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Fundamental Data Record for Atmospheric Composition

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1 Introduction

1.1 Purpose and Scope of the Document

The project FDR4ATMOS (Fundamental Data Records in the domain of satellite Atmospheric Composition) has been initiated by the European Space Agency (ESA). A Fundamental Data Record (FDR) is a long-term record of selected Earth observation Level 1 parameters (radiance, irradiance, reflectance), possibly multi-instrument, which provides improvements of performance with respect to the individual mission datasets. The focus of this project is a FDR targeting the retrievals of sulphur dioxide and ozone in the UV range and for nitrogen dioxide in the visible range from the time series data of GOME-1 and SCIAMACHY.

The document describes the content and scope of the FDR4ATMOS Level 1a and Level 1b products to enable users to use them for their applications. For details of the harmonisation algorithms the reader is referred to the ATBD [9].

In this document we use the following convention: Internal document links are marked in darkgreen can be clicked to navigate through the document. External links are marked in red and can be clicked to access the corresponding URL with a standard internet browser.

1.2 Documents

[1] J. P. Burrows et al. “SCIAMACHY- Scanning Imaging Absorption Spectrometer for Atmospheric Chartography”. In: *Acta Astronautica* 35.7 (1995), p. 445.

[2] John P. Burrows et al. “The Global Ozone Monitoring Experiment (GOME): Mission Concept and First Scientific Results”. In: *Journal of the Atmospheric Sciences* 56.2 (1999), pp. 151–175. DOI: 10.1175/1520-0469(1999)056<0151:tgomeg>2.0.co;2.

[3] M. Coldewey-Egbers et al. “The Global Ozone Monitoring Experiment: review of in-flight performance and new reprocessed 1995–2011 level 1 product”. In: *Atmos. Meas. Tech* 11 (2018). https://doi.org/10.5194/amt-11-5237-2018, pp. 5237–5259.

[4] Melanie Coldewey-Egbers et al. “Long-term analysis of GOME in-flight calibration parameters and instrument degradation”. In: *Applied Optics* 47.26 (2008), p. 4749.

[5] *ENVISAT-1, Mission & System Summary*. ESA EO Web page, https://earth.esa.int/eogateway/missions/envisat/description, retrieved on 18.12.2023. 2023.

[6] A. P. H. Goede. “SCIAMACHY Instrument Concept”. In: *Proceedings ESAMS 99 - European Symposiumon Atmospheric Measurements from Space*. Vol. 1. ESA WPP-161. ESA. 1999, pp. 147–155.

[7] M. Gottwald and H. Bovensmann, eds. *SCIAMACHY - Exploring the Changing Earth’s Atmosphere*. Springer Netherlands, 2011. DOI: 10.1007/978-90-481-9896-2.

[8] T. Hilbig et al. “The New SCIAMACHY Reference Solar Spectral Irradiance and Its Validation”. In: *Solar Physics* 293.8 (2018), p. 121.

[9] G. Lichtenberg, M. Coldewey-Egbers and FDR4ATMOS Team. *FDR4ATMOS Algorithm Theoretical Basis Document (ATBD), FDR4ATB-ATBD-DLR-008*. Tech. rep. issue 1. DLR-IMF, Sept. 2023.

[10] D. Loyola and T. Ruppert. “A new PMD cloud-recognition algorithm forGOME”. In: *ESA Earth Observation Quarterly* 58 (1998), pp. 45–47.

[11] S. Slijkhuis and B. Aberle. *GOME / ERS-2 Level 0 to 1b ATBD (GOME-DLR-L1-ATBD)*. TN. DLR-IMF, June 2016.

[12] S. Slijkhuis and G. Lichtenberg. *SCIAMACHY L0-1c Processor ATBD (ENV-ATB-DLR-SCIA-0041)*. TN. Version 8. DLR-IMF, Oct. 2020.

[13] Pieter De Vis et al. *FDR4ATMOS Uncertainty Characterisation, FDR4ATB-TN-NPL-020*. 1. NPL/DLR/IUP.

1.3 Abbreviations

FDR	Fundamental Data Record

GOME	Global Ozone Monitoring Experiment
NIR	Near InfraRed (spectral range)
PIC(S)	Pseudo-Invariant Calibration (Site)
PUG	Product User Guide
SCIAMACHY	Scanning Imaging Absorption spectroMeter for Atmospheric CHartographY
SoW	Statement of Work
UV	Ultraviolet (spectral range)
VIS	Visible (spectral range)

1.4 Document Overview

After a short introuction of the GOME-1 and SCIAMACHY missions in Sec. 2 we give a quick start guide to users who want to have a first look on the data before delving into the details (Sec. 3). Section 4 describes the content of the product in more detail. Changes of the SCIAMACHY data in comparison to the original mission products are described in Sec. 4.4. An overview about the harmonisation of the data is given in Sec. 4.5. Uncertainties are described in Sec. 5 and future plans in 6. After that we list all variables with descriptions, data type and units in Sec. 7 for the Level 1b product and in Sec. 8. The structure of these sections is the same for Level 1a and Level 1b:

- Global attributes can be found in the first subsection of the main chapter, e.g. Sec. 7.1
- netCDF top level groups are in there own subsection (e.g. the sun mean reference data can be found in Sec. 7.5)
- Groups below the top levels can be found in subsubsections (e.g. sun mean reference data for GOME are in Sec. 7.5.1) and groups below that level can be found in subsubsubsections and so on.

2 Summary of GOME-1 and SCIAMACHY Instruments and Missions

2.1 The GOME Instrument

2.1.1 Introduction

The Global Ozone Monitoring Experiment (GOME) was a nadir-scanning ultraviolet and visible spectrometer for global monitoring of atmospheric ozone. GOME achieved global coverage for observations of total ozone, nitrogen dioxide and related cloud information. The main objective of GOME was to observe upwelling solar radiation reflected or scattered in Earth's atmosphere and from its surface. A key feature of GOME was its ability to detect other chemically active atmospheric trace-gases as well as aerosol distribution: the measured spectrum contains absorption features which can be used to derive quantitative information on the presence of ozone, and of a number of other atmospheric chemicals. The ERS-2 mission GOME instrument was operational for about 16 years, from April 1995 until July 2011.

Details of the Level 0-1 processing and instrument calibration can be found in the GOME-1 Level 0-1 ATBD [11].

2.1.2 Instrument Characteristics

From an optical point of view, GOME is a double spectrometer. A quartz prism produces a moderate spectral dispersion, which is split into four channels. High dispersion is obtained by means of diffraction gratings in each of the four channels. Fig. 1 shows a schematic design of the optical paths.

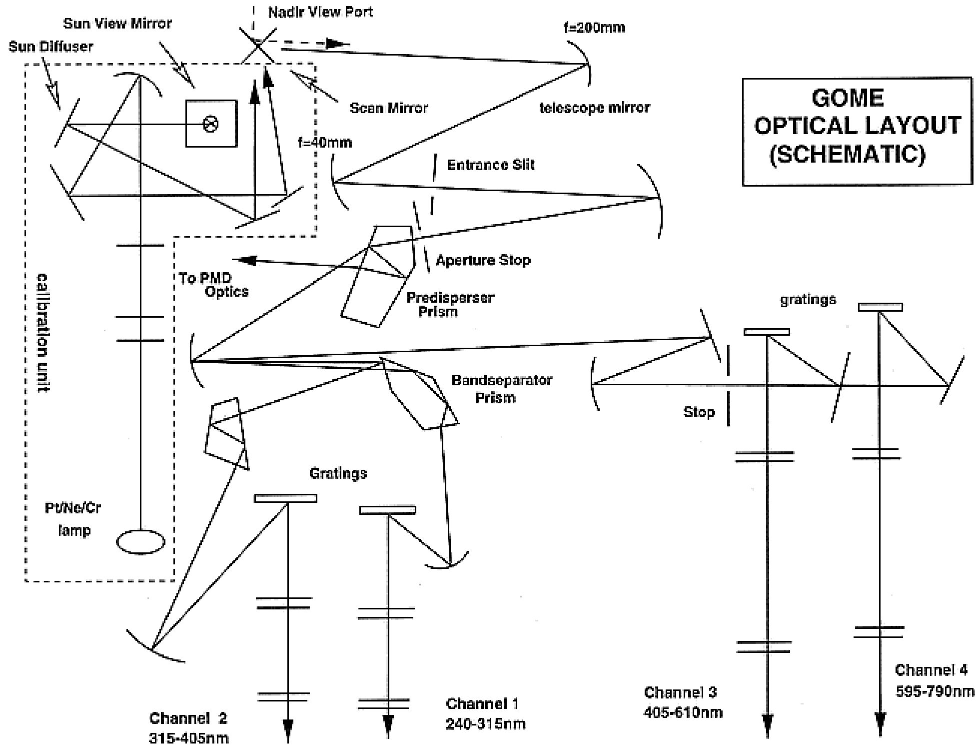


Figure 1: *Schematic instrumental setup of GOME. The GOME instrument is a four-channel spectrometer. Attached to the spectrometer is a calibration unit housing a Pt/Cr/Ne hollow cathode discharge lamp and the fore optics for solar viewing. Not shown is an additional mirror, which directs the lamp light to the solar diffuser plate for diffuser reflectivity monitoring (from [2]).*

The first optical element is the scan mirror, which reflects the optical beam into the telescope focusing it on the spectrometer slit. The diverging beam is then collimated by an off-axis parabola and is dispersed in the predisperser prism. The low dispersion spectrum is then focused onto the channel separator, which provides the separation between channels 1 and 2 by a combination of reflecting and transmitting coatings. The long wavelength part of the spectrum passes the channel separator unaffected and is split between channels 3 and 4 by a dichroic filter. Each individual channel consists of a diffraction grating and an objective which focuses the dispersed spectra on the detectors, housed in their Focal Plane Assemblies. By setting the scan mirror to the proper position, it is possible to insert the signals coming from the Calibration Unit. At the predisperser prism, light, with the polarisation plane parallel to the entrance slit leaks out at the backside and is channelled to a detector with three spectral bands corresponding to about the spectral ranges of channels 2, 3, and 4. Table 1 shows the spectral range of the channels.

Table 1: *GOME-1 channel and PMD boundaries (measured)*

Channel Nr.	Spectral Range [nm]	PMD	Spectral Range [nm]
1A	240-307		
1B	307-316	A	295-307
2	311-405		
3	405-611	B	397 - 585
4	595-793	C	580 - 745

The slit limits the instantaneous field of view to 2.9° x 0.142° or 40 x 2 km on the ground. Note that a default scan lasts 4 x 1.5 = 6 seconds (3 exposures in forward direction and 1 exposure during the backscan) in which time the spacecraft moves 40 km. We thus get a scanning pattern as depicted in 2, with continuous ground coverage in successive forward scans.

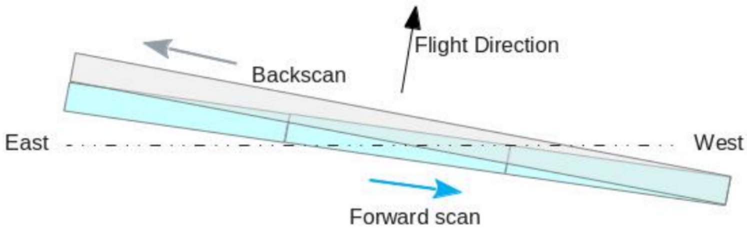


Figure 2: *GOME scan pattern with 3 readouts of 1.5 second in forward scan and 1 readout of 1.5 second in backscan (East/West indicated for descending part of orbit)*

2.1.3 Major Mission Events

Some of the major mission events for GOME were

- loss of last gyro February 2001
- tape recorder loss June 2003 leading to a reduction of geographical coverage

A complete list can be found at the ESA GOME-1 web page

2.2 The SCIAMACHY Instrument

2.2.1 Introduction

SCIAMACHY (SCanning Imaging Absorption spectroMeter for Atmospheric CHartographY) was an AO (announcement of opportunity) instrument for ESA's ENVISAT mission [5]. The AO- Providers, which fund the instrument, are the space agencies of Germany (DLR-Bonn, formerly DARA) and of The Netherlands (NSO), with a contribution from Belgium (BIRA). The instrument is build by an industrial consortium with prime contractors Astrium (formerly Dornier Satellite Systems) and SJT (itself a consortium of Fokker Space, TNO-TPD and SRON) - a large part of the project documentation referenced in the Bibliog- raphy of this ATBD stems from these sources. Apart from the project documentation, technical details of the instrument can be found in [1] and [6] .

SCIAMACHY is one of the earth observation research instruments that was included as part of the payload of the ESA (European Space Agency) ENVISAT-1 platform that was launched in the year 2002. The main scientific objective of SCIAMACHY was to measure distributions of a number of chemically important atmospheric trace species on a global basis. SCIAMACHY has a spectrometer and telescope system designed to observe light transmitted through and reflected and scattered from the Earth's atmosphere over a spectral range of 240 - 2400 nm. It has an alternate limb and nadir viewing capability, and was able to perform solar and lunar occultation measurements. SCIAMACHY was operational for just over ten years before a platform failure caused the end of the mission on April 8th 2012.

Nadir measurements provide Top of the Atmosphere (TOA) radiance and reflectance, together with limited polarisation information, in the Level 1c data product; Level 2 processing generates UV/visible global column distributions of O3 , NO2 and a number of other trace species (BrO, OClO, SO2 , HCHO, CHOCHO, tropospheric BrO and NO2). Level 2 processing of Nadir infrared measurements generate column distributions of CH4 and CO. SCIAMACHY also provided Limb and Occultation measurements. The FDR products only contain Nadir measurements in the UVN spectral range that match spectral windows for target species O_3, SO_2 and NO_2 and the O2A-Band.

