

AEROSOL PRODUCT DEVELOPMENT ACTIVITIES AT EUMETSAT



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P. Watts (AIA)



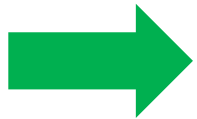
EUMETSAT operational products

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:

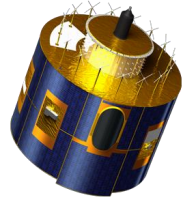
- **High availability (>98%)**
- **Delivery within 3 hours from sensing (LEO)**
- **Delivery within minutes to 1 hour of sensing (for GEO)**
- **24/7 maintenance / monitoring support**



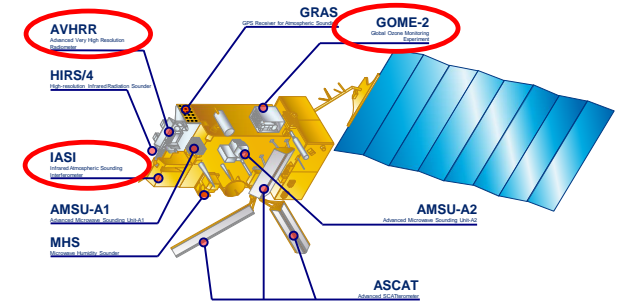
Severely limits the number of products and algorithms suitable for being implemented as this kind of operational product!

EUMETSAT Missions

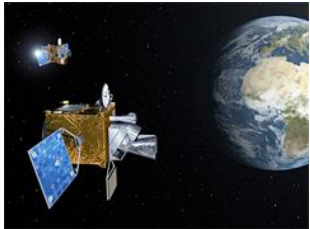
Providing Aerosol and Volcanic Ash Operational Products in NRT



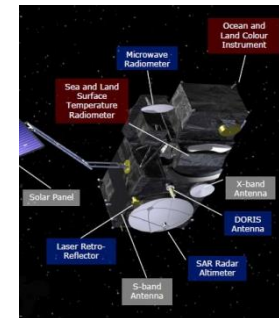
Metop Multi-mission product (PMAp)
Metop GOME-2 (Metop-A/B/C 2007-2025)
MSG (Seviri 1997-2025)



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



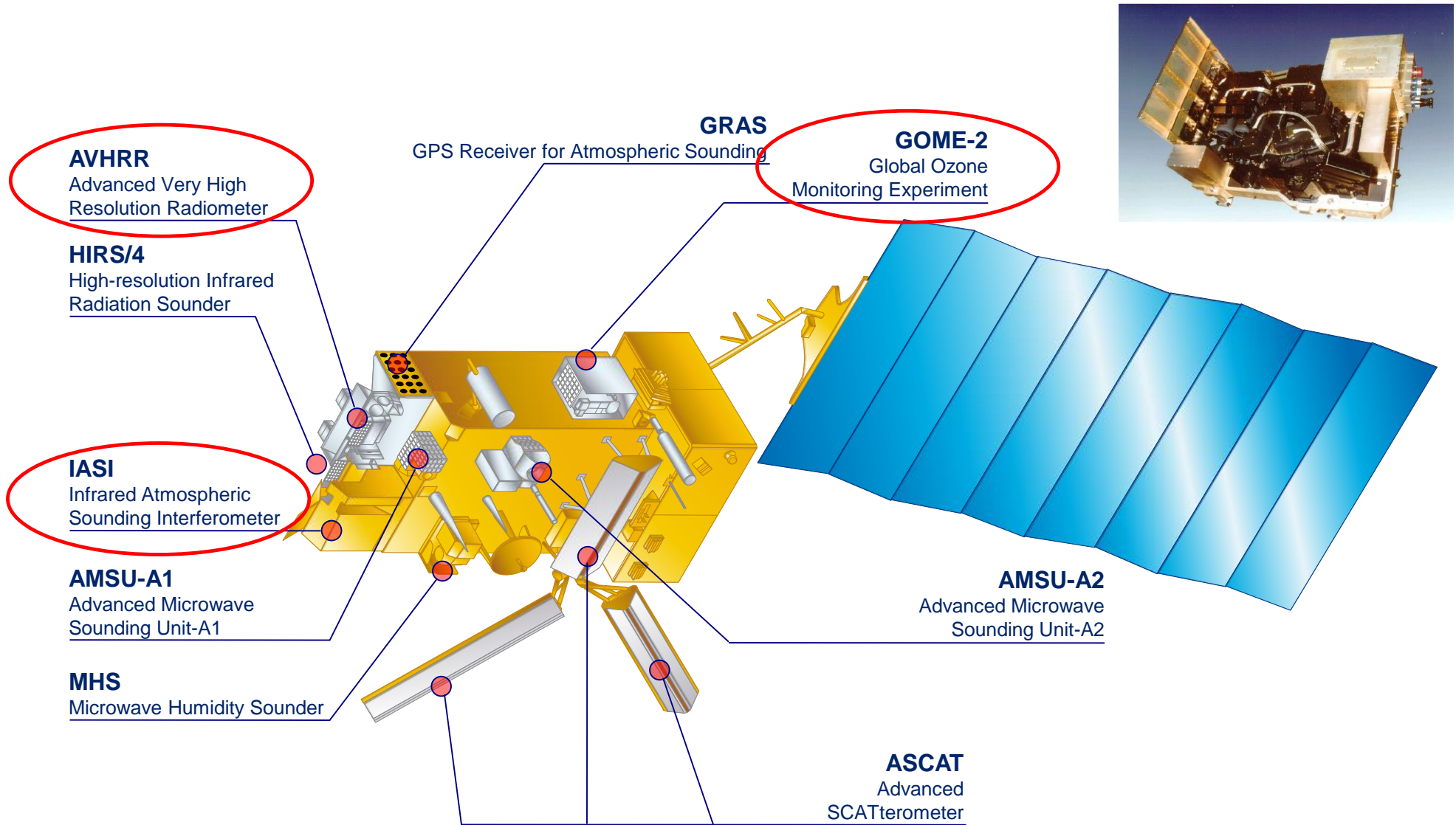
MTG UVN (Sentinel-4)
MTG FCI & IRS (MTG launch in 2020)



