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EXECUTIVE SUMMARY

of

FINAL REPORT

of the study

Development of an Optimised Algorithm for Routine p,T and VMR Retrieval from MIPAS Limb Emission Spectra

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1. Introduction

MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) is an ESA developed high resolution Fourier Transform spectrometer that has been operating on board ENVISAT-1 since the 1st of March 2002. It detects spontaneous black-body emission of the atmosphere in the middle infrared and more precisely in the 685 - 2410 cm-1 spectral region with a spectral resolution of 0.025 cm-1 (unapodized). This spectral region is measured with four detectors that observe in contiguous spectral intervals with optimised radiometric performances. The measurements of the four detectors are collected in five bands referred to as band A, band AB, band C and band D. The radiometric sensitivity, expressed in terms of Noise Equivalent Spectral Radiance (NESR), is designed to be 50, 40, 20, 6 and 4.2 nW/cm2/sr/cm-1, respectively in the five bands. The middle infrared contains the vibrational spectra of most of the atmospheric constituents that in this spectral region can be continuously observed with a passive remote sensing technique.

The observations are made at the limb with an elevation pointing that can be varied from 5 to 210 km in tangent altitude and an Instantaneous Field of View (IFOV) of 3 x 30 km^2 (height per width, at 10 km tangent altitude). A full resolution spectrum (a sweep of the interferometric drive) is acquired in 4.6 sec. A typical limb scan sequence (an elevation scan) is made of 17 spectra that look at different tangent altitudes and is acquired in 75 sec. This time corresponds to a ground track of about 500 km.

For its whole lifetime, expected to be 5 years, MIPAS will continuously perform measurements during both day and night, providing each day a full coverage of the globe.

During each orbit MIPAS performs 75 limb scans (plus measurements used for the instrument calibration). The analysis of each limb scan sequence allows the determination of the vertical profile of several atmospheric constituents, as well as temperature and pressure profiles. Combining the 75 profiles of each orbit, the distribution of the geophysical parameters as a function of altitude and latitude can be determined.

The determination of the vertical profiles requires the solution of a complex inversion problem. This matemathical complexity when combined with the management complexity of the large data flow leads to challanging and competing requirements of time efficiency and accuracy.

The data inversion from the spectra measured by MIPAS to the geophysical parameters is the Level 2 processing step of MIPAS analysis.

2. Objective of the Study

The objective of the Study is the development and the validation of the scientific code for the Near Real Time (NRT) Level 2 analysis of MIPAS measurements on ENVISAT. In particular, the code developed in the frame of this Study, named Optimised Retrieval Code (ORM), is designed to retrieve, starting from the geo-located and calibrated spectra provided by the Level 1 processor, atmospheric vertical profiles of temperature, pressure and concentrations of O3, H2O, CH4, HNO3, N2O and NO2, in the altitude range from 12 to 68 km. These atmospheric constituents are identified as the target species of MIPAS instrument.
The ORM code is the basis for the industrial prototype of the Level 2 analysis of MIPAS instrument data, which, in turn, is used as the reference code for the development of MIPAS Level 2 operational code.
The requirements for the ORM are:
robustness, to operate in an automated and continuous manner;
accuracy, to produce useful products;
efficiency, to be able to process a large amount of data in an accurate way using computing time shorter than measuring time.

Given the expected spectral radiometric sensitivity of MIPAS measurements, that is expressed in terms of band dependent NESR, the specified performance requirements for the retrieval code were:
Temperature error < 2 K at all the altitudes covered by the typical MIPAS limb scan (8-53 km);
Tangent pressure error: < 3%;
Error on the retrieved VMR of the key species: < 5 % at all the altitudes covered by the standard MIPAS scan.
The preliminary objective for run-time performance of p,T and VMR retrieval of the five MIPAS target species from a limb-scanning sequence of 16 limb-views was a maximum of one hour on a SUN SPARC station 20.

3. Study team

The Study, that started in October 1995 and finished at the end of 2003 after the successful ENVISAT launch and the completion of the Commissioning Phase of MIPAS on ENVISAT, was performed by an European consortium lead by IFAC-CNR and composed by:
IFAC-CNR (former IROE-CNR), responsible of the development and the validation of ORM code;
University of Bologna, involved, together with IFAC-CNR, in the development and the validation of the ORM code;
F. M. A., involved in the validation activity (a consultancy with ISM-CNR was activated through F. M. A.);
University of Oxford: responsible of Microwindow database selection, Occupation Matrices, cross-sections Look Up Tables (LUT), Irregular Grids;
University of Leicester: responsible of the definition of climatological atmospheric variability and cloud filtering;
IMK: responsible of line selection and validation activity;
LPPM: responsible of spectroscopic database.

4. Description of the Study

MIPAS measurements provide, continuously during both day and night, the atmospheric limb emission spectra in the middle infrared region. The spectra relative to each limb scan sequence can be 'inverted' to determine the concentration profiles of many of atmospheric constituents. In particular the six target species listed in Sect. 2 have been found to have scientific priority and to be measurable from a single limb sequence.
Since middle infrared emission spectra are strongly sensitive to temperature, and in general limb observations are strongly affected by the observation geometry (identified by the 'tangent pressure', defined as the value of pressure at tangent altitudes), a correct interpretation and analysis of the observed spectra for the retrieval of the atmospheric constituents requires a good knowledge of these quantities.
For each limb scan sequence, the profiles of temperature, tangent pressures and the VMR of the six target species are obtained by means of a retrieval algorithm, based on the non-linear least square fit. It consists in the fit of the observations **S** to a theoretical forward model **F(p, x)** that simulates the observations and depends on a set of instrument and geophysical parameters **p** and on the unknown quantities **x**. The parameters **p** are considered to be known and the quantities **x** have to be retrieved. The solution is found by means of an iterative procedure, using the Gauss-Newton method modified according to the Levenberg-Marquardt criterion. According to this method, for each iteration *iter* the unknown profile $\mathbf{x}_{iter}$ is given by :

$$\mathbf{x}_{iter} - \mathbf{x}_{iter-1} = (\mathbf{K}_{iter-1}^{T}\mathbf{V}_{n}^{-1}\mathbf{K}_{iter-1} + \lambda\mathbf{I})^{-1}\mathbf{K}_{iter-1}^{T}\mathbf{V}_{n}^{-1}\mathbf{n}_{iter-1} \qquad (1)$$

where $\mathbf{x}_{iter-1}$ is the result of the previous iteration, $\mathbf{K}_{iter-1} = \dfrac{\partial \mathbf{F}(\mathbf{p}, \mathbf{x}_{iter-1})}{\partial \mathbf{x}_{iter-1}}$ the Jacobian relative to the profile $\mathbf{x}_{iter-1}$, $\mathbf{n}_{iter-1} = \mathbf{S} - \mathbf{F}(\mathbf{p}, \mathbf{x}_{iter-1})$ the residuals, and $\mathbf{V}_{n}$ the Variance Covariance Matrix of the observations. The factor λ, that at each iteration is increased or decreased depending on whether the
function increases or decreases, is an empirical factor that reduces the amplitude of the variation of the unknown at each iteration step and avoids oscillations around the convergence values.
At convergence, the errors associated with the solution of the inversion procedure can be characterized by the variance-covariance matrix $\mathbf{V}_{\mathbf{x}}$ of **x** given by:

$$\mathbf{V}_{\mathbf{x}} = (\mathbf{K}_{c}^{T}\mathbf{V}_{n}^{-1}\mathbf{K}_{c})^{-1} \qquad (2)$$

where $\mathbf{K}_{\mathbf{c}}$ is the Jacobian matrix evaluated at convergence.

