

2.6.3 Trajectory Analysis

A recent study of source apportionment and trajectory analysis of PM_{2.5} speciation results for approximately the first year at the Blair St. site in St. Louis (Basil Coutant et al., Revised Draft Report on Source Apportionment of PM_{2.5} Speciation Trends Data, Battelle Memorial Institute, prepared for US EPA, September 2002) included analysis of back trajectory modeling results generated using HYSPLIT (www.arl.noaa.gov/ready/hysplit4.html). HYSPLIT generates back trajectories using an 80 kilometer grid of meteorological data and so does not have the spatial resolution to identify local point sources. However, source contribution function plots for worst sulfate days (plots on a map of the probability that a worst-day trajectory passes through a region) support the conclusion that sulfate originates in regions with a high density of coal burning including the Ohio River Valley and adjacent states. In addition, trajectories for high sulfate days typically show clockwise curvature, indicating flow around a high pressure area, with corresponding downward vertical flow that would tend to trap emissions near the ground. Trajectories for high nitrate days generally show air flow from the north on colder days conducive to nitrate condensation rather than indicating specific source regions. These results are consistent with those discussed above and with speciation results presented in Section 2.3, all suggesting that sulfate results from widespread sources, while nitrate may result from more localized sources.

The Missouri Department of Natural Resources Air Pollution Control Program has also conducted back trajectory modeling using HYSPLIT for all days with PM_{2.5} concentrations greater than 25 µg/m³ at one or more locations in the St. Louis area, including Illinois sites, for 2004 and 2005. The trajectories were run using the following parameters and their corresponding values.

Parameter	Value
Start time (UTC)	22
Total run time (hours)	72 hours
Start height (meters)	500 meters
Start location	Blair Street site

Figure 2.6-6 presents back trajectories in summer. The trajectories show clockwise curvature (around a high-pressure area) and are mostly from an easterly direction (the Ohio River Valley), consistent with the source contribution results described above, or show flow from a westerly direction, originating in the area of Texas. Both of these types of trajectories enter the St. Louis area from the south, consistent with wind rose results showing a dominant southerly flow.

Figure 2.6-7 presents a spider plot of back trajectories in winter. The majority of the trajectories in winter are long-range and originate from the north-northwest. This characteristic is consistent with cool conditions conducive to the formation of nitrate particles and is consistent with those described above.

Figures 2.6-8 and 9 present back trajectories in spring and fall. There is no distinct pattern characterizing the trajectories in spring and fall. Rather they seem to be typically short to

medium in range from numerous directions. This could explain a mixture of high nitrate cool days and high sulfate warm days. This may be in addition to the high organic and/or elemental carbon days during which the trajectories may have originated from local sources. As mentioned above, this trajectory analysis does not resolve local source contributions well because of the coarseness of the grid of meteorological data.

Additional analysis of air mass trajectories was done for days with PM_{2.5} concentrations greater than 25 µg/m³. A Conditional Probability Integrative Analysis (CoPIA) was applied to further help identify transport patterns and likely areas of influence. Similar analysis of the air mass movement was done on days with high values of major species, i.e., sulfate, nitrate, and organic carbon, at the Blair St. site. Figure 2.6-10 provides an example of the procedure for selecting high days for sulfate; a similar selection procedure was used for the other species. Similar input parameters as described above were used in the CoPIA.

Results of the analysis are presented in Figures 2.6-11 through 2.6-17. These figures show the probability that the air traveled over each grid cell during the high PM_{2.5} mass or major species relative to the probability over the grid under all conditions. A value of one indicates that all trajectories passed near the given area, while a value close to zero denotes an area over which very few trajectories passed.

Figure 2.6-11 shows the CoPIA surface for the high PM_{2.5} mass days in summer. The plot indicates a high likelihood of transport from the Ohio River Valley to the receptor site, Blair St. This finding is in agreement with back trajectory analysis results described above. As expected, the conditional air mass flow on high sulfate days (Figure 2.6-12) shows transport that is generally from an easterly direction, just as on high PM_{2.5} mass days, since sulfate is a major contributor to the mass, especially in summer.

Figure 2.6-13 shows the CoPIA plots for high-mass days in winter. As shown in the figure, the air mass is likely to have originated from west through northwest. This transport is probably not an indication of source locations, but rather of cool conditions favorable for nitrate condensation, as indicated above. A similar finding is seen in Figure 2.6-14, in which the air mass is shown to flow from a northwesterly or northeasterly direction to the site.

Figures 2.6-15 and 2.6-16 for the high days in spring and fall, respectively, show movement of air masses that is not clearly resolved. As with the back trajectory results, the CoPIA analysis is based on gridded meteorological data with a resolution of 80 km prior to April 2004 or 40 km for more recent dates.

Figure 2.6-17 for organic carbon high days shows a high likelihood that the air mass originated to the south of the Blair St. site. The identified area of origin is fairly consistent with agricultural areas where agricultural burning is carried out in the spring and fall seasons.

