EUMETSAT **O3M SAF**

The EUMETSAT
Network of
Satellite
Application
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O3M SAF
Ozone and Atmospheric
Chemistry Monitoring

PRODUCT USER MANUAL

Near real-time and offline Aerosol products

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DOCUMENT STATUS SHEET

Issue	Date	Modified Items / Reason for Change
0.1	2007-05-14	First draft version
0.2	2007-06-06	Revised after ORR-A2 comments
0.3	2007-10-03	Revised after ORR-A2 review
0.4	2007-10-30	Revised after ORR-A2 CloseOut
0.5	2008-05-23	Product format update: AscNodeCrossingLon is now a string. Azimuth angles added. Disposition mode updated. Updates indicated in Green New Product Format Version: 3.4
0.6	2008-09-30	Revisions for ORR-B
0.7	2009-04-15	Granularity: explicitly mentioned the pixel size as 40x80 km
0.8	2009-09-01	SoftwareVersion 1.20 / OPF v3.6: IndexInScan represents index of the ground pixel in the scan movement, not index in the MDR. First spectral pixel in a L1b file (usually a backscan) is skipped due to incomplete information on UTC date/time. PCloudAdjustedToPSurface flag added to the QualityInputFlags record. Update indicated in DarkYellow.
1.0	2010-04-29	Software v1.23, output format v3.7; Added information on the UNS, Sunglint flag and scattering angle. Updated some logos; Added to Geolocation group: ScatteringAngle. Added to DataGroup: SunGlintFlag. Product updates indicated in light blue.
1.01	2010-05-12	Replaced 'scan' with 'ground pixel' in SunGlintFlag section
1.02	2010-05-25	Added intro O3MSAF, added text about ftp access.
1.1	2013-05-28	Added optional UncorrectedResidue and CorrectionFactor fields to store residues not corrected for instrument degradation and the degradation correction factor. Added ScanDirection and ScannerAngle. Valid for Software version 1.28, OPF version 4.0
1.2 & 1.3a/b	2013-06-16 & 2013-06-28	Changes based on ORR RIDs. Editorial: 4.1. Output format changes: Quality Flags..
1.4	2013-09-02	Adaptation of the recommendation for Sun Glint Flag use: Also use value 1 (land)
1.41	2014-04-23	Section 4.5: User Access: NRT data via EUMETCast.
1.42	2014-04-24	Section on Sunglint flags updated. Description of the scattering angle updated.

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1. INTRODUCTION

1.1 Purpose

This document is the Product User Manual for the Offline ARS aerosol products retrieved within the context of the Satellite Application Facility on Ozone and Atmospheric Chemistry Monitoring (O3MSAF). This document first presents some background information and a brief description of the retrieval algorithm. Next, the document provides information and guidance to the user on how to use and interpret the data product.

1.2 Scope

This PUM provides information on the ARS product of the O3MSAF. This document does not go into much detail with regards to the algorithm or design of the software; please refer to the Algorithm Theoretical Basis Document (ATBD) for that information.

As the instruments go through phases of degradation, the product quality is affected. This Product User Manual does not describe the product quality beyond an initial demonstration of the output. For monitoring the product quality of the aerosol products, the reader is referred to the O3MSAF Validation Report on the Aerosol products. (SAF/O3M/KNMI/VR/001)

1.3 Glossary

1.3.1 Acronyms

AAI	Absorbing Aerosol Index
ARS	Aerosol Retrieval System
ATBD	Algorithm Theoretical Basis Document
ECMWF	European Centre for Medium-range Weather Forecast
ERS	European Remote Sensing Satellite
ESA	European Space Agency
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FRESCO	Fast Retrieval Scheme for Cloud Observables
FWHM	Full Width Half Maximum
GDP	GOME Data Processor
GOME	Global Ozone Monitoring Instrument
KNMI	Royal Netherlands Meteorological Institute
LUT	Look Up Table
O3MSAF	Satellite Application Facility on Ozone Monitoring

OMI	Ozone Monitoring Instrument
OPERA	Ozone Profile Retrieval Algorithm
PMD	Polarization Measurement Device
PUM	Product User Manual
RMS	Root Mean Square
RTM	Radiative Transfer Model
SAF	Satellite Application Facility
SCI	SCattering Index
SZA	Solar Zenith Angle
TOMS	Total Ozone Mapping Spectrometer
UV	Ultra Violet
VIS	Visible

1.4 Reference documents

[RD1]   Algorithm Theoretical Basis Document for ARS, version 2.2, dd 2013-06-16

[RD2]   de Graaf, M., P. Stammes, O. Torres, and R. B. A. Koelemeijer (2005), Absorbing Aerosol Index: Sensitivity analysis, application to GOME and comparison with TOMS, J. Geophys. Res., 110, D01201, doi:10.1029/2004JD005178

[RD3]   O3MSAF Validation Report of the Absorbing Aerosol Index products, SAF/O3M/KNMI/VR/001, issue 3/2013, 2013-06-11.

2. INTRODUCTION TO EUMETSAT SATELLITE APPLICATION FACILITY ON OZONE AND ATMOSPHERIC CHEMISTRY MONITORING (O3MSAF)

2.1 Background

The need for atmospheric chemistry monitoring was first realized when severe loss of stratospheric ozone was detected over the Polar Regions. At the same time, increased levels of ultraviolet radiation were observed.

