Meteorology of Winter Air Pollution In Fairbanks

Jim Brader, Forecaster, 20 years

NWS Fairbanks

James.Brader@noaa.gov

Austin Cross, UAF Graduate Student and Intern NWS Fairbanks

Austin.Cross@noaa.gov

Winter Air Pollution in Fairbanks

- **Very Poor Dispersion**
- Forecasting Very Poor Dispersion
- PM 2.5 Violation Day Conditions
- Human Introduced Pollutants

- Air Pollution is a function of human introduced pollutants and very poor dispersion.

- Dispersion is a function of surface based temperature lapse rate, mixing height, and wind speed.

- Very Poor Dispersion is caused by the combination of very strong surface based inversions, very low mixing heights, and low wind speeds.

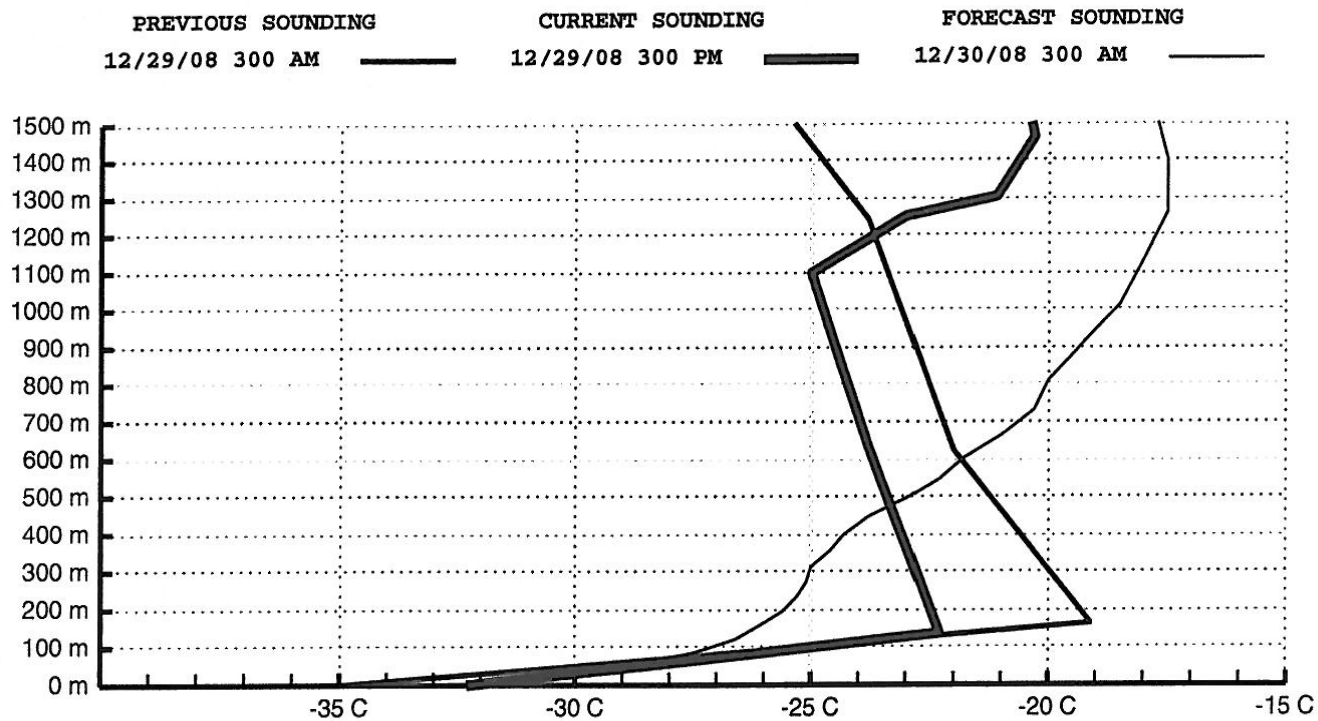
So why does Fairbanks have an air pollution problem?

- Among the strongest surface based inversions in the U.S.
- Surface based inversions are present 80% of time in December and January.
- Very low winds speeds.

Fairbanks Inversion

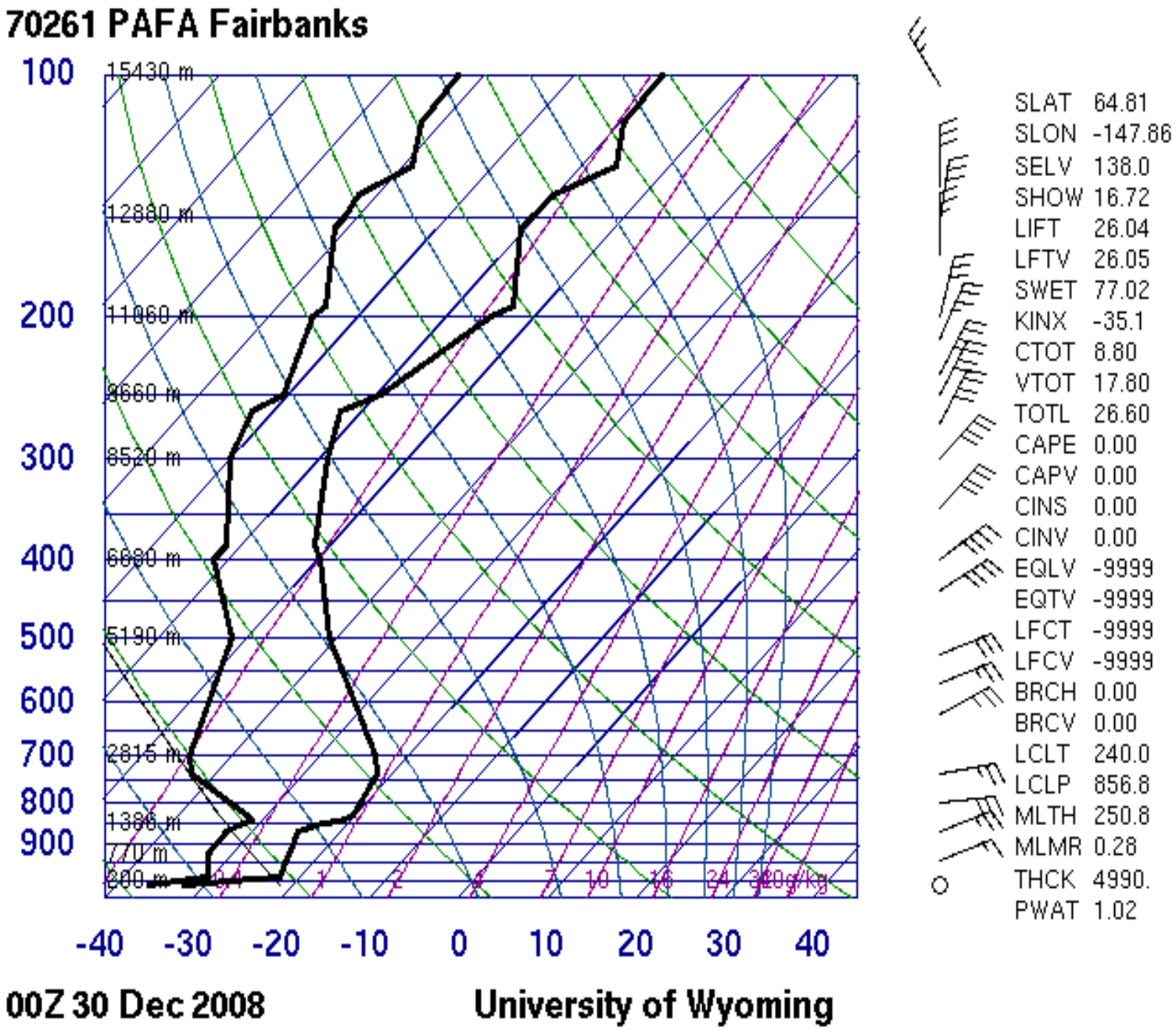
- Surfaced based lapse rates commonly exceed 10C/100m, and at times as strong as 30C/100m in the lowest 30m.
- Extreme cases have as much as 40C difference between the surface and the top of the inversion.
- Inversion top is often 3000 ft MSL or higher, but the greatest change in temperature is normally below 1500 ft MSL.

