Introducing a new CM SAF Climate Data Record of Aerosol Optical Depth & Synergy with GERB observations.

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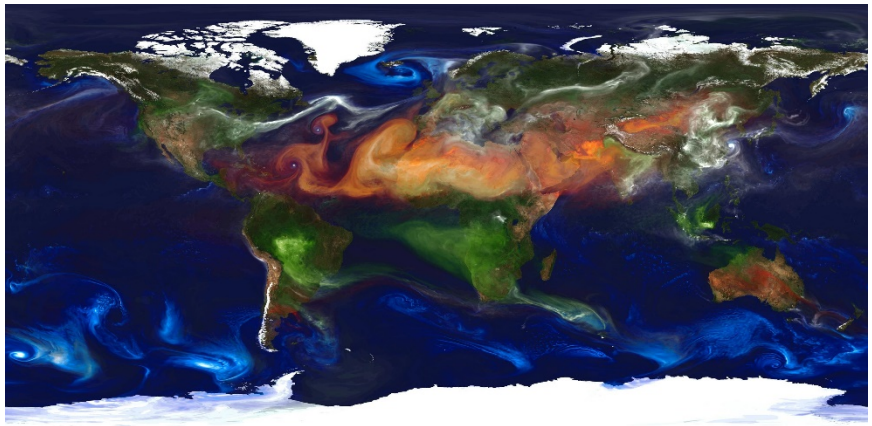
Aerosol Product for Climate Monitoring

- Aerosol properties is one of the Global Climate Observing Systems (GCOS) Essential Climate Variables (ECVs).
- Direct effect on the Earth Radiation Budget.
- Aerosol characterization is also a fundamental input for the retrieval of many ECVs like : the surface albedo, the LST, …
- Requirements from GCOS-154:
  - Quantities: Aerosol Optical Depth (AOD) at 550nm.
  - 2nd importance: the Single Scattering Albedo (SSA) or Absorption Aerosol Optical Depth (AAOD)
  - Spatial : 5 - 10km
  - Temporal : 4 hours
  - Accuracy : Max(0.03, 10%) for AOD
  - Stability : < 0.01 / decade



Optimum : $|AOD - AOD_{ref}| < 0.03 + 0.1\ AOD_{ref}$

Target : $|AOD - AOD_{ref}| < 0.05 + 0.2\ AOD_{ref}$

Threshold : $|AOD - AOD_{ref}| < 0.10 + 0.4\ AOD_{ref}$

The Land Daily Aerosol (LDA) retrieval

- Developed at EUMETSAT (MPEF/CF) by Y. Govaerts and S. Wagner but never put in "operation"
- Main input: diurnal cycle of SEVIRI visib band observations (0.6µm, 0.8µm, 1.6µm)
- Based on the Optimal Estimation
- Simultaneous retrieval of aerosol and surface properties:
  - AOD at 550nm
  - Surface RPV parameters (ρ, k, θ, h) in th 3 bands

  -> Total of 13 unknowns / pixels
- Look-Up Tables (LUTs) constructed off-line
- Can use several aerosol models and select the best-suited.
- Also estimate the uncertainty on the retrieved AOD

Aerosol models provided in LDA		Activated for CM-21101
LDA_SPH_NONABS	Spherical Non Absorbing	yes
LDA_SPH_MODABS	Spherical Moderately Absorbing	yes
LDA_SPH_ABSORB	Spherical Absorbing	yes
LDA_NSP_SMARAD	Non Spherical Small Radius	no
LDA_NSP_MEDRAD	Non Spherical Medium Radius	yes
LDA_NSP_LARRAD	Non Spherical Large Radius	no

h	RPV parameter controlling the hot spot peak (unit less)	0.15
TCWV	total column of water vapor (kg/m²)	0 to 60 by step of 10
TCO3	total column of ozone (Dobson)	200 to 400 by step of 50
SZA	Solar Zenith Angle (°)	0° to 70° by step of 2°
VZA	Viewing Zenith Angle (°)	0° to 70° by step of 2°
RAA	Relative Azimuth Angle (°)	0° to 180° by step of 10°

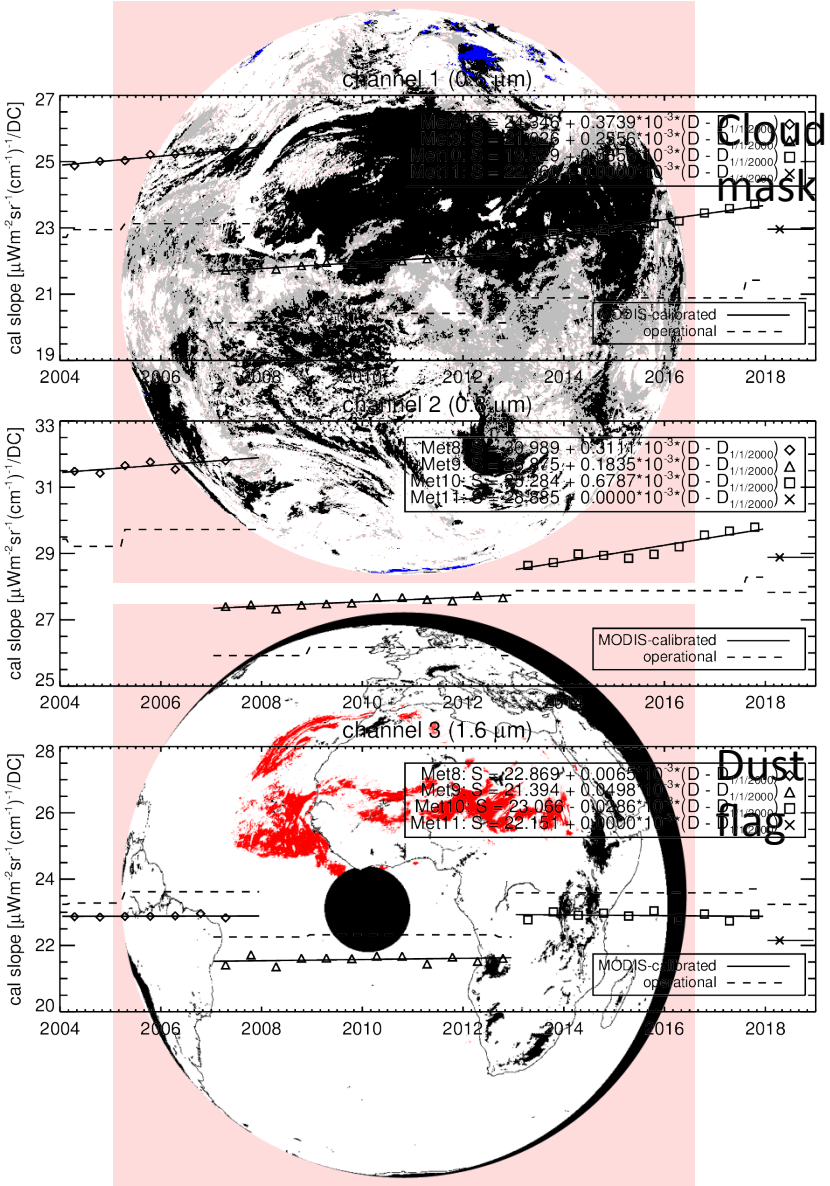
CM-21101

Figure 1: Processing flowchart

Algorithm adaptations for Climate Monitoring

- Cloud mask from CM SAF CLAAS data record (CM-21012)
  - Based on the SAF NWC GEO cloud mask (PGE01)
  - Rejection of cloudy and “snow” pixels
  - Accept the “dust” pixels

