PMAp v.2.2
Aerosol Optical Properties
operational retrieval at global scale

R. Lang, A. Cacciari, A. Holdak, M. Grzegorski, R. Munro, B. Fougnie J. Chimot, R. Lindstrot, G. Poli, R. Huckle, N. Hao, S. Gimeno Garcia
The Polar Multi-sensor Aerosol Product
Operational near-real time AOD from EPS/Metop

OUTLINE

- Sensors’ characteristics and PMAp Aerosol product
- PMAp retrieval algorithm: current operational version 2.1
- New release: version 2.2
  - Impact of the new features
    - IASI IR spectral information for improved ash and dust detection
    - Degradation correction for GOME-2 PMD radiances
  - AERONET Validation outcome
- What’s next
The Polar Multi-sensor Aerosol Product
Operational near-real time AOD from EPS/Metop

**PMAp: Polar Multi-sensor Aerosol product**
from GOME-2, AVHRR and IASI on Metop

- AOD @550nm over land & water aerosol type classification
- at GOME-2 PMD spatial resolution
  10x40 km² Metop-B; 5x40 km² Metop-A
- Retrieval over water
  fully operational product since October 2014
- Retrieval over water & land
  PMAp version 2
  fully operational product since February 2017

**PMAp/A & PMAp/B v2.1** over ocean and land assimilated by CAMS
PMAp: creating a hyper-instrument
Merging spectral and spatial information from GOME-2, AVHRR and IASI

Combining hyper-spectral with hyper-spatial information in a new hyper-instrument
### METOP Level-1 data

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Spatial resolution</th>
<th>Spectral range</th>
<th>comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOME PMD</td>
<td>10 x 40 km Metop-B&lt;br&gt;5 x 40 km Metop-A</td>
<td>311nm-803nm, 15 bands</td>
<td>AOD, aerosol type, AAI Stokes fraction (polarization)</td>
</tr>
<tr>
<td>AVHRR</td>
<td>1.08 x 1.08 km</td>
<td>580nm-12500nm, 5 bands</td>
<td>Clouds, scene heterogeneity, dust/ash</td>
</tr>
<tr>
<td>IASI</td>
<td>12km (circular)</td>
<td>3700–15500nm, resolution 0.5 cm⁻¹</td>
<td>volcanic ash, desert dust, aerosol heights</td>
</tr>
</tbody>
</table>

### Auxiliary data & static DB

<table>
<thead>
<tr>
<th>Data</th>
<th>Purpose</th>
<th>comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECMWF forecast</td>
<td>Wind speed&lt;br&gt;Surface pressure</td>
<td>- ocean reflection parameterization&lt;br&gt;Rayleigh scattering over land</td>
</tr>
<tr>
<td>Surface Reflectance DB</td>
<td>- over land retrieval</td>
<td>Minimum LER&lt;br&gt;(from G.Tilstra, KNMI)</td>
</tr>
<tr>
<td>GOME2 LER DB (angular dependent)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface elevation DB E-TOPO5</td>
<td>- over land retrieval</td>
<td></td>
</tr>
<tr>
<td>RT data LUT - TOA Reflectance and Stokes fraction for 28 aerosol models</td>
<td>- RT calculation interpolation</td>
<td>Hasekamp et al., 2008</td>
</tr>
</tbody>
</table>
PMAp AOP retrieval algorithm design

v 2.1 current operational release

Cloud / Aerosol Discrimination

- **Volcanic Ash Detection**
  10 set of thresholds tests AVHRR + IASI BTDs tests → Ash presence

- **Clouds’ Detection & Correction**
  clouds detection and cloud fraction calculation (CF)
  cloud free PMD Reflectance .OR. PMD Reflectance Correction (for CF < 0.65; partly cloudy pixels)

- **Preliminary Aerosol Type**
  if Ash presence → aerosol type = ash
  VIS/NIR test for Coarse/Fine mode determination

Retrieve AODs

- AODs retrieval for all aerosol models in the LUT
  over water PMD 12 (617.867 - 661.893 nm)
  over land PMD 8 (399.581 - 428.585 nm) or PMD 7 (380.186 - 383.753 nm)

best fit selection

- Microphysics fit : \( \chi^2 \) minimization of the AODs
  if cloud free: list of preselected aerosol types
  if partly cloud: all aerosol models
- Estimation of error on AOD

\[ \text{best } \{\text{AOD, aerosol type}\} \]
Volcanic Ash Detection
10 set of thresholds tests AVHRR + IASI BTDs tests \(\rightarrow\) Ash presence

