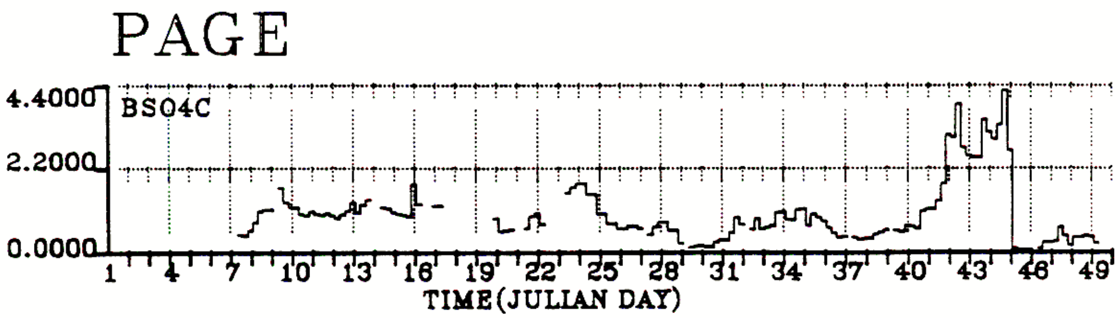

Figure 8.5: Sulfate ion concentration (μg m^{-3}) at Page for the WHITEX period.

it might be expected that sulfate concentrations at Page and Bullfrog would also be relatively high during the same time period, since the direction of flow of the air mass is up and down the terrain, without specific directional preference. Again Figures 8.5 and 8.6 tend to support this hypothesis for the first case analyzed, as sulfate concentrations at these sites were elevated during February 9 through 13. One might also expect the northern sites to be high for the mid-January and February 1–3 events due to the transport of a polluted airmass from a source to the north of the WHITEX area. This would be unlikely due to the relatively small sources of sulfur emissions to the north (see Table 6.1). This argument holds true for all sources to the north except for the Bridger Power Plant in southwest Wyoming which would not be expected to impact the WHITEX area due to the transport time required for these events and the obstruction of a plume by the Book Cliffs which are between the Bridger Power Plant and the WHITEX area.

The low sulfate events during WHITEX indicate that the lowest concentrations occur when there is a polar high, but its duration is very short (< 3 days) and there is no significant synoptic northeasterly flow. Then the concentration of pollutants around NGS does not have time to increase to significant levels before the air mass is transported to Hopi Point. Another synoptic condition which is associated with low sulfate concentrations is moderate or strong winds from westerly or southerly directions.

8.3 Extreme Sulfur Events During November 1986 - March 1987

Because the National Park Service has operated a fine particulate sampler at Hopi Point since August, 1979, it is possible to examine some historic data for this site to determine whether or not the meteorological conditions associated with extreme sulfur concentrations during WHITEX are similar to those observed in the past. Particulate samples are collected on stacked filter units (SFUs) twice each week. From August 1979 through May 1986, the sampling duration was 72 hours in length. Beginning June 1986, the length of the sampling time was changed to 24 hours. Eldred et al.[3] discusses these measurements in detail.

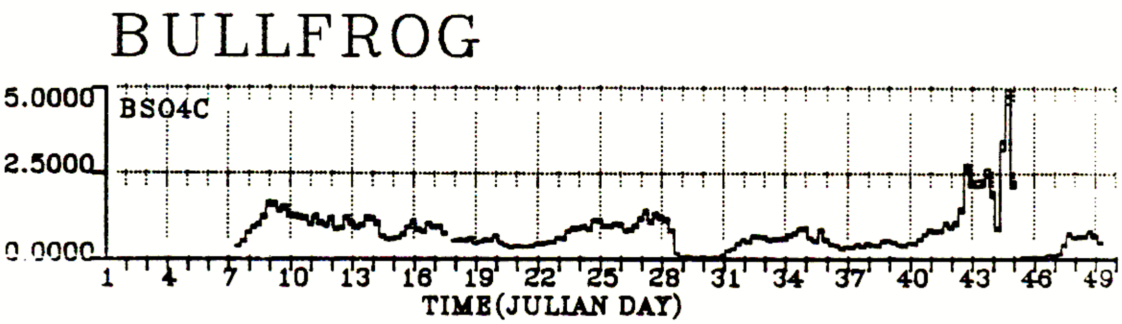

Figure 8.6: Sulfate ion concentration (μg m^{-3}) at Bullfrog for the WHITEX period.

