Allegheny County Health Department
Air Quality Program
301 39th St., Bldg. #7
Pittsburgh, PA 15201

Allegheny County $PM_{2.5}$ Source Apportionment Results using the Positive Matrix Factorization Model (PMF Version 1.1)

Model Timeframe: July 2003 through August 2005

January 13, 2006
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1. Executive Summary

The Positive Matrix Factorization Model (PMF Version 1.1)[1] is a Windows-based software tool developed by EPA as a method to estimate source contributions based on actual monitored results. PMF performs a least-squares fit over an array of species measured simultaneously at a monitoring site.

The Allegheny County Health Department operates $PM_{2.5}$ speciation monitors at Lawrenceville in the City of Pittsburgh and at Liberty Borough near the southeastern tip of Allegheny County. Each speciation monitor measures 54 different species of $PM_{2.5,}$ including total mass concentration.

Sample concentrations were entered into PMF along with date-matched uncertainties. Source factors were then calculated by the model as a result of iterative methods 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, and a conceptual model of the area. A conceptual model is a fundamental understanding of how pollutants behave based on emissions inventory, monitored results, meteorological conditions, and transport phenomena.

This report is based on preliminary results using PMF Version 1.1. It is anticipated that future receptor modeling will be performed at a later date using a larger array of samples for the Lawrenceville and/or Liberty sites. This may also include wind direction or trajectory analysis for specific factors.

PMF modeling resulted in the following 11 source factors for Lawrenceville:

Secondary Ammonium Sulfate	Secondary Ammonium Nitrate	Diesel Vehicles + Misc. Road Dust	Diesel Vehicles + Ferromanganese-Rich Industrial	Incinerators	Gasoline Vehicles + Tire Wear	Gasoline Vehicles + Selenium-Rich Industrial	Airborne Crustal (Silicon-Rich)	Airborne Crustal (Other)	Road Dust (Road Salt-Rich)	Misc. Burning and Cooking
5.49	2.81	0.42	0.26	0.45	0.79	0.58	0.28	0.52	0.38	2.40

PMF modeling also resulted in the following 12 source factors for Liberty:

Secondary Ammonium Sulfate	Secondary Ammonium Nitrate	Carbon-Rich Industrial	Selenium-Rich Industrial	Zinc-Rich Sources	Halogen-Rich Sources	Diesel Vehicles	Gasoline Vehicles	Airborne Crustal (Silicon-Rich)	Airborne Crustal (Other)	Road Dust	Vegetative Burning
4.33	1.75	4.00	0.12	0.46	1.03	1.35	1.11	0.28	0.52	0.15	1.37

The values shown above are concentrations for each factor in units of µg/m³. Detailed results for Lawrenceville and Liberty are given in Section 4 and Section 5, respectively.

[1] PMF 1.1 is currently under peer review and is not yet available for distribution. See disclaimer at the end of this document.

2. Sites

The Lawrenceville monitor site is an urban residential site, downwind from the Pittsburgh Central Business District (Downtown). Monitored data shows that Lawrenceville is affected by both regional flow and urban excess for $PM_{2.5}$. The regional flow is presumably due to upwind power plant emissions, but may also include $PM_{2.5}$ from biogenic sources such as trees. The urban excess sources should be anthropogenic sources such as light industry, mobile source emissions residential and commercial burning/heating.

The Liberty Borough monitor site is located in the Monongahela Valley, which contains a mix of urban residential, heavy industrial, and rural areas. Monitored data shows that regional flow is evident for some $PM_{2.5}$ species, while concentrations of other species do not follow regional flow. It is assumed that species that do not follow regional flow may be originating at sources resident to the area, both stationary and mobile.

Uncertainties for speciation data were uploaded to AQS beginning with July 2003 data. Data used in this PMF modeling spans the dates July 2003 through August 2005.

Over this timeframe, 206 samples were modeled for the Lawrenceville site (a 1-in-3 sampling frequency). Dates on or near the Fourth of July were removed due to outliers in the concentrations due to fireworks. Potassium nitrate and other ingredients can lead to abnormal concentration levels of trace elements, some of which rarely exceed minimum detection limits (MDLs) on average days.

Since Liberty is a 1-in-6 sampler and only began operation in October 2003, only 91 samples were modeled for the Liberty site. Independence Day firework outliers were also observed at this site, and corresponding dates were removed from the modeling input file.

3. Methodology

Model operation was followed according the user's guide and modeling workbook. The PMF model was tested under many different species and factor combinations. Species are excluded if they exhibit low signal-to-noise ratios, are frequently below the minimum detection limit (MDL), or do not easily fit into a least-squares solution.

The major species measured from the speciation monitors show the highest concentrations, strongest signal-to-noise ratios, and are usually a sign of specific sources. These species can strongly affect the model. These species include:

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

The following trace element species also had significant concentrations and strong signal-to-noise ratios. They may also be important tracer elements, associated with specific sources. These species include:

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

Over half of the trace element species available were *excluded* from the modeling based on frequent concentrations that were less than the MDL. These elements provide little weight in the fit of a solution. These species include:

Antimony	Gold	Phosphorus	Terbium
Barium	Hafnium	Rubidium	Tin
Cadmium	Indium	Samarium	Tungsten
Cobalt	Iridium	Scandium	Yttrium
Cerium	Lanthanum	Silver	Zirconium
Cesium	Magnesium	Sodium	
Europium	Molybdenum	Strontium	
Gallium	Niobium	Tantalum	

Sulfur as a trace element has also been excluded from the model, since nearly all sulfur as a component of $PM_{2.5}$ in the Pittsburgh region is accounted for by sulfate.

Total $PM_{2.5}$ was used PMF an strength indicator for each factor but was down weighted in order to lower its influence on the fit of the model. Down weighting increases the uncertainty by a factor of 3.

Trace element species with low signal-to-noise ratios (less than 3.0) were down weighted. Low signal-to-noise ratios mean that a species' concentrations and uncertainties are nearly equal.

Trace element species that fit less perfectly than other species into a convergent solution were also down weighted. A poor fit is reflected by poor diagnostics from regression, standard deviation, and residual statistics.

Additionally, a 5% uncertainty was applied to the entire model (based on EPA recommendation) for samples taken from Speciation Trends Network (STN) speciation monitoring sites, used by Allegheny County.

The number of <u>source factors</u> in the model are increased or decreased based on the performance of the model and the rationality of the results. A source factor does not necessarily represent a single source but rather a source type or scenario (or combination thereof) that leads to contributions at the monitor site. Too few sources factors indicate a lack of uncertainty and creates profiles with species that are clustered. Too many source factors indicate too much uncertainty and leads to profiles that cannot be characterized or are too small in overall concentration to have significance.

The goodness-of-fit parameter (Q) for a perfect theoretical model is calculated as:

Q = (# samples * # good species) + [(# samples * # weak species)/3] – (# samples * # factors being estimated)

Source factors are varied in the model until the modeled Q converges on a solution that approaches the perfect theoretical Q. The source factor profiles for near-perfect model runs are then examined for physical validity.[2]

Some factors may be associated with a similar source type but are separated into more specific source factors by the model. For example, a source type of road dust may comprise a source factor that has a strong year-round presence and another factor that is seasonal. There may also be overlap of some source types. For example, a factor dominated by secondary ammonium sulfate may also include carbons and trace elements that may or may not be originating from the sulfate sources but are peaking simultaneously with sulfate.

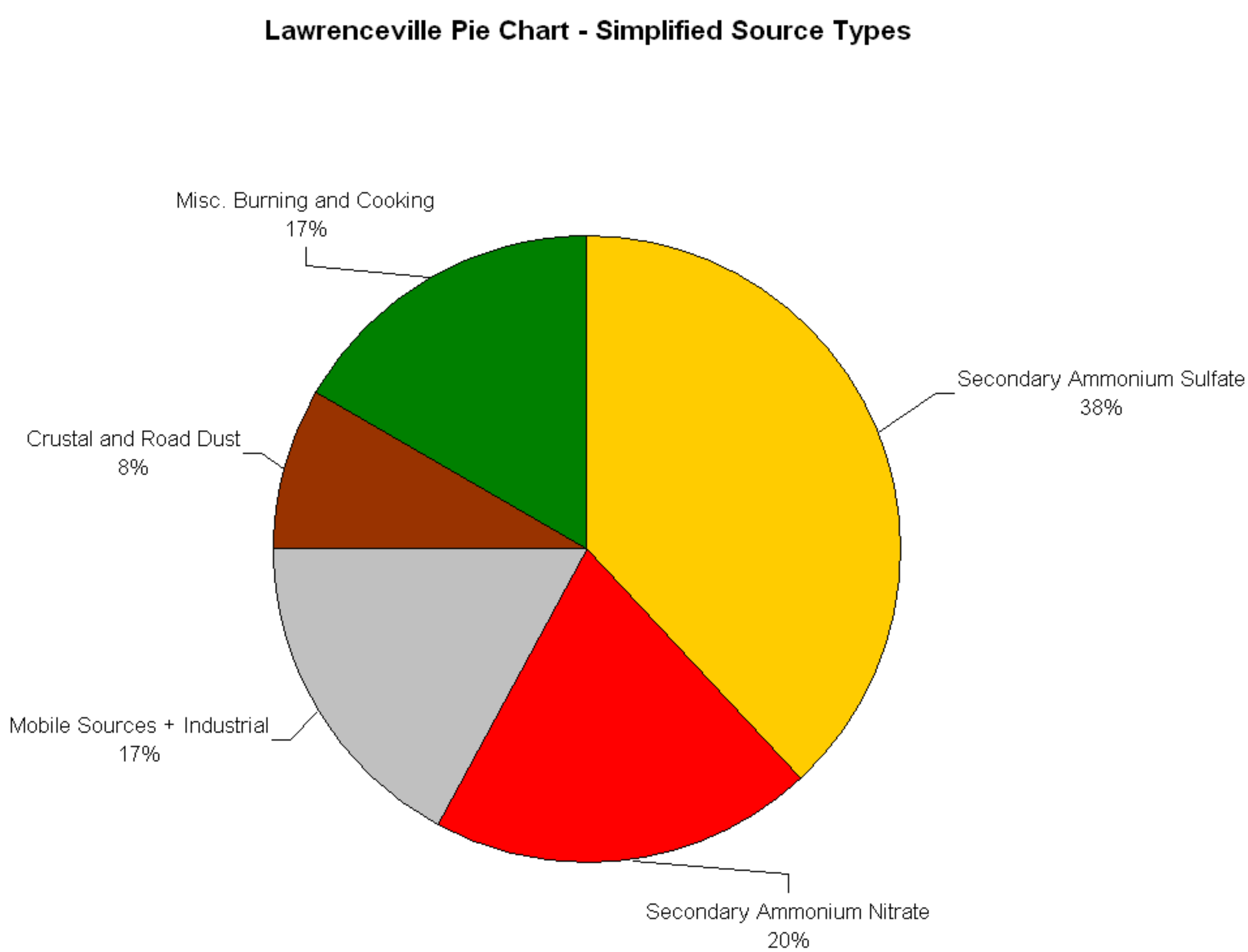
[2] Results were compared to previously-compiled source profiles. See the References section of this document.

4. Modeled Results: Lawrenceville

A total of 206 Lawrenceville samples were input into the model. The best model runs were able to resolve 11 source factors. The following trace elements were down weighted in the model runs: Al, As, Br, Cr, Hg, K, Ni, Ti, and V.

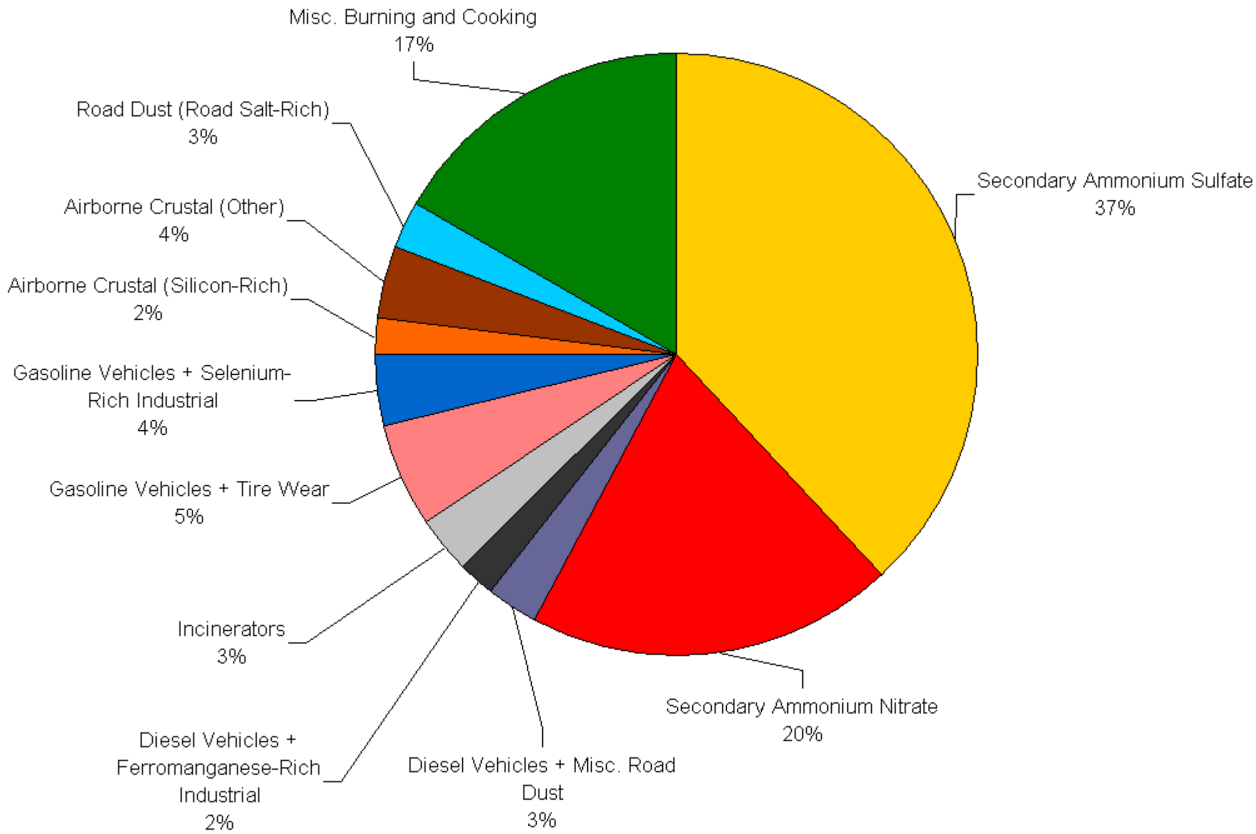
In addition to Fourth of July samples removed on account of trace element outliers, the sample taken on 4/10/2005 has been removed from the modeling. An exceptional event was identified on this date in which crustal elements (geological dust, or airborne soil) were higher than the norm.

Lawrenceville results exhibited source factors that are common to urban areas. A simplified pie chart of the best-guess source types (by percentage of summed concentrations) is shown below.



An expanded pie chart of the source types is also shown below.

Lawrenceville Pie Chart - Expanded Source Types



Lawrenceville source factor profiles and associated source types are given in the table below. Species concentrations that were considered to be indicators of the specific source types are shown in bold.

	Secondary Sulfate/Nitrate		Mobile and Industrial Sources					Crustal and Road Dust			Misc. Burning and Cooking
	Secondary Ammonium Sulfate	Secondary Ammonium Nitrate	Diesel Vehicles + Misc. Road Dust	Diesel Vehicles + Ferromanganese-Rich Industrial	Incinerators	Gasoline Vehicles + Tire Wear	Gasoline Vehicles + Selenium-Rich Industrial	Airborne Crustal (Silicon-Rich)	Airborne Crustal (Other)	Road Dust (Road Salt-Rich)	Misc. Burning and Cooking
Factor	1	8	5	2	6	7	9	4	11	10	3
Total	6.4161	2.5224	0.2664	0.3167	0.5161	1.0412	0.7419	0.5796	0.4859	0.4923	2.8246
Ammonium	**1.1737**	**0.5381**	0.0702	0.0304	0.0728	0	0	0.0572	0	0.0799	0.0530
Nitrate	0.0497	**1.3083**	0	0	0	0	0	0.0083	0.1195	0.1390	0
Sulfate	**3.7984**	0.4717	0.0688	0.0748	0.2202	0.0531	0.1002	0.1150	0.0001	0.0662	0.4070
Org_Carbon	0.4347	0.4330	0	0	**0.0834**	**0.6498**	**0.4265**	0	0.3544	0.0522	**1.6817**
Elem_Carbon	0.0312	0.0416	**0.2051**	**0.1017**	**0.0540**	**0.0599**	**0.0365**	0.0327	0	0.0181	**0.2118**
Al	0	0.0029	0	0.0011	0	0.0003	0.0003	0.0001	**0.0048**	0	0.0014
As	0.0003	0	0	0.0001	0	0.0003	0.0009	0.0001	0	0.0002	0.0012
Br	0.0004	0.0009	0.0005	0	0	0.0004	0.0004	0.0002	0.0001	0.0002	0.0010
Ca	0.0044	0	0	0.0061	0	0	0.0022	0	**0.0280**	0.0023	0
Cl	0	0.0004	0	0	0.0003	0	0.0001	0	0	**0.0180**	0
Cr	0.0002	0.0003	0.0005	0.0005	0.0007	0.0006	0.0005	0	0	0	0
Cu	0.0002	0	**0.0036**	0	0	0.0006	0.0002	0.0001	0	0	0
Fe	0	0.0020	**0.0649**	**0.0373**	0.0100	0	0	0	0.0049	0.0017	0.0126
Pb	0	0	0	0	**0.0094**	0	0.0021	0	0	0	0
Mn	0	0	0	**0.0065**	0	0.0001	0.0004	0.0001	0	0.0002	0
Hg	0.0001	0.0003	0.0001	0	0	0	0.0004	0	0	0	0.0004
Ni	0	0.0004	0.0009	0.0001	0	0.0001	0	0	0	0	0.0002
K	0	0.0075	0.0045	0	0.0003	0.0057	0.0062	0.0028	0.0083	0.0009	**0.0247**
Se	0.0003	0.0003	0	0	0	0	**0.0047**	0.0002	0	0.0002	0
Si	0	0.0008	0	0	0.0010	0	0.0016	**0.0639**	0.0026	0.0009	0
Ti	0.0004	0.0004	**0.0014**	0	0.0001	0.0005	0	0.0003	**0.0011**	0	0.0003
V	0.0002	0.0002	0	0	0	0	0	0	0	0.0002	0.0005
Zn	0	0.0021	0	0.0047	0.0026	**0.0162**	0	0.0008	0.0009	0.0026	0
SUM (exc. total)	*5.4942*	*2.8112*	*0.4205*	*0.2633*	*0.4548*	*0.7876*	*0.5832*	*0.2818*	*0.5247*	*0.3828*	*2.3958*

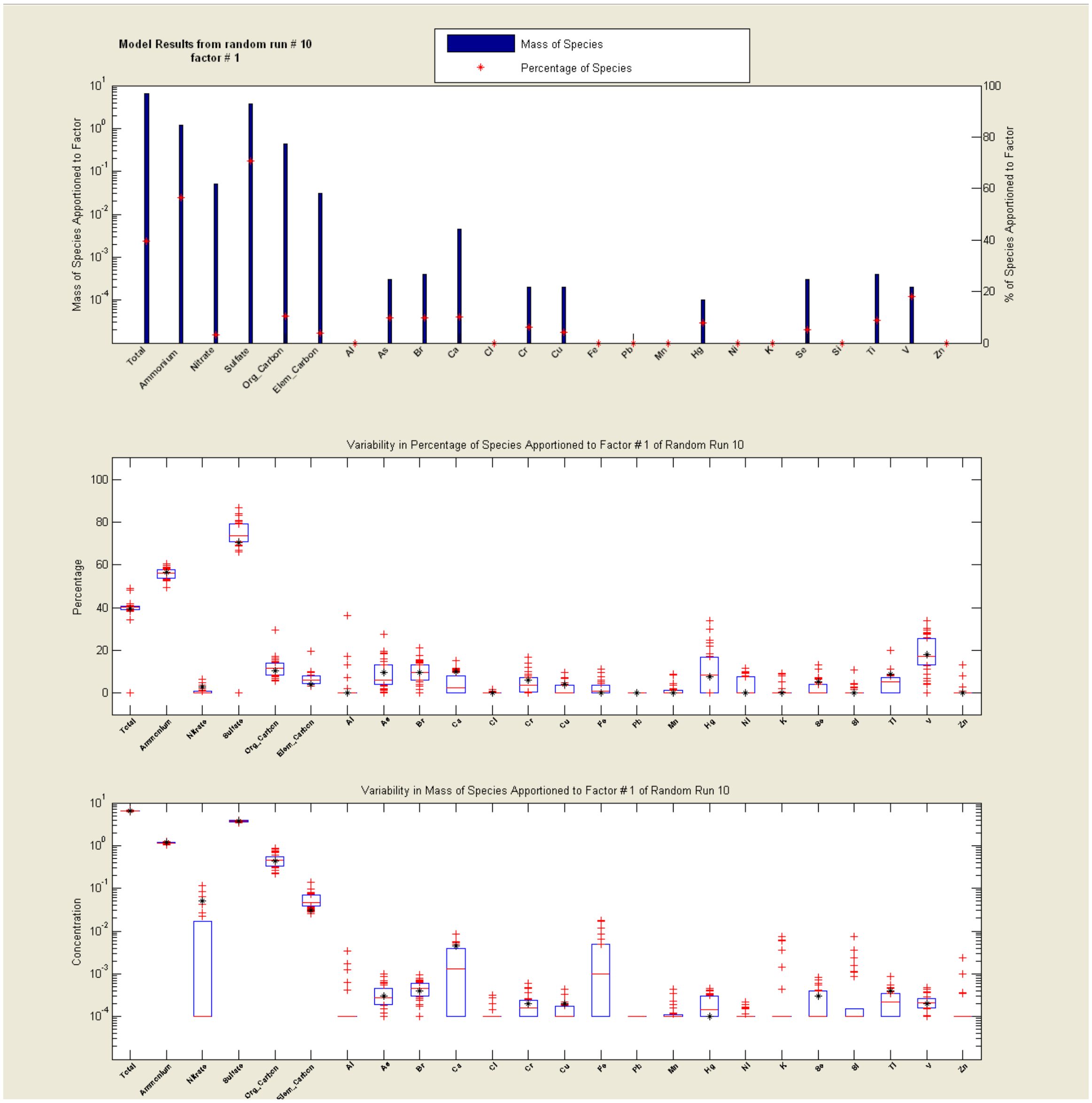
Analysis and graphical results for each factor are given on subsequent pages. Graphical results are copied directly from the model output and include the following for each factor:

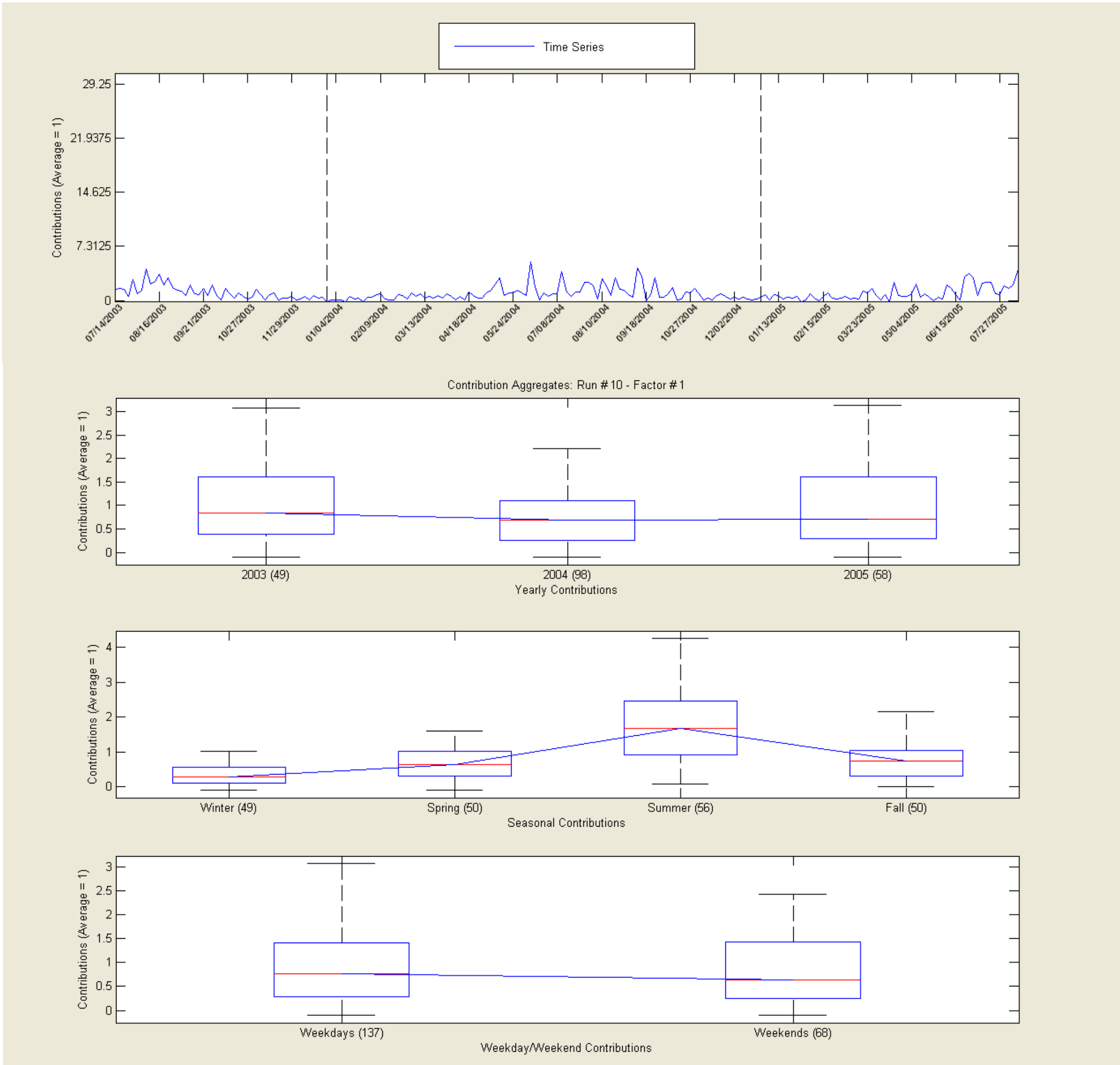
- Concentration by value and percentage of total for each species
- Variability (bootstrapping) for each concentration and percentage
- Time series plot by overall factor concentration
- Contribution aggregates according to season and day of the week

Note: Factors and runs are generated randomly by PMF and are not ranked according to any one species.

