

INTERNAL CONSISTENCY OF MIPAS LEVEL 2 PRODUCTS

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ABSTRACT

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 are routinely retrieved from the measurements of the MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) instrument operating on board the ENVISAT satellite. Some internal consistency checks are performed on these measurements in order to verify the quality of the measurement system that includes the satellite measurements and the data processing. Good internal agreement is in general obtained, but in some cases the comparison with the a-priori understandings identifies the presence of some biases that need to be further investigated.

1. INTRODUCTION

MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) is a high resolution Fourier transform spectrometer operating on board the ENVISAT satellite. It measures the atmospheric limb emission in the middle infrared. Four spectral bands are simultaneously observed in the spectral interval from 685 to 2410 cm⁻¹ (corresponding to wavelengths from 14.6 to 4.15 μm) with an unapodised spectral resolution of 0.025 cm⁻¹.

For each orbit MIPAS performs 75 limb scans (plus measurements used for the instrument calibration). The analysis of each limb scanning sequence allows to determine the vertical profiles of O₃, H₂O, CH₄, HNO₃, N₂O and NO₂, as well as the temperature and pressure profiles, in the altitude range from 12 to 68 km. The data processing includes the Level 1 analysis [1] in which the Fourier transformation of the interferograms and the spectral calibrations are made and the Level 2 analysis in which the retrieval of the vertical profiles of the geophysical quantities is made.

The retrieval is performed using the Optimised Retrieval Model (ORM) [2] that was developed under an ESA contract for near real time (NRT) analysis. The baseline assumptions adopted in the ORM code have been verified in [3]. In [4] the ORM retrieval capabilities have been exploited to determine some instrumental parameters. In this paper the products of Level 2 analysis are used for some internal consistency checks.

In Sect. 2 the profiles of some minor atmospheric constituents are retrieved using different spectral intervals of the same measured spectra. In Sect. 3 the correlation between the volume mixing ratio (VMR) of CH₄ and N₂O, two atmospheric tracers expected to reflect the same diffusion process, is studied. Finally in Sect. 4 the maps of H₂O and CH₄ are combined in order to verify the conservation of the hydrogen budget in the atmosphere.

2. INDEPENDENT RETRIEVALS FROM THE SAME MEASUREMENTS

The retrieval is carried-out using a set of narrow (less than 3 cm⁻¹ width) spectral intervals, called 'microwindows' (MW) [5], that are selected as those intervals containing the best information on the target parameters and are less affected by systematic errors. The systematic errors are important not only for the selection of the MWs themselves, but also for the choice of the optimum set of MWs that can be used for the retrieval. This implies that in a retrieval the set of used MWs does not necessarily include all the MWs available from a pre-calculated database [5].

