ANALYSIS OF GOMOS OZONE PROFILES COMPARED TO GMBCD DATASETS (bright/dark, star magnitude, star temperature)

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ABSTRACT

GOMOS ozone profiles were analyzed in a joint contribution of the Ground-based Measurement and Campaign Database (GBMCD) subgroup. In the analysis study 131 collocated ozone profiles of ground-based lidar systems, microwave radiometers, and balloon sondes were used for the validation. We have distinguished between three different parameters which might influence the GOMOS data quality. The pairs of collocated profiles were separated by (1) brightness of the limb during the GOMOS observation, and (2) the magnitude value and (3) temperature of the observed star. For each selection the mean difference between the GOMOS and GBMCD ozone profile was calculated. The GOMOS retrieved ozone profile is strongly affected by the brightness of the limb in which the star occults. Bright limb situations give poor results. Although, in this situation there is an exception for stars with a magnitude value smaller than 1. In that case the results are reasonable between 30 and 50-km altitude, but GOMOS is lower by 10-15%. Twilight limb conditions give better results, but there are still large deviations and it needs further research. Good results come from ozone profiles measured in dark limb situation. Then the bias between 18 and 45-km altitude is within 5 to 10%. The ozone profiles between 45 and 65-km altitude, measured in the dark limb using cold stars, give poor results, but using only hot stars results in a bias lying within 20%. In this case though, it is a significant non-random bias and this suggests a possibility for improvement.

1. INTRODUCTION

Validation of ENVISAT instruments is performed in several subgroups of the Atmospheric Chemistry Validation Team (ACVT). This paper on the validation of GOMOS ozone profiles is a joint contribution of the Ground-based Measurement and Campaign Database (GBMCD) subgroup. For the GOMOS Cal/Val-team it is very important to get unanimous recommendations on the quality of their product. Therefore within the GBMCD subgroup, we have centralized the analysis of the data involving ozone profile measurements. In addition, we hope to be able to extract some information on the global validity of the product, because we have only a limited number of months available and we can not rule out seasonal effects using one geolocation. In the next section we will briefly present the origin of the data used in the analysis and the criteria applied for defining a collocated measurement. In section 3 we present the analysis of the GOMOS data compared to the GBMCD data with respect to several important GOMOS measurement parameters. The analysis is initially separated by instrument, but later brought together in an overall analysis. Finally we present the conclusions and the recommendations.

2. DATA

2.1 GOMOS data

As will be clear from several other papers, the data flow towards the validation teams has suffered from severe problems in the data distribution system. For GOMOS data this resulted in no available data at all through the normal data flow channels. Fortunately, ACRI could offer us data on request using their prototype processor with software version GOPR_LV2_5.3. Each AO team submitted data requests based on the provided overpass tables. The standard file output does not contain information about the position of the Sun. In addition to the normal format, we have calculated and added the solar zenith angle (SZA) with respect to the geolocation (latitude and longitude) of the lowest tangent point.

2.2 GBMCD data

The GBMCD subgroup enfolds several different instruments at several geolocations. In Table 1 we have listed all the AO-teams that have contributed to this paper and also which instruments where involved. For a more detailed description of each project we refer to the project proposals.

Table 1. Overview of Validation Teams and Type of Instruments Involved in the Analysis.

Validation team	PI-name	Institute	Type of Instruments Involved
AO 153	S. Pal	SAAI/MSC	Lidar
AO 158	J.-C. Lambert	BIRA	Microwave, lidar and sonde
AO 179	A. Matthews	NIWA	Microwave and sonde
AO 191	T. Blumenstock	FZK/IMK	FTIR
AO 300	D. de Muer	RMI	Sonde
AO 360	P. Keckhut	CNRS	Lidar
AO 429	E. Kyro	FMI	Sonde
AO 9003	D. Swart	RIVM	Lidar

2.3 Geolocation

In order to compare GOMOS to the GBMCD ozone profiles, we need to define certain criteria for the differences in space and time of the observations. Each team has decided which criterion is appropriate for their instrument. For the lidars, balloon sondes and FTIR, the observations were paired when the GOMOS measurement was within a 1000-km radius and in time within 24 hours. Note that, due to accurate planning of the balloon soondes and lidar observations, these criteria relate to the maximum differences. For the microwave radiometers the criterion in space is also 1000-km, but the time criterion is now 4-hours. The latter criterion is more stringent because in the lower and middle mesosphere there is a strong diurnal variation in the ozone profile. In Table 2 we have listed all the measurement sites per instrument, and for each of them the total number of profiles used in the analysis.

Table 2. Overview of Measurement Sites per Instrument and Number of Used Profiles

Lidar	Ballooon sonde	Microwave radiometer	FTIR
Toronto	Scoresbysund	Payern	Kiruna
Lauder	Hohenpeissenberg	Lauder	
Alomar	Sodankyla	Mauna Loa	
Table Mountain	Payern	Table Mountain	
Mauna Loa	Uccle		
Hohenpeissenberg	Lauder		
Obs. Haute Prov.			
Total used: 57	**39**	**35**	**0**

Total number of collocated GOMOS-GBMCD paired profiles	
Listerd paired profiles:	**226**
Paired profiles without altitude overlap:	**-13**
GOMOS profiles unavailable for coordinator	**-82**
Total available pairs for this analysis study	**131**

As you can see in the lower part of Table 2, the total number of files listed was not always useful or available for the analysis. Some collocated profiles did not have overlap with the GBMCD data and hence were not useful. We also had

