SGPGET: AN SBDART Module for Aerosol Radiative Transfer

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Abstract

Quantification of the aerosol direct effect and climate sensitivity requires accurate estimates of optical properties as inputs to a radiative transfer model. Long-term measurements of aerosol properties at the Southern Great Plains (SGP) site can be used as an improvement over a best guess or global average for optical properties (e.g., asymmetry factor of 0.7) used in Atmospheric Radiation Measurement (ARM) products such as the Broadband Heating Rate Profile Value-Added Product (VAP). To make this information available to the ARM community and others, an add-on module for a commonly used radiative transfer model, the Santa Barbara DISORT Atmospheric Radiative Transfer (SBDART) (Ricchiazzi et al. 1998), is being developed. A look up table and algorithm will provide aerosol related model inputs including aerosol optical and atmospheric state properties at high temporal resolution. These inputs can be used in conjunction with any mode of operation and with any other information, for example, cloud properties, in SBDART or any other radiative transfer model. Aerosol properties measured at three visible wavelengths are extrapolated so that flux calculations can be made in any desired wavelength across the shortwave spectrum. Several sources of uncertainty contribute to degraded accuracy of the aerosol property estimation. The effect of these uncertainties is shown through error analysis and comparisons of modeled and observed surface irradiance. A module is also being developed for the North Slope of Alaska locale.

Aerosol Data

Long-term data from the Aerosol Observing System (AOS) at the SGP site are available since 1996 at hourly, daily, and monthly average time scales in both clear-sky and cloudy conditions. These data provide the potential for a continuous set of aerosol properties at any desired time scale for radiative transfer modeling of radiation fluxes and heating rates in the atmosphere. Observations are made at three wavelengths for most aerosol properties and at one wavelength for others. For climate relevance, measurements across the shortwave spectrum are desired. A subset of the AOS data, shown in Figure 1, is used as the basis for determining wavelength dependence of relevant aerosol properties for radiative transfer in the shortwave. These data represent hourly averages for the full time series of measurements available for the SGP site. Scattering and backscattering data measured under dry conditions (≤40% relative humidity [RH]) have been converted to ambient relative humidity conditions using the measured $f(RH)_{(85\% / 40\%)}$ and ambient RH at the site. The f(RH) parameter is a factor that represents the enhancement in aerosol scattering or backscattering due to water uptake. Aerosol scattering is measured at a range of relative humidity's between 40% and 85% and a two-parameter fit is used to provide the relationship among the points. The scattering measured under dry condition is then adjusted to ambient conditions through this relationship. The enhancement in scattering can be reliably derived for ambient conditions up to 90% humidity. Observations that occurs under relative humidity's greater than 90% have been excluded from the dataset.

