Improving the quality of O_3 profiles as derived from ground-based infrared and microwave measurements for the validation of ENVISAT O_3 data

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INTRODUCTION

Within the ENVISAT validation ground-based measurements will be performed at different stations including several techniques like Fourier Transform InfraRed (FTIR) spectrometers and a millimeter wave radiometer (MIRA) [AO-191]. While column retrieval of ground-based FTIR measurements is a well-established method, the profile retrieval technique from ground-based FTIR spectra has been developed recently. This technique is based on the pressure broadening of the absorption lines, and allows to derive profiles of species with pressure dependent absorption signatures like O_3, HCl, HF, HNO_3, N_2O, and CH_4. For millimeter wave radiometry the profile retrieval of stratospheric constituents using the pressure broadening of the spectral lines is in common use. In particular in the case of MIPAS-ENVISAT validation, profiles are better suited for the validation rather than column amounts. In order to crosscheck the data quality of different techniques the retrieved O_3 profiles have been compared with O_3 sonde data. Furthermore, a method is described to match the different height resolution of in-situ data to those of ground-based remote sensors.

EXPERIMENTAL

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 [1].

MIRA

MIRA (Microwave Radiometer) measurements have been made at IRF Kiruna (68°N, 20°E). This ground-based radiometer, which has been developed by IMK Karlsruhe, measures in the frequency range from 268 – 280 GHz with a bandwidth of 1.3 GHz and a spectral resolution of about 1.2 MHz [2]. Vertical profiles of O_3, ClO, HNO_3, and N_2O can be retrieved from these spectra.

OZONE SONDES

On Tenerife Island ozone soundings are performed at St. Cruz on a routine basis about once per week. St. Cruz is at the northeastern coast of Tenerife, about 30 km apart of Izaña Observatory. For comparison of Kiruna data O_3 sonde data from Esrange have been taken. Esrange is about 40 km apart of Kiruna and is launching ozone sondes on request.

DATA ANALYSIS

FTIR

The FTIR spectra have been analyzed with the radiative transfer code KOPRA (Karlsruher Optimized Precise Radiative-transfer Algorithm) [3] and the retrieval code PROFFIT (Profile Fit) [4] using Phillipps-Tikhonov approach. PROFFIT allows a simultaneous inversion of several gases in several microwindows (MW). In the case of O_3 two MWs are used: 782.56 - 782.86 cm^{-1} and 788.85 - 789.37 cm^{-1}. The vertical resolution is obtained by considering the pressure broadening of absorption lines and is about 8 km in a height range from 10 to 35 km.

MIRA

For inversion of MIRA spectra Optimal Estimation Method was used which was extended for simultaneous inversion of several constituents [5] and the fit of standing waves within the inversion process [6]. Vertical resolution is obtained by taking advantage of the pressure broadening and is about 8 km in an altitude range from 17 to 55 km.

OZONE SONDES

For the profile comparison the resolution of the sonde profiles have been degraded corresponding to the resolution of the FTIR and MIRA profiles, respectively. Therefore, synthetic spectra based on O_3 sonde profiles have been calculated for each day of comparison. Profile retrieval of these synthetic spectra has been performed using the same procedure as described above. This has been made independently for MIRA and FTIR using their individual data analysis method. The height range of the sonde profile extends from ground to about 30 km.

RESULTS

KIRUNA

As an example O_3 profiles measured by MIRA, FTIR and sonde on March 7, 2000 are shown in Figs. 1 and 2. The sonde profile is valid up to 28 km. The original O_3 sonde profile has been matched to the height resolution of the remote sensors as described above. The profiles of both sensors agree well with the smoothed sonde profile. The error bars are given as 1σ noise error.

