Validation of MIPAS, and SCIAMACHY data by ground-based spectroscopy at Kiruna, Sweden, and Izaña, Tenerife Island (AOID-191)

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ABSTRACT

Within this ENVISAT validation project [AO-191] ground-based measurements of different techniques have been performed at Kiruna in the Arctic and on Tenerife Island in the subtropics. These ground-based data were used to validate column amounts derived from SCIAMACHY as well as profiles from MIPAS. While SCIAMACHY O_3 columns of versions up to 3.53 differ significantly from ground-based DOAS and FTIR measurements, the agreement of more recent 4.0 data is quite reasonable. Also SCIAMACHY NO_2 column amounts obtained with software version 4.0 agree quite nicely with ground-based DOAS (a.m.) and FTIR results from Tenerife Island. While SCIAMACHY NO_2 version 3.53 data compared with ground-based DOAS and FTIR data from Kiruna show some offset. MIPAS O_3 profiles measured before November 13, 2002 show an error in altitude assignment of about 1.5 km, which is consistent with other validation studies. This results in a MIPAS O_3 profile which is about 0.8 ppmv too large at low altitudes and about 0.8 ppmv too low at altitudes around 30 km. Considering the altitude shift or using MIPAS profiles versus pressure the agreement is much better. The mean differences of MIPAS O_3 profiles compared to ground-based FTIR are less than 0.4 ppmv. MIPAS HNO_3 concentration gradients as a function of altitude are reduced compared to FTIR, resulting in a maximum which is broader. MIPAS N_2O profiles agree nicely above about 18 km, but are too large for lower altitudes. The MIPAS CH_4 profile show some oscillations and the gradient of the MIPAS CH_4 profiles is different as compared to the ground-based profiles.

1. INTRODUCTION

For the ENVISAT validation different ground-based techniques have been used. All instruments used are operated within the NDSC (Network for the Detection of Stratospheric Change). The instruments as well as the retrieval algorithm used participated in several comparison studies made within the NDSC [1]. Results of different instruments at the same site have been used for comparison in previous studies and showed good agreement [2-4].

2. INSTRUMENTS

2.1 FTIR

FTIR measurements have been made at Izaña Observatory on Tenerife Island (28°N, 16°W) and at IRF Kiruna (68°N, 20°E). At Kiruna a Bruker IFS 120HR and at Izaña a Bruker IFS 120M is used; their spectral resolution is about 0.003 cm^{-1}. Two detectors (MCT and InSb) and the NDSC optical filter set covering the spectral range of 700 - 5000 cm^{-1} were used to increase the signal to noise ratio. Solar absorption spectra were recorded, while coadding up to 10 min. Further experimental details are published elsewhere [5].

Profiles are derived from ground-based FTIR spectra by using the retrieval code PROFFIT [6]. KOPRA, which has been developed for the analysis of MIPAS-ENVISAT spectra, is used as forward model [7]. The profile retrieval technique uses the pressure broadening of absorption lines, and therefore allows us to derive profiles of species with pressure dependent absorption signatures like O_3, HCl, HF, HNO_3, N_2O, and CH_4. The vertical resolution is about 8 to 10 km in a height range from ground to about 30 km. To minimize the effect of instrumental artifacts on the retrieved profiles cell measurements are made routinely and analyzed with LINEFIT software [8].

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2.2 DOAS

Ground-based UV-Vis spectroscopy measurements are taken around twilight to make use of the enhanced optical path to increase the signal to noise ratio. For ozone a simple average of morning (a.m.) and evening (p.m.) data have been used for the intercomparison. In order to best match the NO_2 column with the ENVISAT overpass, the average of the data collected between 89º and 91º a.m. has been considered as agreed within the UV-Vis community. This choice was made after analyzing the diurnal NO_2 column variation based on a photochemical modeling by IASB and University of Leeds [9]. The night evolution of NO_2 slightly decreases due to its conversion to N_2O_5 reservoir. At sunrise, an abrupt drop occurs, as NO_2 is photolyzed. The diurnal conditions are established at sza of about 87º. Later on, the NO_2 increases through N_2O_5 photo-dissociation. As a consequence, the ground-based DOAS at around 90º am are of the same magnitude of that observed by the SCIAMACHY instrument at 10:30 UT in nadir mode (Fig. 1). SCIAMACHY data range from 34º to 28º (nothing at lower latitudes). The average of all data in every orbit is taken as the value to be compared with.

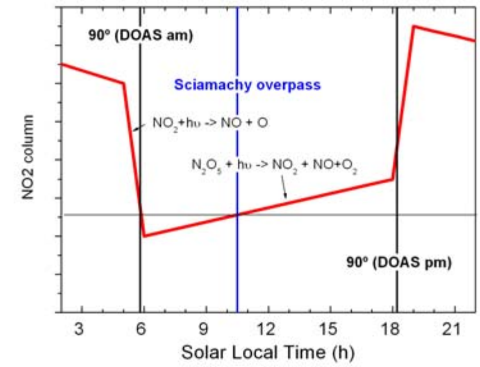

Fig. 1. Schematics of the NO_2 column photochemical diurnal evolution.

