PM$_{2.5}$ SOURCE CONTRIBUTIONS

DEANNA HUFF

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

OVERVIEW

- Collaboration

- Speciation Source Apportionment

- Emissions Inventory

- Air Quality Modeling

- Summary

COLLABORATIVE EFFORT

- ADEC, FNSB and EPA R10 staff – organization, monitor operation, funding, direction & integration

- Sierra Research – emissions inventory development and air quality modeling

- Penn State – meteorological modeling

- UAF – air quality modeling, chemical analyses

- CCHRC – Space heating fuel use and wood moisture level

- University of Montana – chemical analysis and modeling

- Washington University in St Louis – analysis of black carbon measurements

- University of Massachusetts – chemical tracer measurements

- OMNI-Test Laboratories – space heating emission measurements

SPECIATION SOURCE APPORTIONMENT PROCESS SUMMARY

- **Emissions** of particulate matter from all sources are captured at the monitors.

- **Monitors** give the concentrations (mass) of PM 2.5 on filters.

- **Speciation** is the analysis of filters to determine the unique chemical components of PM 2.5 (organic carbon, sulfate, nitrate…..).

- **Source apportionment** models (PMF and CMB) process the **speciation** data assigning contributions to different sources, or source groupings.

  - PMF and CMB are models that identify sources by their chemical patterns (fingerprints) and can pull apart each different sources contribution to the total.

  - Sources with similar chemical patterns are difficult to distinguish.

Emissions Sources

Monitors

Speciation

Source Apportionment

Mobile Sources

(CARS)

Industrial Sources

(POWER PLANTS)

Area Sources

NOx, VOC, PM, SOx

(HOME CHIMNEYS)

24-Hour Sample

Unused sample

Wood Burning Contribution

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%

52%

68%

90%

78%

Fairbanks

North Pole

PMF   CMB

Pattern Recognition

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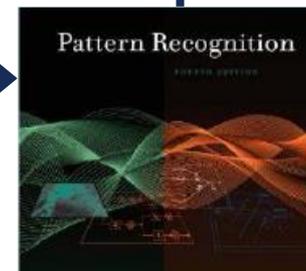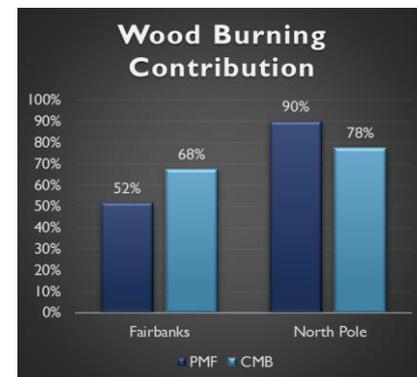
MONITORING TRENDS OF PM$_{2.5}$ CONCENTRATIONS IN FAIRBANKS AND NORTH POLE
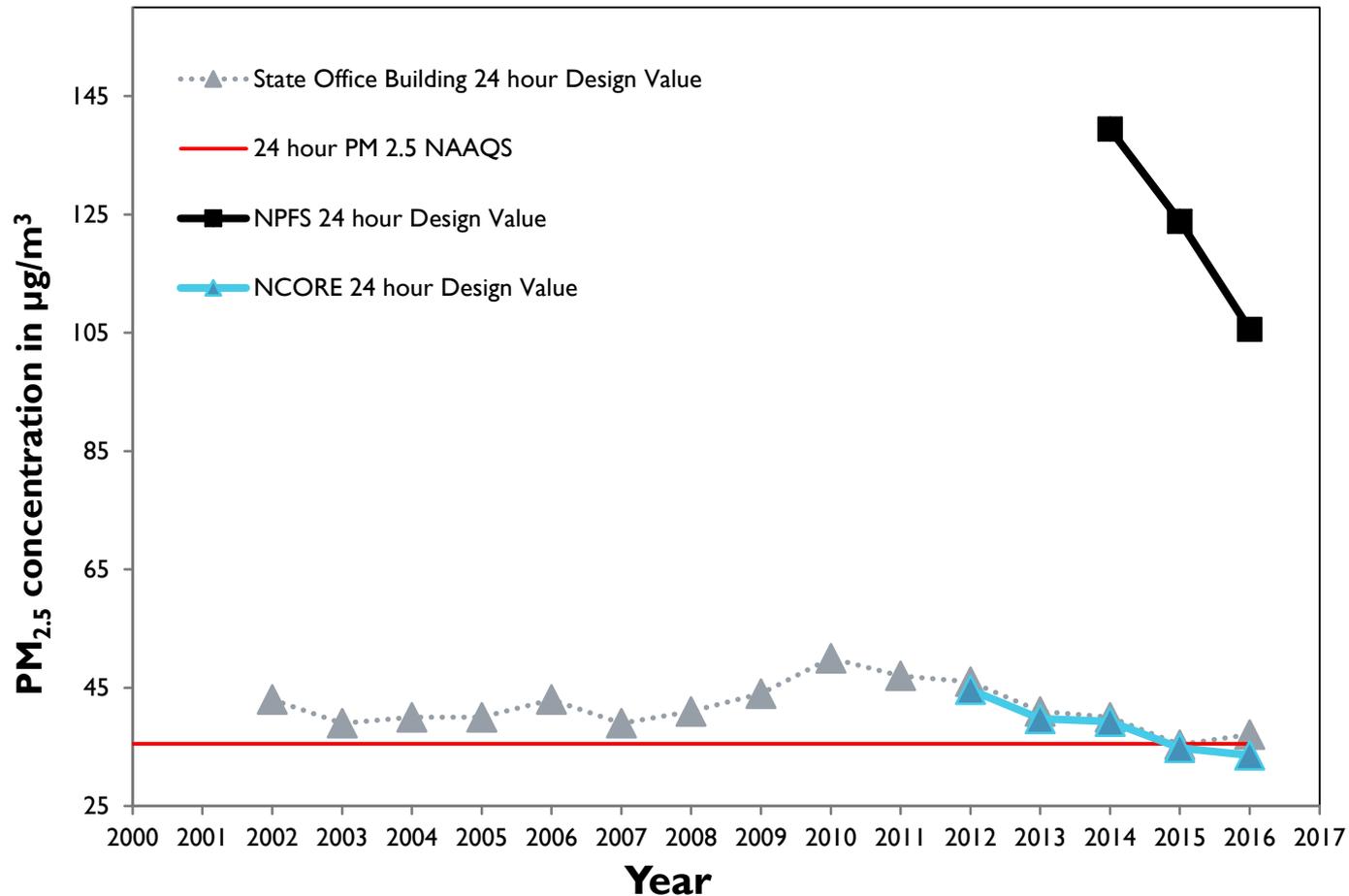
# FAIRBANKS AND NORTH POLE REGULATORY MONITOR LOCATIONS SINCE 2008

