EUMETSAT

Polar Multi-Sensor Aerosol Product: User Guide

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Document Change Record

Issue / Revision	***Date***	***DCN. No***	***Summary of Changes***
V1	24 January 2014		First version-released during pre-operational testing.
V1A	27 March 2014		Information on quality flags added in Section 3.6
V1B	1 April 2014		Background information changed in Section 3.1. Section on specifications for Quality Flags added.
V1C	10 October 2014		Prepared for start of operational dissemination.
V1D	23 December 2014		Update for PMAp 1.0.10.
V2	30 December 2015		Update for PMAp 2.0 Added netcdf4 data model for version 2
V2A	31 July 2018		Update for PMAp 2.1
V2B	28 April 2021		Update for PMAp 2.2.4

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1 INTRODUCTION

This User Guide contains useful information and specifications for users of the Polar Multi-Sensor Aerosol Properties Product (PMAp).

1.1 Purpose of this document

This document provides an overview of the inversion algorithm used for the Polar Multi-sensor Aerosol Product (PMAp) for the METOP satellite. This algorithm uses the Polarization Monitoring Devices (PMD) from the GOME-2 instrument in combination with data from other METOP instruments–in particular the AVHRR (Advanced Very High Resolution Radiometer) and IASI (Infrared Atmospheric Sounding Interferometer) instruments. In addition, this document provides a description of the netcdf4 product format and details the definition of enumerated parameters, like flags and algorithm settings. It also provides some example of the main product output parameters and how to get access to the data and to data monitoring and quality information.

All of the technical documents and a more condensed version of this document (fact-sheet) related to PMAp are available at this web address:

www.eumetsat.int > Data > Technical Documents > GDS Metop > PMAp

1.2 Applicable Documents

The document shall be used as a companion document to the algorithm theoretical baseline description document (ATBD) the user requirement document and, in case applicable, to the EPS native format description both the generic one, concerning all native products form Metop (GPFS), and the specific one to the PMA product (PFS). These documents are listed here. The last two are for those users who want to make use of the EPS-native PMA product available offline from the EO archive at EUMETSAT.

In this document	*Document on EUMETSAT Technical Documents Page*	*EUMETSAT Reference Number*	*Version*
AD1	Polar Multi-Sensor Aerosol Product: User Requirements	EUM/TSS/REQ/13/688040	Version: 2
AD2	Polar Multi-Sensor Aerosol Product: Algorithm Theoretical Basis Document	EUM/TSS/SPE/14/739904	Version: 3F
AD3	Polar Multi-Sensor Aerosol Product: Product Format Specification	EUM/TSS/SPE/14/740198 and EUM/OPS-EPS/DOC/12/0639	Version: 1B
AD4	EPS Generic Product Format Specification	EPS/GGS/SPE/96167	Version: 8A
AD 5	IASI Level 1 Product Guide	EUM/OPS-EPS/MAN/04/0032	Version: 2
AD 6	AVHRR Level 1b Product Guide	EUM/OPS-EPS/MAN/04/0029	Version: 3C

1.3 Acronyms and Definitions

The following table lists definitions for all some common acronyms used in this document. Each acronym will be spelled out on first usage.

Acronym	*Meaning*

AER	Aerosol Product
AOD	Aerosol Optical Depth
ARA	Aerosol Retrieval Algorithm
ATBD	Algorithm Theoretical Basis Document
BT	Brightness Temperature
BTD	Brightness Temperature Difference
CMa	Cloud Mask
CFR	Cloud fraction ratio
COD	Cloud optical depth
IR	Infrared
LUT	Look-Up Table
NIR	Near Infrared
PMAp	Polar Multi-sensor Aerosol Product
RAZI	Relative Azimuth Angle
RTM	Radiative Transfer Model
PMD	Polarization Monitoring Device
SAF	Satellite Application Facility
SZA	Solar Zenith Angle
TIR	Thermal Infrared
TOA	Top Of Atmosphere
VIS	Visible (solar)
VZA	Viewing Zenith Angle

2 OVERVIEW

Aerosols are suspended particulate matter in the atmosphere carried by air masses. Aerosol particles can be solid or liquid and can cover a wide range of particle sizes (0.005 µm – 100 µm, depending on aerosol type). This leads to a large variation in scattering and absorption characteristics.

This algorithm is dedicated to retrieve aerosol optical depth (AOD) at 550 nm and further parameters under daylight conditions, for clear-sky and partially cloudy scenes both over continents and sea.

The retrieval algorithm focuses on the GOME instrument with support of AVHRR and IASI. A detailed description of the algorithm is provided in [AD2]. A complete list of user requirements applicable to PMAp is provided in [AD1].

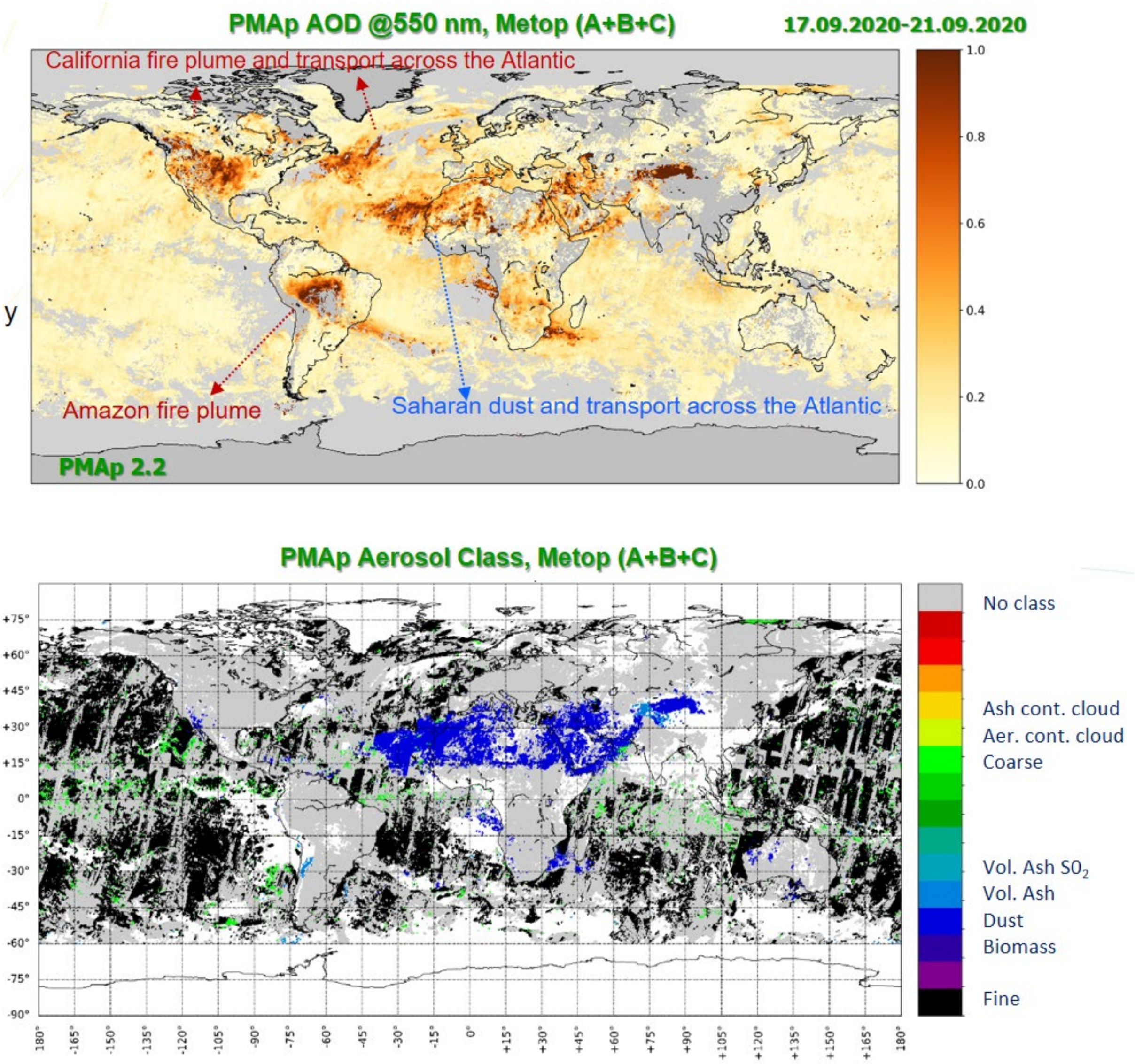

Figure 1: Upper panel: PMAp-derived AOD values from Metop-A, B and C platform using level-1b data from GOME-2 PMD, AVHRR and IASI measurements, bottom panel: corresponding aerosol class.

2.1 PMAp processor and format version history

Version	Start sensing	End sensing	PFS native[1]	Nectdf4[2]
1.0	26 March 2014	*March 2016*	1	1
2.0	*March 2016*	*August 2018*	2	2
2.2	*May 2021*		2	2

[1]PFS document major version number
[2]Product user manual document major version number

2.2 The GOME instrument

GOME-2 is a medium-resolution double UV-VIS 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. The scan mirror directs light into a telescope, designed to match the field of view of the instrument to the dimensions of the entrance slit. This scan mirror can also be directed towards internal calibration sources or towards a diffuser plate for calibration measurements using the sun.

GOME-2 comprises four main optical channels which focus the spectrum onto linear silicon photodiode detector arrays of 1024 pixels each, and two Polarisation Measurement Devices (PMDs) containing the same type of arrays for measurement of linearly polarised intensity in two perpendicular directions.

The PMDs are required because GOME-2 is a polarisation sensitive instrument and therefore the intensity calibration must take account of the polarisation state of the incoming light. This is achieved using information from the PMDs.

For this algorithm the radiances and stokes fractions measured by the PMD are used to retrieve aerosol optical properties. PMDs are available for the following wavelength ranges:

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 1: GOME-2 PMD band definitions (v3.1) as adapted by EUMETSAT based on level 1B spectral calibration of PMD data from PPF version 3.8 from orbit 3372 (14 June 2007). This set of definitions has been uploaded for orbit on 11 March 2008.

A continuous signal degradation is observed in GOME-2 due to the ageing of the instrument. This causes a spectral degradation in reflectance (resulting from the combination of differential radiance and irradiance signal degradations) which could impact the retrieval of L2 products.
A list of contributors to the observed signal degradation of GOME-2 has been identified as thermal instability of the optical bench, internal contamination of the optical path, degradation of the scan mirror with viewing angle dependent response and solar optical path degradation. The signal degradation in time is considered as an essential 'feature' of the instrument performance, it will very likely continue to be so and it is routinely monitored [RD13].
Being spectrally non-homogeneous this degradation could impact significantly aerosol optical properties retrieval especially over land. The degradation effect is actually largest in blue part of the spectrum range mostly used by PMAp for the retrieval of AOD over land. A degradation model – based on a statistical approach - has been developed to compensate for this degradation providing a set of platform dependent correction coefficients allowing correction of GOME-2 radiances separately for the solar and the earthshine data (reference will be added later, under preparation).
This radiometric correction is now in use in PMAp for Metop-A, B and C with the possibility for update of the correction coefficients used in the calculation.

