VALIDATION OF ENVISAT PRODUCTS FROM SAOZ BALLOON FLIGHTS

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ABSTRACT

Dedicated balloon flights have been organised in order to validate the chemical instruments (GOMOS, MIPAS and SCIAMACHY) on-board the ENVISAT satellite. One of the validation instruments is the uv-visible SAOZ spectrometer dedicated to the measurement of the vertical profiles of minor atmospheric constituents, mainly O_3, NO_2, BrO, H_2O, O_2, but also O_4 (the dimer of O_2), optical extinction, pressure and temperature. SAOZ is a light instrument, easy to be launched, even in windy conditions and since the beginning of the Calibration/Validation period 4 flights have occured at various latitudes allowing to conduct comparisons with satellite coincident measurements in different conditions. Here, we report on results between SAOZ and GOMOS vertical profiles in the Arctic and mid-latitudes in summer together with the first very preliminary comparison of SAOZ and SCIAMACHY NO_2 limb profiles. The analysis is still in progress as only few orbits of GOMOS have been provided to the validation team and even none of the SCIAMACHY and MIPAS profiles but the results concerning GOMOS look very promising.

1. DESCRIPTION OF THE SAOZ SPECTROMETER

Fig. 1 SAOZ housing

SAOZ (Système D'Analyse par Observations Zénithales) is a UV-visible spectrometer making measurements by the solar occultation method during the ascent of the balloon and from float during the sunrise and the sunset. A simple conical mirror replaces the gondola orientation or sun tracker systems generally used on large balloon platforms. The balloon version of the SAOZ instrument is very similar to the one used for ground-based measurements of total ozone and NO_2 [1]. It is a commercial flat field, 360 grooves/mm, holographic grating spectrometer equipped with a 1024-diode linear array and an entrance slit of 50 µm. In this arrangement, measurements are made between 290 and 640 nm, with an average resolution of 0.8 nm. Ozone is measured in the visible from 450 to 620 nm, where its absorption cross-section is relatively insensitive to temperature. The SAOZ is equipped with a Global Positioning System (GPS) receiver, which allows its location to be determined in three dimensions with an uncertainty of ± 150 m.

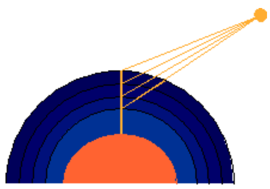

Fig. 2a: Measurements configuration during the balloon ascent

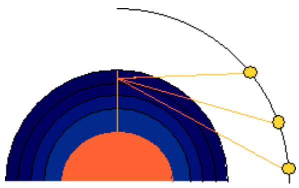

Fig. 2b: Measurements configuration from float during the sunset/sunrise

The spectral analysis and the inversion scheme used for SAOZ are discussed in [1]. The inversion assumes the scattered light component to be negligible, an important point because of the use of a 360° conical mirror plus diffuser instead of a tracker.

Ozone is measured in the visible Chappuis bands between 451 and 619 nm using cross-sections by [2] normalised on [3] by multiplying by a constant factor 1.021. The random error in the retrieved ozone profiles varies from 0.1% at 30 km to 1 - 2 % at 11 km. Including the maximum expected cross section errors (1%) and errors in the reference spectrum used in the spectral analysis (0.5%), the total accuracy of the SAOZ ozone (random + systematic) ranges from approximately 1.5 % at 30 km to 3.4 % at 11 km. The vertical resolution of the measurements is 1.4 km and the data are sampled at 1 km intervals.

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NO_2 is measured in the spectral region near 448 nm (from 410-530 nm) using cross-sections measured at 220 K by [4] (3% accuracy). The average precision derived from the spectral fit varies from 4-8% at 24 km, to 20% at 21 km and 37% at 17 km. The SAOZ NO_2 data are not corrected for diurnal variations along the line of sight.

There are three configurations of the instrument, all of them are equipped with GPS and PTU sensors allowing a vertical resolution of 250 m for altitude, pressure, temperature and humidity.

Table1: List of the SAOZ configurations

SAOZ configurations	**SAOZ-Standard**	**SAOZ-BrO**	**SAOZ-H2O**
Wavelength range	270-620 nm	350-420 nm	400-1000 nm
Resolution	0.9 nm	0.9 nm	0.9 nm
Constituents measured	O_3, NO_2, O_4, O_2, Trop. H_2O, Aerosols extinction.	BrO, OClO, CH_2O, O_3, NO_2, O_4.	O_3, NO_2, O_4, O_2, Trop. and Strat. H_2O, Aerosols extinction.