Details of the Level 0-1 processing and instrument calibration can be found in the SCIAMACHY ATBD [12]. An overview of the mission including the Level 2 processing can be found in the SCIAMACHY book [7][1]

[1] A manuscript version is available at the DLR SCIAMACHY pages

2.2.2 Instrument Characteristics

SCIAMACHY is a medium-resolution UV-VIS-NIR spectrometer, fed by two nearly-orthogonal scan mirrors which enable across-track scanning in Nadir and in Limb, as well as sideways viewing for occultation and calibration measurements of Sun and Moon.

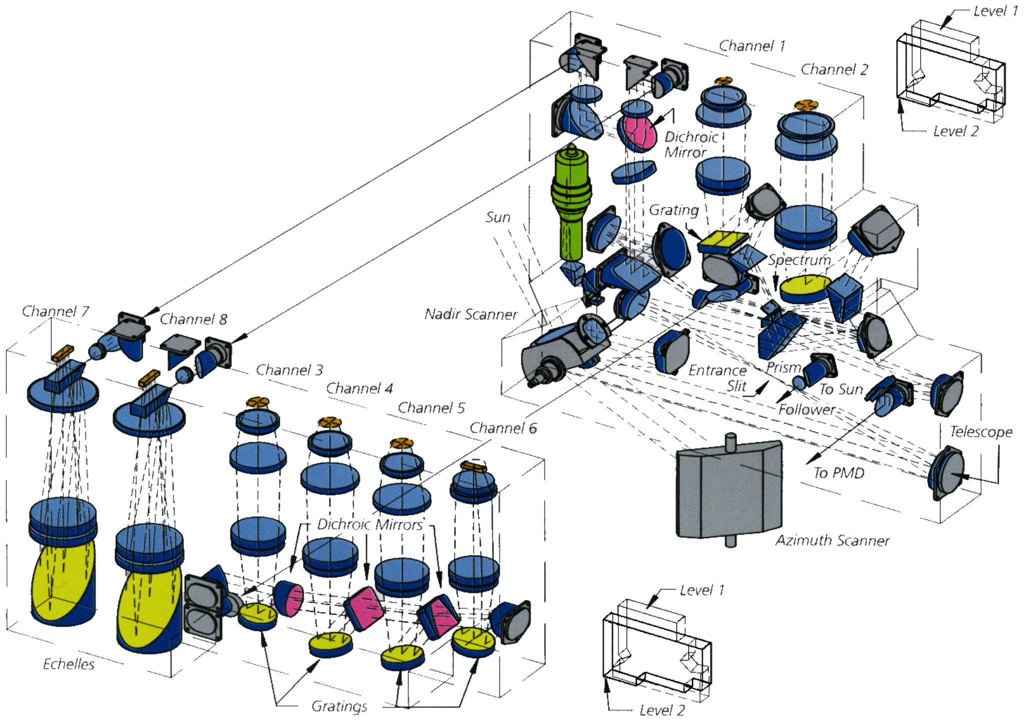


Figure 3: *SCIAMACHY optical lay-out.*

SCIAMACHY contains 8 channels which focus the spectrum on linear detector arrays of 1024 pixels each, and 7 Polarisation Measurements Devices (PMDs) containing photo diodes which measure linearly polarised intensity over a ≈ 100 nm wide spectral band. Six PMDs measure polarisation parallel to the spectrometer slit, and one measures polarisation at a 45° direction.

Channels 1-6 provide continuous spectral coverage of the wavelengths between 240-1750 nm with a resolution between 0.2 nm (at 240 nm) and 1.5 nm (at 1750 nm). Channels 7 and 8 provide 0.4 nm resolution in bands around 2.0 and 2.3 µm. Calibrated channel and PMD ranges are listed in Table 2. The spectra are formed by reflection gratings. Since the reflecting properties of these gratings are polarisation-dependent, the intensity calibration of SCIAMACHY has to take account of the polarisation of the incoming light, using information from the PMDs.

Table 2: *Calibrated channel boundaries (cut off at 5% level) and PMD boundaries (20% level)*

Channel Nr.	Spectral Range [nm]	PMD	Spectral Range [nm]
1	240 - 314		
2	307 - 405	A	302 - 385
3	391 - 605	B	441 - 527
4	598 - 809	C	602 - 707
5	776 - 1051	D	785 - 913
		45°	≈ 800 - 912
6	1033 - 1765	E	1447 - 1641
7	1938 - 2043		
8	2259 - 2383	F	2262 - ≈ 2400

The optical layout of the instrument is schematically shown in Figure 3. Light enters the telescope via two ultra-smooth (reduced straylight) scan mirrors. In Nadir observation mode, only the Nadir (or 'Elevation') scan mirror (ESM) is used. In Limb and in Solar/Lunar measurement modes, the light is directed to the Nadir Scanner via the Azimuth scanner (ASM); in these modes the Nadir scanner determines the elevation (in Limb or Occultation: the limb tangent height) of the measurement. In order to monitor a possible degradation of the Azimuth Scanner, which is the optical element most exposed to contaminants and solar UV radiation, a special Sun port is present which enables viewing the Sun over the Nadir Scanner only (if the geometry is favourable). In normal operations, a solar irradiance calibration is performed once a day with the Sun shining over the Azimuth scanner on a diffuser plate which is mounted on the backside of the Nadir scan mirror. Other calibration sources such as the Spectral Light Source (SLS, for wavelength calibration) and the White Light Source (WLS, for pixel-to-pixel gain and etalon correction) are directed to the Nadir scanner using auxiliary optics.

The telescope (3 cm diameter) projects the light beam onto the slit which determines the instantaneous field-of-view of 1.8° by 0.045°. For direct Sun viewing, an aperture can be inserted which reduces the amount of light entering the telescope. After the slit, the beam is collimated again and enters a predisperse prism, which has two functions. Brewster reflection at the back of the prism splits off part of one polarisation direction to the PMDs. The prism furthermore forms a low-dispersion spectrum, from which parts are picked-off to separate the light into the channels. Picked off are channel 1, channel 2, channels 3-6, and channel 7 - 8. In the channel 3-6 light beam a Neutral Density filter may be inserted to cut down high light levels. Further channel separation is performed using dichroics. A grating in each channel then further disperses the light which is subsequently focused onto the detector array.

The detectors are cooled to temperatures between 235 K (UV channels) and 150 K (NIR channels) to reduce dark signal. SCIAMACHY's optical bench is cooled to a stabilised temperature of -18° C to provide a stable, low thermal background for the NIR channels 7 and 8.

A late addition to the instrument is a second diffuser plate, mounted on the back of the Azimuth scanner (not shown in the figure). This diffuser plate is not absolutely calibrated, but can provide additional information to check in-flight properties of the default diffuser, and it can provide relative solar measurements useful in certain level 1 to 2 applications (DOAS).

2.2.3 Cluster Concept

An important concept for the data packet structure is that of the 'cluster' or band. A cluster is a subdivision of a channel and contains data of a certain wavelength region. The cluster concept was partly driven by the wish to have certain important spectral windows with a higher spatial resolution (i.e. a faster readout during scanning) than would be possible on grounds of data rate limitations. The consequence is that on the data product not each readout contains the whole spectrum, but that depending on which readout is finished more or less clusters (spectral regions) are present. Several clusters are in fact read out at high rate, but then co-added on-board to reduce the data rate between SCIAMACHY and on-ground receiving stations (in particular, the detector array in each channel can only be read out as a whole, and therefore the cluster with the shortest integration time in the channel determines the detector readout time; clusters which shall have a longer integration time have these short exposures co-added to obtain their nominal integration time). While SCIAMACHY has the same scanning strategy as GOME, the cluster concept leads to differently sized ground pixels, depending on orbit phase (latitude) and spectral region. Fig. 4 shows an example for 2 integration times

In the FDR product we scale all signals in a given band to the minimum integration time in that band to have a uniform coverage over the orbit. For details see Sect. 4.4.1.

2.2.4 Major Mission Events

For SCIAMACHY the only major event (before the loss of contact with the ENVISAT platform) was the orbit lowering from 799.8 km to 782 km in October 2010, which slightly changed the size of the ground pixels. Anomalies concerning the data quality can be found in the individual Level 1b files and on the DLR pages

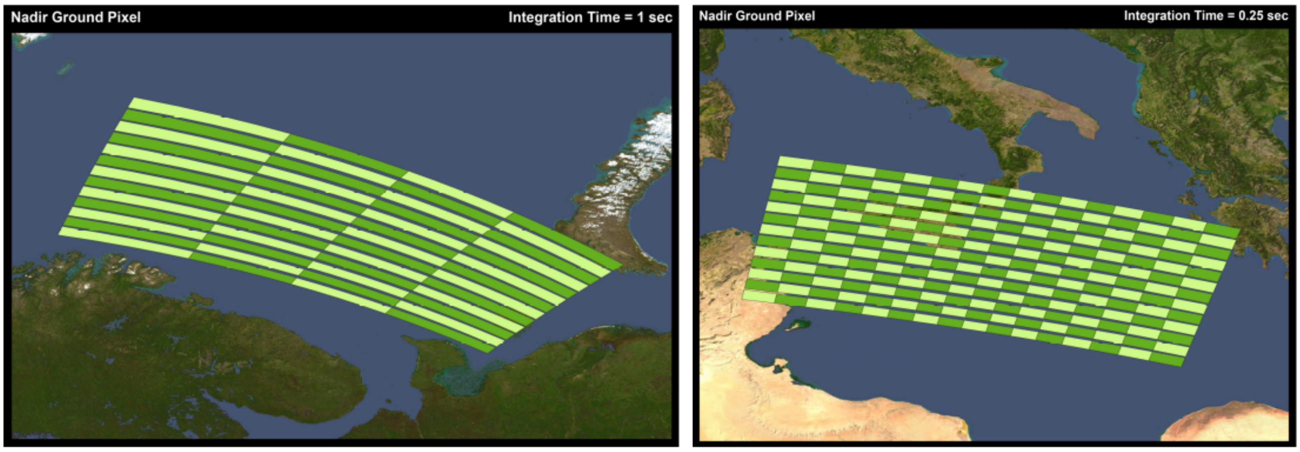


Figure 4: *The pattern of ground pixels in a nadir measurement for an integration time of 1 sec (left) and 250 msec (right). Backward scans are not shown; this causes the along-track gaps between consecutive scans which vary in width due to a projection effect. Across-track extent is defined by the integration time while along-track the size reflects the dimension of the IFoV with only a small contribution of the integration time. (Courtesy: DLR-IMF; background maps: NASA)*

2.3 GOME and SCIAMACHY in Comparison

In many ways GOME was a pre-cursor to SCIAMACHY. For SCIAMACHY the spectral range was extended and the ability to observe in Limb and Occultation geometry was added. A few lessons learned from GOME were also used to improve the instrument concept for SCIAMACHY. Table 3 shows the main characteristics of both missions

Table 3: *FDR relevant characteristics of the GOME and SCIAMACHY instruments. For SCIAMACHY, only the channels for the spectral range of GOME are shown.*

Item	GOME	SCIAMACHY
Launch	April 21st 1995	March 1st 2002
End of Mission	September 5th 2011	April 8th 2012
Orbit	sun-synchronous, 790 km	sun-synchronous, 799.8km
Local Time (DNX)	10:30 am	10:00 am ± 5 Min
Observation Geometries	Nadir	Nadir, Limb, Occultation
Ground Pixel Size	40 × 320 km^2	32 × 233 km^2 to 26 × 30 km^2
Number of channels	4	8
Pixel Per Channel	1024	1024
Total Spectral Range	237 - 793 nm	212 - 2386 nm
UV Channel Range/Resolution	311 - 405 nm/0.17 nm	300 - 412 nm/0.26 nm
VIS Channel Range/Resolution	405 - 611 nm/0.29 nm	383 - 628 nm/0.44 nm
NIR Channel Range/Resolution	595 - 793 nm/0.33 nm	595 - 812 nm/0.48 nm

Both instruments also employ Polarisation Measurement Devices (PMDs); photocells with broadband spectral filters measuring one polarisation direction.

Despite the large overlap (10 years) of the mission time there are no co-locations, i.e. there are no ground scenes that are observed at exactly the same time. Thus, in order to generate an FDR combining both instruments one has to rely on scenes of known radiance or at least on scenes where one can assume that the radiances are reasonably similar (taking into account the different observation geometries).

3 Quick Start

Two types of FDR products are generated in the FDR4ATMOS project:

1. *Level 1b products* are available to all users. The DOI is `10.5270/ESA-852456e`.
2. *Level 1a products* for expert users that contain additional information not strictly needed for typical applications. These products are available on request from ESA. The DOI is `10.57780/en1-c36d669`.

The goal of the project is to generate a harmonised GOME/SCIAMACHY cross-calibrated time series for the later retrieval of trace gases. This requires cross-calibrated reflectances. The retrievals depend on the structure of the absorption features of the target species. Previous cross-calibrations (e.g. in the FIDUCEO project) were done for instruments with comparable coarse spectral resolution. Cross instrument time series using spectrometers were done on Level-2 basis using the so-called "soft calibration approach" (e.g. in the CCI project) for specific trace gases. The harmonisation of spectrally highly resolved reflectances was not systematically done so far, but has the advantage that is potentially useful for other species than the ones targeted in this project, since the reflectance is the starting point for Level 2 retrievals. We also provide harmonised solar irradiances for GOME and SCIAMACHY.

Since this is the first systematic attempt to cross-calibrate spectrally resolved data, the methods described here are developed having cross-calibration of other instruments in mind. Thus, we strive to be as instrument-agnostic as possible. This will facilitate the incorporation of other instruments into a long time series. In this sense the FDR4ATMOS project is a path finder to develop long-time series of atmospheric spectra spanning not only heritage missions but also current and future spectral imagers like the Sentinel class instruments.