In addition, US EPA Region 7 has conducted systematic trajectory cluster analysis using sulfate, nitrate, and organic carbon PM_{2.5} speciation measurement results from the Blair St. site in St. Louis. This analysis generates back trajectories using HYSPLIT and then groups trajectories into clusters. Trajectory clusters are generated by comparing the four-dimensional (latitude,

longitude, pressure, and time) data defining each air parcel trajectory with the data for every other trajectory. Trajectories are then grouped into clusters by their proximity to one another using a chosen radius of proximity. Once the first cluster is generated in this way, the remaining trajectories are analyzed in the same way and the process repeated. Remaining trajectories are then assigned to clusters if they are within twice the radius of proximity of a cluster.

This analysis resulted in eight trajectory clusters. In general, results were consistent with those described above. The average trajectories for clusters with higher than average sulfate showed clockwise curvature and paths either along the Ohio River Valley or upper Mississippi River Valley. The average trajectories for clusters with higher than average nitrate showed paths from the north or northwest. The average trajectories for clusters with higher than average organic carbon showed either flow through the Ohio River Valley or flow from the west, with minimal deviation from the average, suggesting that local sources may be relatively more important for organics.

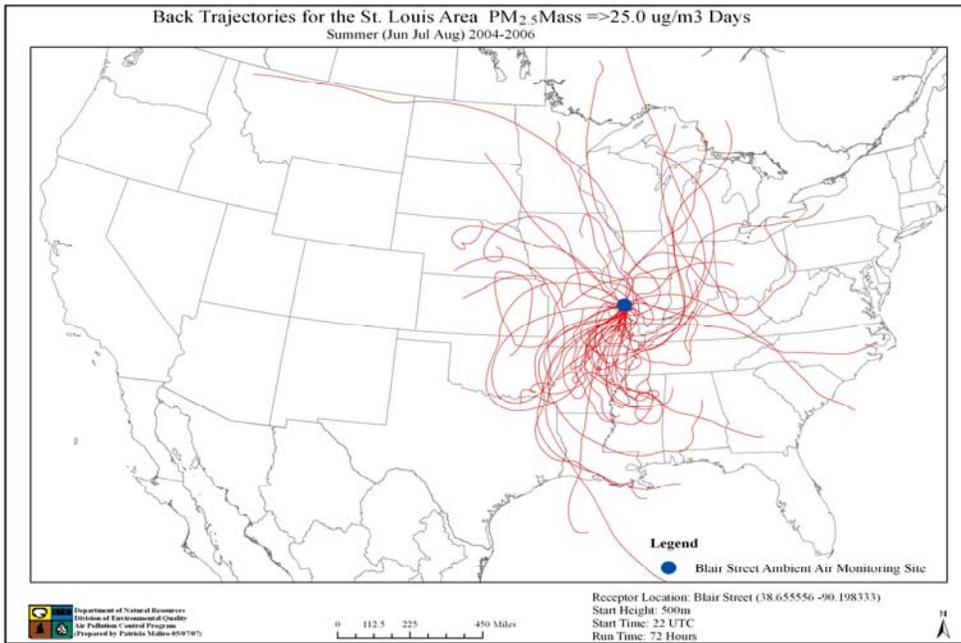


Figure 2.6-6. Summer back trajectories on high PM_{2.5} mass days.

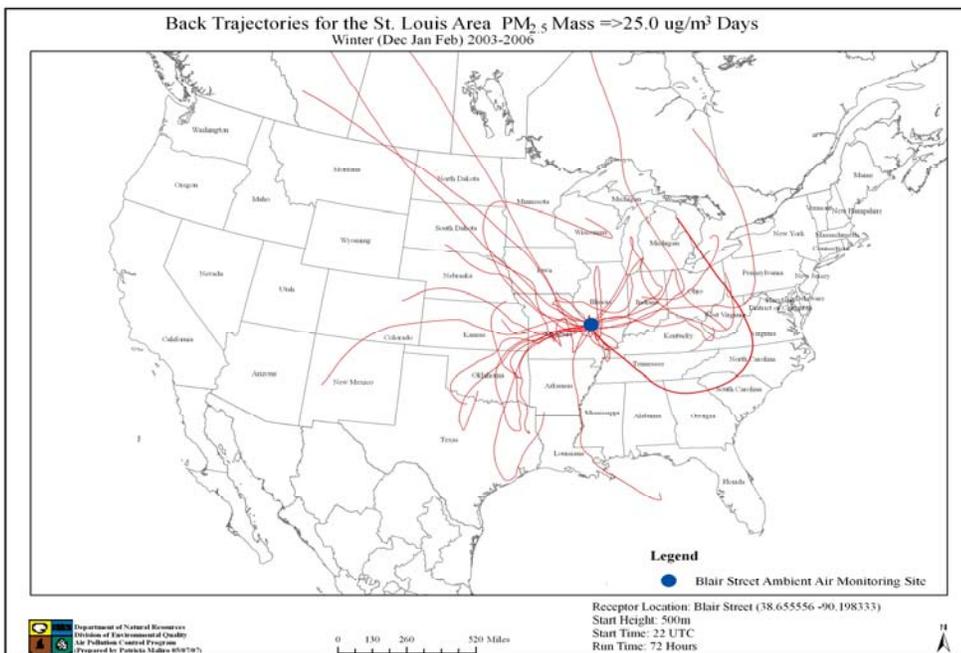


Figure 2.6-7. Winter back trajectories on high PM_{2.5} mass days.

