Aerosol Remote Sensing from space: application to POLDER & MODIS data

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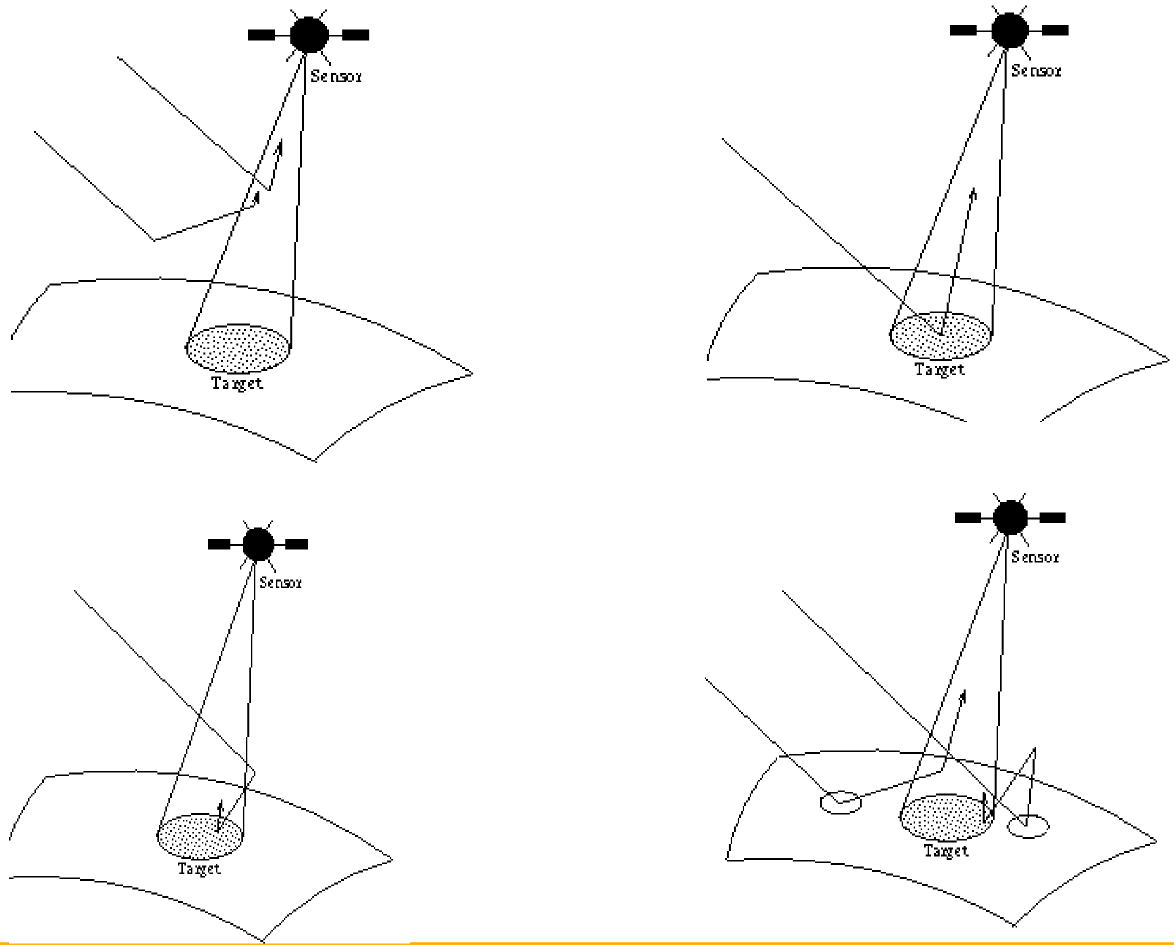
(LOA/LSCE/CNES, POLDER)

(SA/IPSL, Lidar)

(GSFC/ NASA, MODIS)

Scattering of Sunlight by the Earth-Atmosphere-Surface System



Scattering of Sunlight by the Earth-Atmosphere-Surface System

For a lambertian & uniform ground

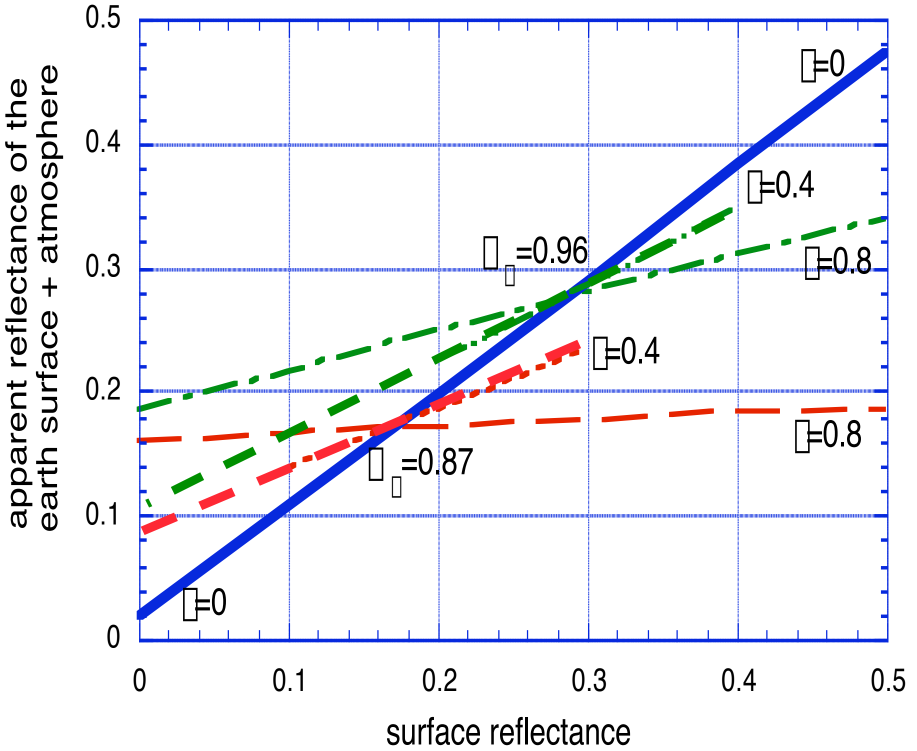
$$\rho(0;u_s,\phi_s;u,\phi) = \rho_a(0;u_s,\phi_s;u,\phi) + \rho_s \frac{T(u_s) \cdot T(u_v)}{1 - \rho_s \cdot S}$$

