has been updated on the basis of observed spectra by MIPAS and laboratory studies. The simultaneous implementation of a cloud filter has allowed to extend the retrieval altitude range of the atmospheric parameters in cloud-free situations and to reduce the errors in the relevant altitude range. More stringent convergence criteria have led to a reduction of the fitting error. The improvement of the detector non-linearity correction has reduced the oscillation in the retrieved profiles.

These improvements are not all implemented in the Near Real Time Processor due to time constraints but are all applied in the Off-line Processor which has started operation on 4 November 2003.

A number of pending issues has been identified. In case of temperature retrieval an updated climatology of CO₂ mixing ratios has to be included. Problems in H₂O profiles at high altitudes have been recognized which may be caused by not optimally selected micro-windows. Residual oscillations are obvious in CH₄, N₂O, NO₂, and H₂O profiles; because no explicit regularization is applied in the inversion procedure an increase of the number of micro-windows may lead to better data quality.

The future operation of the interferometer at reduced spectral resolution is not expected to diminish the overall quality of measurements of most target species. Also, the extension of the operational code utilization to the processing of some MIPAS special modes and to the derivation of additional species is possible.

4. GENERAL REMARKS TO VALIDATION

During the workshop it became clear that the various scientific groups have used different coincidence criteria for intercomparison of their measurements with MIPAS data. But, differences in space and time need to be restricted dependent on the atmospheric situation, i.e. dependent on horizontal gradients or diurnal variations of the observed parameters. Standard coincidence criteria could be a distance of 300 km and a few hours time difference. Larger differences are acceptable if the atmosphere is proven to be homogeneous or if the results at one location are transformed to the other measurement location with the use of a numerical model.

Measurements with different instruments exhibit very often distinct different vertical resolutions. For intercomparisons of such data it is necessary to apply averaging kernels to the highly resolved vertical profiles.

Scientists have sometimes used partial columns from ground based measurements for intercomparison with satellite measurements. Resulting considerable differences show that the calculation of partial columns needs to be standardized among the various scientific teams and needs to be based on the retrieved MIPAS pressure altitude instead of the geometrical altitude.

Most of the MIPAS data from the operational processing are of good quality but there are also some spurious results included in these data sets. As a consequence it is necessary to remove these partly unphysical data, in particular identified in the temperature and H₂O profiles, from the data sets.
Furthermore, consistency checks, as e.g. by investigating the hydrogen budget and tracer correlations, may help to verify the quality of the generated data sets.

In order to test more rapidly new versions of the data processing code a limited data set of MIPAS measurements and coincident high-quality validation measurements should be established. By doing this it can be avoided that a larger number of special validation measurements are available but not the corresponding MIPAS data as generated with the latest version of processing code.

In principle, it is not easy to determine the precision and accuracy of satellite measurements. The quality of the validation measurements is sometimes not better in comparison with the satellite data. The vertical resolution of the validation measurements can be worse or the systematic error of these measurements is not well known. Also, a certain number of comparisons is required for a statistically founded result. In case of the precision of the satellite data one can derive this quantity from the satellite measurements themselves when a relatively homogeneous region of the atmosphere is identified. In such a case the standard deviation of the satellite measurements in this region will provide the solution.

5. VALIDATION OF OPERATIONALLY GENERATED PARAMETER PROFILES

Data products from the operational MIPAS data processing are vertical profiles from temperature, \( \text{O}_3 \), \( \text{H}_2\text{O} \), \( \text{CH}_4 \), \( \text{N}_2\text{O} \), \( \text{HNO}_3 \), and \( \text{NO}_2 \). In the following the quality of these products will be assessed. Due to the fact that the altitude assignment of the operational data is not very accurate it is strongly recommended to use the retrieved pressure as the vertical coordinate for data intercomparisons.

5.1 Temperature profiles

The validation of temperature profiles resulted in general to be in good quality. A. Dethof (ECMWF) has summarized a number of intercomparisons of temperature data from different sources (see Table 1). In the lower stratosphere there is very good agreement with new CHAMPS (GPS measurements) data; MIPAS temperatures have a positive bias to ECMWF and UK METO data. In the middle stratosphere the MIPAS results lay between ECMWF and UK METO data. The larger deviation with respect to ECMWF is probably caused by an ECMWF problem. In the mesospheric region the MIPAS measurements are probably better than the other temperature data as used for intercomparison. On the other hand, the intercomparison of the MIPAS operational data with the MIPAS results of an expert support laboratory shows that the MIPAS operational temperature data may be a bit too low in the mesosphere.

From the intercomparisons a mean deviation of 2-4 K in the stratosphere has been estimated but it is not clear as to how much this deviation is caused by atmospheric variability and the limited precision of the validation data.

<table>
<thead>
<tr>
<th>Systematic deviations to other data sets (provided by A. Dethof, ECMWF, see this volume).</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIPAS IMK</td>
</tr>
<tr>
<td>Mesosphere/stratopause</td>
</tr>
<tr>
<td>Upper stratosphere (&lt;10 hPa)</td>
</tr>
<tr>
<td>Lower stratosphere</td>
</tr>
</tbody>
</table>

Even if the quality of the MIPAS temperature data is generally good there are a few unphysical values in the large data set already available (see paper by K.H. Fricke et al., this volume). As a consequence, quality checks of the temperature profiles have to be carried out and unphysical data have to be flagged or removed.

