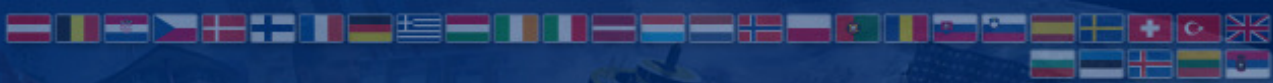


Retrieval of aerosol optical properties for cloudy scenes from METOP

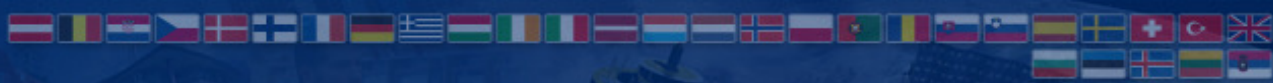
M. Grzegorski, R. Lang, G. Poli, A. Holdak and R. Munro





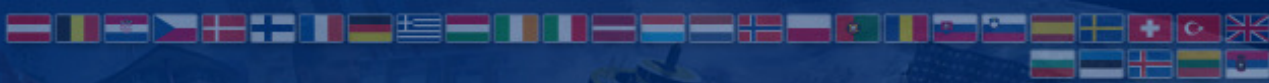
Overview

- A few words about GOME-2 PMD measurements
- **PMAp**: **P**olar **M**ulti-sensor **A**erosol **p**roduct developed at EUMETSAT
 - 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 instruments within the project

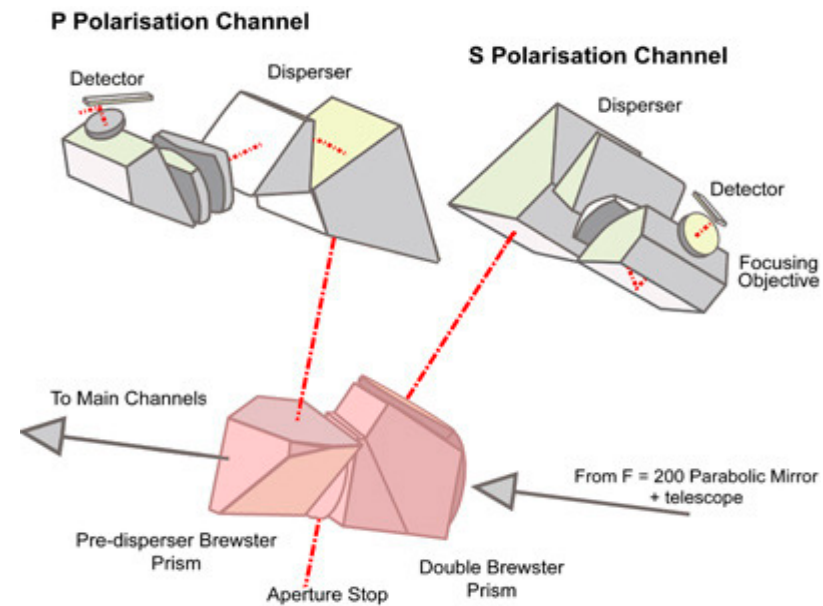
Instrument		Spatial resolution	Spectral range	comments
GOME	Main science channel	80 x 40 km	240nm -800nm, res. 0.25-0.5nm	AAI, bad spatial resolution
	Polarization Monitoring Device	10 x 40 km	311nm-803nm, 15 bands	AOD, aerosol type, AAI
AVHRR	-	1.08 x 1.08 km	580nm-12500nm, 5 bands	Clouds, scene heterogeneity, 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

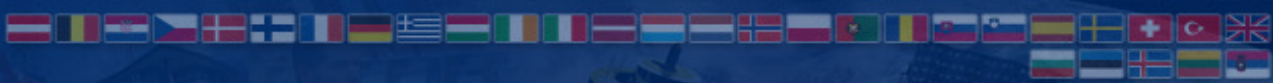


The Polarization Monitoring Devices

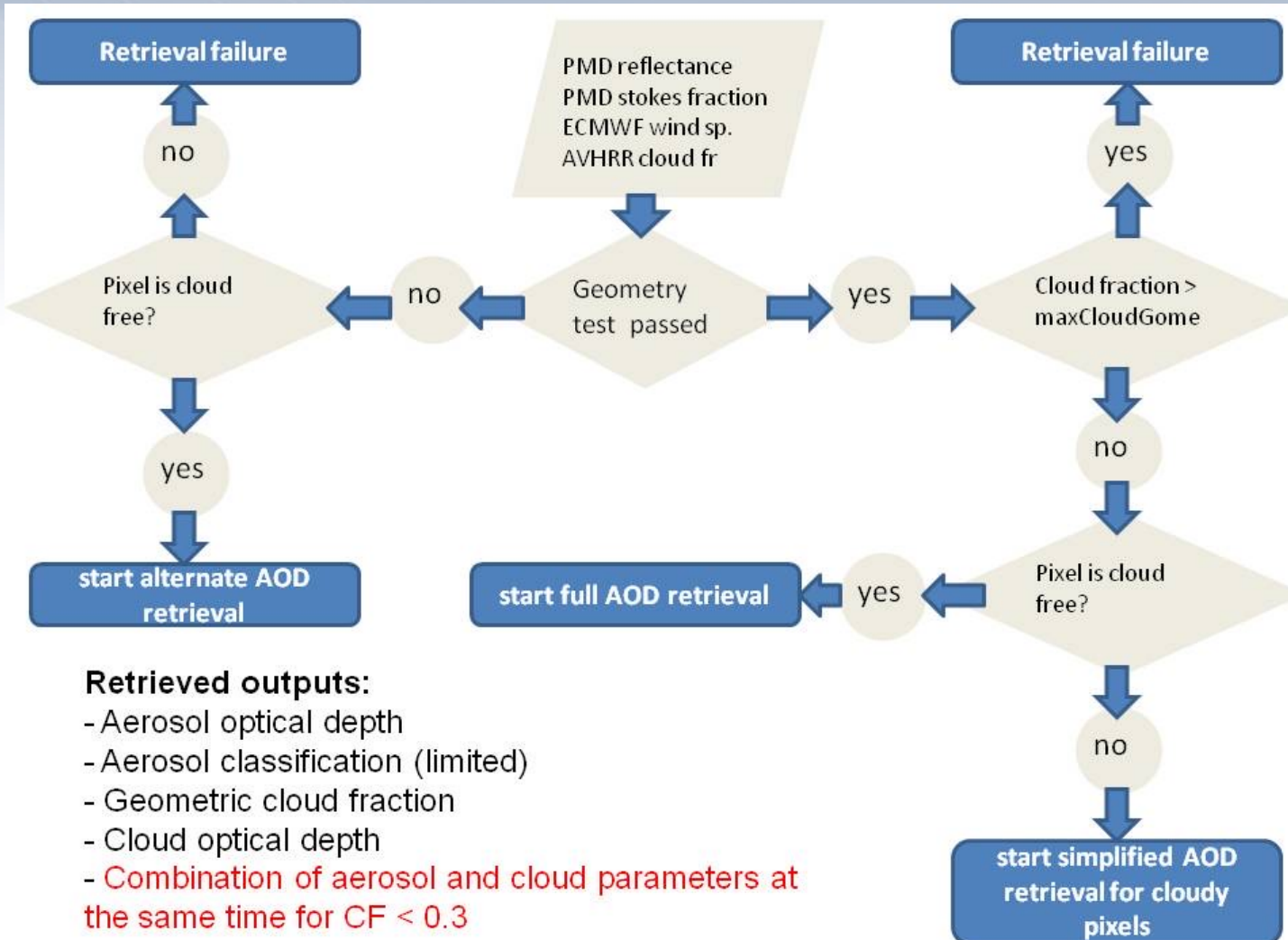
Band-S				
No.	pix1	pixw.	wav1	wav2
1	22	5	311.709	314.207
2	30	4	316.762	318.720
3	37	12	321.389	329.139
4	50	6	330.622	334.443
5	57	6	336.037	340.161
6	84	17	360.703	377.873
7	102	4	380.186	383.753
8	117	19	399.581	428.585
9	138	27	434.083	492.066
10	165	18	494.780	548.756
11	183	2	552.474	556.262
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: AOD retrieval algorithm