Lawrenceville Source Factor 1: Secondary Ammonium Sulfate

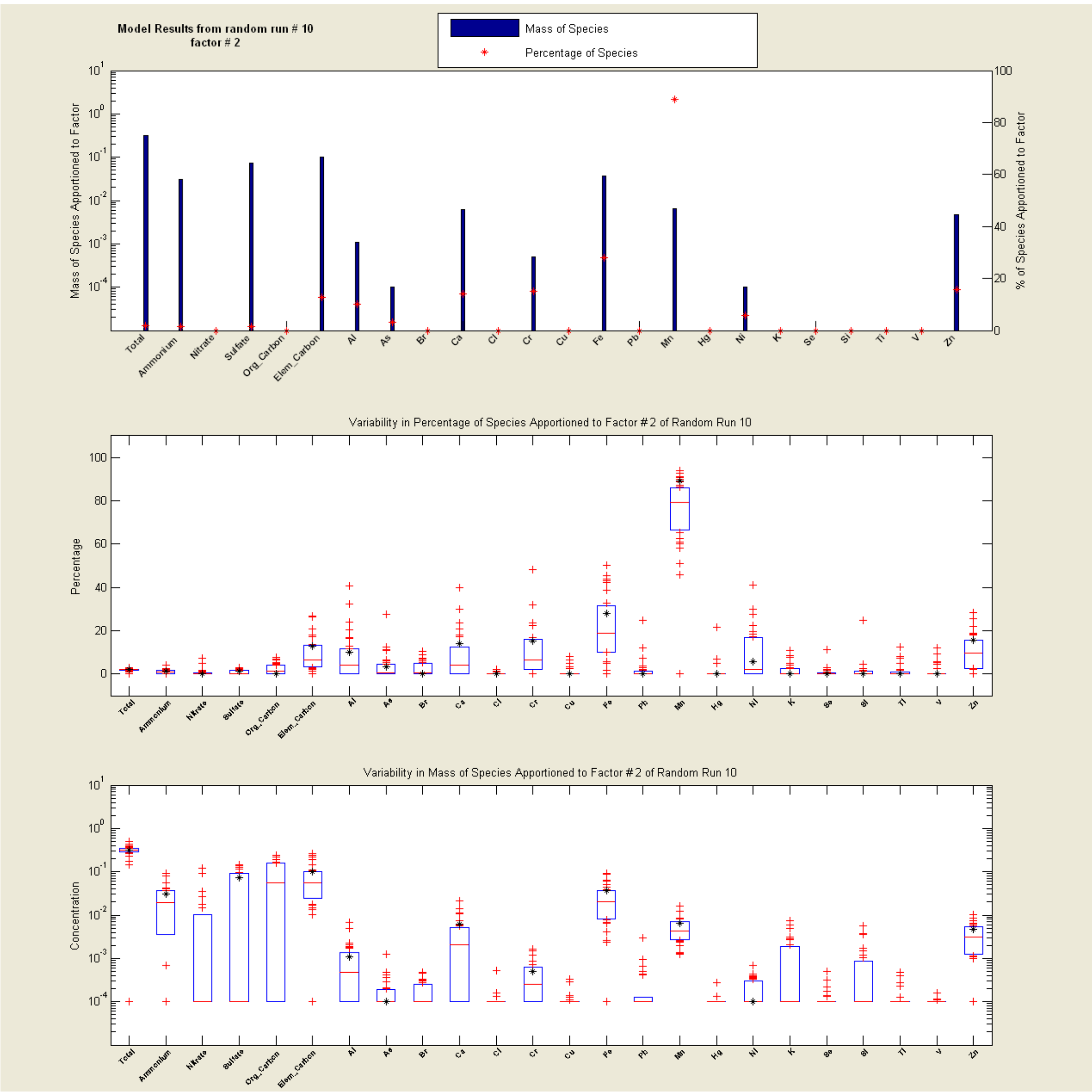
Factor 1 is the largest source factor by summed concentration and comprises the majority of ammonium sulfate at Lawrenceville. Contributions are highest in summer, when sulfate is most prevalent. Sulfate exists as secondary $PM_{2.5}$ in the Pittsburgh region, formed from upwind SO_2 sources such as coal-fired power plants. Factor 1 also contains some carbons and trace elements that are likely peaking concurrently with the sulfate. The organic carbon may be secondary in nature as well. Graphical results are shown below.

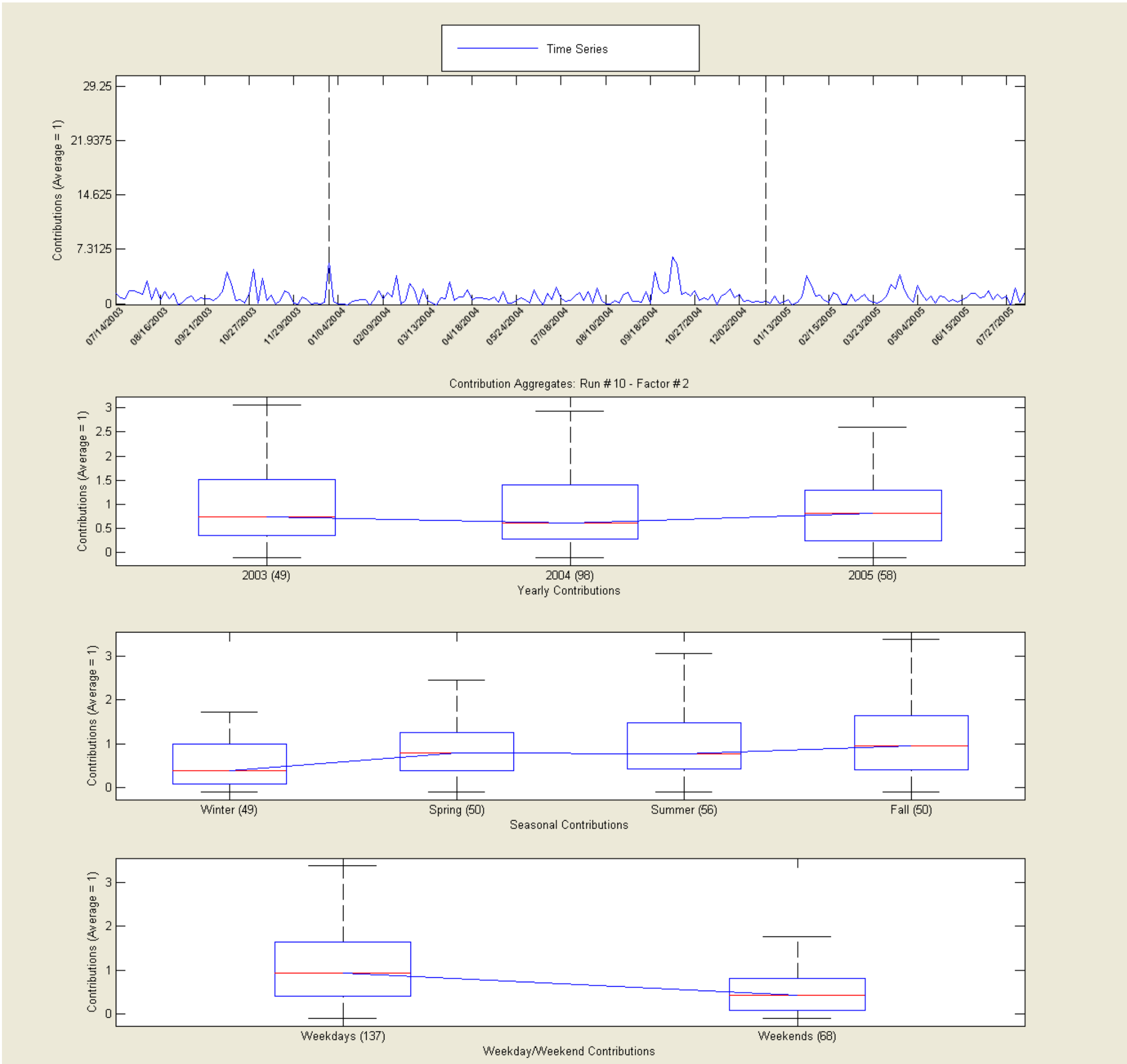



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 1
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 2: Diesel Vehicles + Ferromanganese-Rich Industrial

High elemental carbon and weekday contributions are indicative of diesel vehicles for Factor 2. There is also a strong presence of iron and manganese associated with this factor, which may be related to steel industry operations. Diesel and steel emissions may be originating from the same wind direction for this factor.

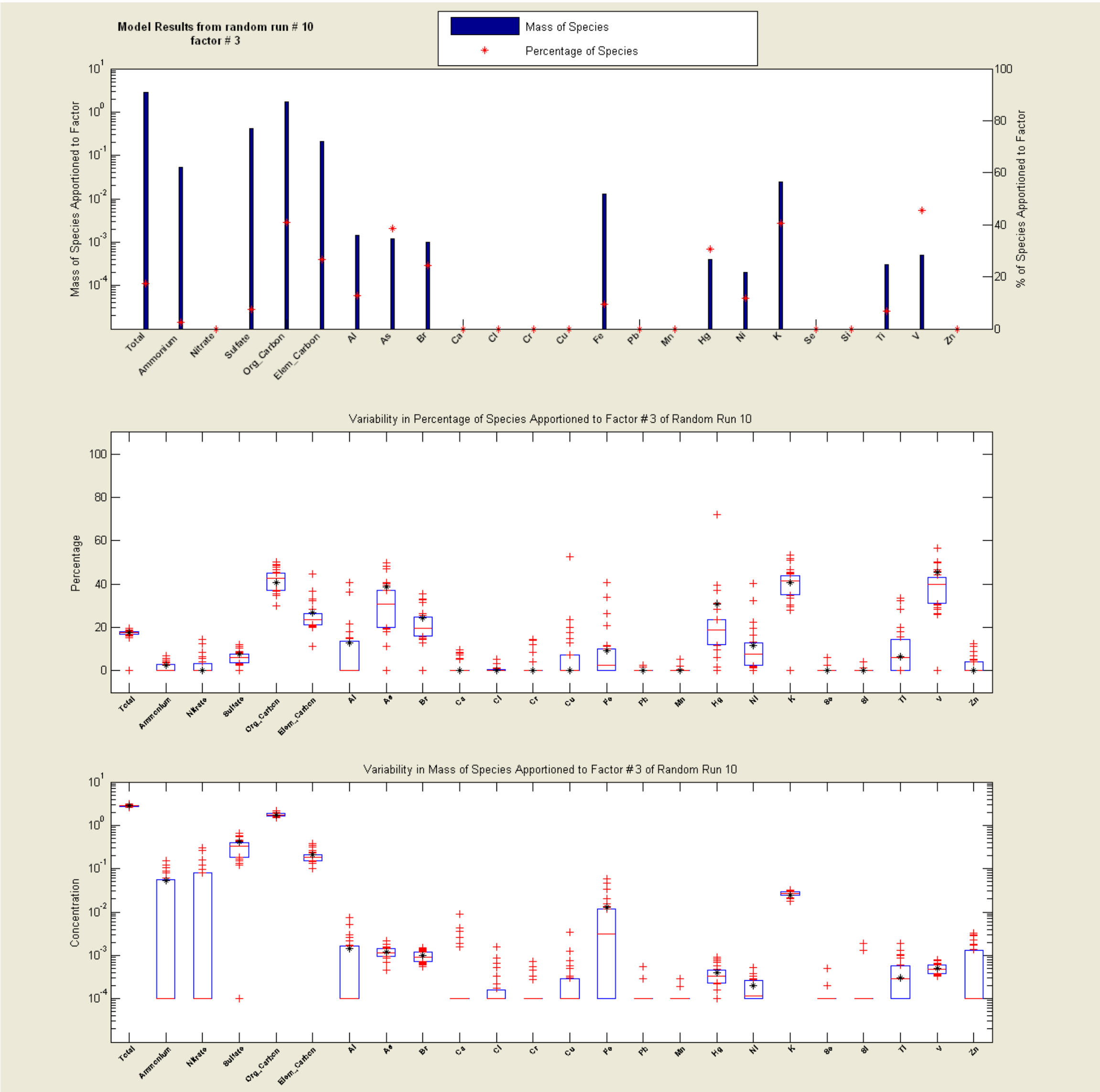


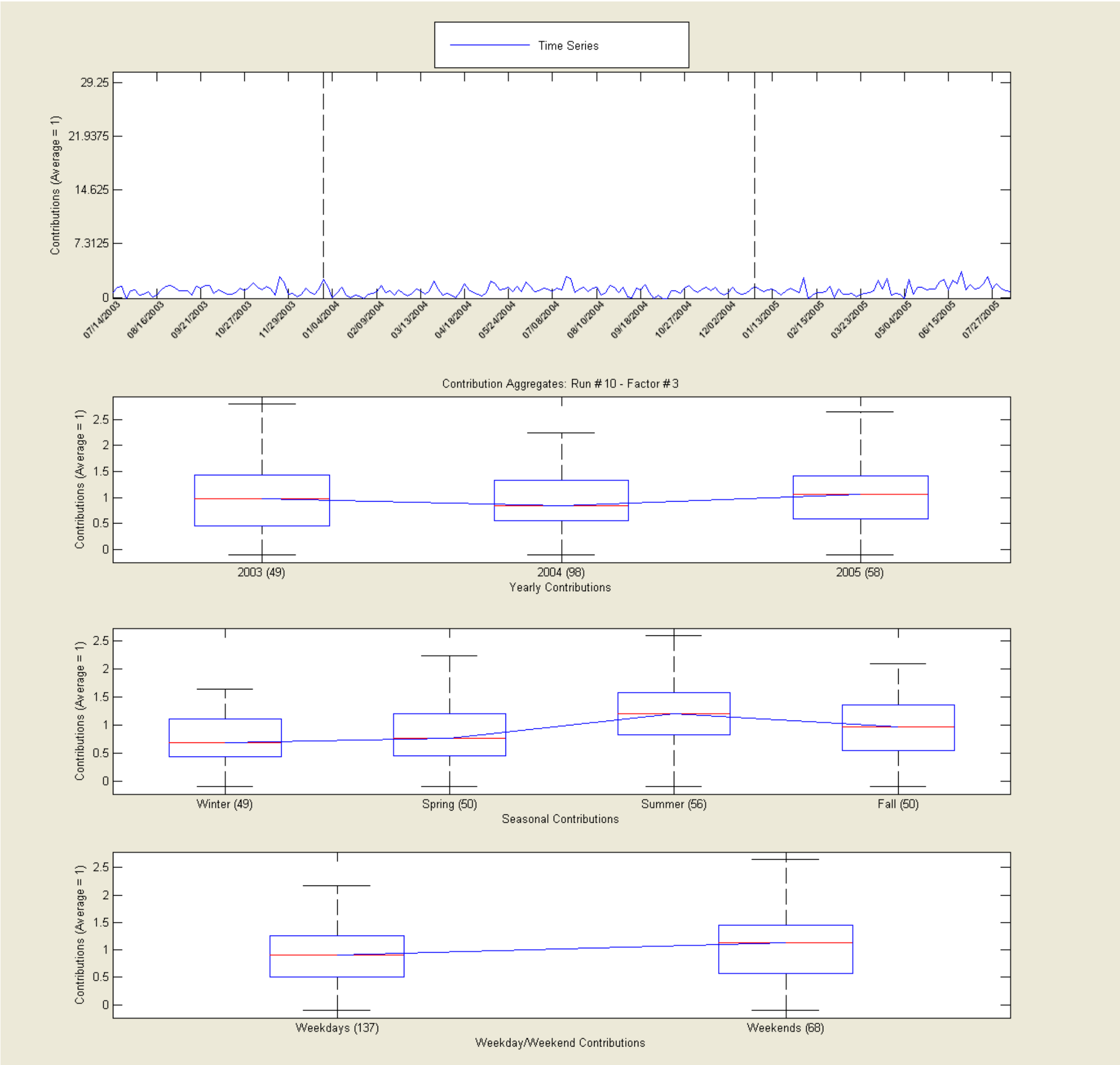


Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 2
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 3: Miscellaneous Burning and Cooking

Factor 3 contains high amounts of carbons together with potassium, which are usually indicators of vegetative burning and cooking. This factor is slightly higher on weekends and in summer, perhaps due to recreational open burning and cooking. Arsenic, bromine, mercury, and vanadium are also high in percentage, perhaps due to oil/coal burning, either residential or commercial.

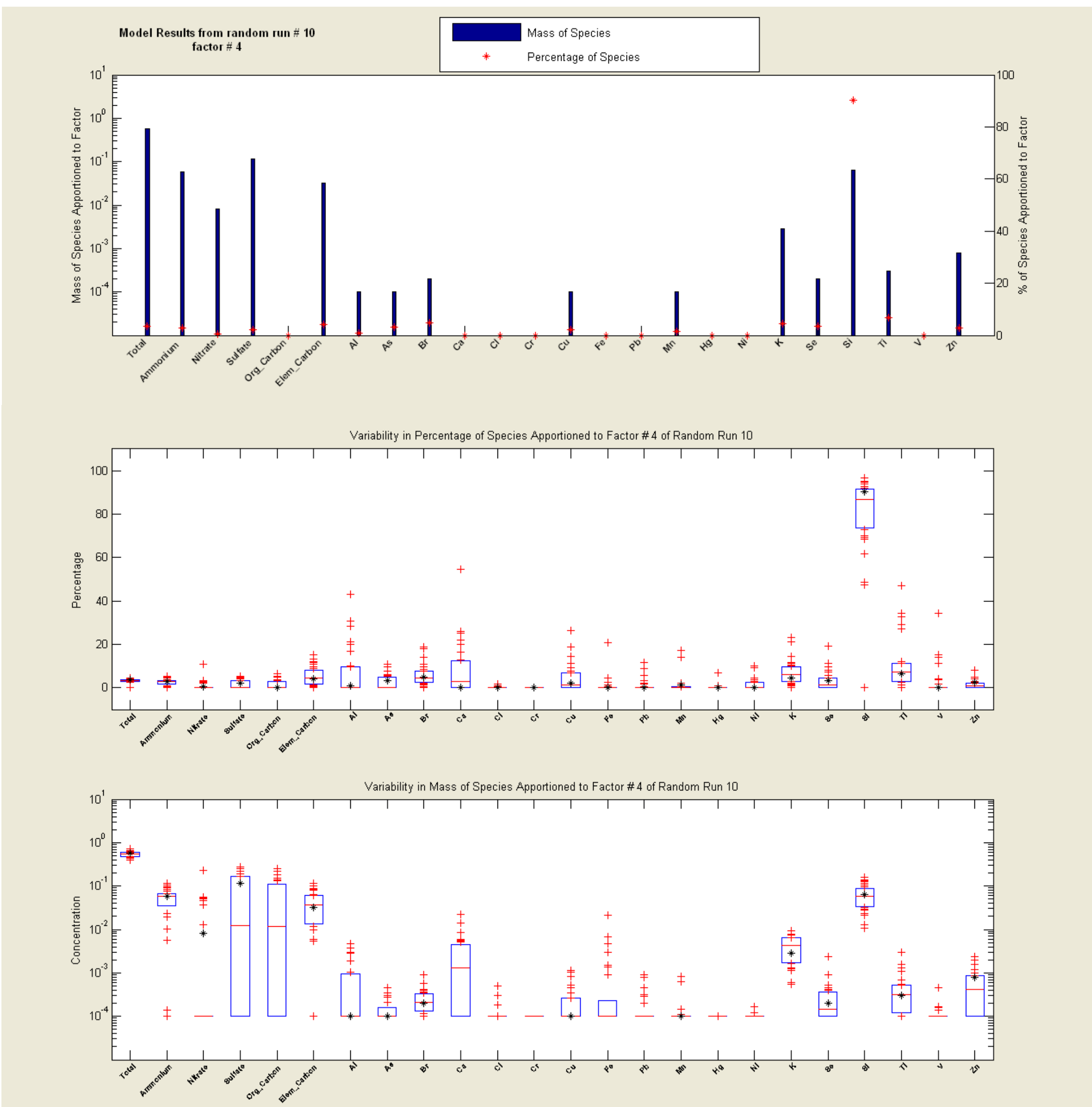


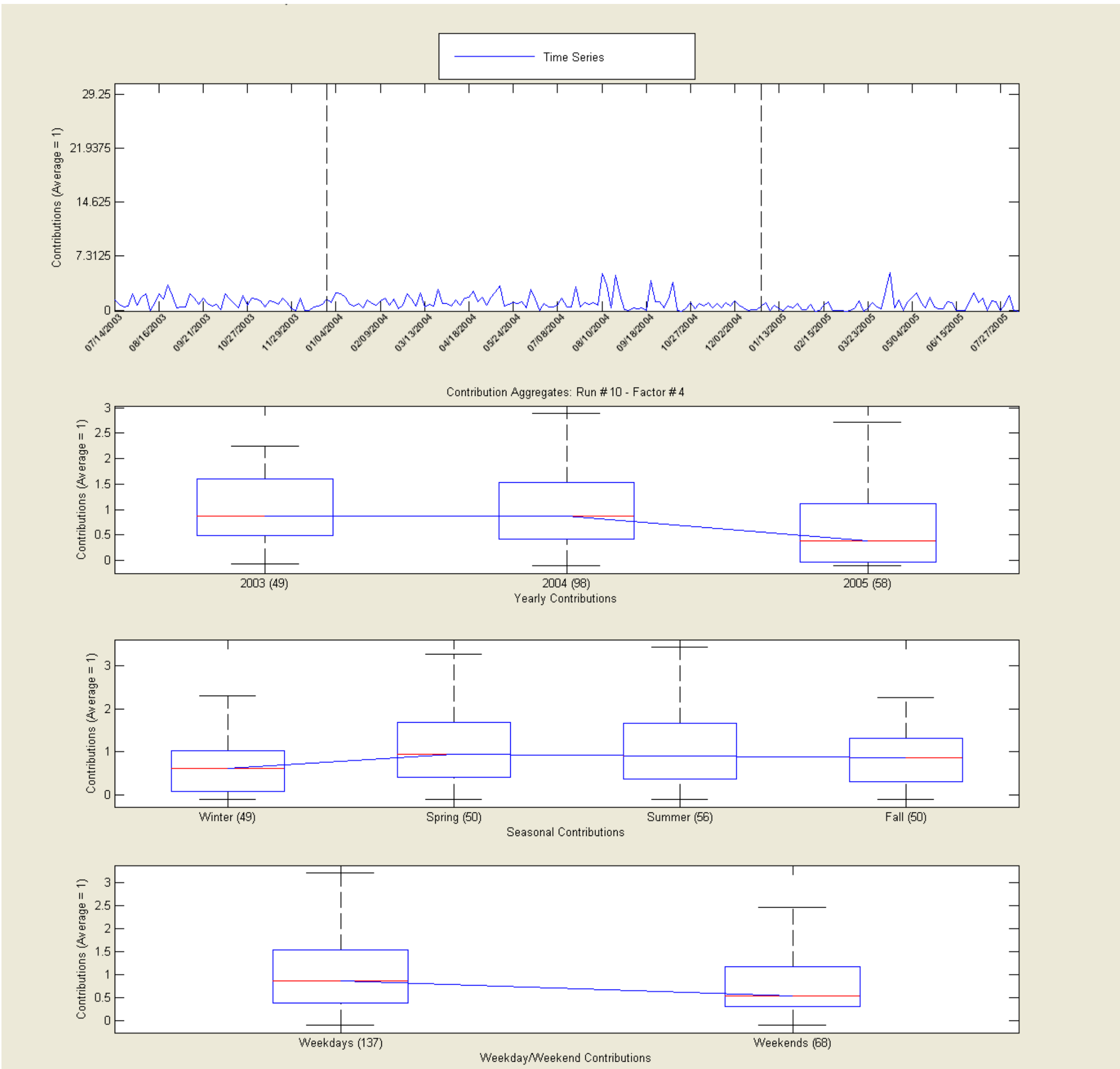


Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 3
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 4: Airborne Crustal (Silicon-Rich)

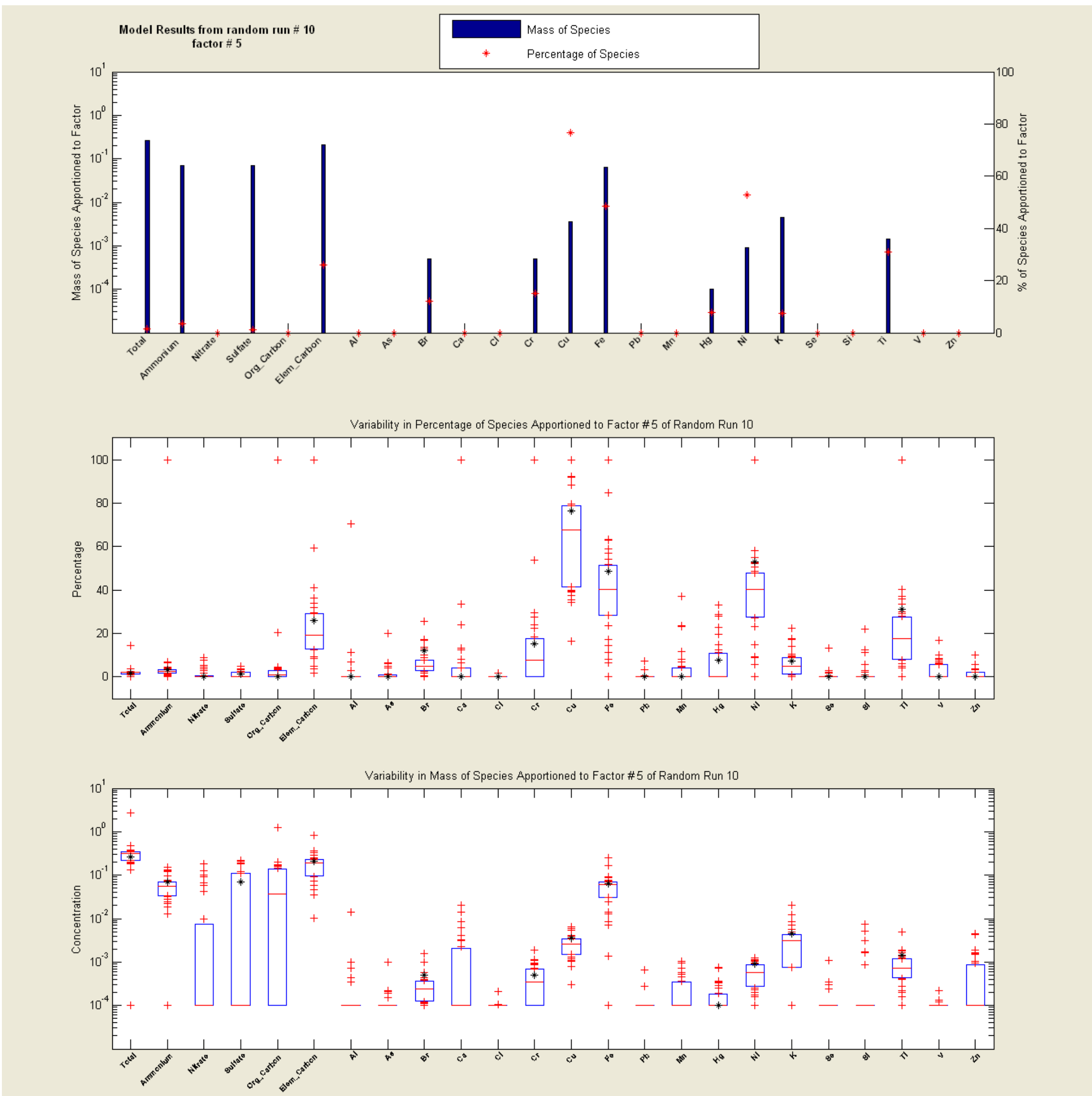
Crustal elements include aluminum, calcium, iron, silicon, and titanium. These elements are the basic make-up of fine airborne soil. Factor 4 is best attributed as the silicon portion of airborne crustal component. Contributions are slightly higher during weekdays, possibly due to traffic forcing up road and crustal dust. Springtime contributions are also slightly higher. Some silicon may be also due to primary power plant emissions.

