

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.

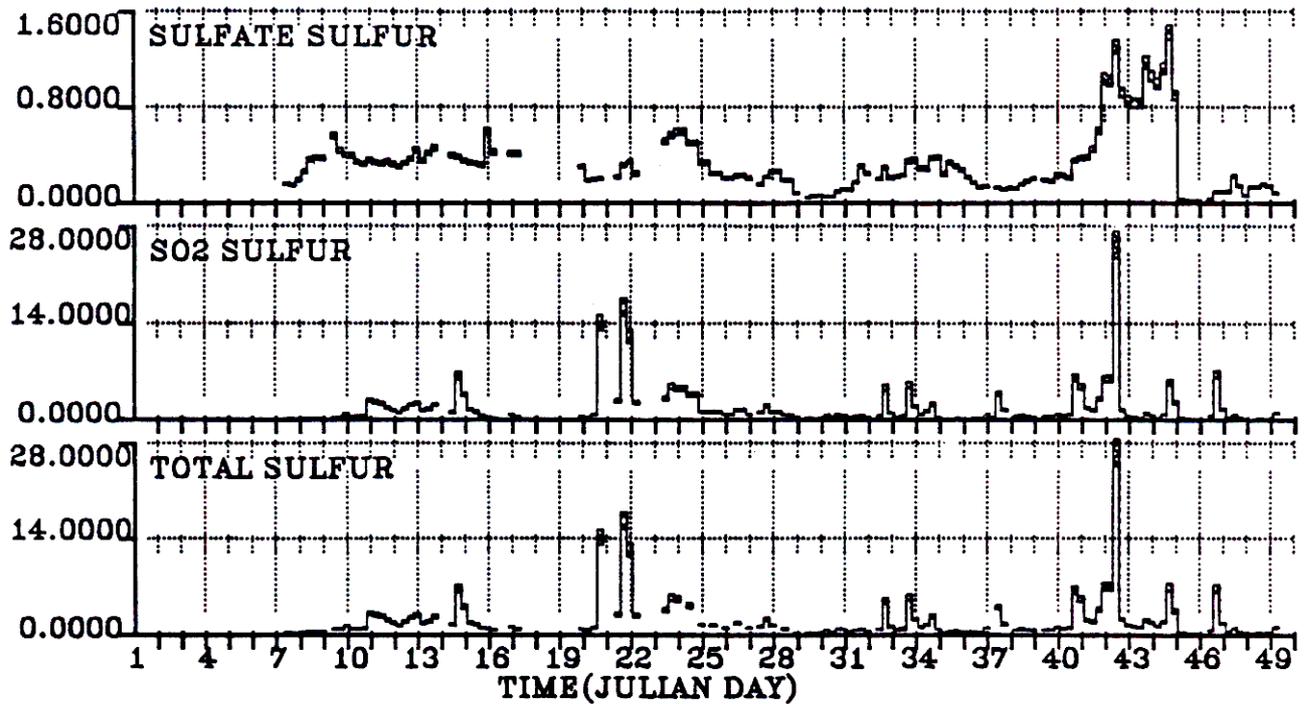
For completeness, the temporal history of scattering and visibility reducing components of fine mass at Bullfrog are shown in Figure 4.10. Bullfrog experienced ammonium sulfate concentrations very similar to Page and the association with scattering during the episode is clear.

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

PAGE SULFUR



HOPI SULFUR

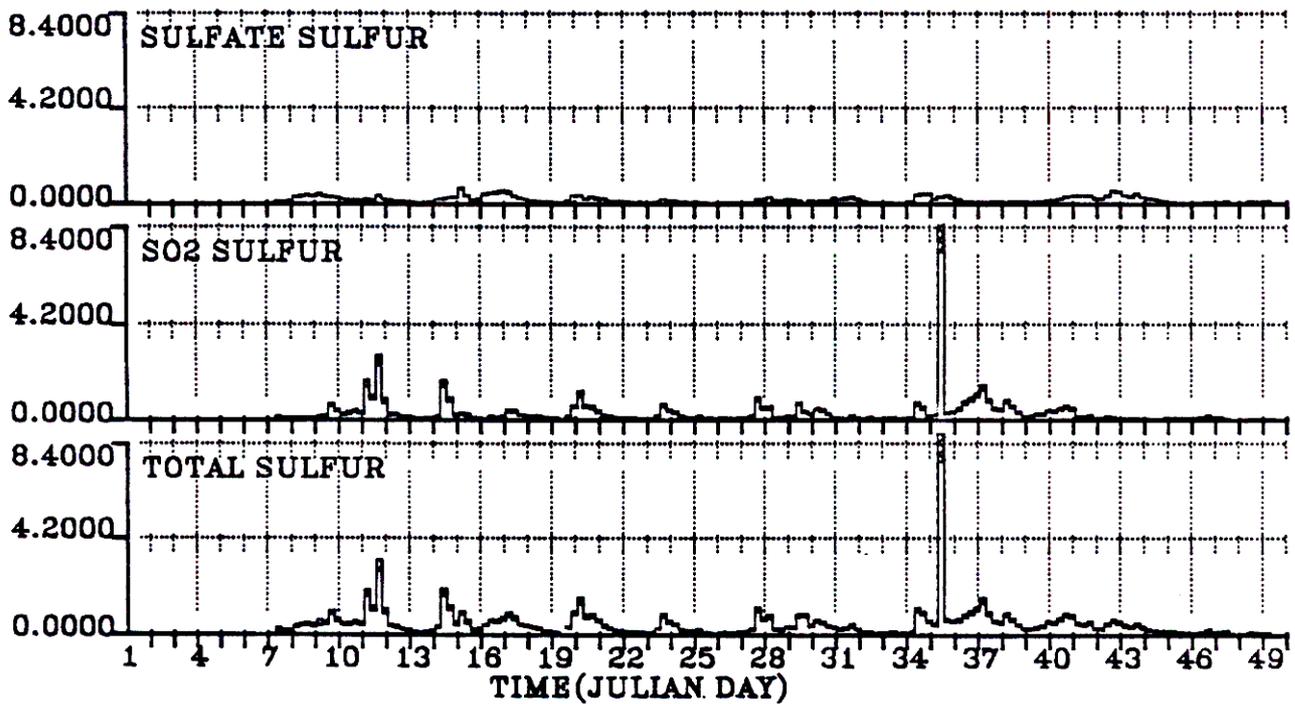
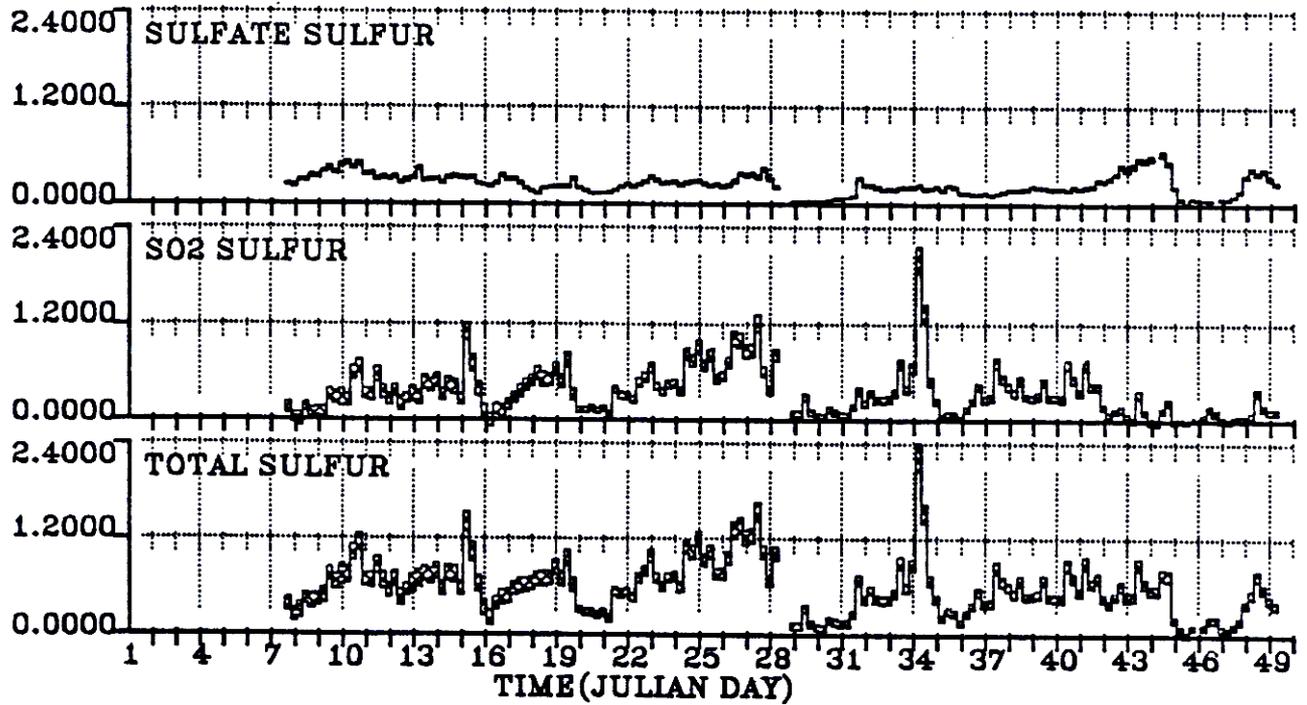