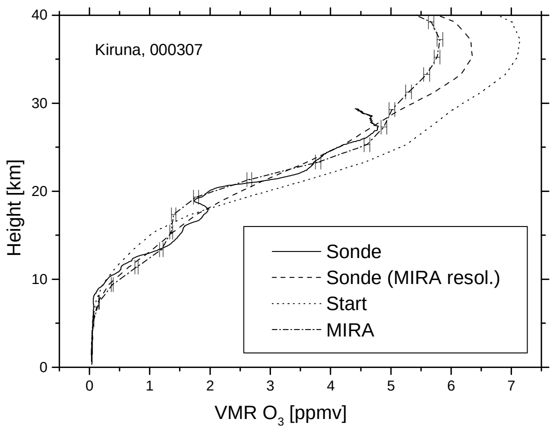

Fig. 1. Profiles of ozone as measured by MIRA and sonde at Kiruna on March 7, 2000.

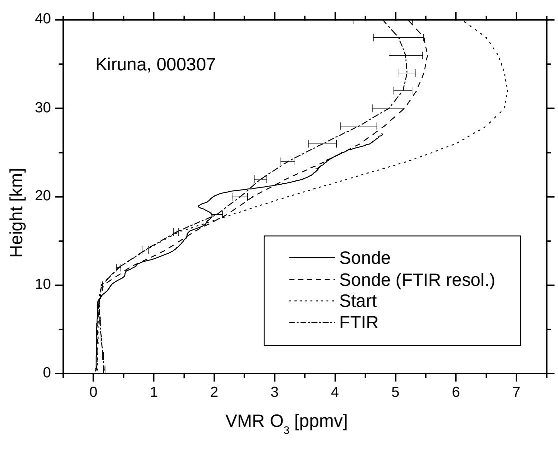

Fig. 2. Profiles of ozone as measured by FTIR and sonde at Kiruna on March 7, 2000.

In order to quantify the differences the mean differences for all coincidences of winter 1999/200 have been calculated (Fig. 3 and 4). For MIRA 9 coincidences and for FTIR 6 coincidences are available. The mean differences are about 10%. In the case of FTIR the differences are about 10% up to 15 km and decreasing with increasing height. For MIRA different spectral regions have been used to retrieve the ozone profiles used for Fig. 3. The comparison with the O_3 sonde data showed that using the O_3 double line around 278 GHz give the most reliable results.

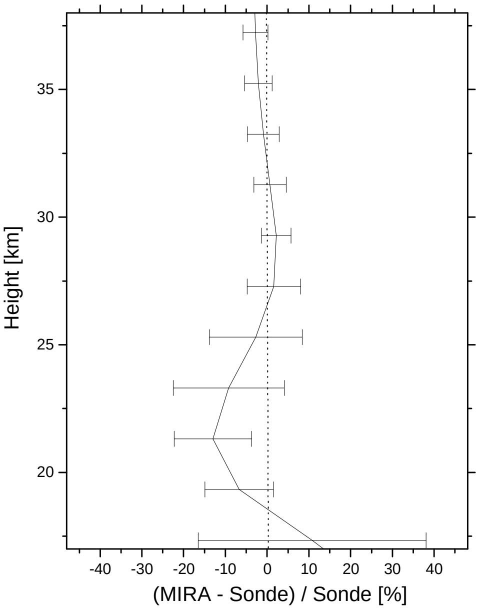

Fig. 3. Statistics of differences between MIRA and sonde data including 9 coincidences in winter 99/ 00.

