

Abstract

We present the strongly revised IMK/IAA MIPAS-ENVISAT CH₄ and N₂O data products for the MIPAS full resolution (versions V5H_CH4_21 and V5H_N2O_21) and for the reduced resolution period (versions V5R_CH4_224, V5R_CH4_225, V5R_N2O_224 and V5R_N2O_225). Differences to older retrieval versions which are known to have a high bias are discussed. The usage of the HITRAN 2008 spectroscopic dataset leads to lower values for both gases in the lower part of the profile. The improved correction of additive radiance offsets and handling of background radiance continua allows for aerosol contributions at altitudes in the upper stratosphere and above. These changes lead to more plausible values both in the radiance offset and in the profiles of the continuum absorption coefficients. They also increase the fraction of converged retrievals. Some minor changes were applied to the constraint of the inverse problem, causing small differences in the retrieved profiles, mostly due to the relaxation of off-diagonal regularisation matrix elements for the calculation of jointly retrieved absorption coefficient profiles. Spectral microwindows have been adjusted to avoid areas with saturated spectral signatures. Jointly retrieving profiles of water vapour and nitric acid serves to compensate spectroscopic inconsistencies. We discuss the averaging kernels of the products and their vertical resolution.

1 Introduction

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS, Fischer et al., 2008) is a Fourier transform spectrometer on board of the Environmental Satellite (ENVISAT). This satellite was launched in March 2002 and operated by the European Space Agency (ESA) until April 2012, when it ceased all communication to ground. During that time, MIPAS measured atmospheric emission spectra in the infrared between 685 and 2410 cm⁻¹ in limb geometry. There are two MIPAS measurement periods: during the full resolution period from June 2002 until March 2004, the instrument mea-

AMTD

8, 7805–7842, 2015

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Pliening et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



sured with the originally specified spectral resolution of 0.025 cm^{-1} (0.0483 cm^{-1} after an apodisation). Due to a malfunction in the interferometer slide system, there is a data gap until January 2005 when the instrument recommenced measuring with a so-called reduced resolution of 0.0625 cm^{-1} (0.121 cm^{-1} after the apodisation). The instrument has been operated in several different measurement modes with different tangent altitude patterns. For this study, only spectra from the MIPAS nominal measurement mode have been used; this covers about 80 % of the total measurement time. For the full resolution period, one limb scan contains 17 different spectra with tangent altitudes from 6 to 68 km. A limb scan in the reduced resolution period consists of 27 different spectra and their tangent altitudes are latitude dependent. The lowest tangent altitude ranges from 6 km at the polar regions to 9 km at the equator and the highest tangent altitude increases from 70 km in polar regions to 73 km at the equator.

The processor developed at the Institute of Meteorology and Climate Research in cooperation with the Instituto de Astrofísica de Andalucía (CSIC) retrieves profiles of temperature and various trace gases. The retrieval of CH_4 and N_2O with this processor was first described in Glatthor et al. (2005) for the full resolution period and in von Clarmann et al. (2009) for the reduced resolution period.

Various studies showed CH_4 and N_2O profiles retrieved from MIPAS-ENVISAT to have a positive bias in the lower part of the profiles. In Glatthor et al. (2005) the largest CH_4 and N_2O values are compared to tropospheric climatological data and found to be 0.7 ppmv higher for CH_4 and 80 ppbv higher for N_2O . Höpfner et al. (2007) compared MIPAS full resolution CH_4 and N_2O profiles versions V3O_CH4_9 and V3O_N2O_9 to those measured by ACE-FTS in version 2.2. This study uses profiles measured during northern polar winter. Below 15 to 18 km, MIPAS CH_4 profiles showed a high bias of around 0.2 ppmv while for N_2O a MIPAS bias of around 25 ppbv was found below 15 to 18 km. von Clarmann et al. (2009) state that the bias in the reduced resolution period is smaller than in the full resolution, but still present. Laeng et al. (2015) did a detailed validation of MIPAS reduced resolution V5R_CH4_222, comparing to profiles from ACE-FTS, SCIAMACHY, HALOE, SOFIE, Mark IV balloon interferometer and

cryosampler in situ measurements. They found MIPAS profiles to be biased high below 25 km by about 0.2 ppmv.

The aim of this study has been the improvement of the MIPAS IMK/IAA CH₄ and N₂O products.

2 General retrieval descriptions

Here we discuss the latest retrieval setup of CH₄ and N₂O. For the full spectral resolution period this refers to data versions V5H_CH4_21 and V5H_N2O_21 and for the reduced resolution period to data versions V5R_CH4_224, V5R_CH4_225, V5R_N2O_224 and V5R_N2O_225. For simplicity, in the following only the last part of the version code will be used. This simplification, however, is not expandable beyond this work because version identifiers are gas specific. Versions 224 and 225 are almost identical. Version numbers are different only to guarantee complete traceability. The only technical difference is the source of the ECMWF analysis used to constrain the preceding temperature retrievals. This has no discernible effect on the CH₄ and N₂O profiles. Thus, we do not discuss these versions separately. The data sets of these versions are disjoint in a sense that one observation is either 224 or 225. Thus the data sets are complementary. All this applies also to older pairs of versions i.e. 220 and 221, as well as to 222 and 223. Table 1 offers an overview of the data versions discussed.

Volume mixing ratios (vmr) of CH₄ and N₂O are retrieved in MIPAS channel B in several microwindows between 1220 and 1320 cm⁻¹ in the P-branch of the ν_4 band of CH₄ with the MIPAS-ENVISAT data processor developed at IMK and IAA (von Clarmann et al., 2003). The level 1b data used for the retrievals was version MIPAS/5.02–5.06.

For each MIPAS limb scan profiles of CH₄ and N₂O are retrieved. Since there are strong cross-interferences between the CH₄ and the N₂O lines, both species are retrieved simultaneously in one retrieval step to minimise mutual error propagation. In addition, mixing ratios of the interfering species HNO₃ and H₂O are jointly fitted to im-

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



prove the spectral residual. The profiles of temperature, pressure and ozone as well as the spectral shift correction are known from previous retrieval steps and are not treated as variables in the CH_4 and N_2O retrieval, but their retrieved profiles are used within the radiative transfer calculations. An additive radiance offset correction is retrieved for each microwindow. It is constant for all tangent heights. Additionally, for each microwindow continuum absorption coefficient profiles are retrieved that account for continuum spectral contributions of atmospheric aerosol, uncertainties in the modelling of the continua of O_3 , H_2O and N_2 and contributions of distant lines which sum up to a quasi-continuum (von Clarmann et al., 2003).

A first order Tikhonov finite differences constraint (e.g. Tikhonov, 1963; Steck and von Clarmann, 2001) is used to fight ill-posedness and to reduce vertical oscillations. The a priori profiles for both gases are zero. Therefore, not the mixing ratios themselves, but differences between adjacent profile values with respect to the a priori profile are constrained. Since the a priori profile is chosen all zero, this type of regularisation acts as a smoothing constraint. For methane, above 70 km a diagonal element in the regularisation matrix is used additionally. It pulls the profile in that height region towards the a priori profile. The regularisation matrix entries related to the continuum absorption coefficient contain some off-diagonal elements to prevent neighbouring microwindows from differing too much.

