EUMETSAT

Polar Multi-Sensor Aerosol Product: User Requirements

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1 INTRODUCTION

1.1 Purpose and Scope

The purpose of this document is to define the user requirements for a polar multi-sensor aerosol product (PMAp) making use of level 1 data from three Metop sensors: AVHRR, IASI, and GOME-2.

This EUMETSAT level-2 product development is part of the EUMETSAT EPS Product Development Plan.

1.2 Basic Concept

The approach followed for this product is laid out in detail in [AD 1]. Here, only the basic approach as detailed in section 5 of [AD 1] is summarized. The initial version of PMAp will be restricted to the retrieval of Aerosol Optical Depth (AOD) over ocean. There are several good reasons for this initial restriction:

- The AOD is the optical property most accurate and consistently retrieved by various instruments. This is a good starting point for GOME-2, because most quantities sensitive to aerosols are also sensitive to AOD.
- The retrieval over land is significantly more complicated than the retrieval over ocean, because the results are very sensitive to surface reflectance. A successful retrieval over ocean should be available first and form a solid basis for a later extension to pixels over land.
- Cloud screening over ocean is simpler compared to pixels over land.

However, the processor framework will be fully compatible with subsequent developments extending to AOD over land and providing additional aerosol optical properties (see below). The first base algorithm has been recommended to be developed with respect to the following criteria:

- The LUT of the GOME-2 PMD algorithm developed by the O3MSAF consortium and made available to EUMETSAT CAF shall be used as a starting point.
- The inversion scheme applied to the PMD data will include ideas similar to those used in retrieval from POLDER, the SYNAER algorithm for ATSR/GOME, and prototypes developed in the O3SAF [AD1]. A set of AOD values is retrieved assuming different aerosol type models. GOME-2 PMD band radiance values and Stokes vectors are then used to select the correct aerosol model (and the corresponding AOD).
- The GOME-2 PMD bands used for inversion are selected dependent on the strength of the surface reflectance compared to the aerosol signal, the quality of the calibration and the sensitivity of signal to wind speed and chlorophyll. Information on surface wind-speed is derived from the ECMWF forecasts provided in the CGS.
- The crucial cloud screening of signals is carried out by a highly efficient and accurate collocation of AVHRR cloud flags and radiances, providing a geometric cloud fraction and homogeneity index for any GOME-2 PMD ground pixel with a pixel size of 40 x 10 km^2.

- A simplified AOD algorithm is implemented for partly cloudy pixels with a geometric cloud fraction below a pre-defined threshold. The algorithm uses PMD channels with similar wavelengths as the AVHRR/3 channels. The AVHRR/3 instrument is used to calculate a cloud correction factor for the PMD reflectance.
- A volcanic ash flag is implemented based on brightness temperature differences of AVHRR/3 channels 4 and 5.
- Geometric cloud fraction and cloud optical depth are provided as additional parameters.

After successful validation of the base algorithm it shall be extended to retrieval over land pixels and further aerosol optical properties in the following way:

- IASI level 1C broad band information shall be used to identify the present of coarse mode particles, especially desert dust and volcanic ash.
- GOME-2 main science channels (MSC) and UV data both from PMD and MSC may be used to provide additional coarse mode information in a similar fashion than already used for aerosol absorbing index product available from the O3MSAF
- Over land, the channels used for AOD may be selected dependent on the surface type (the signal of the aerosol should be as large as possible compared to the surface). A new wavelength-dependent surface albedo database is required, because the current database used in the ground segment does not fulfil the requirements in accuracy and spatial resolution. Cloud screening over land may be different to the correction scheme over ocean.

The extension of the product to land surfaces will however be subject to a subsequent ECR.

1.3 Targeted User Community

The targeted user community of AOD, both over land and ocean, comprises the VAAC's, MACC and other GMES service providers. The latter shall use the data for operational purposes, such as air quality monitoring and forecast, volcanic ash monitoring and forecast, and in the future to support the provision of quantitative precipitation forecasts. Data may also be used operationally in the future to support aerosol correction schemes, for example, for surface-properties retrievals from imagers like AVHRR or from the Sentinels.

AOD information will also be used by the scientific and climate community for model validation and process studies, in particular for cloud processing, atmospheric chemistry and health studies.

1.4 Open Issues and Assumptions

There are no open issues.