SPECIATION MONITORS

| Site	Start Date (M/D/Y)	End Date (M/D/Y)
State Office Building	1/2/2006	12/31/2014
NCORE	11/2/2011	Present
North Pole Fire Station	3/1/2012	3/30/2014
North Pole Elementary	11/2/2011	3/29/2013

- All monitors are filter based and collocated on a 1 in 3 day frequency
- All filters are weighed and shipped out for analysis

Emissions Sources | Monitors | Speciation | Source Apportionment

Mobile Sources
(CARS)

Industrial Sources
(POWER PLANTS)

Area Sources
(HOME CHIMNEYS)

NOx, VOC, PM, SOx

24-Hour Sample   Unused sample

Wood Burning Contribution

Pattern Recognition

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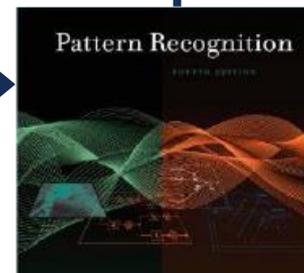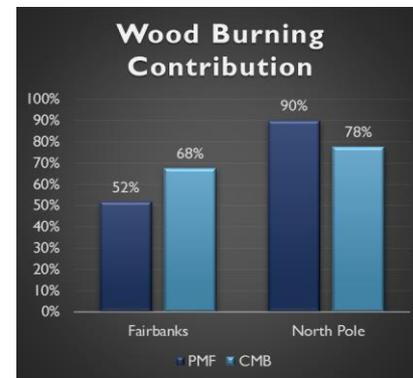
# High PM 2.5 day of 45 ug/m3 at the State Office Building Monitor from 2006-2010

- Filter based concentrations

- Determining the amount of each species present is required for source apportionment models.

- Organic Carbon is our highest contributor, but **OC is emitted from many sources**.

- Need many source apportionment tools to get at what contributes to OC and $PM_{2.5}$ as a whole.

Ammonium 9%

Other Particulates 1%

nitrate 4%

Elemental Carbon 7%

Sulfate 18%

Organic Carbon 61%
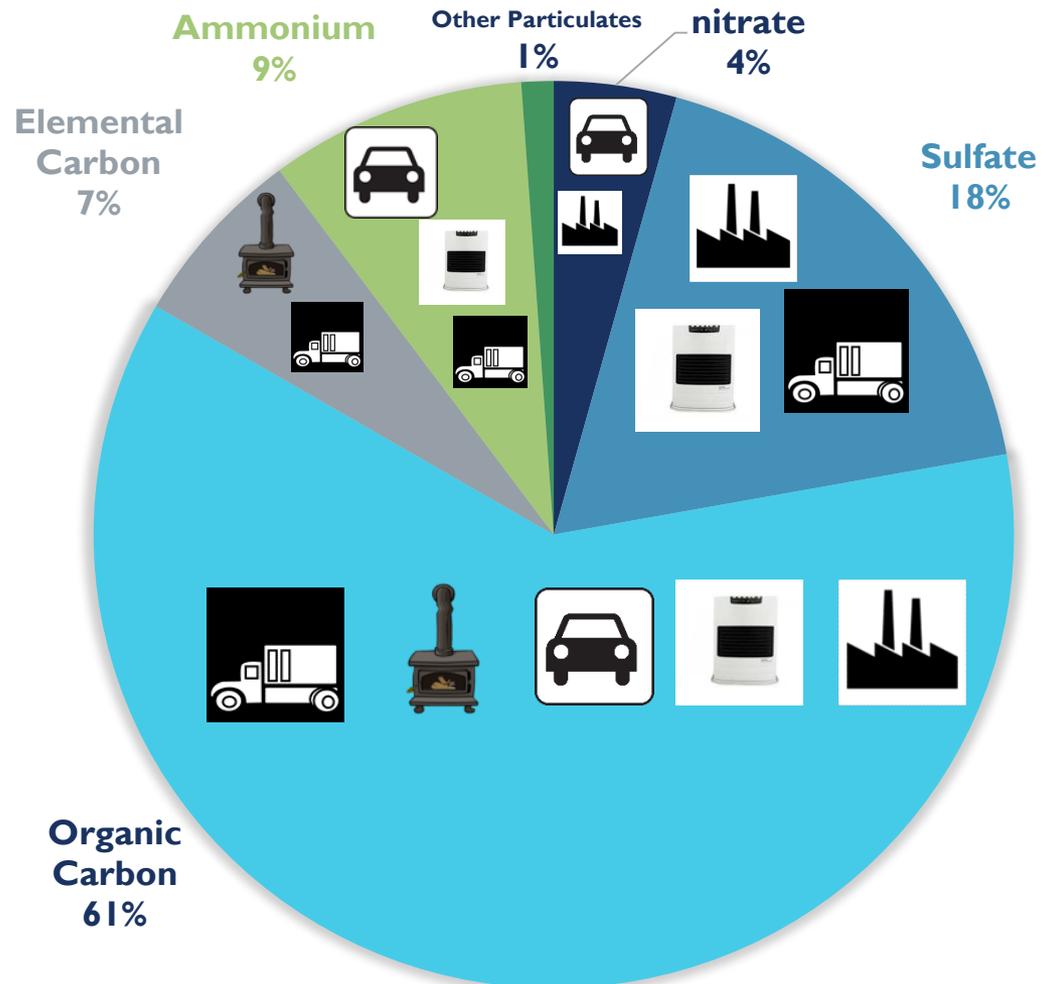
SPECIATION MONITOR DATA FROM STATE OFFICE BUILDING AND NORTH POLE FIRE STATION