The retrieval is done on a fine vertical grid with a spacing of 1 km between 4 and 70 km. Above that range the grid is getting coarser and consists of the following grid points: 75, 80, 85, 90, 100 and 120 km.

The retrieval setup version 21 for the full resolution spectra is an adaption of the reduced resolution spectra setup 224 and 225. All changes described in Sect. 3 are applied to these data versions as well. The only difference is a slightly different selection of the spectral microwindows.

3 Changes in the retrieval setup

As mentioned in the introduction, the main drawback of previous data versions is the high bias of CH₄ and N₂O below 25 km. In order to improve the data, a number of major modifications in the retrieval setup were adopted. To make our data traceable, all modifications since versions 220 and 221 are reported and discussed in the following.

The first part (Sects. 3.1 and 3.2) deals with the changes which led to the data product versions 222 and 223. The second part (Sects. 3.3 to 3.5) explains the further changes which were included in the current product versions 224 and 225. In Table 1 the included changes are listed for each data version.

To illustrate the influence of the individual changes a test dataset of 110 orbits from the reduced resolution measurement period with 10439 limb scans is used. These spectra were measured between 05 June and 18 August 2010. Figure 1 shows the zonal mean vmr distributions for this dataset.

Almost all the changes implemented in the 224 and 225 setup for the reduced resolution spectra have been included in the new 21 setup for the full resolution spectra as well. Only the selection of the spectral microwindows is slightly different. A dataset of 1054 measurements from 16 orbits between 10 January and 20 February 2004 was calculated to investigate this new retrieval setup. In Fig. 2 the latitude dependent mean vmr profiles for those calculations are shown.

3.1 Usage of HITRAN 2008

Previous retrievals of CH₄ and N₂O (up to versions 220 and 221) relied on the HITRAN 2000 spectroscopic dataset with updates from 2001 for N₂O and HITRAN 2004 for CH₄. The spectroscopic datasets of CH₄ and N₂O received an update in the HITRAN 2008 release (Rothman et al., 2009). Hence in the new CH₄ and N₂O retrieval setup, these new line datasets have been used.

In Fig. 3 the influence of the usage of the updated spectroscopic dataset is presented. Areas where the new spectroscopy leads to higher mixing ratios are red, those

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



where it produces lower mixing ratios are blue. Both in CH₄ and N₂O the mixing ratios are smaller in the lower part of the measured profiles. For CH₄ the main changes are below 20 km in the tropics and below 15 km in the polar regions. The differences are most pronounced in the troposphere at the lower boundary of the data product, where new spectroscopic data lead to values of up to 0.18 ppmv lower than the old ones. These findings agree with Alvarado et al. (2014) who examined the influence of the HITRAN 2008 spectroscopy on the CH₄ profiles retrieved from the NASA AURA Tropospheric Emission Spectrometer (TES, Beer et al., 2001) and found the values to be lower with the new dataset. The N₂O profiles with the HITRAN 2008 spectroscopy show smaller values up to almost 35 km. Only the lowermost part of the valid data has a difference of less than -10 ppbv, the minimum in differences is -19 ppbv. The main differences in the retrieved CH₄ and N₂O result from updates of spectroscopic parameters for lines already existing in the database. Only very small differences between the old and new spectroscopy can possibly be attributed to new lines added within the used microwindows.

3.2 Spectral offset and continuum contributions

For the data versions 220 and 221 the continuum absorption coefficient was fitted up to an altitude of 32 km, which was the original suggestion of von Clarmann et al. (2003) for the retrieval of temperature. However, in some publications (e.g. Bardeen et al., 2008) relevant aerosol abundances above that altitude are discussed. To account for contributions from particles in this altitude range, we extended the upper boundary for the fit of the continuum absorption coefficient to 60 km.

The residual radiance offset in versions 220 and 221 has been fitted independently for each individual tangent height. In combination with the fitting of the continuum absorption coefficient, this leads to an ill-posed inverse problem, where the contributions of both these variables can hardly be distinguished: too high continuum absorption coefficients can nearly compensate too low radiance corrections and vice versa. This leads to linearly dependent rows in the Jacobians of the retrieval. Thus, increasing the

some slightly negative retrieved volume mixing ratios in the zonal mean at 75 km. Our analysis shows, that the introduction of the diagonal element to the regularisation matrix **R** does not alter the volume mixing ratio profiles below that altitude. Hence these physically still erroneous values above do not affect the quality of the data product below.

A further change was applied with respect to the off-diagonal matrix elements which pull the continuum absorption coefficient profiles of neighbouring microwindows towards each other. These entries have been considerably reduced, which allows a more pronounced spectral structure of the background emission. This leads to slightly decreased values of CH₄ at 20 km altitude and N₂O below 15 km. This is shown in Fig. 5, where the difference between the calculations with the new constraint setup minus those with the old setup is plotted. The degrees of freedom of CH₄ were reduced by 0.25 and of N₂O were increased by 0.25, while the continuum absorption coefficient profiles have gained about 14 degrees of freedom.

3.4 Spectral microwindows

Usually high resolution spectroscopy retrievals do not invert the entire measured spectra, but only narrow spectral windows containing lines of the target species, so-called microwindows (e.g. von Clarmann and Echle, 1998). The selection of these spectral microwindows has been changed compared to previous data versions. The microwindows from 1270 cm⁻¹ towards higher wavenumbers have been restricted to higher altitudes because the spectra in that region were saturated around the position of the line centres below. Additional microwindows at 1225, 1239 and 1245 cm⁻¹ and in the range of 1257 to 1270 cm⁻¹ have been introduced to compensate the related loss of information at the higher wavenumbers and to stabilise the joint fit of H₂O (see Sect. 3.5).

The selection of the microwindows used in versions 220, 221, 222 and 223 are compared to those of versions 224 and 225 in Fig. 6.

Figure 7 shows the impact of the new microwindow selection on the mean profiles of CH₄ and N₂O. For both species the volume mixing ratios below 20 km did decrease at

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Pliening et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



all latitudes. In the subtropics and tropics between 20 and 30 km an increase in volume mixing ratio can be observed. Convergence of the iterative retrieval was achieved in a larger part of cases: instead of 10 399 in setup versions 222 and 223, now 10 421 measurements (of 10 439 total) did converge. The changes in the microwindows led to a slight decrease in the root mean square difference between the measured and the best-fit spectra (RMS) and to an increase in degrees of freedom for methane. For N₂O the degrees of freedom dropped slightly.

3.5 Joint fit of water vapour and nitric acid

To improve the fit and to reduce the systematic residuals in the best fit spectra, the mixing ratios of HNO₃ and H₂O are retrieved additionally to CH₄ and N₂O, continuum absorption coefficient and spectral offset (joint fit approach) in the latest versions. Versions 222 and 223 and earlier used the volume mixing ratio profiles which were retrieved in previous retrieval steps as constant parameters. The new approach can compensate any spectroscopic inconsistency between the spectral microwindows of the specific gas retrievals (in this case HNO₃ and H₂O) and those used in the setup for the retrieval of CH₄ and N₂O.

The influence of the joint fit of HNO₃ and H₂O on the results for CH₄ and N₂O is shown in Fig. 8. Both the profiles of CH₄ and N₂O are moderately reduced below 20 km altitude. The RMS does hardly change and the degrees of freedom for CH₄ and N₂O decrease slightly.