Figure 4.4: Sulfate sulfur, SO_2 sulfur, and total elemental sulfur ($\mu g/m^3$) at Page and Hopi.

CANYONLANDS SULFUR



BULLFROG SULFUR

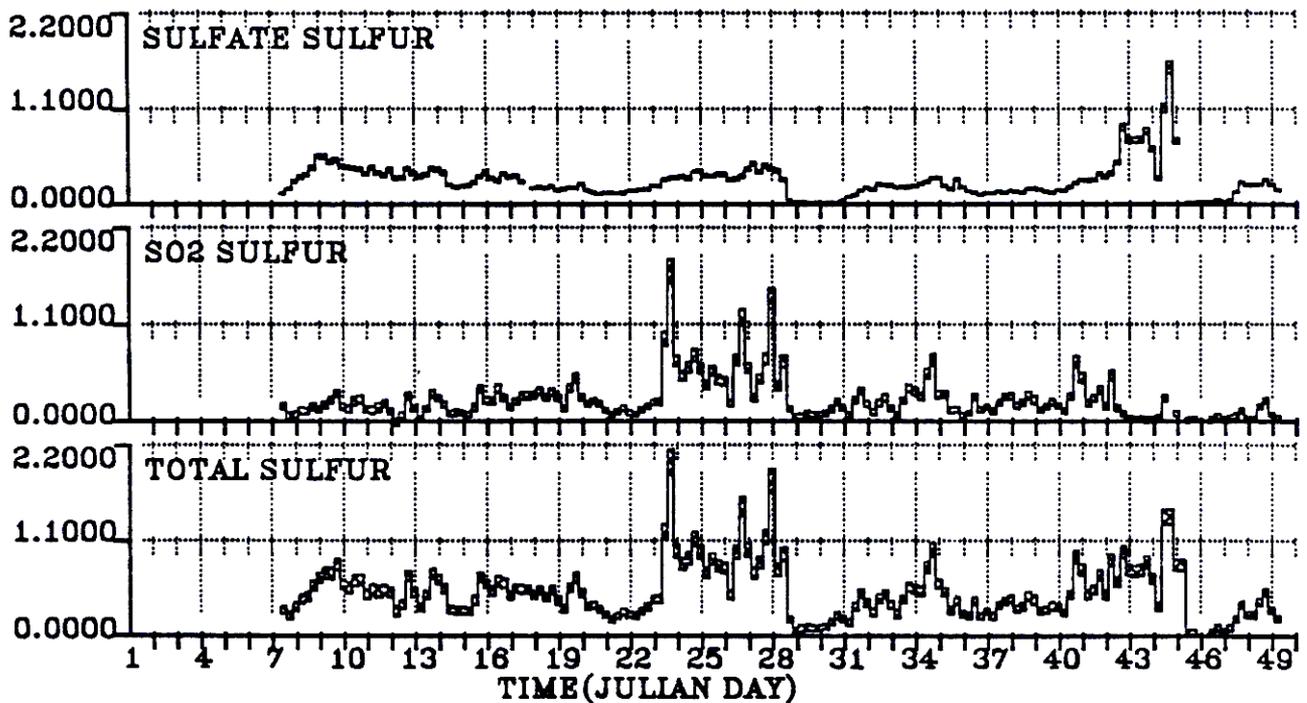
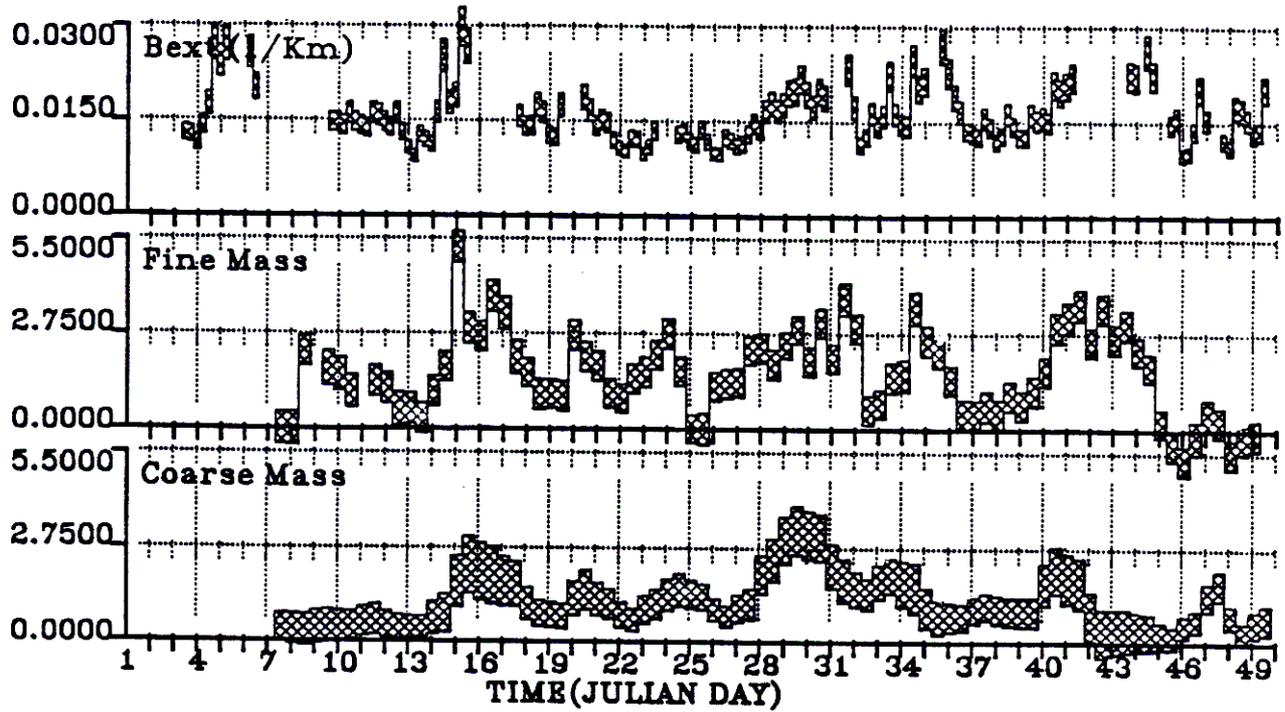


Figure 4.5: Sulfate sulfur, SO_2 sulfur, and total elemental sulfur ($\mu g/m^3$) at Canyonlands and Bullfrog.