STATE OFFICE BUILDING AVERAGE WINTER HIGH PM 2.5 DAYS (38.9 UG/M3) FROM YEARS 2011-2015

Other 1%
Ammonium 7%
Nitrate 7%
Sulfate 20%
Elemental Carbon 11%
Organic Carbon 54%
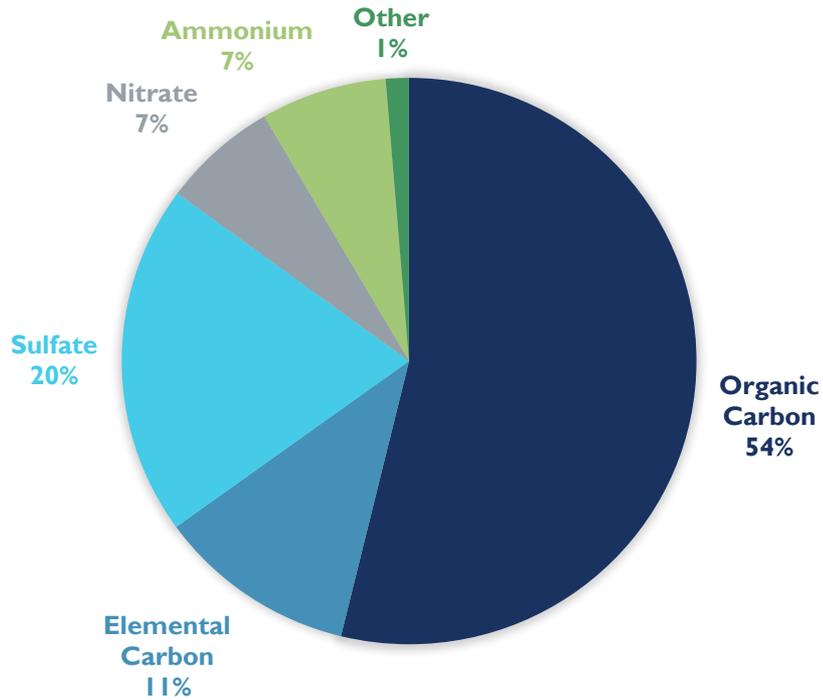
NPFS WINTER AVERAGE HIGH PM 2.5 DAYS (131.6 UG/M3) FROM YEARS 2011-2015
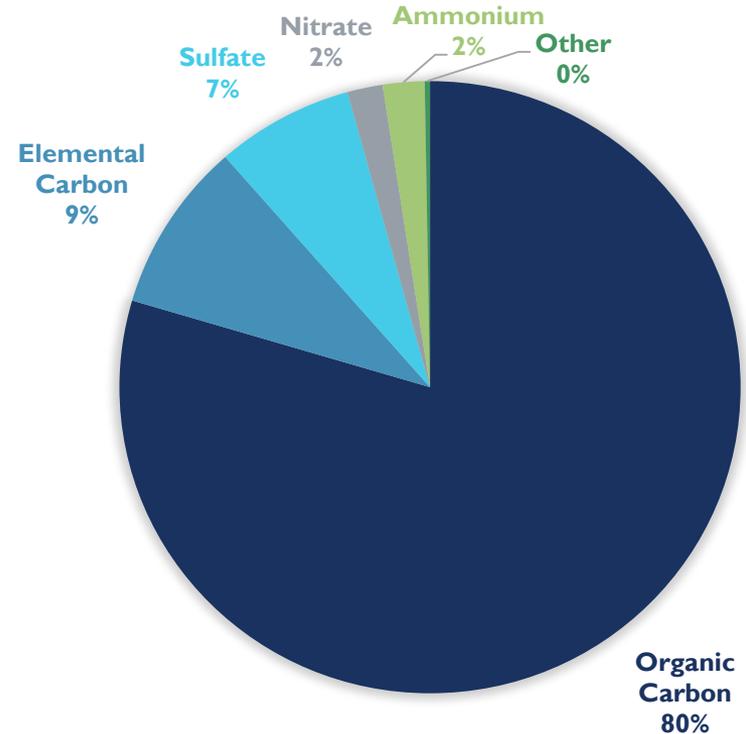
Nitrate 2%
Ammonium 2%
Other 0%
Sulfate 7%
Elemental Carbon 9%
Organic Carbon 80%

Emissions Sources | **Monitors** | **Speciation** | **Source Apportionment**

Mobile Sources

(CARS)

Industrial Sources

(POWER PLANTS)

Area Sources

(HOME CHIMNEYS)

NOx, VOC, PM, SOx

24-Hour Sample | Unused sample

Wood Burning Contribution

52% | 68% | 90% | 78%

Fairbanks | North Pole

PMF | CMB

Pattern Recognition

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# FILTER-BASED SOURCE APPORTIONMENT SCIENCE STUDIES - CMB

- Source Apportionment Model – Chemical Mass Balance (CMB)[1]

- Uses pattern recognition to identify which sources are present in the speciated measurements.

