

VALIDATION OF MIPAS O₃, NO₂, H₂O AND CH₄ PROFILES (V4.61) WITH COLLOCATED MEASUREMENTS OF HALOE AND SAGE II

A. Bracher, K. Bramstedt, M. Sinnhuber, M. Weber, J. P. Burrows

Institute of Environmental Physics (IUP), University of Bremen, P.O. Box 330440, D-28334 Bremen, Germany, Email: bracher@uni-bremen.de

ABSTRACT

The MIPAS operational data products of selected trace gases (O₃, H₂O, NO₂ and CH₄, all v4.61) are validated by comparison with the space borne instruments HALOE (v19) and SAGE II (6.2). The data were limited to the validation reference data set (July 2002 to December 2002). The results of these satellite intercomparisons presented in this paper show a reasonable data quality for these validated MIPAS trace gas products: MIPAS O₃ profiles are within 5 to 15% (RMS <15%) and the H₂O profiles show a positive bias of 1 to 15% (RMS 5-25%) compared to HALOE and SAGE II. MIPAS NO₂ profiles (including photochemical corrections for HALOE NO₂ data) are within -15 to 30% (RMS 10-35%) and the CH₄ profiles show a positive bias of 5 to 15% (RMS 10-25%) compared to HALOE.

1 INTRODUCTION

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is part of the atmospheric instrumentation on the Environmental Satellite (ENVISAT) launched in March 2002. MIPAS measures the atmospheric limb emission spectra from 685-2410 cm⁻¹ (14.5 to 4.1 μm) over the altitude range from 6 to 68 km. Besides other atmospheric constituents these spectra allow quantification of concentration profiles of numerous atmospheric trace gas species. The level-2 data retrieval accuracy of selected trace gases (O₃, NO₂, H₂O, CH₄) from MIPAS on ENVISAT was assessed by validation with the space borne occultation instruments Halogen Occultation Experiment (HALOE, data version v19) and the Stratospheric Aerosol and Gas Experiment II (SAGE II, data version 6.2). The use of independent satellite measurements to validate trace gas products of these instruments has the great advantage that pole-to-pole coverage for all seasons is available and that validation activities are not limited to a certain period and location. HALOE, since 1991 onboard of UARS, is an infrared (2.45 to 10.0 μm) solar limb radiometer and SAGE II, since 1984 onboard ERBS, is an UV-VIS-NIR (0.385 to 1.02 μm) solar limb radiometer.

The complete MIPAS data sets of O₃, NO₂, H₂O, and CH₄ profiles from the validation reference set (data from 2002/07/18–2002/12/27) are searched for coincident measurements with HALOE and SAGE II with the coincidence criteria, that the tangent point of

the HALOE or SAGE II is within 250 km of MIPAS and measurements were performed during the same day.

During the time period of the validation reference data set altitude errors up to 3 km due to an ENVISAT pointing problem have been observed. Because of that and since the pressure level can be retrieved from the MIPAS emission spectra, comparisons in this study were based on pressure levels and volume mixing ratios. For each collocated measurement pair the relative deviation is determined as in Eq. 1:

$$\text{Relative deviation} = (\text{SP}_{\text{MIPAS}} - \text{SP}_{\text{SAT}}) / \text{SP}_{\text{SAT}} \quad (1),$$

where SP is the concentration of the trace gas species and SAT is the correlative measurement, either of HALOE or SAGE II.

2 O₃ VALIDATED WITH HALOE AND SAGE

For the O₃ profile comparisons with HALOE, 78 collocations are found. The collocation distribution is highly biased towards the northern latitudes, with 51 at 30°N to 60°N, 13 at 60°N to 90°N, 8 in the tropics, and only 6 in the mid and high southern latitudes. Fig. 1 shows examples of collocated O₃ profiles from MIPAS and HALOE in the high southern latitudes and the subtropics. In both examples, there is a good agreement between the two measurements at 0.1 to 100 hPa and the O₃ maximum is within the same pressure level, although MIPAS O₃ VMR seem to be slightly higher than HALOE. From all matches the mean relative deviation and the RMS of the mean relative deviation is calculated and shown in Fig. 2. MIPAS O₃ VMR show a consistent positive bias of 5 to 15% to HALOE with an RMS of 5 to 15% between 0.5 and 50 hPa.

