Retrieving the Relative Number of Fine to Coarse Mode Aerosol from Ground-Based Visible and Infrared Observation

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Introduction

The size distribution of the radiatively important atmospheric aerosol is described typically by a bi-modal lognormal size distribution. Many groups attempt to retrieve the aerosol size distribution from passive radiometers that measure aerosol optical depth at a variety of wavelengths. Most of these ground-based instruments use silicon detectors and thus the aerosol optical depth observations are at wavelengths less than 1 μm; therefore, there is little sensitivity in these observations to the number of coarse mode aerosol. We have developed a technique that uses atmospheric emitted radiance interferometer (AERI) observations from 3-12 μm, together with the multi-filter rotating shadowband radiometer (MFRSR) aerosol optical depth at 0.5 μm, to retrieve the relative number of fine to coarse mode aerosol. We applied this retrieval to data collected on several days during the 2003 Atmospheric Radiation Measurement (ARM) Aerosol Intensive Observation Period (IOP) at the Southern Great Plains (SGP) site. During this experiment, aerosol size distribution measurements were made at the surface by a CLIMET optical aerosol particle counter, which measures the aerosol number in 16 bins from 0.3 to 13 μm. We will show comparisons of the AERI+MFRSR retrieved fine-to-coarse mode ratio to a similar value derived from the CLIMET observations, showing the skill and utility of this combined retrieval.

Method

Aerosol optical depth can be retrieved from the AERI observations using the retrieval technique of Turner (2005), where the "cloud" is a layer of aerosol with an assumed composition (i.e., refractive index is specified) and shape (typically spheres). The AERI retrievals are sensitive to the assumed particle size distribution (PSD). We take advantage of this sensitivity by assuming a bi-modal PSD with each mode given by a lognormal, where we assume different relative numbers of fine mode to coarse mode aerosol. The AERI retrieval is run multiple times, where the relative number of fine mode aerosols is 1e2, 1e3, 1e4, and 1e5 times greater than the number of coarse mode aerosols. These runs provide a set of aerosol optical depth for each AERI sample (the optical depth increases as the relative fine-to-coarse mode aerosol number increases). The aerosol optical depth data are translated from an infrared optical depth to a geometric-limit optical depth (i.e., $Q_{ext} = 2$), and then compared to the optical depth derived from the MFRSR data at 500 nm. This allows us to determine the relative number of fine-to-coarse mode aerosols that were required to yield a consistent optical depth from the AERI and the MFRSR.

Results

The method was applied to data collected at the ARM SGP site during the Aerosol IOP in May 2003. During this IOP, ARM instrumentation was augmented by additional aerosol instrumentation, including a CLIMET optical aerosol particle counter, which provides an aerosol size distribution measurement from 0.3 μm to 13 μm at the surface. We then fit a bi-modal lognormal size distribution to the CLIMET data and thus produced the relative fine-to-coarse mode aerosol number (i.e., the same quantity that is retrieved by the AERI + MFRSR method).

An example from this IOP is shown in Figure 1 for 10 May 2003. During this day, the vertical distribution of aerosol, as observed by the Raman lidar (not shown), changed dramatically and provided a distinct N_{fine}/N_{coarse} signal. The AERI+MFRSR retrievals, which are only valid in cloud-free periods, track the values derived from the CLIMET data well, especially considering that the former method is a column-integrated technique and the latter an in situ method. The AERI+MFRSR N_{fine}/N_{coarse} retrievals are also well correlated with the Angstrom exponent derived from the 500 and 870 nm channels of the MFRSR, which is also sensitive to the PSD.

