POLAR MULTI-SENSOR AEROSOL PROPERTIES FROM METOP A & B

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EUMETSAT

Overview

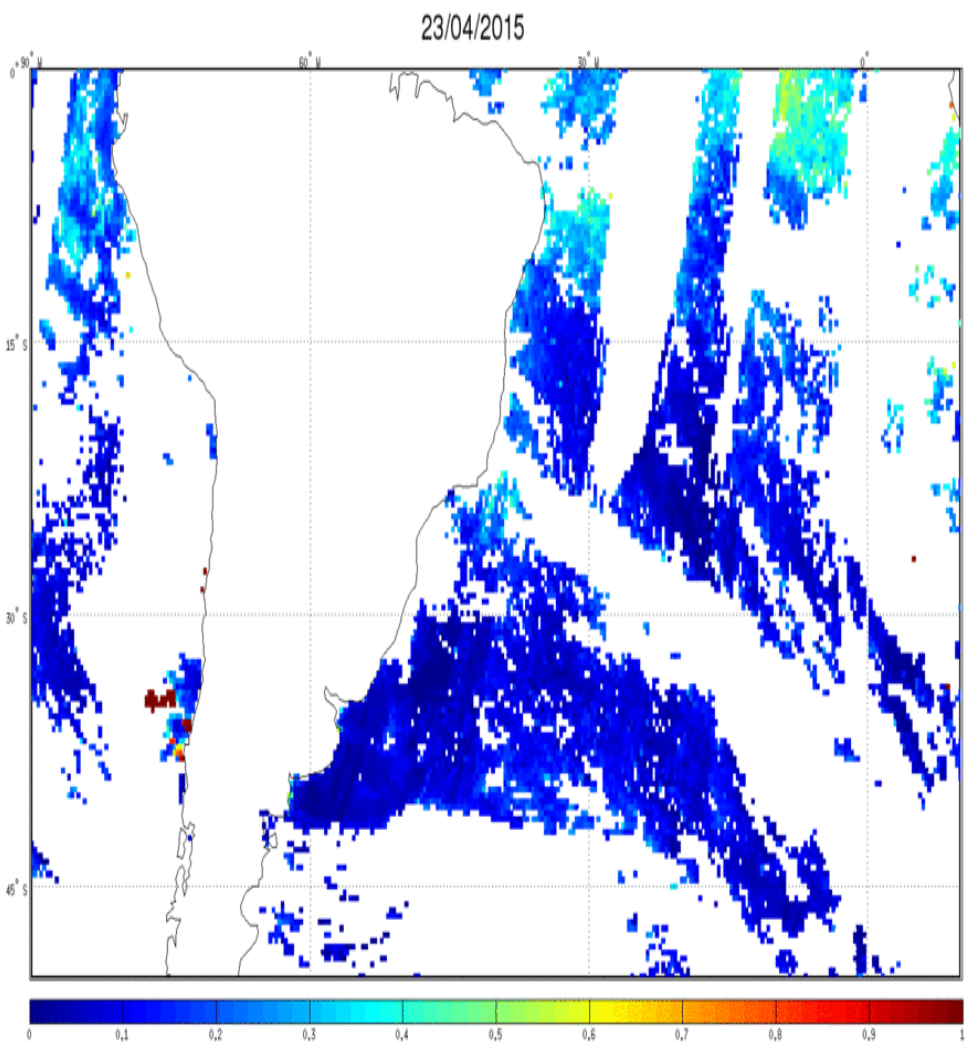
- PMAp: Polar Multi-sensor Aerosol product: Product overview
- Instruments & collocation
- Retrieval methods: Operational PMAp release 1.0.10
- Validations and verifications
  - AERONET
  - ECHAM model
- PMAp error calculation
- PMAp release 2 for pixels over land
  - Retrieval methods
  - Results

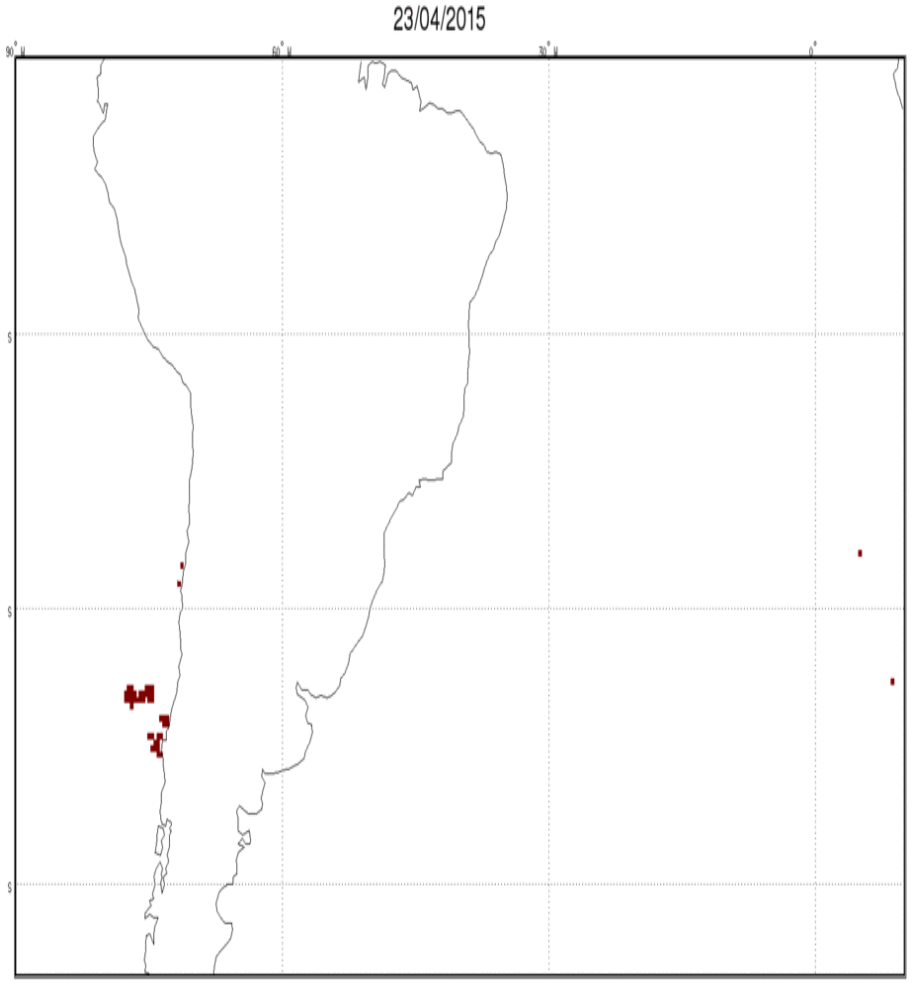
Overview

- **PMAp: Polar Multi-sensor Aerosol product developed at EUMETSAT**
  - *AOD over ocean, aerosol classification (volcanic ash)*
  - *Delivered as a GOME-2 product*
  - *Distributed by EUMETCast in netcdf4*
  - *Pre-operational since Q2/2014*
  - *fully operational status: since October 2014*
  - *Major update / improvement since January 20th 2015*

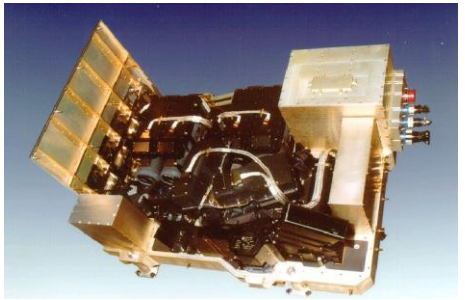
- **PMAp Release 2: Extension to pixels over land, GOME UV index, IASI ash index**
  - Preliminary results for AOD over land
  - Q4/2015: Distribution of the operational product to users

PMAp aerosol events: Volcanic ash plume June 2015





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

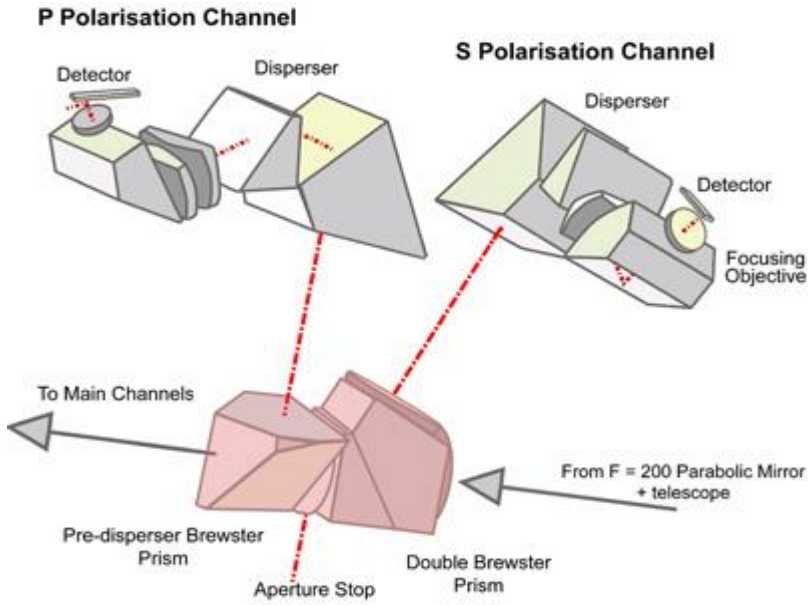
Instrument		Spatial resolution	Spectral range	comments
GOME-2	Main science channel	80 x 40 km	240nm -800nm, res. 0.25-0.5nm	AAI, low spatial resolution, not used
	Polarization Monitoring Device	10 x 40 km Metop-B 5 x 40 km Metop-A	311nm-803nm, 15 bands	AOD, aerosol type, AAI
AVHRR	-	1.08 x 1.08 km	580nm-12500nm, 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

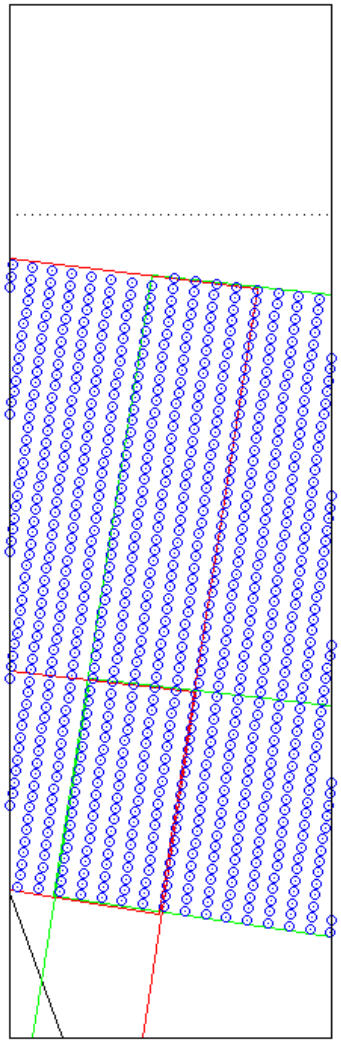
The Polarization Monitoring Devices

Band-S				
No.	pix1	pixw.	wav1	wav2
1	22	5	311.709	314.207
2	30	4	316.762	318.720
3	37	12	321.389	329.139
4	50	6	330.622	334.443
5	57	6	336.037	340.161
6	84	17	360.703	377.873
7	102	4	380.186	383.753
8	117	19	399.581	428.585
9	138	27	434.083	492.066
10	165	18	494.780	548.756
11	183	2	552.474	556.262
12	187	11	568.070	612.869
13	198	9	617.867	661.893
14	218	4	744.112	768.269
15	224	2	794.080	803.072

