burning that occurred on the previous days, if transport conditions were correct. Extensive burning occurred on February 28, but the EC measurements fell below the springtime and annual means at both sites, although not statistically significant at a 95% confidence level. On March 6, 15, and 24, the KNS mass concentrations exceeded the mean springtime and annual KNS concentrations for both sites, and the relative contribution of KNS in comparison to K is also higher on these dates. The elevated KNS also suggests influence from wood burning on these days. Air mass trajectories were run to further investigate the potential influence of prescribed burns on ambient measurements, as discussed in Section C.9.

Figure C-10 compares the mass concentration ratios of EC to OCM and of KNS to K for the selected dates to the annual median ratios. The KNS to K ratios from March 6, 15, and 24 clearly exceed the annual ratio, indicating a relatively large contribution of KNS during these dates. Since KNS largely derives from wood smoke, emissions from nearby burns likely influenced the IMPROVE sites. The EC to OCM ratio from March 15 also clearly exceeds the annual ratio, further suggesting fire influence on this day.

C.7 DO HIGH CONCENTRATIONS OCCUR ON DAYS OF PRESCRIBED BURNS?

In addition to isolating the dates associated with extensive burning from the fire history data and analyzing corresponding ambient measurements, we also isolated the dates with high mass concentrations from the ambient measurements and analyzed corresponding fire history data. For each site, we ranked the 2002 IMPROVE data by the mass concentrations of EC, OCM, KNS, and K. We summarized the selected dates, ranks of each compound, whether a fire occurred, and the total acres burned within the sphere of influence of each site in **Tables C-5** and **C-6**.

At both sites, the dates of higher EC and OCM mass concentrations overlap more with each other than with the dates of higher K mass concentrations, as EC and OCM both commonly derive from combustion sources and K derives largely from soils. At Upper Buffalo Wilderness, three of the five highest EC mass concentrations were measured on the dates that we had isolated during the previous analysis of fire occurrence, namely March 6, 24, and April 5. Since EC partly derives from wood smoke and extensive burns occurred on the day of and the day before these dates, the elevated EC emissions could derive from nearby prescribed burns. We further analyze the potential connection between elevated emissions of key species and fire occurrence in the next section, utilizing air mass trajectories for select dates.

