The Ozone Deficit Budget as observed by GOMOS on ENVISAT

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Abstract. Measurements of ozone in the upper stratosphere (35-50 km) have indicated in the past a higher abundance than photo-chemical models predictions. This long-standing puzzle has not yet received a completely satisfactory explanation, and is revisited by comparing the GOMOS ozone measurements with the most recent predictions of the Reprobus Chemistry Transport Model (CTM) model. Sample data taken near the equator are selected for comparison. While the model prediction is excellent in the range 28 - 40 km, there is a marked deficit in the model between 42 and 55 km, with a peak deficit of 28 % at 46 km. This is slightly larger than the deficit measured by HALOE on UARS (25 %) as reported by Khosravi et al. (1998).

Ozone measurements with GOMOS on ENVISAT.

GOMOS (Global Ozone monitoring by Occultation of Stars) is performing about 400 stellar occultation per day, measuring the atmospheric spectral transmission from 250 nm to 940 nm. Vertical profiles of O_3, NO_2, NO3, together with temperature, aerosols and H_2O, are retrieved from the data inversion of each occultation, at various latitudes (Bertaux *et al.*, 1988; 1991).

The GOMOS night time measurements on board ENVISAT are of specially high accuracy (about 2-4 % for individual vertical profiles), and their altitude is perfectly known (better than 30 m), a particularity of the star occultation technique.

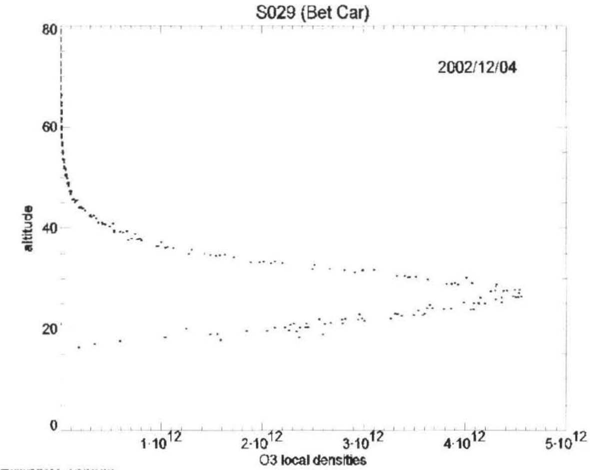

Figure 1. A series of 10 vertical ozone profiles are plotted together. They are obtained with the same star Beta Carinae, near the equator, in a single day: December 4, 2002.

Comparison of GOMOS data to Reprobus Model.

The Reprobus Chemistry Transport Model (CTM) contains the most recent and currently admitted chemical schemes and reaction rates. The transport is calculated from the ECMWF wind field, and the temperature is also taken from ECMWF. On figure 2 are compared two ozone profiles: the GOMOS data (a two weeks average of ozone profiles obtained near the equator with the same star Beta Carina), and the corresponding Reprobus prediction.

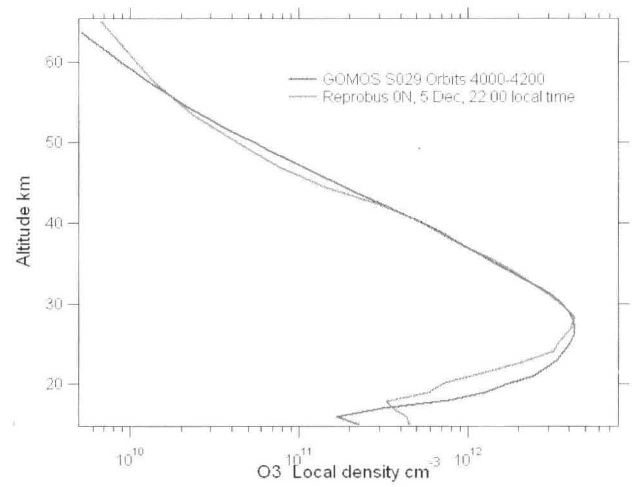

Figure 2. Comparison of ozone vertical profiles as measured by GOMOS (blue line, average of 2 weeks) and the corresponding prediction of the CTM Reprobus model (red line).

