Validation of MIPAS version 6 cloud-processed ozone and temperature profiles

VALID

Satellite validation with lidar

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<u>Validation of MIPAS version 6 cloud-processed ozone and temperature profiles using ground-based and balloon-borne measurements.</u>

Data and methods

Validation data

In this study we have used ozone and pTu-sondes together with lidar and microwave radiometer data to validate the MIPAS ozone and temperature profiles. The data were acquired from the NADIR database, where the lidar data have been provided via the VALID projects.

An issue was identified with the ozone sonde data for Haute Provence and Dumont d'Urville. In some cases, the values provided for the fill value (VAR_FILL_VALUE) and the factor for the conversion to SI units (VAR_SI_CONVERSION) are incorrect. The data supplier and instrument PIs have been notified and a correction has been implemented.

MIPAS version 6 data

<u>Ozone</u>: collocations were sought within 800 km and 20 hours; MIPAS data were restricted to a maximum error of 30%. Furthermore, data are required to have valid values (0 or 1) for chi2_vmr_flag and marq_vmr_flag. The quality_flag (o3_retrieval_mds) for the full profile may not be -1 and only data within the profiles where lrv_vmr_flag equals 1 are used. The following matches were found after application of the averaging kernels:

10536 matches with balloon soundings: applicable altitude range: ground - 30 km
8147 matches with lidar profiles: applicable altitude range: 18-45 km
2769 matches with microwave radiometer profiles" applicable altitude range: 30-70 km

MIPAS averaging kernels (AVKs) have been applied for the ozone profile comparison; subsequent filtering on convoluted data to remove outlier values <0 & $>10^{19}$ molec/m^3. All data are compared on the corrected altitude axis as no pressure is retrieved by the lidars and the altitudes of the averaging kernel correspond to the corrected altitude grid data. MIPAS data at altitudes with a flag indicating a bad retrieval are not considered. At the edges of the profiles errors may be introduced due to the application of the averaging kernels if the corresponding altitude range is only partially covered by the ground-based data.

<u>Temperature</u>: data were collocated within 300 km and 5 hours; MIPAS data were restricted to a maximum error of 5 K. Data are required to have valid values (zero or one) for chi2_p_t_flag and marq_p_t_flag. The profile's quality_flag (pt_retrieval_mds) may not be -1 and only data within the profile having lrv_pt_flag equal to 1 are used.

Data were compared both on the engineering (numbers between brackets) and the corrected altitude grid. The datasets consisted of the following combinations:

5335 (5335) matches with sondes: applicable altitude range: ground - 30 km
588 (591) matches with lidar profiles: applicable altitude range: 15 - 70 km (instrument dependent)

No averaging kernels have been applied as the available AVKs appear to be on the pressure grid.

Important!

The figures from the two MIPAS versions are not fully comparable as the available datasets do not have the same number of collocating pairs, which can introduce differences due to spatial/temporal /instrumental issues.