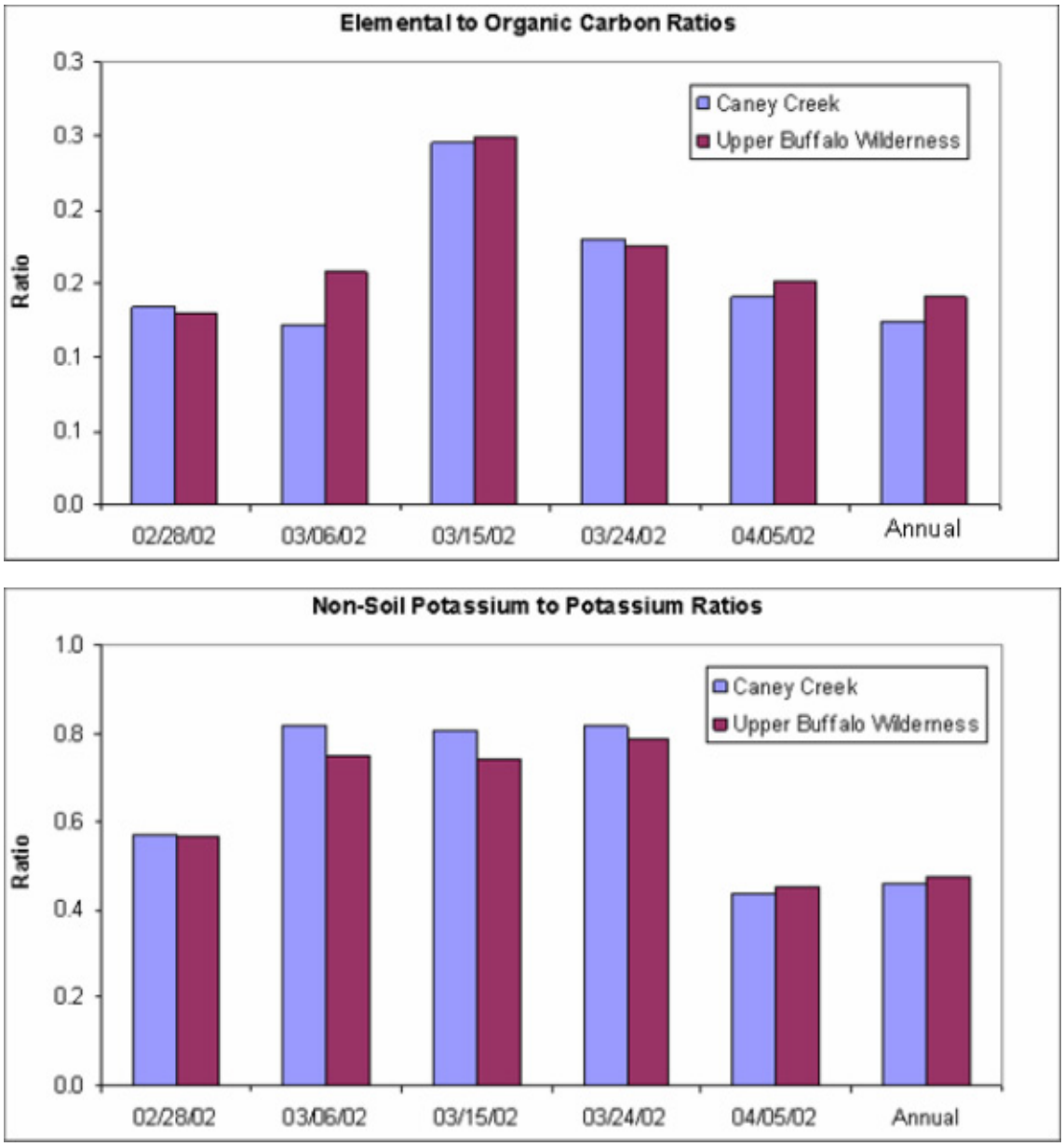

Figure C-10. EC to OCM and KNS to K mass concentration ratios for select dates compared to the annual median ratios for both sites

Table C-5. Dates with high measured EC, OCM, KNS and K mass concentrations and total acres burned within the sphere of influence of Caney Creek. The ranks order the days according to the five highest measured mass concentrations of each species.

Date	EC Rank	OCM Rank	KNS Rank	K Rank	Day of or before fires?	Total Acres
01/17/02	2				Of and Before	4,618
03/06/02			5		Of and Before	19,509
05/02/02			3		No Fires	0
05/08/02			2	4	Of and Before	N/A
06/22/02	5	5			Day Before	107
07/01/02				1	Day Of	41
07/04/02				5	No Fires	0
07/31/02				2	Of and Before	1,157
08/06/02		3			Of and Before	1,727
08/09/02	3	4			Of and Before	388
08/30/02	4				Of and Before	476
09/05/02		2	4		Of and Before	1,973
09/14/02	1	1	1	3	Of and Before	135

Table C-6. Dates with high measured EC, OCM, KNS, and K mass concentrations and total acres burned within the sphere of influence of Caney Creek. The ranks order the days according to the five highest measured mass concentrations of each species.

Date	EC Rank	OCM Rank	KNS Rank	K Rank	Day of or before fires?	Total Acres
03/06/02	5				Of and Before	20771
03/24/02	2				Of and Before	28567
04/05/02	4				Of and Before	8190
05/08/02			2	4	Of and Before	N/A
06/19/02	3	3	3		Of and Before	661
06/22/02	1	4	4		Day Before	356
07/01/02				1	Day Of	41
07/10/02		2			Of and Before	2114
07/31/02				3	Of and Before	927
08/03/02				5	Of and Before	189
08/06/02		5			Of and Before	1729
09/14/02		1	1	2	Of and Before	253
11/25/02			5		Of and Before	208

C.8 AIR MASS TRAJECTORIES

Back trajectories of air masses for the selected dates were created using the National Oceanic and Atmospheric Administration (NOAA) Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model. The NOAA HYSPLIT model is a three-dimensional air mass trajectory model based on weather model data and can be obtained from the NOAA web site at http://www.arl.noaa.gov/ready/hysplit4.html. The final (FNL) product of the Global Data Assimilation System (GDAS) that uses the Global Spectral Medium Range Forecast (MRF) model provides the weather data for the HYSPLIT model. The HYSPLIT model uses National Weather Service soundings and other diagnostic parameters such as temperature, relative humidity and radiative and momentum fluxes. It uses a 129 x 129 polar stereograph (three-dimensional) grid, with approximately 190 km resolution and 12 vertical layers, and is run at 6-hour increments. Back trajectories were run from 1800 CST with ending heights of 1000 and 500 meters in order to capture short-range transport in the lower boundary layer.