1.5 Applicable Documents

No.	*Document Title*	*EUMETSAT Reference*
AD 1	Review of aerosol optical properties retrieval algorithms for Metop	EUM/MET/TEN/09/0797, v2
AD 2	EPS Product Development Plan	EUM/STG/60/12/DOC/19
AD 3	Polar Multi-Sensor Aerosol Product: ATBD	EUM/TSS/SPE/14/39904
AD 4	AVHRR Level 1b Product Guide	EUM/OPS-EPS/MAN/04/0029
AD 5	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*	EPS.MIS.SPE.97228

1.6 Reference Documents

No.	*Document Title*
RD 1	Product User Manual for the ARS aerosol products, O3MSAF/KNMI/PUM/002
RD 2	Sensitivity Study: Retrieval of aerosol optical properties using GOME PMD, EUM/MET/TEN/12/0136
RD 3	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 4	Polar Multi-Sensor Aerosol Properties Product Processor Requirements, EUM/RSP/REQ/13/688467

2 INTRODUCTION TO REQUIREMENTS

The user requirements are separated in four parts

- Product configuration and application
- Product output and format
- Product availability and timeliness
- Product quality and validation

All functional, system and interface requirements necessary to implement these requirements are detailed in a separate requirements document [RD4].

3 REQUIREMENTS

3.1 Product configuration and application

REQ 3.1-1

The product shall be provided for input data acquired by the following instruments and platforms:

1. Metop-A / GOME (full resolution, including PMD)
2. Metop-B / GOME (full resolution, including PMD)
3. Metop-C / GOME (full resolution, including PMD)
4. Metop-A / AVHRR/3 (full resolution)
5. Metop-B / AVHRR/3 (full resolution)
6. Metop-C / AVHRR/3 (full resolution)
7. Metop-A / IASI (full resolution)
8. Metop-B / IASI (full resolution)
9. Metop-C / IASI (full resolution)

REQ 3.1-2

The product shall make use of wind speed data from ECMWF forecast, a wavelength dependent surface albedo dataset, surface elevation data and LUT data for cloud and aerosol optical properties. An update of these data sets shall be foreseen.

REQ 3.1-3

The product generation function shall be configurable.

REQ 3.1-4

The product generation function shall be able to apply the retrievals on a pixel basis.

REQ 3.1-5

The product generation function shall be able to co-locate AVHRR/3 data to each GOME pixel. This includes radiances for all AVHRR/3 channels, AVHRR/3 cloud products and AVHRR/3 surface type information. The collocated data shall contain the following AVHRR/3 information:

- Average radiance for all channels
- Separate cloud fraction for all AVHRR cloud tests
- Radiance of all AVHRR channels for the AVHRR pixel with the lowest T4-T5 temperature difference of AVHRR
- Median AVHRR radiance (all channels) for the clear sky part of the GOME pixel (if applicable)
- Average AVHRR radiance (all channels) for the cloudy part of the GOME pixel

REQ 3.1-6
The product generation function shall be able to co-locate IASI data to each GOME pixel. The collocation function should be configurable.

REQ 3.1-7
For reprocessing the processor shall make use of already pre-existing co-location information from the various sensors, in case they have been processed before by the same co-location algorithm version. If pre-existing information is unavailable, the processor calculates new co-location information and stores them for the actual and future retrievals.

3.2 Product Output and Format

REQ 3.2-1
The output of the processor shall be provided in netCDF 4, as well as in Encapsulated Post Script (EPS) native format depending on the type of dissemination.

REQ 3.2-2
The product shall contain quantities of aerosol optical depth over ocean.

REQ 3.2-3
The product shall be expandable to contain quantities of aerosol optical depth over land.

REQ 3.2-4
The product shall be expandable to contain information on the aerosol type both over ocean and land.

REQ 3.2-5
The product shall be expandable to contain information on volcanic ash plume height.

REQ 3.2-6
The product shall contain geo-referencing and satellite pointing parameters.

REQ 3.2-7
The product shall contain information on wind speed obtained from ECMWF forecast.

REQ 3.2-8
The product shall contain quantities of geometric cloud fraction and cloud optical depth over ocean and land.

REQ 3.2-9
The product shall be expandable to contain quantities of cloud heights.

REQ 3.2-10
The product shall contain radiance inhomogeneity information within the GOME pixel.

REQ 3.2-11
The product shall contain quantities of the fractional coverage of land surfaces.

REQ 3.2-12
The product shall contain quantities of the average brightness temperature difference of AVHRR/3 channel 4 and 5.

REQ 3.2-13
The product shall contain an aerosol and a cloud section. Both parts refer to different geolocations. The geolocation should refer to the channel with the biggest impact on the retrieval.

REQ 3.2-14
The aerosol section shall provide at least: aerosol optical depth, aerosol type, cloud fraction, T4-T5 difference, radiance Inhomogeneity and land fraction.

REQ 3.2-15
The cloud section shall provide at least: cloud optical depth, cloud fraction, radiance inhomogeneity and land fraction.

REQ 3.2-16
The product generation function shall provide two sets of quality indicators for the aerosol and cloud retrieval respectively. The flags indicate occasions of lower accuracy for the results or problems within the retrieval.

