Mobile $PM_{2.5}$ Measurements in Fairbanks in the Winter of 2007-2009

James Conner — Fairbanks North Star Borough
Barbara Trost Alaska — Department of Environmental Conservation
Frank DiGenova and Bob Dulla — Sierra Research

Studies conducted with US DOT CM/AQ funding

A Little Background

- 2006 - knew there were high $PM_{2.5}$ concentrations at our single FRM monitor in downtown Fairbanks and that lowering the NAAQS would put us out of compliance ...BUT...
  - How far did the high $PM_{2.5}$ extend? Beyond city limits? To the Valleys North or East or West of Fairbanks? Regional?
  - Was it more or less severe in other areas? Was the downtown monitor at the right location to serve is an indicator?
  - Was the problem caused mainly by coal burning (as gross emission projections may predict), or by motor vehicles (as EPA MOBILE modeling may project), or by OWBs or other wood burning?

Stationary vs. Moveable vs. Mobile Monitoring (we're doing all 3)

- Stationary monitoring only provides information for a single point on the map, little insight into sources
- A moveable monitor (e.g. RAMS trailer) is valuable, but limited to a small set of sites
- Mobile monitoring potentially identifies peak locations AND provides insight into potential sources and where to focus our efforts
- The Non-Attainment area is a very large and diverse area


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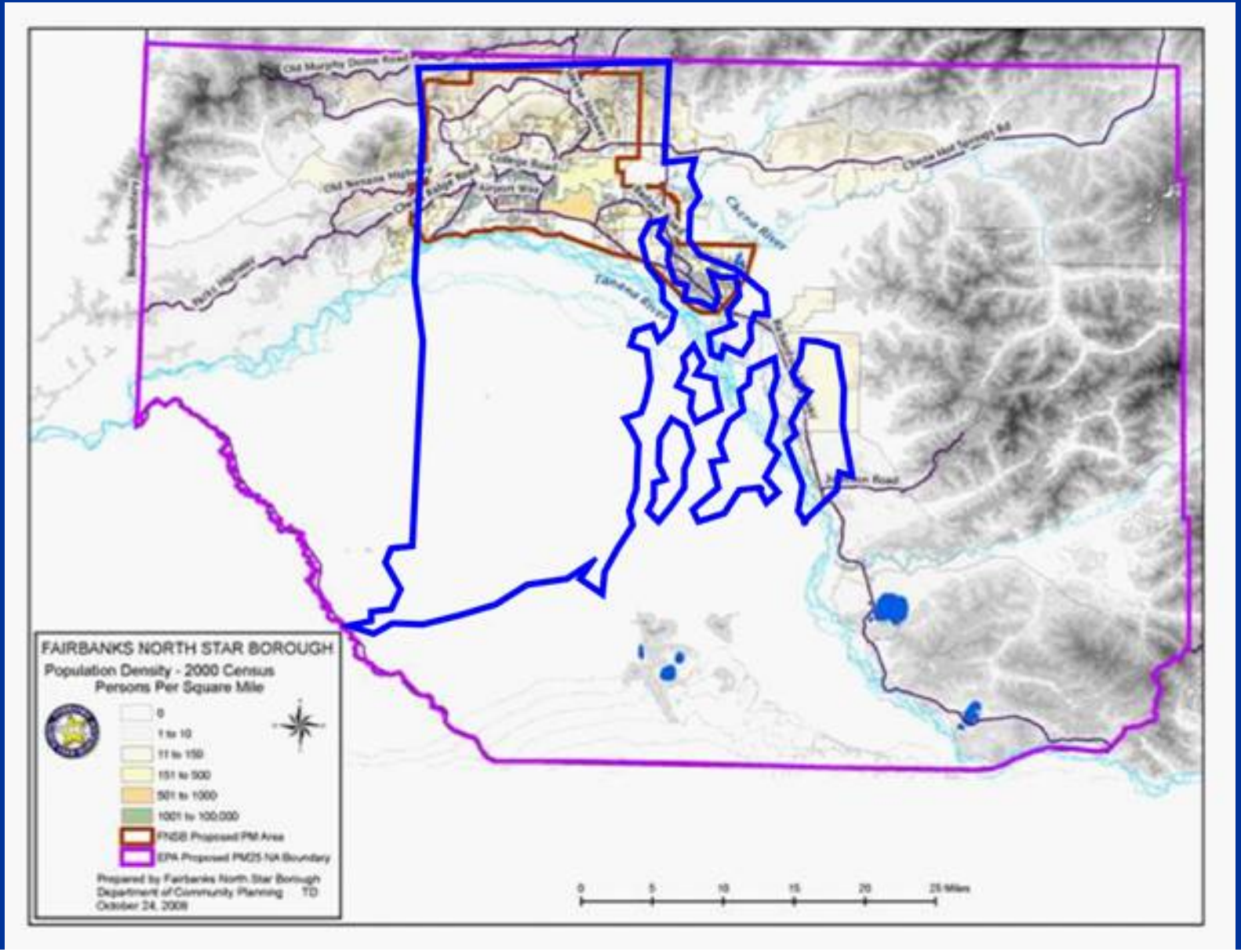
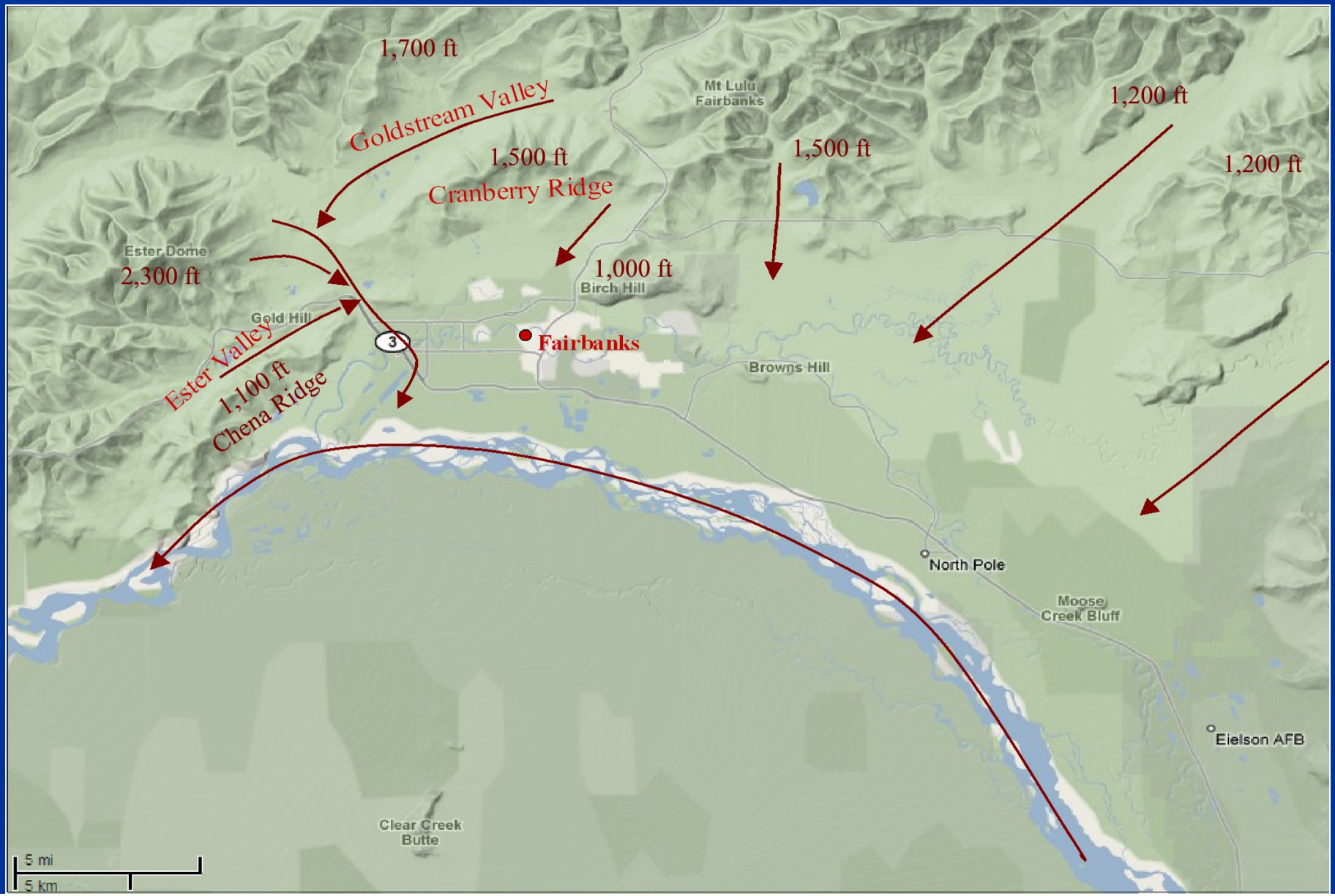
PM2.5 Nonattainment Boundary and Outline of Rhode Island comparison for scale



Topography & Drainage Flows in Fairbanks Area

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A Little History

- Speciation results indicated about 25% of our particulates were sulfates.
- Early 2007 – conducted a Tier 2 Gasoline Benefits Study (Sierra Research, the Fairbanks North Star Borough, and the Alaska DEC) which provided some mobile monitoring results and the beginnings of a method to expand mobile monitoring.