The different phases of the study are here summarised, focusing on code development, optimisations of the code and of the auxiliary databases, and validation activity.

4.1 Code development

For an accurate retrieval, it is necessary to use an accurate forward model of the atmosphere.

Features that have been taken into account are:

- the effect of refractive index in the ray tracing of the limb geometry
- Voigt profile for line shape modelling
- use of a fine grid in the spectral domain in order to correctly account for the frequency dependence of the saturation effect in the atmospheric spectrum
- Curtis-Godson approximation for cross section calculation in order to reduce the vertical segmentation of the atmosphere
- convolution of the atmospheric spectrum with the Instrument Line Shape (ILS) and Field of View (FOV) of the instrument for the determination of the measured spectrum.

On the other hand, Non-Local Thermal Equilibrium (NLTE) effects, line mixing and pressure shift have not been considered in the forward model, but are accounted for in the error budget. Assumption has been made that the atmosphere is horizontally homogeneous and that hydrostatic equilibrium applies.

The retrieval strategy adopted to handle the multiplicity of unknowns and the redundancy of the data is based upon the following three choices:

1. Sequential Retrieval of the Species
   The large number of unknowns is retrieved following an hierarchy of operations: first temperature and tangent pressures are retrieved simultaneously (p, T retrieval), then the target species VMR profiles are individually retrieved following the order of their reciprocal spectral interference, i.e.: H2O first, followed by O3 , HNO3, CH4, N2O and NO2 (see Fig. 1). Besides the target parameters, each retrieval determines also the parameters of atmospheric continuum (that includes all the emission effects that are not accounted in line-by-line calculations) and instrument zero-level offset.

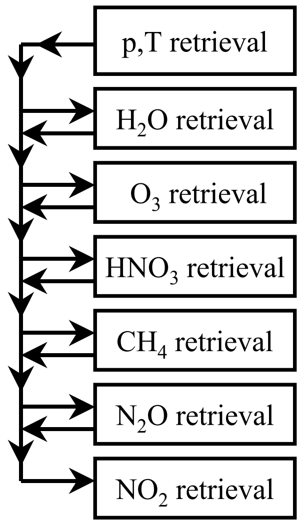


Figure 1 Sequence of the retrievals that are performed in the ORM code

2. Use of 'Microwindows'
   The retrieval is performed in a set of narrow (less than 3 cm^{-1} wide) spectral intervals, called 'microwindows', that are selected as those intervals that contain the best information on the target parameters and are less affected by systematic errors. Fig. 2 show the location in the five bands and the altitude range of the microwindows selected for each retrieval.

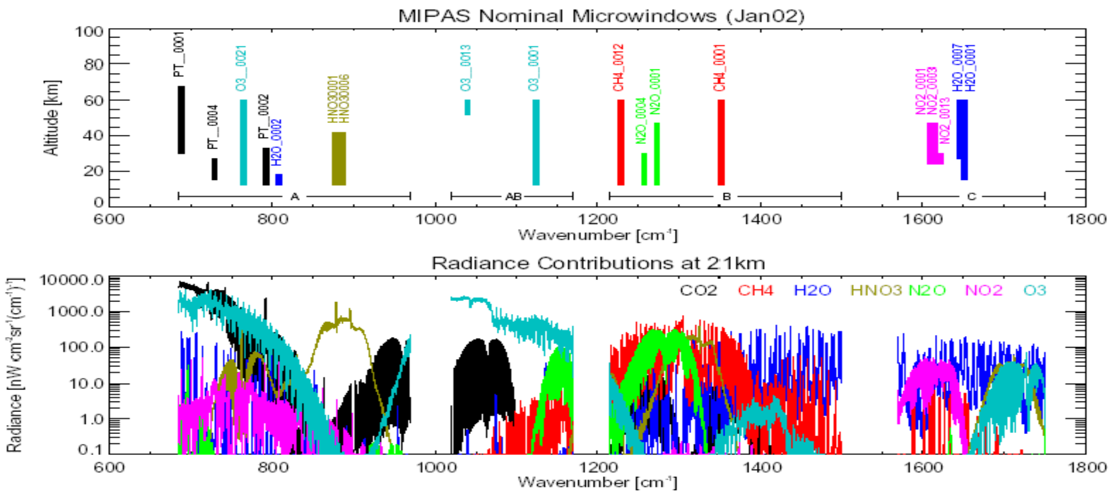


Figure 2. Frequency location and altitude range of the microwindows that have been selected for each retrieval

3. Global Fit Analysis of the Limb Scanning Sequence.
   All the spectral data related to a complete limb scan sequence are fitted simultaneously for the retrieval of each vertical profile. This approach is referred to as global fit. Figure 3 shows the global fit of a microwindow. The spectra measured at the different tangent altitudes are simultaneously analysed and contiguously plotted. The top panel shows the comparison between the measured and calculated spectra and the bottom panel shows the residuals compared with the NESR of the measurement.

