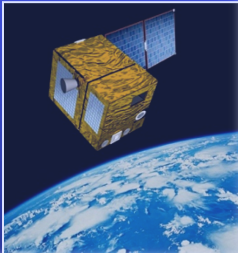
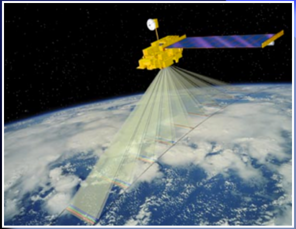
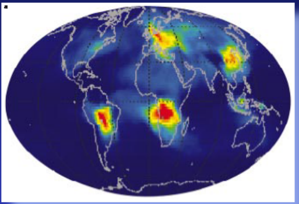
The optimized algorithm for deriving detailed properties of aerosol from satellite observations.







O. Dubovik, M. Herman, A. Holdak, T. Lapyonok, D. Tanré, F. Ducos, Y. Govaerts, A. Lopatin

Science and Technology University of Lille, CNRS, France

- ✓ the concept of the algorithm;
- ✓ testing of the algorithm;
- ✓ application to the POLDER/PARASOL data

Aerosol and cloud workshop, Paris, 12-14 September, 2011

“independent” POLDER/PARASOL measurements :

GLOBAL: every 2 days SPATIAL RESOLUTION: 5.3km × 6.2km

VIEWS: $N_{\Theta} = 16$: $(80^0 \le \Theta \le 180^0)$

INTENSITY: $N^t_{\lambda} = 6$: (0.44, 0.49, 0.56, 0.67, 0.865, 1.02 μm)

POLARIZATION: $N^P_{\lambda} = 3$: (0.49, 0.67, 0.865 μm)

SINGLE OBSERVATION:

$$(N^t_{\lambda} + N^P_{\lambda}) \times N_{\Theta} = (6+3) \times 16 = 144$$

a lot !!! – as much as AERONET

independent measurements

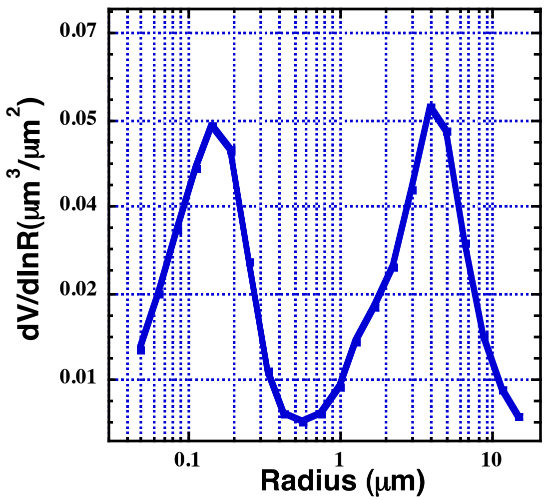
$$(N^t_{\lambda} + N^P_{\lambda}) \times N_{\Theta} = (8+8) \times 140 > 2000$$

APS !!!

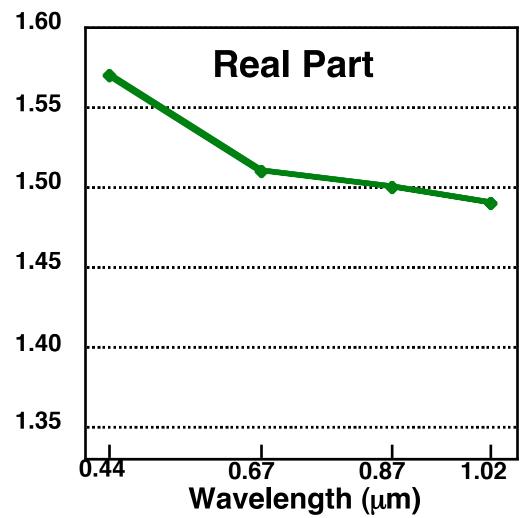
AERONET retrievals are driven by 31 variables :

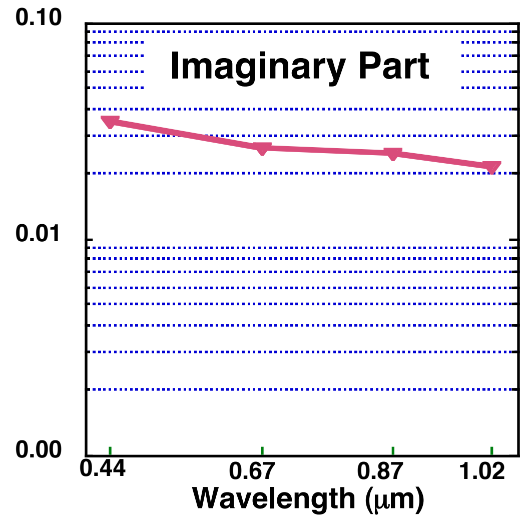
dV/lnr - size distribution (22 values);
n(λ) and k(λ) - ref. index (4 +4 values)
C_{spher} (%) - spherical fraction (1 value)

Particle Size Distribution: 0.05 μm ≤ R (22 bins) ≤ 15 μm



Complex Refractive Index at λ = 0.44; 0.67; 0.87; 1.02 μm





Single - Pixel Retrieval:

O. Dubovik
M. Herman
J.-L. Deuzé
F. Ducos
D. Tanré

f_j^* - ***PARASOL data***:

Angular measurements (~15 angles) of

- ***Intensity*** (λ = 0.49; 0.67; 0.87; 1.02 μm)
- ***Polarization*** (λ = 0.49; 0.67; 0.87 μm)

a_j - ***Parameters to be retrieved***:

-***Aerosol*** propetries:

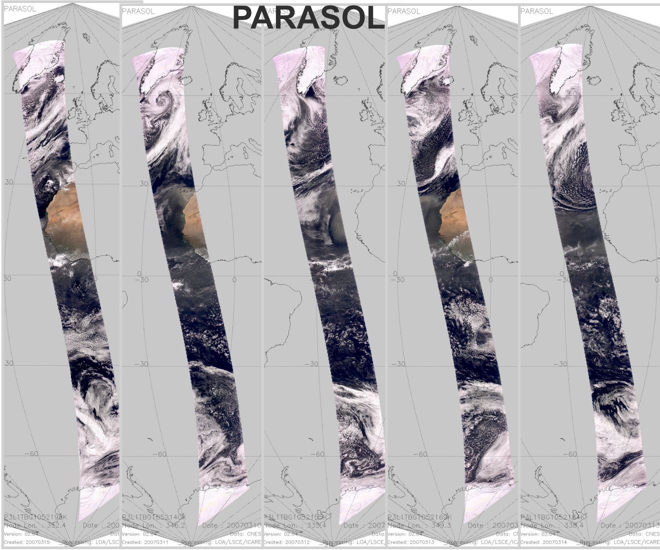
- size distribution; - real refractive index
- imaginary refractive index; - particle shape, - height

-***Surface*** properties (***over land***):

- BRF parameters; - BPRF parameters

!!!

$$\begin{cases} f_j^* \\ 0_j^* \end{cases} = \begin{pmatrix} \mathbf{F}_j \\ \mathbf{D}_j \end{pmatrix} a_j + \begin{matrix} \Delta_j^m \\ \Delta_j^a \end{matrix}$$



A Priori Constraints limiting derivatives (e.g. *Dubovik 2004*) of

- for aerosols (e.g. in AERONET, *Dubovik and King 2000) :*

- aerosol size distribution variability over size range;
- spectral variability of complex refractive index;

- for surface (e.g. in AERONET/satellite retrievals, *Sinuyk et al. 2007) :*

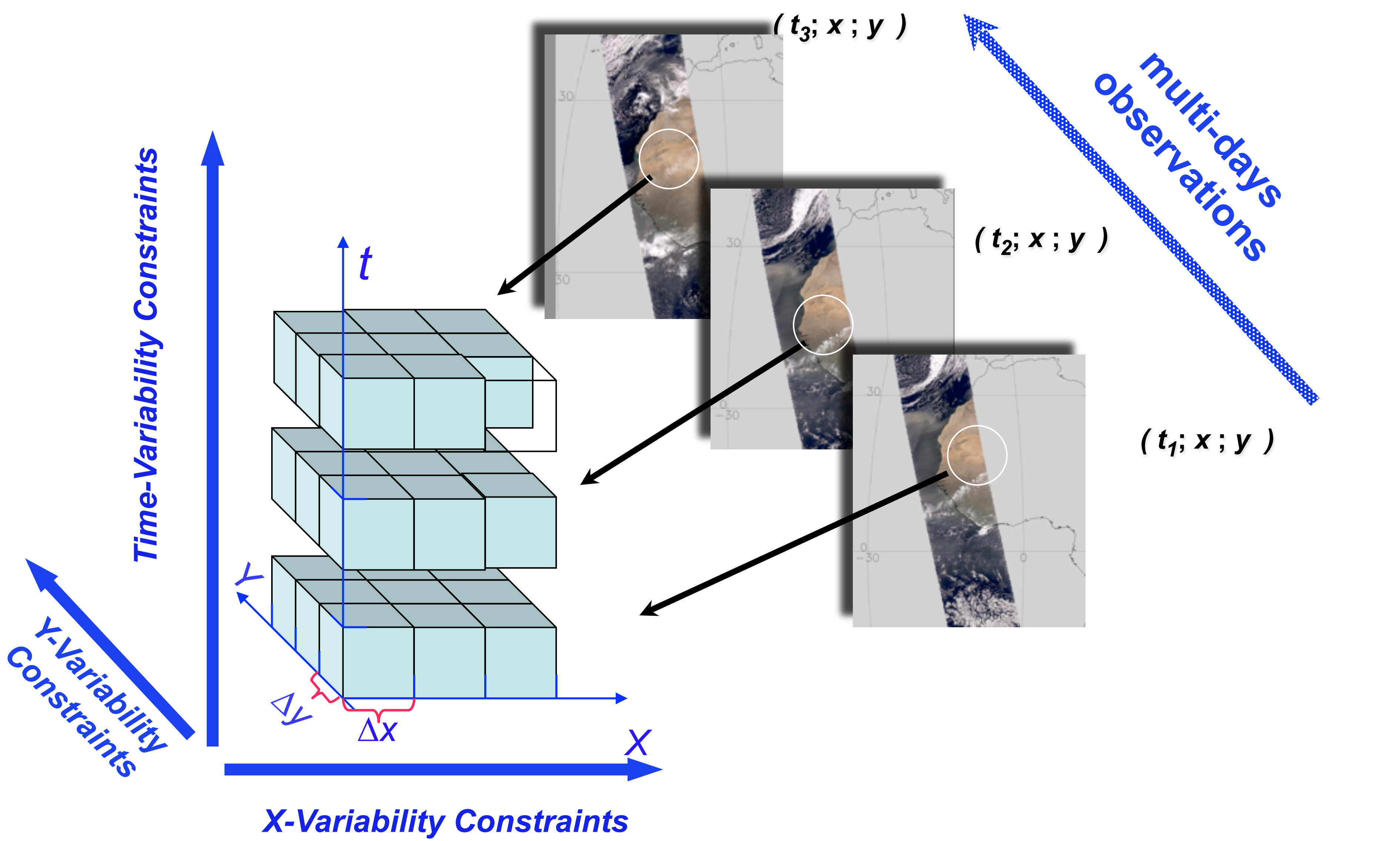
- spectral variability of BRF/ PBRF parameters.

