Alaska Department of Environmental Conservation

Amendments to:

State Air Quality Control Plan

Vol. III: Appendix III.D.7.9

{Appendix to Volume II. Analysis of Problems, Control Actions; Section III. Area-wide Pollutant Control Program; D. Particulate Matter; 7. Fairbanks North Star Borough PM2.5 Control Plan, Serious Requirements}

Public Review Draft

August 19, 2024

Michael J. Dunleavy, Governor

Emma Pokon, Commissioner

Note: DEC proposes to repeal and replace this appendix to the State Air Quality Control Plan section to address the disapproval of the Fairbanks North Star Borough $PM_{2.5}$ Serious SIP and the 2020 Amendments. To aid in the public comment process, the currently adopted section of the air quality plan can be found and referenced at the following internet site: https://dec.alaska.gov/air/anpms/sip/fbks-pm2-5-regs-amends-2020/

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Appendix III.D.7.9

Contents

Alaska Department of Environmental Conservation

State Air Quality Control Plan

Quantification of 2022/2023 Winter Fairbanks/North Pole $PM_{2.5}$ Nonattainment Area Wood Burning Compliance with Air Quality Alerts

Draft

Date

Contents

Section 1. Introduction

The 2019 Targeted Airshed Grant (TAG) provides funds for collecting information on compliance with wood burning curtailments (i.e., burn bans) by conducting surveys over a 5-year period in Fairbanks and North Pole along routes constructed from unbiased samples of known wood burning households. Surveys have been conducted in the 2021/22, 2022/23 winters and are ongoing in the 2023/24 winter. Considerable effort was devoted to the development of a survey framework (survey design, operating procedures, staff training, identification of active wood burning households, route design, conduct of surveys on Alert days, data assembly/analysis, etc.). Software was developed to assemble routes for the available datasets of known wood burning households and assemble data collected in the surveys. The results for the first year were limited as the process for identifying active wood burning households needed to be revised after field staff indicated a low confidence in the accuracy of initial Alert Day surveys of those homes. This led to a halt in the surveys and revisions to the identification procedures (e.g., stack identification, visibility from the roadway, the amount of time observing homes to confirm that plumes were not coming from fuel oil heaters, etc.). The implementation of these procedures resulted in a much smaller sample of active wood burning homes and delayed the conduct of Alert Day surveys until later in the winter which resulted in a significantly reduced sample of observations. The limited sample did not support robust confidence in the findings.

The results of the first year of Alert Day compliance provided a firm foundation for the conduct of the survey in the second winter 2022/23. One of the seasonal field staff from the previous winter returned, which resulted in less training and earlier assembly of the field staff. Environmental Compliance Consultants (ECC), a local contractor, was hired and tasked with much of the survey work, which significantly expanded the field staff available to (a) identify active wood burners and (b) conduct surveys of compliance on Alert days. The Alaska Department of Environmental Conservation (ADEC) revised the format used to record information on active wood burners so drawings and links to pictures of roofs with identified wood burning stacks was available to field staff conducting surveys on Alert days. ADEC also expanded software development to facilitate downloading survey observations and assembly of data for analysis. Additional effort was spent evaluating the ability of FLIR cameras to accurately measure thermal signatures under day and nighttime conditions.

ADEC trained ECC on the procedures for identifying active wood burners, the conditions under which that data could be collected and the format to be used in recording the data. ECC initially focused on expanding the sample of active wood burners (through confirming that active wood burners identified the previous winter continued to burn wood and to identify new active burners); once the sample exceeded 50 homes in each community, surveys of compliance on Alert days started. ECC staff continued to expand the sample of active wood burners on non-Alert days in both communities, eventually approaching the TAG survey target of 100 homes in each community. ADEC staff also collected observations of compliance behavior on Alert days at the same homes that ECC observed. The data they collected was contrasted with the data collected by ECC and differences were noted in the observations collected. This resulted in the development of a correction factor to adjust the data collected by ECC to address differences in decisions on smoke observations. It also pointed to the need for more regular ADEC/ECC meetings and training.

The data collected in the 2022/23 winter survey was analyzed for overall compliance and patterns of behavior. Separately ADEC conducted a Home Heating Survey to collect information on the type of fuel and the amount used during the winter. The survey also included a question about the number of hours after an Alert is called and becomes effective that active wood burning homeowners stopped loading their stove. Since the field surveys only record data on wood burning behavior during daylight hours (typically from 10 am to 2 pm) on the day(s) following the initial call of an Alert, the home heating survey question responses provide insight into behavior during the nighttime hours.

This appendix provides a summary of the data collected, corrections and resulting analysis of each survey (the field surveys are referred to as the TAG survey and the Home Heating survey to distinguish between the datasets). The results of those surveys were combined to provide the most accurate measurement/estimate of Alert Day compliance during the 2022/23 winter. This value replaces the forecast included in the 5% Plan for the Fairbanks nonattainment area. The compliance rate employed in that Plan for the baseline and forecast years was based on engineering judgement with limited measurements of actual behavior. The remainder of this Appendix includes separate sections addressing: (a) the TAG survey, (b) the Home Heating Survey, (c) the estimation methodology, and (d) the 2022/2023 Compliance Rate.

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Section 2: Targeted Airshed Grant Survey

As noted in the Introduction, the results from the 2021/2022 survey provided the foundation for the development of the survey conducted in the 2023/23 winter. ADEC contracted with ECC, a local consulting firm with an office in North Pole. In preparation for training ECC on how to conduct the survey, ADEC established a design that drew on the experience gained in collecting data during the previous winter. That design included the following elements:

- Focus on daylight hours – visual observations of stack emissions cannot be collected during nighttime hours, which starting in late October last from ~ 5:30 pm – 9:30 am decline to ~ 3:00 pm to 10:45 am in December and then expand to ~ 6:14 pm to 7:45 am in February. Recognizing data cannot be collected in the dark[1], surveys were focused on the period between 10 am and 2 pm, with more or less coverage depending on the time of year. Observations were collected on both weekdays and weekend days, depending on when Alerts were called and staff availability.

- ID homes to be observed – the first step in the survey, beyond the design, was the identification of likely wood burning homes. While many options are available, including driving during daylight hours looking for homes with active plumes, looking for homes with wood piles visible from the street, contacting businesses selling wood to identify the address of recent deliveries, following wood delivery trucks, searching through registration data to identify homes that with known wood burning devices, etc. A mixture of these options was used to compile a list of potential wood burning homes. The addresses of these homes were organized into a database and software was used to organize routes with ~ 20 homes that could be driven so that observations could be efficiently collected to confirm whether the candidate homes were in fact active wood burners.

