

# VALIDATION OF GOMOS, MIPAS AND SCIAMACHY OZONE AND TEMPERATURE MEASUREMENTS BY GROUND BASED MEASUREMENTS AT UCCLE (BELGIUM)

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## ABSTRACT

The ozone and temperature measurements by the three atmospheric physics instruments GOMOS, MIPAS and SCIAMACHY aboard the ENVISAT satellite are being compared with the measurements performed with the Brewer 16 spectrophotometer and the ozone- and radiosoundings at the Royal Meteorological Institute of Belgium.

Regarding the SCIAMACHY total ozone values, there is a negative bias of about -5% compared to our Brewer measurements. There was no possibility to study the influence of clouds or solar zenith angle. The importance of the distance of the SCIAMACHY pixel from our stations is shown.

The GOMOS ozone profiles have been compared to our ozone soundings, but due to the poor quality of the GOMOS profiles measured during daytime, the comparison is made in a qualitative way. For the temperature measurements, there was more co-located data available using radiosondes. The GOMOS low resolution temperature profiles compare very well with the radiosonde profiles. However, from the data it was not clear which values were actually retrieved and which values were taken from a climatology.

The MIPAS temperature measurements have been analyzed as a function of distance, pressure level and time of measurement. The general agreement with the radiosonde data is within 2%. There is an indication of a dependency on the altitude when using nighttime data which has to be confirmed when a larger dataset becomes available.

## 1 Reference datasets

Since the late 1960's, total ozone measurements at Uccle (50.8N, 4.35E) are being performed with the Dobson n° 40 spectrophotometer. During 1983 the automated Brewer n° 16 spectrophotometer became operational. In this study, only the measurements of the latter have been used. A detailed description of the calibration of the spectrophotometer can be found in [1]. The most reliable Brewer total ozone measurements are the direct sun measurements, which have an accuracy of about 1%. However, when a direct sun measurement is impossible because of e.g. cloudiness, less reliable zenith sky measurements are performed. The accuracy of the zenith sky measurements for our Brewer instrument is investigated in [5] and is not more than 3% higher compared to the direct sun measurements. In this study, both direct sun and zenith sky measurements have been used in order to obtain a larger dataset.

Ozone sounding measurements have been used for the validation of the GOMOS and MIPAS ozone profiles. At the Meteorological Institute of Belgium, an extensive dataset of 31 years of regular ozone soundings (3 times/week) is available. Until March 1997 the sondes were of the Brewer-Mast type, from then on ECC-sondes are in use. In order to ensure the homogeneity and quality of the dataset, several studies have been carried out [3, 4, 6, 8]. The dataset has been used for previous validation efforts e.g. for the validation of satellite data [7] and lidar [2] data. In addition to the routine sounding launches, several ozone sondes have been launched in order to achieve better co-locations.

For the validation of GOMOS and MIPAS temperature profiles, the dataset of radiosoundings available at the institute has been used. Radiosondes (of the VAISALA type) are launched twice a day (at noon and at midnight) in the framework of the Global Observing System of the WMO (World Meteorological Organisation). This large dataset allows us to validate much more temperature profiles compared to the ozone profiles.

## 2 SCIAMACHY Total Ozone Validation

We have compared SCIAMACHY total ozone values with the ozone measurements of our Brewer spectrophotometer for the period from the 17th of September to the 31th of October. Only the pixels closer than 400 km from Uccle and within a

3 hour time window from a Brewer measurement were taken into account. In figure 1, the results are plotted. In the upper graph, the total column (in Dobson units) of the Brewer instrument is plotted in red, the SCIAMACHY pixels are plotted in black.

