Detection of aerosols and other climatological effects by remote sensing using GERB/SEVIRI

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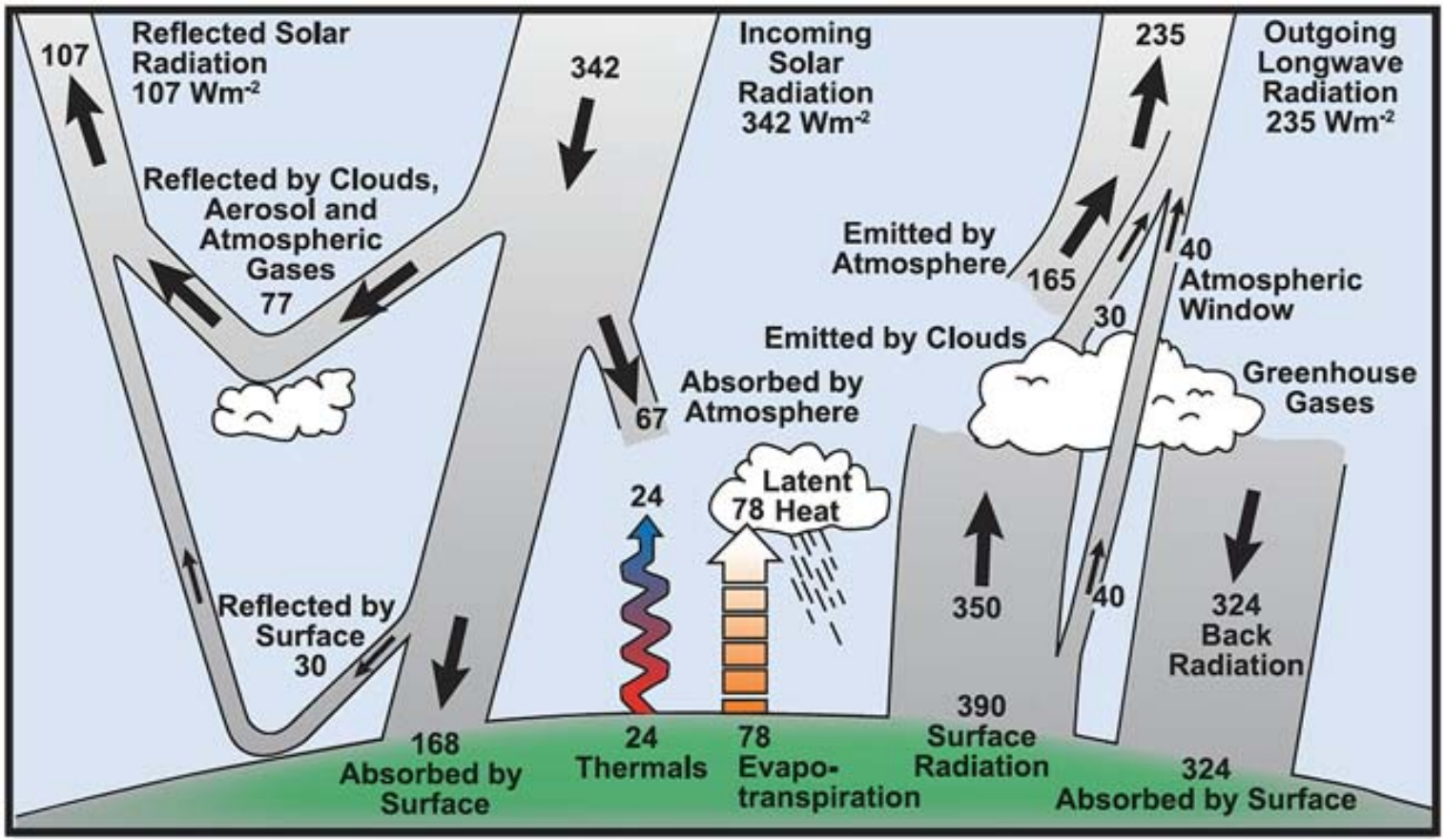
Outline

Earth Radiation Budget

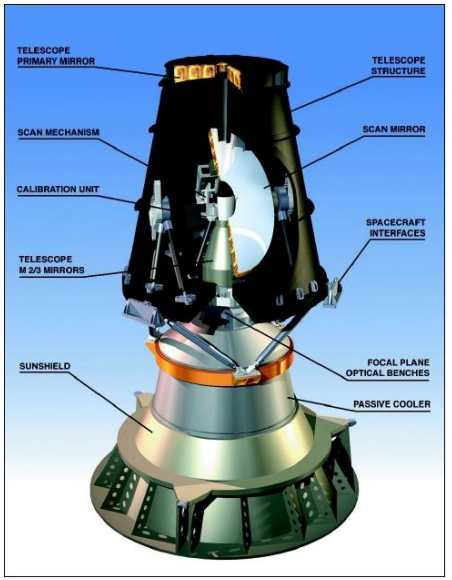


- Main interest GERB team at RMIB.

SERVIRI

- Spinning Enhanced Visible and Infrared Imager.
- Main instrument aboard MSG satellite (2004-...).
- Spectral properties:
  - 12 narrow-band channels

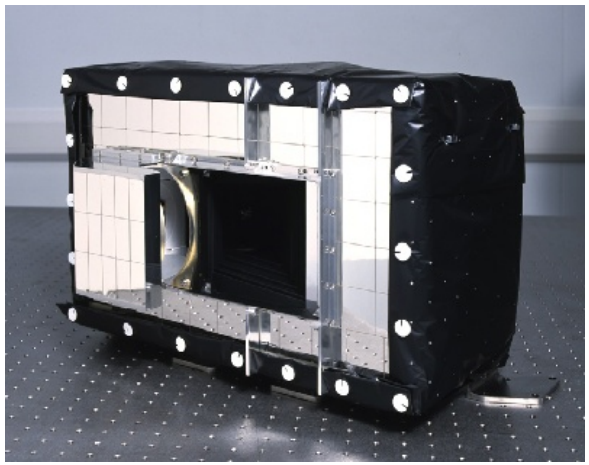
  $\longrightarrow$ chosen for specific detection purposes.