  - the instrumentation is relatively easy to set up and integrate with GPS
  - sampling at a point above the vehicle and while moving did not present any obvious problems.
  - same qualitative trends as BAM but reads reads 40-60% lower

April 2007 Sniffer-*lite* preview

- Test Ultra Low Sulfur PM benefits
- Diesel particulate monitor & 2.5 µ SCC
- DR4000 2.5 µ impactor
- Five Gas Analyzer (CO & CO2)
- Leased DataRAM4000 PM monitors
- Data logger
- Video recorder
- Sample line heater
- Garmin GPS
- temperature loggers

A Little History

However, from this initial study:

- No instances of extremely low temperatures or ice fog occurred during that initial study (27 to 62ºF) - Expect Winter ambient temperatures well below minimum operating temperature of the DataRAM, even with the heated inlet line.
- Effect of evaporating semi-volatile organic matter was not evaluated
- No information collected to specifically address the question of how the DataRAM responds to different types of aerosol.

A Little History

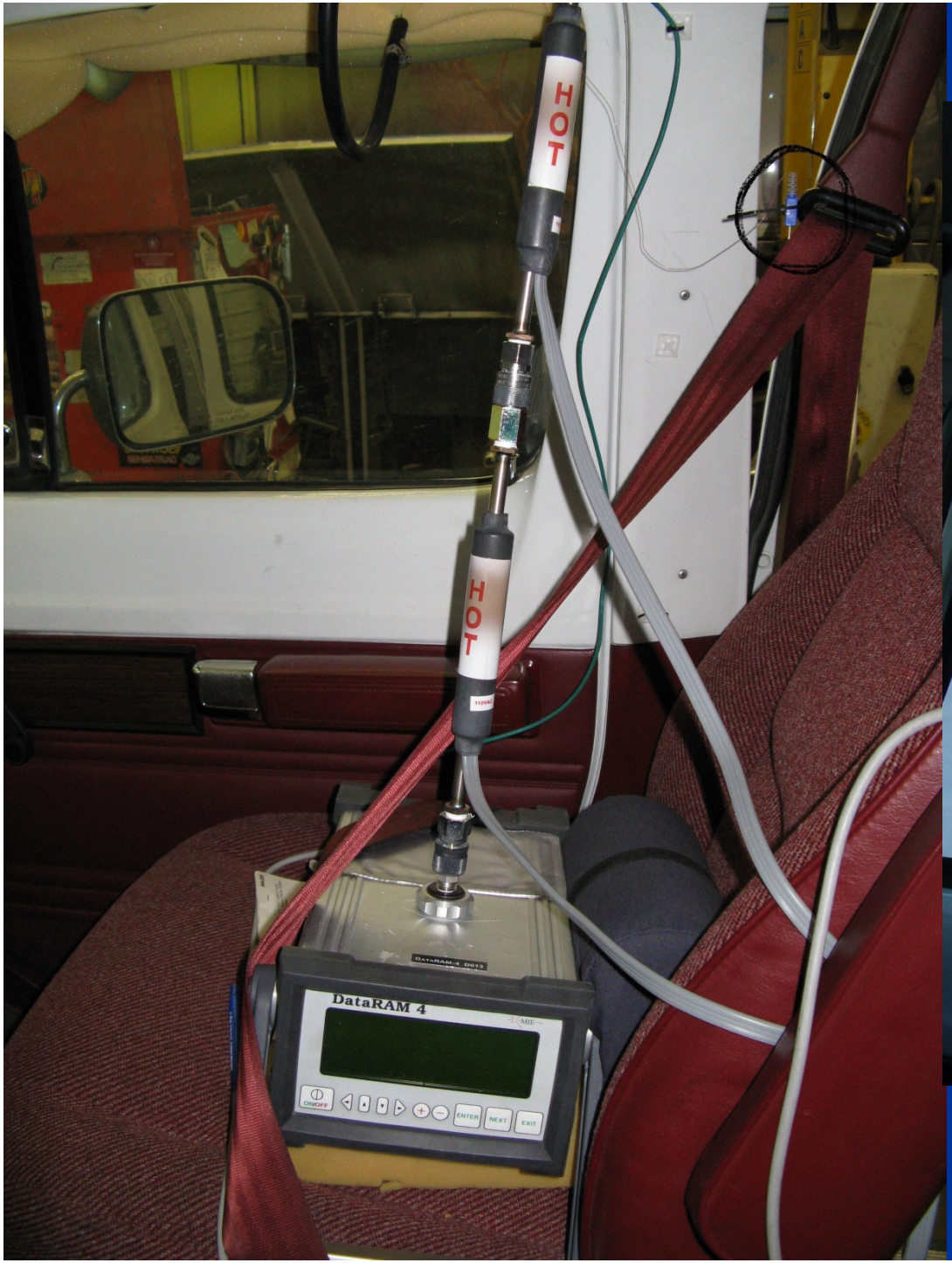
Winter 2007-2008 with borrowed equipment /staff we initiated a mobile monitoring experiment "Sniffer-Lite" to gain as much insight as possible and:

- characterize the spatial extent and relative severity of our winter time $PM_{2.5}$ problem,
- characterize daily changes in concentrations, and
- gain insight into the sources (e.g. space heating, other stationary sources, Diesels and other mobile sources) and their relative importance.
- Prelude to a larger mobile source emission study planned for winter 2009-2010

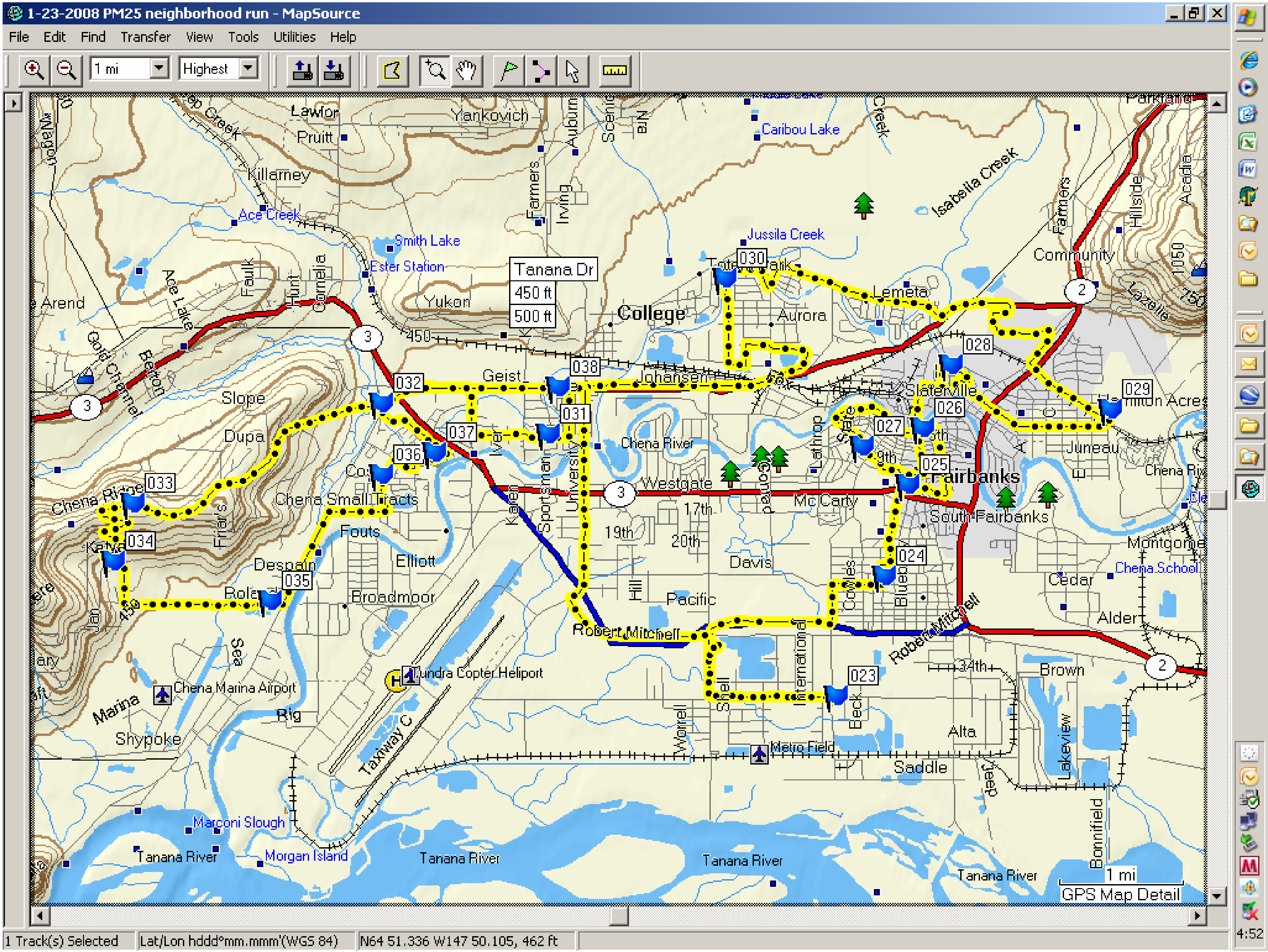
Winter 2007-2008 Sniffer*-lite*

- 13 year old rear wheel drive Dodge Van
- US Fire Service in Montana kindly loaned 5 DataRAM4000 PM monitors (to get two that worked reliably)
- BGI PM2.5 sharp cut cyclone
- Sample line heaters
- Garmin GPS; temperature loggers
- 300W power inverter
- Used a DryCal flow calibrator
- Vehicle chassis was grounded using a commercial (drag type) grounding strap.

