

Simulations of Optical Properties of Dust and Sea Salt for Use in Global Climate Models

*C. C. Chuang and K. E. Grant
Atmospheric Sciences Division
Lawrence Livermore National Laboratory
Livermore, California*

Introduction

Assessments of radiation impact by atmospheric aerosols rely on a precise description of aerosol optical properties and an accurate representation of temporal and spatial variations of aerosol distributions. Parts of our earlier studies have been aimed at developing an understanding of global aerosol abundances as well as developing parameterizations for use in global climate models to treat the spectral optical properties of sulfate and carbonaceous aerosols (Liousse et al. 1996; Chuang et al. 1997; Penner et al. 1998; Grant et al. 1999). In this study, we extended our treatment to dust and sea salt in order to compute their contribution to the total aerosol optical thickness in a global scale. This new development will allow us to examine the forcing and response of the climate system to changes of all important aerosol types.

Size Distribution

Optical properties of aerosols are determined by the size distribution and the refractive index. We used different size distributions to represent background dust, wind-carrying dust, particles generated by desert dust storms as well as sea salt particles in the maritime environment (see Figure 1). Each distribution is expressed as the superposition of three log-normal functions,

$$\frac{dN}{d \log r} = \sum_{i=1}^3 \frac{N_i}{\sqrt{2\pi \log \sigma_i}} \exp \left[-\frac{(\log r - \log R_i)^2}{2(\log \sigma_i)^2} \right] \quad (1)$$

Size distribution parameters are listed in Table 1. Sea salt particles, unlike dust, are hygroscopic. Its size will change with the ambient relative humidity. The growth of sea salt particles with relative humidity is approximated by

$$r_w = \left[\frac{C_1 r_d^{C_2}}{C_3 r_d^{C_4} - \log S} + r_d^3 \right]^{1/3} \quad (2)$$

where r_w is the wet particle radius (cm), r_d is the dry radius, S is the relative humidity, $C_1 = 0.7674$, $C_2 = 3.079$, $C_3 = 2.573 \times 10^{-11}$, and $C_4 = 01.424$ (Gerber 1985).

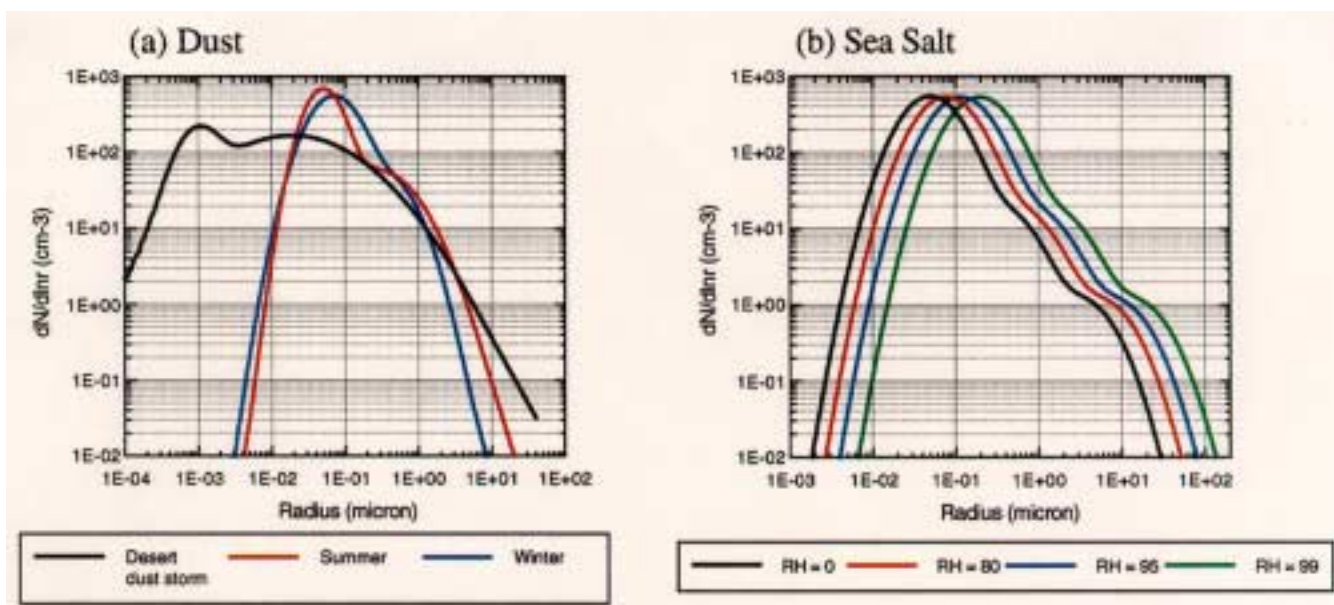


Figure 1. Size distributions for dust and sea salt particles.

