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Chapter 4

Discussion of Data

4.1 Introduction

Prior to an intensive analysis, much insight can be gained from an overview of the data. To this end, time plots of extinction, scattering, fine mass, the components of fine mass and CD_4 concentrations are presented first. Following this are descriptive statistics of the plotted variables. The temporal histories of meterological data will then be presented. Finally, scatterplots of selected variables will be discussed.

Measurement uncertainty values have been derived for all variables (see chapter 3) and have been incorporated into the time plots and scatterplots. For the time plots two traces are drawn. The bottom trace is the data value minus the uncertainty, and the top trace is the data value plus its uncertainty; the resulting polygon is filled with a cross hatch pattern for clarity. Scatter plots have the uncertainties incorporated by plotting crosses. The length of the horizontal arm is the uncertainty of the variable on the x-axis, and the length of the vertical arm is the uncertainty of the variable on the y-axis.

4.2 Temporal History of WHITEX Study Period

Table 4.1 lists all monitoring sites where data were gathered during the WHITEX study period and gives their latitude, longitude, elevation and site designation. Sites were designated as either major receptor, gradient, satellite, or background according to the role they were expected to play in the WHITEX experiment. A large variety of monitors were employed during the WHITEX study period, table 4.2 lists the locations of monitors by monitor type.

Depending on the data gathered and the monitor types used, there were three different sample duration times - 6, 12, and 24 hours. Sample start times were 0800 hours for 24 hour data, 0800 and 2000 hours for 12 hour data, and 0200, 0800, 1400, and 2000 hours for 6 hour data. Much analysis was carried out using 12 hour data requiring that some 6 hour data be averaged for 12 hour values, and in one case 24 hour data was disaggregated to 12 hour data. Sample duration times and data treatments will be discussed below as needed.

Aerosol concentrations are provided by IMPROVE, SCISAS, SFU, and DRUM samplers. Gases such as SO_2, NO_x, and O_3, were measured by IMPROVE, DREXEL (gas chromatograph), and Brigham Young University (BYU). Elemental carbon and organic carbon were measured by IMPROVE and SCISAS samplers. The techniques, filter media, sample duration time, and variables measured varied from site to site and between sampler type. For example, IMPROVE elemental analysis used PIXE and has a sample duration time of 12 hours while SCISAS elemental used XRF