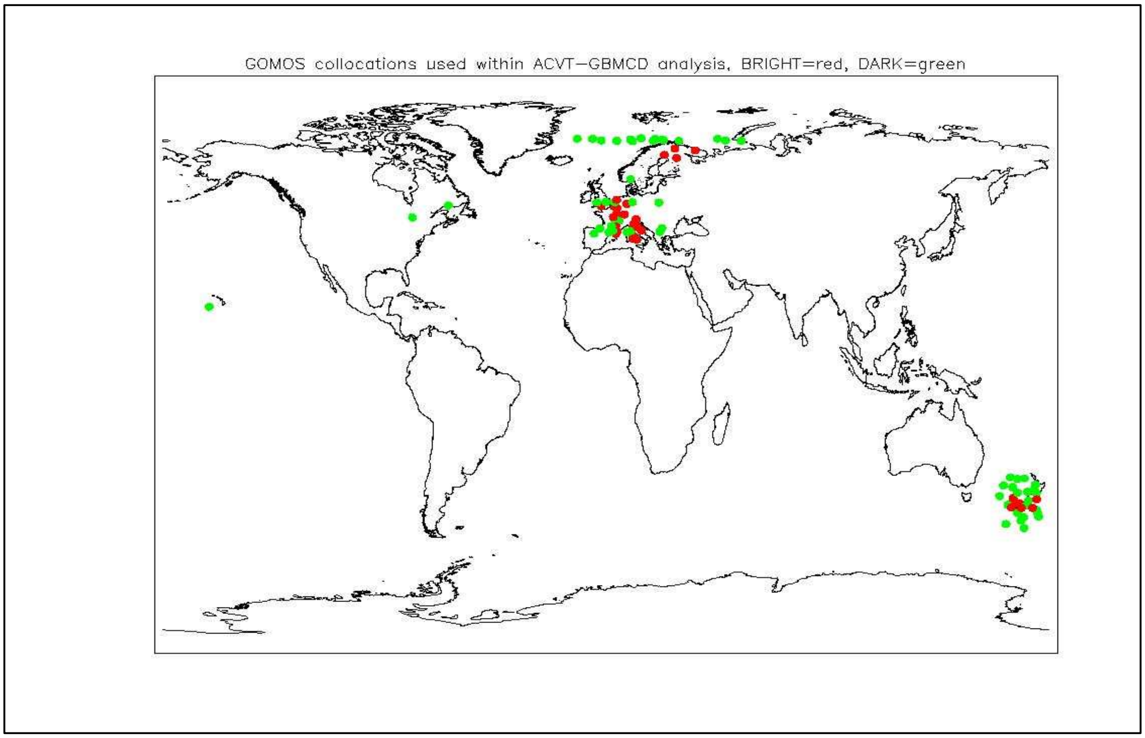

Fig. 1. Overview of GOMOS measurement locations (dots) used in the analysis. The color of the dots reflect the measurement situation during the stellar occultation, red corresponds to bright limb (SZA<90^0) and green to dark limb (SZA>90^0).

a logistical problem, because quite a substantial number of GOMOS ozone profiles were not available to the coordinator to incorporate in this analysis study. The total number of useful collocated GMBCD and GOMOS profiles is 131. An overview of the geolocation of all the 131 GOMOS measurements used in the analysis is shown in Fig. 1.

3. ANALYSIS

The comparison of different data sets brings along several important issues in order to ensure they are comparable. For example, to account for differences in altitude resolution. Unfortunately, we could not address all of these issues due to the limited timeframe between receiving the GOMOS data and the Validation Workshop in Frascati. Though, we have been able to perform this first analysis study and it will already give a lot of insight in the performance of GOMOS.

We have analyzed the ozone profile quality according to three important observational parameters of GOMOS. Since GOMOS is an instrument that makes use of the stellar occultation technique, its quality will depend on the stars used. The star magnitude value will determine the signal strength on the detectors. The star temperature will determine the emitted stellar spectrum. A higher star temperature corresponds to shorter wavelengths, and especially the ultra-violet part of the spectrum is used in the retrieval of ozone values. In addition, from individual comparisons we have noticed that the detectors or the retrieval seem to be strongly affected by the brightness of the atmosphere in which the star occults. In Table 3 we have listed the parameters which were used in analyzing the comparisons. We have distinguished between three types of atmospheric limb conditions, namely the bright, twilight, and dark limb situation. The differences in observed stars were accounted for by separating the analysis in star magnitude value and (equivalent black body) star temperature. The ranges used in the analysis are listed in Table 3.

Table 3. List of Parameters as Used in the Analysis and Their Ranges.

Solar position (SZA)	**Star Magnitude Value (MV)**	**Star Temperature (K)**
Bright limb: $0^o – 90^o$	Strong: -2 to 1	Cold: 1,000 to 7,000
Twilight limb: $90^o – 110^o$	Weak: 1 to 5	Hot: 7,000 to 100,000
Dark limb: $110^o – 180^o$		

The analysis according to these GOMOS parameters has also been separated by instrument. In this way we can rule out possible instrumental effects, but in the end we have also analyzed all 131 collocations by comparing the data of all instruments with the GOMOS data.

We have converted all data to a 200-m altitude grid and ozone number density. We have accepted the smaller errors due to converting pressure to geopotential height and not geometric altitude. For each individual collocated profile pair we calculated the difference between GOMOS and GBMCD data in percentage relative to the latter. Then we selected collocated profile pairs, according to the above mentioned GOMOS parameters, and calculated the mean ozone profile and its standard deviation. From the selection we also calculated for each altitude point the average difference and its standard deviation. Since not all profiles of GOMOS and the GBMCD data cover the same altitude range, this average difference will not always have been calculated over the (maximum) specified number of collocations. For example, in the selection there are 30 collocated GOMOS and balloon sonde pairs, but there are only two balloon sondes reaching up to 31-km altitude. The mean at this altitude is not over 30 pairs, but from the average of these two values only.