- Confirm homes are current wood burners – Both ADEC and ECC staff then drove the routes during daylight hours and collected information on each of the candidate homes, including the location of the stack thought to be from a wood burning appliance, the presence of a plume, the presence of a wood pile, etc. In some cases, multiple stacks were observed to be closely spaced and staff would need to wait to confirm that the plume was not from a water heater or other home heater that stopped emitting after a thermostat set point was reached (which would typically occur in less than 20 minutes, often less). Staff were directed to observe the candidate homes multiple times (time of

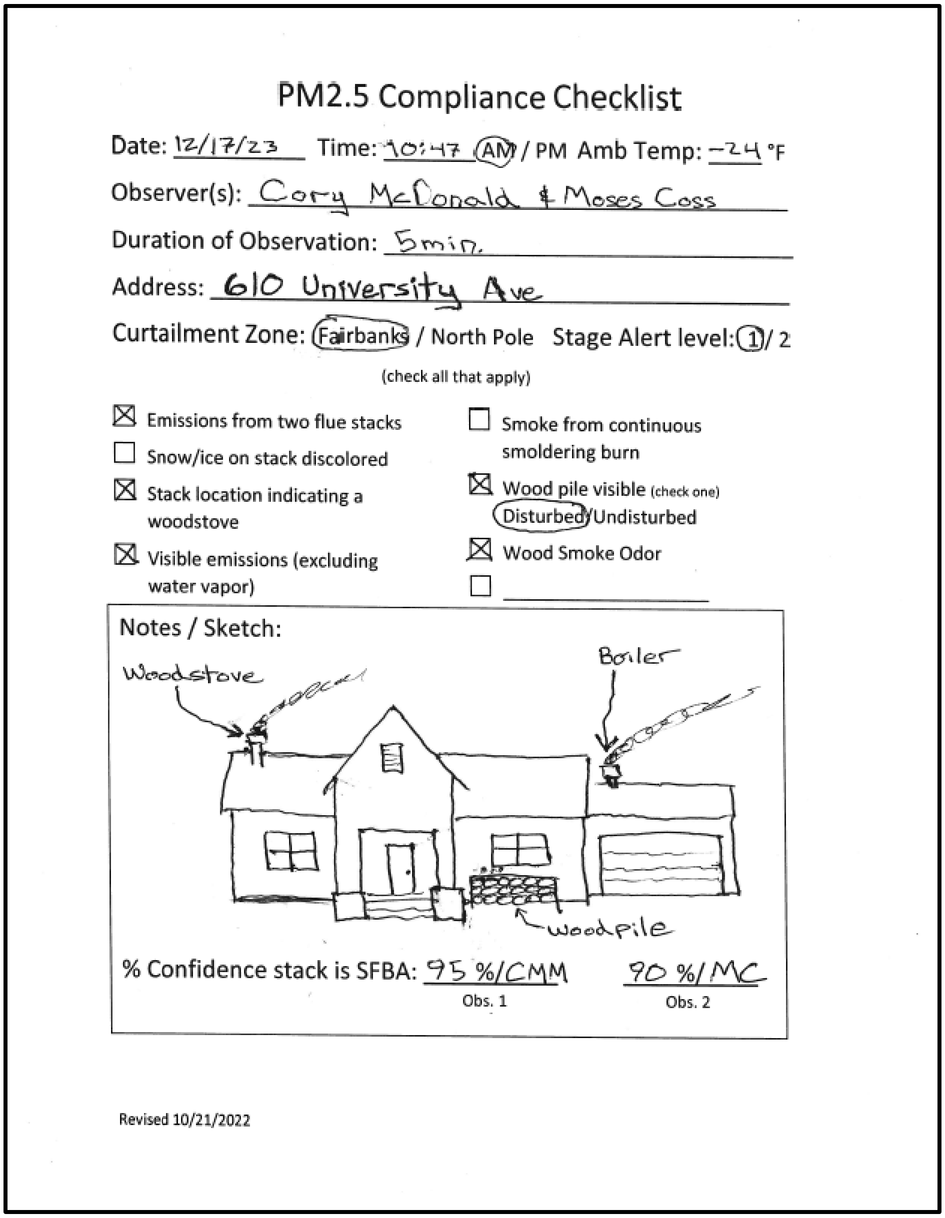
[1] ADEC assessed the ability of staff to correctly identify stack plumes using FLIR cameras, a non-contact device that detects infrared energy (heat) and converts it into a visual image. Initial tests had staff observe stacks from operating wood burning stoves distant from roadways adjacent to Borough facilities to determine the magnitude of the image representing an active plume. Information on the accuracy as a function of distance and weather conditions were also considered, but the testing was conducted during summer months, so winter representation was not assessed. Issues to be addressed in the additional testing included assessing the ability of the cameras to distinguish between plumes from adjacent stacks (wood burning from actively operating water heaters and fuel oil and natural gas heaters) along with effects of distance and obstructions (i.e., trees, etc.). This information is needed before procedures can established for operating the cameras to reliably identify active wood burning stacks. For these reasons, FLIR cameras could not be used to assess wood burning compliance during nighttime hours in the 2022/23 survey.

day, day of week, weekend, etc.) to collect more than one observation confirming the operation of a wood burning device. The vehicles driving the initial routes typically had 2-person teams (a driver and an observer), with the observer directing the route and noting on a paper form information about the observations.

- Construct routes (Fairbanks & North Pole) – The observations collected to identify active wood burners was reviewed to assess the information used to determine the wood burning status of the observed home (# of observations recorded, evidence of obstructions, time of day, etc.). Based on that independent review of the collected data, a database of active wood burning homes was complied and software was used to construct routes of ~ 20 homes that linked homes into a sequence that could be driven efficiently. Multiple routes were developed for each community (Fairbanks and North Pole).

- Prepare information package on each home – the goal was to provide information to facilitate the efficient observation of homes under less than perfect conditions (e.g., early morning light, low light, dark skies, obstructions, etc.). This was achieved by preparing an information sheet (i.e., checklist, see figure below) for each home that provided a format to record the date, time, observers, home, duration of observations, the location of the wood burning stack on the roof of the house via a drawing (the figure below displays a fictional home that provides an example of the format and drawing identifying relevant features of the home being observed). The format also records information about the curtailment zone, Alert level and conditions being observed (e.g., # of stacks, emissions visibility, presence of water vapor, wood pile visibility, odor, etc.). The form also records the confidence that observer places on the accuracy that the stack being observed is from a solid fuel burning device (SFBD) for each observation of the home. As noted in the lower left corner of the figure it was revised at the end of the 2021/2022 winter, reflecting field experience that season. The subjective assessment of confidence collected in the initial survey, which was on the order of 50%, prompted ADEC to cease the conduct of the survey and revise the format of the information provided to field staff conducting the surveys, which is reflected in the example format displayed below.

- Use ADEC/Contractors to observe behavior on Alert Days – ADEC staff alone were used to conduct the survey the first winter and while staff time was specifically allocated to the survey, conflicts were encountered when prioritizing time spent on enforcement versus time spent conducting the survey on Alert days. An additional issue encountered was the need to approve weekend time spent on the survey (which conflicted with personal priorities) and frequent lack of clarity as to whether an Alert would be called. For these reasons, ADEC decided to hire a local contractor with staff working and in many cases living in the curtailment zones being observed. Their familiarity with these communities, how homeowners react to vehicles parked for extended periods of time in front of their homes, the layout of the community, etc. all called for the use of a local contractor. Letters documenting their status as an ADEC contractor and business cards for ADEC staff were distributed to ECC so their staff could provide this information when challenged, which occurs occasionally, about the purpose of their presence.



PM2.5 Compliance Checklist

Date: 12/17/23 Time: 10:47 (AM) / PM Amb Temp: -24 °F

Observer(s): Cory McDonald & Moses Coss

Duration of Observation: 5min.

