The Fairbanks, Alaska $PM_{2.5}$ Source Apportionment Research Study

State Building (Winters of 2005/2006, 2006/2007, and 2007/2008)
Winter 2011/2012 (State Building, North Pole, NCORE, RAMS, and NPF3)

Final Report

March 1, 2013

by

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1.0. Executive Summary

Fairbanks, Alaska has some of the highest measured ambient $PM_{2.5}$ (particulate matter less than or equal to 2.5 microns in diameter) concentrations in the United States, with wintertime levels often exceeding the 24-hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS) of 35 µg/m^3. In an effort to understand the sources of $PM_{2.5}$ in the Fairbanks airshed, source apportionment using Chemical Mass Balance (CMB) modeling was conducted for the winters of 2005/2006, 2006/2007, and 2007/2008 at the State Building site and five locations (State Building, North Pole, Relocatable Air Monitoring System (RAMS), NCORE, and NPF3) during the winter of 2011/2012.

Throughout the period of study, $PM_{2.5}$ concentrations averaged between 18.3 and 24.2 µg/m^3, with multiple exceedances of the 24-hour NAAQS on the scheduled sample days. The results of the CMB modeling using source profiles developed by the Environmental Protection Agency (EPA) and a previous Missoula, Montana study revealed that wood smoke (likely residential wood combustion) was the major source of $PM_{2.5}$ throughout the winter months in Fairbanks, contributing between ~58% and 86% of the measured $PM_{2.5}$ at the five sites. The other sources of $PM_{2.5}$ identified by the CMB model were secondary sulfate (8-21%), ammonium nitrate (3-10%), diesel exhaust (not detected-9%), and automobiles (2-6%). Approximately 1% of the $PM_{2.5}$ was unexplained by the CMB model.

Additional chemical analyses were carried out to confirm the results of the CMB modeling. ^{14}C analyses were conducted on a subset of the filter samples from each of the five sites during the winter of 2011/2012, with the results showing that ~42 - 50% of the measured ambient $PM_{2.5}$ came from a new carbon, or a wood smoke source. In summary, CMB modeling results, coupled with the ^{14}C results, support that wood smoke is the major contributor to the ambient $PM_{2.5}$ in the Fairbanks airshed during the winter months.

2.0. Overview

A research study was conducted by The University of Montana, Center for Environmental Health Sciences (UM-CEHS) to identify the major sources of ambient $PM_{2.5}$ in Fairbanks, Alaska. Within this report, the sampling, analytical, and computer modeling methodologies are described in Sections 3.0 through 5.0, respectively. Section 6.0 presents the results of the $PM_{2.5}$ sampling and CMB modeling program. Sections 7.0, 8.0, and 9.0 present a discussion of all of the CMB modeling findings, results of the ^{14}C findings, and results of the Quality Assurance/Quality Control (QA/QC) program, respectively.

3.0. $PM_{2.5}$ Sampling Program

3.1. Sampling Program Experimental Method

For the winters of 2005/2006, 2006/2007, and 2007/2008, $PM_{2.5}$ sampling was conducted every three days following the EPA's fixed monitoring schedule at the State Building site, with CMB modeling focused on the periods of November through March. Samples were also collected every three days during the winter 2011/2012 at each of five sites (State Building, North Pole, RAMS, NCORE, and NPF3). Samples were collected between early November 2011 and March 2012 at the State Building, North Pole, and NCORE sites, while the RAMS site (December 20, 2011-February 27, 2012) and the NPF3 site (March 1, 2012-March 31, 2012) had abbreviated sampling programs. The State Building site is both a State and Local Air Monitoring Site (SLAMS) for $PM_{2.5}$ as well as a Speciation Trend Network (STN) site, while the other sites are Special Purpose Monitoring (SPM) sites.

Within Fairbanks, 24-hour $PM_{2.5}$ sampling was conducted using a MetOne (Grants Pass, OR) Spiral Ambient Speciation Sampler (SASS) at each of the sites. During each 24-hour sampling event, the SASS collected ~9.7 m^3 of air through Teflon, nylon, and quartz filter media, respectively. In addition to these three filters, UM-CEHS provided quartz filters so that an extra quartz filter could be collected during each sampling event (at each of the sites). This filter was later analyzed for ^{14}C as described in Section 4.0.

3.2. Sampling Program Quality Assurance / Quality Control (QA/QC)

A stringent QA/QC program was employed throughout this study. Prior to sampling, clean filters (Teflon, nylon, and quartz) were provided by Research Triangle Institute (RTI, Research Triangle Institute, NC). Following the sampling events, exposed filters were then sent back to RTI for laboratory analyses. The UM-CEHS quartz filters were purchased pre-cleaned from Chester LabNet (Tigard, OR) at the onset of the study. During shipment of both clean and exposed filter sample media, all $PM_{2.5}$ filters remained in their protective containers and were FedEx overnighted in a cooler containing cold packs during transport.

Throughout the sampling program, the air samplers were maintained by Fairbanks North Star Borough (FNSB) Air Quality staff, with support from Alaska Department of Environmental Conservation (ADEC) staff. During each sampling event (24-hour period), the filters were subjected to temperatures that did not exceed the ambient temperature by more than five °C for more than 30 minutes continuously. Fairbanks site personnel removed the exposed filters from the samplers within 48 hours after the episode ended, and refrigerated the exposed filters immediately upon collection. The air samplers were also audited with an independent transfer standard during the program to verify the accurate measurement of air flow rates, ambient/filter temperatures, and barometric pressures. In addition, $PM_{2.5}$ filter field blanks were collected periodically throughout the program in an effort to determine any artifact contamination.

4.0. Analytical Program

4.1. $PM_{2.5}$ Speciation Data

The Met One Super SASS located at each of the sites collected ambient $PM_{2.5}$ on Teflon, nylon, and quartz filter media, respectively. Exposed SASS filter samples were analyzed by RTI. From the Teflon filter, a gravimetric analysis (RTI, 2008) was initially performed followed by an elemental analysis (RTI, 2009a) using energy-dispersive X-ray fluorescence (EDXRF) where 36 elements were quantified. From the nylon filter, ions (including ammonium, potassium, sodium, nitrate, and sulfate) were measured by ion chromatography (IC) (RTI, 2009b; RTI, 2009c). From the quartz filter, Elemental Carbon and Organic Carbon (EC/OC) concentrations were quantified by Thermal Optical Transmittance (RTI, 2009d). Following the analyses, sample results (including analyte concentrations and uncertainties) were provided to UM-CEHS for use in the CMB source apportionment model.

4.2. Carbon 14 (^{14}C) Analyses

The abundance of ^{14}C in an organic molecule provides information on the source of its carbon. If ^{14}C is present at concentrations relatively equal to the 'normal' levels found in the atmosphere, then the molecule must have come from a recent plant product. If a molecule contains no detectable ^{14}C, it must have come from a petrochemical, fossil fuel, or other ancient source. Thus, analyzing the $PM_{2.5}$ samples for ^{14}C provides additional information on the sources of $PM_{2.5}$ in an airshed. Specifically, it helps to separate the $PM_{2.5}$ emitted by wood combustion ('new' carbon – measurable ^{14}C) versus that emitted by fossil fuel combustion, including diesel / car exhaust ('old' carbon - no ^{14}C).

In addition to the traditional $PM_{2.5}$ speciation analyses described above in section 4.1, information on ^{14}C was obtained from an extra quartz filter that was collected at each of the sites during the scheduled winter 2011/2012 sampling episodes in an effort to confirm and validate the results of the CMB modeling. In this study, the University of Arizona's Accelerator Mass Spectrometry Laboratory

Facility was contracted for the ^{14}C analyses. ^{14}C analyses were conducted on half of a 47-mm quartz filter sample, with the other half of the filter archived for future analyses. Only a subset of the samples collected during the winter of 2011/2012 (from each of the five sites) were analyzed for ^{14}C due to the expense of this analysis. The remainder of the filter halves are currently being archived within the Ward laboratory at The University of Montana. It should be noted that quartz filters were not available from the 2005/2006, 2006/2007, and 2007/2008 State Building sampling programs for ^{14}C analyses. Teflon filters were provided by RTI for these winters. However, Teflon filters cannot be analyzed for ^{14}C due to the thermal combustion procedures utilized in the ^{14}C analyses.

4.3. Analytical Program QA/QC

Both the RTI ($PM_{2.5}$ speciation) and the University of Arizona (^{14}C analyses) laboratories were responsible for QA/QC activities within their respective laboratories.

5.0. Computer Modeling Program

In this project, the most recent version of the Chemical Mass Balance (CMB) computer model (Version 8.2) was utilized to apportion the sources of $PM_{2.5}$ in Fairbanks. The CMB receptor model (Friedlander, 1973; Cooper and Watson, 1980; Gordon, 1980, 1988; Watson, 1984; Watson et al., 1984; 1990; Hidy and Venkataraman, 1996) is based on an effective-variance least squares method, and consists of a solution to linear equations that expresses each receptor chemical concentration as a linear sum of products of source fingerprint abundances and contributions.

For each sample day (from the four sites), the CMB modeling process began by selecting from a combination of 91 sources (**see Table 1**) and 43 chemical species (36 elements, 5 ions, OC and EC, **Tables 5-10**) in an effort to reconstruct the measured Fairbanks ambient $PM_{2.5}$ mass and chemical composition. As part of the CMB modeling procedure, multiple combinations would be tried for each sample run in an effort to select the best combination of sources and species, with an evaluation of the diagnostic performance measures conducted each time until an optimal fit could be obtained. The resulting output file contained the source contribution estimate (SCE) of each identified source, along with the associated standard errors (STD ERR). Unexplained concentrations were also calculated by taking the difference between the actual measured mass and the CMB predicted mass for each sample.

5.1. CMB Model Source Profiles

Discussions were held with Sierra Research, FNSB, and ADEC in an effort to identify all of the potential sources of $PM_{2.5}$ in Fairbanks prior to setting up the CMB model. Following these discussions, a comprehensive list of sources that could potentially contribute $PM_{2.5}$ to the Fairbanks airshed was developed. For each identified source, an attempt was made to locate a source profile. Source profiles are the fractional mass abundances of measured chemical species relative to primary $PM_{2.5}$ mass in source emissions, and are part of the input data loaded into the CMB model. Source profiles represent a general source category rather than any local, individual, $PM_{2.5}$ emission source.

Table 1 presents the source profiles used in the Fairbanks CMB study. The profiles in this table are listed together as source groups, and can be broken down into profiles for street sand and road dust (Profiles 1- 6), pure secondary source emissions (Profiles 7-9), gasoline and diesel exhaust emissions (Profiles 10 – 40), tire and brake wear (Profiles 41 - 48), meat cooking (Profiles 49 - 53), residential wood combustion (Profiles 54 – 78), and other local sources / industry in Fairbanks (Profiles 79-91). Multiple source profiles for each source were used because source compositions can vary substantially among sources, even within a single source over an extended period of time. These variations are caused by:

1) transformation and deposition between the emissions point and the receptor;
2) differences in fuel type and operating processes between similar sources or the same source in time; and
3) uncertainties or differences between the source profile measurement methods (Watson et al., 1998).

Source profiles were either taken directly from the most recent version of SPECIATE 4.0 (USEPA, 2006) or from previous Missoula Valley CMB applications (Carlson, 1990; Schmidt, 1996; Ward and Smith, 2005). SPECIATE 4.0 is EPA's repository of Total Organic Compound (TOC) and Particulate Matter (PM) speciated source profiles for use in source apportionment studies. For each source found in the database, both the compound fraction and uncertainty for the source-specific compounds are presented. Since Missoula and Fairbanks have similar topographies (i.e. valley locations impacted by temperature inversions, cold winter temperatures, etc.) and many of the same sources of $PM_{2.5}$, several of the CMB source profiles developed in past Missoula CMB applications were included in the Fairbanks $PM_{2.5}$ source apportionment program. These include profiles for street sand (Profiles 1), secondary sulfate (Profile 7), secondary ammonium sulfate (Profile 8), secondary ammonium nitrate (Profile 9), diesel train (Profile 39) and diesel truck exhaust (Profile 40), and residential wood combustion (Profile 56). All SPECIATE and Missoula CMB profiles used in the Fairbanks CMB were reviewed before being loaded into the CMB model. For those chemical species known to be absent from specific source types, default values of zero for the mass fraction and uncertainty of 0.0001 were used.

One assumption of the CMB model is that compositions of source emissions are constant over the period of ambient and source sampling, and that chemical species do not react with each other. CMB is well suited for apportioning sources of primary aerosols (those emitted directly as particles). However, it is difficult to attribute secondary aerosols formed through gas-to-particle transformation in the atmosphere to specific sources. Sulfate, nitrate, and ammonium abundances in directly emitted particles are not sufficient to account for the concentrations of these species measured in the atmosphere. Therefore, to account for secondary aerosol contributions to $PM_{2.5}$ mass, sulfate (Profile 7), ammonium sulfate (Profile 8), and ammonium nitrate (Profile 9) were expressed as "pure" secondary source profiles, and represented by their chemical form.

Table 1: $PM_{2.5}$ Source Profiles Used in the Fairbanks CMB.