Ultraviolet radiation is known to be dangerous to humans and animals (causing e.g. skin cancer, cataract, immune suppression) and having harmful effects on agriculture, forests and oceanic food chain. In addition, the global warming - besides affecting the atmospheric chemistry - also enhances the ozone depletion by cooling the stratosphere. Combined, these phenomena have immense effects on the whole planet. Therefore, monitoring the chemical composition of the atmosphere is a very important duty for EUMETSAT and the world-wide scientific community.

2.2 Objectives

The main objectives of the O3MSAF are process, archive, validate and disseminate atmospheric composition products ($O3$, $NO2$, $SO2$, $OClO$, $HCHO$, BrO, $H2O$), aerosols and surface ultraviolet radiation utilising the satellites of EUMETSAT. The majority of the O3MSAF products are based on data from the GOME-2 spectrometer onboard MetOp-A satellite.

Another important task of the O3MSAF is the research and development in radiative transfer modelling and inversion methods for obtaining long-term, high-quality atmospheric composition products from the satellite measurements.

2.3 Product families

Near real-time Total Column (NTO)

   O3, NO2, O3Tropo, NO2Tropo

Near real-time Ozone Profile (NOP)

Near real-time UV Index (NUV)

Offline Total Column (OTO)

O3, NO2, O3Tropo, NO2Tropo, SO2, BrO, H2O, HCHO, OClO

Offline Ozone Profile (OOP)

Offline Surface UV (OUV)

Aerosols (ARS)

2.4 Product timeliness and dissemination

Data products are divided in two categories depending on how quickly they are available to users:

Near real-time products are available in less than three hours after measurement. These products are disseminated via EUMETCast (NTO, NOP), GTS (NTO, NOP) or Internet (NUV).

Offline products are available in two weeks from the measurement and they are archived at the O3MSAF archives in Finnish Meteorological Institute (OOP, OUV, ARS) and German Aerospace Center (OTO).

Only products with "pre-operational" or "operational" status are disseminated. Up-to-date status of the products and ordering info is available on the O3MSAF website.
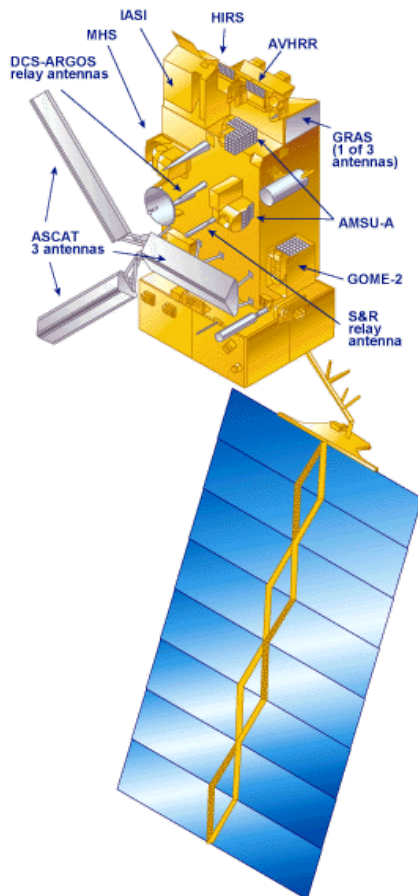
2.5 Information

Information about the O3MSAF project, products and services: http://o3msaf.fmi.fi/

O3MSAF Helpdesk: o3msaf@fmi.fi

3. METOP AND GOME-2

3.1 MetOp

The MetOp satellite series is the core element of the EUMETSAT Polar System (EPS), developed in partnership with the European Space Agency. It carries a complement of new European instruments, as well as versions of operational instruments flown on the corresponding NOAA satellites of the USA.

The EUMETSAT programme includes provision for the development of the MetOp spacecraft in conjunction with the European Space Agency (ESA), the construction and launch of three new MetOp spacecraft, the development of the corresponding instruments and ground infrastructure, and provision for routine operations over a period of 15 years from the date of first launch. This polar system is complementary to EUMETSAT's existing Meteosat satellites in geostationary orbit.

The EPS MetOp satellites (MetOp-A and MetOp-B) fly in a sun-synchronous polar orbit at an altitude of about 840 km, circling the planet 14 times each day and crossing the equator at 09:30 local (sun) time on each descending (south-bound) orbit. Successive orbits are displaced westward due to the Earth's own rotation, giving global coverage of most parameters at least twice each day, once in daylight and once at night.

The spacecraft carries a comprehensive set of instrumentation, designed primarily to support operational meteorology and climate monitoring, but also supporting many additional applications.

3.2 GOME-2

METOP carries a number of instruments including the Global Ozone Monitoring Experiment-2 (GOME-2). This instrument is designed to measure the total column and profiles of atmospheric ozone and the distribution of other key atmospheric constituents. GOME-2 is a nadir viewing across-track scanning spectrometer with a swath width of 1920 km. It measures the radiance back-scattered from the atmosphere and the surface of the Earth in

the ultraviolet and visible range. The instrument uses four channels to cover the full spectral range from 200 to 790 nm with a spectral sampling of 0.11 nm at the lower end of the range, rising to 0.22 nm at the higher end. The instrument employs a mirror mechanism which scans across the satellite track with a maximum scan angle that can be varied from ground control, and three multi-spectral samples per scan. The ground pixel size of GOME-2 is 80 x 40 km² for the shortest integration times, but is usually 8 times larger for the detector measuring the shortest UV wavelengths.