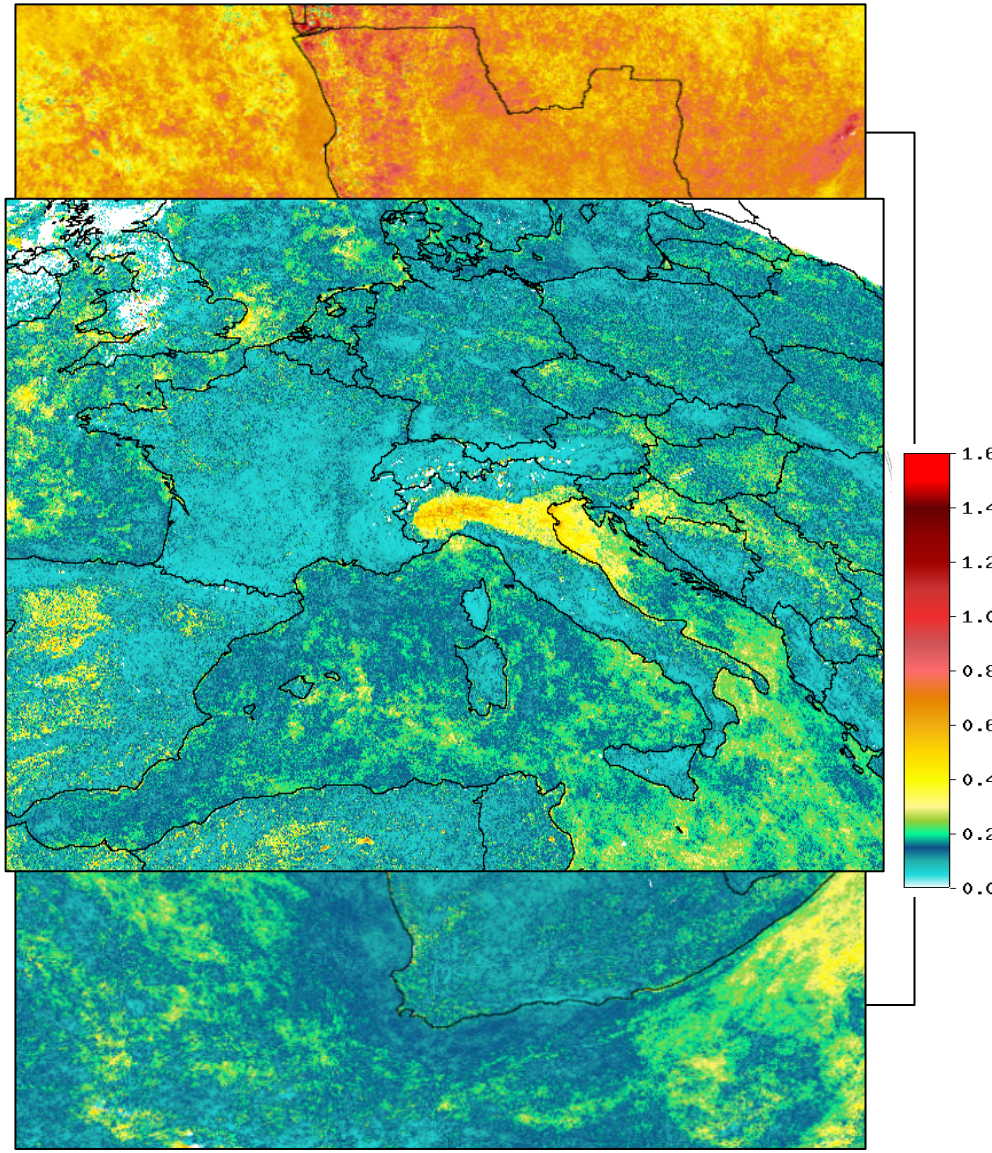
- SEVIRI solar channel calibration from Meirink et al (2013)
  - based on MODIS Aqua
  - Follows the instrument ageing
  - Avoid “jumps” in the SSCC operational calibration



Data record generation, main features and illustrations

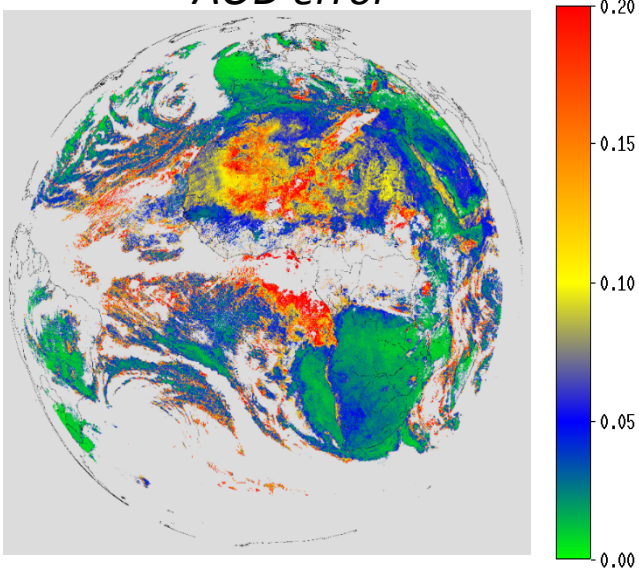
- Applied to Meteosat-8 and -9 : 1st Feb. 2004 to 31 Dec. 2012 (9 years)
- Processing on the ECMWF supercomputers
  - 2 (cca & ccb) x 30 (tasks) x 48 (threads) = 2880 threads in parallel for about 2 months
  - Costed : ~30 billions SBU (ECMWF processing billing units)

- Area : Meteosat FOV limited at VZA<=70° and SZA<=70°
- Spatial : 3km sub-satellite
- Temporal : daily and monthly mean
- AOD range : 0.05 to 1.5
- Same algorithm over land and ocean (consistency)

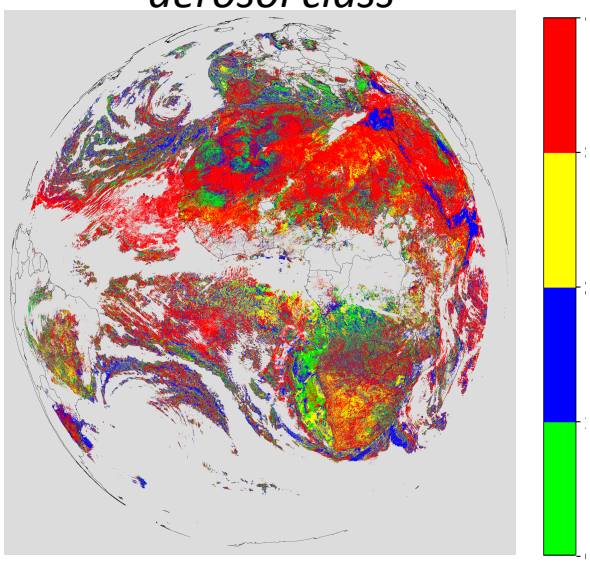


CDR – Ancillary fields (daily product)

