Validation of GOMOS vertical profiles using the stratospheric balloon-borne AMON and salomon UV-visible spectrometers

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VALIDATION OF GOMOS VERTICAL PROFILES USING THE STRATOSPHERIC BALLOON-BORNE AMON AND SALOMON UV-VISIBLE SPECTROMETERS

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ABSTRACT

The stratospheric balloon-borne UV-visible spectrometers AMON and SALOMON, which use stars and Moon as light source, respectively, are involved in the validation of the UV-visible spectrometer GOMOS onboard ENVISAT, which uses also stars as light source. A low spectral resolution UV-visible spectrometer, AMON-RA, is also implanted in the AMON gondola, for the analysis of the chromatic scintillation effect. A flight of SALOMON occurred in September 19, 2002, at mid latitude from Aire sur l'Adour, France. An AMON (and AMON-RA) flight occurred at high latitude from Kiruna (northern Sweden) on March 1, 2003. The vertical profiles are compared to those obtained by GOMOS. Taking into account the effect of the chromatic scintillation on the transmission spectra, recommendations will be proposed in order to improve the GOMOS retrievals.

1. SALOMON FLIGHT

SALOMON is an UV-visible spectrometer which uses Moon as light source [1]. The conditions of measurements and the retrieved vertical profiles for the SALOMON flight on September 19, 2002 around 21h30 UT from Aire sur l'Adour (France), have been already published [2]. From the comparison between SALOMON and GOMOS data, and after using the algorithm developed in our group (hereafter called "LPCE" algorithm), we have concluded that the GOMOS transmissions are potentially good for the O_3, NO_2 and NO_3 retrievals. Nevertheless, improvements on the GOMOS algorithms are necessary. We have proposed the following improvements:
1) A sliding average must be applied on three consecutive spectra in order to remove the residual of the chromatic scintillation.
2) Spectral window centred on the strongest absorption lines of the species must be used.
3) UV domain and the region where ozone cross-sections are inaccurate (around 400 nm) must be excluded for the ozone retrieval, and a third order polynomial must be used for the (simultaneous) aerosol retrieval.
4) The DOAS method must be used for the NO_2 retrieval.
5) A careful analysis of the agreement between the wavelength scales of GOMOS transmission spectra and NO_2 cross-sections must be done.
6) Only the 662-nm line must be considered for the NO_3 retrieval.
7) Due to the possible presence of local gradient of temperature and then of NO_3, only the global shape of the profile must be searched for.

We will focus below on the second part of our validation program: measurements at high latitudes.

2. CONDITIONS OF MEASUREMENTS

The UV-visible spectrometer AMON [3] and the rapid photometer AMON-RA [4], which use stars as light sources, like GOMOS, were launched on the evening of 1 March 2003 from Kiruna (Northern Sweden). Two star sets were observed by AMON: Sirius (α Canis Major) with a magnitude of –1.5, at around 22h UT, and Alnilam (ε Orionis) with a magnitude of 1.7, at around 23h UT. The vertical profiles were then obtained at around (64°N, 16°-25°E) and (66.5°N, 18°-27°E). It must be noticed that the pointing conditions were perfect. The measurements were conducted well inside the polar vortex, where temperatures around –80°C were encountered. This temperature range is in favour of the presence of (liquid) Polar Stratospehric Clouds. An ozone sounding was also performed at the same time.

An acceptable coincidence was available with a star observed by GOMOS (star number 100) with a magnitude of 2.58 at 22h47 UT and at around (72°N, 27°-38°E), also inside the polar vortex.

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3. OZONE RETRIEVAL

The AMON measurements were conducted in particular conditions. Ozone profile exhibits strongly stratified layers, and then a strong vertical variability, as shown by the sounding. Comparison between the two sets of AMON measurements shows also a horizontal variability, at least for altitudes below 25 km (Fig.1). One can conclude that the hypothesis of spherical symmetry, imposed by the inversion, is quite inaccurate in this case, and could generate strong oscillations. Then the question is: what mean these remote-sensing measurements? If the slant column profiles are smoothed before inversion, it can be expected to be able to retrieve (only) the global shape of ozone profile.