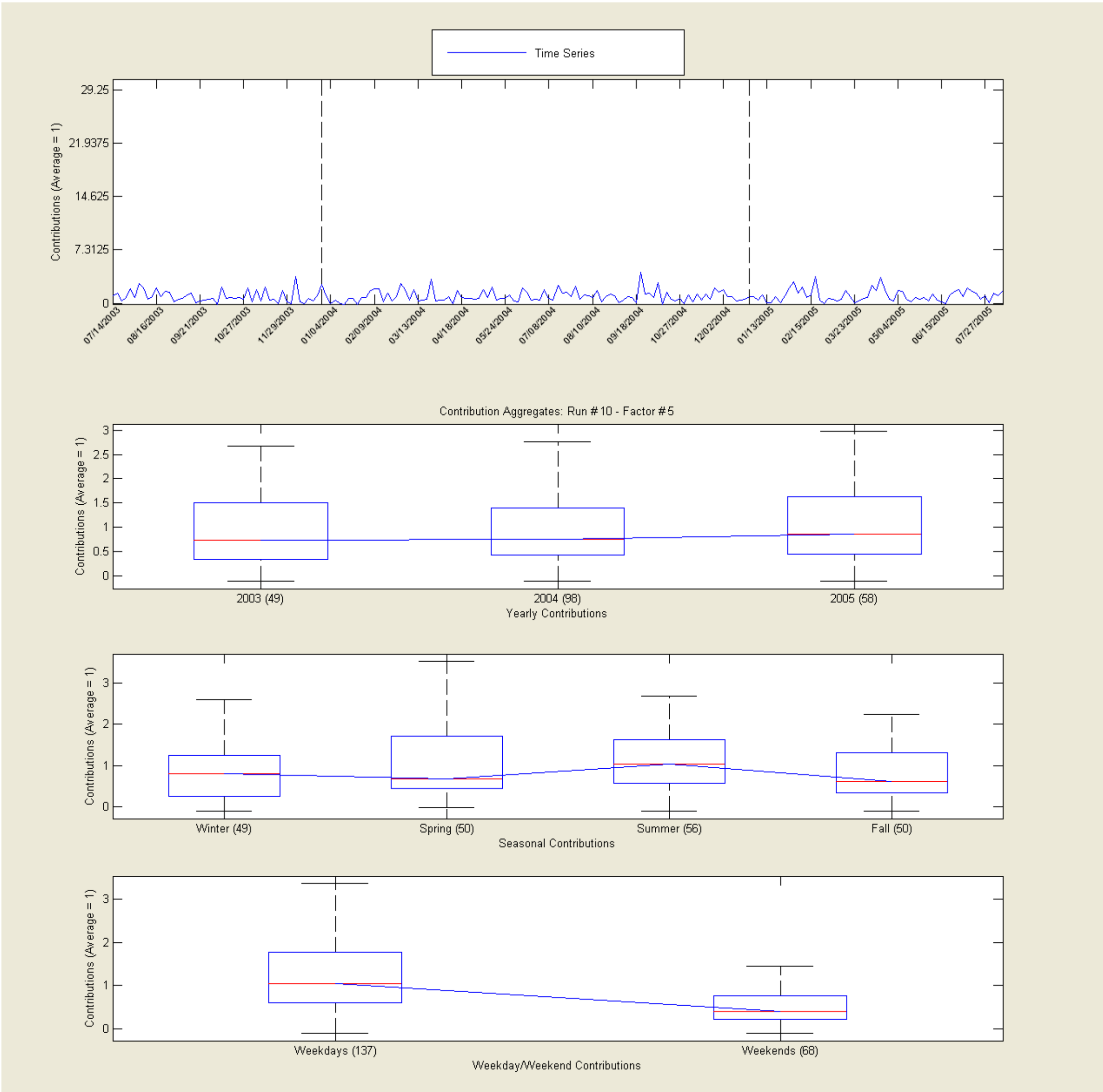



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 4
Contributions (Average = 1)
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Contributions (Average = 1)
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Contributions (Average = 1)
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 5: Diesel Vehicles + Miscellaneous Road Dust

Factor 5 contains a large percentage of elemental carbon with high weekday contributions. Large percentages of copper and nickel are also present, along with crustal iron and titanium. These trace elements have been grouped as miscellaneous road dust.

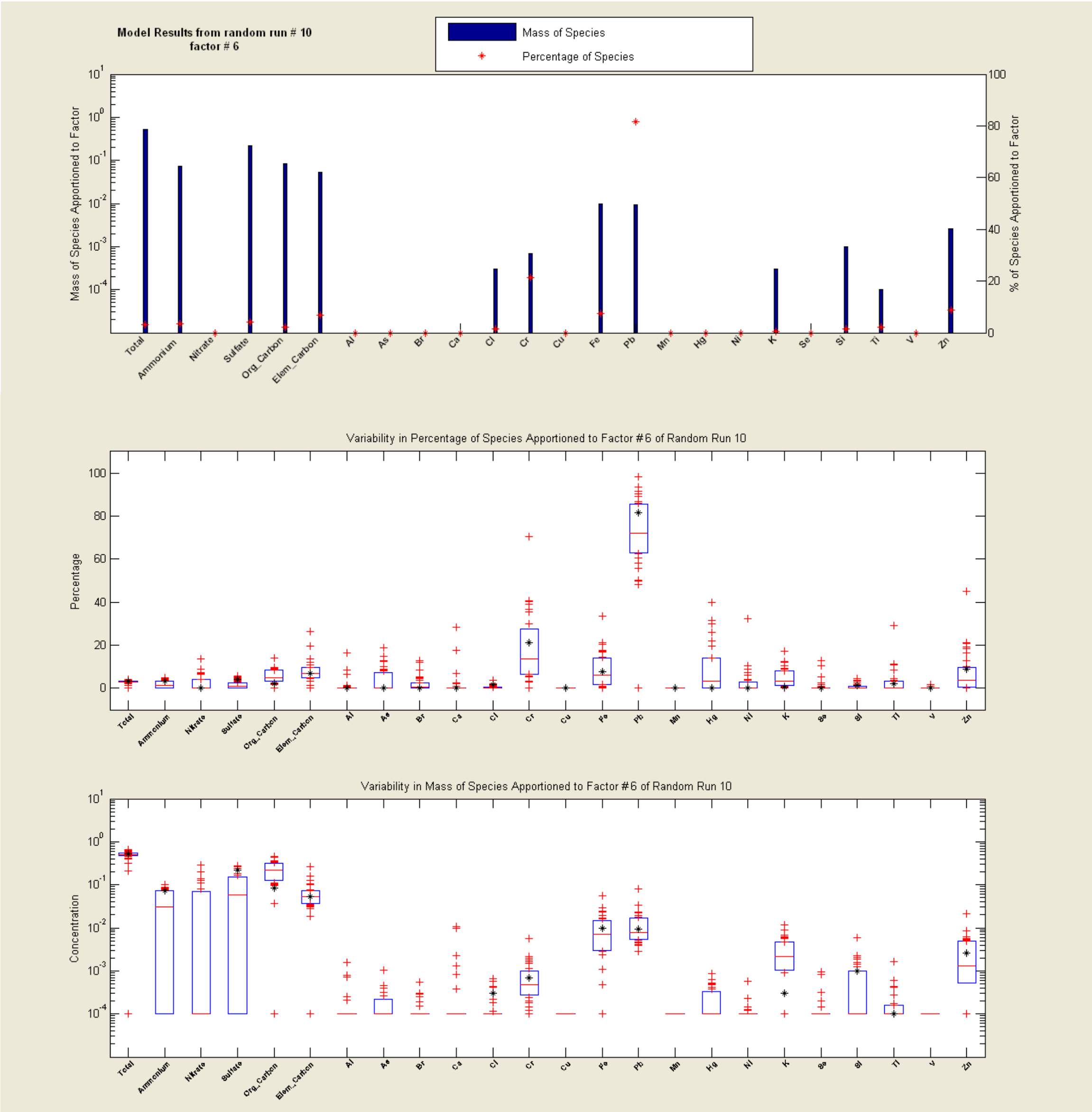


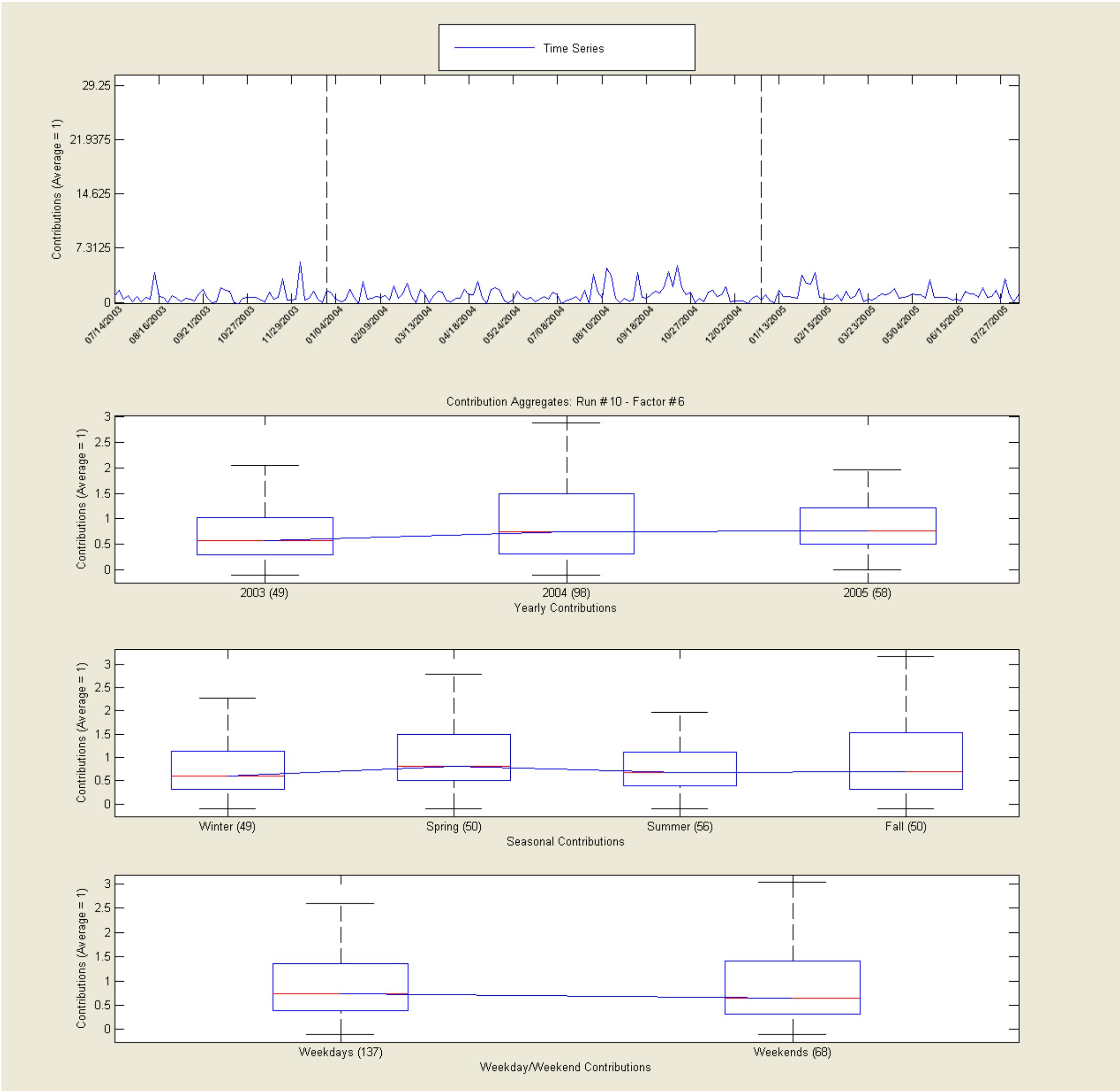


Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 5
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 6: Incinerators

Factor 6 has a high percentage of lead, along with significant percentages of carbons and zinc. The carbon ratios are different from most vehicle profiles, and there is little variation between weekday/weekend contributions. Source factors with these characteristics are associated with municipal waste incinerators and sewage sludge incinerators.

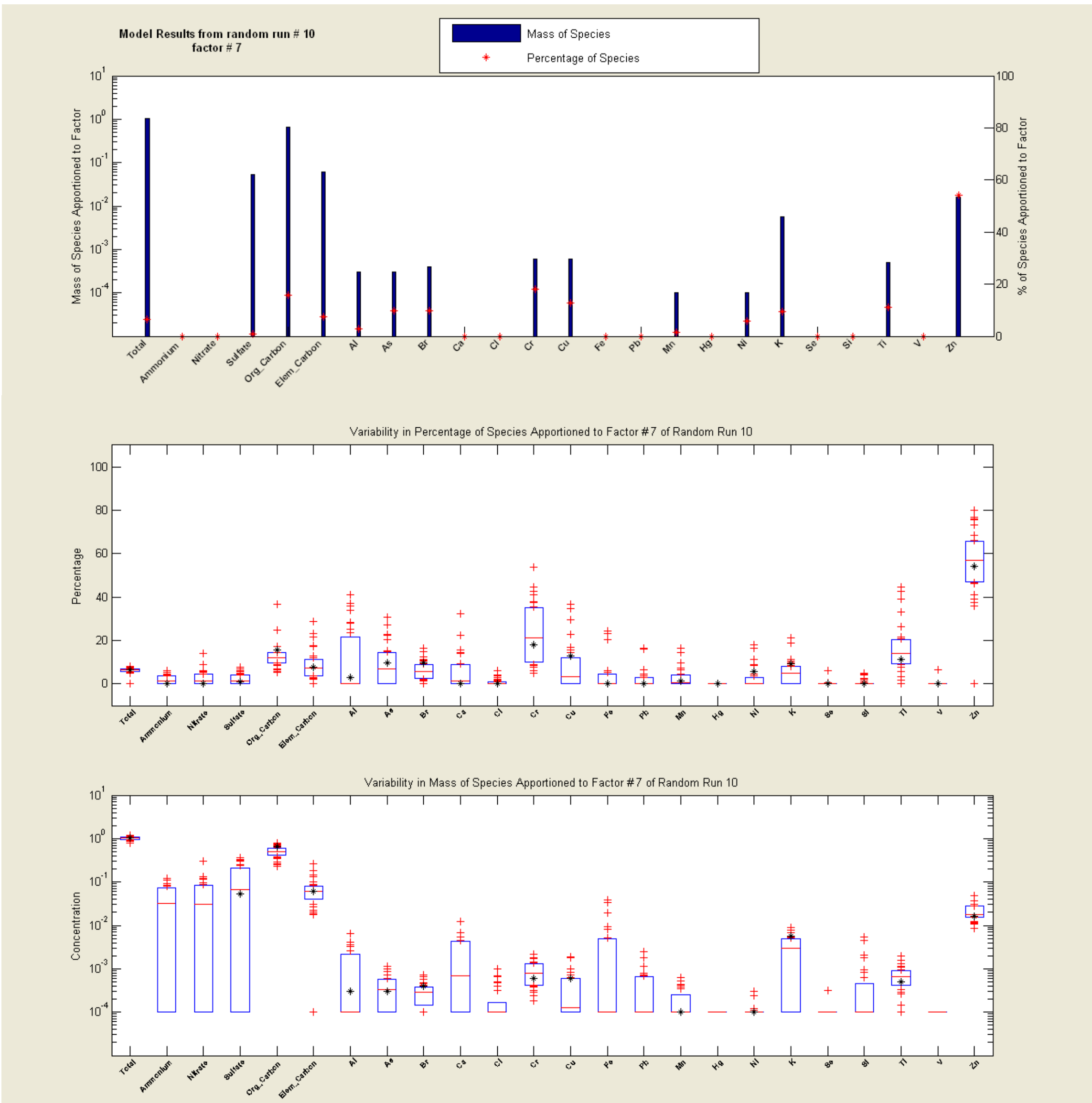


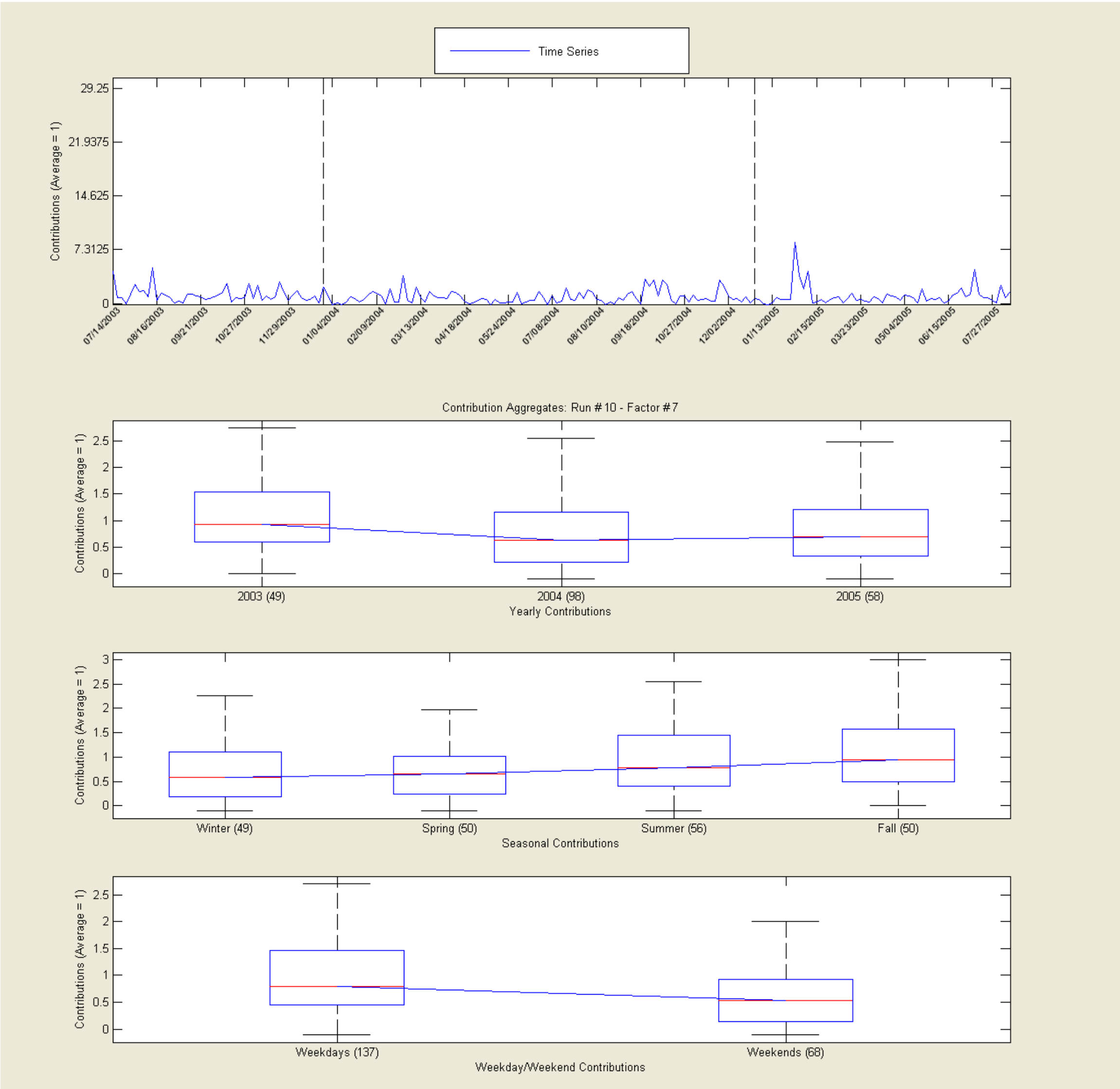


Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 6
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 7: Gasoline Vehicles + Tire Wear

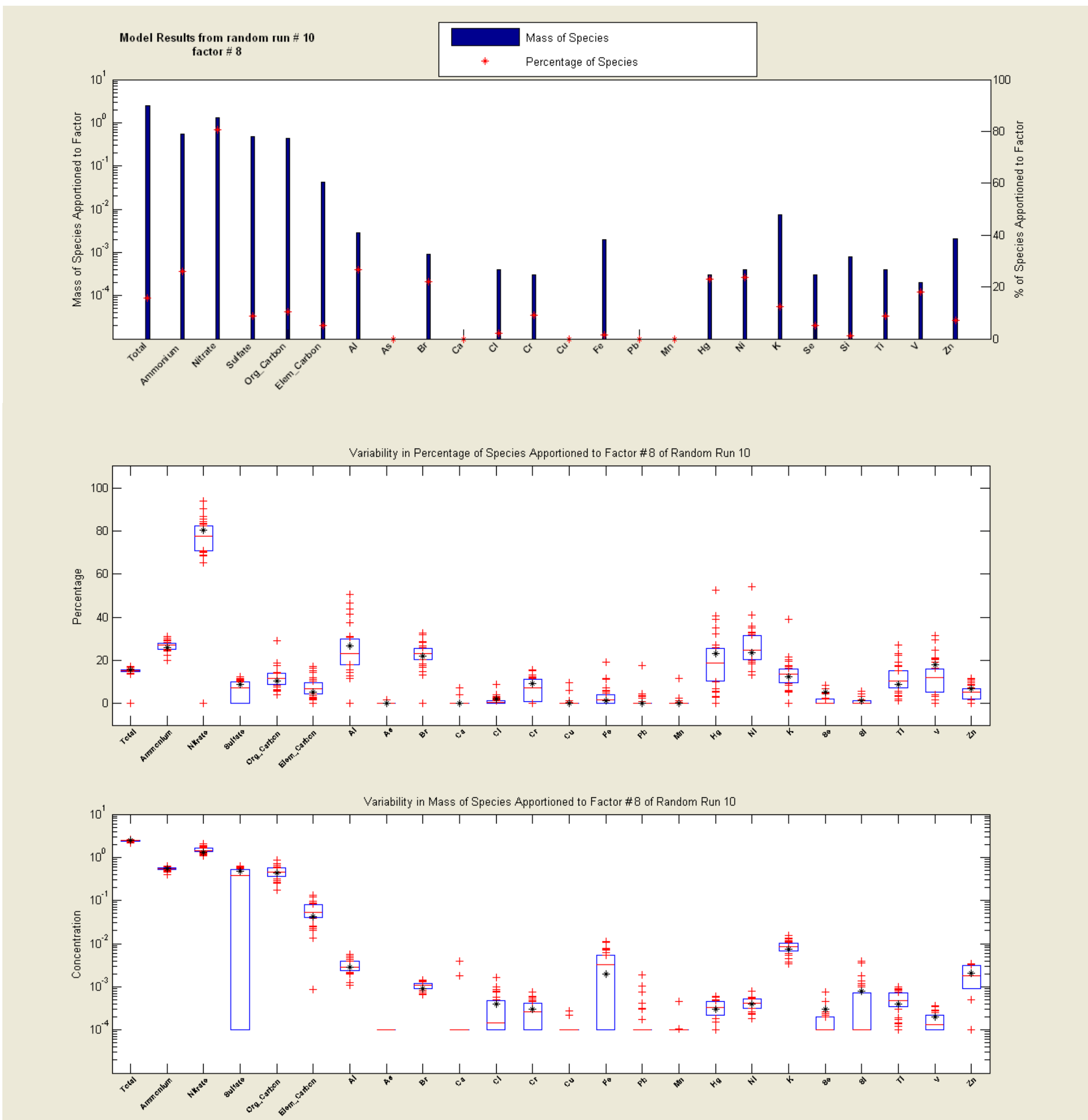
Factor 7 has high percentages of organic and elemental carbons and zinc, showing high contributions on weekdays. The carbon ratio is indicative of gasoline vehicles, and zinc is associated with tire wear from vehicles. Minor concentrations of other trace elements are also present.

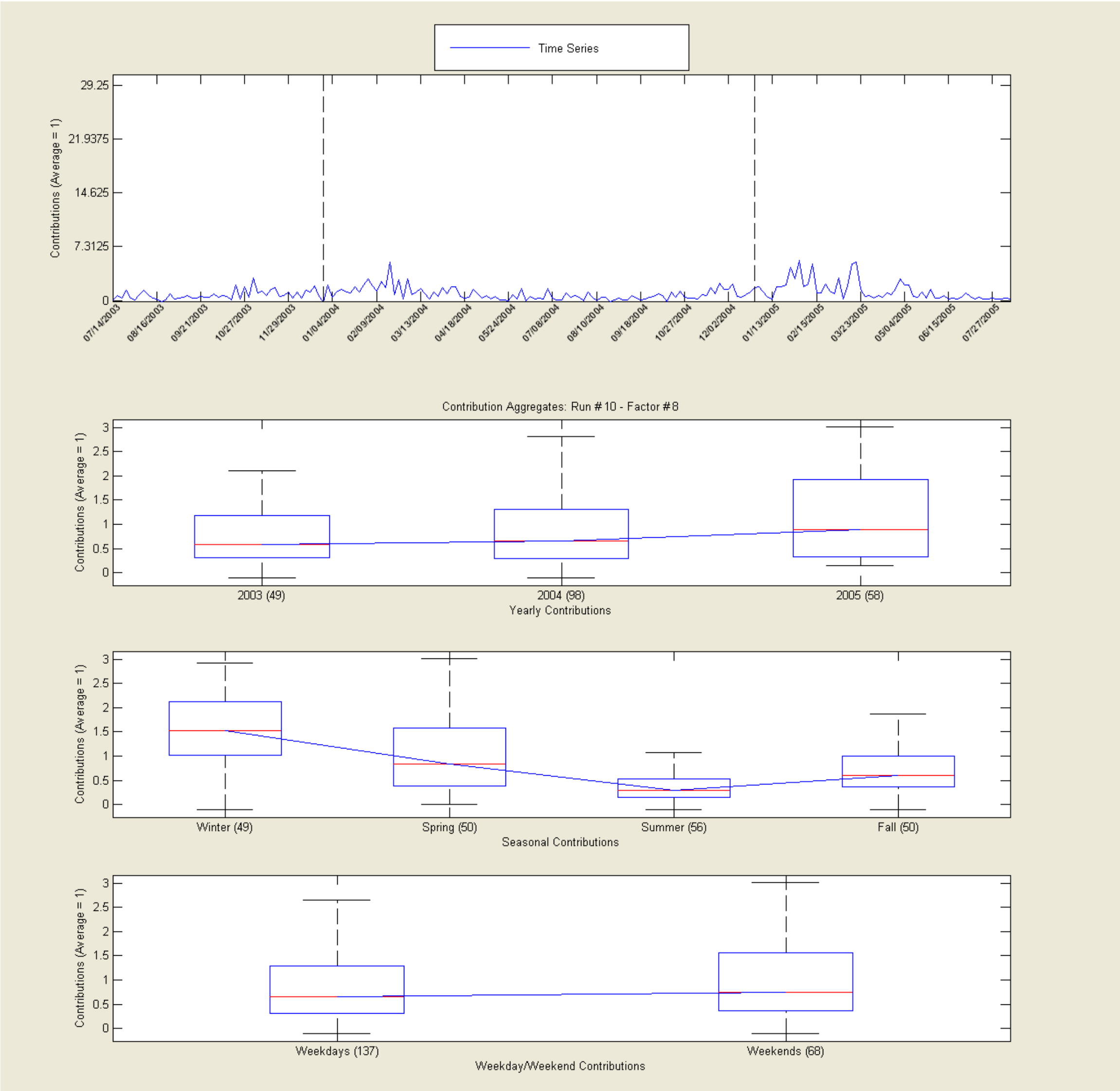



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 7
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

<u>Lawrenceville Source Factor 8</u>: Secondary Ammonium Nitrate

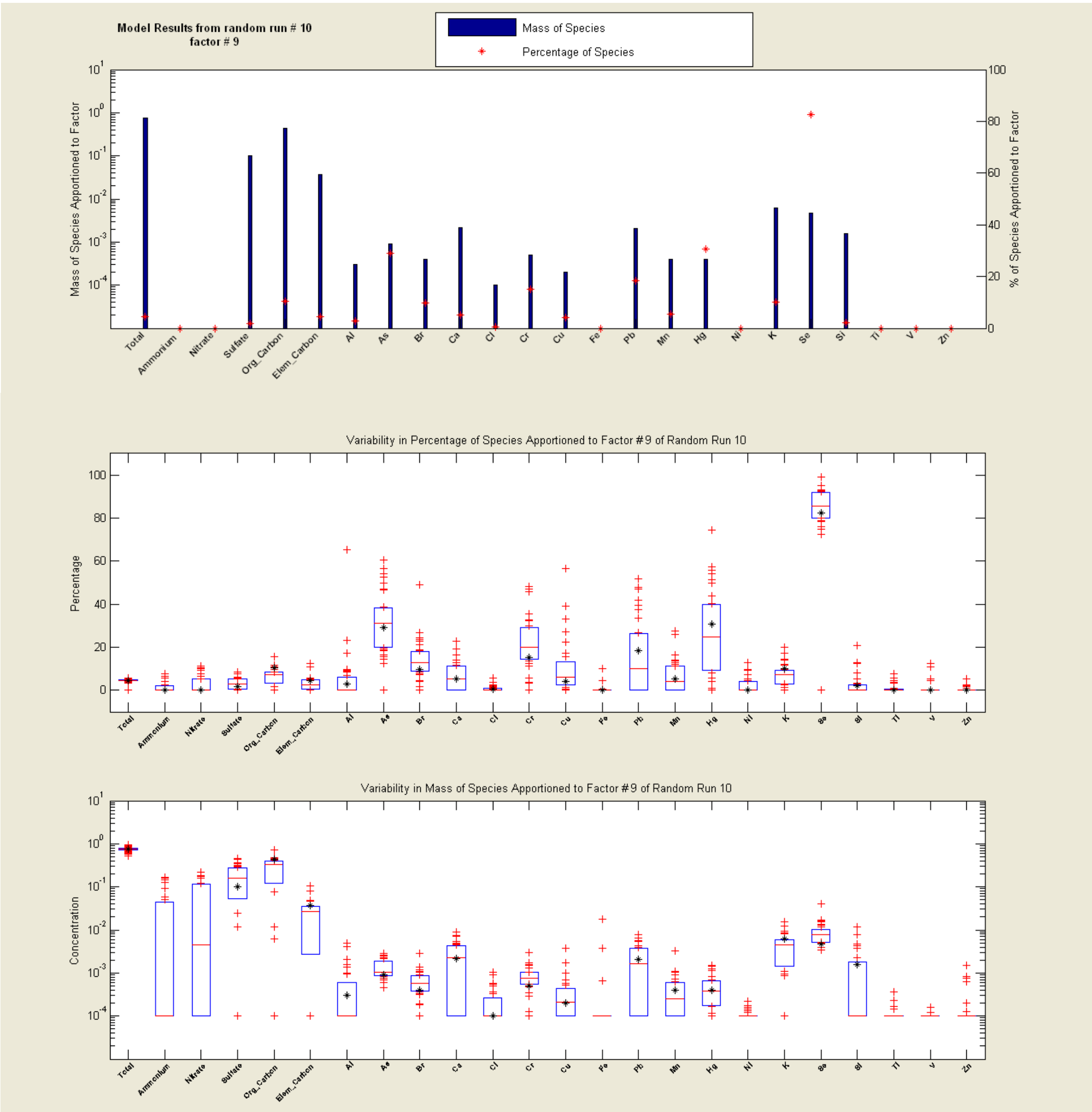
Factor 8 is the majority of secondary ammonium nitrate at the monitor, dominant in cold weather. Nitrate is a secondary species created by upwind NOx sources such as fossil fuel-fired boilers. Other species such as carbons and aluminum are grouped with this factor as well, perhaps representing cold-weather fractions of their total contribution.