Temperature

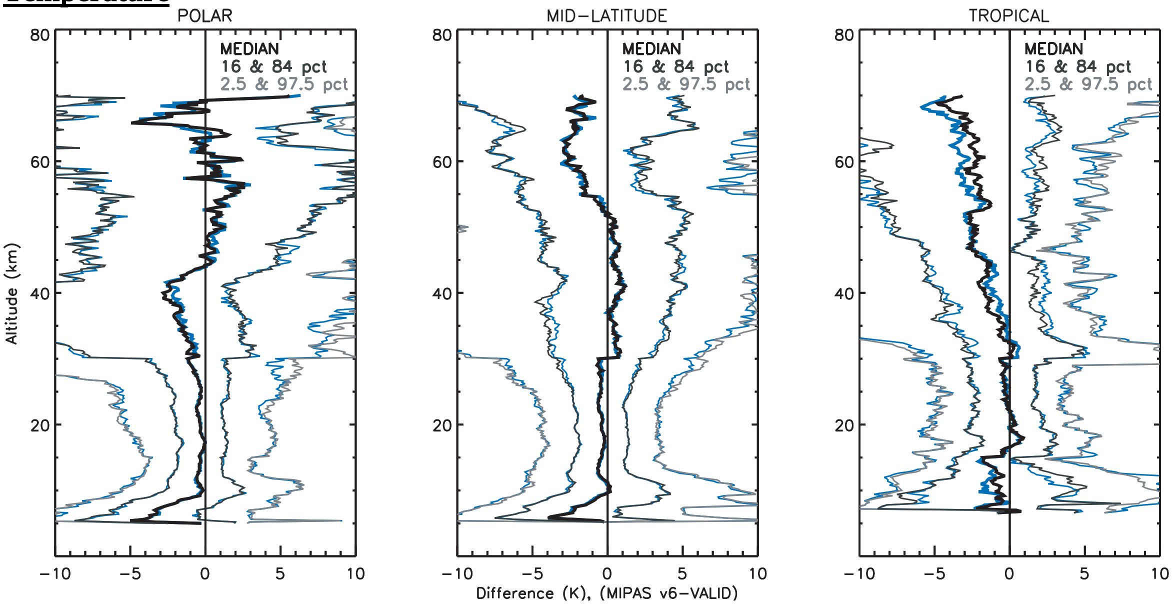

Figure 1. Validation results for MIPAS version 6 temperature based on the engineering altitudes (black) and corrected altitudes (blue) for the three latitude regions; from left to right: polar, mid-latitudes and tropics. Shown are the differences (various percentiles corresponding to the median and the mean plus minus 1 and 2 sigma for a normal distribution) with respect to the verification data (lidar and sonde) as a function of altitude. The number of cases is not shown as they differ between altitude groups, although they are similar.

Figure 1 shows that no obvious improvements are seen when using the corrected altitude axis, but this version does not yet have the correction based on ECMWF data implemented.

The results of version 6 are very similar to those obtained with version 5.05. We still observe an apparent shift in altitude, especially for the mid-latitude and strongest in the tropics. In the polar regions, we see that the fit is best for the Northern hemisphere (Figure 2, upper row), whereas the comparison on the Southern hemisphere (Figure 2, bottom row) shows substantial deviations. For the altitudes above 30 km, these are all in comparison to the Dumont d'Urville lidar, where the bias is ranging from +7K to over -10K (off-scale, see Figure 3). The sonde data from Dumont d'Urville also show a strong deviation (~-5K, not shown), but few collocations were found. A more detailed study is required to investigate if these differences are due to local heterogeneity.