- Temporal resolution: 15 minutes interval
- Spatial resolution: 3km$\times$3km at nadir (1km HRVIS)

GERB

- *Geostationary* Earth Radiation Budget instrument.
- Announcement of opportunity instrument on MSG.
- Spectral properties:
  - 2 broad-band channels
  - Short wave: 0.32- 4 μm
  - $\longrightarrow$ solar channel
  - Total: 4 - 30 μm
  - Longwave: by subtraction
  - $\longrightarrow$ thermal channel

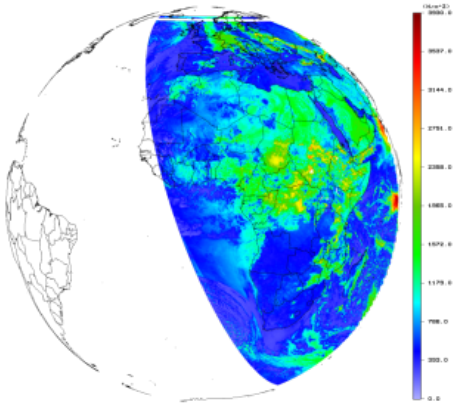


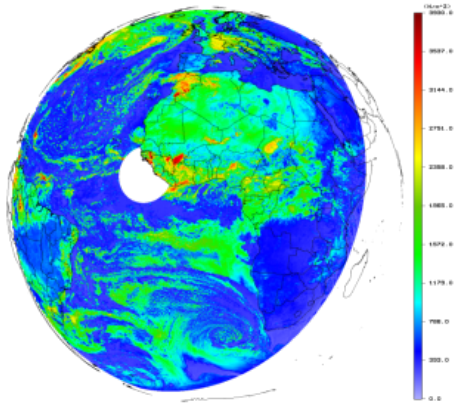
- Temporal resolution: 15 minutes interval
- Spatial resolution: 44.5km$\times$39.3km at nadir (NS x EW)

$\longrightarrow$ Upsampling using SEVIRI: 9km$\times$9km

GERB High Resolution Example

Reflected solar radiation.





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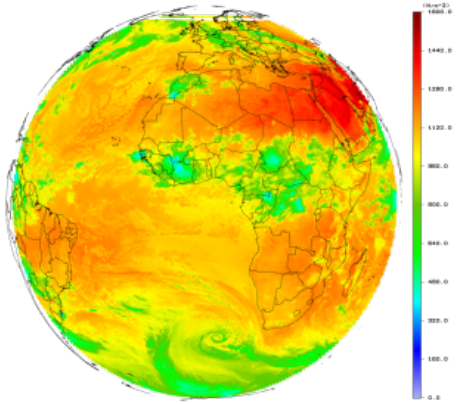
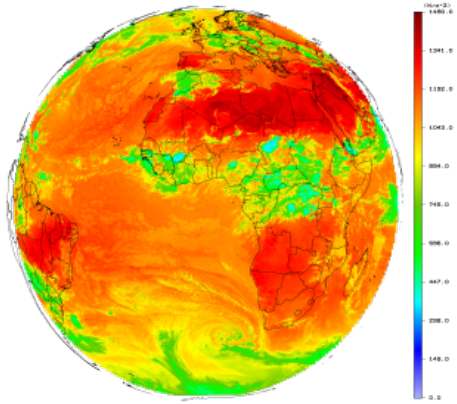




Emitted thermal radiation.

Top Of Atmosphere Products (TOA)

- We provide three TOA products (CM-SAF) form 2004 on:
  - Total Incoming Solar radiation (TIS).
  - Total Reflected Solar radiation (TRS).
  - Total Emitted Thermal radiation (TET).
- Daily mean, monthly mean diurnal cycle and monthly mean.
- To get these (and much more):
  - http://www.cmsaf.eu
  - http://cmsaf.oma.be

Total Incoming Solar Radiation (TIS)

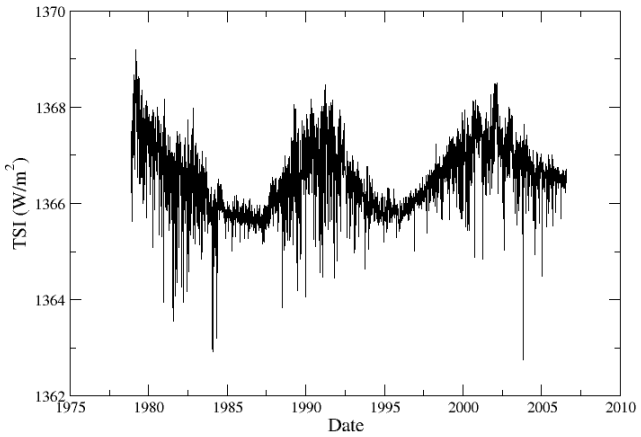
- Computed from TSI (Total Solar Irradiance)