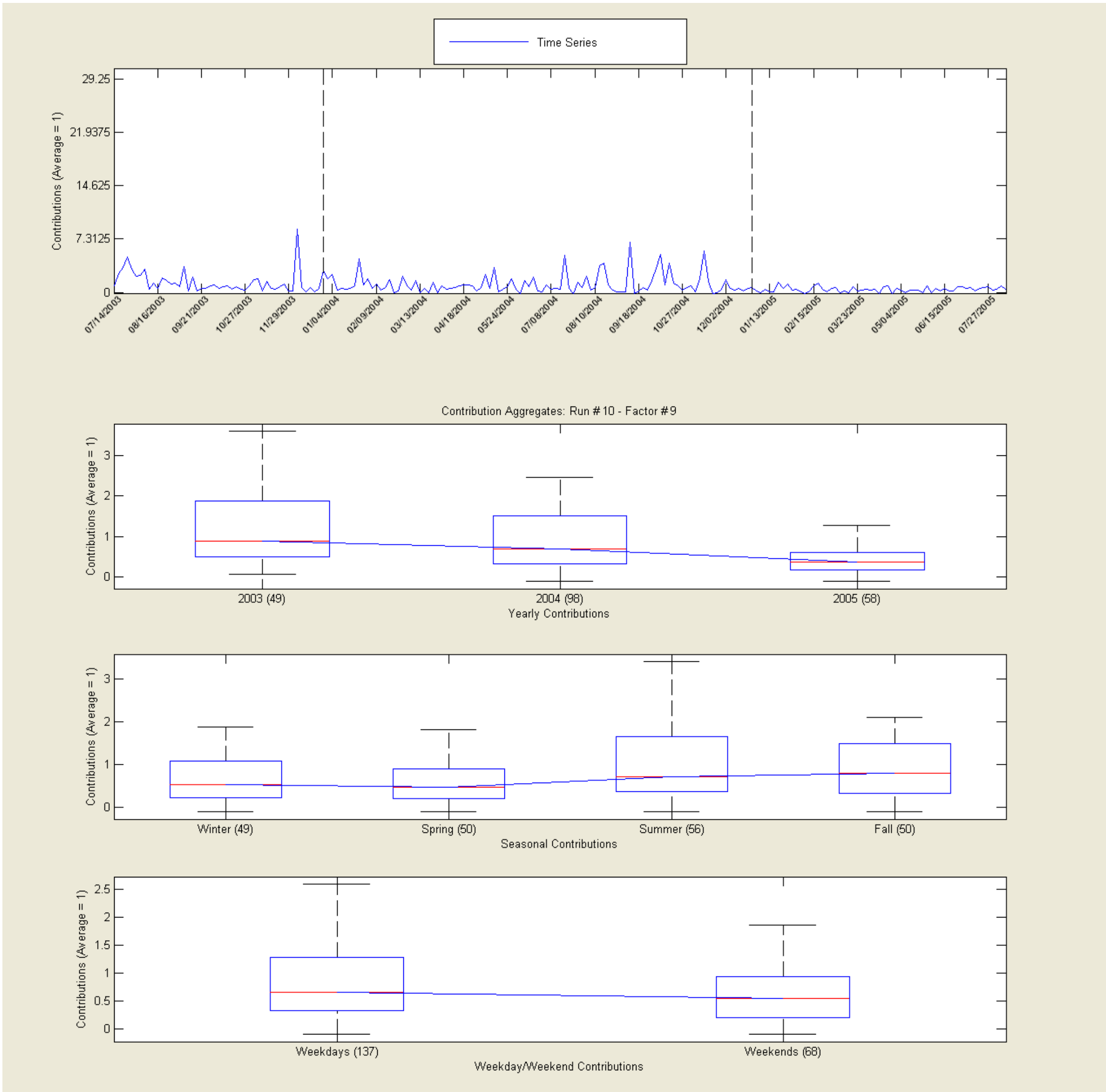



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 8
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

<u>Lawrenceville Source Factor 9</u>: Gasoline Vehicles + Selenium-Rich Industrial

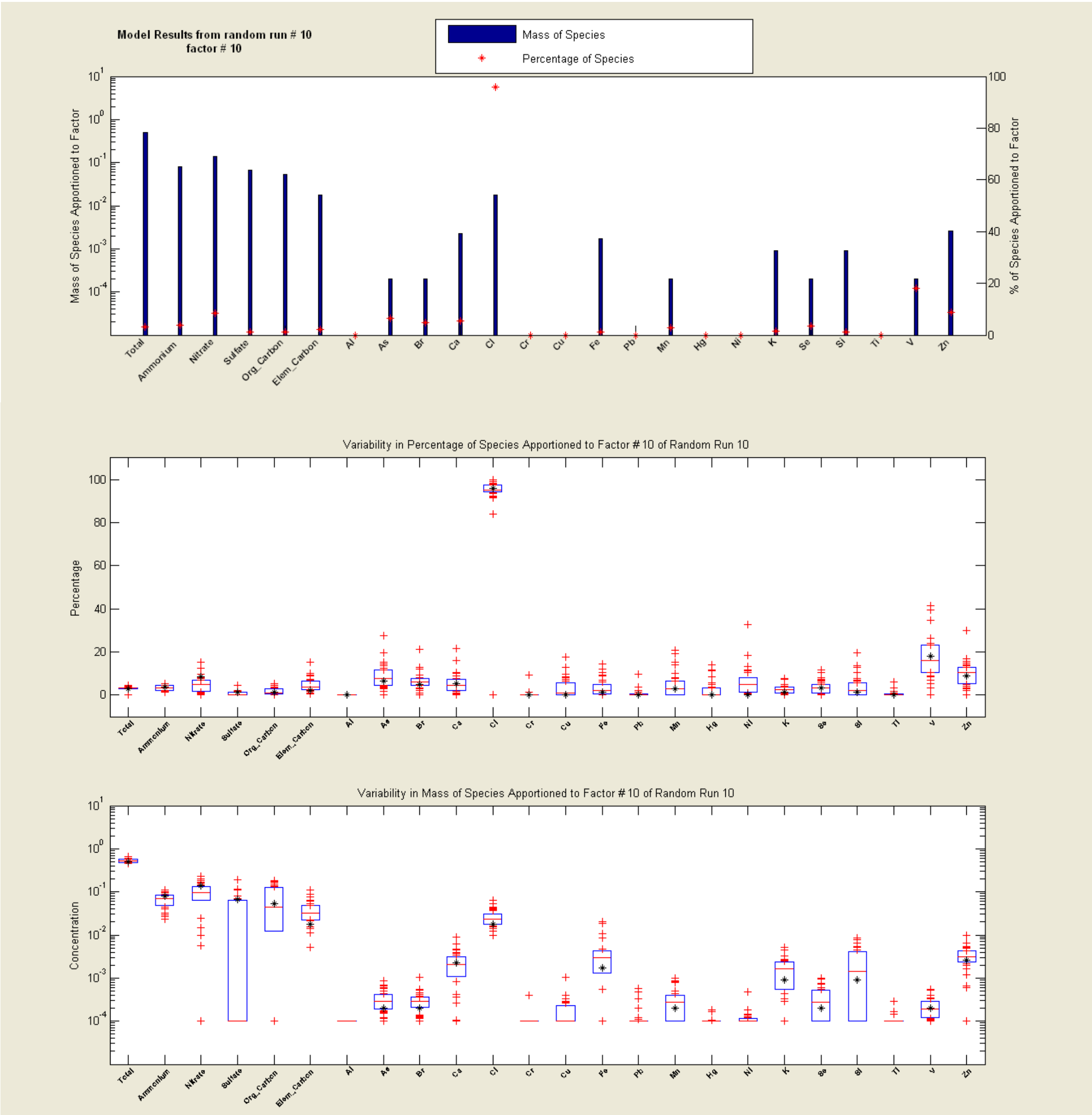
Factor 9 shows strong weekday organic and elemental carbon concentrations, indicating light-duty gasoline vehicle emissions. Also peaking with this factor is selenium, perhaps originating from the same area as the vehicle emissions. Selenium is sometimes associated with primary coal-fired boiler emissions but is also present in some glass manufacturing emissions. Total factor emissions decreased noticeably in 2005.

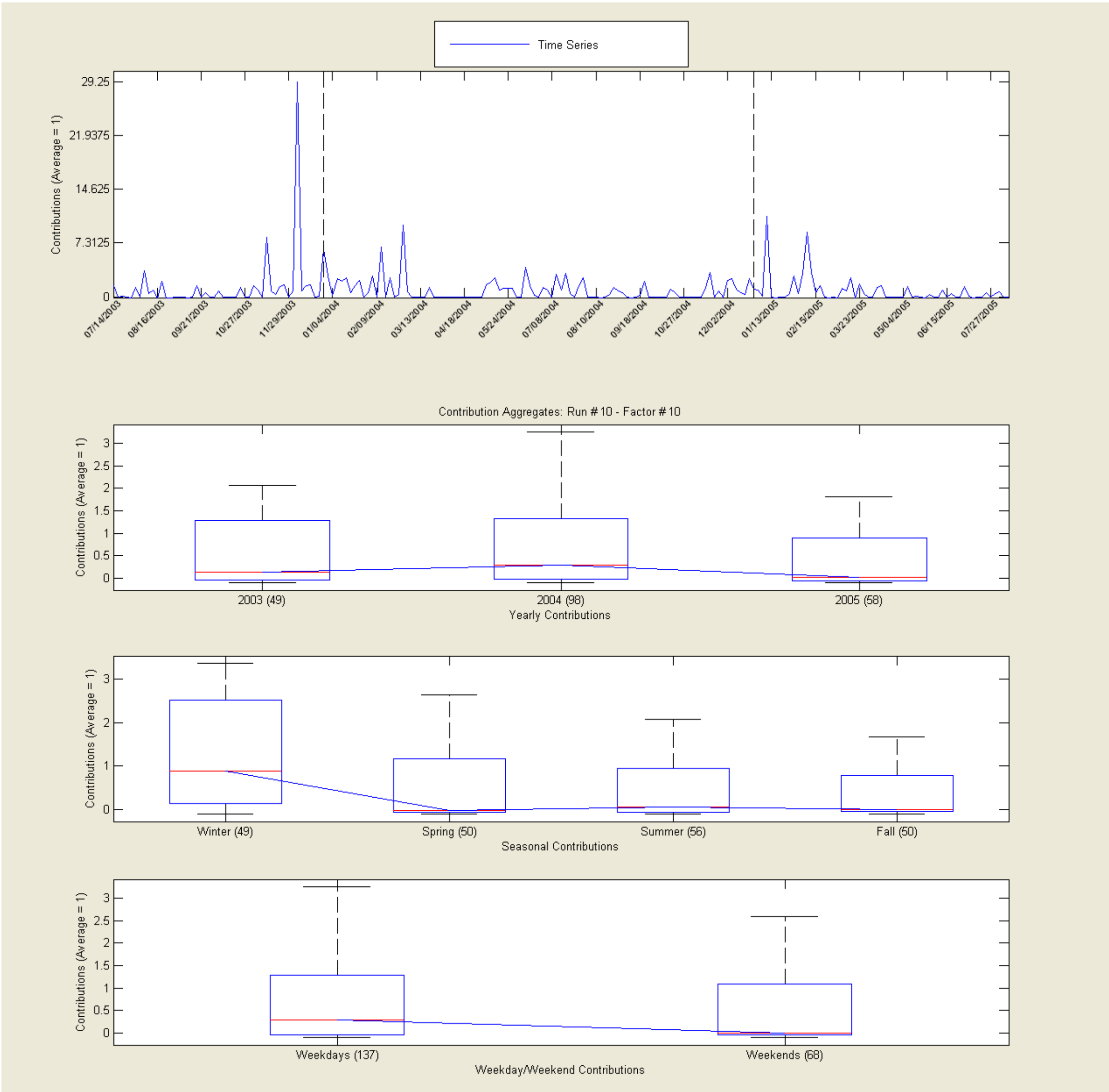



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 9
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 10: Road Dust (Road Salt-Rich)

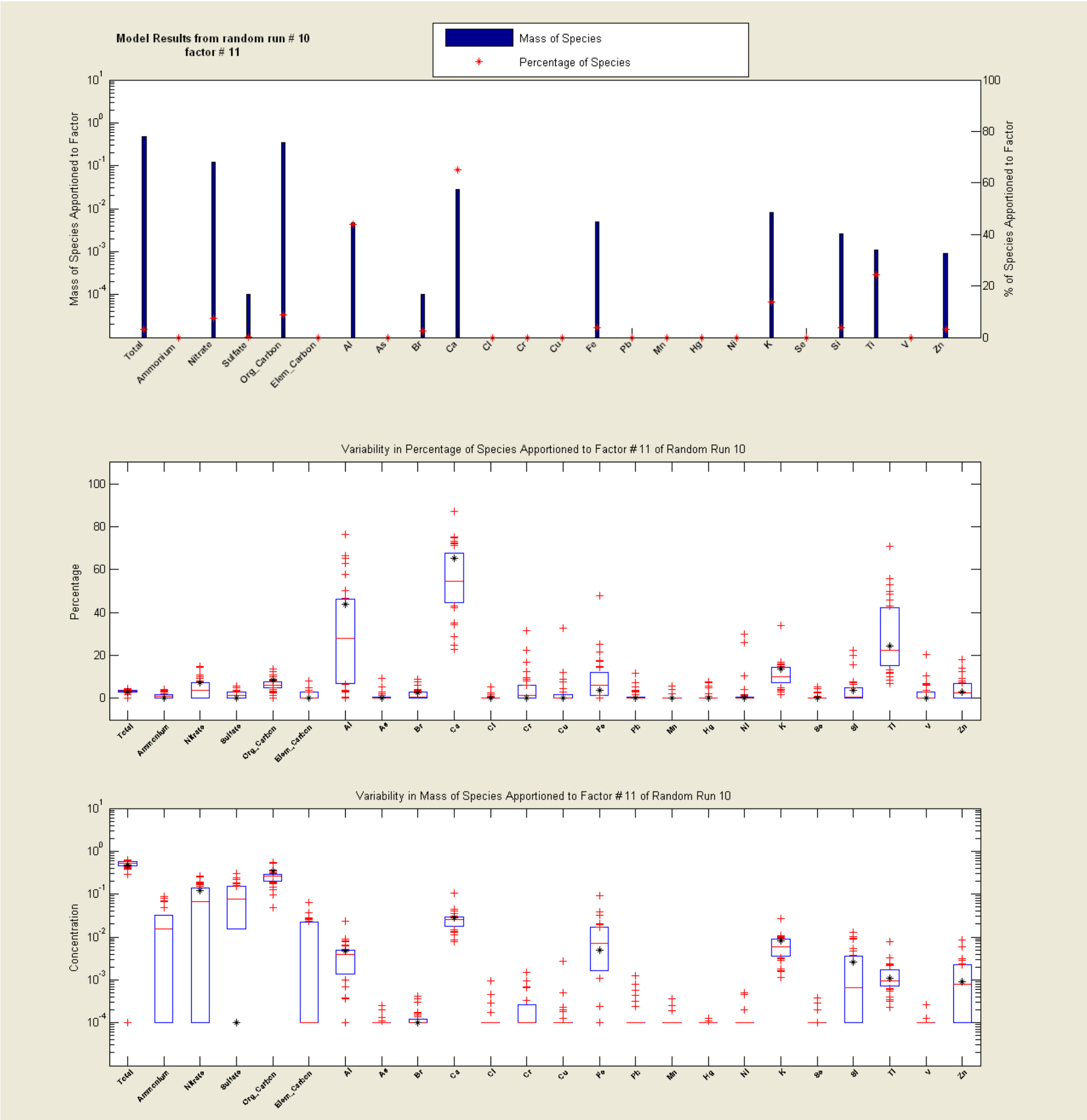
Factor 10 contributes almost all of the chlorine at Lawrenceville. Since it peaks on winter weekdays, it is likely due to airborne road salt along with other miscellaneous road dust compounds.

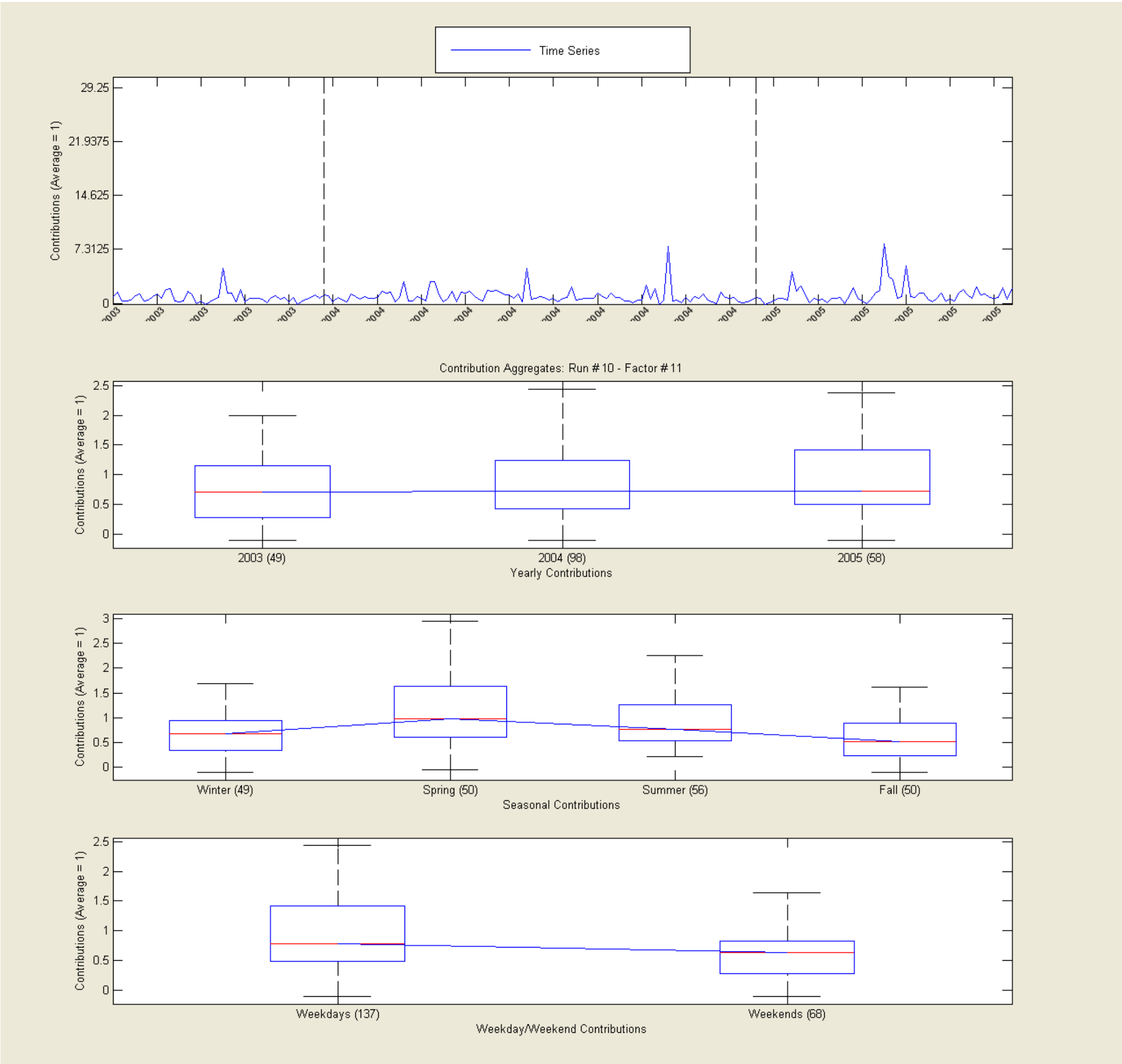



Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
07/14/2003
08/16/2003
09/21/2003
10/27/2003
11/29/2003
01/04/2004
02/09/2004
03/13/2004
04/18/2004
05/24/2004
07/08/2004
08/10/2004
09/18/2004
10/27/2004
12/02/2004
01/13/2005
02/15/2005
03/23/2005
05/04/2005
06/15/2005
07/27/2005
Contribution Aggregates: Run # 10 - Factor # 10
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

Lawrenceville Source Factor 11: Airborne Crustal (Other)

Like Factor 4 (silicon-rich crustal), Factor 11 is composed of crustal elements and is higher on weekdays and in spring. Aluminum, calcium, and titanium show the highest percentages for this factor.




Time Series
Contributions (Average = 1)
29.25
21.9375
14.625
7.3125
0
Contribution Aggregates: Run # 10 - Factor # 11
2003 (49)
2004 (98)
2005 (58)
Yearly Contributions
Winter (49)
Spring (50)
Summer (56)
Fall (50)
Seasonal Contributions
Weekdays (137)
Weekends (68)
Weekday/Weekend Contributions

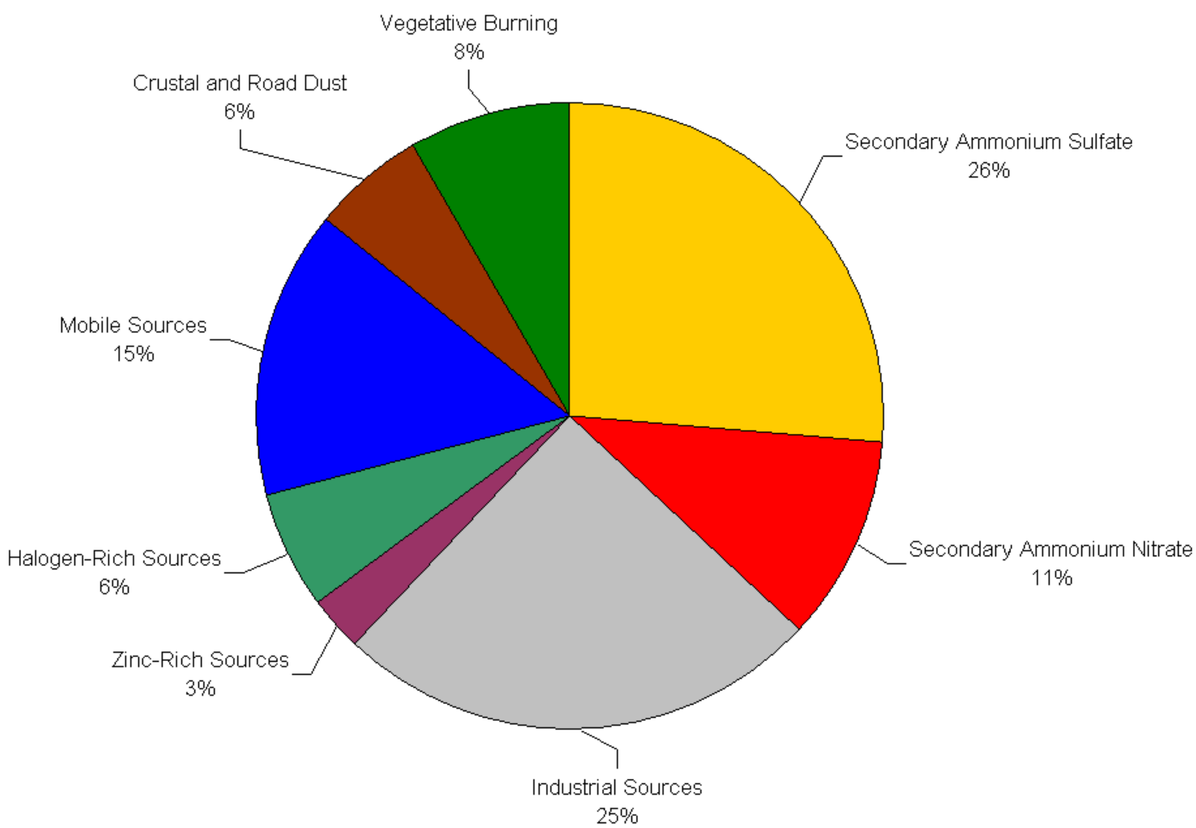
5. Modeled Results: Liberty

A total of 91 Liberty samples were input into the model. The best model runs were able to resolve 12 source factors. The following trace elements were down weighted in the model runs: Al, As, Cr, Hg, Mn, Ni, Ti, and V.

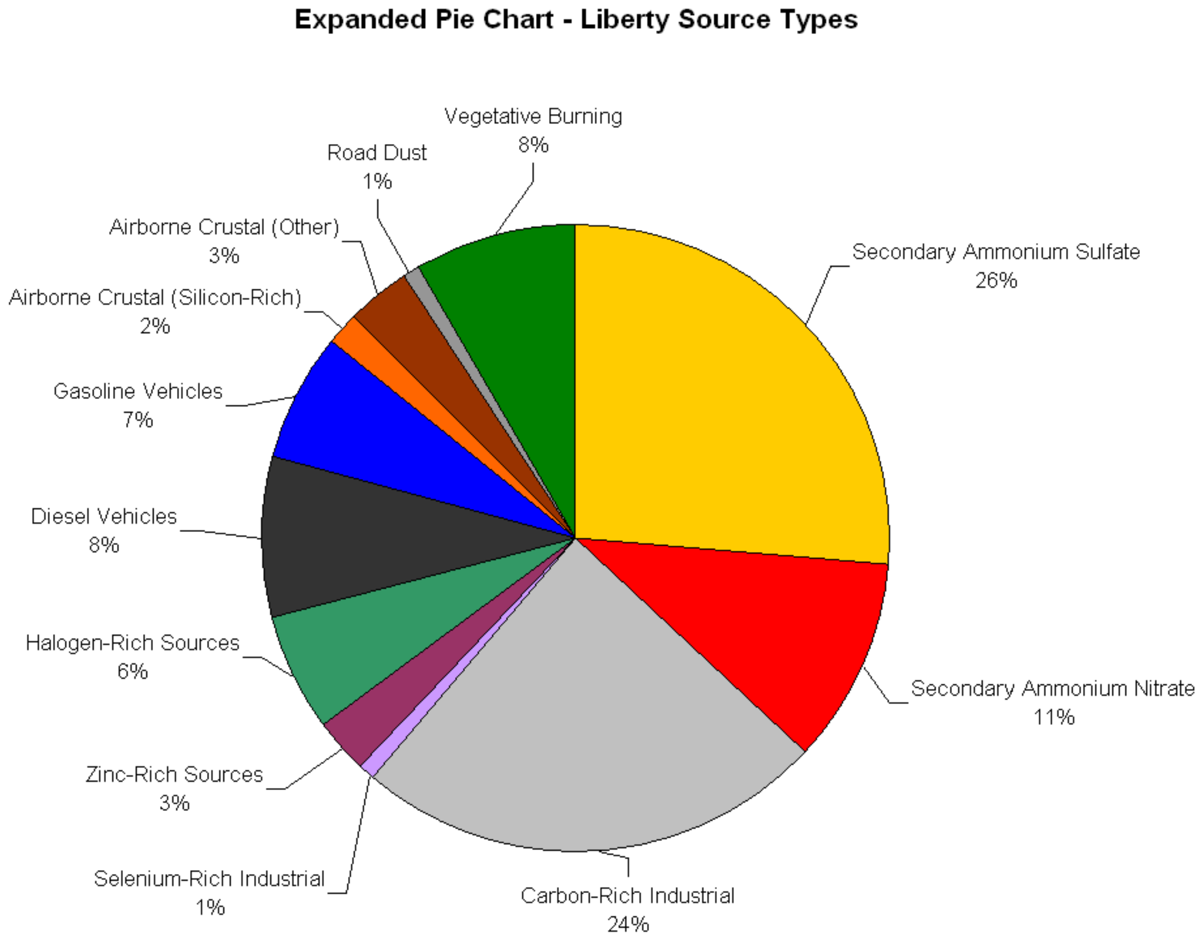
In addition to Fourth of July samples removed on account of trace element outliers, the samples taken on 2/3/2005 and 5/10/2005 were removed from the modeling. An exceptional event was identified on these dates in which crustal elements (geological dust, or airborne soil) were higher than the norm.