HOPPI



PAGE

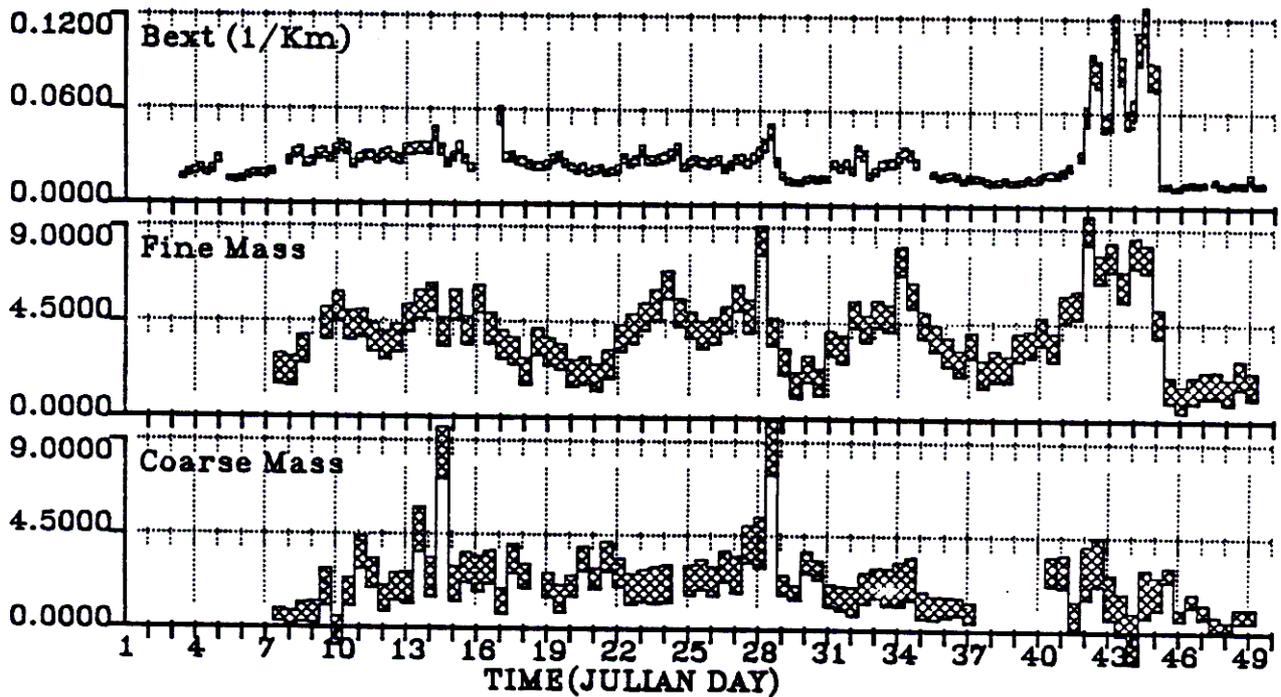


Figure 4.6: Temporal history of extinction (1/km), fine mass, and coarse mass ($\mu\text{g}/\text{m}^3$) at Hopi and Page.

PAGE

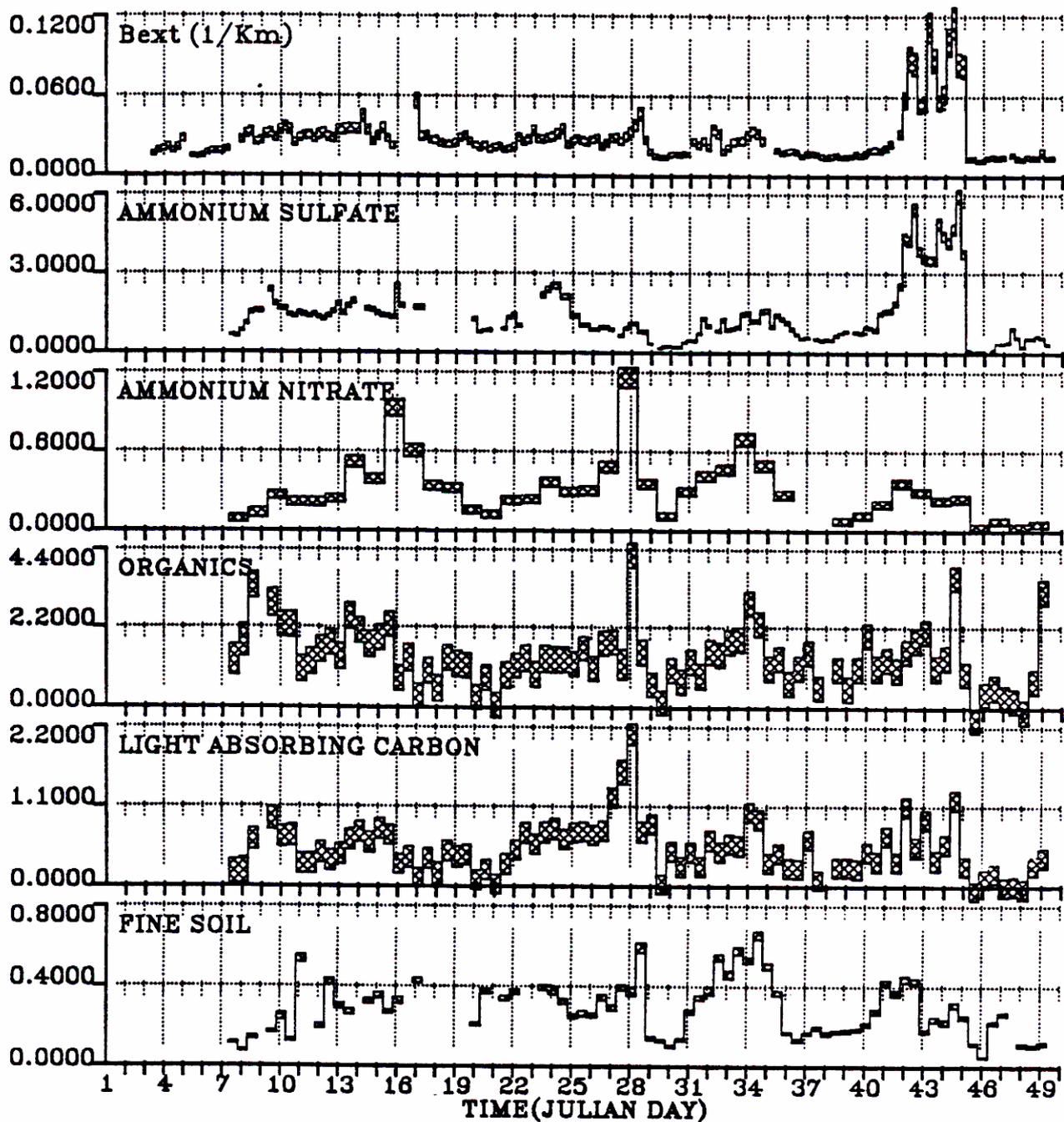


Figure 4.7: Temporal history of extinction (1/km) and the components of fine mass ($\mu\text{g}/\text{m}^3$) at Page.

