VALIDATION OF GOMOS VERTICAL PROFILES USING BALLOON-BORNE INSTRUMENTS AND SATELLITE DATA

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ABSTRACT

Six balloon-borne instruments were involved in the validation of GOMOS during two campaigns, at mid-latitude on September-October 2002 and at high latitude on January-March 2003. The vertical profiles obtained with these instruments, and by the satellite instruments POAM and SAGE, are compared to GOMOS profiles. The new version of the GOMOS vertical profiles of ozone, NO_2, NO_3 and water vapour is strongly improved. In particular, the unrealistic oscillations in the previous profiles are now removed. Nevertheless, significant discrepancies remain between GOMOS results and balloons data. Based on the LPCE processor applied to the GOMOS transmission spectra, recommendations are proposed in order to improve the retrieval, in particular by better taking into account the effect of the chromatic scintillation and the contribution of aerosols.

1. INTRODUCTION

In a previous paper [1], we had compared GOMOS vertical profiles to balloon-borne measurements performed by the SALOMON instrument on September 19, 2002 above Aire sur l'Adour (France). One main problem was that the GOMOS profiles exhibited strong oscillations. Then, recommendations for the improvement of GOMOS data reduction have been proposed, based on the LPCE processor developed from the already-existing SALOMON algorithm. Some of these recommendations have been taken into account for producing the new version of GOMOS profiles that was released at the beginning of 2004.

In this paper, we will compare the new ozone, NO_2, NO_3 and H_2O GOMOS vertical profiles to those obtained by various balloon-borne instruments. We will focus mainly on two validation campaigns: at mid-latitude (Aire sur l'Adour) on September-October 2002, and at high latitude (Kiruna, Sweden) on January-March 2003. One water vapour profile obtained during the March 2004 validation campaign at Kiruna, will be also used. Some satellite data from POAM III and SAGE II will be also considered.

2. BALLON-BORNE MEASUREMENTS

Six balloon-borne instruments are used for the GOMOS validation: AMON, ELHYSA, MIPAS-B2, SALOMON, SAOZ, and SPIRALE. AMON is a UV-visible spectrometer [2] which uses stars as light source, like GOMOS. A flight was performed on March 1, 2003 from Kiruna, during a small Polar Stratospheric Clouds (PSCs) event; this will allow us to estimate the effect of PSCs on data reduction for ozone, NO_2 and NO_3. ELHYSA is a hygrometer [3]; two flights at high latitude, inside the polar vortex on January 16, 2003, and outside vortex on March 11, 2004, will be used as reference data for water vapour. MIPAS-B2 is a limb viewing Fourier Transform Infra-Red (FTIR) Spectrometer [4], like MIPAS onboard ENVISAT. The flight performed ad mid-latitude on September 24, 2002, will be used for the NO_2 validation. SALOMON is a UV-visible spectrometer [5] using the Moon as light source. A flight performed a few days before

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MIPAS, on September 19, 2002, will be considered for O_3, NO_2 and NO_3 validation. SAOZ is a UV-visible spectrometer using the Sun as light source [6]. Two flights, at mid-latitude on October 1, 2002 and high latitudes on March 30, 2003, will be used for the ozone and NO_2 validation. SPIRALE is a tunable diode laser absorption spectrometer [7]. This instrument allows in-situ measurements of species, and the January 21, 2003,flight will be used for the validation of high latitude measurements of NO_2.

3. OZONE

Figure 1 presents the comparison between SALOMON measurements and GOMOS vertical profile. It has been shown previously [1] that this SALOMON profile is in perfect agreement with an ozone sounding performed at the same time. Then, these data can be used unambiguously as reference data. A significant discrepancy appears between SALOMON and GOMOS for the absolute value of maximum concentration, and for its altitude. This effect is removed if the GOMOS transmission spectra (level 1b) are analysed by the LPCE processor. Then, the problem does not come from an instrumental bias in GOMOS raw measurements, but arises from the GOMOS processor used to produce the level 2 data.