Table 1; GOME-2 properties (of MetOp-A)

Spectrometer type	double spectrometer with pre-disperser prism and four holographic gratings
Spectral range	240 –790 nm
Field of view	0.286° (across track) x 2.75° (along track)
Entrance slit	0.2 mm (across track) x 9.6 mm (along track)
Channels (Bands) & sampling & resolution	1a: 203 – 306 nm & 0.14 - 0.11 nm & 0.24 – 0.29 nm 1b: 306 – 322 nm & +/- 0.11 nm & 0.24 – 0.29 nm 2a: 290 – 399 nm & +/- 0.13 nm & 0.26 – 0.28 nm 2b: 299 – 412 nm & +/- 0.13 nm & 0.26 – 0.28 nm 3: 391 – 607 nm & +/- 0.22 nm & 0.44 – 0.53 nm 4: 584 – 798 nm & +/- 0.22 nm & 0.44 – 0.53 nm
Polarisation monitoring unit	250 detector pixels 312 – 790 nm in 12 programmable bands spectral resolution: 2.8 nm at 312 nm to 40 nm at 790 nm
Swath widths	1920 km (nominal mode), 960 km, 320 km, 240 km, 120 km
Solar calibration	Once per day
Spectral calibration	fixed angle (once per day to once per month)
White Light Source Dark signal	fixed angle (night side of the orbit)
Default spatial resolution and integration time	Band 1a: 640 km x 40 km (1920 km swath and integration time of 1.5 s) Band 1b – 4: 80 km x 40 km (1920 km swath and int. time of 0.1875 s) PMD: 10 km x 40 km (for polarisation monitoring)

4. ALGORITHM BACKGROUND

4.1 Absorbing Aerosol Index

The Absorbing Aerosol Index (AAI) indicates the presence of elevated absorbing aerosols in the troposphere like desert dust and smoke. It separates the spectral contrast at two ultraviolet (UV) wavelengths caused by absorbing aerosols from that of other effects, including molecular Rayleigh scattering, surface reflection, gaseous absorption and aerosol and cloud scattering.

The AAI emerged as an error estimate in the Total Ozone Mapping Spectrometer (TOMS) ozone retrieval algorithm. As TOMS instruments have flown, on various platforms, from 1978 to 2006 providing nearly daily global coverage, the TOMS AAI record is the longest aerosol record available and it is used extensively to investigate aerosol impact on climate and study heavy dust, biomass burning and volcanic eruption events.

Traditionally, aerosol optical thickness measurements are being made using space-borne sensors operating in the visible and infrared (IR), where multiple scattering in the atmosphere is less important than in the ultraviolet (UV) and inversion calculations are relatively simple. In the visible and near-IR the large surface albedos of many land types make retrieval of aerosols difficult over these regions. With the ongoing development of numerical radiative transfer codes and increasing computational speeds accounting for multiple scattering is no longer a problem, allowing for new techniques of aerosol measurements in the UV. Because the surface albedos of both land and ocean are small in the UV, this wavelength range should be suitable for aerosol detection over land.

The AAI is derived directly from another quantity, the residue, which is defined in the following way (Herman (1997)):

$$r_\lambda = -100 \cdot \left\{ {}^{10}\!\log\!\left(\frac{R_\lambda}{R_{\lambda 0}}\right)^{meas} - {}^{10}\!\log\!\left(\frac{R_\lambda}{R_{\lambda 0}}\right)^{Ray} \right\} \tag{1}$$

In this equation, R_λ denotes the Earth's reflectance at wavelength λ. The superscript R^{meas} refers to TOA reflectances which are measured by GOME-2, while the superscript R^{Ray} refers to modelled TOA reflectances. These modelled reflectances are calculated for a cloud-free and aerosol-free atmosphere in which only Rayleigh scattering, absorption by molecules, Lambertian surface reflection as well as surface absorption can take place. As a result, the residue is a residual term caused by the presence of cloud and aerosols in the real scene as opposed to the modeled scene. More details about the calculation of the residue can be found in the ATBD ([RD1]).

The presence of clouds tends to make the residue negative. Scattering aerosols will generally do the same. Absorbing aerosols, on the other hand, increase the residue and will lead to a positive residue. For that reason, the AAI is defined as the positive part of the residue. The two wavelengths λ and λ_0 that constitute the AAI wavelength pair are set to 340 and 380 nm, respectively.

The name AAI is traditionally used for indicating absorbing aerosols, for which the residue has positive values. In the GOME-2 ARS product *we will use the AAI as being synonymous to the residue*, so the full range of residue values, positive as well as negative, will be reported in the AAI product.

4.2 Interpretation

The direct interpretation of the AAI in terms of aerosol properties is difficult. The residue (AAI/SCI) is a unitless quantity that depends on many aspects of the aerosol scene. In the paper by de Graaf et al. [RD2] a sensitivity study was performed.

In this sensitivity study it was shown that there are at least two possibilities to create a positive residue. Firstly, an absorbing aerosol layer can absorb Rayleigh scattered radiation from below the layer. Because the Rayleigh optical thickness is strongly wavelength dependent this creates a difference in the reflectance at two UV wavelengths relative to that of a Rayleigh atmosphere, even with gray absorbers (i.e. wavelength independent absorbing particles). When the absorbing ability of the layer increases more radiation is absorbed and the deviation increases, increasing the residue. The same is true when the amount of atmosphere under the absorbing layer increases.