Desert Dust Detection
IASI dust index \(\rightarrow\) Dust presence

Clouds’ Detection & Correction
clouds detection and cloud fraction calculation (CF)
cloud free PMD Reflectance .OR. PMD Reflectance Correction (for CF < 0.65; partly cloudy pixels)

Preliminary Aerosol Type
if Ash presence \(\rightarrow\) aerosol type = ash
if Dust presence \(\rightarrow\) aerosol type = dust
VIS/NIR test for Coarse/Fine mode determination

List of preselected aerosol types

Retrieve AODs
- AODs retrieval for all aerosol models in the LUT
  over water PMD 12 (617.867 - 661.893 nm)
  over land PMD 8 (399.581 - 428.585 nm) or PMD 7 (380.186 - 383.753 nm)

Best fit selection
- Microphysics fit: \(\chi^2\) minimization of the AODs
  if cloud free: list of preselected aerosol types
  if partly cloud: all aerosol models
- Estimation of error on AOD
  \(\rightarrow\) best {AOD, aerosol type}
The Polar Multi-sensor Aerosol Product
Operational near-real time products from EPS/Metop

Product delivery features

• **NRT 3 minutes granules**: maximum 3 hours after sensing time - Available via EUMETCast in netcdf4.

• **Full orbit offline data** - Available from the EUMETSAT archive EPS native and netcdf4. [http://archive.eumetsat.int](http://archive.eumetsat.int)
PMAp v.2.2 AOP retrieval

Dust detection scheme
Unified approach to detect aerosol type exploiting the IR spectral range

**Distance approach**

Set of ‘polluted’ spectra
ash, dust, same aerosol type

\[ \mu_p \text{ mean spectra } \]

by RTM simulation \( \mu_p = K + \mu_c \)
or measured

Set of clear spectra
not affected by aerosol

\[ \mu_c \text{ mean spectra } \]

\[ S_c \text{ clear covariance matrix } \]

\[ R_N = \frac{(\mu_p - \mu_c)^T S^{-1}}{\sqrt{(\mu_p - \mu_c)^T S^{-1} (y - \mu_c)}} (y - \mu_c) \]

\( Y = \text{measured spectra} \)
\( G = f(\lambda, \text{surf\_type}) \)
\( C = \text{bias correction}; f(\text{lon,lat}) \)

threshold to be manually tuned

\[ R_N = G (y - \mu_c) + C \]

\( \geq \text{threshold} \)

PMAp AOP retrieval
desert dust detection

A unified approach to infrared aerosol remote sensing and type specification

L. Clarisse\(^1\), P.-E. Coheur\(^1\), F. Prata\(^1\), J. Hadji-Lazaro\(^1\), D. Hurtmans\(^1\), and C. Clerbaux\(^3,4\)

**Atmos. Chem. Phys., 13, 2195–2221, 2013**

[www.atmos-chem-phys.net/13/2195/2013/](http://www.atmos-chem-phys.net/13/2195/2013/)

doi:10.5194/acp-13-2195-2013

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PMAp AOP retrieval
desert dust detection

Dust Index

Aerosol Class
- 0 fine mode
- 1 coarse mode
- 3 volcanic ash / t
- 4 volcanic ash wil
PMAp AOP retrieval
desert dust detection
The Polar Multi-sensor Aerosol Product
Operational near-real time products from EPS/Metop

Aerosol Class
- fine mode
- coarse mode
- volcanic ash / thick dust
- volcanic ash with SO$_2$

AOD @ 550 nm
The Polar Multi-sensor Aerosol Product (AOP) from EPS/Metop

16 – 23 / 05
Metop A & B
PMAp v2.2 AOP retrieval

Lev1B → Lev1C: impact on AOD retrieval
PMAp AOP retrieval
Lev1B → Lev1C: impact on AOD retrieval

over water
PMD 12 (617.867 - 661.893 nm)

over land
PMD 8 (399.581 - 428.585 nm)
PMD 7 (380.186 - 383.753 nm)
PMAp AOP retrieval
Lev1B → Lev1C: impact on AOD retrieval