	N_i	R_i (μm)	σ_i
Winter Dust (background dust) (d'Almeida et al. 1991)	927.440	0.07	1.95
	72.463	0.39	2.00
	0.097	1.90	2.15
Summer Dust (wind-carrying dust) (d'Almeida et al. 1991)	854.240	0.05	1.65
	145.687	0.27	2.67
	0.073	4.00	2.40
Desert Dust Storm (Jaenicke 1988)	254.6	0.001	1.766
	745.3	0.0188	5.888
	0.1	10.8	2.742
Sea Salt (d'Almeida et al. 1991)	970.0	0.05	2.03
	28.0	0.40	2.03
	2.0	3.30	2.03

Optical Properties

The optical properties were calculated from Mie theory using the volume average of refractive index for each aerosol component at wavelengths between 0.175 μm and 4 μm . We assumed a dry density of 2.0 g/cm^{-3} for dust and 2.216 g/cm^{-3} for sea salt. The optical properties from our detailed Mie calculations were then averaged over 12 wavelength bands for use in global climate models, weighted by the solar energy available at each wavelength within the band. There are nine bands in the ultraviolet

and visible wavelengths (0.175 μm to 0.7 μm) and three bands in the near-infrared (0.7 μm to 4 μm). Figure 2 presents the calculated optical properties as a function of wavelength as well as the averages over each wavelength band.