Secondly, the aerosol absorption itself can be wavelength dependent, creating a spectral difference in the TOA reflected radiation. This will also create a positive residue if the absorption at the shorter wavelength is stronger, even when the aerosol layer is close to the surface. When the spectral absorption difference increases the residue will increase, meaning that different aerosol types produce different residues under the same circumstances.

For an atmosphere which is dominated by scattering (either by particles, molecules, the surface or clouds) the reflectance will not deviate much from the reflectance of a Rayleigh atmosphere with an adjusted surface albedo, yielding zero or small negative residues.

The residue is sensitive to sunglint, which should be flagged. Sunglint is expected in GOME-2 data at the east side of the swath.

The residue is very sensitive to the absolute radiometric calibration of satellite radiances at 340 and 380 nm [RD1]. Deviations in the residue due to calibration errors may be presents in the level 1B data.

The residue (or AAI in case of GOME-2) ranges typically from about -1 for cloudy scenes to +2 and larger for desert dust or smoke plumes.

4.3 Level 1 Input

The basic level 1B data consists of a calibrated solar spectrum and spectra of calibrated geo-located radiances; each spectrum comes with a wavelength grid, error estimates and status flags. In the geolocation record, solar and line-of-sight viewing angles are specified at the spacecraft, satellite height and earth radius are specified for the sub-satellite point, and for each nadir-view footprint the centre co-ordinates (surface latitude and longitude) are given. The spectral level 1b data used in the calculation of the AAI are 1-nm averaged reflectances at 340 and 380 nm.

4.4 Level 2 output

Aerosol data are calculated and written as one or more HDF5 product files per orbit. The product contains the geolocation, angles and the retrieved AAI. At a later stage, the other aerosol parameters will be added to the product as they come available.

4.5 Delivery time to users / user access

The Aerosol Absorbing Index is classified as an NRT product, and can be obtained via EUMETCast or the EUMETSAT/O3MSAF archive. Please see the O3MSAF website at http://o3msaf.fmi.fi or contact the O3MSAF helpdesk at o3msaf@fmi.fi for more information.

The delivery time of the offline ARS product to the EUMETSAT/O3MSAF archive will be within two weeks maximum, but usually within a day or two.

4.6 Geographical coverage and Granularity of the level 2 product

The geographical coverage of the aerosol product is practically all of the sun-lit side of the earth. The swaths of the GOME-2 instrument do not cover the earth completely every day at the equator, but at latitudes higher than 45 degrees there is a possibility that the same surface area is viewed more than once a day.
Because the algorithm uses information from the wavelength region between 340 and 380 nm, the granularity of the default AAI output product is the same as the Band 2b measurements. This means that with nominal conditions the pixel size is 40x80km in flight-direction x cross track-direction.

5. THE ARS/AAI PRODUCT

5.1 Structure of the ARS Product File

The format of the offline Level 2 ARS profile product file is HDF5. The data in the HDF5 file is organized in four groups: *Metadata*, *Product_Specific_Metadata, Geolocation* and *Data* (see Figure 1). The values in all groups are taken either from the level-1b or other input data files, copied from the configuration file, or calculated by the program.
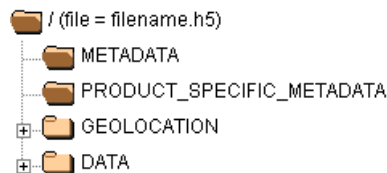

Figure 1: Structure of the HDF5 file.

The *Metadata* group contains parameters about the satellite instrument required by UMARF, such as metadata given in the O3MSAF software requirements, the scanning mode, the algorithm version and other general information about the product.

The *Product_Specific_Metadata* group is reserved for additional information specific to this product (*e.g.* parameters related to the algorithm) which has been used to generate the product. All values in the Metadata and Product_Specific_Metadata groups are stored as attributes.

The geolocation information of each ground pixel can be found in *Geolocation* group. It contains all information such as corner and center coordinates. See Figure 2 and Figure 3 for the definition of the seven points of the ground pixel.
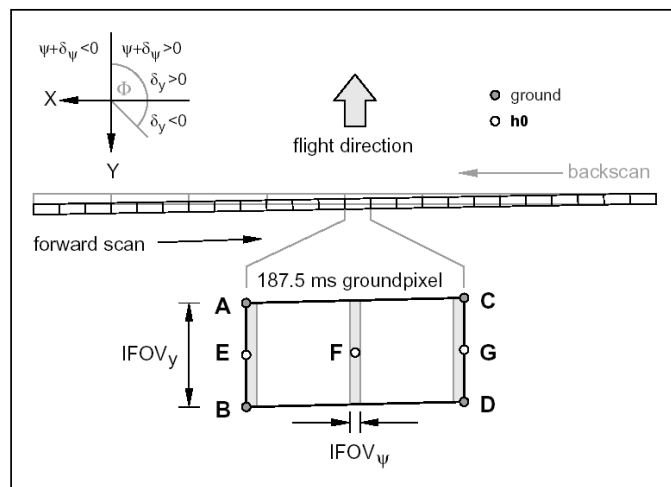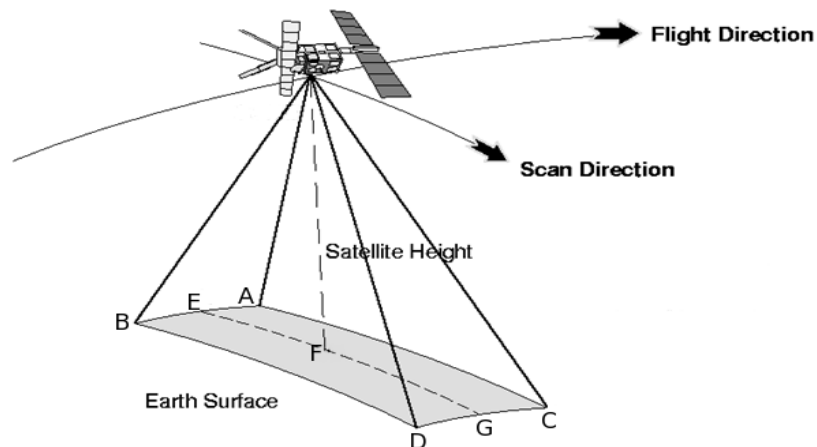
Figure 2: Ground pixel geometry.