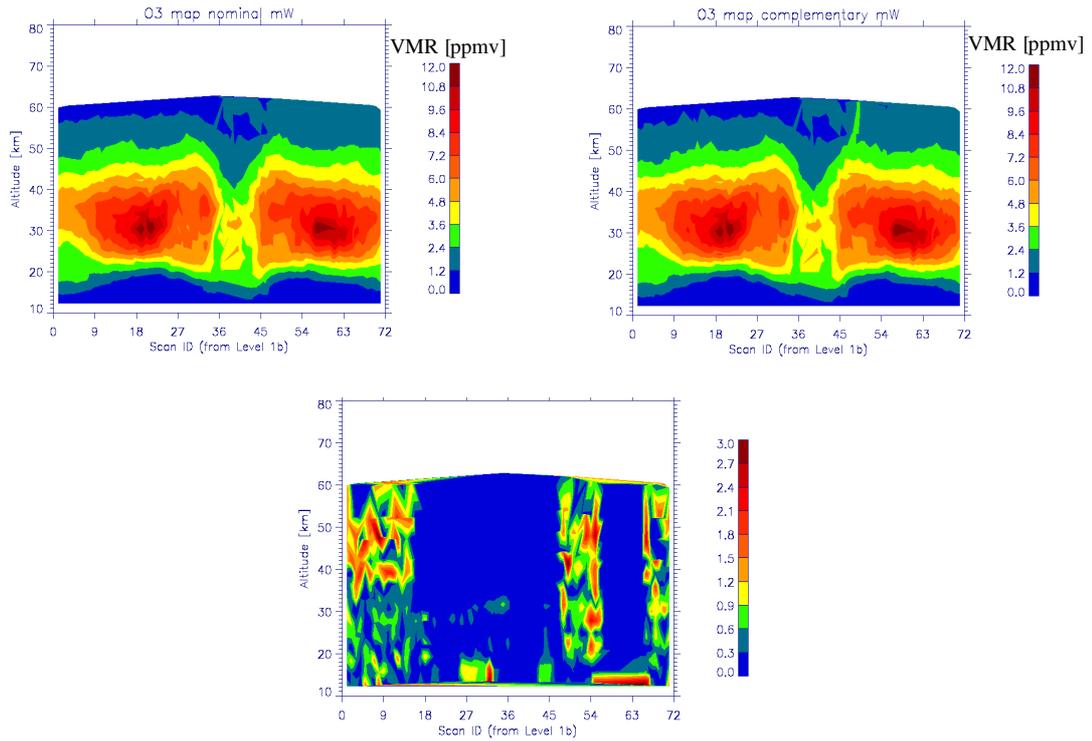


Fig.1. Maps of ozone VMR retrieved with two complementary sets of MWs (top two panels) and their difference normalized to its random error (bottom panel). Measurements performed by MIPAS during orbit 2081 on July 24th, 2002.

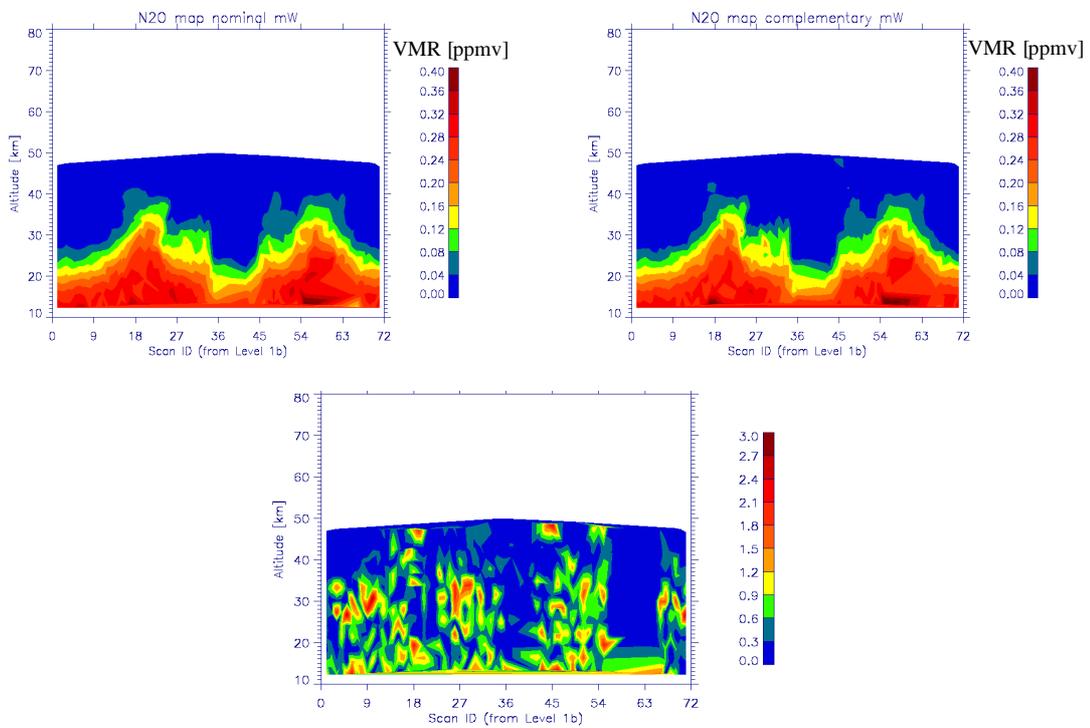


Fig.2. Maps of N₂O VMR retrieved with two complementary sets of MWs (top two panels) and their difference normalized to its random error (bottom panel). Measurements performed by MIPAS during orbit 2081 on July 24th, 2002.

In the case of some minor atmospheric constituents, such as ozone and N_2O , from the available MW database it is possible to choose two complementary sets of MWs providing fully independent measurements. Figs 1 and 2 show a comparison of the maps obtained for these two constituents using complementary sets of MWs. Measurements relating to orbit 2081 were used for this comparison.

In all maps the horizontal scale indicates the sequence number with the numbering conventions adopted in Level 1b outputs. According to this numbering convention, scan 1 corresponds to 83° N latitude, equator descending node is between scans 20 and 21, south pole region is from scan 36 to scan 43, equator ascending node corresponds to scan 56. The vertical scale indicates the altitude. The first two maps of each figure show the retrieved VMR obtained using two complementary sets of MWs. The third map shows the difference between the previous two measurements, normalised to the combined random error of the two retrievals (systematic errors are not considered because are in large part common to the two retrievals).

In case of ozone, above 20 km and for sequences from 18 to 45 it is not possible to find a set of MWs complementary with respect to the nominal set, therefore the two test retrievals reported in the top maps of Fig.1 have been carried-out using identical MWs for these scans and altitudes. This explains the artificially low (and meaningless) differences between the considered retrievals for scans from 18 to 45.