2.3 The GOME instrument operations and monitoring

The GOME-2 flight model 3 (FM3) instrument has been operated on the Metop-A platform number 2 (M02) since 2006. Level 1 data has been available since 2007. GOME-2 flight model number 2 (FM2) has been operated on Metop-B platform number 1 (M01) since 2012. The GOME-2 flight model 1 (FM!) is hosted on Metop-C platform number 3 (M03) and operated since 2018.

Note : The operational processing of PMAp data version 1 started in February 2014. The only available PMAp data dates from February 2014 for both platforms.

This PMAp product is based on the footprint and the swath width settings of the two GOME-2 instruments on the Metop-A and Metop-B platforms and follows the operational 29-day cycle used for both. The instrument operations for both are in Figure 2 and Figure 3. Since 15 July 2013, both GOME-2 instrument on board Metop-A and Metop-B have been operated in tandem with changed swath settings of GOME-2 / Metop-A to a full-width of 960 km, while GOME-2 on Metop-B remains on the full swath width of 1920 km. Accordingly, the ground pixel footprint of GOME-2 PMD devices and the corresponding PMAp scientific products is 5 x 40 km for Metop-A and 10 x 40 km for Metop-B. The multi-sensor PMAp product is produced as GOME-2 product with the spatial resolution of the GOME-2 PMD footprint:

Satellite Platform	***Spatial resolution (GOME-2 PMD spatial resolution)***	***Swath***
Metop-A	5 km × 40 km (since 15th July 2013)	960 km
Metop-B	10 km × 40 km	1920 km
Metop-C	10 km × 40 km	1920 km

If you want to look at daily performance for both instruments, see the dedicated GOME website:

http://gome.eumetsat.int

The 29-day instrument operations plans for Metop-A and Metop-B are in Figure 2 and Figure 3. The 29 days repeat cycle of routine operations and viewing configuration has also changed recently for both instruments. The monthly calibration sequence is issued for both instrument at the same day with two nadir static orbits (no scanning) followed by one orbit during which the PMD data is down-linked at full spectral resolution (256 channels for both PMDs) but at reduced spatial read-out resolution (12 read-outs in forward and 4 read-outs in backward scanning direction at the same ground spatial resolution for PMDs, i.e. with gaps in between the read-outs). The latter configuration is called the monthly PMD RAW read-out configuration.

Note: PMAp data is not available for both nadir static orbits nor is it available for the PMDRAW orbit issued every 29 days in one sequence. PMAp data is available for all other calibration modes as indicated in Figure 2 and Figure 3**.**

GOME-2 / Metop-A is configured to operate once per month at a reduced swath width of 320 km. Both 29 days operational schedules are summarized in Figure 2 and Figure 3 (see also http://gome.eumetsat.int > Timelines).

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)

Figure 2: The 29-day instrument operation cycle for GOME-2 on Metop-A. Different colours and ID tags indicate different instrument operations settings as explained in the document key.

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)

Figure 3: The 29-day instrument operation cycle of GOME-2 on Metop-B. Different colours and ID tags indicate different instrument operations settings as explained in the document key.

For more details on GOME-2 operations and the instrument settings, see the GOME-2 factsheet available here:

http://www.eumetsat.int
> Data > Technical Documents > GDS Metop > GOME-2 >GOME-2 factsheet

2.4 The AVHRR Instrument

The AVHRR/3 is a six-channel scanning radiometer providing three solar channels in the visible/near-infrared region and three thermal infrared channels. The AVHRR/3 has two one-micrometre wide channels between 10.3 and 12.5 micrometres. The instrument utilises a 20.32 cm (8-inch) diameter collecting telescope of the reflective Cassegrain type. Cross-track scanning is accomplished by a continuously rotating mirror directly driven by a motor. The three thermal infrared detectors are cooled to 105 °K by a two-stage passive radiant cooler. A line synchronisation signal from the scanner is sent to the spacecraft MIRP processor which in turn sends data sample pulses back to the AVHRR.

Although AVHRR/3 is a six-channel radiometer, only five channels are transmitted to the ground at any given time. Channels 3a and 3b cannot operate simultaneously. The transition from channel 3a to 3b (and vice-versa) is done by telecomm and reflected in the science data. For Metop-A, channel 3a is operated during the daytime portion of the orbit and channel 3b during the night-time portion.

Reference Note: The text of this section has been adapted from AD 6.

The following table summarises the spectral characteristics of AVHRR/3:

Channel	*Central wavelength (µm)*	*Half power points (µm)*	*Channel noise specifications*	
S/N @ 0.5 % reflectance			NEdT @ 300 °K	
1	0.630	0.580 - 0.680	9:1	-
2	0.865	0.725 - 1.000	9:1	-
3a	1.610	1.580 - 1.640	20:1	-
3b	3.740	3.550 - 3.930	-	<0.12K,0.0031 mW/(m^2 sr cm^{-1})
4	10.800	10.300- 11.300	-	<0.12 K, 0.20 mW/(m^2 sr cm^{-1})
5	12.000	11.500- 12.500	-	<0.12 K, 0.21 mW/(m^2 sr cm^{-1})

Table 2: Spectral Characteristics of AVHRR/3

2.5 The IASI Instrument

The Infrared Atmospheric Sounding Interferometer is composed of a Fourier transform spectrometer (IASI) and an associated Integrated Imaging Subsystem (IIS). The Fourier transform spectrometer provides infrared spectra with high resolution between 645 and 2760 cm^{-1} (3.6 µm to 15.5 µm). The IIS consists of a broad band radiometer with a high spatial resolution. However, the IIS information is only used for co-registration with the Advanced Very High Resolution Radiometer (AVHRR).
The main goal of the IASI mission is to provide atmospheric emission spectra to derive temperature and humidity profiles with high vertical resolution and accuracy. Additionally it is used for the determination of trace gases such as ozone, nitrous oxide, carbon dioxide and methane, as well as land- and sea surface temperature and emissivity and cloud properties.

IASI has 8461 spectral samples, aligned in three bands between 645.0 cm^{-1} and 2760 cm^{-1} (15.5µm and 3.63 µm), with a spectral resolution of 0.5 cm^{-1} (FWMH) after apodisation (L1c spectra). The spectral sampling interval is 0.25 cm^{-1}. The IASI sounder is coupled with the
IIS, which consists of a broad band radiometer measuring between 833 cm^{-1} and 1000 cm^{-1} (12µm and 10µm) with a high spectral resolution.

The following table summarises the spectral characteristics of IASI:

Band	***wavelength (µm)***	***wave number (cm^{-1})***
1	8.26 – 15.50	645.0 – 1210.0
2	5.00 – 8.26	1210.0 – 2000.0
3	3.62 – 5.00	2000.0 – 2760.0

Table 3: Special Characteristics of IASI.

Note: Information in this section is taken from [AD 5].

3 AERSOSOL AND CLOUD RETRIEVAL ALGORITHM

This **P**olar **M**ulti-**S**ensor **A**erosol product **(PMAp)** is dedicated to retrieve aerosol optical depth (AOD) at 550nm and further aerosol parameters. The algorithm uses a multi-sensor approach combining GOME, AVHRR and IASI. The product is delivered as a GOME product with the (spatial) target resolution of the GOME PMDs.

3.1 Motivation for a multi-sensor approach

Aerosols are suspended particulate matter in the atmosphere carried by air masses. Aerosol particles can be solid or liquid and can cover a wide range of particle sizes (0.005 µm – 100 µm, depending on aerosol type). This leads to a large variation in scattering and absorption characteristics.

- In many cases, the presence of aerosols over ocean increases the measured TOA reflectance. This signal is correlated with the aerosol optical depth. There are some situations where this assumption does not hold (absorbing aerosols in the UV, sun glint conditions).
- The reflectance of the ocean surface is very low in the near-infrared (PMDs from 640 nm to 790 nm) which allows the retrieval with a small impact of surface reflectance, except for sun glint conditions.
- The measured reflectance over ocean also depends on wind speed and chlorophyll load. Channels with a very strong sensitivity to chlorophyll are not a good choice for AOD retrievals over ocean.
- Over land, the presence of aerosols can increase the measured TOA reflectance if the surface albedo is low. There is often no significant contrast between aerosol and surface for scenes with high surface albedo. For lots of surfaces types the surface albedo increase with wavelengths. VIS/NIR reflectances for wavelengths higher than 600 nm are usually not usable for aerosol retrievals over land except of specific conditions (e.g. dark pixels caused by dense vegetation).

If only the points listed above would be taken into account, a single-band retrieval would already give the AOD in clear-sky cases–if a band with a low surface reflectance is selected. But the measured signal is not only determined by the AOD of the aerosol. The measured radiance is sensitive to various aerosol optical properties like phase function and single scattering albedo. These parameters are connected to aerosol microphysics characterized–by particle size distribution, particle shape and refractive index. In addition, usually more than one aerosol type is present in an individual scene. A bimodal aerosol distribution is usually assumed. To address this problem, as much independent information as possible from different bands and instruments should be used, but the system is still not fully defined.

We can use several kinds of information to retrieve the aerosol type: The wavelength dependency of the GOME reflectances, the stokes fractions measured by GOME, the UV absorbing index of GOME, the wavelength dependency between VIS channels and the NIR channels of AVHRR, the split window technique of the thermal infrared channels of AVHRR, the SO_2 absorption measured by IASI and the fine structure of the IASI spectra.

However, the combination of different instruments introduces new error sources which can be caused by calibration problems of the instruments (which may change in time), collocation problems (different size and shape of footprints), different windows (wavelength range of the channel, spectral response function) etc. The measured signals of aerosols are usually very small, in particular one order of magnitude smaller compared to clouds. This leads to the problem that the errors introduced by a combination of different instruments can easily be larger than the contrast between aerosol and surface. The combination of different instruments needs to take into account these problems.