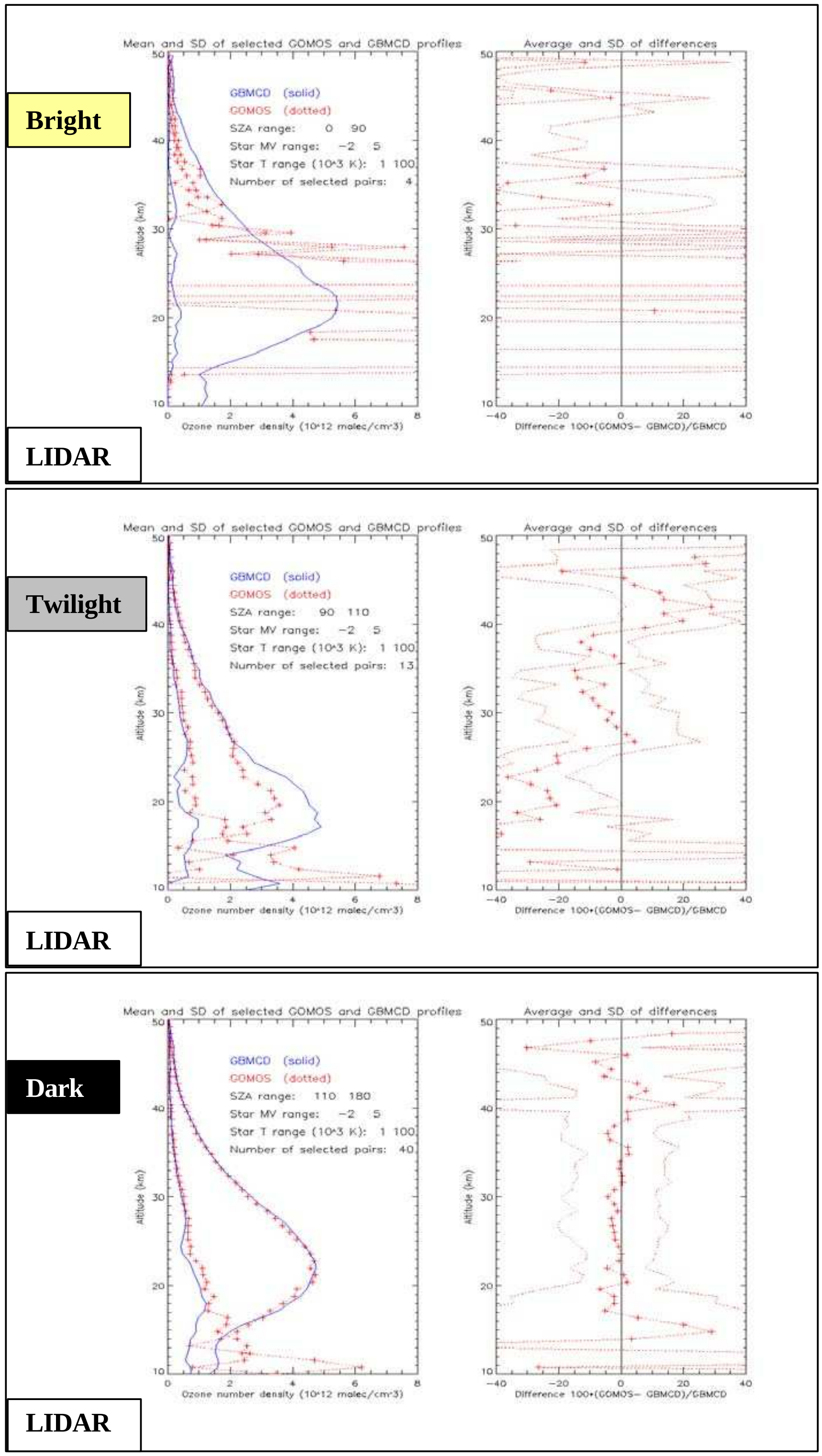

Fig. 2. Analysis of **lidar** compared to **GOMOS** ozone profiles with respect to the SZA during GOMOS observation. Top, middle, and bottom panel show the results for bright, twilight, and dark conditions respectively. Left plots show the mean ozone profiles and their standard deviation. Right plots show average differences between GOMOS and GBMCD profiles and std. deviation in percentage relative to the latter.

3.1 <u>Lidar vs GOMOS</u>

In this section we present the analysis of the 57 lidar and

GOMOS collocated ozone profiles. Initially we have differentiated this selection by pairs including GOMOS measurements in bright, twilight and dark limb conditions, see top, middle and bottom panel of Fig. 1 respectively. Even though there were only four cases, it is clear that the bright limb condition gives poor results. The results from the 13 profiles from the twilight limb condition are better, but there are still large deviations. Though, all twilight limb cases result from the collocations with the Alomar station, and we have some doubt whether the deviations are solely due to the GOMOS retrieval. For example, the lidar observations at this Arctic station could also be affected by the twilight, or perhaps the inhomogeneous ozone layer close to the Polar vortex should require more stringent collocation criteria. More research is needed to determine the quality of the GOMOS ozone profiles measured under the twilight conditions.

