

Aerosol observations from current and future EUMETSAT and Copernicus Missions

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Aerosol Product Map

Missions & Products

Operational

In development

Not yet committed
(under study)

Not Applicable

| Product* / Instrument | Metop | MSG | Sentinel 3 | | | Metop-SG | | | MTG | |
|------------------------------------|-------------|-------------|-------------------|-------------------|----------------|-------------------|----------------|-------------------|----------------|----------------|
| | PMAP | SEVIRI | OLCI | SLSTR | SYN | 3MI | S5 UVNS | MAP | FCI | S4 UVN |
| Cloudy pixel identification | Operational | | Operational | Operational | In development | In development | | In development | | |
| Aerosol type | Operational | | | | | In development | | In development | | |
| Fine mode fraction | Operational | | | In development | | In development | | In development | | |
| Aerosol Optical Depth | Operational | Operational | Not yet committed | In development | | In development | In development | In development | In development | In development |
| Aerosol Optical Depth (multi-band) | | | Not yet committed | In development | | In development | | In development | | |
| Single Scattering Albedo | | | Not yet committed | | | In development | | In development | | |
| Refractive index – real | | | | | | In development | | In development | | |
| Refractive index – imaginary | | | | Not yet committed | | In development | | In development | | |
| Effective radius | | | Not yet committed | | | In development | | In development | | |
| Aerosol height | | | Not yet committed | | | In development | In development | In development | | In development |
| Aerosol Absorbing Index | | | | | | Not yet committed | In development | Not yet committed | | In development |
| Side Product: BPDF | | | | | | In development | | In development | | |
| Side Product: BRDF | | | | | | In development | | In development | | |

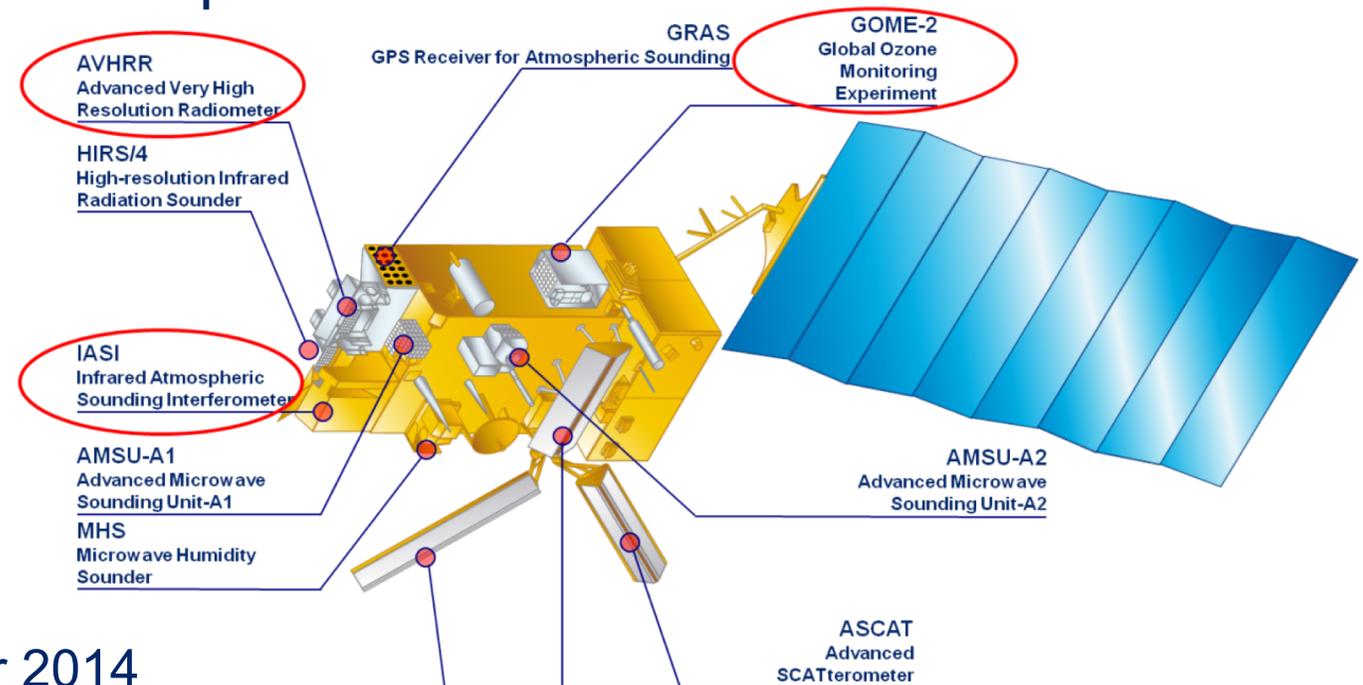
* Some aerosol products at Satellite Application Facilities : Climate Monitoring (CM-SAF) and Atmospheric Composition (AC-SAF)

The Polar Multi-sensor Aerosol Product (PMAp)

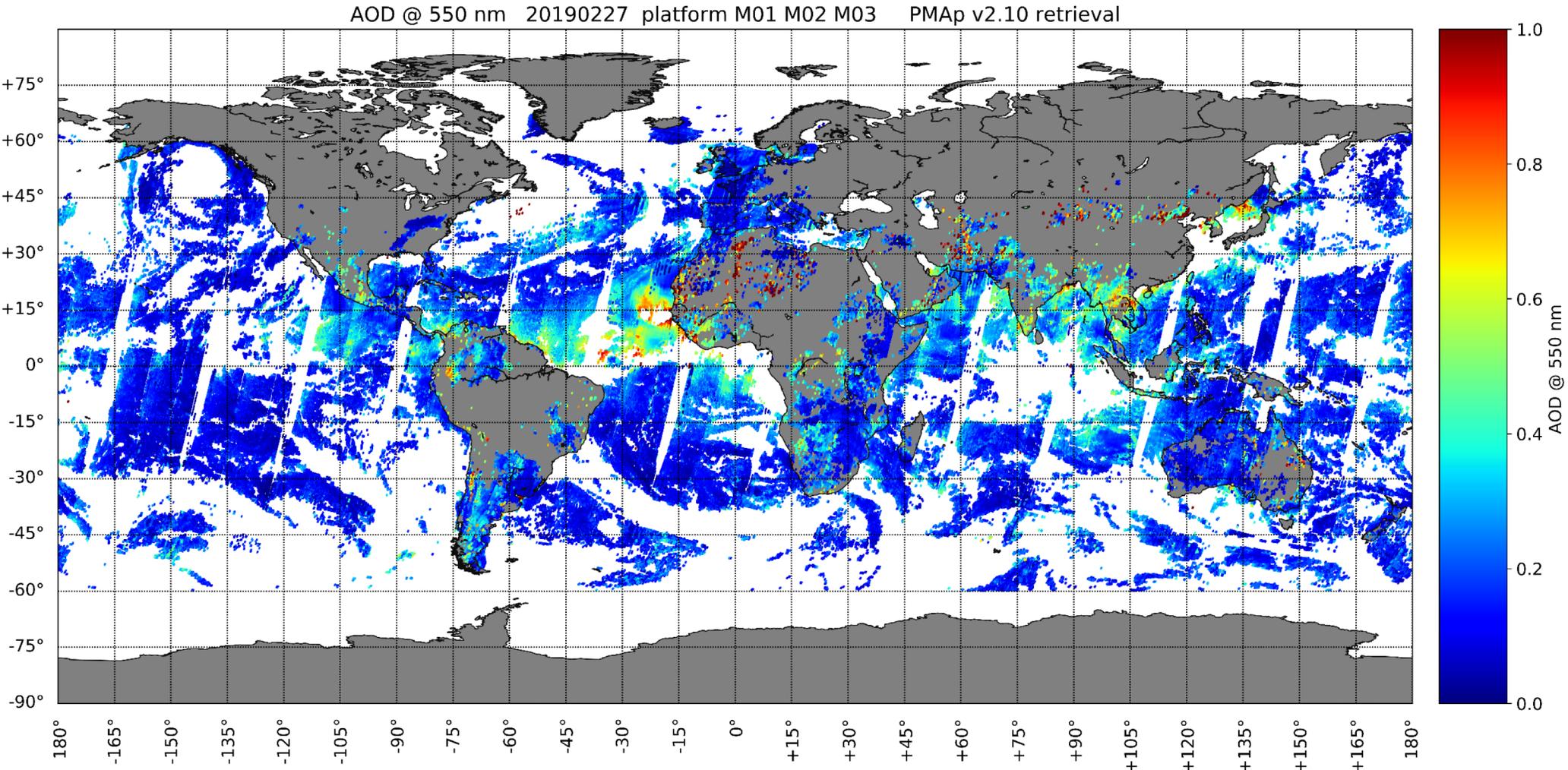
Operational near-real time AOD from EPS/Metop

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

- AOD @550nm over land & ocean, aerosol type classification
- at GOME-2 PMD spatial resolution
10x40 km² Metop-B and -C
5x40 km² Metop-A
- Retrieval over water (PMAp version 1)
fully operational product since October 2014
- Retrieval over water & land (PMAp version 2)
fully operational product since February 2017 (PMAp version 2.1.)



