Long-term validation of GOMOS, MIPAS and SCIAMACHY ozone and temperature profiles by the ENVISAT quality assessment with lidar (EQUAL) project

Yasjka J. Meijer[(1)], J.-L. Baray[(2)], G.E. Bodeker[(3)], H. Claude[(4)], K.H. Fricke[(5)], P. von der Gathen [(6)], S. Godin-Beekmann[(7)], G. Hansen[(8)], P. Keckhut[(9)], T. Leblanc[(10)], D.E. Lolkema[(1)], I.S. McDermid[(10)], H. Nakane[(11)], S. Pal[(12)], P. Snoeij[(13)], and D.P.J. Swart[(1)]

(1) RIVM, LVM, Postbus 1, 3720 BA Bilthoven, Netherlands
(2) IPSL, Uni. La Reunion, St. Denis, France
(3) NIWA, PB 50061, Lauder, New Zealand
(4) DWD, Observatory Hohenpeissenberg, Germany
(5) Uni. Bonn, (Esrange), Bonn, Germany
(6) AWI, Polar and Marine Research, Potsdam, Germany
(7) CNRS, SA, Paris, France
(8) NILU, (Alomar), Tromso, Norway
(9) CNRS, Universite´ de Versailles Saint-Quentin, Verrieres-le-Buisson, France
(10) JPL, Table Mountain, Wrightwood (CA), United States
(11) NIES, Tsukuba, Japan
(12) SAAI, for MSC, Toronto, Canada
(13) ESA-ESTEC, Noordwijk, Netherlands

ABSTRACT

The Envisat Quality Assessment with Lidar (EQUAL) project supports the long-term validation of ENVISAT's three atmospheric chemistry instruments. This ESA funded project started in 2004 and involves eleven, and since 2006 thirteen, lidar stations around the world measuring ozone and temperature profiles. Over the period 2002–2006 more than 4000 lidar profiles are available for correlative studies. The assessment focuses on the ozone profiles of GOMOS (cf. IPF 5.0) and MIPAS (IPF 4.61/4.62), which show excellent and good agreement with lidar, respectively. SCIAMCHY ozone profile validation awaits the new processor release. GOMOS temperature validation (HRTP) is still at a preliminary stage. MIPAS the temperature profiles (IPF 4.61/4.62) show a good agreement with lidar, with a mean bias smaller than 2 K, between 18 and 65 km altitude.

1 INTRODUCTION

In March 2002 the European Space Agency (ESA) launched the Environmental Satellite (ENVISAT) with on board three instruments measuring the Earth's atmosphere. Making use of a variety of measurement techniques, these three instruments should significantly enrich the number of detectable species and their vertical distribution. The Global Ozone Monitoring by Occultation of Stars (GOMOS) instrument is a medium-resolution star-occultation spectrometer operating in the ultraviolet–visible–near-infrared (UV-VIS-NIR) spectral range. The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) instrument is a Fourier transform spectrometer detecting the Earth's limb emission in the mid infrared. The Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument is an UV-VIS-NIR spectrometer allowing observations in nadir, limb-emission and solar-occultation mode.

An initial geophysical validation campaign has been carried out during the Commissioning Phase of the mission (covering originally the first six months after launch, later extended to a total of 9 months). The preliminary validation results of this campaign were presented during the ENVISAT validation workshop from 9-12 December 2002 in Frascati, Italy [1].A more extended validation exercise has been performed on GOMOS ozone profiles [2] using ozonesondes, lidar and microwave instruments. The same data set was used for the evaluation for the choice of the new GOMOS processor, of which a full overview can be found in [3]. The data of this new processor are presented in this paper.

Geophysical validation activities now rely on projects that are part of the long-term validation program of Envisat. The Envisat Quality Assessment with Lidar (EQUAL) project is part of this program and is described in section 2. In section 3 some more details about the satellite instruments is provided. In section 4 the analysis results of the comparison with lidar data are presented, followed in section 5 with the conclusions.