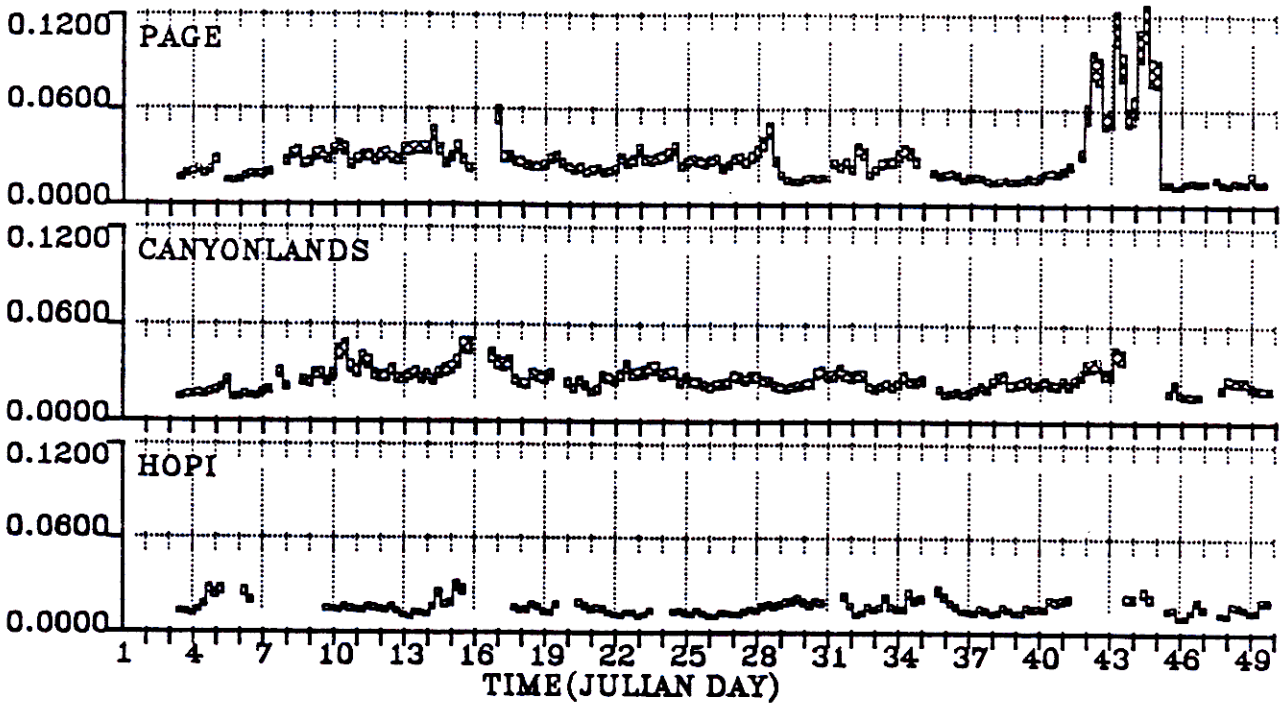

Figure 4.1: Extinction data (1/km) from Page, Hopi and Canyonlands.

and had a sample duration time of 24 hours. For a complete discussion the reader is referred to Chapter 3. The aerosol concentrations are reported as $\mu g/m^3$.

For this report, a subset of the available data was used for the bulk of the analysis. This was done deliberately to obtain a minimal data set without duplicate variables whenever possible for those sites that had multiple samplers. For example, IMPROVE particulate data were used wherever possible in lieu of SCISAS or SFU particulate data. The decision to exclude other data was made by intercomparison of the data; whenever IMPROVE data agreed with SCISAS or SFU, then only IMPROVE data were used; whenever there were apparent discrepancies, all data were used. Similarly, IMPROVE SO_2 data were used rather than gas chromatograph SO_2 data at Canyonlands or the SRP data at Page.

During the WHITEX study, extinction derived from transmissometers and scattering from nephelometers were measured at the three major receptor sites - Canyonlands, Page, and Hopi Point, while at Bullfrog only scattering was measured. The units of scattering and extinction are reported as km^{-1} and are of 6 hours duration. At Canyonlands and Page the instruments were collocated enabling a comparison between extinction and scattering. At Hopi Point the two instruments were about 30 km apart.

Figure 4.1 shows time lines for the extinction data obtained at the three transmissometer sites. Extinction at Page and Canyonlands are fairly comparable to each other for most of the time varying around 0.03 1/km. The most obvious feature is the episode of relatively degraded visibility at Page on Julian Days 42 through 44. Unfortunately, due to clouds interfering with transmissometer site paths, extinction data were frequently missing at Hopi and Canyonlands during this episode.

By examining the nephelometer data at all four sites (Figure 4.2) the episode is quite apparent at Page and Bullfrog. During the episode, Bullfrog experienced its highest scattering value which

Table 4.1: WHITEX monitoring sites.

SITE NAME	LAT	LON	ELEV (FT)
MAJOR RECEPTOR SITES			
Canyonlands National Park, Utah	38.45	109.83	5925
Hopi Point – Grand Canyon National Park, Arizona	36.07	112.15	7100
Page, Arizona Also called Glen Canyon National Recreation area	36.93	111.49	4180
Desert View – Met Data	36.04	111.83	7511
GRADIENT SITE			
Bullfrog Marina, Utah	37.55	110.72	4167
SATELLITE SITES			
Green River, Utah	38.97	110.22	4100
Cisco, Utah	39.17	109.17	4450
Monticello, Utah	37.93	109.33	6998
Mexican Hat, Utah	37.15	109.85	4700
Hite, Utah	37.88	110.37	3840
Navajo National Monument, Arizona	36.68	110.53	7100
Wupatki National Monument, Arizona	35.52	111.53	5250
Meadview – Lake Mead National Recreation Area, Arizona	36.01	114.04	9709
BACKGROUND SITE			
Bryce Canyon National Park, Utah	37.57	112.18	7950
SITE OF TRACER RELEASE			
Navajo Generating Station – Near Page, Arizona	36.91	111.22	4365
PHYSICAL STACK HEIGHT = 775 FT ABOVE GROUND LEVEL			

Table 4.2: Locations of monitors by monitor type.

IMPROVE SAMPLERS	TRANSMISSOMETERS
Canyonlands	Canyonlands
Hopi Point	Hopi Point
Bullfrog	Page
Page	
Green River	NEPHELOMETERS
Cisco	Canyonlands
Monticello	Hopi Point
Mexican Hat	Bullfrog
Hite	Page
	Hite
SCISAS SAMPLERS	Aircraft
Page	
Hopi Point	GAS CHROMATOGRAPH SO_2
Bryce Canyon	Canyonlands
Meadview	
	BYU SAMPLERS
STACKED FILTER UNITS (SFUs)	Page
Canyonlands	Bryce Canyon
Bryce Canyon	
Hanksville	DRUM SAMPLERS
Navajo National Monument	Canyonlands
Wupatki National Monument	Hopi Point
	Bullfrog
SURFACE METEOROLOGY	Page
Canyonlands	
Desert View (Grand Canyon)*	TRACER - CD_4
Bullfrog	Canyonlands
Page	Hopi Point
Green River	Bullfrog
Cisco	Page
Monticello	Green River
Hite	Monticello
Bryce Canyon	Mexican Hat
	Hite
UPPER AIR METEOROLOGY	Navajo Generating Station
Page	Aircraft
Canyonlands	SRP GASEOUS POLLUTANTS -
	Page