Profile	Description
1	CITY STREET SANDING PILE, STREET SAND
2	SPECIATE 411302.5, PAVED ROAD DUST – COMPOSITE
3	SPECIATE 412202.5, UNPAVED ROAD DUST – COMPOSITE
4	SPECIATE 92053, PAVED ROAD DUST – SIMPLIFIED
5	SPECIATE 92088, UNPAVED ROAD DUST – SIMPLIFIED
6	SPECIATE 92073, SAND & GRAVEL – SIMPLIFIED
7	SULFATE (SO4 IS ONLY SPECIE, THEREFORE IS ONLY NONZERO CONCENTRATION)
8	AMMONIUM SULFATE (INCLUDES NH4)
9	AMMONIUM NITRATE (INCLUDES NH4)
10	SPECIATE 311052.5 LIGHT DUTY VEHICLE-LEADED COMPOSITE
11	SPECIATE 312022.5 LIGHT DUTY VEHICLE-UNLEADED
12	SPECIATE 321022.5 LIGHT DUTY VEHICLE-DIESEL
13	SPECIATE 321032.5 LIGHT DUTY VEHICLE-DIESEL (2ND PROFILE OF THIS TYPE)

14	SPECIATE 322032.5, HEAVY DUTY VEHICLE-DIESEL
15	SPECIATE 311082.5, LIGHT DUTY VEHICLE - NON CATALYST
16	SPECIATE 311072.5, LIGHT DUTY VEHICLE - WITH CATALYST
17	SPECIATE 322022.5, HEAVY DUTY DIESEL
18	SPECIATE 322082.5, HEAVY DUTY DIESEL TRUCKS
19	SPECIATE 312012.5, LIGHT DUTY VEHICLE – UNLEADED
20	SPECIATE 312032.5, LIGHT DUTY VEHICLE – UNLEADED
21	SPECIATE 3875, GASOLINE EXHAUST - WINTER, SMOKER
22	SPECIATE 3884, GASOLINE EXHAUST - WINTER, LOW EMITTER PROFILE 1
23	SPECIATE 3888, GASOLINE EXHAUST - WINTER, LOW EMITTER PROFILE 2
24	SPECIATE 3892, GASOLINE EXHAUST - WINTER, HIGH EMITTER PROFILE 1
25	SPECIATE 3896, GASOLINE EXHAUST - WINTER, HIGH EMITTER PROFILE 2
26	SPECIATE 3900, GASOLINE EXHAUST - WINTER, NON-SMOKER
27	SPECIATE 3904, GASOLINE EXHAUST - WINTER, SMOKER PROFILE 1
28	SPECIATE 3908, GASOLINE EXHAUST - WINTER, SMOKER PROFILE 2
29	SPECIATE 3878, DIESEL EXHAUST PROFILE 1
30	SPECIATE 3879, DIESEL EXHAUST PROFILE 2
31	SPECIATE 3880, DIESEL EXHAUST PROFILE 3
32	SPECIATE 3912, DIESEL EXHAUST PROFILE 4
33	SPECIATE 3913, DIESEL EXHAUST PROFILE 5
34	SPECIATE 3914, DIESEL EXHAUST PROFILE 6
35	SPECIATE 92035, HDDV EXHAUST – SIMPLIFIED
36	SPECIATE 92042, LDDV EXHAUST – SIMPLIFIED
37	SPECIATE 92049, NON-CATALYST GASOLINE EXHAUST – SIMPLIFIED
38	SPECIATE 92050, ONROAD GASOLINE EXHAUST – SIMPLIFIED
39	DIESEL TRAIN (SENT FROM MISSOULA)
40	DIESEL TRUCK (SENT FROM MISSOULA)
41	SPECIATE 340022.5, TIRE WEAR PROFILE 1
42	SPECIATE 340032.5, TIRE WEAR PROFILE 2
43	SPECIATE 340082.5, TIRE WEAR PROFILE 3
44	SPECIATE 3156, TIRE WEAR PROFILE 4
45	SPECIATE 92087, TIRE DUST – SIMPLIFIED
46	SPECIATE 340042.5, BRAKE LINING – ASBESTOS
47	SPECIATE 3157, BRAKE WEAR
48	SPECIATE 92009, BRAKE LINING DUST – SIMPLIFIED
49	SPECIATE 160002.5, MEAT COOKING – CHARBROILING
50	SPECIATE 160012.5, MEAT COOKING – FRYING
51	SPECIATE 4383, COOKING
52	SPECIATE 91005, COOKING - CHARBROILING COMPOSITE
53	SPECIATE 92015, CHARBROILING – SIMPLIFIED
54	SPECIATE 421042.5 RESIDENTIAL WOOD SMOKE FROM MEDFORD, OR
55	SPECIATE 421052.5 RESIDENTIAL WOOD SMOKE FROM POCATELLO, ID
56	RESIDENTIAL WOOD COMBUSTION (SUPPLIED BY MISSOULA)
57	SPECIATE 423182.5, RESIDENTIAL WOOD COMBUSTION
58	SPECIATE 423032.5, RESIDENTIAL WOOD COMBUSTION, COMPOSITE
59	SPECIATE 423302.5, COMPOSITE OF RESIDENTIAL WOODBURNING SOURCES
60	SPECIATE 421022.5, WOOD STOVES - AVERAGE ALL FUELS
61	SPECIATE 421012.5, WOOD STOVES - PINE FUELS
62	SPECIATE 3235, RESIDENTIAL WOOD BURNING PROFILE 1

63	SPECIATE 3236, RESIDENTIAL WOOD BURNING PROFILE 2
64	SPECIATE 3238, RESIDENTIAL WOOD BURNING PROFILE 3
65	SPECIATE 3239, RESIDENTIAL WOOD BURNING PROFILE 4
66	SPECIATE 3240, RESIDENTIAL WOOD BURNING PROFILE 5
67	SPECIATE 3769, RESIDENTIAL WOOD BURNING PROFILE 6
68	SPECIATE 3770, RESIDENTIAL WOOD BURNING PROFILE 7
69	SPECIATE 423192.5, RESIDENTIAL WOOD COMBUSTION COMPOSITE
70	SPECIATE 423312.5, RESIDENTIAL WOODSTOVE COMPOSITE
71	SPECIATE 91031, RESIDENTIAL WOOD COMBUSTION: HARDSOFT – COMPOSITE
72	SPECIATE 91032, RESIDENTIAL WOOD COMBUSTION: HARDSOFTN/A – COMPOSITE
73	SPECIATE 91033, RESIDENTIAL WOOD COMBUSTION: SOFT – COMPOSITE
74	SPECIATE 92067, RESIDENTIAL WOOD COMBUSTION: HARD – SIMPLIFIED
75	SPECIATE 92068, RESIDENTIAL WOOD COMBUSTION: HARDSOFT – SIMPLIFIED
76	SPECIATE 92069, RESIDENTIAL WOOD COMBUSTION: HARDSOFT N/A – SIMPLIFIED
77	SPECIATE 92071, RESIDENTIAL WOOD COMBUSTION: SYNTHETIC – SIMPLIFIED
78	SPECIATE 92090, WILDFIRES – SIMPLIFIED
79	SPECIATE 92006, ASPHALT ROOFING – SIMPLIFIED
80	SPECIATE 92025, DISTILLATE OIL COMBUSTION – SIMPLIFIED
81	SPECIATE 92048, NATURAL GAS COMBUSTION – SIMPLIFIED
82	SPECIATE 92052, OVERALL AVERAGE / DEFAULT (WASTE DISPOSAL, MISC) – SIMPLIFIED
83	SPECIATE 92060, PROCESS GAS COMBUSTION – SIMPLIFIED
84	SPECIATE 92063, RESIDENTIAL NATURAL GAS COMBUSTION – SIMPLIFIED
85	SPECIATE 92072, RESIDUAL OIL COMBUSTION – SIMPLIFIED
86	SPECIATE 92075, SEA SALT – SIMPLIFIED
87	SPECIATE 92079, SINTERING FURNACE-SIMPLIFIED (ZINC PROD, FLUE DUST HANDLING)
88	SPECIATE 92082, SOLID WASTE COMBUSTION – SIMPLIFIED
89	SPECIATE 92084, SUBBITUMINOUS COMBUSTION – SIMPLIFIED
90	SPECIATE 92085, SURFACE COATING – SIMPLIFIED
91	SPECIATE 92086, TIRE BURNING – SIMPLIFIED

5.2. CMB Modeling Program QA/QC

A comprehensive QA/QC plan was applied throughout the CMB modeling program to ensure accurate results, including the use of the CMB validation protocol (Watson et al., 2004). The QA/QC protocol:

1) determines model applicability;
2) selects a variety of profiles to represent identified contributors;
3) evaluates model outputs and performance measures;
4) identifies and evaluates deviations from model assumptions;
5) identifies and corrects model input deficiencies;
6) verifies consistency and stability of source contribution estimates; and
7) evaluates CMB results with respect to other data analysis and source assessment methods.

For each model run, evaluations of several different combinations of source profiles were used, with the number of chemical species always exceeding the number of source types. As described in **Table 2**, statistical parameters used to evaluate the validity of source contribution estimates included TSTAT, R^2, Chi^2, DF, and R/U ratios. The results of these fitting parameters (for each modeling run) have to be within the EPA target ranges for the modeling results to be considered valid. It should also be noted that concentrations of species found on field/trip blanks were not subtracted (or blank-corrected) from the ambient sample concentrations before the modeling was conducted.

Table 2: Statistical Criteria for the CMB Model.

Output / Statistic	Abbreviation	EPA Target	Explanation
Std. Error	STD ERR	<SCE	The standard error of the SCE.
T-statistic	TSTAT	> 2.0	The ratio of the value of the SCE to the uncertainty in the SCE. A T-STAT greater than 2 means that the SCE has a relative uncertainty of less than 50%.
R-square	R-SQUARE (R^2)	0.8 to 1.0	A measure of the variance of the ambient concentration explained by the calculated concentration.
Chi-square	CHI-SQUARE (Chi^2)	0.0 to 4.0	A term that compares the difference between the calculated and measured ambient concentrations to the uncertainty of the difference. A perfect fit has a chi-square of 0.0, and a chi-square less than 2 usually indicates a good fit.
Percent Mass Explained	% MASS	100% ± 20%	The ratio of the total calculated to measured mass.
Degrees of Freedom	DF	> 5	The difference between the number of fitting species and the number of fitting sources.
Ratio of Calculated to Measured	RATIO C/M	0.5 to 2.0	The ratio of the calculated to measured concentration of an ambient species. Ideally, this value should be 1.0.
Ratio of Residual to Uncertainty	RATIO R/U	–2.0 to 2.0	The ratio of the residual (calculated minus measured) to the uncertainty of the residual (square root of the sum of squares of the uncertainties).

6.0. Sampling and CMB Modeling Results

6.1. $PM_{2.5}$ Mass

$PM_{2.5}$ mass was measured from Teflon filters collected at each of the sites. **Table 3** presents the $PM_{2.5}$ mass measured at the State Building for the winters of 2005/2006, 2006/2007, and 2007/2008, respectively, while **Table 4** presents the mass measured at five sites during the winter of 2011/2012. Please note that there were several sample days throughout the programs that were excluded from the overall average calculations due to sampler malfunctions or collection errors. These sample days (which are listed in **Appendix A**) were also excluded from use in the CMB modeling.

Table 3: Average $PM_{2.5}$ Mass Concentrations (µg/m^3) – Winters 2005/2006, 2006/2007, and 2007/2008.

	State Building 11/3/05 – 3/30/06 n= 36	State Building 11/1/06 – 3/31/07 n=39	State Building 11/2/07 – 3/31/08 n=40	MDL
$PM_{2.5}$ mass	18.9	19.9	18.7	0.740

Note: MDL–minimum detection limit.

Table 4: Average $PM_{2.5}$ Mass Concentrations (µg/m^3) – Winter 2011/2012.

	State Building 11/2/11 – 3/31/12 n=38	North Pole 11/2/11 – 3/25/12 n=35	RAMS 12/20/11 – 2/27/12 n=16	NCORE 11/2/11 – 3/31/12 n=44	NPF3 3/1/12 – 3/31/12 n=7
$PM_{2.5}$ mass	20.0	24.2	22.1	19.5	18.3

6.2. $PM_{2.5}$ Speciation Data

Tables 5 through **10** present the average concentrations (in µg/m^3) of elements, ions, and OC/EC, respectively, measured throughout the sampling programs at each of the sites/years. The minimum detection limits (MDL) in µg/m^3 for each compound are also presented, with the bolded values (within the tables) indicating analyte concentrations measured at or above the MDL. All MDLs were provided by RTI.

Table 5: Average $PM_{2.5}$ Elemental Concentrations (µg/m^3) – State Building, Winters of 2005/2006, 2006/2007, and 2007/2008.

	State Building 11/3/05 – 3/30/06 n= 36	**State Building 11/1/06 – 3/31/07 n=39**	**State Building 11/2/07 – 3/31/08 n=40**	**MDL**
Magnesium	0.009	0.008	0.006	0.011
Aluminum	**0.020**	**0.031**	0.009	0.013
Silicon	**0.063**	**0.042**	**0.048**	0.011
Phosphorus	0.000	0.002	0.001	0.010
Sulfur	**1.339**	**1.249**	**1.153**	0.007
Chlorine	**0.017**	**0.068**	**0.073**	0.005
Potassium	**0.083**	**0.081**	**0.102**	0.004
Calcium	**0.056**	**0.029**	**0.029**	0.005
Titanium	**0.005**	0.000	0.001	0.004
Vanadium	0.001	0.001	0.000	0.003
Chromium	**0.002**	**0.012**	**0.002**	0.002
Manganese	**0.002**	**0.002**	0.001	0.002
Iron	**0.069**	**0.084**	**0.052**	0.001
Nickel	**0.001**	**0.004**	**0.001**	0.001
Copper	**0.004**	**0.006**	**0.004**	0.001
Zinc	**0.043**	**0.040**	**0.039**	0.003
Gallium	0.001	0.000	0.000	0.002
Arsenic	**0.001**	**0.001**	**0.001**	0.001
Selenium	0.001	0.000	0.000	0.002
Bromine	**0.005**	**0.004**	**0.003**	0.002
Rubidium	0.001	0.000	0.000	0.002
Strontium	**0.006**	**0.006**	**0.002**	0.002
Yttrium	0.001	0.000	0.000	0.003
Zirconium	0.001	0.001	0.000	0.004
Molybdenum	0.000	0.000	0.000	0.006
Silver	0.003	0.002	0.001	0.013
Cadmium	0.003	0.001	0.001	0.017
Indium	0.003	0.001	0.000	0.018
Tin	0.005	0.003	0.002	0.025
Antimony	0.004	0.001	0.001	0.038
Barium	**0.016**	0.002	0.002	0.010
Lanthanum	0.006	0.000	0.000	0.008
Mercury	0.002	0.001	0.000	0.007
Lead	**0.007**	**0.004**	**0.004**	0.004
Sodium	**0.045**	**0.041**	0.028	0.037
Cobalt	0.000	0.000	0.000	0.001

Note: MDL–minimum detection limit.
Bolded values indicate concentrations measured at or above the MDL.

Table 6: Average $PM_{2.5}$ Elemental Concentrations ($\mu g/m^3$) – Winter 2011/2012.