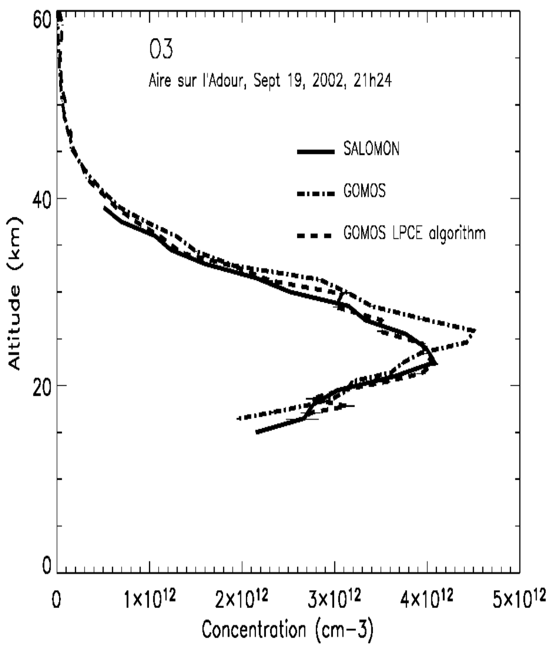

Fig. 1. Comparison between GOMOS and SALOMON at mid-latitude

Figure 2 presents two GOMOS ozone profiles, obtained one day before and just after SAOZ measurements. Once again, significant discrepancies appear for the values of maximum concentrations between the balloon and the GOMOS data.

Figure 3 presents a comparison between SAOZ and GOMOS at high latitude. As previously, the same problem is detected. An excellent agreement with SAOZ measurements can be obtained if the LPCE processor is used for the retrieval of the GOMOS profile.

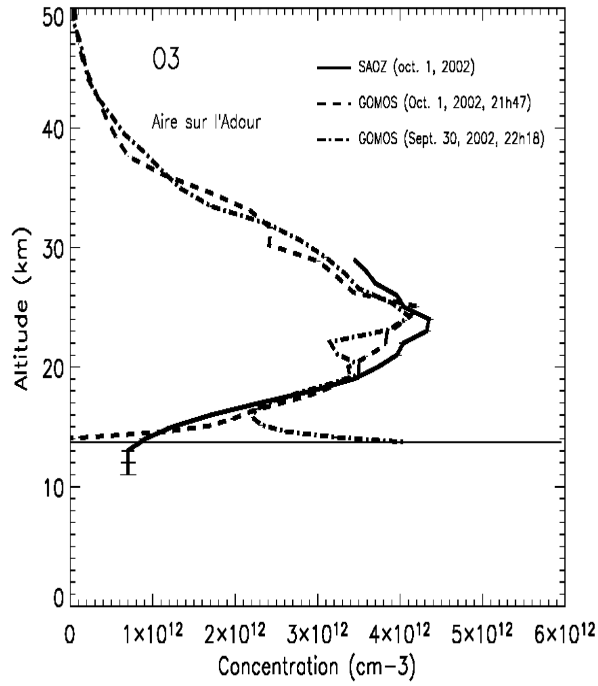

Fig. 2. Comparison between GOMOS and SAOZ at mid-latitude

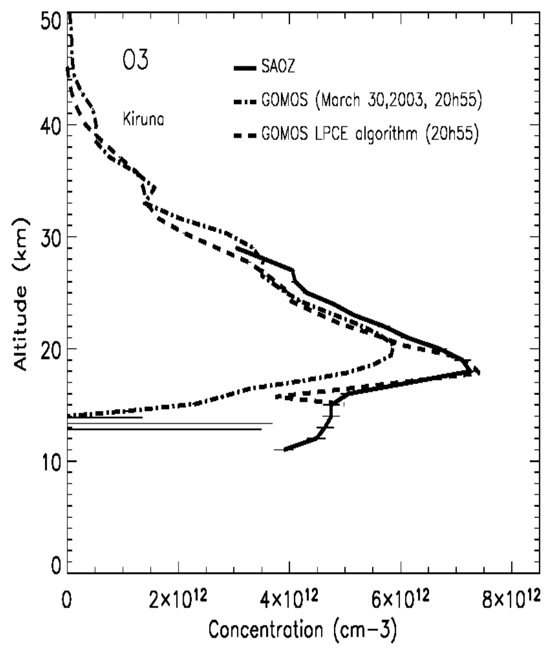

Fig. 3. Comparison between GOMOS and SAOZ at high latitude

Figure 4 presents a comparison between AMON and GOMOS measurements, during a PSC event. The presence of PSC induces additional noise and wavelength fluctuations in the transmission spectra that are difficult to remove. Then, oscillations can appear in the profiles. In that case, even the LPCE processor is not able to improve the GOMOS retrieval.