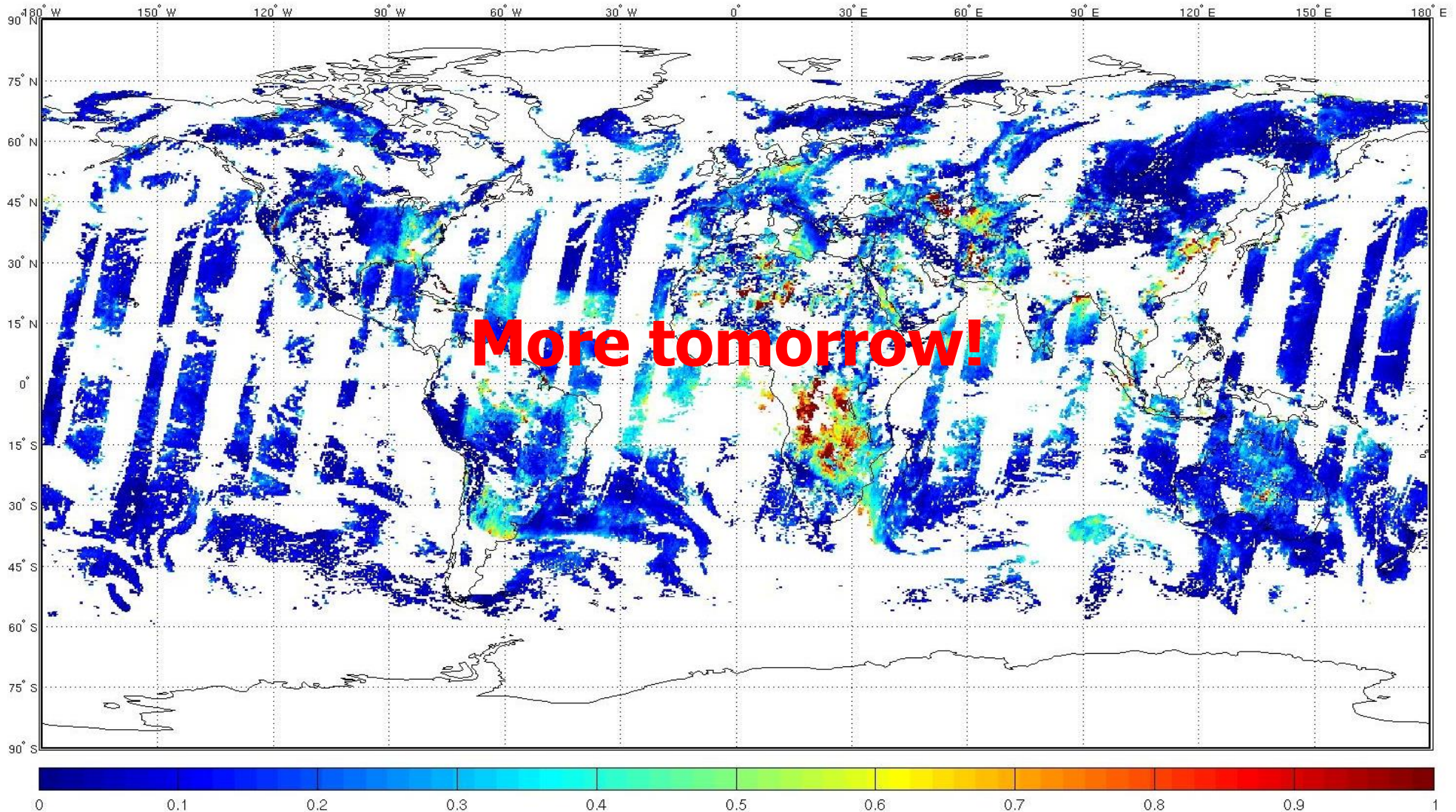
EPS-SG 3MI
EPS-SG UVNS (Sentinel-5)
EPS-SG VII
EPS-SG IAS (EPS-SG launch in 2021)



Current Capabilities - EUMETSAT Polar System



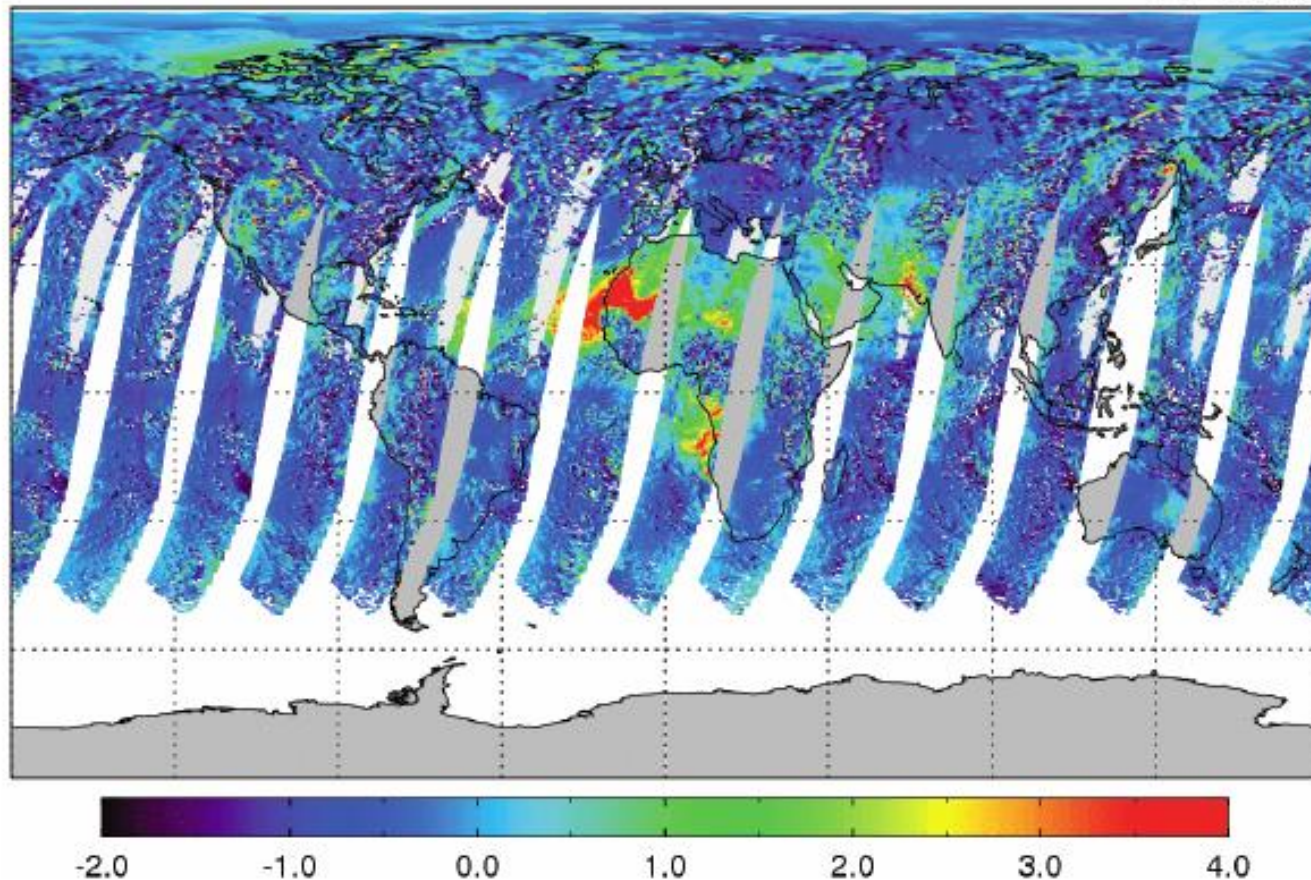
PMAp results: AOD Metop A & Metop B (30/08/2013)



Metop-GOME-2 level 2 products

Absorbing and Scattering Aerosol/UV Index (UVAI)

KNMI O3MSAF EUMETSAT 16 July 2007 Metop-A/GOME-2 AAI time stamp:
21-04-2010 15:31



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

$$UVAI = -100 \cdot \left\{ {}^{10}\log\left(\frac{I_{\lambda}}{I_{\lambda_0}}\right)^{meas} - {}^{10}\log\left(\frac{I_{\lambda}}{I_{\lambda_0}}\right)^{Ray} \right\}$$

$\lambda = 340 \text{ nm}$

$\lambda_0 = 380 \text{ nm}$

No cloud filter applied!