Temperature vs. Height Dec 29, 2008



HEIGHT(m)	TEMPERATURE(C)	DEG/100m
0	-32.3	0.0
65	-27.5	7.4
137	-22.3	7.2
635	-23.8	-0.3
1098	-25.0	-0.3
1251	-23.0	1.3
1303	-21.1	3.7
1462	-20.3	0.5

HEIGHT(m)	WIND DIRECTION	WIND SPEED(mph)
0	000	0
65	060	3
300	060	9
600	070	19
635	080	22
900	080	22
1200	070	26
1251	070	28

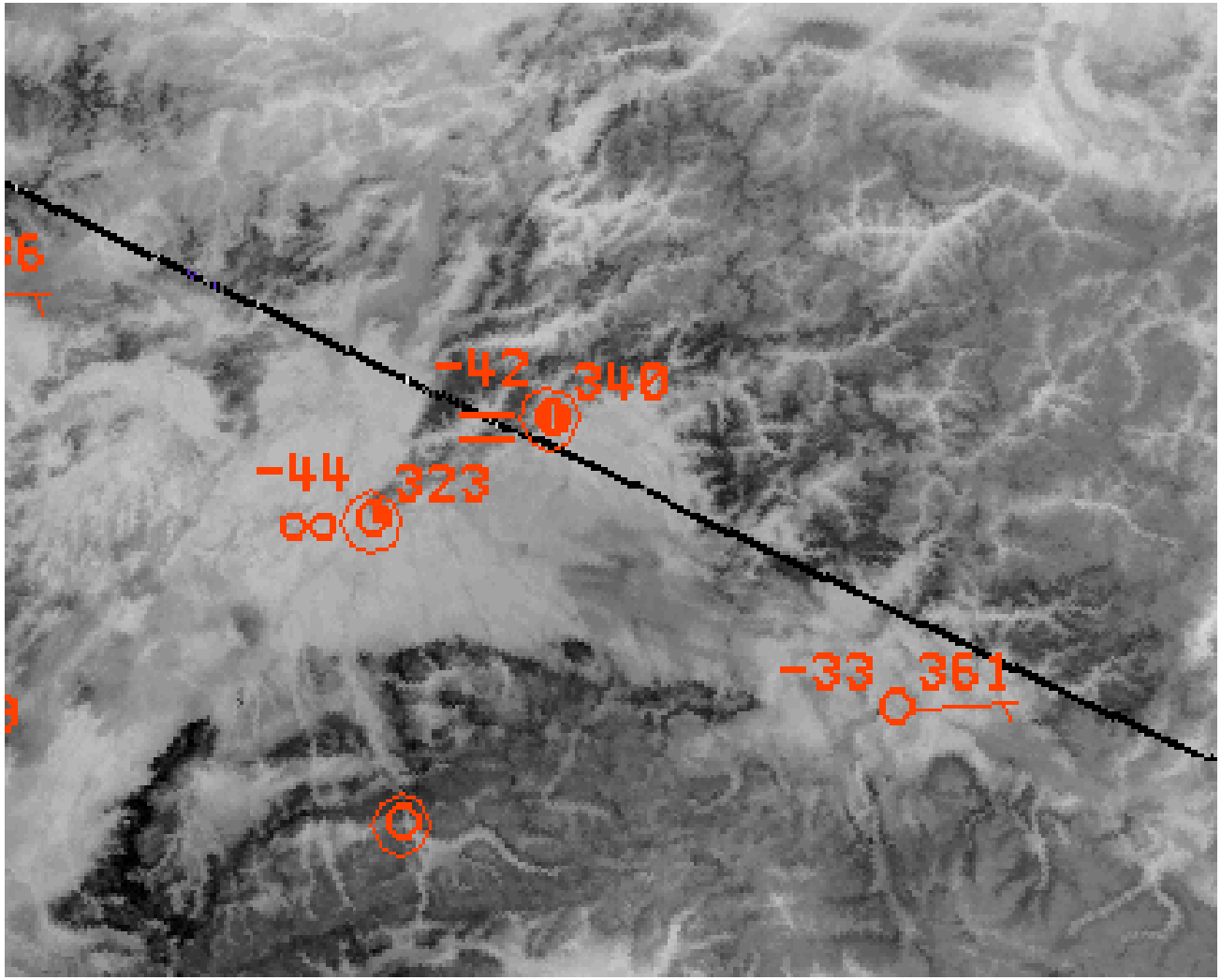

70261 PAFA Fairbanks
100
200
300
400
500
600
700
800
900
15430 m
12880 m
11060 m
9660 m
8520 m
6680 m
5190 m
2815 m
1386 m
770 m
200 m
-40
-30
-20
-10
0
10
20
30
40
00Z 30 Dec 2008
University of Wyoming
SLAT 64.81
SLON -147.86
SELV 138.0
SHOW 16.72
LIFT 26.04
LFTV 26.05
SWET 77.02
KINX -35.1
CTOT 8.80
VTOT 17.80
TOTL 26.60
CAPE 0.00
CAPV 0.00
CINS 0.00
CINV 0.00
EQLV -9999
EQTV -9999
LFCT -9999
LFCV -9999
BRCH 0.00
BRCV 0.00
LCLT 240.0
LCLP 856.8
MLTH 250.8
MLMR 0.28
THCK 4990.
PWAT 1.02

Why does Fairbanks have such strong Inversions?

- Fairbanks is located at the bottom of a bowl formed by a ring of 3000 ft high hills.
- Little incoming solar radiation from Nov-Feb, combined with plenty of outgoing surface radiation allows cool air to form at the surface.
- Cool air is heavy and pools in the bowl over Fairbanks.

Fairbanks Bowl

Fairbanks Bowl shown by Jan 2008 IR Satellite



Mixing Heights

- Mixing heights of 10m or less are common during periods of poor dispersion.
- Mixing heights as low as 6m reported.
- Personal observation of smoke layers below city street lights verifies this.

Low Mixing Heights Seen Jan 2009

Wind Speed

- Among the lowest wind speeds in U.S.

- Mean wind speed for Nov-Feb is 2.8 mph at airport.