PMAp A+B+C for one full day



PMAp version 2.2 Upgrades

- Degradation correction (M01, M02) and user-required adjustment (M01)
- Improved IASI dust/ash detection + flagging of aerosol contaminated clouds.
- LER database upgrades:

- Angular dependency of the surface with the VZA (θ) for each GOME pixel

$$A_{D LER} = A_{LER} + a + b\theta + c\theta^2$$

- Temporal interpolation from consecutive monthly averaged LER maps

$$A_{LER_interp} = ((1.0 - \text{FracMonth}) * A_{LER\ FloorMonth}) + (\text{FracMonth} * A_{LER\ CeilingMonth})$$

PMAp v2.2 AOP Retrieval CAMS Evaluation

- CAMS (external user evaluation)

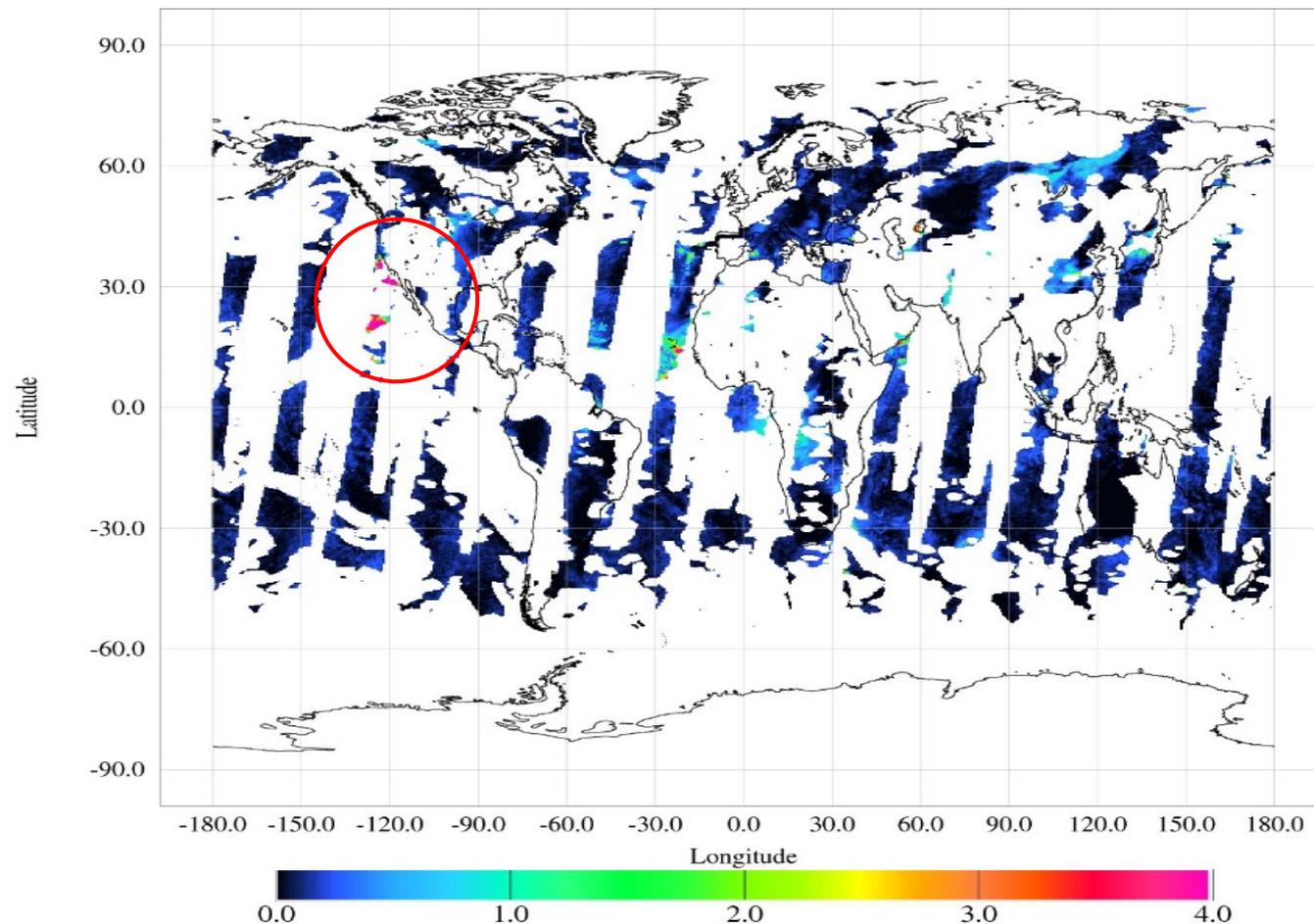
PMAp Validation Data Set

period 1. June - September 2013

period 2. February - May 2015

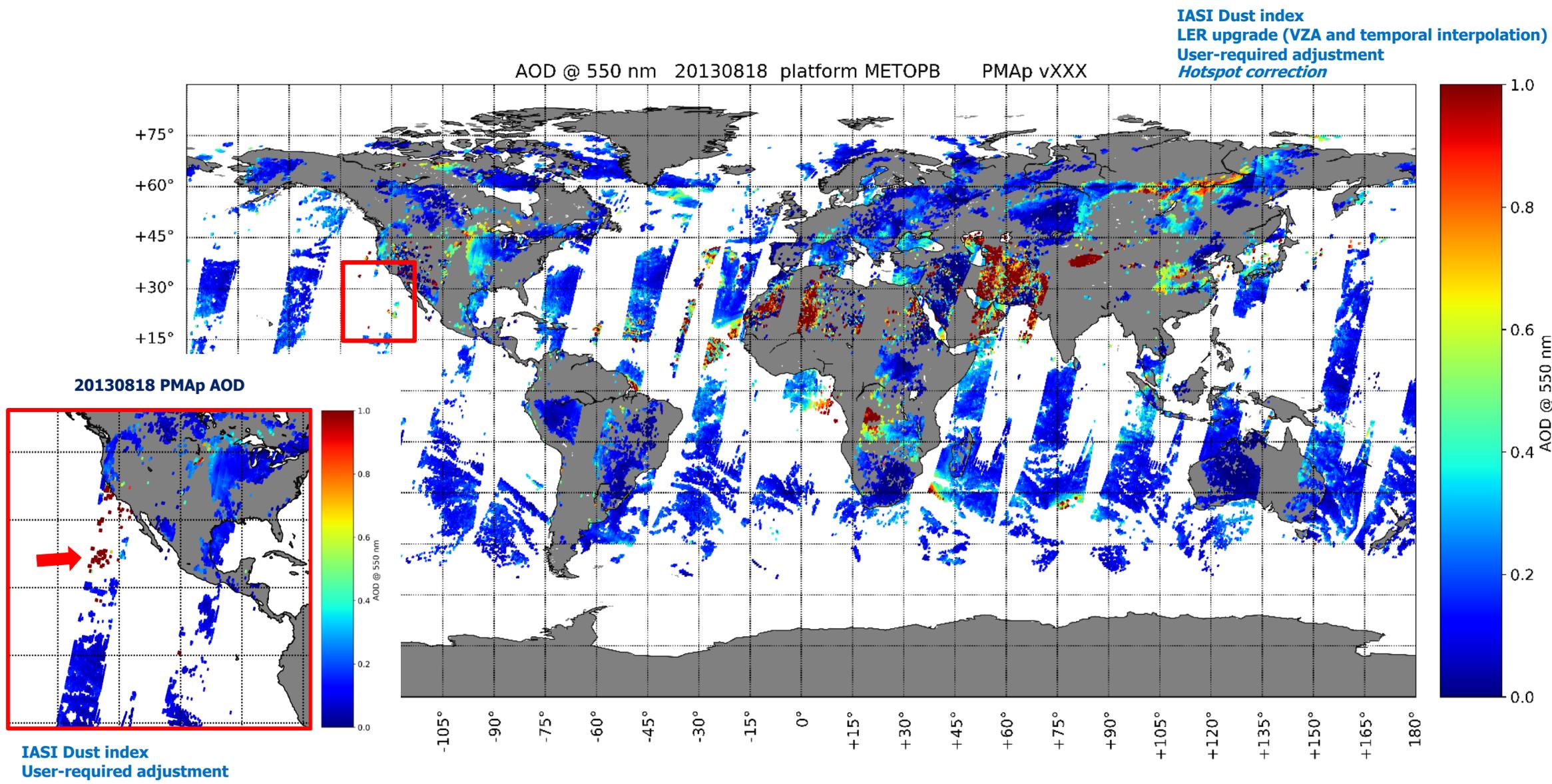
- Instrument offset correction (M01)
- Observation of “hotspots”:
 - Relatively large regions of **AOD == 4**
 - Not present in v. 2.1.
 - Not frequent
 - Aerosol type: **DUST**.