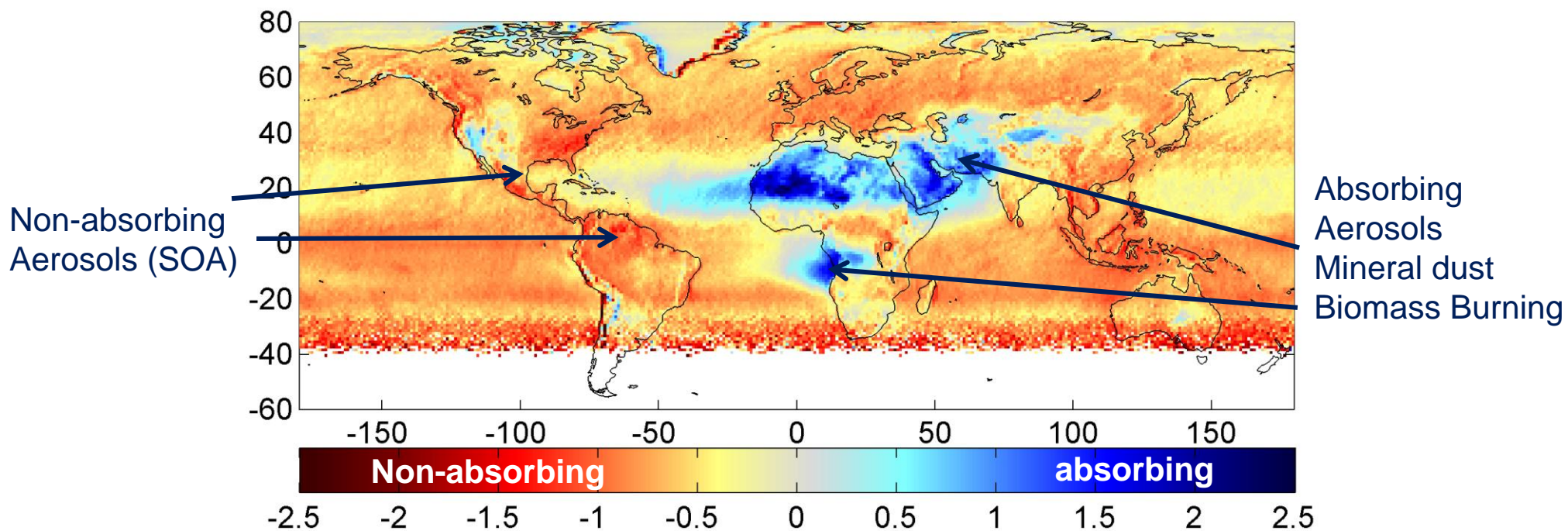
Courtesy Tilstra, Tuinder, Stammes, KNMI

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

The screenshot displays the SACS website interface. At the top, it features the ESA logo and the text "Support to Aviation Control Service" and "Belgian Institute for Space Aeronomy". Navigation tabs include "NEAR REAL-TIME", "NOTIFICATIONS", "PRODUCTS", and "HIGHLIGHTS".

On the left side, there are links for "latest SO₂ notification" and "latest ASH notification", along with a "subscription SACS notif." button. Below this, the "Instrument" section lists "UV-Vis" (GOME 2 [A&B], OMI, OMPS) and "InfraRed" (IASI [A], IASI [B], AIRS). The "Time of observations" section shows "30 November 2014" with navigation options for day, month, and year, and a "today" button. A "World view" map is located at the bottom left.

The main content area shows "obs. of" with buttons for "SO₂", "Ash / AAI", and "Cloud". Two maps are displayed for "30 November 2014":

- SO2 detection:** SO2 vertical column [DU] composite GOME-2 [MetOp A&B] - DLR/BIRA-IASB/EUMETSAT. The map shows a color-coded SO2 vertical column over the Atlantic Ocean, with a prominent plume from the Cap Verde volcanic region. A blue arrow points to this plume with the label "Cap Verde volcanic SO2 emissions".
- Aerosols / Ash:** Absorbing aerosol index (using PMDs) GOME-2 (METOP-B) - KNMI/OMSAF/EUMETSAT. The map shows a color-coded aerosol index over the same region, with a plume from the Cap Verde volcanic region. A blue arrow points to this plume with the label "Dust signal".

Below the maps, the text "30. November 2014" is displayed. A "Back" button is visible on the right side of the map area.

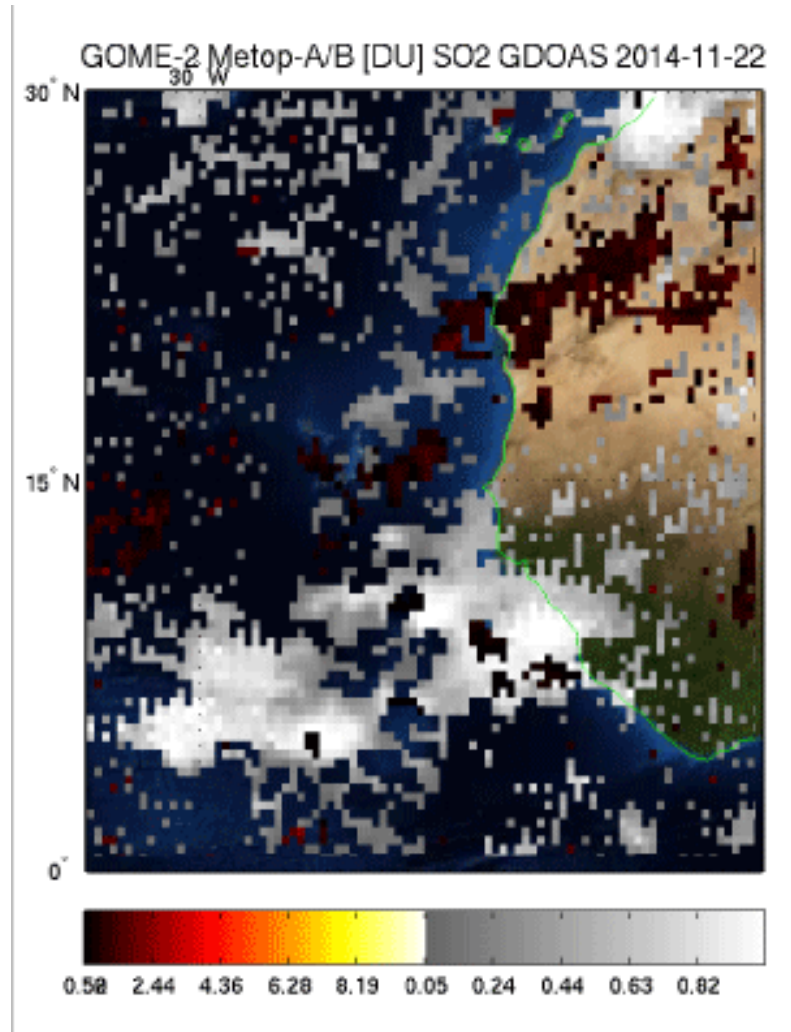
<http://sacs.aeronomie.be>

SO2 monitoring from Metop (GOME-2 / IASI)

