

Contents

8	Climatology of Extreme Sulfate Episodes	8-1
8.1	Introduction	8-1
8.2	Extreme Sulfur Episodes During WHITEX	8-2
8.2.1	High Sulfur Episodes	8-2
8.2.2	Low Sulfur Episodes	8-6
8.2.3	Summary of WHITEX Episodes	8-8
8.3	Extreme Sulfur Events During November 1986 - March 1987	8-9
8.3.1	High Events	8-10
8.3.2	Low Events	8-13
8.4	High Sulfur Events During 1982 - 1986	8-14
8.4.1	November 1 to November 4, 1983	8-14
8.4.2	March 29 to April 1, 1986	8-15
8.4.3	January 22 to January 25, 1985	8-15
8.4.4	November 5 to November 7, 1983	8-15
8.4.5	November 23 to November 26, 1982	8-15
8.4.6	March 1 to March 3, 1986	8-16
8.5	Summary of Historic Episodes	8-16
8.6	Overall Summary and Conclusions	8-16

List of Tables

- 8.1 List of the seven *S* events above 250 ng m⁻³ (high) and the three *S* events below 90 ng m⁻³ (low) at Hopi Point from the NPS network data after June 1986 for the months of November through March. 8-11
- 8.2 High measurements of *S* from the NPS network monitor at Hopi Point for winter months before June 1986. 8-14

List of Figures

8.1	Schematic drawing of terrain in the WHITEX study area.	8-3
8.2	Sulfate ion concentration ($\mu\text{g m}^{-3}$) at Hopi Point for the WHITEX period.	8-4
8.3	Illustration of circulation induced by radiational heating of elevated terrain.	8-6
8.4	Wind vectors at WHITEX sites on Feb. 9, 1987.	8-7
8.5	Sulfate ion concentration ($\mu\text{g m}^{-3}$) at Page for the WHITEX period.	8-9
8.6	Sulfate ion concentration ($\mu\text{g m}^{-3}$) at Bullfrog for the WHITEX period.	8-10
8.7	Light geostrophic synoptic wind - polar high.	8-18
8.8	Strong geostrophic wind - polar high.	8-19
8.9	Upper level trough.	8-20
8.10	Long range transport from southern Arizona.	8-21
8.11	Long range transport from southern California.	8-22

Chapter 8

Climatology of Extreme Sulfate Episodes

8.1 Introduction

In Chapter 5 of this report, it was found that during time periods with the poorest visibility, scattering by fine ammonium sulfate was the dominant cause of light extinction. In Chapter 6, analysis of the CD_4 tracer data indicated that, during the time periods with the highest sulfate concentrations, the sulfate at Glen Canyon (Page) and Grand Canyon (Hopi Point) came mostly from the Navajo Generating Station (NGS). In this chapter, the meteorology associated with extreme (highest and lowest) sulfate concentrations measured both during WHITEX and in the routine National Park Service (NPS) particulate monitoring network during the winter months will be examined with two purposes in mind. These are 1) to understand the meteorological conditions which lead to transport of sulfur from NGS to Hopi Point during WHITEX; and 2) to examine the historic wintertime sulfate data at Hopi Point to see if the types of meteorological conditions which existed during WHITEX high sulfate episodes also existed during wintertime high sulfate conditions in other winters. Hopi Point will be the only site analyzed because there were relatively high concentrations of tracer measured there and because historic data were available.

Several studies^{1,2,4,7,12} have linked the highest sulfur concentrations measured at Hopi Point to long range transport from distant sources, with southern California and southern Arizona generally found to be the most important. All of these studies, however, relied on a mixed layer trajectory model which is accurate only when the synoptic scale flow as obtained from the standard National Weather Service (NWS) rawinsonde network is representative of the wind field which actually transport pollutants toward the receptor. This type of model is generally most accurate during the summer months, when the troposphere is more well-mixed than in the winter. Also, since the highest concentrations (usually defined as one standard deviation above the geometric mean) occur during the warm months of summer and early fall, the results of these previous studies are useful for determining the locations of sources which cause "high" sulfate concentrations where "high" is determined by comparison with the annual average. However, since Pielke et al.^{9,10} have shown that the meteorological conditions which contribute to air quality degradation in rural areas of the southwestern United States are quite seasonally dependent, it is necessary to examine the wintertime sulfate episodes with a different type of analysis.

During the winter months the synoptic (large scale) pressure field in the southwest is often dominated by a polar high pressure system (see Chapter 2). Areas near the center of a high pressure, where the geostrophic winds are weak, appear to be dominated by local sources if they