For the comparisons with SAGE II, 137 collocations are found. The collocation distribution is highly biased towards the northern latitudes, with 66 at 60°N to 90°N, 28 at 30°N to 60°N, 24 at 60°S to 90°S, 13 in the tropics, and 6 at 30°S to 60°S. Fig. 3 shows examples of collocated O₃ profiles from MIPAS and SAGE II in the mid southern latitudes and the tropics. In the example from the mid latitudes MIPAS is significantly higher around the O₃ maximum than SAGE, but in the tropics

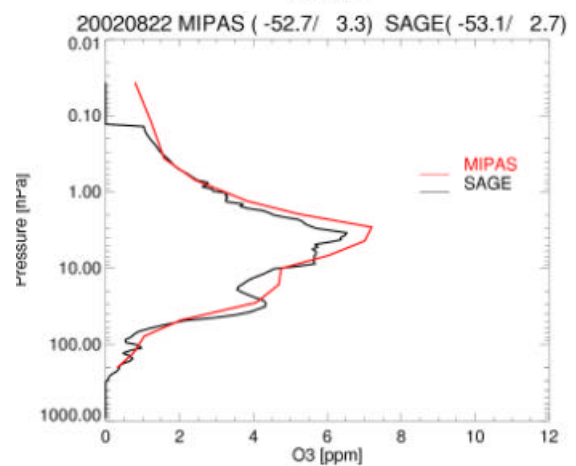
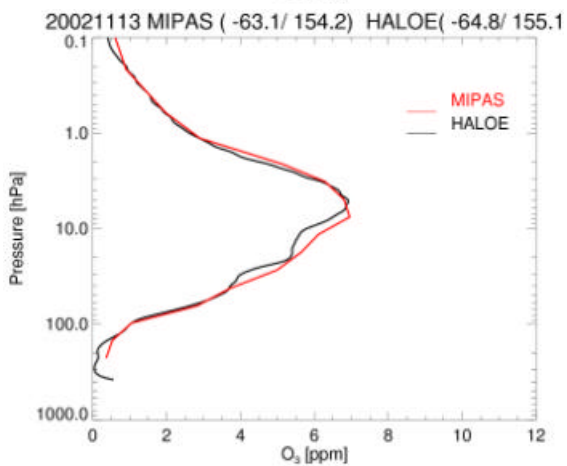
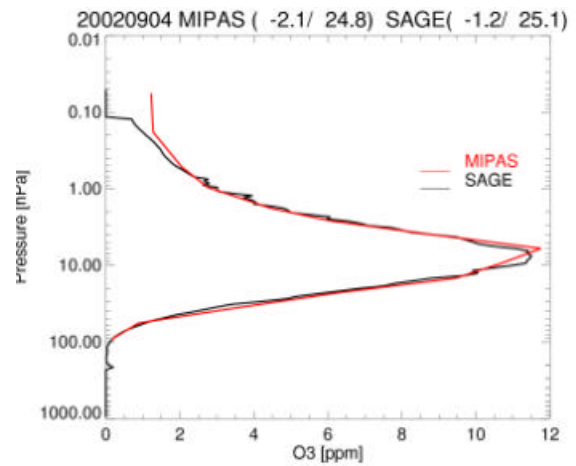
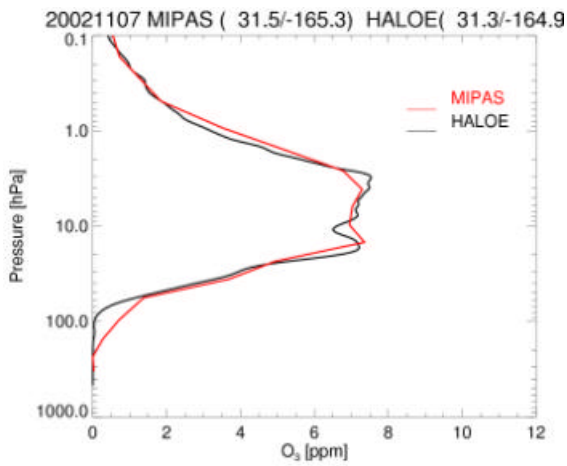


Fig. 1. Example of collocated O_3 profile measurements (top: subtropics and bottom: high southern latitudes) from HALOE (black) and MIPAS (red).

Fig. 3. Example of collocated O_3 profile measurements (top: tropics and bottom: high southern latitudes) from SAGE II (black) and MIPAS (red).