Scattering of Sunlight by the Earth-Atmosphere-Surface System

- **Calculated apparent reflectance of the earth surface + atmosphere as observed from space at nadir (□=0.66 μm, $□_□$=32°).**

- **Solid blue line - no aerosol (□=0) only molecular scattering, broken lines - with low absorption, $□_o$=0.96 (green), and high absorption, $□_o$=0.87 (red), respectively.**

- **Optical thickness, □, of 0.4 and 0.8 is indicated.**



(From Kaufman et al., 1987)

Scattering of Sunlight by the Earth-Atmosphere-Surface System

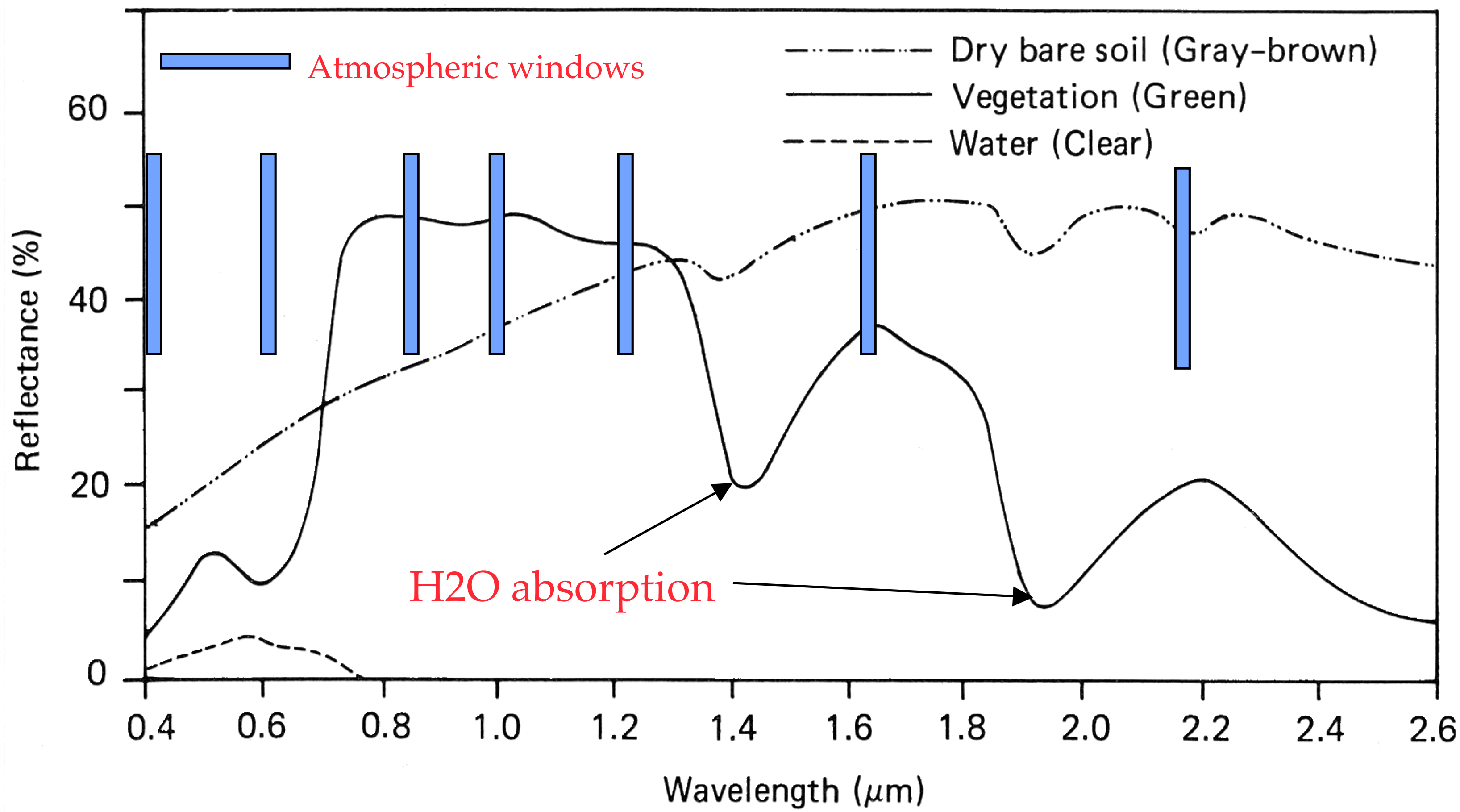
For a lambertian & uniform ground

?

$$\rho(0;u_s,\phi_s;u,\phi) = \rho_a(0;u_s,\phi_s;u,\phi) + \rho_s \frac{T(u_s)\,T(u_v)}{1 - \rho_s\, S}$$

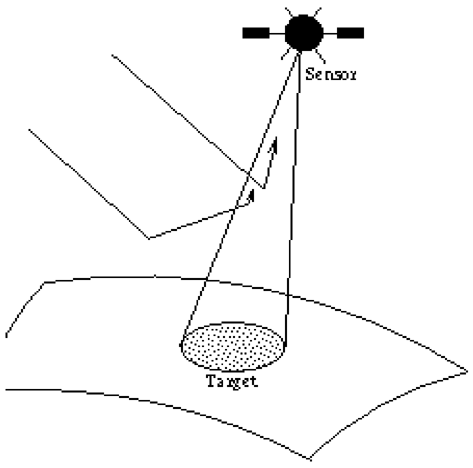
AEROSOLS

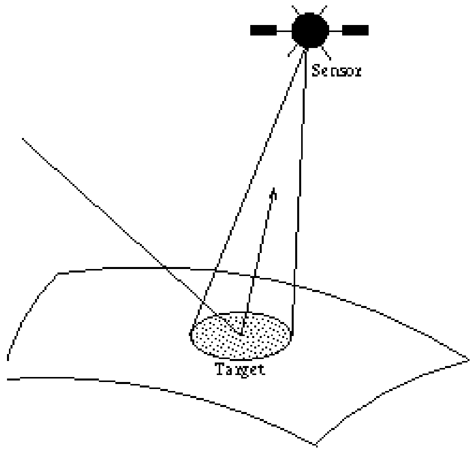
Aerosol Remote sensing by the use of Scattering of Sunlight



