COMPARISON OF STRATOSPHERIC OZONE COLUMNS FROM OZONESONDES, RADIOMETER, MIPAS AND GOMOS INSTRUMENTS

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ABSTRACT

In this contribution, ozone profiles from ozonesondes, SOMORA radiometer, MIPAS and GOMOS instruments are compared for two main purposes. Firstly, the validation and correlation of partial ozone columns between the different systems are analysed. Secondly, two aspects of the sonde data processing procedures are tested by comparison with the other systems. These are the pump efficiency correction and the constant mixing ratio method used to extrapolate the profile above the balloon burst altitude. This study is based on partial ozone columns on the altitude range 20 to 55 km. Five kilometres wide altitude layers are considered to overcome the problem of the various vertical resolution.

1. INTRODUCTION

The ozone sounding stations network plays an important role in the validation of the satellites instruments for ozone measurements primarily because of their high altitude resolution and the long measurement series. But the continuous increase of satellites performances at low altitude and in their altitude resolution require that the sounding technique improves accordingly to keep his status of ground based reference system.

The microwave radiometer SOMORA instrument measuring at the Payerne station is used for ozone monitoring of the middle-upper stratosphere above the sondes burst level. The SOMORA has an averaging interval of 30 minutes measuring therefore 48 profiles per day independently of the weather conditions. This high frequency allows studying coincidence for almost all overpasses of the station by satellites.The combined ozonesondes and radiometer measurements represent an optimal validation point when high temporal and vertical resolutions are required. In general, the sondes-radiometer systems agree within less then 10% with satellites instruments [1, 2]. But going beyond this limit require a careful attention on how the data are produced and processed by the different systems.

Presently, the ozonesondes have proved to be reliable systems and the operating procedures are well established [3]. However, systematic biases of a few percent cannot be excluded especially in the middle stratosphere (highest part of the sounding) and in the troposphere where the ozone level is quite low. There is presently an important effort of the ozonesondes community to explain and optimize the operating procedures to achieve a better homogeneity of the ozone sounding stations network. Various atmospheric simulator experiments in the last ten years have been conducted at the Jülich facility [3]. A large balloon experiment (BESOS) has been organised at Laramie, Wyoming to confirm the simulator results. In parallel, stations around the world have launched multiple sondes (2-6 sondes) balloons as a further complement of the other two experiments. The aims of theses experiments were to measure the effect of different factors affecting significantly the sondes response. In particular, the sondes providers (ENSCI vs SPC Companies), the potassium iodide (KI) sensing solution concentration and the preparation procedures are the most important factors studied in these experiments.

One of the indirect quality control of the ozonesonde data consists in evaluating the ozone column from the profile and to compare it to an independent measurement, (e.g. Dobson or Brewer sun spectrophotometer data). This analysis shows some systematic differences that are only partially explained. Two related issues of the sondes data processing are addressed in the present contribution:

- the pump efficiency correction and
- the residual ozone column above balloon burst.

The mechanical pump used to sample the ambient air has a decrease of efficiency at low pressure, typically above 25 km. In the data processing, a smooth altitude dependant correction is applied to the raw data. This correction has been measured in laboratories and the results depend on the experimental procedures. The corrections measured at 5mPa are between 1.02 and 1.04, increasing at 0.7 hPa to 1.09 and 1.16 respectively. Therefore, the correction changes between these two pressures are almost twice as large, 0.07 [4] compared to 0.12 [5]. In the analysis presented here, the comparison with independent coincident satellites and radiometer profiles for different altitude layer is used to check whether the pump efficiency correction [4] applied to the Payerne data does introduce a systematic bias. The series named “ECCp” later correspond to raw data without pump correction while the series “ECC” include the correction.

The second issue is connected to the estimation of the residual ozone column above the sondes profiles necessary in case of normalisation of the sondes profiles to independent column measurements. Two options are usually considered:

- assuming a constant mixing ratio (CMR) for ozone above the balloon burst requesting that the balloon reach at least a certain altitude (~ 28 - 30km),
- using satellite partial columns climatology.

In the first option, the information is strictly from the sondes profiles while in the second case, external information is introduced in the data processing. At mid-latitude, the residual column represents typically 10 to 20 % of the whole column depending on the season.
Reference [6] has published in 1997 a table of partial column climatology based on SBUV satellite data for use as residual ECC sondes column. Reference [7] has published the equivalent climatology from a radiometer in 2003. In this last paper, the bias introduced by the CMR rule was estimated. It turns out that in the case of the Brewer-Mast ozonesonde, the bias is less than 5% for the range of altitude attained by the balloons.