Version 1 of the products should be regarded as experimental. While we tested the impact of the harmonisation on the Level 2 target species SO_2, O_3 and NO_2 (the quality of the Level 2 was not degraded), the size of the test data set to investigate influences of e.g. scene differences was limited mainly due to the impact the Corona pandemic had on our work. A follow-on project is already agreed with ESA that will

- increase the test data size and include thorough sensitivity studies for the harmonisation parameters
- incorporate GOME-2 data to build a time series that spans the GOME-1, SCIAMACHY and GOME-2 A-C missions
- build a transfer function between the instruments and evaluate its usefulness

Currently the FDR products offer the following improvements for the user:

1. GOME-1 solar irradiances are harmonised using a validated SCIAMACHY solar reference spectrum. This solves the problem of the fast changing etalon in the original GOME-1 Level 1b data (see also [4])
2. Reflectances are available for both, GOME-1 and SCIAMACHY in the FDR product
3. SCIAMACHY data are scaled to the lowest integration time in the spectral band using high frequent PMD measurements in the same wavelength range (see Sect. 4.4.1). This simplifies working with SCIAMACHY data, which in the original level 1b data have a changing integration time over the orbit and spectral band. Scaled data can be identified by a `scaling_flag` in the product.
4. GOME-1 reflectances are harmonised to degradation corrected SCIAMACHY reflectances, using collocated data from PIC sites. The degradation of the reflectances present in the original data (see [3]) is not yet corrected in this version of the FDRs. In the next phase of the project a correction will be investigated and if feasible, applied.
5. The GOME-1 viewing angle dependency in the UV spectral region is mitigated by the harmonisation.

Each product covers 1 day of data from the start of the GOME-1 mission to the end of the SCIAMACHY mission. The spectral coverage of the harmonised sun mean reference data is the overlap regions of the SCIAMACHY and the GOME-1 data:

Table 4: *Approximate spectral range for harmonised GOME SMR data.*

Spectral Band	Spectral Range
UV	313 - 404 nm
VIS	410 - 595 nm
NIR	600 - 790 nm

The SCIAMACHY sun data were not changed and are available for the full spectral range of the channels 2-4.

For harmonised Earth data we cover the retrieval windows for SO_2, O_3 and NO_2 as well as the O_2A band spectral range:

Table 5: *Approximate spectral range for Earth data.*

Spectral Band	Spectral Range
UV	313 - 347 nm
VIS	424 - 495 nm
NIR	754 - 776 nm

Data with a SZA larger than 89 degrees are excluded from the FDR data product.

The harmonisation was done with a broadband transfer function (3-5 nm, depending on channel). We kept the original spectral and spatial resolution for both instruments. A validation done for SO_2, O_3 and NO_2 retrieved with DOAS and showed perfect agreement with Level 2 data retrieved from the original level 1 products. Reflectances were calculated for both instruments separately. GOME reflectances were then harmonised to SCIAMACHY reflectances. Details of the method can be found in the ATBD [9].

Fig. 5 shows the structure of the FDR products: The data from individual orbits are stacked along the `time` dimension. We have typically 14 orbits per day for SCIAMACHY and GOME-1. However, this number may very if an instrument anomaly occured (these data are excluded in the FDR product) or if calibration orbits were done on a particular day.

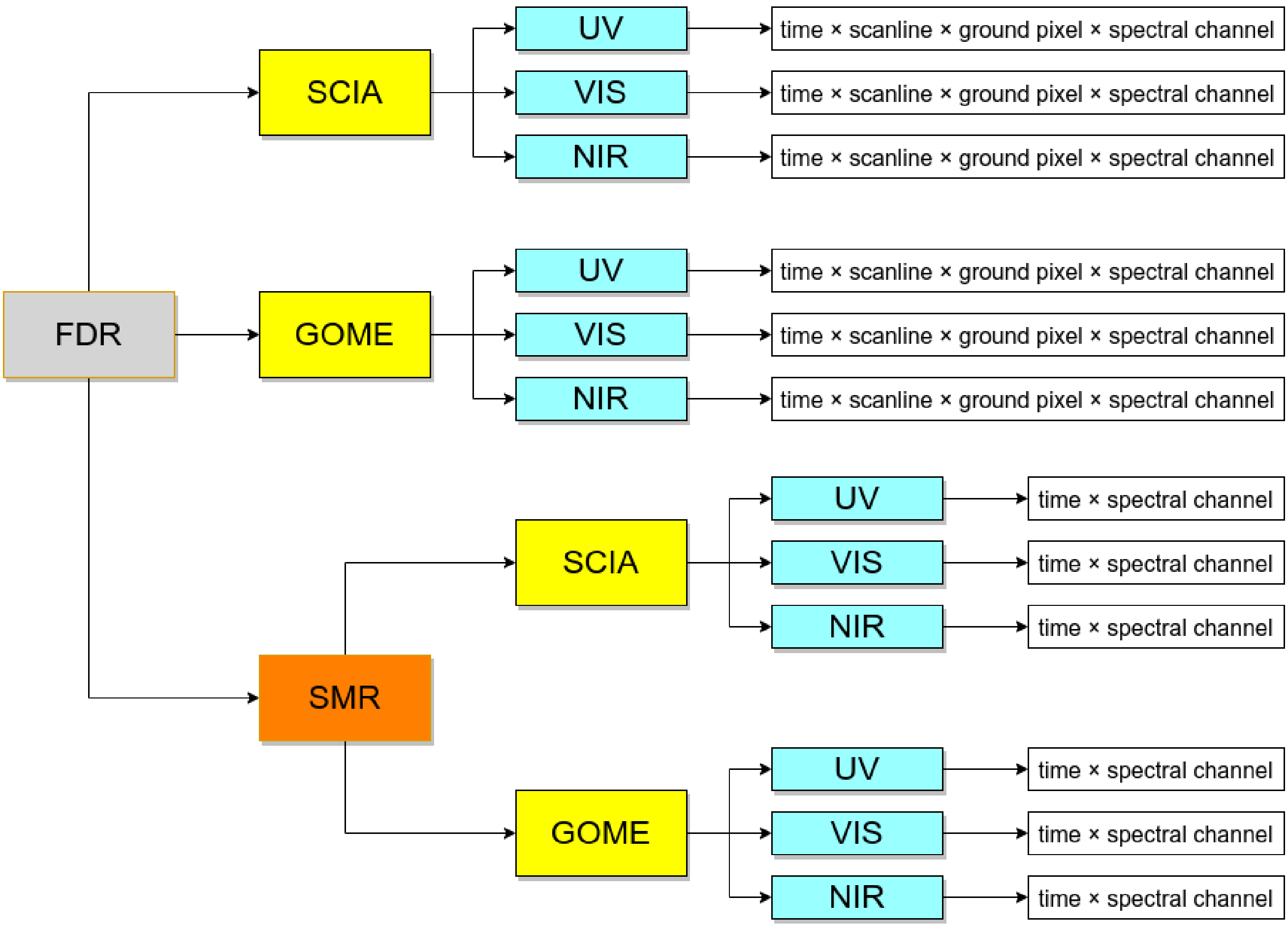


Figure 5: *File structure for FDRs: Earth measurements are in separate groups for GOME and SCIAMACHY. Sun Mean References (SMR) have their own top group. The data are also separated into the three channels.*

Names of the main FDR variables have the suffix `_fdr`. The table below gives a quick overview of these variables:

Table 6: *Short description of main FDR variables.*

Variable	Description
Sun Mean Reference	in the SUN_MEAN_REFERENCE/<UV,VIS,NIR> group
GOME-1 smr_fdr SCIAMACHY smr_fdr	Calibrated SMR data, harmonised using a SCIAMACHY validated SMR Calibrated SMR data unchanged from the original product
Earth Data	in the <UV,VIS,NIR>/OBSERVATIONS group
SCIAMACHY radiance_fdr reflectance_fdr	 Calibrated radiances, scaled to the minimum integration time in the channel Reflectances, scaled to the minimum integration time in the channel
GOME-1 reflectance_fdr radiance_fdr	 Reflectances harmonised to SCIAMACHY data Synthetic radiances calculated from the solar irradiances and harmonised reflectances

3.1 Group Description Links

The table below shows links to the section where the variables of the netCDF groups are described:

Table 7: *Locations of the detailed group variable descriptions.*

Group	Description	Section
GOME		
./COLLECTION	References to GOME-1 Level 1 input data and orbits	8.5.1
./<UV,VIS,NIR>	Top group for GOME-1 Earth Observations	8.5.3
./../CLOUDDATA	Copy of GOME-1 Level 1 cloud data	8.5.3.1
./../GEODATA	Geolocations and observation geometry data	8.5.3.2
./../OBSERVATIONS	Earth observation data of GOME-1	8.5.3.3
SCIAMACHY		
./COLLECTION	References to SCIAMACHY Level 1 input data and orbits	8.6.1
./<UV, VIS, NIR>	Top group for SCIAMACHY Earth Observations	8.6.3
./../CLOUDDATA	Nearest neighbour cloud data from SCIAMACHY Level 2 products	8.6.3.1
./../GEODATA	Geolocations and observation geometry data	8.6.3.2
./../OBSERVATIONS	Earth observation data of SCIAMACHY	8.6.3.3
SUN_MEAN_REFERENCE		
./GOME/<UV, VIS, NIR>	GOME harmonised sun mean reference data	8.7.1.1
./SCIAMACHY/<UV, VIS, NIR>	SCIAMACHY harmonised sun mean reference data	8.7.2.1

4 Data Products

4.1 Time Span and Granularity

FDR products are available from the first GOME-1 Level 1 products from April 1995 to the last SCIAMACHY Level 1 products in April 2012. During the overlapping period from August 2002 to July 2011 where both, GOME-1 and SCIAMACHY provided data, the FDR product contains data for both instruments. Outside this period only GOME-1 or SCIAMACHY data are available.

One product contains all available data for one day, i.e. all measurements that *started* after midnight UTC on that day. The date can be identified from the filename (see next section) and the `time_reference` and `time_coverage` global attributes (see Sec. 7.1).

4.2 Filename

The filename for the products follows the general rules for the ESA groundsegment. An ESA file name has the following elements:

```
MMM_CCC_TTTTTTTTTT_<instance ID>
```

Table 8 and Fig. 6 show the individual file name elements. An underscore is used as field separator and for blank strings. The FDR covers the UV, VIS and NIR spectral ranges (string `UVN`). For the user the most important information is the product coverage and the version string.

Table 8: *File name elements derived from the ESA standard.*

Name Element (ESA)	Value
Mission ID	ESA
File Class	FDR
File Type with	ATMOS__L1B
→ Semantic (observable)	ATMOS
→ Product Level	L1B
Instance ID with	UVN__YYYYMMDD_YYYYMMDDTHHMMSS_v01_00
→ Semantic (spectral)	UVN_
→ Measurement Start Day	YYYYMMDD
→ Processing Date and Time	YYYYMMDDTHHMMSS
→ version	vXX_YY

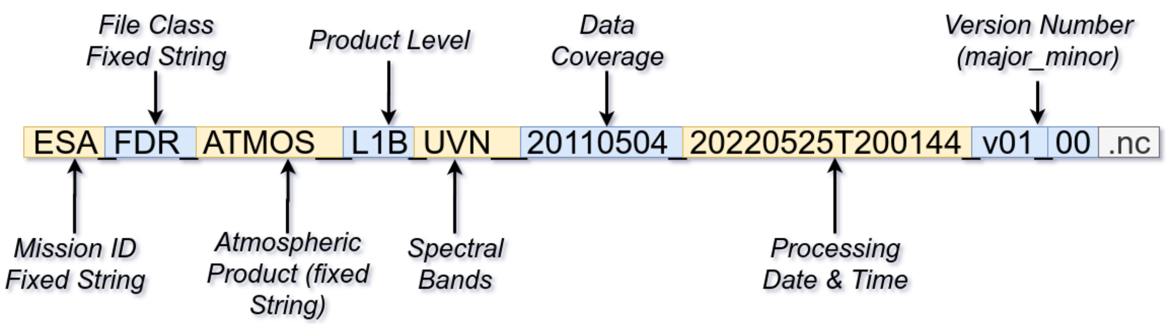


Figure 6: *File name elements and their meaning. Example for a file covering measurements from May 4th, 2011 that was processed on May 25th 2022 at 20:01:44 with FDR processor version 1.0. Data coverage can be found in the middle of the name and version at the end of the name.*

4.3 File Structure

The file structure was kept as near as possible to the Level 1 files of other missions. At the top level we have the two instrument groups with Earth measurements and the `SUN_MEAN_REFERENCE` group with the irradiance measurements. Below these groups we have the spectral bands UV, VIS and NIR and below that the usual split into `OBSERVATION` and `GEODATA` groups with measurements, coordinates and observation geometry (see also Fig. 5). In the original Level 1 products the `time` dimension was always one. For the FDR we use this dimension to collect all orbits occuring on a given day. Apart from this, the array structure is the same as in the original Level 1b products.

Table 9: *Typical dimensions of the observational data.*

Dimension	FDR (SCIA group)	FDR (GOME group)
time	14	14
scanline	~400	~500
ground_pixel	20-40	4

time corresponds to orbit on the given day.

scanline corresponds to one complete sensor image of the 2-dimensional sensor For SCIAMACHY it corresponds to one complete East-West scan.

ground_pixel corresponds to the across-track scans of a scanning spectrometer generated by scan mirror movement.