3. RESULTS
3.1 SCIAMACHY O_3 COLUMNS

Since SCIAMACHY O_3 column amounts retrieved from window 1 (425-450 nm) are about a factor of 20 too large, all comparisons with SCIAMACHY O_3 columns are made with those derived from window 0 (325-335 nm), so called DOAS_0 data.

3.1.1 KIRUNA

SCIAMACHY O_3 column amounts are compared with ground-based FTIR measurements made at Kiruna (Fig. 2). SCIA data released so far have been generated with different data-processor software versions. While O_3 columns obtained with software version 3.51 and 3.52 are about 30% too low, data from version 3.53 are 5 – 10% too low. As discussed on the ENVISAT validation workshop the remaining difference of 3.53 data with respect to ground-based data is due to using cross-sections derived from GOME instead of SCIAMACHY laboratory spectra [10]. These results are consistent with comparisons with FTIR data from different NDSC sites [11].

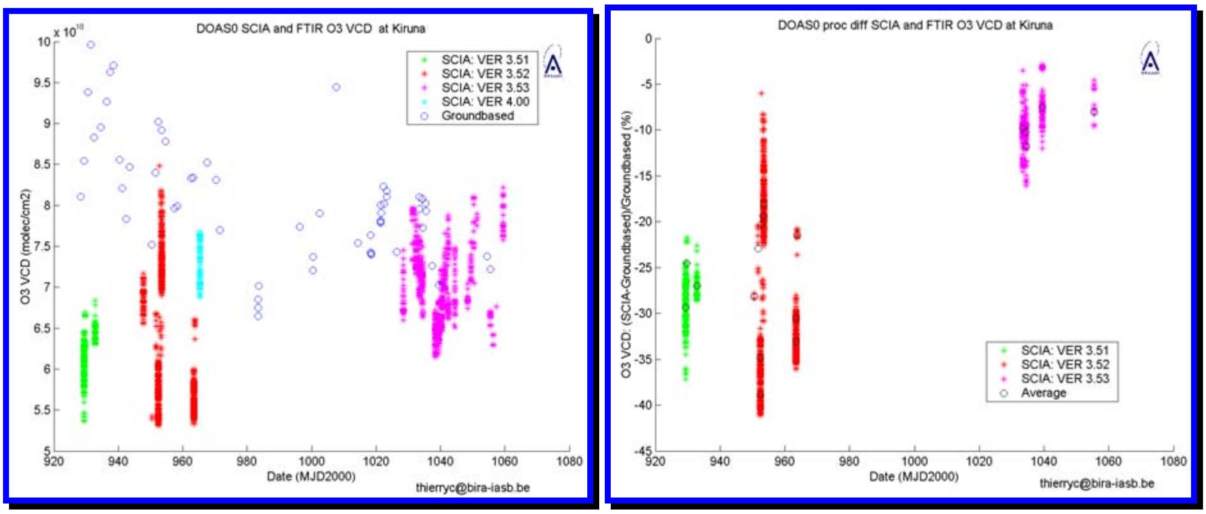

Fig. 2. Comparison of SCIAMACHY O_3 columns with ground-based FTIR at Kiruna. (Figure courtesy of J.-C. Lambert, AO-158.) [12]. The coincidence criterion is a maximum difference of 500 km in space and 12 hours in time.

Focusing on SCIAMACHY version 3.53 data, Fig. 3 shows a comparison with DOAS and FTIR measurements made at Kiruna.