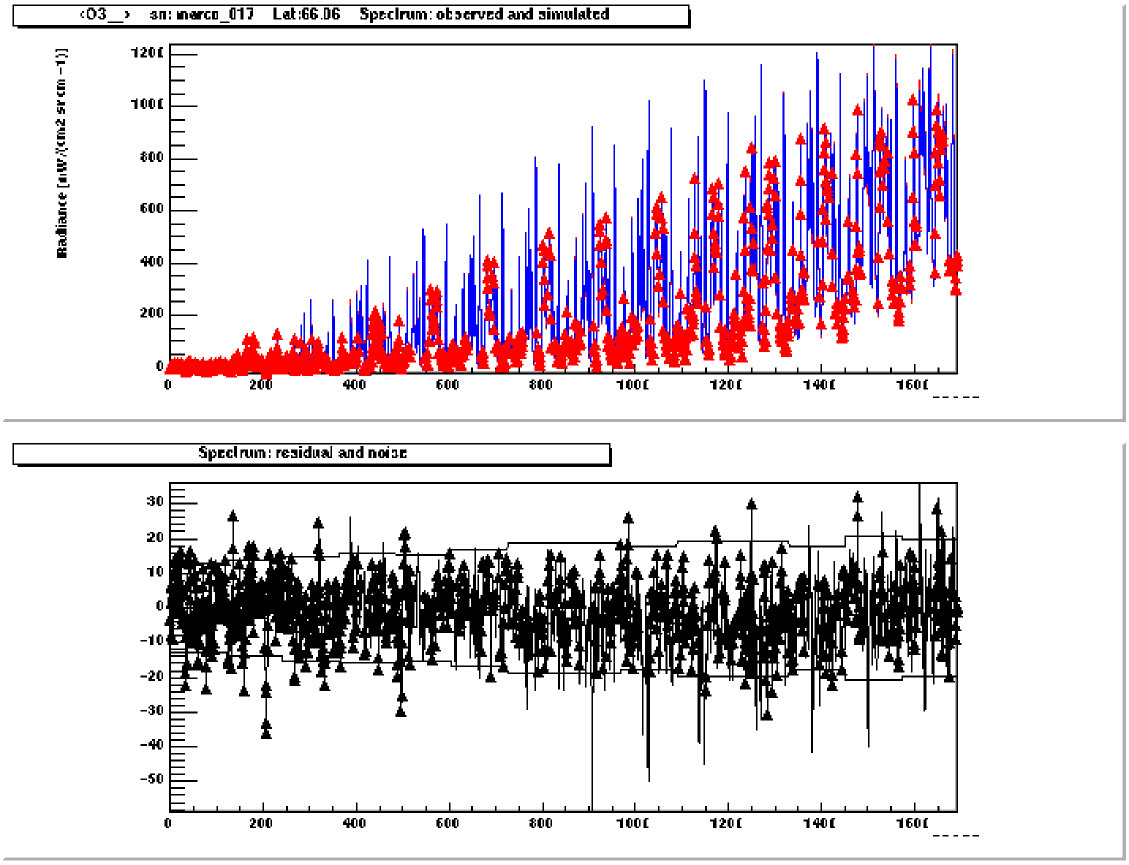


Figure 3. Global fit of the 15 measurements at different tangent altitude of a microwindow.

4.2 Code optimisations and refinements

The core and the most time consuming part of the retrieval code is the Forward Model (Optimised Forward Model - OFM). The OFM computes also the Jacobian used in Eq. 1. A series of mathematical and physical optimisations have been used in order to optimise the trade-off between accuracy and computing time. The main optimisations implemented in the OFM are:

- definition of an appropriate sequence of operations that avoids the repetition of the same calculations and minimises the number of memorised quantities;
- use of analytical derivatives for the calculation of the Jacobian;

- apodisation of the spectrum in order to limit the spectral range by which the microwindow has to be extended for the calculation of the atmospheric spectrum that is to be convoluted with the ILS;
- FOV convolution performed by means of the determination of the tangent altitude dependence of the spectrum by means of a polynomial interpolation of the spectra;
- use of cross-section Look-Up Tables (LUTs) in order to avoid time consuming line-by-line calculations. Compressed LUTs using the singular value decomposition have been used.
- use of an optimised sub-set of frequency points, the so-called irregular grid (IG), for the computation of the high-resolution simulated spectra. Figure 4 shows an example of the approximation introduced with the use of the IG. Typically it is found that only 5-10% of the complete fine grid is sufficient for a satisfactory reconstruction of the spectral distribution.

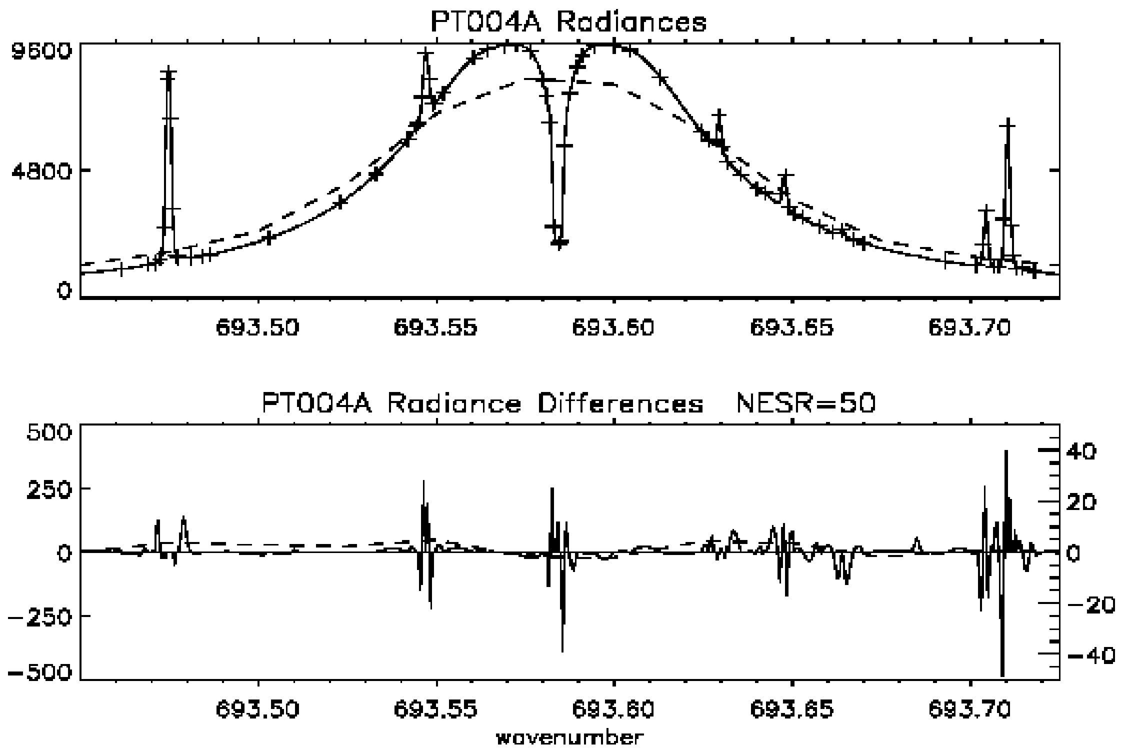


Figura 4. 44 km tangent height spectral radiance from a microwindow (frequency range 693.45 - 693.725 cm^{-1}) selected for p, T retrieval. The upper plot shows the high-resolution radiance (solid line), the irregular grid points (+), and the convolved radiance (dashed line). The lower plot shows the difference between the original and interpolated radiances, on both the high-resolution grid (solid line, left axis) and the convolved radiances (dashed line, right axis).

A recent refinement is the cloud-detection algorithm that was proposed by the ORM team for implementation in the Level 2 pre-processor. This algorithm is used to detect and filters out measurements affected by clouds before starting the retrieval analysis so that instabilities and waste of computing time that are caused by these measurements can be avoided.
With this filtering the retrieval can be extended down to 6 km whenever clear sky conditions are encountered.

4.3 Code validation

The code was validated with test retrievals performed with simulated observations generated with a Reference Forward Model (RFM) and with real measurement performed by the MIPAS-B balloon instrument. These tests pointed out a few upgrades:

- Upgraded calculation of the VCM of the observations in the case of reduced spectral resolution
- Use of band dependent FOV
- Introduction of a pT - H_2O loop in the retrieval chain in order to overcome the problem of lack of convergence in case of assumed or initial guess water profiles "too far" from truth.
- Improvement of the algorithm robustness in case of large tangent altitude corrections.

With the exception of the pT - H_2O loop that is a pending option, all the other upgrades have been implemented for operational use.