The netCDF arrays are organised as

time × scanline × ground pixel × spectral channel

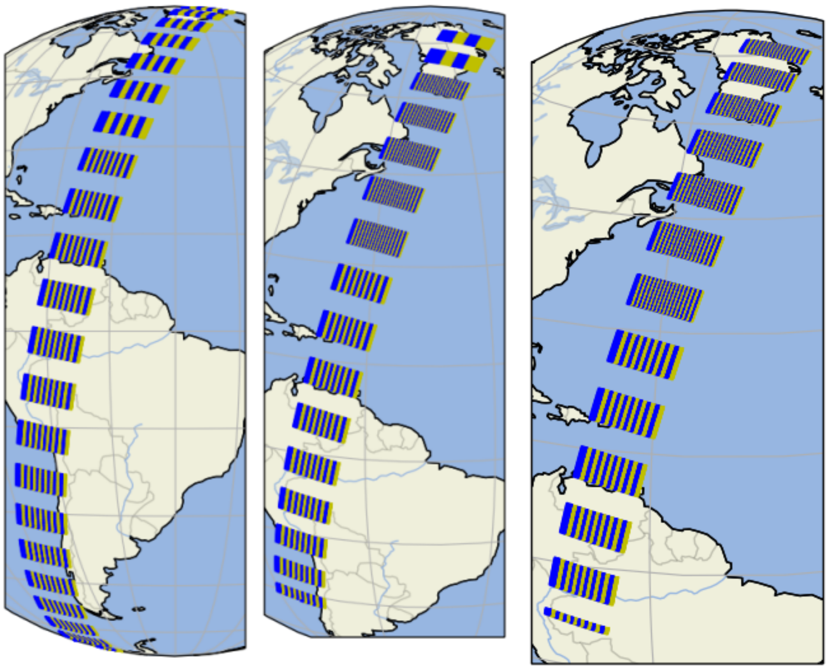
4.4 Changes Applied to Original SCIAMACHY Data Products

4.4.1 Scaling of SCIAMACHY data

The channels of SCIAMACHY are divided into so called clusters or spectral bands that can have their own integration time. Additionally the integration time can be variable over one orbit. This was done to get the optimal signal for the spectral range and viewing geometry. However, it complicates the interpretation of data, since the ground pixel size becomes latitude dependent. Table 10 shows the integration times (IT) for the spectral bands relevant for the FDR production and Figure 7 illustrates the change in ground pixels for one orbit and the 3 bands.

Table 10: *Integration times of the orginal SCIAMACHY data.*

Band	IT [s]
UV (Band 09)	1
	0.500
	0.250
UV (Band 10)	1
	0.500
	0.250
VIS (Band 15)	1
	0.125
	0.250
NIR (Band 26)	1
	0.125
	0.250



(a) UV **(b)** VIS **(c)** NIR

Figure 7: *Groundpixelsizes for Nadir observations. In East-West scan direction, the pixels are coloured alternately in blue and green to show their varying size due to the changing integration time.*

In order to facilitate the use of the data, for Level 1b the data are scaled to the *smallest* integration time in the cluster with the help of the PMD data. The PMDs signal is recorded with 32Hz in the Level 1b product and thus give highly resolved information about the time evolution of the signal during the exposure of the science detectors. Under the assumption that the ratio of science signal to PMD signal is constant during the measurement time, the signal for smaller integration time can be estimated. Scaled data can be identified using the `scaling_flag` in the FDR data product.

4.4.2 Addition of Cloud Paremters to SCIAMACHY Data

Contrary to GOME-1 Level 1b products, SCIAMACHY Level 1 products do not contain any cloud data. The cloud fractions for SCIAMACHY are only calculated in the Level 1b-2 processor using the OCRA algorithm [10].

Instead of re-implementing the Level 1b-2 cloud algorithm in the FDR processor we build up a database for the cloud parameters using the existing SCIAMACHY Level 2 products as input. The data base with cloud parameters, orbit number and geographical coordinates is then used to look up matching data for the Level 1c products. In order to get the cloud parameters for given measurement, we compare the centre coordinates for the ground pixels with the minimum integration time with the coordinates in the database. Database data with the shortest distance to the Level 1c coordinates are copied to the Level 1c product. If the distance is larger than a limit of 0.2, no data are selected. In the FDR processing the cloud data are just copied from Level 1c to the FDR product (see Fig. 8)

4.5 Harmonised Data

4.5.1 Sun Mean References

During nominal operations, GOME and SCIAMACHY measured the sun one time per day. For the purpose of harmonisation it can be assumed that the sun signal is stable and only varies over the year due to changing Sun-Earth distance. However, the GOME spectra contain artefacts from a changing, unpredictable etalon effect,

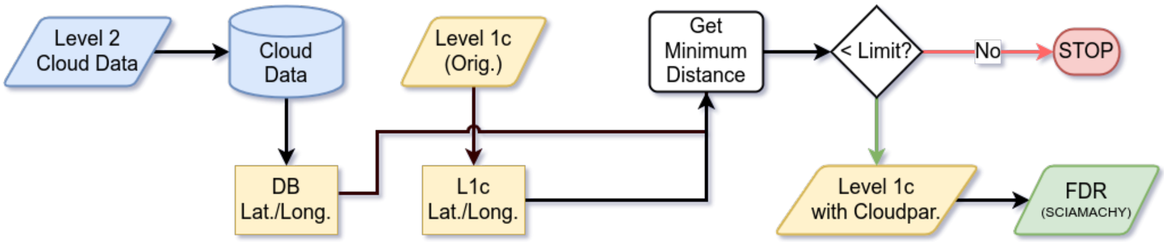


Figure 8: *For SCIAMACHY data, cloud parameters are taken from the Level 2 product for each spectral band, matched geographically and finally copied to the FDR product.*

which could not be corrected for during the calibration. For the retrieval of trace gases this has no impact, since the reflectances are used and the etalon effect cancels. Since SCIAMACHY does not show etalon artefacts, it was decided to take the SCIAMACHY solar irradiance as reference for the harmonisation. Specifically we chose the SMR from 27 February 2003, which was extensively validated [8].

The harmonisation steps are shown in Fig. 9. Details can be found in the ATBD [9].

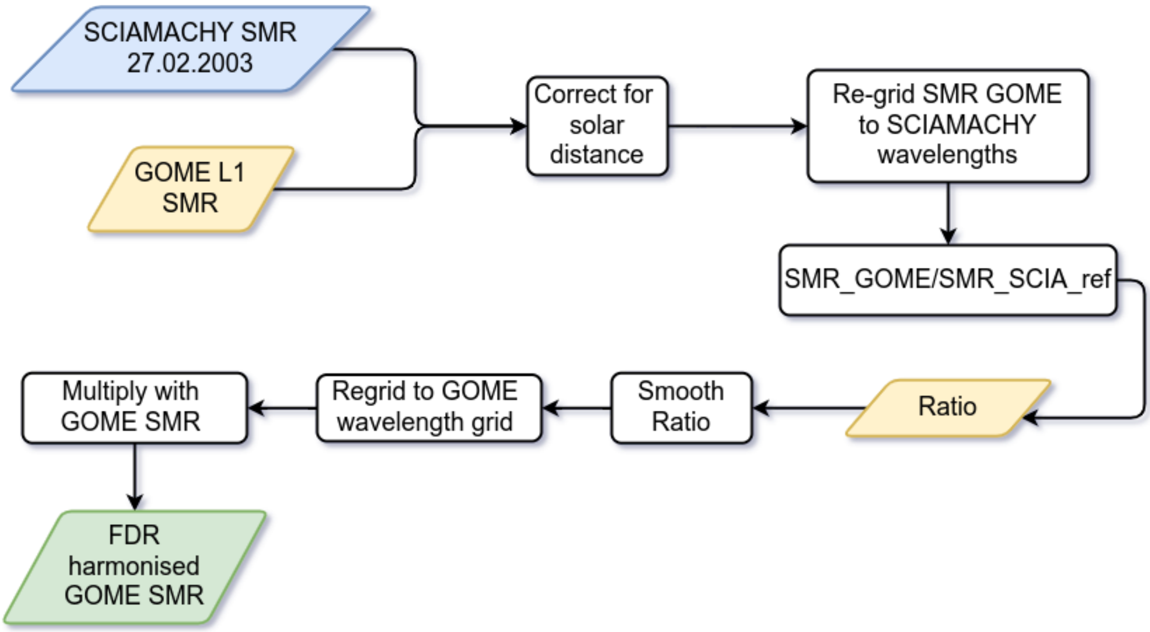


Figure 9: *Schematic flow of the steps for the harmonisation of GOME solar data to the validated SCIAMACHY reference. The procedure is applied to all SMRs of GOME, using the validated, fixed SCIAMACHY reference spectrum.*

Fig. 10 shows an example of the harmonisation result for the UV and day of year 100 over the whole mission. Before the harmonisation we see clear changes over time for certain wavelengths. The harmonised data set only shows the spectral structure of the irradiance.

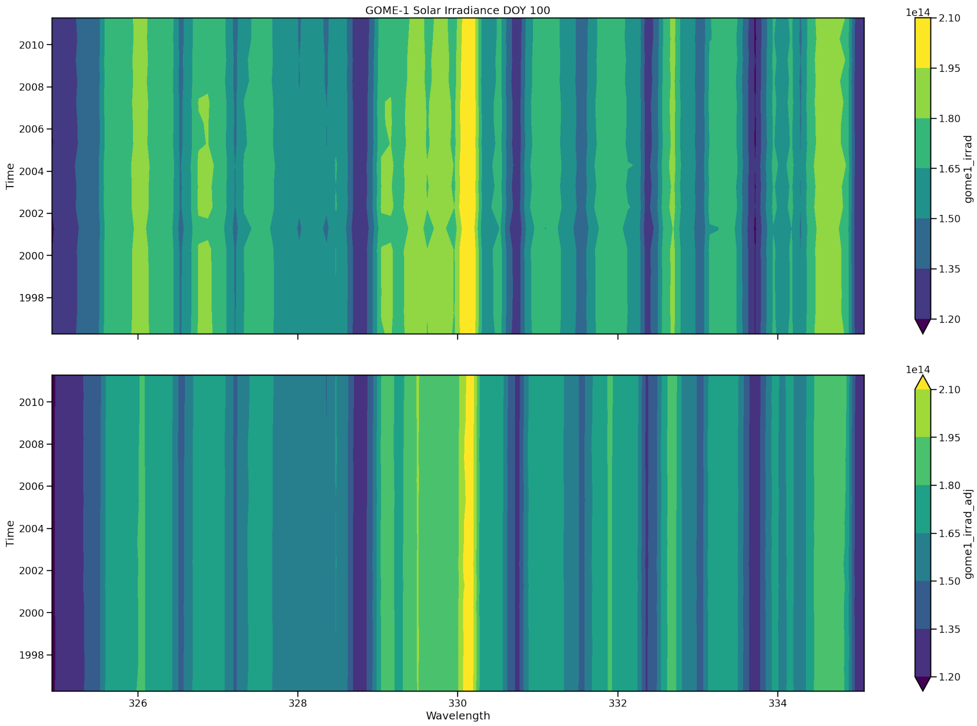


Figure 10: *Harmonisation of the solar irradiance for day of year 100 for the complete mission (y-axis) in the UV (x-axis). Top: Before harmonisation. Bottom: After harmonisation. Irradiance values are colour coded in ph/(s.cm^2.nm).*

In nominal operations GOME and SCIAMACHY measured the sun once per day and calculated the calibrated sun mean reference. The FDR product contains the *unchanged* SMR measured with the ESM diffuser from SCIAMACHY in the `SUN_MEAN_REFERENCE/SCIMACHY/smr_fdr` variable for each day with nadir measurements. The harmonised GOME-1 SMR can be found in the `smr_fdr` variable of the `SUN_MEAN_REFRENCE/GOME` group. All spectra from 1995 to the end of the GOME-1 mission were harmonised using the validated SCIAMACHY spectrum from 27.02.2002. In this way, the fast changing etalon in the GOME solar spectra was corrected. The GOME-1 SMR are on the original GOME wavelength grid with the GOME-1 spectral resolution: The harmonisation was done with a broad band function (see above). For both instruments we also provide the correct wavelength axis in the SMR group, there is no need any more to retrieve it from the calibration group as in the Level 1b mission data products. In total, the FDR provides a harmonised time series of solar irradiances from 1995 to 2012.

4.5.2 Earth Reflectance

We chose the year 2003 and SCIAMACHY as our reference for the calculation of the transfer function, since

- SCIAMACHY degradation was still very low in 2003 and the reference point for the SCIAMACHY degradation is February 27th 2003. Choosing the same year minimises the influence of a residual, uncorrected degradation
- GOME-1 reflectances suffer from instrumental degradation of the signal
- Investigations for some wavelengths show that in 2003 the GOME-1 degradation of the reflectance is again near 1 [3], i.e. the throughput is nearly the same as in the beginning of the mission

The transfer function derived from 2003 will be applied to *all* measurements of GOME-1, i.e. from 1995 to 2011. The harmonisation of the Earth reflectance of GOME and SCIAMACHY is based on comparisons of co-located measurements. After careful inspection of other scenes, i.e. two areas over the Atlantic and Pacific Ocean and for both cloud free and fully cloudy conditions, it was decided to limit the derivation of the transfer function to measurements over the three PICS listed in Table 11. The results from other areas turned out to be too noisy.

Table 11: *PIC sites chosen as input for the harmonisation*

Location	Lat. Min.	Lat. Max.	Long. Min.	Long. Max.
Mauretania1	18.95	20.00	-9.75	-8.00
Libya4	28.05	29.50	22.59	24.76
Algeria5	30.57	31.47	1.78	2.68

Figure 11 shows a schematic flow for the calculation of the harmonised reflectances.