We ran trajectories for March 6, 15, and 24 and plotted them along with fires that occurred the day of and the day before the selected dates. **Figures C-11 through C-13** show the maps for March 6, 15, and 24. On these dates, the EC and KNS mass concentrations exceeded the annual means for each site, as summarized in Figure C-9.

Air mass trajectories demonstrated no influence from known burns at the Caney Creek site on March 6. However, the inventory does not include detailed fire history data for the southeastern corner of Oklahoma or for the eastern portion of Texas, over which the air mass advected before reaching the site. On approach to the Upper Buffalo Wilderness site, the air did pass directly over extensive fires that occurred on March 5. Therefore, the elevated EC and KNS emissions measured at Upper Buffalo Wilderness on March 6 could derive from wood smoke emissions from the previous day that influenced the site over a 24 hour period. Additionally, there were numerous nearby fires to Caney Creek on March 5 and 6 that would have affected the site via flow below 500 meters.

Similar to the situation on March 6, the air flowed directly over burns reported in the emissions inventory before reaching Upper Buffalo Wilderness on March 15, but the air did not flow over the reported burns when approaching Caney Creek. The elevated EC and KNS emissions measured at Upper Buffalo Wilderness on March 15 could be attributed to the wood smoke emissions from the extensive March 14 burns, and detailed fire history data from neighboring states would allow more definitive conclusions to be drawn about the measurements from Caney Creek. Also, the similarity in $PM_{2.5}$ composition at the two sites on this day indicates they were influenced from similar sources, again suggesting local low level flow advecting smoke to Caney Creek that is not shown by the trajectories.

Finally, on March 24, the air approaching Caney Creek circumvented the extensive fires reported by the inventory, while the air approaching Upper Buffalo Wilderness passed directly over them. Once again, the higher than average EC and KNS mass concentrations observed on March 24 at Upper Buffalo Wilderness could have originated from prescribed burning emissions, while more information would support definitive conclusions as to the Caney Creek emissions. Overall, the $PM_{2.5}$ composition and air mass trajectories show that fire influence from large-scale burns can be seen in the ambient data at Caney Creek and Upper Buffalo Wilderness. More

extensive emission inventory data is needed to better assess the impact of prescribed burn emissions in the CENRAP region.