2. INSTRUMENTS AND DATASET

The ozonesondes are coupled to aerological sondes with simultaneous in situ profile measurement of ozone, pressure and temperature. The vertical resolution is of the order of 150 m from the ground to the top of the flight, usually the balloon burst between 30 and 35 km. The measurement program consists of three profiles per week on Monday – Wednesday – Friday noon. ECC sondes from ENSCI-SCI Company with a 0.5% KI concentration solution are used.

The SOMORA radiometer has been developed by the University of Bern for continuous ozone monitoring under the MeteoSwiss responsibility. It is described in [8]. The ozone profile is retrieved from the 142.17 GHz emission line with the optimal estimation method. The instrument is in continuous operation since 2002 in Payerne.

The ENVISAT data from GOMOS (GOPR_LV2/6.0) and MIPAS (IMK V3O_O3_8) instruments have been used in this comparison. The coincidence criteria for profiles selections were “distance satellites - Payerne” < 800 km and “time interval” < 24h. The numbers of coincident profiles between the ENVISAT GOMOS and MIPAS instruments and the ground-based ECC and radiometer instruments are given in table 1.

Table 1. Number of coincident profiles found between the different instruments.

Systems	***ECC***	***SOMORA***	***GOMOS***	***MIPAS***
ECC	121+55	121+55	121	55
SOMORA		260+118	260	118
GOMOS			272	15
MIPAS				122

The measured parameters are:

- Sondes: ozone in [hPa], altitude, P and T.
- Radiometer: Ozone in [ppmv], altitude, P and T.
- GOMOS: ozone in [ppmv], altitude, air number density and T.
- MIPAS: ozone in [ppmv], altitude, P and T.

The focus of this analysis is on partial ozone columns above the ozone layer calculated on 5 km (or more) depth altitude layers. In these cases, the problem of altitude resolution mismatch between the sondes and the other remote sensing instruments is reduced because the profiles in the middle stratosphere are relatively smooth. Here, the sondes columns are calculated from the measured profiles up to the balloon burst and extended above using the CMR method for both the ECC and ECCp series.

3. RESULTS

A comparison of the partial column is done with the corresponding quantities from the satellites and the radiometer to judge and verify if the pump efficiency correction and the constant mixing ratio rule produce consistent results.

3.1. Examples of profiles comparison

In the figs. 1 and 2, a few coincident profiles for MIPAS, respectively GOMOS, radiometer and ozonesondes are reported to illustrate the overall agreement between these systems. In this selection, good results are given but some of the coincidences are not as good. They present oscillations of one or both remote sensing instruments. However, some detailed features of the sondes profiles are captured by both satellite based instruments to an effective vertical resolution of a few kilometres. In some cases, two successive profiles on the same orbit could be quite different. The SOMORA radiometer shows a lower effective altitude resolution of about 5 km, finer scale structures are only slightly noticed on the radiometer retrieved profiles. In general both single and double peaks structure of the ozone profiles are reproduced by the remote systems.

