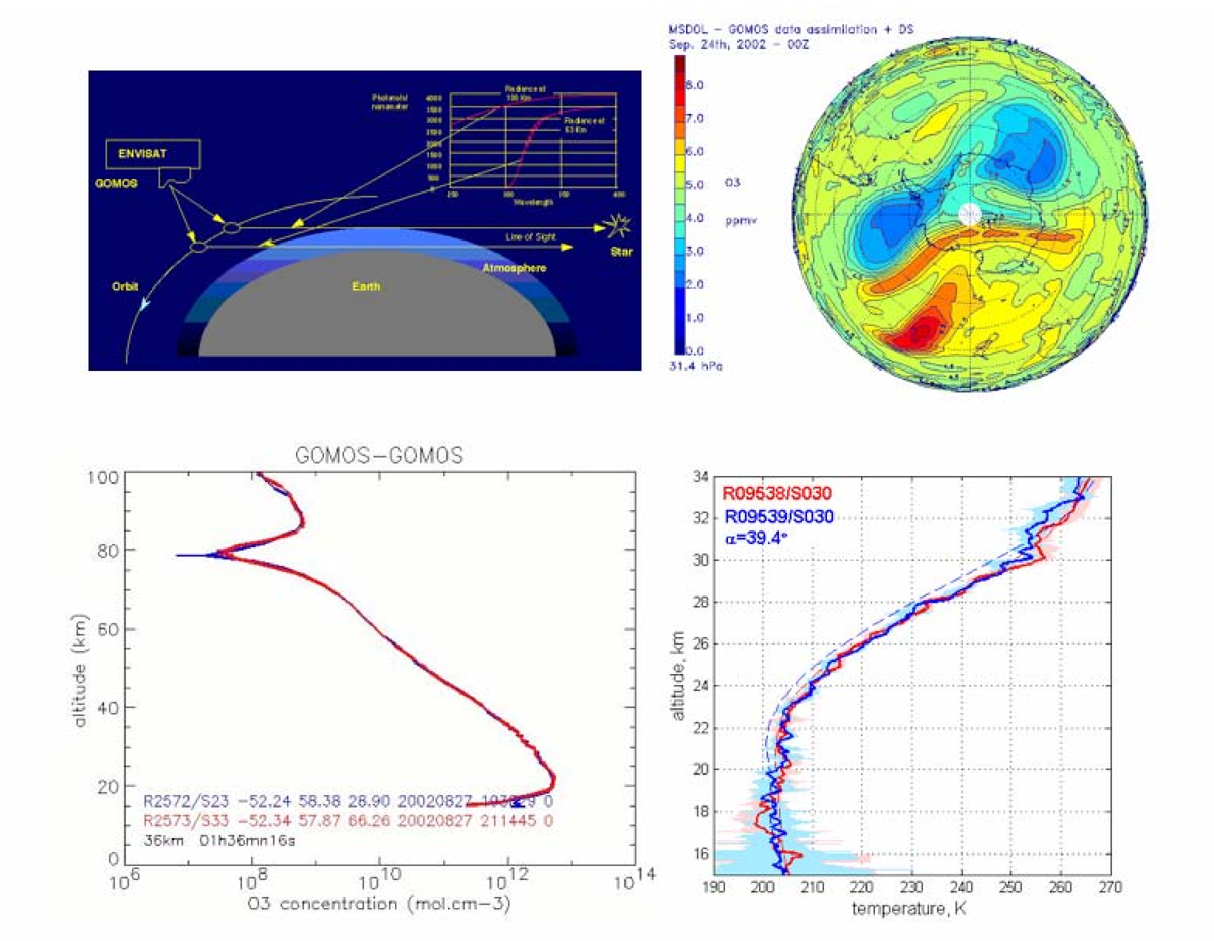
GOMOS Product Handbook



European Space Agency - GOMOS Product Handbook
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1 Presentation of the instrument and the measurements

1.1 Introduction

GOMOS (Global Ozone Monitoring by Occultation of Stars) is one of the three instruments dedicated to atmospheric composition sounding on board the ESA-satellite ENVISAT, launched on 1 March, 2002. Using the star occultation technique, GOMOS combines the features of high vertical resolution, good global coverage and self-calibration.

The key objective of the GOMOS mission is the long-term monitoring of the global vertical ozone distribution from the upper troposphere to the upper mesosphere on a global coverage, with a high vertical resolution, and with a very high and a long-term stable accuracy. Other objectives of the mission include the stratospheric gas-phase chemistry and mesospheric ozone and clouds.

This chapter is dedicated to a brief description of the GOMOS instrument and of the stellar occultation technique. More details on the instrument and the measurement technique may be found in the GOMOS ATBD and on the ESA web pages related to GOMOS (document references and addresses of web pages are given in Chapter 4). Characteristics of the measurements such as coverage, resolution and accuracy are presented in the second part of this chapter.

1.2 Instrument description and measurement principle

1.2.1 Presentation of the instrument and its components

GOMOS is a medium resolution spectrometer measuring in the ultraviolet, the visible and in the infrared and using the stellar occultation technique.

The four spectrometers of the instrument cover the spectral ranges: 248-371 nm, 387-693 nm, 750-776 nm and 915-956nm. This wavelength coverage allows monitoring O_3, NO_2, NO_3, atmospheric density from Rayleigh extinction and aerosols (UVIS measurements), O_2 and H_2O (IR measurements) from the upper troposphere to the mesosphere. The integration time of the spectrometers' measurements is 0.5s.

GOMOS is also equipped with two fast photometers sampling at the frequency of 1kHz in the ranges 644-705nm and 466-528nm. Their measurements are used to correct perturbations from scintillation effects and to determine vertical profiles of temperature of high resolution (200 m).

The instrument parameters are summarized in Table 1.1.

Table 1.1: Summary of GOMOS instrument parameters.

Instrument parameters			
Optical performance parameters	Channel	Spectral range	Spectral resolution
	UV-VIS	250 nm–675 nm	1.2 nm
	IR 1	756 nm–773 nm	0.2 nm
	IR 2	926 nm–952 nm	0.2 nm
	PHOT 1	650 nm–700 nm	broadband
	PHOT 2	470 nm–520 nm	broadband
data rate	226 kb / sec		
mass	160 kg		
power	200 W		
operation	continuously over full orbit		

A block diagram of the instrument is given in Figure 1.1. The optic detector system is also illustrated in Figure 1.1.

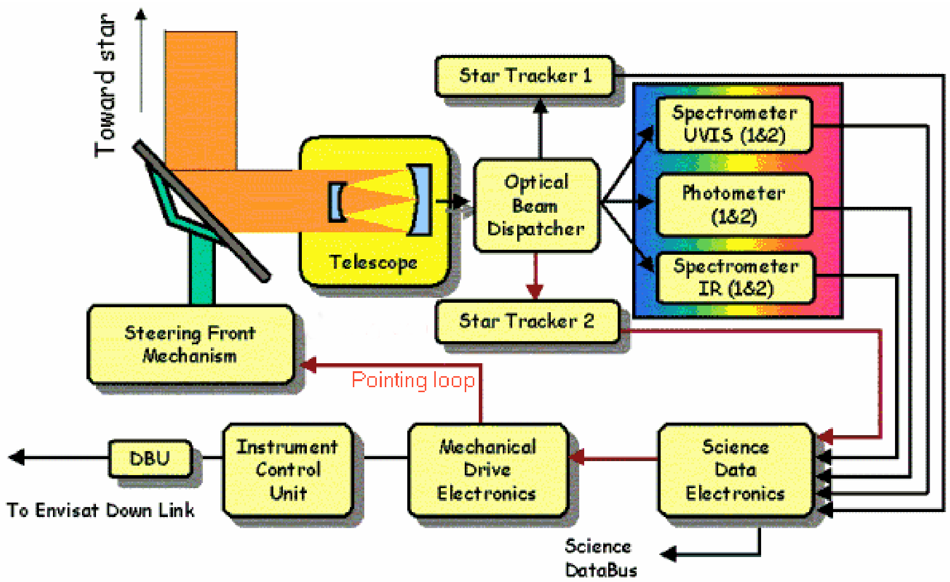

Figure 1.1: Block diagram of the GOMOS instrument.

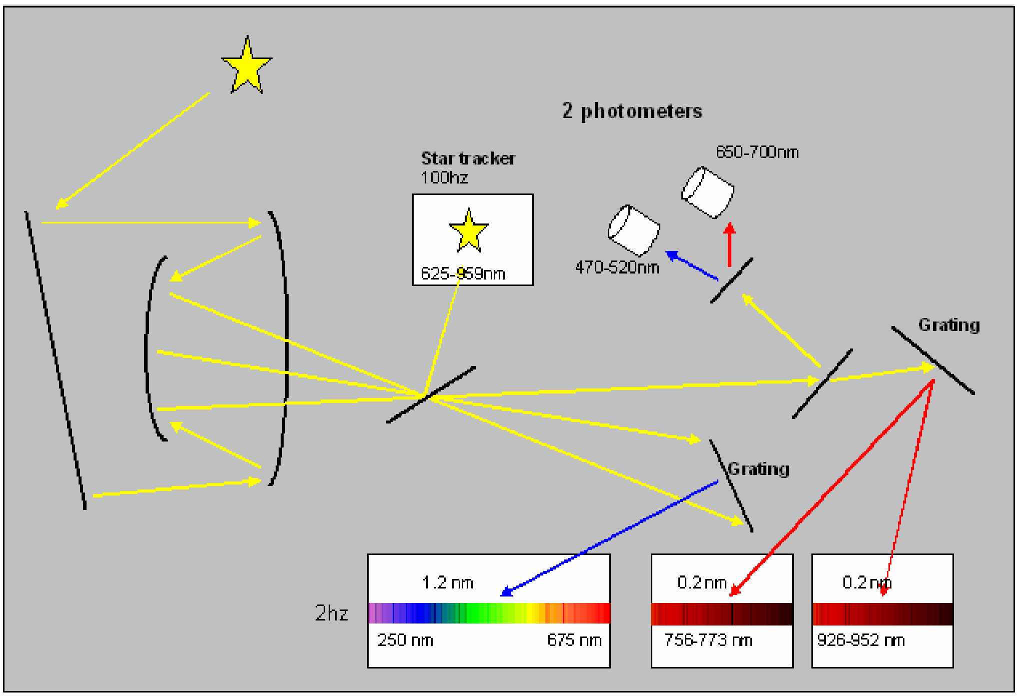

Figure 1.2: GOMOS detector system.

Due to the requirement on operating also on fainter stars, the sensitivity requirement to the instrument is very high. A large telescope (30cm x 20cm aperture) and detectors with high quantum efficiency and very low noise allow to collect sufficient signal and to achieve the required signal to noise ratios.

The large scanning mirror is controlled by the star tracker. The acquisition of a star includes three phases. The first phase is a rallying phase during which the telescope mechanism is directed towards the expected position of the star. Subsequently the acquisition procedure enters into detection mode, where the SATU star tracker output signal is pre-processed for spot presence survey and for the location of the most illuminated couple of adjacent pixels. The Most Illuminated Pixel (MIP) defines the position of the first SATU centering window. The second phase is then initiated. It is the centering phase during which the SATU output signal is pre-processed for spot presence survey over the maximum of 10x10 pixel field. The third phase is then the tracking phase. The star tracker is sensitive inside the range 600nm-1000nm; it is able to keep the stellar spectrum fixed with an accuracy of 1 pixel. The star tracker may follow the star down to 5-20 km, depending on the star, the state of the atmosphere and the illumination conditions.

1.2.2 Measurement technique

The stellar occultation technique relies on the measurements of the series of spectra emitted by one star during its setting while the platform is moving along its orbit (Figure 1.3). The comparison between these spectra modified by the atmospheric constituents present along the line-of-sight between the source and the instrument and a reference star spectrum measured outside the atmosphere allows to infer the density of atmospheric constituents.

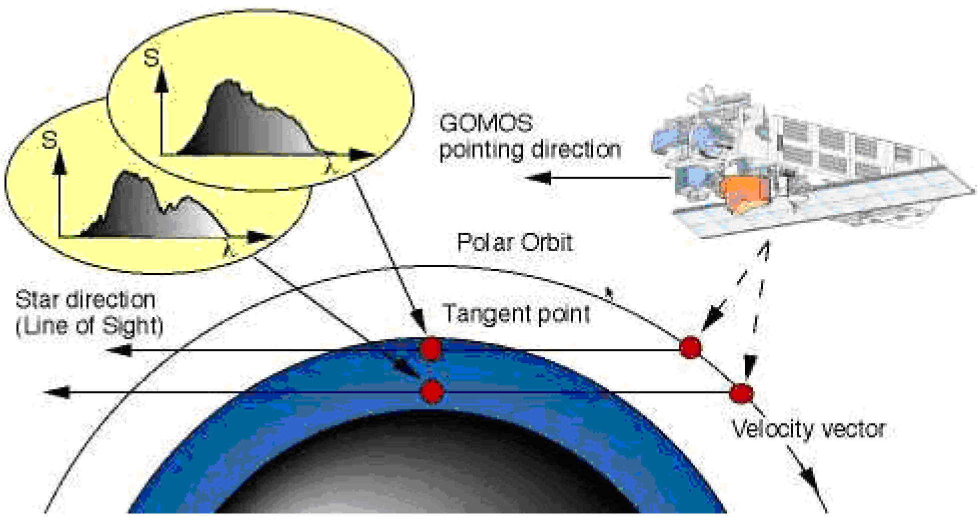

Figure 1.3: Geometry of the stellar occultation measurement by GOMOS.

First, the spectrum of this star is measured when the line of sight star-to-spacecraft is well above the atmosphere (typically 120 km), without absorption (reference stellar spectrum). Then, due to the orbiting motion of the spacecraft, as the line-of-sight goes deeper and deeper in the atmosphere, the star spectra measured by the instrument from the spacecraft contain absorption features depending on the composition of the atmosphere along the line-of-sight. The atmospheric transmission is obtained by dividing the star spectra inside of the atmosphere by the star spectrum outside of the atmosphere.

The atmospheric constituent densities are then obtained by retrieval of these transmissions. The line density or integrated quantity of ozone (and other constituents) along the line-of-sight is obtained at various altitudes z. The vertical distribution of the ozone local density (and other ozone constituents) is then retrieved from this series, assuming that the atmosphere is locally spherically symmetric.

Assuming that the change in the instrument response function can be considered as constant during the relatively short time of a single occultation (typically 40 seconds), nearly calibration-free horizontal transmission spectra are obtained. Even if the spectral sensitivity of the instrument is changing with time, this method is inherently self-calibrated.

The main key features of the GOMOS measurements are summarized in Table 1.2.

Table 1.2: Main key features of the GOMOS measurements.

Measurement parameters	
geographical coverage	Global
number of measurements	about 400 occultations/day before 01/2005

Measurement parameters	
	about 280 occultations/day since 07/2005
altitude range	< 20 km - > 100 km
sampling vertical resolution	1.7 km or better
Accuracy	varying from one occultation to another
calibration issues	self-calibrated

1.2.3 Calibration phase and monitoring activities

As defined by CEOS, the calibration is the process of quantitatively defining the system response to known, controlled signal inputs. After the ENVISAT launch, between March 2002 and November 2002, specific observations in monitoring mode were performed in order to verify the nominal operation for all the components of the instrument (command and control system, pointing system, rallying, centering, tracking, and acquisition phases, thermic and opto-mechanic behaviour, mirror behaviour, pixel response non-uniformity,…). The correct answer of the instrument to several anomalies was checked (impossible tracking, non detected star) as well as the general data handling. The outputs of this calibration phase allowed to confirm that most of the in-flight performances were consistent to the ground measurements performed before the launch, during the dedicated ground characterisation phase. It had also highlighted a high sensitivity of the CCD measurements to the proton radiation, and the subsequent need to calibrate the DC at each orbit for correction. This is achieved by using one specific occultation performed in full dark limb condition, the instrument looking at a so-called "dark sky area" (or DSA), where no input flux is expected at the entrance of the instrument.

The Quality assessment of the instrument and of the products is crucial for the mission success. It is a continuous task, implying various aspects such as the performance assessment and the anomaly investigation, the calibration activities and the delivery of auxiliary data files, the daily and long-term monitoring of the instrument health, and the daily and long-term monitoring of the products. Daily and monthly reports on these aspects are made available to the user community at the following addresses:

http://earth.esa.int/pcs/envisat/gomos/reports/daily/
(current day and access to archives) and

http://earth.esa.int/pcs/envisat/gomos/reports/monthly/
(previous month and access to archives).

From 1 May 2003, the operations of the instrument during the star rallying phase had been affected by an anomalous behaviour of the mirror drive unit at low azimuth angles, due to Voice Coil Saturation (excessive current drawn by a coil in the mirror drive unit). As a first bypass solution, the field of view for the star selection had been reduced. However, this reduction of the field of view resulted in the unavailability of the highest quality occultation opportunities and the anomalies were still degrading. After detailed analysis and further testing by the Anomaly Review Board (ARB) and the Envisat Mission Manager, it was decided to switch operations to the redundant "B" ICU (instrument control unit) and MDE (mechanism drive electronics). Nominal measurements with the redundant side and data dissemination resumed on 19 July 2003, using the complete GOMOS field of view [-10.8°, +90.0°] for the star selection.

Between January 2005 and July 2005, a failure in the telescope elevation drive, the so called "elevation voice coil", which is part of the Steering Front Mechanism, prevented the nominal operations of the instrument. The anomaly occurs during the rallying of the telescope in the preparation for the star observation. Based on a series of tests, the ARB recommended to limit the rallying time by operating the instrument in a reduced horizontal azimuth range. Nominal operations resumed in September 2005 in the azimuth range [-5°, 20°]. The GOMOS Quality Working Group was solicited to advise about the choice of the boundaries of the azimuth range, in order to achieve the optimum of scientific return from the reduced operation scenario.

1.3 Mission planning

1.3.1 Nominal mission planning

The global coverage of the GOMOS measurements is made possible by the large number of star targets suitable for occultation measurements. Depending on the time of the year, there are about 150 to 300 stars bright enough for GOMOS to track and which are in its field of view at specific times during an orbit. Since the actual occultation time windows often overlap with each other, they can not all be observed. Therefore a number of alternative occultation sequences can be generated. The GOMOS mission planning sets the sequence of occultations to be measured, which fulfil at the best the scientific requirements and the mission objectives (long-term monitoring, campaign and specific events objectives), by taking into account the set of possible occultations and the corresponding mission planning database.

1.3.2 Modified mission scenario since August 2005

Following VCCS ARB outputs, the horizontal azimuth range of instrument operations has been reduced to 25° after August 2005 in order to limit the risk of VCCS failures. Instead of operating in the nominal azimuth range (between -10° and 90°), GOMOS has been operating in the azimuth range between -5° and 20° between September 2005 and February 2006. The choice of these limits was a trade-off between the number of possible occultations and the verticality of occultations. However, for given fixed limits of the azimuth window, the latitude coverage is strongly changing during the year. It has thus been suggested to change the lower and upper limits of the azimuth window while keeping its amplitude fixed to 25°. At ARB's request, the QWG produced a mission scenario with boundaries of the azimuth range changing every week in order to optimize the mission objectives (global coverage, validation campaigns objectives, minimum azimuth limit not lower than -5° to avoid the vignetting effects) and taking into account the reduced number of stars likely to be observed. This new mission scenario has been in operation since

February 2006. The monitoring activities allowed to confirm that this reduced and varying horizontal azimuth range has no impact on data quality of profiles. However, as it results in a loss of about 50% in the number of occultations compared to a mission planning with a complete horizontal azimuth range. Possibilities of progressively broadening the azimuth window by step of 5° will be investigated.

1.4 Star characteristics

The list of the 300 brightest stars selected for use by GOMOS measurements is provided in the Appendix B of this document. Over 2003, 177 different stars were used for the occultation measurements.

The star characteristics impact the quality and the accuracy of the measurements and of the retrieved products. The visual magnitude of the star gives an indication of the star brightness. It ranges from -1.44 for the brightest one (Sirius) to 4.5 for the faintest ones. A star is usually considered as being strong if its visual magnitude is lower than 0.8 and as being faint if it is higher than 2. Only stars with a visual magnitude lower than 3.553 are used for the GOMOS measurements.

The spectral type of the star (the shape of its spectrum) is approximated by its effective temperature. It ranges from 2800 K to 39000 K. A star is usually considered as being cold if its effective temperature is lower than 6000 K and as being hot if it is higher than 10000 K.

The signal-to-noise ratio of the measurement depends on both the visual magnitude of the star and its effective temperature.

1.5 Measurement characteristics

1.5.1 Vertical coverage and vertical sampling

The altitude coverage of vertical profiles retrieved from GOMOS measurements is generally between 120 km and an altitude level in the upper troposphere. The lower altitude limit actually varies for each occultation, depending on the star characteristics, on the state of the atmosphere and on the illumination condition.

The limb viewing geometry, the point source nature of stars and the short measurement integration time lead to a good vertical resolution of the profiles retrieved from GOMOS measurements. During one occultation GOMOS measures the stellar light in 0.5 s integration time intervals. This corresponds in the worst case (occultation in the orbital plane) to an interval of 1.7 km of altitude projected at the limb. The sampling vertical resolution is therefore 1.7 km in the case of an occultation in the orbital plane and better than 1.7 km for oblique occultations.

1.5.2 Geographical and time coverage

Besides the self-calibration and the good vertical resolution, the advantage of the stellar occultation method is the excellent global coverage provided by the multitude of suitable star targets. A typical weekly coverage is shown in Figure 1.4 and Figure

1.5. Until early January 2005, the daily number of measurements was about 400. The nominal measurements were then stopped, because of a failure in the telescope rallying drive. They resumed in July 2005, but with a reduced daily total number of measured occultations estimated to be about 280.

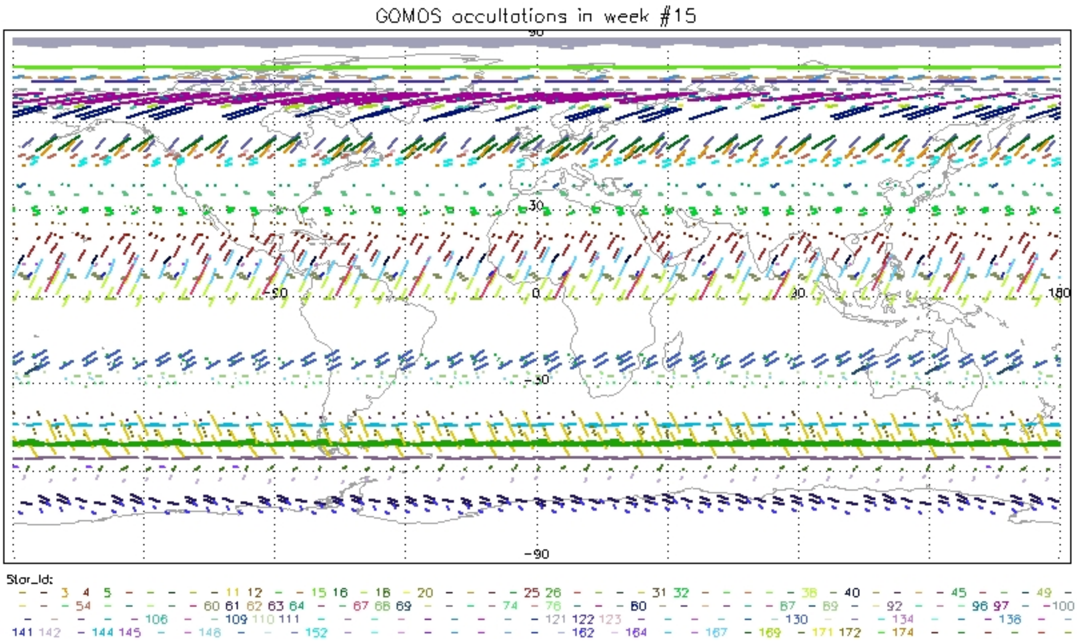

Figure 1.4: Example of geographical coverage of GOMOS measurements (measurements planned between 6 and 13 April 2004). The colour code for each occultation corresponds to the star ID.

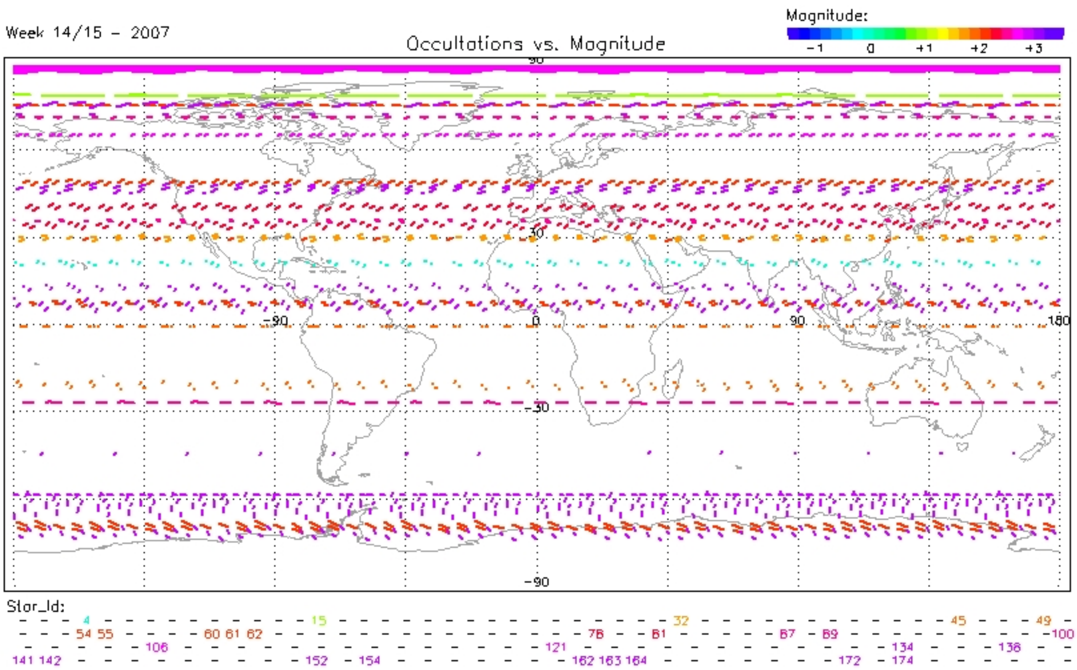

Figure 1.5: Example of geographical coverage of GOMOS measurements (measurements planned between 7 and 14 April 2007). The colour code for each occultation corresponds to the star ID and its magnitude.

The variation of the latitude-longitude coverage with the obliquity for each occultation is illustrated in Figure 1.6.

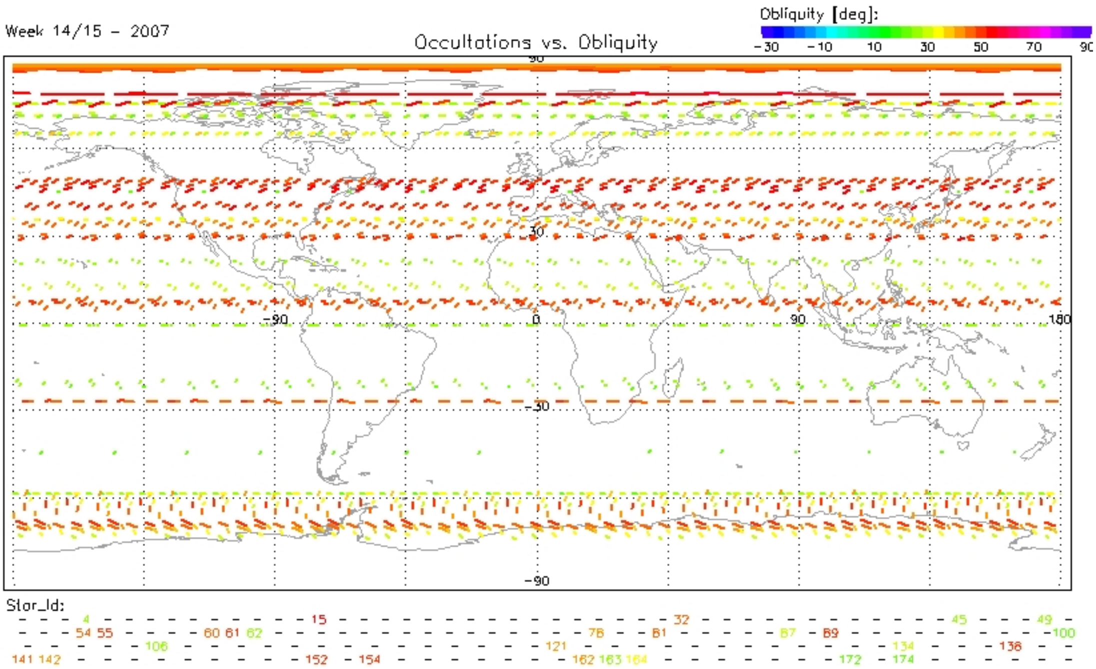

Figure 1.6: Area probed by occultations planned between 7 and 14 April 2007 and highlighted by occultation obliquity range.

1.5.3 Occultation obliquity

The occultation obliquity is defined as the angle between the motion of the line of sight (with respect to the atmosphere) and the direction of the Earth's centre. The altitude chosen to calculate the obliquity is fixed to 35 km for any occultation. For a tangent occultation, this altitude may be never reached, and in that case, the obliquity is arbitrarily fixed to 90°. For a purely vertical occultation, the obliquity is equal to 0°. The obliquity varies in the same direction as the azimuth direction of the line-of-sight. This is illustrated in Figure 1.7 for an example set of 5000 occultations. For occultations taking place in the orbital plane (azimuth value close to 0), the obliquity is close to 0 (close to vertical occultations). Occultations measured with a field-of-view outside the orbital plane (larger azimuth value) are oblique.

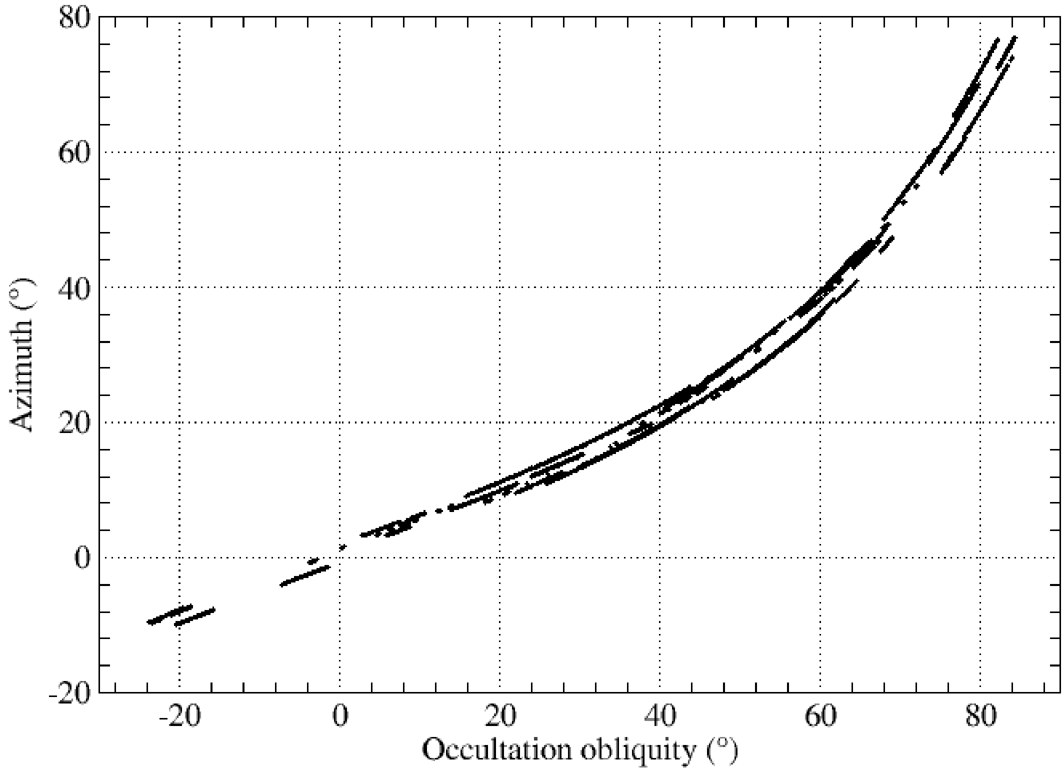

Figure 1.7: Occultation obliquity (°) versus instrument azimuth direction (°) (measurements made between 08/03/2004 and 20/03/2004).

1.5.4 Accuracy

The special feature of the GOMOS retrieval is that the accuracy of a species product varies from one occultation to another. The key factors are the characteristics of the occulted star, and some specificities of the occultation geometry. We discuss here how those key factors may impact the accuracy of the products, and we present the vertical profiles of accuracy for the local density of O_3, according to the star type and to the occultation geometry.

In order to select the highest quality data, it is recommended to apply some criteria on the stars and on the occultation geometry. Those criteria are detailed in the Chapter "How to?".

1.5.4.1 Effect of the star characteristics

1.5.4.1.1 Star brightness

Due to the weakness of the stellar fluxes, the star visual magnitude is an important factor to the accuracy; it directly affects the S/N ratio. This is a crucial factor for NO2, NO3 and H2O profiles, for which only the occultations of the brightest stars should be used. It also affects the quality of O3 vertical profiles in the stratosphere, for which occultations of dimmest stars produce noisy values of the profiles in the lowest stratosphere.

The star brightness for each measured occultation is provided in the corresponding products.

1.5.4.1.2 Star temperature

Above 30 km, where ozone retrieval is based on UV-wavelengths, the ozone profile retrieval accuracy strongly depends on the star effective temperature, as cold stars radiate only little at UV-wavelengths. Only occultations of hot stars are able to provide information about ozone at high altitudes. A star with an effective temperature of around 10000K provides about the same accuracy for all altitude levels between 25 km and 60 km. A star with an effective temperature higher than 10000K provides an improved accuracy for the upper stratosphere and lower mesosphere. The best accuracy can be achieved around 60 km. At this level, a 30000K star provides a retrieval accuracy around 0.5% (visual magnitude equal to 0) or 3% (visual magnitude equal to 2).

At altitudes lower than 30 km, where the Chappuis band is used to determine ozone, the accuracy does not depend on the star temperature. The accuracy at 25 km altitude is about 3% (for a star with a visual magnitude equal to 0) to 10% (visual magnitude equal to 2).

The star effective temperature for each measured occultation is provided in the corresponding products.

1.5.4.2 Effect of the occultation geometry

1.5.4.2.1 Occultation obliquity

Small-scale irregularities of air density cause scintillations in the light intensity detected by GOMOS. These variations of light intensity do not occur simultaneously at all wavelengths, thus the spectrum of a star seen through the atmosphere is not only affected by absorption, but is also deformed by scintillations. A scintillation correction is set up from the measurements of scintillations by the two fast-photometers, allowing removal the deformation of individual transmission spectra. The scintillation correction is considered as reliable only for vertical (in the orbital plane) occultations. The incomplete scintillation correction for the oblique occultations between 20 km and 40 km is reflected by corresponding error bars (additional turbulence error added to the overall error budget).

The O_3 error estimates of oblique occultations are comparable to the ones of vertical occultations. They are even lower for oblique occultations in some cases and some altitude ranges, especially in the mesosphere. This is more detailed in section 1.5.4.4.

The occultation obliquity also impacts the HRTP validity altitude range and accuracy.

- For vertical occultations, the validity range is 18 km-35 km (the upper limit depends on the scintillation strength). For oblique occultations, it is 20 km-30 km.

- The best accuracy of HRTP products is reached for vertical occultations. It is estimated to be about 1 or 2 K between 18 km and 30 km for vertical and close to vertical occultations.

The obliquity for each measured occultation is provided in the corresponding products.

1.5.4.2.2 Illumination conditions

On the day-side bright limb, the limb brightness is an extended source competing with the stellar signal. Day-side occultations achieve less accurate results than night-side occultations because of a larger noise. Three other illumination conditions than full dark (night-side measurements) and bright limb (day-side measurements) conditions have been characterized: twilight, straylight, and twilight+straylight. For each occultation, the illumination conditions are inferred from the computation of the sun zenith angles at both instrument and tangent point locations.

The illumination condition for each measured occultation is provided in the corresponding products.

1.5.4.3 Altitude range of validity per species

Within the retrieved altitude range, because of some limitations of the processing and of the dependence of the accuracy with the star and the occultation geometry, it is recommended to use the vertical profiles of species in reduced altitude ranges only.

Those validity altitude ranges are detailed in Table 1.3.

Table 1.3: Validity assessment and vertical resolution by altitude range and by species.

Species	Validity/altitude range	Vertical resolution in the validity range (km)
O_3	valid at all altitudes for hot stars; for cold stars, data above 40 km should be considered with caution	2 in the lower stratosphere; 3 in the upper stratosphere and above
NO_2	valid between 20 km and 50 km; data at other altitudes should be considered with caution	4
NO_3	valid between 25 km and 45 km, but noisy retrieved values within this altitude range; data at other altitudes should be considered with caution	4
Aerosols	data below 10 km and above 35 km should be considered with caution	4
H_2O	retrieved only up to 50 km; in this altitude range, poor results, with large noise	2 in the lower stratosphere; 4 in the upper stratosphere
O_2	valid at all altitudes; noise is observed on some profiles	3 in the lower stratosphere; 5 in the upper stratosphere
HRTP	18-35 km for vertical occultations; 20-30 km for oblique occultations	0.2

1.5.4.4 Error estimates

The error estimates provided in the GOMOS products are calculated without taking into account the modelling errors and assuming normal Gaussian error statistics. Those error estimates are not fully validated. The specification of the modelling errors is still an ongoing activity, and the addition of the modelling errors to the error budget is currently under investigation.

We present here vertical profiles of the median of the relative error estimates for the local density of several species, from GOMOS night-time measurements during 2003. Results are presented by category of star brightness, by category of star temperature and for two categories of verticality occultation, in order to highlight the possible impact of the star characteristics and of the occultation geometry on the accuracy of the vertical profiles.

The three categories of stars according to their brightness are defined by range of visual magnitude (Mv):

- bright stars for Mv lower than 0.8;
- stars of medium brightness for Mv between 0.8 and 2.0;
- dim stars for Mv higher than 2.0.

The three categories of stars according to their temperature are defined as:

- cold stars for T lower than 6000 K;
- stars of medium temperature with T between 6000 K and 10000 K;

- hot stars for T higher than 10000 K.

The two categories of occultations according to their obliquity are defined as:

- occultations very close to the vertical, with a verticality value between -5° and +5° ("V" category in the figure legend or vertical occultations in the text hereafter);
- oblique occultations, with a verticality between 55° and 65° ("O" category in the figure legend).

1.5.4.4.1 Error estimates of O_3 local density

The comparison of the average profiles of O_3 error estimates for the oblique occultations and for the vertical occultations shows that generally values for the oblique occultations are comparable to values for the vertical occultations. In some cases and within some altitude ranges, especially in the mesosphere, the error estimates of the oblique occultations are even lower than the error estimates of the vertical occultations.

This is illustrated in Figure 1.8, plotting the vertical profiles of average O_3 error estimates by category of star T and of occultation obliquity, for different categories of star magnitude. The accuracy degradation for cold stars in the upper stratosphere and in the mesosphere is obvious. As expected for O_3 at altitudes lower than 30 km, the average value of the error estimates are similar in most cases for all categories of star temperature (for typical and dim stars). At these levels, the average error estimates show lower values for brighter stars than for dimmer stars. For stars of medium or of low magnitude, the minimum relative error estimates up to 25 km-30 km for the oblique occultations are lower than for the vertical ones for most categories of star T. For hot stars of medium or low magnitude, the accuracy of oblique occultations at 90 km is similar to the accuracy around 30km; it is very good between 50 km and 70 km (and similar to the precision of the cross-section). For hot stars of medium and low magnitude, the relative error is lower in the mesosphere for the oblique occultations than for the vertical ones. For hotter and brightest stars, the relative error estimate for the oblique occultations is excellent around 20 km. However, between about 30 km or 35 km and 40 km, the error estimates for the vertical occultations are lower than for the oblique occultations, illustrating the effect of the additional turbulence error on the oblique occultations.