3.3 Product Availability and Timeliness

REQ 3.3-1
The product shall be made available in near-real time via EUMETCast in netCDF version 4.

REQ 3.3-4
The product shall be available offline from the EUMETSAT data centre in Encapsulated Post Script native format.

3.4 Product Quality and Validation

REQ 3.4-1
The product quality shall fulfil the accuracy defined in the PMAp product tables. See also Section 4.

REQ 3.4-2
PMAp products shall be validated for representative subsets of the areas where they have been generated.

REQ 3.4-3
EUMETSAT shall provide validation datasets to allow validation activities of external users, teams or organizations.

REQ 3.4-4
EUMETSAT shall compare aerosol optical depth, cloud optical depth and cloud fraction of selected orbits to datasets from other satellites and/or ground based measurements to verify the results.

4 PMAP PRODUCT TABLES

In this section, each product component in the PMAp main product is described in a separate product table. Along with a basic description of the product, specifications for dissemination, accuracy, and timeliness are also listed per individual product.

Number	*Name*
PMAp-01	Aerosol Optical Depth
PMAp-02	Aerosol Class
PMAp-03	Geometric cloud fraction (aerosol footprint)
PMAp-04	Average T4-T5 difference
PMAp-05	Wind speed
PMAp-06	Land fraction AOP (Aerosol Footprint)
PMAp-07	Radiance Inhomogeneity (Aerosol footprint)
PMAp-08	Cloud Optical Depth
PMAp-09	Geometric Cloud Fraction (Cloud Footprint)
PMAp-10	Land Fraction AOP (Cloud Footprint)
PMAp-11	Radiance Inhomogeneity (Cloud Footprint)

4.1 Aerosol Optical Depth Product Table

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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
0.1 (abs. threshold), 30% (rel. Threshold)	10% (cloud free) 20% (cloudy)	5% (cloud free) 10% (cloudy)
Verification method	comparison to MODIS, GOME-2 UV index	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40km	≤ 3 hours

Table 1: Aerosol Optical Depth Product Table

4.2 PMAp-02 Aerosol Class

PMAp-02	*Aerosol Class*	
Type	Product	
Applications and users	Air quality, traffic, climate	
Characteristics and Methods	Classification dependent on AVHRR cloud flags and thresholds in AVHRR reflectances	
Comments	Aerosol and cloud products refer to different footprints. This parameter 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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
n/a	n/a	n/a
Verification method	Case studies	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 2: Aerosol Class

4.3 PMAp-03 Geometric Cloud Fraction (Aerosol Footprint)

PMAp-03	*Geometric cloud fraction (aerosol footprint)*	
Type	Product	
Applications and users	Air quality, traffic, climate	
Characteristics and Methods	Composite of different AVHRR cloud flags to a unique cloud fraction product for GOME-2.	
Comments	Accuracy does not include errors in AVHRR retrieval Aerosol and cloud products refer to different footprint. 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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	Comparison to other satellites and GOME-2 effective cloud fraction	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 3: Geometric Cloud Fraction (Aerosol Footprint)

4.4 PMAp-04 Average T4-T5 Difference

PMAp-04	*Average T4-T5 difference*	
Type	Product	
Applications and users	applications with NRT ash detection: air traffic	
Characteristics and Methods	Average brightness temperature difference for AVHRR channel 4 and AVHRR channel 5	
Comments	Volcanic ash information in case of wrong aerosol retrieval Accuracy does not include errors in AVHRR retrieval. 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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	case study analysis	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 4: Average T4-T5 Difference

4.5 PMAp-05 Wind Speed

PMAp-05	*Wind speed*	
Type	Product	
Applications and users	Input for aerosol retrieval, interpretation of the data	
Characteristics and Methods	ECMWF wind speed forecast	
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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
n/a	n/a	n/a
Verification method	n/a	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 5: Wind Speed

4.6 PMAp-06 Land fraction AOP (Aerosol Footprint)

PMAp-06	*Land fraction AOP (aerosol footprint)*	
Type	Product	
Applications and users	Input for aerosol retrieval, interpretation of the data	
Characteristics and Methods	Fractional part of the pixel covered by land based on AVHRR Level 1B data	
Comments	Accuracy does not include errors in AVHRR retrieval. 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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	n/a	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 6: Land fraction AOP (Aerosol Footprint)

4.7 PMAp-07 Radiance Inhomogeneity (Aerosol footprint)

PMAp-07	*Radiance Inhomogeneity (aerosol footprint)*	
Type	Product	
Applications and users	interpretation of the aerosol data	
Characteristics and Methods	Variance of AVHRR channel 1 reflectances within the PMD footprint	
Comments	Accuracy does not include errors in AVHRR retrieval. 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	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	n/a	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 7: Radiance Inhomogeneity (Aerosol footprint)