AOD error



aerosol class



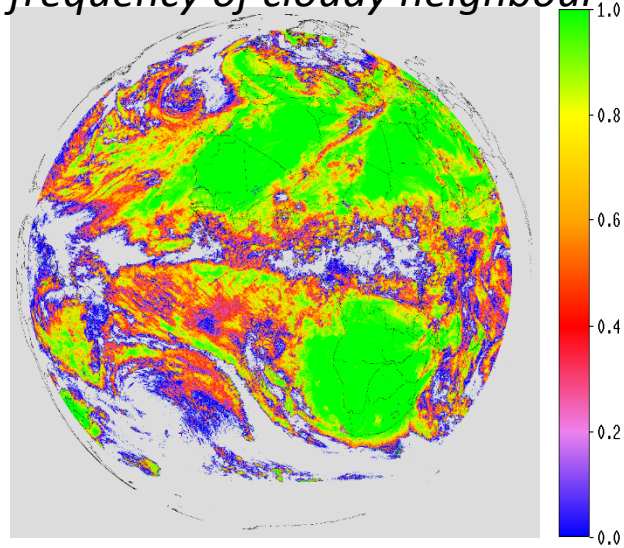
non spherical medium radius

spherical non absorbing

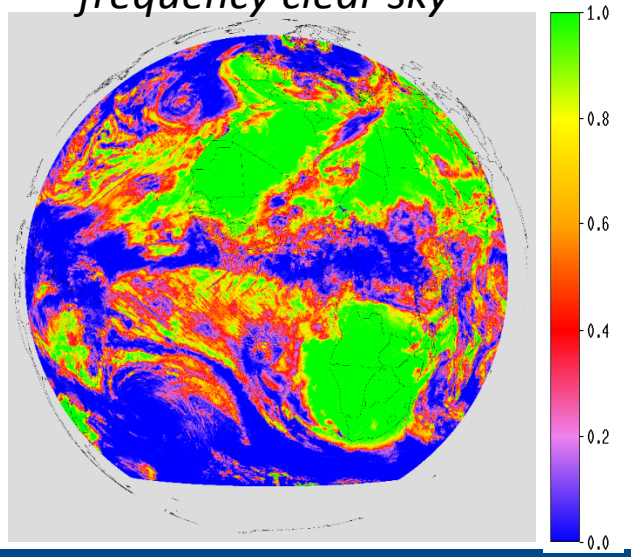
spherical moderately absorbing

spherical absorbing

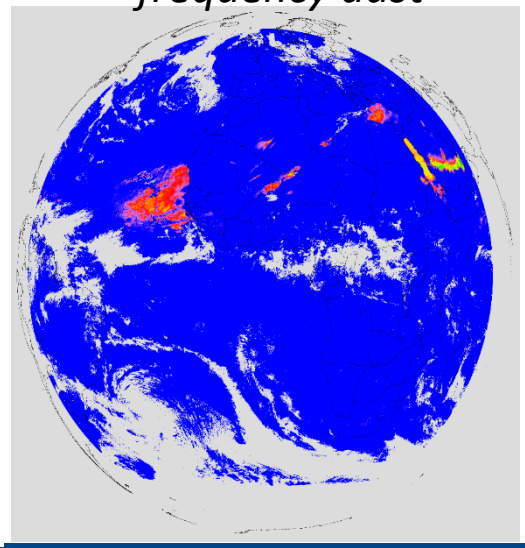
frequency of cloudy neighbour



frequency clear sky



frequency dust



$\Delta AOD < 0.1 + 0.4\ AOD$

Validations – comparison with AeRoNet - daily

- Most stations: good results in terms of bias and RMS difference.
- Many African stations: desert dust events with AOD higher than 1.5 affects the linear fit, e.g. at Dakar, Capo Verde or Agoufou.
- Overestimation for AeRoNet stations located on mountains: e.g. Izana, Tenerife island (2367m) or Davos (1596m).
- Coastal stations: in general less good results due to l1.5 rectification, e.g. at Ascension Island.

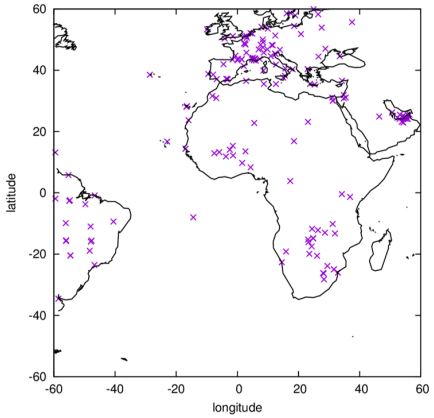
- Product within threshold requirement

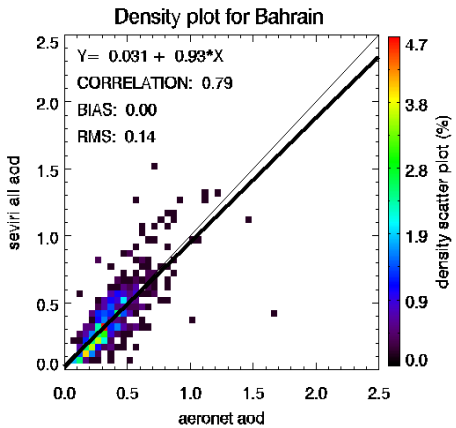
$$| AOD - AOD_{ref} | < 0.1 + 0.4\ AOD_{ref}$$

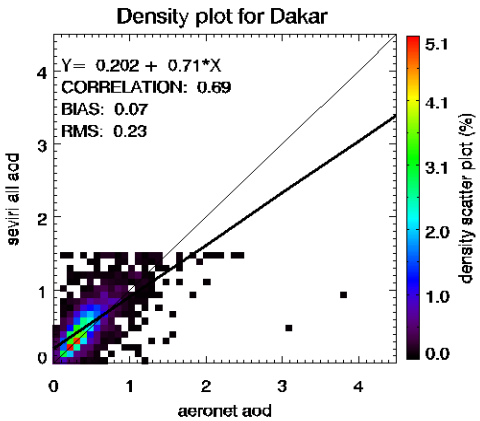
- Product close to target requirement

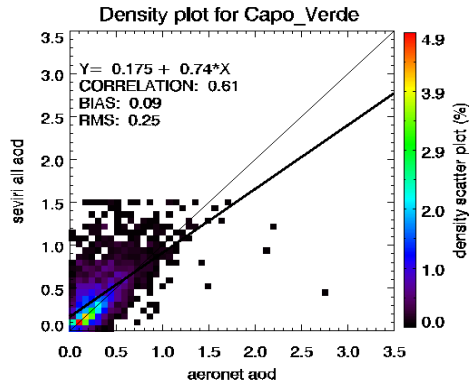
$$| AOD - AOD_{ref} | < 0.05 + 0.2\ AOD_{ref}$$

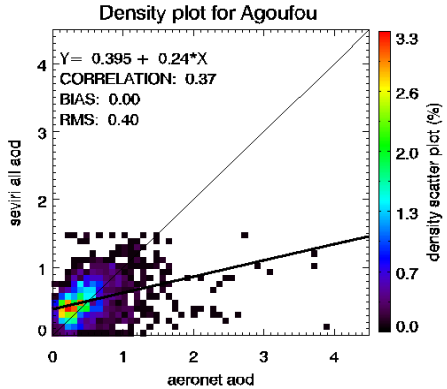
114 AeRoNet stations provide useful measurements for validation