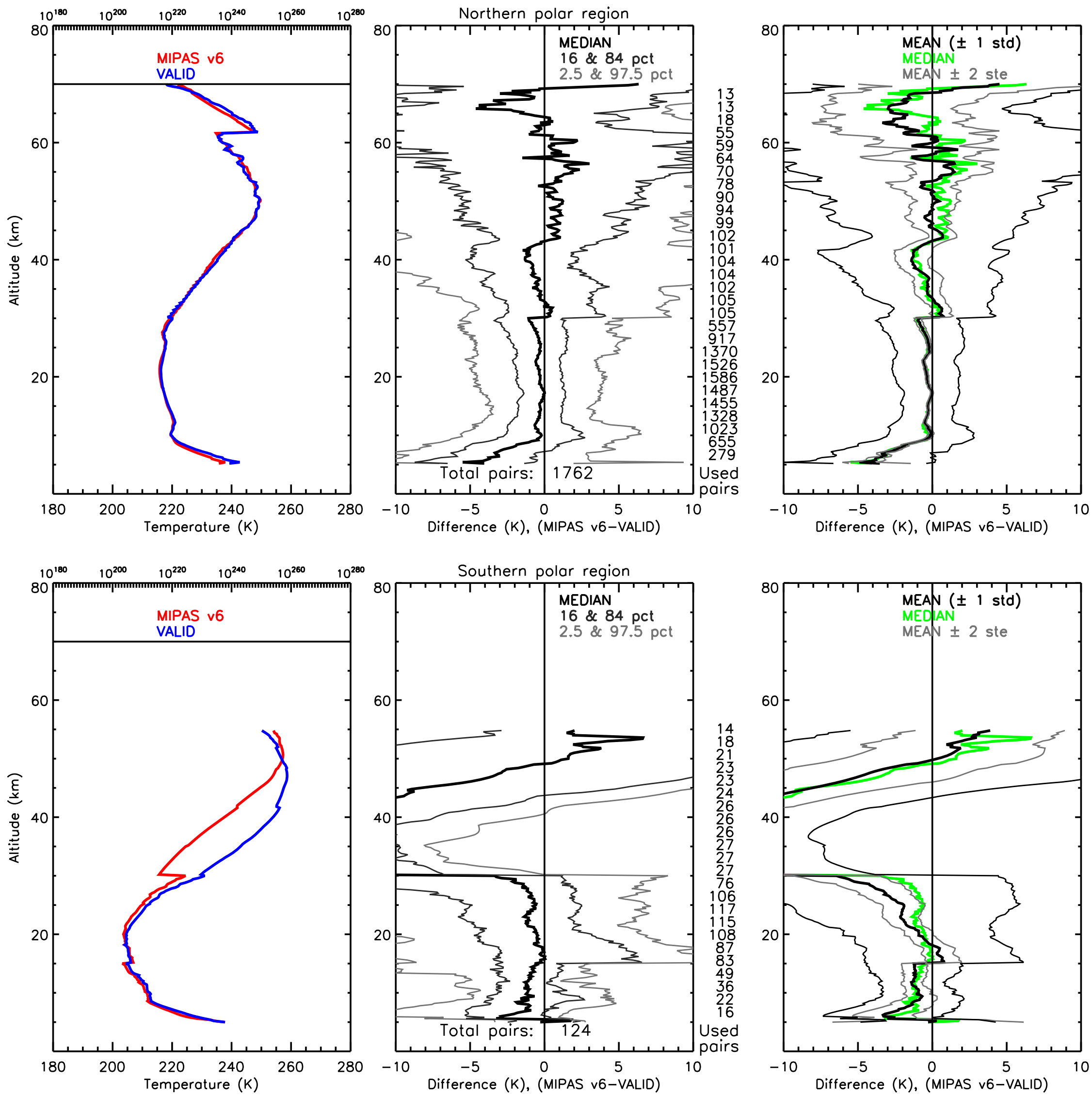

Figure 2. Top: Northern polar region. Bottom: Southern polar region. Left panels show the mean temperature as a function of altitude for MIPAS in red and for the lidar in blue. The middle panels show the mean (thick black line) deviation plus/minus 1 standard deviation (thin black lines) and 2 standard errors (thin grey lines) together with the median deviation. On the right axes the number of collocations for a given altitude is shown. The right panels show the 5 percentile deviations as in Figure 1.

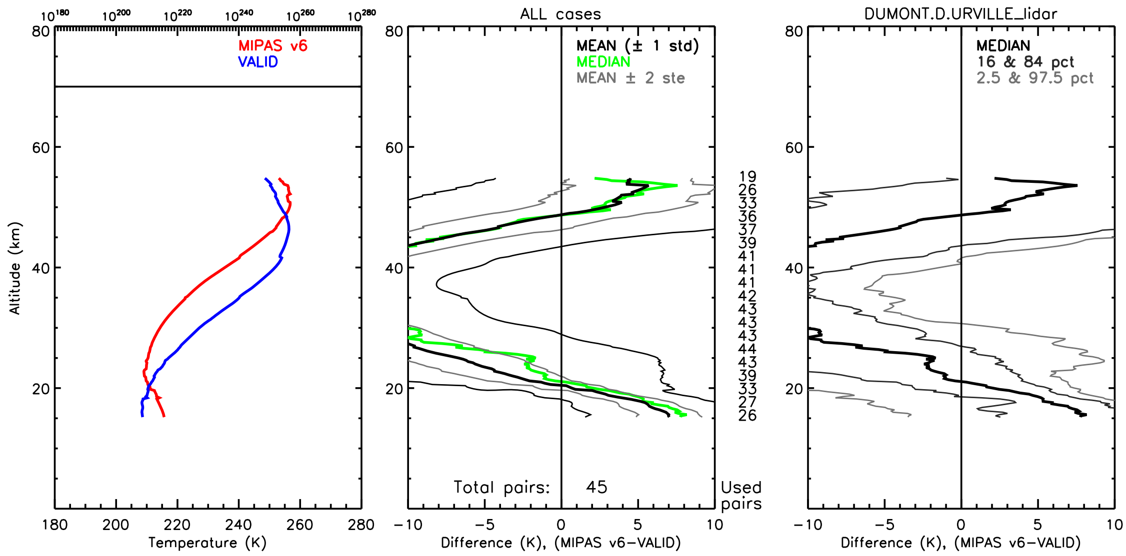

Figure 3. Validation results using the Dumont d'Urville lidar. Engineering altitude grid is used. Plot composition as in Figure 2.