- Geometry dependent test with intercomparison of:

- calculated surface signal
- calculated wind speed dependence
- calculated aerosol signal

- Cloud filter:

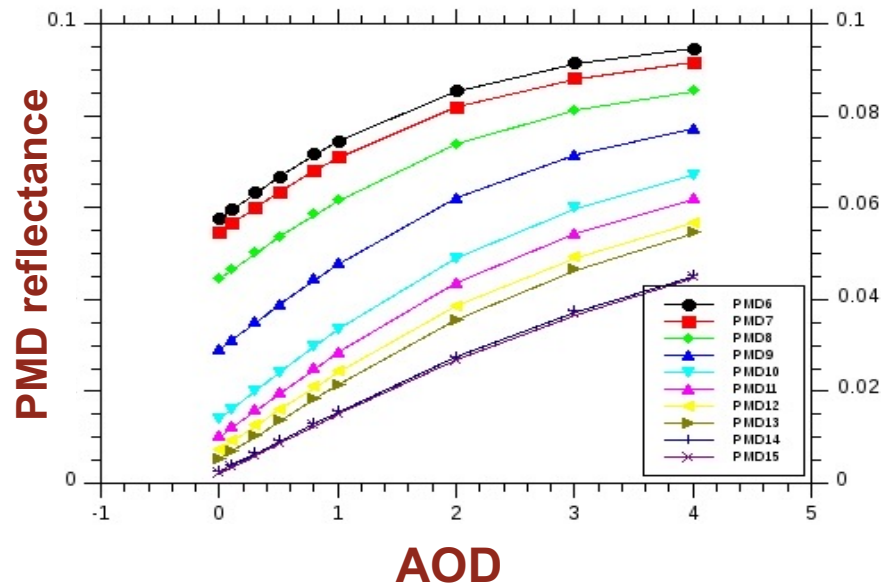
- AVHRR/VIS
- AVHRR/IR



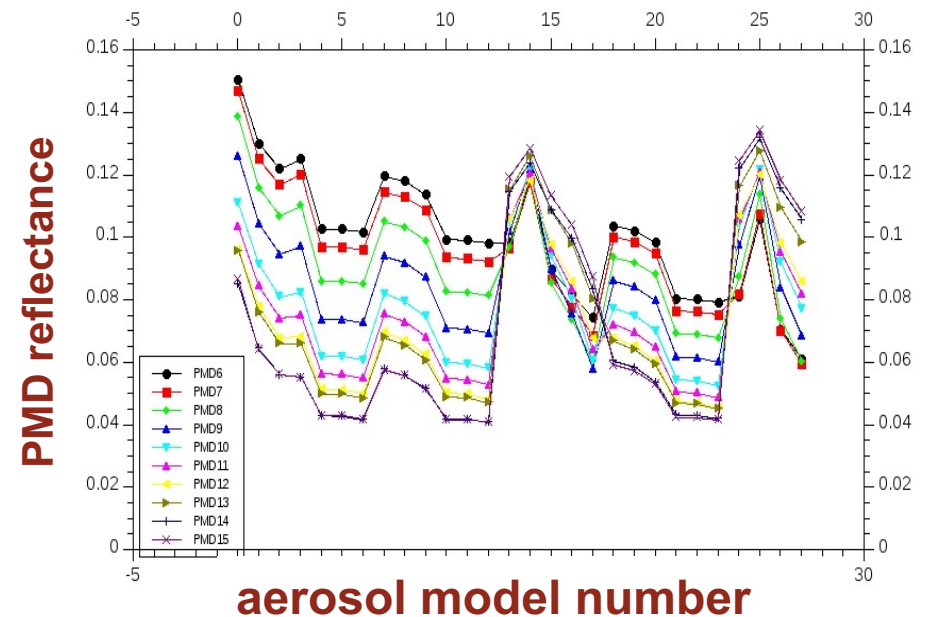
Best case: Retrieval clear sky & dark surface

