5.8. Modeling

5.8.1. Overview

A variety of modeling studies using different analytical techniques have been performed to provide alternate insights into emission source significance and assess chemical mechanisms influencing particle formation in the atmosphere under conditions associated with exceedances of the 24-hour ambient $PM_{2.5}$ standard. The insight gained from these studies focused attention on the sources that needed to be characterized in the emissions inventory and the chemical mechanisms that needed to be considered in the modeling used to assess the impact on $PM_{2.5}$ concentrations in future years due to control strategies and emission inventory changes over time.

This section provides a review of initial modeling studies used to characterize source apportionment, including (1) a statistical evaluation (using positive matrix factorization or PMF) of the variance in speciated measurements of $PM_{2.5}$ collected on filters at the Federal Reference Monitor (FRM) located at the state office building in downtown Fairbanks, to attribute source significance; (2) another statistical evaluation using Chemical Mass Balance (CMB) modeling to compare the mix of chemical compounds collected at multiple Fairbanks monitoring sites to the mix of chemical compounds emitted from each emission source, to prioritize source significance; (3) Carbon-14 (^{14}C) assessment of the age distribution of carbon molecules found at each site, to provide insight into the distribution of emissions from wood burning versus fossil fuels; and (4) analysis of an organic chemical compound known as levoglucosan, which is a unique byproduct of wood burning, to assess its significance. In addition to the statistical analyses, a dispersion modeling study using CALPUFF was used to assess the impact of pollutants emitted from the six power plants located in Fairbanks on the State Office Building monitor. That study provided insight into how pollutants emitted above the mixed (i.e., inversion) layer were dispersed during the 2008 Jan/Feb modeling episode.

Recognizing that sulfate particles collected on the monitoring filters are a mix of primary (i.e., directly emitted) and secondary particles formed from gases emitted into the atmosphere, an analysis of the chemical mechanisms governing sulfate formation was conducted. The results were used to assess how well secondary particulate formation could be simulated in photochemical modeling. An analysis of the organic chemical composition of $PM_{2.5}$ from Fairbanks was also prepared to identify and quantify the chemical species emitted from fossil fuel combustion.

As discussed earlier, baseline emission inventory estimates were prepared for 2015 and 2019. Control measures were then applied to these inventories to quantify their effect on emissions in these years. The inventory estimates—baseline and with controls (discussed in Section 5.06)—were combined with meteorological inputs developed for the selected episodes (discussed in Section 5.3) and available chemistry mechanisms in the Community Multiscale Air Quality (CMAQ) Modeling System to assess the ability of Fairbanks to demonstrate attainment in 2015 and assess the potential for attainment in 2019. A detailed summary of the CMAQ modeling results is presented in this section.

5.8.2. Sources of $PM_{2.5}$ Emissions In and Around Fairbanks:

Winters in Fairbanks, Alaska present unique meteorological conditions; cold air is trapped close to the ground, causing minimal vertical mixing within the stable boundary layer; a lack of weather systems at this latitude limits the amount of horizontal mixing. These conditions lead to elevated concentrations of air pollutants from local emissions of $PM_{2.5}$ and its precursors, especially sulfur dioxide (SO_2). To further understand these elevated concentrations, Sierra Research conducted an initial source contribution analysis based on monitoring data from a site in downtown Fairbanks. The study used a statistical analysis approach called positive matrix factorization (PMF)[1] to analyze the co-variance[2] in air quality measurements in Fairbanks in an attempt to understand the number and types of sources that are contributing to the elevated $PM_{2.5}$ concentration. Figure 5.8-1 summarizes the source contributions to total $PM_{2.5}$ concentrations in Fairbanks from March 2005 through April 2008. As shown, the principal factors responsible for the elevated concentrations were secondary aerosols (sulfate and nitrate), wood burning, and an unidentified zinc-related source, with smaller contributions from sea salt, motor vehicles, and soil.

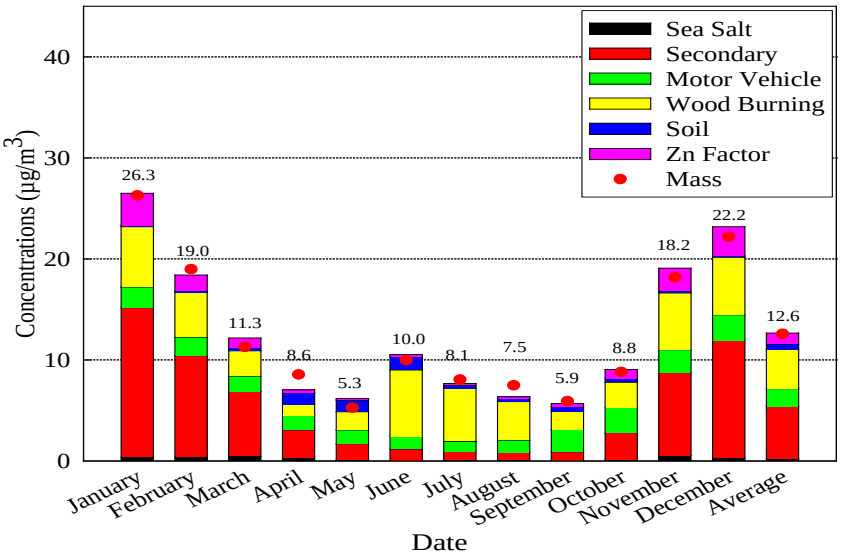

Figure 5.8-1. PMF Source Contributions to Total $PM_{2.5}$ Mass in Fairbanks, Alaska (03/17/2005-4/12/2008)

[1] Eberly, S.,(2005), "EPA PMF 1.1 User's Guide", June 30, 2005. USEPA, National Exposure Research Laboratory, http://www.epa.gov/heasd/products/pmf/pmf.htm.
[2] "Co-variance" quantifies the correlation between measured values, reflecting how changes in one variable are associated with changes in a second variable. *http://mathworld.wolfram.com/Covariance.html*

The study found that, in winter months, secondary aerosols—such as sulfate and nitrate—make up about 40 to 55 percent of the monthly average mass concentrations of $PM_{2.5}$. The concentrations are highest in January, the coldest month.

The source of the zinc factor was unknown and viewed as an anomaly. Possible sources may be the burning of waste lubricating oil for space heating, burning of lubricating oil by motor vehicles, other local trace sources, or distant sources of zinc mining and ore handling. A study done by Cahill[3] indicated that very fine, ultra fine, and nano-particles of zinc were from burned lubricating oil. If this is true, the motor vehicle contribution to $PM_{2.5}$ shown in the graph would be much greater than shown from the PMF analysis.

The monthly average PMF analysis did not reflect the worst-case scenarios—emissions from space heating, including both the burning of wood and sulfur-bearing fuel oil, would be expected to be significantly higher on the coldest days compared to the average winter days. Atmospheric conditions on the coldest days may be quite different from average winter days, resulting in stagnant air that contributes to elevated air pollutants.

During the same time period as the PMF analysis, speciation concentrations from November 2005 to February 2008 were correlated, $PM_{2.5}$ concentrations in Fairbanks in winter are correlated inversely with temperature, as shown in Figure 5.8-2[4]. The correlation is weak due to several confounding factors.

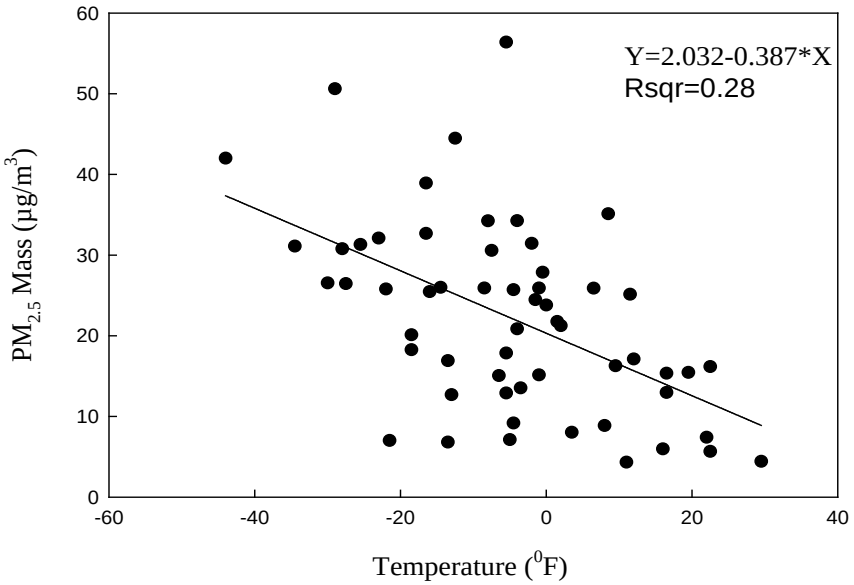

Figure 5.8-2. $PM_{2.5}$ vs. Temperature

[3] T. Cahill, "Persistence of Very-fine, Ultra-fine, and Nano-particles in the Ambient Atmospheric Environment," University of California, Davis; http://www.cce.umn.edu/pdfs/cpe/conferences/nano/Thomas_Cahill.pdf

[4] Appendix III.D.5.8, Updated Speciation Analysis for Fairbanks, 2008

These include (1) the increase in emissions as the temperature decreases; and (2) the decrease in atmospheric dispersion with decreased temperature due to lower wind speeds, lower mixing depths, and more extreme lapse rates, which retards vertical mixing.

The PMF analysis was able to resolve profiles for six possible sources of $PM_{2.5}$ concentrations in Fairbanks: wood burning, secondary aerosols, motor vehicles, zinc, soil, and sea salt. These profiles and their contributions are described below.

- Wood burning is characterized by organic carbon (OC), elemental carbon, (EC) and potassium (K). The sources are from home heating (e.g., wood stoves, fireplaces, inserts and wood boilers, etc.) and transport from occasional wildfires. Smoke from wild fires is a significant contributor to particulates in summer months and home heating is in winter months.

- Secondary particulates occur from sulfate, nitrate, ammonium, and OC, with the contribution of secondary particulate being lower in the summer months than in the winter. This seasonal variation is thought to be caused by the higher emissions of precursor gases (SO_2, oxides of nitrogen [NO_x], and OC) from increased fossil fuel consumption during the winter, as well as the seasonal change in the inversion height.

- Zinc profiles include zinc (Zn), lead (Pb), EC, and OC, and are thought to represent the municipal incinerators and smelters that are burning waste oil or possibly the lubricating oil in automobiles. Sources may be from local incinerator use, burning of waste oil, or some other activity that is unknown. There are no smelters in the local area. Contributions are significantly higher in the winter than in the summer and spring months.

- Emission profiles for motor vehicles, soil, and aged sea salt were also resolved. All three sources contribute very little to the $PM_{2.5}$ concentrations during the winter months.

Figure 5.8-1 and Figure 5.8-2 represent the average values for all measurements recorded and do not distinguish between speciation values collected on violation days and those from non-violation days. Figure 5.8-3 displays the PMF-estimated source contributions on each of the 12 violation days on which values recorded at the speciation monitor exceeded the 24-hour ambient $PM_{2.5}$ standard. The graph shows uniformly high concentrations of $PM_{2.5}$, but no clear trends. Comparing the source contributions in Figure 5.8-3 to those in Figure 5.8-1 for the winter months (November to February)

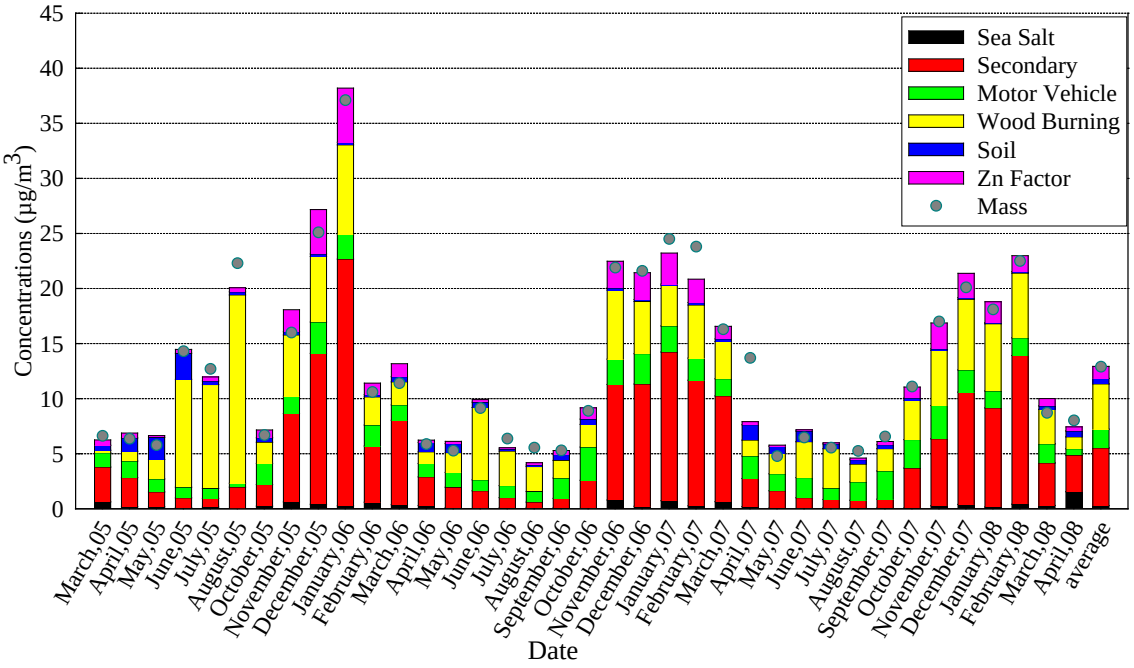

Figure 5.8-3. PMF Assessment of Source Contributions to Total $PM_{2.5}$ Mass in Fairbanks, Alaska (3/17/2005-4/12/2008)

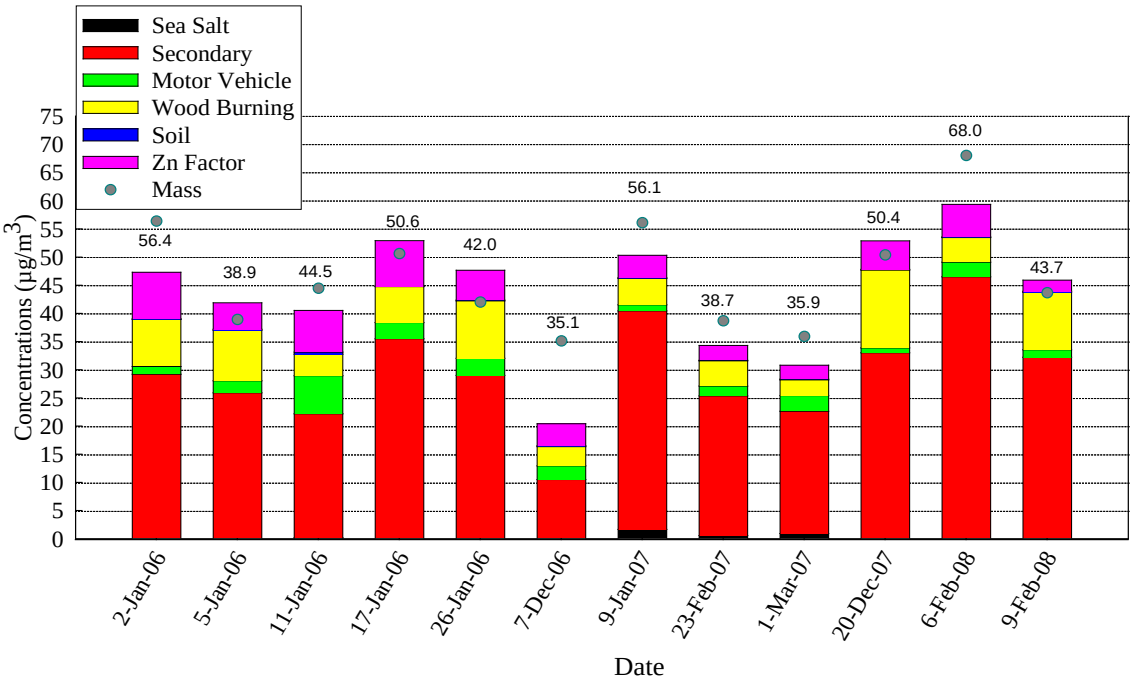

Figure 5.8-4. PMF Source Contributions ($PM_{2.5}$ > 35 µg/m^3) to Total $PM_{2.5}$ Mass During Winter Time at FNSB, Violation Days Only (3/17/2005-4/12/2008)

shows that secondary aerosols (sulfate+nitrate), wood burning, and the zinc factor are still the major sources. On average, the absolute source contributions increased for the violation days.

The results of this preliminary study led to a number of questions regarding the sources of the $PM_{2.5}$ in Fairbanks. To address these questions, further studies such as chemical mass balance (CMB) modeling were conducted to estimate future $PM_{2.5}$ concentrations. This initial emissions study led to Alaska-specific WRF modeling by Penn State. Subsequently, data collected from these meteorological studies were used for regional air quality modeling with CMAQ.

5.8.3. Fairbanks $PM_{2.5}$ Source Apportionment Estimates Study

To understand the sources of $PM_{2.5}$ in the Fairbanks airshed, the University of Montana, Center for Environmental Health Sciences, conducted a source apportionment study based on monitoring data collected during the winters of 2008/2009, 2009/2010, and 2010/2011. This information was critical to the Borough's efforts to identify which sources need to be controlled in order to reduce wintertime $PM_{2.5}$ concentrations in Fairbanks.

Up until the winter of 2008/2009, chemical speciation $PM_{2.5}$ monitoring data were available only from the State Office Building in downtown Fairbanks. To have a better understanding of the particulate problem, three additional monitoring sites were added in the winter of 2008/2009: North Pole Elementary School, Peger Road at the Borough Transportation Center, and a field located to the northwest of the intersection between Geist Road and the Parks Highway (Reindeer site). A map depicting the location of each site is shown in Figure 5.8-5.

Figure 5.8-5. Location of the $PM_{2.5}$ Monitors in Fairbanks, Alaska

The University of Montana employed several source apportionment techniques to analyze the data collected—Chemical Mass Balance (CMB) modeling, Carbon-14 (^{14}C) analysis, and a chemical analysis focusing on wood burning. Because of the uncertainty in each method, use of several methods provided a broader range of insight into emission source contributions.

CMB modeling[5][6], which is a U.S. Environmental Protection Agency (EPA) approved statistical analysis procedure, was used to compare the chemical compounds collected at each site to chemical compounds emitted from each emission source. Based on source profiles developed by EPA, the CMB modeling found that wood smoke was the major source of $PM_{2.5}$ throughout the three winter months study in Fairbanks, contributing between 60% and nearly 80% of the measured $PM_{2.5}$ at the four sites. The other sources of $PM_{2.5}$ identified by the CMB model were secondary sulfate (8-20%), ammonium nitrate (3-11%), diesel exhaust (not detected-10%), and automobiles (not detected-7%). Approximately 1% of the $PM_{2.5}$ was unexplained by the CMB model. The EPA source profile CMB modeling results from the winter of 2008/2009 for all four sites are displayed in Figure 5.8-6.

[5] Friedlander, S.K., 1973. Chemical element balances and identification of air pollution sources. *Environ. Sci. Technol.*, 7, 235-240.

[6] Watson, J.G., Robinson, N.F., Chow, J.C., Henry, R.C., Kim, B.M., Pace, T.G., Meyer, E.L., Nguyen, Q., 1990. The USEPA/DRI chemical mass balance receptor model, CMB 7.0. *Environ. Software*, 5, 38-49.

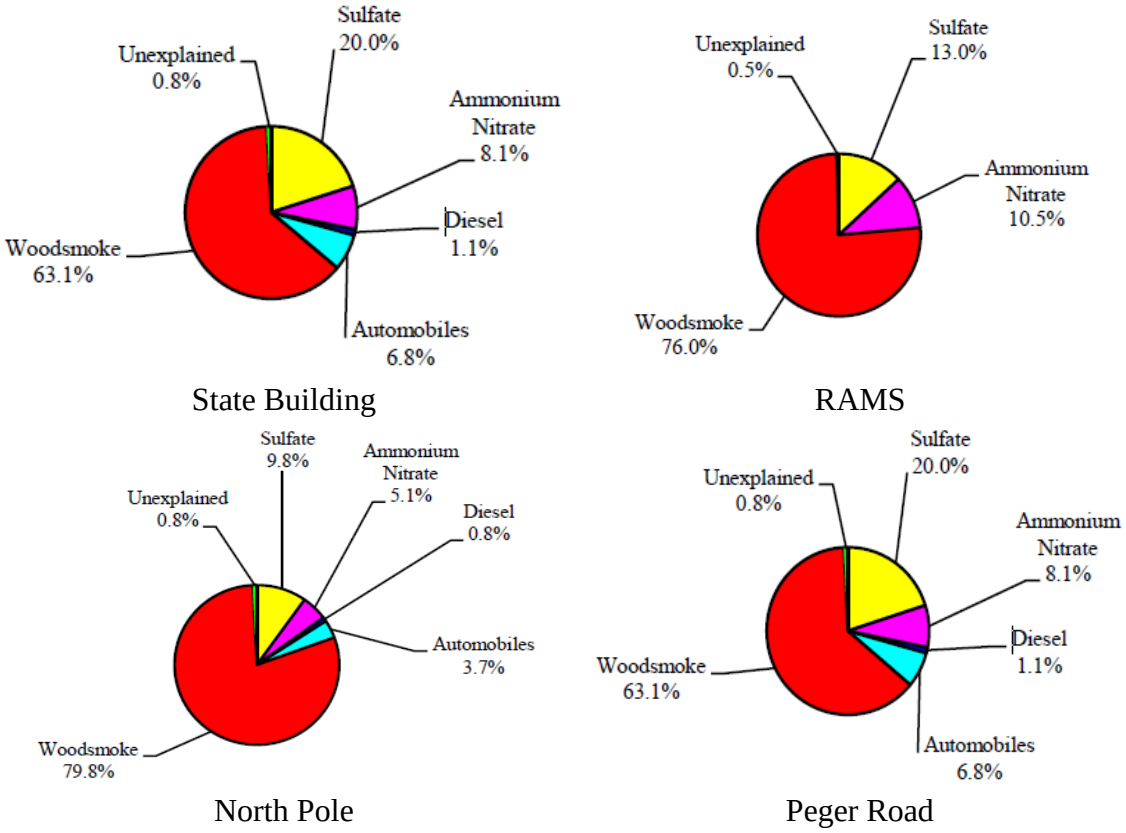

Figure 5.8-6. Emission Source Contribution Estimated from CMB Analysis

To address Fairbanks-specific home heating fuel types and meteorological conditions, CMB modeling was also conducted for winter 2008/2009 using source profiles developed by OMNI Environmental Services and the results were compared to those from the EPA-developed source profiles. The results were consistent with the EPA modeling in identifying wood smoke as being the largest source of $PM_{2.5}$ at all four site OMNI source profiles did not include automobile and diesel exhaust; instead, No. 2 fuel oil combustion was identified as contributing 11.1% to 27.2% of the ambient $PM_{2.5}$ at each of the four sites. Figure 5.8-7shows the results from one of the sites using OMNI profiles in CMB modeling.

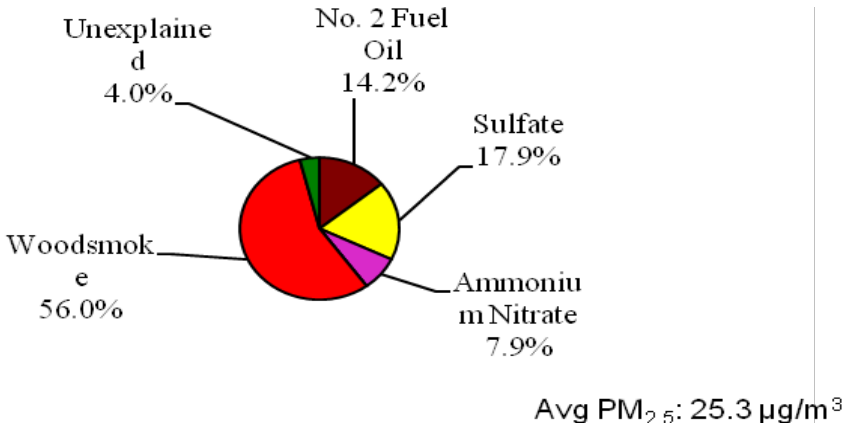

Figure 5.8-7. State Office Building CMB Results Using OMNI Profiles (November 8, 2008 – April 7, 2009)

The second approach used in identifying the main source of $PM_{2.5}$ was Carbon-14 (^{14}C) analysis, which looks at the age distribution of carbon molecules found at each site—the newer carbon is generally associated with wood burning, while the older carbon is associated with petrochemicals or fossil fuels. The third approach was to measure the organic chemical compound known as levoglucosan (an organic compound), which is a unique byproduct of wood burning.

The Carbon isotope ^{14}C and levoglucosan results, analyzed from a subset of filters collected from each of the four monitoring sites, also showed that approximately 50% to 80% of the measured ambient $PM_{2.5}$ came from a new-carbon source (i.e., a wood smoke source). The CMB modeling coupled with the ^{14}C and Levoglucosan results support that wood smoke is the largest contributor to the ambient $PM_{2.5}$ in the Fairbanks airshed during the winter months.

5.8.3.1 Using the CALPUFF Dispersion Model to Characterize the Fairbanks Power Plant Plumes

EPA Region 10 suggested running a dispersion model to assess the plumes from the point sources located at the Non-Attainment Area. ADEC and EPA agreed that CALPUFF would be an appropriate model to run to characterize the plumes from the power plants located within the vicinity of the nonattainment area.

CALPUFF is a non-steady-state meteorological and air quality modeling system used by the EPA for studies that include long-range transport of pollutants. The model was configured with WRF inputs using Mesoscale Model InterFace (MMIF) program and was modified to handle 38 vertical layers representing Fairbanks, with the lowest layer being 4 meters above ground level on a 1.33 x 1.33 km grid cell. Listed below are the six point

sources in the Fairbanks $PM_{2.5}$ nonattainment area that were modeled for the design episode January 23- February 10, 2008.

1. Fort Wainwright (Facility ID 1121) – Coal is the fuel source; hourly emissions provided.

2. University of Alaska Fairbanks (Facility ID 315) – Coal is the base fuel and distillate fuel oil is the secondary fuel used to satisfy increased loads; hourly emissions were provided.

3. GVEA Zehnder – One of GVEA's two facilities, the Zehnder peaking facility (Facility ID 109) is north of downtown and burns high sulfur distillate fuel oil on an intermittent basis; hourly emissions provided.

4. GVEA North Pole – The second of GVEA's facilities, North Pole (Facility ID 110) is a larger facility and burns a mixture of high sulfur distillate fuel oil and naptha (very low sulfur); hourly emissions provided.

5. Aurora Energy (Facility ID 315) – This power plant, located in downtown Fairbanks, is owned by the coal company and burns a mixture of coal and distillate fuel oil. It sells power to GVEA, and hot water and steam to office buildings and a limited number of homes in the downtown area. Only constant yearly emissions were provided.

6. Flint Hills Refinery (Facility ID 71) – Located in North Pole, this is a distillation refinery, no cracking; all heavy ends go back into the pipeline. Hourly emissions were provided.

Figure 5.8-8 represents the modeling domain 201 x 201 in the X and Y direction with a grid cell size of 1.33 x 1.33 km. In addition to the gridded receptors, the model used discretely placed receptors at specific locations with vertical resolution of the WRF data's first 12 layers to obtain the average surface concentration of the entire domain. Summary of the six major point sources average surface concentration of $PM_{2.5}$and SO_2 is tabulated below in Table 5.8-1.

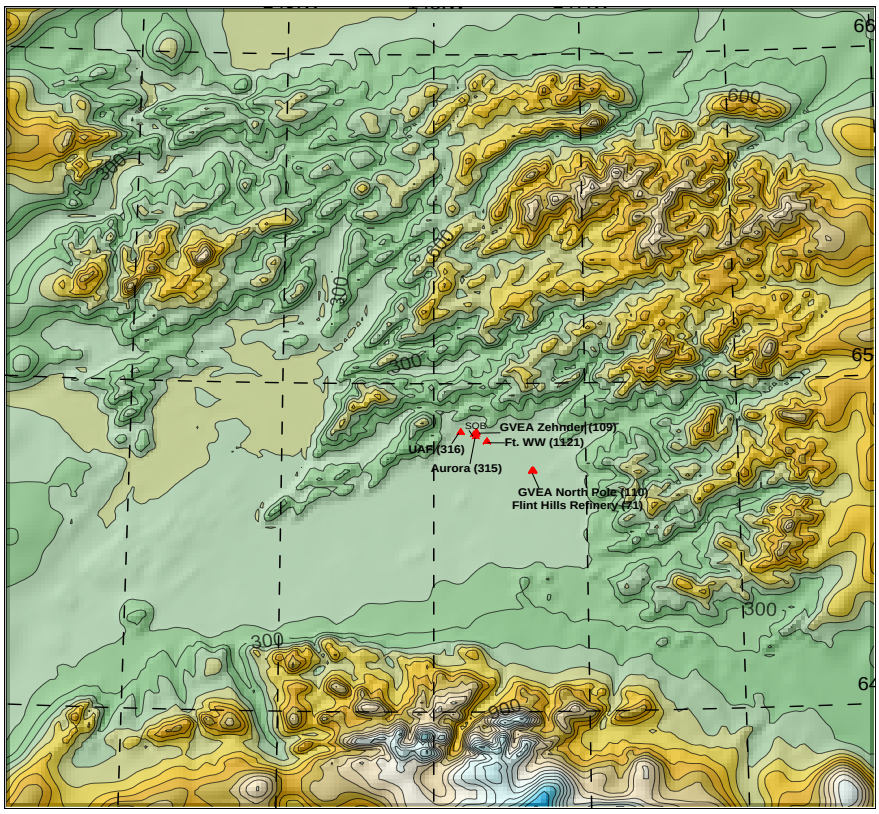

Figure 5.8-8. Fairbanks point source locations are represented by red triangles and are labeled by facility ID number and abbreviated name. The SOB (State Office Building) that houses the FRM (Federal Reference Method) monitor is labeled with a red triangle. The domain represented is 201 x 201, 1.33 km grid cells.

Table 5.8-1. Summary of Six Major Fairbanks Point Source Plumes from CALPUFF for the Episode (Jan. 23rd to Feb. 9th, 2008) Average Surface Concentrations at the State Office Building of $PM_{2.5}$ and SO_2 in $\mu g/m^3$

Power Plant	Episode average SO_2 ($\mu g/m^3$)	Episode average $PM_{2.5}$ ($\mu g/m^3$)
UAF- 316	2.75	0.16
Aurora- 315	0.75	0.02
Zehnder-109	0.48	0.19
Flint Hills-071	0.016	0.38
GVEA NP-110	3.8	1.45
Ft. WW- 1121	14	1.6
Total surface concentration	21.8	3.8

CALPUFF modeling showed that the two largest sources that influence $PM_{2.5}$ concentrations at the downtown State Office Building site were the GVEA North Pole and Ft. Wainwright power plants. Monitoring data from the State Office Building was selected for comparison because it was the only location for which January 2008 episode data were available. The average SO_2 concentration from all sites for the entire episode was 4.4 $\mu g/m^3$ and the highest were from the aforementioned two sources.

5.8.4. Sulfur Formation in Fairbanks

According to observations for the highest concentration winter days between 2006 and 2010, the second largest component of $PM_{2.5}$ is sulfur-containing particles amounting to 18% of the $PM_{2.5}$ composition. Sulfur is emitted to the atmosphere through biogenic or anthropogenic sources; anthropogenic sources are quite extensive, resulting from the combustion of petro-fuel such as heating oil, diesel, and coal.

Due to the significance and complexity of sulfate formation, Dr. Richard Peltier drafted a comprehensive review of the heterogeneous and homogenous reactions that control the conversion of SO_2 to sulfate. In Fairbanks, the specific sources of sulfur are thought to be from coal-fired power plants, on-road diesel fuel, and home heating oil; however, the mechanisms of formation of sulfate are not fully understood. SO_2 gas phase reactions from point sources are not likely a major source of sulfate. According to several studies, heterogeneous process is most likely the mechanism involved in formation of sulfur bound particles; the mediating factors needed for the formation are oxidants such as metal catalysis, hydroxyl radical, ozone, organic peroxides, etc.

The aerosol acidity profiles of the $PM_{2.5}$ data collected by FNSB differed for winter and non-winter months. There was an excess of positively charged ammonium ions during the winter season, which suggests that sulfur conversion reactions were not highly favored; however, sulfur compounds are the second highest contributor of $PM_{2.5}$ in Fairbanks. Measurements of elemental sulfur and particulate sulfate examined in Fairbanks show significant wintertime spikes in sulfate.
The understanding of aerosol chemistry related to sulfur is quite poor in Fairbanks. Additional studies pertaining to the formation of ice fog, air quality model calibration, and source apportionment are needed to better understand the elevated $PM_{2.5}$ levels and develop strategies to reach attainment.

Source contributions and possible chemical mechanisms have not been fully resolved in the case of particulate sulfate in Fairbanks. These analyses provide context to understanding the model performance for secondary sulfate as a component of $PM_{2.5}$.

5.8.5. Organics Analysis for Residential Oil Burner Emissions

Several studies conducted for possible sources of $PM_{2.5}$ in Fairbanks Alaska determined that residential heating, transportation, and coal combustion are a few of the major sources attributing to the elevated concentrations of particulate matter. ADEC contracted

with the University of Montana to characterize the organic chemical composition of $PM_{2.5}$ from Fairbanks with the goal of identifying and quantifying chemical species that can be used to indicate and monitor $PM_{2.5}$ emissions from fossil fuel combustion.

Selected samples representing typical or high $PM_{2.5}$ days from the winter of 2009-2010 in Fairbanks were analyzed for organic compounds: hopanes, steranes, and polynuclear aromatic hydrocarbons (PAHs). Emphasis was placed on sulfur-containing compounds such as dibenzothiophene known emission of diesel fuels and residential oil burners. The PAH picene was also looked at in determining the emissions from coal combustion.

The study found high concentrations of hopanes, steranes, picene and thiophenes in the air and $PM_{2.5}$ composition, indicating that coal combustion may account for a significant level of the sulfur/sulfate fraction of $PM_{2.5}$. Overall, the results indicated that fossil fuel and coal combustion significantly add to the $PM_{2.5}$ problem seen in Fairbanks.

These sources potentially contribute to the total sulfur and carbon measured in particles in Fairbanks. This study provides some insight into the importance of oil burning and coal burning sources that can be useful comparison points for air quality modeling outputs.

5.8.6. Rationale for Model Selections

Air quality attainment modeling is divided into three different modeling tasks: (1) meteorological modeling/processing, (2) emissions modeling/processing, and (3) photochemical transport modeling. There are a number of available computer models for each of these tasks. The models chosen for the meteorological and photochemical transport tasks are explained below. A rationale is not required in the selection of the emissions modeling system.

5.8.6.1. Meteorology

The Weather Research Forecasting Model (WRF) Advanced Research WRF (WRF-ARW) model was chosen as the meteorological model. Typically either the Mesoscale Meteorological Model Version 5 (MM5) or the WRF model are considered for generating gridded, regional meteorological data as inputs for a photochemical transport model. For Fairbanks, the meteorological model must be able to accurately represent a subarctic environment with extreme atmospheric inversions, cold ambient temperatures, and low wind speeds over long periods.

Based on past research at the University of Alaska Fairbanks (UAF)[7]and Penn State University,[8] the WRF model was ultimately selected as the meteorological model for this

[7] Mölders, N. and G. Kramm, 2010: A case study on wintertime inversions in interior Alaska with WRF. Atmos. Res., 95, 314-332

[8] Gaudet, B., D. Stauffer, N. Seaman, A. Deng, K. Schere, R. Gilliam, J. Pleim, and R. Elleman, 2009:

SIP. Researchers at UAF have had success adapting WRF to the unique winter surface conditions of the subarctic region around Fairbanks. As part of an EPA-funded Regional Applied Research Effort (RARE), project researchers at Penn State tested WRF model sensitivity when optimized to represent a low wind speed under extreme cold conditions.[9]

5.8.6.2. Air Quality

The Community Multiscale Air Quality (CMAQ) Modeling System was chosen as the model for the $PM_{2.5}$ attainment test in Fairbanks for the SIP. Generally, EPA defines an air quality attainment model as one that accurately represents the observed ambient particulate matter concentrations across a geographic region. Model considerations include the following:

1. Are the model's functions and their implementation well documented and tested?

2. Does the model support the relevant atmospheric physical and chemical functions?

3. Are experienced personnel available to deploy the model?

4. Would implementation of the model produce a prohibitive cost in time or effort?

5. Is use of the model consistent with the efforts in neighboring regions (U.S. EPA 2007)?[10]

The CMAQ model has a long track record of use in the study of regional air quality and $PM_{2.5}$ attainment modeling.[11] The model is well documented,[12] peer reviewed,[13,14] and

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Modeling extremely cold stable boundary layers over interior Alaska using a WRF FDDA system. 13th Conference on Mesoscale Processes, 17 - 20 Aug, Salt Lake City, UT, American Meteorological
Society.

[9] Gaudet, B.J., and D.R. Stauffer, 2010: Stable boundary layer representation in meteorological models in extremely cold wintertime conditions. Final Report, Purchase Order EP08D000663, Environmental Protection Agency.

[10] U.S. EPA, 2007, Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze, EPA-454/B07-002.

[11] San Joaquin Valley 2008 and 2012 SIPs
http://www.arb.ca.gov/planning/sip/sjvpm25/24hrsjvpm25.htm

[12] Community Modeling & Analysis System provides a detailed user's guide and technical documentation
https://www.cmascenter.org/cmaq/documentation/5.0.2/users_guide.cfm

[13] Aiyyer, A., Cohan, D., Russell, A., Stockwell, W., Tanrikulu, S., Vizuete, W., and Wilczak, J., 2007, Final Report: Third Peer Review of the CMAQ Model, submitted to

supported actively by EPA and a broader academic community.[15,16,17] The CMAQ model is a 3-D Eulerian photochemical transport model that can simulate atmospheric aerosols, gaseous compounds, acidity and visibility. Contractors with photochemical modeling experience were hired by ADEC to support the use of the model for the SIP. Prior to the SIP limited past efforts had been made to adapt photochemical models to the Fairbanks region; however, the broader support of CMAQ was deemed favorable in reducing the cost and effort required. Neighboring regional modeling efforts were not considered due to the spatially isolated nature of the Fairbanks air quality exceedances.

At the time of the original SIP development CMAQv4.7.1[18] (Foley et al., 2010) was the most current version of the model and used throughout the modeling process. Versions 5.0[19] (September 2011) and 5.0.1[20] (July 2012) were released during the SIP development process, but these versions were not used due to the effort already invested in adapting version 4.7.1 for Fairbanks.

5.8.7. Model Setup

Several computer models are used in the process of attainment modeling. The configuration of the meteorological, emissions, and photochemical-transport models is described below.

5.8.7.1. Meteorology

WRF model version 3.1 using data assimilation was used to complete the meteorological modeling for both episodes. For the SIP modeling WRF version 3.1 was used with CMAQ because Penn State conducted the metrology study under the EPA RARE project. The newer versions of WRF since that study were not used due to the considerable

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the Community Modeling and Analysis System Center, University of North Carolina, Chapel Hill

[14] Byun, D., Schere, K.L., (2006), Review of the governing equations, computational algorithms, and other components of the models-3 Community Multiscale Air Quality (CMAQ) modeling system. Applied Mechanics Reviews 59, 51-77.

[15] Chemel, C., et al. "Application of chemical transport model CMAQ to policy decisions regarding PM2. 5 in the UK." Atmospheric Environment 82 (2014): 410-417.

[16] Shimadera, Hikari, et al. "Sensitivity analyses of factors influencing CMAQ performance for fine particulate nitrate." Journal of the Air & Waste Management Association 64.4 (2014): 374-387

[17] Zhang, Y., Liu, P., Liu, X., Pun, B., Seigneur, C., Jacobson, M.Z., and Wang, W., 2010, Fine scale modeling of wintertime aerosol mass, number, and size distributions in Central California, Journal of Geophysical Research, 115, D15207, doi:10.1029/2009JD012950..

[18] http://www.epa.gov/AMD/Research/CMAQ/release4_7_1.html

[19] http://www.airqualitymodeling.org/cmaqwiki/index.php?title=CMAQ_version_5.0_%28February_2012_ release%29_Technical_Documentation

[20] http://www.airqualitymodeling.org/cmaqwiki/index.php?title=CMAQ_version_5.0.1_%28July_2012_ release%29_Technical_Documentation

resources invested in adapting WRF to Fairbanks.[21] The model configurations are shown in Table 5.8-2 through Table 5.8-4. A nested gridding configuration was used to simulate three grids: Grid 1 a 401x301 cell area with 12km horizontal resolution, Grid 2 a 202x202 cell area with 4km horizontal resolution, and Grid 3 a 202x202 cell area with 1.33km horizontal resolution. The nesting configuration is shown in Table 5.8-3. Vertical gridding was held constant between the cells at 39 layers with heights described in Table 5.8-2. Further details of the meteorological modeling are available in Appendix III.D.5.8.

Table 5.8-2. Grid-Independent Features of WRF Simulations

WRF Feature	Value
nesting procedure	one-way concurrent
model top (hPa)	50
Number of vertical layers	39
eta value of full levels	1.0, 0.9995, 0.999, 0.9984, 0.99705, 0.99415, 0.99155, 0.986, 0.78, 0.966, 0.95, 0.034, 0.918, 0.902, 0.886, 0.866, 0.842, 0.814, 0.78, 0.74, 0.694, 0.648, 0.602, 0.556, 0.51, 0.464, 0.418, 0.372, 0.326, 0.282, 0.24, 0.2, 0.163, 0.128, 0.096, 0.066, 0.04, 0.018, 0
Approximate height above ground level of half levels (m)	2.0, 6.0, 10.5, 18.4, 35.5, 57.8, 90.9, 146.2, 228.3, 344.5, 478.7, 614.8, 752.7, 892.5, 1052.3, 1251.1, 1491.2, 1785.4, 2148.4, 2587.7, 3079.8, 3598.2, 4146.0, 4727.3, 5346.7, 6010.4, 6725.8, 7502.6, 8333.4, 9208.6, 10135.5, 11190.6, 12139.8, 13234.2, 14408.4, 15652.1, 16921.7, 18193.7
Exclude nudging from the boundary layer	No
G for analysis nudging, when used (s^{-1})	0.0003
G for obs nudging, when used (s^{-1})	0.0004
obs nudging half-time window (hr)	2
Specified, relaxed zone width	1, 9

[21] Appendix III.D.5.8 – EPA RARE project

Table 5.8-3. Grid-Dependent Features of Baseline WRF-Model Configuration

	Grid 1	Grid 2	Grid 3
Horizontal extent	401 x 301	202 x 202	202 x 202
Horizontal Δx (km)	12	4	1.33
i parent start	-	156	103
j parent start	-	106	106
Time step (s)	24	8	4
Sound step ratio	8	8	4
Dampcoef	0.0	0.0	0.0
Analysis nudging	yes	no	no
obs nudging	yes	yes	yes
Surface obs nudging xy radius (km)	100	100	75
Topographic dataset	USGS 10 m	USGS 2 m	USGS 30 s

Table 5.8-4. Grid-Independent WRF Preprocessor System (WPS) Features

Feature	Value
Projection	Lambert conformal
Reference latitude, longitude	64.8, -148.0
True latitudes	50.0, 70.0
Standard longitude	-148.0
Initial conditions	0.5 degree GFS analyses
Analysis interval (hr)	6

The high-resolution Grid 3 outputs were used in the processing of the emissions and air quality modeling. All grids used a Lambert conformal projection with reference latitude and longitude of 64.8, -148.0. Meteorology fields were processed through the Meteorology-Chemistry Input Processor (MCIP) version 3.6. Minor changes were made to MCIP due to bugs during the execution of the air quality model.[22]

[22] "Fairbanks North Star Borough $PM_{2.5}$ Non-Attainment Area CMAQ Modeling: Final Report Phase I," Project: 398831 CMAQ-DEC, Mölders, N., Leelasakultum, K. University of Alaska Fairbanks, Geophysical Institute, College of Natural Science and Mathematics, Department of Atmospheric Sciences, December 1, 2011

5.8.7.2. Emissions Processing

Emission inventories are prepared for the air quality model using the Sparse Matrix Operator Kernal Emissions (SMOKE) model. SMOKE will convert inventories to the needed spatial, temporal, and speciation formats for the air quality model. Inventories for the SMOKE model cover the following source categories: home heating, industrial point sources, onroad mobile, nonroad, air travel, and area sources (excluding home heating). Raw inventory summaries are provided in the emissions inventory overview section (SIP Section 5.6). SMOKE version 2.7.5b was used to create 3-D photochemical transport model ready inputs for CMAQ. Modifications to SMOKE were made to allow for importing of hourly home heating gridded area source inventories. Modifications have been outlined in Appendix III.D.5.8 along with bug fixes to the model in the areas of the inventory importing (SMKINVEN), gridding (GRDMAT), temporal (TEMPORAL) and merging (SMKMRG) processes of the source code. Bugs were also addressed in the MOVESMRG source code used for importing and processing of MOVES mobile source emission rates.

MOVES version 2010a was used to generate mobile source emission rates lookup tables by hour using modeled temperature data generated by WRF and processed through MCIP.

5.8.7.3. Air Quality

Computer simulations of the two model episodes were performed with the Community Multiscale Air Quality (CMAQ) model version 4.7.1. CMAQ was compiled on a Linux custom-built computer (Intel i7 950 4 core/8 thread, 8 GB system memory, 1 TB hard disk drive) running Ubuntu 10.04 OS using the Portland Group Fortran compiler version 11.4.

The CMAQ model was configured with the modules shown in Table 5.8-5. The module selection followed the default options for CMAQ-4.7.1 with the exceptions of vertical diffusivity and photolysis modules. These modules were chosen based on a review of the CMAQ-model conducted by Mölders and Leelasakultum at UAF.[23]

The model was compiled with version 11.4 of the PGI Fortran compiler with the Message Passing Interface Library (MPICH 2 version 1.3.2). The CMAQ source code was modified to incorporate changes from a UAF study of the CMAQ-model usage in the Fairbanks North Star Borough $PM_{2.5}$ non-attainment area.[24]

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[23] Ibid.

[24] "Fairbanks North Star Borough $PM_{2.5}$ Non-Attainment Area CMAQ Modeling: Final Report Phase I," Project: 398831 CMAQ-DEC, Mölders, N., Leelasakultum, K. University of Alaska Fairbanks, Geophysical Institute, College of Natural Science and Mathematics, Department of Atmospheric Sciences, December 1, 2011 *http://dec.alaska.gov/air/anpms/comm/docs/fbxSIPpm2-5/CMAQ_final_report_December_1_2011_Molders_Leelasakultum.pdf*

Table 5.8-5. CMAQ Model Module Configuration Options

CMAQ Module	Selected Option[25]	Description[26]
Horizontal Advection	*hyamo*	"Global mass-conserving scheme"
Vertical Advection	*vyamo*	"Global mass-conserving scheme"
Horizontal Diffusivity	*multiscale*	"Use diffusion coefficient based on local wind deformation"
Vertical Diffusivity	*eddy*	"eddy diffusivity theory"
Photolysis	*photo_inline*	inline photolysis rate calculations
Gas-phase Chemistry Solver	*ebi_cb05cl_ae5*	"Euler Backward Iterative solver optimized for Carbon Bond-05 mechanism with chlorine and extended aerosols"
Aerosol	*aero5*	"fifth-generation model CMAQ aerosol model with extensions for sea salt emissions and thermodynamics and anew formulation for secondary organic aerosol"
Deposition	*aero_depv2*	"second-generation CMAQ aerosol deposition velocity routine"
Cloud Chemistry	*cloud_acm_ae5*	"ACM cloud processor that uses the ACM"
Mechanism	*cb05cl_ae5_aq*	"CB05 gas-phase mechanism, fifth-generation CMAQ aerosol mechanism with sea salt, aqueous/cloud chemistry, and active chlorine"

5.8.8. Model Performance

A model performance evaluations serves to provide confidence in the final attainment demonstration. Outputs from the meteorological and air quality models are compared against measurements for the modeling episodes. A number of statistical techniques are employed to ensure that the models are behaving within stated criteria.

[25] Ibid.

[26] Descriptions are reproduced from Operational Guidance for the "Community Multiscale Air Quality (CMAQ) Modeling System Version 4.7.1 (June 2010)" accessed from *https://www.cmascenter.org/cmaq/documentation/4.7.1/Operational_Guidance_Document.pdf*

5.8.8.1. Weather Research and Forecasting Model (WRF)

Observed meteorology data from METAR stations are compared against the final configuration of the WRF model (dubbed TWIND2X30 in Appendix III.D.5.8). The met statistics presented here are comparable to the met statistics suggested in EPA $PM_{2.5}$ modeling guidance.[27] The statistics presented are for root-mean-square error (RMSE), mean absolute error (MAE), and bias. A comparison of the observed meteorology statistics between the final WRF model outputs of the Nov 2008 and Jan-Feb 2008 episodes (Table 5.8-6) shows that the modeled version of the Jan-Feb 2008 episode arguably has better statistics than the Nov 2008 episode, despite the more extreme cold present in the former. However, the more negative temperature bias in the Nov 2008 versus the Jan-Feb 2008 episode is consistent with the relative absence of extreme cold periods in Nov 2008 and the configurations general tendency to have a negative temperature bias in milder winter conditions for the Fairbanks region. While the model tends to be too warm during the periods of the coldest temperatures, the coldest temperature periods also tend to be of short duration.

Table 5.8-6. Comparison of Statistics for Nov 2008 and Jan-Feb 2008 Episodes for the WRF Model Outputs

	Nov 2008 RMSE (MAE for wind direction)	Nov 2008 Bias	Jan-Feb 2008 RMSE (MAE for wind direction)	Jan-Feb 2008 Bias
Temperature (°C)				
Fairbanks	2.75	-1.16	2.22	-0.12
Eielson AFB	2.03	-0.47	2.05	-0.23
Ft. Wainwright	2.38	-0.97	1.83	0.51
Three Stations	2.43	-0.86	2.07	0.00
Relative Humidity (%)				
Fairbanks	5.43	0.71	8.15	2.55
Eielson AFB	5.93	3.35	12.45	-2.49
Ft. Wainwright	12.48	-10.39	17.09	-13.67
Three Stations	7.14	0.05	12.44	-3.32
Wind Speed (m s-1)				
Fairbanks	1.27	0.91	1.51	0.86
Eielson AFB	1.63	1.28	1.18	0.69
Ft. Wainwright	0.95	0.45	1.21	0.25
Three Stations	1.41	1.00	1.34	0.68

[27] Tesche, T.W.and D.E.McNally, and C.Tremback, (2002), "Operational evaluation of the MM5 meteorological model over the continental United States: Protocol for annual and episodic evaluation."

	Nov 2008 RMSE (MAE for wind direction)	Nov 2008 Bias	Jan-Feb 2008 RMSE (MAE for wind direction)	Jan-Feb 2008 Bias
Wind Direction (degrees)				
Fairbanks	32.8	6.1	21.6	-5.6
Eielson AFB	38.6	18.2	26.0	-10.3
Ft. Wainwright	50.8	17.9	40.3	3.4
Three Stations	41.3	13.6	29.2	-3.6

5.8.8.2. Photochemical Transport Modeling (CMAQ)

Baseline air quality model performance was evaluated for daily 24-hour average $PM_{2.5}$ over both 2008 episodes. Modeled results were compared at the State Office Building grid cell in the model using speciated $PM_{2.5}$ FRM measurement data and BAM corrected total $PM_{2.5}$ concentrations at the State Office Building monitor. Figure 5.8-9 shows the trends over the modeling episode days for observed concentrations at the State Office Building (blue line) and the modeled concentrations (green line). The modeled and observed days for episode 1 show good agreement on both high and low concentration days. In episode 2 the model does not reproduce the maximum and minimums as accurately as in episode 1, but the periods of the high and low concentrations do generally match.

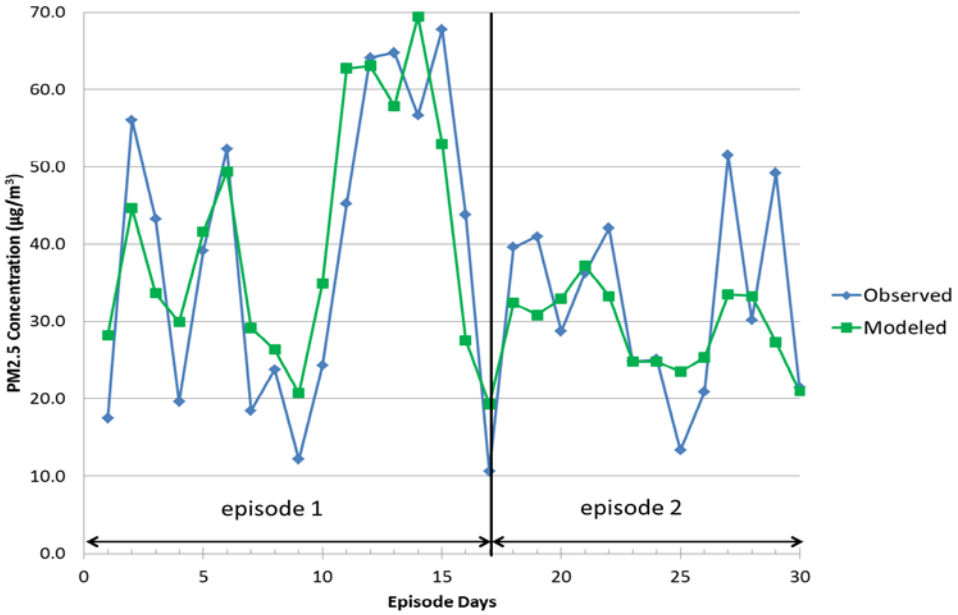

Figure 5.8-9. Modeled and Observed 24-hour Averaged $PM_{2.5}$ at the State Office Building Monitor for Both Winter Episodes

On a day-to-day basis the observed and modeled concentrations during the episodes generally track a 1:1 line seen in the scatter plot below (Figure 5.8-10). For episode days with observations on the low end of the range of measured $PM_{2.5}$ concentrations, the model tends to overestimate the $PM_{2.5}$ concentrations. Days with higher observed concentrations tend to show the model under-predicts total $PM_{2.5}$.

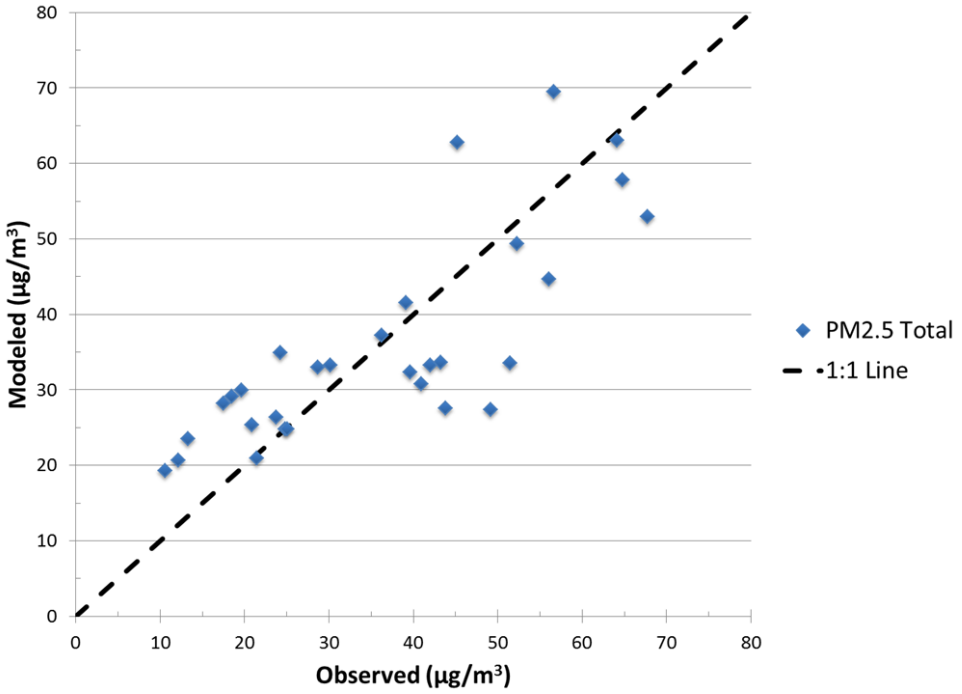

Figure 5.8-10. Scatter Plot of Observed and Modeled State Office Building Daily Episodic 24-hr $PM_{2.5}$ Concentrations

The breakdown of total particulate concentrations during the modeling episodes by percent contribution for each species is given in Figure 5.8-11 for the modeled and observed $PM_{2.5}$ at the State Office Building monitor. Observations show the $PM_{2.5}$ during the two modeling episodes is largely composed of the following in order of their contribution: organic carbon (OC), sulfate (SO_4), other primary particulates (OTH), ammonium (NH_4), elemental carbon (EC), and nitrate (NO_3). The modeled concentrations similarly reflect OC as the primary contributing species to total $PM_{2.5}$; however, the model tends to over-predict the contribution of OC and EC while under predicting the contributions of SO_4, OTH, and NH_4. The CMAQ model's low estimates of sulfate and ammonium are likely due to underperforming chemistry limiting the production of sulfate from SO_x precursor gases. This under-prediction of sulfate and ammonium increases the apparent share of OC and EC in the modeled $PM_{2.5}$. The under-prediction of $PM_{2.5}$ OTH is most likely caused at the level of the emissions inventory, as OTH is not formed in the atmosphere but contributed solely by direct emissions.

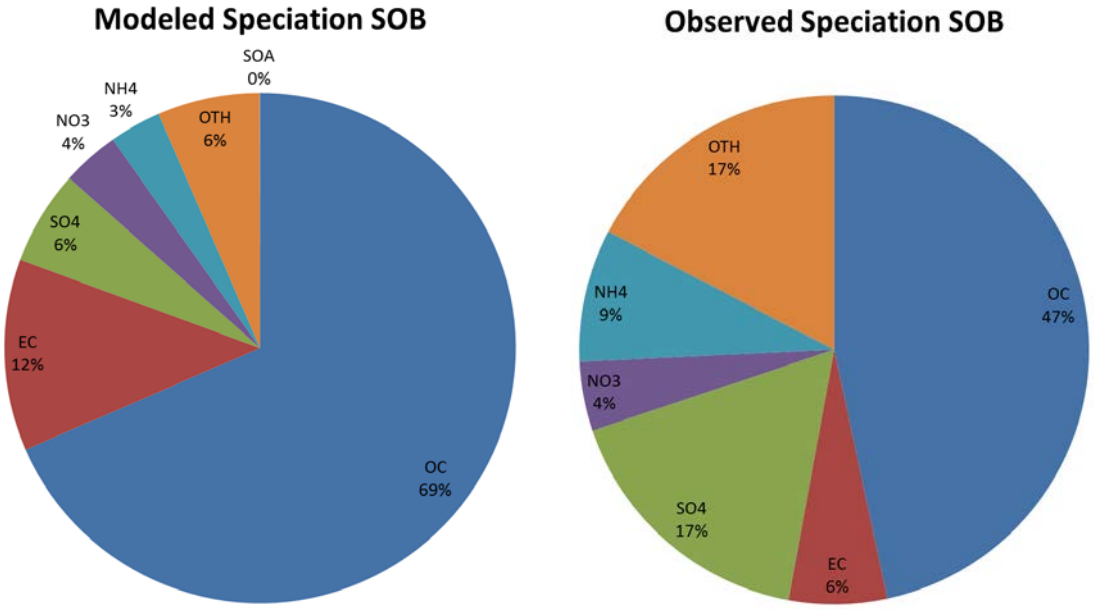

Figure 5.8-11. Baseline 24-hour Averaged Modeled and Observed $PM_{2.5}$ Speciation Over all Episode FRM Days

Speciation profiles of the PM emissions may be the cause considering that the direct emitted OC and EC are over-predicted.

Table 5.8-7 shows the average modeled and observed concentrations in micrograms per cubic meter for the winter episodes. The total $PM_{2.5}$ for the modeled and observed match to within 0.4 $\mu g/m^3$; however, the species show the over-prediction of carbon-containing compounds (OC and EC) and under-prediction of SO_4, NH_4, and OTH.

Table 5.8-7. Comparison of Modeled and Observed Particulate Matter Components

Species	Observed ($\mu g/m^3$)	Modeled ($\mu g/m^3$)
$PM_{2.5}$	36.1	35.7
OC	17.0	24.5
EC	2.3	4.3
SO_4	6.2	2.1
NO_3	1.6	1.3
NH_4	3.1	1.2
OTH	6.3	2.3
SOA	N/A	0.01

Field plots of the 2008 baseline $PM_{2.5}$ throughout the nonattainment area are shown in Figure 5.8-12 through Figure 5.8-18. The plots show the 24-hour average $PM_{2.5}$ over all episode days for $PM_{2.5}$ total, OC, EC, SO_4, NO_3, NH_4, and Other. Most of the emissions activity is contained within the nonattainment area as are the highest particulate concentrations. The model shows the highest concentrations within the downtown Fairbanks area and in grid cells to the west of town, with values in the 35 to 45+ $\mu g/m^3$ range. The model shows the next-highest $PM_{2.5}$ concentrations in the area of North Pole with values in the 25 to 30 $\mu g/m^3$. During the modeling episode, the only monitor available for $PM_{2.5}$ comparisons against the model is the State Office Building site. Assessment of model performance outside of that location is not possible. Generally, the highest concentration areas match those same areas with the highest emissions density.

The spatial extent of gaseous SO_2 concentrations is shown in Figure 5.8-19. Sulfur dioxide is an important precursor gas leading to the formation of particulate sulfate in Fairbanks, as seen in the observed PM speciation. Considering the model's under prediction of sulfate, it is useful to highlight the areas most likely to form sulfate in the atmosphere.

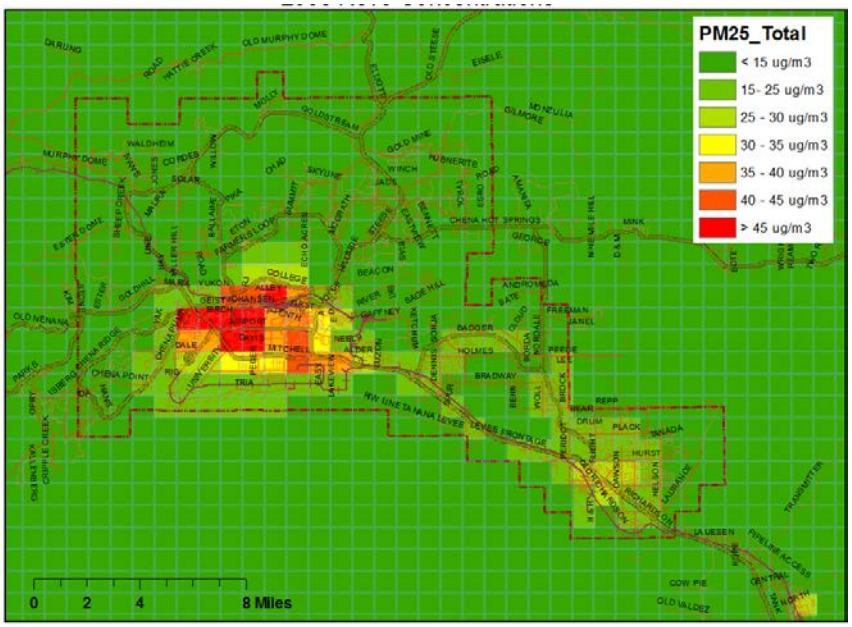

Figure 5.8-12. Baseline 24-hour Averaged Model Total $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

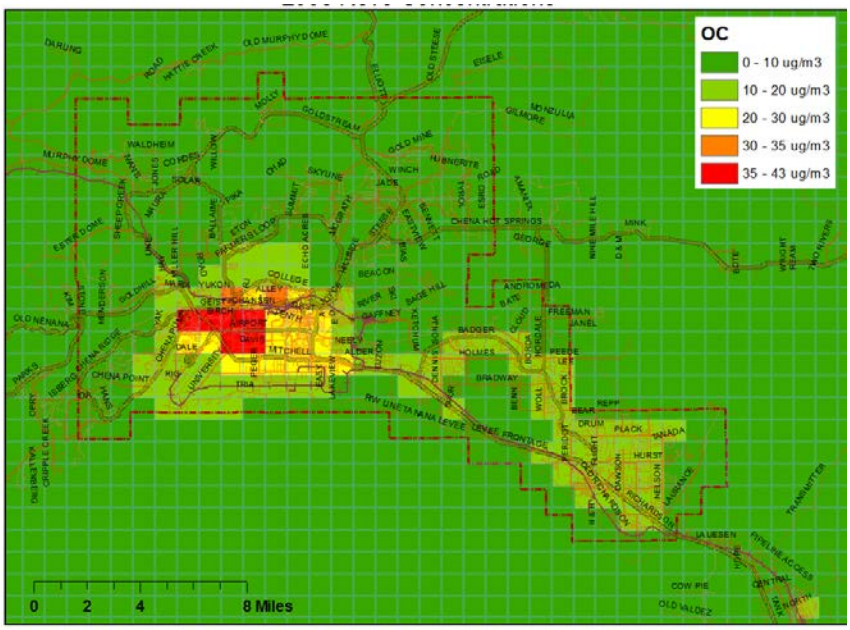

Figure 5.8-13. Baseline 24-hour Averaged Model OC $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

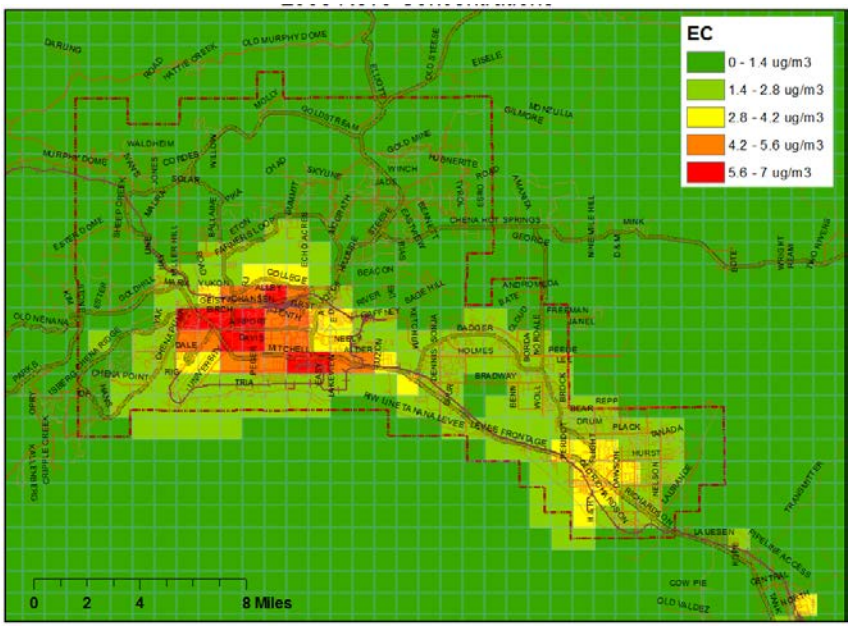

Figure 5.8-14. Baseline 24-hour Averaged Model EC $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23rd to February 10 and November 2 to 17, 2008)

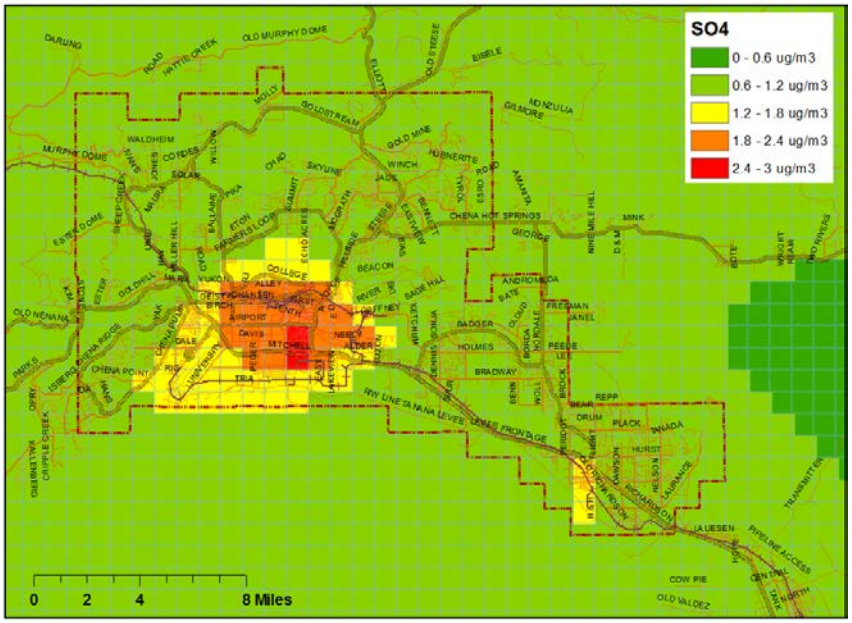

Figure 5.8-15. Baseline 24-hour Averaged Model SO_4 $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

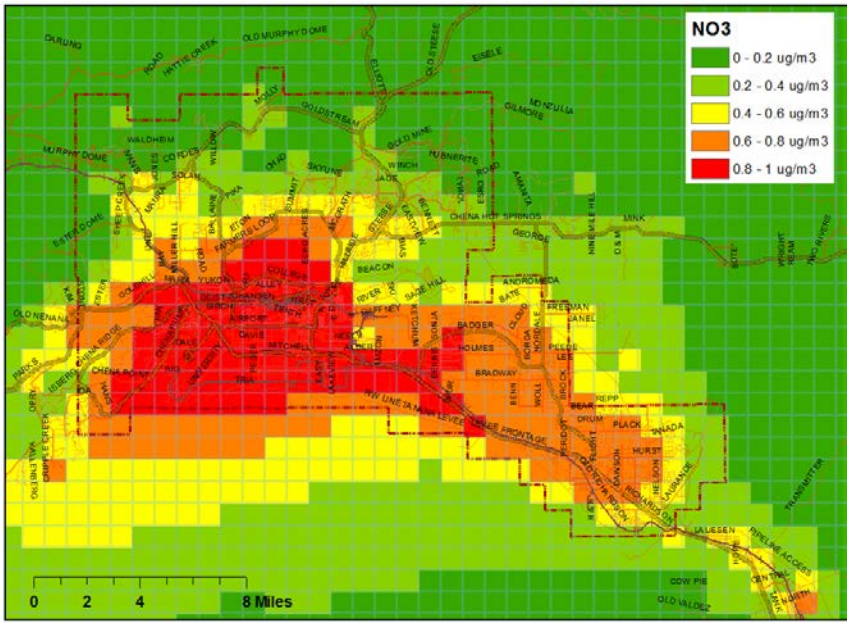

Figure 5.8-16. Baseline 24-hour Averaged Model NO_3 $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

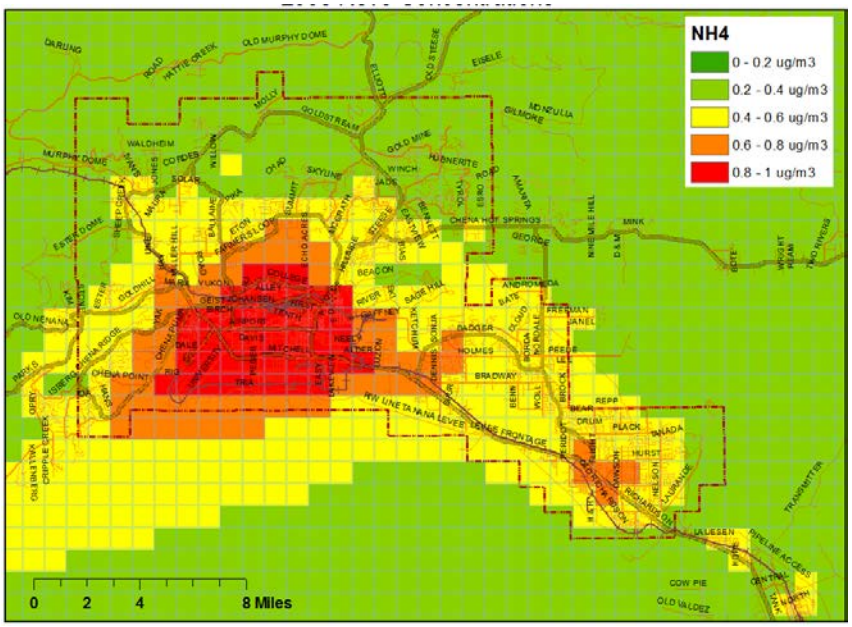

Figure 5.8-17. Baseline 24-hour Averaged Model NH4 $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

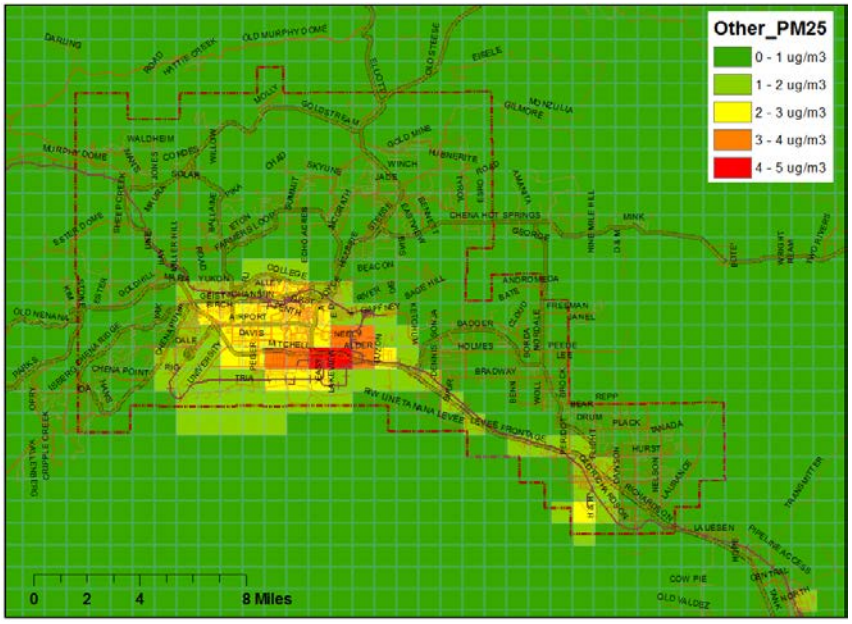

Figure 5.8-18. Baseline 24-hour Averaged Model Other $PM_{2.5}$ Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

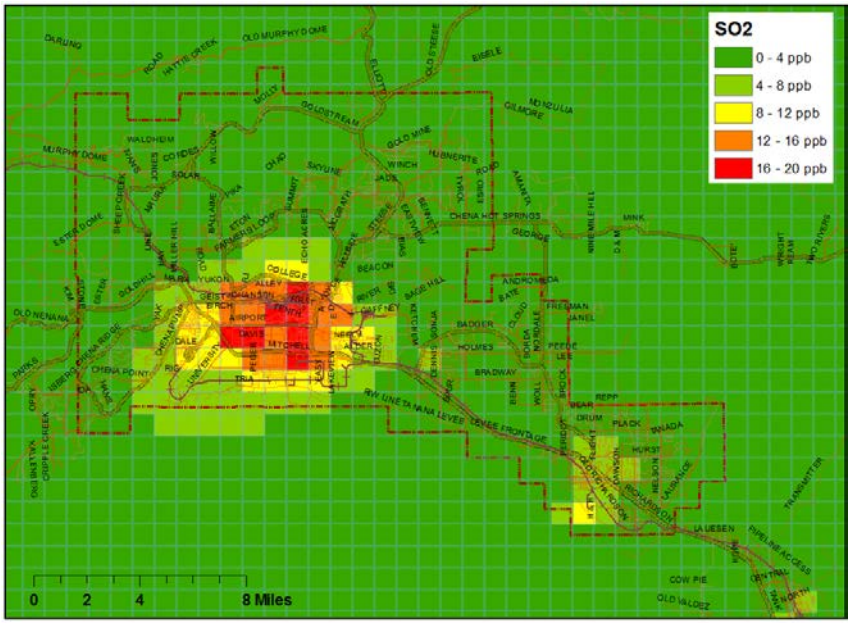

Figure 5.8-19. Baseline 24-hour Averaged Model Gaseous SO_2 Concentrations for the Nonattainment Area over All Episode Days (January 23 to February 10 and November 2 to 17, 2008)

Model performance is quantified using the mean fractional error and mean fractional bias metrics per EPA's guidance. Mean fractional error is calculated using the following formula:

$$MFE = \frac{2}{N}\sum_{1}^{N}\left(\frac{|Model - Obs|}{Model + Obs}\right) \times 100\%$$

This formula states that the error is the sum of the absolute value of the difference between Model and Observed concentrations (Model – Obs) divided by the sum of the Model and Observed concentrations (Model + Obs) over all observation days (N) multiplied by 2, divided by the number of observation days and multiplied by 100%. The error is always a positive value with a target goal of 50% or better and a criterion of 75% or better. Values can range above the criterion depending on the modeling location and the ambient concentrations to up to 125%.[28,29,30,31]

[28] Boylan, J., VISTAS, "PM Model Performance Goal and Criteria", National RPO Modeling Meeting, Denver, CO, 2005a..

[29] Morris, R., et al., "Application of Multiple Models to Simulation Fine Particulate in the Southeastern US", National RPO Modeling Meeting, Denver, CO, 2005a

Mean fractional bias is calculated in a similar fashion, except the absolute value of the Model and Observation difference is not used. MFB can be either a positive or negative value and gives an indication of whether the model is over- or under-predicting a given species.

$$MFB = \frac{2}{N}\sum_{1}^{N}\left(\frac{Model - Obs}{Model + Obs}\right) \times 100\%$$

Goal and criteria values for MFB are stated as ±30% and ±60%. [32] The range of MFB can also vary by region and pollutant with values shown up to 180% variation.

The MFE and MFB values for the baseline model are shown in Table 5.8-8. The values for MFE range from 30.2% to 88.5%. $PM_{2.5}$, OC, EC, and NO_3 are within EPA's stated criteria for MFE (<75%) with $PM_{2.5}$ and OC within the goal range (<50%). SO_4, NH_4, and OTH are outside of the criteria but within an error range comparable to other studies. MFB is shown to be within criteria ranges (<±60%) for $PM_{2.5}$, OC, EC, and NO_3 with $PM_{2.5}$ within the goal range (<±30%). SO_4, NH_4, and OTH are outside of the criteria but within a bias range comparable to other studies. Overall the total $PM_{2.5}$ response at the

Table 5.8-8. Mean Fractional Error and Mean Fractional Bias

Species	MFE (%)	MFB (%)
$PM_{2.5}$	30.2%	8.0%
OC	37.3%	34.2%
EC	52.8%	52.8%
SO_4	88.5%	-88.5%
NO_3	57.9%	-35.2%
NH_4	79.9%	-79.9%
OTH	87.3%	-87.3%

State Office Building monitor site is very good even though some components perform less well. Since there were no other monitors operating within the nonattainment area collecting speciated $PM_{2.5}$ during the episodes the performance metrics are only calculated for the State Office Building site.

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[30] Tonnesen, G., et al., "Regional Haze Modeling: Recent Modeling Results for VISTAS and WRAP", CMAS Annual workshop, RTP, NC, 2003.
[31] Morris, R., et al., "Model and Chemistry Inter-comparison: CMAQ with CB4, CB4-2002, SAPRC99", National RPO Modeling Meeting, Denver, CO, 2005b
[32] [32] Boylan, J., VISTAS, "PM Model Performance Goal and Criteria", National RPO Modeling Meeting, Denver, CO, 2005a..

The performance metrics stated above can also be visualized as a soccer plot of the values. The soccer plot (Figure 5.8-20) shows the same trends as stated in the tables above. These metrics can fail to reflect that typically less stringent goals and criteria are used for less abundant species such as NO_3 and EC.[33]

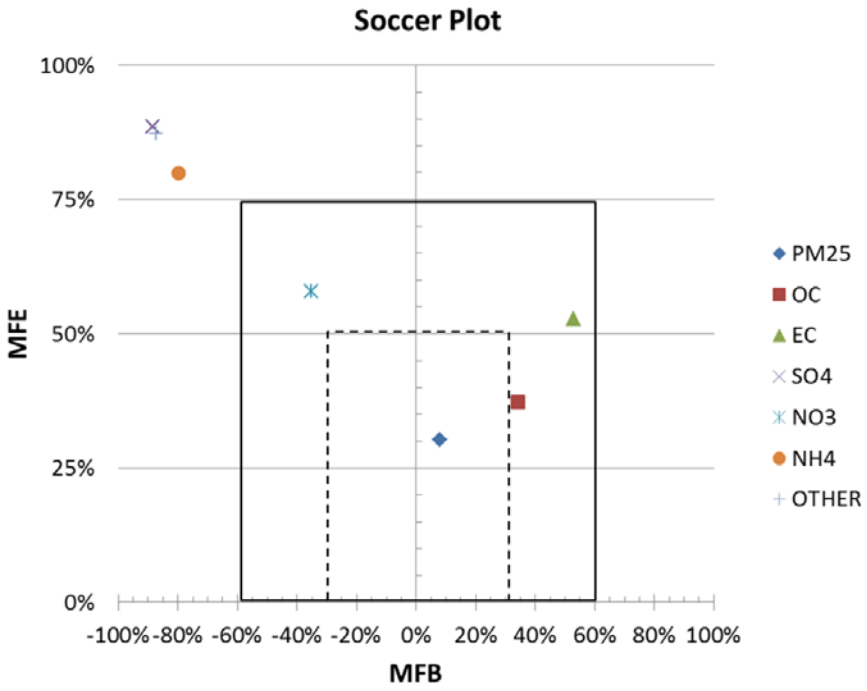

Figure 5.8-20. Soccer Plot of Mean Fractional Error and Bias at the State Office Building Monitor for Fairbanks 2008 $PM_{2.5}$ Winter Modeling Episodes

Figure 5.8-21 and Figure 5.8-22 show the MFB and MFE metrics with a higher tolerance for observations below 2.5 µg/m^3. Both EC and NO_3 are closer to the goal lines for MFE and MFB on these figures, with the NO_3 MFB falling into the goal range.

[33] Boylan, J., VISTAS, "PM Model Performance Goal and Criteria", National RPO Modeling Meeting, Denver, CO, 2005a.

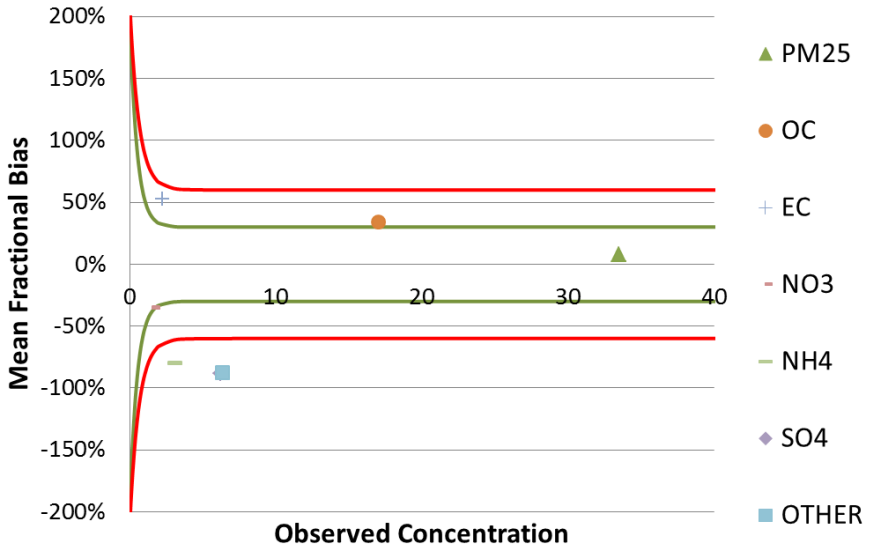

Figure 5.8-21. Mean Fractional Bias with Less Stringent Goals at Low Concentrations

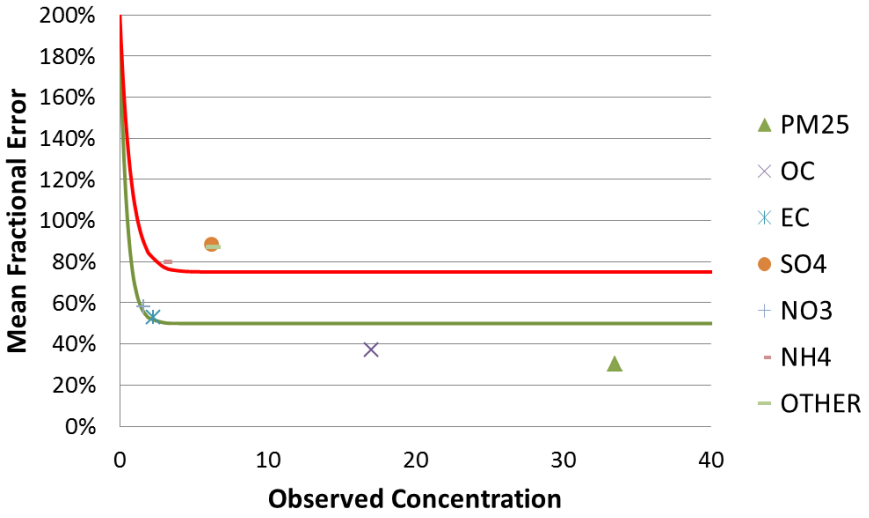

Figure 5.8-22. Mean Fractional Error with Less Stringent Goals at Low Concentrations

Overall, the model performance shows that the model does provide confidence in the prediction of total $PM_{2.5}$ at the State Office Building monitor site. Some components will receive extra scrutiny such as sulfate, ammonium, and other primary particulates as the control scenarios are evaluated due to their performance.

5.8.9. Attainment

5.8.9.1. Requirements

The modeling of attainment requires the calculation of future design values using the Species Modeled Attainment Test (SMAT) method discussed below. Modeling must be completed for the year 2015 with projected growth and control scenarios in place prior to December 31, 2014. If the projected control scenario shows attainment at the monitoring cites, then an unmonitored area analysis (UMAA) must be performed to demonstrate attainment in other grid cells.[34]

5.8.9.2. Modeling Ambient Air Quality Data using Sandwich_SMAT Methods

40 CFR part 58 requires states to monitor $PM_{2.5}$ mass concentrations using Federal Reference Method (FRM) devices to determine compliance with the NAAQS. Following 2007 EPA Modeling Guidance and Attachment B (Fox, 2011), ADEC produced the Species Modeled Attainment Test (SMAT) for the 24-hour $PM_{2.5}$ NAAQS. The method uses winter quarterly (Q1 and Q4) average FRM-derived species concentrations from the STN (speciation trend network) monitor.

The FRM monitor uses a gravimetric weight-based analysis compared to the nylon filter and denuder set up on the STN monitor. The methodology for the recommended treatment of the species data references Section 5.1.4 of the EPA (2007) guidance incorporating the Frank (2006) paper and several others. The SMAT technique uses the design value site at the Fairbanks, Alaska State Office Building (SOB) to calculate the quarterly average species mass fractions. Collocated at this site are the FRM monitor used in designation of Fairbanks as a non-attainment area and an STN monitor. The data used in the quarterly calculations are 2006-2010 for the following seven major components of $PM_{2.5}$ as recommended (USEPA, 2007):

- Measured sulfate [SO_{4STN}];
- Adjusted nitrate [NO_{3FRM}] (retained on the FRM filter);
- Adjusted ammonium [NH_{4FRM}] (retained on the FRM filter);
- Measured elemental carbon [EC_{STN}] (corrected IMPROVE to NIOSH analysis);
- Organic carbonaceous mass estimated from a mass balance [OCMmb];
- Estimated particle bound water [PBW]; and
- Estimated other primary $PM_{2.5}$ components [OPP].

[34] Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5 , and Regional Haze U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group Research Triangle Park, North Carolina - EPA -454/B-07-002 April 2007

Details on how each of the major components were calculated are provided in Appendix III.D.5.8.

Quarterly average FRM-derived species mass fractions for the wintertime quarters 1 and 4 for 2006-2010 are represented in species mass fraction percentages in Table 5.8-9. The top 25% of total number of days for quarter 1 and 4 were used for the baseline concentrations for 2006-2010.

Table 5.8-9. Quarterly average percentage of SANDWICH'ed $PM_{2.5}$ Calculated from the Top 25% of $PM_{2.5}$ Days for Years 2006-2010

	SO_{4STN}	NO_{3FRM}	NH_{4FRM}	PBW	$EC_{IM>NI}$	OPP	$OCMmb_{IM>NI}$	Non blank FRM
Q4	17.40	3.64	7.57	5.82	6.89	1.25	57.43	100
Q1	19.15	5.03	8.54	6.27	6.19	1.01	53.82	100

The FRM-derived mass species fractions are used to estimate the species contributions to the baseline design value concentration of 44.7 $\mu g/m^3$ calculated from the EPA (2007) updated attachment B guidance document. Relative response factors (RRFs) determined below are multiplied into the individual species to determine the future design value (FDV) as calculated following the method specified by SMAT test steps 4-9 of EPA (2007) attachment B. The attainment demonstration is based on the calculated FDV following this methodology.

That guidance recommends using the average of the three design value periods centered on the year of the base year emissions. Since 2008 is the base year for planning, design values for 2006-2008, 2007-2009, and 2008-2010 were used to calculate the design value for use in attainment modeling. A description of that calculation is presented in Appendix III.D.5.8.

5.8.9.3. 2015 Attainment Modeling

Discussed below is the photochemical transport modeling of the 2015 emissions scenarios with projected activity levels and control packages. The 2015 control scenario includes benefits from the Alaska Resource Agency (ARA) Outdoor Hydronic Heater (OHH) retrofits, and Wood Stove Change Out (WSCO) program. In addition to those programs, the 2015 baseline shows some benefits from the natural turnover of vehicles and home heating devices. Voluntary measure benefits of 0.5 $\mu g/m^3$ are also included in all calculations.[35]

[35] Calculated based on a weighted average of 6% benefit from area sources and a 3% benefit for mobile sources. Calculations are shown in the Appendix III.D.5.8. and follow

For the attainment modeling, the 2015 baseline projections were modeled for all source sectors with point sources operating at potential to emit levels (PTE). For the control package analysis for 2015, two scenarios were modeled for point source emissions: one with PTE levels and one with actual levels (Actual). The relative response factors (RRF) are calculated over the average of all episode days (minus two episode days at the start of each episode allowed for model spin up) for each of the species of $PM_{2.5}$, with three exceptions: sulfate, ammonium, and particle-bound water (PBW). Due to the model performance for sulfate, the RRF of sulfate is held at 1.00 to avoid a bias in the final control calculations. Sensitivity to this assumption is discussed in a subsequent section. The ammonium and PBW RRFs are calculated based on the RRFs for nitrate and sulfate based on EPA's guidance in "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM 2.5 , and Regional Haze."[36] Details for how these adjustments are calculated can be found in Appendix III.D.5.8.

For all other species, the RRF is calculated as the ratio of the 2015 episode 24-hour averaged concentration of a species by the 2008 episode 24-hour averaged concentration:

$$RRF_i = \frac{[i_{2015}]}{[i_{2008}]}$$

where *RRF* is the relative response factor of species *i* and [*i*] is the concentration of *i* for 24-hours averaged over all episode days in 2008 and 2015.

Table 5.8-10 summarizes the RRFs for the 2015 projected baseline with PTE-level point sources, 2015 control package with PTE-level point sources, and 2015 control package with Actual-level point sources. These RRFs are always calculated against a 2008 baseline with Actual-level point sources.

The calculated RRFs for 2015 show values < 1.00 except in the case of SO_4 and other primary particulate (OTH). Generally the OTH values are biased by the presence of PTE-level point source emissions in 2015, and sulfate is held constant. Values of RRFs less than 1.00 represent a reduction in particulate concentrations for a given species. Each species' RRF has a different impact on the overall future design value (FDV) $PM_{2.5}$ concentration based on that species contribution to total $PM_{2.5}$. The FDV as described in

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guidance from *INCORPORATING EMERGING AND VOLUNTARY MEASURES IN A STATE IMPLEMENTATION PLAN (SIP)* - Air Quality Strategies and Standards Division Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711 http://www.epa.gov/ttn/oarpg/t1/memoranda/evm_ievm_g.pdf

[36] *Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM 2.5 , and Regional Haze* U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Air Quality Analysis Division Air Quality Modeling Group Research Triangle Park, North Carolina - EPA -454/B-07-002 April 2007

the SMAT section is the estimate of the concentration at the State Office Building monitor in the projected year 2015. The FDV is compared to the 24-hour $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$.

Table 5.8-10. 2015 RRF Values for Projected Baseline and Control Scenario (PTE and Actuals) against a 2008 Baseline with Actual Point Source Emissions

Scenario Name	Organic Carbon (OC)	Elemental Carbon (EC)	SO_4	NO_3	Other Primary Particulate (OTH)
2015 Baseline (PTE)	0.96	0.90	1.00	0.97	1.80
2015 Control Package (PTE)	0.85	0.82	1.00	0.92	1.80
2015 Control Package (Actual)	0.85	0.80	1.00	0.91	0.92

For Fairbanks the RRF of OC has the most impact on the total $PM_{2.5}$ FDV concentration, which is also reflected by OC making up the largest share of the total aerosol mass. The OTH or other component of PM has the weakest impact on the FDV. The FDV calculated from the RRF values are shown in Table 5.8-11.

Table 5.8-11. 2015 FDV for Projected Baseline and Control Scenario (PTE and Actuals) Calculated against a 2008 Baseline with Actual Point Source Emissions

Scenario	Description	Future Design Value ($\mu g/m^3$)
2015 Baseline (PTE)	Projected 2015 baseline with point sources at PTE levels	43.2
2015 Control Package (PTE)	2015 projection with all control scenarios applied, voluntary measures, and point sources at PTE levels	40.1
2015 Control Package (Actual)	2015 projection with all control scenarios applied, voluntary measures, and point sources at actual levels	39.6

The 2015 control package with actual point source levels reaches an FDV of 39.6 $\mu g/m^3$. This value is still well above the 24-hour $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$ with a further 4.6 $\mu g/m^3$ reduction in $PM_{2.5}$ required. The breakdown of individual program contributions is shown in Table 5.8-12 below. The control contributions are the same for both the PTE

and Actual scenarios. Using Actual emissions for point sources reduces concentrations by 0.5 $\mu g/m^3$. Of the available controls the Fairbanks North Star Borough's Wood Stove Change Out program provides the largest benefit with 3.0 $\mu g/m^3$ (60%) of the total PM reduction modeled for 2015.

Voluntary programs operating in the Borough include public education programs and a curtailment program. The educational component of the voluntary programs increases public awareness of air quality problems and encourages home heating practices that reduce particulate emissions. Voluntary curtailment can also reduce $PM_{2.5}$ emissions through reduced use of solid-fuel combustion on high concentration days. Voluntary measures are calculated as the maximum possible contributions of 3% of the total needed reductions for mobile source contributions and 6% of the total needed reductions from all other sectors. Discussion of these benefits is in RACM in the Appendix III.D.5.7 and calculations are provided in Appendix III.D.5.8.

Table 5.8-12. 2015 Control Benefits

Control Program	Individual Contributions to Control Scenario Reductions	Concentration Reduction ($\mu g/m^3$)
Voluntary Measures	10.5%	0.54
Natural Turnover	29.2%	1.50
Outdoor Hydronic Heater Retrofits	0.7%	0.04
Wood Stove Change Out	59.6%	3.06

5.8.9.4. 2015 Weight of Evidence/Sensitivity

The FDV of 39.6 $\mu g/m^3$ for the 2015 control scenario reflects a best case for the adopted controls. The impacts of PTE emissions and sulfate assumptions can affect the outcome of the FDV calculations. When using PTE emissions for point sources, the increased emissions drive the FDV up to a range of 40.1 – 43.5 $\mu g/m^3$. The low end of the range fixes sulfate RRFs to 1.0 in future years, and the high end calculates sulfate RRFs based on primary sulfate and sulfur dioxide as shown in Appendix III.D.5.8. The attainment calculations above in table 5.8-11 depend on the sulfate being held constant. When sulfate RRFs vary, the range of FDVs can vary for actual emissions of point sources by 39.6 to 40.1 $\mu g/m^3$. If secondary sulfates are estimated from changes in SO_x emissions, the actuals final FDV would be adjusted to 40.1 $\mu g/m^3$. Calculations for these ranges are shown in Appendix III.D.5.8.

The CMAQ and SMOKE modeling estimates that wood burning's share of the inventory is on the higher end of the winter averages established by CMB, C-14 and PMF analyses , but the results are not outside of their range of estimates. Each of these techniques can provide some insight into the local sources that contribute to higher concentrations, but they are not perfect estimates and show disagreements as to the importance of secondary

pollutants. If the modeled contributions from home heating are overestimated, the control impacts may also be overestimated; the FDV would thus be higher than the value provided.

Modeled concentrations show overestimates of direct (OC and EC) PM and underestimates of secondary (sulfate and ammonium) PM. Since the SANDWICH methodology anchors the species to actual measurements and all control impacts are calculated on a relative basis the impacts of over/underpredicting a species is somewhat mitigated.

In total, the considerations above point towards a higher FDV than 39.6 $\mu g/m^3$. A best estimate of the adjusted FDV would be over 40.1 $\mu g/m^3$. Due to the relative nature of the RRF calculations, over/underestimating a species does not appear to have a significant impact on FDV estimates. Inventory assumptions could also impact the FDV; however, the contribution of CMAQ-modeled home heating sources is within the range of other modeling technics such as CMB. This agreement provides confidence in the modeled control effectiveness.

5.8.9.5. 2015 Unmonitored Area Analysis

Given the state of modeled FDVs at the State Office Building in 2015, the need to show attainment in other grid cells is eliminated. However, the UMAA has been performed for 2015 to show the range of estimated concentrations in the nonattainment area following the application of the control package. As shown in Figure 5.8-23, surface impacts of $PM_{2.5}$ appear highest in the western portions of downtown Fairbanks and to the southeast of the State Office Building monitor cell. North Pole area concentrations also show exceedances, but do not reflect concentrations as high as those in the downtown Fairbanks area. Details on the UMAA was performed see Appendix III.D.5.8.

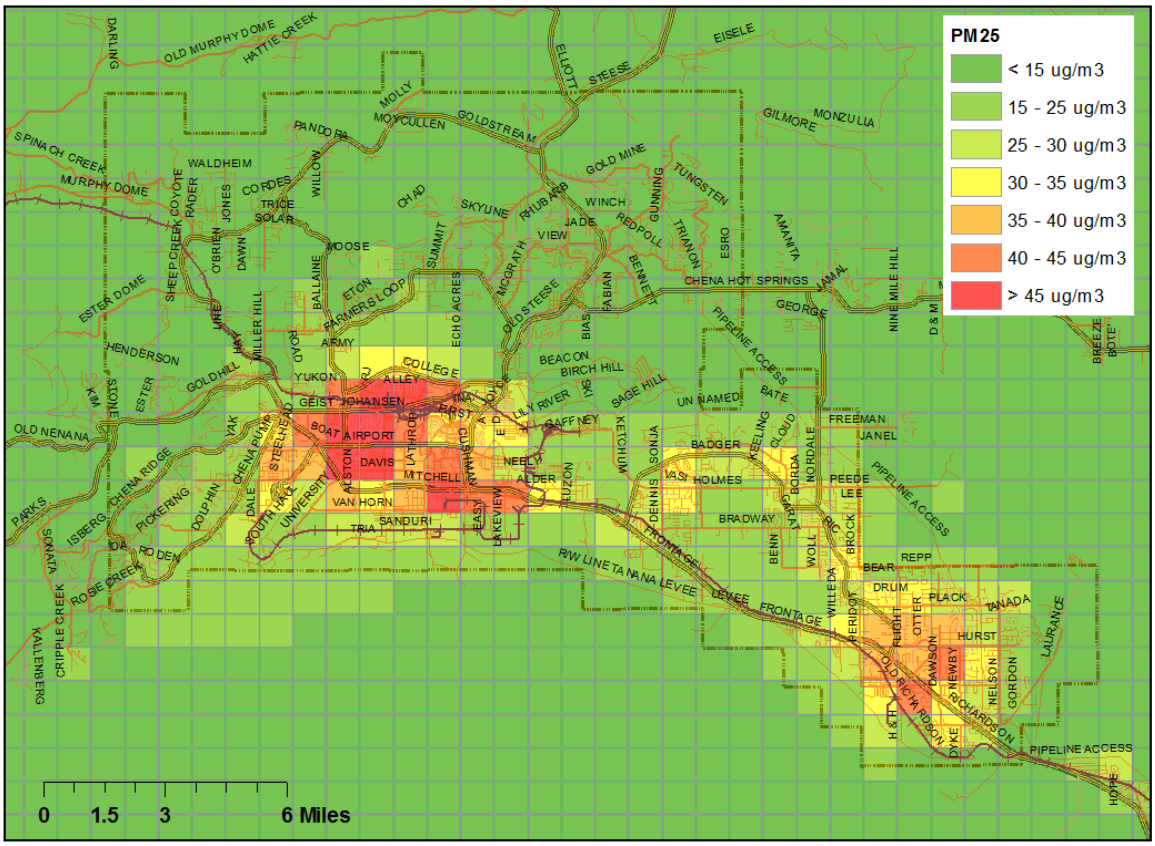

Figure 5.8-23. Unmonitored Area Analysis of 24-hour $PM_{2.5}$ for the 2015 Control Scenario

5.8.9.6. 2019 Attainment Modeling

The following modeling results are included to show the effectiveness of control programs when projected to 2019. There is no requirement to demonstrate attainment for the year 2019. Based on projections for the current control programs for 2015 to 2019 along with the addition of new control programs, a FDV was calculated for a 2019 control package. This control package contains the ARA OHH, WSCO, State standards, natural gas expansion, dry wood, natural turnover, and voluntary measures. The RRFs by species are shown in Table 5.8-13 for the baseline projected inventory and the control packages for 2019 with PTE. As with the 2015 RRF calculations, the RRFs are relative to 2008 and sulfate is held constant. Ammonium and PBW are derived from the nitrate and sulfate concentrations.

Table 5.8-13. 2019 RRF Values for Projected Baseline and Control Scenario (PTE)

Scenario Name	Organic Carbon (OC)	Elemental Carbon (EC)	SO_4	NO_3	Other Primary Particulate (OTH)
Baseline PTE	0.97	0.87	1.00	0.97	1.79
Control Package with PTE	0.60	0.59	1.00	0.99	1.79

Using the RRFs presented in Table 5.8-13, the FDV for the 2019 control package reduces concentrations to 33.5 $\mu g/m^3$ at the State Office Building site (Table 5.8-14). The projected control scenario reduces concentrations to below the 35 $\mu g/m^3$ 24-hour average $PM_{2.5}$ NAAQS.

Table 5.8-14. 2019 FDV for Projected Baseline and Control Scenario (PTE and Actuals)

Scenario	Description	Future Design Value ($\mu g/m^3$)
Baseline PTE	Projected 2019 baseline with point sources at PTE levels	43.4
Control Package with PTE	2019 projection with all control scenarios applied and point sources at PTE levels	33.5

5.8.9.7. 2019 Weight of Evidence/Sensitivity

The above control scenario does not include the adoption of energy logs in the Fairbanks region by wood-burning households. A modeling analysis has shown that energy logs can contribute to a reduction in wood burning particulate emissions by up to 2.5 $\mu g/m^3$ during the modeling episodes. These estimates conservatively assume a supply of 3,700 tons of energy logs available by 2019, far below state expansion capacity.

5.8.9.8. 2019 Unmonitored Area Analysis

Figure 5.8-24 depict the results of the unmonitored area analysis for 2019, showing that high concentrations do persist away from the monitor in the 2019 control package. It is unclear how much these concentrations persist as a result of assumptions or uncertainties in the high resolution (1.33 x 1.33 km) modeling or reflect actual hot spots in the region. Additionally, some of these grid cells may show higher concentrations due to PTE-level point source emissions.

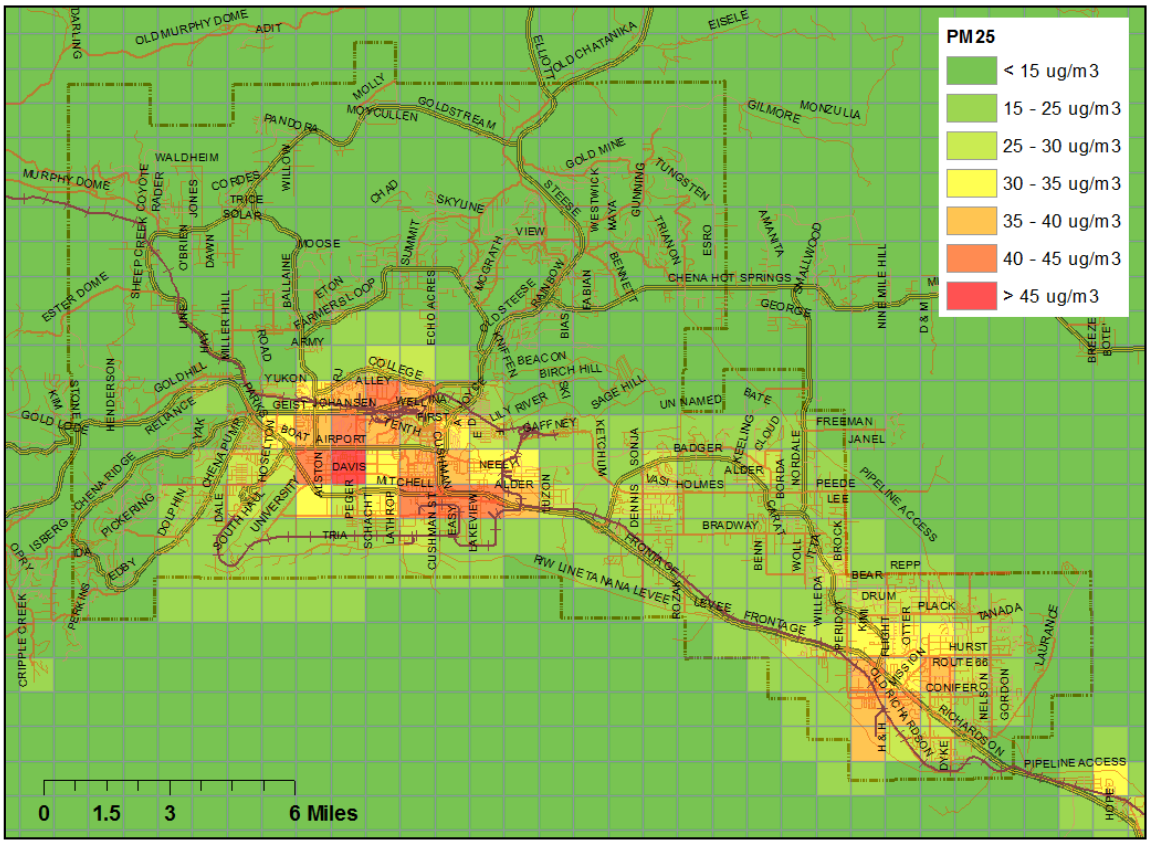

Figure 5.8-24. Unmonitored Area Analysis of 24-hour $PM_{2.5}$ for the 2019 Control Scenario