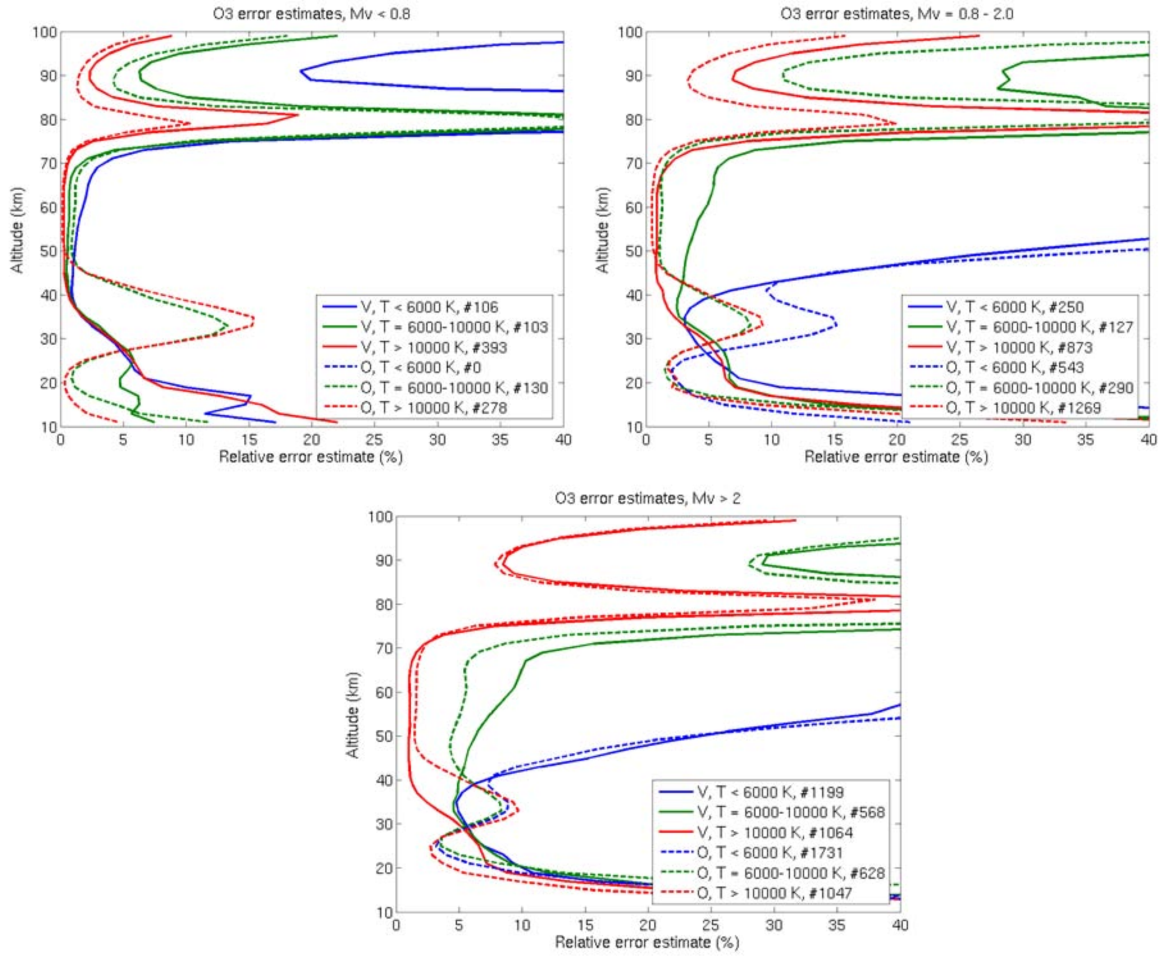

Figure 1.8: Vertical profiles of the median of the relative error estimates for O_3 local density, from GOMOS night-time measurements during 2003; each plot corresponds to a category of star brightness (bright stars of visual magnitude lower than 0.8; typical stars of visual magnitude between 0.8 and 2.0; dim stars of visual magnitude higher than 2.0). Results on each plot are given by category of star T (hot stars of T > 10000K; typical stars of T between 6000K and 10000K; cold stars of T lower than 6000K) and by occultation obliquity (V for close to vertical occultations; O for oblique occultations; see text for details). The number of profiles used to calculate the median profile for each category is given in the curve label.

1.5.4.4.2 Error estimates of NO_2 local density

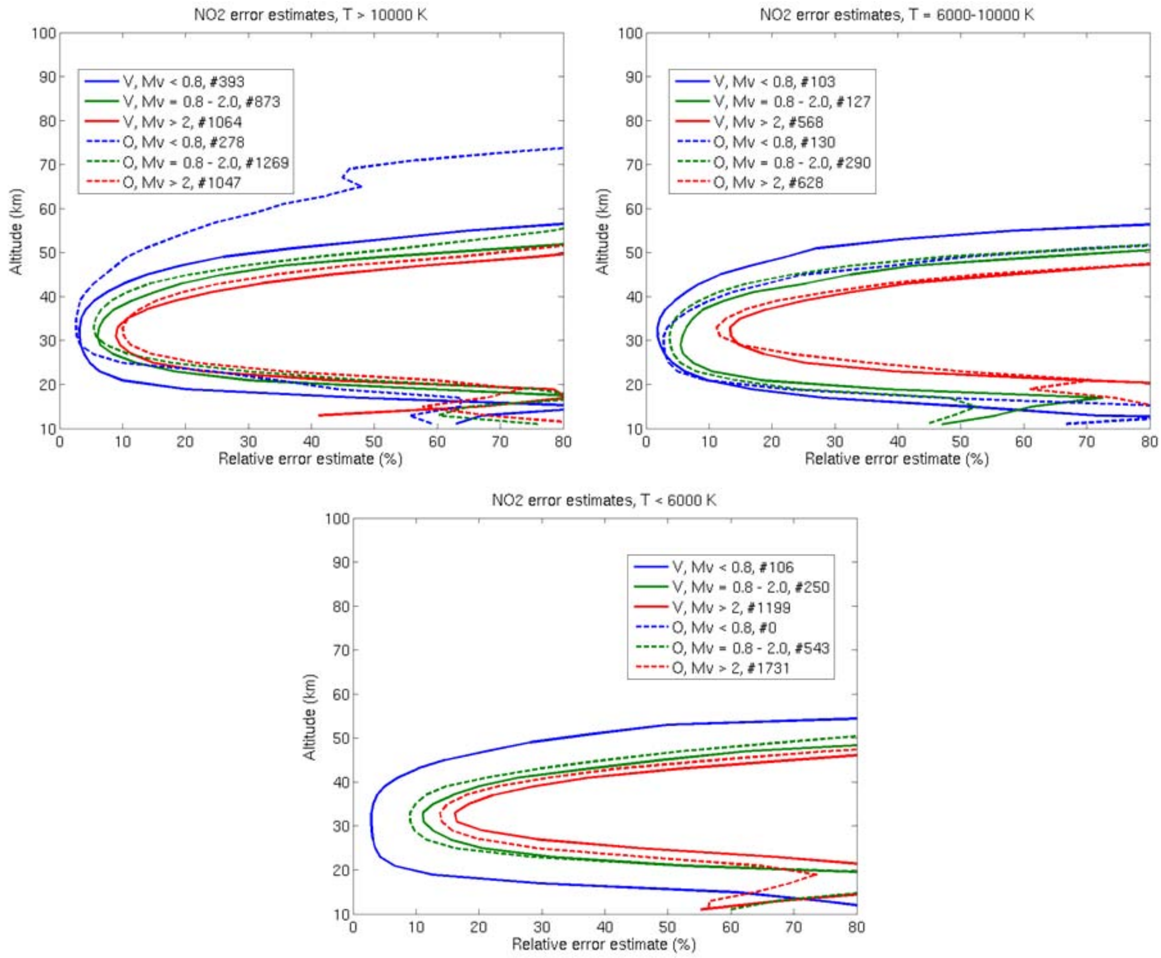

Figure 1.9: Vertical profiles of the median of the relative error estimates for NO_2 local density, from GOMOS night-time measurements during 2003; each plot corresponds to a category of star T (hot stars of T > 10000K; typical stars of T between 6000K and 10000K; cold stars of T lower than 6000K). Results on each plot are given by category of star brightness (bright stars of visual magnitude lower than 0.8; typical stars of visual magnitude between 0.8 and 2.0; dim stars of visual magnitude higher than 2.0) and by occultation obliquity (V for close to vertical occultations; O for oblique occultations; see text for details). The number of profiles used to calculate the median profile for each category is given in the curve label.

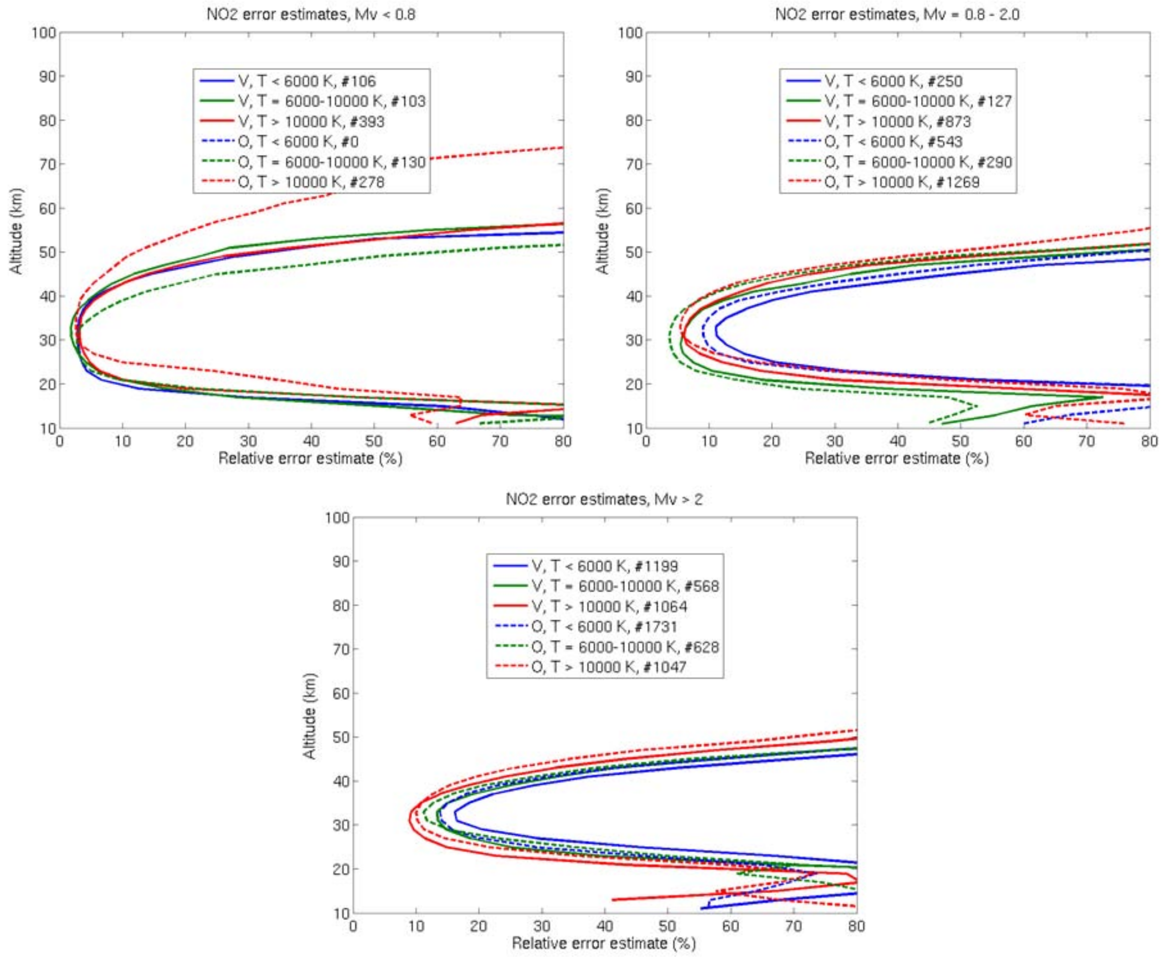

Figure 1.10: Vertical profiles of the median of the relative error estimates for NO_2 local density, from GOMOS night-time measurements during 2003; each plot corresponds to a category of star brightness (bright stars of visual magnitude lower than 0.8; typical stars of visual magnitude between 0.8 and 2.0; dim stars of visual magnitude higher than 2.0). Results on each plot are given by category of star T (hot stars of T > 10000K; typical stars of T between 6000K and 10000K; cold stars of T lower than 6000K) and by occultation obliquity (V for close to vertical occultations; O for oblique occultations; see text for details). The number of profiles used to calculate the median profile for each category is given in the curve label.

1.5.4.4.3 Error estimates of NO_3 local density

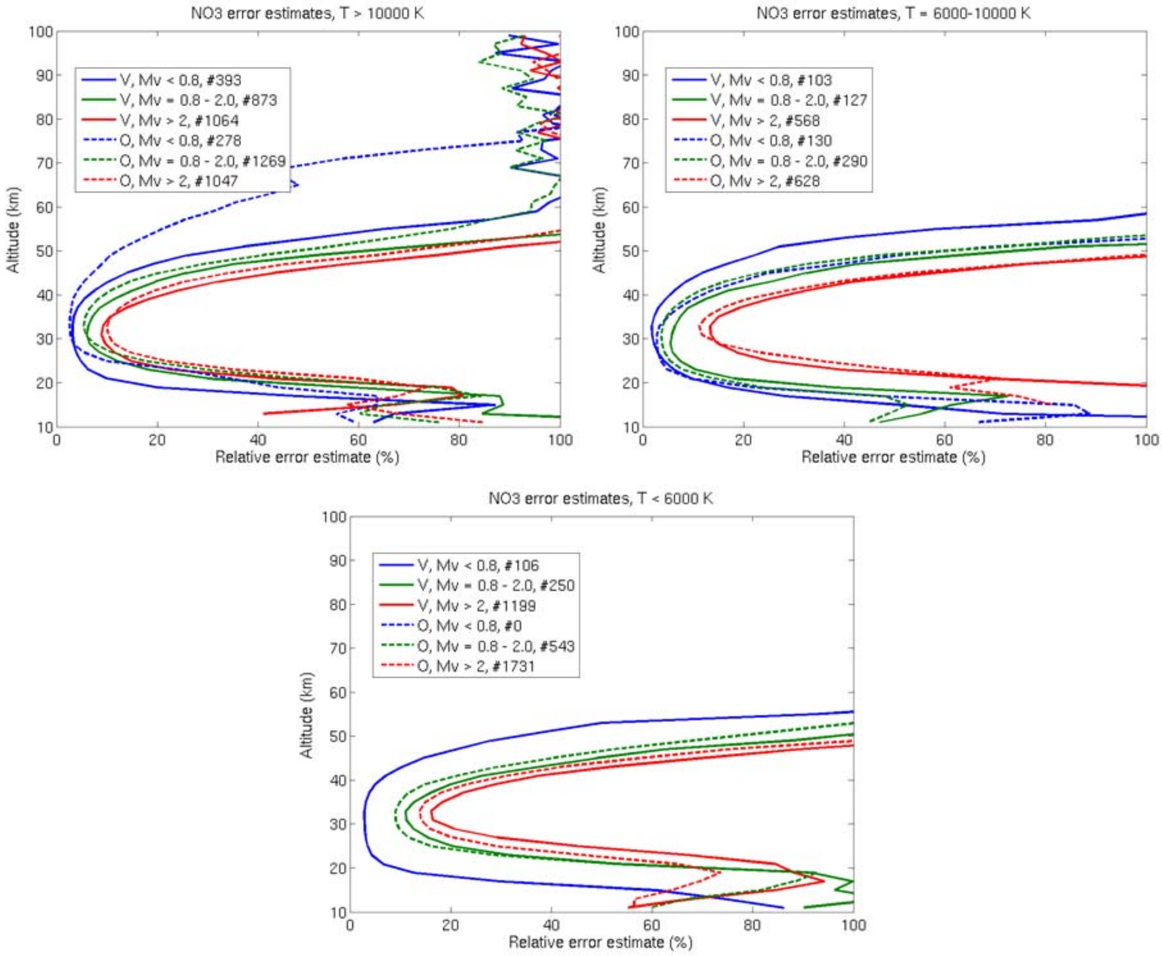

Figure 1.11: Vertical profiles of the median of the relative error estimates for NO_3 local density, from GOMOS night-time measurements during 2003; each plot corresponds to a category of star T (hot stars of T > 10000K; typical stars of T between 6000K and 10000K; cold stars of T lower than 6000K). Results on each plot are given by category of star brightness (bright stars of visual magnitude lower than 0.8; typical stars of visual magnitude between 0.8 and 2.0; dim stars of visual magnitude higher than 2.0) and by occultation obliquity (V for close to vertical occultations; O for oblique occultations; see text for details). The number of profiles used to calculate the median profile for each category is given in the curve label.

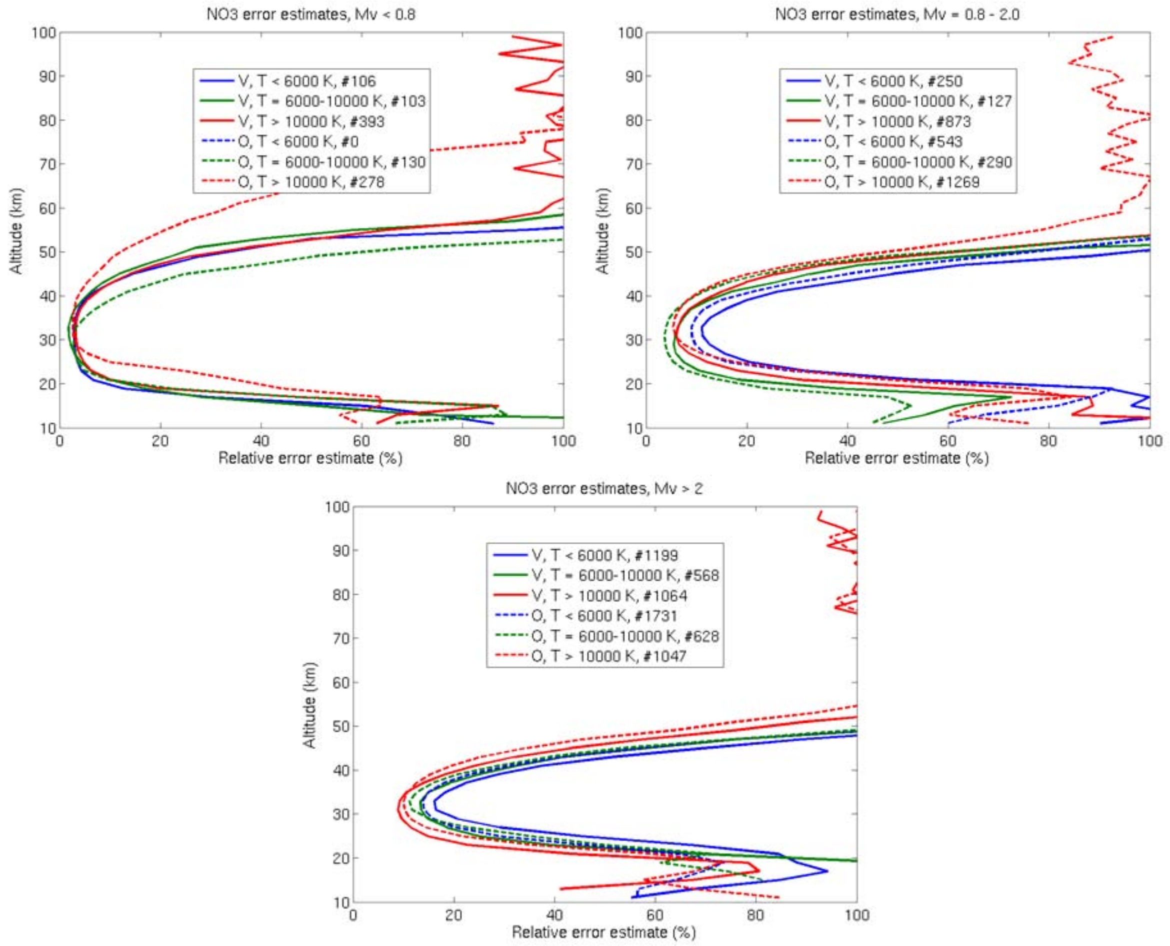

Figure 1.12: Vertical profiles of the median of the relative error estimates for NO_3 local density, from GOMOS night-time measurements during 2003; each plot corresponds to a category of star brightness (bright stars of visual magnitude lower than 0.8; typical stars of visual magnitude between 0.8 and 2.0; dim stars of visual magnitude higher than 2.0). Results on each plot are given by category of star T (hot stars of T > 10000K; typical stars of T between 6000K and 10000K; cold stars of T lower than 6000K) and by occultation obliquity (V for close to vertical occultations; O for oblique occultations; see text for details). The number of profiles used to calculate the median profile for each category is given in the curve label.

1.6 Validation results

As defined by CEOS, the validation is the process of assessing by independent means the quality of the data products derived from the system outputs. Validation studies must involve a sufficiently large number of correlative measurements of sufficient quality, covering a large area and a wide range of conditions. Good candidates for the validation of GOMOS products are ground-based, balloon-borne (upper troposphere and stratosphere regions), and other satellite measurements (up to the lower thermosphere) such as MIPAS, OSIRIS, ACE, ... Validation studies based on the comparison of individual profiles and on statistical data analysis as well as algorithm verification studies are expected to provide feedback to the calibration, recommendation for the algorithm improvement, and support for the monitoring of geophysical data quality during the mission lifetime.

Various validation activities have been performed since Summer 2002. For O_3 products for instance, vertical profiles of local density have been systematically compared with NDSC lidar measurements (methodology described in [Meijer et al., 2004]). The average relative difference (GOMOS-lidar) is between –2% and 1% at altitudes between 18 km and 22 km (Figure 1.13). It is between 0 and –2% between 22 km and 32 km, between 0 and +1% between 32 km and 41 km, and between 0 and –5% between 41 km and 45 km. Best results are obtained at mid-latitudes. In these regions, the average relative difference (GOMOS-lidar) is between –1% and 4% for altitudes between 18 km and 40 km (). For the polar regions, a negative average difference (GOMOS-lidar) is calculated at all altitudes: about –5% for the relative value around 20 km; between 0 and –5% in the altitude range 29 km-36 km; between –5% and –10% in the altitude range 37 km-41 km. For the tropical cases, positive values up to 18% are calculated around 18 km, but this bias decreases to nearly 0 around 23 km. The comparison with balloon measurements at low latitudes also shows a positive average difference in the lower stratosphere.

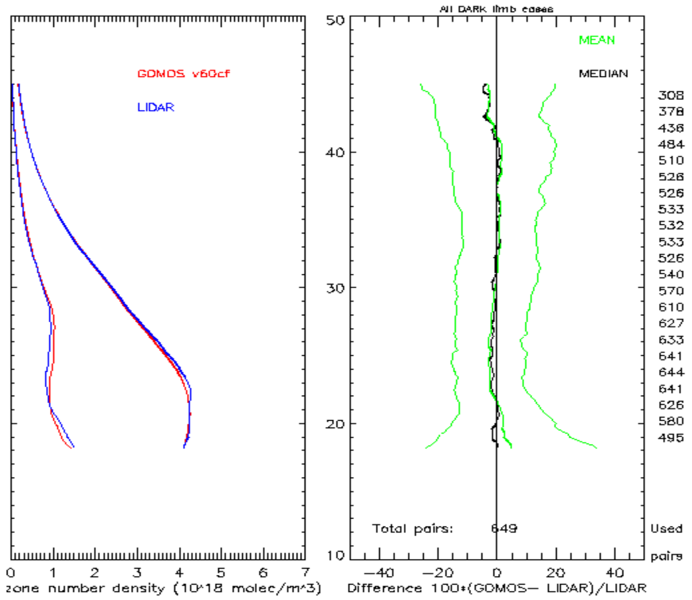

Figure 1.13: Left figure: Vertical profiles of the average and of the dispersion of O_3 local density from GOMOS products (red line), and measured by ground-based lidar instruments (blue line) between 0 and 50km. Right figure: Vertical profiles of the average relative difference between O_3 local density from GOMOS products and measured by ground-based lidar instruments (green lines: mean profile of the distribution with variability envelop; black line: median profile of the distribution). Coincidence criteria between GOMOS profiles and lidar profiles are a distance lower than 500 km and a time difference lower than 20 h. Only GOMOS measurements from occultations in pure dark limb have been used.

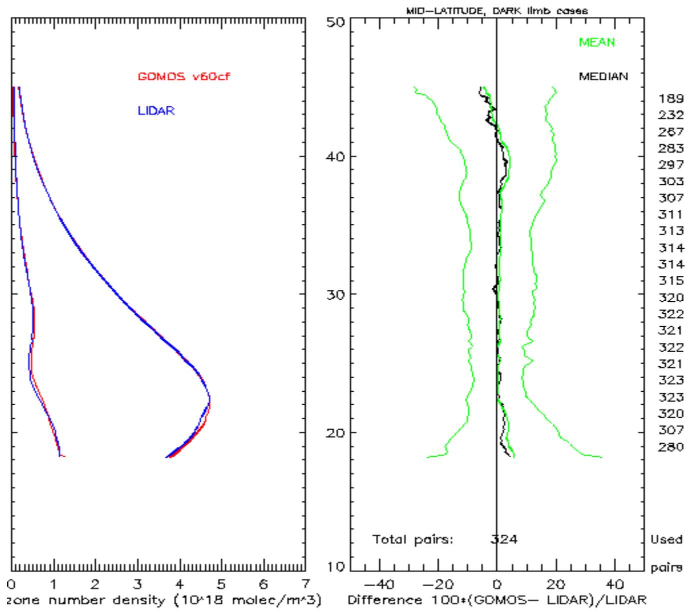

Figure 1.14: Same as Figure 1.13 for mid-latitude measurements.

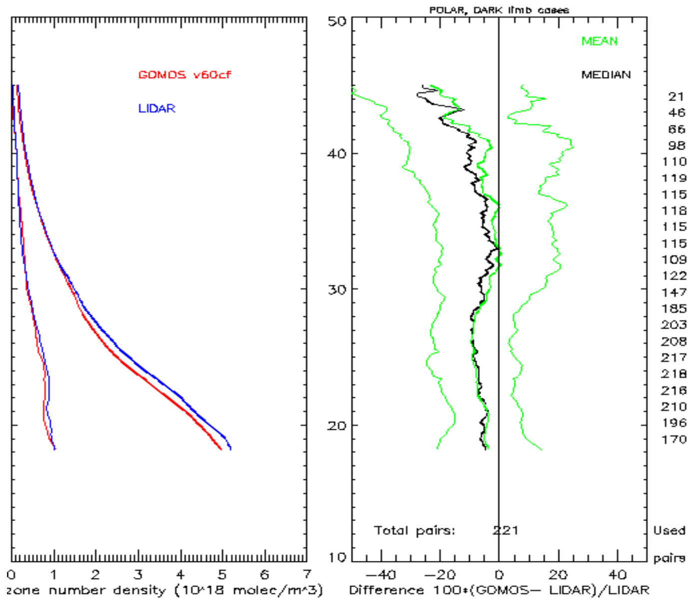

Figure 1.15: Same as Figure 1.13 for polar measurements.

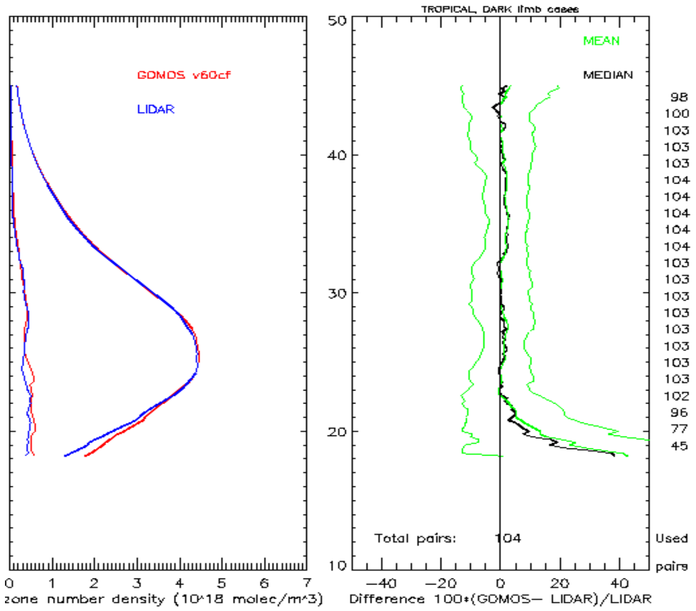

Figure 1.16: Same as Figure 1.13 for tropical measurements.

Results of recent studies of validation of all species products from the current operational processor (IPF 5.00) were presented in the Atmospheric Chemistry Validation Experiment workshop held in December 2006. For O_3 profiles measured in dark limb, from the comparison with measurements from lidar, sondes, balloon-borne instruments, MIPAS and OSIRIS satellite instruments, it is estimated a bias lower than 5% (upper troposphere, stratosphere and mesosphere). The precision is estimated to be lower than 10%. NO_2 profiles have been found free of bias. Their precision is estimated to be about 20%. The precision of NO_3 profiles is estimated to be about 30%. No systematic comparison has been performed for aerosol products, but individual profiles have shown a good agreement with balloon measurements. Results from the validation of HRTP have shown that best results are obtained between 23 km and 30 km; however, even in this altitude range, many profiles contain spurious values. Statistical analyses on GOMOS-GOMOS coincidences highlighted an overestimation of the additional error turbulence for O_3 local density in the range 20 km -40 km.

It has been stated that the limb flagging is too conservative. It is recommended to revise this limb flagging to a criterion on the solar zenith angle. It has also been stated that the species flagging in the products needs to be improved.

1.7 Scientific achievements

Publications in peer-reviewed journals as well as many presentations and contributions proceedings of conferences have been released since the ENVISAT launch. A detailed list of papers and reports is given in Chapter 4 of this document.

The night-time ozone distribution in the stratosphere and in the mesosphere measured by GOMOS in 2003 is presented in [Kyrölä et al., 2006]. Results of the systematic comparison of O_3 vertical profiles with external measurements are detailed in [Meijer et al., 2003, 2004]. The first simultaneous global distribution of stratospheric NO_2 and NO_3 from night-time GOMOS measurements is presented in [Hauchecorne et al., 2005]. The first global determination of the stratospheric OClO distribution as measured in 2003 by GOMOS is reported in [Fussen et al., 2006]. Investigations on the mesospheric sodium layer are discussed in [Fussen et al., 2004, 2005]. The comparison of aerosol extinction with external measurements is presented in [Vanhellemont et al., 2005], and the stratospheric aerosol extinction and PSC climatology in [Vanhellemont et al., 2005]. The analysis of the scintillation measurements and results of stratospheric turbulence studies are presented in [Gurvich et al., 2005], [Dalaudier et al., 2006] and [Sofieva et al., 2007]. Studies specific to mesospheric issues are reported in [Hauchecorne et al., 2007] and in [Sofieva et al., 2004]; the impact of solar proton events in the middle atmosphere is discussed in [Seppälä et al., 2004, 2006] and in [Verronen et al., 2005].

2 Presentation of the GOMOS products

2.1 General presentation

2.1.1 Organization and relation of the products

2.1.1.1 Processing levels and main products

The GOMOS products, like all the ENVISAT products, are grouped according to the processing level:

- **Level 0 products**: Reformatted and time-ordered satellite data
- **Level 1b products**: Geolocated calibrated engineering data
- **Level 2 products**: Geolocated geophysical products

2.1.1.1.1 High level data flow

Figure 2.1 shows the high level data flow of the GOMOS ground processing. The level 0 products are processed by the Level 1b processing chain that creates two products: the level 1b product (mnemonic TRA) and the limb product (mnemonic LIM). Only the first one is used by the Level 2 processing chain to generate two other products: the level 2 product (mnemonic NL) and the residual extinction product (mnemonic EXT).

Besides these products processed off-line, Near Real Time products are generated within 3 hours of ground reception. Their processing uses the predictions of the external atmospheric data, instead of the a posteriori analysis used by the standard off-line processing. The so-called meteo products contain selected profiles extracted from the Near Real Time products at a reduced spatial resolution. They are delivered mainly to the meteorological community.

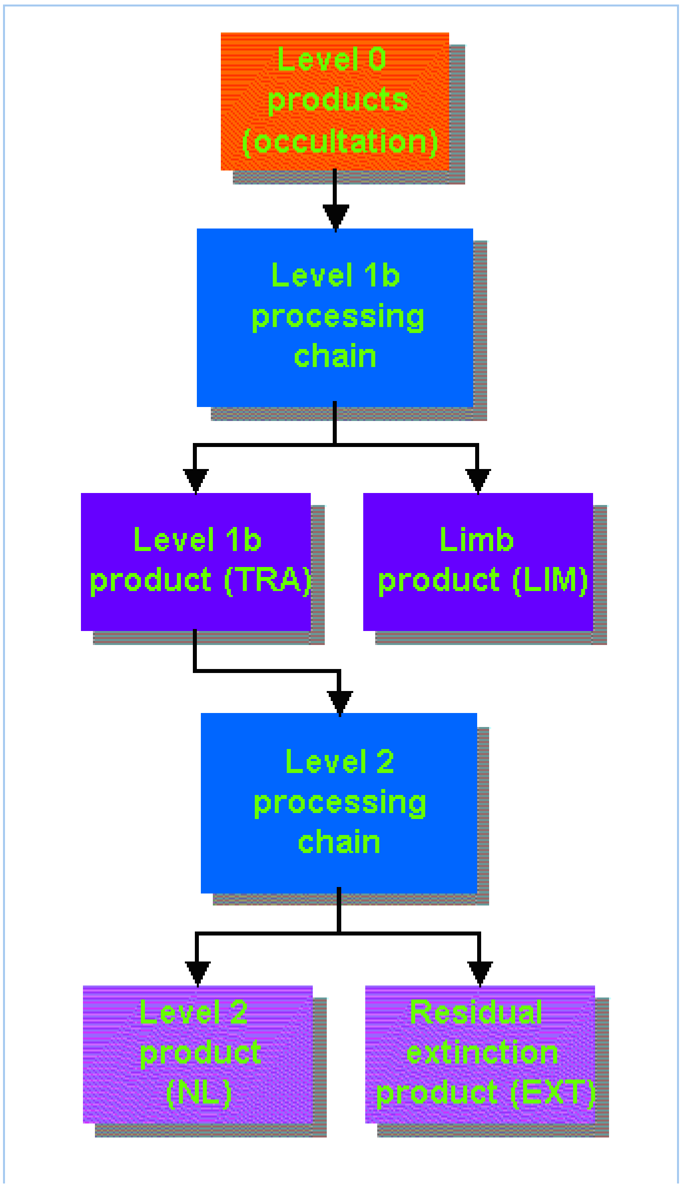

Figure 2.1: High level data flow of GOMOS processing.

Table 2.1 lists the GOMOS Level 0 products, the Level 1b products, the Level 2 products, including the meteo products, with the naming convention and the general description of their content.

Table 2.1: List of GOMOS Level 0 products, Level 1b products, and Level 2 products.

Processing level	Naming convention	File description
Level 0	GOM_NL_0P	GOMOS nominal Level 0 product
	GOM_MM_0P	GOMOS monitoring Level 0 product
Level 1b	GOM_TRA_1P	GOMOS Geolocated and Calibrated Transmission Spectra Product

Processing level	Naming convention	File description
	GOM_LIM_1P	GOMOS Geolocated and Calibrated Background Spectra (Limb) Product
Level 2	GOM_NL__2P	GOMOS Temperature and Atmospheric Constituent Profiles
	GOM_EXT_2P	GOMOS Residual Extinction
	GOM_RR__2P	GOMOS NRT Extracted Profiles for Meteo Users

2.1.1.1.2 Level 0 processing

The Level 0 processing includes a simple set of operations: the determination of the satellite position and the conversion of satellite binary time to universal time coordinates. There are actually two types of GOMOS Level 0 products: the nominal Level 0 products (the sensor is in nominal occultation measurement mode), and the monitoring Level 0 products (the sensor is in calibration monitoring mode).

2.1.1.1.3 Level 1 processing

The input data for the Level 1 processing are the Level 0 products and relevant auxiliary data. Level 1 products are divided into two categories: Level 1a and Level 1b. The Level 1a products are the Level 0 products after they have been sorted and filtered by low-level quality checks. They will not be further detailed in the document. The Level 1b products are generated by the Level 1b processing chain from the Level 0 products. The aim of the Level 1b processing is to estimate a set of horizontal transmission functions in the UV-visible-near IR between 250 nm and 952 nm using data measured by the GOMOS spectrometers. There are two types of Level 1b products: the geolocated and calibrated transmission spectra products and the geolocated and calibrated background spectra limb products.

The main steps of the Level 1b processing are illustrated in Figure 2.2.

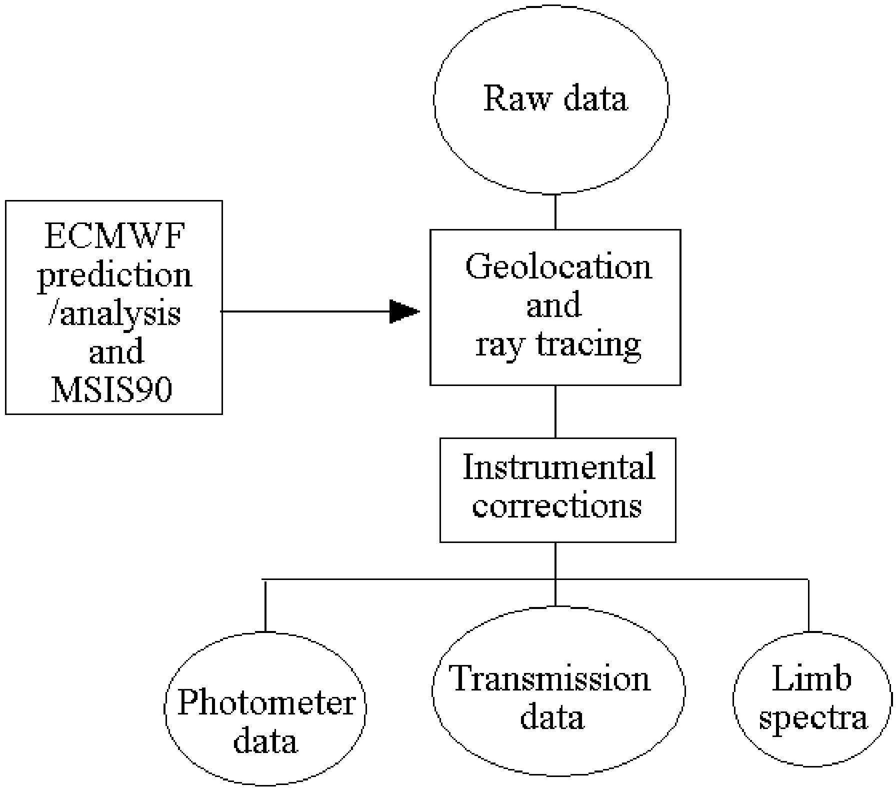

Figure 2.2: Simplified architecture of the Level 1b processing.

In a first step, the nominal wavelength assignment, geolocation and datation processing are performed. The nominal wavelength assignment corresponding to a perfect tracking of the star during the measurement is provided by the spectral assignment of one CCD column and by the spectral dispersion law of the spectrometers read in the calibration auxiliary product. Then spectral shifts due to vibrations and imperfect tracking are estimated thanks to the pointing data history produced by the SATU (Star Acquisition Tracking Unit). Each CCD column is then spectrally assigned during each spectrometer measurement. Each measurement of the atmospheric transmission is precisely geo-located, from the satellite location and the known direction of the star. Because of the atmospheric refraction, the light from the star to the instrument does not follow a straight line. A full ray tracing is performed through the atmosphere to compute the exact path of the stellar light, the refraction effects being inferred from the state of the atmosphere given by the ECMWF and MSIS90.

The processing of the spectrometer data is then performed. Anomalies and outliers are first detected and corrected (saturated samples, bad pixels, cosmic ray, modulation correction). Dark charge is removed and a few other instrumental corrections (correction of the SFA mirror reflectivity, internal and external straylight correction, vignetting correction, flat-field correction) are applied. In bright limb occultations, the estimate of the scattered solar light is removed from the central band to get the star signal alone. This background signal is estimated from the signals measured in the upper and lower CCD bands, and it is stored in the geolocated and calibrated background spectra limb product. The full transmission spectra are then computed as the ratio of the estimated star spectrum to the reference spectrum of the current occultation (average of several star spectra measured outside the atmosphere during the occultation). They are stoed in the geolocated and calibrated transmission spectra product.

The processing of the fast photometer data includes some steps similar to the ones applied to the spectrometer samples (detection and correction of anomalies). The estimated central background computed for the spectrometers is substracted from the photometer signals.

The processing steps and the generation of the Level 1b products are presented in more detail in the ATBD reference document (see Chapter 4 for reference).

2.1.1.1.4 Level 2 processing

The input data needed for the Level 2 processing are the Level 1b products and relevant auxiliary data. The main Level 1b quantities needed are the transmission spectra at different tangent point heights, and the photometric data from the two fast photometers. The aim of the Level 2 processing is to retrieve the vertical profiles of O_3, NO_2, NO_3, O_2, H_2O and other trace gases profiles, the temperature profile, the aerosol extinction coefficient and wavelength dependency parameters, and information about atmospheric turbulence from the full atmospheric transmission spectra. There are three types of Level 2 products: the products storing the profiles of temperature and atmospheric constituents, the residual extinction products and the products storing selected profiles processed in NRT for meteo users.

The geolocation data and the a priori atmospheric data are also used to deal with the refractive effects and to initialise the inversion. These data are partly replaced by new data from the GOMOS Level 2 processing.

The main steps of the Level 2 processing are illustrated in Figure 2.3.

