DRAFT

Results from Yellowstone National Park

Winter Air Quality Study
2005-2006

John D. Ray, Ph.D.
Atmospheric Chemist
NPS Air Resources Division

Executive Summary

The air quality in Yellowstone National Park was monitored at two locations as part of the adaptive management program on the use of over-snow winter motor vehicles. The leading indicators used were carbon monoxide (CO) and particulate matter of 2.5 micron or less (PM2.5), Emission measurements in the last`two years had indicated that snowmobiles and snow coaches may have approximately equal contributions to the concentrations of CO. Detailed entry counts of each type of vehicle at the west entrance were used in the analysis.

The West Entrance near the town of West Yellowstone is the primary indicator for overall air quality and the relationship to traffic because detailed entry counts could be obtained at that site. Old Faithful is a destination for most of the winter use vehicles; they arrive mid-day and area represents the highest density of vehicles.

This report is an update to prior air quality and emission studies. The notable findings this year are:

- Air quality at both locations is good during the winter and is now well below the national air quality standards
- The CO concentrations were about the same as last year despite a large increase in the number of winter vehicle entries (over last year's shorter season) at the west entrance.
- Even though summer traffic volumes are nearly 60 times higher than winter traffic volumes, the highest hourly CO concentrations at both locations occur during the winter. However, the mean CO concentrations in winter have decreased over the last several years to be less than a factor of 2 higher than the summer concentrations.
- PM concentrations now correlate only weakly to traffic counts at the West Entrance and not at all at Old Faithful. This reflects a clean up of winter vehicle emissions.

- The combination of reduced winter vehicle entries to the park and reduced emissions by the snowmobiles have greatly reduced the CO concentrations. Air quality has been stable or improving over the last three winters.

Recommendations

- Monitoring could be reduced. The particulate monitoring sees more PM2.5 from summer wildfires than from motor vehicles. The PM2.5 and meteorological measurements at Old Faithful could be reduced to just winter-time CO without compromising the adaptive management metrics.

- The question of how much CO concentrations will increase if snowmobile traffic is allowed to increase up to the winter use plan limit is unresolved. It is recommended that the monitoring at the West Entrance continue.

- Efforts should continue to keep the amount of vehicle queuing at the West Entrance to a minimum and to spread out the entry of vehicles. The direct emissions testing indicates that older snowcoaches are now more polluting than BAT snowmobiles. Some effort should be made to equalize the snowcoach emissions (such as a snowcoach BAT) and to take advantage of the lower emissions that are possible.

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Contents

Background

The effects of winter vehicle exhaust, primarily snowmobiles, on air quality became an issue in the later 1990's at Yellowstone National Park. For the last three years, ambient air quality monitoring has been conducted at two locations in the Park as part of the adaptive management plan to determine the impact on air quality of implementing the Yellowstone Winter Use Plan[9]. Several changes were expected to reduce the emissions from the snowmobiles, primarily the reduction in allowed daily entries and the clean engine technology (best available technology, BAT) that was required. Pre-sales of entry passes and guided groups for rental snowmobiles were also required which also influenced air quality. These actions appear to have greatly decreased measured concentrations of carbon dioxide (CO) and particulate matter (PM2.5) at congested vehicle traffic points last winter season[1].

The US Environmental Protection Agency (EPA) has documented adverse health effects[2] by CO and PM2.5 which lead to National Ambient Air Quality Standards[3]. This report

summarizes the monitoring data from winter 2005-2006 and gives a historical perspective of monitoring data. The primary interest is trends in air quality that might reflect winter use policy and comparison to the national standards set by the Environmental Protection Agency (EPA).

Experimental

In-park monitoring

Two ambient monitoring locations were used, one at Old Faithful and another at the West Entrance. The Old Faithful monitoring shelter was located to the east of the main parking lot for the Visitor Center and south of the Old Faithful geyser (see figure 1 for location). Instrumentation at the site included a Beta Attenuation Monitor (BAM) for collection of PM2.5, a carbon monoxide (CO) analyzer, wind speed/wind direction sensors, ambient temperature, and a relative humidity sensor. A digital camera was installed on the weather tower that overlooked a portion of the main vehicle parking lot at the visitor center. Images and current data are available from a web site (http://www2.nature.nps.gov/air/WebCams/parks/yellcam/yellcam.htm). The NPS field support contractor, Air Resource Specialists, operated the station, processed and validated the data, and provided a data transmittal report. For full details on the monitoring, maps of locations, winds roses, data plots, and data tables, please consult the contractor data report[4.5].

The Old Faithful shelter was located within 50 feet of one of the warming huts in the Old Faithful visitor area. The warming huts were heated by wood-burning stoves from about 6:30 am until mid-afternoon. The digital camera image below was taken from the Old Faithful monitoring site showing snowmobiles in the close-in parking lot. In previous years this view would have captured a large number of snowmobiles parked in the main lot, however, usage was down and few vehicles parked there.

Webcam view of Old Faithful parking lot in Feb, 2006.

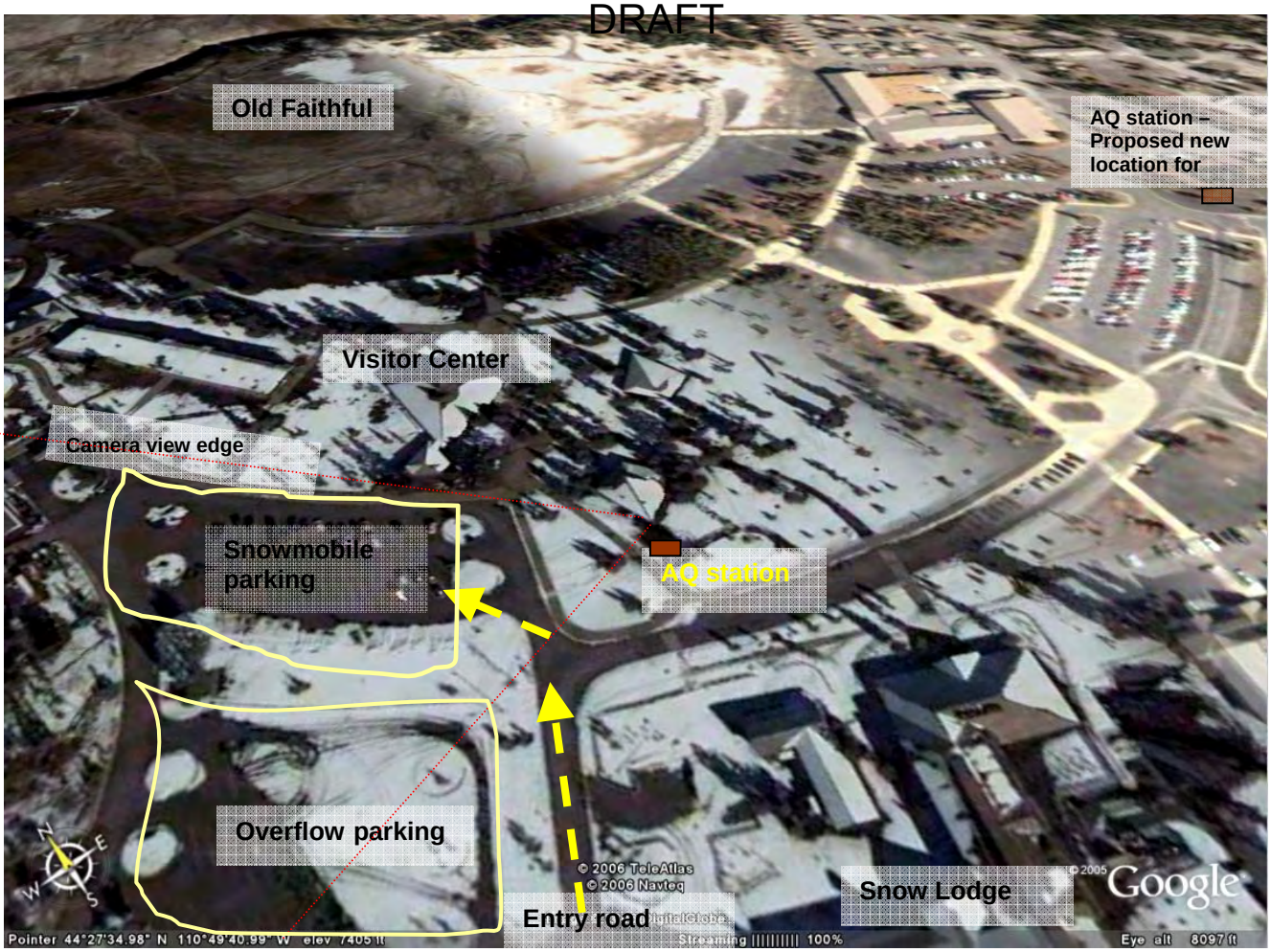

Figure 1. Aerial view of Old Faithful area showing the location of the winter vehicle parking and the air quality monitoring station. Old Faithful geyser is in the upper background.