The other lidar site on the southern hemisphere providing data for this study is La Reunion. Here we see a persistent cold bias that is increasing with altitude (Figure 4) which requires further study as the comparison at the other tropical lidar site - Mauna Loa - does not exhibit such a behaviour (Figure 5).

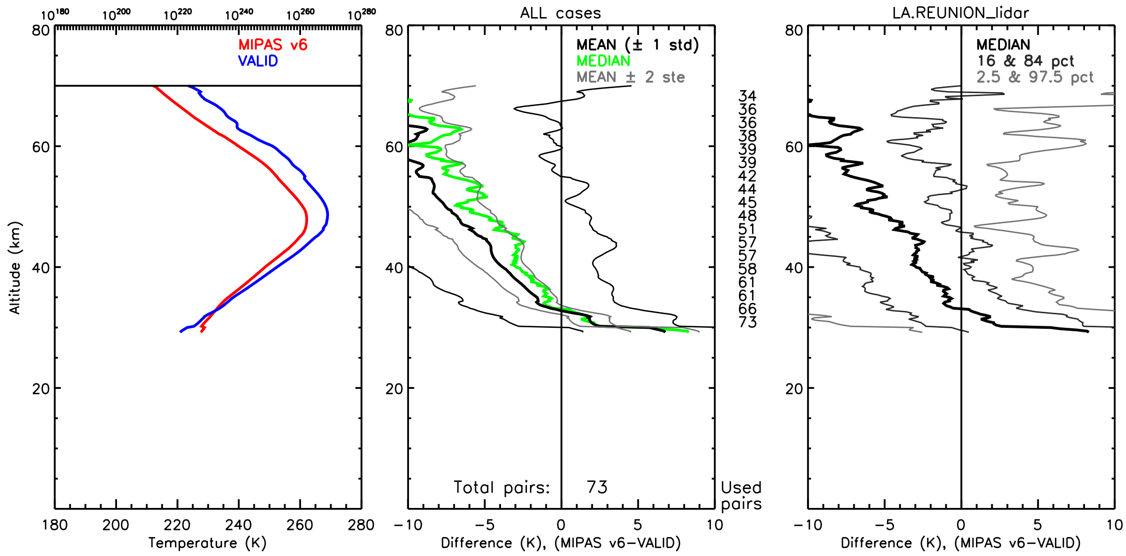

Figure 4. Validation results using the lidar at La Reunion. Engineering altitude grid is used. Plot composition as in Figure 2.

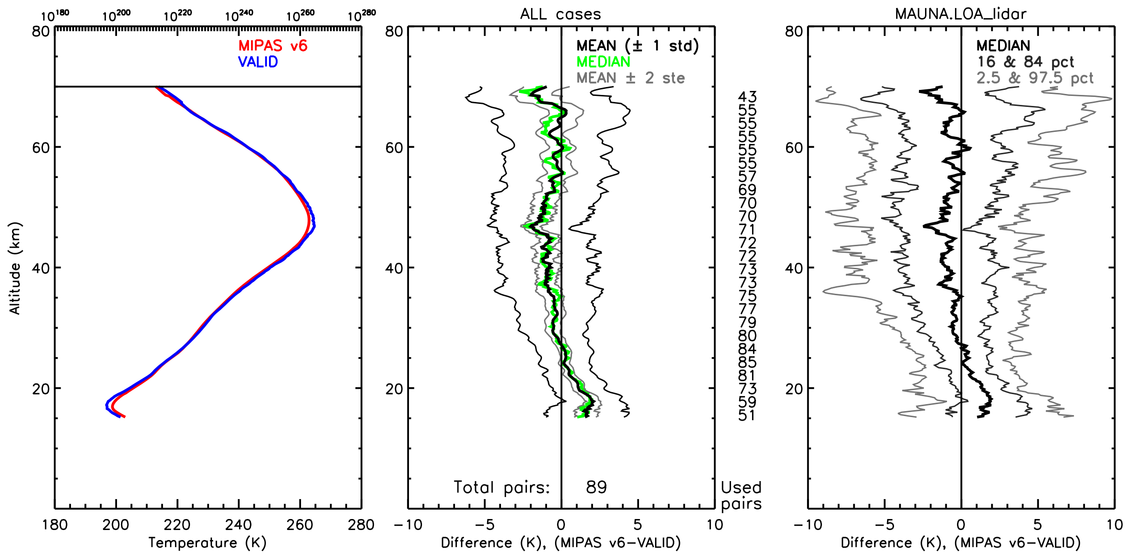

Figure 5. Validation results using the lidar at Mauna Loa. Engineering altitude grid is used. Plot composition as in Figure 2.