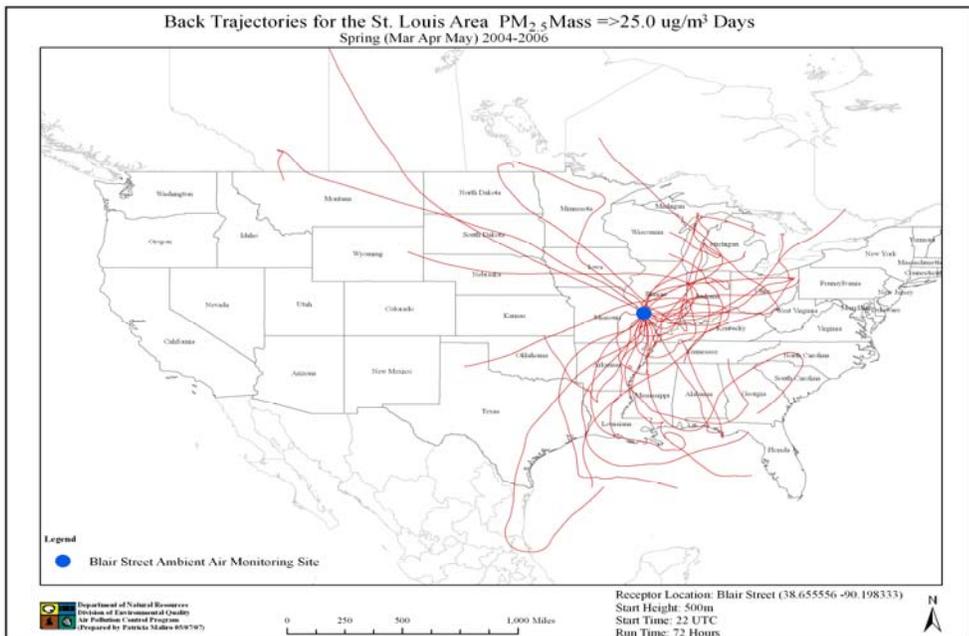


Figure 2.6-8. Spring back trajectories on high $PM_{2.5}$ mass days.

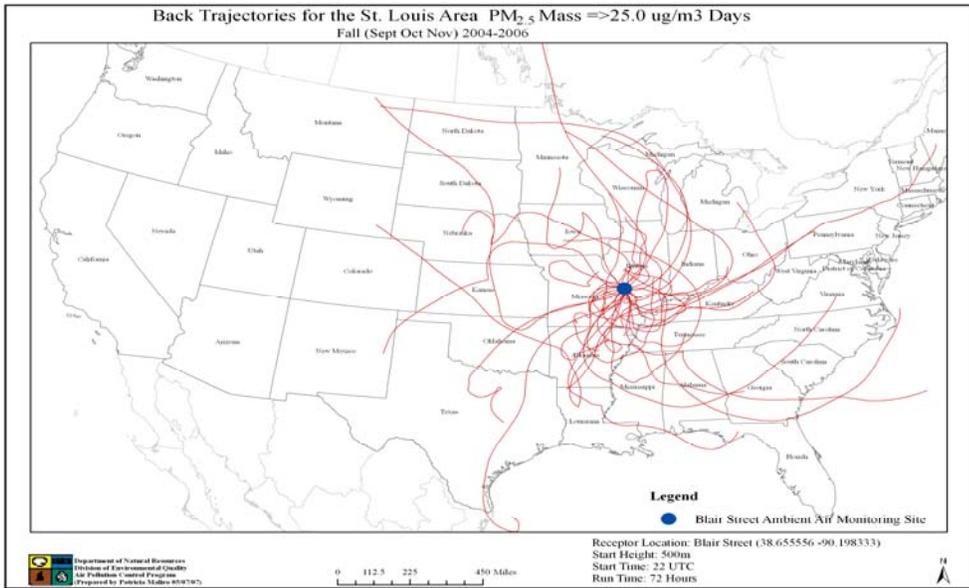
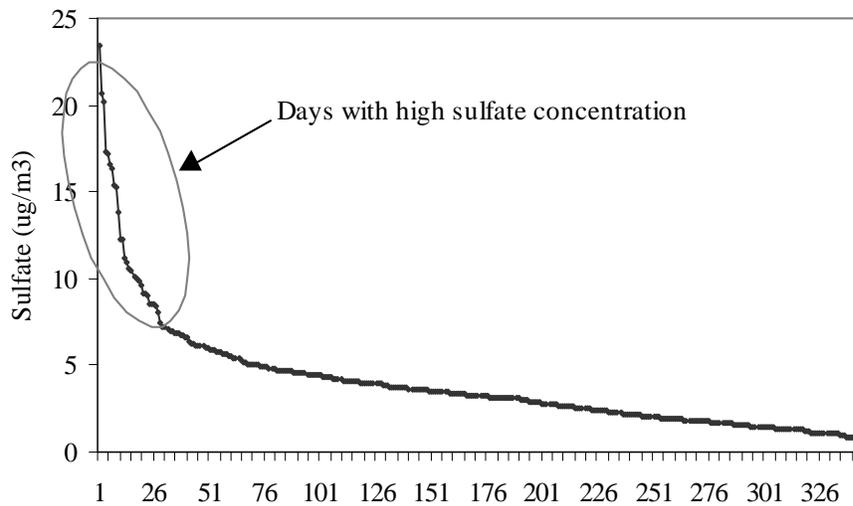


Figure 2.6-9. Fall back trajectories on high $PM_{2.5}$ mass days.