- Winds downtown often lower than at airport

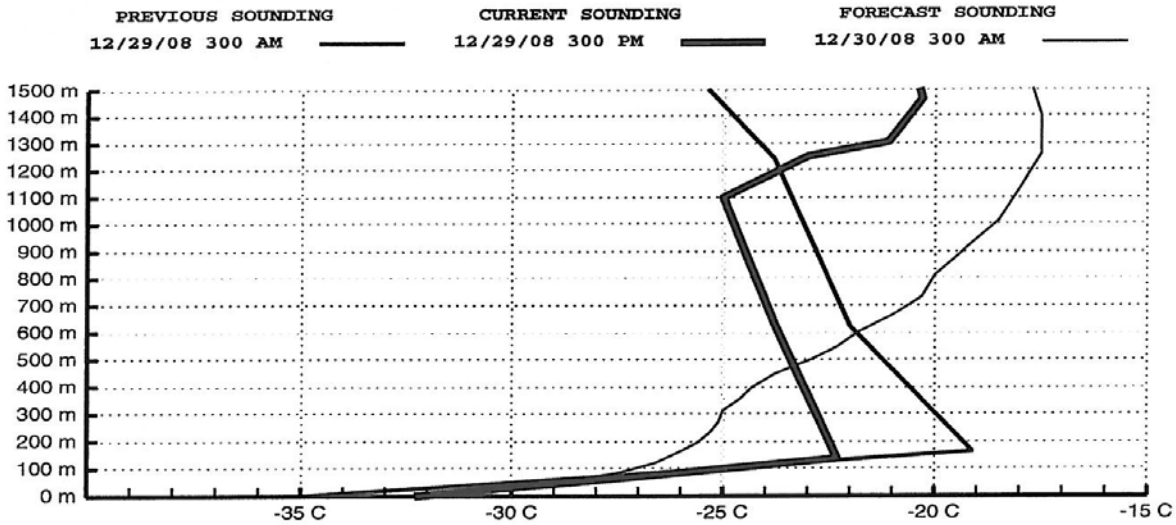
(≤ 2.0 mph 60% of time Nov-Feb 1995-2001)

Winter Air Pollution in Fairbanks

- Very Poor Dispersion
- **Forecasting Very Poor Dispersion**
- PM 2.5 Violation Day Conditions
- Human Introduced Pollutants

Met Tower Lapse Rate (deg C/100m)	Met Tower 10m Winds (mph)	Dispersion Class	Violation Possible?
>10	< or = 2	very poor	yes
	>2	poor to fair	no
5 to 9	<1	very poor	yes
	1.1 - 2	very poor to poor	yes
	>2	poor-fair	no
0 to 5	<1	very poor	yes
	1.1 - 2	poor	no
	>2	fair	no
0 to -1	<1	poor	no
	1.1 - 2	fair	no
	2-9	good	no
	>10	excellent	no
any	3-5	fair- good	no
	5-9	good	no
	>10	excellent	no

Table 1. Dispersion Forecast Guidelines Developed for CO .



HEIGHT(m)	TEMPERATURE(C)	DEG/100m
0	-32.3	0.0
65	-27.5	7.4
137	-22.3	7.2
635	-23.8	-0.3
1098	-25.0	-0.3
1251	-23.0	1.3
1303	-21.1	3.7
1462	-20.3	0.5

HEIGHT(m)	WIND DIRECTION	WIND SPEED(mph)
0	000	0
65	060	3
300	060	9
600	070	19
635	080	22
900	080	22
1200	070	26
1251	070	28

MIDDLE TANANA VALLEY FORECAST

.TONIGHT...MOSTLY CLEAR. PATCHY ICE FOG. LOWS 15 TO 45 BELOW.
WARMEST AT HIGHER ELEVATIONS. LIGHT WINDS...EXCEPT LOCALLY
NORTHEAST 15 TO 25 MPH THIS EVENING.
.TUESDAY...MOSTLY CLEAR. PATCHY ICE FOG. HIGHS 10 TO 40 BELOW.
WARMEST AT HIGHER ELEVATIONS. LIGHT WINDS.
.TUESDAY NIGHT...MOSTLY CLEAR. PATCHY ICE FOG. LOWS 15 TO
50 BELOW. WARMEST AT HIGHER ELEVATIONS. LIGHT WINDS.

	TEMPERATURE				/	PRECIPITATION			
FAIRBANKS	-40	-32	-42	-33	/	0	0	0	0

DISPERSION FORECAST

TONIGHT: VERY POOR
TOMORROW: VERY POOR
SYNOPSIS: A VERY COLD AIRMASS WILL CONTINUE TO MAINTAIN A STRONG INVERSION WITH
CALM WINDS AND NO MIXING OF THE AIR.

Dispersion Rules of Thumb

- Dec-Feb accounted for the majority (96%) of days violating federal CO standards (1986-2001).

- All of the CO exceedances (1996-2001) occurred with a synoptic weather pattern where Fairbanks was in the NE quadrant of a low pressure system lying in the Gulf of Alaska and with high pressure in Northeast Alaska.

Dispersion Rules of Thumb Worsening

- Low level warm advection causes dispersion to worsen

- Very poor dispersion often occurs with low level warm advection following a cold spell (temperatures <-30C for several days). Conditions worsen as the warm advection continues, causing the inversion to strengthen and the mixing height to lower (common with southerly “Chinook flow”).

Dispersion Rules of Thumb Worsening

- Very poor dispersion is possible on calm, clear days in late February when sunset occurs about 5pm.

- Winds downtown are often lower than reported at airport.

Dispersion Rules of Thumb Improving

Surface inversions weaken and dispersion improves when:

A) clouds with ceilings lower than 8000 ft move over Fairbanks,

B) winds ≥ 10 mph surface downtown (even for just an hour) temporarily improving dispersion enough to significantly reduce pollution levels,

C) snow or ice fog occurs.

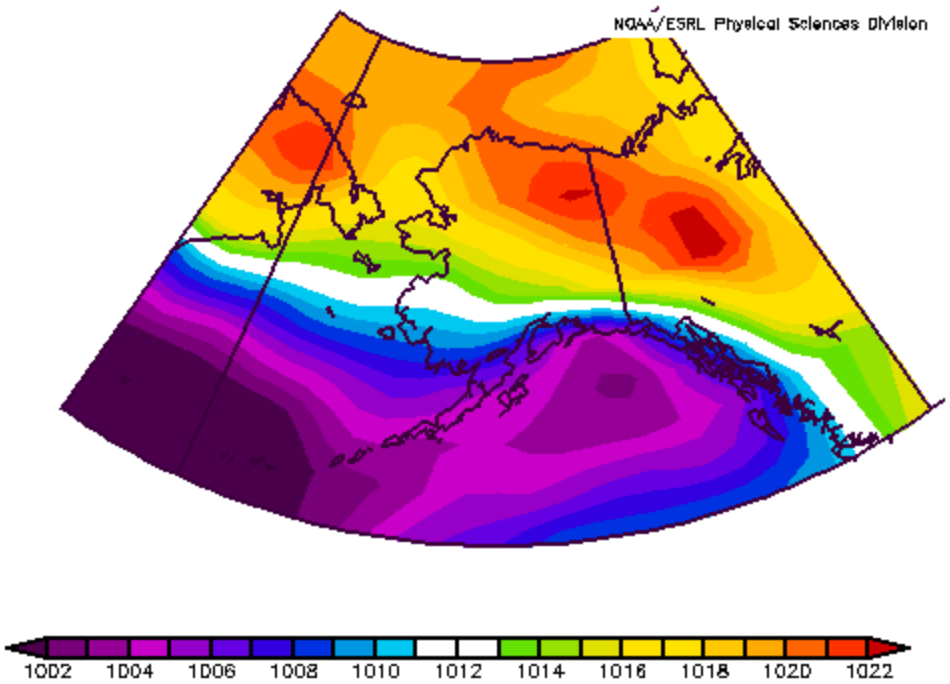
Dispersion Rules of Thumb Improving

- Low-level cold advection weakens the inversion and improves dispersion.