4 Retrieval characterisation

The CH₄ and N₂O profiles from the reduced resolution period derived with the new setup versions 224 and 225 show significantly reduced oscillations in polar regions compared to those retrieved with versions 222 and 223. The fraction of converged retrievals of the entire dataset has significantly increased compared to the older versions.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



With the new setup 0.37% of the retrievals did not converge, compared to 1.02% of the profiles with setup versions 220 and 221, and 1.27% with versions 222 and 223.

The mean vertical resolution of the test dataset (see Sect. 3) is shown in Fig. 9 both for CH₄ and N₂O. For CH₄ a good resolution of about 2.5 to 7 km can be obtained below 60 km. Above it becomes rather coarse, due to the larger tangent height spacing. At altitudes below 20 km there is a slightly degraded resolution. The best resolved part of the profile is the altitude range between 25 and 35 km, where the resolution reaches up to 2.2 km. N₂O is resolved well between 20 km (15 km in mid latitudes) and 50 km, where the resolution is about 2.5 to 6 km. Above this range the volume mixing ratios are too small to allow for a good signal in the spectra. For both gases the mid latitude regions have a better resolution than the tropical or polar areas.

In Fig. 10 the averaging kernels for a sample profile of CH₄ are shown. This reduced resolution scan was measured in orbit 43202 at 39.4° N, 78.9° E on 05 June 2010, 05:02:29 UTC. The upper panel shows the rows of the averaging kernel: each black cross on one curve denotes the nominal altitude of the related averaging kernel. The rows of the averaging kernels represent the weights of the true atmospheric states at various altitudes in the retrieval at the nominal altitude. For most curves the black cross lies at the maximum position, i.e., the atmospheric state at a certain altitude has the largest impact on a retrieved value in the same grid height. The curves are roughly symmetric to this point in shape. This allows a straight-forward interpretation of the retrieved profiles. Above 55 and below 15 km the curves have their maximum not always on the nominal grid point and/or are asymmetric in shape. Without considering the averaging kernels, this can cause biases, and thus, interpretation of the retrieved profile should be conducted more carefully. The curves in the lower panel picture the columns of the averaging kernel. They indicate where the information from a value in the atmosphere (marked with a black cross) impacts the retrieved profile. Again the curves for values between 15 and below 55 km are symmetric and their maxima are located at the retrieved grid points. Figure 11 shows the averaging kernels for the retrieval of N₂O for the same measurement. Roughly symmetric curves can be found

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



between 20 and 50 km both in the plots of rows and columns. All the information for the retrieved values above 50 km are almost entirely dependent on the values below. Outside this range the data without explicit consideration of the averaging kernels is prone to misinterpretation.

5 Along with the retrieval, for each profile the impact of the instrument noise on the retrieved profile is calculated as a routine data product. However there are various additional error sources which have to be considered. These errors have been estimated for certain example profiles. The following errors have been assumed: for the uncertainty of the line of sight (los) 0.15 km vertical pointing; for the spectral shift 0.005 cm^{-1} ; 10 for the instrumental calibration error (gain) 1%; for the instrumental line shape error (ils) 3%; and for the temperature gradient in latitudinal direction 0.01 K km^{-1} (constant with respect to altitude). The spectroscopic errors were extracted from the HITRAN database (Rothman et al., 2009), with a correction of the actual line intensity in dependence of the rotational quantum number as suggested by Flaud and Piccolo (2001). 15 Resulting line intensity uncertainties are between 2 and 5% for CH_4 and between 4 and 7% for NO_2 for low J values. The representative uncertainties in air broadening coefficients have been estimated at 15% for CH_4 and 3.5% for N_2O . Since no information on the error correlations between the individual transitions was available, these errors were assumed to be fully correlated, which implies that the error estimation is 20 on the conservative side. The profiles of temperature and O_3 are known from previous retrieval steps; related retrieval errors were propagated onto the CH_4 and N_2O results. The contribution of CO_2 , SO_2 , NO_2 , HOCl , HCN , H_2O_2 , C_2H_2 , COF_2 , CFC-14 , N_2O_5 and ClONO_2 to the spectra was calculated based on climatological abundances. For these gases, estimated profiles of 1-sigma were used to estimate corresponding CH_4 25 and N_2O retrieval errors. The estimated error contributions of all these sources are shown in Fig. 12 for the measurement at 05 June 2010, 05:02:29 UTC along with the derived profiles. Below 15 km the instrument noise is the most contributing source to the error for both gases. Above, the other errors have larger contributions. Especially the estimated spectroscopic error is very large and dominates the error budget between

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



about 17 and 42 km for CH₄ and between 20 and 38 km for N₂O. It has, however, to be mentioned that these spectroscopic error estimates are speculative because the inter-transition correlations of the errors are not known. The assumption of full correlations may be over-conservative. Inter-transition correlations of less than unity would lead to partial randomisation of this kind of error and the resulting uncertainty would be largely reduced. The second largest error contribution is the uncertainty of the vertical pointing of the line of sight. For CH₄, below 60 km the relative total error is between 5 and 17 %. The relative total error of N₂O below 30 km is around 5 to 10 %, above it increases with height to values in the order of 10 to 15 %, until it further increases above 40 km. Tables 2 and 3 give numeric values for the more important error contributions for a few selected altitude grid points.

For the full resolution spectra, oscillations in the CH₄ profiles were considerably reduced in the version 21. However, a larger fraction of the retrievals did not converge (8.50 % instead of 2.78 %).

Figure 13 shows the mean vertical resolution of a test data set for the full resolution spectra. Between 15 and 40 km the resolution is in the order of 3 to 6 km for both gases. The resolution is not as good as in the period of reduced spectral resolution, because each limb scan consists of fewer tangent altitudes.

The averaging kernels of the test measurement between 15 and 50 km generally look well behaved (Figs. 14 and 15), but in some cases, particularly at very high or low altitudes, are slightly off centre. This should be kept in mind for further interpretation of the data. In most cases the retrieved data points are most sensitive to atmospheric volume mixing ratios slightly below the altitudes they are calculated for (between 1 and 2 km).

The error budget shown in Fig. 16 makes clear that the instrument noise is larger than the other errors at the altitudes below 15 km. Again the largest contributor to the error above that altitude is the spectroscopic error, followed by the uncertainty of the tangent altitude pointing (line of sight). The relative error of CH₄ is between 5 and 20 %. For N₂O it is between 5 and 10 % below 25 km and between 5 and 20 % between 25

and 45 km. As said before, the spectroscopic error may be over-estimated, because the assumption of inter-transition correlations of these errors may be too pessimistic. Numeric values for certain altitude grid points and the more important error contributions are reported in Tables 4 and 5.

5 Conclusions

The new MIPAS-ENVISAT CH₄ and N₂O profiles versions 21, 224 and 225 are now available for the complete MIPAS measurement period. The usage of the HITRAN 2008 spectroscopic dataset, improved continuum and offset handling, minor changes in the constraint, inclusion of H₂O and HNO₃ to the retrieval vector and different selection of spectral microwindows overall lead to improved data products where the known high bias has been reduced. Averaging kernels are found to be symmetric in the stratosphere. The vertical resolutions there are in the order of 2.5 to 7 km for CH₄, and 2.5 to 6 km for N₂O during the reduced resolution period and in the order of 3 to 6 km for both gases during the full resolution period. The relative errors in the lower part of the profiles are mostly around 15 % for CH₄ and below 10 % for N₂O. They increase above 25 or 30 km to values between 10 and 20 %, except for CH₄ from the reduced resolution period, where the error remains below 15 % over almost the entire profile below 60 km. It turned out that knowledge of the air broadening coefficients and line intensities of the individual lines is insufficient to reliably estimate the propagation of spectroscopic errors on the retrieved vmr profiles. In addition, information on the inter-transition correlations of these errors is needed. Comparisons to other instruments will be the subject of an upcoming paper.