Figure 2.6-10. Distribution of 2004-2006 sulfate concentrations at the Blair Street site



Summer Conditional Air Mass flow to the Blair Site on $\geq 25.0 \mu\text{g}/\text{m}^3$ PM_{2.5} Mass Days (2004-2006)

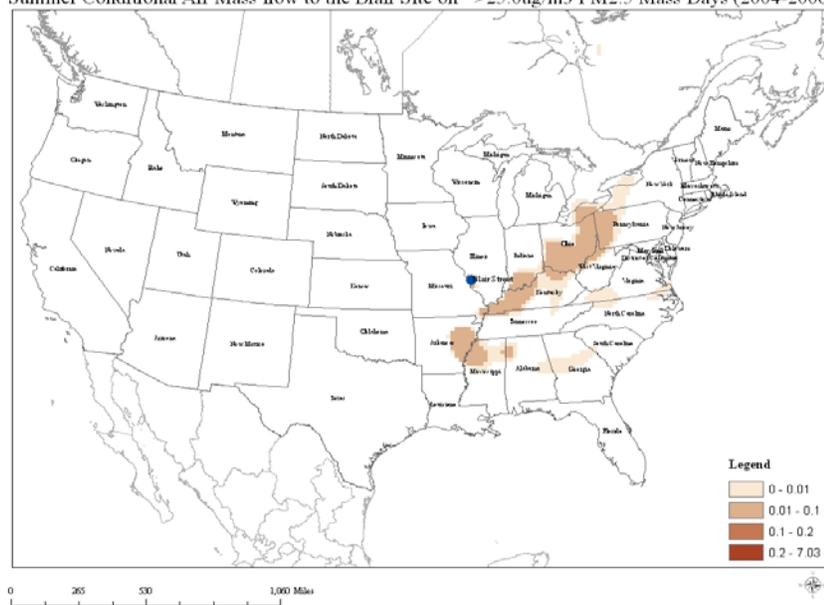


Figure 2.6-11. Summer conditional air mass movement on high PM_{2.5} mass days.

Conditional Air Mass flow to the Blair Site on high Sulfate Days (2004-2006)

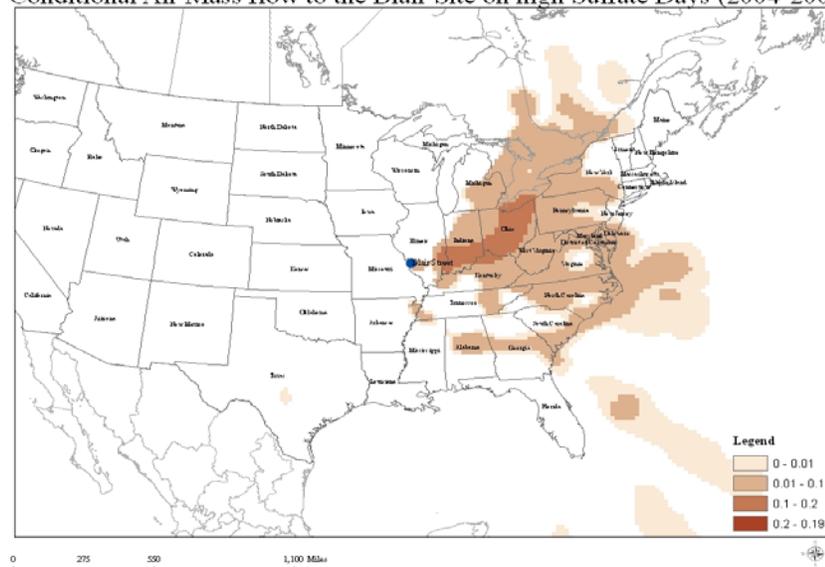


Figure 2.6-12. Conditional air mass movement on high sulfate days.