Address: 610 University Ave

Curtailment Zone: (Fairbanks) / North Pole Stage Alert level: (1) / 2

(check all that apply)

- ☒ Emissions from two flue stacks
- ☐ Snow/ice on stack discolored
- ☒ Stack location indicating a woodstove
- ☒ Visible emissions (excluding water vapor)
- ☐ Smoke from continuous smoldering burn
- ☒ Wood pile visible (check one) (Disturbed) / Undisturbed
- ☒ Wood Smoke Odor
- ☐ ________

Notes / Sketch:

Woodstove

Boiler

woodpile

% Confidence stack is SFBA: 95 %/CMM (Obs. 1) 90 %/MC (Obs. 2)

Revised 10/21/2022

- Training – ECC staff, both management and field staff, along with seasonal ADEC staff hired for both compliance survey and enforcement observing met with ADEC management staff to review procedures for collecting observations, which included: interfacing with the public, contacting ADEC staff when challenges occurred or guidance was required to review the procedures to be followed in identifying new candidate solid fuel burning houses, confirmation of active SFBD status for previously identified/surveyed homes from the previous winter and new homes identified as candidates and the surveillance of confirmed SFBD homes on Alert days. Also discussed were procedures for quality assuring (QA) the collected data and procedures for uploading the QA'd data to ADEC's SharePoint site. Following this meeting, teams of observers and ADEC management staff drove sample routes, observed candidate homes and discussed procedures to be followed and answered questions about them, contingency issues and contact.

- Develop/implement QA procedure – ADEC staff spent time after the first winter reviewing the surveys of each home to assess the information collected, the confidence recorded, and the basis for their compliance decision (was it based on a plume, odor, was the stack observed consistent with the information provided, were photographs of the stacks obtained displaying plumes, etc.). This review led to follow up discussions with the teams conducting the surveys to better understand the basis of questionable compliance decisions. Based on the survey review and surveillance team discussions a set of procedures was established for reviewing the surveys, identifying questionable compliance decisions, interviewing field staff quickly while their memory of the survey was fresh and revising the recorded data as needed. A database format was established for transferring the written information into a data structure and reviewed before transmitting the survey data to ADEC.

- Parallel Surveys – To assess consistency in compliance observations made by ECC and ADEC staff, observations were collected by teams from each organization on the same route, same day and near same time. To avoid disturbing homeowners and neighborhoods, the teams did collect their observations at the same time, but they were collected within xx minutes of each other. This approach assumed that no changes in wood burning behavior occurred between the time of the surveys. The surveys were contrasted for consistency and differences could be used to make adjustments to reflect the greater experience of observations collected by ADEC staff. Differences also provided the basis for determining ECC observation changes.

A summary of the households observed, differences noted between ECC and ADEC observations and related adjustments is presented below in Section 4. Also presented is an analysis of the adjusted compliance rates as a function of average ambient temperature on the days of the observations for each community. The overall average compliance rate calculated for each community is also presented along with information on the distribution of compliance rates for homes with multiple observations.

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Section 3: Home Heating Survey

During Spring 2023, ADEC conducted a new comprehensive survey of home heating devices and fuel use in the Fairbanks $PM_{2.5}$ nonattainment area. The survey was performed for the SIP revision in order to collect current information on residential space heating practices in Fairbanks, updating the prior SIP surveys conducted in 2011-2015. Key elements and findings from the 2023 Home Heating (HH) survey are summarized below.

Survey Method – Unlike the earlier 2011-2015 HH surveys which were telephone-based, the 2023 survey was conducted using an online survey instrument. This online-based approach was developed in consultation with Hays Research (the Alaska survey firm that had also conducted the earlier surveys) to make the survey more convenient for respondents and to apply dynamic ranges checks (where applicable) to each response as it was entered to reduce anomalous data errors. To incentivize participation, households received mailers prior to the survey with local agency/stakeholder support and offers of a set of prizes (airline miles, gift cards) to be randomly awarded for full completion of the survey.

Survey Sample – The target population was residential households within the nonattainment area. According to the 2020 U.S. Census, there were over 31,000 occupied households within the nonattainment area. An "NG911" emergency address database compiled by the Alaska Geospatial Office as of November 2022 was used to identify residential locations and provide addresses for the pre-survey mailers, which included a web link for participating in the online survey.

Based on the combined 2011-2015 survey sample size of just over 3,000 households, the target sample size for the 2023 survey was set to 3,000. The survey was conducted between March 30 and May 15, 2023, and a total of 2,698 fully or partially completed responses were obtained.

Survey Structure and Content – The structure of the 2023 survey was "tiered" similar to that of the earlier surveys in that a short set of demographic questions were asked along with listing the specific heating devices present in the household. Based on the list of devices present in the household, the survey then branched into a series of additional questions specific to each type of heating device (and fuel), including device type (e.g., woodstove vs. fireplace), fuel usage and recent fuel price paid.

A new question was added to the end of this survey to gain insight on Alert burning behavior. It asked homeowners with solid fuel burning devices to respond to the following:

How many hours do you wait to stop burning after an Air Quality Alert?

The format for responses was – zero, 1, 2, 3, 4, 5-8, 9-12, 13-18, 19-24. A summary of the responses and findings is presented below in Section 4.

Respondent Data Validation – In addition to applying plausible range checks for each response element in the online survey, several multi-field reasonableness and consistency checked were applied to the responses database after the survey was completed. These included:

- Comparing total energy used by the household (based on all heating devices present) to Fairbanks climate-specific residential building heating energy intensity ranges (annual BTU/sq ft) developed from information provided by the Cold Climate Housing Research Center (CCHRC) to ensure that the total heating energy was consistent with the livable dwelling size,
- Reviewing fuel usage, cost, and price data to ensure consistency, and
- Looking at additional data (e.g., model, certification status, etc.) to ensure wood devices were properly categorized.

Based on these post-survey validation checks, a number of responses were found to be either incomplete or had errors in fuel usage, prices or total building heating energy. In some instances, these errors were obvious and easily corrected. When that was not possible, the response was rejected from subsequent use in the SIP emissions inventory. All told, 1,654 responses were identified as complete and valid.

Key Findings and Comparisons to 2011-2015 Survey – The overall findings from the 2023 survey indicated that the fraction of wood devices and wood usage dropped notably from levels found in the 2011-2015 surveys, and though still relatively small the fraction of households heating with natural gas increased significantly from the earlier surveys. These key changes are below in Figure 1, which shows the fractions of respondent estimated wintertime (October-March) heating energy use by device type. As highlighted in red, average household wood device energy usage dropped from 19.2% to 11.7% and natural gas usage increased threefold from 2.4% to 7.6%.

In addition, the fraction of dirtier uncertified woodstoves and fireplace inserts dropped notably from 19.1% in the 2011-2015 surveys to 8.2% in the 2023 survey.

Finally, wood use per device also dropped between the 2011-2015 and 2023 surveys. For woodstoves/inserts, average wintertime cordwood usage decreased from 3.48 cords to 2.31 cords (a 34% reduction). Fireplace wood use also dropped from 2.07 cords to 1.99 cords (a 4% reduction).