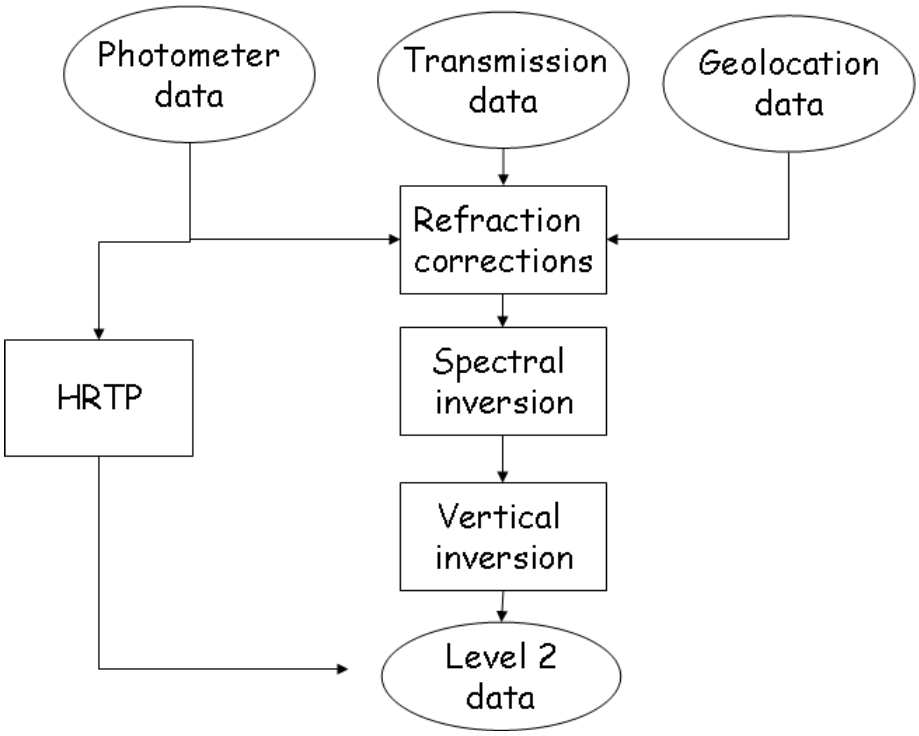

Figure 2.3: Simplified architecture of the Level 2 processing.

In a first step, the transmission spectra are corrected for the attenuation and dilution caused by refraction and modulations by scintillations. The measurements from the photometers are used to correct the measured transmissions from the scintillation effects. The spectral inversion of the transmission spectra is then performed to retrieve the constituent line densities. A separate spectral inversion for the IR spectrometers (retrieval of H_2O and O_2 densities in the 756-773 nm and 926-952 nm spectral ranges) is applied.

- spectral inversion UV-VIS (O_3, NO_2, NO_3):

The model transmission function is fitted to the refraction-corrected transmissions. The minimization is done by a nonlinear Levenberg-Marquardt method, simultaneously at all wavelengths. For NO_2 and NO_3, chromatic scintillations caused by isotropic turbulence produce perturbations in the transmission spectra, and subsequent unrealistic oscillations in the vertical profiles of species, mainly NO_2 and NO_3 below 40 km. The scintillation correction is unable to remove these perturbations in the spectra. A Global DOAS iterative method has been implemented for the retrieval of NO_2 and NO_3.

- spectral inversion IR (O_2, H_2O):

A different algorithm is used for the spectral inversion of O_2 and H_2O, to take into account the dependence of the apparent cross-sections on the integrated densities. Reference transmission spectra are calculated for different integrated densities of O_2 or of H_2O. A direct model is used to take into account the dependence of the reference transmissions with the pressure.

After the spectral inversion, the vertical inversion of the line densities is applied to produce the local density values of each constituent. It is performed with the onion-peeling method. Tikhonov regularisation is applied in order to attenuate unphysical oscillations in the profiles, due to noisy data and scintillations. A new temperature profile is also produced from Rayleigh scattering from the UVIS spectrometer and from O_2 density from the IR spectrometer. This profile is used to recalculate the effective cross-sections. Then the spectral and the vertical inversions are activated. It has been shown that this iterative process improves the results. The GOMOS temperature profile is also used to update the ray path from the previous computation made during the Level 1b processing and basing on ECMWF/MSIS90 data.

The measurements from the two fast photometers are used to retrieve a high resolution temperature profile of the atmosphere. Due to the variation of the index of air refraction with wavelength, the light beam of an occulted star is more bent in the blue part of the spectrum than in the red part. Thus the time delay between the signals of the two fast photometers provides indications on the density and the temperature profiles in the atmosphere which may be inferred with a high vertical resolution.

The processing steps and the generation of the Level 2 products are presented in more detail in the ATBD reference document (see Chapter 4 for reference).

2.1.1.2 Auxiliary files

The auxiliary product files are used by the GOMOS geophysical processing facility and the calibration processing environment. Figure 2.4 illustrates the data flow of the calibration and the configuration files for GOMOS processing.

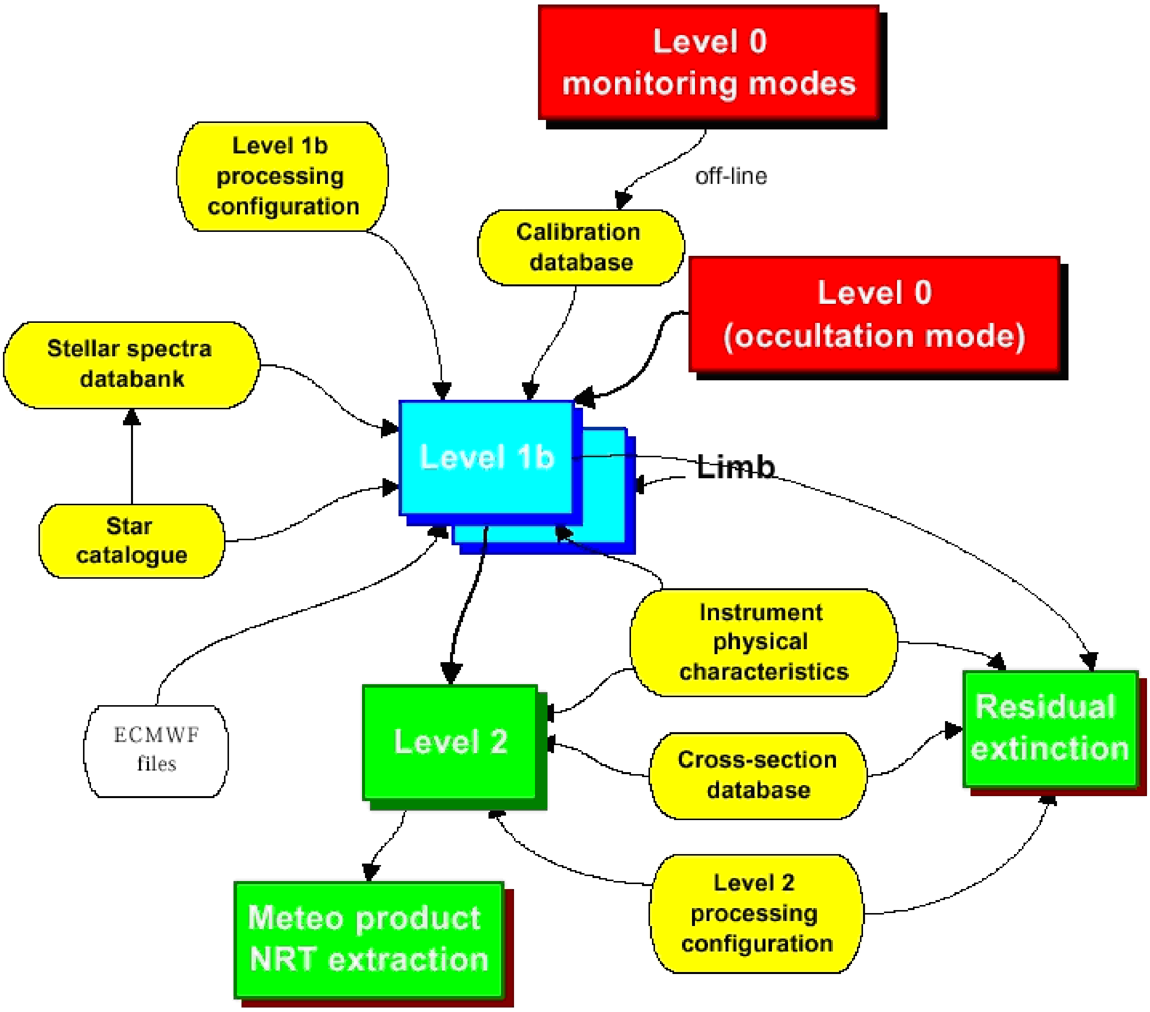

Figure 2.4: Data flow of the calibration and the configuration files for GOMOS processing.

Table 2.2 lists the auxiliary files with the naming convention, the general description of their content and the processing level for which they are used.

Table 2.2: List of GOMOS auxiliary files.

Naming convention	File description	Processing level
GOM_CAL_AX	Calibration database	Level 0 to 1b processing
GOM_CAT_AX	Star catalogue	Observation planning
GOM_STS_AX	Stellar Spectra	Level 0 to 1b processing
AUX_ECF_AX	ECMWF forecast data	Level 0 to 1b processing

Naming convention	File description	Processing level
GOM_PR1_AX	Level 1b processing configuration database	Level 0 to 1b processing
GOM_PR2_AX	Level 2 processing configuration database	Level 1b to 2 processing
GOM_CRS_AX	Cross section database	Level 1b to 2 processing
GOM_INS_AX	Instrument physical characteristics data	Level 0 to 1b processing, Level 1b to 2 processing

The calibration file GOM_CAL_AX is used only by the Level 1b processor. The star catalogue GOM_CAT_AX is used by the mission planning software. It contains all possible stars (selected) for use by GOMOS, as well as 7 planets and dark regions (for dark calibration). The star catalogue is used by the Level 1b processor and is also used as a reference for reading the stellar spectra databank file (by the Level 1b processor).

The Cross-section database GOM_CRS_AX contains the specific trace-gas cross sections and is read by the Level 2 processor.

The characterisation file GOM_INS_AX contains the instrument parameters which are assumed to change (due to instrument ageing) during the instrument lifetime: the CCD size, the focal length, … The characterisation file provides inputs to both the Level 1b and the Level 2 processors.

The Level 1b and the Level 2 processor configuration files GOM_PR1_AX and GOM_PR2_AX are used for setting up the geophysical processors.

The stellar spectra database GOM_STS_AX is continuously updated and contains the averaged stellar spectra, as recorded by GOMOS outside the atmosphere.

The file AUX_ECF_AX contains the ECMWF meteorological forecast data needed to compute the atmospheric model used for the processing of the Near Real Time products.

2.1.2 Data size

Table 2.3 and Table 2.4 give the typical size of the main GOMOS products and of the auxiliary files. Figures for the main products are given for occultations of various durations, as the size of those products depends on the occultation duration. The size of the auxiliary products does not depend on the occultation duration.

Table 2.3: Typical size of GOMOS products for several occultation durations (Mbytes).

Product	30s duration	50s duration	75s duration	255s duration
Level 0	0.7	1.2	1.8	6.1
Level 1b	2.7	4.5	6.7	22.8
Limb	1.7	2.8	4.3	14.4
Level 2	0.08	0.13	0.19	0.63
Extinction	1.8	3.1	4.6	15.5

Table 2.4: Typical size of GOMOS auxiliary products (Kbytes).

Auxiliary product	Naming convention	Size (kBytes)
Calibration database	GOM_CAL_AX	1846
Star catalogue	GOM_CAT_AX	426
Stellar Spectra	GOM_STS_AX	843
Level 1b processing configuration database	GOM_PR1_AX	2
Level 2 processing configuration database	GOM_PR2_AX	19
Cross section database	GOM_CRS_AX	12267
Instrument physical characteristics data	GOM_INS_AX	10

Table 2.5 gives the typical size for a set of all level products. Figures are given for a case of 35 occultations per orbit (typical case before 01/2005) and for a case of 20 occultations per orbit (typical case after 08/2005).

Table 2.5: Size figures (Mbytes) for sets of all level products, for a case with 35 occultations per orbit and for a case with 20 occultations per orbit. The occultation duration is assumed to be of 50s.

Product set	35 occultations per orbit	20 occultations per orbit
One occultation: L0+L1b+L2	12	12
One orbit: L0+L1b+L2	400	240
One day (14 orbits): L0+L1b+L2	5900	3400
One week (7 days): L0+L1b+L2	41200	23500

2.1.3 Time availability

The ground processing of the GOMOS measurements includes the near-real time processing and the off-line processing. Table 2.6 gives figures of the typical delivery delay between the date of the measurements and the release of the end products.

Table 2.6: Typical delivery delay between the data acquisition and the release of end products.

Processing level	File type	Availability of NRT product	Availability of off-line product
Level 0	GOM_NL_0P	1 day	2 weeks
Level 1b	GOM_TRA_1P	3 hours	3 weeks
	GOM_LIM_1P	3 hours	3 weeks
Level 2	GOM_NL__2P	3 hours	3 weeks
	GOM_EXT_2P	3 hours	3 weeks
	GOM_RR__2P	3 hours	

2.2 Description of the products

2.2.1 Product naming convention

For each product, the file name is built up from a fixed number of fields, in a fixed order:

filename = **<product_ID> <processing_stage_flag><originator_ID><start_day> <“_”> <start_time> <“_”> <duration> <phase> <cycle> <“_”> <relative_orbit> <“_”> <absolute_orbit> <“_”><counter><“.”> <satellite_ID> <.extension>**

Those fields are:

<product_ID>	specific string describing the sensor, the mode and the processing level (10 characters)
<processing_stage_flag>	N for Near Real Time product; V for fully validated product; letters between N and V in order level of consolidation
<originator_ID>	processing centre of the product (3 character string; DPA for D-PAC; FIN for FINPAC; ACR for ACRI; …)
<start_day>	starting day of the product from the UTC time of the first DSR
<start_time>	starting time of the product from the UTC time of the first DSR
<duration>	time coverage of the product in s
<phase>	mission phase identifier
<cycle>	cycle number within the mission phase
<relative_orbit>	Relative orbit number within the cycle at the beginning of the product
<absolute_orbit>	Absolute orbit at the beginning of the product
<counter>	For a given product type the counter is incremented by 1 for each new product generated by the product originator.
<satellite_ID>	N1 stands for ENVISAT.

For instance, the file name:

GOM_NL__2PNACR20021205_140901_000000402011_00439_04000_0001.N1

corresponds to a GOMOS Level 2 product ("GOM_NL__2P") processed in Near-Real Time ("N") at ACRI ("ACR"), containing measurements starting on 05/12/2002, 14:09:01 UTC ("20021205_140901") and for 40s ("00000040"), during the ENVISAT ("N1") phase 2 ("2) and cycle 11 ("011"); the relative orbit of ENVISAT was 439 ("00439"), and the absolute orbit was 4000 ("04000").

2.2.2 Product structure

All products follow the same structure and contain three main fields, the Main Product Header, the Specific Product Header, and the Data Sets.

Main Product Header (MPH):

The MPH is in ASCII format. Its size and its structure are fixed and are common to all ENVISAT instruments.

It contains information on the main characteristics of the product. Table 2.7 lists some of the records of the MPH. The exhaustive list of these records is given in the document ENVISAT-1 products specifications, Issue 3, rev. 1, ref. PO-RS-MDA-GS-2009, 2005.

Table 2.7: Records of the MPH (non-exhaustive list). See the document ENVISAT-1 products specifications, Issue 3, rev. 1, ref. PO-RS-MDA-GS-2009, 2005 for a complete description.

Record	**Description**	**Unit**
product	Product File Name	ascii
proc_stage	Processing Stage Flag: N = Near Real Time, T = test product, V= fully validated (fully consolidated) product, S = special product. Letters between N and V (with the exception of T and S) indicate steps in the consolidation process. If not used, set to X	ascii
acquisition_station	Acquisition Station ID (up to 3 codes). Not used characters are set to blank space characters	ascii
proc_center	Processing Center ID which generated current product. If not used, set to ∅∅∅∅∅∅	ascii
proc_time	UTC Time of Processing (product generation time). If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅	UTC
software_ver	Software Version number of processing software Format: Name of processor (up to 10 characters)/ version number (4 characters) -- left justified (any blanks added at end). If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅	ascii
sensing_start	UTC start time of data sensing (first measurement in first data record) UTC Time format. If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅	UTC
sensing_stop	UTC stop time of data sensing (last measurements last data record) UTC Time format. If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅	UTC
cycle	Cycle number. If not used, set to +000	-
rel_orbit	Start relative orbit number. If not used, set to +00000	-

Record	**Description**	**Unit**
abs_orbit	Start absolute orbit number. If not used, set to +00000	-
state_vector_time	UTC of ENVISAT state vector. UTC time format. If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅	UTC
utc_sbt_time	UTC time corresponding to SBT below (currently defined to be given at the time of the ascending node state vector). If not used, set to ∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅∅	UTC
sat_binary_time	Satellite Binary Time (SBT) 32bit integer time of satellite clock. Its value is unsigned (=>0). If not used, set to +0000000000	-

Specific Product Header (SPH):

The SPH is in ASCII format. Its size and its structure are fixed for a specific product.

It contains information specific to the product itself.

The SPH contains Data Set Descriptors fields (DSD).

Those DSD point to and describe the Data Sets (DS) contained in the product. There is one DSD per DS.

The DSD may also provide references to external files relevant to the current product.

Some DSD of the SPH of the Level 1b products and of the SPH of the Level 2 products are similar. They provide information on the date, the location of the measurements, and the star characteristics of which occultation was measured. These DSD are listed in Table 2.8. The complete description of the SPH for the different products is given in the IODD.

Table 2.8: DSD of the SPH of the Level 1b products (non exhaustive list), also contained in the Level 2 products; see the IODD for a complete description of the SPH. (*) The list of stars selected for use by GOMOS is given in Appendix B.

Field	**Description**	**Unit**
START_TIME	Start time of the occultation	UTC
STOP_TIME	Ending time of the occultation	UTC
START_TANGENT_LAT	Latitude of the tangent point at START_TIME	(1e-6) deg (positive = North)
START_TANGENT_LONG	Longitude of the tangent point at	(1e-6) deg

Field	Description	Unit
	START_TIME	(positive = East)
STOP_TANGENT_LAT	Latitude of the tangent point at STOP_TIME	(1e-6) deg (positive = North)
STOP_TANGENT_LONG	Longitude of the tangent point at STOP_TIME	(1e-6) deg (positive = East)
STAR_ID	Star identifier in the star catalogue (*)	
STAR_MAG	Star visual magnitude	1e-3
STAR_TEMP	Star effective temperature	(1e-1)K

Data Sets (DS):

The DS are stored in a mixed ASCII-binary format. Each DS is composed of one or more Data Set Records (DSR).

The DS may be Measurement Data Set or Annotation Data Set.

Global Annotation Data Set (GADS):

Each GADS contains auxiliary data relevant to the product (nominal wavelength assignment, reference star spectrum, LUT, …). A GADS is made of only one DSR.

Annotation Data Set (ADS):

Each ADSR contains auxiliary data applicable to one measurement. An ADS is made of one or several DSR.

Measurement Data Set (MDS):

The MDS contains measurements and/or processed data. A MDS is made of one or several DSR.

2.2.3 Product content

We provide here a general description of the headers and of the data sets stored in the products. We also present in more detail some of the data sets of the Level 1b products and Level 2 products. The exhaustive presentation of the content of the GOMOS products is given in the IODD reference document (see reference in Chapter 4 of this document). A more detailed definition of the terms used in the following sections is available in the Appendix A of this document.

2.2.3.1 Level 0 products

The Level 0 products contain only raw data, which are:

- UV-visible spectrometer data
- IR spectrometer data
- Photometer 1 data
- Photometer 2 data
- Occultation recording time
- Photometer recording time
- Auxiliary data (e.g. satellite location, mirror position)

They store the data corresponding to a full orbit.

2.2.3.1.1 Level 0 nominal products (GOM_NL_0P)

The Level 0 nominal products contain the GOMOS source packets in occultation mode for a full orbit (time ordered Annotated Instrument Source Packets recording the occultation measurements of the GOMOS instrument). They are generated from raw data and they are produced systematically when the instrument is in occultation mode. They are the basis for all higher level processing.

The structure of the Level 0 nominal products is detailed in Table 2.9

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Table 2.9: Content of the Level 0 monitoring products GOM_NL_0P.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
MDS	GOMOS source packets	GOMOS_SOURCE_PACKETS

2.2.3.1.2 Level 0 monitoring products (GOM_MM_0P)

The Level 0 monitoring products contain the GOMOS source packets in monitoring mode for a full orbit (time ordered AISP which hold data acquired while the instrument is in self-calibration monitoring mode). They are used for the validation and the calibration of the instrument.

There are three modes in which GOMOS is not acquiring stellar occultation data (monitoring mode), but is acquiring data used to establish operating parameters, and to set up look-up tables which are used in subsequent GOMOS data processing. These modes are:

- Linearity Monitoring Mode,
- Uniformity Monitoring Mode, and

- Spatial Spread Monitoring Mode.

The structure of the Level 0 monitoring products is given in Table 2.10.

Table 2.10: Content of the Level 0 monitoring products GOM_MM_0P.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
MDS	GOMOS source packets	GOMOS_SOURCE_PACKETS

2.2.3.2 Level 1b products

2.2.3.2.1 Transmission spectra products (GOM_TRA_1P)

Those products are the main Level 1b products. They are the basis for further Level 2 processing. The transmission spectra products contain the geolocated and calibrated data, mainly the full transmission (computed as the ratio of the estimated star spectrum to the reference spectrum of the current occultation, without any correction for scintillations and dilution), and the covariance spectra needed by the Level 2 processing. The full transmission spectra show the perturbation of the star spectra due to the presence of the atmospheric constituents. The covariance spectra give an estimation of the errors due to both instrument measurements and Level 1b processing tasks.

Those products also contain a copy or a reference to the auxiliary data, a reference to the algorithms used to generate the product, the datation of the measurements and of the processing, the product confidence indicators at product level and at data level.

Each Level 1b transmission spectra product contains the data corresponding to a whole occultation.

The structure of the geolocated and calibrated transmission spectra products is detailed in Table 2.11.

Table 2.11: Content of the transmission spectra products GOM_TRA_1P; list of GADS, MDS and ADS.

Field	Data set	Data set name
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	Summary quality	TRA_SUMMARY_QUALITY
GADS	Occultation data	TRA_OCCULTATION_DATA
GADS	Nominal wavelength assignment	TRA_NOM_WAV_ASSIGNMENT
GADS	Reference star spectrum	TRA_REF_STAR_SPECTRUM
GADS	Reference atmospheric density profile	TRA_REF_ATM_DENS_PROFILE
MDS	Transmission	TRA_TRANSMISSION
MDS	SATU data and SFA angles	TRA_SATU_AND_SFA_DATA
ADS	Auxiliary data	TRA_AUXILIARY_DATA
ADS	Geolocation	TRA_GEOLOCATION

Summary quality GADS

This GADS includes the observation illumination condition "PCD_ILLUM" (see table 3.2 in section 3.3.2.1), as well as other PCD at occultation level.

Occultation data GADS

This GADS stores among other quantities the DS related to the radiometric sensitivity curves (star and background), needed to convert the spectra (star and limb respectively) provided in electrons into physical units.

The radiometric sensitivity curve is given for each occultation as a LUT of conversion factors ("Radiometric sensitivity curve") for a series of wavelength values ("Abscissae of the radiometric sensitivity curve"), which size is given by the DS "Size of the radiometric sensitivity curve". A linear interpolation of the conversion factor is needed to use this curve for any sample of the spectra.

The occultation data GADS is detailed in Table 2.12.

Table 2.12: Occultation data GADS in the Level 1b transmission product.

Occultation data GADS	Unit
Number of points of the spectra	Dl
Number of photometer output data per measurement	Dl
Number of SATU output data per measurement	Dl
Photometers central wavelength	(1.e-1)nm

Occultation data GADS	Unit
Spectrometer effective sampling time	S
Effective time shift for ray tracing/geolocation	S
Ref. wavelength for the ray tracing	(1.e-1)nm
Size of the radiometric sensitivity curve (background)	Dl
Abscissae of the radiometric sensitivity curve (background)	(1.e-3)nm
Radiometric sensitivity curve (background)	Lf per e
Size of the radiometric sensitivity curve (star)	S
Abscissae of the radiometric sensitivity curve (star)	(1.e-3)nm
Radiometric sensitivity curve (star)	Sf per e
Thermistor temperature (SP)	(1.e-2)K
Thermistor temperature (FP)	(1.e-2)K
Dark charge used for the spectrometer dark charge correction	E
Mean spectrometer dark charge (3 bands)	E
Mean photometer dark charge	E
Offset between thermistor and CCD arrays temperature	(1.e-2)K
Sun coordinates in the geocentric equatorial inertial system	Dl

Nominal wavelength assignment

This is the nominal wavelength of the centre of each pixel, valid for the whole occultation.

Reference star spectrum

It is obtained by averaging several star spectra measured outside the atmosphere at the beginning of the occultation; the averaging is made to minimise the noise. It is given in electrons and must be converted into physical units (ph/s/cm2/nm) by multiplying the flux values in electrons by the conversion factor inferred from using the radiometric sensitivity curve (star) provided as a LUT in the occultation data GADS (see the description of the Occultation data GADS).

Reference atmospheric density profile

This profile is extracted from a meteorological field analysis (ECMWF) completed by MSIS90 at higher altitudes (at levels of pressure lower than 1hPa). It is used to compute during the Level 1b processing the refraction of the line-of-sight, by full ray-tracing computation.

Transmission

This MDS stores among other quantities the full transmission spectra and the covariance. The transmission spectrum is obtained by dividing each spectrum by the reference star spectrum. It is described as ' full ' because it is the actually measured transmission, not corrected for refraction effects (dilution, scintillation, chromatic refraction) nor for variable PSF. Each spectrum is re-sampled on the wavelength pixel grid of the reference spectrum to get the transmission.

The covariance (which is actually the variance of each pixel signal) is computed from the analysis of S/N ratio.

The scaled estimated central background is the estimated background contribution to the total signal in the central band, which is subtracted to yield the pure stellar signal. Due to the high variation of these spectra with altitude, the coding is dynamic and uses a gain and an offset for each measurement. This gain and this offset are stored in the auxiliary data ADS (see the description of the auxiliary data ADS). The values stored in the MDS must be decoded by applying: background (in electrons) = offset + background code / gain. The decoded spectra are obtained in electrons. They must be converted then into physical units (ph/s/cm2/nm/sr) by multiplying the flux values in electrons by the conversion factor inferred from the radiometric sensitivity curve (background) provided as a LUT in the occultation data GADS (see the description of the Occultation data GADS).

This MDS also stores the photometer data, scintillation data expressed in electrons.

The transmission MDS is detailed in Table 2.13. It is made of several MDSR, one for each measurement time of 0.5s.

The maximum error bar for the estimated central background is set to 6500%.

Table 2.13: Transmission MDS in the Level 1b transmission product.

Transmission MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Full transmission spectra	dl
Covariance function of the full transmission	dl
Scaled estimated central background	dl
Error bar for the estimated central background	(1.e-1)%
Photometers engineering data (FP1)	e
Photometers engineering data (FP2)	e
Error bar for the photometers engineering data (FP1)	(1.e-1)%
Error bar for the photometers engineering data (FP2)	(1.e-1)%
PCD at sample level (SP)	dl

PCD at sample level (FP)	dl

SATU data

This is the position of the centroid of star image on the SATU CCD (Stellar Tracking Unit), which enables to know where to find each wavelength in the series of pixel.

Auxiliary data

This ADS contains a copy or a reference to the auxiliary product used during the processing. It stores among other quantities the offset and the gain needed for the decoding of the estimated central background contribution. The scaled estimated central background stored in the transmission MDS must be decoded by applying: background (in electrons) = offset + background code / gain

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The transmission ADS is detailed in Table 2.14. It is made of several ADS records, one for each measurement time of 0.5s.

Table 2.14: Auxiliary data ADS in the Level 1b transmission product.

ADS	Unit
Start time of the measurement	mjd
Attachment flag	dl
Spectral shift of the star spectra	(1.e-4) nm
Offset for the background spectra coding	e
Gain for the background spectra coding	dl
PCD at measurement level	dl

Geolocation

This includes both the position of ENVISAT spacecraft and the position of the tangent point of the line-of-sight. All the geolocation information is provided for the reference wavelength used for the ray tracing (equal to 500 nm). For example the localisation of the ray nodes and of the tangent point node are provided for this wavelength although at one given time inside the atmosphere, and due to chromatic refraction effects, each wavelength is looking at a different altitude.

This ADS also stores the apparent altitude of the central background, given at half-measurement, for the centre of the band.

2.2.3.2.2 Limb products (GOM_LIM_1P)

The limb products are used for the calibration and the validation of the instrument. The limb products contain the geolocated and calibrated background spectra actually measured with the two external bands of CCD spectrometers. Those products also contain a copy or a reference to the auxiliary data, a reference to the algorithms used to generate the product, the datation of the measurements and of the processing, the product confidence indicators at product level and at data level.

Each limb product contains the data corresponding to a whole occultation.

The structure of the background spectra limb products is detailed in Table 2.15.

Table 2.15: Content of the background limb spectra products GOM_LIM_1P; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	Summary quality	LIM_SUMMARY_QUALITY
GADS	Occultation data	LIM_OCCULTATION_DATA
GADS	Nominal wavelength assignment	LIM_NOM_WAV_ASSIGNMENT
MDS	Limb	LIM_MDS
ADS	Auxiliary data and geolocation ADS	LIM_ADS

All the products issued from the Level 1b processing are accompanied by error estimates. These estimates are calculated assuming that there are no modelling errors and that the error statistics follow a normal Gaussian distribution. The pixel data are assumed to be independent on each other. All correlations between pixels are ignored even if the Level 1b data processing may generate some.

Summary quality GADS

This GADS includes the observation illumination condition "PCD_ILLUM" (see table 3.2 in section 3.3.2.1), as well as other PCD at occultation level similar to the ones of the Level 1b transmission product.

Occultation data GADS

This GADS stores among other quantities the DS related to the radiometric sensitivity curves (background), needed to convert the limb spectra provided in electrons into physical units (ph/s/cm2/nm/sr).

The radiometric sensitivity curve is given for each occultation as a LUT of conversion factors ("Radiometric sensitivity curve") for a series of wavelength values ("Abscissae of the radiometric sensitivity curve"), which size is given by the DS "Size of the radiometric sensitivity curve". A linear interpolation of the conversion factor is needed to use this curve for any sample of the spectra.

The occultation data GADS is detailed in Table 2.16.

Table 2.16: Occultation data GADS in the Level 1b limb product.

Occultation data GADS	Unit
Number of points of the spectra	dl
Size of the radiometric sensitivity curve (background)	dl
Abscissae of the radiometric sensitivity curve (background)	(1.e-3)nm
Radiometric sensitivity curve (background)	lf per e
Spectrometer effective sampling time	s
Effective time shift for ray tracing/geolocation	s
Sun coordinates in the geocentric equatorial inertial system	dl

Limb MDS

This MDS includes the background spectra from upper and lower bands. The uncorrected spectra and the spectra after straylight and IR-vignetting corrections are stored.

Due to the high variation of these spectra with altitude, the coding is dynamic and uses a gain and an offset for each measurement. This gain and this offset are stored in the auxiliary data ADS (see the description of the auxiliary data ADS). The values stored in the MDS must be decoded by applying: background (in electrons) = offset + background code / gain. The decoded spectra are obtained in electrons. They must be converted then into physical units (ph/s/cm2/nm/sr) by multiplying the flux values in electrons by the conversion factor inferred from the radiometric sensitivity curve (background) provided as a LUT in the occultation data GADS (see the description of the Occultation data GADS).

The MDS is detailed in Table 2.17. It is made of several MDSR, one for each measurement time of 0.5s.

Table 2.17: MDS in the Limb product.

MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Scaled upper and lower background spectra before straylight correction	e
Scaled upper and lower background spectra after straylight and IR-vignetting corrections	e
Error bar for the upper and lower background spectra after straylight and IR-vignetting corrections	%
PCD at sample level	dl

The maximum error bar for the upper and lower background spectra is set to 255%.

ADS layout

This ADS stores among other quantities the offset and the gain for the background spectra coding. The scaled upper and lower background spectra stored in the limb MDS must be decoded by applying: background (in electrons) = offset + background code / gain.

The altitude of the apparent tangent point stores actually two values per DSR; the first one is given for the upper band and the second one is given for the lower band. In both cases, it is given at half-measurement for the centre of each band.

The limb ADS is detailed in Table 2.18. It is made of several ADS records, one for each measurement time of 0.5s.

Table 2.18: ADS in the limb product.

ADS	Unit
Start time of the Data Set Record	mjd
Attachment flag	dl
Offset for the background spectra coding	e
Gain for the background spectra coding	dl
Latitude of the spacecraft	(1.e-6) deg
Longitude of the spacecraft	(1.e-6) deg
Altitude of the spacecraft	(1.e-2) m
Latitude of the apparent tangent point	(1.e-6) deg
Longitude of the apparent tangent point	(1.e-6) deg
Altitude of the apparent tangent point	(1.e-2) m
Error on the latitude of the apparent tangent point	(1.e-7) deg

ADS	Unit
Error on the longitude of the apparent tangent point	(1.e-7) deg
Error on the altitude of the apparent tangent point	(1.e-3) m
Sun zenith angle at the spacecraft	deg
Sun zenith angle at the tangent point	deg
Sun azimuth angle at the tangent point	deg
PCD at measurement level	dl

2.2.3.3 Level 2 products

2.2.3.3.1 Temperature and atmospheric constituent profiles (GOM_NL__2P)

The Level 2 temperature and atmospheric constituent products are generated from Level 1b data. They contain the retrieved vertical profiles, the retrieved tangent line densities, the auxiliary data and reference of the algorithms used to generate the product, datation of the measurement and of the processing, product confidence indicators at product level and at data level.

A set of flags is raised at several stages of the Level 2 processing. These flags give information concerning the validity of the outputs of spectral inversion, vertical inversion, aerosol processing, turbulence processing, and GOMOS atmospheric profiles.

Each Level 2 temperature and atmospheric constituent product contains the data corresponding to a whole occultation.

The structure of the temperature and atmospheric constituent products is detailed in Table 2.19.

Table 2.19: Content of the temperature and atmospheric constituent products GOM_NL__2P; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	Summary Quality	NL_SUMMARY_QUALITY
MDS	Local density of species	NL_LOCAL_SPECIES_DENSITY
MDS	Tangent line density of species	NL_TANGENT_LINE_DENSITY
MDS	Aerosols	NL_AEROSOLS
MDS	High Resolution Temperature	NL_HIGH_RES_TEMPERATURE
ADS	Geolocation	NL_GEOLOCATION
ADS	Accuracy estimation	NL_ACCURACY_ESTIMATION

Summary quality GADS

This GADS includes the observation illumination condition "PCD_ILLUM" (see table 3.2 in section 3.3.2.1), as well as other PCD at occultation level similar to the ones of the Level 1b transmission product. It also provides the "verticality" of the occultation (in °). Values of the "verticality" close to 0 correspond to occultations close to the vertical direction, while high values of the "verticality" correspond to oblique occultations.

Local density of species

The local species density MDS is detailed in Table 2.20. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.20: Local species density MDS in the Level 2 temperature and atmospheric constituents product.

Local species density MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Local O_3 density	cm-3
Standard deviation for the local O_3 density	(1.e-1)%
Vertical resolution for the local O_3 density	m
Local NO_2 density	cm-3
Standard deviation for the local NO_2 density	(1.e-1)%
Vertical resolution for the local NO_2 density	m
Local NO_3 density	cm-3
Standard deviation for the local NO_3 density	(1.e-1)%
Vertical resolution for the local NO_3 density	m
Local air density	cm-3
Standard deviation for the local air density	(1.e-1)%
Vertical resolution for the local air density	m
Local O_2 density	cm-3
Standard deviation for the local O_2 density	(1.e-1)%
Vertical resolution for the local O_2 density	m
Local H_2O density	cm-3
Standard deviation for the local H_2O density	(1.e-1)%
Vertical resolution for the local H_2O density	m
Local OClO density	cm-3

Local species density MDS	Unit
Standard deviation for the local OClO density	(1.e-1)%
Vertical resolution for the local OClO density	m
PCD summary	dl

The vertical profiles of the local density of O3, NO2, NO3, O2, H2O and air are the main outputs of the vertical inversion of line densities, assuming local spherical symmetry. OClO is actually not retrieved with the operational processor; the corresponding local density and standard deviation are set to 0.

In the current operational IPF version (IPF5.00), the vertical inversion on air is not activated, and the local density values, the standard deviation and the vertical resolution for this species are set to 0 in the products (as well as the terms related to air in the covariance matrix for local densities after the vertical inversion).

The standard deviation DSR stores the error estimates for the different species. Errors are estimated throughout the processing chain and are propagated along the chain to the final data products. It is assumed that the error statistics follow a normal Gaussian distribution. Values are expressed in % of the local density and correspond to 1σ. The maximum value of the error estimate is set to 6553.5%.

The PCD summary contains flags dedicated to the validity of the outputs of the vertical inversion i.e. the retrieval of the local density profiles. After vertical inversion, local densities are checked for flag setting. There is one flag per acquisition and per species: parameter PCDV(i,j), where index j denotes the acquisition number, and index i denotes the species among the following species list in this order: O3, NO2, NO3, air, O2, H2O, OClO.

Tangent line density of species

The tangent line density of species MDS is detailed in Table 2.21. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.21: Tangent line density of species MDS in the Level 2 temperature and atmospheric constituents product.

Tangent line density of species MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Tangent line density for O_3	cm-2
Standard deviation for O_3 tangent line density	(1.e-1)%
Tangent line density for NO_2	cm-2

Tangent line density of species MDS	Unit
Standard deviation for NO_2 tangent line density	(1.e-1)%
Tangent line density for NO_3	cm-2
Standard deviation for NO_3 tangent line density	(1.e-1)%
Tangent line density for air	cm-2
Standard deviation for air tangent line density	(1.e-1)%
Tangent line density for O_2	cm-2
Standard deviation for O_2 tangent line density	(1.e-1)%
Tangent line density for H_2O	cm-2
Standard deviation for H_2O tangent line density	(1.e-1)%
Tangent line density for OClO	cm-2
Standard deviation for OClO tangent line density	(1.e-1)%
Number of iterations in the spectral inversion	dl
PCD summary	dl

Aerosols

The aerosols MDS is detailed in Table 2.22. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.22: Aerosols MDS in the Level 2 temperature and atmospheric constituents product.

Aerosols MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Extinction coefficient at $\lambda = \lambda_{ref}$	km-1
Standard deviation of the extinction coefficient at $\lambda = \lambda_{ref}$	(1.e-1)%
Spectral parameters of the extinction coefficients	km-1, nm-1.km-1, nm-2.km-1, …
Standard deviation of the spectral parameters of the extinction coefficients	(1.e-1)%
Tangent integrated extinction profile at $\lambda = \lambda_{ref}$	dl
Standard deviation of the tangent integrated extinction profile at $\lambda = \lambda_{ref}$	(1.e-1)%
Spectral parameters of tangent integrated extinction profile	cm-2, cm-2.nm-1, cm-2.nm-2, …

Aerosols MDS	Unit
Standard deviation of the spectral parameters of the tangent integrated extinction profile	(1.e-1)%
PCD summary	dl

The wavelength dependence of aerosol extinction may vary, even over one occultation. A polynomial expression is used to describe this wavelength dependence of the aerosol extinction; for a polynomial in degree n:

$$\beta(z,\lambda) = d_0(z) + d_1(z)(\lambda - \lambda_{ref}) + d_2(z)(\lambda - \lambda_{ref})^2 + ... + d_n(z)(\lambda - \lambda_{ref})^n$$

For each measured transmission, it is calculated:

- the extinction coefficient at the reference wavelength λ_{ref}, corresponding to d0, given in km-1
- the other spectral parameters corresponding to the coefficients d1(z) to dn(z) in the polynomial expression, given in nm-1.km-1, …, nm-n.km-1

The reference wavelength value is stored in the SPH of the product ("Reference wavelength used for the ray tracing"); it is equal to 500nm. It is also given in the SPH of the residual extinction product and in the Occultation data GADS of the Level 1b product.

The extinction coefficient at $\lambda=\lambda_{ref}$ is stored twice in the MDS. It is given in the dedicated MDSR "Extinction coefficient at $\lambda=\lambda_{ref}$" and as the first spectral parameter of the MDS "Spectral parameters of the extinction coefficients". In the current operational processor (IPF 5.00), a polynomial in degree 2 is implemented, so that two other coefficients are given in the MDS "Spectral parameters of the extinction coefficients": $d_1(z)$ and $d_2(z)$ in $nm^{-1}.km^{-1}$ and in $nm^{-2}.km^{-1}$ respectively.

The wavelength dependence of the aerosol optical thickness may be described as:

$$\tau(\lambda) = \sigma_{ref}(r_0 + r_1(\lambda - \lambda_{ref}) + r_2(\lambda - \lambda_{ref})^2 + ... + r_n(\lambda - \lambda_{ref})^n)$$

The MDS *Tangent integration extinction profile at* $\lambda= \lambda_{ref}^n$ stores the value τ calculated at $\lambda= \lambda_{ref}$ (dimensionless). The MDS "Spectral parameters of tangent integrated extinction profile" stores the coefficients r_0 to r_n, retrieved by the spectral inversion processing: r_0 is the integrated retrieved density column of aerosols given in cm^{-2}; the other parameters r_1 to r_n are given in $cm^{-2}.nm^{-1}$, … $cm^{-2}.nm^{-n}$. In the case of a polynomial in degree 2 as in the current operational processor (IPF 5.00), three coefficients are thus stored: r_0, r_1 and r_2.