$$TSI = \frac{TIS \cos(\theta_{sol})}{d^2}$$

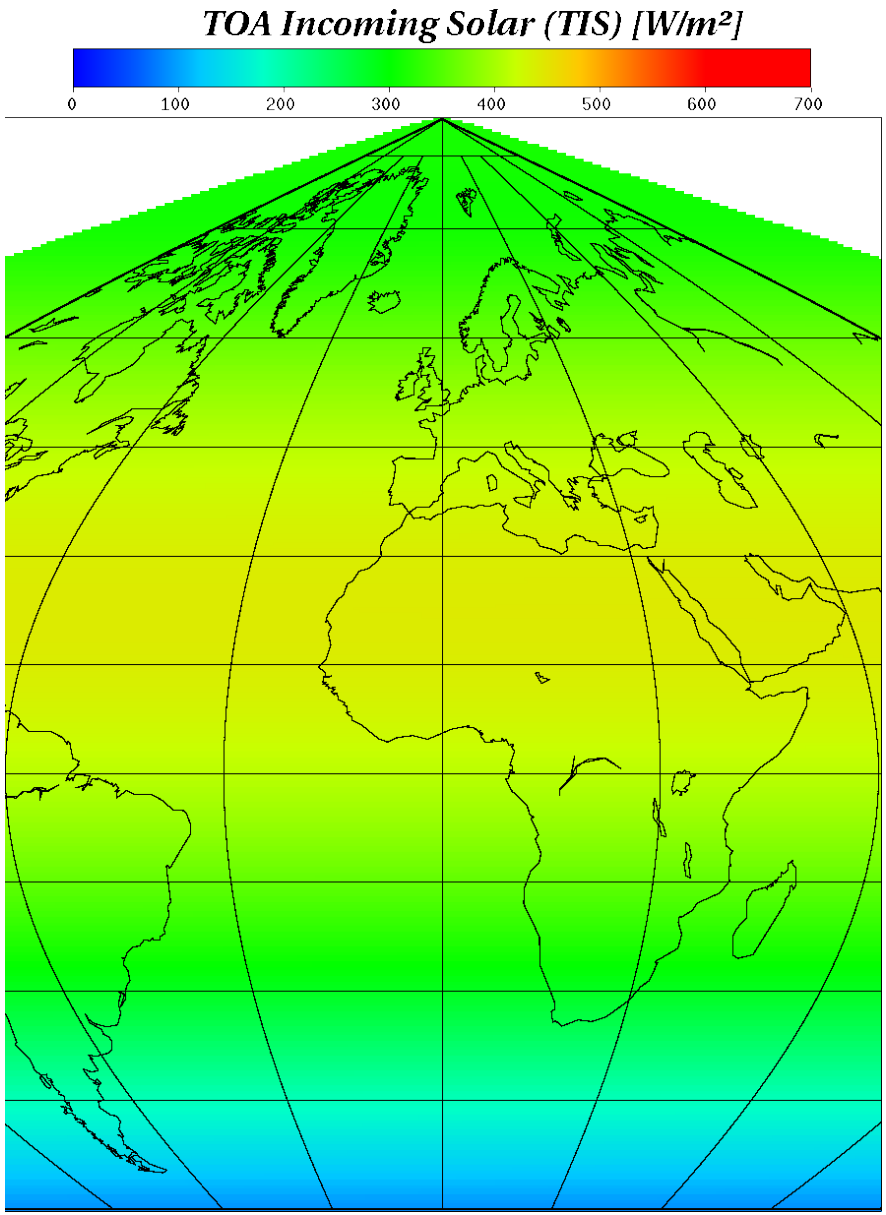
where,

  - d = distance pixel sun (astronomical units).
  - θ_{sol} = solar zenith angle

- TSI measured over 3 decades:



Example TIS

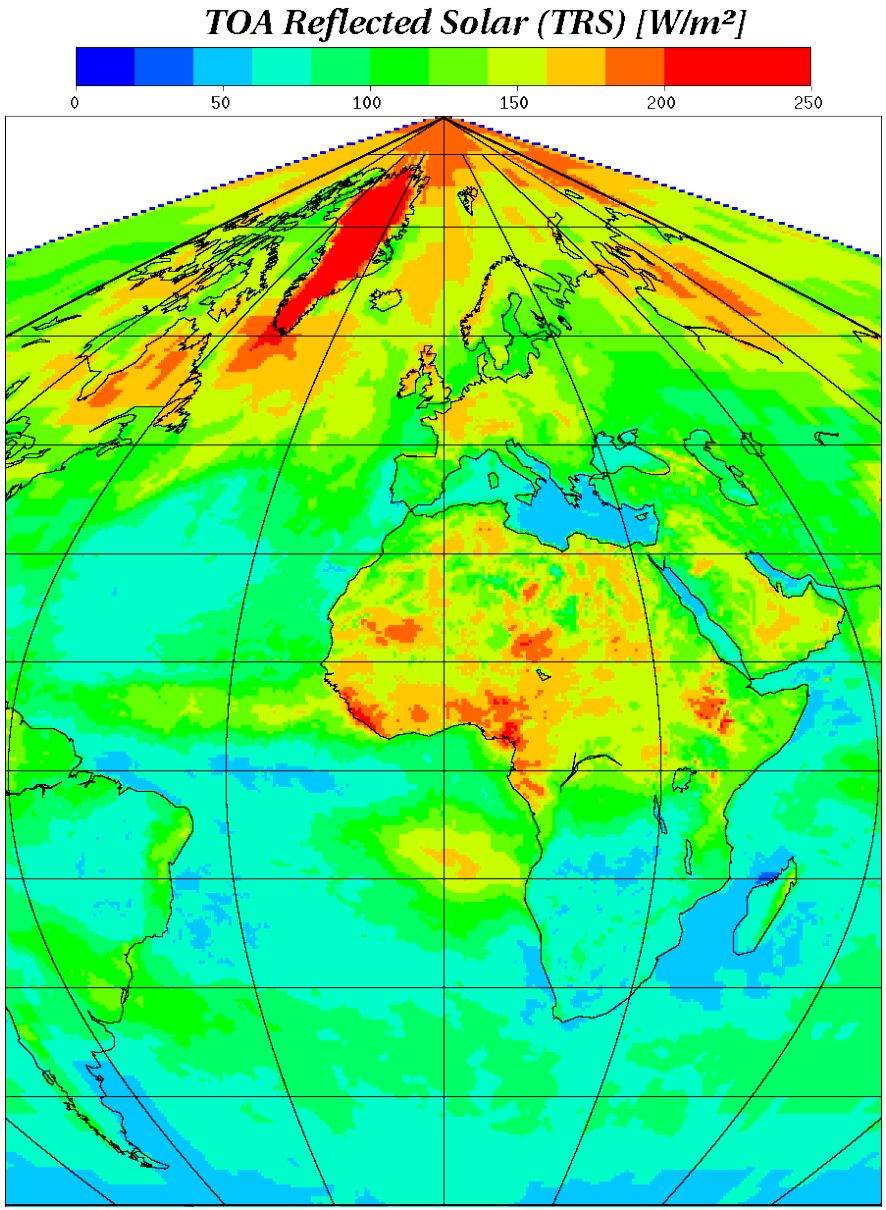


TRS and TET

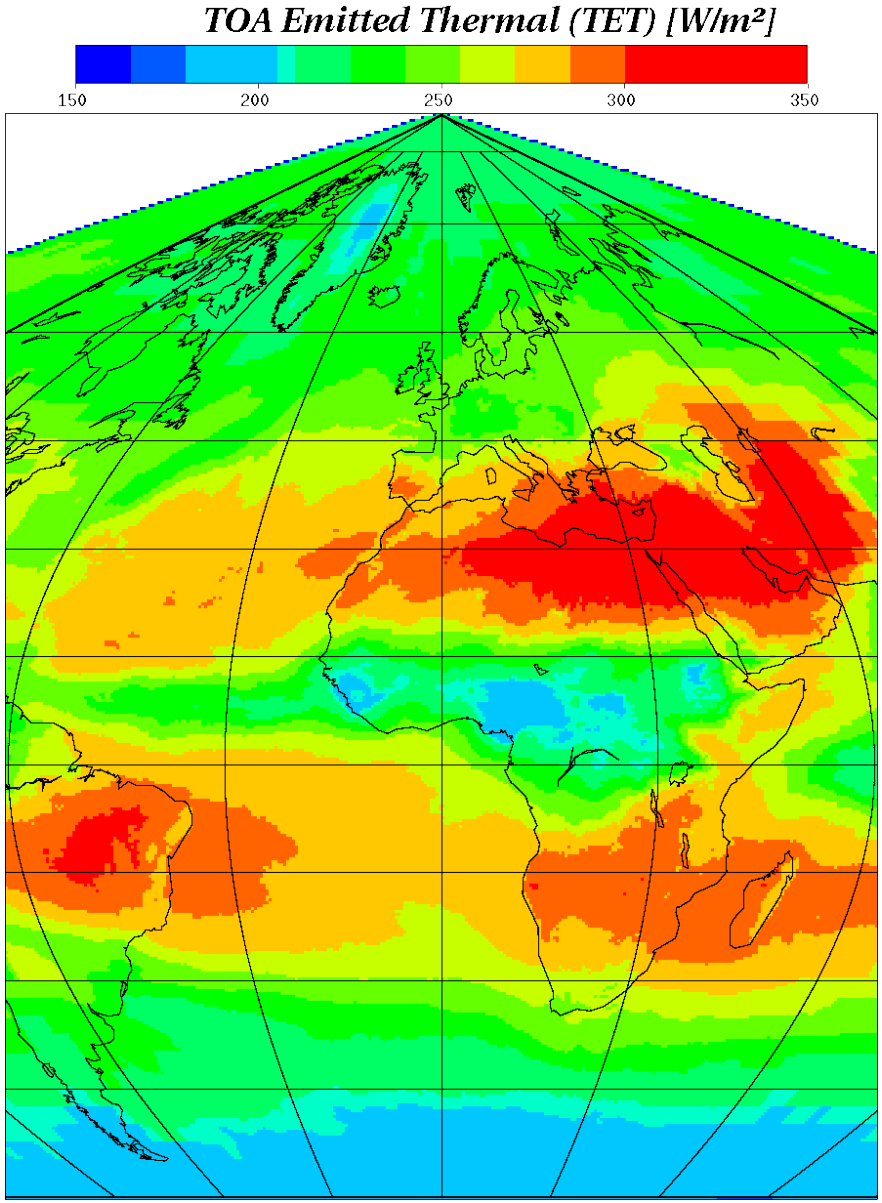
- Obtained from GERB instrument
  - GERB field of view.
  - ADM to correct for angles.
  - Spatial upsampling.
- \+ CERES experiment $\longrightarrow$ polar region.
- \+ SEVIRI
  - If no GERB data available.

  $\longrightarrow$ narrow to broadband conversion: GERB-like data.
  - The future: no GERB instument on MTG.
  - And the past: no GERB instument on MFG.