Liberty results revealed many of the same source factors that were evident at Lawrenceville, while also indicating additional sources specific to the Liberty area. A simplified pie chart of the best-guess source types (by percentage of summed concentrations) is shown below.

Simplified Pie Chart - Liberty Source Types



An expanded pie chart of the source types is also shown below.



Liberty source factor profiles and associated source types are given in the table below. Species concentrations that were considered to be indicators of the specific source types are shown in bold.

	Secondary Sulfate/Nitrate		Industrial Sources		Zinc-Rich Sources	Halogen-Rich Sources	Mobile Sources		Crustal and Road Dust			Vegetative Burning
	Secondary Ammonium Sulfate	Secondary Ammonium Nitrate	Carbon-Rich Industrial	Selenium-Rich Industrial	Zinc-Rich Sources	Halogen-Rich Sources	Diesel Vehicles	Gasoline Vehicles	Airborne Crustal (Silicon-Rich)	Airborne Crustal (Other)	Road Dust	Vegetative Burning
Source Factor	3	11	2	8	7	6	4	1	5	10	9	12
Total	4.8529	1.4586	4.7404	0.2820	0.0000	0.9354	1.1247	1.4644	0.3113	0.5434	0.6755	2.0641
Ammonium	**0.8185**	**0.4406**	0.3981	0.0341	0.0672	0.1845	0.1705	0.1142	0.0474	0	0	0
Nitrate	0.1455	**0.9814**	0	0.0040	0	0.0369	0.1301	0	0	0	0	0.0872
Sulfate	**2.8271**	0.3140	0.0268	0.0491	0.3188	0.2365	0.3232	0.4012	0	0.1023	0.0410	0.2162
Org_Carbon	0.4784	0	**2.0157**	0.0205	0.0526	0.2387	0.3288	**0.5657**	0.1092	0.3292	0.0621	**0.9952**
Elem_Carbon	0.0508	0	**1.5418**	0	0	0.0340	**0.3706**	0	0.0383	0.0379	0	0.0421
Al	0.0039	0	0	0	0	0	0	0	0.0006	**0.0031**	0.0010	0
As	0.0002	0	**0.0030**	0	0.0013	0	0	0	0.0002	0	0	0.0004
Br	0	0.0007	**0.0057**	0.0002	0.0004	**0.0020**	0	0	0	0.0004	0.0006	0
Ca	0	0	0	0.0008	0.0003	0.0022	0	0.0035	0.0030	**0.0244**	0	0
Cl	0	0.0024	0	0.0036	0	**0.2813**	0.0001	0	0.0017	0	0.0016	0.0082
Cr	0.0001	0	0	0	0	0	0.0002	0	0	0.0004	0.0009	0.0004
Cu	0	0	0	0	0	0	0.0004	0.0044	0	0.0002	0	0
Fe	0.0028	0	0.0099	0.0006	0.0029	0	0	0.0156	0.0017	0.0048	**0.0384**	0
Pb	0.0002	0	0	0.001	0	0.0024	0.0095	0.0004	0	0	0	0.0004
Mn	0	0.0004	0	0	0.0007	0	0	0.0001	0	0	0.0012	0.0003
Hg	0	0.0001	0	0	0.0002	0.0006	0	0.0017	0.0005	0	0	0
Ni	0.0001	0	0	0	0	0.0001	0.0001	0	0	0	0.0009	0.0002
K	0	0.0041	0	0.0003	0.0035	0.0020	0	0.0045	0.0031	**0.0129**	0.0005	**0.0226**
Se	0.0002	0	0.0009	**0.0079**	0.0003	0	0.0007	0	0	0.0002	0	0.0004
Si	0	0	0	0	0	0.0090	0.0084	0	**0.0728**	0	0	0
Ti	0.0001	0.0001	0	0.0002	0	0.0001	0	0.0003	0.0001	**0.0019**	0.0005	0
V	0.0002	0.0002	0	0.0001	0	0	0	0.0004	0.0001	0	0.0001	0
Zn	0	0.0012	0.0005	0	**0.0144**	0.0013	0.0098	0	0	0.0004	0	0
SUM (exc. total)	*4.3281*	*1.7452*	*4.0024*	*0.1224*	*0.4626*	*1.0316*	*1.3524*	*1.1120*	*0.2787*	*0.5181*	*0.1488*	*1.3736*

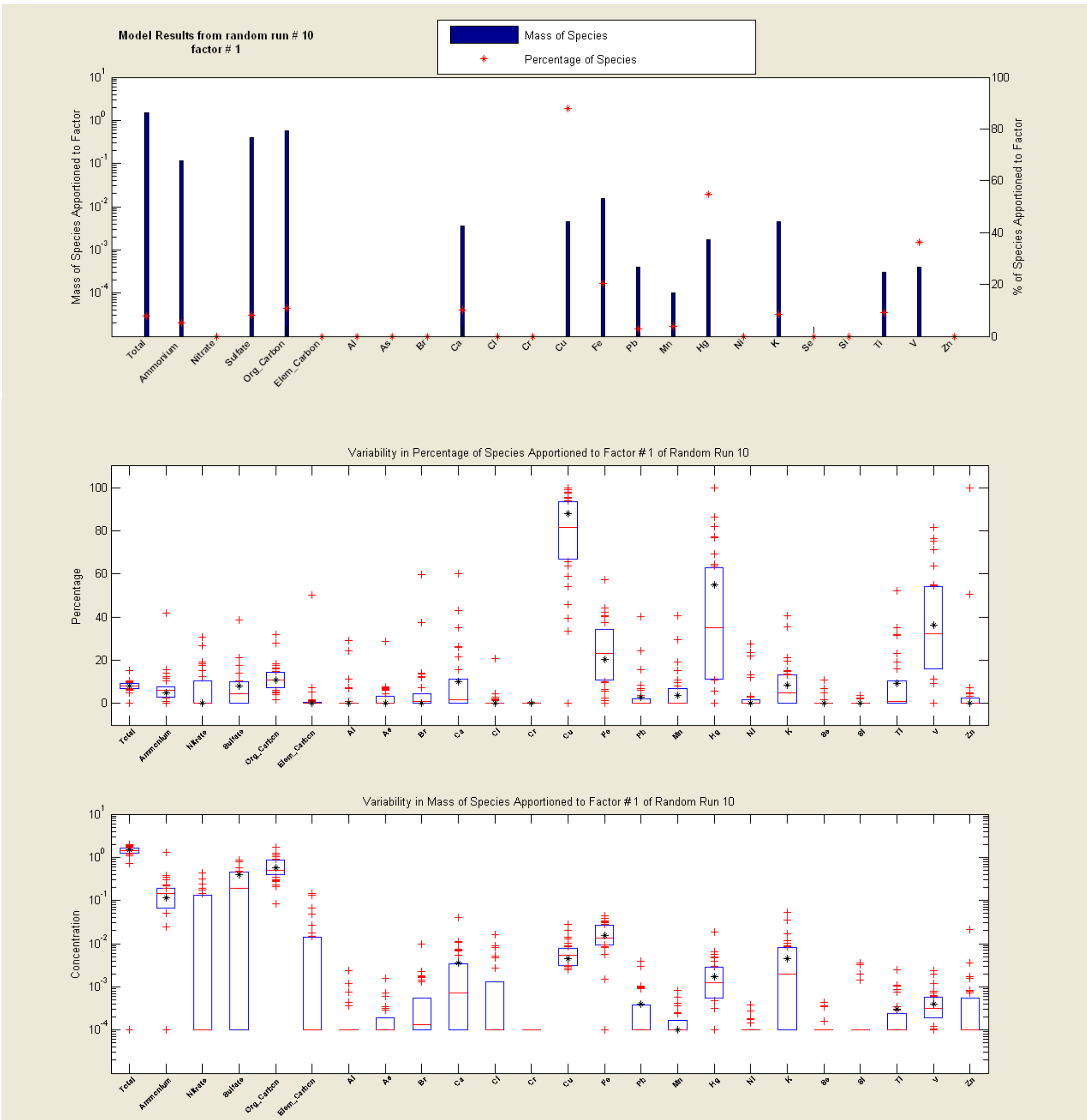
Analysis and graphical results for each factor are given on subsequent pages. Graphical results are copied directly from the model output and include the following for each factor:

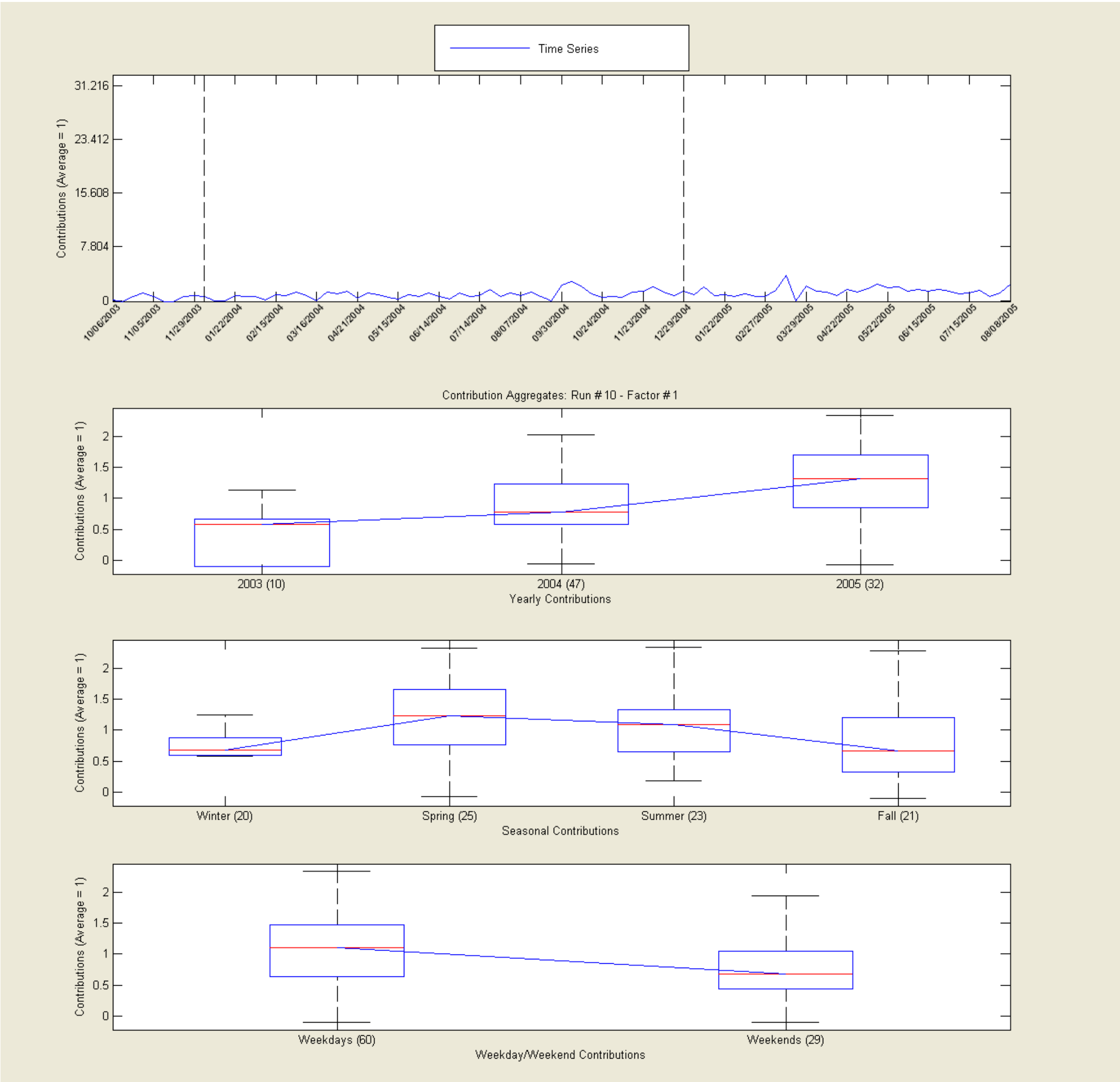
- Concentration by value and percentage of total for each species
- Variability (bootstrapping) for each concentration and percentage
- Time series plot by overall factor concentration
- Contribution aggregates according to season and day of the week

Note: Factors and runs are generated randomly by PMF and are not ranked according to any one species.

<u>Liberty Source Factor 1</u>: Gasoline Vehicles

Factor 1 is high in weekday organic carbon, indicating light-duty gasoline vehicle emissions. Copper, mercury, vanadium, and copper also have high percentages with this factor.

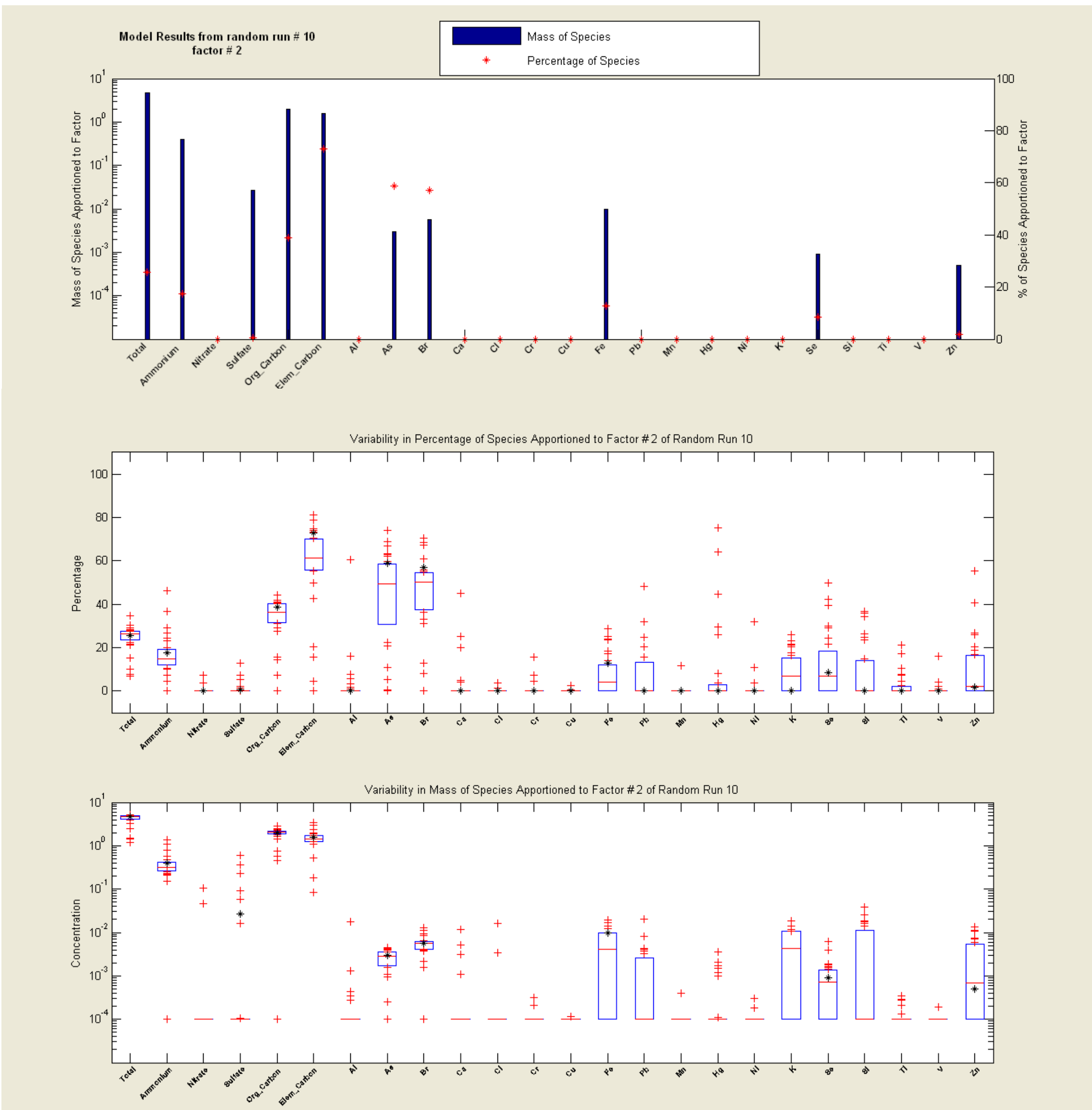


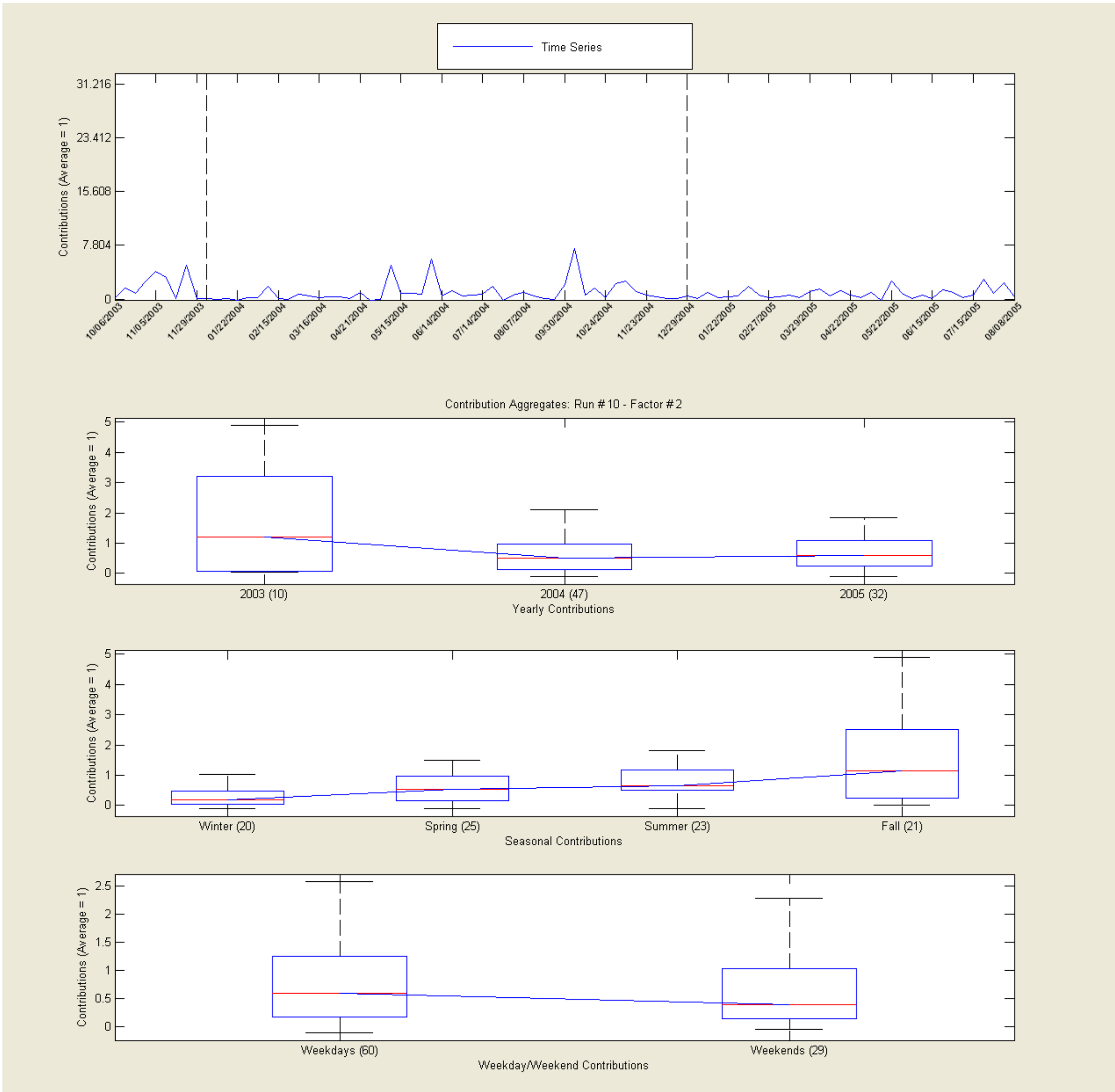


Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
Contribution Aggregates: Run # 10 - Factor # 1
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 2: Carbon-Rich Industrial

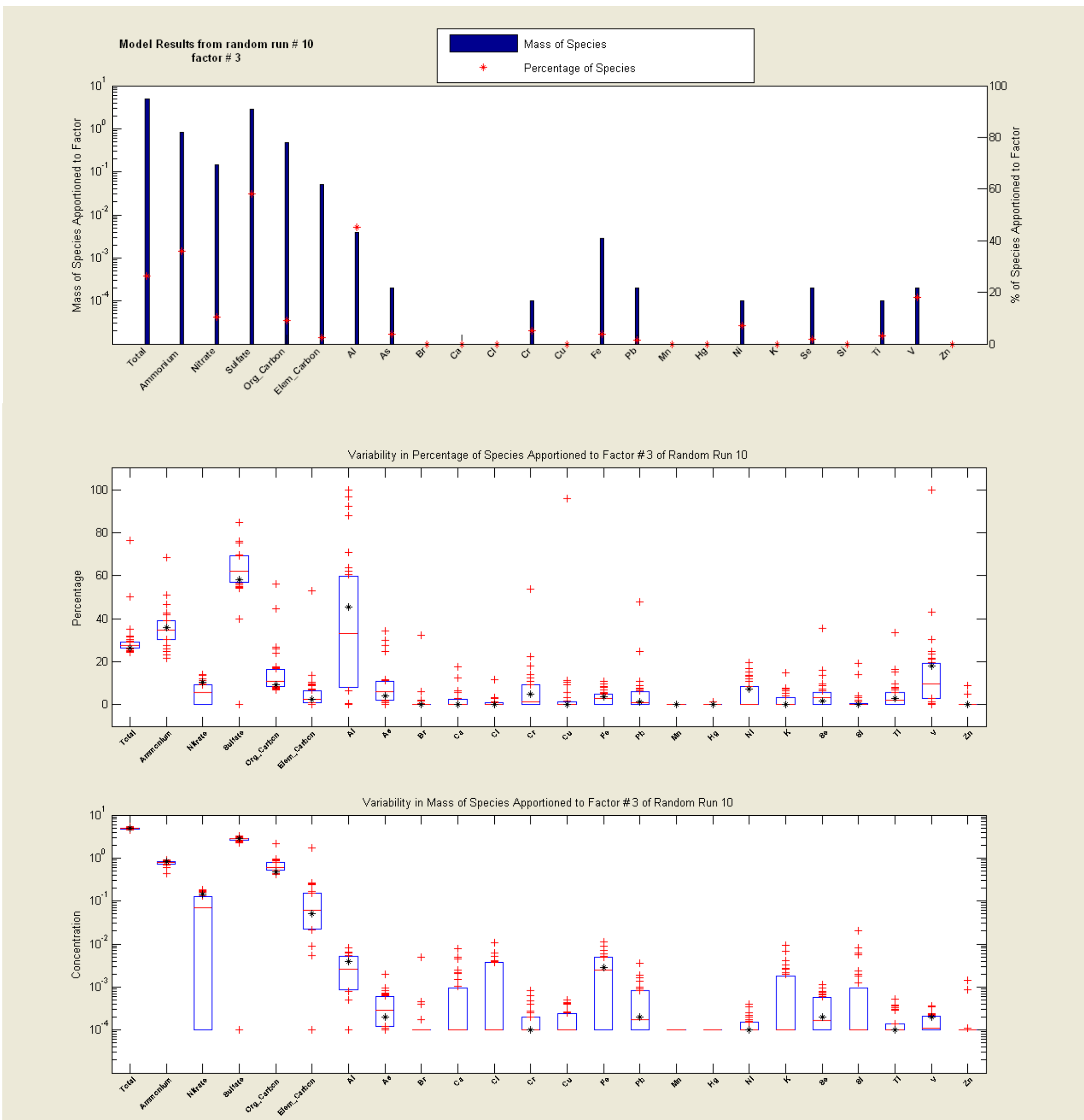
Factor 2 contains high percentages of elemental and organic carbon, as well as noticeable percentages of arsenic, bromine, and ammonium. Contributions are slightly higher in fall and on weekdays, perhaps due to background mobile source emissions or secondary organic carbons. It is assumed that the majority of this factor represents a constant source, best classified as a carbon-rich industrial source or combination of sources.