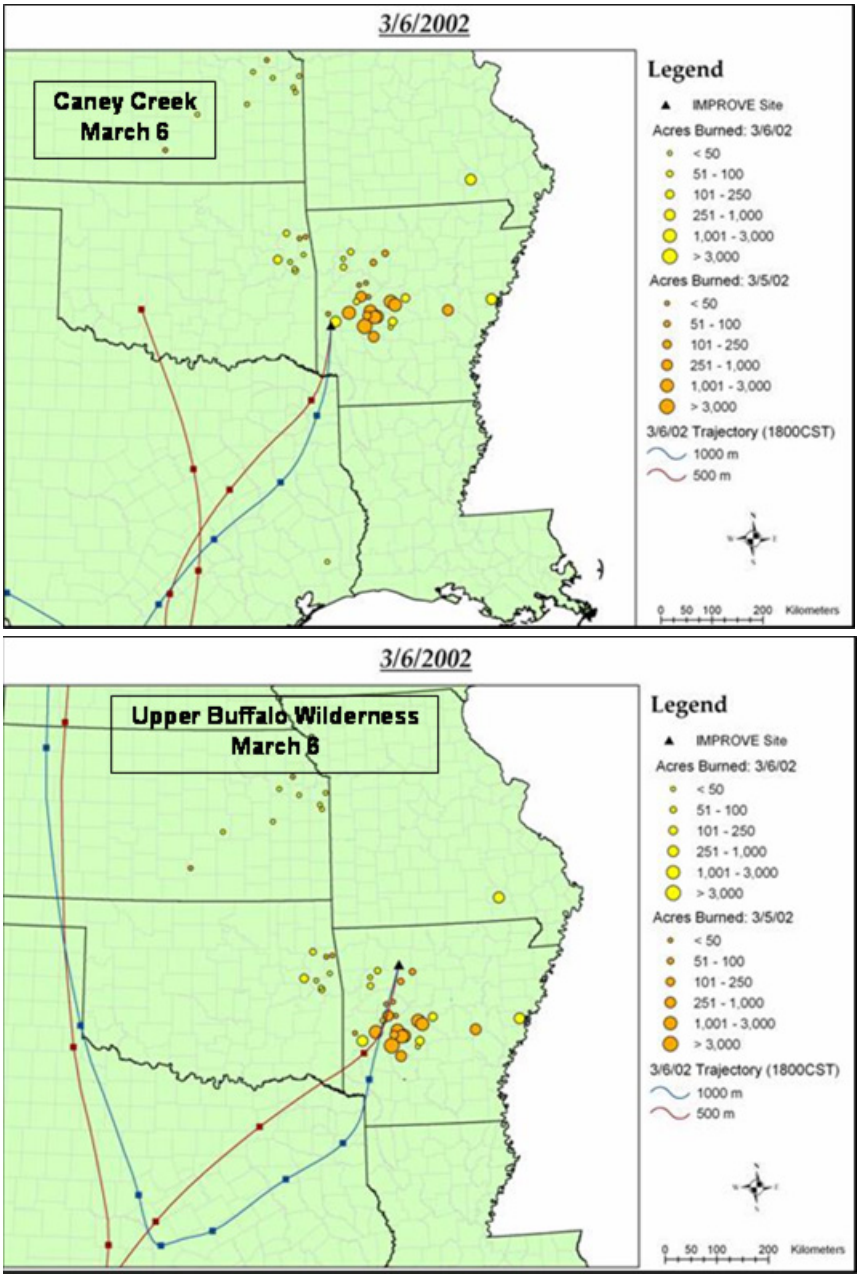

Figure C-11. Air mass trajectories and associated fires for March 6. Squares along each trajectory are placed every 6 hours.

