Aerosol Optical Depth Retrieval from Geostationary Satellites

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3rd CM SAF User Workshop, Rostock, 2010/09/07

Outline

Motivation

Tropospheric aerosol particles originate from:

- Urban/industrial activities.
- Biomass burning associated with land use processes.
- Wind-blown dust.
- Natural sources.

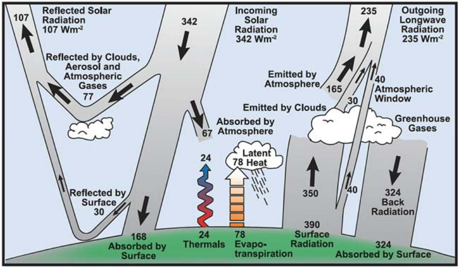
Global observations from space required due to:

- Short lifetime (a few days).
- High spatial variability in aerosol optical and radiative properties.

Motivation (bis)

Major uncertainty in predicting climate change due to:

- Direct radiative forcing → radiation is scattered or absorbed by the aerosols.
- Indirect radiative forcing → influence on cloud microphysics.
- Modify concentration of climate-influencing constituents such as greenhouse gases trough heterogeneous chemistry.



Input

- SEVIRI level 1.5 images at wavelengths 600, 800 and 1600 nm.
- CM SAF cloud mask, based on NWC SAF software.

← planned replacement for current inadequate cloudmask.

- Cloud shadows also need to be implemented.

Reflectance (Rescaled BRDF)

- Single scatter approximation → separation

$$\mathcal{R}(\lambda, \mu_i, \mu_o) = \mathcal{R}_{surface} + \mathcal{R}_{rayleigh} + \mathcal{R}_{aerosol}$$

- The aerosol reflectance is given by,

$$\mathcal{R}_{aerosol} = \frac{\tau \tilde{\omega} P(\theta)}{4 \cos(\omega_i) \cos(\omega_o)}$$

where,

  - τ = aerosol optical depth (AOD).
  - $\tilde{\omega}$ = aerosol single scatter albedo.
  - $P(\theta)$ = aerosol phase function.

- $\mathcal{R}_{rayleigh}$ is calculated using RTE.

Ocean Reflectance

- $\mathcal{R}_{surface} \leftarrow$ a fixed value chosen according to statistics on marine reflectance synthesis.

$\longrightarrow$ works far away from sun glint region, where:

  - $\mathcal{R}_{surface}$ peaks.
  - Depends on wind speed.

- Upgrade to LUT from Cox-Munk surface model planned.

Land Minimum Reflectance

$\mathcal{R}_{surface}$ calculated assuming

- $\mathcal{R}_{surface}$ constant over sufficiently long period (15d).
- τ (AOD) reaches its background value in this period.
- $\mathcal{R}(\lambda = 600nm)$ increases with increasing AOD.

$\longrightarrow$ only true when $\mathcal{R}_{surface}$ is small (dark surface).

Background aerosol day = day in the period under consideration when

$$\mathcal{R}(\lambda = 600nm) - \mathcal{R}_{rayleigh}(\lambda = 600nm)$$

reaches its minimum.

Land Minimum Reflectance (bis)

The surface reflectance (for all λ) is then given by:

$$\mathcal{R}_{surface} = \tilde{\mathcal{R}} - \tilde{\mathcal{R}}_{rayleigh} - \tilde{\mathcal{R}}_{aerosol}$$

where,

- the RHS is taken on the background day.

$\rightarrow$ $\tilde{\mathcal{R}}_{aerosol}$ = aerosol background reflectance
fixed background value for AOD = 0.03

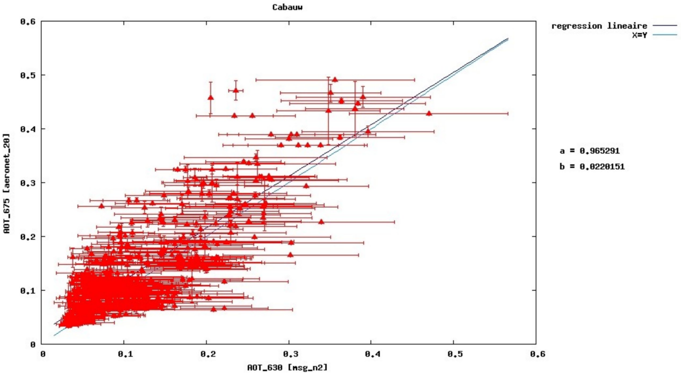
AOD Retrieval

- $\mathcal{R}_{surface}$ is now known.
- Retrieval performed for 6 different aerosol classes:
  - Derived from an analysis of AERONET retrieval.
  - Maritime model WMO, moderately absorbing, continental WMO, urban-industrial, smoke and spherical dust.
  - All are spherical and some are too similar.

  $\longrightarrow$ Introduction of different (non-spherical) aerosol models.
- AOD is calculated form a best fit using the 3 solar channels with simulated reflectances using LUT.