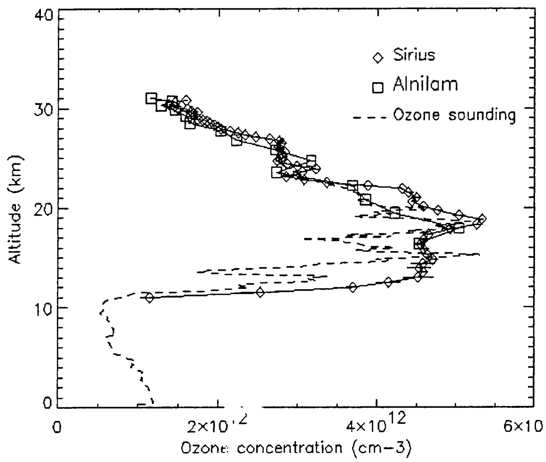

Fig. 1. Ozone profile, from AMON observations (Sirius and Alnilam) and from sounding.

The GOMOS transmission spectra were noisy (Fig 2., top). It seems also that the AMON transmission spectra are noisier than during the previous flights are high latitude. Of course the main reason of the distortion on the spectra is the chromatic scintillation, which can be empirically reduced by applying sliding smoothing procedure over 3 or 5 consecutive spectra (Fig 2. bottom). The noise could also result from the presence of aerosols, which seems to be observed in larger amounts by various instruments during this winter in the polar vortex, and by the presence of Polar Stratospheric Clouds.

The ozone retrieval from the GOMOS observation was performed in the 460-680 nm spectral window. Fig. 3 presents the comparison between the available GOMOS vertical profile and the profile using the "LPCE" algorithm. Although there is a significant improvement using the "LPCE" algorithms, it failed also to retrieve accurately the concentration in the lower stratosphere since the minimum altitude of the profile is 18 km (the last line of sight of GOMOS was in that case at 16 km).

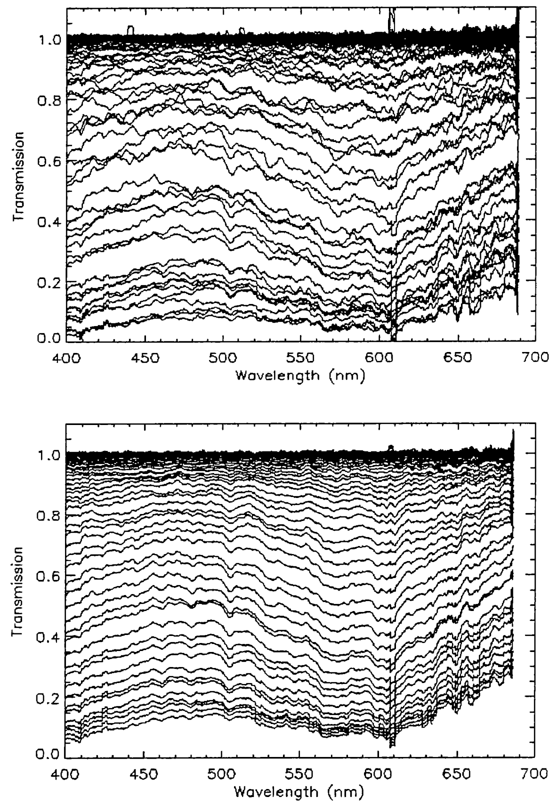

Fig. 2. GOMOS transmission for the star number 100. Up: spectra after a sliding smoothing over 10 consecutive pixels. Bottom: Same as above, but after a sliding smoothing over 5 consecutive spectra.

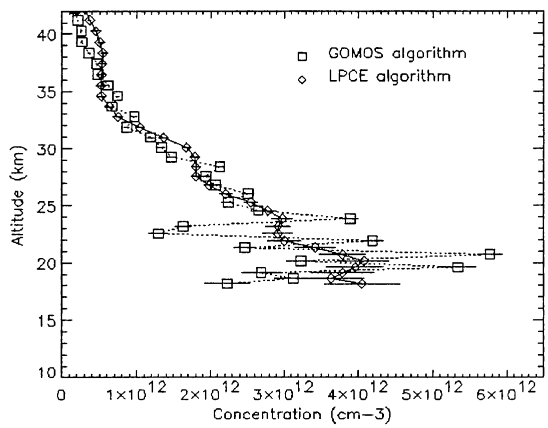

Fig 3. Ozone vertical profile from GOMOS transmission of star number 100.

