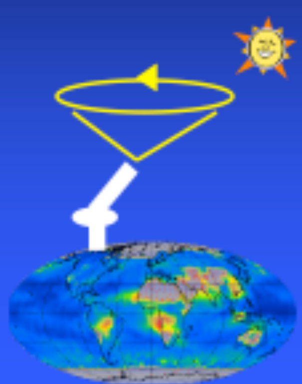
AERONET Aerosol Retrievals

Oleg Dubovik (UMBC / GSFC, Code 923)

Outlines:

- ***Aerosol retrievals from inversions of AERONET data***
- ***Inversions of combined AERONET/aircraft/satellite observations***



Forward model:

-Spectral and angular scattering by particles with different sizes, compositions and shapes

- Accounting for multiple scattering in atmosphere

(Dubovik and King, JGR, 2000)

Observations

Numerical inversion:

-Accounting for noise

-Solving Ill-posed problem

- Setting a priori constraints

aerosol particle sizes,

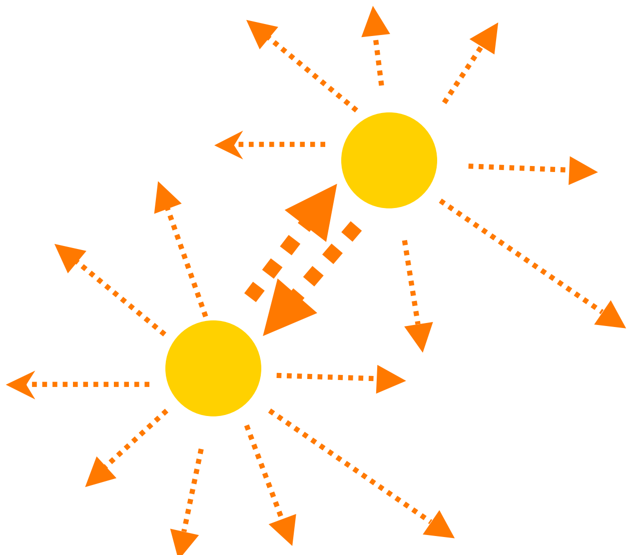
refractive index,

single scattering albedo, etc.

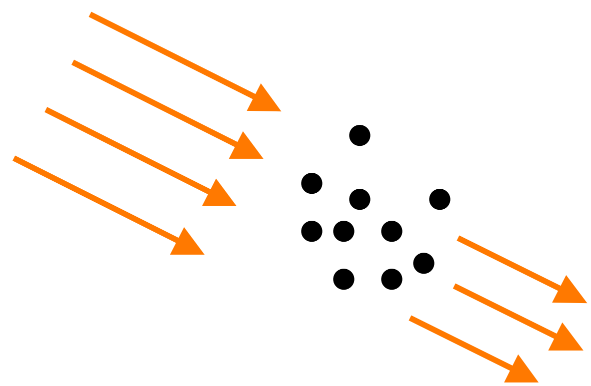
Multiple Scattering

Multiple scattering effects *are accounted by solving* ***scalar*** *radiative transfer equation with assuming* ***Lambertian ground reflectance*** *(Nakajima – Tanaka code)*