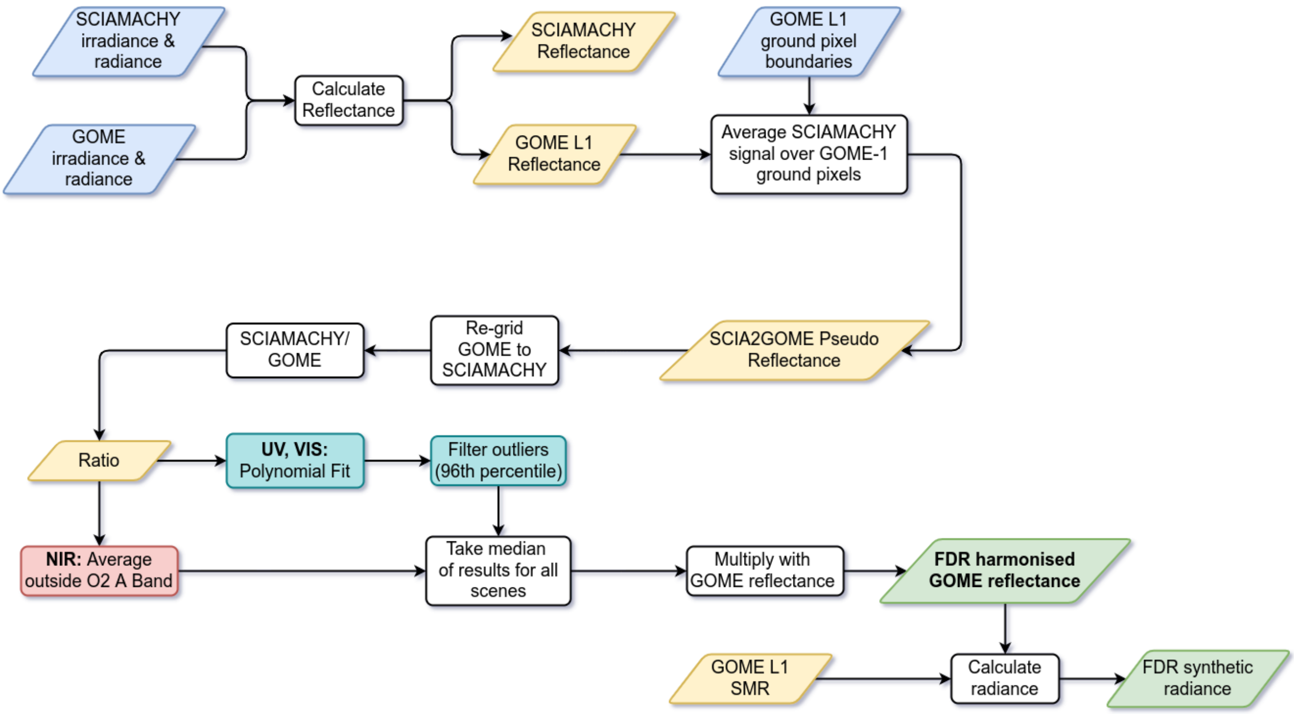


Figure 11: *Flow diagram for the calculation of harmonised GOME-1 reflectances. The transfer function is calculated from a ratio of GOME and pseudo SCIA2GOME signals for the PIC sites. UV,VIS and NIR are differently treated. For the UV each viewing angle has its own transfer function (not shown). From the harmonised reflectances and the irradiance we calculate a synthetic, harmonised radiance.*

The reflectance for individual GOME ground pixels is compared with the weighted average of the SCIAMACHY reflectance. From the scene files the reflectance for three wavelength windows (see Table 12) is extracted for each site and overpass in 2003.

Table 12: *Spectral regions used for the harmonisation factors. For the NIR channel we excluded the O2A-band only for the calculation of the transfer factors; the FDR data contain the whole spectral range.*

Spectral region	GOME band	SCIAMACHY band(s)	Wavelength interval(s)
UV (ultra-violet)	2B	09 & 10	313 - 347 nm
VIS (visible)	3	15	424 - 495 nm
NIR (near-infrared used for harmonisaton)	4	26	756 - 757 nm & 773 - 774 nm
NIR (FDR spectral range)			754- 776 nm

The GOME reflectance (R_{GOME}) is regridded to the SCIAMACHY wavelength grid (λ_S) from the corresponding averaged measurement using the Akima interpolation scheme. Then the ratio $SGR(\lambda_S)$ of the reflectances is computed for each co-located measurement n:

$$SGR(\lambda_S, n) = R_{SCIAMACHY}(\lambda_S, n)/R_{GOME}(\lambda_S, n). \quad (1)$$

We investigated the influence of

- the GOME-1 East-West viewing angle
- the solar zenith angle (SZA)
- reflectance value of GOME-1
- the cloud fraction

on the ratio and did not find any correlation: The harmonisation seems to be independent from the above parameters with the exception of the GOME viewing angle in the UV, which we take into account. This result is surprising and maybe caused by the selection of the scenes. We will widen the data for the harmonisation and investigate this further in the planned follow-on project. For the current harmonisation we only exclude statistical outliers, but do not include scene dependent adjustments apart from the UV viewing angle.

In case of the UV and visible wavelength region, a third order polynomial fit as a function of wavelength is applied to each ratio.

The median of all valid measurements from 2003 is taken to compute the transfer function. Figure 12 shows the final transfer functions that have to be applied to GOME data in the UV spectral range (left) and in the visible spectral range (right). The orange curves denote the individual polynomial fits for each co-located measurement. The blue curves denote the measurements that were identified as outliers and that are not taken into account. The black curves denote the median of all orange curves and the dark grey shading corresponds to the standard deviation. Note that for the UV the viewing zenith angle dependence is taken into account, i.e. separate transfer functions for GOME east, nadir, and west pixels are computed. This is not needed for the visible and near-infrared wavelength windows.

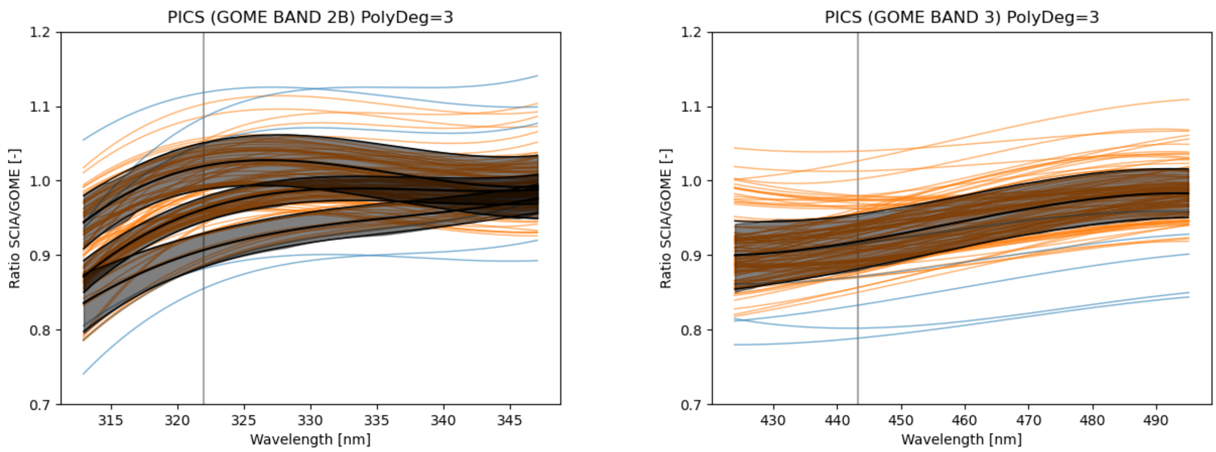


Figure 12: *Final transfer functions for GOME in the UV spectral range (left) and in the visible spectral range (right). The orange curves denote the individual polynomial fits for each co-located measurement. The blue curves denote the measurements identified as outliers and not taken into account. The black curves denote the median of all orange curves and the dark grey shading corresponds to the standard deviation. Note that for the UV the viewing zenith angle dependence is taken into account, i.e. separate transfer functions for GOME east, nadir, and west pixels are computed.*

For the near-infrared region the average of the mean ratio in both 1 nm-wide wavelength intervals (see Table) to the left and to the right of the O_2 A-band is computed for each measurement. Then the median of these average values is taken as the (wavelength-independent) transfer function to be applied to GOME reflectances.

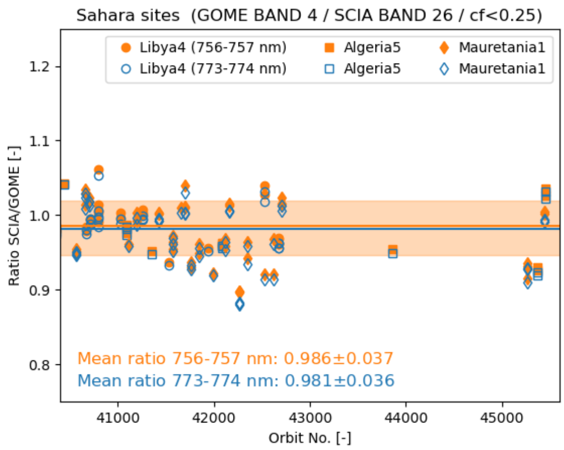


Figure 13: *Reflectance ratio SCIAMACHY/GOME for two 1 nm-wide bands (756-757 nm (orange) and 773-774 nm (blue) to the left and to the right of the O_2 A-band as a function of the orbit number (in 2003). The orange horizontal line denotes the corresponding median ratio and the standard deviation for the 756-757 nm window.*

Finally, the transfer functions $C(i)$ derived in the steps described above are applied to GOME data as follows:

$$R_{GOME,adj}(i) = R_{GOME}(i) \cdot C(i). \tag{2}$$

$R_{GOME,adj}(i)$ is the harmonized GOME reflectance, $R_{GOME}(i)$ is the measured GOME reflectance for detector pixel i ($i = 0, ..., 1023$). Note that the wavelength-dependence for UV and VIS (see Fig. 12) is converted into a pixel-dependence $C(i)$ at first.

The harmonised Earth reflectance is the main product of the FDR. We use the following reflectance definition:

$$R(\lambda) = \frac{\pi I_{earth}(\lambda)}{\cos\mu \cdot E_{sun}(\lambda)} \tag{3}$$

with

R	Reflectance
I_{earth}	calibrated radiance as measured by the instrument
μ	Solar zenith angle for the observation
E_{sun}	Solar irradiance as measured by the instrument

Before the harmonisation, the reflectance for each instrument is calculated. We use the SMR and the radiance measured by the instrument on *the same day*, i.e. we do not use the harmonised SMR. This was done to avoid any residual instrumental or degradation effects that are not corrected. Using a reflectance calculated in this way and harmonise the data afterwards has the advantage that any multiplicative differences automatically cancel in the calculated reflectance (including the fast etalon of GOME-1). As already mentioned above we use a broadband polynomial function to harmonise the reflectances to keep the spectral features needed for the retrieval of atmospheric parameters.

For SCIAMACHY we provide the radiance and reflectance scaled to the minimum time in the band (see Sec. 4.4.1 in the variables `reflectance_fdr` and `radiance_fdr`. For GOME-1 we provide the reflectance calculated with Eq. 3 in the `reflectance` variable and the harmonised reflectance in the variable `reflectance_fdr`. Since many retrievals rely on the radiance and irradiance as separate input we also provide a "synthetic" radiance calculated by inverting Eq. 3, using the solar irradiance and the *harmonised* reflectance. This radiance can be found in the variable `radiance_fdr` in the GOME-1 group. All reflectance calculations are done on the radiance wavelength grid that can be found in the `lambda` variable of the `OBSERVATION` group for each band and instrument.

For the reflectances we also provide a quality flag that shows if the reflectance is between 0 and 1 (flag = 0), smaller than 0 (flag = -1) or larger than 1 (flag = 1).

A quick summary of the main variables can be found in Tab. 6 in Sec. 3.

4.6 Tracing Harmonised Data Back to Original Level 1 Products

In order to be able to find the original data on which the FDR values are based, data are provided in the `COLLECTION` group, separately for GOME-1 and SCIAMACHY. It contains the following elements (see also Sec's. 8.5.1 and 8.6.1 for GOME-1 and SCIAMACHY, respectively):

orbit The orbits for the measurements of the day

products The name of the pre-cursor product (Level 1b for GOME-1 and Level 1c for SCIAMACHY)

time_reference The time reference used to determine the `delta_time` in the `OBSERVATION` groups. Usually this should be always the same as in the global attributes for all orbits

valid_scan_count The valid scanlines for each orbit. The size of the `scan_line` dimension can be different for each orbit. In order to be able to stack the data along the `time` dimensions, the size of the `scan_line` dimension has to be identical for all arrays. Before aggregating the data of one day we filled up this dimension to the maximum number of scan lines for that day with fill values. The variable `valid_scan_count` gives the number of scan lines for each orbit of the product.

L1b_products (SCIAMACHY only) For SCIAMACHY no calibrated Level 1 products are distributed operationally. Therefore we here give also the name of the Level 1b products that are the source of the Level 1c products used for the FDR and referenced in the `products` variable.

4.7 Additional Information in Level 1a Products

Apart from the main data groups and variables, the Level 1a product contains additional information. The following groups are copied from the source products of GOME and SCIAMACHY:

- `SCIA|GOME/UV|VIS|NIR/POLARISATION`
- `SCIA|GOME/PMD`

In addition to the Level 1b, the Level 1a contains the groups

- `CALIBRATION` with the transfer functions for the reflectance and sun mean reference
- `PROCESSOR` with the FDR processor configuration parameters

The following variables are added to the groups already existing in the Level 1b products:

1. `SUN_MEAN_REFERENCE/GOME` : The orginal, not harmonised sun mean reference of GOME-1
2. `SUN_MEAN_REFERENCE/SCIA` : The Doppler-shift at 500nm
3. `GOME/UV|VIS|NIR/OBSERVATIONS`:
   a) Original radiance variables from the source GOME Level 1b products
   b) The regridded sun mean reference used for the reflectance (`smr_regridded` variable)
   c) The temperature of the pre-disoerser prism (`temperature` variable)
4. `SCIAMACHY/UV|VIS|NIR/`: The regridded sun mean reference used for the reflectance (`smr_regridded` variable)

The FDR4ATMOS Level 1a FDR products are not part of the nominal dissemination to users. The data will however be made available upon submission and approval by ESA of a special Data Service Request (DSR) using the form at the following link after login with the ESA EO Sign In account: https://esatellus.service-now.com/csp?id=dsr&dataset=SpecialDSR

In the form, the user shall briefly describe objectives, methods, deliverables and schedule for the activity. Information on the exact data and delivery requirements shall also be specified.

5 Uncertainties

Uncertainties for the data products in the FDR have been derived following the guidelines of the Quality Assurance framework for Earth Observation (QA4EO).