The standard deviation DSR stores the error estimates. Values are expressed in % and correspond to 1σ. An empirical error estimate has been added after inversion to the aerosol extinction coefficient to account for the effects of turbulence (incomplete scintillation correction).

The PCD summary provides the spectral and vertical PCD (first and seventh values) of the extinction coefficient at the reference wavelength, the other values are set to 0.

High Resolution Temperature Product

The High Resolution Temperature MDS is detailed in **Table** 2.23. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.23: High Resolution Temperature MDS in the Level 2 temperature and constituents product.

High Resolution Temperature MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Tangent altitude including fluctuations	m
High resolution temperature profile	(1.e-2)K
High resolution density profile	cm-3
Error bar of the high resolution temperature profile	(1.e-1)%
Error bar of the high resolution density profile	(1.e-1)%

High resolution vertical profiles of temperature and of local density are computed from the analysis of the Fast Photometers signals.

They are derived from the time delay between the peaks of red and blue photometers, if this time delay is significant enough to be analysed.

The maximum error bar for the High Resolution profiles is set to 6500%.

There is no high resolution temperature profile computed in bright limb condition. The output frequency of the HRTP is 40Hz. This corresponds to 20 values for each processed measurement during the Level 2 processing (frequency 2Hz).

Geolocation and Atmospheric profile

Geolocation data include the position of the spacecraft and of the tangent point, and the tangent point pressure and temperature from the external model (ECMWF completed by MSIS90 at pressure levels lower than 1hPa). All the geolocation information is provided for the reference wavelength used for the ray tracing (equal to 500 nm) and stored in the SPH of the product. For example the localisation of the ray nodes and of the tangent point node are provided for this wavelength although at one given time inside the atmosphere, and due to chromatic refraction effects, each wavelength is looking at a different altitude.

The geolocation ADS is detailed in Table 2.24. It is made of several ADSR, one for each processed measurement during the Level 2 processing.

Table 2.24: Geolocation ADS in the Level 2 temperature and atmospheric constituents product; (*) variables are provided at the beginning and during the measurements, generally at half measurement (the temporal shift is given by the time shift for ray tracing/geolocation stored in the Summary Quality GADS).

Geolocation ADS	Unit
Start time of the Data Set Record	Mjd
Attachment flag	Dl
Latitude of the spacecraft (*)	(1.e-6) deg
Longitude of the spacecraft (*)	(1.e-6) deg
Altitude of the spacecraft (*)	(1.e-2) m
Latitude of the tangent point (*)	(1.e-6) deg
Longitude of the tangent point (*)	(1.e-6) deg
Altitude of the tangent point (*)	(1.e-2) m
Error on the latitude of the tangent point (*)	(1.e-7) deg
Error on the longitude of the tangent point (*)	(1.e-7) deg
Error on the altitude of the tangent point (*)	(1.e-3) m
Instrument pointing direction (azimuth) (*)	(1.e-6) deg
Instrument pointing direction (elevation) (*)	(1.e-6) deg
Tangent point atmospheric pressure (from external model)	Pa
Tangent point temperature (from external model)	K
Tangent point density (from external model)	cm-3
Local air density from GOMOS atmospheric profile	cm-3
Standard deviation for the local air density	(1.e-1)%
Local temperature	K
Standard deviation for the local temperature	(1.e-1)%
PCD summary	Dl
Sun zenith angle at the spacecraft (*)	Deg
Sun zenith angle at the tangent point (*)	Deg
Sun azimuth angle at the tangent point (*)	Deg

The local air density from GOMOS atmospheric profile and the local temperature are not provided in the geolocation ADS products with the current operational version of the processor (IPF 5.00). They are set to 0 and the corresponding standard deviations are set to the maximum value 6553.5.

Accuracy estimation

The accuracy estimation ADS is detailed in Table 2.25. It is made of several ADSR, one for each processed measurement during the Level 2 processing.

Table 2.25: Accuracy estimation ADS in the Level 2 temperature and atmospheric constituents product.

Accuracy estimation ADS	Unit
Start time of the Data Set Record	mjd
Attachment flag	dl
χ^2 final value	dl
Scale factor for the elements of the covariance matrix (spectral inversion)	dl
Covariance matrix for local densities after spectral inversion	cm-4
Scale factor for the elements of the covariance matrix (vertical inversion)	dl
Covariance matrix for local densities after vertical inversion	cm-6

For the spectral inversion, the χ^2 (final best fit) is given.

The covariance matrix for the spectral inversion provides information on the influence of each gas on the others. It is a 12 x 12 matrix whose terms are in the following order: O_3, NO_2, NO_3, air, OClO, aerosols (a maximum of 6 parameters) and a spare gas. This matrix is symmetrical and only the relevant part (78 terms) is written in the product.

The covariance matrix for the vertical inversion provides information on the influence of each altitude on the other. It is symmetrical. 12 species are given in the following order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO, aerosols and 4 spare gases. Only the diagonal terms and 6 off-diagonal terms are given in the product, as a 12 x 7 matrix for each acquisition. The scale factor for the elements of the covariance matrix DS gives the power of 10 to be applied to the covariance matrix elements read in the product in order to interpret them (same value for all species):

$$V = V_p \times 10^{fact}$$

where:

V: the covariance matrix element calculated in the Level 2 processing

V_p: the scaled covariance matrix element read in the product

fact: the scale factor read in the product.

More details on the storage of the elements of the covariance matrix are given in Appendix A of this document.

2.2.3.3.2 Residual extinction products (GOM_EXT_2P)

The residual extinction products are used for instrument calibration and validation purposes. They also contain information needed to build a high resolution aerosol product.

The residual extinction products are generated by the GOMOS Level 2 processing. They contain the spectral transmission corrected for scintillation and dilution effects.

Each residual extinction product contains the data corresponding to a whole occultation.

The structure of the residual extinction products is detailed in Table 2.26.

Table 2.26: Content of the residual extinction products GOM_EXT_2P; list of GADS, MDS and ADS.

Field	Data set	Data set name
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	Summary quality	EXT_SUMMARY_QUALITY
GADS	Nominal wavelength assignment	EXT_NOM_WAV_ASSIGNMENT
MDS	Residual extinction MDS	EXT_MDS
ADS	Residual extinction ADS	EXT_ADS

Summary quality GADS

This GADS includes the observation illumination condition "PCD_ILLUM" (see table 3.2 in section 3.3.2.1), as well as other PCD at occultation level similar to the ones of the Level 1b transmission product. It also provides the "verticality" of the occultation (in °). Values of the verticality close to 0 correspond to occultations close to the vertical direction, while high values of the "verticality" correspond to oblique occultations.

Residual extinction MDS

The residual extinction MDS is detailed in Table 2.27. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.27: Residual extinction MDS in the residual extinction product.

Residual extinction MDS	Unit
Start time of the Data Set Record	mjd

Residual extinction MDS	Unit
Attachment flag	-
Transmission corrected for scintillation and dilution effects	dl
Covariance function of the transmission after scintillation and dilution corrections	dl
Transmission model function	dl
Flags for transmission model	dl

They contain the spectral transmission corrected for scintillation and dilution effects, along with the result of a forward model of the transmission with the "best fit" values of the parameters. This may allow to verify that the difference T_{mes} - T_{mod} is really randomly distributed in wavelength (non-random features may contain some information). These products could be used to compare the outputs of GOMOS processing with the outputs of other off-line processing.

2.2.3.3.3 Meteo products (GOM_RR__2P)

These products contain selected vertical profiles processed in NRT. They are distributed mainly to meteo users. The primary application is NRT global atmospheric modelling and monitoring.

The processing is identical to the standard processing, but the atmospheric model used is based on meteorological forecast for pressure levels up to 1 hPa (if available) and MSIS90 model above. If the meteorological forecast is not available, data from the MSIS90 model are used from the bottom of the atmosphere. For the processing of off-line products, the atmospheric model is based on the meteorological analysis up to 1 hPa, and on MSIS90 above. Thus, the available orbit data may be less precise than for off-line processing, and some external data may be sub-optimal. But in all cases, the most accurate orbit at the time of processing is used.

Table 2.28 indicates the source of external atmospheric data depending on the end product and on the availability of ECMWF data.

Table 2.28: Possible sources of external atmospheric data for the processing of NRT and off-line products.

End product	Meteorological data			Climatological model
NRT	ECMWF 24h forecast if available	if not available: most recent ECMWF data	if none available: MSIS90	MSIS90
Off-line processing	ECMWF analysis if available	if not available: most recent ECMWF data	if none available: MSIS90	MSIS90

Each meteo product contains the extracted profiles corresponding to a whole occultation, with the structure detailed in Table 2.29.

Table 2.29: Content of the meteo products GOM_RR__2P; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
MDS	Local species density	RR_LOCAL_SPECIES_DENSITY
ADS	Geolocation	RR_GEOLOCATION
MDS	High Resolution Temperature	RR_HIGH_RES_TEMPERATURE

Local species density

The local species density MDS is detailed in Table 2.30. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.30: Local species density MDS in the meteo product.

Local species density MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Local O_3 density	cm-3
Standard deviation for the local O_3 density	(1.e-1)%
Vertical resolution for the local O_3 density	m
Local NO_2 density	cm-3
Standard deviation for the local NO_2 density	(1.e-1)%
Vertical resolution for the local NO_2 density	m
Local NO_3 density	cm-3
Standard deviation for the local NO_3 density	(1.e-1)%
Vertical resolution for the local NO_3 density	m
Local air density	cm-3
Standard deviation for the local air density	(1.e-1)%
Vertical resolution for the local air density	m
Local O_2 density	cm-3
Standard deviation for the local O_2 density	(1.e-1)%
Vertical resolution for the local O_2 density	m
Local H_2O density	cm-3
Standard deviation for the local H_2O density	(1.e-1)%
Vertical resolution for the local H_2O density	m
Local OClO density	cm-3
Standard deviation for the local OClO density	(1.e-1)%
Vertical resolution for the local OClO density	m
PCD summary	dl

OClO is actually not retrieved with the operational processor; the corresponding local density and standard deviation are set to 0.

In the current operational IPF version (IPF5.00), the vertical inversion on air is not activated, and the local density values, the standard deviation and the vertical resolution for this species are set to 0 in the products (as well as the terms related to air in the covariance matrix for local densities after the vertical inversion).

The standard deviation stores the error estimates for the different species. Errors are estimated throughout the processing chain and are propagated along the chain to the final data products. It is assumed that the error statistics follow a normal Gaussian distribution. Values are expressed in % of the local density and correspond to 1σ. The maximum value of the error estimate is set to 6553.5%.

The PCD summary contains flags dedicated to the validity of the outputs of the vertical inversion i.e. the retrieval of the local density profiles. After vertical inversion, local densities are checked for flag setting. There is one flag per acquisition and per species: parameter PCDV(i,j), where index j denotes the acquisition number, and index i denotes the species among the following species list in this order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO.

Geolocation

The geolocation ADS is detailed in Table 2.31. It is made of several MDSR, one for each processed measurement during the Level 2 processing. All the geolocation information is provided for the reference wavelength used for the ray tracing (equal to 500 nm). For example the localisation of the ray nodes and of the tangent point node are provided for this wavelength although at one given time inside the atmosphere, and due to chromatic refraction effects, each wavelength is looking at a different altitude.

Table 2.31: Geolocation ADS in the meteo product; (*) variables are provided at the beginning and during the measurements, generally at half measurement.

Geolocation ADS	Unit
Start time of the Data Set Record	mjd
Attachment flag	dl
Latitude of the spacecraft (*)	(1.e-6) deg
Longitude of the spacecraft (*)	(1.e-6) deg
Altitude of the spacecraft (*)	(1.e-2) m
Latitude of the tangent point (*)	(1.e-6) deg
Longitude of the tangent point (*)	(1.e-6) deg
Altitude of the tangent point (*)	(1.e-2) m
Error on the latitude of the tangent point (*)	(1.e-7) deg
Error on the longitude of the tangent point (*)	(1.e-7) deg
Error on the altitude of the tangent point (*)	(1.e-3) m
Instrument pointing direction (azimuth) (*)	(1.e-6) deg
Instrument pointing direction (elevation) (*)	(1.e-6) deg
Tangent point atmospheric pressure (from external model)	Pa

Geolocation ADS	Unit
Tangent point temperature (from external model)	K
Tangent point density (from external model)	cm-3
Local air density from GOMOS atmospheric profile	cm-3
Standard deviation for the local air density	(1.e-1)%
Local temperature	K
Standard deviation for the local temperature	(1.e-1)%
PCD summary	dl
Sun zenith angle at the spacecraft (*)	deg
Sun zenith angle at the tangent point (*)	deg
Sun azimuth angle at the tangent point (*)	deg

The local air density from GOMOS atmospheric profile and the local temperature are not provided in the geolocation ADS products with the current operational version of the processor (IPF 5.00). They are set to 0 and the corresponding standard deviations are set to the maximum value 6553.5.

The illumination condition is not provided in the meteo product; however, it may be determined from the altitude of the tangent point, the sun zenith angle at the spacecraft, and the sun zenith angle at the tangent point stored in the geolocation ADS, by applying requirements for the different illumination conditions as defined in Table 3.2 in section 3.3.2.1.

High Resolution Temperature

The High Resolution Temperature is detailed in Table 2.32. It is made of several MDSR, one for each processed measurement during the Level 2 processing.

Table 2.32: High Resolution Temperature MDS in the meteo product.

High Resolution Temperature MDS	Unit
Start time of the Data Set Record	mjd
Data Quality Indicator	-
Tangent altitude including fluctuations	m
High resolution temperature profile	(1.e-2)K
High resolution density profile	cm-3
Error bar of the high resolution temperature profile	(1.e-1)%
Error bar of the high resolution density profile	(1.e-1)%

The maximum error bar for the High Resolution profiles is set to 6500%.

There is no high resolution temperature profile computed in bright limb condition.

The output frequency of the HRTP is 40Hz. This corresponds to 20 values for each processed measurement during the Level 2 processing (frequency 2Hz).

2.2.3.4 Auxiliary products

2.2.3.4.1 Calibration database (GOM_CAL_AX)

The content of this auxiliary product is given in Table 2.33.

Table 2.33: Content of the calibration database auxiliary product GOM_CAL_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	General	CAL_GENERAL
GADS	Bad pixel map	CAL_BAD_PIXEL
GADS	Non-linearity functions	CAL_NON_LINEARITY
GADS	Fast photometer dark charge maps	CAL_FP_DARK_CHARGE
GADS	Fast photometer non-uniformity maps	CAL_FP_PRNU
GADS	Fast photometer straylight	CAL_SUN_STRAYLIGHT
GADS	Instrument noise	CAL_INSTRUMENT_NOISE
MDS	Spectrometer dark charge	CAL_SP_DARK_CHARGE
MDS	Spectrometer non-uniformity maps	CAL_SP_PRNU
MDS	External sun straylight maps	CAL_SUN_STRAYLIGHT
MDS	External Earth straylight maps	CAL_EARTH_STRAYLIGHT

2.2.3.4.2 Star catalogue (GOM_CAT_AX)

The content of this auxiliary product is given in Table 2.34.

Table 2.34: Content of the star catalogue auxiliary product GOM_CAT_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	General	CAT_GENERAL
GADS	Annotation	CAT_ANNOTATION
MDS	Star catalogue file	CAT_STAR_INFORMATION

2.2.3.4.3 Cross section database (GOM_CRS_AX)

The content of this auxiliary product is given in Table 2.35.

Table 2.35: Content of the cross-section database product GOM_CRS_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	O_3 cross-sections (SPA)	CRS_O3_CROSS_SECT_SPA_GADS
GADS	O_3 cross-sections (SPB)	CRS_O3_CROSS_SECT_SPB_GADS
GADS	NO_2 cross-sections	CRS_NO2_CROSS_SECT_GADS
GADS	NO_3 cross-sections	CRS_NO3_CROSS_SECT_GADS
GADS	OClO cross-sections	CRS_OCLO_CROSS_SECT_GADS
GADS	O_2 cross-sections	CRS_O2_CROSS_SECT_GADS
GADS	H_2O cross-sections	CRS_H2O_CROSS_SECT_GADS
MDS	O_3 cross-sections (SPA)	CRS_O3_CROSS_SECT_SPA_MDS_
MDS	O_3 cross-sections (SPB)	CRS_O3_CROSS_SECT_SPB_MDS
MDS	NO_2 cross-sections	CRS_NO2_CROSS_SECT_MDS
MDS	NO_3 cross-sections	CRS_NO3_CROSS_SECT_MDS
MDS	OClO cross-sections	CRS_OCLO_CROSS_SECT_MDS
MDS	O_2 cross-sections	CRS_O2_CROSS_SECT_MDS
MDS	H_2O cross-sections	CRS_H2O_CROSS_SECT_MDS

2.2.3.4.4 Instrument physical characteristics data (GOM_INS_AX)

The content of this auxiliary product is given in Table 2.36.

Table 2.36: Content of the instrumental physical characteristics data product GOM_INS_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	General	INS_GENERAL
GADS	Static spectral PSF GADS for spectrometer A	INS_SPA_SPECTRAL_PSF
GADS	Static spectral PSF GADS for spectrometer B	INS_SPB_SPECTRAL_PSF
GADS	Static spatial PSF GADS for spectrometer A	INS_SPA_SPATIAL_PSF
GADS	Static spatial PSF GADS for spectrometer B	INS_SPB_SPATIAL_PSF

2.2.3.4.5 Level 1b processing configuration database (GOM_PR1_AX)

The content of this auxiliary product is given in Table 2.37.

Table 2.37: Content of the Level 1b processing configuration database auxiliary product GOM_PR1_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	General	PR1_GENERAL
GADS	Atmosphere	PR1_ATMOSPHERE

2.2.3.4.6 Level 2 processing configuration database (GOM_PR2_AX)

The content of this auxiliary product is given in Table 2.38

Table 2.38: Content of the Level 2 processing configuration database auxiliary product GOM_PR2_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	Atmosphere	PR2_ATMOSPHERE
GADS	Parameters	PR2_GENERAL
GADS	Convergence criteria	PR2_CONV_CRITERIA_GADS
MDS	Convergence criteria	PR2_CONV_CRITERIA_MDS
MDS	Reference line densities	PR2_REF_LINE_DENSITIES
MDS	Group of species (initialisation phase)	PR2_GROUP_OF_SPECIES_INIT
MDS	Group of species	PR2_GROUP_OF_SPECIES
MDS	Spectral windows (initialisation phase)	PR2_SPECTRAL_WINDOWS_INIT
MDS	Spectral windows	PR2_SPECTRAL_WINDOWS

2.2.3.4.7 Stellar Spectra databank (GOM_STS_AX)

The content of this auxiliary product is given in Table 2.39.

Table 2.39: Content of the stellar spectra auxiliary product GOM_STS_AX; list of GADS, MDS and ADS.

Field		
MPH		
SPH		
Field	**Data set**	**Data set name**
GADS	General	STS_GENERAL
GADS	Annotation	STS_ANNOTATION
GADS	Wavelength assignment	STS_WAV_ASSIGNMENT
MDS	Star information	STS_STAR_INFORMATION
MDS	Star spectrum	STS_STAR_SPECTRUM

3 How to?

3.1 Getting the data

GOMOS higher-level products are routinely disseminated to the users.

GOMOS Level1b products are available on request to the EO Helpdesk (e-mail address: EOHelp@esa.int).

GOMOS Level2 products (atmospheric and constituent profiles and near-real time products) are available for the whole mission on specific ftp servers as detailed below (for information on passwords, please contact the EO Helpdesk: EOHelp@esa.int).

Consolidated level2 products GOM_NL__2P:

The consolidated products GOM_NL__2P for dates after 23 July 2006 are available at D-PAC ftp server:

ftp://gomo2usr@ftp-ops.de.envisat.esa.int.

They are made available about three weeks after the measurement time (one tar file of GOMOS products per day).

Reprocessed level2 products GOM_NL__2P:

The reprocessed products GOM_NL__2P for dates between 26 August 2002 and 4 July 2006 are available also at D-PAC ftp server: ftp://gomo2usr@ftp-ops.de.envisat.esa.int.

Near Real Time level2 products GOM_RR__2P:

The near-real time products may be downloaded from the servers:

ftp://gomosusr@oa-es.eo.esa.int (for ESRIN data)

and ftp://gomosusr@oa-ks.eo.esa.int (for Kiruna data).

They are made available usually about three hours after the measurement time and for about 7 days (they are then stored in archives).

All Level2 data (reprocessed, NRT and consolidated) are generated with the same version of GOMOS processor (IPF 5.00, made operational in August 2006). Some datasets reprocessed with a previous version of the prototype (see Appendix B of this document for details) are also available (measurements for 2003 and for the period between March and December 2004) at D-PAC ftp server.

3.2 Data availability

There are two main periods of time during which instrument failures prevented operational measurements. Between May 2003 and July 2003, due to a steering system problem and the consequent progressive reduction of the instrument Field of View, the measurement efficiency was lower. The measurement frequency resumed after the switch to the redundant electronics chain. A second steering system problem (failure of the Elevation voice-coil) occurred in early January 2005 and prevented operational measurements until July 2005, when a new mission scenario with a reduced azimuth range was implemented. This new scenario affects the effective global coverage of the measurements (see section 0 of this document).

3.3 Data selection

3.3.1 Illumination conditions

Information on the illumination condition is provided for each occultation, basing on the sun zenith and azimuth angles at both instrument and tangent point locations. Those angles are computed by the geolocation process, in the Level1b chain. The illumination condition is then determined according to the requirements given in Table 3.1.

Table 3.1: Requirements on the occultation geometry for the definition of illumination condition; SZA stands for solar zenith angle

Illumination condition	Flag index value ("PCD_ILLUM")	Requirements
full dark	0	not in bright limb nor twilight nor straylight conditions
Bright	1	SZA at tangent point < 97° for at least one measurement with ALT at tangent point < 50 km
pure twilight	2	not in bright limb and SZA at tangent point < 110° for at least one measurement with ALT at tangent point < 100 km
Straylight	3	not in bright limb and SZA of ENVISAT < 120° for at least one measurement
twilight+straylight	4	not in bright limb and both conditions for twilight and for stray light are verified.

The illumination condition is stored in the flag index "PCD_ILLUM" in the Level1b transmission and limb products and in the Level2 temperature and atmospheric constituent products of each occultation. It is not stored in the Level2 meteo product.

However, it may be determined by using the solar zenith angle of the tangent point, the solar zenith angle of the satellite, and the altitude of the tangent point given in the geolocation ADS of the Level2 meteo product, and by applying the requirements detailed in Table 3.1.

The full dark measurements ("PCD_ILLUM" = 0) may be used with no restriction.

Occultations measured in bright limb illumination conditions ("PCD_ILLUM" = 1) are of quite bad quality. The bright limb is an extended source competing with the stellar signal and the accuracy of these measurements is strongly degraded because of their large noise.

Occultations measured in twilight illumination conditions ("PCD_ILLUM" = 2) are in a lesser extent of quite bad quality. They correspond to measurements made when the Sun is just below the horizon, and they are contaminated by solar light.

Occultations are measured in straylight illumination conditions ("PCD_ILLUM" = 3) if the instrument optics are illuminated by light (solar light scattered by the grating or by ENVISAT hardware, or coming from the sun-illuminated limb or nadir). Straylight measurements are actually considered as of good quality.

Some measurements may be characterized as in both straylight and twilight illumination condition ("PCD_ILLUM" = 4). It is not recommended to use them because of the solar light contamination.

3.3.2 Star properties

Three categories of star brightness are usually defined from the star visual magnitude. A star with a visual magnitude lower than 0.8 is considered as a bright star; a star with a visual magnitude higher than 2 is considered as a dim star; a star with a visual magnitude higher than 0.8 and lower than 2.0 is considered as of medium brightness. Similarly, a star is considered as cold if its effective temperature is lower than 6000 K, as hot if it is higher than 10000 K and as of medium temperature if it ranges between 6000 K and 10000K.

It is recommended to use full dark and straylight occultations only from a subset of stars, which brightness and effective temperature fill criteria specific to each species, and depending on the altitude range.

Vertical profiles of O_3 local density:

The retrieval from the occultation of hot stars is of good quality at all altitude levels. Profiles retrieved from the occultation of cold stars (star temperature lower than 6000 K) should not be used in the mesosphere (altitude levels higher than 40 km).

Vertical profiles of NO_2 local density:

Profiles retrieved from the occultation of bright stars may be used in the NO_2 validity range (between 20 km and 50 km; see table 1.1 in section 1.4.3.3). Profiles retrieved from the occultation of weaker stars should not be used (stars of visual magnitude higher than 2).

Vertical profiles of NO3 local density:

Profiles retrieved from the occultation of bright stars may be used in the NO_3 validity range (between 25 km and 45 km; see table 1.1 in section 1.4.3.3). Profiles retrieved from the occultation of weaker stars should not be used (stars of visual magnitude higher than 2).

Vertical profiles of H_2O local density:

Profiles of acceptable quality are provided only from the 9 brightest stars in the near-IR (cold bright stars or very bright stars). Those stars are of star ID: 1, 2, 3, 4, 13, 14, 16, 26, 63.

The impact of the star characteristics on the quality of the vertical profiles of O_3, NO_2, NO_3, H_2O is summarised in Table 3.2.

Table 3.2: Impact of the star characteristics on the quality of vertical profiles of local density of O_3, NO_2, NO_3, and H_2O; (*) in the validity altitude range: 20 km-50 km for NO_2 and 25 km-45 km for NO_3 (see also Table 1.1 of 1.4.3.3). A star is considered as cold if its effective temperature is lower than 6000 K; a star is considered as dim if its visual magnitude is higher than 2. It is supposed here that only occultations measured in full dark and in straylight illumination conditions are considered.

Species	Temperature category		Brightness category	
	cold stars	hot stars	dim stars	bright stars
O_3	valid only below 40 km	valid profiles	noisy profiles in the lower stratosphere	valid profiles
NO_2	valid profiles (*)	valid profiles (*)	not to be used	valid profiles (*)
NO_3	valid profiles (*)	valid profiles (*)	not to be used	valid profiles (*)
H_2O	only from stars of ID: 1, 2, 3, 4, 13, 14, 16, 26, 63			

3.3.3 Obliquity

Occultations are considered as vertical or close to vertical if their "verticality" is lower than 10°. This information is provided in the Summary Quality GADS of the Level2 products (temperature and atmospheric constituents products and residual extinction products). Because of the less reliable scintillation correction for oblique occultations at altitudes between 20 km and 40 km (see section 1.4.3.2.1), vertical profiles retrieved from these oblique occultations should be considered cautiously at these altitudes.

As detailed in section 1.4.3.2.1, the validity altitude range of HRTP profiles is larger for vertical occultations (the upper limit of this range depending on the scintillation strength); and the best accuracy is reached for vertical occultations (see Table 3.3).

HRTP data outside the validity altitude range (18 km-35 km for vertical occultations) should be considered cautiously.

Table 3.3: HRTP validity altitude range for vertical occultations and for oblique occultations and altitude range for best accuracy.

	Vertical occultations	Oblique occultations
validity altitude range	18 km-35 km	20 km-30 km
accuracy	1-2K in 18 km-30 km	lower accuracy

3.3.4 PCD summary in the Level2 products

Flag values are provided as Product Confidence Data (PCD). These PCD provide indications on the configuration and the performance of the processing at several stages of the retrieval. The meaning of the possible PCD values for the different datasets of the products is detailed in Appendix A.

In the case of the tangent line density MDS and of the local density MDS in the Level2 products, these flags give information about the validity of the outputs of the spectral inversion, the vertical inversion and the aerosol processing. For these data sets, only the non-flagged values (for which PCD is equal to 0) should be used.

Tangent line density

The PCD summary provides the PCD of tangent line densities for the following species in this order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO.

Local density

The PCD summary provides the PCD of local densities for the following species in this order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO.

Aerosol products

The PCD summary provides the spectral and vertical PCD (first and seventh values) of the extinction coefficient at the reference wavelength (500 nm), the other values are set to 0.

3.4 Access tools

We present here 3 different tools allowing to read and to handle the GOMOS products.

3.4.1 The BASIC Envisat Atmospheric Toolbox (BEAT)

The Basic Envisat Atmospheric Toolbox project (BEAT) provides a set of tools for ingesting, processing, analysing and plotting data from GOMOS, MIPAS and SCIAMACHY products (and from other atmospheric instruments). It consists of several software packages, with the main packages being BEAT and VISAN. The BEAT package contains a set of libraries, command line tools, and interfaces to IDL, MATLAB, Fortran, and Python that allow to access data, to select product files according to time and/or geolocation, to select co-located data, to import and export data to and from ASCII, binary, HDF-4, HDF-EOS, HDF5, HDF5-EOS, to perform operations on spectral and spatial data (interpolation, resampling, gridding, binning, …). Command line tools (namely beatcheck, beatdump, beatfind) are also provided, for checking, viewing or exporting the content of a product, or searching for specific products within a set of files. The VISAN package contains an application that can be used to visualise and analyse the data that have been retrieved using the BEAT interface.

Its platform-independent design makes it portable on major operating systems (e.g. SunOS, Solaris, Linux, MS Windows and MacOS). It is provided as Open Source Software, under the terms and conditions of the GNU General Public License. The most recent version of BEAT (4.2.0) was released in February 2007.

More information is available from the ENVISAT web site at
http://envisat.esa.int/beat
and from the Science & Technology web site:
http://www.science-and-technology.nl/beat/ and
http://www.science-and-technology.nl/beat/documentation/.

The BEAT modules can be separated into two chief layers. The first layer, called BEAT-I, consists of all modules that deal with direct access to product data. With the BEAT-I software it is possible to access each and every piece of data inside a product. The BEAT-I interface provides functions to dynamically retrieve structural information of a product, but the Data Dictionary documentation

(at: http://www.science-and-technology.nl/beat/documentation/datadict/)

also provides an overview of the structure descriptions for the BEAT supported products. The second layer, called BEAT-II, provides a common data structure for each of the basic classes of data: spectral readout data (for Level 1b products), vertical profile and ground-pixel data (for Level 2 products) and world map data (for Level 3 and Level 4 products). BEAT-II provides a single ingestion function that allows to easily extract data from a product file into one of the basic data classes. Unlike BEAT-I, it is not possible with BEAT-II to access all information from a product file. However, it provides other powerful functionalities such as the ingestion of multiple files at once and the ingestion of only data that match certain time, geolocation, or wavelength criteria. The overview of products supported by BEAT-II is given at:

http://www.science-and-technology.nl/beat/documentation/beatl2-data/

For each product type there is a description of the kind of data that will be returned from an ingestion. Each ingestion will return a record with data, but depending on the product file and the filter options the type of the record may differ.

In the description of the product content (see 2.2.3 of this document) and in the IODD reference document, the unit and the possible conversion factor used to store the Data Sets are detailed. It is important to note that BEAT tools handle those conversion factors and thus return "decoded" data set values. For instance, all standard deviation data set records are stored in (1.e-1)% in the products. The data values returned after ingestion by BEAT tools are given in %.

A tutorial package is made available on the BEAT web site. Examples are also provided with the downloadable package. The IDL examples reported below illustrate how to get the MPH, SPH, and DSD arrays as obtained from the headers of a given product file (**Table** 3.4) and how to plot the transmission data versus the nominal wavelength assignment (Table 3.5) stored in a Level 1b transmission product. In Table 3.6, we provide an IDL example of the use of BEAT-II tools, illustrating how to plot the vertical profile of O_3 local density stored in a Level 2 T atmospheric and constituent product. We also provide the corresponding Matlab example for extracting and plotting the vertical profile of O_3 local density (Table 3.7).

Table 3.4: Example of use of the BEAT-I tools in IDL: getting the MPH, SPH and DSD arrays.

```
PRO show_headers, filename

  ; open the product file. If an error occurred, report it.
  pf  = beat_open(filename)
  IF beat_is_error(pf) THEN BEGIN
    print, 'Error while opening the product: ', pf.message
    RETURN
  ENDIF

  ; show the MPH and SPH.
  help, beat_fetch(pf, 'MPH'), /struct
  help, beat_fetch(pf, 'SPH'), /struct

  ; get the array of DSDs, and show info of every DSD.
  dsdarray = beat_fetch(pf, 'DSD')
  FOR i=0,n_elements(dsdarray)-1 DO BEGIN
    help, beat_fetch(dsdarray[i]), /struct
  ENDFOR

  ; close the product file.
  dummy = beat_close(pf)

END
```

Table 3.5: Example of use of the BEAT-I tools in IDL: extraction of the transmission data and the nominal wavelength assignment.

```
PRO gomos_level_1b, filename

  device, decomposed=0
```

```
  loadct, 27
  tvlct, [0],[0],[0], 255  ; map color #255 to black

  ; open the product file. If an error occurred, report it.
  pf = beat_open(filename)
  IF beat_is_error(pf) THEN BEGIN
    print, 'Error while opening the product: ', pf.message
    RETURN
  ENDIF

  bright_limb = beat_fetch(pf, 'sph', 'bright_limb')
  star_mag    = beat_fetch(pf, 'sph', 'star_mag')

  ; fetch the data: star name, pixel-to-wavelength map, TRANSMISSION
MDS.
  starname   = beat_fetch(pf, 'sph', 'star')
  lambda_map = beat_fetch(pf, 'tra_nom_wav_assignment', 0, 'nom_wl')
  trans_mds  = beat_fetch(pf, 'tra_transmission')

  ; determine start-time. This is useful for providing display of
  ; time since start-of-occultation.
  Tstart = beat_fetch(trans_mds[0], 'dsr_time')

  ; traverse the TRANSMISSION records.
  FOR i=0, n_elements(trans_mds)-1 DO BEGIN

    ; fetch time and spectrum contained in this MDSR.
    T        = beat_fetch(trans_mds[i], 'dsr_time')
    spectrum = beat_fetch(trans_mds[i], 'trans_spectra')

    ; plot the spectrum and some annotation info.
    plot, lambda_map, spectrum, xstyle = 1, ystyle = 1, yrange = [-
0.2, 1.2],                $
          title  = STRING(format='(%"star: %s magnitude: %6.3f time:
%s (%6.3f s)")', $
                 starname, star_mag, beat_time_to_string(T), (T-
Tstart)),                          $
          xtitle = 'wavelength [nm]', ytitle = 'transmission [-]',
color=255

    ; small pause for animation
    wait, 0.1

  ENDFOR

  ; close the product file.
  dummy = beat_close(pf)

END
```

Table 3.6: Example of use of the BEAT-II tools in IDL: extraction of the O_3 local density profile and corresponding plot.

```
PRO plot_one_GOMOS_profile, filename

IF KEYWORD_SET(filename) EQ 0 THEN filename= DIALOG_PICKFILE()

beatl2_ingestion_string       = 'species=O3'

beatl2_data = BEATL2_INGEST(filename, beatl2_ingestion_string)

IF BEATL2_IS_ERROR(beatl2_data) THEN RETURN

; Plot height vs O3.
plot, beatl2_data.value, beatl2_data.altitude, title = 'GOMOS Level-
2: Ozone Profile',   $
      xtitle = 'Local O!I3!N Density at tangent height
['+beatl2_data.value_unit+' ]',        $
      yrange=[0,75], ystyle=1, ytitle='Height [ km ]', color=255

END
; Note that altitude is already converted to KM by the BEAT_L2_INGEST
routine.
```

Table 3.7: Example of use of the BEAT-I tools in Matlab: extraction of the O_3 local density profile and corresponding plot.

```
%Plots GOMOS local ozone profile(s) using a file dialog
[name2,path2]=uigetfile({'*.*','All files (*.*)'},'Select GOM_NL-
file(s)','MultiSelect','on');
[dummy,nofiles]=size(name2);

figure(1)
for occ=1:nofiles
    filename2=strcat(path2,name2{:,occ});
    pf  = beat_open(filename2);
    o3 = beat_fetch(pf, 'NL_LOCAL_SPECIES_DENSITY', -1, 'o3');
    alt = beat_fetch(pf, 'nl_geolocation', -1, 'tangent_alt')/1000;
    beat_close(pf);
    plot(o3,alt,'LineWidth',2)
    hold on
end
title('Ozone local density','FontSize',14)
xlabel('Local density (cm^{-3})','FontSize',14)
ylabel('Altitude (km)','FontSize',14)
hold off
```

3.4.2 EnviView

EnviView is a free application that allows to open any Envisat data file (Level0, Level1b, Level2 and auxiliary PDS data file), and to examine its content and the value of any given field in any data set (except raw source packets). It allows the basic visualisation of data through simple 2D graphs and a representation of the geographic coverage. It is also made possible to export data to HDF, ASCII or binary data files and to save the contents of a record as HTML text.

It is guaranteed to run on Unix, Windows and MacOS and potentially other platforms too. More information is available from the ENVISAT web site at

http://earth.esa.int/enviview/.

The User Manual of EnviView is available at:

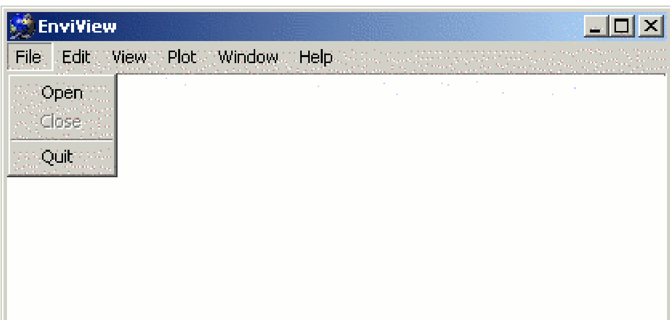
http://earth.esa.int/services/download/EnviViewUserGuide_v2.07.pdf.

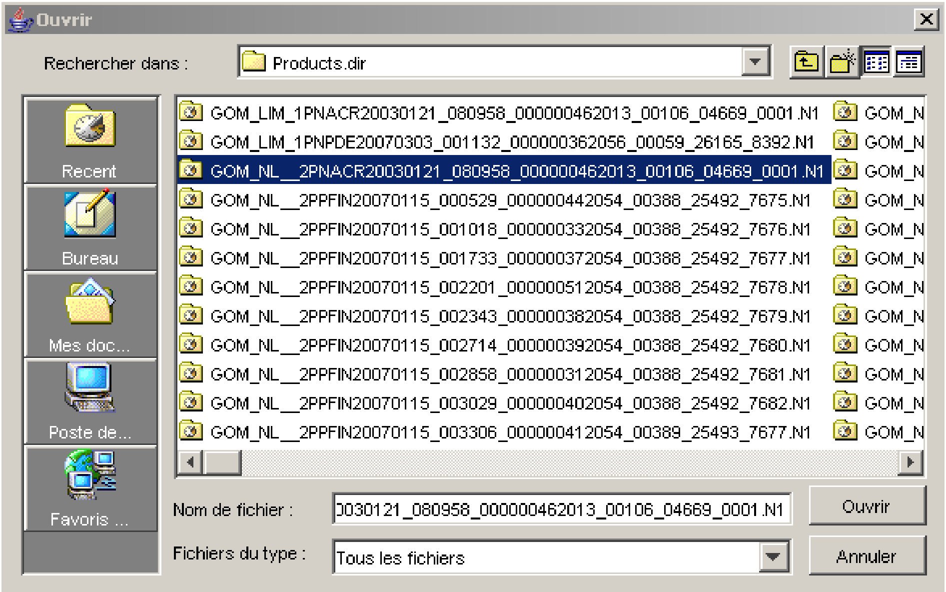
The main steps for opening and visualising a dataset stored in a product are described below. They are based on the most recent version of EnviView, version 2.6.4. Examples are given for the access to a Level2 product, to a Level1b limb product, and to a Level1b transmission product.

In the description of the product content (see section 2.2.3 of this document) and in the IODD reference document, the unit and the possible conversion factor used to store the Data Sets are detailed. Unlike BEAT and the GOMOS products toolbox, EnviView does not take into account the conversion factor possibly used to store the data values and returns them as they are stored in the product. However, this possible conversion factor and the unit for each data set are given in EnviView windows detailing the data set content or plotting the data sets.

