EUMETSAT

GOME-2 Factsheet

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Document Change Record

Issue / Revision	Date	DCN. No	Summary of Changes
V1	15/09/10		Draft version with updated links, document change record and signature table.
V3	23/11/10		Published version after final editing,
V3A	01/06/12		Corrected spectral resolution specifications. Added budget summary
V4	08/01/14		Added content to support GOME-2 Polar Multi-Sensor Aerosol product (PMAp). Added a set of Frequently-Asked Questions
V4A	20/05/14		Some typos and editing issues fixed in Section 7.4 Added section 6.3 on spatial aliasing
V4B	17/03/15		Corrected Eq. 2 and 4 and δ_{rd} in Section 6.3 on spatial aliasing correction and read-out duration time.
V4C	15/01/16		Updated validity tables in 5.1. Added note on at which levels angles and coordinates are provided. Type on Band setting change orbit corrected. Added description of how to read native level-1 data with CODA.
V4D	26/04/17		Update to specifications based on user input, specifically use of L1B data with BEAT.
V5	25/06/2019		Update for GOME-2 / MetopC (FM1)

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1 THE GOME-2 INSTRUMENT

The Global Ozone Monitoring Experiment 2 (GOME-2) is an optical spectrometer, fed by a scan mirror which enables across-track scanning in nadir, as well as sideways viewing for polar coverage and instrument characterisation measurements using the moon (Figure 1). GOME-2 senses the Earth's backscattered radiance and extraterrestrial solar irradiance in the ultraviolet and visible part of the spectrum (240 nm – 790 nm) at a high spectral resolution between 0.26 nm and 0.51 nm. There are 4096 spectral points from four detector channels transferred for each individual GOME-2 measurement. See Figure 2.

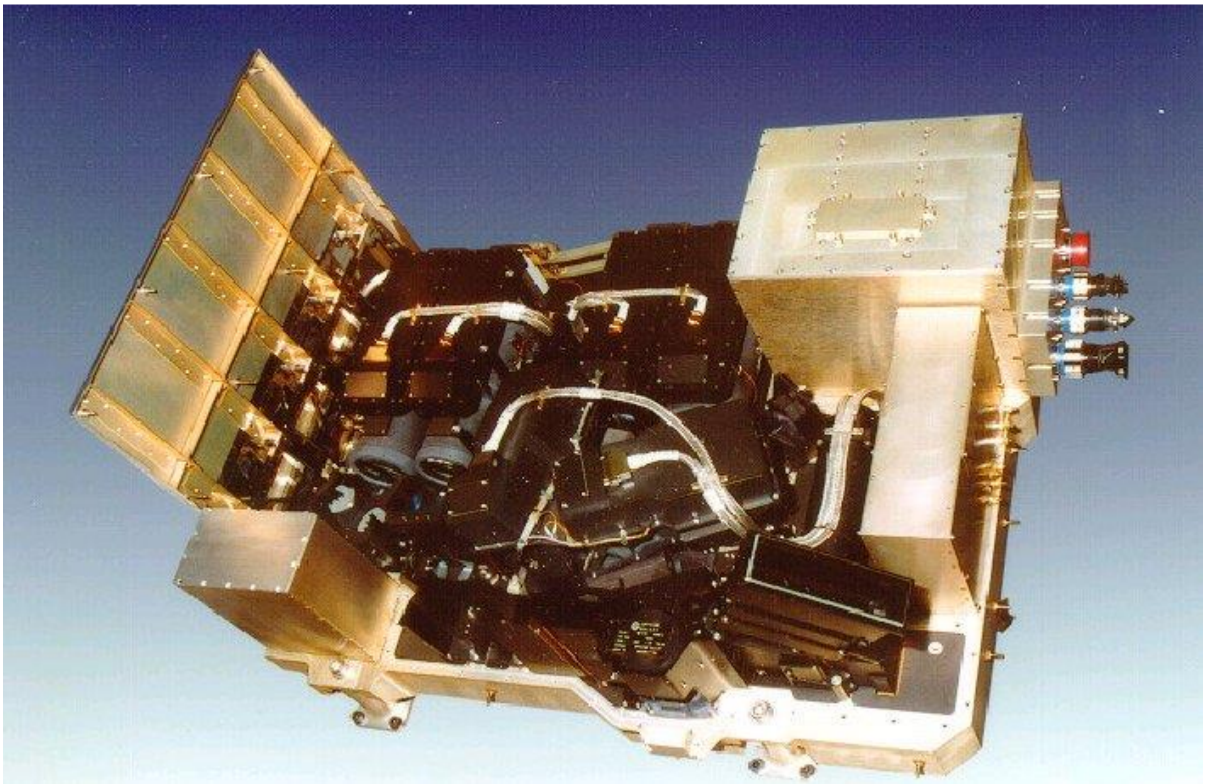


Figure 1: The Global Ozone Monitoring Experiment–2 (GOME-2)

The footprint size is 80 × 40 km (Metop-B) and 40 × 40 km (Metop-A) for main channel data. The instrument also measures the state of linear polarisation of the backscattered earthshine radiances in two perpendicular directions. The polarisation data is down-linked in 15 spectral bands covering the region from 312 nm to 800 nm for both polarisation directions with a footprint of 10 km × 40 km.

The GOME-2 instrument was developed by Selex ES in Florence, Italy, under a joint contract from EUMETSAT and the European Space Agency (ESA). The GOME-2 instrument has been in orbit on Metop-A since October 2006 and on Metop-B since September 2012. Since July 2013, the two instruments on Metop-A and Metop-B operated in tandem with a wide swath of 1920 km at 40 × 80 km ground pixel resolution for Metop-B and a narrow swath of 960 km at 40 × 40 km resolution for Metop-A.

2 GOME-2 SUMMARY BUDGETS

Item	Budget
Spectral band (nm)	240 nm to 790 nm
Spectral resolution (nm)	0.26 to 0.51
Spatial resolution Metop-A (km2) before 15 July 2013	40 × 80 (main channels) 40 × 10 (PMD)
Spatial resolution Metop-A (km2) after 15 July 2013	40 × 40 (main channels) 40 × 5 (PMD) after 15 July 2013
Spatial resolution Metop-B (km2)	40 × 80 (main channels) 40 × 10 (PMD)
Spatial resolution Metop-C (km2)	40 × 80 (main channels) 40 × 10 (PMD)
Swath width Metop-A (km) before 15 July 2013	1920
Swath width Metop-A (km) after 15 July 2013	960
Swath width Metop-B (km)	1920
Swath width Metop-C (km)	1920
Spectral channels	4096
Polarization channels	30
Calibration system	Spectral lamp, white lamp, solar diffuser

Table 1:GOME-2 instrument budgets

2.1 Platform (M0x) and Flight models (FMx)

Platform	Platform ID	Instrument model ID
Metop-A	*M02*	*FM3*
Metop-B	*M01*	*FM2*
Metop-C	*M03*	*FM1*

Table 2: Platform and instrument model identifiers

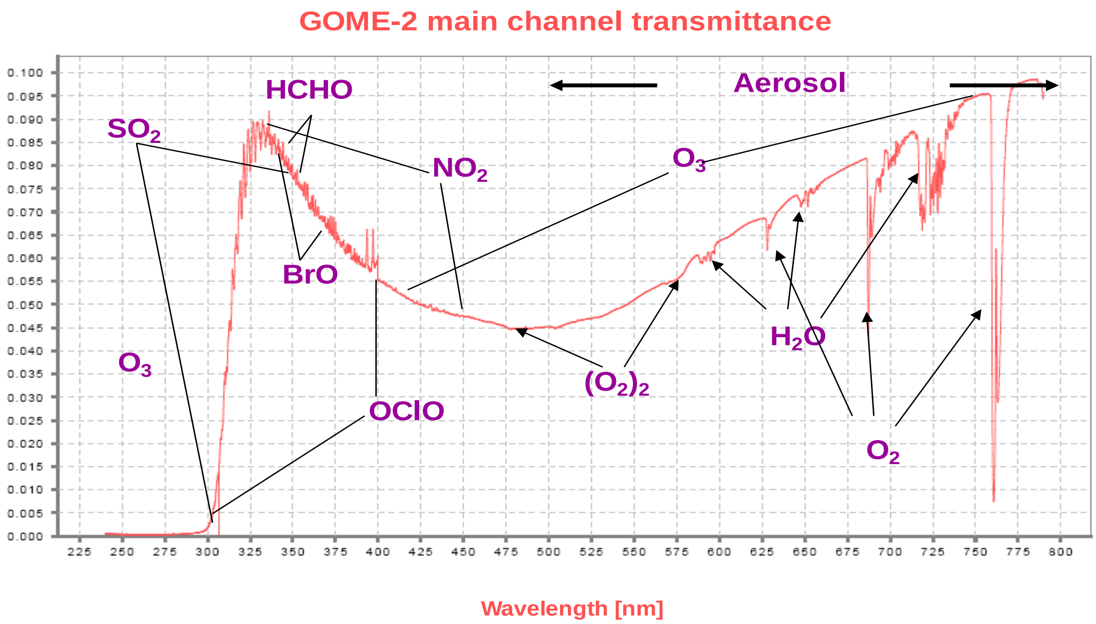


Figure 2: GOME-2 transmittance as derived from the GOME-2 level 1b radiance.