The State of Montana collected carbon monoxide, $PM_{2.5}$, and meteorological data at the West Entrance of the park in a cooperative effort. Their shelter is located near the out-bound lane on the northeast side of the west entrance canopy (figure 2). Data was retrieved from EPA AQS database and directly from the State of Montana, Department of Environmental Quality (http://www.deq.state.mt.us/AirMonitoring/index.asp). All data collection, validation, and quality assurance steps were performed by the State of Montana, DEQ. We are grateful for DEQ's assistance and for allowing us to use data back to 1998 when they started the station.

Figure 2. Aerial view of the West Entrance area near the town of West Yellowstone. The air quality monitoring station is on the north side of the road near the roofed entrance structure. Winter vehicles queue up on the west side of the gate.

Results

Summary statistics

In past reports, the statistics in Table 1a,b have been presented for the Winter periods of roughly December 15 to March 15 of the next year[2]. The last four winters are compared in the tables for carbon monoxide (CO) and for particulate matter of 2.5 um size cut (PM2.5). Both CO and PM are emitted from snowmobiles and snow coaches; details on how much are available from an emission report prepared by Dr. Bishop at University of Denver[6]. Table 1c presents the concentrations for the national standards for these pollutants[3].

Table 1a. Statistical comparison of CO between Yellowstone NP winter monitoring stations.

CO concentration data

Park →		Yellowstone								
Location →		Old Faithful				West Entrance				
Statistic	Winter season → parameter ↓	2005-2006	2004-2005	2003-2004	2002-2003	2005-2006	2004-2005	2003-2004	2002-2003	Units
Max 1-hr	CO	**2.0**	1.4	2.2	2.9	**2.1**	2.8	6.4	8.6	ppm
% of Std	CO	**6%**	4%	6%	8%	**6%**	8%	18%	25%	
Max 8-hr	CO	**0.6**	0.6	0.9	1.2	**0.9**	1	1.3	3.3	ppm
% of Std	CO	**6%**	7%	10%	13%	**10%**	11%	14%	37%	
Average	CO	**0.18**	0.12	0.26	0.24	**0.23**	0.24	0.26	0.57	ppm
90th percentile	CO	**0.26**	0.29	0.5	0.5	**0.40**	0.43	0.5	1.3	ppm

Table 1b. Statistical comparison of PM2.5 between Yellowstone NP winter monitoring stations.

PM 2.5 Data

Park →		Yellowstone								
Location →		Old Faithful				West Entrance				
Statistic	Winter season → parameter ↓	2005-2006	2004-2005	2003-2004	2002-2003	2005-2006	2004-2005	2003-2004	2002-2003	Units
Max 1-hr	PM2.5	**56**	38	151	200	**44**	21	29	81	ug/m3
Max Daily (24-hr)	PM2.5	**8.9**	7	17	32.1	**7.2**	6	8	18.6	ug/m3
98th percentile	PM2.5	**8.5**	9	9	21.3	**6.3**	6	7	16.9	ug/m3
% of Std	PM2.5	**13%**	14%	14%	33%	**10%**	9%	11%	26%	
Avg	PM2.5	**3.5**	4	4.9	6.9	**1.9**	2.9	4	8.2	ug/m3

Table 1c. EPA National Ambient Air Quality Standards (NAAQS)

Standard	Pollutant	1-hr CO (ppm)[1]		8-hr CO (ppm)[1]	
National AAQS	CO	---	**35**	**---**	**9**
Montana AAQS	CO	---	**23**	**---**	**9**

1 Not to be exceeded more than once per year.
Link to EPA NAAQS standards: http://www.epa.gov/air/criteria.html

Standard	Pollutant	24-hr $PM_{2.5}$ 98%tile (ug/m^3)[1]
National AAQS	PM 2.5	**65**
Montana AAQS	PM 2.5	**65**

1 The 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 65 ug/m^3.
2 The winter 98th percentile is given only to demonstrate the improvement between winter seasons. Comparison with the annual standard is not shown. For consistency, the 24-hour day is used to average the hourly PM2.5 data.
3 Link to EPA NAAQS standards: http://www.epa.gov/air/criteria.html

Although CO concentrations in the late 1990's had approached the NAAQS standard, the current CO concentrations are only about 6% of the standard while the PM2.5 is about 13% of the standard. These concentrations are above the background concentrations for the region, but are concentrations that would generally be considered acceptable and according to EPA do not present a human health concern. CO concentrations have remained about the same while PM2.5 concentrations are up slightly at the two monitoring locations from last winter. At the present concentrations, these pollutants are not thought to represent a hazard to park staff or visitors. Concentrations may be briefly higher next to or behind operating vehicles, however.

The West Entrance used to be much higher for CO that Old Faithful, however, now the concentrations are nearly the same. For PM2.5 the Old Faithful site continues to have higher concentrations. Since the highest PM occurs in early morning or at night at Old Faithful when snowmobiles aren't present, local sources are believed to contribute.

Seasonal Variations

The monitoring stations operated throughout 2005 so that a complete winter to winter cycle could be determined. The winter and other seasons are broken out in tables 2a and 2b. The seasons are partly defined by the park's opened and closed periods. For CO, the winter periods have the highest concentrations, summer maximums are about half the winter maximums, and the period in the Fall when park roads are closed has the lowest concentrations. The average and 90th percentile CO concentrations are closer in summer and winter than the maximum values. These seasonal concentrations are in line with observation made in the winter 2004-2005 report that winter CO concentrations are now in the approximate range of the summer CO concentrations[1].

Table 2a. Statistical comparison of CO between Yellowstone NP winter monitoring stations.

Park ==>		**Yellowstone**					
Location ==>		**Old Faithful**					
Statistic	**Summer season → parameter ↓**	**Winter0405**	**Spring**	**Summer**	**Fall**	**Dec**	**Winter0506**
Max 1-hr	**CO**	1.57	0.79	0.78	0.28	1.02	**2.0**
Max 8-hr	**CO**	0.70	0.28	0.37	0.17	0.50	**0.6**
Average	**CO**	0.24	0.18	0.20	0.11	0.19	**0.18**
90th percentile	**CO**	0.39	0.22	0.27	0.15	0.32	**0.26**
Period	- -	Dec 15 – Mar 15	Mar 16 – Apr 19	Apr 20 – Oct 31	Nov 1 – Nov 30	Dec 1 – Dec 14	Dec 15 – Mar 15

Table 2b. Statistical comparison of PM2.5 between Yellowstone NP winter monitoring stations.

Park ==>		Yellowstone					
Location ==>		Old Faithful					
Statistic	Summer season → parameter ↓	Winter0405	Spring	Summer	Fall	Dec	Winter0506
Max 1-hr	PM2.5	38.0	28.0	39.0	36.0	27.0	**56.0**
Max Daily(24-hr)	PM2.5	7.0	6.6	14.0	11.0	11.0	**8.9**
98th percentile	PM2.5	9.0	6.6	11.1	11.0	11.0	**8.5**
Avg	PM2.5	4.0	4.2	5.7	3.7	3.9	**3.5**

The Yellowstone PM2.5 concentrations follow a very different pattern than the CO for the seasonal values. The summer period has some extended PM2.5 high concentrations compared to the winter. A review of regional wildfires and the transport of smoke plumes based on satellite aerosol images leads to the conclusion that the high PM during summer comes not from automobile traffic, but from wildfire smoke plumes. The air quality for PM2.5 is actually worse during the summer than at other times of the year at Yellowstone. The second point to recognize is that the PM2.5 concentrations are well below the national standard for both the 24-hour average and the annual average.

Table 2c. Number of vehicles entering park for different seasons based on monthly use statistics[7].

Period	Vehicles**	Months
Winter04-05	11,314	Dec-Mar
Spring05	5,271	Apr
Summer05	661,114	May-Oct
Fall05	24,121	Nov
Winter05-06	14,475	Dec-Mar

** These vehicle counts correspond roughly to the season labels in table 2b. The monthly public use statistics don't provided for finer resolution. The assumption is that much of the traffic ends up at Old Faithful.

The air quality in the winter periods can be compared to other seasons for both the West Entrance and Old Faithful. In figure 3, four winter periods are compared to summer when there is wheeled-vehicle traffic and to periods between summer and winter when the park is closed (no traffic). The winter background CO concentration is roughly 0.2 ppm for Yellowstone. During the Fall period, when the park is closed, both locations have 8-hour maximum CO concentrations that are lower than either the summer or winter periods. There is still contractor and park staff activity in the park that may account for the above background values plus some mobile source activity from the town of West Yellowstone. Summertime CO concentrations are well above the concentrations during the park-closed periods. The Old Faithful area gets a lot of summer traffic which is reflected in its higher measured CO than the West Entrance. All of the winter periods have higher CO concentrations than summer.