Winter 2007-2008 Sniffer-*lite*


HOT
HOT
DataRAM 4
ON/OFF
ENTER
NEXT
EXIT


HOT
8 12:17PM


1-23-2008 PM25 neighborhood run - MapSource
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1 mi
Highest
Tanana Dr
450 ft
500 ft
College
Fairbanks
South Fairbanks
Aurora
Lemeta
Slaterville
Johansen
Geist
Westgate
Chena River
Chena Small Tracts
Fouts
Elliott
Broadmoor
Despain
Pacific
Davis
McCarty
Robert Mitchell
Tundra Copter Heliport
Chena Marina Airport
Metro Field
Shypoke
Marina
Marconi Slough
Morgan Island
Tanana River
Smith Lake
Ester Station
Ace Creek
Killarney
Lawlor
Pruitt
Yankovich
Caribou Lake
Jussila Creek
Isabella Creek
Community
Hamilton Acres
Juneau
Montgomery
Chena School
Cedar
Alder
Brown
Alta
Saddle
Yukon
Slope
Dupa
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Chena Ridge
030
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1 mi
GPS Map Detail
1 Track(s) Selected
Lat/Lon hddd°mm.mmm'(WGS 84)
N64 51.336 W147 50.105, 462 ft
4:52

Lessons learned from “Sniffer Lite”

Achieved the goal of demonstrating the utility of collecting $PM_{2.5}$ measurements during episodes of high concentrations.

Quality Assure: Need to maintain a rigorous protocol for collecting concentration measurements adjacent to fixed monitoring sites

Use a voice recorder to supplement the log used to record details, unusual events, etc. while operating the vehicle.

Lessons learned from “Sniffer Lite”

Establish a fixed set of routes which are followed on a daily basis.

Repeat routes are needed to assess the effect of varying meteorological conditions on collected data as well as trends over time.

Identify a methodology for forecasting when high concentration days are expected to occur.

Focus data collection efforts on days when high concentrations are expected to occur. Collect data for extended periods of time (i.e., 24-hours/day) on high concentrations days.

Winter 2008-2009 Sniffer Full

2008 - CM/AQ Funds from the US DOT became available to study transportation sources of PM2.5 and we began a characterization study that winter (2008-2009) with dedicated resources

Winter 2008-2009 Sniffer Full Equipment

- 2007 Ford Explorer (FNSB-owned)
- Thermo Fisher Scientific DataRAM4000 PM monitor
- BGI $PM_{2.5}$ sharp cut cyclone, model SCC1.062;
- Sample line heaters (two Thermo Fisher Scientific DR-TCH temperature conditioning heaters);
- Garmin E-Trex Summit GPS;
- DryCal flow calibrator;
- Two Omega OM-CP temperature loggers;
- Die Hard (Sears)750W power inverter.
- stainless steel (SS) tubing sample lines of minimal length and with minimal number of bends. Where required, SS segments were joined by short segments of electrically conductive flexible tubing, which was kindly provided by TSI, Inc.

Winter 2007-2008 Sniffer Full Equipment

- It is recognized that the use of a sample line heater could evaporate some particles that might be condensed at ambient conditions, however the DataRAM measurements correlated well with other PM measurements used in the study.
- Loggers were used to record inside and outside temperature
- DataRAMs recorded two second measurements. The internal relative humidity correction was “enabled” and size correction was disabled at the recommendation of Thermo Fisher Scientific.

Cab, showing DataRAM (L), flow calibrator (R)


Sampling cyclone
Temperature Probes
Sample line
Sample line Heaters(2)
DataRAM
EXIT

Summary of Data Collection Procedures

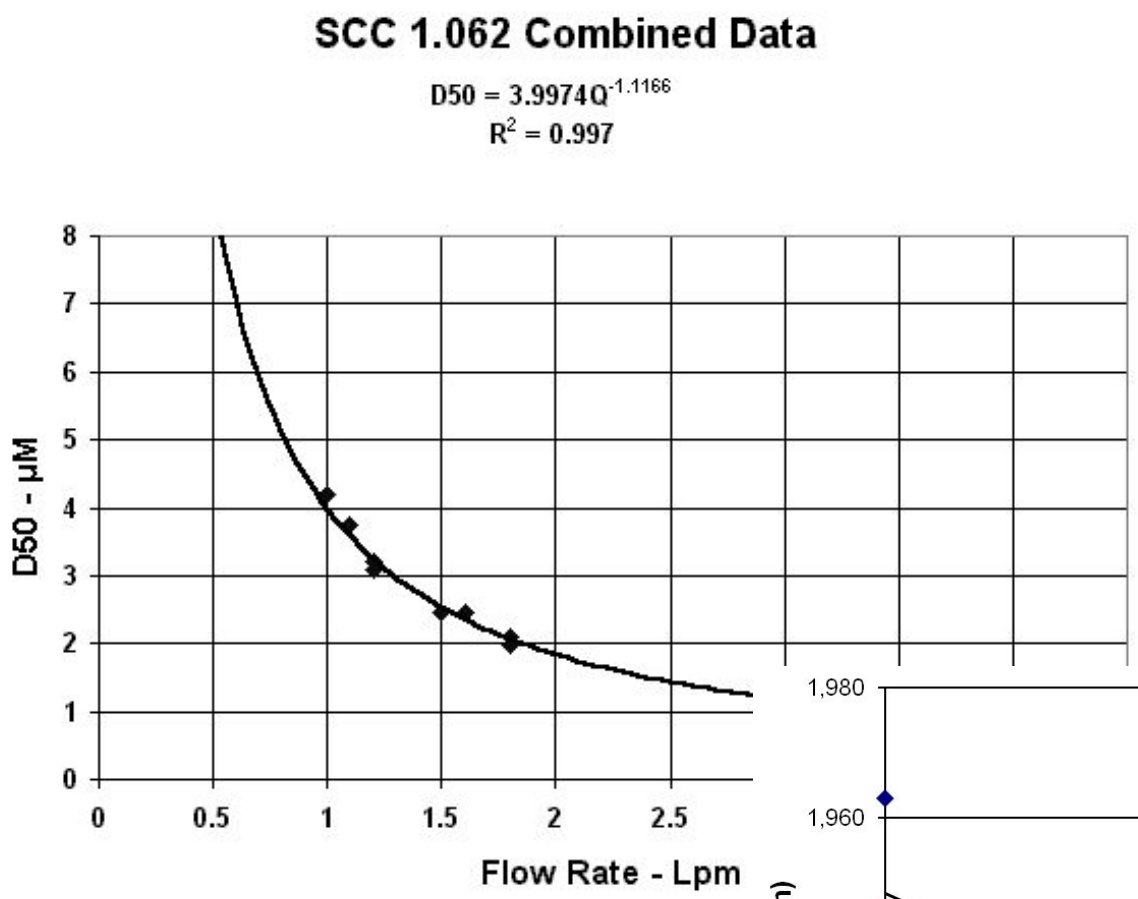
- Generally prescribed routes (City, Hills, North Pole, other)
- Flexibility to “follow plumes and high neighborhood concentrations”
- 2-4 drives/day (goal) during the winter (more drives during episodes, less/none when clean; half to be City drives)
- Day/night, weekday/weekend (and holiday)
- Collocation $PM_{2.5}$ monitoring at Peger Road (BAM) (1-hour) or Nordale School (TEOM/FDMS) (set on 12 minute averages)
- Drivers recorded (audio) and transcribed notes
- Photos of plumes, conditions, emission sources (everyone had a camera)