3 GOME-2 PRODUCTS AND DOCUMENTATION

3.1 Level 1B Products

Products	*Product Format Type*
Sun-normalised nadir radiance	EPS native
Absolute nadir radiance	EPS native
Absolute sun radiance	EPS native
Spectral calibration parameters	EPS native
Sun mean reference spectrum	EPS native
Effective cloud fraction	EPS native
Effective cloud fraction	EPS native
Cloud Top Pressure	EPS native

3.2 Level 2 Products

The Satellite Application Facility (SAF) on Atmospheric Composition Monitoring (AC SAF) has the responsibility for extraction of meteorological or geophysical (level 2) products from GOME. Detailed information on the products, including NRT, offline and data records, with validation and latest images are at this address:
https://acsaf.org/

3.2.2 Product and Format List

	Product	*Format Type*
NRT product	Total column O3	HDF5 and BUFR
	O3 high- resolution profiles	HDF5 and BUFR
	O3 tropospheric	HDF5 and BUFR
	NO2 column	HDF5 and BUFR
	NO2 tropospheric column	HDF5 and BUFR
	SO2 total column	HDF5 and BUFR
	HCHO total column	HDF5 and BUFR
	Absorbing Aerosol Index	HDF5
	UV index Clear Sky	PNG, HTML
	UV index Cloud corrected	PNG, HTML
Offline products	Total column ozone	HDF5
	O3 high- resolution profiles	HDF5 and BUFR
	O3 coarse-resolution profiles	HDF5
	NO2 column	HDF5
	NO2 tropospheric	HDF5
	SO2 total column	HDF5
	HCHO total column	HDF5
	BrO total column	HDF5
	H2O total column	HDF5
	Absorbing Aerosol Index	HDF5
	Surface UV	
	O3 tropospheric column	HDF5
	O3 tropical tropospheric column	NetCDF
	Reprocessed Total column ozone	HDF5

	Product	*Format Type*
Data Records	Reprocessed total NO2 column	HDF5
	Reprocessed tropospheric NO2 column	HDF5
	Reprocessed total SO2 column	HDF5
	Reprocessed total HCHO column	HDF5
	Reprocessed total BrO column	HDF5
	Reprocessed total H2O column	HDF5
	Reprocessed OClO column	HDF5
	Reprocessed LER surface albedo data record	HDF5

3.3 Data Provision

GOME-2 data product meta-data is available from the EUMETSAT Product Navigator Portal:

http://navigator.eumetsat.int/discovery/Start/Explore/Quick.do

You can order GOME-2 data products from the EUMETSAT Earth Observation Portal:
http://www.eumetsat.int/website/home/Data/DataDelivery/DataRegistration/index.html

3.4 GOME-2 Pre-Operational Data Service Dates of Service

Metop-A

GOME-2 level-1B

Since 25 January 2007 with reprocessed data version R2

Since 25 January 2012 in NRT (R0).

GOME-2 level-2

See https://acsaf.org/ -> Products

Metop-B

GOME-2 level-1B
Since 17 February 2013 in NRT.

GOME-2 level-2

See https://acsaf.org/ -> Products

Metop-C

GOME-2 level-1B
Since 01 July 2019 in NRT.

GOME-2 level-2

See https://acsaf.org/ -> Products

3.5 GOME-2 Product Documentation

Document Name	*Contents*
EPS Generic Format Specification (GPFS)	Generic description of the EPS native format
GOME-2 Product Format Specification (PFS)	Description of the GOME-2 level 1 native format
GOME-2 User Guide	General description of the product content and format.
GOME-2 Level 1 Product Generation Specification (PGS)	Level-1 product Algorithm Theoretical Basis Document

Table 3: Product reference documents for GOME-2

These and related technical documents about the GOME-2 instrument and products are available at this address:

www.eumetsat.int
> Data
> Technical Documents
> Operational Service
> Metop-GDS
> GOME-2 level 1B

3.6 GOME-2 Product Validation Reports

A complete set of validation reports for the entire lifespan of the product is available in the following documents.

GOME-2 on Metop-A

Document Name	*Contents*
GOME-2/Metop-A Level 1B Product Validation Report No. 5: Status at Reprocessing G2RP-R2	Validation of the latest reprocessing R2 of GOME-2 level-1 2007 to 2012.
GOME-2/Metop-A Reprocessed L1B-R2 Data-Set User Guide	User guide for reprocessed data-set R2.
GOME-2 PMD Band Definitions 3.0 and PMD Calibration	Defines the on-board co-added spectral polarisation measurement device bands.

Table 4: Product validation documents for GOME-2 on Metop-A

GOME-2 on Metop-B

Document Name	*Contents*
EPS Metop-B Product Validation Report: GOME-2 level 1	Contains a validation of level 1b data-quality before the start of operations
Metop-B / GOME-2 PMD Band Definitions and PMD Calibration	Definitions of on-board co-added spectral polarisation measurement device bands.

Table 5: Product validation documents for GOME-2 on Metop-B

GOME-2 on Metop-C

Document Name	*Contents*
EPS Metop-C Product Validation Report: GOME-2 level 1	Contains a validation of level 1b data-quality before the start of operations
Metop-C / GOME-2 PMD Band Definitions and PMD Calibration	Definitions of on-board co-added spectral polarisation measurement device bands.

Table 6: Product validation documents for GOME-2 on Metop-C

3.7 GOME-2 Instrument and Product Monitoring

http://gome.eumetsat.int

3.8 GOME-2 Instrument Status and Product Update

http://gome.eumetsat.int
-> Documentation
-> Processor change history

3.9 GOME-2 Instrument key-data

3.10 Spectral response functions are also contained on this page.

http://gome.eumetsat.int
> Documentation
> Instrument calibration key-data

Note: The spectral response function packages are available under the FTP link: *Slit-function key-data.*

3.11 GOME-2 Main Channel (80/40 × 40 km) Cloud Product in Level 1b (Fresco+)

Document Name	*Contents*
Support for Upgrade to FRESCO+ in the GOME-2 PPF - Final Report	Validation and description of the FRESCO+ algorithm for cloud fraction and cloud top height in the level 1b product.

Table 7: Product validation document for the GOME-2 main channel cloud product

3.12 GOME-2 newsletter

The GOME-2 newsletter provides information quarterly about the latest development and testing of the GOME-2 instruments and the status of level 1 products. The newsletter is posted here:

www.eumetsat.int
> News
> Technical bulletins
> GOME-2

4 INSTRUMENT OPERATIONAL CONCEPT

4.1 Earth Observation Modes

Earth observation–also called e*arthshine* –modes are those modes where the earth is in the field of view of GOME-2. They are usually employed on the dayside of the earth (the sun lighted part of the orbit). The scan mirror can be at a fixed position (static modes), or scanning around a certain position (scanning modes). All internal light sources are switched off and the solar port of the calibration unit is closed.

Nadir static

In this mode, the scan mirror is pointing towards nadir. Typically, the mode will be used for two orbits during the monthly calibration. It is valuable tool for validation and long-loop sensor performance monitoring.

Nadir scanning

GOME-2 is in this mode most of the time. In this mode, the scan mirror performs a nadir swath as described above. The swath width is command able; its default value is 1920 km. Scanning can be performed either with constant ground speed, which results in equally-sized ground pixels. This is the default. Scanning can also be done with a constant angular speed (known as GOME-1 mode) which results in larger ground pixels for the extreme swath positions when compared to pixels at swath centre.

4.2 Calibration Modes

In-orbit instrument calibration and characterisation data are acquired in the various calibration modes. They are usually employed during eclipse–except for the solar calibration, which is performed at sunrise. Both internal (white light source, spectral light source, LED) and external light sources (sun, moon) can be employed. The sources are selected based on the scan mirror position. Each source setting is described below:

Dark

The scan mirror points towards the GOME-2 telescope. All internal light sources are switched off and the solar port is closed. Dark signals are typically measured every orbit during eclipse.

Sun (over diffuser)

The scan mirror points towards the diffuser. All internal light sources are switched off and the solar port is open. Solar spectra are typically acquired once per day at the terminator in the Northern hemisphere. The Sun Mean Reference spectrum will be derived from this mode.

White light source (direct)
The scan mirror points towards the white light source (WLS) output mirror. The white light source is switched on and the solar port is closed. The WLS can be operated at four different currents: 360 mA, 380 mA, 400 mA, and 420 mA. Etalon and Pixel-to-Pixel Gain calibration data will be derived from this mode.

Spectral light source (direct)
The scan mirror points towards the spectral light source (SLS) output mirror. The SLS is switched on and the solar port is closed. Wavelength calibration coefficients will be derived from this mode.

Spectral light source over diffuser
In this mode, the scan mirror points towards the diffuser. The SLS is switched on and the solar port is closed. Light from the SLS reaches the scan mirror via the diffuser. This mode is employed for in-orbit monitoring of the sun diffuser reflectivity.

LED
The scan mirror points towards the GOME-2 telescope. The LEDs are switched on and the solar port is closed. PPG calibration data is derived from this mode.

Moon
The scan mirror points towards the moon; typical viewing angles are +70º to +85º. As the spacecraft moves along the orbit, the moon passes the GOME-2 slit within a few minutes. ***Note***: This mode can be employed only if specified geometrical conditions (lunar azimuth, elevation and pass angle) permit it. These specified geometrical conditions typically occur only a few times each year.

4.3 Metop-A: Calibration and Monitoring Timeline Plan

The two tables in this section show a timeline for GOME-2 Metop-A instrument operations before and after start of tandem operations. Table 2 shows the schedule at the beginning of Tandem operations on 15 July 2013.

GOME-2 timeline planning per 412/29 repeat cycle. Version 4.0, 22 Feb 2008																
day	orbit offset	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	X	X	X	M1	M2	D1	D2	X	X	S	S	R	X	X	X
2	15	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
3	29	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
4	43	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
5	57	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
6	72	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
7	86	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
8	100	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
9	114	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
10	128	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
11	143	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
12	157	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
13	171	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
14	185	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
15	199	N	N	N	N	N	D1	D2	N	N	N	N	N	N	N	N
16	214	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
17	228	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
18	242	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
19	256	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
20	270	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
21	285	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
22	299	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
23	313	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
24	327	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
25	341	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
26	356	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
27	370	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
28	384	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
29	398	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
		D1	CAL6		Daily calibration, part 1 (SLS/WLS)											
		D2	CAL0		Daily calibration, part 2 (Sun)											
		M1	CAL4		Monthly calibration, part 1 (LED, WLS, SLS modes)											
		M2	CAL5		Monthly calibration, part 2 (SLS over diffuser mode)											
		N	NS		Narrow swath (320 km)											
		S	NADIR		Nadir static											
		R	PMDRAW		PMD monitoring (nominal readout/raw transfer mode)											
		X	NOT1920		Nominal swath (1920 km)											

Table 8: Metop-A instrument timeline planning for a 29-day cycle.
Schedule valid only after 22 February 2008

GOME-2/Metop-A timeline planning per 412/29 repeat cycle. Version 5.0, July 2013 - Start of Tandem Operations																
day	orbit offset	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	X	X	X	**M1**	**M2**	**D1**	**D2**	X	X	**S**	**S**	**R**	X	X	X
2	15	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
3	29	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
4	43	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
5	57	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	X
6	72	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
7	86	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
8	100	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
9	114	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
10	128	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	X
11	143	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
12	157	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
13	171	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
14	185	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
15	199	N3	N3	N3	N3	N3	**D1**	**D2**	N3	N3	N3	N3	N3	N3	N3	N3
16	214	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
17	228	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
18	242	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
19	256	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
20	270	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	X
21	285	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
22	299	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
23	313	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
24	327	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
25	341	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	X
26	356	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
27	370	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
28	384	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	
29	398	X	X	X	X	X	**D1**	**D2**	X	X	X	X	X	X	X	

D1	CALNS6	Daily calibration, part 1 (SLS/WLS) with 960 km swath
D2	CALNS0	Daily calibration, part 2 (Sun) with 960 km swath
M1	CALNS4	Monthly calibration, part 1 (LED, WLS, SLS modes) with 960 km swath
M2	CALNS5	Monthly calibration, part 2 (SLS over diffuser mode) with 960 km swath
N3	NOT320	Narrow swath (320 km)
S	NADIR	Nadir static
R	PMDRAWNS	PMD monitoring (nominal readout/raw transfer mode) with 960 km swath
X	NOT960	Nominal swath (960 km)

Table 9: Metop A in orbit instrument timeline planning for a 29-day cycle.
Only valid after beginning of Tandem operations on 15 July 2013.