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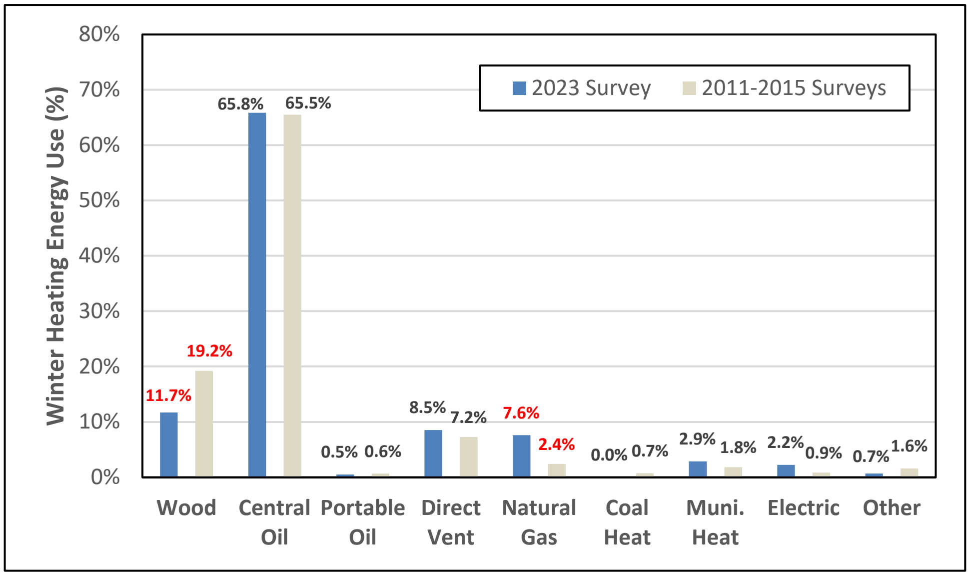
Figure 1
Distribution of Wintertime Household Heating Energy Use by Device



These difference in heating device and fuel usage between 2011-1015 and 2023 are consistent with expected changes due to on-going control programs such as the Borough's Wood Stove Change Out Program and the State's Solid-Fuel Burning Curtailment Program.

The results from the 2023 survey were used to reflect heating device and fuel usage patterns in the nonattainment area for the Space Heating portion of the SIP inventory. Further details regarding the 2023 survey are contained in Appendix III.D.7.06 of the SIP.

###

Section 4: Analysis of TAG and Home Heating Survey Results

Section 4.1 TAG Paired Household Sample

Analysis of the TAG survey results begins with the paired household sample done to determine the consistency of compliance observations made by ECC and ADEC personnel. As described earlier, ADEC personnel followed ECC's route to make their own determinations of compliance. While not made at exactly the same times, the ADEC observations were usually within __ minutes of ECC. It is a reasonable simplification to assume that the actual burning/not burning status of the households was unchanged and that ECC and ADEC observers should make the same determinations.

A total of 64 households in North Pole were visited by the two teams on January 19, 2023, with the results summarized in Table 4-1. For 11 households, ADEC detected signs of wood burning activity that the ECC observers did not detect. While it is not a surprise that two observers could reach a difference conclusion from the same observations, we accept the ADEC observations as being correct in this case because of their experience in surveilling wood burning. This means that ECC misclassified 11 of 39 households at "not burning" for an error of omission rate of 28.2 percent. ECC observed signs of burning in 2 of the 30 household that ADEC classified as "not burning". While this could be a correct result (e.g., a burndown was completed between the observations), to be even-handed, we elected to classify these cases as errors of omission, with a rate of 2 of 30 = 6.7 percent.

Table 4-1. TAG Compliance Results for Paired Household Sample January 19, 2023 in North Pole

Observer	Households	Compliance Determination	
	Total	Burning	Not Burning
ECC	64	25	39
DEC	64	34	30
Difference	—	+11	-9

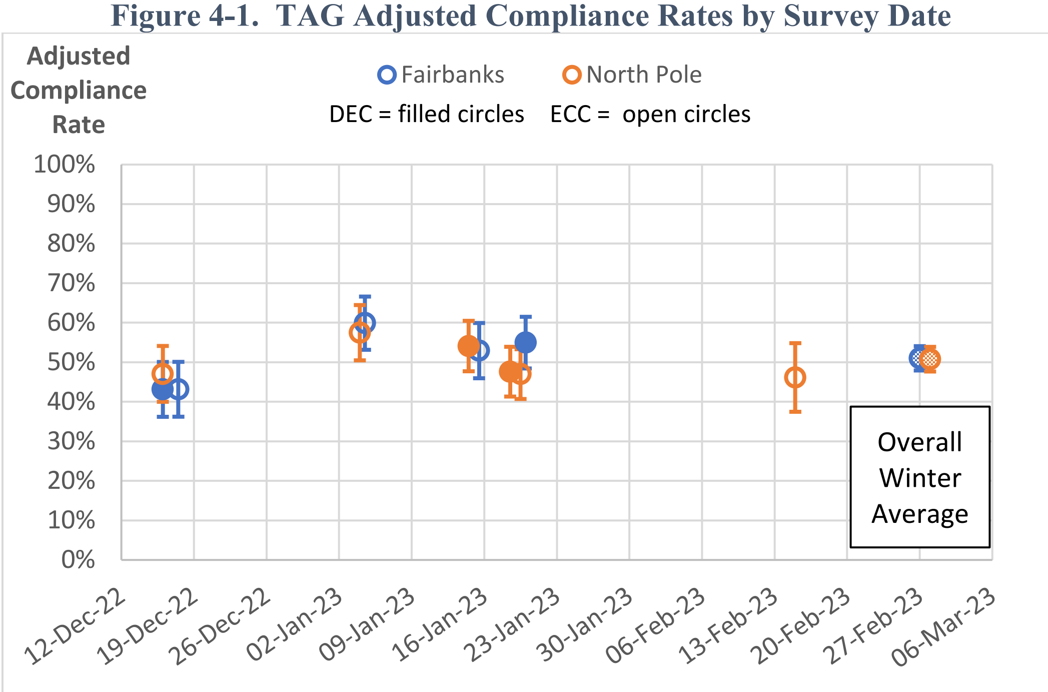
These error rates are used to adjust the aggregate compliance rates observed by the survey teams throughout the winter. For surveys conducted by ECC, 28.2 percent of "not burning" households were reclassified as "burning" before computing the adjusted compliance rate. For surveys conducted by ADEC, 6.7 percent of "not burning" households were reclassified as 'burning" before computing the adjusted compliance rate.

Section 4.2 TAG Adjusted Compliance Rates in Winter 2022-2023

Figure 4-1 presents the adjusted compliance rates by survey date as determined in the Winter 2022-23 TAG survey. Compliance rates are given for Fairbanks (blue circles) and North Pole (orange circles) along with the corresponding error bars (± 1 sigma). Filled circles indicate surveys done by ADEC; open circles indicate ones done by ECC. Table 4-2 (see the next section) gives the data plotted in the figure.

Overall, there is a remarkable consistency of compliance rate results by survey date between ADEC and ECC observers and in Fairbanks and North Pole. In the first survey runs in December 2022, ADEC and ECC reported 43% ± 7% adjusted compliance rates in Fairbanks on December 16th and 17th, respectively, while ECC reported a 47% ± 7% rate in North Pole on December 16th. Similar rates were reported in North Pole in January and February 2023. In contrast, somewhat higher adjusted compliance rates of between 53% and 60% were reported in Fairbanks and North Pole on other survey dates in January. For Winter 2022-2023 overall, the adjusted compliance rate was 51% ± 3% in Fairbanks and 51% ± 3% in North Pole.

