AEROSOL PRODUCT DEVELOPMENT ACTIVITIES AT EUMETSAT

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EUMETSAT operational products

What is a near real time operational product?

EUMETSAT purpose is to supply weather and climate-related satellite data, images and products — **24 hours a day, 365 days a year** — to the National Meteorological Services of our Member and Cooperating States in Europe, and other users worldwide.

EUMETSAT operational NRT products require:

- High availability (>98%)
- Delivery within 3 hours from sensing (LEO)
- Delivery within minutes to 1 hour of sensing (for GEO)
- 24/7 maintenance / monitoring support

Severely limits the number of products and algorithms suitable for being implemented as this kind of operational product!
EUMETSAT Missions
Providing Aerosol and Volcanic Ash Operational Products in NRT

Metop Multi-mission product (PMAp)
Metop GOME-2 (Metop-A/B/C 2007-2025)
MSG (Seviri 1997-2025)

Sentinel-3 OLCI & SLSTR (S3 launch in 2016)

MTG UVN (Sentinel-4)
MTG FCI & IRS (MTG launch in 2020)

EPS-SG 3MI
EPS-SG UVNS (Sentinel-5)
EPS-SG VII
EPS-SG IAS (EPS-SG launch in 2021)
Current Capabilities - EUMETSAT Polar System

- AVHRR: Advanced Very High Resolution Radiometer
- HIRS/4: High-resolution Infrared Radiation Sounder
- IASI: Infrared Atmospheric Sounding Interferometer
- AMSU-A1: Advanced Microwave Sounding Unit-A1
- MHS: Microwave Humidity Sounder
- GRAS: GPS Receiver for Atmospheric Sounding
- GOME-2: Global Ozone Monitoring Experiment
- AMSU-A2: Advanced Microwave Sounding Unit-A2
- ASCAT: Advanced SCATterometer
PMAp results: AOD Metop A & Metop B (30/08/2013)

More tomorrow!
Metop-GOME-2 level 2 products
Absorbing and Scattering Aerosol/UV Index (UVAI)

Extracted from the operational validation report for GOME-2/Metop-B level 2 products:
http://o3msaf.fmi.finn.

\[
\text{UVAI} = -100 \cdot \left[ 10 \log \left( \frac{I_340}{I_{380}} \right) + 10 \log \left( \frac{I_380}{I_{405}} \right) \right]
\]

\( \lambda = 340 \text{ nm} \)
\( \lambda_0 = 380 \text{ nm} \)

No cloud filter applied!

Courtesy Tilstra, Tuinder, Stammes, KNMI
Metop-GOME-2 level 2 products
Absorbing and Scattering Aerosol/UV Index (UVAI)

UVAI from GOME-2 level-1b data: Jun-Aug 2007-2008
No cloud filter applied!

Courtesy Marloes Penning de Vries, MPI-Chemistry, Mainz
Aerosol and SO2 monitoring from Metop
Observing volcanic eruption and dust events for aviation control

30. November 2014

Cap Verde volcanic SO2 emissions

Dust signal

http://sacs.aeronomie.be
SO2 monitoring from Metop (GOME-2 / IASI)
Observing volcanic eruption and dust events for aviation control

Cap Verde eruption
November 2014

GOME-2 Metop-A/B
Combining aerosol and trace-gas level 2 products from Metop GACA

GACA
Global Aerosol Characterization Algorithm

- Satellite remote sensing of aerosol properties is difficult
- Aerosols and trace gases often have similar sources
- Study relationship between NO₂, HCHO, SO₂, CO and AOT
- UV Aerosol Indices and extinction Ångström exponent indicate particle properties (absorption, size)
- Input: monthly mean maps with 1°x1° resolution
- Output: seasonal maps (2°x2°) of main aerosol type and source

1 Veefkind et al., ACP 2011

Penning de Vries et al.: Atmospheric Chemistry and Physics Discussions 05/2015; 15:13551-13605
MSG Aerosol Optical Depth Product
Current products and planned developments

- EUMETSAT currently disseminates the MSG AES “Aerosol Properties Over Sea” product
  - Look-up table method providing a daily averaged product
  - Not serving the needs of the data assimilation community