Acknowledgements. This work is a contribution to the “Helmholtz Climate Initiative REKLIM” (Regional Climate Change), a joint research project of the Helmholtz Association of German research centres (HGF). We thank ESA for providing the MIPAS level-1b data.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



References

- Alvarado, M. J., Payne, V. H., Cady-Pereira, K. E., Hegarty, J. D., Kulawik, S. S., Wecht, K. J., Worden, J. R., Pittman, J. V., and Wofsy, S. C.: Impacts of updated spectroscopy on thermal infrared retrievals of methane evaluated with HIPPO data, *Atmos. Meas. Tech.*, 8, 965–985, doi:10.5194/amt-8-965-2015, 2015. 7811
- Bardeen, C. G., Toon, O. B., Jensen, E. J., Marsh, D. R., and Harvey, V. L.: Numerical simulations of the three-dimensional distribution of meteoric dust in the mesosphere and upper stratosphere, *J. Geophys. Res.*, 113, doi:10.1029/2007JD009515, D17202, 2008. 7811
- Beer, R., Glavich, T. A., and Rider, D. M.: Tropospheric emission spectrometer for the Earth Observing System's Aura satellite, *Appl. Optics*, 40, 2356–2367, 2001. 7811
- Fischer, H., Birk, M., Blom, C., Carli, B., Carlotti, M., von Clarmann, T., Delbouille, L., Dudhia, A., Ehnhalt, D., Endemann, M., Flaud, J. M., Gessner, R., Kleinert, A., Koopman, R., Langen, J., López-Puertas, M., Mosner, P., Nett, H., Oelhaf, H., Perron, G., Remedios, J., Ridolfi, M., Stiller, G., and Zander, R.: MIPAS: an instrument for atmospheric and climate research, *Atmos. Chem. Phys.*, 8, 2151–2188, doi:10.5194/acp-8-2151-2008, 2008. 7806
- Flaud, J.-M. and Piccolo, C.: Spectroscopic Database updates, Tech. Rep. TN-LPM-IROE-01, Issue 1, Laboratoire de physique des matériaux (LPM) – CNRS, Nancy and Istituto Ricerca Onde Elettromagnetiche (IROE) – CNR, Florence, appendix 3, 2001. 7816
- Glatthor, N., von Clarmann, T., Fischer, H., Funke, B., Grabowski, U., Höpfner, M., Kellmann, S., Kiefer, M., Linden, A., Milz, M., Steck, T., Stiller, G. P., Mengistu Tsidu, G., and Wang, D. Y.: Mixing processes during the Antarctic vortex split in September/October 2002 as inferred from source gas and ozone distributions from ENVISAT-MIPAS, *J. Atmos. Sci.*, 62, 787–800, 2005. 7807
- Höpfner, M., von Clarmann, T., Engelhardt, M., Fischer, H., Funke, B., Glatthor, N., Grabowski, U., Kellmann, S., Kiefer, M., Linden, A., López-Puertas, M., Milz, M., Steck, T., Stiller, G., Wang, D., Ruhnke, R., Kouker, W., Reddmann, T., Bernath, P., Boone, C., and Walker, K.: Comparison between ACE-FTS and MIPAS IMK/IAA profiles of O₃, H₂O, N₂O, CH₄, CFC-11, CFC-12, HNO₃, ClONO₂, NO₂, N₂O₅, CO, and SF₆ in February/March 2004,

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



in: Proc. Third Workshop on the Atmospheric Chemistry Validation of Envisat, (ACVE-3), 04–07 December 2006, ESRIN, Frascati, Italy, vol. ESA SP-642, CD-ROM, ESA Publications Division, ESTEC, Postbus 299, 2200 AG Noordwijk, the Netherlands, 2007. 7807

Laeng, A., Plieninger, J., von Clarmann, T., Grabowski, U., Stiller, G., Eckert, E., Glatthor, N., Haenel, F., Kellmann, S., Kiefer, M., Linden, A., Lossow, S., Deaver, L., Engel, A., Hervig, M., Levin, I., McHugh, M., Noël, S., Toon, G., and Walker, K.: Validation of MIPAS IMK/IAA methane profiles, *Atmos. Meas. Tech. Discuss.*, 8, 5565–5590, doi:10.5194/amtd-8-5565-2015, 2015. 7807

Rodgers, C. D.: *Inverse Methods for Atmospheric Sounding: Theory and Practice*, vol. 2 of Series on Atmospheric, Oceanic and Planetary Physics, edited by: Taylor, F. W., World Scientific, Singapore, New Jersey, London, Hong Kong, 2000. 7812

Rothman, L. S., Gordon, I. E., Barbe, A., Benner, D. C., Bernath, P. F., Birk, M., Brown, L. R., Boudon, V., Champion, J. P., Chance, K. V., Coudert, L. H., Dana, V., Devi, M. V., Fally, S., Flaud, J. M., Gamache, R. R., Goldman, A., Jacquemart, D., Lacome, N., Mandin, J. Y., Massie, S. T., Mikhailenko, S., Nikitin, A., Orphal, J., Perevalov, V., Perrin, A., Rinsland, C. P., Šimečková, M., Smith, M. A. H., Tashkun, S., Tennyson, J., Toth, R. A., Vandaele, A. C., and der Auwera, J. V.: The HITRAN 2008 molecular spectroscopic database, *J. Quant. Spectrosc. Ra.*, 110, 533–572, 2009. 7810, 7816

Steck, T. and von Clarmann, T.: Constrained profile retrieval applied to the observation mode of the Michelson Interferometer for Passive Atmospheric Sounding, *Appl. Optics*, 40, 3559–3571, 2001. 7809, 7812

Tikhonov, A.: On the solution of incorrectly stated problems and method of regularization, *Dokl. Akad. Nauk. SSSR+*, 151, 501–504, 1963. 7809

von Clarmann, T. and Ehle, G.: Selection of optimized microwindows for atmospheric spectroscopy, *Appl. Optics*, 37, 7661–7669, 1998. 7813

von Clarmann, T., Glatthor, N., Grabowski, U., Höpfner, M., Kellmann, S., Kiefer, M., Linden, A., Mengistu Tsidu, G., Milz, M., Steck, T., Stiller, G. P., Wang, D. Y., Fischer, H., Funke, B., Gil-López, S., and López-Puertas, M.: Retrieval of temperature and tangent altitude pointing from limb emission spectra recorded from space by the Michelson Interferometer for Passive Atmospheric Sounding (MIPAS), *J. Geophys. Res.*, 108, 4736, doi:10.1029/2003JD003602, 2003. 7808, 7809, 7811

von Clarmann, T., Höpfner, M., Kellmann, S., Linden, A., Chauhan, S., Funke, B., Grabowski, U., Glatthor, N., Kiefer, M., Schieferdecker, T., Stiller, G. P., and Versick, S.: Retrieval of temper-

ature, H₂O, O₃, HNO₃, CH₄, N₂O, ClONO₂ and ClO from MIPAS reduced resolution nominal mode limb emission measurements, Atmos. Meas. Tech., 2, 159–175, doi:10.5194/amt-2-159-2009, 2009. 7807