HOPI

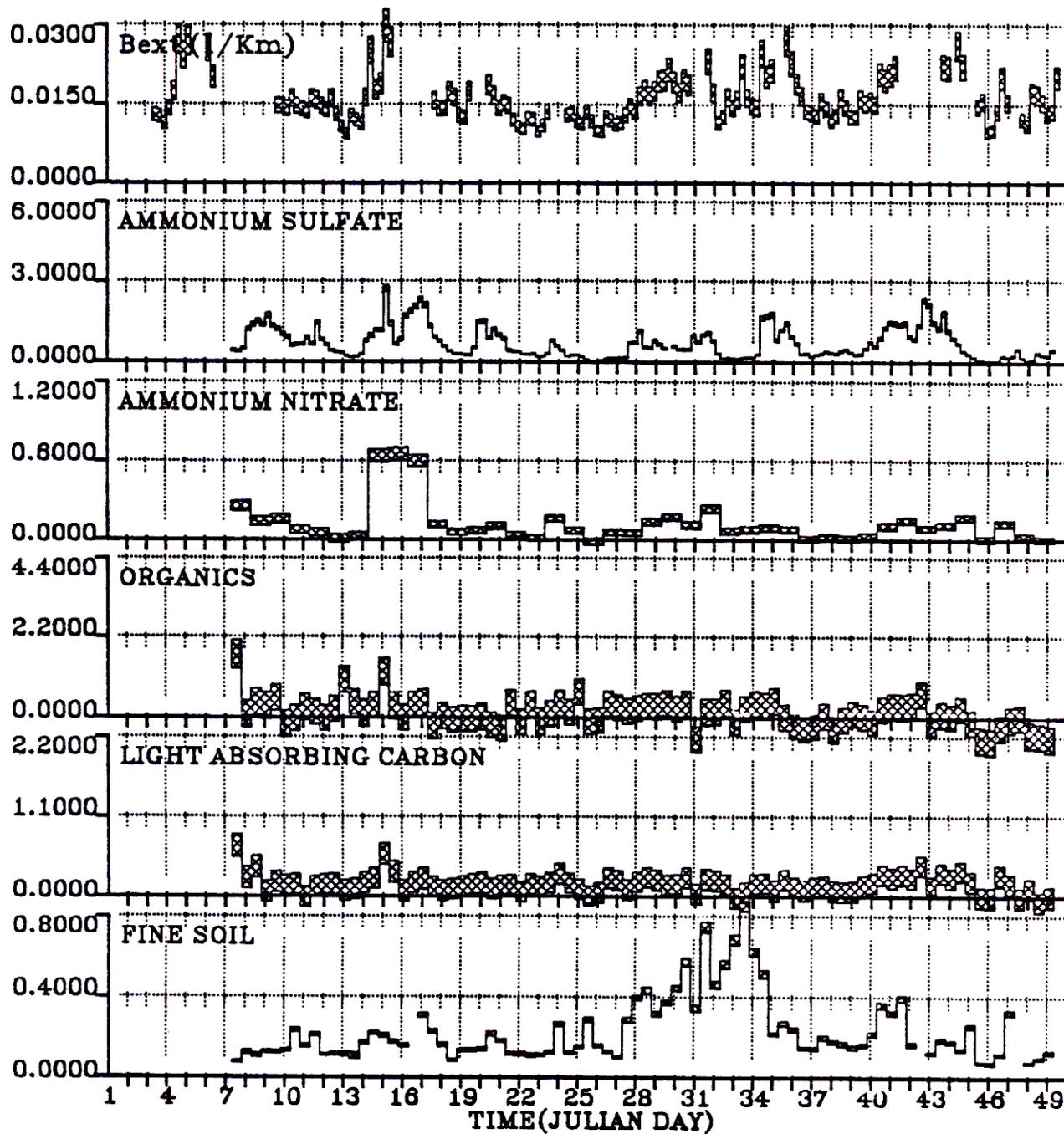


Figure 4.8: Temporal history of extinction ($1/km$) and the components of fine mass ($\mu g/m^3$) at Hopi.

CANYONLANDS

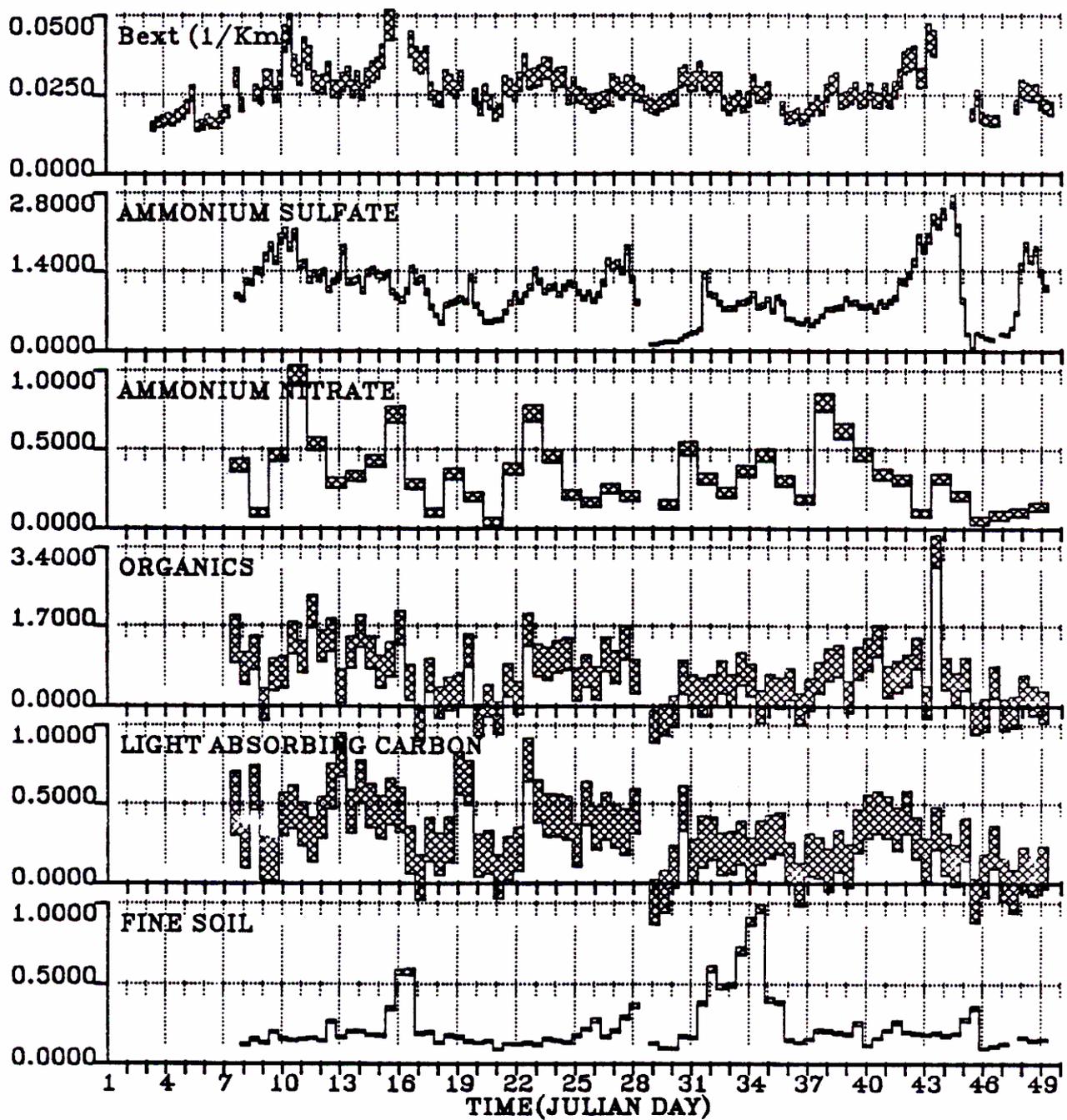


Figure 4.9: Temporal history of extinction (1/km) and the components of fine mass ($\mu\text{g}/\text{m}^3$) at Canyonlands.

