DLR

Deutsches Zentrum
für Luft und Raumfahrt e.V.

Product Specification Document
of the
GOME Data Processor

ER–PS–DLR–GO–0016

Iss./Rev. 4/B

December 15, 2004

Deutsches Zentrum für Luft– und Raumfahrt e.V. – DLR

Institut für Methodik der Fernerkundung – IMF

Oberpfaffenhofen, Germany

prepared by D. Loyola, DLR/IMF, _____ Date _____

W. Thomas, former DLR/IMF, _____ Date _____

W. Balzer, DLR/IMF, _____ Date _____

Distribution List

Available to the Public via the Internet

Document Change Log

Rev.	Date	Section	Description of Change	approved by	Sign
1/A	30.09.94	all	Completely new		
2/A	11.09.95	all	Minor corrections		
		appendix	Product formats were moved from ISD to PSD		
3/A	04.04.96	all	Minor corrections		
		appendix	Changes in Level 1 and Level 2 Data Product formats		
3/B	30.07.96	all	Minor corrections		
3/C	30.09.96	all	Minor corrections		
3/D	15.05.00	2, 3.4	CD label and exclusion of level 2 products from L1 CDs,		
		3.3	Geolocation gaps closed		
		appendix	Correction of the byte positon on the FCD fields (table 5)		
4/A	10.04.02	appendix	minor changes in ICFA and AMF index flags (tables 18, 20)		
4/B	15.12.04	1	new product file name convention and updated ftp server		
		3	level 2 data format updated.		
		A.2	table 12 to 17 byte positions updated.		
			table 17, content changed starting with field 7.		
			tables 18 and 21 from previous issues remove		
		A.4	table 38 and 39, byte positions updated.		
			table 42, content changed starting with field 12.		
		appendix	typo on the “integation time” field of table 11 on page 31		

Table of Contents

Appendix

1 Introduction

1.1 Purpose and Scope

At its meeting in June 1990, the ESA Council approved the satellite project which followed the first European Remote Sensing Satellite (ERS–1). This new satellite (ERS–2), is intended to provide data continuity between ERS–1 and the European polar platforms. Its launch was performed on April, 21st 1995.

In addition to the mission objectives of ERS–1, ERS–2 is intended to make a significant contribution to atmospheric chemistry. Thus, in addition to the instruments on ERS–1 (AMI, ATSR, RA, PRARE, etc.), it also carries the Global Ozone Monitoring Experiment (GOME). This instrument is intended to measure a range of atmospheric trace constituents both in the troposphere and in the stratosphere.

GOME is a nadir–viewing spectrometer which in its normal mode scans across–track in three steps. The field of view of each steep may be varied in size from 40 km x 40 km to320 km x 40 km – a total of five options. The mode with the largest footprint (three steps with a total coverage of 960 km x 40 km) provides global coverage at the equator within 3 days.

GOME demonstrates the feasibility of using the differential absorption technique (DOAS) to observe trace constituents including ozone. Existing nadir–viewing instruments such as SBUV exploit the fact that the height at which solar radiation is back–scattered by the atmosphere varies with wavelength. However, this approach depends on an accurate radiometric calibration.

Besides the on–line components at the ground stations and the Mission Management and Control Center (MMCC) the GOME Data Processor (GDP) system is the operational off–line ground segment for GOME. It incorporates a Level 0 to 1 processing chain, the complete GOME data archive, a DOAS O_3 total column retrieval process (Level 1 to 2), and an image processing chain for the generation of higher–level products.

The first issue of the present product specification document (PSD) was one of the primary results of the Architectural Design (AD) phase of the GDP project. It was distributed as part of the Critical Design Review Data Package (CDR–DP) to the participants of this review and to the members of the geophysical validation group selected from the AO proposals by ESA. By that time it just contained the description of the proposed data products. The detailed specification of the product formats was contained in the Interface Specification Document (ISD) [A1]. This separation required the distribution of two documents to those who wanted to work with GOME data products and most of the content of the ISD was for internal use only. Therefore, a re–structuring of the PSD/ISD documents was done in issue 2/A of the PSD which includes also the format specification of the products.

Besides the new structure also the content was changed, mainly the format description due to changes imposed by new or modified requirements on the GDP such as the use of the ERS propagator.

Due to the large interest on the GOME sun and moon measurements on its own and because the sun reference spectra as part of the Level 1 data products do not include all the intermediate processing results, these sun and moon measurements have been added to the Level 1 Data Product. The details about these new products are described in the corresponding section.

1.2 Acronyms and Abbreviations

A list of about all abbreviations and acronyms which are used throughout the specification is given below:

AD	Architectural Design
AMF	Air Mass Factor
AO	Announcement of Opportunity
BBM	Bread Board Model
BDDN	Broadband Data Distribution Network
BSDF	Bi–directional Scattering Distribution Function
BU	Binary Units
CD–R	Compact Disc (Write Once, Read Multiple)
CEOS	Committee on Earth Observation Satellites
CDR–DP	Critical Design Review Data Package
DFD	Deutsches Fernerkundungsdatenzentrum
DOAS	Differential Optical Absorption Spectroscopy
DSR	Data Set Record
EGOC	Extracted GOME Calibration Data
ERS	European Remote Sensing Satellite
ESA	European Space Agency
FTP	File Transfer Protocol
GDP	GOME Data Processor
GVC	Ghost Vertical Column
GOME	Global Ozone Monitoring Experiment
ICFA	Initial Cloud Fitting Algorithm
ISD	Interface Specification Document
ISIS	Intelligentes Satellitenbild Informationsystem
MMCC	Mission Management Control Centre
MPH	Main Product Header
OCRA	Optical Cloud Recognition Algorithm
PMD	Polarisation Measurement Device
PSD	Product Specification Document
ROCINN	Retrieval of Cloud Information using Neural Networks
SBUV	Solar Backscatter Ultra–Violet
SPH	Specific Product Header
UTC	Universal Time Coordinated
VCD	Vertical Column Density

1.3 References and Documents

The following documents are referenced in this specification:

[A1] Interface Specification Document of the GDP, ER–IS–DLR–GO–0004, Issue 2, 11.9.95

[A2] GOME Level 0 to 1 Algorithms Description, ER–TN–DLR–GO–0022, Issue 5/B, 21.12.2001

[A3] GOME Level 1 to 2 Algorithm Theoretical Basis Document, ER–TN–DLR–GO–0025, Issue 4/A, 15.12.2004

[A4] GOME Software Databases for Level 1 to 2 Processing, ER–TN–IFE–GO–0018, Issue 3/A, 21.12.2001

[A5] EECF to PAF Interface Specifications, ER–IS–EPO–GE–0102, Issue 3.0, 29.1.90

[A6] GOME Science Packet Description, ER–TN–ESA–GO–0096, Issue 2, 29.8.1991

[A7] GOME Flight Spare Model Software F.5 Test Report, ER–TR–ESA–GO–0467, Issue 1 – draft, 7.8.95

The following documents are applicable for this specification:

[A8] System Requirements Document of the GOME Data Processing, ER–SR–DLR–GO–0020, Issue 1/B, 15.10.93

[A9] Functional Software Requirements of the GOME Data Processor (Level 1), ER–SR–DLR–GO–0008, Issue 1/B, 15.10.93

[A10] Functional Software Requirements of the GOME Data Processor (Level 2), ER–SR–DLR–GO–0009, Issue 1/B, 15.10.93

[A11] Architectural Design Document of the GDP, ER–AD–DLR–GO–0021, Issue 1, 11.4.94

[A12] Architectural Design Document of the GDP (Level 1), ER–AD–DLR–GO–0011, Issue 1, 11.4.94

[A13] Architectural Design Document of the GDP (Level 2), ER–AD–DLR–GO–0012, Issue 1, 11.4.94

[A14] ESA Software Engineering Standards, ESA PSS–05–0, Issue 2, Feb. 1991

[A15] LRDPF Re–Host – Interface Specification, RH–IC–SPT–SY–0001, Issue 1/2, 15.12.93

[A16] GOME Requirements Specification, ER–RS–ESA–GO–0001, Issue 1, 5.7.1991

[A17] GOME Command Description, ER–TN–ESA–GO–0171, Issue1, 10.9.91

1.4 Overview

The present document is divided into the following sections:

- Products Overview
  This section gives a short overview about the products of GDP
- Level 1 Radiance/Irradiance Product
  This section gives a detailed description of the Level 1 Product
- Level 2 Total Column Product
  This section gives a detailed description of the Level 2 Total Column Product
- Detailed Product Formats
  This appendix gives a detailed bit–by–bit description of the specified products and their extraction formats

2 Products Overview

GOME Level 1 and Level 2 products are distributed to the users via ftp server (off–line and near–real–time products) and CD–R (off–line products only).

2.1 Level 1 Radiance/Irradiance Product

A limited number of off–line Level 1 data products from the regular ground stations are available at the D–PAF NAS FTP–server: ***ftp–ops.de.envisat.esa.int***
The data is organized in directories as follows:

products/level_1/YYYY/MM/DD

where YYYY is the year, *MM* the month, DD the day.

A CD–R including the Level 1 data products of approximately 3 days (35 orbits) containing the Earthshine spectra and the daily Sun reference spectrum corresponding to this period.
The label of the LVL13 CDs is:

DLR_ERS2_GOME_L1_YYYY_MON_DD_R<revision_id>

where *YYYY_MON_DD* is the Temporal_Coverage_Start of the LVL13, i.e. of the first included Level–1 product, and <*revision_id*> is the Level–1 Product Revision Identifier.
Example:

DLR_ERS2_GOME_L1_1995_DEC_01_R03

Due to the large interest on the GOME sun and moon measurements on their own, these measurements are being included in the Level 1 Data Product as described in Section 3.

2.2 Level 2 Trace Gases Total Column Product

The Level 2 off–line data products for the complete instrument lifetime are available at the D–PAF NAS FTP–server: ***ftp–ops.de.envisat.esa.int***
The data is organized in directories as follows:

products/level_2/YYYY/MM/DD

where YYYY the year, *MM* the month, DD the day.

A CD–R including the Level 2 data products of one month is also available.
The label of the LVL21 CDs is:

DLR_ERS2_GOME_L2_*YYYY_MON*_R<revision_id>

where *YYYY_MON* is the year and month covered by the LVL21 and <*revision_id*> is the Level–2 Product Revision Identifier. Example:

DLR_ERS2_GOME_L2_1998_MAR_R03

2.3 NRT Product

A limited number of GOME Level 1 and Level 2 near–real–time (EGOC+EGOI) data products are available at the D–PAF NAS FTP–server: ***ftp–ops.de.envisat.esa.int***
The NRT data is organized as the off–line data, but under the directory *nrt_products*.

2.4 Filename Convention

The filename indicates the UTC start date and time of the product as well as the corresponding orbit number. The name is composed as following:

YYYYMMDDhhmm_#####.TTT

where *YYYY* is the year, *MM* the month, *DD* the day, *hh* the hours and *mm* the minutes of first processed ground pixel. ***#####*** is the orbit number, and *TTT* the product type.

E.g.: 199507032344_01058.lv2 (the Level 2 Product from 03.07.1995 23:44 UTC, orbit 1058).

2.5 CD–R Organization

The CD–R has the following directory structure:

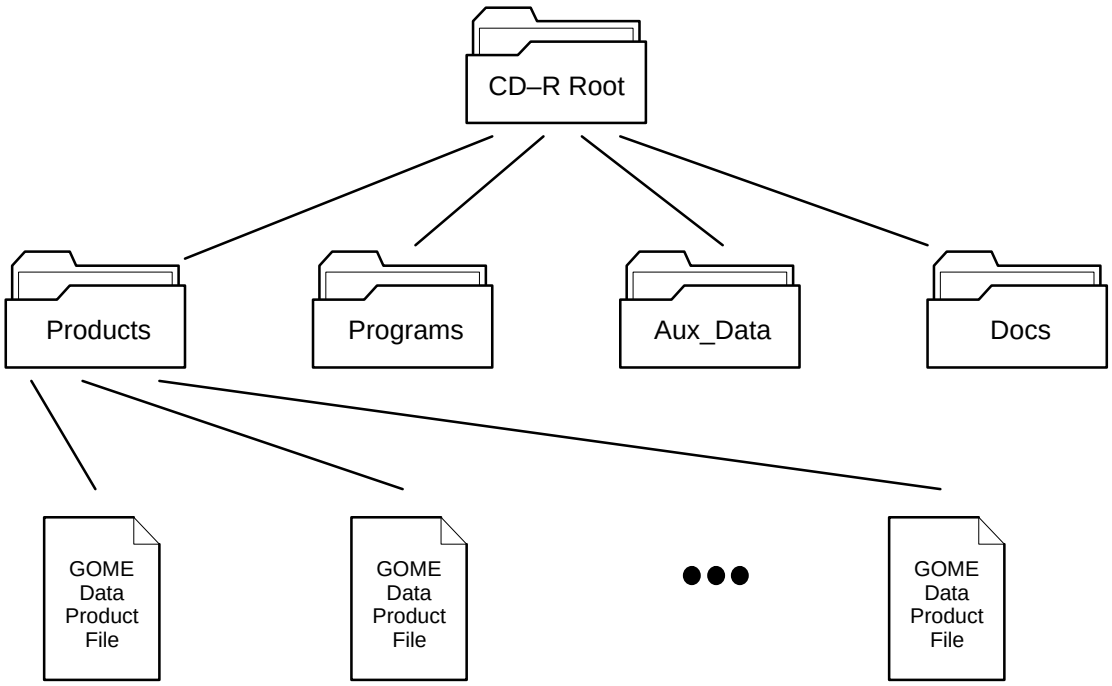

Figure 1: Distribution CD–R Content

The GOME data files which are included in the *Products* directory on the distribution CD–Rs are specified in section 3 for the Level 1 Data product and in section 4 for the Level 2 Data product.

The *Programs* directory include at least the programmes to extract Level 1 data from the Level 1 Data products, and the programmes to extract Level 2 Data products in ASCII representation. Other utilities for visualisation etc. are envisaged.

The *Aux_Data* directory include a copy of the KeyData version used for the Level 0 to 1 Processing, the climatological and spectroscopic data bases of the Level 1 to 2 processing, and GIF files with the graphical representation of the geolocation information of each Level 2 product.

The *Docs* directory include any type of documentation which is necessary at least to read and use the content of the CD–R (including a PostScript and PDF version of the present document).