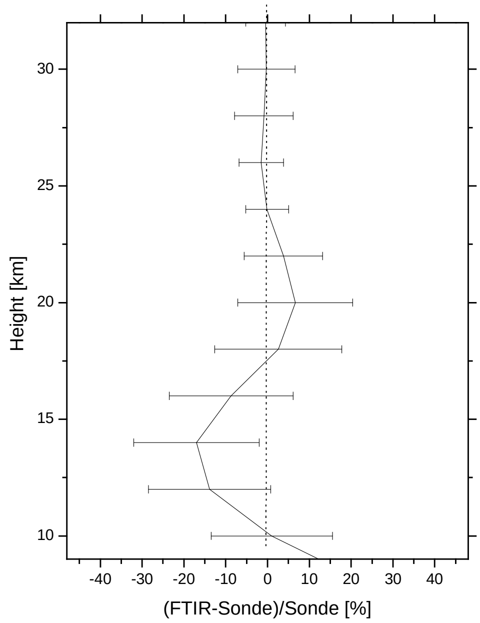

Fig. 4. Statistics of differences between FTIR and sonde data including 6 coincidences in winter 99/ 00.

The error bars (1σ) given in Fig. 3 and 4 indicate that no significant systematic deviations occurr.

TENERIFE ISLAND

Due to regular O_3 soundings and good conditions for FTIR measurements on Tenerife Island a lot of coincidences have been found. A typical example is given in Fig. 5. Besides the profile comparison the column amount deduced from sonde and FTIR profile agree well, too. A more comprehensive comparison of column amounts with Brewer data (Fig. 6) demonstrate a good agreement which would probably not been achievable with pure scaling of an initial profile.

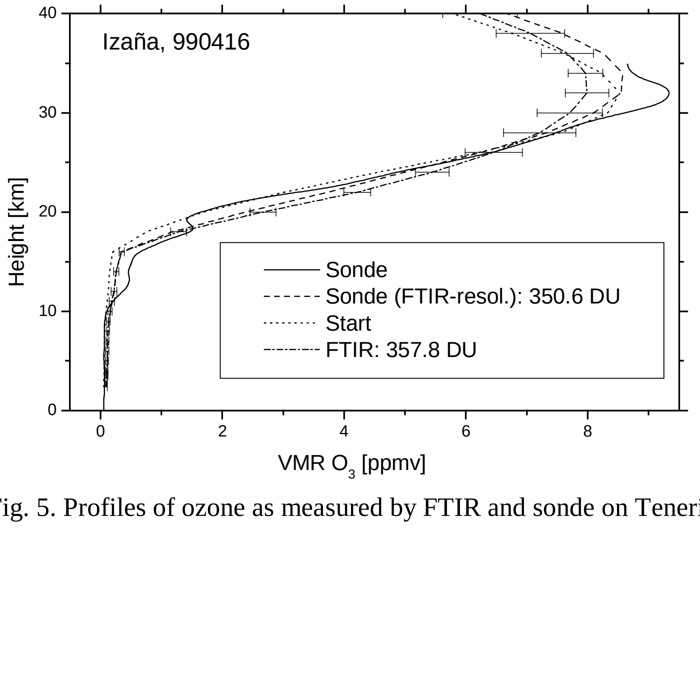

Fig. 5. Profiles of ozone as measured by FTIR and sonde on Tenerife Island

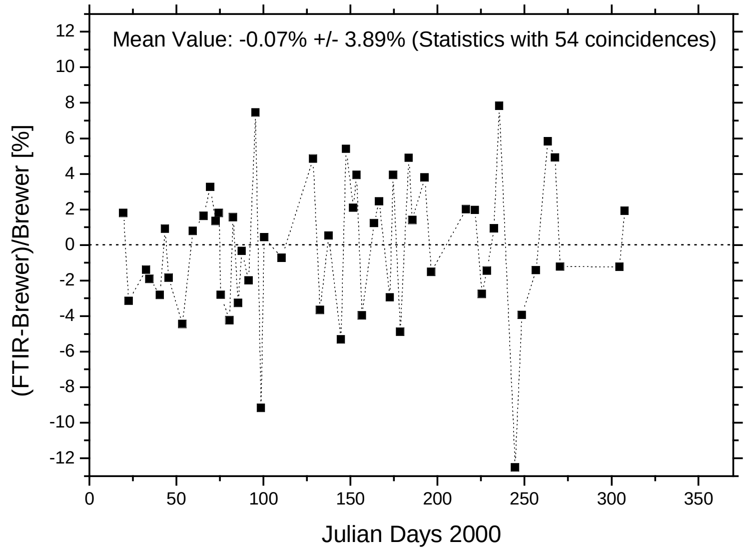

Fig. 6. Comparison of column amounts of O_3 as measured by FTIR and Brewer on Tenerife Island.

