AERONET Inversion Products

Optical properties of the aerosol in the **total atmospheric column** are retrieved by two inversion codes: the code of *Nakajima et al.* [1983, 1996] and the new code developed by the AERONET project (described in the papers by *Dubovik and King*, [2000] and *Dubovik et al.* [2000]).

1. Inversions by the *Nakajima et al.* code.

1.1. The code inverts:

default - sky radiances simultaneously at four wavelengths (440; 670; 870; 1020 nm) in the aureole angular range ($2.8° < \Theta < 40°$; Θ -scattering angle);

option *"single channel inversion"* – separately at each of four wavelengths (440; 670; 870; 1020 nm) in the whole solar almucantar ($2.8° < \Theta$);

1.2 Inversions assumptions:

Aerosol particles are **homogeneous spheres** with a **fixed index of refraction:** $n(\lambda) = 1.45$, $k(\lambda) = 0.005$.

1.3 Inversions results:

1.3.1 Microphysics

$d\mathbf{V}(r)/d\ln r$ – ($\mu m^3/\mu m^2$) volume particle size distribution in range of sizes:

$$0.057\ \mu m \le r \le 8.76\ \mu m$$

1.3.2. Radiative properties

$\tau(\lambda)$ - scattering optical thickness at 440,670,870,1020nm ;
$\mathbf{P}(\Theta; \lambda)$ - phase function at 440,670,870,1020nm;

Standard parameters of phase function:
$\langle COS(\Theta)\rangle$ - asymmetry parameter;

2. Inversions by *new AERONET* code.

2.1 The code inverts:

default - sky radiances simultaneously at four wavelengths (440; 670; 870; 1020 nm)) in whole solar almucantar ($2.8° < \Theta$) together with $\tau(\lambda)$ at the same wavelengths

2.2 Inversions assumptions:

Aerosol particles are **homogeneous spheres** (index of refraction is not fixed);

2.3 Inversions results:

2.3.1 Microphysics

d*V(*r*)/*d*ln*r –($\mu m^3/\mu m^2$) volume particle size distribution in range of sizes 0.05 $\mu m \le r \le 15\ \mu m$

Standard parameters* for total (t), fine (f) and course (c) aerosol modes:
(*****) -the definition of the parameters are given in the Appendix below.

C_v – ($\mu m^3/\mu m^2$) volume concentration (t, f, c);
r_v- volume median radius (t, f, c);
σ - standard deviation (t, f, c);
r_{eff} - effective radius (t, f, c);

NOTE: the parameters for the fine and coarse modes can be used only if the retrieved $dV(r)/\ln r$ is bi-modal. There is no automatic check for bi-modality.

***n*(λ)** – real part of the complex refractive index ($1.33 \le n(\lambda) \le 1.6$) at 440,670,870,1020nm

***k*(λ)** – imaginary part of the complex refractive index ($0.0005 \le k(\lambda) \le 0.5$) at 440,670,870,1020nm

2.3.2 Radiative properties

$\omega_0(\lambda)$ - wavelength dependent Single Scattering Albedo at 440,670,870,1020nm ;
P(Θ; λ) - phase function at 440,670,870,1020nm

Standard parameters of phase function:
<*COS*(Θ)> - asymmetry parameter;

2.4 Accuracy of the retrievals:

To select the retrievals with the highest possible accuracy we suggest pursuing the following recommendations *of the paper by Dubovik et al.* [2000] ***:***

2.4.1 Urban-industrial, biomass burning or other aerosol not dominated by coarse particles:

- use cloud screened and quality assured data if available, is not available when select the cases where Angstrom parameters is higher than 0.6 (this will eliminate strongly cloud contaminated cases)

Note: Smoothness and symmetry checks are performed on the almucantar radiance scans which result in effective cloud screening for most cases, except for homogeneous layer clouds.

- select the cases where solar zenith angle ≥ 45°;
- select the cases where of sky-radiance fitting error is small (≤ 5-7%);
- for retrieval of $\omega_0(\lambda)$, ***n*(λ), *k*(λ)** select the cases with $\tau_{\mathbf{aer}}(440) \geq 0.4$;

select the number of the scattering angles in inverted almucantar 21 or more *(there is a criterion of almucantar symmetry. According to that criterion, the sky-radiances in the left and right parts of almucatar should be very similar. If they are too different we consider it as a cloud or other contamination and eliminate this measurement from almucantar. Correspondingly, the cases with strongly reduced number of scattering angles are less reliable).*

Expected accuracy:

***d*V(*r*)/ln*r*:** 15-25% for 0.1 µm ≤ *r* ≤ 7 µm;
25-100% (or $< 10\%$ of $dV(r)/d\ln r$ in maximum) for $r < 0.1$ µm and r >7µm

$\omega_0(\lambda)$: 0.03

***n*(λ):** 0.04

***k*(λ):** 30% - strongly absorbing aerosol;
50% - weakly absorbing aerosol;

<u>*2.4.3. Desert dust or other aerosol dominated by coarse particles:*</u>

- use cloud screen and quality assured data if available, if not contact Dr. Smirnov (asmirnov@aeronet.gsfc.nasa.gov)
- *for retrieval* of $\omega_0(\lambda)$, ***n*(λ), *k*(λ)** select the cases where solar zenith angle ≥ 45°;
- *for retrieval* of $\omega_0(\lambda)$, ***n*(λ), *k*(λ)** select the cases with $\tau_{\mathbf{aer}}(440) \geq 0.5$;

Expected accuracy:

***d*V(*r*)/ln*r*:** 15-25% for *r* ≥ 0.5 µm;
25-100% (or $< 10\%$ of $dV(r)/d\ln r$ in maximum) for $r < 0.5$ µm

Note: It is possible to obtain non-realistically high fine mode with maximum at r < 0.1 µm. This happens because of non-sphericity This effect is maximum at high solar zenith angle and minimum at low solar zenith angle (20 - 30°). In these situations sky-radiance fitting error is rather high (up to 15-20 %).

$\omega_0(\lambda)$: 0.03;

***k*(λ):** 50%;

***n*(λ):** 50%;

Note: It is possible to obtain strongly wavelength dependent ***n*(λ)** (increasing with wavelength from n(440) close to 1.33). This is an another indicator of non-sphericity. This dependence is non-realistic. In this case, only values at 870 and 1020 are close to real ones. The expected accuracy is:

***n*(870):**	0.05;
***n*(1020):**	0.04;

Appendix: The formulas for calculating standard parameters of the particle size distribution.

It should be noted that we have decided to consider all particles smaller than **0.6 μm** as particles that are **fine** mode and all particles larger than **0.6 μm** as particles of the **coarse** mode. This definition is not completely correct in all size distributions. Nevertheless, from our experience, it works in the majority of the practical cases.

Thus, everywhere below we assume:

	r_{min}	r_{max}
total (t)	0.05 μm	15 μm
fine (f)	0.05 μm	0.6 μm
coarse (c)	0.6 μm	15 μm

Effective radius:

$$r_{eff} = \frac{\int_{r_{min}}^{r_{max}} r^3 \frac{dN(r)}{d\ln r} d\ln r}{\int_{r_{min}}^{r_{max}} r^2 \frac{dN(r)}{d\ln r} d\ln r}; \qquad (1)$$

We retrieve the aerosol size distribution of the particle volume $\frac{dV(r)}{d\ln r}$. It relates to the distribution of particle number as follows:

$$\frac{dV(r)}{d\ln r} = V(r)\frac{dN(r)}{d\ln r} = \frac{4}{3}\pi r^3 \frac{dN(r)}{d\ln r}. \qquad (2)$$

We use this equation in the calculation of above formulas.

Volume median radius (mean logarithm of radius):

$$\ln r_V = \frac{\int_{r_{\min}}^{r_{\max}} \ln r \frac{dV(r)}{d\ln r} d\ln r}{\int_{r_{\min}}^{r_{\max}} \frac{dV(r)}{d\ln r} d\ln r}; \tag{3}$$

<u>Standard deviation</u> from volume median radius (mean logarithm of radius):

$$\sigma_V = \sqrt{\frac{\int_{r_{\min}}^{r_{\max}} \left(\ln r - \ln r_V\right)^2 \frac{dV(r)}{d\ln r} d\ln r}{\int_{r_{\min}}^{r_{\max}} \frac{dV(r)}{d\ln r} d\ln r}}. \tag{4}$$

Volume concentration ($\mu m^3/\mu m^2$)* :

$$C_V = \int_{r_{\min}}^{r_{\max}} \frac{dV(r)}{d\ln r} d\ln r. \tag{5}$$

(*) Please, **note** that we consider the particle size distribution in the total atmospheric column.

References.

Dubovik, O. and M. D. King, "A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements", *J. Geophys. Res., 105*, 20,673-20,696, 2000.

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Nakajima, T., M. Tanaka, and T. Yamauchi, Retrieval of the optical properties of aerosols from aureole and extinction data, *Appl. Opt., 22*, 2951-2959, 1983.

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