- **Radiances & stokes fraction**
- **better spatial resolution**
- **stokes fraction s = Q/I**



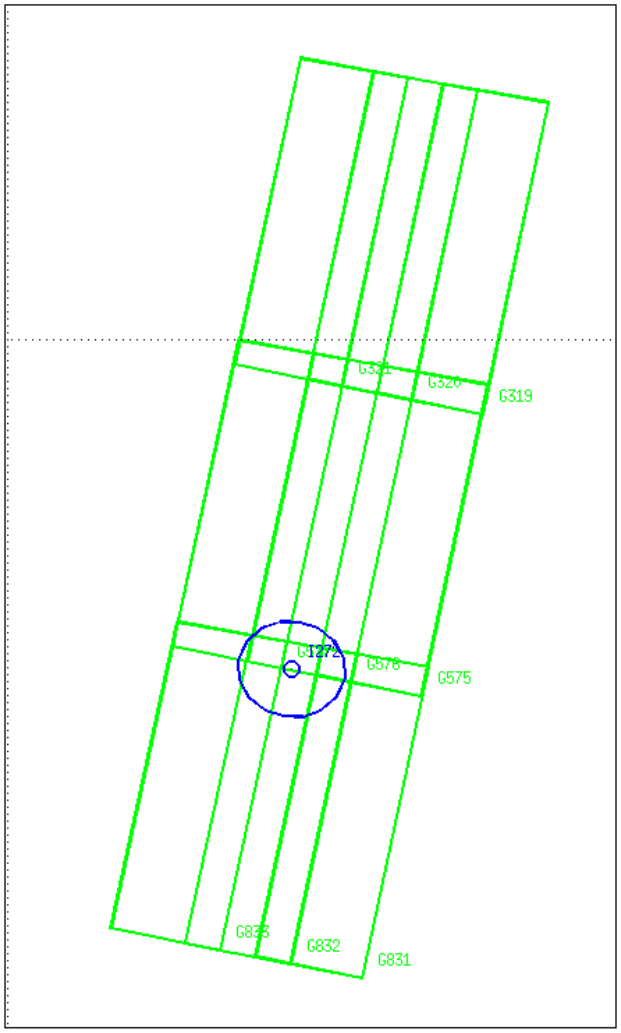
PMAp: Very accurate co-location of AVHRR and IASI to the GOME-2 PMD pixel footprints



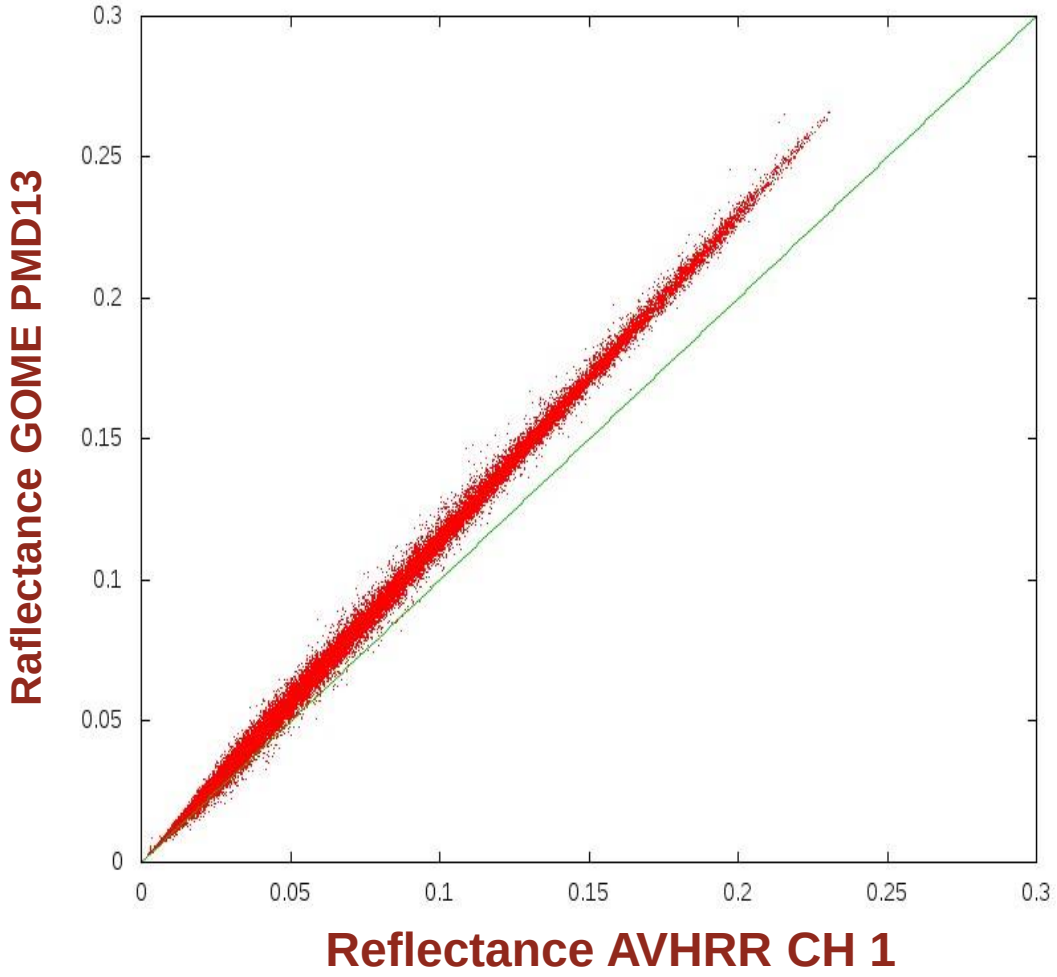
AVHRR collocation:
an AVHRR pixel is collocated to a GOME-2 PMD pixel if it is inside the GOME-2 pixel

Spatial aliasing due to read-out timing of detectors is taken into account!

IASI collocation:
a IASI pixel may span up to 6 GOME-2 PMD pixels.
Which GOME-2 pixel should it be collocated to?



Collocation of AVHRR and GOME-2: slope and scatter



- Significant calibration error of AVHRR (slope, almost no offset).
- Scatter due to different shapes of footprints (+ contribution of convolution effects). Used for error calculation.
- 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-2 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-2 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-2 based on the variation of the AVHRR radiances within the GOME-2 pixels

PMAp: AOD retrieval algorithm

Three step retrieval:

Step1: Pre-classification by AVHRR

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

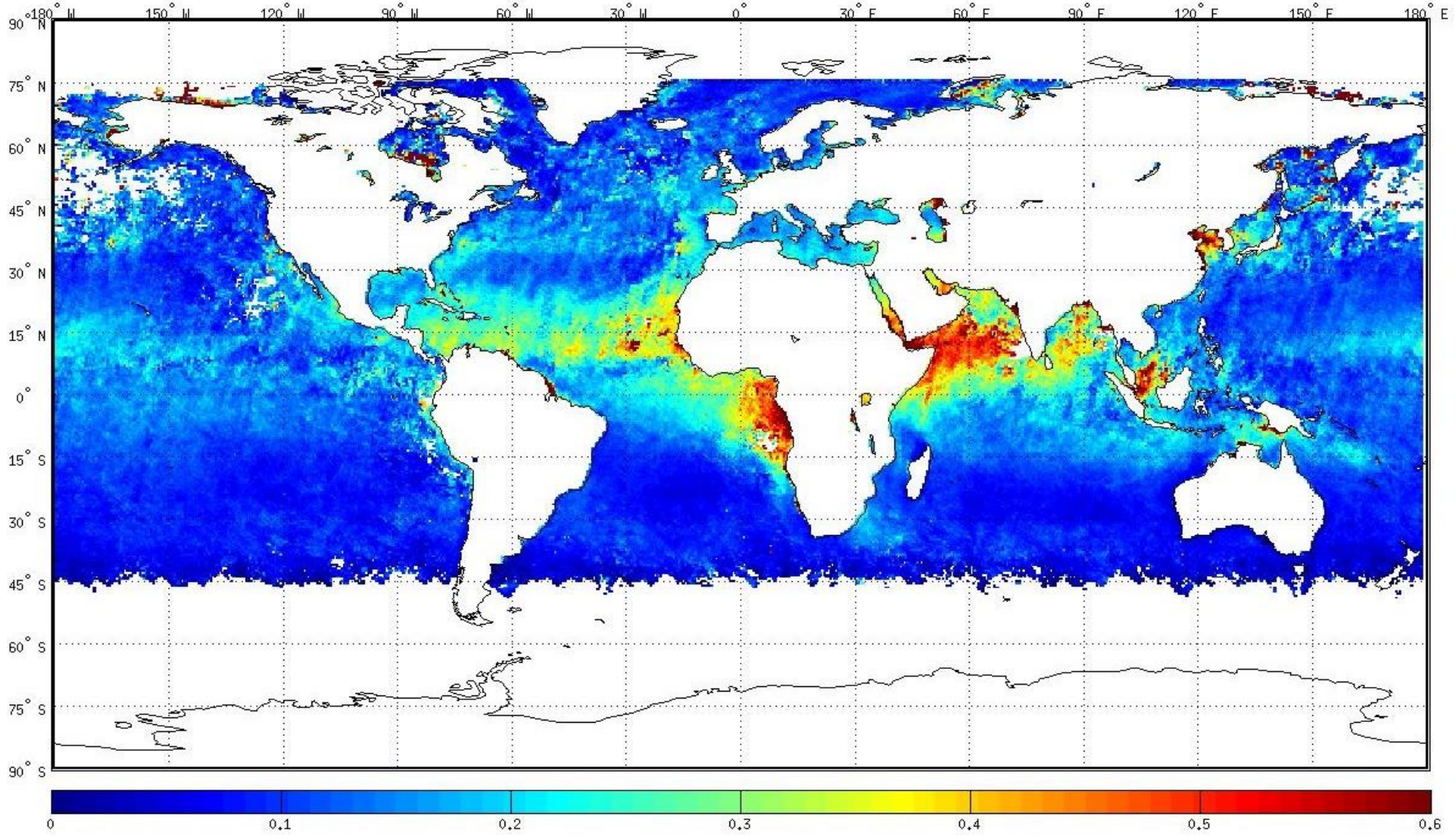
Step2: Retrieval of a set of candidate AODs (one PMD band)

- based on a set of aerosol models from LUT provided by O. Hasekamp (O3MSAF), model selection dependent on step 1.
- Chlorophyll fitted for clear sky pixels (otherwise a priori)

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)

PMAp AOD: Metop A (June+July 2013)