AOD_1B - AOD_1C

over water
PMD 12 (617.867 - 661.893 nm)

over land
PMD 8 (399.581 - 428.585 nm)
PMD 7 (380.186 - 383.753 nm)
PMAp Validation Data Set
period 1. June - September 2013
period 2. February - May 2015

AERONET Data Set
Co-located: 30 min & 30 km
AERONET AOD@ 550 nm

Over Ocean 23 sites
Over Land 121 sites

PMAp vs AERONET
### PMAP v2.2 AOP retrieval

#### AOD Validation

**Water surface**

#### PMAP 2.1 vs Aeronet Lev2  Over Ocean

<table>
<thead>
<tr>
<th></th>
<th>June - Sept 2013</th>
<th>Feb-May 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>METOP-B</td>
<td>METOP-A</td>
</tr>
<tr>
<td><strong>gain</strong></td>
<td>0.838</td>
<td>0.783</td>
</tr>
<tr>
<td><strong>bias</strong></td>
<td>0.076</td>
<td>0.045</td>
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<tr>
<td><strong>correlation</strong></td>
<td>0.870</td>
<td>0.836</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>110</td>
<td>90</td>
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</tbody>
</table>

#### PMAP 2.2 vs Aeronet Lev2  Over Ocean

<table>
<thead>
<tr>
<th></th>
<th>June - Sept 2013</th>
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<tbody>
<tr>
<td></td>
<td>METOP-B</td>
<td>METOP-A</td>
</tr>
<tr>
<td><strong>gain</strong></td>
<td>0.949</td>
<td>0.922</td>
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<tr>
<td><strong>bias</strong></td>
<td>0.098</td>
<td>0.049</td>
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<tr>
<td><strong>correlation</strong></td>
<td>0.549</td>
<td>0.819</td>
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<tr>
<td><strong>N</strong></td>
<td>110</td>
<td>92</td>
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</table>

(Popp et al. 2016)
PMAp v2.2  AOP retrieval
AOD Validation
Water surface

AOD @ 550 nm  PMAp/METOP–B

AOD @ 550 nm  PMAp/METOP–A
### PMAp 2.1 vs Aeronet Lev2  Over Land

<table>
<thead>
<tr>
<th></th>
<th>June - Sept 2013</th>
<th>Feb-May 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>METOP-B</strong></td>
<td>0.597</td>
<td>0.540</td>
</tr>
<tr>
<td><strong>METOP-A</strong></td>
<td>0.752</td>
<td>0.503</td>
</tr>
<tr>
<td><strong>gain</strong></td>
<td>0.113</td>
<td>0.168</td>
</tr>
<tr>
<td><strong>bias</strong></td>
<td>0.081</td>
<td>0.158</td>
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<tr>
<td><strong>correlation</strong></td>
<td>0.589</td>
<td>0.552</td>
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<tr>
<td><strong>N</strong></td>
<td>906</td>
<td>1232</td>
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</tbody>
</table>

### PMAp 2.2 vs Aeronet Lev2  Over Land

<table>
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<tr>
<th></th>
<th>June - Sept 2013</th>
<th>Feb-May 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>METOP-B</strong></td>
<td>0.762</td>
<td>0.839</td>
</tr>
<tr>
<td><strong>METOP-A</strong></td>
<td>0.979</td>
<td>0.615</td>
</tr>
<tr>
<td><strong>gain</strong></td>
<td>0.128</td>
<td>0.189</td>
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<tr>
<td><strong>bias</strong></td>
<td>0.057</td>
<td>0.108</td>
</tr>
<tr>
<td><strong>correlation</strong></td>
<td>0.431</td>
<td>0.559</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>931</td>
<td>1675</td>
</tr>
</tbody>
</table>

(Popp et al. 2016)
PMAp v2.2 AOP retrieval
AOD Validation
Land surface

Pokhara

AERONET station: Pokhara
AOD @ 550 nm PMAp/METOP–B

Silpakorn

AERONET station: Silpakorn Univ
AOD @ 550 nm PMAp/METOP–A

Beijing - radi

AERONET station: Beijing PACE
AOD @ 550 nm PMAp/METOP–A

Kaust Campus
What comes next?

- PMAp v.2.2 validation data set delivered to CAMS for evaluation
  
  Internal Validation Review Board

  Product ready for dissemination by September 2018

  Metop-A and Metop-B

- PMAp operational chain tests for Metop-C

  launch scheduled on 21 September 2018

  extending the 2006 - 2017 data record to 2006 - 2027
Thank you