BULLFROG

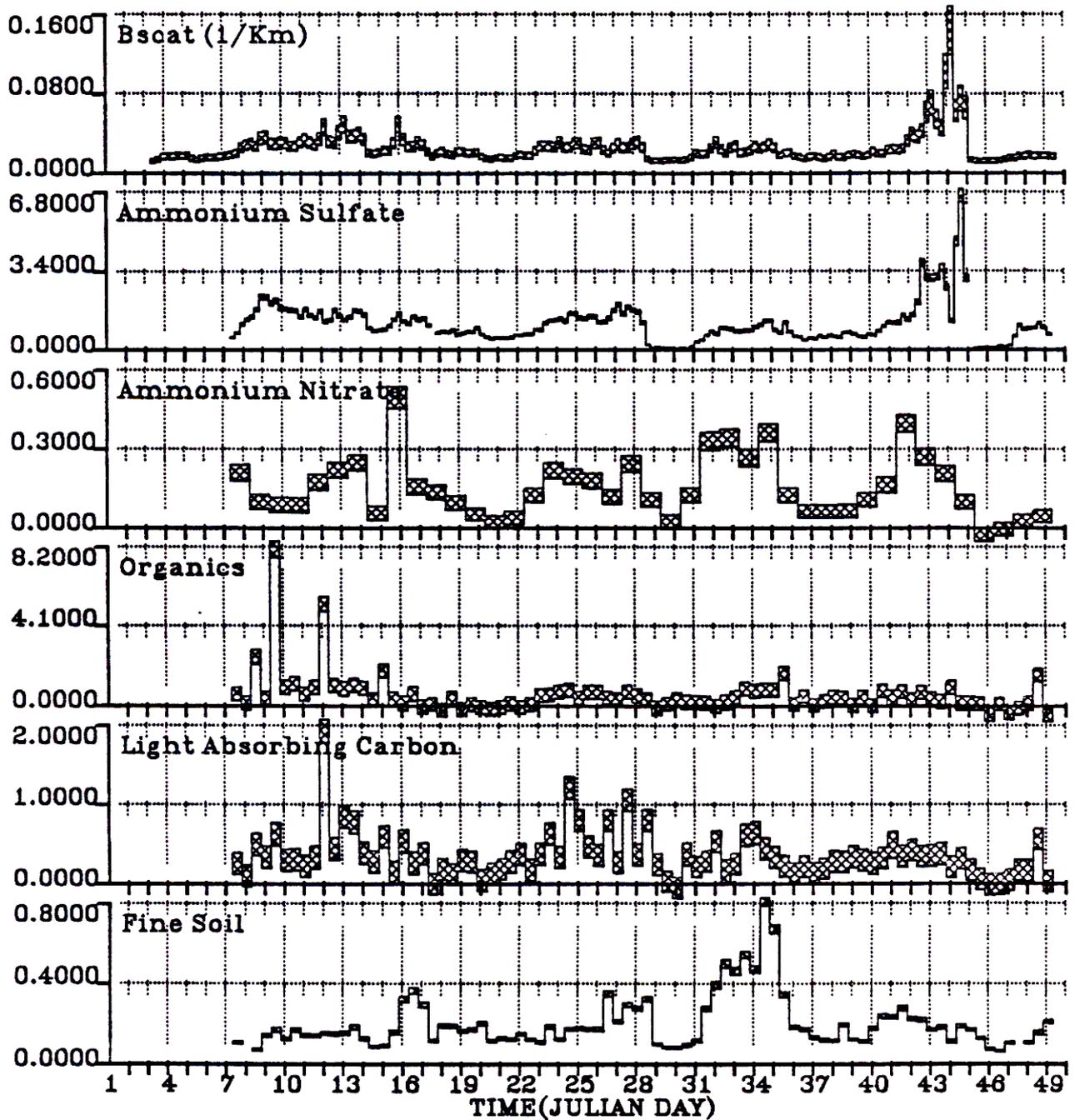


Figure 4.10: Temporal history of scattering (1/km) and the components of fine mass ($\mu\text{g}/\text{m}^3$) at Bullfrog.

PAGE TRACE ELEMENTS

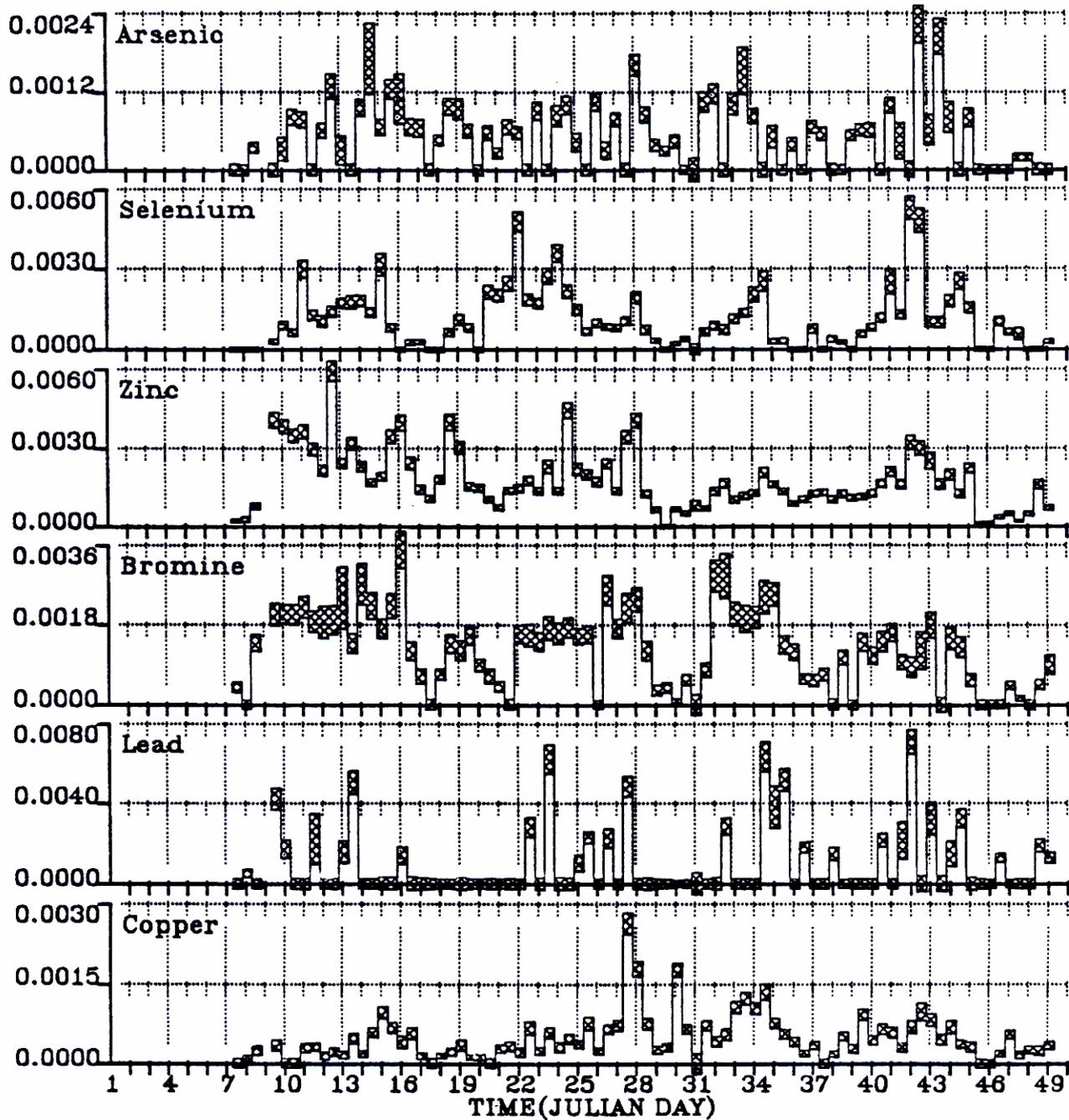


Figure 4.11: Temporal history of trace element concentrations ($\mu\text{g}/\text{m}^3$) at Page.

