POLAR MULTI-SENSOR AEROSOL PROPERTIES FROM METOP A & B

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EUMETSAT

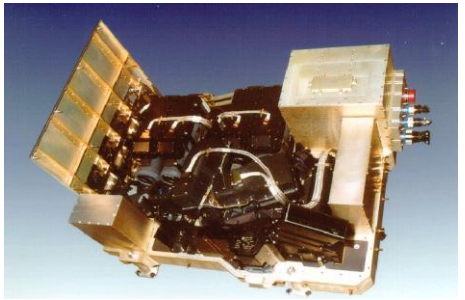
Overview

- PMAp: Polar Multi-sensor Aerosol product developed at EUMETSAT
  - *product overview*
  - *operational retrieval over ocean*
- Validation and monitoring of the PMAp product
  - Continuous comparison of PMAp to AERONET AOD
- From the ocean retrieval to the land retrieval
  - What will be changed for the land retrieval?
  - First (preliminary) results for AOD over land

PMAp operational product

- PMAp: Polar Multi-sensor Aerosol product
  - *AOD over ocean, aerosol type classification (volcanic ash)*
  - *Delivered as a GOME product (PMD resolution)*
  - *Pre-operational since Q2/2014*
  - *Fully operational product quality status since October 14th 2014*
  - *Distributed by EUMETCast in netcdf4*
- Q1-2/2015: *Implementation of PMAp Release 2 including retrieval over land on the core ground segment (expected)*

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

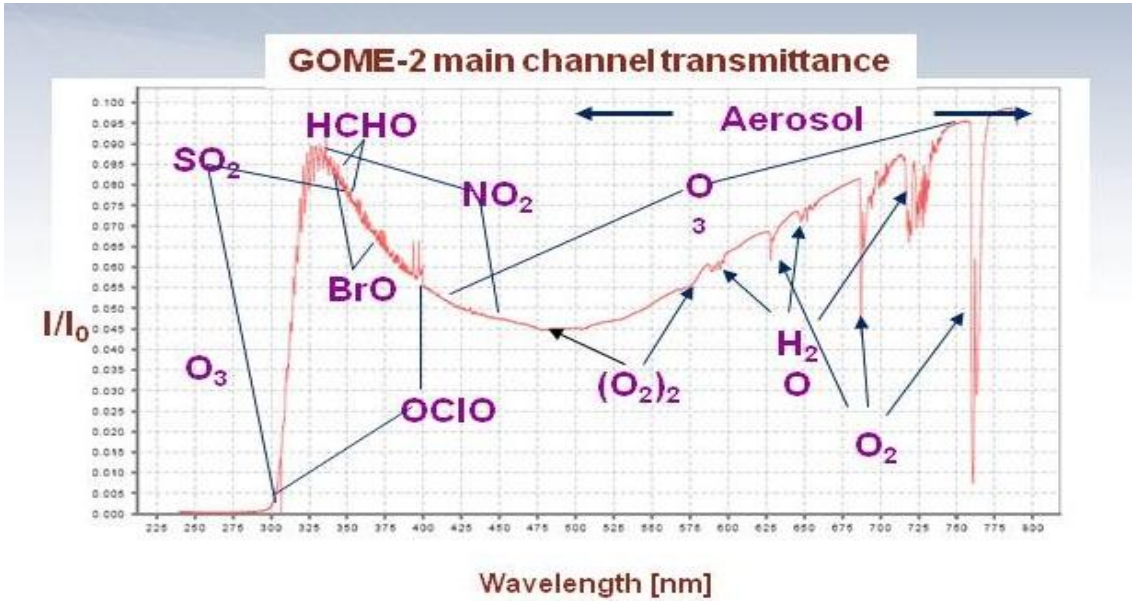
METOP instrument level-1 data used by PMAp

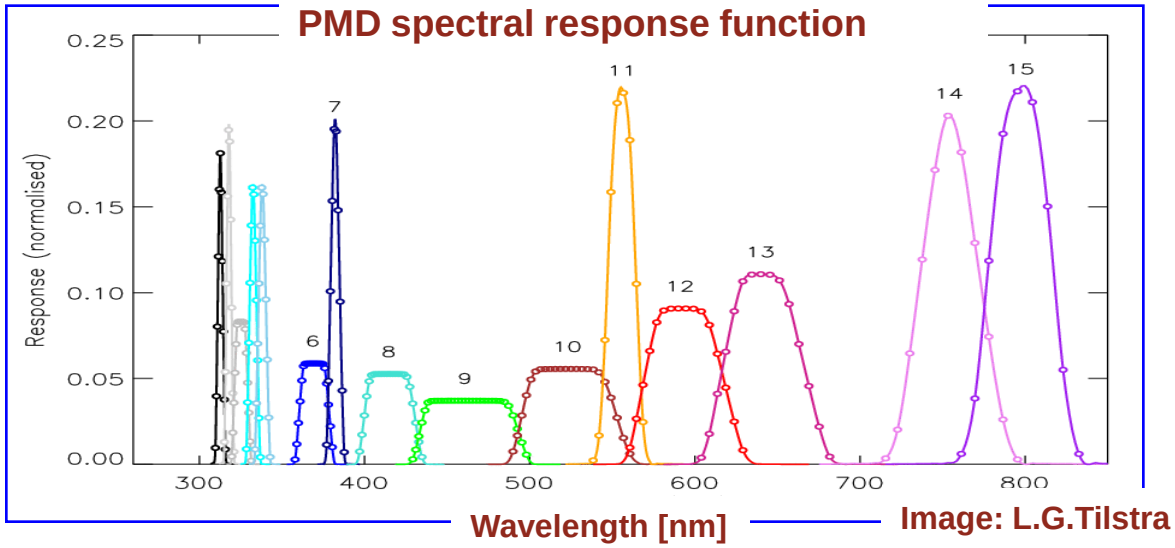
Instrument		Spatial resolution	Spectral range	comments
GOME	Main science channel	80 x 40 km	240nm -800nm, res. 0.25-0.5nm	AAI, low spatial resolution, not used
	Polarization Monitoring Device	10 x 40 km Metop-B 5 x 40 km Metop-A	311nm-803nm, 15 bands	AOD, aerosol type, AAI
AVHRR	-	1.08 x 1.08 km	580nm-12500nm, 5 bands	Clouds, scene heterogeneity, dust/ash
IASI	-	12km (circular)	3700–15500nm, resolution 0.5 cm^{-1}	desert dust, volcanic ash aerosol heights
Auxiliary data	ECMWF wind speed (forecasting)	Temporal interpolation necessary	-	Required for retrievals over ocean
	surface albedo, Surface elevation	-	-	Required for retrievals over land

Target spatial resolution

The GOME-2 instrument on Metop

Measuring atmospheric composition

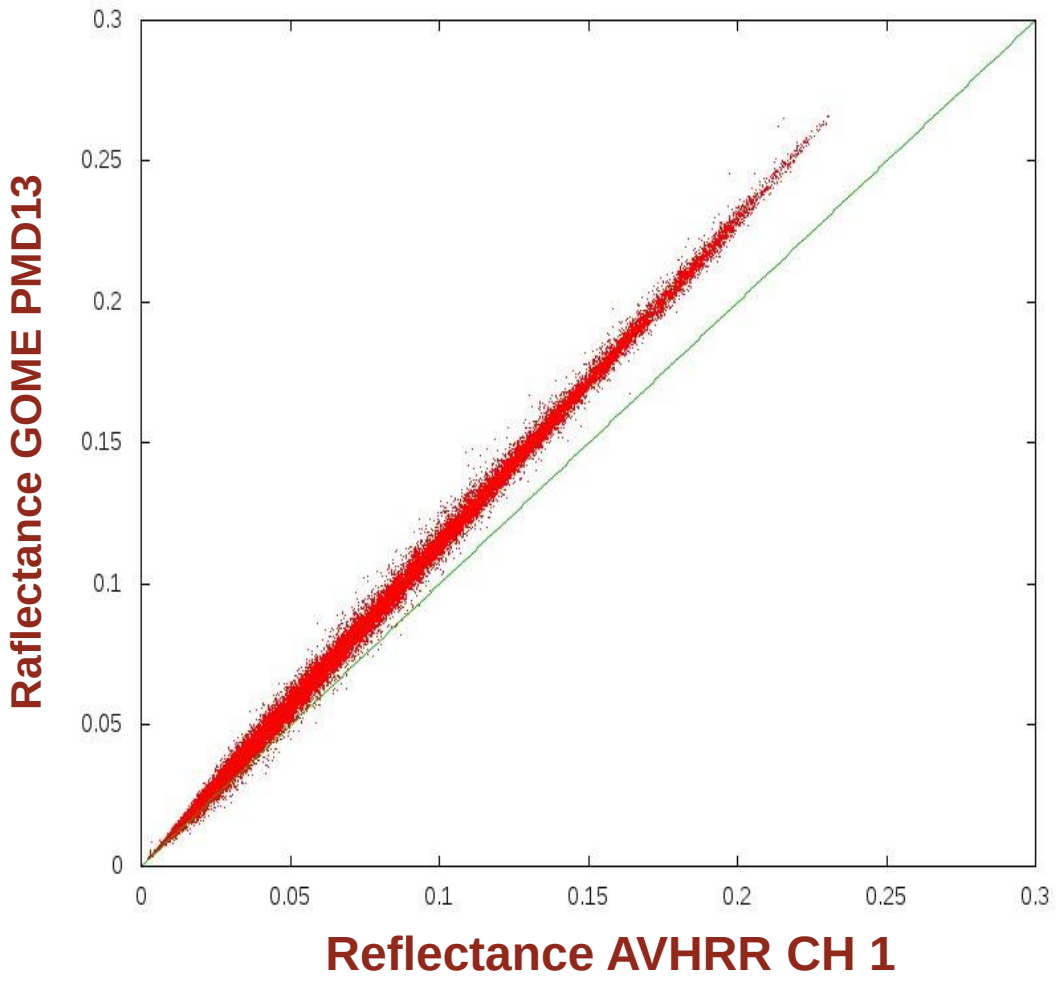




GOME-2:

- series of 3 instruments on Metop (Metop A launched in 10/2006)
- sun-synchronous orbit, 09:30
- 412 orbits (29 days) repeat cycle
- Global coverage 1.5 days
- 240 nm to 800 nm
- 0.25 to 0.5 nm spectral resolution (FWHM)
- 4 channels with 4098 energy measurements of polarisation corrected radiances (40 x 80 km^2)
- 2 channels with 512 energy measurements of linear polarised light in perpendicular direction (S/P) (40 x 10 km^2)

Collocation of AVHRR and GOME: slope and scatter



- Significant calibration error of AVHRR (slope, almost no offset).
- Scatter due to different shapes of footprints (+ contribution of convolution effects).
- Spatial aliasing can lead to differences in averaged radiances / cloud fractions for the different PMD bands.
- Work in progress: Online calibration of AVHRR CH 1, 4 and 5 and GOME PMD using GOME main channels & IASI.

Strategy for AVHRR / GOME combination

- Avoid optimization using one fit over different satellite instruments
  - Problems for heterogeneous scenes (different footprints)
  - Problems due to different calibration errors
  - Problems due to different degradation effects (observed for AVHRR/GOME on METOP-A)
- Apply quantitative retrieval on the GOME instrument
- Use AVHRR to
  - detect clear sky scenes based on VIS/IR thresholds
  - detect dust and ash events based on VIS/IR thresholds
  - retrieve cloud correction factors for GOME based on the variation of the AVHRR radiances within the GOME pixels

PMAp: AOD retrieval algorithm

used over land and ocean, ocean retrieval discussed first

Three step retrieval:

Step1: Pre-classification by AVHRR (WIP: IASI)

- Cloud detections and cloud corrections, distinguish clouds from dust/ash
- Aerosol type pre-classification (no dust, dust, ash, no classification)

Step2: Retrieval of a set of candidate AODs

- based on a set of aerosol models from LUT provided by O. Hasekamp (O3MSAF), model selection dependent on step 1.
- Over ocean: Chlorophyll fitted for clear sky pixels (otherwise a priori)
- Over land: surface albedo a priori (fit not meaningful for nadir-only retrieval)

Step3: Selection of the best fit

- select the best result of step 2 using least-square minimization for all GOME PMD bands (+ stokes fractions dependent on condition)

Cloud correction by AVHRR

- AVHRR cloud tests:
  - Albedo test
  - T4 test
  - Uniformity test
  - T4T5 test
- Clear sky PMD reflectance for cloudy pixels:
  - Spectral overlap required
-

$$R_{corrected}(cloudfree) = R_{PMD}\frac{\tilde{R}_{AVHRR}(cloudfree)}{\overline{R_{AVHRR}(all)}}$$

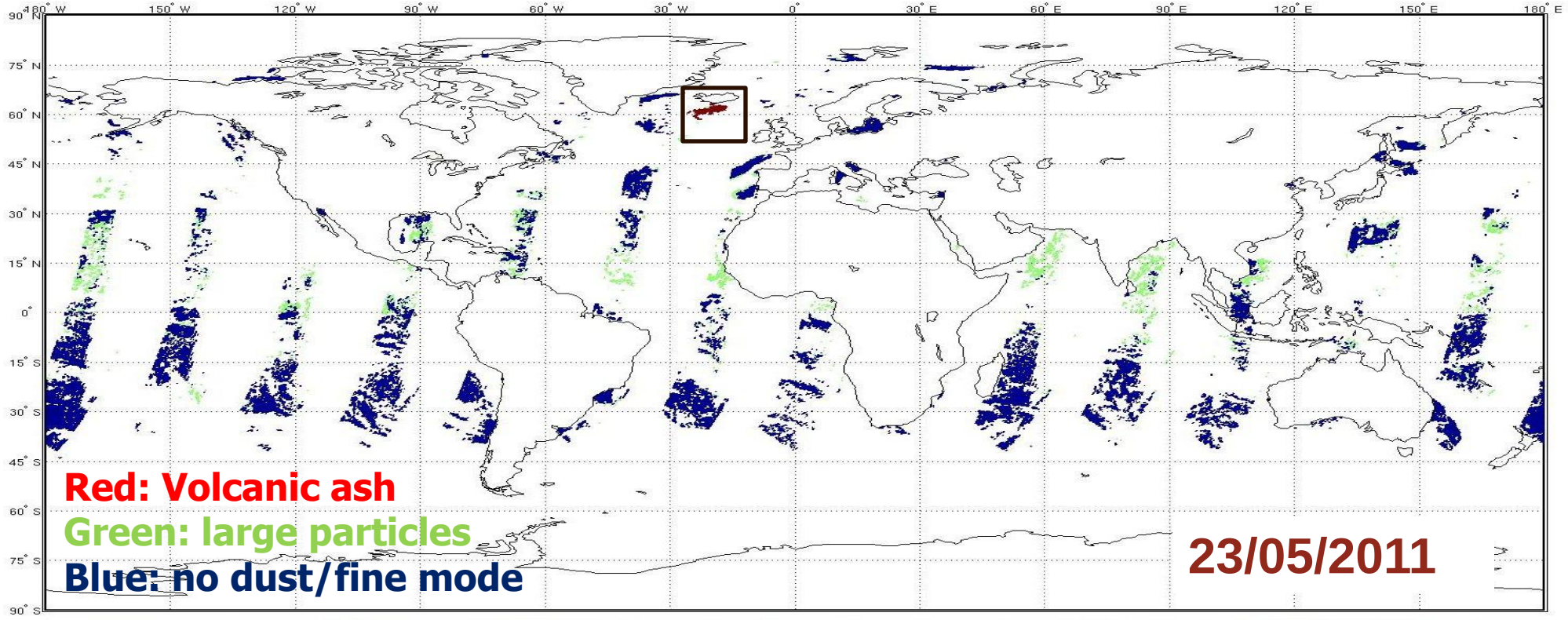
Channel	Central wave-length[µm]	Wavelength range [µm]
1	0.630	0.580 - 0.680
2	0.865	0.725 - 1.000
3A	1.610	1.580 - 1.640
3B	3.740	3.550 - 3.930
4	10.800	10.300- 11.300
5	12.000	11.500- 12.500

Geometric cloud fraction:

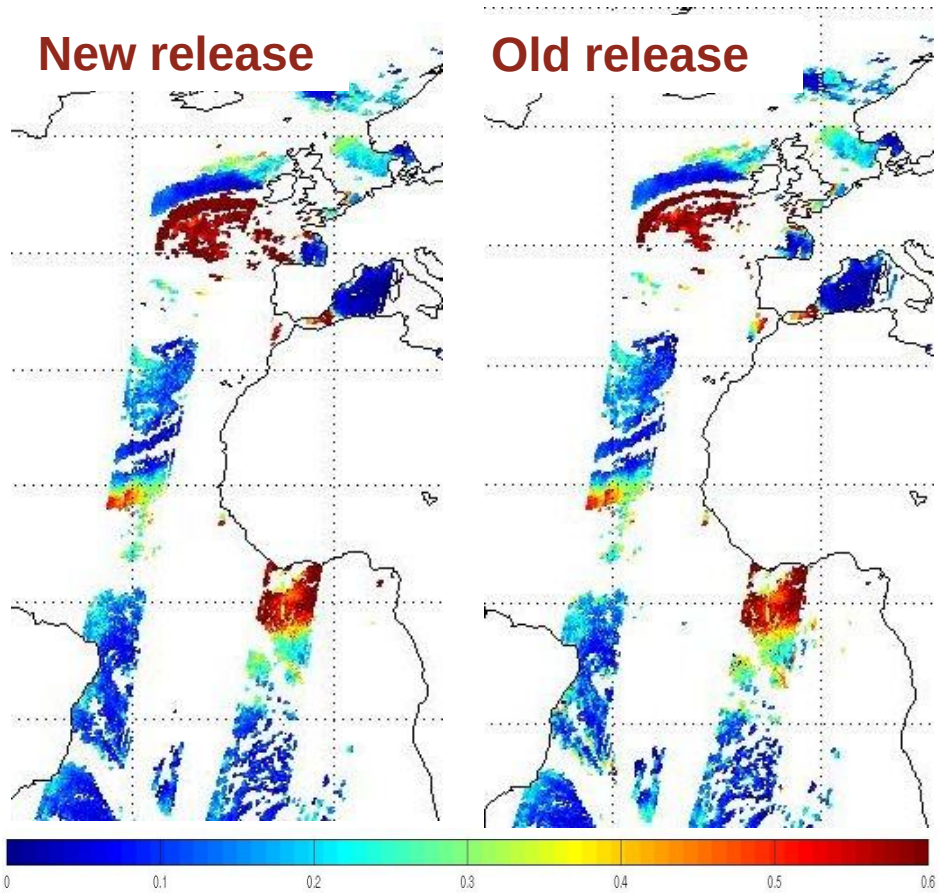
$$CF(GOME) = \frac{n_{cloudy}(AVHRR)}{n_{collocated}(AVHRR)}$$

Aerosol type pre-classification

- Distinguish clouds from volcanic ash & thick dust
  - Brightness temperature difference T4-T5 (10 µm – 12 µm)
  - Thresholds in VIS and NIR to detect false alarms
- Aerosol type pre-classification for negative cloud & ash tests
  - weak (large particle) and strong (no dust/fine mode) wavelength dependency VIS/NIR



Upcoming improvements of the PMAp processor



- Extended/improved dust detection
  - AVHRR VIS+NIR+TIR
- Cloud free pixels classified dependent on aerosol type
  - Heterogeneity of the radiance
  - Wavelength dependence of the heterogeneity
- Implementation: 11/2014
  - Improved calibration AVHRR CH4+5 (Joerg Ackermann)

- Further improvements in dust detection in PMAp R2 (Q1-2/2015):
  - UV absorbing index, IASI aerosol detection

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used over land and ocean, ocean retrieval discussed first

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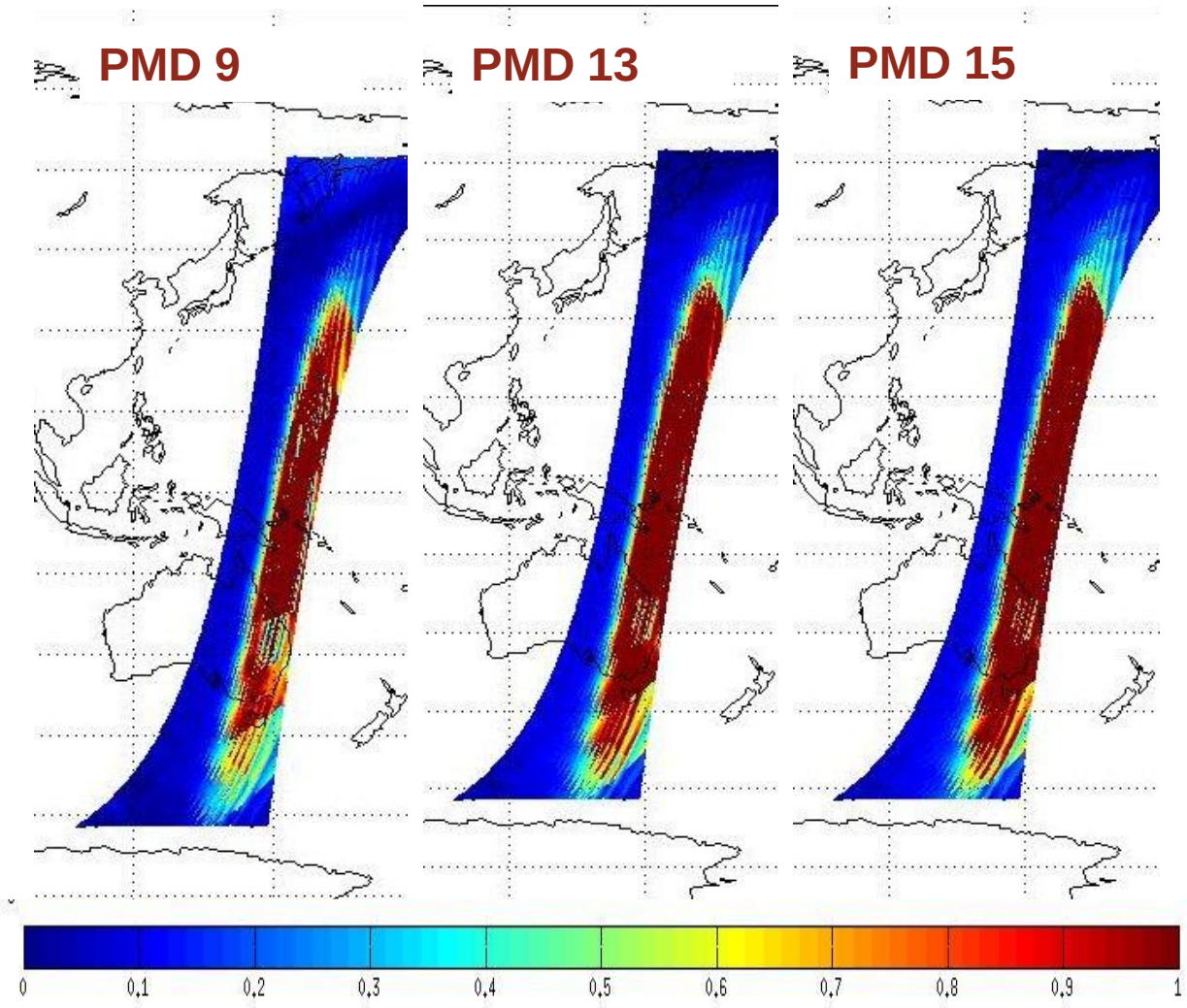
Variability of the surface vs. aerosol signal

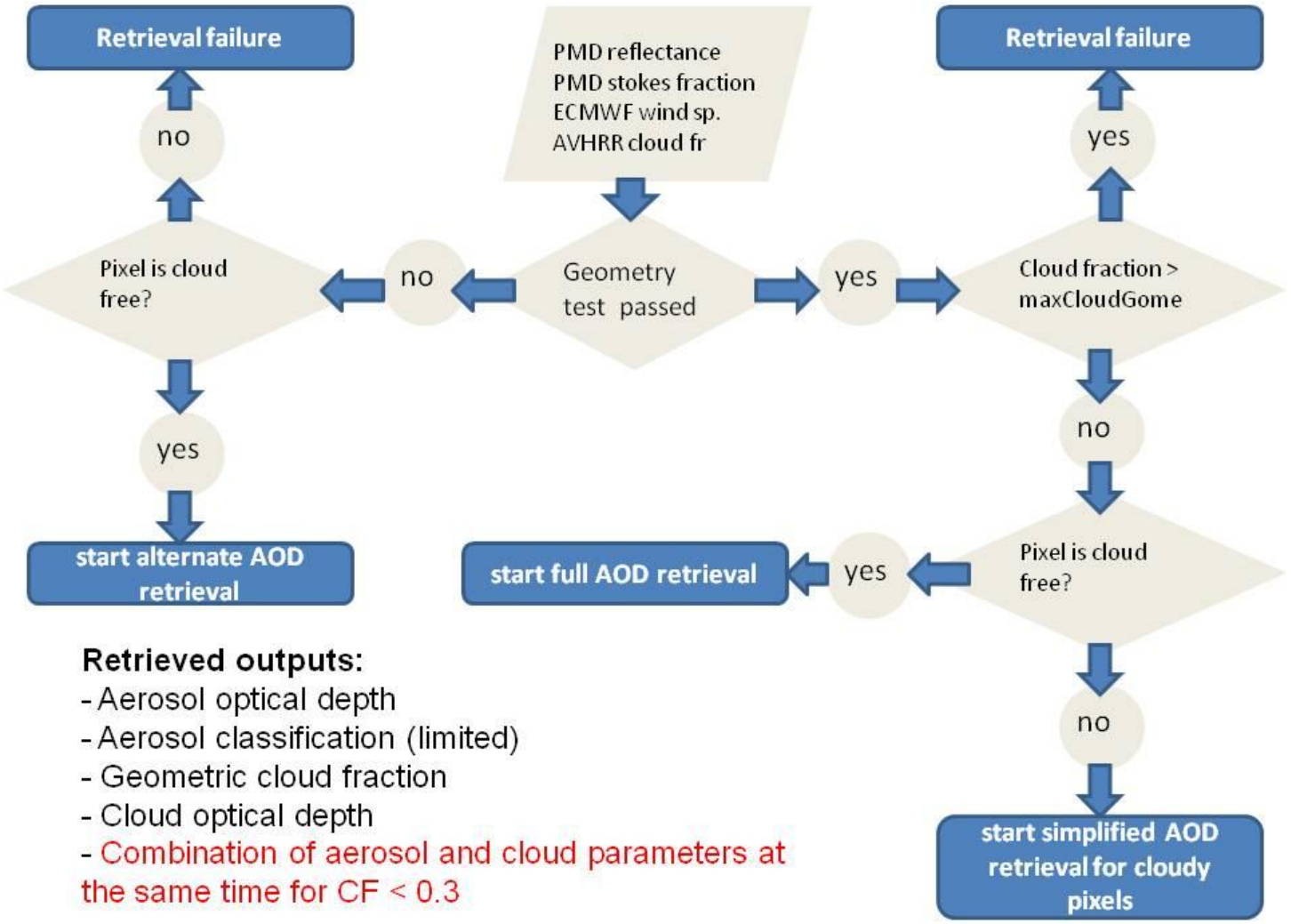


- Variablility of the surface reflectance with wind speed can be as large as the signal of an aerosol (AOD=0.3) :

$$\frac{\left|R_{clear}(12m/s) - R_{clear}(3m/s)\right|}{R_{aerosol} - R_{clear}}$$

- AOD retrieval will depend on a surface test comparing:
  - calculated clear-sky signal
  - calculated wind speed dependence
  - calculated aerosol signal

PMAp: AOD retrieval algorithm

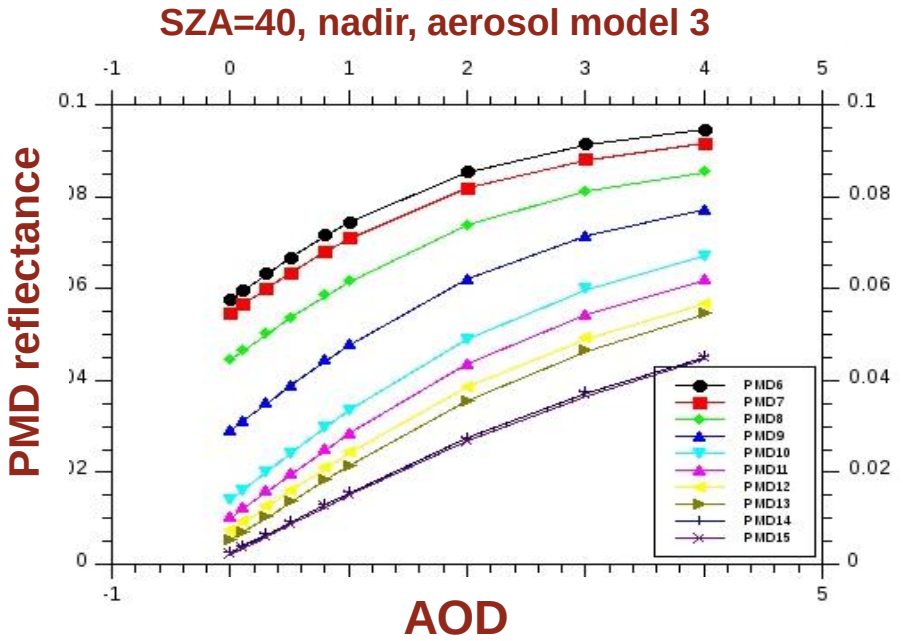


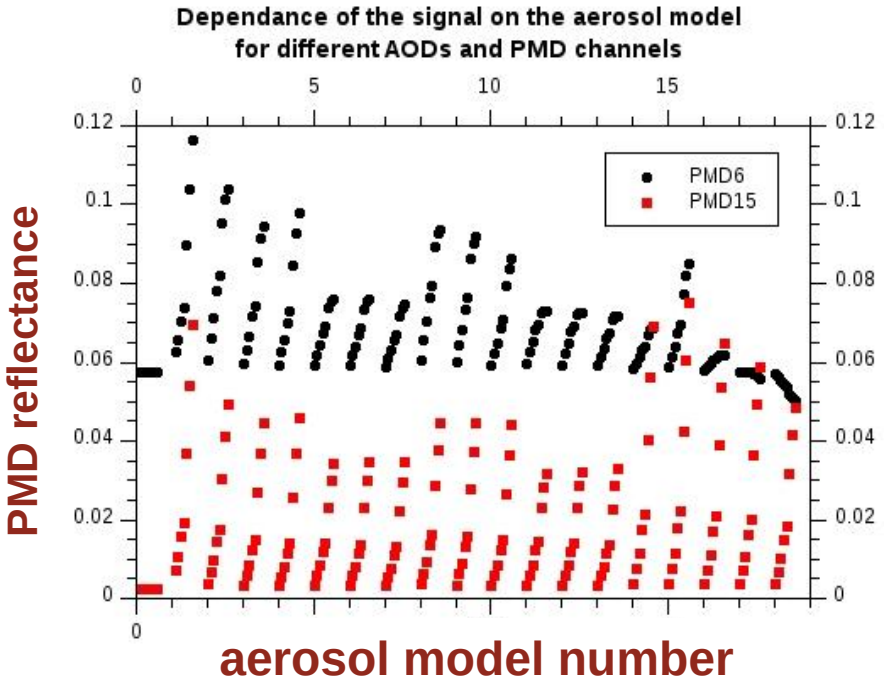
Retrieved outputs:
- Aerosol optical depth
- Aerosol classification (limited)
- Geometric cloud fraction
- Cloud optical depth
- Combination of aerosol and cloud parameters at the same time for CF < 0.3

- Geometry dependent test with intercomparison of:
  - calculated surface signal
  - calculated wind speed dependence
  - calculated aerosol signal
- Cloud filter:
  - AVHRR/VIS
  - AVHRR/IR