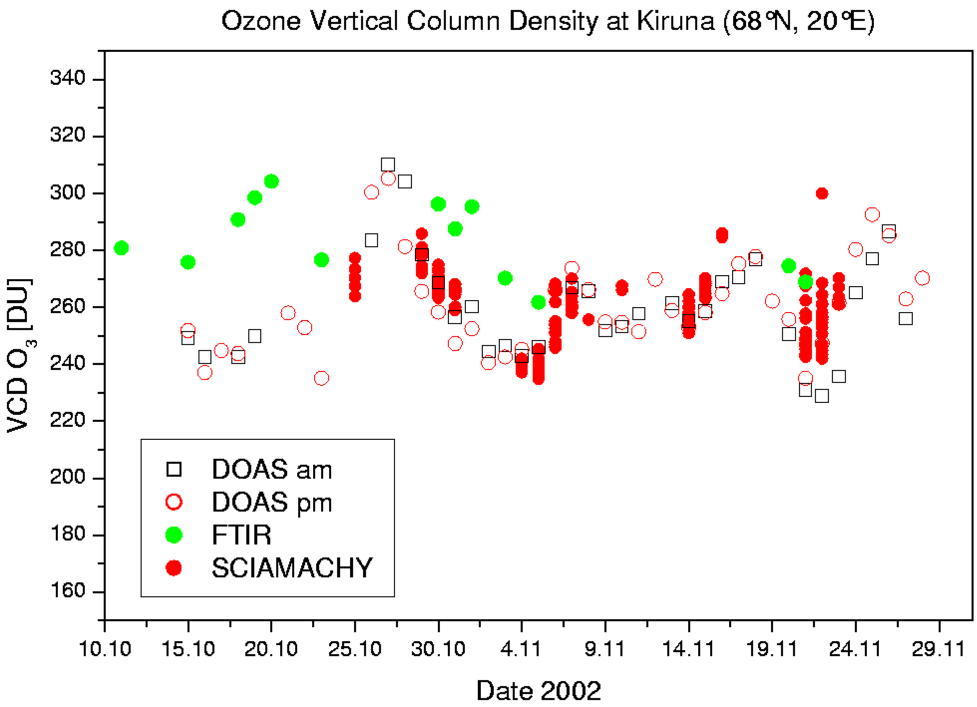

Fig. 3. Comparison of SCIAMACHY O_3 columns with ground-based DOAS and FTIR at Kiruna.

3.1.2 TENERIFE ISLAND

Fig. 4 shows a time series of O_3 from ground-based DOAS and FTIR measurements and SCIA data during the ENVISAT commissioning phase. SCIA data are of version 4.0 and show a much better agreement as compared to previous versions (Fig. 2). The mean difference [100*(scia-gb)/gb] is 1.6 ± 4.9 % but the available data used for the intercomparison are still limited.

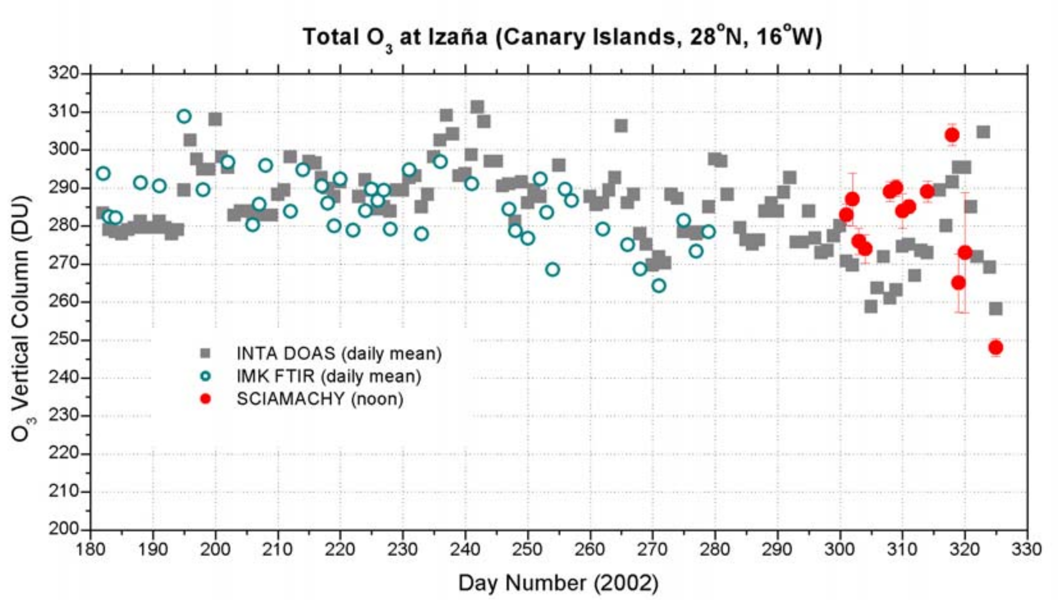

Fig. 4. Comparison of SCIAMACHY O_3 columns with ground-based DOAS and FTIR at Izaña on Tenerife Island.

3.2 SCIAMACHY NO_2 COLUMNS

3.2.1 KIRUNA

Fig. 5 shows a time series of NO_2 from SCIAMACHY and ground-based DOAS and FTIR at Kiruna. While DOAS and FTIR data agree quite nicely SCIAMACHY version 3.53 data show some offset as compared to DOAS and FTIR data.