Typical Spectral Reflectance Curves for Vegetation, Soil, and Water

Scattering of Polarized Sunlight by the Earth-Atmosphere-Surface System



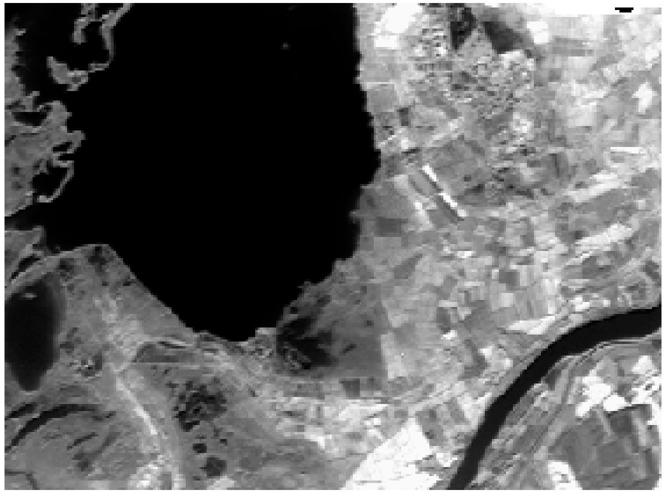


Scattering of Polarized Sunlight by the Earth-Atmosphere-Surface System

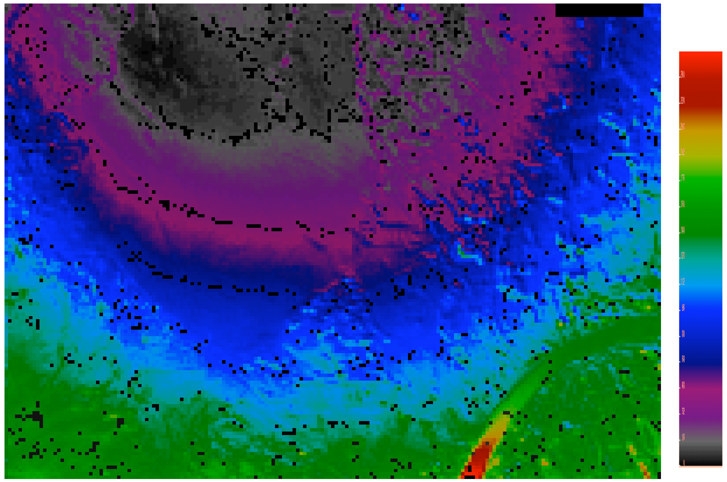
Satellite Polarized radiance=
Molecular contribution
+ Surface contribution
+ Aerosol contribution

- *Molecular contribution (well known)*
- *Surface contribution is expected to be smaller than the aerosol contribution with little spatial variability*

Scattering of Polarized Sunlight by the Earth-Atmosphere-Surface System



Ltot:high spatial variability



Lpol: smoother, depending on the scattering angle, atmospheric signal

650nm

Applications to MODIS and POLDER

- Description of the two instruments
- Over ocean (similar approaches)
- Over land (different approaches)
- Combining active and passive sensors

MODIS & POLDER instruments

- **MODerate-resolution Imaging Spectroradiometer**
- Terra (1999)& Aqua(2001) series
  - 705 km polar orbits, alternating descending & ascending (10:30 a.m. & 1:30 p.m.)

- Sensor Characteristics
  - 36 spectral bands ranging from 0.41 to 14.385 μm
  - cross-track scan mirror with 2,300 km swath width
  - Spatial resolutions:
    - » 250 m -1000 m
  - 2% reflectance calibration accuracy
  - onboard solar diffuser & SDSM

- POLarization and Directionality of the Earth's Reflectances (ADEOS-1 & 2)
- Two-dimensional CCD detector array
- Wide field of view lens :± 43° along track, ± 51° cross track
- 2400 km x1800 km ;Pixel at nadir :6 km x 7 km
- 9 spectral bands (443, 490, 565, 670, 763, 765, 865, 910 nm), 3 are polarized (443, 670, 865 nm)
- Up to 14 ≠ viewing angles per pixel for a single satellite pass

Algorithm Description Over ocean LUT Approach

- **Cox & Munk for ocean reflectance.**
- **Foam from Koepke**
- **V=5m/s**
- **Glint mask**

Algorithm Description Over ocean

POLDER-1

- **based on single mode : Lognormal-size distribution**
- **Reff (4 Values □=0.0, 0.3, 0.8, 1.4)**
- **Fixed □=0.40**
- **Refractive index (1.33, 1.40, 1.50)**

MODIS

- **based on 2 Lognormal-size distributions**
- **Reff (0.10-0.25μm small mode; 1.0-2.5μm large mode**
- **Fixed □=0.4□0.6**
- **Fixed refractive index**

Algorithm Description Over ocean

POLDER

Radiance data (670, 865nm)

- **L670/L865 to derive the aerosol size distribution**
- **Polarized radiance L865 to use the most appropriate refractive index m**
- **Radiance L865 to derive □**