Multi-term LSM statistically optimized ***Solution*** (*Dubovik and King 2000, Dubovik 2004*) :

$$a_j = \left(\mathbf{F}_j^T \mathbf{W}_j^{-1} \mathbf{F}_j + \gamma_j \Omega_j\right)^{-1} \left(\mathbf{F}_j^T \mathbf{W}_j^{-1} f_j^*\right)$$

,where $\Omega_j = \mathbf{D}_j^T \mathbf{D}_j; \; \mathbf{W}_i = \frac{1}{\varepsilon_f^2} \mathbf{C}_f; \quad \gamma_j = \frac{\varepsilon_f^2}{\varepsilon_a^2}$

The concept of multi-pixel retrieval



Multi - Pixel Retrieval:

$$\begin{cases}\begin{pmatrix} \boldsymbol{f}_1^* \\ o_1^* \\ \boldsymbol{f}_2^* \\ o_2^* \\ \boldsymbol{f}_3^* \\ o_3^* \\ \dots \\ O_t^* \\ O_x^* \\ O_y^* \end{pmatrix} = \begin{pmatrix} \mathbf{F}_1 & 0 & 0 \\ \mathbf{D}_1 & 0 & 0 \\ 0 & \mathbf{F}_2 & 0 \\ 0 & \mathbf{D}_2 & 0 \\ 0 & 0 & \mathbf{F}_3 \\ 0 & 0 & \mathbf{D}_3 \\ \mathbf{D}_{t,1} & \mathbf{D}_{t,2} & \mathbf{D}_{t,2} \\ \mathbf{D}_{x,1} & \mathbf{D}_{x,2} & \mathbf{D}_{x,3} \\ \mathbf{D}_{y,1} & \mathbf{D}_{y,2} & \mathbf{D}_{y,3} \end{pmatrix} \begin{pmatrix} \boldsymbol{a}_1 \\ \boldsymbol{a}_2 \\ \boldsymbol{a}_3 \end{pmatrix} + \begin{pmatrix} \Delta_1^m \\ \Delta_1^a \\ \Delta_2^m \\ \Delta_2^a \\ \Delta_3^m \\ \Delta_3^a \\ \Delta_t^a \\ \Delta_x^a \\ \Delta_y^a \end{pmatrix}\end{cases}$$

Single-Pixel Data (PARASOL measurements and physical a priori constraints) ***are used by the same way as in Single-Pixel retrieval.***

Multi-Pixel a priori constraints (*e.g.Dubovik et al. 2008*):

- limited ***spatial*** variability of each aerosol /surface parameter
- limited ***temporal*** variability of each aerosol /surface parameter

NOTE: *degree of variability constraints (smoothnes) can be different and adequately chosen for each parameter*

Multi-term LSM ***Multi-Pixel Solution:***

$$\begin{pmatrix} \boldsymbol{a}_1 \\ \boldsymbol{a}_2 \\ \boldsymbol{a}_3 \end{pmatrix} = \left[\begin{pmatrix} \mathbf{F}_1^T \mathbf{W}_1^{-1} \mathbf{F}_1 & 0 & 0 \\ 0 & \mathbf{F}_2^T \mathbf{W}_2^{-1} \mathbf{F}_2 & 0 \\ 0 & 0 & \mathbf{F}_3^T \mathbf{W}_3^{-1} \mathbf{F}_3 \end{pmatrix} + \begin{pmatrix} \gamma_1 \Omega_1 & 0 & 0 \\ 0 & \gamma_2 \Omega_2 & 0 \\ 0 & 0 & \gamma_3 \Omega_3 \end{pmatrix} + \gamma_x \Omega_x + \gamma_y \Omega_y + \gamma_t \Omega_t \right]^{-1} \begin{pmatrix} \mathbf{F}_1^T \mathbf{W}_1^{-1} \Delta \boldsymbol{f}_1^p \\ \mathbf{F}_2^T \mathbf{W}_2^{-1} \Delta \boldsymbol{f}_2^p \\ \mathbf{F}_3^T \mathbf{W}_3^{-1} \Delta \boldsymbol{f}_3^p \end{pmatrix}$$

,where $\Omega_x = \mathbf{D}_x^T \mathbf{D}_x;\ \Omega_y = \mathbf{D}_y^T \mathbf{D}_y;\ \Omega_t = \mathbf{D}_t^T \mathbf{D}_t;\ \gamma_x = \frac{\varepsilon_f^2}{\varepsilon_x^2};\ \gamma_y = \frac{\varepsilon_f^2}{\varepsilon_y^2};\ \gamma_t = \frac{\varepsilon_f^2}{\varepsilon_t^2}$

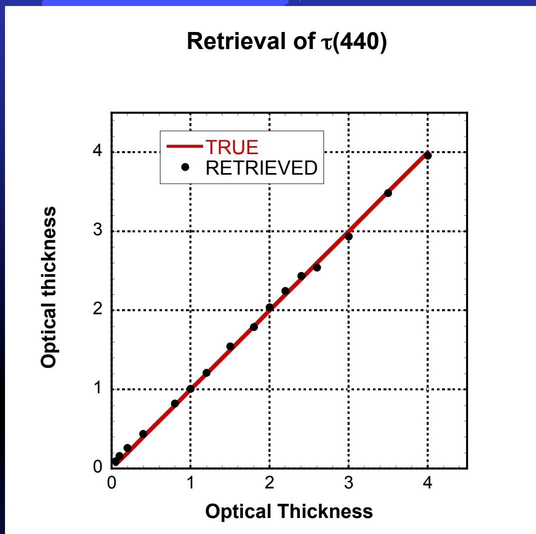
***PARASOL**: 0.44, 0.49 (p+), 0.565, 0.675 (p+), 0.87(p+), 1.02 μm*

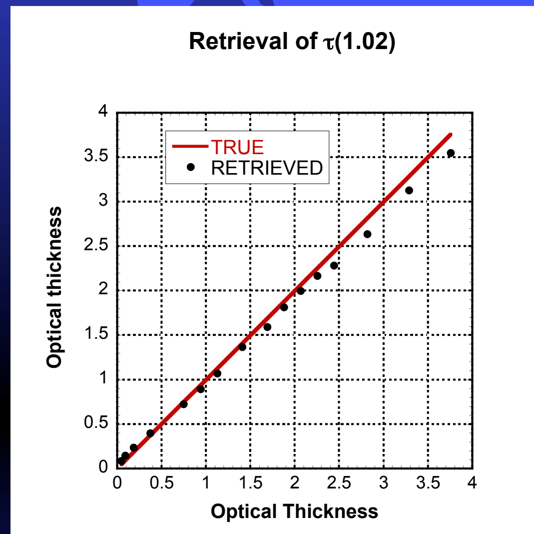
NOISE ADDED: 1% for I(λ), 0.5% for Q(λ)/I(λ) and U(λ)/I(λ) !!!

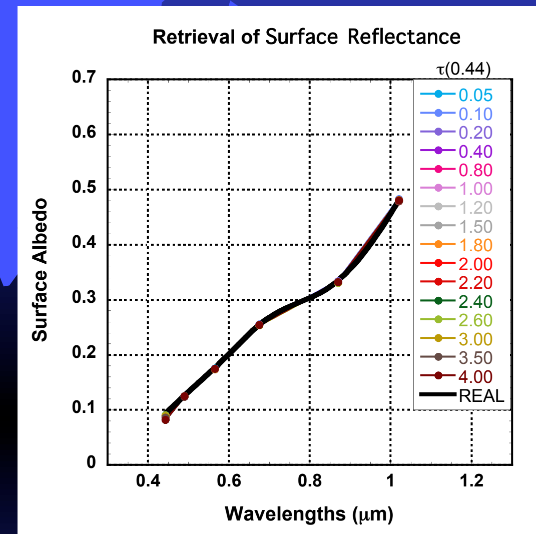
<u>Multi-Pixel Retrieval</u> (i.e. temporal and spatial variability of surface and aerosol is limited)

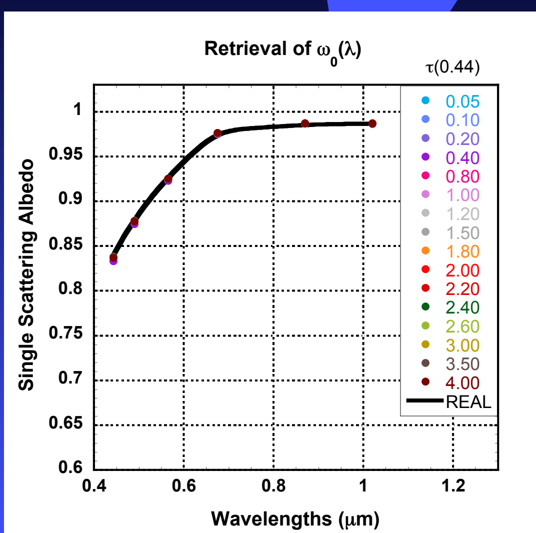
Desert Dust aerosol (non-spherical!!!)