Furthermore, a validation was made of the adopted spectroscopic database. Initially the HITRAN96 database was used, but then a dedicated spectroscopic database has been built starting from HITRAN96 with improvements obtained through new laboratory studies or new calculations. The new database has been validated performing comparisons between atmospheric simulated spectra and atmospheric spectra measured by the ATMOS experiment that flew on the Shuttle.

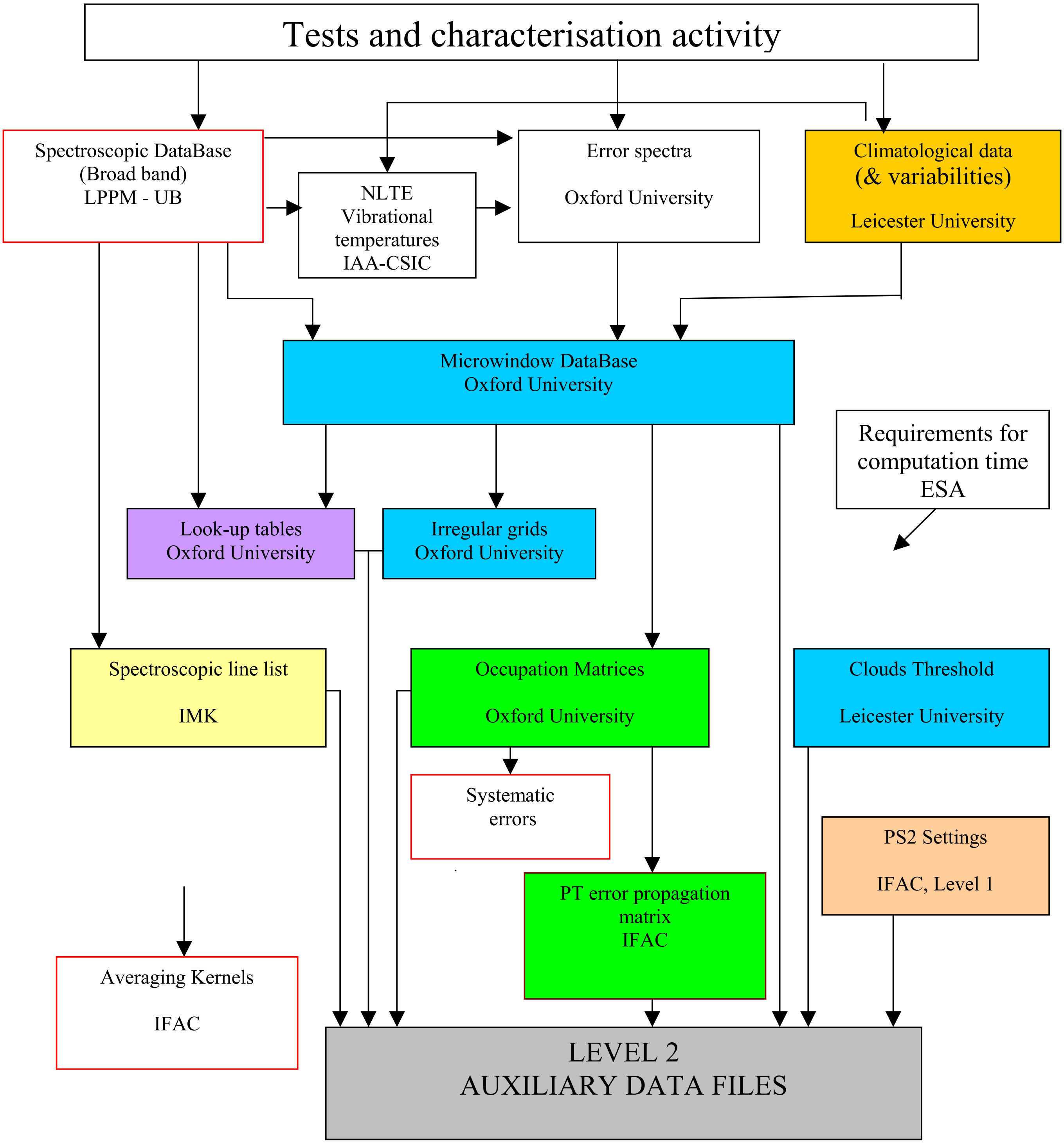


Figure 5: Chain for generation of Level 2 auxiliary data, that are represented in coloured boxes (the boxes with the same colours indicate auxiliary data that are contained in the same file). The boxes with red contours indicate data that are not part of the Level 2 auxiliary data, but that are needed to further characterise Level 2 products and are available off-line.

4.4 Auxiliary and ancillary data

Together with the development of the code, a big effort was made for the definition and the generation of the auxiliary and ancillary data, i.e. all the input data of the retrieval apart from the MIPAS observations that are needed either to better characterise the measurements (ILS, FOV) or to characterise the retrieval. The chain for the generation of the Level 2 auxiliary and ancillary data is reported in Figure 5. This shows the inputs needed for the generation of each database and the relationship between them.
A key element of the MIPAS Level 2 processor auxiliary data files is given by the spectroscopic database. Other important data input are the climatological profiles that are used for the definition of initial guess and assumed profiles, and the Non-Local Thermal Equilibrium (NLTE) modeling that is used for the definition of this error. This information, together with the calculated error spectra are used for the determination of the microwindows. For each microwindow IG and LUTs are calculated. The microwindow database is them used for the determination of the Occupation Matrices (OM) that, according to the available measurements, determine which set of microwindows will be used for each retrieval.
For each version of the spectroscopic database and for each microwindow database, a MIPAS dedicated line selection is performed removing from the database the lines of the molecules whose contribution to the total emission spectrum is smaller than a given threshold. The resulting dedicated line list is used as an input for the back-up option of line-by-line calculations that is present in the code.
In order to fully characterize the retrieved profiles, their total error budget and the Averaging Kernels are needed.
As far as the total error budget is concerned, different types of errors must be taken into account:

- noise error, due to the mapping of radiometric noise into the retrieved profiles;
- errors in retrieved VMR due to temperature and line of sight error;
- systematic error, due to incorrect input parameters in the forward model.

The variance covariance matrix $\mathbf{V}_{\mathbf{x\ random}}$ of the noise error is computed by ORM using Eq. 2 and is provided for each retrieved profile in the Level 2 standard products.
The errors in retrieved VMR profiles due to temperature and line of sight errors can be computed a-posteriori using pre-tabulated matrices **E** providing the mapping of p, T error (characterized by a VCM $\mathbf{V}_{\mathbf{PT}}$) on the retrieved VMR profiles:

$$\mathbf{V}_{\mathbf{x\ PT}}=\mathbf{E}\ \mathbf{V}_{\mathbf{PT}}\,\mathbf{E}^{\mathbf{T}}\ . \qquad (3)$$

The matrix **E** has been computed for 6 latitude bands for the standard set of microwindows MWs and is included in the Level 2 auxiliary data set.
The systematic errors can also be computed a-posteriori as a combination of the error spectra of the individual forward model uncertainties. The effect of the propagation of these errors on the retrieved profiles ($\mathbf{V}_{\mathbf{x\ syst}}$) have been computed for the nominal occupation matrices.
The total VCM of the retrieved profile can be computed summing the VCMs of the single contributions:

$$\mathbf{V}_{\mathbf{x\ tot}}=\mathbf{V}_{\mathbf{x\ random}}+\mathbf{V}_{\mathbf{x\ PT}}+\mathbf{V}_{\mathbf{x\ syst}}\ . \qquad (4)$$

The Averaging Kernels are the derivative of the retrieved profiles with respect to the true profiles performed in a particular state of the atmosphere (linearization point). The averaging kernels provide information on the vertical resolution of the retrieved profile. Since the AKMs depend on the profile of the linearization point the averaging kernels corresponding to the four seasons and six latitude bands have been computed.