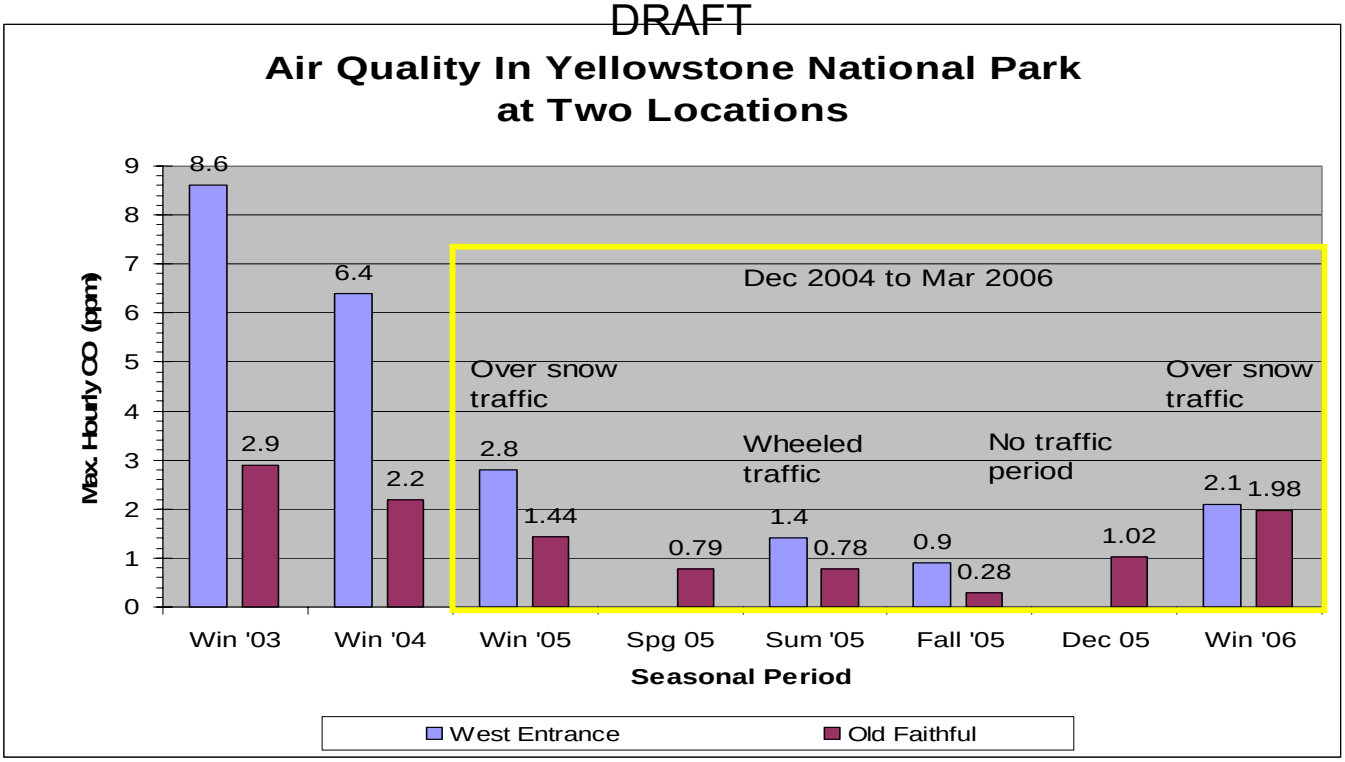

Figure 3. CO concentrations at two locations are compared to the seasonal periods at Yellowstone. Lowest CO concentration are when the park is closed in the Fall. Winter CO peak concentrations are still higher than in the Summer when traffic volume is much higher.

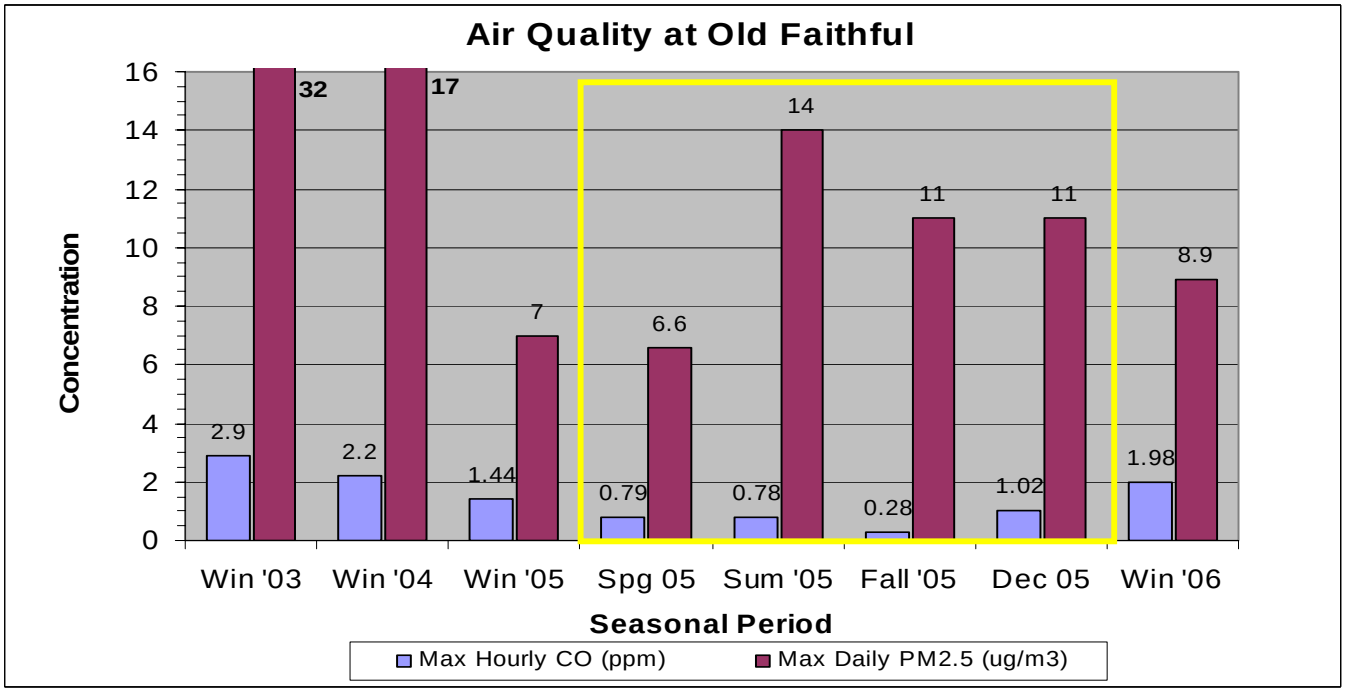

Figure 4. Old Faithful is a high traffic area both summer and winter. Summer concentrations of CO are low, but the PM2.5 goes high in July and into the Fall from wildfire smoke that is transported to the park.

A comparison of CO and PM over the different seasonal periods at Old Faithful (figure 4) illustrates how PM2.5 concentrations are unexpected high during summer. The Spring period when the park was closed had almost as high of PM2.5 daily maximum as the winter period which supports our conclusion that much of the PM2.5 at Old Faithful is unrelated to winter vehicle use.

Traffic effects on air quality

The effects of winter traffic on air quality is best characterized at the West Entrance where both air quality data and detailed traffic counts are available. There is a general trend in the second highest hourly CO and the 98th percentile of daily maximum PM2.5 that follows the changes in winter traffic and the vehicle emissions (figure 5). The second highest hourly CO concentration for the winter season tracks when the pollutant conditions were worse for each year. For the west entrance, the winter of 2000-2001 was a high point and CO concentrations have decreased since then. Over the last three winters the decrease in CO concentrations at the West Entrance has been small, but still trending downward. The PM2.5 follows a similar pattern at both the West Entrance and Old Faithful locations. The changes that have driven the decreases in CO and PM2.5 concentrations are smaller numbers of snowmobiles entering the park and a switch to cleaner snowmobiles that meet the BAT, mostly by using 4-stroke engines in the snowmobiles. The reduction in aerosol emissions (unburned oil and fuel) from the snowmobiles has been especially noticeable as reduced odor and reduced PM2.5.