4. OTHER SPECIES

NO_2, NO_3 and OClO were detected by AMON but the "LPCE" algorithm fails to detect these species in the GOMOS transmission spectra, as well as current GOMOS algorithm. It is then interesting to compare the two retrieval methods for the bright star Sirius where it is expected that NO_2, NO_3 and OClO can be easily retrieved. Surprisingly, the GOMOS transmission spectra of Sirius in 8 February 2003 at 17:08 UT, at around (70°N, 32°E) are noisier than the spectra of weaker stars obtained in September 2003 at mid latitude and analysed in the previous report. This fact can also result from the presence of aerosols and PSC. Then the retrieval of species other than ozone is difficult in the polar vortex. The LPCE algorithm has also failed to retrieve meaningful slant column densities of NO_3 and OClO due to the strong noise.

5. MIDLATITUDE GOMOS MEASUREMENTS

In the frame of a comparison work at mid latitude between GOMOS measurements and SPIRALE observations (balloon-borne infrared in-situ spectrometer, operated by Guy Moreau, at LPCE-CNRS, Orléans) using modelling work (done by Michel Pirre, also at LPCE-CNRS, Orléans) with backward and forward trajectories, we have searched for ozone, NO_2 and NO_3 in various GOMOS observations performed in October 2002 at mid latitude. As previously at such latitudes, we have succeeded to retrieve these species (Fig. 4 and Fig 5.) for star number 63, which is a cold (red) star with a magnitude of 2.15, on 26 September 2002 at 21:03 UT and at around (42°N, 4°E). In this case, the spectra window for the NO_2 retrieval must be slightly reduced (435-545 nm instead of 420-545 nm) because of greater noise for shorter wavelengths.

6. SCINTILLATION MEASUREMENTS BY AMON-RA

The rapid photometer AMON-RA onboard the AMON gondola has allowed to record the Sirius and Alnilam occultation with sequences of 6000 spectra per 580 seconds. A gap of 25 seconds occurs between the sequences in order to store the data on the onboard disk.

The chromatic scintillation is due to local gradient of temperature, implying variation of the air refractive index. This phenomenon generates flux enhancements which propagate from red to blue. It induces distortions in the GOMOS transmission spectra, which bias the retrieval of the species for observations in the middle and lower stratosphere.

AMON-RA photometric data are available in 14 spectral windows of 25-nm width, from 400-425 to 725-750 nm. The Sirius occultation lasted 90 minutes (Fig. 6); the data are available for elevations from +2° down to –5°, which correspond to an altitude in the 31-11 km range (the balloon float altitude was equal to 31 km). The Alnilam data are available only from +2.5° down to -1.5°. Fig. 7 presents a 1-minute sequence for the Sirius occultation, at an elevation centred on –4.1°, which correspond to a tangent altitude of 16 km. The flux enhancement propagation from red to blue lasts around 3 seconds at this altitude.

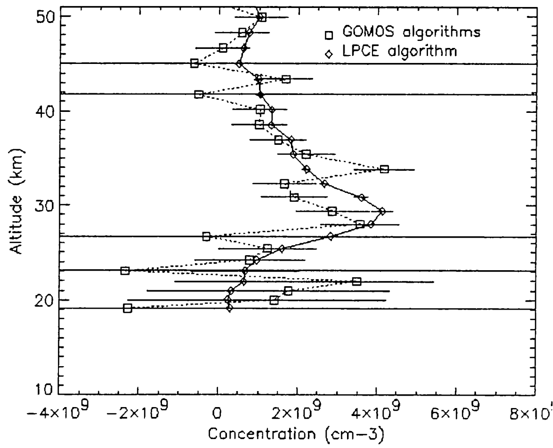

Fig.4. NO_2 profile from GOMOS observations of star number 63, on 26 September 2003.

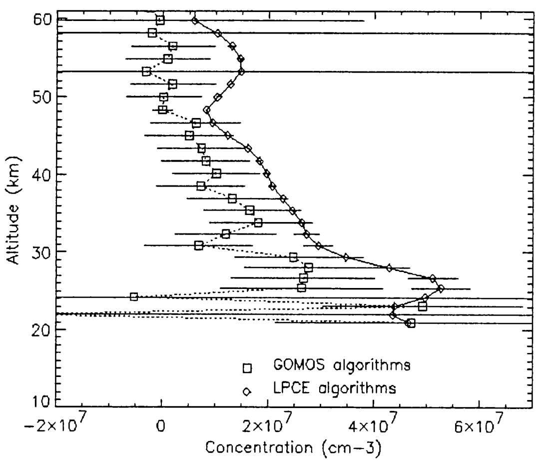

Fig.5. NO_3 profile from GOMOS observations of star number 63, on 26 September 2003.