3.2 Structure of the Algorithm

The PMAp aerosol algorithm consists of three parts:

- **Step 1**: At the beginning, a pre-classification is applied based on AVHRR, IASI both co-located in this phase to the GOME-2 pixel used as a pivot. This includes the detection of clouds, calculation of cloud correction factors (for subpixel-cloud decontamination), the detection of strong aerosol events (in particular volcanic ash and dust) and a pre-classification of possible aerosol types.
- **Step 2:** A set of AODs at 550nm are retrieved using one GOME-2 PMD band. The selected band depends on the condition (dark ocean, ocean with slight glint effects, dense vegetation, bright surfaces/deserts or continents with moderate albedo). Each of these AODs is retrieved with respect to different aerosol types and microphysical properties. At this point it is not known which selection of aerosol type and microphysical properties is the best representation of the given scene. For clear sky pixels over ocean, the chlorophyll pigment concentration is fitted in addition.
- **Step 3:** In a third step, one of the AODs from step 2 is selected which fits best to the GOME-2 PMD measurements (reflectances and stokes fractions) which are usable for the given scene. The included bands may depend e.g. on the surface albedo, the predicted clear-sky top of atmosphere stokes fraction and the cloud coverage.

Remarks:

- The aerosol cases included to the retrieval within step 2 can be defined by external parameters (usually a subset of the 28 cases over ocean and 6 cases over land. The radiative transfer data for these cases is provided by a Look up table.
- It should be stated that most of the information available in the GOME-2 data is already used by retrieving one AOD-related parameter. Most information is obtained for clear sky pixels over ocean far from sun glint conditions because both clouds and bright surfaces are avoided for all bands. However, a lot of this additional information is needed to fit the chlorophyll pigment concentration. It is impossible to distinguish all cases provided by the LUT, because the remaining independent information is usually equal or lower than the noise of the measured signal. Nevertheless, some information remains dependent on the observation geometry. The algorithms use this information to improve the retrieved AOD. The information on the aerosol

type and additional microphysical parameters available in addition to the AVHRR pre-classification should be considered as quite limited.

3.3 Radiative transfer – Look Up table (LUT)

The look-up-table (LUT) is taken from [RD 5] and [RD 6].

3.3.1 Look up table for the AOD retrieval over sea

The LUT contains reflectances and stokes fractions for ten PMD bands (PMD5 – PMD14, cp. Section. 2.1) and 28 aerosol models. The reflectances are modelled on observation geometry: solar zenith angle (SZA), relative azimuth angle (RAZI), viewing zenith angle (VZA), wind speed and the amount of chlorophyll. The models are characterized by Hasekamp et. al. and dependent on microphysical properties of the aerosols: effective radius and the variance of the effective radius for small and coarse mode respectively, the real and the imaginary part of the refractive index (m_r and m_i) and the fraction of the aerosol coarse mode f_l. This Look-up table is shown in Table 4.

Aerosol model	*Eff. Radius liquid*	*Eff. Radius solid*	*Eff. Variance small*	*Eff. Variance large*	f_l	m_r	m_i	*Aerosol type*
1	0.11	0.84	0.65	0.65	1.53e^{-2}	1.40	-4.0e^{-3}	oceanic
2	0.12	2.19	0.18	0.81	4.36e^{-4}	1.40	-4.0e^{-3}	industrial
3	0.13	2.24	0.50	0.81	4.04e^{-4}	1.40	-4.0e^{-3}	industrial
4	0.21	2.50	0.18	0.81	8.10e^{-4}	1.45	-4.0e^{-3}	industrial
5	0.14	2.15	0.22	0.62	7.00e^{-4}	1.45	-1.2e^{-2}	industrial
6	0.15	2.26	0.22	0.62	6.84e^{-4}	1.45	-1.2e^{-2}	industrial
7	0.18	2.69	0.22	0.62	6.84e^{-4}	1.45	-1.2e^{-2}	industrial
8	0.12	2.43	0.20	0.87	1.70e^{-4}	1.50	-1.0e^{-2}	biomass
9	0.15	2.70	0.20	0.87	2.06e^{-4}	1.50	-1.0e^{-2}	biomass
10	0.20	3.42	0.20	0.87	2.94e^{-4}	1.50	-1.0e^{-2}	biomass
11	0.11	2.52	0.17	0.70	2.07e^{-4}	1.50	-2.0e^{-2}	biomass
12	0.12	2.67	0.17	0.70	2.05e^{-4}	1.50	-2.0e^{-2}	biomass
13	0.14	3.28	0.17	0.70	1.99e^{-4}	1.50	-2.0e^{-2}	biomass
14-18	0.10	1.60	0.32	0.42	4.35e^{-3}	1.53		dust
19-28	Same as model 7-16 with altitude 3-4 km (model 0-18: altitude 1-2 km)							

*Table 4: Radiative transfer LUT classification used in PMAp. [*RD 5*] and [*RD 6*].*

3.3.2 Look up table for the AOD retrieval over land

The LUT for the AOD retrieval over land contain a subset of the cases available over ocean. The aerosol LUT over land contains 5 models (aerosol nr. 1-5). The microphysical properties of these cases are identical to the aerosol models 2,5,8,12,16 over ocean. The reflectances and stokes fractions are stored dependent on solar zenith angle, viewing zenith angle, relative azimuth angle, surface albedo and surface pressure.

3.4 Clouds, volcanic ash, desert dust and aerosol classes

Cloud fraction and the volcanic ash flag are also retrieved by PMAp. The result is used as an input for the AOD algorithm. Then, in addition, the cloud optical depth (COD) is retrieved after the AOD retrieval. The AOD is required as input for the COD retrieval.

3.4.1 Cloud fraction and cloud filter

The first guess cloud fraction is based on the cloud product distributed by the AVHRR Level-1 product [L1AVH]. The AVHRR instrument provides 4 x 2 cloud tests: Four tests for clear-sky and cloudy pixels each. This product defines an AVHRR pixel as cloudy if one of the four tests gives a "true" flag for the "cloudy or fail" tests and a false for the "clear or fail" test. In fact, an AVHRR pixel is considered as cloudy if one test indicates a cloud. Pixels with failures for all the AVHRR cloud tests are treated as cloudy. The geometric cloud fraction is then given by collocation of the AVHRR pixels to GOME-PMD.

These cloud tests are available from AVHRR:

- T11 test (brightness temperature of AVHRR channel 4) to reveal low temperature to medium or high clouds
- T11-T12 test (difference in brightness temperature of channel 4 and 5) to detect cirrus clouds
- Albedo test (reflectances in the two VIS channels to detect bright clouds)
- T4 spatial coherence test over sea to detect cloud edges, thin cirrus and small cumulus over sea

The thresholds for the different tests depend on season, geographical location, satellite viewing angle and availability of distinct data sets (forecast data and/or climatological data).

The cloud fraction is used as a first guess of the cloud situation. PMAp retrieves a cloud free reflectance dependent on the aerosol class. This calculation is based on a combination of the AVHRR cloud flags, additional thresholds and the analysis of spatial homogeneity in the VIS, NIR and TIR. A pixel is classified as cloud free if the average radiance of the AVHRR pixels within the GOME footprint is close to the cloud free reflectance. Details are described in AD2.

Note: The AVHHR cloud fraction distributed within the EUMETSAT GOME Level-1 product is different from the cloud fraction retrieved within the aerosol product PMAp.

3.4.2 Volcanic ash detection

PMAp uses two retrieval algorithms to detect volcanic ash.

The first algorithm selects one AVHRR pixel within the PMD footprint that has the lowest (highest negative) brightness temperature difference T4-T5 using channel 4 and channel 5 of AVHRR. For this AVHRR pixel, the radiances of all AVHRR channels are read. The algorithms apply a set of ten test settings to detect volcanic ash. If one of the test settings is passed, the presence of volcanic ash is assumed by the algorithm, totally independent of the cloud flags for the AVHRR pixel. Each test setting contains a combination of six thresholds which make use of the split-window technique (T4-T5), the wavelength dependency of the signal (600 nm – 1600 nm) and homogeneity tests. All threshold tests must be passed to return a positive ash result. The details of the test settings and sequence are provided in AD2. The wavelength dependency between 600nm – 1600nm cannot be used for pixels over land, because the surface albedo show a strong wavelength dependency as well. The UV absorbing index calaculated from the GOME UV channels is used in combination with brightness temperature difference instead.

The second volcanic ash algorithm is based on IASI measurements and combines the brightness temperature difference technique between 10 and 12 microns with other brightness tempereature differences including channels sensitive to SO_2 absorption.

3.4.3 Desert dust detection

In order to better identify desert dust aerosol over sea and land surfaces, even over bright surfaces, a detection scheme based on the unified approach to aerosol remote sensing in the infrared spectral range developed by Clarisse [RD12].

A desert dust index is calculated making use of one hundred channels selected in the infrared thermal spectra provided by IASI, a previously collected mean clear sky and polluted spectra (i.e. spectra affected by the presence of a selected aerosol type, which is represented in our case by desert dust). The index consists thus in comparing the distance between polluted and clear sky spectra to the distance between measured and clear sky spectra. A threshold is set for the comparison of these distances which has been manually set by looking at a large number of assumed clear and polluted observations.
IASI to GOME-2 collocated data are used for computing the desert dust index.

In case desert dust is detected the whole cloud masking phase is skipped leading straightforward to the retrieval in Step2. In this case the AOD retrieval is forced to the use of the desert dust aerosol type. If no dust aerosol is detected in the currently analyzed GOME-2 pixel, PMAp cloud screening procedure takes place.

3.4.4 Classification of aerosol class

The PMAp algorithm uses a pre-classification of the aerosol class based on AVHRR, the GOME UV index and IASI based tests. The classification is used as an input for the aerosol optical depth retrieval on GOME (step 2 and step 3 of the retrieval, see above) and as a useful output for the users of the PMAp product. Within the least square fit over several aerosol models, only a subset of the data available in the LUT is used. This depends on limitations defined by external parameters (useModel) and subsets predefined for each pre-classification. These aerosol classes are listed in Table 5.

Nr	*Class*	*Characterization*
0	No dust/fine mode (ocean only)	BTD ash tests negative and strong wavelength dependency of the measured signal between 0.6µm and 1.6 µm.
1	coarse mode (ocean only)	Desert dust, ash or coarse mode sea-salt without significant BTD signal but weak wavelength dependency in VIS/NIR

2	Thick biomass burning	Over ocean: UV index indicate UV absorbing aerosol, coarse mode tests negative, TIR dust/ash tests negative. Over land: Stokes fraction and UV index tests positive.
3	Desert dust	IASI dust index
4	Thick dust/volcanic ash	Volcanic ash or thick dust, BTD in TIR indicate dust/ash, weak wavelength dependency in VIS/NIR (ocean) or UV index indicate absorbing aerosol Calculation of the dust index from IASI channel detecting dust presence – over land and ocean.
5	Volcanic ash with SO_2	Volcanic ash, IASI ash test positive (including tests with SO2 TIR channels), confirmation by AVHRR VIS/NIR or GOME-2 UV tests
10	Aerosol contaminated cloud	AVHRR confirms the presence of cloud but IASI indicates dust
11	Ash contaminated cloud	AVHRR confirms the presence of cloud but IASI indicates ash
15	No classification	

Table 5: Aerosol classes, PMAp algorithm

For details on the derivation of the aerosol classes and the selection of the fitted aerosol models, please refer to AD2.