The analysis of all dark limb situations gives good results. Between 18 and 45-km altitude there are no systematic biases in the GOMOS ozone profile. These cases have been separated by star magnitude and star temperature. The star magnitude does not seem to have a clear influence, not shown. The number of cases in which GOMOS made use of strong stars was too limited to draw stronger conclusions. The influence of star temperature is shown in Fig. 3. Very similar results are derived from cases in which GOMOS used cold

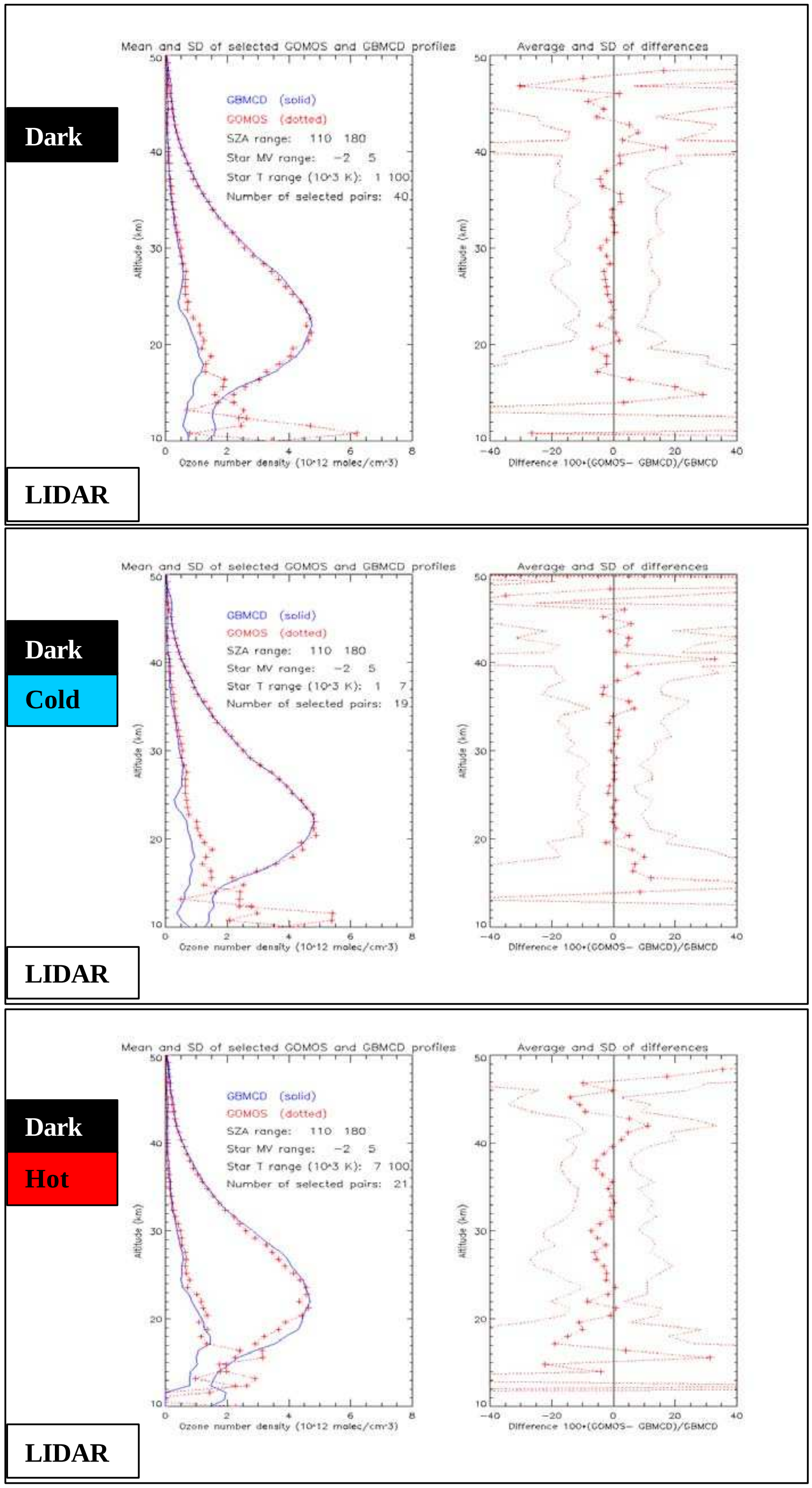

Fig. 3. As Fig. 2, but now is presented the analysis of **lidar** compared to **GOMOS** ozone profiles using all dark limb cases (top panel), which have been separated by cold (middle panel) and hot (bottom panel) star temperatures.

and hot stars. Therefore, we conclude that the star temperature does not seem to have a clear influence.

3.2 <u>Sonde vs GOMOS</u>

In this section we present the analysis of the 39 sonde and GOMOS collocated ozone profiles. We have also differentiated this selection by pairs including GOMOS measurements in bright, twilight and dark limb conditions. No twilight cases were found and the bright limb conditions give poor results; results are not shown, but are similar to those shown in the top panel of Fig. 2. The analysis of all dark limb situations gives good results, see top panel of Fig. 4. Between 18 and 35-km altitude there is a small systematic bias of 5 to 10% in the GOMOS ozone profile (GOMOS lower).

There was only one case in which GOMOS made use of a strong star and we could not draw any conclusion from this.

The influence of star temperature is shown in Fig. 4, and it seems to indicate that below 22-km altitude the results from cold stars are better that from hot stars and above this altitude vice versa. The preliminary conclusion on this subject has to be verified when we can perform better statistics in the future.