Observing volcanic eruption and dust events for aviation control

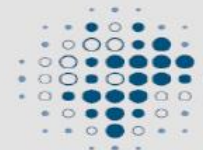
Cap Verde eruption
November 2014

GOME-2 Metop-A/B



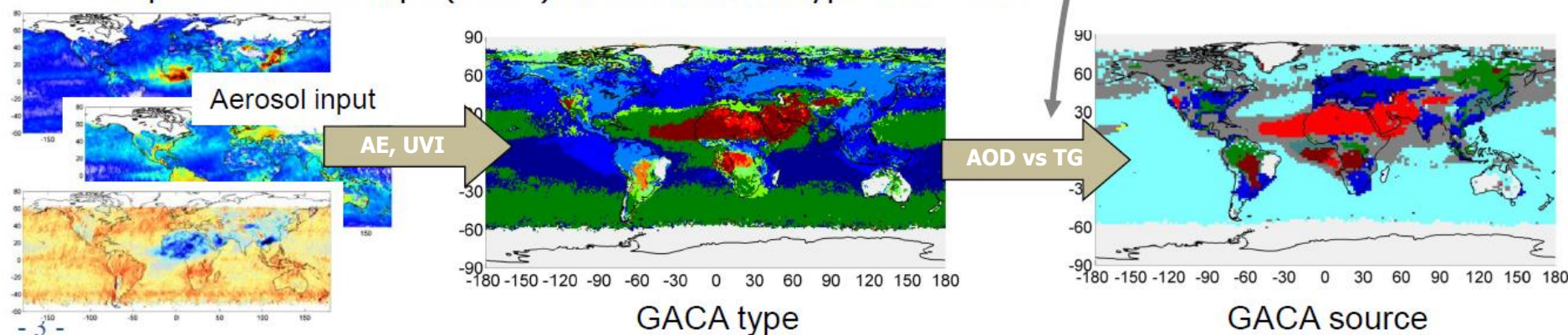
Combining aerosol and trace-gas level 2 products from Metop GACA

GACA Global Aerosol Characterization Algorithm



MAX-PLANCK-INSTITUT
FÜR CHEMIE

- Satellite remote sensing of aerosol properties is difficult
- Aerosols and trace gases often have similar sources
- Study relationship between NO_2 , HCHO , SO_2 , CO and AOT ¹
- UV Aerosol Indices and extinction Ångström exponent indicate particle properties (absorption, size)
- Input: monthly mean maps with $1^\circ \times 1^\circ$ resolution
- Output: seasonal maps ($2^\circ \times 2^\circ$) of main aerosol type and source



¹Veefkind 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

τ_{cloud} , R_e , Hgt



OCA

O.E. Cloud, IR+VIS

τ_{cloud} , R_e



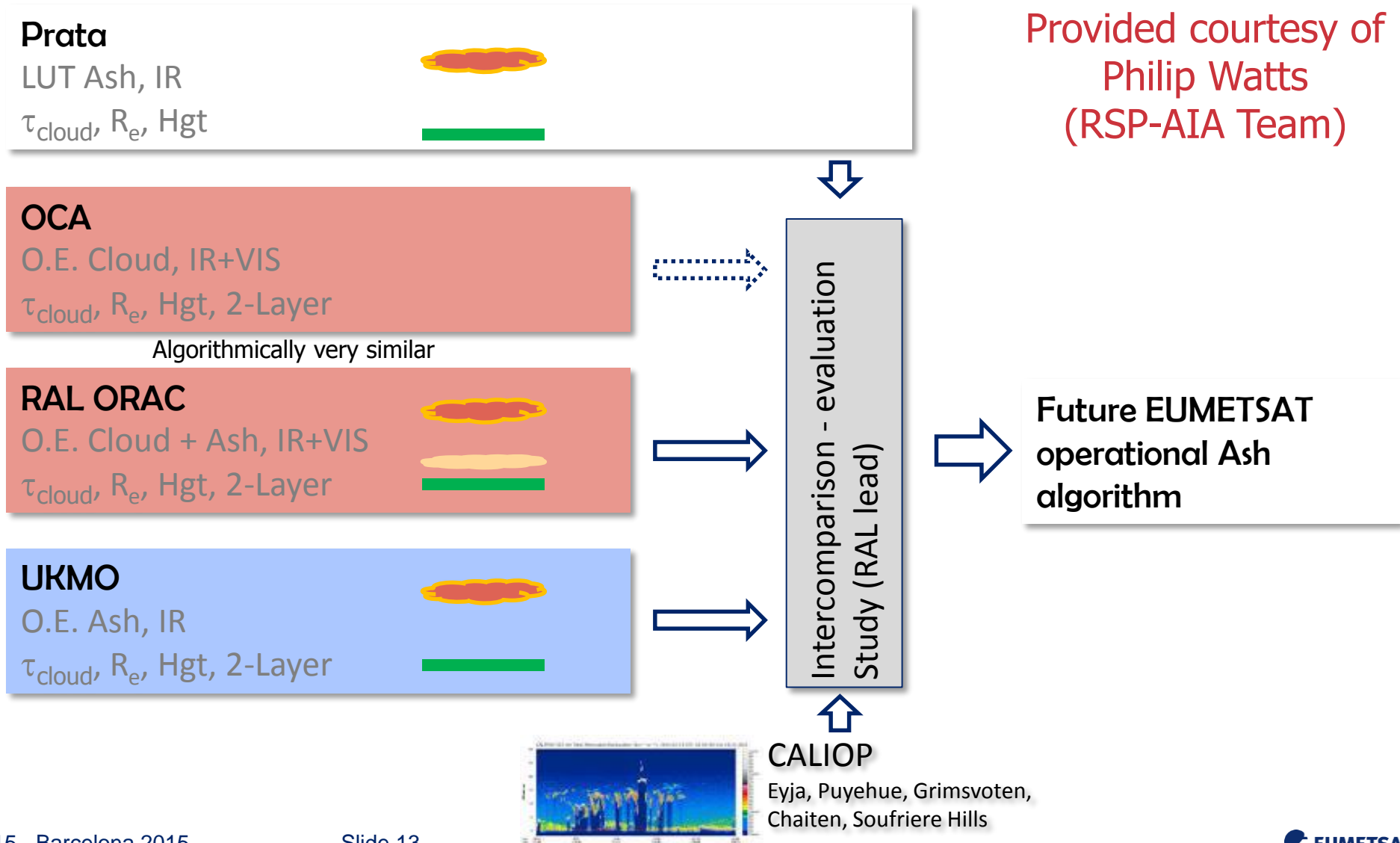
Provided courtesy of
Philip Watts
(RSP-AIA Team)