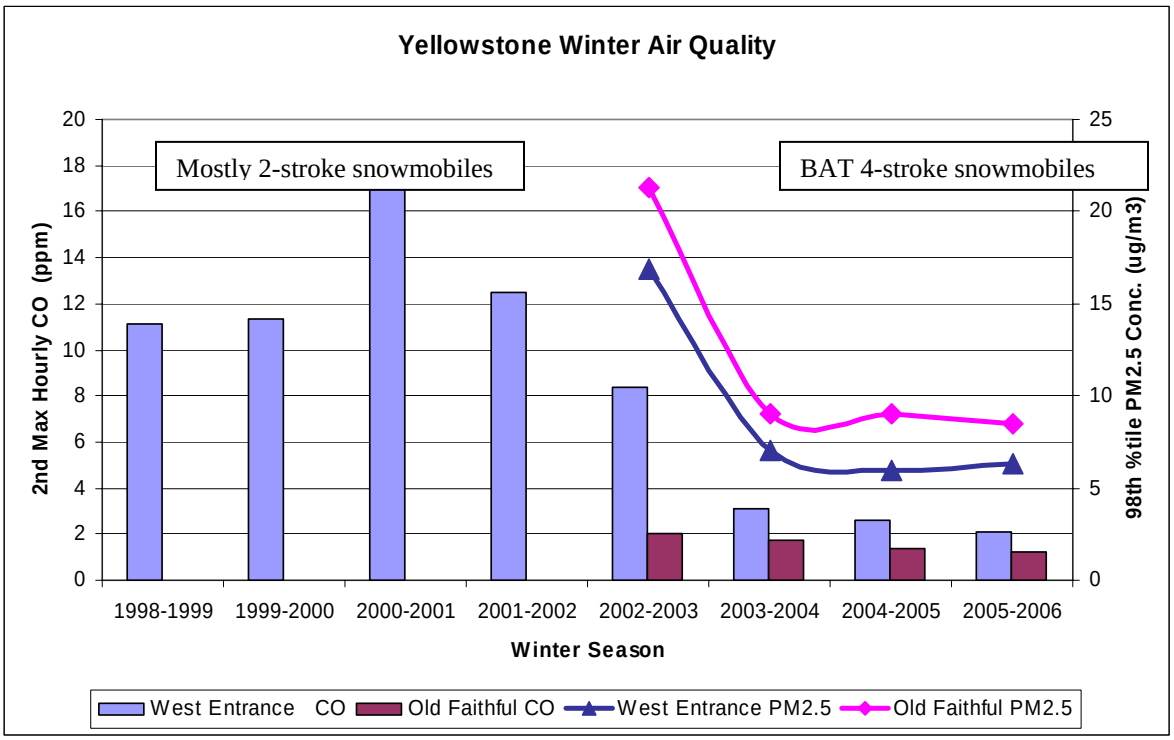

Figure 5. Air pollutant changes by winter season for the last 8 years. Both CO and PM2.5 have dropped since 2002 at both monitoring locations.

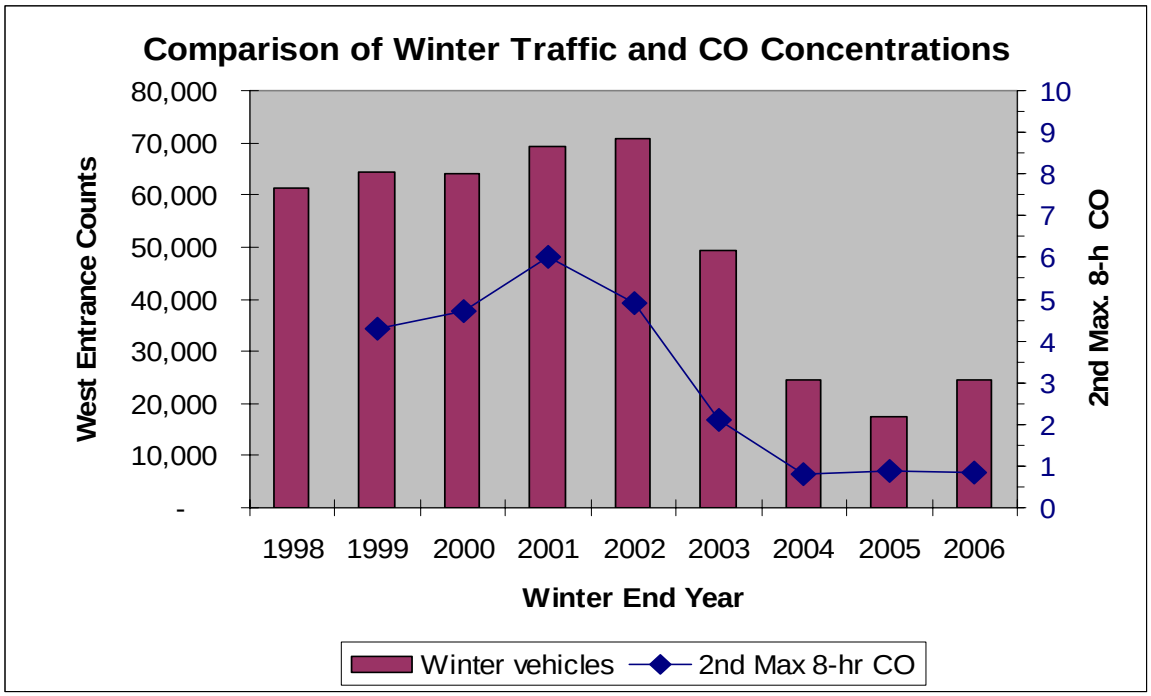

Figure 6. Winter vehicle counts decreased after 2002 and second maximum hourly CO followed that pattern. Although West Entrance winter traffic counts were up slightly from last year, the high CO concentrations were about the same. The plot is based on the public statistics[7].

Tables 3 – 5 provide detail on the numbers of vehicles and the air quality indicator concentrations from 1998 to 2006. The West Entrance is broken out from the totals, because there is a monitoring station at that entrance and none at the other entrances.

Table 3. Traffic counts[7] and air quality values for the West Entrance of Yellowstone for the winter seasons ending in the year listed.

Year	Snowmobiles	Snowcoaches	Total	Average traffic per day	CO 1-hr 1st max	CO 8-hr 2nd max.
1998	40,869	706	41,575	467	- -	- -
1999	44,213	767	44,980	505	18.2	4.3
2000	42,620	777	43,397	488	13.5	4.7
2001	45,689	816	46,505	523	17.9	6.0
2002	50,888	889	51,777	582	16.0	4.9
2003	33,458	998	34,456	387	8.6	2.1
2004	14,765	1,181	15,946	179	6.4	0.8
2005	8,743	1,185	9,928	112	2.8	0.9
2006	13,104	1,371	14,475	163	2.1	0.9

Table 3b. Additional detail for West Entrance CO statistics.

Location	Winter Period Years	1-hr CO (ppm)[1]		8-hr CO (ppm)[2]	
		1st Max	2nd Max	1st Max	2nd Max
West Entrance	1998-1999	18.2	11.1	8.9	4.3
	1999-2000	13.5	11.3	5.4	4.7
	2000-2001	17.9	17.4	6.1	6
	2001-2002	16	12.5	5.4	4.9
	2002-2003	8.6	8.4	3.3	2.1
	2003-2004	6.4	3.1	1.3	0.8
	2004-2005	2.8	2.6	1	0.9
	2005-2006	2.1	2.1	0.91	0.86

Table 4. Total traffic[7] for all entrances to Yellowstone for the winter seasons ending in the year listed.

Year	Snowmobile totals	Snowcoach totals	Total
1998	60,110	1,326	64,204
1999	62,878	1,396	63,927
2000	62,531	1,535	69,188
2001	67,653	1,591	70,787
2002	69,196	1,605	49,404
2003	47,799	1,653	24,076
2004	22,423	2,058	17,753
2005	15,695	1,926	23,819
2006	21,893	1,965	23,858

Table 5. PM2.5 statistics at entrance stations with nearby monitors.

Location	Winter Period Years	24-hr $PM_{2.5}$ (ug/m^3)[3] 1st Max	98th% Conc.
West Entrance	2002-2003	18.6	16.9
	2003-2004	8.0	7.0
	2004-2005	6.4	6.0
	2005-2006	7.2	6.3
Old Faithful	2002-2003	32.1	21.3
	2003-2004	16.5	14.5
	2004-2005	6.1	5.4
	2005-2006	8.9	8.5
Flagg Ranch #	2002-2003	16.4	10.7

The daily pattern of air pollutants at the West Entrance (figure 7) follows the times for entrance and exit of the winter vehicles[8]. The peak in the CO concentration is centered on the same 9 am hour as the peak in snowmobile counts. The secondary CO peak at 5 pm corresponds to the rush of snowmobiles exiting the park. The delay in the PM2.5 peak (10 am) and the long tail in the afternoon and evening suggests another PM source besides snowmobiles is contributing.