3.3 <u>Microwave vs GOMOS</u>

In this section we present the analysis of the 35 microwave and GOMOS collocated ozone profiles. We have also differentiated this selection

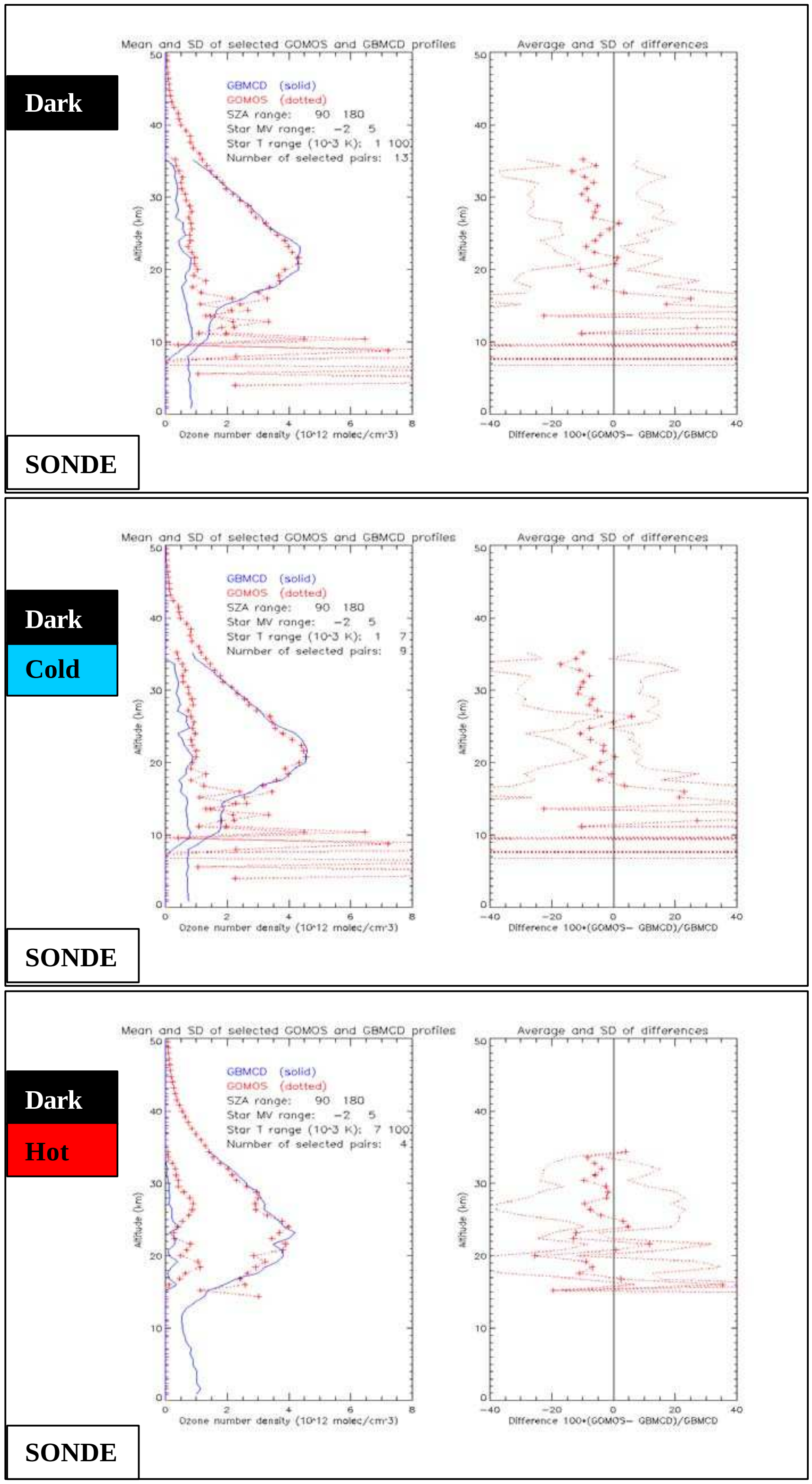

Fig. 4. As Fig. 2, but now is presented the analysis of **sonde** compared to **GOMOS** ozone profiles using all dark limb cases (top panel), which have been separated by cold (middle panel) and hot (bottom panel) star temperatures.

by pairs including GOMOS measurements in bright, twilight and dark limb conditions. No twilight cases were found and the bright limb conditions give poor results; results are not shown, but are similar to those in the top panel of Fig. 2. The analysis of all dark limb situations gives good results, see top panel of Fig. 5. Note the higher altitude range of the microwave data, which was not covered by the other instruments. We conclude that the dark limb cases, between 20 and 45-km altitude, have a bias which is within 20%.

There were no cases in which GOMOS made use of strong stars.

There is a clear influence of star temperature for the ozone profile above 45-km altitude, shown in the lower part of Fig. 5. The cold stars used in the observations give poor results in the retrieval for the range of 45 to 65-km altitude. On the contrary, the hot stars in the same range show a bias which is within 20%. This bias though, is significant and non-random, which suggests there is a possibility for improvement.

3.4 All instruments vs GOMOS

An overall analysis was performed using all 131 GBMCD and GOMOS collocated ozone profiles. Unlike the analysis presented before, we are able to analyze the total amount collocations more thoroughly due to the larger number. The results using all collocations are presented in the top panel of Fig. 6. It immediately shows the need for applying