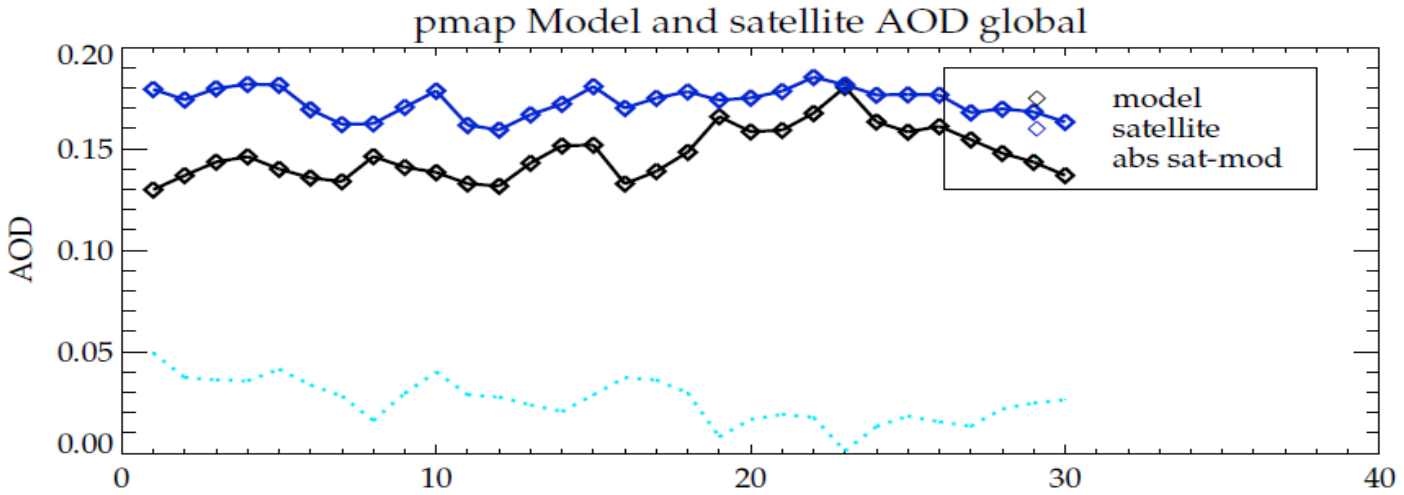


Important changes in PMAp 1.0.10 (since 20/01/2015)

- Correction of the calibration (AVHRR thermal bands)
- Cloud correction dependent on aerosol type:
  - Inhomogeneities correction dependent on aerosol type:
    - The fine mode should give no signal at 1.6µm and 10µm. Inhomogeneities are clouds if weak coarse mode.
    - If an aerosol causes inhomogeneities at 10 µm, it should also cause inhomogeneities at 0.6 µm.
  - A pixel is defined as completely cloud free, if the average AVHRR reflectance is close to the clear-sky AVHRR reflectance retrieved dependent on aerosol class.

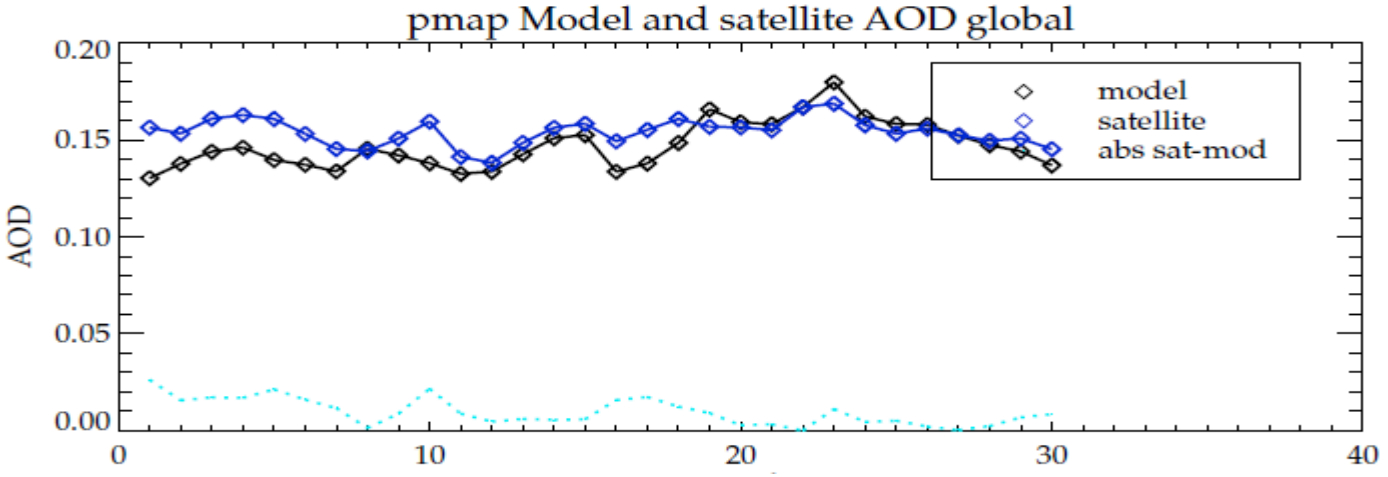
PMAp: Comparison to ECHAM model: Global time series comparison Metop-A 06/2013

Version 1.0.8



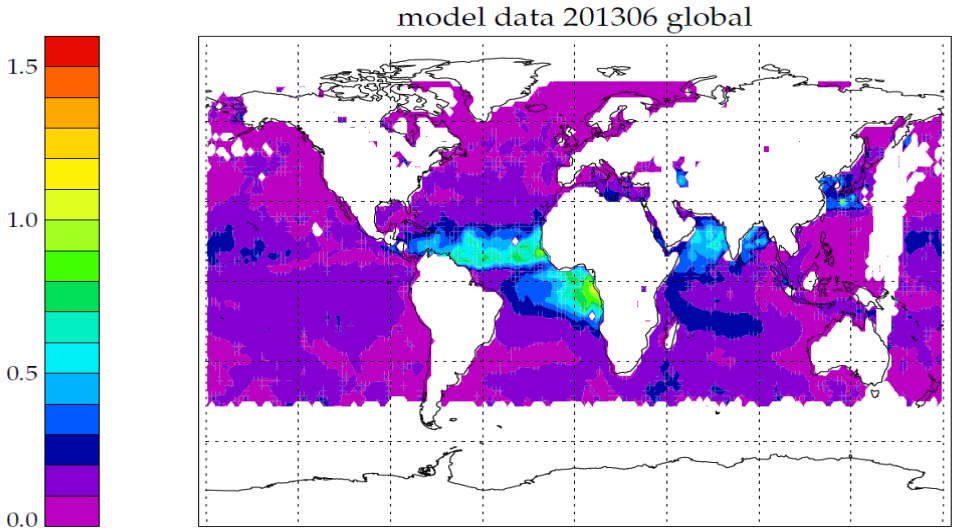
provided by C.Poulsen, RAL

Version 1.0.10



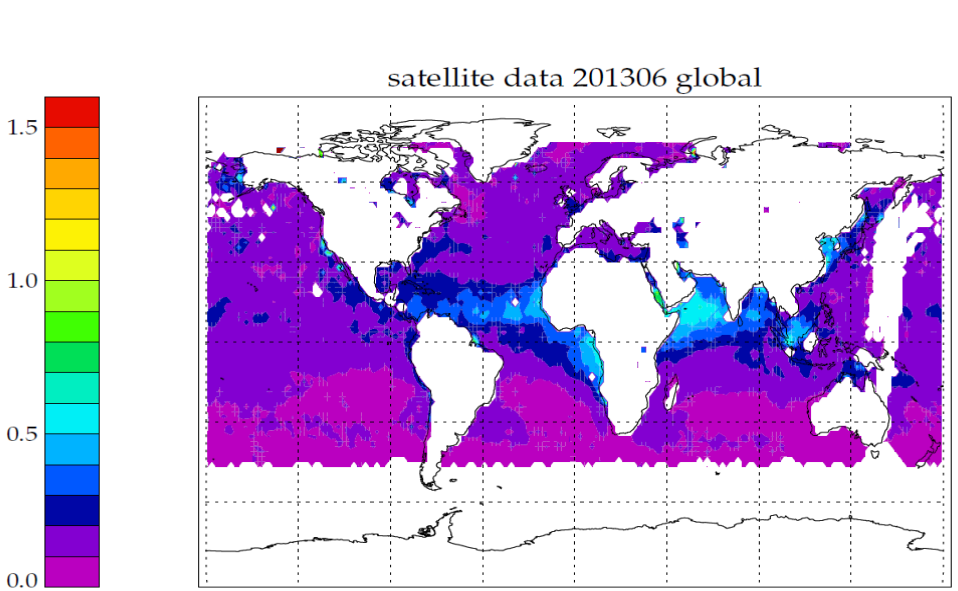
RAL/University Oxford Validation of PMAp Version 1 using ECHAM-HAM (Stier, Shutgens)

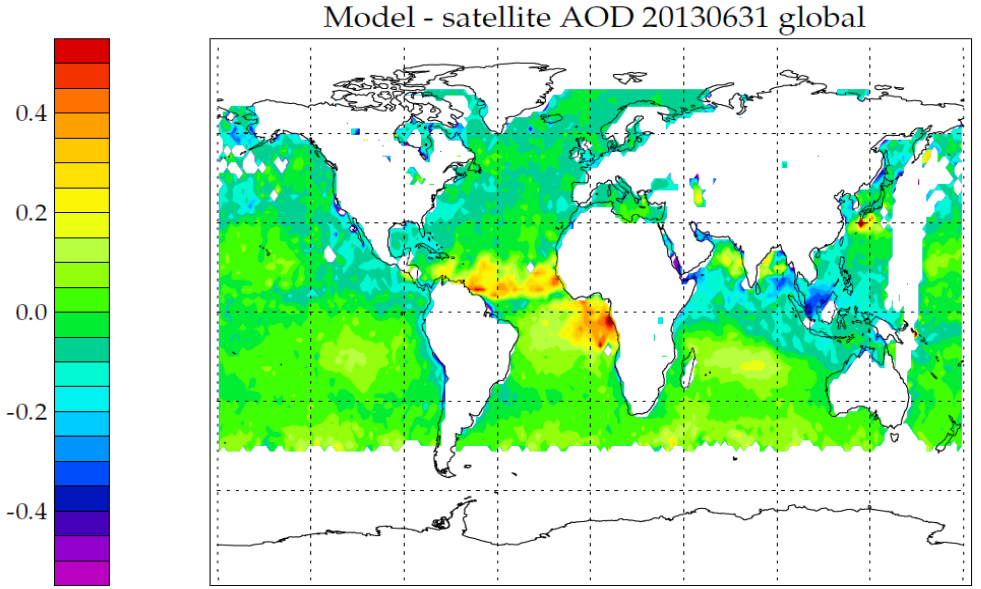
ECHAM-PMAp comparison June 2013



provided by C.Poulsen, RAL

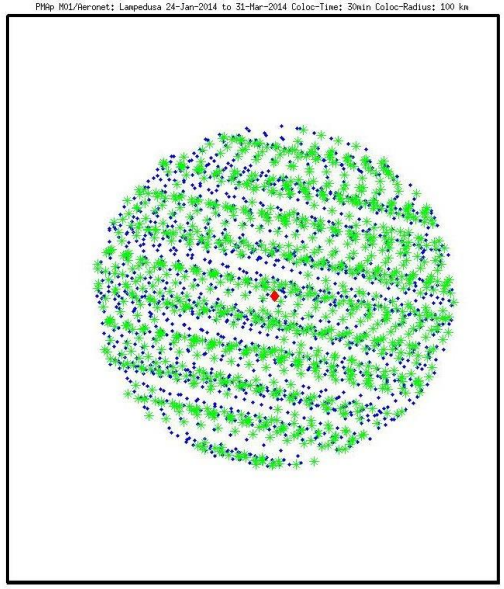
Blue= higher satellite values
Red=lower satellite values