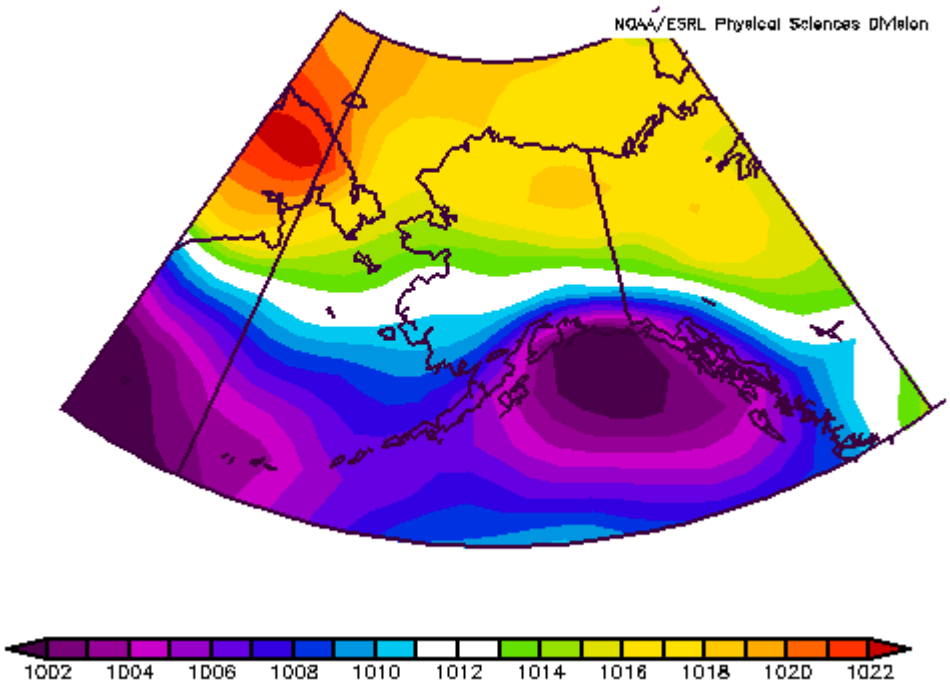
Winter Air Pollution in Fairbanks

- Very Poor Dispersion
- Forecasting Very Poor Dispersion
- **PM 2.5 Violation Day Conditions**
- Human Introduced Pollutants

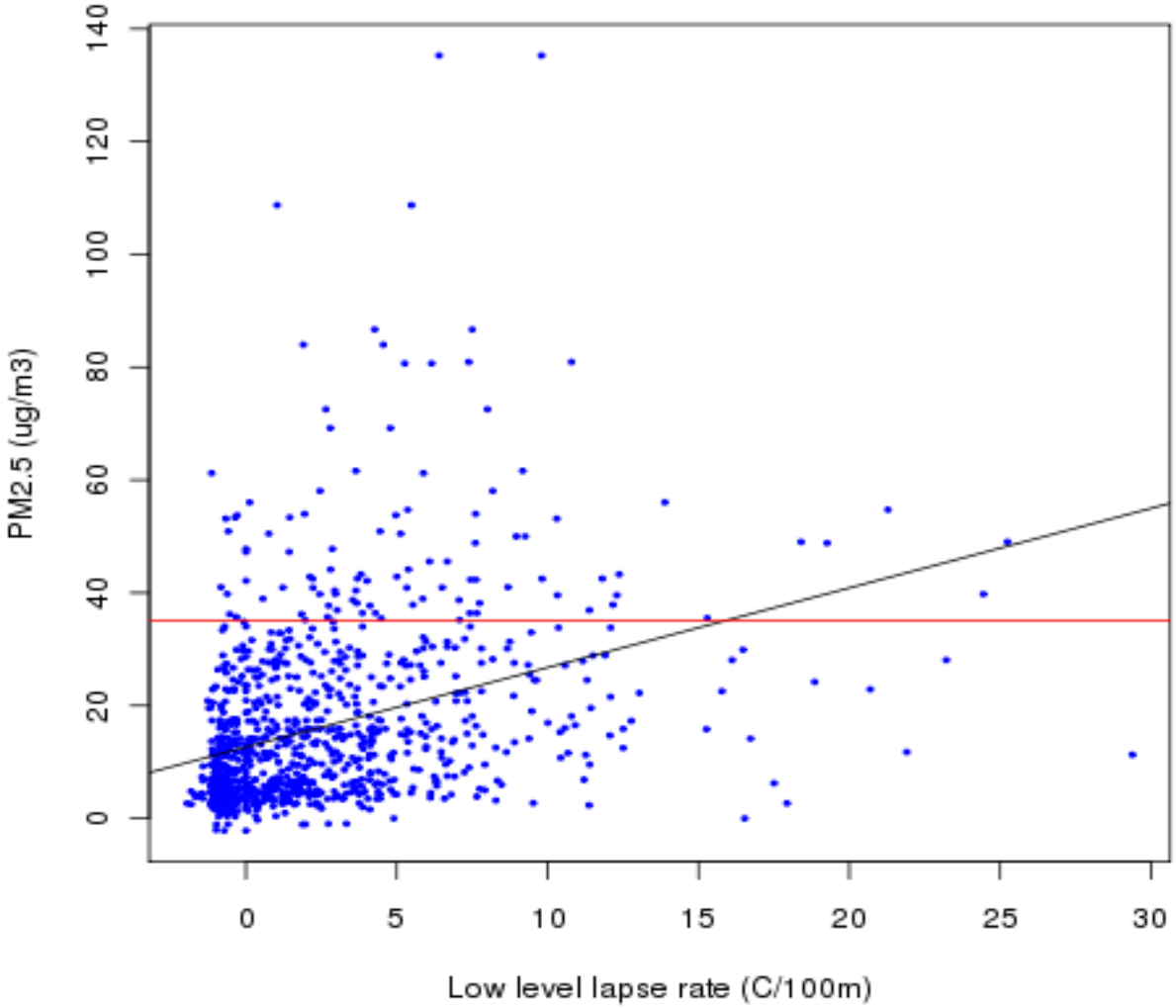
PM2.5 2007-2009 Violation Day SLP Composite