- Multiple sites and days
  - Winter speciation filters from 2005-2013
  - Uses source profiles from different sources

Diesel 0-11%

Ammonium nitrate 3-11%

Sulfate 7-21%

Wood Smoke 60-80%
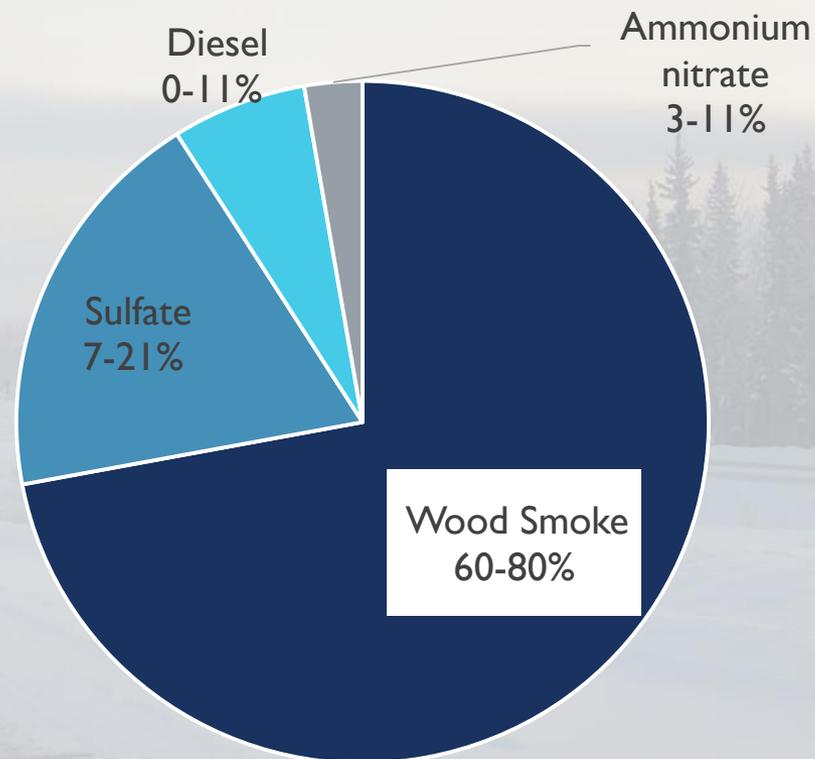
7/20/2017   13

[1] The Fairbanks, Alaska PM2.5 Source Apportionment Research Study Winters 2005/2006-2012/2013, and Summer 2012, Tony J. Ward, Ph.D., December 2013

FILTER-BASED SOURCE APPORTIONMENT SCIENCE STUDIES - PMF

- Source Apportionment Model - Positive Matrix Factorization (PMF)[1]
  - 2010-2015
  - Fairbanks and North Pole speciation filters
- Whole winter average
- Wood burning is a major contributor.
- Results agree with CMB on wood burning dominating PM2.5.

Wood Burning Contribution

Fairbanks: PMF 52%, CMB 68%
North Pole: PMF 90%, CMB 78%

[1]Source apportionment of PM2.5 at multiple Northwest U.S. sites: Assessing regional winter wood smoke impacts from residential wood combustion, Robert A. Kotchenruther, 2016
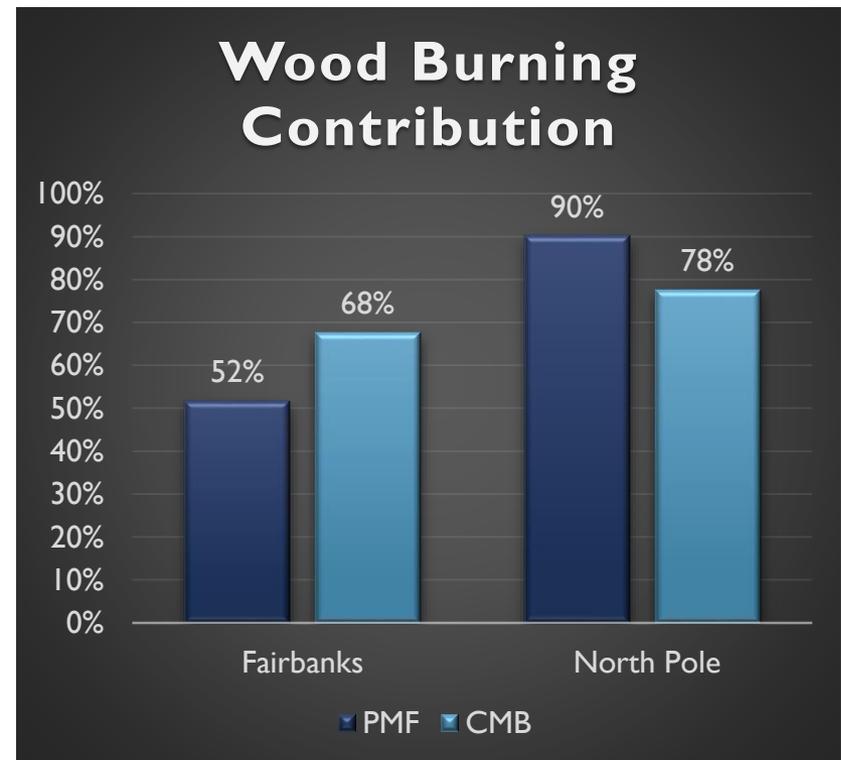
SOURCE CONTRIBUTION APPROACHES

In addition to the source apportionment of speciation data we have other tools to estimate source contributions in the nonattainment area.

