$PM_{2.5}$ SIP

Appendix C

Speciation and Source Apportionment Analysis

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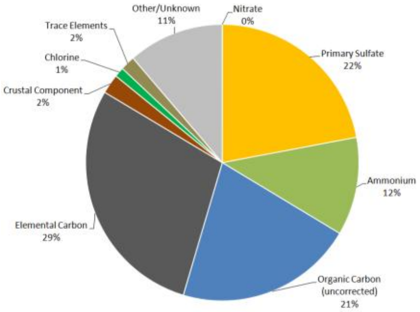
PM$_{2.5}$ Chemical Speciation and Source Apportionment Analysis

Allegheny County, PA
PM$_{2.5}$ Nonattainment Area
2012 NAAQS



Allegheny County Health Department
Air Quality Program

March 2019

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1 OVERVIEW

This report focuses on $PM_{2.5}$ chemical speciation data analysis along with source apportionment using the Positive Matrix Factorization (PMF) model for Allegheny County and surrounding sites over the timeframe of 2009-2017. This speciation and source apportionment analysis serves as supporting and underlying data for the attainment demonstration in the $PM_{2.5}$ 2012 NAAQS State Implementation Plan (SIP) for the Allegheny County, PA nonattainment area (NAA).

Year 2017 is the most recently available full year of speciation data at the time of this report, with 2009-2013 as the weighted timeframe (and 2011 as the weighted base case year) of the SIP. The full timeframe of 2009-2017 is diverse, with scenarios that include low production/emissions in 2009, decreasing concentrations overall (specifically for SO_2), high frequency of temperature inversions in 2017, and above normal precipitation and temperatures in more than one year.

1.1 Background

The Pittsburgh Metropolitan Statistical Area (MSA) shows $PM_{2.5}$ design values that are similar to many other areas in the U.S., while Liberty shows unique localized concentrations. Figure 1-1 below shows a time series chart of annual $PM_{2.5}$ design values[1] over the 10-year period of 2008-2017, averaged by region, comparing Liberty and the Pittsburgh MSA (without Liberty) to other nonattainment areas in the country.

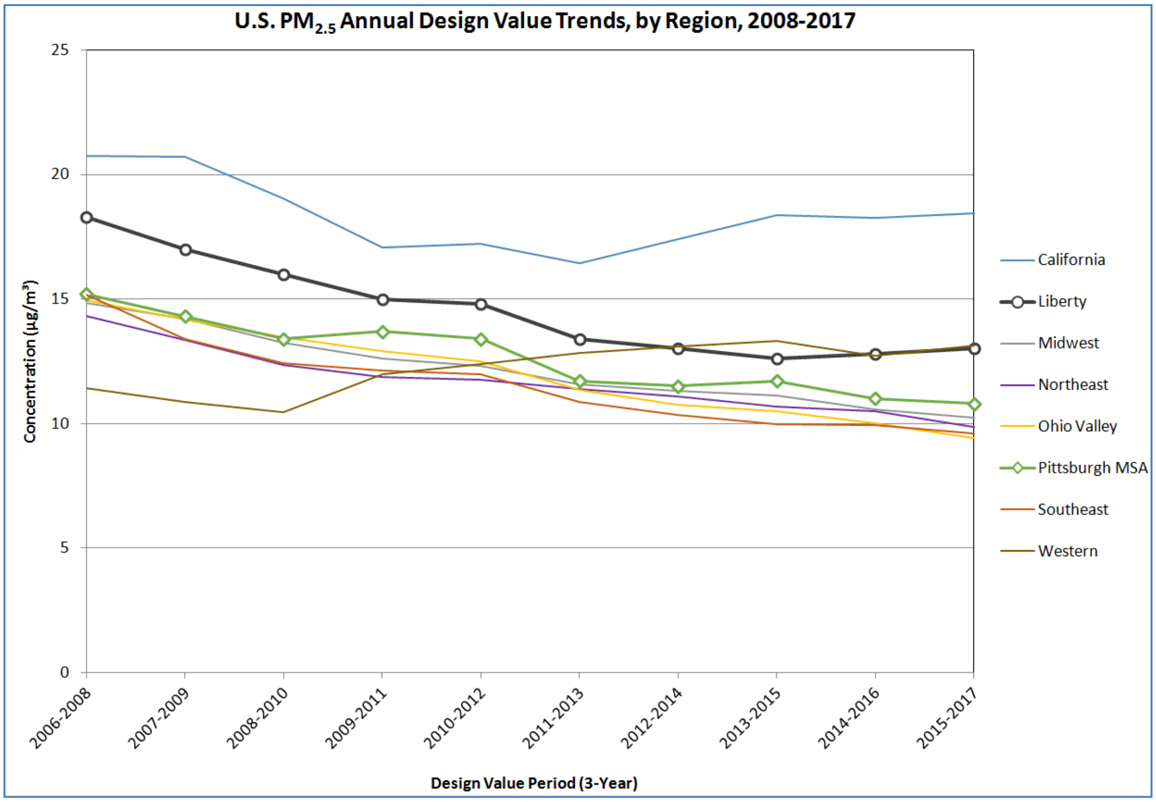

Figure 1-1. Annual Design Values for U.S. Regions, 2008-2017

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[1] Taken from: https://www.epa.gov/air-trends/air-quality-design-values

Note: Regions in Figure 1-1 were grouped as follows:

Region	**States Included**
California	CA (Urban Areas)
Liberty	PA (Liberty Only)
Midwest	OH, IL, IN, MI, MO
Northeast	CT, DE, MD, NY, NJ, PA
Ohio Valley	IN, KY, OH, WV
Pittsburgh MSA	PA (Pittsburgh MSA excluding Liberty)
Southeast	AL, GA, NC, TN
Western	CA (Rural Areas), ID, MT

$PM_{2.5}$ can show different compositions in different regions of the country. However, design values (and design value trends) are similar for most areas in the country, except for California urban areas, rural Western areas, and Liberty. Liberty is an outlier for $PM_{2.5}$ concentrations in the Pittsburgh MSA as well as areas in the Ohio Valley, Midwest, and Northeast. The examination of the composition of $PM_{2.5}$ at Liberty and surrounding monitor sites can provide insight into the nonattainment factors for the area.

1.2 Conceptual Model

To focus on the regional and local nature of $PM_{2.5}$ in Allegheny County, speciation concentrations can examined for tri-state monitor sites. Figure 1-2 below shows the conceptual model of the behavior of $PM_{2.5}$ throughout the tri-state area.

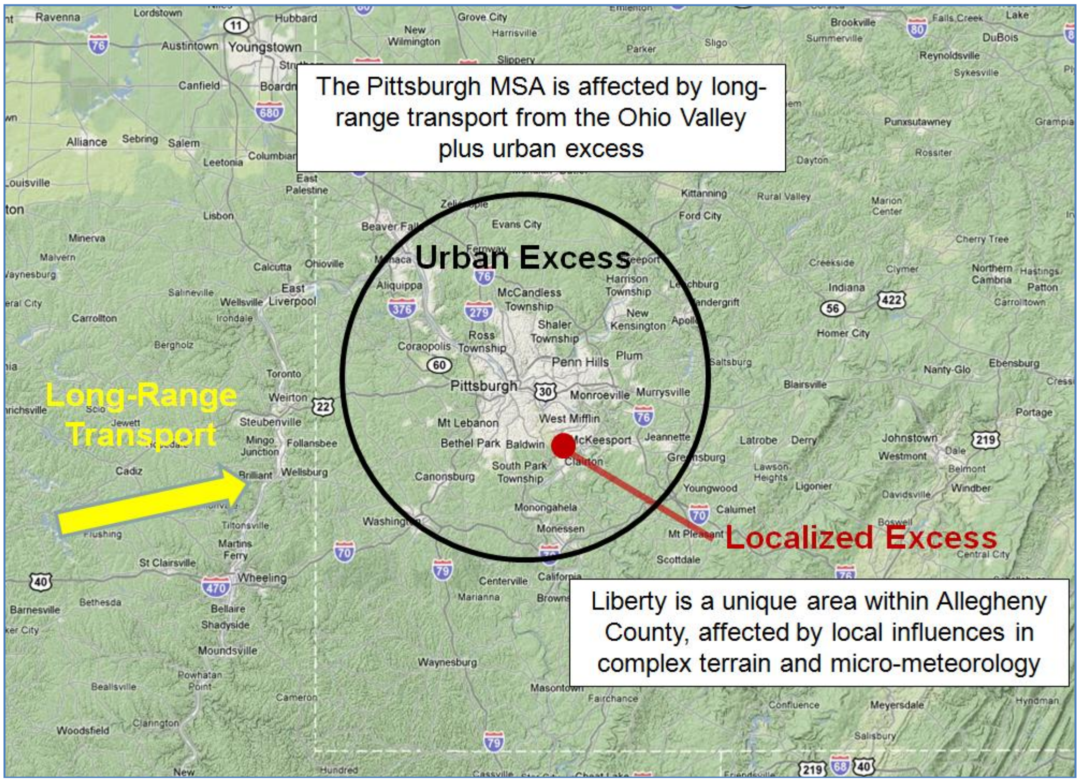

Figure 1-2. Conceptual Model of $PM_{2.5}$ in the Tri-State Region

Based on the conceptual model, some species should be common throughout the area, while others should indicate specific contributions from different types of sources. For example, transported ammonium sulfate should be fairly consistent for all tri-state sites, while carbons or trace elements could indicate the presence or urban and/or local influences at individual sites.

1.3 Speciation Sites

Speciation data were examined for sites within Allegheny County and in the surrounding tri-state area, as described below.

> The Lawrenceville monitor site is an urban residential site, downwind from the Pittsburgh Central Business District (Downtown). Lawrenceville is a NCore site and includes several other monitors, including a 1-in-1 day Federal Reference Method (FRM) and continuous Federal Equivalent Method (FEM) $PM_{2.5}$ monitors.[2] Sampling frequency for the CSN speciation monitor is 1-in-3 days.
>
> The Liberty monitor site is a 1-in-6 day CSN frequency site located in the Monongahela Valley, which contains a mix of urban residential, heavy industrial, and rural land use. Like Lawrenceville, Liberty also has a 1-in-1 day FRM monitor along with other pollutant monitors.
>
> Additional sites have been examined for regional species trends within the surrounding Pittsburgh MSA.[3] These include Florence (Washington Co.) and Greensburg (Westmoreland Co.) CSN sites, which are 1-in-6 day sites, operated by PA DEP.
>
> Rural sites that were examined include Quaker City, OH and Dolly Sods, WV. These sites are 1-in-3 day federal IMPROVE sites[4] that have been used previously by EPA as background speciation sites for the Pittsburgh area.

Figure 1-3 shows a map of the tri-state sites in OH/PA/WV used in this speciation analysis.

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[2] FRM/FEM monitors are used for the official designations for areas.

[3] Some additional state-operated sites in the OH/WV/PA tri-state region have full or incomplete data over the 2009-2017 timeframe. These sites were not used in this analysis, with the focus on the Pittsburgh MSA sites.

[4] Interagency Monitoring of Protected Visual Environments: http://vista.cira.colostate.edu/improve/

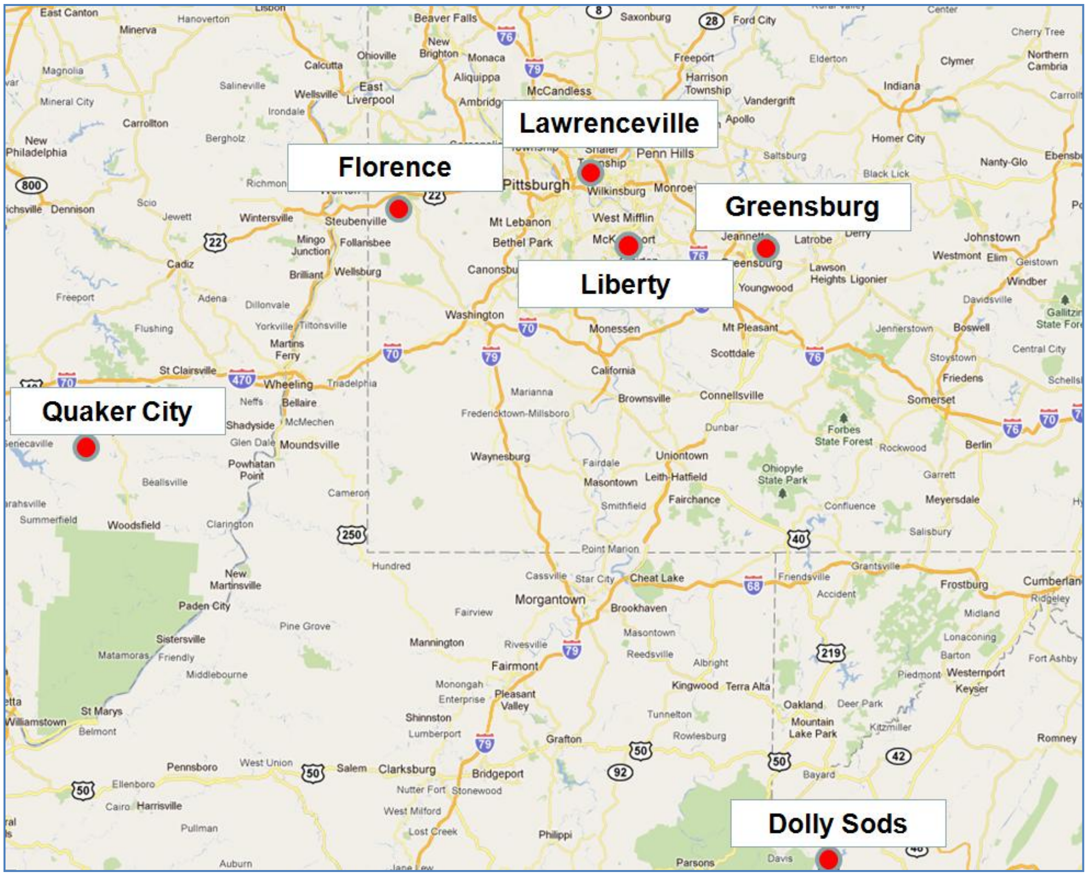

Figure 1-3. Tri-State Sites Examined for $PM_{2.5}$ Species Compositions

2 CHEMICAL SPECIATION ANALYSIS

Both raw data (as measured by the monitor network) and adjusted data (as corrected to FRM conditions, based on EPA methodology) were examined in the speciation data analysis.