Case 1 & 2: Geometry/Surface test passed

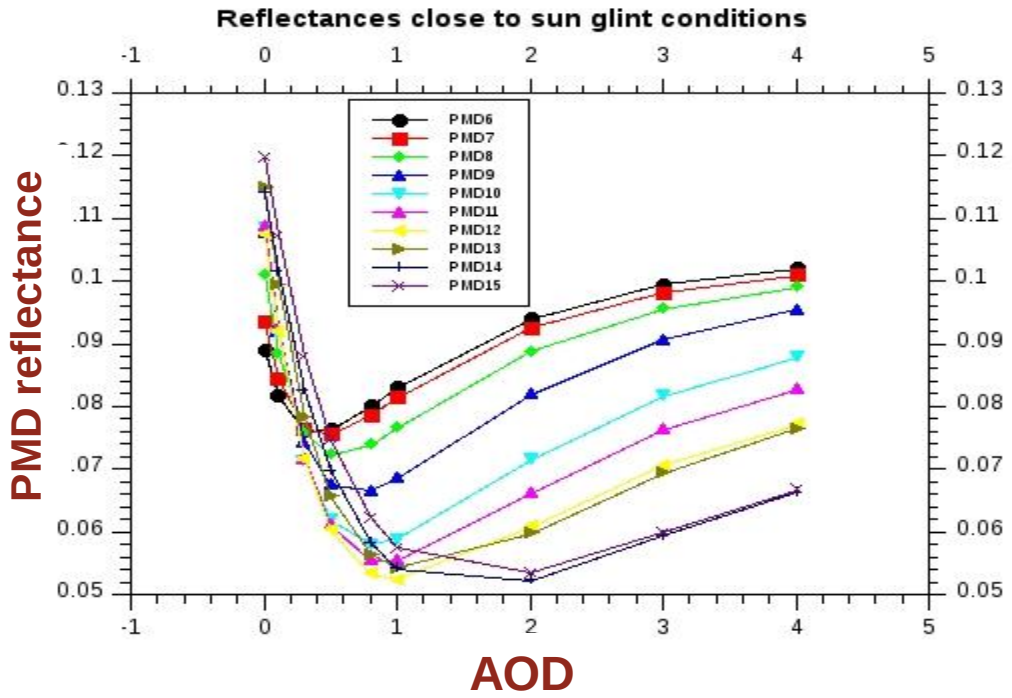
- A set of AODs (for all AVHRR preselected models) and chlorophyll corrections is estimated:
  - **Clear sky**: **UV [380 nm]**, **VIS/green [520 nm]**, **VIS/red [640 nm]**
  - **Cloudy**: **VIS/red [640 nm],** a priori chlorophyll, AVHRR cloud correction

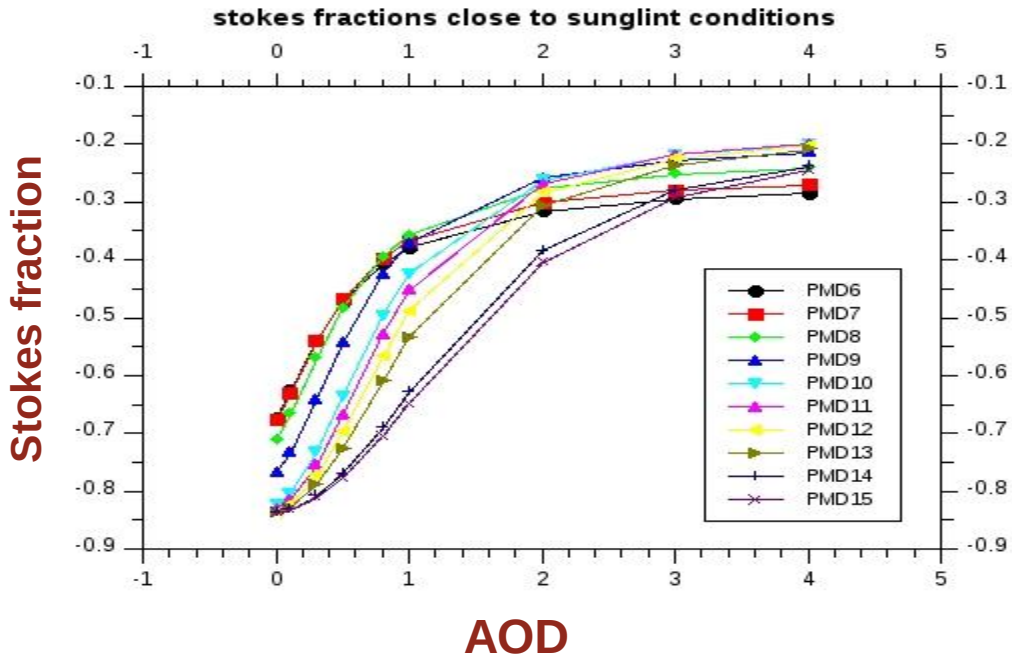




Case 3: Alternate retrieval combining reflectances & stokes fractions

- Estimate an AOD using one channel (reflectance or stokes fraction) using different aerosol models and a priori surface
- Check reliability: $\chi^2 = \sum_N \frac{(R_{PMD} - R_{modelled})^2}{R_{modelled}} + \sum_M \frac{(q_{PMD} - q_{modelled})^2}{q_{modelled}} < chi2max$





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Step3: Selection of the best fit

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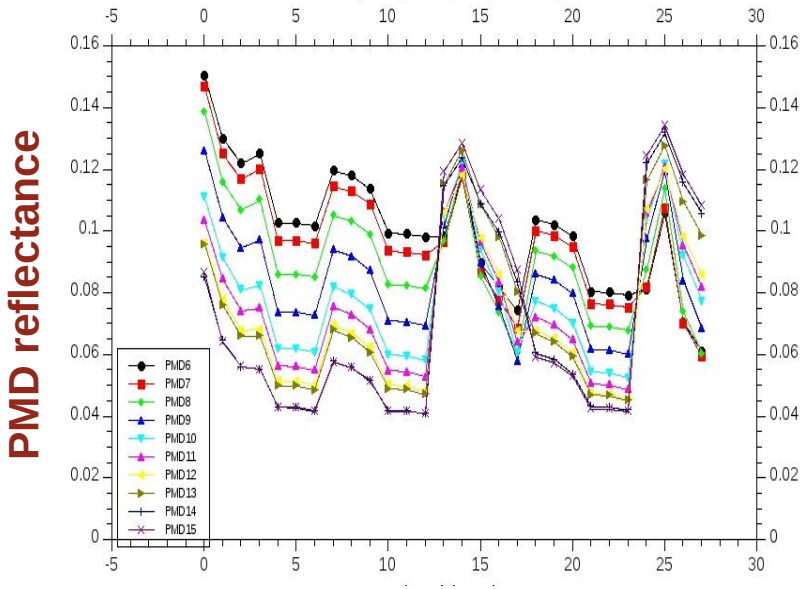
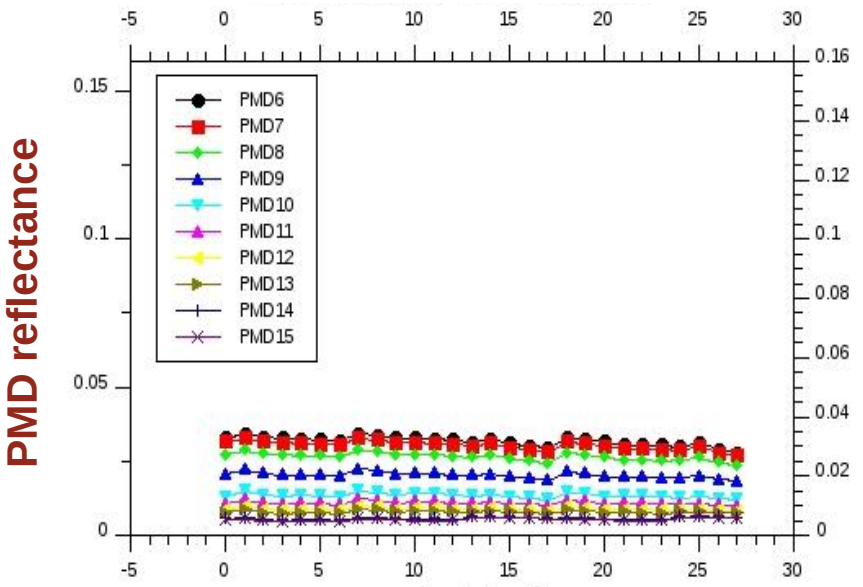
Selection of the aerosol model: Reflectances ...

$$\chi^2 = \frac{\sum_O \frac{(R_{PMD} - R_{modelled})^2}{R_{modelled}} + \sum_P \frac{(q_{PMD} - q_{modelled})^2}{q_{modelled}}}{O + P}$$

SZA=40, cos(RAZI)=-1, VZA=45, AOD=4

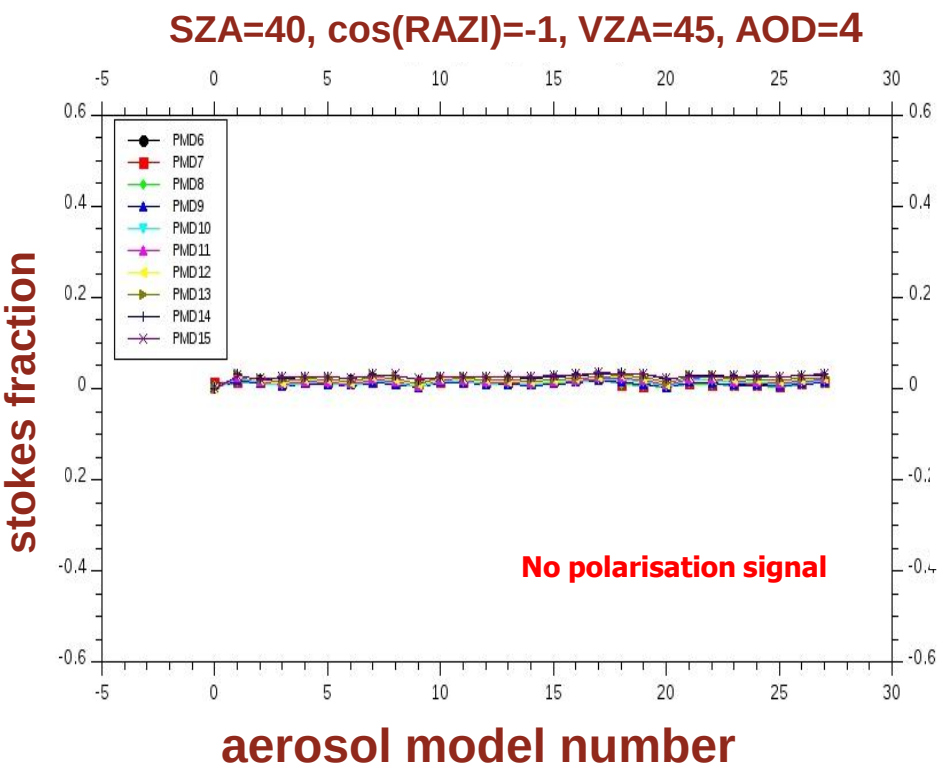


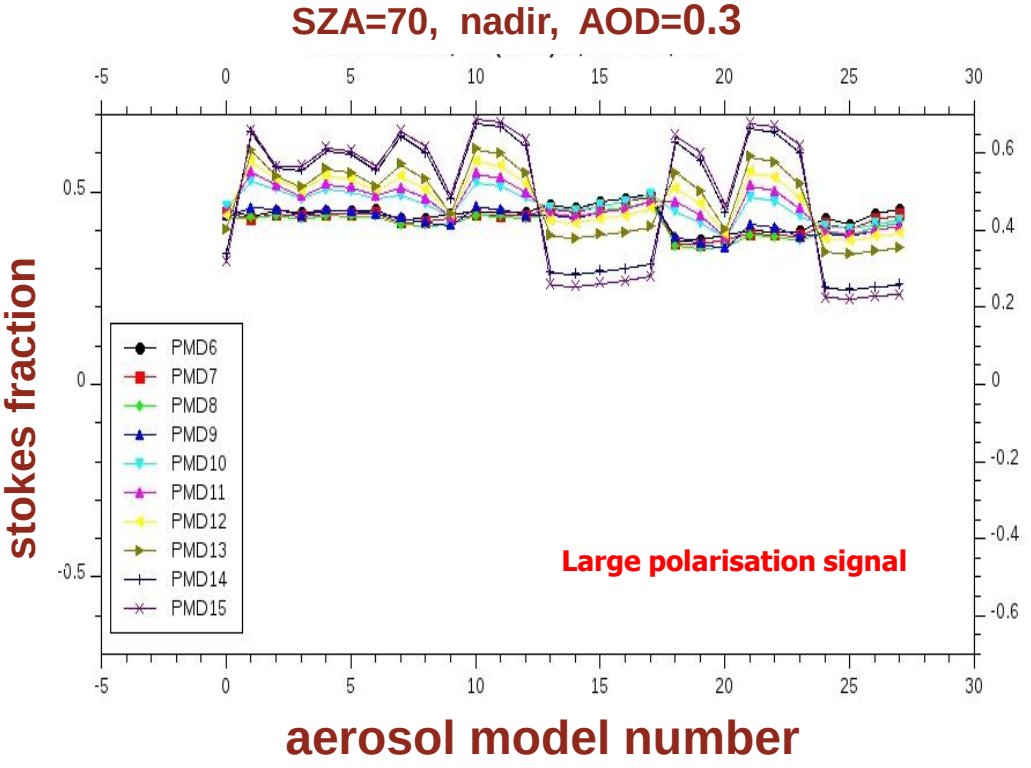
SZA=70, nadir, AOD=0.3



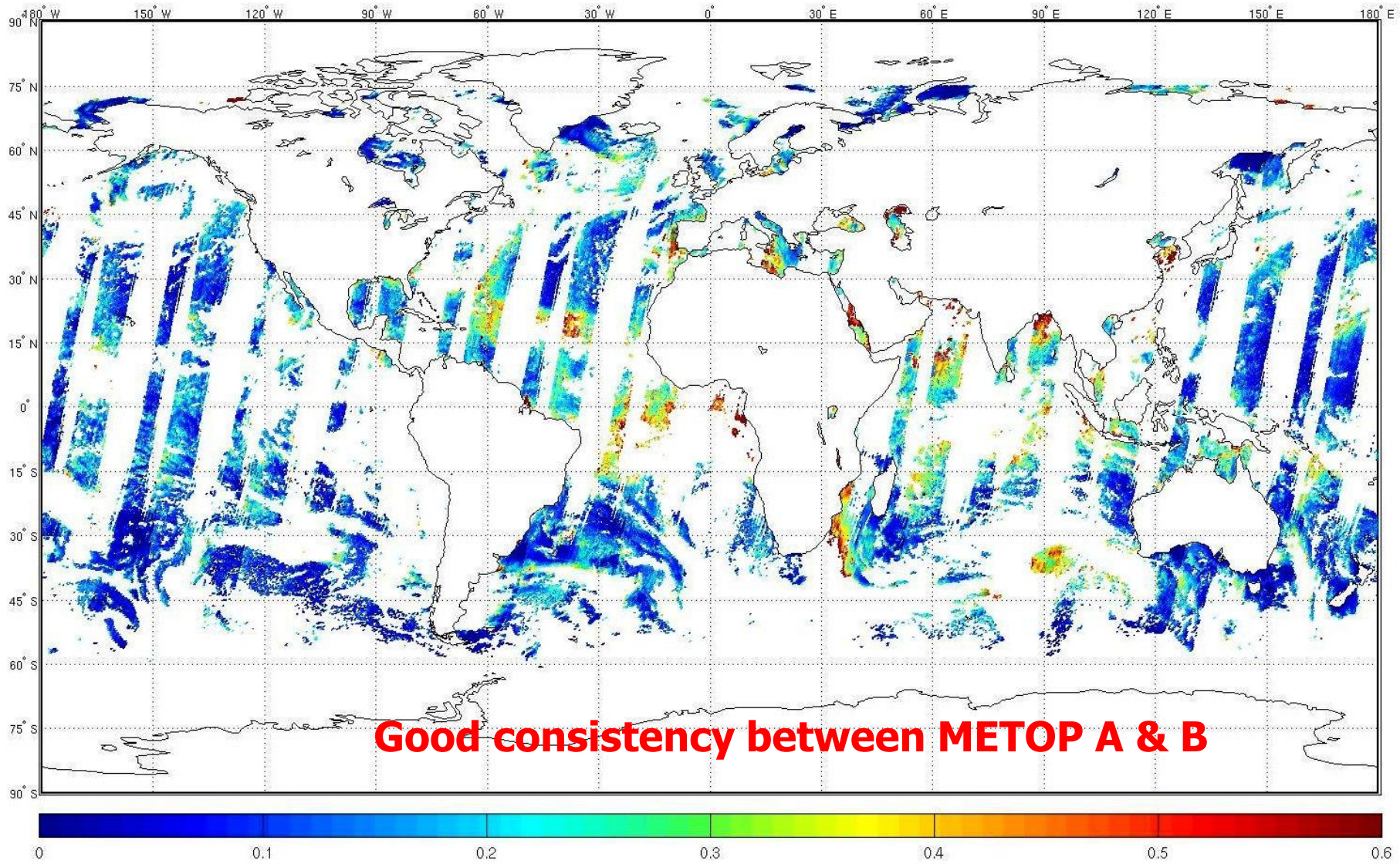
... and stokes fractions

- Stokes fractions are used in addition to reflectances if observation geometry shows significant polarization (see examples below)