	State Building 11/2/11 – 3/31/12 n=38	North Pole 11/2/11 – 3/25/12 n=35	RAMS 12/20/11 – 2/27/12 n=16	NCORE 11/2/11 – 3/31/12 n=44	NPF3 3/1/12 – 3/31/12 n=7	MDL
Magnesium	**0.011**	**0.019**	**0.015**	**0.017**	**0.023**	0.011
Aluminum	0.009	0.001	0.009	0.007	0.010	0.013
Silicon	**0.042**	**0.017**	**0.037**	**0.033**	**0.031**	0.011
Phosphorus	0.000	0.000	0.000	0.000	0.000	0.010
Sulfur	**1.203**	**0.655**	**0.971**	**1.049**	**0.584**	0.007
Chlorine	**0.080**	**0.150**	**0.113**	**0.112**	**0.164**	0.005
Potassium	**0.114**	**0.264**	**0.200**	**0.132**	**0.164**	0.004
Calcium	**0.028**	**0.017**	**0.032**	**0.026**	**0.014**	0.005
Titanium	0.003	0.001	0.001	0.001	0.000	0.004
Vanadium	0.000	0.000	0.000	0.000	0.000	0.003
Chromium	**0.002**	0.001	0.001	0.001	0.000	0.002
Manganese	0.001	0.001	**0.002**	**0.002**	0.001	0.002
Iron	**0.042**	**0.020**	**0.062**	**0.039**	**0.015**	0.001
Nickel	0.000	0.000	**0.001**	0.000	0.000	0.001
Copper	**0.003**	**0.004**	**0.006**	**0.004**	**0.001**	0.001
Zinc	**0.041**	**0.023**	**0.039**	**0.037**	**0.012**	0.003
Gallium	0.000	0.000	0.000	0.000	0.000	0.002
Arsenic	0.000	0.000	0.000	**0.001**	0.000	0.001
Selenium	0.000	0.000	0.000	0.000	0.000	0.002
Bromine	**0.005**	**0.004**	**0.003**	**0.005**	**0.008**	0.002
Rubidium	0.000	0.000	0.000	0.000	0.000	0.002
Strontium	**0.003**	**0.002**	**0.006**	**0.003**	0.000	0.002
Yttrium	0.000	0.000	0.000	0.000	0.000	0.003
Zirconium	0.001	0.001	0.002	0.001	0.000	0.004
Molybdenum	0.000	0.000	0.000	0.000	0.000	0.006
Silver	0.001	0.000	0.000	0.000	0.002	0.013
Cadmium	0.003	0.001	0.000	0.001	0.000	0.017
Indium	0.002	0.002	0.001	0.002	0.001	0.018
Tin	0.004	0.001	0.005	0.002	0.000	0.025
Antimony	0.007	0.008	0.005	0.008	0.005	0.038
Barium	0.000	0.004	**0.023**	**0.010**	0.000	0.010
Lanthanum	0.000	0.000	0.000	0.000	0.000	0.008
Mercury	0.000	0.000	0.000	0.000	0.000	0.007
Lead	0.001	0.001	0.002	0.002	0.000	0.004
Sodium	**0.097**	**0.098**	**0.076**	**0.107**	**0.148**	0.037
Cobalt	0.000	0.000	**0.001**	**0.001**	0.000	0.001

Note: MDL–minimum detection limit.
Bolded values indicate concentrations measured at or above the MDL.

Table 7: Average $PM_{2.5}$ Ion Concentrations ($\mu g/m^3$) –
State Building, Winters of 2005/2006, 2006/2007, and 2007/2008.

Analyte	State Building 11/3/05 – 3/30/06 n= 36	State Building 11/1/06 – 3/31/07 n=39	State Building 11/2/07 – 3/31/08 n=40	MDL
Sulfate	3.816	3.479	3.215	0.010
Nitrate	1.102	1.054	0.954	0.007
Ammonium	1.648	1.573	1.446	0.017
Potassium	0.072	0.064	0.095	0.014
Sodium	0.066	0.072	0.076	0.027

Note: MDL–minimum detection limit.

Table 8: Average $PM_{2.5}$ Ion Concentrations ($\mu g/m^3$) – Winter 2011/2012.

Analyte	State Building 11/2/11 – 3/31/12 n=38	North Pole 11/2/11 – 3/25/12 n=35	RAMS 12/20/11 – 2/27/12 n=16	NCORE 11/2/11 – 3/31/12 n=44	NPF3 3/1/12 – 3/31/12 n=7	MDL
Sulfate	3.283	1.817	2.883	2.900	1.576	0.010
Nitrate	0.924	0.502	0.949	0.827	0.462	0.007
Ammonium	1.228	0.491	0.969	0.991	0.432	0.017
Potassium	0.095	0.237	0.157	0.105	0.114	0.014
Sodium	0.104	0.101	0.071	0.094	0.143	0.027

Note: MDL–minimum detection limit.

Table 9: Average $PM_{2.5}$ Total, Elemental and Organic Carbon Concentrations ($\mu g/m^3$)
State Building, Winters of 2005/2006, 2006/2007, and 2007/2008.

Analyte	State Building 11/3/05 – 3/30/06 n= 36	State Building 11/1/06 – 3/31/07 n=39	State Building 11/2/07 – 3/31/08 n=40	MDL
Total Carbon	10.4	10.9	11.1	0.24
Organic Carbon	8.7	9.3	9.2	0.24
Elemental Carbon	1.7	1.6	1.8	0.24

Table 10: Average $PM_{2.5}$ Total, Elemental and Organic Carbon Concentrations ($\mu g/m^3$)
Winter 2011/2012.

Analyte	State Building 11/2/11 – 3/31/12 n=38	North Pole 11/2/11 – 3/25/12 n=35	RAMS 12/20/11 – 2/27/12 n=16	NCORE 11/2/11 – 3/31/12 n=44	NPF3 3/1/12 – 3/31/12 n=7	MDL
Total Carbon	8.5	13.7	12.4	10.6	12.5	0.24
Organic Carbon	7.3	12.5	10.6	9.0	11.3	0.24
Elemental Carbon	1.2	1.2	1.8	1.6	1.2	0.24

Out of the 36 elements quantified, only about 13 were consistently measured at or above their reported MDLs. Sulfur had the highest concentration of the measured elements, followed by chlorine and potassium. Regarding the ions measured, sulfate had the highest concentration at each of the sites, followed by ammonium and nitrate. Organic Carbon (OC) concentrations averaged between 7.3-12.5 µg/m^3 throughout these studies, with EC concentrations between 1.2 and 1.8 µg/m^3. Results from the field and trip blanks for the species listed in the above tables were minimal throughout the sampling/analytical program, therefore data were not corrected prior to using in the CMB model.

6.3. Chemical Mass Balance Modeling

Table 11 presents the $PM_{2.5}$ sources identified by the CMB model for each of the five sites/years, including source contribution estimates (± standard errors) and % of total $PM_{2.5}$. In addition, CMB results are summarized as pie charts as presented in **Figures 1-8** for each of the winters/sites. In total, five source profile types were identified by the CMB model as contributors to the ambient $PM_{2.5}$ throughout the winter months. Wood smoke (likely residential wood combustion) was the major source of $PM_{2.5}$ identified, contributing between ~58% and ~86% of the measured $PM_{2.5}$. The other sources of $PM_{2.5}$ identified by the CMB model were secondary sulfate (8-21%), ammonium nitrate (3-10%), diesel exhaust (not detected-9%), and automobiles (2-6%). Approximately 1% of the $PM_{2.5}$ was unexplained by the CMB model.

Table 11: Source Contribution Estimates ± Standard Errors (µg/m^3).
Note that percentages in parentheses are percent contributions to overall ambient $PM_{2.5}$ mass.

State Building	Sulfate	Ammonium Nitrate	Diesel	Autos	Wood Smoke	Unexplained	$PM_{2.5}$ Mass	n	Sampling Dates
2005/2006	4.0±0.5 (21.0 %)	1.8 ±0.5 (9.6 %)	1.3±0.4 (7.1 %)	0.4±0.2 (2.3 %)	11.3±1.7 (59.8 %)	0.1 (0.3 %)	18.9	36	11/3/05-3/30/06
2006/2007	3.7±0.5 (18.7 %)	1.7 ±0.5 (8.4 %)	1.5±0.5 (7.6 %)	1.1±0.4 (5.8 %)	11.5±2.0 (57.9 %)	0.3 (1.6 %)	19.9	39	11/1/06-3/31/07
2007/2008	3.4±0.4 (18.2 %)	1.5±0.5 (8.1 %)	1.7±0.5 (9.0 %)	1.2±0.4 (6.2 %)	10.9±1.6 (58.5 %)	0.02 (0.1 %)	18.7	40	11/2/07-3/31/08
2011/2012									
State Building	3.5±0.4 (17.8 %)	1.5±0.5 (7.5 %)	0.2±0.0 (1.2 %)	0.4±0.1 (2.1 %)	14.0±1.4 (70.4 %)	0.2 (1.0 %)	20.0	38	11/2/11-3/31/12
North Pole	1.8±0.2 (7.8 %)	0.7±0.2 (3.1 %)	0.1±0.0 (0.6 %)	0.3±0.1 (1.2 %)	20.4±2.3 (85.5 %)	0.4 (1.9 %)	24.2	35	11/2/11-3/25/12
RAMS	2.9±0.3 (13.2 %)	1.4±0.4 (6.4 %)	1.2±0.3 (5.7 %)	0.9±0.4 (4.0 %)	14.9±1.8 (69.0 %)	0.4 (1.8 %)	22.1	16	12/20/11-2/27/12
NCORE	3.0±0.3 (15.8 %)	1.3±0.4 (6.8 %)	1.4±0.5 (7.5 %)	0.8±0.3 (4.2 %)	12.4±1.6 (64.4 %)	0.2 (1.3 %)	19.5	44	11/2/11-3/31/12
NPF3	1.7±0.2 (9.2 %)	0.7±0.2 (3.8 %)	0.9±0.4 (4.9 %)	0.8±0.4 (4.2 %)	14.2±2.0 (77.0 %)	0.2 (1.0 %)	18.3	7	3/1/12-3/31/12

Figure 1: State Building CMB Results (November 3, 2005 – March 30, 2006) Winter 2005/2006.

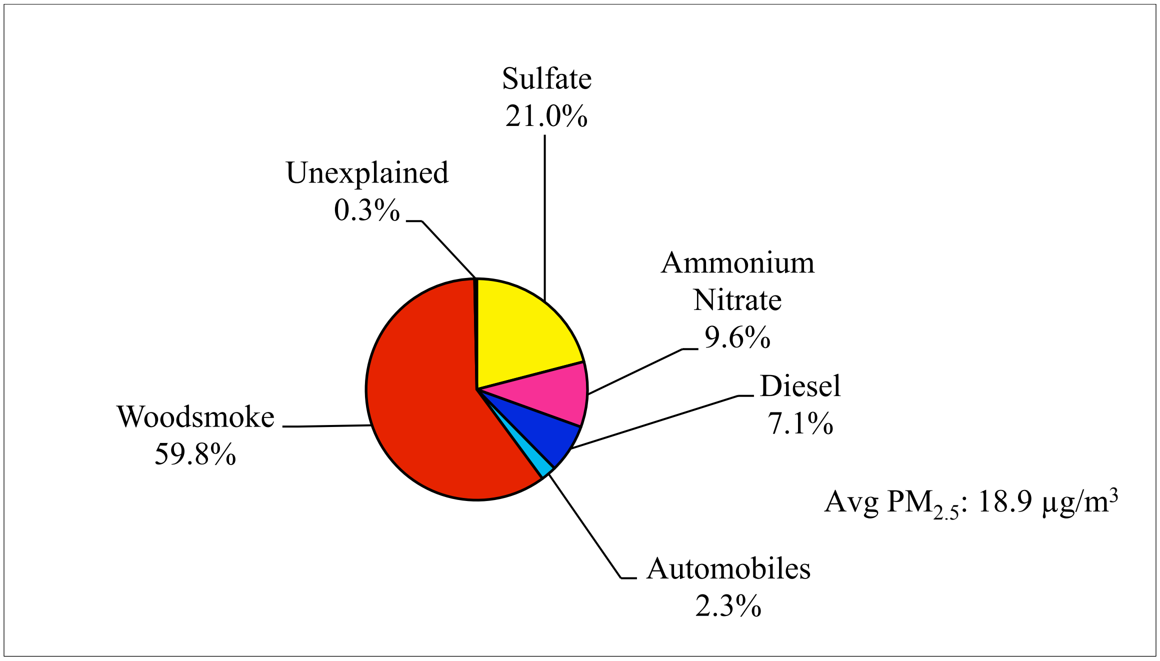


Figure 2: State Building CMB Results (November 1, 2006–March 31, 2007) Winter 2006/2007.

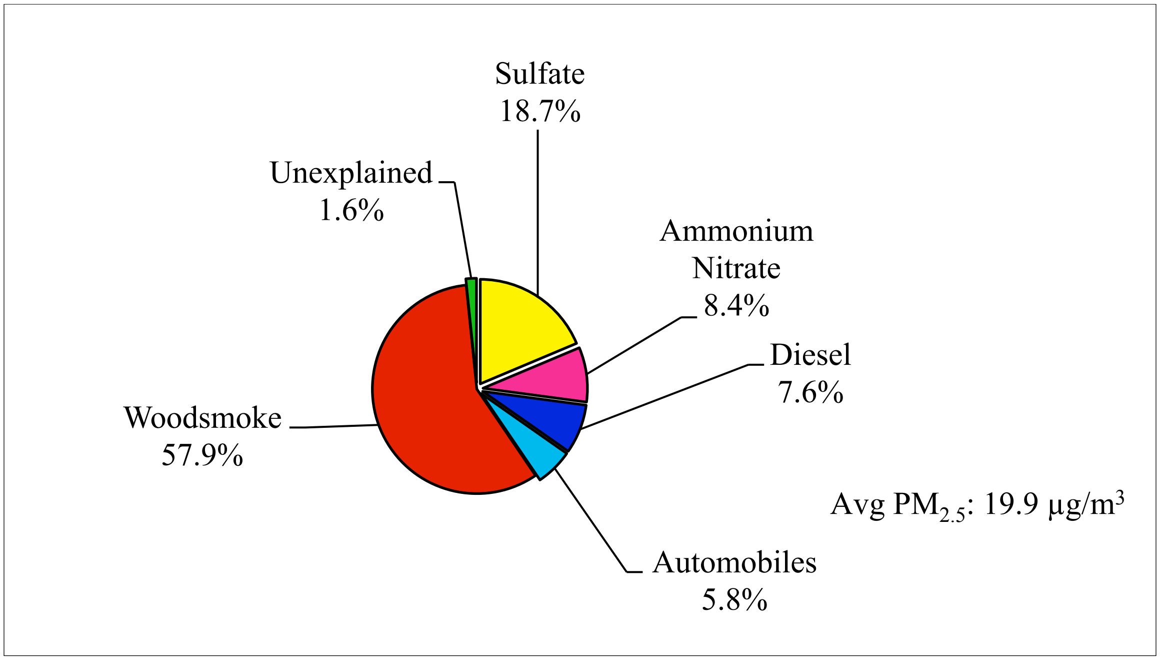


Figure 3: State Building CMB Results (November 2, 2007 – March 31, 2008) Winter 2007/2008.