Current operational
operational Ash
(Prata) and cloud
(OCA) algorithms

MSG-Seviri Volcanic Ash

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

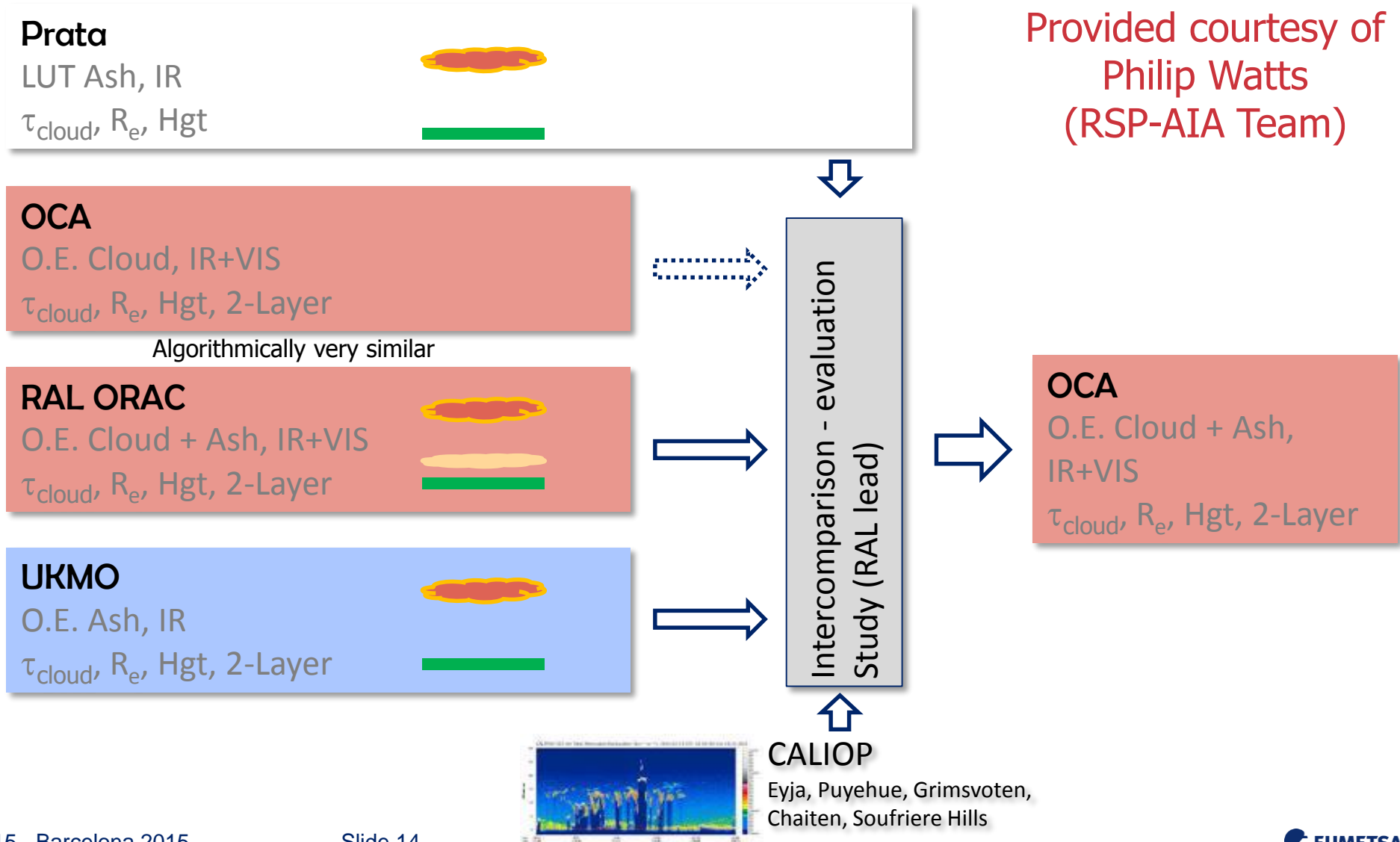
Provided courtesy of
Philip Watts
(RSP-AIA Team)



MSG-Seviri Volcanic Ash

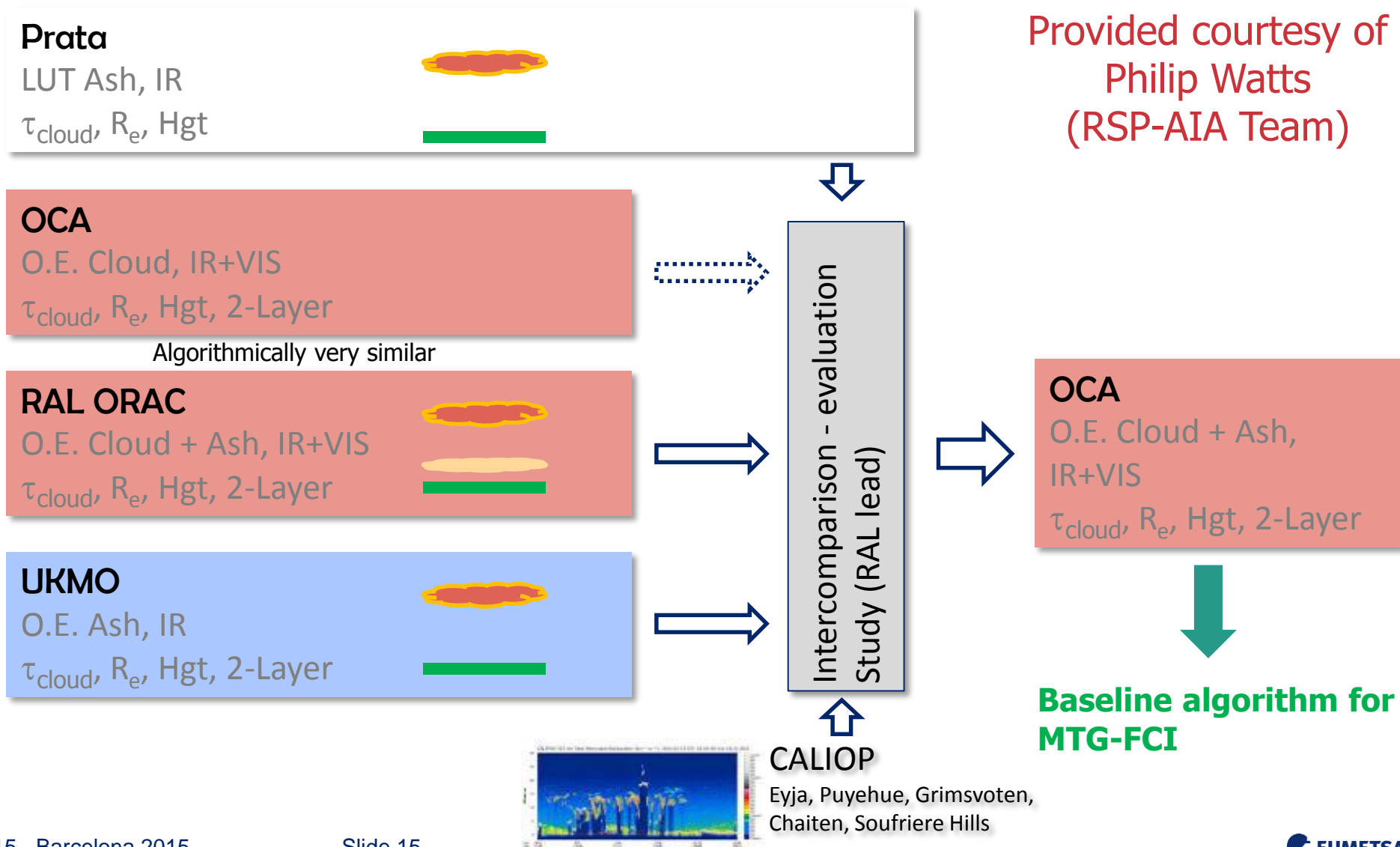
Ash (and cloud) product development – Inter-comparison Study (RAL)

Provided courtesy of
Philip Watts
(RSP-AIA Team)



MSG-Seviri/MTG Volcanic Ash

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



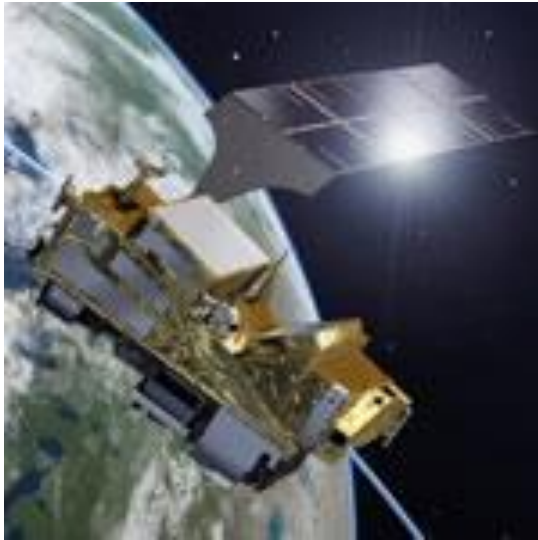
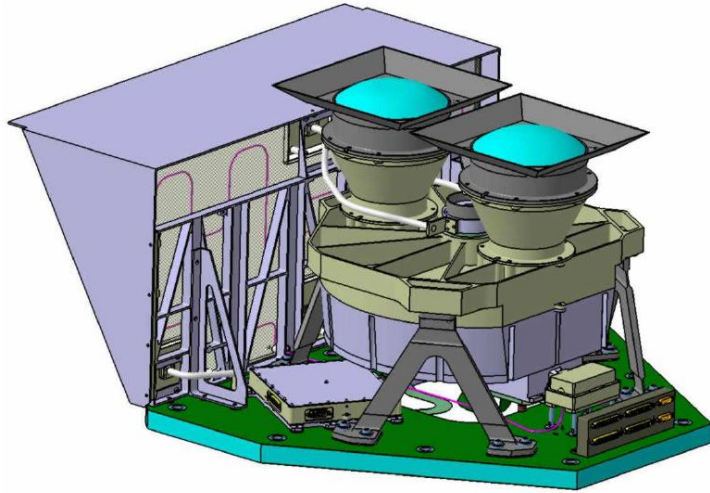
Aerosol Products from EPS-SG

EPS-SG 3MI

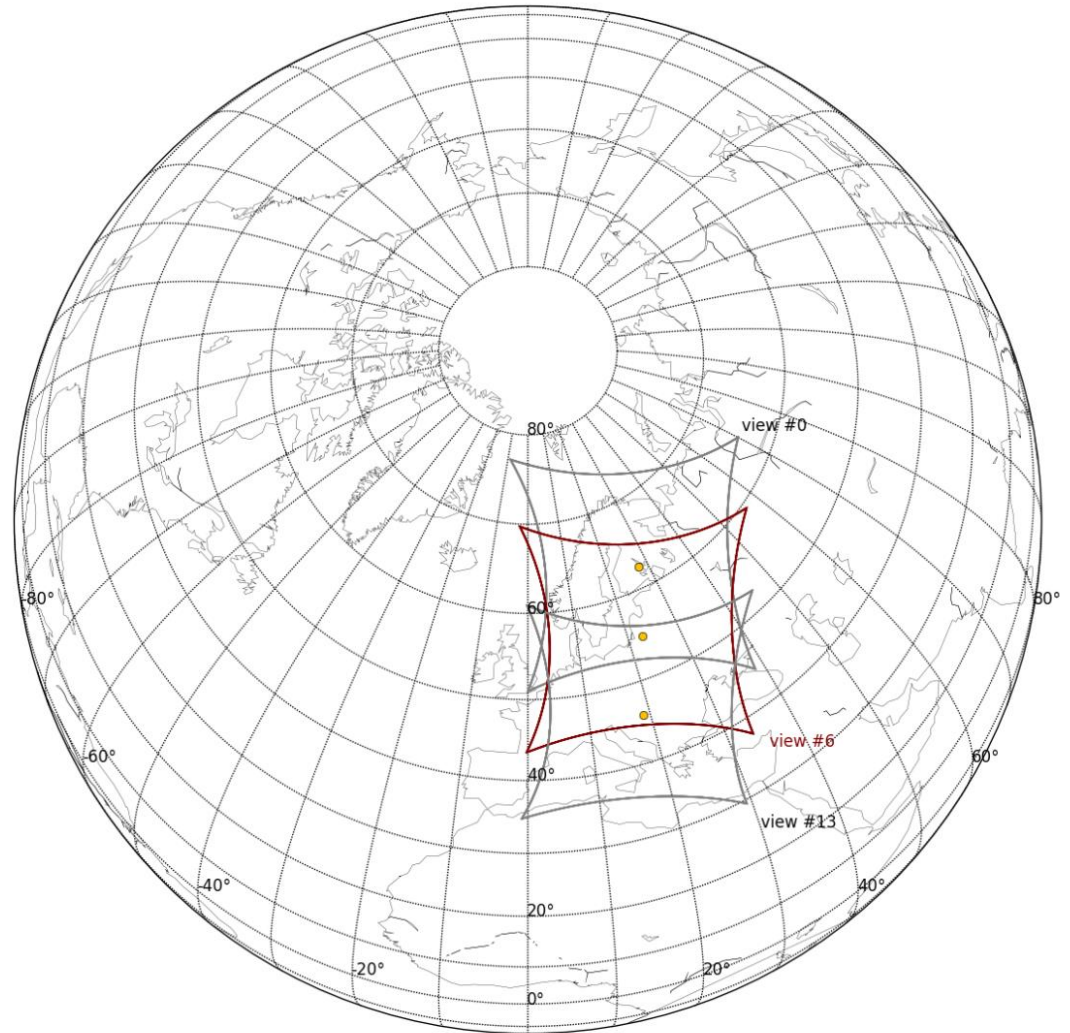
- Dedicated to aerosol characterisation for:
 - Climate monitoring
 - Air quality monitoring and forecasting
 - Numerical Weather Prediction
- 2D Push-broom radiometer (2200 km swath, 4 km pixel at nadir)
- Provide images of the Earth TOA outgoing radiance using:
 - Multi-view (10 to 14 views; angular sampling in the order of 10°)
 - Multi-channel (12 channels from 410 to 2130 nm)
 - Multi-polarisation (9 channels with -60° , 0° , $+60^\circ$ 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



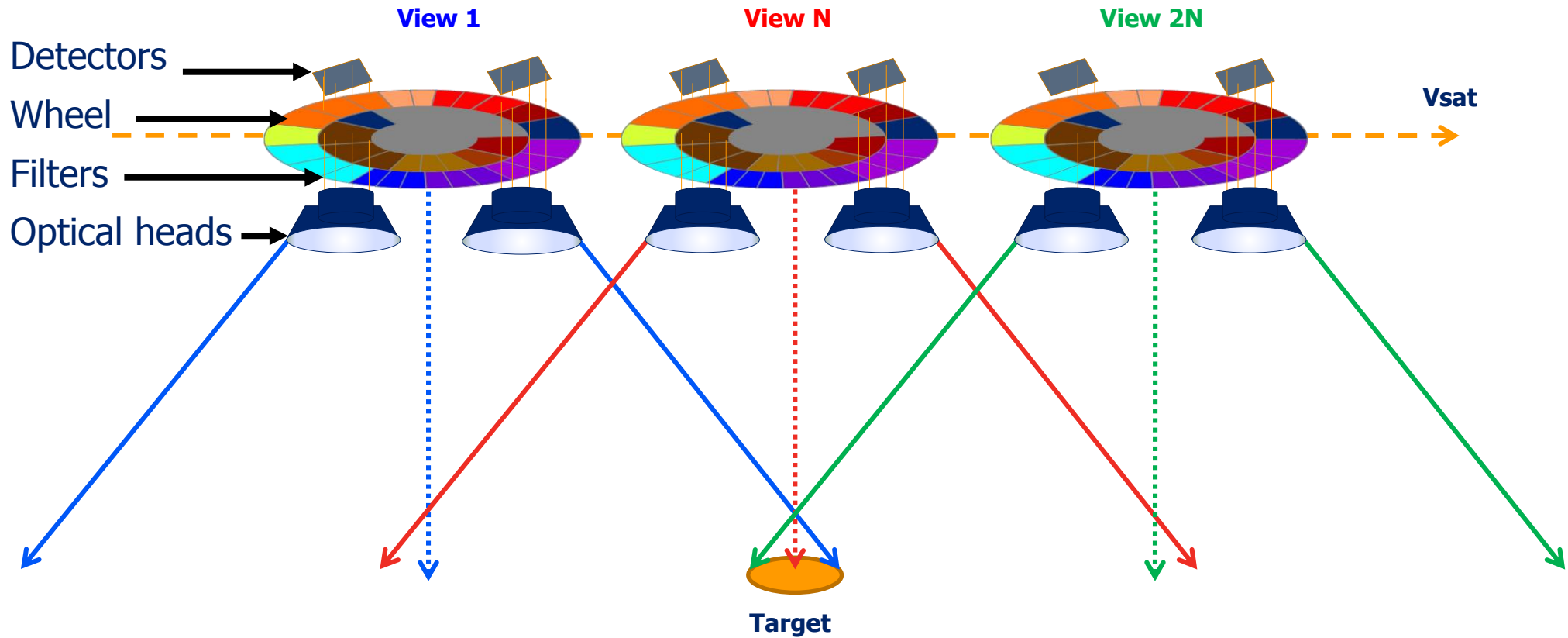
3MI footprint (ref. ch. 670 nm)
Orthogonal plot of ref. view #06 and view #00
[lmin,lmax=000,511; pmin,pmax=000,511]