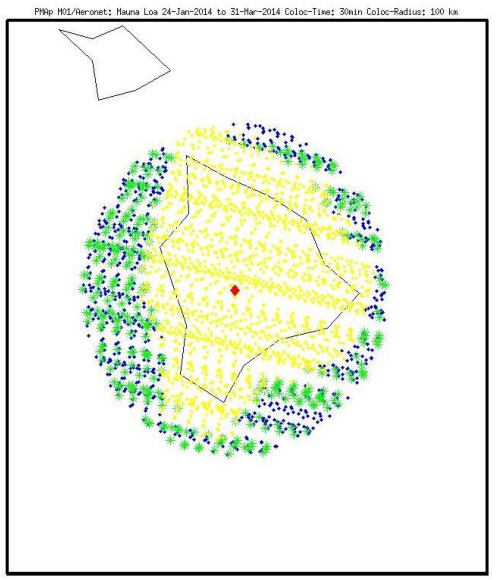


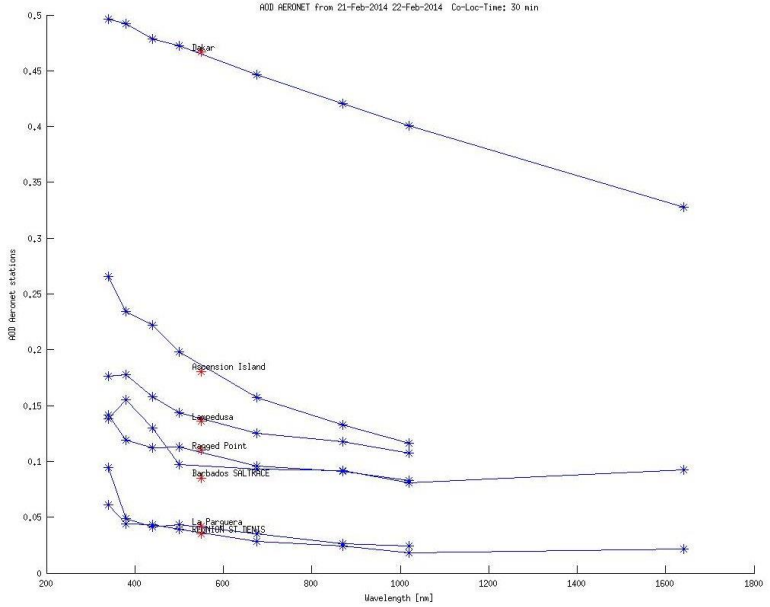


Operational monitoring of PMAp using AERONET

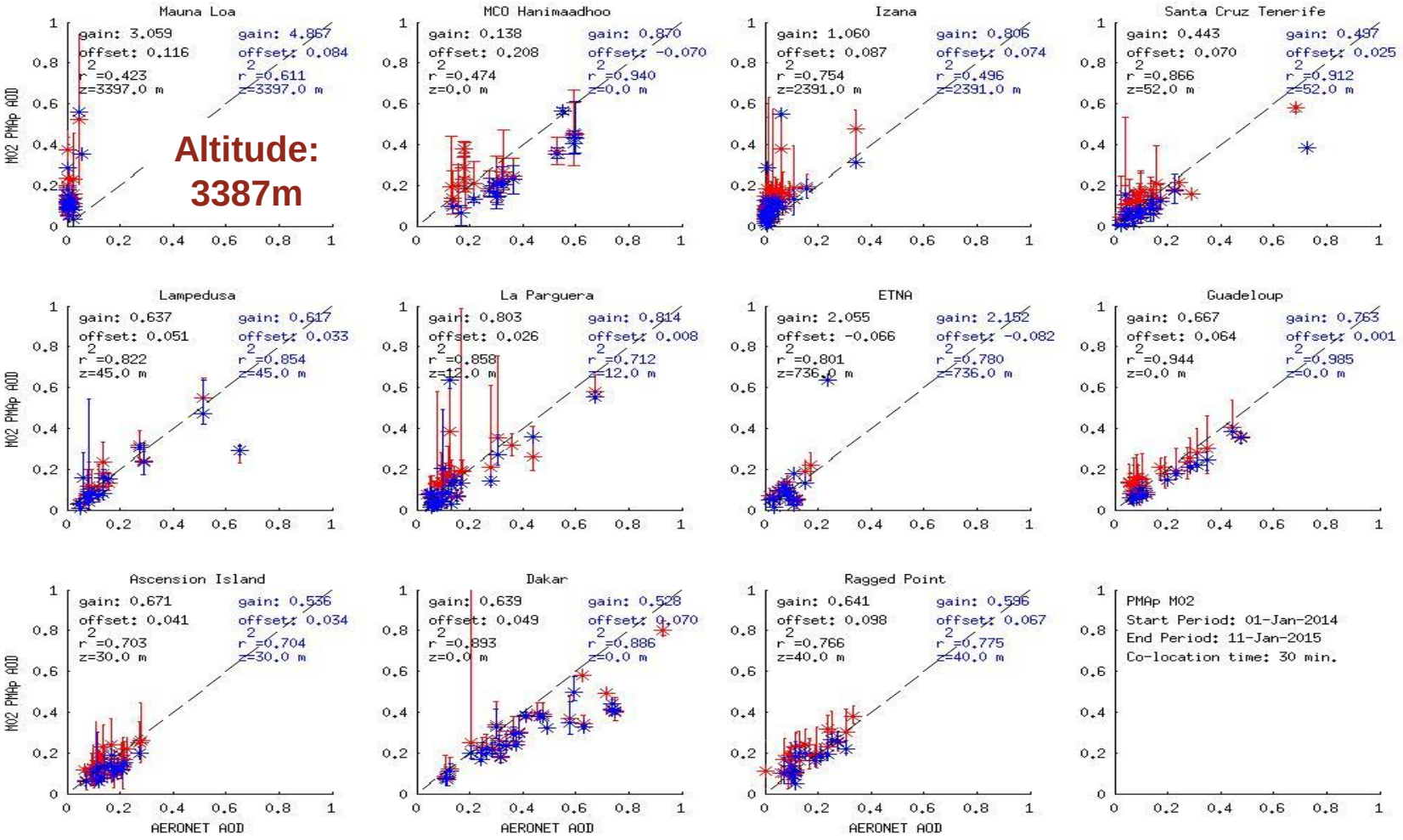
- Stations on islands and selected coastal stations
- Max temporal difference: 30min,
- Max spatial difference: 60km
- Continuous monitoring since January 2014







Comparisons to AERONET: Results Metop A



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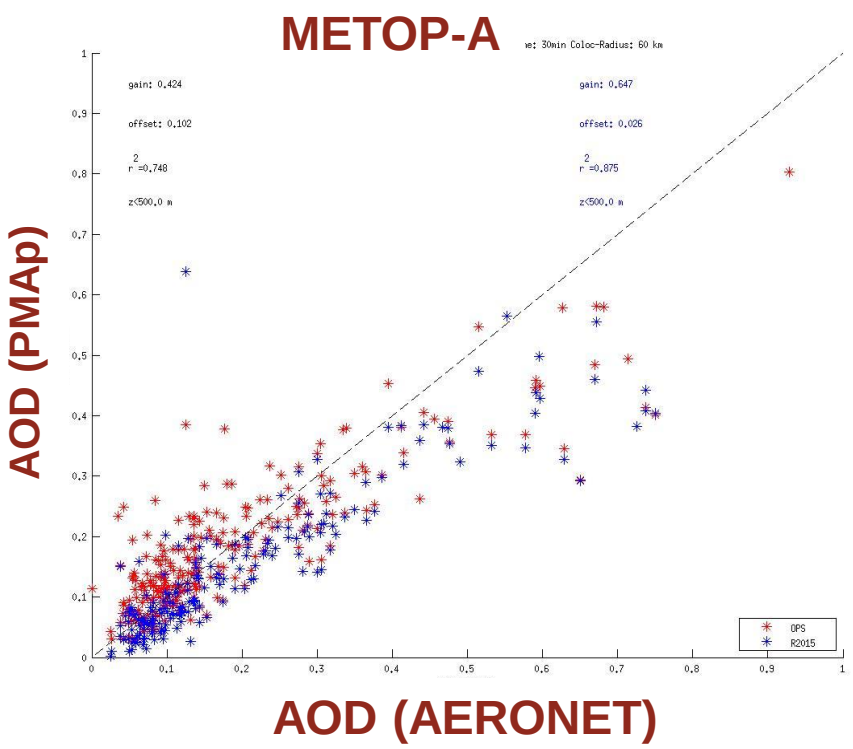
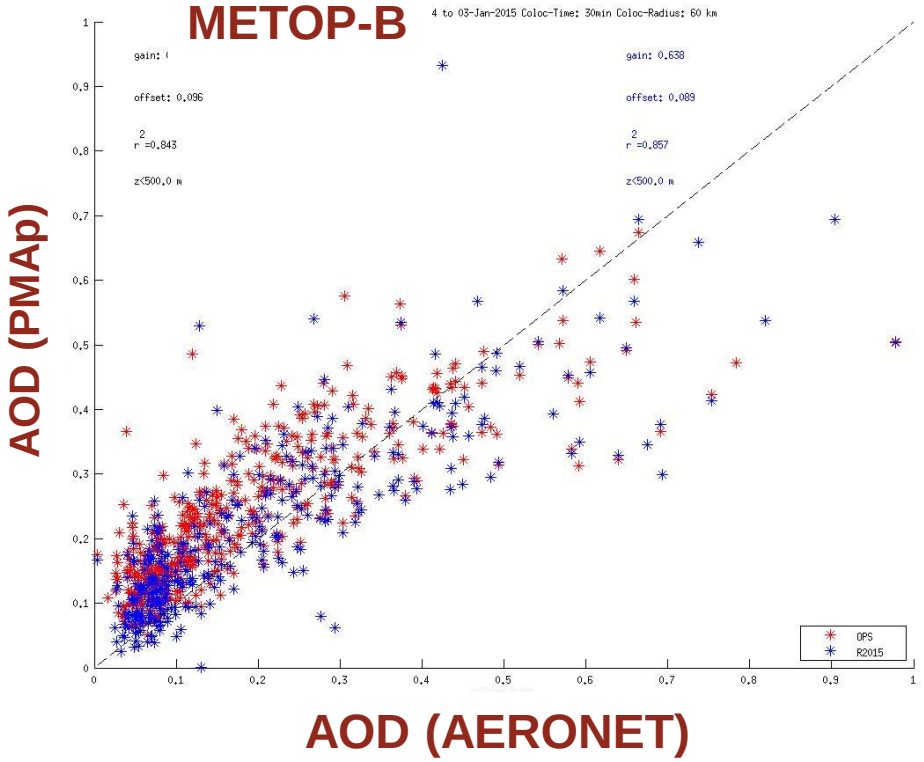
Comparisons to AERONET: Results Metop A & B