Figs. 7 and 8 show the differences between FTIR and sonde data for coincidences in 1999 and 2000. Again, the mean differences are less than 10%.

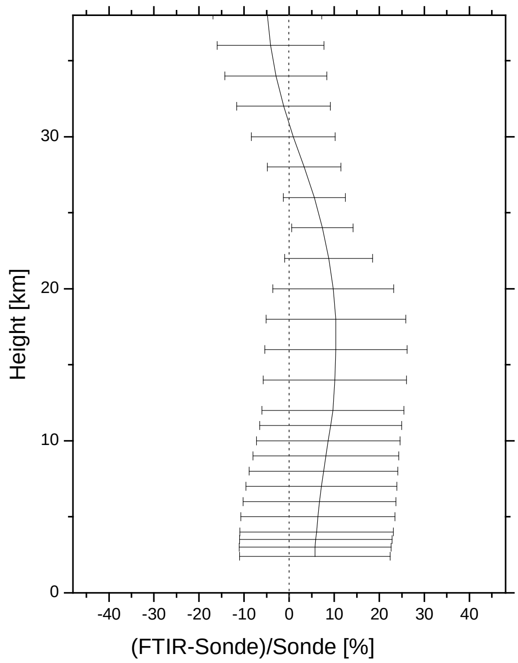

Fig. 7. Statistics of differences between FTIR and sonde data including 21 coincidences recorded on Tenerife Island in 1999.

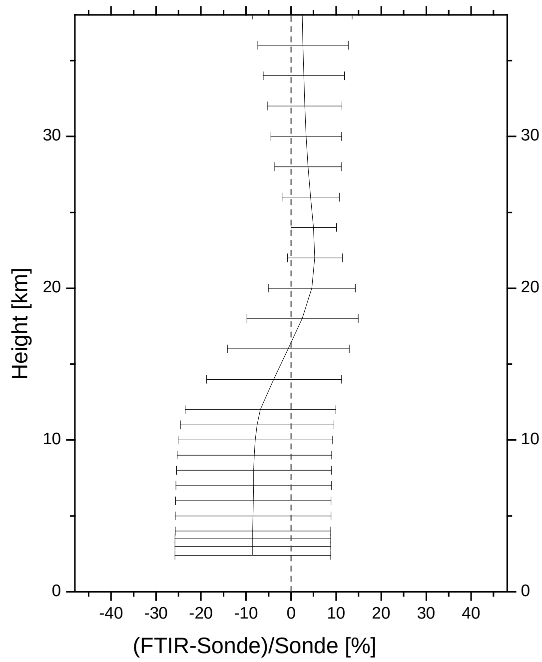

Fig. 8. Statistics of differences between FTIR and sonde data including 15 coincidences recorded on Tenerife Island in 2000.

CONCLUSIONS

O3 profiles from ground-based remote sensors like MIRA and FTIR agree well with sonde data. In particular, the large number of coincidences as observed on Tenerife Island allows to conclude that the retrieval of O_3 profiles from ground-based FTIR gives reliable results. Besides useful height information the quality of corresponding column amounts is also improved. For MIRA the comparison of the retrieved profiles with sonde data enabled the decision which ozone signature is best suited for measurements. Since ground-based sensors allow many observations a good statistics for ENVISAT validation is expected. Furthermore, this technique allows to retrieve profiles of additional species like HCl, HF, HNO_3, NO, N_2O, and CH_4 for FTIR and ClO, HNO_3 and N_2O for MIRA.

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