4.8 PMAp-08 Cloud Optical Depth

PMAp-08	*Cloud optical depth*	
Type	Product	
Applications and users	Air quality, climate	
Characteristics and Methods	Cloud optical depth retrieval based on AVHRR heterogeneity information and one-channel GOME-2 inversion	
Comments	Aerosol and cloud products refer to different footprints. This product is retrieved for the cloud footprint.	
Generation Frequency	MetOp GOME-2 PDU dissemination frequency: every 3 minutes on daylight side of orbit	
Input satellite data	GOME-2, AVHRR	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
8%	5%	3%
Verification method	Satellite-cross intercomparison, comparison to GOME-2 effective cloud fraction	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40km	≤ 3 hours

Table 8: Cloud Optical Depth

4.9 PMAp-09 Geometric Cloud Fraction (Cloud Footprint)

PMAp-09	*Geometric cloud fraction (cloud footprint)*	
Type	Product	
Applications and users	Air quality, traffic, climate	
Characteristics and Methods	Composite of different AVHRR cloud flags to a unique cloud fraction product for GOME-2	
Comments	Accuracy does not include errors in AVHRR retrieval Aerosol and cloud products refer to different footprint. This product is retrieved for the cloud footprint.	
Generation Frequency	MetOp GOME-2 PDU dissemination frequency: every 3 minutes on daylight side of orbit	
Input satellite data	GOME-2, AVHRR	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	Comparison to other satellites and GOME-2 effective cloud fraction	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 9: Geometric Cloud Fraction (Cloud Footprint)

4.10 PMAp-10 Land Fraction AOP (Cloud Footprint)

PMAp-10	*Land fraction AOP (cloud footprint)*	
Type	Product	
Applications and users	Input for aerosol retrieval, interpretation of the data	
Characteristics and Methods	Fractional part of the pixel covered by land based on AVHRR Level 1B data	
Comments	Accuracy does not include errors in AVHRR retrieval. Aerosol and cloud products refer to different footprints. This product is retrieved for the cloud footprint.	
Generation Frequency	MetOp GOME-2 PDU dissemination frequency: every 3 minutes on daylight side of orbit	
Input satellite data	GOME-2, AVHRR	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	n/a	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 10: Land Fraction AOP (Cloud Footprint)

4.11 PMAp-11 Radiance Inhomogeneity (Cloud Footprint)

PMAp-11	*Radiance Inhomogeneity (cloud footprint)*	
Type	Product	
Applications and users	interpretation of the aerosol data	
Characteristics and Methods	Variance of AVHRR channel 1 reflectances within the PMD footprint	
Comments	Accuracy does not include errors in AVHRR retrieval. Aerosol and cloud products refer to different footprints. This product is retrieved for the cloud footprint.	
Generation Frequency	MetOp GOME-2 PDU dissemination frequency: every 3 minutes on daylight side of orbit	
Input satellite data	GOME-2, AVHRR	
Dissemination		
Format	Means	Type
EPS native	EUMETCast, Internet	NRT, offline
Accuracy		
Threshold	Target	Optimal
5%	2%	1%
Verification method	n/a	
Coverage, Resolution and Timeliness		
Spatial coverage	Spatial resolution	Timeliness
Global	GOME-2 PMD resolution 10 km x 40 km	≤ 3 hours

Table 11: Radiance Inhomogeneity (Cloud Footprint)

APPENDIX A REQUIREMENT TRACE

This document defines the high level requirements of the product.

APPENDIX B ACRONYMS AND TERMS USED IN THIS DOCUMENT

Acronym	*Meaning*
AER	Aerosol Product
AAI	Aerosol Absorbing Index
AOD	Aerosol Optical Depth
ARA	Aerosol Retrieval Algorithm
ATBD	Algorithm Theoretical Basis Document
CGS	Core Ground Segment
CMa	Cloud Mask
CFR	Cloud fraction ratio
COD	Cloud optical depth
FPA	GOME-2 Focal Plane Assembly (GOME-2 main channel detector assembly)
GMES	Global Monitoring for Environment and Security
IR	Infrared
LUT	Look-Up Table
NRT	Near-Real Time
NIR	Near Infrared
RAZI	Relative Azimuth Angle
PMD	GOME-2 Polarization Monitoring Devices
PMAp	Polar Multi-sensor Aerosol properties product
SAF	Satellite Application Facility
SCIAMACHY	GOME-2 type UV/Vis/IR instrument on ENVISAT
SZA	Solar Zenith Angle
TOA	Top Of Atmosphere
VAAC	Volcanic Ash Advisory Centres
VIS	Visible (solar)
VZA	Viewing Zenith Angle