Figure 4-1. TAG Adjusted Compliance Rates by Survey Date



Section 4.3 TAG Adjusted Compliance Rates by Ambient Temperature

An effort was made in the TAG survey to run data collection on days that would sample different conditions of ambient temperature. The objective was to test the hypothesis that wood burning behavior and compliance rates vary during the winter in response to environmental conditions.

Wood is the lowest-cost fuel for home heating and the economic impact of switching to fuel oil is greatest on the coldest days.

To test this hypothesis, data on ambient temperatures were assembled from temperature records at FAI Airport in western Fairbanks and Eielson AFB south of North Pole. We do not expect that the decision to burn wood in violation of a curtailment order is one taken hour by hour. Rather, the overall economic gain from avoiding fuel oil use is accrued over the period of hours that an alert is effective. To account for this, an 18-hour average ambient temperature was calculated beginning at 9 pm on the day before and running until 2 pm of the survey day. The 9 pm start gives the homeowner time to consider overnight and next-day temperatures in deciding whether to re-load wood into a stove or other appliance in violation of a curtailment.

Figure 4-3 shows the relationship between the adjusted compliance rates observed and the 18-hour ambient temperatures in Fairbanks and North Pole. A direct relationship is found in which the highest compliance rates are found at and near 0°F with rates trending downward (with scatter above and below the trend line) as the temperature drops. The slope of the trend line is statistically significant at the $p \leq 0.05$ level. The trendline indicates that, on average, one would expect an adjusted compliance rate of 54% at 0°F, which would drop by 4.6% for every 10°F drop in temperature to reach a 40% rate at -30°F. The data used in the graph, along with ambient temperatures reported by the ADEC and ECC observers, are reported in Table 4-2.

Figure 4-3. Relationship of TAG Adjusted Compliance Rate to Ambient Temperature

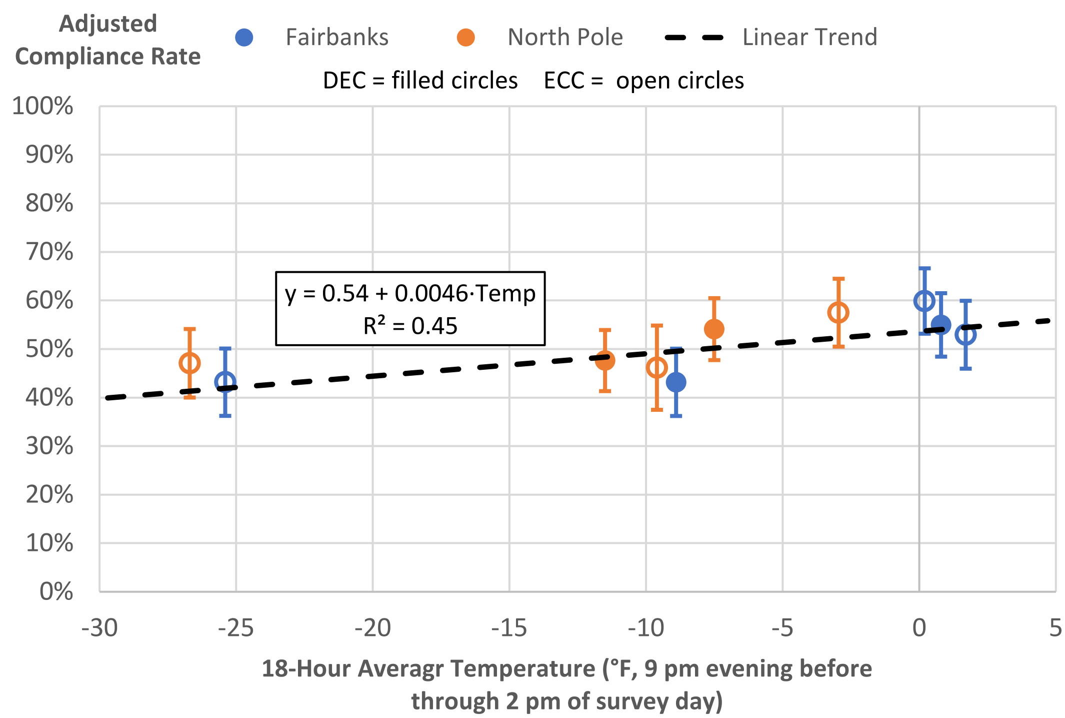


Table 4-2. TAG Adjusted Compliance Rates and Ambient Temperature by Survey Date

	Observer	Observer Reported Temperature (°F)	18-Hr Average Temperature [a/] (°F)	Adjusted Compliance Rate	Std Error
Fairbanks					
12/16/2022	DEC	-8 to -24	-8.9	43%	7%
12/17-18/22	ECC	-6 to -28	-25.4	43%	7%
1/4-5/2023	ECC	-9 to +14	0.2	60%	7%
1/14-17/23	DEC	-8 to +16	1.7	53%	7%
1/20/2023	ECC	-2 to + 8	0.8	55%	7%
North Pole					
12/16/2022	ECC	-25 to -28	-26.7	47%	7%
1/3-5/2023	ECC	-7 to +4	-3.0	57%	7%
1/14/2023	ECC	-17 to +6	-7.5	54%	6%
1/19/2023	DEC [b/]	-12 to -12	-11.5	48%	6%
2/15/2023	ECC	-9 to -12	-9.6	46%	9%

[a/] FAI Airport for Fairbanks and Eielson AFB for North Pol[e]
[b/] Paired Household Sample. ECC results are not reported for this date as they are duplicative of ADEC results.

Section 4.4 The Distribution of TAG Household Compliance Rates

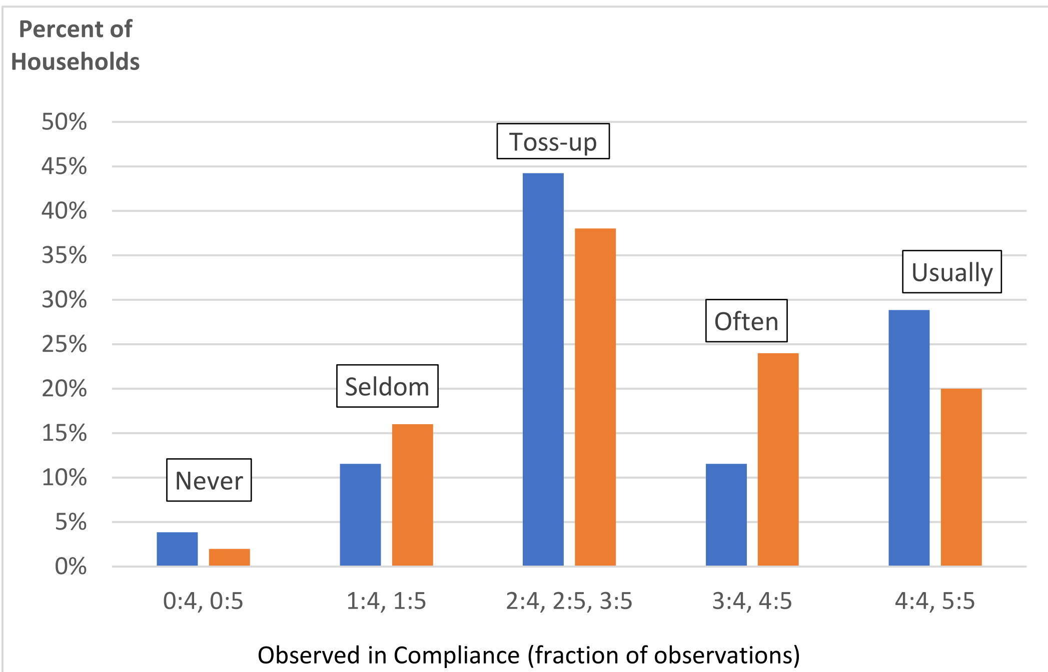
In addition to measuring actual compliance rates in Fairbanks and North Pole, it was hoped that the TAG survey would yield some insight on how consistently households comply with burn-ban orders. To examine this, an adjusted compliance rate was calculated for each of the N=58 households that were surveyed 4 or 5 times. Figure 4-4 presents a histogram of these results.