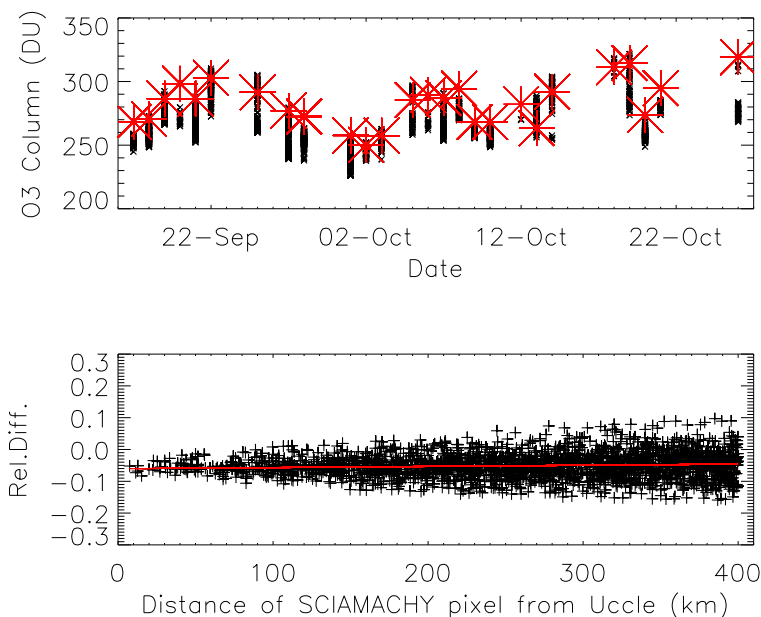


Fig. 1: Upper plot : Brewer measurements in red, SCIAMACHY measurements in black for the period from 17th of September to the 26th of October 2002. Lower plot : The relative difference between Brewer and SCIAMACHY ( $(S-B)/B$ ) versus distance.

From figure 1, we can conclude that first of all, there is a clear bias between the two datasets. The SCIAMACHY instrument seems to underestimate the total ozone values with respect to the Brewer instrument. The mean difference is about -5% with a standard deviation of 4%. Also, the scatter of the differences becomes clearly larger the further the pixels are away from our station. Therefore, when more data will be available, it would be advisable to use only the closest pixels in space and time. As an illustration of the negative bias, a scatter plot is shown in figure 2.

Unfortunately, there was little extra information available about the pixels like e.g. the solar zenith angle or cloudiness. The influence of these factors on the SCIAMACHY total ozone data quality will be the subject of further investigation.

### 3 GOMOS Temperature and Ozone Profile Validation

As already mentioned in the introduction, the GOMOS temperature and ozone profile measurements will only be presented in a qualitative way because of the small amount of profiles available. In addition to the already short period of retrieved profiles, the dataset is even further diminished because of the problems GOMOS encounters when measuring during the day. Unfortunately, the majority of our ozone soundings are launched at noon, which will complicate the comparison because of the (sometimes) large time difference between GOMOS measurement and balloon launch. Only a few individual comparisons with our radio- and ozonesoundings will be shown. Our findings however, will be included in the overview articles dealing with GOMOS temperature and ozone measurements.

#### 3.1 GOMOS Low Resolution Temperature Profiles

In figure 3, six different GOMOS low resolution temperature profiles have been plotted together with a temperature profile obtained from the closest radiosounding in space and time. The time difference never exceeds 24 hours and the the GOMOS profiles lie within a 1000 km range from our station. The radiosounding has been rebinned to reflect the resolution of the GOMOS profile using a Gaussian smoothing function. The agreement between the two datasets is actually very good, as can be seen in figure 4. From this figure, we conclude that the agreement is within 1%, with a

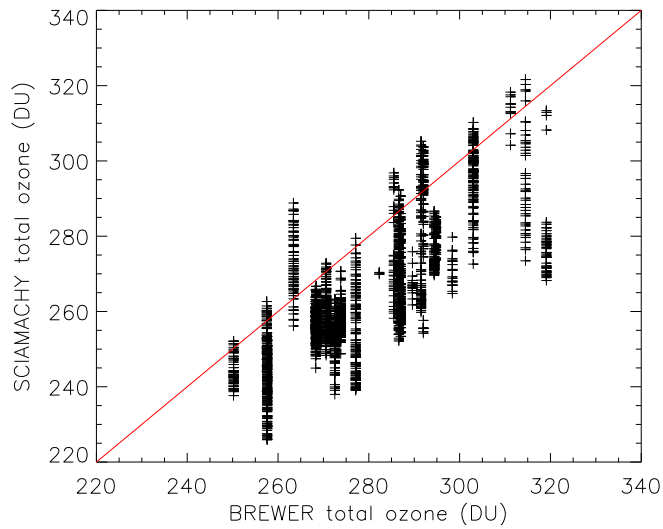


Fig. 2: Scatter plot of SCIAMACHY and Brewer total ozone measurements (in Dobson units).

positive bias. Ofcourse, one has to be very cautious in the interpretation of this plot because of the small dataset used (10 profiles). An additional complicating factor is that the GOMOS temperature profiles are contaminated with climatological values (see [9]). It was impossible to determine which values were actually retrieved from the measurement and which values were not.