HOPI TRACE ELEMENTS

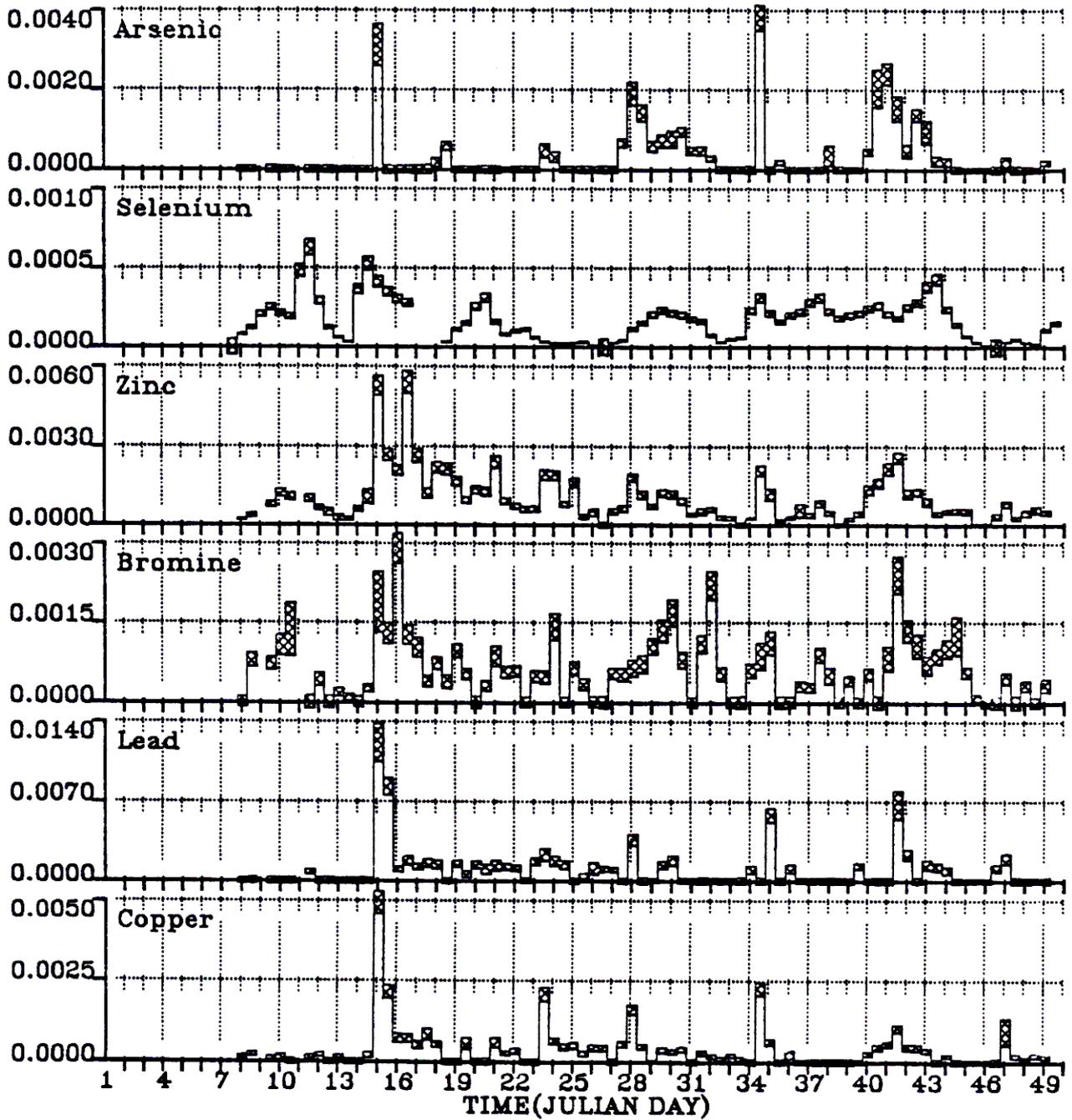


Figure 4.12: Temporal history of trace element concentrations ($\mu\text{g}/\text{m}^3$) at Hopi.

CANYONLANDS TRACE ELEM

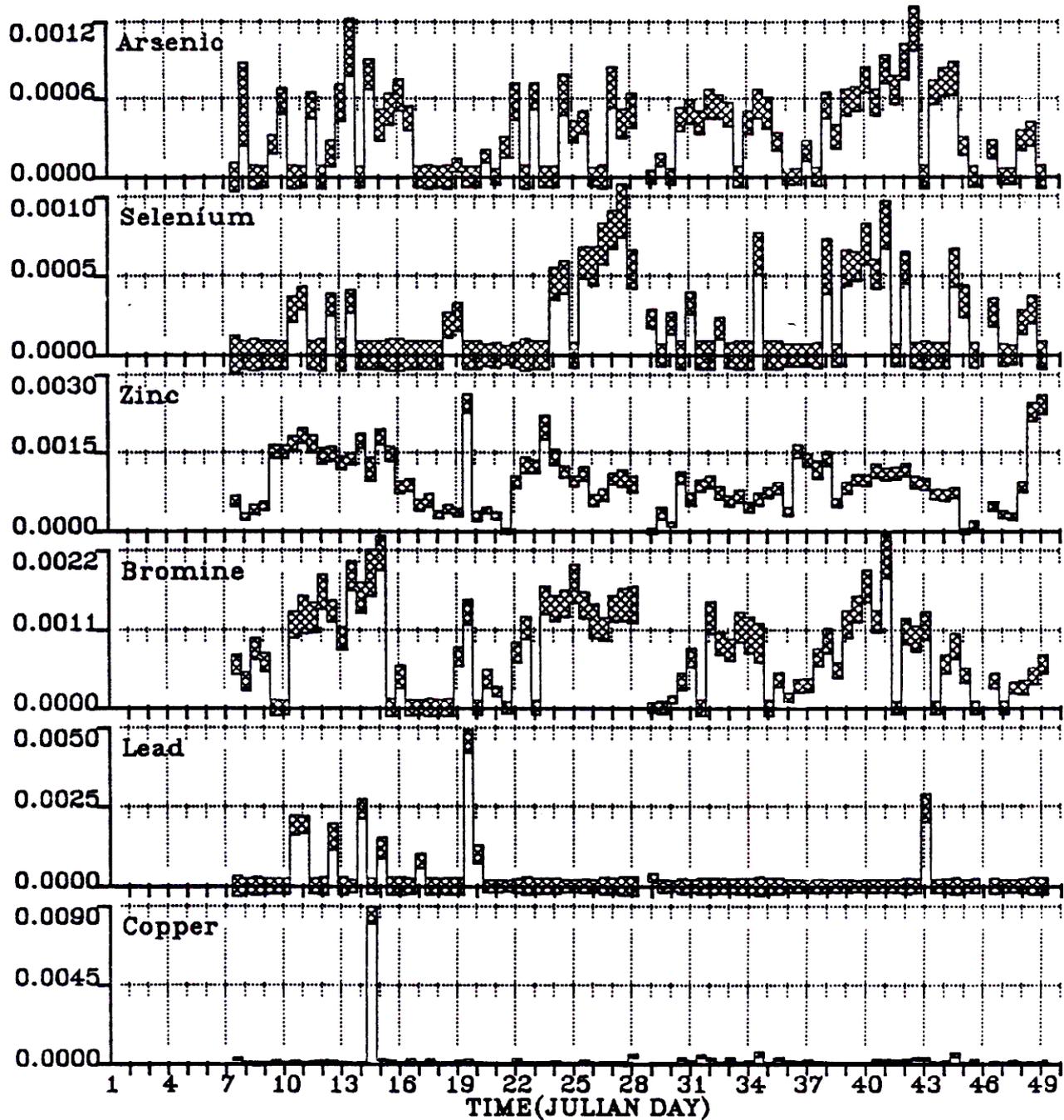


Figure 4.13: Temporal history of trace element concentrations ($\mu\text{g}/\text{m}^3$) at Canyonlands.