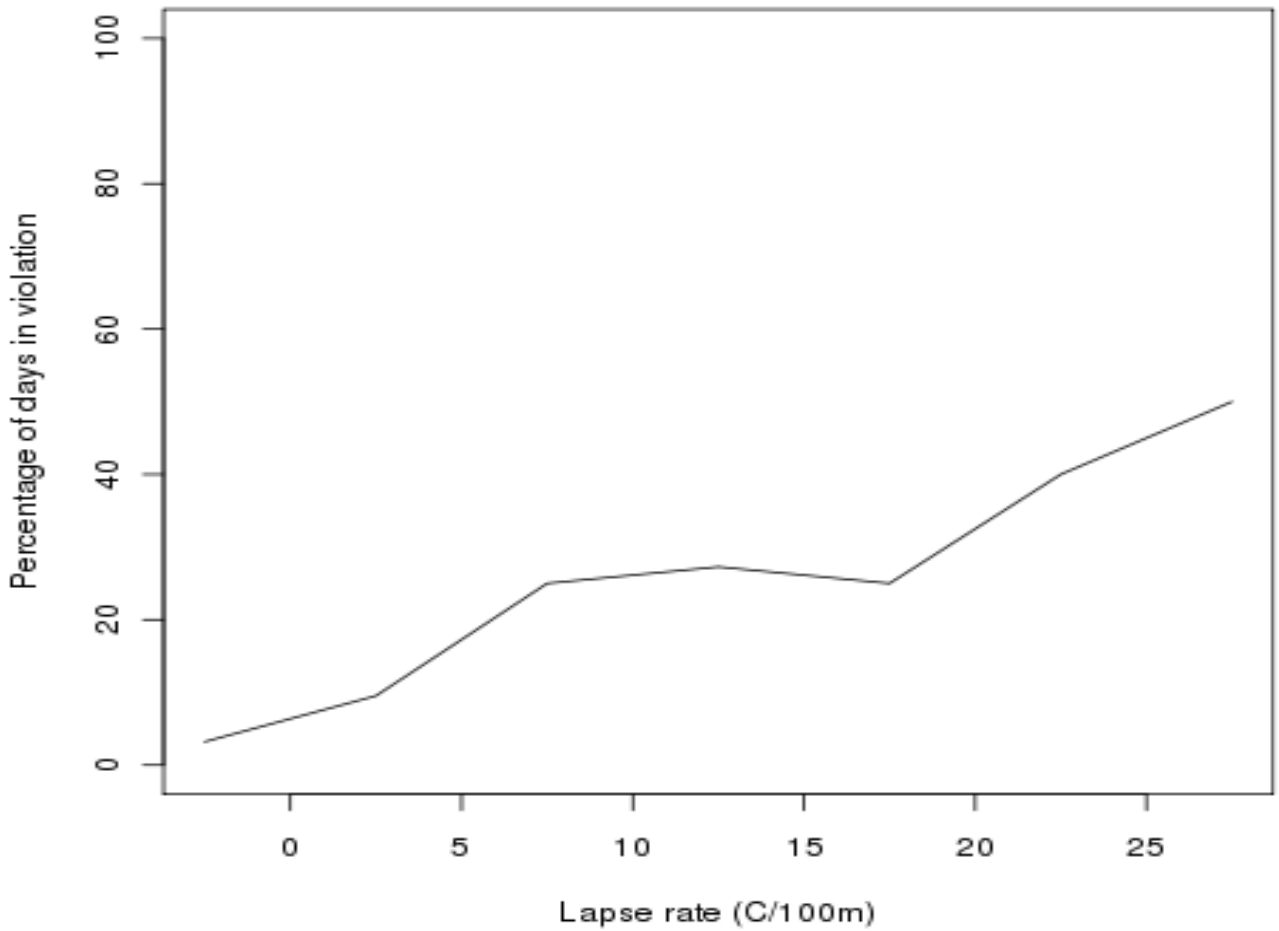
Dec-Feb 2007-2009 Composite SLP



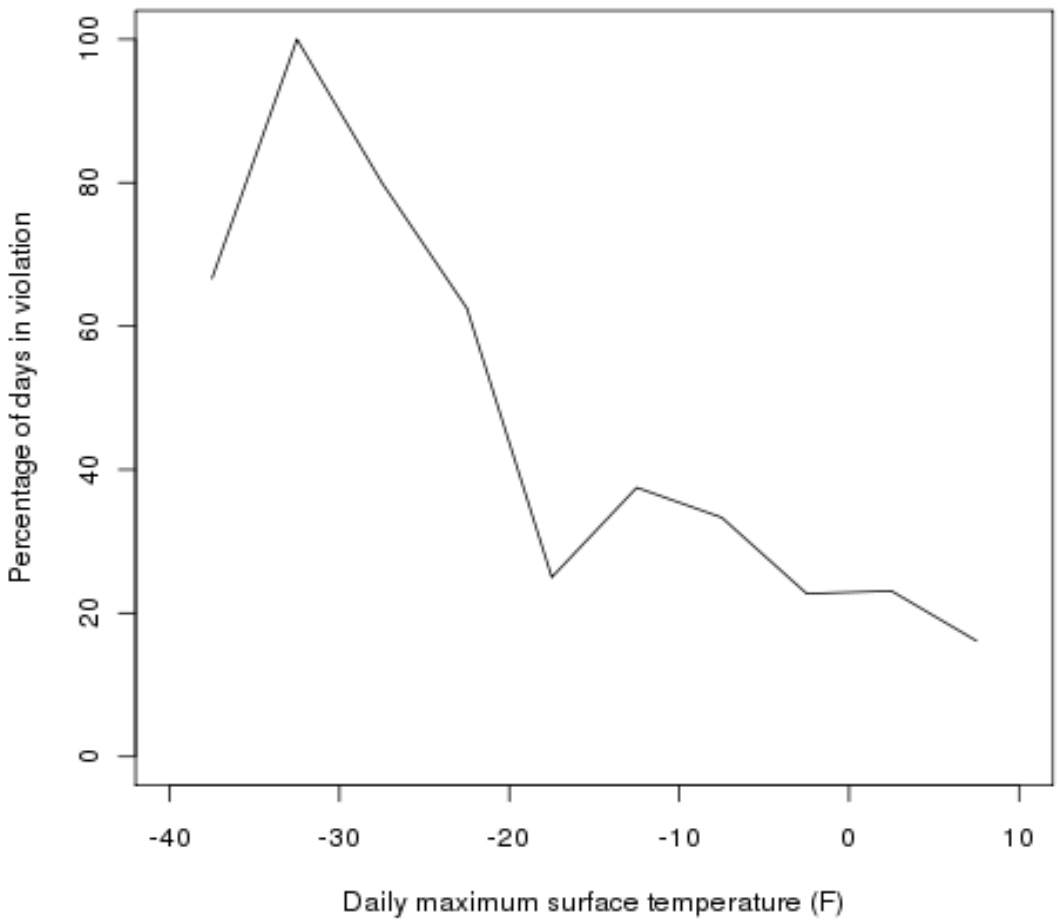
PM2.5 vs. Surface Lapse Rate



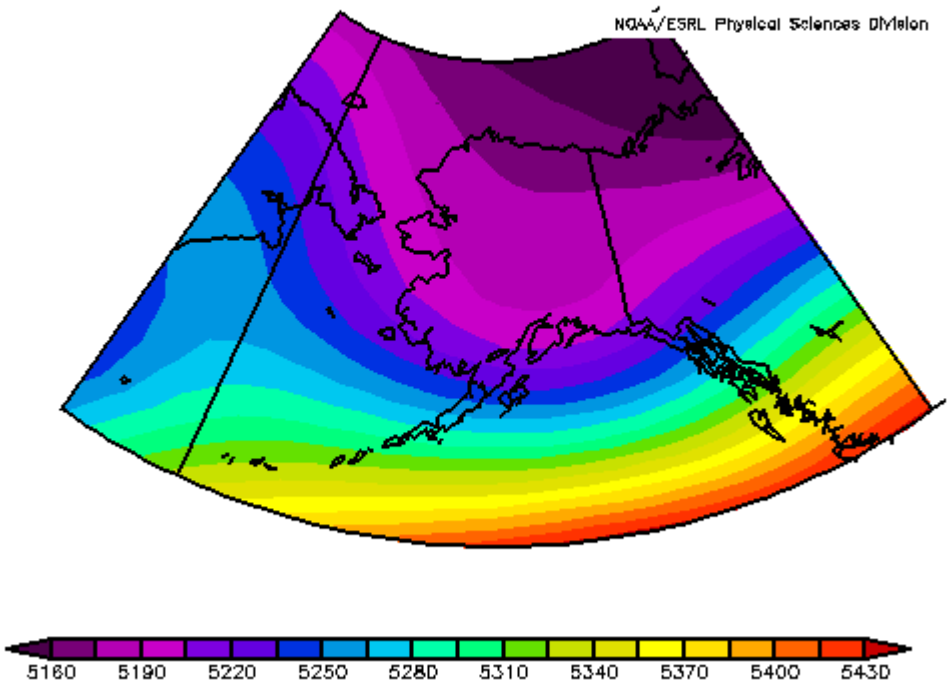