Apart this contingent problem due to unavailability of uncorrupted MWs for ozone, in general the observed differences are somewhat larger than what is expected from the random errors, but no significant bias can be observed. The presence of some residual oscillations in the retrieved profiles is expected to be the cause of the observed peak values in the difference maps. The internal consistency of both the spectral calibration and the spectroscopic database is confirmed.

3. CORRELATION OF TRACERS

Long lived atmospheric tracers are subject to a slow depletion and their VMR in the atmosphere depends on their life time. In the same air-parcels long lived species have the same lifetime and the VMR of one species has a close relationship with the VMR of the others [6].

Two long lived species, namely N_2O and CH_4 , are measured by MIPAS. Fig. 3 shows the scatter plot of N_2O VMR and CH_4 VMR measured by MIPAS along orbit 2081 of July 24th 2002. MIPAS measurements are compared with the expectations of the CTM model STRATAQ [7] corresponding to the atmosphere of April 14th 1997. STRATAQ model provides fields that are in general good agreement with other models and satellite global data [7,8].

The difference in time between the model and observations reduces the value of the comparison, but the change in methane production that has occurred in the last five years is certainly much smaller than the observed differences. Furthermore, possible errors in CH_4 and/or N_2O total amounts in the CTM fields for the chosen period, due to uncertainty in ground sources, should be also considered.

The scatter plot of the measurements has a large spread, but the values are very promising considering that no processing (regularisation and averaging) has been made in order to reduce the errors. The slopes of the two distributions are very similar, but either an excess of methane or a defect of N_2O may be observed in the measurements.

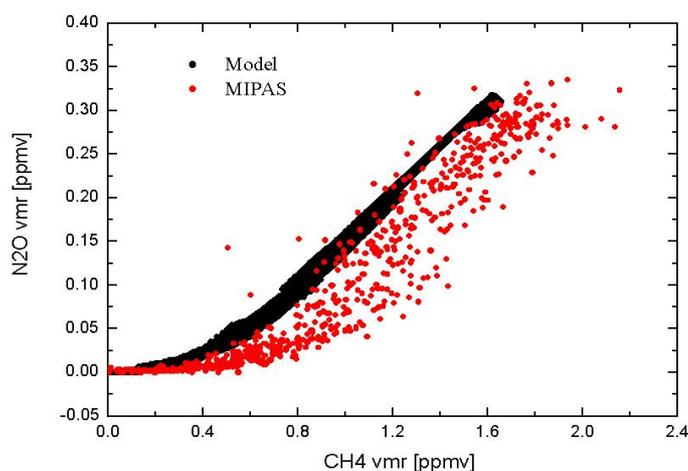


Fig. 3 Scatter plot of N_2O VMR as a function of CH_4 VMR. The red points show the values obtained from the MIPAS measurements from orbit 2081 on July 24th 2002. The black points show the values taken from the STRATAQ model corresponding to the atmosphere of April 14th 1997.

4. HYDROGEN BUDGET

Methane oxidation is the main source of water vapour in the stratosphere, followed by direct water vapour injections at the tropics.

On the basis of the main source of water vapour we expect therefore the number of hydrogen atoms to be conserved in the reaction of methane oxidation and the VMR summation of $\text{H}_2\text{O} + 2 \text{CH}_4$ is, in first approximation, a constant in the stratosphere [6].

Figure 5 shows a map of the VMR of $\text{H}_2\text{O} + 2 \text{CH}_4$ measured by MIPAS along orbit 2081. Some discrepancies occur at the lowest and highest retrieval altitudes that are affected by the truncation of the retrieval range, and around sequence number 38, that corresponds to the Antarctic region. Apart from these differences a field that varies from 6.5 to 9 ppm is observed. Also in this case raw data without any regularisation and/or averaging are shown in Fig. 5. The dispersion of the data is reasonable, but the measured values are larger than expected [6]. Furthermore, this observed excess cannot be explained by the possible methane excess that was noticed in Fig.3, because methane contributes mainly to the values at low altitudes and the largest values are observed above 35 km. We conclude that an excess of water vapour is detected by MIPAS.

