

# Validation of MIPAS Temperature, Density and Water Vapour Profiles

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## ABSTRACT

The validation results of MIPAS temperature, density and water vapour measurements using three different reference datasets is presented. The MIPAS temperature and density profiles have been compared to a statistical falling sphere model and to radiosonde data. The MIPAS water vapour measurements were validated using lidar data.

Regarding the MIPAS density profiles, a bias of about -20% compared to the statistical model seems to be present. This is probably related to the fact that no in-flight line-of-sight calibration had been applied to data products generated before 13 November 2002.

The difference between the MIPAS temperature data and the radiosonde data is within about 2% and does not seem to depend on altitude. Nevertheless, there are indications of a dependency on temperature. Also, there seems to be an underestimation of the temperature by MIPAS for measurements at nighttime. The small dataset however, does not allow us to reach statistical significant conclusions for this topic.

MIPAS water vapour measurements could only be validated at altitudes below 14 km. A preliminary analysis indicates a systematic underestimation by MIPAS of the water vapour mixing ratio compared to lidar data.

## 1 INTRODUCTION

The Michelson Interferometer for Passive Atmospheric Sounding (MIPAS) is a rapid scanning Fourier transform spectrometer operating in the infrared. It is able to observe many trace gasses simultaneously, e.g. O<sub>3</sub>, H<sub>2</sub>O, CO<sub>2</sub> and several others (see e.g. [1]). Besides the retrieval of trace gasses, the MIPAS instrument is also capable of retrieving temperature and air density profiles using the CO<sub>2</sub> emission features present in the different spectral bands of MIPAS. In this paper we give an overview of the studies performed by three different groups regarding the validation of MIPAS water vapour profile measurements and MIPAS pressure and temperature profiles. For the validation of pressure and temperature, two different reference datasets have been used:

- A falling sphere statistical model of the Arctic Summer middle atmosphere model based on the measurements at the Andøya Rocket Range in Northern Norway by the University of Bonn.
- The radiosounding data obtained at the Royal Meteorological Institute of Belgium, located in Uccle (50.8N, 4.35E).

Regarding the validation of MIPAS water vapour profiles, the Raman lidar system located at the IMAA-CNR in Tito Scalo (40N, 15E) has been used.

## 2 REFERENCE DATASETS

The different datasets used in this analysis are complementary in the altitude ranges of their observations. The statistical falling sphere model provides data beyond about 30km. The IMAA lidar system and the Uccle radiosoundings measure from the ground up to 35km. It is important to note that the different datasets have been compared to MIPAS data generated with different configurations of the processor, especially in view of the observed MIPAS altitude registration error (see the section on the MIPAS density profiles). The statistical model has been used to validate the MIPAS data from July and August 2002, the Uccle radiosoundings have been compared to the October and November 2002 measurements and the MIPAS data compared to the IMAA lidar spanned the September to November 2002 period.

We will now give a short overview of the different reference datasets.

## 2.1 Statistical Falling Sphere Model

The data of a decade of measurements with falling spheres (FS) at the Andøya Rocket Range in Northern Norway has been used by the University of Bonn to model the Arctic summer middle atmosphere. Because FS measurements provide calibrated density profiles, this model is suited for the validation of MIPAS air density profiles. Although this model does not provide one with the true atmospheric situation at the time of the MIPAS measurement, comparison of the model with lidar measurements during several summers in northern Scandinavia shows that there is little interannual variability in the arctic summer atmosphere. The model has been compared to MIPAS measurements in a 1500km range from the Esrange station in northern Sweden. More details can be found in [2].

## 2.2 Radiosoundings

At the Royal Meteorological Institute of Belgium, radiosondes (Vaisala) 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 provides us with a large dataset of reference profiles that have a time difference of maximum half a day from a MIPAS overpass. The radiosonde data has been used for the validation of MIPAS temperature profiles measured from the 24th of October until the 26th of November 2002 and within a range of 1000 km from Uccle. More details can be found in [4].

## 2.3 Lidar measurements

The lidar system located at the IMAA in Italy performs water vapour measurements from the ground up to 13 km of height and aerosol measurements for an altitude range between ground level and 35 km. For this system, the observations were always accompanied by a radiosonde launch. For more details see [3].

## 3 VALIDATION OF MIPAS AIR DENSITY PROFILES

Figure 1 shows the results of the comparison of the statistical falling sphere model of the Arctic summer atmosphere to the MIPAS density profiles measured in July and August 2002.