3.5 Cloud optical depth

Cloud optical depth is retrieved using single-band retrieval. In a first step, the "effective albedo" is inverted from TOA reflectance using a RTM-based LUT that depends on satellite observation geometry. The effective albedo is the albedo of a lambertian reflector at the surface, which gives the same TOA reflectance as the surface combined with the aerosol.

This approach is only used for geometric cloud fractions lower than 0.7. For high cloud fractions, the effective albedo is based on external data. Over ocean, a theoretical input radiance is calculated by the aerosol LUT that depends on wind speed and observation geometry and assumes an aerosol-free atmosphere and a default value for chlorophyll contribution. This theoretical reflectance is used as an input for the inversion of the effective ocean albedo. For high cloud fractions over land, surface albedo from MERIS [Popp et al, 2011] is used instead of an effective albedo.

Cloud optical depth is *not* retrieved:

1.) if the surface reflectance is large compared to the cloud reflectance
2.) if problems are expected for a given observation geometry
3.) for areas with persistent seasonal snow/ice coverage. Persistent snow/ice coverage is estimated from the surface albedo climatology [RD 4] using the following criteria:
    a.) if the surface albedo is high for high wavelengths over ocean, sea ice is assumed
    b.) if the surface albedo is high for low and high wavelengths over land and the wavelength dependency of the albedo is significantly smaller than expected for deserts, persistent seasonal snow/ice coverage is assumed.

For details on the derivation of COD we refer to AD2.

The RTM data used for the COD inversion is based on [RD-3].

Acknowledgement: EUMETSAT would like to thank Tim Deutschmann (University of Heidelberg) and T. Wagner (MPI for Chemistry, Mainz) for using McArtim data in our test data stream to model TOA reflectance of a cloud (and pure Rayleigh atmosphere) described by a Henyey-Greenstein phase function dependent on SZA, VZA, RAZI, lambertian surface albedo and COD**.**

The COD product is not yet an official validated product as of 03 April 2014. We plan to replace the database as we intend to use one RTM for all applications within the PMAp product framework in the future.

3.5.1 Cloud top temperature and ash plume brightness temperature

The temperature products are not considered as a final product, and are introduced for validation purposes only. Nevertheless, the cloud product in particular may provide some meaningful data.

The average radiances of the cloudy AVHRR pixels are calculated for AVHRR channel 4 and 5. The brightness temperature calculated from AVHRR channel 4 is given as cloud top temperature if the following criteria are fulfilled:

1. The brightness temperature difference between channel 4 and channel 5 is lower than 100 °K (black body test)

2. The impact of the surface reflectance to the total signal is small in the visual wavelength range. This is assumed to be fulfilled if the surface-related quality flags in the COD retrieval are not raised.

If the aerosol class is set to volcanic ash, the brightness temperature of AVHRR channel 4 for the pixel with the highest negative BTD within the GOME footprint is copied into the Level-2 output (column: volcanic ash plume temperature). This is provided for verification purposes.

3.6 Quality flags and error calculation

3.6.1 Quality flags

PMAp removes bad pixels from the datasets. If the algorithm or the input dataset indicates that the AOD from PMAp is not meaningful, the value is removed from the dataset. There is usually no need to apply a specific filter. If you have a specific requirement in accuracy stricter than settings of PMAp, you may apply a limit in the AOD error and remove values where no error value is available (see below).

The PMAp quality flags indicate MDRs where problems in the input data are found. Flags for GOME, AVHRR and IASI are provided separately and are described in sect. 5.1.9. If there are problems in the GOME or the AVHRR input data, no AOD is retrieved. If there are problems in the IASI input data, AOD is retrieved without using the IASI part of the retrieval. This limits in particular the detection of volcanic ash and may be used as a filter if PMAp data is used to detect volcanic ash or thick dust.

3.6.2 PMAp Retrieval Flags

The PMAp aerosol product delivers a set of up to 16 (currently: 7) retrieval flags. A positive retrieval flag does not mean a general bad quality of the retrieval (bad retrievals are filtered out automatically and bad inputs are accessible by the quality flags). The quality flags are delivered as an integer and need to be converted to the binary system by the user.

Example: quality flag 50 = 0110010.

Bit 0	*Large cloud contribution to the signal (correction factor low) over sea*
The cloudy part is much brighter than the clear-sky part which enhances the error caused by the different shape of the footprints. Usually all unusable pixels are filtered out so that the value is not needed to filter bad AODs. However, for bright clouds we currently assume that the AOD error value could be less accurate due to enhanced collocation issues. This flag could be useful to investigate the AOD error value within the product validation. Note: This flag is not raised over land, because values fulfilling the filter criterion are skipped over land because over land cloud correction and AOD are retrieved at different wavelengths.	

Bit 1:	*Observation geometry with typically enhanced errors in the retrieval over ocean and land*

A set of pixels close to the limits set for observation angles (SZA, VZA, scattering angle). For applications specifically analysing dependencies on observation geometry this flag should be applied together with bit 3 and bit 4. As all these effects are taken into account in the AOD error appropriately and unusable values are thrown away, this flag needs not be applied for stardard-users of AOD or for assimilation.

Bit 2	*Measured signal exceeds upper or lower limits over sea and land*
AOD is set to 0 or 4, but the mathematically retrieved AOD is lower than 0 or higher than 4. Can be important for comparisons to other retrievals, if there is a systematic bias & slope, as the artificial setting to 0/4 has an impact on the correlation. AOD values lower than 0 can appear caused by overestimation of the surface reflectance.	

Bit 3	*Limitation in aerosol type pre-classification over sea, in particular fine/coarse mode classification.*
The expected clear-sky and aerosol free reflectance is large compared to the total signal for a sea salt aerosol with an optical depth of 0.3 The AVHRR pre-classification fine/coarse mode is not available and dust detection is limited for small optical depth as well. This is reflected in the AOD error, the flag should not be used for most application of the AOD. The quality flag may be used if 1.) the aerosol class/type is used 2.) if one is looking specifically for volcanic ash because there is a higher risk that ash is undetected (misclassified as cloud).	

Bit 4	*Signal has an enhanced dependence on the actual wind speed*
Uncertainty in wind speed impacts results, to be used together with OBSGEO. The error of this effect is appropriately reflected within the AOD error column, the interesting point of this flag is a known systematic effect dependent on the viewing geometry.	

Bit 5	*Bad fit*
The fit over all PMD bands (stokes fraction & reflectances) are bad. However, as some of the fitted bands - in particular all stokes fraction - are available for clear-sky pixels only, this flag is useful only if one limits the application to completely clear-sky pixels because the fit over partly cloudy pixels is usually good because of the large overestimation of the system. As two third of the pixels are partly cloudy and the AERONET comparisons also don't show a big decrease of the quality for partly cloudy pixels, it is usually not recommended to use this as a filter. One should also be aware, that the limitation to completely clear sky pixels could maybe systematically remove thick aerosols (e.g. dust aerosols)	

Bit 6	*Thick aerosols*
Pixels are detected as aerosols, but AVHRR sees cloud fraction above limits. Flag regularly raised for thick dust and volcanic ash. Higher risk for AOD overestimation due to undetected cloud. If one is interested in the AOD of an individual measurement, flag	

should not be used. Could be useful for time series or creation of climatologies to exclude single events with large AOD.

3.7 Error calculation

The error is calculated as a standard deviation of a set of AODs obtained using the manipulation of inputs or intermediate results. We retrieve a randomized error, which does not include errors which introduce a constant offset or slope to the result. This statistical approach is selected to provide an error suitable for assimilation purposes.

The inputs and intermediate results manipulated to retrieve a set of AODs for the error calculation are different for the retrieval over ocean and land. In both cases the following parameters are varied:

- the cloud correction factor. The maximum and minimum values are obtained from the scatter between averaged AVHRR reflectances and the GOME-2 reflectance (standard deviation of the linear fit).
- The solar zenith angle, the relative azimuth angle, the viewing zenith angle (the two nearest neighbours are used instead of the values of the actual measurements)
- The aerosol model. All models included to the fit (sect. **Error! Reference source not found.**) are used

Over ocean, variations are included in addition for:

- The wind speed
- The chlorophyll pigment concentration

Over land, variations are included in addition for

- Errors in the surface albedo (the surface albedo is manipulated by a pre-defined offset and/or a pre-defined factor which should be chosen with respect to the expected error in the database.

At least 30 different AODs (under different assumptions) need to be calculated to retrieve an error of the AOD. If this is not possible (e.g. because of retrieval failures), no AOD error is calculated, but the retrieved AOD may not be accurate for these cases.

3.7.1 Cloud Optical Depth Product Quality Flags

The cloud optical depth product provides a set of up to 8 (currently: 4) quality flags.

Bit 0	*Observation geometry with typically enhanced errors in the retrieval*
Same as Bit 1 in the PMAp, but different settings are used here.	

Bit 1	*Albedo retrieval failed, albedo taken from climatology*

The surface albedo is not taken from the individual measurement because the cloud fraction is too large. If this flag is raised, an enhanced error is expected for low COD over bright surfaces because surface information is obtained from climatology (land) or based on modelled reflectances (ocean).

Bit 2	*Large error due to a significant impact of the surface on the retrieval*
The expected or retrieved contribution of the surface to the total signal is large. This leads to lower accuracy of the retrieved COD.	

Bit 3	*Sun glint*
Sun glint test of the GOME Level-1 input data is positive. The sunglint test is calculated from the observation angles and does not take into account individual measurements and wind speed.	

4 THE PMAP PRODUCT

4.1 Product accuracy requirements

The product user requirements in table form for each element of the PMAp product are given in the Product User Requirements document AD1. For reference, we have provided the User Requirement table for the main parameter Aerosol Optical Depth (AOD). For all other parameter accuracy requirements, please refer to AD1.