4.5 Results of the tests performed during the Commissioning Phase.

As soon as level 1 data became available, the Level 2 code worked correctly proving the first atmospheric profiles.
While the ground segment was successfully producing the data for the available orbits, several test have been made as part of this study.
Some tests involved the tuning of the input parameters of the retrieval and the validation of some choices made for the optimization of the code performances in terms of retrieval accuracy and computing time.
Other test involved the verification of some instrument performances and Level 1 calibrations. It is interesting to note that the quality of some of these performances was assessed by means of Level 2 analysis. In particular, errors in the computation of the ILS and in the frequency calibration were found thanks to the results of the tests performed by the Level 2 analysis. In fact in level 2 analysis a frequency calibration that is much better than the requirements was achieved indicating the possibility of retrieving the speed of atmospheric winds from MIPAS spectra.
The existence of a good quality offset calibration was also verified.
On the other hand, another crucial issue is the radiometric calibration. The correctness of gain calibration is difficult to be assessed from the Level 2 analysis, but is crucial for a good accuracy of the products.
The pointing accuracy and the FOV (Field of View) characterization could not be determined from Level 2 analysis.
Other tests were aimed at the verification of critical baselines, used both in the code and in the auxiliary data. These tests provided the following indications:

- suggested the use for some molecules of a retrieval altitude range slightly extended with respect to the original choice,
- confirmed the assumption of an horizontally uniform atmosphere and of hydrostatic equilibrium,
- underlined the importance of the spectroscopic database. An example of a significant change introduced as a consequence of the Commissioning Phase activity is given by the new spectroscopic data for HNO_3 with a consequent change of about 14% in the retrieved HNO_3 VMR. On the other hand no unexpected interfering species was observed.

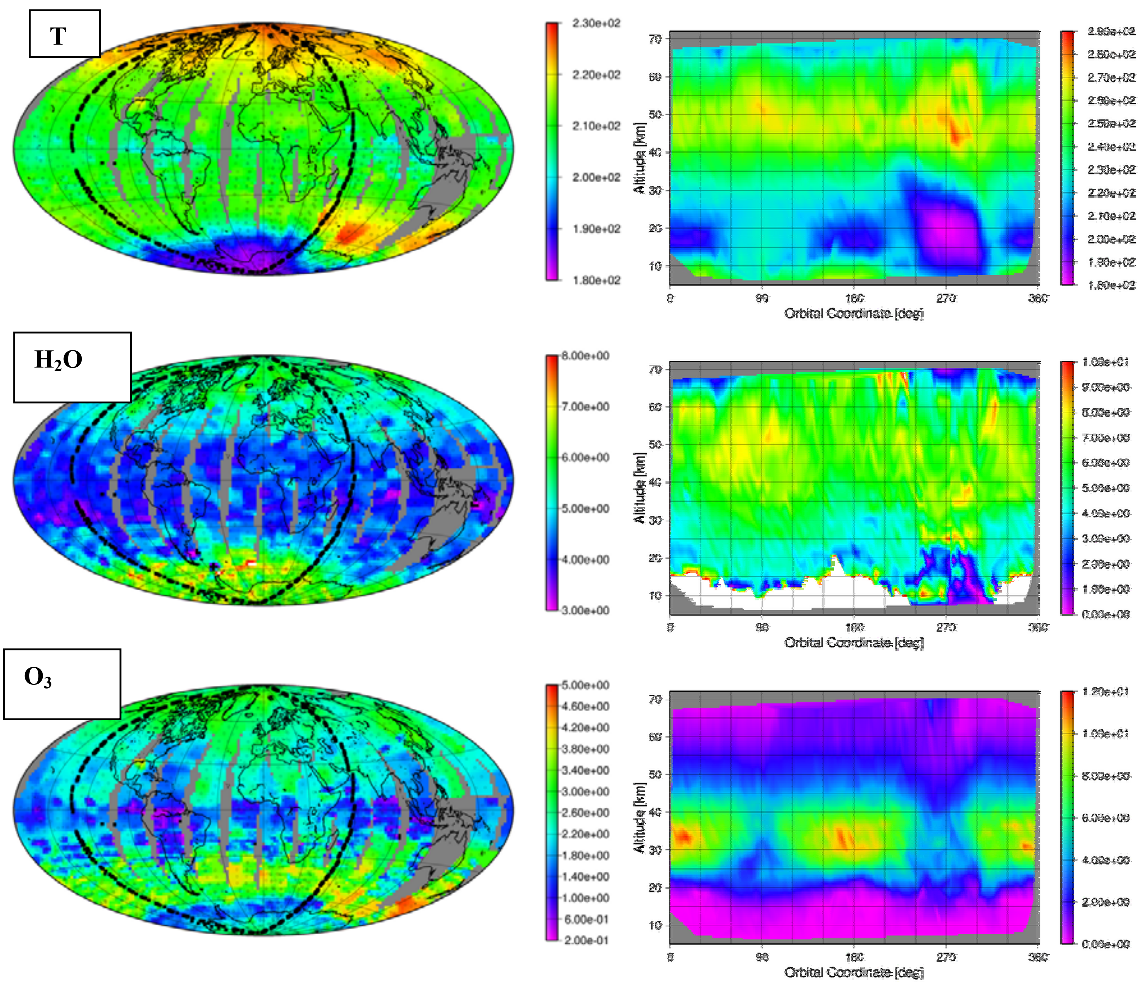
- showed that no major change was necessary in our modeling of the non-local thermal equilibrium effects
- confirmed the correctness of our modeling of line-mixing effect in CO_2
- showed the criticality of the convergence criteria. If a too large weight is given to the computing time requirements and, in order to reach convergence with a small number of iterations, the thresholds used for convergence criteria are not sufficiently stringent, the convergence error induced on the retrieved profile may be greater than the random error.
- showed the criticality of the extrapolation rule. The approximation used in the forward model for handling the profiles above and below the retrieval range introduces an error in the highest and lowest retrieved points. The altitude retrieval range should include the points that are useful for the retrieval and which are not necessarily all useful points.
- showed that the approximation used in the FOV convolution can also be the cause of some problems at low altitudes.

Some new monitoring tools were developed for the study of the statistical correlation between the residual spectra and the error spectra of the various systematic errors, as well as for the statistic of adopted Occupation Matrices.