- For information: Algorithm developed by Météo-France implemented at ICARE – (SEVIRI AERUS) provides a daily (daytime) AOD product

- Further development of this algorithm, including the transition to a three hourly product, planned in the frame of the Land SAF – central implementation at EUMETSAT to support NRT production considered
MSG-Seviri Volcanic Ash
Currently operational ash (and cloud) products

**Prata**
LUT Ash, IR
$\tau_{\text{cloud}}, R_e, \text{Hgt}$

**OCA**
O.E. Cloud, IR+VIS
$\tau_{\text{cloud}}, R_e$

Provided courtesy of Philip Watts (RSP-AIA Team)

Current operational operational Ash (Prata) and cloud (OCA) algorithms
MSG-Seviri Volcanic Ash
Ash (and cloud) product development – Inter-comparison Study (RAL)

**Prata**
LUT Ash, IR
$\tau_{\text{cloud}}, R_e, \text{Hgt}$

**OCA**
O.E. Cloud, IR+VIS
$\tau_{\text{cloud}}, R_e, \text{Hgt}, 2$-Layer

**RAL ORAC**
O.E. Cloud + Ash, IR+VIS
$\tau_{\text{cloud}}, R_e, \text{Hgt}, 2$-Layer

**UKMO**
O.E. Ash, IR
$\tau_{\text{cloud}}, R_e, \text{Hgt}, 2$-Layer

Algorithmically very similar

- Provided courtesy of Philip Watts (RSP-AIA Team)
- Future EUMETSAT operational Ash algorithm

**Intercomparison - evaluation Study (RAL lead)**

**CALIOP**
Eyja, Puyehue, Grimsvoten, Chaiten, Soufriere Hills
**MSG-Seviri Volcanic Ash**

Ash (and cloud) product development – Inter-comparison Study (RAL)

**Prata**

- LUT Ash, IR
- \( \tau_{\text{cloud}}, R_e, Hgt \)

**OCA**

- O.E. Cloud, IR+VIS
- \( \tau_{\text{cloud}}, R_e, Hgt, 2\)-Layer

**RAL ORAC**

- O.E. Cloud + Ash, IR+VIS
- \( \tau_{\text{cloud}}, R_e, Hgt, 2\)-Layer

**UKMO**

- O.E. Ash, IR
- \( \tau_{\text{cloud}}, R_e, Hgt, 2\)-Layer

**Provided courtesy of Philip Watts (RSP-AIA Team)**

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Baseline algorithm for MTG-FCI

Provided courtesy of Philip Watts (RSP-AIA Team)
Aerosol Products from EPS-SG

**EPS-SG 3MI**

- Dedicated to aerosol characterisation for:
  - Climate monitoring
  - Air quality monitoring and forecasting
  - Numerical Weather Prediction

- 2D Push-broom radiometer (2200 km swath, 4 km pixel at nadir)

- Provide images of the Earth TOA outgoing radiance using:
  - Multi-view (10 to 14 views; angular sampling in the order of 10°)
  - Multi-channel (12 channels from 410 to 2130 nm)
  - Multi-polarisation (9 channels with -60°, 0°, +60° polarisers)

- POLDER heritage

- A *synergetic aerosol product* using (VII) METimage, UVN (Sentinel-5) and IAS (IASI-NG) is also planned
3MI observation concept
3MI Multi Viewing Angle Acquisition

3MI footprint (ref. ch. 670 nm)
Orthogonal plot of ref. view #06 and view #00
[lmin, lmax=000,511; pmin, pmax=000,511]
3MI observation concept
3MI Multi Viewing Angle Acquisition

up to 14 views: N = 7
3MI observation concept
3MI Multi Viewing Polarisation Measurements