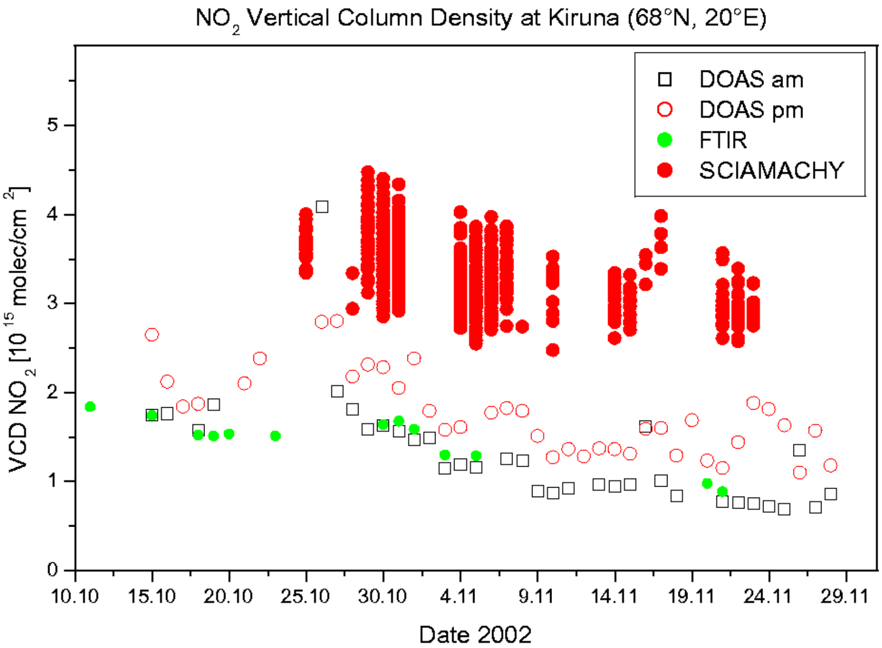

Fig. 5. Comparison of SCIAMACHY NO_2 columns of with ground-based DOAS and FTIR at Kiruna.

3.2.2 TENERIFE ISLAND

Fig. 6 shows a time series of NO_2 from ground-based DOAS and FTIR measurements and SCIA data during ENVISAT commissioning phase. SCIAMACHY data are of version 4.0 and show a nice agreement with DOAS (a.m.) and FTIR results. For a more detailed study the time of the day has to be considered and more SCIA version 4.0 data are needed. The percent difference between DOAS and SCIAMACHY for the data available is – 2.1 ± 12.2 %.

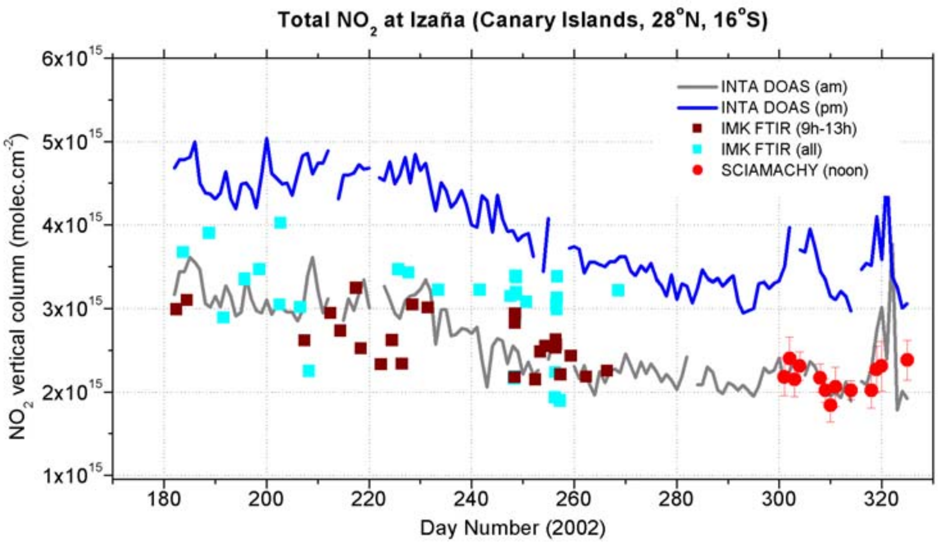

Fig. 6. Comparison of SCIAMACHY NO_2 columns of with ground-based DOAS and FTIR at Izaña on Tenerife I.

3.3 MIPAS O_3 PROFILES

All MIPAS data used in this paper are processed with software version 4.53. The coincidence criteria are 3° in latitude and 10° in longitude, and 12 hours in time. Typically the difference in time was about 2 hours.

3.3.1 TENERIFE ISLAND

Fig. 7 shows two examples of a comparison of MIPAS O_3 profiles with data from ground-based FTIR at Izaña Observatory. Since the height resolution of the ground-based instrument is lower than those of MIPAS the original MIPAS profiles have been 'smoothed' by convolving them with averaging kernels of ground-based FTIR. Both comparisons show a shift in altitude of about 1 to 1.5 km. Besides that, the comparison from Oct. 31 shows quite good agreement. In contrast, the MIPAS profile from November 14 shows some differences compared to the FTIR profile. Furthermore, there are some oscillations on the MIPAS profile, which are still partly present in the smoothed profile, but could not observed in the FTIR profile.