The figure shows there is a -20% bias present in the density values. In view of the assumption of an atmosphere in hydrostatic equilibrium this is a large deviation. The deviation is most probably related to an error in the MIPAS altitude registration. This issue is handled in more detail in [2]. An update in the MIPAS data processing should have resolved this issue for the MIPAS data after the 13th of November.

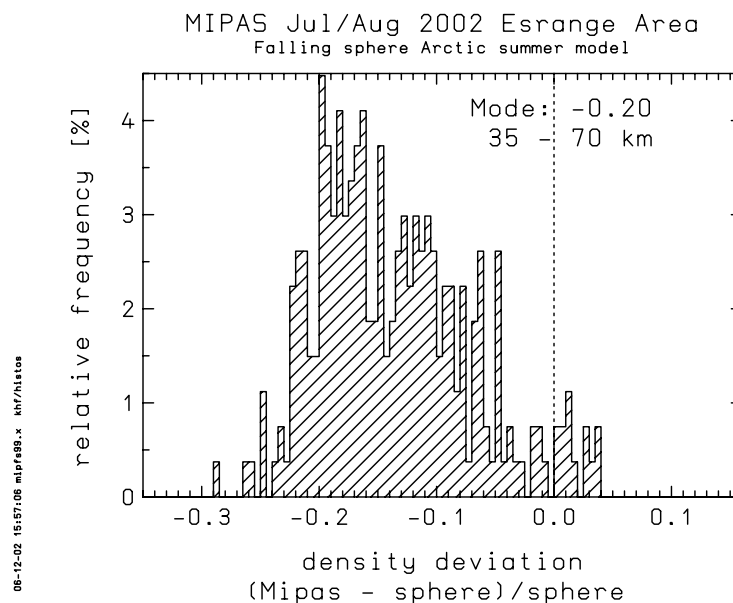


Fig. 1: Comparison of MIPAS density profiles to the statistical falling sphere model of the Arctic summer atmosphere

## 4 VALIDATION OF MIPAS TEMPERATURE PROFILES

### 4.1 Comparison with the statistical falling sphere model

Figure 2 shows a good agreement between MIPAS temperature profiles and the statistical FS model in the order of about 2%.

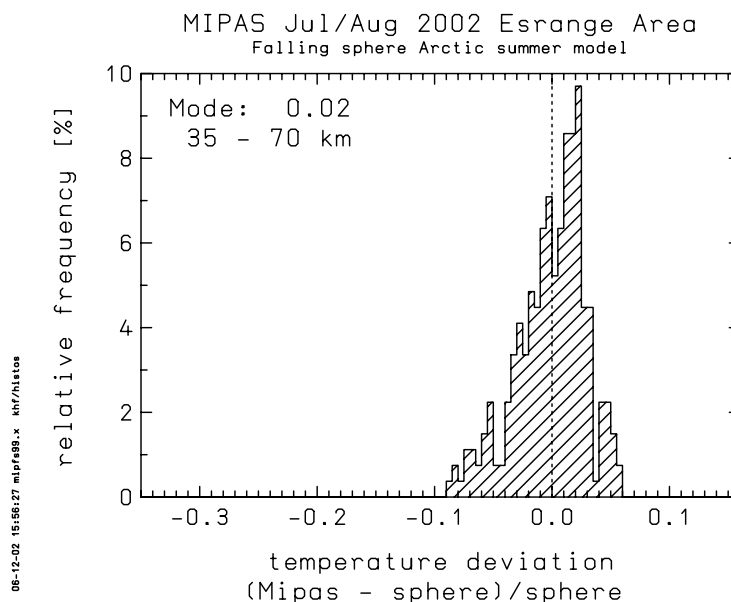


Fig. 2: Comparison of MIPAS temperature profiles to the statistical falling sphere model of the Arctic summer atmosphere

### 4.2 Comparison with Uccle radiosoundings

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 the analysis will not be influenced by the error in the MIPAS altitude registration. Because of the large number of radiosonde launches, 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. For every MIPAS height level, the corresponding value from the radiosounding profile has been calculated by applying a Gaussian smoothing function to the radiosonde temperature profile. This will ensure that the two profiles have the same resolution and that the comparison is more reliable because the smoothing removes any small scale features MIPAS is unable to detect due to its lower resolution.