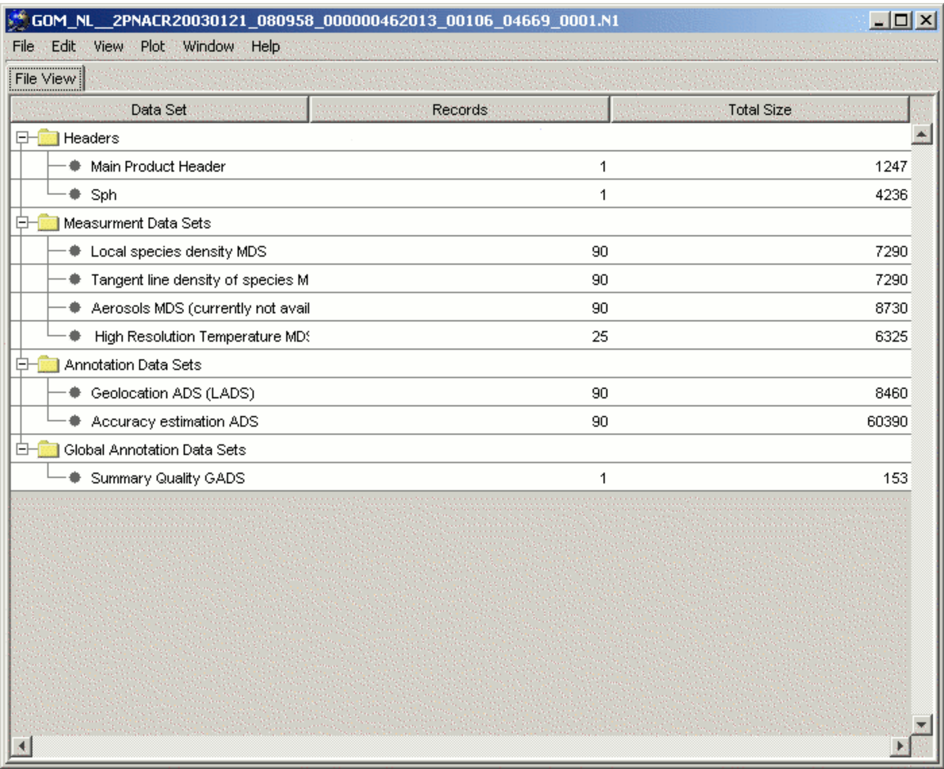
3.4.2.1 Example for a Level2 product

The choice of the GOMOS product file to be opened is made by selecting File and Open in the main menu, then by selecting the file in the correct folder.



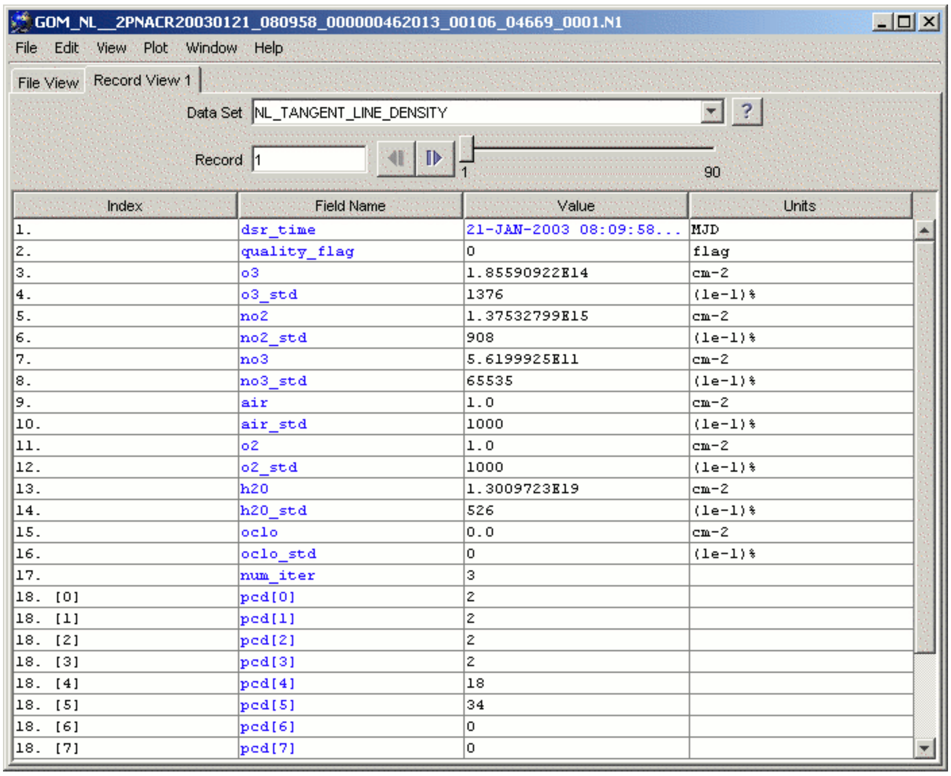


Information on the product content is then provided in a new window ("File View" window): the headers (main header and secondary header), the list of the MDS, of the ADS (containing additional information describing the data) and of the GADS, as well as the number of records and their size.



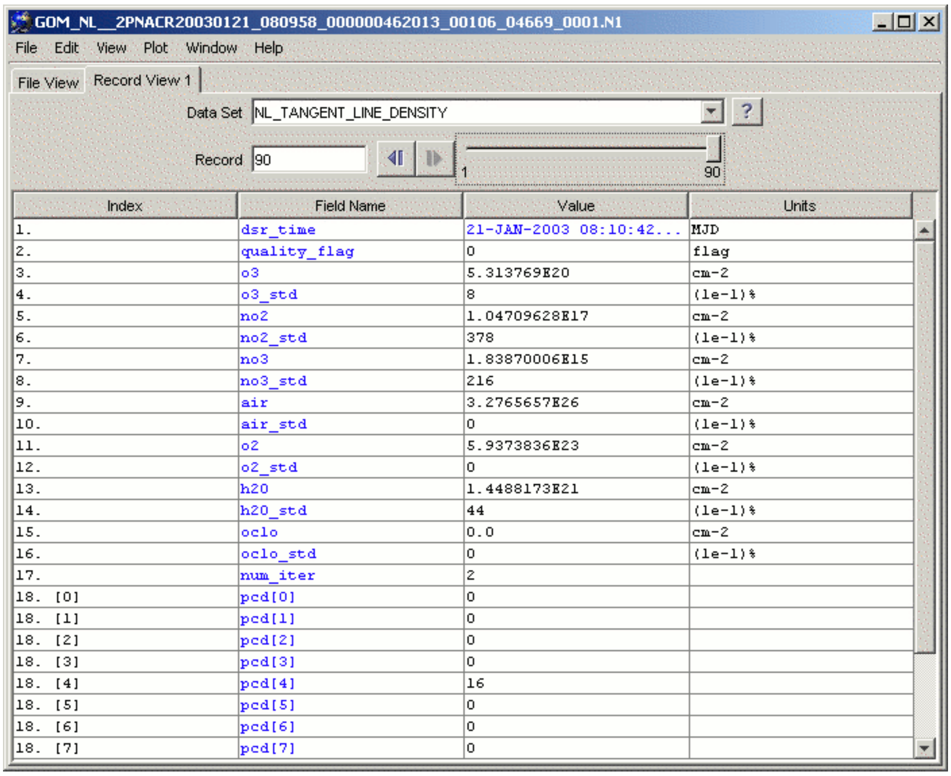
Information on the elements listed as above may then be obtained in a new window ("Record View 1" window) by double-clicking on the relevant name. By default, this information is provided for the first record of the data set. The record number may be changed (the number of records is given). All data set fields of the element are then listed along with information on their value and the units.

Details for record 1 of NL_TANGENT_LINE_DENSITY:



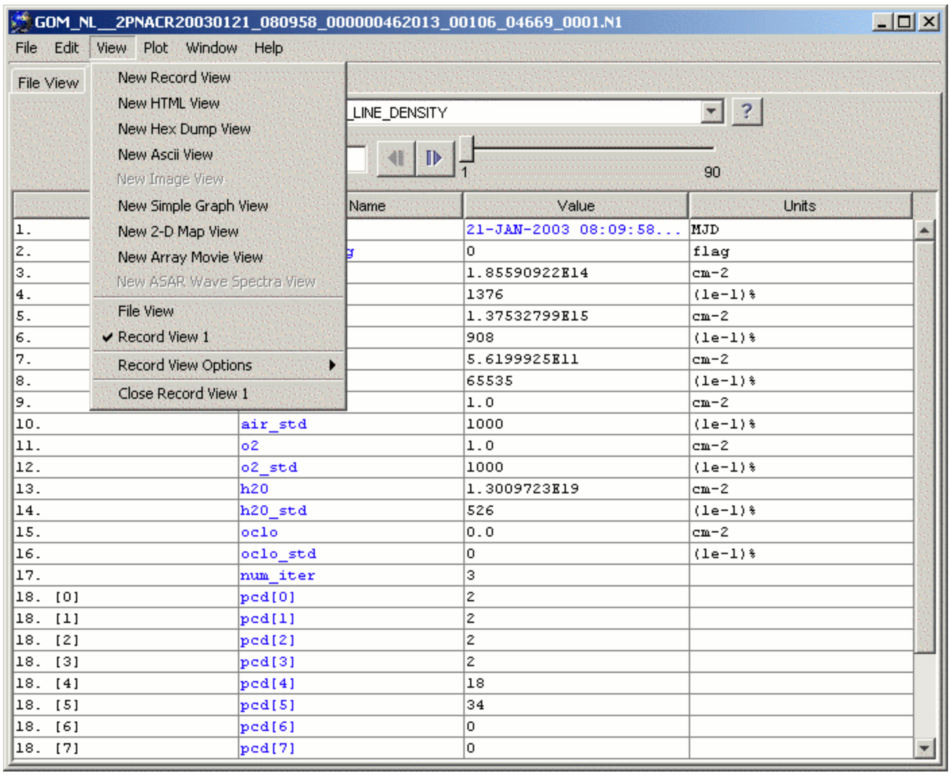
Index	Field Name	Value	Units
1.	dsr_time	21-JAN-2003 08:09:58...	MJD
2.	quality_flag	0	flag
3.	o3	1.85590922E14	cm-2
4.	o3_std	1376	(1e-1)%
5.	no2	1.37532799E15	cm-2
6.	no2_std	908	(1e-1)%
7.	no3	5.6199925E11	cm-2
8.	no3_std	65535	(1e-1)%
9.	air	1.0	cm-2
10.	air_std	1000	(1e-1)%
11.	o2	1.0	cm-2
12.	o2_std	1000	(1e-1)%
13.	h2o	1.3009723E19	cm-2
14.	h2o_std	526	(1e-1)%
15.	oclo	0.0	cm-2
16.	oclo_std	0	(1e-1)%
17.	num_iter	3	
18. [0]	pcd[0]	2	
18. [1]	pcd[1]	2	
18. [2]	pcd[2]	2	
18. [3]	pcd[3]	2	
18. [4]	pcd[4]	18	
18. [5]	pcd[5]	34	
18. [6]	pcd[6]	0	
18. [7]	pcd[7]	0	

Details for record 90 of NL_TANGENT_LINE_DENSITY:

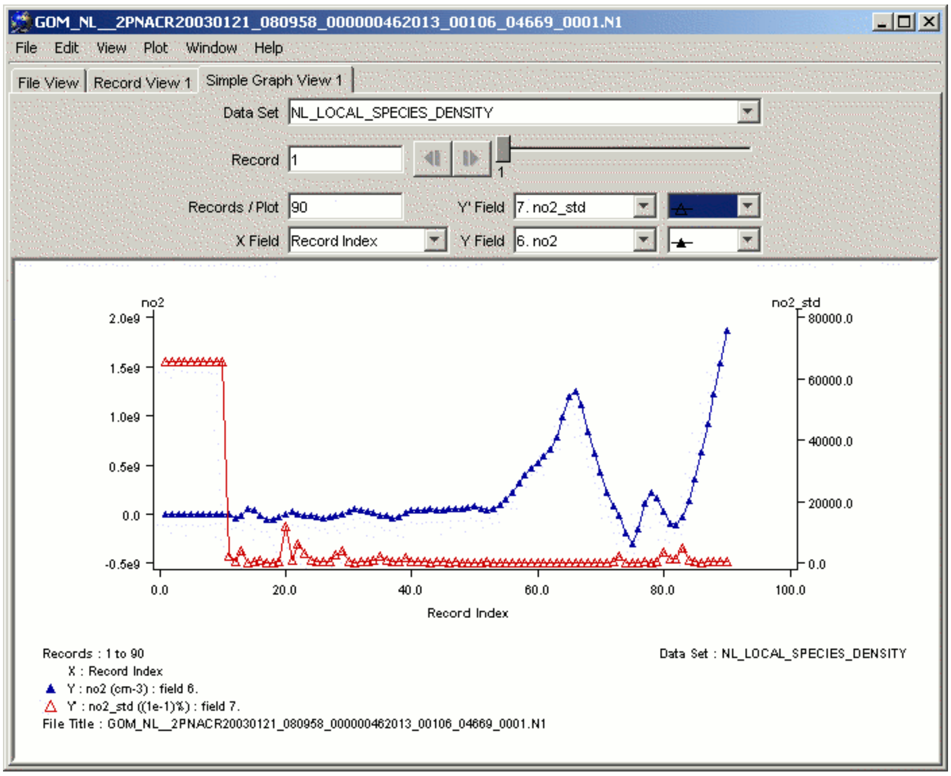


Index	Field Name	Value	Units
1.	dsr_time	21-JAN-2003 08:10:42...	MJD
2.	quality_flag	0	flag
3.	o3	5.313769E20	cm-2
4.	o3_std	8	(1e-1)%
5.	no2	1.04709628E17	cm-2
6.	no2_std	378	(1e-1)%
7.	no3	1.83870006E15	cm-2
8.	no3_std	216	(1e-1)%
9.	air	3.2765657E26	cm-2
10.	air_std	0	(1e-1)%
11.	o2	5.9373836E23	cm-2
12.	o2_std	0	(1e-1)%
13.	h2o	1.4488173E21	cm-2
14.	h2o_std	44	(1e-1)%
15.	oclo	0.0	cm-2
16.	oclo_std	0	(1e-1)%
17.	num_iter	2	
18. [0]	pcd[0]	0	
18. [1]	pcd[1]	0	
18. [2]	pcd[2]	0	
18. [3]	pcd[3]	0	
18. [4]	pcd[4]	16	
18. [5]	pcd[5]	0	
18. [6]	pcd[6]	0	
18. [7]	pcd[7]	0	

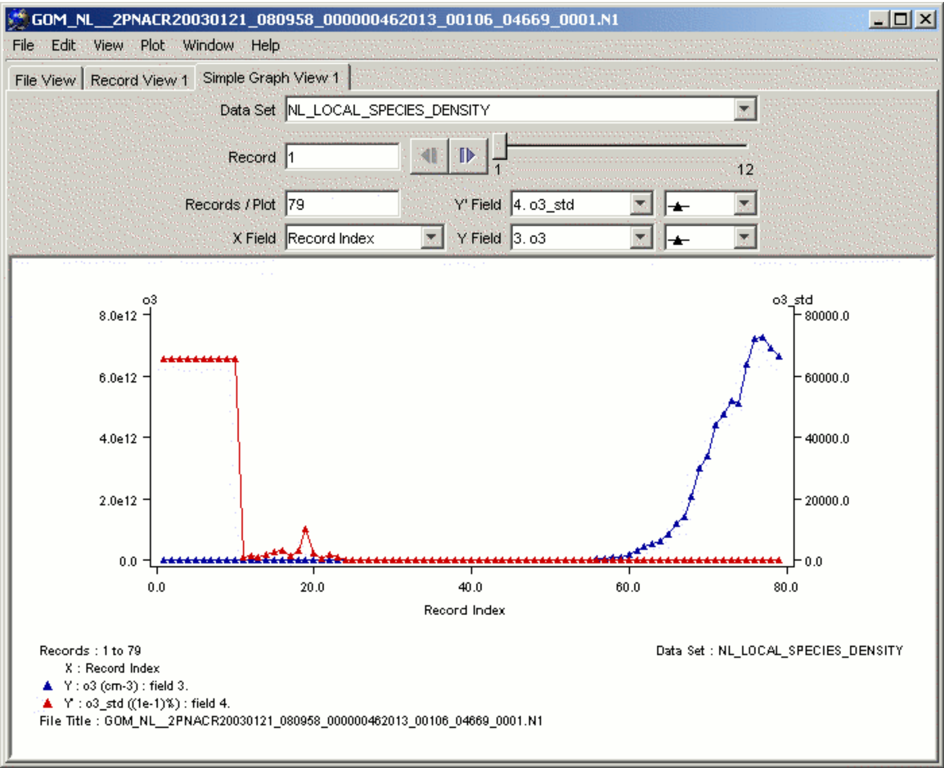
It is also possible to plot the field values by selecting View and New Simple Graph View. In the new window opened ("Simple Graph View 1"), the quantities to be plotted may be selected in the X field and Y field menus. Additional parameters may be changed: Y' field (allowing to plot a second quantity), the plotting symbols, and the number of records to be plotted on the same plot.



The following two figures plot the values of the NO_2 line density and of the O_3 local density respectively (scale on the left y-axis) as a function of the index record. The standard deviation of the main quantities are also plotted (scale on the right y-axis). The 79 records of the data set are plotted on the same figure.

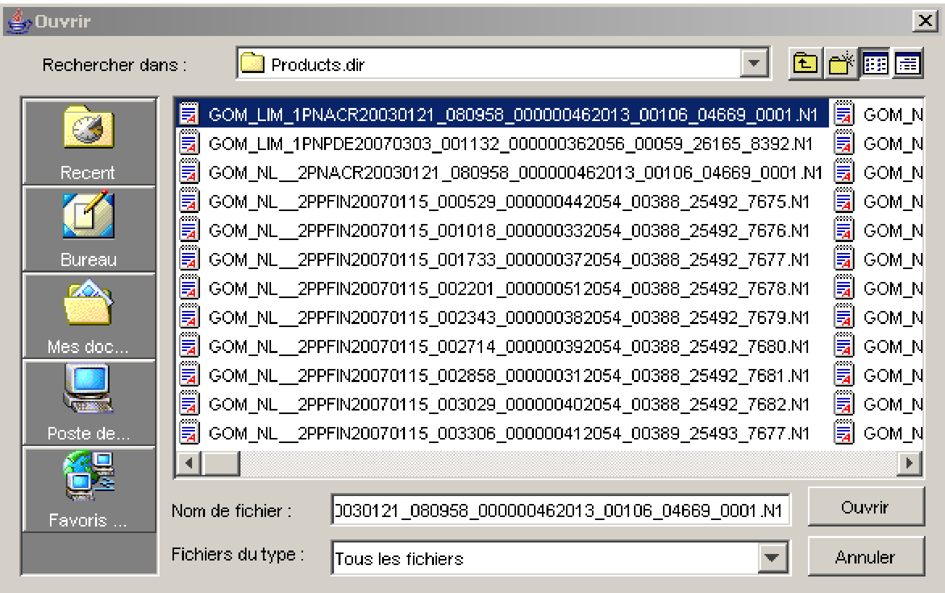


The following figure plots the values of the O_3 local density (scale on the left y-axis) and of the associated standard deviation (scale on the right y-axis) are plotted as a function of the index record. The 79 records of the data set are plotted on the same figure.

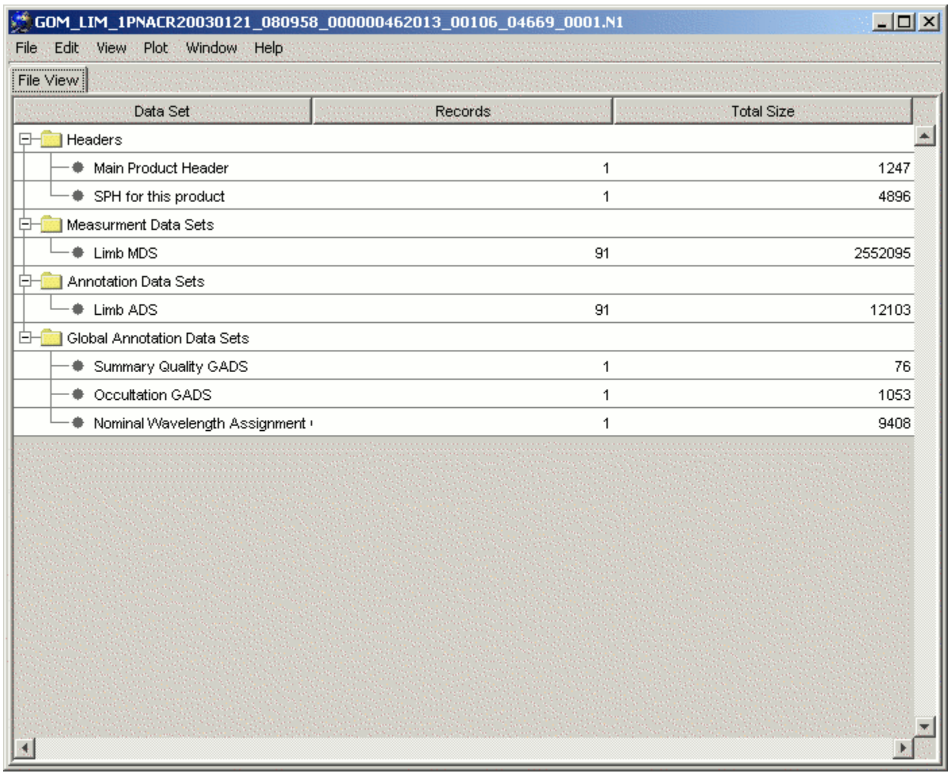


3.4.2.2 Example for a Level1b limb product

Selection of the limb product:

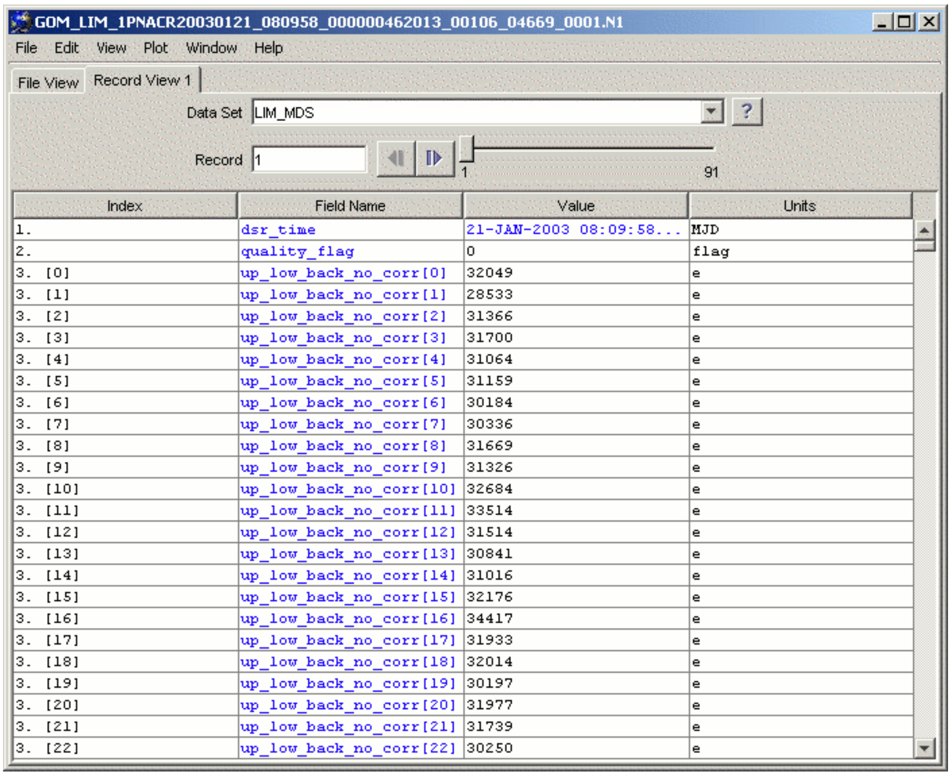


Information on the product content:



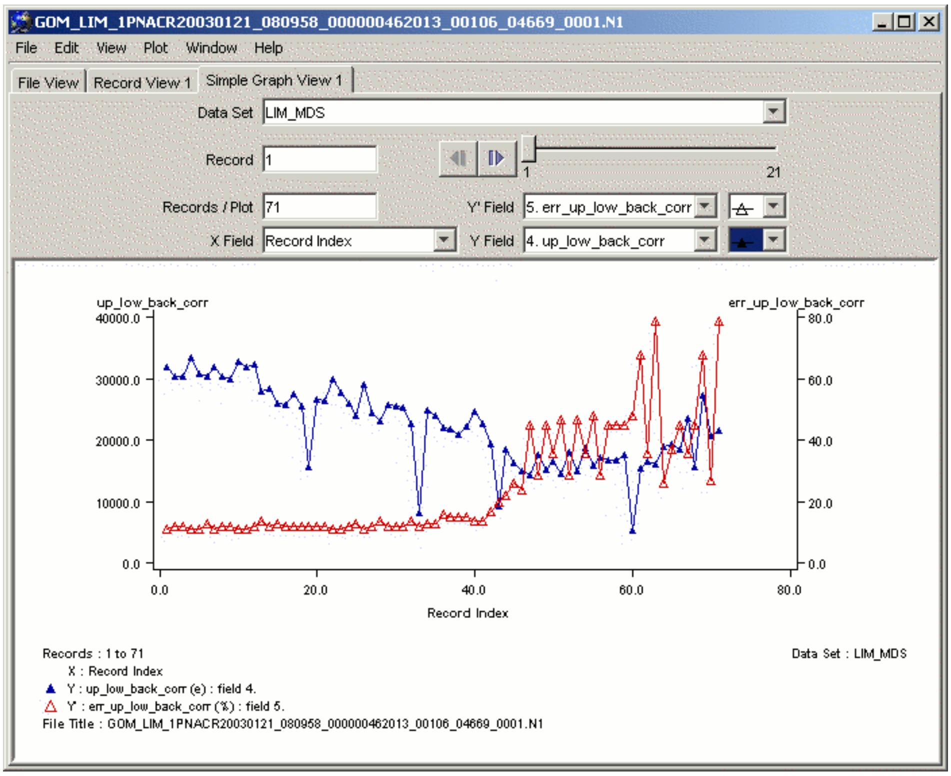
Data Set	Records	Total Size
Headers		
Main Product Header	1	1247
SPH for this product	1	4896
Measurment Data Sets		
Limb MDS	91	2552095
Annotation Data Sets		
Limb ADS	91	12103
Global Annotation Data Sets		
Summary Quality GADS	1	76
Occultation GADS	1	1053
Nominal Wavelength Assignment	1	9408

Details for record 1 of LIM_MDS:



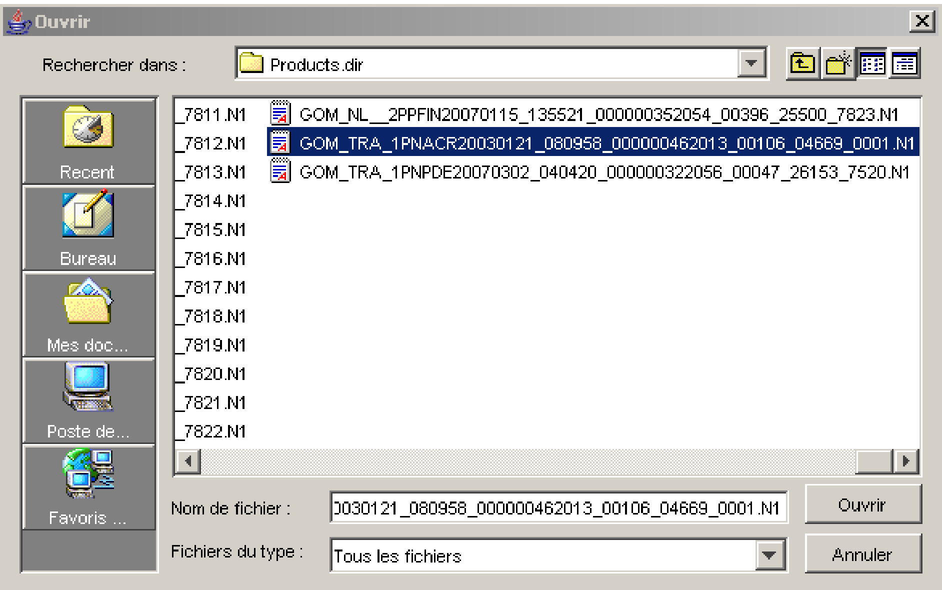
Index	Field Name	Value	Units
1.	dsr_time	21-JAN-2003 08:09:58...	MJD
2.	quality_flag	0	flag
3. [0]	up_low_back_no_corr[0]	32049	e
3. [1]	up_low_back_no_corr[1]	28533	e
3. [2]	up_low_back_no_corr[2]	31366	e
3. [3]	up_low_back_no_corr[3]	31700	e
3. [4]	up_low_back_no_corr[4]	31064	e
3. [5]	up_low_back_no_corr[5]	31159	e
3. [6]	up_low_back_no_corr[6]	30184	e
3. [7]	up_low_back_no_corr[7]	30336	e
3. [8]	up_low_back_no_corr[8]	31669	e
3. [9]	up_low_back_no_corr[9]	31326	e
3. [10]	up_low_back_no_corr[10]	32684	e
3. [11]	up_low_back_no_corr[11]	33514	e
3. [12]	up_low_back_no_corr[12]	31514	e
3. [13]	up_low_back_no_corr[13]	30841	e
3. [14]	up_low_back_no_corr[14]	31016	e
3. [15]	up_low_back_no_corr[15]	32176	e
3. [16]	up_low_back_no_corr[16]	34417	e
3. [17]	up_low_back_no_corr[17]	31933	e
3. [18]	up_low_back_no_corr[18]	32014	e
3. [19]	up_low_back_no_corr[19]	30197	e
3. [20]	up_low_back_no_corr[20]	31977	e
3. [21]	up_low_back_no_corr[21]	31739	e
3. [22]	up_low_back_no_corr[22]	30250	e

Plot of the upper and lower background spectra after correction and of the corresponding error:

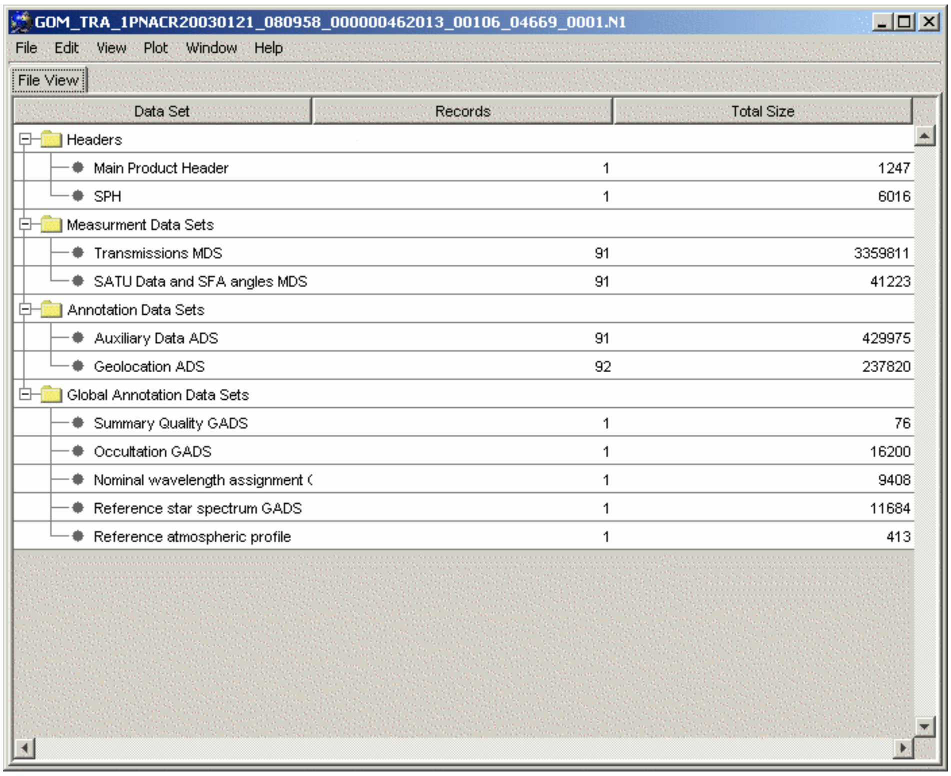


3.4.2.3 Example for a Level1b transmission product

Selection of the transmission product:



Information on the product content:



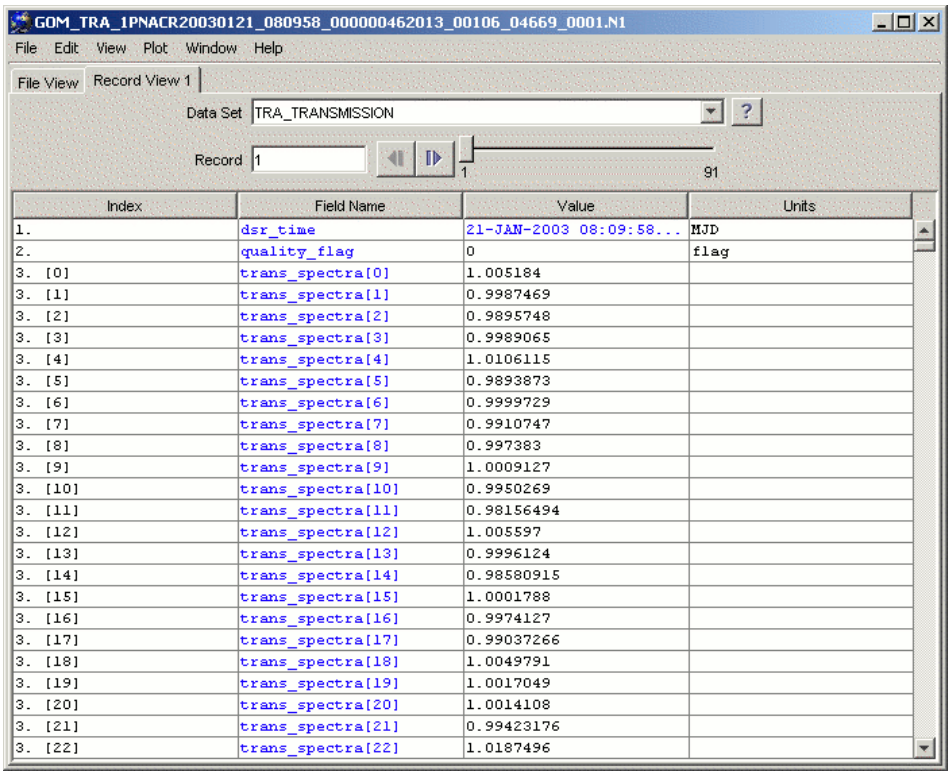
GOM_TRA_1PNACR20030121_080958_000000462013_00106_04669_0001.N1

File Edit View Plot Window Help

File View

Data Set	Records	Total Size
Headers		
Main Product Header	1	1247
SPH	1	6016
Measurment Data Sets		
Transmissions MDS	91	3359811
SATU Data and SFA angles MDS	91	41223
Annotation Data Sets		
Auxiliary Data ADS	91	429975
Geolocation ADS	92	237820
Global Annotation Data Sets		
Summary Quality GADS	1	76
Occultation GADS	1	16200
Nominal wavelength assignment (	1	9408
Reference star spectrum GADS	1	11684
Reference atmospheric profile	1	413

Details for record 1 of TRA_TRANSMSSION:



GOM_TRA_1PNACR20030121_080958_000000462013_00106_04669_0001.N1

File Edit View Plot Window Help

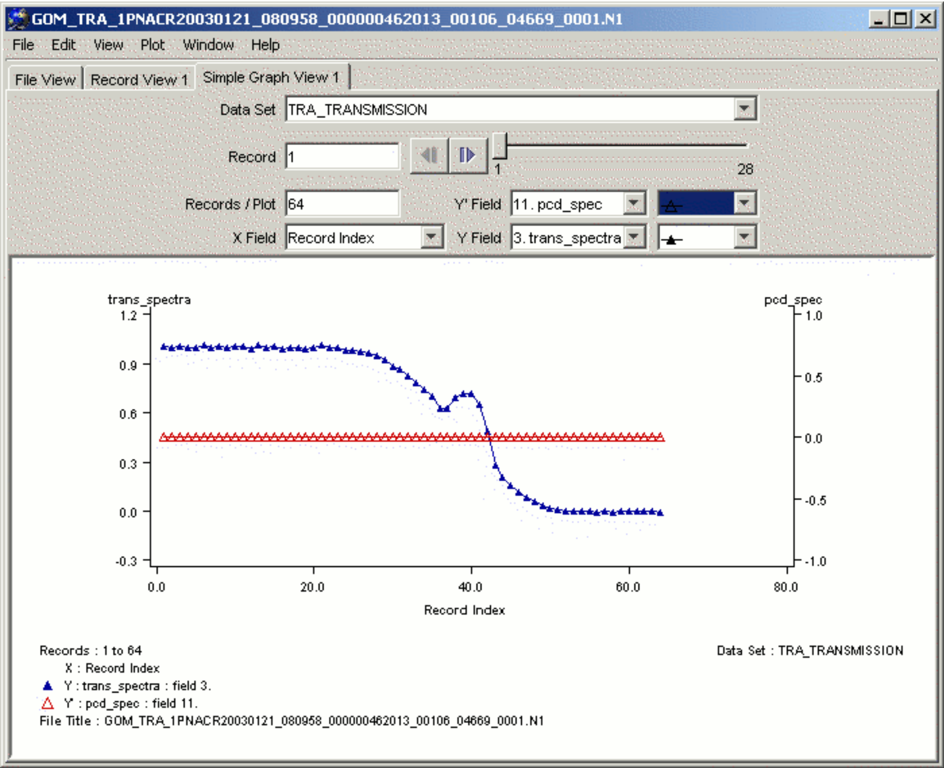
File View | Record View 1

Data Set TRA_TRANSMISSION

Record 1 (1 – 91)

Index	Field Name	Value	Units
1.	dsr_time	21-JAN-2003 08:09:58...	MJD
2.	quality_flag	0	flag
3. [0]	trans_spectra[0]	1.005184	
3. [1]	trans_spectra[1]	0.9987469	
3. [2]	trans_spectra[2]	0.9895748	
3. [3]	trans_spectra[3]	0.9989065	
3. [4]	trans_spectra[4]	1.0106115	
3. [5]	trans_spectra[5]	0.9893873	
3. [6]	trans_spectra[6]	0.9999729	
3. [7]	trans_spectra[7]	0.9910747	
3. [8]	trans_spectra[8]	0.997383	
3. [9]	trans_spectra[9]	1.0009127	
3. [10]	trans_spectra[10]	0.9950269	
3. [11]	trans_spectra[11]	0.98156494	
3. [12]	trans_spectra[12]	1.005597	
3. [13]	trans_spectra[13]	0.9996124	
3. [14]	trans_spectra[14]	0.98580915	
3. [15]	trans_spectra[15]	1.0001788	
3. [16]	trans_spectra[16]	0.9974127	
3. [17]	trans_spectra[17]	0.99037266	
3. [18]	trans_spectra[18]	1.0049791	
3. [19]	trans_spectra[19]	1.0017049	
3. [20]	trans_spectra[20]	1.0014108	
3. [21]	trans_spectra[21]	0.99423176	
3. [22]	trans_spectra[22]	1.0187496	

Plot of the transmission and the corresponding PCD:



3.4.3 GOMOS products toolbox

The GOMOS products toolbox allows to visualise and edit the GOMOS products. It is relevant to all GOMOS products: auxiliary products, Level1b and Level2 products including the meteo products. In order to extract data from the GOMOS products, a specific data dictionary must be available in the working environment of the user. The toolbox has been developed for Sun Unix platforms, system Solaris 2.6.

We provide here only the main guidelines for the use of the toolbox. The User Manual of the GOMOS Products Toolbox is available at:

http://www.acri-st.fr/tools/gomos/gomos_toolbox_user_is2r0.pdf

(issue 2.0, 2003). More information is available on request at: gb@cri-st.fr (Gilbert Barrot, ACRI-ST company).

The toolbox contains a set of several programs, whose main functionalities are to extract data from a product for plotting, and to modify a field in a product.

gomtab extraction of data from a GOMOS Level0 products

display_prextraction of data from a GOMOS product (except a Level0 product)

info_pr returns the number of elements of a specified field of a product

export_pr extraction of data from a GOMOS product; the output format is compatible with the input format of modify_pr

modify_pr allows to modify a product; reads an ASCII file generated by export_pr and stores the data in a product.

The input data must be fully compatible with the product (same size of the field)

diff_pr comparison of two products

header_pr writing of the header of a product on the standard output

extract_pr extraction of the values of a variable written in a file generated by display_pr or export_pr.

More details on the use of the programs are given in Table 3.8.

Table 3.8: Specificities and instructions for use of the GOMOS toolbox programs.