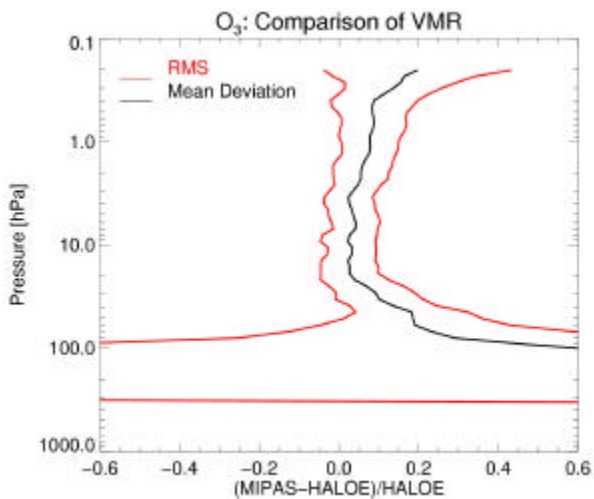


Fig. 2. Mean relative deviation (black) and root mean square of mean relative deviation (red) of the comparison of all collocated MIPAS ozone profiles ($n=78$) with HALOE profiles from the validation reference set in 2002

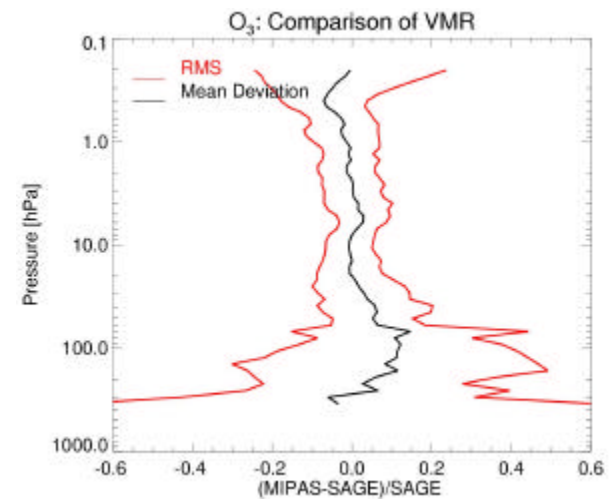


Fig. 4. Mean relative deviation (black) and root mean square of mean relative deviation (red) of the comparison of all collocated MIPAS ozone profiles ($n=137$) with SAGE II profiles from the validation reference set in 2002

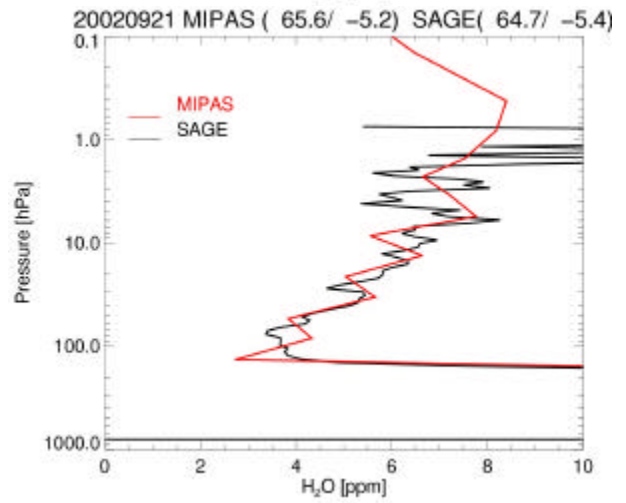
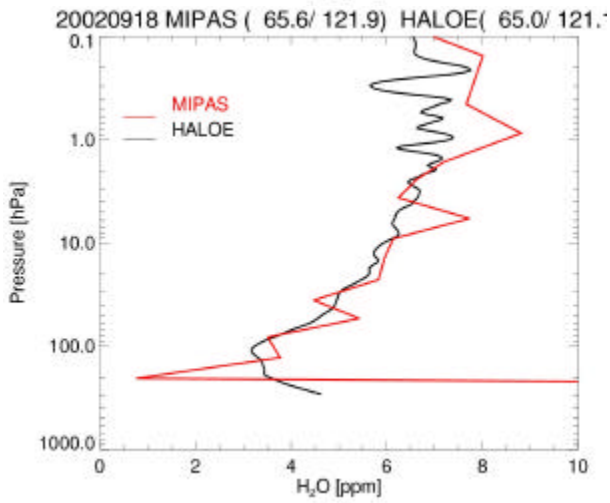
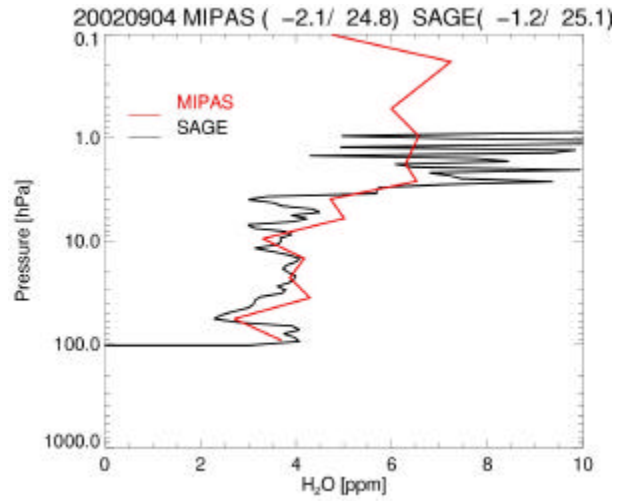
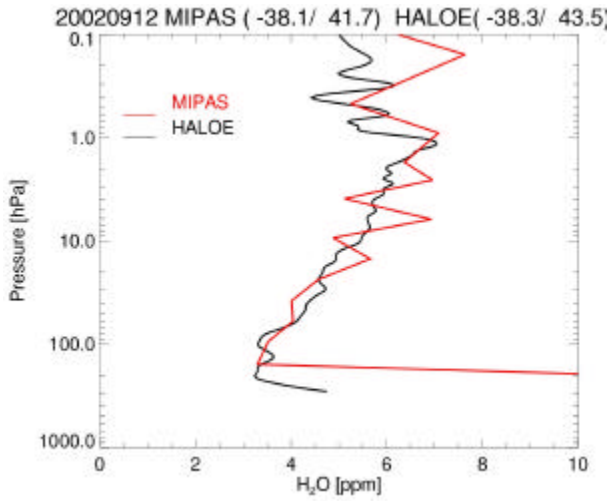