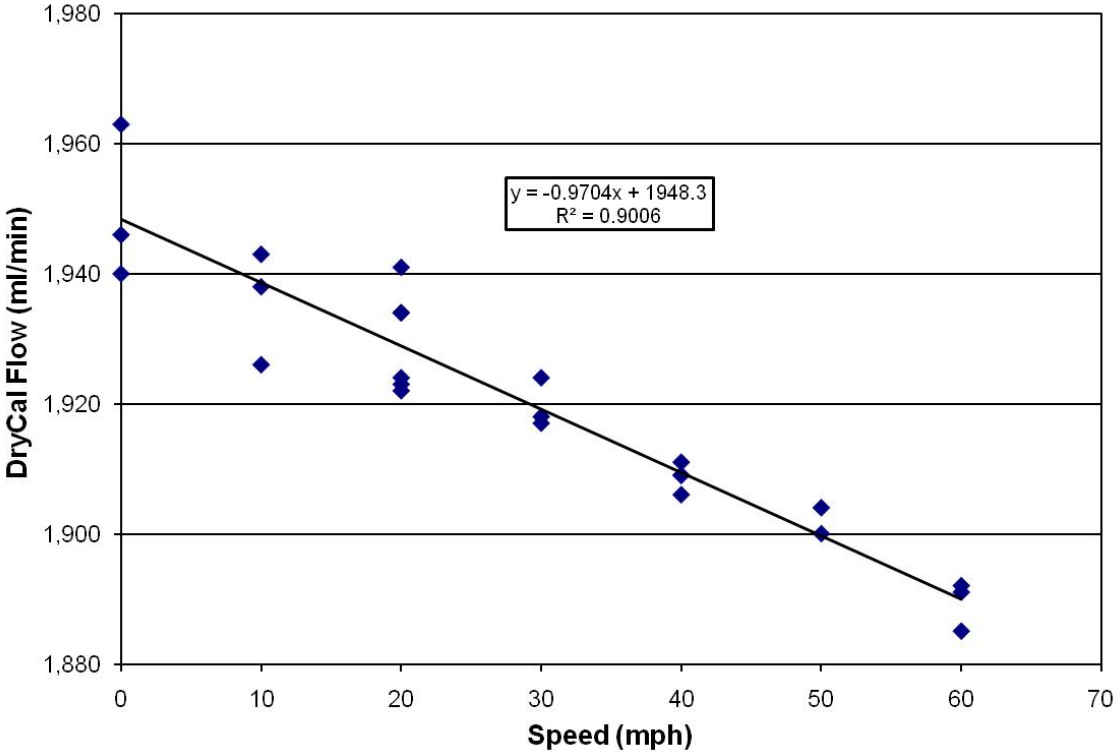
Flow Calibration

- Flow Measurements – DataRAM4000 flow rates are controlled and can be set to any desired level within the nominal range of the instrument.
- To ensure that vehicle speed did not have an undue influence on sample flow, a brief series of experiments was conducted in which the flow meter was positioned in the sample train between the DataRAM and the downstream sample line heater, and flow was measured as a function of vehicle speed over a range of steady-state speeds.
- The results of this experiment show that flow does vary with vehicle speed, but the effect is negligible

Flow Calibration

Used the Ideal gas law to correct for temperature and set the flow at 1.75 Lpm





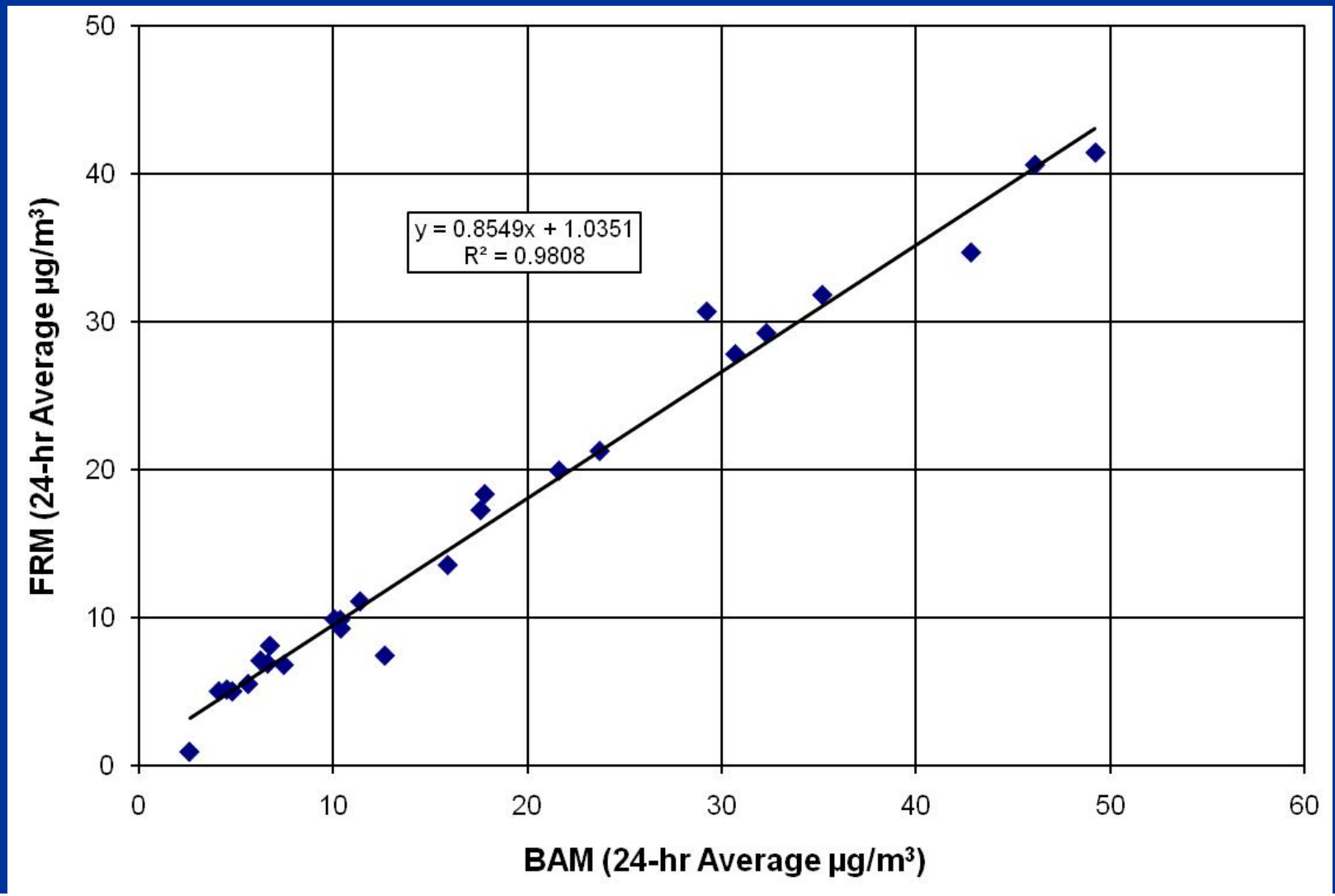
Mobile Measurement
Instrument Calibration and Quality Control

- How do these mobile, photometric, size-fractioned , heated samples, measured every two seconds compare with the stationary instruments?

- The next two graphs compare the FRMs to the BAM at Peger and the TEOM/FDMS at Nordale.

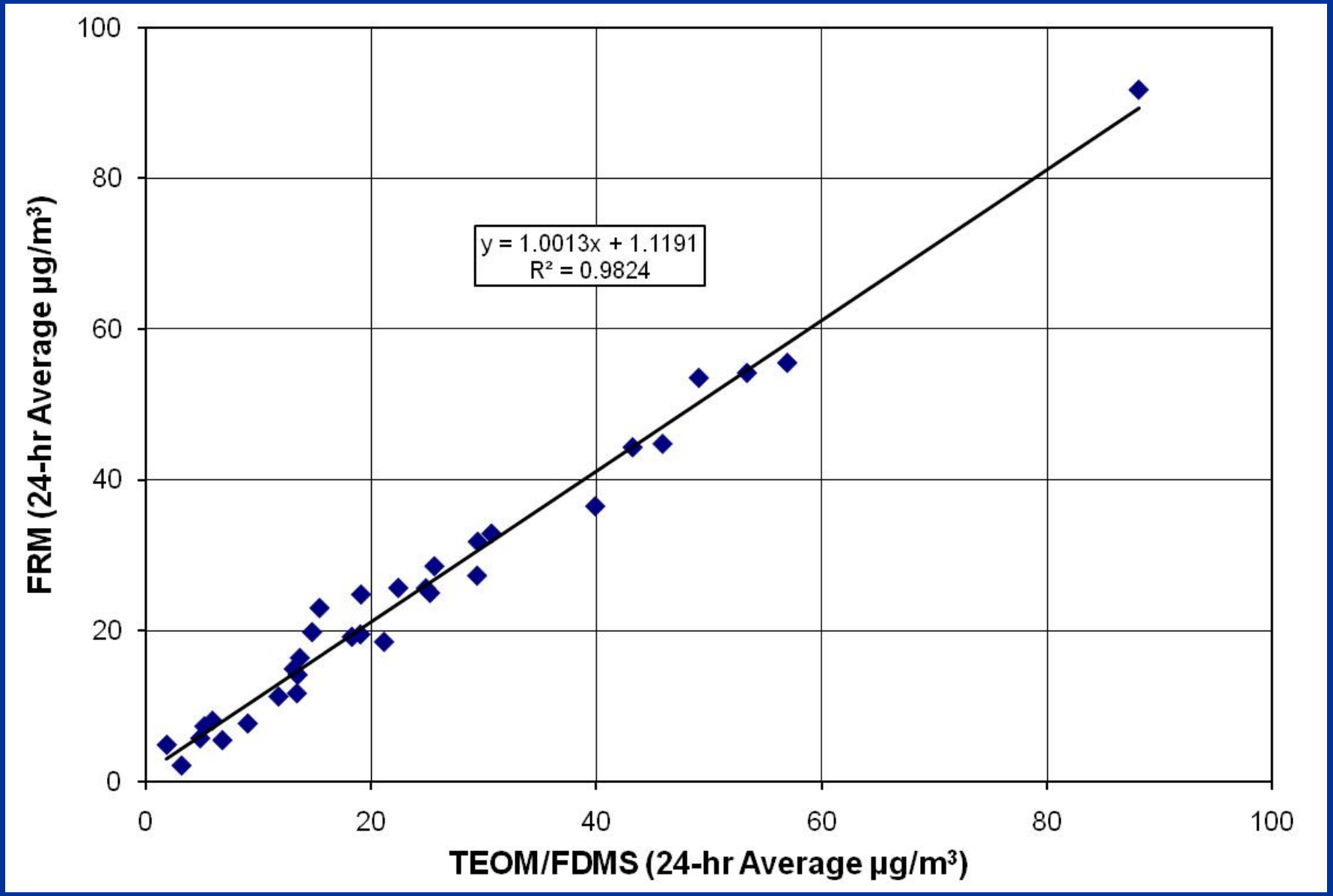
Mobile Measurement Instrument Calibration and Quality Control

FRM vs. BAM at Peger
(n=26, 24-hr Average Measurements)



Mobile Measurement Instrument Calibration and Quality Control

FRM vs. TEOM/FDMS at Nordale (n=32)



Mobile Measurement
Instrument Calibration and Quality Control

- The next step was to compare mobile DataRAM measurements collected during collocation with either the FRM-calibrated Peger BAM or Nordale TEOM/FDMS measurements. These correlations are shown in the next two slides.