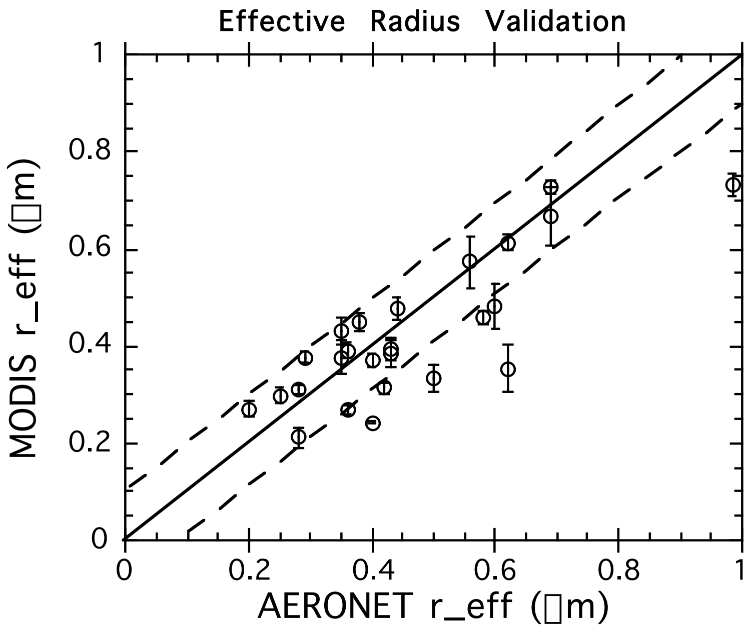
MODIS

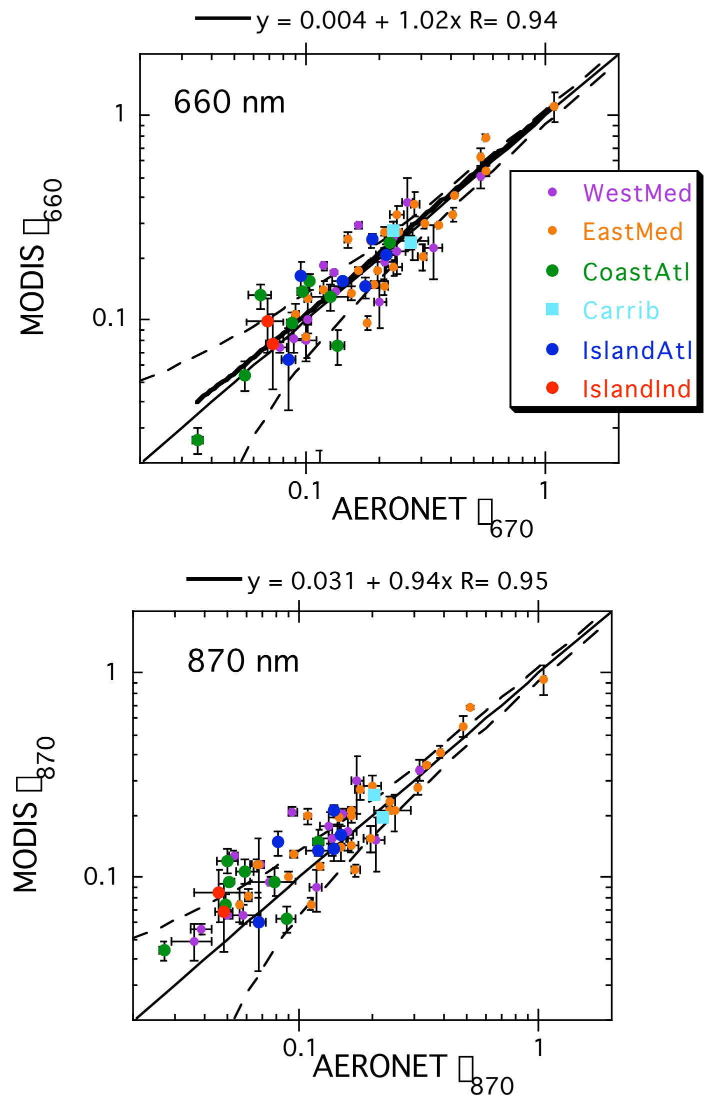
Radiance data (550-2130nm)

- **Spectral radiances to derive the aerosol size distribution**
- **Radiance L865 to derive □**

MODIS □□=±0.03±0.05□ AERONET □□=±0.01

MODIS validation: Ocean

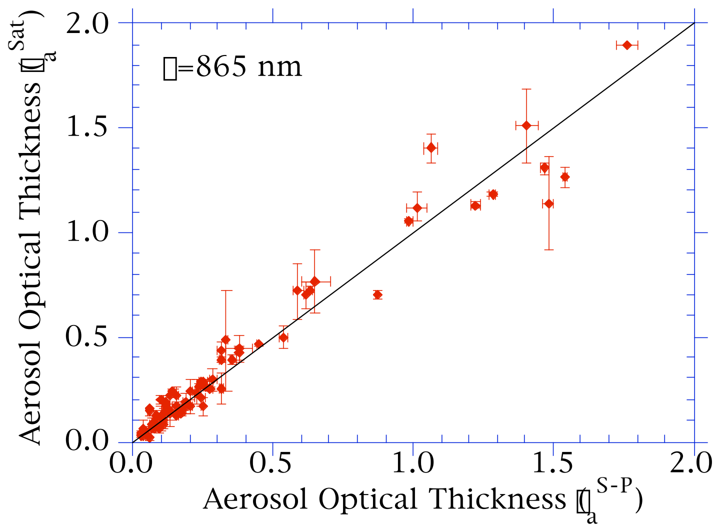


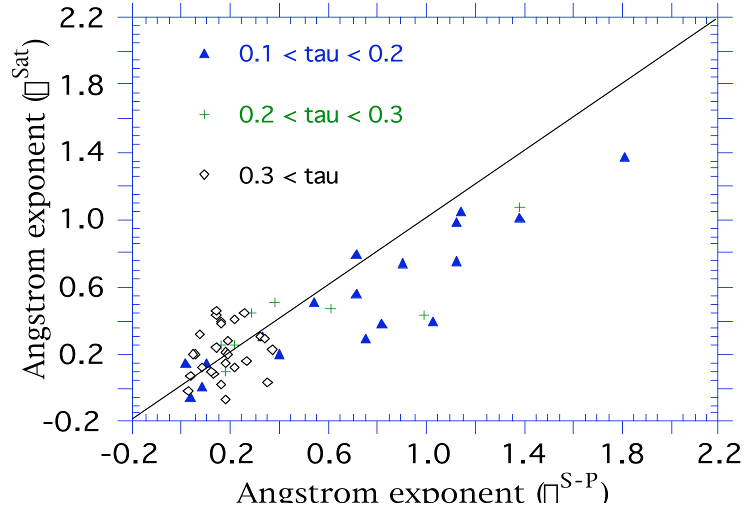


64 co-located measurements during 2 months representing 11 stations.