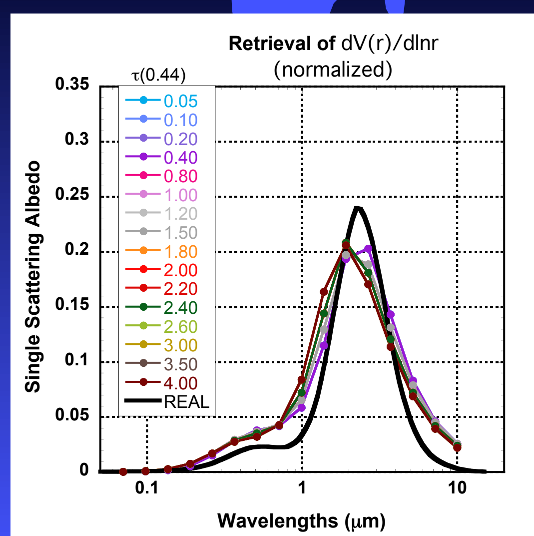
Dubovik et al. AMT, 2011

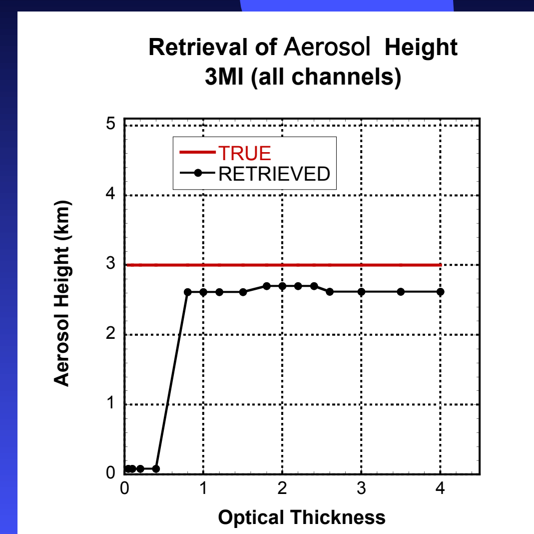




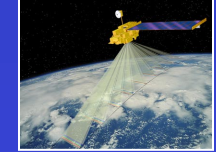
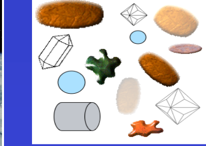
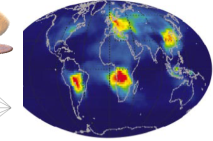








Described in Dubovik et al., AMT, 2011

Algorithm Status:

1. <u>Core Algorithm is developed and performs well:</u>

- uses very elaborated aerosol and RT models;
- based on rigorous statistical optimization;
- *performs well in numerical test (Dubovik et al. 2011, Kokhanovsky et al. 2010);*
- *has a lot of flexibility for constraining retrieval: both for single-pixel and/or multi-pixel scenarios)*

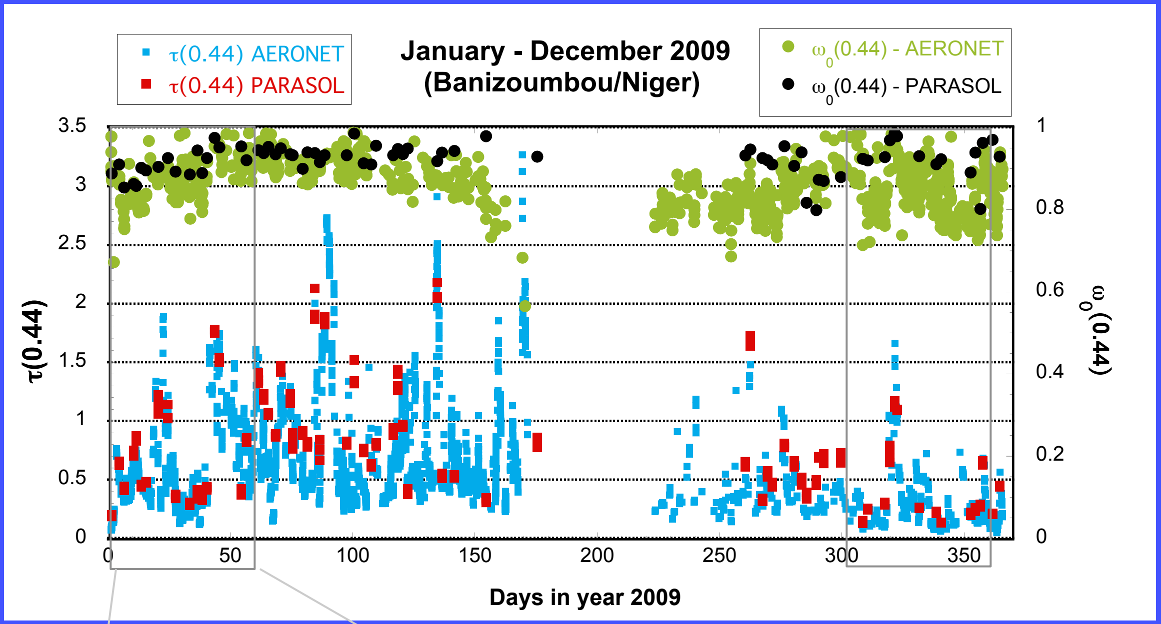
2. <u>Issues:</u>

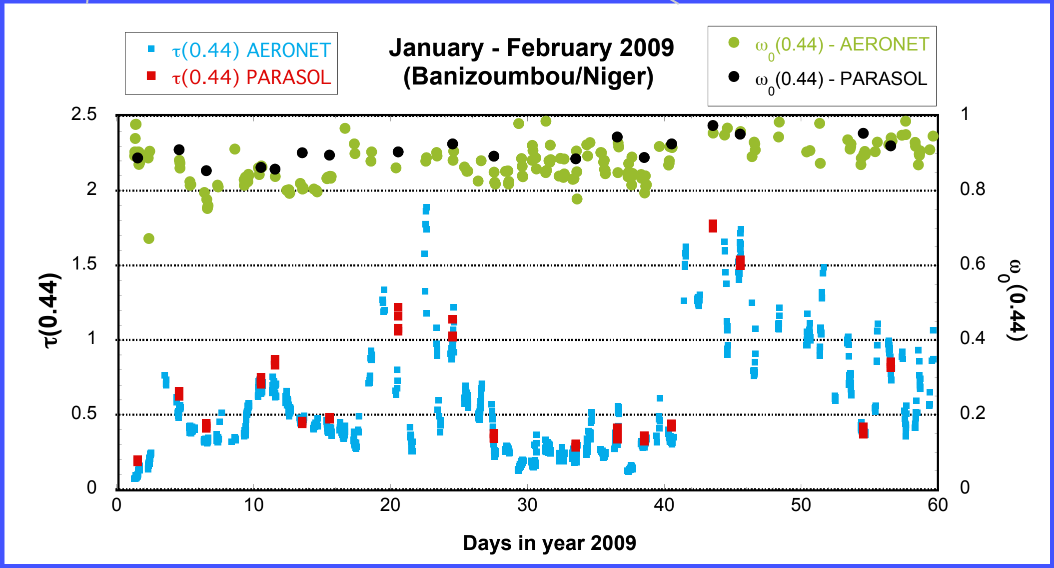
- too long - 10 sec per 1 pixel!!!
- needs to be optimally set for operational processing
- cloud – screening – need to be improved !!!