- All AERONET station with altitude < 500m
- **Red = all PMAp values**, **blue = PMAp clear sky values**
- **R= 0.85-0.95** – data selection sensitive, clear sky case better



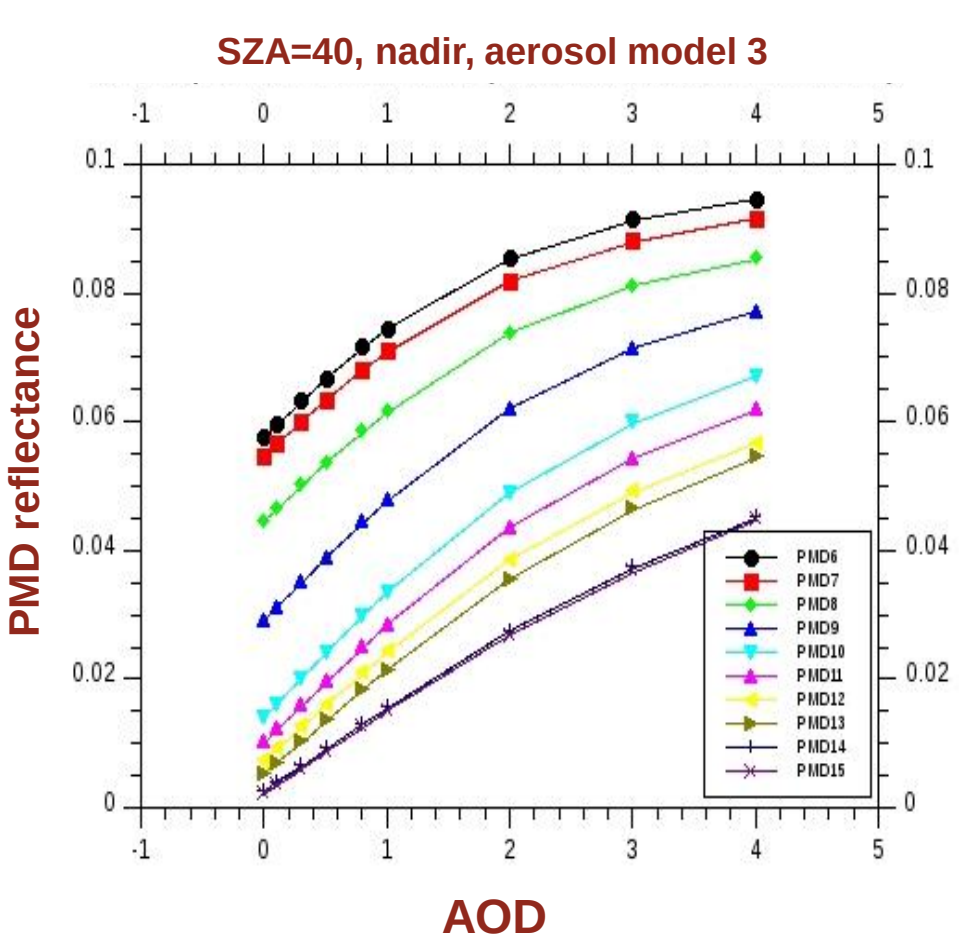


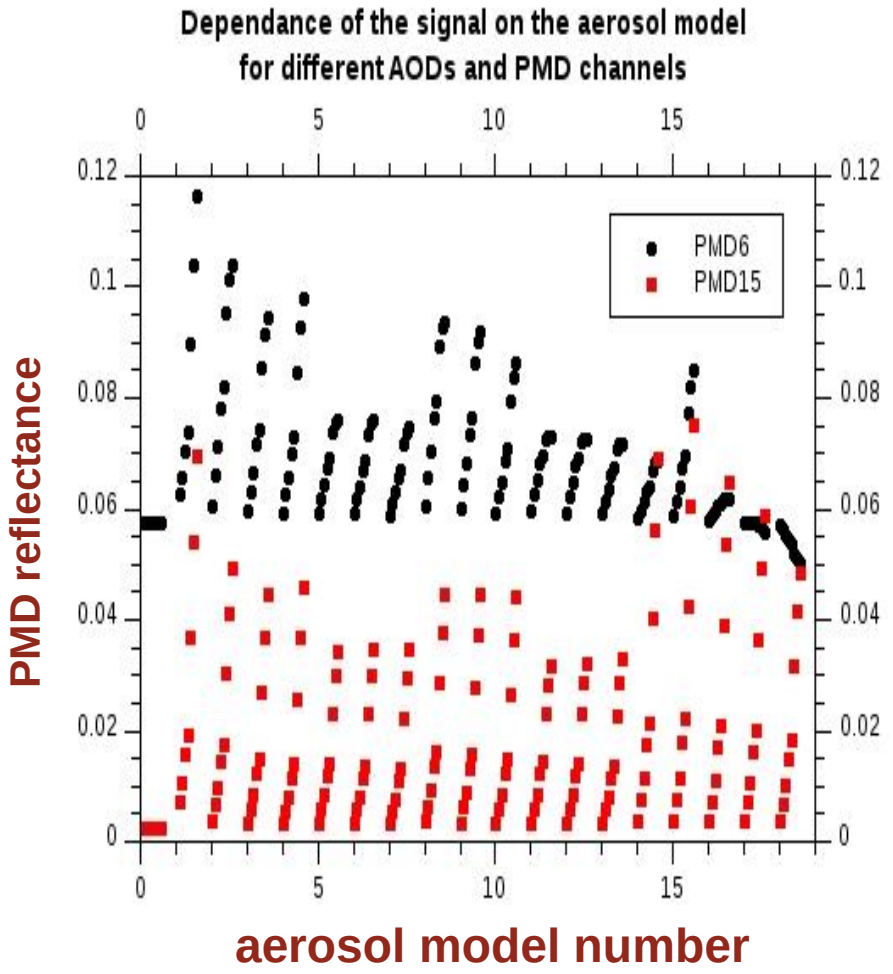
PMAp error calculation

- PMAp does not use optimal estimation methods.
- A set of AOD is calculated using simplified inversion.
  - Example: variation of the chlorophyll pigment concentration
- A standard deviation of these AODs is calculated.
- PMAp calculates a randomized error
- Specific contributions discussed in this presentation:
  - Errors from AVHRR/GOME-2 collocations
  - Wrong selection of the aerosol type (microphysics)
  - Dependence of the surface reflectance on wind speed.

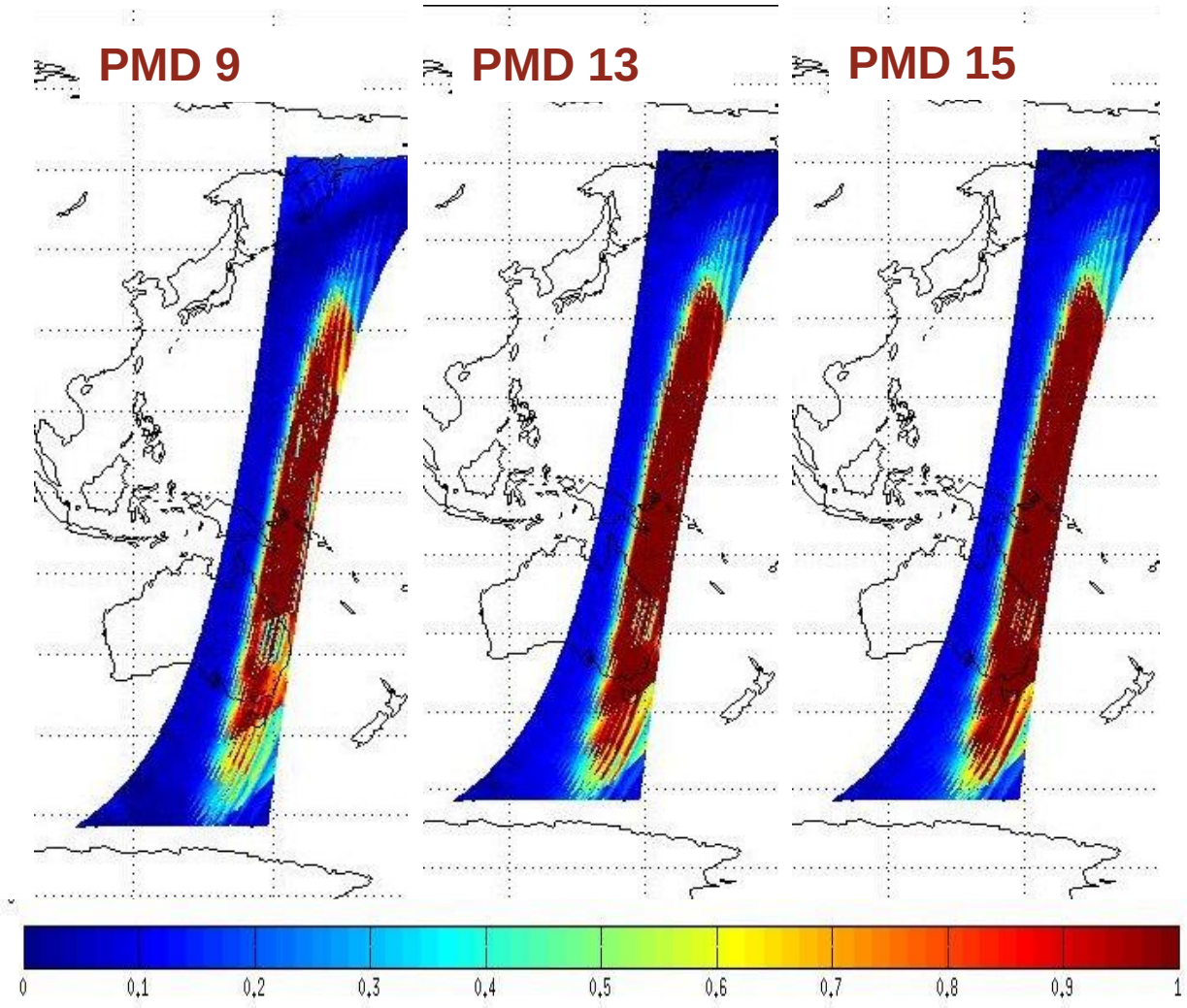
Error caused by wrong aerosol type selection

- Worst case scenarios: Error up to a factor of 2 possible (in practice smaller)