Validation

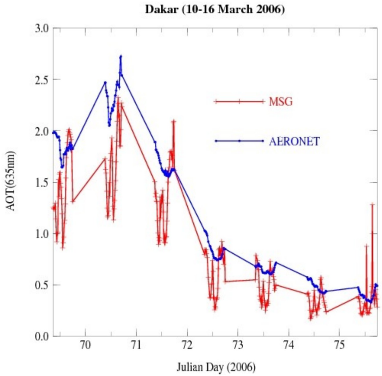
- Based on comparison with AERONET observations.
- July 2006: $>$ 200 co-registrations with Cabauw.



- slope $= 0.96$ intercept $= 0.02$.

Observation Temporal Changes in Aerosol Load

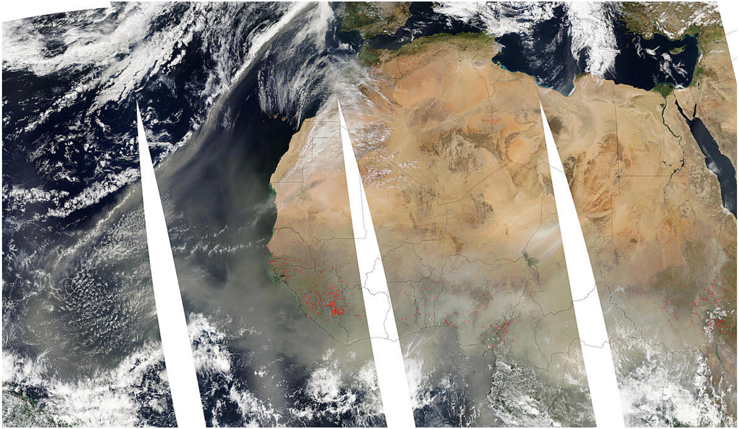
- Dust event Dakar with AOD varying from > 2.0 till 0.3 in 7 days.



- Same trends AERONET and SEVIRI.
- SEVIRI tends to underestimate the aerosol load.

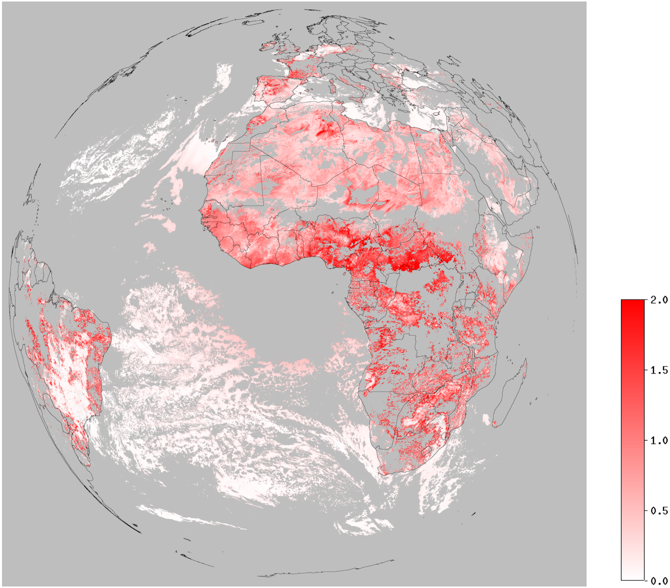
$\rightarrow$ Background day: assumed AOD $= 0.03 +$ high AOD during the reference period $\Rightarrow$ systematic bias.

Dust storm across Central and West Africa

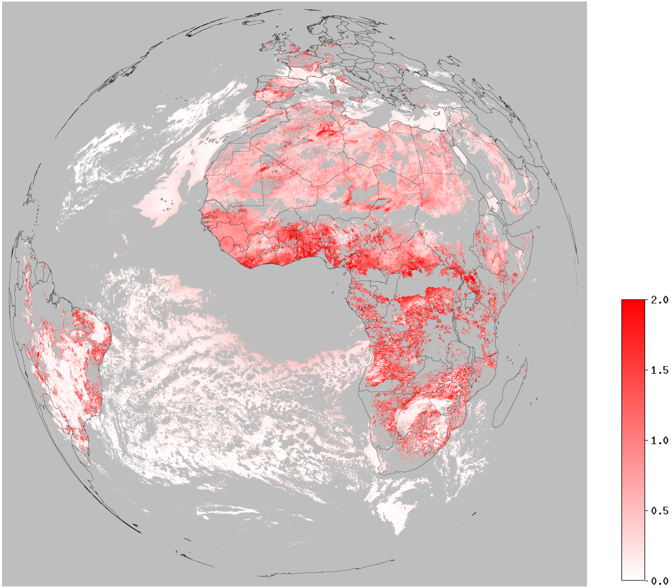


08/03/2004 Aqua Satellite

Example (08/03/2004)

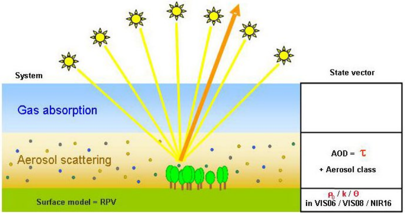


Example (09/03/2004)



Algorithm Presentation

- Optimal estimation → simultaneous derivation of
  - Surface reflectance.
  - Aerosol optical depth.
- Observation vector:
  - Daily accumulated SEVIRI observations.
  - 0.6, 0.8 and 1.6 band.
- State vector:
  - Parameters RPV model describing surface BRDF.
  - Aerosol optical depth (AOD) of the processed aerosol class.