Figure 3: Ground pixel geometry

The calculated results are stored in the *Data* group. It contains information about the quality of the retrieval, auxiliary information, the definition of the state vector and the retrieval results.

Because the output product contains information for series of pixels, all information in the Data and Geolocation group is organized in multi-dimensional arrays. The first dimension always corresponds to the total number of pixel sets which has been processed, hereafter referred to as *NSets*, the total number of retrievals per set is referred to as *NElements*.

If a value could not be calculated, a fill value is written to the array as a placeholder, indicating no data (in contrast to invalid data).
Each array has five attributes: Title, Unit, FillValue, ValidRangeMin and ValidRangeMax, which are used to describe the contents of the array.

5.1.1 Metadata Group

The content of the Metadata group is shown in the following table. The allowed values for the parameters which are required by UMARF are consistent with the requirements given in Table 2. The allowed values given in *italics* mean any value of the given type (e.g. *string* means that the attribute can contain any string, within the UMARF size limit).

Table 2. Metadata group contents.

Attribute name	Data Type	Description	*Allowed values*
SatelliteID	string	Platform identifier (mission and spacecraft the product originated from).	*Mnn*
OrbitType	string	Coverage of the product (global, local).	*LEO*
StartOrbitNumber	int	First of the two orbit numbers in the EPS product, valid at the start of sensing, i.e. at the beginning of a dump.	*int*
InstrumentID	string	Instrument which acquired the product.	GOME
InstrumentMode	string	Scanning mode of the instrument at the time of the acquisition.	NORTH_POLAR_VIEW, SOUTH_POLAR_VIEW, NARROW_VIEW, NORMAL_VIEW, STATIC_VIEW, UNKNOWN
SensingStartTime	String(23)	UTC date and time at acquisition start of the product.	*Date in CCSDS format*
SensingEndTime	String(23)	UTC date and time at acquisition end of the product.	*Date in CCSDS format*
ReceivingCentre	string	Centre that received the data.	*String*
ProcessingCentre	string(5)	Centre that generated the data.	O3KNM *or other String*
ProcessingMode	string(1)	Processing mode applied for generation of the product.	N(ominal), B(acklog), R(eprocessing), V(alidation)
ProcessingLevel	string(2)	Processing level applied for generation of the product.	02
ProcessingTime	String(23)	UTC date and time at processing end of the product.	*Date in CCSDS format*
BaseAlgorithmVersion	string(4)	Version of the algorithm	*string*

		which was used to generate the L1B or L2 EPS parent product, upon which the product is based.	
ProductAlgorithmVersion	string(4)	Version of the algorithm that produced the product.	*string*
ParentProducts	string	Name of the parent products, upon which the product is based.	*string*
ProductType	string	Abbreviated name for the product type, or rather product category.	O3MOOP, O3MNOP, O3MARS
ProductFormatType	string	Data format of the product.	HDF5
ProductFormatVersion	string	Version number of the product format	*string*
SubSatellitePointStartLat	float	Latitude of the sub-satellite point at start of acquisition. (For EPS products: either the first measurement or first complete scan start point **(tbd)**, at start of dataset.)	-90 to 90
SubSatellitePointStartLon	float	Longitude of the sub-satellite point at start of acquisition.	-180 to 180
SubSatellitePointEndLat	float	Latitude of the sub-satellite point at end of acquisition.	-90 to 90
SubSatellitePointEndLon	float	Longitude of the sub-satellite point at end of acquisition.	-180 to 180
OverallQualityFlag	string	Overall quality flag for the L2 product.	OK, NOK
QualityInformation	string	Several miscellaneous quality indicators for the L2 product.	*string*
DegradedRecordCount	int	Number of degraded and incomplete Earthshine MDRs detected by L2 software.	*int*
DegradedRecordPercentage	int	Percentage of degraded and incomplete MDRs	0 - 100

		detected by L2 software, w.r.t total number of read Earthshine MDRs.	
MissingDataCount	int	Number of Earthshine MDR records skipped by L2 software due to time breaks or other data requirement failures.	*int*
MissingDataPercentage	int	Percentage of Earthshine MDR records skipped by L2 software due to time breaks or other data requirements, w.r.t total number of read Earthshine MDRs.	0 - 100
GranuleType	string	Type description of the item.	DP (Data Product)
DispositionMode	string(1)	Disposition mode applied for generation of the product	O(perational), P(re-operational), D(emonstrational)
ReferenceTime	string	A reference time mainly used for the product file names. Time when the product is generated TBC	*Date in CCSDS format*
AscNodeCrossingTime	string	Ascending Node Crossing Date and Time	*Date in CCSDS format*
AscNodeLongitude	String (9)	Ascending Node Longitude	*String*

5.1.2 Product_Specific_Metadata Group

The metadata definition specific for the ARS products given in the following table. The parameters are stored as attributes of the Product_Specific_Metadata group.