Winter Conditional Air Mass flow to the Blair Site on $\geq 25 \text{ } \mu\text{g}/\text{m}^3 \text{ PM}_{2.5}$ Mass Days (2004-2006)

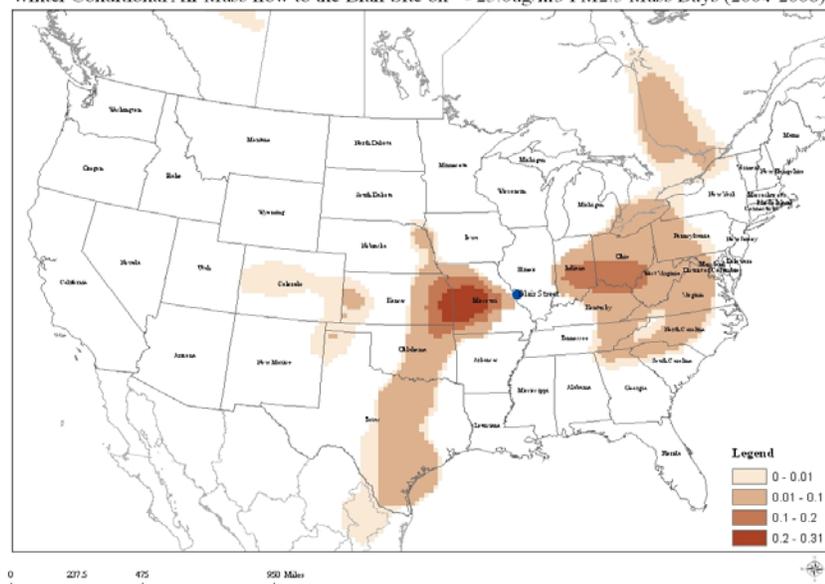


Figure 2.6-13. Winter conditional air mass movement on high $\text{PM}_{2.5}$ mass days.

Conditional Air Mass Flow to the Blair Site on High Nitrate Days (2004-2006)

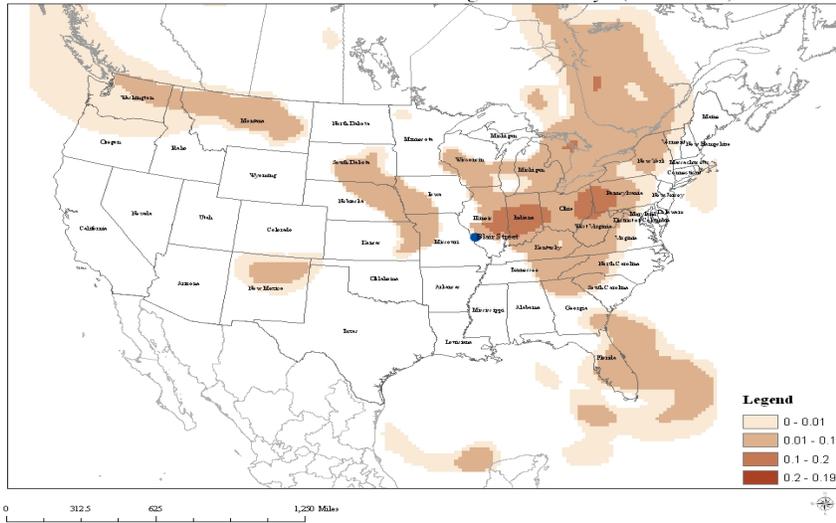


Figure 2.6-14. Conditional air mass movement on high nitrate days.

Spring Conditional Air Mass flow to the Blair Site on $\geq 25.0 \mu\text{g}/\text{m}^3$ PM_{2.5} Mass Days (2004-2006)

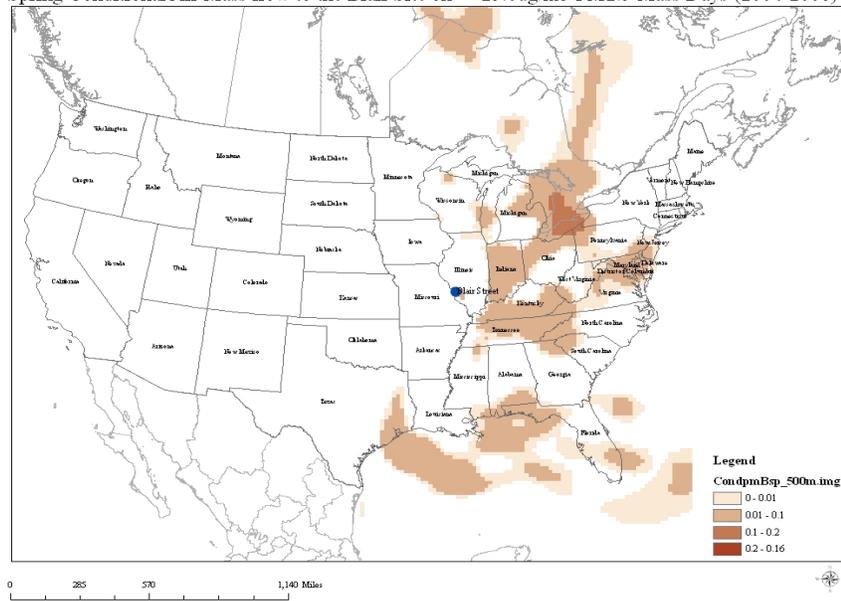


Figure 2.6-15. Spring conditional air mass movement on high PM_{2.5} mass days.