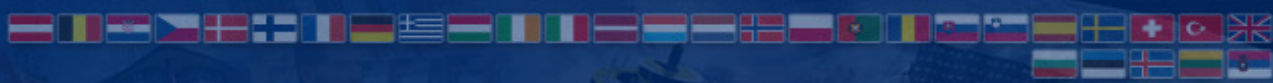
- **Step 1:** A set of AODs (for 8 selected models) and chlorophyll corrections is estimated using three channels: **UV [380 nm]**, **VIS/green [520 nm]**, **red edge [800 nm]** using least-square minimization. AOD interpolation done at 800nm.
- **Step 2:** Selection of a aerosol type / chlorophyll / AOD set using least-square minimization of measured and modelled reflectances in all PMD channels. **Stokes fractions are used in addition if applicable.**

SAZA=40, nadir, aerosol model 3



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





Cloud correction by AVHRR

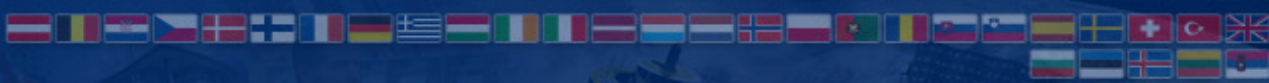
- AVHRR cloud tests:
 - Albedo test
 - T4 test
 - Uniformity test
 - T4T5 test
- Retrieval for partly cloudy pixels:
 - Limitation to PMD 13/15
 - Correct for cloud reflectance

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

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:

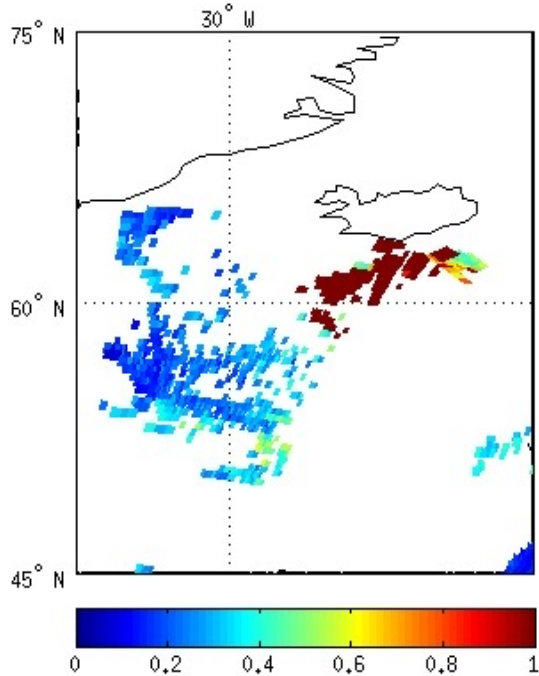
$$CF(GOME) = \frac{n_{cloudy}(AVHRR)}{n_{collocated}(AVHRR)}$$



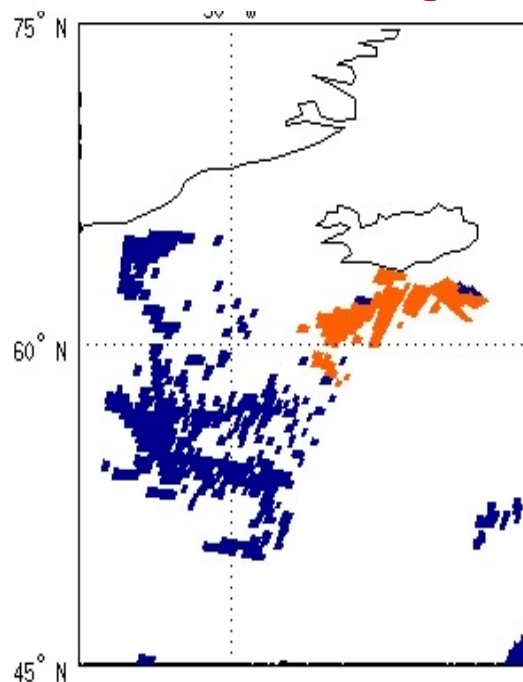
Identify pixels misclassified as cloud: Volcanic ash

- Brightness temperature difference T4-T5 ($10\ \mu\text{m} - 12\ \mu\text{m}$)
- 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:

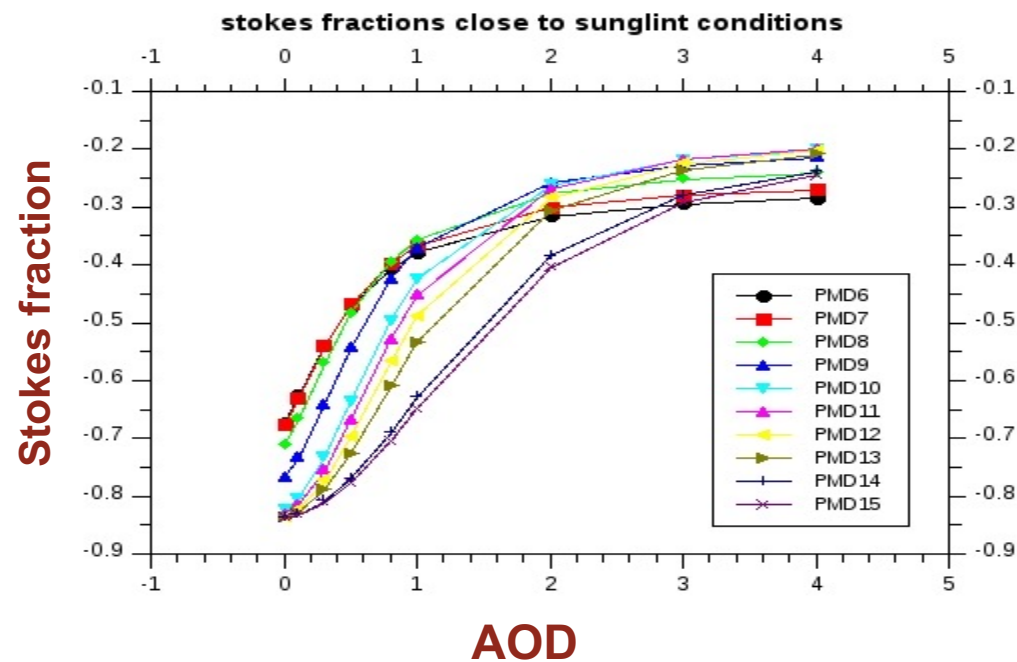
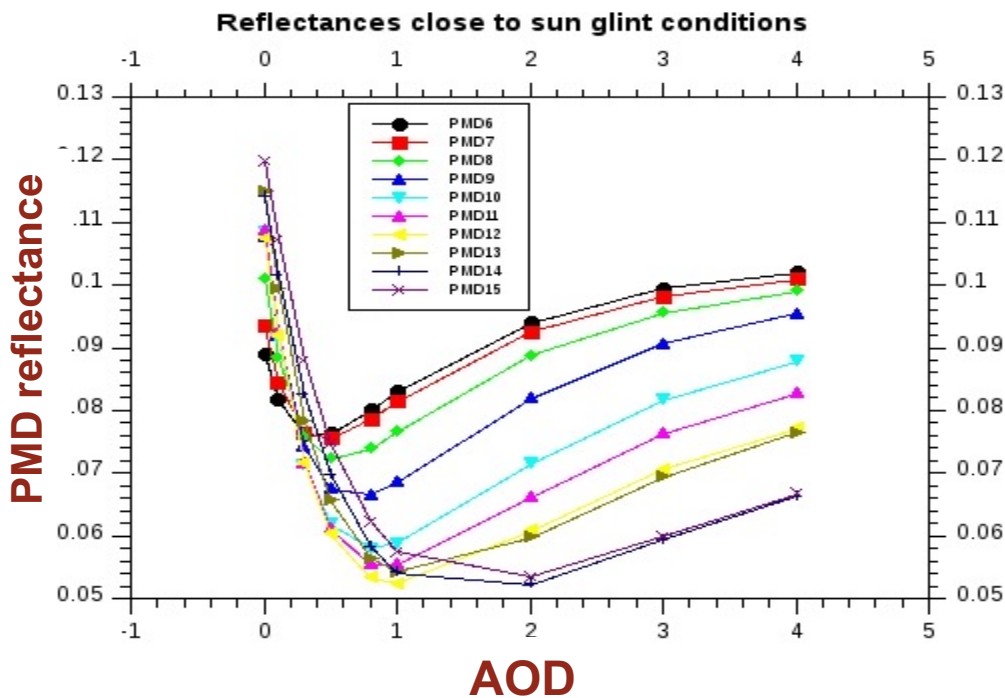
- no retrieval or
- cloud fraction > 0.3 and negative ash test

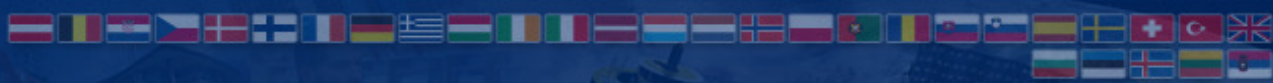


Alternate retrieval combining reflectances & stokes fractions

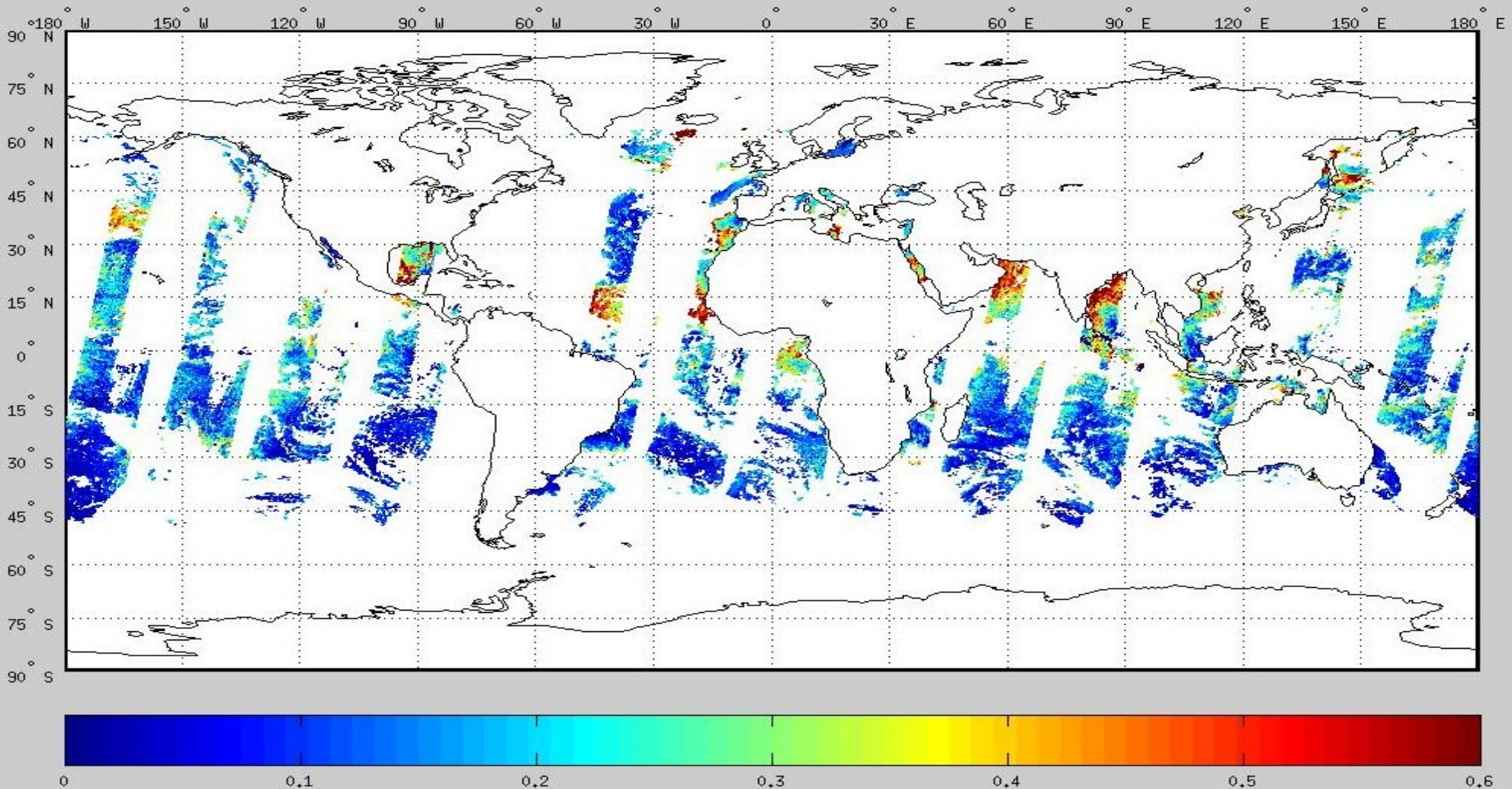
- Guess an AOD using one channel (reflectance or stokes fraction) using different aerosol models and a priori surface