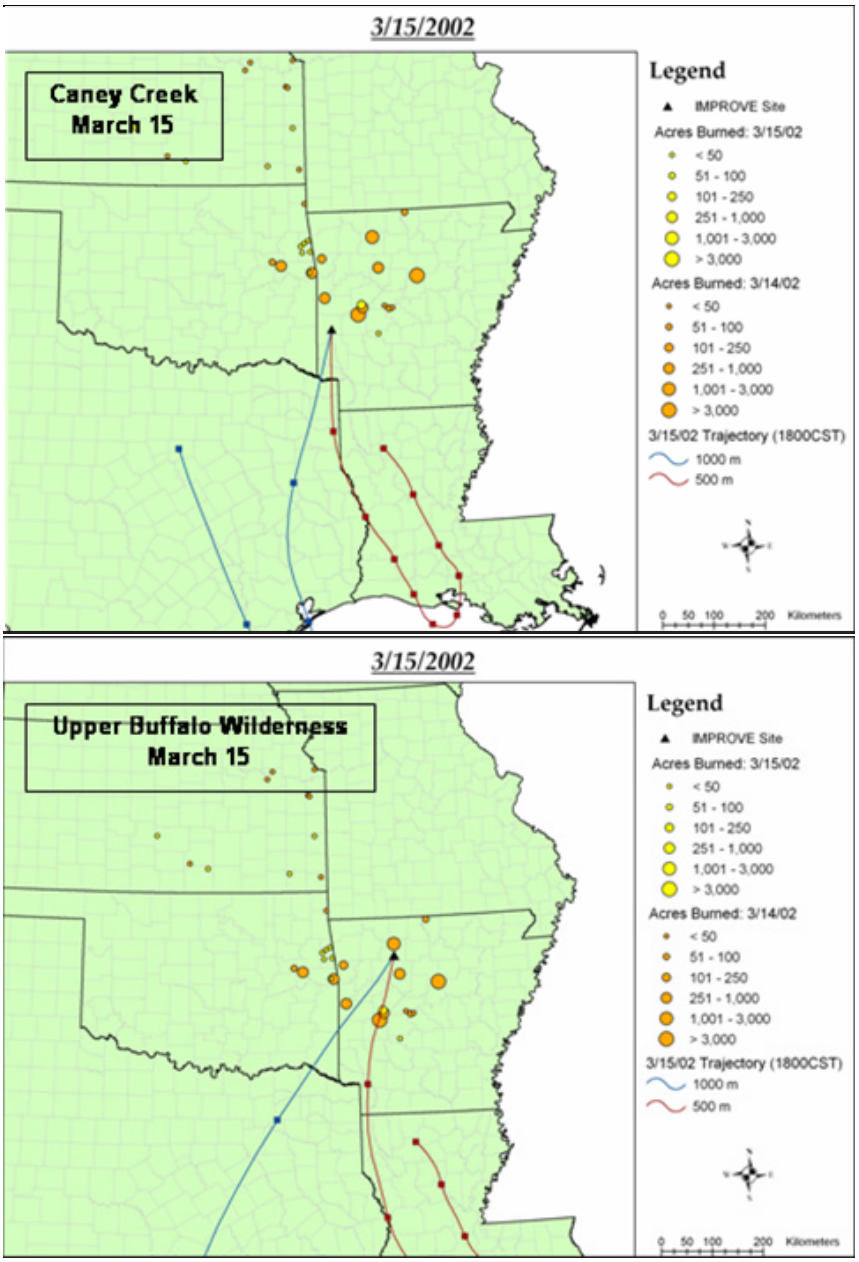

Figure C-12. Air mass trajectories and associated fires for March 15. Squares along each trajectory are placed every 6 hours.