BULLFROG TRACE ELEMENTS

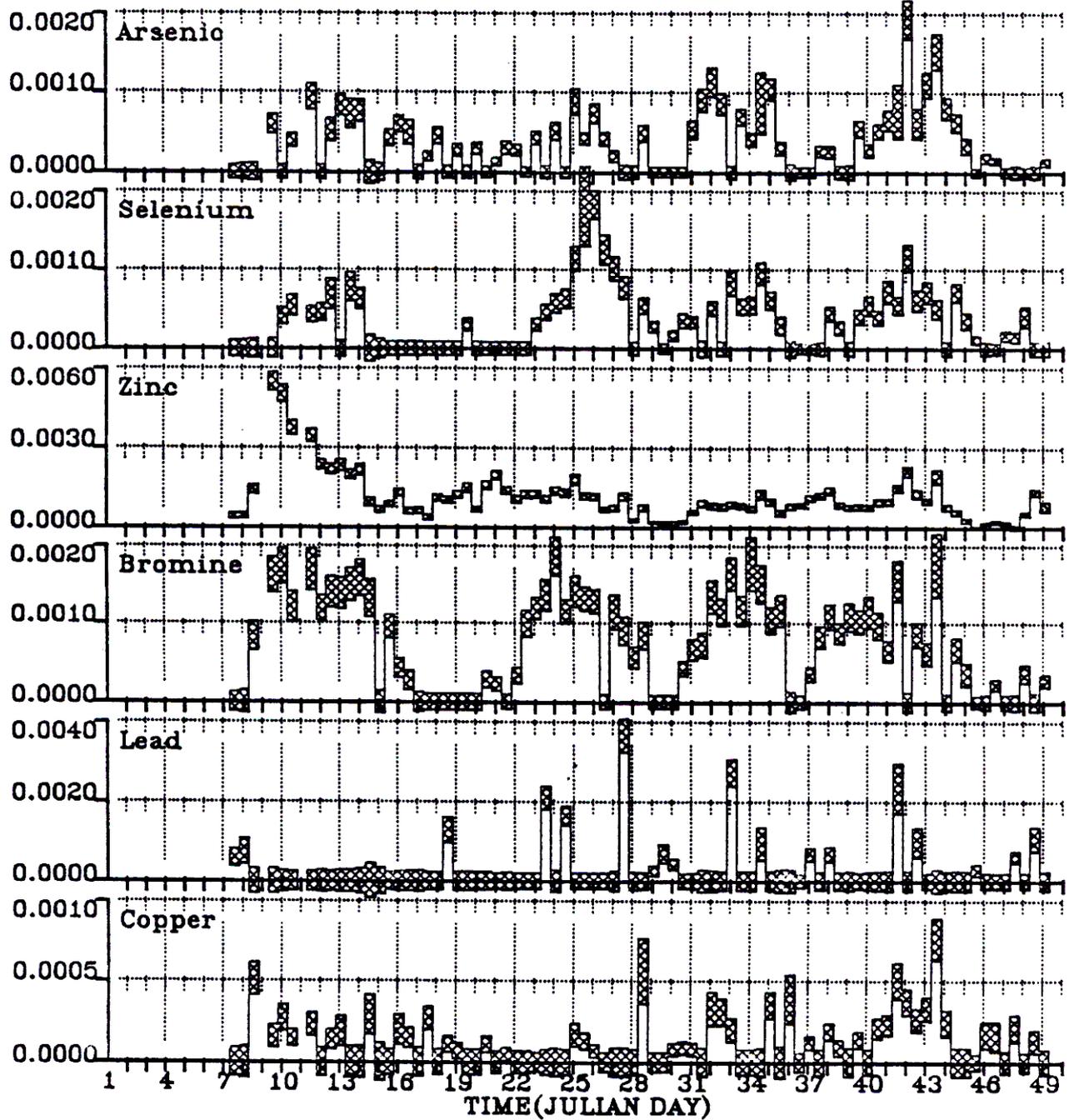


Figure 4.14: Temporal history of trace element concentrations ($\mu\text{g}/\text{m}^3$) at Bullfrog.

were selected for analysis. The first episode is characterized by extreme sulfate concentrations at Hopi Point on Julian Days 14 through 18 and data from all sites, except Hite and Monticello, were analyzed. The second episode is the major sulfate episode on Julian Days 41 through 44 and data from all sites were analyzed. Also, samples across all sites except Hite were analyzed during a period of relatively clean or good visibility on JD=31 through JD=36, before the major episode. At Page and Hopi Point, many samples from JD=27 through JD=46 were analyzed for obtaining relationships between CD_4 , sulfur dioxide and visibility reducing aerosols.

Figure 4.15 shows the temporal history of the CD_4 samples across all eight sites. Fully scaled CD_4 is plotted at Page and Hopi. The scaling of CD_4 is discussed in Sections 6.2.3 and 6.6.1; scaling takes into consideration the tracer release rate which varies considerably and the plume age. Maximum concentrations at Page are highest during the major (second) episode, at Hopi the maximum is about one fourth the maximum at Page. The maximum concentrations at the remaining six sites are less than one fourth the maximum at Hopi which means that they are more than a factor of 10 less than the maximum at Page.

CD_4 sample duration times vary considerably from site to site. At Page the CD_4 data are of 6 hours duration. At Hopi Point, the raw CD_4 data are mostly 12 hour with a few 6 hour data points; thus, Hopi Point's scaled CD_4 data has been averaged to 12 hour values for consistency. Similarly, the raw data at Bullfrog and Canyonlands are a mixture of 6 and 12 hour data points which are not treated in any way. For the remaining satellite sites (Mexican Hat, Hite, Monticello, and Green River), the samples were of several days duration. Because the scaled CD_4 data at Hopi Point and other trace element data at all sites are 12 hour data, Page's scaled CD_4 data averaged to 12 hours from February 16 (JD=27) through February 14 (JD=45) will be discussed for the remainder of this chapter. Only during the time period from JD=27 through JD=45 was Page's CD_4 data used for regression analysis presented later in Chapter 6.

Figures 4.16 and 4.17 are temporal histories of ammonium sulfate, sulfur dioxide, fully scaled CD_4 , and the trace elements arsenic, selenium, copper, zinc, lead, and bromine at Hopi and Page. The relationship between CD_4 and sulfur species seems to be as expected, whenever CD_4 is high, either or both, ammonium sulfate and sulfur dioxide is high. The relationship between CD_4 and arsenic at Hopi is particularly interesting in that whenever CD_4 is high arsenic is low and vice versa. The CD_4 peaks at Hopi are associated with ammonium sulfate peaks except when arsenic is high. An example of this temporal trend is found in the high sulfate episode between JD=40 through JD=43. Arsenic is high from JD=40 through JD=41 and low from JD=42 to 43 while CD_4 concentrations are low at the beginning of the episode and high toward the end.

WHITEX CD4

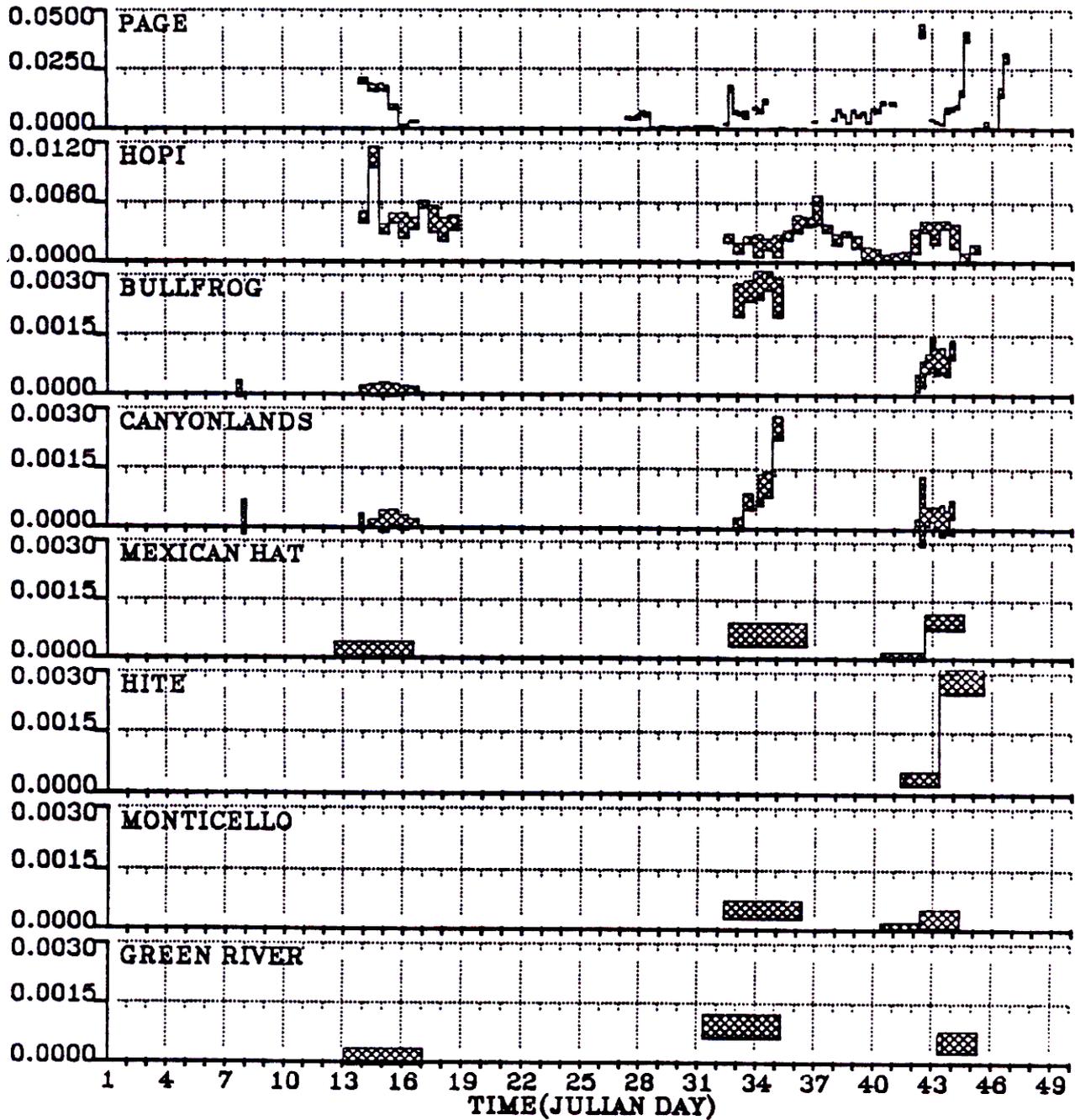


Figure 4.15: CD_4 concentrations (ppt) at eight WHITEX receptor sites.