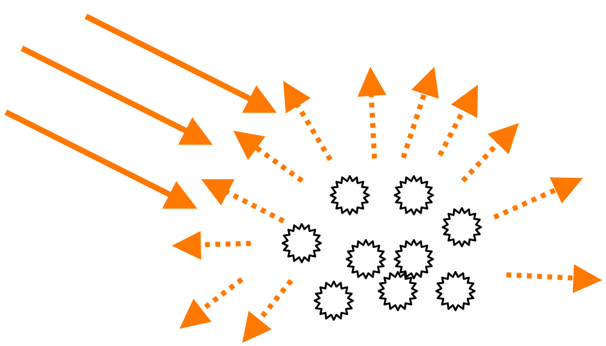
Aerosol scattering



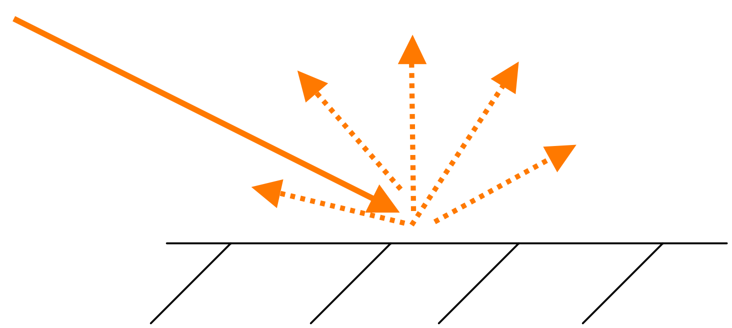
Gaseous absorption



Molecular scattering

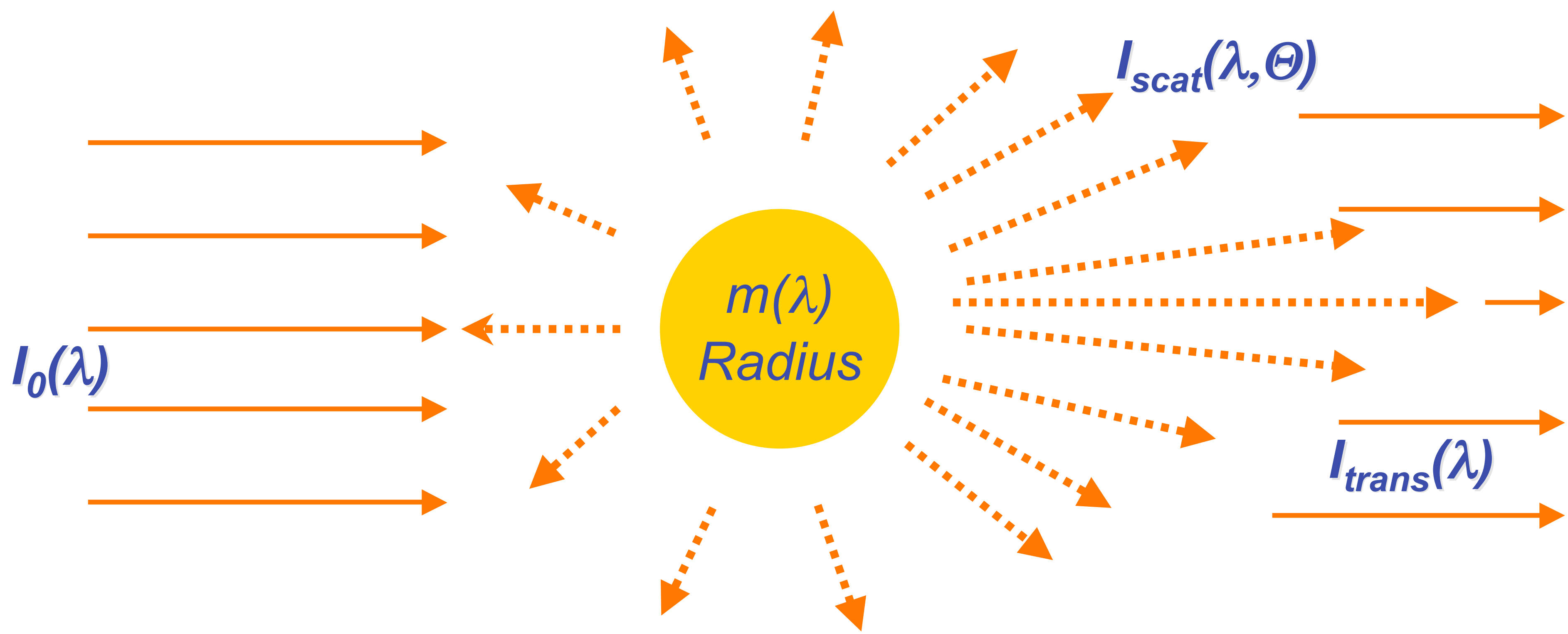


Surface reflection



Single Scattering by Single Particle

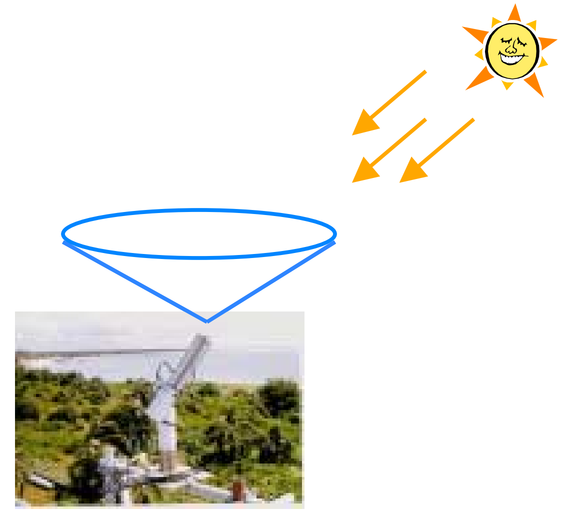
Scattering and Absorption *is modeled assuming aerosol particle as homogeneous sphere with spectrally dependent complex refractive index ($m(\lambda)= n(\lambda) - i\,k(\lambda)$) - "Mie particles"*



$P(\Theta)$- Phase Function;
$\tau(\lambda)$ - extinction optical thickness;
$\omega_0(\lambda)$ -single scattering albedo
$\tau(\lambda)\omega_0(\lambda)$ - absorption optical thickness

***Statistically optimized fitting*:**

(Dubovik and King, 2000)



weighting

***Lagrange** parameters*

$$\sum_{(\lambda,\theta)_i} \frac{\varepsilon_0^2}{\varepsilon_i^2}\left(f_i^* - f_i(\mathbf{x})\right)^2 + \sum_i \frac{\varepsilon_0^2}{\varepsilon_i^2}\left(f_i^a - f_i(\mathbf{x})\right)^2 \rightarrow (N_{total} - N_x)\hat{\varepsilon}_0^2$$

Measurements:

i=1 - *optical thickness*

i=2 - *sky radiances*

-their covariances

(should depend on λ and Θ)

-lognormal error distributions

***a priori** restrictions on*

norms of derivatives of:

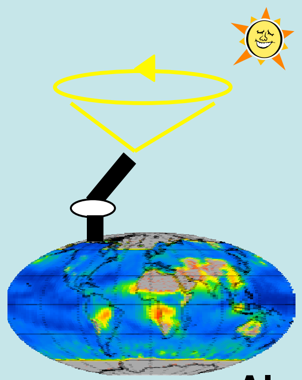
i=3 ***-size distr.* variability;**

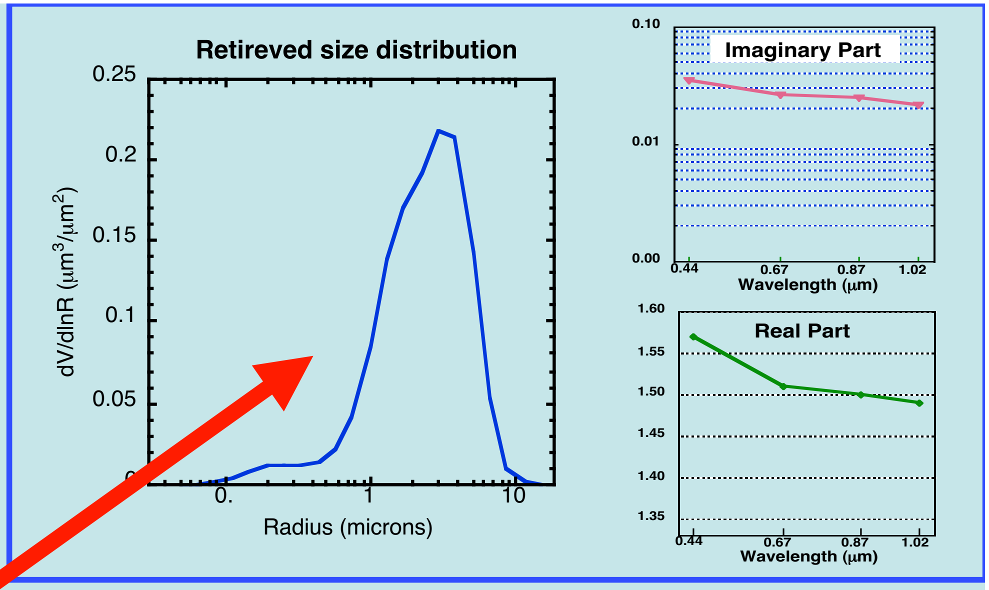
i=4 ***-n* spectral variability;**

i=5 ***-k* spectral variability;**

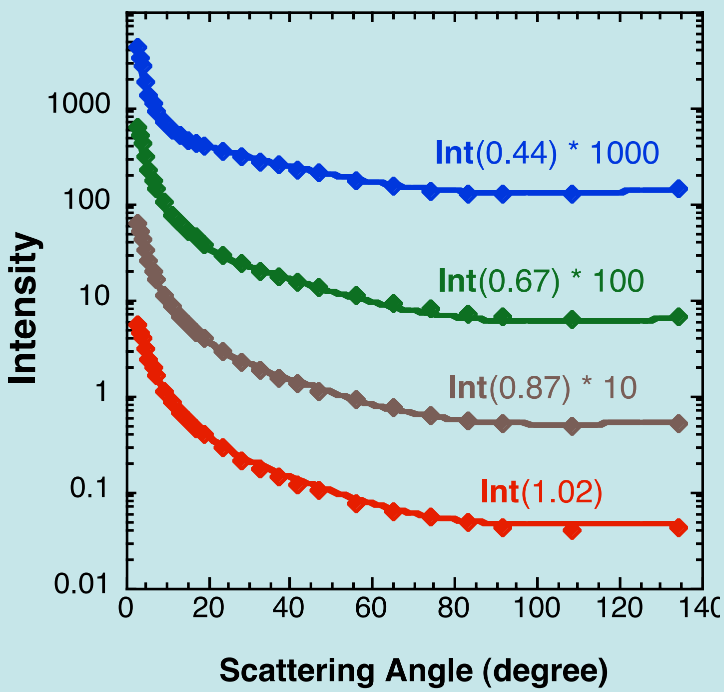
consistency Indicator

Fitting as a retrieval strategy

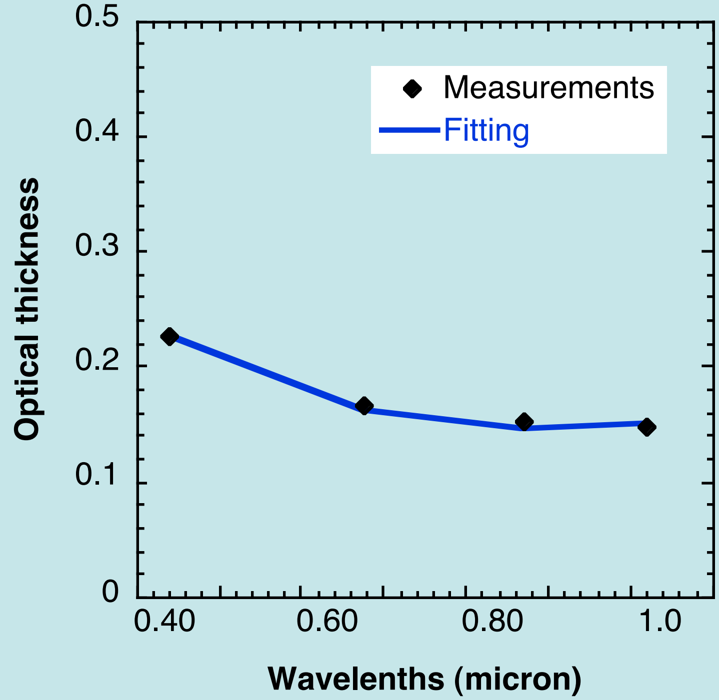




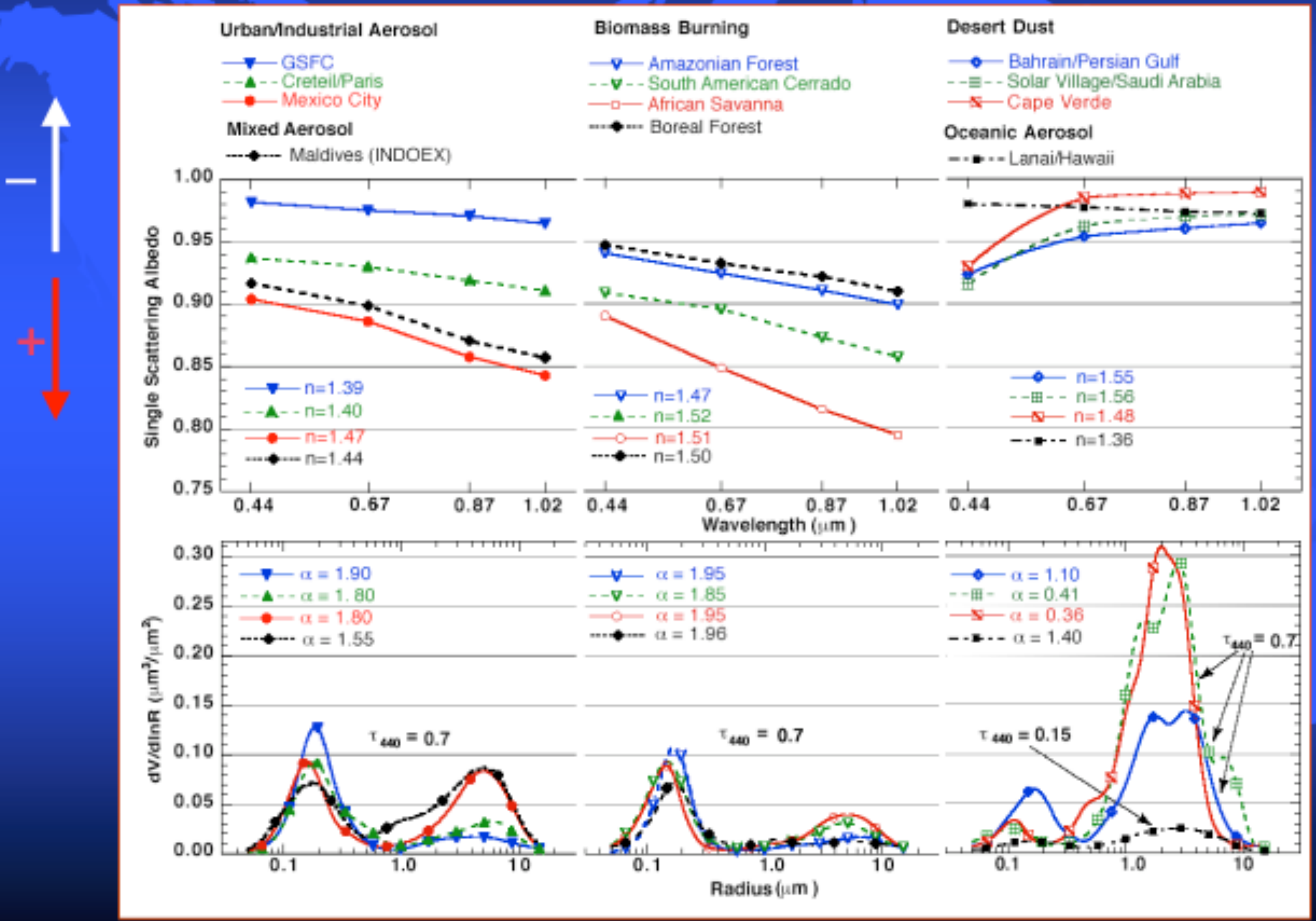
Almucantar Fitting



Fitting of optical thickness in retrievals



The averaged optical properties of various aerosol types (Dubovik et al., 2002, JAS)