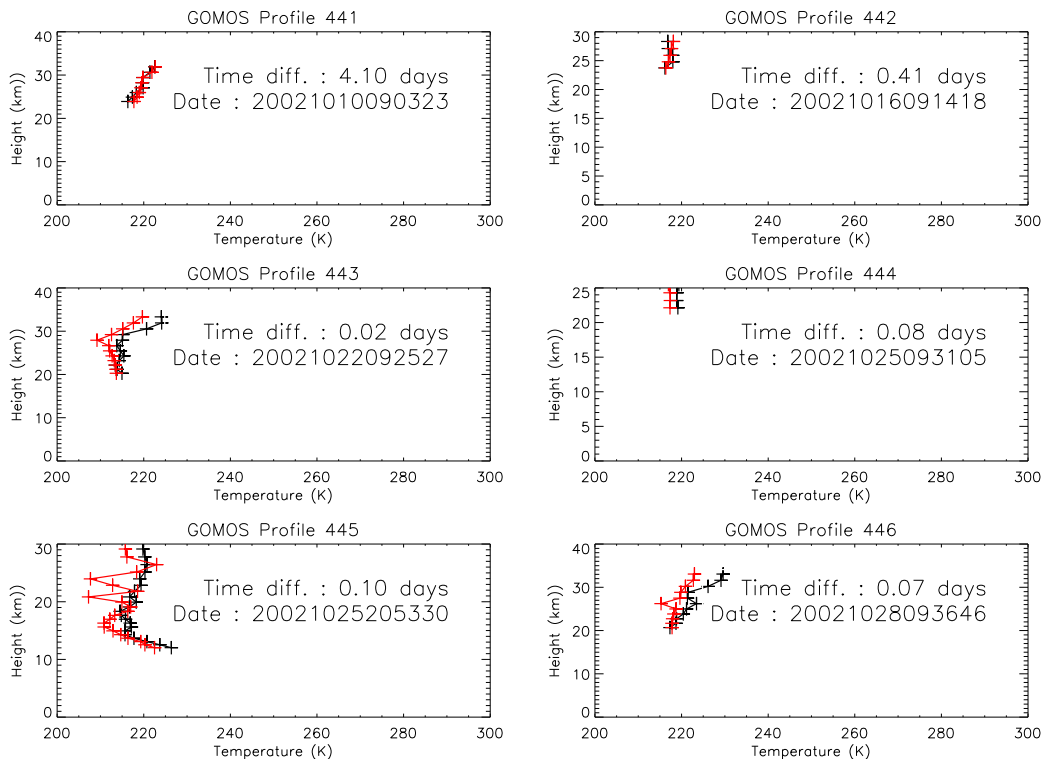


Fig. 3: Six GOMOS temperature profiles (red) and the closest profile from a radiosounding (black). The radiosounding has been rebinned to the resolution of the GOMOS profile using a Gaussian smoothing.