The documentation of FDR Uncertainties has been split into four parts:

1. A description of the basics of the QA4EO principles, included in the main uncertainty description document [13].
2. A detailed description of the "Measurement Functions". These are analytical expressions that describe step by step components of the measurement process and associated uncertainties, as well as external inputs (e.g. model data) and their uncertainties as used in Level 1b data processing. This document will be attached to the main uncertainty description document.
3. The "Effect Tables", which contain a quantitative description of each uncertainty from the measurement functions. This includes the magnitude of each uncertainty effect, but also spectral and/or temporal error correlation scales, form of the error correlation function, and maturity of the analysis. The full effect tables are available on the FDR4ATMOS website. A summary table with the most relevant effects has been included in the measurement function document.
4. Examples of end-to-end uncertainties on irradiance and radiance, using the uncertainty propagation model described by the measurement functions and the uncertainty data from the effect tables. These have been included in the main uncertainty description document.

All documents and data, including example NetCDF data files with combined uncertainties and spectral error correlation matrices for combined temporally random uncertainties, and combined temporally systematic uncertainties can be found on the ESA FDR4ATMOS landing web page.

There are several differences between the FDR uncertainties and the uncertainties in the original Level 1b data products (and associated documentation):

- The quantitative result of the measurement function evaluation is presented in the form of spectral/temporal FDR uncertainties with an associated spectral error correlation matrix. This is in contrast to the uncertainties in the original L1b products, that were merely split into "relative" uncertainties (mostly spectrally broadband accuracy) and "absolute" uncertainties (mostly spectral pixel-to-pixel precision).
- The uncertainties in the original L1b products (there called "errors", which is not quite correct as an error implies a deviation from truth, whereas uncertainty denotes lack of knowledge) were limited to Level 1b processing uncertainties: noise-like uncertainties and uncertainties in on-ground or in-flight calibration key data. The uncertainty analysis of the FDR has a wider scope of catching all uncertainties involved in the measurement process and in Level 0-to-1b data processing.
- The measurement functions try to describe each uncertainty effect separately, while the original L1b products provide lump-sum uncertainties. Having said that, it was not always possible to quantitatively determine uncertainties on each effect.

A practical difficulty has been that spectral error correlation scales were not considered in uncertainty estimates on on-ground calibration key data. To estimate these so many years after the on-ground calibration, based only on (often scarce) documentation, has been challenging and was not always possible.

For reflectance, we have the practical difficulty that uncertainties may be highly dependent on the input scene. This is especially true for atmospheric polarisation and for inhomogeneous scenes. Scene inhomogeneity may not only directly lead to radiance calibration errors, but also indirectly via additional errors in the Level 1b derivation of the polarisation correction.

In the literature there have been validation studies of GOME and SCIA polarisation retrieval, that indicate that errors on the retrieval of polarisation may be substantial. However, these are lump-sum errors that include all possible causes for uncertainty. Therefore, they are not very useful for quantitative use in the uncertainty propagation model described by the measurement functions. Note that for DOAS Level 2 retrieval, errors in the L1b polarisation correction are not significant, as these are spectrally broadband. These errors are accommodated by the DOAS polynomial closure term, as has been shown by switching off polarisation correction in L1b test data.

The FDR documentation provides measurement functions for Irradiance and radiance/reflectance. For polarisation, spectral calibration, and geolocation, a description of uncertainties is given but no analytical functions.

Effect tables are provided for irradiance and radiance. Since the main FDR product contains reflectances instead of radiances (as in the original L1b products), uncertainty values that cancel in the reflection have been omitted from the radiance effect tables. The uncertainties quoted in the effect tables are 1σ (1 standard deviation).

When using the measurement functions and effect tables to calculate end-to-end uncertainties, it may be very important to pay attention to the correlation scales. End-to-end uncertainties with large spectral error correlation scales, i.e. spectrally broadband, are overwhelmingly larger than those with small spectral error correlation scales. However, for Level 2 retrievals that use a closure term (e.g. the DOAS polynomial) only the uncertainties on small spectral scales matter.

For GOME L1b reflectance, it was found that significant systematic effects were present due to uncorrected wavelength dependent degradation, especially for the years after 2003. Although this certainly leads to systematic errors in the reflectance, it has been characterised here as a random uncertainty, because its spectral dependence could not be established within this work. These errors have not been mitigated in this FDR (i.e. are the same as for original GOME L1b data), but the issue will be addressed in a future version of the FDR.

6 Future Plans

At the time of writing ESA has already agreed to a follow-on project. While the details are still being worked out, the following activities will likely be done:

1. Incorporation of GOME-2 A,B,C data in a time series spanning GOME-1, SCIAMACHY and GOME-2
2. Development of a lunar model using SCIAMACHY and GOME-2 lunar measurements
3. Investigations to widen the basis for the reflectance harmonisation, i.e. incorporate more areas and possibly times
4. Investigations to correct the GOME-1 reflectance degradation
5. Improved uncertainties for the FDRs
6. Build a transfer function between instruments and evaluate its usefulness

7 Level 1b Detailed Structure

7.1 Global Attributes

Table 13: *Global Attributes*

Name	Value
Conventions	CF-1.8
title	FDR4ATMOS GOME/SCIAMACHY FDR in UVN spectral range
institution	ESA
processing_center	Deutsches Zentrum fuer Luft- und Raumfahrt (DLR)
source	satellite observations
filename	ESA_FDR_ATMOS__L1B_UVN__20030915_20231127T140649_v01_00.nc

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Name	Value
product_type	ATMOS__L1B
time_coverage_start	2003-09-15T00:11:59.201Z
time_coverage_end	2003-09-16T01:21:18.791Z
time_reference	2003-09-15T00:00:00.000Z
date_created	2023-11-27T14:06:49Z
history	FDR GOME-1/SCIAMACHY processing 2023
platform	ERS-2/ENVISAT
sensor	GOME/SCIAMACHY
level	L1b
processor	FDR4ATMOS Processor V1.0
temporal	daily
version	1.0
reference_document	FDR4ATMOS Products Format Specification FDR4ATB-PFS-DLR-0010
references	https://atmos.eoc.dlr.de/FDR4ATMOS/
project	ESA FDR4ATMOS
contact	eohelp@esa.int
identifier_product_doi	10.5270/ESA-852456e
identifier_product_doi_authority	http://dx.doi.org/

7.2 Metadata

Table 14: *Metadata attributes for group ISO_METADATA*

Group/Name	Value
ISO_METADATA	
gmd:dateStamp	2023-11-27
gmd:fileIdentifier	urn:ogc:def:EOP:ESA:ENV.FDR_L1B
gmd:hierarchyLevelName	EO Product Collection
gmd:metadataStandardName	ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data
gmd:metadataStandardVersion	ISO 19115-2:2009(E)
objectType	gmi:MI_Metadata
./gmd:characterSet	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode
codeListValue	utf8
objectType	gmd:MD_CharacterSetCode
./gmd:contact	
gmd:individualName	ESA/DLR
gmd:organisationName	Deutsches Zentrum fuer Luft- und Raumfahrt (DLR)
gmd:positionName	
objectType	gmd:CI_ResponsibleParty
././gmd:contactInfo	
objectType	gmd:CI_Contact
./././gmd:address	
gmd:electronicMailAddress	eohelp@esa.int
objectType	gmd:CI_Address
././gmd:role	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_RoleCode
codeListValue	pointOfContact
objectType	gmd:CI_RoleCode
./gmd:dataQualityInfo	
objectType	gmd:DQ_DataQuality
././gmd:lineage	
objectType	gmd:LI_Lineage
gmd:statement	L1b radiance dataset produced by DLR/IMF from the GOME ERS-2 L1b and SCIAMACHY ENVISAT L1c product for ESA FDR4ATMOS
./././gmd:processStep	
gmd:description	Processing of GOME L1b and SCIAMACHY L1c data to FDR4ATMOS product
objectType	gmi:LE_ProcessStep

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Group/Name	Value
./././gmd:source	
gmd:description	GOME ERS-2 L1b and SCIAMACHY ENVISAT L1c product
objectType	gmi:LE_Source
gmd:title	
././././gmi:processedLevel	
gmd:code	L1c
objectType	gmd:MD_Identifier
./././gmi:output	
gmd:description	ESA FDR4ATMOS radiance product
objectType	gmi:LE_Source
././././gmd:sourceCitation	
gmd:title	ESA_FDR_ATMOS__L1B_UVN__20030915_20231127T140649_v01_00.nc
objectType	gmd:CI_Citation
./././././gmd:date	
gmd:date	2023-11-27T14:06:49Z
objectType	gmd:CI_Date
./././././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	creation
objectType	gmd:CI_DateTypeCode
././././gmi:processedLevel	
gmd:code	L1c
objectType	gmd:MD_Identifier
./././gmi:processingInformation	
objectType	gmi:LE_Processing
././././gmi:documentation#1	
objectType	gmd:CI_Citation
gmd:title	FDR Processing ATBD (ENV-ATB-DLR-SCIA-0041)
./././././gmd:date	
gmd:date	2023
objectType	gmd:CI_Date
./././././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
././././gmi:documentation#2	
gmd:title	FDR netCDF Product User Guide (ENV-IODD-DLR-SCIA-0136)

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Group/Name	Value
objectType	gmd:CI_Citation
./././././gmd:date	
gmd:date	2023
objectType	gmd:CI_Date
./././././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
././././gmi:identifier	
gmd:code	DLR FDR processor
objectType	gmd:MD_Identifier
././././gmi:softwareReference	
gmd:title	FDR processor description
objectType	gmd:CI_Citation
./././././gmd:date	
gmd:date	2023
objectType	gmd:CI_Date
./././././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	creation
objectType	gmd:CI_DateTypeCode
./././gmi:report	
gmi:description	GOME L1b and SCIAMACHY L1c processed to FDR data using the DLR FDR processor
gmi:fileType	netCDF
gmi:name	ESA FDR4ATMOS processing report
objectType	gmi:LE_ProcessStepReport
./gmd:report	
objectType	gmd:DQ_DomainConsistency
././gmd:result	
gmd:pass	true
gmd:explanation	INSPIRE Data specification for orthoimagery is not yet officially published so conformity has not yet been evaluated
objectType	gmd:DQ_ConformanceResult
././././gmd:specification	
objectType	gmd:CI_Citation
gmd:title	INSPIRE Data Specification on Orthoimagery - Guidelines, version 3.0rc3
././././gmd:date	
gmd:date	2013-02-04
objectType	gmd:CI_Date

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Group/Name	Value
./././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
././gmd:scope	
objectType	gmd:DQ_Scope
./././gmd:level	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_ScopeCode
codeListValue	series
objectType	gmd:MD_ScopeCode
./gmd:hierarchyLevel	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_ScopeCode
codeListValue	series
objectType	gmd:MD_ScopeCode
./gmd:identificationInfo	
gmd:abstract	GOME/SCIAMACHY spectrometer on ERS-2/ENVISAT measurements
gmd:credit	ESA
gmd:language	eng
gmd:topicCategory	imageryBaseMapsEarthCover
objectType	gmd:MD_DataIdentification
././gmd:characterSet	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode
codeListValue	utf8
objectType	gmd:MD_CharacterSetCode
././gmd:citation	
gmd:title	FDR4ATMOS GOME/SCIAMACHY FDR in UVN spectral range
objectType	gmd:CI_Citation
./././gmd:date	
gmd:date	2023-11-27
objectType	gmd:CI_Date
././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	creation
objectType	gmd:CI_DateTypeCode
./././gmd:identifier	
gmd:code	urn:ogc:def:EOP:ESA:ENV.FDR_L1B_RAD_BD
objectType	gmd:MD_Identifier

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Group/Name	Value
./../gmd:descriptiveKeywords	
gmd:keyword	orthoimagery
objectType	gmd:MD_Keywords
./../../gmd:thesaurusName	
gmd:title	GEMET - INSPIRE themes, version 1.0
objectType	gmd:CI_Citation
./../../../gmd:date	
gmd:date	2008-06-01
objectType	gmd:CI_Date
./../../../../gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
./../../gmd:type	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_KeywordTypeCode
codeListValue	theme
objectType	gmd:MD_KeywordTypeCode
./../gmd:extent	
objectType	gmd:EX_Extent
./../../gmd:geographicElement	
gmd:eastBoundLongitude	180.0
gmd:northBoundLatitude	90.0
gmd:southBoundLatitude	-90.0
gmd:westBoundLongitude	-180.0
objectType	gmd:EX_GeographicBoundingBox
./../../gmd:temporalElement	
objectType	gmd:EX_TemporalExtent
./../../../gmd:extent	
gml:beginPosition	2003-09-15T00:11:59.201Z
gml:endPosition	2003-09-16T01:21:18.791Z
objectType	gml:TimePeriod
./../gmd:pointOfContact	
gmd:individualName	eoHelp
gmd:organisationName	ESA
gmd:positionName	Order Desk
objectType	gmd:CI_ResponsibleParty
./../../gmd:contactInfo	

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Group/Name	Value
objectType	gmd:CI_Contact
./././gmd:address	
gmd:electronicMailAddress	eohelp@esa.int
objectType	gmd:CI_Address
././gmd:role	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_RoleCode
codeListValue	distributor
objectType	gmd:CI_RoleCode
./gmd:resourceConstraints	
gmd:useLimitation	no conditions apply
objectType	gmd:MD_LegalConstraints
././gmd:accessConstraints	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_RestrictionCode
codeListValue	copyright
objectType	gmd:MD_RestrictionCode
./gmd:spatialRepresentationType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_SpatialRepresentationTypeCode
codeListValue	grid
objectType	gmd:MD_SpatialRepresentationTypeCode
./gmd:spatialResolution	
gmd:distance	240.0
objectType	gmd:MD_Resolution
uom	km
./gmd:language	
codeList	http://www.loc.gov/standards/iso639-2/
codeListValue	eng
objectType	gmd:LanguageCode
./gmi:acquisitionInformation	
objectType	gmi:MI_AcquisitionInformation
./gmi:platform	
objectType	gmi:MI_Platform
././gmi:description	
gco:characterString	ERS2ENVISAT
././gmi:identifier	
gmd:code	ERS-2/Envisat
gmd:codeSpace	http://www.esa.int/