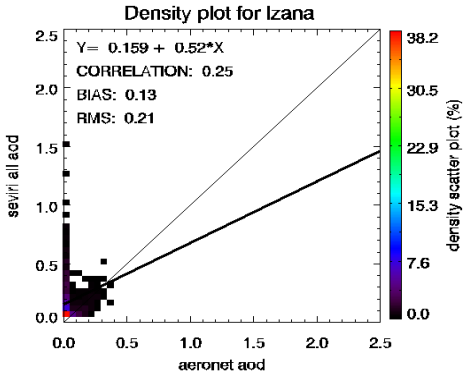


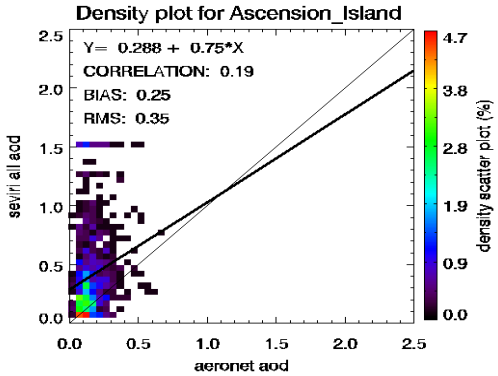








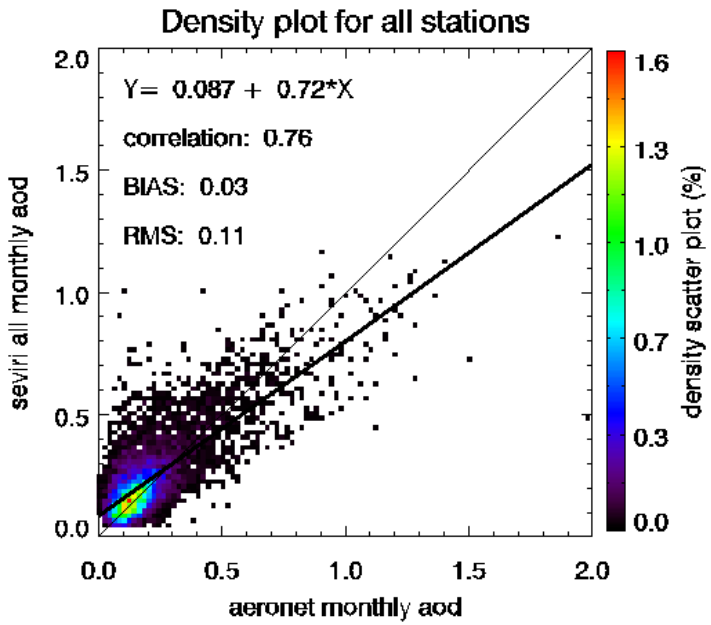


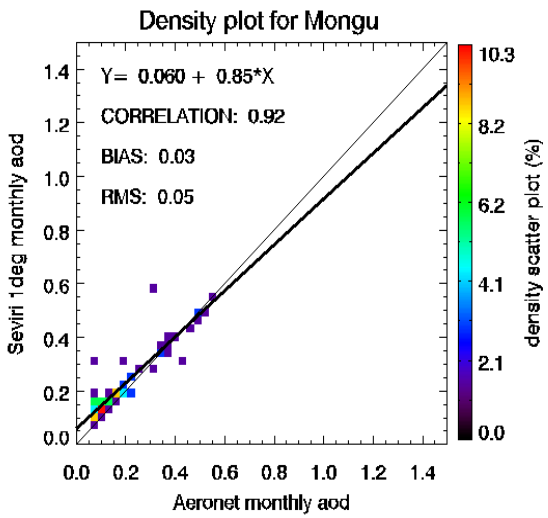


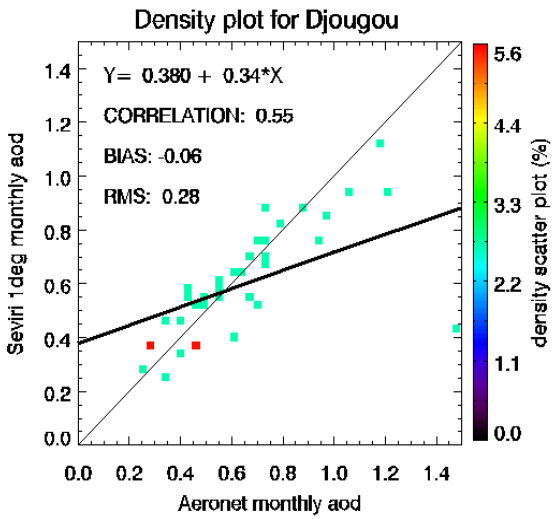
Validations – comparison with AeRoNet - monthly

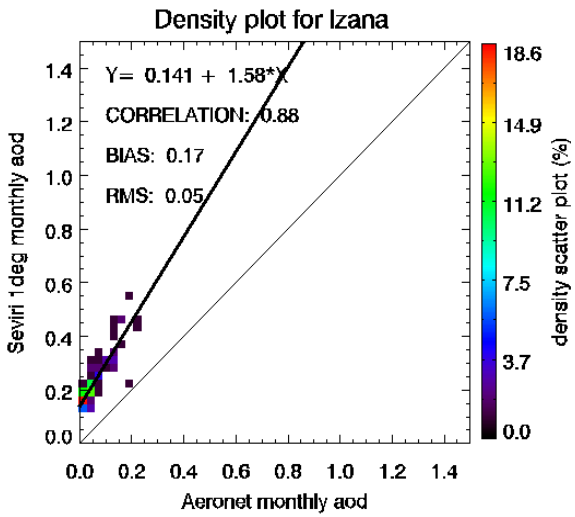
- Monthly AOD product within target requirement:

$$| AOD - AOD_{ref} | < 0.05 + 0.2\ AOD_{ref}$$



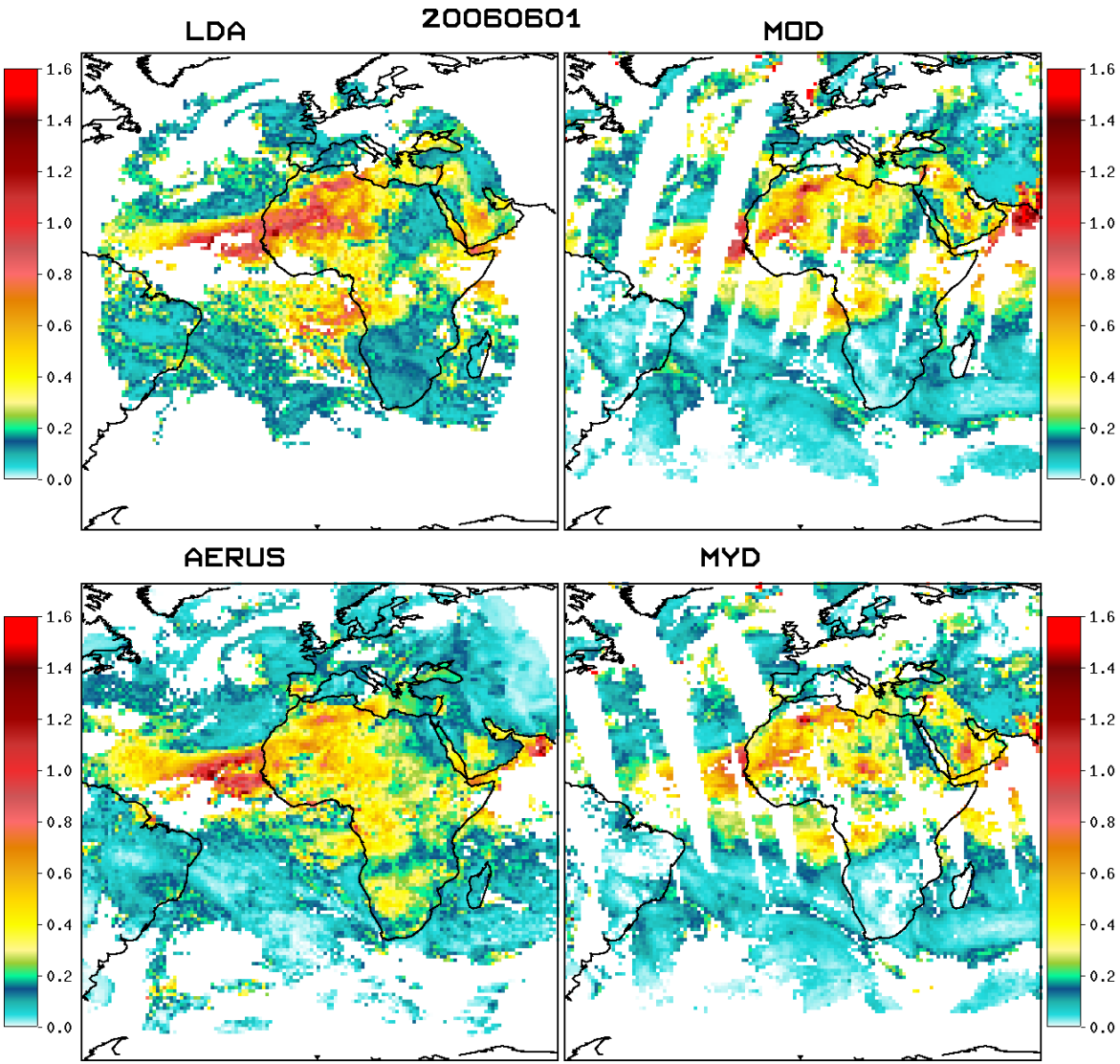




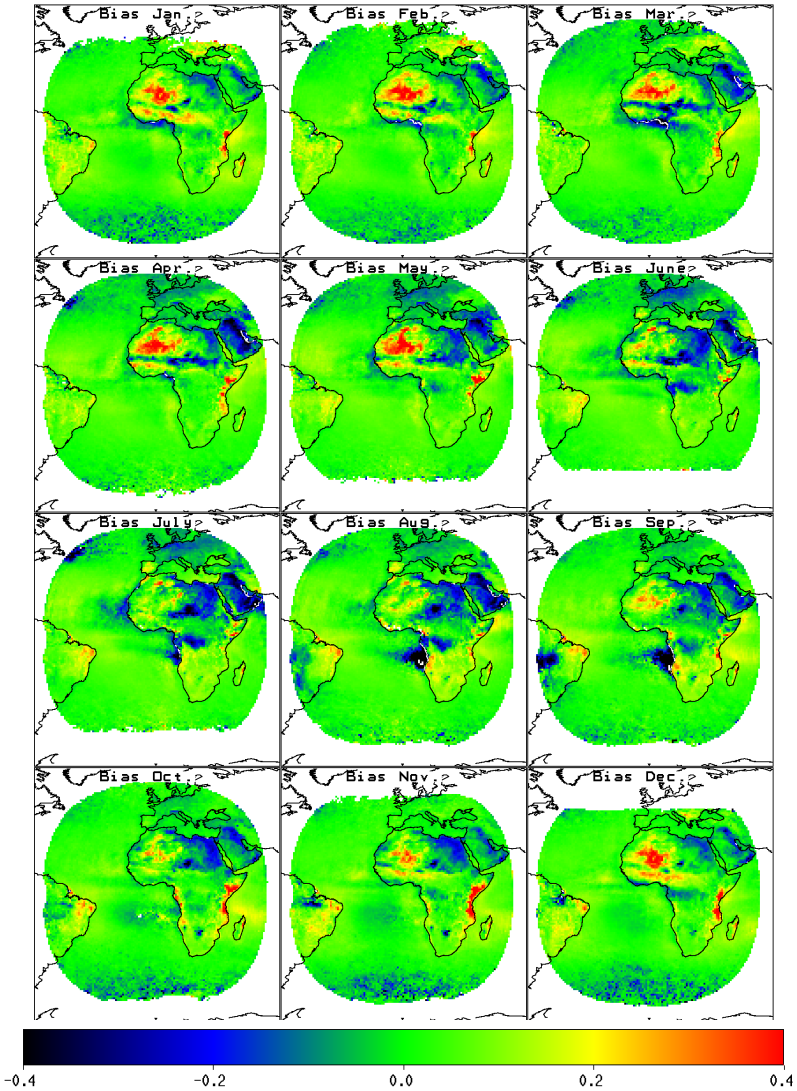


Validations – comparison with MODIS/AERUS-GEO products - daily

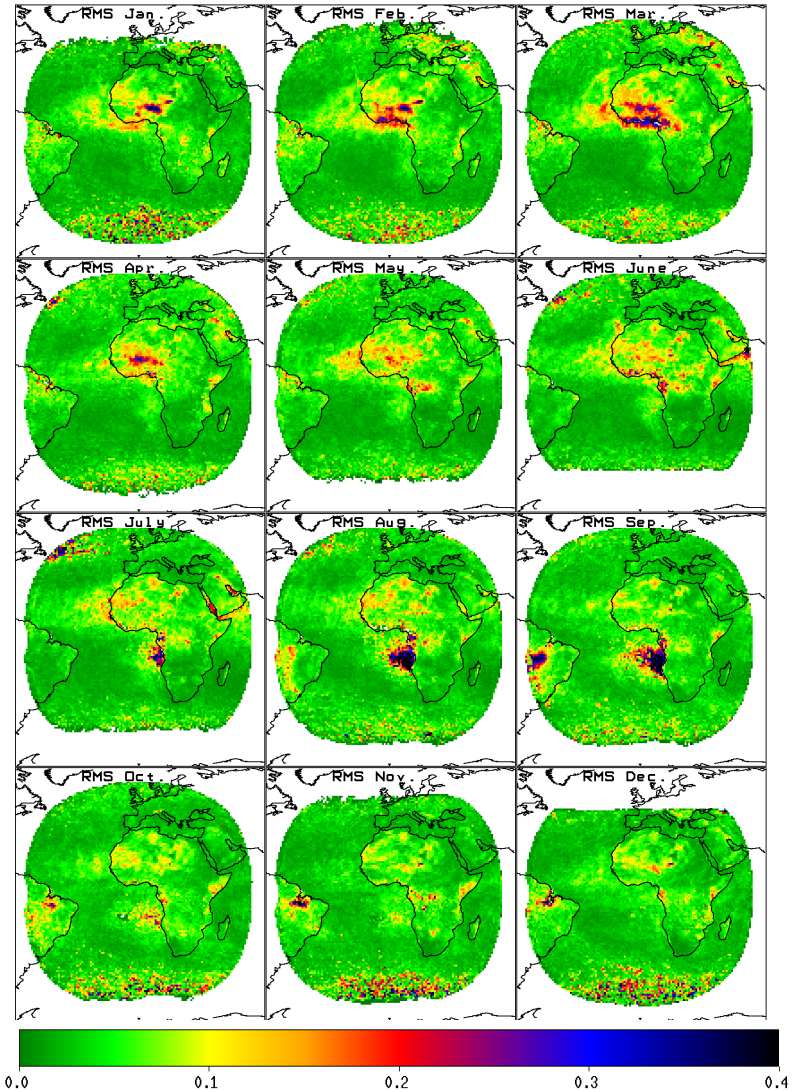
- Verify results over the ocean and over areas without AeRoNet stations
- MOD/MYD: MODIS Terra/Aqua level 3 aerosol combining the "dark target" and "deep blue" algorithms (collection 6).
- AERUS-Geo : Aerosol and surface albEdo Retrieval Using a directional Splitting method – application to Geo data (Meteo-France).



Comparison with MODIS – monthly bias/RMS



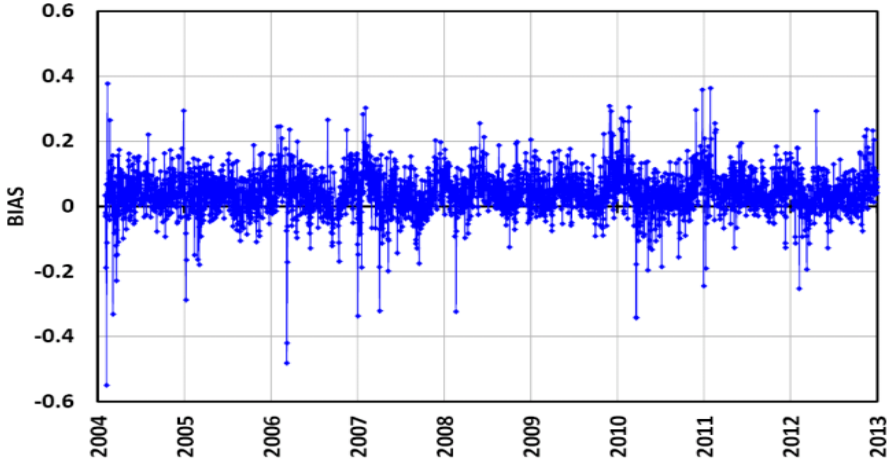
Bias between monthly mean AOD and MxD (average of MOD and MYD) for the 12 calendar months