Lorraine Remer et al 2001

POLDER Validation: AERONET data





- Comparison of POLDER retrievals to sunphotometer measurements
- Very goot agreement on the optical thicknesses
- Some bias on the Angstrom coefficient
- Large optical thicknesses are limited to dust events due to the position of the sunphotometers

Algorithm Description Over land

- **MODIS: Spectral information.**
- **POLDER: Polarized information.**

MODIS aerosol over land

- In the visible MODIS observes smoke and the surface
- In the mid Infra-Red "there is no smoke" MODIS observes only the surface
- The "difference" = the smoke concentration or optical thickness

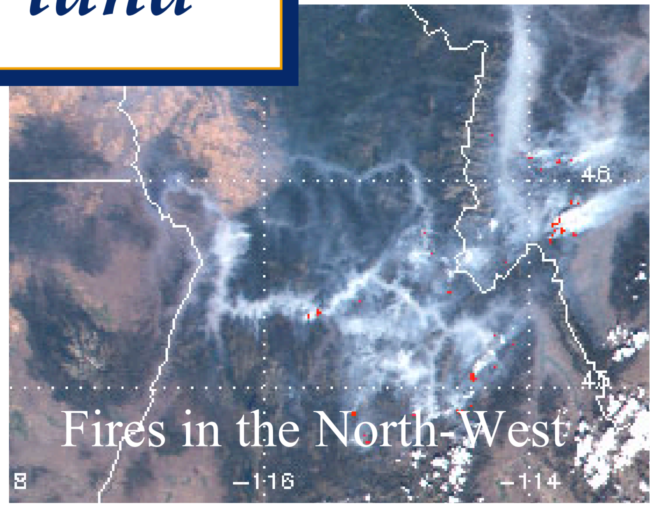
(not as sensitive to dust)

(µm)

