BNL-79287-2007-AB

ANALYTIC EXPRESSIONS FOR AEROSOL LIGHT-SCATTERING CROSS SECTION AND ÅNGSTRÖM EXPONENT

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September 2007

For presentation at the
American Geophysical Union Fall Meeting
San Francisco, CA
December 10-14, 2007

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ABSTRACT

The light-scattering cross section σ_{sca} and its dependence on wavelength λ, which is parameterized by the Ångström exponent $\mathring{a}$, are intrinsic properties of an aerosol. These quantities are important for understanding Earth's radiative balance and yield information on the sizes of particles that provide the dominant contribution to the scattering; aerosols for which the scattering is dominated by particles much smaller than the wavelength are characterized by larger values of $\mathring{a}$ than aerosols for which scattering is dominated by much larger particles, for which $\mathring{a}$ is near zero. For an aerosol consisting of spherical particles σ_{sca} can be calculated by integration over the size distribution given knowledge of the scattering efficiency of a particle Q_{sca}, which depends on the radius of the particle, the wavelength, and the index of refraction m, and $\mathring{a}$ can be determined from the derivative of σ_{sca} with respect to wavelength. However, calculation of these quantities in this manner is computationally laborious and does not explicitly illustrate the dependences on properties of the size distribution or on wavelength or relative humidity.

By using scaling arguments and an approximation for the scattering efficiency, an analytic expression can be derived for the scattering cross section of an aerosol with a lognormal size distribution characterized by geometric radius r_0 and geometric standard deviation σ that is accurate over a wide range of these parameters. This expression is computationally much more efficient, and permits derivation of a simple analytic expression for the Ångström exponent

$$\mathring{a} = \frac{-1.14 - 2(\ln\sigma)^2 - \ln\left[\frac{r_0(m-1)}{\lambda}\right]}{0.28 + (\ln\sigma)^2}$$

which explicitly shows the dependence on parameters of the size distribution r_0 and σ and on the wavelength and index of refraction. Other formulae are presented for situations outside the range of validity of this expression, permitting a computationally efficient yet accurate means of determining the Ångström exponent.