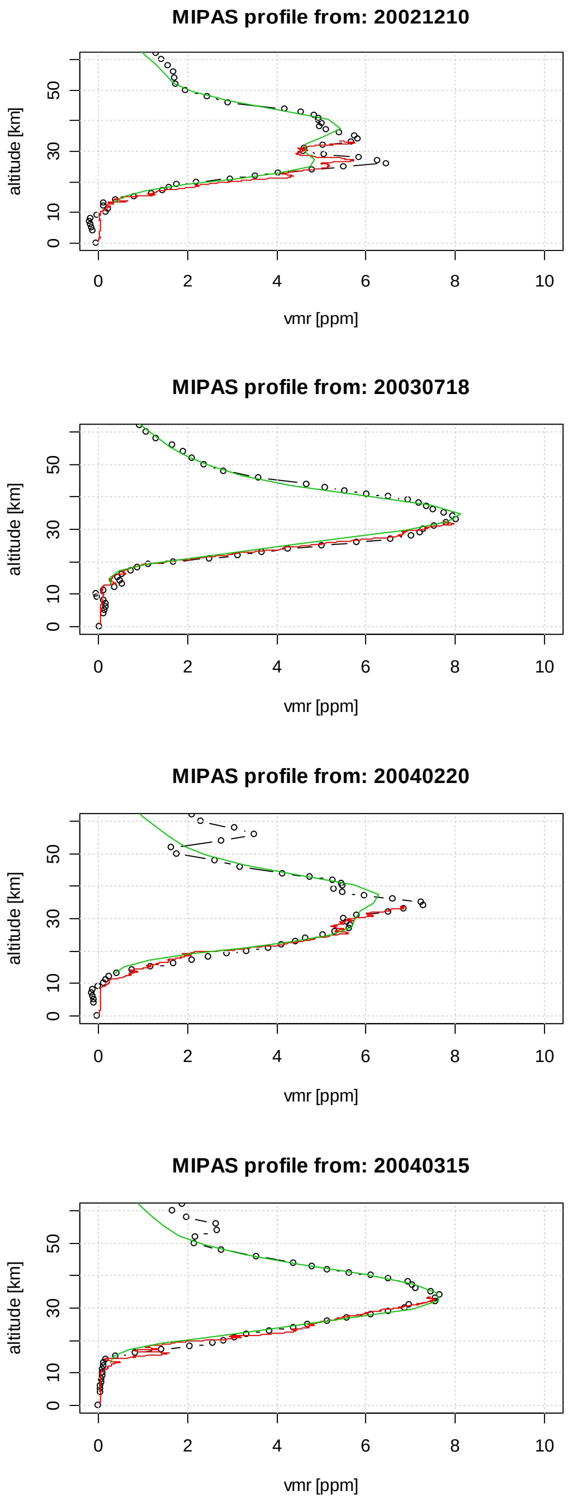

Figure 1. Example of coincident ozone profile over Payerne from MIPAS (black line + circles), sonde (red) and radiometer (green) instruments.

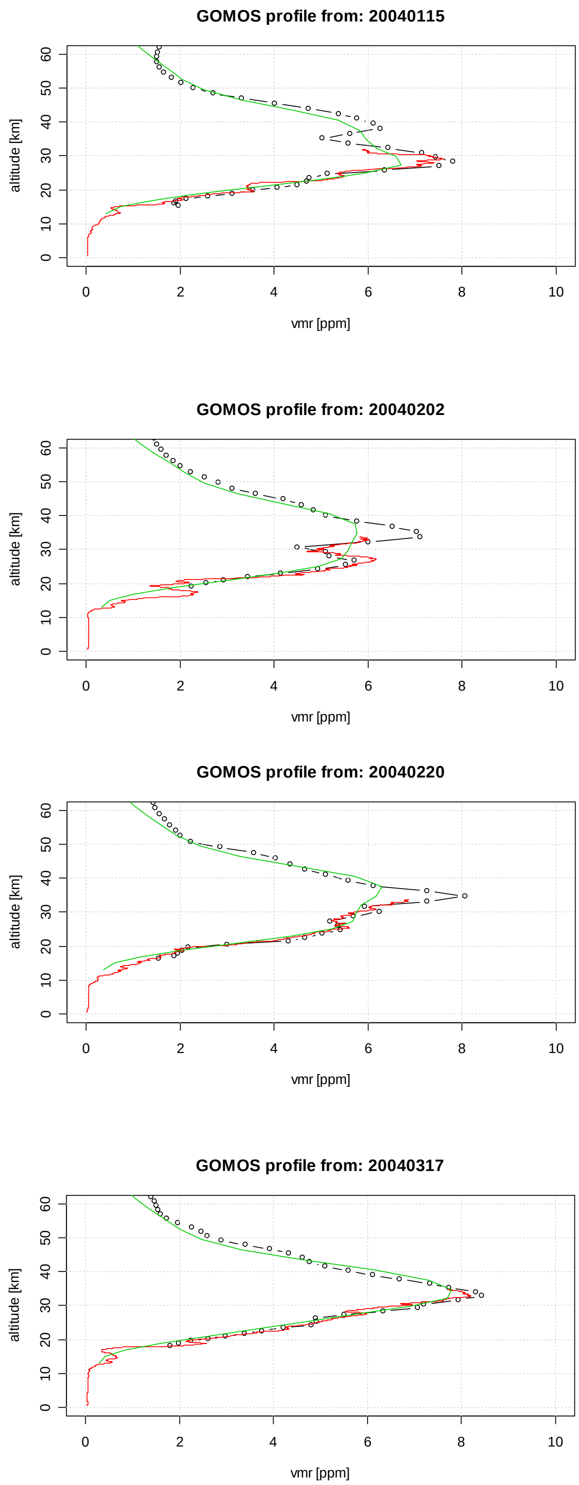

Figure 2. Example of coincident ozone profile over Payerne from GOMOS (black line + circles), sonde (red) and radiometer (green) instruments.