Finally, tests performed on the measured integrated radiance highlighted for some bands the presence of an oscillation in the gain calibration. The oscillation appears to be correlated with the forward/reverse direction of the sweep and is more evident in those bands in which a non-linearity correction has to be applied to the detectors.

5. Results

MIPAS provides daily a nearly full coverage of the globe. The analysis of MIPAS measurements with ORM allows to determine the three dimensional distribution (latitude, longitude and altitude) of the atmospheric composition with daily repetition.
Examples of the overall picture of the atmosphere that is obtained with this new set of measurements is provided in Figure 6, where a global map at one altitude and a vertical section along one orbit are shown for the VMR of each species. The global map is shown using the Hammer projection and the vertical section is shown as a function of the orbital coordinate defined equal to 0 at the equator , 90° at the North Pole and 270° at the South Pole. In this figure all the available measurements of two consecutive days (30 and 31 August 2003) have been used.



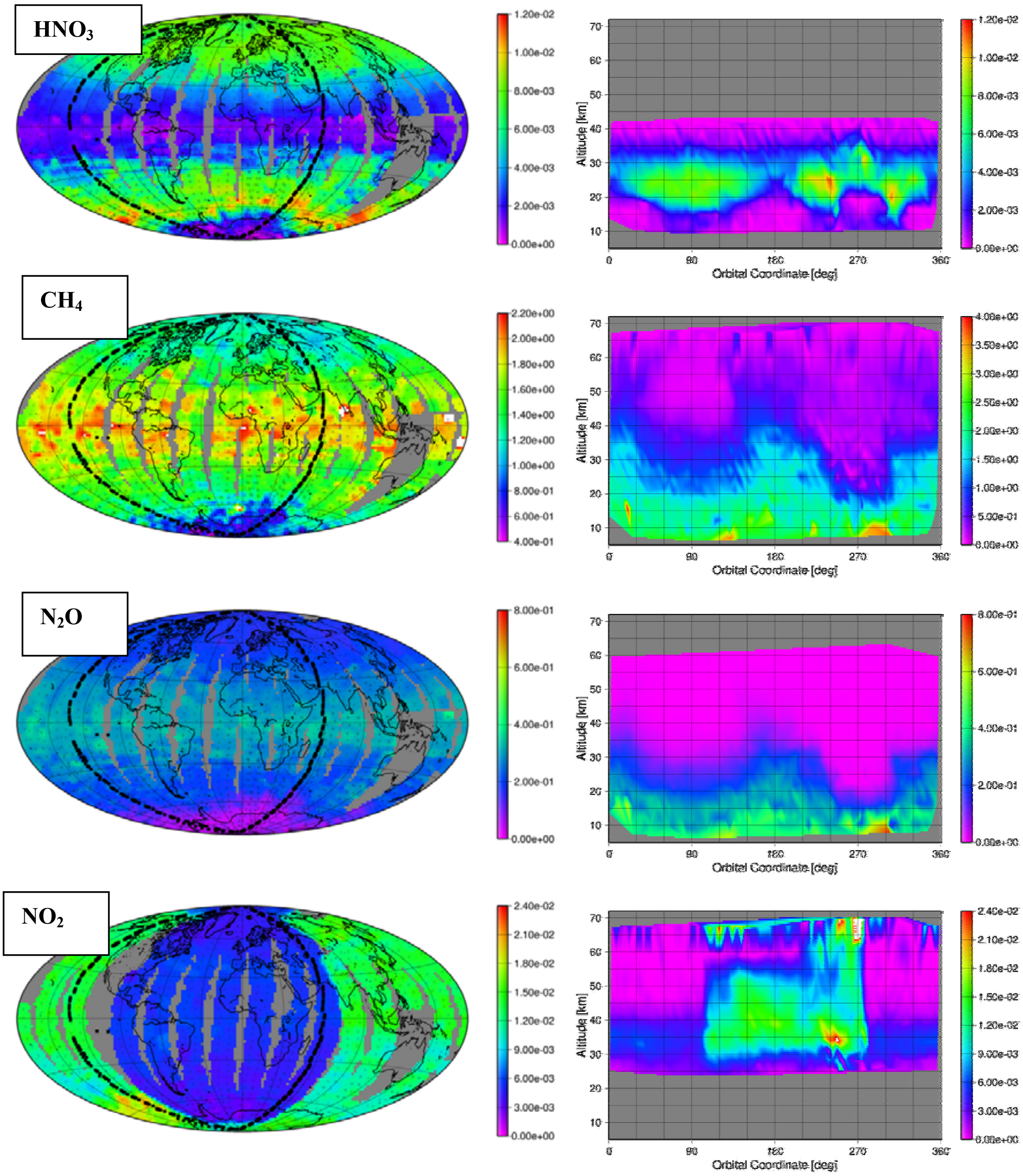
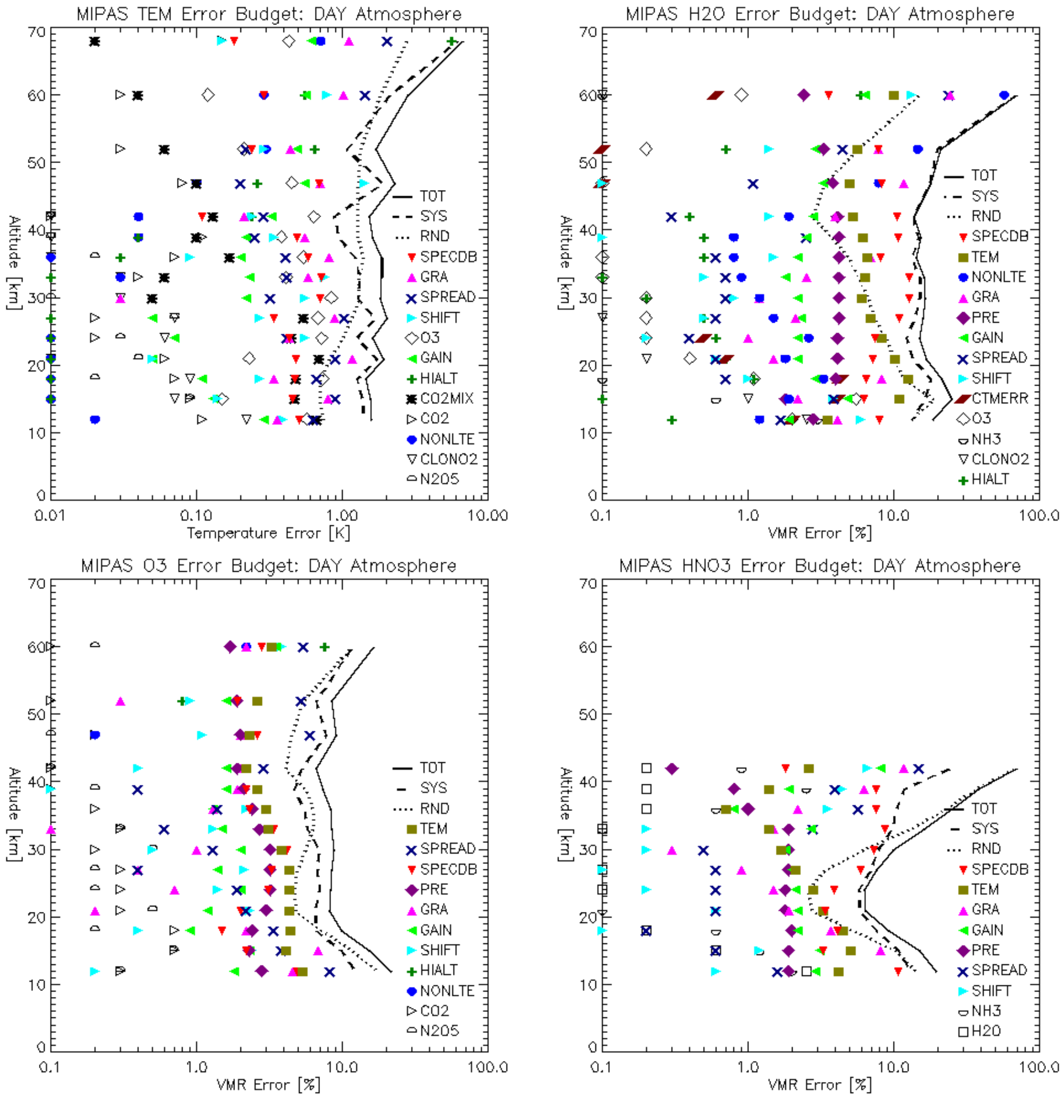