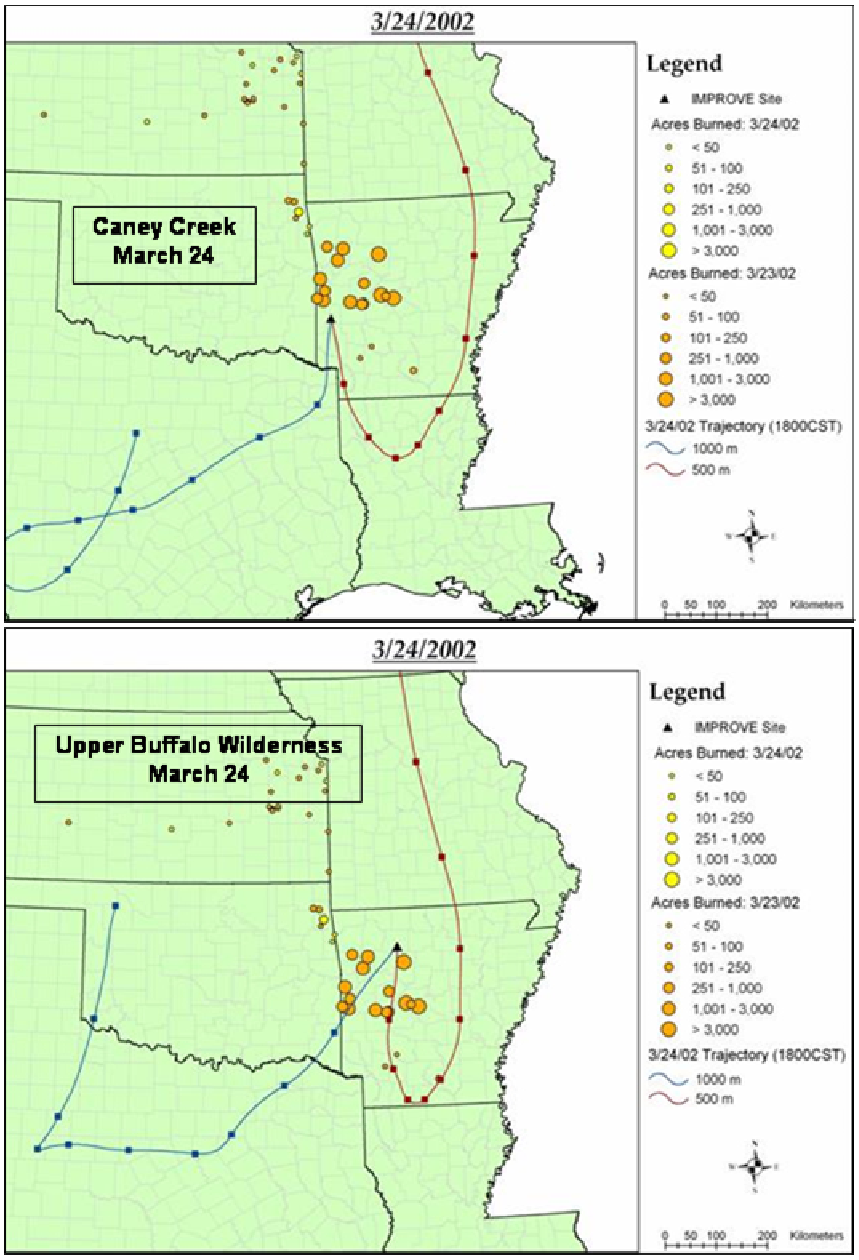

Figure C-13. Air mass trajectories and associated fires for March 15. Squares along each trajectory are placed every 6 hours.

C.9 EFFECTS ON VISIBILITY

We have demonstrated a potential connection between prescribed burn occurrence and elevated EC and KNS emissions at Upper Buffalo Wilderness via comparative analyses of ambient data and fire history data and air mass trajectories. In order to assess the impact that the elevated emissions have on visibility, we plotted the median $PM_{2.5}$ mass compositions of the annual, best visibility, and worst visibility data sets from Upper Buffalo Wilderness in order to

compare them to the mass and visibility compositions measured on the select dates March 6, 15, and 24, as illustrated in **Figure C-14**. The $PM_{2.5}$ mass compositions consist of the measured NH_4NO_3, $(NH_4)_2SO_4$, soil elements, OCM, and EC mass concentrations. The worst visibility data set is characterized by high $(NH_4)_2SO_4$ and OCM measurements, while the best visibility data set is characterized by relatively low concentrations of all the species. Since $(NH_4)_2SO_4$ does not derive from wood smoke, and OCM can derive from other sources, the species that dominate poor visibility conditions are not necessarily connected with emissions from wood smoke.

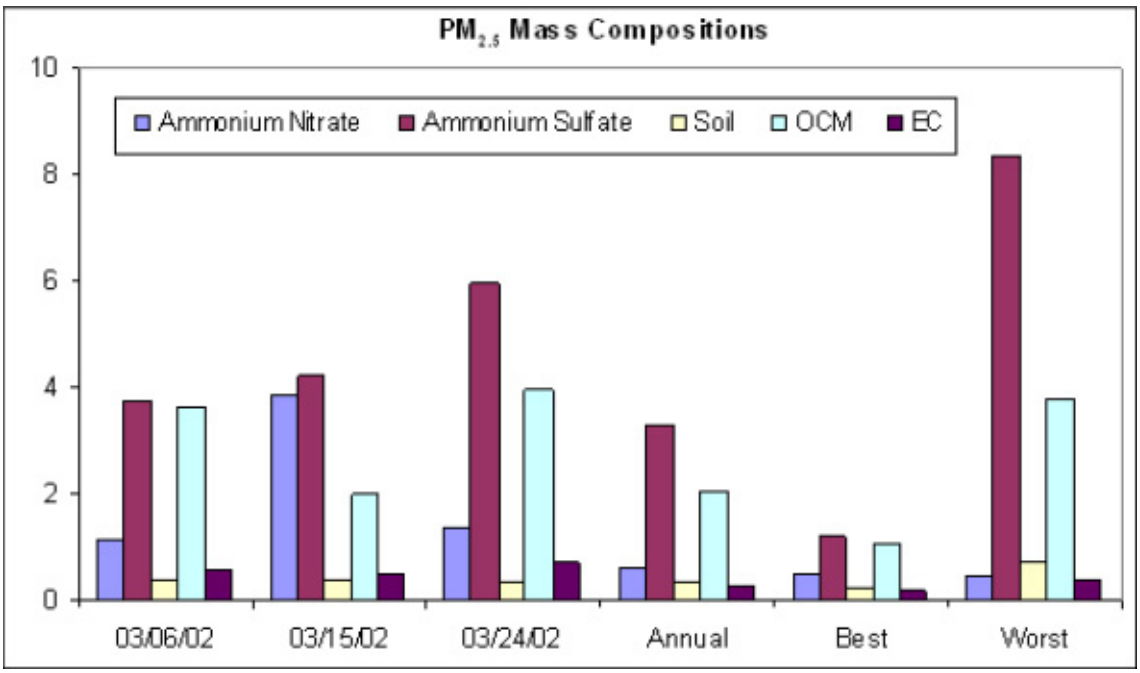

Figure C-14. $PM_{2.5}$ mass compositions for select dates and for the annual, best visibility, and worst visibility data sets.