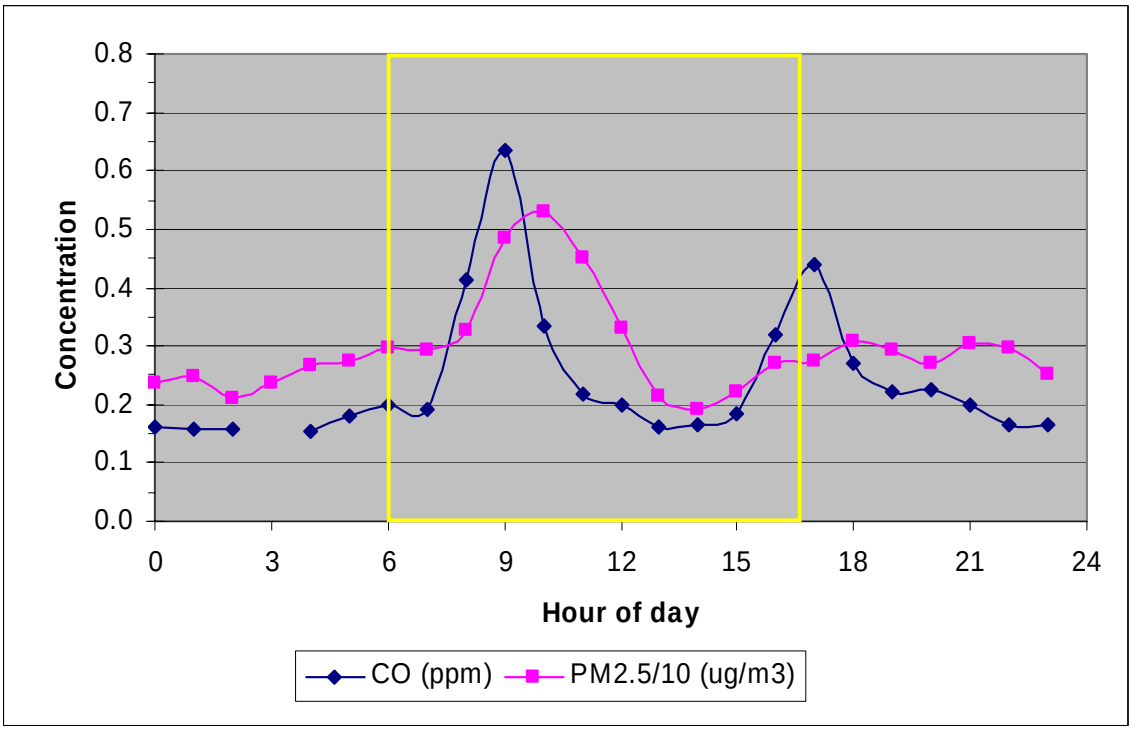

Figure 7. Average CO and PM2.5 at the West Entrance by hour of day. The yellow box is the period when entrance counts are recorded. There are no records for the exit counts.

The entrance counts[8] illustrate a difference in when the snowmobiles enter the park compared to the snow coaches (figures 8 & 9). Snowmobiles come in groups lead by guides; the period between 8-11 am is when most of the traffic enters. Snow coaches are more spread out during the day, although the West, North, and East gates tend to get most entries during the morning.

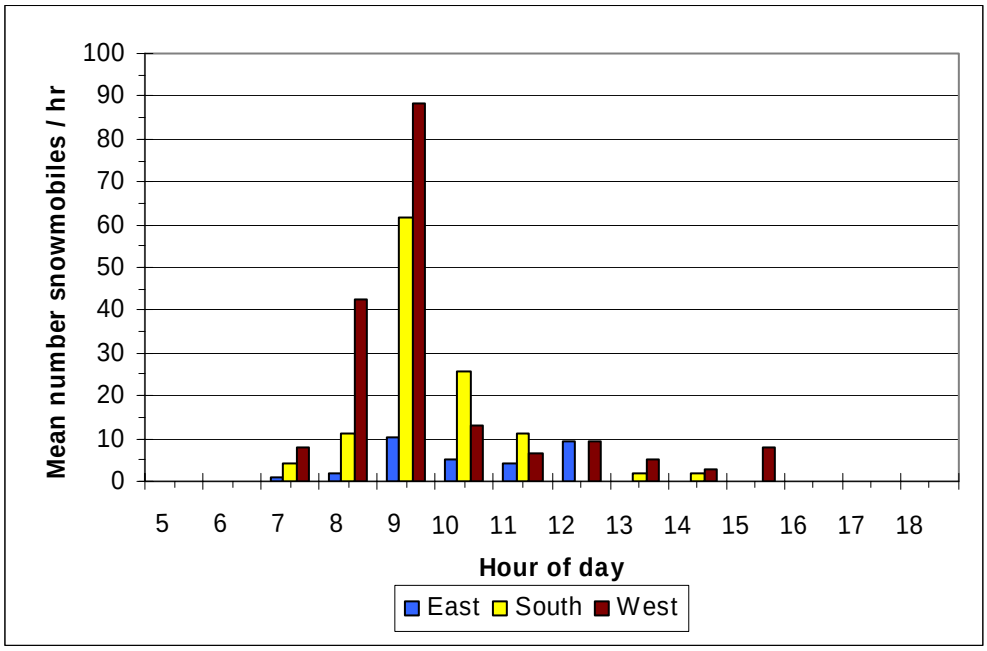

Figure 8. Average entrance counts for snowmobiles. Dark red bars are the west entrance mean counts per day and hour.

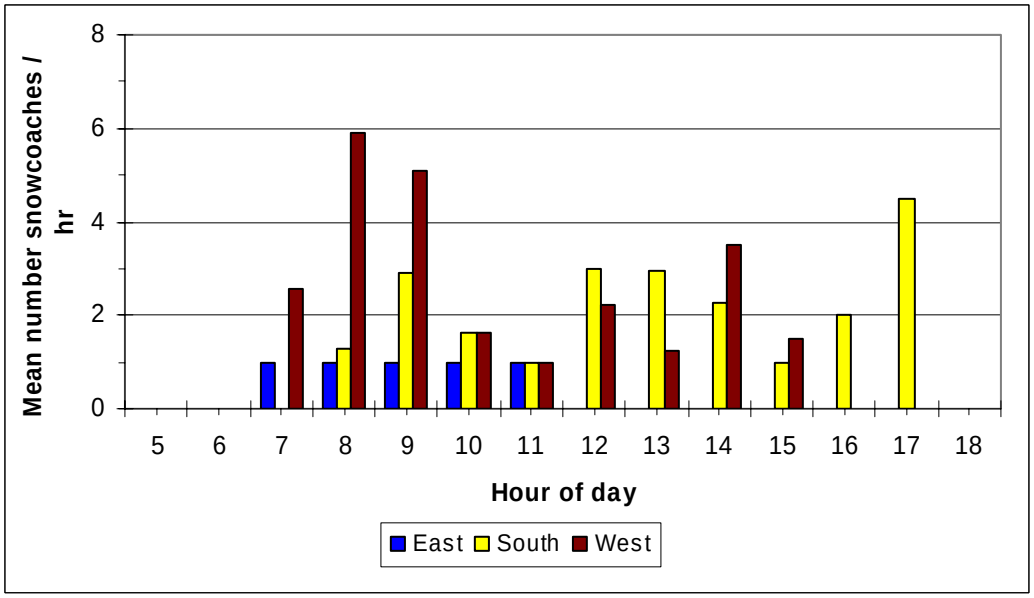

Figure 9. Average entrance counts for snowcoaches. Dark red are the west entrance mean counts per day and hour.

The snowcoach traffic starts a little earlier and has a second peak midday. Peak snowmobile entry is 9-10am; arrival at Old Faithful is about 2 hours later. Counts are for entry only, not exit. The CO hourly data has peaks for entry and exit. The exit peak is smaller because snowmobile traffic does not stop, are more spread out, and traveling at higher speed. PM also has a double peak but with a 1-hour lag (this may be a difference in how data is recorded). Afternoon peak is much more spread out and continued will after dark when there is no traffic exiting the park. This is most likely wood smoke from nearby West Yellowstone.

Incremental Pollutant Changes with Traffic Volume

The change in CO with the change in traffic volume over the last eight years is plotted in figure 10. This plot suggests a high sensitivity to the number of snowmobiles[1] that enter the west entrance each day. However, more than just the volume of traffic changed over this period. Only the 3 points labeled by winter year represent BAT snowmobiles. The quality of this estimate is suspect for that reason and the estimate of 12 ppm CO as maximum hourly CO is probably an upper limit for the expected CO concentration at 400 snowmobiles per day.

Monthly maximum CO concentrations were compared to the monthly traffic totals for the last two winters (figure 11) for only BAT snowmobiles. Although reasonable regressions were obtained, the slopes were very different for the two winters. The 2005-2006 winter CO concentrations were much less sensitive to changes in the amount of traffic through the entrance gate. The mean CO had a dual daily peak that corresponded to peak traffic through the entrance. PM2.5 did not show such a pattern (figure 7).