Proc. of the First 'Atmospheric Science Conference', ESRIN, Frascati, Italy
8 – 12 May 2006 (ESA SP-628, July 2006)

Table 1. Overview of LIDAR systems: locations and parameters			
Groundstation	**Latitude**	**Longitude**	**Parameter**
Eureka	80.05	-86.42	Ozone, temperature
Ny Ålesund	78.92	11.93	Ozone, temperature
Alomar	69.30	16.00	Ozone, temperature
Esrange	67.88	21.10	Temperature
Hohenpeissenberg	47.80	11.02	Ozone, temperature
Obs. Haute Provence	43.94	5.71	Ozone, temperature
Tsukuba	36.05	140.13	Ozone, temperature
Table Mountain	34.40	-117.70	Ozone, temperature
Mauna Loa	19.54	-155.58	Ozone, temperature
La Reunion	-21.80	55.50	Ozone, temperature
Lauder	-45.04	169.68	Ozone, temperature
Rio Gallegos	-51.55	-69.14	Ozone, temperature
Dumont d'Urville	-66.67	140.01	Ozone, temperature

2 EQUAL PROJECT

The Envisat Quality Assessment with Lidar (EQUAL) project supports the long-term validation of Envisat's three atmospheric chemistry instruments. This ESA funded project started in 2004 and involves eleven, and since 2006 thirteen, lidar stations around the world measuring ozone and temperature profiles. The participating stations are (from north to south) located in Eureka, Ny Alesund, Alomar, Esrange, Hohenpeissenberg, OHP, Tsukuba, Table Mountain, Mauna Loa, La Reunion, and Lauder. In 2006 two additional lidar stations, located in Rio Gallegos (Southerrn Argentina) and Dumont d'Urville (Antacrtic), joined the consortium (see Table 1). Over the period 2002–2006 in total over 4000 lidar data files have been submitted (in HDF) and are available in the correlative database at NILU (Norway).

Besides the required coordination of the data acquisition, this project involves dedicated validation activities to assess the data quality. The data under investigation are the ozone and temperature profiles of GOMOS, MIPAS and SCIAMACHY. The main focus will be on the quality of the operational ESA products, in which the data quality is monitored during satellite's lifetime (health of instruments and processing chain), and new data releases (processor upgrades) are validated. The focus might sometimes also change toward products of scientific institutes exploring retrieval algorithms of (potential) future operational products. The vast amount of lidar data covering several latitudinal regions allows the analysis for possible dependencies of these data on several geophysical (e.g., latitude) and observational (e.g., star characteristics) parameters. In this paper the main analysis results will be presented for each of the six Envisat data products under investigation.

3 ENVISAT INSTRUMENTS

3.1 GOMOS

GOMOS observes stellar occultations employing medium-resolution spectrometer operating in UV-VIS-NIR spectral range. Its retrieved ozone profiles are in the altitude range (typically) 15–100 km with 2–3 km vertical resolution. The second product relevant here is the high-resolution temperature profile (HRTP) which is (typically) retrieved for the altitude range 20–40 km with about 100 m vertical resolution. The data used in this paper come from the prototype (GOPR) version 6.0cf, which is the same as the operational version IPF 5.0. Reprocessed GOMOS data are available for the period 28-08-2002 to 02-01-2006, and compromise about 342,000 profiles (36 Gb), of which about 10,000 profiles are collocated with one of the 13 stations within a 500km range. GOMOS data are unavailable for May 2004, and the period February 2005 to August 2005.

3.2 MIPAS

MIPAS observes the Earth's limb emission in the midinfrared employing a Fourier transform spectrometer. Its retrieved ozone profiles are in the altitude range (typically) 5–70 km with 3–4 km vertical resolution. The second product relevant here is the temperature profile which is (typically) retrieved for the altitude range 5–70 km with 3–4 km vertical resolution. The data used in this paper come from operational version IPF 4.61 and IPF 4.62. Reprocessed MIPAS data are available for the period 07-2002 to 03-2004, compromising about 7,000 orbit files (57 Gb). The data measured within a 500 km range from one of the 13 lidar stations have been converted to an HDF file for each collocated profile, resulting in about 32,000 profiles. MIPAS data are unavailable for the period April 2004 to January 2005. Since January 2005 MIPAS is operational again, but it only measures for 1/3 of the time and no profile data are yet available.