Table 3. Product_Specific_Metadata group contents.

Level 1 Usage Section		
Attribute name	**Data Type**	**Description**
Wavelengths	Float array,	Wavelengths used for calculating the AAI

	rank 1	
FullWidthTriangle	Float	FullWithHalfMaximum of the reflectance averaging function around the Wavelengths above.

5.1.3 Table Attibutes

Attributes attached to all datasets in the Geolocation group and Data group are shown in the table below.

Table 4. Attributes for the geolocation and data group datasets.

Attribute name	Data Type	Description
Title	string	Description of the dataset, e.g. "Solar noon UV index"
Unit	string	Unit of the values in the array, e.g. DU, second
FillValue	same as the dataset	Value in the array, in case actual data value is missing
ValidRangeMin	same as the dataset	Minimum allowed value for the data in the array
ValidRangeMax	same as the dataset	Maximum allowed value for the data in the array

5.1.4 Geolocation Group

The datasets in the Geolocation group are given in the following table. The data type and value of the Unit attribute are given for each dataset.

Table 5. Geolocation group contents.

Dataset name	Data type	Unit	Description
Time	String array rank 2	-	UTC time in CCSDS format
LongitudeCenter	Float arr rank 2	degree	Longitude of the center of the ground pixel (F)
LatitudeCenter	Float arr rank 2	degree	Latitude of the center of the ground pixel (F)
LongitudeCorner	Float arr rank 3	degree	Longitude of corner A of the pixel

Dataset name	Data type	Unit	Description
LatitudeCorner	Float arr rank 3	degree	Latitude of corner A of the pixel
SolarZenithAngle	Float arr rank 2	degree	Solar zenith angle center of the ground pixel
SolarAzimuthAngle	Float arr rank 2	degree	Solar Azimuth angle w.r.t. north for center of ground pixel at H0
LineOfSightZenithAngle	Float arr rank 2	degree	LineOfSight zenith angle for center of the ground pixel
LineOfSightAzimuthAngle	Float arr rank 2	degree	Line of Sight Azimuth angle w.r.t. north of the ground pixel
RelAzimuthAngle	Float arr rank 2	degree	Relative Azimuth angle between sun and viewing angles
SubSatellitePointLongitude	Float arr rank 2	degree	Geocentric longitude of subsatellite point
SubSatellitePointLatitude	Float arr rank 2	degree	Geodetic latitude of subsatellite point
ScatteringAngle	Float arr rank 2	degree	Total scattering angle the photon made from sun beam to satellite assuming single scattering
ScanDirection	Float arr rank 2	N/A	Direction of the scan mirror (1 = forward, 2 = backward)
ScannerAngle	Float arr rank 2	Degree	Angle of the scan mirror.
NrOfPixelsInScan	Int arr rank 2	N/A	Number of pixels within the scan line.
NElements	Int arr rank 2	N/A	Number of pixels in each AAI set
IndexInScan	Int arr rank 2	N/A	Index of the pixel within the scan line. This indicates whether the pixel is a forward scan pixel (indices 1 – 12 (1–24)) or backscan pixel (indices 13 – 16 (25 – 32)).

5.1.5 Data Group

The datasets in the Data group are given in Table 6. The data type and value of the Unit attribute are given for each dataset.

Attributes attached to all datasets in this group the same as for the Geolocation group.

Table 6. Data group contents.

Quality Section			
Dataset name	**Data type**	**Unit**	**Description**
QualityInput	Int arr, rank 2, size 32	N/A	Quality flags for the input data. 0 = false, 1 = true 0: Non-nominal level 1 due to instrument degradation; DEGRADED_INST_MDR in Level1b [RD1]) 1: Non-nominal level 1 due to processing degradation; DEGRADED_PROC_MDR in Level1b [RD1] 2: Groundpixel is in SAA; F_SSA in Level1b/PCD_BASIC [RD1] 3: Sunfile of date missing: older sunfile used 4: [not used] 5: [not used] 6: [not used] 7: Earthshine radiance data missing 8: Earthshine radiance data invalid 9: Solar irradiance data missing 10: Solar irradiance data invalid 11: [not used] 12: [not used] 13: Absorbing Aerosol Index data invalid (due to input errors ((ir-)radiance) or out of bound geometry conditions (Solar Zenith Angle, Solar Azimuth Angle, Viewing Zenith Angle, Viewing Azimuth Angle, Relative Azimuth Angle, ScatteringAngle) or external input valies like out of bound surface pressure or total ozone column). 14: Failure in setup of the Forward Model Input 15: [not used] 16: Sunglint flag 17: [not used] 18: Cloud Pressure Adjusted to Surface Pressure

			19: Other error
			20 – 31: reserved for future use
QualityProcessing	Int arr, rank 2, size 32	N/A	Quality flags for processing. 0 = false, 1 = true, -999 = No Retrieval done, -1 = value not initialized / not used
			0 – 5: [not used]
			6: No retrieval done! (due to any kind of input errors)
			7 – 31: reserved for future use

Output Section			
Dataset name	**Data type**	**Unit**	**Description**
NElements	Int arr, rank 1	-	Number of AAI elements per set
AAI	Float arr, rank 2	-	Absorbing Aerosol Index Dimension = NElements x NSets
SunGlintFlag	Float arr rank 2	-	Flag is sum of following subflags: 0=no sun glint; 1=land, 4=Cloud fraction >0.3; 8=Cloud pressure <850 hPa (and Cf >0.1), 32=sun glint angle <18 degrees, 64=sun glint angle <11 degrees. Use only flag values 0, 1, 4, 8, 33-63, not 32 or >=64.
CorrectionFactor	Float arr rank 2	-	Optional Degradation Correction factor
UncorrectedResidue	Float arr rank 2	-	Optional Residue values that were not corrected for degradation.