4.1.1 Aerosol Optical Depth product user requirements

PMAp-01	*Aerosol Optical Depth*	
Type	Product	
Applications and users	Air quality, traffic, climate	
Characteristics and Methods	Multi-wavelength measurements of reflectances and stokes fractions, Radiative transfer modelling	
Comments	Aerosol and cloud products refer to different footprints. This product is retrieved for the aerosol footprint.	
Generation Frequency	MetOp GOME-2 PDU dissemination frequency: every 3 minutes on daylight side of orbit	
Input satellite data	GOME-2, AVHRR, IASI	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
0.2 (abs. threshold) or 30% (rel. Threshold) over sea 0.3 (abs threshold) or 40% (rel. Threshold) over land	10% or 0.05 (cloud free, ocean) 20% or 0.1 (cloudy, ocean and cloud free, land) 30% or 0.15 (cloudy, land)	0.05 or 5% (cloud free ocean) 10% (cloudy ocean and cloud free land) 20% (cloudy, land)
Verification method	comparison to MODIS, GOME-2 UV index, AERONET	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40km	≤ 3 hours

Table 6: PMAp-01 Aerosol Optical Depth product user requirements.

4.2 Data access

4.2.1 Offline data access

PMAp level-2 data, in both EPS native format as well as in netcdf4 format, can be accessed via the EUMETSAT EO portal (http://archive.eumetsat.int). This portal provides full Metop orbits of PMAp data offline. Follow the instructions below to access the data. Instructions for using netcdf4 format are in the following section.

Start from the EUMETSAT EO-Portal: https://eoportal.eumetsat.int/userMgmt

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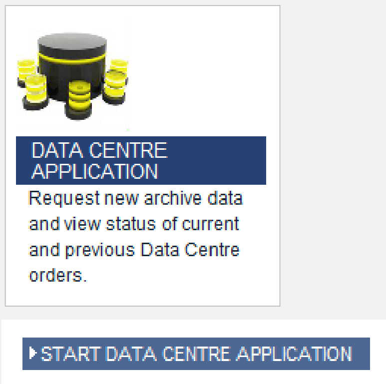
<tr><td>Start the Data Center Application.</td><td>
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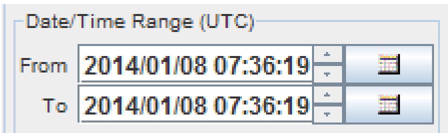
<tr><td>Specify a date and time range.</td><td>
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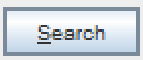
<tr><td>Choose Search.</td><td>
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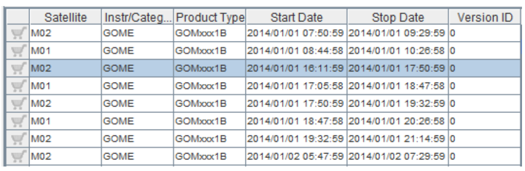
<tr><td>Select an orbit from results returned.</td><td>
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</table></td></tr>
<tr><td>Choose the Check-out icon below the listing when you have finished.</td><td></td></tr>
</table>

The data naming convention for offline archived full-orbit data is

GOME_PMA_02_[satellite_plattform]_[sensing_start]_[sensing_stop]_N_O_[processing_time]

Here is a sample product name:

GOME_PMA_02_M01_20140108114758Z_20140108115058Z_N_O_20140108123307Z

4.2.2 Online near-real time data access

PMAp level-2 data in netcdf4 can be received in near-real time via the EUMETSAT EUMETCast system. Data is bzip2 compressed and only available 3 hours after a specified sensing time, a three-hour lag in presentation.. EUMETCast data is in 3-minute increments called Product Dissemination Units (PDUs). Here is the netcdf4 address:

EUMETCast Channel 1
PID: 510,
Multicast Address: 224.223.222.230

The data naming convention for this data follows the WMO naming convention standard. This convention is specified here:
www.wmo.int > Programmes
> Space
> Data Access and Use
> Formats and Standards.

Sample product name:

W_XX-EUMETSAT- Darmstadt,
SOUNDING+SATELLITE,METOPA+GOME_O_EUMC_20130501233254_33902_eps_o_pmap_l2.nc.bz2

4.3 Data Availability

PMAp level-2 data will be available starting 1 March 2014. It is based on GOME-2 PMD level-1 data availability and GOME-2 instrument operations (see Section 2.3).

Note: PMAp data is not available for the two nadir static orbits nor for the PMDRAW orbit issued every 29 days in one sequence. However, PMAp data is available for all other calibration modes as indicated in Figure 2 and Figure 3 in Section 2.3.

PMAp AOD data is available under day-light condition and over ocean surfaces only. PMAp COD data is available under day-light condition but over all surfaces.

PMAp makes also use of AVHRR and IASI level 1 data. If one or both of the latter level-1 data streams are not available, PMAp data will also not be available.

For details and current instrument and product-status monitoring for both GOME-2 and IASI, see the dedicated GOME web page on the EUMETSAT web site:

http://gome.eumetsat.int

4.4 Main parameter description and enumerated values of netcdf4

4.4.1 Aerosol section

Parameter	***Description***
aerosol_optical depth	Aerosol optical depth at 550nm retrieved for the GOME-2 PMD ground pixel.
error_aerosol_optical_depth	Error of the AOD retrieved
aerosol_class	0: no dust / fine mode (ocean) 1: coarse mode (ocean) 2: Thick Biomass burning 3: Desert dust 4: volcanic ash/thick dust 5: volcanic ash with SO_2 10: Aerosol contaminated cloud 11: Ash contaminated cloud 15: no classification
flag_ash	0: no ash 1: ash 15: no classification
pmap_geometeric_cloud_fraction	Cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval) as used for AOD PMAp for cloud-screening.
chlorophyll_pigment_concentration	Chlorophyll pigment concentration in mg/m^3 (ocean, clear sky)
quality_flags_aerosol	Quality flags of the aerosol product (1=problem found, 0=no problem detected). We provide the following flags: 1. Large cloud contribution to the signal (correction factor low) over sea 2. Observation geometry with typically enhanced errors in the retrieval over sea and land. 3. Measured signal exceeds upper or lower limits over sea and land 4. Limitation in aerosol type preclassification over sea, in particular fine/coarse mode classification. 5. Signal has an enhanced dependence on the actual wind speed 6. Bad fit 7. Thick aerosols
retrieval_algorithm	Retrieval algorithm used by the AOD retrieval 0: ocean, main retrieval for clear-sky pixels (Section. **Error! Reference source not found.**) 1: ocean, simplified retrieval for partly cloudy pixels (Section **Error! Reference source not found.**) 2: ocean, alternate retrieval, AOD from reflectance (Section. **Error! Reference source not found.**)

	3: ocean, alternate retrieval, AOD from stokes fraction (Section. **Error! Reference source not found.**) >3: land, not implemented 4: land, daek surfaces, cloud free 5: land, normal mode, cloud free 6: land, bright surfaces, cloud free 7: land, dark surfaces, partly cloudy 8: land, normal mode, partly cloudy 9: land, bright surfaces, partly cloudy 15: no retrieval
avhrr_geometric_cloud_fraction	Geometric cloud fraction retrieved from AVHRR pixels inside the GOME-2 pixel.
flag_cirrus_cloud	Flag indicating the presence of cirrus clouds based on AVHRR measurements
flag_snow_ice	Flag indicating if a pixel is partly or completely covered by snow or ice. The flag is derived from the AVHRR cloud product.
split_window_btd	Average brightness temperature of AVHRR channel 4 and AVHRR channel 5
wind_speed	10m wind speed from ECMWF forecast [m/s]
land_fraction	Fractional coverage of land surfaces within the PMD
reflectance_inhomogeneity	Variance of the reflectances in AVHRR channel 1 within the GOME-2 PMD pixel.

4.4.2 Cloud section

Parameter	*Description*
cloud_optical_depth	Cloud optical depth retrieved for the GOME-2 PMD ground pixel.
cloud_top_temperature	Cloud top temperature from AVHRR channel 4
quality_flag_cloud	Quality flags of the cloud product (1=problem found, 0=no problem detected). We provide the following flags: 0: low accuracy for the actual observation geometry 1: albedo retrieval failed, surface albedo taken from climatology 2: large error due to significant impact of the surface on the result 3: sun glint
avhrr_geometric_cloud_fraction	Geometric cloud fraction retrieved from AVHRR pixels inside the GOME-2 footprint.
land_fraction	Fractional coverage of land surfaces within the PMD
reflectance_inhomogeneity	Variance of the radiances in AVHRR channel 1 within the GOME-2 PMD pixel.

5 THE NETCDF4 DATA MODEL

NetCDF (Network Common Data Form) is a machine-independent, self-describing, binary data format standard for exchanging scientific data; it is supported by many high-level languages using dedicated APIs. The project homepage is hosted by the Unidata program at the University Corporation for Atmospheric Research (UCAR). All details on how to access netcdf version 4-type data are provided, including links to viewers and readers as well as API libraries.

In the following pages, we provide the list of parameters following the specific netcdf 4 data model used for PMAp version 2 (Section) and 1 (Section). The PMAp netcdf *long-name* parameter naming is following the Climate and Forecast (CF) governance standard applied by EUMETSAT to support product development in the frame of the GSICS Data Management Working Group [RD 2]. The following tables provide the CF long-name along with the unit, where applicable, as well as the parameter type and a description of the variable available in the *netcdf* attribute.

Note: The data model described here applies only to the products provided in netcdf4. All PMAp products which are provided via EUMETCAST in NRT are provided in netcdf4 exclusively. When ordering PMAp data offline from the EUMETSAT EO portal (http://archive.eumetsat.int; see Section 4.2.1) data can be ordered in both native EPS and netcdf4 data. For information on the native product format see Section 6.