2.1 Long-Term Raw Averages

Long-term averages (2009-2017) of the raw major species data for the tri-state sites are shown in the cluster column chart in Figure 2-1 below. Major species are defined as the largest components of $PM_{2.5}$, generally nitrate ions, sulfate ions, ammonium ions, carbons, and crustal component. Because of the large presence of chlorine at Liberty, this element has also been included with the major species. Additionally, the sum of all trace elements not associated with crustal component or chlorine has been grouped as "elements."

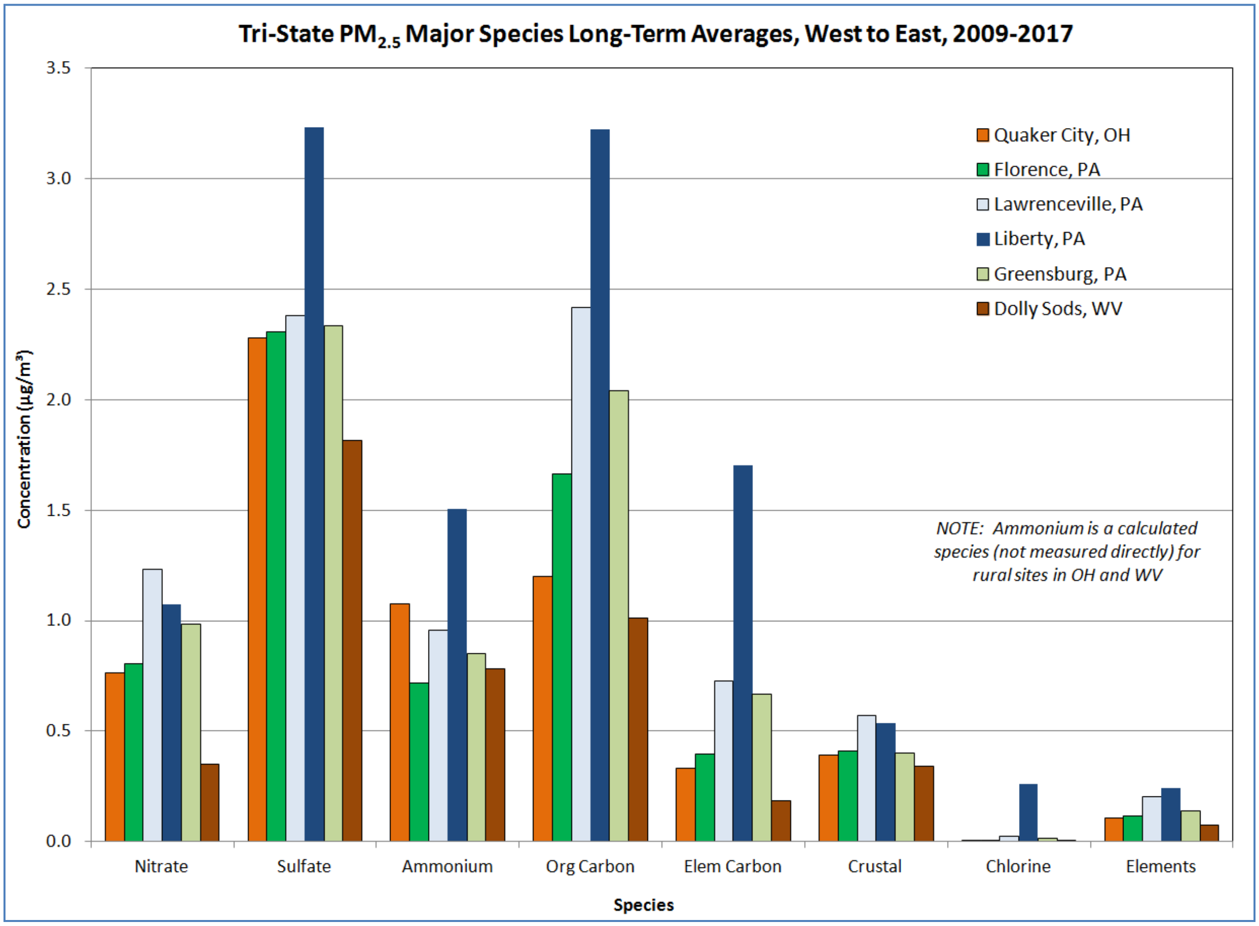

Figure 2-1. Tri-State Major Species Averages, 2009-2017

Long-term averages show fairly consistent concentrations for species such as sulfate and crustal component throughout most of the tri-state region, while Liberty shows species that are not consistent with tri-state area. As mentioned in the conceptual model, a substantial portion of the $PM_{2.5}$ species can be attributable to upwind sources in OH/WV and other surrounding states. Urban activity contributes to concentrations within the Pittsburgh MSA, and Liberty is compounded by localized concentrations in addition to the widespread transported and urban components.

Note: Results in Figure 2-1 are similar to the results for 2011 shown in Section 2 (Problem Statement) of the SIP. Results were consistent overall for $PM_{2.5}$ behavior throughout the longer timeframe of 2009-2017.

2.2 Significant Contributions of Precursors

As part of a comprehensive precursor demonstration for the SIP, the EPA Precursor Guidance (U.S. EPA, 2016) recommends an ambient concentration-based analysis as a first step to determine significance of precursors for the area. Significant contribution thresholds of 0.2 µg/m³ (annual basis) and 1.3 µg/m³ (24-hour basis) are recommended for determining the effect of a precursor on an area.

For comparing precursors to chemical species concentrations, the following associations are assumed:

- For NO_x: Since nitrate exists as ammonium nitrate (NH_4NO_3), include all measured nitrate along with the corresponding amount of ammonium. (Assume a stoichiometric ratio of 0.29 ammonium ion to 1.00 nitrate ion.)
- For SO_2: Use the measured sulfate (SO_4) ion concentration.
- For NH_3: Similar to above, since ammonium exists with nitrate, use measured all ammonium and nitrate ion concentrations.
- For VOC: Since there is no measured secondary organic aerosol (SOA) component available with the speciation data, assume that all measured organic carbon (OC) represents VOC, as a conservative approach.

Table 2-1 below shows the long-term average major species concentrations for the Allegheny County speciation sites (Lawrenceville and Liberty) for the 2009-2017 timeframe, based on the above precursor-to-species associations.

Table 2-1. Concentration-Based Significant Contributions (in µg/m³)

Precursor	NO_x	SO_2	NH_3	VOC
Associated Species	Ammonium Nitrate	Sulfate	Ammonium + Nitrate	Organic Carbon
Lawrenceville	1.589	2.381	2.186	2.414
Liberty	1.386	3.231	2.580	3.224

From these results, with all values above the annual significant contribution threshold of 0.2 µg/m³, all precursors in Allegheny County are determined to be significant from the concentration-based analysis.

The EPA Precursor Guidance outlines a modeled sensitivity analysis that can be used as a second step to determine significance for any precursor. This analysis was performed for VOC and NH_3 for the NAA, as described in Section 5 (Modeling Demonstration) and Appendix I.4 (Precursor Insignificance Demonstration) of the SIP, and VOC and NH_3 were found to be insignificant precursors.

2.3 Speciation Excess

The concept of "excess" $PM_{2.5}$ species for an area is based on the type of contributions of $PM_{2.5}$. Excess can be determined by subtracting components of one site/area from another. Based on the conceptual model and the long-term averages for the tri-state sites, the urban and local excess can be calculated as follows:

- Rural transport: The average species of the rural sites (Quaker City and Dolly Sods) represent the widespread transported component.

- MSA Excess: The average species of the three MSA sites (Lawrenceville, Florence, and Greensburg, excluding Liberty) minus the rural transport species represent the urban increment in the tri-state area. The total regional component for the MSA is the urban excess plus the transported component.

- Liberty Excess: The average Liberty species minus the total regional species represent the unique localized component that contributes to nonattainment at Liberty.

Figure 2-2 shows the long-term raw species averages by area contributions in stacked columns. This represents the same data shown in Figure 2-1, but lumped into type or origin of contribution.

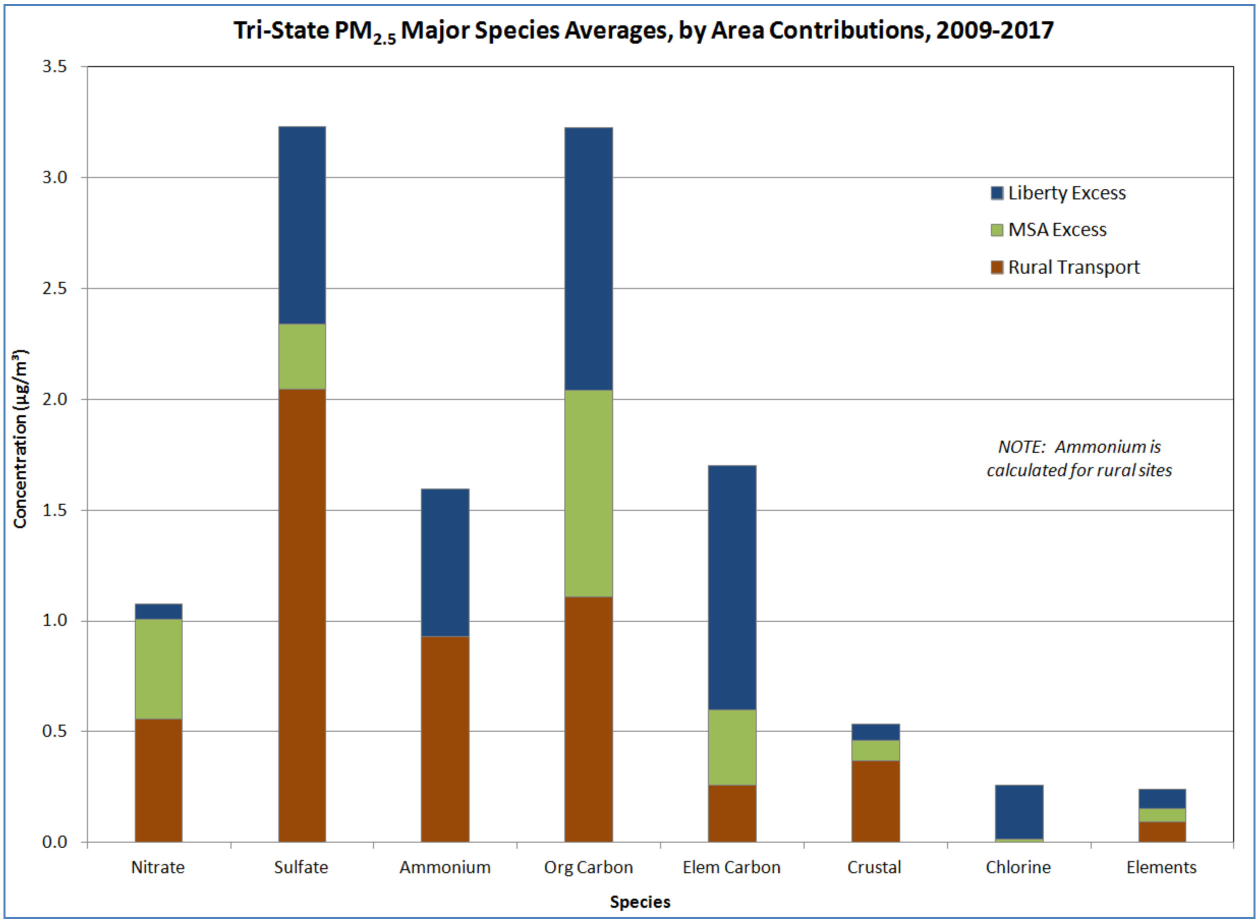

Figure 2-2. Tri-State Major Species Averages, by Area Contributions, 2009-2017

The excess species at Liberty are important to the understanding of nonattainment at Liberty. Source apportionment provides clues as to specific source factors that contribute to the localized excess (shown later in this document).

Figure 2-3 shows a pie chart of the Liberty excess, based on Liberty average species concentrations minus the average species concentrations of the MSA sites.

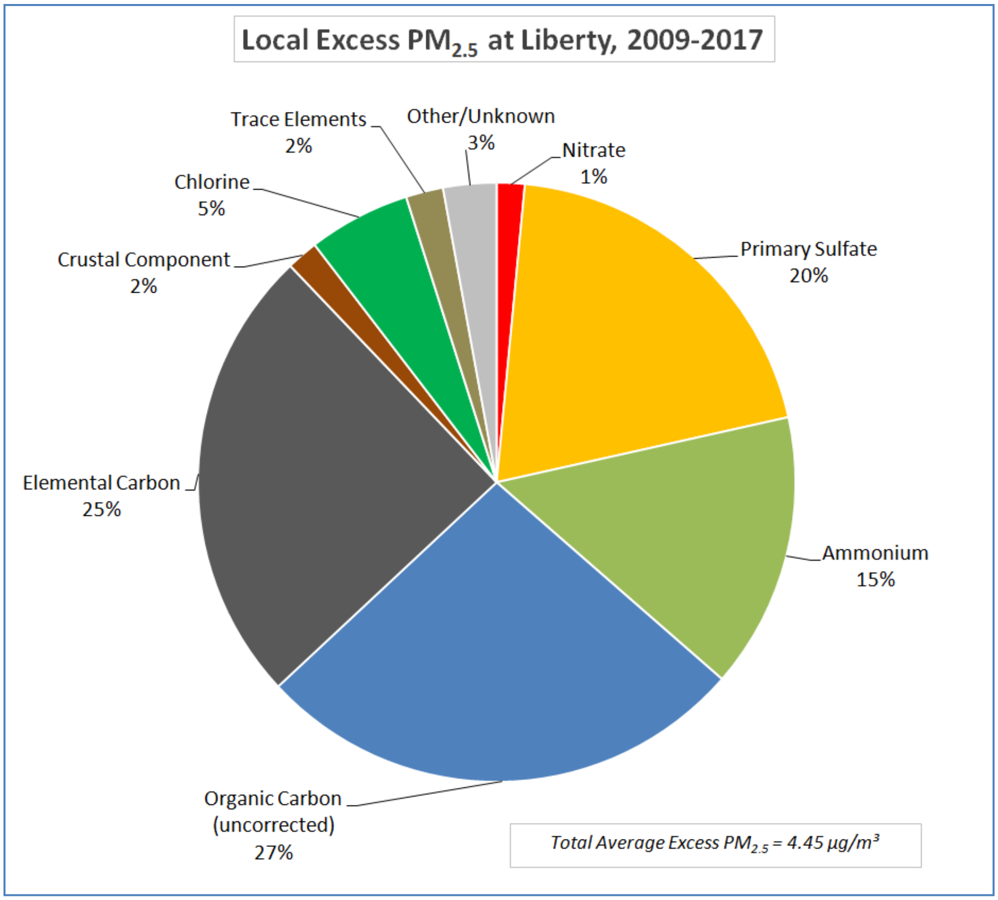

Figure 2-3. Liberty Local Excess by Species Composition, 2009-2017

The source emissions that lead to these species were therefore the focus of the SIP. Because modeling showed that there is little transformation of precursors in the Liberty near-field area, the excess is considered to be almost entirely primary in nature. For example, excess sulfate can be considered primary sulfate (i.e., exiting source release points as sulfate and not formed in the atmosphere), as labeled on the chart. Ammonium is present in unknown forms that are not ammonium sulfate or ammonium nitrate, as the mass of ammonium is not in proportion to the ammonium ion of these compounds. Chlorine is highly specific to Liberty, with elevated concentrations that are not representative of typical road salt or sea salt.