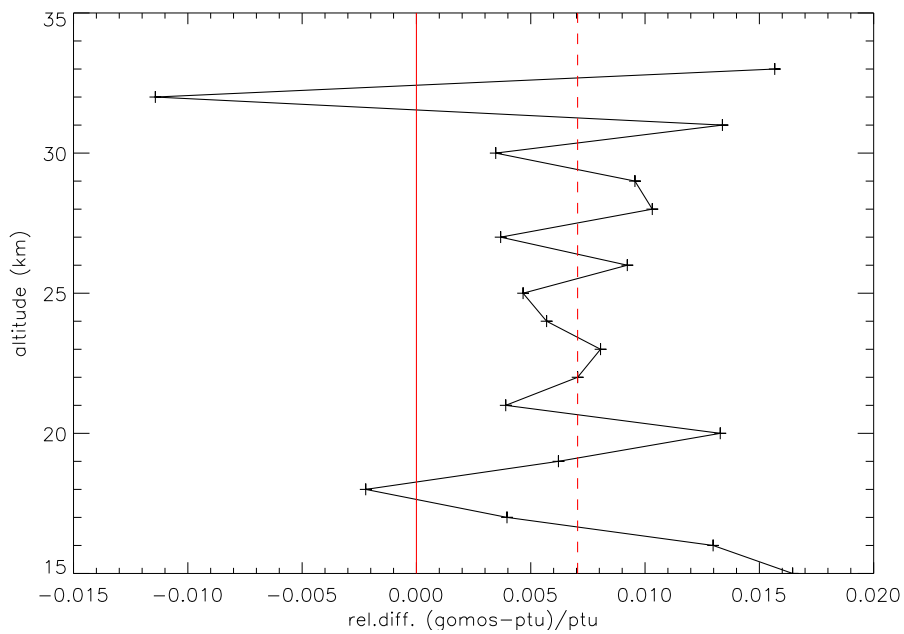


Fig. 4: Relative difference between GOMOS and radiosounding,  $(\text{GOMOS} - \text{sonde})/\text{sonde}$ , for different height levels.

### 3.2 GOMOS Ozone Profiles

To illustrate that GOMOS is able to retrieve ozone profiles of good quality, provided they are measured after sunset, we have plotted in figure 5 a GOMOS profile together with an ozonesounding profile. The GOMOS profile follows nicely the shape of the ozonesounding profile, but at lower altitudes an oscillatory behaviour shows up. At the institute, we are launching extra ozone soundings after sunset and close to a GOMOS overpass in order to obtain a good co-located dataset that will allow us to draw quantitative conclusions about the GOMOS ozone profile quality.

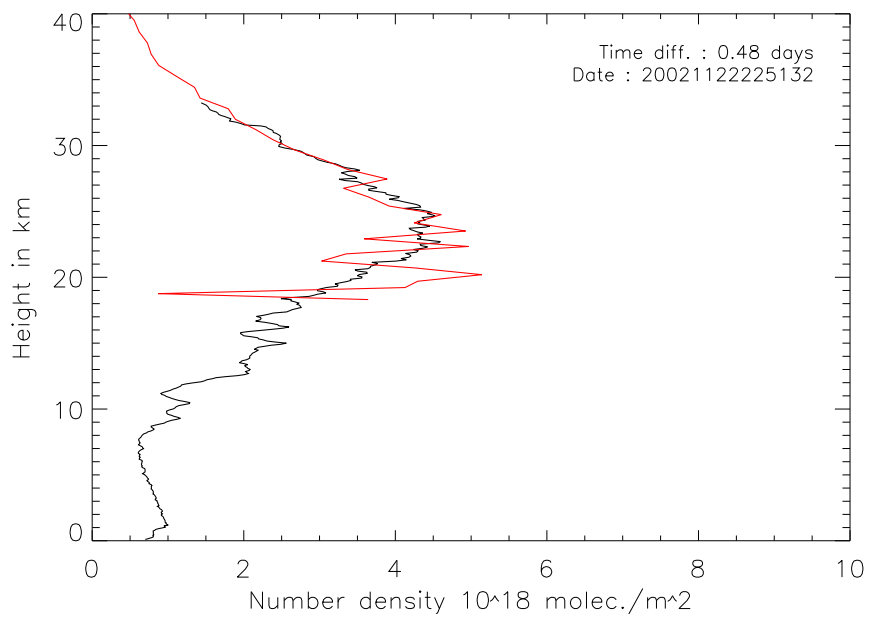


Fig. 5: Illustration of a GOMOS ozone profile (red), plotted together with an ozone sounding (black).

## 4 MIPAS Temperature and Ozone Profile Validation

Regarding the MIPAS data, we have focussed our efforts on the validation of the temperature profiles for the period from the 24th of October until the 26th of November. Similar to the GOMOS validation, the MIPAS ozone profiles are only added as an illustration.

### 4.1 MIPAS Ozone Profiles

MIPAS ozone profile are only shown to illustrate the altitude correction applied in the data processor on the 13th of November. After this date, an in-flight line-of-sight calibration has been performed. Figure 6 shows in the left an uncorrected ozone profile and in the right a profile with the altitude correction applied. The importance of the correction is clear, the altitude shift apparently has disappeared completely. Still, it would be advisable to perform the validation of the ozone profiles versus pressure so the whole dataset from July 2002 on, can be used.

