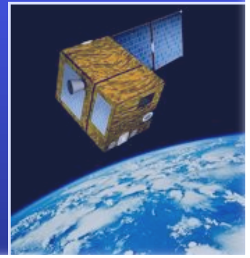
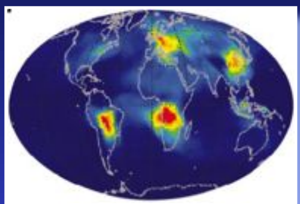
An approach for comprehensive retrieval of aerosol properties from enhanced satellite observations.





O. Dubovik, M. Herman, A. Holdak, T. Lapyonok, D. Tanré, J.-L. Deuzé, F. Ducos, 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

EGU General Assembly, Vienna, Austria , 03 – 08 April 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:

a lot !!!

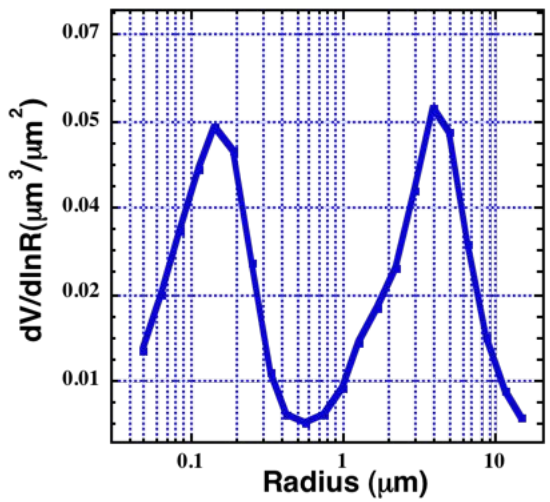
$$(N^t_\lambda + N^P_\lambda) \times N_\Theta = (6+3) \times 16 = 144$$

independent measurements

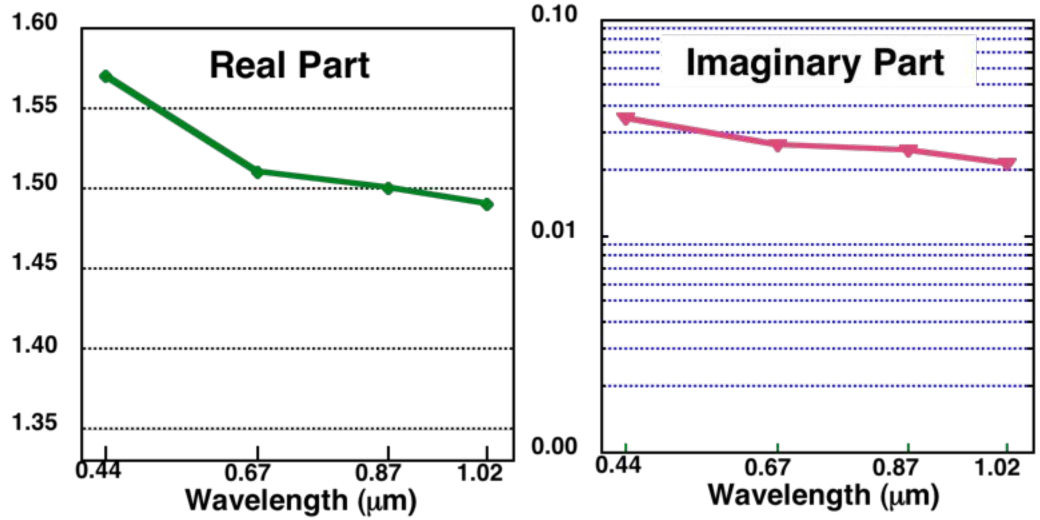
AERONET retrievals are driven by 31 variables :

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

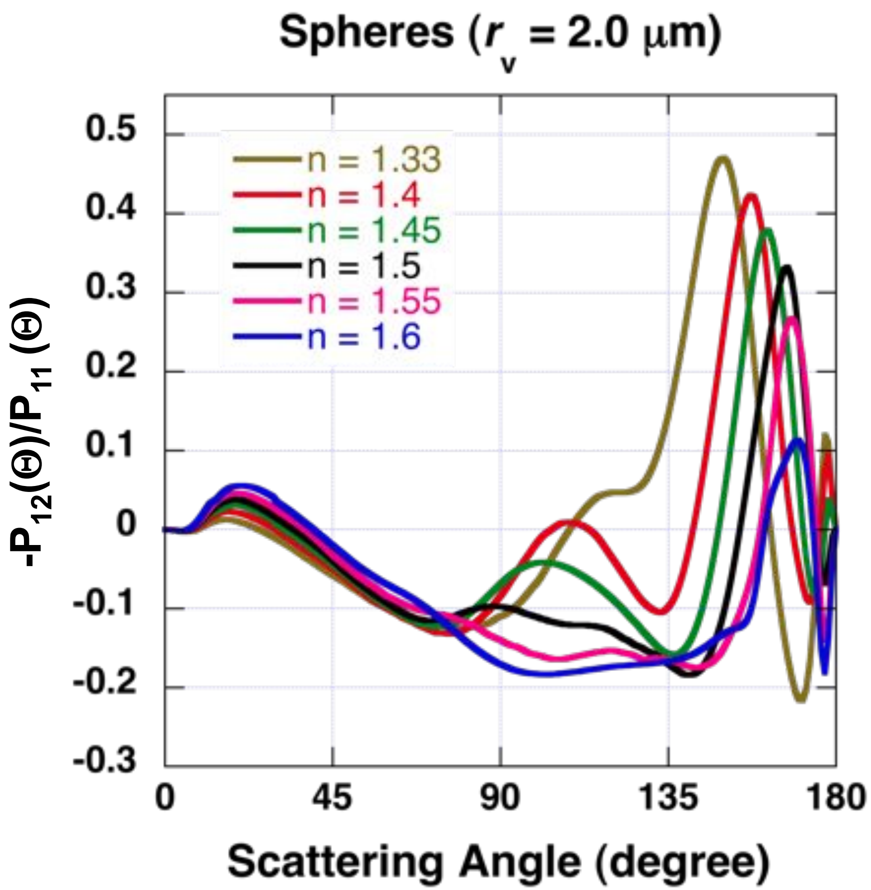


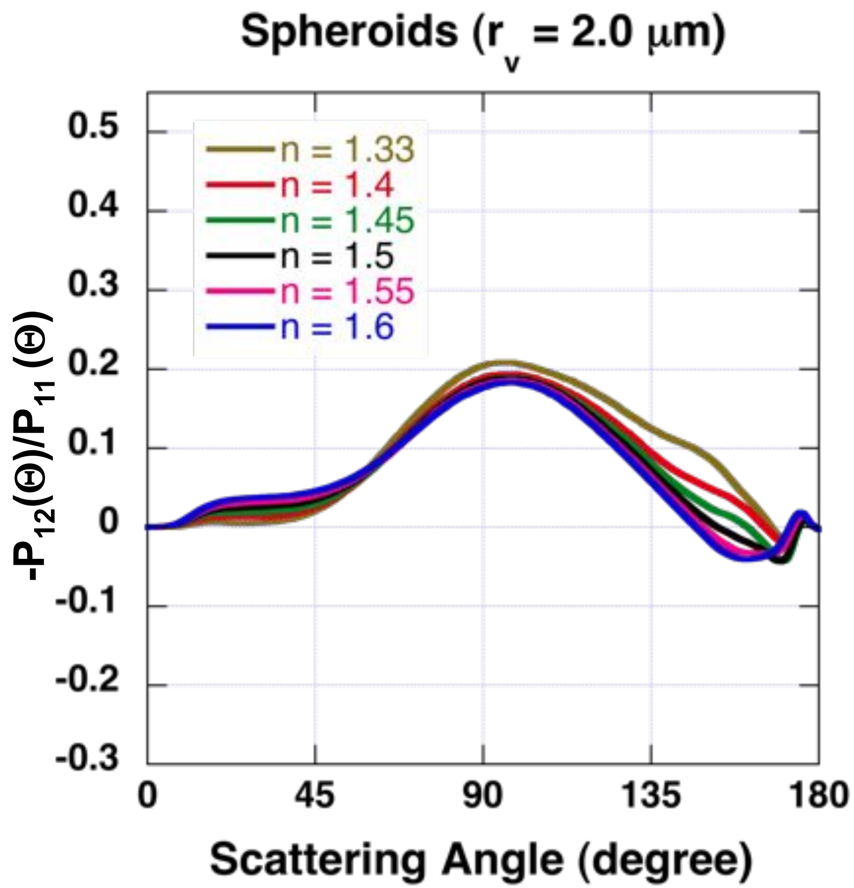
Complex Refractive Index at λ = 0.44; 0.67; 0.87; 1.02 μm



Sensitivity of polarization to particle shape

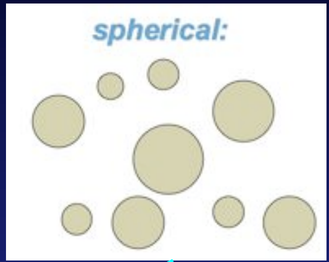
Coarse aerosol



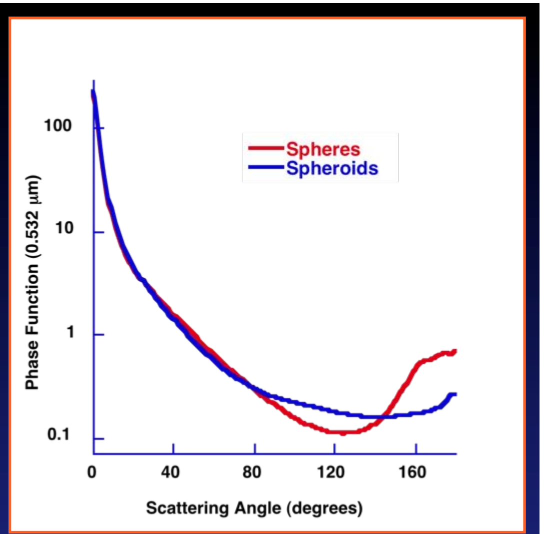


Mixing of particle shapes

retrieved

C × 

+ (1-C) × 



$$\tau(\lambda) = C\int_{r_{min}}^{r_{max}} K_\tau^{spherical}(k;n;r)V(r)dr + (1-C)\int_{r_{min}}^{r_{max}}\left(\int_{\varepsilon_{min}}^{\varepsilon_{max}} K_\tau^{\varepsilon}(k;n;r,\varepsilon)N(\varepsilon)d\varepsilon\right)V(r)dr$$