Speciation Source Apportionment

Emission Inventory

Air Quality Modeling

Woodburning Contribution
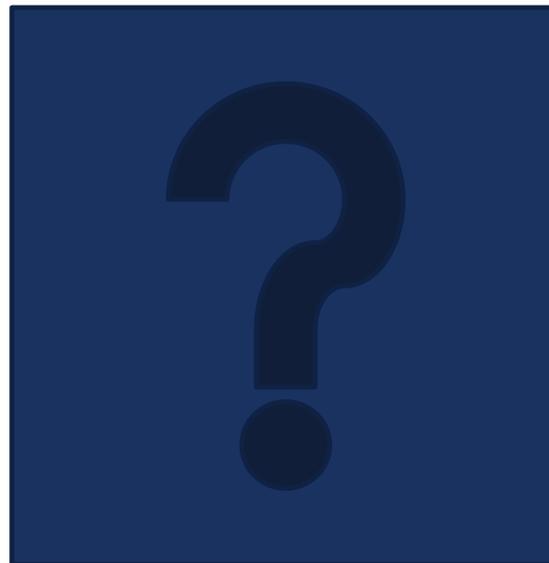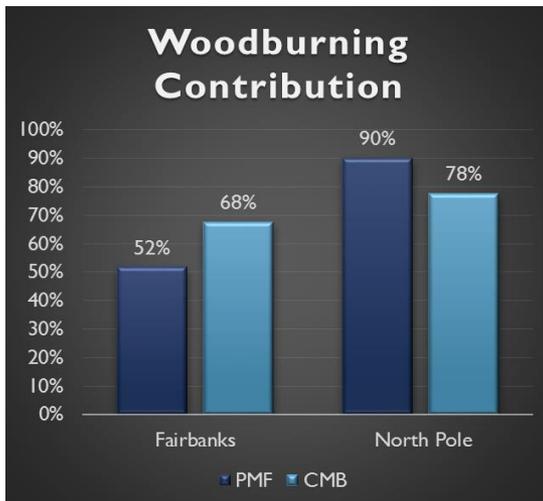
EMISSIONS INVENTORY PROCESS

- Local information is collected:

  - Population

  - Activity

  - Fuels

  - Types of sources

  - Meteorology

- Emissions are calculated for sources impacting the nonattainment area with EPA approved methods using local data.

EMISSIONS SOURCE CHARACTERIZATION

- Home Heating
  - Multi-year phone survey
  - In-home measurement study
  - Local fuel and device lab testing
  - Vertical allocations
- Episode specific point source emissions
- Transportation Modeling (MOVES)
  - Local fleet – DMV
  - Fairbanks activity – parking survey
  - Winter meteorology

EMISSIONS SOURCE AVERAGES INTO THE ENTIRE NON ATTAINMENT AREA FOR 2013 (EARLY DRAFT)

Source Category	%
Space Heating – Wood	55%
Point Sources*	32%
On-Road Vehicles	7%
Other Sources (Other Area & Non-Road)	4%
Space Heating – Heating Oil	2%
Space Heating – Other (coal, waste oil, etc.)	<1%
TOTAL	100%

* Not emitted at ground level

SOURCE CONTRIBUTION APPROACHES

Speciation Source Apportionment
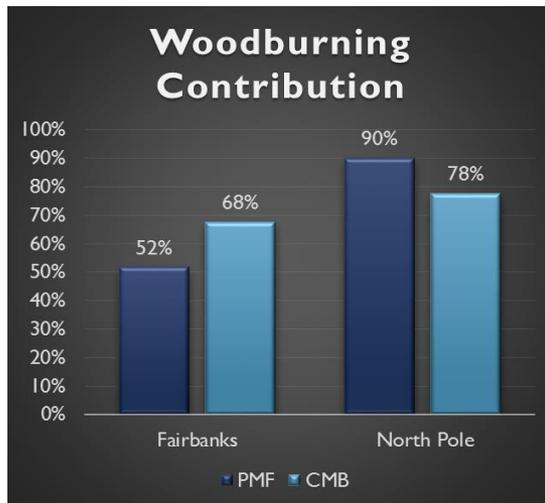
Emission Inventory

Nonattainment Area Wide PM2.5 Emissions
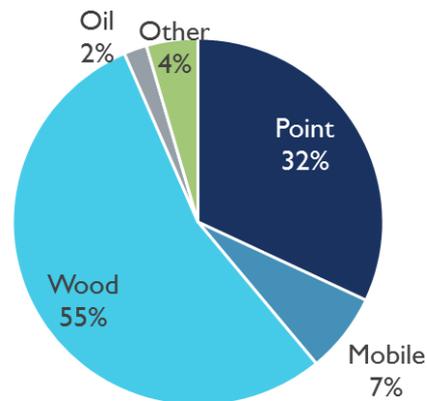
Air Quality Modeling

AIR QUALITY MODELING PROCESS

- Air quality models can estimate the concentrations of $PM_{2.5}$ within the nonattainment area as well as source contributions.

- These models combine meteorology, emissions inventories, and chemistry to determine source contributions.

- Air quality models account for both the location and height of the stack of a source when estimating contribution.

- Both the directly emitted $PM_{2.5}$ and precursor contributions are determined by the model.

# PRELIMINARY MODELED SOURCE CONTRIBUTIONS FOR FAIRBANKS

2013 State Office Building Contributions

Sulfate 17%
Point 9%
Oil 6%
Mobile 10%
Other 10%
Wood 48%
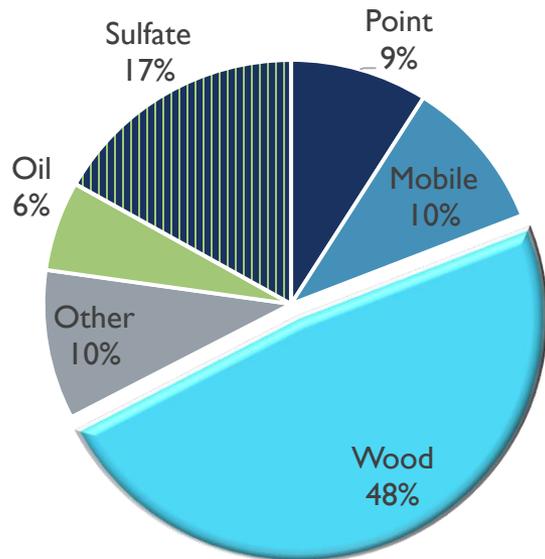
2013 North Pole Fire Station Contributions
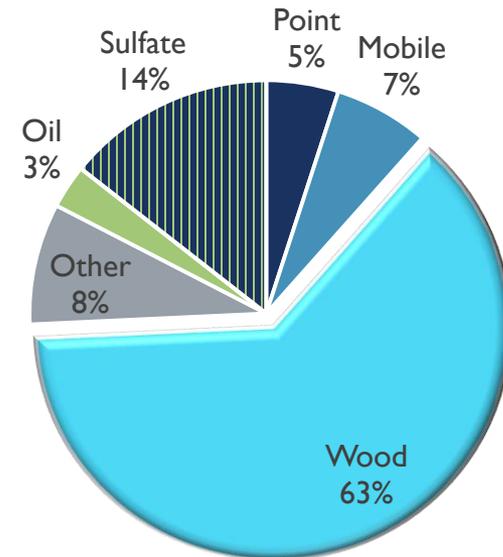
Sulfate 14%
Point 5%
Mobile 7%
Oil 3%
Other 8%
Wood 63%