3.2. Partial ozone column comparison

The vertical extensions of the retrieved profiles extend well above 50 km but we have limited the analysis to 55 km. The first reason being that it is far above the sondes maximum altitude and second, it turns out that a lot of retrieved profiles from satellites instruments show very large oscillations compared to the SOMORA at high altitude. It is not clear if the radiometer has excessively smooth profiles but the oscillations of the satellites instruments seem to originate in the retrieval algorithms procedure itself.

The calculated partial ozone columns have been evaluated for the different systems on the following altitude layers:

- 20 - 25 km: in this altitude range, the ozone layer is present with the maximum ozone partial pressure. The ozone signal is maximized and it is therefore expected to find a good agreement between the various systems,
- 25 - 30 km: in this range, the substructures of the "ppmv vs altitude" profiles make the test of the systems correspondences more stringent,
- 27 - top: this layer is used to include the part of the sondes profiles above 30 km without constant mixing ratio extrapolation,
- 27 - 45 km: this altitude range added a significant contribution due to extrapolation, testing the appropriateness of the constant mixing ratio extrapolation method,
- 27 - 55 km: in this range, the test is more towards the difference between ground-based vs. space borne remote sensing instruments.

In fig. 3, the scatter plots for the different instruments pairs are reported, the different partial columns being identified by the colours. The correlation coefficients are also given in this figure.