Fine (< 2.5 μm diameter) sulfur concentrations at Hopi Point for the wintertime months, defined as November, December, January, February, and March will be examined. Only the 37 wintertime fine sulfur concentrations for the 24 hour sampling periods (after May 1986) will be examined in this section. This is because it is difficult to identify the exact date or dates on which the high S occurred for the 72 hour duration samples, making it harder to analyze the data with respect to the meteorology which can change significantly over a three day sampling period. The three day samples before June 1986 will be discussed in the next section.

Comparison of the WHITEX fine sulfur data with the network 24-hour concentrations on January 14 and January 17, 1987 of 320 and 204 ng m^{-3}, respectively, points out a problem in using even the 24 hour samples once every three days to identify peak sulfur concentrations. The high January 14 SO_4 value can be seen in the WHITEX data (Figure 8.2) to be a short duration local pulse of only six hours in length which produced a large 24-hour average S value in the network data. The lower network value on January 17 can again be explained by the WHITEX data since the network sampler was not started on January 17 until after the peak in the WHITEX data had dropped off sharply. (Network samplers operate from midnight to midnight.)

Table 8.1 shows the seven times when fine S at Hopi Point was greater than 250 ng m^{-3} during the wintertime months, excluding events during the WHITEX study which were covered in more detail in the previous section. Table 8.1 also indicates the three times when S concentrations were below 90 ng m^{-3}. The meteorological conditions associated with these 10 values of S will be discussed in this section.

8.3.1 High Events

December 17, 1986

Photographs taken during the December 17–24 time period can be seen in Photographs 8-32 through 8-36. Pictures taken on December 17 and 20 were completely clouded over and no photographs exist for December 24.

Table 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.

Date of S Measurement	S (ng m^{-3})
December 17, 1986	666
December 20, 1986	596
December 24, 1986	272
March 25, 1987	465
November 1, 1986	392
November 15, 1986	330
November 29, 1986	267
November 8, 1986	77
December 3, 1986	61
January 3, 1987	48

The S concentration of 666 ng m^{-3} measured on December 17 is due to a local buildup of S near NGS during a long stagnation event with light synoptic winds. The accumulation of pollution occurred due to the presence of a strong subsidence inversion and light geostrophic wind flow which often occurs with polar highs which persist for several days centered in this area. A 12 day persistent polar high was evident throughout this period starting on December 8 and ending December 19. On the day of the high S, a Great Basin high was situated to the north with strong northeast geostrophic winds which developed, apparently in response to a weak surface low to the southeast. This northeast geostrophic wind of greater than 10 m s^{-1} was apparently sufficient to transport pollutants which had accumulated to the northeast near NGS toward Hopi Point. In addition there were clouds both in the canyon and above indicating high relative humidity and thus enhanced conversion of SO_2 to SO_4. The transport mechanism for this day is similar to the WHITEX mechanism 1.

December 20, 1986

This high S (596 ng m^{-3}) is highly correlated with the previous high S event on December 17, 1986. The synoptic conditions for the day of December 20 suggest a transition time between moderately light southeast geostrophic winds switching to strong northeast geostrophic winds by the next morning. Both conditions are present due to the movement of an upper level trough over the area. Such troughs would normally tend to reduce or eliminate the subsidence inversion produced by the polar high that had persisted for 12 days prior to December 20. This trough, however, had little low level support; there was no surface front. Therefore, the pollutants remained trapped under the weakened but persistent inversion. The strong northeast geostrophic winds would be expected to transport these pollutants to Hopi Point causing the high S concentration. The transport mechanism for this day is similar to the WHITEX mechanism 1. Visibility was completely obscured throughout the day.

December 24, 1986

The meteorology associated with the S concentration of 272 ng m^{-3} on this date is closely related to the last two dates. Because the synoptic conditions up to this point were not strong enough to completely vent out the pollutants from within the very complex terrain around this area there was still an existing accumulation of pollution. On December 23, 1986, a weak low level front passed over the area with prefrontal conditions allowing venting of some of the pollutants towards the northeast. However, this was only a weak front which did not completely flush all of the pollutants from the area. On December 24, the polar high was reestablished and produced significant geostrophic winds from the northeast which transported the airmass to Hopi Point producing high S readings. This time period was also cloudy. The transport mechanism is again similar to WHITEX mechanism 1.