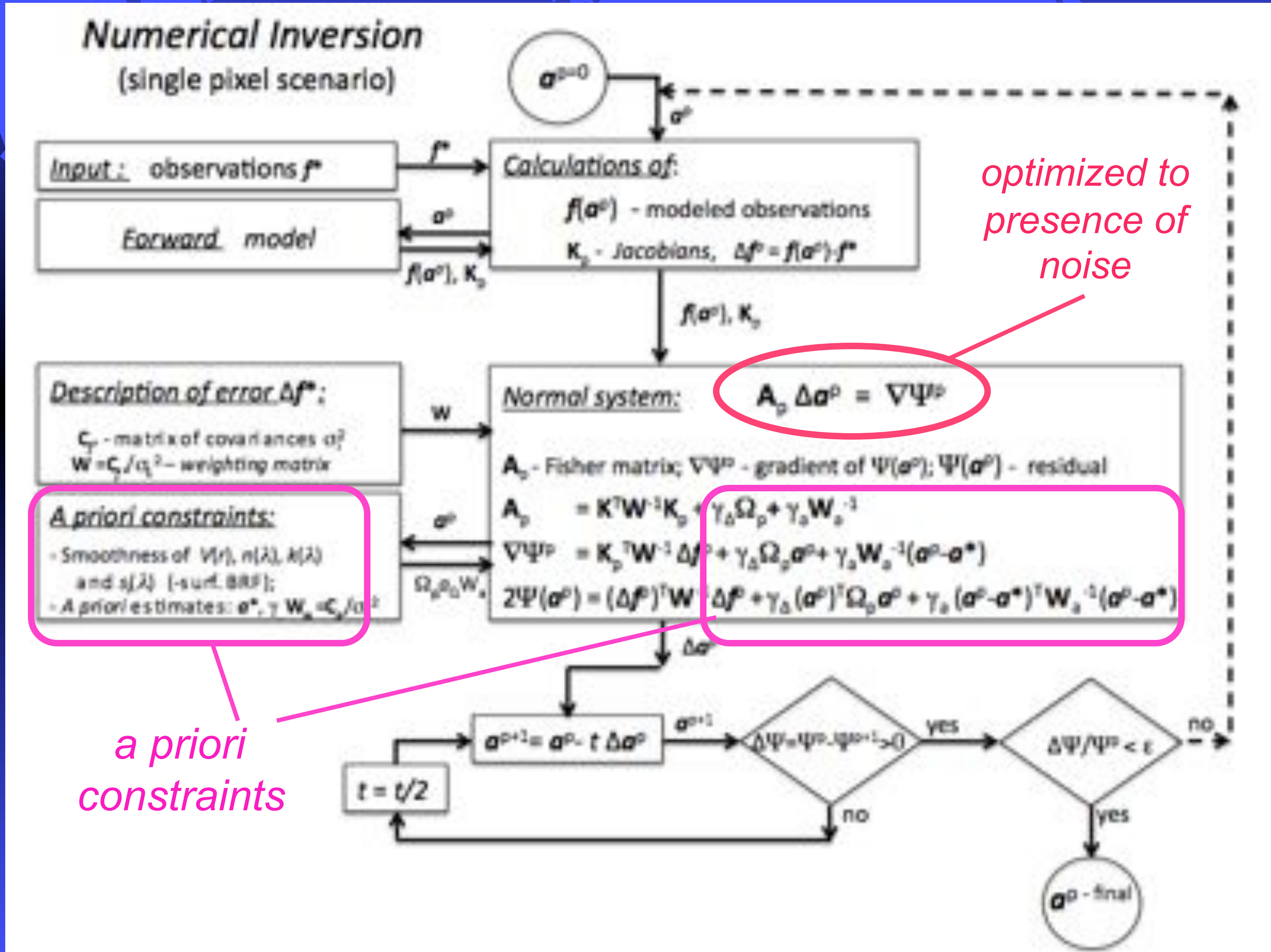
Aspect ratio distr.

ASSUMPTIONS:

- dV/dlnr - volume size distribution is the same for both components;
- non-spherical - mixture of randomly oriented polydisperse spheroids;
- aspect ratio distribution N(ε) is fixed to the retrieved by Dubovik et al. 2006

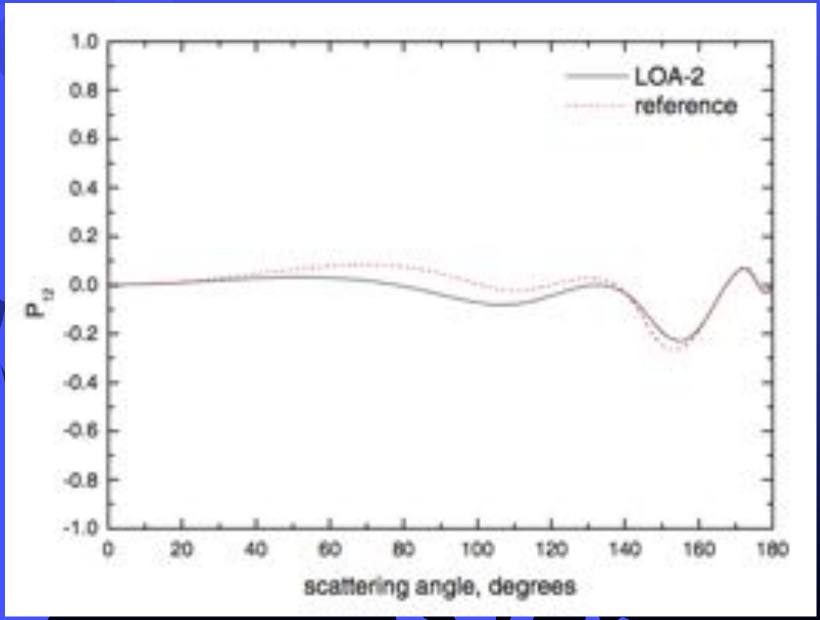
« AERONET like » statistically optimized « no look-up tables » inversion

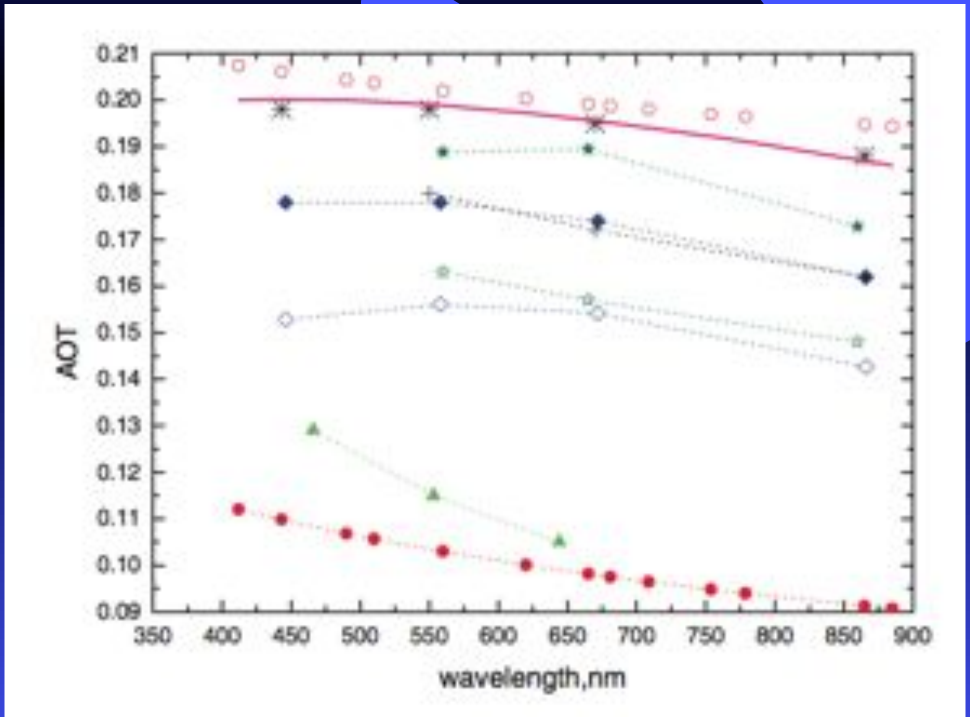
Dubovik et al., AMTD, 2010

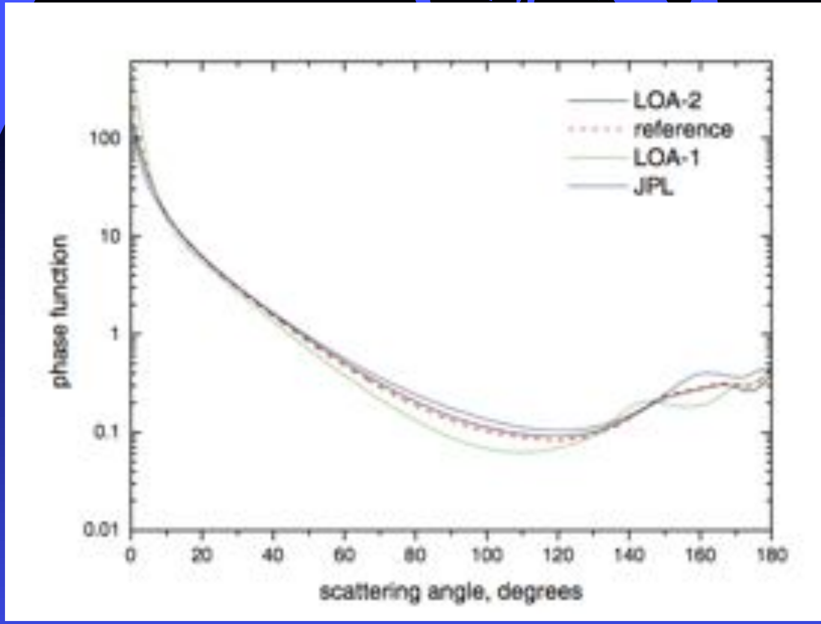


Tests over dark surface (« *Blind* » *Test*)

Kokhanovsky, et al, The inter-comparison of major satellite aerosol retrieval …., Atmos. Meas. Tech., 3, 909–932, 2010.