PMAp Aerosol Optical Depth 201308180000 201308190000



PMAp v2.2 AOP retrieval

Hotspot correction

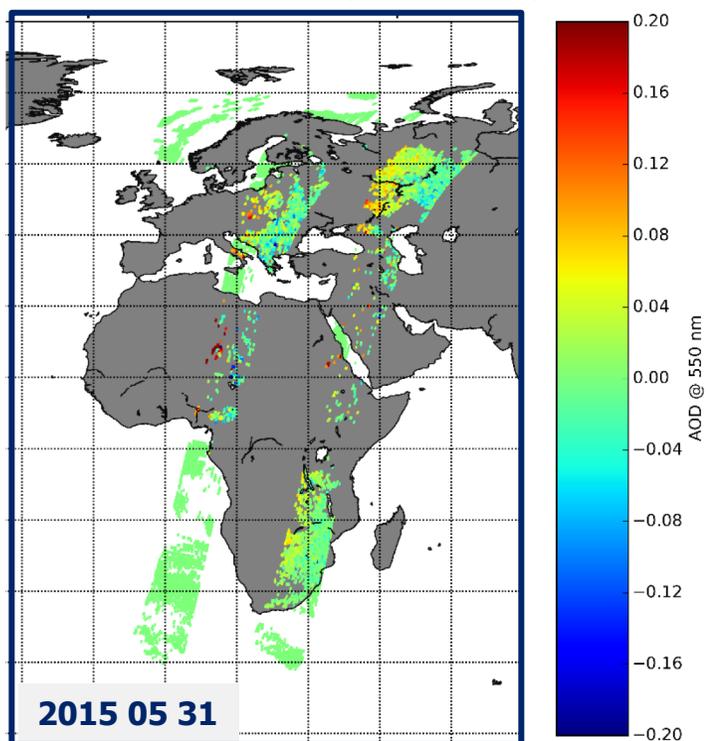


PMAp version 2.2. Upgrades Lambertian Equivalent Reflectance (LER)

Angular dependency of the surface
with the VZA (θ) for each GOME pixel

$$A_{D LER} = ALER + a + b\theta + c\theta^2$$

Difference in AOD between angular and "regular" LER



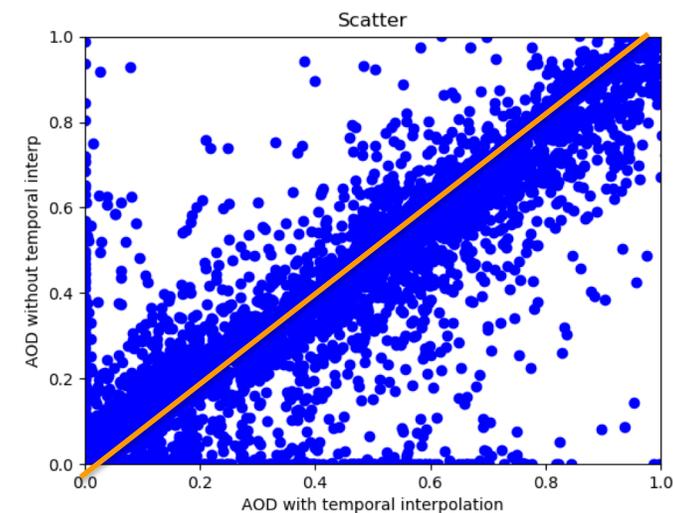
Temporal interpolation from consecutive monthly average LER maps

$$A_{LER interp} = ((1 - FracMonth) * ALER_{FloorMonth}) + (FracMonth * ALER_{CeilingMonth})$$

$$\begin{aligned} y &= mx + b \\ m &= 0.9999 \\ b &= -0.019 \\ r &= 0.9999 \\ stddev &= 1e-06 \end{aligned}$$

Difference in AOD between
non temporally interpolated and
temporally interpolated LER

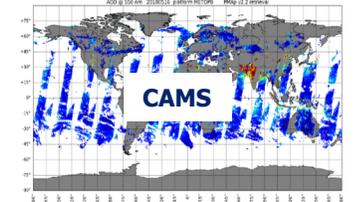
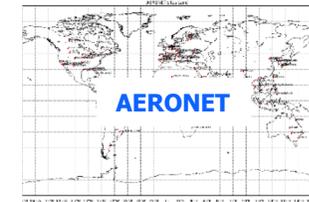
2019 04 01, over land



The Polar Multi-sensor Aerosol Product

Operational near-real time AOD from EPS/Metop

- Internal **Aeronet** validation (ongoing)
- PMAp v.2.2 benchmarking periods
to be delivered to **CAMS** for evaluation (processing)
- Internal Review Board
- PMAp operational chain tests
- Planned start of dissemination: **Summer 2019**



Sentinel-3 Aerosol NRT – SLSTR AOD

- Initial Algorithm & Processor

- Developments in the framework of S3 Mission Performance Centre (MPC) under ESA contract.
- Final Delivery to EUMETSAT in October 2018.
- EUMETSAT fully in charge of maintenance, long-term evaluation, validation monitoring, evolution, deployment.

- Scientific approach

University of Swansea (P. North, et al., S3 AOD NRT ATBD, 2016)

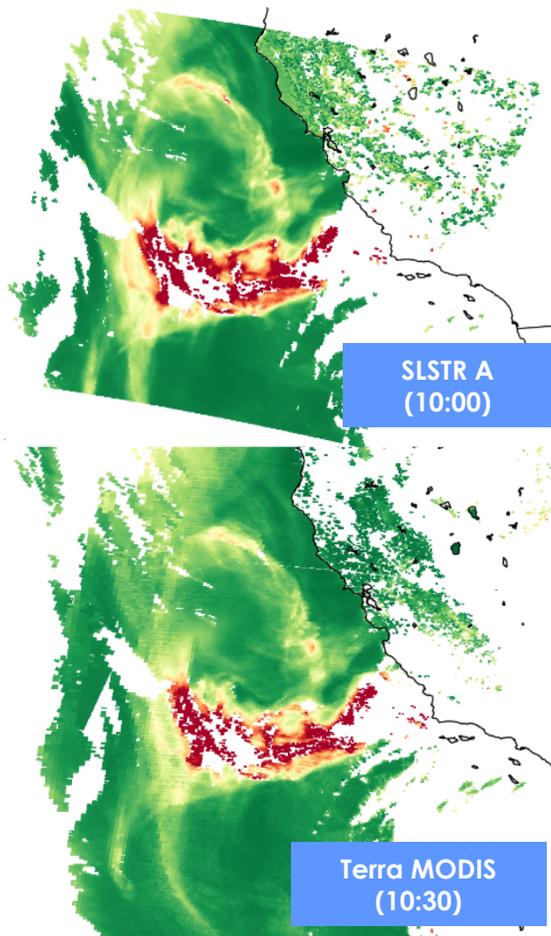
- ✓ Historically applied to dual-view instruments ATSR 1&2, AATSR (ref. ESA CCI_aerosol project)
- ✓ 5 spectral channels at 554 nm, 659 nm, 868 nm, 1.613 um, 2.255 um
- ✓ Viewing constraints: multi-angular – dual-view over land, nadir view over ocean
- ✓ Physical based surface model - Iterative optimization of AOD, aerosol model & surface reflectance
- ✓ Spatial resolution 4.5 km

- On-going analyses / validation performed by EUMETSAT for necessary evolutions before operational release:

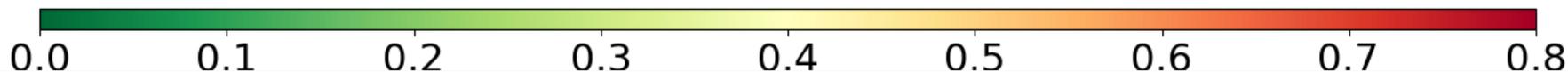
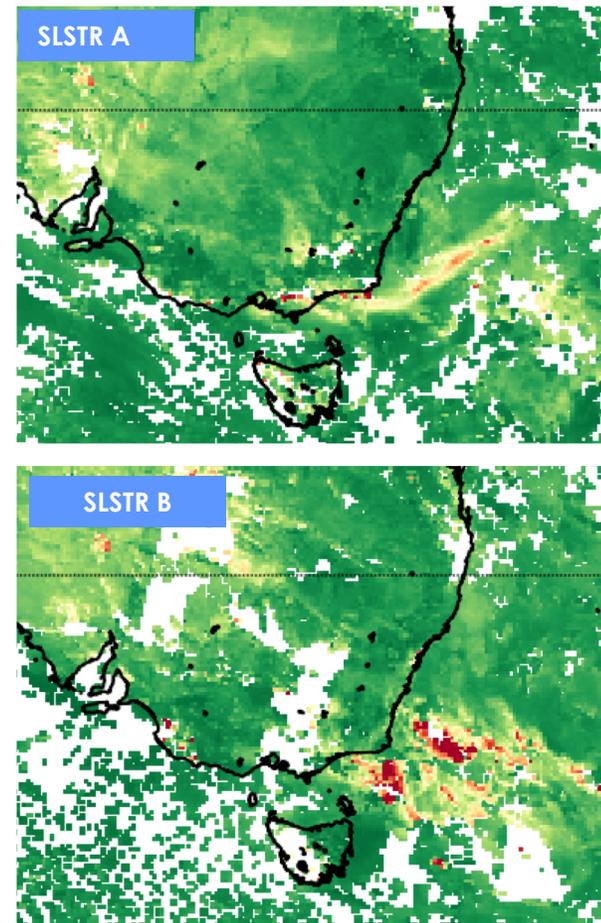
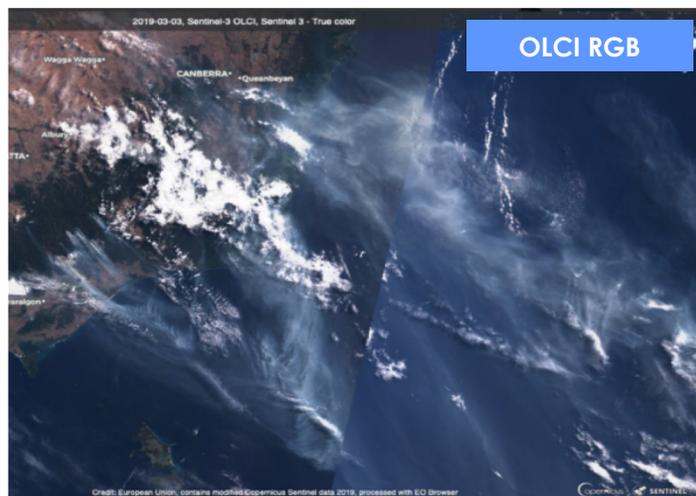
- ✓ Optimal adaptation based on up-to-date knowledge of SLSTR sensor specificities (e.g. geometry, radiometry calibration, etc..)