Two caveats must be noted before considering these results. First, the small number of times (4 or 5) that households were observed leads to discrete binning of results - that is, the number of frequency bins that can be populated. Thus, the frequency of compliance is grouped categorically and given qualitative labels describing the frequency of compliance. Second, the ECC and ADEC error of omission rates are applied across-the-board to all households in calculating the adjusted compliance rate, which means that 100% compliance does not occur in the statistics even though it was observed in the field. To account for this, the categorical groups are translated back to the equivalent of what was observed. For example, a household observed compliant 5 of 5 times in the survey has an imputed adjusted compliance rate of 100*(1.000-0.282) = 71.8 percent. Nevertheless, this is categorized as 5 of 5 in the graph for simplicity but is labeled "Usually" compliant to recognize that the compliance rate in the group would be less than 100 percent.

The most important conclusion to be drawn is that most households comply about one-half the time (the Toss-Up group) or better (Often or Usually). The fraction of households classified as Never or Seldom compliant is the same within statistical errors: 16% in Fairbanks and 18% in North Pole. The Never group was seen to burn wood in all survey visits and is the one group not affected by the adjustment for errors of omission; they account for less than 5 percent of households in Fairbanks and North Pole.

One should not make too much of the apparent differences between the distributions for Fairbanks and North Pole due to the sample size and the caveats associated with the analysis. The one possible difference to note is that Fairbanks appears to fall into two groups to at least some extent: Toss-up (50:50) or Usually. North Pole appears more homogenous in behavior with a smoother trend from Toss-up to Usually.

Figure 4-4. Distribution of TAG Adjusted Compliance Rate among TAG Households Surveyed 4 or 5 Times



Section 4.5 Home Heating Survey (HHS) Responses

A summary of responses to the question about the # of hours homeowners waited to stop burning after an air quality Alert becomes effective is displayed below in Table 4.3. The responses are tabulated to provide a distribution over the 24-hour period following the call of an Alert. Overall, 341 homeowners responded as either complying or not complying out of the 841 wood burning households participating in the survey (a 41% response rate). Out of the 341 responses, 210 answered that they complied with the Alert in the first 3 hours after it was called which is interpreted as complying indicating a compliance rate of 61.6%. The remaining 131 respondents that waited 4 or more hours to comply with the Alert are interpreted as not complying with the Alert. While Alerts are called at different times of the day, they frequently become effective at 4 pm, thus those homeowners waiting 4 or more hours are likely to have loaded their stoves for an overnight burn, thus not reaching compliance the following morning as stoves typically loaded at night have their air reduced to extend the burn time.

Table 4.3. 2022/23 Home Heating Survey Responses

Time After an Alert	Number of Respondents
Zero	153
1 hour	23
2 hours	25
3 hours	9
4 hours	14
5-8 hours	28
9-12 hours	23
13-18 hours	8
19-24 hours	58
Not Answered	494
All Wood Households	835
All Answered Wood Households	341

The value of the Home Heating Survey is that it provides insight into behavior that is not captured by the TAG survey which typically runs from 10 – 2 pm the following morning, which starts roughly 16 hours after an Alert is called.

Section 4.6 Key Findings

In summary the analysis of TAG survey data found:

- Both Fairbanks and North Pole had adjusted compliance rates of 51% ± 3%;
- The compliance rate is temperature dependent with a value of 54% at 0°F and falls by 4.6% for each temperature drop of 10°F;
- There is no compliance difference between the curtailment zones;
- The data suggest that households in Fairbanks fall into 2 main groups – comply ½ time or usually comply;
- In North Pole the largest group is complies ½ time. The remaining compliance tends to either often or usually comply categories; and
- Observations are biased towards daylight hours, which typically span the period of 10 am to 2 pm on the day after an Alert is called.
- These observations capture decisions about whether to continue to load a stove after an Alert was called or to start loading a stove in the morning hours of the day after an Alert is called. Thus, TAG observations provide at best, limited insight into burning behavior during the evening and nighttime period of the preceding day.

The Home Heating Survey provides the following insights:

- 62% of the responding households comply within 3 hours of an Alert being called;
- While compliance is indicated for 4-24 hours after an Alert, it is likely that those homes continue to burn over night;
- Burning behavior is captured during the evening and nighttime period of the day preceding the TAG survey, which records behavior starting roughly 16 hours after an Alert is called.

###

Section 5: 2022/2023 Compliance Rate

Insight into overall compliance behavior requires the melding of observations collected from both surveys. Two scenarios were considered:

- Scenario 1: Do not count the non-answer responses from the Home Heating Survey or proportion them the same as those who answered.

- Scenario 2: Count all non-answer responses as noncompliant.

Both surveys capture behavior in the morning hours on the day after the survey is called. Disentangling the overlap is problematic and difficult to resolve. For this reason, it was decided that the simplest approach would be a 50/50 weighting of the overall compliance rate calculated for each survey. This approach provides the best defense against bias. The compliance rate computed for each scenario is:

- Scenario 1 – HHS (61.6%), TAG (51%), Averaged (56.3%)
- Scenario 2 – HHS (25.2%), TAG (51%), Averaged (38.1%)

The adoption of Scenario 1 would ignore a large number of wood burning households and fail to provide a conservative estimate as the lack of a response could be easily interpreted as a reflection of noncompliance. Thus, it was decided to adopt Scenario #2. This value reduces the SIP 2023 forecast of 45% to 38%. Since the SIP forecast was based on very limited survey data and engineering judgement, the revised value is well grounded and provides a much more defensible estimate of compliance.

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1. Background

The DEC air advisory program is an important element of Alaska's State Implementation Plan to address the wintertime fine particulate problem in the Fairbanks North Star Borough. The use of wood-burning devices (and other solid fuels) for space heating is a major cause of elevated $PM_{2.5}$ levels in winter. The air advisory program helps to address this problem by restricting the use of wood and other solid fuels when $PM_{2.5}$ concentrations are expected to reach levels of 20 to 30 $\mu g/m^3$ (Stage 1) and of 30 $\mu g/m^3$ (Stage 2) for sustained periods.