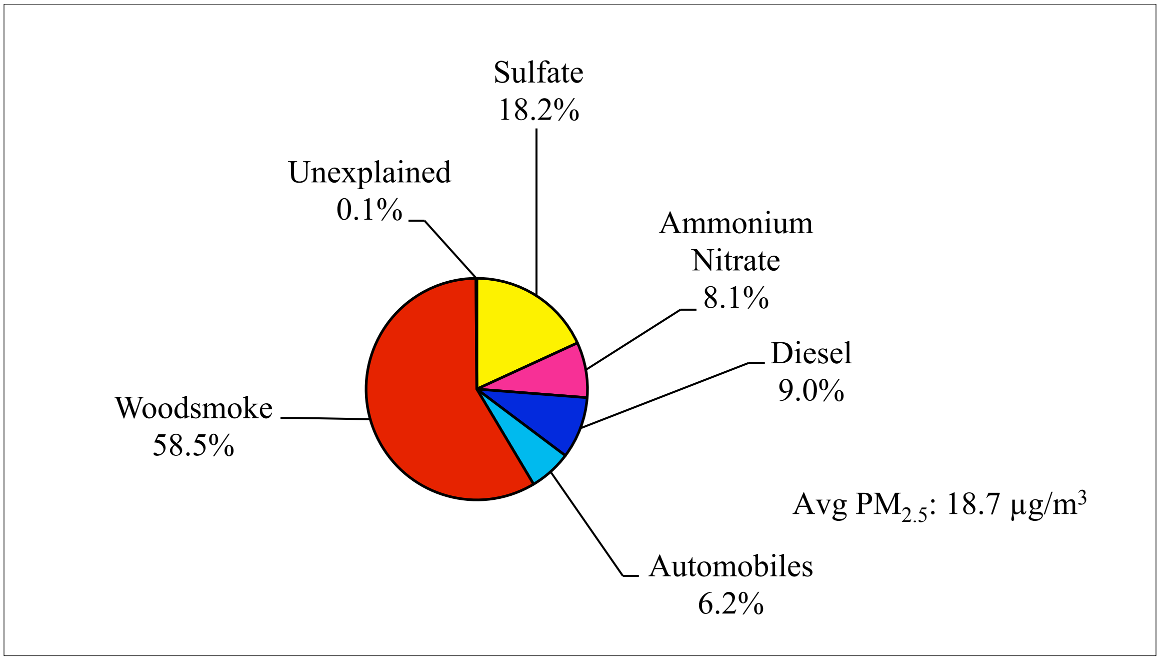


Figure 4: State Building CMB Results (November 2, 2011 – March 31, 2012) Winter 2011/2012.

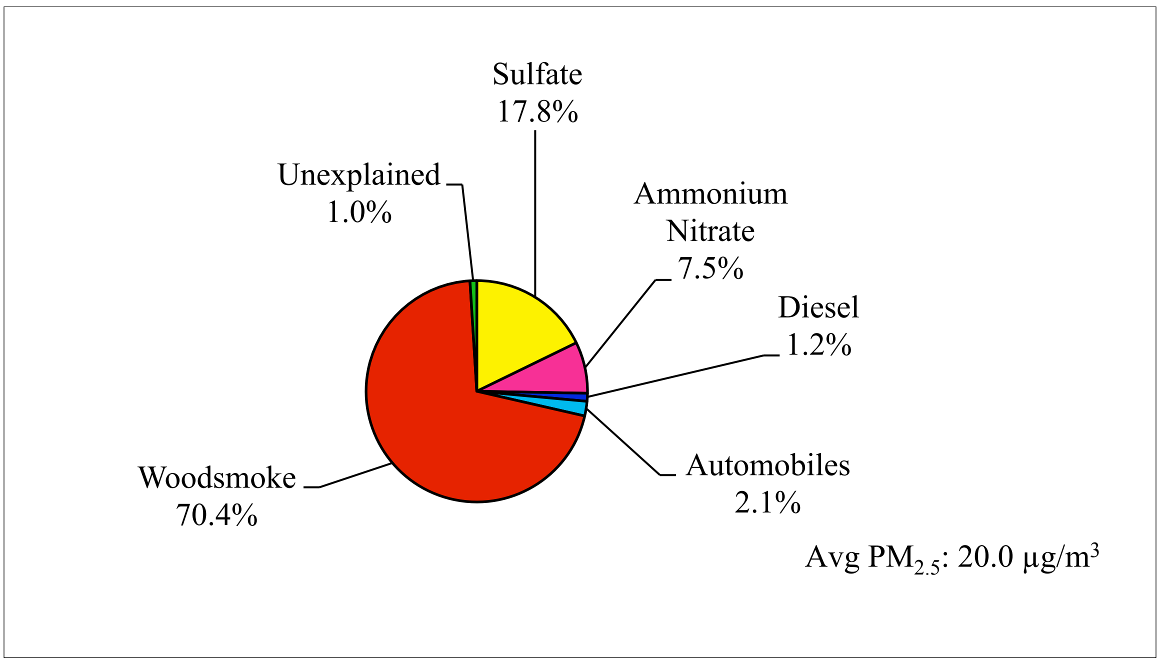


Figure 5: North Pole CMB Results (November 2, 2011 – March 25, 2012) Winter 2011/2012.

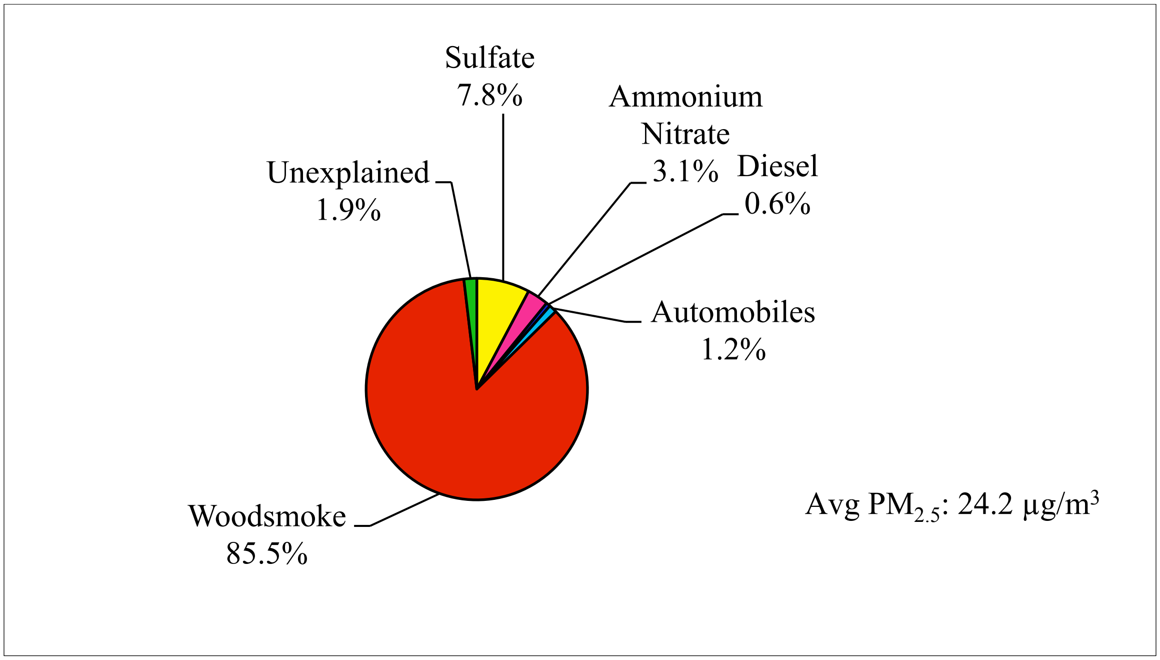


Figure 6: RAMS CMB Results (December 20, 2011 – February 27, 2012) Winter 2011/2012.

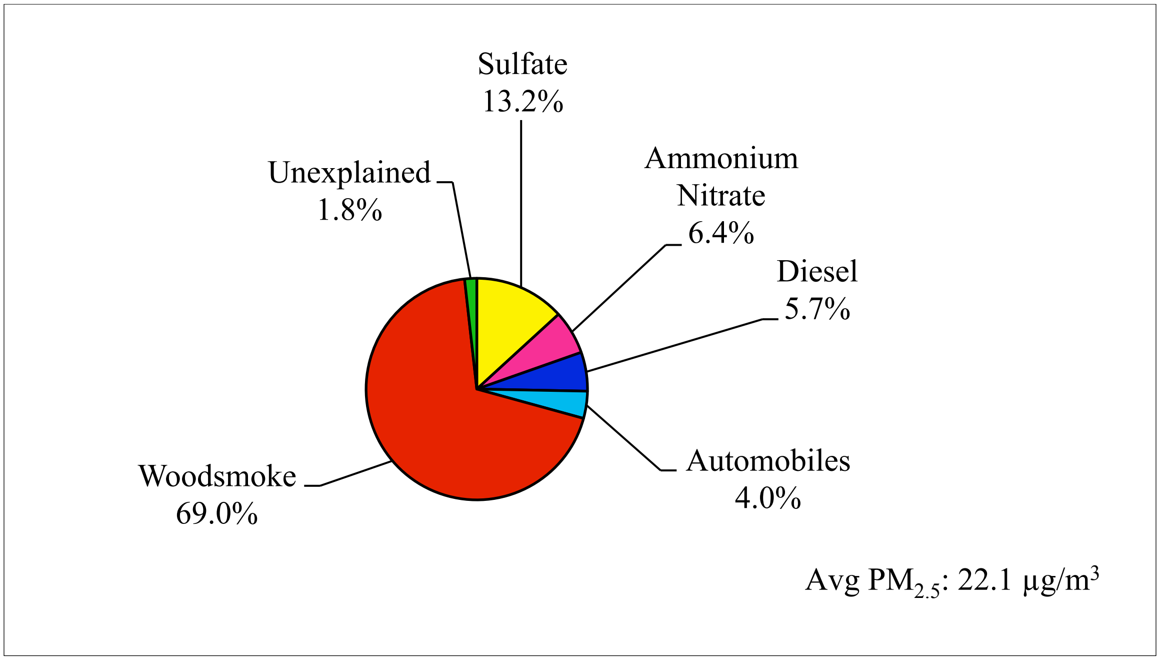


Figure 7: NCORE CMB Results (November 2, 2011 – March 31, 2012) Winter 2011/2012.

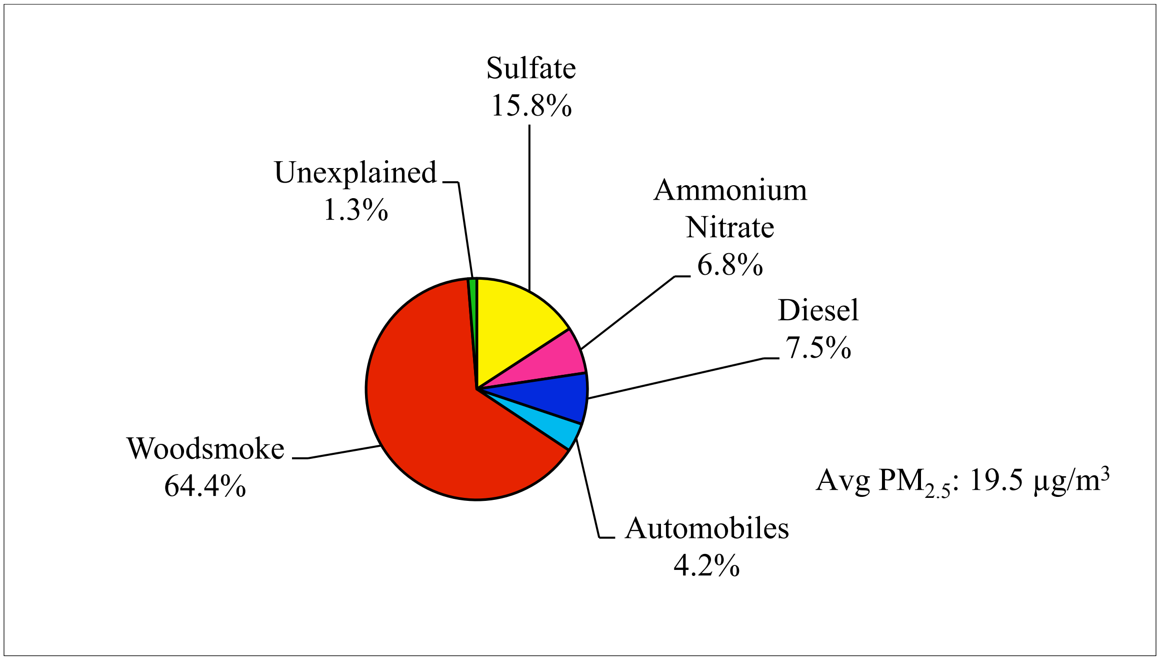
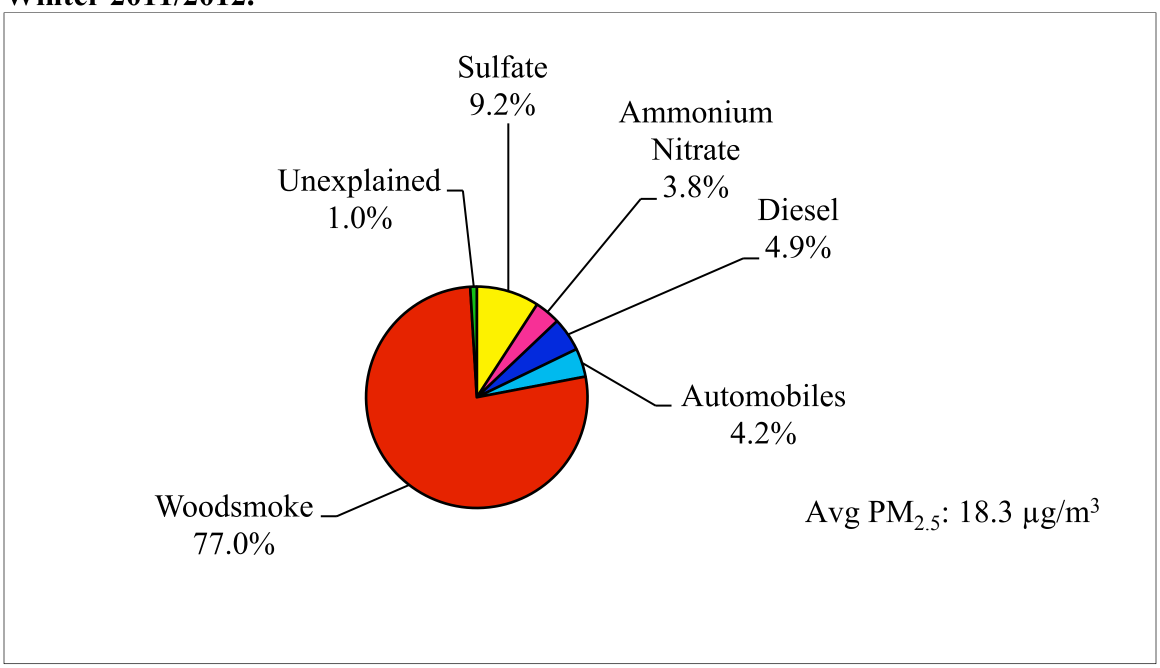


Figure 8: NPF3 CMB Results (March 1, 2011 – March 31, 2012) Winter 2011/2012.