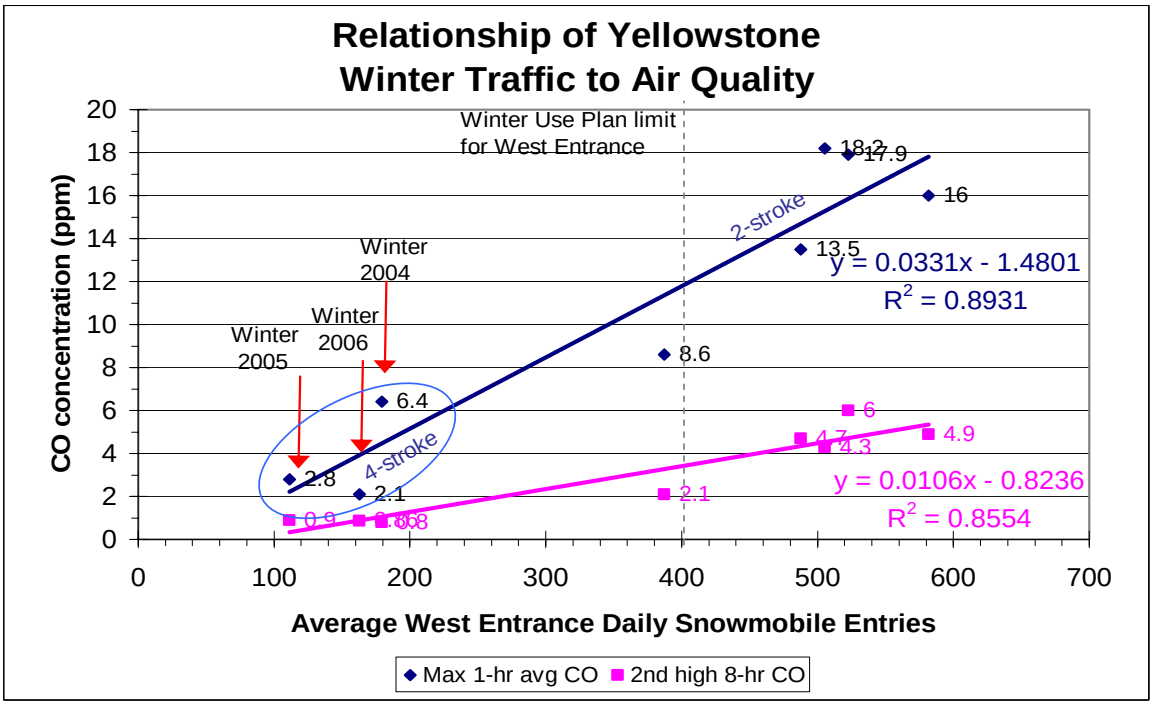

Figure 10. Relationship between winter peak CO concentrations and average daily snowmobile entrance counts at West Yellowstone for two CO statistics. Based on data[7] from 1998 to 2006. Note the switch over of engine types and the assumption that number of snowmobiles makes most of the difference in pollutant concentrations.

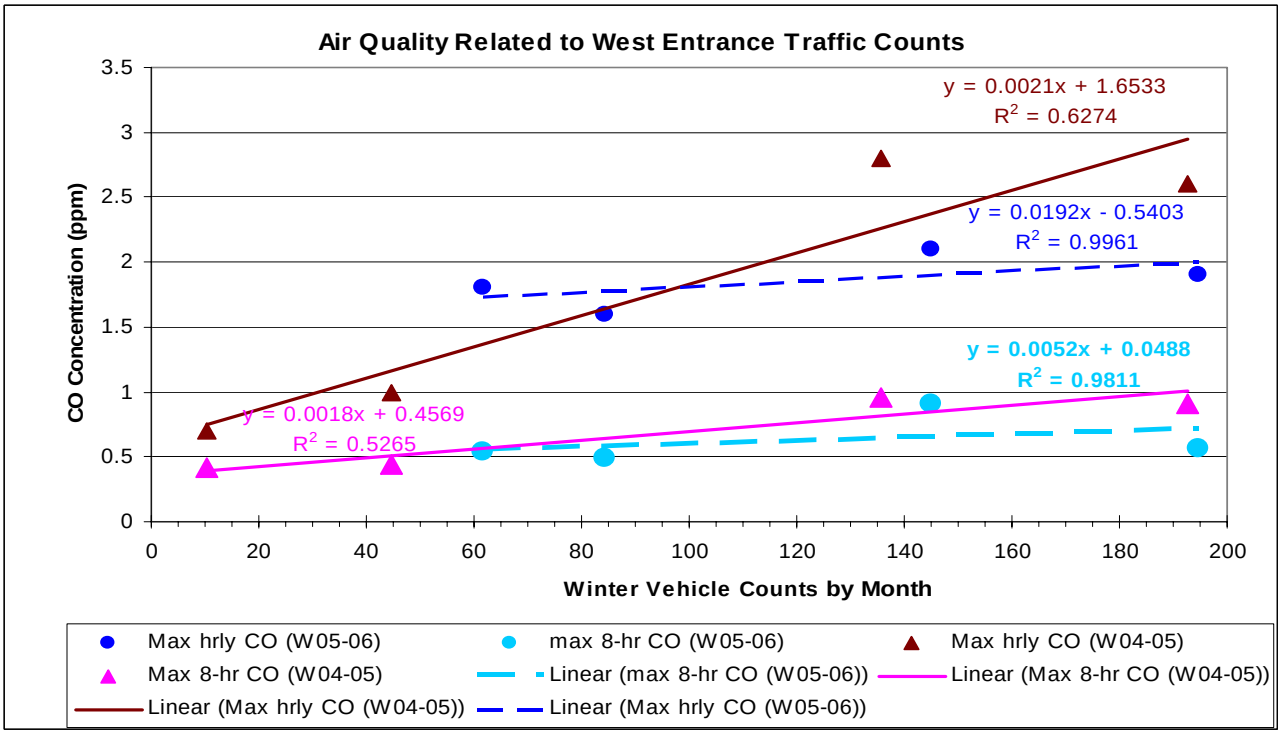

Figure 11. Relationship of monthly CO concentrations to monthly average winter vehicle counts[7] at the West Entrance for BAT snowmobiles and uncontrolled snowcoaches is a more realistic estimation approach. Winter 2004-2005 data are the sold lines in red; winter 2005-2006 data are the dotted lines in blue.

If the regression model is used to estimate by extrapolation the expected maximum hourly CO concentration for the allowable number of snowmobiles per day through the entrance, the CO might range between 2.5 and 7 ppm. This is too wide a range to be useful.

It seems unlikely that all the meteorology, traffic patterns, and alternate emissions sources can be accounted for from the observational data. Computer modeling takes many of these factors into account and is likely to be a better approach for estimating the affect of traffic volume vs. the emission levels of the winter vehicles for determining the CO concentrations. The main point to be made from the observation data is that the present CO and PM2.5 concentrations are well below the national standards and approaching the range of values seen during the height of summertime traffic.

The pollutant and entrance count data for the West Entrance have been examined carefully for the winter 2005-2006 to determine relationships. As before, it was difficult to get good linear relationships between the traffic counts and daily pollutant measurements. There does seem to be some relationship between the observed maximum CO concentrations for a winter season and the amount of traffic for that year (figure 11). It is not intuitive why

seasonal traffic counts should relate to the seasonal maximum CO while the daily values do not. The winter 2005-2006 CO concentration fell below the regression line. During the period plotted in figure 6 there was a change from 2-stroke to 4-stroke snowmobile engines and the entrance procedures changed. It seems very likely also that the build up of pollutants near the gate is related to the length of the queue and the relationship is non-linear. At lower traffic volume, when there is no queue, pollutant build up would be expected to be less.

Seasonal Traffic and Air Quality

The monthly and seasonal changes in amount of traffic and the peak monthly air pollutants can be see in figure 12 and 13. Note the log scale for the number of vehicles on the y-axis; summer traffic is 60 times the amount of winter traffic. The peak CO concentrations are 2-3 times larger in winter than summer for the last two winters despite the much larger number of vehicles in summer.

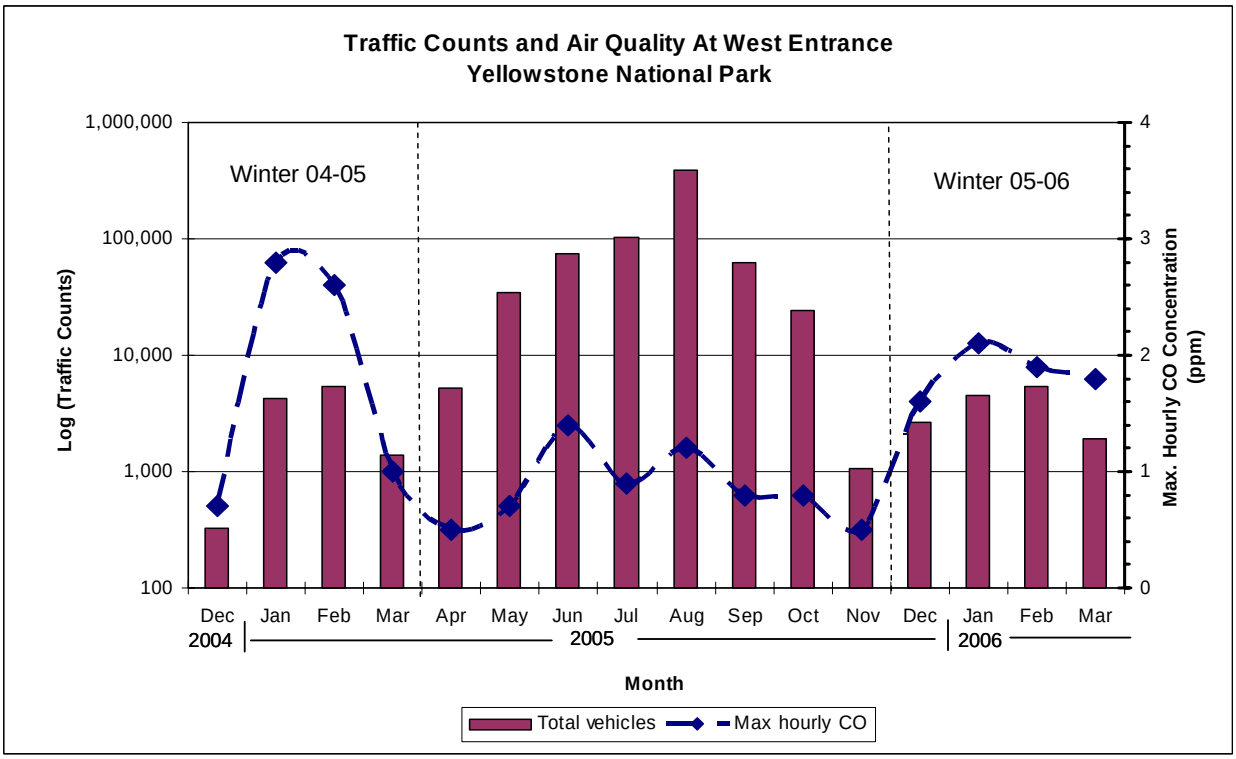

Figure 12. Comparison of vehicle traffic in the West Entrance compared to CO concentrations by month. CO concentrations are highest during the winter periods when total number of vehicle counts is small (note the logarithmic scale). Lowest CO periods correspond to the lowest traffic periods in late March and November.

