Comparison of AMIL2DA results for MIPAS-ENVISAT data with external data (D64, D66, D67, D69, D71, D72)

Mathias Milz[1], Heinrich Bovensmann[6], Astrid Bracher[6], Thomas von Clarmann[1], Anu Dudhia[2], Bernd Funke[4], Sergio Gil[4], Norbert Glatthor[1], Siegfried Hilgers[5], Victoria Jay[3], Sylvia Kellmann[1], Vivienne Payne[2], Jolyon Reburn[3], Alexej Rozanov[6], Christian von Savigny[6], Gottfried Schwarz[5], Richard Siddans[3], Tilman Steck[1], Gabriele P. Stiller[1], Ding-Yi Wang[1]

[1] Institut für Meteorologie und Klimaforschung, Universität Karlsruhe, Germany

[2] Atmospheric, Oceanic and Planetary Physics, Oxford University, United Kingdom

[3]Rutherford Appleton Laboratory Chilton, Didcot, United Kingdom

[4]Instituto di Astrofisica de Andalucia, Granada, Spain

[5]DLR Oberpfaffenhofen Wessling, Germany

[6]Institut für Umweltphysik Universität Bremen, Germany

July 1, 2003

1 Introduction

To approve the reliability of an instrument the results need to undergo a comparison and validation with results of other instruments. The measurements of the instruments used for the comparison should provide measurements of the same parameters. For instruments with different locations of the measurements, such as satellite borne instruments, time and locations of the measured data to be compared should be temporal and spatial close enough to the measurement of the instrument that shall be validated. For the validation of retrieval results obtained from MIPAS/Envisat several instruments have been used.

Obviously instruments using the same platform have the advantage to provide measurements that are close enough, both in time and space. Thus the measurements to be compared are expected to represent the same air parcel or air parcels with only small differences due to their vicinity. Two instruments onboard Envisat were used for comparison: The *SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY* (SCIAMACHY) and *Global Ozone Monitoring by Occultation of Stars* (GOMOS).

Other satellite borne instruments such as GOME, HALOE, SABER were used for further intercomparison. For these instruments results for locations close to the MIPAS measurements have been selected for the comparison.

MIPAS temperature retrievals have been compared to assimilated stratospheric data from the United Kingdom Meteorological Office (UKMO).

Further parts of this report are the assessment of microwindows. a priori data and other reasons for systematic residuals.

2 Inter-Envisat comparison MIPAS – GOMOS

The results of this workpackage are presented in a dedicated report (deliverable D70).

3 Inter-Envisat comparison MIPAS – SCIAMACHY (D71, WP5620)

M. Milz, A. Bracher, C. v. Savigny, A. Rozanov, B.Funke, N. Glatthor, S. Gil, H. Bovensmann, G. Schwarz

3.1 Introduction

Since both atmospheric instruments at ENVISAT, MIPAS and SCIAMACHY, measure a few trace gases which are the same, many coincidences which are very close together in time and space can be found. Therefore cross validation between the two data sets should enable good statistical analyses of comparisons and enable to look for zonal and seasonal peculiarities. Unfortunately until the time of this report, only scientific SCIAMACHY O_3, NO_2, BrO and OClO limb profiles can be retrieved from Level_0 (Lv0) and Level_1 (Lv1) data. Due to the limited availability of these SCIAMACHY data and also of MIPAS Lv1 data, the number of coincidences between measurements of the two instruments is up until now rather scarce. Therefore, the time around the ozone split (September 20 and 23, 2002) was chosen for a first cross validation of scientific O_3 and NO_2 products, because then more or less the largest complete data sets of Lv0 and Lv1 data for both instruments are available.

3.2 The SCIAMACHY instruments and data products used in this study

The SCIAMACHY instrument is an UV/Vis/NIR grating spectrometer covering the spectral range from 220 - 2380 nm with a moderate spectral resolution of 0.2 - 1.5 nm. The instrument measures atmospheric radiance from scattered, reflected and transmitted sunlight, extraterrestrial solar irradiance and lunar radiance in the three geometries nadir, limb and occultation and achieves global coverage within 6 days at the equator. SCIAMACHY limb measurements are made from 0-100 km with a vertical resolution of around 2.6 km. The duration of a limb sequence is 60 s. The horizontal resolution in azimuth direction is 240 km (120 km min.) by a swath of 960 km and in flight direction 400 km. The observation modes are optimised to match the limb with the nadir measurements.

Until now operational products from SCIAMACHY are only available for trace gas columns from nadir measurements, while the first release of a limited data set for the operational limb products O_3 and NO_2 is planned for September 2003.

At the IUP O_3 profiles from SCIAMACHY limb measurements are retrieved from all available Lv0 and Lv1 data with a solar zenith angle (SZA) $< 90°$ by the method described in [15]. The retrieval uses 3 wavelengths of the O_3 Chappuis bands and then a non-linear, iterative version of optimal estimation together with the RTM SCIARAYS [12]. Tangent heights (TH) are systematically corrected by -2 km because of limb pointing offset [15]. The sensitivity of these SCIAMACHY O_3 profiles is between 15 and 35 km where the information is really taken out of the measurement. An extended validation study of SCIAMACHY-IUP ozone profiles with HALOE, showed that between 19-35 km SCIAMACHY data show a good quality with a mean relative deviation of -5% to +5% (+/-15%) of SCIAMACHY ozone to HALOE [11].

At the IUP NO_2 profiles from SCIAMACHY limb measurements are retrieved from all available Lv1 data by the method described in [14]. The retrieval uses the spectrum within 420 - 490 nm and a ratio of limb measurements at different tangent heights, with the 45 km tangent height as a reference. With optimal estimation the vertical profile is retrieved using measured and modeled limb radiances with all corrections from pre-fit routine applied, weighting functions from RTM and a priori information. These SCIAMACHY NO_2 profiles are sensitive for the altitudes from 15 to 40 km. A SCIAMACHY-IUP NO_2 profile has been compared to collocated DOAS balloon NO_2 measurements (ascent and occultation) from direct sun [13]. Data show that the SCIAMACHY-IUP NO_2 profile with a SZA of 65° is showing comparable values close to the ascent DOAS measurement with a SZA of 80°-89°. Considering the fact that NO_2 does not change very much between these two SZA, the quality of the SCIAMACHY-IUP NO_2 profile seems to be quite high. Also comparisons of SCIAMACHY-IUP NO_2 profiles with HALOE measurements scaled by a model to the SZA of the SCIAMACHY measurements showed quite a good agreement between the compared coincident profiles [11].

3.3 Compared data sets

O_3 and NO_2 products from 20. and 23.09.02 from both instruments were compared to each other. The sample of collocations was limited to the availability of MIPAS Lv1 data to the IMK and of SCIAMACHY Lv0 and Lv1 (for NO_2 only) data to the IUP. Collocated SCIAMACHY and MIPAS O_3 and NO_2 profiles were identified where measurements of the two satellite instruments were taken within the same or next orbit and using a 650 km collocation radius between the tangent point of the MIPAS measurement and the centre of the nearest SCIAMACHY tangent point. Since the SCIAMACHY horizontal resolution perpenicular to the line of sight is ca. 1000 km as opposed to the rather small MIPAS horizontal field of view of 30 km, by this requirement we tried to compromise between having two really close measurements and having a large enough sample for statistical analysis. All collocated measurements were from the Southern hemisphere and some of them were within, at the edge or outside of the polar vortex. Therefore, in order to avoid to compare collocated measurements from different airmasses, the potential vorticity (PV) data (given from the UKMO dataset) at 475 K were checked for the time and place of each collocated measurements. Only collocations where both measurements were within (< -40 PVU), at the edge (<30 PVU to >-40 PVU) or outside the polar vortex (> -30 PVU) have been included in the comparisons. The collocations compared by SCIAMACHY-IUP and IMK are listed in Tab. (1) and (2).

Onboard Envisat both instruments are looking in different directions: SCIAMACHY is looking into flight direction while MIPAS is looking against flight direction. While sounding the same air parcel at low tangent altitudes the line of sight of the two instruments may pass different air parcels in layers above the tangent points.

Additionally results for MIPAS/Envisat retrieved by the University of Oxford (OXF), Rutherford Appleton Laboratory (RAL) and the Instituto de Astrofisica de Andalucia (IAA) have been used for the comparison. The retrievals performed by IAA have been produced by the IMK retrieval processor RCP, using the forward model KOPRA plus some dedicated non-LTE routines from IAA. While IMK performed ozone retrievals assuming LTE conditions, IAA used a retrieval set-up considering non-LTE conditions. OXF performed the retrievals using the retrieval algorithm OPTIMO with the foward model RFM. For the solution of the inverse problem RAL used the RET2D code with the forward model FM2D.

Retrieval results from OXF, RAL and IAA were not available for all geolocations and both species, ozone and NO_2. Where available, retrievals have been included.

The collocations of MIPAS and SCIAMACHY measurements used for this comparison are shown in Fig. (1).