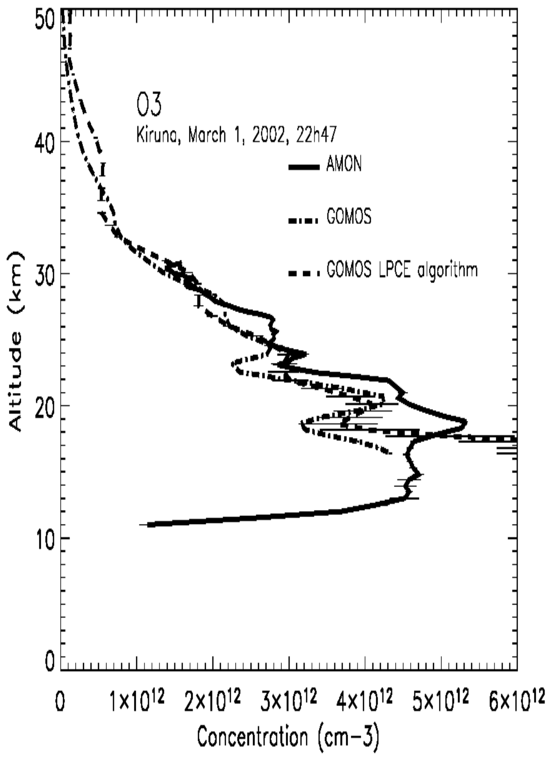

Fig. 4. Comparison between GOMOS and AMON at high latitude during a PSC event

The main difference between the LPCE processor and the GOMOS processor is the estimation of the contributions of chromatic scintillation [8] and of the aerosols. In order to minimise the effect of the scintillation, the LPCE processor applies a sliding average over three consecutive GOMOS spectra. This empirical method gives satisfactory results, as shown in the previous paper [1]. The SALOMON measurements, which not suffer the problem of the chromatic scintillation, have shown that the aerosol contribution can be retrieved using a third order polynomial in the 400 –700 nm spectral range [9]. In the case of GOMOS measurements, the polynomial can also allows us eliminating the residuum of the scintillation. We recommend using this method, which looks like a DOAS (Differential Optical Absorption Spectrometry) technique.

4. NO_2

NO_2, which is more difficult to measure than ozone, due to its lower concentrations, can be detected by various techniques. Then, it is necessary to verify the consistency of measurements coming from different instruments. Figure 5 presents the SALOMON, MIPAS-B2, SPIRALE and SAOZ measurements compared to MIPLASMO modelling outputs using an assimilation technique, for the September-October 2002 campaign at mid-latitude. It appears that all the measurements are consistent to each others, allowing us to consider them as reference data.