The SAOZ instrument has already participated in various satellite instruments validation - POAM III for O_3 and NO_2, [5, 6] and ILAS for NO_2 [7].

2. LIST OF SAOZ FLIGHTS

In order to validate ENVISAT instruments in various conditions, measurements have been performed from different sites and different conditions (sunrise or sunset).

Table 2: List of the SAOZ flights for the ENVISAT validation done in 2002

Location	**Date**	**Instruments**	**Constituents**	**Ascent**	**Sunset**	**Sunrise**
Kiruna 68 N	12/8/02	SAOZ + SAOZ-BrO	O_3, NO_2, O_4, O_2, Ext., BrO, P, T	O_3, NO_2, BrO, P, T	O_3, NO_2, O_4, O_2, Ext.	
Kiruna	13/8/02	SAOZ-BrO		P, T		O3, NO2
Vanscoy 52 N	03/9/02	SAOZ (MANTRA)	O_3, NO_2, O_4, O_2, Ext., P, T	P, T		O_3, NO_2, O_4, O_2, Ext.
Vanscoy	04/9/02	SAOZ (MANTRA)			O_3, NO_2, O_4, O_2, Ext.	.
ASA 44 N	1/10/02	SAOZ + SAOZ-BrO	O_3, NO_2, O_4, O_2, Ext., BrO, P, T	O_3, NO_2, BrO, P, T	O_3, NO_2, O_4, O_2, Ext.	
ASA	4/10/02	SAOZ +SAOZ-H2O *DIRAC**	O_3, NO_2, O_4, O_2, H_2O, Ext., P, T + *N_2O**	P, T, *N_2O**		O_3, NO_2, H_2O, O_4, O_2, Ext.,

3. EXAMPLE OF SAOZ PROFILES

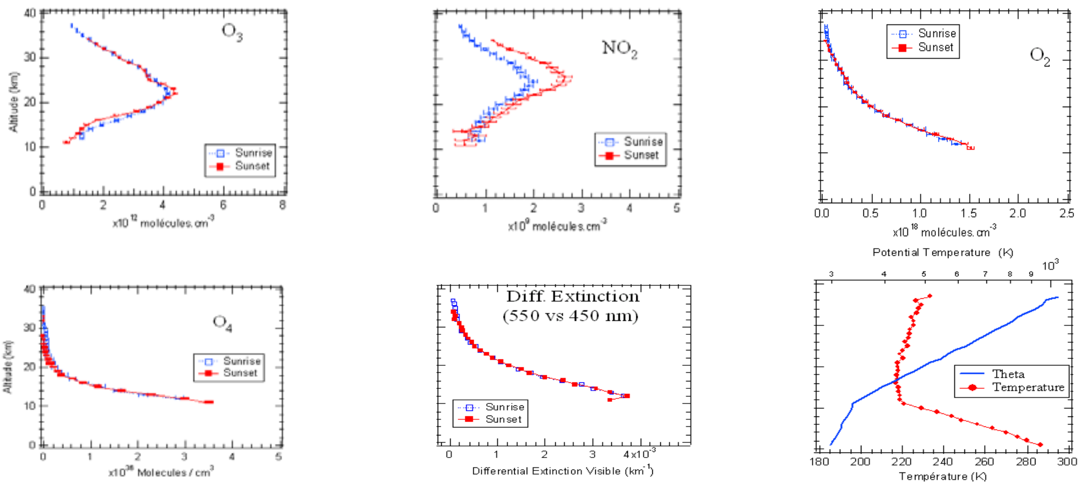


Fig. 3 Example of vertical profiles obtained during the Vanscoy flight

Table 3: SAOZ measurement conditions for the Vanscoy flight

	Date	UT Time	Tangent Point Latitude	Tangent Point Longitude
Sunrise	3 sep 02	11:52 UT	53.56 N	98.69 W
Sunset	4 sep 02	1:48 UT	53.44 N	106.90 W

On Fig 3. are represented various profiles obtained during the Vansoy balloon flight. This flight was part of the MANTRA campaign. The measurements have been performed during sunrise and sunset and table 3 shows the location of the tangent point as well as the time of the observation. The ozone is very stable in summer and there are very small variations between sunrise and sunset. It is not the case for NO_2 and the diurnal variation is well captured by the SAOZ. Other species like O_2 and O_4 (the dimer of O_2) are also presented showing that the number density for O_4 is high up to 23 km and this molecule must be considered in the visible wavelength range retrieval algorithm. The differential extinction profile indicates that there was no clouds above 11 km, altitude of the tropopause on that day as displayed on the temperature plot.