Mobile Measurement
Instrument Calibration and Quality Control

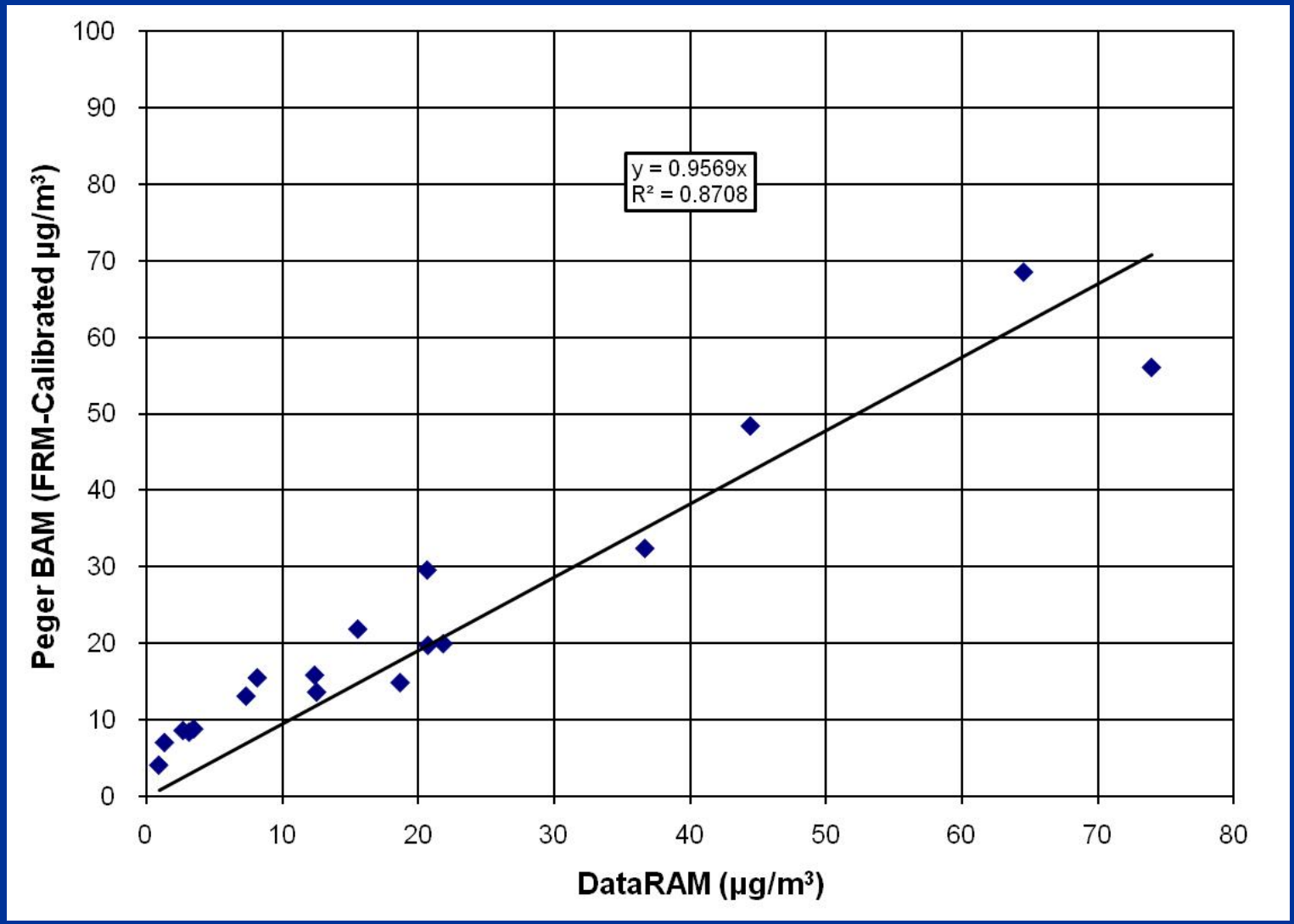
- It's noteworthy that vehicle stops varied in duration, from as little as 5 minutes up to 2 hours

- The mobile DataRAM to stationary BAM and TEOM/FDMS correlations, shown in the graphs (r2~0.96 and 0.84, respectively) are somewhat lower than the correlations shown earlier.

- Nevertheless, we find these satisfactory for the purpose of estimating spatial patterns, particularly when we expect the sites to have a different source mix (residential Nordale, and industrial at Peger).

Mobile Measurement Instrument Calibration and Quality Control

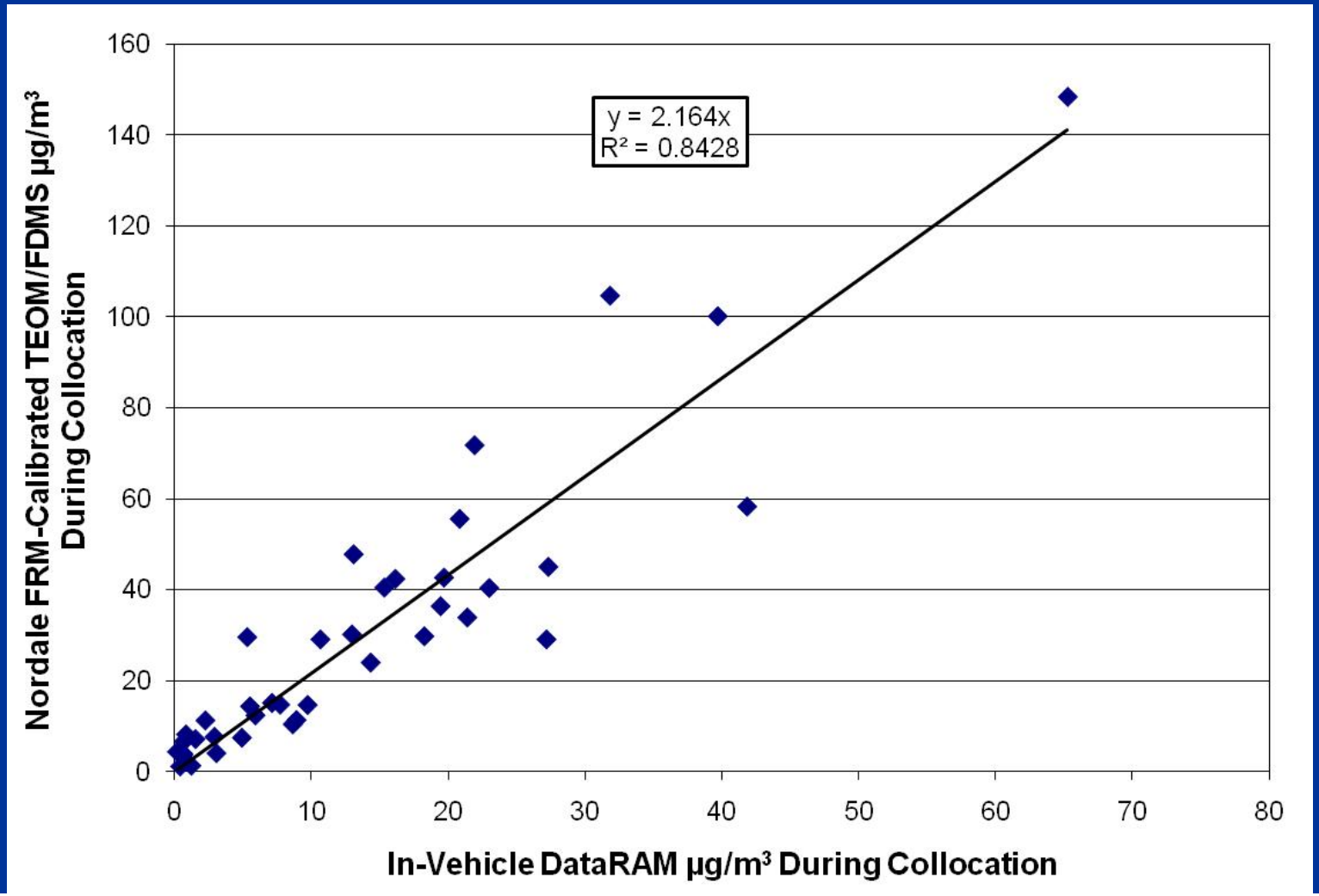
DataRAM (Size Correction Enabled) / BAM Collocated at PEGER (n = 19)



Mobile Measurement Instrument Calibration and Quality Control

Figure 4

Nordale FRM-Calibrated TEOM/FDMS PM2.5 vs. Collocated In-Vehicle DataRAM (n=39, size correction disabled)