Zig-zag behaviour of volume mixing ratio profiles has been recognized only for trace species with absorption bands at shorter wavelengths, where the temperature dependence of the Planck function is strong. This may be caused by small temperature oscillations in the temperature profiles and has to be reviewed.

5.2 Ozone profiles

From the beginning of intercomparisons between MIPAS \( \text{O}_3 \)-profiles and validation data the deviations were relatively small and the good quality of MIPAS-\( \text{O}_3 \)-data was obvious. In particular, no bias can be found in the altitude region between 20 and 55 km and the precision is about 10 to 15%. At lower altitudes MIPAS data seems to have a high bias in comparison to the validation data sets. This degraded quality of the MIPAS data below 20 km has to be investigated in more detail.

Systematic differences between MIPAS and HALOE \( \text{O}_3 \)-data in the mesosphere have been indicated (see Fig. 2). But these differences can be explained by the diurnal variations of \( \text{O}_3 \)-values in these height regions.
Taking into account that MIPAS is measuring during day and during night and HALOE during sunrise and during sunset the mesospheric signature in Figure 2 is understandable.

5.3 H2O profiles

Intercomparisons of MIPAS H2O profiles with data of various instrumentation show that MIPAS H2O profiles are generally of good quality in the altitude region between 15 and 30 km and the deviations are smaller than the combined error bars. In the lower-most stratosphere the MIPAS profiles seem to have a low bias while at altitudes above 30 km the MIPAS concentrations tend to be too high. The latter statement is confirmed when considering the hydrogen budget in the upper stratosphere.

Some oscillations in the upper stratosphere are observed which are not caused by atmospheric variability. Comparisons of satellite data to climatology can also help to judge their quality. A corresponding investigation of MIPAS H2O profiles for the latitude region between 20 and 60°S in July 2003 shows a large scatter with partly unphysical values (see Figure 3).

Certainly, these MIPAS H2O values are not generated with the latest version of the data processor and, therefore, this study has to be reiterated. On the other hand, also the current data set (Version 4.61) contains some unphysical H2O profiles as identified by M. Milz/IMK (see paper of H. Oelhaf et al., in this volume).

5.4 CH4 and N2O profiles

The validation of these two trace gases is treated in one paragraph because the problems are very similar. First, a relatively small number of coincident measurements is available up to now. A high bias of the CH4 and N2O profiles in the lower stratosphere is identified, in particular in mid-latitudes. The oscillations in the profiles are reduced in the Version 4.61 of the data.
processor compared to older versions. Figure 4 shows a corresponding example for CH$_4$ by intercomparing with measurements of the MIPAS balloon experiment. Certainly, the oscillations did not disappear completely and have to be studied further. In order to check the consistency of the data the correlation between N$_2$O and CH$_4$ values has been considered. Outliers in the N$_2$O-CH$_4$ correlation plot indicate that an improvement of the N$_2$O and CH$_4$ profiles has to be achieved (not shown here, see paper by Camy-Peyret, in this volume).

The validation of NO$_2$ profiles (see Wetzel et al., this volume) is aggravated by the strong diurnal variation of this trace species. The quality of coincidence in time and space between MIPAS and validation measurements is, therefore, more crucial than for other trace species. Consequently, comparisons between limb sounding and occultation measurements require the use of a photochemical model.

The seasonal variation of NO$_2$ columns as detected by ground-based instruments is fairly well captured by MIPAS. The operational MIPAS NO$_2$ profiles seem to have a high bias in the middle mesosphere, but the reason for this is currently not clear.


diagram
6. CONCLUSIONS AND RECOMMENDATIONS

The quality of the MIPAS operational data products is already good even if some problem areas have been identified in the validation process. Further improvements in the data processing, e.g. the more effective suppression of the oscillations in CH₄, N₂O, and NO₂ profiles, are necessary.

A few unphysical trace gas profiles in the large data sets have to be removed and special measurement conditions have to be marked. With ongoing reprocessing of the MIPAS measurements the data basis for validation has to be enlarged by including corresponding measurements during the year 2003.

Up to now the validation has mainly been focused on the operational MIPAS data. But, enormous potential exists for the more than 20 non-operational MIPAS products which have partly been validated to a certain degree.

It is recommended that

- a MIPAS SAG type group is now established in order to define the future nominal mode at reduced spectral resolution, to decide on the operation scenario for the MIPAS special observation modes and to specify future validation needs, and
- dedicated small science groups for each validation product are formed and financially supported in order to achieve the necessary progress in validation activities and to reach firm conclusions about the accuracy and precision of the MIPAS parameter profiles.

7. ACKNOWLEDGEMENTS

The authors would like to thank all the scientists who are participating in the validation of MIPAS products, the MIPAS Quality Working Group and the ESA colleagues as involved in the MIPAS experiment. We thank also G. Perron and B. Carli who gave support for the summary of the Level 1 and Level 2 data processing. In addition, the authors are grateful to the whole IMK-MIPAS team for many contributions to the data processing and the validation process.

8. REFERENCES