<u>Main Objective:</u>

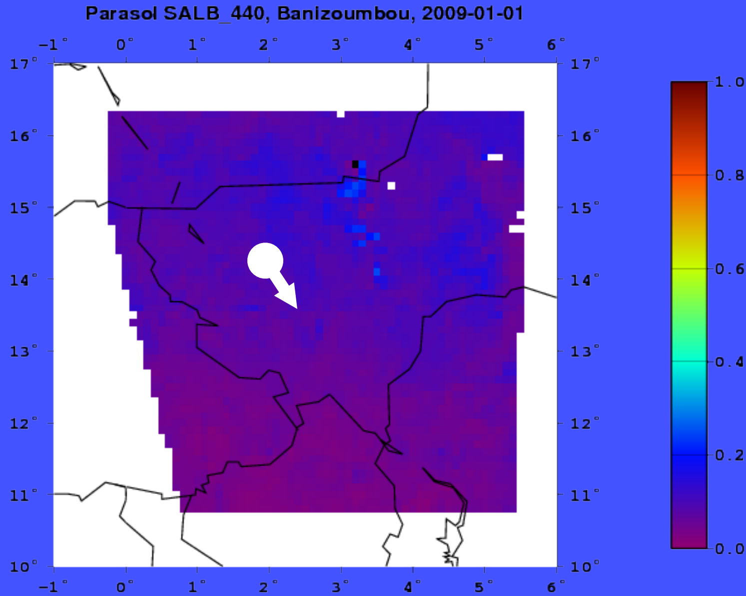
to make algorithm practical

Banizoumbou NIGER





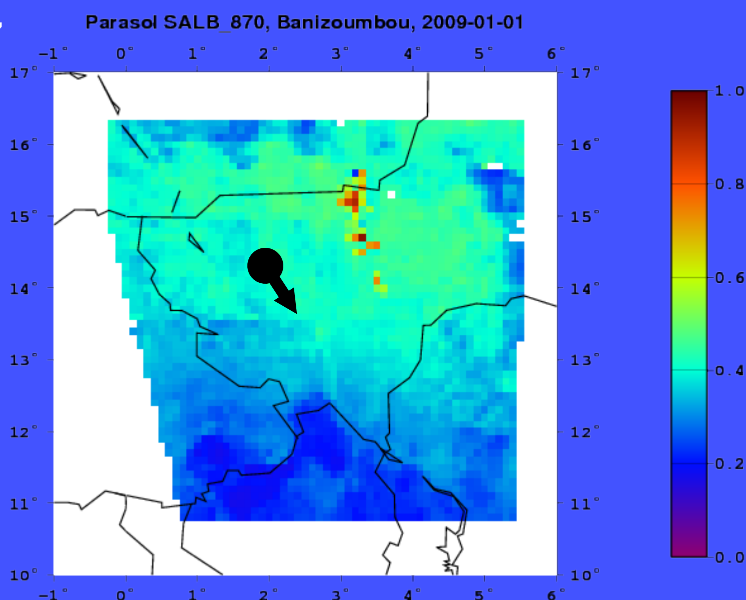
0.44



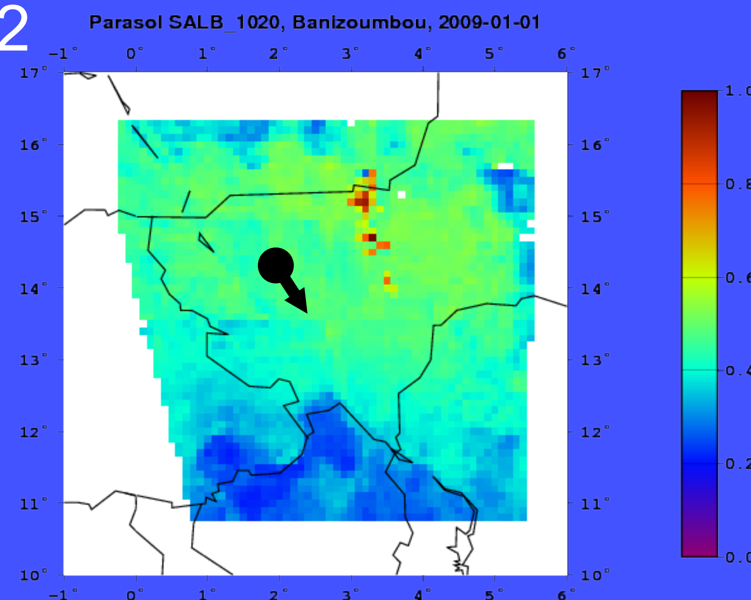
Surface Albedo

Banizoumbou
NIGER

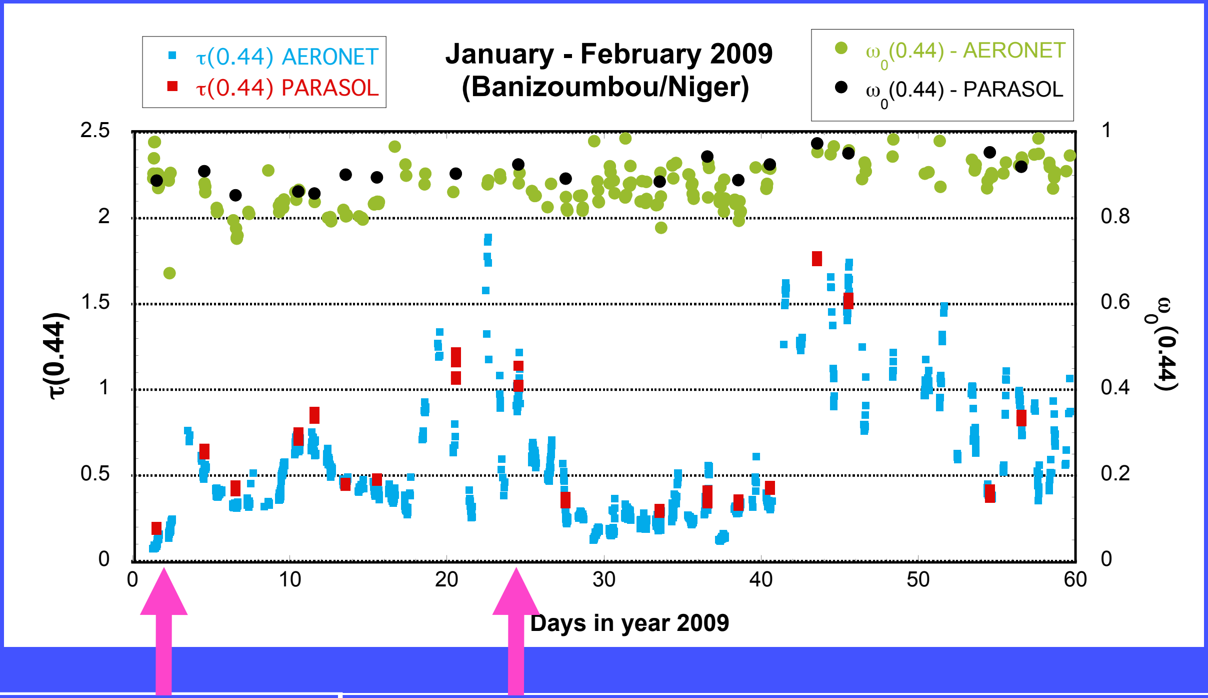
0.87

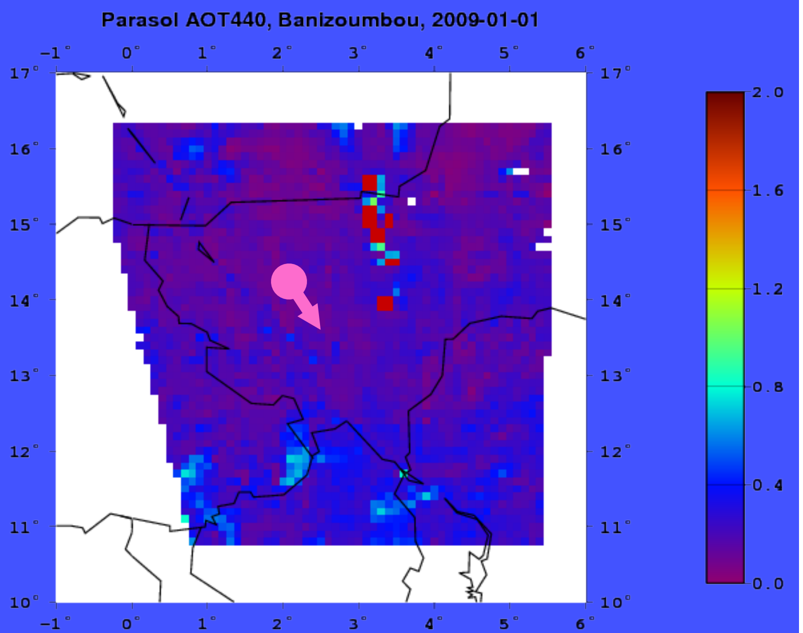


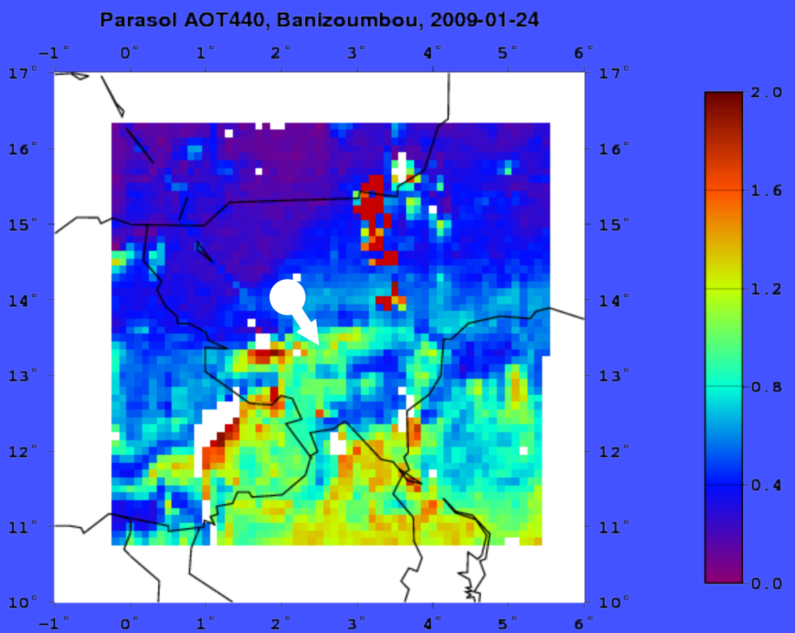
1.02



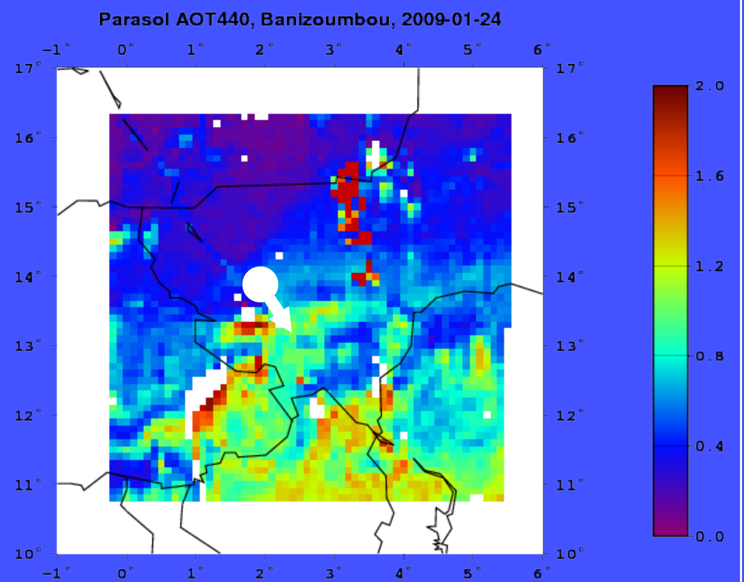