5.2 Data Types

The data types to be used in the HDF5 files are given in the table below.

Table 7. Data types for the HDF5 files.

Data type	HDF5 predefined data type
char	H5T_STD_I8LE
short int	H5T_STD_I16LE
int	H5T_STD_I32LE
float	H5T_IEEE_F32LE
double	H5T_IEEE_F64LE

String	Fortran: H5T_FORTRAN_S1
	C: H5T_C_S1

5.3 File name convention

File names of product are following the names of the input files. For GOME2, these are foreseen as having the following layout for the HDF5 format files:

S-O3M_GOME_ARS_02_AAA_SSSS_EEEE_W_Z_PPPP.hdf5

Where AAA is the flight model number. On MetOp-A this number is M02. The SSSS is a placeholder for the SensingStartTime: (YYYYMMDDhhmmssZ); the EEEE is the placeholder for the SensingEndTime (also YYYYMMDDhhmmssZ), the PPPP is the processing time (also in the same format as SSSS and EEEE); The W indicates the Processing-Mode and Z indicates the Disposition-Mode of the file.

5.4 File size estimate

5.4.1 Estimated size of ARS output file

The size of the output file can vary. The size is affected by different string lengths, the maximum number of profiles per set, the actual number of AAI retrievals, the addition of optional data sets to the file, and possibly the compression factor in the HDF5 output file.

On average, each PDU-sized data product of ARS data is about 113Kb.

5.5 Using the data

5.5.1 AAI

An example of the Absorbing Aerosol Index is given in Figure 4. In this figure, a large Saharan desert dust plume is transported over the Atlantic Ocean from Africa to South America.
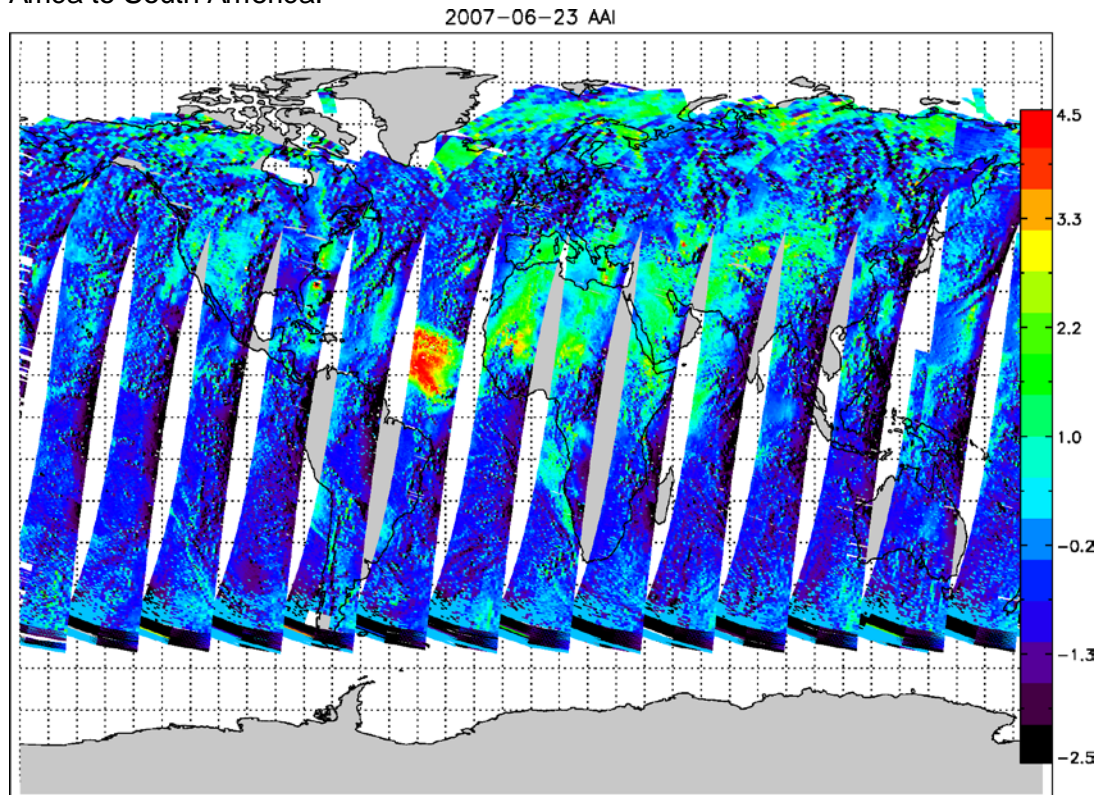

Figure 4: Absorbing Aerosol Index (AAI) from GOME-2 for June 23rd 2007.