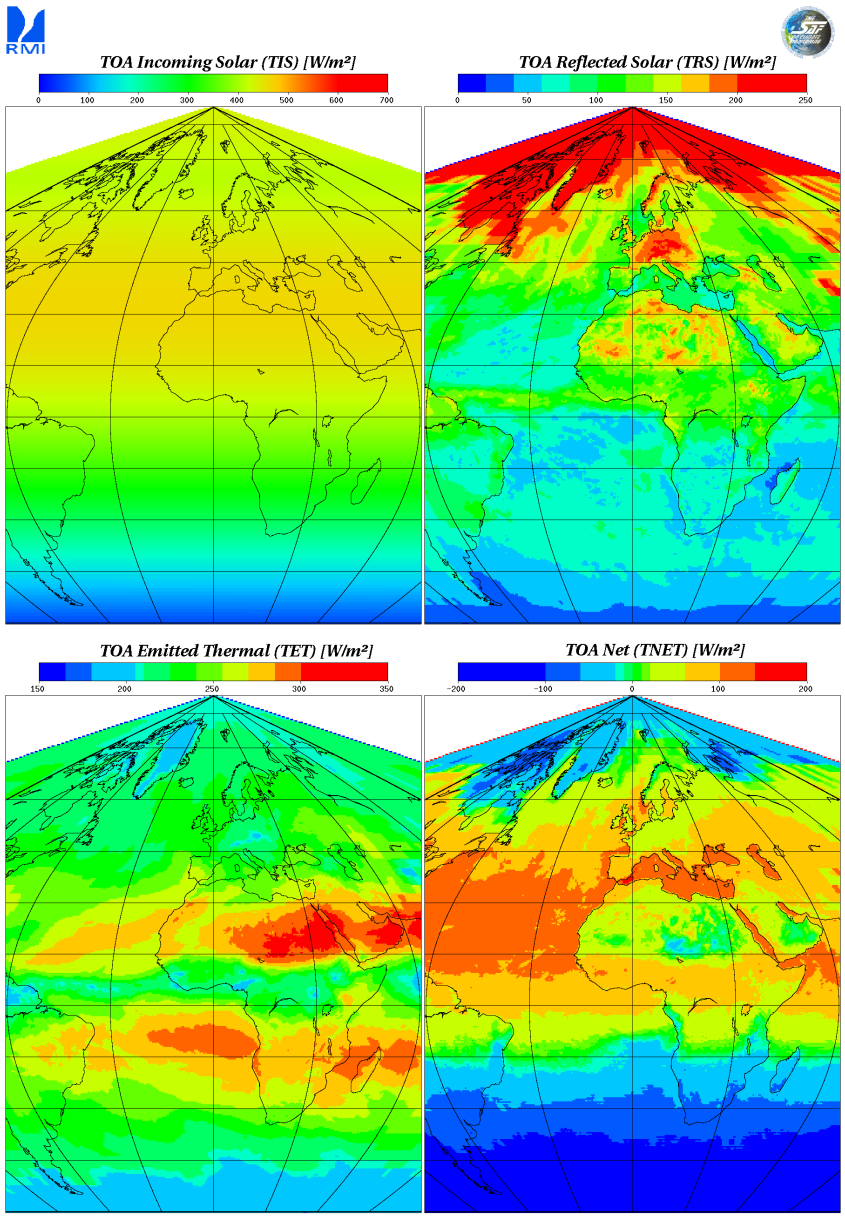
Example TRS



Example TET



Example with Netto Irradiance at TOA



Motivation

Tropospheric aerosol particles originate from:

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

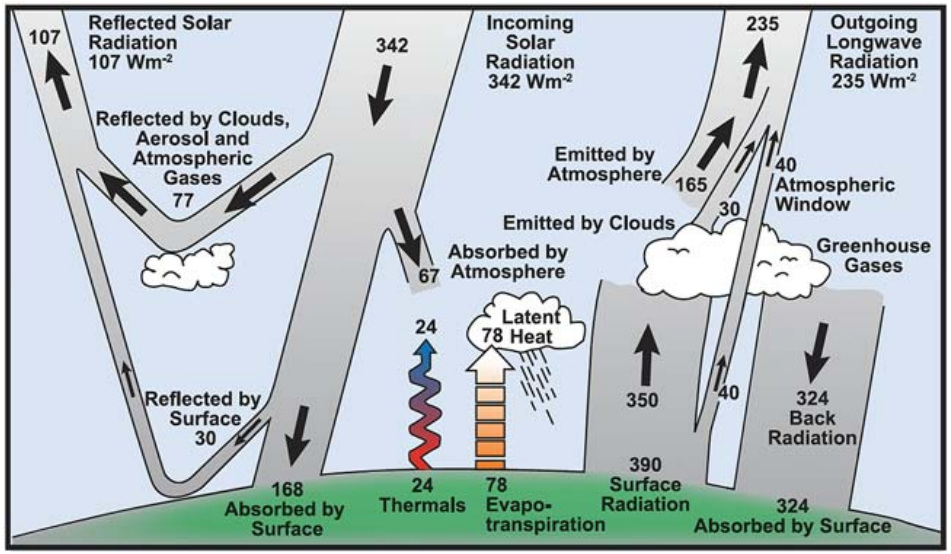
Global observations from space required due to:

- 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 $\rightarrow$ radiation is scattered or absorbed by the aerosols.
- Indirect radiative forcing $\rightarrow$ 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 $\longrightarrow$ 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.