The winter to summer difference in PM2.5 is even more dramatic, but it has little to do with vehicle traffic. Western wildfires bring smoke into Yellowstone, sometimes from distances of hundreds of miles. This has a bigger effect on summer air quality than the motor vehicle traffic at the locations we measured.

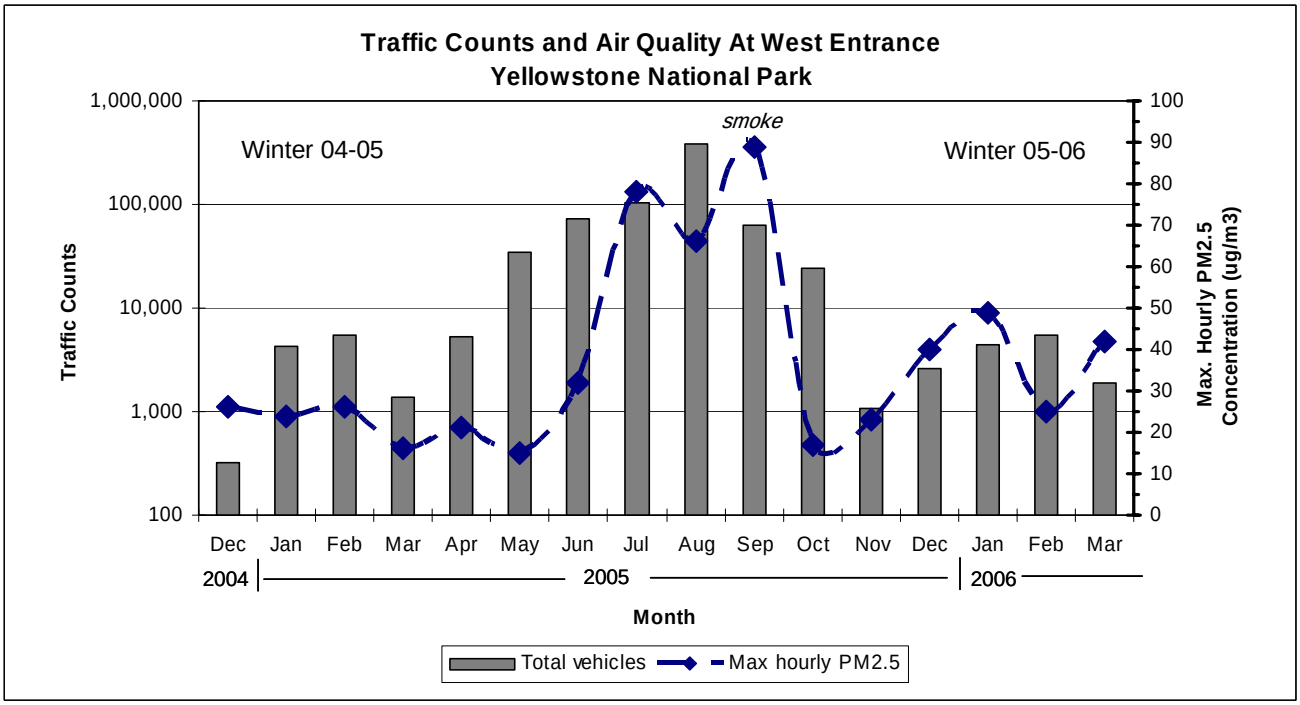

Figure 13. Comparison of vehicle counts at the West Entrance with maximum hourly PM2.5 by month. The PM concentration seems to have little to do with the traffic counts. The highest PM is during the summer months when wildfire smoke is thought to be the major contribution.

Air pollutant concentration visualizations

The visualization of pollutants by color coding concentrations for every hour and day is a good way to the daily and between-day relationships. The differences between the two monitoring sites and the relation between pollutants and winter vehicles is easily seen with the color coded plots in figures 14 and 15. The shaded areas are approximate nighttime periods. The dotted lines with labels mark when the highest traffic periods are for the two sites.

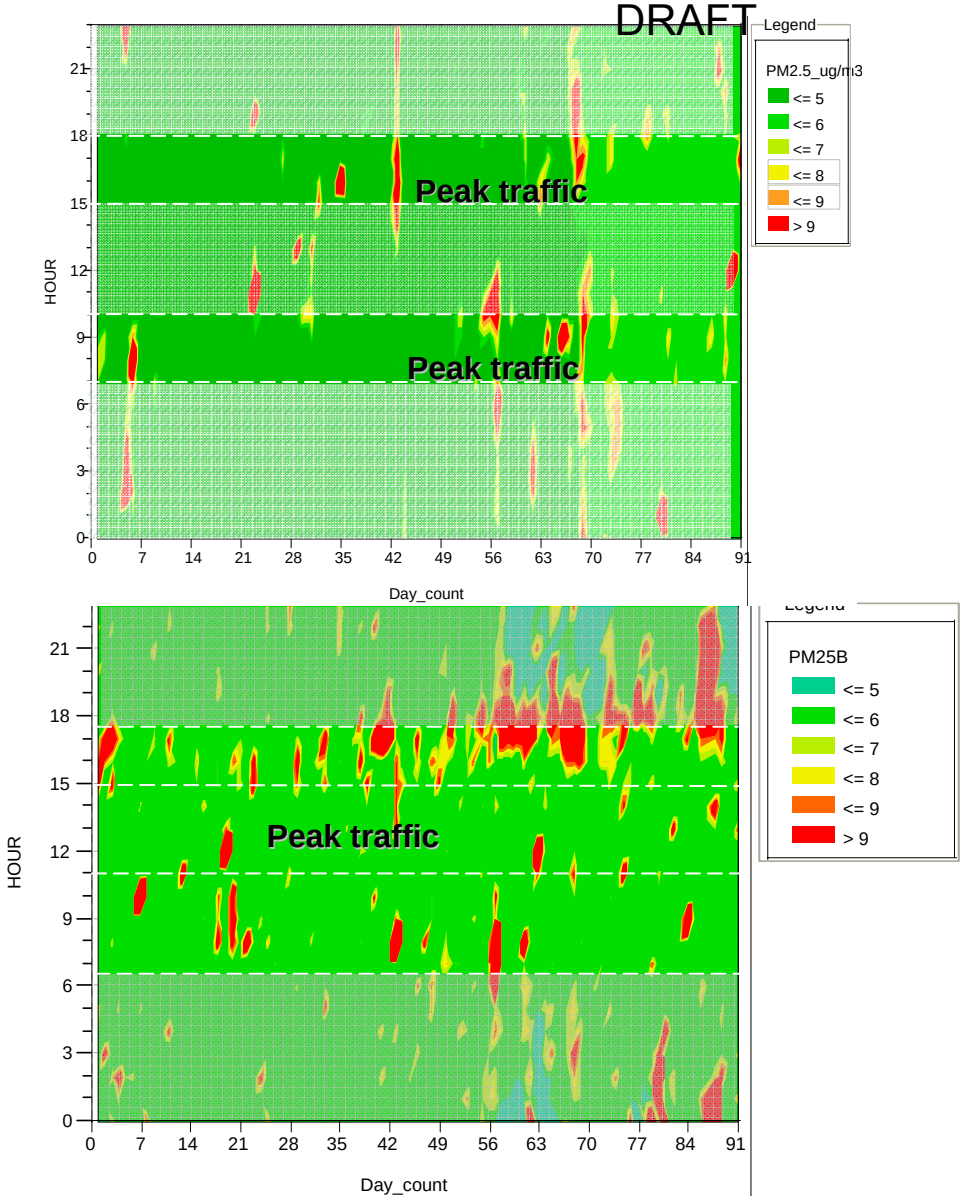

Figure 14 Upper - West Entrance; Lower - Old Faithful. Ambient PM2.5 hourly concentrations for every hour of the 2005-2006 winter season. Day counts start on Dec. 15 and end Mar. 15 of the next year.