Fall Conditional Air Mass flow to the Blair Site on $\geq 25.0 \mu\text{g}/\text{m}^3$ PM_{2.5} Mass Days (2004-2006)

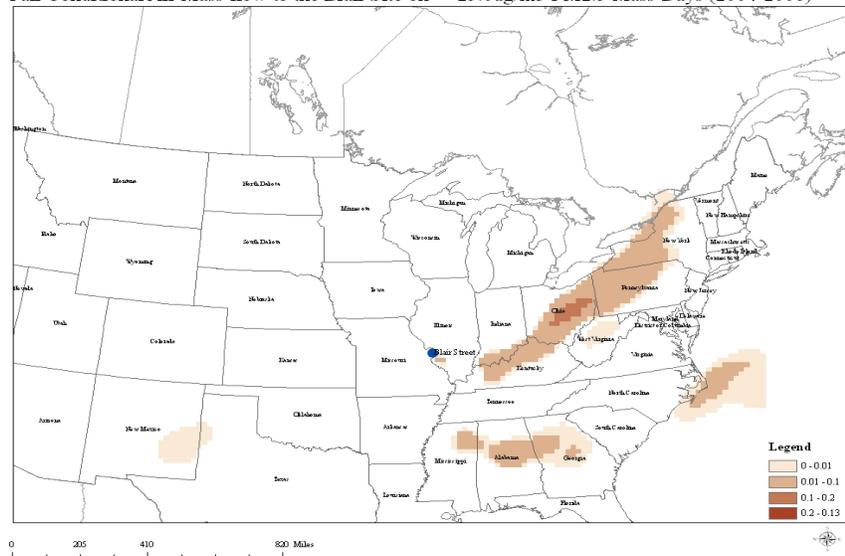


Figure 2.6-16. Fall conditional air mass movement on high PM_{2.5} mass days.

Conditional Air Mass Flow to the Blair Site on High Organic Carbon Days (2004-2006)

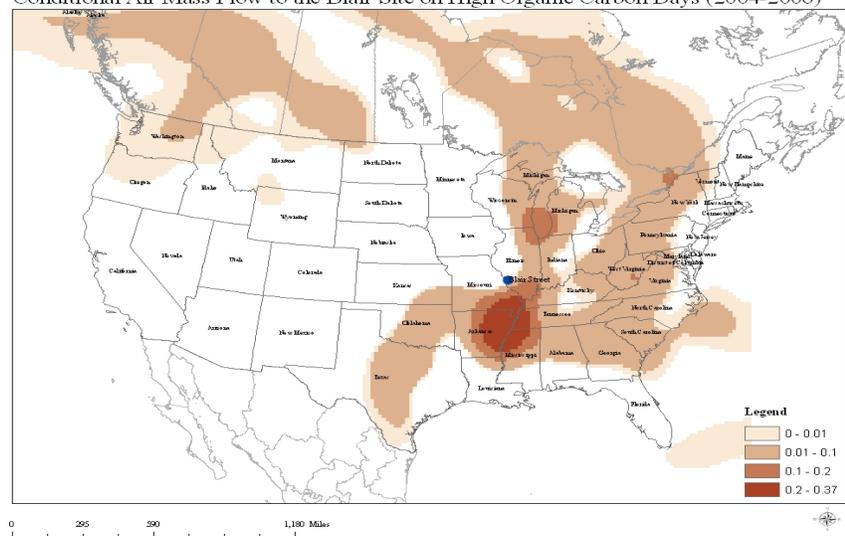


Figure 2.6-17. Conditional air mass movement on high organic carbon days.

2.7 GEOGRAPHY AND TOPOGRAPHY

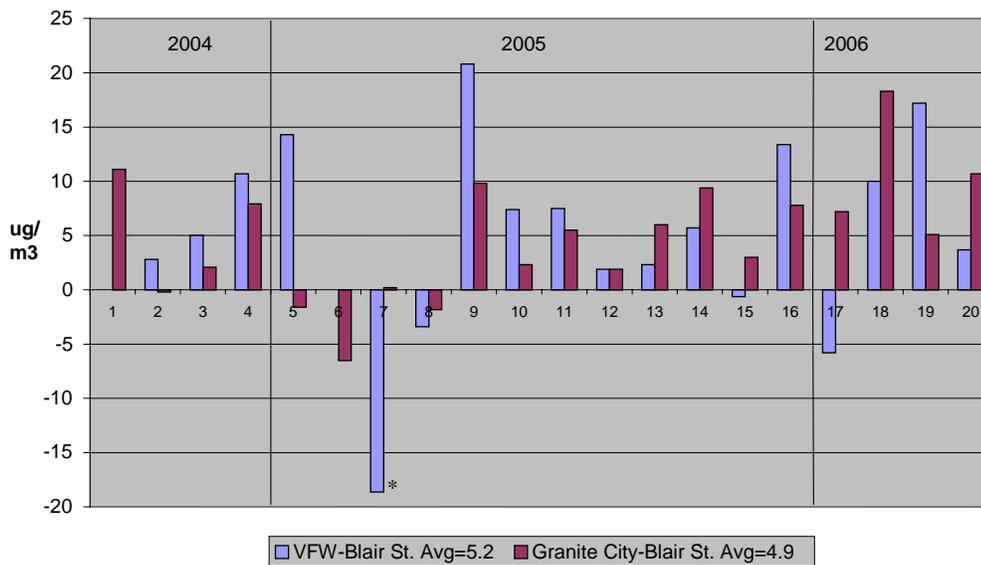
St. Louis lies at the confluence of the Missouri and Mississippi Rivers, and the rivers are, of course, at the lowest elevations in the area. The elevation changes approaching the river are gradual, and this effect, if present, does not appear to result in large pollutant concentration gradients in the direction of elevation change. There may be some accumulation of air pollution along the rivers, especially along the Mississippi River, and especially during periods of relative calm.