$\rightarrow$ 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

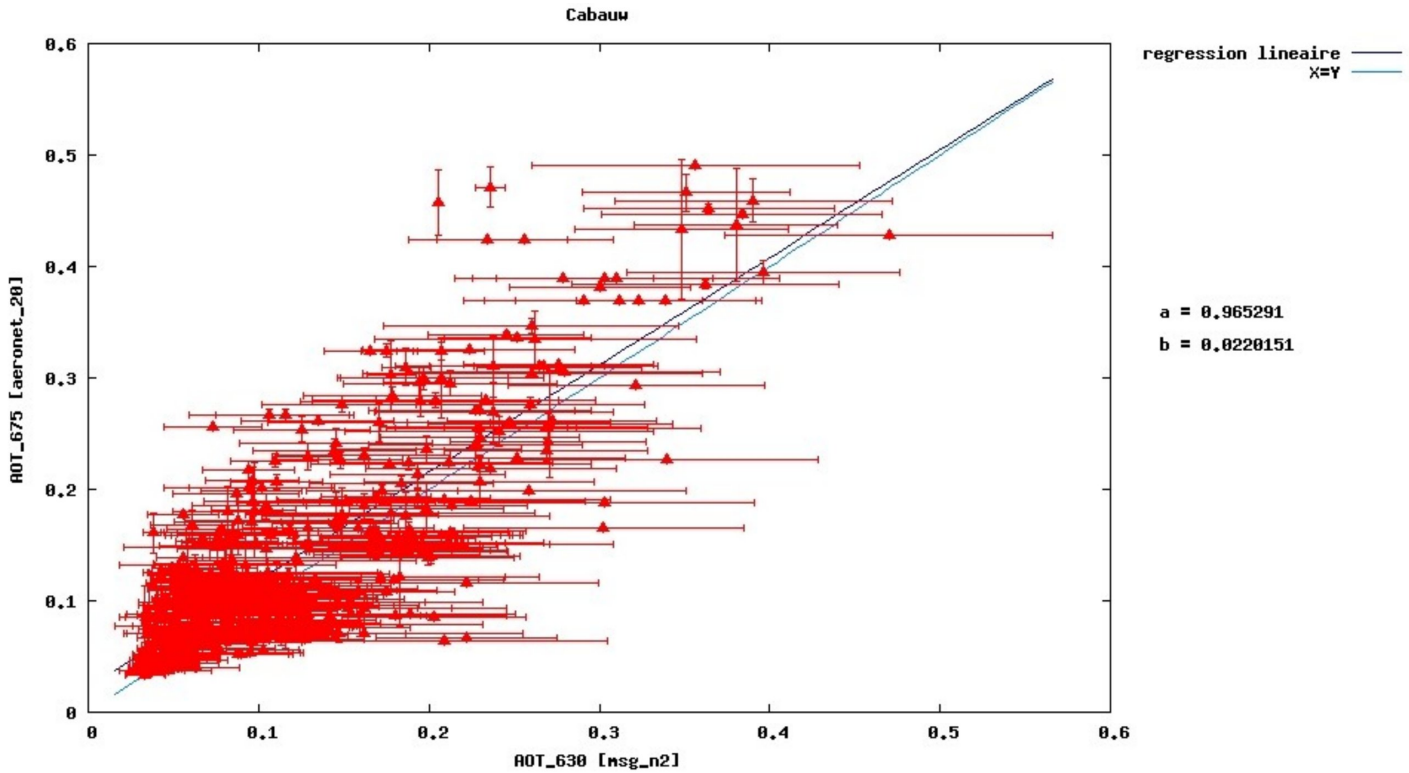
AOD Retrieval

- $\mathcal{R}_{surface}$ 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.

  $\rightarrow$ 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

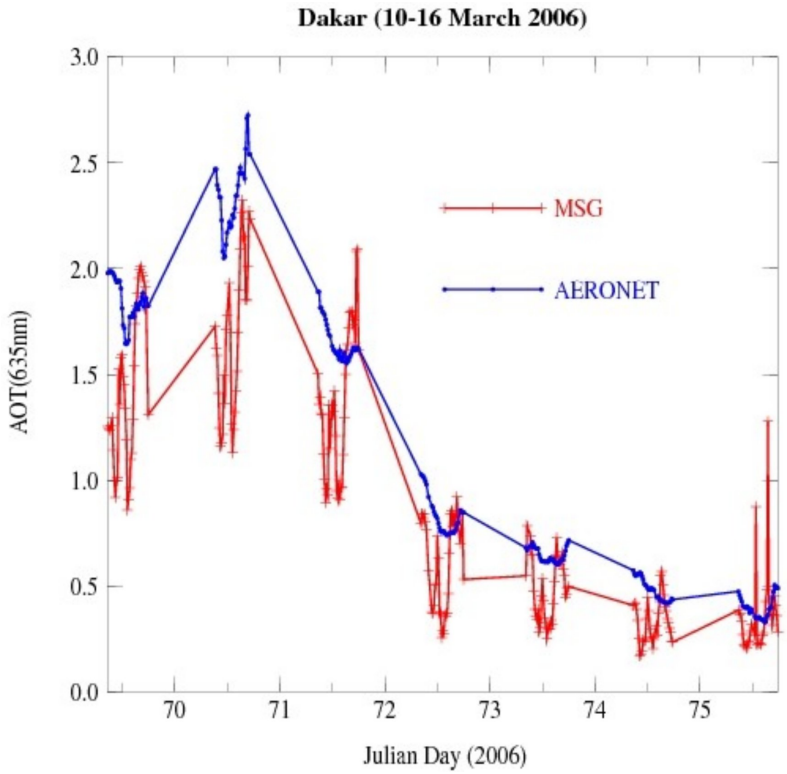
- Based on comparison with AERONET observations.
- July 2006: $>$ 200 co-registrations with Cabauw.



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

Observation Temporal Changes in Aerosol Load

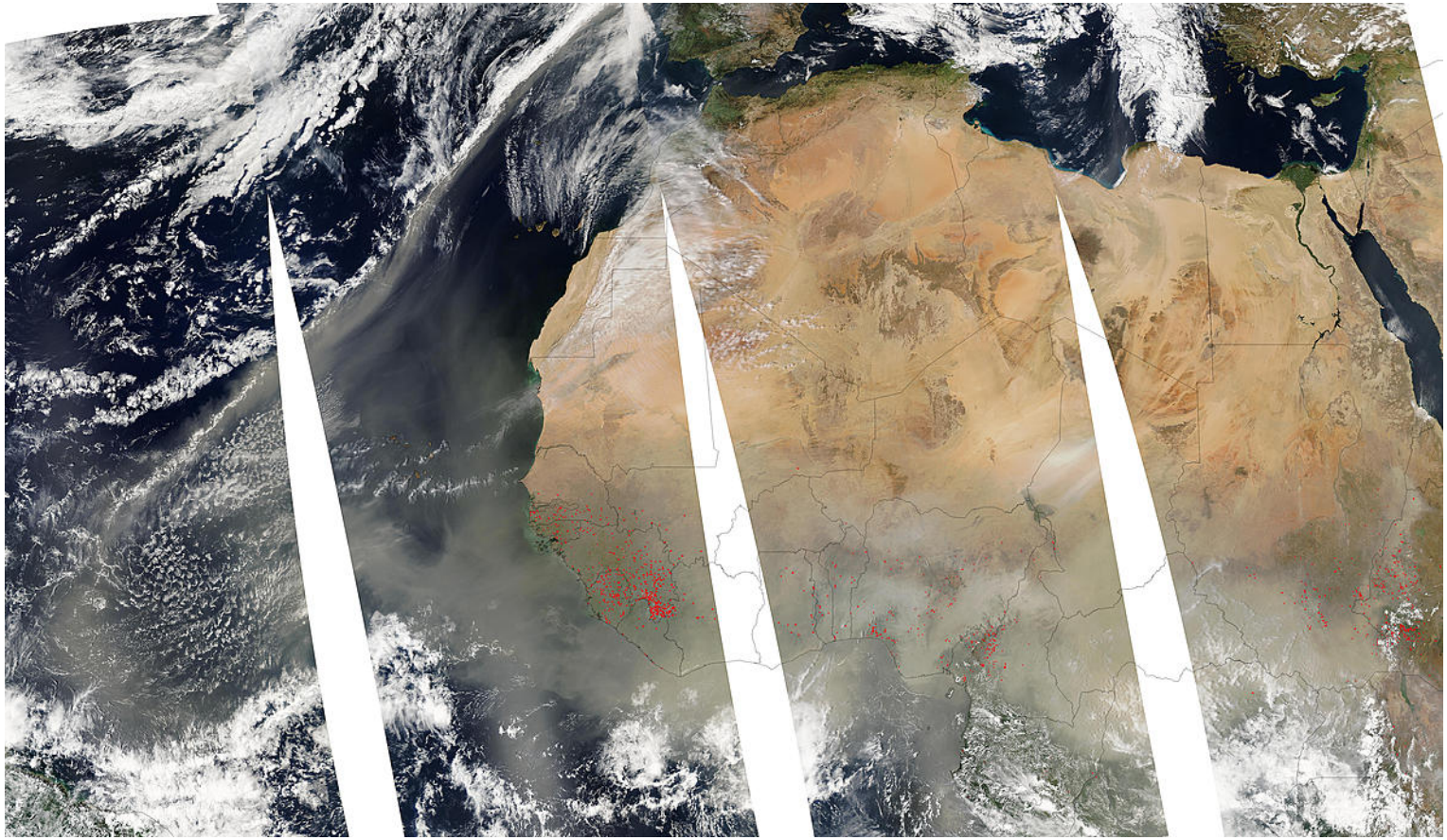
- Dust event Dakar with AOD varying from > 2.0 till 0.3 in 7 days.