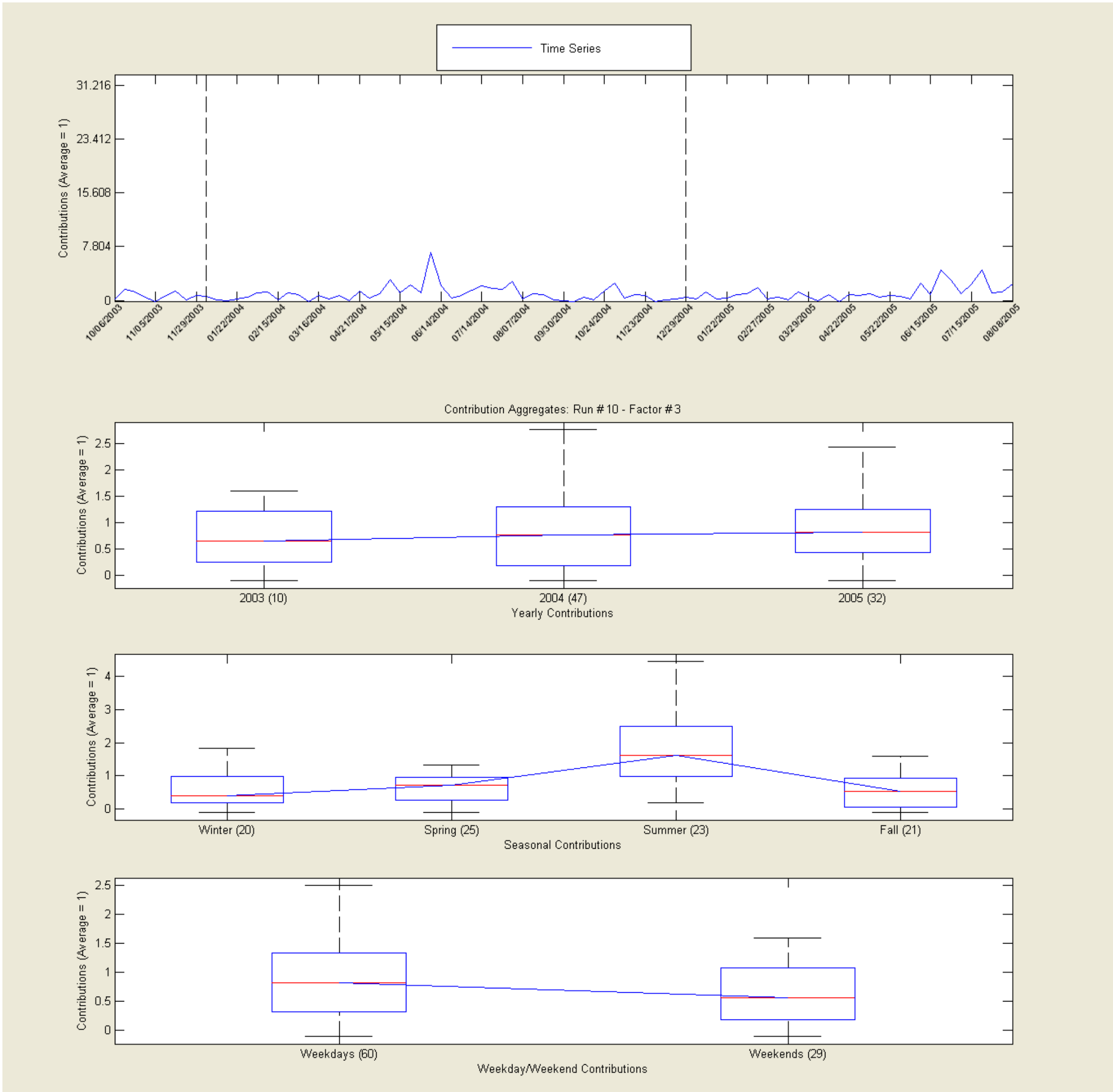



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 2
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

<u>Liberty Source Factor 3</u>: Secondary Ammonium Sulfate

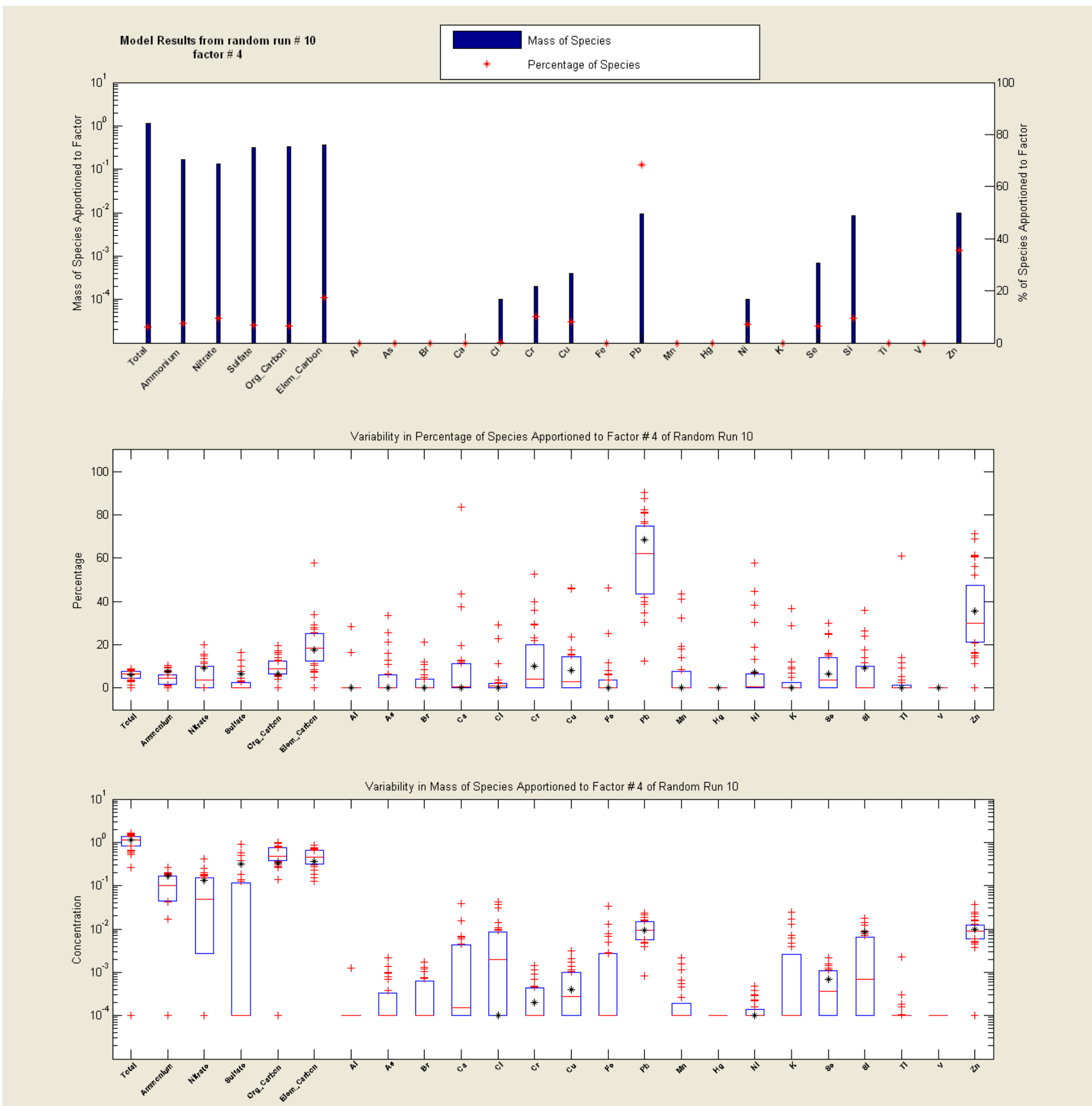
Factor 3 is comprises the majority of ammonium sulfate at Liberty. Contributions are highest in summer, when sulfate is most prevalent. Sulfate exists as secondary $PM_{2.5}$ in the Pittsburgh region, formed from upwind SO_2 sources such as coal-fired power plants. Factor 3 also contains some carbons and trace elements that are likely peaking concurrently with the sulfate. The organic carbon may be secondary in nature as well. Aluminum may be a result or either airborne crustal dust or primary coal-fired power plant emissions.

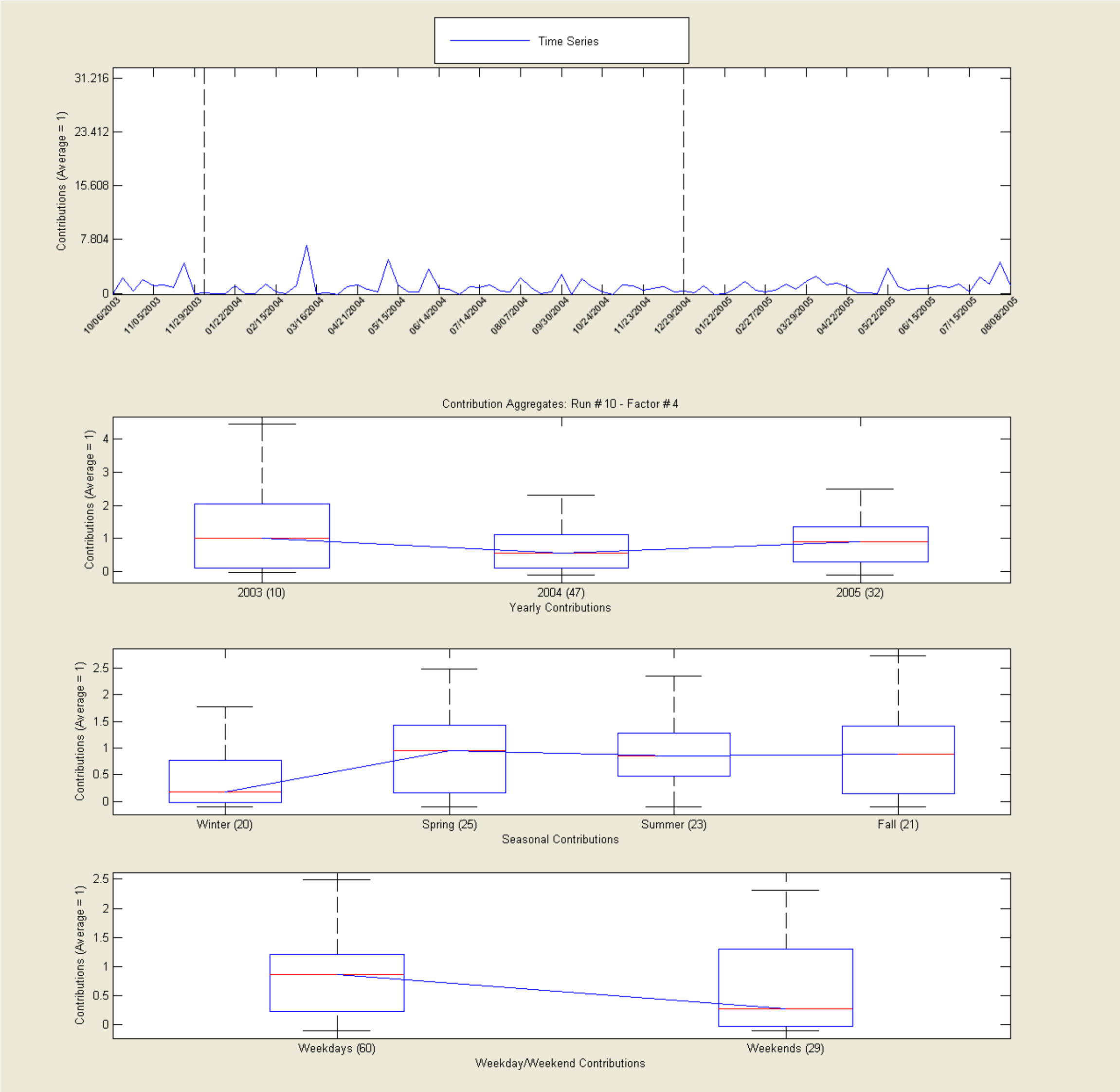



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 3
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 4: Diesel Vehicles

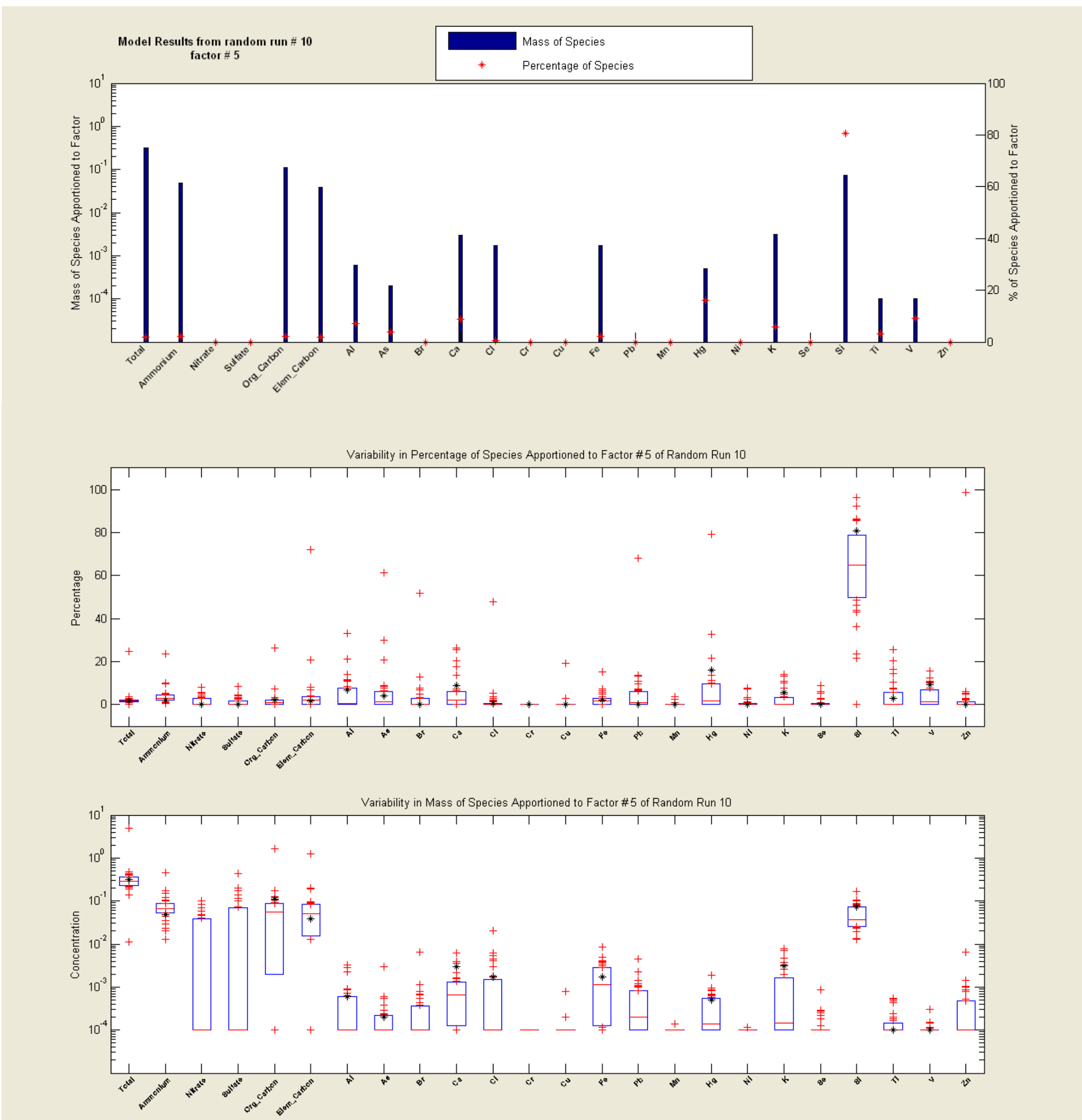
Factor 4 is assumed to be primarily diesel vehicle emissions due to the strong presence of weekday elemental carbon. High percentages of lead and zinc are also present, possibly due to tire wear, municipal waste incinerators, or other sources. Minor percentages of ammonium, nitrate, and sulfate are also included in this factor.

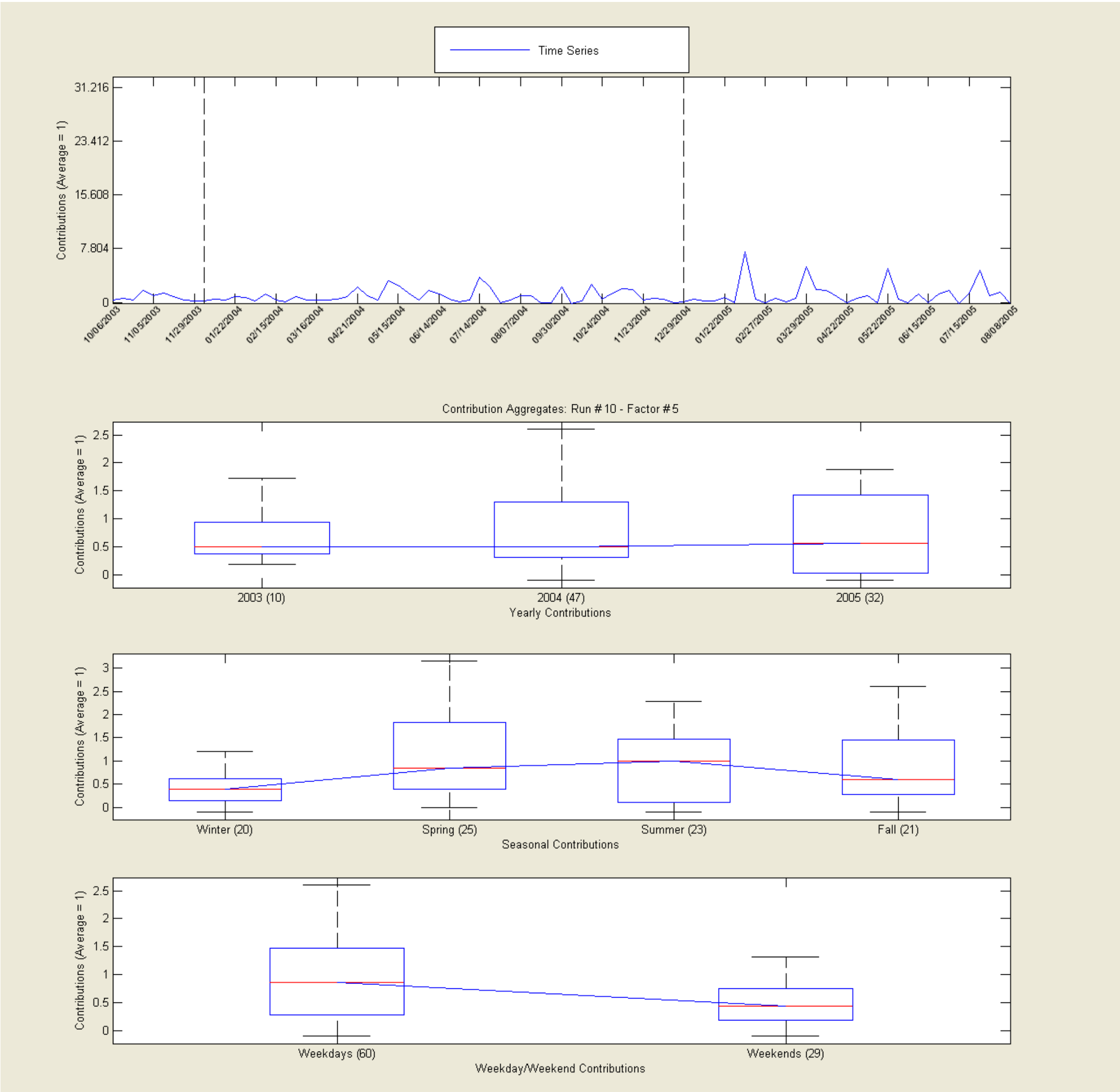



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 4
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 5: Airborne Crustal (Silicon-Rich)

Crustal elements include aluminum, calcium, iron, silicon, and titanium. These elements are the basic make-up of fine airborne soil. Factor 5 is best attributed as the silicon portion of airborne crustal component. Contributions are slightly higher during weekdays, possibly due to traffic forcing up road and crustal dust. Springtime contributions are also slightly higher. Some silicon may be also due to primary power plant emissions.

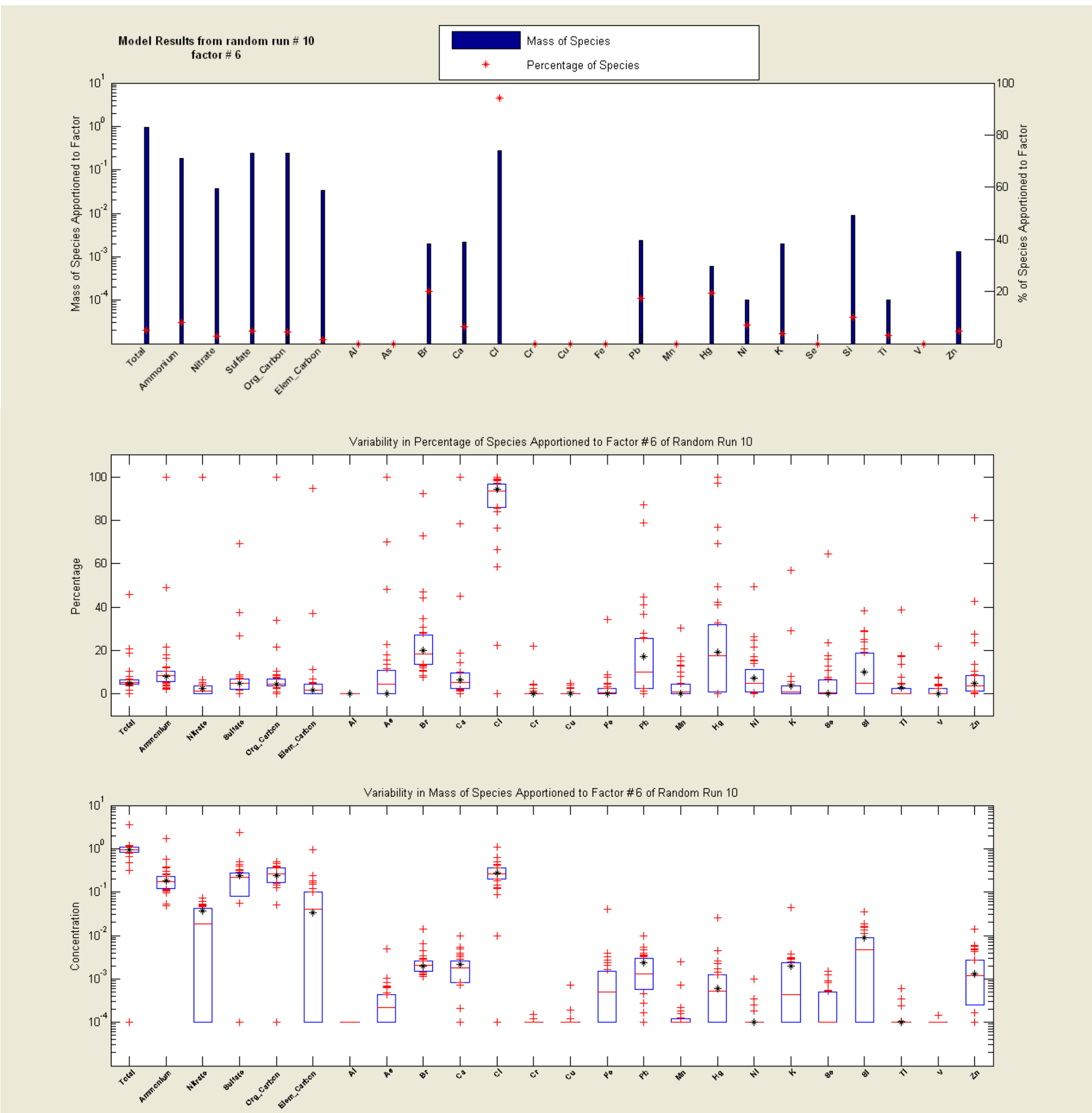


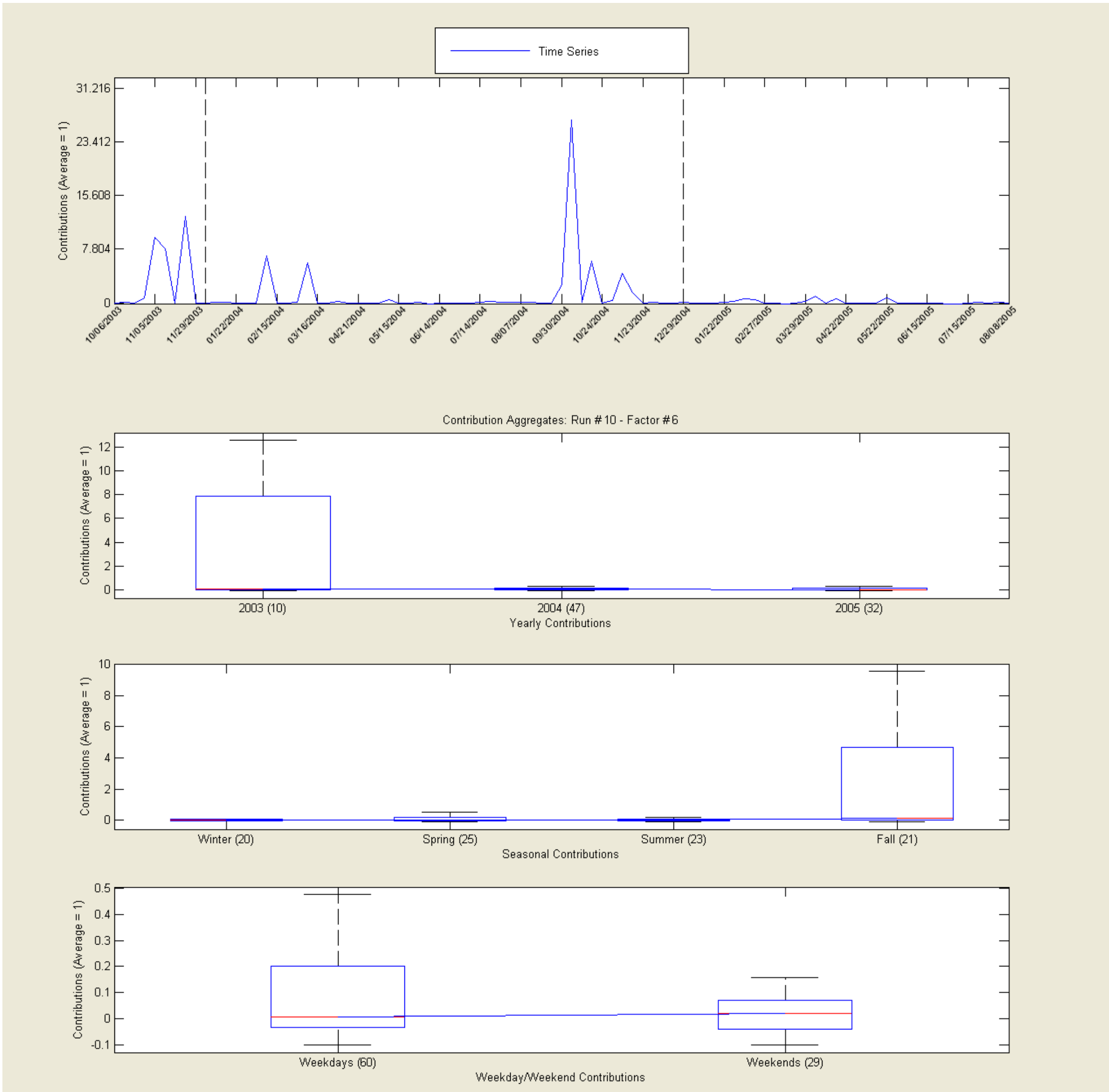


Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
Contribution Aggregates: Run # 10 - Factor # 5
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 6: Halogen-Rich Sources

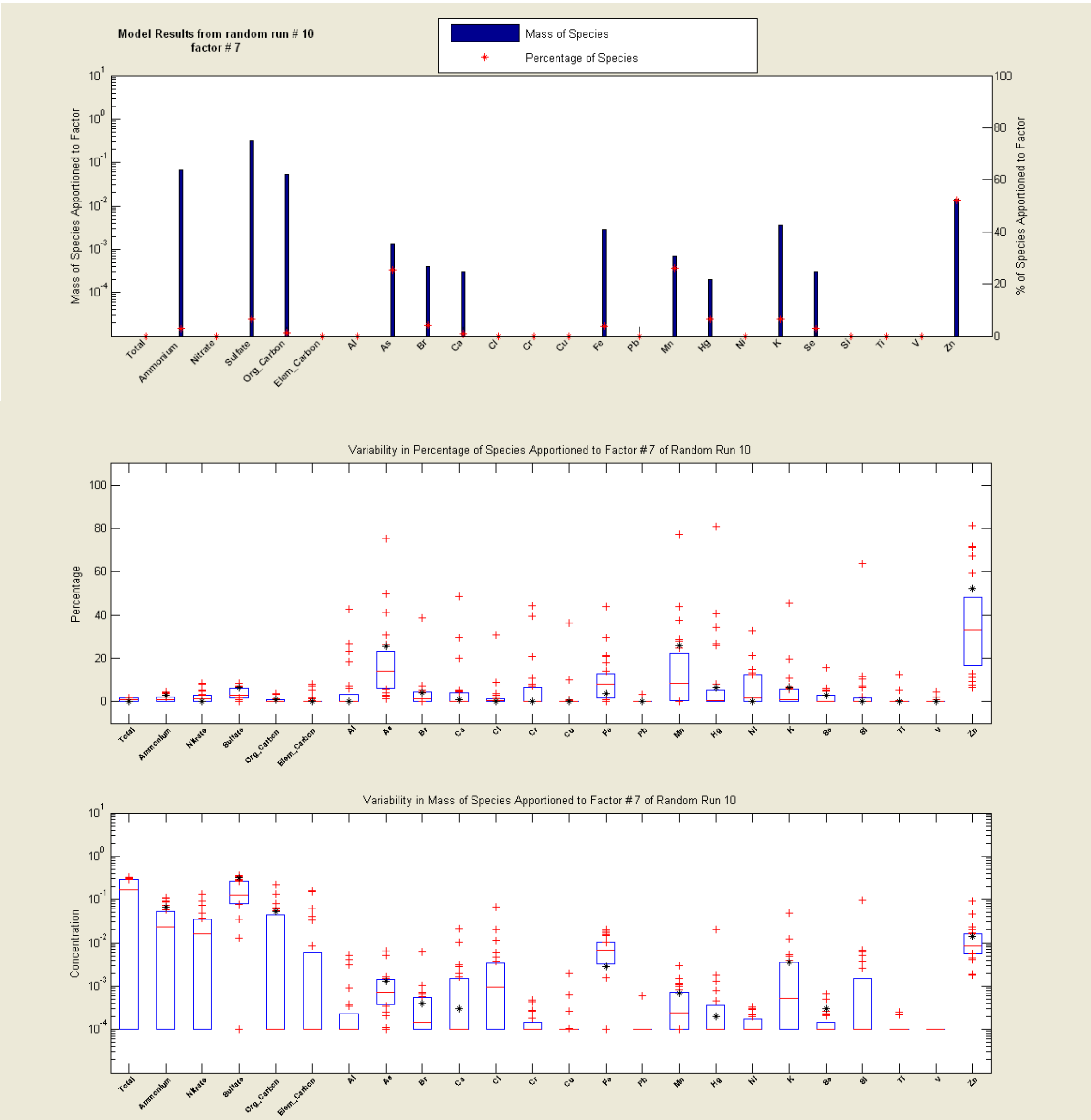
Factor 6 contains high percentages of chlorine and bromine, and contributions are highest in fall. Contributions from this factor are extremely specific, as only a few large peaks are evident throughout the year. Previous analysis of speciation data has shown that chlorine tracks the carbons during cold weather only. This may indicate that the halogens are originating from the same wind direction.