The Tables in **Appendix B** present the $PM_{2.5}$ sources identified by the CMB model (including source contribution estimates and standard errors) for each sample day (for each site for each winter, respectively). The standard error is a single standard deviation. When a standard error value is multiplied by two or three times, the result may be taken as a measure of the upper and lower limit of an individual source's contribution. There is about a 66% probability that the true source contribution is within one standard error and about a 95% probability that the true contribution is within two standard errors of the source contribution estimate.

7.0. Discussion - CMB Modeling

Using the EPA and Missoula, Montana profiles, the results of the CMB modeling revealed that wood smoke (likely residential wood combustion) was the major source of $PM_{2.5}$ throughout the study periods in Fairbanks, contributing between ~58% and 86% of the measured $PM_{2.5}$ at the five sites. The other sources of $PM_{2.5}$ identified by the CMB model were ammonium nitrate, secondary sulfate, diesel exhaust, and automobiles. Approximately 1% of the $PM_{2.5}$ was unexplained by the CMB model.

7.1. Wood Smoke

The wood smoke source identified by the CMB model should be viewed as a general source predominantly composed of wood stove emissions. In addition to residential wood stoves, other biomass combustion emission sources could have contributed to the wood smoke results in Fairbanks, including smoke from outdoor boilers, residential open burning of biomass waste, and small industrial sources. A source profile (Profile 56 in Table 1) developed in Missoula, Montana in the late 1980s served as the best statistically fitting wood smoke profile for each of the five sites when conducting the Fairbanks CMB analyses. It should also be noted that many other residential wood combustion source profiles from the EPA SPECIATE database gave good statistical fits throughout the computer modeling process for each of the sites, including the following wood smoke profiles listed in Table 1: 61, 62, 65, and 66. When compared to profiles of other sources, these wood smoke profiles typically had higher levels of elemental potassium, potassium ion, and OC. Generally, both elemental potassium and the potassium ion gave good fits when modeling, with the elemental form usually providing the better statistical fit.

Given that each of these wood smoke profiles provided strong statistical fits (i.e. gave the best results), this supports that wood smoke is the major source of $PM_{2.5}$ in the Fairbanks airshed throughout the winter months. The CMB results identifying wood smoke in the Fairbanks airshed are consistent with findings from other recent source apportionment studies demonstrating the significant impact that biomass smoke can have on ambient $PM_{2.5}$ (Ward et al., 2006; Sheesley et al., 2007; Gelencser et al., 2007; Puxbaum et al., 2007; Szidat et al., 2007; Caseiro et al., 2009; Ward et al., 2010).

7.2. Secondary Pollutants

"Pure secondary" aerosols such as ammonium nitrate and sulfate are actually formed through gas-to-particle transformations in the atmosphere, and are represented by their chemical form in the model. As noted earlier, one assumption of the CMB model is that compositions of source emissions are constant over the period of ambient and source sampling, and that chemical species do not react with each other. CMB is well suited for apportioning sources of primary aerosols (those emitted directly as particles). However, it is difficult to attribute secondary aerosols formed through gas-to-particle transformation in the atmosphere to specific sources. Using the secondary sulfate and the ammonium nitrate profiles allows us to account for the secondary aerosol contributions to $PM_{2.5}$ mass.

Following wood smoke, the second largest source contributor to ambient $PM_{2.5}$ was sulfate (SO_4), representative of particles directly emitted during combustion and secondary particles formed in the atmosphere. The third largest source identified was ammonium nitrate (NH_4NO_3), also a secondary particle. It should be noted that even though ammonium sulfate was not detected by the CMB model as a $PM_{2.5}$ source (secondary) when both sulfate and ammonium nitrate were used as fitting species, it is likely a significant contributor to the measured $PM_{2.5}$ levels. When using the secondary sulfate source profile in the model, sulfur was used as the fitting species in each model run to apportion sulfate contributions.

Ammonia (NH_3) and oxides of nitrogen (NOx) are the precursors for ammonium nitrate particles, with just under half all NOx emissions in the United States estimated to come from the transportation sector (Seinfeld and Pandis, 1998; Dreher and Harley, 1998). $PM_{2.5}$ has been found to correlate with gaseous emissions of NOx from vehicles, with heavy duty vehicles contributing significantly greater amounts of NOx and particulate matter on a per vehicle basis than light duty vehicles (Gillies et al., 2001). Between 40 and 45% of all NOx emissions in the United States are estimated to come from transportation, with about half of this coming from light-duty gasoline trucks and cars and approximately one-quarter from heavy-duty gasoline and diesel vehicles (Seinfeld and Pandis, 1998; Dreher and Harley, 1998). Other sources of NOx in Fairbanks might include industry, natural gas furnaces, and residential wood combustion. In other parts of the lower 48, ammonia emissions to the atmosphere can arise from many sources including the decay of livestock waste, use of chemical fertilizers, emissions from sewage waste treatment plants, and biological processes in soils (Fraser and Cass, 1998). In Fairbanks, combustion processes such as motor vehicles likely are a significant source of ammonia.

7.3. Mobile Sources

Profiles for this source group typically had higher levels of EC when compared to the wood smoke profiles. When using the EPA/Missoula profiles, the CMB model determined that vehicles were a measurable source of $PM_{2.5}$ at each of the sites throughout the winter months. At the State Building site, diesel exhaust was identified in over 40% of the sample days between the winters of 2005/2006 and 2007/2008, while automobiles were detected only 10 times. Interestingly, diesel was only detected once during the winter of 2011/2012 at the State Building, while automobiles were identified twice. Also during the winter of 2011/2012, the CMB model identified diesel exhaust in nearly half of the sample days at the NCORE site, with automobiles identified only four times. At the North Pole, RAMS, and NPF3 sites, both automobiles and diesel exhaust were measured infrequently during the winter of 2011/2012.

7.4. Other Sources

When conducting CMB modeling using the EPA source profiles, there were other sources identified by the CMB model as contributors to the ambient $PM_{2.5}$. However, these sources were not identified as statistically significant contributors (i.e. evaluated based on statistical criteria). These sources include the following: street sand, distillate oil combustion, natural gas combustion, residual oil combustion, and sub bituminous coal combustion. Street sand was detected by the CMB model from filters collected during the early spring, but never in concentrations that were considered statistically significant (TSTAT >2). In addition, the source profile for natural gas combustion was identified on several occasions, but never in amounts that were statistically significant.

Regarding the combustion sources such as distillate oil, residual oil, and sub bituminous coal, primary $PM_{2.5}$ emissions were not identified as being statistically significant from these individual sources. To investigate this further, the CMB model was run with both the EPA SPECIATE distillate oil and coal profile in the model, and in the absence of the secondary sulfate profile (using both the sulfur and sulfate fitting species). In both instances, the model provided very poor statistical fits. Using the secondary sulfate profile (as a potential surrogate for these sources) provided excellent statistical fits on nearly each sample run.

8.0. ^{14}C Results

8.1. ^{14}C Data

Through discussions with ADEC and FNSB, it was determined that a subset of quartz filters from each of the five sites from the winter of 2011/2012 would be analyzed for ^{14}C. Once identified, these filters were sent to The University of Arizona's Accelerator Mass Spectrometry Laboratory Facility where ^{14}C analyses were conducted on half of the quartz filter samples (with the other half of the filters archived).

Following the methodologies developed by Dr. Jay Turner (Turner, 2012), the following equation was used to calculate the percentage contribution of biomass to the ambient $PM_{2.5}$ mass:

$$PM_{2.5}\ (\%\ \text{biomass}) = (x_{C,biomass} * TC_{measured})/(y_{C,biomass} * PM_{2.5,grametric}) * 100$$

Where:

- $x_{C,biomass}$ = mass fraction of carbon on the filter that originates from biomass from the radiocarbon analysis;
- $y_{C,biomass}$ = mass fraction of carbon in the biomass emissions from emission source profiles. A value of 0.837 from the OMNI hybrid wood smoke emission source profile was utilized in this equation;
- $TC_{measured}$ = $PM_{2.5}$ total carbon concentration from the speciation sampler;
- $PM_{2.5,gravimetric}$ = $PM_{2.5}$ gravimetric mass concentration from the speciation sampler.

The calculated percent (minimum and maximum) contributions of wood smoke to ambient $PM_{2.5}$ are presented in **Table 12**. For comparison, **Table 12** also presents the wood smoke contribution identified by CMB modeling (not using the OMNI profiles).

Table 12: ^{14}C Results.

State Building	**$PM_{2.5}$ Mass ($\mu g/m^3$)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Minimum)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Maximum)**	**% Wood Smoke $PM_{2.5}$ Identified by CMB Model**
11/17/11	32.8	39.3%	47.3%	73.9%
11/20/11	34.2	36.0%	43.4%	No CMB Conducted
12/17/11	37.3	33.9%	40.9%	81.1%
12/29/11	31.8	32.7%	39.4%	77.7%
1/1/12	23.3	30.0%	36.1%	No CMB Conducted
1/4/12	14.3	33.1%	39.9%	79.1%
1/28/12	36.8	14.2%	17.1%	65.0%
2/18/12	25.6	21.4%	25.8%	70.9%
3/10/12	9.5	22.9%	27.6%	62.8%
3/19/12	10.6	22.8%	27.5%	65.0%
North Pole	**$PM_{2.5}$ Mass ($\mu g/m^3$)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Minimum)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Maximum)**	**% Wood Smoke $PM_{2.5}$ Identified by CMB Model**
11/20/11	82.6	66.6%	78.1%	86.9%
12/17/11	36.4	45.3%	54.5%	90.1%
12/26/11	38.3	37.9%	45.0%	92.1%
12/29/11	34.1	55.3%	66.6%	90.0%
1/1/12	33.5	37.8%	45.5%	89.8%
1/28/12	64.9	33.1%	39.8%	88.8%

2/18/12	29.2	42.3%	51.0%	88.9%
3/4/12	26.0	70.6%	82.0%	69.9%
3/10/12	11.1	69.6%	80.0%	81.3%
3/19/12	18.3	69.3%	82.4%	84.3%
RAMS	**$PM_{2.5}$ Mass ($\mu g/m^3$)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Minimum)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Maximum)**	**% Wood Smoke $PM_{2.5}$ Identified by CMB Model**
12/26/11	45.0	21.0%	25.3%	84.1%
12/29/11	24.6	48.7%	58.7%	77.9%
1/1/12	21.3	46.8%	56.3%	48.9%
2/18/12	25.9	35.7%	43.0%	49.2%
NCORE	**$PM_{2.5}$ Mass ($\mu g/m^3$)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Minimum)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Maximum)**	**% Wood Smoke $PM_{2.5}$ Identified by CMB Model**
11/17/11	38.1	36.2%	43.6%	81.3%
11/20/11	30.4	49.1%	59.2%	61.4%
12/17/11	29.7	44.6%	53.7%	54.5%
12/26/11	24.9	41.8%	50.3%	44.3%
12/29/11	23.6	49.1%	59.1%	68.5%
1/1/12	28.0	37.5%	45.2%	83.3%
1/4/12	33.6	10.2%	12.3%	92.8%
1/28/12	28.1	29.1%	35.0%	73.8%
2/18/12	26.9	38.1%	45.9%	49.8%
3/4/12	13.1	42.6%	51.3%	56.4%
3/10/12	9.8	46.9%	56.6%	69.4%
3/19/12	12.1	37.0%	44.6%	69.6%
NPF3	**$PM_{2.5}$ Mass ($\mu g/m^3$)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Minimum)**	**% $PM_{2.5}$ Resulting from Wood Smoke (^{14}C Maximum)**	**% Wood Smoke $PM_{2.5}$ Identified by CMB Model**
3/4/12	37.4	76.9%	87.2%	80.8%
3/10/12	20.5	56.5%	68.1%	86.4%
3/19/12	27.8	60.0%	72.3%	67.7%

When using the values for fraction of modern carbon for each of the sample days, the percent wood smoke component of the $PM_{2.5}$ can be calculated. For all of the filter samples analyzed by The University of Arizona, results show that ~42 - 50% of the measured ambient $PM_{2.5}$ came from a new carbon, or a wood smoke source (across all sites). When we compare the percent wood smoke component identified by the CMB model to the wood smoke identified by the ^{14}C analyses, the CMB model (not using the OMNI profiles) frequently over-reports the wood smoke contribution. Overall, the ^{14}C results confirm that wood smoke is a large contributor to the overall $PM_{2.5}$ mass in the Fairbanks airshed.