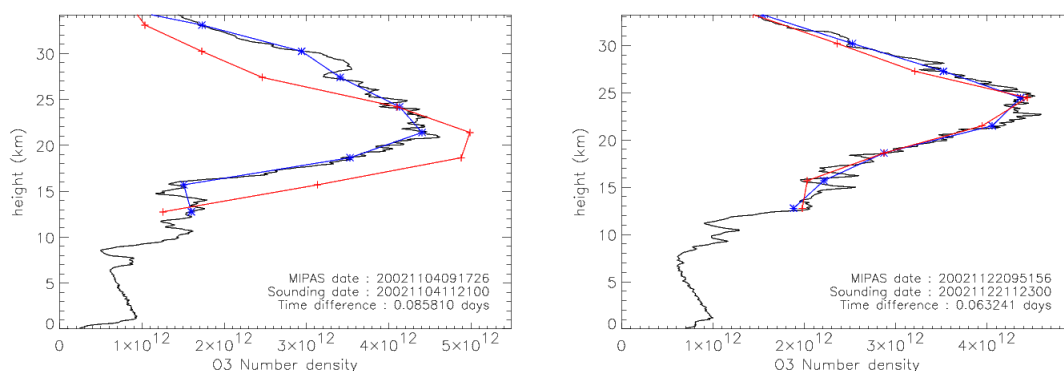


Fig. 6: Left : MIPAS profile (red), ozone sounding profile (black) and rebinned ozone sounding profile (blue) before the altitude correction. Right : after the altitude correction.

### 4.2 MIPAS Temperature Profiles

Similar to the GOMOS temperature measurements, we have used the data obtained from radiosoundings to validate the MIPAS temperature profiles. Because the balloon soundings do not provide us with an independent measurement of the altitude, all profiles have been analyzed versus pressure. This also means that our study will not be influenced by the error in the MIPAS altitude registration. In general the time difference between a radiosounding measurement and a MIPAS overpass never exceeded two hours. The influence of the distance from Uccle, the time of the day and the temperature itself on the agreement between MIPAS and radiosounding has been investigated.

Before comparing the radiosonde profile to the MIPAS profile, the radiosonde profile has been smoothed using a Gaussian function. This way the two profiles have the same resolution and the comparison will be more reliable.

#### 4.2.1 General agreement

The frequency plot in the left of figure 7 shows good agreement between MIPAS and radiosounding temperature measurements. The mean difference using all the data from all height levels is 0% with a standard deviation of 2%. The plot on the right side shows the relative difference at the various altitude levels as the logarithm of the pressure. There does not seem to be a statistically significant dependency of the relative difference on the altitude. The standard deviation increases with height because of the lower number of radiosonde data at higher levels.

#### 4.2.2 Distance

For the investigation of the influence of the distance of the MIPAS measurement from Uccle on the data, we have plotted the relative difference of the data of all height levels in figure 8. The plot shows that beyond about 500 km, large

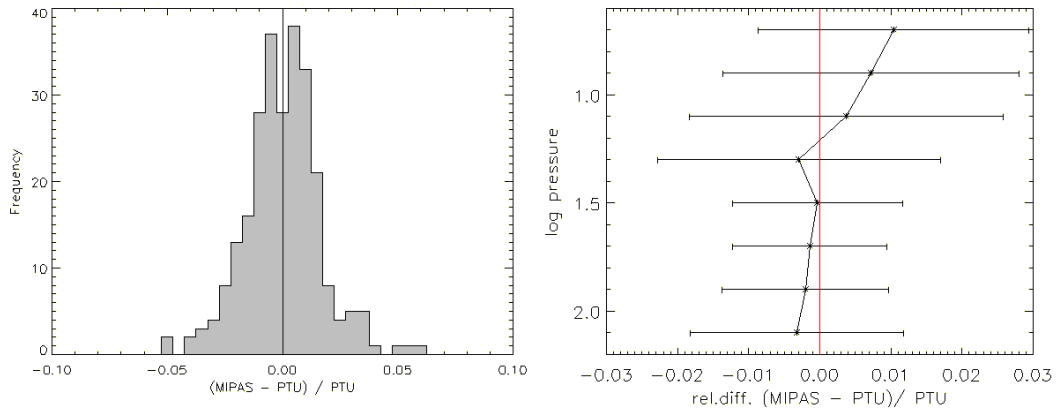


Fig. 7: Left : Frequency distribution of the relative difference between MIPAS and radiosondes. Right : Relative difference at different height levels (in log pressure) and the associated standard deviation. All MIPAS profiles within a 1000 km range from Uccle were used.

differences show up. This means that the two instruments are probably probing different airmasses. It is therefore important to use appropriate criteria when choosing which profiles can be compared to each other. Nevertheless, because of the small dataset available at this moment, we have included also the profiles further than 500 km from our station. This should be kept in mind when interpreting the results.