SLSTR AOD NRT – Expected potential (some examples)

•Massive Thomas fire, California, 2017.12.10

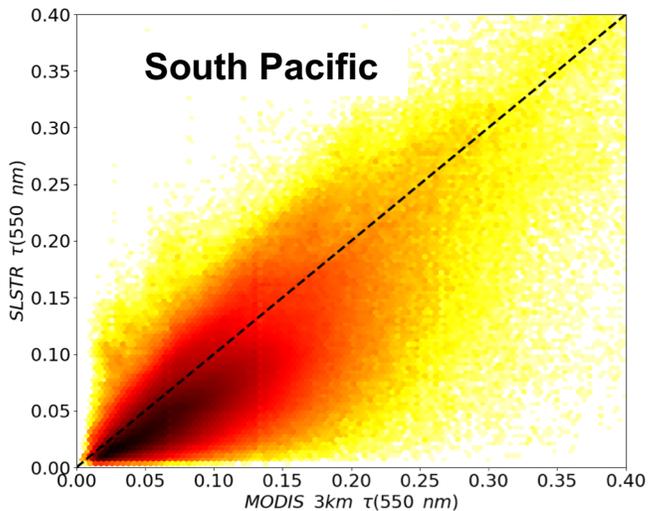
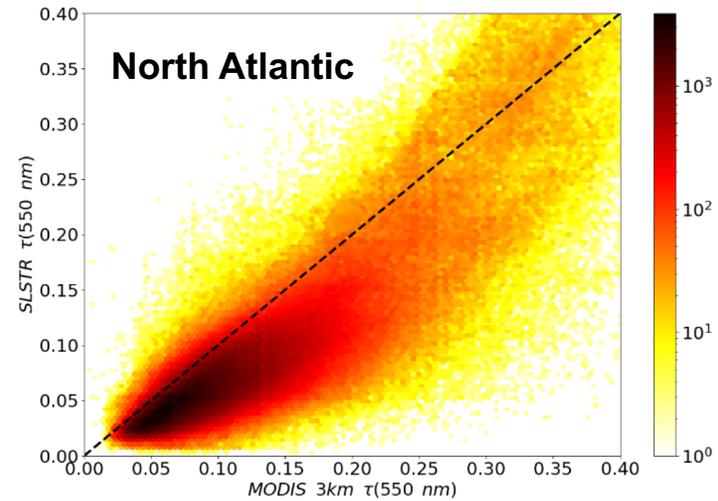


Victoria hills wildfire, Australia, 2019.03 (~10 days)



S3/SLSTR AOD NRT Product – Evaluation over ocean

Collocation with MODIS Terra AOD 3 km (Collection 6.1) Spring 2019 (2019.03.01 – 2019.05.20)



Over OCEAN

| SLSTR – MODIS 3 km | N cloud-free collocation | Mean | Std | RMS | R |
|--------------------|--------------------------|-------|------|-------|------|
| North Atlantic | 870 828 | -0.02 | 0.05 | 0.06 | 0.96 |
| South Atlantic | 1 272 592 | -0.02 | 0.03 | 0.043 | 0.89 |
| South Pacific | 2 583 706 | -0.02 | 0.03 | 0.036 | 0.83 |
| Indian | 1 152 797 | -0.03 | 0.03 | 0.041 | 0.78 |

Sentinel-3 for Atmosphere – SLSTR AOD Global

An initial processor from the ESA S3 Mission Performance Centre (MPC) is at EUMETSAT

- Historically applied to dual-view instruments ATSR 1&2, AATSR (ref. ESA CCI_aerosol project)
- Evolutions necessary thanks to up-to-date knowledge about SLSTR specifics (*cf.* geometry)
- Specification & validation of the algorithm evolutions by EUMETSAT

University of Swansea (P. North)



Swansea University

In parallel – Independent activity / frame

- Better understand SLSTR instrument specificities (geometry, radiometric calibration)
- Quantify theoretical SLSTR multi-spectral AOD product performance w.r.t NRT requirements
- KOM 2019.04.24

Finnish Meteorological Institute (FMI) – G. de Leeuw, P. Kolmonen,
A. Lipponen, L. Sogacheva, T. Virtanen.



FINNISH METEOROLOGICAL
INSTITUTE

SLSTR AOD(550 nm) Requirements = 0.05 (sea), 0.1 (land).
Future SLSTR AOD product expected to be assimilated by CAMS

NB: a new **OLCI AOD** activity has started - To exploit the OLCI high spatial resolution for a **multi-term statistical retrieval approach with spatial / temporal constraints** between fine pixels in view of a **continuous aerosol & surface** retrieval

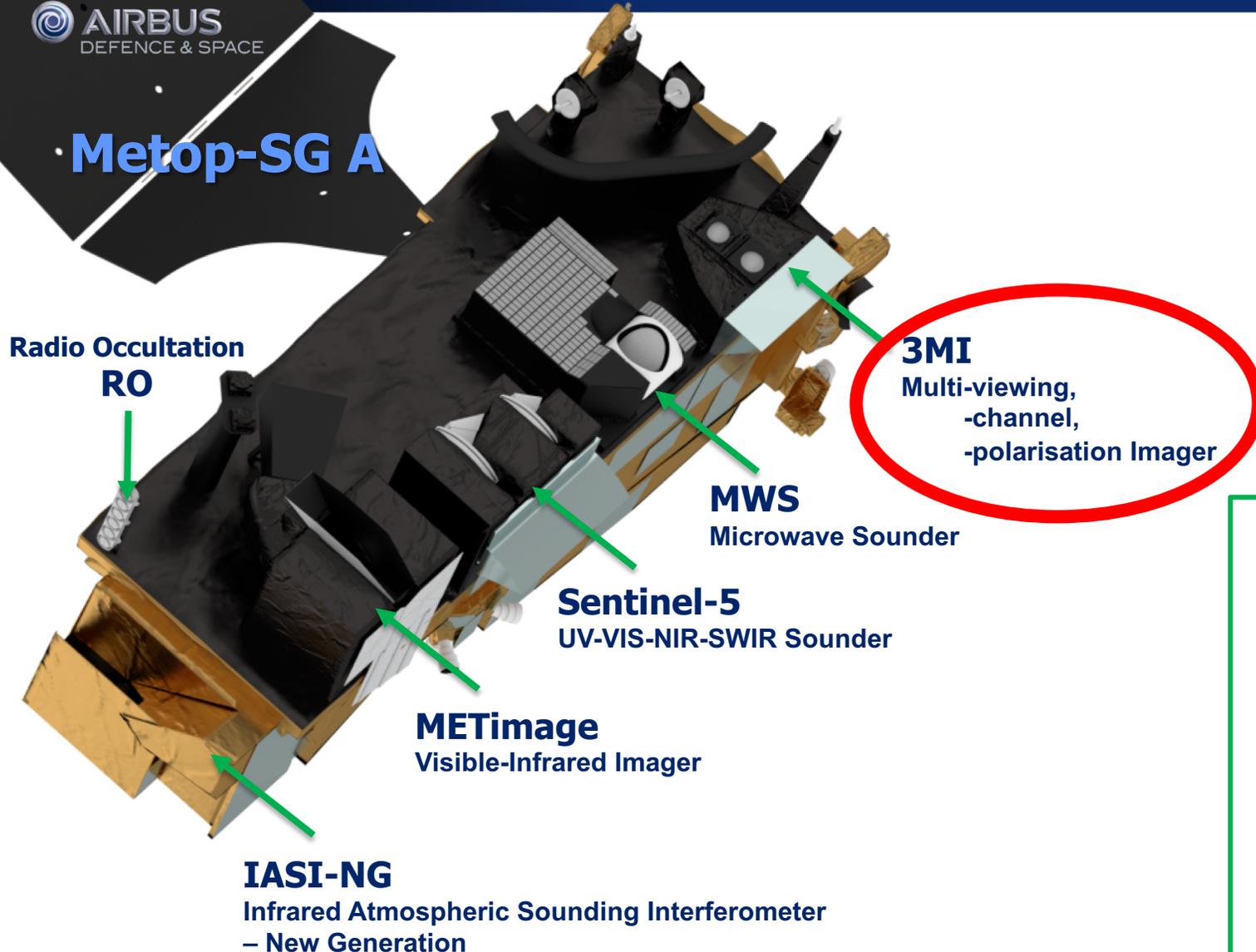
Catalysts  **GRASP**
In principle, yes!