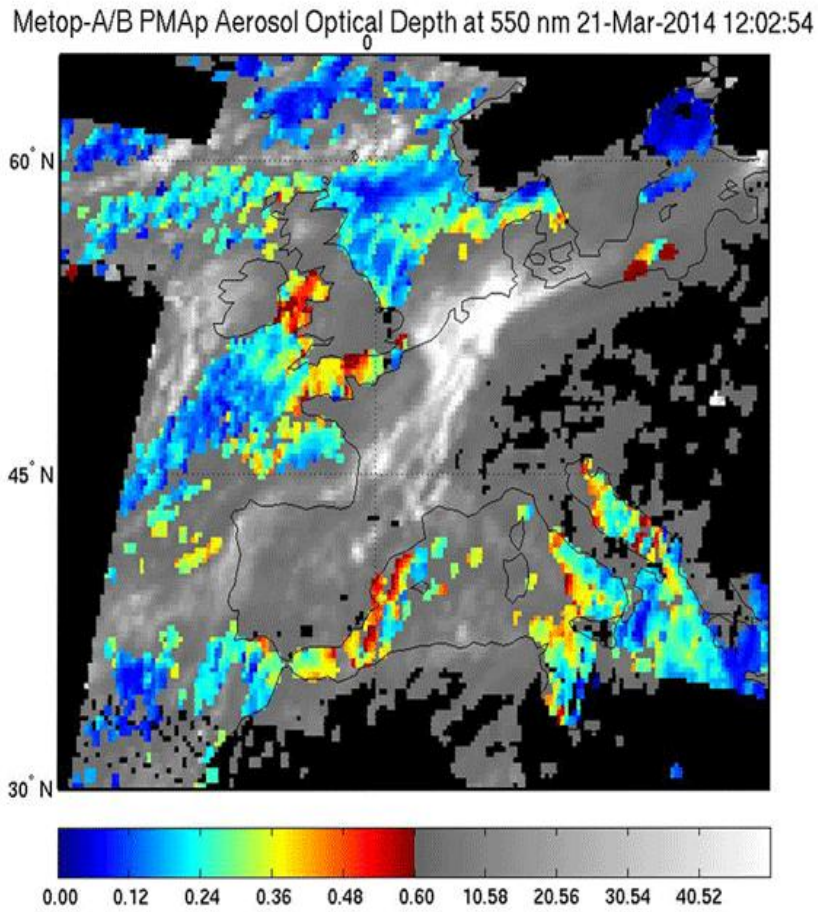




PMAp results: AOD Metop A & Metop B (30/08/2013)

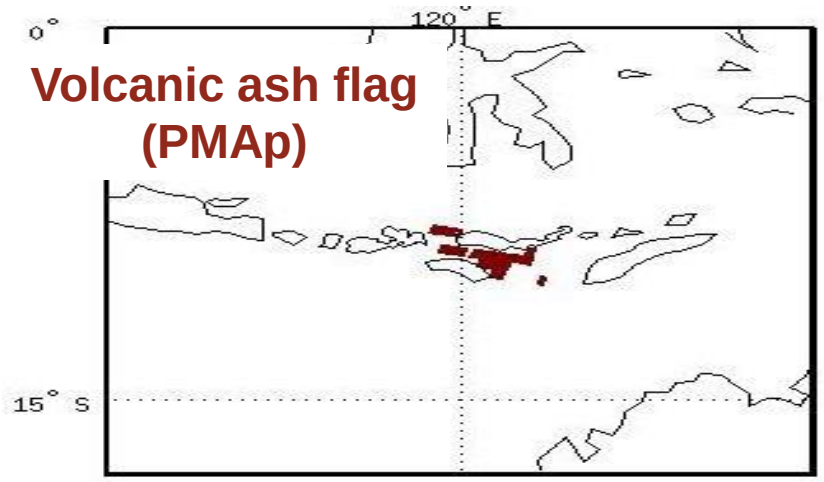


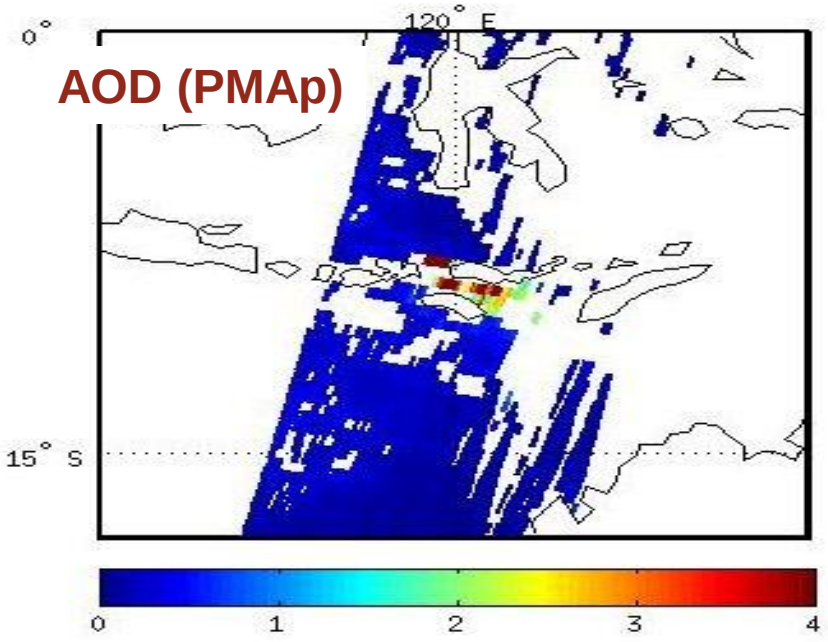
PMAp aerosol events: Dust storm event



http://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_2187633.html

PMAp aerosol events: Volcanic ash plume June 2014





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Volcanic ash cloud grounds flights in North Australia

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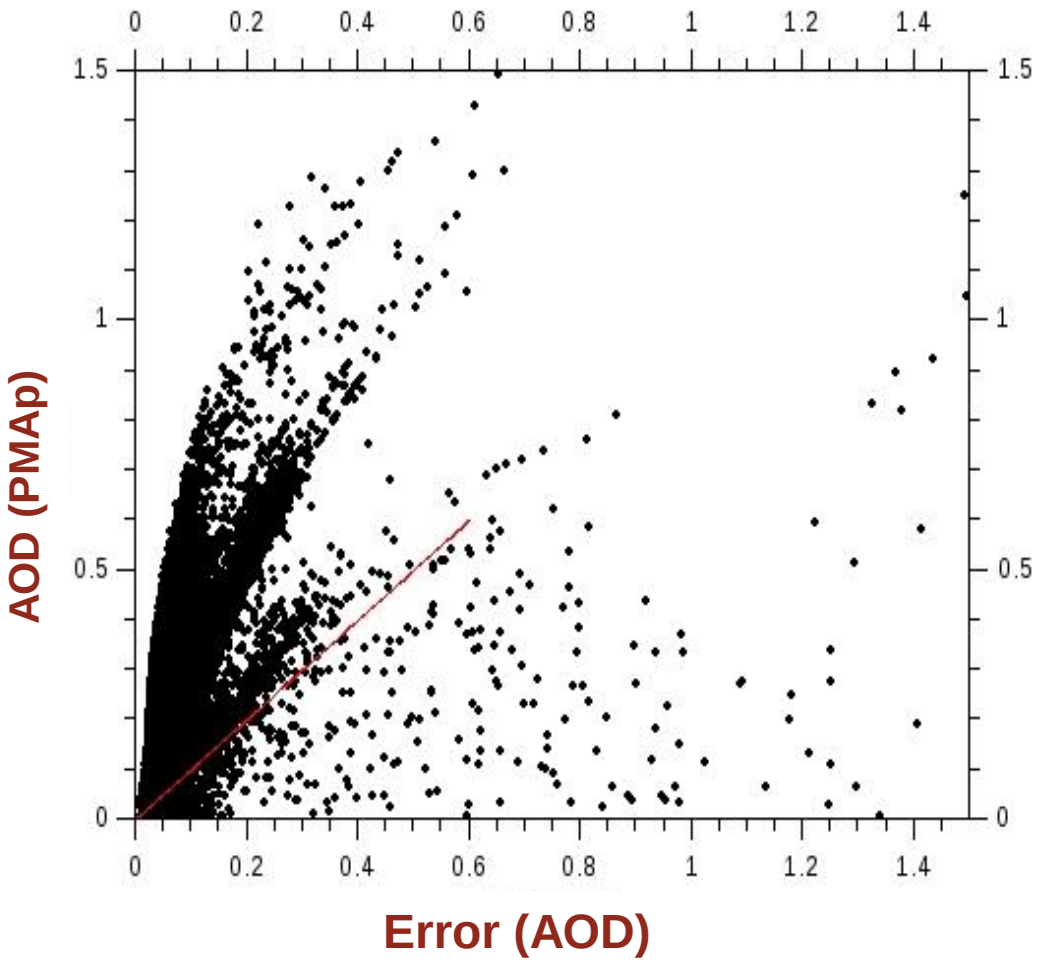
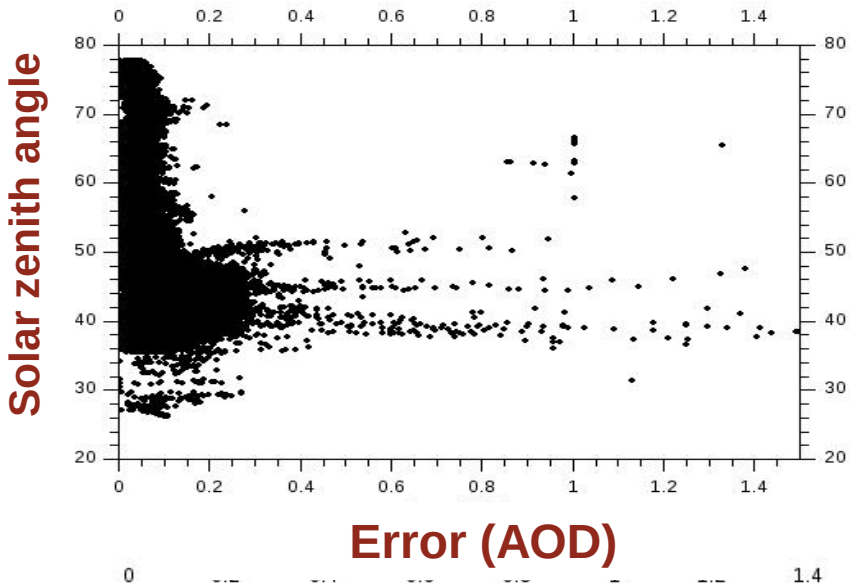
PMAp error retrieval

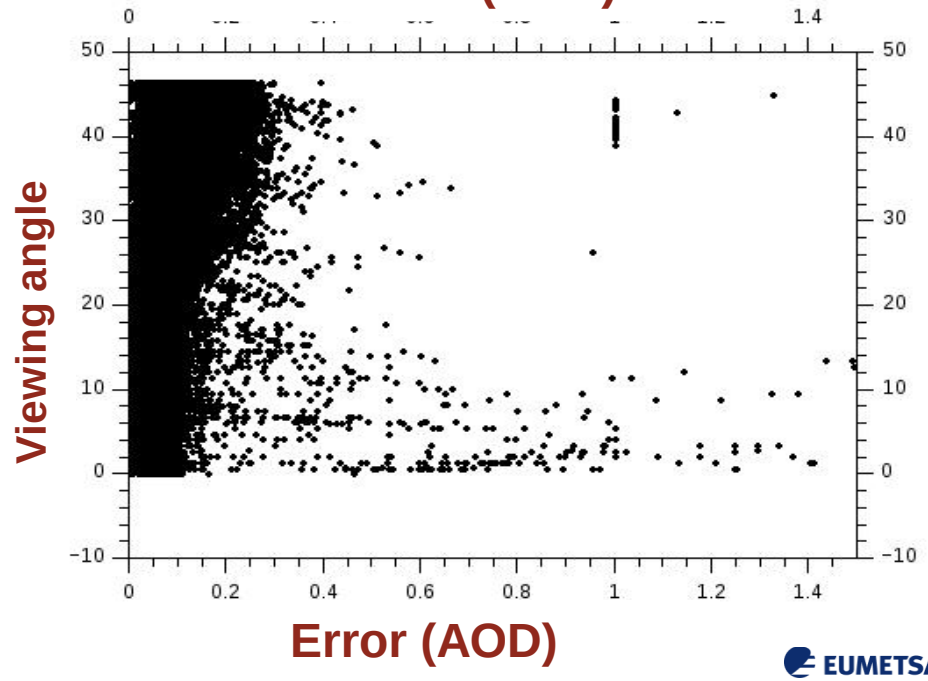
- PMAp does not use optimal estimation methods.
- A set of AOD is calculated using simplified inversion.
  - Examples:
    - Variation of the chlorophyll pigment concentration
    - Errors of AVHRR/GOME collocations
    - Dependence of the surface reflection on wind speed
    - Selection of a wrong aerosol type / microphysical properties
- A standard deviation of these AODs is calculated.
- PMAp calculates a randomized error optimized for assimilation

PMAp errors dependent on different parameters

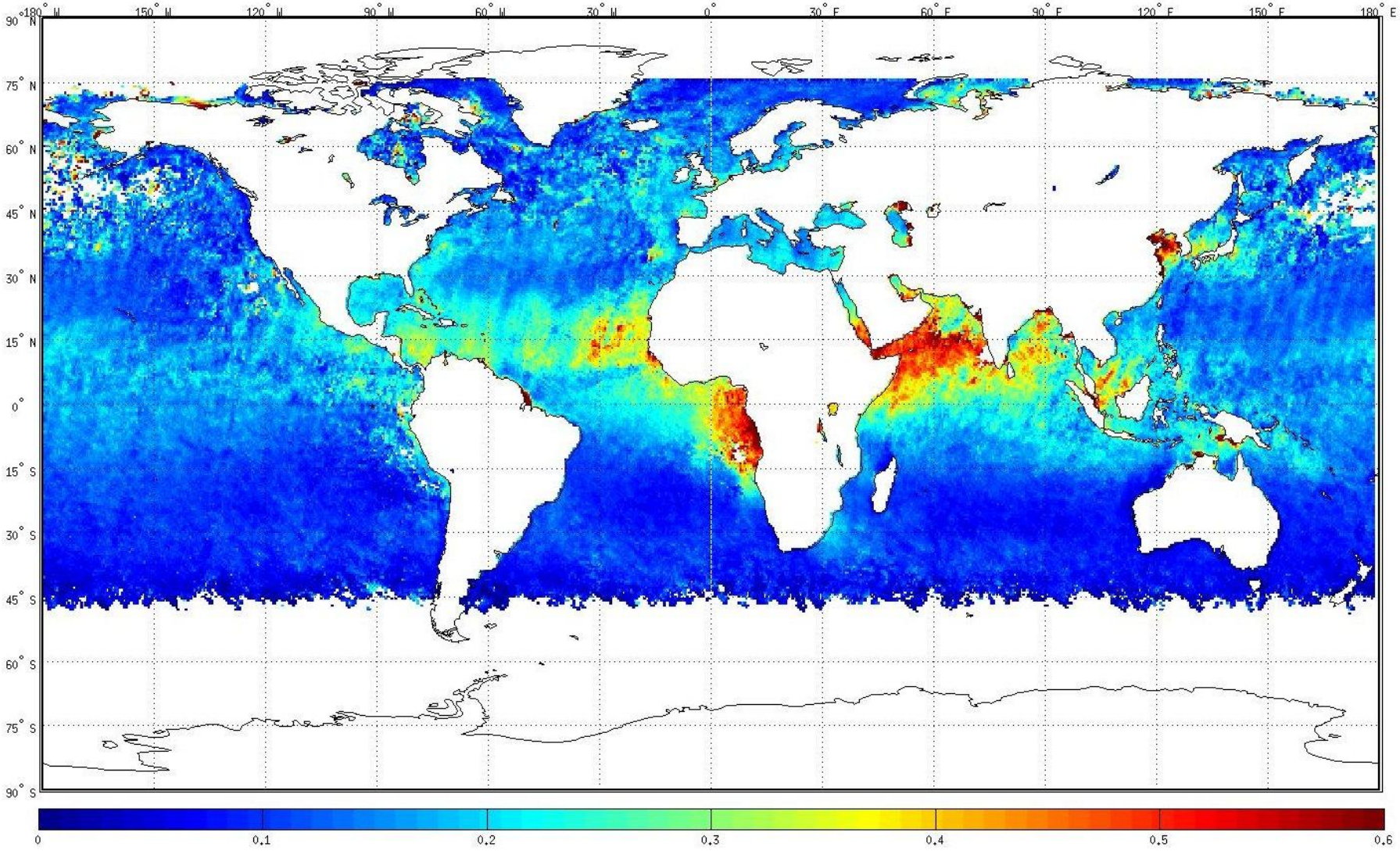
- PMAp error is used to skip bad quality pixels from the product







PMAp AOD Metop A
(June/July 2013)