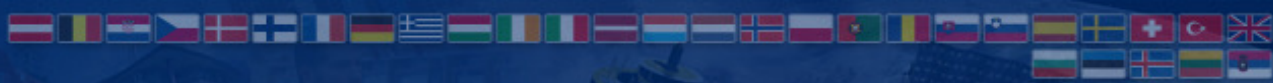
- Check reliability:
$$\chi^2 = \sum_N \frac{(I_{measured} - I_{modelled})^2}{I_{modelled}^2} + \sum_M \frac{(q_{measured} - q_{modelled})^2}{q_{modelled}^2} < MAX$$



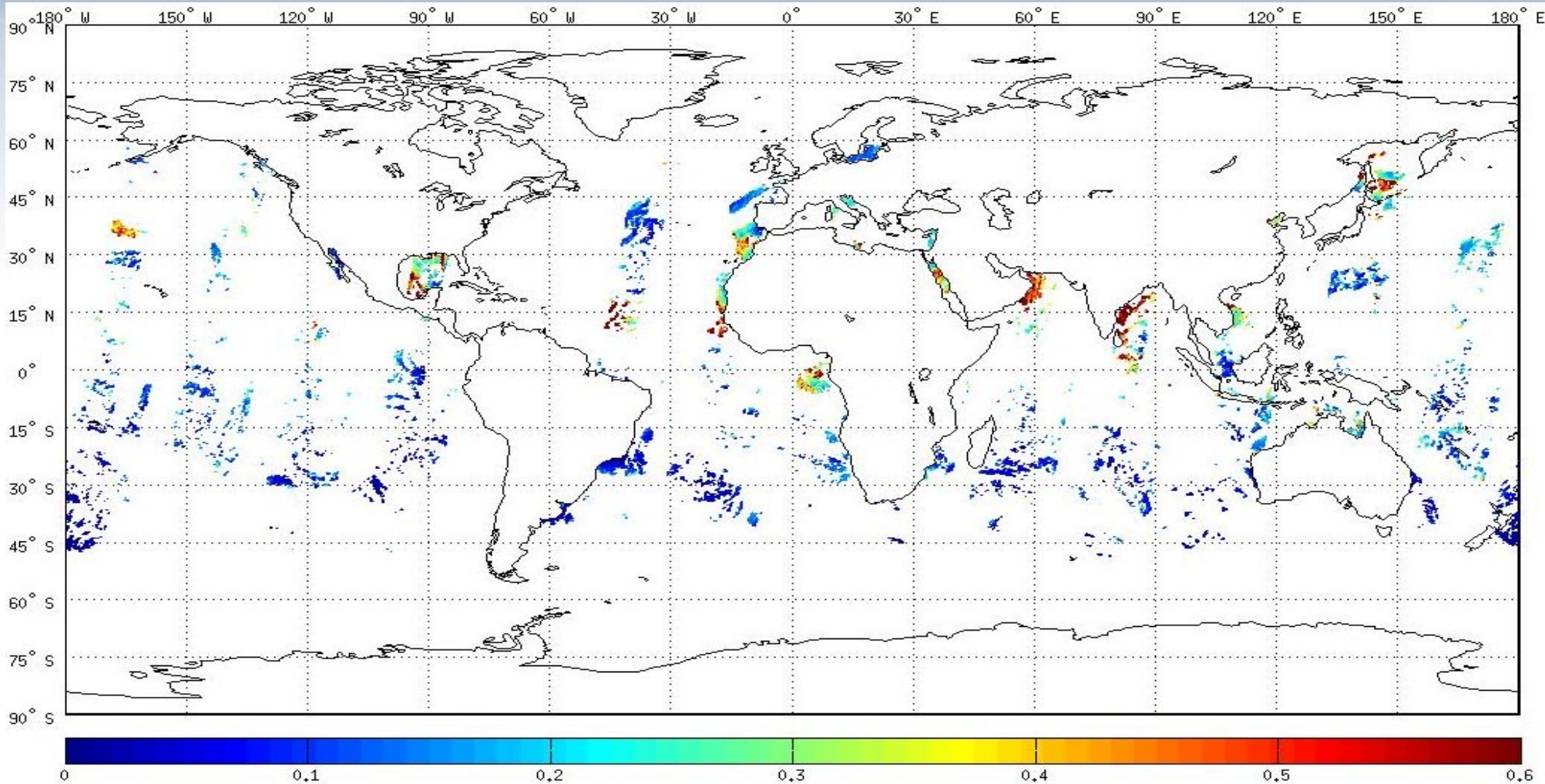


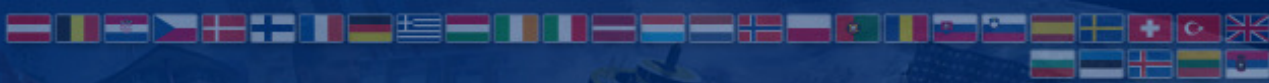
PMAp results: Aerosol Optical Depth (23/05/2011)