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Group/Name	Value
objectType	gmd:RS_Identifier
./././gmi:instrument	
objectType	gmi:MI_Instrument
./././././gmi:identifier	
gmd:code	GOME/SCIAMACHY
gmd:codeSpace	http://www.esa.int/
objectType	gmd:RS_Identifier
./././././gmi:type	
codeList	
codeListValue	UV-VIS-NIR-SWIR scanning spectrometer
objectType	gmi:MI_SensorTypeCode

7.3 GOME

7.3.1 COLLECTION

Table 15: *Variables of group COLLECTION.*

Name	Description	Unit	Type	# Dim.
orbit	Orbits of measurements	1	<class 'str'>	1
products	Product name, can be used with the time index to identify source of individual data points	1	<class 'str'>	1
time_reference	Use together with delta times to determine the measurement time	1	<class 'str'>	1
valid_scanline_count	Can be used to get the number of scanlines for each individual orbit.	1	uint16	1

7.3.2 UV/VIS/NIR

Table 16: *Variables of groups for spectral band data (one group for UV, VIS, NIR each).*

Name	Description	Unit	Type	# Dim.
detector	detector channel	1	int16	-
start_pixel	start-index in detector array	1	int16	-
end_pixel	end-index in detector array	1	int16	-
start_wavelength	start wavelength band	1e-09m	float64	-
end_wavelength	end wavelength band	1e-09m	float64	-

7.3.2.1 CLOUDDATA

Table 17: *Variables of group CLOUDDATA.*

Name	Description	Unit	Type	# Dim.
cloud_fraction	cloud fraction	1	float32	3
cloud_fraction_precision	cloud fraction precision	1	float32	3
cloud_albedo	cloud albedo	1	float32	3
cloud_albedo_precision	cloud albedo precision	1	float32	3
cloud_height	cloud height	m	float32	3
cloud_height_precision	cloud height precision	m	float32	3
cloud_optical_thickness	cloud optical thickness	1	float32	3
cloud_optical_thickness_precision	cloud optical thickness precision	1	float32	3
cloud_pressure	cloud pressure	hPa	float32	3
cloud_pressure_precision	cloud pressure precision	hPa	float32	3
surface_albedo	surface albedo	1	float32	3
sun_glint	sun glint flag	1	int8	3

7.3.2.2 GEODATA

Table 18: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4

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Name	Description	Unit	Type	# Dim.
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
solar_zenith_angle_sat	SZA at satellite height	degree	float32	4
solar_azimuth_angle_sat	SAA sat satellite height	degree	float32	4
viewing_zenith_angle_sat	VZA at satellite height	degree	float32	4
viewing_azimuth_angle_sat	VAA at satellite height	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3
earth_radius	earth radius	m	float32	3

7.3.2.3 OBSERVATIONS

Table 19: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
reflectance	reflectance	1	float32	4
reflectance_quality_flag	reflectance quality flag	1	int8	4
reflectance_fdr	harmonised reflectance	1	float32	4
reflectance_fdr_quality_flag	harmonised reflectance quality flag	1	int8	4
radiance_fdr	synthetic radiance	photons/cm2.nm.s	float32	4
lambda	radiance wavelength	1e-09m	float64	4
delta_time	offset from the associated reference start time	s	float64	3
integration_time	integration time	s	float32	2
radiance_flags	radiance flags	1	int8	4
scan_line	along track dimension index	1	int32	2

7.4 SCIAMACHY

7.4.1 COLLECTION

Table 20: *Variables of group COLLECTION.*

Name	Description	Unit	Type	# Dim.
orbit	Orbits of measurements	1	<class 'str'>	1
products	Product name, can be used with the time index to identify source of individual data points	1	<class 'str'>	1
L1b_products	For SCIAMACHY, Level1c products are used as FDR input which are generated from the product listed here with the scial1c tool	1	<class 'str'>	1
time_reference	Use together with delta times to determine the measurement time	1	<class 'str'>	1
valid_scanline_count	Can be used to get the number of scanlines for each individual orbit.	1	uint16	1

7.4.2 UV/VIS/NIR

Table 21: *Variables of group UV.*

Name	Description	Unit	Type	# Dim.
detector	detector channel	1	int16	-
start_pixel	start-index in detector array	1	int16	-
end_pixel	end-index in detector array	1	int16	-
start_wavelength	start wavelength band	1e-09m	float32	-
end_wavelength	end wavelength band	1e-09m	float32	-

7.4.2.1 CLOUDDATA

Table 22: *Variables of group CLOUDDATA.*

Name	Description	Unit	Type	# Dim.
cloud_fraction	cloud fraction	1	float64	3
cloud_top_height	cloud top height	m	float64	3
cloud_optical_thickness	cloud optical thickness	1	float64	3

7.4.2.2 GEODATA

Table 23: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
esm_position	elevation scan mirror position	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3
earth_radius	earth radius	m	float32	3
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4

7.4.2.3 OBSERVATIONS

Table 24: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
radiance_fdr	scaled radiance	photons/cm2.nm.s	float32	4
reflectance_fdr	reflectance	1	float32	4
reflectance_fdr_quality_flag	reflectance quality flag	1	int8	4
scaling_flag	scaling flag radiance	1	int8	2
integration_time	integration time	s	float32	2
delta_time	offset from the associated reference start time	s	float64	3
lambda	radiance wavelength	1e-09m	float64	3
backscan_flag	0 = forward-scan, 1 = back-scan	1	int8	3
orbit_phase	orbit phase	1	float32	2
radiance_fdr_flags	radiance flags	1	int8	3
scan_line	along track dimension index	1	int32	2

7.5 Sun Mean References

7.5.1 GOME

7.5.1.1 UV/VIS/NIR

Table 25: *Variables of spectral band groups.*

Name	Description	Unit	Type	# Dim.
lambda	sun mean reference wavelength GOME	1e-09m	float64	2
smr_fdr	harmonised sun mean reference GOME	photons/cm2.nm.s	float64	2

7.5.2 SCIAMACHY

7.5.2.1 UV/VIS/NIR

Table 26: *Variables of spectral band groups.*

Name	Description	Unit	Type	# Dim.
lambda	sun mean reference wavelength SCIAMACHY	1e-09m	float64	2
smr_fdr	original sun mean reference SCIAMACHY	photons/cm2.nm.s	float64	2

8 Level 1a Detailed Structure

8.1 Global Attributes

Table 27: *Global Attributes*

Name	Value
Conventions	CF-1.8
title	FDR4ATMOS GOME/SCIAMACHY FDR in UVN spectral range
institution	ESA
processing_center	Deutsches Zentrum fuer Luft- und Raumfahrt (DLR)
source	satellite observations
filename	ESA_FDR_ATMOS__L1A_UVN__20030915_20231127T140649_v01_00.nc
product_type	ATMOS__L1A
time_coverage_start	2003-09-15T00:11:59.201Z
time_coverage_end	2003-09-16T01:21:18.791Z
time_reference	2003-09-15T00:00:00.000Z
date_created	2023-11-27T14:06:49Z
history	FDR GOME-1/SCIAMACHY processing 2023
platform	ERS-2/ENVISAT
sensor	GOME/SCIAMACHY
level	L1a
processor	FDR4ATMOS Processor V1.0
temporal	daily
version	1.0
reference_document	FDR4ATMOS Products Format Specification FDR4ATB-PFS-DLR-0010
references	https://atmos.eoc.dlr.de/FDR4ATMOS/
project	ESA FDR4ATMOS
contact	eohelp@esa.int
identifier_product_doi	10.57780/en1-c36d669
identifier_product_doi_authority	http://dx.doi.org/

8.2 Metadata

Table 28: *Metadata attributes for group ISO_METADATA*

Group/Name	Value
ISO_METADATA	
gmd:dateStamp	2023-11-27
gmd:fileIdentifier	urn:ogc:def:EOP:ESA:ENV.FDR_L1B
gmd:hierarchyLevelName	EO Product Collection
gmd:metadataStandardName	ISO 19115-2 Geographic Information - Metadata Part 2 Extensions for imagery and gridded data
gmd:metadataStandardVersion	ISO 19115-2:2009(E)
objectType	gmi:MI_Metadata
./gmd:characterSet	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode
codeListValue	utf8
objectType	gmd:MD_CharacterSetCode
./gmd:contact	
gmd:individualName	ESA/DLR
gmd:organisationName	Deutsches Zentrum fuer Luft- und Raumfahrt (DLR)
gmd:positionName	
objectType	gmd:CI_ResponsibleParty
././gmd:contactInfo	
objectType	gmd:CI_Contact
./././gmd:address	
gmd:electronicMailAddress	eohelp@esa.int
objectType	gmd:CI_Address
././gmd:role	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_RoleCode
codeListValue	pointOfContact
objectType	gmd:CI_RoleCode
./gmd:dataQualityInfo	
objectType	gmd:DQ_DataQuality
././gmd:lineage	
objectType	gmd:LI_Lineage
gmd:statement	L1b radiance dataset produced by DLR/IMF from the GOME ERS-2 L1b and SCIAMACHY ENVISAT L1c product for ESA FDR4ATMOS
./././gmd:processStep	
gmd:description	Processing of GOME L1b and SCIAMACHY L1c data to FDR4ATMOS product
objectType	gmi:LE_ProcessStep

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Group/Name	Value
./././gmd:source	
gmd:description objectType gmd:title	GOME ERS-2 L1b and SCIAMACHY ENVISAT L1c product gmi:LE_Source
././././gmi:processedLevel	
gmd:code objectType	L1c gmd:MD_Identifier
./././gmi:output	
gmd:description objectType	ESA FDR4ATMOS radiance product gmi:LE_Source
././././gmd:sourceCitation	
gmd:title objectType	ESA_FDR_ATMOS__L1B_UVN__20030915_20231127T140649_v01_00.nc gmd:CI_Citation
./././././gmd:date	
gmd:date objectType	2023-11-27T14:06:49Z gmd:CI_Date
./././././././gmd:dateType	
codeList codeListValue objectType	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode creation gmd:CI_DateTypeCode
././././gmi:processedLevel	
gmd:code objectType	L1c gmd:MD_Identifier
./././gmi:processingInformation	
objectType	gmi:LE_Processing
././././gmi:documentation#1	
objectType gmd:title	gmd:CI_Citation FDR Processing ATBD (ENV-ATB-DLR-SCIA-0041)
./././././gmd:date	
gmd:date objectType	2023 gmd:CI_Date
./././././././gmd:dateType	
codeList codeListValue objectType	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode publication gmd:CI_DateTypeCode
././././gmi:documentation#2	
gmd:title	FDR netCDF Product User Guide (ENV-IODD-DLR-SCIA-0136)

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Group/Name	Value
objectType	gmd:CI_Citation
./././././gmd:date	
gmd:date objectType	2023 gmd:CI_Date
./././././././gmd:dateType	
codeList codeListValue objectType	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode publication gmd:CI_DateTypeCode
./././././gmi:identifier	
gmd:code objectType	DLR FDR processor gmd:MD_Identifier
./././././gmi:softwareReference	
gmd:title objectType	FDR processor description gmd:CI_Citation
./././././gmd:date	
gmd:date objectType	2023 gmd:CI_Date
./././././././gmd:dateType	
codeList codeListValue objectType	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode creation gmd:CI_DateTypeCode
././././gmi:report	
gmi:description gmi:fileType gmi:name objectType	GOME L1b and SCIAMACHY L1c processed to FDR data using the DLR FDR processor netCDF ESA FDR4ATMOS processing report gmi:LE_ProcessStepReport
././gmd:report	
objectType	gmd:DQ_DomainConsistency
./././gmd:result	
gmd:pass gmd:explanation objectType	true INSPIRE Data specification for orthoimagery is not yet officially published so conformity has not yet been evaluated gmd:DQ_ConformanceResult
././././gmd:specification	
objectType gmd:title	gmd:CI_Citation INSPIRE Data Specification on Orthoimagery - Guidelines, version 3.0rc3
./././././gmd:date	
gmd:date objectType	2013-02-04 gmd:CI_Date

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Group/Name	Value
./././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
./../gmd:scope	
objectType	gmd:DQ_Scope
./././gmd:level	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_ScopeCode
codeListValue	series
objectType	gmd:MD_ScopeCode
./gmd:hierarchyLevel	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_ScopeCode
codeListValue	series
objectType	gmd:MD_ScopeCode
./gmd:identificationInfo	
gmd:abstract	GOME/SCIAMACHY spectrometer on ERS-2/ENVISAT measurements
gmd:credit	ESA
gmd:language	eng
gmd:topicCategory	imageryBaseMapsEarthCover
objectType	gmd:MD_DataIdentification
././gmd:characterSet	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_CharacterSetCode
codeListValue	utf8
objectType	gmd:MD_CharacterSetCode
././gmd:citation	
gmd:title	FDR4ATMOS GOME/SCIAMACHY FDR in UVN spectral range
objectType	gmd:CI_Citation
./././gmd:date	
gmd:date	2023-11-27
objectType	gmd:CI_Date
././././gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	creation
objectType	gmd:CI_DateTypeCode
./././gmd:identifier	
gmd:code	urn:ogc:def:EOP:ESA:ENV.FDR_L1B_RAD_BD
objectType	gmd:MD_Identifier