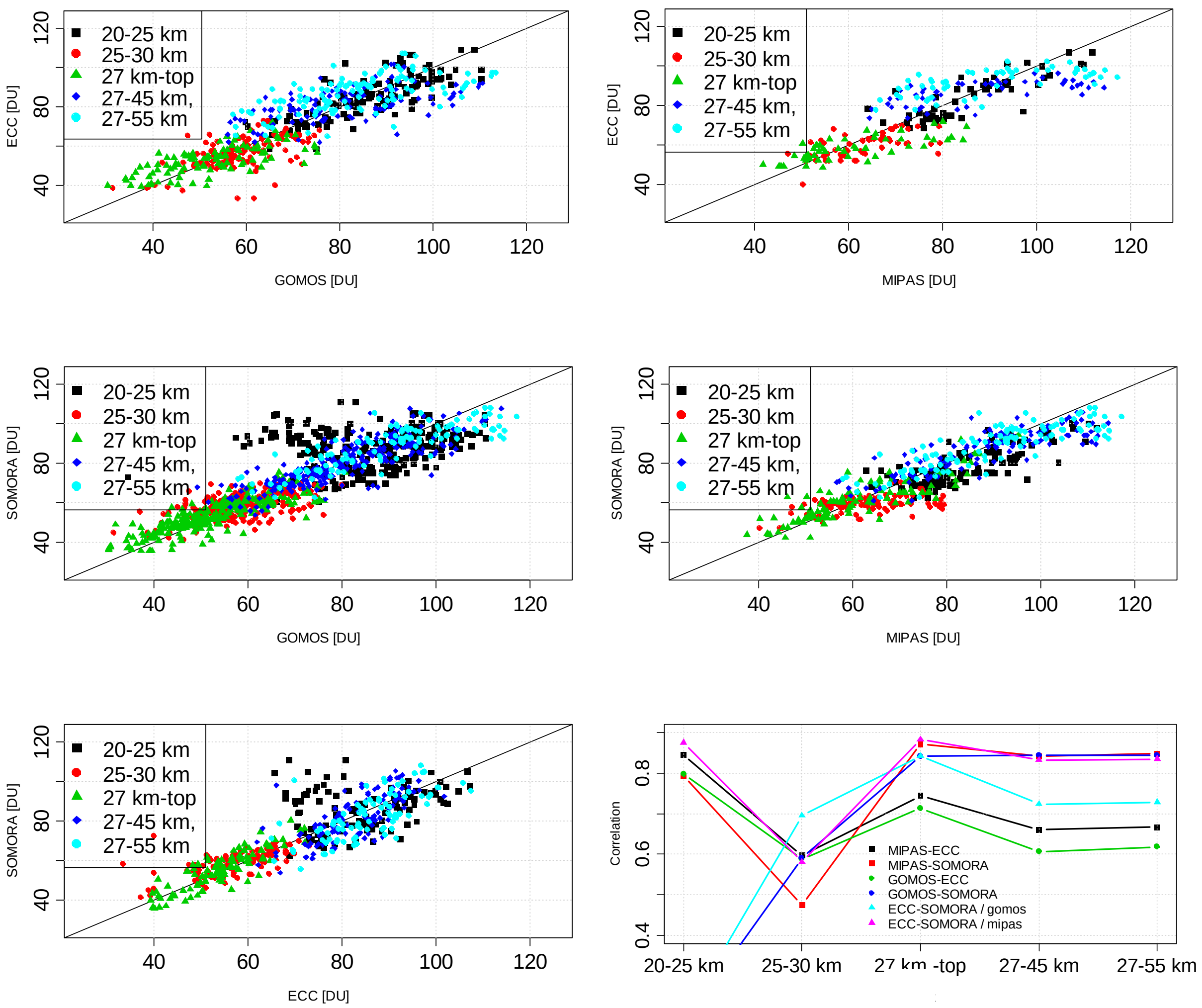

Figure 3. Scatter plots of the ozone partial columns [DU] for the various pairs of instruments written along the axis. The correlation coefficients for the different layers and instruments pairs is summarised in the last plot.

Generally, the data are well distributed around the 1:1 line. GOMOS and MIPAS agree equally well compared to the ECC sondes and the radiometer. The correlations are good except for the lower 20 - 25 km layer for the coincidence with the GOMOS instruments, where the SOMORA correlations with GOMOS and ECC are surprisingly low. A more detailed analysis of the SOMORA data is needed to explain these low numbers. The layer 25 - 30 km presents a dip of 0.2 units in the correlation for all combinations of instruments. Fig. 3 shows the presence of outliers but they are probably not the main reason of the correlation decrease.

The absolute values are best illustrated in fig. 4 where a quantitative comparison is possible. The boxes are designed to represent the 25% - 75% quartile range with the median as the thick line. The “notches” on the side of the boxes represent a 95% confidence interval for the median. The width of the boxes within a graph is proportional to the square root of the number of observations.