It should be understood that the observed variance σ^2 of ozone density as measured by GOMOS is a quadratic combination of the natural variability, and the precision of the GOMOS measurements. In tropical or equatorial regions, it was found that the observed variance is very small when the sampling is limited to ten orbits (within one day) ,with a corresponding relative standard deviation σ = 4%.It gives a strong upper limit for the precision of 4% ,but a careful study of the observed variance (Hauchecorne *et al.*, 2004a) is showing that the precision is rather of the order of 1 to 3% maximum, for an individual vertical GOMOS ozone profile recorded for this particular star magnitude. Therefore, since about 120 profiles were averaged together on Fig.2, the precision of the GOMOS averaged profile is well below 1% (still, we cannot discard systematic errors that would be connected to error in the ozone absorption cross-section, but they are believed to be known to a 1% level absolute accuracy).

On figure 3 is represented the relative difference between the Reprobus prediction ozone abundance and. GOMOS data : (Reprobus-GOMOS)/GOMOS (a two weeks average of ozone profiles obtained near the equator with the same star Beta Carina).

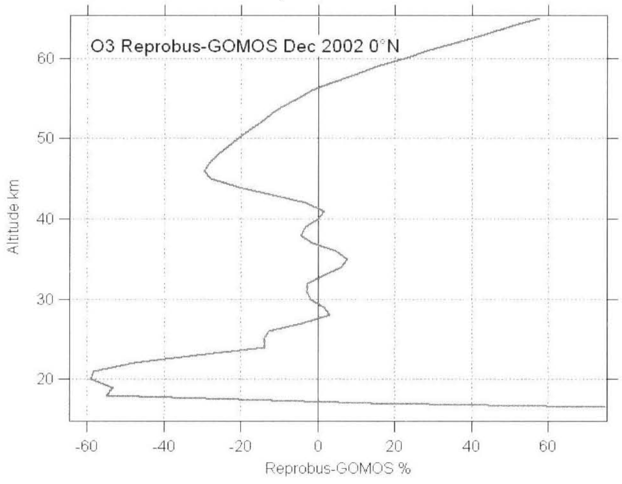

Figure 3. Relative difference between the Reprobus prediction ozone abundance and. GOMOS data.

The relative difference is small in the region from 28 to 42 km of altitude. Below 28 km, the difference is certainly of dynamical nature, since the lifetime of ozone is long, and this subject will be addressed in other studies. Here we are interested in the region above 42 km, where the "classical " ozone deficit in the model is clearly confirmed (perhaps even with a higher deficit than previously reported by Khosravi et al., 1998,which reported a peak deficit of 25 %). This is certainly of a chemical nature, because the ozone lifetime (in fact, $O+O_3$) is quite short, some 10^4 s. But it is seen that the relative difference is changing sign above 56 km, adding to the puzzle. This strongly suggests that the reasons for discrepancy are not the same below and above 56 km, and the purpose of the exercise is to find a cause to both discrepancies.

We remind here that the model parameters that were changed in the study of Khosravi *et al.* were:

The first model modification was to force the temperature field by UKMO analysis, which is cooler than their free-running baseline model by as much as 5 K above 40 km, and cooler below. As a result, the ozone deficit decreased as much as 8-10%. This is due to a great sensitivity of the Chapman destruction reaction $O + O_3 \rightarrow 2 O_2$. The loss rate decreases by 3% for 1 K reduction in temperature. While constraining further the model by the observed NOx field did not modify the deficit, the situation was quite different with ClO. This is because ozone loss is dominated by the ClO field (in addition to T and NOx), the deficit was reduced to 10%.

By changing further the reaction rate of $HO_2 + O \rightarrow OH + O_2$ (reduction of 40%), the ozone deficit was further reduced to a few percent above 40 km, within the rms errors of the HALOE measurements, but then the deficit was enhanced below 40 km.

It is clear that the higher accuracy of GOMOS O_3 measurements will be helpful to determine the causes of the discrepancies with the model.

The ozone model deficit (Model - Observation) will be studied for various latitudes and seasons to identify patterns in its distribution. GOMOS measurements of both NO_2 and NO_3 (Hauchecorne *et al.*, 2004b) will be also compared to Reprobus predictions to detect possible other discrepancies, since in this region ozone should be in a state of rapid photo-chemical equilibrium

Finally, we need to resolve these discrepancies if we have to build some confidence in the evolution of ozone as predicted by models.

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