2.8 DISCUSSION OF FACTORS AND CONCLUSIONS

The PM_{2.5} air monitoring data presented in Section 2.1 show attainment of the 24-hour standard for the years 2004-2006 for all of the monitoring sites in the St. Louis area in Missouri, as summarized in Table 2.8-1. Only two of the St. Louis area sites in Illinois, Granite City and VFW are not in attainment of the standard, and monitoring data from these two sites are not well-correlated with other sites in the area. Correlation of Missouri sites with other Missouri sites is above the average of 0.7006 for 14 of 15 site-to-site correlations, whereas only 35 of 66 combined Missouri plus Illinois correlations are above the average. This indicates that concentration values at the Missouri sites are not affected by source differences to the extent that some sites in the Illinois part of the area are.

As shown in Figure 2.8-1, the VFW and Granite City sites in Illinois, on most days with high PM_{2.5} concentrations, show higher concentrations than at the Blair St. site in St. Louis. This result is likely caused by local sources near the two Illinois sites.

Figure 2.8-1. PM_{2.5} Concentration Differences on Days with High Concentrations, VFW and Granite City minus Blair St.



* outlier value

Dr. Jay Turner of Washington University has conducted preliminary analysis of speciated mass for FRM measurements from the Granite City and VFW sites, in comparison with the Margaretta site using the top quartile of the concentration difference distribution for data for 2001-2004. This analysis was directed at analysis for the annual average, but points to the continued elevation of values at the Granite City and VFW sites. Margaretta was selected because it appears not to be affected by any nearby major point sources. It too shows consistency in the PM_{2.5} 24-hour NAAQS design values with the other sites in the Missouri portion of the St. Louis area. Mean and median values of the PM_{2.5} daily mass difference distribution for Granite City and VFW with respect to Margaretta were 3.2 and 2.2, respectively. As can be seen below, Dr. Turner has constructed a Conditional Probability function plot from the data, which indicated that much of the excess mass originates from Granite City Steel and other related activities nearby (within the green boundary). Dr. Turner indicates that further work to define the actual contribution of Granite City Steel is ongoing. The above data indicates that the effect on average days is significant. Undoubtedly, 98th percentile values are effected to an even greater extent by nearby sources.

Figure 2.8-2. Conditional Probability Function Plot for the Granite City, IL PM2.5 site compared to excess PM2.5 mass at the St. Louis, MO Margaretta St. Station



Comparison of PM_{2.5} mass and speciation measurement results for the St. Louis area to those for rural areas shows an urban excess of 4 to 6 µg/m³, which (on an annual basis) is predominantly carbonaceous material (organic compounds and elemental carbon) and nitrate. Differences in these species (carbonaceous material and nitrate) also appear between urban core and suburban sites in the St. Louis area. Sulfate, on the other hand, appears to be more regional. It should be noted that most of the high carbonaceous days do not add to high PM_{2.5} above the level of the 24-hour standard at the Blair St or Arnold locations.

PM_{2.5} speciation results in the St. Louis area (Section 2.3) indicate that the species contributing most of the PM_{2.5} mass are ammonium sulfate, ammonium nitrate, and carbonaceous material (organic compounds and elemental carbon). The sulfate contribution is highest in the summer, and the nitrate contribution is highest in the winter. Analysis of speciation results on summer days with high mass concentration shows that the excess over average summer days is dominated by ammonium sulfate, which is widespread in the region. The combined effect of the regional and urban emissions in the area is to create levels of PM_{2.5} during high pollution events that, in St. Louis, Missouri, are primarily due to either regional sources of sulfate and/or urban-wide/regional sources of nitrate. However, as noted above, the Granite City and VFW sites in Illinois usually show higher mass concentrations; this consistent difference is believed to result from local sources near those two sites.

Emission inventory data and population data for St. Louis (Sections 2.4 and 2.5) are presented to aid in understanding the urban excess PM_{2.5} in the St. Louis area, but these emissions are not sufficient to cause a violation of the 24-hour standard in the St. Louis, Missouri area. In fact, the impact of emissions at sites in the St. Louis, Missouri area is highly consistent among the sites, with Design Values for the period 2004-2006 in a range of 31.9 to 32.5 for all but Mound St. (33.6), also well below the standard.