Program name	**Short description and use**
gomtab	Extract the data from a GOMOS level 0 product

	`gomtab prd_name [nrec]`
	`prd_name is the level 0 product filename`
	`nrec is the occultation measurement number`
	`<output on the standard output device>`
	`Note: today only level 0 with only one occultation can be processed with gomtab.`

display_pr	Extract the data from a product

	`display_pr prd_type prd_name [code]`
	`prd_type is the type of the product`
	`prd_name is the product filename`
	`code is the GOPR data dictionary code (like 6403).`
	`If not specified, then all the product is displayed`
	`<output on the standard output device>`

info_pr	Returns the size of a product field

	`info_pr prd_type prd_name code`
	`prd_type is the type of the product`
	`prd_name is the product filename`
	`code is the GOPR data dictionary code (like 6403).`
	`<output on the standard output device>`

export_pr	Similar to display_pr except that the output format is compatible with the input format of **modify_pr**

	`export_pr prd_type prd_name ascii_name [code]`
	`prd_type is the type of the product`
	`prd_name is the product filename`
	`ascii_name is the name of the output file (ASCII format)`
	`code is the GOPR data dictionary code (like 6403).`
	`If not specified, then all the product is exported`
	`<output in the ascii_name file>`

modify_pr	Allows to modify a product. Read an ASCII file generated by **export_pr** and store the data in a product. Note that the input data must be fully compatible with the product (same size of the data)
	`modify_pr ascii_name prd_name prd_type` `ascii_name is the name of the input file (ASCII format)`

<table>
<tr><th>Program name</th><th>Short description and use</th></tr>
<tr><td></td><td><code>prd_name is the product filename
prd_type is the type of the product
<no output - prd_name file is modified></code></td></tr>
<tr><td>diff_pr</td><td>Comparison of two products</td></tr>
<tr><td></td><td><code>diff_pr prd_type prd_name1 prd_name2
prd_type is the type of the product
prd_name1 is the first product filename
prd_name2 is the second product filename
<output on the standard output device></code></td></tr>
<tr><td>header_pr</td><td>Write the header of a product on the standard output</td></tr>
<tr><td></td><td><code>header_pr prd_name prd_type
prd_name is the product filename
prd_type is the type of the product
<output on the standard output device></code></td></tr>
<tr><td>extract_pr</td><td>Extract the values of a variable written in a file generated by display_pr or export_pr</td></tr>
<tr><td></td><td><code>extract_pr file code nval INT|REAL|MJD MDS|GADS [f0] [k0]
file is a file created by a display_pr or export_pr command
code is the GOPR data dictionary code (like 6403)
nval is number of values to be read by record
INT|REAL|R8|MJD specifies if the data type is integer, real or date
MDS|GADS is the type of the record to be read (if this is a GADS,
only one value must be read (and there is no additional value
after the variable description in the input file).
f0: if the type is a MDS, and if f0 is specified, then extract
only the record number f0 (this is useful to extract only one
MDS record like for the transmission). All MDSR by default
when f0 is not specified or set to -1
k0: only element k0 of the extracted vector is displayed. All vector
is displayed if k0 is not specified.
<output on the standard output device></code></td></tr>
</table>

In the description of the product content (see section 2.2.3 of this document) and in the IODD reference document, the unit and the possible conversion factor used to store the Data Sets are detailed. It is important to note that the GOMOS products toolbox, similarly to BEAT tools, handle those conversion factors and thus return "decoded" data set values. For instance, all standard deviation data set records are stored in (1.e-1)% in the products. The data values returned by the toolbox programs are given in %.

Two examples of use are presented in Table 3.9 and Table 3.10.

Table 3.9: Example of use of the GOMOS toolbox programs: extraction of the transmission for plotting versus nominal wavelength.

Extraction of transmission values and nominal wavelength assignment from a Level1b product.
The GOPR data dictionary codes for the transmission and the wavelength assignment are 1602 and 1301 respectively.

```
sh> display_pr 1
GOM_TRA_1PNACR20030121_080958_000000462013_00106_04669_0001.N1 1301
1602 > zzz.dat
sh> NVAL=`info_pr 1
GOM_TRA_1PNACR20030121_080958_000000462013_00106_04669_0001.N1 1301`
NVAL contains the number of elements of field 1301
sh> extract_pr zzz.dat 1301 $NVAL REAL GADS > wl.dat
wl.dat contains the nominal wavelengths extracted from zzz.dat file
sh> extract_pr zzz.dat 1602 $NVAL REAL MDS 50 > trans.dat
trans.dat contains the transmission of the 51-th measurement
extracted from zzz.dat file
sh> paste wl.dat trans.dat > plot.dat
```

the transmission data and the wavelength data are merged in a single file named plot.dat

sh > xmgrace plot.dat

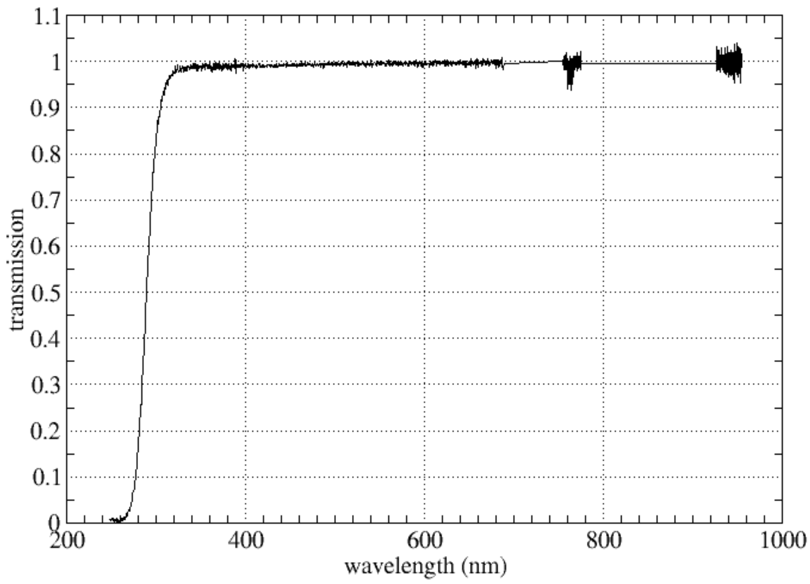


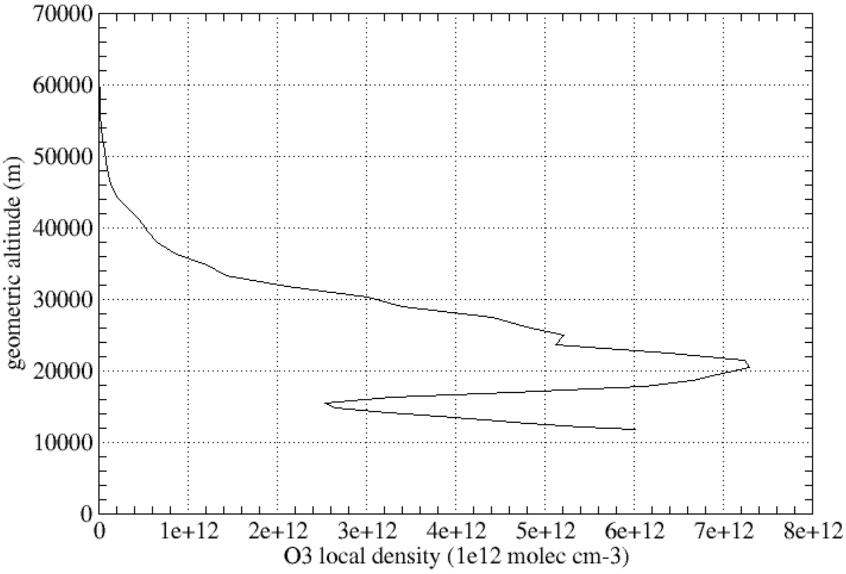
Table 3.10: Example of use of the GOMOS toolbox programs: extraction of the O_3 local density for plotting versus the vertical altitude.

Extraction of the vertical profile of O_3 local density from a Level2 product.
The GOPR data dictionary codes for the O_3 local density and the tangent point altitude are 3607 and 3202 respectively.

```
sh> display_pr 3
GOM_NL__2PNACR20030121_080958_000000462013_00106_04669_0001.N1 3202
3607 > zzz.dat
sh> NVAL=`info_pr 3
GOM_NL__2PNACR20030121_080958_000000462013_00106_04669_0001.N1 3202`
NVAL contains the number of elements of field 3202
sh> extract_pr zzz.dat 3607 $NVAL REAL MDS > alt.dat
alt.dat contains the tangent point altitude extracted from zzz.dat
file
sh> extract_pr zzz.dat 3202 $NVAL REAL MDS > o3.dat
o3.dat contains the O3 local density values extracted from zzz.dat
file
sh> paste o3.dat alt.dat > plot.dat
```

the O_3 local density data and the tangent point altitude data are merged in a single file named plot.dat

sh > xmgrace plot.dat



3.5 FAQ

Measurement method and characteristics

- **What is the measurement principle of GOMOS?**

  The measurement method of GOMOS is the star occultation technique. This method is detailed in Chapter 1.

- **What is the geographical coverage for GOMOS measurements?**

  The geographical coverage of GOMOS measurements is constrained by the planning, specifying the star targets. Until early January 2005, the daily number of measurements was about 400. Since July 2005, it is about 280. See section 0 of this document for more details.

- **What is the spatial resolution of GOMOS measurements?**

  The spatial resolution of GOMOS measurements is constrained by the planning, specifying the star targets. Until early January 2005, the daily number of measurements was about 400. Since July 2005, it is about 280. See section 0 of this document for more details.

- **What is the vertical sampling and the vertical resolution of GOMOS measurements?**

  The vertical sampling varies from one occultation to the other, depending on the occultation geometry. During one occultation GOMOS measures the stellar light in 0.5 s integration time intervals. This corresponds in the worst case (occultation in the orbital plane) to an interval of 1.7 km of altitude projected at the limb. The vertical sampling is therefore 1.7 km in the case of an occultation in the orbital plane and better than 1.7 km for oblique occultations.

  The limb viewing geometry, the point source nature of stars and the short measurement integration time lead to a good vertical resolution of the profiles retrieved from GOMOS measurements. Figures of the vertical resolution by species and by altitude range are given in Table 1.3 of Section 1.5.3.3 of this document.

- **What is the accuracy of GOMOS measurements? In what extent does it depend on the star characteristics and the geometry of the measurement?**

  The accuracy of GOMOS measurements varies from one occultation to the other. The key factors are the characteristics of the occulted star (visual magnitude and effective temperature), and some specificities of the occultation geometry. See section 0 of this document for more details.

- **Are there instrument anomalies impacting the frequency of measurements?**

  Since the launch of ENVISAT and the beginning of nominal operations for GOMOS, there has been two main periods of perturbations. Between May 2003 and July 2003, the progressive reduction of the instrument Field of View on the nominal side impacted the number of effective measurements which was lower than the planned one. Between January 2005 and August 2005, the nominal operations were stopped, due to the failure of the Elevation voice-coil system. Operations resumed after the implementation of a new mission scenario with a reduced azimuth field of view. With this new mission scenario, the average number of daily occultations has been reduced from about 400 to about 280.

  More details are given in the Appendix B of this document.

Processing and generalities on products

- **What are the main steps of the processing?**

  The generation of scientific products from GOMOS measurements is obtained from successive processing steps.

  The products of lowest level are the Level0 products. The only algorithms applied to generate the Level0 products from the raw data are the determination of the satellite position and the conversion of satellite binary time to UTC. The Level0 products are used as input for the processing of higher level.

  The aim of the Level1b processing is to estimate a set of horizontal transmission functions in the UV-visible-near IR between 250 nm and 956 nm using data measured by the GOMOS spectrometers. There are two types of Level1b products: the geolocated and calibrated transmission spectra products (transmission products) and the geolocated and calibrated background spectra limb products (limb products).

  The aim of the Level2 processing is to retrieve the vertical profiles of O_3, NO_2, NO_3, O_2, H_2O and other trace gases profiles, the temperature profiles, the aerosol extinction coefficient and wavelength dependency parameters, and information about atmospheric turbulence, from the full atmospheric transmission spectra. There are three types of Level2 products: the products storing the profiles of temperature and atmospheric constituents; the residual extinction products; the products storing selected profiles processed in NRT for meteo users.

  More details are given in sections 2.1.1 and 2.3.3 of this document.

- **How are the product files organised?**

  The Level 0 products (in occultation mode) are input products for the Level1 b processing. The Level 1b products are input products of the Level 2 processing. More details are given in section 2.1.1 of this document.

- **Have there been successive versions of the operational processor?**

  Details on the current version of the operational processor (IPF 5.00) are given in Appendix B of this document. This version has been activated in August 2006. The previous version was IPF 4.02. Measurements for dates between August 2002 and July 2006 have been reprocessed with the version of the processor currently in operation, so that all measurements since August 2002 are now available from the same updated processor version.

- **What is the typical size of the GOMOS products?**

  The typical figures of the size of the products are given in section 2.1.2 of this document.

- **Which data are available to the users? Where and how to get the GOMOS products?**

  GOMOS Level1b products are available on request. GOMOS Level2 products are disseminated to the users through dedicated ftp sites. Detailed information about the access to the data is given in section 3.1 of this document.

- **What is the naming convention of the GOMOS products?**

  The naming convention for the different level products is explained in section 2.2.1. It follows ESA specifications for ENVISAT products.

- **Where to get in the products the date and the location of the measurement?**

  The date, the latitude and the longitude of the tangent point are given for the first and the last measurements of the occultation in the SPH of the Level1b products and of the Level2 products (see table 2.8 of section 2.2.2 of this document). The geolocation ADS in the Level1b transmission product and the Level2 atmospheric and constituent product also provides the latitude and the longitude of the tangent point at the beginning and during the measurement, generally at half-measurement (see table 2.20 in section 2.2.3.3.1). The measurement starting date of the first DSR of the product (day, time) is also contained in the product name, following the convention described in section 2.2.1).

- **What is the structure and the content of the GOMOS products?**

  All products follow the same structure. They are organised in Product Headers and Datasets. The Main Product Header and the Specific Product Header provide information on the product. The Annotation Data Sets contain auxiliary data relevant to the product. The Measurement Data Sets contain measurements and/or processed data.

  More details are given in sections 2.2.2 and 2.2.3 of this document.

Product content

- **How to handle and read the data stored in the products?**

  Access tools specific to ENVISAT products have been developed. They allow to extract some specific fields stored in the products, and to handle data sets for plotting. Three access tools (BEAT, ENVIVIEW, GOMOS products toolbox) are presented in section 3.4 of this document. An important specificity of BEAT tools and of GOMOS product toolbox should be noted. As described in the IODD reference document, and for some datasets in the Section 2.2.3 of this document, values of some data set records are stored after multiplication by a conversion factor. Both BEAT tools and programs from the GOMOS products toolbox handle those conversion factors and thus return the unconverted data values i.e. the values ready to be used for any analysis purposes. For instance, all standard deviation data set records are stored in (1.e-1)% in the products. The data values returned after ingestion by BEAT tools or from the GOMOS products toolbox programs are given in %.

- **In which product are stored the transmission spectra?**

  The full transmission spectra at different tangent heights are stored in the Transmission MDS of the Level 1b transmission products (see 2.2.3.2.1), for each measurement time of 0.5s. They are described as 'full' because it is the actually measured transmission, not corrected for refraction effects (dilution, scintillation, chromatic refraction) nor for variable PSF. They are obtained by dividing each measured spectrum (re-sampled on the wavelength pixel grid of the reference spectrum) by the reference star spectrum.

  The transmission spectra corrected for the scintillation and dilution effects are stored in the Residual Extinction MDS of the Level2 residual extinction products (see section 2.2.3.3.2 of this document).

- **What is the reference star spectrum and in which product is it stored?**

  The reference star spectrum is computed by averaging several star spectra outside the atmosphere at the beginning of the occultation. The current nominal number of averaged spectra is ten. The two first spectra are not used for pointing instability reason. The reference star spectrum is used to calculate the transmission spectrum which is obtained by dividing each measured spectrum by the reference star spectrum.

  The reference star spectrum is stored in the Reference star spectrum GADS of the Level 1b transmission product (see 2.2.3.2.1). It is given in electrons and must be converted into physical units (ph/s/cm2/nm) by multiplying the electron values by the conversion factor inferred from the radiometric sensitivity curve (star) provided as a LUT in the Level 1b transmission product.

- **How to build up the reference star spectrum from the values stored in the Reference star spectrum GADS of the Level 1b transmission product?**

  The spectra values stored in electrons in the Level 1b products must be converted into physical units (ph/s/cm2/nm) by using the radiometric sensitivity curve (star). This radiometric sensitivity curve is given for each occultation as a LUT in the occultation data GADS of the Level 1b transmission product (see section 2.2.3.3.2 of this document). The conversion factors are given by the DS Radiometric sensitivity curve, for a series of wavelength values given in the DS Abscissae of the radiometric sensitivity curve. The size of the curve is given by the DS Size of the radiometric sensitivity curve. A linear interpolation of the conversion factor is needed to use this curve for any sample of the spectra. The spectra in physical units are then obtained by multiplying the flux values in electrons by this conversion factor.

- **What are the background limb spectra and in which product are they stored?**

  The estimated central background is the estimated background contribution to the total signal in the central band, which is subtracted to yield the pure stellar signal. It is computed from the signals measured in the upper and lower bands. It is stored in the Transmission MDS of the Level 1b transmission product (see section 2.2.3.2.1 of this document), for each measurement time of 0.5s.

  The background limb spectra in upper and lower bands are stored in the Limb MDS of the Level 1b limb products (see section 2.2.3.2.2 of this document), for each measurement time of 0.5s. Both uncorrected spectra and corrected spectra from straylight and IR-vignetting effects are stored in this MDS.

  The quantities stored for the background limb spectra are actually scaled dimensionless values. It is needed first to decode those values to transform them to fluxes in electrons, then to convert the flux values into physical units (ph/s/cm2/nm/sr) by multiplying the electron values by the conversion factor inferred from the radiometric sensitivity curve (background) provided as a LUT in the Level 1b products.

- **How to build up the background spectra from the quantities stored in the MDS of the Level 1b transmission and limb products?**

  Due to the high variation of the background spectra with altitude, the coding of these quantities in the products is dynamic and it uses a gain and an offset for each measurement. This gain and this offset are stored in the auxiliary data ADS of the Level 1b transmission product for the estimated central background (see section 2.2.3.2.1 of this document) and in the auxiliary data ADS of the Level 1b limb product for the upper and lower background spectra (see 2.2.3.2.2). The values stored must be decoded by applying: background (in electrons) = offset + background code / gain.

  The decoded spectra obtained in electrons must be converted then into physical units (ph/s/cm2/nm/sr) by using the radiometric sensitivity curve (background).

This radiometric sensitivity curve is given for each occultation as a LUT in the occultation data GADS of the Level 1b transmission product and of the Level 1b limb product (see 2.2.3.2.1 and 2.2.3.2.2). The conversion factors are given by the DS Radiometric sensitivity curve, for a series of wavelength values given in the DS Abscissae of the radiometric sensitivity curve. The size of the curve is given by the DS Size of the radiometric sensitivity curve. A linear interpolation of the conversion factor is needed to use this curve for any sample of the spectra. The spectra in physical units are then obtained by multiplying the flux values in electrons by this conversion factor.

- **What is the apparent tangent altitude? Where is it stored?**

  Several altitude definitions are used for the processing of GOMOS measurements. The apparent altitude is the tangent altitude computed with a virtual straight ray directed toward the virtual star direction, while the tangent altitude is the one computed for the real ray path i.e. including refractive effects. The definition of these altitudes, along with the different ray geometries (with no atmospheric refraction effects or with atmospheric refraction effects) is illustrated in Figure A.1 of the Appendix A.

  Star spectra are given for tangent altitude heights, while limb spectra are given for apparent altitude heights.

  The apparent altitude of the central background is stored in the Geolocation ADS of the Level 1b transmission product (see section 2.2.3.2.1 of this document).

  The altitude of the apparent tangent point is stored in the limb ADS of the Level 1b limb product (see section 2.2.3.2.2 of this document). Two values are actually stored for each DS record: the first one corresponds to the apparent altitude of the upper background band and the second one corresponds to the apparent altitude of the lower background band.

  In all cases, the apparent altitude is given at half-measurement, for the centre of each band.

- **What are the main atmospheric product quantities of GOMOS?**

  The tangent line densities and the vertical profiles of local density are retrieved from the spectrometer measurements for several species: O_3, NO_2, NO_3, air, O_2, H_2O. With the current operational IPF (IPF5.00), neutral density is actually no more vertically retrieved. The air local density, the error bar on the air local density, the vertical resolution for air, as well as the terms related to air in the covariance matrix for local densities after vertical inversion are all set to 0 in the Level 2 temperature and atmospheric constituent products generated with this IPF version. Also, OClO is not operationally retrieved, though datasets specific to OClO exist in the products (of which values are set to 0). Other atmospheric products include the spectral parameters of the extinction coefficients, and high resolution temperature and density profiles retrieved from the Fast-Photometer signals. Those quantities are all stored in the Level2 temperature and atmospheric constituent products (see section 2.2.3.3.1 of this document). Star light transmissions and limb data are stored in the Level1b transmission and the Level1b limb products respectively (see sections 2.2.3.3.1 and 2.2.3.3.2).

- **What is the altitude range of validity for the vertical profiles of local density?**

  The altitude range of validity for the vertical profiles of species local density, of aerosol extinction coefficient and of HRTP is given in section 0. The impact of the star characteristics and of the occultation geometry on the data accuracy with respect to the altitude range is detailed in sections 3.3.1 and 3.3.2.

- **In which product are stored the tangent line densities of O_3, NO_2, NO_3, O_2, H_2O?**

  The tangent line densities of O_3, NO_2, NO_3, O_2, H_2O are stored in the Tangent line density of species MDS of the Level2 temperature and atmospheric constituent products (see section 2.2.3.3.1).

- **In which product are stored the vertical profiles of local density of O_3, NO_2, NO_3, O_2, H_2O?**

  The vertical profiles of local density of O_3, NO_2, NO_3, O_2, H_2O are stored in the Local species density MDS of the Level2 temperature and atmospheric constituent products (see section 2.2.3.3.1).

- **In which product are stored the spectral parameters of the aerosol extinction coefficient?**

  The spectral parameters of the aerosol extinction coefficient are stored in the Aerosols MDS of the Level2 temperature and atmospheric constituent products. The extinction coefficient at the reference wavelength and the other coefficients are given in this MDS. The spectral parameters of the tangent integrated extinction profile are also given. The reference wavelength is given in the Occultation data GADS of the Level 1b product ("Ref. wavelength for the ray tracing"), and in the SPH of the Level 2 temperature and atmospheric constituents product and of the residual extinction product. It is equal to 500 nm.

  More details are presented in section 2.2.3.3.1 and Appendix A.

- **In which product is the HRTP (High Resolution Temperature Profile) stored?**

  The HRTP is stored in the High Resolution Temperature MDS of the Level2 temperature and atmospheric constituent product (see section 2.2.3.3.1). In the same MDS is also stored the High Resolution density profile. The output frequency of the High Resolution profiles is 40Hz, corresponding to 20 values for each spectrometer measurement of 0.5s. No High Resolution profile is calculated in bright limb condition.

- **What is the meaning of the quality flags and how to use them?**

  For several quantities, flag values are stored in Product Confidence Data (PCD). They provide indications on the configuration and the performance at several stages of the retrieval. The meaning of the possible PCD values for the different datasets of the products is detailed in Appendix A.

  For the local density species MDS and the tangent line density species MDS stored in the Level2 products, the PCD provides information about the validity of the outputs of the spectral and the vertical inversion, for the following species and in the listed order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO. Only values of data sets with PCD equal to 0 (non-flagged values) should be used (see also section 3.3.3).

- **Why is it possible to get negative non-flagged values of local density and of tangent line density in the products?**

  In the current operational version of the processor (IPF 5.00), negative column densities and local densities are not systematically flagged anymore (i.e. their PCD value may be equal to 0). The quality flag provided in the PCD summary of products with this processor version is actually a processor flag, indicating if the retrieval has been successful or not. Negative values of line densities after the spectral inversion may be kept, and non-flagged negative values (i.e. with PCD value equal to 0) may be included in the vertical profiles. Filtering out all the negative non-flagged values may yield an artificial positive bias in statistical averages computed from a specific dataset. It is recommended instead to apply complementary selection criteria based on the "standard deviation" values stored in the products.

- **Where are the error bars on the species local density and tangent line density stored?**

  The error estimates of the density values are stored in the local species density MDS and in the tangent line species density MDS, in the Level2 temperature and atmospheric constituent products. They are given in % of the density value and correspond to 1σ. The maximum error bar for the species local density and tangent line density is set to 6553.5. An empirical error estimate has been added after inversion to the error bar of O_3 line densities, of NO_3 line densities and of aerosol extinction coefficient to account for the effects of turbulence (uncorrected scintillation). No modelling error is included in the overall error budget.

- **Which criteria should be applied to select the best quality data?**

  The accuracy of the local density vertical profiles depends on the star characteristics and on the occultation geometry. Depending on the retrieved species and on the altitude range, it is recommended to apply criteria on the star effective temperature, on the star visual magnitude, on the occultation obliquity, and on the illumination condition. Those criteria are detailed in sections 3.3.1, 3.3.2, and 3.3.3 of this document.

- **Where are the star ID and its characteristics stored?**

  The star ID, along with the star visual magnitude and the star effective temperature, is stored in the SPH of the Level1b and of the Level 2 products.

- **In which products is stored the illumination condition of the occultation?**

  The illumination condition of the occultation is stored in the Summary Quality GADS of the Level 1b products and of the Level 2 atmospheric constituents products and residual extinction products (see sections 2.2.3.2 and 2.2.3.3). The meaning of the illumination condition is stated in table Table 3.1. The illumination condition is not given in the meteo products; however, it may be determined by using the solar zenith angle of the tangent point, the solar zenith angle of the satellite, and the altitude of the tangent point given in the geolocation ADS, and by applying the requirements detailed in table Table 3.1

- **How is the occultation obliquity defined and where is it stored?**

  The occultation obliquity is defined as the angle between the motion of the line of sight (with respect to the atmosphere) and the direction of the Earth's centre. The altitude chosen to calculate the obliquity is fixed to 35 km for any occultation. For a purely vertical occultation (field-of-view inside the orbital plane), the obliquity is equal to 0°. For an occultation with a field-of-view outside the orbital plane, the obliquity takes larger values. The obliquity quantity is actually called "verticality" in the products: "verticality" values close to 0 correspond to occultations close to the vertical, while high values of the "verticality" correspond to oblique occultations

  The verticality of occultation is stored in the Summary Quality GADS of the Level2 temperature and atmospheric constituent product and of the Level2 residual extinction product (see sections 2.2.3.3.1 and 2.2.3.3.2).

- **Where to get the orbit in the products?**

  The orbit of the satellite corresponding to the measurement is given in the product name, as described in the presentation of the product name convention (see section 2.2.1). It is also given in the MPH of the products (see section 2.2.2).

4 Other sources of information

4.1 Reference documents

GOMOS Level 1b Detailed Processing Model, Issue 6, rev. 3, PO-RS-ACR-GS-0002

GOMOS Level 2 Detailed Processing Model, Issue 3, rev. 2, PO-RS-ACR-GS-0001

GOMOS Input/Output Data Definition, Issue 6, rev. 1, ref. PO-RS-ACR-GS-0003

GOMOS Algorithm Theoretical Basis Document, version 2.0, edited by E. Kyrölä and L. Blanot, 2007.

Formulation of disclaimer for GOMOS Level1b and Level2 products, Issue 3, rev. 2, ref. PO-TN-ACR-GS-1003

GOMOS Products Toolbox, User's manual, Issue 2, rev. 0, ACRI-ST, 2003

ENVISAT-1 products specifications, Issue 3, rev. 1, ref. PO-RS-MDA-GS-2009, 2005

GOMOS Geometry Library User Guide, Issue 3, rev. 0, ref. PO-MA-ACR-GS-0007

GOMOS Assumptions on the Ground Segment, PO-RS-DOR-SY-0029, Issue 1

GOSS - Description of sub-models (DSM), Issue 5, rev. 0, ref. PO-RS-ACR-SY-003

Envisat-1 Ground Segment Concept, Issue 5, rev.3, September 1994, ref. ESA/PB-EO(94)24

Explanatory supplement to the astronomical almanac, Edited by P.Kenneth Seidelmann, US Naval Observatory - Washington D.C., 1992

Extension of the MSIS thermosphere model into the middle and lower atmosphere, A. E. Hedin, JGR, vol.96, A2, pp. 1159-1172, 1991

ECMWF - PDS Interface, PO-RP-ESA-GS-00622, Issue 1, April 18, 1997

A fast procedure for calculating minimum cross-validation cubic smoothing splines, M.F. Hutchinson, CSIRO Division of Mathematics and Statistics

Guidelines for the specification of ground processing algorithms, Issue 1, PO-RS-ESA-GS-0252

OAD Standards: Time and Coordinate Systems for ESOC Flight Dynamics Operations, Issue 1, May 94, ESOC

4.2 Other technical reports by members of GOMOS SAG, ESL and QWG

4.2.1 Level1b processing

Background separation algorithms, J.L. Bertaux, ref. PO-TN-SA-GS-0001

Specification for the stellar spectra databank, J.L. Bertaux, ref. PO-TN-SA-GS-0006

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4.4.12 Assimilation of GOMOS products

The Msdol Project: Assimilation Of Gomos Ozone Data In A 3-D Chemistry-Transport Model, Bertaux J.L., A. Hauchecorne, A. Mangin, C. Cot, B. Théodore, O. Talagrand, D. Fussen, P.C. Simon, E. Kyrölä, H. Roscoe, O. Hembise, and G.P. Brasseur , COSPAR, 1998.

The Msdol Project: Assimilation Of Gomos Ozone Data In A 3-D Chemistry-Transport Model, Bertaux J.L., A.Hauchecorne, A.Mangin, C.Cot , B.Théodore, O.Talagrand, D.Fussen, P.C.Simon, E. Kyrölä, H. Roscoe, O. Hembise, and G.P. Brasseur, *Phys. Chem. Earth, Vol. 24, N°5, 435-437*, 1999.

Assimilation of simulated GOMOS data of vertical ozone profiles in a 3-D chemistry-dynamics-transport model in the frame of MSDOL project, Hauchecorne, A., B. Théodore, J.L Bertaux., C. Cot, C. Deniel, A. Mangin, G. Bérenger, O. Hembise, O. Talagrand, D. Fussen, E. Kyröla, S. Hassinen, J. Damski, Vuorikatu, H. Roscoe. and G. P. Brasseur, Proceedings of European Symposium on Atmospheric Measurements from Space (ESAMS), ESA-ESTEC, Noordwijk, The Netherlands, 18-22 January 1999, ESA WPP-161, Vol 1, 309-313.

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Validation of ENVISAT ozone products through assimilation in a CTM: first results obtained with GOMOS, AO 160 - OZVAL: GOMOS instrument CAL/VAL review, Théodore, B., M. Guirlet, A. Hauchecorne, O. Hembise, and A. Mangin, ENVISAT Validation Review, ESRIN, 2002.

4.5 GOMOS-related ESA web pages

Presentation of the instrument:
http://envisat.esa.int/instruments/gomos/

GOMOS products specification:
http://earth.esa.int/pub/ESA_DOC/ENVISAT/Vol10_Gomos_3i.pdf

Maps of planned occultation per week:
http://earth.esa.int/pcs/envisat/gomos/planning_maps/

GOMOS performance reports (daily and monthly reports):
http://earth.esa.int/pcs/envisat/gomos/reports/

List of ENVISAT Cal/Val reports:
http://earth.esa.int/pcs/envisat/calval_res/

List of GOMOS-related publications on the ESA web site:
http://earth.esa.int/pcs/envisat/gomos/articles/

5 Glossary

5.1 Conventions and definitions

5.1.1 Instrument components and processing definitions

Wavelength assignment	This is the wavelength assignment of the centre of each pixel, for each transmission measurement (it may change during one occultation due to imperfect tracking of the

	star). The algorithms to retrieve the species concentration from the GOMOS measurements need a good accuracy of the spectral assignment of the star spectra samples.
Reference star spectrum	Several star spectra measured outside the atmosphere are used to computed an averaged spectrum (diminution of the noise). Inside the atmosphere, the star spectra are divided by this reference spectrum to obtain the transmission.
Reference atmospheric profile	A reference atmospheric profile is used to complete the GOMOS atmospheric profile (under and above the extreme altitudes covered by the GOMOS measurements) in the Level 2 processing.
Full transmission spectra and covariance	Main product of the Level 1b processing, the transmission and covariance spectra are computed from the star spectra measured by the GOMOS instrument, after several stages of corrections and conversions. The Level 2 processing will use these transmissions to retrieve the species concentrations.
Central background estimate and error	GOMOS measures the signal coming from both star and partly illuminated atmosphere. Two of the GOMOS bands (upper and lower bands) are used to compute an estimation of the background signal included in the central band. This quantity is subtracted from the band samples to get only the signal due to the star. The maximum error bar for the central background estimate is forced to 6500%.
Photometers data and error	Fast photometers are used to estimate the high frequency variations of the amplitude of the star photonic flux, especially in the low layers of the atmosphere. These variations may also be used in the level 1b processing during the flat-field correction of the star signal. They are also needed to correct the transmission from scintillation at the beginning of the level 2 processing. The time delay between the signal of the two photometers is also used to derive the High Resolution Temperature Profile.
SATU data	Signal coming from the SATU at a frequency of 100 Hz. This information is used to locate the star spectra on the CCD arrays during each spectrometer measurement. This information is crucial for the flat-field correction of the star spectra. The SATU information is provided as deviation angles (deg) in both X and Y directions.
SFA angle	These measurements provide information related to the pointing direction of the GOMOS telescope during the

measurements	spectrometer measurements (at 10 Hz, i.e. 5 times per measurement). They are expressed in degrees.
Wavelength assignment of the spectra	Actually, this is the spectra shift between the effective spectral assignment of the transmission and covariance spectra written in the product and the nominal wavelength assignment. If the transmission spectra have been resampled on the nominal spectral grid, then all these vectors are equal to 0 (this is the default processing mode).
Geolocation and error	A good location of the tangent point is important to affect the species concentrations on the Earth. A specific algorithm included in the Level 1b processing is dedicated to this task. Longitude, latitude and altitude are provided.
Upper and Lower Background Spectra and error	Spectra measured by GOMOS at the same time as it measures the star spectra. These additional information could be used to estimate the dark charge at the beginning of the occultation (as this is only possible in full dark limb conditions, this function is not activated in the processor) and to estimate the contribution of the limb signal in the central/target band if the observation has been performed in straylight, twilight or bright limb conditions. The maximum error bar for the upper and lower background spectra is forced to 255%.
Bad pixel	A list of bad pixels is included in the Calibration auxiliary product. These pixels present a very high dark charge or a very poor quantum efficiency. In both cases, their S/N is poor. Any CCD column flagged for containing one bad pixel is not used in the GOMOS ground processing.
Dark charge	Electrons are generated in the GOMOS spectrometer CCD arrays due to thermal effects. These electrons must be estimated in order to correct the measured spectra. Several options are available in the ground processing, based on on-ground characterisation dark charge maps or on an estimation based on the first measurements of the occultations (see the dark charge correction step in the Level 1b processing). Since the Cal/Val phase, one specific occultation is performed every orbit, in full dark limb condition, the instrument looking at a so-called "dark sky area" (or DSA), where no input flux is expected at the entrance of the instrument. The measurements of this occultation are used to estimate a dark charge map, valid for all occultations of the same orbit.
Non uniformity	Each CCD pixel has its own radiometric sensitivity, due to physical variations from one pixel to the other (material,

	size...). As the star spectrum is moving in front of the CCD due to pointing instabilities, the response of the instrument depends on which pixels the star flux is falling. The estimation of the star movement combined with the knowledge of the pixel response non uniformity (PRNU) allows to correct the star spectra from this effect.
Illumination condition PCD	This is the actual illumination of the observation, computed from geometrical configuration between the Sun, the satellite and the GOMOS instrument pointing direction. 0: full dark limb condition 1: bright limb condition 2: pure twilight condition 3: straylight condition 4: twilight+straylight condition This flag is not dependent on the dark/bright limb flag that is read in the Level 0 product; as this latter comes from the mission scenario and may not fully reflect the actual observation conditions.
Occultation obliquity	The occultation obliquity is defined as the angle between the motion of the line of sight (with respect to the atmosphere) and the direction of the Earth's centre. The altitude chosen to calculate the obliquity is fixed to 35 km for any occultation. The obliquity varies in the same direction as the azimuth direction of the line-of-sight. For a purely vertical occultation with a field-of-view inside the orbital plane (azimuth value equal to 0°), the obliquity is equal to 0°. For an occultation with a field-of-view outside the orbital plane (larger azimuth values), the obliquity takes larger values. For a tangent occultation, the altitude of 35 km may be never reached, and in that case, the obliquity is arbitrarily fixed to 90°. This quantity is actually called "verticality" in the products.
Apparent altitude	Several altitude definitions are used for the processing of GOMOS measurements. The apparent altitude is the tangent altitude computed with a virtual straight ray directed toward the virtual star direction, while the tangent altitude is the one computed for the real ray path i.e. including refractive effects. The definition of these altitudes, along with the different ray geometries (with no atmospheric refraction effects or with atmospheric refraction effects) is illustrated in Figure 5.1. Star spectra are given for tangent altitude heights, while limb spectra are given for apparent altitude heights.

Depending on the final use of the data, different ray geometries, star directions and altitudes are defined for the geometry and the processing of GOMOS measurements.

The **nominal star direction** is the direction as it is outside the atmosphere,

The **virtual star direction** is affected by the refraction effects (so a few mdeg above the previous one),

The **apparent altitude (1)** , h_b, is the tangent altitude computed with a virtual straight ray directed toward the virtual star direction,

The **direct altitude** is the tangent altitude of a straight ray directed toward the nominal star direction.

Except when specified, the **tangent altitude,** h_0, is the one computed for the real ray path i.e. including refractive effects.

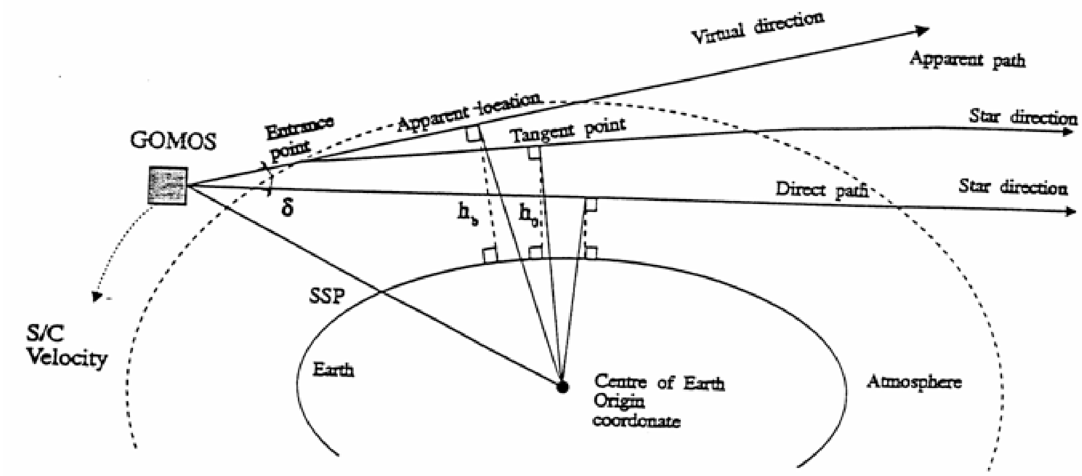

Figure 5.1: Ray geometries and illustration of the different altitudes.

5.1.2 Product types and structure

5.1.2.1 Types of products by processing level

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1 In order to determine the apparent geolocation, (including in particular the apparent altitude h_b (b=L,C,U) used in the central background estimation algorithms, and written in the limb product), the star displacement in the SATU and its relation with the spectrometers reference frames have to be taken into account in order to avoid wrong allocation of measurements.

Level 0	The Level0 products are build from the source packets products by GOMOS. Actually, The level 0 product contains Annotated Instrument Source Packets (AISP). These are Instrument Source Packets as received from the instrument, with a small header attached by the Front End Processor (FEP). The packets contain the three band measurements, the photometer data, the SATU and SFA data for one or several occultations. Nominally, there should be one product per orbit (consolidated products) or a mix of two consecutive orbits (NRT products).
Level 1b	The Level1b products are generated from the Level 0 products by the Level 1b processing. There are two types of Level 1b products: the geolocated and calibrated transmission spectra products (Level1b transmission products), containing the full transmission and the covariance spectra needed for the Level2 processing; and the geolocated and calibrated background spectra limb products (Level 1b limb products), containing the background spectra measured by the two external bands of the CCD spectrometers. Each Level 1b product corresponds to one occultation.
Level 2	The Level2 products are generated from the Level 1b products by the Level 2 processing. There are three types of Level 2 products: the Level 2 atmospheric and constituent profile products which are the main outputs of the Level 2 processing; the Level 2 residual extinction products containing the spectral transmission corrected for scintillation and dilution effects and a result of a forward model of the transmission with the "best fit" values of the parameters; and the Level 2 meteo products containing selected vertical profiles processed in Near Real Time. Each Level 2 product corresponds to one occultation.

5.1.2.2 Structure of the products

MPH (Main Product Header)	contains information on the main characteristics of the product. Its size and its structure are fixed and are common to all ENVISAT instruments. It is in ASCII format.
SPH (Specific Product Header)	contains information specific to the product itself. This information is described in the DSD of the SPH. Its size and its structure are fixed for a specific product. It is in ASCII format.
DSD (Data Set Descriptor)	points to and describes the DS contained in the product. There is one DSD per DS. May also provide references

	to external files relevant to the current product.
DS (Data Set)	composed of one or more DS Records, in an ASCII-binary mixed format. The DS may be MDS or ADS.
GADS (Global Annotation Data Set)	contains auxiliary data relevant to the product (nominal wavelength assignment, reference star spectrum, LUT, …). A GADS is made of only one DS Record.
ADS (Annotation Data Set)	contains auxiliary data applicable to one measurement. Made of one or several DSR.
MDS (Measurement Data Set)	contains measurements and/or processed data. Made of one or several DSR.