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

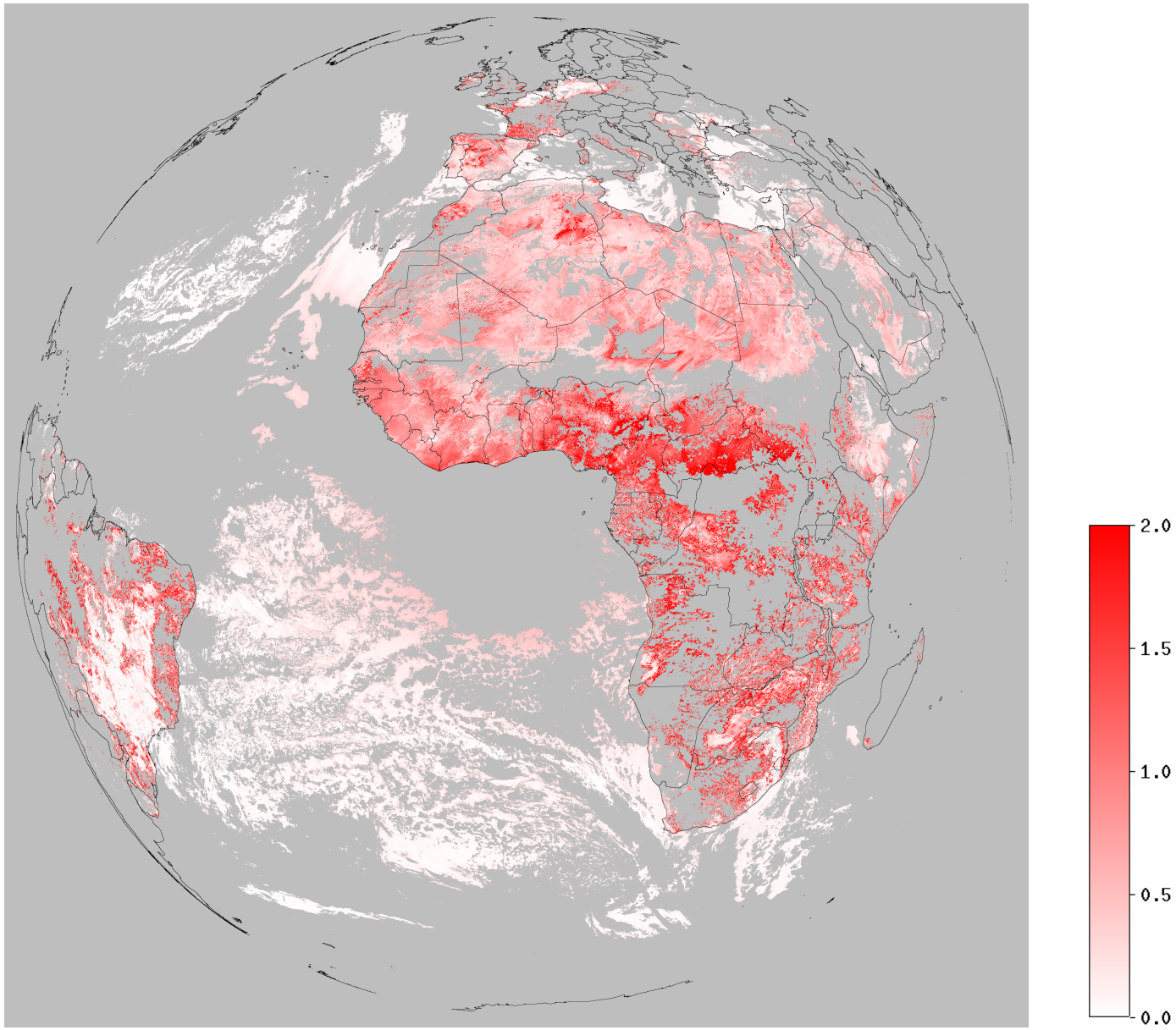
$\rightarrow$ Background day: assumed AOD $= 0.03 +$ high AOD during the reference period $\Rightarrow$ systematic bias.