9.0. Quality Assurance / Quality Control Results

9.1. Sampling Program QA/QC

For the Fairbanks sampling program, Alaska DEC and FNSB personnel maintained and audited the $PM_{2.5}$ samplers at each of the sites. There were several days throughout the program where samples were not collected (and therefore CMB analyses were not conducted) due to sampler malfunctions. These sample days are identified in **Appendix A**. In addition, CMB source apportionment was not conducted on additional sample days due to low $PM_{2.5}$ mass. If the measured $PM_{2.5}$ concentration is less than 7 μg/m^3, the percent mass may be outside of the acceptable ranges because the uncertainty in the mass measurement is approximately 1 to 2 μg/m^3. These days are also identified in **Appendix A**.

9.2. Analytical Program QA/QC

RTI (speciation analyses) and The University of Arizona (^{14}C) were responsible for QA/QC activities within their respective laboratories. To monitor for artifact contamination in the field and in the laboratory, Teflon, nylon, and quartz filter field blanks were collected throughout the sampling programs. The results of the $PM_{2.5}$ speciation field blank analyses show that the Teflon and quartz filters collected throughout the program did not measure significant artifacts for mass, elements, or Total Carbon. Several ions measured from the nylon filter blanks had levels above the MDLs, including sulfate, nitrate, ammonium, and sodium. Care was taken when utilizing these ions as fitting species to avoid inaccurate source apportionment to the fine PM.

9.3. CMB Program QA/QC

EPA's validation protocol (Watson et al., 2004) was followed throughout this CMB modeling program to ensure accurate results. For each model run, several different combinations of source profiles were evaluated, and the number of chemical species always exceeded the number of source types. The source contribution estimates and the statistics and diagnostic information were reviewed for each model run to determine the validity of the initial model results. The analysis was repeated by eliminating source profiles that gave negative source contribution estimates or standard errors that exceeded the source contribution estimates. When conducting the CMB model runs, only sources with TSTATs >2 were reported. If a TSTAT was <2, then the source was not considered a significant contributor for that sample day.

The majority of the CMB fitting parameters used to evaluate the validity of source contribution estimates were well within EPA target ranges. **Tables 13 and 14** present the program average key 'goodness-of-fit' statistics commonly evaluated for CMB models, the results for the Fairbanks CMB runs, and the EPA target ranges for each parameter. The values for R^2, Chi^2, DF, and % mass explained for each CMB model run were generally well within the EPA target ranges. For the most part, the R/U ratios were all less than 2, and source collinearity (similarities between identified sources) was not a problem throughout this modeling application.

Table 13: Average Goodness-Of-Fit Parameters for the State Building Multi-Year CMB.

Goodness-of-Fit Parameter	State Building 2005/2006 CMB	State Building 2006/2007 CMB	State Building 2007/2008 CMB	EPA Target
R^2	0.94	0.95	0.96	**0.8 - 1.00**
Chi^2	0.35	0.27	0.21	**0.00 – 4.0**
Degrees of Freedom	27	26	32	**> 5**
% Mass Explained	99.7	98.4	100.1	**80 – 120%**
TSTAT	>2	>2	>2	**>2**

Table 14: Average Goodness-Of-Fit Parameters for the 2011/2012 Fairbanks CMB.

Goodness-of-Fit Parameter	State Building CMB	North Pole CMB	RAMS CMB	NCORE CMB	NPF3	EPA Target
R^2	0.96	0.97	0.98	0.97	0.98	0.8 - 1.00
Chi^2	0.25	0.18	0.13	0.18	0.10	0.00 – 4.0
Degrees of Freedom	37	38	37	37	36	> 5
% Mass Explained	99.0	98.1	98.3	98.8	100.1	80 – 120%
TSTAT	>2	>2	>2	>2	>2	>2

It is believed that all of the $PM_{2.5}$ emission sources (or at least the source types) were identified during this CMB modeling program. Missing source types are identified by a low percent mass explained (<80%) and/or a RATIO R/U <<-2.0 for chemical species which are in the missing source. In addition, a "high negative" residual for one or more species and a large Chi^2 can be indicative of missing sources. The good agreement between the calculated source contributions and the measured ambient concentrations indicate that all of the major source types are included in the calculations, and that ambient and source profile measurements are reasonably accurate.

CMB is intended to complement rather than replace other data analysis and modeling methods. For this project, the sensitivity of the CMB model's results to the errors in the source profiles were evaluated by using different chemical abundances of a source type and by changing the fitting species used in the source type. The results of the sensitivity tests for each run showed that the CMB calculations carried out in this study were acceptable. Although there were a few cases where the fitting parameters were outside the EPA target range, none of these cases were considered invalid, and all of the fits were quite strong. Therefore, the source contribution estimates identified in this project can be considered valid.

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Appendix A. Days On Which CMB Modeling Was Not Conducted.

State Building Winter 2005/2006		State Building Winter 2006/2007		State Building Winter 2007/2008	
11/9/05	*	11/1/06	5.7**	11/14/07	*
11/18/05	4.3**	11/13/06	*	12/2/07	5.4**
11/24/05	*	11/16/06	*	12/14/07	4.0**
12/3/05	*	12/16/06	*	12/20/07	*
12/13/05	*	12/19/06	*	2/24/08	*
12/27/05	*	12/25/06	*	3/1/08	5.2**
1/2/05	*	1/9/07	*	3/7/08	5.8**
1/5/06	*	1/18/07	*	3/10/08	*
1/11/06	*	2/2/07	*	3/16/08	*
1/17/06	*	2/20/07	*	3/25/08	5.7**
2/4/06	*	3/1/07	*	3/31/08	5.7**
2/13/06	5.9**	3/7/07	*		
2/19/06	4.4**				
3/24/06	4.8**				

*No, incomplete, or invalid CMB data set.
**Mass was too small to conduct a CMB analysis.

State Building Winter 2011/2012		North Pole Winter 2011/2012	
11/5/11	*	11/2/11	***
11/20/11	*	12/5/11	2.5**
12/5/11	*	12/23/11	5.6**
12/11/11	*	1/22/12	***
12/23/11	6.3**	1/25/12	***
1/1/12	*	2/3/12	***
1/22/12	*	2/9/12	***
2/3/12	6.5**	2/12/12	***
2/24/12	5.0**	2/24/12	3.5**
2/27/12	4.3**	2/27/12	2.1**
3/4/12	*	3/1/12	5.1**
3/7/12	*	3/7/12	4.1**
3/31/12	5.4**	3/13/12	4.3**
		3/16/12	5.5**

*No, incomplete, or invalid CMB data set.
**Mass was too small to conduct a CMB analysis.
***Could not get a good statistical fit for CMB analysis.

RAMS Winter 2011/2012		**NCORE Winter 2011/2012**	
1/13/12	***	12/5/11	5.1**
1/19/12	3.1**	12/23/11	5.6**
1/22/12	0.8**	1/22/12	3.3**
1/25/12	0.7**	2/24/12	5.7**
1/28/12	2.8**	2/27/12	3.6**
2/3/12	5.6**	3/25/12	***
2/24/12	5.9**	3/31/12	5.6**
2/27/12	3.5**		

*No, incomplete, or invalid CMB data set.
**Mass was too small to conduct a CMB analysis.
***Could not get a good statistical fit for CMB analysis.

NPF3 Winter 2011/2012	
3/1/12	4.5**
3/13/12	5.1**
3/28/12	5.2**
3/31/12	4.8**

*No, incomplete, or invalid CMB data set.
**Mass was too small to conduct a CMB analysis.

Appendix B. CMB Results for Each Sample Day.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors (µg/m^3) State Building – Winter 2005/2006.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
11/3/05	17.8	3.93	0.44	1.57	0.51	0.00	0.00	0.00	0.00	13.24	1.44
11/6/05	12.8	2.18	0.24	1.68	0.32	0.00	0.00	0.00	0.00	8.94	1.11
11/9/05*											
11/12/05	20.8	3.84	0.61	1.33	0.50	6.60	2.50	0.00	0.00	7.67	2.17
11/15/05	30.5	6.36	1.00	2.62	0.82	0.00	0.00	5.05	1.92	15.38	2.47
11/18/05**											
11/21/05	9.1	1.87	0.21	1.26	0.25	0.00	0.00	0.00	0.00	6.26	0.81
11/24/05*											
11/27/05	26.4	4.83	0.77	2.14	0.74	0.00	0.00	3.25	1.25	14.48	2.21
11/30/05	21.7	3.72	0.58	4.64	0.65	0.00	0.00	2.42	1.01	9.92	1.60
12/3/05*											
12/6/05	17.1	2.87	0.32	1.95	0.57	0.00	0.00	3.43	0.97	9.19	1.51
12/9/05	16.1	2.69	0.30	0.00	0.00	0.00	0.00	4.40	1.03	8.43	1.46
12/13/05*											
12/15/05	25.1	4.97	0.55	1.88	0.88	0.00	0.00	4.93	1.37	12.87	2.13
12/18/05	25.8	5.25	0.84	2.25	0.80	0.00	0.00	3.58	1.33	13.84	2.19
12/21/05	25.9	4.81	0.54	1.62	0.61	0.00	0.00	6.37	1.64	12.75	2.13
12/24/05	24.4	4.24	0.47	2.22	0.55	0.00	0.00	4.35	1.45	13.19	2.03
12/27/05*											
12/30/05	34.2	7.34	0.81	3.00	0.94	0.00	0.00	0.00	0.00	25.19	2.98
1/2/06*											
1/5/06*											
1/8/06	31.4	6.09	0.67	2.67	0.78	0.00	0.00	0.00	0.00	23.81	2.17
1/11/06*											
1/14/06	18.2	3.25	0.36	1.58	0.42	0.00	0.00	0.00	0.00	12.67	1.48
1/17/06*											
1/20/06	31.1	6.47	1.03	2.35	0.82	0.00	0.00	0.00	0.00	23.93	3.09
1/23/06	26.5	5.65	0.89	1.72	0.74	8.96	3.98	0.00	0.00	11.99	2.21
1/26/06	42	12.05	1.34	2.85	1.51	0.00	0.00	0.00	0.00	27.05	3.30
1/29/06	30.7	7.47	0.84	3.63	0.96	0.00	0.00	0.00	0.00	20.04	2.38
2/1/06	7	1.25	0.14	1.13	0.18	0.00	0.00	0.00	0.00	5.58	0.85
2/4/06*											
2/7/06	15.3	2.94	0.46	1.99	0.57	0.00	0.00	3.34	0.88	7.07	1.30
2/10/06	7.4	1.32	0.15	0.51	0.17	0.00	0.00	0.00	0.00	5.79	0.75
2/13/06**											
2/16/06	12.9	2.25	0.25	1.63	0.39	0.00	0.00	2.03	0.70	7.46	1.25
2/19/06**											
2/22/06	7.1	1.57	0.19	0.57	0.20	0.00	0.00	0.00	0.00	4.43	0.71
2/25/06	15.1	3.88	0.43	1.55	0.49	0.00	0.00	0.00	0.00	9.93	2.84
2/28/06	20.1	3.40	0.42	1.42	0.43	0.00	0.00	0.00	0.00	14.18	1.71
3/3/06	23.2	5.04	0.56	3.88	0.69	0.00	0.00	5.33	1.62	8.90	1.67
3/6/06	15.1	3.64	0.41	1.72	0.47	0.00	0.00	0.00	0.00	9.56	1.22
3/9/06	7.9	2.64	0.29	0.74	0.33	0.00	0.00	0.00	0.00	4.22	0.77
3/12/06	9.4	2.83	0.32	0.73	0.35	0.00	0.00	0.00	0.00	5.50	0.88
3/15/06	8.5	2.66	0.42	0.98	0.34	0.00	0.00	0.00	0.00	4.72	0.74
3/18/06	11.3	2.53	0.39	1.06	0.32	0.00	0.00	0.00	0.00	6.97	0.97
3/21/06	9.4	2.22	0.36	1.34	0.29	0.00	0.00	0.00	0.00	5.82	0.89
3/24/06**											
3/27/06	10.6	2.06	0.33	1.35	0.28	0.00	0.00	0.00	0.00	7.10	1.93
3/30/06	13.7	2.78	0.31	1.58	0.36	0.00	0.00	0.00	0.00	9.62	2.57
Average	**18.9**	**3.97**	**0.51**	**1.81**	**0.53**	**0.43**	**0.18**	**1.35**	**0.42**	**11.32**	**1.72**