ABSORPTION of SMOKE

flaming combustion
Rio Branco, Brazil

smoldering combustion
Quebec fires, July 2002

Retrieval using combinations of up-looking Ground-based and down-looking satellite observations

Retrieved:

<u>Aerosol Properties</u>:
- *size distribution*
- *real ref. ind.*
- *imag. ref. ind*

(AERONET sky channels)

<u>Surface Parameters</u>:

-BRDF (MISR channels)

-Albedo (MODIS IR channels)

AERONET/ MISR/ MODIS retrieval

- AERONET Ground-based Sun-sky radiometer:

– $\tau(\lambda) \pm 0.02$ at

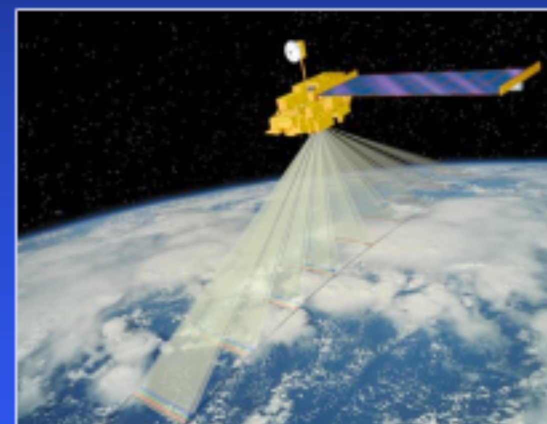
6 channels: 0.34, 0.38, 0.44, 0.67, 0.87, 1.02, 1.65 μm