0.47

0.55

0.66

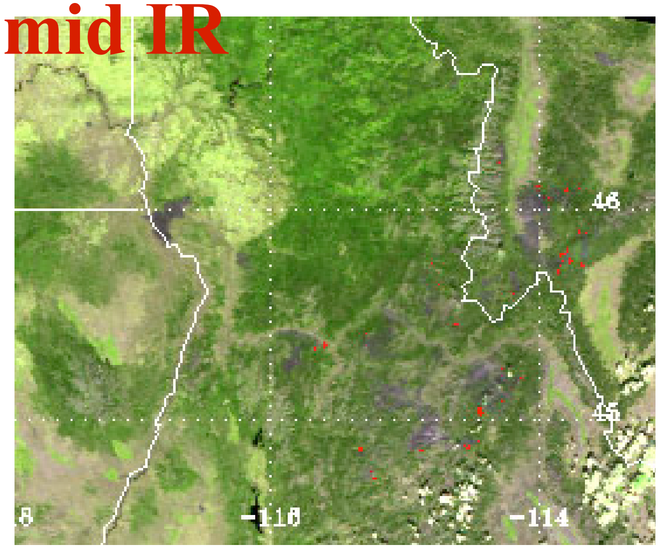


mid IR

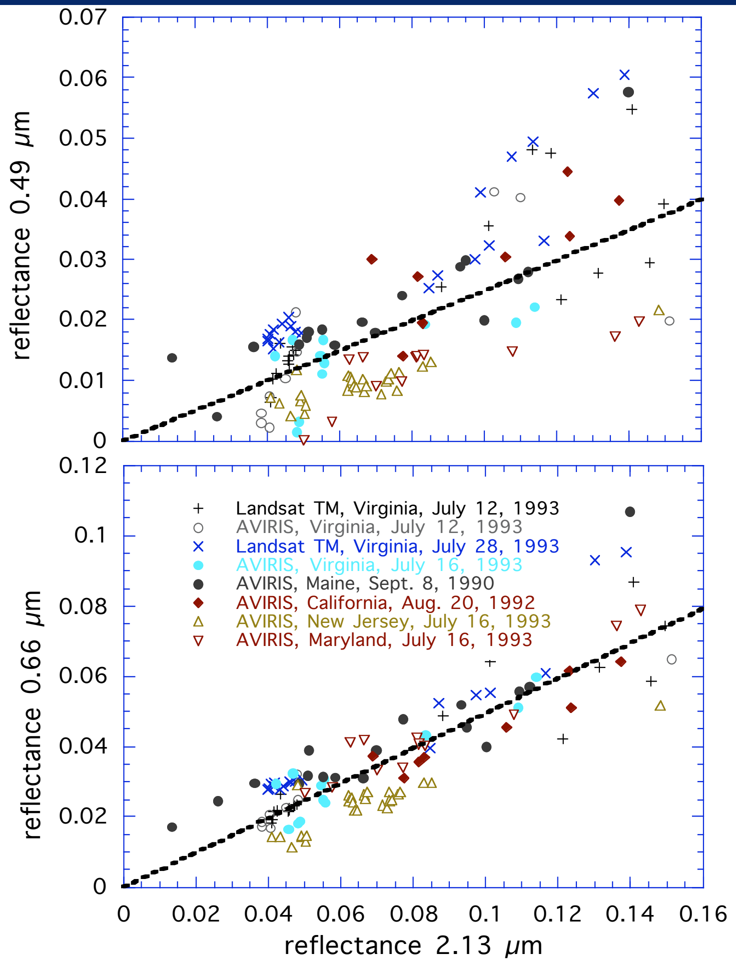
1.2

1.6

2.1



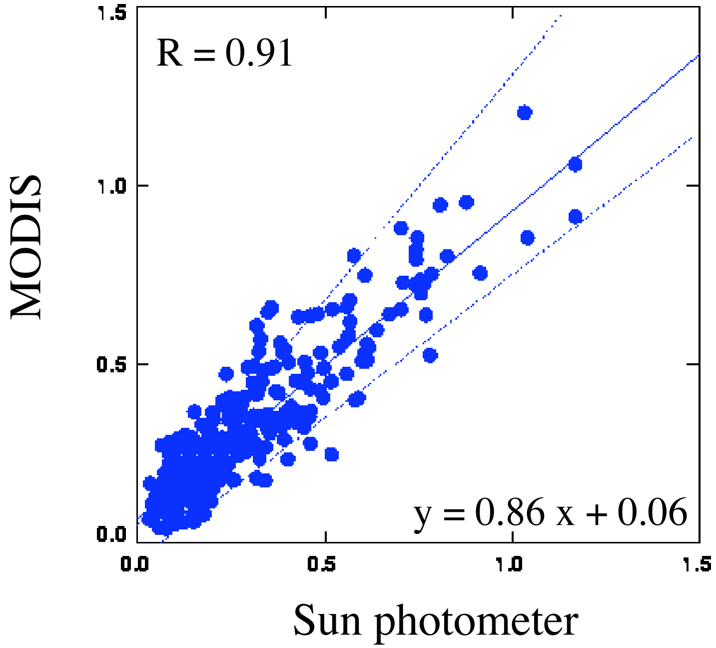
MODIS aerosol over land



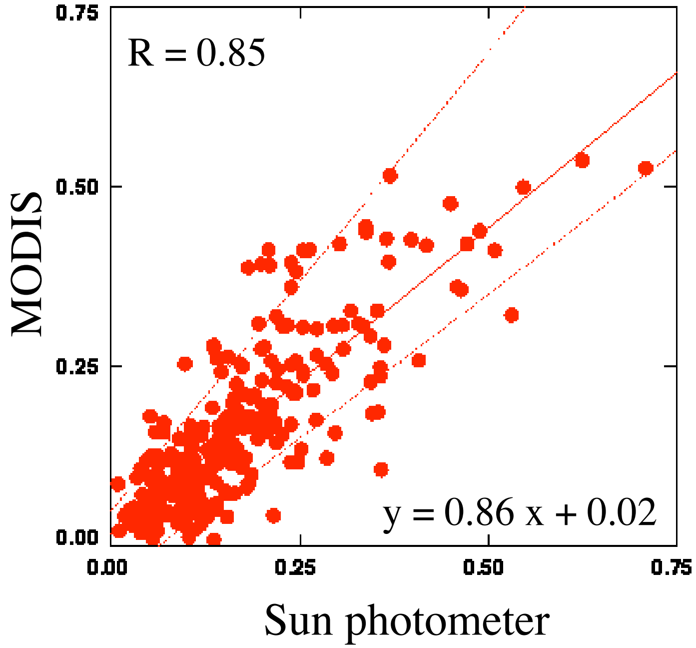
- **MODIS 250m and 500m data in 3 wavelengths ($\square_{0.47\mu m}$, $\square_{0.66\mu m}$, $\square_{2.13\mu m}$)**
- **2.13 μm identifies dark pixels and estimates surface at 0.47μm and 0.66μm: $\square_{0.47\mu m} = \square_{2.13\mu m}/4$; $\square_{0.66\mu m} = \square_{2.13\mu m}/2$**
- **Water/Shadows/snow are excluded**

MODIS Validation: land

At 0.47 μm



At 0.66 μm



Total points = 315

AERONET Δτ=±0.01

MODIS Δτ=±0.05±0.20τ

Note: excluding Venice and El Arenosillo sites

Allen Chu et al 2002

POLDER aerosol over land

- Surface Polarized Radiance is more uniform than surface total radiance.

- Spectrally independent.

- Contribution of the surface to the polarized radiance at the TOA is expected to be smaller that the contribution of the atmosphere ("dark" target).

POLDER aerosol over land

- The polarized light do not carry any information on the coarse mode.

- Spectral domain (670 & 865) too narrow for getting information on the aerosol size.

- Definition of an aerosol index which is representative of the aerosol loading □x□, (corresponds to anthropogenic aerosols □=1)