Notes: *No or incomplete CMB data set. **Mass was too small to conduct a CMB analysis.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors (µg/m^3) State Building – Winter 2006/2007.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
11/1/06**											
1/4/06	27.9	4.46	0.55	2.26	0.58	0.00	0.00	0.00	0.00	22.36	2.59
1/7/06	13.5	1.77	0.22	1.19	0.24	3.55	1.65	0.00	0.00	6.07	1.53
1/10/06	21.3	3.10	0.38	1.58	0.40	0.00	0.00	3.31	1.19	12.13	1.86
11/13/06*											
11/16/06*											
1/19/06	25.8	6.16	0.76	1.90	0.77	0.00	0.00	0.00	0.00	16.08	1.96
1/22/06	12.7	1.85	0.23	1.47	0.32	0.00	0.00	1.35	0.60	8.55	1.33
1/25/06	32.1	6.18	0.76	2.04	0.78	0.00	0.00	0.00	0.00	23.02	5.93
1/28/06	25.7	5.22	0.65	2.21	0.79	0.00	0.00	3.46	1.31	13.52	2.09
2/1/06	8.0	1.66	0.20	0.85	0.22	0.00	0.00	0.00	0.00	5.84	0.76
2/4/06	15.5	2.32	0.29	2.54	0.46	0.00	0.00	2.48	0.75	8.29	1.36
2/7/06	35.1	3.92	0.48	1.71	0.50	15.23	3.41	0.00	0.00	10.23	1.97
2/10/06	16.3	2.68	0.33	1.26	0.49	0.00	0.00	2.81	0.90	9.54	1.52
2/13/06	15.1	2.62	0.32	1.35	0.34	4.76	1.98	0.00	0.00	5.43	1.67
12/16/06*											
12/19/06*											
2/22/06	26.0	6.93	0.86	2.08	0.97	0.00	0.00	3.39	1.59	13.43	2.20
12/25/06*											
2/28/06	23.8	3.84	0.47	1.54	0.66	0.00	0.00	3.58	1.13	13.47	2.01
2/31/06	16.9	4.06	0.50	1.39	0.57	0.00	0.00	1.98	0.89	10.66	1.70
/3/07	11.0	2.14	0.26	1.27	0.28	0.00	0.00	0.00	0.00	7.15	0.97
/6/07	19.8	3.53	0.43	1.21	0.47	5.84	2.83	0.00	0.00	10.04	1.75
1/9/07*											
/12/07	30.4	5.34	0.66	3.06	0.70	0.00	0.00	5.24	1.72	15.68	2.43
/15/07	16.3	2.21	0.28	0.87	0.30	0.00	0.00	0.00	0.00	13.11	2.83
1/18/07*											
/21/07	23.8	4.42	0.55	2.17	0.57	0.00	0.00	3.66	1.45	12.11	1.93
/24/07	17.4	3.72	0.46	1.85	0.48	0.00	0.00	2.81	1.26	8.52	1.47
/27/07	31.6	5.94	0.72	2.80	0.77	6.88	3.37	0.00	0.00	14.54	3.26
/30/07	25.0	3.86	0.47	1.97	0.50	0.00	0.00	7.74	1.52	10.24	1.79
2/2/07*											
2/5/07	34.6	5.30	0.65	3.29	0.74	8.37	3.83	0.00	0.00	18.32	2.91
2/8/07	14.8	2.96	0.39	0.79	0.39	0.00	0.00	0.00	0.00	11.07	1.30
2/11/07	14.6	2.00	0.25	1.13	0.26	0.00	0.00	0.00	0.00	10.16	1.39
2/14/07	18.0	3.29	0.41	1.72	0.60	0.00	0.00	3.37	1.04	9.98	1.55
2/17/07	21.5	4.13	0.51	1.58	0.52	0.00	0.00	2.10	0.99	13.66	1.96
2/20/07*											
2/23/07	38.7	8.38	1.03	3.23	1.06	0.00	0.00	0.00	0.00	27.02	5.90
2/26/07	15.1	3.28	0.40	1.07	0.43	0.00	0.00	0.00	0.00	10.50	2.89
3/1/07*											
3/4/07	18.8	4.06	0.50	2.01	0.55	0.00	0.00	0.00	0.00	12.83	1.54
3/7/07*											
3/10/07	10.6	2.42	0.30	0.66	0.30	0.00	0.00	0.00	0.00	7.84	1.15
3/13/07	14.6	3.67	0.45	1.04	0.48	0.00	0.00	0.00	0.00	9.54	2.60
3/16/07	13.7	3.03	0.37	0.91	0.40	0.00	0.00	0.00	0.00	10.30	2.73
3/19/07	14.3	2.86	0.35	1.46	0.51	0.00	0.00	2.86	0.92	7.25	1.27
3/22/07	7.2	1.27	0.16	0.36	0.17	0.00	0.00	0.00	0.00	5.44	0.87
3/25/07	15.8	3.36	0.41	1.50	0.43	0.00	0.00	2.69	1.19	7.37	1.32
3/28/07	18.2	3.57	0.44	2.33	0.47	0.00	0.00	3.44	1.26	8.05	1.42
3/31/07	14.0	2.65	0.32	1.60	0.35	0.00	0.00	2.42	1.05	7.62	1.30
Average	**19.9**	**3.7**	**0.5**	**1.7**	**0.5**	**1.1**	**0.4**	**1.5**	**0.5**	**11.5**	**2.0**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors (μg/m^3)
State Building – Winter 2007/2008.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
11/2/07	11.0	1.49	0.18	0.84	0.21	0.00	0.00	0.00	0.00	9.41	1.03
11/5/07	23.5	3.20	0.39	1.32	0.43	0.00	0.00	0.00	0.00	19.41	1.79
11/8/07	13.1	1.90	0.23	0.62	0.25	0.00	0.00	4.38	1.02	6.03	1.13
11/11/07	23.8	3.79	0.46	2.25	0.50	0.00	0.00	5.49	1.42	11.75	1.91
11/14/07*											
11/17/07	9.1	0.74	0.16	1.47	0.26	1.72	0.84	0.00	0.00	5.16	1.05
11/20/07	18.4	2.37	0.31	0.63	0.31	0.00	0.00	3.76	0.85	11.76	1.69
11/23/07	11.7	1.28	0.18	0.61	0.17	0.00	0.00	2.33	0.66	7.40	1.13
11/26/07	12.7	1.75	0.21	0.63	0.23	0.00	0.00	3.87	0.98	5.95	1.11
11/29/07	29.3	5.00	0.61	1.96	0.64	11.64	3.14	0.00	0.00	9.74	2.83
12/2/07**											
12/5/07	24.2	3.14	0.39	1.27	0.42	9.74	2.84	0.00	0.00	10.06	1.79
12/8/07	17.7	2.93	0.36	1.70	0.56	0.00	0.00	3.27	0.97	9.25	1.51
12/11/07	11.8	1.69	0.21	1.00	0.35	0.00	0.00	2.22	0.75	6.78	1.15
12/14/07**											
12/17/07	25.6	4.49	0.55	1.77	0.67	0.00	0.00	2.87	1.18	16.50	2.41
12/20/07*											
12/23/07	32.5	6.31	0.79	2.44	1.16	0.00	0.00	6.72	1.58	18.01	2.82
12/26/07	13.0	3.00	0.37	1.46	0.43	0.00	0.00	1.54	0.73	7.00	1.22
12/29/07	16.4	2.74	0.34	1.79	0.63	0.00	0.00	4.11	0.94	7.94	1.42
1/1/08	24.4	5.03	0.62	1.34	0.66	7.26	3.57	0.00	0.00	10.21	1.93
1/4/08	10.2	1.43	0.18	1.28	0.25	0.00	0.00	1.25	0.57	6.93	1.13
1/7/08	20.8	4.19	0.51	1.67	0.68	0.00	0.00	3.43	1.13	11.22	1.73
1/10/08	7.3	1.53	0.19	0.57	0.20	0.00	0.00	0.00	0.00	5.19	0.71
1/13/08	8.4	1.44	0.18	0.55	0.19	0.00	0.00	0.00	0.00	6.26	0.80
1/16/08	25.1	3.88	0.48	1.94	0.53	7.54	3.07	0.00	0.00	12.36	2.06
1/19/08	26.4	4.36	0.54	2.62	0.57	0.00	0.00	5.64	1.52	13.16	2.12
1/22/08	7.8	1.43	0.18	0.55	0.27	0.00	0.00	1.56	0.61	4.62	0.82
1/25/08	18.2	4.44	0.55	1.48	0.66	0.00	0.00	2.76	1.14	9.53	1.61
1/28/08	24.4	4.32	0.52	1.39	0.55	8.31	2.74	0.00	0.00	8.46	2.40
1/31/08	26.2	4.58	0.56	2.64	0.64	0.00	0.00	0.00	0.00	19.04	1.83
2/3/08	24.2	4.60	0.56	2.10	0.59	0.00	0.00	0.00	0.00	16.54	1.91
2/6/08	68.0	17.15	2.10	5.04	2.16	0.00	0.00	0.00	0.00	48.28	5.97
2/9/08	43.7	11.11	1.37	3.46	1.40	0.00	0.00	0.00	0.00	27.45	3.70
2/12/08	9.5	2.14	0.26	0.77	0.27	0.00	0.00	0.00	0.00	7.31	1.07
2/15/08	8.7	1.76	0.22	0.61	0.22	0.00	0.00	0.00	0.00	6.07	0.85
2/18/08	14.9	2.03	0.25	1.17	0.52	0.00	0.00	3.64	0.90	8.31	1.38
2/21/08	7.5	1.11	0.14	0.78	0.15	0.00	0.00	0.00	0.00	6.20	0.76
2/24/08*											
2/27/08	17.2	3.12	0.39	1.21	0.51	0.00	0.00	2.24	0.81	11.27	1.73
3/1/08**											
3/4/08	24.7	3.13	0.38	2.74	0.44	0.00	0.00	6.27	1.35	12.42	1.93
3/7/08**											
3/10/08*											
3/13/08	11.0	2.07	0.25	1.98	0.30	0.00	0.00	0.00	0.00	7.08	0.88
3/16/08**											
3/19/08	6.6	1.33	0.17	0.57	0.17	0.00	0.00	0.00	0.00	4.48	0.74
3/22/08	10.1	2.29	0.28	0.96	0.29	0.00	0.00	0.00	0.00	6.36	0.91
3/25/08**											
3/28/08	8.5	1.43	0.17	1.18	0.20	0.00	0.00	0.00	0.00	6.01	0.83
3/31/08**											
Average	**18.7**	**3.39**	**0.42**	**1.51**	**0.49**	**1.16**	**0.41**	**1.68**	**0.48**	**10.92**	**1.65**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors (µg/m^3) by Sample Day State Building – Winter 2011/2012.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
11/2/11	11.0	2.17	0.27	0.76	0.27	0.00	0.00	0.00	0.00	8.21	0.72
11/5/11*											
11/8/11	10.3	1.58	0.19	0.45	0.20	0.00	0.00	0.00	0.00	8.40	1.18
11/11/11	8.9	1.09	0.14	0.54	0.14	0.00	0.00	0.00	0.00	7.22	0.21
11/14/11	24.6	3.63	0.44	1.24	0.46	0.00	0.00	0.00	0.00	19.78	1.56
11/17/11	32.8	6.18	0.76	2.09	0.78	0.00	0.00	0.00	0.00	23.42	5.72
11/20/11*											
11/23/11	14.8	2.10	0.26	0.85	0.27	0.00	0.00	0.00	0.00	11.48	0.73
11/26/11	24.7	4.38	0.53	1.64	0.56	0.00	0.00	0.00	0.00	18.29	1.55
11/29/11	27.2	4.59	0.56	1.45	0.58	0.00	0.00	0.00	0.00	20.15	1.68
12/2/11	14.7	1.88	0.24	1.03	0.25	0.00	0.00	0.00	0.00	11.53	2.08
12/5/11*											
12/8/11	27.2	4.41	0.55	1.88	0.56	0.00	0.00	0.00	0.00	21.07	1.72
12/11/11*											
12/14/11	24.7	3.95	0.48	1.63	0.50	8.16	2.35	0.00	0.00	9.91	1.31
12/17/11	37.3	5.86	0.74	1.52	0.73	0.00	0.00	0.00	0.00	31.64	5.82
12/20/11	13.8	1.52	0.19	0.83	0.20	0.00	0.00	0.00	0.00	12.07	0.39
12/23/11**											
12/26/11	23.1	3.98	0.49	1.59	0.51	7.97	2.37	0.00	0.00	10.89	1.40
12/29/11	31.8	5.69	0.70	1.65	0.72	0.00	0.00	0.00	0.00	25.54	2.12
1/1/12*											
1/4/12	14.3	2.01	0.25	0.96	0.26	0.00	0.00	0.00	0.00	11.22	0.88
1/7/12	15.6	3.16	0.39	1.09	0.40	0.00	0.00	0.00	0.00	11.01	0.99
1/10/12	24.4	4.03	0.49	1.21	0.52	0.00	0.00	0.00	0.00	18.04	2.58
1/13/12	23.2	4.83	0.60	1.24	0.61	0.00	0.00	0.00	0.00	17.89	0.91
1/16/12	29.1	6.13	0.76	2.38	0.78	0.00	0.00	8.78	1.57	12.15	1.61
1/19/12	40.5	8.08	0.98	3.98	1.04	0.00	0.00	0.00	0.00	27.33	1.52
1/22/12**											
1/25/12	9.8	1.77	0.22	0.77	0.23	0.00	0.00	0.00	0.00	6.93	0.45
1/28/12	36.8	7.63	0.93	2.21	0.96	0.00	0.00	0.00	0.00	18.30	1.96
1/31/12	18.7	4.87	0.60	1.81	0.62	0.00	0.00	0.00	0.00	11.41	1.24
2/3/12**											
2/6/12	24.8	3.87	0.48	2.14	0.51	0.00	0.00	0.00	0.00	18.42	1.24
2/9/12	18.1	2.34	0.29	1.22	0.31	0.00	0.00	0.00	0.00	13.82	0.85
2/12/12	18.3	2.10	0.26	1.90	0.30	0.00	0.00	0.00	0.00	14.79	0.85
2/15/12	27.0	4.54	0.56	2.21	0.59	0.00	0.00	0.00	0.00	20.19	2.88
2/18/12	25.6	3.94	0.49	3.23	0.55	0.00	0.00	0.00	0.00	17.48	1.23
2/21/12	13.7	2.90	0.35	1.67	0.38	0.00	0.00	0.00	0.00	9.77	0.89
2/24/12**											
2/27/12**											
3/1/12	9.0	2.19	0.27	0.79	0.28	0.00	0.00	0.00	0.00	5.84	0.42
3/4/12*											
3/7/12*											
3/10/12	9.5	2.16	0.27	1.32	0.29	0.00	0.00	0.00	0.00	5.90	0.41
3/13/12	13.9	2.71	0.34	1.38	0.35	0.00	0.00	0.00	0.00	9.66	0.77
3/16/12	16.3	3.37	0.42	1.27	0.43	0.00	0.00	0.00	0.00	11.55	0.95
3/19/12	10.6	2.55	0.31	1.17	0.33	0.00	0.00	0.00	0.00	6.91	1.08
3/22/12	13.3	2.97	0.37	1.35	0.38	0.00	0.00	0.00	0.00	9.20	0.81
3/25/12	11.0	1.72	0.21	1.16	0.23	0.00	0.00	0.00	0.00	7.91	0.54
3/28/12	8.6	1.38	0.17	1.01	0.19	0.00	0.00	0.00	0.00	6.34	0.44
3/31/12**											
Average	**20.0**	**3.53**	**0.44**	**1.49**	**0.45**	**0.42**	**0.12**	**0.23**	**0.04**	**13.99**	**1.41**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors ($\mu g/m^3$) by Sample Day North Pole – Winter 2011/2012.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
11/2/11* **											
11/5/11	8.8	0.48	0.06	0.20	0.07	0.00	0.00	0.00	0.00	7.66	1.35
11/8/11	9.2	0.63	0.07	0.27	0.08	0.00	0.00	0.00	0.00	7.70	0.89
11/11/11	12.3	0.50	0.06	0.26	0.07	0.00	0.00	0.00	0.00	12.41	1.22
11/14/11	30.5	1.37	0.16	0.58	0.22	0.00	0.00	0.00	0.00	27.46	4.08
11/17/11	23.2	1.83	0.21	0.70	0.23	0.00	0.00	0.00	0.00	21.72	2.51
11/20/11	82.6	7.68	0.86	1.97	0.96	0.00	0.00	0.00	0.00	63.92	7.09
11/23/11	12.6	0.65	0.07	0.39	0.09	0.00	0.00	0.00	0.00	10.41	0.97
11/26/11	22.4	1.52	0.17	0.75	0.20	0.00	0.00	0.00	0.00	19.15	2.22
11/29/11	30.4	2.63	0.32	0.88	0.33	0.00	0.00	0.00	0.00	28.53	5.68
12/2/11	10.5	0.94	0.11	0.41	0.12	0.00	0.00	0.00	0.00	8.61	1.12
12/5/11 **											
12/8/11	42.0	2.81	0.31	0.99	0.36	0.00	0.00	0.00	0.00	38.13	3.32
12/11/11	7.9	0.40	0.05	0.13	0.06	0.00	0.00	0.00	0.00	7.04	1.26
12/14/11	16.1	1.05	0.13	0.43	0.14	0.00	0.00	0.00	0.00	14.62	2.99
12/17/11	36.4	2.77	0.31	0.78	0.35	0.00	0.00	0.00	0.00	32.20	2.05
12/20/11	12.5	0.77	0.09	0.28	0.10	0.00	0.00	0.00	0.00	11.62	1.29
12/23/11 **											
12/26/11	38.3	1.88	0.21	0.98	0.24	0.00	0.00	0.00	0.00	33.29	2.28
12/29/11	34.1	2.59	0.29	0.96	0.33	0.00	0.00	0.00	0.00	31.81	2.86
1/1/12	33.5	2.82	0.38	0.79	0.35	0.00	0.00	0.00	0.00	31.54	2.33
1/4/12	11.6	0.86	0.10	0.69	0.12	0.00	0.00	0.00	0.00	9.49	0.95
1/7/12	10.0	0.86	0.10	0.41	0.11	0.00	0.00	0.00	0.00	8.19	0.86
1/10/12	16.5	1.31	0.16	0.45	0.17	0.00	0.00	0.00	0.00	14.69	3.01
1/13/12	17.8	2.13	0.24	0.55	0.27	4.49	2.20	0.00	0.00	11.23	1.65
1/16/12	43.0	2.60	0.29	1.16	0.39	0.00	0.00	0.00	0.00	39.84	5.87
1/19/12	39.5	3.03	0.34	1.80	0.39	0.00	0.00	5.18	1.32	28.15	3.51
1/22/12* **											
1/25/12* **											
1/28/12	64.9	4.65	0.52	1.50	0.58	0.00	0.00	0.00	0.00	48.53	3.11
1/31/12	14.5	2.10	0.24	1.05	0.27	0.00	0.00	0.00	0.00	12.28	1.15
2/3/12* **											
2/6/12	42.8	2.96	0.33	1.59	0.38	0.00	0.00	0.00	0.00	32.88	2.27
2/9/12* **											
2/12/12* **											
2/15/12	9.0	0.65	0.07	0.35	0.08	0.00	0.00	0.00	0.00	8.29	1.08
2/18/12	29.2	2.08	0.23	1.08	0.30	0.00	0.00	0.00	0.00	25.41	3.82
2/21/12	13.2	0.55	0.06	0.32	0.10	0.00	0.00	0.00	0.00	12.51	2.00
2/24/12 **											
2/27/12 **											
3/1/12 **											
3/4/12	26.0	2.13	0.24	0.80	0.27	5.19	2.34	0.00	0.00	18.84	2.50
3/7/12 **											
3/10/12	11.1	1.37	0.15	0.61	0.17	0.00	0.00	0.00	0.00	8.56	1.12
3/13/12 **											
3/16/12 **											
3/19/12	18.3	1.91	0.21	0.83	0.24	0.00	0.00	0.00	0.00	14.71	1.77
3/22/12	8.3	1.35	0.15	0.54	0.17	0.00	0.00	0.00	0.00	6.79	0.94
3/25/12	6.5	0.84	0.09	0.42	0.11	0.00	0.00	0.00	0.00	4.89	0.69
Avg	**24.2**	**1.85**	**0.21**	**0.74**	**0.24**	**0.28**	**0.13**	**0.15**	**0.04**	**20.37**	**2.34**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis. ***Couldn't get a good statistical fit during CMB modeling.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors ($\mu g/m^3$) by Sample Day RAMS – Winter 2011/2012.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
12/20/11	21.8	1.46	0.16	0.87	0.19	0.00	0.00	0.00	0.00	15.55	1.41
12/23/11	13.7	0.98	0.11	0.39	0.13	0.00	0.00	0.00	0.00	8.84	1.08
12/26/11	45.0	3.97	0.44	1.58	0.50	0.00	0.00	0.00	0.00	29.41	2.27
12/29/11	24.6	3.93	0.44	1.44	0.49	0.00	0.00	0.00	0.00	18.86	2.27
1/1/12	21.3	3.48	0.39	1.37	0.44	6.70	2.82	0.00	0.00	11.05	1.75
1/4/12	15.1	2.03	0.23	1.04	0.26	0.00	0.00	1.90	0.93	9.92	1.41
1/7/12	23.4	2.72	0.31	0.98	0.34	0.00	0.00	0.00	0.00	18.08	1.74
1/10/12	16.2	2.80	0.31	0.85	0.37	0.00	0.00	0.00	0.00	15.61	1.39
1/13/12* **											
1/16/12	13.5	1.68	0.19	1.46	0.24	0.00	0.00	0.00	0.00	16.11	1.37
1/19/12**											
1/22/12**											
1/25/12**											
1/28/12**											
1/31/12	23.5	3.65	0.41	1.18	0.48	0.00	0.00	0.00	0.00	19.80	1.71
2/3/12**											
2/6/12	24.8	4.07	0.45	1.94	0.52	0.00	0.00	0.00	0.00	17.95	4.61
2/9/12	19.4	2.32	0.26	1.21	0.30	0.00	0.00	4.34	1.08	10.99	1.58
2/12/12	18.1	2.12	0.24	1.69	0.28	0.00	0.00	3.66	1.02	9.33	1.39
2/15/12	30.8	4.40	0.49	2.09	0.56	0.00	0.00	6.87	1.54	14.51	2.10
2/18/12	25.9	3.77	0.42	2.91	0.50	7.03	2.97	0.00	0.00	13.28	2.00
2/21/12	17.0	2.40	0.27	1.21	0.31	0.00	0.00	2.90	1.03	9.61	1.42
2/24/12**											
2/27/12**											
Average	**22.1**	**2.86**	**0.32**	**1.39**	**0.37**	**0.86**	**0.36**	**1.23**	**0.35**	**14.93**	**1.84**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis. ***Couldn't get a good statistical fit during CMB modeling.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors (µg/m^3) by Sample Day NCORE – Winter 2011/2012.