3.3 SCIAMACHY

SCIAMCHY performs observations in nadir- and limb-viewing, and solar/lunar occultation-viewing mode employing an UV-VIS-NIR spectrometer. Its retrieved ozone profiles are in the altitude range (typically) 15–50 km with 3–4 km vertical resolution. The retrieval of temperature profiles was originally foreseen by using the spectral observations of the NIR-channels, but this retrieval is obstructed by ice built up which corrupts the retrieval. The data used in this paper come from operational version IPF 2.5. Data from the operational processor using version 2.5 are available since 11-2004 until now, compromising about 7,000 orbit files (70 Gb). Part of these data have been converted to one HDF file per profile, and an (estimated) 18,000 ozone profiles are collocated within a 500km range of one of the 13 lidar stations. Since the start of the SCIAMACHY measurements in 07-2002, there have been no major interruptions of its operations.

4 QUALITY ASSESSMENT RESULTS

4.1 GOMOS Ozone

For the ozone analysis results we have compared GOMOS data measured within 500 km distance and within 20 hours of a lidar observation. These criteria result in 1410 useful collocations. From this data set we have selected (following the GOMOS data disclaimer) only those observations with a solar zenith angle (SZA) larger than 108 degrees (hereafter called dark) at the tangent point of the GOMOS observation. Comparison results are shown in Fig. 1. In addition, we have assessed the dependency of the results on the global region. The dark limb measurements have been sub-divided in profiles obtained in polar (66.5^o–90^o), mid-latitude (23.5^o–66.5^o) and tropical (0^o–23.5^o) regions, shown in the Fig. 2 left, middle and right panel, respectively.

4.2 GOMOS Temperature (HRTP)

The data of GOMOS HRTP have only recently become available. A preliminary validation has been performed by one of the EQUAL partners at NILU and results are presented in [4].

4.3 MIPAS Ozone

For the ozone analysis results we have compared MIPAS data measured within 400 km distance and within 10 hours of a lidar observation. These criteria result in 621 useful collocations. In order to compare the MIPAS data to lidar data, we converted the MIPAS pressure grid to a common geometric altitude grid using ECMWF data. The provided nominal altitude grid in the MIPAS files could not be used due to problems with the ENVISAT attitude problem. Comparison results are shown in Fig. 3. In addition, we have assessed the dependency of the results on the global region. The measurements have been sub-divided in profiles obtained in polar (66.5^o–90^o), mid-latitude (23.5^o–66.5^o) and tropical (0^o–23.5^o) regions, shown in the Fig. 4 left, middle and right panel, respectively. Analysis results also involving other correlative instruments are presented in [5].