March 25, 1987

The S concentration was 465 ng m^{-3} on this date. This is an episode which cannot be explained completely by any of the mechanisms discussed in this chapter. The postfrontal conditions with moderately strong northeast geostrophic winds on March 25 might suggest mechanism 1 as the transport mechanism, but postfrontal conditions need to be preceeded by a stagnant polar high to be purely mechanism 1. A persistent polar high prior to March 25 does not exist. On March 24, there were postfrontal conditions with moderately light geostrophic winds from the north. On March 23, there was a polar high with moderately light northeast geostrophic winds. On March 22, postfrontal conditions existed. This type of oscillating synoptic pattern continued back in time until March 14 which is the last day of a five day polar high persistence event. The Photographs (8-39 and 8-40) show that the day was partly cloudy.

November 1, 1986

On this day, 392 ng m^{-3} of S was measured. This high S event was preceeded by an 8 day persistent polar high with the geostrophic winds during the last four days of the persistent polar high being light and variable. This caused a buildup of S to the northeast of Hopi Point. On October 31, a front passed through the area and moved rapidly to the east with northeast flow behind the system. This flow would tend to transport the pollutants down from the northeast to Hopi Point. The transport mechanism is similar to WHITEX mechanism 1. The day was overcast as can be seen in Photograph 8-27.

November 15, 1986

The S concentration of 330 ng m^{-3} obtained on this date was most likely associated with long range transport from sources to the south or southeast of Hopi Point. This conclusion is drawn based on two factors. The first factor involves a persistent high pressure which lasted for 10 days beginning November 9 and ending November 18. Therefore, the only synoptic condition during and for several days before and after this measurement period was a polar high. The second factor involves geostrophic wind direction. The day of the measurement period suggests synoptic transport from the southeast over the WHITEX area due to moderately light geostrophic winds out of the southeast. This type of synoptic pressure patten persisted for four days before the high S measurement period with geostrophic winds from the south or southeast at moderately light to moderately strong speeds. Thus NGS to the northeast would not be expected to be the major S contributor for this case.

The only factor keeping this case from being classified as mechanism 2 which is dominated by mesoscale transport is the two days of moderately strong geostrophic winds on November 13 and November 14 which suggests synoptic instead of mesoscale forcing. Photographs on November 15 indicate a high broken cloud layer above the canyon rim (see Photographs 8-29 and 8-30).

November 29, 1986

The S concentration was 267 ng m^{-3} on this date. A four day persistent polar high started on November 26 and ended November 29 which would cause a local buildup of pollutants near NGS. There would be little mesoscale transport to Hopi Point due to moderately strong and strong geostrophic winds with a southeasterly and southwesterly component on November 28 and November 29. The transport mechanism was probably strong northeast winds from postfrontal conditions on November 30 created by a fast moving surface polar front which was centered in northern Nevada on the morning of November 29 and central Kansas on the next day. These conditions suggest mechanism 1 as the reason for the high S measurement. Photographs for this day were all of poor quality, but suggest hazy conditions in the canyon around Hopi Point with some high level clouds above the canyon rim (see Photograph 8-31).

8.3.2 Low Events

November 8, 1986

The sulfur concentration on this day was 77 ng m^{-3}. This can be explained by the presence of a strong polar front passing through the area on November 6, producing strong southwest winds which flushed out the pollutants around NGS. This frontal passage was followed by a light wind polar high which set up on the day the measurement was taken. S may have accumulated around NGS but would not have had time to be transported to Hopi Point. It appears that light wind polar highs usually do not show signs of buildup at Hopi Point until at least two days have passed under the same light wind polar high conditions.

The photographs for this day show visibility which is not as pristine as might be expected based on the low sulfur concentration (see Photograph 8-28). Skies were generally cloudless and any visibility reduction which occurred was probably due to windblown soil. This hypothesis is based on the high wind speeds and the relatively high fine iron (indicative of soil) concentration. No coarse mass data were available to confirm the hypothesis.

December 3, 1986

On this date there was a S concentration of only 61 ng m^{-3}. The synoptic conditions on this date suggest transport from the southeast under the influence of a polar high centered to the east. This polar high was first evident on December 1 and persisted until December 4. This high was preceded on November 30 by a strong polar front passage over the area which flushed pollutants out of the area. The polar high persistence event began with moderately strong easterly geostrophic flow on December 1 which is not conducive to local pollutant build-up. The following day, December 2, calm conditions were present suggesting some local buildup, but this was only one day before the low S reading on December 3. This would not allow sufficient time for large local accumulation near NGS and resultant mesoscale transport to Hopi Point. Photographs for this day were all overexposed.