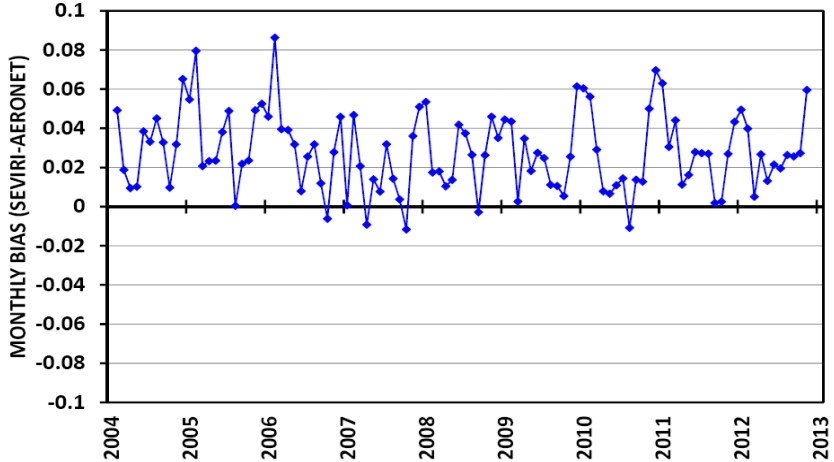
RMS difference between monthly mean AOD and MxD (average of MOD and MYD) for the 12 calendar months

Validation – CDR stability wrt AeRoNet

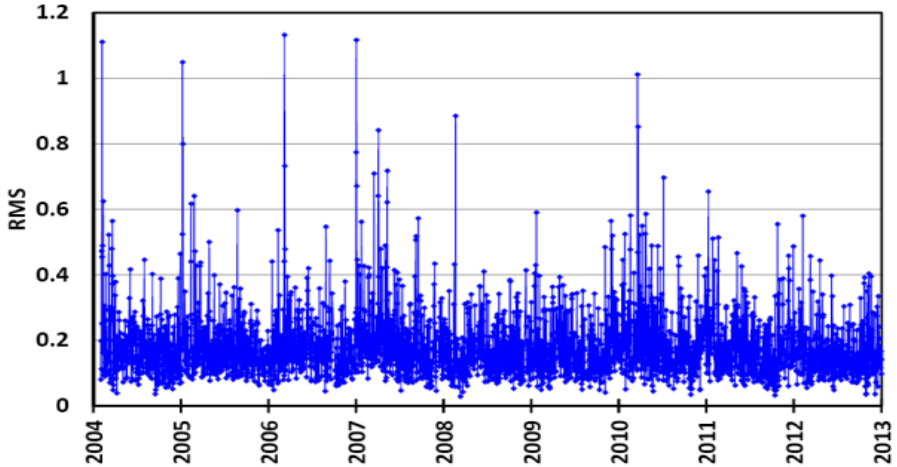
Bias in daily AOD



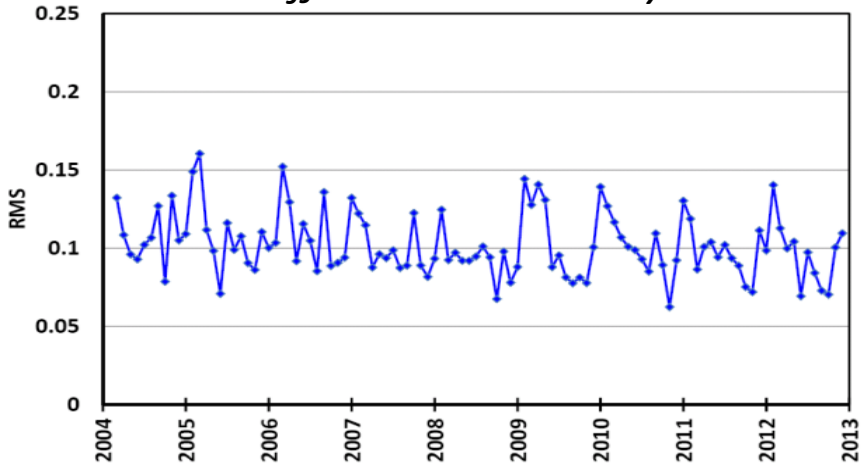
Bias in monthly AOD



RMS difference in daily AOD



RMS difference in monthly AOD



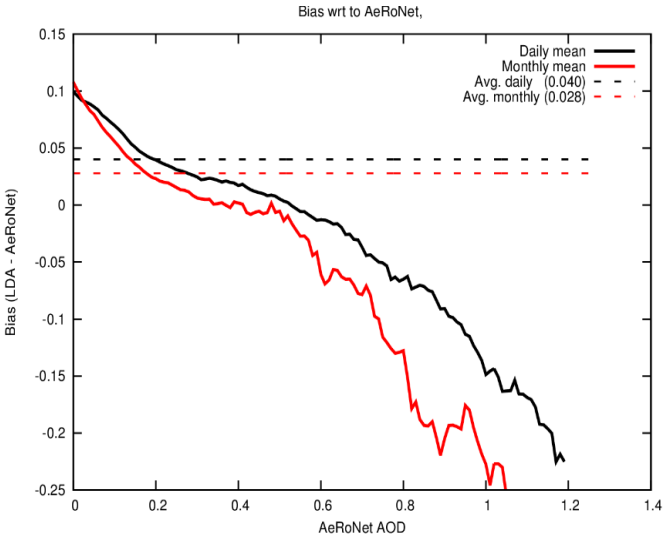
Strengths and limitations

The **strength** points of CM-21101 are:

- **Good spatial sampling** of the product (3km at sub-satellite point) that permits the study of fine scale aerosol patterns, e.g. the pollution in cities/industrial regions, effect of sea breeze and local winds, …
- More **frequent daily retrievals** than with polar satellite observations, especially in the Equatorial region. For instance, in the region 30°S - 30°N, the frequency of retrievals (in boxes of 1°x1°) is about 77 while limited to about 60% in the MODIS level 3 data record.
- **Synergy with other CM SAF CLAAS and GERB products** (surface and TOA radiation, cloud properties, …)
- The **consistency between the land and ocean retrievals** is obtained by using the same algorithm and the same LUTs over both surface types.
- **Cloud mask** : the product is based on an accurate, stable in time, and well documented cloud screening. This cloud screening accounts for the presence of dust.

Clear **limitations** also exist:

- A **positive bias for low AOD** is observed with respect to AeRoNet, MODIS and AERUS-Geo, likely due to the minimum AOD value of 0.05 (lower values are observed at AeRoNet stations in about 8% of the time).
- A **negative bias is observed at high AOD** due to the maximum AOD of 1.5. LDA.
- Possible **problems in separating the surface and aerosol signal** in some limited regions: Niger/Mali and South of Algeria, Eastern Africa.
- The **retrieval is limited to VZA<70° and SZA<70°**



Variation of the bias as a function of the AeRoNet AOD for the daily and monthly products.

Combining with GERB data

CM-21301 (aka "CM SAF GERB ed02"):

- Combine GERB/SEVIRI
- Feb. 2004 – Apr. 2015
- Daily mean, Monthly mean and monthly mean diurnal cycle
- GERB L2 High-Resolution (HR) grid + regrid to reg. lat-lon @ 0.1°x0.1°
- "Allsky" and "clearsky" fluxes
- Available from CM SAF (http://www.cmsaf.eu)