Results


N


01/10/2009 12:25

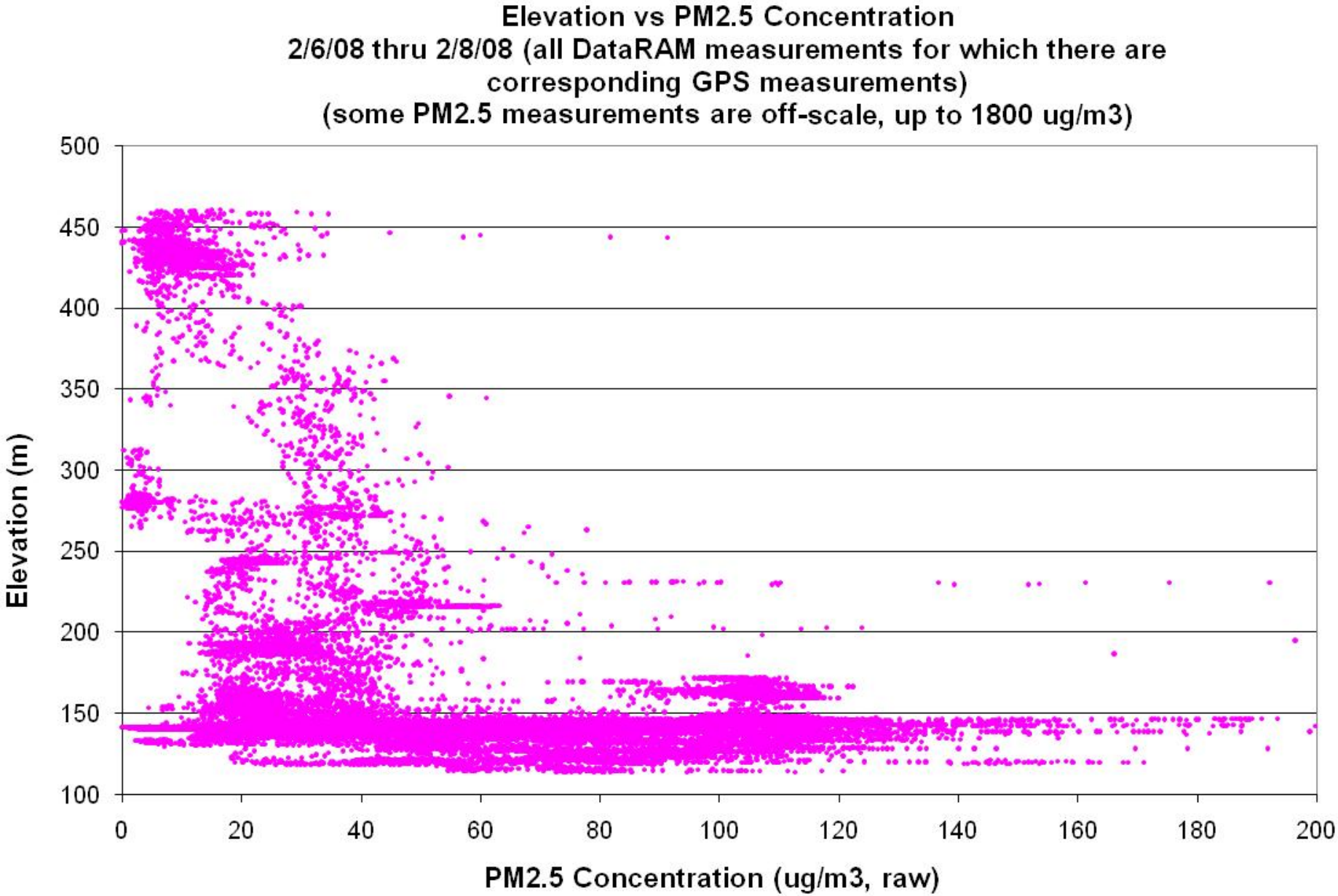

01/10/2009 12:26


JAN 29 2008


N
monitor
Peger Rd BAM
Image © 2008 DigitalGlobe
2.90 mi
Google
lat 64.869559° lon -147.746504°
elev 450 ft
Eye alt 10.26 mi


Ft. Wainwright
FB Mem Hosp
Aurora Energy
UAF
2
3
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
Image © 2008 TerraMetrics
9207 ft
lon -147.879596°
elev 467 ft
Eye alt 12257 ft
©2008 Google

DataRAM 4000 Concentration vs. Altitude




Aurora Energy
monitor
FB Mem Hosp
Well Street
Slater Street
Driveway Street
College Road
Old Steese Highway
Steese Highway
Hamilton Avenue
2nd Street
Front Street
Clay Street
Dunkel Street
Hall Street
Lacey Street
Slater Drive
Kopy Drive
Eielson Street
Noble Street
Cushman Street
Stacia Street
Mary Ann Street
Laurene Street
Schaible Street
Airport Way
Alsace Loop
16th Avenue
18th Avenue
20th Avenue
14th Avenue
12th Avenue
11th Avenue
10th Avenue
9th Avenue
6th Avenue
4th Avenue
3rd Avenue
2nd Avenue
Denali Way
Badger Street
Cleary Street
Kellum Street
West Cowle Street
Stewart Street
Lathrop Street
Pedro Street
Crosson Avenue
McCarty Avenue
Bluebell Street
Image © 2008 DigitalGlobe
© 2008 Tele Atlas
2979 ft
Google
717° lon -147.728480°
elev 447 ft
Eye alt 11620 ft

Data Analysis/Results

- Compiled, screened, time-aligned the measurements:
  - $PM_{2.5}$ concentration, mass median particle size, GPS position (lat/long/elev), ambient temperature
  - 116 drives, ~370 hrs of driving (avg >3hrs/drive),
  - 664,000 data records

- Identified 409 solid fuel burners, including:
  - 133 outdoor solid fuel burners (OWBs, OCBs, etc.)
  - 276 wood stoves

- On several drives, the highest measured concentrations were from following vehicles with visible PM plumes.
  - 2 seasonally waiver vehicles identified on-road and cited.

$PM_{2.5}$ Concentration Measurements for Selected Drives ("dot plots")

- Measurements every two seconds
- Dot size shows avg particle size (by DataRAM):
  - range is about 0.02 to 0.4 microns
  - relatively clean Arctic air is ~0.2-0.4 microns
- Color scale shows concentration $PM_{2.5}$ (ug/m^3):

  0-35 deep green

  105 olive

  210 orange

  350 red

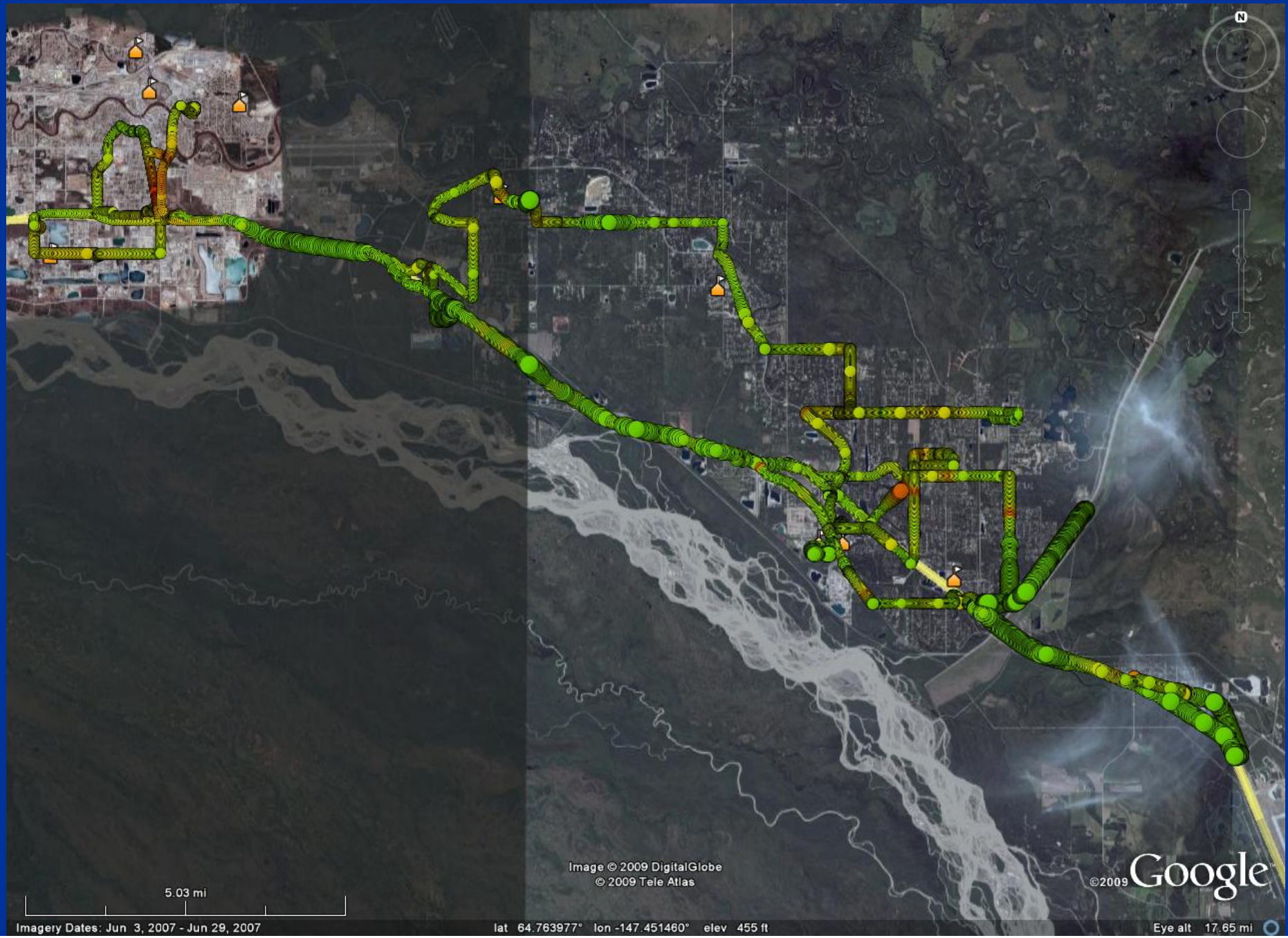
  >350 grey

$PM_{2.5}$ Concentrations and Size 12/29/08_0328hrs "City Drive"