Format
netcdf4

5.1 PMAp version 2

5.1.1 Groups: /root (Global Attributes)

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description or value*
conventions	scalar_dim	nc_string	conventions		set to e.g."CF-1.6"
metadata_conventions	scalar_dim	nc_string	metadata_conventions		set to e.g. ". "Unidata Dataset Discovery v1.0"
product_name	scalar_dim	nc_string	product_name		Product name, e.g. **"GOME_PMA_02_M01_20140108114758Z_20140108115058Z_N_O_20140108123307Z"**
title	scalar_dim	nc_string	title_summerizing_product_content		"Polar Multi-Sensor Aerosol Product"
summery	scalar_dim	nc_string	summery_description_product_content		"Aerosol optical properties retrieved from METOP using a multi-instrument approach combining GOME, AVHRR/3 and IASI. The product provides AOD both over land and ocean and contains limited information on aerosol type, in particular volcanic ash classification"
keywords	scalar_dim	nc_string	keywords		Aerosol, AOD, aerosol optical depth, optical thickness, volcanic ash, aerosol type, cloud fraction, METOP, GOME, AVHRR, IASI
organization	scalar_dim	nc_string	organization		"EUMETSAT"
spacecraft	scalar_dim	nc_uint	space_craft_ID		

CF name	Dimension	Data-type	CF long name	Unit	Description or value
product_level	scalar_dim	nc_string	product_processing_level		Level "2" = geolocated geophysical variables
disposition mode	scalar_dim	nc_string	disposition_mode		Identification of the type of processing ("Test" | "Commissioning" | "Operational") Test = test data used Commissioning = produced during commissioning Operational = routine operations
sensing_start_time_utc	scalar_dim	nc_string	sensing_start_time_utc		UTC time of start of sensing data formatted in CF date and time format The format is: **(YYYY)"-"(MM)"-"(DD)" "(hh)":"(mm)":"(ss)"."(ddd)**
sensing_end_time_utc	scalar_dim	nc_string	sensing_end_time_utc		UTC time of end of sensing data formatted in CF date and time format The format is: **(YYYY)"-"(MM)"-"(DD)" "(hh)":"(mm)":"(ss)"."(ddd)**
orbit_start	scalar_dim	nc_uint	orbit_number_at_sensing_start		
orbit_end	scalar_dim	nc_uint	orbit_number_at_sensing_end		

5.1.2 Groups: /root/Status/InstrumentStatus

CF name	Dimension	Data-type	CF long name	Unit	Description
flag_input_instruments	number_of_measurements	nc_ubyte	flag_indicating_input_instruments_used_for_processing		Input instruments flag (bit 0: for GOME-2, bit 1: for AVHRR, bit 2: for IASI). This flag shows, if an

					instrument is actually used. Might also serve as a collocation indicator. Corresponds to each processed pixel.
flag_iasi	scalar_dim	nc_ubyte	flag_indicating_activation_of_IASI_retrieval		IASI activation flag (0: IASI input is not used; 1: otherwise). This flag shows the configurational setting, i.e. if IASI processing was enabled from configuration flags for the given retrieval.

5.1.3 Groups: /root/ [Dimensions]

Dimensions	*Length*	*Description*
scalar_dim	1	Scalar
number_of_measurements	variable	Total number of measurements in file: number of scans times the number of read-outs per scan.
number_of_footprint_corners	4	Number of ground foot-print corners
number_of_scans	variable	Number of GOME-2 scans from level-1 input
number_of_channels	6	Number of GOME-2 channels

number_of_sensor_bands	10	Number of GOME-2 sensor bands
number_of_PMD_bands	15	Number of GOME-2 PMD bands per individual PMD channel
arbitrary_size	variable	Variable
number_of_ECMWF_parameters	10	Number of ECMWF parameters
number_of_ECMWF_ATIA	2	Number of ATIA files used for ECMWF inputs
number_of_pmd_kinds	2	PMD-p and PMD-s

5.1.4 Groups: /root/Data/MeasurementData/GeoData

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
year	scalar_dim	nc_short	year_for_reference_readout		
month	scalar_dim	nc_short	month_for_reference_readout		
day	scalar_dim	nc_short	day_for_reference_readout		
hour	scalar_dim	nc_short	hour_for_reference_readout		
minute	scalar_dim	nc_short	Minute_for_reference_readout		
aerosol_sensor_readout_start_time	number_of_measurements	nc_uint64	aerosol_sensor_readout_start_time	1	UTC time associated with the read-out of the detector pixel of the reference PMD band used for aerosol properties retrieval.
cloud_sensor_readout_starttime	number_of_measurements	nc_uint64	cloud_sensor_readout_starttime	1	UTC time associated with the read-out of the detector pixel of the reference PMD

					band used for cloud properties retrieval.
aerosol_corner_latitude	number_of_measurements, number_of_footprint_corners	nc_double	aerosol_corner_latitude	degrees	Geodetic latitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
aerosol_corner_longitude	number_of_measurements, number_of_footprint_corners	nc_double	aerosol_corner_longitude	degrees	Geocentric longitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
aerosol_center_latitude	number_of_measurements	nc_double	aerosol_center_latitude	degrees	Geodetic latitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
aerosol_center_longitude	number_of_measurements	nc_double	aerosol_center_longitude	degrees	Geodetic longitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used

					for aerosol properties retrieval.
cloud_corner_latitude	number_of_measurements, number_of_footprint_corners	nc_double	cloud_corner_latitude	degrees	Geodetic latitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
cloud_corner_longitude	number_of_measurements, number_of_footprint_corners	nc_double	cloud_corner_longitude	degrees	Geocentric longitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
cloud_center_latitude	number_of_measurements	nc_double	cloud_center_latitude	degrees	Geodetic latitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
cloud_center_longitude	number_of_measurements	nc_double	cloud_center_longitude	degrees	Geodetic longitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used

					for cloud properties retrieval.
solar_zenith_angle	number_of_measurements	nc_double	solar_zenith_angle	degrees	Solar zenith angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
solar_azimuth_angle	number_of_measurements	nc_double	solar_azimuth_angle	degrees	azimuth angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
platform_zenith_angle	number_of_measurements	nc_double	satellite_platform_zenith_angle	degrees	Satellite zenith angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
platform_azimuth_angle	number_of_measurements	nc_double	satellite_platform_azimuth_angle	degrees	Satellite azimuth angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
sensor_scan_angle	number_of_measurements	nc_double	sensor_scan_angle_scanner_angle	degrees	GOME-2 scanner viewing angle corresponding to PMD pixel
single_scattering_angle	number_of_measurements	nc_double	single_scattering_angle	degrees	Scattering angle corresponding to PMD pixel centre, point F
relative_sensor_azimuth_angle	Number_of_measurements	nc_double	relative_sensor_azimuth_angle	degrees	Relative azimuth angle corresponding to PMD pixel centre, point F

5.1.5 Groups: Data/MeasurementData/ObservationData/Aerosol

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
aerosol_optical_depth	number_of_measurements	nc_double	AOD_aerosol_optical_depth_at_550nm	1	Aerosol Optical Depth (AOD) at 550nm
error_aerosol_optical_depth	number_of_measurements	nc_double	error_aerosol_optical_depth	1	Error on Aerosol Optical Depth (AOD).
aerosol_class	number_of_measurements	nc_ubyte	aerosol_class_number	1	Value indicating aerosol classification/type.
flag_ash	number_of_measurements	nc_ubyte	flag_volcanic_ash_high_probability	1	Flag indicating presence of ash
pmap_geometric_cloud_fraction	number_of_measurements	nc_double	pmap_geometric_cloud_fraction_as_assumed_for_aerosol_retrievals	1	Cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval) as used for AOD PMAp for cloud-screening.
chlorophyll_pigment_concentration	number_of_measurements	nc_double	chlorophyll_pigment_concentration_over_sea_if_retrieved	$mg\ m^{-3}$	Chlorophyll load
aerosol_retrieval flag	number_of_measurements	nc_ushort	aerosol_flags_indicating_detailed_situation_of_retrieval		Product retrieval flags

5.1.6 Groups: Data/MeasurementData/ObservationData/Aerosol/Auxiliary

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
retrieval_algorithm	number_of_measurements	nc_ubyte	retrieval_algorithm_type_number	1	Number indicating the retrieval algorithm used (specifies also whether the retrieval is on Land or Sea).

CF name	Dimension	Data-type	CF long name	Unit	Description
avhrr_geometric_cloud_fraction	number_of_measurements	nc_double	avhrr_geometric_cloud_fraction	1	AVHRR cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval). Combination othe 4 cloud tests used in AVHRR Level-1 product. This cloud fraction differs from the one used in PMAp.
flag_cirrus_cloud	number_of_measurements	nc_ubyte	flag_single_layer_cloud_cirrus_type	1	Flag indicating the presence of cirrus clouds based on AVHRR measurements. The flag is set if the cirrus tests are true and other cloud tests are false.
flag_snow_ice	number_of_measurements	nc_ubyte	flag_snow_ice	1	Flag indicating if a pixel is partly or completely covered by snow or ice. The flag is derived from the AVHRR cloud product.
split_window_BTD	number_of_measurements	nc_double	AVHRR_split_window_brightness_temperature_difference_between_channel_4_and_channel_5	K	AVHRR T4-T5 averaged difference co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
wind_speed	number_of_measurements	nc_double	wind_speed_at_10_meter_from_ecmwf_forecast	m $^{s-1}$	10 meter wind speed, taken from ECMWF forecast databases.
land_fraction	number_of_measurements	nc_double	land_area_fraction	1	Land fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).

CF name	Dimension	Data-type	CF long name	Unit	Description
reflectance_inhomogeneity	number_of_measurements	nc_double	reflectance_inhomogeneity_avhrr_channel_1_variance_within_PMD	1	Reflectance inhomogeneity: Variance of the AVHRR CH1 reflectance within the AOD footprint (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).

5.1.7 Data/MeasurementData/ObservationData/Cloud

CF name	Dimension	Data-type	CF long name	Unit	Description
cloud_optical_depth	number_of_measurements	nc_double	COD_cloud_optical_depth	1	Cloud optical depth (COD) retrieved at 630nm (demonstrational)
cloud_top_temperature	number_of_measurements	nc_int	CTT_cloud_top_temperature	K	Brightness temperature from AVHRR CH4 for cloudy pixels (demonstrational)
cloud_retrieval_flags	number of measurements	nc_int	cloud_retrieval_flags_indicating_retrieval_mode_or_situation		Cloud_retrieval_flags

5.1.8 Group: Data/MeasurementData/ObservationData/Cloud/Auxiliary

CF name	Dimension	Data-type	CF long name	Unit	Description
avhrr_geometric_cloud_fraction	number_of_measurements	nc_double	avhrr_geometric_cloud_fraction	1	AVHRR cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the

CF name	Dimension	Data-type	CF long name	Unit	Description
					reference PMD band used for aerosol properties retrieval).
land_fraction	number_of_measurements	nc_double	land_area_fraction	1	Land fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for cloud properties retrieval).
reflectance_inhomogeneity	number_of_measurements	nc_double	reflectance_inhomogeneity_avhrr_channel_1_variance_within_PMD	1	Reflectance inhomogeneity: Variance of AVHRR CH1 reflectance (corners corrected according to the time shift of the reference PMD band used for cloud properties retrieval).