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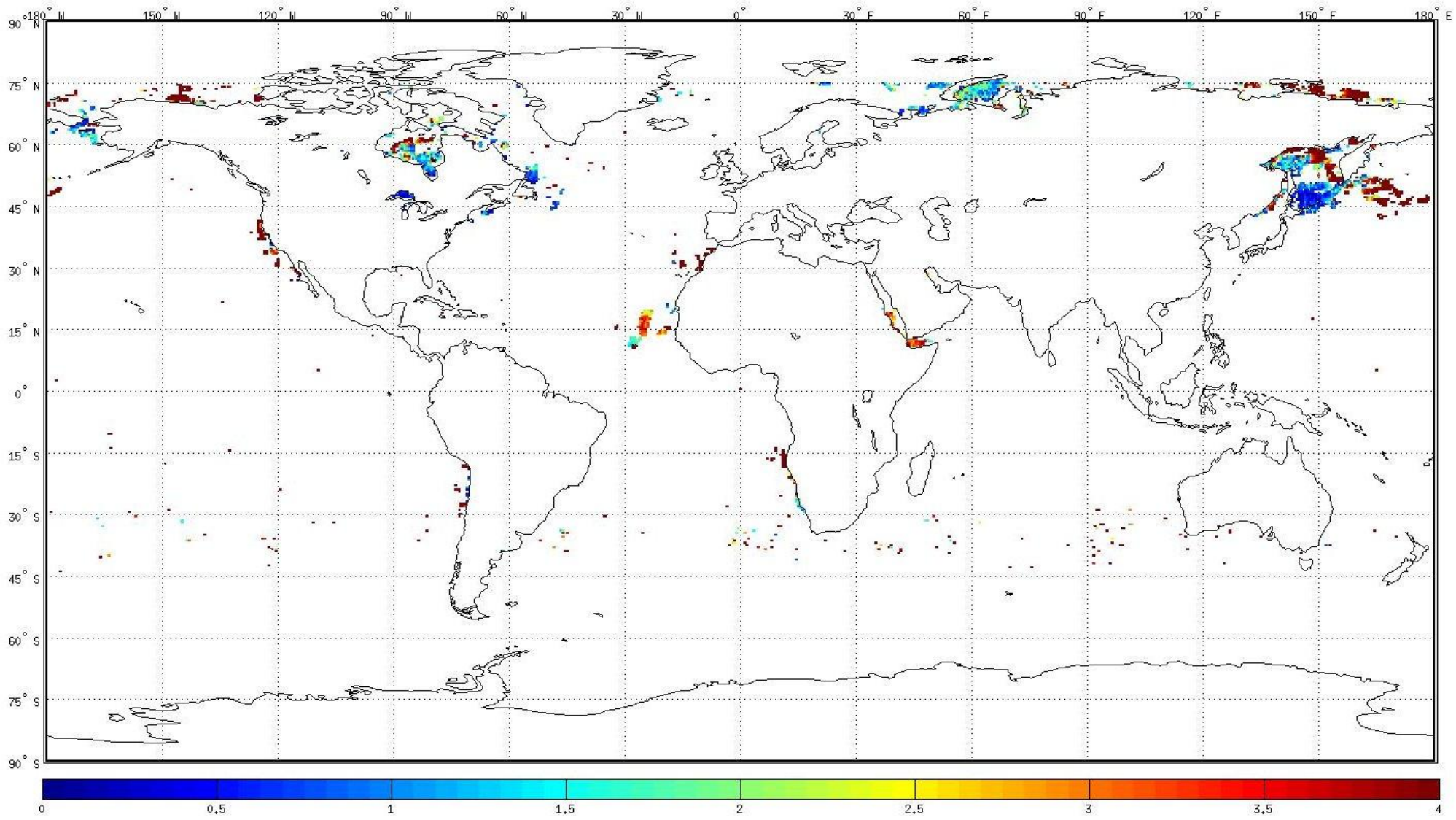
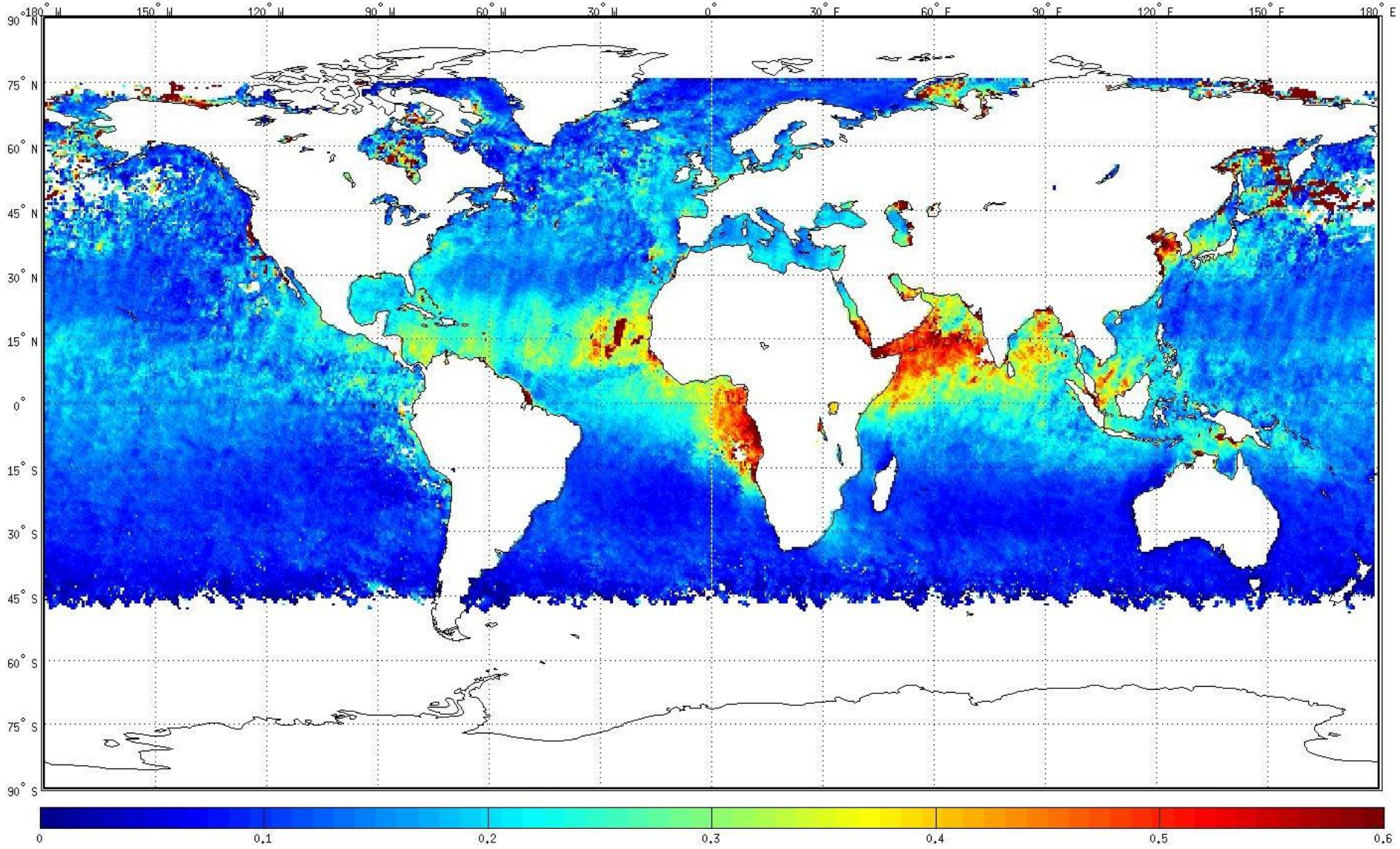
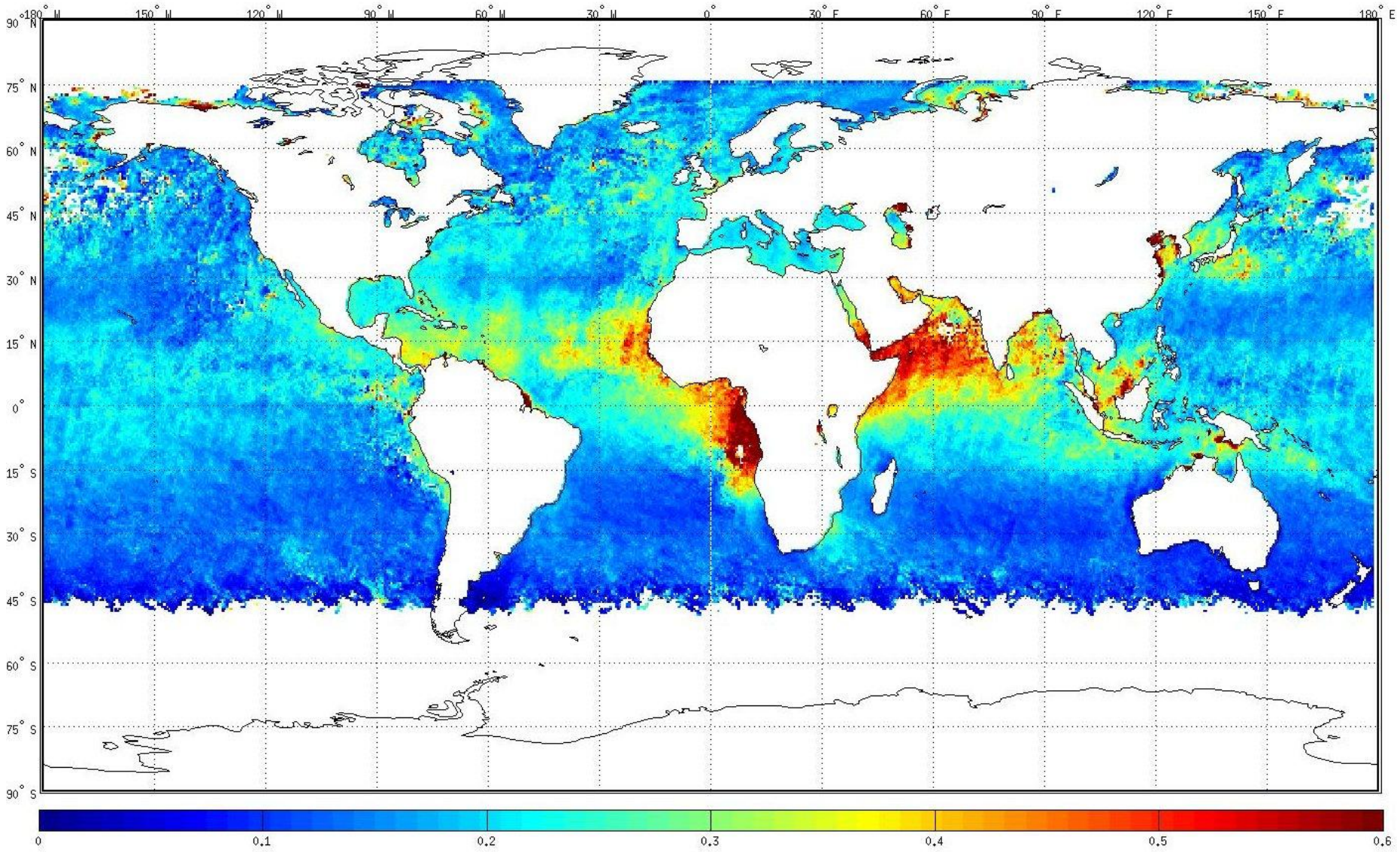
PMAp AOD Metop A – Thick events (0.3% of all)
(June/July 2013)



PMAp AOD Metop A – including thick events
(June/July 2013)



PMAp AOD Metop B
(June/July 2013)



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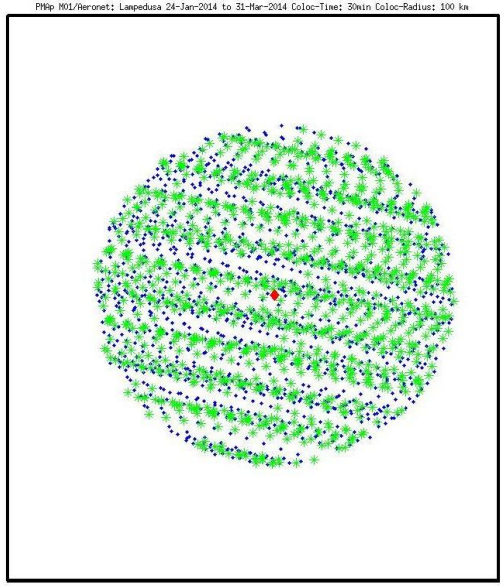
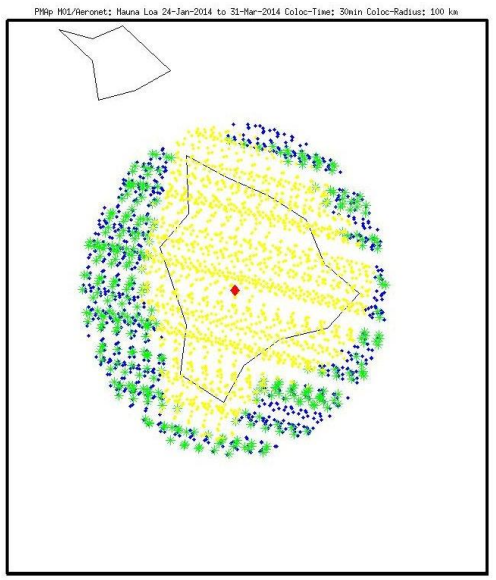
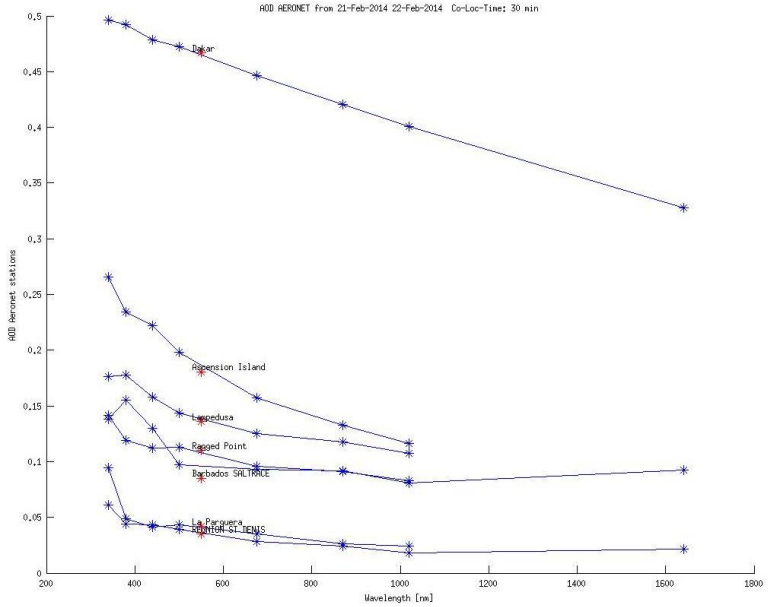
Operational monitoring of PMAp using AERONET

- Stations on island and selected coastal stations
- Max temporal difference: 30min,
- Max spatial difference: 60km
- Continuous monitoring since January 2014