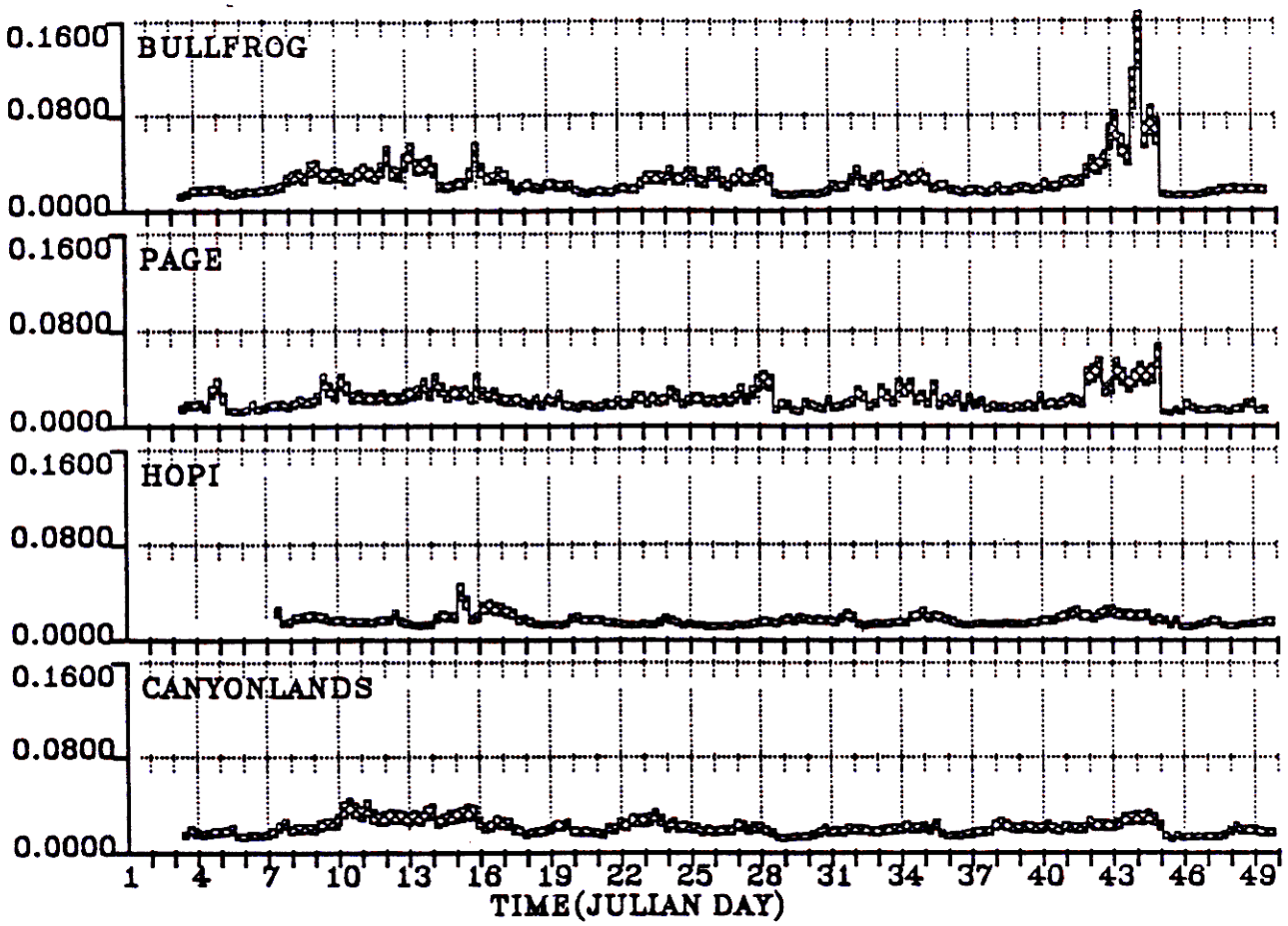

Figure 4.2: Scattering data (1/km) at Page, Bullfrog, Canyonlands, and Hopi.

exceeds the highest extinction that occurred at Page. One can only speculate that extinction at Bullfrog would be greater were it measured concurrently and would have the maximum extinction for all sites.