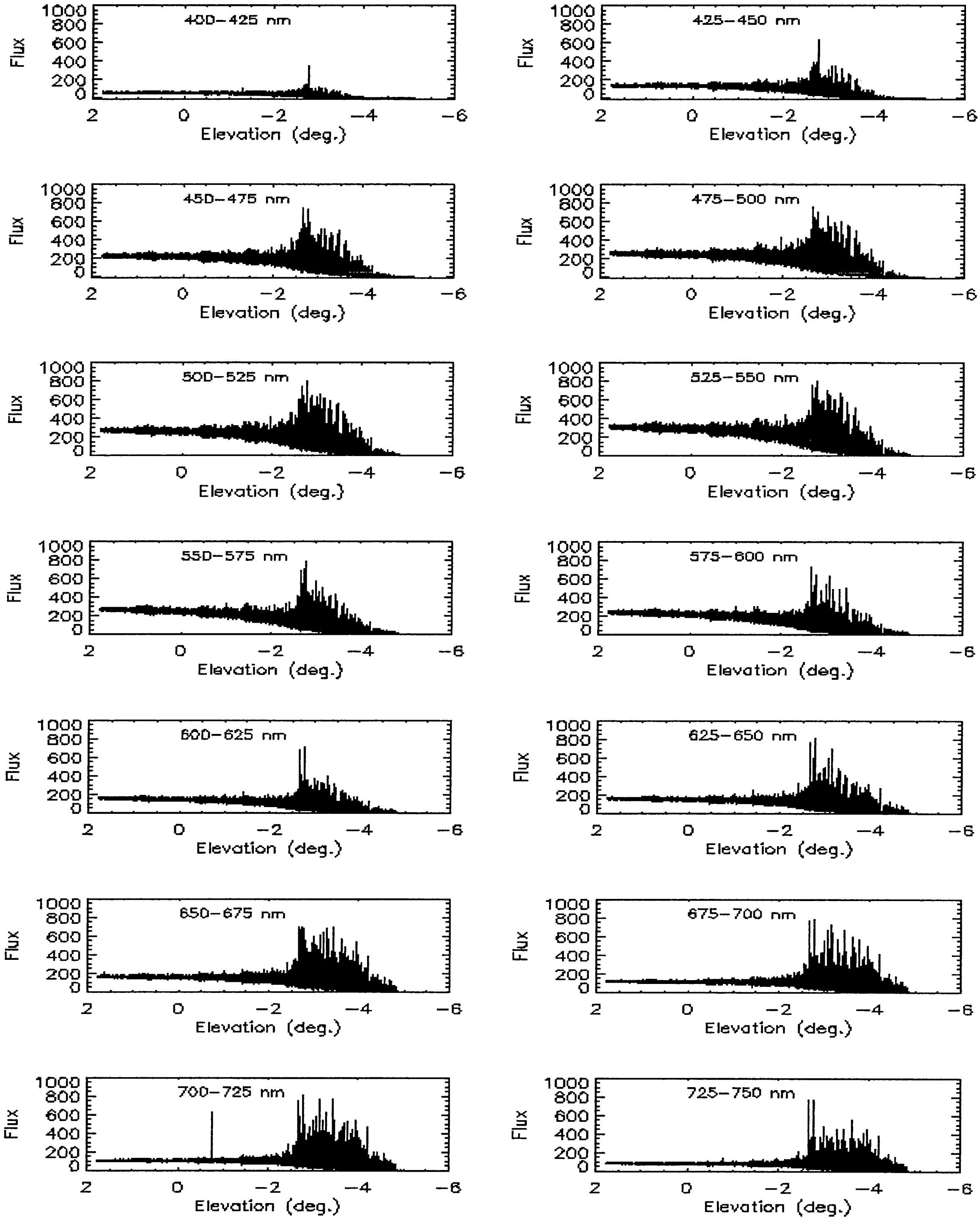

Fig.6. The 14 spectral domains of AMON-RA; flux enhancements due to chromatic scintillation are obvious for elevations below – 2°.