5.1.9 Group: Data/MeasurementData/ObservationData/QualityInformation

CF name	Dimension	Data-type	CF long name	Unit	Description
flag_degraded_instrument	number_of_scans	nc_ubyte	flag_degraded_processing		Quality of MDR has been degraded from nominal due to a instrument degradation
flag_degraded_processing	number_of_scans	nc_ubyte	flag_degraded_processing		Quality of MDR has been degraded from nominal due to a processing degradation
flag_gome_degraded_instrument	number_of_scans	nc_ubyte	flag_gome_degraded_instrument	1	Quality of MDR has been degraded from nominal (flag is true) due to an instrument

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
					degradation (flag is taken from input GOME L1B product)
flag_gome_degraded_processing	number_of_scans	nc_ubyte	flag_gome_degraded_processing	1	Quality of MDR has been degraded from nominal due to a processing degradation (flag depends both from input GOME L1B product and L2 processing.
flag_avhrr_degraded_instrument	number_of_scans	nc_ubyte	flag_avhrr_degraded_instrument	1	Quality of MDR has been degraded from nominal (flag is true) due to an instrument degradation (flag is taken from input AVHRR L1B product)
flag_avhrr_degraded_processing	number_of_scans	nc_ubyte	flag_avhrr_degraded_processing	1	Quality of MDR has been degraded from nominal due to a processing degradation (flag depends both from input AVHRR L1B product and L2 processing.
flag_iasi_degraded_instrument	number_of_scans	nc_ubyte	flag_iasi_degraded_instrument	1	Quality of MDR has been degraded from nominal (flag is true) due to an instrument degradation (flag is taken from input IASI L1C product)
flag_iasi_degraded_processing	number_of_scans	nc_ubyte	flag_iasi_degraded_processing	1	Quality of MDR has been degraded from nominal due to a processing degradation (flag depends both from input IASI L1C product and L2 processing.

5.1.10 Group:Data/MeasurementData/ObservationData/QualityInformation/GOME2

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
channel_number	number_of_channels	nc_short	channel_number	1	Channel number
start_valid_pixel	number_of_channels	nc_short	start_valid_pixel	1	Approximate start pixel of the valid data in the specified channel
end_valid_pixel	number_of_channels	nc_short	end_valid_pixel	1	Approximate end pixel of the valid data in the specified channel
start_valid_wavelengths	number_of_channels	nc_double	start_valid_wavelengths	1	Start wavelength of the valid data in the specified channel
end_valid_wavelengths	number_of_channels	nc_double	end_valid_wavelengths	1	End wavelength of the valid data in the specified channel
channel_readout_sequence	scalar_dim	nc_ubyte	channel_readout_sequence	1	Sequence of detector pixel read-out. 0: from short to long wavelength; 1: from long to short wavelength
band_channel_number	number_of_sensor_bands	nc_short	band_channel_number	1	Channel number per band
band_number	number_of_sensor_bands	nc_short	band_number	1	Band number
start_pixel	number_of_sensor_bands	nc_short	start_pixel	1	Start pixel of the band in the specified channel
number_of_pixels	number_of_sensor_bands	nc_short	number_of_pixels	1	Number of pixels in the specified band
start_wavelength	number_of_sensor_bands	nc_double	start_wavelength	nm	Start wavelength
end_wavelength	number_of_sensor_bands	nc_double	end_wavelength	nm	End wavelength

pmd_band_start_pixel	number_of_PMD_bands, number_of_pmd_kinds	nc_ushort	pmd_band_start_pixel	1	PMD band start pixel, 15 bands, PMD-p first
pmd_band_pixel_length	number_of_PMD_bands, number_of_pmd_kinds	nc_ushort	pmd_band_pixel_length	1	PMD band length in pixels, 15 bands, PMD-p first
wavelength_pmd	number_of_PMD_bands, number_of_pmd_kinds	nc_double	wavelength_pmd	nm	PMD band wavelength (nm), 15 bands, PMD-p first

5.1.11 Group: Data/MeasurementData/ObservationData/QualityInformation/AVHRR

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
flag_read_BT_conversion_cefficients_from_product	scalar_dim	nc_ubyte	flag_read_brighness_temperature_conversion_coefficients_from_avhrr_level_1		if the flag is raised, all coefficients used for radiance to brightness temperature conversion (8 following parameters) are read from the AVHRR Level-1 product. Otherwise a specific set of values are defined for PMAp.
ch4_sensor_band_central_wavelength	scalar_dim	nc_double	CH4_sensor_band_central_wavelength	cm-1	AVHRR ch.4 central wavenumber (Gamma) for radiance to brightness temperature conversion
ch4_bt_offset_correction	scalar_dim	nc_double	CH4_BT_offset_correction	K	AVHRR ch.4 offset correction coefficient 1 (A) for brightness temperature linear correction
ch4_bt_slope_correction	scalar_dim	nc_double	CH4_BT_slope_correction	K/K	AVHRR ch.4 slope correction coefficient 2 (B) for brightness temperature linear correction

ch4_sensor_band_central_wavelength	scalar_dim	nc_double	CH5_sensor_band_central_wavelength	cm-1	AVHRR ch.5 central wavenumber (Gamma) for radiance to brightness temperature conversion
ch5_bt_offset_correction	scalar_dim	nc_double	CH5_BT_offset_correction	K	AVHRR ch.5 offset correction coefficient 1 (A) for brightness temperature linear correction
ch5_bt_slope_correction	scalar_dim	nc_double	CH5_BT_slope_correction	K/K	AVHRR ch.5 slope correction coefficient 2 (B) for brightness temperature linear correction
constant_c1	scalar_dim	nc_double	constant_C1_for_BT_conversion	mW/(m^2 sr cm^{-4})	Constant C1 for radiance to brightness temperature conversion (C1 = 2hc2, h: Planks constant, c: speed of light)
constant_c2	scalar_dim	nc_double	constant_C2_for_BT_conversion	K/cm-1	Constant C2 for radiance to brightness temperature conversion (C2=hc/k, h: Planks constant, k: Boltzmanns constant)
calibration_slope_ch4	scalar_dim	nc_double	calibration_slope_ch4_for_correction_of_avhrr_radiance_by_IASI		linear calibration correction for AVHRR channel 4, slope of fit function.
calibration_offset_ch4	scalar_dim	nc_double	calibration_offset_ch4_for_correction_of_avhrr_radiance_by_IASI		linear calibration correction for AVHRR channel 4, offset of fit function.
calibration_slope_ch5	scalar_dim	nc_double	calibration_slope_ch5_for_correction_of_avhrr_radiance_by_IASI		linear calibration correction for AVHRR channel 5, slope of fit function.
calibration_offset_ch5	scalar_dim	nc_double	calibration_offset_ch5_for_correction_of_avhrr_radiance_by_IASI		linear calibration correction for AVHRR channel 5, offset of fit function.

5.1.12 Group: Data/MeasurementData/ObservationData/QualityInformation/ECMWF

CF name	*Dimension*	*Data-type*	*CF long name*	*Unit*	*Description*
ecmwf_parameters	number_of_ECMWF_parameters	nc_uint	ecmwf_parameter		ECMWF parameters used for the processing (165, 166) [ref.: ECMWF GRIB API Parameters,

					http://www.ecmwf.int/publications/manuals/d/gribapi/param]
spatial_resolution	number_of_ECMWF_ATIA	nc_uint	spatial_resolution		Spatial resolution of forecast model (number of elements in longitude and latitude) (720, 361)
process_ID	number_of_ECMWF_ATIA	nc_uint	generating_process_id		GRIB Generating process identification number of the two ATIA files used for the processing [ref.: ECMWF Atmospheric model identification numbers, http://www.ecmwf.int/products/data/technical/model_id/]
start_time	number_of_ECMWF_ATIA	nc_uint64	start_time		Start time (from the product file name) of the two ATIA files used for the processing
forcast_base_time	number_of_ECMWF_ATIA	nc_uint64	forecast_base_time		Forecast base time of the two ATIA files used for the processing
forecast_start_time	number_of_ECMWF_ATIA	nc_uint64	forecast_start_time		Forecast start time of the two ATIA files used for the processing
stop time	number_of_ECMWF_ATIA	nc_uint64	stop_time		Stop time (from the product file name) of the two ATIA files used for the processing

5.2 PMAp version 1

Dimensions	*Length*	*Description*
Dim1	1	Scalar
Dim2	variable	Total number of measurements in file: number of scans times the number of read-outs per scan.
Dim3	4	Number of ground foot-print corners
Dim4	variable	Number of GOME-2 scans from level-1 input
Dim5	6	Number of GOME-2 channels
Dim6	10	Number of GOME-2 sensor bands
Dim7	15	Number of GOME-2 PMD bands per individual PMD channel
Dim8	variable	Variable

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
StartOrbit	Dim1	int32			
EndOrbit	Dim1	int32			
SpaceCraftID	Dim1	int16			
Year	Dim1	int16			
Month	Dim1	int16			
Day	Dim1	int16			
Hour	Dim1	int16			
Minute	Dim1	int16			

Variables	Dimension	Data-type	CF name	Unit	Description
DegradedInstMd	Dim4	int16	Degraded instrument flag	1	Quality of MDR has been degraded from nominal (flag is true) due to an instrument degradation (flag is taken from input GOME L1B product)
DegradedProcMdr	Dim4	int16	Degraded processing flag	1	Quality of MDR has been degraded from nominal due to a processing degradation (flag depends both from input GOME L1B product and L2 processing.
SunZenithAngle	Dim2	double	solar zenith angle	degrees	Solar zenith angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
SunAzimutAngle	Dim2	double	solar_azimuth_angle	degrees	azimuth angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
SatZenithAngle	Dim2	double	platform_zenith_angle	degrees	Satellite zenith angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
SatAzimutAngle	Dim2	double	platform_azimuth_angle	degrees	Satellite azimuth angle at height h0 corresponding to PMD pixel centre, point F (topocentric CS)
ScannerAngle	Dim2	double	sensor_scan_angle	degrees	GOME-2 scanner viewing angle corresponding to PMD pixel
ScattAngle	Dim2	double	single_scattering_angle	degrees	Scattering angle corresponding to PMD pixel centre, point F
RelativeAzimutAngle	Dim2	double	relative_sensor_azimuth_angle	degrees	Relative azimuth angle corresponding to PMD pixel centre, point F
InputInstr	Dim2	int16	Instrumentation used	1	Input instruments flag (bit 0: for GOME-2, bit 1: for AVHRR, bit 2: for IASI)

Table 7: Netcdf4 format parameters

Note: Dim 1 is omitted for vectors 1-d.

5.2.1 Groups: /GOME2/

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
ChannelNumber	Dim5	int16			
StartValidPixel	Dim5	uint16			
EndValidPixel	Dim5	uint16			
StartValidWavelengths	Dim5	double			
EndValidWavelengths	Dim5	double			
ChannelReadoutSeq	Dim1	int16			
BandChannelNumber	Dim6	int16			
BandNumber	Dim6	int16			
StartPixel	Dim6	uint16			
NumberOfPixel	Dim6	uint16			
StartLambda	Dim6	double			
EndLambda	Dim6	double			
StartPixelPmd	Dim8,Dim7	uint16			
LengthPixelPmd	Dim8,Dim7	uint16			
WavelengthPmd	Dim8,Dim7	double			

Table 8: Groups GOME2/ Parameters

Note: Dim 1 is omitted for vectors 1-d.