Banizoumbou
NIGER







$\tau(0.44)$

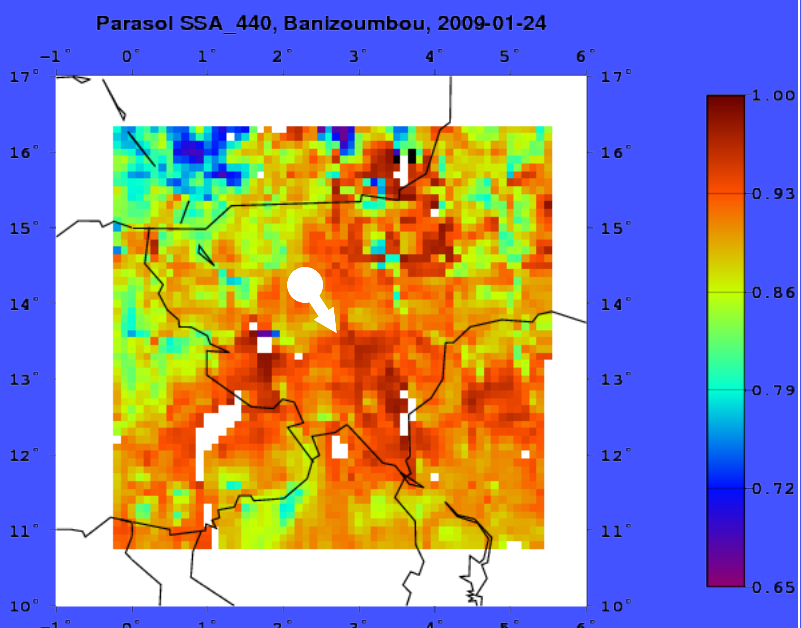


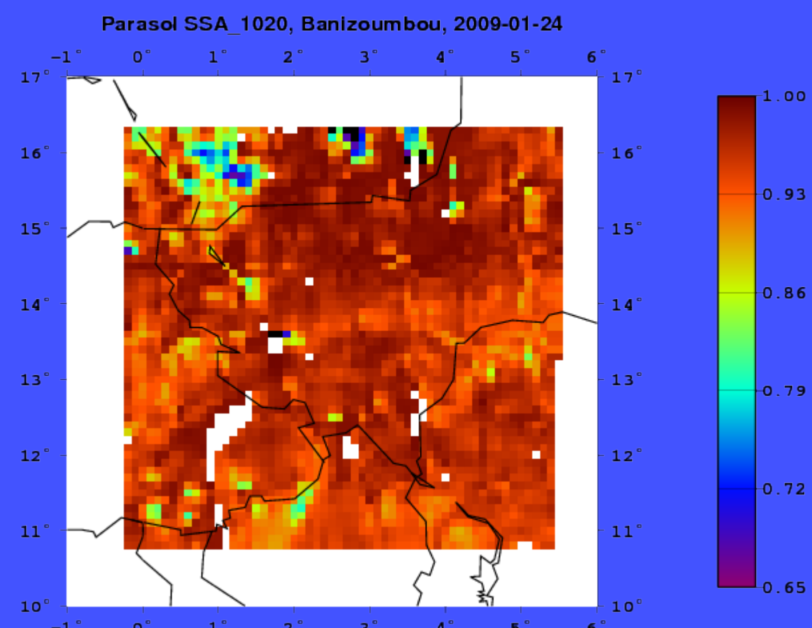
Banizoumbou

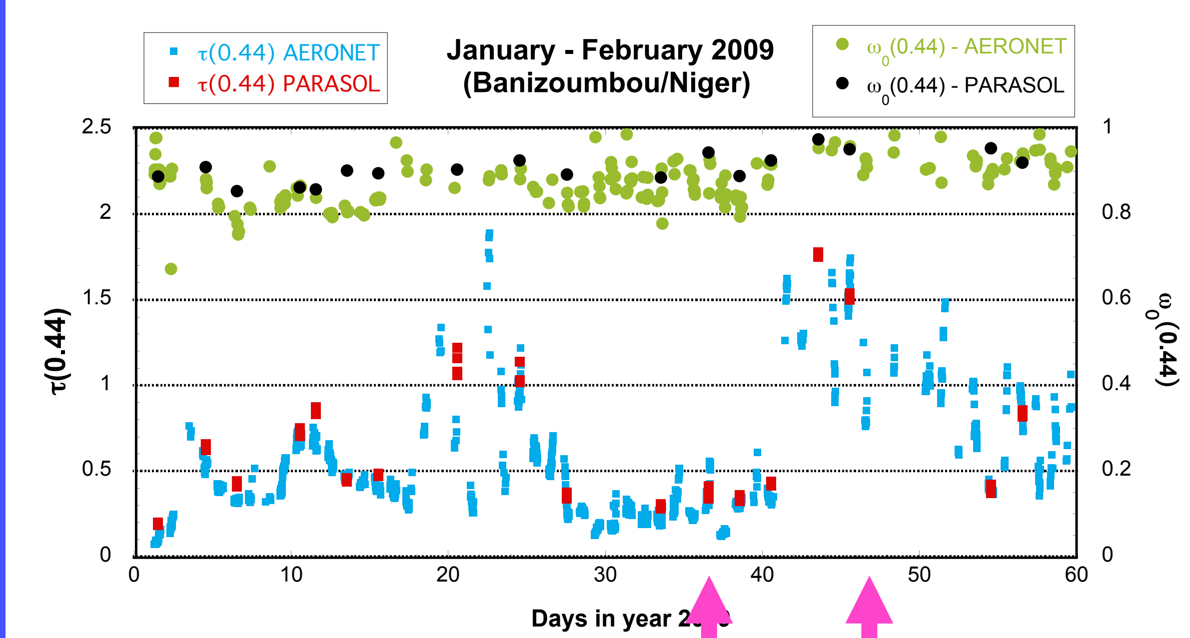
NIGER

$\omega_0(0.44)$

$\omega_0(1.02)$

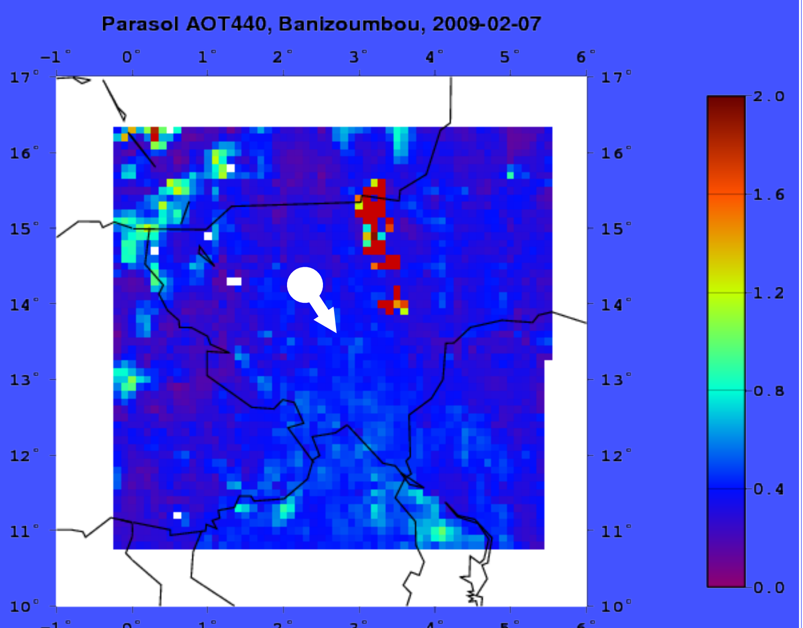


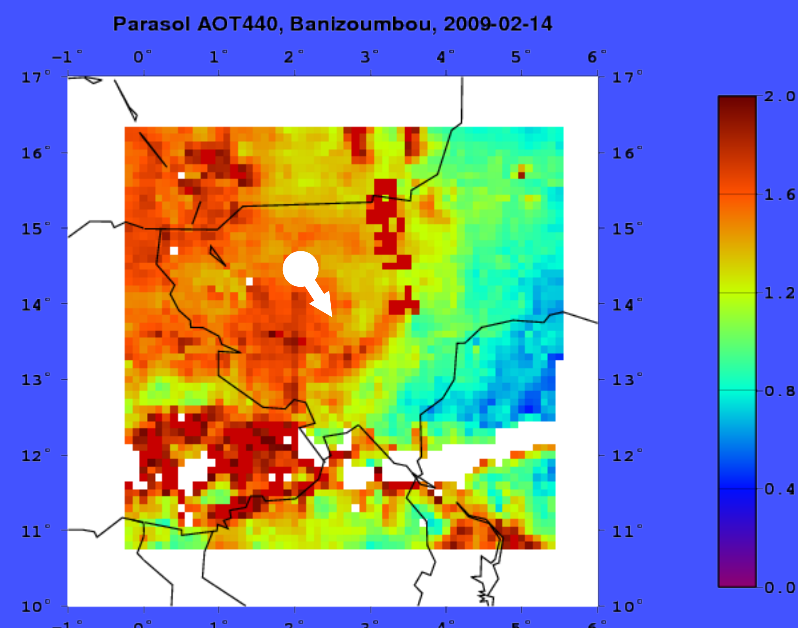




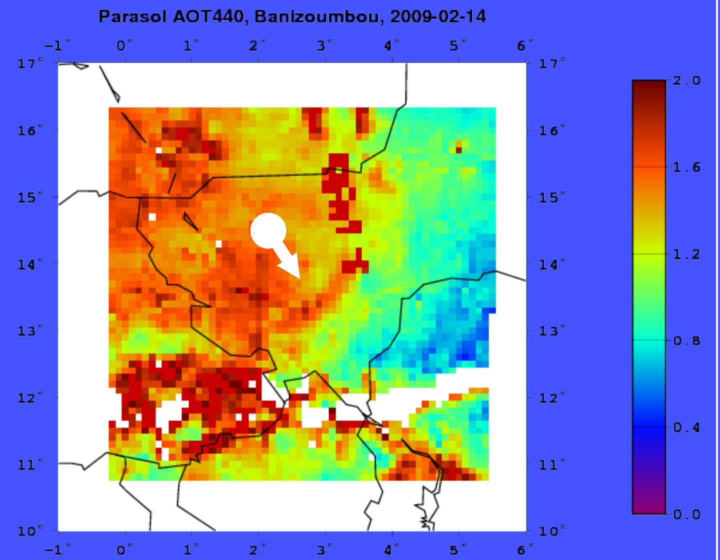
Banizoumbou

NIGER





τ(0.44)

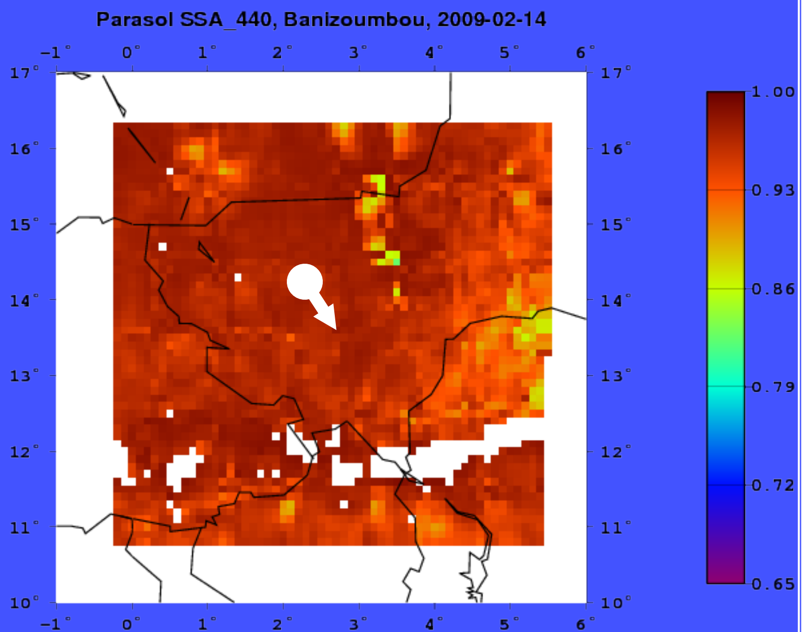


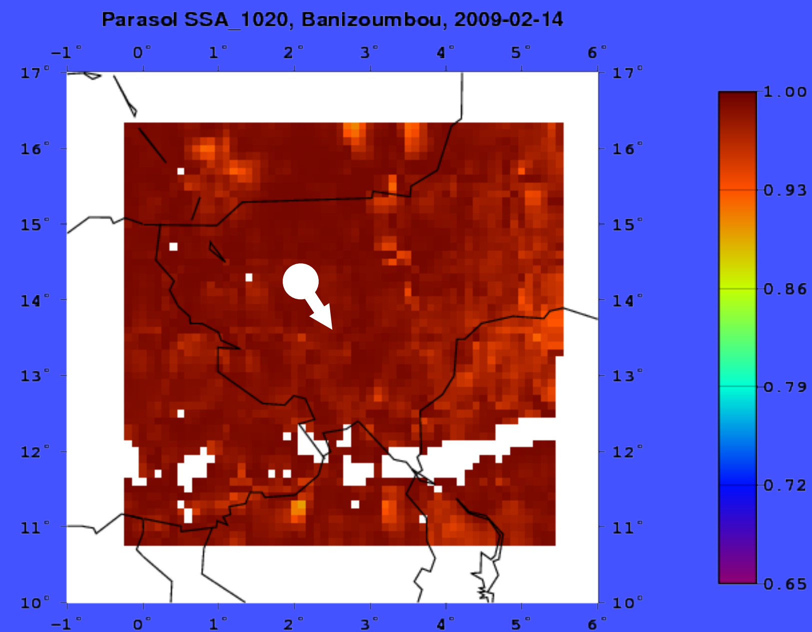
Banizoumbou

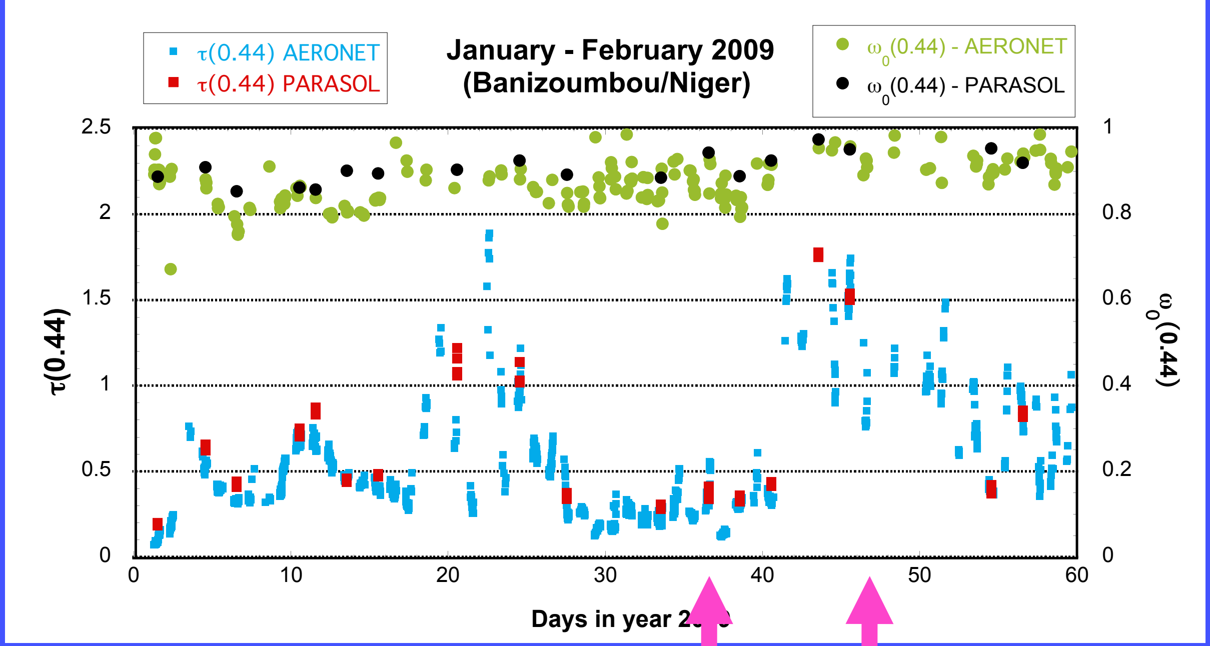
NIGER

$\omega_0(0.44)$

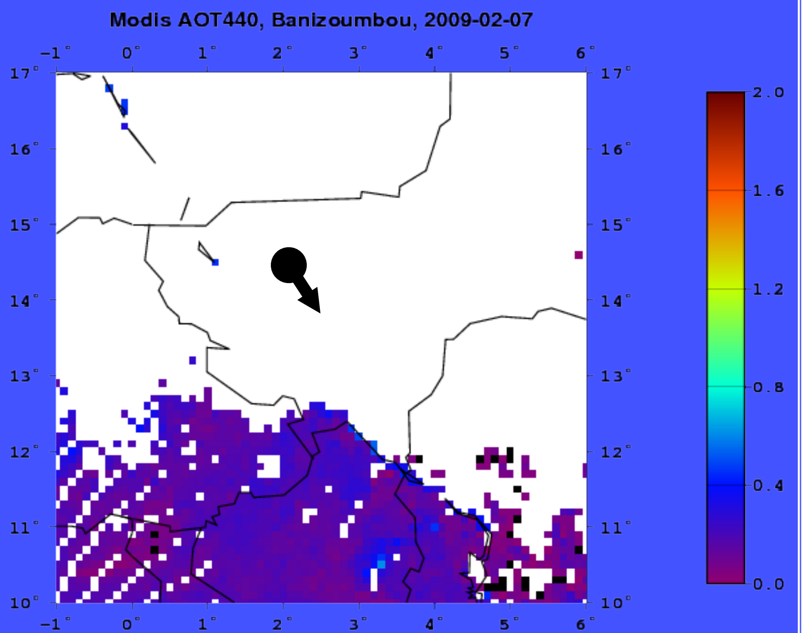
$\omega_0(1.02)$

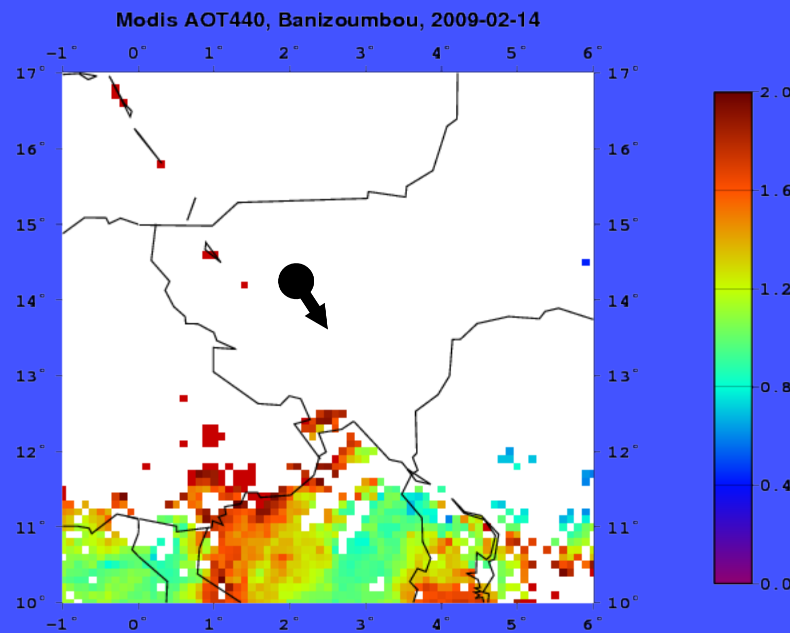






MODIS (dark target)



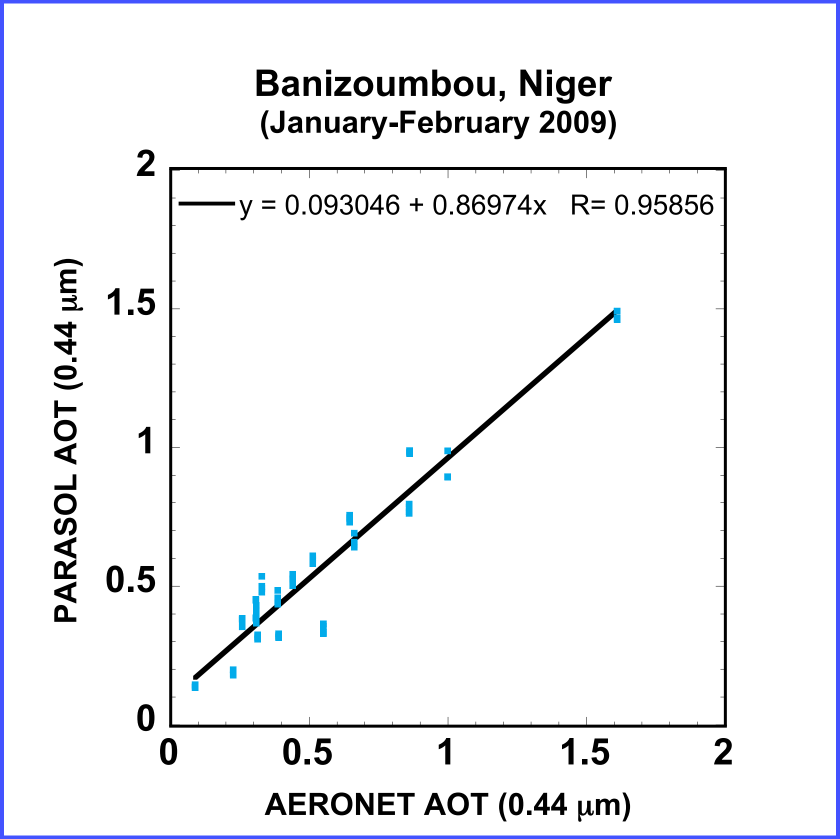


Dust and biomass
Banizoumbu/Niger

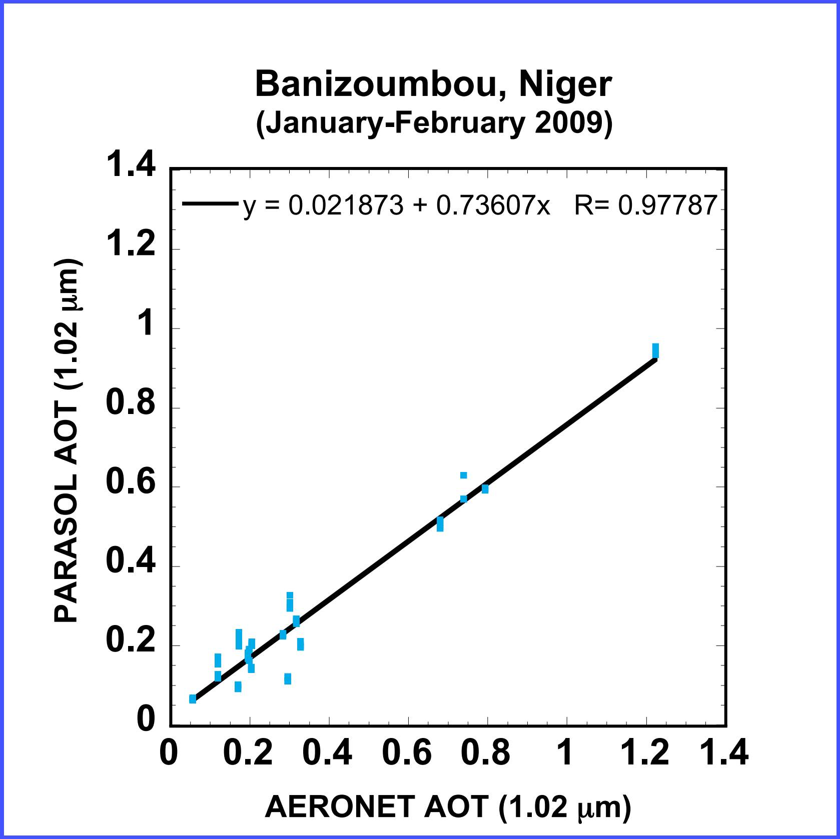
Optical Thickness

PARASOL versus AERONET

0.44 μm



1.02 μm

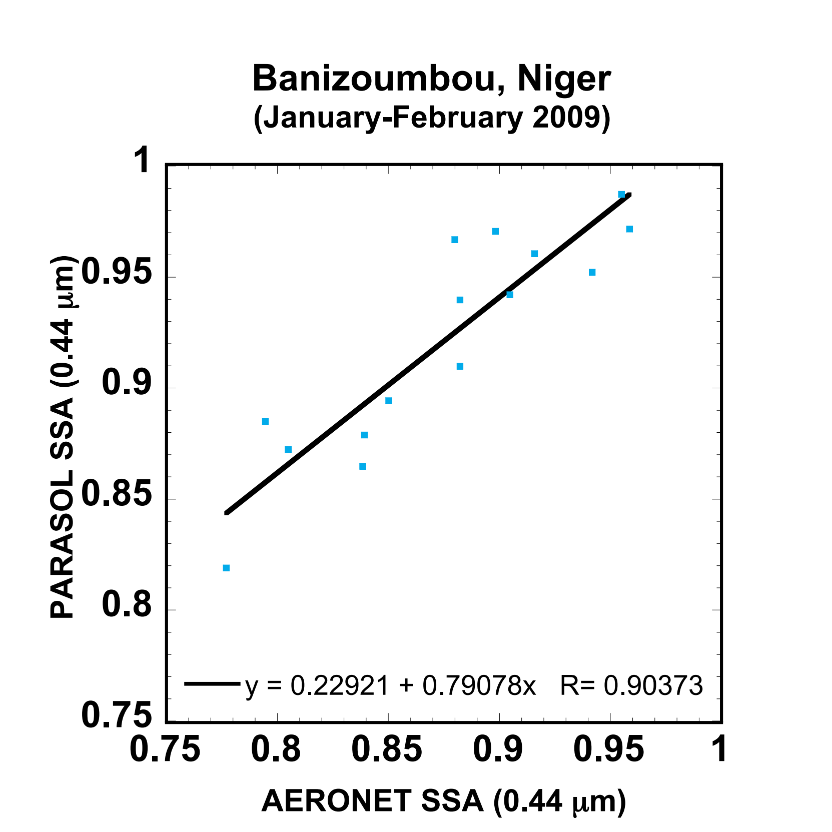


Dust and biomass
Banizoumbu/Niger

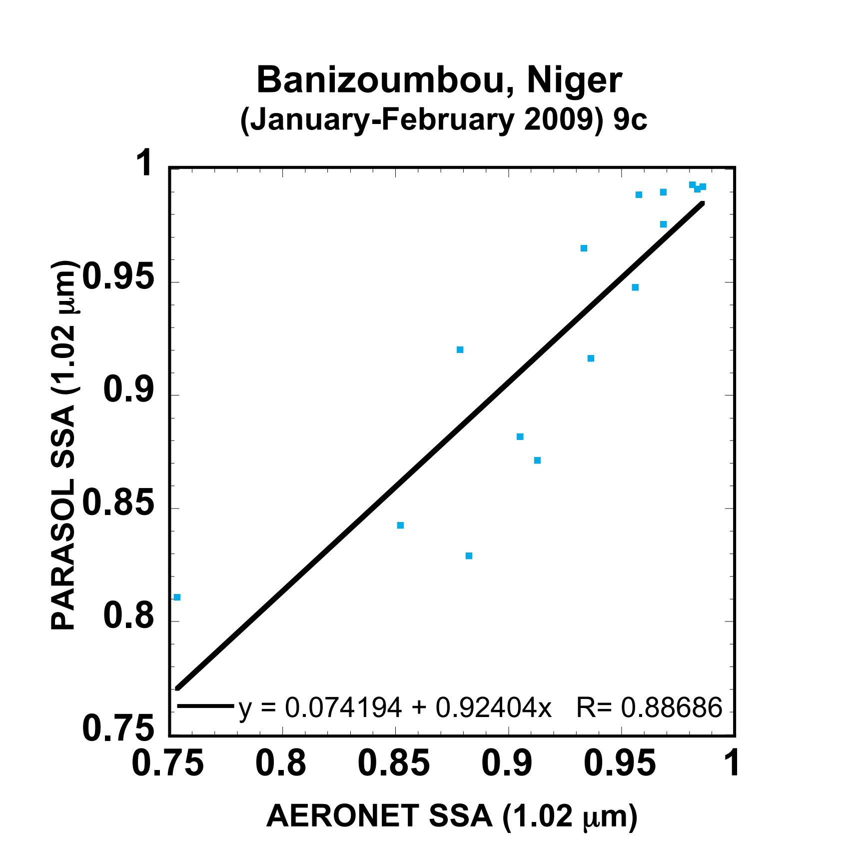
Single Scattering Albedo

PARASOL versus AERONET

0.44 μm

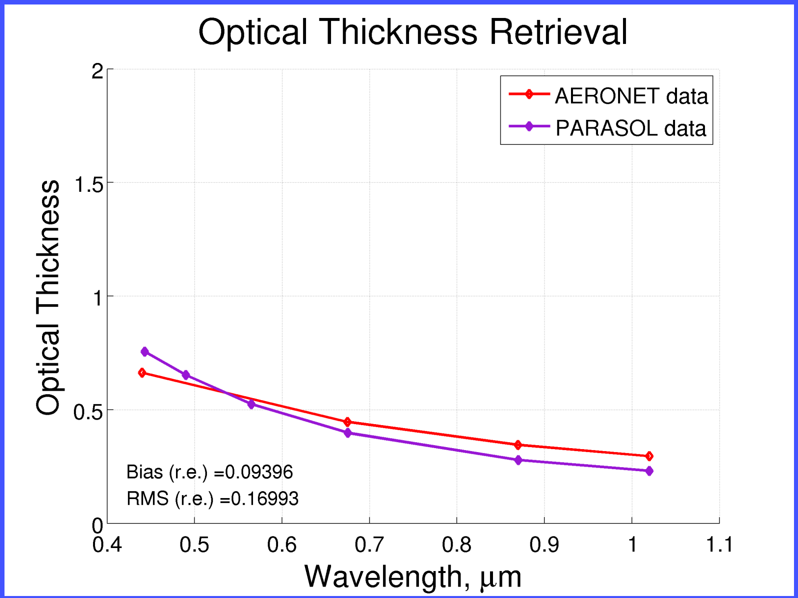


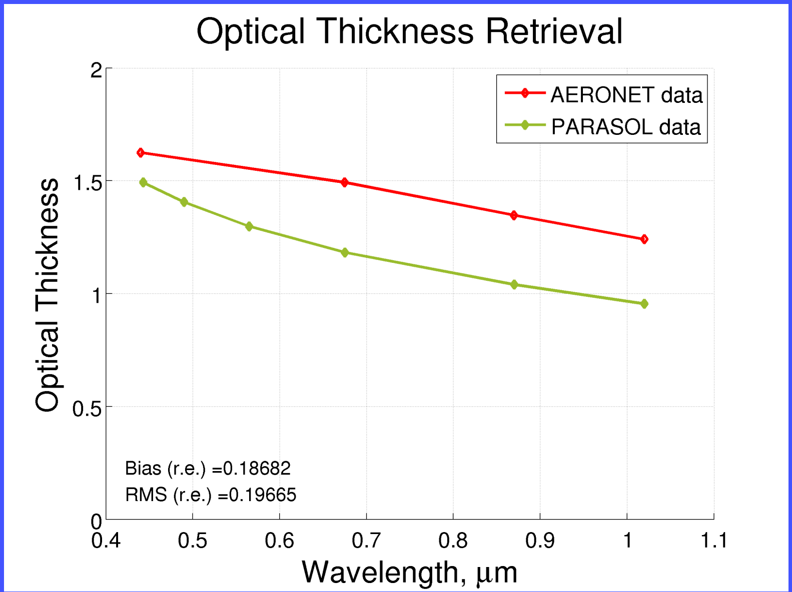
1.02 μm

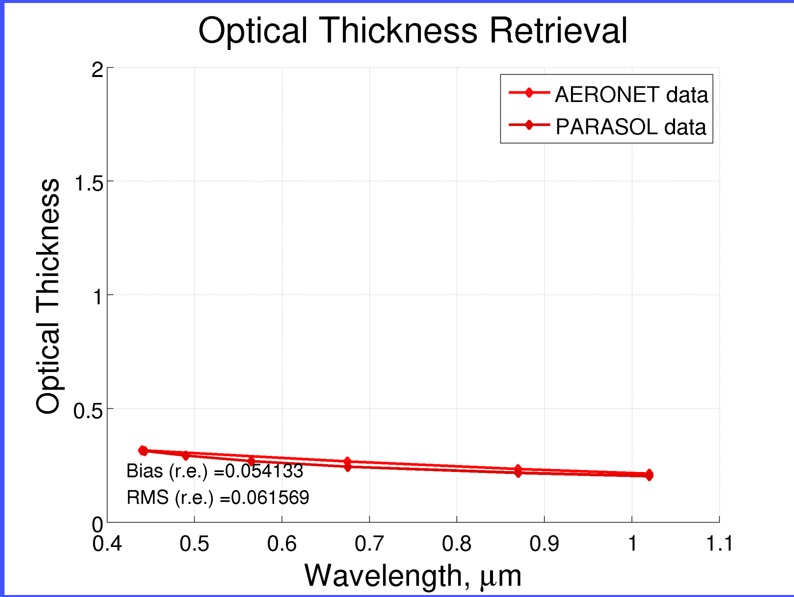


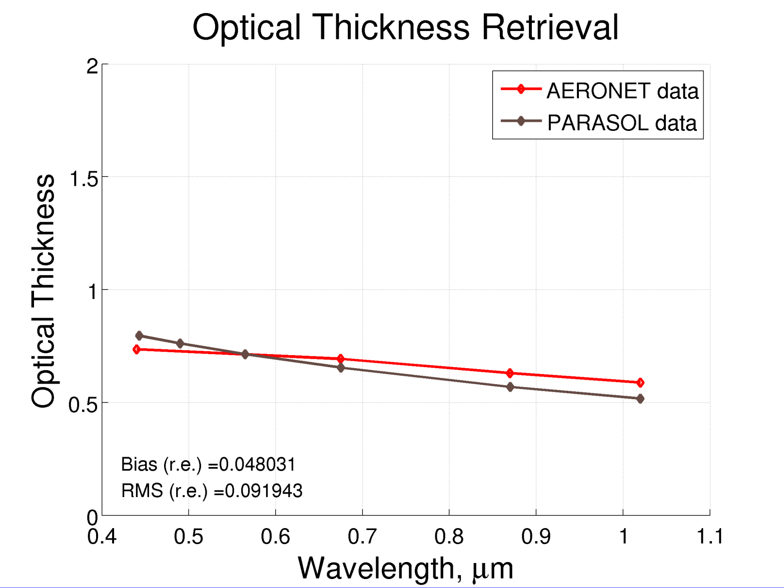
PARASOL versus AERONET

Dust and biomass
Banizoumbu/Niger



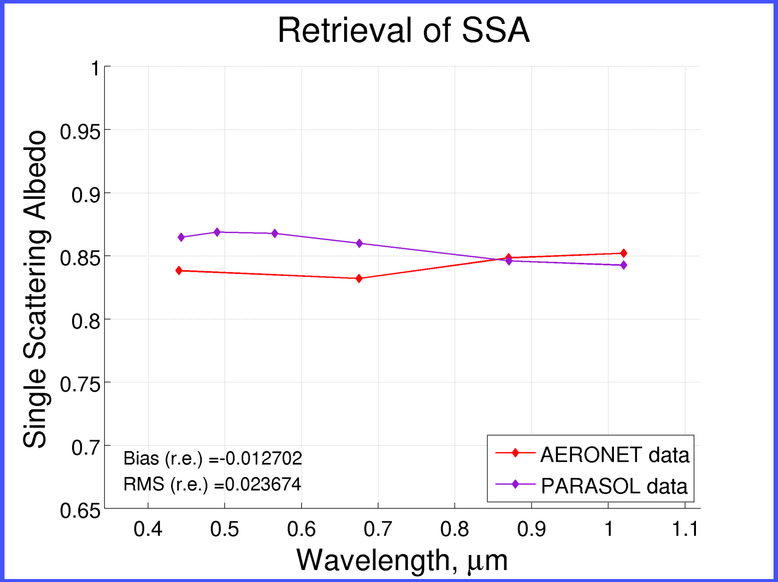


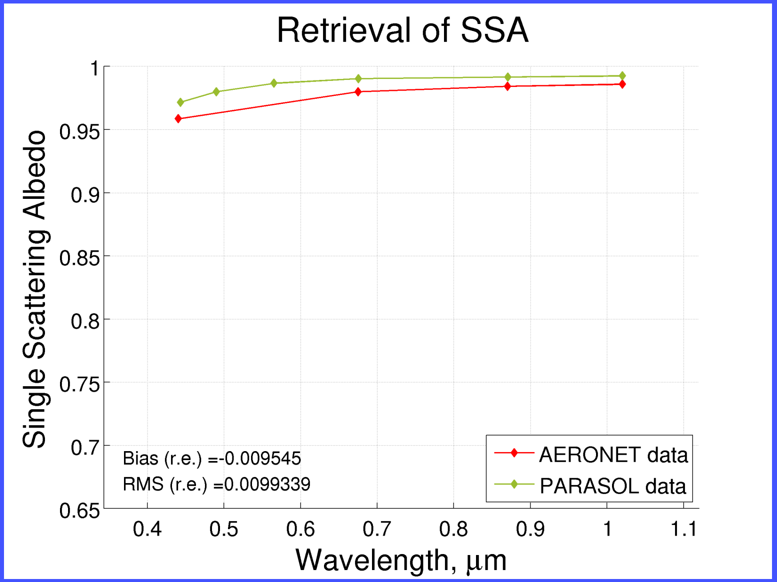