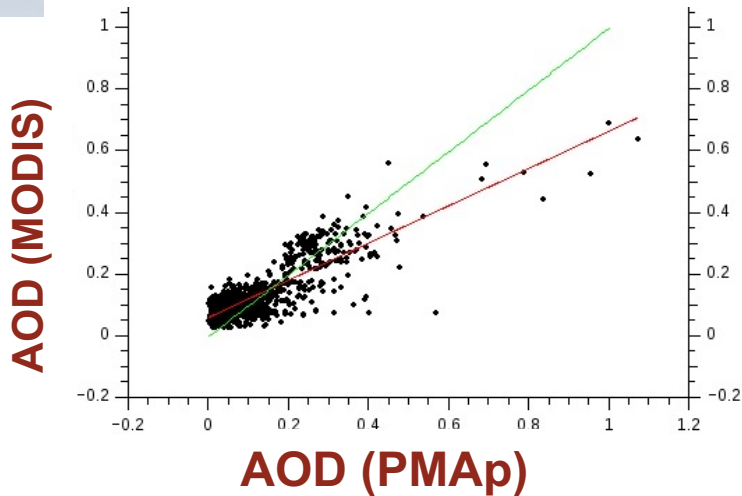
PMAp results: AOD clear sky cases (23/05/2011)



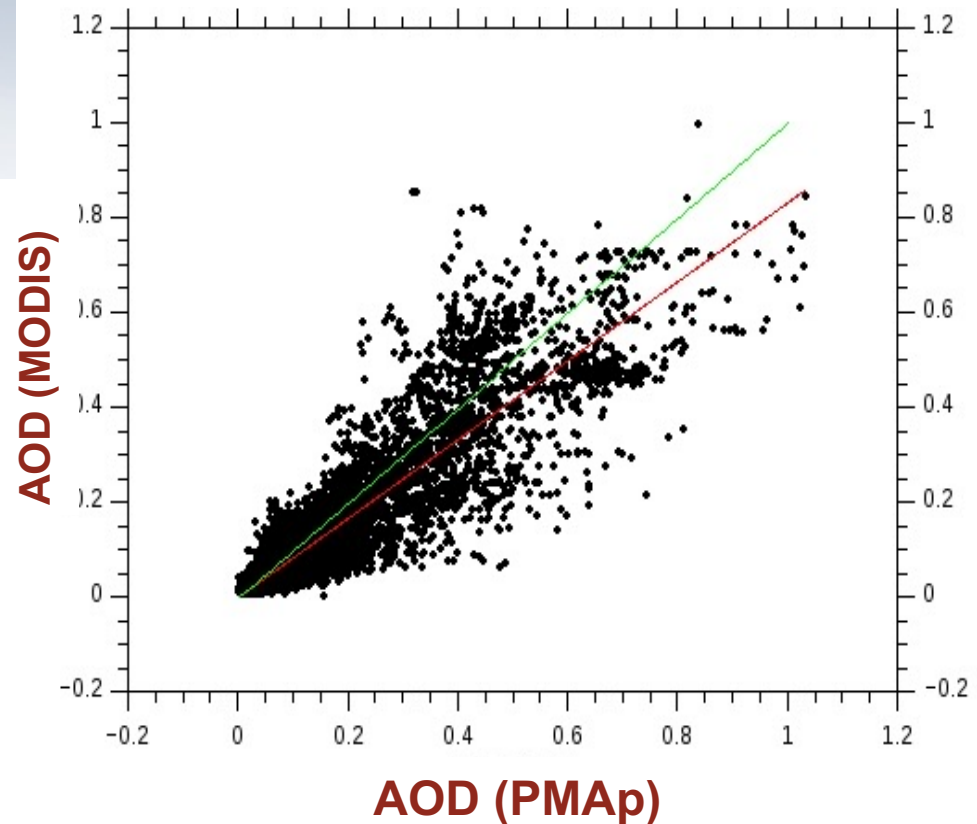


Verification of PMAp: Comparison to MODIS

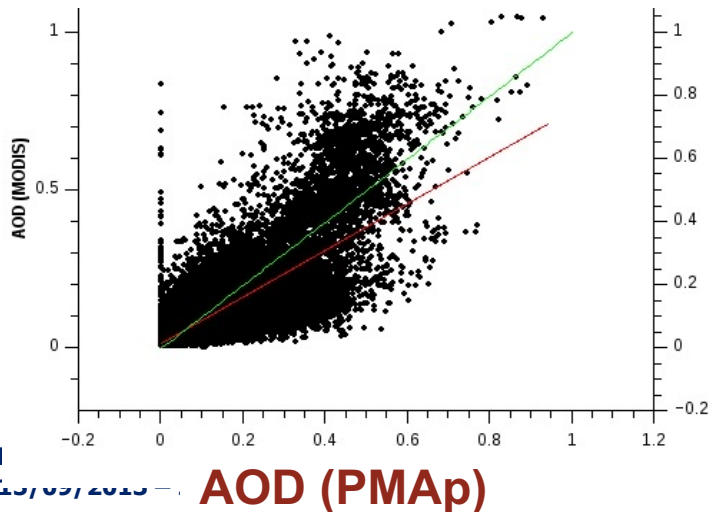
Alternate retrieval $R = 0.83$



Main retrieval $R = 0.89$



Cloudy pixels $R = 0.71$

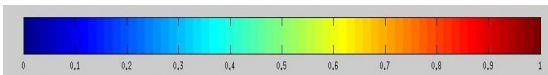
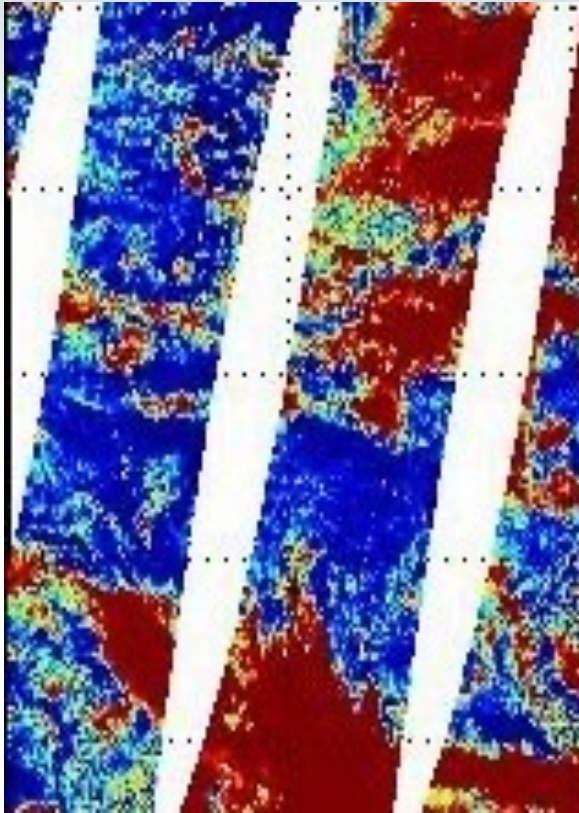