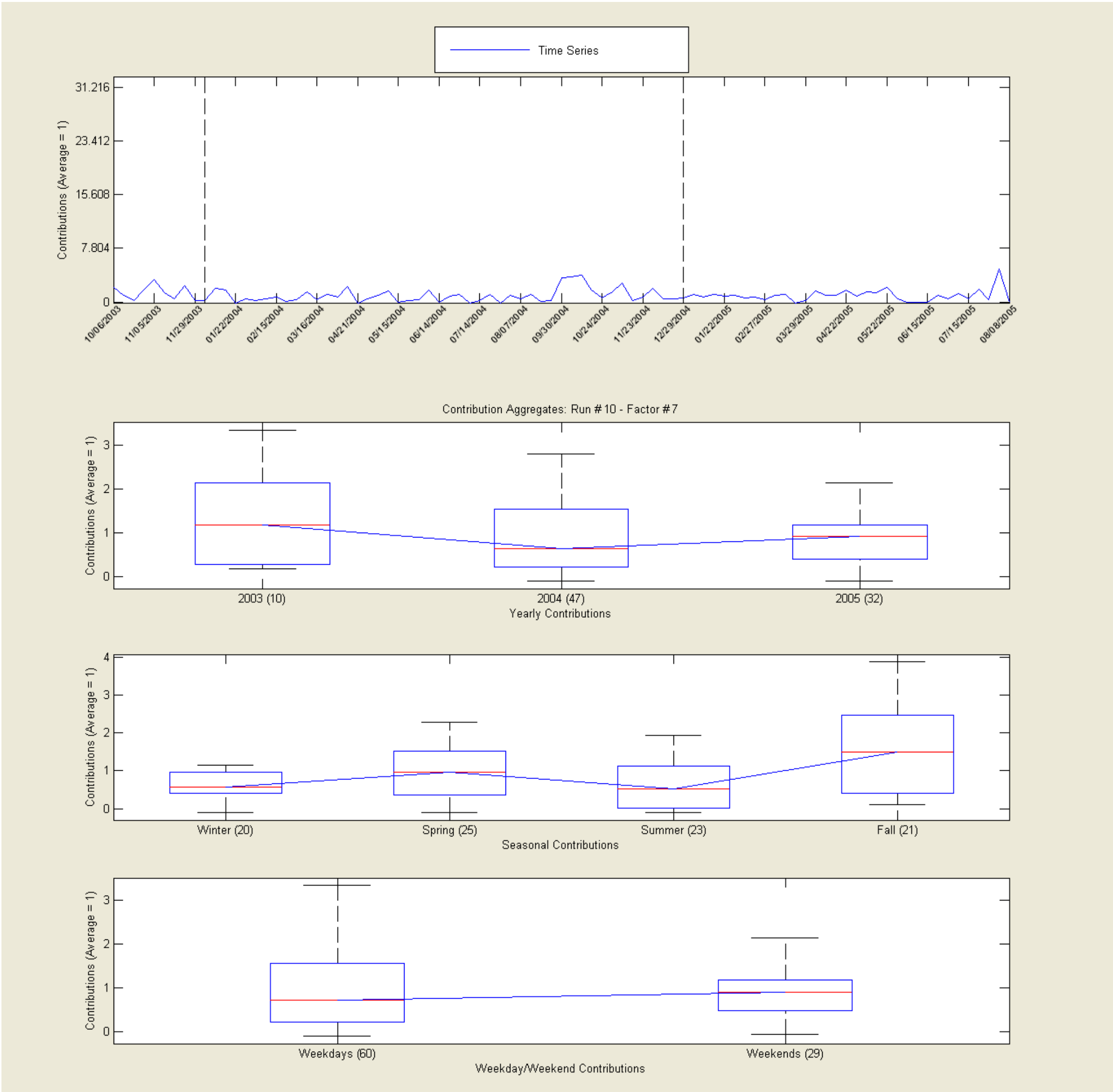



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 6
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 7: Zinc-Rich Sources

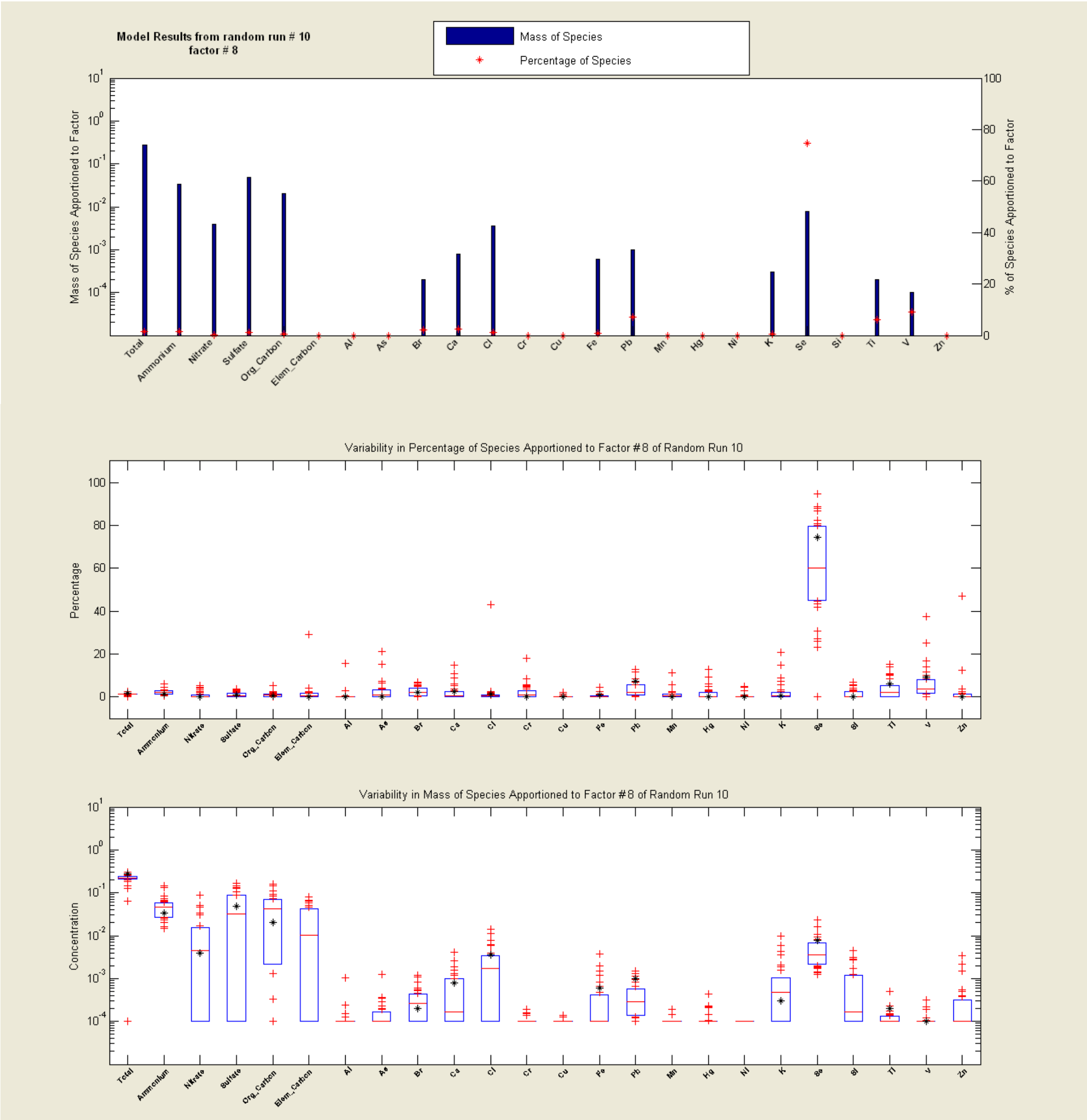
Factor 7 contains a high percentage of zinc, along with smaller percentages arsenic, manganese, and sulfate. Factors with these characteristics are often classified as municipal waste incinerators or metallurgical (galvanizing) facilities.

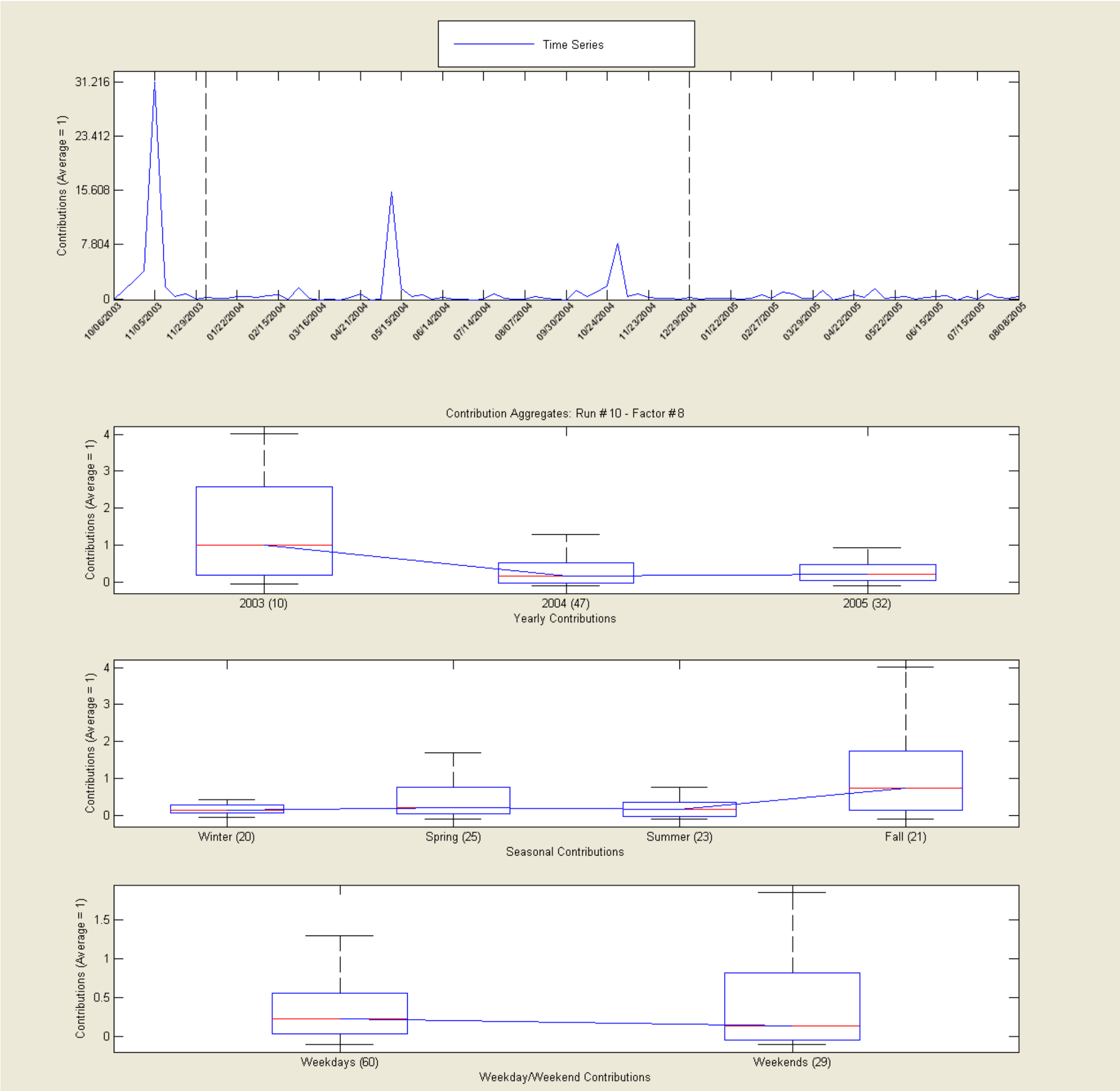



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 7
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 8: Selenium-Rich Industrial

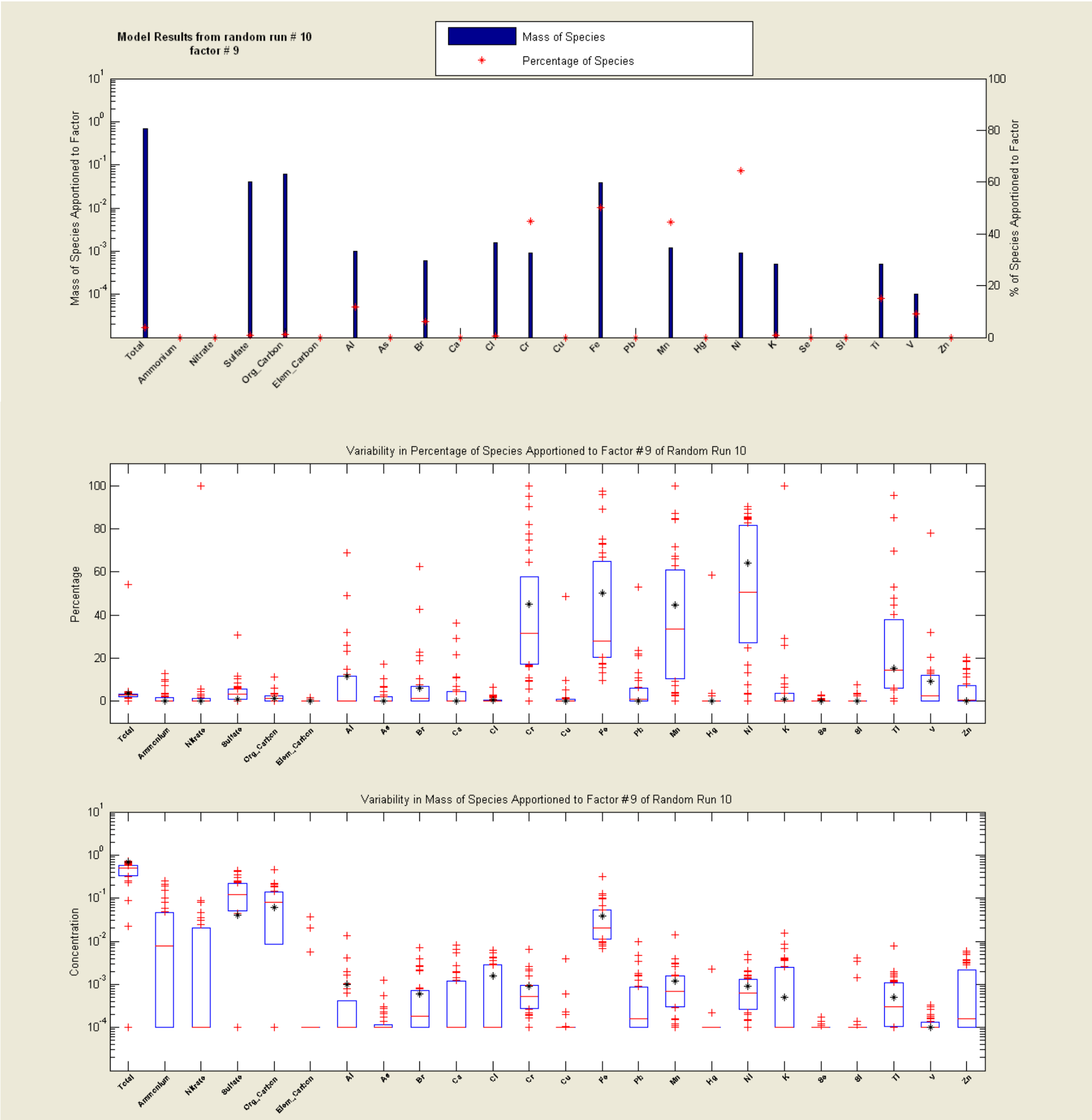
Factor 8 contains a high percentage of selenium, with nearly negligible percentages of all other species. Selenium is sometimes associated with primary coal-fired boiler emissions but is also present in some glass manufacturing emissions.

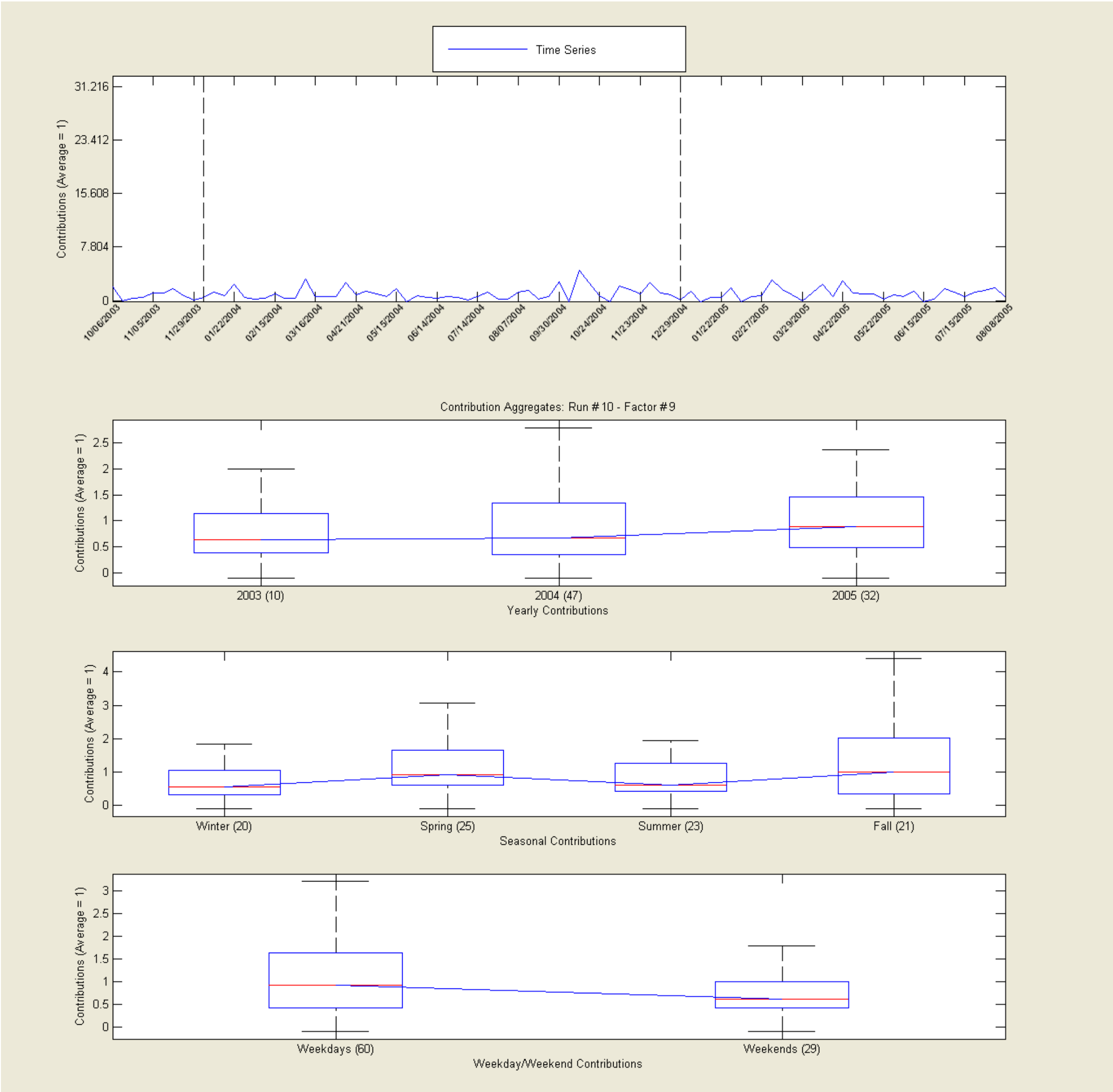



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 8
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 9: Road Dust

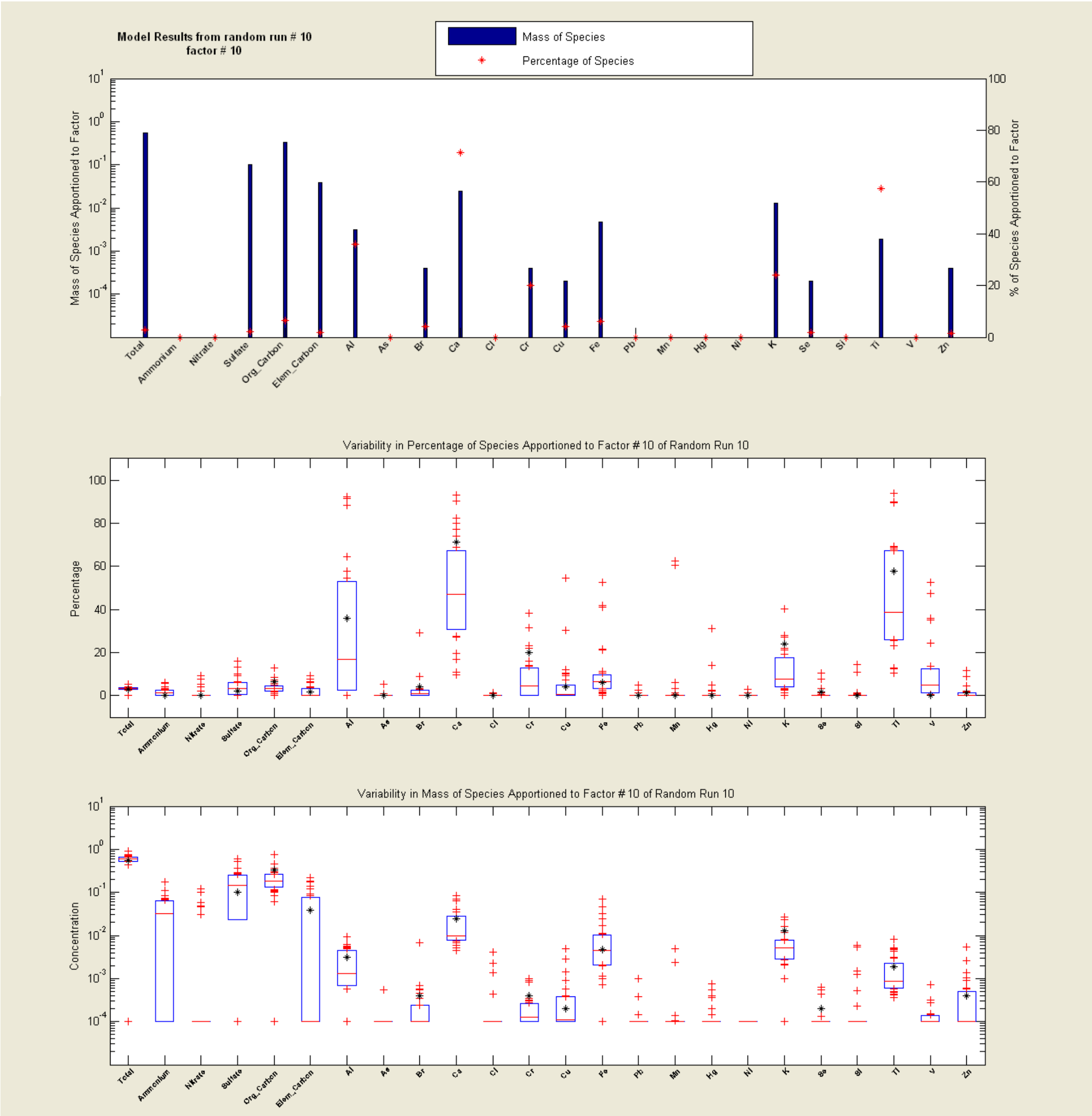
Factor 9 contains percentages of iron, aluminum, and titanium, as well as chromium, nickel, and manganese, and is higher on weekdays. It is best classified as miscellaneous road dust, with some contributions possibly from metallurgical facilities.

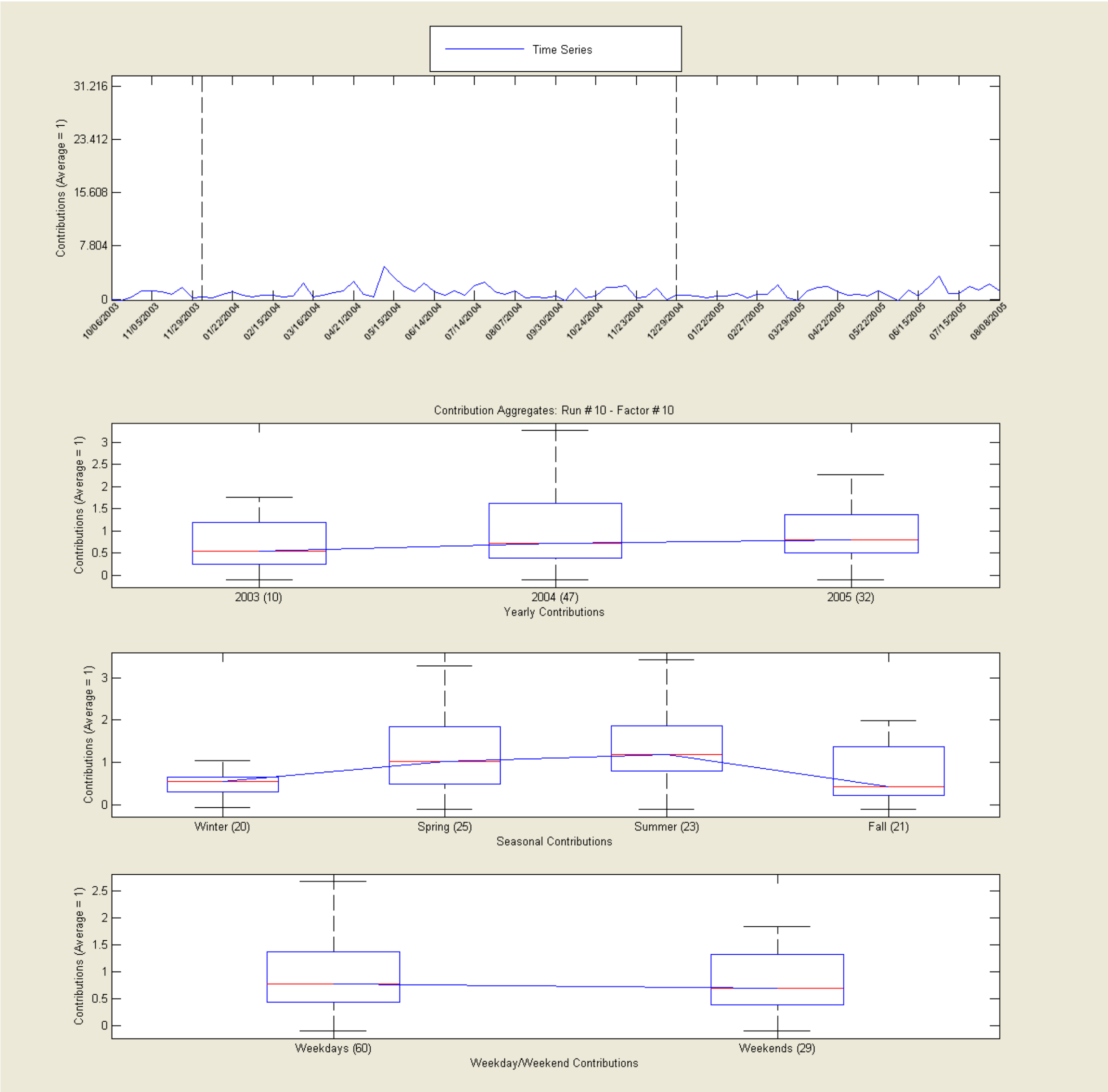



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
Contribution Aggregates: Run # 10 - Factor # 9
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 10: Airborne Crustal (Other)

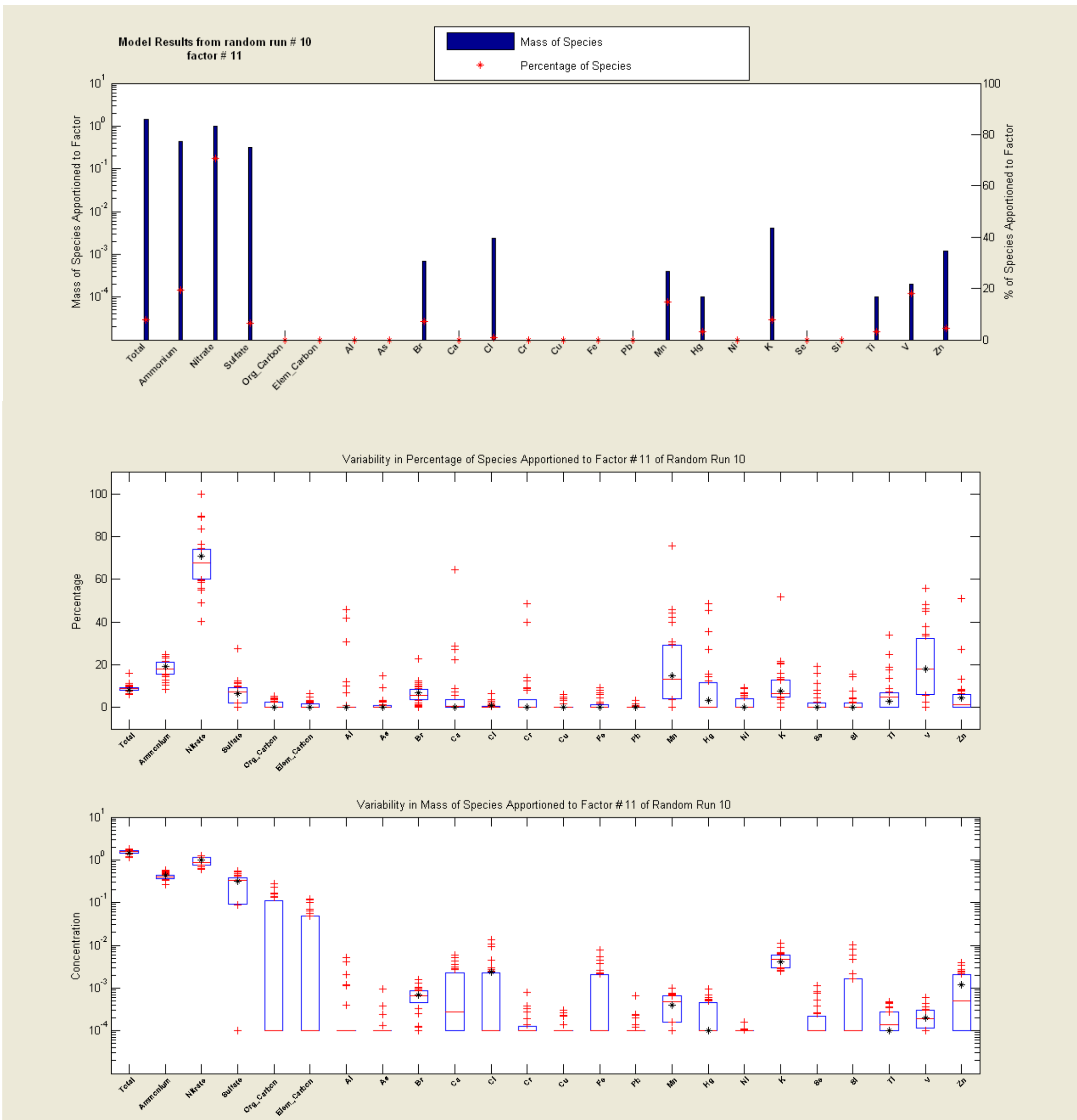
Like Factor 5 (silicon-rich crustal), Factor 10 is composed of crustal elements and is higher on weekdays and in spring. Aluminum, calcium, and titanium show the highest percentages for this factor.