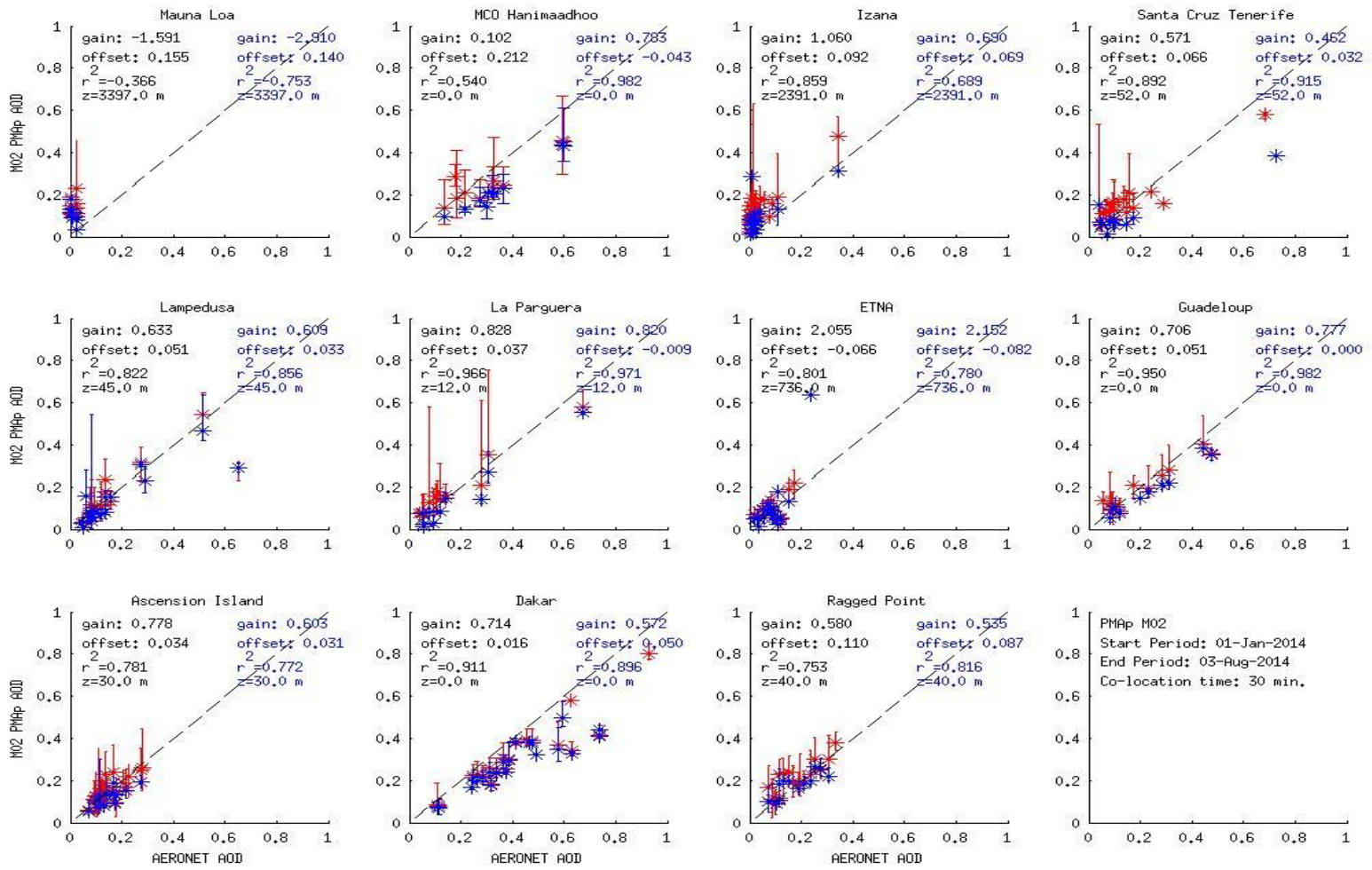






Comparisons to AERONET: Results Metop A

Blue: clear sky (PMAp), red = partly cloudy (PMAp)



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Comparisons to AERONET: Results Metop B

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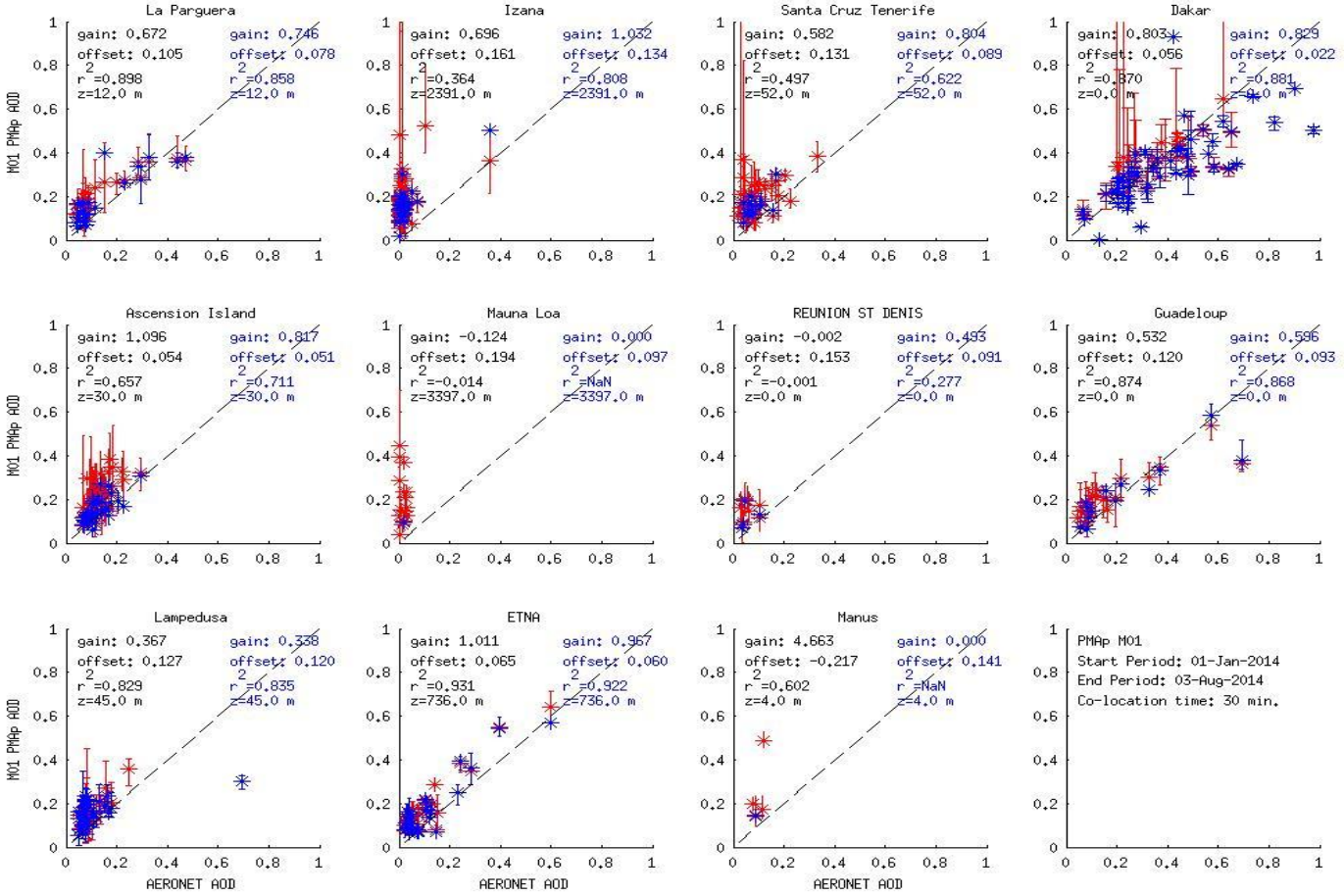

AOD PMAp

AOD AERONET

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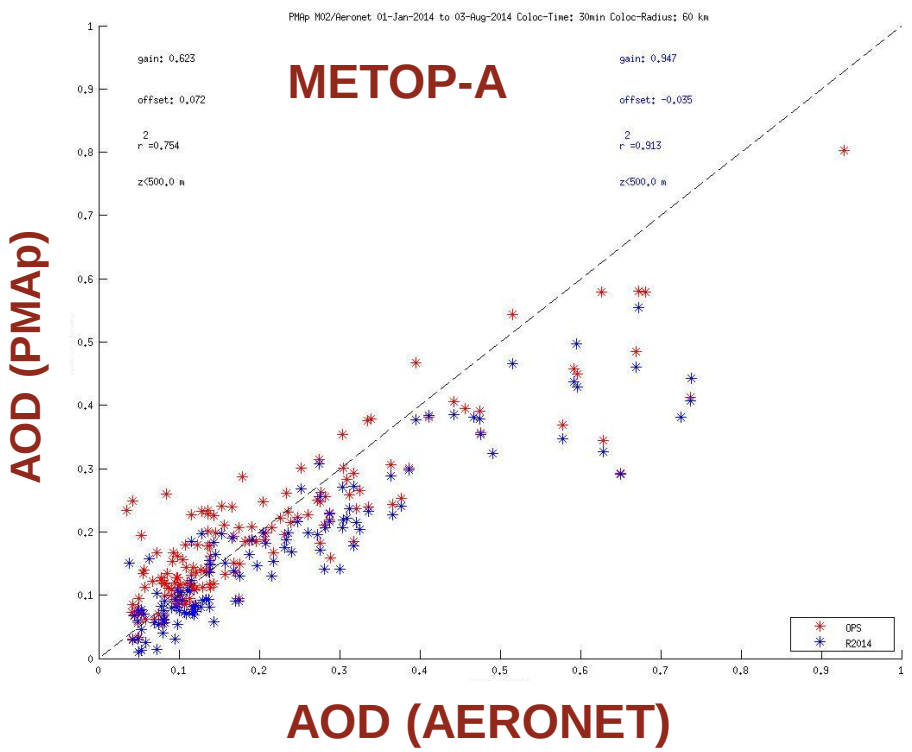
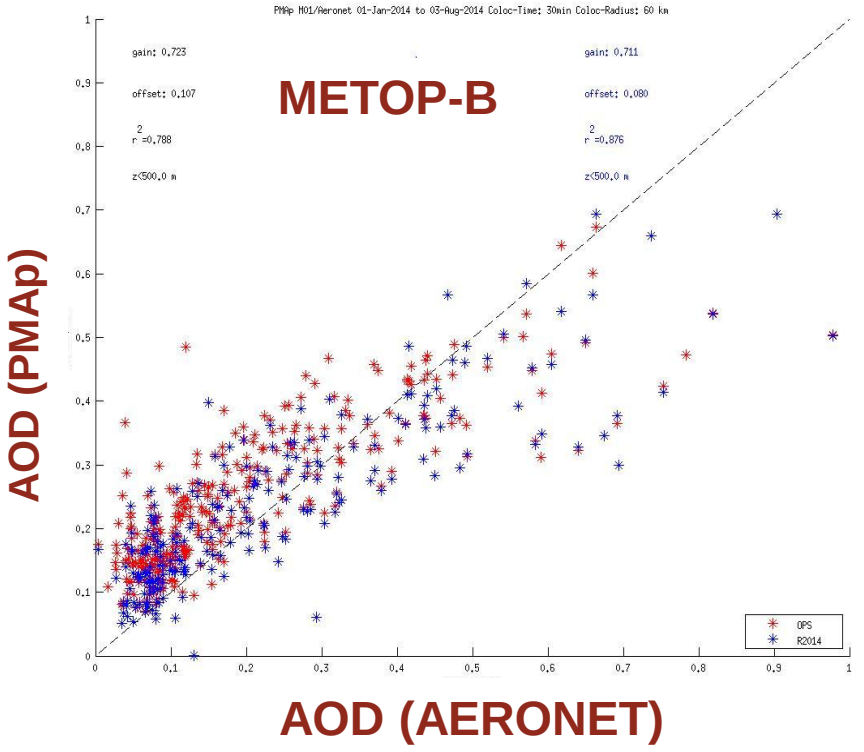
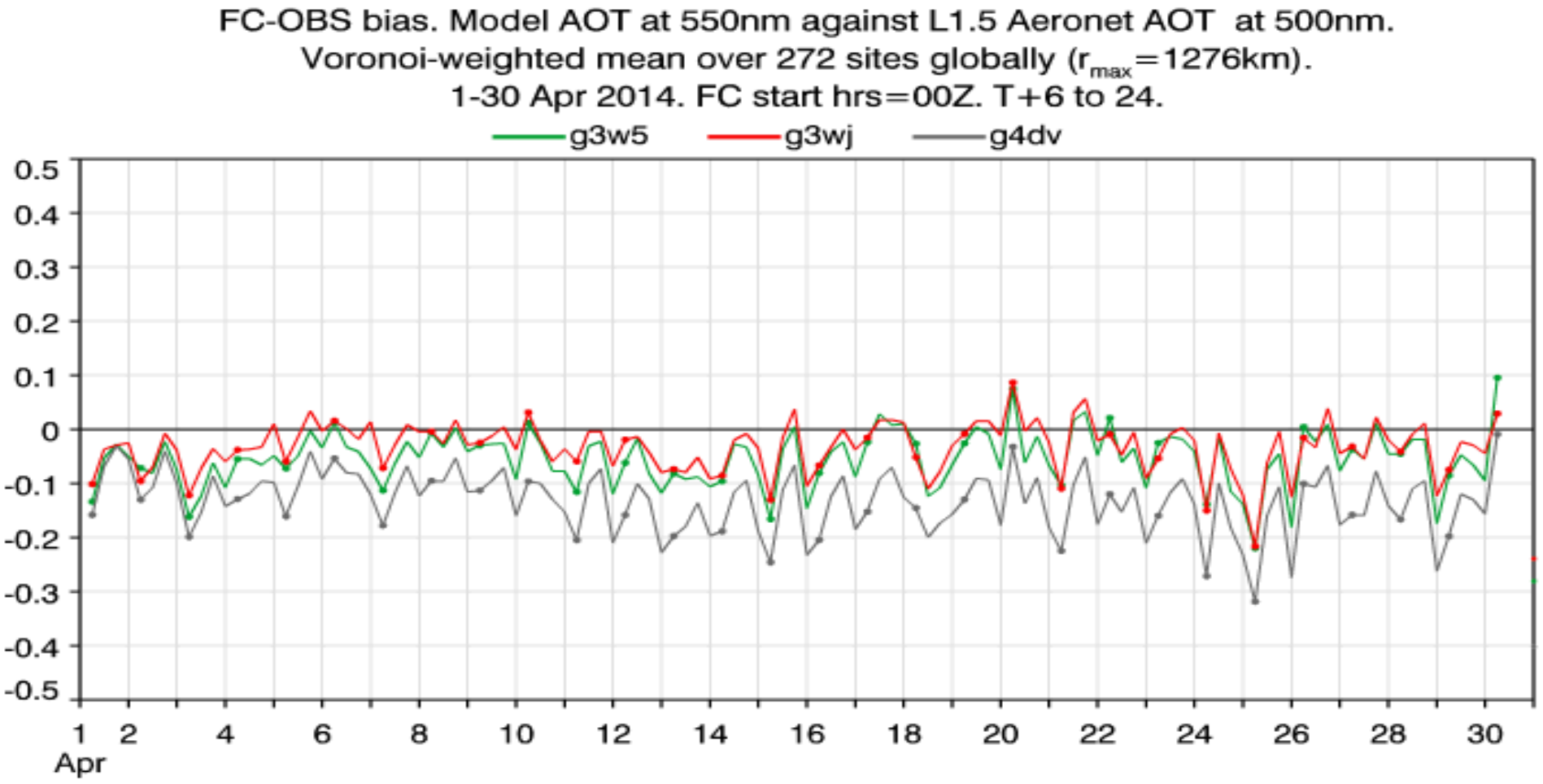
Comparisons to AERONET: Results Metop A & B

- All AERONET station with altitude < 500m
- **Red = all PMAp values**, **blue = PMAp clear sky values**
- **R= 0.86/0.88, R=0.95/0.93** – data selection sensitive