2.6 Product Ordering

GOME Level 1 and Level 2 products are generated at DLR on behalf of ESA. For ordering/registration please contact:

EO Help Desk
ESA ESRIN
Via Galileo Galilei, I–00044 Frascati, Italy
Phone: +39 06 94180 777
Fax: +39 06 94180 272
E–mail: eohelp@esa.int
Web Site: http://earth.esa.int

3 Level 1 Radiance/Irradiance Product

3.1 Definition

The Level 1 Data product includes a header, fixed calibration data, ground–pixel specific calibration parameters and GOME science data in ten spectral bands. With the different integration times, these bands (six spectrum bands, because channel 1 and 2 are divided into two electronically independent bands; three *'straylight'* bands; one *'blind'* band) are handled as separate logical units of data. The header includes reference to input data, processing software and pre–flight data versions, time correlation, and orbital information. The fixed calibration data includes leakage current, and noise characteristics, spectral, and radiometric calibration parameters, sun reference spectra, and polarisation sensitivity parameters. The pixel specific calibration parameters include geolocation information, eight fractional polarisation values, and header information retained from the Level 0 Data. Using the included calibration data, the ADC readings of the diode arrays in the individual band data records may be converted to geolocated, spectrally and radiometrically calibrated radiances, including the correction for polarisation, leakage current and straylight. This may be accomplished by an extraction programme being part of a Level 1 Data product.

3.2 Description

Input

To generate GOME Level 1 Data products the following inputs are required:

- GOME extracted product files (EGOC) from Level 0 Tapes or directly from the receiving ground stations, as described in [A1]. At least one EGOC product file (covering 1 orbit) is required to make up one Level 1 Data product.
- Restituted orbit information of the covered time period. The main product headers (MPH) of an extracted product file (EGOC) include state vectors of a predicted orbit. This orbit information may be used whenever the Restituted Orbit file of the requested period is not available. In this case the accuracies of the geolocation information and the sun reference spectrum are reduced.
- Pre–flight calibration data. *Conversion to Engineering Units*: Polynomial coefficients of analog data package measurements and other semantic explanations of the data package content; *Correction for Straylight*: Centre pixels of ghost columns, their efficiencies and defocussing; *Radiometric Calibration*: Bi–directional scattering distribution function of the diffuser in the calibration unit, Instrument response function, Polarisation characteristic of the calibration unit; *Polarisation Correction*: Polarisation sensitivity per pixel, Correction factor for the polarisation sensitivity per pixel to correct for the various scan mirror positions, Wavelength dependency of the PMDs, the PMD ratios.
- In–flight calibration data (Leakage current correction, Pixel–to–pixel gain information, Spectral calibration parameters, Sun reference spectra measurements).

Algorithms

The algorithms which are used to generate Level 1 Data products are listed below. A detailed description of these algorithms may be found in [A2].

- Conversion to Engineering Units
- Correction for Leakage Current and Determination of Noise
- Correction for pixel–to–pixel gain
- Correction for Straylight

- Spectral Calibration
- Radiometric Calibration
- Polarisation Correction
- Quality Flagging and Determination of Errors

Output

The extraction programme of the Level 1 Data product generates the following output:

- Geolocation Information for a 1.5 seconds pixel (independent of the actual integration time)
  - UTC Date & Time of Pixel at end of integration time, point {C} from figure 2
  - 3 Solar Zenith and Azimuth Angles at Satellite w.r.t North
  - 3 Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t North
  - 3 Solar Zenith and Azimuth Angles at Satellite w.r.t Spacecraft
  - 3 Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t Spacecraft
  - Satellite Geodetic Height w.r.t. CEM–6 ellipsoid and Earth Radius of Curvature in the across track direction. Both values are given at point {B} from figure 2
  - 4 Corner Coordinates of Ground Pixel (Lat., Long.) at points {1, 2, 3, 4} from figure 2
  - Centre Coordinate of Ground Pixel at point {5} from figure 2
- PMD Data normalized to PMD measurements of Sun
- Earth– Sun– and Moon– shine Spectrum Data
  - Wavelength
  - Solar Irradiance
  - Earth–/Moon–shine Radiance
  - Associated Errors
  - Flags indicating quality of measurement

The geolocation information of a Ground Pixel is represented graphically in figures 2 to 4.

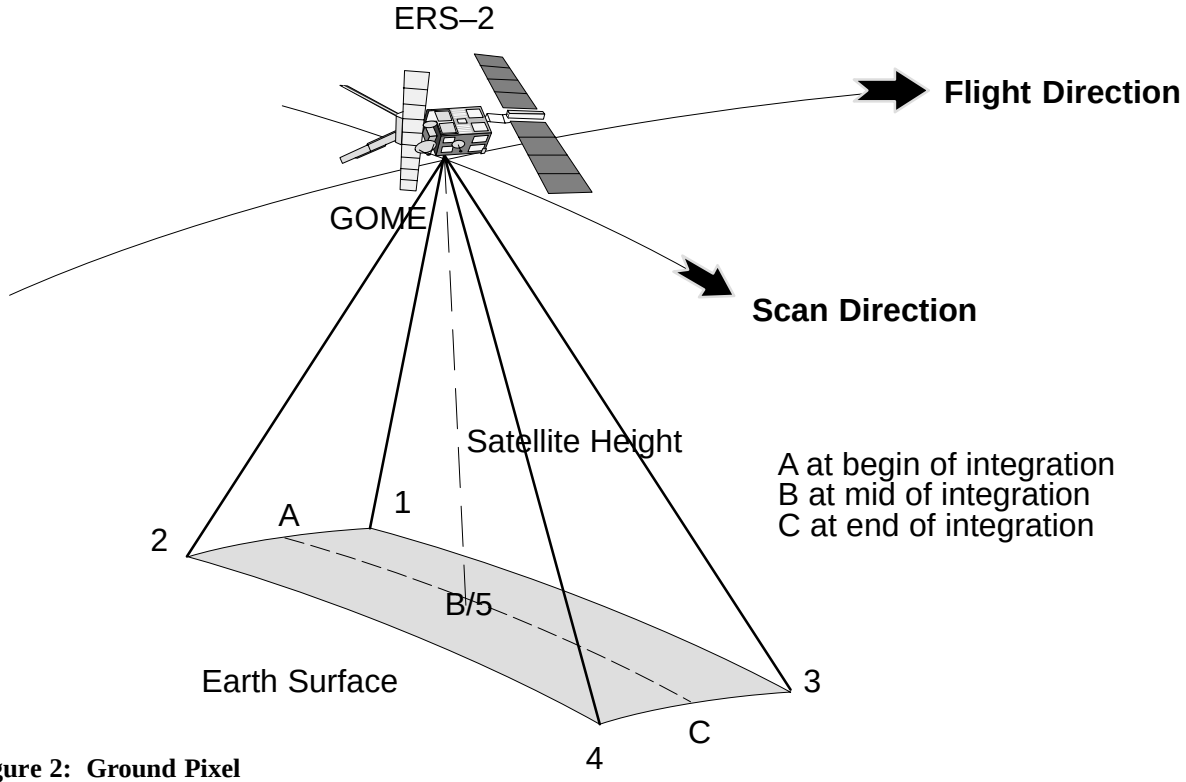

Figure 2: Ground Pixel

The Zenith angles are given at points {A, B, C} from figure 2. Those angles are defined w.r.t. North and w.r.t. Spacecraft (S/C) as shown in figure 3, a side view of Sun, GOME and Earth.

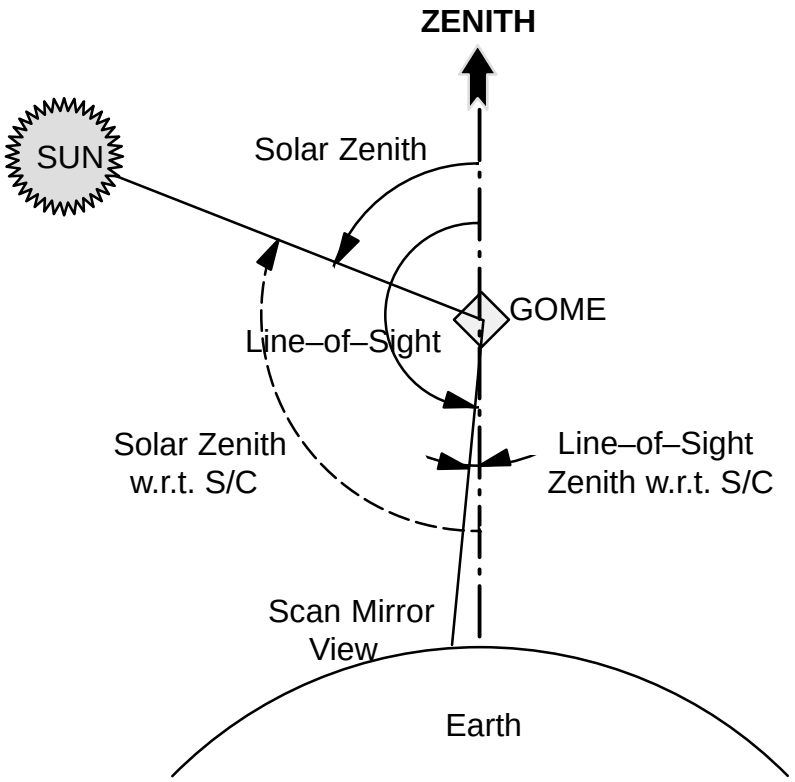

Figure 3: Zenith Angles

The Azimuth angles are given at points {A, B, C} from figure 2. Figure 4 shows a north pole view of Earth, Sun and GOME representing Azimuth angles w.r.t. North as continuous lines, and Azimuth angles w.r.t. Spacecraft (S/C) as dotted lines. Azimuth angles are positive in orientation from Flight

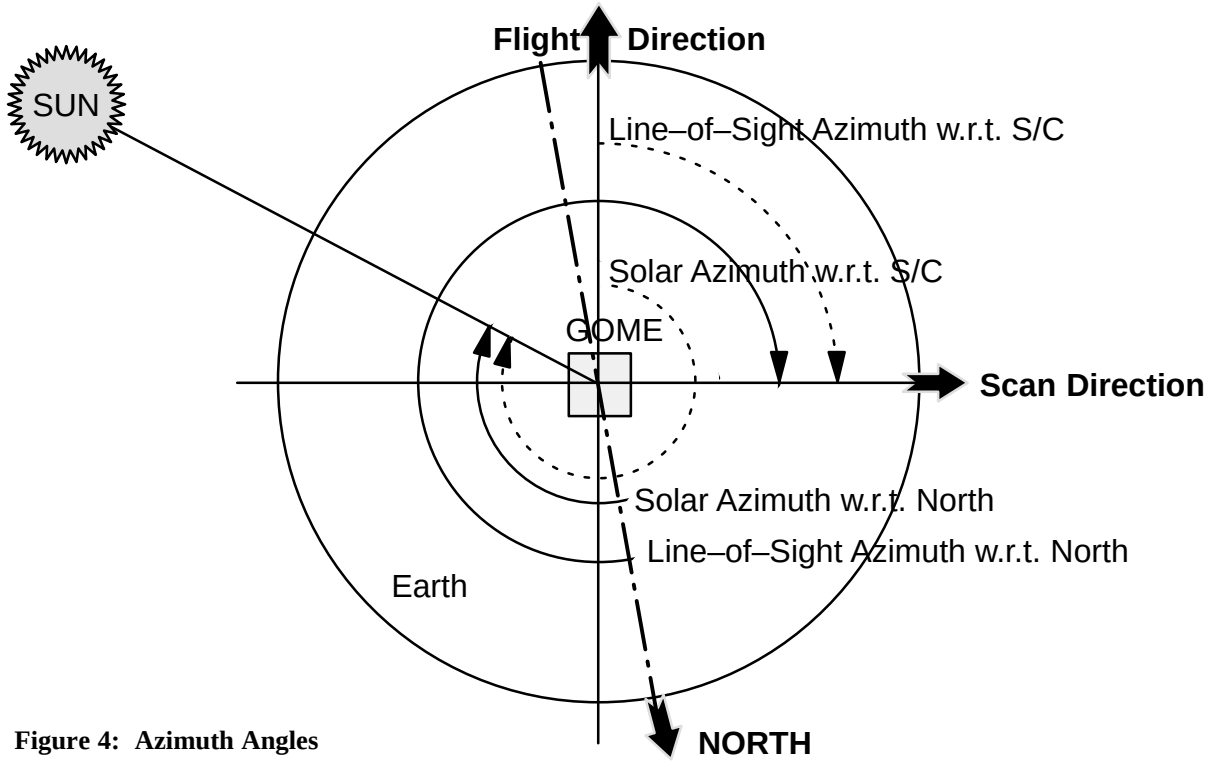

Figure 4: Azimuth Angles

Direction to Scan Direction. Angles w.r.t. S/C are counted from the Flight Direction.