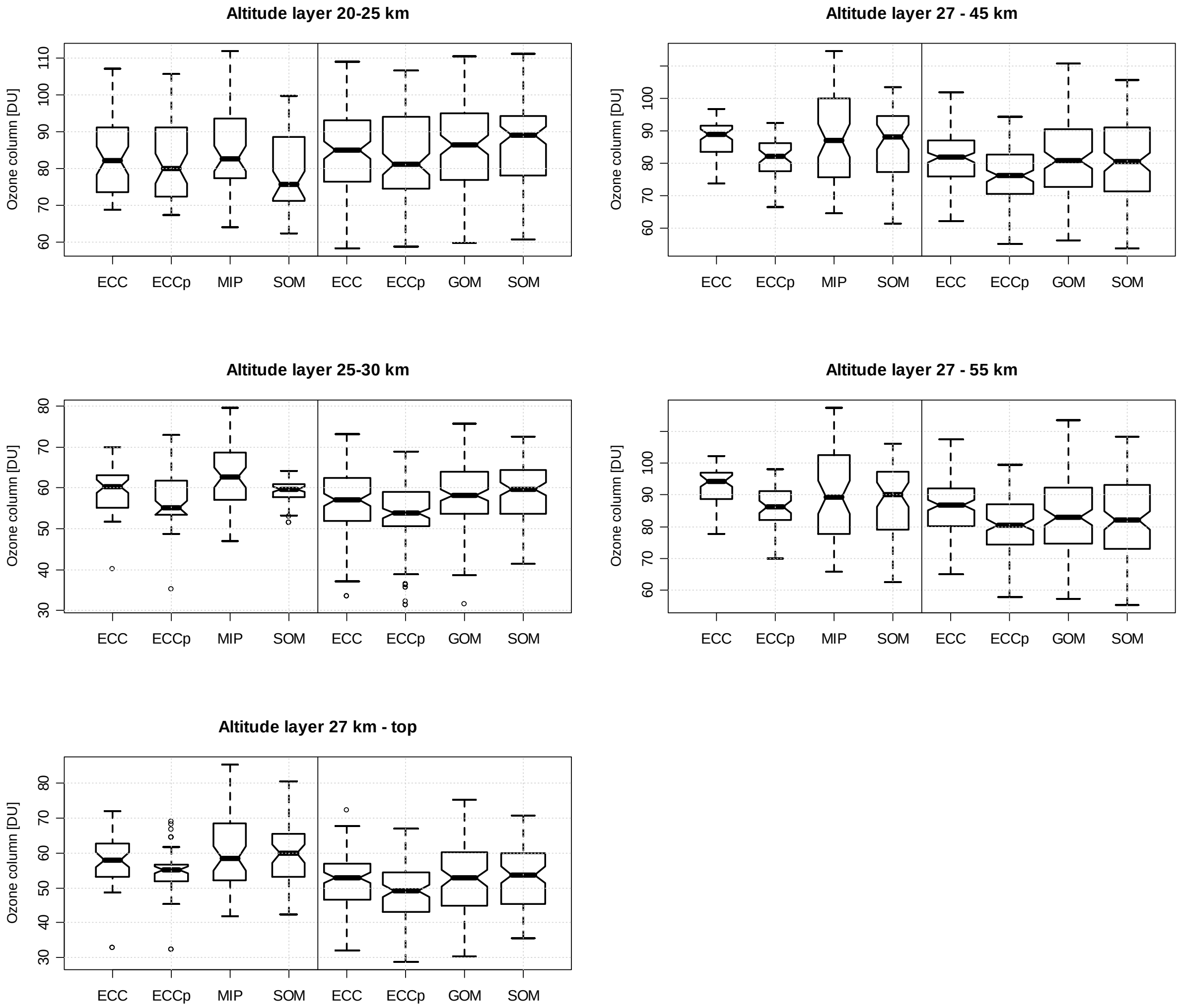

Figure 4. Box plots of the ozone partial columns [DU] for the coincident with the ENVISAT instruments. On each graphs, the left (right) panel corresponds to MIPAS (GOMOS) coincident dataset.

The pump efficiency correction is seen as the difference between the boxes labelled “ECC” (corrected) and “ECCp” (not corrected). The test of the appropriateness of this correction being that the “ECC” boxes stay in better agreement with the other instruments then the “ECCp” boxes. It is well verified by the three series from 20 km to the top (left part of the fig. 4) which show that the median of the ECC series agree to within the 95% confidence interval with the satellite instruments. For SOMORA, except for the lower layer the same conclusion is reached. The agreement is also good between the radiometer and the satellite instruments: above 27 km up to 55 km, the partial ozone columns agree to within the 95% confidence intervals.

Above the top of the soundings, the last two graphs on the right of fig. 4 show that the agreement stay very good between the extrapolated sondes columns and the other three instruments. The increase between the “27 km - top” and “27 - 45 km” columns is of the order of 50% (20 - 30 DU). The “ECC” data still agree better with the other instruments than the “ECCp”. The increase from “27 - 45 km” to “27 - 55 km” adds up about ~2 DU for the remote instruments while the sondes increase by ~4 DU. The CMR calculated at the top of the ECC profiles (~33 km) appears about twice larger then the one which would be appropriate at ~50 km. But, the 2 DU difference is below 1% of the total column which is around 320 DU at Payerne station.

4. CONCLUSION

In this contribution, the upper stratospheric ozone contents measured by the operational ECC sondes are compared to the ground based radiometer SOMORA and the ENVISAT MIPAS and GOMOS instruments. The analysed quantities are partial ozone columns calculated on different altitude layers.

The results show that:

- the correction applied to the sonde data to compensate the pump efficiency decrease is appropriate,
- the constant mixing ratio method applied to extrapolate the sondes profiles above the burst level gives consistent result to the percentage level,
- the ECC, satellites and radiometer partial ozone column agree together to the 95% confidence level above about 27 km,
- the MIPAS and GOMOS instruments show an effective altitude resolution close to ~3 km while the radiometer is ~ 5 km,
- the correlations between the space borne and ground based remote sensing instruments partial ozone columns are between 0.8 - 0.9 in the middle/upper stratosphere. The same coefficient are found between the ECC sondes and the collocated radiometer,
- the correlation between the sondes and the satellites instruments are between 0.6 – 0.7.

This preliminary analysis could be refined to include a proper treatment of the altitude resolution mismatch, a better screening of the outliers especially for the retrieved profiles which show inconsistent oscillations. A systematic comparison with the published partial column climatology from other systems would be a valuable extension of the present analysis.

5. REFERENCE

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