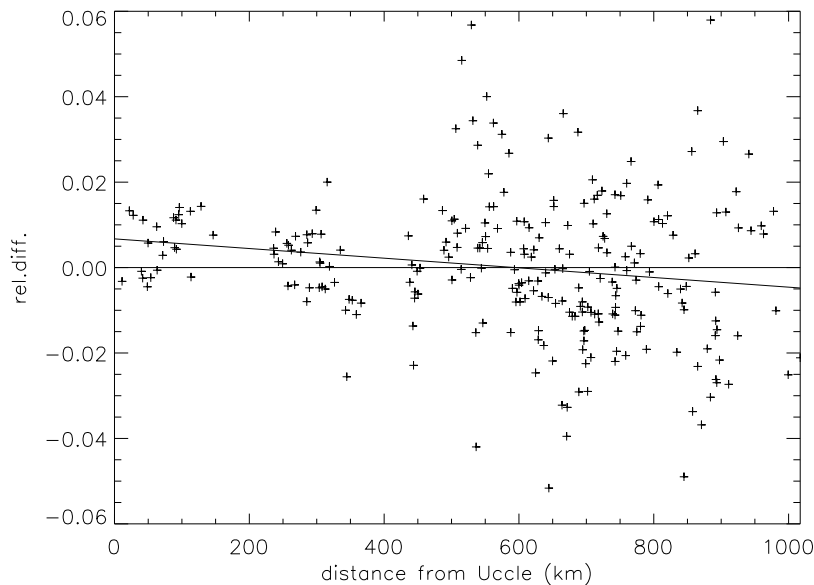


Fig. 8: The difference between MIPAS and radiosonde temperature versus distance from Uccle, all heights combined.

#### 4.2.3 Temperature

The relative difference between MIPAS and radiosonde versus radiosonde temperature for all height levels is plotted in figure 9. We have made a distinction between the MIPAS profiles closer than 500 km from Uccle (the square datapoints) and those between 500 and 1000 km from Uccle (the plus-signs). For both sets, the linear fit is also shown (in red for the close profiles, in blue for the others). Using all profiles an indication of an underestimation by MIPAS at higher tempera-

tures and an overestimation at lower temperatures can be seen, although the results are not statistically significant at this stage. This discrepancy is reduced when taking into account only the profiles closer than a 500 km range from our station, which indicates that the comparison is probably influenced by a horizontal temperature gradient present at the time of the measurement.

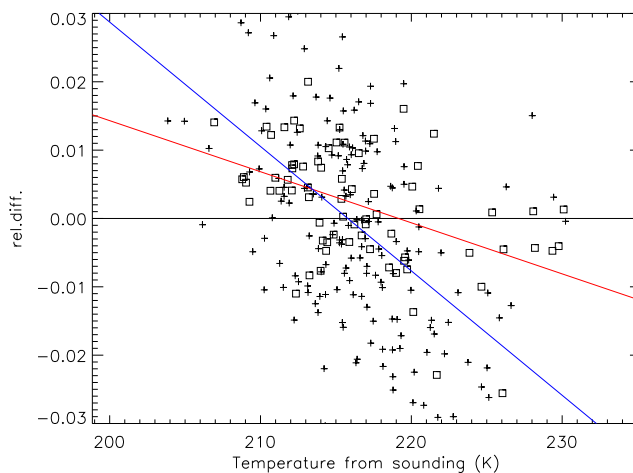


Fig. 9: The relative difference between MIPAS and radiosonde temperature versus radiosonde temperature, all heights combined, all profiles within a 1000 km range from Uccle. The squares represent the MIPAS profiles within a 500 km range from our station. In blue is a linear fit using all profiles between a 500 and 1000 km distance. In red a linear fit using only the profiles closer than 500 km from Uccle.