Dependence of the surface reflectance on wind speed

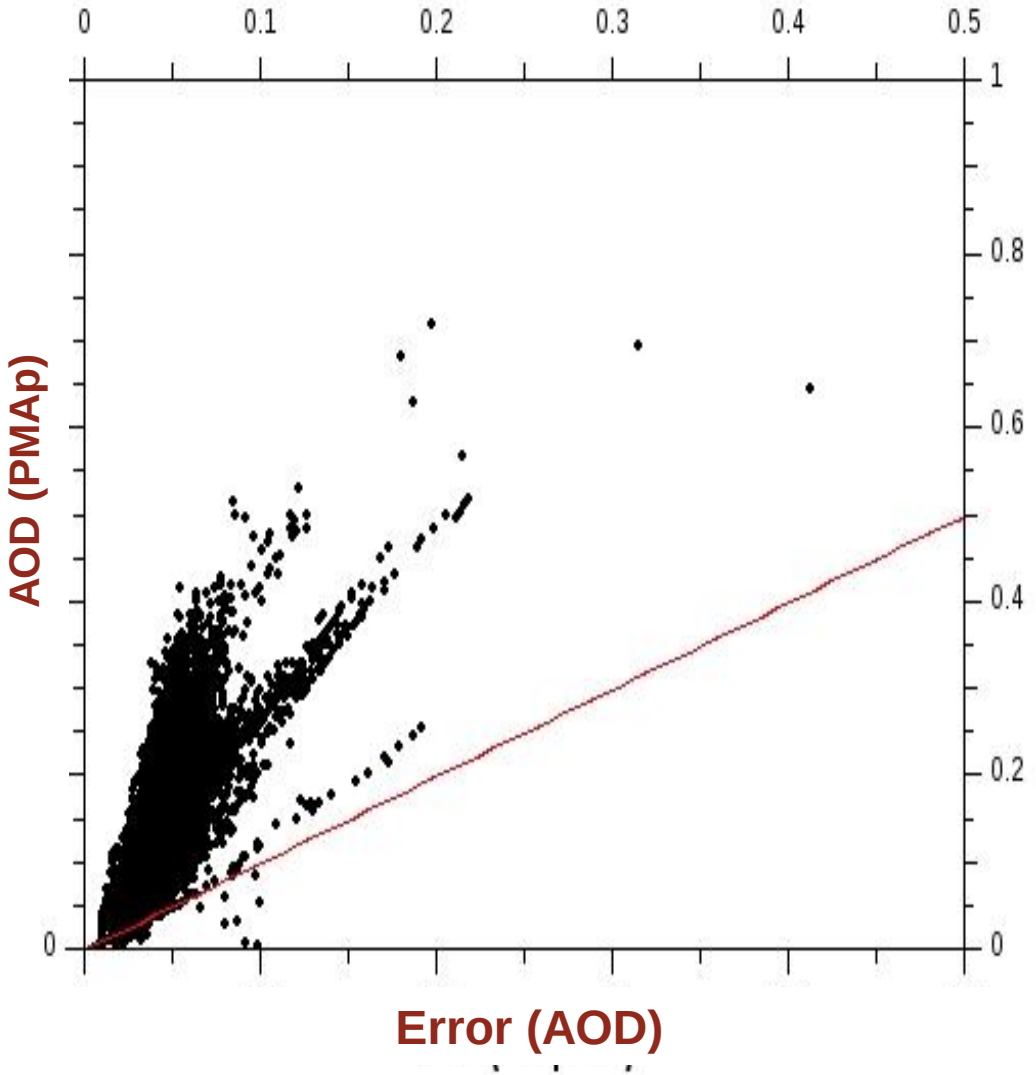


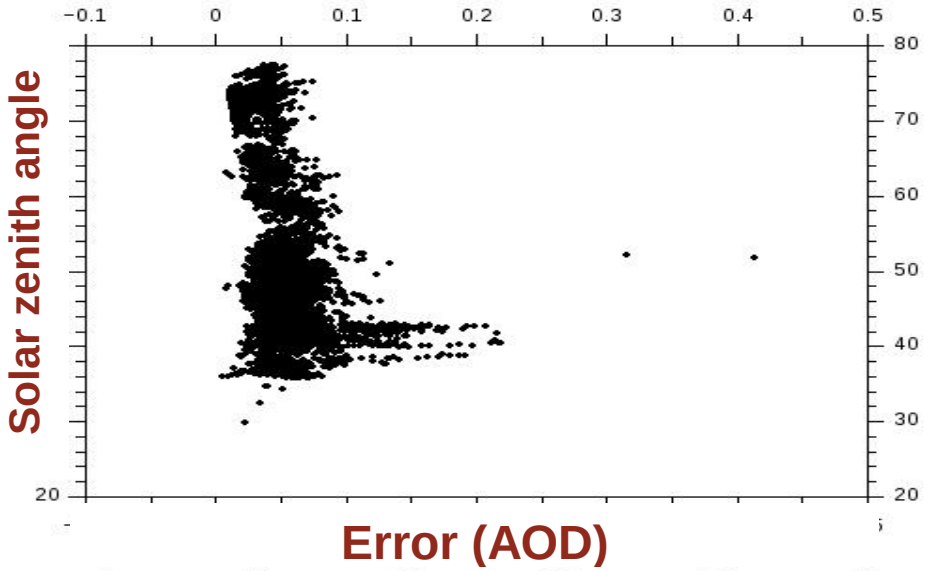
- Variablility of the surface reflectance with wind speed can be as large as the signal of an aerosol (AOD=0.3) :

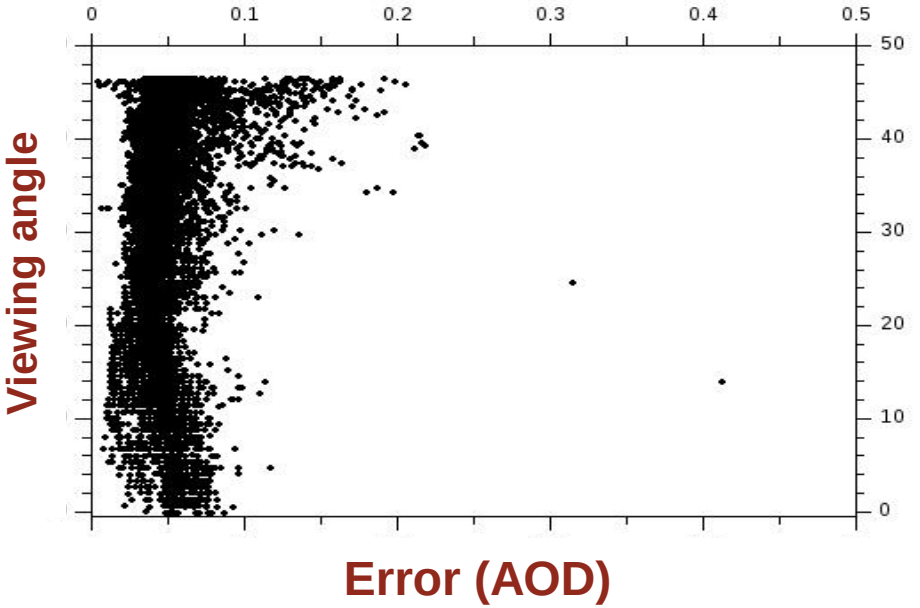
$$\frac{\left| R_{clear}\ (12\ m\ /\ s) - R_{clear}\ (3 m\ /\ s) \right|}{R_{aerosol} - R_{clear}}$$

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

PMAp errors dependent on different parameters







Looking forward to PMAp2: AOD retrieval algorithm

Retrieval algorithm over land

Three step retrieval:

Step1: Pre-classification by AVHRR (w.i.p GOME UV and IASI)

- Cloud detections and cloud corrections, distinguish clouds from dust/ash
- Aerosol type pre-classification (volcanic ash, dust, biomass burning)
- Default aerosol model selection includes TIR measurements
- Results are inputs for the GOME-2 retrieval

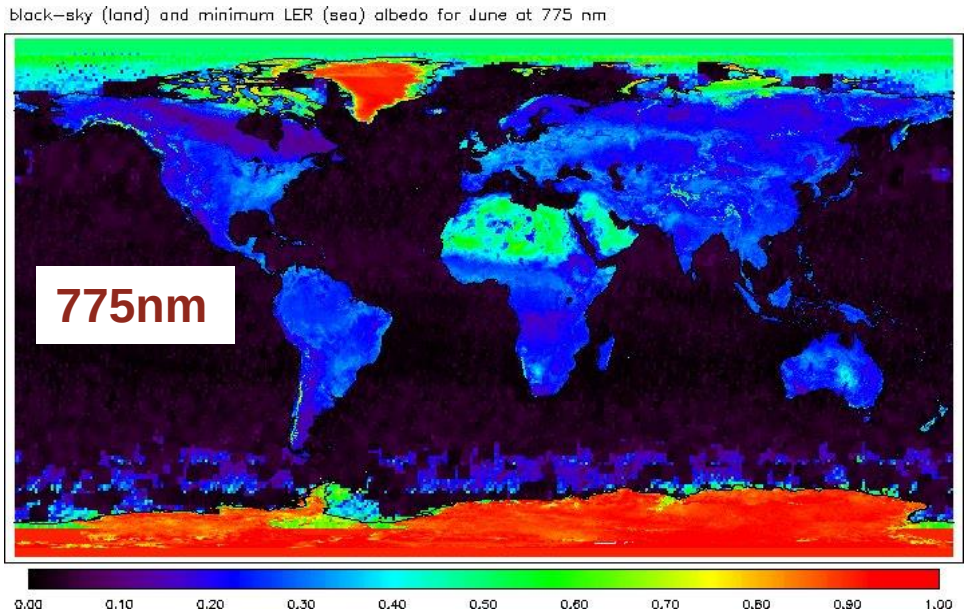
Step2: Retrieval of a set of candidate AODs (one PMD band)

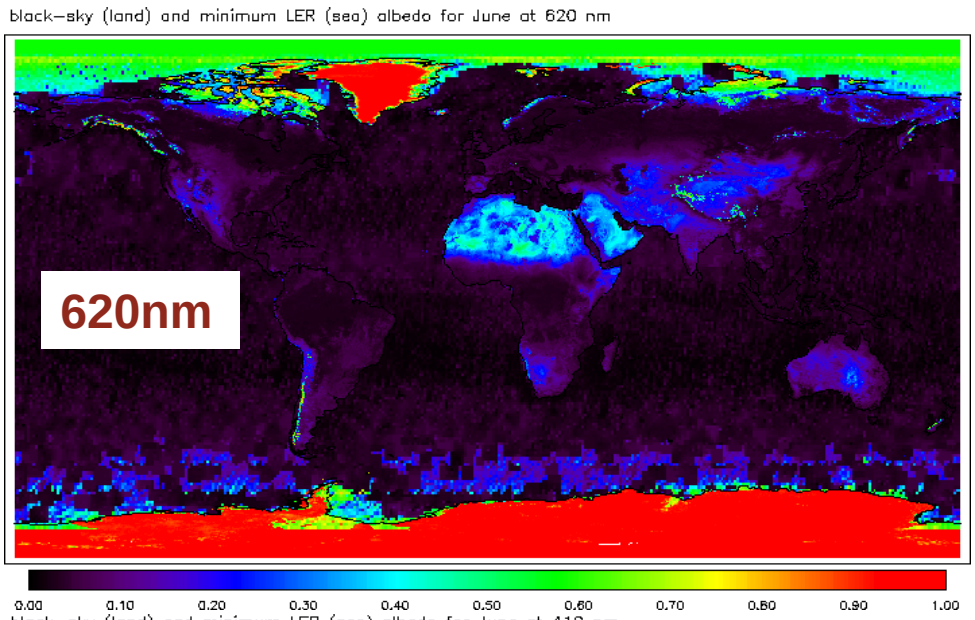
- based on a set of aerosol models from LUT provided by O. Hasekamp (O3MSAF), model selection dependent on step 1.