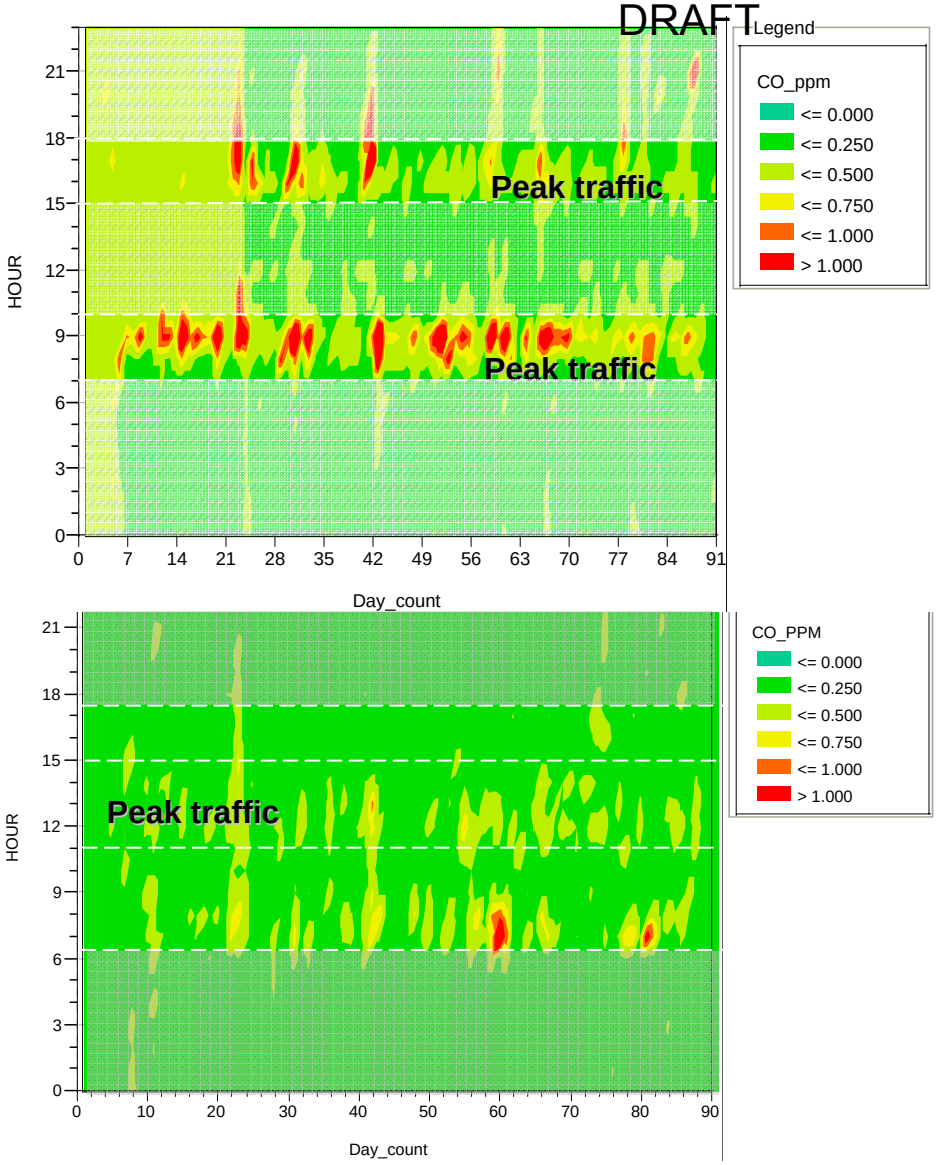

Figure 15 Upper - West Entrance; Lower - Old Faithful. Ambient CO concentrations for every hour of the day for the 2005-2006 winter season.

West entrance traffic enters the park mostly between 7-10 am, is at Old Faithful between 11am and 3pm, and exits the west gate between 4 and 6pm. Peak PM2.5 concentrations (figure A1.1) seem to have little to do with the peak traffic periods at either site. Old Faithful has a local source that shows up most evenings. The magnitude of the PM concentrations and length of time gets larger as the season progresses. CO is much more directly related to traffic at the west entrance as seen in figure A1.2. The peak CO concentration periods are primarily during the peak traffic periods. At both sites the CO goes down to low values overnight. Old Faithful has a CO local source that starts in the morning near daybreak. The timing of this source corresponds to the normal time when the maintenance staff light up the wood-burning stoves in the warming hut.

Conclusions

Direct measurements at two locations within Yellowstone National Park, the West Entrance and Old Faithful, show that air quality has improved over the last several years. The magnitude of peak CO events and the overall concentration and number of events have decreased. Although the West Entrance continues to have higher CO concentrations than those at Old Faithful, the difference is becoming smaller. At Old Faithful, the total number of winter vehicles present during mid-day is greater than at the peak hours at the West Entrance, however, arrival and departures are spread out temporally and the vehicles do not usually idle for long. Along the roads leading to Old Faithful, the vehicles are spread out and at lower density usually. The exceptions are when the vehicles stop in clumps to view or let wildlife pass and the stops made at the warming huts and thermal-feature parking lots.

The enhancement in CO concentrations by the snowmobile and snowcoach traffic is clearly seen in the dual daily peaks, the high spikes that occur only during the winter, and the overall increasing in CO when low traffic periods are compared to the winter open season. The PM2.5 is less clearly related to the winter vehicle traffic at present. Although there is some enhancement and dual daily peaks at about the same time as the CO peaks at the West Entrance, there are also peaks in early morning and in the evening when there is no traffic through the gate. At Old Faithful, the PM2.5 does not relate closely to traffic and has high concentrations mostly during periods when winter vehicle traffic is not present. The fact that other PM sources than snowmobiles have become dominate is mainly because of the lower PM emissions by the 4-stroke snowmobiles.

The analysis of the monitoring data has been unable to estimate with any great certainty the incremental level of air pollution with traffic volume of the BAT snowmobiles. A 32% increase in winter vehicle traffic through the West Entrance this winter (2005-2006) had a very small influence on the air quality. It is likely that meteorological differences between the winters are playing a larger part in determining the changes in CO concentrations near the entrance than the total numbers of winter vehicles.

The air quality monitoring data shows that the plan to reduce both the number of snowmobiles and their emissions has been a successful strategy towards improving the air quality in Yellowstone. If it can be assumed that the amount of air pollution from mobile sources in the park during the summer is an acceptable level, then winter use vehicles will need to have lower emissions or fewer vehicles be admitted. The number of snowmobiles currently entering the park during the winter are below the allowable limits set in the winter use plan[9]. The snowmobile BAT has reduced emissions, but snowmobiles are still much dirtier than light-duty cars and trucks. The emissions tests on winter vehicles entering Yellowstone by the University of Denver researchers[6] clearly shows that both the snowmobiles and the snowcoaches are high pollutant emitters compared to summer vehicles. The small amount of improvement in air quality over the last three winters suggests that additional measures will have to be taken or the present air pollutant concentrations are likely to be the continuing condition.

References

1. **2004-2005 Yellowstone Winter Air Quality Overview Report**, NPS Air Resources Division, March 2005. Available from: **http://www2.nature.nps.gov/air/Pubs/index.cfm**

2. EPA CO and PM effects on health http://www.epa.gov/air/urbanair/6poll.html

3. EPA NAAQS http://www.epa.gov/ttn/naaqs/

4. **Data Transmittal Report for the Yellowstone National Park Winter Use Air Quality Study**, 2004-2005 – Mar. 15, 2006, Air Resource Specialists, Ft Collins, CO (August, 2006). Available from: http://www2.nature.nps.gov/air/Pubs/index.cfm

5. **Data Transmittal Report for the Yellowstone National Park Winter Use Air Quality Study**, 2005-2006 – Draft Aug, 2006, Air Resource Specialists, Ft Collins, CO (August, 2006). Available from: http://www2.nature.nps.gov/air/Pubs/index.cfm .
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7. National Park Service, Public Use Statistics, Yellowstone visitor and vehicle count statistics http://www2.nature.nps.gov/mpur/

8. Private communication, Hourly records of vehicle entries collected by ranger staff

9. Yellowstone Winter Use Plan and other Winter Use Technical Documents http://www.nps.gov/yell/parkmgmt/winterusetechnicaldocuments.htm

Data Access

Air monitoring and emission study reports, journal publications, and data:
http://www2.nature.nps.gov/air/studies/yell/20042005yellAQwinter.cfm

Hourly CO, PM2.5, and meteorological data:
http://12.45.109.6/

MT DEQ's West Entrance monitoring station data and station information:
http://www.deq.state.mt.us/AirMonitoring/index.asp

Other MT DEQ monitoring stations:
http://www.deq.state.mt.us/AirMonitoring/sites/QueryAQsitelocation.asp

Old Faithful area webcam, current weather, and current pollutant data:
(http://www2.nature.nps.gov/air/WebCams/parks/yellcam/yellcam.htm