PAGE

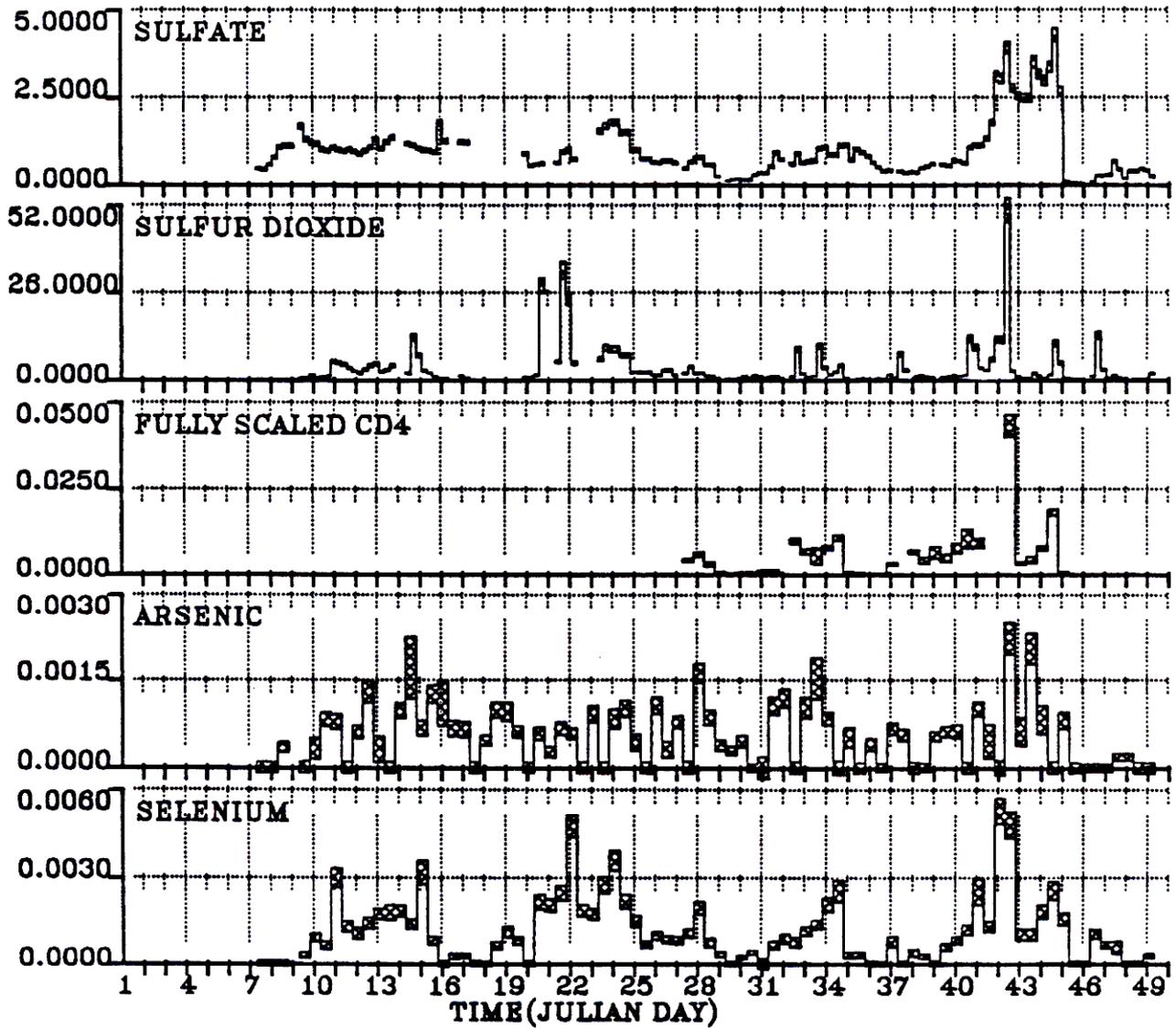


Figure 4.16: Temporal history of sulfur species ($\mu\text{g}/\text{m}^3$), fully scaled CD_4 (ppt) and trace elements arsenic and selenium ($\mu\text{g}/\text{m}^3$) at Page.

HOPHI

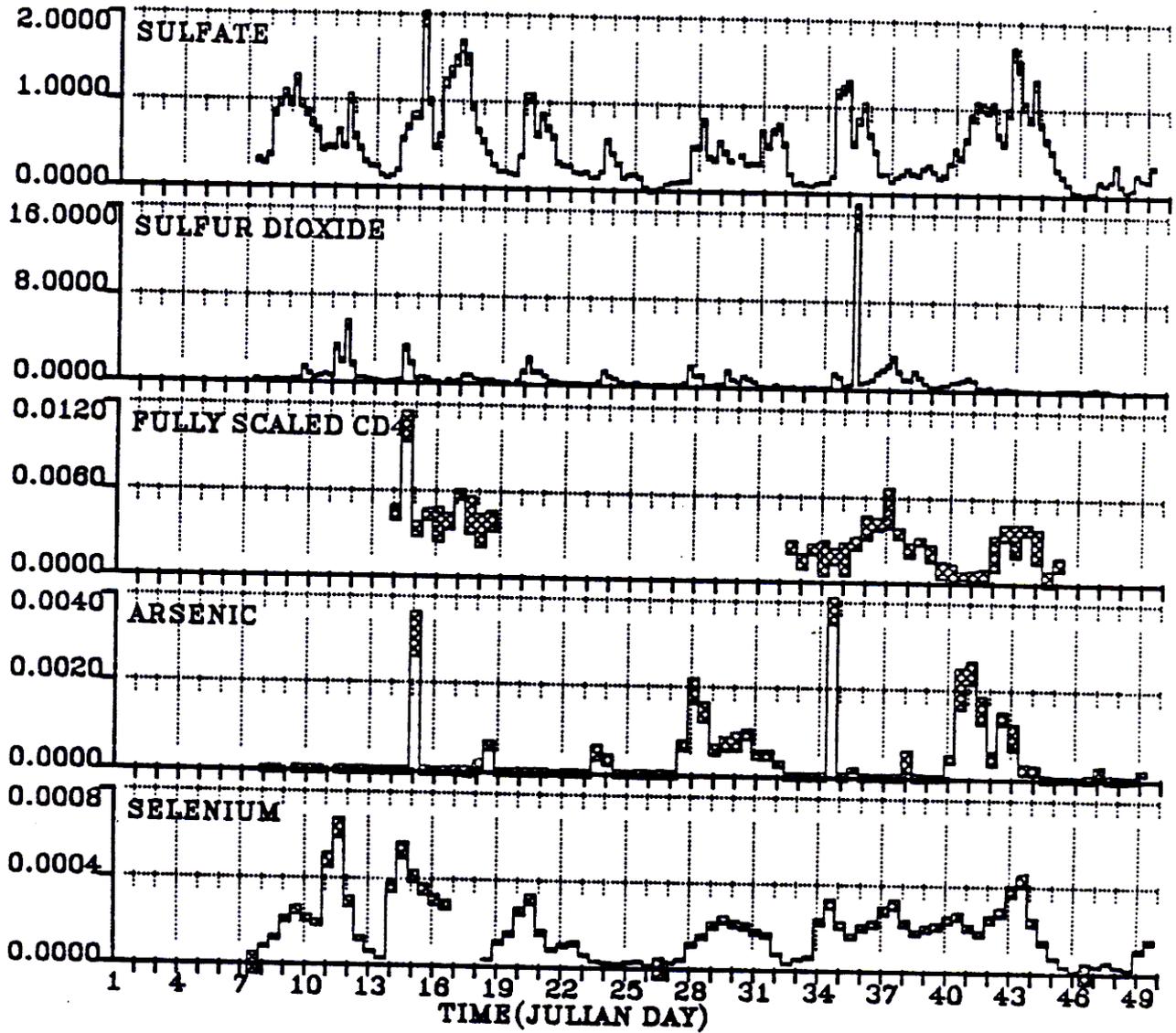


Figure 4.17: Temporal history of sulfur species ($\mu\text{g}/\text{m}^3$), fully scaled CD_4 (ppt) and trace elements arsenic and selenium ($\mu\text{g}/\text{m}^3$) at Hopi.