Meteorological analysis results (Section 2.6) complement the results of speciation measurements. High PM_{2.5} mass and sulfate days in summer appear to result from air flow either from the Ohio River Valley area, which has numerous large sulfur oxide sources, or from the west. Both types of trajectories enter the St. Louis area from the south. High nitrate days in winter appear to result from air flow from the north, which is likely more of an indicator of cold weather enhancing nitrate condensation than of source direction. High carbonaceous material days, typically in fall, do not show a consistent trajectory pattern, probably because the sources are relatively local.

In conclusion, the air monitoring data show attainment of the 24-hour PM_{2.5} standard by all St. Louis, Missouri sites on a consistent basis across the area. In addition to these air monitoring results, the other eight factors recommended by EPA have been discussed in this document. Analysis of all of these factors indicates that St. Louis City, St. Louis County, St. Charles County, Jefferson County and Franklin County are connected with respect to these factors, which results in none of these counties being in violation of the 24-hour PM_{2.5} standard. In contrast, the Illinois sites at VFW and Granite City are monitoring violations of the standard, show poor correlation with Missouri sites, and also elevated levels inconsistent with Missouri monitoring. These data indicate that exceedances at the Granite City and VFW sites likely result from the additional contribution of local sources that do not impact the Missouri sites in a way that alters compliance or affects overall air quality levels to a significant extent. Based on this result and on

the above supporting analysis, it is recommended that St. Louis City and all of the counties in the St. Louis area in Missouri be designated as in attainment of the 24-hour standard.

Table 2.8-1. 98th percentile 24-hour PM_{2.5} mass concentration ($\mu\text{g}/\text{m}^3$), St. Louis MO area sites. Standard = 35.

West Alton	31.9
Margaretta	32.3
Blair Street	32.5
Mound St.	33.6
S. Broadway	32.5
Clayton	32.3
Arnold	32.4

3.0 REMAINDER OF MISSOURI

3.1 PM_{2.5} AIR MONITORING RESULTS

There were eight Federal Reference Method (FRM) PM_{2.5} monitoring sites in the Kansas City area during 2004 to 2006, three in Missouri and five in Kansas. There were four FRM PM_{2.5} monitors in outstate Missouri (the remainder of the State outside the St. Louis and Kansas City areas).

3.1.1 Annual Average

As listed in Table 3.1-1, annual average PM_{2.5} concentrations measured at the sites in the Kansas City area are comparable to or only slightly above those measured at background sites. None of these sites is in violation of the annual average standard. The maximum 3-year average concentrations in the Kansas City area were at the Troost site in Kansas City, Missouri and the JFK Recreation Center site in Kansas City, Kansas.

Concentrations measured at outstate sites vary in concentration from low at the El Dorado Springs background site to slightly higher at the Ste. Genevieve site. Ste. Genevieve is on the Missouri River and likely influenced by the same regional impacts that affect St. Louis, in addition to local sources. The concentration at the Springfield site is near the background level. The concentration at the St. Joseph site is similar to that in the Kansas City area. None of the outstate sites is in violation of the annual standard.

3.1.2 24-hour Average

As shown in Table 3.1-1, design values based on 24-hour averages for Kansas City and outstate Missouri sites varied in a similar manner to annual averages. None of the Kansas City area sites or outstate Missouri sites exceeded the 24-hour standard during 2004 to 2006.

Table 3.1-1. Annual PM_{2.5} Total Mass for 2004-2006

	24-hr Std = 35 µg/m ³ , 98 th percentile				Annual Mean Std = 15.0 µg/m ³			
	<u>2004</u>	<u>2005</u>	<u>2006</u>	<u>Design Value 04-06</u>	<u>2004</u>	<u>2005</u>	<u>2006</u>	<u>Design Value 04 - 06</u>
Kansas City MO								
Liberty	26.5	31.2	25.4	27.7	9.5	12.2	10.5	10.7
Troost	27.3	34.2	22.1	27.9	12.0	14.1	11.5	12.5
RG- South	22.7	31.4	21.1	25.1	9.8	11.6	10.1	10.5
Kansas City KS								
Johnson Co. Just. Ctr., Overland Pk.	23	30	21	24.7	9.8	11.8	9.7	10.4
Black Bob Elem., Olathe	25	28	21	24.7	10.0	11.7	10.0	10.6
W. 159 th , Olathe	23	29	19	23.7	9.1	10.6	9.1	9.6
JFK Rec. Ctr., KC	28	35	24	29.0	11.8	14.0	11.6	12.5
Midland Trail Elem., KC	25	31	22	26.0	10.3	11.8	10.3	10.8
Outstate MO								
El Dorado Springs	25.7	33.1	21.4	26.7	9.9	12.1	11.9	11.3
Ste. Genevieve	25.8	36.1	29.3	30.4	12.4	15.0	11.8	13.1
MSU, Springfield	25.2	33.6	21.6	26.8	10.9	13.0	10.3	11.4
St. Joseph	32.0	35.1	26.9	31.3	11.4	14.5	12.0	12.6

3.2 CONCLUSIONS

The PM_{2.5} air monitoring data presented in Section 3.1 support a recommendation that all counties in Missouri in addition to those in the St. Louis area that are discussed in Section 2.0, be designated as in attainment for the 24-hour PM_{2.5} NAAQS.