5.1.3 Content of the products

5.1.3.1 General common fields to all products

SPH descriptor	ASCII string describing the product.
Start time	start time of the measurements included in the MDSR. Expressed in Julian Date 2000.
Attachment flag	flag indicating if MDSRs are attached to the current ADSR 1: no corresponding MDSRs 0: there are corresponding MSDRs In the case of GOMOS, the attachment flag is always set to 0, indicating that a MDSR is attached to the ADSR.
Data Quality indicator	indicator of the quality of the data included in the MDSR -1: blank MDSR 0: data are available and valid In the case of GOMOS, the attachment flag is always set to 0, indicating that the MDSR is not empty (as there is no empty MDSR in the GOMOS products).
Creation time	creation time of the data set record. Usually inserted at the beginning of the DSRs corresponding to calibration data. Expressed in Julian Date 2000 (transport format).
Spare	dummy bytes.

5.1.3.2 Level 1b product

5.1.3.2.1 Definitions related to the SPH and the DS

Definitions related to the SPH

Definitions related to the SPH	
Start time of the occultation	Starting time of the first acquisition of the occultation.
Time of the end of the occultation	Ending time of the last acquisition of the occultation.
Latitude and longitude of the tangent point at the start time	Location of the tangent point at the starting time of the occultation. Positive latitudes are North; positive longitudes are East. Computed during the geolocation process. Provided for the reference wavelength, which is equal to 500 nm.
Latitude and longitude of the tangent point at the stop time	Location of the tangent point at the ending time of the occultation. Positive latitudes are North; positive longitudes are East. Computed during the geolocation process. Provided for the reference wavelength, which is equal to 500 nm.
Occultation duration	Duration of the occultation expressed in seconds. Computed during the datation process.
Sampling duration	Nominal value is 0.5 second.
Number of measurements	Number of acquisitions performed during the occultation. This number is computed when the GOMOS packets are read from the Level 0 product.
Status of the instrument	The Redundancy Definition vector and the Instrument Configuration fields are used to determine in which mode the GOMOS instrument was during the measurements. These two fields are read in the Source Data Field Header of the first valid packet of the occultation. Status is set to 0 if the instrument is in extended mode i.e. if: • Bit 12 of the Redundancy Definition vector set to 1 • Bit 13 of the Redundancy Definition vector set to 0 • Bit 14 and 15 of the Instrument Configuration set to 1 • Bit 4 and 5 of the Instrument Configuration set to 0 and status is set to 1 in another configuration
Occultation number in the orbit	This information is provided by the Source Data Packet extraction processing.
Star name and associated information	These information are read from the star catalogue auxiliary product once the star identifier of the current occultation has been read in the GOMOS packets.
Star identifier in the star catalogue	Star identifier read in the Source Data Field Header of the first valid packet of the occultation.

Definitions related to the SPH	
Star direction in the quasi-true of date frame (Cartesian)	Star direction computed in the geolocation processing.
Dark/bright limb flag	Flag read in the GOMOS packets. A value of 0 means that the electronic gain settings of the instrument has been set to optimise the measurement of the star signal (this is usually called dark limb settings), while a value of 1 means that the gain settings has been set in order to perform the observation assuming some limb signal (this is usually called bright limb settings). Note that this value is defined in the mission planning and, although it is generally in line with the actual illumination conditions, it may not reflect the actual illumination conditions. The real illumination condition is given by the illumination condition PCD and is computed from the sun zenith angle at both the instrument and the tangent point locations.

Definitions related to GADS	
Summary quality	The meaning of the possible flag values stored in the Summary Quality GADS is detailed in section 5
Number of points of the spectra	The programmable number of transmitted columns per CCD array. The values are read in the GOMOS packets. In the Level 1b product, the data coming from the 4 CCDs are joined together in a single vector. This is true for the transmission and covariance spectra but also for the reference star spectrum, the limb spectra and the wavelength assignment vectors. This parameter must be used to distinguish between the different CCD arrays inside these global vectors. For instance, if this parameter is equal to the current nominal values: [450, 966, 420, 500], it means that in each global vector (e.g. transmission) the 450 first samples belong to the UV CCD (SPA1), the following 966 belong to the VIS CCD (SPA2), the 420 next to the IR1 CCD (SPB1) and the last 500 to the IR2 CCD (SPB2). The total number of transmitted columns is currently equal to 2336.
Number of photometer output data per measurement	This is the number of fast photometer output data per spectrometer measurement. Nominal value is 500. This number will never change during the instrument life.
Number of SATU output data per	This is the number of SATU output data per spectrometer measurement. Nominal value is 50. This number will never

Definitions related to GADS	
measurement	change during the instrument life.
Photometer central wavelength	This is the wavelength corresponding roughly to the middle of the spectral range of each photometer. The nominal values are 499.5 nm for the blue photometer and 672.0 nm for the red one.
Time shift for ray tracing / geolocation	This time indicates the time shift between what is called 'beginning of measurement' and 'half measurement' in the ray tracing processing. Geolocation results are provided at these two times for each measurement.
Spectrometer effective sampling time	Actual duration of one spectrometer measurement. Nominal value is 0.4999639 second. This is a constant value.
Reference wavelength for the ray tracing	All the geolocation information is provided for this reference wavelength. For example the localisation of the ray nodes and of the tangent point node are provided for this wavelength although at one given time inside the atmosphere, and due to chromatic refraction effects, each wavelength is looking at a different altitude. It is also the reference wavelength for the aerosol products. It is equal to 500 nm.
Radiometric sensitivity curve (background)	This curve has been built from the radiometric sensitivity of the instrument measured during its on-ground characterisation and updated in-flight. It allows the conversion of the background spectra expressed in electrons in the product into physical units (ph/s/cm2/nm/sr). It is given as **a LUT of conversion factors.** A linear interpolation of the conversion factor is needed to use this curve for any sample of the background spectra.
Radiometric sensitivity curve (star)	This curve has been built from the radiometric sensitivity of the instrument measured during its on-ground characterisation and updated in-flight. It allows the conversion of the star spectra expressed in electrons in the product into physical units (ph/s/cm2/nm). It is given as **a LUT of conversion factors.** A linear interpolation of the conversion factor is needed to use this curve for any sample of the star spectrum.
Thermistor temperature (SP and FP)	Thermistor temperature read from the GOMOS packets and converted into degrees using a conversion LUT calibrated on-ground. This temperature is used to adjust the dark charge map to the actual temperature. The actual thermistor temperature are transmitted once per occultation, in the first packet. The coding accuracy of the

Definitions related to GADS	
	thermistor temperature is roughly 0.4°.
Spectrometer dark charge at band level used for the dark charge correction	Dark charge at band level for each of the 3 bands (upper, central and lower) and for each of the transmitted CCD column.
Mean dark charge for the spectrometers	The mean dark charge level over the CCD array, expressed in electrons. This mean dark charge is assumed to be constant during all the occultation. It is provided in this order: SPA1 upper, target and lower bands, SPA2 upper, target and lower bands, then SPB1 and SPB2.
Mean dark charge for the photometers	The mean dark charge level over the CCD array, expressed in electrons. This mean dark charge is assumed to be constant during all the occultation. It is provided in this order: FP1, FP2.
Offset between thermistor and CCD arrays temperature	Offsets directly read from the Calibration auxiliary product. These offsets may be used to estimate the CCD temperature. They are currently not used in the Level 1b processing which uses directly the thermistor temperature.
Sun coordinates in the geocentric equatorial inertial system	The Sun coordinates are provided for the middle of the first measurement only.
Nominal wavelength assignment	Nominal wavelength assignment of the transmission and covariance spectra written in this product. The limb spectra can be directly associated with this spectral assignment because they are not affected by pointing errors. The spectral assignment of the transmission and covariance must take the spectral shift parameter into account. This quantity, provided for each measurement, must be added to the nominal wavelength assignment to obtain the effective wavelength assignment of each spectrum. Note that if the spectrum resampling process has been performed on the nominal spectral grid, then the effective wavelength assignment is identical to the nominal assignment (in this case, the spectral shift is equal to 0 for all the measurements in the product). The nominal wavelength assignment is a global vector. The nominal wavelength assignment of the CCD columns of each spectrometer CCD array is coded in the Level 1b product on 32 bits with an accuracy of 1.e-6 nm. The spectra provided in the Level 1b product are always in increasing spectral order CCD per CCD whatever the original spectral orientation of the CCD is (for example, the

Definitions related to GADS	
	samples of the VIS CCD (SPA2) are re-ordered). There may be configurations where there is a spectral overlap between the UV and the VIS CCDs. In this case, the global vector is not in increasing order.
Effective number of star spectra used for the computation of the reference star spectrum	This is the number of star spectra that have been averaged to obtain the reference star spectrum. A maximum number of spectra is allowed as well as a minimum altitude of the tangent point to be sure that the observation is actually outside the atmosphere.
Reference star spectrum	The reference star spectrum is computed by averaging several star spectra outside the atmosphere at the beginning of the occultation. The current nominal value is 10 spectra. Note that the 2 first spectra (see the PCD at measurement level) are not used for pointing instability reason. It is given in electrons and must be converted into physical units (ph/s/cm2/nm) by multiplying the electron values by the conversion factor inferred from the radiometric sensitivity curve (star) provided as a LUT.
Reference atmospheric density profile	These variables fully describe the reference density profile used during the ray tracing computation. • Size of the reference atmospheric profile • First altitude of the profile • Altitude discretisation • Reference atmospheric density profile The reference atmospheric density profile is computed in the Atmosphere preparation process.

Definitions related to DS	
Full transmission spectra and associated covariance	The transmission spectra are computed as the ratio of each measured star spectrum by the reference star spectrum, computed from star spectra measured outside the atmosphere. It is said full because it is the actually measured transmission, not corrected, neither from refraction effects (dilution, scintillation, chromatic refraction) nor from the dynamic PSF. The covariance (here, in fact, the variance of each pixel signal) is computed from analysis of S/N ratio. There is one transmission spectrum and one covariance spectrum per spectrometer measurement. The transmission and covariance spectra are global vectors (see the "Number of points of the spectra" field).

<table>
<tr><th colspan="2">Definitions related to DS</th></tr>
<tr><td>Scaled estimated central background</td><td>Estimation of the background signal measured by the target band. The estimated central background spectra values are coded on 16 bits. Due to the high variations of these spectra with the altitude, the coding is dynamic and uses an offset and a gain for each measurement. The offset and the gain are stored in the Auxiliary data ADS of the product. For each measurement, the offset is computed as the minimum value of the spectrum to store (f_{min}) and the gain is computed as $65535/(f_{max}-f_{min})$ where f_{min} (resp. f_{max}) is the minimum (resp. the maximum) value of the spectrum for the current measurement.

Note that the background spectra are divided by the PRNU correction factor before being scaled.

The following table presents the accuracy (in number of electrons) for several ranges of background spectra:

<table>
<tr><th>Range (in e)</th><th>Accuracy (LSB)</th></tr>
<tr><td>100</td><td>< 0.1 e-</td></tr>
<tr><td>1000</td><td>< 0.1 e-</td></tr>
<tr><td>10000</td><td>0.2 e-</td></tr>
<tr><td>30000</td><td>0.5 e-</td></tr>
<tr><td>100000</td><td>1.5 e-</td></tr>
<tr><td>300000</td><td>4.6 e-</td></tr>
<tr><td>500000</td><td>7.6 e-</td></tr>
<tr><td>1000000</td><td>15.0 e-</td></tr>
</table>

To decode the value read in the product, one must compute: Background (in electrons) = Offset + Background Code / Gain

The decoded spectra values obtained in electrons must then be converted into physical units (ph/s/cm2/nm/sr) by multiplying them by the conversion factor inferred from the radiometric sensitivity curve (star) provided as a LUT.</td></tr>
<tr><td>Error bar for the estimated central background</td><td>The error bars for the estimated central background data are computed as the shot noise of the background signal and expressed in relative percentage. The maximum error bar is set to 6500%.</td></tr>
</table>

Definitions related to DS	

	for each measurement f = 1, f_{size}
	for each CCD column: k = 1, k_{size}
	if ($\hat{N}_k^B(f)$ #0) then
	$\delta N_k^B(f) = \frac{100}{\sqrt{\lvert \hat{N}_k^B(f) \rvert}}$
	else
	$\delta N_k^B(f) = 0.$
	endif
	/* truncate the error to 6500 percent (coding limit) */
	if ($\delta N_k^B(f)$ > 6500.) $\delta N_k^B(f)$ = 6500.
	end for k
	end for f
	
	Where f_{size} is the number of spectrometer measurements and k_{size} is the total number of transmitted pixels (global vectors)
	
	They are stored in the product in 16 bits. They represent the relative percentage of error for each estimated central value. This coding allows an accuracy of at least 0.1 percent.

Photometers engineering data	Fast photometer samples converted into electrons and corrected from dark charge, straylight, background contribution and flat-field.
Error bar for the photometers engineering data	The error bar vector (50 elements) is made of 25 couples of (mean value, standard deviation) of the photometer shot noise. For each spectrometer measurement, 500 photometer samples are available. They are split into 25 sets. For each set, the mean value of the measurement shot noise and its standard deviation (based on 20 samples) are computed and are written in the product.
PCD at sample level (SP)	The meaning of the possible PCD values for the spectrometers stored in this MDS is detailed in section 5.1.3.2.2
PCD at sample level (FP)	The meaning of the possible PCD values for the photometers stored in this MDS is detailed in section 5.1.3.2.2
SATU mispointing angles	SATU data read from the Level 0 products and converted into angles (X and Y directions).
SFA angles measurements	SFA data read from the Level 0 products and converted into angles (azimuth and elevation).
Spectral shift of the star spectra	This quantity, provided for each measurement, must be added to the nominal wavelength assignment to obtain the effective wavelength assignment of each spectrum. Note that if the

Definitions related to DS	
	spectrum resampling process has been performed on the nominal spectral grid, then the effective wavelength assignment is identical to the nominal assignment (in this situation, the spectral shift is equal to 0 for all the measurements of the product).
Offset and gain for the background spectra coding	For each measurement, the offset is computed as the minimum value of the background spectrum to store (f_{min}) and the gain is computed as 65535/(f_{max}-f_{min}) where f_{min} (resp. f_{max}) is the minimum (resp. the maximum) value of the background spectrum for the current measurement. This offset and this gain must be used to decode the values of the background spectra written in the product for both before and after straylight and vignetting corrections. To decode the value read in the product, one must compute: Background (in electrons) = Offset + Background Code / Gain There is one couple of gain and offset values per spectrometer measurement.
PCD at measurement level	The meaning of the possible flag values stored in this ADS is detailed in section 5.1.3.2.4.
Latitude, longitude and altitude of the spacecraft	Spacecraft location computed during the geolocation processing. These quantities are provided at the beginning and during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). The altitude is expressed in meters.
Latitude, longitude and altitude of the tangent point and associated errors	Tangent point location and associated errors computed during the geolocation processing. They are given for the reference wavelength for ray tracing computation (equal to 500 nm and given in the Occultation data GADS). These quantities are provided at the beginning and during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). The altitude is expressed in meters.
Distance spacecraft - tangent point	Distance between the satellite and the tangent point computed during the geolocation processing. It is given for the reference wavelength for ray tracing computation (equal to 500 nm and given in the Occultation data GADS). This quantity is provided at the beginning and during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).The distance is expressed in meters.
Instrument pointing direction	Instrument pointing direction (azimuth and elevation) in the GOMOS frame. These values are computed in the geolocation process and do not use the SFA angles but only the

Definitions related to DS	
	geometrical characteristics of the measurements: satellite and star location, GOMOS frame definition, orbit properties.
Virtual star direction in the quasi-true of date frame	Virtual star direction in the quasi-true of date frame provided at the beginning and during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).
Number of nodes of the ray tracing	The ray path is computed during the ray tracing / geolocation process. The ray is made from 3 nodes outside the atmosphere up to 150 nodes inside. If more than 150 nodes have been necessary during the processing, the ray path is resampled in order to reduce the number of nodes. This field indicates how many values are significant in the following arrays.
Index of the tangent point in the list of the ray tracing node	Index of the tangent point in the list of the ray tracing node. There is one index per spectrometer measurement (i.e. per ray tracing). This index must be used to locate the tangent point information in the ray tracing output arrays.
Interpolation factors P and Q for the law delta (lambda)	These factors may be used to compute the chromatic deviation for a specified wavelength as: deviation expressed in radians is equal to Q+P*EDLEN(λ) where EDLEN is the Edlen's function, with λ expressed in nm: $$a(\lambda) = \left(83.4213 + \frac{24060.3}{130 - \frac{10^6}{\lambda^2}} + \frac{159.97}{38.9 - \frac{10^6}{\lambda^2}}\right)\frac{10^{-6}}{1.00062}$$ where the factor 1.00062 stands for temperature and pressure correction. These parameters are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).
Interpolation factors P and Q for the law h_0 (lambda)	These factors may be used to compute the tangent point altitude at any wavelength in the spectral range of the spectrometers. The altitude expressed in meters is equal to Q+P*EDLEN(λ) where EDLEN is the Edlen's function described above.
Latitude, longitude and altitude of the ray tracing grid nodes	Location of the ray path nodes computed during the geolocation process. The tangent point is always included in these nodes. These parameters are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).
Air density and atmospheric pressure at the tangent point	These values are given only for the tangent point. They are computed from the ECMWF data and MSIS90 model. The air density is expressed in cm^{-3} and the atmospheric pressure is expressed in Pa. They are provided during the measurement,

Definitions related to DS	
	generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).
Air temperature at the ray tracing grid nodes	Air temperature at the ray path nodes computed by using the data from the ECMWF data and MSIS90 model. The tangent point is always included in these nodes. These values are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).
Sun-zenith angle at the spacecraft location	Angle computed at the middle of each spectrometer acquisition
Sun-zenith angle at the tangent point location	Angle computed at the middle of each spectrometer acquisition
Sun-azimuth angle at the tangent point location	Angle computed at the middle of each spectrometer acquisition
Apparent altitude of the central background	Altitude computed at the middle of each spectrometer acquisition

5.1.3.2.2 PCD and flags: PCD at Sample Level (SP)

The flags at sample level set during the Level 1b processing are combined together in a 16-bits integer before being written in the Level 1b transmission product (corresponding field in the transmission MDS) and in the limb product (corresponding field in the MDS). The way this combination is done is described in the following table.

Bit #	Flag name	Comments
0	$FL_{sat}(k,L,f)$	saturation flag for the lower band (0: no saturation, 1: saturation)
1	$FL_{sat}(k,C,f)$	saturation flag for the central band (0: no saturation, 1: saturation)
2	$FL_{sat}(k,U,f)$	saturation flag for the upper band (0: no saturation, 1: saturation)
3	$FL_{bad}(k,L)$	bad pixel flag for the lower band (0: no bad pixel in the band, 1: at least one bad pixel in the band)
4	$FL_{bad}(k,C)$	bad pixel flag for the central band (0: no bad pixel in the band, 1: at least one bad

Bit #	Flag name	Comments
		pixel in the band)
5	$FL_{bad}(k,U)$	bad pixel flag for the upper band (0: no bad pixel in the band, 1: at least one bad pixel in the band)
6	$FL_{cr}(k,L,f)$	cosmic ray flag for the lower band (0: no cosmic ray detected in the data, 1: cosmic ray has been detected in the data)
7	$FL_{cr}(k,C,f)$	cosmic ray flag for the central band (0: no cosmic ray detected in the data, 1: cosmic ray has been detected in the data)
8	$FL_{cr}(k,U,f)$	cosmic ray flag for the upper band (0: no cosmic ray detected in the data, 1: cosmic ray has been detected in the data)
9-10	$FL_{bg}(k,f)$	from the spectrometers central background estimation processing 0: central background is computed with no flagged samples 1: less than 25 percent of flagged samples 2: less than 50 percent of flagged samples 3: more than 50 percent of flagged samples
11-12	$FL_{ft}(k,f)$	from the transmission and covariance computations processing 0: no problem identified 1: reference star spectrum value is zero 2: one of the spatial band is saturated
13	$FL_{off}(k)$	from the wavelength assignment processing 0: pixel is in a valid spectral range 1: pixel is in an invalid spectral range
14	$FL_{rsp}(k,f)$	from the reference star spectrum and transmission computation processings 0: no problem 1: current data computed with flagged data
15		Not used

Note: bit 0 is the lowest significant bit of the byte (bits are counted from right).

5.1.3.2.3 PCD and Flags:PCD at Sample Level (FP)

As for the spectrometer flags at sample level, the photometer flags at sample level are combined together in a 16-bits integer before being written in the Level 1b product (corresponding field in the transmission MDS). The way this combination is done is described in the following table.

Bit #	Flag name	Comments
0	$FL_{sat}^{FP}(fc,f,fp)$	photometers saturation flags (0: no saturation, 1: saturation)
1-15		Not used

Note: bit 0 is the lowest significant bit of the byte (bits are counted from right).

5.1.3.2.4 PCD and Flags:PCD at measurement level

Each flag is affected to a whole spectrometer measurement i.e. gives global information concerning all the spatial bands, all the CCD columns of the spectrometers and all the photometer samples during the measurement. There are two kinds of flags at measurement level: the first set is made of flags explicitly set at measurement level such as the data valid flag (read in the GOMOS packets), the flags indicating if SATU outputs have been used for correction or if the star spectrum was outside the central band ... The second set of flags is built from the flags at sample level and can be seen as a flag summary at measurement level.

The PCD at measurement level are written in the auxiliary data ADS of the Level 1b transmission product and in the ADS of the Level 1b limb product.

Flags explicitly set at measurement level:

Variable	Description	Range - References
$FLAG_{DV}(f)$	data valid flag (measurement level)	from the SDP extraction processing 0: anomaly 1: time-out 3: fully successful 9: missing packet
$FLAG_{time}(f)$	datation flag	from the datation processing 0: no datation problem 1: problem in the datation processing 2: invalid measurement ($FLAG_{DV}(f)$=0 or 1) 9: missing packet
$FLAG_{rt}(f)$	ray-tracing flag	from the geolocation processing 0: no problem 1: wrong pointing (not in the direction of the atmosphere) 2: ray path across the Earth

Variable	Description	Range - References
$FLAG_{gl}(f)$	geolocation flag	from the geolocation processing 0: no problem 1: geolocation problem
$FLAG_{irv}(f)$	vignetting correction flag	from the spectrometers vignetting correction processing 0: no vignetting 1: vignetting occurs for this measurement
$FLAG_{out}(f)$	indicates if the star spectrum falls outside the central band during the measurement	from the star spectrum computation 0: star spectrum is inside the central band 1: centre line of star spectrum image is outside the central band
	indicates the number of fast photometers saturation during the spectrometer measurement	from the photometers saturated samples processing fc: FP1, FP2
$FLAG_{stab}(f)$	indicates instable measurements	The number of instable measurements at the beginning of the occultation (f_{stab}) is read from the Calibration auxiliary product. For all measurements before f_{stab} (including it), $FLAG_{stab}(f)$ is set to 1 and for all following measurements $FLAG_{stab}(f)$ is set to 0.
$FLAG_{mod}(f)$	modulation correction flag	from the spectrometer demodulation processing 0: no problem +1: problem of structure for SPA1 upper band +2: problem of structure for SPA1 lower band +4. inconsistent upper and lower band structures for SPA1 +10: problem of structure for SPA2 upper band +20: problem of structure for SPA2 lower band +40. inconsistent upper and lower band structures for SPA2 Note that the flag values between SPA1 and SPA2 may be mixed, ie flag values like 11, 21, 32, 23, 41, 24

Variable	Description	Range - References
		can exist
$FLAG_{UC}(f)$	ratio between the averaged upper band signal and the averaged star signal over the SPA2 spectral range	from the star spectrum computation n<65535: computed ratio expressed in % 65535: star signal is equal to 0

Note: FLAGDV(f) and FLAGDB are read in the GOMOS packets. They are not generated by the Level 1b processing.

Flags at measurement level computed from flags at sample level:

The following flags at measurement level are computed as the sum over the number of CCD columns of the corresponding flags at sample level.

Variable	Description	Range - References
$FLAG_{sat}(f)$	number of saturated samples per measurement	from the spectrometers saturated samples processing
$FLAG_{cr}(f)$	number of cosmic ray detections per measurement	from the spectrometers cosmic rays detection processing
$FLAG_{bg}(f)$	number of background flagged data per measurement	from the estimated central background processing
$FLAG_{ft}(f)$	number of samples per measurement for which $FL_{ft}(k,f)$ has been raised	from the transmission and covariance computations processing
$FLAG_{sum}(f)$	PCD at measurement level (summary)	16 integer values - filled with the various flags at each measurement (see next table); written in the Level 1b and Limb products

For each spectrometer measurement, each component of the working array $FLAG_{sum}(f)$ (16 integer values) is set to one of the flags at measurement level as shown in the following table. The array $FLAG_{sum}(f)$ is written in each Auxiliary data ADSR of the Level 1b and Limb products.

The order of the flags is described in the table below.

Array index	Flag name	Comments
$FLAG_{sum}(f)(1)$	$FLAG_{DV}(f)$	data valid flag

Array index	Flag name	Comments
$FLAG_{sum}$(f)(2)		not used
$FLAG_{sum}$(f)(3)	$FLAG_{time}$(f)	datation flag
$FLAG_{sum}$(f)(4)	$FLAG_{rt}$(f)	ray-tracing flag
$FLAG_{sum}$(f)(5)	$FLAG_{gl}$(f)	geolocation flag
$FLAG_{sum}$(f)(6)	$FLAG_{sat}$(f)	saturation flag (SP)
$FLAG_{sum}$(f)(7)	$FLAG_{cr}$(f)	cosmic ray flag
$FLAG_{sum}$(f)(8)	$FLAG_{irv}$(f)	vignetting flag
$FLAG_{sum}$(f)(9)	$FLAG_{bg}$(f)	background flag
$FLAG_{sum}$(f)(10)	$FLAG_{out}$(f)	star spectrum out of band
$FLAG_{sum}$(f)(11)	$FLAG_{ft}$(f)	transmission flag
$FLAG_{sum}$(f)(12)	$FLAG_{sat}^{FP}(1,f)$	saturation flag (FP1)
$FLAG_{sum}$(f)(13)	$FLAG_{sat}^{FP}(2,f)$	saturation flag (FP2)
$FLAG_{sum}$(f)(14)	f_{stab}	stability flag
$FLAG_{sum}$(f)(15)	not used	set to 0
$FLAG_{sum}$(f)(16)	not used	set to 0

5.1.3.2.5 PCD and Flags: PCD at occultation level

Each flag characterises the whole occultation. There are three kinds of flags at occultation level:

- the first set is made of flags explicitly set **at occultation level** (e.g. dark/bright limb flag, star reference spectrum fatal flag...).
- the second set of flags is built from the flags **at measurement level** (e.g. saturated samples, cosmic rays...) and can be seen as a flag summary.
- the third set of flags is built from **flags at sample level** (e.g. samples containing bad pixels).

Flags explicitly set at occultation level:

Variable	Description	Range - References
PCD_{ist}	PCD for internal straylight correction processing	from the internal straylight correction processing 0: the internal straylight correction has been applied 1: the internal straylight correction has not been applied

Variable	Description	Range - References
PCD_{earth}	PCD for external earth straylight correction processing	from the external straylight correction processing 0: the external earth straylight correction has been applied 1: the external earth straylight correction has not been applied
PCD_{sun}	PCD for external sun straylight correction processing	from the external straylight correction processing 0: the external sun straylight correction has been applied 1: the external sun straylight correction has not been applied
PCD_{slit}	PCD for slit transmission correction processing	from the slit transmission correction processing 0: the slit transmission correction has been applied 1: the slit transmission correction has not been applied
PCD_{ref}	PCD indicating that the reference star spectrum is computed with a small number of star spectra	from the reference star spectrum computation processing 0: no problem 1: the reference star spectrum has been computed with a small number of measurements 2: no valid measurements in the occultation to compute the reference star spectrum (see PCD_{sbd} and PCD_{fatal})
PCD_{sdb}	PCD indicating if the star spectrum has been read in the Stellar Spectra Database	from the reference star spectrum computation processing 0: the reference star spectrum is computed from the measurements 1: the reference star spectrum is read in the Stellar spectra database 2: the reference star spectrum has not been found in the Stellar spectra database (see PCD_{fatal})
PCD_{fatal}	PCD indicating that the reference star spectrum has not been computed	from the reference star spectrum computation processing 0: the reference star spectrum has been computed 1: the reference star spectrum has not been computed (no transmission computed)

Variable	Description	Range - References
PCD_{SATU}	PCD indicating that the SATU data are used for flat-field correction	from the Level 1b processing configuration database (same value as OK_{SATU}) 0: the SATU data are not used 1: the SATU data are used
PCD_{lv0}	PCD read from the Level 0 product	from the SDP extraction processing 0: standard occultation 1: first part of a tangent occultation 2: last part of a tangent occultation
PCD_{atm}	PCD for atmosphere file	from the preparation of the Atmosphere model 54: one ECMWF file used. Time record is included in the occultation period. 102: one ECMWF file used. Time record before the beginning of the occultation ($\Delta t \leq 24h$). 103: one ECMWF file used. Time record after the beginning of the occultation ($\Delta t \leq 24h$). 106: one ECMWF file used. Only one time record in the validity interval ($\Delta t \leq 24h$). 155: two ECMWF files used. 201: no ECMWF file available. Use MSIS model alone. 202: only old ECMWF files ($\Delta t > 24h$). Use MSIS model alone. 203: only future ECMWF files ($\Delta t > 24h$). Use MSIS model alone. 206: no ECMWF file available in the validity interval ($\Delta t > 24h$). Use MSIS model alone. In case of no convergence of the ray tracing, the PCD_{atm} flag is increased by 10. Example, an initial value of 106 of PCD_{atm} will be actually set to 116 in case of no convergence.
PCD_{dc}	PCD for dark charge correction	from the dark charge correction processing indicates the dark charge correction processing applied and if problems have occurred

Variable	Description	Range - References
		0: dark charge map used 1: first measurements used 2: no dark charge correction applied 11: first measurements not available - DC correction with DC maps 12: first measurements not available and missing 1st packet - DC correction with DC maps without temperature dependence 21: dark charge map computed from DSA observation has been used
ok_{back}	Background correction activation switch	from the level 1b processing configuration or modified by the background correction processing. indicates which background correction has been effectively performed. Note that in full dark limb condition, no correction is applied to SPA samples, whatever the value of the activation switch read from the level 1b processing configuration. 0: no correction 1: background correction applied (linear interpolation) 2: background correction applied (exponential interpolation) 3: background correction applied (general method)

Flags at occultation level for the photometers:

Variable	Description	Range - References
PCD_{dc}^{FP}	PCD for dark charge correction of the photometers samples	from the photometers dark charge correction indicates the dark charge correction processing applied (0:DC correction performed; 1:no DC correction)
PCD_{sat}^{FP}	PCD for saturation: number of photometers saturated samples	from the photometers bad pixels processing

Flags at occultation level computed from flags at measurement level:

The following flags at occultation level are computed as the sum over the number of measurements of the corresponding measurement flags.

Variable	Description	Range - References
PCD_{fvalid}	No valid data flag	set to 1 if $PCD_{DV} = f_{size}$ set to 0 otherwise
N_{err}	Number of source packets containing errors	from the SDP extraction processing number of invalid or missing measurement
PCD_{DB}	PCD for dark/bright limb conditions	from the SDP extraction processing 0: dark limb 1: bright limb
PCD_{illum}	Observation illumination condition	from the geolocation processing. This is the actual illumination of the observation, computed from geometrical configuration between the Sun, the satellite and the GOMOS instrument pointing direction. 0: full dark limb condition 1: bright limb condition 2: pure twilight condition 3: straylight condition 4: twilight+straylight condition This flag is not dependent on the dark/bright limb flag that is read in the Level 0 product; as this latter comes from the mission scenario and may not fully reflect the actual observation conditions.
PCD_{DV}	PCD of the SDP extraction processing	from the SDP extraction processing number of invalid or missing measurements
PCD_{time}	PCD for datation: indicates the number of measurements where flags have been raised	from the datation processing
PCD_{rt}	PCD for ray tracing: indicates the number of measurements with invalid ray path	from the geolocation processing
PCD_{gl}	PCD for geolocation: indicates the number of measurements performed	from the geolocation processing note: set to 1000 if the occultation is completely performed outside the

Variable	Description	Range - References
	outside the atmosphere	atmosphere
PCD_{sat}	PCD for saturation: indicates the number of measurements containing saturated samples	from the spectrometers saturated samples processing number of measurements where saturated samples have been detected
PCD_{cr}	PCD for cosmic rays: indicates the number of measurements where cosmic rays has been detected	from the cosmic rays detection processing number of measurements where cosmic rays have been detected
PCD_{mod}	PCD for modulation correction processing	from the modulation correction processing number of measurements where the modulation correction has not been applied
PCD_{irv}	PCD for vignetting correction processing	from the vignetting processing number of measurements where the vignetting correction has been applied
PCD_{bg}	PCD of the central background computation	from the estimated central background processing number of measurements where $FLAG_{bg}(f)$ has been raised
PCD_{out}	PCD for flat-field correction: indicates the number of measurements where the star falls outside the central band	from the star signal computation processing number of measurements where part of the star spectrum is outside the central band
PCD_{ft}	PCD indicating that a problem has occurred during the computation of the transmission or of the covariance	from the transmission and covariance computations processing number of measurements where a problem has been detected during the full transmission computation

Flags at occultation level computed from flags at sample level:

The following flags at occultation level are computed as the sum over the number of CCD columns of the corresponding flags at sample level.

Variable	Description	Range - References
PCD_{bad}	PCD for bad pixels	from the spectrometers bad pixels processing number of bad pixels (same value for

		all the measurements)

The PCDs at occultation level are written in the Summary quality GADS of the Level 1b transmission products, of the Level 1b limb products, of the Level 2 atmospheric constituents products, and of the Level 2 residual extinction products.

5.1.3.3 Limb product

Most of the fields included in the limb product are also included in the GOMOS level 1b products. Only the different fields are explained in the table below. For the other fields, please refer to the previous level 1b description chapter.

Definitions related to DS	
Summary quality	The meaning of the possible flag values stored in the Summary Quality GADS is detailed in section 5.1.3.2.1
Radiometric sensitivity curve (background)	This curve has been built from the radiometric sensitivity of the instrument measured during its on-ground characterisation and updated in-flight. It allows the conversion of the background spectra expressed in electrons in the product into physical units (ph/s/cm2/nm/sr). It is given as a LUT of conversion factors. A linear interpolation of the conversion factor is needed to use this curve for any sample of the background spectra.
Scaled upper & lower background spectra without straylight correction	Estimation of the background signal measured by the upper and lower bands before applying the straylight and the IR-vignetting corrections. The estimated background spectra values are coded on 16 bits. Due to the high variations of these spectra with the altitude, the coding is dynamic and uses an offset and a gain for each measurement. The offset and the gain are stored in the Auxiliary data ADS of the product. For each measurement, the offset is computed as the minimum value of the spectrum to store (f_{min}) and the gain is computed as 65535/(f_{max}-f_{min}) where f_{min} (resp. f_{max}) is the minimum (resp. the maximum) value of the spectrum for the current measurement. To decode the values read in the product, one must compute: Background (in electrons) = Offset + Background Code / Gain Note that the background signal is divided by the average PRNU map before being scaled. The following table presents the accuracy (in number of electrons) for several ranges of background spectra:

<table>
<tr><th colspan="2">Definitions related to DS</th></tr>
<tr><td></td><td>
<table>
<tr><th>Range (in e)</th><th>Accuracy (LSB)</th></tr>
<tr><td>100</td><td>< 0.1 e-</td></tr>
<tr><td>1000</td><td>< 0.1 e-</td></tr>
<tr><td>10000</td><td>0.2 e-</td></tr>
<tr><td>30000</td><td>0.5 e-</td></tr>
<tr><td>100000</td><td>1.5 e-</td></tr>
<tr><td>300000</td><td>4.6 e-</td></tr>
<tr><td>500000</td><td>7.6 e-</td></tr>
<tr><td>1000000</td><td>15.0 e-</td></tr>
</table>
The decoded spectra values obtained in electrons must then be converted into physical units (ph/s/cm2/nm/sr) by multiplying them by the conversion factor inferred from the radiometric sensitivity curve (star) provided as a LUT.
</td></tr>
<tr><td>Scaled upper & lower background spectra after straylight and IR vignetting corrections</td><td>
Estimation of the background signal measured by the upper and lower bands after applying the straylight and IR-vignetting corrections. The estimated background spectra values are coded on 16 bits. Due to the high variations of these spectra with the altitude, the coding is dynamic and uses an offset and a gain for each measurement. The offset and the gain are stored in the Auxiliary data ADS of the product. For each measurement, the offset is computed as the minimum value of the spectrum to store (f_{min}) and the gain is computed as $65535/(f_{max}-f_{min})$ where f_{min} (resp. f_{max}) is the minimum (resp. the maximum) value of the spectrum for the current measurement. To decode the values read in the product, one must compute: Background (in electrons) = Offset + Background Code / Gain
Note that the background signal is divided by the average PRNU map before being scaled.
The following table presents the accuracy (in number of electrons) for several ranges of background spectra:
</td></tr>
</table>

Definitions related to DS

Range (in e)	Accuracy (LSB)
100	< 0.1 e-
1000	< 0.1 e-
10000	0.2 e-
30000	0.5 e-
100000	1.5 e-
300000	4.6 e-
500000	7.6 e-
1000000	15.0 e-

The decoded spectra values obtained in electrons must then be converted into physical units (ph/s/cm2/nm/sr) by multiplying them by the conversion factor inferred from the radiometric sensitivity curve (star) provided as a LUT.

Error bar for the upper & lower background spectra after straylight and IR vignetting corrections

The error bars for the upper and lower background spectra after straylight and vignetting corrections are computed as their square root and are expressed as a relative percentage. The maximum error bar for the upper and lower background spectra is set to 255%.

for each measurement f = 1, f_{size}
for each CCD column: k = 1, k_{size}
if ($N^{NST}_{k,b}(f)$ #0) then

$$\delta N^{NST}_{k,b}(f) = \frac{100}{\sqrt{|N^{NST}_{k,b}(f)|}}$$

else

$$\delta N^{NST}_{k,b}(f) = 0.$$

endif
/* truncate the error to 255 percent (coding limit) */
if ($\delta N^{NST}_{k,b}(f)$ > 255.) $\delta N^{NST}_{k,b}(f)$ = 255.
end for k
end for f

Where f_{size} is the number of spectrometer measurements and k_{size} is the total number of transmitted pixels (global

Definitions related to DS	
	vectors)
PCD at sample level	The meaning of the possible PCD values stored in this MDS is detailed in section 5.1.3.2.2.
Offset and gain for the background spectra coding	For each measurement, the offset is computed as the minimum value of the background spectrum to store (f_{min}) and the gain is computed as 65535/(f_{max}-f_{min}) where f_{min} (resp. f_{max}) is the minimum (resp. the maximum) value of the background spectrum for the current measurement. This offset and this gain must be used to decode the value of the background spectra written in the product for both before and after straylight and vignetting corrections. To decode the value read in the product, one must compute: Background (in electrons) = Offset + Background Code / Gain There is one couple of gain and offset values per spectrometer measurement.
PCD at measurement level	The meaning of the possible PCD values stored in this MDS is detailed in section 5.1.3.2.4.

5.1.3.4 Level 2 product

Definitions related to GADS	
Summary Quality	The meaning of the possible flag values stored in the Summary Quality GADS is detailed in section 3.3.2.
Level 1b PCD check	This PCD is initialised when the Level 1b product is read, following the logic: First of all, read the summary quality GADS in the Level 1b product: C1 : no valid data test if PCD_{fvalid}=1 (field 1 of the GADS) C2 : second part of a tangent occultation test if PCD_{lv0}=2 (field 12 of the GADS) C3 : geolocation is not valid test if PCD_{gl}=1000 (field 20 of the GADS) C4 : reference star spectra missing, i.e. transmission terms not valid for the whole occultation test if PCD_{fatal}>0 (field 8 of the GADS) Initialise PCD_{lv1}=0 If C1 is true set PCD_{lv1} to 1

Definitions related to GADS	
	If C2 is true set PCD_{lv1} to 2 If C3 is true set PCD_{lv1} to 3 If C4 is true set PCD_{lv1} to 4
Chromatic refraction mode for the measured transmission	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. The possible values are: 0 : no correction 1 : correction is performed
Chromatic refraction mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: no correction 1: correction is performed
Chromatic refraction mode for the transmission model (third and further spectral inversions)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: no correction 1: correction is performed
Instrument function mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: no correction 1: correction is performed
First altitude where the ratio U/C is greater than 25%	This value is computed from the PCD at measurement level provided in the Level 1b product (see Section 2.1.1.1.3). It is specified in km, truncated to the nearest integer value. If the ratio is lower than 25% at all altitudes, this altitude is set to 0.
Vertical inversion mode	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. The possible values are: 2: linear (only one mode is available in the processor)
Smoothing mode (after the spectral	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Smooth or not the density column used by the vertical

Definitions related to GADS	
inversion)	inversion. If the smooth mode is not activated only the flagged value of the density column are filled. 0: no smoothing 1: Gaussian filter 2: Tikhonov's regularisation
Time mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the database value: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: zero order term 1: second order term
Time mode for the transmission model (third and further spectral inversions)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the database value: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: zero order term 1: second order term
Number of iterations for the main loop (also called q loop)	Number of main loop iterations actually performed.
Number of iterations for the inversion loop (also called p loop)	Number of inversion loop iterations actually performed.
Number of points in profile column densities where chi2 > chi2_warn	chi2_warn is a parameter read in the Level 2 processing configuration auxiliary product (LUT versus altitude).
Number of flagged points in profile for the column densities	Number of points where the corresponding PCD (tangent line density PCD) is not equal to 0.
Number of flagged points in profile for the local densities	Number of points where the corresponding PCD (local density PCD) is not equal to 0.