SOURCE CONTRIBUTION APPROACHES

Speciation Source Apportionment

Emission Inventory

Nonattainment Area Wide PM2.5 Emissions

Air Quality Modeling

2013 State Office Building Contributions
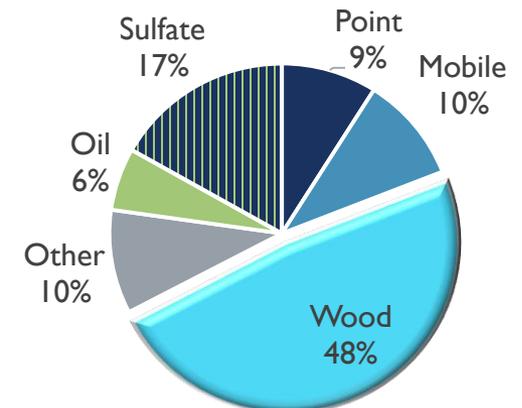
SOURCE CONTRIBUTION SUMMARY

- Collaborative effort using multiple approaches

- Wood burning is consistently found to be the major contributor to winter $PM_{2.5.}$

- This contribution holds true across multiple sites and years.

- Point sources are not the largest contributor to the ground level concentrations.

NEXT STEPS

- Develop emissions and air quality projections to 2019

- Analyze control measures – emission reductions, implementation issues, costs, and cost-effectiveness

- Use results to:

  - Assess continuation/change in existing measures

  - Assemble packages of measures to demonstrate attainment

  - Assess time required to attain standard

- Presentations of findings to the public and Assembly

ACKNOWLEDGEMENTS

- Mark Hixson, Sierra Research

- Bob Dulla, Sierra Research

- Denise Koch, Director, DEC

- Bob Kotchenruther, USEPA Region10

- Rob Elleman, USEPA Region10

EXAMPLE ** KEY FAIRBANKS MODELING STEPS

Mobile Sources

(CARS)

NOx, VOC, PM, SOx

Industrial Sources

(POWER PLANTS)

NOx, VOC, PM, SOx

Area Sources

(HOME CHIMNEYS)