5.2.2 Groups: /AVHRR/

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
Ch4CentralWavenumber	Dim1	double	CH4_sensor_band_central_wavelength	cm-1	AVHRR ch.4 central wavenumber (Gamma) for radiance to brightness temperature conversion
Ch4Constant1	Dim1	double		K	AVHRR ch.4 offset correction coefficient 1 (A) for brightness temperature linear correction
Ch4Constant2Slope	Dim1	double		K/K	AVHRR ch.4 slope correction coefficient 2 (B) for brightness temperature linear correction
Ch5CentralWavenumber	Dim1	double	CH5_sensor_band_central_wavelength	cm-1	AVHRR ch.5 central wavenumber (Gamma) for radiance to brightness temperature conversion
Ch5Constant1	Dim1	double		K	AVHRR ch.5 offset correction coefficient 1 (A) for brightness temperature linear correction
Ch5Constant2Slope	Dim1	double		K/K	AVHRR ch.5 offset correction coefficient 1 (A) for brightness temperature linear correction
ConstantC1	Dim1	double		mW/(m^2 sr cm^{-4})	Constant C1 for radiance to brightness temperature conversion (C1 = 2hc2, h: Planks constant, c: speed of light)
ConstantC2	Dim1	double		K/cm-1	Constant C2 for radiance to brightness temperature conversion (C2=hc/k, h: Planks constant, k: Boltzmanns constant)

Table 9: Groups AVHRR/ Parameters

Note: Dim1 is omitted for vectors 1-d.

5.2.3 Group: /IASI/

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
IASIFlag	Dim1	int16			IASI activation flag (0: IASI input is not used; 1: otherwise)

Table 10: Groups IASI / Parameters

Note Dim 1 is omitted for vectors 1-d.

5.2.4 Group: /ECMWF/

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*

Note: Dim1 is omitted for vectors 1-d.

5.2.5 Group: /AOP/

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
CORNER_LAT	Dim3, Dim2	double	corner latitude	degrees	Geodetic latitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
CORNER_LON	Dim3, Dim2	double	corner longitude	degrees	Geocentric longitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
CENTRE_LAT	Dim3, Dim2	double	center latitude	degrees	Geodetic latitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
CENTRE_LON	Dim2	double	center longitude	degrees	Geodetic longitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for aerosol properties retrieval.
RetreivalAlgorithm	Dim2	int16	retrieval algorithm type	1	Flag indicating the retrieval algorithm used (specifies also whether the retrieval is on Land or Sea).
AOD	Dim2	double	aerosol optical depth	1	Aerosol Optical Depth (AOD).
Error AOD	Dim2	double	error_aerosol_optical_depth	1	Error on Aerosol Optical Depth (AOD).
Aerosol Class	Dim2	int16	aerosol class	1	Flag indicating aerosol classification/type.
AVHRRCloudFracAOP	Dim2	double	AVHRR geometric cloud fraction	1	AVHRR cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
AVHRRAvT4T5Diff	Dim2	double	AVHRR channel 4/5 to a radiance difference	K	AVHRR T4-T5 averaged difference co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
ChlorophyllLoad	Dim2	double	chlorophyll load	mg m^{-3}	Chlorophyll load

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
WindSpeed	Dim2	double	wind speed	m $^{s-1}$	10 meter wind speed, taken from ECMWF forecast databases.
AshTemp	Dim2	double	aerosol plume temperature	K	Temperature of ash plumes.
LandFracAOP	Dim2	double	land fraction	1	Land fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
RadInhomogenityAOP	Dim2	double	avhrr geometric radiance inhomogeneity	1	Radiance inhomogeneity (land processing) (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
QualityFlagAOP	Dim2	int16	quality flags		Product quality flags related to aerosol optical properties retrieval.
ReadoutStarttimeAOP	Dim2	uint64	sensor readout start time		UTC time associated with the read-out of the detector pixel of the reference PMD band used for aerosol properties retrieval.

Table 11: Group AOP / Parameters

Note: Dim1 is omitted for vectors 1-d.

5.2.6 Group: /COP/

Variables	Dimension	Data-type	CF name	Unit	Description
CORNER_LAT	Dim3,Dim2	double	corner latitude	degrees	Geodetic latitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
CORNER_LON	Dim3,Dim2	double	corner longitude	degrees	Geocentric longitude at ground of PMD pixel, points ABCD (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
CENTRE_LAT	Dim3,Dim2	double	center latitude	degrees	Geodetic latitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
CENTRE_LON	Dim2	double	center longitude	degrees	Geodetic longitude at ground of PMD pixel centre, point F (earth-fixed CS), corrected according to the time shift of the reference PMD band used for cloud properties retrieval.
AVHRRCloudFracCOP	Dim2	double	avhrr geometric cloud fraction	1	AVHRR cloud fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for aerosol properties retrieval).
CloudOpticalDepth	Dim2	double	cloud_optical_depth	1	Cloud optical depth (COD).
CloudTopTemp	Dim2	int16	air_temperature_at_cloud_top	K	Cloud-top temperature.
LandFracCOP	Dim2	double	land area fraction	1	Land fraction co-located with PMD pixel (corners corrected according to the time shift of the reference PMD band used for cloud properties retrieval).

Variables	*Dimension*	*Data-type*	*CF name*	*Unit*	*Description*
RadInhomogenityCOP	Dim2	double	avhrr geometric radiance inhomogeneity	1	Radiance inhomogeneity (land processing) (corners corrected according to the time shift of the reference PMD band used for cloud properties retrieval).
QualityFlagCOP	Dim2	int16	quality_flags		Product quality flags related to cloud optical properties retrieval.
ReadoutStarttimeCOP	Dim2	uint64	sensor readout starttime		UTC time associated with the read-out of the detector pixel of the reference PMD band used for cloud properties retrieval.

Table 12: Group COP Parameters

Note: Dim1 is omitted for vectors 1-d.

6 EPS NATIVE PRODUCT FORMAT

The description of PMAp products provided as full orbits offline in EPS Native format provided in AD3 is available from the technical documentation section on the EUMETSAT Technical Documents web page:

www.eumetsat.int > Data > Technical Documents > GDS Metop > PMAp

Note: The EPS Native product contains additional information on instrument status and instrument data mode flagging, which is not relevant for the scientific or operational use of PMAp level-2 data.

7 REFERENCE DOCUMENTS

In this document	*Document Reference Title*	*Reference Number*
RD 1	GOME-2 Level 1 Product Generation Specification	EPS/SVS/SPE/990011
RD 2	EUMETSAT Data Centre Proposed CF Standard Names and Units	EUM/TSS/SPE/14/739904
RD 3	T. Deutschmann, S. Beirle, U. Frieß, M. Grzegorski, C. Kern, L. Kritten, U. Platt, C. Prados-Román, T. Wagner, B. Werner, K. Pfeilsticker, *The Monte Carlo atmospheric radiative transfer model McArtim: Introduction and validation of Jacobians and 3D features*,	Journal of Quantitative Spectroscopy & Radiative Transfer - J QUANT SPECTROSC RADIAT , vol. 112, no. 6, pp. 1119-1137, doi: 10.1016/ j.jqsrt.2010.12.009, 2011.
RD 4	C. Popp, P. Wang, D. Brunner, P. Stammes, Y. Zhou and M. Grzegorski, *MERIS albedo climatology for FRESCO+ O_2 A-band cloud retrieval*, Atmos. Meas. Tech., 4, 463-483, doi:10.5194/amt-4-463-2011, 2011.	Atmos. Meas. Tech., 4, 463-483, doi:10.5194/amt-4-463-2011, 2011.
RD 5	O.P. Hasekamp and J. Landgraf, *Retrieval of aerosol properties over the ocean from multispectral single-viewing-angle measurements of intensity and polarization*: *Retrieval approach, information content and sensitivity study*,	Jour. Geophys. Res., Vol 110, doi:10.1029/2005JD006212, 2005.
RD 6	O. Hasekamp, O. Tuinder and P. Stammes, *Final report of the O3M-SAF activity: Aerosol retrieval from GOME-2: Improving computational efficiency and first application,* 2008.	
RD 7	A.A. Kokhanovsky, G. de Leeuw, Satellite Aerosol Remote Sensing Over Land	Springer, 2009
RD 8	R.C. Levy, L.A. Remer, D. Tanre, S. Mattoo and Y.J. Kaufman, *Algorithm for remote sensing of tropospheric aerosol over dark targets from MODIS*: Collections 005 and 051, ATBD, Product ID: MOD/MYD04, Revision 2, 02/2009	Collections 005 and 051, ATBD, Product ID: MOD/MYD04, Revision 2
RD 9	C. Popp, P. Wang, D. Brunner, P. Stammes, Y. Zhou and M. Grzegorski, *MERIS albedo climatology for FRESCO+ O2 A-band cloud retrieval*,	Atmos. Meas. Tech., 4, 463-483, doi:10.5194/amt-4-463-2011, 2011
RD 10	L.A. Remer, D. Tanre, Y.L. Kaufman, C. Ichoku, S. Mattoo, R. Levy, D.A. Chu, B. Holben, O. Dobovik, A. Smirnov, J.V. Martins, R.R. Li and Z. Ahmad, *The MODIS Aerosol Algorithm, Products and Validation,*	Geophys. Res. Let., vol. 29, 12, doi:10.1029/2001GL013204, 2002
RD 11	T. X.-P. Zhao, I. Laszlo, P. Minnis and L. Remer, *Comparison and analysis of two aerosol retrievals over the ocean in the Terra/Clouds and the Earths Radiant Energy System–Moderate Resolution Imaging Spectroradiometer single scanner footprint data*:	
RD12	Clarisse, L., P.F. Coheur, F. Prata, J. Hadji-Lazaro, D. Hurtmans and C. Clerbaux (2013), A unified approach to infrared aerosol remote sensing and type specification, Atmosph. Chem Phys., 13, 2195-2221, doi:10.5194/acp-13-2195-2013	

RD13	Munro, R., Lang, R., Klaes, D., Poli, G., Retscher, C., Lindstrot, R., Huckle, R., Lacan, A., Grzegorski, M., Holdak, A., Kokhanovsky, A., Livschitz, J., and Eisinger, M.: The GOME-2 instrument on the Metop series of satellites: instrument design, calibration, and level 1 data processing – an overview, Atmos. Meas. Tech., 9, 1279–1301, https://doi.org/10.5194/amt-9-1279-2016, 2016.	doi:10.5194/amt-9-1279-2016