The species “other/unknown” is also included in Figure 2-3 and is not shown on the other figures in this document. Other/unknown component is the excess of the total mass at Liberty that is not accounted for in the sum of the other species. Other/unknown can be unmeasured/unknown species, particle bound water, or differences due to analytical testing methods used for the raw speciation data.

2.4 Liberty SANDWICH Species

Raw data for speciation monitors are based on different analytical methods and can include some amount of error between the measurements. Additionally, designations and comparison to the NAAQS are based on FRM/FEM monitors. The EPA SANDWICH[5] technique (U.S EPA, 2018; U.S. EPA, 2014b; Abt Associates, 2014), used for attainment tests for the SIP, adjusts species to better represent FRM concentrations. The timeframe of 2009-2013 was used for the SANDWICH data, since this timeframe was used for the weighted monitored data for the SIP. (Additionally, year 2015 is the most recent year of SANDWICH data available, so long-terms trends for 2009-2017 could not be examined.)

Several assumptions are used for the SANDWICH technique:

- Retained nitrate (NO3r) ion is calculated by EPA using temperature, relative humidity, and dissociation constants.
- Sulfate (SO4) and elemental carbon (EC) are used directly as measured and are not adjusted for SANDWICH.
- Retained ammonium (NH4r) ion is calculated indirectly from SO4 and NO3r and degree of neutralization (DON).
- Crustal component (CRUSTAL) is fine soil, calculated by the alternate formula using Ca, Fe, Si, and Ti, without Al.
- Organic carbonaceous material by mass balance (OCMmb) is calculated as the total FRM mass minus the major species.
- Without measured ammonium at federal sites, ammonium is derived from fully neutralized sulfate (DON=0.375).
- Particle bound water (PBW) is calculated from SO4, NO3r, and NH4r.
- For cases where no FRM value is present, CSN mass is used.

The SANDWICH method essentially converts the raw species into more probable compounds while conserving overall measured mass. Some species are normalized by the analysis based on the indirect associations, with uncertainties lumped into the OCMmb species.

For the SIP attainment tests calculations, the SANDWICH species were grouped into local and regional components. Data were also used on both quarterly and high-day bases for the annual and 24-hour NAAQS, respectively. Figures 2-4 and 2-5 show the average local and regional portions of the SANDWICH species, in stacked column charts, on year-round and high-day bases for 2009-2013.

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[5] SANDWICH: sulfate, adjusted nitrate, derived water, inferred carbonaceous material balance approach

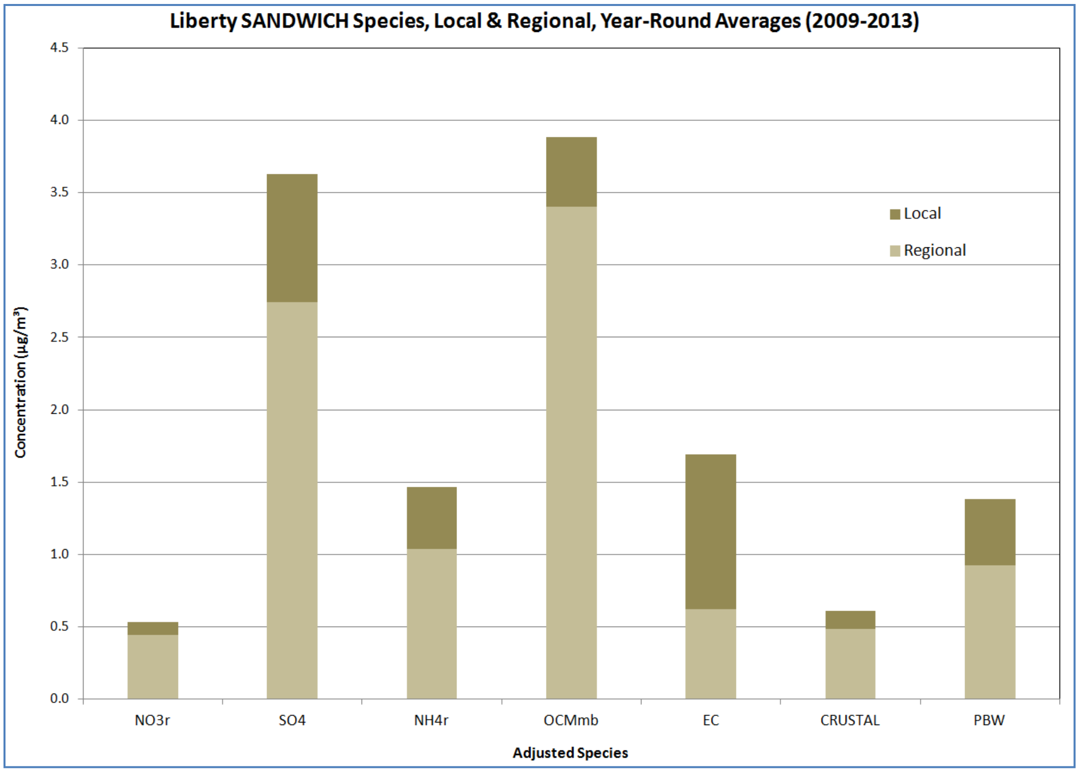

Figure 2-4. Average SANDWICH Species, Local and Regional Components, Year-Round Basis, 2009-2013

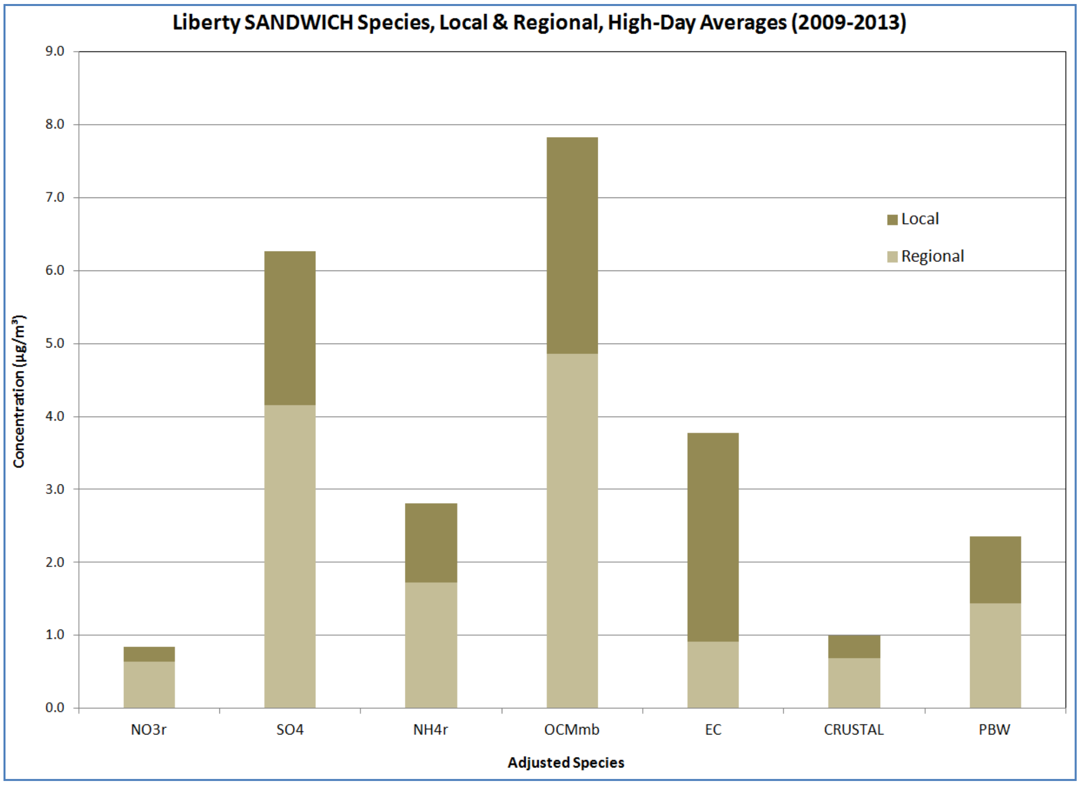

Figure 2-5. Average SANDWICH Species, Local and Regional Components, High-Day Basis, 2009-2013

The SANDWICH data shows similar overall results to the raw species data, with sulfate and carbons showing the largest excess for the local component. Noticeable in Figure 2-5 are larger portions of the local component on a high-day basis than on a year-round basis, indicating that the short-term peaks are influencing the longer-term results.

Note that NH4r and PBW are not necessarily associated with SO4 and NO3r in the SANDWICH local excess, since NH4r and PBW are calculated before the subtraction of regional species from the Liberty species. However, excess ammonium is present with the raw data, and particle bound water could be associated with any of the compounds of $PM_{2.5}$. Due to the large amount of condensate plumes in the near-field area, Liberty species are presumed to have a considerable degree of hydration.

For the modeling for the Liberty local area analysis (LAA), since AERMOD is not capable of chemistry and since the Liberty excess is primary in nature, the Liberty local SANDWICH components were lumped into one LPM (local primary material) compound. CAMx regional results were used for the regional components, and the attainment tests were based on the combination of CAMx and AERMOD projections.

2.5 Liberty Temporal Averages

Liberty raw data species were also examined for day of the week and monthly temporal patterns, shown in the stacked column charts in Figures 2-6 and 2-7, respectively.

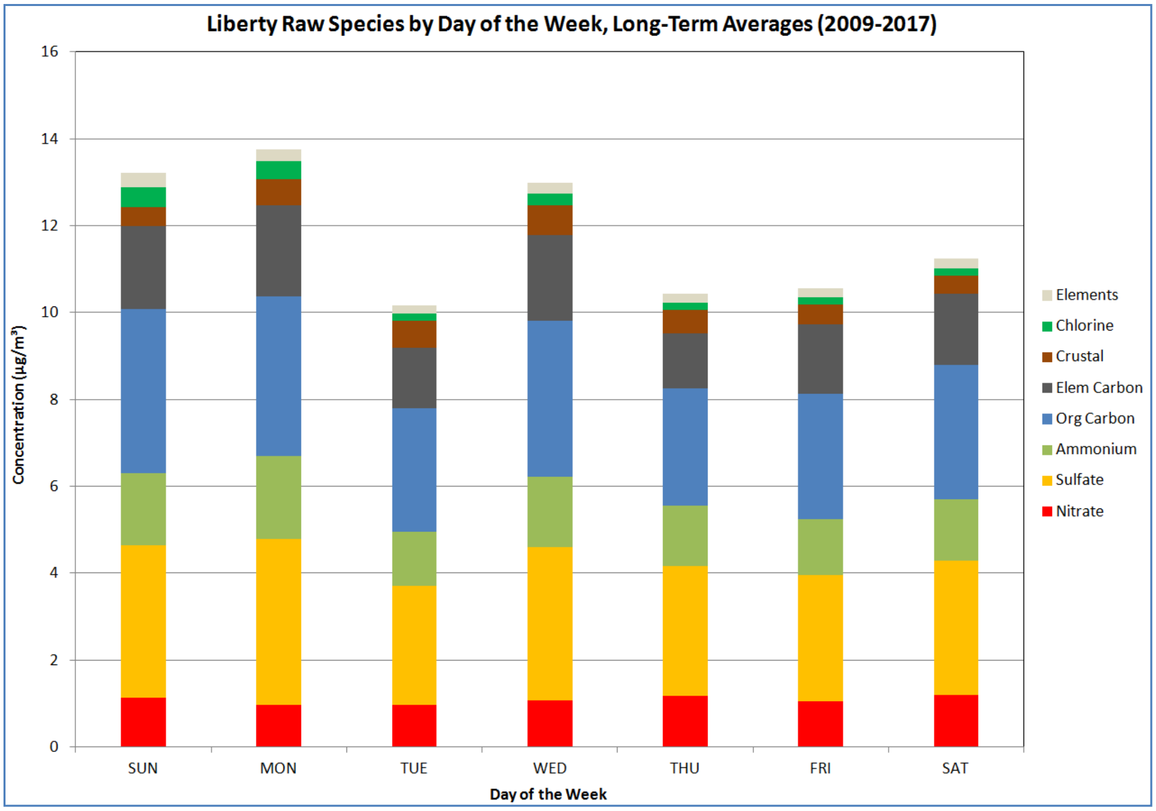

Figure 2-6. Liberty Species Averages by Day of the Week, 2009-2017

Figure 2-6 shows some differences in overall concentration by day of the week, with compositions that are fairly consistent. Nearby industrial sources are continuous in operation, so contributions from these sources should be uniform. Higher concentrations for total $PM_{2.5}$ and carbons on weekends may be due to increased residential and recreational activities, such as wood burning and nonroad equipment use.