Once issued, the air advisories prohibit the use of wood and other solid fuels for periods as long as 24 hours after the initial 3-hour grace period expires:

- For Stage 1 Alerts, solid-fuel use is prohibited except in households that operate a certified low-emission wood-burning device or because they have no other adequate source of heat (NOASH).
- For Stage 2 Alerts, solid-fuel use is prohibited in all devices except in NOASH households.

The advisories are issued prospectively in anticipation of elevated $PM_{2.5}$ concentrations based on forecasts of meteorological conditions and the concentration levels observed at BAM monitors located in Fairbanks and North Pole.

The AQ Alert Model is one tool used by DEC air quality staff to assess the need for advisories. First developed more than 10 years ago, the Alert Model retrieves a range of meteorological observations and forecasts for both surface and upper-air conditions. Statistical equations developed from past experience turn the meteorological information into predictions of $PM_{2.5}$ concentrations at the monitors. The predictive performance is monitored for accuracy during the winter and the equations are updated to incorporate new experience after each winter's close.

This document presents a performance assessment for the Alert Model and the DEC air advisory program. It is based on data through Winter 2022-23, the latest winter for which QA/QC'd FRM data are available to quantify the $PM_{2.5}$ concentrations that were encountered. The first section below describes the Alert Model's method for predicting concentrations and documents the accuracy of its predictions when meteorology is known. The following section shows results of the DEC air advisory program for Winter 2022-23 and discusses its successes and occasional misses when issuing Alerts in circumstances when meteorology is *forecast* and not known.

2. Accuracy of the AQ Alert Model

The Alert Model's predictions of $PM_{2.5}$ concentrations are developed from underlying "predictive equations" that represent how a range of behavioral and meteorological variables influence the ambient $PM_{2.5}$ concentrations in the Borough. The dependent variable is the hourly $PM_{2.5}$ concentration recorded by the BAM monitor at each site. While BAM values are not definitive measurements of the ambient concentration, they are the only information available in near-real time to the public and the DEC personnel involved in the advisory program. The information here is taken from the latest update of the predictive equations using data for 5 winters from 2017-18 through 2022-23.

2.1 Accuracy of the Underlying Predictive Equations for $PM_{2.5}$ Concentrations

The specific formulation of the predictive equation varies somewhat by monitor site, but the general form is indicated in Eq. 1 below.

$$
\begin{aligned}
PM_{2.5} = \; & \text{ZeroPt}(w,m) \qquad \text{(Eq. 1)} \\
& + \{ \; f \cdot \text{lag}(PM_{2.5}) + [\; \text{Diurnal}(hr, pan) \cdot E_0(w) \cdot \exp(T_C(w) \cdot \text{Temp}_C) \\
& \qquad / \; \text{InvHt}(\text{Met1}) \;] \\
& \; \} \cdot \text{WSpd}^C \cdot \text{Disp}(\text{Snow})
\end{aligned}
$$

where the indices are: w = winter; m = month of winter; hr = hour of day. Index "pan" indicates that the term contains a pandemic-related effect for Winter 2020-21.

The zero-point terms are simply intercepts that vary by winter and by month during winter (November-March). Beyond these, the ambient concentration (the term in braces) is modeled as the carry-over of a fraction "f" of the concentration from the previous hour plus the concentration produced by particulate emissions in the current hour (the term in braces). These concentrations are reduced due to dispersal by winds (as a function of the wind speed) and by the presence of snow, which tends to lift the base of the surface inversion.

The bracketed term follows a box model formulation in which the numerator is proportional to the mass of particulate emissions and the denominator estimates the vertical height of the surface inversion at the monitor site. The surface area of the box is the area of influence around each monitor, although it is not known or estimated. Ambient temperature Temp_C is used to estimate the rate at which particulates are emitted by home-heating devices and other sources. The response coefficient T_C varies by winter to account for time trends in the inventory and behavioral choices such as the mix of wood versus fuel oil used in home heating. The denominator estimates the inversion height based on a multivariate variable created using Principal Components Analysis. Met1 measures the strength of the classic radiation-induced surface inversion under clear skies. Other such Met variables may be used as well.

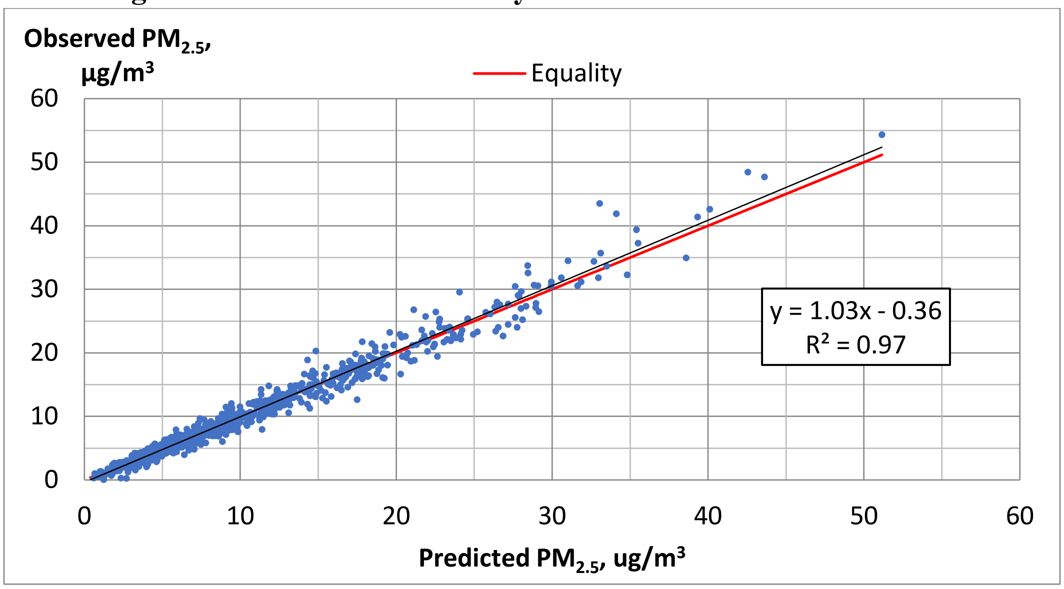
A diurnal term represents the hourly pattern of particulate emissions and concentrations, which was found to differ during the pandemic winter (2020-21) as many people worked from home. The diurnal term can differ by monitor site depending on the mix of sources. For example, the Hurst Rd model a pure space-heating model, in which the diurnal term follows the typical daily pattern of when wood devices are fired, reloaded, and burn down. For NCORE, which is located near a major roadway, the diurnal pattern is more closely related to the daily pattern of travel to and activity in downtown Fairbanks.

A statistical analysis is conducted following the end of each winter to incorporate that winter's experience into the predictive equations. The prior winter plus as many as 4 preceding winters are included. Once re-estimated, the predictive models are exercised to predict $PM_{2.5}$ concentrations for the historical winters and evaluated for performance and accuracy as shown below.

Fairbanks

The most basic measure of predictive performance is the comparison of observed versus predictive values for the dependent variable. For purposes of this presentation, the hourly BAM $PM_{2.5}$ concentrations predicted by the equations have been combined into 24-hour averages for calendar days. As Figure 1 shows, the predictive equation for the NCORE monitor is a highly accurate representation of $PM_{2.5}$ concentrations over the 5 winters. Observed 24-hour averages differ only slightly from the predictions, with a small offset (intercept) and a slope within 3% of equality. There is a scatter of ± 9% in the predictions.