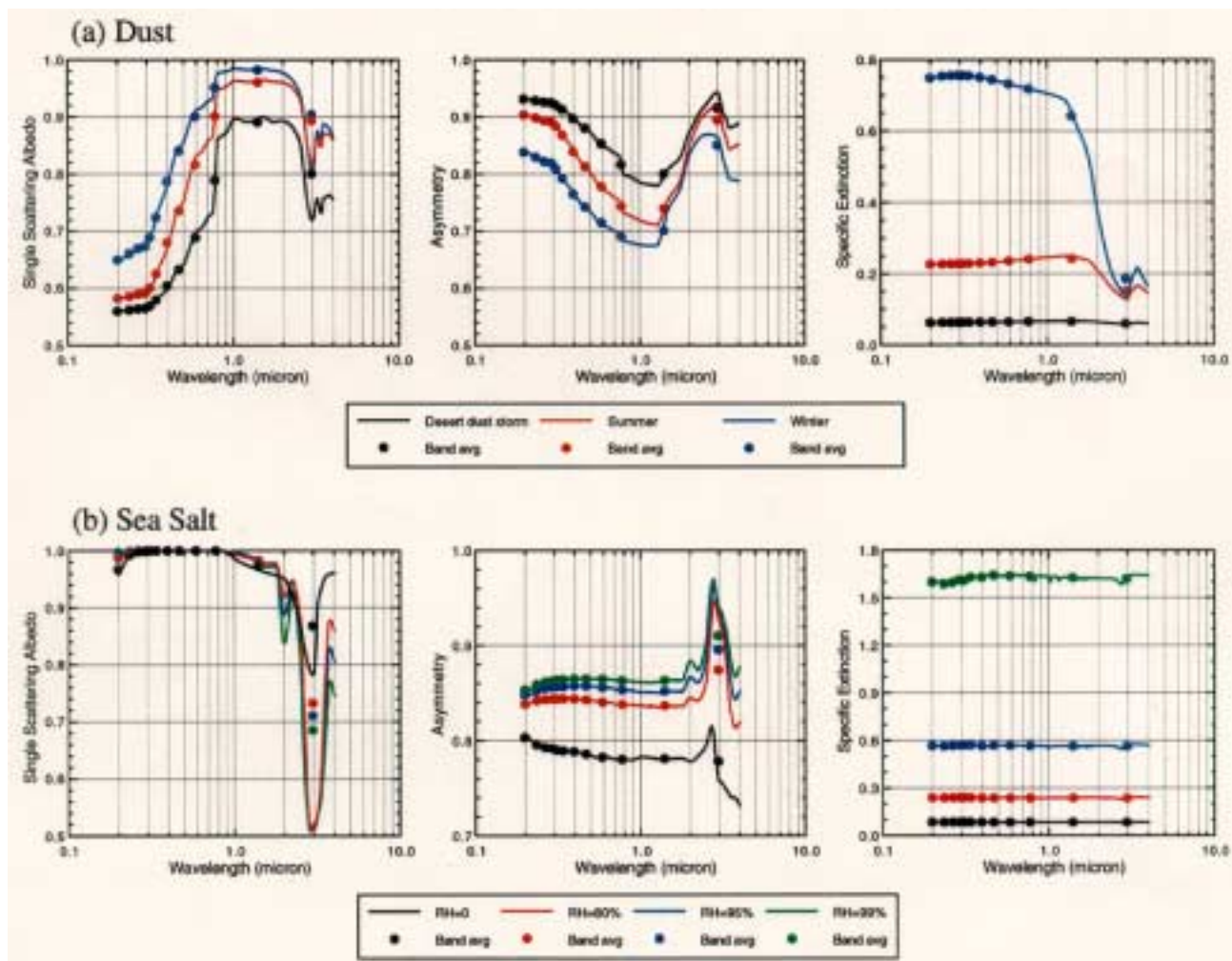


Figure 2. Calculated optical properties for dust and sea salt as a function of wavelength. Also shown are the values averaged over each wavelength band.

The variation of the optical properties of sea-salt particles with relative humidity can effectively be modeled by the equation:

$$y = 1 + C_1 \left[e^{C_2 S^{C_3}} - 1 \right] + C_4 \left[1 - e^{-C_5 S} \right] \quad (3)$$

where y is the optical property to be modeled, and C_n are numerical fit coefficients. Relative to the dry aerosol properties, the variation with S can show two general features: a sharp rise at high humidity and an initial toe at the very low humidity followed by a level or slowly increasing region. The second and third terms on the right-hand side of Eq. (3) were chosen to model these features, respectively. The

three coefficients of the second term (C_1 , C_2 , and C_3), although not independent, determine a particular feature of the high humidity exponential rise: the maximum, the sharpness of the increase, and the location of the increase. We determined the coefficients of Eq. (3) by a least squares fit to the band averages at different relative humidity, as shown in Figure 3.