Figure 6 Global map at one altitude and vertical section of temperature (measured in K) and of the VMR (measured in ppm) of the MIPAS target species retrieved by ORM. A black track shows the orbit of the vertical section in the global map and the altitude of the global map in the vertical section.

An assessment of the quality of the retrieved profiles is given in Figure 7 that reports, for mid latitude day-time condition and the nominal set of microwindows, the total error profile for each retrieved profile, as well as the single contributions, i.e. the random error and the systematic error. The contributions due to the different systematic errors are also shown.
The total error is larger than the accuracy requirements of the study. The present accuracy limitations are due to the existing uncertainties in the systematic errors and not to a shortcoming of the retrieval. As the systematic errors are reduced a new microwindow selection can be accordingly be performed for a proportional reduction of the random errors leading to a reduced error budget.



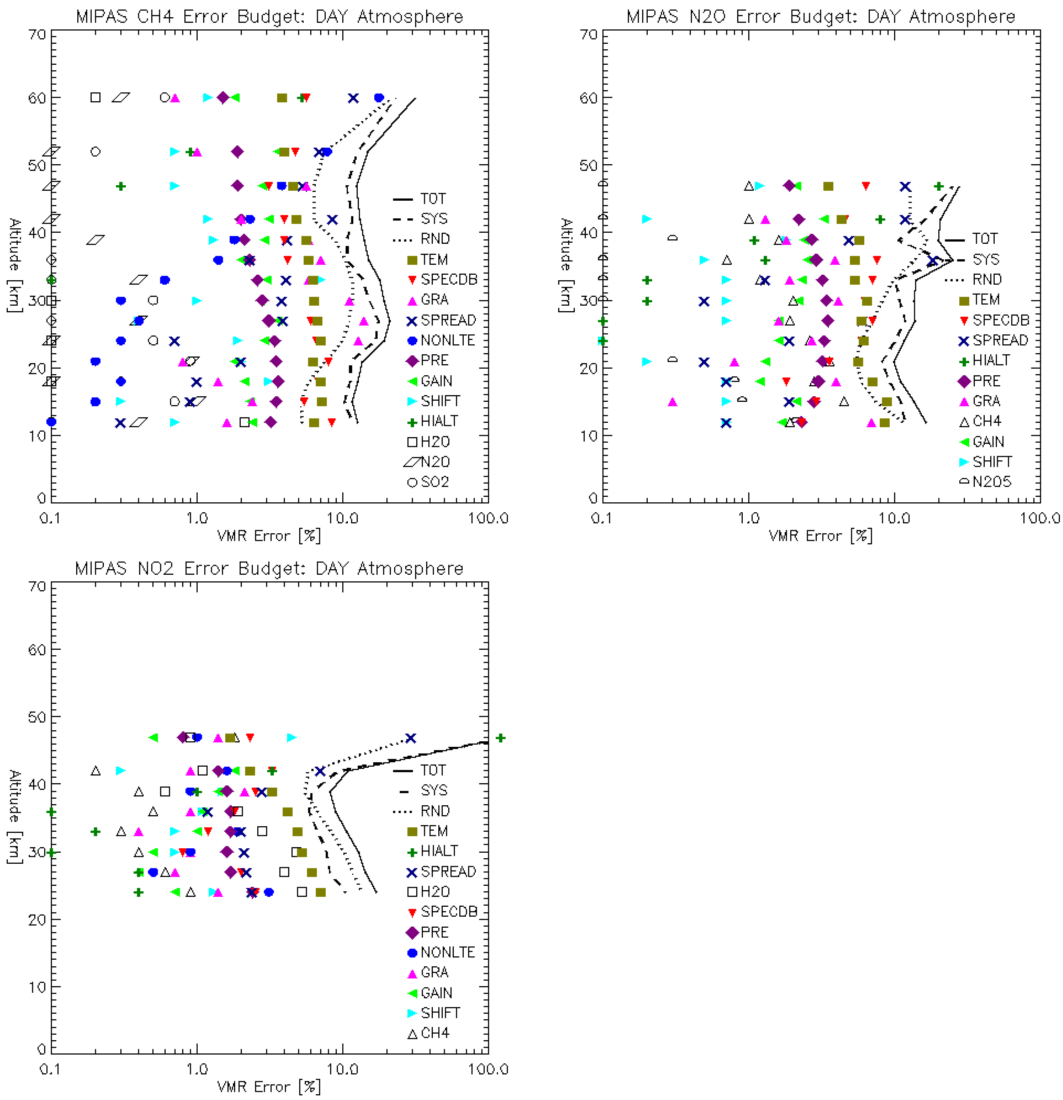


Figure7. Error profiles for all retrieved profiles. Continuous line: total error; dotted line: contribution to the total error due to random error; dashed line: contribution to the total error due to the a-priori estimate of systematic errors; colour scatter points: contribution to the systematic error coming from different types of systematic errors.

The vertical resolution of the retrieved profiles is characterised by the averaging kernels that are shown in Figure 8 in case of ozone retrieval for the 20° North – 65° North latitude band in July.