3.3 Specifications

Units

Angles	[degree]
Satellite Geodetic Height	[km]
Earth Radius of Curvature	[km]
Geographical Coordinates (long., lat.)	[0 to 360 degrees]. [–90 to +90 degrees]
PMD Data	[–]
Wavelength	[nm]
Radiance	[photons s^{-1} sr^{-1} cm^{-2} nm^{-1}] or [mW sr^{-1} m^{-2} nm^{-1}]
Irradiance	[photons s^{-1} cm^{-2} nm^{-1}] or [mW m^{-2} nm^{-1}],
Errors	[absolute]

Geographical Coverage

Nominal: global

Depending on the scanning mode which will be used the measured ground pattern may be different. Only the largest footprint results in global coverage at the equator after three days. (see note below on spatial resolution)

Radiometric Resolution

16 Bit

Spectral Resolution

240 – 400 nm: ~0.2 nm
400 – 790 nm: ~0.4 nm

Spatial Resolution

Nominal: 3 ground pixels across–track with 40 km along–track, 320 km across–track

GOME scans across–track in three steps. Each step has a duration of 1.5 seconds. The flyback is done within 1.5 seconds. The scanning pattern is shown in figures 5. Up to GDP Level 0–to–1 ver-

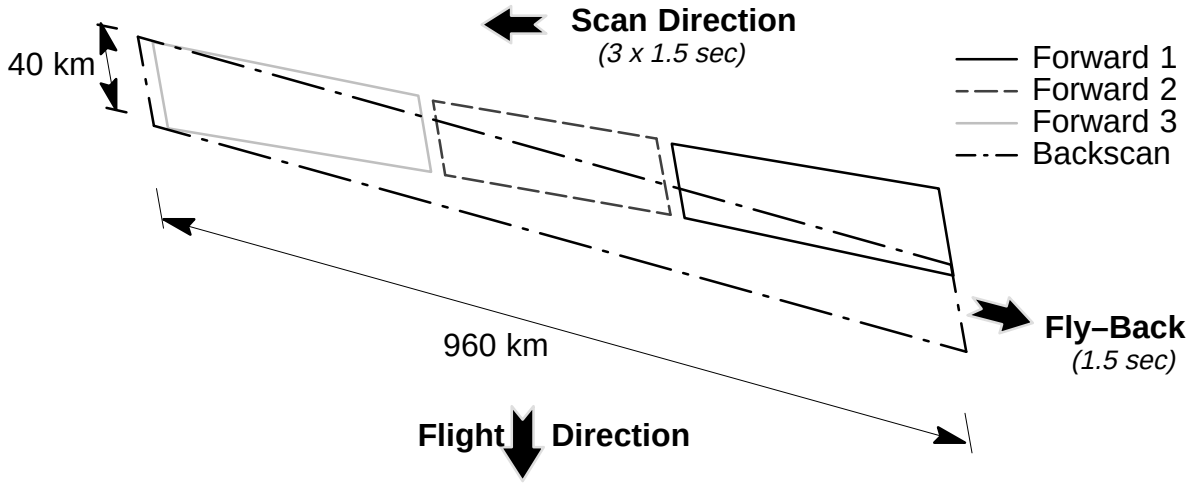

Figure 5: Scanning Pattern

sion 1.35 there were gaps between the leading edge of a ground pixels and the trailing edge of the previous ones are due to the scan mirror position readout time elapsed between the first scan mirror

readout of the current pixel and the last scan mirror readout of the previous one (93.75 ms). Since version 1.4 the geolocations gaps are closed. Depending on the scanning mode (swath width) the across–track range of one ground pixel may be: 320, 160, 120, 80 or 40 km.

Note: GOME data up to end of March 1996 have a reduced integration time (1.5 sec to 0.375 sec) to avoid saturation on the detector arrays. Only the last quarter of each ground pixel is covered by the recorded measurements using nominal mode. New sensor modes have been proposed and implemented on the GOME FS by ESA/ESTEC to overcome this problem. The 'co–adding' modes with integration time of 1.5 seconds is active since end of March 1996. A detailed description of these modes is given in [A7].

Absolute Radiometric Accuracy

GOME Level 1 data products are validated in two Geophysical Validation Campaigns, for the validation of the 240 – 400 nm wavelength region data from SOLSTICE and SSBUV have been used.. It was shown that the average deviation is ~ 3%. The deviation is time dependent due to instrument degradation.

Relative Radiometric Accuracy

< 1%

Spectral Accuracy

0.01 – 0.02 detector elements corresponding 0.002 – 0.0045 nm

Spatial Accuracy

Restituted Orbit: 60 m along–track, 15 m across–track
Predicted Orbit: 920 m along–track, 15 m across–track (whenever the restituted orbit is not available)

Sizing

Level 1 Data is calculated in granules of one orbit from an ascending node to the next. 35 orbits stored in 35 different files covering approximately a period of 3 days are logically packed to be one Level 1 Data product. Whenever the Level 2 Data product covering the same period is available, it will be also part of the Level 1 Data product.

3.4 Data Volume

One Level 1 CD–R with about 600 MBytes contains Level 1 data products of approximately 3 days (~595 MB, 35 Orbits per 17 MB) and the additional programmes and documentation (~5 MB)

3.5 Data Availability

The Level 1 data products are available on CD–R. One part of these products is the extraction programme to yield Level 1 extracted data. The format of the Level 1 data product and the extraction format is described in A.1 on page 22 and in A.3 on page 39, respectively.

3.6 Remarks

- ***General***

The Level 1 Data product includes not directly the calibrated radiances, but the Level 0 Data values and the associated calibration parameters. This information has to be combined using a programme

which is also part of the Level 1 Data product. The following requirements have driven the design of the Level 1 Data product format:

– Storage space should be saved in the archive and on distribution media;
– Most of the information included in the Level 0 Data should be retained in the Level 1 Data product;
– Error values should be given on the earth–shine spectra and on the sun reference spectrum separately.

These requirements imply a format as given in appendix A.1 where no calibration data is actually applied to the spectrum data. To get calibrated radiances (Extracted Level 1 Data), the additional data processing step for the *extraction* of this data from a Level 1 Data product must be carried out in order to perform the application of the calibration data to the signal data and to calculate the associated errors (see format in A.3).

- ***Geolocation***

The geolocation information is given at Satellite for a 1.5 seconds pixel, independent of the actual integration time of each band.

- ***Variable Portions***

There are several places in the product where variable portions have been used to keep the product as compact as possible. This is always done by specifying the number of records prior to records themselves. The following places are found in the product:

– Pixel specific Calibration Records
– Band Data Records
– Input Data References
– State Vectors
– Hot Pixel Occurrences
– Spectral Calibration Parameters
– Sun Reference Measurements
– Polarisation Sensitivity Parameters
– Array Data Values

- ***Indexing***

To reduce redundant information and to increase flexibility in the reading of the product, an indexing scheme was used. The elements of some of the lists mentioned in the *Variable Portion* remark above are referred to by an index (number of the element in this list, starting with number 0) into other portions of the product. The following indices are used:

- From the Pixel specific Calibration Records into
  – the Band Data Records
  – the Spectral Calibration Parameters
  – the Polarisation Sensitivity Parameters
- From the Spectral Band Records into
  – the Pixel specific Calibration Records

This scheme allows the sequential read by time via the Pixel specific Calibration Records with indices to the available (depending on the integration time) spectral bands and the corresponding spectral calibration and polarisation sensitivity parameters. It also allows the sequential read of just one spectral band with indices to the Pixel specific Calibration Records which again give access to the necessary calibration data.

- ***Hot Pixels***

Individual detector pixels may be hit by high energy particles, such as protons. The worst situation could be permanent damage to the detector pixel; this case will be identified by a zero value in the pixel–to–pixel gain array in the Fixed Calibration Data Record. Another possibility is a transient effect whereby a detector pixel shows several abnormal (most probably very high) readouts before returning to normal operation. Such an occurrence, the so–called ”Hot Pixel”, will be identified by the Level 0 to 1 Processing and entered in this list. In the current implementation, Hot Pixel detection is done only for dark measurements.

- ***Spectral Calibration Parameters***

Depending on the temperature of the optical bench, the dispersion of the pre–disperser prism is different resulting in different spectral properties on the detector arrays. Using the spectral calibration lamp of the calibration unit, a set of spectral calibration parameters is calculated for each occurring temperature. Measurements with GOME BBM in the thermal–vacuum chamber at Galileo have shown that the maximum shift for a temperature difference of 60˚C (–20˚ to +40˚) is below one detector pixel. To fulfil the ultimate scientific requirement for the spectral accuracy of $^1/_{100}$th of a detector pixel, it is possible to round the temperature measurements to a $^1/_{10}$th of degree Celsius. Therefore, temperature steps of 0.1˚C is used for the spectral calibration parameters. Measurements with the ERS–2 payload in the thermal–vacuum chamber at ESTEC have shown an orbital temperature variation of about 1˚C. Therefore, about 10 sets of spectral calibration parameters are expected to be in one individual product.

There is one set of spectral calibration parameters which is valid for the sun reference measurements and their mean value. The Intensity Calibration Parameters and the Polarisation Sensitivity values are interpolated to this wavelength grid.

- ***Intensity Calibration Parameters***

The Intensity Calibration Parameters are the interpolated instrument response (radiance sensitivity) function for the four detector arrays. The radiance sensitivity is dependent on the scan mirror angle. Therefore, it is necessary to include for each scan mirror angle occurring during the time period of the product an array of radiance sensitivity values. For a nominal timeline three scan mirror angles are expected; a polar view timeline will yield in six different scan mirror angles.

- ***Sun Reference Spectrum***

The Sun Reference Spectrum is given in form of the individual sun calibration measurements (in BU), the mean value of these measurements using the Bi–directional Scattering Distribution Function (BSDF) of the diffuser and the mean values of the corresponding PMD measurements.

- ***Polarisation Sensitivity Parameters***

The polarisation sensitivity is also dependent on the scan mirror angle. Therefore, it is also necessary to include for each scan mirror angle occurring during time period of the product an array of polarisation sensitivity values.

- ***Level 0 Data Headers***

The Level 1 Data product is the lowest level of GOME data which are delivered to a general user. Therefore, it is a good idea to retain as much information as possible of the raw data. The following information of the Level 0 Data is copied into the Level 1 Data product:

- parts of the Main Product Header (MPH)

  - Product Confidence Data
  - UTC time when MPH was generated
  - Processor software version used to generate Level 0 Data product.

- parts of the Specific Product Header (SPH)
  - Product Confidence Data or Padding Flag
    (padding of the product DSR occurs in the event of missing frames containing GOME science data. The corresponding fields of the DSR are padded with BB hexadecimal)
  - Product Confidence Data

- parts of the Data Set Record (DSR)
  - Primary Header
  - Secondary Header
  - Auxiliary Data of the Science Data Packets

- ***Other Outputs***

With the Level 1 extraction program is possible to print some additional information like general product information, geolocation information or calibration data records. The format of those outputs are not given in these document because they are auxiliary outputs and most of them are selfs explanatory.

4 Level 2 Trace Gases Total Column Product

4.1 Definition

The GOME Level 2 data product comprises the product header, the Level 2 total ozone column amounts and their associated errors, selected geolocation information, and intermediate output. The latter contain total column amounts of all retrieved trace gases, plus selected results and diagnostics from the GDP Level 1 to 2 algorithms, and a small amount of statistical information.

The Level 2 data product represents a compromise between compactness and usefulness – it must emphasize the total ozone column, and yet contain enough diagnostic information for validation and analysis. At the same time it must have the flexibility to allow for other trace gas retrieved columns. It is not feasible to output any detailed spectral information at Level 2.

4.2 Description

Input

The product defined here is the end result of the operational GDP Level 1 to 2 processing scheme. This processing requires the following inputs:

- One Extracted Level 1 data product, comprising
  - Geolocation information
  - Earth–shine radiance values and their absolute errors at specified wavelengths
  - Solar irradiance values and their absolute errors at specified wavelengths
  - Relative errors of the instrument response function
  - PMD data
- Climatological database, comprising
  - Trace gas concentration profiles, temperature and pressure profiles
  - Aerosol loading profiles, aerosol scattering properties
  - Global Surface albedo data set, sea surface albedo data set
  - Global topography data set
  - Cloud–top reflectance data set
  - Trace gas cross–sections data set; other reference spectra
  - GOME slit functions data set
- Input parameter file, comprising
  - DOAS fitting specifications (windows, reference spectra, fitting control,etc..)
  - Parameters controlling execution of Air Mass Factor algorithm
  - Parameters controlling cloud fitting algorithm
  - Overall control of the Level 1 to 2 processing chain

Algorithms

The algorithms to generate Level 2 data products are listed below. A detailed description of these algorithms may be found in technical note [A3].

- DOAS – spectral fitting for generation of slant column amounts
- AMF – calculation of Air Mass Factors
- OCRA&ROCINN – algorithm to generate cloud information
- VCD – computation of vertical column amounts from results of above 3 algorithms
- Computation of statistical information in Level 2 data product

Output

The GDP Level 1 to 2 processing chain generates the following Level 2 output:

- Product Header Information
  - spectral range of DOAS fitting windows
  - Pointers to retrieved species
- Geolocation Information of the actual integration time of bands 2b to 4
  - Pixel Number and pixel subset counter
  - UTC Date & Time of Pixel at end of integration time
  - Solar zenith angle at spacecraft w.r.t North, point {A',B',C'}
  - Line of sight zenith angle at spacecraft w.r.t North, point {A',B',C'}
  - Relative azimuth sun–spacecraft at spacecraft w.r.t North, point {A',B',C'}
  - Solar zenith angle at top of atmosphere w.r.t North, point {A',B',C'}
  - Line of sight zenith angle at top of atmosphere w.r.t North, point {A',B',C'}
  - Relative azimuth sun–spacecraft at top of atmosphere w.r.t North, point {A',B',C'}
  - Satellite Geodetic height at point {B'}
  - Earth Radius of Curvature at point {B'}
  - Ground Pixel location coordinates (four corners and centre), points {1', 2', 3', 4', 5'}
- Main Result Output
  - Total ozone column amount (plus error)
- Intermediate output, comprising
  - Vertical column amounts for all retrieved trace gases (and relative errors)
  - Slant column amounts for retrieved species (and relative errors)
  - Air mass factors for retrieved species (to cloud–top and to ground)
  - DOAS diagnostic information (includes RMS, chi–square, etc..)
  - DOAS fitted temperature, Ring correction factor
  - Ghost vertical column
  - Cloud fractional cover, cloud–top height and pressure, cloud–top albedo (and relative errors)
  - Surface height, pressure and albedo

Top of atmosphere is a variable quantity which is defined in the Static Parameter File of Level 1 to 2 processing.

For integration time of bands 2b to 4 up to 1.5 seconds, the points {1', 2', 3', 4', 5'} and {A', B', C'} are defined as their equivalents {1, 2, 3, 4, 5} and {A, B, C} from figure 2, but using the actual integration time. Figure 6 shows the geolocation for a pixel with integration time < 1.5 seconds.

The geolocation for a Ground Pixel with integration time > 1.5 seconds is shown in figure 7. This figure doesn't show the gap between ground pixels (see section 3.3).

Note: The AMF calculations are always done 3 times each 1.5 seconds for Ground Pixels with integration time $\geq$ 1.5 seconds.

4.3 Specifications

Units

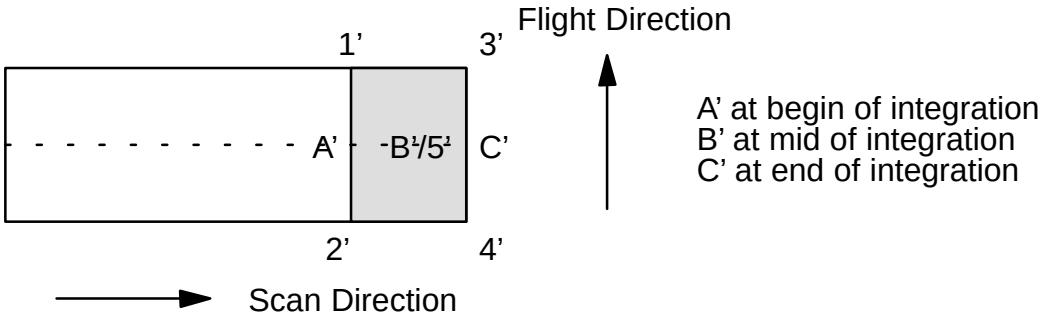

Figure 6: Ground Pixel Geolocation for Integration Time 0.375 seconds

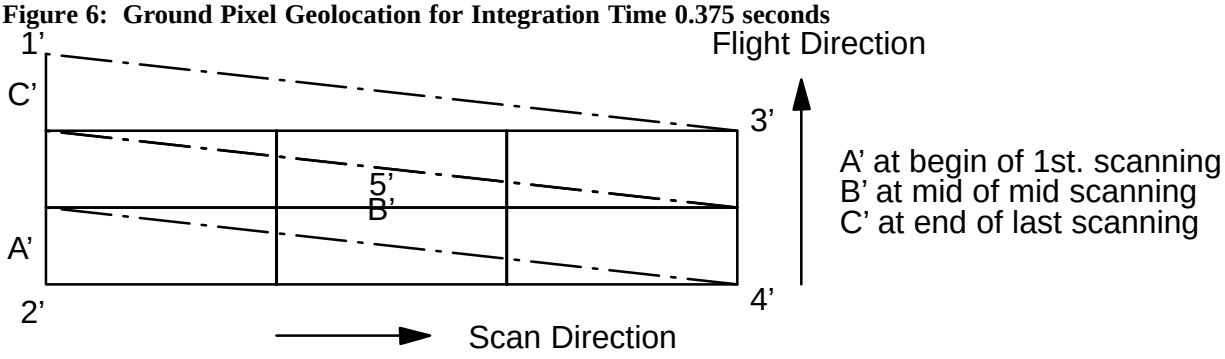

Figure 7: Ground Pixel Geolocation for Integration Time 12 seconds

Angles	[degree]
Geographical Coordinates	[0 to 360 degrees, –90 to +90 degrees]
Total ozone column amount	Dobson Units [DU]
Other trace gas column amounts	$mol.cm^{-2}$
Pressure	millibars
Errors	relative values in %

Geographical Coverage

Nominal: global

Depending on the scanning mode which will be used the measured ground pattern may be different. Only the largest footprint results in global coverage at the equator after three days.

Spatial Resolution and Accuracy

Nominal: 3 ground pixels across–track with 40 km along–track, 320 km across–track

Depending on the scanning mode, the across–track range may be: 320, 160, 120, 80 or 40 km. The accuracy is 60 m along–track, 15 m across–track for the restituted orbit, and 920 m along–track, 15 m across–track for the predicted orbit.

See note on spatial resolution in section 3.3 on page 11.

Accuracy

GOME Level 2 data products are validated in four Geophysical Validation Campaigns, attention is focused on the validation of total ozone and NO_2 column amounts.
The average agreement of GDP 4.0 ozone total column with correlative ground–based measurements falls to the percent level, that is, within the precision level of ground–based sensors. At polar latitudes, and at solar zenith angles beyond 80 deg, preliminary validation indicates that the agreement degrades slightly, however, average differences at low solar elevation do not exceed 5%.

The overall accuracy of GDP 4.0 NO_2 total columns is estimated to fall within the 5% to 10% range provided that the contribution of tropospheric NO_2 to the vertical column remains weak. GDP 4.0 total NO_2 is affected by larger ererrors under particular circumstances, e.g., in the South Atlantic Anomaly and over polluted areas.

A remarkable feature is that, despite the normal degradation of the instrument with time, the total column products do not suffer from any long–term drift of quality.

Sizing

Level 2 data product are sized for one orbit.

4.4 Data Volume

One Level 2 data product contain approximately 2200 individual Level 2 records (covering one full orbit with 2200 ground pixel scenes). This makes up a total of about 950 KBytes.

4.5 Data Availability

Primarily the Level 2 data products are available via ftp server. The Level 2 data products are also available on CD–R containing one month of data. In addition, Level 2 data products are available on the Level 1 CD–R, along with the Level 1 data products (if already processed) and associated software and documentation (see previous section). The format of the Level 2 data product and the ASCII extraction format are described in A.2 on page 33 and in A.4 on page 53, respectively.

4.6 Remarks

- ***Main Result Output***

As ozone is the top priority measurement, the retrieved column of O_3 has been specified and formatted separately in the Level 2 output. O_3 columns are specified in the traditional Dobson Units. Ozone columns are retrieved from the UV window (325–335 nm) or from the visible window (425–450 nm). The given total ozone content in Dobson Units results from the fitting procedure in the UV window. Note that the total ozone amounts retrieved from different windows are different, mainly because the visible window is a compromise to retrieve both NO_2 and O_3 in this spectral range.

The ozone column amount is the *latest value only* – that is, if individual re–processing has been carried out as a result of quality control in the Level 1 to 2 algorithm, only the re–processed value is retained in the product. This also applies to all intermediate results.

- ***Geolocation Output***

The geolocation information is given at Satellite height and Top–of–Atmosphere for the actual integration time of bands 2a to 4 (the integration time for band 2b, 3, and 4 should be the same). When the actual integration time is other than 1.5 seconds, then the geolocation of the Level 1 and Level 2 Data products will be different.

- ***Trace Gas Column Retrievals***

The output of trace gas results other than those for O_3 is governed by the fact that the DOAS fitting windows are optimized for O_3 and NO_2 column retrieval. Currently, trace gases other than O_3 and NO_2 are not included in the operational DOAS algorithm.

Ozone is not singled out from other retrieved trace gas columns in the intermediate output. Columns of O_3 are retrieved routinely for the UV window, and NO_2 columns from the visible window. A flag in the product header indicates which trace gas total column has been retrieved in which window.

- ***Intermediate Results Output***

The intermediate Level 2 results are be classified according to source of information (whether from the Level 1 to 2 algorithms [AMF, VCD, DOAS, OCRA&ROCINN], or from additional sources [statistical output]). The results are accompanied by a small number of flags – these indicate which options have been used in the execution of the algorithms, and for the statistical output, the availability of data.

VCD algorithm
The VCD intermediate output comprise 2 or more vertical column amounts (down to ground) for all retrieved trace gases, including at the least, O_3 and NO_2. Also output are the errors on these quantities (at least 2 entries). The control flag indicates whether individual re–processing was performed, and the method of calculation of the ghost vertical column (see [A14], chapter 5).

DOAS algorithm
The basic level 2 intermediate output from the DOAS algorithm are the effective slant columns (ESCs) and their errors, for all retrieved trace gases (14 entries). Single number fitting diagnostics are given in the product – these include the RMS value, the final chi–square value, number of iterations in the fitting, and the goodness–of–fit statistic (8 entries for the two windows). The flag indexing this DOAS information indicate whether the linear or non–linear fitting has been applied (fixed *versus* varying shifts and squeezes), and a qualitative (good/bad) indication of the accuracy of the fitted shifts and squeezes. The flag also indicate whether reference spectra such as the Ring spectrum were used in the fit.

Not included are the fitting parameters (and their errors) for the low–order polynomial modelling the broad–scale features of the optical density spectrum (aerosols, clouds, surface reflection). Also not included is the correlation matrix of cross–correlations among different trace gas species and fitted polynomial coefficients (broad scale part of the spectrum).

AMF algorithm
The AMF output include the intensity weighted Air Mass Factors for all retrieved trace gases, both down to cloud–top and to ground level (14 entries). AMFs are calculated for 2–point quadrature (forward scan) and 3–point quadrature (back scan), the average result is specified in the product. The flag could indicate model simulation control.

Note that no climatological information is specified in the product.

OCRA&ROCINN algorithms
The main output here is the cloud fraction and its error, and the cloud–top pressure and its error, the cloud–top albedo and its error (6 entries). The surface pressure take from climatology is also specified here. The flag indexing this output indicate the quality of the retrieval, version number and defaults used. Total 6 entries.

Statistical output
These numbers provide additional qualitative information about the measurements. They are supplementary to the main output, and are not derived from any geophysical algorithms. A flag indexes the output (availability of data). Total 2 entries.

- ***Summary Table of Intermediate Output***

	(source)	(description)
–	VCD	Total vertical column amounts to ground
	VCD	Errors on these total vertical columns
	VCD	Flag indexing output
–	DOAS	Slant columns
	DOAS	Errors on these slant columns
	DOAS	RMS, chi–square, goodness–of–fit, iteration number
–	DOAS	Fitted temperature and Ring correction factor
	DOAS	Flag indexing output
–	AMF	Air Mass Factors to cloud–top and ground
	AMF	Total intensity (ground and cloud top)
	AMF	Measured intensity
	AMF	Flag indexing output
–	GVC	Ghost vertical column
–	OCRA	Cloud fraction plus errors
	ROCINN	Cloud–top height, cloud–top pressure and cloud–top albedo plus errors
	Surface	Height, pressure and albedo

A Detailed Format Descriptions

A.1 Level 1 Radiance/Irradiance Product

The Level 1 Product file consist of the following basic elements:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	38	PIR	1–38	Product Identifier Record see table 3
2	96	FSR1	39–134	File Structure Record see table 2
3	292	SPH1	135–422	Specific Product Header see table 4
4	ca. 265,102	FCD	323–265,524	Fixed Calibration Data Record see table 5
5	Nrec*736 ca. 1,619,200	PCD	265,525–1,884,724	Pixel Specific Calibration Records see table 7
6	Nsun*511 ca. 79,205	SMCD	1,884,725–1,963,929	Sun Specific Calibration Records see table 8
7	Nmoon* 511 ca. 1022	SMCD	1,963,930–1,964,951	Moon Specific Calibration Records see table 8
8	ca. 15,576,000	BDR	1,964,952–17,540,952	Band Data Records see table 9

Table 1 : Level 1 Data Product Content

This yields an approximate size of ≈17 MB (16.73 MB for the assumptions as made below) for one Level 1 Data product which covers one complete orbit.

The File Structure Record (FSR1) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Number of SPH1 Records (always 1)
2	4	long	3–6	Length of SPH1 Record
3	2	short	7–8	Number of FCD Records (always 1)
4	4	long	9–12	Length of FCD Record
5	2	short	13–14	Number of PCD Records (Nrec, ca. 2200)
6	4	long	15–18	Length of PCD Record
7	2	short	19–20	Number of SCD Records (Nsun, ca. 155)
8	4	long	21–24	Length of SCD Record
9	2	short	25–26	Number of MCD Records (Nmoon, ca. 2)
10	4	long	27–30	Length of MCD Record
11	2	short	31–32	Spare, null
12	4	long	33–336	Spare, null
13	2	short	37–38	Number of Band 1a Data Records
14	4	long	39–42	Length of Band 1a Data Record
15	2	short	43–44	Number of Band 1b Data Records
16	4	long	45–48	Length of Band 1b Data Record
17	2	short	49–50	Number of Band 2a Data Records
18	4	long	51–54	Length of Band 2a Data Record
19	2	short	55–56	Number of Band 2b Data Records
20	4	long	57–60	Length of Band 2b Data Record
21	2	short	61–62	Number of Band 3 Data Records
22	4	long	63–66	Length of Band 3 Data Record
23	2	short	67–68	Number of Band 4 Data Records
24	4	long	69–72	Length of Band 4 Data Record
25	2	short	73–74	Number of Blind Pixel Data Records
26	4	long	75–78	Length of Blind Pixel Data Record
27	2	short	79–80	Number of Straylight 1a Data Records
28	4	long	81–84	Length of Straylight 1a Data Record
29	2	short	85–86	Number of Straylight 1b Data Records
30	4	long	87–90	Length of Straylight 1b Data Record
31	2	short	91–92	Number of Straylight 2a Data Records
32	4	long	93–96	Length of Straylight 2a Data Record

Table 2 : File Structure Record Content

The Product Identifier Record (PIR) structure is given in the following table, as defined in [A5]:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	A	1–2	Satellite/Mission Identifier (E2)
2	3	A	3–5	Sensor Identifier (GOM)
3	5	A	6–10	Start Orbit Number (e.g. 05765)
4	4	A	11–14	Number of Processed Orbits (e.g. 0001)
5	2	A	15–16	Acquisition Facility Identifier (e.g. KS, if more than one station, this field is DP)
6	5	A	17–21	Product Type (LVL10)
7	1	A	22	Spare, blank
8	2	A	23–24	Processing Facility Identifier (DP)
9	8	A	25–32	Processing Date (YYYYMMDD)
10	6	A	33–38	Processing Time (hhmmss)

Table 3 : Product Identifier Content

The Specific Product Header (SPH1) structure for the Level 1 Data product is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Number of Input Data References (Nref=2)
2	38 * Nref= 76	PIR	1–78	Input Data Reference; see table 3 (Product Type field: LVL0_)
3	5	A	79–83	GDP Software Version, Level 0 to 1 Processing (XX.XX)
4	5	A	84–88	Pre–flight Calibration Data Version (XX.XX)
5	2	A	89–90	Product Format Version (XX)
6	5 * 4 = 20	unsigned long	91–110	Time Correlation Information: – Orbit Number – UTC days since 1.1.1950 – UTC ms since midnight – Satellite Binary Counter – Satellite Binary Counter Period
7	2	short	111–112	GOME Science Package PMD Entry Point
8	2	short	113–114	GOME Science Package Subset Counter Entry Point
9	2	short	115–116	GOME Science Package Integration Status Entry Point

10	2	short	117–118	GOME Science Package Peltier Entry Point
11	2	short	119–120	GOME Instrument Status_2 Entry Point
12	(2 * 3) * 4 = 24	float	121–144	PMD's Conversion Factors
13	(3 * 4 + 6 * 4) = 36	3 * unsigned long 6 * float	145–180	State Vectors (ESOC Supplied Restituted Orbit): – UTC days since 1.1.1950 – UTC ms since midnight – Orbit number – Position vectors (X, Y, Z) in km – Velocity vector (dx/dt, dy/dt, dz/dt) in km/s
14	(3 * 8 + 3 * 8 + 4 + 4) = 56	3 * double 3 * double long long	181–236	Attitude Variables – ATT Combined Effect of AOCS Mis-pointing (yaw around z, pitch around –x, roll around –y) – DATT AOCS Mispointing Rate, deg/sec, w.r.t. Nominal (yaw, pitch, roll) – IATT Attitude Flag (0 Nominal Yaw Steering Mode, 1 and 2 other pointing – Status Returned from GOME_INIT (0 Nominal, 1 and 2 No Convergence, 3 4 and 5 State Vector Outside Nominal ERS
15	(8 + 6 * 8) = 56	double 6 * double	237–292	– Modified Julian Day (MJD50) at True Ascending Node Crossing – Reference Mean Kepler State at True Ascending Node Crossing (Semi–major Axis (km), Excentricity, Inclination (deg), Right Asc. of Asc. Node (deg), Argument of Perigee (deg), Mean anomaly (deg)

Table 4 : Specific Product Header Content (Level 1)

The Fixed Calibration Data Record (FCD) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Detector Confidence Flags: Bit 16–12: always 0 Bit 11: PMD 3 Bit 10: PMD 2 Bit 9: PMD 1 Bit 8–7: Array 4 Bit 6–5: Array 3 Bit 4–3: Array 2 Bit 2–1: Array 1 0 = detector ok 1 = detector is dead 2 = detector has dead pixels (arrays only)
2	10 * 6 = 60	BCR	3–62	Band Configuration Record; see table 6 : 6 Spectral Bands 1 Blind Pixel Band 3 Straylight Bands
3	(7*4*2 + 4,096) * 4 = 16,608	float	63–16,670	Relative Error Budget on KeyData Functions
4	(3+8) * 4 = 44	float	16,671–16714	Bi–directional Scattering Distribution Function Parameters: BSDF_0, Elevation, Azimuth and Coefficients
5	4 * 4 = 16	float	16,715–16,730	Uniform straylight level
6	4*2 * (2*2 + 2*4) = 96	short – float	16,731–16,826	Symmetrical and asymmetrical ghosts characteristics
7	2	short	16,827–16,828	Width of the triangle convolution window used in straylight
8	5 * 4 = 20	float	16,829–16,848	Scale factors for Peltier induced dark signal noise correction
9	2	short	16,849–16,850	Number of Peltier filter coefficients used
10	100 * 4 = 400	float	16,851–17,250	Filter coefficients for Peltier induced dark signal noise correction
11	2	short	17,251–17,252	Number of Leakage Correction Parameter Sets (Nleak, ca. 5; Integration Time Pattern or Time Line variance during one orbit)
12	(5 + 4,096) *4 * Nleak = 82,020	float	17,253–99,272	Array Noise, 3 PMD Offsets, PMD Noise and Dark Current

13	4,096 * 4 = 16,384	float	99,273–115,656	Pixel–to–Pixel Gain
14	2	short	115,657–115,658	Number of Hot Pixel Occurrences during this Orbit (Nhot, e.g. 5, hopefully zero)
15	3 * 2 * Nhot ca. 30	short	115,659–115,688	Hot Pixel Occurrences: Record, Array, Pixel
16	2	short	115,689–115,690	Number of Spectral Calibration Parameter Sets (Nspec, ca. 10; temperature variance during one orbit is expected to be ca. 1˚ and the temperature is resoluted to 0.1˚)
17	(5 * 4 + 4) * 8 * Nspec ca. 1,920	double	115,691–117,610	Spectral Calibration Parameters (4th order polynomial) and Average Pixel Deviation for each channel
18	2	short	117,611–117,612	Index into Spectral Calibration Parameters for the following Calibration Parameters (field 15, 16 and 22) and Sun Specific Calibration Records (table 8)
19	4,096 * 4 = 16,384	float	117,613–133,996	Intensity Calibration Parameters (Interpolated Radiance Response Function)
20	4,096 * 4 = 16,384	float	133,997–150,380	Sun Reference Spectrum (Mean Value)
21	4,096 * 4 = 16,384	float	150,381–166,764	Relative Radiometric Precision of the Sun Reference Spectrum
22	3 * 4 = 12	float	166,765–166,776	PMD Mean Values of the Sun Reference Spectra
23	3 * 4 = 12	float	166,777–166,788	Wavelength of the PMD Mean Values of the Sun Reference Spectra
24	2 * 4 = 8	unsigned long	166,789–166,796	UTC Date & Time of the Sun Refererence Spectrum
25	2	short	166,797–166,798	Number of different scan mirror angles per channel for which the pre–flight calibration parameters ”Interpolated Polarisation Sensitivity” and ”Radiance Response” are calculated (Nang; e.g. 12)
26	(1,024 + 1024) * 4 * Nang = 98,304	float	166,799–265,102	Interpolated Polarisation Sensitivity ($\eta_{nadir} \cdot \varkappa(\omega)$) defined in [A2] section ”Polarisation Correction” and Radiance Response ($H(\lambda,\sigma)$) defined in [A2] section ”Radiometric Calibration”

Table 5 : Fixed Calibration Data Content

The Band Configuration Record (BCR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Detector Array Number (1–4)
2	2	short	3–4	Start Detector of Band (0–1023)
3	2	short	5–6	End Detector of Band (0–1023)

Table 6 : Fixed Calibration Data Content

The Pixel Specific Calibration Records (PCD) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	151	GLR1	1–151	Geolocation Record, see table 10
2	2 * 4 = 8	float	152–160	Dark Current & Noise Correction Factor
3	2	short	161–162	Index to Spectral Calibration Parameters
4	2	short	163–164	Index to Leakage Correction Parameters
5	((7 + 1) * 3 * 4 + 4) = 100	float	165–264	Polarisation Parameters (7+1 fractional polarisation values including the appropriate wavelength value, error and Chi, the angle of the plane of polarisation) defined in [A2] section ”Polarisation Correction”
6	34	MPH: 6, 7, 16	265–298	Extraction of Level 0 Data MPH: fields 6, 7, 16; see [A1]
7	22	SPH: 5, 6 + 1 byte	299–320	Extraction of Level 0 Data SPH: fields 5, 6; see [A1] (last byte reserved to get field even)
8	396	IHR	321–716	Instrument Header Record of the Science Data Packet; see [A6]
9	10 * 2 = 20	short	717–736	Index to the 10 Spectral Bands –1, if the integration time of this band was not completed

Table 7 : Pixel Specific Calibration Data Content

The Sun/Moon Specific Calibration Records (SMCD) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2 * 4 = 8	unsigned long	1–7	UTC Date & Time of the Sun/Moon Measurement at end of integration time
2	2 * 4 = 8	float	8–15	Sun Zenith and Azimuth Angles at Satellite w.r.t North
3	2 * 4 = 8	float	16–23	BSDF Zenith and Azimuth Angles or Moon Zenith and Azimuth Angles at Satellite w.r.t North
4	4	float	24–27	Flag indicating if the record was used in the calculation of the Sun Reference Spectrum (Table 5 , field 15) or Illuminated Fraction of the Moon's Disk
5	2 * 4 = 8	float	28–35	Dark Current & Noise Correction Factor
6	2	short	36–37	Index to Spectral Calibration Parameters
7	2	short	38–39	Index to Leakage Correction Parameters
8	34	MPH: 6, 7, 16	40–73	Extraction of Level 0 Data MPH: fields 6, 7, 16; see [A1]
9	22	SPH: 5, 6 + 1 byte	74–95	Extraction of Level 0 Data SPH: fields 5, 6; see [A1] (last byte reserved to get field even)
10	396	IHR	96–491	Instrument Header Record of the Science Data Packet; see [A6]
11	10 * 2 = 20	short	491–511	Index to the 10 Spectral Bands –1, if the integration time of this band was not completed

Table 8 : Sun/Moon Specific Calibration Data Content

The Band Data Records (BDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	284,900	REC	1–	Band 1a, Nlen=256, Iv=550 (see table 11)
2	2,182,400	REC	...	Band 1b, Nlen=493, Iv=2200
3	52,800	REC	...	Band 2a, Nlen=9, Iv=2200
4	3,436,400	REC	...	Band 2b, Nlen=778, Iv=2200
5	4,518,800	REC	...	Band 3, Nlen=1024, Iv=2200
6	4,518,800	REC	...	Band 4, Nlen=1024, Iv=2200
7	57,200	REC	...	Blind Pixel, Nlen=49, Iv=550
8	58,300	REC	...	Straylight Pixel 1a, Nlen=50, Iv=550
9	233,200	REC	...	Straylight Pixel 1b, Nlen=50, Iv=2200
10	233,200	REC	15,576,000	Straylight Pixel 2a, Nlen=50, Iv=2200

Table 9 : Band Data Records Content

where the values for the number of pixels per spectral band (*Nlen*) are taken from table 5 field 2 (Band Configuration Record, *Nlen = End–Start + 1*) and the number of integration intervals (*Iv*) are estimates for one orbit to calculate the expected size of one Level 1 Data product.

The Geolocation Record (GLR1) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2 * 4 = 8	unsigned long	1–7	UTC Date & Time of the ground pixel at end of integration time
2	6 * 4 = 24	float	8–32	3 Solar Zenith and Azimuth Angles at Satellite w.r.t North for the points {A, B, C}
3	6 * 4 = 24	float	33–56	Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t North for the points {A, B, C}
4	6 * 4 = 24	float	57–80	3 Solar Zenith and Azimuth Angles at Satellite w.r.t Spacecraft for the points {A, B, C}
5	6 * 4 = 24	float	81–104	3 Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t Spacecraft for the points {A, B, C}
6	4	float	105–108	Satellite Geodetic Height at point {B}
7	4	float	109–112	Earth Radius of Curvature at point {B}
8	1	char	113	Possible Sun–glint (0 = no, 1 = yes)
9	(5 * 2 * 4) = 40	float	114–153	4 Corner and Center Coordinates (Latitude and Longitude) at points {1, 2, 3, 4 and 5} of Ground Pixel

Table 10 : Geolocation Record 1 Content

The Spectral Band Record (REC) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Quality Flags: Bit 8–7: Spectral check: 0 = ε < 0.02 px 1 = 0.02 < ε < 0.05 px 2 = ε > 0.05 px Bit 6–5: Saturated pixels Bit 4–3: Hot pixels Bit 2–1: Dead pixels 0 = all pixels ok 1 = less than 1% of pixels affected 2 = more than 1% of pixels affected
2	2	short	3–4	Index to Polarisations Sensitivity Parameters
3	2	short	5–6	Index to Pixel Specific Calibration Parameters Record (PCD)
4	2	unsigned short	7–8	Integration Time (one count corresponds to 93.75 ms)
5	Nlen * 2 = ca. 2048	unsigned short	9–max. 2056	Array Data Values

Table 11 : Spectral Band Record Content

A.2 Level 2 Trace Gases Total Column Product

The Level 2 Product file consist of the following basic elements :

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	38	PIR	1–38	Product Identifier Record see table 3
2	12	FSR2	39–50	File Structure Record see table 13
3	ca. 89	SPH2	51–139	Specific Product Header see table 14
4	Nrec * 390 ca. 858.000	DDR	140– 858.139	DOAS Data Records see table 15

Table 12 : Level 2 Data Product Content

This yields an approximate size of ~950 kB (941.18 kB for the assumptions as made below, i.e. two molecules and two fitting windows) for one Level 2 Data product which covers a one orbit of data.

The File Structure Record (FSR2) structure for the Level 2 Data product is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	2	short	1–2	Number of SPH2 Records (always 1)
2	4	long	3–6	Length of SPH2 Record
3	2	short	7–8	Number of DOAS Data Records (ca. 2200)
4	4	long	9–12	Length of DOAS Data Record

Table 13 : File Structure Record (Level 2) Content

The Specific Product Header (SPH2) structure for the Level 2 Data product is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	38	PIR	1–38	Input Data References see table 3
2	5	A	39–43	GDP Software Version, DOAS Level 1 to 2, (XX.XX)
3	5	A	44–48	GDP Static Parameter File Version, (XX.XX)
4	5	A	49–53	GDP L2 Format Version, (XX.XX) (the current L2 format version is 02.00)
5	2	short	54–55	Number of Fitting Windows (e.g. Nwin=2) †
6	Nwin * 2 * 4 = 16	float	56–71	Window Pair (start and end wavelength in nm)
7	2	short	72–73	Number of Molecules (e.g. Nmol=2) †
8	Nmol * (1 + 5) = 12	A	74–85	Molecule Pair (fitting window number and molecule name, e.g. 2NO2__
9	4	float	86–89	Atmosphere Height

Table 14 : Specific Product Header Content (Level 2)

† Note: The product format is defined for a variable number of *Fitting Windows* (Nwin) and *Number of Molecules* (Nmol). This document uses Nwin=2 and Nmol=2 as examples, these values correspond to the operational GDP level 1–to–2 processor settings.

The DOAS Data Record (DDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	56	GLR2	1–136	Geolocation Record see table 16
2	4	float	137–140	Total Column of Ozone (Dobson Units)
3	4	float	141–144	Relative error on the Total Column (%)
4	246	IRR	145–390	Intermediate Results Record see table 17

Table 15 : DOAS Data Record Content (Level 2)

The Geolocation Record (GLR2) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	4	long	1–4	Ground Pixel Number
2	4	long	5–8	Subset Counter
3	2 * 4 = 8	unsigned long	9–16	UTC Date & Time of the ground pixel at end of integration time
4	3 * 4 = 12	float	17–28	3 Solar Zenith Angles at satellite for the points {A', B', C'}
5	3 * 4 = 12	float	29–40	3 Line–of–Sight Angles at satellite for the points {A', B', C'}
6	3 * 4 = 12	float	41–52	3 Relative Azimuth Angles at satellite for the points {A', B', C'}
7	3 * 4 = 12	float	53–64	3 Solar Zenith Angles at TOA for the points {A', B', C'}
8	3 * 4 = 12	float	65–76	3 Line–of–Sight Angles at TOA for the points {A', B', C'}
9	3 * 4 = 12	float	77–88	3 Relative Azimuth Angles at TOA for the points {A', B', C'}
10	4	float	89–92	Satellite Geodetic Height at point {B'}
11	4	float	93–96	Earth Radius of Curvature at point {B'}
12	10 * 4 = 40	float	97–136	4 Corner and Center Coordinates (Lat., Long.) at points {1', 2', 3', 4' and 5'} of Ground Pixel

Table 16 : Geolocation Record 2 Content

The Intermediate Results Record (IRR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	Nmol * 4 = 8	float	1–8	*VCD*: Total VCD to ground of O_3^{UV}, NO_2^{VIS}
2	Nmol * 4 = 8	float	9–16	*VCD*: Errors on VCDs above
3	2	short	17–18	*VCD*: Flag indexing output
4	Nmol * 4 = 8	float	19–26	*DOAS*: Slant Columns of O_3^{UV}, NO_2^{VIS}
5	Nmol * 4 = 8	float	27–34	*DOAS*: Errors on Slant Columns above
6	Nwin * 4 * 4 = 32	float	35–66	*DOAS*: RMS, χ^2, Goodness of Fit, Iteration Number for the Nwin fitting windows
7	4	float	67–70	*DOAS*: Calculated Ozone Temperature
8	4	float	71–74	*DOAS*: Ozone Ring Correction Factor
9	2	short	75–76	*DOAS*: Flag indexing output
10	Nmol * 4 = 8	float	77–84	*AMF*: AMF to ground for species as listed above (–1 for cloudy pixels)
11	Nmol * 4 = 8	float	85–92	*AMF*: Errors on AMF to ground above
12	Nmol * 4 = 8	float	93–100	*AMF*: AMF to cloud–top for species as listed above (–1 for clear sky)
13	Nmol * 4 = 8	float	101–108	*AMF*: Errors on AMF to cloud–top above
14	2	short	109–110	*AMF*: Flag indexing output
15	4	float	111–114	*GVC*: Ghost Vertical Column
16	2 * 4 = 8	float	115–122	*OCRA*: Cloud fraction and Error
17	2 * 4 = 8	float	123–130	ROCINN: Cloud–top Height and Error (–1 for clear sky)
18	2 * 4 = 8	float	131–138	ROCINN: Cloud–top Pressure and Error (–1 for clear sky)
19	2 * 4 = 8	float	139–146	ROCINN: Cloud–top Albedo and Error (–1 for clear sky)
20	3 * 4 = 12	float	147–158	Surface Height, Surface Pressure and Surface Albedo
21	88	char	159–246	Spare space †

Table 17 : Intermediate Results Record Content

* Note: Vertical Columns and Slant Columns are given in mol/cm^2.
† The spare field was introduced in Iss./Rev. 4/B to keep the IRR size the same as on previous format versions. The actual spare size should be computed as 12*Nwin – 8*Nmol + 80

The following tables define the flag indexing output of the different algorithms:
(bits will be set for underlined condition)

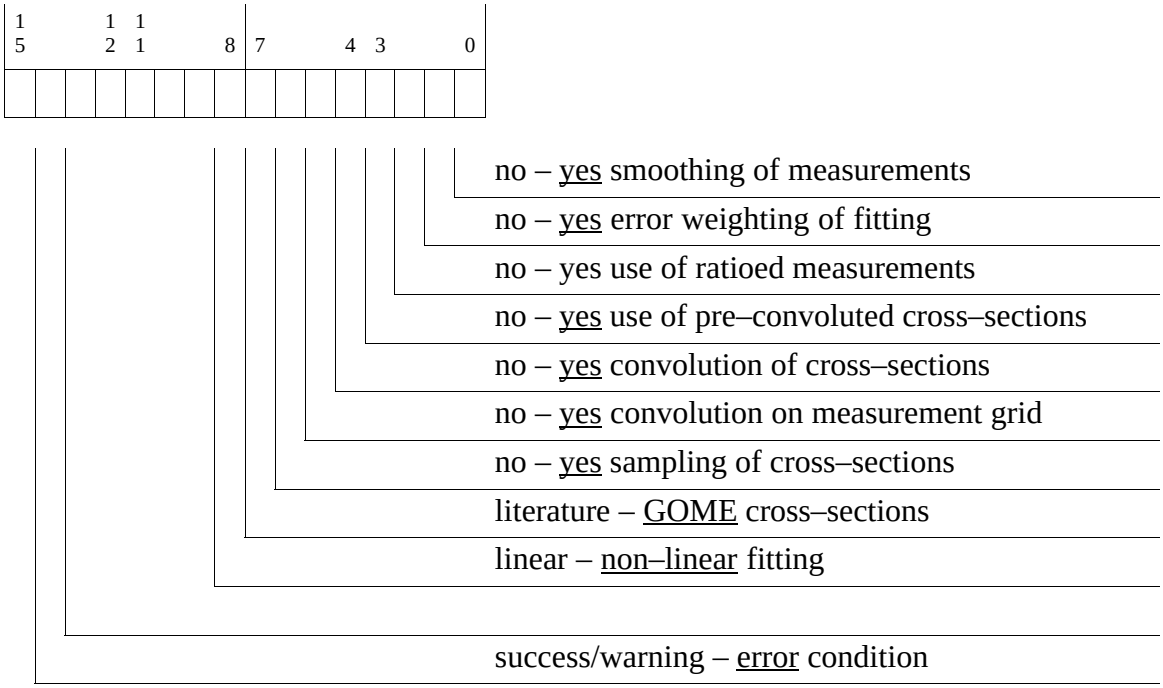

Table 18 : DOAS Flag Indexing Output

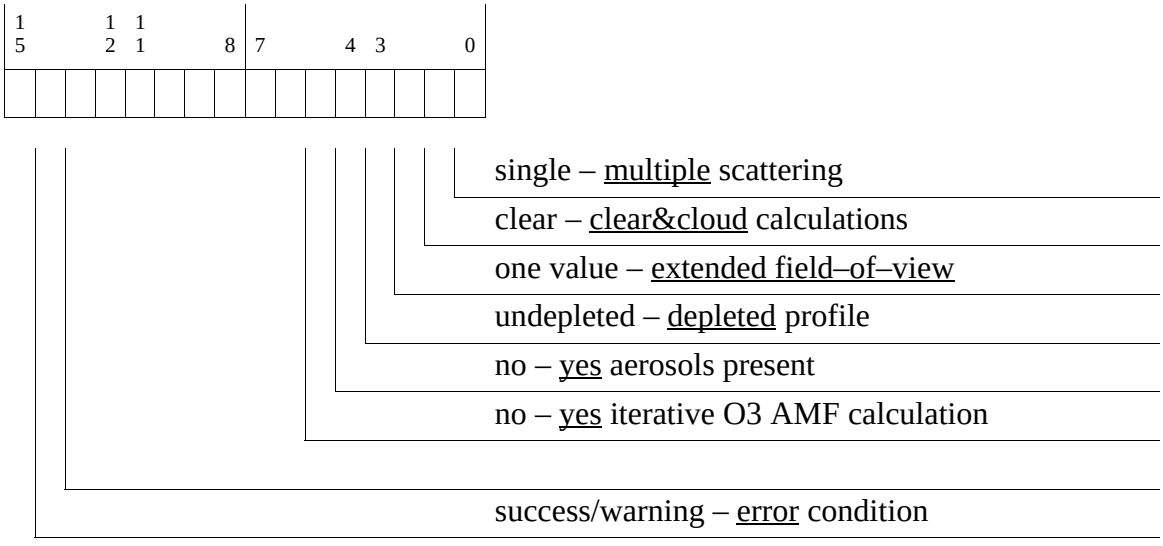

Table 19 : AMF Flag Indexing Output

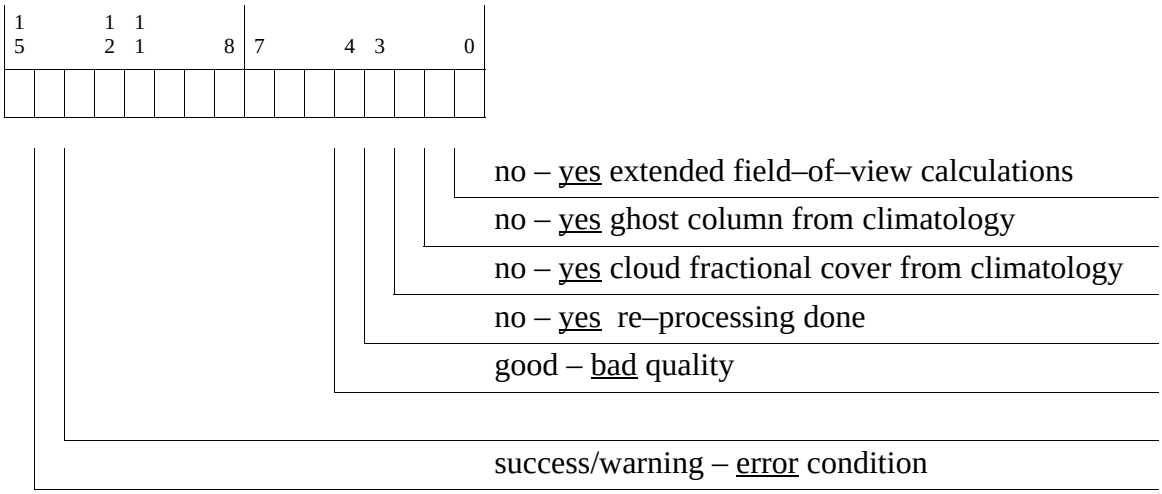

Table 20 : VCD Flag Indexing Output

A.3 Extracted Level 1 Radiance/Irradiance Product

Extracted Level 1 Product files for earthshine ground pixels have the following format:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	432	GSI1	1–432	GDP Software Identifier, see table 22
2	38	PIR	433–470	Product Identifier, see table 3
3	1 or 2	char	471	Line Separator; the number of bytes for this field depends on the operating system the *Extract_Level_1_Data* programme was running on (e.g. UNIX = 1, MS–DOS = 2)
4	303	ERSI	472–773	ERS Orbit Propagator Information, see table 23
5	40	SFS	774–812	Solar Format Specification, see table 24
6	Nchannel * (48,173 or 49,193) = 192,692	CDR	813–193,504	Channel Data Records, (Nchannel = 4), see table 25
7	52 or 53	EFS	193,505–193,556	Earthshine Format Specification, see table 27
8	Nground * (193,656 or 197,736) = ~405 MB	EGP	193,557–	Earthshine Ground Pixels (Nground ca. 2200), see table 28

Table 21 : Extracted Level 1 Data Content

The byte position information is given for the extraction of a complete Level 1 Data product. It is expected that for the normal case only parts (e.g. bands containing wavelength windows for the DOAS fitting) are extracted which is smaller than 405 MB.

The same format is used for Extracted Level 1 Data files for sun/moon measurements. The EFS and EGP are remplaced by the corresponding SMFS (table 34) and SMMD (table 35).

The GDP Software Identifier (GSI1) structure for the Level 1 extraction software is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	80	A	1–80	Separator 1 (/*---------- ---------- ----------*\)
2	1 or 2	A	81	Line Separator, see comment in table 21
3	80	A	82–161	Software Version (** GDP Level 0-to-1 Extracting * Version 9.99 * Copyright c DLR 1996-2004 **)
4	1 or 2	A	162	Line Separator, see comment in table 21
5	80	A	163–242	Separator 2 (*---------- ---------- ----------*/)
6	1 or 2	A	243	Line Separator, see comment in table 21
7	20	A	244–263	Calibration Correction (Calibrations Applied)
8	1 or 2	A	264	Line Separator, see comment in table 21
9	82	A	265–345	Calibration Parameters Applied (Leakage FPA Fixed Straylight Normalize Polarization BSDF Intensity Unit_Conversion)
10	1 or 2	A	346	Line Separator, see comment in table 21
11	5	A	347–351	Units of the Results (Units)
12	1 or 2	A	352	Line Separator, see comment in table 21
13	80	A	353–431	Wavelength, Irradiance and Radiance Units (Wavelength [nm], Irradiance [photons/s.cm^2.nm], Radiance [photons/s.sr.cm^2.nm])
14	1 or 2	A	432	Line Separator, see comment in table 21

Table 22 : GDP Software Identifier

ERS Orbit Propagator Information (ERSI) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	15	A	1–15	Description (`ERS_Information`)
2	1 or 2	char	16	Line Separator, see comment in table 21
3	90	A	17–106	State Vectors (ESOC Supplied Restituted Orbit): – UTC days since 1.1.1950 – UTC ms since midnight – Orbit number – Position vectors (X, Y, Z) in km – Velocity vector (dx/dt, dy/dt, dz/dt) in km/s (`99999_99999999_99999_–9999.999999_–9999.999999_–9999.999999_–9.999999_–9.999999_–9.999999`)
4	1 or 2	char	107	Line Separator, see comment in table 21
5	27	A	108–134	Attitude Variables – ATT Combined Effect of AOCS Mispointing (yaw around z, pitch around –x, roll around –y) – DATT AOCS Mispointing Rate, deg/sec, w.r.t. Nominal (yaw, pitch, roll) – IATT Attitude Flag (0 Nominal Yaw Steering Mode, 1 and 2 other pointing – Status Returned from GOME_INIT (0 Nominal, 1 and 2 No Convergence, 3 4 and 5 State Vector Outside Nominal ERS (`9.9_9.9_9.9_9.9_9.9_9.9_9_9`)
4	1 or 2	char	135	Line Separator, see comment in table 21
5	167	A	136–302	– Modified Julian Day (MJD50) at True Ascending Node Crossing – Reference Mean Kepler State at True Ascending Node Crossing (Semi–major Axis (km), Excentricity, Inclination (deg), Right Asc. of Asc. Node (deg), Argument of Perigee (deg), Mean anomaly (deg) 7 * (`–9.999999999999999e-999_`)
4	1 or 2	char	303	Line Separator, see comment in table 21

Table 23 : ERS Orbit Propagator Information

The Solar Format Specification (SFS) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	15	A	1–15	Description (`Solar_Spectrum_`)
2	12	A	16–27	UTC Date of Solar Spectrum (`DD-MMM-YYYY_`)
3	12	A	28–39	UTC Time of Solar Spectrum (`HH:MM:SS.mmm`)
4	1 or 2	char	40	Line Separator, see comment in table 21

Table 24 : Solar Format Specification Content

The Channel Data Record (CDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	10	A	1–10	Channel Identifier (`Channel 9_`)
3	16	A	11–26	Wavelength Range (nm) (`999.999_999.999_`)
4	4	A	27–30	Number of Detector Pixels Samples (`9999`) (Nsamp)
5	8	A	31–38	Spectral Calibration Error (`9.9999_`)
6	2	A	39–40	Spectral check (9_) 0 = e < 0.02 px 1 = 0.02 < e < 0.05 px 2 = e > 0.05 px
7	2	A	41–42	Saturated pixels (9_) †
8	2	A	43–44	Hot pixels (9_) †
9	2	A	45–46	Dead pixels (9_) †
10	1 or 2	A	47–48	Line Separator, see comment in table 21
11	Nsamp * (47 or 48)	SDR	49–48,173 or 49,193	Solar Data Records, see table 26 (e.g. Nsamp = 1024)

Table 25 : Channel Data Record Content

† 0 = all pixels ok
1 = less than 1% of pixels affected
2 = more than 1% of pixels affected

The Solar Data Record (SDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	9	A	1–9	Wavelength [nm], (`999.9999_`)
2	12	A	10–21	Absolute Irradiance measurement [photons/nm.cm^2.s], (`9.99999e-99_`)
3	12	A	22–33	Absolute Irradiance measurement Error [photons/nm.cm^2.s], (`9.99999e-99_`)
4	12	A	34–45	Irradiance * relative response Error [–], (`9.99999e-99_`)
5	1	A	46	Flag, (`9`) (e.g. 0=Good, 1=Dead, 2=Hot, 3=Saturated, ..., 9=other errors)
6	1 or 2	A	47	Line Separator, see comment in table 21

Table 26 : Solar Data Record Content

The Earthshine Format Specification (EFS) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	20	A	1–20	Description (`Earthshine_Spectrum_`)
2	26	A	21–46	Time Range (`99:99:99_99:99:99_`)
3	5	A	47–51	Number of Ground Pixels (`9999`) (Nground)
4	1 or 2	char	52	Line Separator, see comment in table 21

Table 27 : Earthshine Format Specification Content

The Earthshine Ground Pixel (EGP) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	18	A	1–18	Ground Pixel Number (`Ground_Pixel_9999_`)
2	1	A	19–20	Number of Band Data Samples (9) (Nband)
3	2	A	21	Subset Counter (9_) (’0’ to ’2’ forward, ’3’ backward)
4	1 or 2	char	22	Line Separator, see comment in table 21
5	303–310	AGI	23–325	Geolocation Information in ASCII, see table 29
6	586 or 587	PDR	326–911	PMD Data Values of the corresponding science data packet, see table 30
7	1 or 2	A	912	Line Separator, see comment in table 21
8	Nband * (48,186 or 49,206) = 192,744	BDRA	913–193,656	Band Data Records, see table 32 (e.g. Nband = 4)

Table 28 : Earthshine Ground Pixel Content

The Geolocation Information in ASCII (AGI) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	12	A	1–12	UTC Date of Ground Pixel End (DD–MMM–YYYY_)
2	12	A	13–24	UTC Time of Ground Pixel End (HH:MM:SS.mmm)
3	1 or 2	A	25	Line Separator, see comment in table 21
4	47	A	26–72	3 Solar Zenith and Azimuth Angles at Satellite w.r.t North for the points {A, B, C} , 3 * (–999.99_–999.99_)
5	1 or 2	A	73	Line Separator, see comment in table 21
6	47	A	74–120	3 Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t North for the points {A, B, C} , 3 * (–999.99_–999.99_)
7	1 or 2	A	121	Line Separator, see comment in table 21
8	47	A	122–168	3 Solar Zenith and Azimuth Angles at Satellite w.r.t Spacecraft for the points {A, B, C} , 3 * (–999.99_–999.99_)
9	1 or 2	A	169	Line Separator, see comment in table 21
10	47	A	170–216	3 Line–of–Sight Zenith and Azimuth Angles at Satellite w.r.t Spacecraft for the points {A, B, C} , 3 * (–999.99_–999.99_)
11	1 or 2	A	217	Line Separator, see comment in table 21
12	7	A	218–224	Satellite Geodetic Height at point {B}, (999.99_)
13	8	A	225–232	Earth Radius of Curvature at point {B}, (9999.99_)
14	1	A	233	Possible Sun–glint (9) 0 = no, 1 = yes
15	1 or 2	A	234	Line Separator, see comment in table 21
16	69	A	235–302	4 Corner and Center Coordinates (Lat., Long.) at points {1, 2, 3, 4 and 5} of Ground Pixel, 5 * (–99.99_999.99_)
17	1 or 2	A	303 or 310	Line Separator, see comment in table 21

Table 29 : Geolocation Information in ASCII Content

The PMD Data Record (PDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	9	A	1–9	PMD Flags for PMD 1, PMD 2 and PMD 3 (PMD_9_9_9) 0=Good, 1=Error
2	1 or 2	A	10 or 11	Line Separator, see comment in table 21
3	16 * (36 or 37) = 576	PVDR	11–586	PMD Values Data Record, see table 31
4	1 or 2	A	586 or 587	Line Separator, see comment in table 21

Table 30 : PMD Data Record Content

The PMD Values Data Record (PVDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	12	A	1–12	PMD 1 Data Value relative to Sun [–] (9.99999e-99_)
2	12	A	13–24	PMD 2 Data Value relative to Sun [–] (9.99999e-99_)
3	11	A	25–35	PMD 3 Data Value relative to Sun [–] (9.99999e-99)
4	1 or 2	A	36 or 37	Line Separator, see comment in table 21

Table 31 : PMD Values Data Record Content

The Band Data Record ASCII (BDRA) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	8	A	1–8	Band Identifier (`Band 9a_`)
2	11	A	9–19	Integration Time [s] (`9999.99999_`)
3	16	A	20–35	Wavelength Range (nm) (`999.999_999.999_`)
4	4	A	36–39	Number of Detector Pixels Samples (9999) (Nsamp)
5	8	A	40–47	Spectral Calibration Error (`9.9999_`)
6	2	A	48–49	Spectral check (9_) 0 = e <= 0.02 px 1 = 0.02 < e <= 0.05 px 2 = e > 0.05 px
7	2	A	50–51	Saturated pixels (9_) †
8	2	A	52–53	Hot pixels (9_) †
9	2	A	54–55	Dead pixels (9_) †
10	2	A	56–57	Reflectivity jump (9_) 0 = no jump check done or reflectivity ratio <= 1.1 1 = 1.1 <reflectivity ratio <= 1.4 2 = reflectivity ratio > 1.4
11	1 or 2	A	58–58	Line Separator, see comment in table 21
12	Nsamp * (47 or 48)	EDR	58–48,186 or 49,206	Earthshine Data Records, see table 33 (e.g. Nsamp = 1024)

Table 32 : Band Data Record ASCII Content

The Earthshine Data Record (EDR) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	9	A	1–9	Wavelength [nm], (`999.9999_`)
2	12	A	10–21	Absolute Radiance measurement [photons/ nm.cm^2.s.sr], (`9.99999e-99_`)
3	12	A	22–33	Absolute Radiance measurement Error [photons/nm.cm^2.s.sr], (`9.99999e-99_`)
4	12	A	34–45	Radiance * relative response Error [–], (`9.99999e-99_`)
5	1	A	46	Flag, (`9`) (e.g. 0=Good, 1=Dead, 2=Hot, 3=Saturated, ..., 9=other errors)
6	1 or 2	A	47 or 48	Line Separator, see comment in table 21

Table 33 : Earthshine Data Record Content

The following is an example of an extracted Level 1 Data for the earthshine ground pixels (the text in brackets and the dots are only for information and shortness, not part of the data set).

```
/*-------------------------------------------------------------------------*\   (GSI1)
**  GDP Level 0 to 1 Extracting  –  Version 1.00    –  Copyright DLR 1996     **
\*-------------------------------------------------------------------------*/
Calibrations Applied
Leakage FPA Fixed Straylight Normalize Polarization Intensity Unit_Conversion
Units
Wavelength [nm], Irradiance [photons/s.cm^2.nm], Radiance [photons/s.sr.cm^2.nm]
E2GOM000000001KSEXTR1 DP19940506191143                                    (PIR)
ERS Information                                                           (ERSI)
16638 19672770 1319 –1404.150757 –1300.069946 6893.603516 1.473122 7.208139 1.655951
0.0 0.0 0.0 0.0 0.0 0.0 0 0
1.234567890123456e–123  –1.234567890123456e–123  1.234567890123456e–123  –1.234567890123456e–123
1.234567890123456e–123 1.234567890123456e–123 1.234567890123456e–123
Solar Spectrum 19–MAY–1994 10:35:09.500                                   (SFS)
CHANNEL 1 236.898 314.484 512 0.0315 0 0 0 0                              (SDR)
237.3802 0.00000E+00 0.00000E+00 0.00000E+00 0
237.5007 0.00000E+00 0.00000E+00 0.00000E+00 0
237.6206 0.44720E+14 0.22360E+13 0.89441E+11 0
237.7412 0.52373E+14 0.26186E+13 0.10475E+12 0
237.8616 0.45247E+14 0.22623E+13 0.90494E+11 0
.....
790.0000 0.50000E+15 0.30000E+14 0.20000E+13 0
Earthshine Spectrum 10:35:95.500 12:15:90.000 1500                        (EFS)
Ground Pixel 1 6 0                                                        (EGP)
20–MAY–1994 10:35:09.500                                                  (AGI)
 42.50 205.61  42.46 205.63  42.42 205.65
 10.00  90.00  19.68  90.00  –9.37 270.00
 42.50 205.61  42.46 205.63  42.42 205.65
 10.00  90.00  19.68  90.00  –9.37 270.00
796.65 6361.36 0
–61.90 197.71 –62.23 197.98 –62.59 192.67 –62.93 192.89 –62.41 195.31
PMD 0 0 0                                                                 (PDR)
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
.....
0.12345E+00 0.23456E+00 0.34567E+00
Band 1a 30 236.898 268.121 255 0.0493 0 0 0 0 0                           (BDRA)
237.2598 0.00000E+00 0.00000E+00 0.00000E+00 0
237.3805 0.00000E+00 0.00000E+00 0.00000E+00 0
237.5003 0.00000E+00 0.00000E+00 0.00000E+00 0
237.6206 0.44720E+12 0.22360E+11 0.89441E+09 0
237.7413 0.52373E+12 0.26186E+11 0.10475E+10 0
....
268.1213 0.95544E+13 0.47772E+12 0.19109E+11 0
Band 4 1.5 578.602 780.266 1024 0.0331 0 0 0 0 0                          (BDRA)
...
Ground Pixel 2 1 6                                                        (EGP)
```

The Sun/Moon Format Specification (SMFS) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	16	A	1–16	Description (`Sun/Moon_Spectrum_`)
2	26	A	17–42	Time Range (`99:99:99_99:99:99_`)
3	5	A	43–47	Number of measurements (9999) (Nsun/ Nmoon)
4	1 or 2	char	48	Line Separator, see comment in table 21

Table 34 : Sun/Moon Format Specification Content

The Sun/Moon Measurement Data (SMMD) structure is given in the following table:

1	22	A	1–22	Measurement Number (`Sun/Moon Measurement_9999_`)
2	1	A	23	Number of Band Data Samples (9) (Nband)
3	1 or 2	char	24	Line Separator, see comment in table 21
4	42 or 43	SMGI	25–66	Sun/Moon Geolocation Information, see table 36
5	586 or 587	PDR	67–112	PMD Data Values of the corresponding science data packet, see table 30
6	1 or 2	A	113	Line Separator, see comment in table 21
7	Nband * (48,186 or 49,206) =	BDRA	114–48,308	Band Data Records, see table 32 (e.g. Nband = 4)

Table 35 : Sun/Moon Measurement Data Content

The Sun/Moon Geolocation Information (SMGI) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	12	A	1–12	UTC Date of Measurement End (DD–MMM–YYYY_)
2	12	A	13–24	UTC Time of Measurement End (HH:MM:SS.mmm)
3	1 or 2	A	25	Line Separator, see comment in table 21
4	15	A	26–40	Solar Zenith and Azimuth Angles at Satellite w.r.t North, (–999.99_–999.99)
5	1 or 2	A	41	Line Separator, see comment in table 21
6	15	A	42–56	BSDF Zenith and Azimuth Angles or Moon Zenith and Azimuth Angles at Satellite w.r.t North, (–999.99_–999.99)
7	1 or 2	A	57	Line Separator, see comment in table 21
8	7	A	58–64	Flag indicating if the record was used in the calculation of the Sun Reference Spectrum (9) 0 = no, 1 = yes, _ = no applicable or Illuminated Fraction of the Moon's Disk (9.99999)
9	1 or 2	A	65	Line Separator, see comment in table 21

Table 36 : Sun/Moon Geolocation Information Content

The following is an example of an extracted Level 1 Data for the sum measurements (the text in brackets and the dots are only for information and shortness, not part of the data set).

```
/*-------------------------------------------------------------------------*\
**  GDP Level 0 to 1 Extracting  –  Version 1.00    –  Copyright DLR 1996     **
\*-------------------------------------------------------------------------*/
Calibrations Applied
Leakage Fixed Straylight Normalize Polarization BSDF Intensity
Units
Wavelength [nm], Irradiance [mW/m^2.nm], Radiance [mW/m^2.nm.sr]
E2GOM000000001KSEXTR1 DP19940506191143
ERS Information
16638 19672770 1319 –1404.150757 –1300.069946 6893.603516 1.473122 7.208139 1.655951
0.0 0.0 0.0 0.0 0.0 0.0 0 0
1.234567890123456e–123  –1.234567890123456e–123  1.234567890123456e–123  –1.234567890123456e–123
1.234567890123456e–123 1.234567890123456e–123 1.234567890123456e–123
Solar Spectrum 19–MAY–1994 10:35:09.500
CHANNEL 1 236.898 314.484 512 0.0315 0 0 0 0
237.3802 0.00000E+00 0.00000E+00 0.00000E+00 0
237.5007 0.00000E+00 0.00000E+00 0.00000E+00 0
237.6206 0.44720E+14 0.22360E+13 0.89441E+11 0
237.7412 0.52373E+14 0.26186E+13 0.10475E+12 0
237.8616 0.45247E+14 0.22623E+13 0.90494E+11 0
.....
790.0000 0.50000E+15 0.30000E+14 0.20000E+13 0
Sun Spectrum 10:35:95.500 12:15:90.000 155
Sun Measurement 1 6
20–MAY–1994 10:35:09.500
 42.50 25.61
 34.23 34.65
 1
PMD 0 0 0
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
0.12345E+00 0.23456E+00 0.34567E+00
.....
0.12345E+00 0.23456E+00 0.34567E+00
Band 1a 30 236.898 268.121 255 0.0493 0 0 0 0 0
237.2598 0.00000E+00 0.00000E+00 0.00000E+00 0
237.3805 0.00000E+00 0.00000E+00 0.00000E+00 0
237.5003 0.00000E+00 0.00000E+00 0.00000E+00 0
237.6206 0.44720E+12 0.22360E+11 0.89441E+09 0
237.7413 0.52373E+12 0.26186E+11 0.10475E+10 0
....
268.1213 0.95544E+13 0.47772E+12 0.19109E+11 0
Band 4 1.5 578.602 780.266 1024 0.0331 0 0 0 0 0
...
Sun Measurement 2 6
```

(GSI1)
(PIR)
(ERSI)
(SFS)
(SDR)
(SMFS)
(SMMD)
(SMGI)
(PDR)
(BDRA)
(BDRA)
(SMMD)

A.4 Extracted Level 2 Trace Gases Total Column Product

Extracted Level 2 Product files have the following format:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	243	GSI2	1–240	GDP Software Identifier in ASCII see table 38
2	38	PIR	241–278	Product Identifier Record see table 3
3	1 or 2	char	279	Line Separator; the number of bytes for this field depends on the operating system the *Extract_Level_2_Data* programme was running on (e.g. UNIX = 1, MS–DOS = 2)
4	4	A	280–283	Number of DOAS Data Records in ASCII (ca. 2200) (9999)
5	1 or 2	char	284	Line Separator, see comment in table 37
6	205	SPH2A	285–489	Specific Product Header in ASCII see table 39
7	N_DDR * 1573 = 3.460.600	DDRA	490–3.461.089	DOAS Data Records in ASCII see table 40

Table 37 : Extracted Level 2 Data Content

This yields an approximate size of ~1 MB (0.8 KB for the assumptions as made below) for one Level 2 Data product which covers a one orbit of data.

The GDP Software Identifier in ASCII (GSI2) structure for the Level 2 extraction software is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	79	A	1–79	Separator 1 (/*----------*\)
2	1 or 2	A	80	Line Separator, see comment in table 37
3	79	A	81–159	Software Version (** GDP Level 1-to-2 Extracting * Version 9.99 * Copyright c DLR 1996-2004 **)
4	1 or 2	A	160	Line Separator, see comment in table 37
5	79	A	161–239	Separator 2 (*----------*/)
6	1 or 2	A	240	Line Separator, see comment in table 37

Table 38 : GDP Software Identifier

The Specific Product Header in ASCII (SPH2A) structure for the Level 2 Data product is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	38	PIR	1–38	Input Data References see table 3
2	1 or 2	char	39	Line Separator, see comment in table 37
3	6	A	40–45	GDP Software Version, DOAS Level 1 to 2, (XX.XX_)
4	6	A	46–51	GDP Static Parameter File Version, (XX.XX_)
5	5	A	52–56	GDP L2 Format Version, (XX.XX)
6	1 or 2	char	57	Line Separator, see comment in table 37
7	2	A	58–59	Number of Fitting Windows (Nwin=3) (99)
8	1 or 2	char	60	Line Separator, see comment in table 37
9	Nwin * 2 * 7 = 28	A	61–88	Window Pair (start and end wavelength in nm) (999.99_999.99_)
10	1 or 2	char	89	Line Separator, see comment in table 37
11	2	char	90–91	Number of Molecules (Nmol=7) (99)
12	1 or 2	char	92	Line Separator, see comment in table 37
13	Nmol * (1 + 12) = 26	A	93–118	Molecule Pair (fitting window number and molecule name) (9_XXXXXXXXXX_)
14	1 or 2	char	119	Line Separator, see comment in table 37
15	6	A	120–125	Atmosphere Height (999.99)
16	1 or 2	char	126	Line Separator, see comment in table 37

Table 39 : Specific Product Header Content (Level 2)

The DOAS Data Record in ASCII (DDRA) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	282	GLR2A	1–282	Geolocation Record in ASCII see table 41
2	12	A	283–294	Total Column of Ozone (Dobson) (–9.99999E–99)
3	1 or 2	char	295	Line Separator, see comment in table 37
4	12	A	296–307	Relative error on the Total Column (%) (–9.99999E–99)
5	1 or 2	char	308	Line Separator, see comment in table 37
6	1265	IRRA	309–1573	Intermediate Results Record in ASCII see table 42

Table 40 : DOAS Data Record Content (Level 2)

The Geolocation Record in ASCII (GLR2A) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	18	A	1–18	Ground Pixel Number (Ground_Pixel_9999_)
2	1	A	19	Subset Counter (9), see comment in table 28
3	1 or 2	char	20	Line Separator, see comment in table 37
4	24	A	21–44	UTC Date & Time of the ground pixel at end of integration time (DD.MMM.YYYY_HH:MM:SS.mmm)
5	1 or 2	char	45	Line Separator, see comment in table 37
6	24	A	46–69	3 Solar Zenith Angles at satellite for the points {A', B', C'} (–999.99_–999.99_–999.99_)
7	1 or 2	char	70	Line Separator, see comment in table 37
8	24	A	71–94	3 Line–of–Sight Angles at satellite for the points {A', B', C'} (–999.99_–999.99_–999.99_)
9	1 or 2	char	95	Line Separator, see comment in table 37
10	24	A	96–119	3 Relative Azimuth Angles at satellite for the points {A', B', C'} (–999.99_–999.99_–999.99_)
11	1 or 2	char	120	Line Separator, see comment in table 37

12	24	A	121–144	3 Solar Zenith Angles at TOA for the points {A', B', C'} (–999.99_–999.99_–999.99_)
13	1 or 2	char	145	Line Separator, see comment in table 37
14	24	A	146–169	3 Line–of–Sight Angles at TOA for the points {A', B', C'} (–999.99_–999.99_–999.99_)
15	1 or 2	char	170	Line Separator, see comment in table 37
16	24	A	171–194	3 Relative Azimuth Angles at TOA for the points {A', B', C'} (–999.99_–999.99_–999.99_)
17	1 or 2	char	195	Line Separator, see comment in table 37
18	7	A	196–202	Satellite Geodetic Height at point {B'} (999.99_)
19	8	A	203–210	Earth Radius of Curvature at point {B'} (9999.99_)
20	1 or 2	char	211	Line Separator, see comment in table 37
21	5 * 14 = 70	A	212–281	4 Corner and Center Coordinates (Lat., Long.) at points {1', 2', 3', 4' and 5'} of Ground Pixel, 5 * (–99.99_999.99_)
22	1 or 2	char	282	Line Separator, see comment in table 37

Table 41 : Geolocation Record 2 Content

The Intermediate Results Record in ASCII (IRRA) structure is given in the following table:

Field Number	Number of Bytes	Data Type	Byte Position	Description
1	Nmol * 13 = 26	A	1–26	*VCD*: Total VCD to ground of O_3^{UV}, NO_2^{VIS} (`-9.99999E-99_`)
2	1 or 2	char	27	Line Separator, see comment in table 37
3	Nmol * 13 = 26	A	28–53	*VCD*: Errors on VCDs above (`-9.99999E-99_`)
4	1 or 2	char	54	Line Separator, see comment in table 37
5	5	A	55–59	*VCD*: Flag indexing output (`99999`)
6	1 or 2	char	60	Line Separator, see comment in table 37
7	Nmol * 13 = 26	A	61–86	*DOAS*: Slant Columns of O_3^{UV}, NO_2^{VIS} (`-9.99999E-99_`)
8	1 or 2	char	87	Line Separator, see comment in table 37
9	Nmol * 13 = 26	A	88–113	*DOAS*: Errors on Slant Columns above (`-9.99999E-99_`)
10	1 or 2	char	114	Line Separator, see comment in table 37
11	Nwin * (4*13 + 1) = 166	A	115–220	*DOAS*: RMS, χ^2, Goodness of Fit, Iteration Number for the Nwin fitting windows 4*(`-9.99999E-99_`) Line Separator, see comment in table 37
12	13	A	221–233	*DOAS*: Calculated Ozone Temperature (`-9.99999E-99_`)
13	13	A	234–246	*DOAS*: Ozone Ring Correction Factor (`-9.99999E-99_`)
14	1 or 2	char	247	Line Separator, see comment in table 37
15	5	A	248–252	*DOAS*: Flag indexing output (`99999`)
16	1 or 2	char	253	Line Separator, see comment in table 37
17	Nmol * 13 = 26	A	254–279	*AMF*: AMF to ground for species as listed above (`-9.99999E-99_`)
18	1 or 2	char	280	Line Separator, see comment in table 37
19	Nmol * 13 = 26	A	281–306	*AMF*: Errors on AMF to ground above (`-9.99999E-99_`)
20	1 or 2	char	307	Line Separator, see comment in table 37
21	Nmol * 13 = 26	A	308–333	*AMF*: AMF to cloud–top for species as listed above (`-9.99999E-99_`)
22	1 or 2	char	334	Line Separator, see comment in table 37
23	Nmol * 13 = 26	A	335–360	*AMF*: Errors on AMF to cloud–top above (`-9.99999E-99_`)

24	1 or 2	char	361	Line Separator, see comment in table 37
25	5	A	362–366	*AMF*: Flag indexing output (99999)
26	1 or 2	char	367	Line Separator, see comment in table 37
27	13	A	368–380	*GVC*: Ghost Vertical Column (-9.99999E-99_)
28	1 or 2	char	381	Line Separator, see comment in table 37
29	2 * 13 = 26	A	382–407	*OCRA*: Cloud fraction and Error 2*(-9.99999E-99_)
30	1 or 2	char	408	Line Separator, see comment in table 37
31	2 * 13 = 26	A	409–434	*ROCINN*: Cloud Cloud–top Height and Error 2*(-9.99999E-99_)
32	1 or 2	char	435	Line Separator, see comment in table 37
33	2 * 13 = 26	A	436–461	*ROCINN*: Cloud Cloud–top Pressure and Error 2*(-9.99999E-99_)
34	1 or 2	char	462	Line Separator, see comment in table 37
35	2 * 13 = 26	A	463–488	*ROCINN*: Cloud Cloud–top Albedo and Error 2*(-9.99999E-99_)
36	1 or 2	char	489	Line Separator, see comment in table 37
37	3 * 13 = 39	float	490–528	Surface Height, Surface Pressure and Surface Albedo 3*(-9.99999E-99_)
38	1 or 2	char	529	Line Separator, see comment in table 37

Table 42 : Intermediate Results Record Content

* Note: Vertical Columns and Slant Columns are given in mol/cm^2
For definitions on flag indexing, see appendix A.2.

The following is an example of an extracted Level 2 Data File (the text in brackets and the dots are only for information and shortness, not part of the data set).

```
/*-------------------------------------------------------------------------*\
**  GDP Level 1 to 2 Extracting – Version 4.00  – Copyright © DLR 1996–2004  **
\*-------------------------------------------------------------------------*/
E2GOM032100001ESLVL20 DP20041117190102                                  (PIR)
0002
E2GOM032100001ESLVL10 DP19990809091909
04.00 04.12 02.00                                                       (SPH2A)
 2
325.00 335.00 425.00 450.00
 2
1 O3         2 NO2
 70.00
Ground Pixel  188 0                                                     (GLR2A)
01–DEC–1995 08:11:05.350
  84.55   84.50   84.46
 149.10  158.90  169.80
  66.82   66.82   66.81
  83.01   83.55   84.01
 –34.83  –22.98  –11.36
 –67.22  –67.05  –66.92
794.23 6392.95
 60.78  59.92  61.15  60.32  62.05  54.05  62.37  54.34  61.64  57.12
 2.86906e+02                                                            (IRRA)
 2.59607e+00
 7.70844e+18  1.69861e+15
 2.59607e+00  7.64054e+00
00003
 4.87401e+19  1.40912e+16
 6.09710e–01  7.20260e+00
 2.92306e–03  7.51896e+02  0.00000e+00  9.00000e+00
 1.00487e–03  1.20163e+02  0.00000e+00  1.10000e+01
 2.20403e+02  9.38278e–01
00392
 6.55350e+00  8.20996e+00
 2.81328e+00  2.81328e+00
 6.98240e+00  8.30530e+00
 2.81328e+00  2.81328e+00
00047
 2.37045e+17
 8.40218e–01  3.78050e+00
 3.32270e+00  4.71309e+00
 6.59155e+02  4.71309e+00
 5.83709e–01  8.48448e+00
 2.59555e–01  9.82034e+02  1.96617e–01
Ground Pixel  189 1
01–DEC–1995 08:11:06.850
```

B Basic Data Representations

This appendix describes how GDP represents data in storage, specifically in the data products. This chapter is intended as a guide to programmers who wish to write their own reading modules in other languages or on other machines having a different representation of numbers.

Storage Allocation

The following table shows the storage allocation of the basic numeric data types which are used for GDP products:

Data Type	Internal Representation
`char`	a single 8–bit byte aligned on a byte boundary.
`short`	half word (two bytes or 16 bits), aligned on a two–byte boundary.
`long`	32 bits (four bytes or one word), aligned on a four–byte boundary.
`float`	32 bits (four bytes or one word), aligned on a four–byte boundary. A float has a sign bit, 8–bit exponent, and 23–bit fraction.
`double`	64 bits (eight bytes or two words), aligned on a double–word boundary. A double element has a sign bit, an 11–bit exponent and a 52–bit fraction.

Table 43 : Data Type Storage Allocation

Data Representations

Bit numberings of any given data element used for GDP are as follows:

- Bit 0 is the least significant bit of one byte;
- Byte 0 is the most significant byte of a given data element.

The most significant bit of the `char`, `short` and `long` data types is a sign bit. The `unsigned` versions of these data types use all bits for representation of the number, but do not known negative values.

`float` and `double` data elements are represented according to the ”ANSI IEEE” 754–1985 standard.

Bits	Content
`8–15`	Byte 0
`0–7`	Byte 1

Table 44 : Short Data Type Representation

Bits	Content
`24–31`	Byte 0
`16–23`	Byte 1
`8–15`	Byte 2
`0–7`	Byte 3

Table 45 : Long Data Type Representation

Bits	Name	Content
`31`	Sign	1 if number is negative.
`23–30`	Exponent	Eight–bit exponent, biased by 127. Values of all zeros, and all ones, reserved.
`0–22`	Fraction	23–bit fraction component of normalised significand. The ”one” bit is ”hidden”.

Table 46 : Float Data Type Representation

Bits	Name	Content
`63`	Sign	1 if number is negative.
`52–62`	Exponent	Eleven–bit exponent, biased by 1023. Values of all zeros, and all ones, reserved.
`0–51`	Fraction	52–bit fraction component of normalised significand. The ”one” bit is ”hidden”.

Table 47 : Double Data Type Representation

A `float` and `double` number is represented by the form:

$(-1)^{Sign} \cdot 2^{(exponent - bias)} \cdot 1.fraction$

where ”1.*fraction*” is the significand and ”*fraction*” are the bits in the significand fraction.