#### 4.2.1 General agreement

The frequency plot in figure 3 shows there is a 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 amount 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 between MIPAS and the radiosondes for all height levels in figure 4. It is interesting to note that beyond about 500 km, large differences show up. Most probably these are real physical differences related to the probing

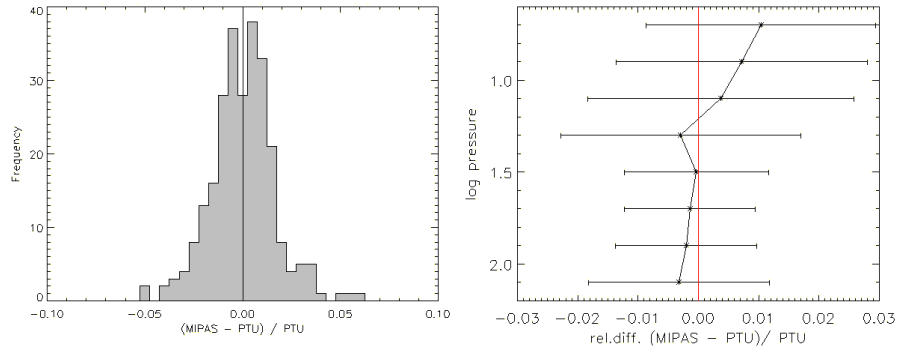


Fig. 3: Left : Frequency distribution of the relative difference between MIPAS and radiosonde. Right : The relative difference between MIPAS and radiosondes for the different MIPAS altitude levels. For both plots, MIPAS profiles within a 1000km range have been used.

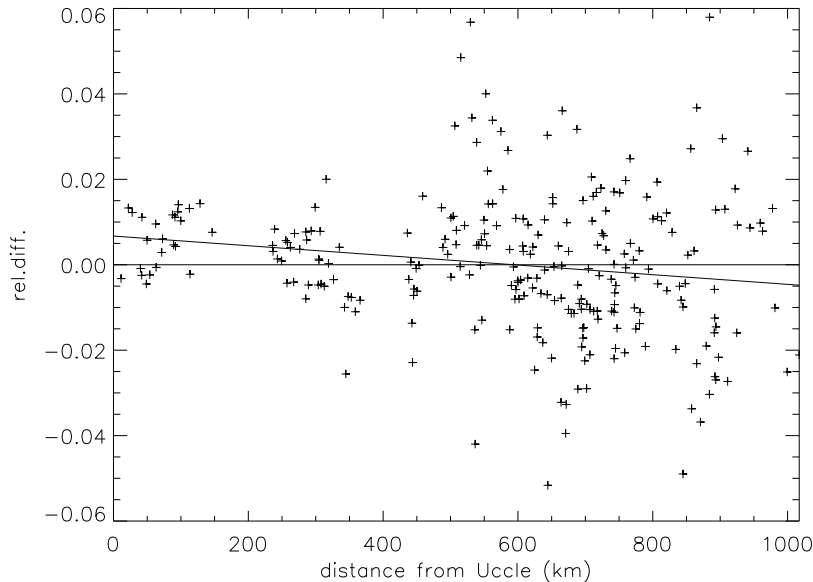


Fig. 4: The relative difference between MIPAS and radiosonde temperature versus distance from Uccle, all heights combined. The linear fit is shown.

of different airmasses by the two instruments. This shows the importance of choosing appropriate selection criteria when deciding which profiles should be compared to each other in the validation study. For this study, however, we have used all profiles within a 1000 km range from Uccle because of the already limited amount of MIPAS data. This should be kept in mind when interpreting the results.

#### 4.2.3 Temperature

The relative difference between MIPAS and radiosonde versus radiosonde temperature for all height levels is plotted in figure 5. A distinction has been made between MIPAS profiles closer than a 500 km range from Uccle and profiles within a 1000 km range. The linear fit for both sets is also shown, in red for the close profiles, in blue for the profiles further from the station. An indication of an underestimation by MIPAS at higher temperatures and an overestimation at lower temperatures can be seen when taking into account all profiles within the 1000 km range. This discrepancy becomes smaller when studying only the profiles closer than 500 km from the groundstation. This is probably related to

a horizontal temperature gradient present at the time of the measurements and shows again the importance of comparing only measurements sufficiently close to each other.