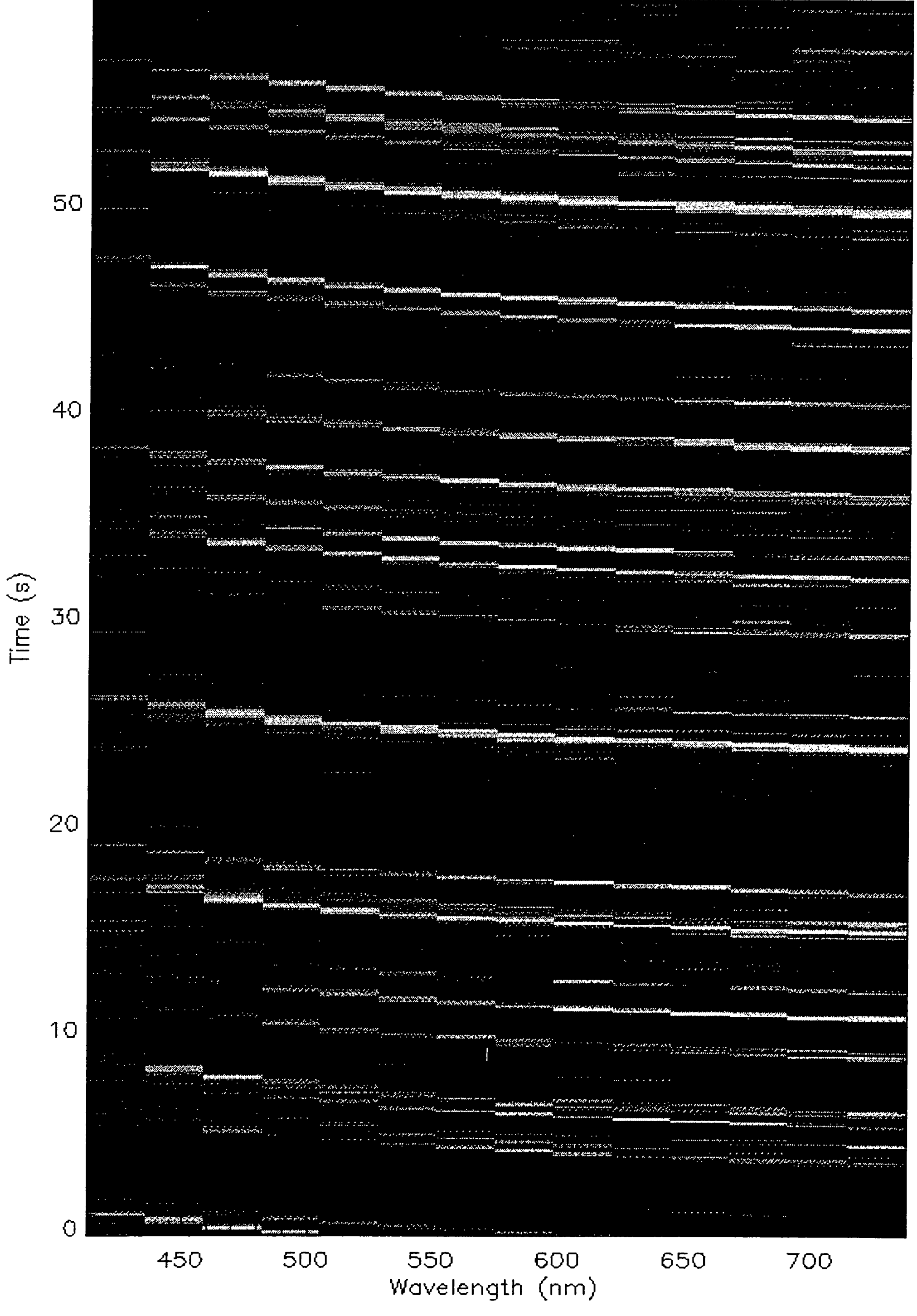

Fig.7. 1-minute sequence for the Sirius occultation, at an elevation centred on –4.1 degrees, which correspond to a tangent altitude of 16 km. Linear scale; black colour corresponds to lower flux; white colour corresponds to higher flux.

7. CONCLUSION

The use of sliding smoothing over consecutive spectra, and the use of dedicated spectral windows, could help to retrieve accurate values for the vertical profiles of the species. Nevertheless, the retrieval of the species other than ozone, and in some cases also for ozone, seems to be difficult in the polar vortex, at least during some weeks of the winter 2002/2003. New validation campaigns are necessary in order to analyse the sensitivity of GOMOS for polar vortex measurements in more favourable conditions. Other campaigns at various latitudes will be also necessary in order to analyse the evolution of the sensibility of GOMOS with time and for different geophysical conditions.

8. REFERENCES

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