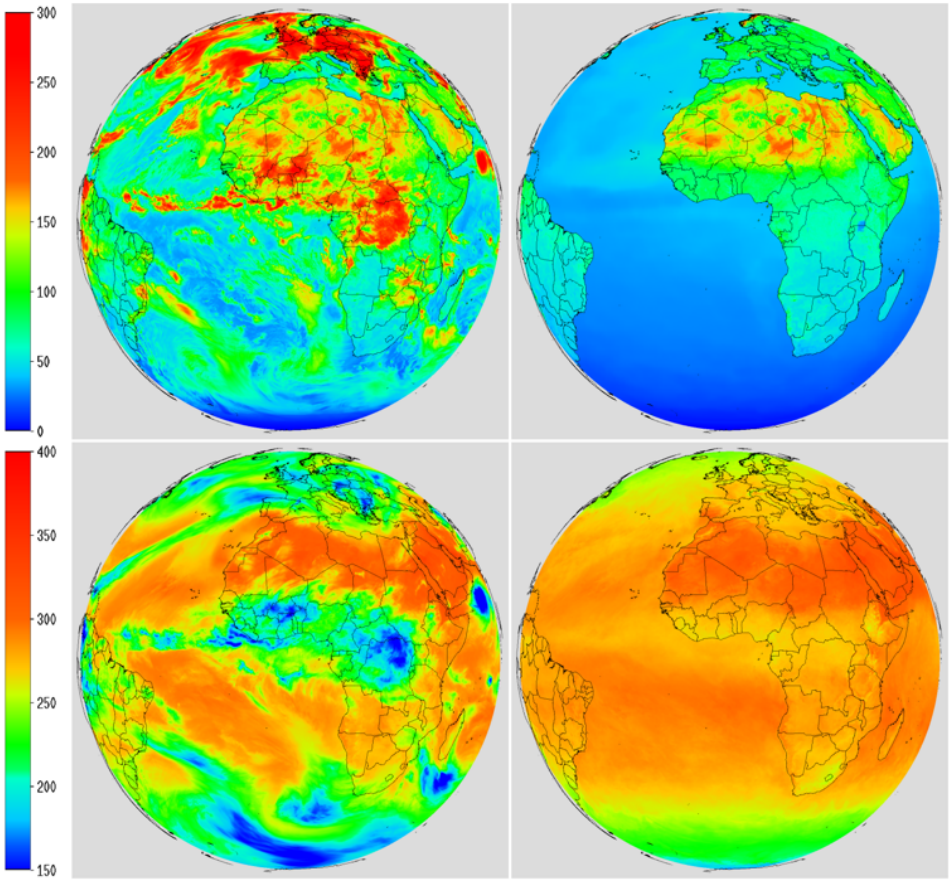
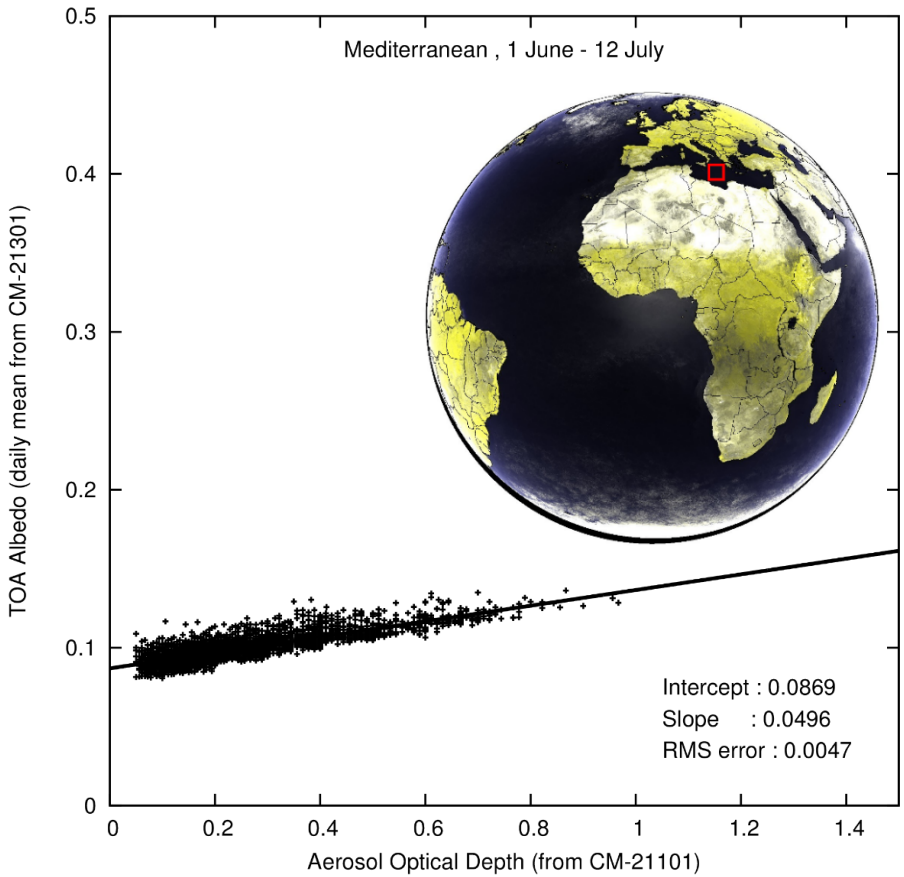


Figure 6 : Daily mean products for 1st June 2010. The upper panels are TRS, lower are TET. Left are allsky fluxes and right is clear sky fluxes. All fluxes are in W/m². The overlaid country borders are obviously not present in the data file.