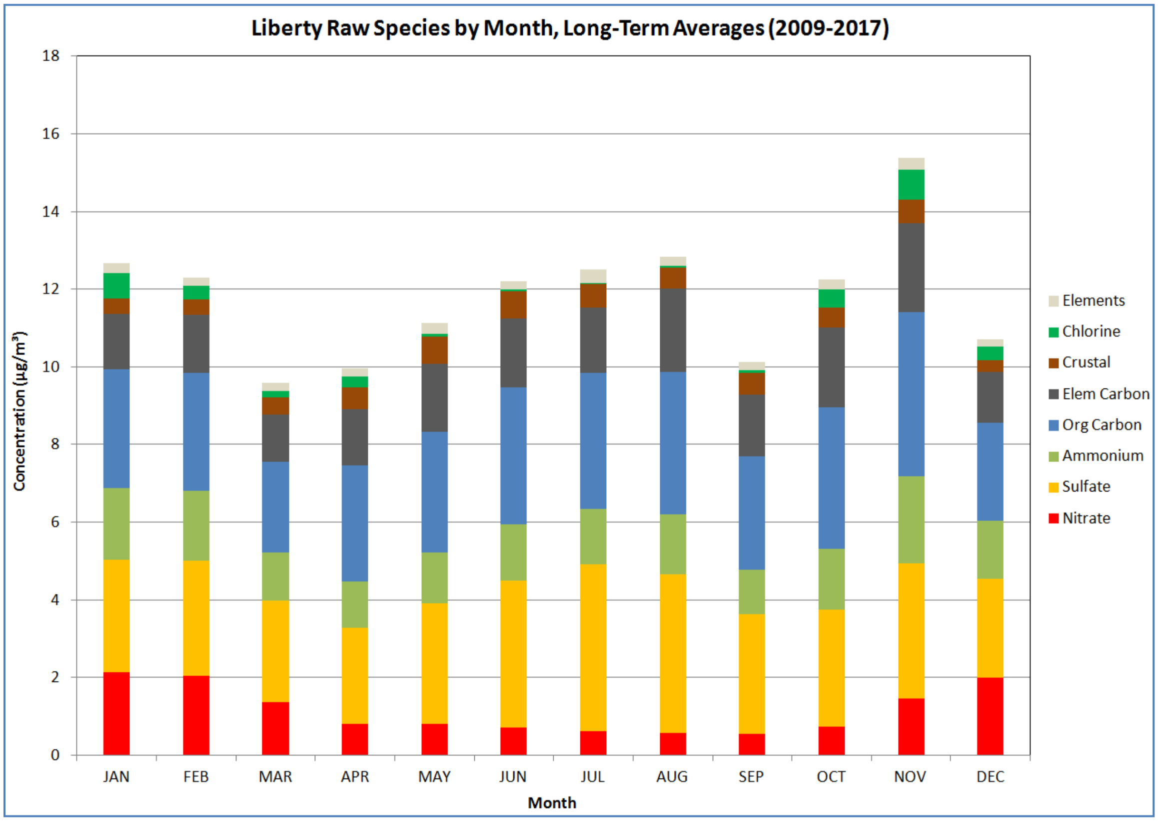

Figure 2-7. Liberty Species Averages by Month, 2009-2017

Figure 2-7 shows expected differences for overall concentration and for some species based on seasonal effects. Nitrates are most prevalent during cold months, while sulfates are highest during summer months. Chlorine is a cool weather element at Liberty, with concentrations occurring mainly from October to February. Overall concentrations are highest during November, when inversions are prevalent and with large temperature differences from surface to aloft.

3 SOURCE APPORTIONMENT

Positive Matrix Factorization (PMF) source apportionment receptor modeling represents a best-guess scenario of probable source factors. PMF performs a least-squares fit over an array of species measured simultaneously at a monitoring site.

For many source factors, there is a mix of components that cannot be resolved by the model, and there is a considerable amount of uncertainty associated with the results. The PMF results should be considered “ballpark” estimates, with the importance lying in the types of factors and overall contributions.

PMF version 5.0.14 was used with raw speciation data from the six tri-state sites for the long-term timeframe of 2009-2017. For this analysis, samples with missing species or exceptional outliers are removed from the model to provide a better fit. Sample concentrations were input into the PMF model along with concurrent uncertainties for each species/sample. Source factors were then calculated by the model as a result of iterations that converge on possible solutions to the array of variables.

Modeled source factors were then matched to possible actual source types according to known species profiles, previous source apportionment studies, wind probabilities, and the conceptual model for the tri-state region.

3.1 Methodology

Model operation followed the PMF 5.0 user’s guide (U.S. EPA, 2014a). The PMF model was tested under different species and factor combinations. Species were excluded if they exhibited concentrations near method detection limits (MDL). Individual samples (all species) were excluded if the sample did not easily fit into a least-squares solution. A poor fit is reflected by poor diagnostics from regression, standard deviation, and residual statistics.

The major species from the speciation monitors show the highest concentrations and strongest signal-to-noise ratios. (High signal-to-noise ratios indicate concentrations that are well above method uncertainties.) These species can strongly affect the model convergence and are usually a sign of specific sources. These species included:

Sulfate
Nitrate
Ammonium
Organic Carbon
Elemental Carbon
Total $PM_{2.5}$

Many trace element species also have concentrations with strong or moderate signal-to-noise ratios. They may also be important tracer elements that are associated with specific sources. These species included:

Aluminum
Arsenic
Bromine
Calcium
Chlorine
Chromium
Copper
Iron
Lead
Manganese
Nickel
Potassium
Selenium
Silicon
Sodium
Titanium
Vanadium
Zinc

PMF uses a strength indicator of strong or weak, assigned to each species. Down-weighting to weak increases the uncertainties for a species by a factor of three. Trace element species with low signal-to-noise ratios (less than 3.5) were down-weighted, along with total $PM_{2.5}$. Total $PM_{2.5}$ is used only as an indicator for overall size of factor contributions and is not included in the species profiles. Based on EPA recommendation, an additional 5% uncertainty was applied to the entire model for all samples.

Some factors may be associated with similar source types but are separated into more specific source factors by the model. For example, a source type that is representative of vehicle emissions may comprise one source factor based on year-round contributions and another factor based on specific traffic conditions.

For other factors, there may overlap of some source types. For example, a factor dominated by ammonium sulfate may also include carbons and trace elements that may or may not be originating from the sulfate sources but are peaking simultaneously in the monitor data. Factor results can be corrected or regrouped based on more probable source contributions.

For sites with meteorological data (Lawrenceville and Liberty), conditional probability function (CPF) analysis was also used to determine directional components of the source factors. CPF compares the frequency of wind directions during high contributions to the average transport pattern of wind directions.

For the CPF analysis, hourly wind directions were first sorted into 30-degree sectors for each 24-hour speciation sample. (Hourly directions from 16-45 degrees are assigned to the 30 degree sector, 46-75 degrees to the 60 degree sector, and so on.) For each modeled factor, the top 25% days of 24-hour contributions were assigned as high days.

CPF for each sector is calculated as the ratio of the hourly count of wind directions from the sector on high days divided the total hourly count of wind directions from the sector:

$$CPF = \frac{\text{number of times wind direction is from the sector when contributions are high}}{\text{number of times wind direction is from the sector}}$$

The result of the equation provides a frequency for which the number of times the source factor showed a high contribution in each wind sector. The 30° sector frequencies are then plotted on a radar chart for each source factor, showing the predominant wind directions on high days of the modeled source factor. The CPF results for Lawrenceville and Liberty are shown in the appendix of this document.

3.2 Results

The results of the PMF source apportionment runs for each site are shown by source factor profiles and normalized time series contributions in the appendix of this document. (Note: For each site, a run number is given – this was the best converged solution of 10 iterations.)

The rural sites (Quaker City and Dolly Sods) and Florence showed the best solutions with six source factors; Greensburg showed the best results with seven source factors; Lawrenceville showed the best results with nine source factors; and Liberty showed the best results with ten factors. As mentioned above, some of the factors can be corrected by reapportioning the species to better known source profiles.

Looking at similar source factors between the six sites, and grouping/correcting some species concentrations based on known data, the PMF results can be shown for common tri-state source factors. The modeled source factor contributions (in µg/m³) for each site are shown in Table 3-1, with the same data shown visually in Figure 3-1 by stacked column chart. The source factors are assigned according to most prevalent indicator species for each source factor, but source factors can contain amounts of other species.

Table 3-1. PMF Source Factor Contributions (in µg/m³), by Site

Source Factor	Quaker City	Florence	Lawrenceville	Liberty	Greensburg	Dolly Sods
Secondary Ammonium Sulfates	2.241	3.027	3.083	3.414	2.889	1.774
Secondary Ammonium Nitrates	0.734	1.107	1.274	1.041	0.941	0.447
Crustal Component	0.165	0.147	0.256	0.223	0.127	0.153
Motor Vehicles	0.516	0.414	2.372	0.858	1.010	0.797
Road Dust/Salt	0.028	0.000	0.234	0.155	0.094	0.035
Incinerators	0.000	0.106	0.000	0.082	0.067	0.000
Burning/Cooking	0.925	1.143	0.562	1.420	1.445	0.254
Metals-Rich Industrial	0.000	0.000	0.173	0.298	0.000	0.000
Chlorine-Rich Industrial	0.000	0.000	0.000	0.436	0.000	0.000
Carbon-Rich Industrial	0.000	0.000	0.000	3.254	0.000	0.000

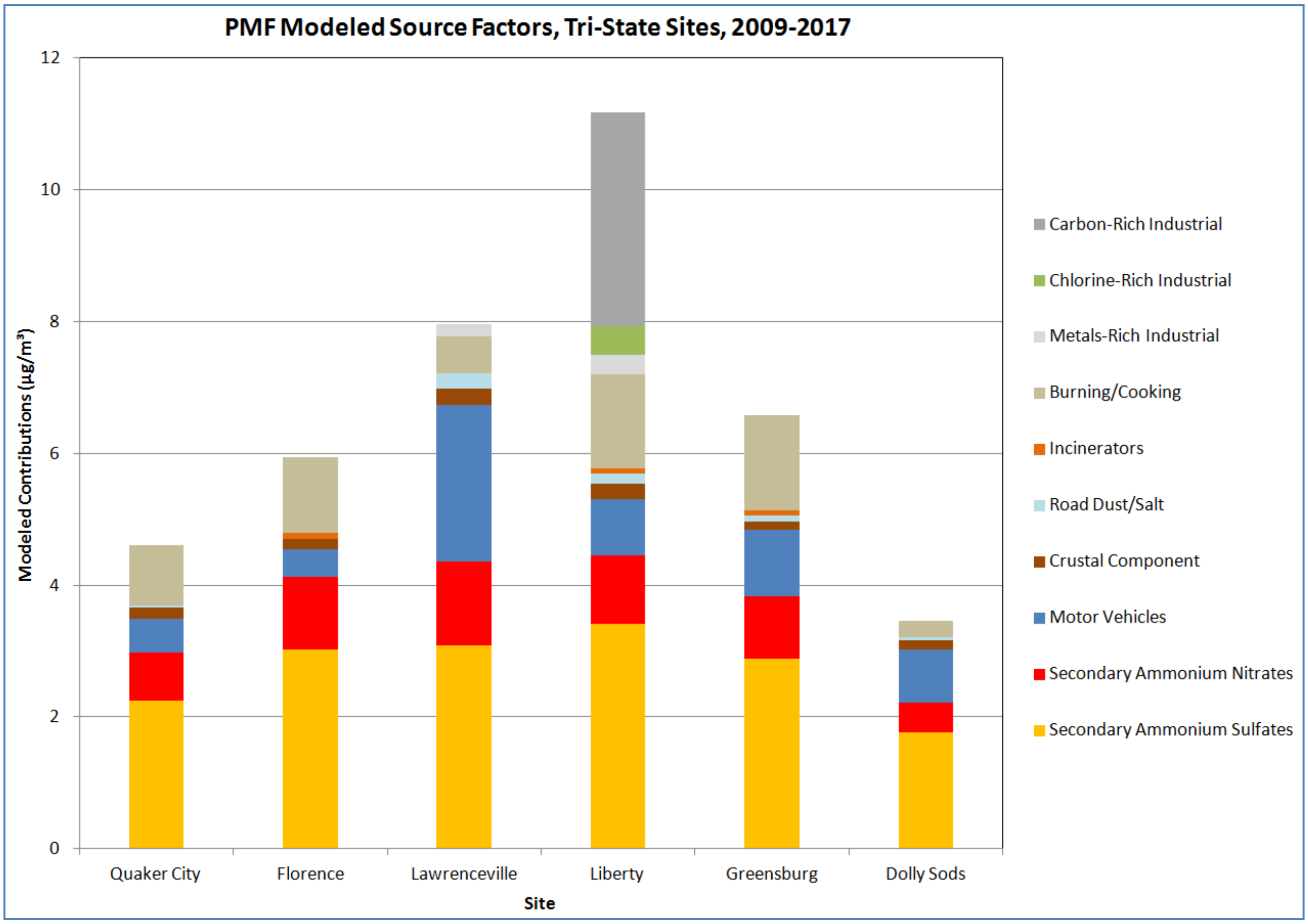

Figure 3-1. PMF Source Factors, by Site, 2009-2017

The modeled source factors show consistency with the speciation analysis and also provides possible sources types. Contributions from regional components such as ammonium sulfate, ammonium nitrate, and crustal component are fairly consistent throughout the tri-state area. Motor vehicles show the highest contributions at the most urban and highest populated site: Lawrenceville. Burning/cooking is a factor at all sites but can vary according to surrounding land use.

Liberty shows a large contribution from carbon-rich industrial sources, not present at the other sites, that contribute carbons as well as primary sulfate and several trace elements. The chlorine-rich factor, although shown as a separate source factor, peaks simultaneously with and is likely associated with the carbon-rich factor. Note that the chlorine-rich source factor is not associated with the road dust/salt component at the Liberty, which is a separate source factor.