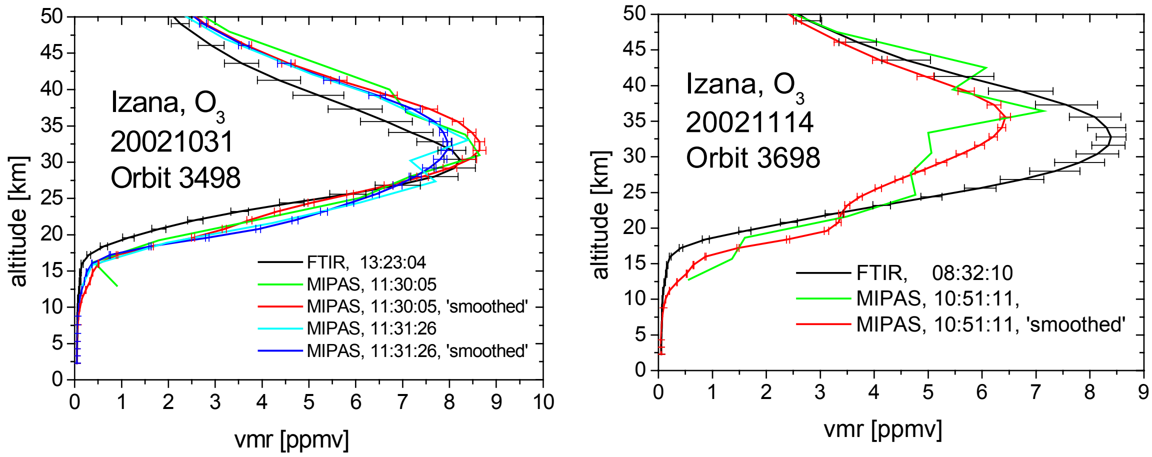

Fig. 7. Comparison of MIPAS O_3 profiles with ground-based FTIR at Izaña on Tenerife Island. 'Smoothed' means convolved with averaging kernels of ground-based FTIR. The difference in geolocation was less than 3° in latitude and less than 6° in longitude.

3.3.2 KIRUNA

Two examples of MIPAS O_3 profiles compared with ground-based FTIR at Kiruna are shown in Fig. 8. Again, the altitude assignment of MIPAS seems to be wrong by about 1.5 km. This has been detected by many validation instruments [e.g. 13] and the MIPAS height assignment has been updated on November 13, 2002 [14]. The altitude assignment has been discussed elsewhere in detail [15].

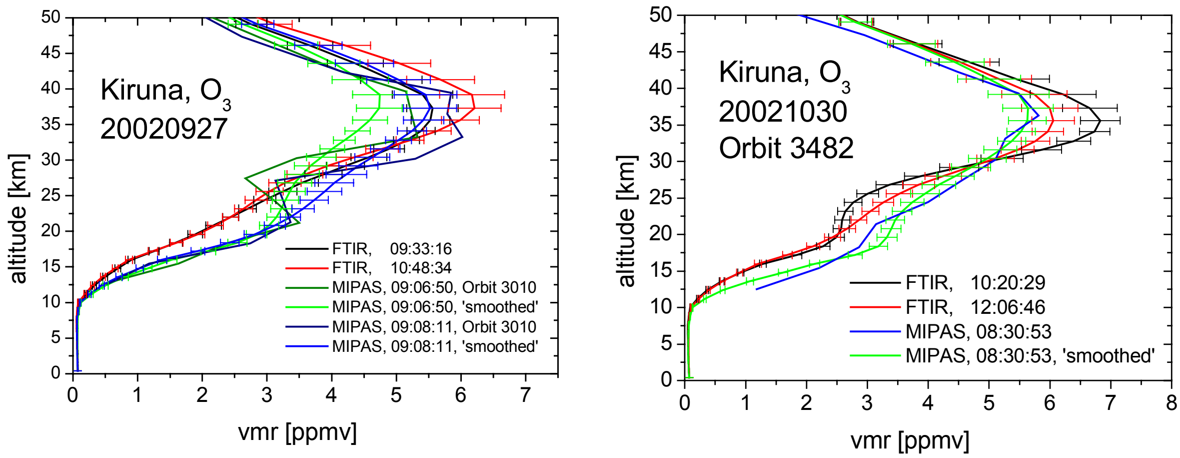

Fig. 8. Comparison of MIPAS O_3 profiles with ground-based FTIR at Kiruna. 'Smoothed' means convolved with averaging kernels of ground-based FTIR. The difference in geolocation was less than 3° in latitude and less than 6° in longitude.