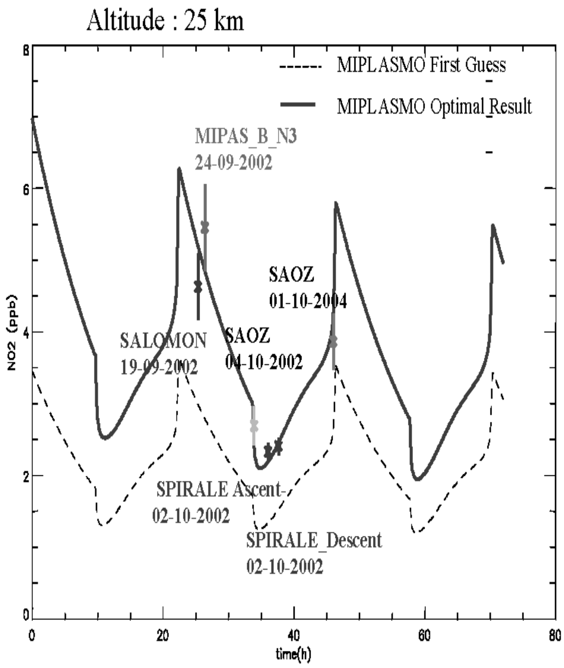

Figure 5: Assimilated NO_2 measurements during the 2002 mid-latitude campaign

The comparison on Figure 6 between SALOMON and GOMOS measurements shows a good agreement, at least for the total amount of NO_2. The improved GOMOS processor now uses a DOAS technique; then the previous oscillations are removed. Nevertheless, the fine-scaled vertical structures observed by SALOMON are lost with the GOMOS processor, although they can be retrieved with the LPCE processor. Figure 7 presents the comparison between MIPAS-B2 and GOMOS vertical profiles. Also, the fine-scaled structures are not well retrieved by the GOMOS processor (in this case-study, the retrieval seems difficult below 25 km, even with the LPCE processor). The same conclusion can be derived from the comparison of

GOMOS and SAOZ profile, after correcting for the NO_2 diurnal variation.

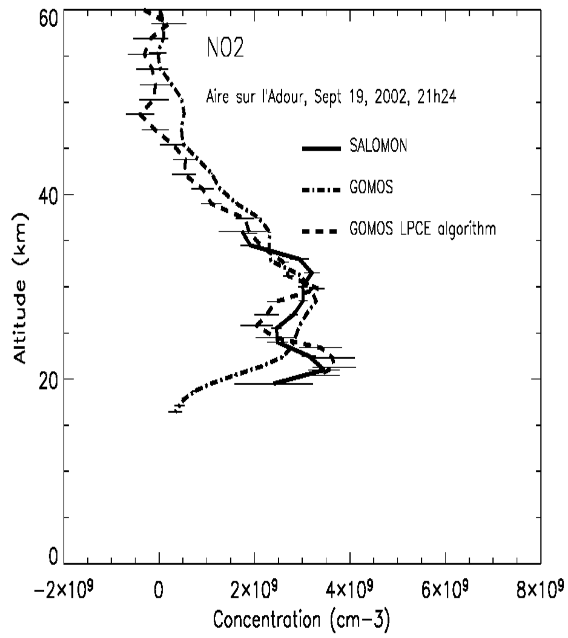

Fig. 6. Comparison between GOMOS and SALOMON at mid-latitude

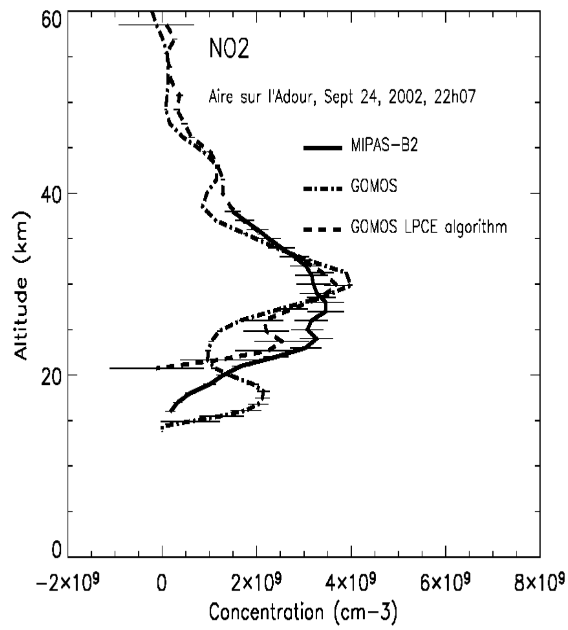

Fig. 7. Comparison between GOMOS and MIPAS-B2 at mid-latitude

The detection of small amount of NO_2 in the polar vortex at high latitudes is quite a challenge with GOMOS. Both GOMOS and LPCE processors are able to retrieve the small amount of NO_2, as presented on Figure 8. Nevertheless, there is a difference of about 2-km for the position of the maximum concentration between the results of the two processors. The in-situ SPIRALE measurements confirm that the LPCE processor gives more accurate results.

An analysis of AMON measurements shows that the retrieval is very difficult during a PSC event. In case of GOMOS measurements, the LPCE processor has rejected the data, since the signal to noise ratio is too low. Thus, further studies will be necessary before giving a conclusion concerning the ability of GOMOS to detect NO_2 during such particular event.