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APPENDIX

PMF Source Factors by Site

Lawrenceville

Table A-1. Lawrenceville PMF Factors

Factor Number	Source Factor Description
Factor 1	Road Salt
Factor 2	Metals-Rich Sources (Cu)
Factor 3	Crustal Component
Factor 4	Secondary Ammonium Sulfates
Factor 5	Secondary Ammonium Nitrates
Factor 6	Motor Vehicles
Factor 7	Burning/Cooking
Factor 8	Metals-Rich Industrial
Factor 9	Road Dust

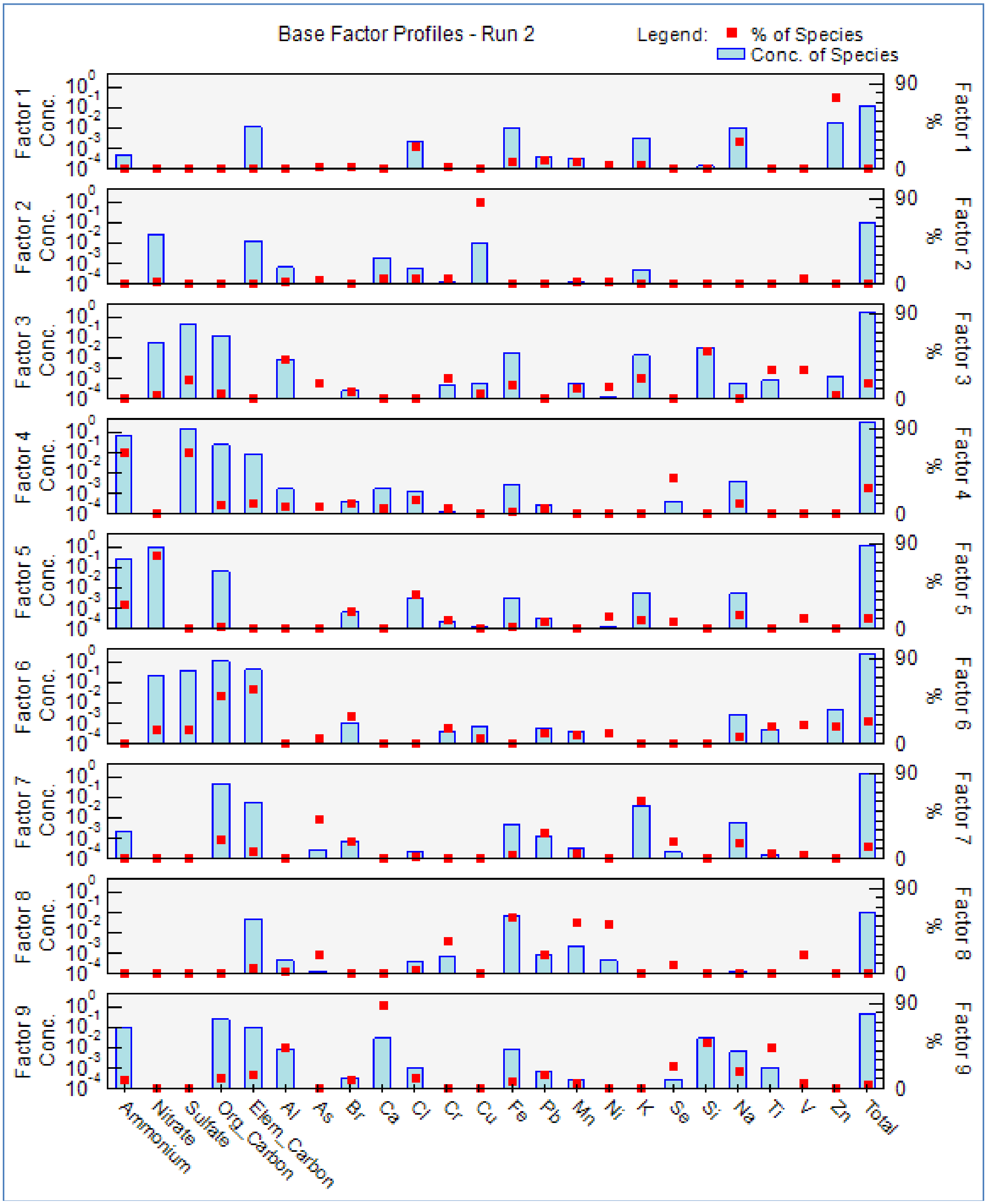


Figure A-1. Lawrenceville PMF Factor Species Profiles

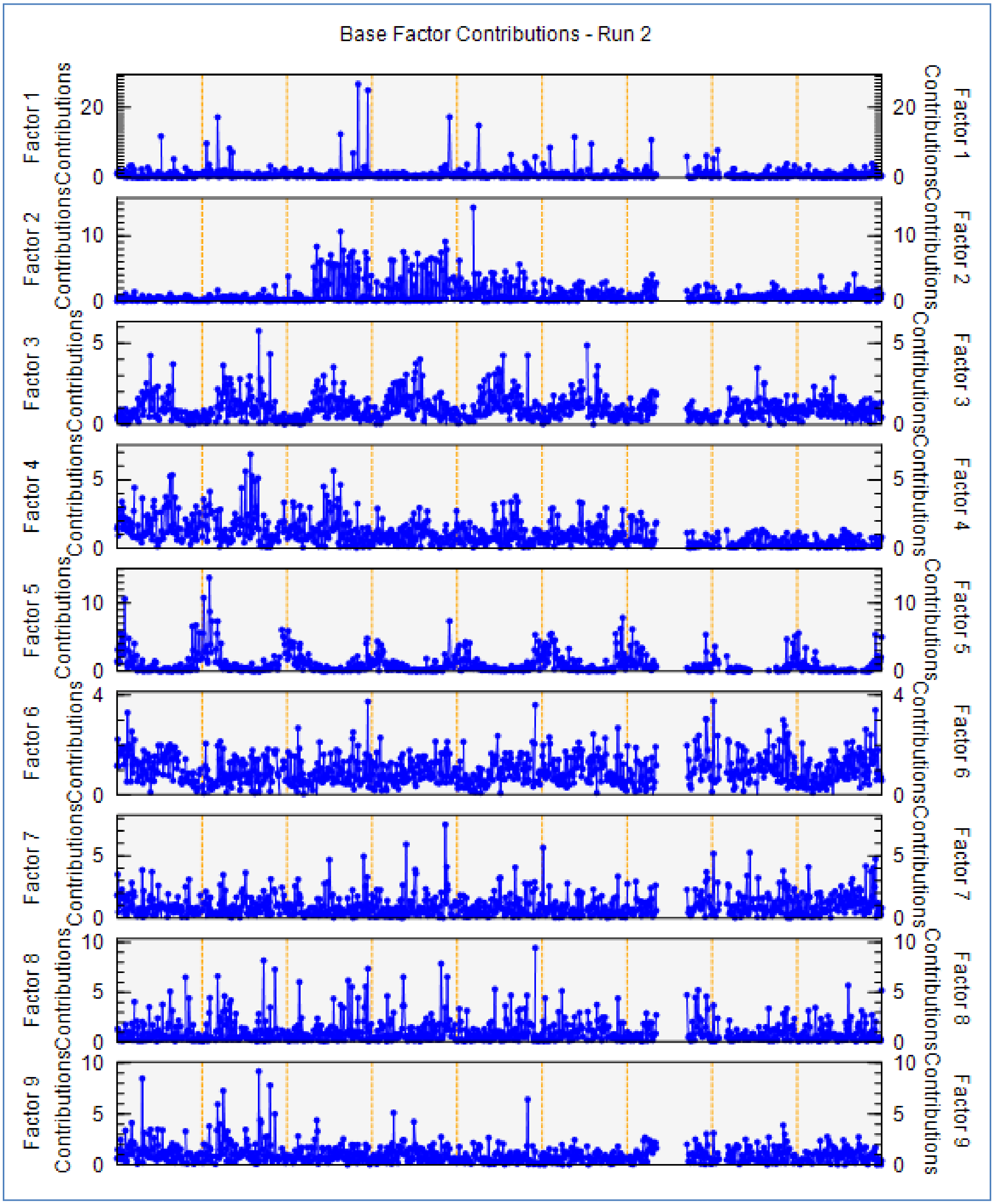
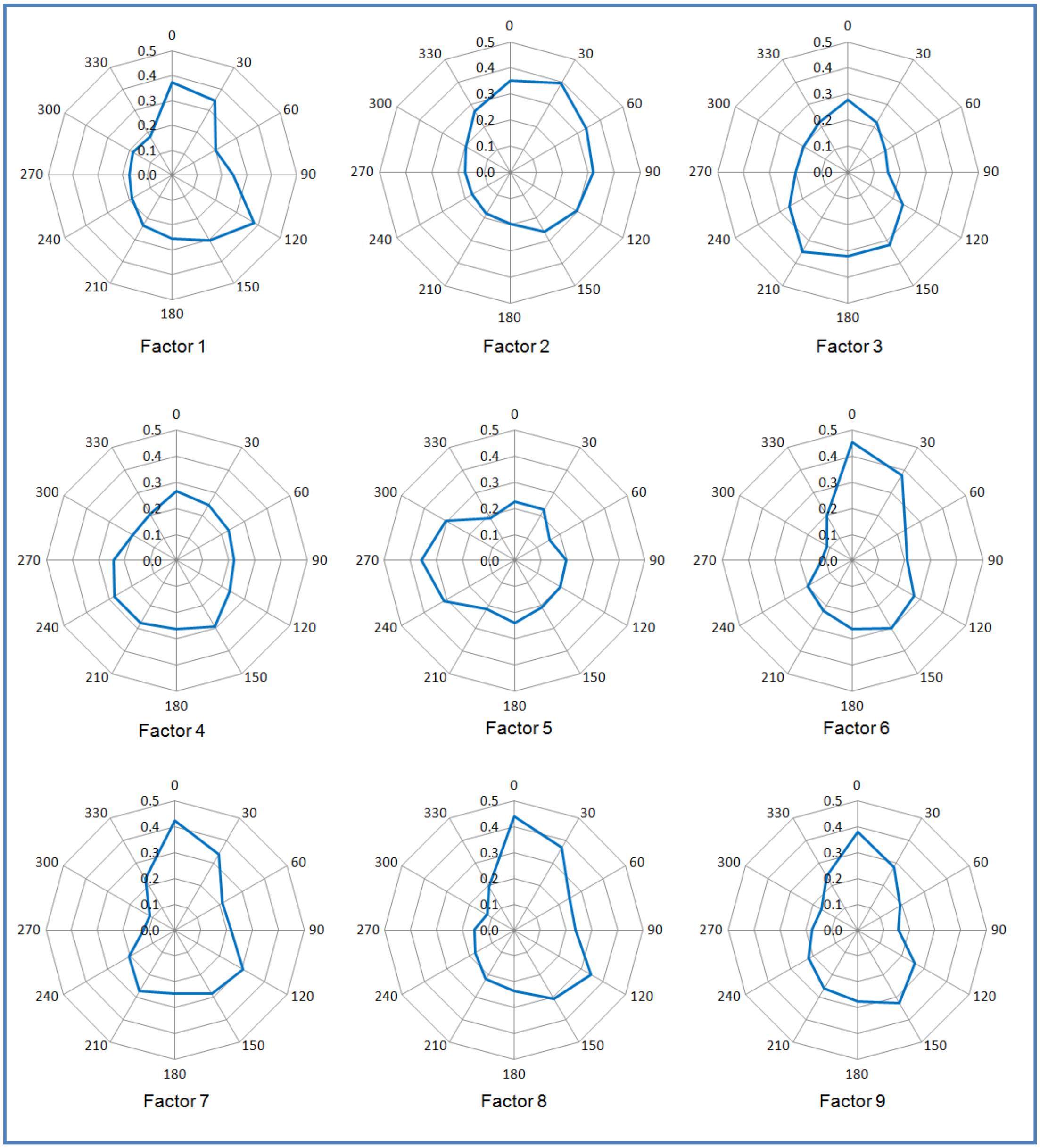


Figure A-2. Lawrenceville PMF Factor Contributions (Time Series)



Factor 1 Factor 2 Factor 3

Factor 4 Factor 5 Factor 6

Factor 7 Factor 8 Factor 9

Figure A-3. Lawrenceville CPF by Source Factor

Liberty

Table A-2. Liberty PMF Factors

Factor Number	Source Factor Description
Factor 1	Metals-Rich Industrial
Factor 2	Secondary Ammonium Nitrates
Factor 3	Motor Vehicles
Factor 4	Carbon-Rich Industrial
Factor 5	Secondary Ammonium Sulfates
Factor 6	Incinerators
Factor 7	Burning/Cooking
Factor 8	Road Dust/Salt
Factor 9	Chlorine-Rich Industrial
Factor 10	Crustal Component