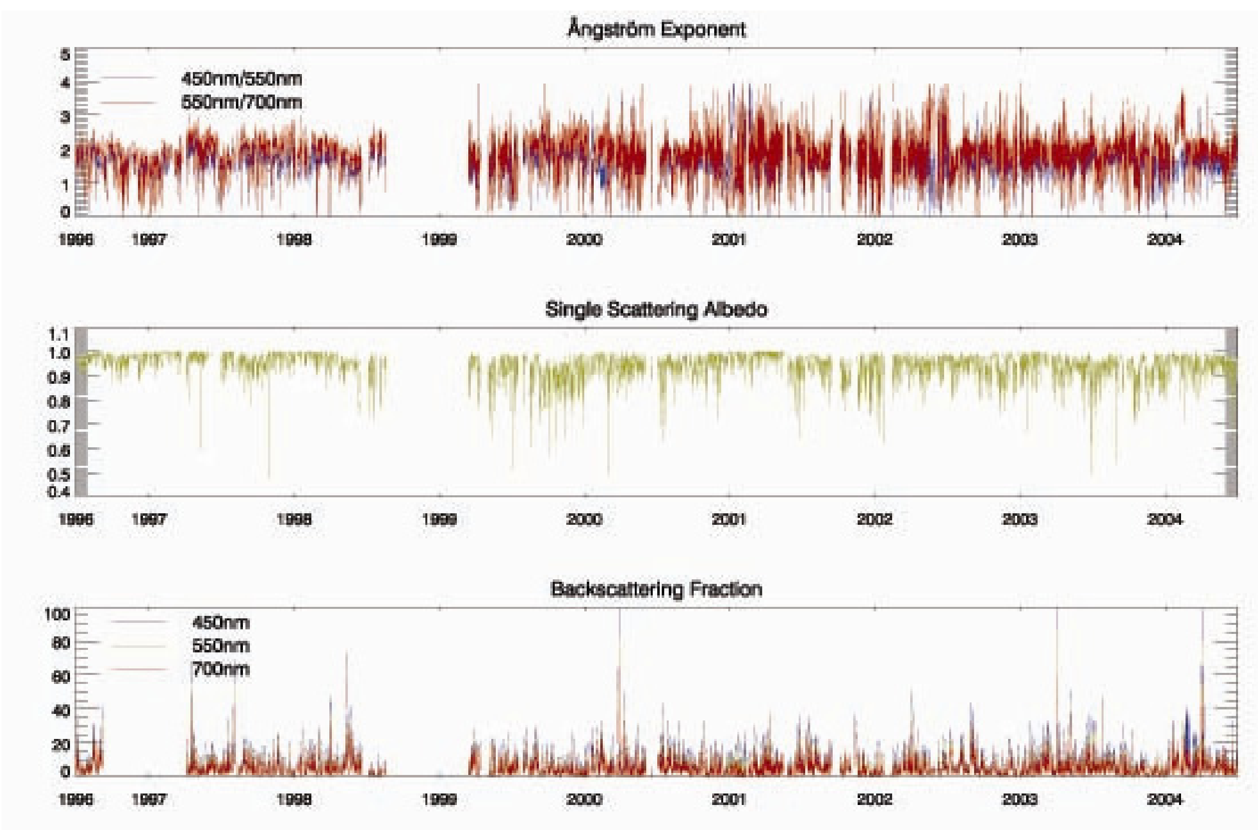

Figure 1. Time series of in situ data from the SGP site for Ångström exponent, single scattering albedo, and backscatter fraction at three wavelengths.

Statistics from Cimel volume distributions can be used to provide an average size distribution to extend known optical properties to wavelengths beyond what are measured. The size data are modeled as a multimode lognormal distribution specified in terms of the mode radius, r_m, standard deviation of log(r), σ_m, and mode population N_m.

$$\frac{dn}{d\log(r)} = \frac{1}{\sqrt{2\pi}} \sum_{m=1,3} \frac{N_m}{\sigma_m} \exp\left(-\frac{1}{2} \frac{\log(r/r_m)^2}{\sigma_m^2} \right)$$

Table 1. Size distribution statistics from Nakajima inversions, SGP.

	mode 1		mode 2		mode 3		mode population	
#modes	**r_m (μm)**	**σ_m**	**r_m (μm)**	**σ_m**	**r_m (μm)**	**σ_m**	**N2 / N1**	**N3 / N1**
2 (71%)*	0.10	0.43	3.03	0.36	------	------	7.1×10^{-4}	------
3 (29%)*	0.11	0.29	1.32	0.21	3.96	0.34	1.9×10^{-2}	3.8×10^{-5}

*2563 observations from April 1994 to April 2004

Alternatively, a size distribution derived from the in situ measurements (Fiebig and Ogren 2005; Fiebig et al. 2005) may be used. This option may be less computationally efficient but avoids using column and surface properties coincidentally. The validity of both approaches can be determined by examining the sensitivity to the size distribution and as outlined below in the accuracy assessment.

Mie calculations using measured aerosol properties at three wavelengths and a size distribution can be used to solve for an aerosol refractive index at all wavelengths across the shortwave. The refractive index is also available from Cimel observations (Dubovik and King 2000) for some clear sky time periods. Together, this information can be used to determine aerosol properties needed for broadband radiative forcing calculations.

Data Tables and the SGPGET Interface

Data tables of aerosol optical and atmospheric state properties are produced from measurements and Mie calculations. Various tables containing these properties are averaged over the different temporal resolutions/climatology listed below. The climatology represents aerosol types determined statistically from long-tern measurements at the SGP site including meteorology and aerosol optical and chemical properties (Payton et al. 2004).

SGPGET Output/SBDART Input:

- optical depth
- single scattering albedo
- asymmetry parameter
- relative humidity
- water vapor
- ozone

Available averaged over:

- hour
- day
- season
- year
- aerosol type (climatological)

Optical depth is derived through the standard relationship between extinction coefficient and the particle distribution using the extinction efficiency produced by Mie calculations.

SGPGET will be accessed though a website with a user-friendly interface. The user supplies desired averaging resolution and time period as well as optional variables further characterizing the aerosol. If optical depth and aerosol vertical distribution measurements exist, they can be entered here to be used instead of the derived extinction efficiency and default vertical aerosol profile. The module produces aerosol parameters that are called in the usual SBDART input format. Any other options can be implemented along with these aerosol data such as the inclusion of clouds or variation in water vapor.

Uncertainty Analysis

The primary sources of error for this product will be

- limitations in instrument accuracy
- extrapolation of surface properties to the whole atmospheric column
- assumptions made in the specification of size distribution and index of refraction for the determination of properties at wavelengths that are not directly measured.

Once the data tables are completed, the error will be summarized through comparisons of modeled and measured surface irradiance as in the specific case shown at right. This example compares mutifilter rotating shadowband radiometer data from a day during the 2003 Aerosol Intensive Operational Period and uses measured values for relative humidity, ozone, and water vapor. Measured values for optical depth, RH, ozone, and water vapor are used here with aerosol properties including single scattering albedo, asymmetry factor, and angstrom exponent at hourly temporal resolution are used in this comparison.

References

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