Lapse Rate vs. PM2.5 Violation Days



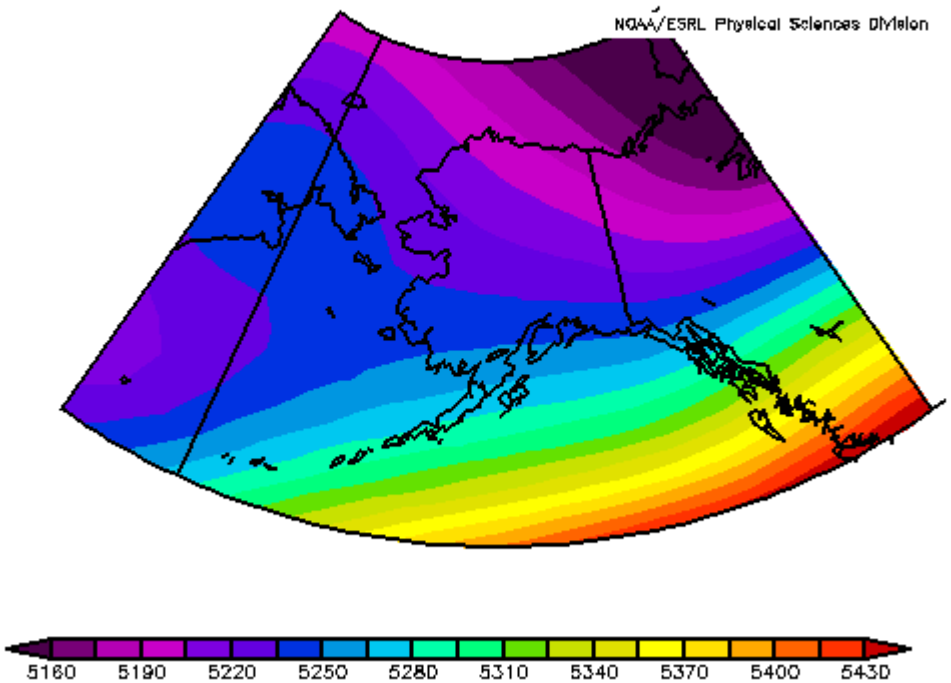
PM2.5 vs Max Temp



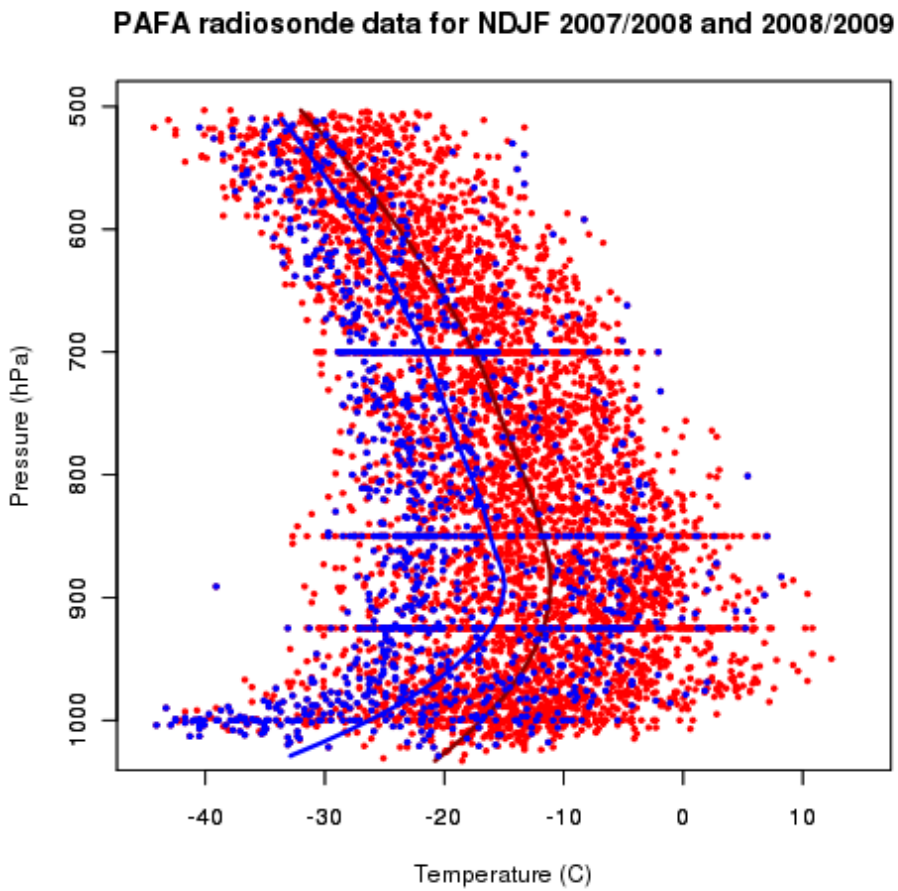
Composite Dec-Feb 500 MB Height field