Date	$PM_{2.5}$ Mass	Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
1/2/11	12.8	2.15	0.24	0.81	0.27	0.00	0.00	0.00	0.00	9.52	1.00
1/5/11	7.5	1.01	0.12	0.42	0.13	0.00	0.00	0.00	0.00	6.43	1.49
1/8/11	12.7	1.60	0.18	0.56	0.20	0.00	0.00	0.00	0.00	10.32	1.00
1/11/11	14.0	1.20	0.13	0.56	0.15	0.00	0.00	0.00	0.00	13.60	1.31
1/14/11	17.8	2.74	0.31	1.07	0.35	0.00	0.00	3.16	1.10	10.99	1.58
1/17/11	38.1	5.22	0.58	1.86	0.66	0.00	0.00	0.00	0.00	30.83	2.19
1/20/11	30.4	5.80	0.65	1.75	0.73	0.00	0.00	4.00	1.75	18.37	2.54
1/23/11	12.6	2.34	0.26	0.95	0.30	0.00	0.00	0.00	0.00	9.74	1.00
1/26/11	31.9	3.73	0.42	1.48	0.47	0.00	0.00	0.00	0.00	25.60	1.83
1/29/11	22.3	3.88	0.44	1.40	0.49	0.00	0.00	1.84	0.94	15.41	2.00
2/2/11	12.8	1.70	0.20	0.91	0.22	0.00	0.00	1.48	0.64	8.94	1.23
12/5/11**											
2/8/11	27.4	3.58	0.40	1.54	0.46	9.91	2.99	0.00	0.00	12.59	1.95
2/11/11	9.0	1.18	0.13	0.55	0.27	0.00	0.00	1.76	0.62	5.82	0.90
2/14/11	28.3	4.12	0.46	1.61	0.52	9.68	3.21	0.00	0.00	12.89	2.02
2/17/11	29.7	5.41	0.60	1.38	0.68	0.00	0.00	6.48	1.73	15.88	2.29
2/20/11	10.8	1.54	0.17	0.92	0.20	0.00	0.00	2.04	0.85	6.16	1.00
12/23/11**											
2/26/11	24.9	4.00	0.45	1.59	0.51	9.45	3.15	0.00	0.00	11.98	1.92
2/29/11	23.6	4.07	0.46	1.53	0.57	0.00	0.00	1.94	0.90	16.38	2.19
/1/12	28.0	3.35	0.38	1.36	0.42	0.00	0.00	0.00	0.00	23.55	2.10
/4/12	33.6	0.78	0.16	1.08	0.12	0.00	0.00	0.00	0.00	23.97	1.80
/7/12	14.6	2.83	0.32	1.00	0.36	0.00	0.00	0.00	0.00	11.00	1.11
/10/12	19.6	3.76	0.42	1.14	0.47	0.00	0.00	0.00	0.00	15.30	1.43
/13/12	19.0	4.30	0.48	1.08	0.54	0.00	0.00	0.00	0.00	13.16	1.48
/16/12	26.4	4.94	0.55	1.97	0.62	0.00	0.00	4.87	1.58	14.42	2.09
/19/12	38.0	6.53	0.73	3.62	0.84	0.00	0.00	6.66	1.98	19.19	2.71
/22/12**											
/25/12	9.0	1.63	0.19	0.65	0.21	0.00	0.00	0.00	0.00	7.11	1.64
/28/12	28.1	5.66	0.63	1.50	0.71	0.00	0.00	0.00	0.00	20.19	3.29
/31/12	20.1	3.82	0.43	1.67	0.65	0.00	0.00	3.54	1.09	11.08	1.65
2/3/12	6.7	1.09	0.12	0.47	0.14	0.00	0.00	0.00	0.00	4.97	1.23
2/6/12	24.7	3.93	0.44	2.01	0.50	0.00	0.00	0.00	0.00	9.01	1.46
2/9/12	24.0	2.35	0.26	1.26	0.30	0.00	0.00	0.00	0.00	14.36	1.45
2/12/12	17.0	2.23	0.25	1.74	0.46	0.00	0.00	2.84	0.76	10.89	1.55
2/15/12	30.7	4.45	0.50	2.18	0.57	0.00	0.00	9.39	1.63	12.67	1.95
2/18/12	26.9	3.92	0.44	3.01	0.52	6.52	3.02	0.00	0.00	13.31	2.01
2/21/12	16.2	2.36	0.27	1.35	0.31	0.00	0.00	1.92	0.73	10.82	1.45
2/24/12**											
2/27/12**											
3/1/12	13.9	2.51	0.29	0.88	0.32	0.00	0.00	1.87	0.74	8.53	1.21
3/4/12	13.1	2.41	0.28	0.92	0.30	0.00	0.00	2.19	0.74	7.13	1.07
3/7/12	6.4	1.03	0.13	0.84	0.14	0.00	0.00	1.33	0.56	3.28	0.62
3/10/12	9.8	2.02	0.22	0.99	0.26	0.00	0.00	0.00	0.00	6.82	0.88
3/13/12	15.8	3.04	0.34	1.35	0.39	0.00	0.00	0.00	0.00	13.05	1.71
3/16/12	17.1	3.19	0.36	1.26	0.40	0.00	0.00	3.93	1.19	8.22	1.33
3/19/12	12.1	2.36	0.26	1.23	0.30	0.00	0.00	0.00	0.00	8.21	0.99
3/22/12	13.3	2.79	0.31	1.32	0.36	0.00	0.00	2.27	1.05	6.51	1.11
3/25/12***											
3/28/12	9.2	1.53	0.17	1.20	0.21	0.00	0.00	0.00	0.00	7.96	1.06
3/31/12**											
Average	**19.5**	**3.05**	**0.34**	**1.32**	**0.40**	**0.81**	**0.28**	**1.44**	**0.47**	**12.41**	**1.59**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis. ***Couldn't get a good statistical fit during CMB modeling.

$PM_{2.5}$ Source Contribution Estimates and Standard Errors ($\mu g/m^3$) by Sample Day – NPF3 – Winter 2011/2012.

Date	$PM_{2.5}$ Mass	Secondary Sulfate	Sulfate STD ERR	Ammonium Nitrate	Ammonium Nitrate STD ERR	Autos	Autos STD ERR	Diesel	Diesel STD ERR	Woodsmoke	Woodsmoke STD ERR
3/1/12**											
3/4/12	37.4	2.74	0.31	1.05	0.35	0.00	0.00	3.28	1.22	29.68	3.65
3/7/12	6.1	0.70	0.08	0.32	0.09	0.00	0.00	1.77	0.75	3.46	0.71
3/10/12	20.5	1.89	0.21	0.76	0.24	0.00	0.00	0.00	0.00	16.89	2.00
3/13/12**											
3/16/12	7.5	1.11	0.12	0.47	0.14	0.00	0.00	0.00	0.00	5.93	0.87
3/19/12	27.8	2.47	0.28	0.91	0.31	5.37	2.45	0.00	0.00	18.29	2.45
3/22/12	15.2	1.87	0.21	0.75	0.29	0.00	0.00	1.30	0.62	12.48	1.67
3/25/12	13.6	1.06	0.13	0.59	0.14	0.00	0.00	0.00	0.00	12.71	2.64
3/28/12**											
3/31/12**											
Avg	**18.30**	**1.69**	**0.19**	**0.69**	**0.22**	**0.77**	**0.35**	**0.91**	**0.37**	**14.21**	**2.00**

Notes: *No, incomplete, or invalid CMB data set. **Mass was too small to conduct a CMB analysis.