C.10 CONCLUSIONS

Speciated $PM_{2.5}$ data collected at IMPROVE sites in Class 1 areas in Arkansas were used to determine whether such data can help to examine the influence of prescribed burning and determine if burns in the emission inventory significantly impact the $PM_{2.5}$ composition and visibility reduction. Overall conclusions include:

- Speciated $PM_{2.5}$ data at IMPROVE sites are useful for characterizing sources impacting $PM_{2.5}$ and visibility reduction, including burns.
- Influence from specific known burns (as seen by elevated concentrations of EC or K) can be seen on select days when the meteorology is conducive for transport.
- Days when high OC or EC concentrations are observed at the sites do not always coincide with known burns; however, the emission inventory is not complete and may be

missing burns in the areas of influence on these days, such as southern Oklahoma and eastern Texas.

- Meteorology plays an important role in determining the areas impacted by prescribed burns.
- EC, the primary marker of smoke, is a relatively small part of both the $PM_{2.5}$ mass and light extinction.
- Ammonium sulfate is generally the largest contributor to the $PM_{2.5}$ mass and light extinction; this component does not originate from burns. This finding is consistent with other work in the Midwest and CENRAP region including Big Bend National Park and Seney Wildlife Refuge.

C.11 RECOMMENDATIONS FOR FUTURE WORK

Additional analyses could be conducted to better quantify the influence of burns on visibility impairment. Such analyses could include:

- Apply analyses conducted in this task to additional IMPROVE sites, such as in Kansas or Minnesota to investigate whether results in this task are indicative of trends throughout the CENRAP region
- Utilize continuous $PM_{2.5}$ in conjunction with meteorological data to determine what meteorological conditions may be responsible for changes in $PM_{2.5}$ concentrations.
- Apply source apportionment tools such as UNMIX or Positive Matrix Factorization (PMF) to quantify influence of specific source types at a site using 24-hour (i.e., IMPROVE, STN, etc) or continuous speciated data (such as at Bondville or St. Louis). These tools can be used to identify individual sources such as diesel, wood burning, etc.
- Develop a better conceptual model of $PM_{2.5}$ in the CENRAP region:
  - *Are there differences in $PM_{2.5}$ composition and meteorology among different locations in the CENRAP region?* Significant differences in $PM_{2.5}$ concentrations and composition among sites in different geographic locations within the CENRAP region may provide insight into $PM_{2.5}$ transport and formation. For example, a surface high pressure system located over the Upper Midwest will often drive southeasterly winds across the CENRAP region, which can transport higher levels of $PM_{2.5}$ from upwind sources within major population centers.
  - *How are $PM_{2.5}$ concentrations and visibility dependent on large-scale meteorological patterns?* The effect of large-scale synoptic patterns on $PM_{2.5}$ concentrations and regional haze is a critical issue because synoptic patterns affect transport, vertical and horizontal dispersion, formation, and the impact of local emissions on an area. For example, transport of warm, moist air from the Gulf of Mexico may result in secondary particle formation within the CENRAP region, reducing visibility.

– *What are the compositional and meteorological differences between days of high and low $PM_{2.5}$ concentrations?* Differences in $PM_{2.5}$ composition may indicate different transport regimes, and might identify which species are dominant on high $PM_{2.5}$ days, both of which would assist forecasters. One useful way of examining the meteorology on these days is to perform several case study analyses of high and low $PM_{2.5}$ concentration episodes. A typical case study analysis would examine:

- *Upper-air and surface synoptic patterns for each day*. These patterns assist meteorologists in determining the extent to which particles may be allowed to mix, or disperse. For example, an upper-level high pressure system is typically associated with sinking air, which will help to trap particles near the surface.
- *Vertical temperature soundings whenever available*. Vertical temperature soundings give meteorologists the ability to assess the vertical structure of the atmosphere, in particular, how much vertical mixing can occur. Typically, a strong surface-based inversion will trap particles near the surface, allowing $PM_{2.5}$ levels to be high.
- *Back-trajectories for each day*. Back-trajectories provide meteorologists with a tool for assessing whether transport of particles could have occurred within a region or from another region.