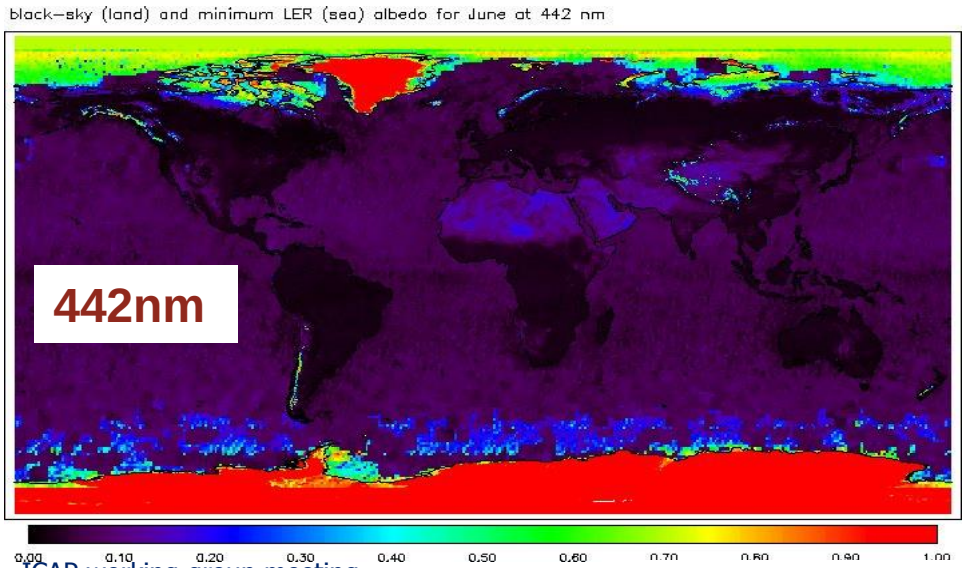
Step3: Selection of the best fit

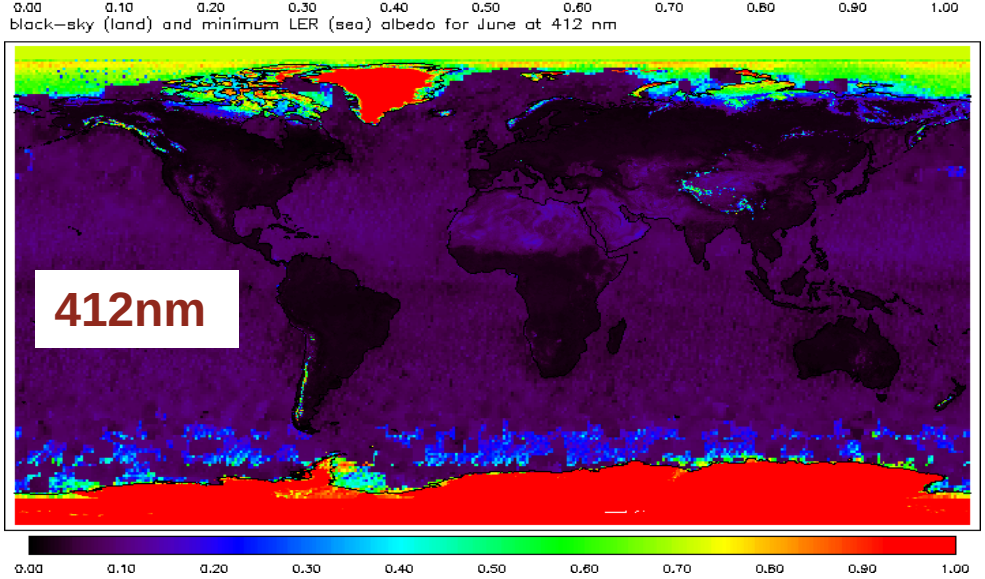
- select the best result of step 2 using least-square minimization for all GOME PMD bands (+ stokes fractions dependent on condition)