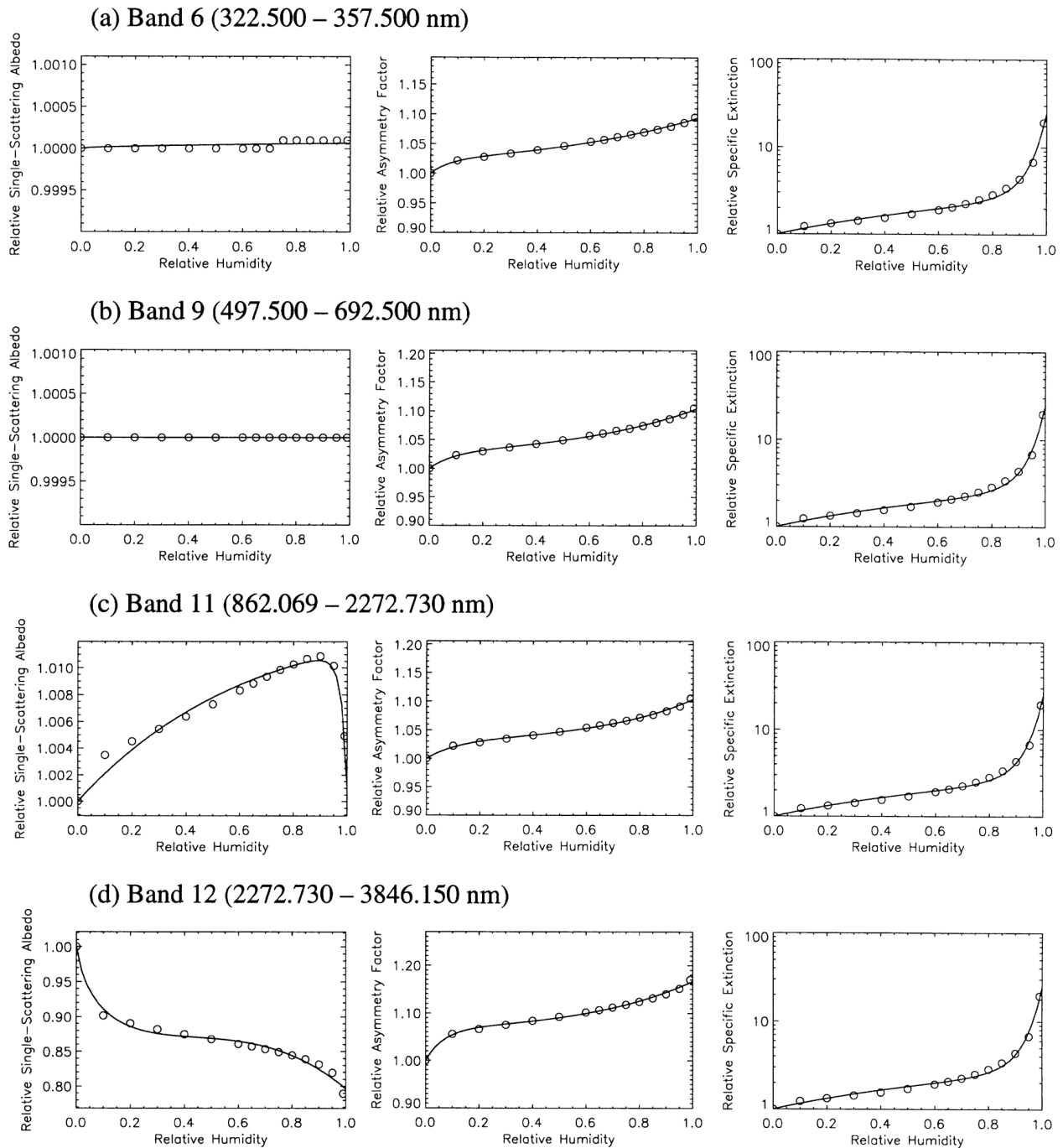


Figure 3. Relative humidity scaling of optical properties of sea salt for selected wavelength bands. The curve is the numerical fit and the circle represents the band average.

Future Work

The calculated optical properties and the newly developed parameterization will be incorporated into our coupled global climate/chemistry model to examine the contribution of dust and sea salt particles to the global aerosol burden. We will compare the simulated total aerosol optical depths and extinction profiles to those retrieved from satellite measurements. We will validate whether our aerosol emission fields are correct and whether our treatment of transport and transformation is reasonable. We are interested in identifying the degree and conditions under which model and the observed aerosols demonstrate significant biases or departures in variability. In regions with significant aerosol extinction, we will characterize scales of spatial covariance and the effects of such variability on radiative forcings.

Corresponding Author

Catherine C. Chuang, chuang1@llnl.gov (925) 423-2572

References

Chuang, C. C., J. E. Penner, K. E. Taylor, A. S. Grossman, and J. J. Walton, 1997: An assessment of the radiative effects of anthropogenic sulfate. *J. Geophys. Res.*, **102**, 3761-3778.

d'Almeida, G. A., P. Koepke, and E. P. Shettle, 1991: *Atmospheric aerosols: Global climatology and radiative characteristics*. A Deepak Publishing, Hampton, Virginia, 561 pp.

Gerber, H. E., 1985: Relative-humidity parameterization of the Navy aerosol model (NAM), NRL Report 8956, National Research Laboratory, Washington, D.C.

Grant, K. E., C. C. Chuang, A. S. Grossman, and J. E. Penner, 1999: Modeling the spectral optical properties of ammonium sulfate and biomass burning aerosols: Parameterization of relative humidity effects and model results. *Atmos. Environ.*, **33**, 2603-2620.

Jaenicke, R., 1988: Chapter 9: Aerosol physics and chemistry. Landolt-Bornstein, New Series, V/4b, Springer, Berlin, 391-457.

Liousse, C., J. E. Penner, C. C. Chuang, J. J. Walton, H. Eddleman, and H. Cachier, 1996: A global three-dimensional model study of carbonaceous aerosols. *J. Geophys. Res.*, **101**, 19,411-19,432.

Penner, J. E., C. C. Chuang, and K. E. Grant, 1998: Climate forcing by carbonaceous and sulfate aerosols. *Clim. Dyn.*, **14**, 839-851.