4.4 Metop-B: Calibration and Monitoring Timeline Plan

The table in this section shows a timeline for GOME-2 Metop B operations in use since 15 November 2012.

GOME-2/Metop-B timeline planning per 412/29 repeat cycle. Version 1.0, July 2013 - Start of Tandem Operations																
day	orbit offset	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	X	X	X	M1	M2	D1	D2	X	X	S	S	R	X	X	X
2	15	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
3	29	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
4	43	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
5	57	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
6	72	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
7	86	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
8	100	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
9	114	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
10	128	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
11	143	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
12	157	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
13	171	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
14	185	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
15	199	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
16	214	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
17	228	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
18	242	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
19	256	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
20	270	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
21	285	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
22	299	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
23	313	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
24	327	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
25	341	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
26	356	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
27	370	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
28	384	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
29	398	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
		D1	CAL6	Daily calibration, part 1 (SLS/WLS) with 1920 km swath												
		D2	CAL0	Daily calibration, part 2 (Sun) with 1920 km swath												
		M1	CAL4	Monthly calibration, part 1 (LED, WLS, SLS modes) with 1920 km swath												
		M2	CAL5	Monthly calibration, part 2 (SLS over diffuser mode) with 1920 km swath												
		S	NADIR	Nadir static												
		R	PMDRAW	PMD monitoring (nominal readout/raw transfer mode) with 1920 km swath												
		X	NOT1920	Nominal swath (1920 km)												

Table 10: Metop-B in-orbit instrument timeline planning for a 29-day cycle.
Valid since 15 November 2012

4.5 Metop-C: Calibration and Monitoring Timeline Plan

The table in this section shows a timeline for GOME-2 Metop C operations in use since 29 January 2019

Metop-C : GOME-2 Timelines planning (29 days repeat cycle)

day	orbit	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0	X	X	X	M1	M2	D1	D2	X	X	S	S	R	X	X	X
2	15	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
3	29	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
4	43	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
5	57	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
6	72	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
7	86	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
8	100	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
9	114	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
10	128	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
11	143	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
12	157	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
13	171	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
14	185	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
15	199	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
16	214	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
17	228	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
18	242	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
19	256	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
20	270	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
21	285	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
22	299	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
23	313	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
24	327	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
25	341	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	X
26	356	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
27	370	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
28	384	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	
29	398	X	X	X	X	X	D1	D2	X	X	X	X	X	X	X	

D1	CAL6	Daily calibration, part 1 (SLS/WLS) with 1920 km swath
D2	CAL0	Daily calibration, part 2 (Sun)á with 1920 km swath
M1	CAL4	Monthly calibration, part 1 (LED, WLS, SLS modes)á with 1920 km swath
M2	CAL5	Monthly calibration, part 2 (SLS over diffuser mode)á with 1920 km swath
S	NADIR	Nadir static
R	PMDRAW	PMD monitoring (nominal readout/raw transfer mode)á with 1920 km swath
X	NOT1920	Nominal swath (1920 km)

Table 11: Metop-C in-orbit instrument timeline planning for a 29-day cycle. Valid since 29 January 2019

5 INSTRUMENT AND PRODUCT SPECIFICATIONS

5.1 GOME-2 on Metop-A / FM3

5.1.1 Channel Settings

Channel	*Spectral range [nm]*	*Detector Pixel size [nm]*	*FWHM [nm]*
1	240 - 314	0.12	0.26
2	310 – 403	0.12	0.27
3	397 – 604	0.21	0.51
4	593 – 790	0.21	0.48
PMD-P PMD-S	312 – 790	0.62 (312nm)–8.8 (790nm)	2.9 (312 nm)–37 (790nm)

Table 12: Channel characteristics of GOME-2 spectral coverage and resolution

5.1.2 Band Settings

Channel	**1**	**1**	**2**	**2**	**3**	**4**	**5/6**
Band	1A	1B	2A	2B	3	4	PMD P/S
Nr of Pixels	877/659[1]	147/365[1]	71	953	1024	1024	256
Spectral range [nm]	240-307/283[1]	307/283-314[1]	Not valid	310-403	397-604	593-790	312 – 790
nm/pixel	0.07	0.07	0.09	0.09	0.2	0.2	2

Table 13: Main channel band settings of GOME-2. See also the Note that follows.

Note: In figures noted as [1] above in table, settings changed on 10 December 2008 on orbit 11119.

5.1.3 Validity Spectral Regions

Channel Number	*Detector Pixel Start/Stop*	*Approximate Wavelength Start/Stop [nm]*
1	310/935	243.4/312.8
2	210/850	316.5/392.1
3	120/1009	417.1/604.1
4	85/989	603.2/790.8
PMD-P	750/997	299.9/842.3
PMD-S	750/998	299.9/852.3

Table 14: Valid spectral regions until 13 June 2013 (valid etalon correction).

Channel Number	*Detector Pixel Start/Stop*	*Approximate Wavelength Start/Stop [nm]*
1	310/921	243/311.5
2	168/909	311.5/399.0
3	34/980	399.0/598.0
4	60/989	604.1/790.8
PMD-P	750/997	299.9/842.3
PMD-S	750/998	299.9/852.3

Table 15: Valid spectral regions from 13 June 2013 (valid etalon correction).

Note: The spectral response function packages are available under the FTP link
Slit-function key data.
See http://gome.eumetsat.int
-> Documentation
-> key-data

5.1.4 Default GOME-2 PMD Band Definitions

Band	*First Pixel in Band from cold start*	*Number of pixels in band*	*Start wavelength λ (nm)*	*Wavelength at stop λ (nm)*
0	19	2	309.2	309.9
1	23	5	311.7	314.4
2	31	4	317.0	319.1
3	37	12	321.2	329.5
4	50	5	331.1	334.3
5	56	43	335.9	377.7
6	100	4	380.1	282.7
7	115	20	399.3	428.4
8	138	43	435.5	552.5
9	183	2	553.6	557.5
10	187	222	569.6	678.6
11	217	2	742.3	750.2
12	219	1	758.2	758.2
13	223	1	792.1	792.1
14	226	1	838.8	838.8

Table 16: Default GOME-2 PMD band definitions (v1.0). Vvalid from date of launch to 11 March 2008 in orbit 7226

5.1.5 GOME-2 PMD Band Definitions (for v. 3.1)

Band-S					Band-P				
No.	*pix1*	*pixw.*	*wav1*	*wav2*	*No.*	*pix1*	*pixw.*	*wav1*	*wav2*
0	22	5	311.709	314.207	0	20	5	311.537	313.960
1	30	4	316.762	318.720	1	29	4	317.068	318.983
2	37	12	321.389	329.139	2	36	12	321.603	329.267
3	50	6	330.622	334.443	3	49	6	330.744	334.560
4	57	6	336.037	340.161	4	56	6	336.157	340.302
5	84	17	360.703	377.873	5	83	17	361.054	378.204
6	102	4	380.186	383.753	6	101	4	380.502	384.049
7	117	19	399.581	428.585	7	116	19	399.921	429.239
8	138	27	434.083	492.066	8	137	27	434.779	492.569
9	165	18	494.780	548.756	9	164	18	495.272	549.237
10	183	2	552.474	556.262	10	182	2	552.967	556.769
11	187	11	568.070	612.869	11	186	11	568.628	613.680
12	198	9	617.867	661.893	12	197	9	618.711	662.990
13	218	4	744.112	768.269	13	217	4	745.379	769.553
14	224	2	794.080	803.072	14	223	2	795.364	804.351

Table 17: GOME-2 PMD band definitions (v 3.1). This set of definitions has been uploaded for orbit on 11 March 2008 during orbit 7227.