AMTD

8, 7805–7842, 2015

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

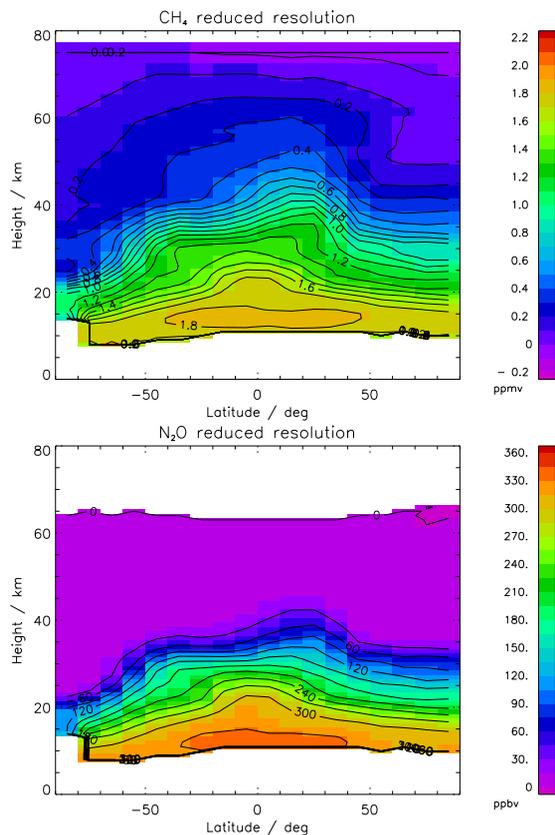


Figure 1. Zonal mean distributions for reduced resolution spectra, measured between 05 June and 18 August 2010. The black lines are the interpolated isopleths. White areas show regions with no valid data at all. On the upper panel for CH₄ (version V5R_CH4_224), on the lower for N₂O (version V5R_N2O_224).

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

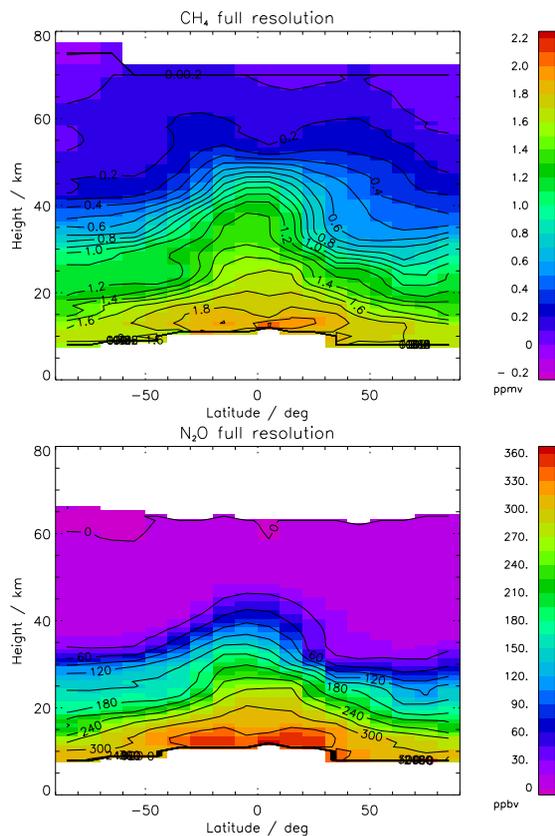


Figure 2. As Fig. 1, but for full resolution spectra, measured between 10 January and 20 February. On the upper panel for CH₄ (version V5H_CH4_21), on the lower for N₂O (version V5H_N2O_21).

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

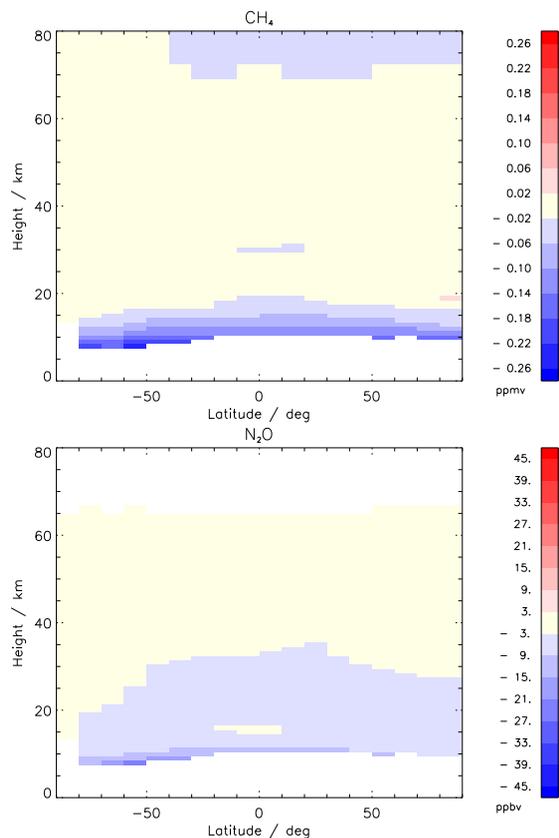


Figure 3. Zonal mean difference distributions. Difference calculation with HITRAN 2008 spectroscopy of CH_4 and N_2O minus calculation with older spectroscopic datasets (for details see text). On the upper panel for CH_4 , on the lower for N_2O .



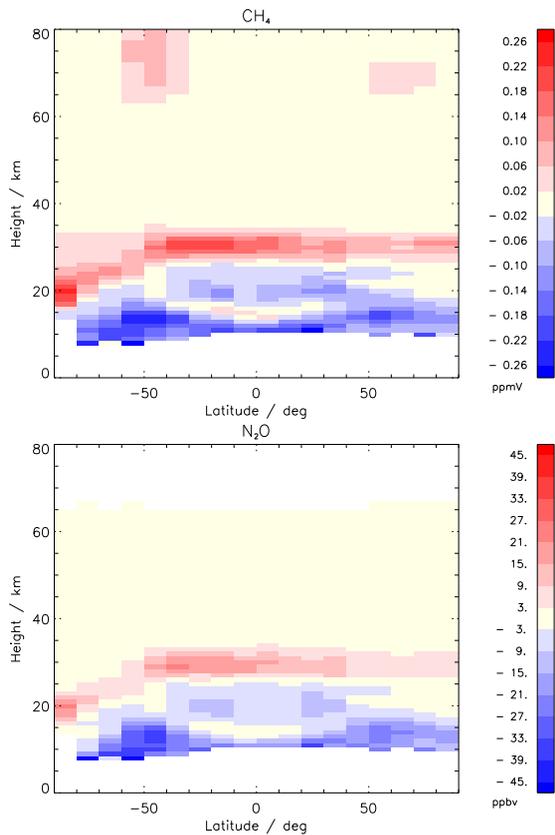


Figure 4. As Fig. 3, but difference retrieval with new offset and continuum setup minus reference with old setup.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
◀	▶
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	