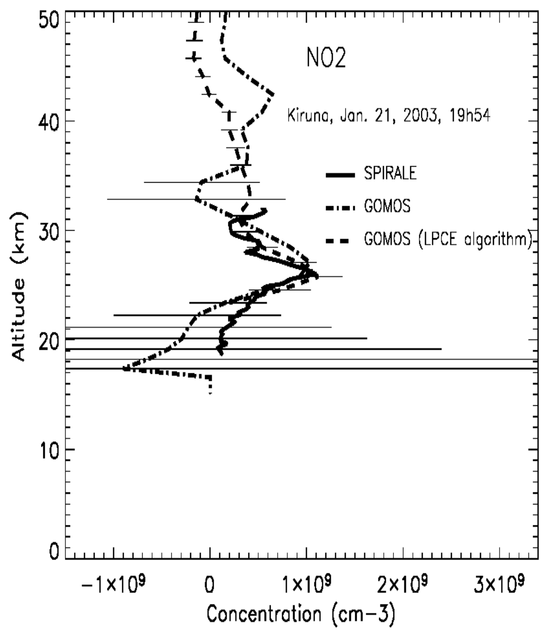

Fig. 8. Comparison between GOMOS and SPIRALE at high latitude inside the vortex

Satellite data can be used for the validation of GOMOS measurements above the float altitude of balloon typically between 35 and 40 km. A statistical analysis of the comparison between GOMOS and POAM III twilight measurements shows that the GOMOS data are quite acceptable in the 20 – 40 km range, at least concerning the shape of the profiles, but not for higher altitudes. Similar work has been conducted using the SAGE II data fort the twilight, stray-light and nighttime GOMOS measurements [9]. With coincidence criteria of less than 250 km, 314 collocations have been found between September 1, 2002 and March 31, 2003. After correction of the diurnal variation of NO_2, a deviation by 30% to 70% remains between GOMOS and SAGE II, in the 25-45 km altitude range.

The main difference between the GOMOS and LPCE processors, both using DOAS technique, is coming from the spectral domain and the smoothing procedure used for the retrieval. We recommend:

- to adapt the spectral domain to the magnitude and the colour of the star;
- to improve the scale of the vertical smoothing procedure.

5. NO_3

The new version of GOMOS data for NO_3 is strongly improved, since the unrealistic oscillations are removed. The estimation of total amount on GOMOS profile is quite correct, compared to SALOMON measurements at mid latitude, as presented in Figure 9. Nevertheless, the GOMOS processor is not yet able to capture the fine-scaled vertical structures. The LPCE processor can retrieve these structures, since it uses one again a DOAS technique and only the 662-nm spectral line, as recently recommended from the analysis of AMON and SALOMON measurements [10].

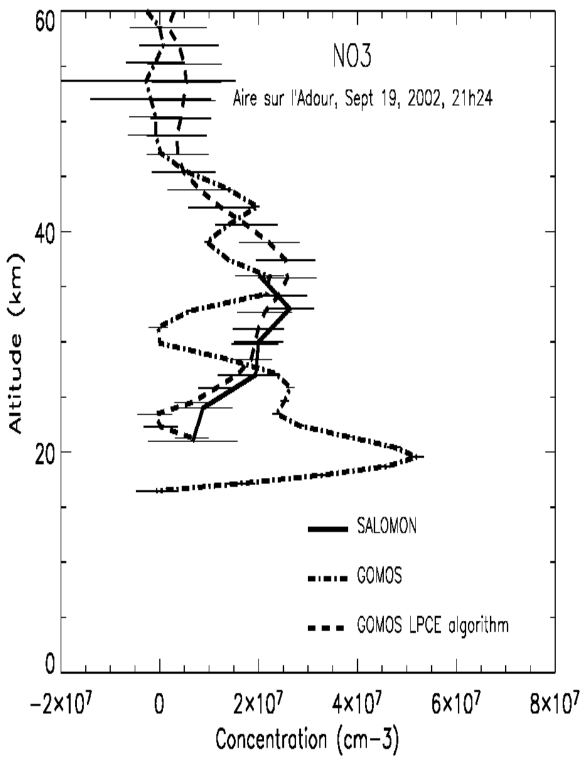

Fig. 9. Comparison between GOMOS and SALOMON at mid-latitude

Small amounts of NO_3 are expected at high latitude. In case of PSC events, the retrieval is impossible both in AMON and GOMOS measurements, even using the LPCE processor. Without the presence of PSC, NO_3 can be sometimes retrieved in the middle and upper stratosphere measurements by GOMOS using the LPCE processor. Nevertheless, we recommend to average GOMOS transmissions spectra obtained during several occultations performed in similar geophysical conditions, in order to retrieve realistic profiles for high latitudes.