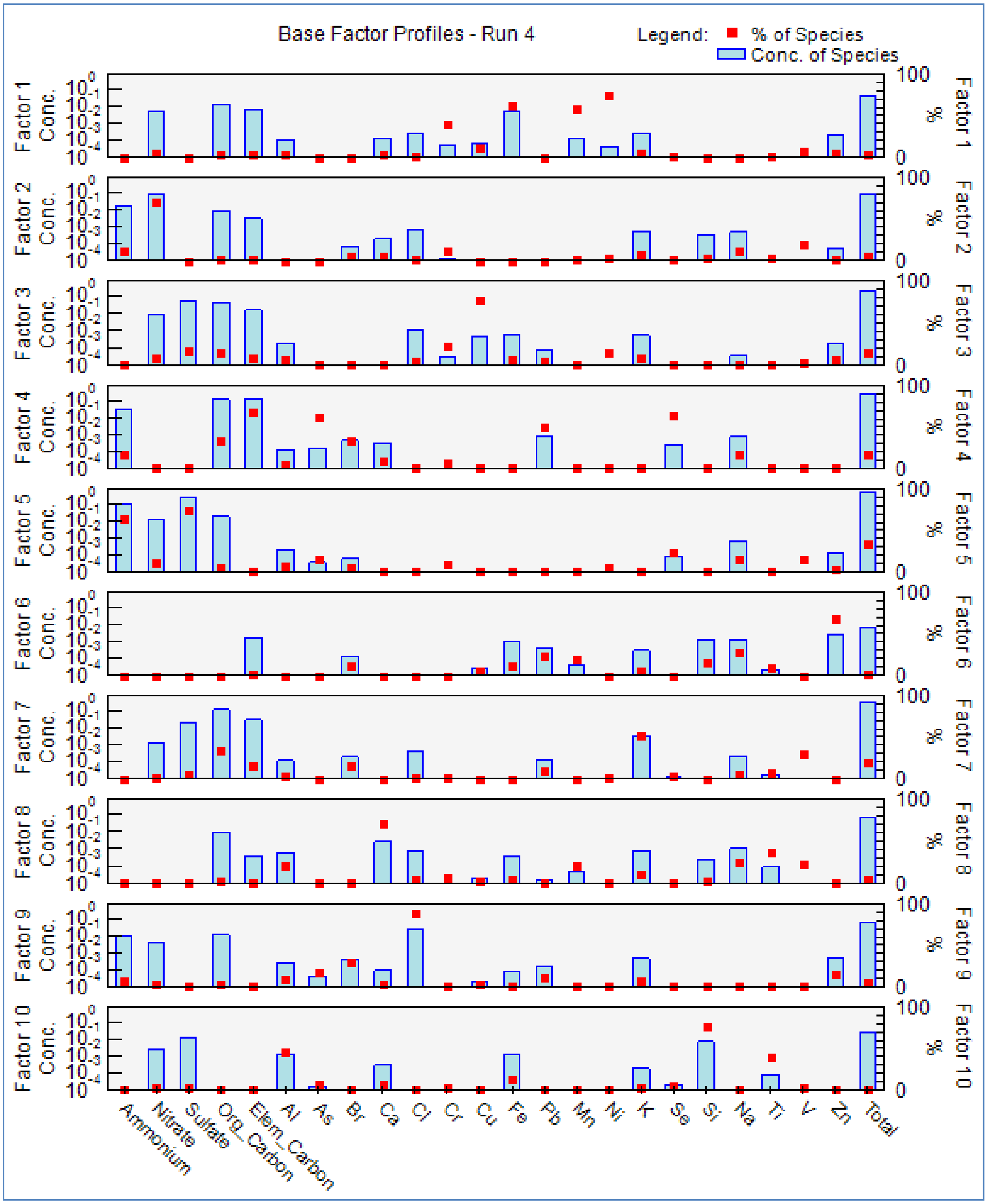


Figure A-4. Liberty PMF Factor Species Profiles

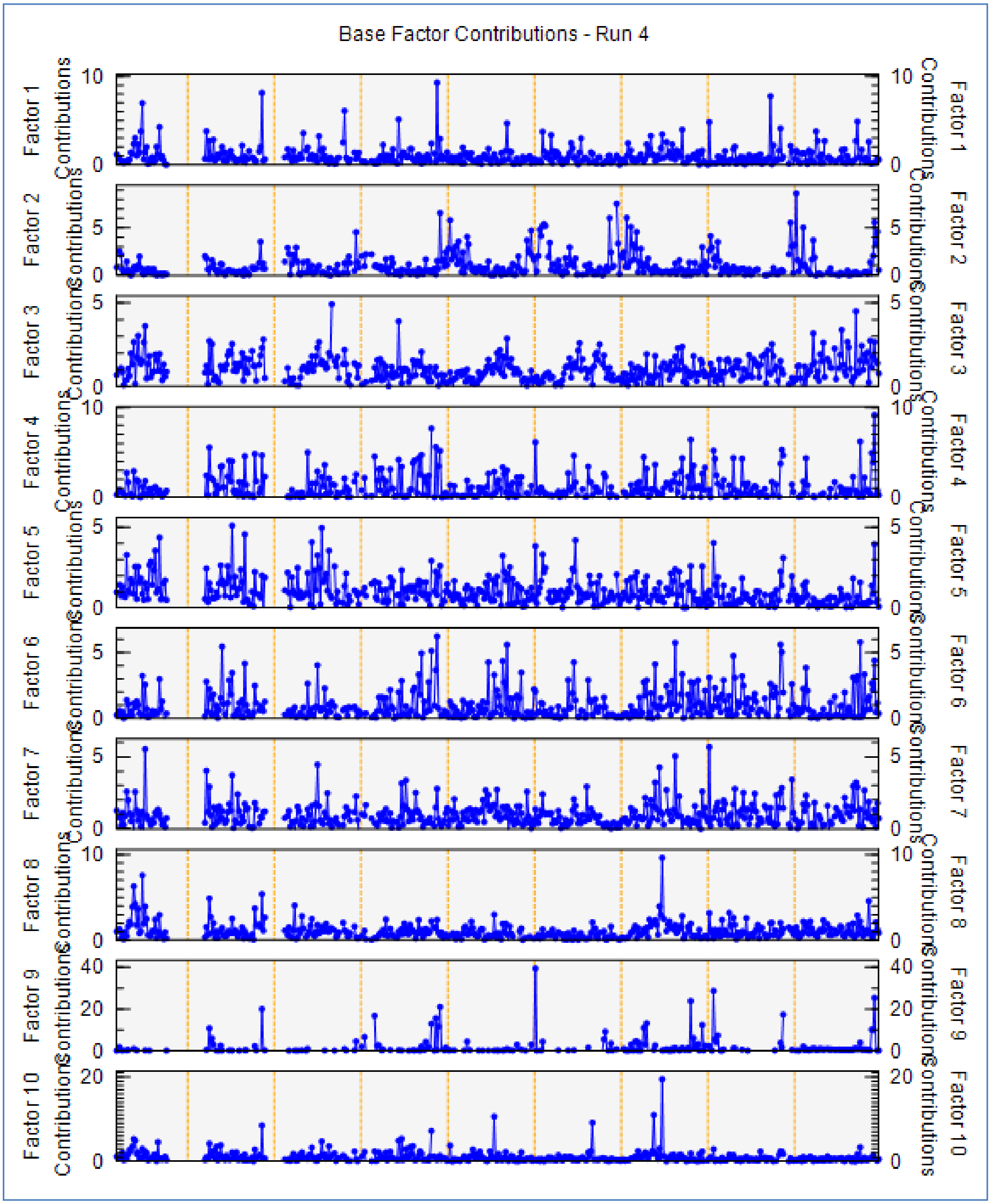
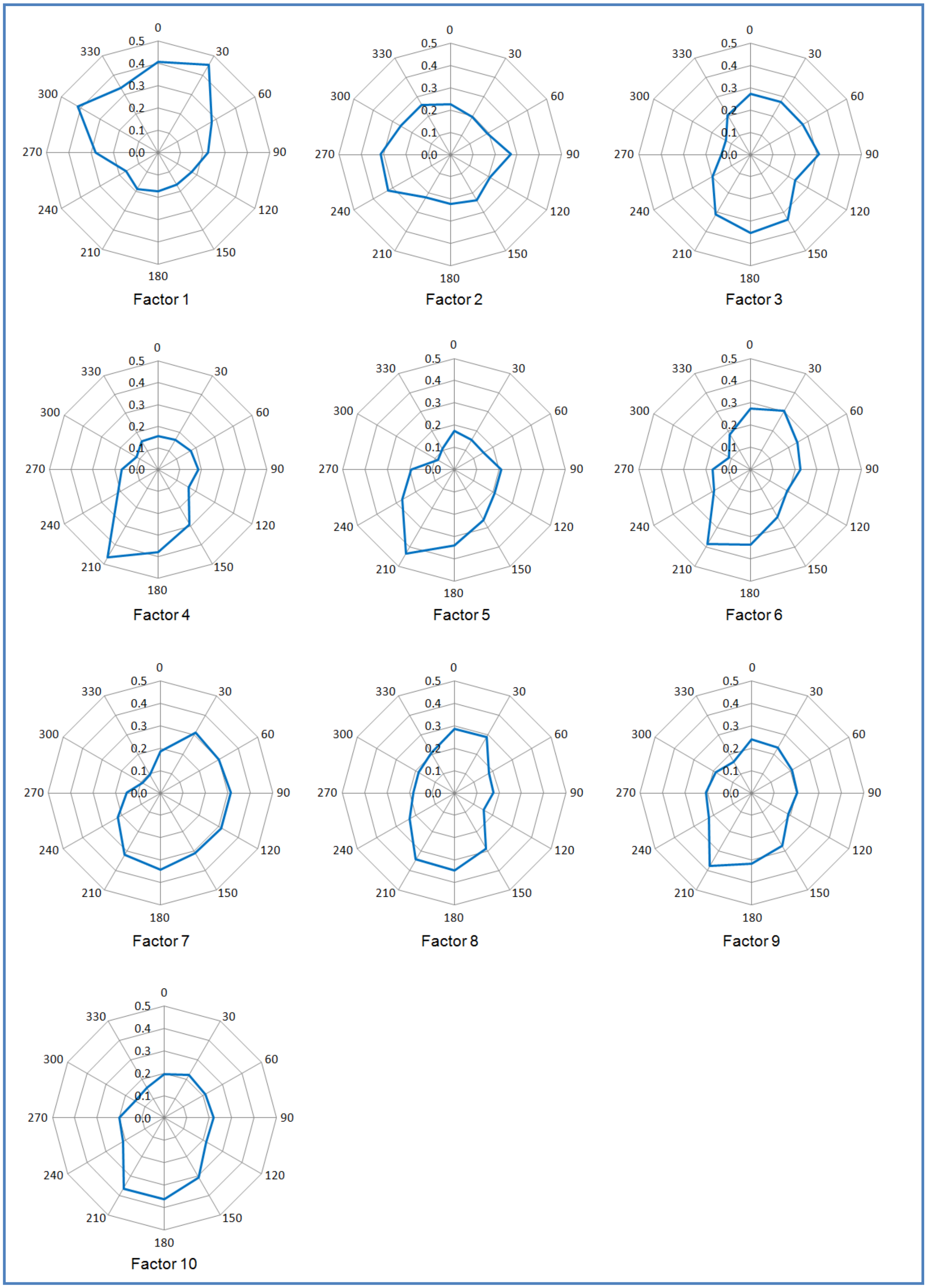


Figure A-5. Liberty PMF Factor Contributions (Time Series)



Factor 1 Factor 2 Factor 3

Factor 4 Factor 5 Factor 6

Factor 7 Factor 8 Factor 9

Factor 10

Figure A-6. Liberty CPF by Source Factor

Florence

Table A-3. Florence PMF Factors

Factor Number	Source Factor Description
Factor 1	Secondary Ammonium Nitrates
Factor 2	Crustal Component
Factor 3	Secondary Ammonium Sulfates
Factor 4	Burning/Cooking
Factor 5	Incinerators
Factor 6	Motor Vehicles