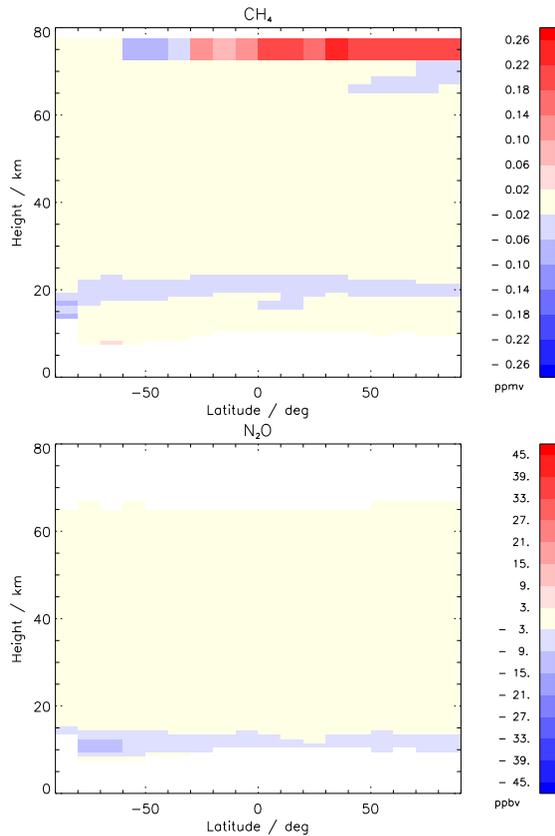


Figure 5. As Fig. 3, but difference retrieval with Tikhonov constraint and relaxed constraint between neighbouring microwindows minus reference with old setup.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
◀	▶
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

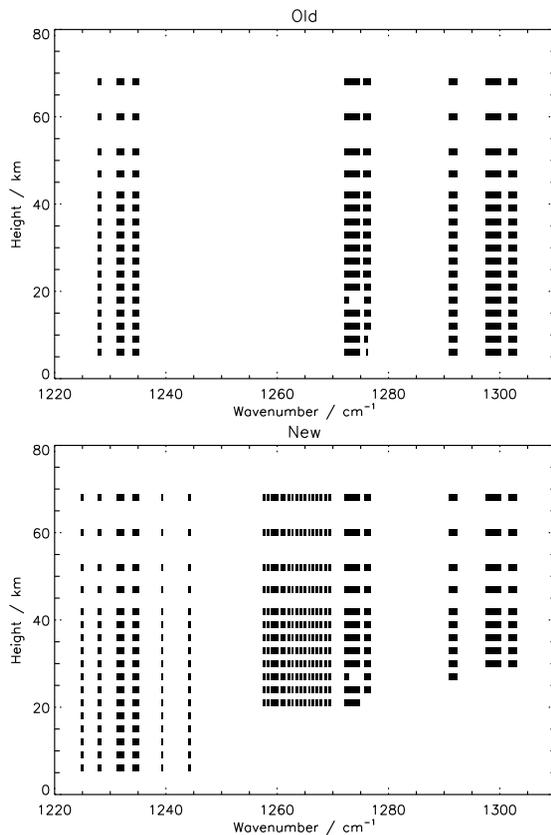


Figure 6. Selected microwindows of the setups V5R_CH4_220, V5R_CH4_221, V5R_N2O_220 and V5R_N2O_221 as well as V5R_CH4_222, V5R_CH4_223, V5R_N2O_222 and V5R_N2O_223 (upper panel) and V5R_CH4_224, V5R_CH4_225, V5R_N2O_224 and V5R_N2O_225 (lower panel) as a function of wavenumbers and tangent altitudes. The microwindows are marked as black patches.

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[◀](#)[▶](#)[◀](#)[▶](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

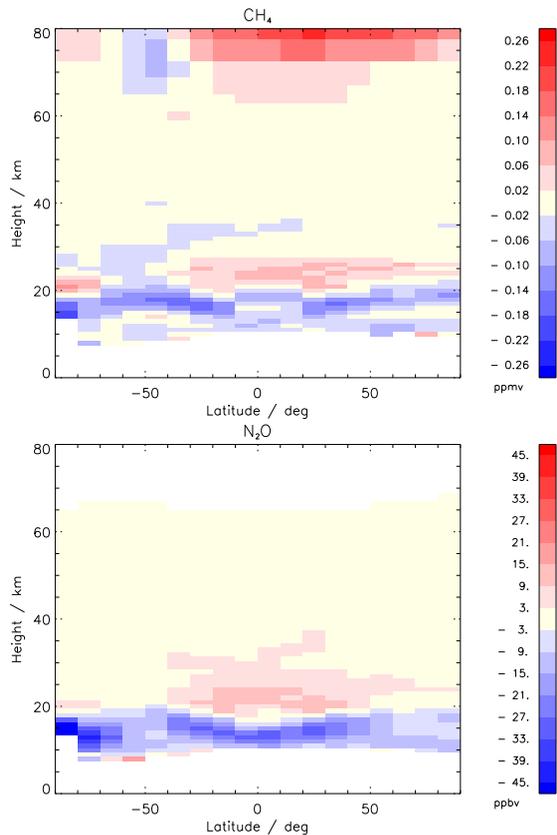


Figure 7. As Fig. 3, but difference retrieval with new selection of microwindows minus reference with old setup.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
◀	▶
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

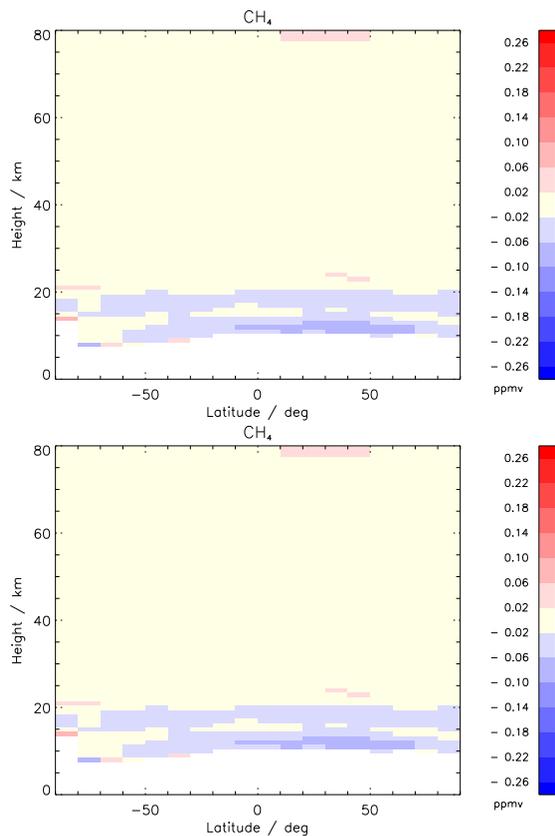


Figure 8. As Fig. 3, but difference retrieval with joint fit of HNO_3 and H_2O minus reference with old setup.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