#### 4.2.4 Day- or nighttime

We have also studied the influence of daylight or darkness on the quality of the MIPAS measurements. Therefore we have split the data in measurements performed in the morning and in the evening at different altitude levels (expressed as the logarithm of pressure). Although this leads to a large reduction in the number of datapoints and we cannot reach statistical significant conclusions, the plot in the right of figure 10 indicates an underestimation of MIPAS at higher height levels.

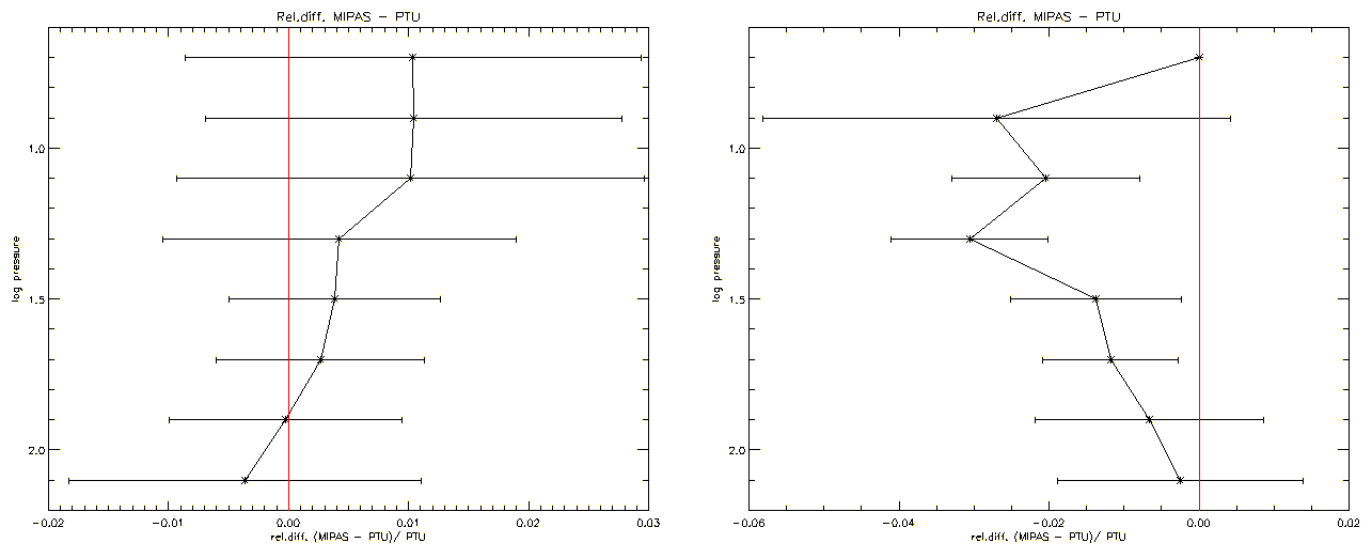


Fig. 10: Left : Relative difference between MIPAS and radiosonde for different pressure levels and measured during daytime. Right : similar but for nighttime MIPAS measurements.

## 5 Conclusions

At this stage of the ENVISAT validation effort, it is difficult to reach statistically significant conclusions about the data quality of the GOMOS, MIPAS and SCIAMACHY instruments. Nevertheless, several remarks can be given :

- SCIAMACHY total ozone values show a negative bias of about -5% compared to our Brewer spectrophotometer data.
- GOMOS profiles, measured in the dark limb, show qualitatively good agreement for temperature and ozone. Regarding the temperature profiles, it is not clear which datapoints are really retrieved and which are obtained from a climatology.
- MIPAS profiles measured before the 13th of November have erroneous values for the altitude. After this date, a correction to the data processor has been applied which corrected for this altitude shift.
- MIPAS temperature profiles show good agreement with radiosounding measurements. Differences larger than 2% show up when the MIPAS profile is measured at distances larger than 500 km from Uccle. For distances between 500 and 1000 km, horizontal temperature gradients influence the agreement between MIPAS and radiosonde measurements.
- There are indications of a dependency of the MIPAS temperature measurements on the temperature and whether the measurement is performed at night or during daylight. The MIPAS instrument seems to underestimate the temperature during nighttime at altitude levels above about 20 km.

## Acknowledgements

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