– $I(\lambda,\Theta)$ ± 0.05% at

4 channels: 0.38, 0.44, 0.67, 0.87, 1.02, 1.65 μm

3° ≤ scattering angles ≤ ~70°

– $P(\lambda,\Theta)$ ± 0.02% at 0.87



- MISR

Reflectance at

4 channels: 0.45, 0.55, 0.67, 0.87 μm

9 viewing angles: ±70.5°, ± 60°, ± 45.6°, ± 26.1°, 0°

- MODIS

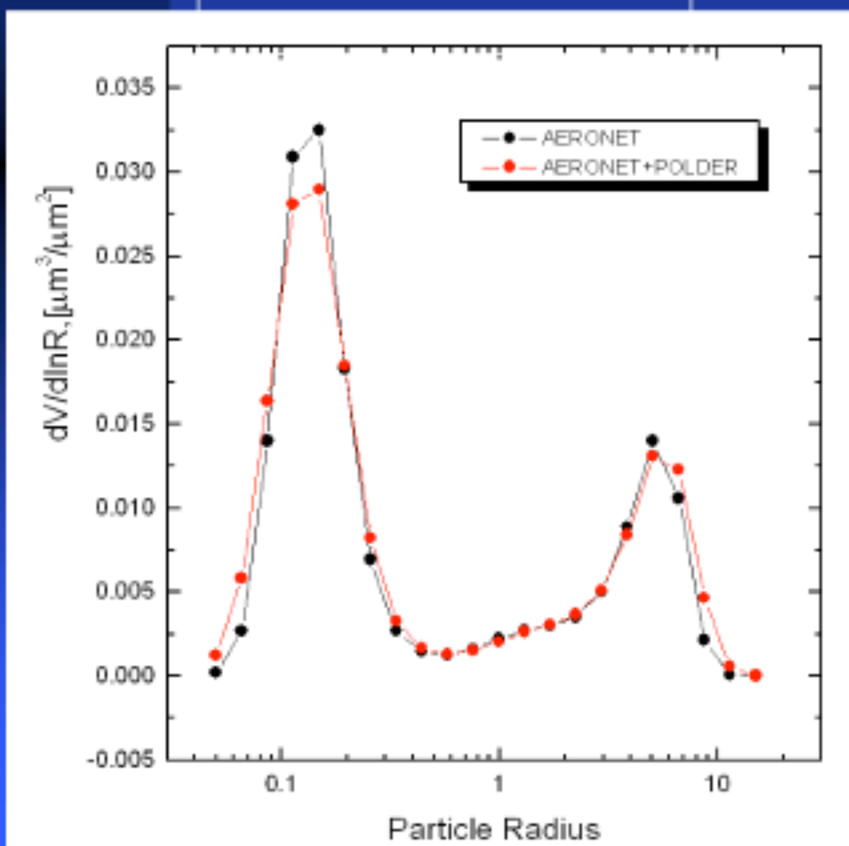
Reflectance at

7 channels: 0.47, 0.55, 0.66, 0.87,1.2, 1.6, 2.1

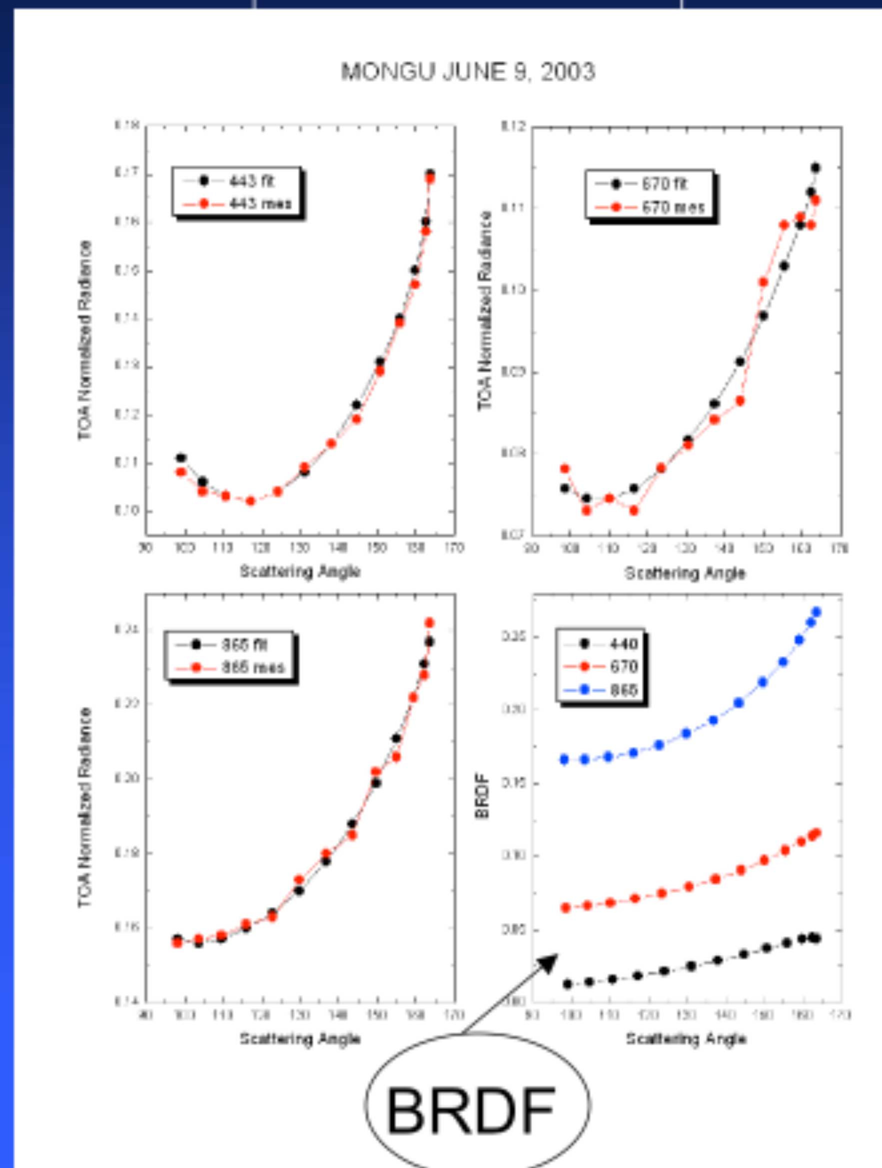
AERONET / POLDER-2 retrieval

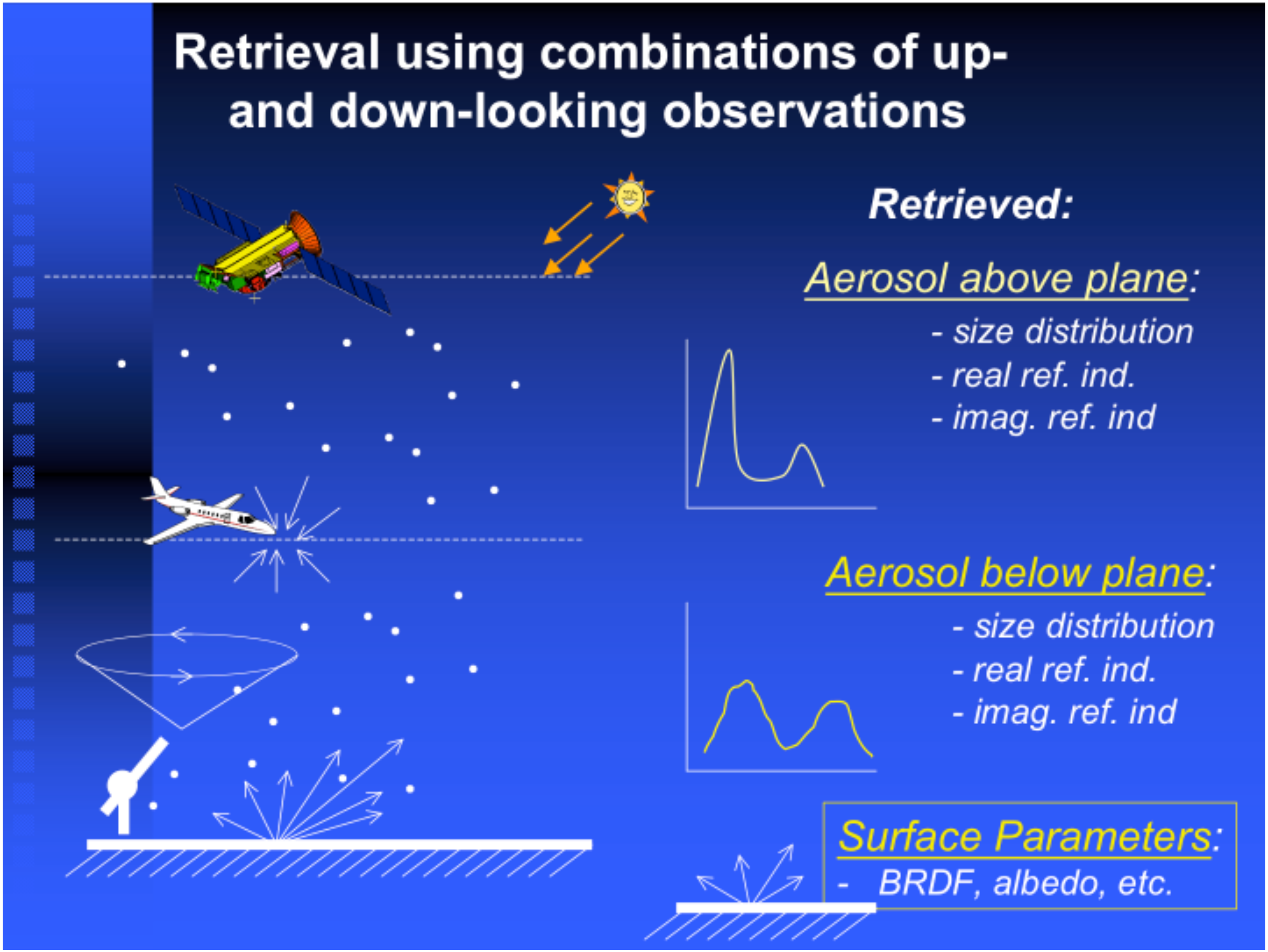
Biomass burning
Mongu, Zambia, June, 2003

Size distribution



POLDER-2 fit




Retrieval using combinations of up- and down-looking observations
Retrieved:
Aerosol above plane:
- size distribution
- real ref. ind.
- imag. ref. ind
Aerosol below plane:
- size distribution
- real ref. ind.
- imag. ref. ind
Surface Parameters:
- BRDF, albedo, etc.