		SCIAMACHY-IUP			MIPAS-IMK			
No.	date	lat. (deg)	long. (deg)	meas. time (UTC)	lat. (deg)	long. (deg)	meas. time (UTC)	distance (km)
1	20-09-2002	-35.5	-3.4	09:41:33	-38.4	1.5	09:57:21	542
2	20-09-2002	-43.2	-5.9	09:43:44	-43.1	0.3	09:58:42	503
3	20-09-2002	-50.9	-8.9	09:45:55	-52.8	-0.6	10:01:24	614
4	20-09-2002	-65.9	-18.8	09:50:18	-67.6	-4.7	10:05:37	650
5	20-09-2002	-33.5	-28.0	11:21:36	-33.7	-22.5	11:36:35	505
6	20-09-2002	-41.3	-30.4	11:23:48	-43.0	-24.8	11:39:17	498
7	20-09-2002	-49.0	-33.2	11:25:59	-47.7	-26.1	11:40:38	545
8	20-09-2002	-56.6	-37.0	11:28:10	-58.1	-27.3	11:43:31	605
9	20-09-2002	-64.1	-42.3	11:30:21	-62.8	-54.1	13:25:27	607
10	20-09-2002	-35.6	-104.0	16:23:59	-33.6	-98.0	16:38:23	594
11	20-09-2002	-35.6	-104.0	16:23:59	-38.3	-99.1	16:39:44	536
12	20-09-2002	-43.3	-106.5	16:26:10	-43.0	-100.3	16:41:05	507
13	20-09-2002	-43.3	-106.5	16:26:10	-47.7	-101.6	16:42:26	627
14	20-09-2002	-51.0	-109.6	16:28:21	-53.4	-101.3	16:43:57	624
15	20-09-2002	-58.6	-113.6	16:30:32	-58.1	-102.7	16:45:18	639
16	20-09-2002	-64.2	-92.6	14:51:35	-62.8	-104.4	16:46:39	604
17	20-09-2002	-66.0	-119.5	16:32:43	-62.8	-129.5	18:27:16	600
18	20-09-2002	-66.0	-119.5	16:32:43	-67.6	-130.4	18:28:37	512
19	23-09-2002	-29.5	22.0	08:05:01	-33.7	26.3	08:21:08	623
20	23-09-2002	-37.2	19.8	08:07:12	-38.3	25.2	08:22:29	493
21	23-09-2002	-44.9	17.2	08:09:23	-43.0	24.0	08:23:50	587
22	23-09-2002	-44.9	17.2	08:09:23	-47.7	22.8	08:26:42	528
23	23-09-2002	-52.6	14.0	08:11:34	-53.4	23.0	08:26:42	610
24	23-09-2002	-60.2	9.7	08:13:46	-62.8	19.9	08:29:24	619
25	23-09-2002	-67.5	3.1	08:15:57	-67.6	-6.1	10:11:21	393

Table 1: Collocated MIPAS-IMK and SCIAMACHY-IUP measurements of O_3 profiles.

		SCIAMACHY-IUP			MIPAS-IMK			
No.	date	lat. (deg)	long. (deg)	meas. time (UTC)	lat. (deg)	long. (deg)	meas. time (UTC)	distance (km)
26	23-09-2002	-37.2	19.8	08:07:12	-38.3	25.2	08:22:29	493
27	23-09-2002	-44.9	17.2	08:09:23	-43.0	24.0	08:23:50	587
28	23-09-2002	-44.9	17.2	08:09:23	-47.7	22.8	08:25:11	528
29	23-09-2002	-52.6	14.0	08:11:34	-53.4	23.0	08:26:42	610
30	23-09-2002	-60.2	9.7	08:13:46	-62.8	19.9	08:29:24	619
31	23-09-2002	-67.5	3.1	08:15:57	-67.6	-6.1	10:11:21	393

Table 2: Collocated MIPAS and SCIAMACHY measurements of NO_2 profiles.

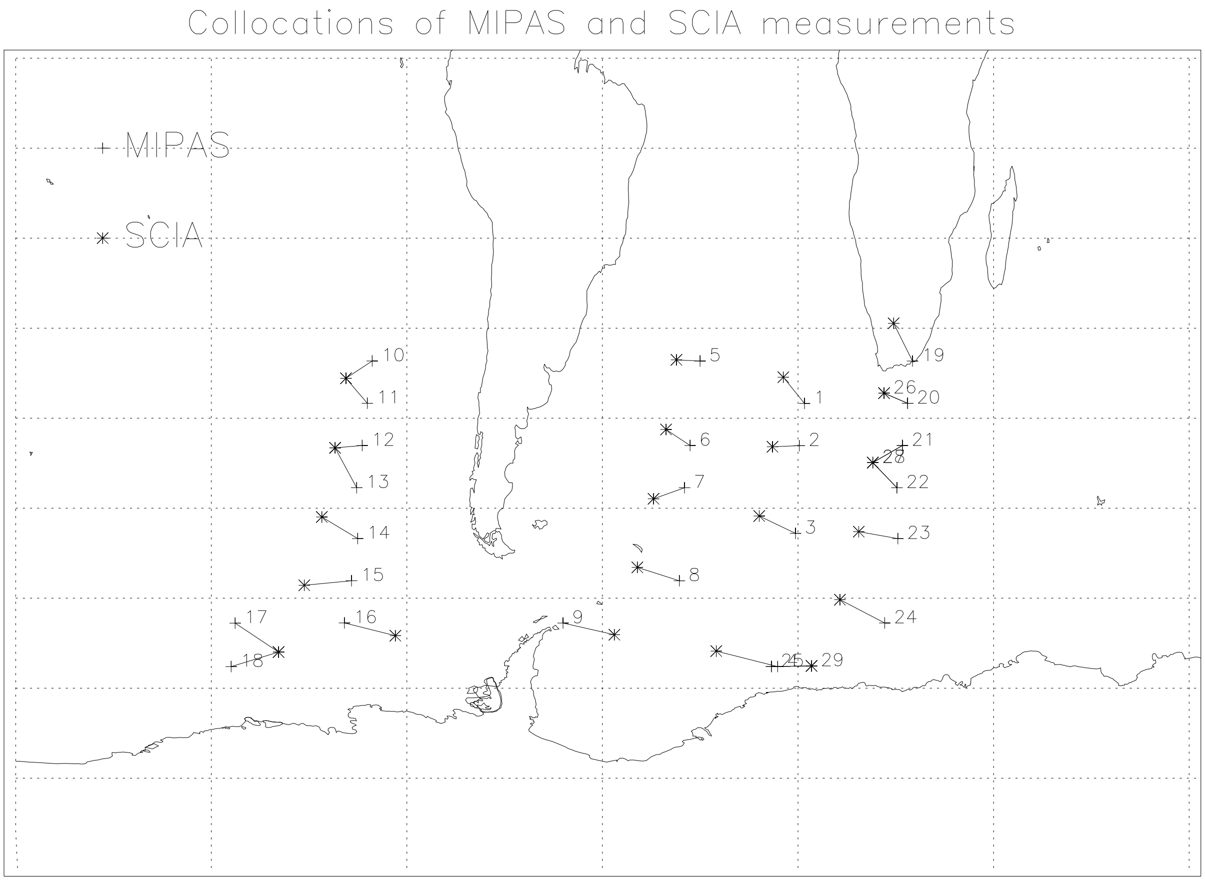

Figure 1: Collocations of MIPAS and SCIACHY measurements used for this comparison.

3.4 Results and Discussions

Out of the total of 25 collocations for O_3 profile measurements, at 15 collocation pairs both measurements were outside the polar vortex and at 6 both were inside the polar vortex. Four collocation pairs were excluded from further comparisons because the collocated MIPAS and the SCIAMACHY measurements were coming from different air masses (collocation no. 7, 10, 18, 23, 29). For the NO_2 comparisons, out of the total of 6 collocations, at 3 collocation pairs both measurements were outside the polar vortex and at 2 both were inside the polar vortex. One collocation pair was excluded from further comparisons because the collocated MIPAS and the SCIAMACHY measurements were coming from different air masses.

3.5 Ozone

As for the MIPAS-IMK O_3 only the tangent heights between around 7–13 km up to 69 km have been used and because of the restricted sensitivity of the SCIAMACHY-IUP O_3 values to the range from 15 to 35 km, only the data above 15 km are compared.

3.5.1 Ozone outside the vortex

The O_3 results for five collocations retrieved by SCIAMACHY-IUP and available MIPAS results of IMK, OXF, RAL, and IAA where both coincidences were outside the polar vortex (no. 1, 2, 15, 20, 21 in Tab. (1)) are shown in Fig. (2).

For all selected collocations in Fig. (2) the maximum is reproduced in the same altitude range and the results look fairly good, but SCIAMACHY values are mostly lower than MIPAS.

At collocations 20 and 21 the IMK results show good agreement with the SCIAMACHY results. But the results obtained by IAA, which have been retrieved considering non-LTE conditions, and OXF and RAL which used different sets of microwindows show larger values at the maximum as for the other results outside the vortex. RAL shows strong oszillations especially below the maximum which are probably the result of weak constraints.

The variations between the MIPAS-results are mainly related to different assumptions and retrieval constraints. All retrieval processors use different spectral microwindows. The different microwindows explain some of the differences as the sensitivity of the retrieval is determined by the spectral regions that are used for the retrieval.

The statistical analyses (Fig. (3)) gives at 18 - 48 km a mean relative deviation of SCIAMACHY-IUP to MIPAS-IMK with -15 - +1% (+/- 10 - 20%).