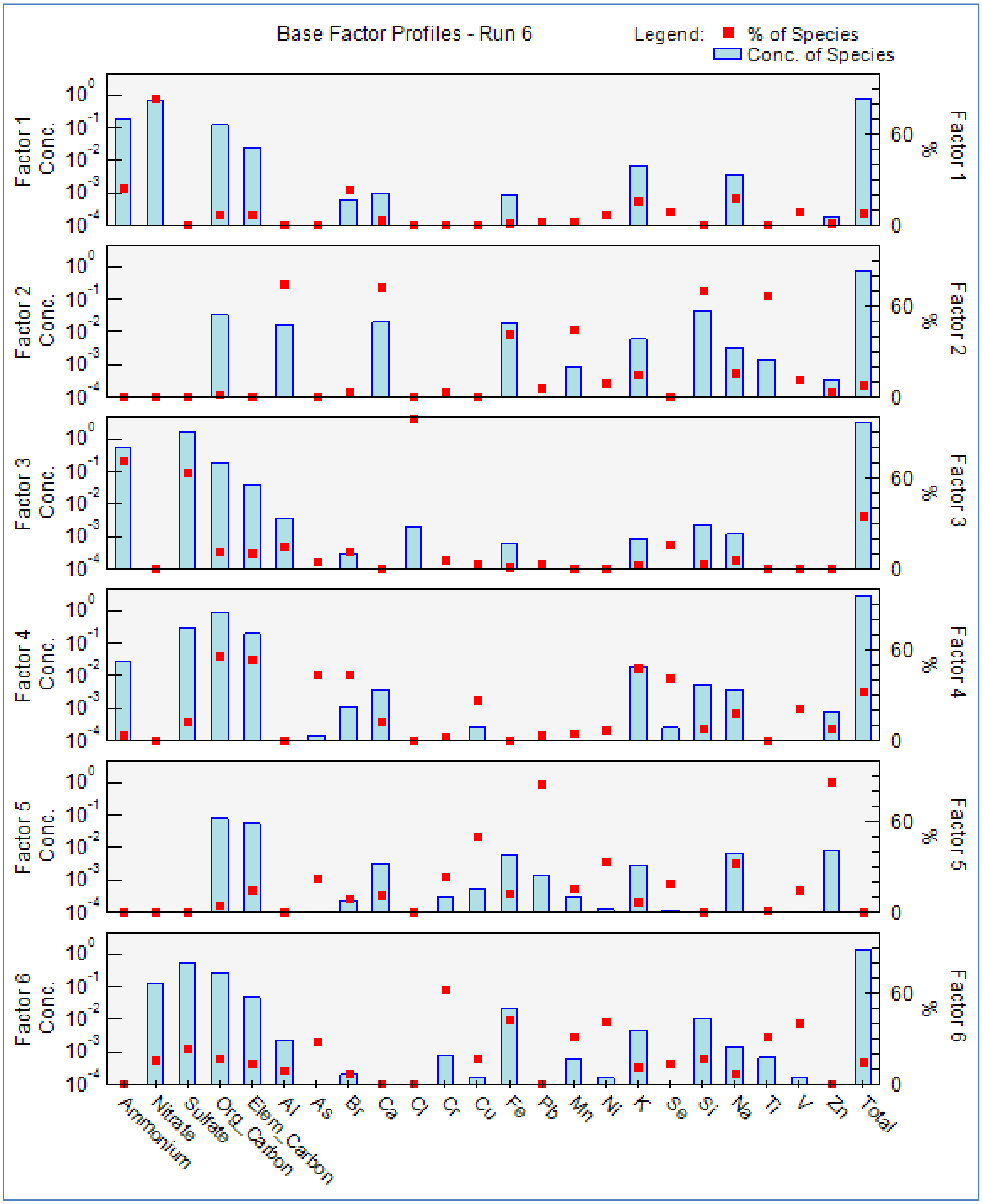


Figure A-7. Florence PMF Factor Species Profiles

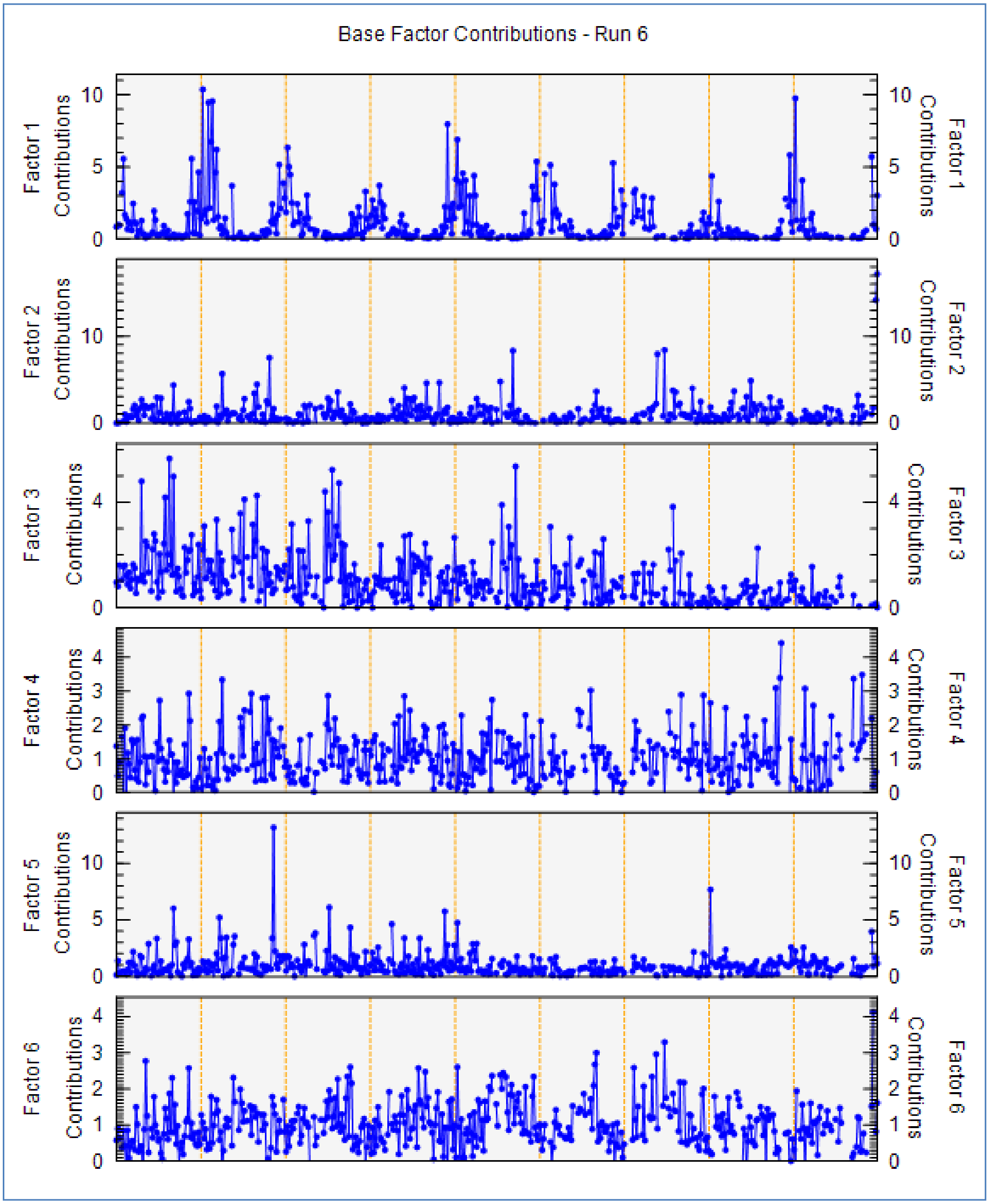


Figure A-8. Florence PMF Factor Contributions (Time Series)

Greensburg

Table A-4. Greensburg PMF Factors

Factor Number	Source Factor Description
Factor 1	Secondary Ammonium Sulfates
Factor 2	Road Dust/Salt
Factor 3	Crustal Component
Factor 4	Incinerators
Factor 5	Burning/Cooking
Factor 6	Motor Vehicles
Factor 7	Secondary Ammonium Nitrates

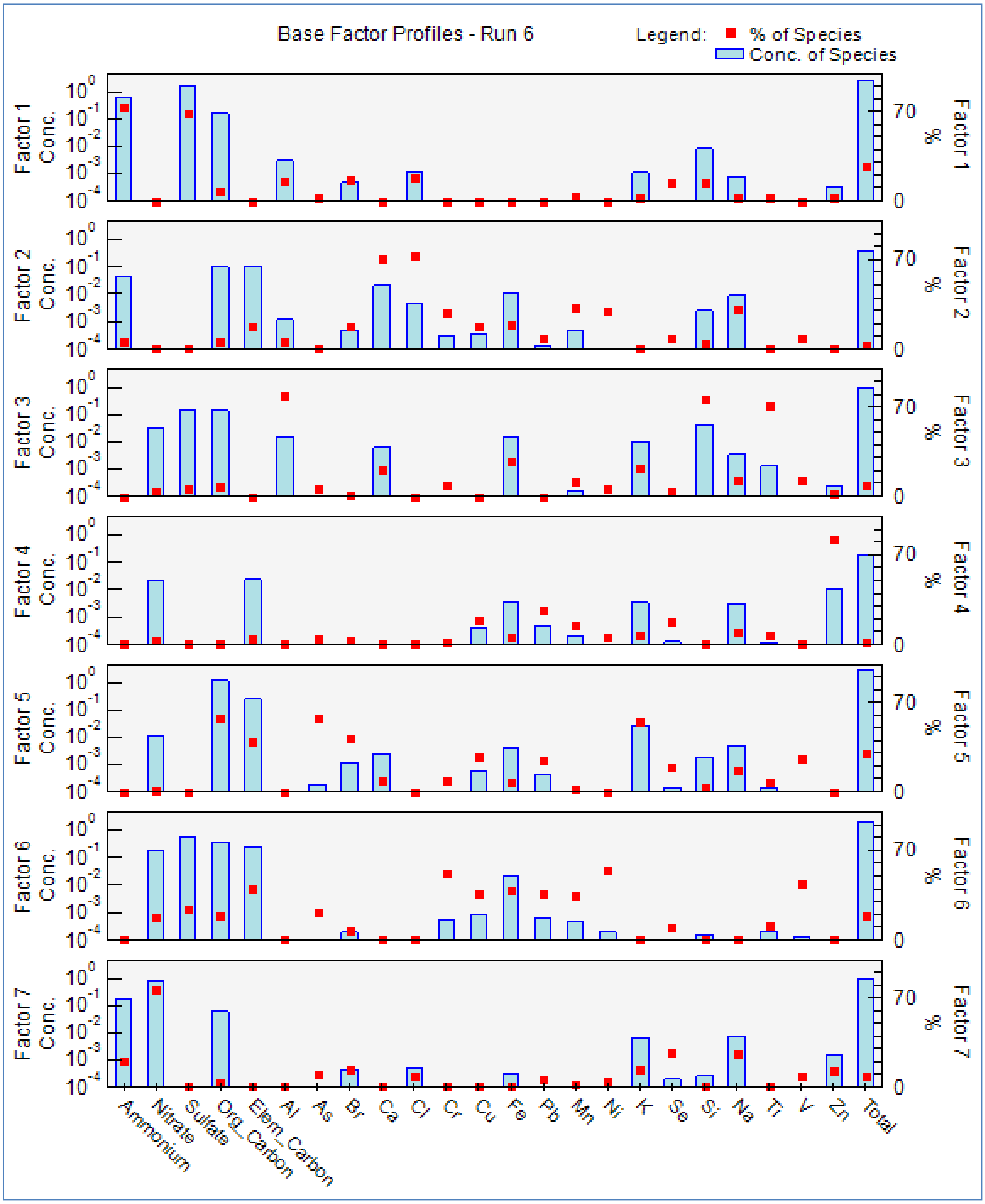


Figure A-9. Greensburg PMF Factor Species Profiles

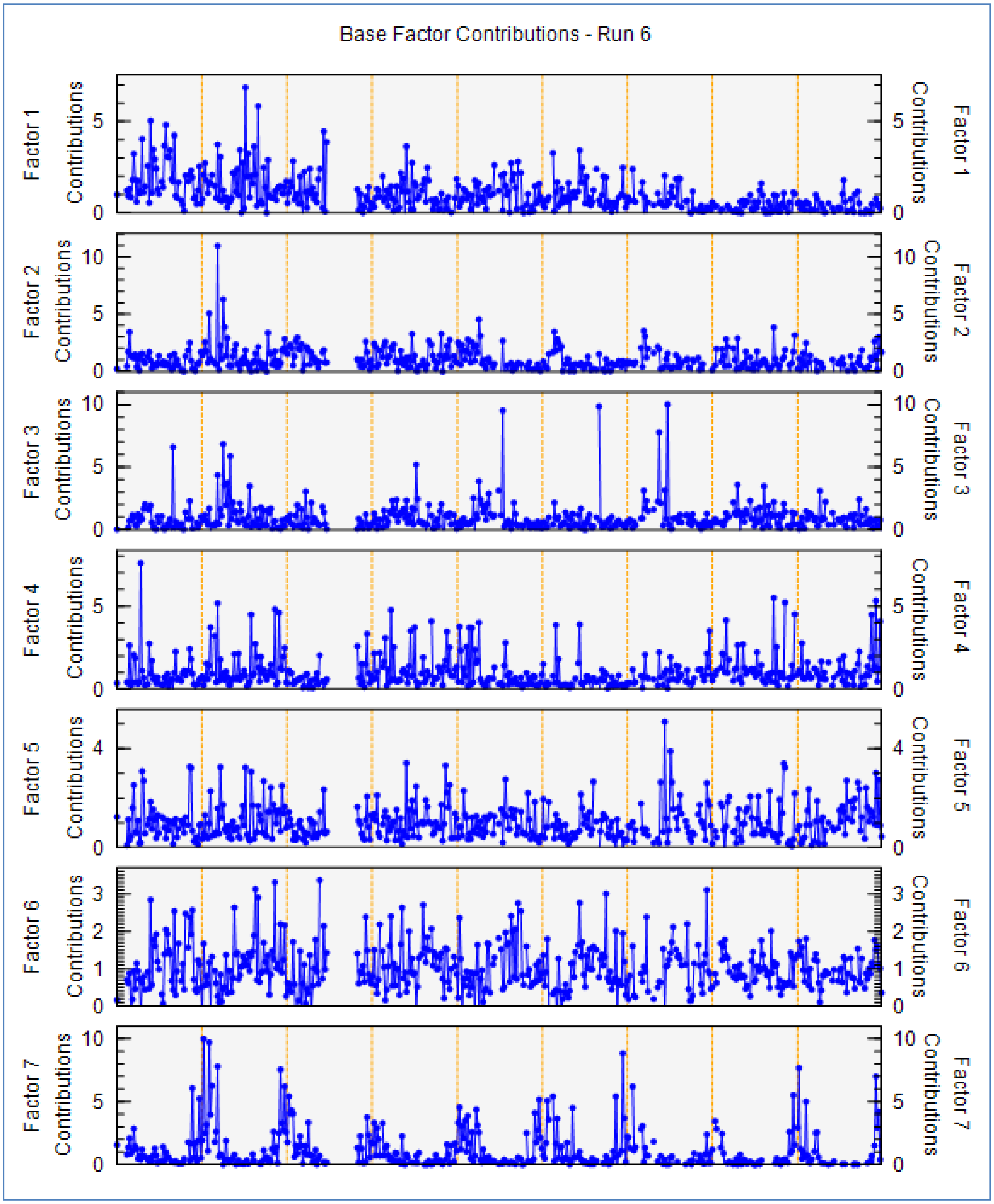


Figure A-10. Greensburg PMF Factor Contributions (Time Series)

Quaker City

Table A-5. Quaker City PMF Factors

Factor Number	Source Factor Description
Factor 1	Crustal Component
Factor 2	Road Dust/Salt
Factor 3	Burning/Cooking
Factor 4	Secondary Ammonium Sulfates
Factor 5	Secondary Ammonium Nitrates
Factor 6	Motor Vehicles