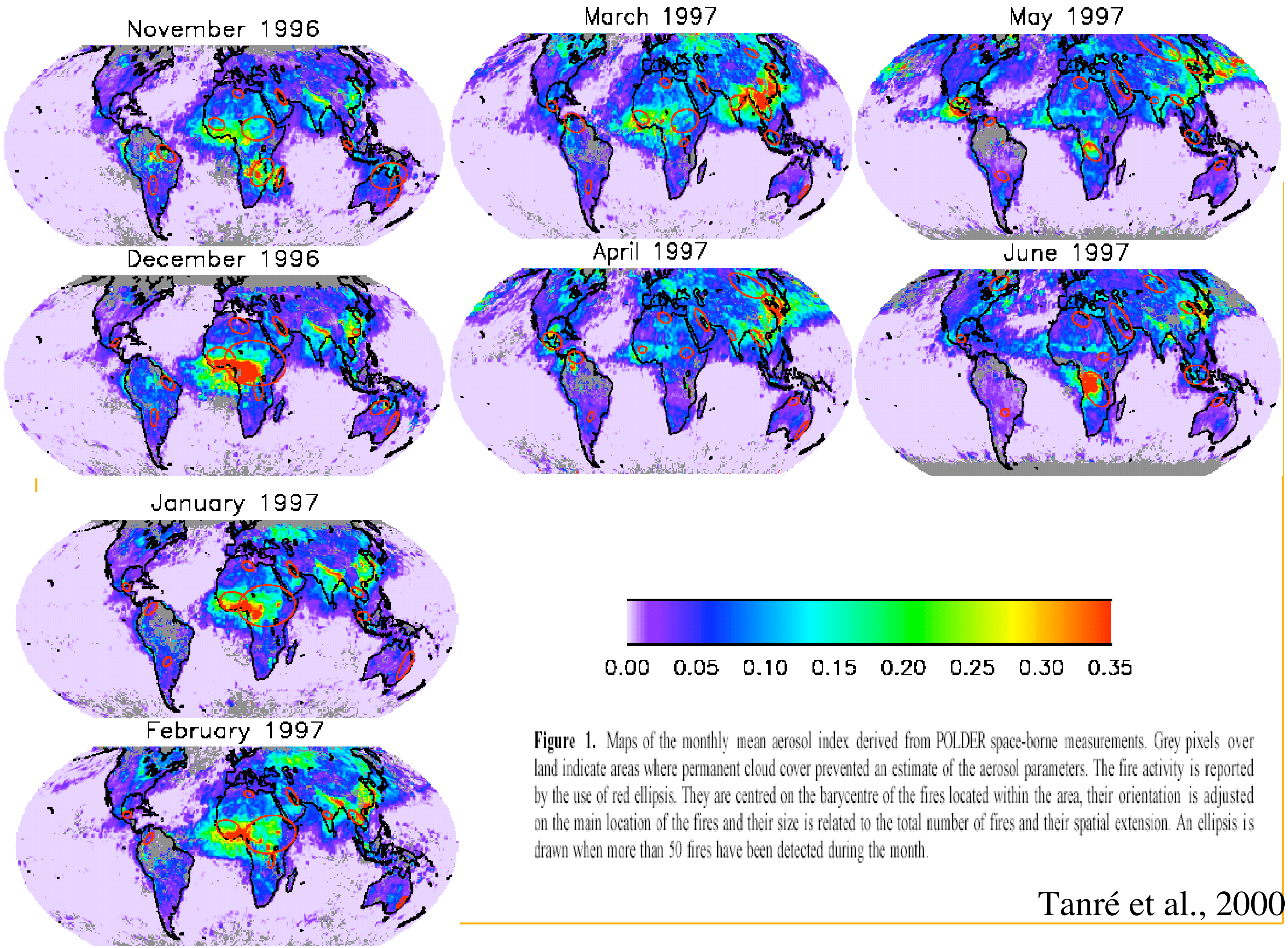


Figure 1. Maps of the monthly mean aerosol index derived from POLDER space-borne measurements. Grey pixels over land indicate areas where permanent cloud cover prevented an estimate of the aerosol parameters. The fire activity is reported by the use of red ellipsis. They are centred on the barycentre of the fires located within the area, their orientation is adjusted on the main location of the fires and their size is related to the total number of fires and their spatial extension. An ellipsis is drawn when more than 50 fires have been detected during the month.

Tanré et al., 2000

Synergy: MODIS-LIDAR

1- MODIS : spectral radiances 440nm 2150nm

Spectral aerosol optical thickness

Effective aerosol model composed of a small (accumulation) and a large (coarse) lognormals mode for a given refractive index

2 - □ lidar : attenuated backscatter coefficient □ at 532 & 1064nm

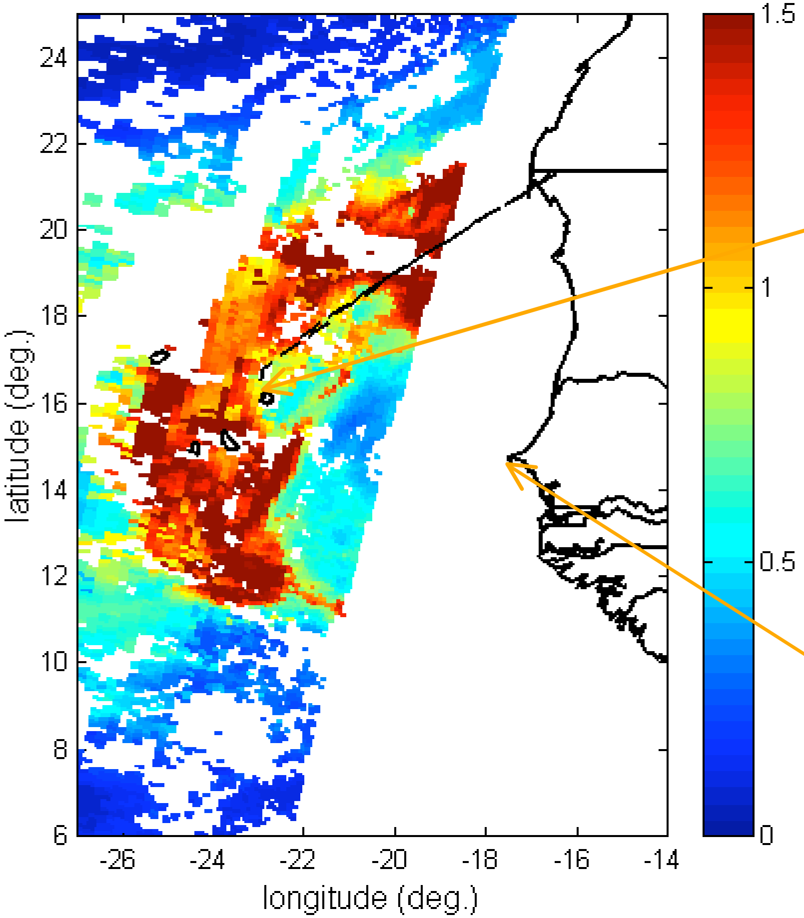
The backscatter to extinction coefficient (from MODIS aerosol model) is required to derived the aerosol extinction from the lidar measurement.

Assume the relative contribution of the small and large mode to the extinction may vary with altitude but the size of each mode do not vary.

Establish the relationship between the spectral behavior observed with the 2 □ Lidar and this relative contribution for a given altitude