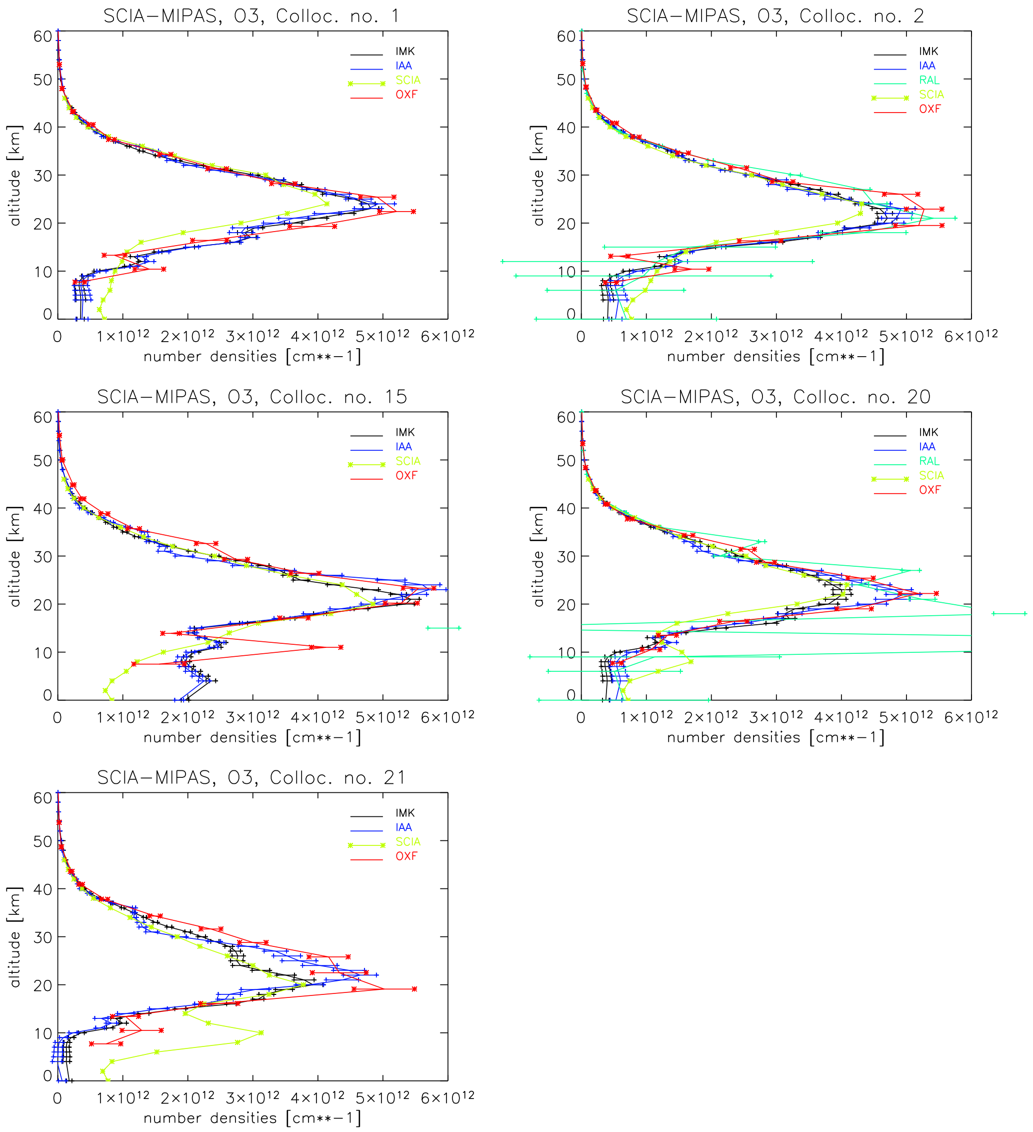

Figure 2: Ozone number density profiles for collocations outside the vortex. Results from UB-SCIA (SCIA, yellow), IMK (black), IAA (blue), OXF (red) and RAL (green).

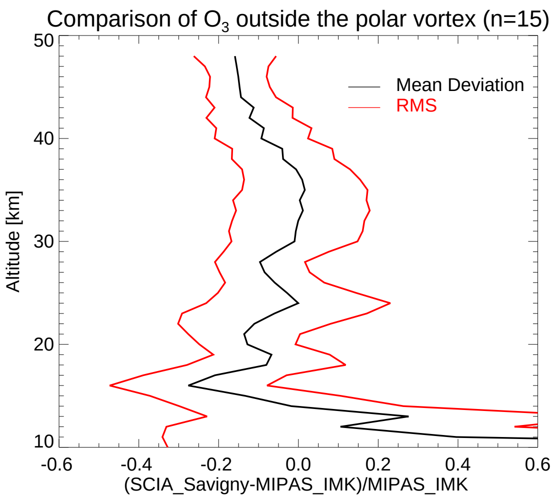

Figure 3: Statistics outside the vortex.

3.5.2 Ozone inside the vortex

A subset of 5 collocations has been selected where both measurements by SCIAMACHY and MIPAS have been inside the polar vortex. The SCIAMACHY-IUP and various MIPAS-retrievals are shown in Fig. (4). Looking at collocations no.

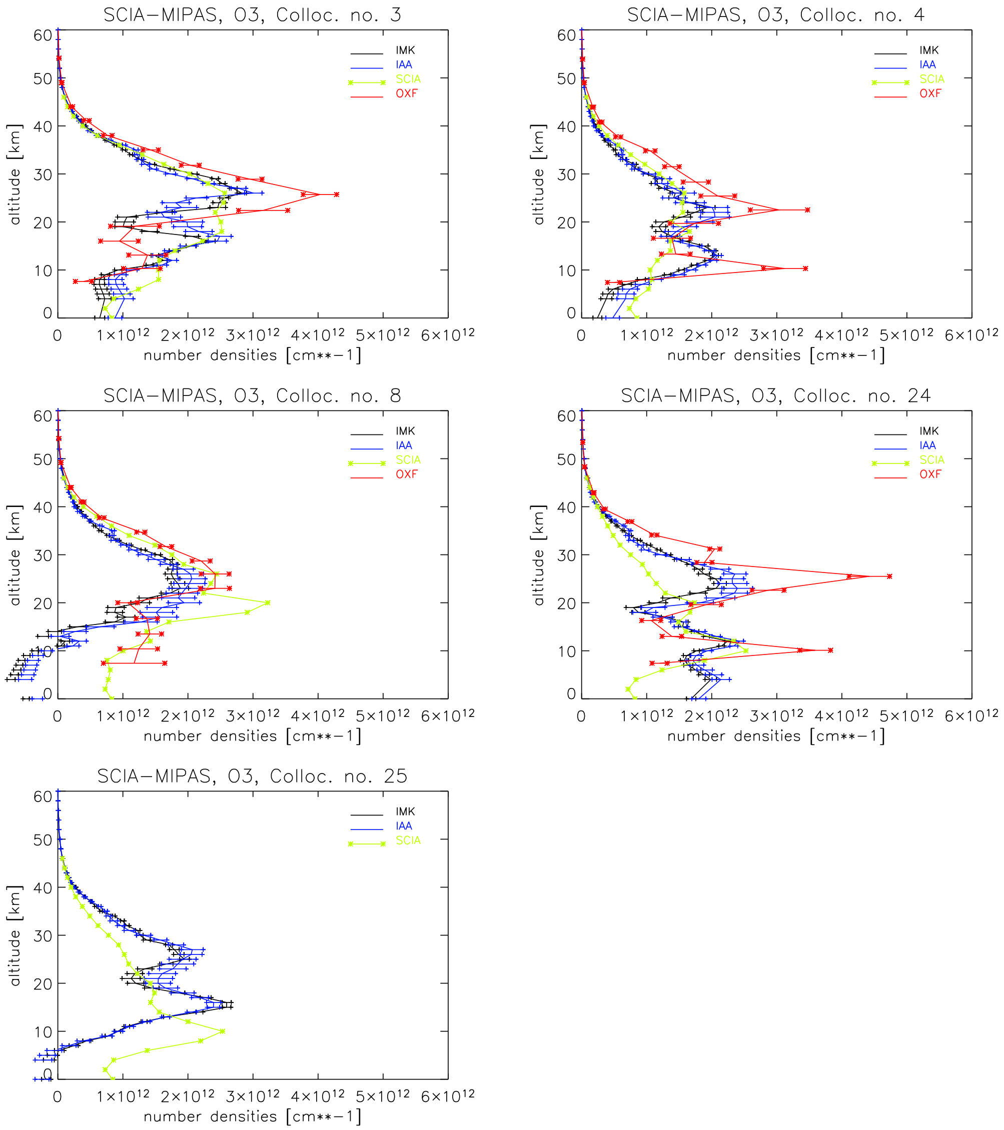

Figure 4: Ozone number density profiles. Collocations inside the vortex.

3, 4, 24, and 25 the MIPAS profiles show a double peaked structure. Although the maximum values for the maxima differ for the different results their position is consistent for all MIPAS retrievals. The reasons for the differences between individual MIPAS results are explained above. The structures which are resolved by the MIPAS retrievals are not as prominent in the SCIAMACHY-IUP retrievals. In collocation no. 3 the double peaks are reproduced but the minimum is not resolved. For collocations 24 and 25 one of the two maxima is resolved and reproduced while the second one cannot be retrieved. Only for collocation no. 8 the maximum in the profile is reproduced by SCIAMACHY-IUP and the MIPAS retrievals.

The maximum values measured inside the vortex are significantly smaller than the ones measured outside indicating a significant ozone depletion. The results show that MIPAS is capable to resolve small scale structures in the ozone profile as they are typical for ozone hole conditions. SCIAMACHY is able to measure the reduced ozone values inside the vortex but small scale structures cannot be resolved as good as with MIPAS. One possible reason is the large area that is covered in the tangent altitude by SCIAMACHY where the signals of different air masses get attributed to one profile and smear the structured profile.

The statistical analyses (Fig. (5)) for the collocations inside the vortex gives at 23 - 48 km a mean relative deviation of SCIAMACHY to MIPAS with -10 - +15% (+/- 10 - 20%)

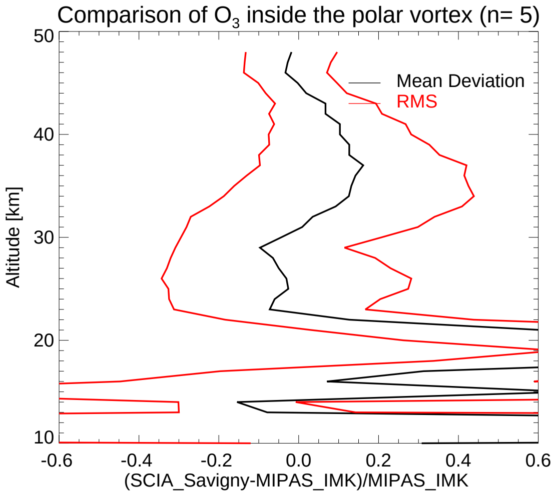

Figure 5: Statistics inside the vortex.

3.6 NO_2

Six collocations of SCIAMACHY and MIPAS NO_2 retrievals were selected for comparison. For both instruments only measurements above 15 km were considered for the retrieval. For this collocations only MIPAS-retrievals by IMK were available. MIPAS retrievals were performed under LTE and non-LTE conditions. The results of the comparisons show large deviations for all collocations (Fig. (6)). The IMK NO_2 results generally have the maximum at too low altitude. The maximum is expected to be at around 30 km. While the results for SCIAMACHY peak in this region, the MIPAS results peak between 20 and 25 km. One reason is the retrieval set-up with too strong regularisation for tangent altitudes below 25 km which forces the retrieval result towards the a priori profile. As the a priori profile used general shows larger values than the result the profile is forced to higher number densities and the maximum moves to lower altitudes. The retrieval scheme is currently being modified and improved and will used for reprocessing of the data.

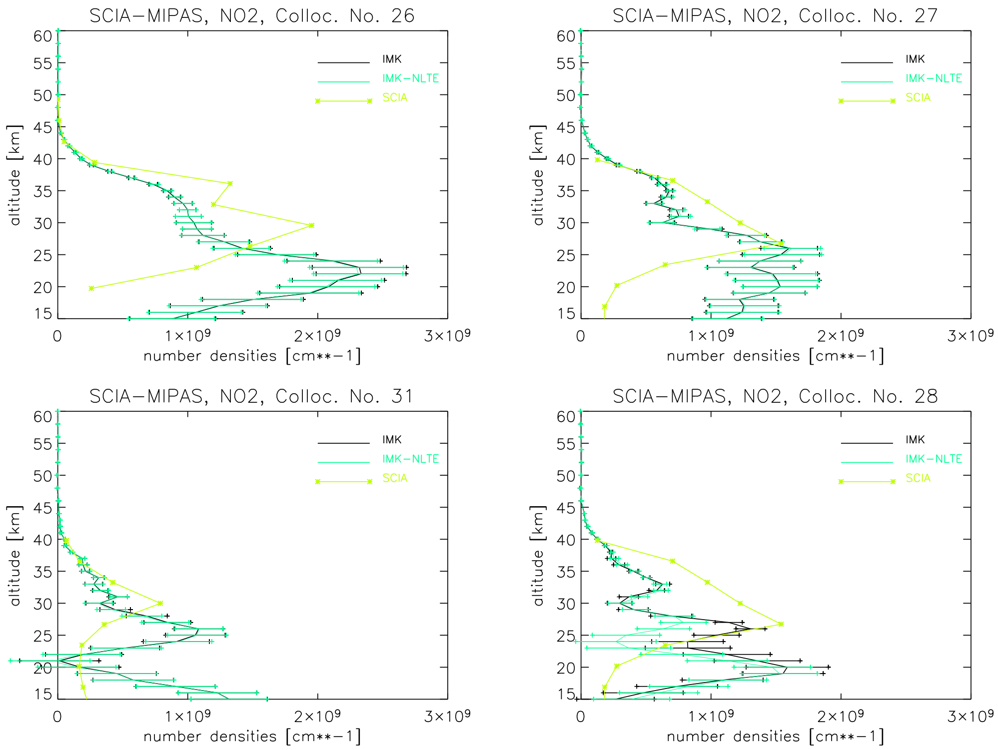

Figure 6: NO_2 number density profiles. MIPAS (IMK) results for LTE conditions in black (incl. random error), results for nonLTE-conditions in green, SCIAMACHY-IUP result in yellow

		MIPAS-IMK		
No.	date	lat. (deg)	long. (deg)	meas. time (UTC)
1	20-09-2002	-43.1	0.3	09:58:42
2	20-09-2002	-33.7	-22.5	11:36:35
3	23-09-2002	-38.3	25.2	08:22:29

Table 3: Collocations of MIPAS-IMK and GOME measurements of O_3 profiles.

4 Intercomparison MIPAS-Envisat with GOME (D72, WP5630)

M. Milz, J.W. Reburn, V. Jay, R. Siddans, S. Gil

4.1 Introduction

Comparison of data recorded from the same satellite offer the best base for a good agreement of the measurement locations, both in time and space. Satellites using the same orbit but with a time delay offer a similar good base for comparison of the observations. Therefore the Global Ozone Monitoring Experiment (GOME) on ERS-2 is an approriate instument for the validation of MIPAS results.

ERS-2 is using the same orbit as Envisat with a time delay of several minutes. Thus GOME onboard ERS-2 is expected to observe the same air masses as MIPAS within a short time range.

GOME is a nadir-scanning ultraviolet and visible spectrometer for global monitoring of atmospheric Ozone and is situated on board ERS-2. GOME is measuring in the UV/VIS/NIR covering the spectral range from 240 to 790 nm with a spectral resolution of 0.2–0.4 nm. The instrument uses nadir geometry to measure sunlight which is scattered and reflected in the earth's atmosphere [16].

4.2 Compared data sets

RAL provided ozone profiles retrieved from GOME data for several collocations with MIPAS measurements. As for the comparison with SCIAMACHY-IUP results two days, september 20 and 23, 2002 have been selected for comparison. Three collocations have been selected for the comparison. the collocations are given in Tab. (3).

4.3 Ozone

Ozone retrievals from GOME and MIPAS have been compared for three collocations. The results are shown in Fig. (7). Both instruments reproduce the maximum and the results look good. The altitude of the maximum is consistent for all MIPAS retrievals and the GOME profile. As the MIPAS results were obtained using different retrieval approaches and constraints the distribution varies, particularly in the maximum region. The IMK results seem to have lower maximum values than the others. For the observed cases the maximum of the GOME ozone profile shows slightly larger values than the MIPAS retrievals. Takeing into account the assumed random errors for MIPAS, MIPAS and GOMOS agree quite good.

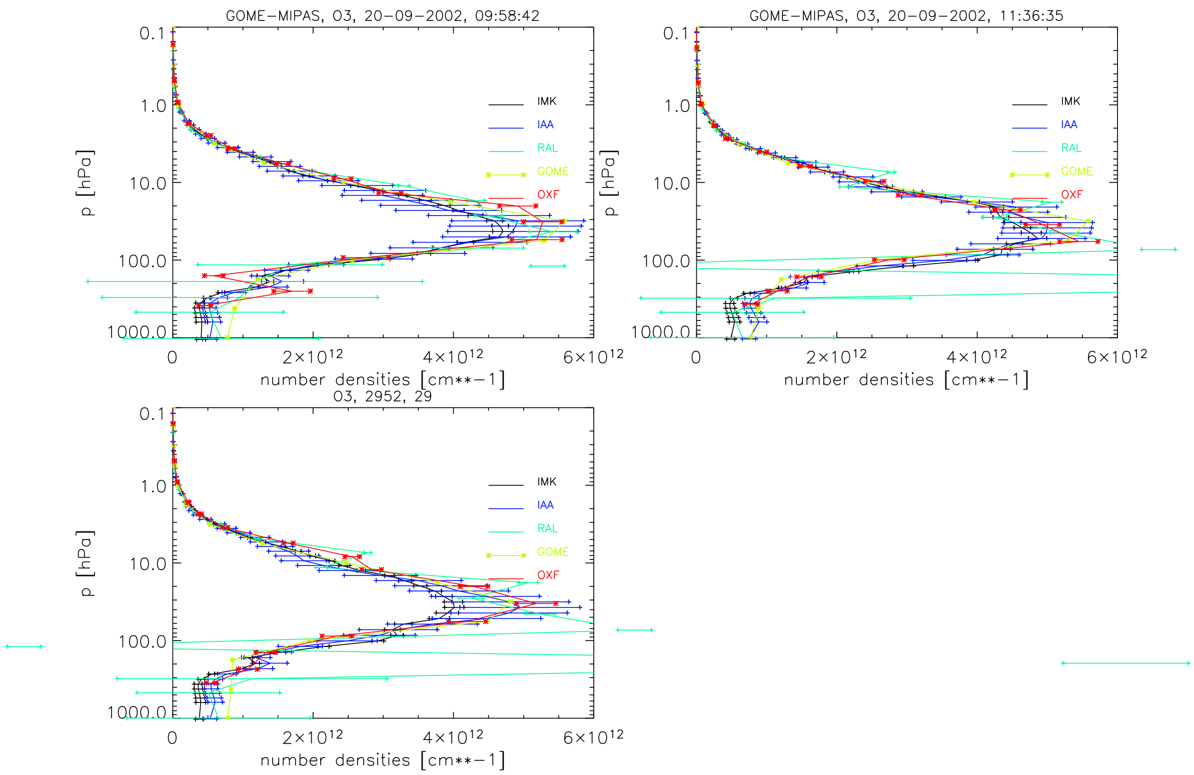

Figure 7: Ozone number density profiles for collocations of MIPAS and GOME. Results from GOME (yellow), IMK (black), IAA (blue), OXF (red) and RAL (green).

5 Comparison to further external validation data (D72, WP5630)

D.-Y. Wang, G. P. Stiller, M. Milz,T. Steck, and T. von Clarmann

5.1 Introduction

An accurate knowledge of the observational geometry and the physical state of the atmosphere is an essential requirement for any space-based limb-viewing remote sensing experiment attempting to characterize the chemical composition of our environment. Thus, the MIPAS-measured temperatures are compared with those observed by a number of other satellites, including HALOE (Halogen Occultation Experiment) [4, 5] (Version 19 L2 data), SABER (Sounding of the Atmosphere using Broadband Emission Radiometry) [6, 7] (Version 1.01 data), and UKMO (United Kingdom Meteorological Office) Stratospheric Assimilated Data [9] (taken from BADC). The UKMO data are produced by analyzing a heterogeneous mixture of operational meteorological observations, including data from NOAA polar orbiters in addition to conventional meteorological observations such as radiosonde data.

Due to different characteristics of the sampling scenarios for the four data sets, it is difficult to achieve excellent spatial and temporal coincidence for individual pairings of MIPAS profiles with correlative HALOE/SABER/UKMO measurements. Thus, as a first order approximation, individual paired-profile comparisons are conducted for those measurements with latitude and longitude differences smaller than 5 and 10 degrees, respectively. The time differences between the paired profiles are required to be less than 1 hour for the MIPAS/SABER and MIPAS/UKMO, but are allowed to be as large as 12 hours for MIPAS/HALOE due to the sampling characteristics of HALOE. One MIPAS profile has one overlapped HALOE measurement, but may have multiple SABER and UKMO coincidences due to higher SABER/UKMO sampling and our coincidence criteria. The paired profiles are then interpolated to a common altitude grid as that used by the MIPAS-IMK data. No resolution or averaging kernel [3] is used in this preliminary study. The numbers of available correlative measurements are listed in Tab. (4).

Table 4: Numbers of MIPAS Measuremnets and Coincidence Profiles Used for Comparison.

Time	MIPAS TOTAL	MIPAS/HALOE	MIPAS/SABER	MIPAS/UKMO
24-JUL-2002	201	13/13	35/77	67/1401
20-SEP-2002	146			24/514
21-SEP-2002	104			9/188
23-SEP-2002	65			20/415
26-SEP-2002	170			16/331
27-SEP-2002	166			14/292

5.2 Comparisons of Individual Profiles

Detailed profile comparisons are performed for the MIPAS measurements between 5 and 70 km at solstice and equinox conditions. As examples, Figures (8), (9), and (10) display comparisons of a few paired MIPAS/HALOE, MIPAS/SABER, and MIPAS/UKMO profiles at different locations. The mean differences and root-mean-squared deviations averaged over all available paired profiles are presented in Figures (11), (12), and (13) for MIPAS/HALOE, MIPAS/SABER, and MIPAS/UKMO, correspondingly.

As seen from these figures, the MIPAS temperatures exhibit reasonable agreements with those of the three other satellite measurements. While planetary and other small-scale waves could have their influences on the observed discrepancies shown in individual paired profiles, there are some general tendencies between the measurements. Below 30 km, the MIPAS temperatures are generally hotter than those of UKMO (Figures (10) and (13)), but colder than those of SABER (Figures (9) and (12)), with the differences less than 1 K and 2 K with respect to UKMO and SABER, respectively. At upper heights between 30 and 55 km, both HALOE

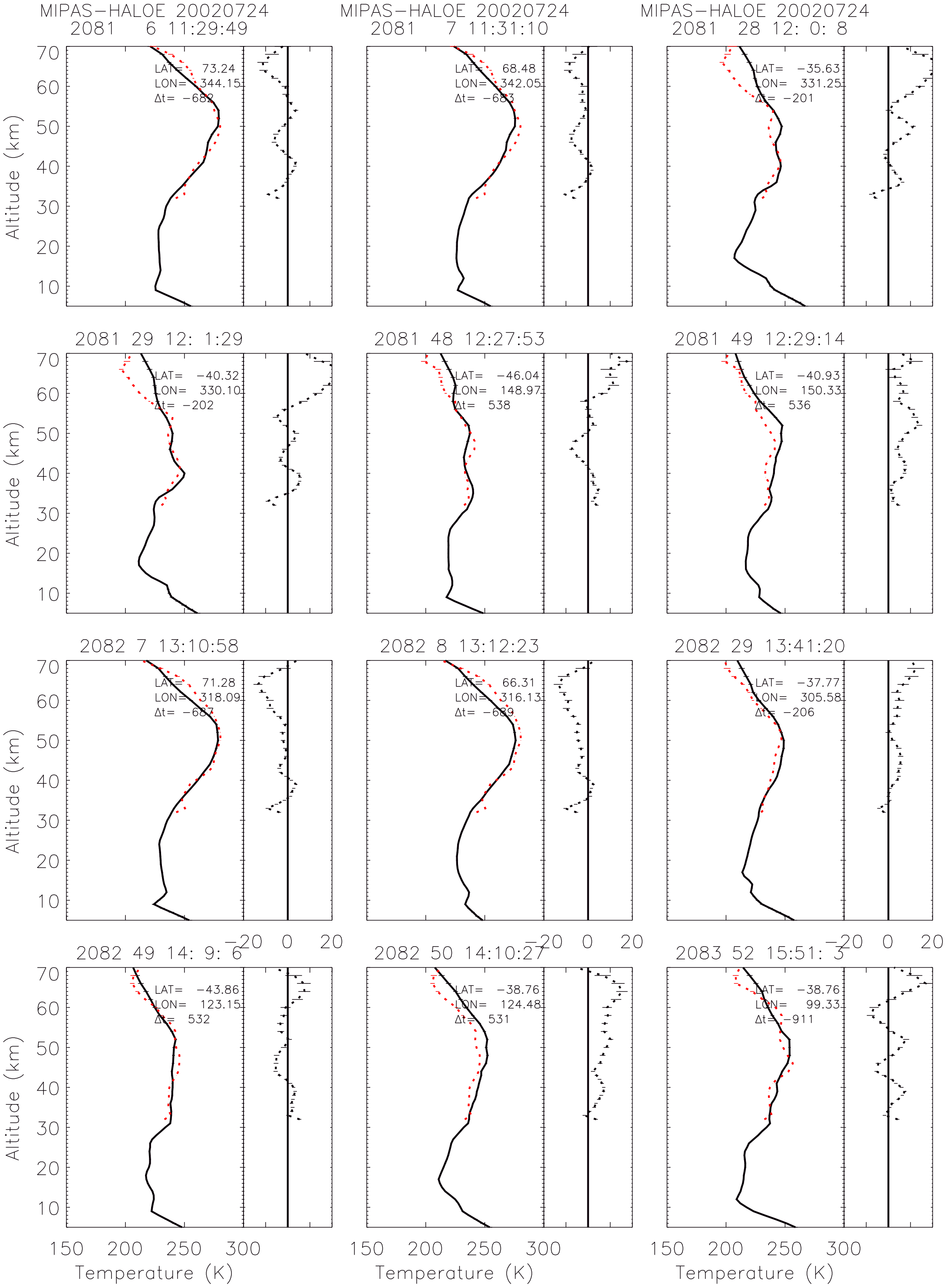

Figure 8: Comparisons of MIPAS and HALOE temperatures on 24 July, 2002. In each panel, the MIPAS (solid) and HALOE (dotted) temperature and measurement error (in Kelvin) profiles are displayed in the left sub-panel, while difference and resultant measurement error (in Kelvin) of the two temperatures are shown in the right sub-panel. The orbit and scan numbers, UT time, latitude and longitude (in degrees) are denoted for the MIPAS measurement. The correlative HALOE observation has latitude and longitude differences smaller than 5 and 10 degrees, respectively. The time difference (or its range if there are multiple correlative measurements) between MIPAS and HALOE observations are indicated by Δt in minutes.

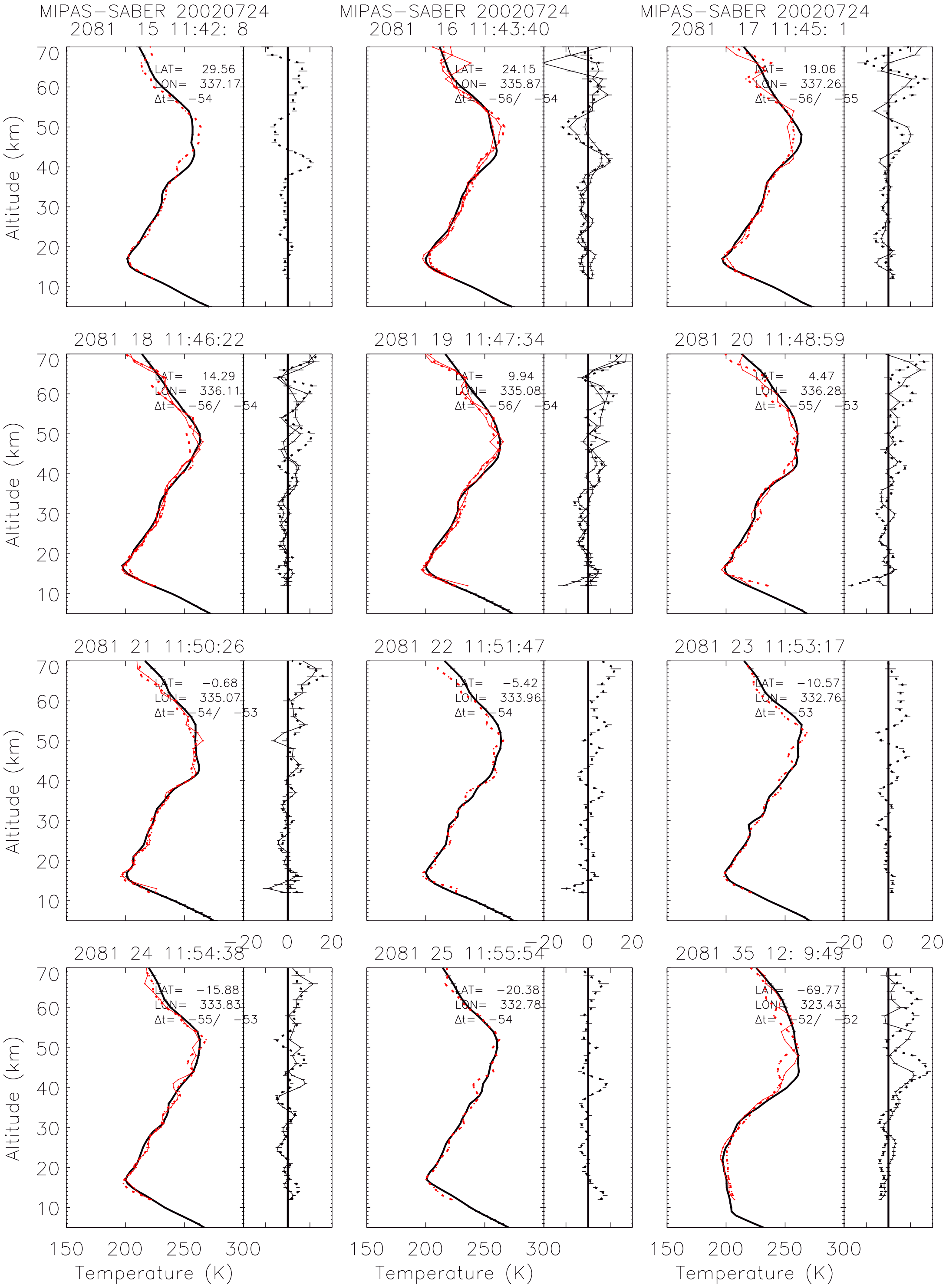

Figure 9: Same as Fig. 8, but for SABER.

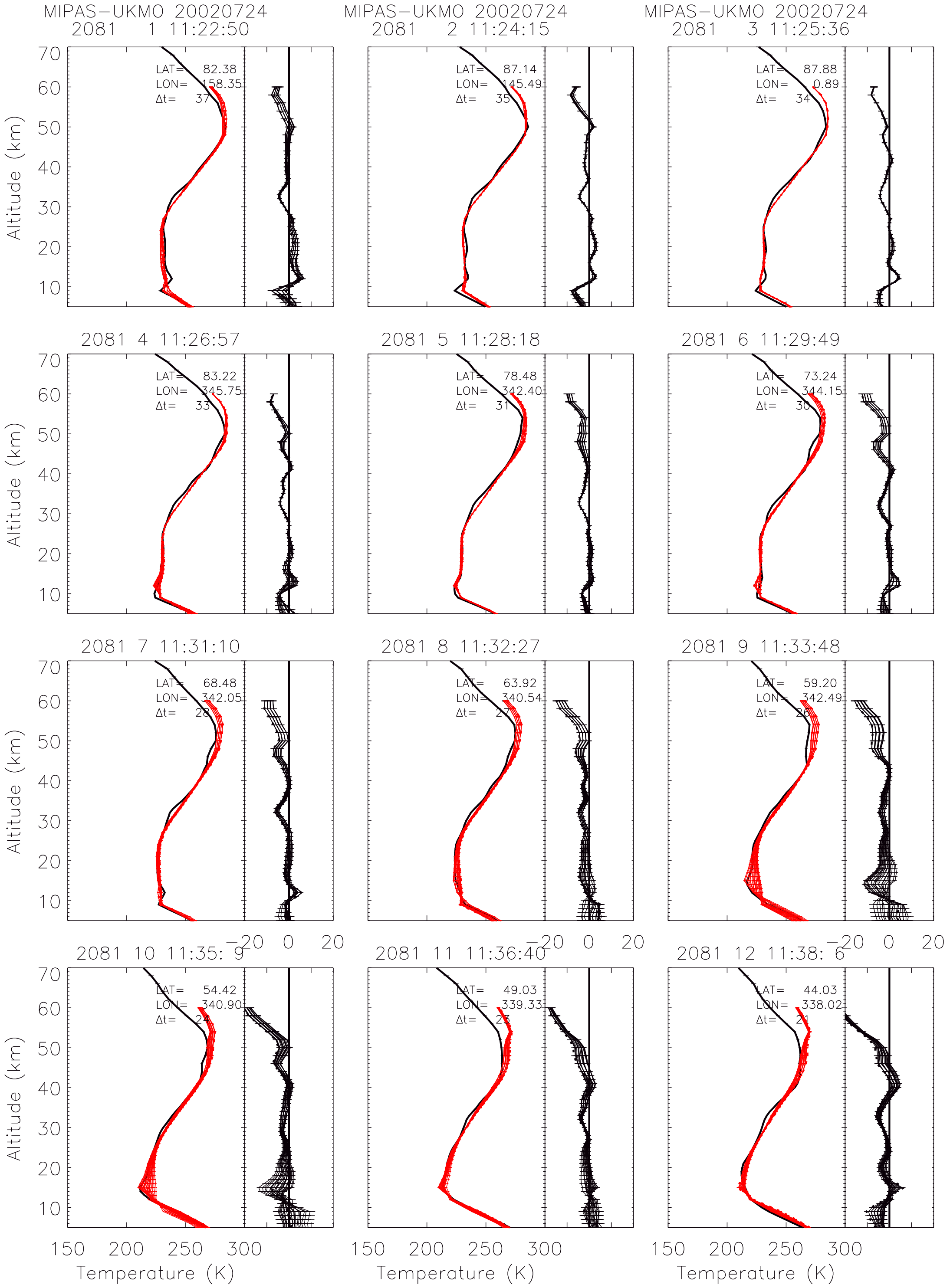

Figure 10: Same as Fig. 8, but for UKMO.

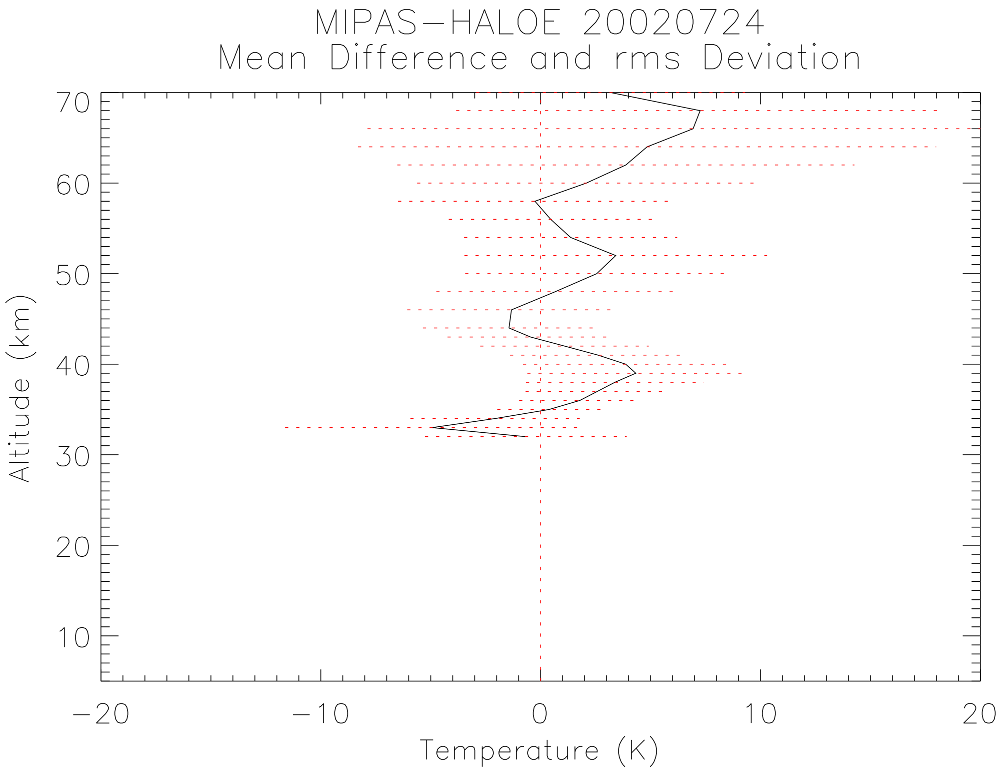

Figure 11: Mean differences (solid) and root-mean-squared deviations (dotted) of MIPAS and HALOE temperatures (in Kelvin). The data are averaged over all available paired profiles on 24 July, 2002 (see Tab. (4)).

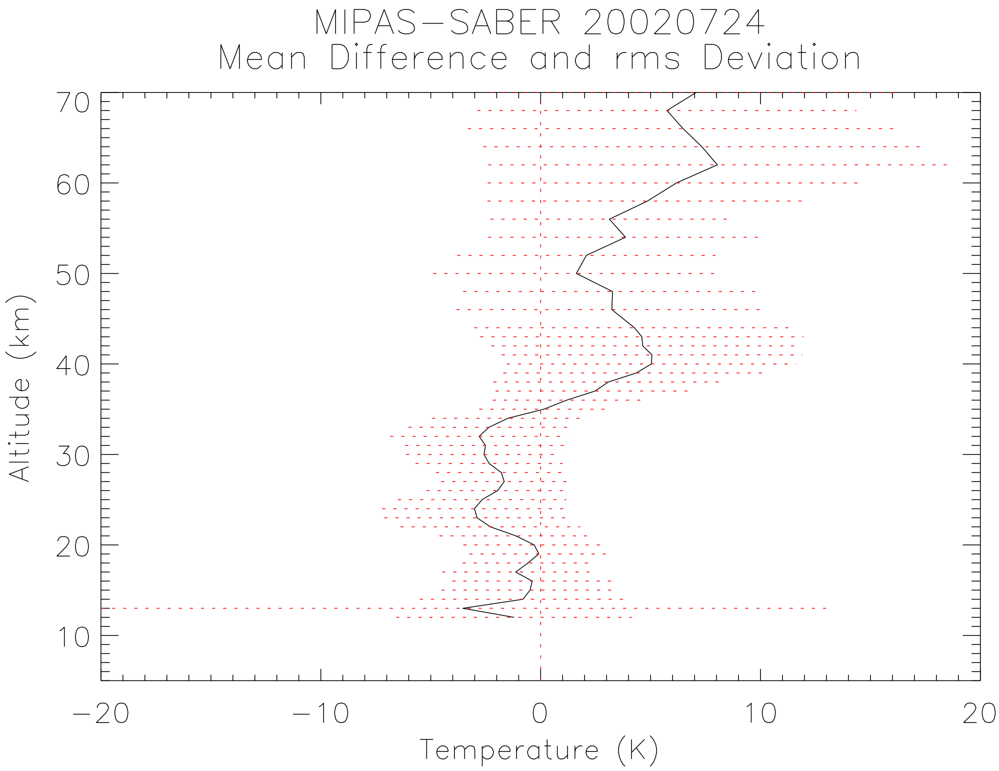

Figure 12: Same as Fig. 11, but for SABER.

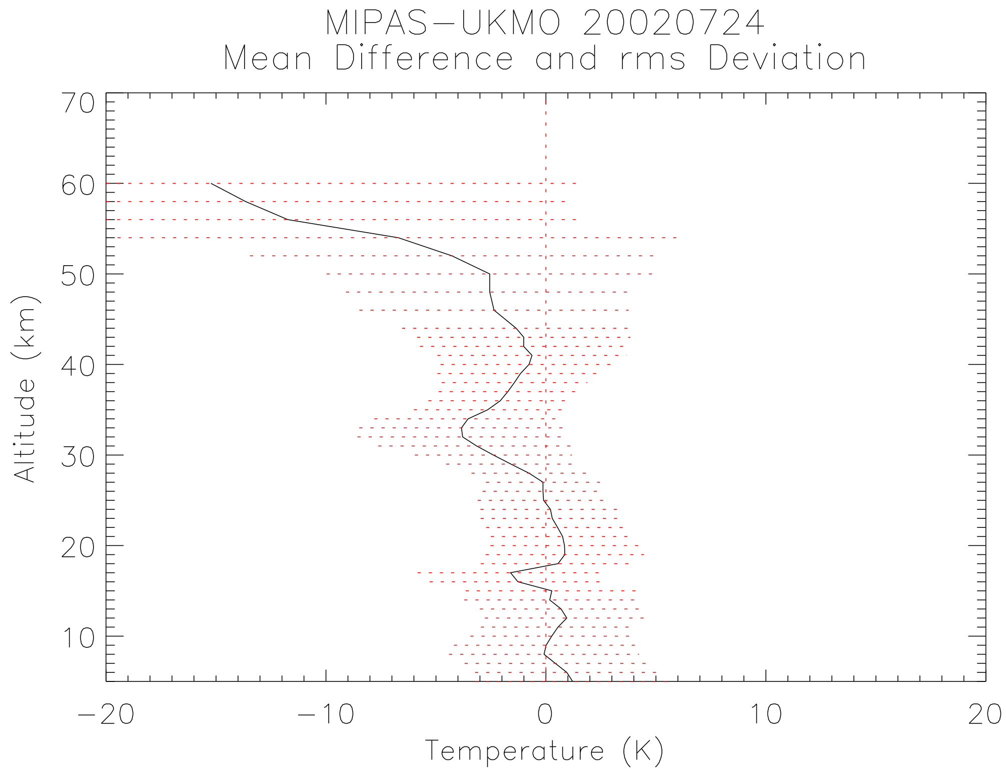

Figure 13: Same as Fig. 11, but for UKMO.

(Figures (8) and (11)) and SABER (Figures (9) and (12)) are colder than MIPAS by 2-3 K, while UKMO (Figures (10) and (13)) hotter by 3-5 K. It is also found that SABER underestimates temperatures above about 3 5 km from internal comparison between SABER 15 and 4.3 μm channels, and that the MIPAS temperatures tend to be consistent with SABER 4.3 μm [López-Puertas et al., Validation of SABER LTE temperatures with MIPAS, presented on SABER Science Meeting, Hampton, VA, USA, 11-13 March, 2003]. New version (V1.02) of SABER data is under processing, further comparisons are required to validate both datasets. Larger deviations of 10-20 K are found above 60 km, where the upper boundary of the MIPAS observations is reached.

The equinoctial MIPAS measurements were taken between 20 and 27 September of 2002, when an Antarctic stratospheric major sudden warming occurred. For that period, few MIPAS/HALOE correlative measurements are available at the moment, since HALOE looked 40°S north, but MIPAS observations are currently processed at IMK only for regions of 30°S south. We have analyzed SABER temperature data for the period and found that the comparison is worst for high latitudes in the polar winter region, with SABER much colder ($\sim$ 20 K) above 35 km. The new version V1.02 of SABER data is under processing. Thus we defer comparisons of MIPAS/HALOE and MIPAS/SABER, but only present those of MIPAS and UKMO here. Due to the coincidence requirement of time difference less than one hour, no MIPAS/UKMO correlative measurement is available on 22, 24 and 25 September.

The features of paired MIPAS/UKMO profiles in the September period are very similar to those shown in Figures (10) and (13) for the solstitial observations on 24 July. While comparisons of the individual paired profiles are not presented here for brevity, the mean differences and root-mean-squared deviations averaged over

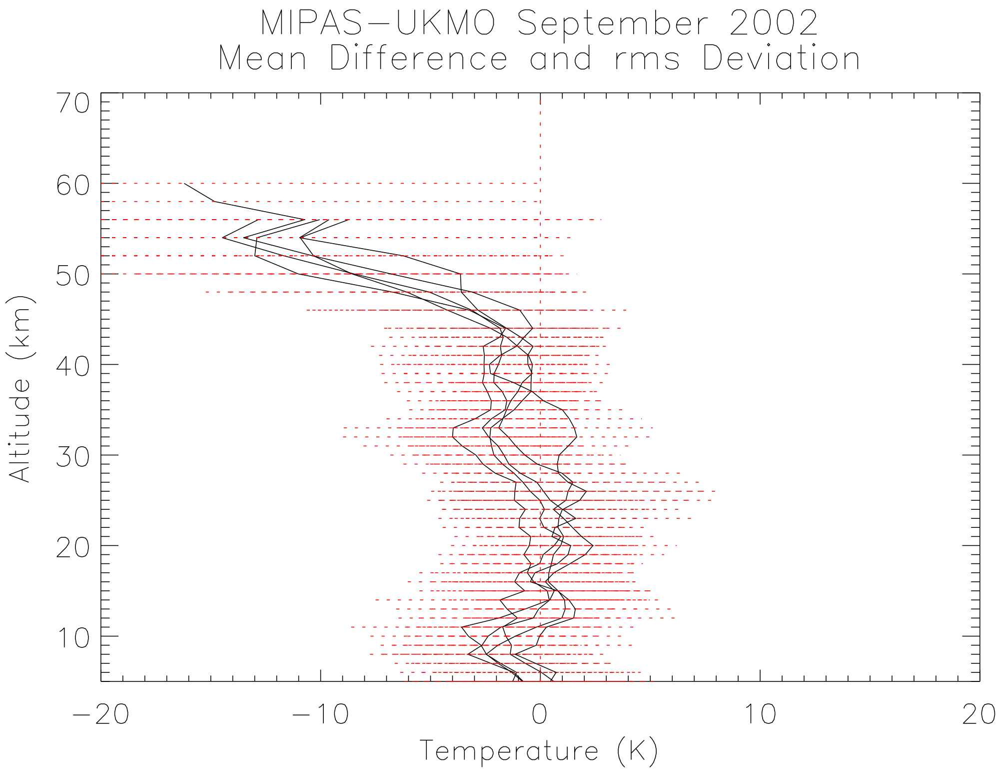

Figure 14: Mean differences (solid) and root-mean-squared deviations (dotted) of MIPAS and UKMO temperatures (in Kelvin). The data are averaged over all available paired profiles during a day for the five days in September of 2002 (see Tab. (4)).

all available paired profiles for each day are displayed in Fig. (14). Between 10 and 30 km, the daily mean differences are of about ±(1-3) K, with larger magnitudes at the lowest and highest levels, and with apparent day-to-day variations. The resultant differences of the five days tend to be zero in this height region, suggesting no apparent systematical deviations between MIPAS and UKMO measurements. At upper heights above 30 km, UKMO is generally hotter than MIPAS by 2-3 K between 30 - 45 km, and the discrepancies increase with increasing height to 10 -20 K at 60 km. It is no secret that the UKMO temperatures are constrained and have a significant warm bias in the lower mesosphere.

5.3 Comparisons of Daily Zonal Mean Temperature Differences

To further examine the statistical consistency between MIPAS and UKMO data, we compare the zonal mean differences between the correlative MIPAS and UKMO measurements. Fig. (15) shows the daily zonal means of the differences during the five days of September (see Tab. (4)). The mean differences are seen to be less than 1 - 2 K in wide latitude and altitude regions for the five days. The large discrepancies are seen to occur around 25 km at higher latitudes of 60°S south, where the MIPAS temperatures are generally hotter than UKMO by a maximum of 6-8 K. This could be due to the deviations between the MIPAS observations and the current UKMO assimilation model, which may not fully reflect the unprecedented event. For example, the forcings of up-going planetary waves could be underestimated[10], since previous theory has assumed that there is not sufficient forcing of planetary waves in the SH winter to induce a sudden warming[8]. Previous study [1] also showed that the largest deviations between ECMWF and UKMO analyses occurred at the mid stratosphere (i.e 10 hPa, about 30 km) during major warming events of December 2001 in the Northern Hemisphere (NH), and that the ECMWF data were systematically colder than UKMO by 5 K, with the rms differences peaking at 6 K, and day-to-day differences locally exceeding 10 K. At upper heights above 40 km, the MIPAS temperatures tend to be colder than UKMO by 4 - 10 K in the southern region of 30°S. In seeking for any explanation of the discrepancy, we must recall that LTE is assumed in the MIPAS retrievals used for this analysis, and that the non-LTE effects might be significant for the upper stratosphere in the polar winter regions [2]. Thus, before drawing any conclusion, more investigations are required.

5.4 Concluding Remarks

Total 208 MIPAS temperature profiles measured at different locations and seasons are compared with other satellite observations (see Tab. (4)). Though the data sets are limited, the results are very promising.

The MIPAS data show general consistencies with those of the correlative HALOE, SABER and UKMO measurements on profile-by-profile basis (Figures (8), (9) and (10)). Planetary and other small-scale waves may have their influences on the observed discrepancies shown in individual paired profiles. Their effects can be significantly reduced by average over all available paired profiles. The mean differences on 24 July of 2002 (Figures (11) and (12)) indicate that the MIPAS temperatures are colder than SABER by 2 K below 30 km (no HALOE data are available in the low altitudes), but hotter than both HALOE and SABER by 2-3 K at upper heights between 30 and 55 km. The discrepancies at the upper heights could be understood by the known bias of SABER data.

Much better agreements are achieved for MIPAS and UKMO data between 10 - 30 km, where no apparent systematical errors are found to exist. For individual days, the MIPAS temperatures in this height region show a weak tendency hotter than UKMO by less than 1 K in July (Fig. (13)), and either hotter or colder by 1-3 K in September (Fig. (14)). However, the resultant differences averaged over all the days are apparently close to zero. The day-to-day variations could be interpretd by the impact of planetary and small-scale waves, whose activities were strong during the September period [10]. At upper heights above 30 km, the discrepancies generally increase with increasing height, with UKMO hotter than MIPAS by 10 -20 K at the upper boundary of UKMO and MIPAS measurements around 60 km. The zonal means of the differences between available correlative MIPAS and UKMO measurements (Fig. (15)) revealed large discrepancies of maximum 6-8 K to occur around 25 km at higher latitudes of 60°S south, with MIPAS generally hotter than UKMO. This behavior suggests that current UKMO assimilation model may not sufficiently describe the unprecedented event. Above 40 km, the MIPAS LTE temperatures are colder than UKMO by 4 - 10 K in the southern latitudes of 30°S. The non-LTE effects could be enhanced in the upper stratosphere in the polar winter regions, and might result in underestimated MIPAS temperatures.

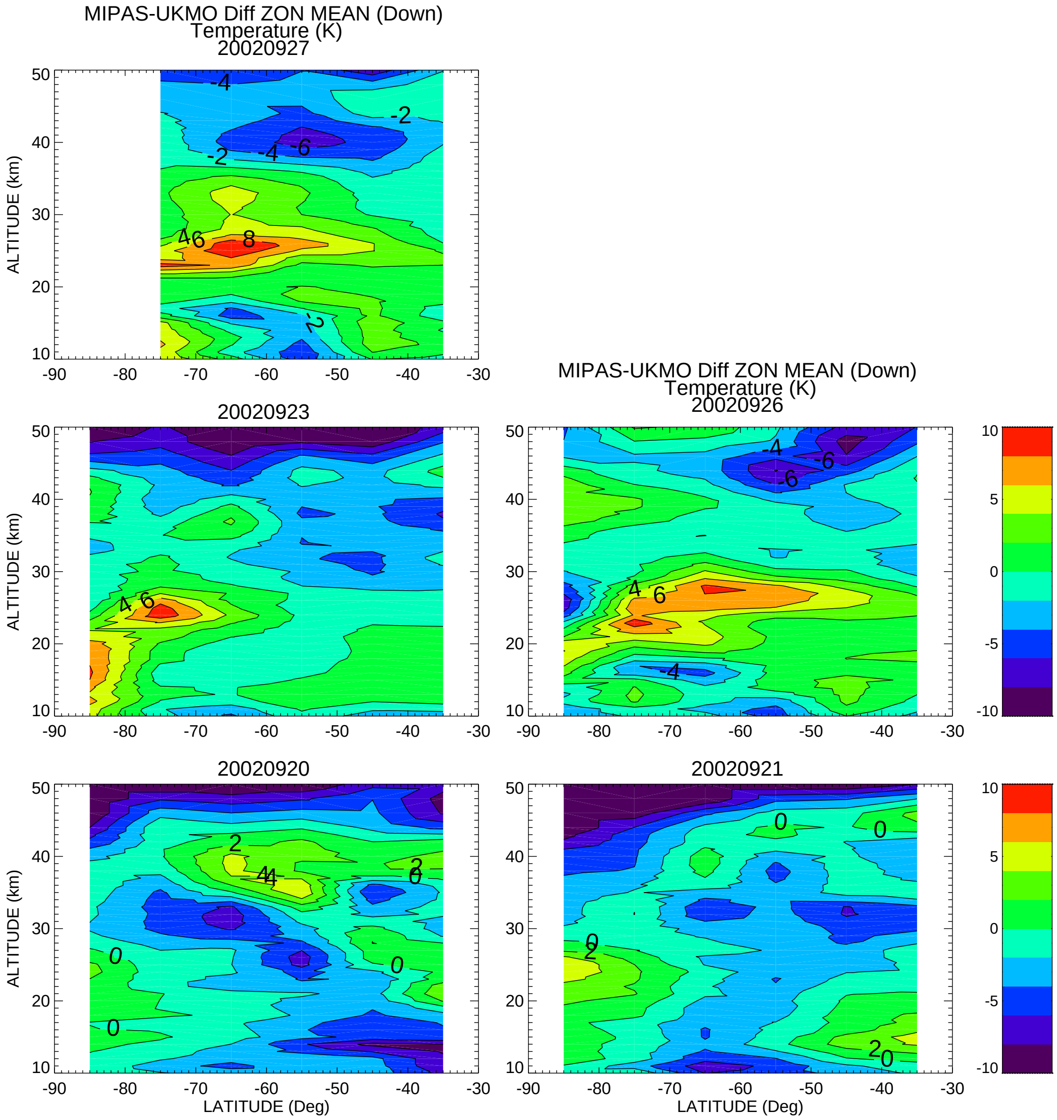

Figure 15: Daily zonally averaged temperature differences (in Kelvin) of correaltive MIPAS and UKMO measurements (See Tab. (4)) The temperatures are contoured by 2 K interval.

6 Assessment of microwindows (D64, WP 5530)

T. von Clarmann, A. Dudhia, S. Hilgers, M. Milz, V. Payne, G. Schwarz

6.1 Introduction

Some of the microwindows used for MIPAS data analysis may be inappropriate and lead to increased fit residuals and/or systematic retreval errrors. This could, e.g., be due to low sensitivity of the microwindow signal to the retrieval parameter at the tangent altitude, large sensitivity of the microwindow signal to the retrieval parameter in altitudes above the tangent altitude, inconsistent spectroscopic data, unpredicted non-local thermodynamic equilibrium signal, larger than expected signal of interfering species and others. Such problems were identified and removed by revision of microwindow selection.

6.2 Method

Three different approaches were used for the assessment of microwindows: (a) visual inspection of resulting vertical profiles of retrieved atmospheric state parameters for physical plausibility; (b) visual inspection of best fit residuals between measured and calculated adiance spectra in order to detect suspicious features hinting at specific modeling problems; and (c) a correlation method, where residuals are correlated with the Jacobians of all potential parameters which might cause a systematic error. While applicability of (a) and (b) is restricted to sample cases, method (c) is applicable in a quasi operational mode.

6.3 Results

The D-PAC processor, which had used an early selection of microwindows which was based on an ad hoc selection without any objective optimization, switched to the operational microwindow set generated by Oxford University and used also by the IFAC (ORM) processor. Thes led to improved retrievals of atmospheric state parameters from real MIPAS measurement spectra.

No further evidence for inappropriate microwindows was found.

6.4 Conclusion

The microwindow selections used by the consortium now are considered as appropriate for the tasks they have been specified for.

7 Assessment of a priori data (D66, WP 5550)

T. von Clarmann, S. Kellmann, D.-Y. Wang

7.1 Introduction

Inappropriate a priori data of either the target parameters or ancillary parameters (e.g. vertical profiles of abundances of interfering species) can cause poor retrievals and large residuals. Therefore it is necessary to check if MIPAS retrievals are affected by a priori data.

7.2 Method

The influence of a priori data was assessed by (a) variation of the a priori data; (b) variation of the regularization strength; (c) testwise inclusion of interferents as joint fit parameters.

7.3 Results

No evidence for anu inappropriate or unexpected mapping of a priori data has been found for the processor settings chosen.

7.4 Conclusion

The a priori data used and the relevant processor settings are considered as appropriate.

8 Assessment of other reasons for systematic residuals (D67, WP 5560)

T. von Clarmann, M. Milz, S. Kellmann

8.1 Introduction

Residuals in best fit spectra can hint at systematic retrieval errors beyond those assessed with the correlation analysis. Therefore, analysis of suspicious residuals is an important step in the quality control of retrievals.

8.2 Method

Contrary to the classic approach, where always full lines were analyzed, some of the retrieval algorithms used in AMIL2DA use so-called spectral masks, which allow the use of selected spectral gridpoints for the retrieval. These spectral gridpoints carry the optimal information in a quantitative sense but are not appropriate for visual inspection since the spectral context is lost. To overcome this, a tool has been written at IMK which supports automated calculation and visualization of context spectra on the basis of retrieved state parameters. This allows a consistency check, i.e. to assess if also spectral target species lines not considered in the retrieval are fitted well.

8.3 Results

No evidence of further problems, beyond those discussed under WPs 5510–5550 has been found.

8.4 Conclusion

The fact that no significant unexplained residuals have been found, does not imply that there are no further errors. It just means, that all errors in spectra or a priori assumption are compensated by the retrieval parameters.

References

[1] K. Schöllhammer, C. Marquardt, K. Labitzke, "Comparison of three different meteorlogical datasets (ECMWF, Met Office and NCEP)," in *First CHAMP Mission Results for Gravity, Magnetic and Atmospheric Studies,* C. Reigber, H. Lühr, and P. Schwintzer, eds., pp. 529–535, Springer, 2003.

[2] T. v. Clarmann, et al., "Retrieval of temperature and tangent altitude pointing from limb emission spectra recorded from space by the Michelson interferometer for passive atmosphere (MIPAS)," *GJR ???* **???**, pp. ????–????, 2003.

[3] C. D. Rodgers and B. J. Connor, "Intercomparison of remote sounding instruments," *OSA Technical Digest*, pp. 46-48, 1999.

[4] J. M. Russell,III, L. L. Gordley, J. H. Park, S. R. Drayson, D. H. Hesketh, R. I. Cicerone, A. F. Tuck, J. E. Frederick, J. E. Harries, and P. J. Crutzen, "The Halogen Occultation Experiment," *J. Geophys. Res.* **98**, pp. 10777–10797, 1993.

[5] J. M. Russell,III, L. L. Gordley, L. E. Deaver, R. E. Thompson, and J. H. Park, "An overview of the Halogen Occultation Experiment (HALOE) and preliminary results," *Adv. Space. Res.* **14, No. 9**, pp(9) 13, 1994a.

[6] J. M. Russell, III, M. G. Mlynczak, and L. L. Gordley, "An overview of the SABER experiment for the TIMED mission," *Proc. SPIE* **2266**, in *Optical Techniques and Instrumentation for Atmospheric and Space Research*, Jinxue Wang and Paul B. Hayes, Eds., pp. 406–414, 1994b.

[7] J. M. Russell, III, M. G. Mlynczak, L. L. Gordley,J. Tansock, and R. Esplin, "An overview of the SABER experiment and preliminary calibration results," *Proc. SPIE*, **3756**, pp. 277–288, 1999.

[8] T. G. Shepherd, "The middle atmosphere," *J. Atmos. Solar-Terr. Phys.* **62**, pp. 1587–1601,2000.

[9] R. Swinbank and A. O'Neill, "A stratosphere-troposphere data assimilation system," *Monthly Weather Review* **122**, pp. 686–702, 1994.

[10] D. Y. Wang et al., "Longitudinal variations of temperature and ozone profiles observed by MIPAS during the Antarctic stratosphere sudden warming of 2002," *J. Atmos. Sci.* **???**, pp ???–???, 2003.

[11] A. Bracher, A. Rozanov, C. von Savigny, M. von Koenig, M. Weber, K. Bramstedt, J. P. Burrows, "First validation of SCIAMACHY O3 and NO2 profiles with collocated measurements from satellite sensors HALOE, SAGE II and POAM III", poster presentation at EGS-AGU-EUG Joint Assembly, Nice, France, April, 2003

[12] J. W. Kaiser, "Retrieval from Limb Measurements", Ph. D. Thesis, University of Bremen, Germany, 2001

[13] K. Pfeilsticker, H. Bsch, J. Burrows, A. Butz, C. Camy-Peyret, M. Dorf, K. Gerilowski, K. Grunow, W. Gurlit, B. Naujokat, C. von Savigny, K. Seitz, C.

Sioris, A. Rozanov, F. Weidner, "Balloon-borne DOAS measurements of SCIAMACHY Level 1 and 2 product", oral presentation at 16th ESA Symposium on European Rocket and Balloon Programmes and related Research, June 2002, St. Gallen, Switzerland

[14] A. Rozanov, V. Rozanov, H. Bovensmann, K.-U. Eichmann, M. von Koenig, S. Noel, C. von Savigny, J.P. Burrows, "Retrieval of SCIAMACHY limb measurements: First results", poster presentation at EGS-AGU-EUG Joint Assembly, Nice, France, April, 2003

[15] C. von Savigny, A. Rozanov, H. Bovensmann, S. Noel, J. Kaiser, "SCIAMACHY limb pointing analysis", *SCIAMACHY internal report*, IUP, Bremen,2003

[16] J. P. Burrows and M. Weber and M. Buchwitz and V. Rozanov and A. Ladstätter-Weißenmayer and A. Richter and R. de Beek and R. Hoogen and K. Bramstedt and K.-U. Eichmann and M. Eisinger and D. Perner, "The Global Ozone Monitoring Experiment (GOME): Mission Concept and first scientific results",*J. Atmos. Sci.*, **56**, 2, p 151-175,1999