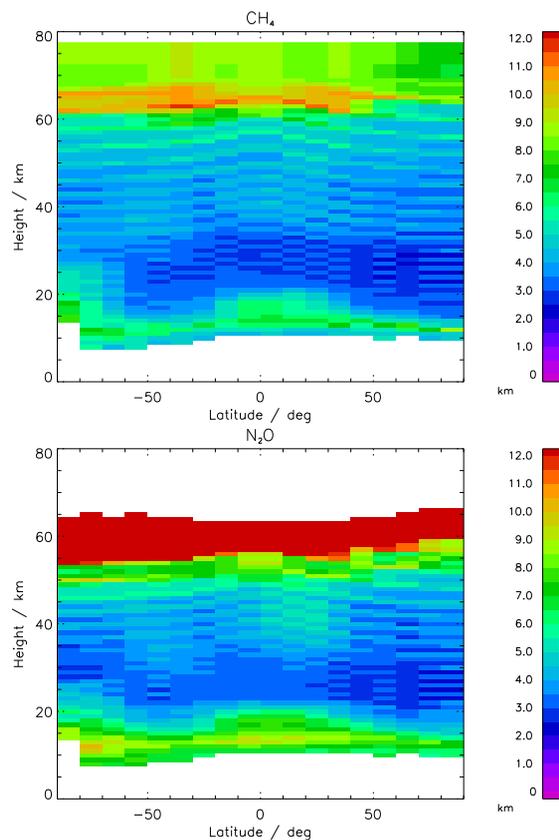


Figure 9. Mean vertical resolution in km for profiles from reduced resolution spectra (versions V5R_CH4_224 and V5R_N2O_224). Upper panel for CH₄, lower panel for N₂O.

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

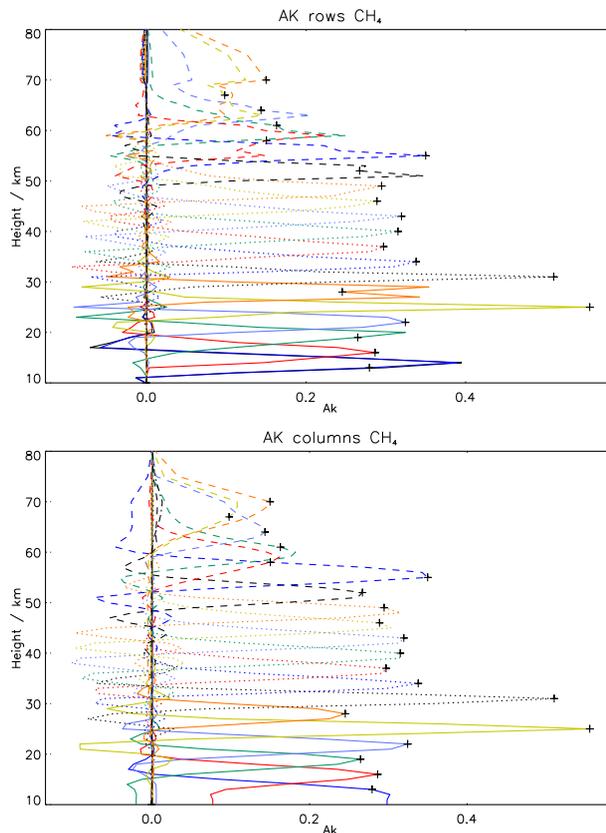


Figure 10. Selected rows (upper panel) and columns (lower panel) of the averaging kernel matrix for the measurement of CH₄ in orbit 43202 at 39.4° N, 78.9° E on 05 June 2010, 05:02:29 UTC (derived from reduced resolution spectra, version V5R_CH4_224). The black crosses highlight the diagonal terms of the averaging kernel matrix.

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[◀](#)[▶](#)[◀](#)[▶](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

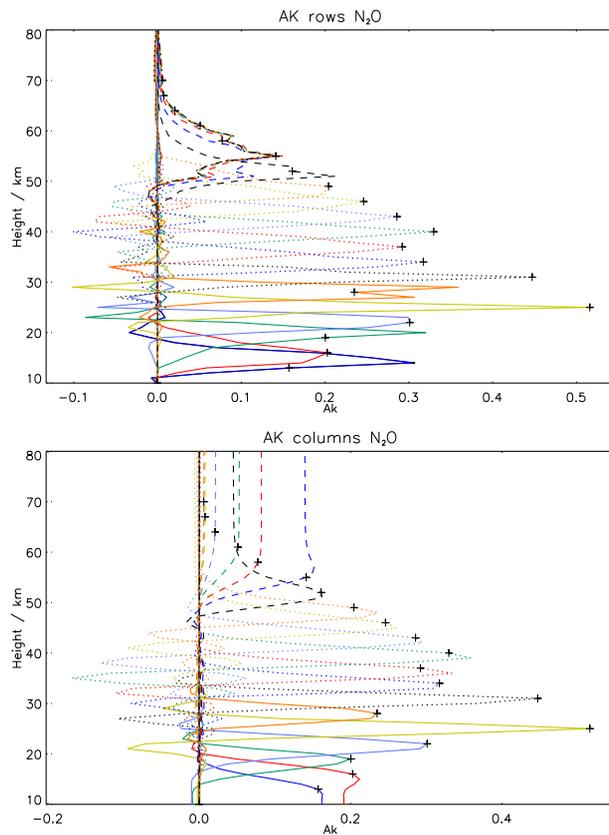


Figure 11. As Fig. 10, but for N₂O (version V5R_N2O_224).

[Title Page](#)[Abstract](#)[Introduction](#)[Conclusions](#)[References](#)[Tables](#)[Figures](#)[Back](#)[Close](#)[Full Screen / Esc](#)[Printer-friendly Version](#)[Interactive Discussion](#)

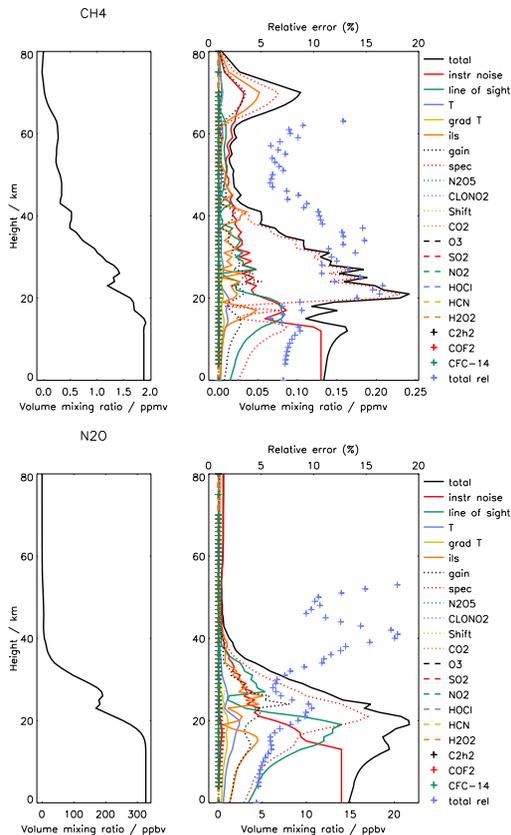


Figure 12. Estimated error contributions for the measurement in orbit 43202 at 39.4° N, 78.9° E on 05 June 2010, 05:02:29 UTC (derived from reduced resolution spectra, versions V5R_CH4_224 and V5R_N2O_224). Left panels: gas profiles, right panels: contributions of different errors. All contributions are absolute values, except for the total relative error, which is given in % (upper axis). Upper panels for CH₄, lower panels for N₂O.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