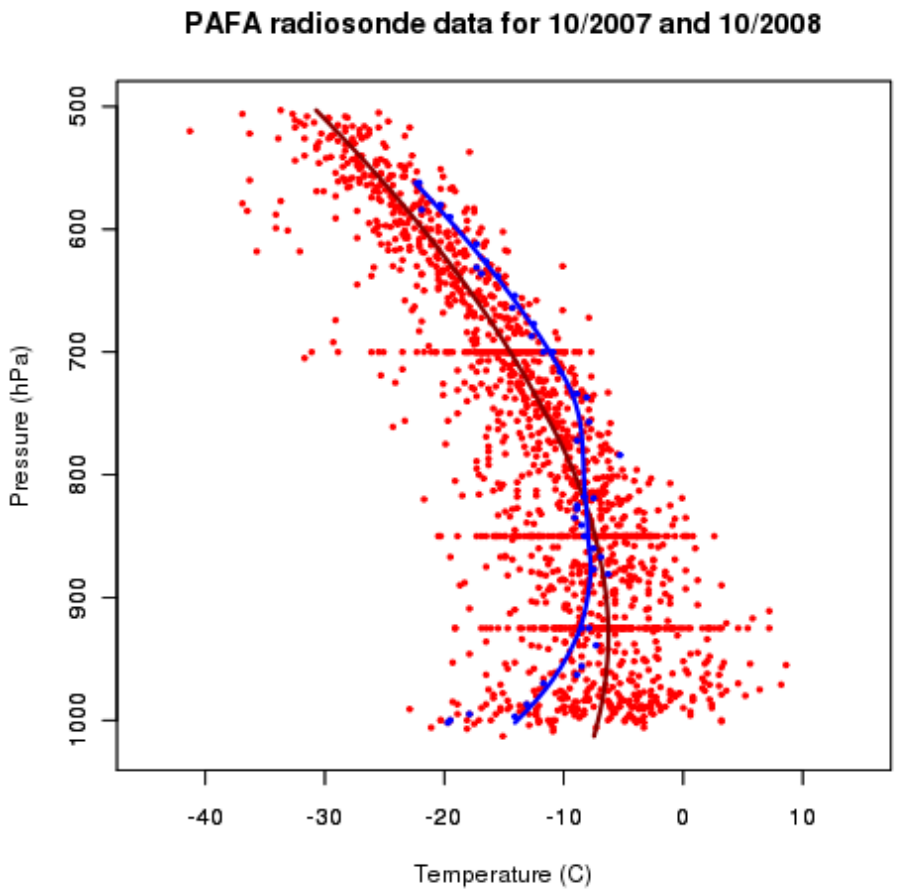
Composite Violation Day 500 MB Height field



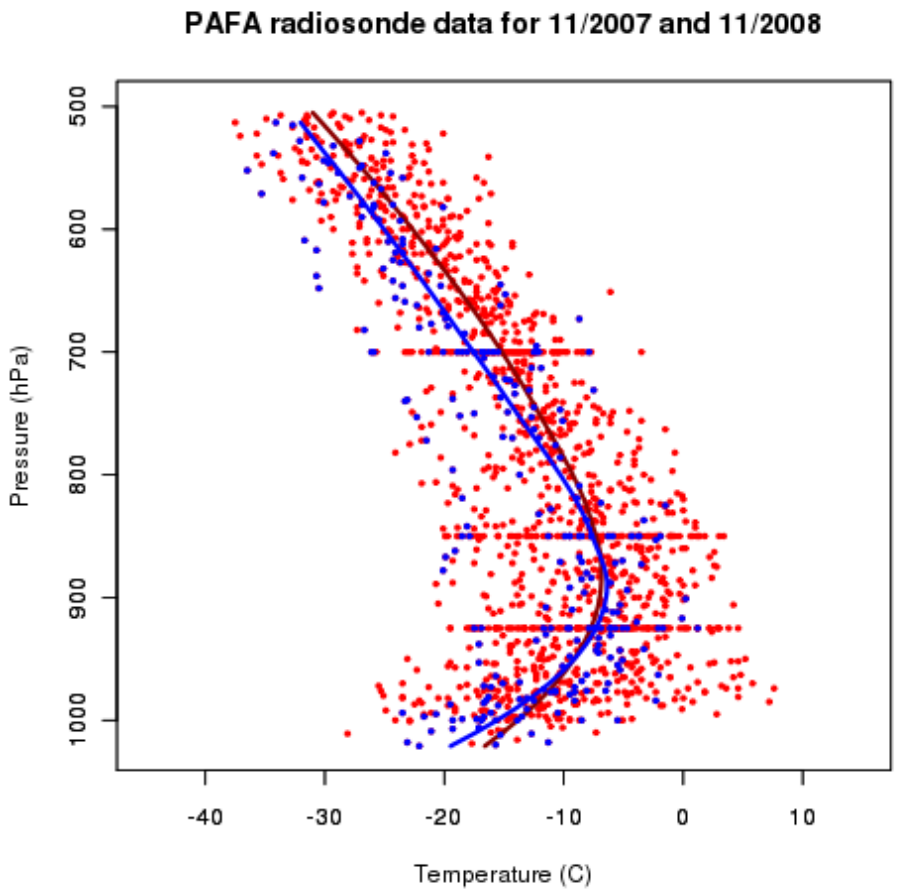
Pressure (Height) vs Temperature Violation day points Blue