Dust storm across Central and West Africa



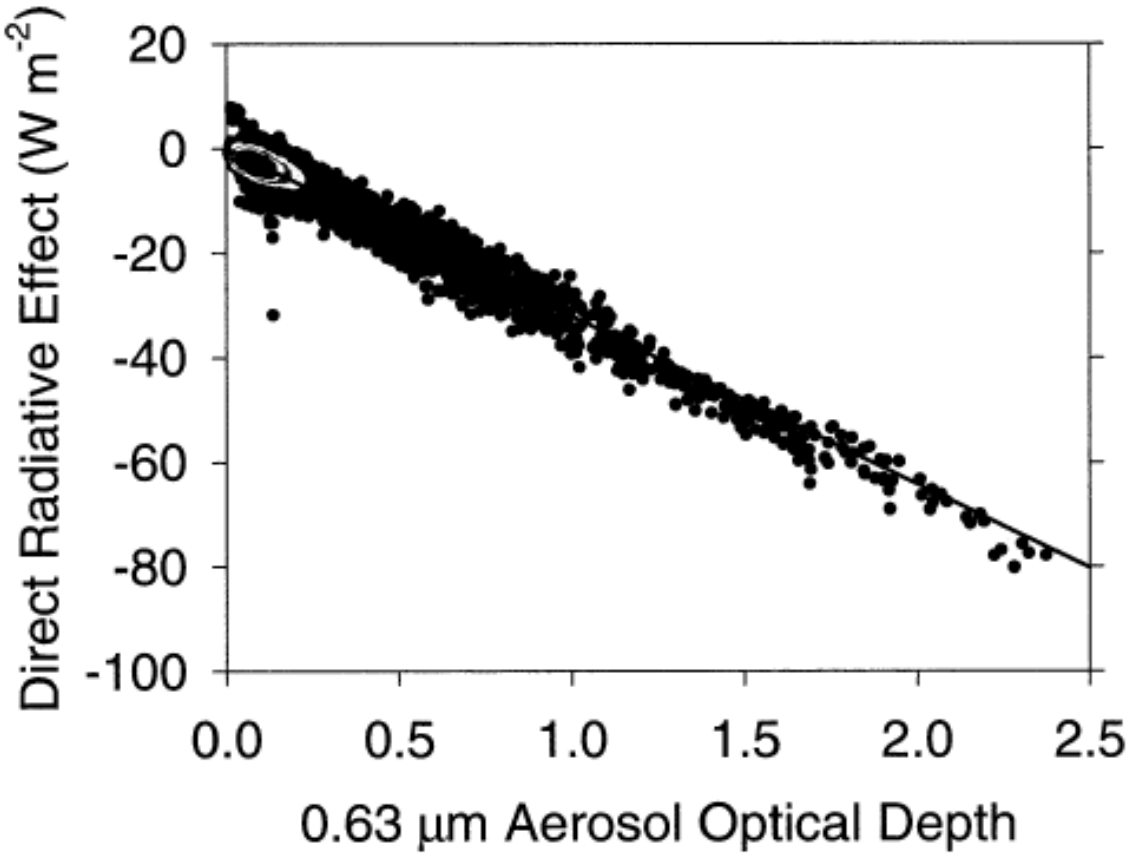
08/03/2004 Aqua Satellite

Example AOD (08/03/2004)



Methodology

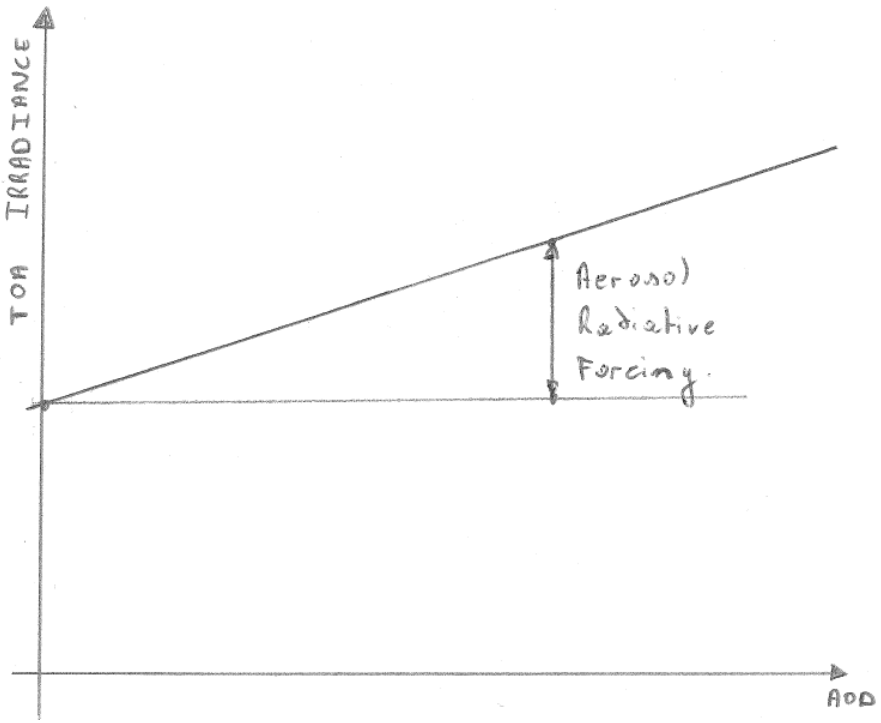
With low AOD there is a linear relation between (clear sky) radiative forcing and AOD.



LLoeb, Norman G., Seiji Kato, 2002)

Methodology (bis)

- Use this relation to calculate slope and intercept in a TRS (or TET) - AOD graph.
- Slope: radiative forcing corresponding with give AOD.



Conclusions

- GERB: provides many interesting products (both direct and derived).
- Aerosols algorithm: constant background AOD of 0.03 unrealistic in high AOD periods.

$\longrightarrow$ Use different algorithm to improve estimation of background AOD.

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

$\longrightarrow$ Use different algorithm for bright surfaces (desert).

- We can combine our products to calculate aerosol radiative forcing.