Title Page	
Abstract	Introduction
Conclusions	References
Tables	Figures
◀	▶
◀	▶
Back	Close
Full Screen / Esc	
Printer-friendly Version	
Interactive Discussion	



Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

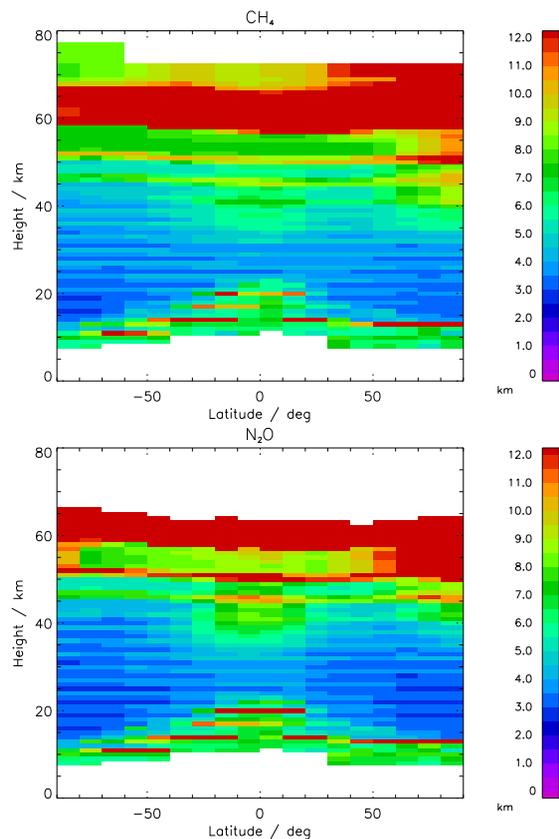


Figure 13. As Fig. 9, but for profiles from full resolution spectra (versions V5H_CH4_21 and V5H_N2O_21).

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

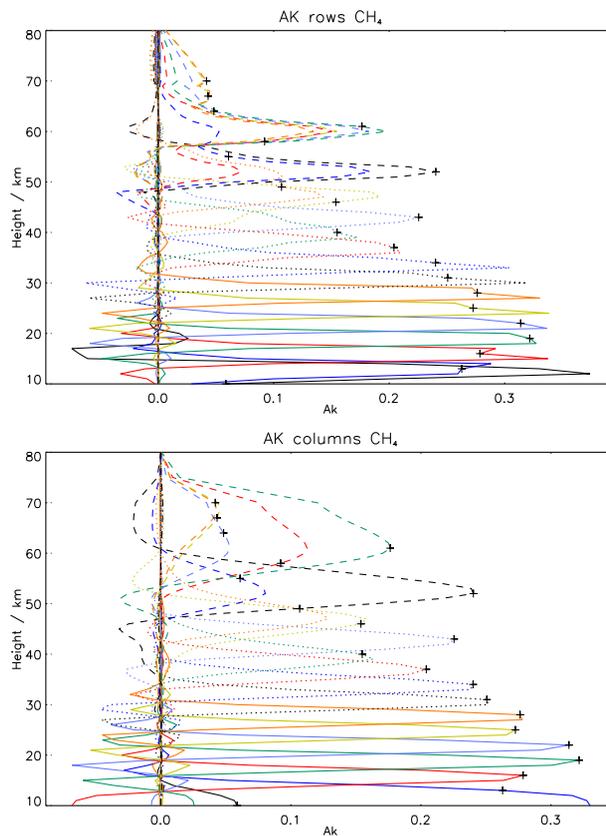


Figure 14. Selected rows (upper panel) and columns (lower panel) of the averaging kernel matrix for the measurement of CH₄ in orbit 10324 at 46.0° N, 144.5° W on 20 February 2004, 07:48:31 UTC (derived from full resolution spectra, version V5H_CH4_21). The black crosses highlight the diagonal terms of the averaging kernel.

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

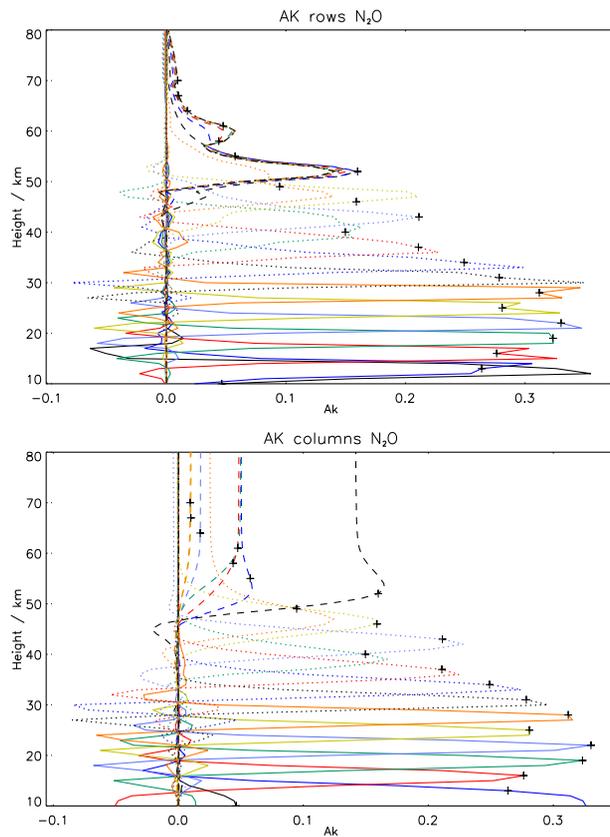


Figure 15. As Fig. 14, but for N_2O (version V5H_N2O_21).

Methane and nitrous oxide retrievals from MIPAS-ENVISAT

J. Plieninger et al.

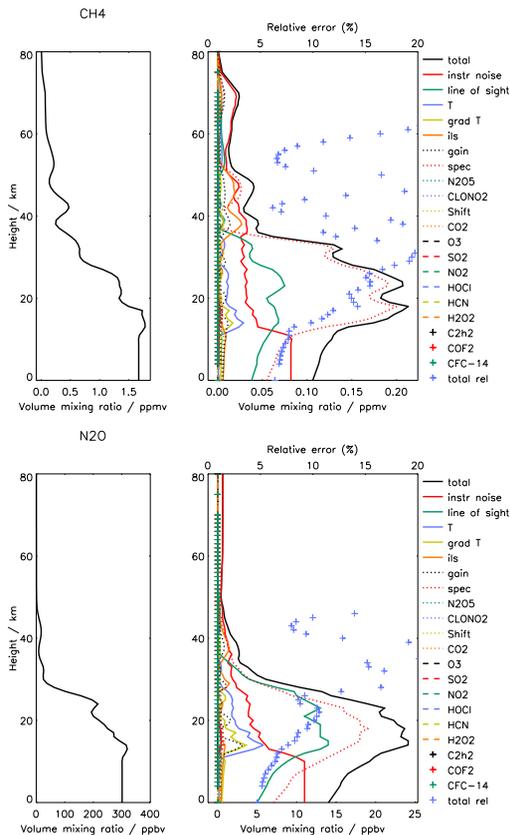


Figure 16. As Fig. 12, but for the measurement of in orbit 10324 at 46.0° N, 144.5° W on 20 February 2004, 07:48:31 UTC (version V5H_N2O_21).

Title Page

Abstract

Introduction

Conclusions

References

Tables

Figures



Back

Close

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