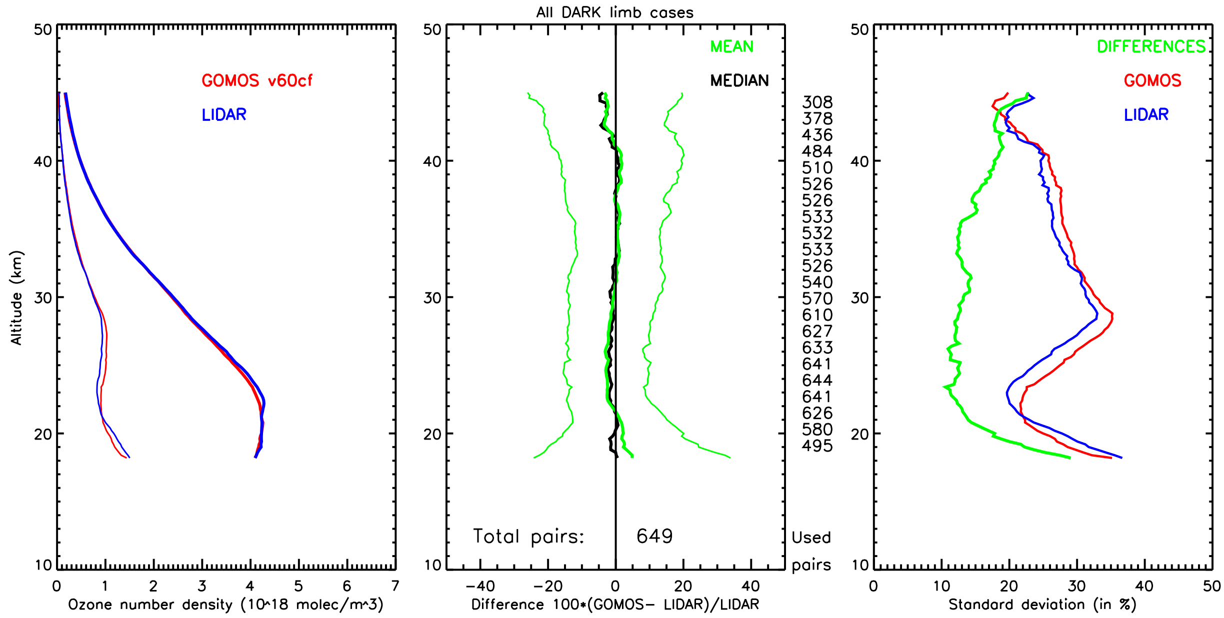

Fig. 1. Intercomparison results of GOMOS and LIDAR ozone data (SZA<108). Left panel shows the mean GOMOS (bold red line) and LIDAR (bold blue line) ozone profiles and their standard deviations (thin lines in corresponding colors). Middle panel shows the mean (green line) and median (black line) differences between all the paired GOMOS and LIDAR data as a percentage of the latter. For the mean profile, we also plotted the (1 σ) standard deviation of the differences (thin green line). Numbers at the right of the middle panel indicate, for some altitude levels, the number of pairs used at that level. Right panel shows a comparison between the standard deviation of the differences (green line) and the standard deviation of all GOMOS (red line) and LIDAR (blue line) ozone profiles.

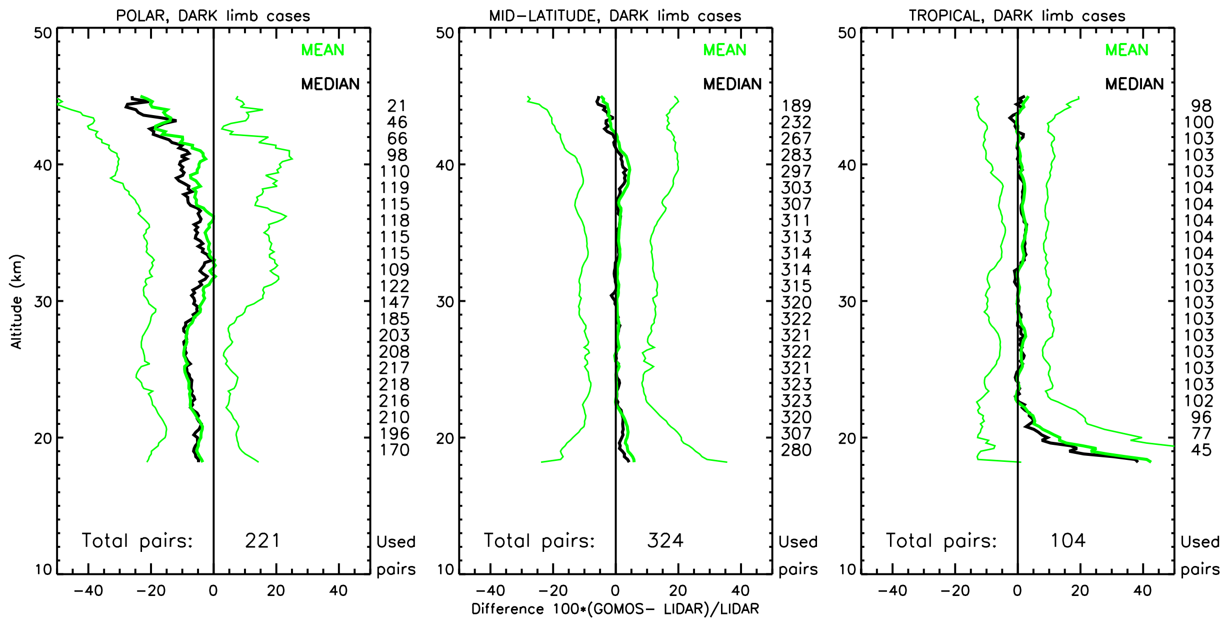

Fig. 2. GOMOS ozone. All panels show similar results as the middle panel of Fig. 1., but now using only the sub-selection of the paired data measured in the polar (left), the midlatitude (middle) and the tropical (right) regions.

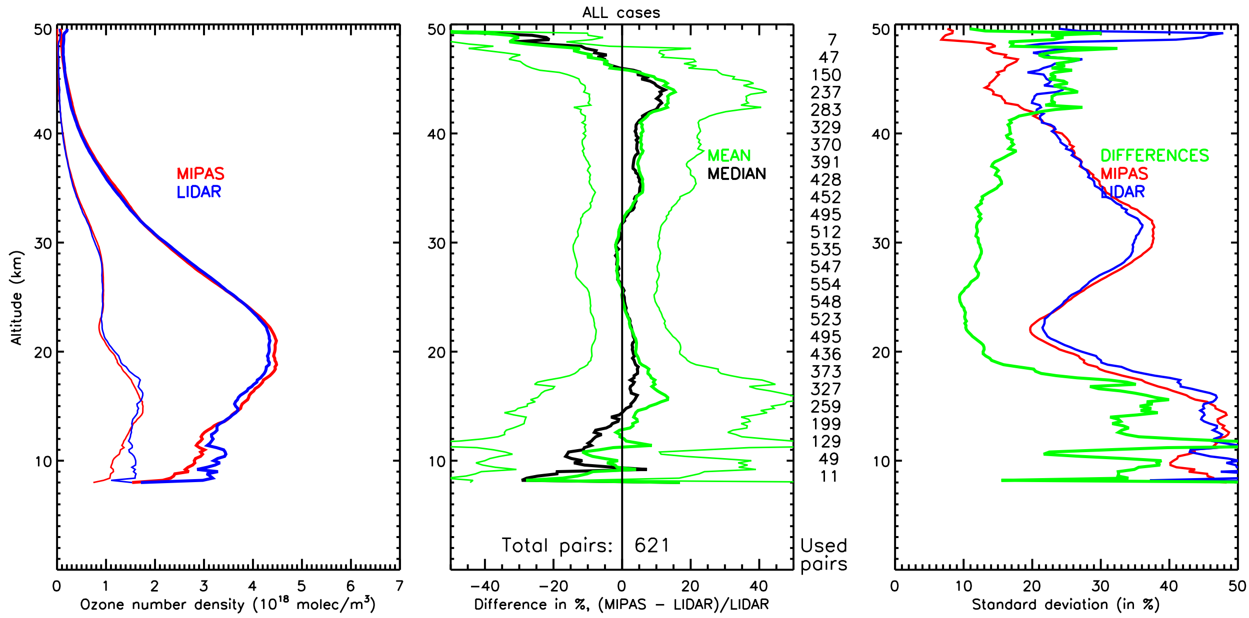

Fig. 3. Same panel definitions as in Fig. 1, but now showing results for MIPAS ozone profiles compared to lidar.

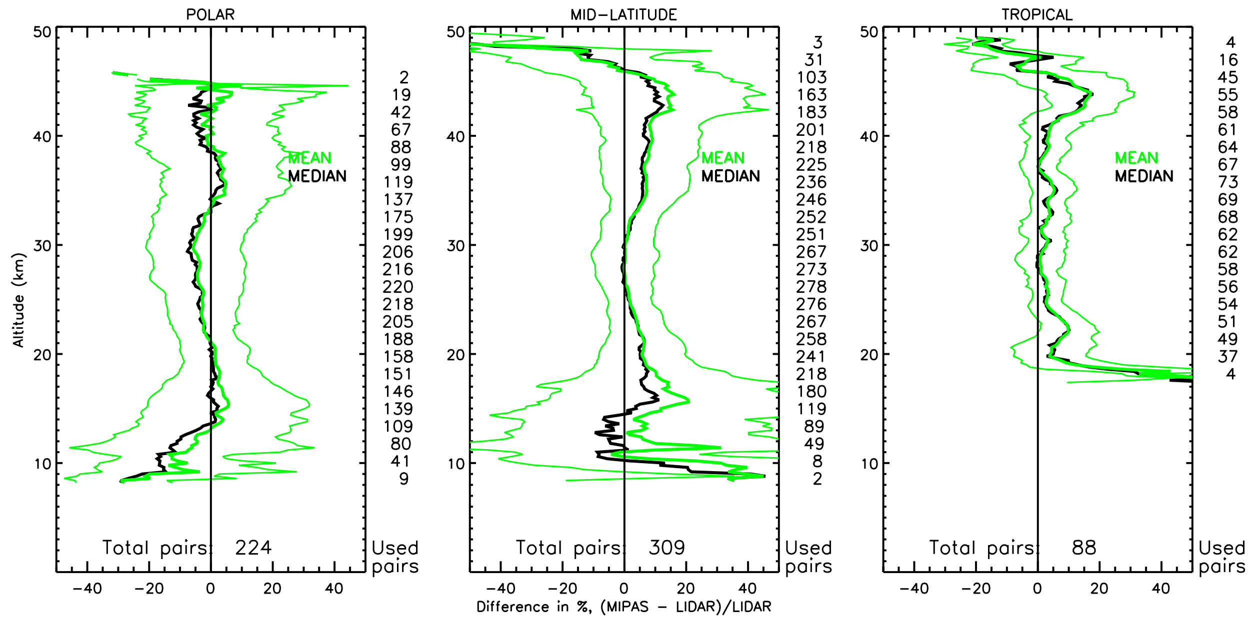

Fig. 4. MIPAS ozone. All panels show similar results as the middle panel of Fig. 3., but now using only the sub-selection of the paired data measured in the polar (left), the midlatitude (middle) and the tropical (right) regions.

4.4 MIPAS Temperature

For the temperature analysis results we have compared MIPAS data measured within 400 km distance and within 10 hours of a lidar observation. These criteria result in 433 useful collocations. In order to compare the MIPAS data to lidar data, we converted the MIPAS pressure grid to a common geometric altitude grid using ECMWF data. The provided nominal altitude grid in the MIPAS files could not be used due to problems with the ENVISAT attitude problem. Comparison results are shown in Fig. 5. More detailed analysis results are presented in [6].