GRASP (Dubovik *et al.*, 2014)

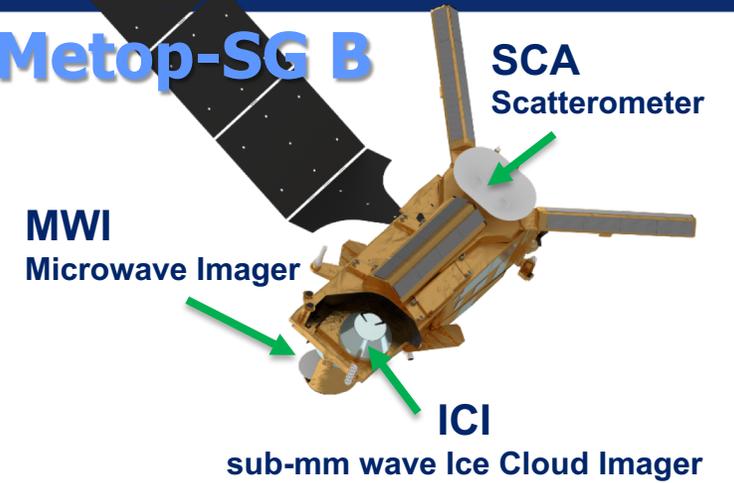
Future Mission EPS-SG: EUMETSAT Polar System - Second Generation



Metop-SG A



Metop-SG B



Two-satellite configuration Metop-SG-A and -B on the same orbit, separated by 90°

Metop-like orbit:

- Sun synchronous
- low earth orbit at 835 km mean altitude
- 09:30 local time of the descending node

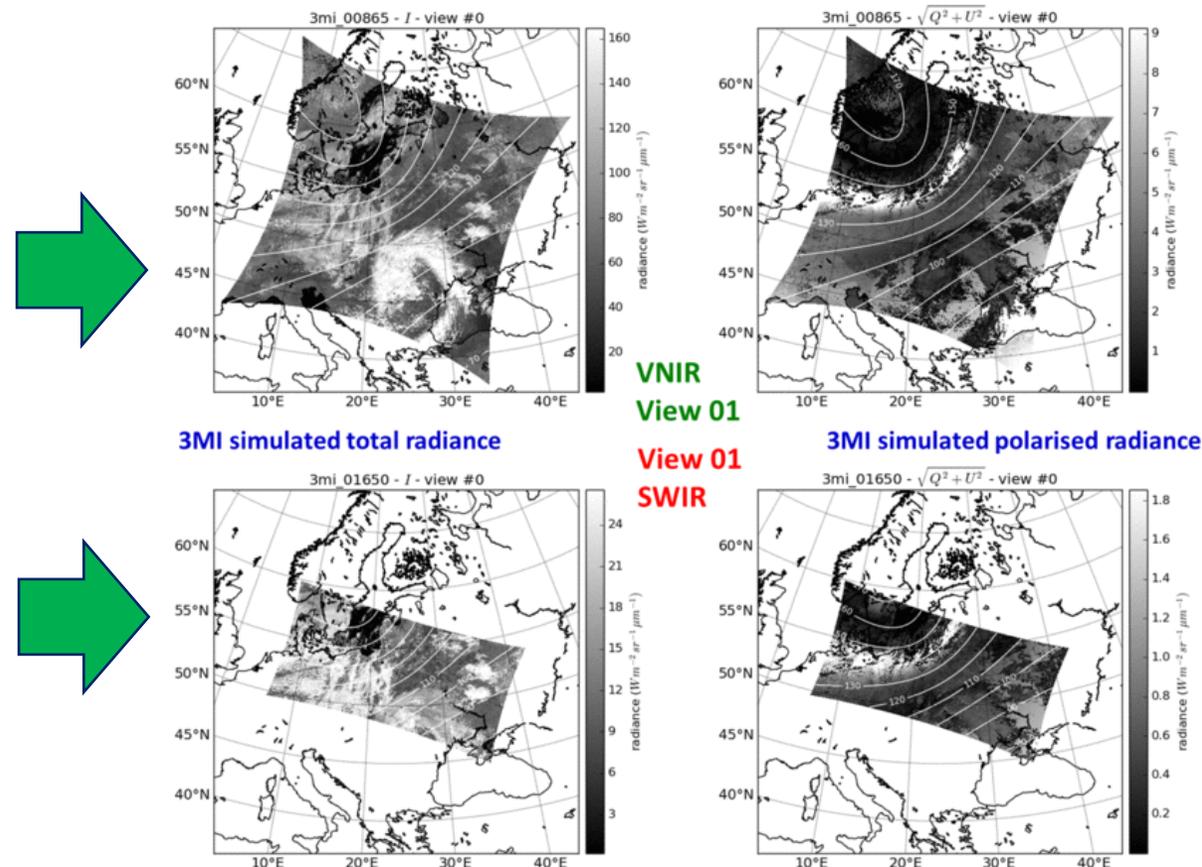
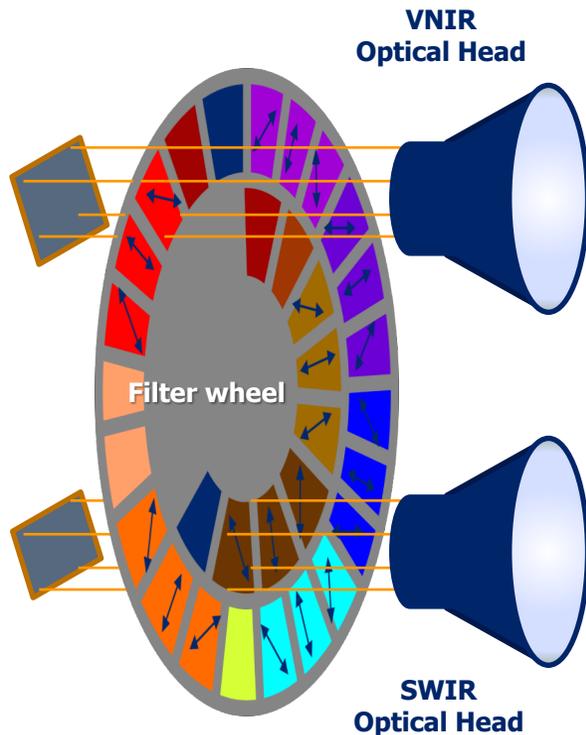
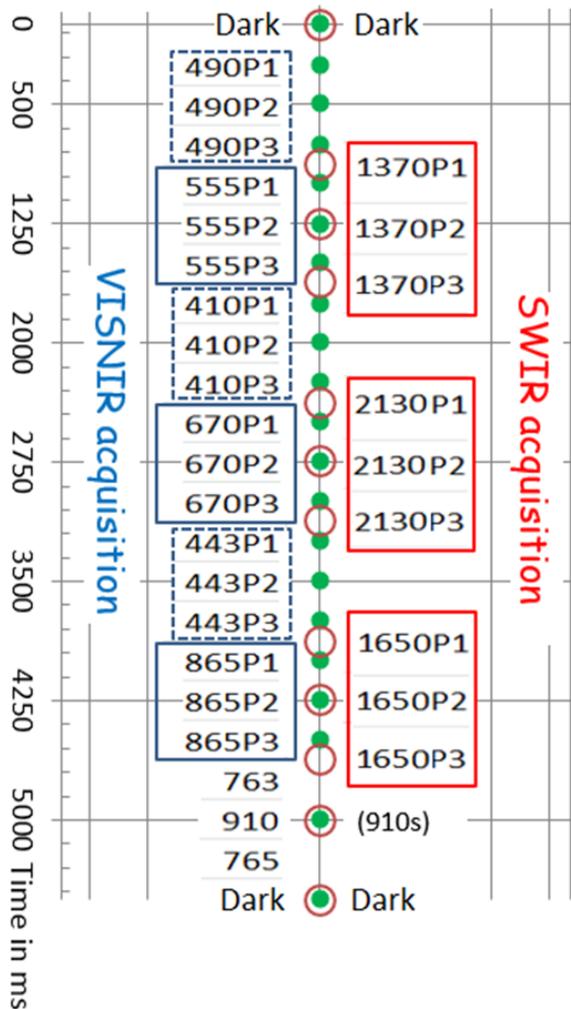
Nominal launches:

| | |
|------------------|------------------|
| 2022 Metop-SG A1 | 2022 Metop-SG B1 |
| 2028 Metop-SG A2 | 2029 Metop-SG B2 |
| 2035 Metop-SG A3 | 2036 Metop-SG B3 |