Definitions related to DS	
Local density product	This is the result of the vertical inversion of line densities,

Definitions related to DS	
	assuming local spherical symmetry. The local density of each species is expressed in cm-3. One value is provided for each measurement. The datation and the geolocation of each point of the local density profile is also provided in the product.
Standard deviation of the local density product	Errors are estimated throughout the processing chain and are propagated along the chain to the final data products. It is assumed that the error statistics follow a normal Gaussian distribution. Values given correspond to 1σ. The error bar associated with the local density of the different species is expressed in % of the local density. The maximum value of the error bar is set to 6553.5%.
PCD summary (for the local density profiles)	The PCD summary contains flags dedicated to the validity of the outputs of the vertical inversion, i.e. the retrieval of the local density profiles. After vertical inversion, local densities are checked for flag setting. There is one flag per acquisition and per species: parameter PCDV(i,j), where index j denotes the acquisition number, and index i denotes the species among the following species list in this order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO.
Tangent line density	Tangent line density of each species (expressed in cm^{-2}). One value is provided for each measurement. The tangent line density profiles are computed during the spectral inversion process.
Standard deviation for the tangent line density	Errors are estimated throughout the processing chain and are propagated along the chain to the final data products. It is assumed that the error statistics follow a normal Gaussian distribution. Values given correspond to 1σ. With the current operational processor (IPF 5.00), an empirical error estimate has been added after inversion to the error bar of O_3 line densities to account for the effects of turbulence (incomplete scintillation correction). The error bar associated with the tangent line density of the different species is expressed in % of the tangent line density. The maximum value of the error bar is set to 6553.5%.
PCD summary (for the tangent line density profiles)	The PCD summary contains flags dedicated to the validity of the outputs of the spectral inversion, i.e. the retrieval of the tangent line density profiles. After spectral inversion, tangent line densities are checked for flag setting. There is one flag per acquisition and per species: parameter PCDV(i,j), where index j denotes the acquisition number, and index i denotes the species among the following species list in this order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO.

Definitions related to DS	
Aerosol product	The wavelength dependence of aerosol extinction may vary, even over one occultation. A polynomial expression is used to describe this wavelength dependence of the aerosol extinction; for a polynomial in degree n: $\beta(z,\lambda) = d_0(z) + d_1(z)(\lambda - \lambda_{ref}) + d_2(z)(\lambda - \lambda_{ref})^2 + \ldots + d_n(z)(\lambda - \lambda_{ref})^n$ For each measured transmission, it is calculated: o the extinction coefficient at the reference wavelength λ_{ref}, corresponding to d_0, given in km^{-1} o the other spectral parameters corresponding to the coefficients $d_1(z)$ to $d_n(z)$ in the polynomial expression, given in $nm^{-1}.km^{-1}$, …, $nm^{-n}.km^{-1}$ The reference wavelength value is stored in the SPH of the product ("Reference wavelength used for the ray tracing"); it is equal to 500 nm. It is also given in the SPH of the residual extinction product and in the Occultation data GADS of the Level 1b product. The extinction coefficient at $\lambda = \lambda_{ref}$ is given in the dedicated MDSR "Extinction coefficient at $\lambda = \lambda_{ref}$" and as the first spectral parameter of the MDS "Spectral parameters of the extinction coefficients". In the case of a polynomial in degree 2 as in the current operational processor (IPF 5.00), two other coefficients are given in the MDS "Spectral parameters of the extinction coefficients": d_1 ($nm^{-1}.km^{-1}$) and d_2 ($nm^{-2}.km^{-1}$). The wavelength dependence of the aerosol optical thickness may be described as: $\tau(\lambda) = \sigma_{ref}(r_0 + r_1(\lambda - \lambda_{ref}) + r_2(\lambda - \lambda_{ref})^2 + \ldots + r_n(\lambda - \lambda_{ref})^n)$ The MDS "Tangent integration extinction profile at $\lambda = \lambda_{ref}$" stores the value τ calculated at $\lambda = \lambda_{ref}$ (dimensionless). The MDS "Spectral parameters of tangent integrated extinction profile" stores the coefficients r_0 to r_n, retrieved by the spectral inversion processing; r_0 is the integrated retrieved density column of aerosols given in cm^{-2}; the

Definitions related to DS	
	other parameters r_1 to r_n are given in $cm^{-2}.nm^{-1}$, … $cm^{-2}.nm^{-n}$. In the case of a polynomial in degree 2 as in the current operational processor (IPF 5.00), three coefficients are stored: r_0 (dimensionless), r_1 ($cm^{-2}.nm^{-1}$) and r_2 ($cm^{-2}.nm^{-2}$).
Extinction coefficient	The extinction coefficient is given at the reference wavelength, in km^{-1}. The reference wavelength is given in the SPH of the product and in the Occultation data GADS of the Level 1b product; it is equal to 500 nm.
Standard deviation of the extinction coefficient	The values of the standard deviation are expressed in % and correspond to 1σ. An empirical error estimate has been added after inversion to account for the effects of turbulence (incomplete scintillation correction).
Spectral parameters of the extinction coefficients	Coefficients of the polynomial expression used to describe the wavelength dependence of the aerosol extinction. The first spectral parameter is the extinction coefficient at the reference wavelength, given in km^{-1}; for a polynomial in second degree, two other parameters are given, in $nm^{-1}.km^{-1}$ and in $nm^{-2}.km^{-1}$ respectively.
Standard deviation of the spectral parameters of the extinction coefficients	The values of the standard deviation are expressed in % and correspond to 1σ.
Tangent integrated extinction profile	The tangent integrated extinction (aerosol optical thickness, dimensionless) profile is given at the reference wavelength. The reference wavelength is given in the SPH of the product and in the Occultation data GADS of the Level 1b product; it is equal to 500 nm.
Standard deviation of the tangent integrated extinction profile	The values of the standard deviation are expressed in % and correspond to 1σ.
Spectral parameters of the tangent integrated extinction profile	Coefficients of the polynomial expression used to describe the wavelength dependence of the aerosol optical thickness. The first spectral parameter is the integrated retrieved density column of aerosols given in cm^{-2}; for a polynomial in second degree, two other parameters are given, in $cm^{-2}.nm^{-1}$ and $cm^{-2}.nm^{-2}$ respectively.
Standard deviation of the spectral parameters of the tangent integrated extinction profile	The values of the standard deviation of the polynomial coefficients of the tangent integrated extinction profile are expressed in % and correspond to 1σ.

Definitions related to DS	
PCD summary	The PCD summary provides the spectral and vertical PCD (first and seventh values) of the extinction coefficient at the reference wavelength; the other values are set to 0.
Turbulence product	From the analysis of fast photometers, the tangent altitude of LOS, and the temperature and density vertical profiles at High Resolution (40 Hz) are retrieved. They are basically derived from the time delay between the peaks of red and blue Fast Photometers, when the time delay between the two photometer signal is significant enough to be analysed. There is no high resolution profiles when the occultation is made in bright limb.
Tangent altitude including fluctuations	Altitude of the high resolution temperature profile.
High resolution temperature vertical profile	High resolution T vertical profile obtained by analysis of the photometer signals. The output frequency of the HRTP is 40Hz. This corresponds to 20 values for each processed measurement during the Level 2 processing (frequency 2Hz). There is no high resolution temperature profile when the occultation is made in bright limb or if the time delay between the two photometer signals is not significant enough to be analysed.
Error bar of the high resolution temperature profile	The values of the error bar are expressed in % and correspond to 1σ. The maximum error bar is set to 6500%.
High resolution vertical profile of the local density	High resolution vertical profile of air local density obtained by analysis of the photometer signals. The output frequency of the HRTP is 40Hz. This corresponds to 20 values for each processed measurement during the Level 2 processing (frequency 2Hz). There is no high resolution air density profile when the occultation is made in bright limb or if the time delay between the two photometer signals is not significant enough to be analysed.
Error bar of the high resolution density profile	The values of the error bar are expressed in % and correspond to 1σ. The maximum error bar is set to 6500%.
Geolocation and atmospheric profile	Geolocation data are the same as for Level 1b and are also provided for the reference wavelength (equal to 500 nm).
Latitude, longitude and altitude of the spacecraft	Spacecraft location read from the Level 1b product. These quantities are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing).The altitude is expressed in meters.

Definitions related to DS	
Latitude, longitude and altitude of the tangent point and associated errors	Tangent point location and associated errors read from the Level 1b product. These quantities are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). The altitude is expressed in meters.
Tangent point atmospheric pressure (from external model)	Pressure profile obtained by the combination of the ECMWF data in the lower part of the profile and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa). The values of the profile are read in the Level 1b product. The values are given in Pa. They are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). *Note: if the ECMWF file is not available for the Level 1b processing, only the MSIS90 model is used. In this case, a specific flag is raised during the Level 1b processing and copied in the Level 2 product.*
Tangent point temperature (from external model)	Temperature profile obtained by the combination of the ECMWF data in the lower part of the profile and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa). The values are given in K. They are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). *Note: if the ECMWF file is not available for the Level 1b processing, only the MSIS90 model is used. In this case, a specific flag is raised during the Level 1b processing and copied in the Level 2 product.*
Tangent point density (from external model)	Air density obtained by the combination of the ECMWF data in the lower part of the profile and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa). The values are given in cm^{-3}. They are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). *Note: if the ECMWF file is not available for the Level 1b processing, only the MSIS90 model is used. In this case, a specific flag is raised during the Level 1b processing and copied in the Level 2 product.*
Local air density from GOMOS atmospheric profile	Local air density profile computed from the measurements. In the current operational IPF version (IPF 5.00), the vertical inversion on air is not activated, and the local density values, the standard deviation and the vertical

Definitions related to DS	
	resolution for this species are set to 0 in the products (as well as the terms related to air in the covariance matrix for local densities after the vertical inversion).
Standard deviation for the local air density	The values of the error bar are expressed in % and correspond to 1σ. The maximum error bar is set to 6553.5%. In the current operational IPF version (IPF5.00), all values are set to the maximum error bar.
Local temperature	Local temperature profile computed from the measurements. In the current operational IPF version (IPF 5.00), the profile values are all set to 0.
Standard deviation for the local temperature	The values of the error bar are expressed in % and correspond to 1σ. The maximum error bar is set to 6553.5%. In the current operational IPF version (IPF5.00), all values are set to the maximum error bar.
Accuracy estimate product	For the spectral inversion, the χ^2 (final best fit) is given. The 12 x 12 covariance matrix (symmetrical) is given, corresponding to the 6 gas species, 5 aerosol parameters and one spare (influence of one gas on the others). For the vertical inversion the covariance matrix is also given (influence of one altitude on the other). A scale factor is applied on the covariance matrix terms before recording.
Chi-2 final value	χ^2 final value from the spectrometer A spectral inversion.
Scale factor for the elements of the covariance matrix (spectral/vertical inversion)	The scale factor is the power of 10 to be applied to the associated covariance matrix elements in order to store/read them in the product. More details are given in the text below.
Covariance matrix for line densities after spectral inversion	The covariance matrix for the spectral inversion provides information on the influence of each gas on the others. It is a 12 x 12 matrix whose terms are in the following order: O_3, NO_2, NO_3, air, OClO, aerosols (a maximum of 6 parameters for aerosol spectral dependency) and a spare gas. The matrix is symmetrical: only half of the matrix (78 values) is written in the product. More details on the storage of these values are given in the text below.
Covariance matrix for local densities after vertical inversion	The covariance matrix for the vertical inversion provides information on the influence of each altitude on the other. It is symmetrical. 12 species are given in the following order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO, aerosols and 4 spare gases. Only the diagonal terms and 6 off-diagonal terms are given in the product, as a 12 x 7 matrix for each

Definitions related to DS	
	acquisition. More details on the storage of these values are given in the text below.

The scale factor for the elements of the covariance matrix DS gives the power of 10 to be applied to the covariance matrix elements read in the product in order to interpret them (same value for all species):

$$V = V_p \times 10^{fact}$$

where:

V: the covariance matrix element calculated in the Level2 processing

V_p: the scaled covariance matrix element read in the product

fact: the scale factor read in the product.

The covariance matrix for spectral inversion is a 12 x 12 matrix whose terms $[A_{x,y}]$ are in the following order: O_3, NO_2, NO_3, air, OClO, aerosols (a maximum of 6 parameters), and a spare gas. This matrix is symmetrical, only the relevant part (78 terms) is written in the product; that is:

For x=1,12

write $A(x,y)=C_{Sli,i',j}$ $y \geq x$, with the species i and i' being those provided by the order x and y defined above

End For

The covariance matrix for vertical inversion is, by construction, symmetrical. Only the diagonal + 6 off diagonal terms are written in the product. 12 species are considered in the following order: O_3, NO_2, NO_3, air, O_2, H_2O, OClO, aerosols and 4 spare gases. Thus, a matrix 12 x 7 (noted B hereafter) is written in the product for each acquisition.

The procedure for the creation of this part of the Level 2 product is the following:

- One row is used for each species
- For each species (row), the diagonal element of the original covariance matrix is written in the last column.
- elements taken from the left of the diagonal in the original matrix are written in the first six columns
- An exception is made for the first 6 acquisitions, where less than 6 elements are available on the left.

For these first 6 acquisitions, the elements are taken instead from the right of the diagonal in the original matrix and are inserted into the matrix B in the first six columns, but in reverse order (so that the elements closest to the diagonal in the original are also closest in the matrix B).

This procedure is more explicitly described below:

For the current acquisition j

if (j>6) then

for i = 1,12

B (i,7+p) = $C_{VIi,j,j+p}$ with p = -6 to 0

end for

else

for i = 1,12

B (i,7-p) = $C_{VIi,j,j+p}$ with p = 6 to 0

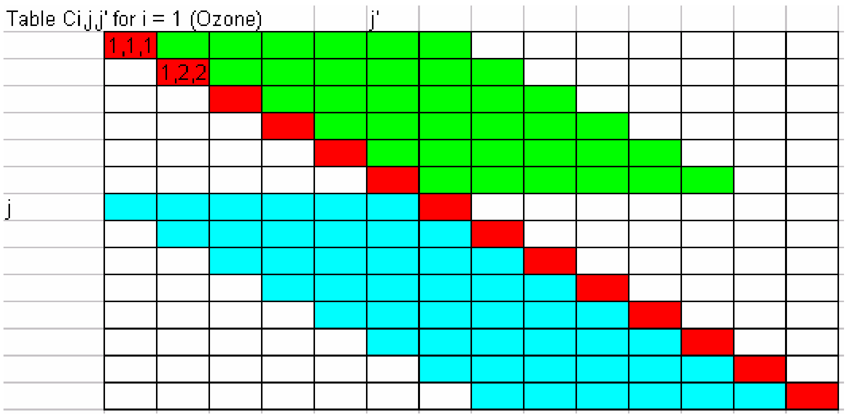
end for

end if

Note 1 : for all spare gases (or non retrieved species), B(i,7-p)=0 with p=6 to 0

Note 2 : the scaling is applied to the matrix term prior to this recording

Explicit illustration is given on the following pictures:



B(i,,j') for j=1

1,1,7	1,1,6	1,1,5	1,1,4	1,1,3	1,1,2	1,1,1
						2,1,1

B(i,,j') for j = 14

1,14,8	1,14,9	1,14,10	1,14,11	1,14,12	1,14,13	1,14,14
						2,14,14

5.1.3.5 Residual extinction product

Definitions related to the SPH	
Number of processed measurements during the Level 2 processing	This is the actual number of measurements included in the product. This number is always lower than the total number of measurements of the occultation (read in the Level 1b product). It may be smaller if problem occurred (e.g. invalid data at the beginning of the occultation).
Reference wavelength used for the ray tracing	All the geolocation information is provided for this reference wavelength. For example the localisation of the ray nodes and of the tangent point node are provided for this wavelength although at one given time inside the atmosphere, and due to chromatic refraction effects, each wavelength is looking at a different altitude. It is also the reference wavelength for the aerosol products. It is equal to 500 nm.
Time shift for the ray tracing / geolocation	This time indicates the time shift between what is called 'beginning of measurement' and 'half measurement' in the ray tracing processing. Geolocation results are provided at these two times for each measurement (actual value read from the Level 1b product)
Mean wavelength of the photometer used for the scintillation correction	Value computed from the photometer spectral range and index of the photometer used for the scintillation correction.

Note: most of the SPH fields are identical to those of the Level 1b product and are not detailed here.

Definitions related to GADS	
Summary quality	The meaning of the possible flag values stored in the Summary Quality GADS is detailed in section 3.3.2.
Level 1b PCD check	This PCD is initialised when the Level 1b product is read, following the logic: First of all, read the summary quality GADS in the Level 1b product: C1 : no valid data test if PCD_{fvalid}=1 (field 1 of the GADS) C2 : second part of a tangent occultation test if PCD_{lv0}=2 (field 12 of the GADS) C3 : geolocation is not valid test if PCD_{gl}=1000 (field 20 of the GADS) C4 : reference star spectra missing, i.e. transmission terms not valid for the whole occultation test if PCD_{fatal}>0 (field 8 of the GADS) Initialise PCD_{lv1}=0 If C1 is true set PCD_{lv1} to 1 If C2 is true set PCD_{lv1} to 2 If C3 is true set PCD_{lv1} to 3 If C4 is true set PCD_{lv1} to 4
Chromatic refraction mode for the measured transmission	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. The possible values are: 0 : no correction 1 : correction is performed
Chromatic refraction mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: no correction 1: correction is performed
Chromatic refraction mode for the transmission model (third and further	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the

Definitions related to GADS	
spectral inversions)	third and subsequent spectral inversions. 0: no correction 1: correction is performed
Instrument function mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the auxiliary product: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: no correction 1: correction is performed
First altitude where the ratio U/C is greater than 25%	This value is computed from the PCD at measurement level provided in the Level1b product (see Section 2.2.3.2). It is specified in km, truncated to the nearest integer value. If the ratio is lower than 25% at all altitudes, this altitude is set to 0.
Vertical inversion mode	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. The possible value is: 2: linear (only one mode is available in the processor)
Smoothing mode (after the spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Smooth or not the density column used by the vertical inversion. If the smooth mode is not activated only the flagged value of the density column are filled. 0: no smoothing 1: Gaussian filter 2: Tikhonov's regularisation
Time mode for the transmission model (second spectral inversion)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the database value: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: zero order term 1: second order term
Time mode for the transmission model (third and further spectral inversions)	Switch read from the Level 2 processing configuration auxiliary product and copied in the Level 2 product. Two numbers are read in the database value: first value is for the second spectral inversion and second value is for the third and subsequent spectral inversions. 0: zero order term 1: second order term

Definitions related to GADS	
Number of iterations for the main loop (also called q loop)	Number of main loop iterations actually performed.
Number of iterations for the inversion loop (also called p loop)	Number of inversion loop iterations actually performed.
Number of points in profile column densities where chi2 > chi2_warn	chi2_warn is a parameter read in the Level 2 processing configuration auxiliary product (LUT versus altitude).
Number of flagged points in profile for the column densities	Number of points where the corresponding PCD (tangent line density PCD) is not equal to 0.
Number of flagged points in profile for the local densities	Number of points where the corresponding PCD (local density PCD) is not equal to 0.
Nominal wavelength assignment	Nominal wavelength assignment read from the Level 1b product and re-ordered in increasing wavelength value. Note that the effective spectral assignment of the transmission spectra written in the product is the combination of the nominal wavelength assignment and of the spectral grid correction.

Definitions related to DS	
Transmission corrected for scintillation and dilution effects	Transmission read in the Level 1b product and corrected from the scintillation and dilution effects.
Transmission model function	The transmission model function is a forward model of the transmission with the "best fit" values of the parameters
Latitude, longitude and altitude of the spacecraft	Spacecraft location read from the Level 1b product. These quantities are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). The altitude is expressed in meters.
Latitude, longitude and altitude of the tangent point and associated errors	Tangent point location and associated errors read from the Level 1b product. These quantities are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). The altitude is expressed in meters.

Definitions related to DS	
Tangent point atmospheric pressure (from external model)	Pressure profile obtained by the combination of the ECMWF data in the lower part of the profile and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa). The values of the profile are read in the Level 1b product. The values are given in Pa. They are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). *Note: if the ECMWF file is not available for the Level 1b processing, only the MSIS90 model is used. In this case, a specific flag is raised during the Level 1b processing and copied in the Level 2 product.*
Tangent point temperature (from external model)	Temperature profile obtained by the combination of the ECMWF data in the lower part of the profile and of the MSIS90 data in the upper part of the profile (smooth transition altitude range around the pressure level 1hPa). The values are given in K. They are provided during the measurement, generally at half-measurement (the actual temporal shift is given by the time shift for the ray tracing). *Note: if the ECMWF file is not available for the Level 1b processing, only the MSIS90 model is used. In this case, a specific flag is raised during the Level 1b processing and copied in the Level 2 product.*
Local air density from GOMOS atmospheric profile	Local air density profile computed from the measurements. In the current operational IPF version (IPF5.00), the vertical inversion on air is not activated, and the local density values are set to 0 in the products.
Spectral grid correction for the transmission model function	This spectral grid is the same as the one stored in the Level 1b product except that it is re-ordered in increasing wavelength (in the spectral overlap between the spectrometers A1 and A2). This quantity is the difference between the reference spectral grid and the actual spectral grid of the transmissions written in this product.

5.1.3.6 Near Real Time meteo product

All fields included in the NRT meteorological products are also included in the GOMOS level 2 products. Please refer to the previous chapter for the explanation of these fields.

5.2 List of abbreviations and acronyms

ACE	Advanced Composition Explorer
ACVT	Atmospheric Chemistry Validation Team
ADF	Auxiliary Data File
ADS	Annotation Data Set
ADSR	Annotation Data Set Record
AISP	Annotated Instrument Source Packet
ANX	Ascending Node Crossing
ARB	Anomaly Review Board
ATBD	Algorithm Theoretical Basis Document
Cal/Val	Calibration/Validation Activities
CCD	Charge Coupled Device
CEOS	Committee on Earth Observation Satellites
DC	Dark Charge
DOAS	Differential Optical Absorption Spectroscopy
DPAC	Data Processing and Archiving Centre
DPM	Detailed Processing Model
DSA	Dark Sky Area
DSD	Data Set Descriptor
DS	Data Set
DSR	Data Set Record
ECMWF	European Centre for Medium-term Weather Forecast
ESA	European Space Agency
ESL	Expert Support Laboratory
ESRIN	European Space Research Institute
FEP	Front End Processor
FMI	Finnish Meteorological Institute
FOV	Field of View
FP	Fast photometers
GADS	Global Annotation Data Set
GDI	Global DOAS Iterative
GOMOS	Global Ozone Monitoring by Occultation of Stars
GOPR	GOMOS prototype
GOSS	GOMOS System Simulator
GS	Ground Segment

HRTP	High Resolution Temperature Profiles
IASB	Institut d'Aéronomie Spatiale de Belgique
ICU	Instrument Control Unit
IDL	Interactive Data Langage
IODD	Input/Output Data Document
IPF	Instrument Processing Facilities
IR	Infra Red
L1b	Level 1b
L2	Level 2
LMA	Levenberg Marquardt Algorithm
LOS	Line of Sight
LSF	Line Spread Function
LUT	Look-Up Table
MDE	Mechanism Drive Electronics
MDS	Measurement Data Set
MDSR	Measurement Data Set Record
MIP	Most Illuminated Pixel
MIPAS	Michelson Interferometer for Passive Atmospheric Sounding
MJD	Modified Julian Day
MJD2000	Modified Julian Day 2000
MPH	Main Product Header
MSIS90	Mass Spectrometer Incoherent Scatter Model (version 90)
NIR	Near Infra-Red
NRT	Near Real Time
OSIRIS	Odin Spectrometer and InfraRed Imager System
PCD	Product Confidence Data
PCF	Product Control Facility
PDS	Payload Data Segment
PRNU	Pixel Response Non-Uniformity
PSF	Point Spread Function
QWG	Quality Working Group
RD	Reference Document
RTS	Random Telegraphic Signal
S/N	Signal to Noise Ratio
SA	Service of Aeronomy

SAA	South Atlantic Anomaly
SAG	Scientific Advisory Group
SATU	Star Acquisition and Tracking Unit
SDP	Spectral Data Points
SFA	Steering Front Assembly
SPA	Spectrometer A (UV: A1; VIS: A2)
SPB	Spectrometer B (IR1 and IR2)
SPH	Specific Product Header
SZA	Solar Zenith Angle
UT	Universal Time
UVVIS	Ultra-Violet - VISible
VCCS	Voice Coil Command Saturation

6 Additional information on GOMOS measurements

6.1 Star catalogue

Table B. 1 provides the list and the characteristics of the stars selected for use by GOMOS measurements. Only the 300 brightest stars are used.

Table B. 1: List of stars in use for GOMOS measurements of occultations, along with their visual magnitude and effective temperature (those stars are the 300 brightest ones).

ID	Name	Mv	T_{eff}	ID	Name	Mv	T_{eff}
1	9Alp CMa	-1.440	11000	151	13Mu Gem	2.89	3000
2	Alp Car	-0.736	7000	152	12Alp2CVn.	2.890	11000
3	16Alp BooIII	-0.050	4250	153	3Bet CMi	2.894	13100
4	Alp1Cen	-0.010	5800	154	22Bet Aqr	2.899	5700
5	3Alp Lyr	0.033	11000	155	41Pi SgrII	2.900	6600
6	13Alp AurIe	0.080	3400	156	20Sig Sco	2.903	28000
7	19Bet Ori	0.1	14000	157	The1Eri	2.906	9300
8	10Alp CMi-V	0.400	6500	158	6Pi Sco.	2.906	28000
9	Alp Erie	0.453	24000	159	Ups Car	2.920	7200
10	Bet CenI	0.610	28000	160	23Gam Per.	2.930	4700
11	53Alp Aql	0.765	8000	161	Tau Pup	2.931	4500
12	Alp1CruIV	0.775	30000	162	34Alp Aqr	2.944	5350

ID	Name	Mv	T_{eff}	ID	Name	Mv	T_{eff}
13	87Alp TauI	0.867	3800	163	7Del Crv	2.945	11000
14	58Alp Orib	0.87	3000	164	44Eta PegII	2.948	5400
15	67Alp VirI-IV	0.976	28000	165	34Gam Eri.	2.950	3200
16	21Alp Scolab-b	1.02	3000	166	17Eps Leo	2.980	6000
17	78Bet GemIb	1.161	4500	167	10Gam2Sgr	2.984	4500
18	24Alp PsA	1.166	9700	168	17Zet Aql	2.986	11000
19	50Alp Cyge	1.246	10500	169	46Gam Hya	2.991	4700
20	Bet CruIV	1.253	30000	170	27Eps Gem	3.000	9700
21	Alp2Cen	1.350	5000	171	2Eps Crv	3.001	4250
22	32Alp Leo	1.360	15200	172	Gam Gru	3.003	13100
23	21Eps CMab	1.502	26000	173	4Bet Tri	3.004	8900
24	66Alp Gem	1.580	10200	174	52Psi UMa	3.004	4400
25	35Lam Sco	1.620	28000	175	39Del Per	3.010	19400
26	Gam CruIII	1.624	2900	176	23Zet Tau	3.02	22000
27	24Gam OriI	1.636	26000	177	1Zet CMa	3.022	26000
28	12Bet TauI	1.650	15200	178	Iot1Sco	3.022	6550
29	Bet Car	1.672	10200	179	24Omi2CMa	3.032	24000
30	46Eps Orib	1.694	30000	180	27Gam Boo	3.040	8000
31	Alp Gru	1.734	15200	181	Bet Mus	3.043	26000
32	77Eps UMa	1.763	11000	182	13Gam UMi	3.047	9700
33	50Zet Orib	1.766	30000	183	7Eps Aur	3.06	7000
34	Gam2Velr	1.793	23000	184	57Del Dra	3.071	4600
35	33Alp Perb	1.795	6250	185	Eta SgrI	3.079	3100
36	50Alp UMa	1.800	6300	186	Mu 1Sco	3.08	28000
37	25Del CMab	1.830	5900	187	6Bet1Cyg	3.080	4600
38	20Eps SgrIII	1.836	11000	188	9Bet Cap	3.080	8900
39	85Eta UMa	1.854	24000	189	Alp IndNvar	3.108	4500
40	The Sco	1.859	7100	190	16Zet HyaII	3.109	4700
41	Eps Car	1.860	4100	191	Lam Cen	3.110	11000
42	34Bet Au	1.900	10200	192	Nu HyaII	3.114	4500
43	Alp TrA-III	1.910	4250	193	Bet Col	3.116	4400
44	24Gam Gem	1.928	11000	194	Zet Ara	3.121	3800
45	Alp Pav	1.940	26000	195	65Del Her	3.123	9700
46	Del Vel	1.954	10600	196	Kap Cen	3.133	26000
47	2Bet CMa/III	1.976	28000	197	9Iot UMa	3.140	8000
48	30Alp Hya-III	1.977	4100	198	40Alp Lyn	3.142	3300
49	1Alp UMib-IIva	1.99	6300	199	N Vel	3.144	3800
50	13Alp AriI	2.007	4250	200	34Mu UMa	3.16	3300
51	41Gam1LeoIb	2.01	4500	201	67Pi Her	3.163	4600

ID	Name	Mv	T_{eff}	ID	Name	Mv	T_{eff}
52	16Bet CetI	2.037	4500	202	10Eta Aur	3.170	24000
53	43Bet AndI	2.048	3300	203	22Zet Dra	3.171	17300
54	5The CenIb	2.055	4500	204	27Phi Sgr	3.172	13100
55	79Zet UMa	2.060	10200	205	Nu Pup	3.173	13100
56	53Kap Orib	2.065	30000	206	2Eps Lep	3.177	3950
57	34Sig Sgr	2.066	26000	207	25The UMa	3.185	6400
58	21AlpAndmnp	2.073	11000	208	1Pi 3Ori	3.187	6400
59	55Alp OphI	2.080	8900	209	5Mu Lep	3.19	11000
60	7Bet UMiI	2.081	3950	210	Mu Cen	3.19	26000
61	8Eps Peg	2.1	3900	211	8Bet Cep	3.190	26000
62	94Bet Leo	2.136	9700	212	Alp Cir	3.194	7100
63	Bet GruI	2.15	2800	213	G Sco	3.202	4500
64	Gam Cen	2.200	10600	214	64Zet Cyg	3.206	5300
65	Lam Vel-II	2.204	4400	215	35Gam Cep	3.208	5000
66	37Gam Cygb	2.208	5900	216	Sig Pup	3.210	3800
67	5Alp CrB	2.221	11000	217	Del Lup	3.216	28000
68	18Alp CasIa	2.225	4500	218	2Eps Oph	3.234	4700
69	33Gam DraI	2.231	3800	219	Gam Hyi	3.237	3100
70	Zet Pup	2.246	39000	220	65The Aql	3.238	11000
71	Iot Car	2.246	7700	221	14Gam Lyr	3.247	11000
72	34Del OriI	2.250	30000	222	58Eta Ser	3.255	4500
73	57Gam1Andb	2.26	13100	223	49Pi Hya	3.265	4250
74	11Bet Cas	2.268	6600	224	Alp Pic	3.266	8000
75	26Eps ScoIII	2.291	4250	225	42The Oph	3.269	26000
76	27GamCaspe	2.30	30000	226	31Del And	3.270	4100
77	Eps CenI	2.303	28000	227	76Del Aqr	3.275	9700
78	Alp LupIII	2.304	28000	228	12Iot Dra	3.291	4250
79	26Bet Per	2.31	13100	229	20Sig Lib	3.293	3000
80	7Del ScoIVe	2.316	30000	230	Alp Dor	3.300	11000
81	Eta CenVne	2.356	28000	231	p Car	3.300	22000
82	48Bet UMa	2.365	10600	232	Ome Car	3.309	13100
83	36Eps Boo	2.378	11000	233	69Del UMa	3.313	9700
84	Alp PheI	2.397	4500	234	Bet Phe	3.317	4700
85	Kap ScoIII	2.407	28000	235	40Tau Sgr	3.318	4400
86	35Eta OphVa	2.430	10200	236	Eta Sco	3.322	6800
87	64Gam UMa	2.433	11000	237	Gam Ara	3.323	28000
88	31Eta CMab:	2.448	20000	238	70The Leo	3.333	10200
89	5Alp Cep	2.451	8000	239	64Nu Oph	3.333	4500
90	54Alp PegI	2.487	11000	240	Alp Ret	3.334	4800

ID	Name	Mv	T_{eff}	ID	Name	Mv	T_{eff}
91	Kap Vel-V	2.490	26000	241	7Xi Pup	3.343	4700
92	53Eps CygI	2.500	4500	242	28Eta Ori	3.35	28000
93	53Bet PegII-III	2.52	3100	243	q Car	3.357	4600
94	92Alp CetIIIa	2.526	3100	244	31Xi Gem	3.359	6500
95	Zet CenIV	2.545	26000	245	30Del Aql	3.360	7200
96	68Del Leo	2.560	9300	246	45Eps Cas	3.368	26000
97	8Bet1ScoV	2.561	30000	247	1Omi UMa	3.370	5150
98	13Zet Oph	2.571	30000	248	Eps Lup	3.373	26000
99	Del Cenne	2.575	26000	249	79Zet Vir	3.377	9700
100	4Gam CrvI	2.580	13100	250	11Eps Hya	3.380	5600
101	11Alp Lep	2.582	7000	251	43Del Vir	3.383	3000
102	24Alp Ser	2.600	4250	252	39Lam Ori	3.390	32000
103	38Zet Sgr	2.600	9700	253	27Kap Oph	3.39	4250
104	27Bet Lib	2.614	13100	254	78The2Tau	3.400	8000
105	6Bet Ari	2.645	8900	255	21Zet Cep	3.4	4000
106	9Bet Crv	2.648	5600	256	Zet Lup	3.405	4700
107	37The Aur.	2.649	11000	257	Nu Cen	3.406	26000
108	Alp Col	2.652	15200	258	42Zet Peg	3.406	13100
109	Bet Lup	2.677	26000	259	86Mu Her	3.410	5600
110	37Del CasIVva	2.678	8900	260	Gam Phe	3.414	3800
111	8Eta Boo	2.680	6000	261	2Alp Tri	3.416	6400
112	Alp Mus	2.688	26000	262	Eta Lup	3.420	26000
113	Mu Vel.	2.692	5000	263	Bet Pav	3.421	8900
114	3Iot Aur	2.693	4600	264	3Eta Cep	3.428	5200
115	34Ups Sco	2.696	26000	265	16Lam Aql	3.430	11000
116	19Del Sgr	2.700	4100	266	a Car	3.432	26000
117	Pi Pup	2.706	3800	267	36Zet Leo	3.435	6800
118	50Gam Aql	2.718	4600	268	31Eta Cet	3.441	4250
119	14Eta Dra	2.727	4700	269	24Eta Cas	3.450	6000
120	1Del OphI	2.734	3200	270	35Lam Tau	3.45	24000
121	29Gam Vir	2.740	7200	271	33Lam UMa	3.450	10200
122	9Alp2Lib	2.747	9700	272	Chi Car	3.457	24000
123	Iot Cen	2.750	10200	273	22Sig CMa	3.464	3950
124	The Car	2.764	30000	274	86Gam Cet	3.468	9700
125	44Iot Ori	2.770	30000	275	Phi Vel	3.480	20000
126	60Bet Oph	2.770	4250	276	12Gam Sge	3.483	3800
127	27Bet Her	2.781	4700	277	49Del Boo	3.487	4700
128	67Bet Eri	2.784	9700	278	Eps Gru	3.488	9700
129	Del Cru	2.793	26000	279	48Mu Peg	3.493	3100

ID	Name	Mv	T_{eff}	ID	Name	Mv	T_{eff}
130	23Bet Dra	2.799	5800	280	52Tau Cet	3.495	5300
131	Gam Lup	2.800	26000	281	44Eta Her	3.495	4700
132	15Rho Pup.	2.803	6900	282	Alp Tel	3.495	24000
133	40Zet Her	2.807	6000	283	55Del Gem	3.500	7200
134	Bet TrA	2.810	6600	284	54Nu UMa	3.507	4100
135	Bet Hyi	2.82	5800	285	42Bet Boo	3.512	4700
136	23Tau Sco	2.822	30000	286	37Xi 2Sgr	3.514	4700
137	22Lam Sgr	2.824	4400	287	30Eta Leo	3.518	12000
138	47Eps Vir	2.828	4700	288	26The Peg	3.519	10200
139	9Bet Lep	2.833	5600	289	32Iot Cep	3.519	4500
140	88Gam Peg	2.834	26000	290	14Omi Leo	3.520	8900
141	Bet AraI	2.840	4600	291	23Del Eri	3.528	5200
142	49Del Cap	2.85	8900	292	17Bet Cnc	3.528	3950
143	Alp Hyi	2.857	7200	293	74Eps Tau	3.535	4500
144	18Del Cyg+	2.860	11000	294	55Xi Ser	3.538	6800
145	Gam TrA	2.872	10600	295	Xi Hya	3.541	4700
146	25Eta Tau	2.873	15200	296	32Mu Ser	3.542	11000
147	Alp Ara	2.877	26000	297	14Zet Lep	3.546	10200
148	Alp Tuc	2.878	4100	298	41Ups4Eri	3.548	11000
149	45Eps Per.	2.888	30000	299	Phi Eri	3.549	13100
150	44Zet Per	2.890	28000	300	Iot Lup	3.553	26000

6.2 Evolution of the IPF

As part of the continuous effort made by the QWG for the improvement of the quality of the GOMOS products, several successive IPF versions have been already developed. A new IPF version bases on the most recent version of the prototype GOPR, once the implementation of configuration changes proposed by the QWG in the prototype is validated. Those changes are then implemented in the IPF baseline. After verification and validation, the new IPF is then activated for operational processing.

The whole evolution cycle of the algorithm includes the following steps:

- specification of the algorithm inputs from the assessment of the current IPF performance;
- implementation in the prototype and validation;
- implementation in the IPF baseline and verification;
- delivery of the IPF and activation

It may take between one and two years for the cycle to be completely achieved.

The most recent version of the IPF (5.00) has been activated in August 2006. All products between July 2002 and August 2006 have been reprocessed (second reprocessing activities) with the version of the prototype corresponding to the IPF currently in operation (version 5.00), so that all consolidated products made available to the user are coherent. Datasets from a first reprocessing performed with a previous version of the prototype are also still available (measurements for 2003 and for the period between March and December 2004). Some of the Level2 changes implemented in IPF 5.00 are presented and compared to the configuration of GOPR used for the first reprocessing in Table B. 2. Level1b changes in IPF 5.00 had implied mostly the implementation of new corrections or the modifications of already existing ones; they are given in Table B. 3.

Table B. 2: Description of the Level2 configuration of the prototype version used for the first reprocessing and of IPF 5.00 (this list is non-exhaustive).

Level2 configuration item	GOPR (1st reprocessing)	IPF 5.00
Aerosol law	$1/\lambda$	$a + b\lambda + c\lambda^2$
Cross-sections	GOMOS cross-sections for all species	ORPHAL cross-section for O_3 (only)
Air retrieval	Air is retrieved	Air is fixed to ECMWF
Additional errors	No additional errors	Additional errors for O_3, NO_3 and aerosols
Flagging strategy	Negative values are systematically flagged	Negative values are not systematically flagged
HRTP		Improvement of the HRTP algorithm

Table B. 3: Description of the Level1b changes implemented in IPF 5.00 (compared to the prototype version used for the first reprocessing); this list is non-exhaustive.

Level1b changes in IPF 5.00 compared to GOPR (1st reprocessing)
Modification of the FP unfolding algorithm
Background correction of SPB in full dark limb applied
Modification of the flat-field correction implementation
Use of corrected reflectivity LUT
Updated wavelength assignment for SPA1, SPA2, SPB1
Correction of the star spectra from reflectivity variations

6.3 Periods of data unavailabilities

Since the launch of ENVISAT in March 2002, some instrument failures specific to GOMOS occurred during operations. Some of the major anomalies prevented the measurements. Also, it may have been necessary to switch-off the instrument for the time needed to characterize the anomaly, to estimate its impact on the operations and on the measurements, and to either solve the problem or find a bypass or workaround solution.

From 1 May 2003, measurement failures had been occurring due to the progressive reduction of the instrument Field of View on the nominal side. Nominal operations resumed on 19 July 2003 after the switch to the redundant System Control Unit.

A failure of the Elevation voice-coil system (telescope elevation drive for the rallying of the telescope to prepare for a star observation) prevented the nominal operations between 24/01/2005 – 18/07/2005. Nominal operations resumed after the implementation of a new mission scenario, taking into account a reduced azimuth Field of View (the last systematic failure occurred on 26/01/2006). GOMOS has been operating in the azimuth range between -5° and 20° (instead of between -10.8° and 90.0° for the nominal case) between September 2005 and February 2006. Since February 2006, time-varying limits of the azimuth window are used in order to optimize the mission objectives, while its range has been kept to 25°. It is estimated that this reduced azimuth range results to a loss of about 50% in the number of measured occultations.

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8 Acknowledgements and contact

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