6. Water vapour

The retrieval of water vapour in the near infrared spectral domain is not easy. Significant improvements have been done since the previous version of the GOMOS data, in particular by removing the unrealistic oscillations. Nevertheless, the retrieval is valid only if very bright stars, like Sirius, are used.

Figure 10 presents one of the best GOMOS profiles available, compared with two ELHYSA profiles, one outside the polar vortex, and one inside. These two profiles represent the lower and upper limit for water vapour. The GOMOS profile seems not too unrealistic below 30 km, with an acceptable estimation of total amount of water vapour. Nevertheless, the real shape of the profile is not yet obtained.

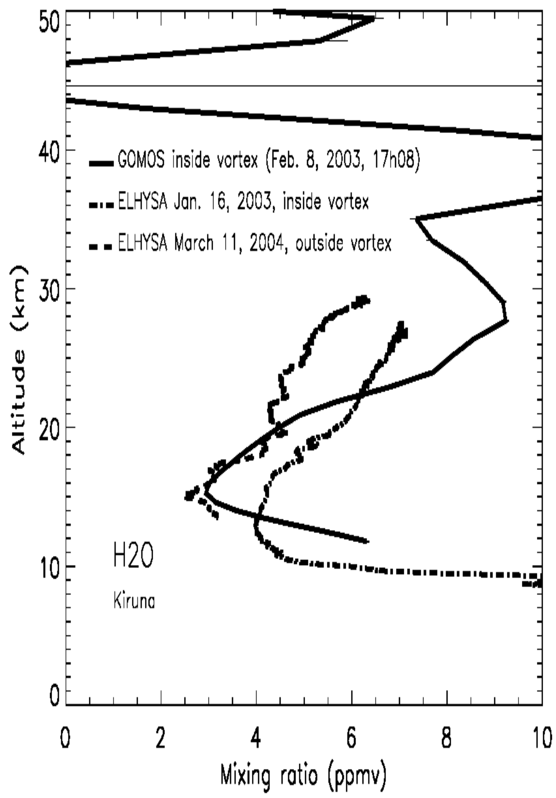

Fig. 10. Comparison between GOMOS and ELHYSA at high latitude

A statistical comparison between GOMOS and SAGE II data has been also conducted. 223 collocations have been found between September 1, 2002 and March 31, 2003 (with a coincidence criteria less than 250 km and during the same day). Unsurprisingly, only few GOMOS profiles are quite similar the SAGE II ones.

6. CONCLUSION

The profiles derived using the LPCE processor show that the GOMOS 1b level products are correct. Then, the validation must be focused on level 2 retrievals. Strong improvements have been done in these retrievals since the previous released of the data. The GOMOS profiles obtained with the brightest stars are more accurate, and can be used for the self-consistency validation exercise [11]. Nevertheless, the validation exercise using balloon-borne instruments have shown that the GOMOS vertical profiles cannot be used randomly, although the improvements in the GOMOS processor are very promising.

New validation campaigns have been conducted, in particular at high latitude in March 2004 and at mid latitude in June 2004. Both GOMOS and balloon data have been recently released, and the analysis is still in progress. The conclusions will be presented in future workshops.

Two other species need validation: OClO, and aerosols. OClO is difficult to detect; a large amount of GOMOS transmissions spectra obtained in similar geophysical conditions must be probably averaged in order to detect this species. A strategy of aerosol validation involving three different balloon instruments (SALOMON for the wavelength extinction, MicroRADIBAL for polarization and radiance [12], and LMD aerosol counter for the granulometry of particles larger in diameter than 0.3 microns) have been conducted in March 2004 at high latitude. The analysis is also still in progress.

Future campaigns will be necessary for the validation of GOMOS profiles. First, they will allow us to validate the new profiles retrieved by the future improved GOMOS processor. Secondly, using the balloon-borne reference data, they will act as a long-term monitoring for evaluating the changes in GOMOS performances, at mid and high latitudes.

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