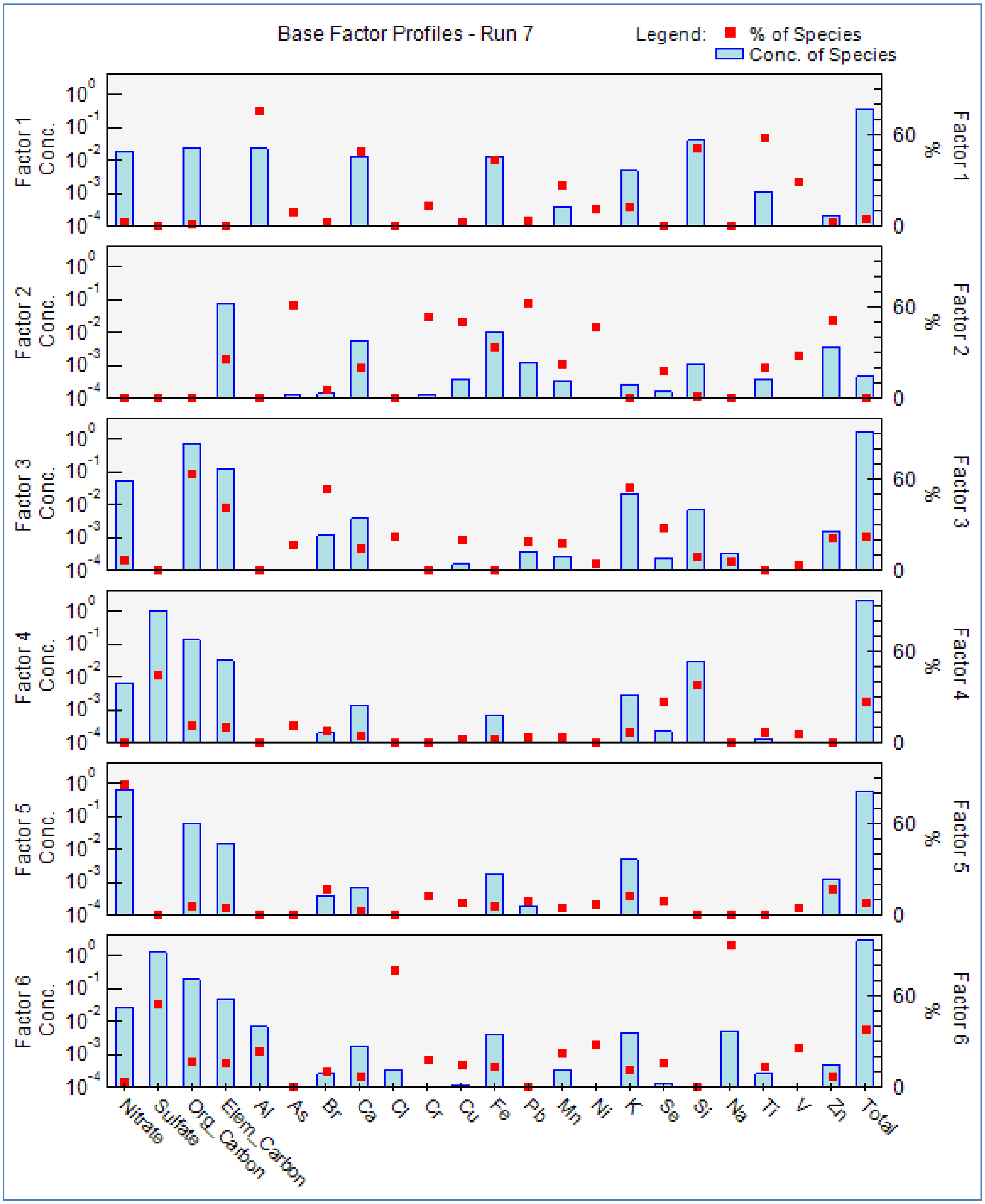


Figure A-11. Quaker City PMF Factor Species Profiles

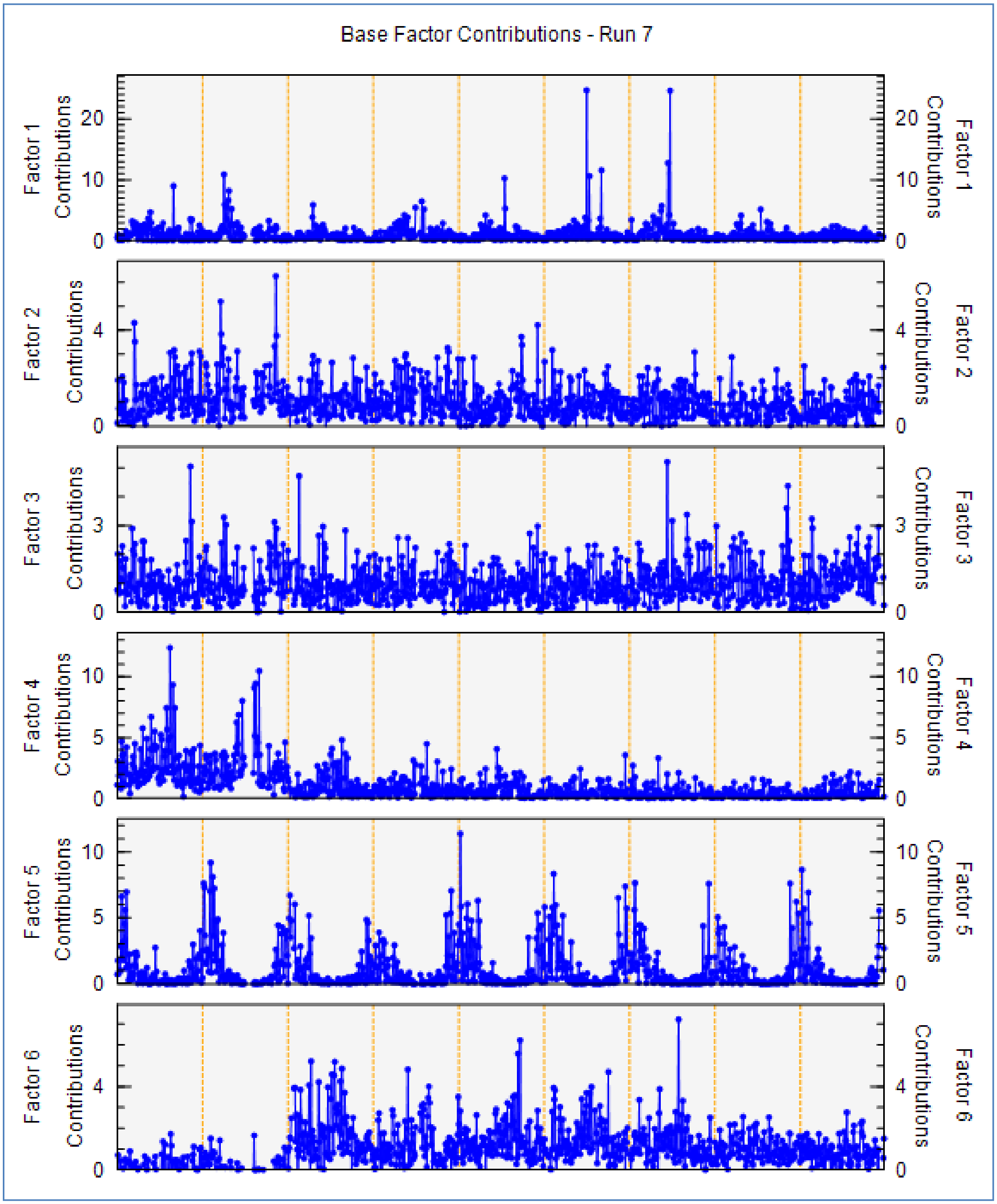


Figure A-12. Quaker City PMF Factor Contributions (Time Series)

Dolly Sods

Table A-6. Dolly Sods PMF Factors

Factor Number	Source Factor Description
Factor 1	Crustal Component
Factor 2	Secondary Ammonium Sulfates
Factor 3	Burning/Cooking
Factor 4	Motor Vehicles
Factor 5	Secondary Ammonium Nitrates
Factor 6	Road Dust/Salt

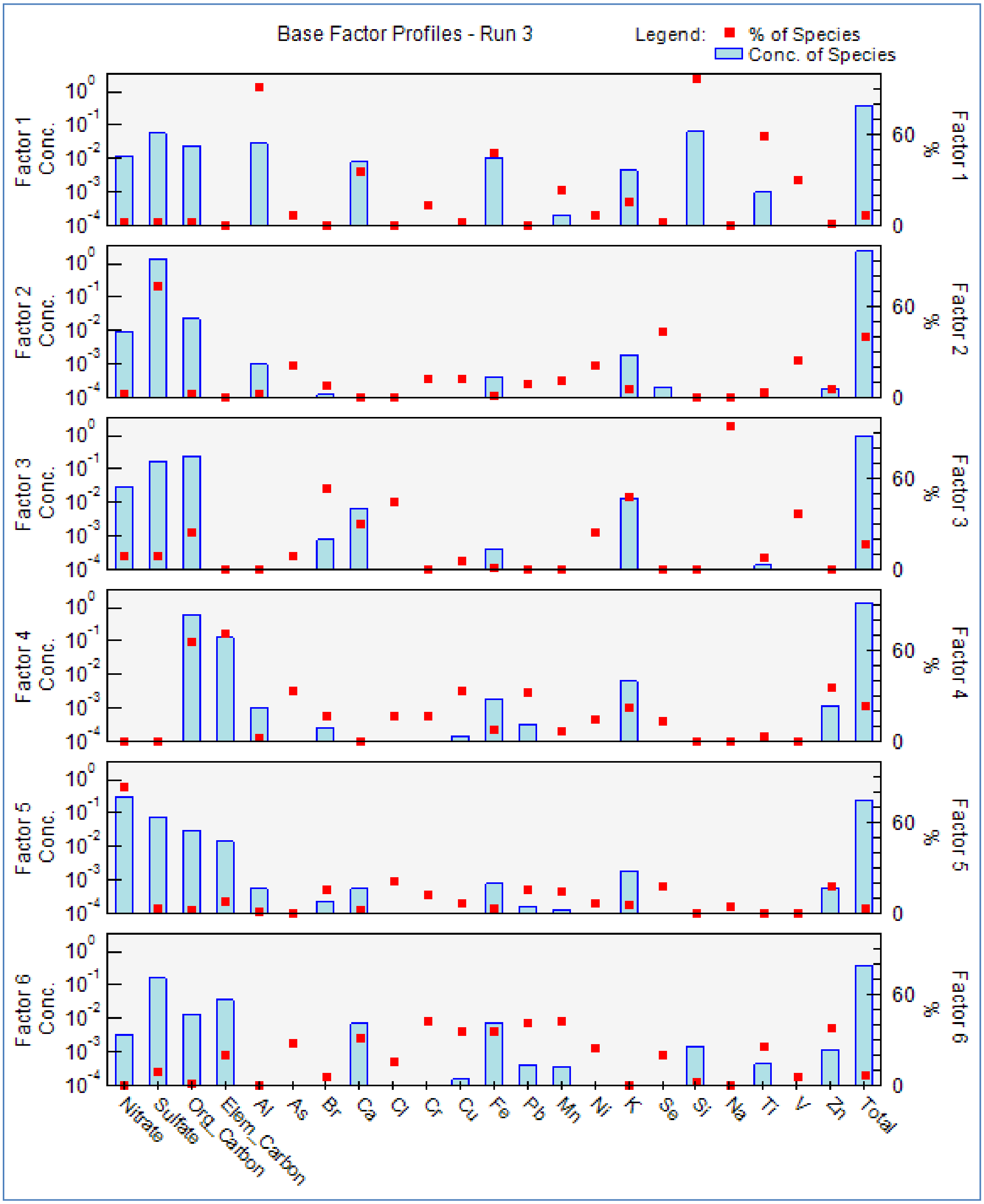


Figure A-13. Dolly Sods PMF Factor Species Profiles

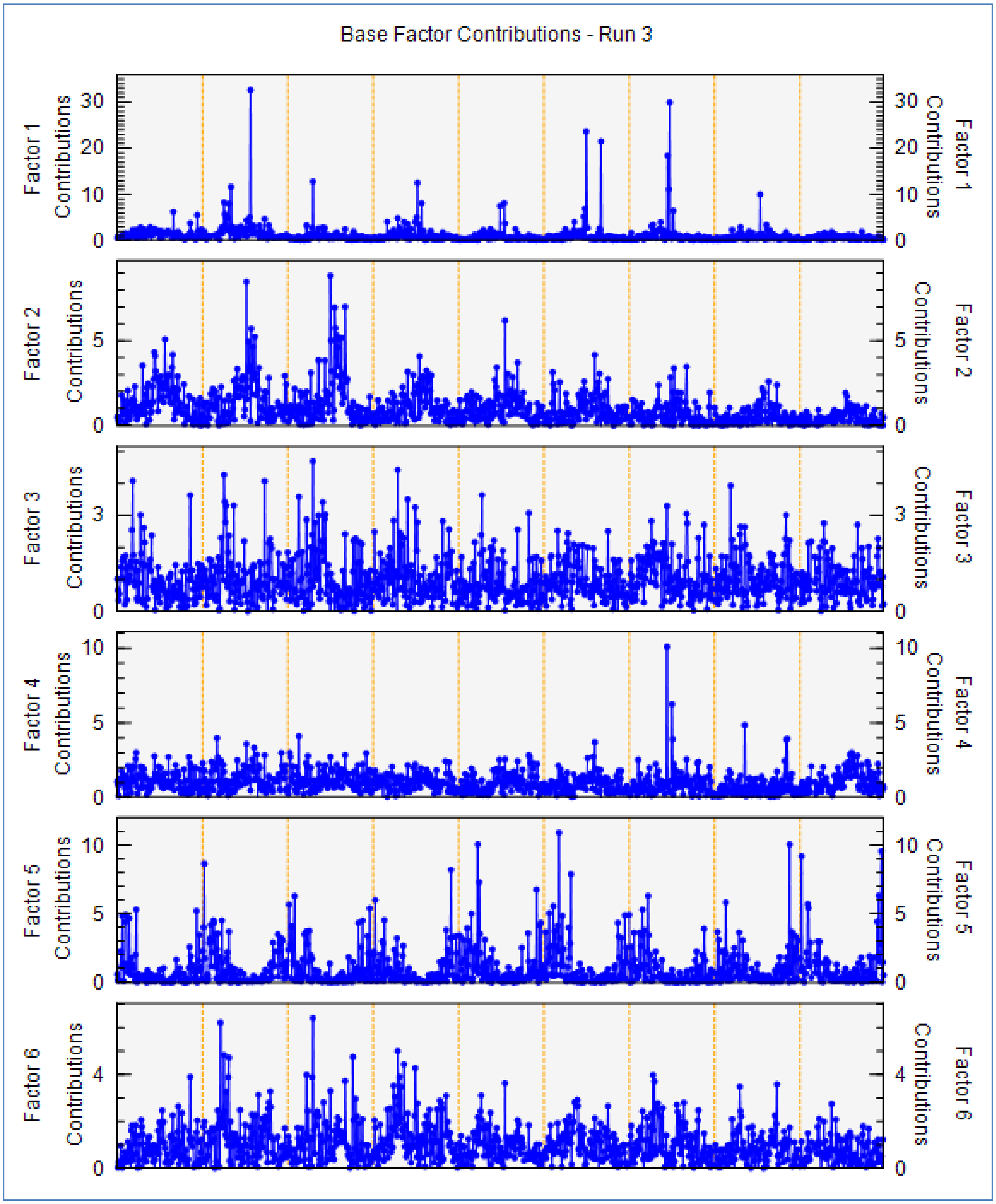


Figure A-14. Dolly Sods PMF Factor Contributions (Time Series)

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