$PM_{2.5}$ Concentrations and Size 12/29/08_0830hrs "City Drive"

PM2.5 Concentrations and Size 12/29/08_1523hrs “City Drive”

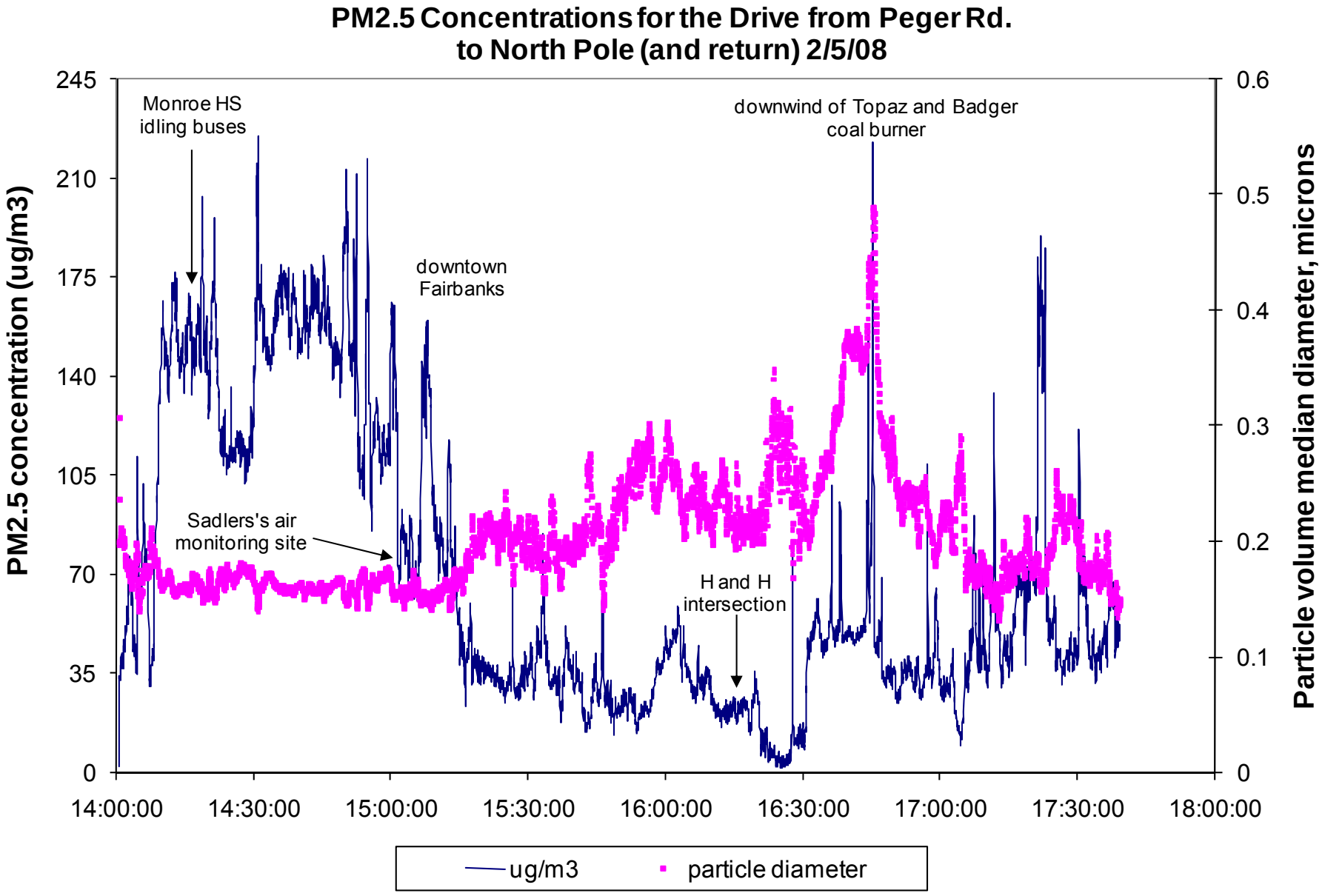
$PM_{2.5}$ Concentrations & Size 12/29/08_1935hrs "North Pole Drive"



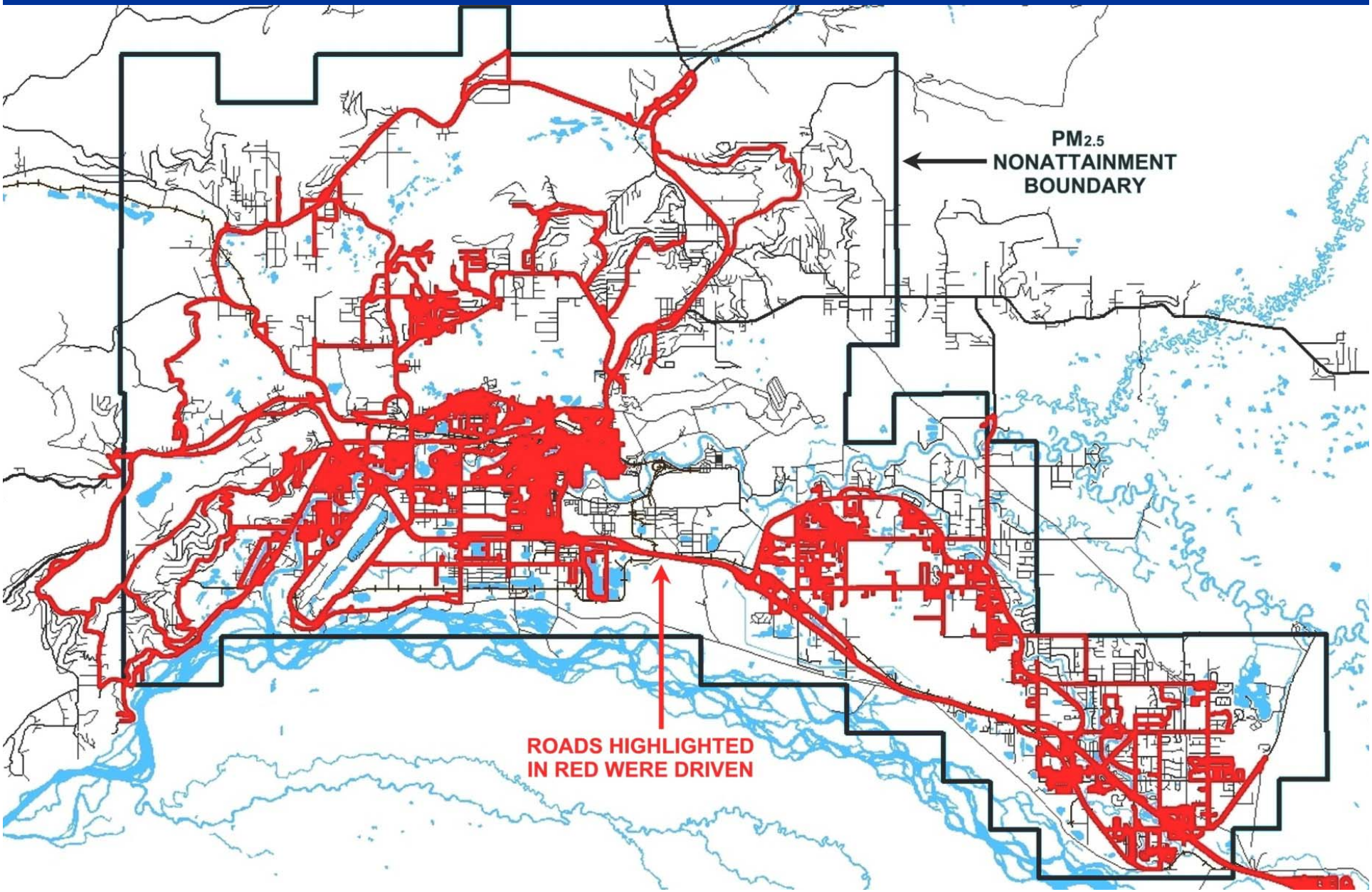
$PM_{2.5}$ Concentrations & Size 12/29/08_1935hrs "North Pole Drive"

$PM_{2.5}$ Concentrations & Size 12/29/08_1935hrs "North Pole Drive"

DataRAM 4000 Concentration vs. Particle Size



Roads Driven Last Winter to Collect $PM_{2.5}$ Measurements Within Nonattainment Area (11/08 – 2/09)



Contour Plotting

Why needed?