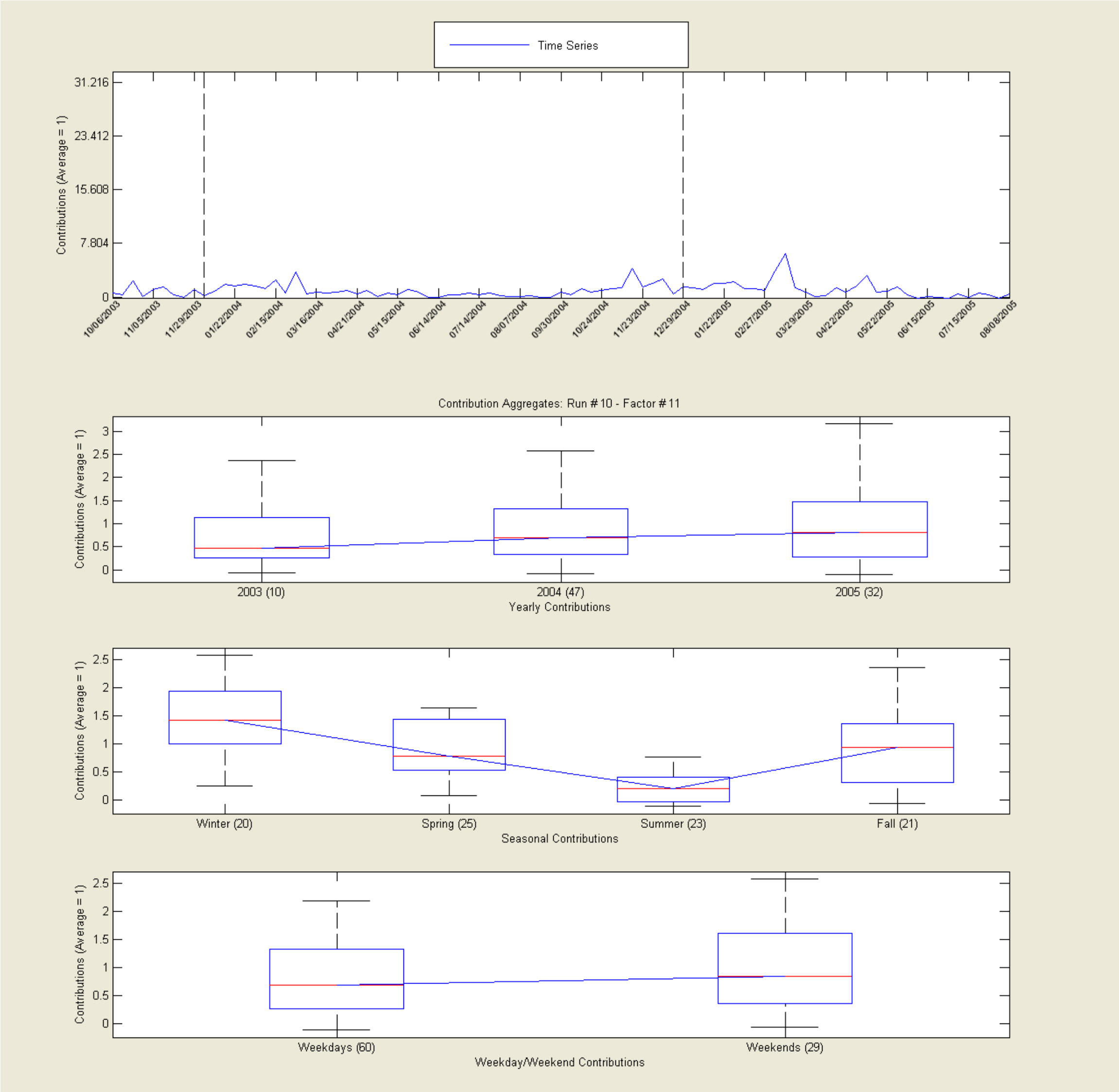



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 10
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 11: Secondary Ammonium Nitrate

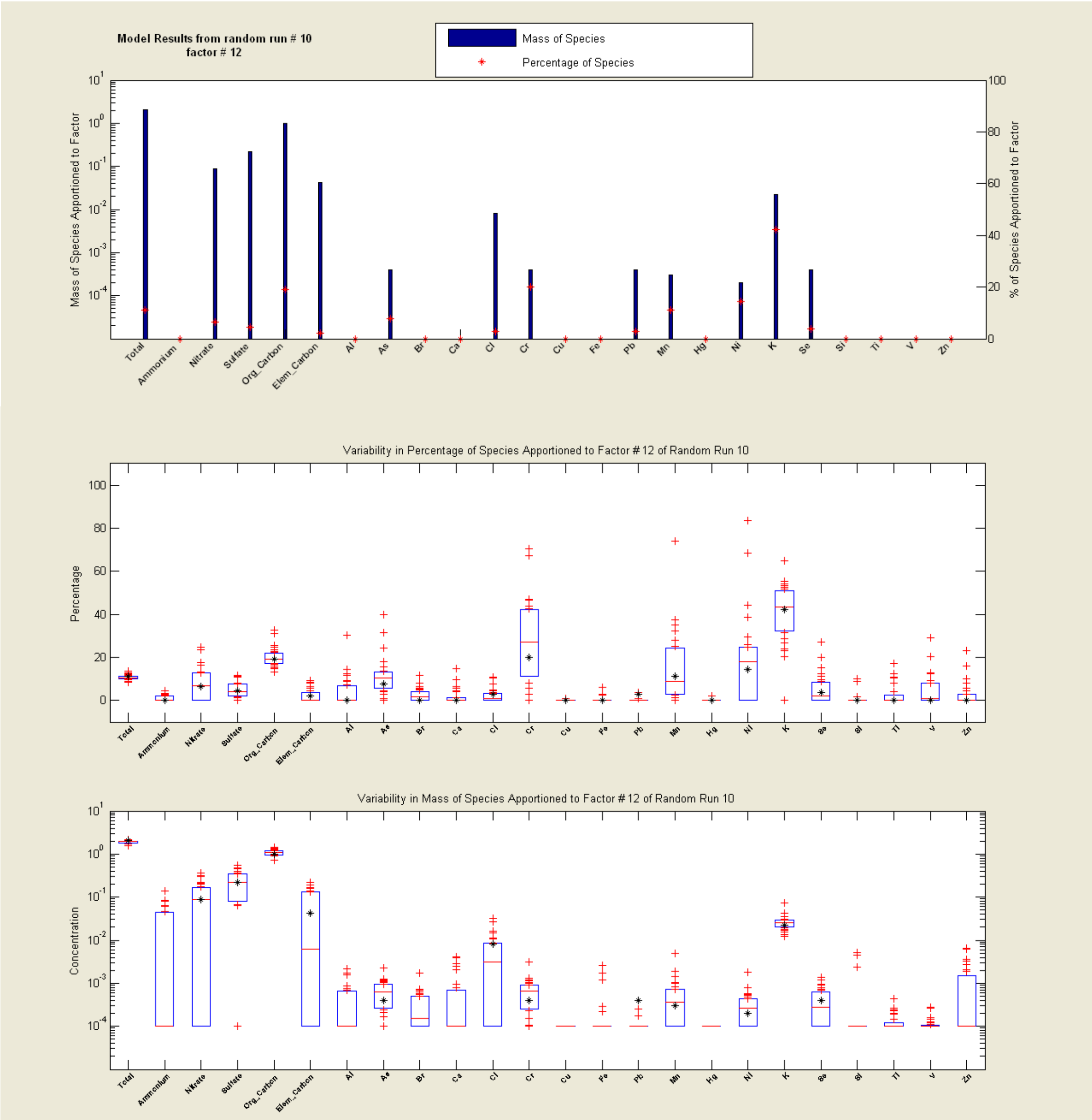
Factor 11 is the majority of secondary ammonium nitrate at the Liberty, dominant in cold weather. Nitrate is a secondary species created by upwind NOx sources such as fossil fuel-fired boilers.

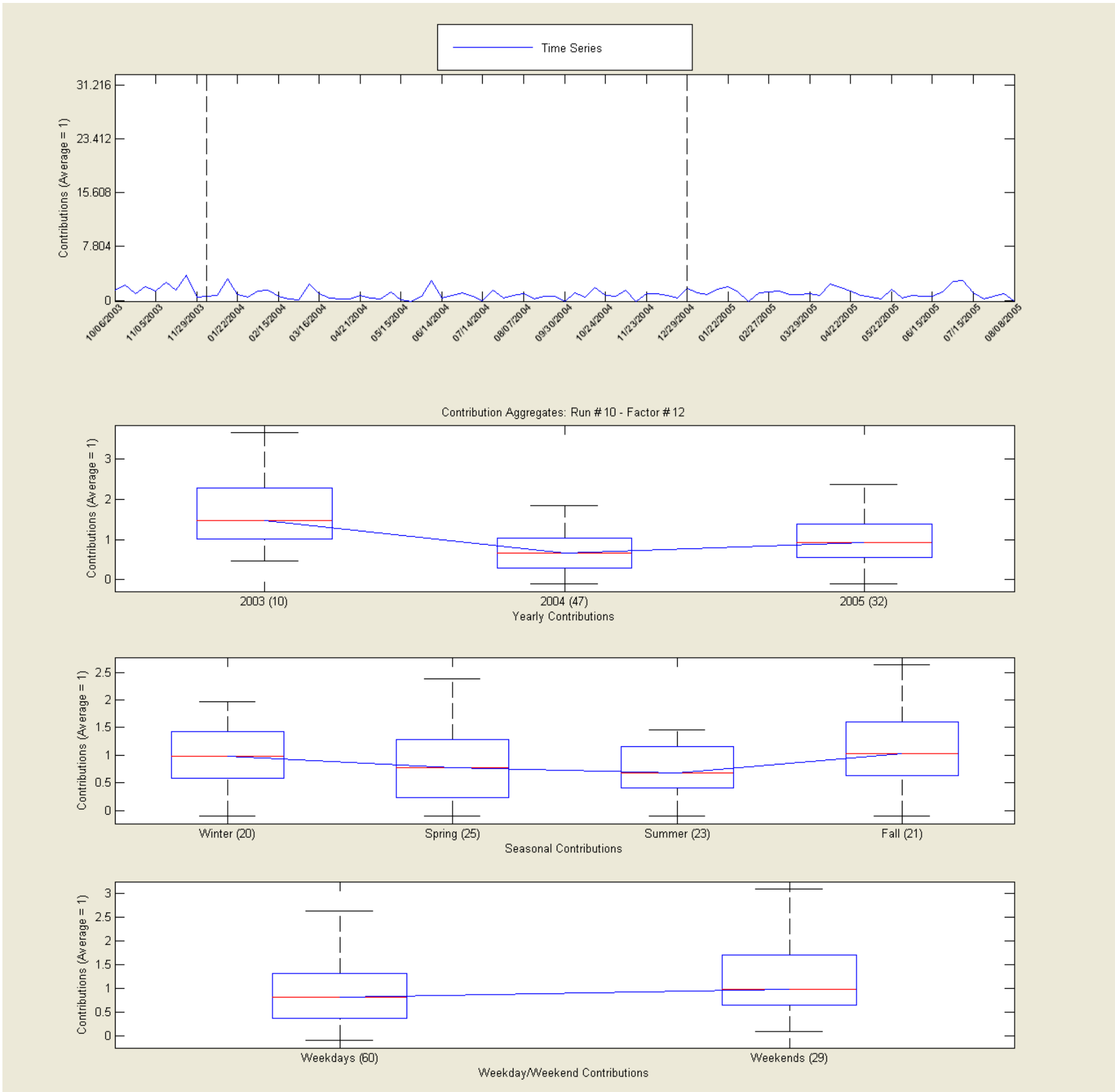



Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 11
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

Liberty Source Factor 12: Vegetative Burning

Factor 12 contains high percentages of organic carbon and potassium and is highest in fall and winter. This is indicative of vegetative burning, most likely for residential-heating in the Liberty area. This differs from the miscellaneous burning factor at Lawrenceville, which is highest in summer and is most likely due to recreational burning and cooking.




Time Series
Contributions (Average = 1)
31.216
23.412
15.608
7.804
0
10/06/2003
11/05/2003
11/29/2003
01/22/2004
02/15/2004
03/16/2004
04/21/2004
05/15/2004
06/14/2004
07/14/2004
08/07/2004
09/30/2004
10/24/2004
11/23/2004
12/29/2004
01/22/2005
02/27/2005
03/29/2005
04/22/2005
05/22/2005
06/15/2005
07/15/2005
08/08/2005
Contribution Aggregates: Run # 10 - Factor # 12
2003 (10)
2004 (47)
2005 (32)
Yearly Contributions
Winter (20)
Spring (25)
Summer (23)
Fall (21)
Seasonal Contributions
Weekdays (60)
Weekends (29)
Weekday/Weekend Contributions

6. Model Diagnostics

<u>Lawrenceville Diagnostics:</u>

Factors = 11
Random Run #10
Perfect Theoretical Q = 1305

===

```
_____________________ANALYSIS START__________________________

Number of random starting points: 10
Number of factors: 11
Seed: Used random seed.
c3 Modeling Constant(Percent): 5.00

Species included:
    Strong - Ammonium,Nitrate,Sulfate,Org_Carbon,
                   Elem_Carbon,Ca,Cl,Cu,
                   Fe,Pb,Mn,Se,
                   Si,Zn,

    Weak (down-weighted) - Total,Al,As,Br,
                   Cr,Hg,Ni,K,
                   Ti,V,

 Species not included:
    Bad (not included) -   No "Bad" variables


~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Q Values for random-start runs
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Random Run  Q(Robust)    Q(True) Converged(Y/N) #Steps
     1     1571.85      1578.03   Yes           1289
     2     1571.84      1578.03   Yes           1313
     3     1571.88      1578.03   Yes           1320
     4     1571.83      1578.01   Yes           1358
     5     1571.88      1578.04   Yes           1471
     6     1571.87      1578.04   Yes           1135
     7     1571.81      1578.01   Yes           1480
     8     1571.88      1578.03   Yes           1228
     9     1571.81      1578.01   Yes           1177
    10     1571.84      1578.02   Yes           1018
```

_____________________START BASE FACTOR ANALYSIS_____________________

Regression diagnostics of run# 10

Species	Intercept	Slope	RMSE	r^2
Total	0.34	0.97	1.41	0.97
Ammonium	0.02	0.98	0.12	0.99
Nitrate	-0.01	1.01	0.08	1.00
Sulfate	0.12	0.97	0.34	0.99
Org_Carbon	0.21	0.94	0.38	0.95
Elem_Carbon	0.13	0.82	0.17	0.82
Al	0.01	0.09	0.01	0.10
As	0.00	0.33	0.00	0.26
Br	0.00	0.41	0.00	0.46
Ca	0.00	0.98	0.00	1.00
Cl	0.00	0.97	0.00	1.00
Cr	0.00	0.19	0.00	0.27
Cu	0.00	0.82	0.00	0.83
Fe	0.01	0.93	0.02	0.96
Pb	0.00	0.98	0.00	0.99
Mn	0.00	0.93	0.00	0.97
Hg	0.00	0.04	0.00	0.02
Ni	0.00	0.27	0.00	0.32
K	0.03	0.38	0.02	0.44
Se	0.00	0.99	0.00	1.00
Si	0.00	1.00	0.00	1.00
Ti	0.00	0.34	0.00	0.41
V	0.00	0.14	0.00	0.13
Zn	0.00	1.00	0.00	1.00

****

Dates (residuals) beyond 3 Std. Dev.

Species	Dates (residuals)
Al	- 03/25/2004(3.2)
As	- 08/31/2004(3.1)
Cr	- 10/09/2003(3.0), 02/21/2005(4.1)
Cu	- 07/23/2003(3.0), 08/25/2003(3.5), 09/21/2003(3.5), 12/17/2003(-4.0), 05/30/2004(4.3), 05/22/2005(3.4), 07/09/2005(4.9)
Fe	- 11/23/2003(3.1), 12/17/2003(3.2)
Ni	- 02/21/2005(3.6)
K	- 01/01/2005(3.1)

```
************************
Species   (residuals) beyond 3 Std. Dev.

Dates               Species   (residuals)

07/23/2003 - Cu          (  3.0  )
08/25/2003 - Cu          (  3.5  )
09/21/2003 - Cu          (  3.5  )
10/09/2003 - Cr          (  3.0  )
11/23/2003 - Fe          (  3.1  )
12/17/2003 - Cu          ( -4.0  ), Fe           (  3.2  )
03/25/2004 - Al          (  3.2  )
05/30/2004 - Cu          (  4.3  )
08/31/2004 - As          (  3.1  )
01/01/2005 - K           (  3.1  )
02/21/2005 - Cr          (  4.1  ), Ni           (  3.6  )
05/22/2005 - Cu          (  3.4  )
07/09/2005 - Cu          (  4.9  )

_____________________END BASE FACTOR ANALYSIS_____________________


_____________________START BOOT STRAP ANALYSIS_____________________

Number of bootstrap runs: 30
Minimum correlation between base and boot factors : 0.600000

Factor Map Frequency table

Number of bootstrap runs :30
Minimum R-Value for base-boot factor mapping: 0.6
Seed: rand

Number of bootstrap runs that converged and are summarized: 30

Number of bootstrap runs that did not converge and are therefore
                                       excluded from the summary: 0


Number of bootstrapped factors mapped to original factor 1 : 30
Number of bootstrapped factors mapped to original factor 2 : 30
Number of bootstrapped factors mapped to original factor 3 : 28
Number of bootstrapped factors mapped to original factor 4 : 30
Number of bootstrapped factors mapped to original factor 5 : 31
Number of bootstrapped factors mapped to original factor 6 : 30
Number of bootstrapped factors mapped to original factor 7 : 30
Number of bootstrapped factors mapped to original factor 8 : 30
Number of bootstrapped factors mapped to original factor 9 : 30
Number of bootstrapped factors mapped to original factor 10 : 30
Number of bootstrapped factors mapped to original factor 11 : 30

Number of bootstrapped factors mapped to no original factor : 1
```

Q(Robust) Percentile Report

Min	25th	Median	75th	Max
1342.28	1466.54	1513.72	1531.55	1693.68

****

Variability in Factor Strengths, Based on Bootstrapping

****

Factors	5th	25th	75th	95th
Factor 1	0.8606	0.9442	1.0654	1.1832
Factor 2	0.4518	0.9284	2.3494	4.7239
Factor 3	0.6176	0.8341	1.0731	1.2811
Factor 4	0.4413	0.6844	1.7348	4.7941
Factor 5	0.6732	0.9509	1.9119	3.7830
Factor 6	0.2797	0.5671	1.6461	2.3106
Factor 7	0.4863	0.6124	1.1508	1.4861
Factor 8	0.5471	0.6790	0.8878	1.0852
Factor 9	0.2811	0.4717	0.8239	1.1209
Factor 10	0.4003	0.5116	1.0112	1.5941
Factor 11	0.3853	0.8075	1.7620	2.4260

_____________________END BOOT STRAP ANALYSIS_____________________

_____________________ANALYSIS END__________________________

Liberty Diagnostics:

Factors = 12
Random Run #10
Perfect Theoretical Q = 546

==

```
____________________ANALYSIS START____________________

Number of random starting points: 10
Number of factors: 12
Seed: Used random seed.
c3 Modeling Constant(Percent): 5.00

Species included:
    Strong - Ammonium,Nitrate,Sulfate,Org_Carbon,
                   Elem_Carbon,Br,Ca,Cl,
                   Cu,Fe,Pb,K,
                   Se,Si,Zn,

    Weak (down-weighted) - Total,Al,As,Cr,
                   Mn,Hg,Ni,Ti,
                   V,

 Species not included:
    Bad (not included) -   No "Bad" variables


~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Q Values for random-start runs
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Random Run  Q(Robust)    Q(True)  Converged(Y/N)   #Steps
     1     573.79       573.79   Yes             1887
     2     573.79       573.79   Yes             1916
     3     573.81       573.81   Yes             2070
     4     573.77       573.77   Yes             1672
     5     573.76       573.76   Yes             1776
     6     573.93       573.93   Yes             1746
     7     573.77       573.77   Yes             1672
     8     573.80       573.80   Yes             1317
     9     573.76       573.76   Yes             1813
    10     573.76       573.76   Yes             1749
```

```
___________________START BASE FACTOR ANALYSIS_______________________

Regression diagnostics of run# 10

Species       Intercept      Slope         RMSE          r^2

Total           0.16         0.97          2.44          0.96
Ammonium        0.08         0.95          0.18          0.99
Nitrate         0.03         0.97          0.08          0.99
Sulfate        -0.04         1.01          0.25          0.99
Org_Carbon      0.20         0.94          0.60          0.98
Elem_Carbon    -0.00         0.97          0.43          0.97
Al              0.01         0.09          0.01          0.20
As              0.00         0.87          0.00          0.77
Br             -0.00         1.01          0.00          0.99
Ca             -0.00         1.00          0.00          1.00
Cl             -0.00         0.99          0.06          1.00
Cr              0.00         0.23          0.00          0.24
Cu              0.00         1.00          0.00          1.00
Fe             -0.00         1.01          0.00          1.00
Pb              0.00         0.99          0.00          1.00
Mn              0.00         0.29          0.00          0.40
Hg              0.00         0.27          0.00          0.57
Ni              0.00         0.31          0.00          0.39
K               0.00         0.97          0.00          0.98
Se              0.00         0.98          0.00          1.00
Si              0.00         1.00          0.00          1.00
Ti              0.00         0.40          0.00          0.46
V               0.00         0.16          0.00          0.16
Zn              0.00         1.00          0.00          1.00
************************
Dates (residuals) beyond 3 Std. Dev.

Species          Dates (residuals)

Al           - 04/21/2004(  3.6  ), 05/15/2004(  3.9  )
Hg           - 10/06/2004(  3.1  )

************************
Species   (residuals) beyond 3 Std. Dev.

Dates       Species   (residuals)

04/21/2004 - Al           (  3.6  )
05/15/2004 - Al           (  3.9  )
10/06/2004 - Hg           (  3.1  )

_____________________END BASE FACTOR ANALYSIS_____________________
```

```
_____________________START BOOT STRAP ANALYSIS_____________________

Number of bootstrap runs: 30
Minimum correlation between base and boot factors : 0.600000

Number of bootstrap runs :30
Minimum R-Value for base-boot factor mapping: 0.6
Seed: rand
Number of bootstrap runs that converged and are summarized: 30

Number of bootstrapped factors mapped to original factor 1 : 30
Number of bootstrapped factors mapped to original factor 2 : 29
Number of bootstrapped factors mapped to original factor 3 : 31
Number of bootstrapped factors mapped to original factor 4 : 28
Number of bootstrapped factors mapped to original factor 5 : 31
Number of bootstrapped factors mapped to original factor 6 : 32
Number of bootstrapped factors mapped to original factor 7 : 25
Number of bootstrapped factors mapped to original factor 8 : 30
Number of bootstrapped factors mapped to original factor 9 : 32
Number of bootstrapped factors mapped to original factor 10 : 28
Number of bootstrapped factors mapped to original factor 11 : 30
Number of bootstrapped factors mapped to original factor 12 : 28

Number of bootstrapped factors mapped to no original factor : 6

Q(Robust) Percentile Report
   Min         25th        Median       75th        Max
  461.76      506.43      540.53      560.06      591.49

********************************************************
Variability in Factor Strengths, Based on Bootstrapping
********************************************************

Factors              5th         25th         75th         95th

Factor 1            0.2080      0.4489      1.2264      1.5371
Factor 2            0.1891      0.6002      0.9719      1.6770
Factor 3            0.7942      0.8733      1.0212      1.0781
Factor 4            0.3861      0.6458      1.4760      2.1156
Factor 5            0.5246      0.9082      2.6555      4.0411
Factor 6            0.4377      0.8355      1.4045      2.5626
Factor 7            0.3114      0.9239      2.1890      4.2387
Factor 8            0.5044      1.0210      3.6669      4.8345
Factor 9            0.2280      0.6735      2.2953      3.5172
Factor 10            0.2869      1.1254      2.5904      4.0050
Factor 11            0.6189      0.8371      1.3037      1.6004
Factor 12            0.5059      0.6783      0.9834      1.2985

_____________________END BOOT STRAP ANALYSIS_____________________

_____________________ANALYSIS END__________________________
```

7. References

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Source Apportionment Analysis of Air Quality Monitoring Data: Phase II. March 2005. Prepared by Desert Research Institute for the Mid-Atlantic/Northeast Visibility Union and Midwest Regional Planning Organization.

$PM_{2.5}$ Chemical Speciation and Related Comparisons at Lawrenceville and Liberty: 18-Month Results Comparison. Maranche, J., Allegheny County Health Department, June 2005.

Additional Information

For more information concerning this report or Allegheny County $PM_{2.5}$ data analysis, contact Jason Maranche at the ACHD Air Quality Program at 412-578-8104 or at jmaranche@achd.net.

With regard to the development of the PMF 1.1 model, the EPA disclaimer is reproduced below: