Retrieval of aerosol optical properties for clear-sky and partially cloudy scenes from METOP sensors

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REMOTE SENSING OF ATMOSPHERIC AEROSOL, CLOUDS, AND AEROSOL-CLOUD INTERACTION
16/12-19/12/2013, BREMEN

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Overview

- The Metop/GOME-2 polarisation measurement devices (PMDs)

- PMAp: Polar Multi-sensor Aerosol product developed at EUMETSAT – A multi-sensor Metop product
  - *AOD over ocean & cloud products: operational in Q1 2014*
- Examples and Verifications

- Work in progress & future plans
- First results: AOD over land (PMAp second generation)

METOP instrument level-1 data used by PMAp

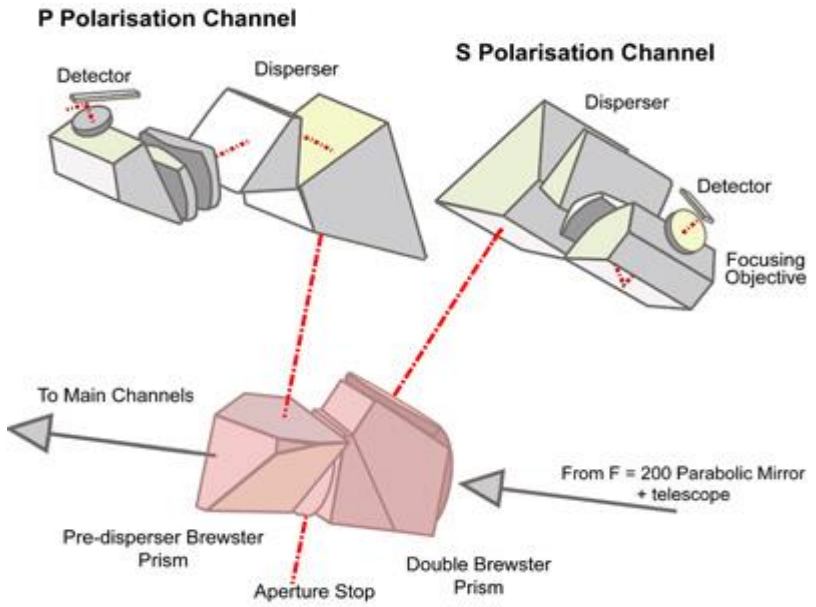
Instrument		Spatial resolution	Spectral range	comments
GOME	Main science channel	80 x 40 km	240nm -800nm, res. 0.25-0.5nm	AAI, low spatial resolution
	Polarization Monitoring Device	10 x 40 km Metop-B 5 x 40 km Metop-A	311nm-803nm, 15 bands	AOD, aerosol type, AAI
AVHRR	-	1.08 x 1.08 km	580nm-12500nm, 5 bands	Clouds, scene heterogeneity, desert dust
IASI	-	12km (circular)	3700–15500nm, resolution 0.5 cm^{-1}	Coarse mode aerosols (desert dust, volcanic ash)
Auxiliary data	ECMWF wind speed (forecasting)	Temporal interpolation necessary	-	Required for retrievals over ocean
	surface albedo, Surface elevation	-	-	Required for land surface retrievals

Target spatial resolution

The GOME-2 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



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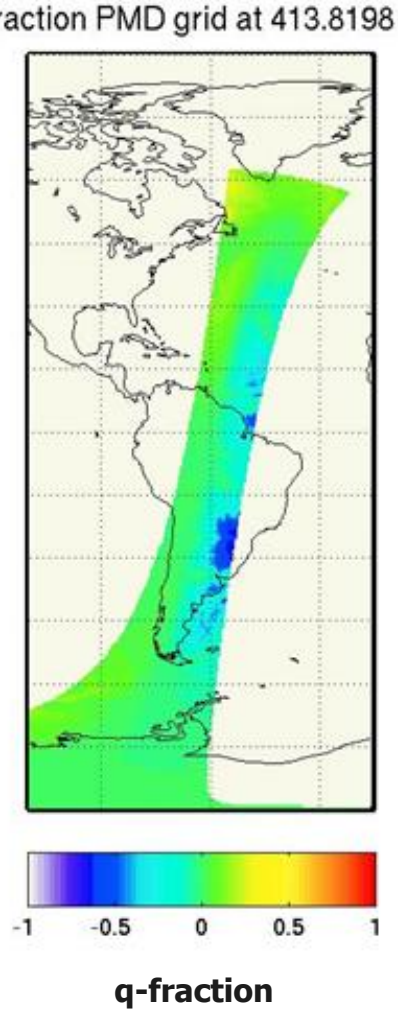
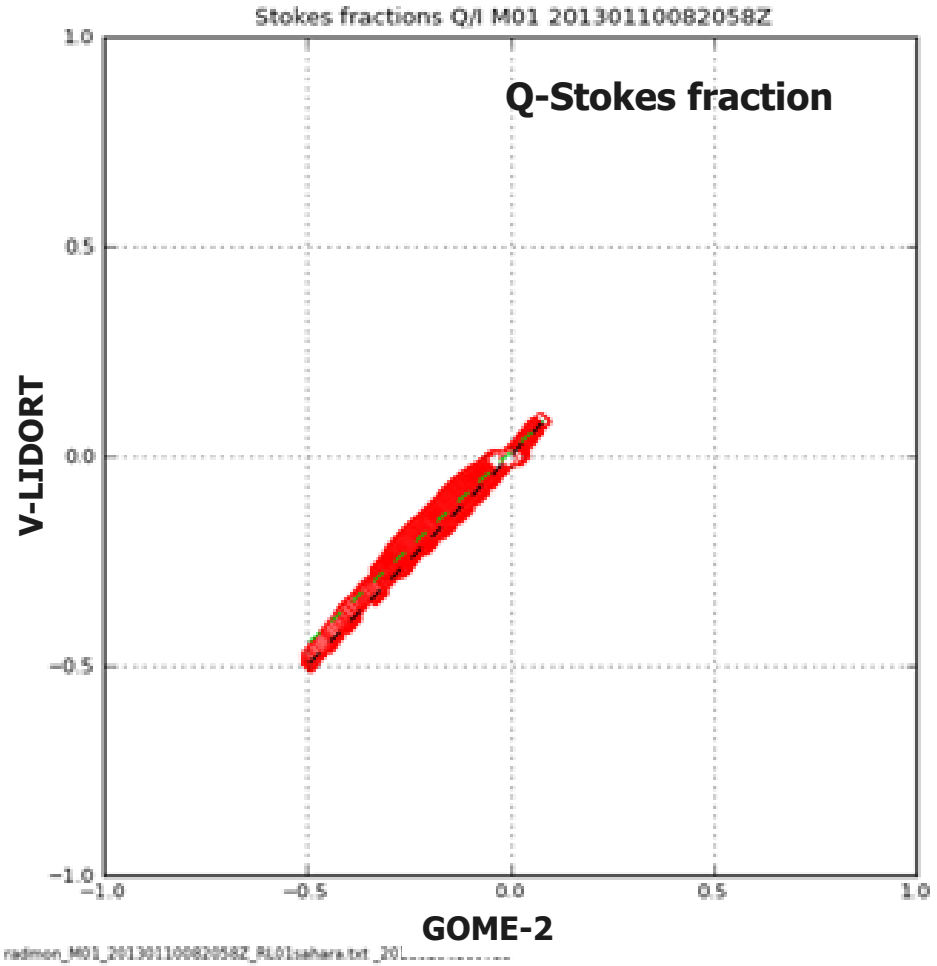
The Polarization Monitoring Devices





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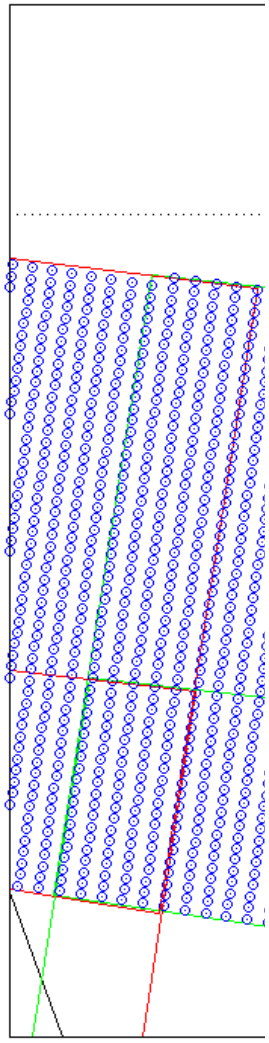
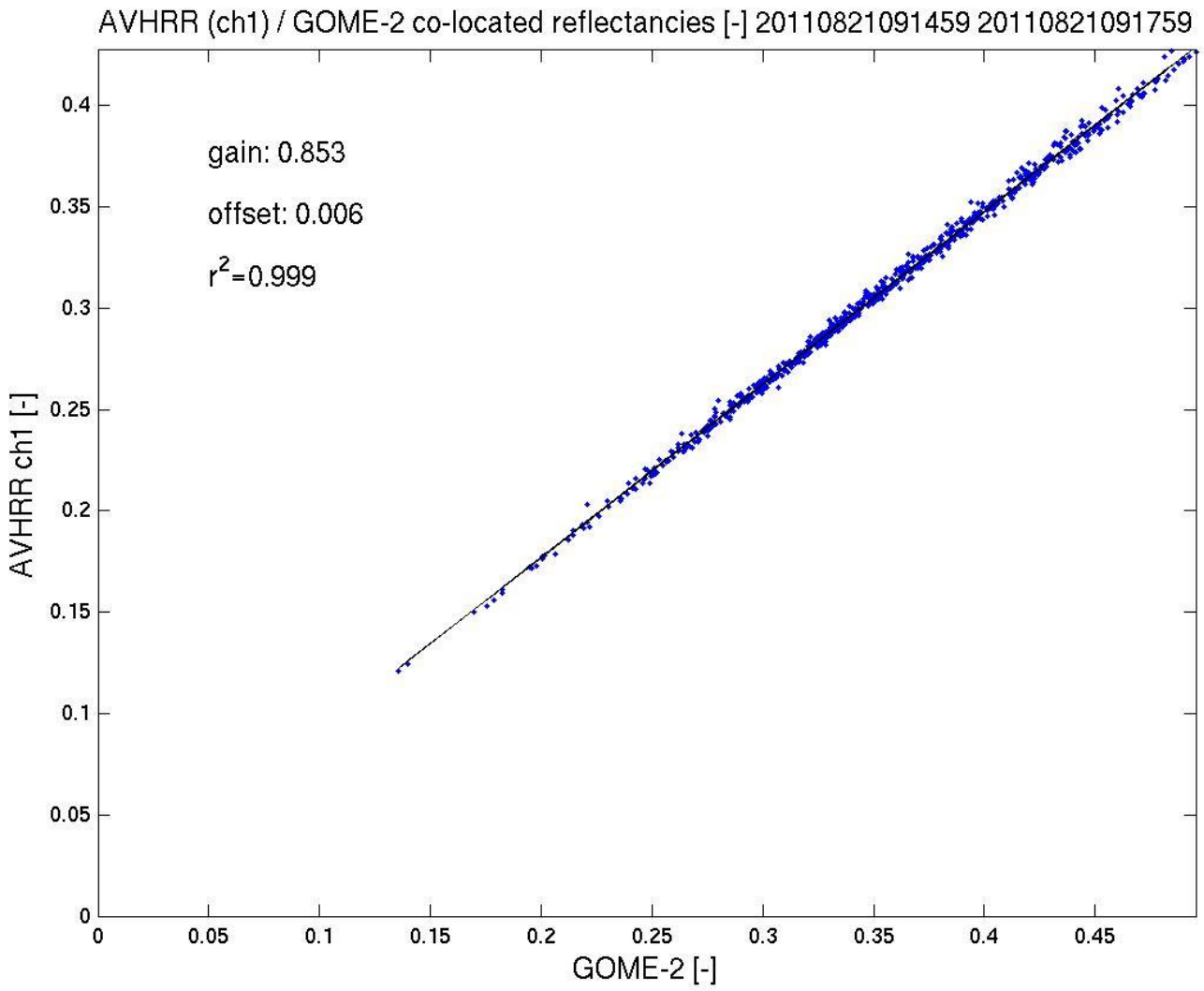
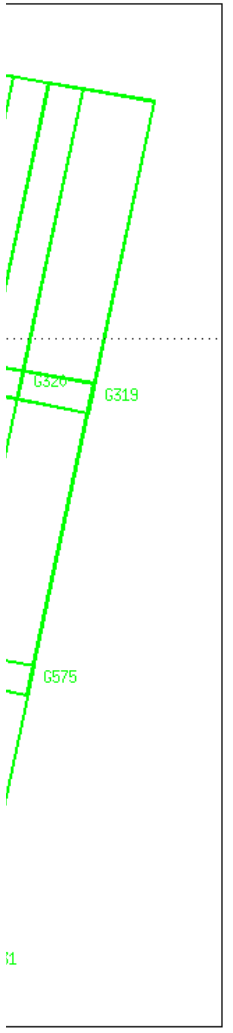
PMAp: Very accurate co-location of AVHRR and IASI to the GOME-2 PMD pixel footprints







PMAp: AOD retrieval algorithm I

Three step retrieval:

Step1: Pre-classification by AVHRR.

- Detection of clouds, cloud fraction
- Strong dust/ash events
- Pre-classification of possible aerosol types (depending on BTD – T4-T5 tests plus VIS/NIR wavelength dependency)

no dust / fine mode, dust, ash, no classification

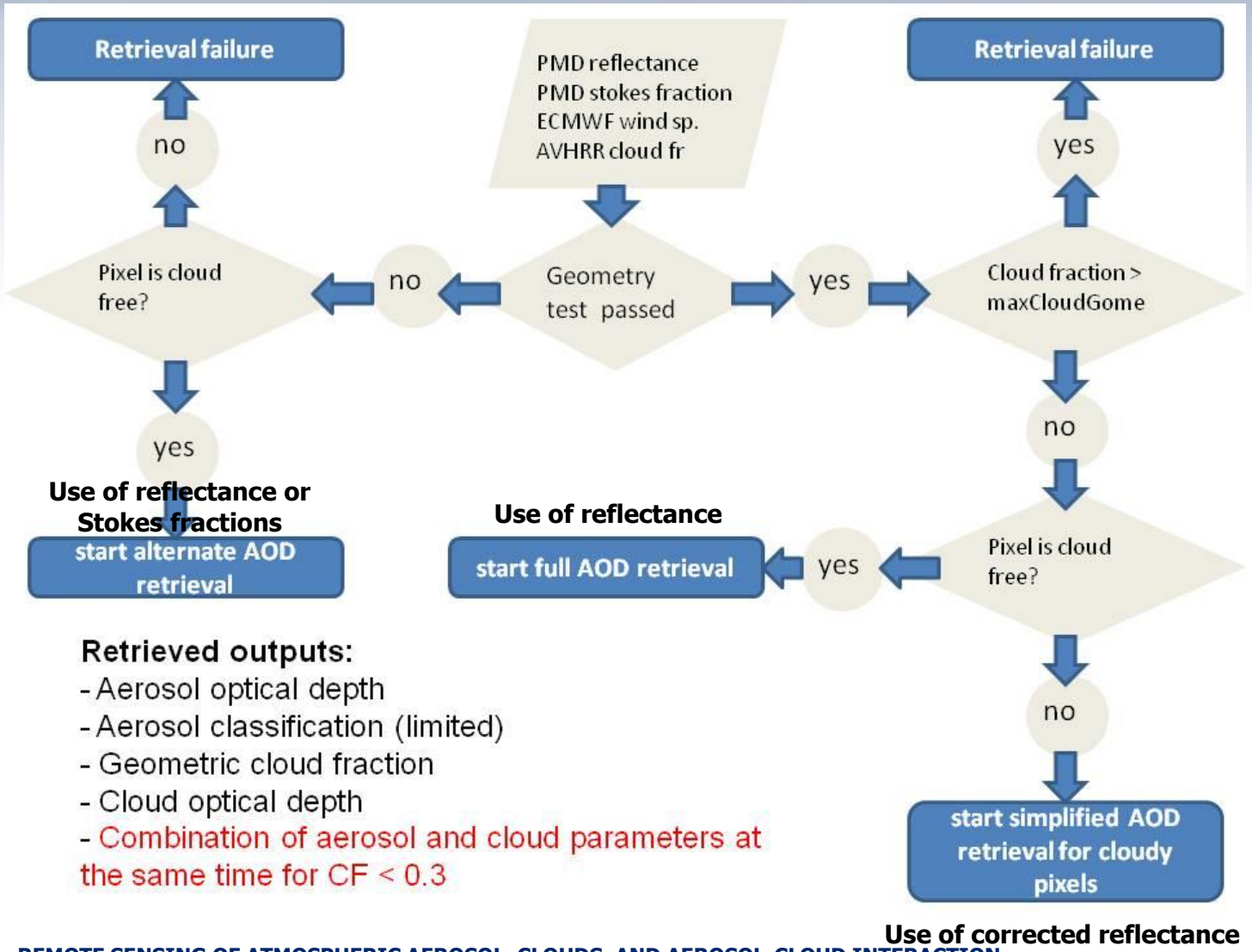
Step2: Retrieval of a subset or all 28 AODs plus chlorophyll correction

- based on max. 28 aerosol models from LUT provided by O. Hasekamp (O3MSAF)
- using three alternative retrievals based on cloud, wind-speed/surface and geometry conditions

Step3: Selection of the best fit

- out of the max. 28 AODs using least-square minimization to all wavelength (between 400 and 800 nm)

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

Criterion: impact on TOA not too large w.r.t expected clear-sky conditions

- Cloud filter:
  - AVHRR/VIS
  - AVHRR/IR

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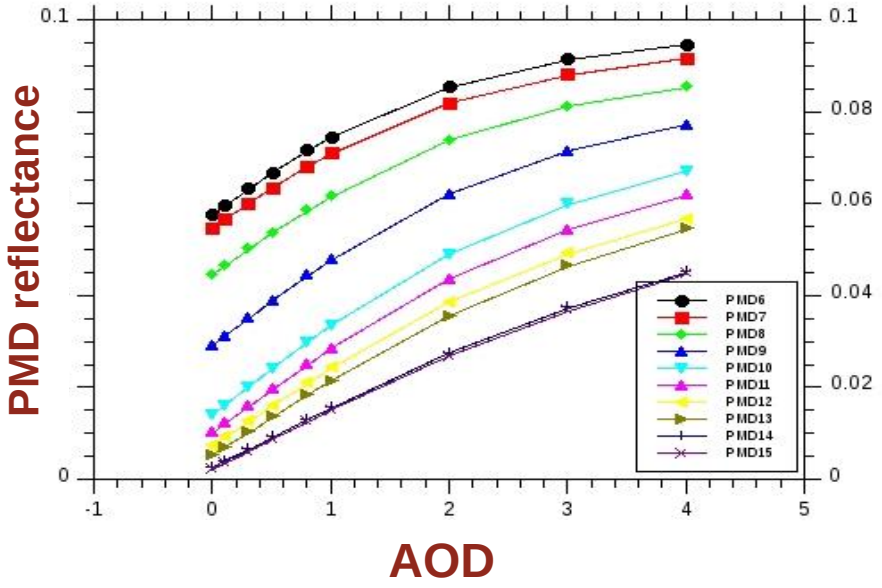
Best case: Retrieval clear sky & dark surface

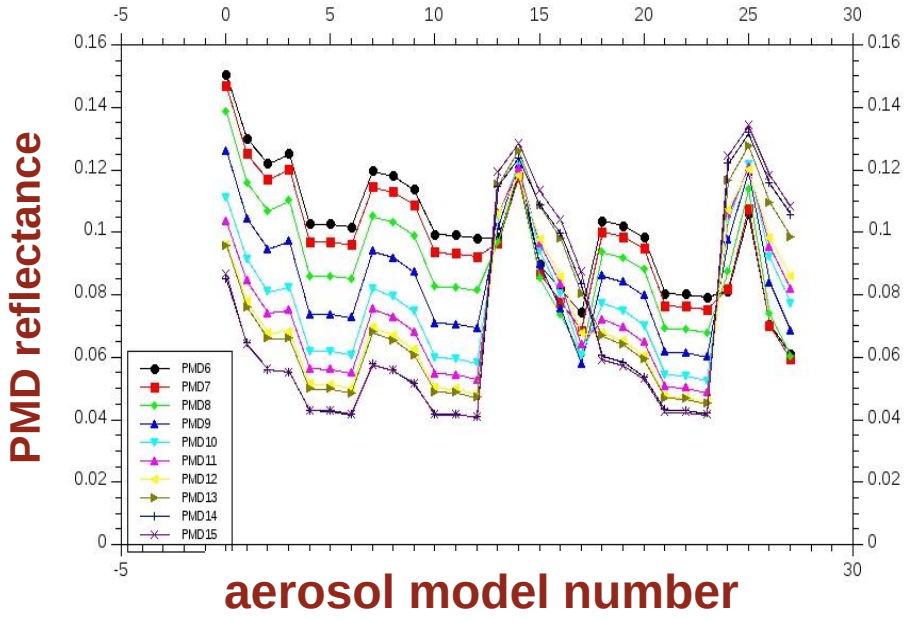
• **Step 2**: A set of AODs (for the pre-selected models) and chlorophyll corrections is estimated using three channels: **UV [380 nm]**, **VIS/green [520 nm]**, **red edge [800 nm; main AOD band]** using least-square minimization. AOD retrieved from 800 nm.

• **Step 3**: Selection of a aerosol type / chlorophyll / AOD set using least-square minimization of measured and modelled reflectance in all PMD channels. **Stokes fractions are used in addition if applicable.** **(East part of the swath and close to sun-glint)**

SZA=40, nadir, aerosol model 3



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

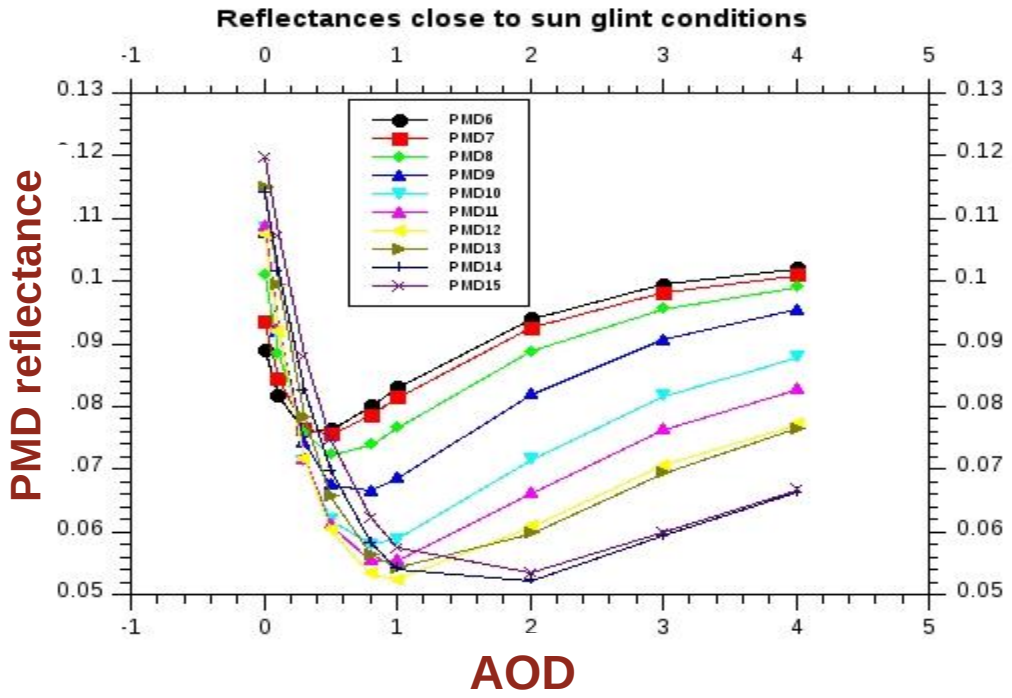


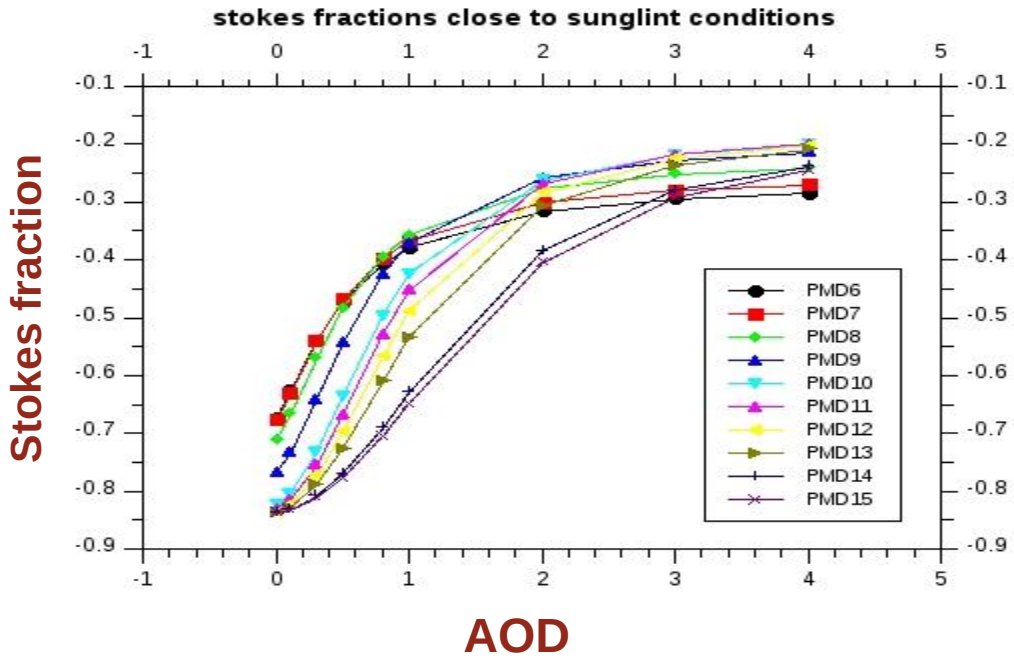
LUT by O. Hasekamp (SRON/O3MSAF)

Alternate retrieval

Combining reflectances & stokes fractions under conditions with large surface contribution

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





LUT by O. Hasekamp (SRON/O3MSAF)

Partially cloudy conditions:
Cloud radiance correction by AVHRR

- AVHRR cloud tests:
  - Albedo test
  - T4 test
  - Uniformity test
  - T4T5 test

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

- Retrieval for partly cloudy pixels:
  - Limited to PMD 13/15
  - Corrected for cloud reflectance

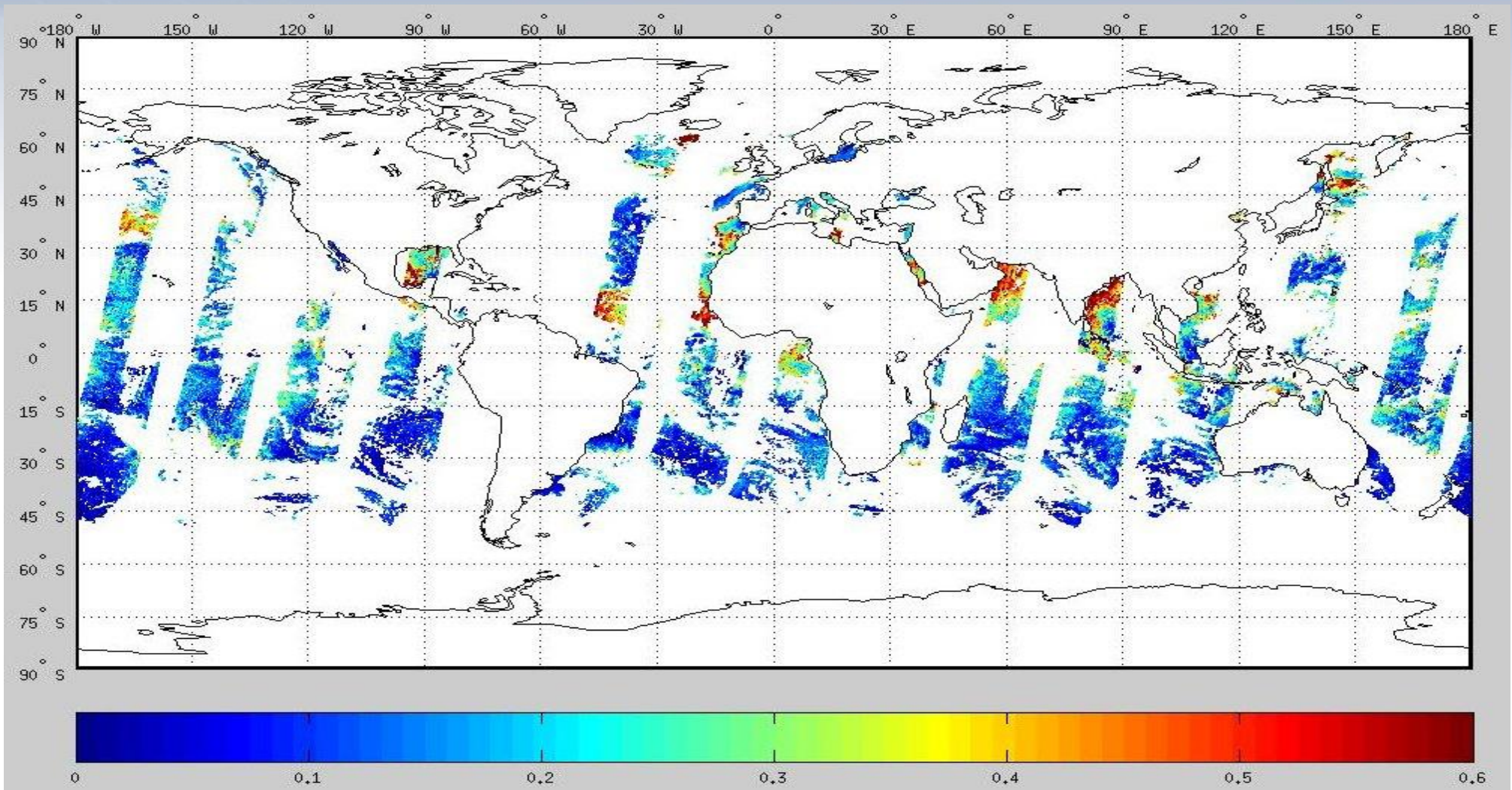
$$R_{cloudfree}(PMD) = R_{all}(PMD)\frac{\tilde{R}_{clearsky}(AVHRR)}{\overline{R_{allpixel}(AVHRR)}}$$

Geometric cloud fraction:

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

Use regular retrieval on corrected reflectances

PMAp results: Aerosol Optical Depth (23/05/2011)



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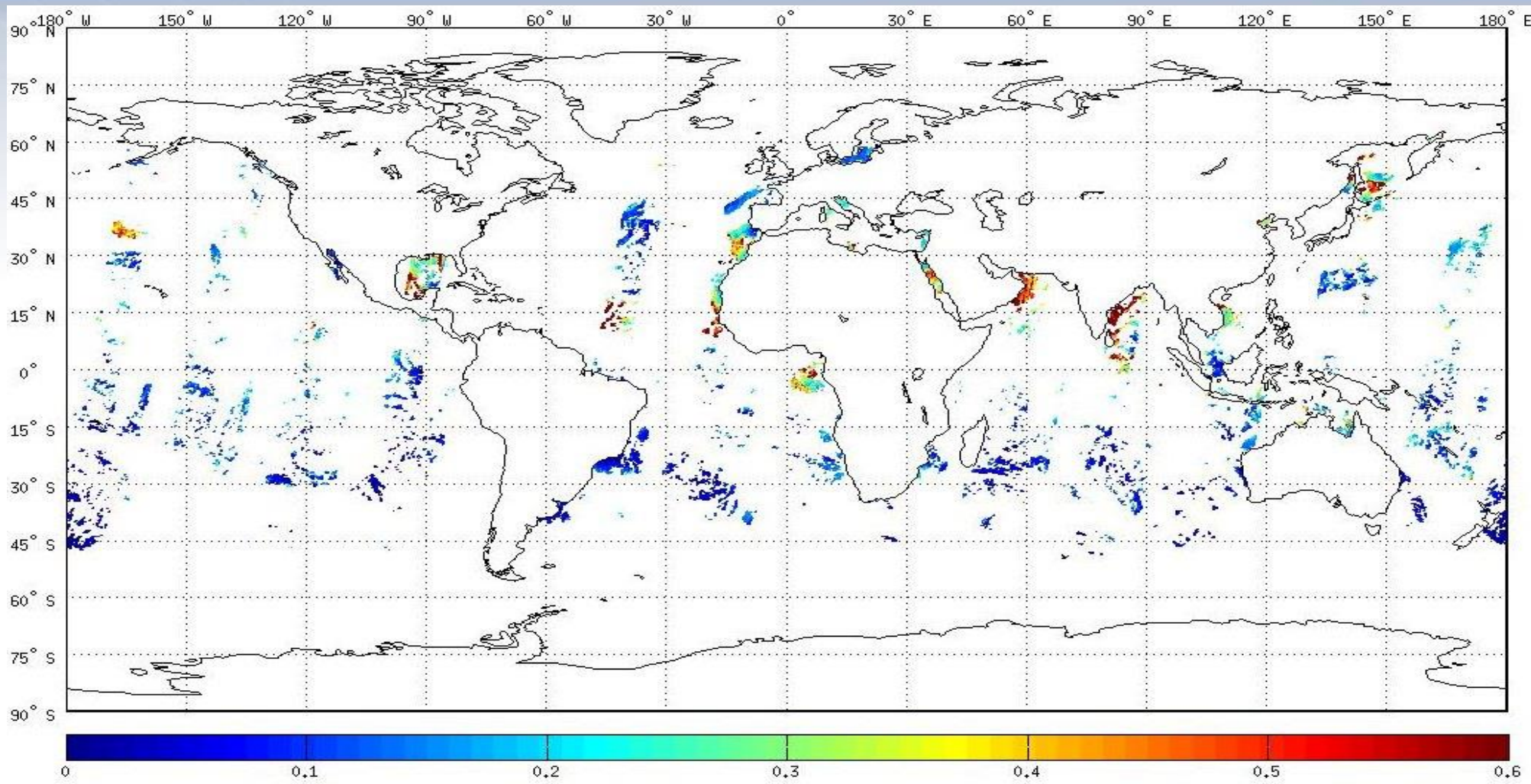
PMAp results: AOD clear sky cases (23/05/2011)



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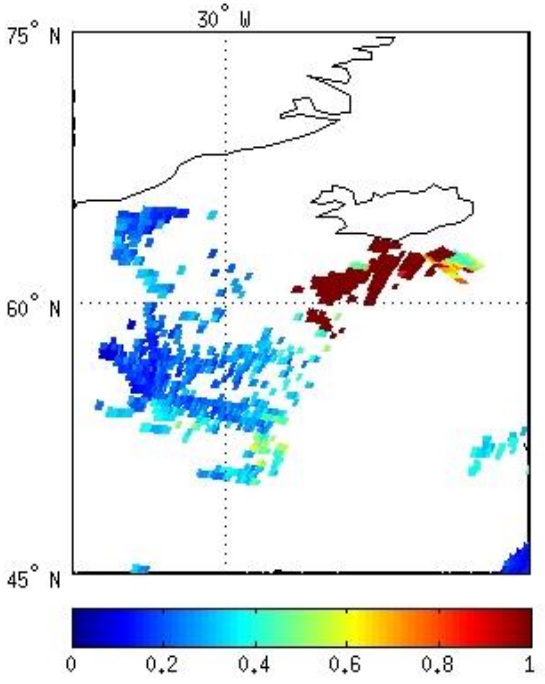
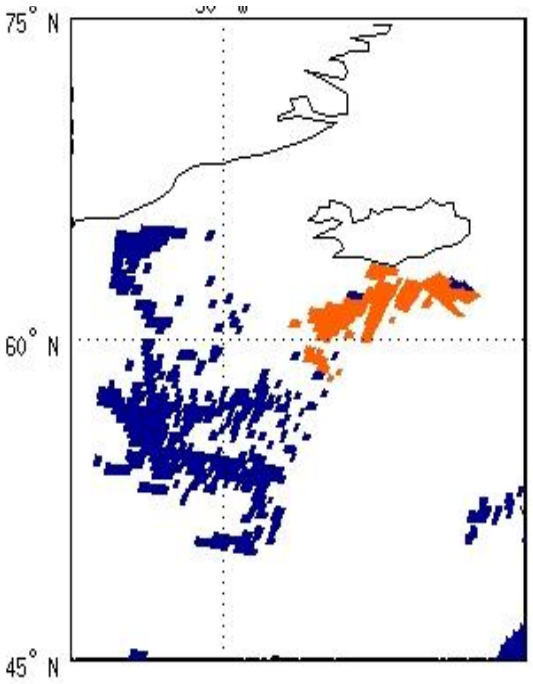
Volcanic ash flag:
Identifying pixels misclassified as cloud

- Brightness temperature difference T4-T5 (10 µm – 12 µm)
- Thresholds in VIS and NIR (e.g. AVHRR CH3A/CH2)

Aerosol optical depth



Volcanic ash flag:



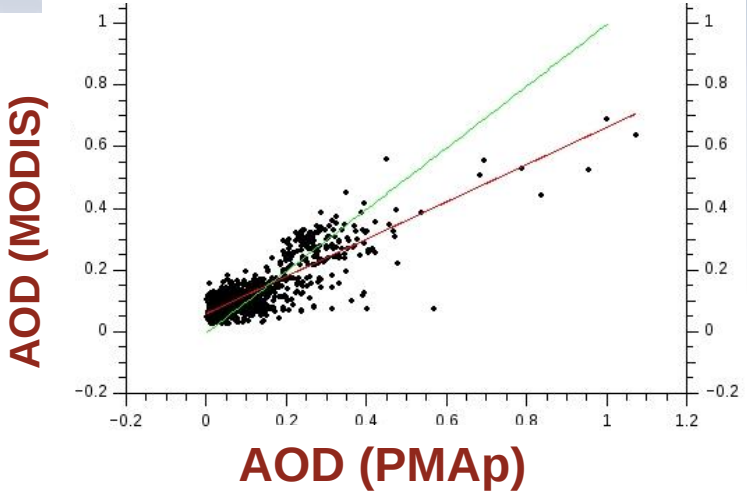
Orange: Strong ash test positive, cloud tests ignored

Blue: cloud fraction < 0.3, AOD retrieved

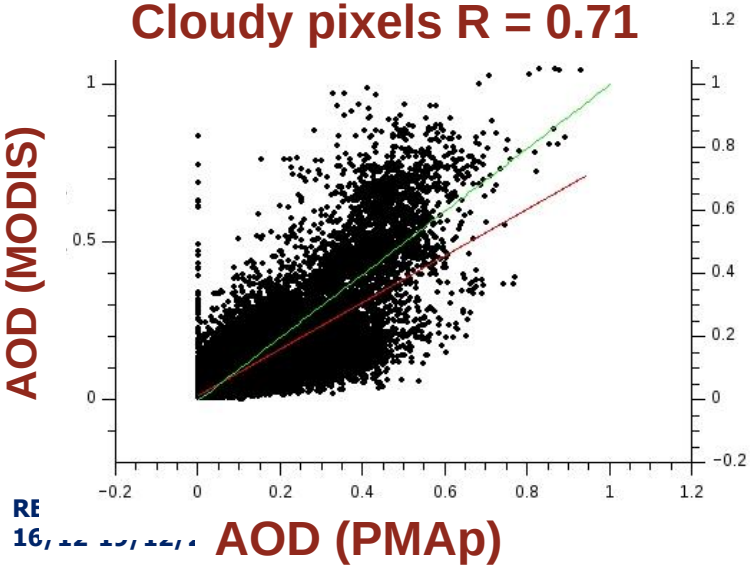
White:
- **no retrieval or**
- **cloud fraction > 0.3 and negative ash test**

Initial Verification of PMAp
Comparison to MODIS

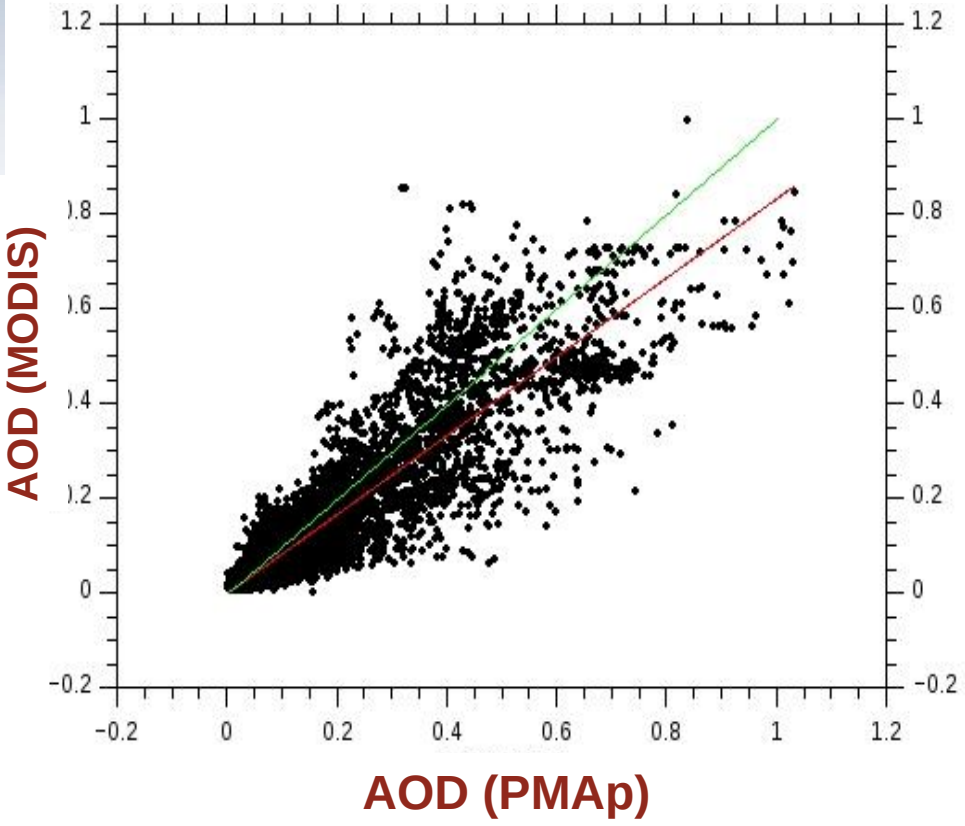
Alternate retrieval R = 0.83



Cloudy pixels R = 0.71



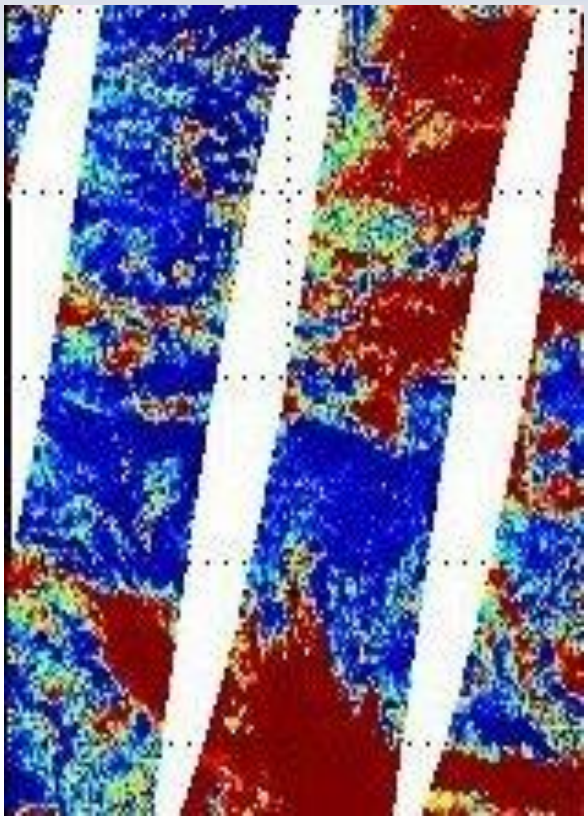
Main retrieval R = 0.89



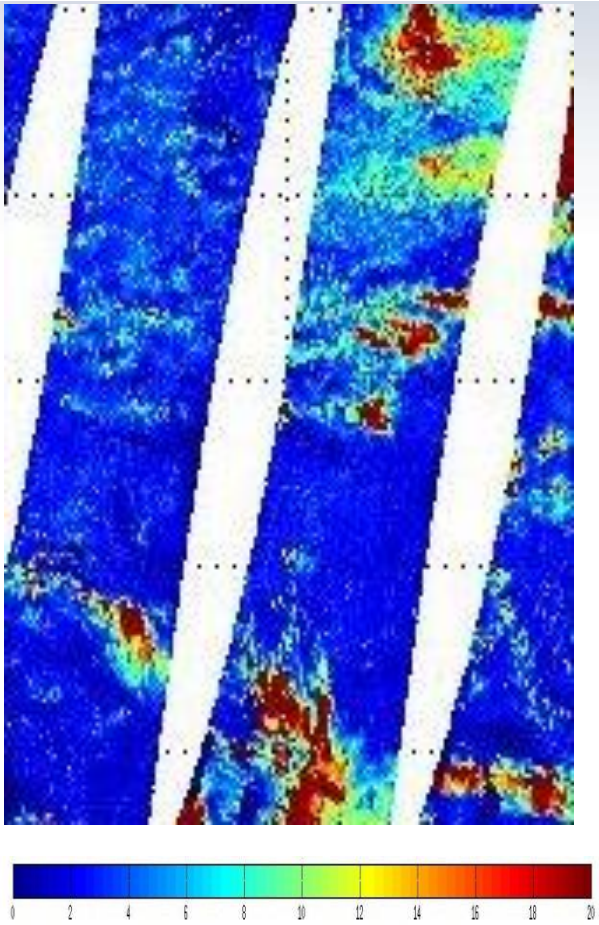
Overpass difference: 1.0h MODIS / Terra and METOP

PMAp Cloud products

PMAp: cloud fraction

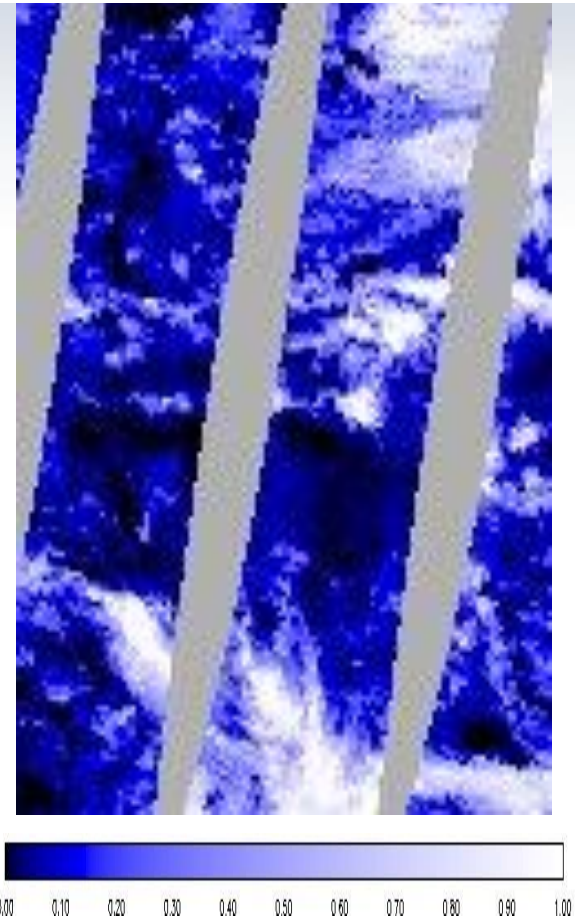


PMAp: cloud optical depth

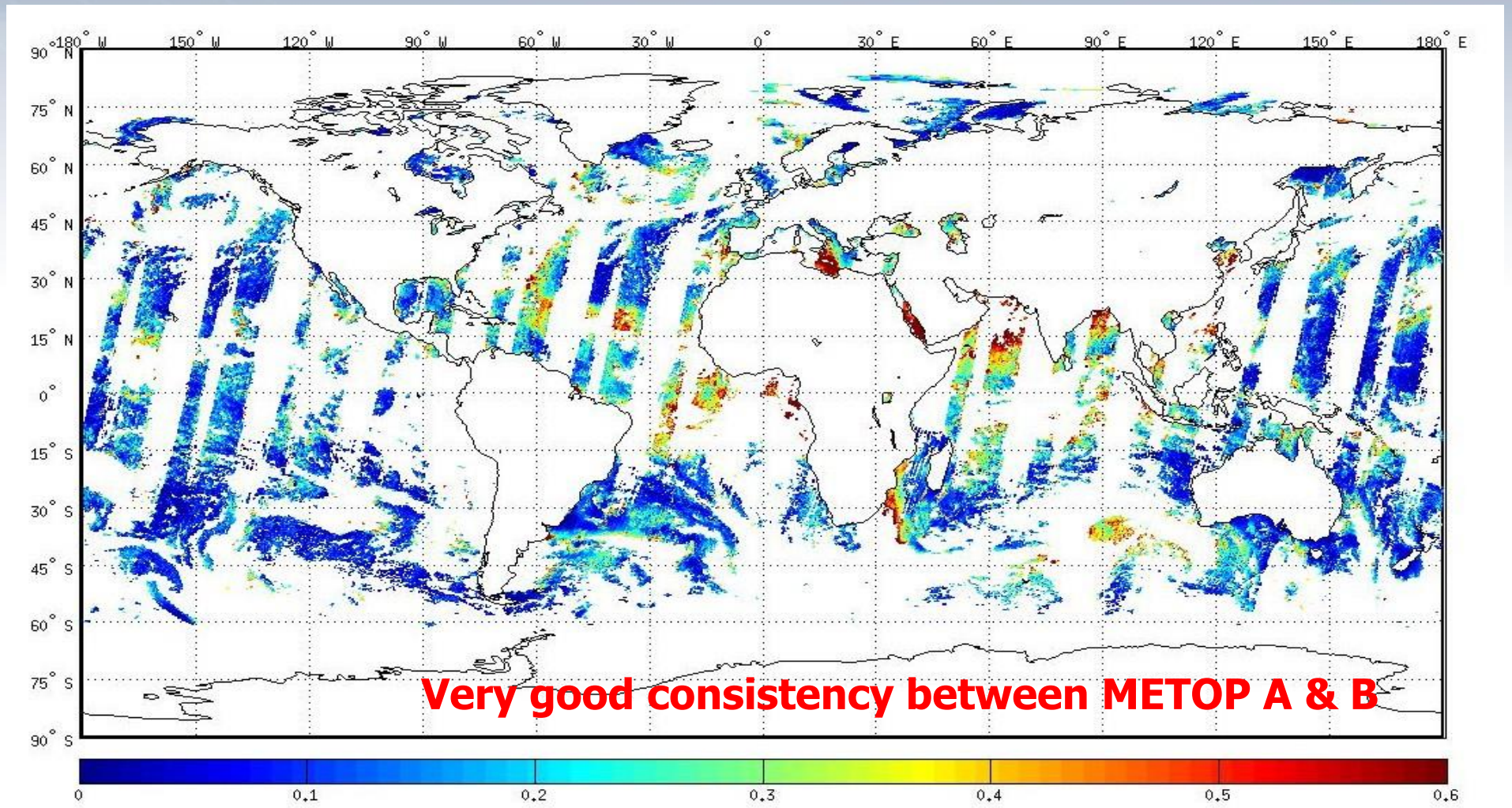


FRESCO (www.temis.nl)

Effective cloud fraction



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



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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

Planned start of demonstrational/pre-operational dissemination:

February/March 2014

The PMAp product test-data
Product test and trail dissemination phase

PMAp runs in EUMETSATs core ground segment #2 in operational mode since 12th of December 2013

- Test data is available since then to interested users

→ on an offline basis (best effort)

→ on an operational test-dissemination basis (starting January 2014)

Want to be a test user?
- early access to data
- early access to al relevant documentation

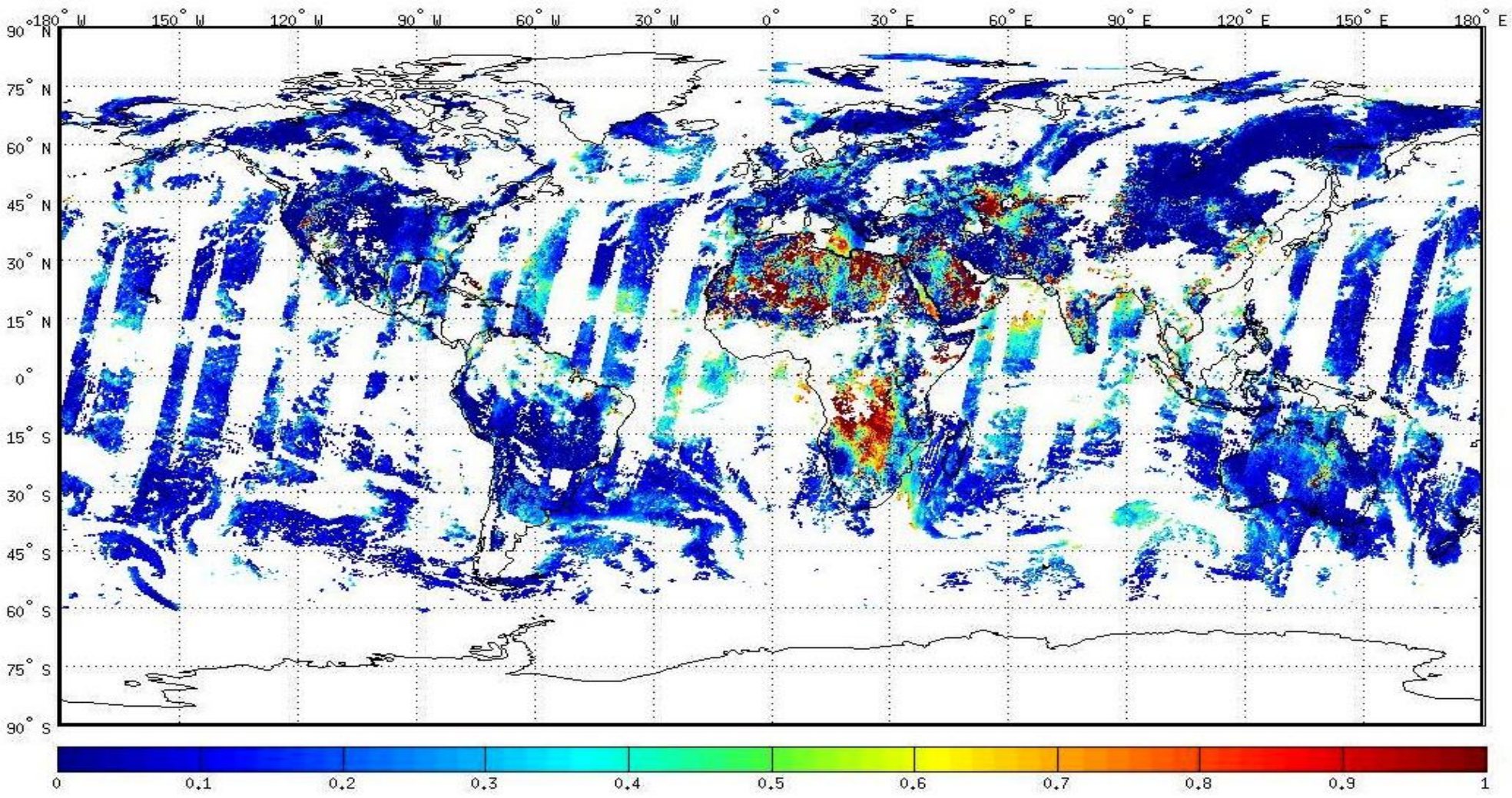
→ ruediger.lang@eumetsat.int, or
ops@eumetsat.int

Future algorithm developments

- Extension of the AOD retrieval to pixels over land (preliminary land retrieval available on prototype level)
  - AOD interpolation for different aerosol types at 460nm
  - AOD type selection using different aerosol indices between 370-460nm
  - Corrections for partly cloudy pixels combining GOME and AVHRR around 630nm
- A dedicated volcanic ash retrieval is currently being developed using the same framework:
  - Temperature differences & NDVI (AVHRR)
  - Shape of the IASI spectra (e.g. concept of Lieven Clarisse)
  - GOME-2 UV ratio
- Online calibration of AVHRR channels 1, 4 and 5 using GOME-2 and IASI (development for PMAp and in the frame of GSICS)

PMAp AOD over land

First result (30/08/2013) from Metop-A and B



Conclusions

- A new aerosol product over ocean from METOP instruments (PMAp) will be provided to users (operational in Q1/2014)
- The aerosol product is developed using a multi-instrument approach combining GOME, AVHRR and IASI
- AOD will be retrieved for clear-sky and partly cloudy scenes
- Cloud fraction, cloud optical depth and limited information on aerosol type like volcanic ash is provided in addition
- Verifications of the algorithms show promising results

- The second generation will provide AOD over land and an improved multi-sensor retrieval of volcanic ash