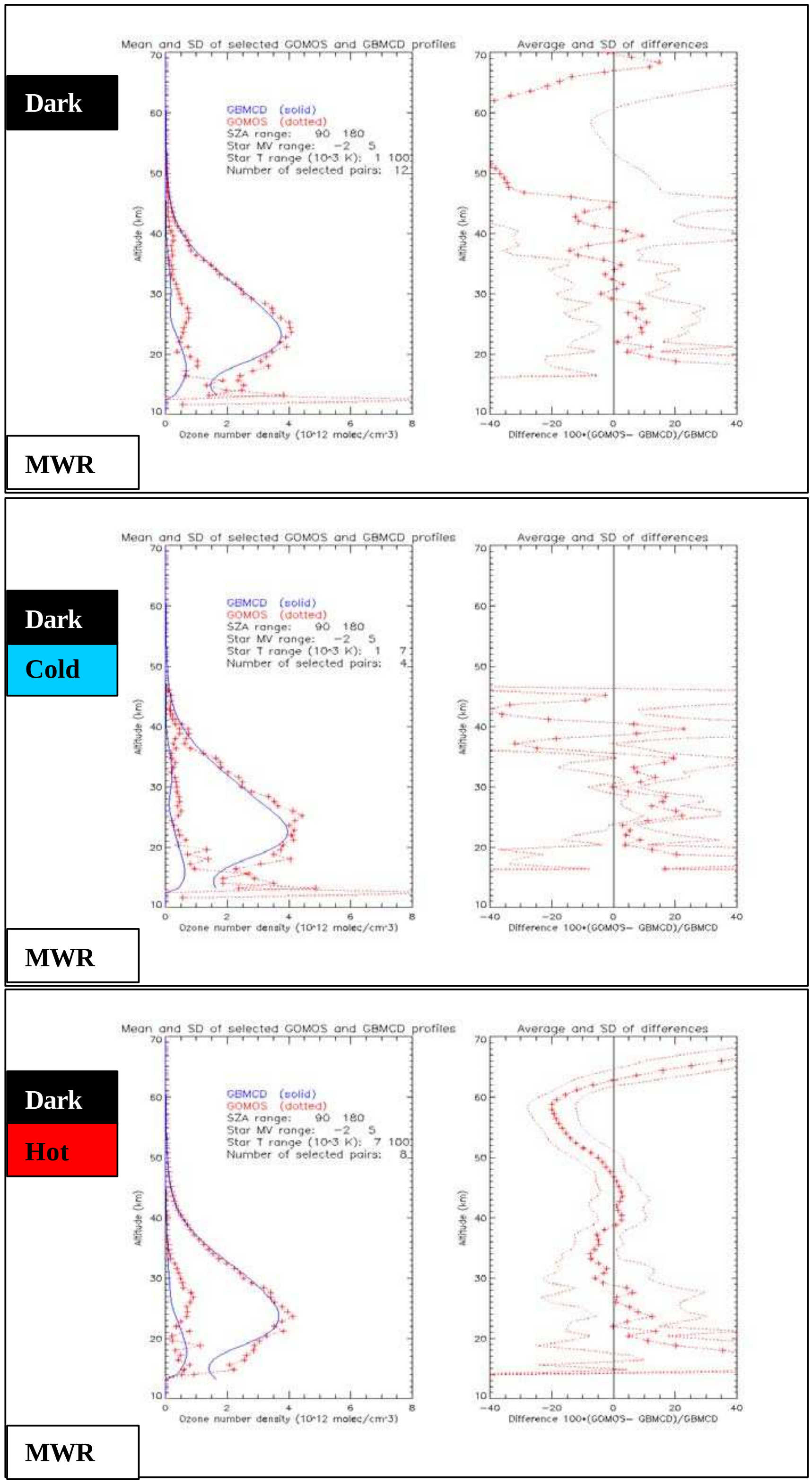

Fig. 5. As Fig. 2, but now is presented the analysis of **microwave** compared to **GOMOS** ozone profiles using all dark limb cases (top panel), which have been separated by cold (middle panel) and hot (bottom panel) star temperatures. Note the higher altitude range.

selection criteria. Most of the deviations arise from the cases in which GOMOS measured under bright limb conditions, see middle panel Fig. 6. Under these circumstances though, we can distinguish that the occultations using strong stars, bottom panel of Fig. 6, give some results above 30-km altitude. Between 30 and 50-km altitude GOMOS is systematically lower by 10 to 15%.

The dark limb cases are much better again and give good results, see top panel of Fig. 7. We could now separate the cases using strong and weak stars, see middle and bottom panel of Fig. 7 respectively. The results are very similar and the preliminary conclusion is that there is no clear influence of the star magnitude.

The influence of the star temperature is presented in Fig. 8. The total number of dark limb cases is nicely split in two, which makes the analysis, based on statistics, comparable. Examination of the results does not show a clear influence of the star temperature. The GOMOS ozone profile for all dark limb cases, between 18 and 45-km altitude, shows a bias which is within 5 to 10% of the GBMCD profiles.

4. CONCLUSIONS

The data from the ACRI prototype processor seem to have no significant biases for the occultations measured under dark limb conditions. Therefore, at the moment we can not think of any objections to release the