Rahman-Pinty-Verstraete (RPV) model ***(Rahman et al., 1993)***

MISR (Martonchik et al. 1998)
SEVIRI (Govaerts et al. 2010)

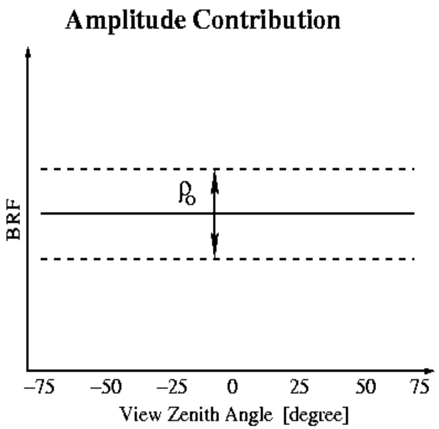
Bi-Directional Surface Reflectance

$$\boxed{\rho_{sfc}(\vartheta_1,\varphi_1;\vartheta_2,\varphi_2) = \rho_0 M_i(k) F_{HG}(\Theta) H(h)}$$

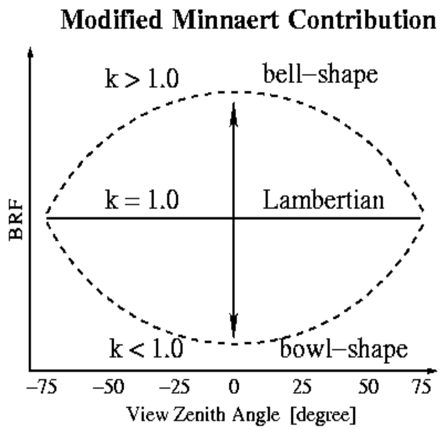
To be retrieved in each wavelength

- $\boxed{\rho_0}$ - controls amplitude level
- $\boxed{k}$ - controls bowl/bell shape
- $\boxed{\Theta}$ - controls forward/backward scattering
- $\boxed{h}$ - controls hot spot peak

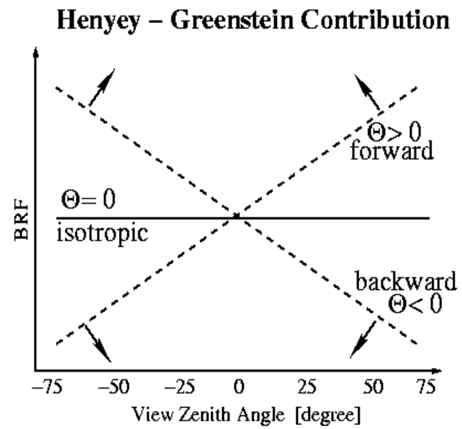
$\boxed{\rho_0}$



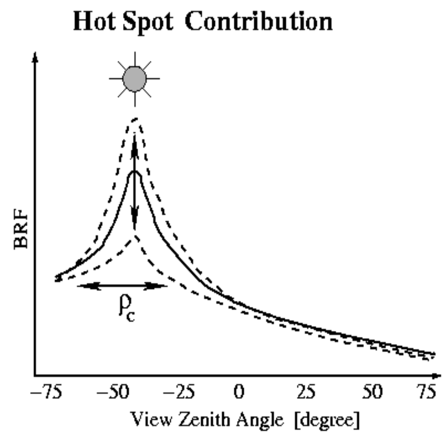
$\boxed{k}$



$\boxed{\Theta}$



$\boxed{h}$

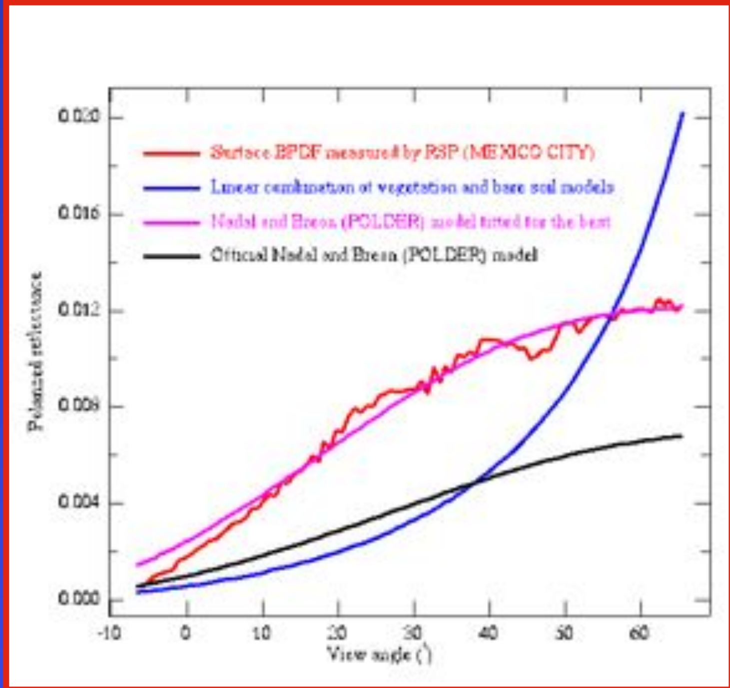


Polarized Reflectance of the Surface:

1. *Nadal and Bréon, (1999):*

$$R_p^{surf}(\theta_s,\theta_v,\varphi_r) = \alpha\left[1-\exp\left(-\beta\frac{F_p(\gamma)}{\mu_s+\mu_v}\right)\right]$$

(α and β - empirical parameters)



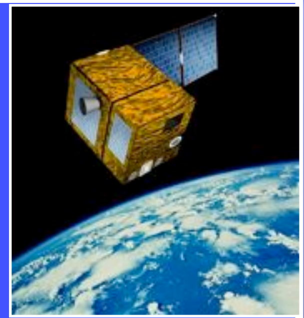
F. Waquet

2. *Maignan et al., (2009):*

$$R_p^{surf}(\theta_s,\theta_v,\varphi_r) = \frac{B\exp(-\tan(\alpha_i))\exp(-v)\,F_p(\gamma)}{4(\mu_0+\mu_1)}$$

(*B* - empirical parameter)

Spectrally independent !!!



parameters to retrieve:

AEROSOL:

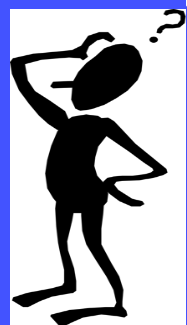
- *dV(r)/dlnr (16 bins from 0.07 to 10 mm);* $N_r = 16$
- *n(λ)* $N_\lambda = 6$
- *k(λ)* $N_\lambda = 6$
- *Fraction of spherical particles* $N_\lambda = 1$
- *Aerosol height* $N_\lambda = 1$

SURFACE:

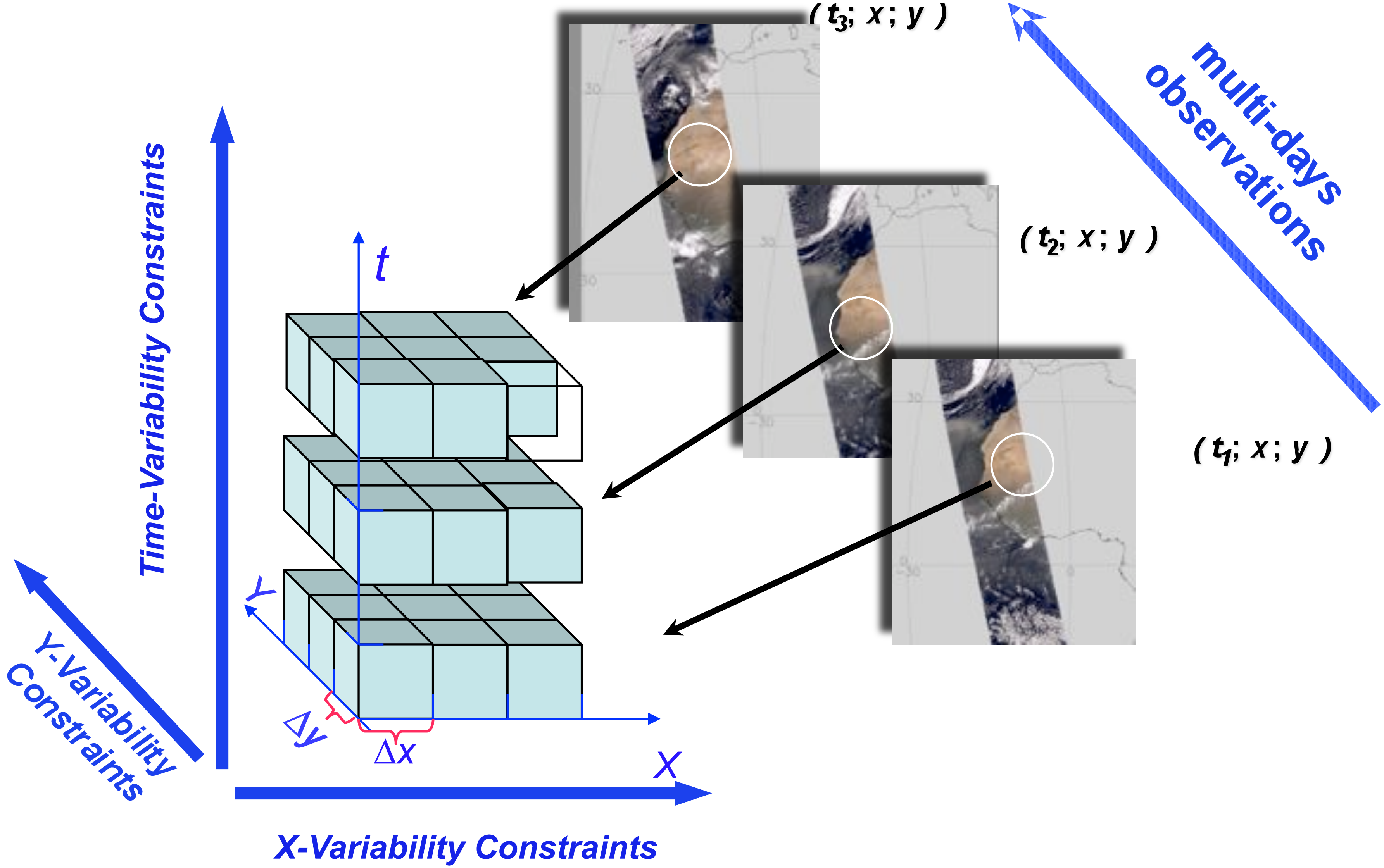
- *BRF (3 parameters for each λ)* $N = 3 \times 6 = 18$
- *BPRF (parameters for each)* $N_\lambda = 6$

TOTAL = 54

over bright surfaces
can we …



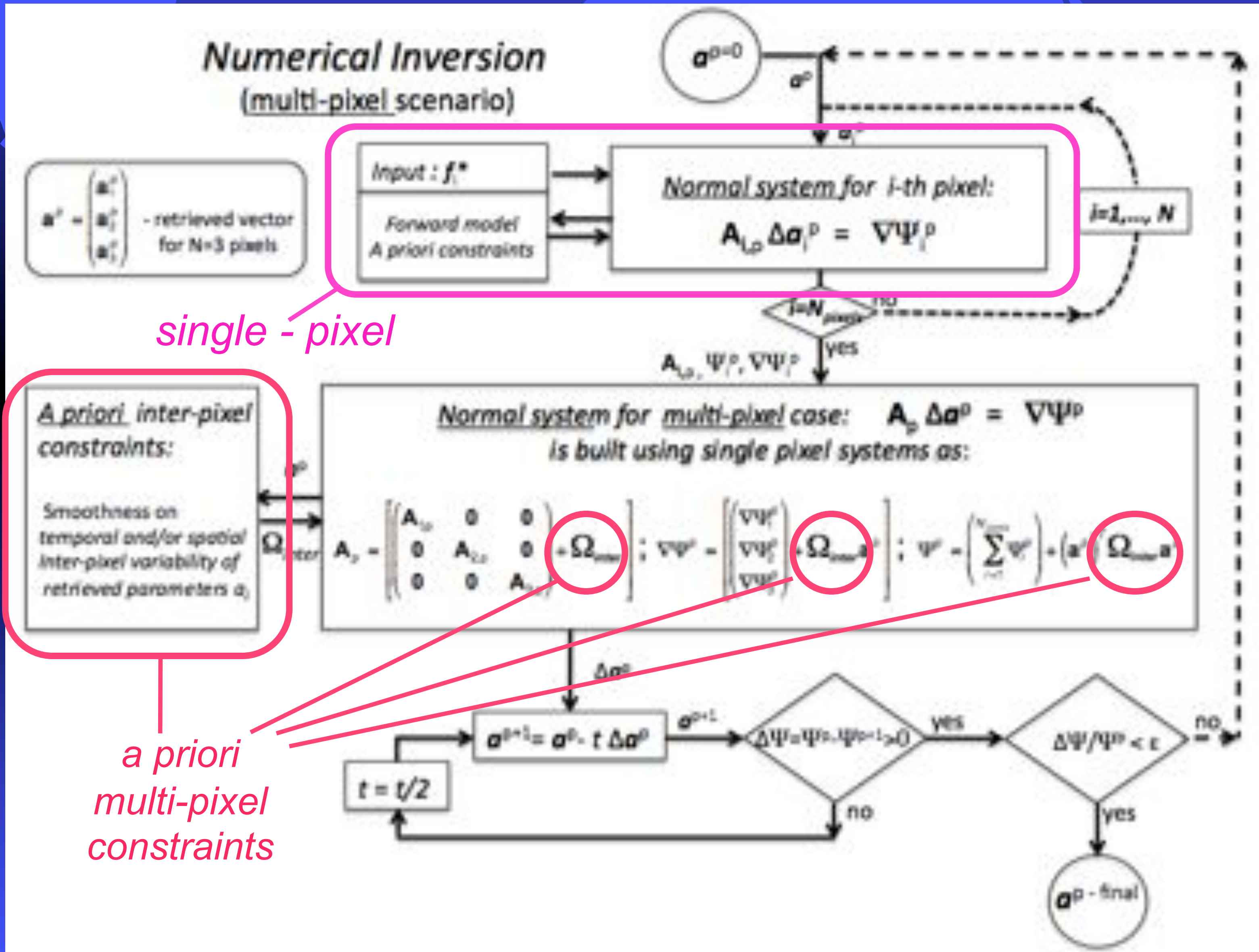
The concept of multi-pixel retrieval



EGU General Assembly, Vienna, Austria , 03 – 08 April 2011.

« PARASOL » statistically optimized « no look-up tables » *multi-pixel* inversion

Dubovik et al., AMTD, 2010



Observational conditions:

- Geometry is the same as for PARASOL over Banizoumbu (as in the example for actual PARASOL inversions)
- Surface is bright;
- Aerosol loadings: 16 cases for $\tau(0.44) = 0.01 – 4$;
- Aerosol types: Dust, Biomass Burning (original from AERONET)
- Aerosol height – 3 km

Retrieved parameters:

AEROSOL:

- $dV(r)/d\ln r$ (16 bins from 0.07 to 10 μm);
- $n(\lambda)$, $k(\lambda)$, $\omega_0(\lambda)$
- Aerosol height
- Fraction of spherical particles

SURFACE:

- BRF 3 parameters for each λ);
- BPRF (1 parameter for each λ)

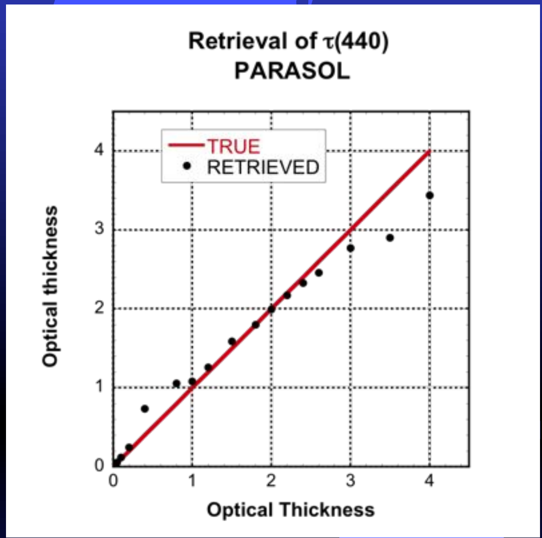
SPATIAL – TEMPORAL:

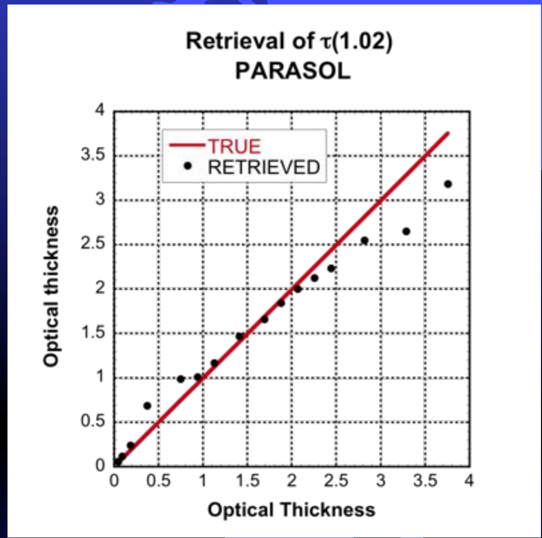
- 4 pixels for each of 4 days

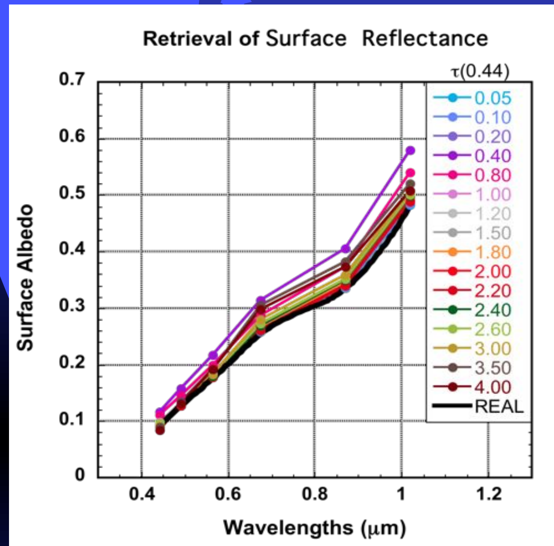
PARASOL: *0.44, 0.49 (p+), 0.565, 0.675 (p+), 0.87(p+), 1.02 μm*

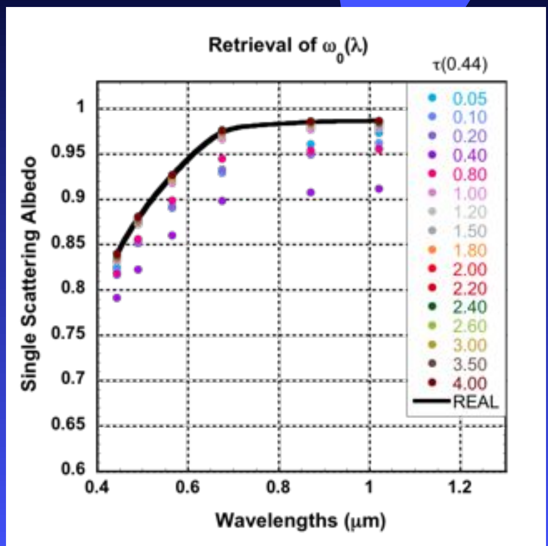
NO NOISE ADDED !!! (minor noise is always present)

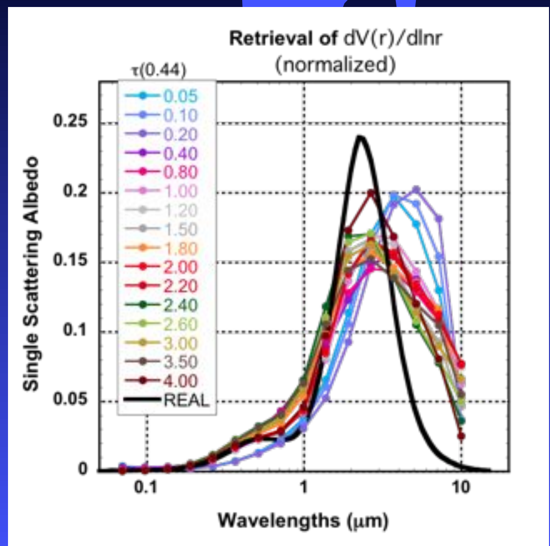
Single-Pixel Retrieval, Desert Dust aerosol (non-spherical!!!)

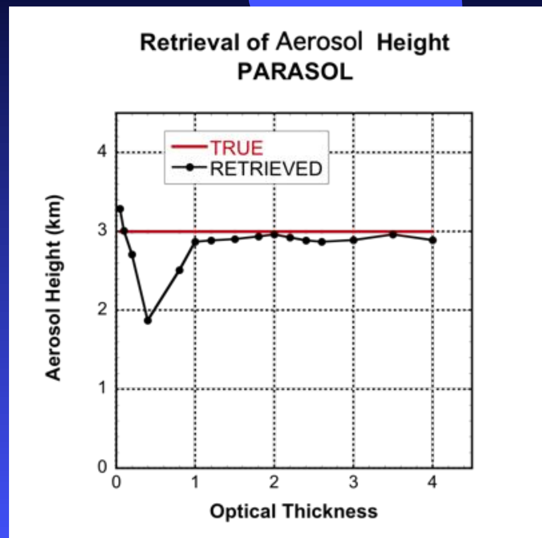








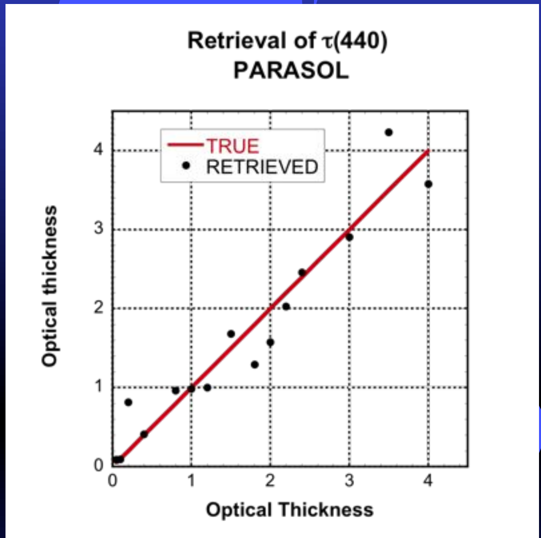


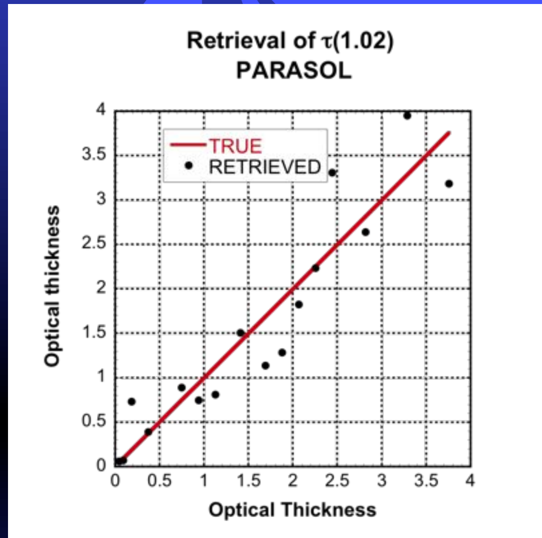


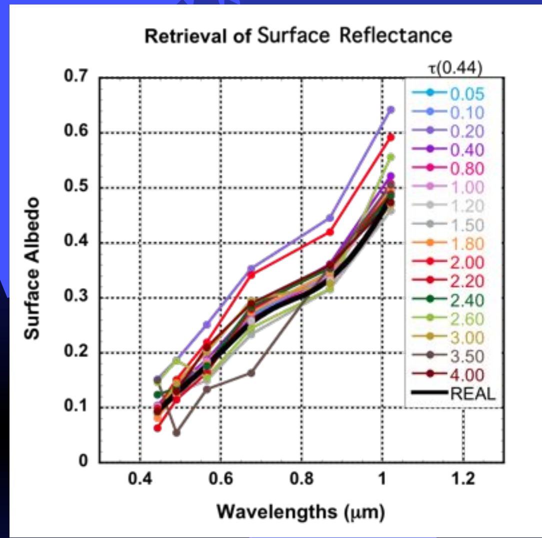
PARASOL: *0.44, 0.49 (p+), 0.565, 0.675 (p+), 0.87(p+), 1.02 μm*

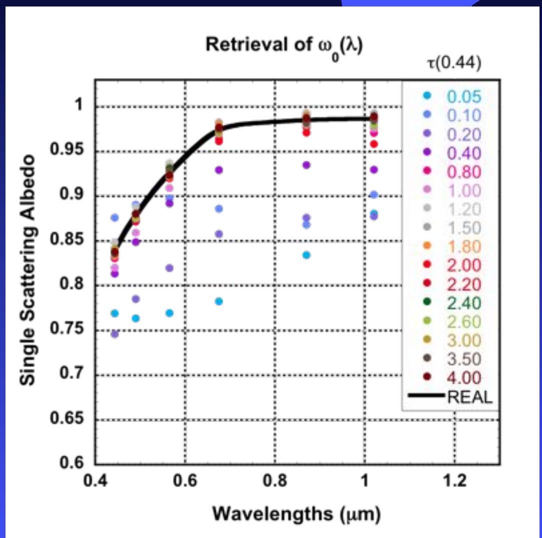
NOISE ADDED: 1% for I(λ), 0.005 for Q(λ)/I(λ) and U(λ)/I(λ) !!!

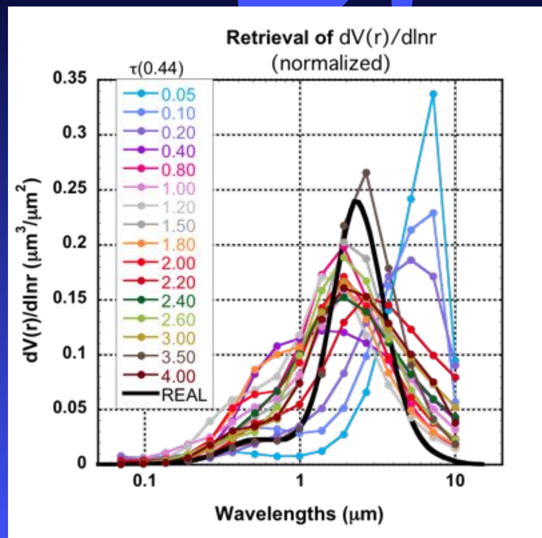
Single-Pixel Retrieval, Desert Dust aerosol (non-spherical!!!)

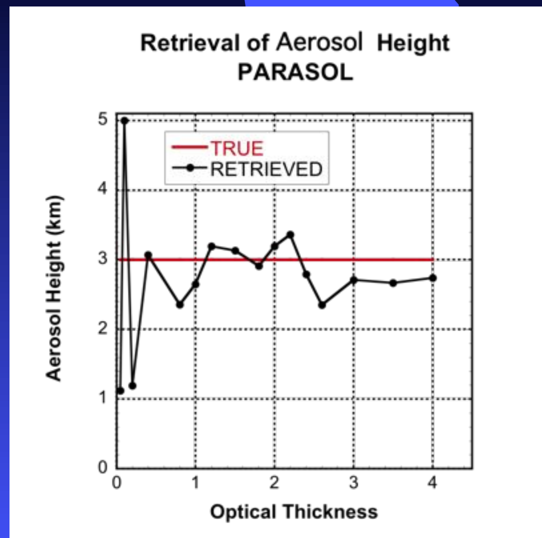










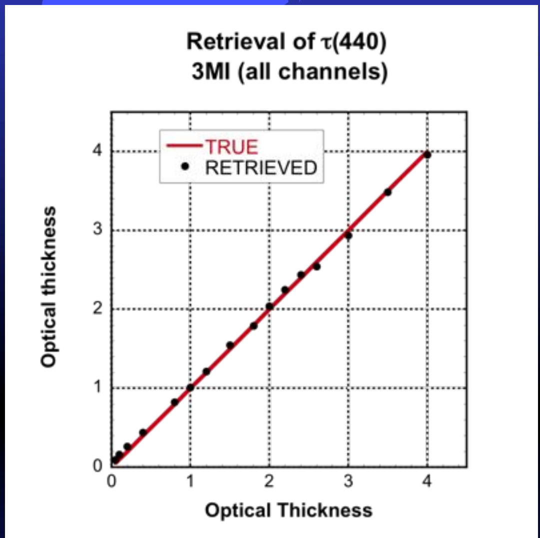


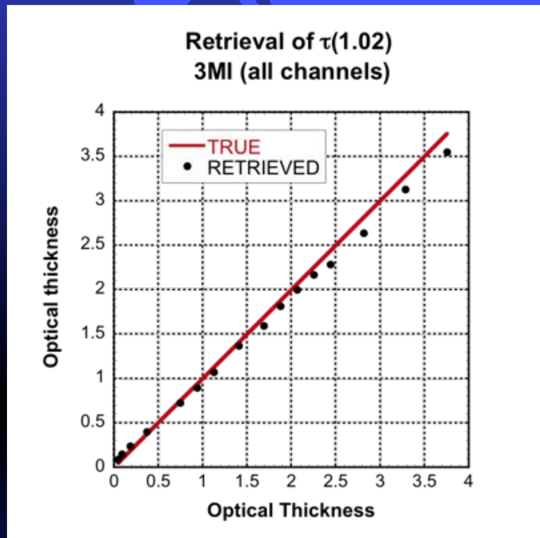
PARASOL: *0.44, 0.49 (p+), 0.565, 0.675 (p+), 0.87(p+), 1.02 μm*

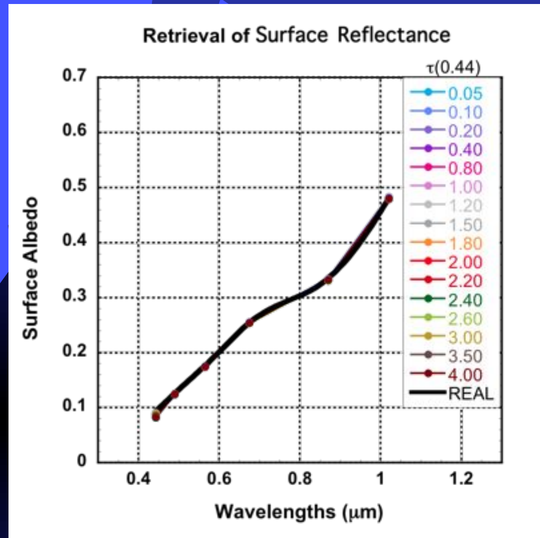
NOISE ADDED: 1% for I(λ), 0.005 for Q(λ)/I(λ) and U(λ)/I(λ) !!!

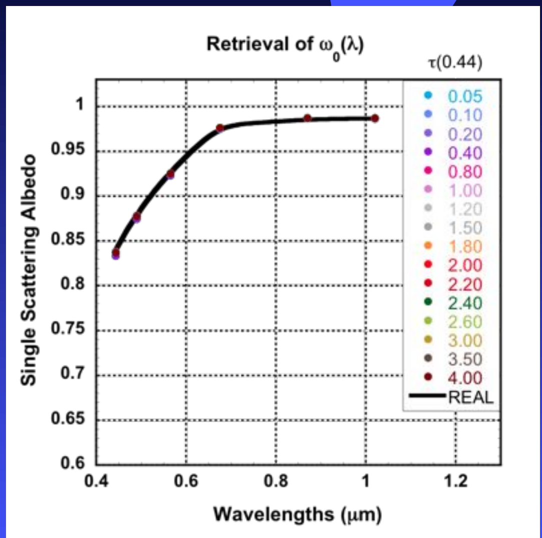
Multi-Pixel Retrieval (i.e. temporal and spatial variability of surface and aerosol is limited)

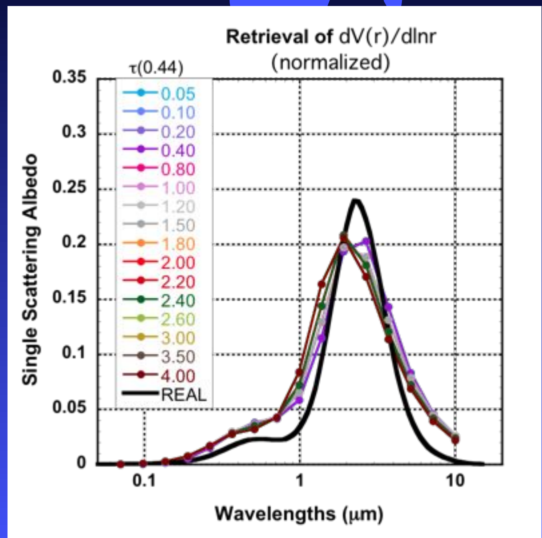
Desert Dust aerosol (non-spherical!!!)

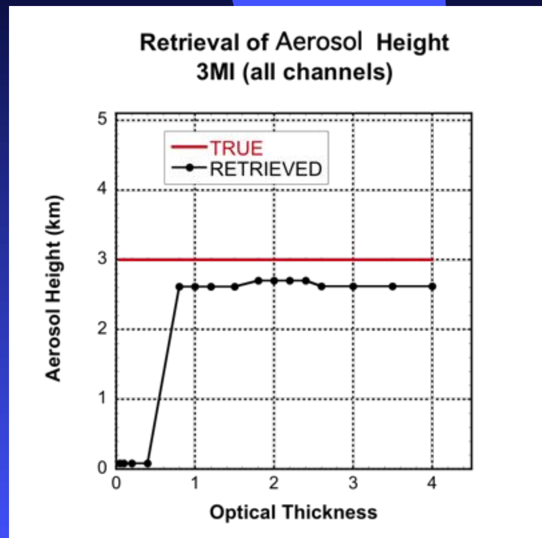


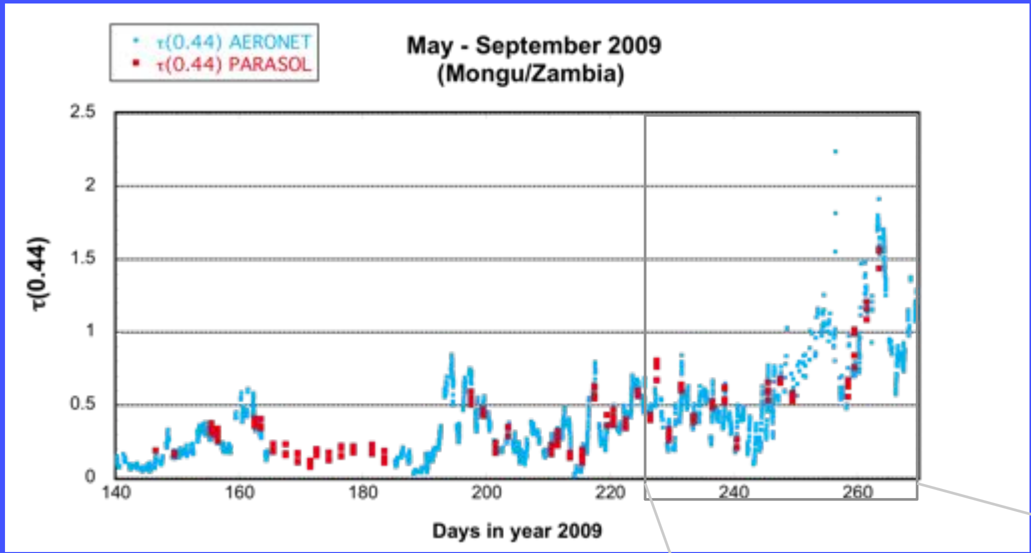




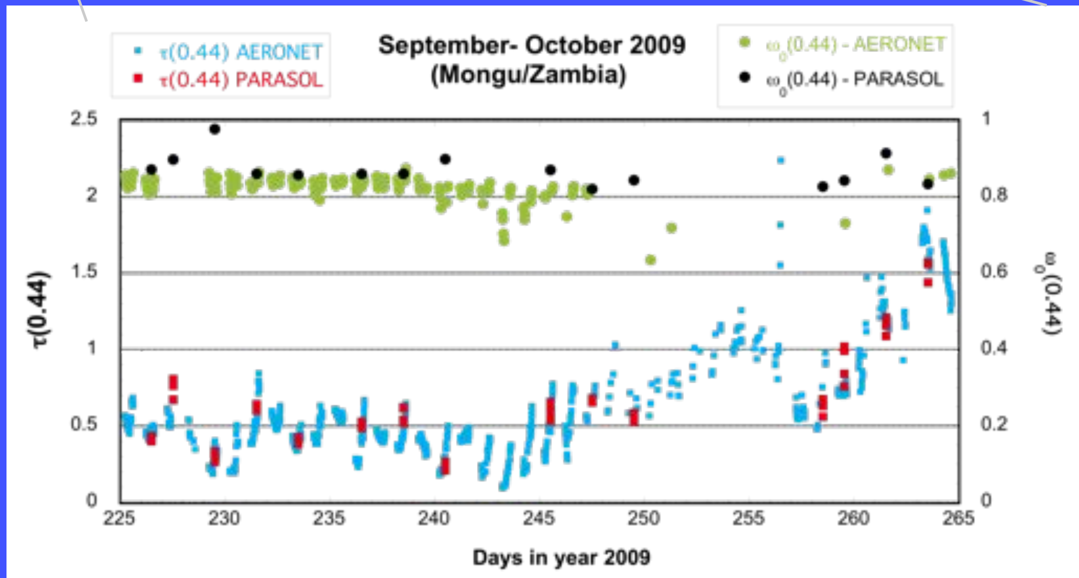


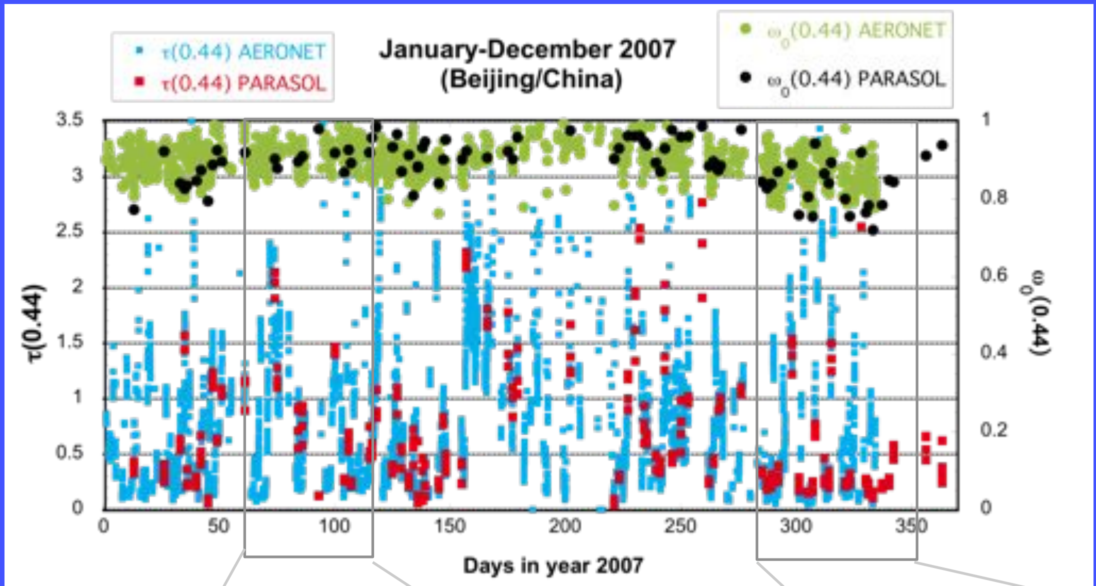




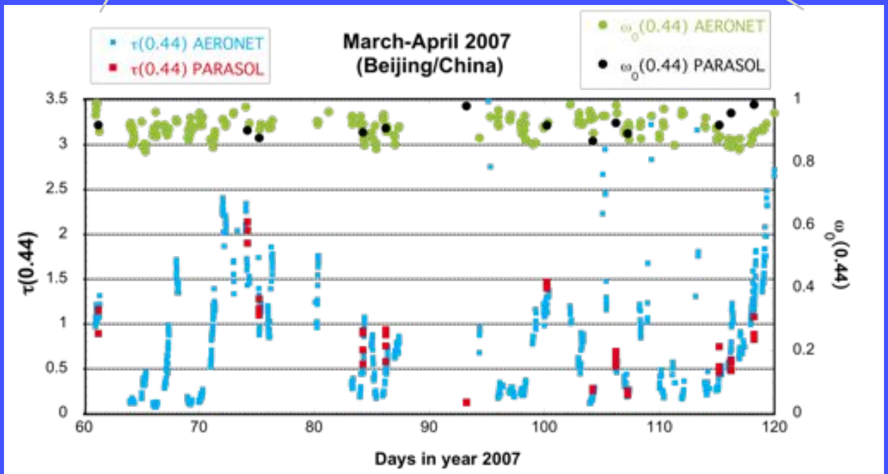


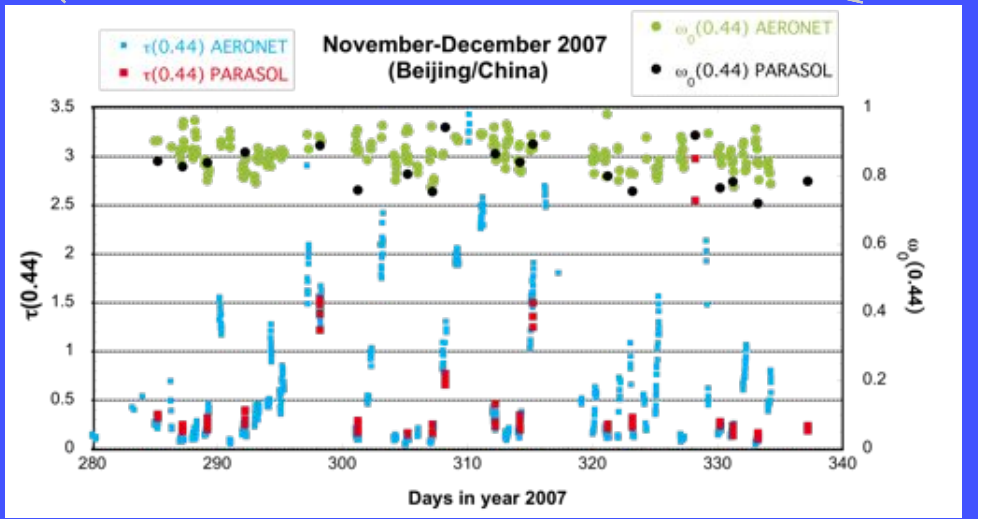
Biomass aerosol
Mongu/Zambia

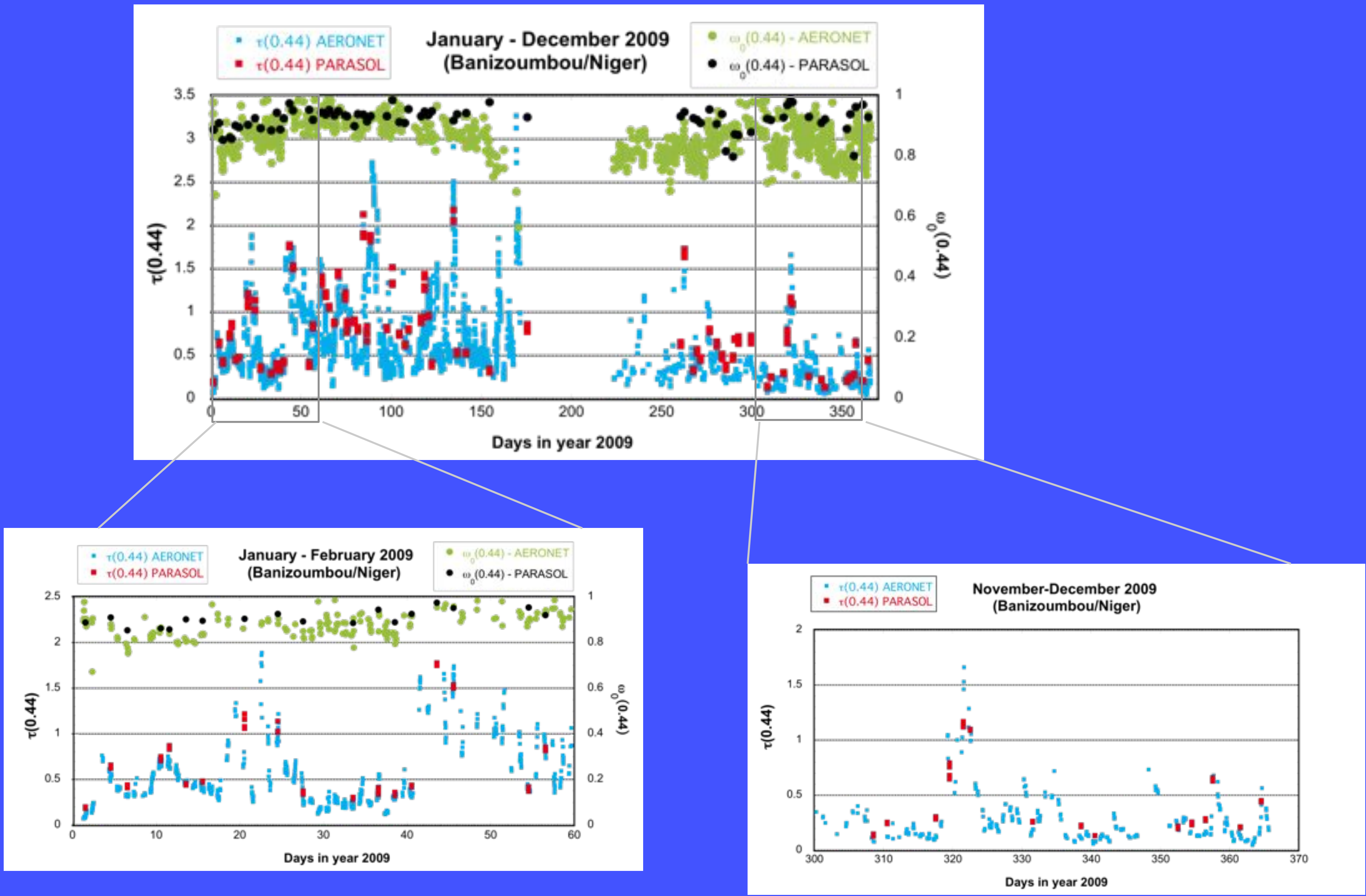




(urban/industrial aerosol Beijing/China)







