AEROSOL AND CLOUDWATER PROPERTIES AT WHITEFACE MOUNTAIN, NEW YORK

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Abstract. A field program for the measurement of the physical and chemical properties of aerosols and clouds was conducted at Whiteface Mountain, N.Y., during an 8-week period in June, July, and August 1983. Analysis of two-stage Nuclepore filter samples by proton-induced X-ray emission (PIXE) spectroscopy showed that most (85 to 90\%) of the aerosol sulfate was in the accumulation mode (modal radius \( r \approx 0.1 \mu\text{m} \)) and that \( \approx 90\% \) of total sulfate originated southwest of the Whiteface Mountain site. During a typical pollution episode originating in the Midwest, the total aerosol sulfate concentration was 19 \( \mu\text{g m}^{-3} \), or 63\% of total dry aerosol, which was \( \approx 30 \mu\text{g m}^{-3} \). Scavenging of sulfate aerosol by clouds was found to be greater than 95\% efficient in clouds of 0.5 g m\(^{-3}\) liquid water content. Measured pH values when the air mass trajectories were from the southwest were systematically lower than when the trajectories were from the northwest or northeast, i.e., 3.4 vs 4.4 and 4.8. In the southwest sector water samples, \( \text{SO}_4^{2-} \) and \( \text{NO}_3^- \) were highly correlated to each other and to free \( \text{H}^+ \), \( \text{Ca}^{2+} \), \( \text{Cl}^- \), \( \text{Pb} \), and \( \text{Ba} \).

1. Introduction

During the summers of 1981, 1982, and 1983, the Air Quality Division, Air Resources Laboratory, NOAA, conducted projects at the Vincent Schaefer Observatory, Whiteface Mountain, N.Y., in cooperation with the Atmospheric Sciences Research Center (ASRC), State University of New York, Albany. The purpose was to document some of the physical and chemical characteristics of aerosols and clouds in polluted and nonpolluted air masses, and to relate differences to source areas or meteorological factors. The characteristics of interest included aerosol and cloud size distributions, the chemical composition of aerosol and water samples, especially \textit{vis-a-vis} the air mass source sectors, the nucleation of clouds and the incorporation of aerosols in the cloud liquid phase.

Pueschel \textit{et al.} (1986) showed that anthropogenic sources hundreds of kilometers distant from Whiteface Mountain cause order-of-magnitude increases in small-particle numbers and in aerosol mass loadings that, in clouds, affect the cloud drop concentration, size distribution, and liquid water content. Falconer and Falconer (1980) suggested that acid input from cloudwater to the ecosystem at Whiteface Mountain is more important than acid input from rain. They reported the mean pH of non-precipitating clouds was 3.55 and 3.50 during 1977 and 1979, but that when precipitation was intercepted concurrently with clouds the sample pH was much higher. Castillo \textit{et al.} (1983) reported a mean pH of 3.6 for all cloud samples from relatively clean continental air masses where the major ions were sulfate, nitrate, K, ammonium, and Ca.

The atmospheric aerosol \textit{sans} water cloud has also been the focus of several research
efforts, since the existing atmospheric particles are what act as condensation nuclei during cloud formation. Parekh and Husain (1982), working at Whiteface Mountain, estimated the relative contributions of particle sulfate from each of 12 compass sectors over an 18-mo study; they reported daily sulfate concentrations of from <0.2 to 35 µg m⁻³. That study indicated that the predominant source region of aerosol sulfate was the industrialized Midwest, and that U.S. sources contribute at least 4 times as much as do Canadian sources. Parekh and Husain used filter paper in high-volume samplers to obtain total particulates. Ferek et al. (1983) collected aerosol samples from an aircraft using a cascade impactor sampler to provide size discrimination. Their study was concentrated near the Ohio River Valley, but included the Adirondack region of upstate New York. Sulfate concentrations were much higher in summer than in fall, 17 ± 10 vs 7 ± 3 µg m⁻³, and S was concentrated in the smallest modal diameter fraction.

This report evaluates analyses of cloudwater, aerosols in the absence of water clouds, cloud and aerosol size distributions, and related air mass trajectories during a June, July, August 1983 project at the Vincent Schaefer Observatory at the summit of Whiteface Mountain, N.Y.

2. Experimental

Continuous in situ pH measurements were made on water collected with the passive omnidirectional collector, described by Falconer and Farrell (1977), that uses the principle of droplet collection on plastic filament as a cloud blows through the filament grid. Wind is necessary for collection of the water. Samples for subsequent chemical analysis were collected with another collector of ASRC design (Fuzzi et al., 1984) that is a variant of the Falconer and Farrell design. It uses a blower to pull air through the filament grid. The theoretical collection efficiency of the passive system is ≥ 50% at wind speeds of 5 m s⁻¹ or more for cloud droplets of radius R = 4 µm, and ≥ 85% for R = 10 µm (Winters et al., 1979). Fuzzi et al. (1984) reported similar collection efficiencies for the blower-operated system, which operates at an inlet velocity of 5 m s⁻¹. The 'blower' collector was fixed in place, oriented toward the most frequent wind, i.e., west–southwest. In sample pairs collected simultaneously from the blower system and from the passive collector, ion concentrations showed no statistical differences at the 1% level confidence (Student's 't' test) when the geometric means were intercompared using a normal distribution test (Castillo, 1984).

The water samples were analyzed at the U.S. Geological Survey Water Laboratory, Arvada, Colo. They were stored at ~5 °C between collection and the time of analysis, and were shipped with 'cold-pack' material to minimize exposure to ambient temperatures. Anions (SO₄²⁻, NO₃⁻, F⁻, Cl⁻, Br⁻, C₂O₄²⁻) were measured by ion chromatography (Fishman and Pyen, 1979); cations (Ca²⁺, Mg²⁺, Na⁺) and metallic elements (Ba, Be, Cd, Co, Cu, Fe, Li, Mn, Mo, Pb, Si, Sr, V) were measured by inductively coupled plasma atomic emission spectrometry (Fishman and Bradford, 1982); K⁺ was analyzed by atomic absorption spectrometry.