Figure 4.3, which has time lines for ammonium sulfate concentrations at all sites, lends insight into the episode. At Page, Hopi, Canyonlands, and Bullfrog 6 hour values for ammonium sulfate, in $\mu g/m^3$, were derived from sulfate concentrations times 1.4; at the remaining sites 12 hour elemental sulfur values were multiplied by 4.125. Sulfate concentrations at Page display the same episodic behavior as extinction. Moreover, not only do sulfate concentrations peak at all other sites during the same episodic time period, most sites experience their maximum sulfate concentration as well. However, Hopi and Bryce Canyon seem to experience many time periods of elevated sulfate concentrations that are comparable to the level that occurred during the episode. Bullfrog seems to experience sulfate concentrations very similar to Page and in fact experiences the highest ammonium sulfate concentration of any site, for all times, during the episode.

Figures 4.4, and 4.5 shows the temporal history of total elemental sulfur in $\mu g/m^3$ and of 6 hours duration at the four main sites where SO_2 data are available. Sulfate sulfur is calculated from SO_4 data by dividing by 3, and SO_2 sulfur from SO_2 by dividing by 2, and of course, total sulfur is the sum of sulfate sulfur and SO_2 sulfur. At Hopi, Bullfrog, and Canyonlands sulfate sulfur and SO_2 sulfur concentrations are comparable. The total sulfur variance is largely due to