Fig. 5. Example of collocated H₂O profile measurements (top: subtropics and bottom: high northern latitudes) from HALOE (black) and MIPAS (red).

Fig. 7. Example of collocated H₂O profile measurements (top: tropics and bottom: high northern latitudes) from SAGE II (black) and MIPAS (red).

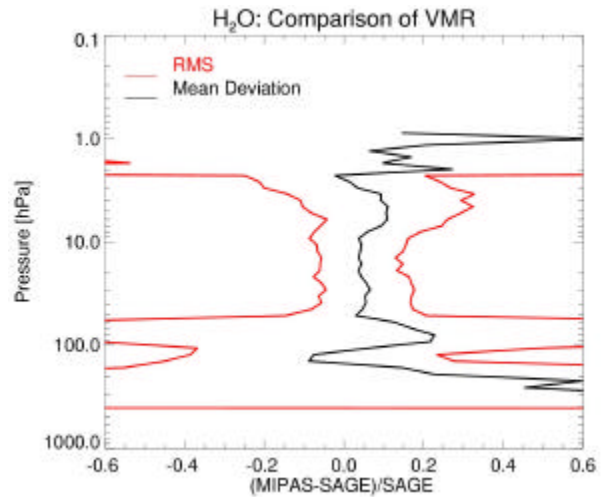
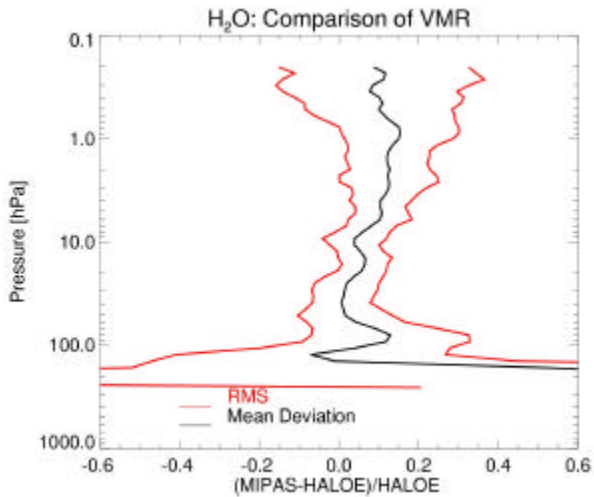


Fig. 6. Mean relative deviation (black) and root mean square of mean relative deviation (red) of the comparison of all collocated MIPAS H₂O profiles (n=100) with HALOE profiles from the validation reference set in 2002

Fig. 8. Mean relative deviation (black) and root mean square of mean relative deviation (red) of the comparison of all collocated MIPAS H₂O profiles (n=137) with SAGE II profiles from the validation reference set in 2002

the two measurements agree very well. The statistical results from these comparisons (Fig. 4) show an agreement within 5% (RMS of 5 to 15%) at 0.5 and 60 hPa between the measurements of the two instruments.

The accuracy of HALOE O₃ profiles is given with about 6% between 30 and 60 km and 20% between 15 to 30 km [1] and of SAGE II with 10% between 10 and 50 km [2]. Taking these accuracies and the generally observed 10% bias between HALOE and SAGE II O₃ values, results show that between 0.5 and 50 hPa reasonable MIPAS O₃ VMR (v4.61) are retrieved.

3 H₂O VALIDATED WITH HALOE AND SAGE

For the H₂O profile comparisons with HALOE, 100 collocations are found. The collocation distribution is highly biased towards the northern latitudes, with 49 at 30°N to 60°N, 31 at 60°N to 90°N, 8 in the tropics, and only 12 in the mid and high southern latitudes. Fig. 5 shows examples of collocated H₂O profiles from MIPAS and HALOE in the high northern latitudes and the subtropics. In both examples, MIPAS cannot resolve the fine vertical structures, but it agrees generally with HALOE at 0.5 to 100 hPa. The statistical results from these comparisons (Fig. 6) show a positive bias of MIPAS to HALOE of 1 to 15% with an RMS of 6 to 12% between 1 and 60 hPa.

For the H₂O profile comparisons with SAGE II, the same 137 collocations as for the O₃ profile comparison are found which are also highly biased towards the northern latitudes. Fig. 7 shows examples of collocated O₃ profiles from MIPAS and SAGE II in the high northern latitudes and the tropics. The examples show about the same picture as for the comparisons with HALOE, but SAGE II values start to oscillate heavily below 3 hPa. The statistical results from these comparisons (Fig. 8) show a positive bias of MIPAS to SAGE II of 4 to 12% with an RMS of 10 to 25% between 2.5 and 50 hPa.

The accuracy of HALOE H₂O profiles is given with about 15% between 30 and 50 km and 25% between 15 to 30 km [3]. The new version (6.2) of SAGE II has been described to have improved significantly to former versions of SAGE II measurements [4], but the validation of this data version is still underway. Taking the given accuracies for HALOE, results show that between 1 and 50 hPa reasonable MIPAS H₂O VMR (v4.61) are retrieved.

4 NO₂ VALIDATED WITH HALOE

For the NO₂ profile comparison with HALOE, 91 collocations are found. The collocation distribution is as

for the other trace gas validations highly biased towards the northern latitudes, with 41 at 30°N to 60°N, 28 at 60°N to 90°N, 12 in the tropics, and only 10 in the mid and high southern latitudes. Since NO₂ by HALOE is measured during local sunrise or sunset, and by MIPAS at different solar zenith angles (SZA, ~10 or 22 LT), the HALOE measurements are scaled to the MIPAS SZA using a 1-dim version of a chemistry and photolysis model with reaction and photolysis rates from the JPL 2000 [5] (method described in [6]). At SZA >100° the higher errors in the HALOE measurements at pressure levels <1hPa result in large errors at the Model output at MIPAS nighttime SZA.

Fig. 9 presents four examples of the comparison of HALOE and MIPAS NO₂ profiles including the results from scaling the HALOE measurement with the photochemical model. MIPAS measurements shown in the examples are taken during daytime (at 46° and 69° SZA), twilight (98° SZA), and nighttime (at 133° SZA). Two kind of modelled NO₂ profiles are shown: The model at 90° signifies where the model was scaled in such a way that NO₂ values correspond to the HALOE NO₂ measurement at the HALOE SZA of 90° in dependence to the type of twilight (sunrise or sunset) during the measurement. Taking this model at 90° NO₂ value and running it to the individual SZA of the MIPAS measurement, gives the modelled NO₂ profile at MIPAS SZA (HALOE_Model at MIPAS SZA). Comparing the model results at 90° to the HALOE measurement illustrates the possibility of the model to be applied for scaling NO₂ in dependence to SZA variations at a certain latitude and a certain time. In all comparisons, the NO₂ value from the model at 90° and the HALOE corresponded well between 1 and 100 hPa. In all examples MIPAS NO₂ data agree fairly well above 1 hPa with the HALOE_Model at MIPAS SZA.

Fig. 10 shows statistical results from these comparisons of MIPAS to HALOE_Model at MIPAS SZA at various SZA ranges: Between 1.5 and 25 hPa a mean relative deviation from MIPAS to HALOE_Model at MIPAS SZA of -15 to +30% (15-35% RMS, n=13) for the SZA range of 25° to 50°, -5 to +20% (10-30% RMS, n=33) for the SZA range of 50° to 75°, -15 to +25% (10-25% RMS, n=14) for the SZA range of 94° to 120°, and -5 to +15% (20-35% RMS, n=31) for the SZA range of 120° to 155° has been calculated. The accuracy of HALOE NO₂ profiles is given with about 15% between 25 and 45 km [7] and the total error of the model between 20 and 40 km was calculated to be ~5% for daytime (SZA <94°) and 10 to 14% for nighttime measurements [6]. Based on this prerequisites, results show that at least between 1.5 and 25 hPa reasonable NO₂ profiles can be retrieved from MIPAS.

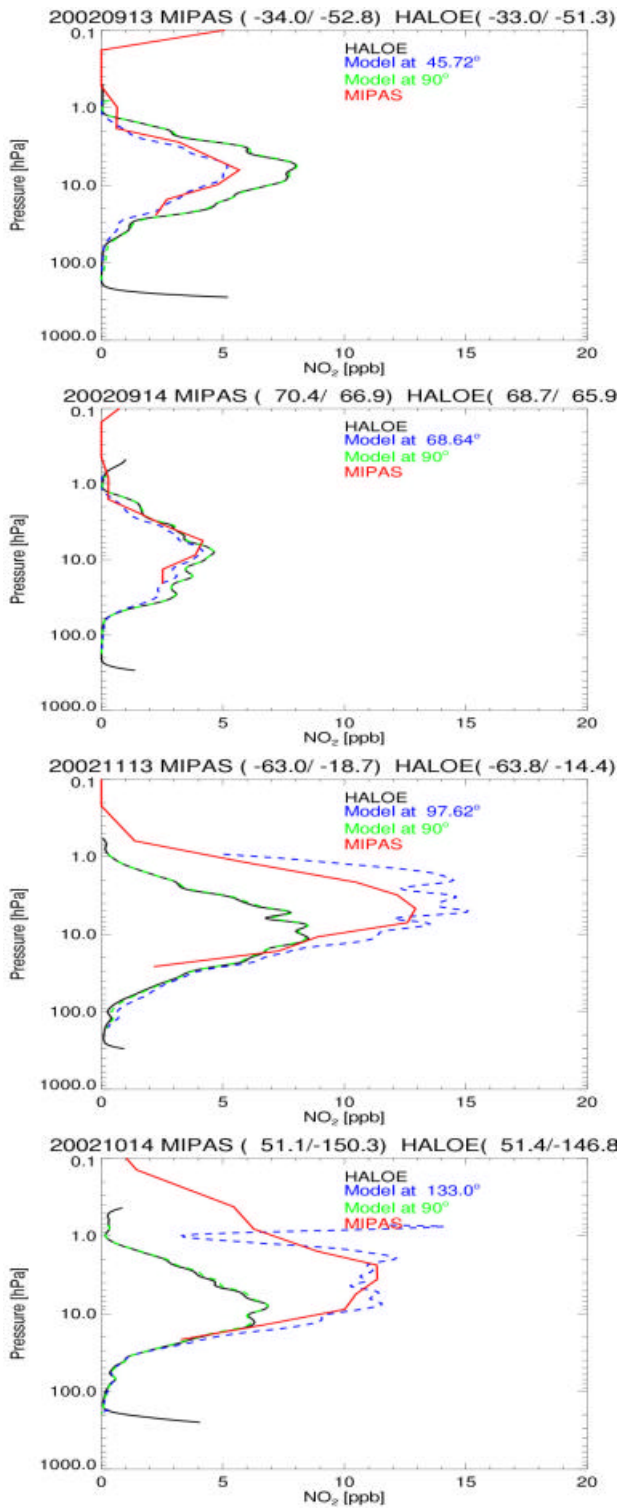


Fig. 9. Comparisons of NO₂ profiles from HALOE (black) and MIPAS (red) matches with results from model runs described in [6]: Model at 90° (green) signifies where model NO₂ values were scaled to correspond to HALOE NO₂ at HALOE SZA of 90°. Model at 90° NO₂ values were scaled to the certain SZA of the MIPAS measurement which gives the modelled NO₂ profile at MIPAS SZA (Model at MIPAS SZA in blue). Examples (from top to bottom) at 46°, 69°, 98° and 133° SZA

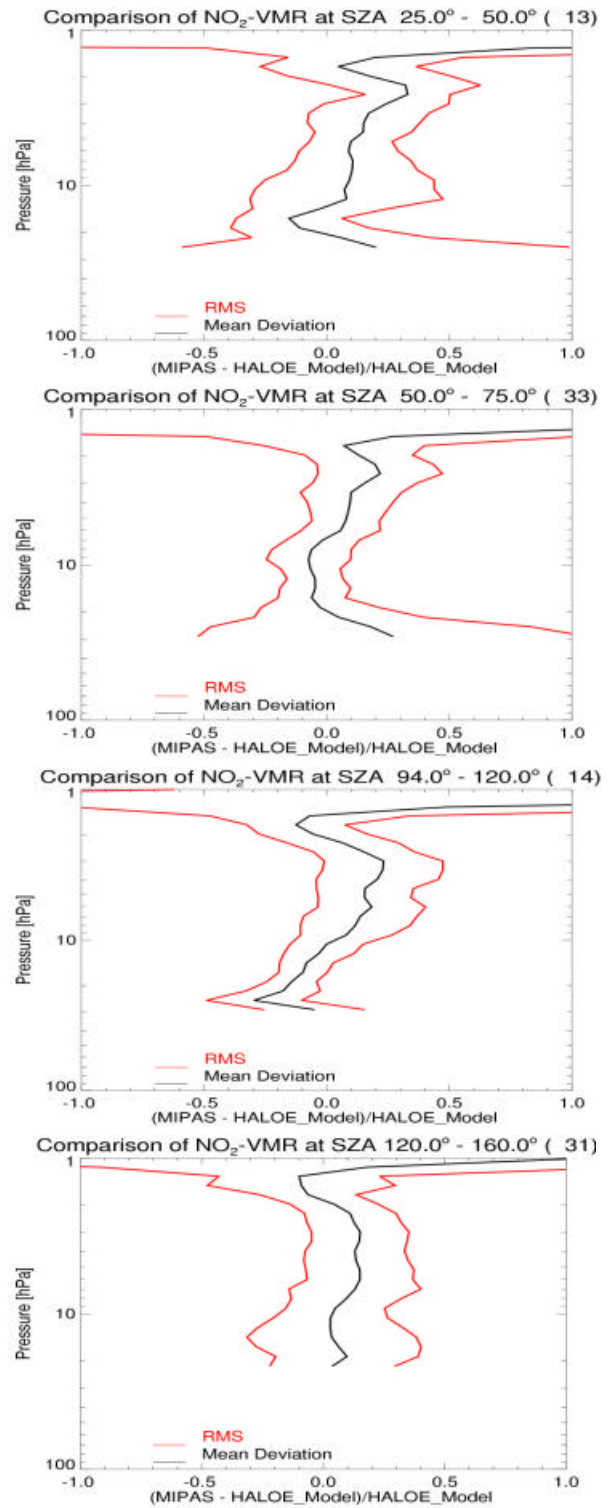


Fig. 10. Statistical results of the comparisons of NO₂ profiles from collocated HALOE and MIPAS measurements from the validation reference set in 2002: Mean relative deviation (black) and RMS of mean relative deviation (red) of all comparisons of NO₂ values from MIPAS to HALOE_Model at the MIPAS SZA at various SZA ranges: at 25° - 50°, 50° - 75°, 94° - 120°, 120 - 160° (from top to bottom)

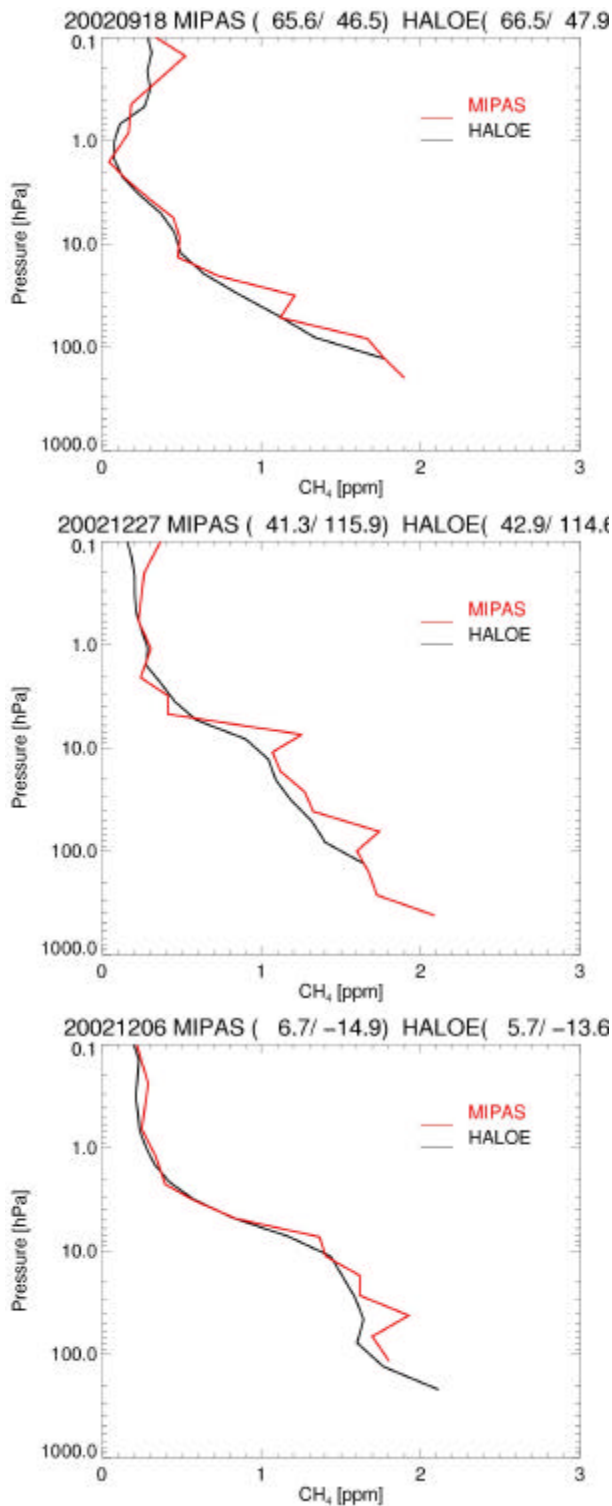


Fig. 11. Example of collocated CH_4 profile measurements (top: high northern latitudes, middle: mid northern latitudes, bottom: tropics) from HALOE (black) and MIPAS (red).

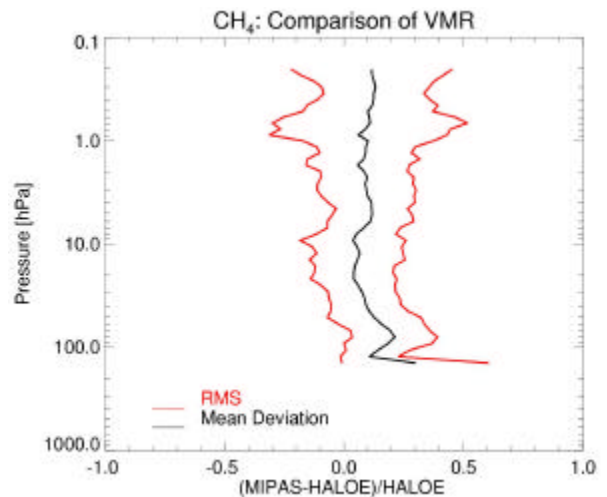


Fig. 12. Mean relative deviation (black) and root mean square of mean relative deviation (red) of the comparison of all collocated MIPAS CH_4 profiles ($n=110$) with HALOE profiles from the validation reference set in 2002

5 CH_4 VALIDATED WITH HALOE

For the CH_4 profile comparisons with HALOE, 109 collocations are found. The collocation distribution is as for the other trace gas validations highly biased towards the northern latitudes, with 54 at 30°N to 60°N , 31 at 60°N to 90°N , 12 in the tropics, and 12 $>30^\circ\text{S}$. Fig. 11 shows examples of collocated CH_4 profiles from MIPAS and HALOE in the high and mid northern latitudes and the tropics. In both examples, MIPAS shows a zick-zack structure above 8 hPa, but overall agrees or is slightly higher with HALOE at 0.1 to 100 hPa. The statistical results from these comparisons (Fig. 12) show a positive bias of MIPAS to HALOE of 5 to 15% with an RMS of 10 to 25% between 1 and 100 hPa. Bearing the given accuracy of HALOE CH_4 profiles with about 15% between 1 and 100 hPa [8], MIPAS CH_4 (v4.61) show reasonable results.

6 CONCLUSIONS

The new data version 4.61 of the MIPAS operational O_3 , H_2O , NO_2 and CH_4 data products show a high quality, as can be concluded from comparisons with HALOE (v19, for all gases) and SAGE II (6.2, only for O_3 and H_2O). For MIPAS O_3 , H_2O and CH_4 profiles the agreement is within 15% (RMS $<25\%$); while comparisons to HALOE show for all three trace gases a positive bias up to 15% for MIPAS, comparisons to SAGE II show this bias only for MIPAS H_2O . Comparisons to other validation instruments will clarify generally, if MIPAS profiles of these trace gas products have a positive bias by a few percent. Also MIPAS NO_2 profiles seem to be reasonable, with an agreement of -15 to +30% (RMS 10-35%) to HALOE. One has to bear in

mind that validation of this data product includes photochemical corrections which imply their own total error between 5% (for daytime) and 10 % (for nighttime measurements).

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