5.2 GOME-2 on Metop-B / FM2

5.2.1 Channel Settings

Channel	*Spectral range [nm]*	*Detector Pixel size [nm]*	*FWHM [nm]*
1	239 – 312	0.1	0.29
2	308 – 402	0.1	0.28
3	395 – 604	0.2	0.55
4	593 – 791	0.2	0.5
PMD-P PMD-S	312 – 790	0.62 (312 nm) to 8.8 (790 nm)	2.9 (312 nm) to 37 (790 nm)

Table 18: Channel characteristics of GOME-2 FM2 spectral coverage and resolution

5.2.2 Band Settings

Channel	*1*	*1*	*2*	*2*	*3*	*4*	*5/6*
Band	1A	1B	2A	2B	3	4	PMD P/S
Spectral range [nm]	239 to 283	238 to 312	Not valid	308 to 402	395 to 604	593 to 791	312 to 790
Nr. of Pixels	659	365	71	953	1024	1024	256
nm/pixel	0.07	0.07	0.09	0.09	0.2	0.2	2^2

Table 19: Main channel band settings of GOME-2 FM2 Metop-B

5.2.3 Validity Spectral Region

Channel Number	*Detector Pixel Start/Stop*	*Approximate Wavelength Start/Stop [nm]*
1	310/929	243.57/312.63
2	85/880	308.34/402.39
3	14/1013	394.57/605.04
4	37/991	592.84/790.92
PMD-P	751/1000	289.95/853.76
PMD-S	750/999	289.81/850.41

Table 20: Valid spectral regions (valid etalon correction)

Note: **S**pectral response function packages are available under the FTP link *Slit-function key-data* under http://gome.eumetsat.int
-> Documentation
-> key-data

5.2.4 PMD Band Definitions

PMD-P					*PMD-S*				
Band Nr	*Start pixel with respect to Block C*	*Width*	*Start*	*End*	*Band Nr*	*Start pixel with respect to Block C*	*Width*	*Start*	*End*
0	23	5	312.001	314.516	0	22	5	311.875	314.375
1	31	4	317.102	319.090	1	30	4	316.948	318.926
2	38	12	321.807	329.675	2	37	12	321.634	329.514
3	51	6	331.172	335.020	3	50	6	331.016	334.872
4	57	6	335.808	339.848	4	56	6	335.661	339.698
5	85	17	360.825	378.308	5	84	17	360.644	378.138
6	103	4	380.706	384.399	6	102	4	380.515	384.170
7	118	19	400.383	428.763	7	117	19	400.059	428.350
8	140	27	435.971	493.963	8	139	27	435.521	493.181
9	167	18	496.683	550.625	9	166	18	495.886	549.510
10	185	2	554.330	558.106	10	184	2	553.192	556.944
11	189	11	569.885	614.699	11	188	11	568.637	612.854
12	200	8	619.714	658.343	12	199	8	617.781	656.047
13	219	4	739.726	763.366	13	218	4	737.179	760.682
14	225	2	788.551	797.300	14	224	2	785.719	794.415

Table 21: GOME-2 Metop-B/FM2 PMD band definitions v . 2.0.
Valid from 29 Oct 2012 18:11:30 (orbit 598).

5.3 GOME-2 on Metop-C / FM1

5.3.1 Channel Settings

Channel	*Spectral range [nm]*	*Detector Pixel size [nm]*	*FWHM [nm]*
1	239-313	0.1	0.29
2	308-401	0.1	0.28
3	395-604	0.2	0.55
4	592-791	0.2	0.5
PMD-P PMD-S	312 – 790	0.62 (312nm)−8.8 (790nm)	2.9 (312nm)−37 (790nm)

Table 22: Channel characteristics of GOME-2 FM1 spectral coverage and resolution

5.3.2 Band Settings

Channel	*1*	*1*	*2*	*2*	*3*	*4*	*5/6*
Band	1A	1B	2A	2B	3	4	PMD P/S
Used Pixels	659	365	71	787	992	957	256
Valid Spectral Range (nm)	239-283	283-313.5	not valid[1]	308.9-401.9	395.4-603.9	592.6-790	290-790
nm/pixel	0.11	0.11	0.12	0.12	0.21	0.2	2[2]

Table 23: Main channel band settings of GOME-2 FM1 Metop-C

5.3.3 Validity Spectral Region

Channel Number	*Detector Pixel Start/Stop*	*Approximate Wavelength Start/Stop [nm]*
1	310/913	239/ 313.52
2	104/841	308.95/401.93
3	30/981	395.4/603.96
4	60/991	592.65/791
PMD-P	775/997	290.74/888.74
PMD-S	745/997	290.19/876.65

Table 24: Valid spectral regions (valid etalon correction)

Note: Spectral response function packages are available under the FTP link *Slit-function key-data* under http://gome.eumetsat.int
-> Documentation
-> key-data

5.3.4 PMD Band Definitions

PMD-P					*PMD-S*				
Band Nr	*Start pixel with respect to Block C*	*Width*	*Start*	*End*	*Band Nr*	*Start pixel with respect to Block C*	*Width*	*Start*	*End*
0	21	5	311.4841	314.0324	0	21	5	311.6453	314.3629
1	28	4	316.0183	318.0653	1	28	4	316.3703	318.3751
2	36	12	321.5690	329.5130	2	36	12	321.7613	329.6242
3	49	6	331.0130	334.8726	3	49	6	331.1154	334.9539
4	56	5	336.4684	339.7504	4	56	5	336.5411	339.8058
5	83	17	360.9858	378.4973	5	83	17	360.9208	378.3251
6	100	4	379.7173	383.4716	6	100	4	379.5629	383.3848
7	115	19	399.6230	428.0830	7	115	19	399.6670	428.0898
8	137	27	435.2885	493.4616	8	137	27	435.3067	493.5455
9	164	17	496.2063	546.9015	9	164	17	496.2875	547.0117
10	181	2	550.5590	554.2848	10	181	2	550.6785	554.4141
11	185	12	565.8935	614.7271	11	185	12	566.0541	614.9512
12	197	8	619.7339	658.9333	12	197	8	619.9566	658.9582
13	216	4	741.2919	764.8414	13	216	4	741.5233	765.4424
14	222	2	789.9711	798.8035	14	222	2	790.9527	799.8332

Table 25: GOME-2 Metop-C/FM1 PMD band definitions (v2.0) valid from 03./12/2018 (orbit 367).

5.4 Product units, ranges and definitions

Parameter	*Unit*
Radiances (Earthshine); *I*	[photons / (nm cm^2 sec sr)]
Irradiance (Solar Mean reference); I_0	[photons / (nm cm^2 sec)]
Angles; Solar Zenith Angle (*SZA*), *SAA*, *VA*	[degrees]
Longitude range	–180° to 180° [degrees]
Reflectance	pi/cos(SZA) × I/I_0
Time and date	UTC, measured in fractional days since 1 January 2000, 00:00:00 h

Table 26: Main parameter definitions and their units.

6 GOME-2 ORIENTATION AND REFERENCE SYSTEMS

6.1 Ground Track Orientation and Co-ordinate Reference Systems

6.1.1 Ground -Track Orientation and Corner Point Order

In Figure 3 below, directions X, Y, and line-of-sight azimuth angle φ refer to the Satellite Actual Reference Coordinate System. The orientation of the ground pixel points is the same for both forward scan and back scan. The orientation of corner points A, B, C, and D is also used for the geo-location of the complete scan.

Note: All angles and coordinates are given at h_0=0, which is the geoid.

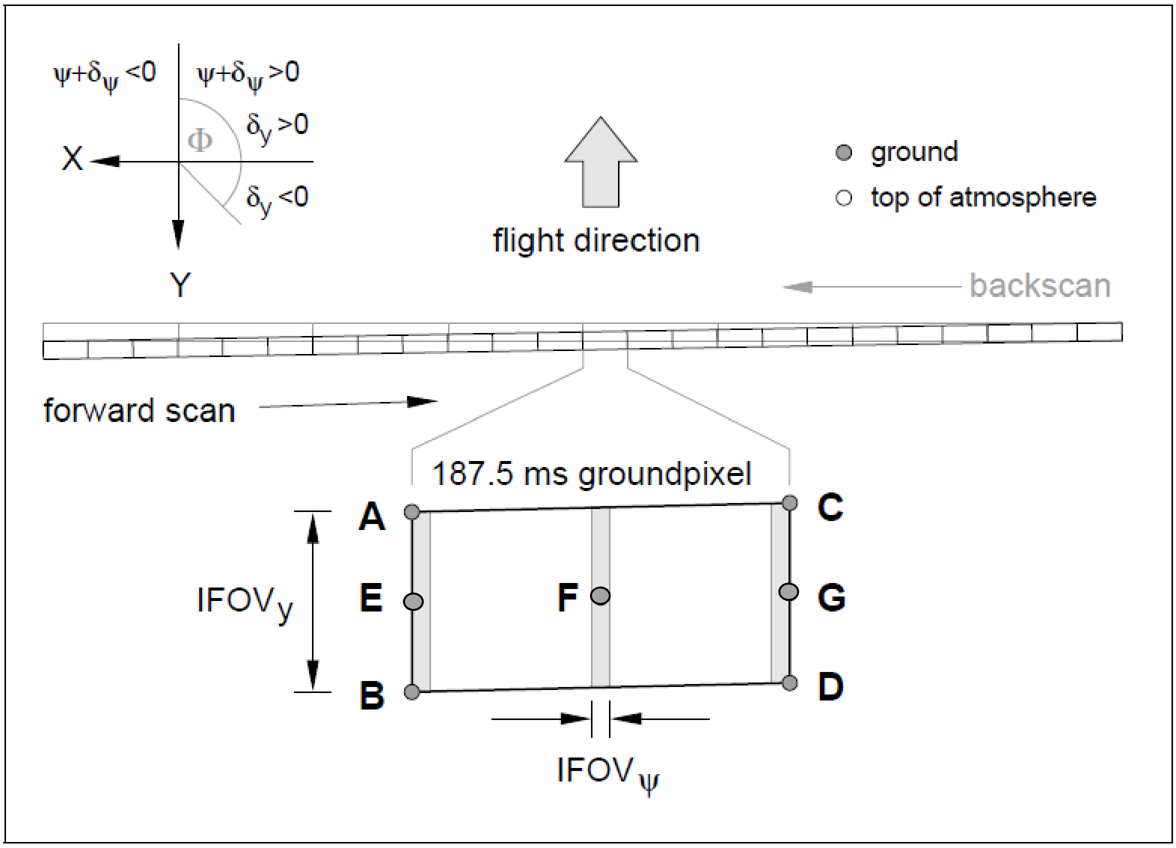


Figure 3: Ground pixel geometry for the level 0 to 1 processing.

6.1.2 Co-ordinate System for viewing angle definitions

The viewing geometry variables are provided in two different coordinate reference frames, either topocentric or as a satellite-relative actual reference system. The reference frame used is always explicitly mentioned in the variable description in the GOME-2 PFS.

6.1.3 Topocentric Reference System

The topocentric coordinate system is used to specify viewing directions from a specified point like the top of the atmosphere, or at the scattering height or specify viewing directions towards a target like the satellite or the sun. The viewing directions are given as azimuth and elevation angles. It is strictly a local coordinate system centred on this specified point.