3MI observation concept

3MI Multi Viewing Angle Acquisition

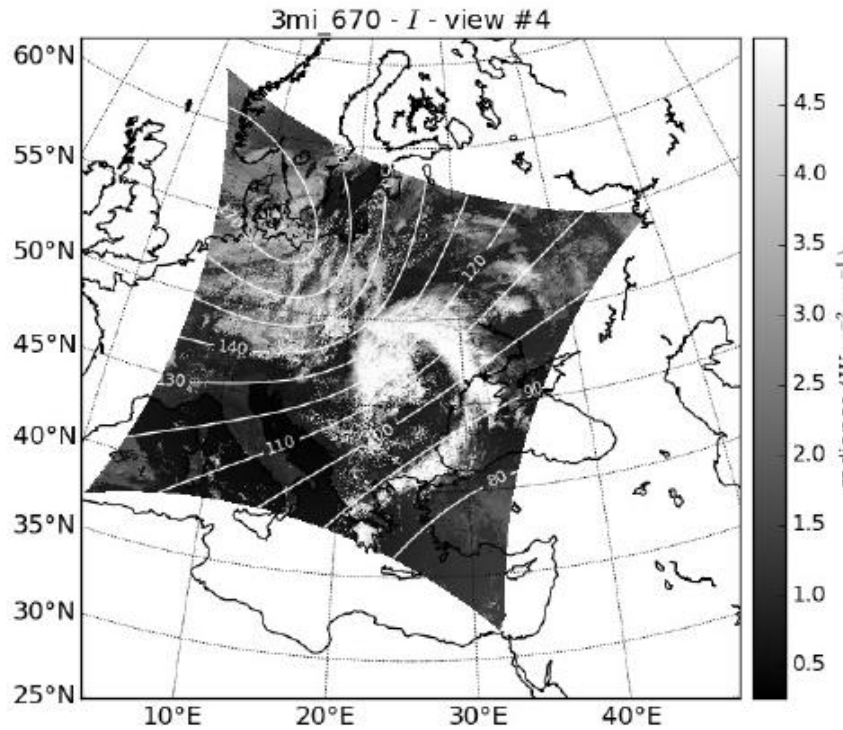
up to 14 views: $N = 7$



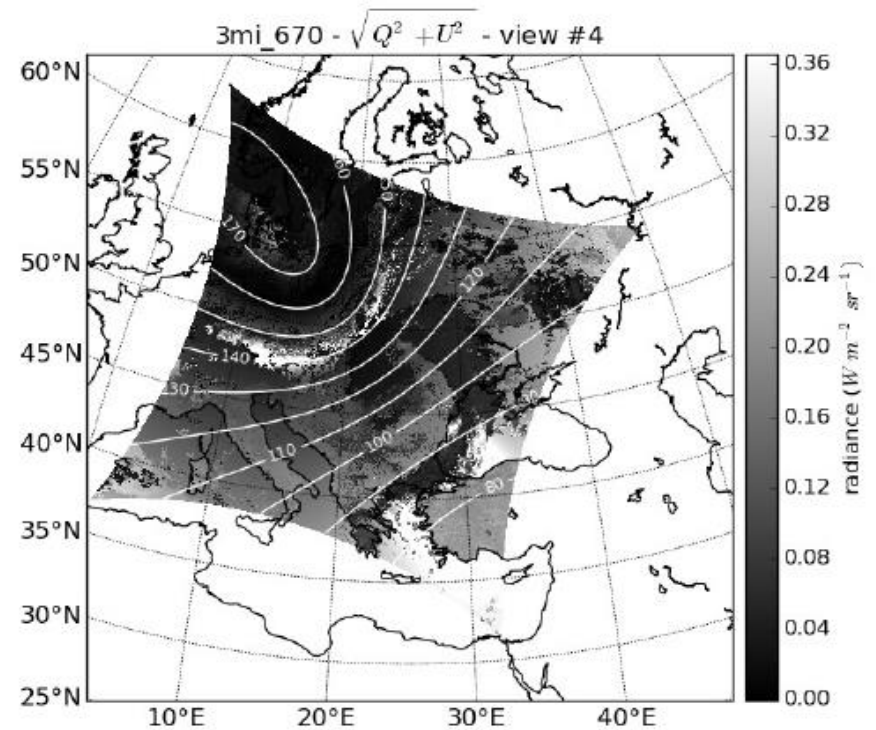
3MI observation concept

3MI Multi Viewing Polarisation Measurements

Radiances



Degree of polarization



EUMETSAT 3MI test-data study



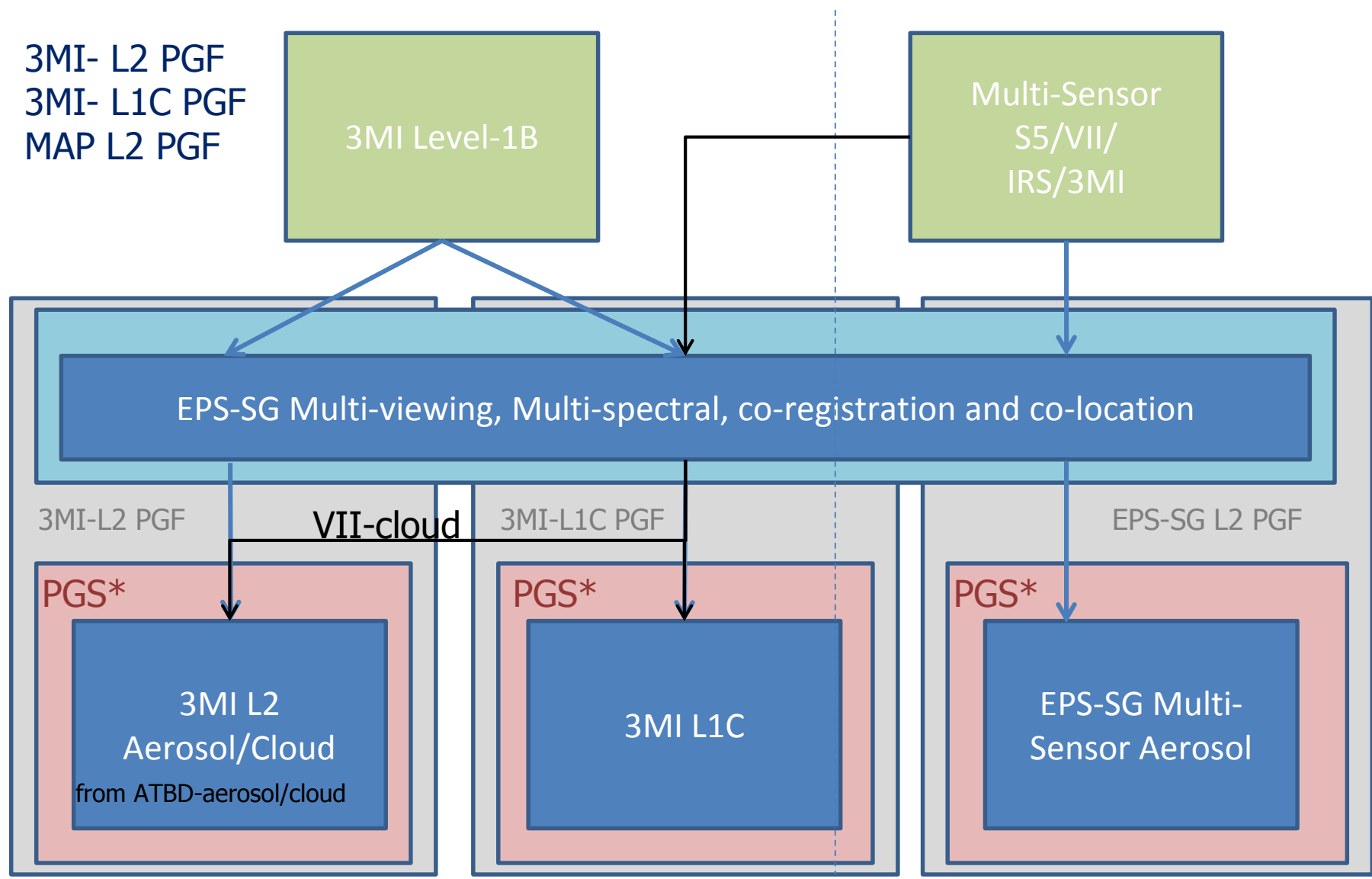
Freie Universität



Berlin

EPS-SG 3MI/Multi-Sensor products

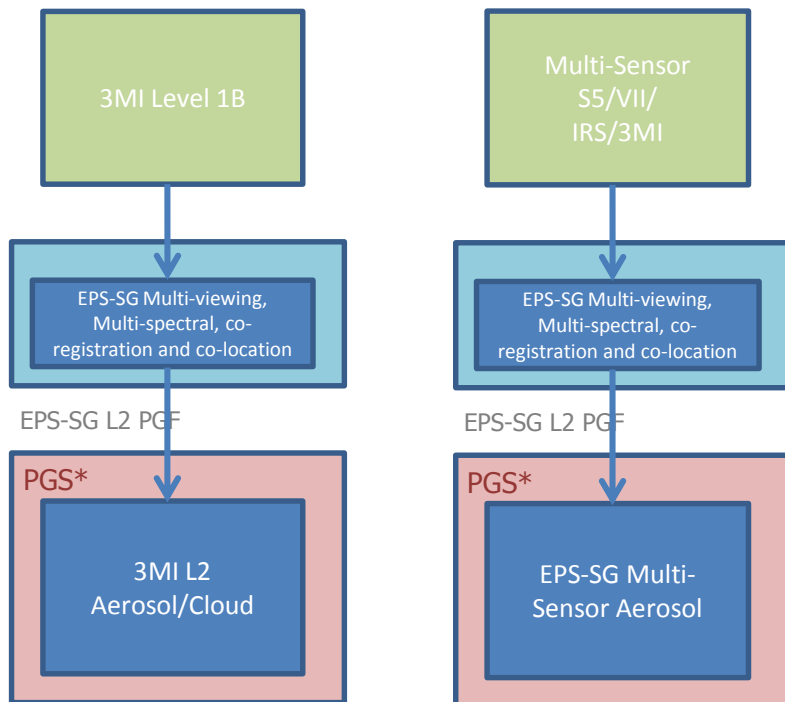
Product chain



EPS-SG 3MI/Multi-Sensor

Day-1 products

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



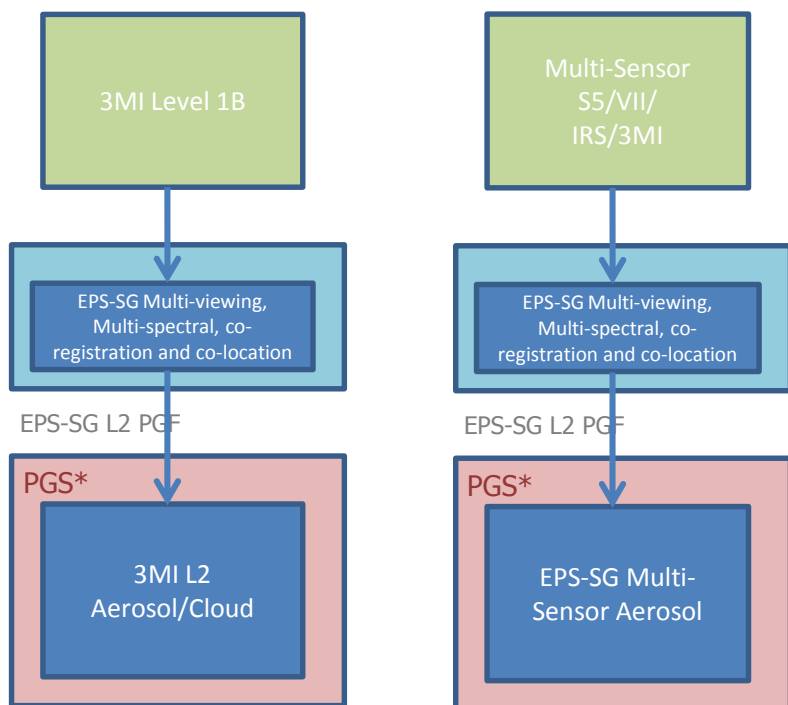
| Aerosol products | Units or flags | References | Comments |
|--|--|--|---|
| 1.1 Aerosol height | km | Buriez et al. (1997); Ferlay et al. (2010); Kokhanovsky and Rozanov(2010); van Didenhoven et al. (2013) | From q at the wavelengths 410nm/865nm and from <i>the ratio</i> of reflectances at the wavelengths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

$$B_{\sigma}^n = n - ik$$

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
“North, P.R.J. et al, 10-09-2012, ESA Climate Change Initiative aerosol_cci, Algorithm Theoretical Basis Document (ATBD), Instruments: AATSR-2 and AATSR, Algorithm: SU-ATSR Version 2.0”

Sentinel-4

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

Sentinel-5

- Aerosol profile product envisaged

**Development of algorithms
under the responsibility of ESA**

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**