3MI: Instrument Concept

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

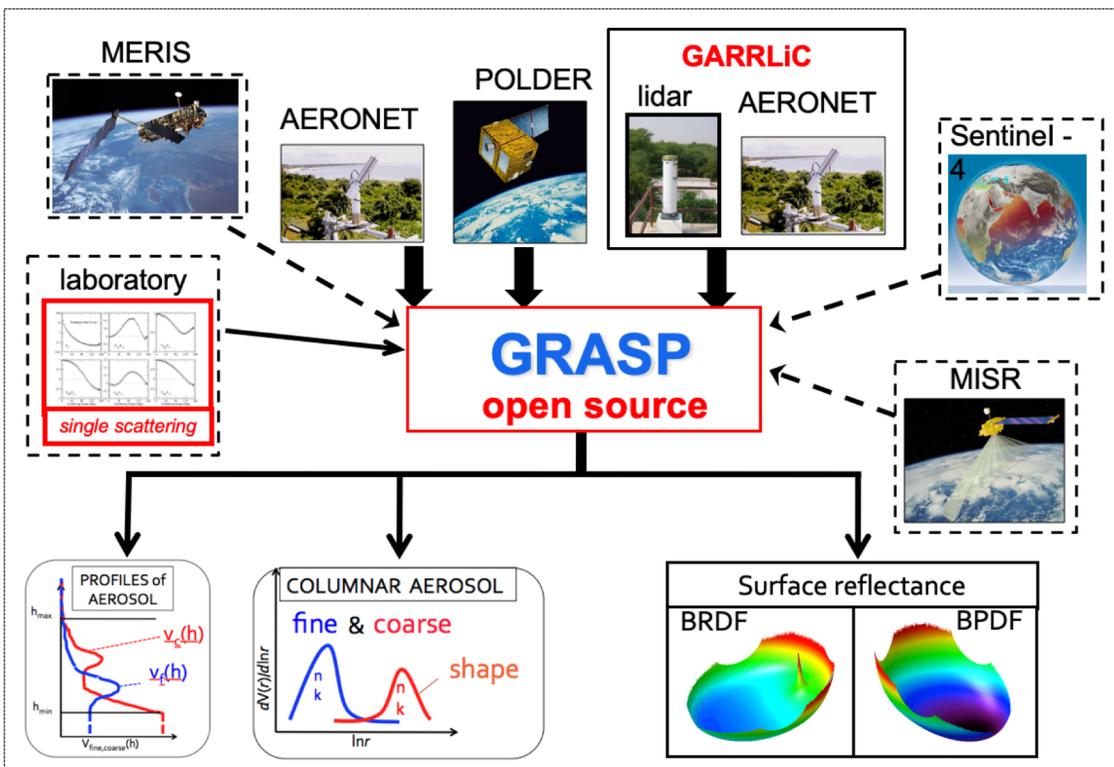
- Multi-view: 1 ground target is seen 14 times
 VISNIR : 1 view every 22s, $\sim 9^\circ$ between 2 successive views
 SWIR : 1 view every 11s, $\sim 4.5^\circ$ between 2 successive views
- Multi-channel (12 channels from 410 to 2130 nm)
- Multi-polarisation (9 channels with $-60^\circ, 0^\circ, +60^\circ$ polarisers)



3MI NRT Aerosol Retrieval: Application of GRASP

- Continuous solution space;
- Rigorous data combination and use of a priori information;
- Globally unique set of a priori constraints;
- No location specific assumptions;
- Surface retrieved simultaneously;

GRASP: Generalized Retrieval of Aerosol and Surface Properties



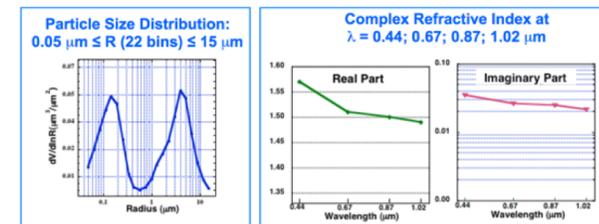
3MI:

- radiances & polarization (410, 440, 490, 560, 670, 870, 1650, 2103 nm)
- 10- 14 viewing directions

240 - 336 measurements

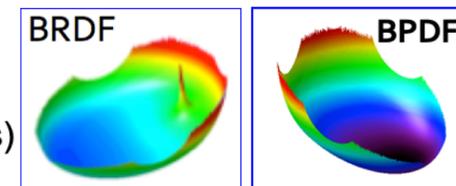
AEROSOL:

- size distribution (~5 bins)
- spectral index of refraction (8λ)
- sphericity fraction;
- aerosol height



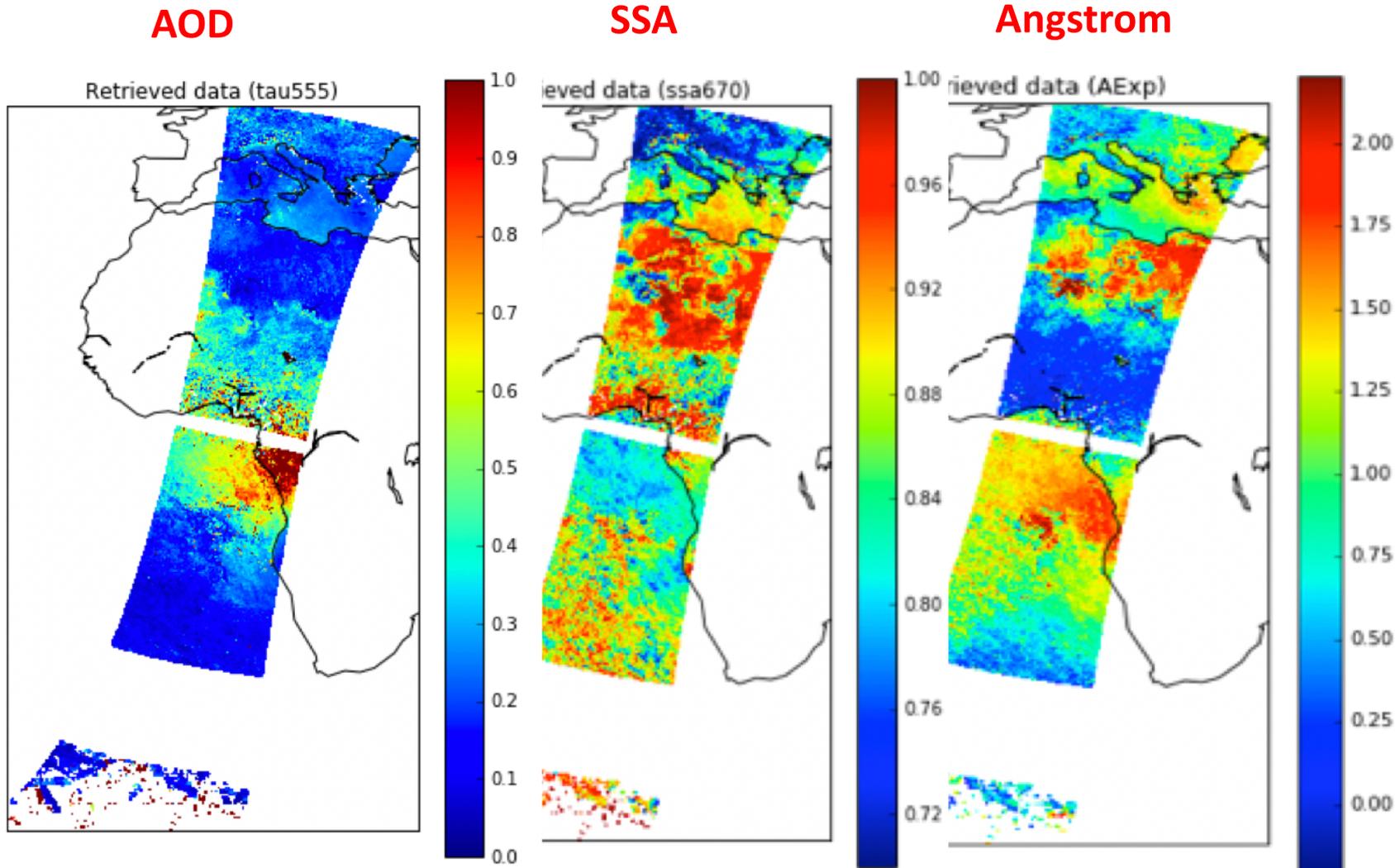
SURFACE:

- BRDF (3 spectrally dependent parameters)
- BPDF (1 or 2 spectrally dependent parameters)

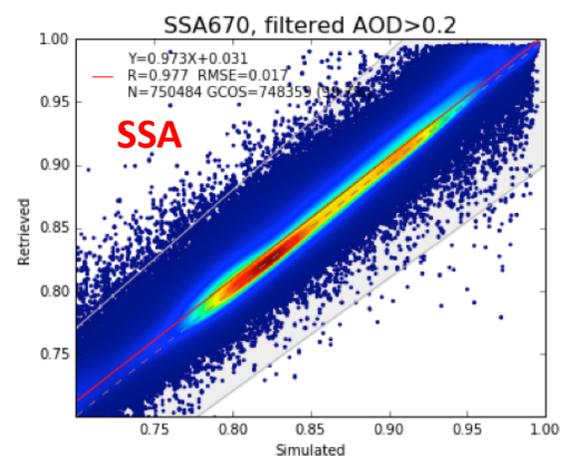
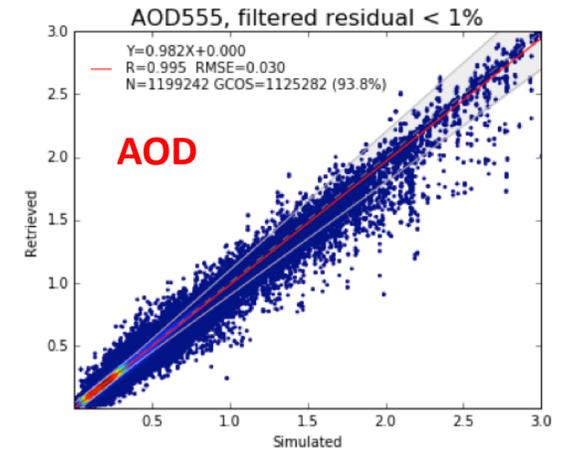


$$55 = (5 \text{ (SD)}) + 16 \text{ (ref. ind.)} + 1 \text{ (nonsp.)} + 24 \text{ (BRDF)} + 8 \text{ (BPDF)} + 1 \text{ (height)}$$

3MI NRT Aerosol Retrieval: Illustration of GRASP-NRT retrievals from 3MI simulated data

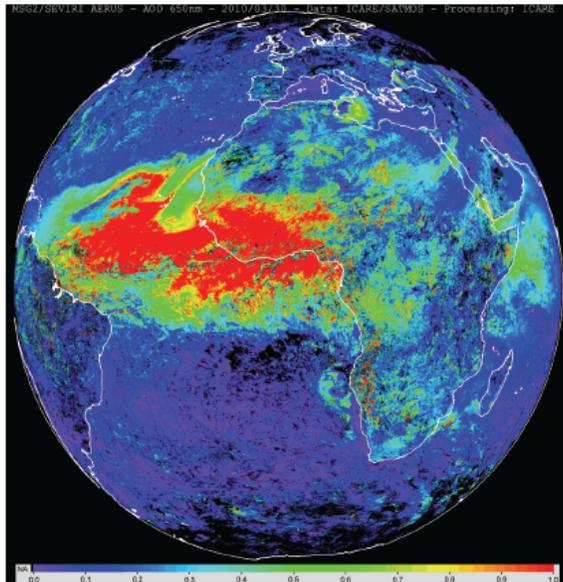


Results of synthetic tests

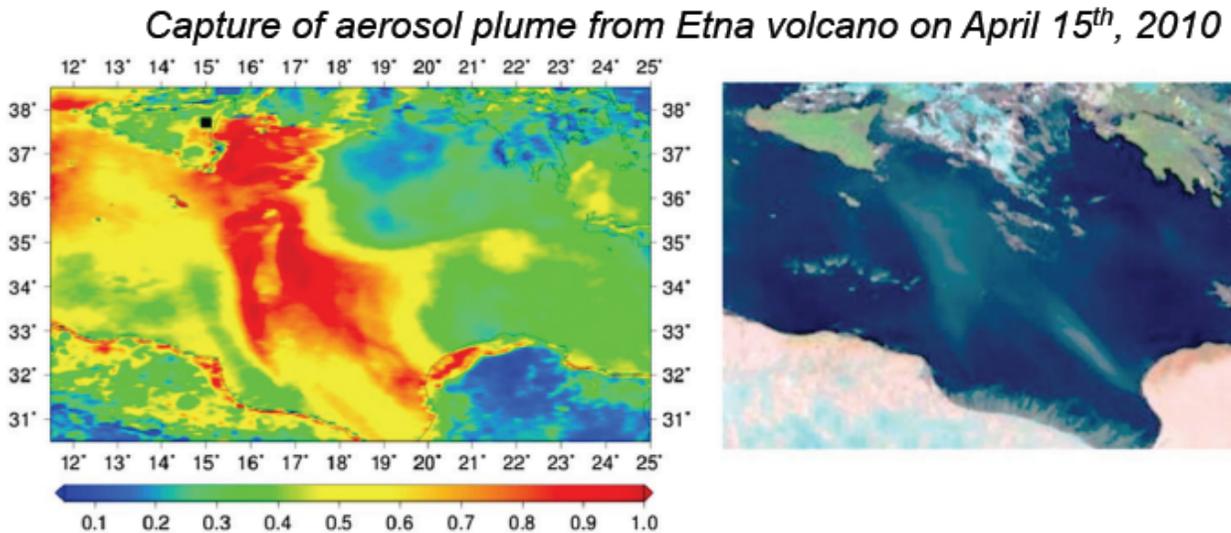


Aerosol Product from MSG : SEVIRI

- Simultaneous aerosol / surface retrieval with AERUS-GEO
- Approach according Carrer et al., 2010; 2014
- Daily retrieval for MSG/SEVIRI available in ICARE
- Instantaneous retrieval (up to 96/day) under development
- Planned to be operationally implemented in EUMETSAT for MTG/FCI



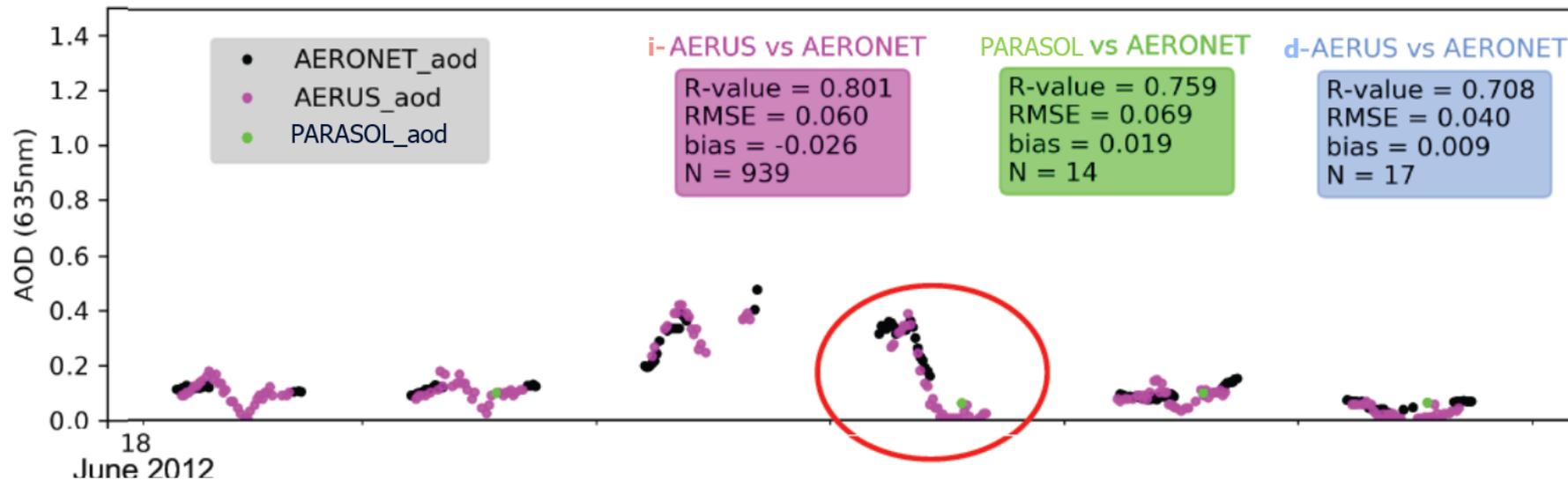
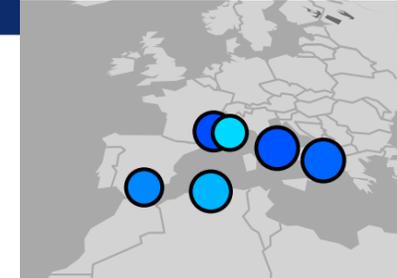
Daily AOD at 0.64 μ m on March 30th, 2010



(Ceamanos et al. 2018)