Overpass difference: 1.0h MODIS / Terra and METOP

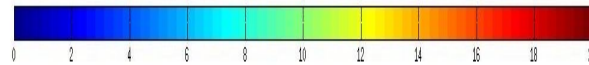
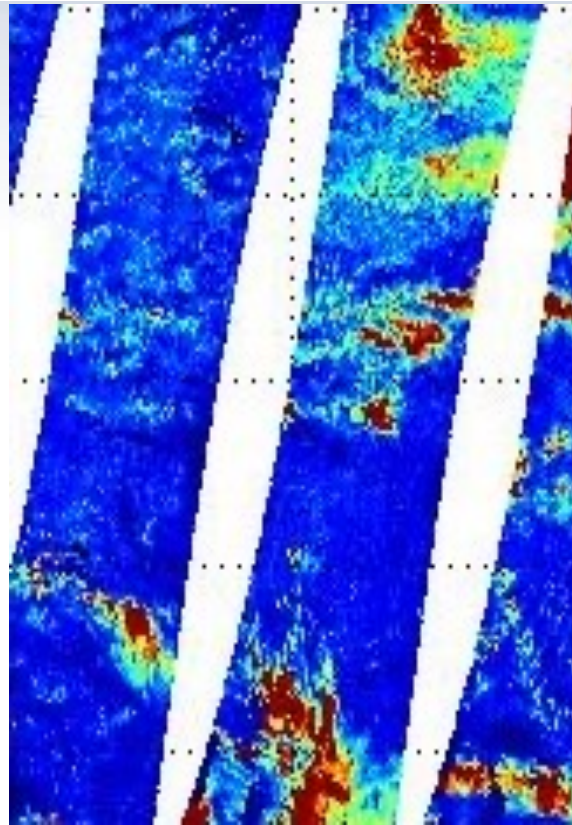


PMAp: Cloud products

PMAp: cloud fraction

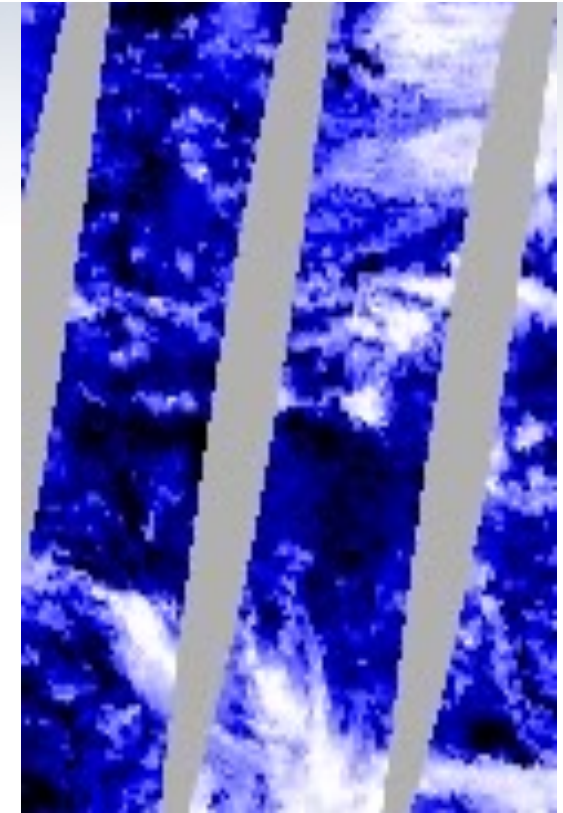


PMAp: cloud optical depth



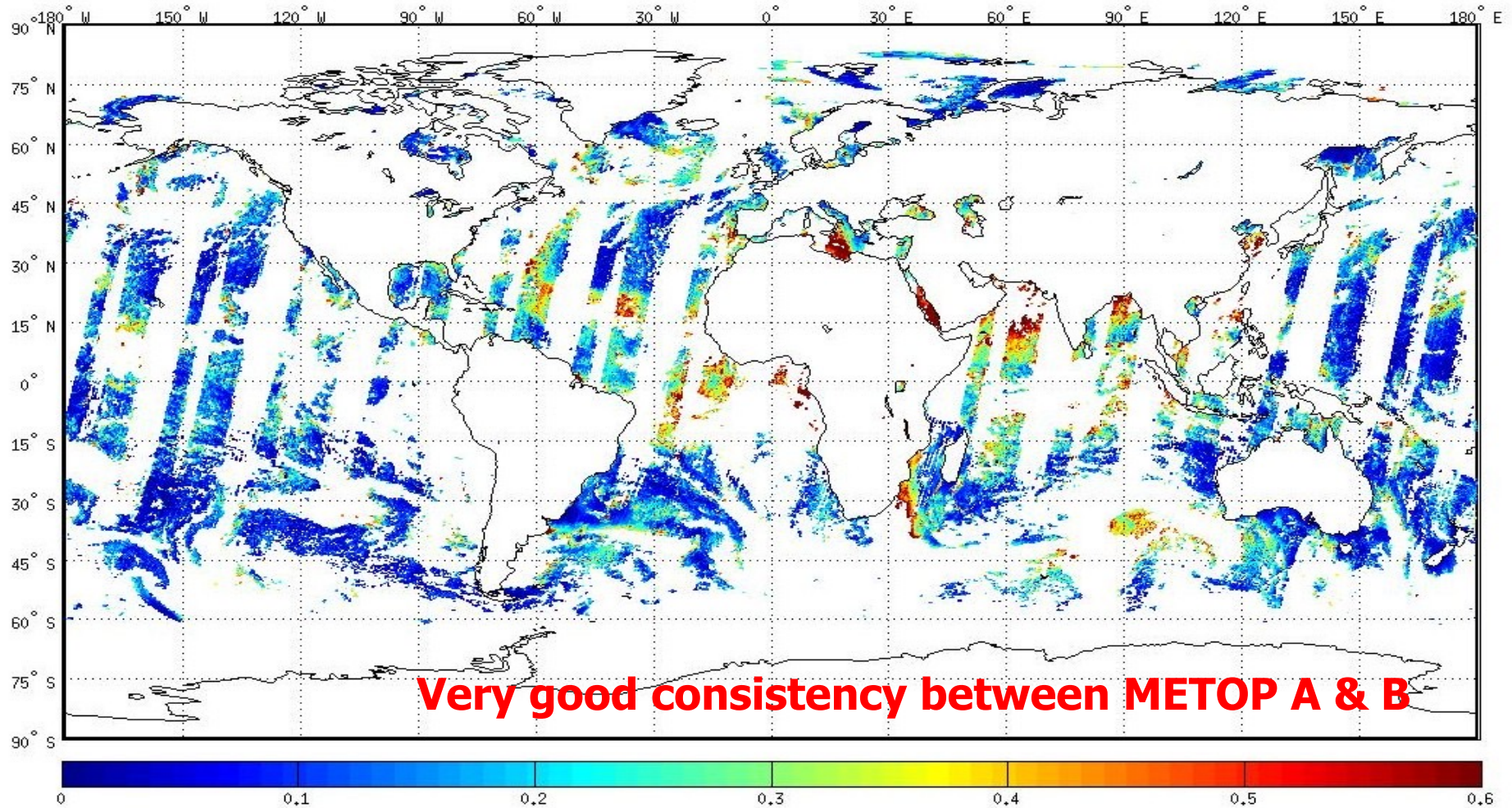
FRESCO (www.temis.nl)