Ozone

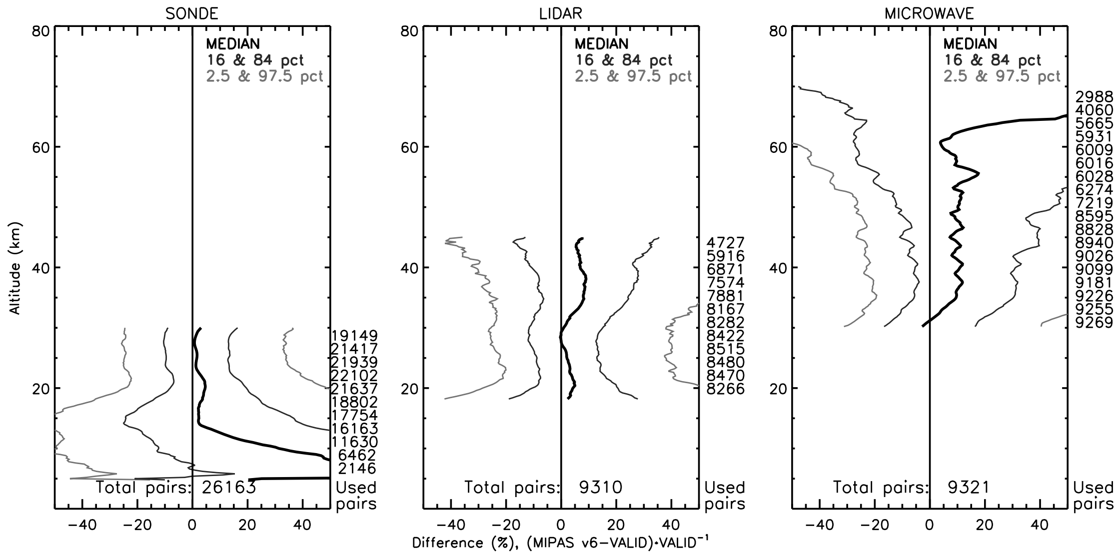

Figure 6. Validation results for the MIPAS v6 ozone profiles compared to the three verification instruments: sonde (left), lidar (middle) and microwave radiometer (right) without application of the averaging kernels. Shown are the percentiles as before of the percent differences with respect to the verification instruments (MIPAS v6 - validation)/validation. Sonde data have been smoothed to a resolution of 3 km.

Figure 6 presents the validation results for MIPAS version 6 data grouped by validation instrument without application of the averaging kernels. The instrument are fairly consistent with each other. Most of the collocated microwave radiometer data originate from the Payerne and Ny Alesund stations. Note that the averaging kernels belonging to the groundbased instruments have not been applied.

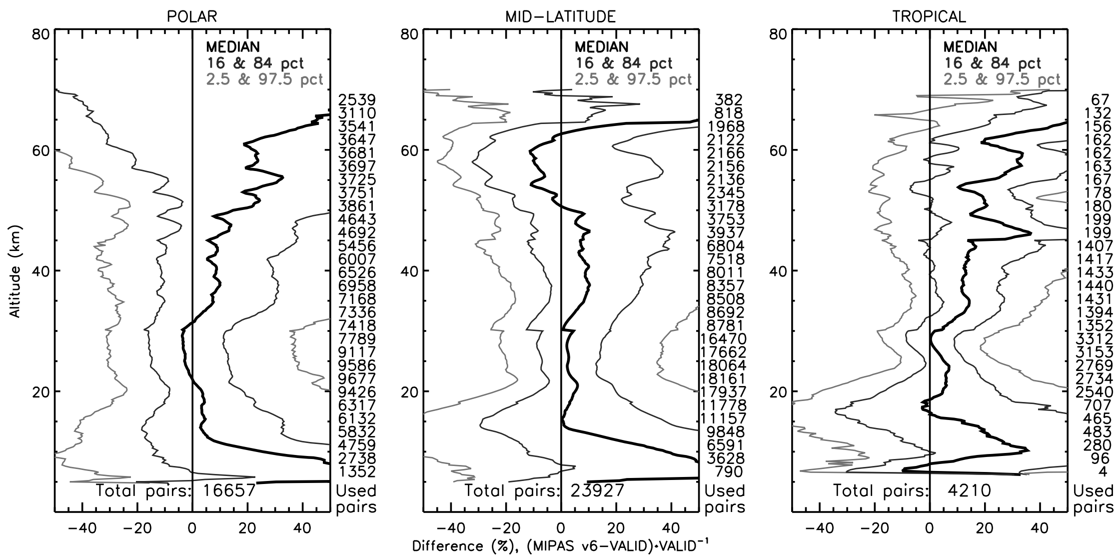

Figure 7. As Figure 6 but showing the results grouped by latitude region.

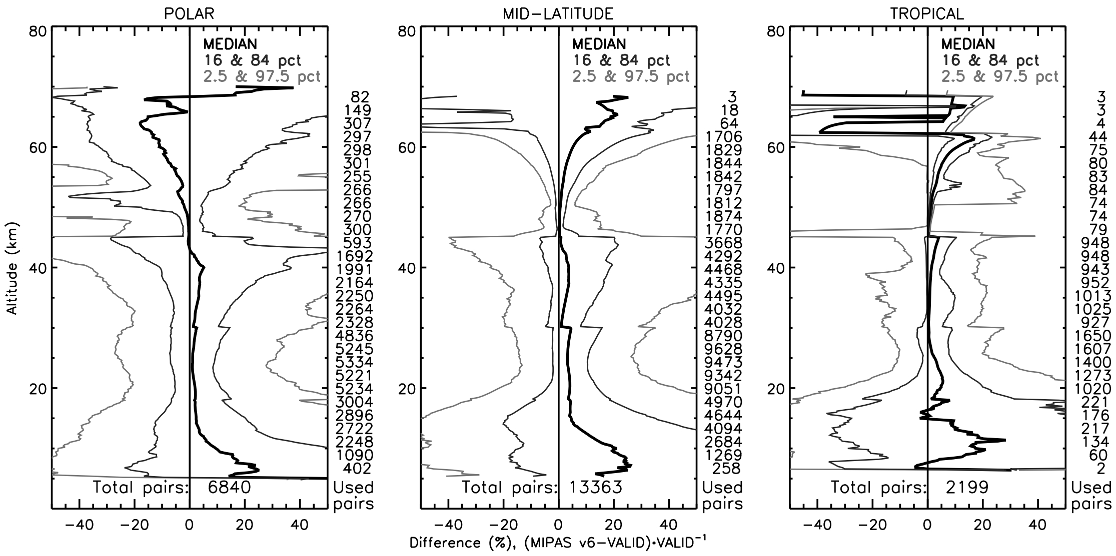

Figure 8. As Figure 7 but with MIPAS averaging kernels applied

From Figure 7 and Figure 8 we can see that with MIPAS' glasses on, differences with the validation instruments are reduced, but so is the number of valid data points. With averaging kernels applied, the agreement is very good for altitudes between ~15 and 50 km. In the mid-latitudes there is a small positive bias and at all latitudes there is a strong overestimation at the lowest altitudes. No differences except in the number of used collocations are seen when limiting the data to have a value of 0 for both the chi2_vmr_flag and marq_vmr_flag (Figure 9).