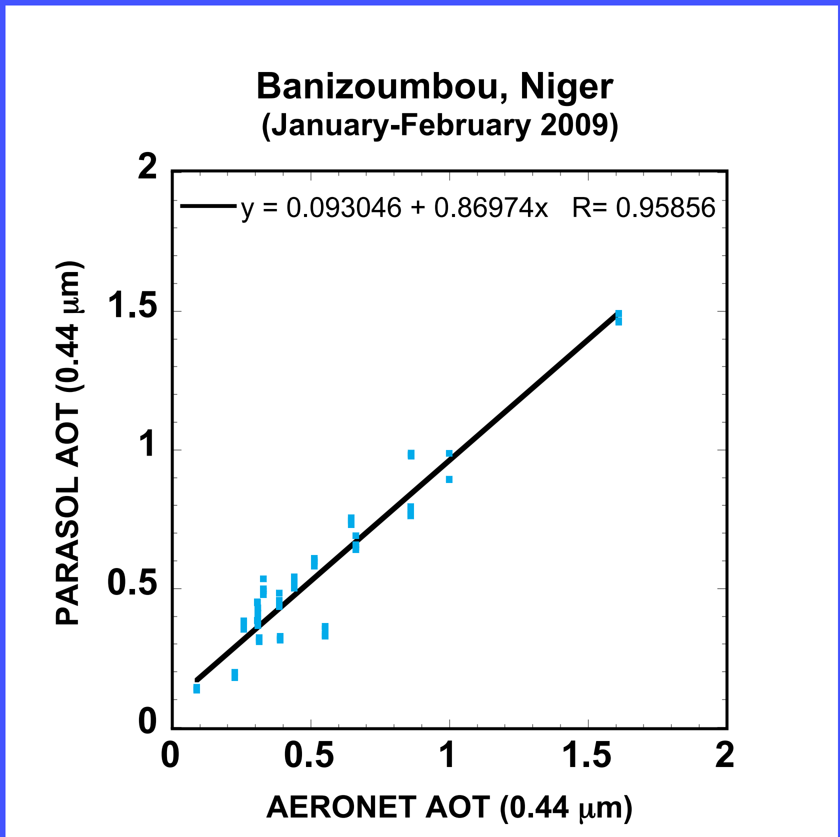
τ(0.44) AERONET
τ(0.44) PARASOL
January - December 2009
(Banizoumbou/Niger)
ω0(0.44) - AERONET
ω0(0.44) - PARASOL
τ(0.44)
ω0(0.44)
Days in year 2009
January - February 2009
(Banizoumbou/Niger)
November-December 2009
(Banizoumbou/Niger)

Dust and biomass
Banizoumbu/Niger

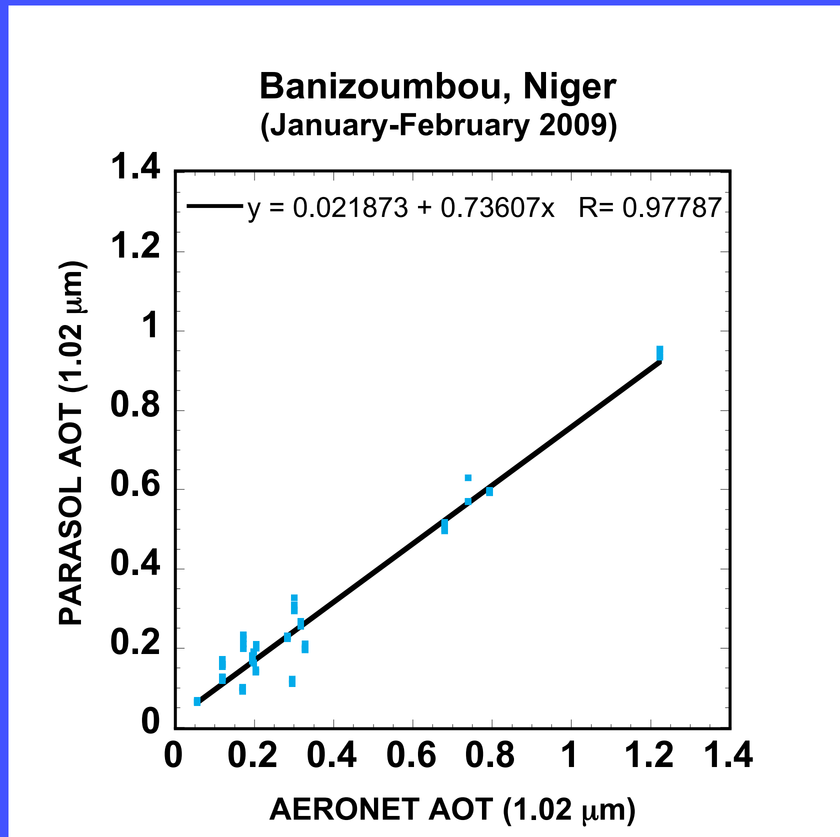
Optical Thickness

PARASOL versus AERONET

0.44 µm



1.02 µm



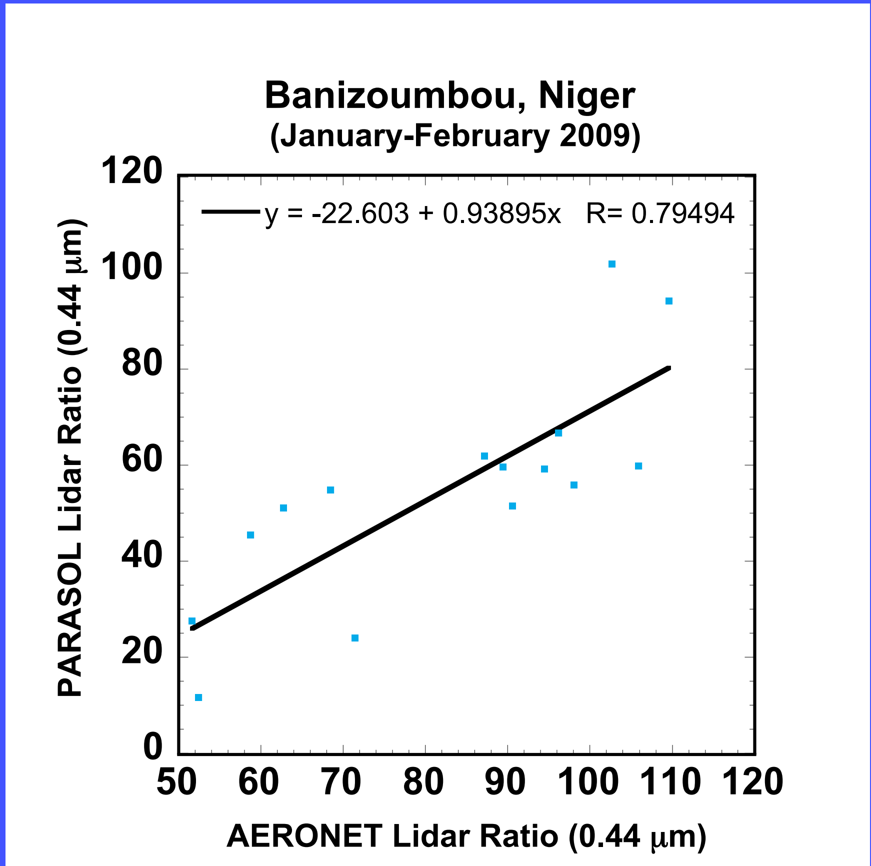
Lidar Ratio

$$S(\lambda) = \frac{4\pi}{\omega_0(\lambda)\, P\left(\lambda, 180^0\right)}$$

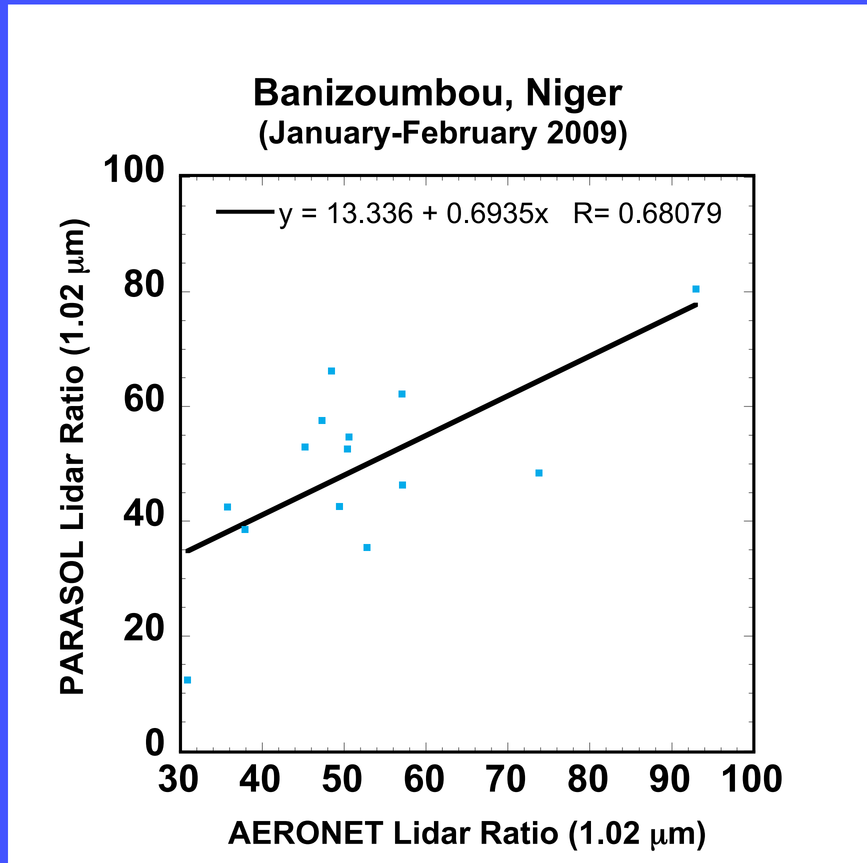
PARASOL versus AERONET

Dust and biomass
Banizoumbu/Niger

0.44 μm



1.02 μm

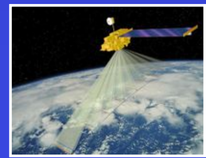


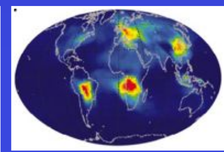
Conclusions/Perspectives:

1. <u>New Algorithm</u> – *promising*

Potential for improvement:

- **harmonizing chemistry - optics model**
- **including chemistry parameters into retrievals**





2. <u>Issues:</u>

- 10 sec per 1 pixel – too long !!!
- spectral dependence – moderate accuracy !!!
- cloud – screening – need to be improved !!!

3. <u>Potential:</u>

- multi-sensor retrieval:
  PARASOL + MODIS
  PARASOL + CALIPSO, GLORY, etc.)
- <u>inverse modeling</u>
  (tuning the models by remote sensing)