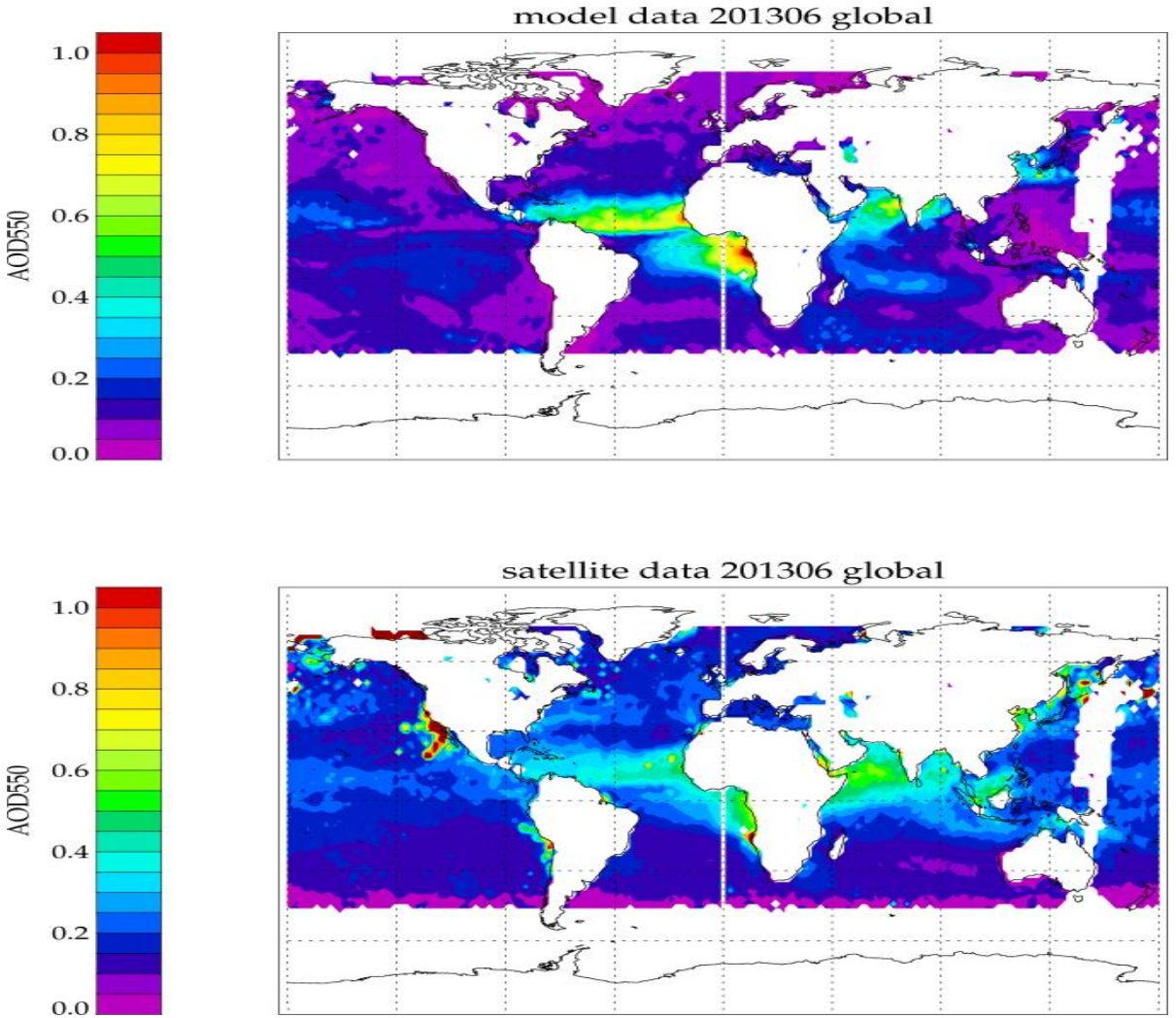


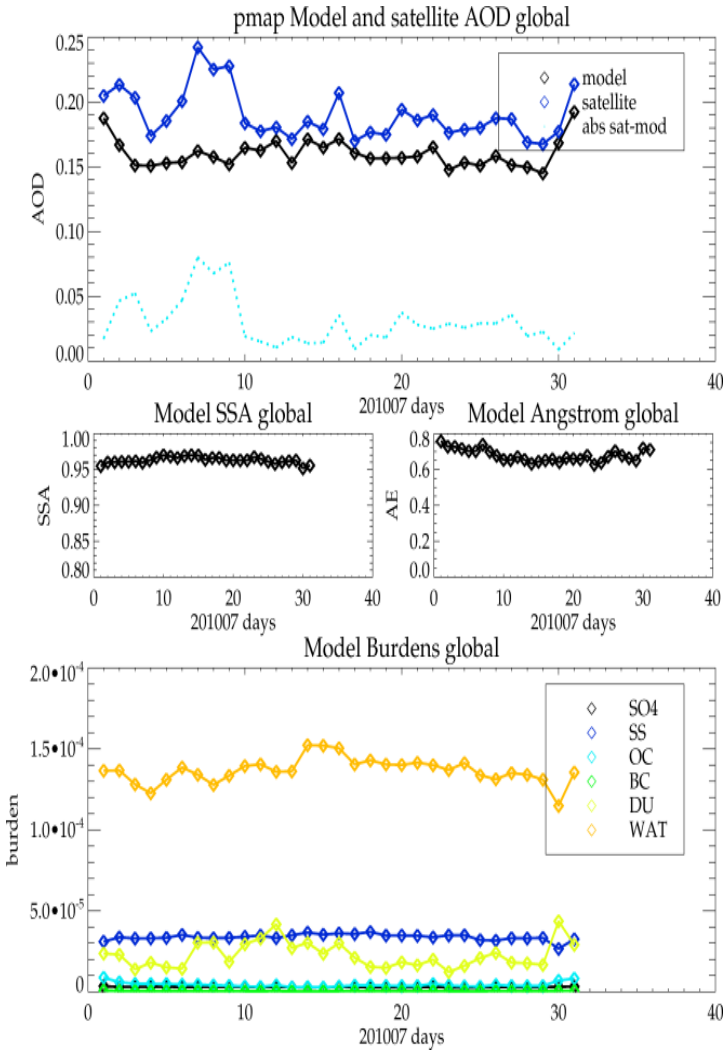


ECMWF test assimilation: PMAp and MODIS
(June/July 2013)

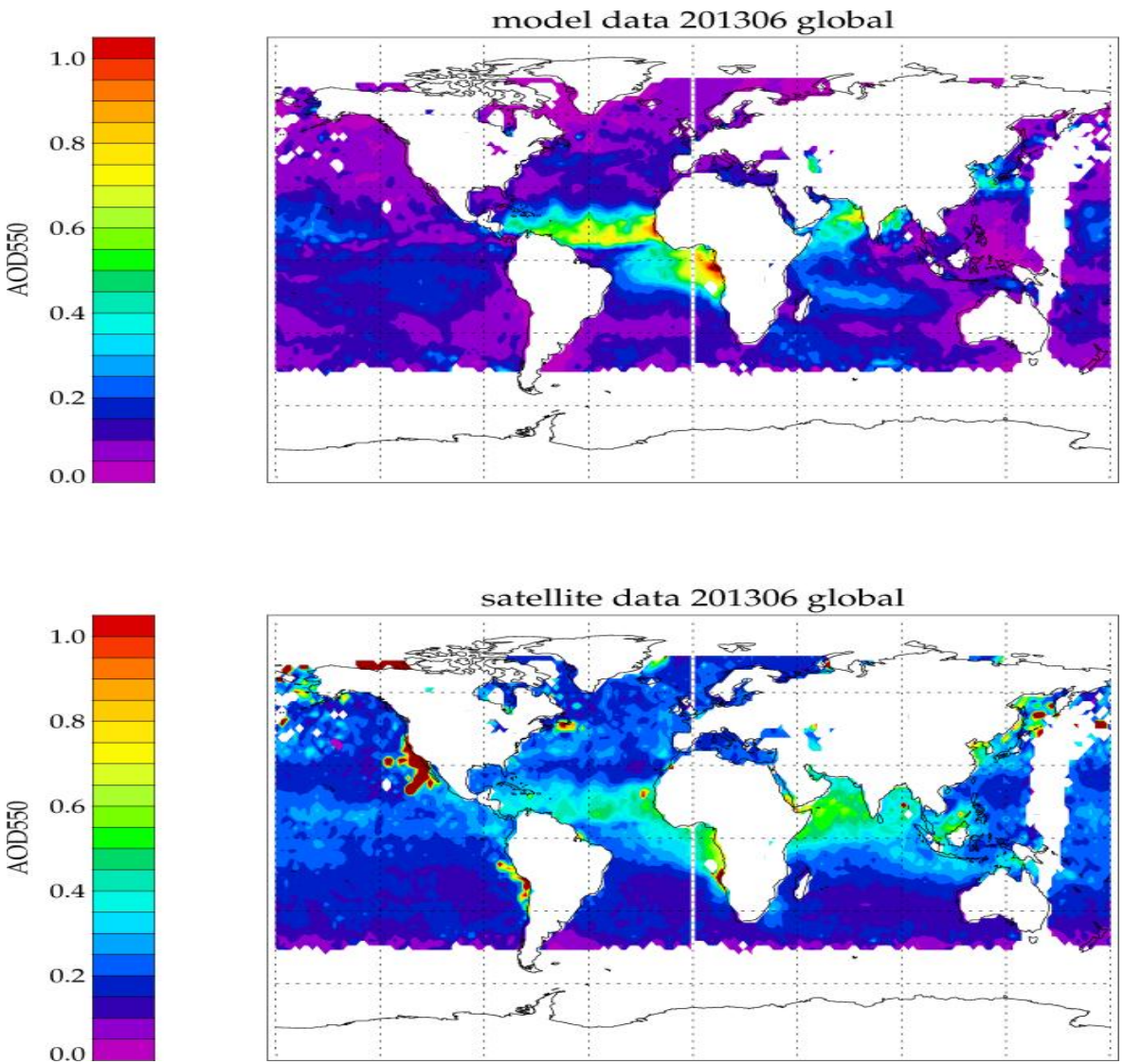


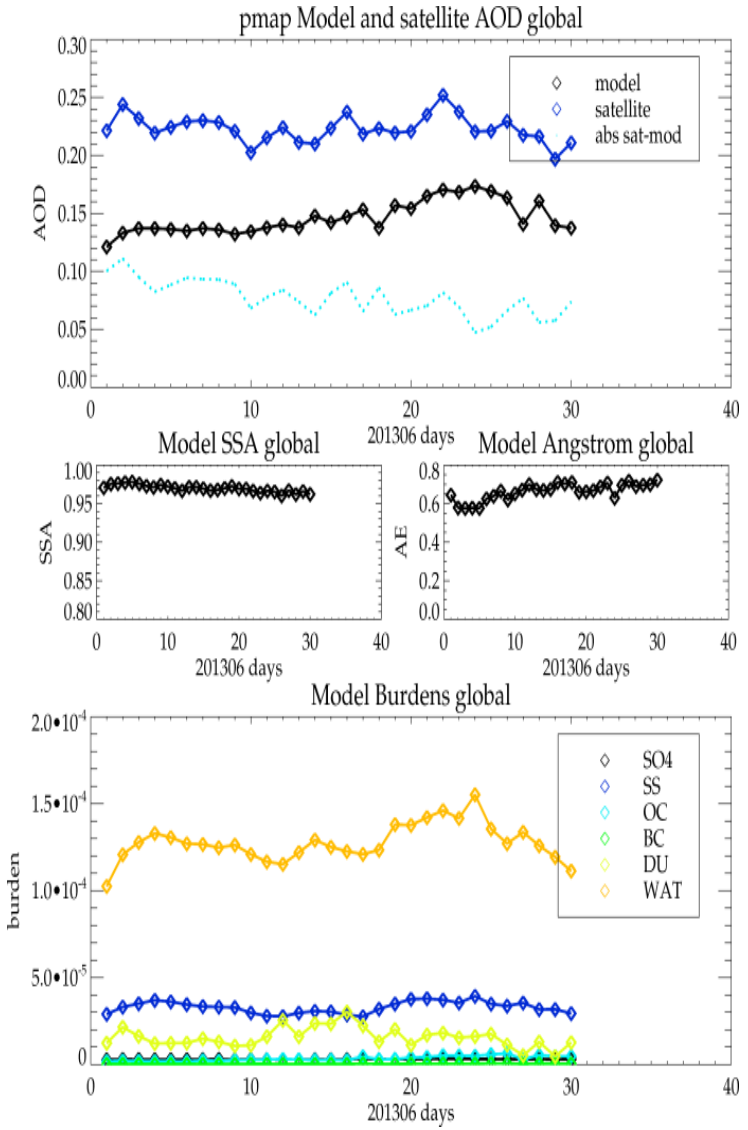
Comparison to ECHAM-HAM model: Metop A global





Comparison to ECHAM-HAM model: Metop B global





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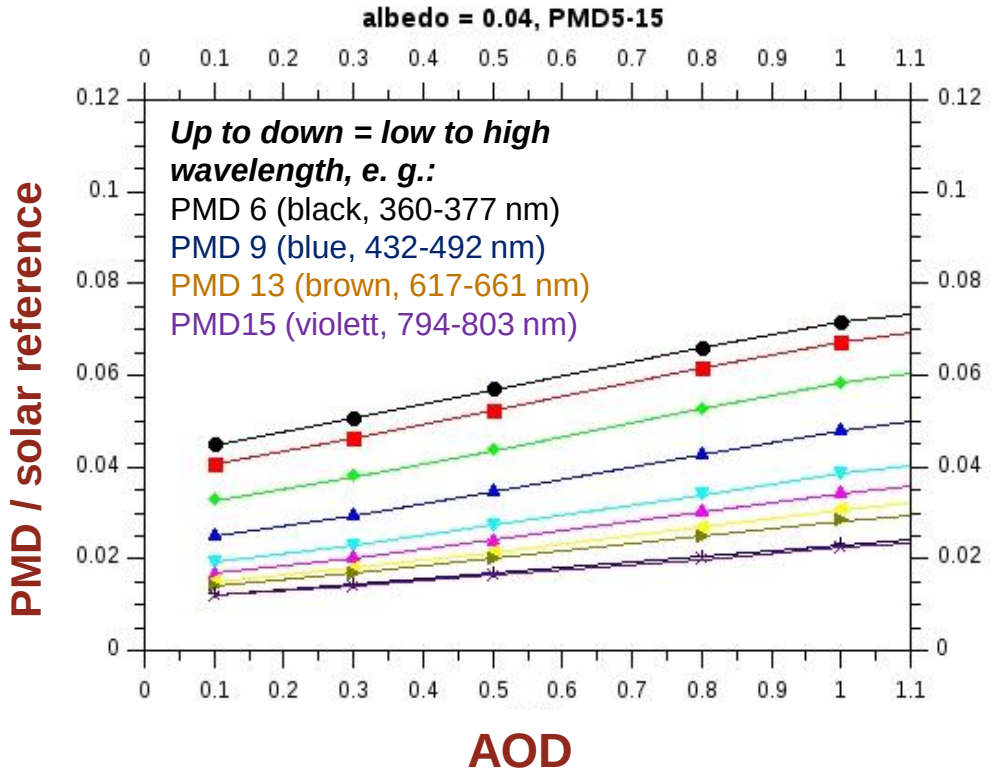
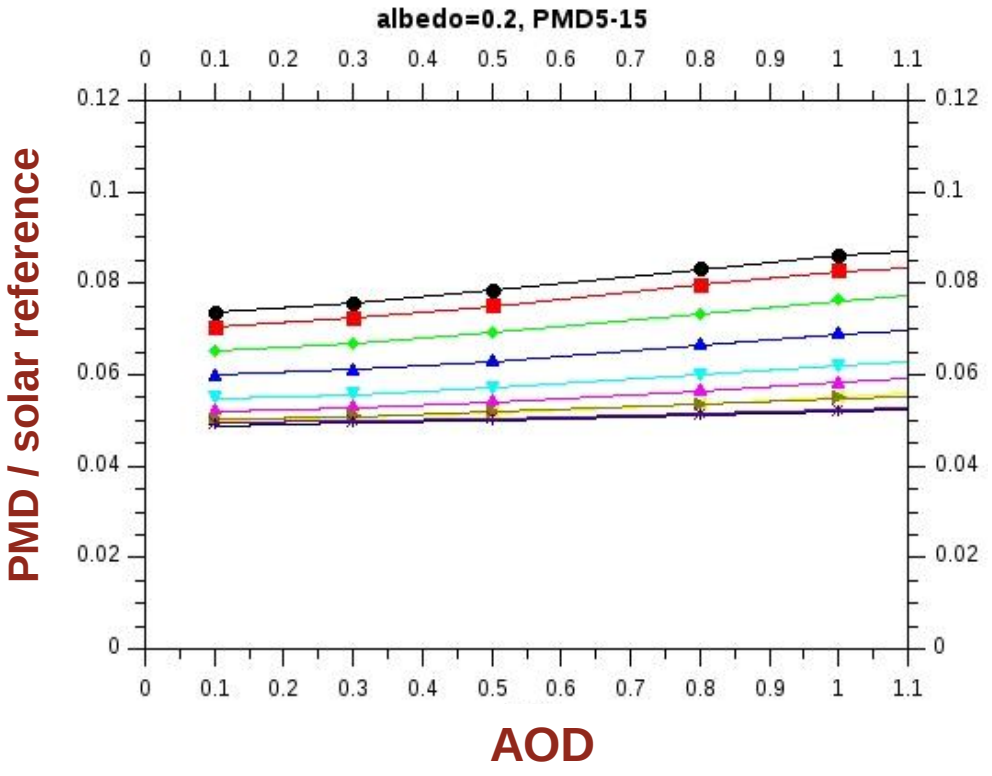
PMAp over land: Channel selection

- **The contrast between aerosol and surface decrease with increasing wavelength & surface albedo**