Radiances

Degree of polarization

EUMETSAT 3MI test-data study

ICAP 2015 - Barcelona 2015  Slide 19
EPS-SG 3MI/Multi-Sensor products

Product chain

3MI- L2 PGF
3MI- L1C PGF
MAP L2 PGF

3MI Level-1B

Multi-Sensor S5/VII/IRS/3MI

EPS-SG Multi-viewing, Multi-spectral, co-registration and co-location

3MI- L2 PGF

3MI-L2 PGF

PGS*

3MI L2 Aerosol/Cloud
from ATBD-aerosol/cloud

VII-cloud

3MI-L1C PGF

PGS*

3MI L1C

EPS-SG L2 PGF

PGS*

EPS-SG Multi-Sensor Aerosol
**EPS-SG 3MI/Multi-Sensor**

**Day-1 products**

**EPS-SG L2 Day-1 aerosol products from 3MI and multi-sensor retrievals**

<table>
<thead>
<tr>
<th>Aerosol products</th>
<th>Units or flags</th>
<th>References</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.1 Aerosol height</strong></td>
<td>km</td>
<td>Buriez et al. (1997); Ferlay et al. (2010); Kokhanovsky and Rozanov (2010); van Diddenhoven et al. (2013)</td>
<td>From $q$ at the wavelengths 410nm/865nm and from the ratio of reflectances at the wavelengths 763, 765nm</td>
</tr>
<tr>
<td><strong>1.2 Aerosol type</strong></td>
<td>1-marine 2-continental 3-polluted 4-smoke 5-dust 6-volcanic ash 7-uncertain</td>
<td>Dubovik et al. (2002) Levy (2009)</td>
<td>The mixed aerosol type can be a mixture of any types of aerosols</td>
</tr>
<tr>
<td><strong>1.3 Effective radius of particles</strong></td>
<td>$\mu$m</td>
<td>Dubovik et al. (2002) Kokhanovsky and de Leeuw (2009)</td>
<td>Most probable value: 0.1-4</td>
</tr>
<tr>
<td><strong>2.1 Aerosol optical thickness</strong></td>
<td></td>
<td>Kokhanovsky and de Leeuw (2009)</td>
<td>Most probable value: 0.05 - 1.0</td>
</tr>
<tr>
<td><strong>2.2 Single scattering albedo</strong></td>
<td></td>
<td>Dubovik et al. (2002)</td>
<td>Most probable value: 0.8 - 1.0</td>
</tr>
<tr>
<td><strong>2.3 Refractive index</strong></td>
<td></td>
<td>Dubovik et al. (2002)</td>
<td>Most probable value: 1) $n=1.34-1.64$; 2) $k=0-0.03$</td>
</tr>
</tbody>
</table>
EPS-SG AC-team 3MI/Multi-Sensor
From Day-1 to Day-2 aerosol products

EPS-SG L2 Day-2 aerosol products from 3MI and multi-sensor retrievals

Day-1: LUT based approach
- Aerosol height
- Aerosol optical depth
- Aerosol type
- Single Scattering Albedo
- Refractive index
- Effective Particle Radius

Day-2: Full scale RTM OE based approach (Full RT-OE or similar)
- Aerosol height
- Aerosol optical depth
- Aerosol type
- Single Scattering Albedo
- Refractive index
- Effective Particle Radius
- ...
- ...
- ...
Aerosol Products from the Sentinels
Sentinel-3/4/5

**Sentinel-3**

- A global Aerosol Optical Depth product will be produced in cooperation with ESA.
- The EUMETSAT – ESA split will be along the lines of near real-time (EUM) and offline, non-time critical (ESA)
  - Version 1 will be based on the University of Swansea algorithm evaluated as part of the ESA Aerosol CCI project

**Sentinel-4**

- Aerosol extinction coeff. profile, column optical depth/type/index products envisaged

**Sentinel-5**

- Aerosol profile product envisaged
Thank You and Questions?
Metop: PMAp operational product

- PMAp: Polar Multi-sensor Aerosol product
  - AOD over ocean, aerosol type classification (fine mode, coarse mode, volcanic ash)
  - Cloud fraction, cloud optical are also provided
  - Delivered as a GOME-2 product (PMD resolution)
  - Pre-operational since Q2/2014
  - Fully operational product quality status since October 14th 2014
  - Distributed by EUMETCast in netcdf4

- Q1/2016: Operational implementation of PMAp Release 2 including retrieval over land