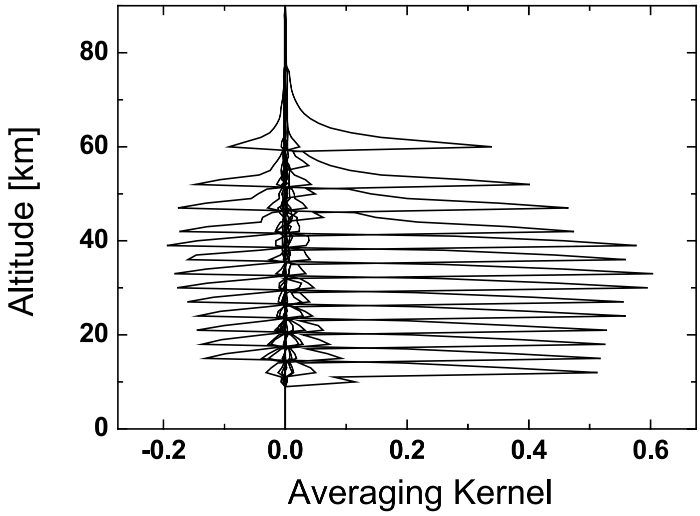


Figure 8 Averaging kernels for the ozone retrieval in the case of 20° North – 65° North latitude band in July

As an example of the unexpected products of MIPAS Figure 9 shows the global cloud top height obtained from the analysis of MIPAS measurements during 20 days in September 2002. The information on cloud top height is used by MIPAS Level 2 pre-processor to exclude from the analysis the sweeps affected by clouds, but they have a value in themselves. The information on cloud top height is presently not contained in the NRT products, but will be added in the future.

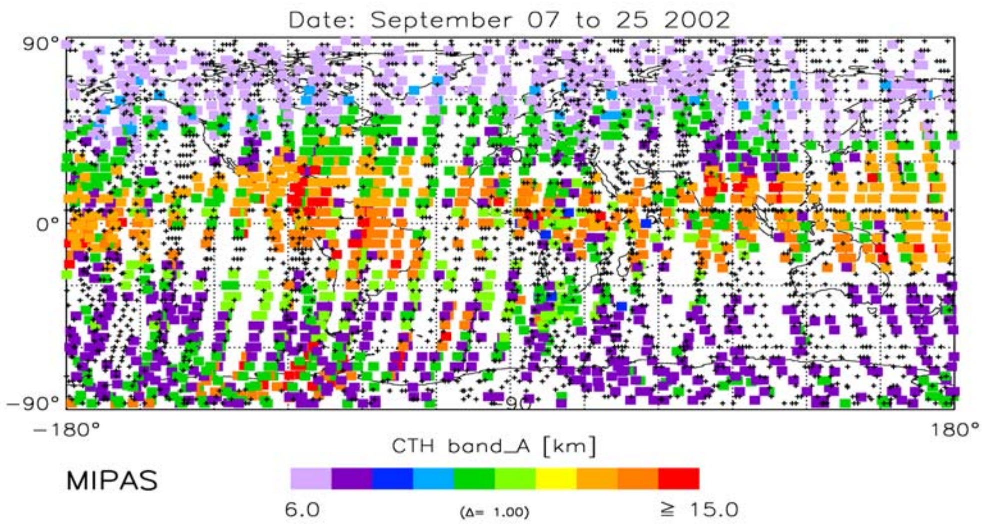


Figure 9 - Cloud top height global coverage obtained from the analysis of about 20 days of MIPAS measurements.

6. Outlook and recommendations

The results of the Commissioning Phase indicate that a continuous monitoring of both the instrument and the algorithm performances is needed. The algorithm is sufficiently robust and flexible to handle instrument instabilities, but a continuous adjustment and refinement of the auxiliary data is necessary if the quality of products has to be maintained at the highest level.

A good quality of the MIPAS products is indicated by the consistency tests performed so far, but the final validation has to be done with independent measurements, which however appear to be difficult to find of comparable quality. A promising validation tool seams to be provided by the assimilation techniques.

The computing time requirement was always a major constrain throughout the Study, but, considering that more and more powerful computers are becoming available, some choices (selection of occupation matrices, convergence criteria thresholds, retrieval range, possibility of retrieving other species) should be reviewed taking advantage of the new performances of computers.

Retrospectively, we find that the performance requirements given to study were correctly formulated and the study was able to evolve with a rational and efficient activity plan. Nevertheless, also thanks to MIPAS and this study, a major evolution is taking place in the field of limb sounding remote sensing of the atmosphere and the formulation of the requirements should be changed for future experiments. The exploitation of auxiliary engineering information used in Level 2 analysis suggests the definition of a requirement in term of variance covariance error for these engineering quantities. Furthermore, the perspective of the development of data assimilation techniques and applications for limb sounding data may in future lead to the definition of an user defined retrieval grid to be used in place of the instrument defined retrieval grid.

The code has potential for the extension of its use also for off-line analysis, in which case the same code can be used for the processing of other trace species (such as F11, F12, $ClONO_2$, N_2O_5) and of other observational modes. This extension of the code utilisation does not require any change in the code itself, but only the preparation of the appropriate auxiliary data file and tuning of the code operations.
In future, as the constrains posed by computing time and computer memory are being relaxed, new codes could be considered in order overcome some of the limitations that are present in the ORM code. In particular, the following improvement can be considered:

- simultaneous retrieval of all the limb sequences of an orbit in order to avoid the assumption of horizontally homogeneous atmosphere and improve the horizontal resolution of the measurements;
- simultaneous retrieval of all species in order to better account for their relative interference,
- use of a "forward-model" error (in place of the masked points) for a more rigorous

weighting of the information provided by the different spectral points.

- identification of new profile representations that are more suitable for data assimilation.

Finally it is important to underline that the frequency accuracy of MIPAS spectra is much better that anticipated from the requirements and this provides the potential for the retrieval of atmospheric wind. Of course only the horizontal component can be retrieved and a dedicated code is required, however this new and unexpected MIPAS product could provide an important improvement to our present capability of measuring this geophysical parameter. A dedicated study for the analysis of MIPAS special mode measurements was issued by ESA-ESRIN and is presently in progress.

7. Conclusions

MIPAS data analysis represents a major evolution with respect to the data processing of previous operational limb-sounding instruments (mainly of radiometric type), since it involves the exploitation of broad-band and high resolution spectral measurements that contain information about several atmospheric constituents that are each observed in several spectral elements.

Furthermore, the requirements of NRT analysis is very demanding because of both the time constraints (computing time shorter than measurement time, and short delay between measurements and processing) and the need for a validated algorithm capable of producing accurate and reliable results in an automated operative mode. Numerous optimisations, as well as a dedicated retrieval strategy, had to be studied and tested to match these requirements.

The code has allowed to successfully perform Level 2 analysis of MIPAS measurements since the first orbits measured by the instrument without any modification in the code and with only some minor modifications in the auxiliary data. The time constraint is successfully meet.

Numerous tests have been performed during the Commissioning Phase to test the impact of approximations implemented in the code and preliminary consistent tests on the Level 2 products were successful, but the final geophysical validation of the products will be done by means of the comparison of the retrieved profiles with the ones produced by independent measurements.

The tests performed during the Commissioning Phase have confirmed the importance of Level 1 product calibration, the need of introducing in the Level 2 pre-processing a filtering for the clouds and the need for refinements of the Level 2 auxiliary data.

The very demanding (and wishful) accuracy requirements of the study are not yet meet because of systematic errors, but as the systematic errors are reduced the code has the potential for meeting those requirements. Continuous revisions of the auxiliary data are in progress for the improvement of the quality of Level 2 products.