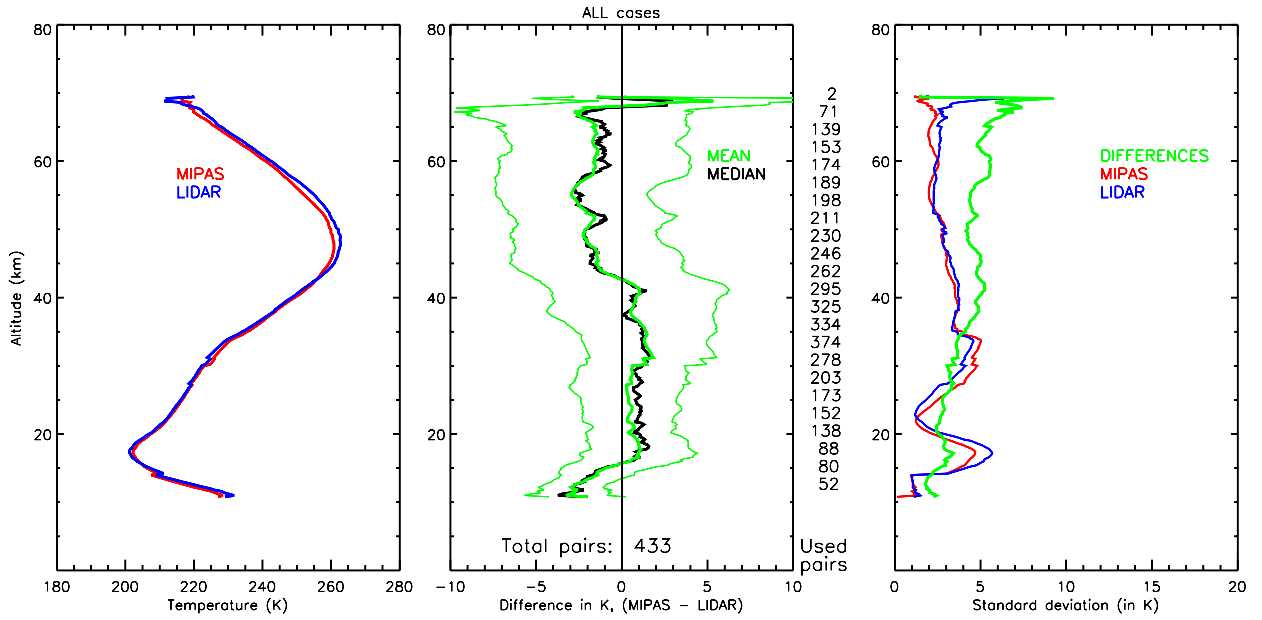

Fig. 5. Same panel definitions as in Fig. 1, but now showing results for MIPAS temperature profiles compared to lidar, and with absolute, rather than relative, differences presented in the middle and right panels.

4.5 SCIAMACHY Ozone (and Altitude Shift)

The SCIAMACHY data of IPF 2.5 have been evaluated in [7]. This current version suffers from the ENVISAT attitude problem which results in profiles shifted 1500 m upward. Validation awaits the release of operational processor version 3.0, which is scheduled for the end of 2006, and includes a new algorithm and corrections to the attitude problem.

5 CONCLUSIONS

The GOMOS ozone profiles from the reprocessed data set (future IPF 5.0) show an excellent agreement with LIDAR. A minor (5%) negative bias is observed in Polar Regions (NH), which will be part of ongoing investigations. The MIPAS ozone profiles from the reprocessed data set (IPF 4.61/4.62), from the mission in full-resolution mode, show a good agreement with LIDAR. A small bias is observed (+2.5%) in Mid-latitude and Tropical regions, while in Polar Regions it is -2.5%. SCIAMACHY results depend on correct ENVISAT attitude information and new data will be pre-validated before the final release of the new IPF (3.) processor version. Validation of the GOMOS HRTP is still at a preliminary stage, and is obstructed by the presence of many strong oscillating profiles. MIPAS temperature profiles show good agreement with LIDAR, with a mean bias compared to LIDAR smaller than 2 K, between 18 and 65 km altitude.

6 REFERENCES

1. ESA, Proceedings of ENVISAT Validation Workshop (Frascati, Italy, 9-12 December 2002), ESA SP-531, 2003.
2. Meijer, Y.J., et al., Pole-to-pole validation of Envisat GOMOS ozone profiles using data from ground-based and balloon sonde measurements, J. Geophys. Res., 109, D23305, doi:10.1029/2004JD004834, 2004.
3. Meijer, Y.J., et al., Overview of EQUAL Analysis Results (in support of ESL processor upgrade verification), EQUAL report, RIVM, Bilthoven, June 2005
4. Stebel, K., et al., Validation of the GOMOS high-resolution temperature product (HRTP) using lidar, Proceedings of Atmospheric Science Conference, Frascati 8-12 May 2006, ESA-SP, 2006.
5. Cortesi, U., et al., Co-ordinated validation activity and quality assessment of MIPAS ENVISAT ozone data, Proceedings of Atmospheric Science Conference, Frascati 8-12 May 2006, ESA-SP, 2006.
6. Ridolfi, M., et al., Geophysical validation of temperature retrieved by the ESA Level 2 processor from MIPAS/ ENVISAT measurements, Proceedings of Atmospheric Science Conference, Frascati 8-12 May 2006, ESA-SP, 2006.
7. Brinksma, E.J., et al., Geophysical validation of SCIAMACHY limb ozone profiles, ACP, 6, 197-209, 2006.