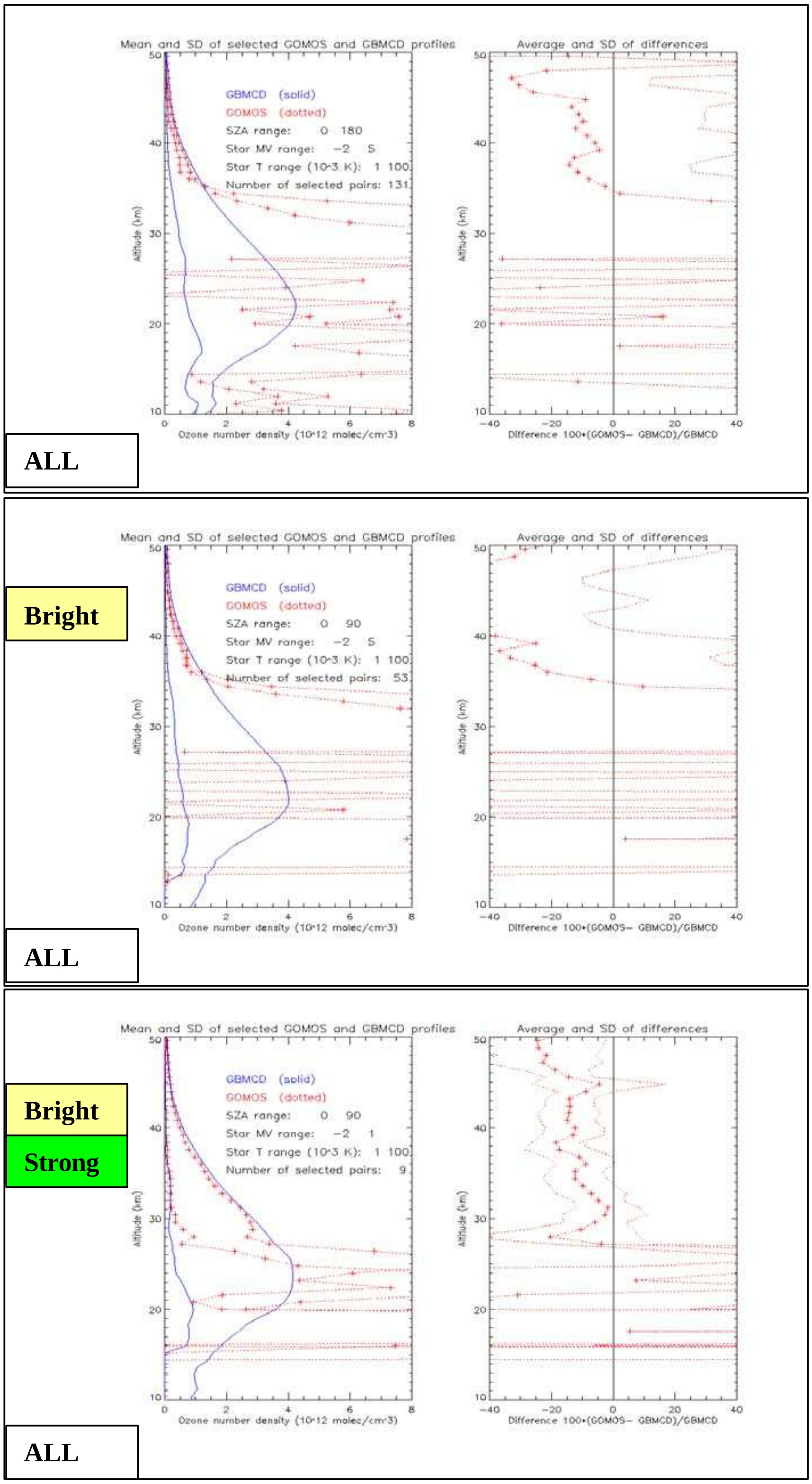

Fig. 6. As Fig. 2, but now is presented the analysis of **all GBMCD** compared to **GOMOS** ozone profiles using all 131 cases (top panel), bright limb cases (middle panel) and bright limb cases using strong stars (bottom panel).

GOMOS data measured under these circumstances. The standard data processor of ESA needs to be upgraded to comply with the status of the ACRI processor. The knowledge of the quality of these profiles is that between 18 to 45-km altitude the bias is within 5 to 10% of GBMCD ozone profiles. The GBMCD profiles used in this analysis were measured both in the southern and northern hemisphere. Below 18-km altitude the results are poor, and between 45 to 65-km altitude the quality seems promising for the occultations of hot stars, but at the moment the bias is up to 20%. Ozone profiles measured in bright limb are only reasonable for strong stars (MV<1) and only above 30-km altitude, but GOMOS is lower by 10 to 15%.

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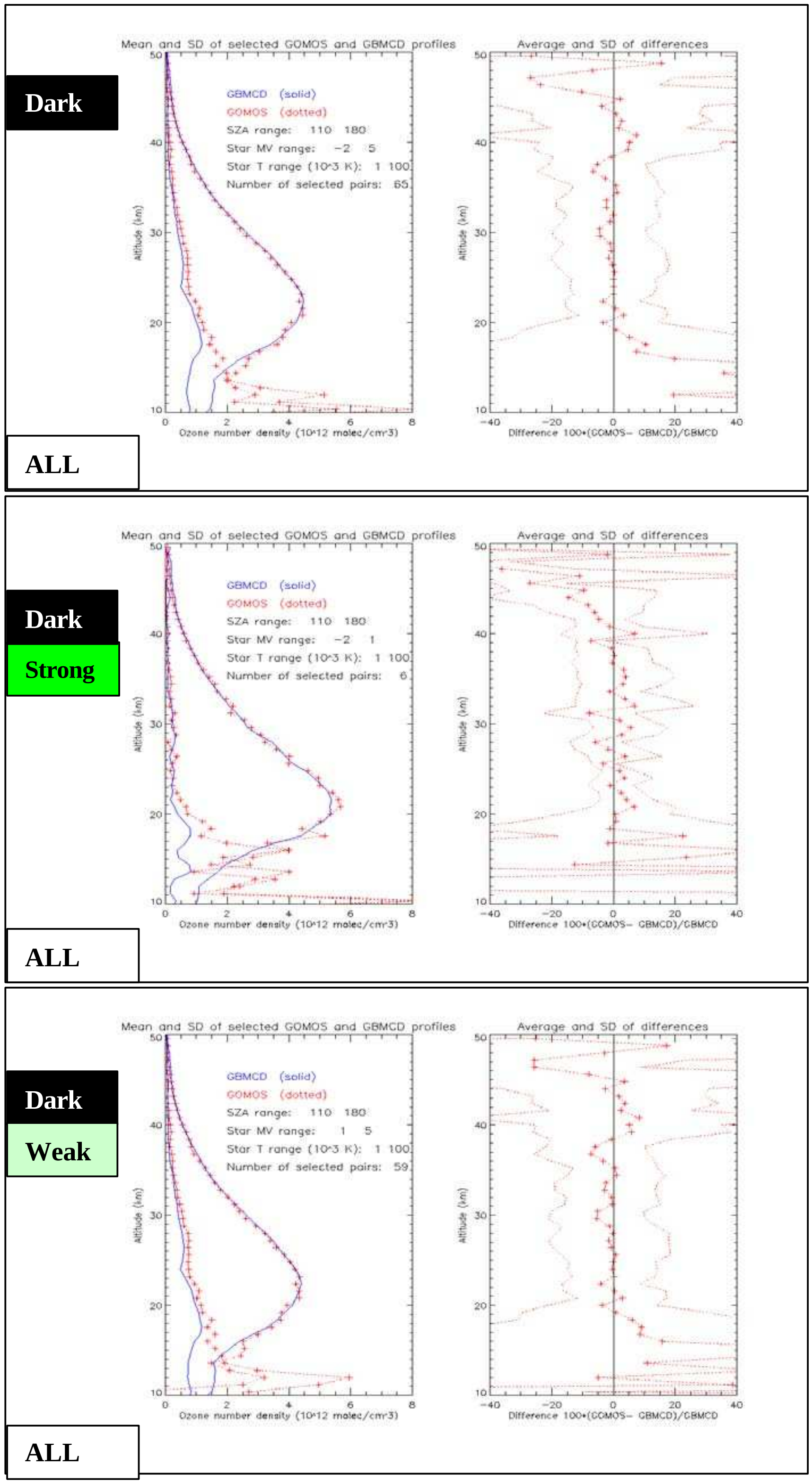