4. COMPARISON SAOZ VERSUS GOMOS DAYTIME OBSERVATIONS

4.1 Geometry of observation

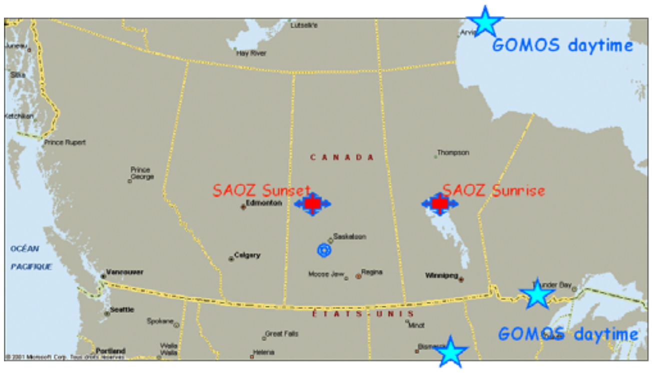


Fig. 4: Respective positions of SAOZ and GOMOS measurements

The balloon has been launched from Vanscoy, a small city located south of Saskatoon (Saskatchevan) in middle part of Canada.

SAOZ sunrise and sunset observations have occured respectively in the North-East and North directions. Only daytime GOMOS occultations are available yet.

The exact position of GOMOS tangent point and distance from SAOZ is given in Table 4 together with information on star magnitude and brightness temperature.

Table 4: Information of GOMOS tangent point position around Vanscoy

	Star	Name	Magnitude	Temperature	Latitude	Longitude	Distance (km)
	90	54Alp Peg	2.49	11000	65 N	96 W	1300
	66	37Gam Cyg	2.21	5900	49 N	93 W	700
	19	50Alp Cyg	1.25	10500	44 N	98 W	1000

4.2 Temperature

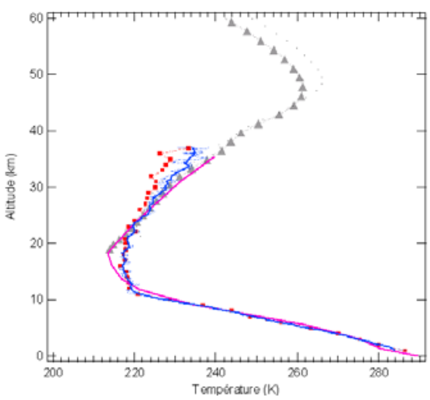


Fig. 5 Temperature profiles

GOMOS temperature is compared to the two PTU sondes on-board the MANTRA gondola (red and blue) and to the ECMWF temperature (pink). For this comparison, only the observation at 700 km from SAOZ has been considered.

It is obvious that the GOMOS temperature found in the GOM_NL__2PNACR20020903_XXX.N1 files and plotted on fig. 5 is mainly dominated by the ECMWF temperature which is underestimated by 5 deg. in the lower part of the profile.

4.3 Oxygen

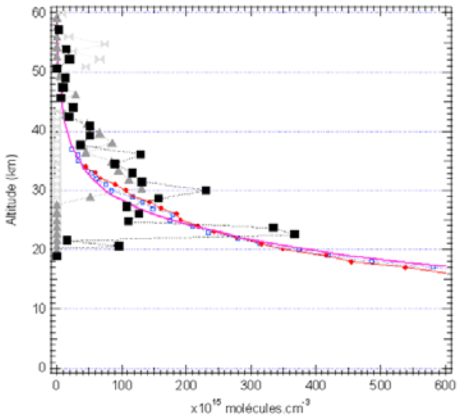


Fig. 6: Oxygen profiles

The GOMOS oxygen profiles obtained with the three occultations (Table 4) have been compared to the SAOZ oxygene profiles obtained during sunrise (blue) and sunset (red) and to a climatological profile (pink) deduced from the density * 0.21 representative of an average oxygen distribution in the atmosphere.

It is obvious that the O_2 GOMOS retrieval is wrong below 60 km showing unrealistic fluctuations.

4.4 Ozone

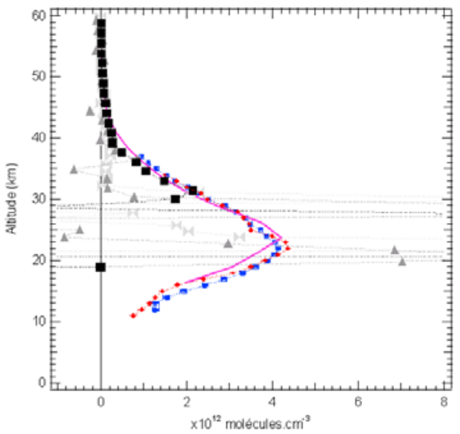


Fig. 7: Ozone profiles

The GOMOS ozone profiles obtained with the three occultations (Table 4) have been compared to the SAOZ ozone profiles obtained during sunrise (blue) and sunset (red) and to a climatological profile (pink) deduced from the UARS/HALOE data base representative of an average ozone distribution at the latitude of 52 N in September.

Below 40 km, the O_3 GOMOS retrieval is wrong except for the most bright star (50Alp Cyg) for which the magnitude was 1.25 and the profile was correct down to 31 km.

4.5 Nitrogen Dioxyde (NO_2) and Water Vapour (H_2O)

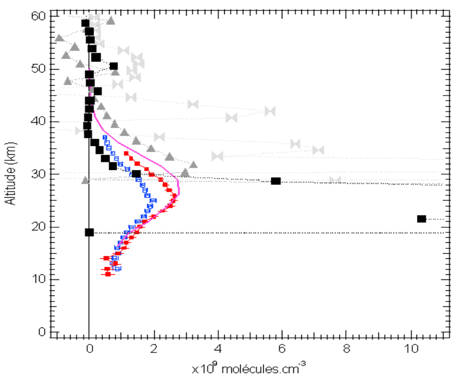


Fig. 8a: Nitrogen dioxyde profiles

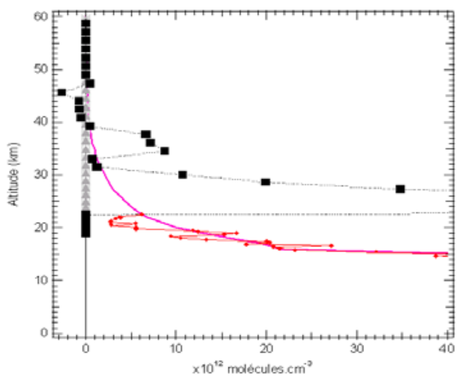


Fig. 8b: Water vapour profiles

The GOMOS NO_2 and H_2O profiles obtained with the three occultations (see Table 4) have been compared to the SAOZ profiles obtained during sunrise (blue) and sunset (red) and to a climatological profile (pink) deduced from the UARS/HALOE data base representative of an average NO_2 and H_2O distribution at the latitude of 52 N in September.

The GOMOS retrieval for NO_2 and H_2O is not correct and does not allow to conduct comparisons.

5. COMPARISON SAOZ VERSUS GOMOS NIGHTTIME OBSERVATIONS

5.1 Geometry of observation

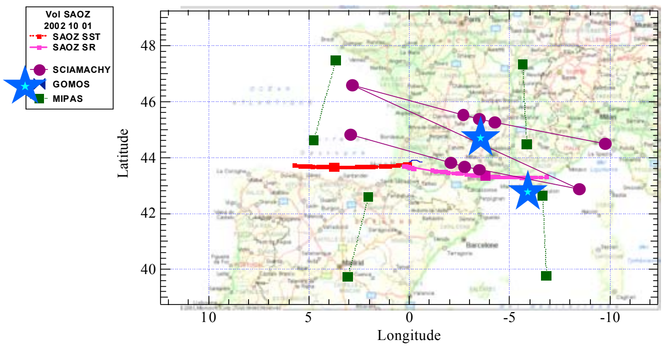


Fig. 9: Respective position of GOMOS, MIPAS and SCIAMACHY

The balloon has been launched from Aire sur l'Adour, south of France on October, 1st, 2002. SAOZ sunset observations have occured respectively in the West direction (red). Three days later, a second balloon has been launched from the same place for sunrise observations which have occured in the East direction (pink). (See Table 5)

The exact position of GOMOS tangent points and distance from SAOZ are given in Table 6 together with information on star magnitude and brightness temperature.

Table 5: SAOZ measurement conditions for the Aire sur l'Adour flight

	Date	UT Time	Tangent Point Latitude	Tangent Point Longitude
Ascent	1 Oct 02	17:00 UT	43.78 N	0.13 W
Sunset	1 Oct 02	17:53 UT	43.65 N	3.87 W
Sunrise	4 Oct 02	5:46 UT	43.39 N	4.72 E

Table 6: Information on GOMOS tangent point position around Aire sur l'Adour

	Star	Name	Magnitude	Temperature	Latitude	Longitude	Distance (km)
	84	Alp Phe	2.40	4500	45 N	4 E	314
	63	Bet Gru	2.15	2800	43 N	6 E	198

5.2 Oxygen

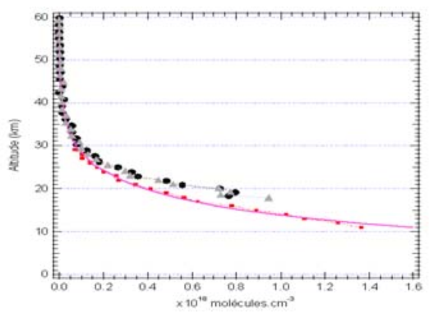


Fig. 10: Oxygen profiles

The GOMOS oxygen profiles obtained with the two occultations (see table 6) have been compared to the SAOZ oxygen profile obtained during sunset (red) and to a climatological profile (pink) deduced from the density * 0.21 representative of an average oxygen distribution in the atmosphere.

The O_2 retrieved from GOMOS is overestimated by a constant factor of 30% between 23 and 35 km increasing up to 50% below 23 km

5.3 Ozone

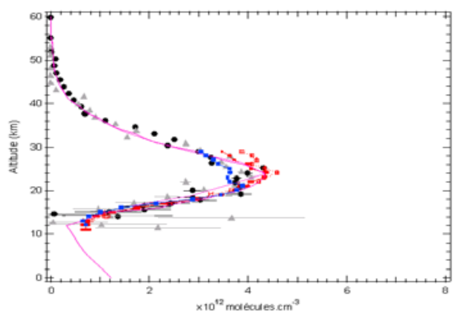


Fig. 11: Ozone profiles

The GOMOS ozone profiles obtained with the two occultations (see table 6) have been compared to the SAOZ ozone profiles obtained during sunset (red) on October 1st, 2002, sunrise (blue) on October 4nd, 2002, and to a climatological profile (pink) deduced from the UARS/HALOE data base representative of an average ozone distribution at the latitude of 44 N in September.

The O_3 retrieved from GOMOS is within 15% in the 23 – 30 km altitude range and up to 30% in the 14 – 23 km altitude range

5.4 Nitrogen Dioxyde (NO_2)

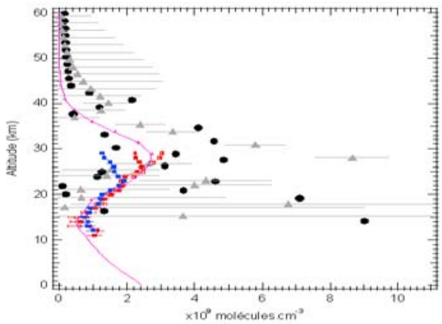


Fig. 12: NO_2 profiles

The GOMOS NO_2 profiles obtained with the two occultations (see table 6) have been compared to the SAOZ profiles obtained during sunset (red) on October 1st, 2002, sunrise (blue) on October 4nd, 2002, and to a climatological profile (pink) deduced from the UARS/HALOE data base representative of an average NO_2 sunset distribution at the latitude of 44 N in September.

The GOMOS retrieval for NO_2 is not correct and does not allow to conduct comparisons, even during nighttime observations.

Same behaviour has been observed for the Kiruna flight.

Table 7: Information of GOMOS tangent point position around Kiruna.

	Star	Name	Magnitude	Temperature	Latitude	Longitude	Distance (km)
	52	16 Bet Cet	2.04	4500	72 N	31 E	555

Table 8: SAOZ measurement conditions for the Kiruna flight

	Date	UT Time	Tangent Point Latitude	Tangent Point Longitude
Ascent	12 Aug. 02	18:44 UT	67.8 N	21.7 E
Sunset	12 Aug. 02	20:12 UT	70.4 N	16.4 E
Sunrise	13 Aug. 02	1:34 UT	69.3 N	32.9 E

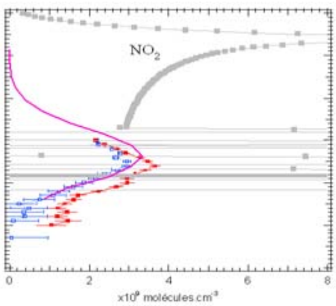


Fig. 13: NO_2 profiles

The GOMOS NO_2 profile obtained during the occultation (see Table 7) has been compared to the SAOZ profiles obtained during ascent (blue) and sunset (red) on August 12°, 2002 (Table 8), and to a climatological profile (pink) deduced from the UARS/HALOE data base representative of an average NO_2 sunset distribution at the latitude of 70 N in August.

The GOMOS retrieval for NO_2 is not correct and does not allow to conduct comparisons.

5.5 Conclusion

Comparison between SAOZ and nighttime GOMOS observations seems possible for the Aire sur Adour flight. The O_3 and O_2 profiles have a correct shape. There are still problems for H_2O and NO_2, the algorithm have to be improved.

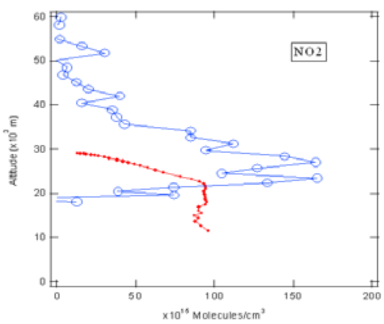


Fig. 14: NO_2 slant columns

An improvment of the GOMOS retrieval for NO_2 has been tested, the modification being based on DOAS method. (see dedicated papers on GOMOS algorithms, same issue).

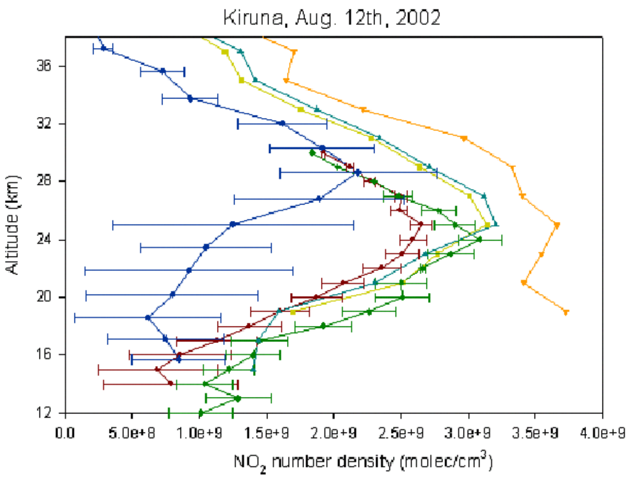
The level 1 GOMOS spectra for the star Bet Gru (see table 8) have been re-processed with the improved algorithm.

The GOMOS NO_2 slant column (blue) has been compared to the SAOZ slant column obtained during sunrise (red) on October 4nd, 2002.

The two profiles have the same order of magnitude. The results are very promising, specially in the 22-50 altitude range.

6. COMPARISON SAOZ VERSUS SCIAMACHY

The SCIAMACHY profiles are not yet available for the cal/val community, however, some work has been done by the SCIAMACHY team. Here below is the first comparison between SAOZ ascent and sunset profiles on August 12°, 2002, and various NO2 SCIAMACHY orbits (Courtesy Chris Sioris). BrO profiles have been also obtained during the ascent of the balloon on August 12, 2002 and are available for comparison with SCIAMACHY.



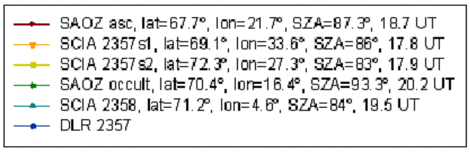


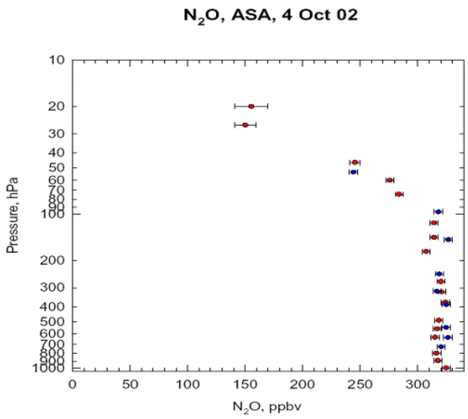
Fig. 15: NO_2 profiles

Except for orbit 2357 s1, for which both algorithms, the one called DLR and the one of C. Sioris are far away from the SAOZ ascent profile, there is a good agreement between SAOZ and SCIAMACHY.

SAOZ sunset profile is in good agreement with orbits 2357 s2 and 2358 profiles. Above 25 km, Sciamachy overestimates by 20% and below there is an underestimation by 10%.

7. COMPARISON SAOZ/DIRAC VERSUS MIPAS

The MIPAS profiles are not yet available for the cal/val community. During the October 4°, 2002 flight, a piggy back instrument was installed on the SAOZ flight train (see Table 1). This instrument, DIRAC, is a gas chromatrograph developped by UCAM (University of Cambridge). In its standard configuration, DIRAC is dedicated to the measurement of CFC's. For this flight a new configuration (pump) has been tested in order to be able to give an accurate profile of N_2O during the balloon ascent and descent.



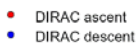


Fig. 16: N_2O profiles

DIRAC ascent and descent profiles are available for MIPAS intercomparison.

8. SUMMARY AND FUTUR PLANS

Comparisons between SAOZ and GOMOS profiles have been conducted and presented here. Retrieval of O_2, O_3, NO_2, and H_2O are not validated yet. Spectra have to be reprocessed for a better quality, specially for NO_2 and H_2O where a DOAS method should be used. It is suggested to add information in the GOMOS temperature files, so that the user can be informed on what is coming from the GOMOS retrieval and what is coming from the model (ECMWF). It is also suggested not to provide the daytime profiles as the data are certainly perturbed by limb illumination by sun light.

Comparisons between SAOZ and SCIAMACHY are very preliminary and data acquired during the balloon campaigns have to be processed for the cal/val community. This is also the case for the MIPAS profiles.

A few flights of the SAOZ instrument are planned for 2003 in atmospheric conditions different of what has been already studied in 2002, new latitudes and new seasons. The list of the planned flights is given in table 7.

Table 7: List of the SAOZ flights for the ENVISAT validation planned for 2003

Location	Date	Instruments	Constituents	Ascent	Sunset	Sunrise
Bauru 20 S	Feb. /03	SAOZ + SAOZ-BrO + *Dirac**	O_3, NO_2, O_4, O_2, Ext., BrO, P, T + *N_2O**	O_3, NO_2, BrO, P, T	O_3, NO_2, O_4, O_2, Ext.	
Bauru	Feb. /03	SAOZ + SAOZ-H2O + *MicroLidar**	O_3, NO_2, O_4, O_2, H_2O, Ext., P, T	P, T, *Aer**		O_3, NO_2, H_2O, O_4, O_2, Ext.,
Bauru	Feb. /03 **1 Month**	2 Long Duration Balloon SAOZ	O_3, NO_2, O_4, O_2, Ext., P, T	P, T	O_3, NO_2, O_4, O_2, Ext.	O_3, NO_2, O_4, O_2, Ext.
Kiruna 68 N	Mar. /03 1st week	SAOZ + SAOZ-BrO	O_3, NO_2, O_4, O_2, Ext., BrO, P, T + *N_2O**	O_3, NO_2, BrO, P, T	O_3, NO_2, O_4, O_2, Ext.	
Kiruna	Mar. /03 3rd week	SAOZ + SAOZ-H2O	O_3, NO_2, O_4, O_2, H_2O, Ext., P, T	P, T		O_3, NO_2, H_2O, O_4, O_2, Ext.,
Vanscoy 52 N	Aug. /03 ?	SAOZ + MANTRA	O_3, NO_2, O_4, O_2, Ext., P, T	P, T	O_3, NO_2, O_4, O_2, Ext.	O_3, NO_2, O_4, O_2, Ext.

9. ACKNOWLEDGMENTS

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