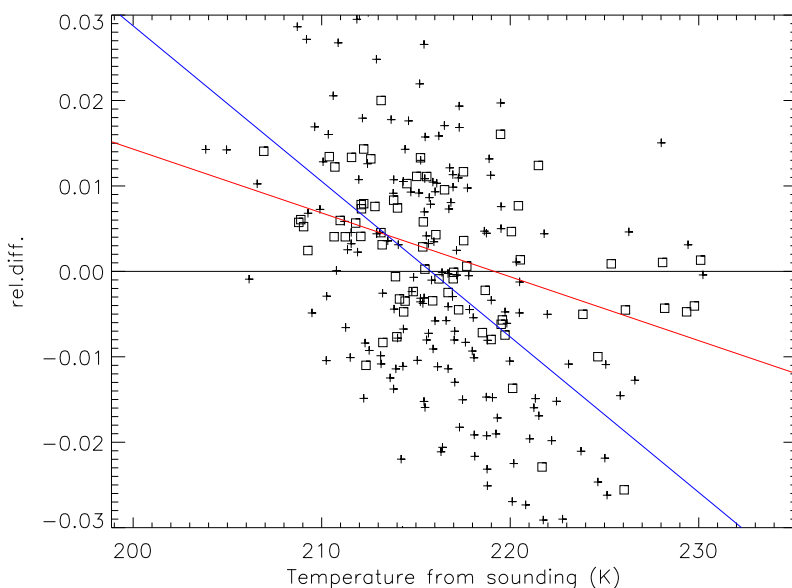


Fig. 5: The relative difference between MIPAS and radiosonde temperature versus radiosonde temperature, all heights combined. The squares represent the MIPAS measurements closer than 500 km from Uccle. The +’s represent the MIPAS measurements between 500 km and 1000 km from Uccle. A linear fit is shown in red for the close profiles, in blue for profiles further from the station.

#### 4.2.4 Day- or nighttime

We also tried to investigate whether daylight or darkness influences the MIPAS data quality. 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, the plot in the right of figure 6 indicates an underestimation of MIPAS at higher height levels. Again, statistical significance can only be ascertained when a larger dataset will be available.

## 5 VALIDATION OF MIPAS WATER VAPOUR MEASUREMENTS

The first results of the validation of MIPAS water vapour measurements are illustrated in figure 7. These two plots show the MIPAS profile, the lidar profile and the radiosonde profile of the water vapour mixing ratio for the 31st of October and the 7th of November 2002. For the period from the 18th of September until the 28th of November a total of 10 intercomparisons has been made. The plots show that only the lowermost MIPAS measurement at about 13 km can be compared with the lidar measurement, because the signal from the lidar system becomes too weak for higher altitudes. Although it is difficult to achieve a statistical significant conclusion for this small set of co-located measurements, there is an indication that MIPAS underestimates the water vapour mixing ratio at this altitude.

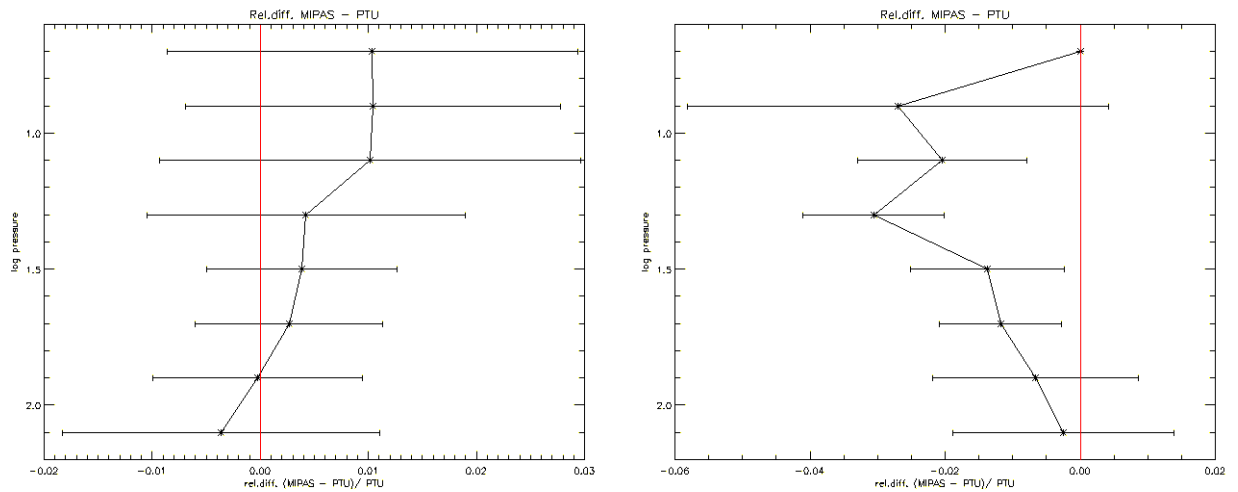


Fig. 6: Relative difference between MIPAS and radiosonde data for different height levels. In the left only profiles measured during daylight, in the right profiles measured during nighttime.