M. King, C. Gatebe

CAR - Cloud Absorption Radiometer

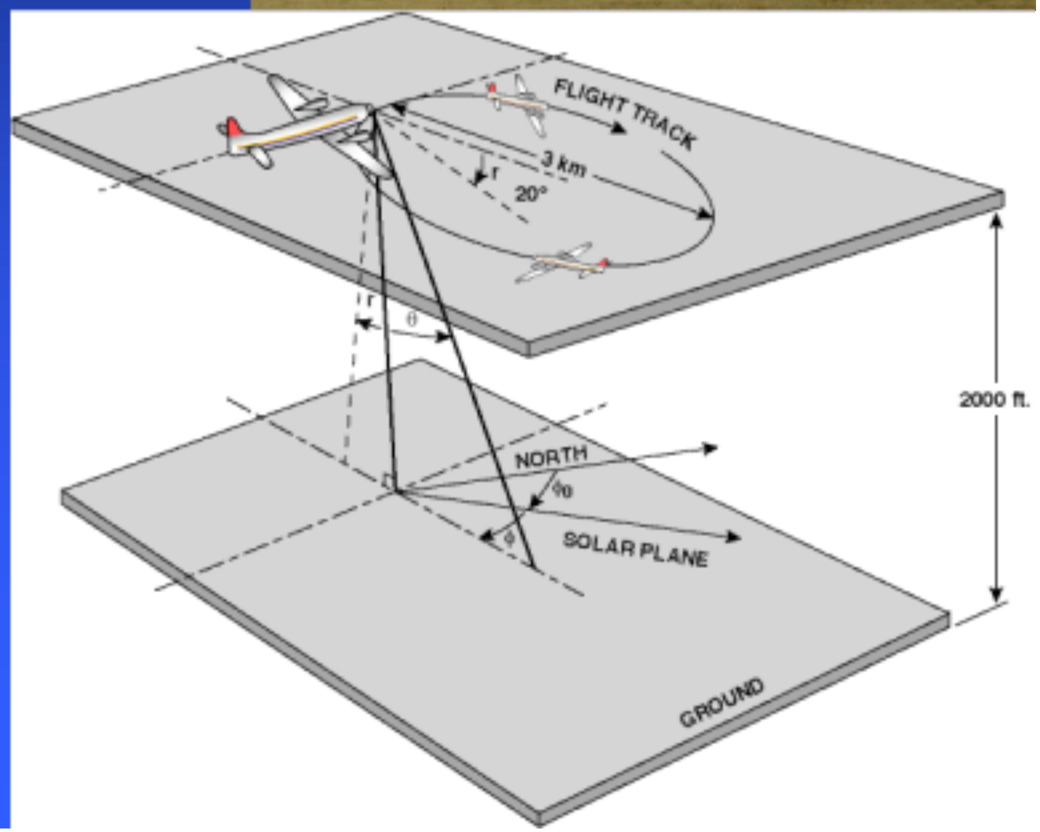
Flown by CV-580 aircraft at ~ 700 m above ground

8 spectral channels:
0.34, 0.38, 0.47, 0.68, 0.87, 1.03, 1.19, 1.27 μm

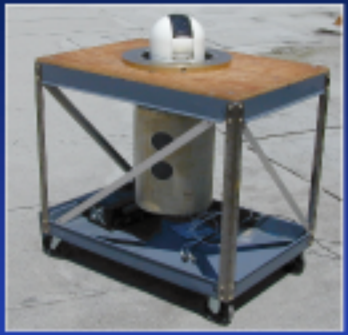
Measures radiation *transmitted** and *reflected:*

0° ≤ Obs. Zenith ≤ 180°
0° ≤ Obs. Azimuth ≤ 360°

* *Stray light problems for scattering angles ≤ 10°*



Up-looking Sunphotometer data:



- AATS-14 - NASA Ames Tracking 14- channel Sun-photometer (λ = 0.35, 0.38, 0.45, 0.50, 0.53, 0.60, 0.68, 0.78, 0.87, 0.94, 1.02, 1.24, 1.56, 2.14) :

– **τ(λ) ± 0.02** used **8** values (some interpolated for CAR λ): 0.34, 0.38, 0.47, 0.68, 0.87, 1.03, 1.20, 1.27 μm

- AERONET Ground-based Sun-sky radiometer:

– **τ(λ) ± 0.02 at**
6 channels: 0.34, 0.38, 0.44, 0.67, 0.87, 1.02 μm

– **I(λ,Θ) ± 0.05% at**
4 channels: 0.44, 0.67, 0.87, 1.02 μm
3° ≤ scattering angles ≤ ~70°

SAFARI 2000

Southern Africa Region
August- September, 2000

Combined Observations (September 6):

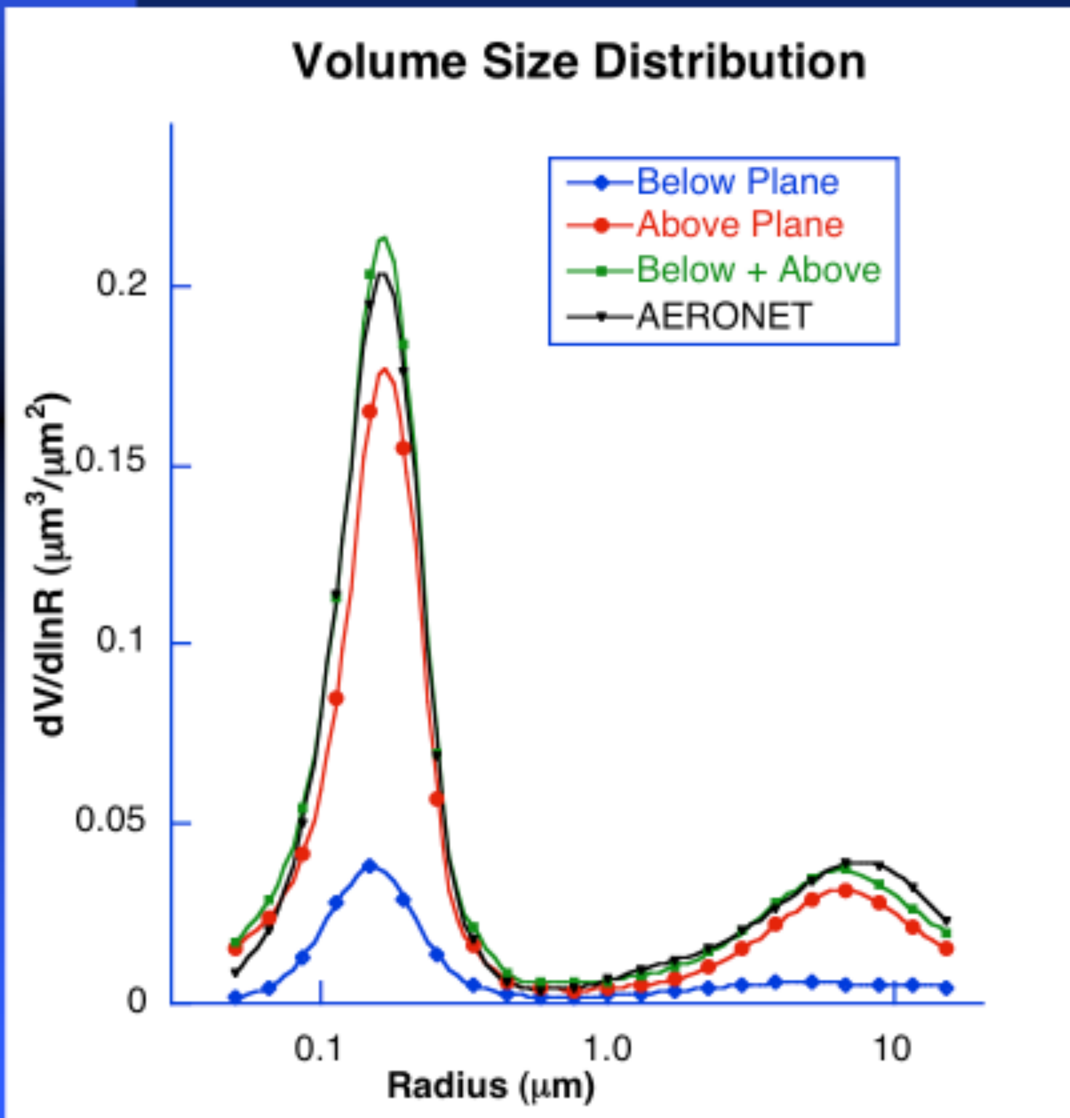
Up-looking :