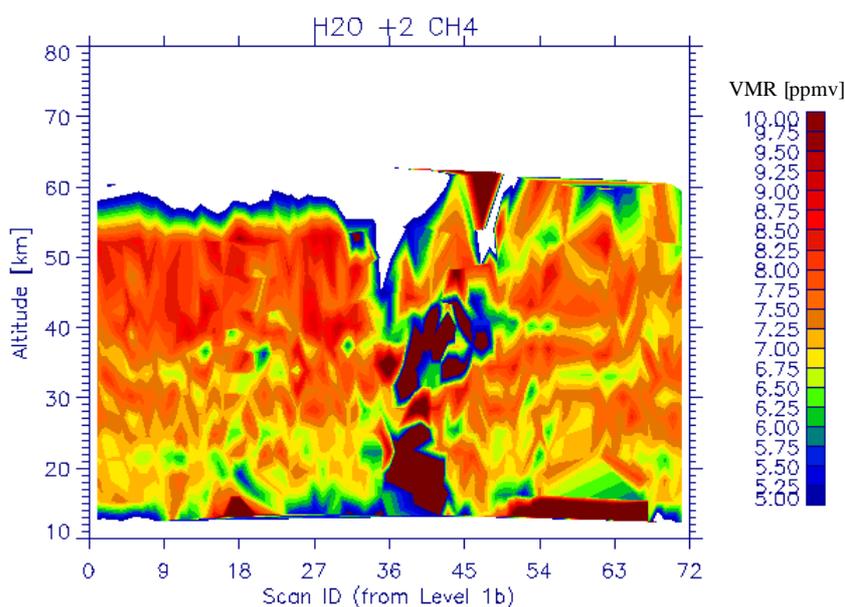


Fig.5 Map of $\text{H}_2\text{O} + 2 \text{CH}_4$ VMRs measured by MIPAS along orbit 2081.

5. CONCLUSIONS

The MIPAS products obtained with the operational NRT retrieval code have been analysed and some internal consistency checks have been performed.

The profiles of ozone and N_2O were retrieved using complementary sets of MWs. Occasional peaks are observed in the differences between the two retrievals, but no systematic effect is detected confirming the internal consistency of the spectral calibration and of the spectroscopic data base.

The correlation between the VMRs of two trace constituents (N_2O and CH_4) that are observed by MIPAS has a distribution with a slope that is in a good agreement with models, but either an excess of CH_4 or a defect of N_2O are detected by MIPAS.

The study of the VMR map of the quantity $\text{H}_2\text{O} + 2 \text{CH}_4$ obtained from MIPAS measurements shows a field that only in first approximation corresponds to the expectations. MIPAS measurements indicate an excess of water vapour.

These consistency checks provide important guidelines for the identification of the strength and weaknesses of MIPAS measurement procedure and lead to important critical considerations in view of the validation intercomparison with field measurements.

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6. REFERENCES

1. R. L. Lachance, 'MIPAS level 1B algorithm technical baseline document: an overview', in Proceedings of the European Symposium on Atmospheric Measurements from Space, ESA Earth Science Division, ed. (European Space Agency, ESTEC, Noordwijk, The Netherlands, 1999), Vol. 1, pp. 51-63.
2. Ridolfi M., B.Carli, M.Carlotti, T.v.Clarmann, B.M.Dinelli, A.Dudhia, J.-M.Flaud, M.Hoepfner, P.E.Morris, P.Raspollini, G.Stiller, R.J.Wells, 'Optimized forward model and retrieval scheme for MIPAS near-real-time data processing' *Appl. Optics*, Vol. 39, No. 8, p. 1323 – 1340.
3. Ridolfi M., D.Alpaslan, B.Carli, M.Carlotti, E.Castelli, S.Ceccherini, B.M.Dinelli, A.Dudhia, J.-M.Flaud, M.Höpfner, V.Jay, L.Magnani, H.Oelhaf, V.Payne, C.Piccolo, M.Prosperi, P.Raspollini, J.Remedios, R.Spang, 'MIPAS Level 2 processor performance and verification', this publication.
4. Raspollini P., D.Alpaslan, B.Carli, M.Carlotti, E.Castelli, S.Ceccherini, B.M.Dinelli, L.Magnani, M.Prosperi, M.Ridolfi, 'MIPAS INstrument and level 1 verifications using Level 2 retrieval code', this publication.
5. A. Dudhia, V. L. Jay and C.D. Rodgers, 'Microwindow selection for high-spectral-resolution sounders', *App. Optics*, 41, 3665-3673 (2002).
6. Barbara J. Finlayson-Pitts, James N. Pitts, Jr., 'Chemistry of the Upper and Lower Atmosphere - Theory, Experiments and Applications', Academic Press, New York (2000).
7. Grassi B., G. Redaelli and G. Visconti, STRATAQ: a three-dimensional chemical transport model of the stratosphere, *Annales Geophysicae*, 20, 847-862, 2002
8. Grassi B., G. Redaelli and G. Visconti, Data assimilation of stratospheric ozone using a Chemical Transport Model, *subm. to Il Nuovo Cimento*, 2003.