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Group/Name	Value
./../gmd:descriptiveKeywords	
gmd:keyword	orthoimagery
objectType	gmd:MD_Keywords
./../../gmd:thesaurusName	
gmd:title	GEMET - INSPIRE themes, version 1.0
objectType	gmd:CI_Citation
./../../../gmd:date	
gmd:date	2008-06-01
objectType	gmd:CI_Date
./../../../../gmd:dateType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_DateTypeCode
codeListValue	publication
objectType	gmd:CI_DateTypeCode
./../../gmd:type	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_KeywordTypeCode
codeListValue	theme
objectType	gmd:MD_KeywordTypeCode
./../gmd:extent	
objectType	gmd:EX_Extent
./../../gmd:geographicElement	
gmd:eastBoundLongitude	180.0
gmd:northBoundLatitude	90.0
gmd:southBoundLatitude	-90.0
gmd:westBoundLongitude	-180.0
objectType	gmd:EX_GeographicBoundingBox
./../../gmd:temporalElement	
objectType	gmd:EX_TemporalExtent
./../../../gmd:extent	
gml:beginPosition	2003-09-15T00:11:59.201Z
gml:endPosition	2003-09-16T01:21:18.791Z
objectType	gml:TimePeriod
./../gmd:pointOfContact	
gmd:individualName	eoHelp
gmd:organisationName	ESA
gmd:positionName	Order Desk
objectType	gmd:CI_ResponsibleParty
./../../gmd:contactInfo	

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Group/Name	Value
objectType	gmd:CI_Contact
./././.gmd:address	
gmd:electronicMailAddress	eohelp@esa.int
objectType	gmd:CI_Address
./././gmd:role	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#CI_RoleCode
codeListValue	distributor
objectType	gmd:CI_RoleCode
././gmd:resourceConstraints	
gmd:useLimitation	no conditions apply
objectType	gmd:MD_LegalConstraints
./././gmd:accessConstraints	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_RestrictionCode
codeListValue	copyright
objectType	gmd:MD_RestrictionCode
././gmd:spatialRepresentationType	
codeList	http://www.isotc211.org/2005/resources/Codelist/gmxCodelists.xml#MD_SpatialRepresentationTypeCode
codeListValue	grid
objectType	gmd:MD_SpatialRepresentationTypeCode
././gmd:spatialResolution	
gmd:distance	240.0
objectType	gmd:MD_Resolution
uom	km
./gmd:language	
codeList	http://www.loc.gov/standards/iso639-2/
codeListValue	eng
objectType	gmd:LanguageCode
./gmi:acquisitionInformation	
objectType	gmi:MI_AcquisitionInformation
././gmi:platform	
objectType	gmi:MI_Platform
./././gmi:description	
gco:characterString	ERS2ENVISAT
./././gmi:identifier	
gmd:code	ERS-2/Envisat
gmd:codeSpace	http://www.esa.int/

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Group/Name	Value
objectType	gmd:RS_Identifier
./././gmi:instrument	
objectType	gmi:MI_Instrument
././././gmi:identifier	
gmd:code	GOME/SCIAMACHY
gmd:codeSpace	http://www.esa.int/
objectType	gmd:RS_Identifier
././././gmi:type	
codeList	
codeListValue	UV-VIS-NIR-SWIR scanning spectrometer
objectType	gmi:MI_SensorTypeCode

8.3 Calibration

8.3.1 HARMONISATION

Table 29: *Variables of group HARMONISATION.*

Name	Description	Unit	Type	# Dim.
reflectance_transfer_factor	reflectance transfer factor	1	float32	3
reflectance_transfer_factor_sigma	reflectance transfer factor variance	1	float32	3
smr_transfer_factor	transfer factors sun mean reference	1	float32	3
smr_harmonisation_reference	sun mean reference harmonisation reference	photons/cm2.nm.s	float32	2
band_name	band names for band dimensions	1	<class 'str'>	1
smr_harmonisation_reference_filename	File name of reference scia	1	<class 'str'>	-

8.4 Processor

8.4.1 CONFIG

Table 30: *Variables of group CONFIG.*

Name	Description	Unit	Type	# Dim.
configuration	fdr processor configuration	1	<class 'str'>	-

8.5 GOME

8.5.1 COLLECTION

Table 31: *Variables of group COLLECTION.*

Name	Description	Unit	Type	# Dim.
orbit	Orbits of measurements	1	<class 'str'>	1
products	Product name, can be used with the time index to identify source of individual data points	1	<class 'str'>	1
time_reference	Use together with delta times to determine the measurement time	1	<class 'str'>	1
valid_scanline_count	Can be used to get the number of scanlines for each individual orbit.	1	uint16	1
missing_files	missing files	1	<class 'str'>	-

8.5.2 PMD

Table 32: *Variables of group PMD.*

Name	Description	Unit	Type	# Dim.
integration_time	integration time of the PMDs	s	float32	-

8.5.2.1 GEODATA

Table 33: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
solar_zenith_angle_sat	SZA at satellite height	degree	float32	4
solar_azimuth_angle_sat	SAA sat satellite height	degree	float32	4
viewing_zenith_angle_sat	VZA at satellite height	degree	float32	4
viewing_azimuth_angle_sat	VAA at satellite height	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3
earth_radius	earth radius	m	float32	3

8.5.2.2 OBSERVATIONS

Table 34: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
radiance	original radiance	photons/cm2.nm.s	float32	4
radiance_flags	quality_flags	-	int8	4
wavelength	spectral channel wavelength	1e-09m	float32	4
delta_time	offset from the associated reference start time	s	float64	3
scan_line	along track dimension index	1	int32	2

8.5.3 UV/VIS/NIR

Table 35: *Variables of group UV.*

Name	Description	Unit	Type	# Dim.
detector	detector channel	1	int16	-
start_pixel	start-index in detector array	1	int16	-
end_pixel	end-index in detector array	1	int16	-
start_wavelength	start wavelength band	1e-09m	float64	-
end_wavelength	end wavelength band	1e-09m	float64	-

8.5.3.1 CLOUDDATA

Table 36: *Variables of group CLOUDDATA.*

Name	Description	Unit	Type	# Dim.
cloud_fraction	cloud fraction	1	float32	3
cloud_fraction_precision	cloud fraction precision	1	float32	3
cloud_albedo	cloud albedo	1	float32	3
cloud_albedo_precision	cloud albedo precision	1	float32	3
cloud_height	cloud height	m	float32	3
cloud_height_precision	cloud height precision	m	float32	3
cloud_optical_thickness	cloud optical thickness	1	float32	3

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Name	Description	Unit	Type	# Dim.
cloud_optical_thickness_precision	cloud optical thickness precision	1	float32	3
cloud_pressure	cloud pressure	hPa	float32	3
cloud_pressure_precision	cloud pressure precision	hPa	float32	3
surface_albedo	surface albedo	1	float32	3
sun_glint	sun glint flag	1	int8	3

8.5.3.2 GEODATA

Table 37: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
solar_zenith_angle_sat	SZA at satellite height	degree	float32	4
solar_azimuth_angle_sat	SAA sat satellite height	degree	float32	4
viewing_zenith_angle_sat	VZA at satellite height	degree	float32	4
viewing_azimuth_angle_sat	VAA at satellite height	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3
earth_radius	earth radius	m	float32	3

8.5.3.3 OBSERVATIONS

Table 38: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
radiance	original radiance	photons/cm2.nm.s	float32	4
reflectance	reflectance	1	float32	4
reflectance_quality_flag	reflectance quality flag	1	int8	4
reflectance_fdr	harmonised reflectance	1	float32	4
reflectance_fdr_quality_flag	harmonised reflectance quality flag	1	int8	4
radiance_fdr	synthetic radiance	photons/cm2.nm.s	float32	4
smr_regridded	regridded sun mean reference	photons/cm2.nm.s	float64	4
lambda	radiance wavelength	1e-09m	float64	4
delta_time	offset from the associated reference start time	s	float64	3
integration_time	integration time	s	float32	2
radiance_flags	radiance flags	1	int8	4
radiance_precision	radiance precision	1	float32	4
scan_line	along track dimension index	1	int32	2
temperature	the temperature of the predisperser prism	K	float32	3

8.5.3.4 POLARISATION

Table 39: *Variables of group POLARISATION.*

Name	Description	Unit	Type	# Dim.
polarisation_q_pmd	fractional polarisation q of the pmd	1	float32	4
polarisation_q_pmd_error	error on the fractional polarisation q of the pmd	1	float32	4
polarisation_q_pmd_wavelength	wavelength of the fractional polarisation q of the pmd	1	float32	4
polarisation_q_overlap	fractional polarisation q of the overlap region	1	float32	4
polarisation_q_overlap_error	error on the fractional polarisation q of the overlap region	1	float32	4
polarisation_q_overlap_wavelength	wavelength of the fractional polarisation q of the overlap region	1	float32	4
polarisation_q_theoretic	fractional polarisation q of the UV part	1	float32	3
polarisation_q_theoretic_error	error on the fractional polarisation q of the UV part	1	float32	3
polarisation_q_theoretic_wavelength	wavelength of the fractional polarisation q of the UV part	1	float32	3
polarisation_chi	plane of the polarization angle	degree	float32	3

8.6 SCIAMACHY

8.6.1 COLLECTION

Table 40: *Variables of group COLLECTION.*

Name	Description	Unit	Type	# Dim.
orbit	Orbits of measurements	1	<class 'str'>	1
products	Product name, can be used with the time index to identify source of individual data points	1	<class 'str'>	1
L1b_products	For SCIAMACHY, Level1c products are used as FDR input which are generated from the product listed here with the scial1c tool	1	<class 'str'>	1
time_reference	Use together with delta times to determine the measurement time	1	<class 'str'>	1
valid_scanline_count	Can be used to get the number of scanlines for each individual orbit.	1	uint16	1

8.6.2 PMD

Table 41: *Variables of group PMD.*

Name	Description	Unit	Type	# Dim.
integration_time	integration time of the PMDs	s	float32	-

8.6.2.1 GEODATA

Table 42: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
esm_position	elevation scan mirror position	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4

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Name	Description	Unit	Type	# Dim.
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3
earth_radius	earth radius	m	float32	3
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4

8.6.2.2 OBSERVATIONS

Table 43: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
radiance	original radiance	photons/cm2.nm.s	float32	4
delta_time	offset from the associated reference start time	s	float64	3
scan_line	along track dimension index	1	int32	2

8.6.3 UV/VIS/NIR

Table 44: *Variables of group UV.*

Name	Description	Unit	Type	# Dim.
detector	detector channel	1	int16	-
start_pixel	start-index in detector array	1	int16	-
end_pixel	end-index in detector array	1	int16	-
start_wavelength	start wavelength band	1e-09m	float32	-
end_wavelength	end wavelength band	1e-09m	float32	-

8.6.3.1 CLOUDDATA

Table 45: *Variables of group CLOUDDATA.*

Name	Description	Unit	Type	# Dim.
cloud_fraction	cloud fraction	1	float64	3
cloud_top_height	cloud top height	m	float64	3
cloud_optical_thickness	cloud optical thickness	1	float64	3

8.6.3.2 GEODATA

Table 46: *Variables of group GEODATA.*

Name	Description	Unit	Type	# Dim.
latitude	pixel center latitude	degrees_north	float32	3
longitude	pixel center longitude	degrees_east	float32	3
esm_position	elevation scan mirror position	degree	float32	3
solar_zenith_angle	solar zenith angle	degree	float32	4
solar_azimuth_angle	solar azimuth angle with respect to north	degree	float32	4
viewing_zenith_angle	viewing zenith angle	degree	float32	4
viewing_azimuth_angle	viewing azimuth angle with respect to north	degree	float32	4
satellite_altitude	satellite altitude	m	float32	3

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Name	Description	Unit	Type	# Dim.
earth_radius	earth radius	m	float32	3
latitude_subsatellite	sub satellite latitude	degree	float32	3
longitude_subsatellite	sub satellite longitude	degree	float32	3
latitude_bounds	latitude bounds	degrees_north	float32	4
longitude_bounds	longitude bounds	degrees_east	float32	4

8.6.3.3 OBSERVATIONS

Table 47: *Variables of group OBSERVATIONS.*

Name	Description	Unit	Type	# Dim.
radiance_fdr	scaled radiance	photons/cm2.nm.s	float32	4
reflectance_fdr	reflectance	1	float32	4
reflectance_fdr_quality_flag	reflectance quality flag	1	int8	4
scaling_flag	scaling flag radiance	1	int8	2
integration_time	integration time	s	float32	2
delta_time	offset from the associated reference start time	s	float64	3
smr_regridded	regridded sun mean reference	photons/cm2.nm.s	float64	3
lambda	radiance wavelength	1e-09m	float64	3
backscan_flag	0 = forward-scan, 1 = back-scan	1	int8	3
orbit_phase	orbit phase	1	float32	2
radiance_fdr_flags	radiance flags	1	int8	3
scan_line	along track dimension index	1	int32	2

8.6.3.4 POLARISATION

Table 48: *Variables of group POLARISATION.*

Name	Description	Unit	Type	# Dim.
polarisation_lambda	wavelength of polarisation values	1e-09m	float32	4
polarisation_q	Q value of Stokes vector	1	float32	4
polarisation_u	U value of Stokes vector	1	float32	4
polarisation_q_error	error of Q value	1	float32	4
polarisation_u_error	error of U value	1	float32	4
polarisation_GDF	GDF of polarisation	1	float32	4

8.7 Sun Mean References

8.7.1 GOME

8.7.1.1 UV/VIS/NIR

Table 49: *Variables of group UV.*

Name	Description	Unit	Type	# Dim.
lambda	sun mean reference wavelength GOME	1e-09m	float64	2
smr	original sun mean reference GOME	photons/cm2.nm.s	float64	2
smr_fdr	harmonised sun mean reference GOME	photons/cm2.nm.s	float64	2

8.7.2 SCIAMACHY

Table 50: *Variables of group SCIAMACHY.*

Name	Description	Unit	Type	# Dim.
doppler_shift	doppler shift	1e-09m	float32	1

8.7.2.1 UV/VIS/NIR

Table 51: *Variables of group UV.*

Name	Description	Unit	Type	# Dim.
lambda	sun mean reference wavelength SCIAMACHY	1e-09m	float64	2
smr_fdr	original sun mean reference SCIAMACHY	photons/cm2.nm.s	float64	2