Algorithm Presentation (bis)

- Retrieval performed for 6 different aerosol classes.
  - Derived from an analysis of AERONET retrieval.
  - 3 spherical and 3 non-spherical classes.
- Prior information on the surface reflectance

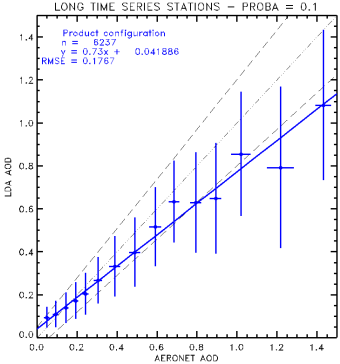
$\longrightarrow$ derived from temporal stability of surface radiative properties.

- The LDA algorithm provides also an error estimate of the retrieved AOD.

Validation

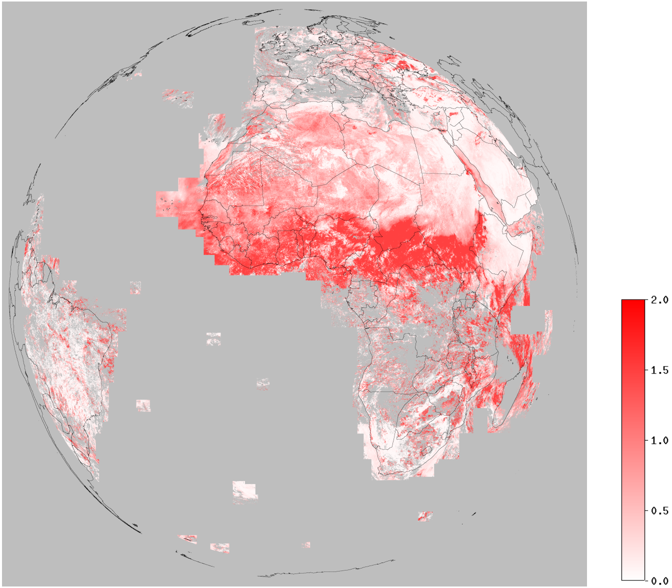
- Validation based on comparison with AERONET observations.
- 2005 has been processed for the about 70 AERONET stations in the SEVIRI disk.
- Next slide: scatterplot of this comparison
  $\longrightarrow$ based on more than 6000 observations.

Validation (bis)

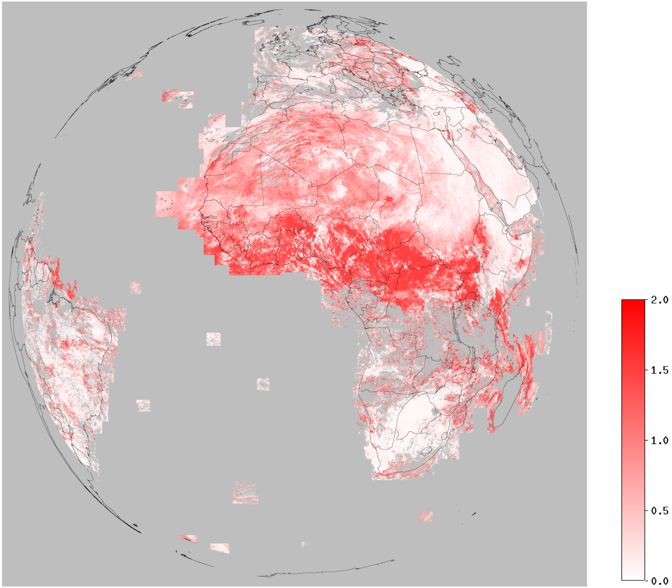


- AOD $<$ 0.1: slight overestimation $\leftrightarrow$ AERONET.
- AOD $>$ 0.1: slight underestimation $\leftrightarrow$ AERONET.
- AOD $>$ 1.0: large discrepancy $\leftrightarrow$ AERONET.
  - Might be due to the assumption that AOD is constant during the day.
  - Often violated in case of high aerosol load.

Example (08/03/2004)



Example (09/03/2004)



Conclusions and Outlook

- LMR: switch to CM SAF cloud mask, based on NWC SAF software is foreseen.
- LMR: Constant background AOD of 0.03 unrealistic in high AOD periods.

$\longrightarrow$ Use LDA to improve estimation of background AOD.

- LMR: works only when $\mathcal{R}_{surface}$ is small (dark surface).

$\longrightarrow$ Use LDA for bright surfaces (desert).

- LMR-LDA: use consistent aerosol models.
- We will build an AOD product using both algorithms.
  - Research on how to merge the two is needed.
- Strategy on quality assurance and validation.
  - Regular comparison with MODIS.
  - Regular comparison with AERONET.

Example LMR-LDA (08/03/2004)