NOx, VOC, PM, SOx

Chemistry

Meteorology

Models

Weather

Photo-chemical

Statistical
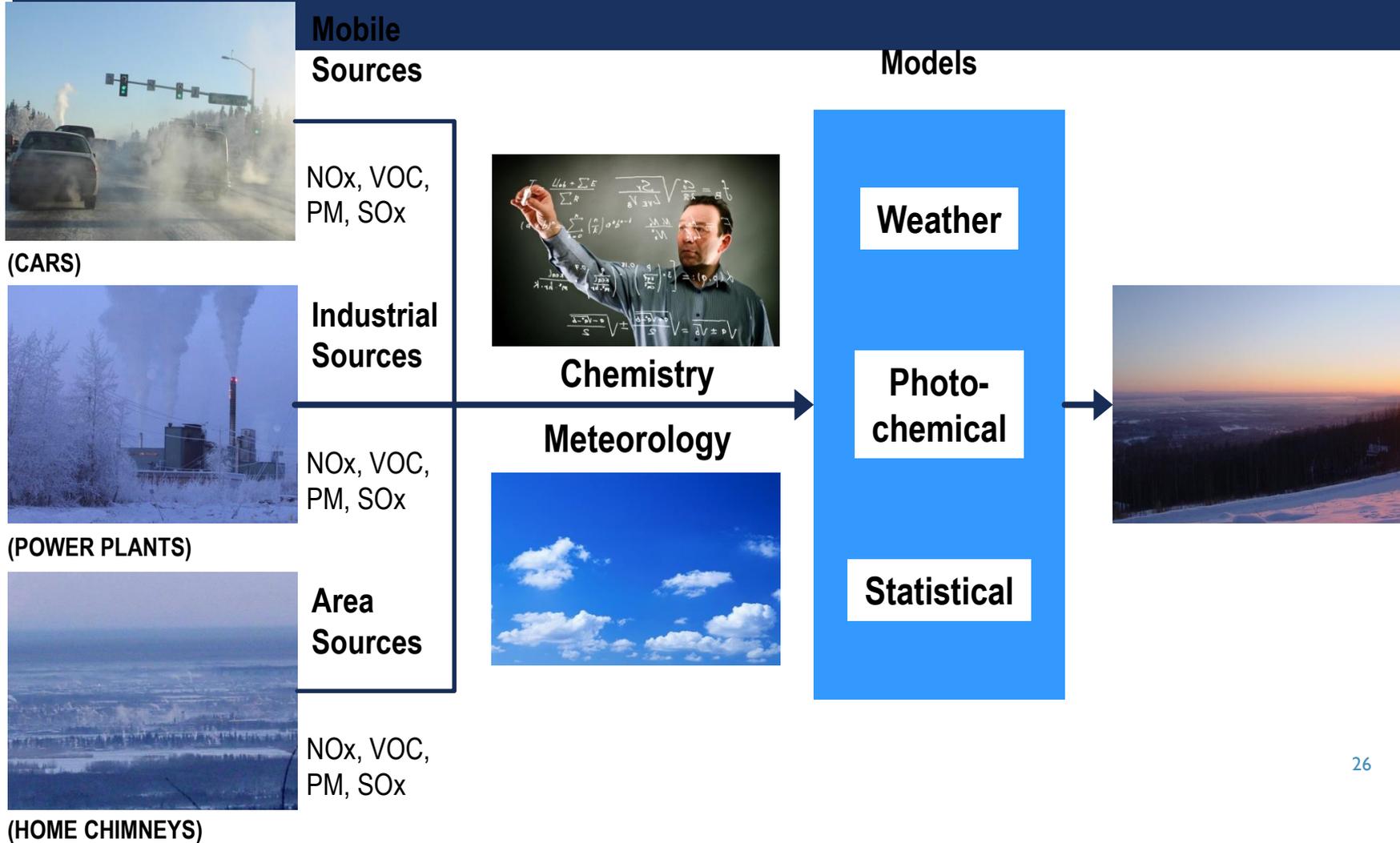
FAIRBANKS MONITOR FILTERS

EPA PMF

Average December & January Results

Monitor location	Primary wood smoke mass (µg/m3)	Primary wood smoke mass (%)	Aged wood smoke & SOA mass (µg/m3)	Aged wood smoke & SOA mass (%)	Primary + aged wood smoke (assumed RWC) (µg/m3)	Primary + aged wood smoke (assumed RWC) (%)
	Primary		**Aged**		**Primary + Aged (RWC)**	
	mass	%	mass	%	mass	%
Fairbanks	9.8	39.9	3.0	12.0	12.8	51.8
Fresno	not found	not found	mixed(3)	mixed(3)		
Bakersfield	mixed(1)	mixed(1)	mixed(4)	mixed(4)	3.5	11.4
Sacramento	mixed(2)	mixed(2)	mixed(3)	mixed(3)		
Boise	not found	not found	mixed(2)	mixed(2)		
Klamath Falls	15.6	66.7	4.6	19.7	20.2	86.4
Lakeview	19.0	78.5	3.4	14.1	22.4	92.7
Oakridge	12.9	73.1	3.1	17.7	16.0	90.7
Portland	5.8	47.3	1.3	10.6	7.1	57.9
Bountiful	1.8	12.1	1.5	9.9	3.3	22.0
Salt Lake City	mixed(2)	mixed(2)	mixed(3)	mixed(3)		
Lindon	1.6	9.0	1.6	8.8	3.3	17.8
Vancouver	mixed(2)	mixed(2)	0.9	7.6		
Seattle (Duwamish)	2.3	22.6	0.7	7.0	3.0	29.5
Seattle (Beacon Hill)	2.0	30.4	mixed(5)	mixed(5)		
Tacoma (South L St.)	8.1	59.6	mixed(6)	mixed(6)		
Tacoma (Alexander Ave.)	3.9	35.3	1.1	9.7	5.0	45.0
Marysville	mixed(2)	mixed(2)	0.8	6.5		
Yakima	5.4	31.7	mixed(3)	mixed(3)		

(1) Mixed with Aged Wood Smoke & SOA   (4) Mixed with Primary Wood Smoke
(2) Mixed with Motor Vehicles   (5) Mixed with Residual Fuel Oil Combustion
(3) Mixed with Ammonium Sulfate   (6) Mixed with Sulfate Rich

CHEMICAL MASS BALANCE MODEL

- Speciation filters from State Office Building, NCORE North Pole Elementary, North Pole Fire Station, RAMS, Peger Road

- Source mix changes based on meteorology, focus is on high PM 2.5 days

- Years of data (2005-2013) to cover all winter days, conditions and account for variability

Sulfate 17.9%
Unexplained 0.6%
Ammonium Nitrate 8.0%
Diesel 5.5%
Wood Smoke 67.7%
Autos 0.5%
Avg PM$_{2.5}$: 21.8 µg/m
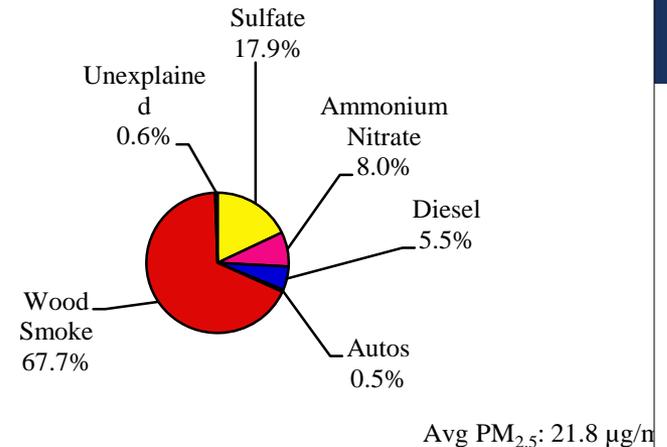
Winter 2012/2013 EPA source profiles State Office

Sulfate 7.4%
Ammonium Nitrate 2.8%
Unexplained 1.0%
Diesel 9.8%
Wood Smoke 77.6%
Autos 1.4%
Avg PM$_{2.5}$: 46.9 µg/m
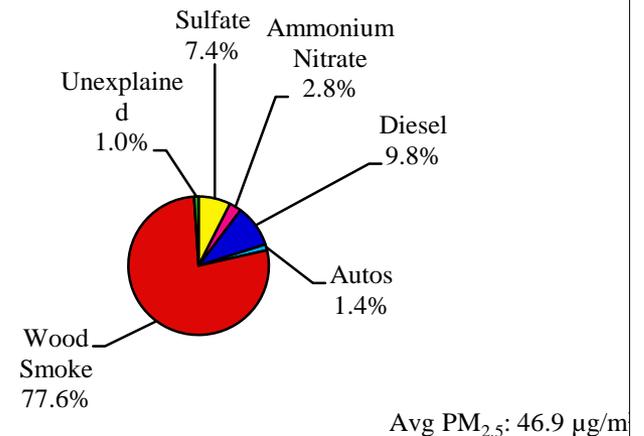
Winter 2012/2013, EPA source profiles NPF3

C14/LEVO/ORGANICS STUDIES

- Comprehensive chemical analyses for levoglucosan, hopanes, steranes and PAHs have been performed on up to 33 ambient PM2.5 samples from Fairbanks.