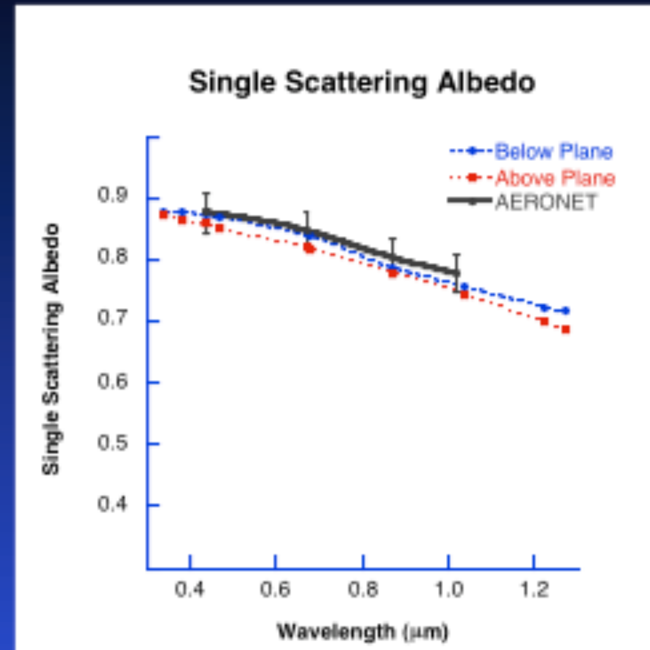
Aircraft: CAR, AATS-14 photometers
Ground: AERONET photometers

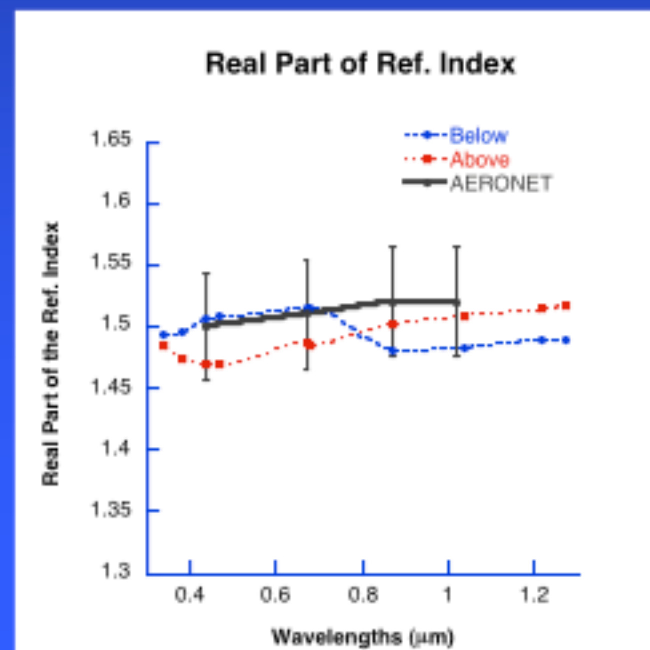
Down-looking :

Aircraft: CAR

Aerosol retrieved from combined CAR - AERONET - AATS-14 obs.







Surface reflectance retrieved from combined CAR-AERONET-AATS observations

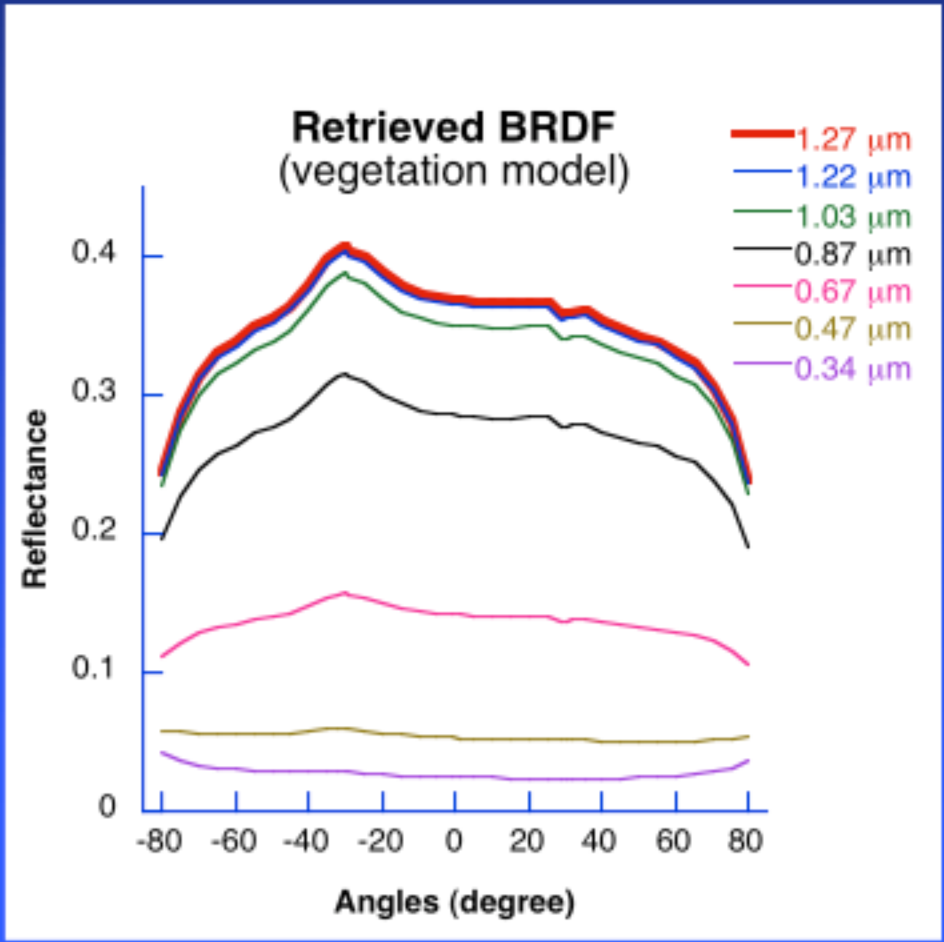
Vegetation model of surface reflectance

Vegetation BRDF Model:
Gobron et al. [1997]:

Spectral properties:
- leaf reflectance;
- leaf transmittance;
- soil albedo (Lambertian);

Spectral properties:
- height of the canopy (~0.4 - 0.9 m);
- leaf area index (~0.26 - 0.32);
- equivalent diameter of a single leaf (~ 6-9 cm)

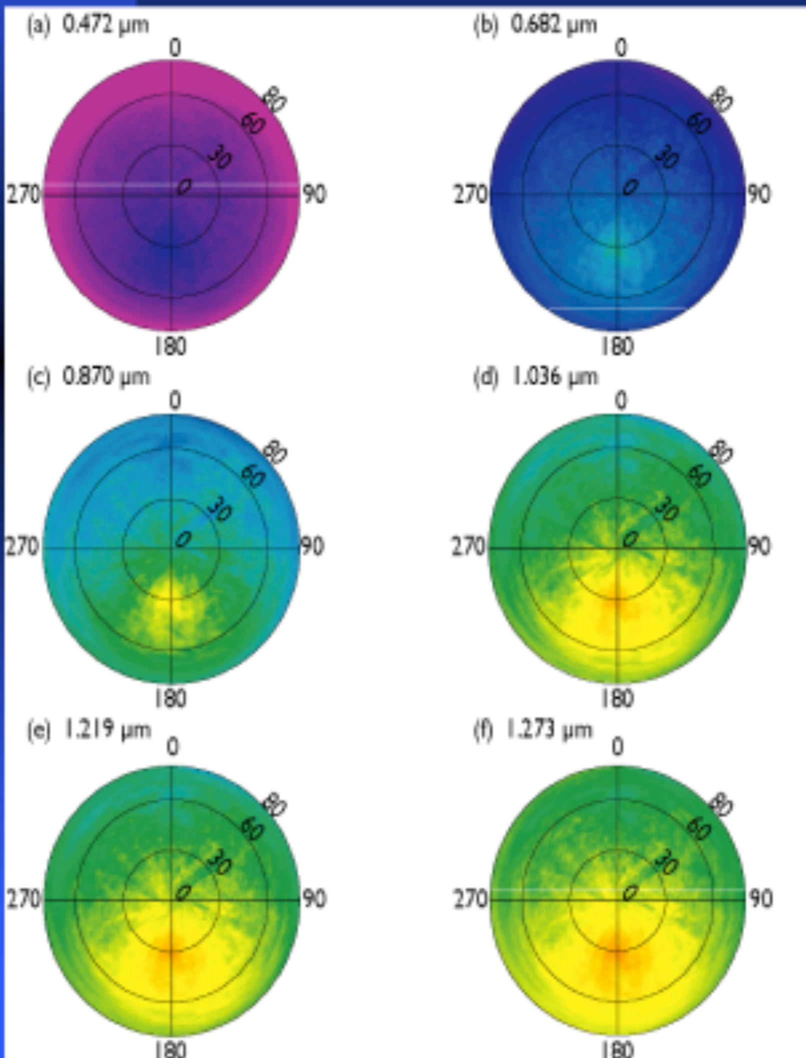
Mongu, Zambia

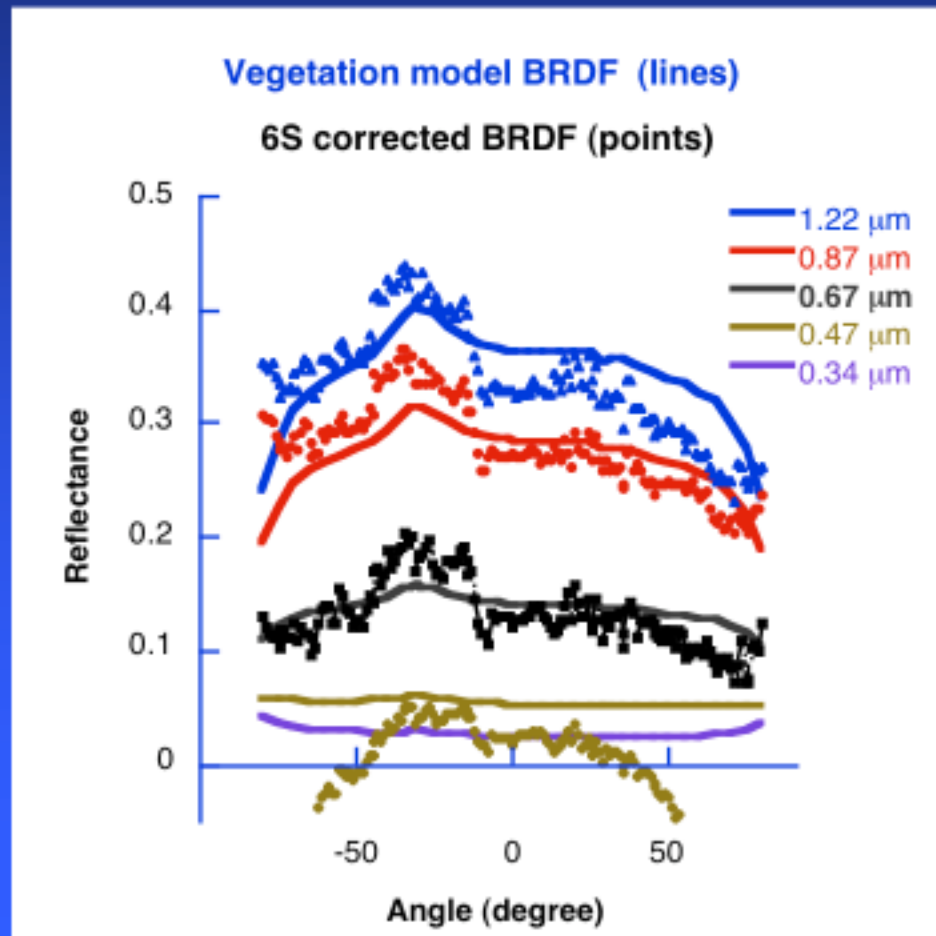


Comparison of model retrieved BRDF with corrected direct BRDF

Gatebe et al. 2003

BRDF constrains model:
- **positive and smooth;**
- **PP symmetrical**





Comparison of retrieved surface reflectance with other observations

Lambertian *approximation*

Mongu, September 6, 2000

Mongu, Zambia