5.5.2 Quality flags

Quality flags are very important as indicators for the correctness of both the input and the retrieved AAI. There are two quality flag groups: QualityInput and QualityProcessing. In the input flags the types of failures are set: missing data (geometry-wise or spectral-wise), or out of range/invalid values. In the input quality flags there is a flag for sun glint. The sun glint causes a spurious AAI signal. This sun glint flag in the QualityInput comes directly from the Level-1b, and is on a scan level basis (i.e.: valid for the whole scan instead for the subpixel.

5.5.3 SunGlintFlag

There is a data record in the Data Group called SunGlintFlag. This indicates on a ground pixel basis whether there is a risk of sun glint. Flag is the sum of the following subflags:

- 0=no sun glint;

- 1=land,

- 4=Cloud fraction >0.3;

- 8=Cloud pressure <850 hPa (and Cf >0.1),

- 32=sun glint angle <18 degrees,

- 64=sun glint angle <11 degrees.

Users are advised to use pixels with flag values exactly 0, 1, 4, 8, 33-63, but not 32 or values larger or equal than 64.

5.5.4 ScatteringAngle

In the north and south eastern edges of the swath there are increased values of the AAI due to geometric effects. The light from the sun is scattered in a forward direction to the satellite and the algorithm does not handle this at the moment.

Users are advised to use pixels with scattering angles larger then 90 degrees.

6. PRODUCT QUALITY AND CHARACTERISTICS

The product quality is determined mainly by the quality of the input parameters reflectances, ozone column, and surface height. The ozone column and surface height are both known with a (relatively) high accuracy. The impact of errors in the radiometric calibration can be strong, though. The most important example of this is the impact of instrument degradation on the AAI. Instrument degradation has a strong impact on the AAI. The GOME-2 AAI from MetOp-A is currently suffering from scan-angle dependent instrument degradation. As a result, there is an east-west bias which amounts to ~3 index points for data measured at the end of 2012. Apart from the east-west bias, there is an overall offset.

A correction for instrument degradation is not applied in the current data version.

As for the quality of the ARS/AAI products, it has been studied using a number of different verification techniques. An extended report of these studies and their results may be found in the O3M SAF Validation Report.

Here we summarise the main conclusions:

(1) Global maps of GOME-2 AAI compare well to global maps of OMI AAI.

(2) From a pixel-to-pixel comparison with the AAI from SCIAMACHY it is found that the GOME-2 MSC AAI is of good quality. This we conclude from the good (one-to-one) correlation between GOME-2 and SCIAMACHY AAI. The offset between the GOME-2 MSC AAI and SCIAMACHY AAI is found to be close to zero. Additionally, the bias-corrected uncertainty in the GOME-2 MSC AAI was found to be ~0.5 index point. This is only an upper limit, because this value is also determined by the quality of the SCIAMACHY AAI and the performance of our intercomparison approach. In any case, the (bias-corrected) value of 0.5 index points relates well to the target uncertainty of 0.5 index points mentioned in the PRD.

(3) More quantitative results follow from the analyses of the global mean residue. The global mean MSC residue in particular revealed a similar seasonal variation for GOME-2 (on MetOp-A) as was found earlier for GOME-1. However, a modest offset of ~0.4 index points w.r.t. the GOME-1 global mean value was found. When the calculation was repeated taking only those measurements that are located in the inner (GOME-1) part of the GOME-2 swath, the offset was reduced to ~0.2 index points.

(4) For GOME-2 on MetOp-B we found the MSC AAI to agree nicely with the MSC AAI from the MetOp-A platform. Only a small offset of ~0.3 index points seems to be present.

(5) The PMD AAI from MetOp-A and MetOp-B show similar behaviour as the MSC AAI products. The statistical analyses show that the PMD AAI from MetOp-A is very close to the MSC AAI from MetOp-A. A small offset of 0.3 index points is found. The PMD AAI from MetOp-B compares reasonably with

the MSC AAI from MetOp-B. An explanation for the differences between the MSC and PMD product is the (known) different radiometric calibration between MSC reflectances and PMD reflectances.

(6) The GOME-2 AAI products have, like any other AAI product, a number of characteristic properties that need to be kept in mind. First of all, sun glint leads to anomalously high values for the AAI. Measurements affected by sun glint should therefore not be used. A sun glint flag is present in the product for filtering out sun glint situations. Secondly, solar eclipse events lead to very high and unphysical values for the AAI. These data should not be used. Thirdly, the GOME-2 AAI shows a modest scan-angle dependence (not caused by instrument degradation). This is another intrinsic property of the AAI. Last, but not least, at the east side of the swath at high latitudes (both North and South) there are areas showing too large values for the AAI. This is known behaviour of the AAI product. These data should not be used, or at least treated with caution.

7. FURTHER INFORMATION

7.1 O3MSAF website

Further up to date information and documentation on the ARS aerosol products should be available from the O3MSAF website: http://o3msaf.fmi.fi

Requests for data and questions with regards to O3MSAF products should be directed to the user services. Contact information is also available on the website mentioned above.

7.2 User Notification Service

EUMETSAT maintains a User Notification Service (UNS) that disseminates instantaneous messages relating to the platform (MetOp-A), the GOME-2 instrument and derived L1 and L2 products, and weekly notifications of upcoming ground segment and SAF related scheduled maintenance activities. The SAF recommends that Near Real Time users subscribe to this notification service (at least the instrument related and weekly notifications). This ensures also that the SAF has a channel to notify users of upcoming changes in the L2 format and or quality of the products.