**MIPAS vs IMAA-CNR measurements on 31 Oct 2002    MIPAS vs IMAA-CNR measurements on 07 Nov 2002**

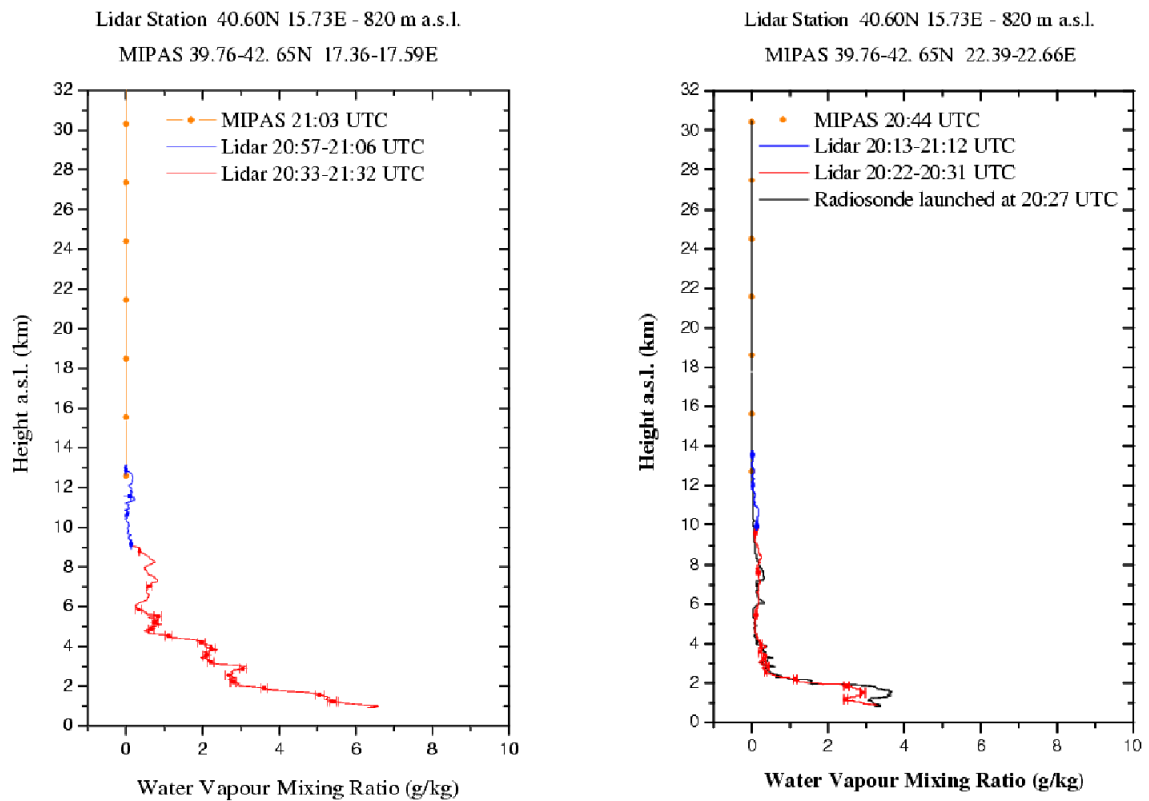


Fig. 7: Comparisons of MIPAS water vapour mixing ratio profiles with Raman lidar and radiosonde measurements performed at IMAA-CNR.

## 6 SUMMARY

This article has given an overview of the efforts by several groups to validate MIPAS density, temperature and water vapour profile measurements by using different datasets. In general, we can conclude that the agreement of MIPAS temperature profiles with the statistical falling sphere model and with the radiosonde data is within 2%. Although not statistically significant, because of the rather small amount of data, there are indications of an underestimation of the temperature by MIPAS for pressure levels between about 63 and 12 hPa during nighttime. Also, the importance of including only those MIPAS measurements which are closer than about 500km from the groundstation is shown.

The comparison of the statistical model with the density profiles revealed a problem in the MIPAS altitude registration. This problem has been circumvented in the temperature analysis by using the pressure as a measure of the altitude.

Regarding the water vapour measurements by MIPAS, there are indications of a systematic underestimation compared with lidar measurements at about 12 km altitude.

## References

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