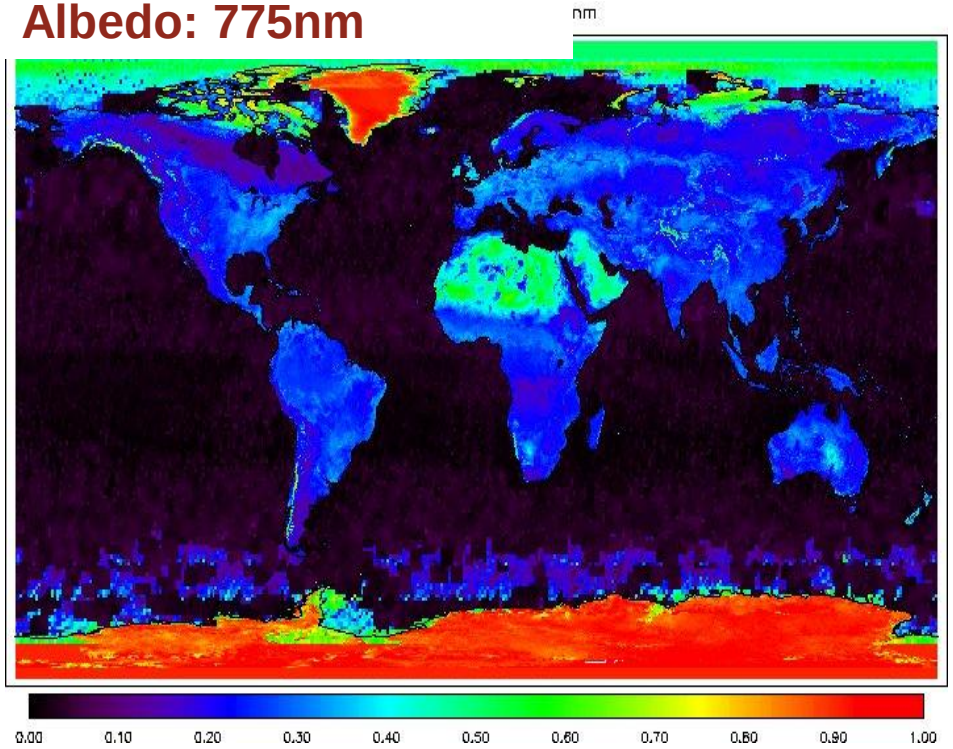


LUT: O. Hasekamp

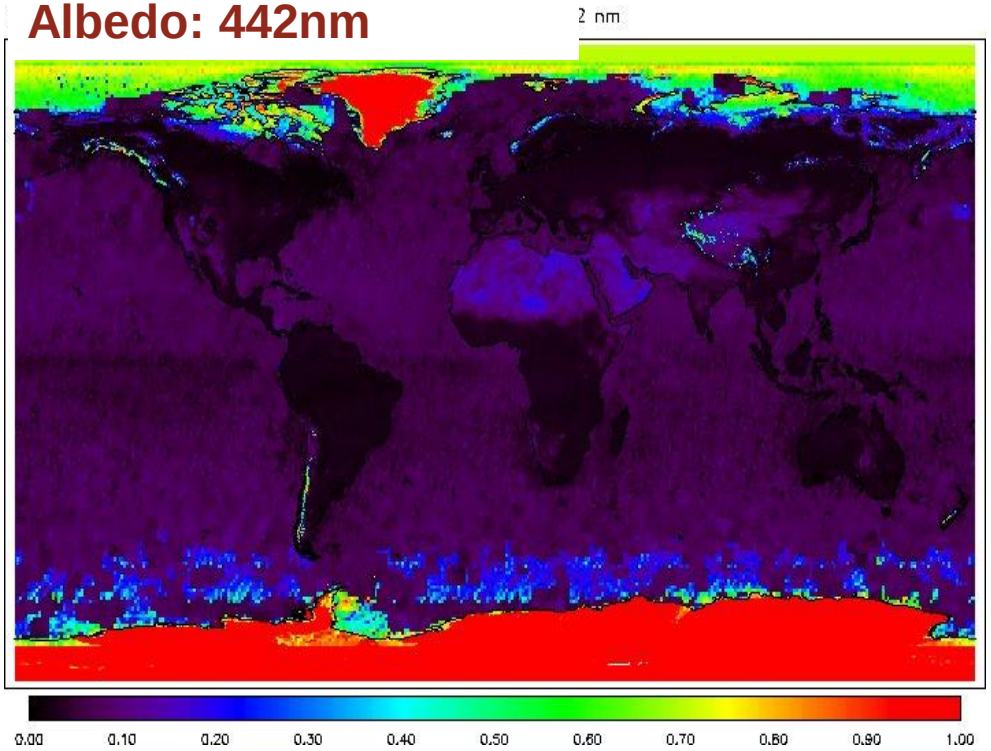
PMAp over land: Retrieval overview

- Clouds/Dust/Volcanic Ash: GOME UV+IASI+AVHRR (w.i.p)
- Cloud correction factors retrieved around 630nm (GOME+AVHRR)
- Interpolation of the AOD in the blue range (400-500nm)
- Bands used to fit aerosol types dependent on surface albedo

Albedo: 775nm

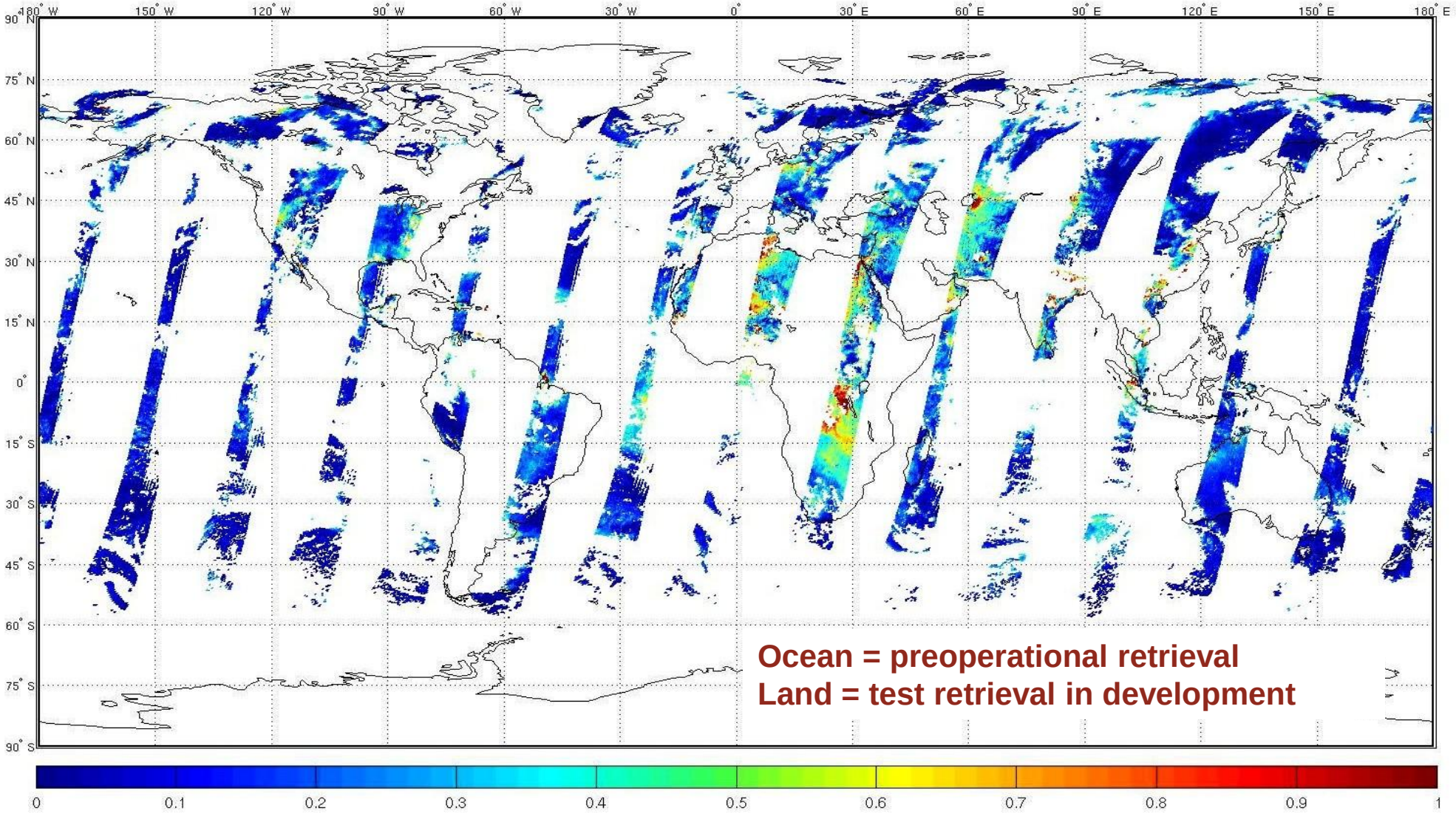


Albedo: 442nm

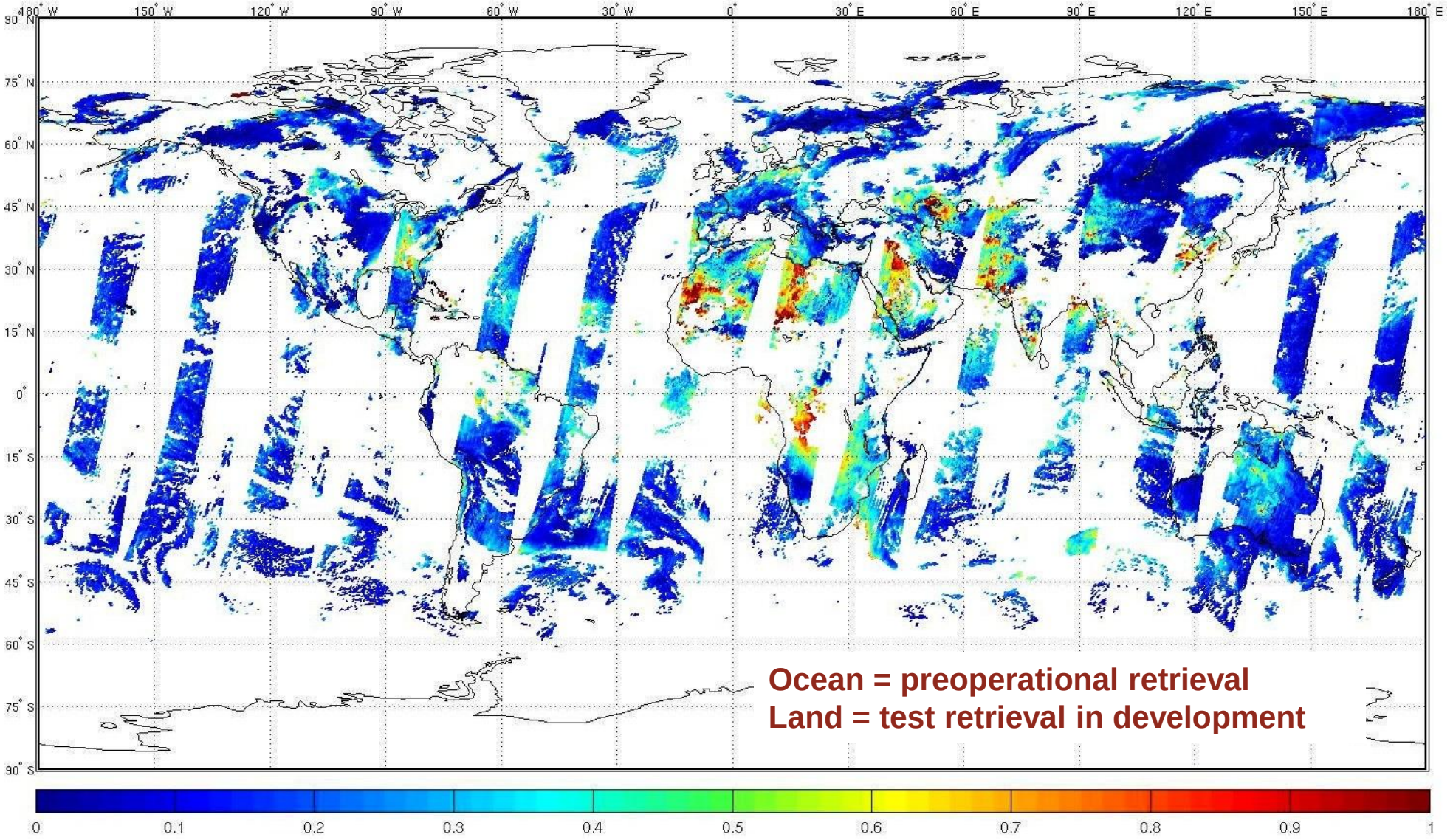


MERIS/GOME-1, C. Popp et. al. 2011

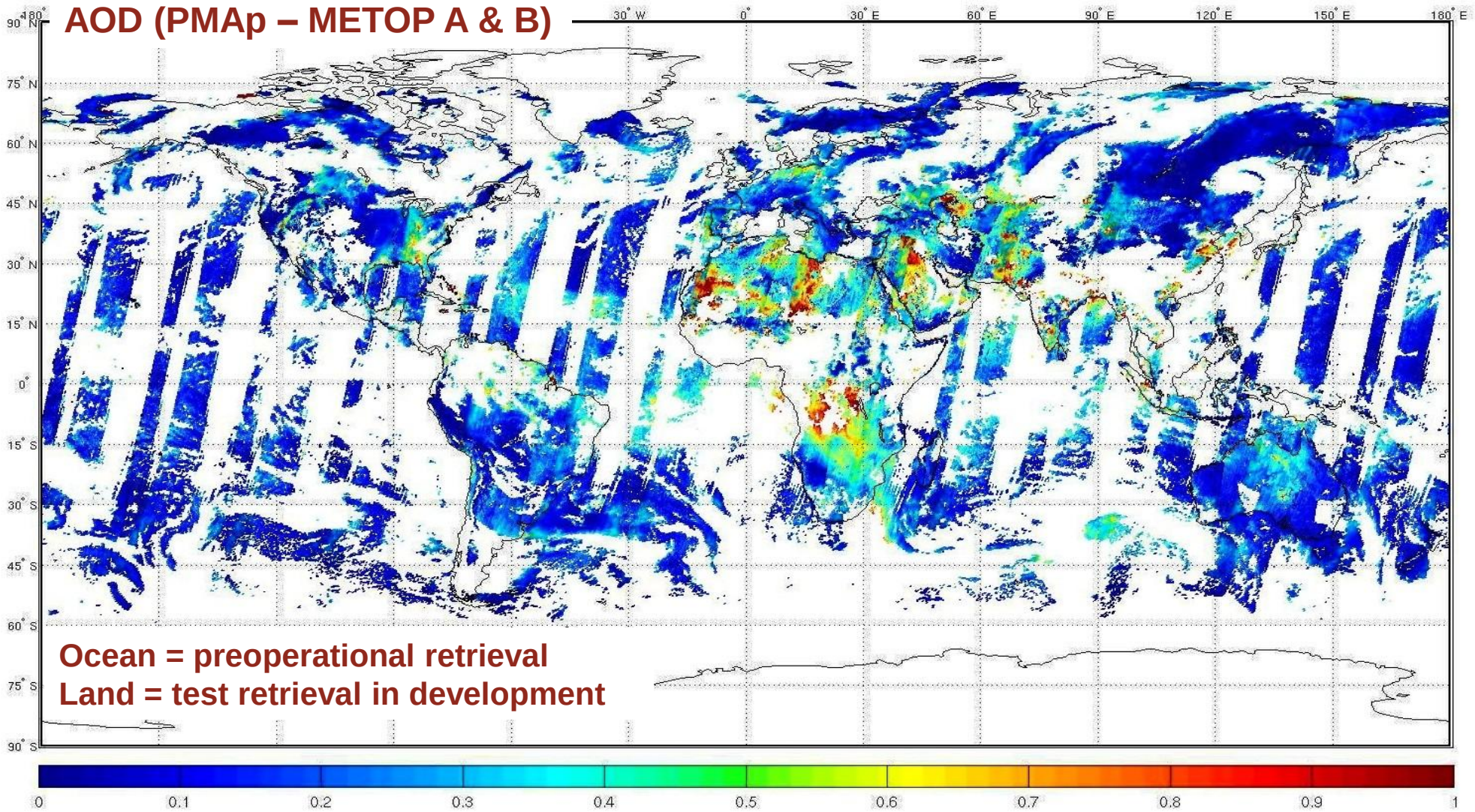
PMAp AOD (preliminary): Metop A (30/08/2013)



PMAp AOD (preliminary): Metop B (30/08/2013)



AOD: PMAp Metop A & B combined



Conclusions

- A new aerosol product over ocean from METOP instruments (PMAp) is delivered to our users
  - Pre-Operational since Q2/2014
  - Fully validated operational status since 14th October 2014
- PMAp is delivered as GOME-2 product using a multi-instrument approach
- Operational monitoring of PMAp using AERONET shows convincing results
- A new PMAp release providing AOD over land is in development
  - First results look promising
  - Start of pre-operations expected in Q1-2/2015

The PMAp product operational implementation
Product features

Product features:

- Near real time 3 minutes granules, maximum 3 hours after sensing time

→ *Available via EUMETCast in EPS native and netcdf4.*

- Full orbit offline data. Available from the EUMETSAT archive

→ http://archive.eumetsat.int

- AOD, COD, volcanic ash flag

Start of dissemination:
29th April 2014

Documentation (user guide):
www.eumetsat.int > Data > Technical documentation > Metop > PMAp