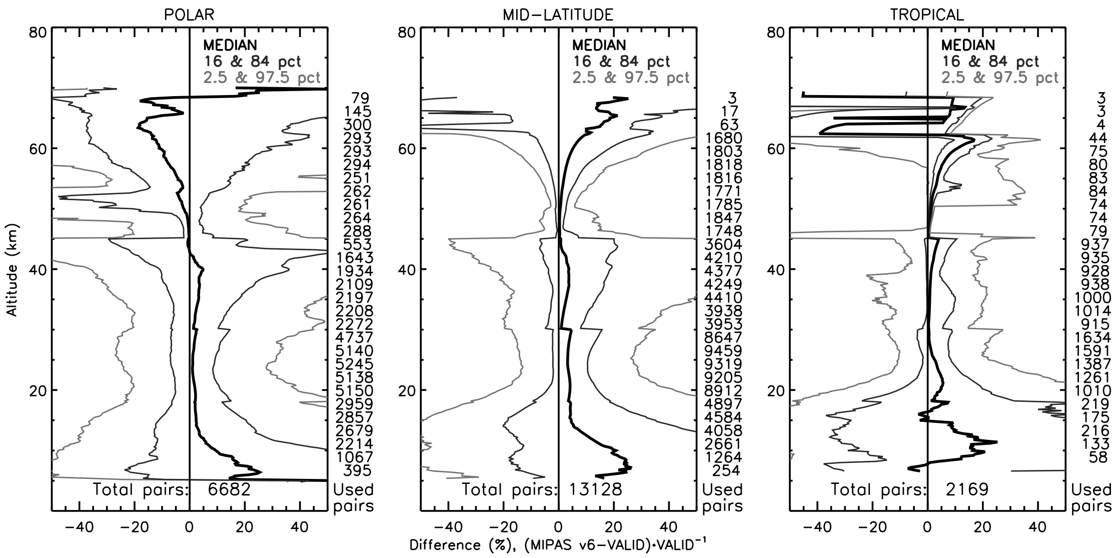

Figure 9. As Figure 8 but limited to MIPAS data having both the chi2_vmr_flag and marq_vmr_flag equal to zero.

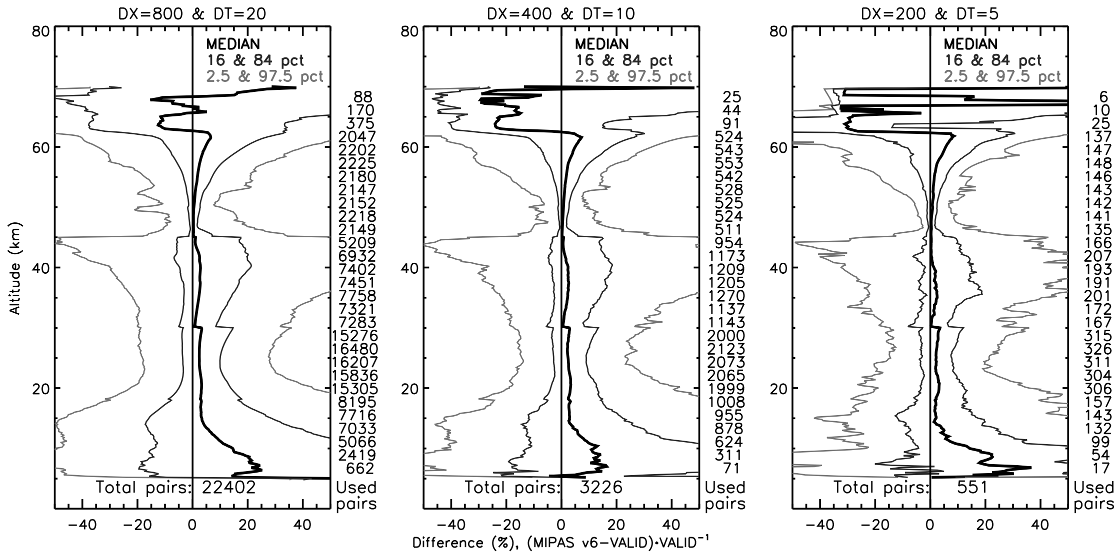

Figure 10. Influence of collocation criteria on validation results. Left panel: max. 800 km and 20 hours (5 hours above 50 km) difference, middle panel: max. 400 km and 10 hours (5 hours above 50 km) difference, and right panel: max. 200 km and 5 hours difference.

No improvements in comparison results are observed for more stringent collocation criteria (Figure 10).

Conclusions in short

No best altitude axis (engineering/corrected) can be identified from the validation results. The next MIPAS level 2 version is expected to include ECMWF data-derived altitudes.

Although the numbers of pairs used in the comparison are not equal, no extreme differences are observed between versions 6 and 5.05. These were also not anticipated.

MIPAS temperatures appear to be on the cold side compared to lidar in the upper stratosphere for the tropics and in the mesosphere also for the mid-latitudes. There, agreement with the lidar and sonde (not used above 30 km) is within 1 K down to 10 km. In the tropics, this is the case between 16 and 35 km and in the polar regions from 10 to 30 km.

For ozone, we see an overestimation by MIPAS below the about 15 km at all latitudes. Above there is a very good match with the validation instruments up to about 55 km. Above the mentioned upper altitudes MIPAS is overestimating the ozone concentrations except in the polar region. Compared to the lidar data alone, differences are between 0 and 5% when the averaging kernels are applied and between 0 and 8% without, with MIPAS predicting too large ozone concentrations.