Effective cloud fraction





PMAp tandem operations: AOD Metop A & Metop B



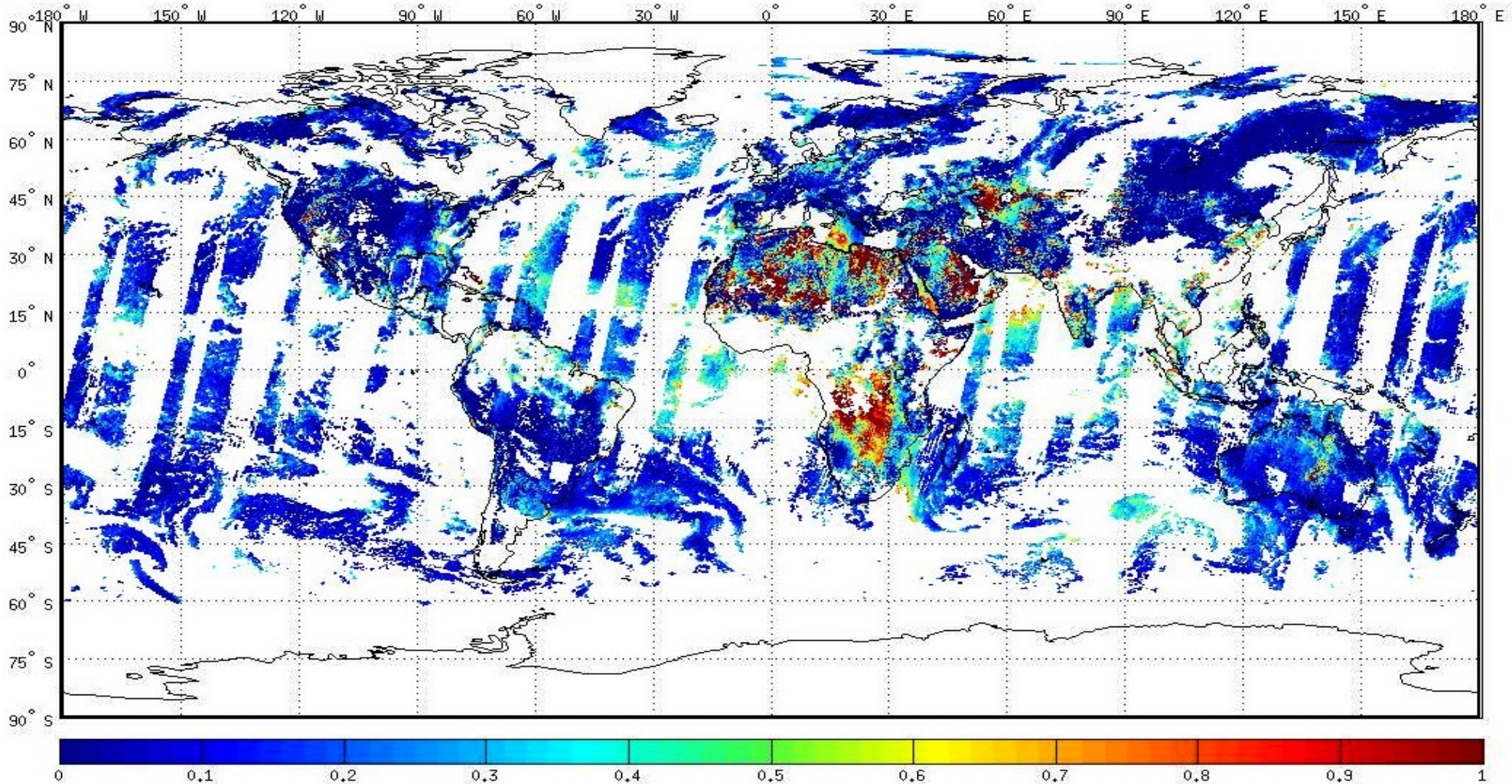


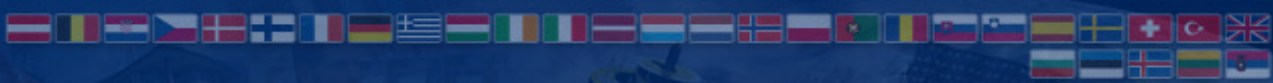
Looking forward: Algorithms in development

- 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



PMAp AOD over land: first results (30/08/2013)





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