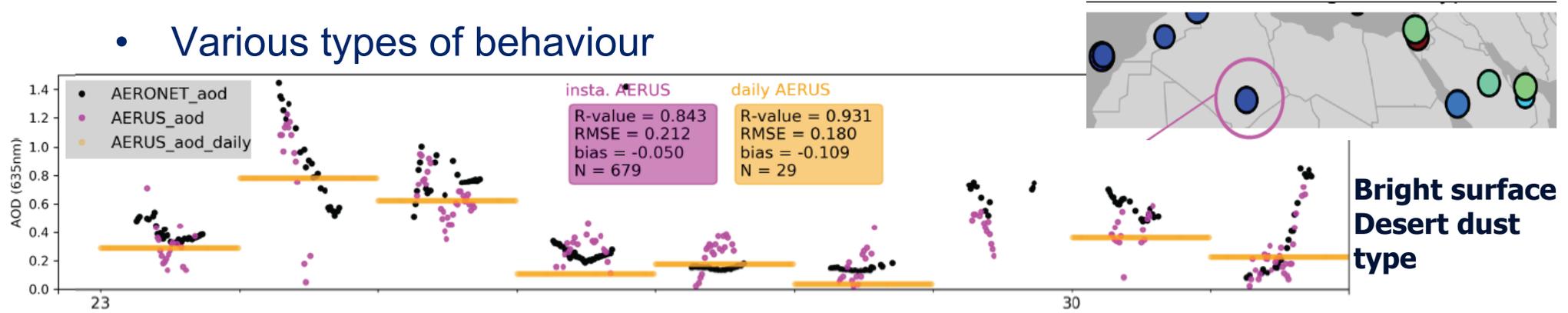
Aerosol Product from MSG : SEVIRI

- Instantaneous retrieval with i-AERUS
 - good estimation of the AOD
 - reveals the diurnal cycle that may be large
- comparison to Aeronet and PARASOL (GRASP)
 - artefacts : identified limitation in backscattering geometry with the aerosol model (phase function)

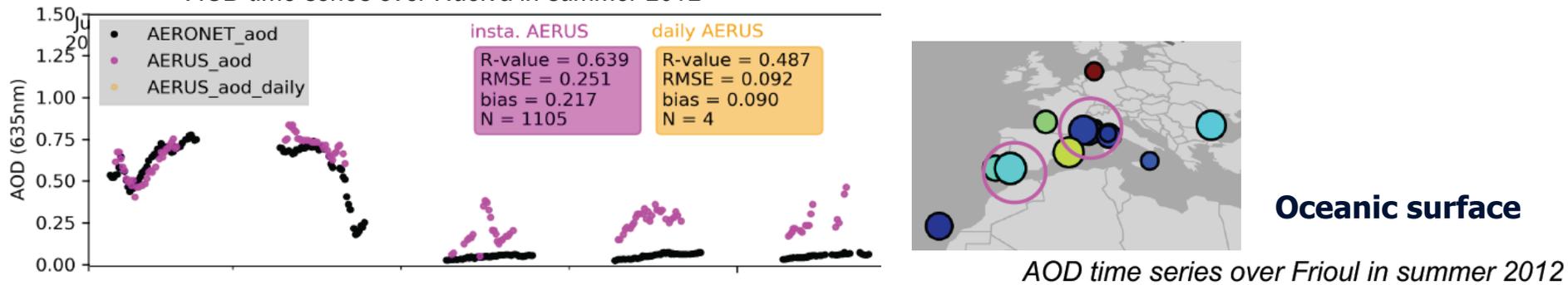


Aerosol Product from MSG : SEVIRI

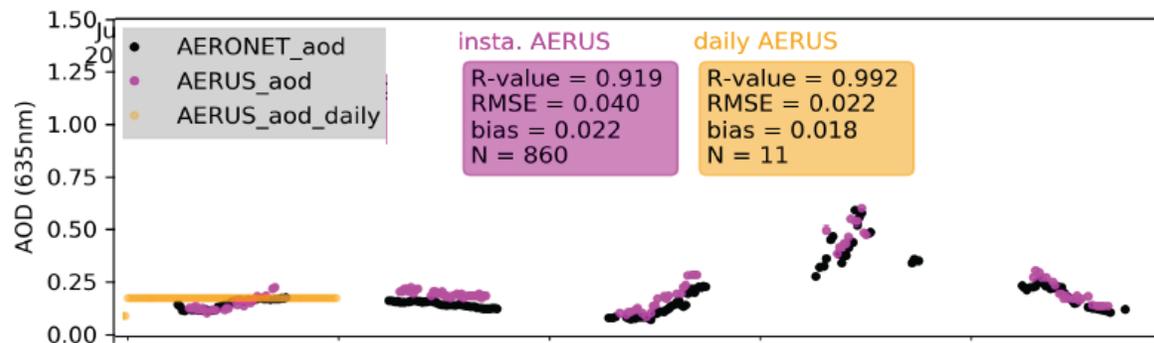
- Instantaneous retrieval with i-AERUS
 - Various types of behaviour



AOD time series over Huelva in summer 2012



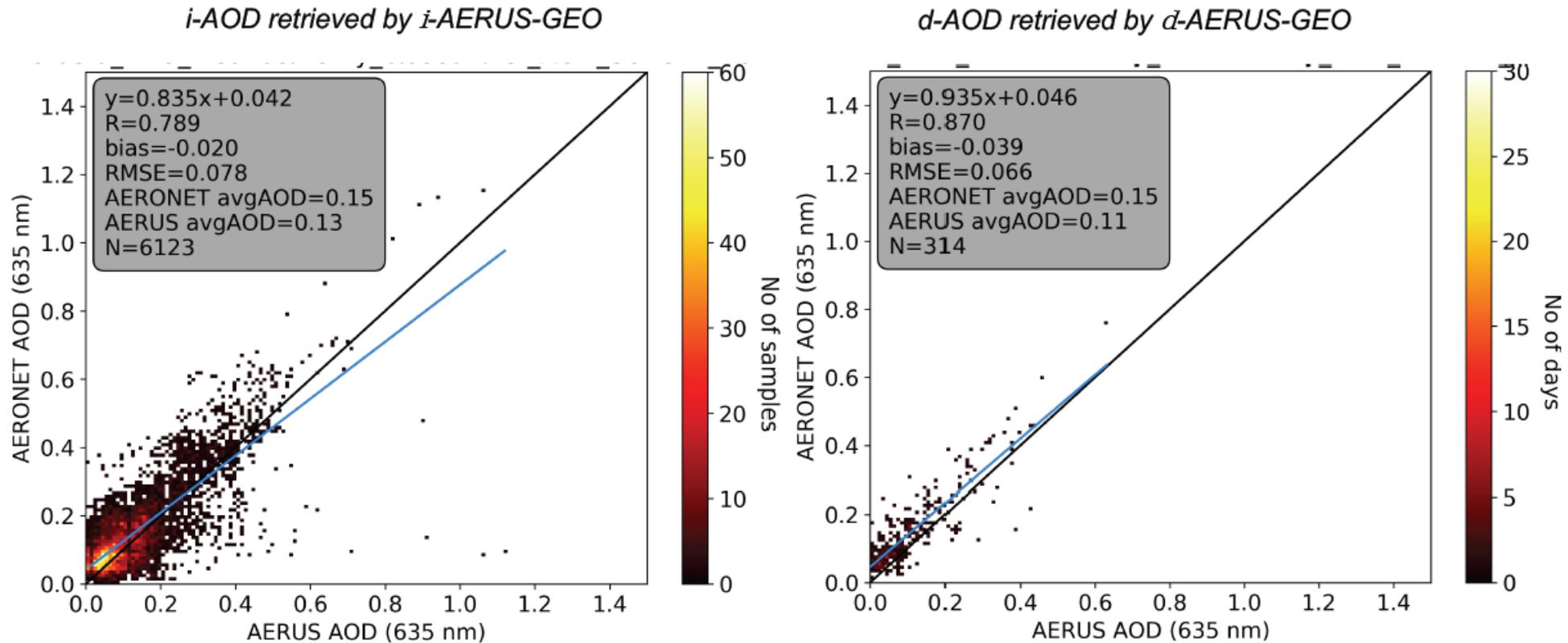
AOD time series over Frioul in summer 2012



Aerosol Product from MSG : SEVIRI

- Instantaneous retrieval with i-AERUS

- Mediterranean basin



Scores are similar to those of the operational *d*-AERUS-GEO

Aerosol Product from MSG to MTG

- Instantaneous retrieval with i-AERUS
 - The i-AERUS product is already at a good level of maturity
- Good information on AOD and its diurnal variation
- Clear need for improvement identified for :
 - Assessment of aerosol type
 - A better treatment of the surface (especially for ocean)
- MTG/FCI will provide more spectral information expected to contribute to a better constraint of the retrieval

Summary

- EUMETSAT has a number of operational NRT aerosol products either currently in operations or in development
- The Copernicus Sentinel 3 mission is expected to significantly enhance the suite of available operational aerosol products
- In the future, the EPS-SG 3MI mission, which is dedicated to the measurement of aerosol properties, will provide state of the art operational aerosol products in NRT.