- Individual days/drives not always representative
- No insight into off-road concentrations
- Difficult to see patterns clearly
- An individual vehicle or plume may unduly influence results

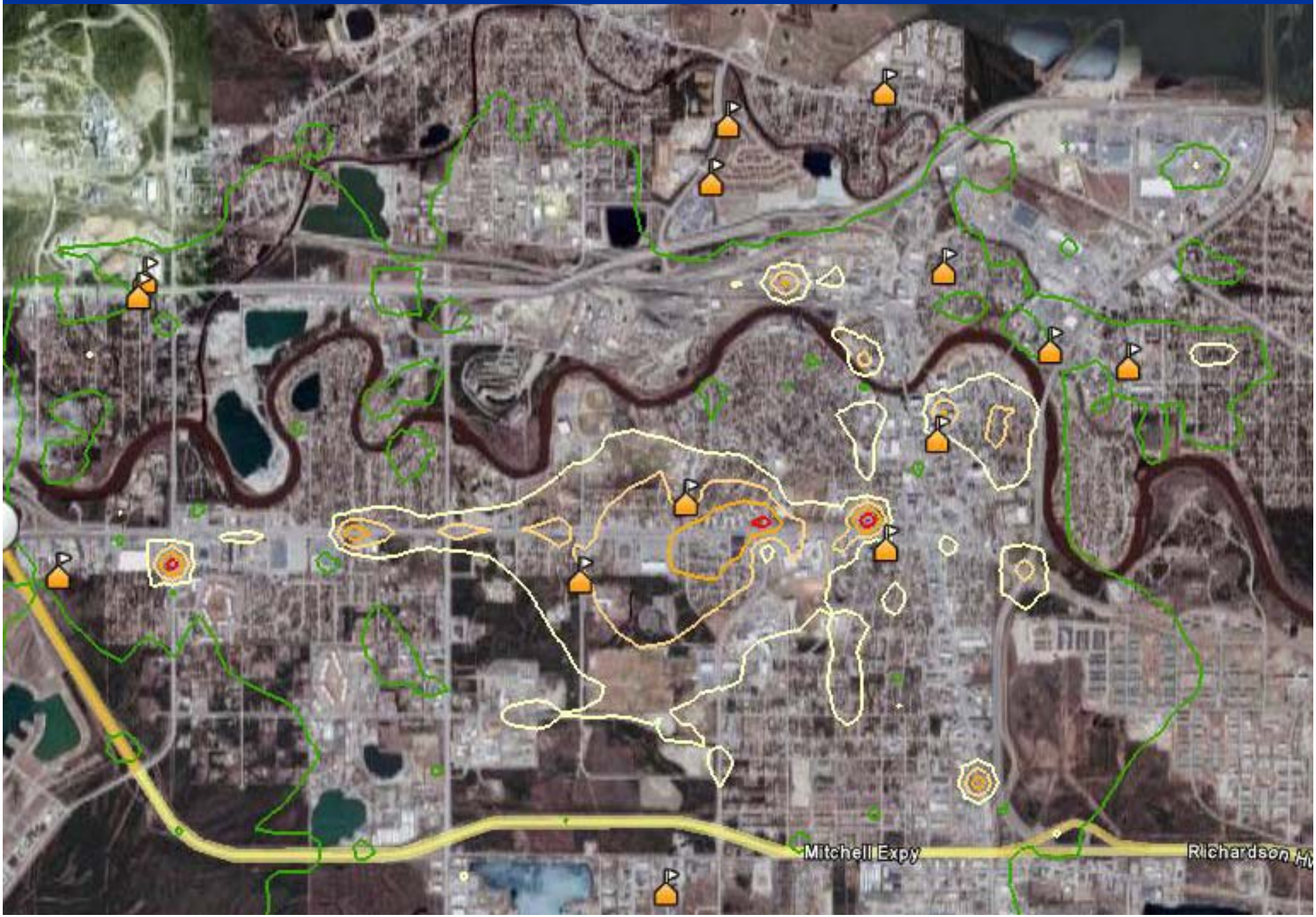
What it accomplishes?

- Shows the pattern across many days/measurements
- Can visualize impacts off the road
- Identifies areas with consistently high values
- Helps avoid bias (e.g. effect of a smoking vehicle)

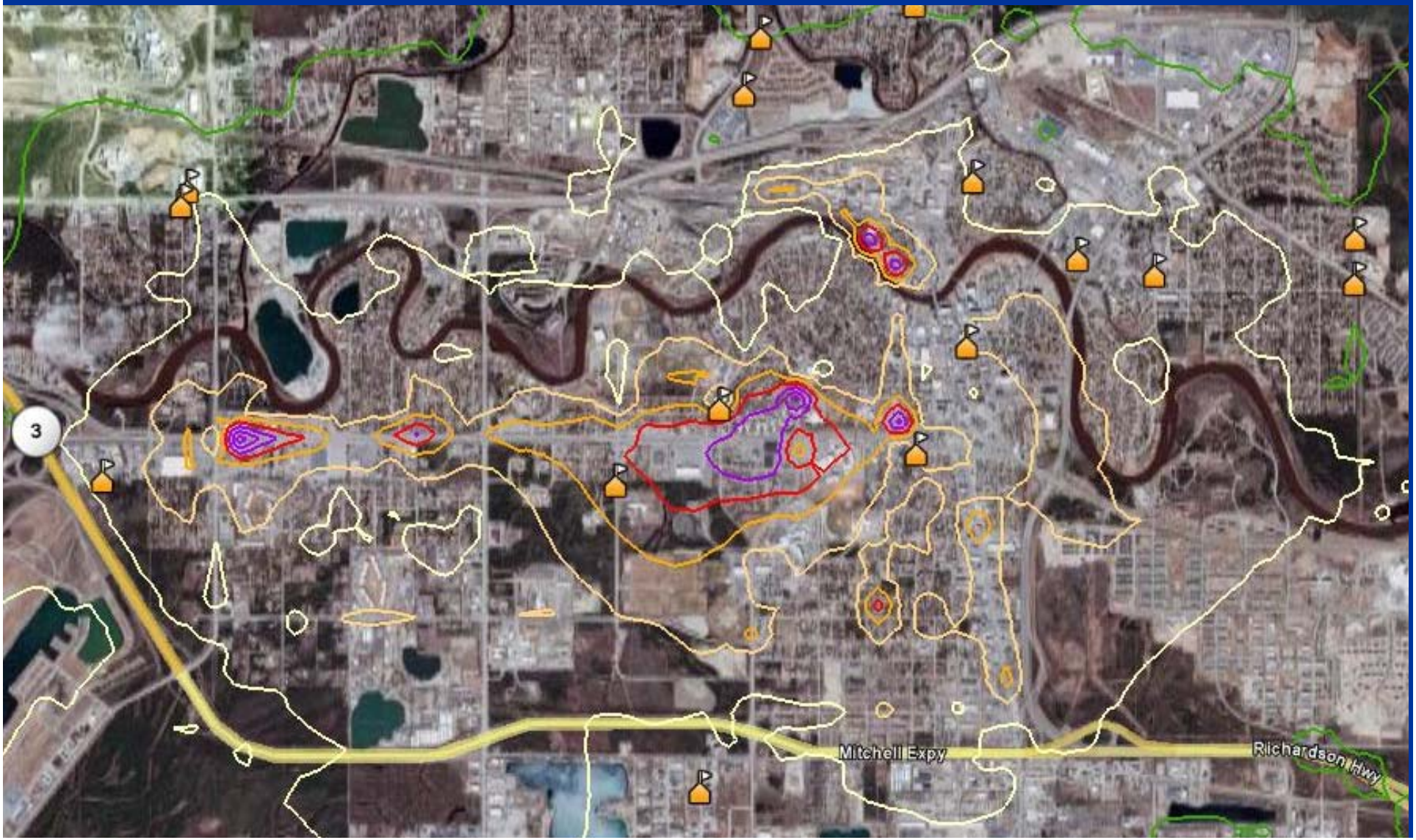
Contours Show Concentration in ug/m^3 (different scale because average concentrations are lower)

- 35 Green
- 70 White
- 105 Beige
- 140 Orange
- 175 Red
- 210 Purple

$PM_{2.5}$ Concentration All Analyzed Drives (n~660,000)



$PM_{2.5}$ Concentration Exceedance Day Drives (17 drives, n~230,000)



$PM_{2.5}$ Concentration – Dec 29-30, 2008

Preliminary Conclusions about $PM_{2.5}$

1. Highest concentrations were observed in the most densely populated areas
2. Certain areas that were included in the Non-attainment area were found to have substantially lower concentrations.
3. Concentrations, especially for daytime, along Airport Way (a busy arterial) were relatively high, but the source contribution is unclear – underscores the need to better understand the motor vehicle contribution.

Preliminary Conclusions about $PM_{2.5}$ (cont.)

4. Highest concentrations in mobile sampling occurred from 4:00 – 6:00 pm.
5. There were pockets of high concentrations that appeared to be located in neighborhoods that were older, had high levels of wood-burning, or were in “low (elevation) spots”.
6. Throughout the region, localized impacts from individual OWBs/OCBs can sometimes be identified in elevated PM values, both for individual drives and in concentrations averaged over numerous drives.

Preliminary Conclusions about $PM_{2.5}$ (cont.)

7. No clear evidence was found for ground-level $PM_{2.5}$ impacts from large, elevated stationary sources (e.g. power plants).

8. Spatial monitoring has helped to identify the spatial extent of the problem and identify likely sources, while ruling out other sources, and has helped to prioritize areas where we need to collect activity data to better characterize emissions.