Comparing MIPAS O_3 profiles versus pressure show a much better agreement (Fig. 9), as well as for the example from October 30 as well as for the mean difference of all 7 coincidences. While MIPAS profiles versus height are up to about 0.8 ppmv too large at altitudes around 20 km, MIPAS profiles are about to 0.8 ppmv too low at altitudes around 30 km. In contrast, MIPAS profiles versus pressure differ less than 0.4 ppmv. That means that most of the differences are due to the incorrect altitude assignment applied before November 13, 2002. Furthermore, the MIPAS profiles on a pressure scale agree quite well with the profiles from ground-based FTIR.

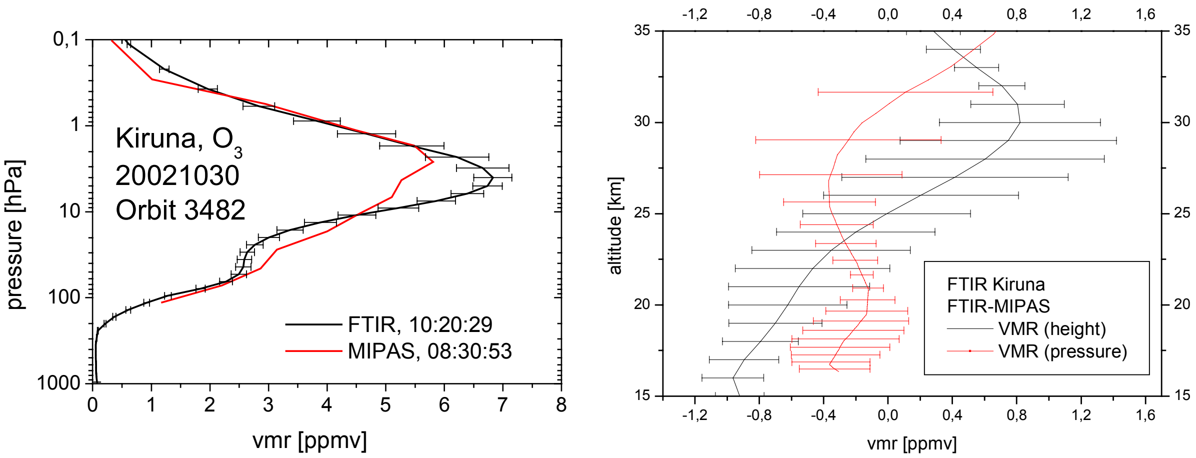

Fig. 9. MIPAS O_3 profile versus pressure compared with a profile from ground-based FTIR at Kiruna (left hand side). The right hand side shows the mean difference and standard deviation of 7 comparisons with ground-based FTIR.

The comparisons shown above are made using data from September 23 to November 5, 2002. During this period of the year there are very little gradients in O_3 as can be seen by assimilated GOME total ozone plots (Fig. 10). So it can be expected that with the given coincidence criteria the comparisons are not distorted by large scale atmospheric variability.

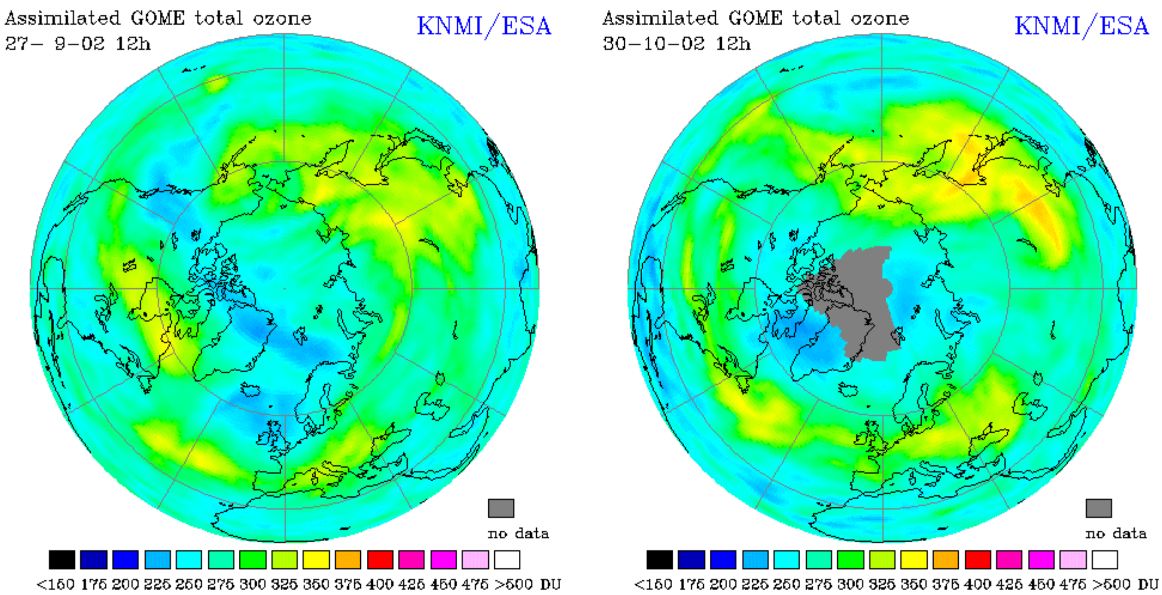

Fig. 10. Assimilated GOME total O_3 fields for 2 days within the period of coincidences with ground-based FTIR observations [16].

3.4 MIPAS HNO_3 PROFILES

Fig. 11 shows a comparison of MIPAS HNO_3 vmr profiles with ground-based FTIR at Kiruna. Besides an altitude error of about 1.5 km as discussed above the height of the retrieved maximum agrees with ground-based FTIR. However, MIPAS HNO_3 concentration gradients as a function of altitude are smoother than those found in the FTIR profile, resulting in a maximum, which is broadened and reduced in amplitude. This has to be analyzed in more detail and with additional MIPAS data.

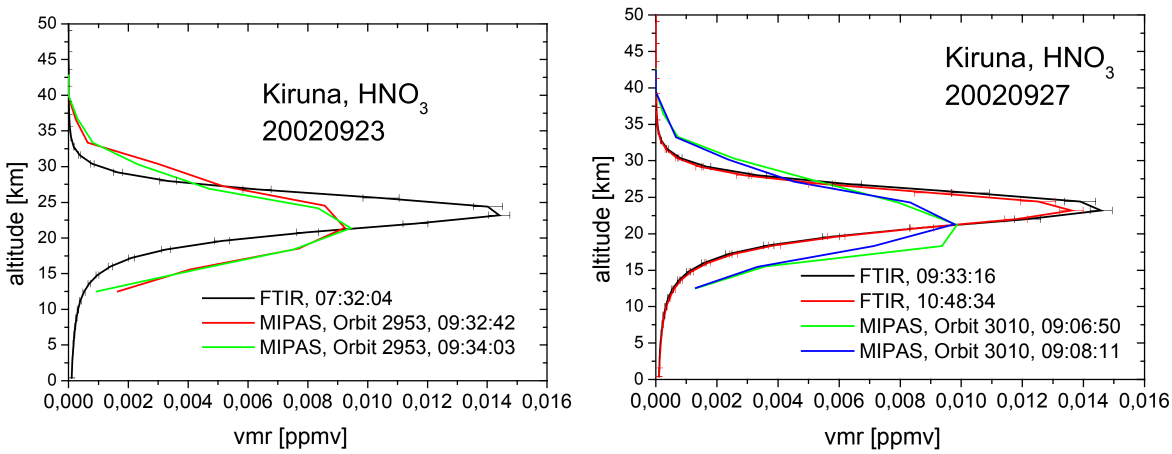

Fig. 11. Comparison of MIPAS HNO_3 profiles with ground-based FTIR at Kiruna. The difference in geolocation was less than 3° in latitude and less than 10° in longitude.

3.5 MIPAS N_2O PROFILES

Two coincident MIPAS N_2O profiles are available and have been compared with ground-based FTIR at Kiruna (Fig. 12). While the agreement above about 18 km is quite good, there are some substantial differences below that altitude.

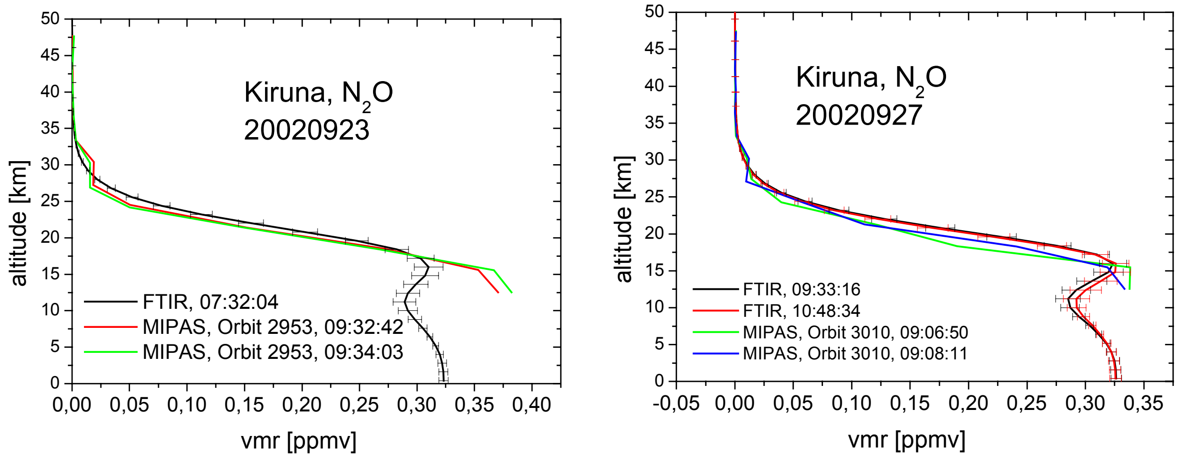

Fig. 12. Comparison of MIPAS N_2O profiles with ground-based FTIR at Kiruna. The difference in geolocation was less than 3° in latitude and less than 10° in longitude.

3.6 MIPAS CH_4 PROFILES

Two coincident MIPAS CH_4 profiles are available and have been compared with ground-based FTIR at Kiruna (Fig. 13). This comparison show substantial differences in the gradient of the profiles. Please note that the sensitivity of ground-based FTIR is decreasing strongly for altitudes above 25 km. However, there are some oscillations on the MIPAS profile, which are most probably not real.

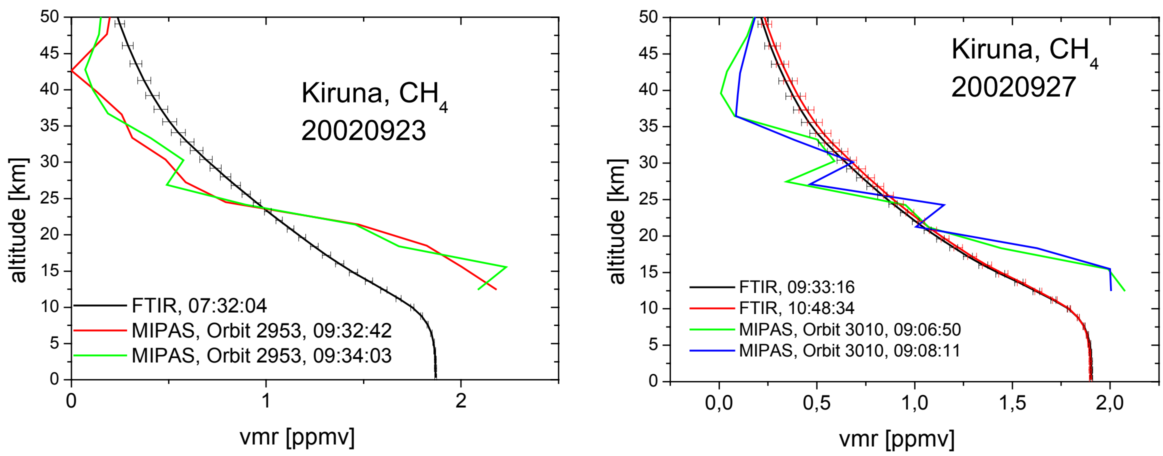

Fig. 13. Comparison of MIPAS CH_4 profiles with ground-based FTIR at Kiruna. The difference in geolocation was less than 3° in latitude and less than 10° in longitude.

4. CONCLUSIONS & OUTLOOK

While SCIAMACHY O_3 columns of versions up to 3.53 differ significantly from ground-based DOAS and FTIR measurements, the agreement of more recent 4.0 data is quite reasonable. Also SCIAMACHY NO_2 column amounts obtained with software version 4.0 agree quite nicely with ground-based DOAS (a.m.) and FTIR results at a low latitudinal site. For a more detailed study the time of the day has to be considered and more SCIAMACHY version 4.0 data are needed. Since SCIAMACHY NO_2 version 3.53 show some offset as compared to ground-based DOAS and FTIR data from Kiruna, SCIAMACHY version 4.0 data are also needed for Kiruna to check for latitudinal effects.

MIPAS O_3 profiles measured before November 13, 2002 show a systematic offset in altitude assignment of about 1.5 km, which is consistent with other validation studies. The update of the pointing characterization in the data processor as implemented on November 13 has clearly solved this problem. MIPAS O_3 profiles (processed before November 13) are about 0.8 ppmv too large at low altitudes and about 0.8 ppmv too low at altitudes around 30 km. If the altitude shift is considered or using MIPAS profiles versus pressure the agreement is much better. The mean differences of MIPAS O3 profiles compared to ground-based FTIR are less than 0.4 ppmv.

MIPAS HNO_3 concentration gradients as a function of altitude are reduced compared to FTIR, resulting in a broader maximum. MIPAS N_2O and CH_4 profiles are too large for lower altitudes (below about 20 km). Furthermore, there are some oscillations on some MIPAS profiles. This is in agreement with comparisons made with the MIPAS-balloon instrument [17].

A more quantitative study will be made when more ENVISAT data are available. Such a study will address day - night differences, seasonal variability and the influence on coincidence criteria like different time and geolocation. Furthermore, some case studies will be made to investigate the influence of retrieval parameters, constraints and a-priori data on MIPAS profiles.

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