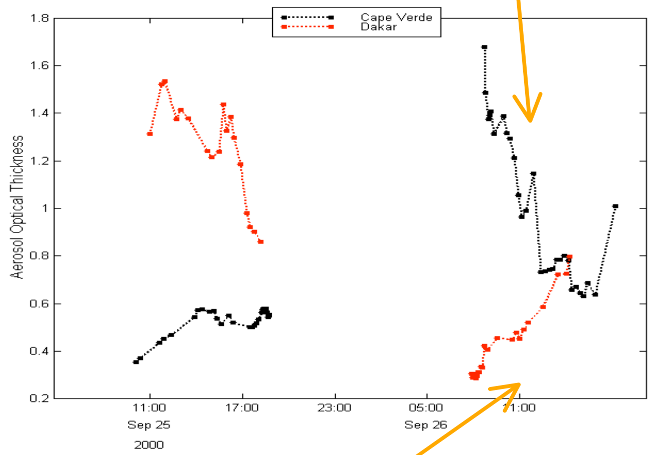
SHADE EXPERIMENT

Modis AOT (532 nm), Sept. 26 2000



Simultaneous aquisition with M20 and Terra/ Modis

Cape Verde



Dakar

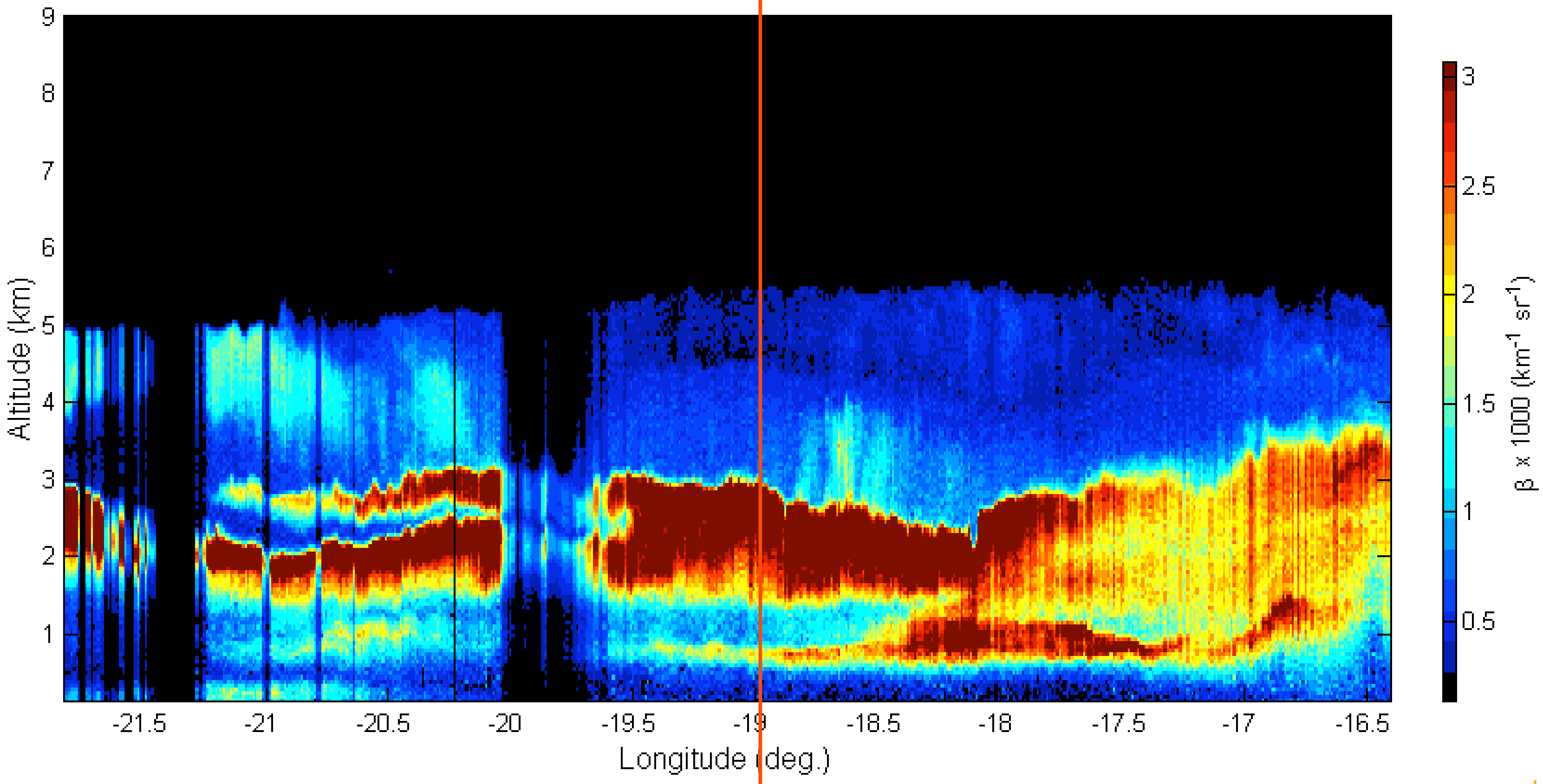
Intense transport of Dust 26/09

Léon et al., 2003

SHADE EXPERIMENT

Modis view

Vertical structure

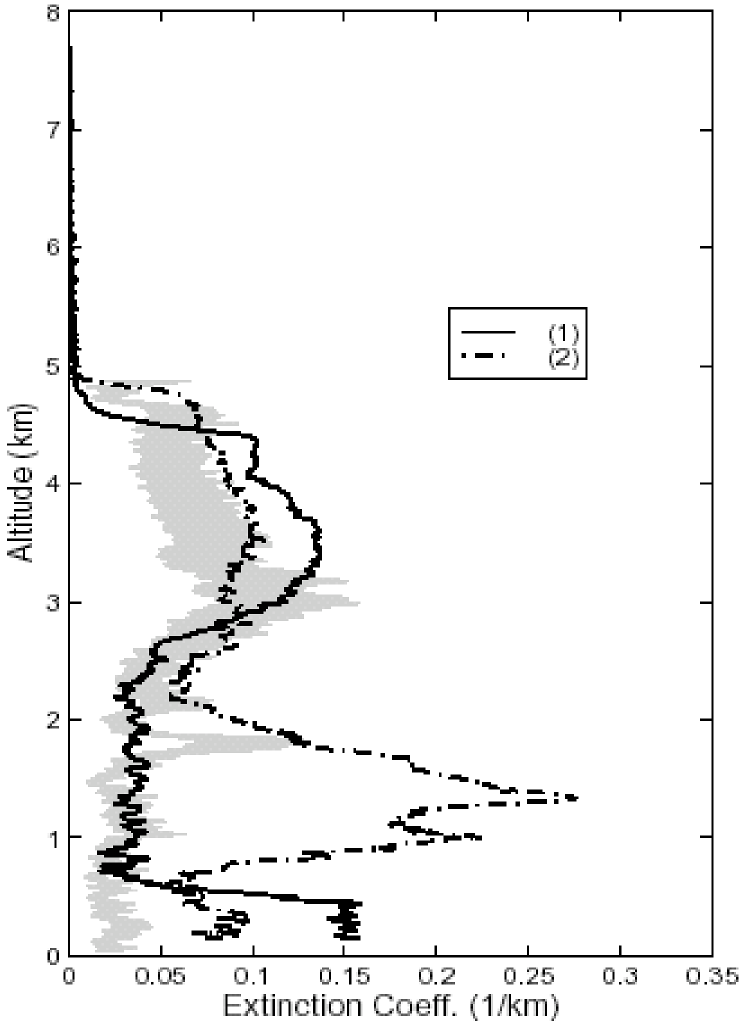


To C.V.

To Nouakchott

Léon et al., 2003

SHADE EXPERIMENT



Comparison between in situ measured extinction coefficient obtained from the C130 (grey area) and lidar retrieved extinction coefficient for two locations (solid and dashed lines) on Sep.25.

Vertical structure extinction coefficient

Léon et al., 2003