PMAp over land: Surface albedo vs wavelength





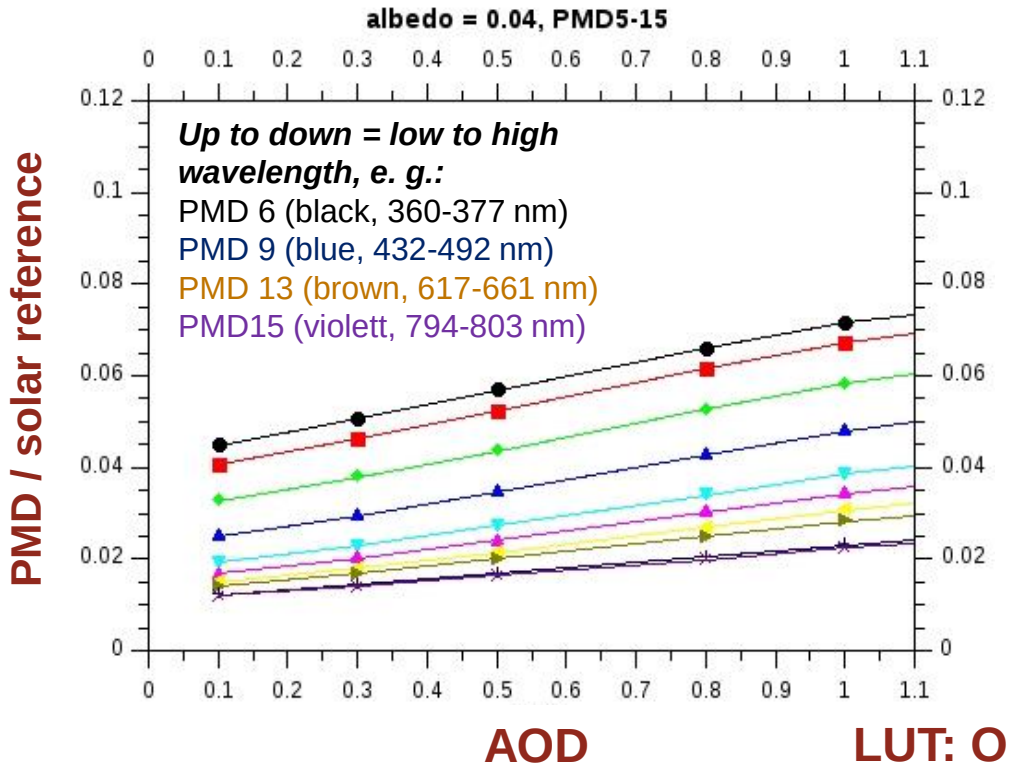


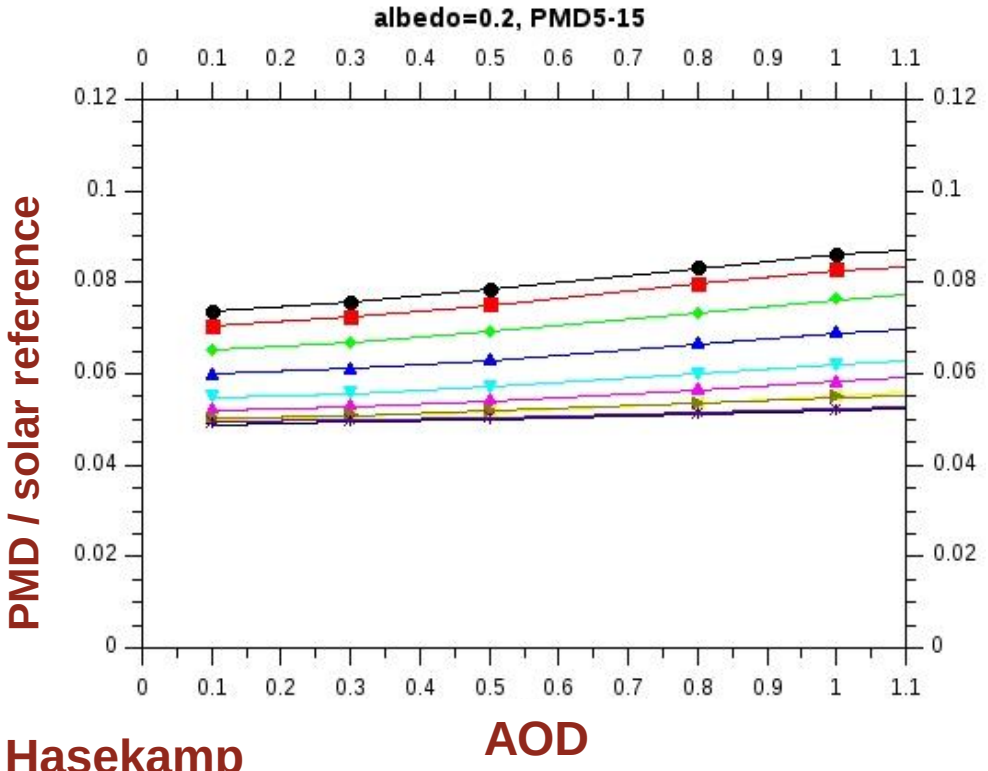


MERIS/GOME-1, C. Popp et. al. 2011

PMAp over land: AOD calculation

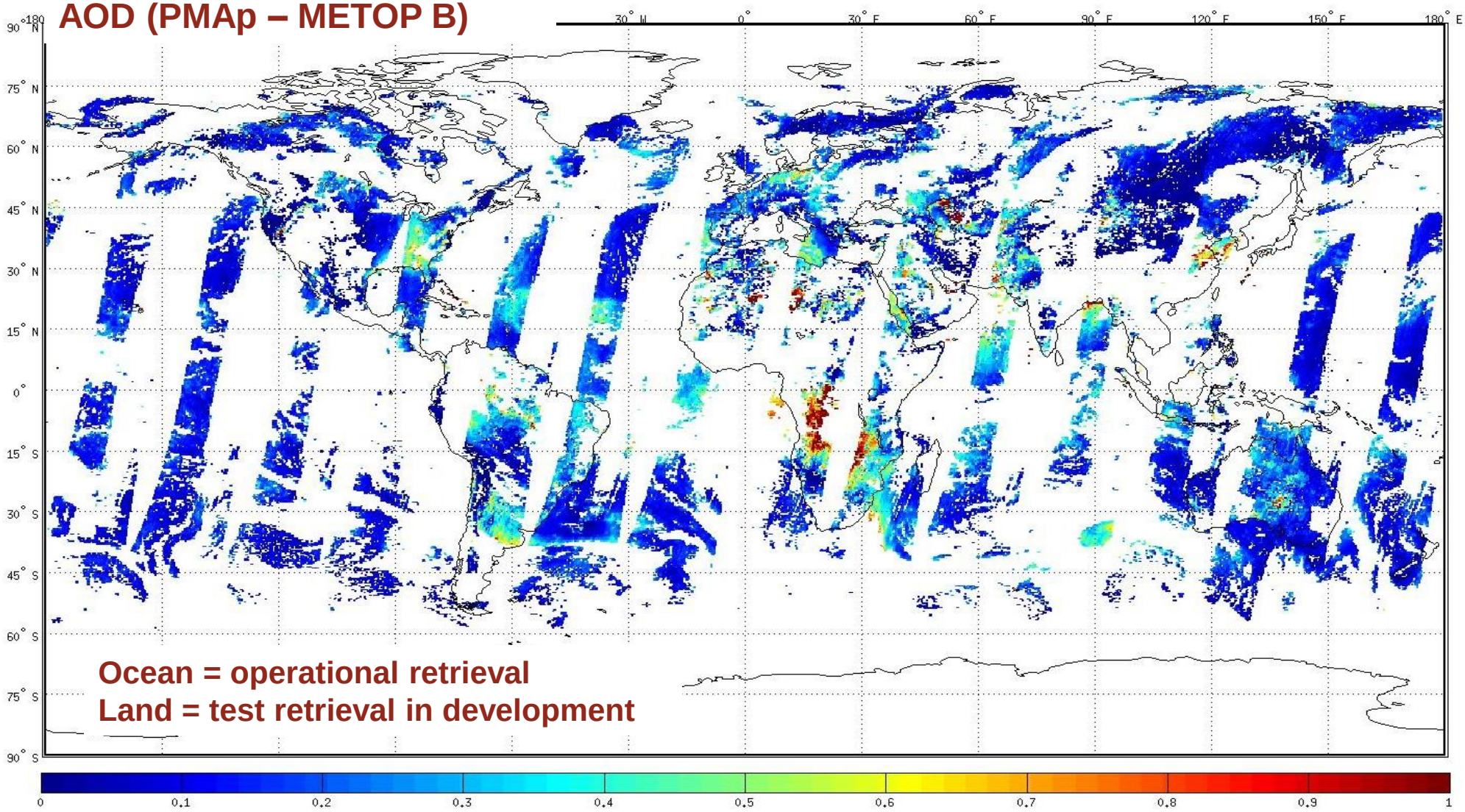
- Interpolation of the AOD at PMD 7, 8 or 12 dep. on surface albedo
  - maximum albedo 0.10, prefer higher wavelength if albedo difference lower than 0.005
- Bands used to fit aerosol types dependent on surface albedo
  - reflectances for channels with albedo < 0.05, Stokes fraction if applicable



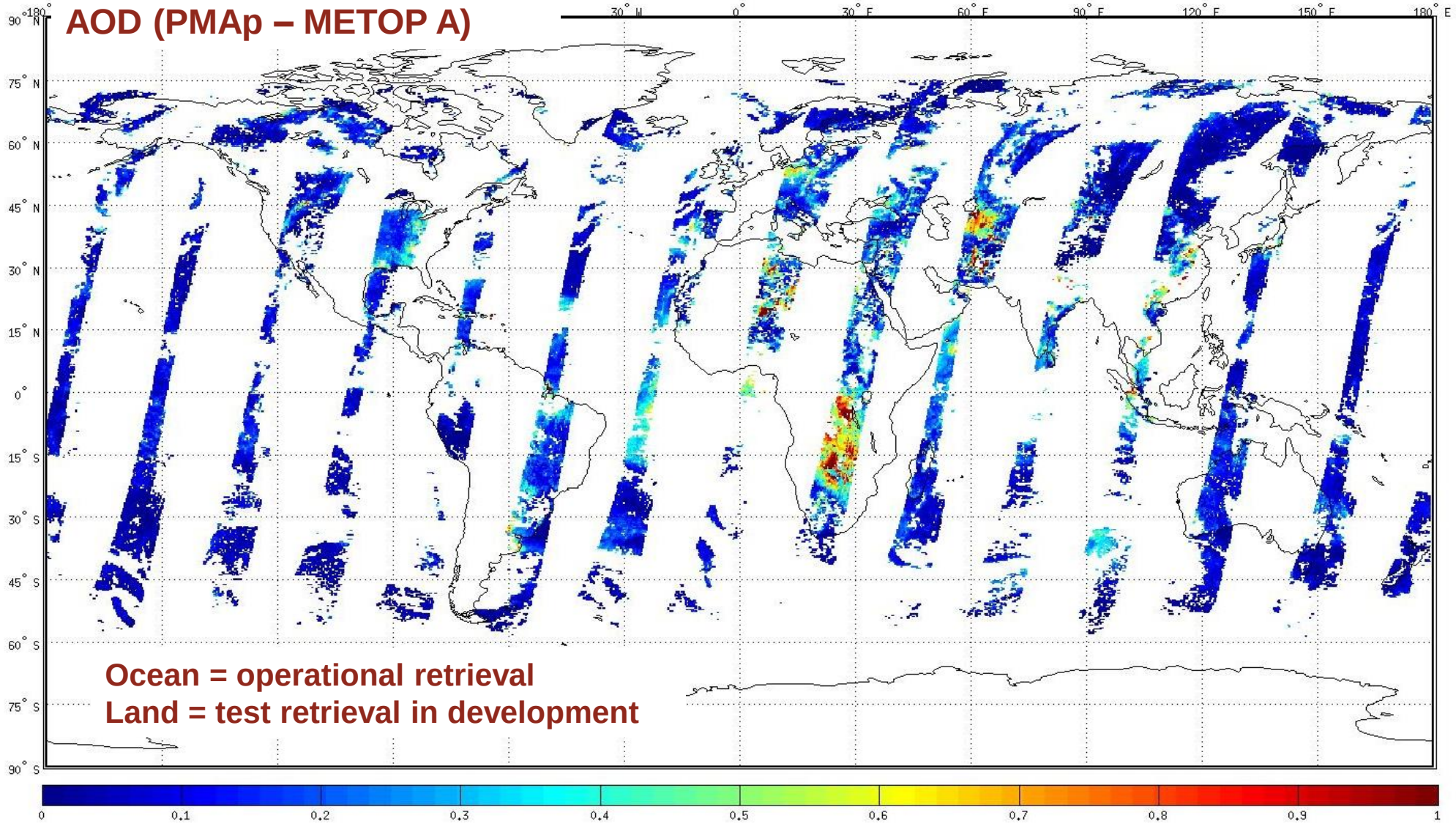


LUT: O. Hasekamp

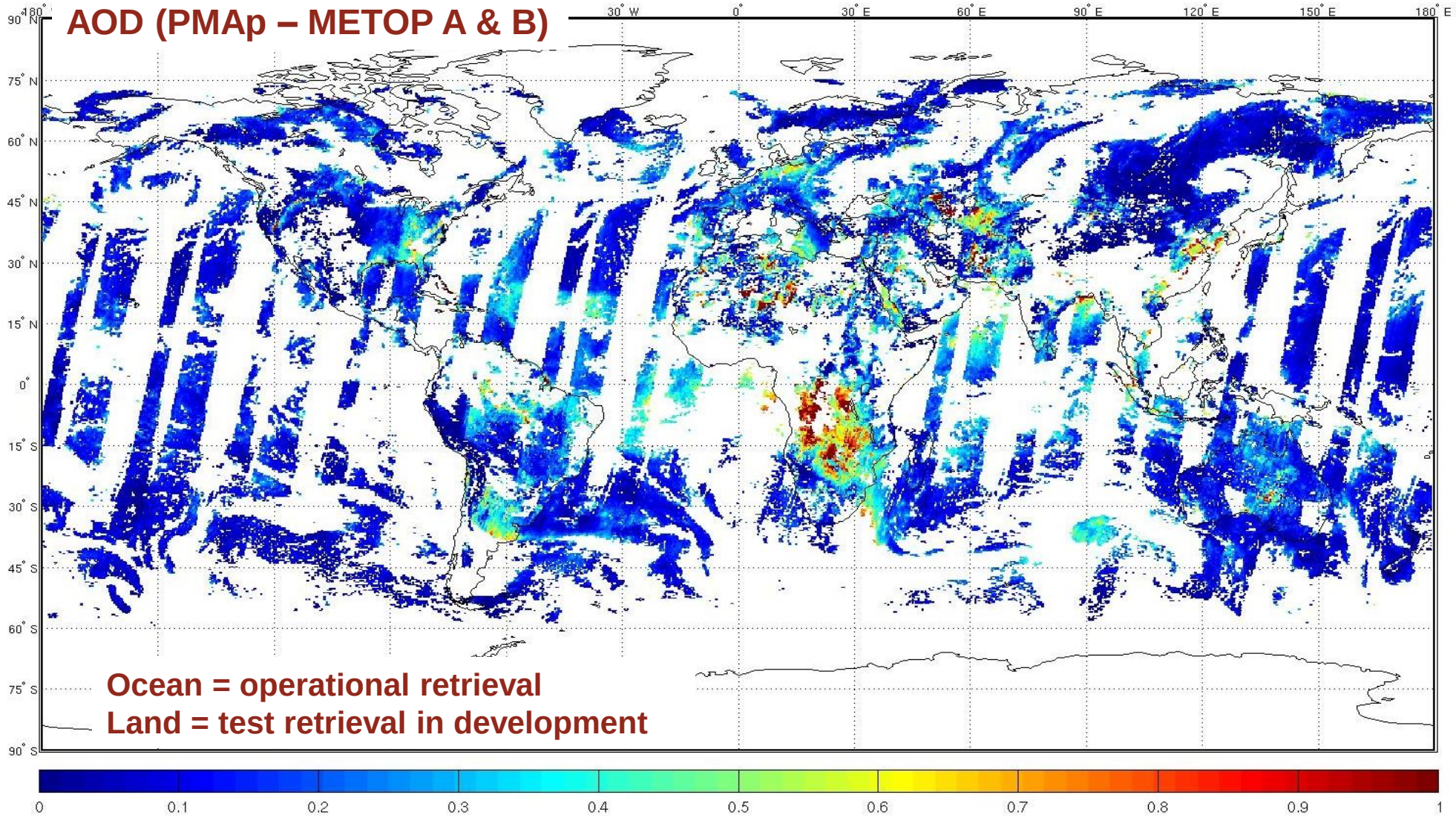
AOD: PMAp Metop B (30/08/2013)



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



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



Conclusions

- A new aerosol product over ocean from METOP instruments (PMAp) is delivered to our users
  - GOME-2 product using a multi-sensor approach
  - Pre-Operational since Q2/2014
  - Fully validated operational status since 14th October 2014
- Operational monitoring of PMAp using AERONET & comparisons to the ECHAM model show convincing results
- Consistent results for the calculated retrieval error
- A new PMAp release providing AOD over land is in development
  - First results look promising
  - Start of pre-operations expected in Q4/2015

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