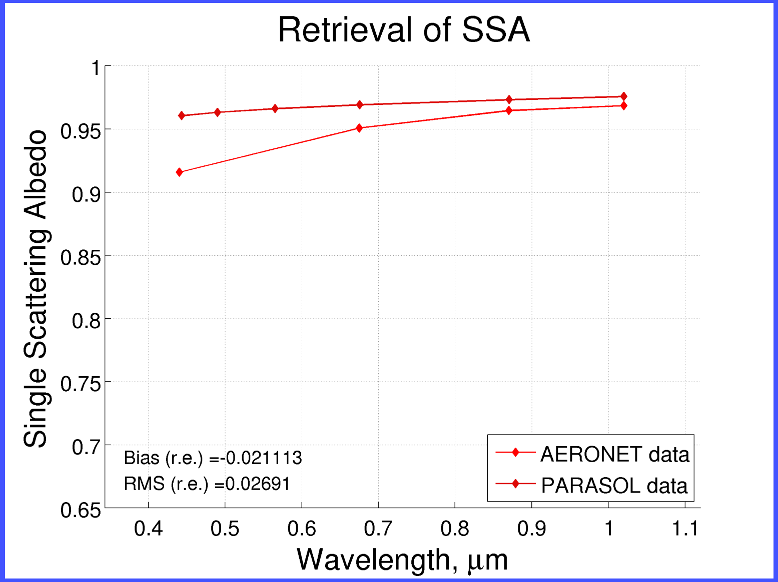


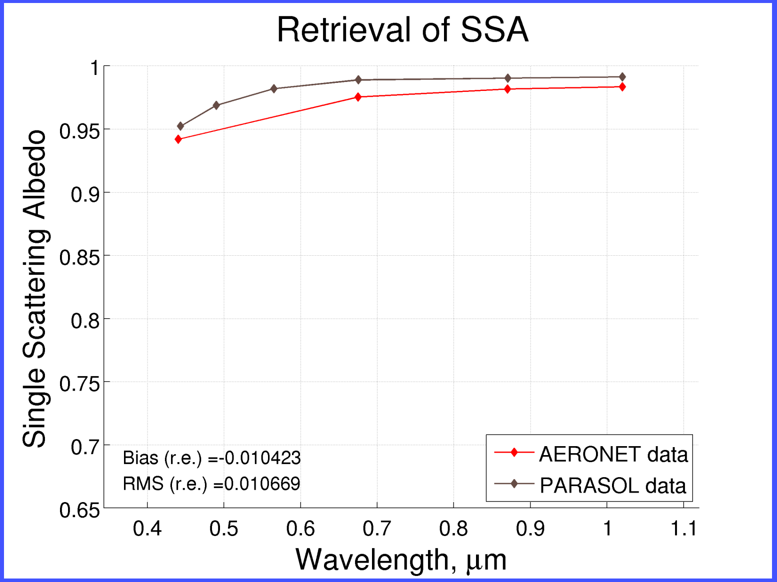
PARASOL versus AERONET

Dust and biomass
Banizoumbu/Niger



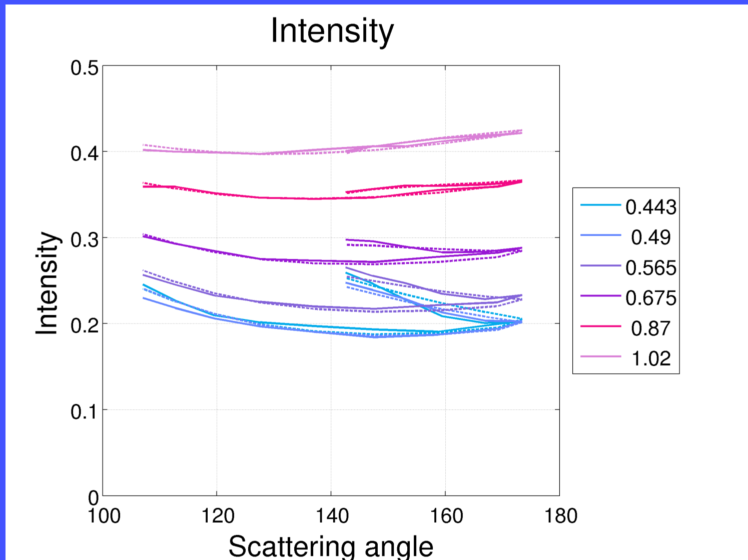


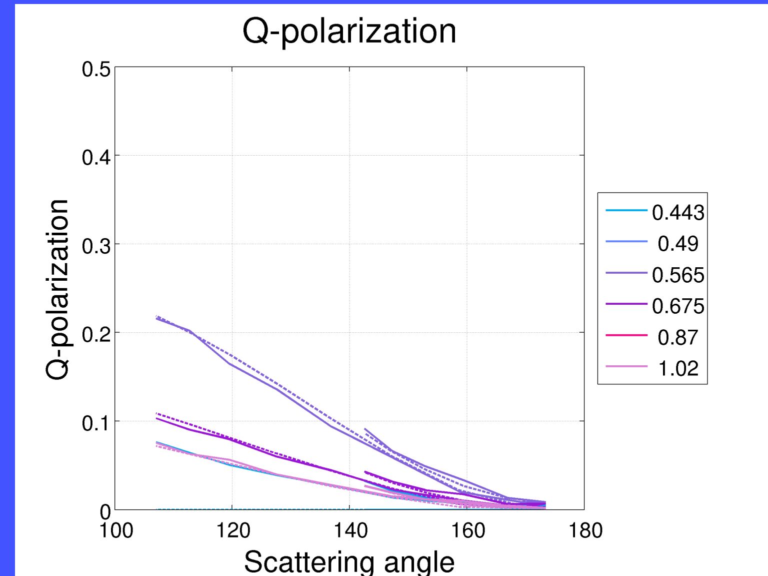


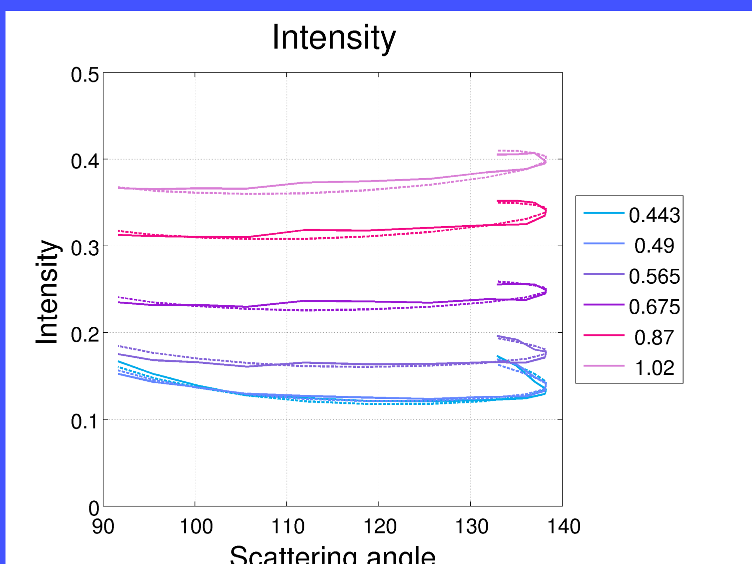


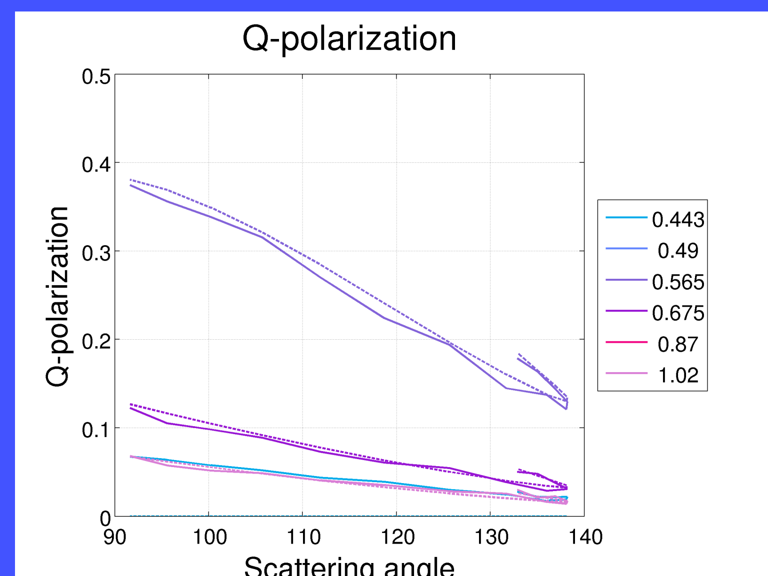
Fit of PARASOL observations

Dust and biomass Banizoumbu/Niger









Sendai, Japan, August 20 - 21, 2010

Life turning contacts

(with ~ 60 years old these days)

Young guy (in 1992....)

IRS '92: Tallinn, Estonia, 3-8 August 1992

Terry and Michael visit Minsk, 1993

Arrived at NASA/GSFC, ~1997

Arrived at LOA/Lille, ~ 2006