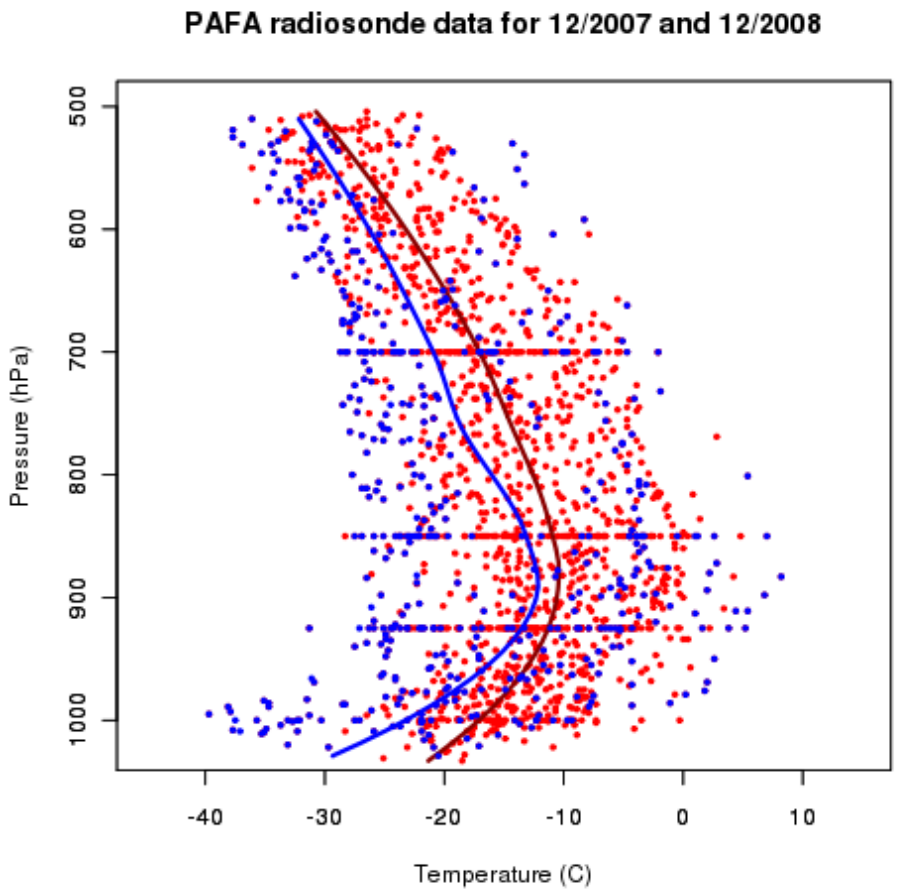
Pressure vs Temp - Oct



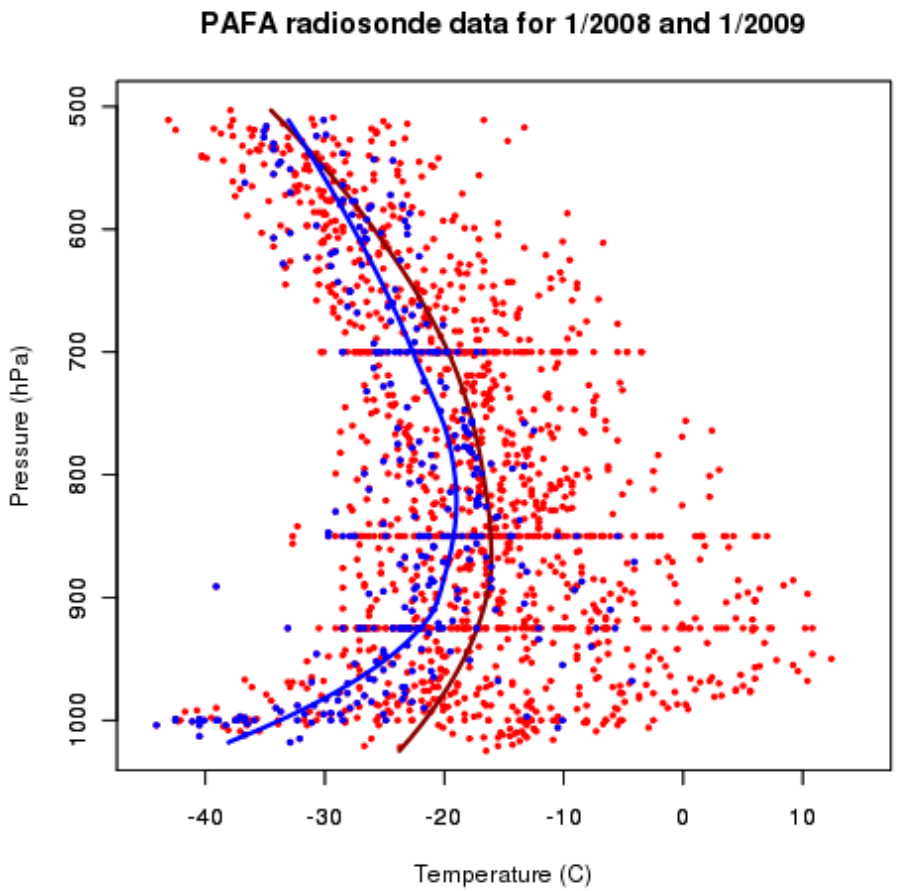
Pressure vs Temp - Nov



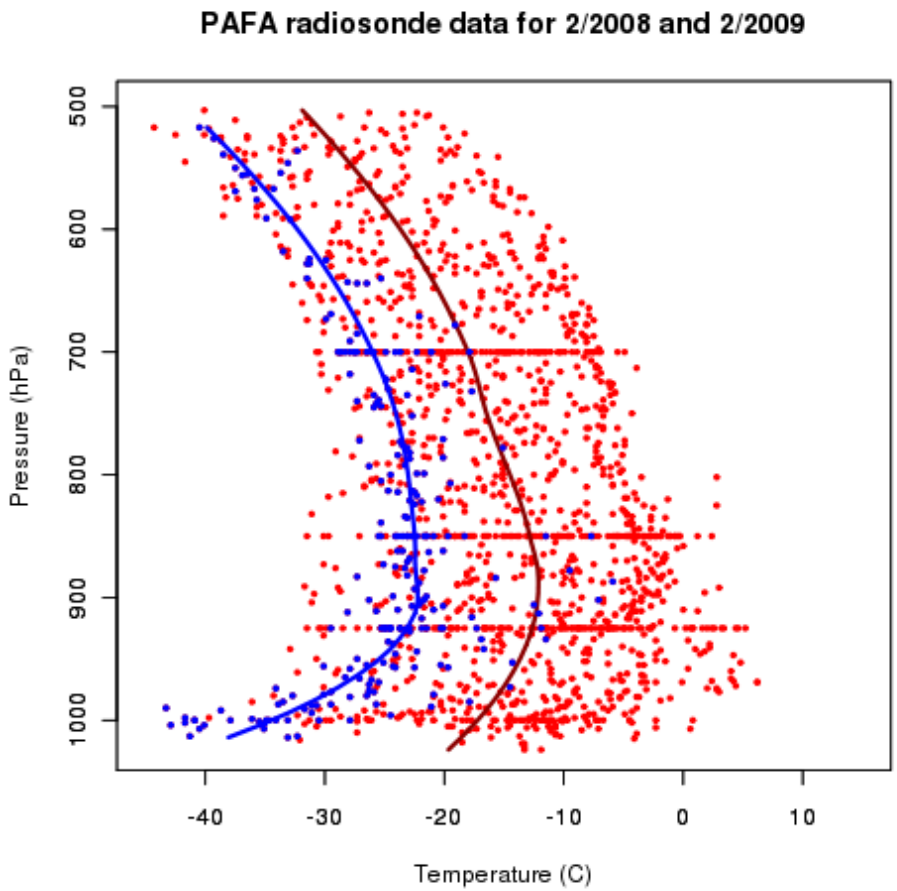
Pressure vs Temp - Dec



Pressure vs Temp - Jan



Pressure vs Temp - Feb



What do Soundings show us?

- Seasonal trend to violation soundings.
- Oct-Dec PM2.5 Violations occur with little difference from normal lapse rates, and with a wide range of sounding temperatures.
- Jan-Feb PM2.5 Violations occur with stronger lapse rates and much colder temperatures than average soundings.

Why Seasonality?

- Oct-Dec period has more cloud cover and snowfall on average than Jan-Feb.
- RH averages 75% Nov, falls to 70% in Feb.
- Are PM2.5 inputs seasonal? (i.e. Do people run low on wood after Christmas and only burn during very cold periods?)
- Other reasons?

Winter Air Pollution in Fairbanks

- Very Poor Dispersion
- Forecasting Very Poor Dispersion
- PM 2.5 Violation Day Conditions
- **Human Introduced Pollutants**

Human Introduced Particulates

- Poor correlation of Meteorological effects on PM2.5 values when pollutant amounts vary with time, depending on type and amount of combustion. We don’t know sources nor amounts of pollutants through time!

Conclusions?

- Poor Dispersion is present much of the winter.
- Poor Dispersion is a necessary, but not sufficient condition for PM2.5 violations.
- Colder surface temperature appears to increase the violations of PM2.5, unlike CO.
- Seasonal trend to Violations at colder conditions later in winter.
- Variation of the Input of particulates is not well understood, but important part of equation.

Where do we go from here?

- CO was reduced dramatically in FNSB by reducing CO emitted, not by changing weather!
- Need to better understand sources of particulates and variations in emissions.
- NWS produced Dispersion Forecast might improve slightly with real-time downtown Met Tower Data. Maybe web based access.

Winter Air Pollution In Fairbanks- The End