Preprint
UCRL-JC-146711

Comparison of Aerosol Properties Within and Above the ABL at the ARM Program's SGP Site

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This article was submitted to
12th Joint Conference on the Applications of Air Pollution Meteorology with the Air and Waste Management Association, Norfolk, Virginia, May 20-24, 2002

U.S. Department of Energy
Lawrence Livermore National Laboratory

February 26, 2002

DISCLAIMER

4.7 COMPARISON OF AEROSOL PROPERTIES WITHIN AND ABOVE THE ABL AT THE ARM PROGRAM'S SGP SITE

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1. INTRODUCTION

The goal of this study was to determine under what conditions, if any, measurements of aerosol properties made at the Earth's surface are representative of the aerosol properties within the column of air above the surface. This project used data from the Atmospheric Radiation Measurement (ARM) site at the Southern Great Plains (SGP) site (Stokes and Schwartz 1994), which is one of the only locations in the world where ground-based and in situ airborne measurements of atmospheric aerosol are made on a routine basis. All flight legs in the one-year period from March 2000 to March 2001 were categorized as either within or above the atmospheric boundary layer (ABL) using an objective mixing height determination technique. The correlations between the aerosol properties measured at the surface and those measured within and above the ABL were then computed. The conclusion of this comparison is that the aerosol extensive properties (those that depend upon the amount of aerosol that is present in the atmosphere, i.e., either the number or mass concentrations), and intensive properties (those that do not depend upon the amount of aerosol present) measured at the surface are representative of values within the ABL, but not within the free atmosphere.

2. INSTRUMENTATION

The Aerosol Observing System (AOS) is the primary ARM platform for *in situ* aerosol measurements at the surface level (10 m AGL). It has been operational since April 1996 and is currently producing continuous aerosol data.

The primary quantities measured with the AOS system are: total scattering and hemispheric backscattering coefficients in m^{-1} for three wavelengths, absorption coefficient in m^{-1} for one wavelength, total condensation nuclei (CN) concentration in No. cm^{-3}, number distribution in No. cm^{-3} for particles with sizes ranging from 0.1 to 10 m, and ozone concentration in ppbv.

Many quantities of interest to aerosol and radiative transfer modeling research can be derived from these basic aerosol measurements. These quantities include: extinction coefficient, single scatter albedo, co-albedo, hemispheric backscatter fraction, and Angstrom exponent.

Members of the the Aerosol Group at NOAA/Climate Monitoring and Diagnostics Laboratory (CMDL), under ARM Program funding, have recently outfitted a Cessna C-172N single-engine, light aircraft with aerosol instrumentation similar to the AOS. The research flights began in March 2000 and have been conducted several times per week (weather permitting) for a project duration of two years. The aircraft flight track, which covers the SGP site area, consists of an upward spiral interrupted by periods of level flight.

3. MIXING HEIGHT DETERMINATION

Various MH-determination techniques were tested and evaluated. In particular the Blackdar and Tennekes (1968) formula, the Zilitinkevich (1972) formula, the method of Nieuwstadt (1981), the slab model (Tennekes 1973; Carson 1973), the parcel method (Holzworth 1964, 1967), the Surface-Based Temperature Inversion Technique (Anfossi et al 1976; Stull 1983), the Height of Low-level Relative Wind Maximum Technique (Blackadar 1957), and the Heffter Techique (Heffter 1980),

In order to be operationally useful, the chosen MH-determination technique should work in every kind of stability regime and rely upon data frequently available at the ARM SGP site. Although high vertical resolution is often desirable, it was not crucial for this study. The reason for this is that the MH values were used to determine which flight legs was within and above the ABL, and the legs are at altitude intervals of roughly 500 m. Moreover, a method that generally overestimates the MH is preferred because it results in a more conservative correlation of the aerosol properties measured at the surface and within the ABL.

Based on all the above considerations, the method that performs best under the widest possible conditions is the Heffter Technique, applied on radiosonde data. This technique works in every kind of

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stability regime, and almost in every case gives estimates of the ABL depth that are at or above the true MH selected by manually evaluating the temperature, potential temperature, and moisture vertical profile.

4. CONCLUSION

The aerosol extensive properties considered in this study are the absorption coefficient for green light and the total scattering coefficients for blue and green light. Moreover the aerosol intensive properties considered here are the hemispheric backscatter ratios for blue and green channel, the single scattering albedo, and the Angstrom exponent.

Many previous studies (for example Kim et al. 1993, Ahonen et al. 1997, Zelenka 1997) show that the vertical profiles of aerosol extensive properties are significantly affected by the depth of the ML. These studies have shown that a low MH leads to high particle concentrations near the surface, while a larger MH results in lower concentrations near the surface. This difference is caused by dilution of the aerosol in the ABL, when the MH is high. It is also clear that the top of the boundary layer acts as a lid for most aerosol particles, with relatively high and constant number and mass concentrations within the ABL, and lower concentrations above it in the FA. Only a few studies (for example Wendisch et al. 1996) discussed what is known about the vertical variation of aerosol intensive properties.

Using the Heffter technique to determine the MH, averages for all of the extensive and intensive aerosol quantities within and above the ABL were computed for 59 flight days. Then a comparison between those averages and the surface values of the aerosol extensive and intensive properties was performed. The results of this comparison demonstrated that the intensive aerosol properties within the ABL were much more similar to the surface values than those above the ABL. In fact, there was almost no correlation at all between the surface values and those above the ABL. Thus, this analysis indicates that the aerosol intensive properties are affected by the MH in much the same way as the extensive aerosol properties.

Acknowledgments: This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

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