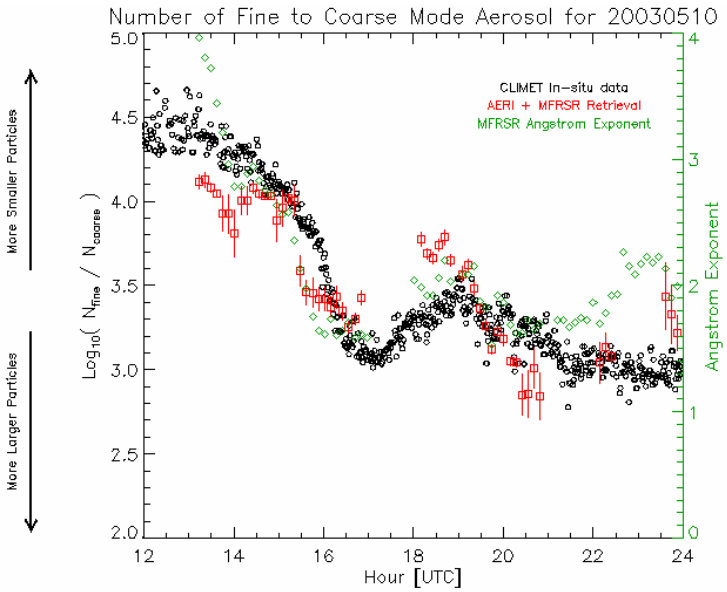

Figure 1. AERI+MFRSR retrievals (squares, with error bars), CLIMET data (dark circles), and MFRSR Angstrom exponent (light diamonds) for 10 May 2003.

The method was applied to 8 days during the Aerosol IOP; the results are shown in Figure 2. There is a fair amount of scatter in the AERI + MFRSR retrievals with the CLIMET data, but the correlation is fair (r = 0.63). The correlation of the AERI + MFRSR retrievals with the MFRSR Angstrom exponent is worse for the entire dataset (r = 0.36); however, if data from the 9th and 27th are excluded, then the correlation improves to 0.76. The Raman lidar data on the 9th and 27th shows that multiple aerosol layers existed on these two days; analysis by other groups suggests that both are aged smoke from biomass burning events in central America and Siberia, respectively. Therefore, it suggests that the AERI + MFRSR retrievals may be sensitive to the intrinsic properties of the aerosol. We are currently pursuing this line of investigation.

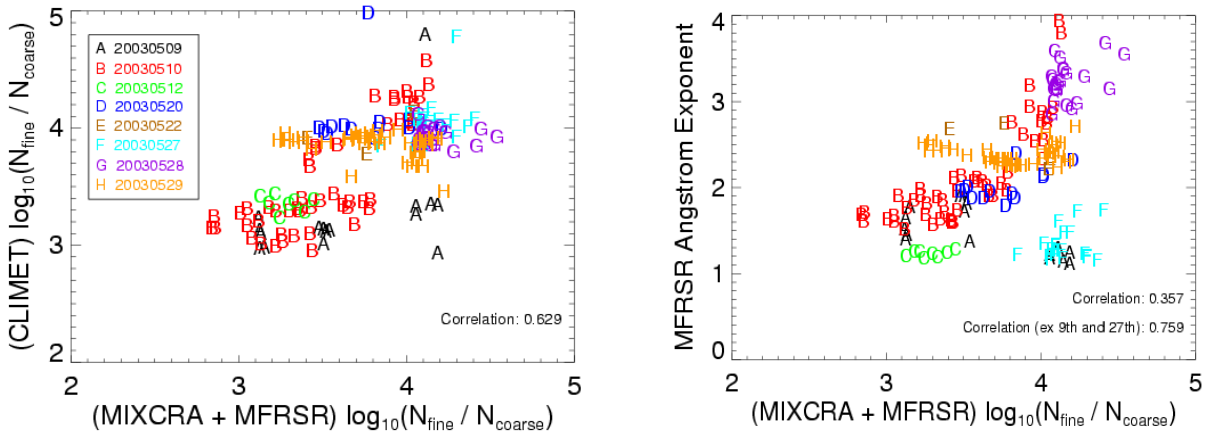

Figure 2. Comparisons of N_{fine}/N_{coarse} from the AERI+MFRSR retrievals with data from CLIMET (left) and the Angstrom exponent (500 to 870 nm) from the MFRSR (right) for 8 days during the 2003 Aerosol IOP.

Summary

The ratio of the number of fine mode aerosols to the number of coarse mode aerosols can be retrieved from the combination of observations from the AERI (infrared) and the MFRSR (visible). The method demonstrates skill in retrieving this ratio as compared to measurements from an optical particle counter at the surface and from the visible/near-infrared Angstrom exponent. The method is sensitive to elevated aerosol layers that are of different composition than the boundary layer aerosol. However, the method does provide a way to separate the total optical depth into the fine mode and coarse mode fractions, which is important for many different aerosol research projects.

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Reference

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