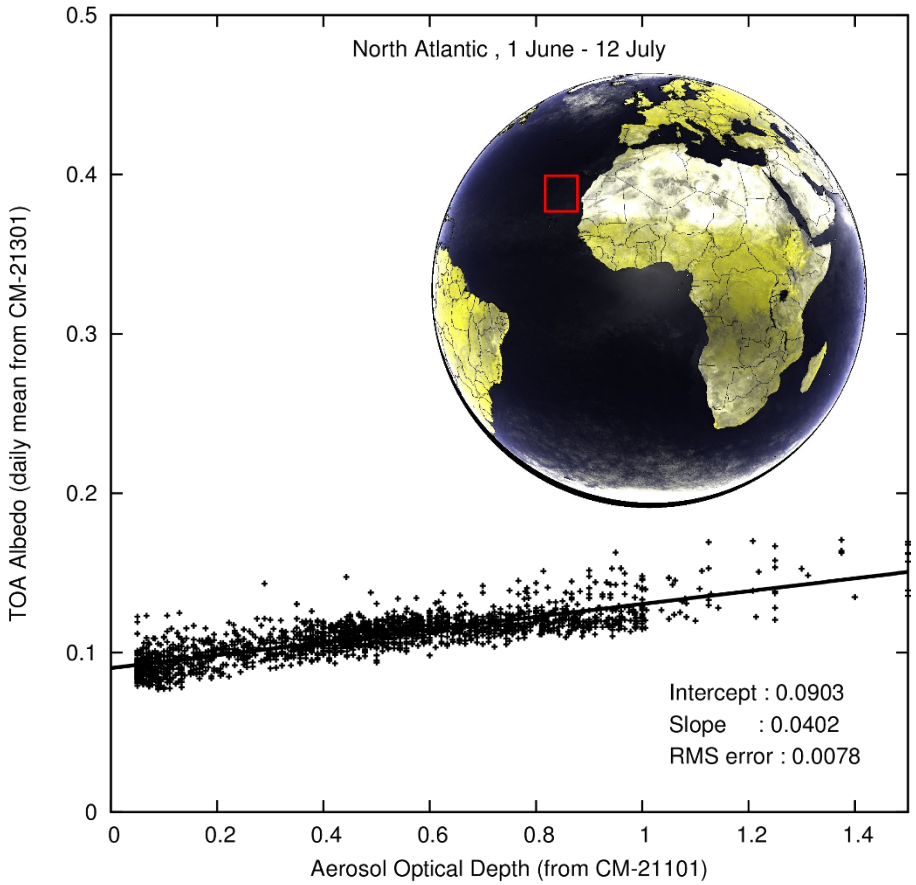
Combining CM-21101 with CM-21301

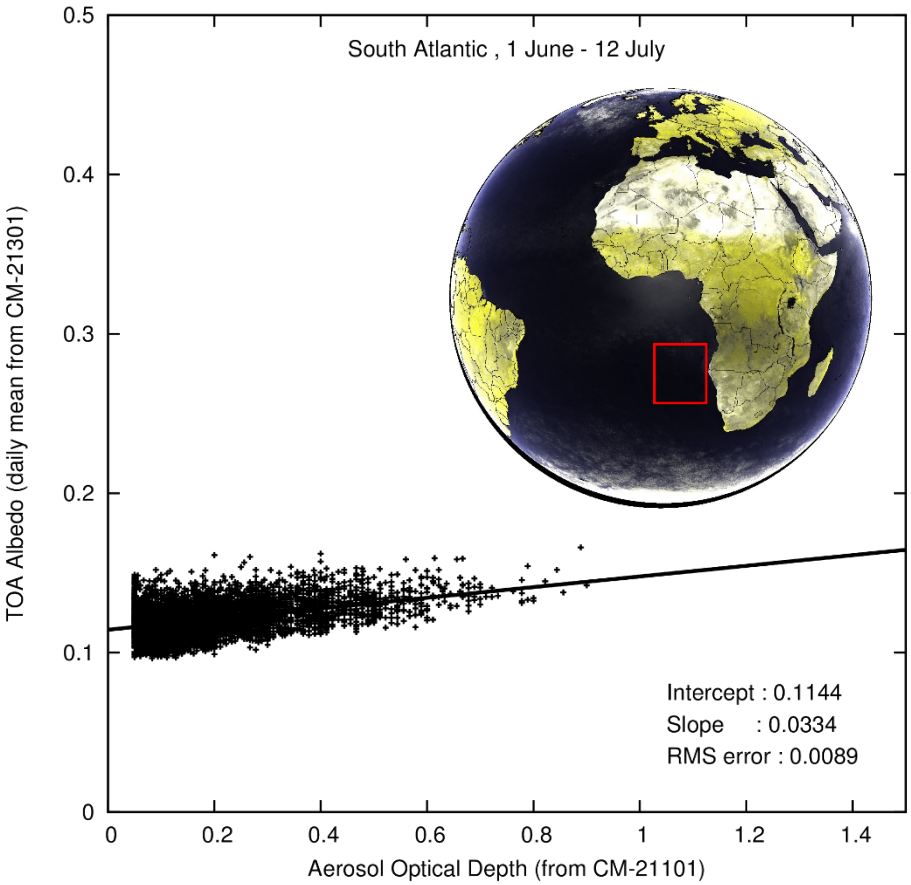
- Period : 1st June – 12 July for years 2004 - 2012
- Mostly GERB (few “GERB-like”)
- Frequency of clear sky should be > 99% (but estimated for SZA < 70°)
- AOD averaged in GERB HR pixels



Area over Mediterranean sea (off Libya)

Combining CM-21101 with CM-21301

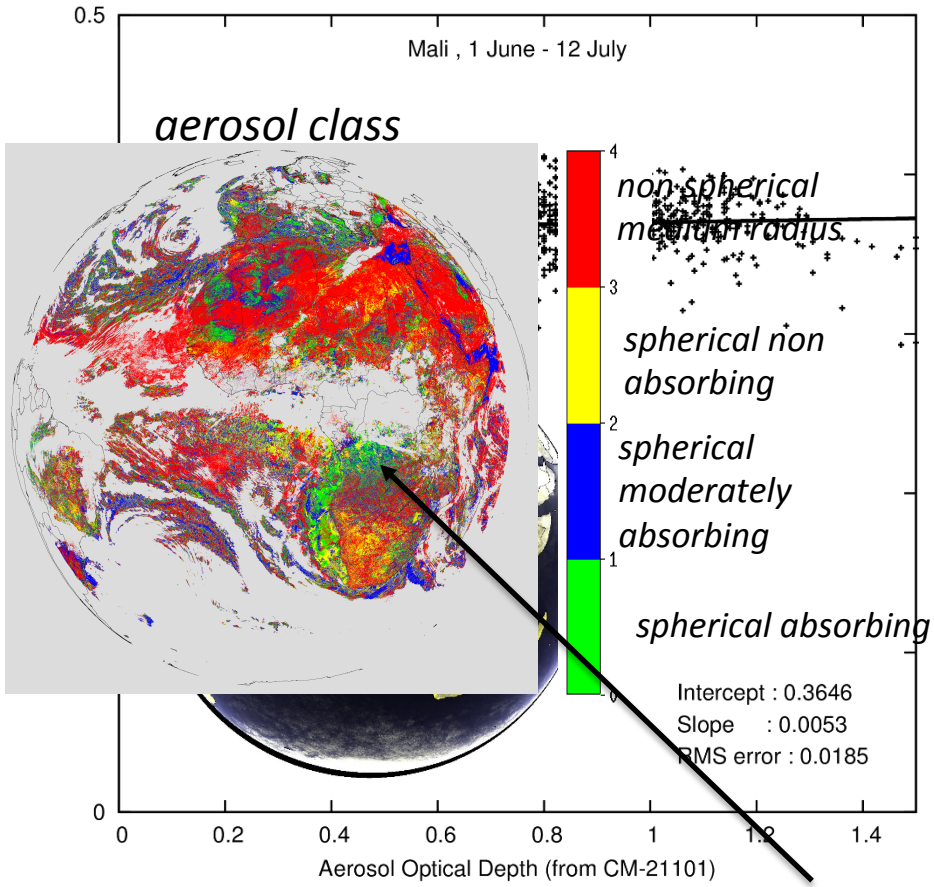


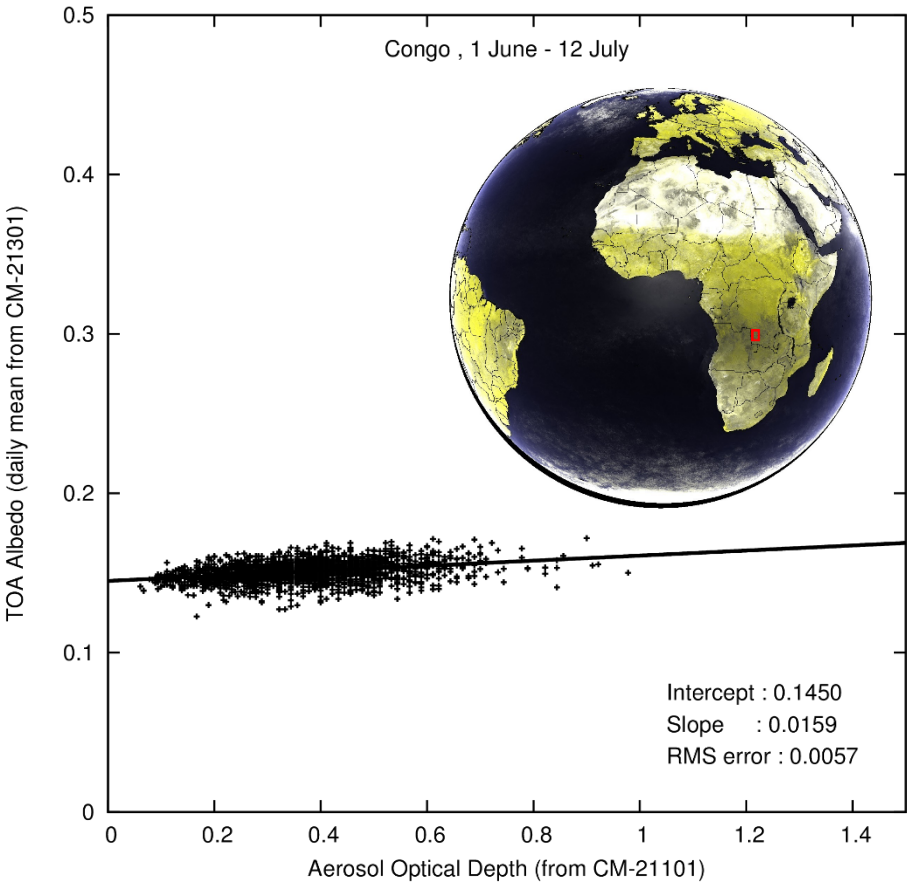


Eastern North Atlantic
off Mauritania coast

Eastern South Atlantic
off Angola/ Namibia coast

Combining CM-21101 with CM-21301





Desert surface in Mali

South of RDC
(absorbing aerosols?)

Summary

- Climate Data Record of MSG/SEVIRI Aerosol Optical Depth based on the Land Daily Aerosol (LDA) algorithm
- Full SEVIRI spatial resolution, daily and monthly
- Data (NetCDF files) and documentation (ATBD, Val Rep, PUM) available via CM SAF (http://www.cmsaf.eu).
- Overall accuracies similar to MODIS and AERUS-Geo products.
- Synergy with the GERB HR fluxes