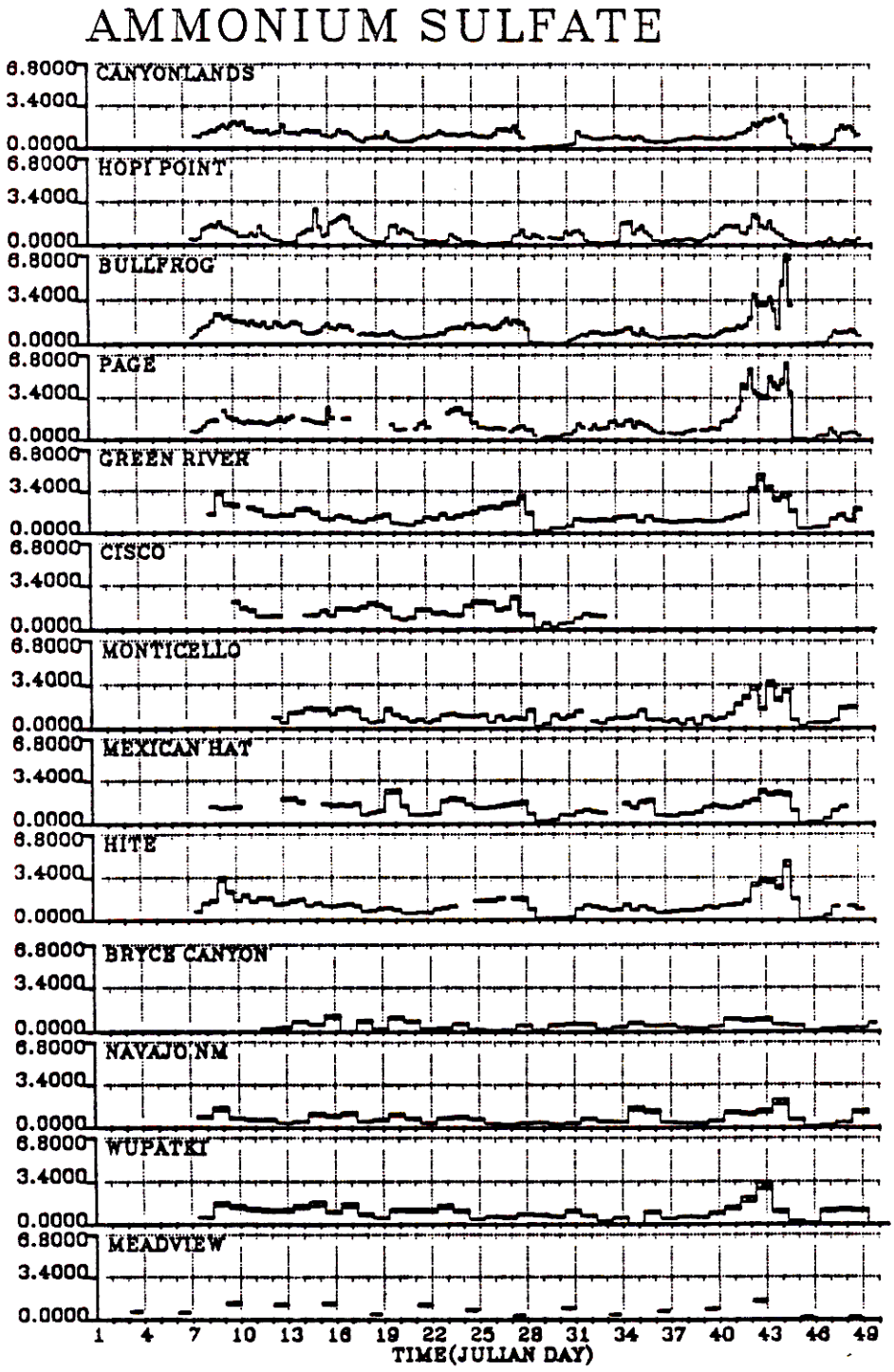

Figure 4.3: Temporal history of ambient ammonium sulfate concentrations ($\mu g/m^3$) for all WHITEX sites, January-February 1987.

SO_2 sulfur variance, and most peak total sulfur concentration times coincide with peaks in SO_2 concentrations. Page, being close to NGS, has significantly higher SO_2 sulfur concentrations than the other three sites.

Using 24 hour SCISAS coarse mass and 12 hour IMPROVE fine mass the temporal history of extinction, fine mass, and coarse mass, is shown in Figure 4.6, at Hopi and Page. The episode at Page is accompanied by sustained high levels of fine mass. Coarse mass, on the other hand, does not seem to follow extinction and does not seem to be associated with fine mass. Similarly, at Hopi, coarse mass peaks are not associated with peaks in extinction but do seem to show a slight correlation with fine mass. Concentrations of fine and coarse mass at Hopi are about one half of concentrations obtained at Page.

Figures 4.7 through 4.9 show temporal histories of extinction and the visibility reducing species of fine mass for Page, Hopi, and Canyonlands. The components of fine mass are ammonium sulfate (6 hour), ammonium nitrate (24 hour), organics (12hour), light absorbing carbon (12hour), and fine soil (12hour). At Page the influence of ammonium sulfate on extinction during the episode is apparent. However, a period of high extinction, which occurred on January 28, seems to be associated with peaks in ammonium nitrate, organics, light absorbing carbon, and fine soil rather than with ammonium sulfate. At Hopi and Canyonlands, where peak and average sulfate values are about half of those attained at Page, a stronger influence from ammonium nitrate is evident. For two days at Hopi, January 14 and 15, elevated levels of nitrate are associated with increased extinction. Nitrate peaks occurred at Canyonlands on Julian Days 11, 15, 23, and 37; two of those days are on the highest extinction days one of which has high levels of ammonium sulfate as well.

For completeness, the temporal history of scattering and and visibility reducing components of fine mass at Bullfrog are shown in Figure 4.10. Bullfrog experienced ammonium sulfate concentrations very similar to Page and the association with scattering during the episode is clear.

Figures 4.11, 4.12, 4.13, and 4.14 show the temporal history of the trace elements arsenic, selenium, zinc, bromine, lead, and copper at Hopi, Page, Canyonlands, and Bullfrog, respectively. The remaining trace elements, zirconium, strontium, and rubidium were not plotted as they were almost always below detection limits. Almost all of the trace element data are 12 hour IMPROVE samples. However, due to small loadings on the filters, IMPROVE selenium samples were frequently below detection limits at Hopi Point; furthermore, the samples that were above detection limits had relatively large uncertainties. This was not the case with Hopi Point's 24 hour SCISAS selenium data where almost all samples were above detection limits and had smaller uncertainties. Because selenium is an important trace element associated with coal fired power plants SCISAS selenium is used in lieu of IMPROVE selenium at Hopi Point. Since other data used for analysis are of 12 hour duration, or 6 hour data averaged to 12 hours, disaggregation of 24 hour SCISAS selenium data to obtain 12 hour values was carried out. The disaggregation procedure is based on quadratic spline interpolation subject to the condition that the 12 hour disaggregated values must recover the original 24 hour values when averaged. For a detailed description of the disaggregation procedure the reader is referred to Appendix 4A.

4.3 Temporal History of CD_4 at Receptors

CD_4 concentrations were sampled at eight sites, the three major sites (Page, Hopi Point, and Canyonlands), the gradient site at Bullfrog, and four satellite sites (Mexican Hat, Hite, Monticello, and Green River). Samples at all eight CD_4 monitoring sites were collected throughout the WHITEX study period, but not all samples were chosen for analysis due to high cost. Samples not analyzed have been stored for possible future use. Samples obtained during two sulfate episodes