Fig. 7. As Fig. 2, but now is presented the analysis of **all GBMCD** compared to **GOMOS** ozone profiles using all dark limb cases (top panel), which have been separated by star magnitude value; strong (middle panel) and weak (bottom panel).

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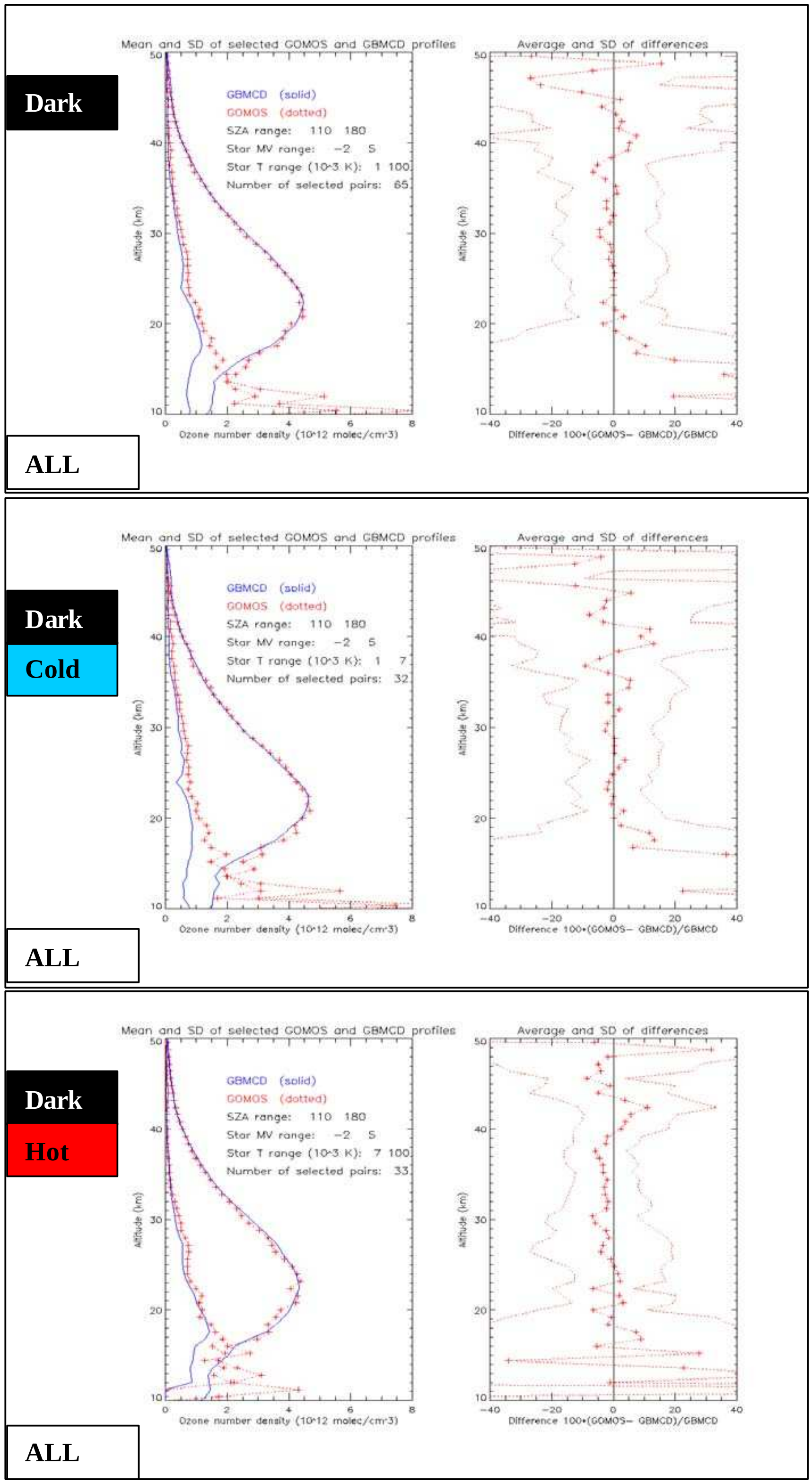

Fig. 8. As Fig. 2, but now is presented the analysis of **all GBMCD** compared to **GOMOS** ozone profiles using all dark limb cases (top panel), which have been separated by cold (middle panel) and hot (bottom panel) star temperatures.