- A more comprehensive approach of source apportionment using full profiles of all sources and ambient PM2.5 is much more appropriate for this analysis. The results suffered from data limitations for Fairbanks sources and ambient PM2.5.

- All tests had conflicting results for tracers that could be marked fuel oil and coal, in the end the results had many qualifiers and were considered inconclusive.

- Estimated Laevoglucosan woodsmoke 30-65% percent

- Fuel Oil with an upper bound of 15%

- Coal at estimated at 2.7%

CALPUFF CONFIGURATION AND INTEGRATION WITH CMAQ

- WRF input files using MMIF and preserved layering

- Modeled six power plants in the nonattainment coal and fuel oil

- Single source impacts at the violating monitor and area wide

- Corroborate with CMAQ on total $PM_{2.5}$ contribution from points (7-22%).
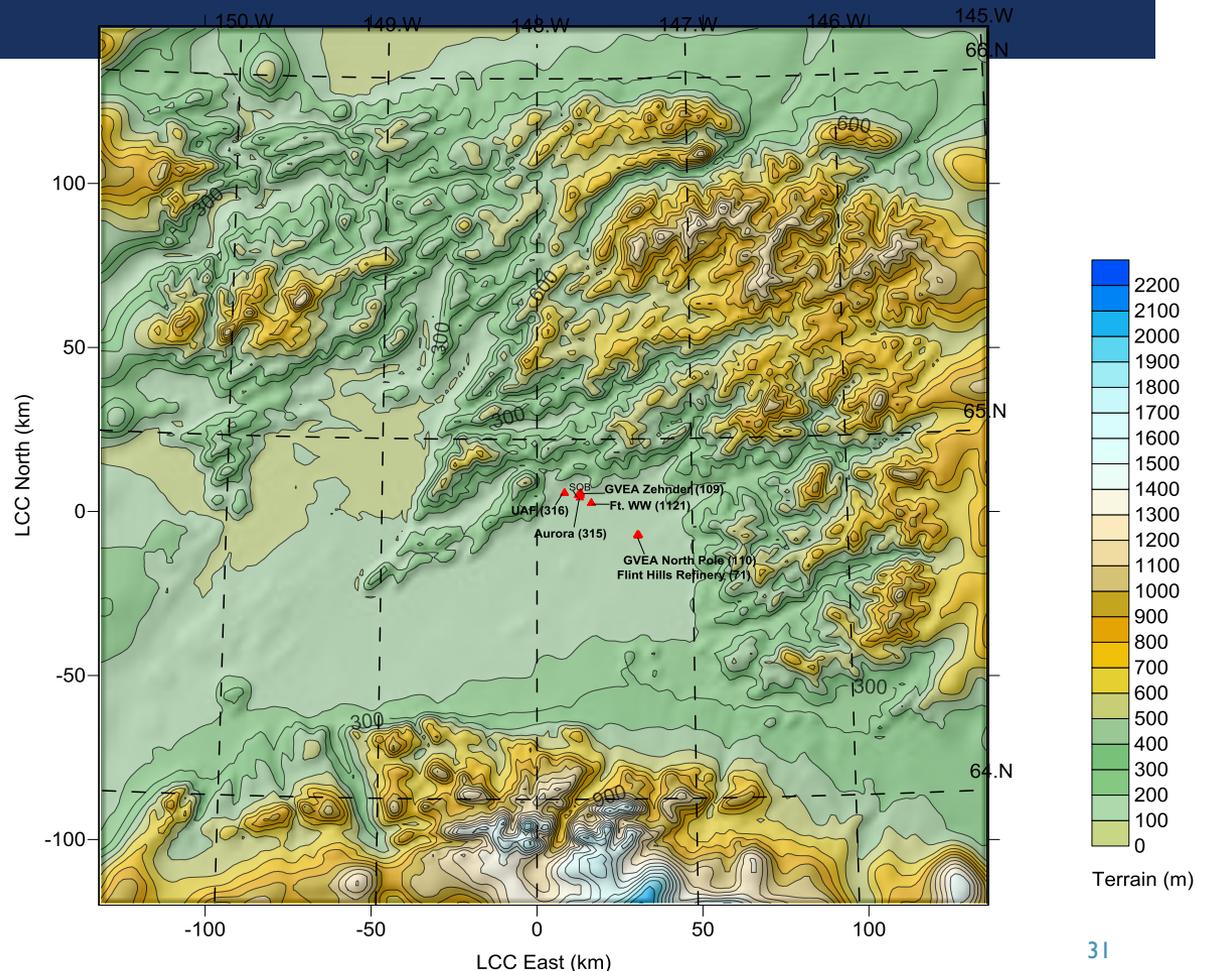
OTHER MONITORING ACTIVITIES

- FNSB:
  - 6 pDRs in Schools
  - Sniffer vehicle
  - 18 neighborhood monitors in two 9 sampler grids
- DEC:
  - North Pole Saturation study
    - 12 pDRs and sniffer vehicle during intensive 2 week sampling study up to 1.5 miles around NPFS SLAMS site
  - 6 additional pDRs available for additional hot spot locations
- Historically: FNSB used short term special purpose monitoring sites
  - 3 sampling trailers available
  - 4-12 weeks in one location
  - Evaluation of hot spots or complaints