These axes are defined as follows in the Topocentric Reference System.

X axis
Points to local east.

Y axis
Points to local north.

Z axis
Z zenith points to zenith (normal to the Earth Reference Ellipsoid).

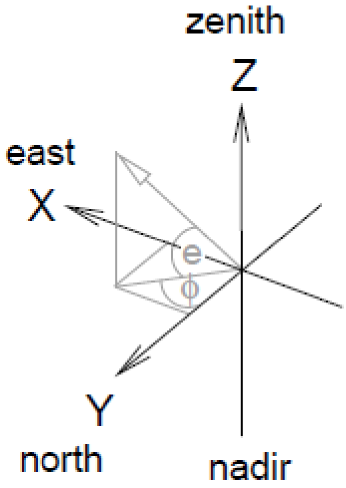


Figure 4: Topocentric reference system

Azimuth angles (**ϕ**) are counted in positive increments from the local north direction (+Y) towards the local east direction (+X). Elevations (**e**) are counted in positive increments from the local horizon plane (XY) to local zenith (+Z).

Examples: The azimuth for local east is + 90°.
The zenith elevation is + 90°.
The nadir elevation is –90°.

6.1.4 Satellite Relative Actual Reference System

This coordinate system is centred on the satellite's in-flight centre of mass. It takes into account the actual satellite orientation as described by the satellite roll, pitch, and yaw angles, as well as any instrument specific misalignment as described by roll, pitch, and yaw or mispointing angles.

These axes are defined as such in the Satellite Relative Actual Reference coordinate system:

+Z axis
Points vertically upwards to approximately zenith–exactly zenith, if all roll, pitch, and yaw angles and any mispointing angles are zero,

+Y axis
Points approximately into the anti-flight direction–exactly the anti-flight direction, if all roll, pitch, and yaw angles and mispointing angles are zero.

+X axis
This is added so that (X, Y, Z) form a right-hand coordinate system.

Look at Figure 4 below, if you look from the top of the satellite (its +Z side) and looked into flight direction (–Y), the +X direction would point to the left. Azimuth angles (Φ) are measured as positive angles from the –Y direction via the –X direction. Elevations (**E**) are counted in positive increments from the XY plane downwards towards –Z.

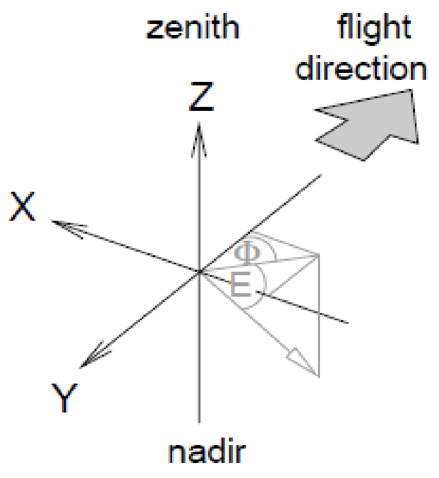


Figure 5: Satellite relative actual reference system

Examples: If all roll, pitch, and yaw angles AND all mispointing angles are zero:
the azimuth of the –Y (forward) direction is 0
the azimuth of the +X (left) direction is 270°
the zenith elevation is –90°
and the nadir elevation is +90°.

6.2 Detector Read-out Synchronisation

As specified, GOME-2 data transmissions are in packets. Each packet contains defined time stamp, scanner positions, and detector readouts. Figure 6 illustrates the synchronization of three values. The data transmitted in packet 0 (the first of a scan) is plotted against the time span and indicated by the filled circles in the schematic below. Open circles show data that belongs to the previous or next data packet. In Figure 6, Δt_{SM} is fixed at –375 ms. The indexing refers to a complete scan with selected quantities from level 0 to 1a processing.

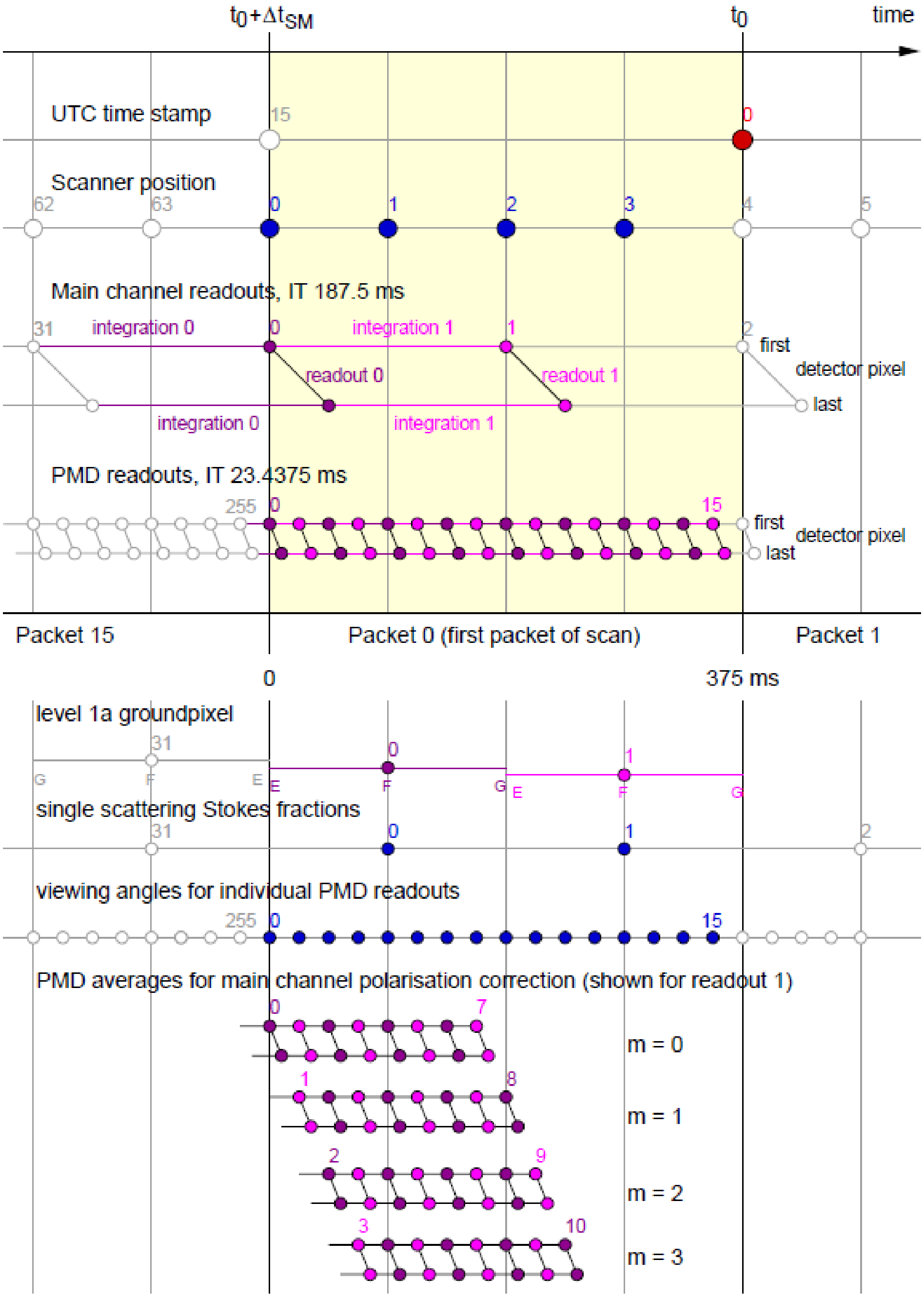


Figure 6: Synchronisation of time stamp, scanner positions and detector readouts within a GOME-2 science data packet, and selected quantities of the level 0 to 1a processing.

6.3 Spatial-aliasing

6.3.1 Spatial aliasing per channel

The effect of *spatial aliasing* has to be accounted for when very accurate geo-referencing is needed for individual measurements, which is often the case when using cloud information data for co-location or masking purposes.

Since the geo-location corner and centre latitude and longitude values, as reported in the GEO_EARTH_ACTUAL section for each channel (FPA and PMDs), are only provided for the first detector pixel readout per channel, and since the satellite is moving at high speed during the integration time of one measurement, every detector pixel of each channel detector-pixel-array sees a slightly different part of the surface than the one seen by the first detector pixel per detector array. The detector arrays are therefore read out in alternating direction in order to make sure that the last and first detector pixels see approximately the same surface where they join in spectral space. Figure 6 illustrates the idea. The readout direction–from first detector pixel to the last (0) or from the last to the first (1) –is given in the GIADR-Channels record available with each product as shown in Figure 7. Figure 7 also provides the information on the time it takes to read out the full detector array: 1024 pixels for FPA, $t_{FPA,\ full}$, and 256 pixels for PMDs, $t_{PMD,\ full}$) as well as for reading one individual detector pixel.

So, after the acquisition of one measurement, the time it takes to readout the content of detector pixel *i* in main channel *j* can be calculated as follows:

$$t_{FPA} = \begin{cases} i \cdot \delta_{rd} & (readout\ sequence\ up) \\ (1023 - i) \cdot \delta_{rd} & (readout\ sequence\ down) \end{cases}$$

Equation 1

while the time it takes to read out the signal stored in detector pixel *k* of one of the two PMD detectors s or p can be calculated as follows:

$$t_{PMD} = \begin{cases} (k - 768) \cdot \delta_{rd} & (readout\ sequence\ up) \\ (1023 - k) \cdot \delta_{rd} & (readout\ sequence\ down) \end{cases}$$

Equation 2

where $\delta_{rd} = 45.776367 \times 10^{-6}$ seconds is the readout time per single detector and the readout sequence is specified in the field CHANNEL_READOUT_SEQ of GIADR-Channels record. This sequence is as follows: 0 for sequence *up*, from short to long wavelength, and 1 for sequence *down*, from long to short wavelength.

To calculate the relative shift with respect to the geo-location data provided for the first detector pixel of the current measurement (read-out *n*) and the next measurement (read-out n+1) for the actual detector pixel *i* (FPA), k (PMD), you must divide t_{FPA}, t_{PMD} by the current integration time *IT* for the used FPA band or PMD band. This is also illustrated in Figure 7. The calculation is, simply:

$$\Delta_{i,FPA} = t_{FPA} / IT_{band} \text{ , and}$$
$$\Delta_{i,PMD} = t_{PMD} / IT_{PMD}$$

Equation 3

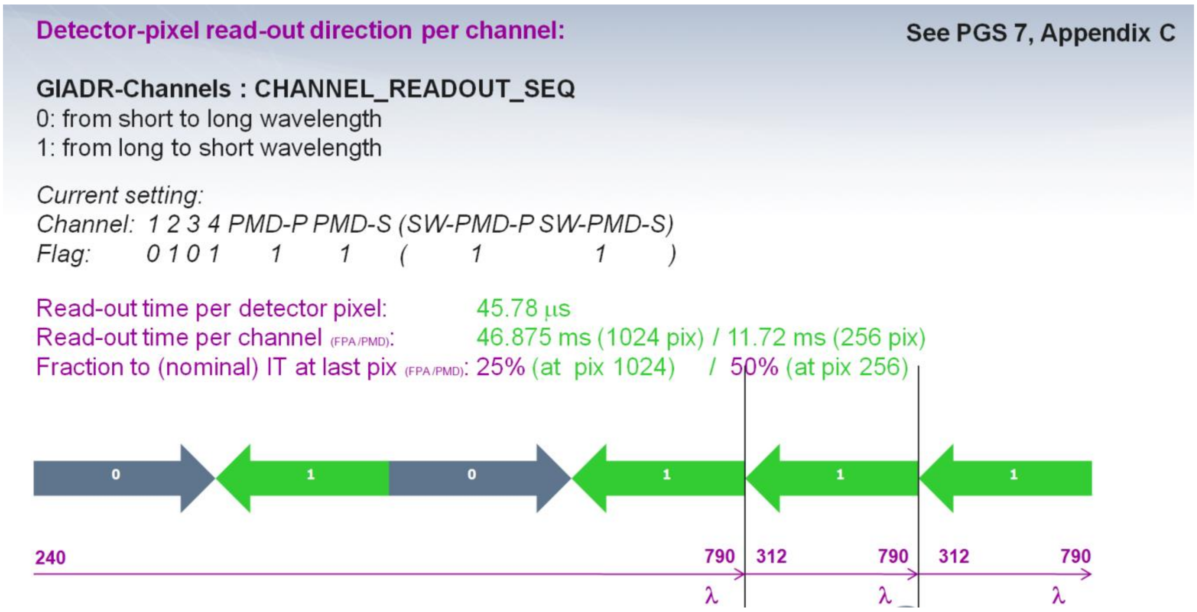


Figure 7: Detector pixel read-out time and read-out direction for main channels (FPA) and for the polarisation measurement device channels PMD p and PMD s and their corresponding spectral coverage. Note: For FPAs, all 1024 detector pixels from 0 to 1023 are used, whereas the PMDs actually use only 256 pixels though they consist of 1024 pixels.

6.3.2 Accounting for spatial-aliasing between PMD and FPA channels

If one applies the cloud properties information from AVHRR provided for the PMD channels at PMD read-out resolution (256 readouts per scan) to results obtained from the main channels (32 readouts per scan). To do this, we use the sub-pixel information provided by the PMDs because there are eight times more measurements. This ensures the spatial aliasing effects outlined above are correctly accounted for.

To do this, we calculate the time offset between FPA and PMD measurements in units of 23.4375 ms, the integration time of a single PMD measurement, as follows:

$$m_{ij}^{r} = (t_{FPA} - t_{PMD}) / 23.4375 \bullet 10^{-3} + 1$$

Equation 4

for the i^{th} detector pixel of channel j of the main science channels (FPAs).

If m^r_{ij} is split into its integer part and its fractional part using a modulus function, and by packaging the PMD cloud fraction information in $m=0,...,3$, averages of 8 PMD read-outs (c_m) each shifted by one PMD read-out k, the corresponding PMD geometric cloud property $c_{s,ij}$ for detector pixel i of channel j of the main science channel can be found by this formula:

$$c_{s,ij} = \left(1 - m_{ij}^{r,frac}\right)\bar{c}_m + m_{ij}^{r,frac}\bar{c}_{m+1}, \quad where\ m = m_{ij}^{r,\mathrm{int}} \qquad \text{Equation 5}$$

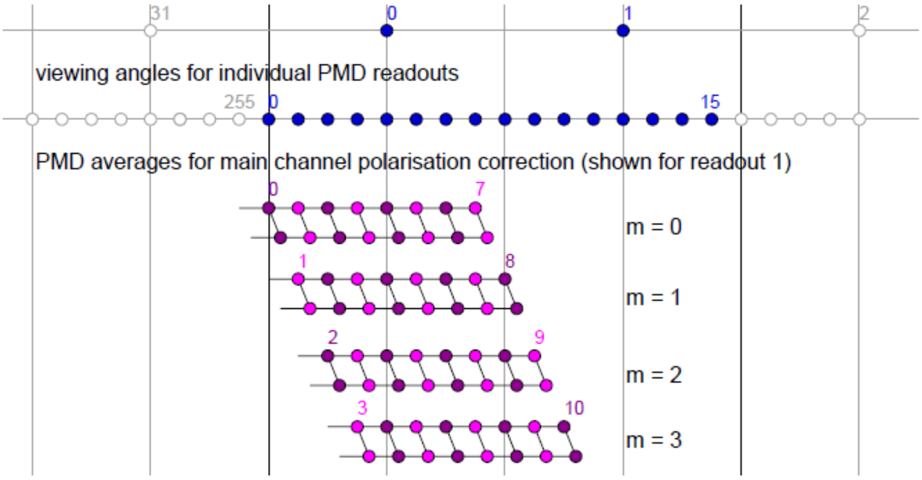


Figure 8: Excerpt from Figure 6: Packaging of 8 PMD cloud properties read-outs k into four packages with m=0,...3 for one main channel read-out n (here n=0, top row). These four averages c_m can be used to accurately calculate the geometrical cloud properties as seen by a detector pixel i of one main channel j See also text in Section 6.3.2.

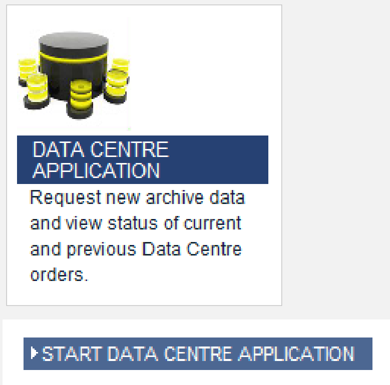
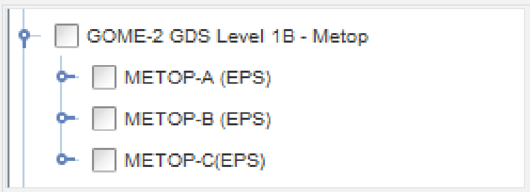
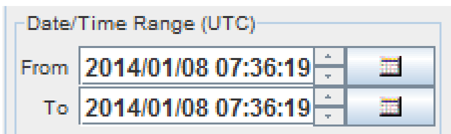
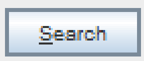
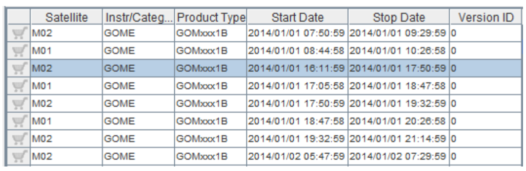
7 QUESTIONS FROM GOME-2 USERS

This section provides a selection of issues and data request and handling recipes as frequently asked by users of level-1b data.

Note: For questions about the handling of level-2 data, ask the helpdesk at http://o3msaf.fmi.fi.

7.1 Where can I get GOME-2 level-1 radiance data?

Go to the EUMETSAT EO-Portal: https://eoportal.eumetsat.int/userMgmt

Step	*You see...*
Login or register.	
Start the Data Center Application.	
Select LEO as the Search Type.	
Select GOME GDS Level1B data and Platform (sub-level).	
Specify a date and time range.	
Choose Search.	
Select an orbit from results returned.	 Satellite / Instr/Categ... / Product Type / Start Date / Stop Date / Version ID M02 / GOME / GOMxxx1B / 2014/01/01 07:50:59 / 2014/01/01 09:29:59 / 0 M01 / GOME / GOMxxx1B / 2014/01/01 08:44:58 / 2014/01/01 10:26:58 / 0 M02 / GOME / GOMxxx1B / 2014/01/01 16:11:59 / 2014/01/01 17:50:59 / 0 M01 / GOME / GOMxxx1B / 2014/01/01 17:05:58 / 2014/01/01 18:47:58 / 0 M02 / GOME / GOMxxx1B / 2014/01/01 17:50:59 / 2014/01/01 19:32:59 / 0 M01 / GOME / GOMxxx1B / 2014/01/01 18:47:58 / 2014/01/01 20:26:58 / 0 M02 / GOME / GOMxxx1B / 2014/01/01 19:32:59 / 2014/01/01 21:14:59 / 0 M02 / GOME / GOMxxx1B / 2014/01/02 05:47:59 / 2014/01/02 07:29:59 / 0
Choose the Check-out icon below the listing when you have finished.	

7.2 How do I get GOME-2 level-2 data?

Go to the EUMETSAT EO-Portal: https://eoportal.eumetsat.int/userMgmt

<table>
<tr><th colspan="2">Step</th><th>You see...</th></tr>
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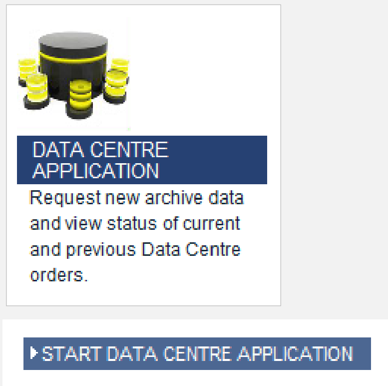
<tr><td colspan="2">Start the Data Center Application.</td><td>
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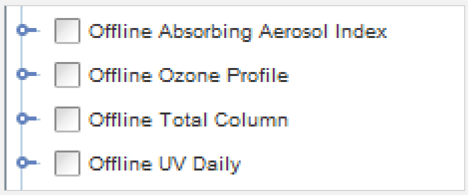
<tr><td colspan="2">Choose an attribute. See the table below:</td><td>
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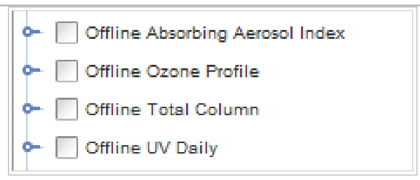
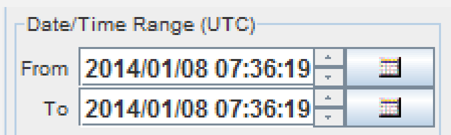
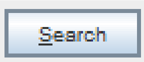
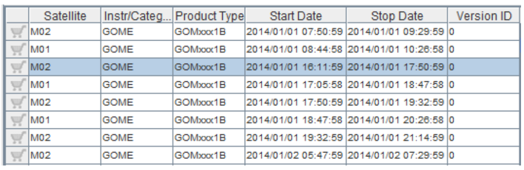
<tr><th>For</th><th>Choose</th><td></td></tr>
<tr><td>O_3
SO_2
NO_2
BrO
Water Vapour and cloud statistics</td><td>Offline total column</td><td rowspan="4">
</td></tr>
<tr><td>O_3 profiles</td><td>Offline Ozone Profile</td></tr>
<tr><td>UV absorbing aerosol index</td><td>Offline Absorbing Aerosol Index</td></tr>
<tr><td>UV daily doses and skin-impact</td><td>Offline UV Daily</td></tr>
<tr><td colspan="2">Specify a date and time range.</td><td>
</td></tr>
<tr><td colspan="2">If necessary, choose a geographical Region of Interest using the map interface.</td><td></td></tr>
<tr><td colspan="2">Choose Search.
For product and naming details, see also http://o3msaf.fmi.fi</td><td>
</td></tr>
</table>

<table>
<tr><th>Step</th><th>You see...</th></tr>
<tr><td>Select an orbit from results returned.</td><td>
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<tr><th></th><th>Satellite</th><th>Instr/Categ...</th><th>Product Type</th><th>Start Date</th><th>Stop Date</th><th>Version ID</th></tr>
<tr><td></td><td>M02</td><td>GOME</td><td>GOMxxx1B</td><td>2014/01/01 07:50:59</td><td>2014/01/01 09:29:59</td><td>0</td></tr>
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<tr><td></td><td>M02</td><td>GOME</td><td>GOMxxx1B</td><td>2014/01/01 19:32:59</td><td>2014/01/01 21:14:59</td><td>0</td></tr>
<tr><td></td><td>M02</td><td>GOME</td><td>GOMxxx1B</td><td>2014/01/02 05:47:59</td><td>2014/01/02 07:29:59</td><td>0</td></tr>
</table></td></tr>
<tr><td>Choose the Check-out icon below the listing.</td><td></td></tr>
</table>

7.3 How can I read GOME-2 level 1b native format?

Go to http://stcorp.nl/beat. Get the latest version of the Basic Envisat Atmospheric Toolbox (BEAT) and the CODA tool boxes. This toolbox can read GOME-2 and IASI level 1 data in C++, Fortran, IDL and MATLAB. For other applications, see the S[&]T company website: http://www.stcorp.nl/

7.4 How can I read GOME-2 level 1b earthshine radiances and solar irradiance values, then construct reflectancies from it?

The complete formula and calculation is contained in the GOME-2 level 1 Product Format Specification Document, Section 3.5. A brief description follows:

To calculate reflectance using formula R = pi/cos(SZA)*I/I_0), you must read the Earthshine radiance data of the MDR class (class number 8) and the MDR-Earthshine (sub-class number 6) from the level 1B files of the eps native data set.

The fields which contain radiance data in photons/(nm sec cm^2 sr) are as follows: Band_1A, Band_1B, Band_2B, Band_3, and Band_4. These fields are compounds of the following three vectors:

- Radiance: RAD
- Random noise error on radiance: ERR_RAD
- Stokes fractions: STOKES_FRACTIONS

The corresponding wavelength calibrations are found in the corresponding *WAVELENGTH_x* fields

Along with the radiances, you must read the daily solar mean reference (SMR) spectra in photons/(nm sec cm^2) and then normalize it by pi/cos(SZA) in order to calculate reflectance. The SMR spectrum is stored as VIADR (Variable Internal Auxiliary Data Record) record called VIADR-SMR. The class number is seven for VIADRs and the sub-class number for VIADR-SMR is 5. Note that the SMR comes with a different wavelength grid and both spectra have to be interpolated on a common grid.

See the sample MATLAB code description in Figure 7.

7.4.2 Sample code to read level-1B data with BEAT

The following description / code sample in MATLAB uses the BEAT toolbox for reading the data. See Section 7.3 for information about the BEAT toolbox.

Note: As of 2017, BEAT is not longer supported by www.stcorp.nl and will be replaced by HARP. The following sample code is based on BEAT versions, which refer to the BEAT-I toolbox. BEAT-II is not supported here. If you do NOT have BEAT-I source code available, use the CODA version of the script in Section 7.5.

```
clear all
% ***************************************************************************
% Filename and filepaths
% ***************************************************************************
%Add the BEAT library path to the matlab path
addpath('/tcc1/home/rlang/Software/BEAT/beat-6.4.0/lib/beat/matlab/')
%Directory path to EPS native GOME-2 file
datapath1B='/tcc1/fbf/tcdras/store/gs1/GOME_xxx_1B_M02/';
%EPS native GOME-2 filename for Metop-A (M02)
filenameBAND1B='GOME_xxx_1B_M02_20131008040559Z_20131008040859Z_N_O_20131008053125Z';
%Read the 'nn's scan line
mdrlist=[1];
pf=beat_open([datapath1B,filenameBAND1B]);

for nn=mdrlist
  %Integration times used for this scan-line per spectral band
  IT{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','INTEGRATION_TIMES');

  %Integration times used this scan
  ITuniq{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','UNIQUE_INT');

  %Number of unique integration times
  N_ITuniq{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','N_UNIQUE_INT');

  %Geo-reference compound (PFS Annex p. 38 and p.7/8 for compound description)
  geo.IT1{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_1');
  geo.IT2{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_2');
  geo.IT3{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_3');

  %The geo reference records are sorted according to integration times used for the current scan
  for l1=[1 2 4 5 6] %For each band of interest do the following
    %Find the index of the IT for the current band in the uniqIT vector
    bi=find(ITuniq{nn}==IT{nn}(l1));
    %Construct the appropriate fieldname for the geo compound ITx
    GEOcompoundfieldname{l1}=['IT',num2str(bi)];
  end

  RADgeo_1A{nn}=geo.(GEOcompoundfieldname{1}){nn}; %Geo record for Band 1
  RADgeo_1B{nn}=geo.(GEOcompoundfieldname{2}){nn}; %Geo record for Band 2
  RADgeo_2B{nn}=geo.(GEOcompoundfieldname{4}){nn}; %Geo record for Band 4
  RADgeo_3{nn}=geo.(GEOcompoundfieldname{5}){nn}; %Geo record for Band 5
  RADgeo_4{nn}=geo.(GEOcompoundfieldname{5}){nn}; %Geo record for Band 6

  %Earthshine Radiance data for all bands. (PFS Annex p. 38)
  RADdata_1A{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_1A'); %Band 1
  RADdata_1B{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_1B'); %Band 2
  %Note Band_2A is outside the valid spectral range!
  RADdata_2B{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_2B'); %Band 4
  RADdata_3{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_3'); %Band 5
```

```
   RADdata_4{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_4'); %Band 6

   %Wavelength for Earthshine data per Band
   WAVdata_1A{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_1A'); %Band 1
   WAVdata_1B{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_1B'); %Band 2
   %Note Band_2A is outside the valid spectral range!
   WAVdata_2B{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_2B'); %Band 4
   WAVdata_3{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_3'); %Band 5
   WAVdata_4{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_4'); %Band 6

   %Valid wavelength regions per channel
   VALID{nn}=beat_fetch(pf,'GIADR_CHANNELS'); % PGS p.21

   %Product confidence record compounds (PFS Annex p. 38 and p.10/11 for compound description)
   pcd_earth{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','PCD_EARTH');
   pcd_basic{nn}=beat_fetch(pf,'MDR',nn,'EARTHSHINE','PCD_BASIC');
end
%Solar Mean Reference spectrum
smr=beat_fetch(pf,'VIADR_SMR');

beat_close(pf);
%Calculate a proper reflectivity for Band 2B within the valid range:
for nn=mdrlist
   Reflectivity2B{nn}=[]; %Init
   cntvalid=1;  %Init

   %Loop over number of measurements per scan.
   for readoutnr=1:length(RADgeo_2B{nn})

      %If we are in the forward scan (SCAN_DIRECTION==1)
      if RADgeo_2B{nn}(readoutnr).SCAN_DIRECTION==1
         %Calculate the reflectivity according to R = pi/cos(SZA)*I/I_O
         %1) pi/cos(SZA)
         Norm=pi/(cos(RADgeo_2B{nn}(readoutnr).SOLAR_ZENITH_ACTUAL(2)*pi/180));
         %2) Select Radiances and wavelength in the valid region of channel 2 using the
        GIADR-Channels information
         WAVvalid=[];radtmp=[];cnt=1;  %Init
         for pix=1:length(WAVdata_2B{nn}) %Loop over individual spectral detector pixels
             %Check if the wavelentgh per detector pixel is inside the valid range of channel 2
             if ( WAVdata_2B{nn}(pix)>=VALID{nn}.START_VALID_WAVELENGTHS(2) &&
             WAVdata_2B{nn}(pix)<=VALID{nn}.END_VALID_WAVELENGTHS(2) )
                 WAVvalid(cnt)=WAVdata_2B{nn}(pix);
                 radtmp(cnt)=RADdata_2B{nn}(readoutnr,pix).RAD;
                 cnt=cnt+1;
             end
         end
         %3) Calculate reflectivity for all forward scan measurements
        Reflectivity2B{nn}(:,cntvalid) =
Norm*radtmp./interp1(smr.LAMBDA_SMR(2,:),smr.SMR(2,:),WAVvalid);

        cntvalid=cntvalid+1;
      end
   end
end
figure(1)
clf
plot(WAVvalid,Reflectivity2B{nn})
```

Figure 9: Description and code sample from MATLAB using the BEAT-I toolbox

7.4.3 Sample code to read level-1B data with CODA

The following description / code sample in MATLAB uses the CODA toolbox (described in Section 7.3) for reading the data. The CODA toolbox is still available and supported by ***www.stcorp.nl*.**

Note: The *EPS-20150324.codadef* file has to be installed in the dedicated CODA installation folder, since it is not part of the CODA installation. This file can be retrieved from the BEAT-II source code.

```
clear all
tic
% *****************************************************************************
%  Filename and filepathes
% *****************************************************************************
addpath('~/coda-2.18.1/lib/coda/matlab') %Add absolute (!) BEAT library path to the matlab path

% NOTE the "EPS-20150324.codadef" file has to be installed in
%      '../../../share/coda/definitions'
% The "EPS-20150324.codadef" file is available from BEAT-II in the
% corresponding "definitions folder" under (e.g.)
%      '~/beat-6.10.2/share/beat/definitions/'
%

datapath1B='~/GOME_xxx_1B_M02/'; %Directory path to EPS native GOME-2 file
filenameBAND1B='GOME_xxx_1B_M02_20170404094754Z_20170404095054Z_N_O_2017040411163
9Z'; %EPS native GOME-2 filename for Metop-A (M02)

mdrlist=[1]; %Read the 'nn's scan line

pf=coda_open([datapath1B,filenameBAND1B]);
for nn=mdrlist

   %Integration times used for this scan-line per spectral band
   IT{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','INTEGRATION_TIMES');

   %Integration times used this scan
   ITuniq{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','UNIQUE_INT');

   %Number of unique integration times
   N_ITuniq{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','N_UNIQUE_INT');

   %Geo-reference compound (PGS p. 38 and p.7/8 for compound description)
   geo.IT1{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_1');
   geo.IT2{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_2');
   geo.IT3{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','GEO_EARTH_ACTUAL_3');

   %The geo reference records are sorted according to integration times used for the current scan
   for I1=[1 2 4 5 6] %For each band of interest do the following
      bi=find(ITuniq{nn}==IT{nn}(I1)); %Find the index of the IT for the current band in the uniqIT
vector
      GEOcompoundfieldname{I1}=['IT',num2str(bi)]; %Construct the appropriate fieldname for the
geo compound ITx
   end

   RADgeo_1A{nn}=geo.(GEOcompoundfieldname{1}){nn}; %Geo record for Band 1
   RADgeo_1B{nn}=geo.(GEOcompoundfieldname{2}){nn}; %Geo record for Band 2
   RADgeo_2B{nn}=geo.(GEOcompoundfieldname{4}){nn}; %Geo record for Band 4
   RADgeo_3{nn}=geo.(GEOcompoundfieldname{5}){nn}; %Geo record for Band 5
```

```
   RADgeo_4{nn}=geo.(GEOcompoundfieldname{5}){nn}; %Geo record for Band 6

   %Earthshine Radiance data for all bands. (PGS p. 38)
   RADdata_1A{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_1A'); %Band 1
   RADdata_1B{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_1B'); %Band 2
   %Note Band_2A is out side the valid spectral range!
   RADdata_2B{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_2B'); %Band 4
   RADdata_3{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_3'); %Band 5
   RADdata_4{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','BAND_4'); %Band 6

   %Wavelength for Earthshine data per Band
   WAVdata_1A{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_1A'); %Band 1
   WAVdata_1B{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_1B'); %Band 2
   %Note Band_2A is out side the valid spectral range!
   WAVdata_2B{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_2B'); %Band 4
   WAVdata_3{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_3'); %Band 5
   WAVdata_4{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','WAVELENGTH_4'); %Band 6

   %Valid wavelength regions per channel
   VALID{nn}=coda_fetch(pf,'GIADR_CHANNELS'); % PGS p.21

   %product confidence record compounds (PGS p. 38 and p.10/11 for compund description)
   pcd_earth{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','PCD_EARTH');
   pcd_basic{nn}=coda_fetch(pf,'MDR',nn,'EARTHSHINE','PCD_BASIC');

end
%Solar Mean Reference spectrum
smr=coda_fetch(pf,'VIADR_SMR');

coda_close(pf);


%Calculate a proper reflectivity for Band 2B within the valid range:
for nn=mdrlist
   Reflectivity2B{nn}=[]; %Init
   cntvalid=1;  %Init
   for readoutnr=1:length(RADgeo_2B{nn}) %Loop over number of measurements per scan.
      if   RADgeo_2B{nn}(readoutnr).SCAN_DIRECTION==1   %If  we  are  in  the  forward  scan
(SCAN_DIRECTION==1)

         %Calculate the reflectivity according to R = pi/cos(SZA)*I/I_O

         %1) pi/cos(SZA)
         Norm=pi/(cos(RADgeo_2B{nn}(readoutnr).SOLAR_ZENITH_ACTUAL(2)*pi/180));

         %2) Select Radiances and wavlength in the valid region of channel 2 using the GIADR-
Channels information
         WAVvalid=[];radtmp=[];cnt=1;  %Init
         for pix=1:length(WAVdata_2B{nn}) %Loop over individual spectral detector pixels
            if          WAVdata_2B{nn}(pix)>=VALID{nn}.START_VALID_WAVELENGTHS(2)          &&
WAVdata_2B{nn}(pix)<=VALID{nn}.END_VALID_WAVELENGTHS(2) %Check if the wavelentgh per
detector pixel is inside the valid range of channel 2
               WAVvalid(cnt)=WAVdata_2B{nn}(pix);
               radtmp(cnt)=RADdata_2B{nn}(readoutnr,pix).RAD;
               cnt=cnt+1;
            end
         end

         %3) Calculate reflectivity for all forward scan measurements
```

```
Reflectivity2B{nn}(:,cntvalid)=Norm*radtmp./interp1(smr.LAMBDA_SMR(2,:),smr.SMR(2,:),WAVvali
d);
         cntvalid=cntvalid+1;
      end
   end
end
figure(1)
clf
plot(WAVvalid,Reflectivity2B{nn})
```

Figure 10: Description and code sample from MATLAB using CODA

7.5 How do I read the corresponding geo-location and angle records for a certain spectral band or region?

The geo-location and viewing geometry records are contained in the GEO_EARTH_ACTUAL_x compounds of the MDR-1b-Earthshine records. The geo-location record is extracted as described in the MATLAB sampling code under Section 7.4.

The *geo_earth_actual* structure is separated with respect to different integration times. One *geo_earth_actual* structure is provided for each unique integration time. They are frequently valid for multiple bands.

Example: If there are three different unique integration times $\boldsymbol{it}_{1a}$, $\boldsymbol{it}_{1b}$ ***it*** $_4$, and $\boldsymbol{it}_{PMD\text{-}P/S}$ present for eight main radiometric bands: main channel band 1a/1b, 2a/2b, 3 and 4, PMD-P and S) only three non-zero sized *geo_earth_actual* structures are provided.

To know which of these *geo_earth_actual* structures holds the correct geo-information for a certain band, you must read the MDR-1B-Earthshine field *integration-times* as well as the field *unique_int*. The former provides one integration time per band, and the latter provides the information that tells you which *geo_earth_actual* structure number ***n*** is linked to which unique integration time. For a certain band with integration time ***it***, the index in the vector of unique integration times for the same ***it*** value is the number ***n*** of the actual geo-earth structure to be read for this radiometric band, *geo_earth_actual* ***n***". The steps are summarized below; for further details, see Section 6.4 of the MATLAB code.

Step	***Action***
1	Find integration time for band *X* (use the INTEGRATION_TIMES field).
2	Find appropriate unique integration time index *n* (use UNIQUE_INT field).
3	Check if the geo-record size is non-zero (use GEO_REC_LENGTH).
4	Use index *n* to access structure geo_earth_actual_n.

7.6 How do I read FRESCO+ cloud information from main channel data (at 80/40 × 40 km resolution)

For FRESCO+ cloud information provided in the GOME-2 level 1B products, you must read the FIT_1 compound field for cloud-top pressure (CTP) and the FIT_2 field for cloud fraction (CFR) in the CLOUD compound of each scan containing Earthshine measurements (MDR-1b-Earthshine with class 8 and sub-class 6; PFS page 37). For the CLOUD compound reference tables please see the GOME-2 Level 1 PFS, Reference Section 0, page 11).

The scaling factor is six (6). This is reported in the SF column of the product PFS. This means that all quantities reported need to be multiplied by 10^{-6} in case this is not automatically done by the reader. For example, BEAT does not do this. At the same time, the FRESCO+ FAIL_FLAG field should be either set to 0 (successful fit) or 4 (numbers of iteration above threshold). You find the meaning of the enumerators in section 4 of the PFS. If the FAIL_FLAG in the CLOUD compound is set to 0 or 4, you will be provided with a meaningful value. Otherwise, the values are not-physical values. In addition, FIT_MODE should be equal to 0, otherwise, for FIT_MODE equals 1, the fields FIT_1 and FIT_2 correspond to the scattering height and the cloud/snow Albedo respectively.

8 APPENDIX

8.1 Reference Documents

Document	*EUMETSAT Document Reference*
GOME-2 Level 1 Product Format Specification	EPS.MIS.SPE.97232
GOME-2 L1 Product Generation Specification	EPS.SYS.SPE.990011
GOME-2 Product Guide	EUM/OPS-EPS/MAN/07/0445

8.2 Acronyms Used in this Document

Acronym	*Meaning*
FRESCO	Fast Retrieval Scheme for Clouds
FPA	Focal Plane Assembly (GOME-2 main channel detectors)
MATLAB	matrix laboratory (Fourth-generation programming language, developed by MathWorks)
MDR	Measurement Data Record
PDU	Product Dissemination Unit (3-minute chunk of EPS data disseminated in near-real time)
PFS	Product Format Specification document
PGS	Product Generation Specification document
PMD	Polarisation Measurement Devices
PPF	Product Processing Facility
VIADR	Variable Internal Auxiliary Data Record