Figure 1. Fairbanks: Accuracy of Predictive Model for NCore

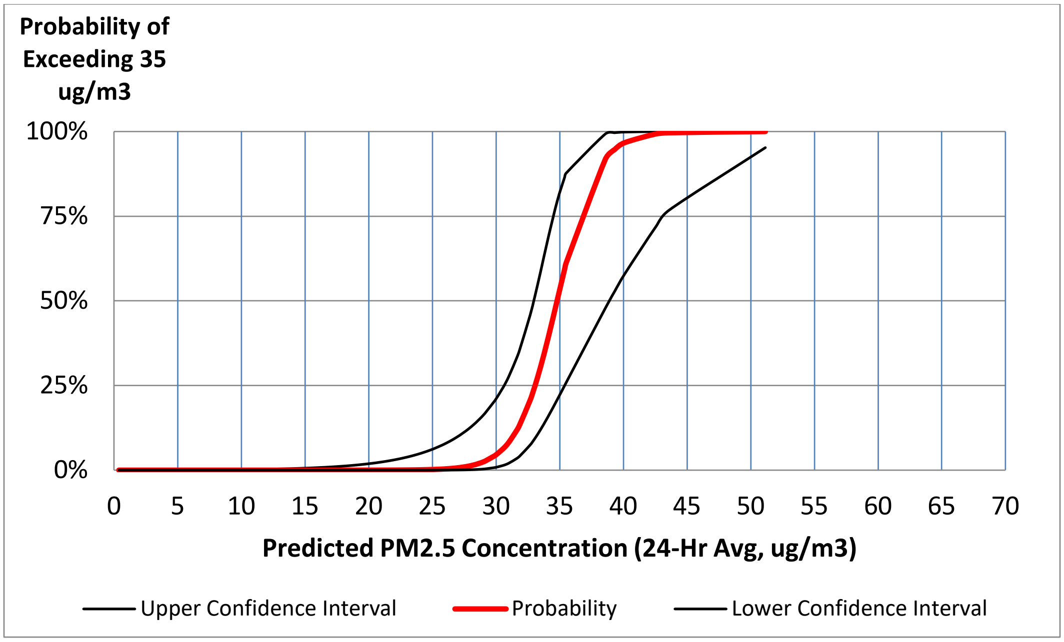


For days with concentrations above the 24-hour standard of 35 µg/m^3, there is a tendency for the observed concentrations to be higher than the predicted values as only 1 of the 8 daily values falls below the line. There are infrequent circumstances affecting NCORE in which airflow over the ridge line immediately to the north skates over (decouples from) the bowl of cold dense air established over the downtown area, capping the surface inversion and increasing $PM_{2.5}$ concentrations. Several attempts have been made to account for this phenomenon in the predictive equations, but without success, as it has proven difficult to identify variables that predict the onset of decoupling. This is the chief limitation of the predictive equation for NCORE and makes it difficult for the Alert Model to distinguish elevated concentrations warranting a Stage 1 Alert from the higher levels that would warrant a Stage 2 Alert and could lead to an exceedance.

By comparing the observed daily $PM_{2.5}$ values to those predicted by the underlying equations, a "switching curve" can be developed to show how the probability of an exceedance varies with predicted $PM_{2.5}$ level itself. As Figure 2 shows, the predictive equation for NCORE exhibits nearly unbiased behavior in predicting the probability of an exceedance. When a concentration of 35 μg/m^3 is predicted, there is a 50:50 chance that an exceedance will occur. This is an unavoidable statistical result since the random errors of the prediction will be both positive and negative.

The sensitivity of the prediction is shown by the slope of the curve near 35 μg/m^3. When the predicted concentration is 30 μg/m^3, one can be highly confident that no exceedance will occur, while the reverse is true at concentrations of 40 μg/m^3 or higher. Overall, this is excellent performance as the basis for issuing advisories.

Figure 2. NCORE: Probability of Exceeding the 24-Hour $PM_{2.5}$ Standard



Finally, the occurrence of errors of omission and commission can be evaluated, as shown in Table 1. Over the period of 5 winters from 2017-18 through 2022-23, there were 761 days in which the NCORE equation predicted that no exceedance of the 24-hour standard would occur. This was correct 99% of the time. On only 4 days did an exceedance occur when the equation predicted otherwise. Conversely, the NCORE equation predicted an exceedance to occur on seven occasions over the 5 winters, which was correct in 6 of the 7 cases (86% of the time). As noted above, even a perfect model will miss one-half the time when its prediction equals the 24-hour standard. The level of performance shown here is excellent.

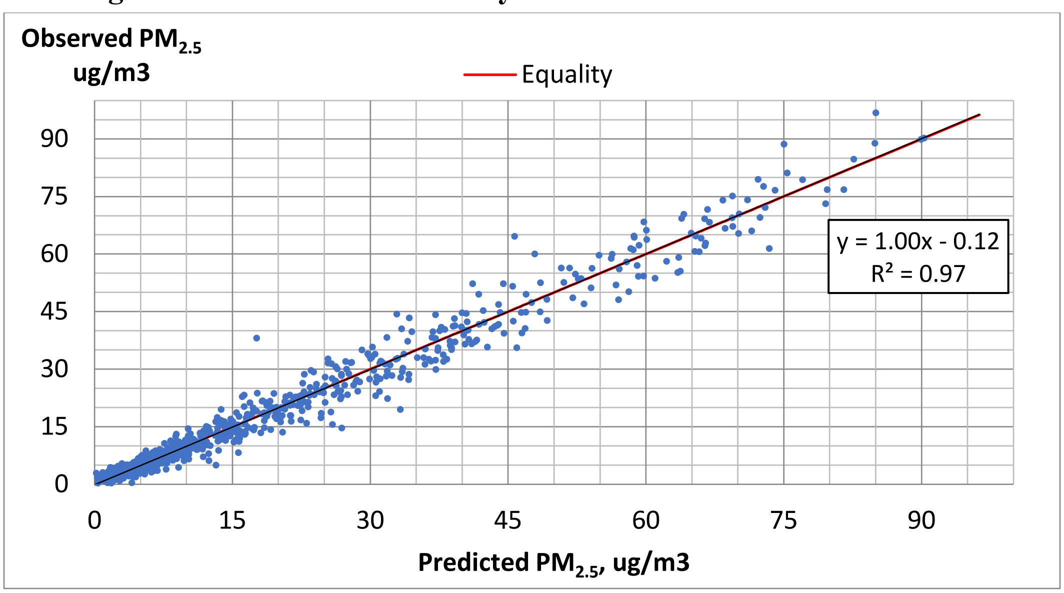
Table 1. Accuracy in Predicting Exceedances of 24-Hour $PM_{2.5}$ Standard.
(5 Winters from 2017-18 through 2022-23. NCore Site in Fairbanks.)

	Number of Days	Percentage	Result
No Exceedance Predicted by Model	761		
$PM_{2.5} < 35$ µg/m^3	757	99%	Correct Prediction
Did Exceed	4	1%	Error of Omission
Exceedance Predicted	7		
$PM_{2.5} \geq 35$ µg/m^3	6	86%	Correct Prediction
Did not Exceed	1	14%	Error of Commission

North Pole

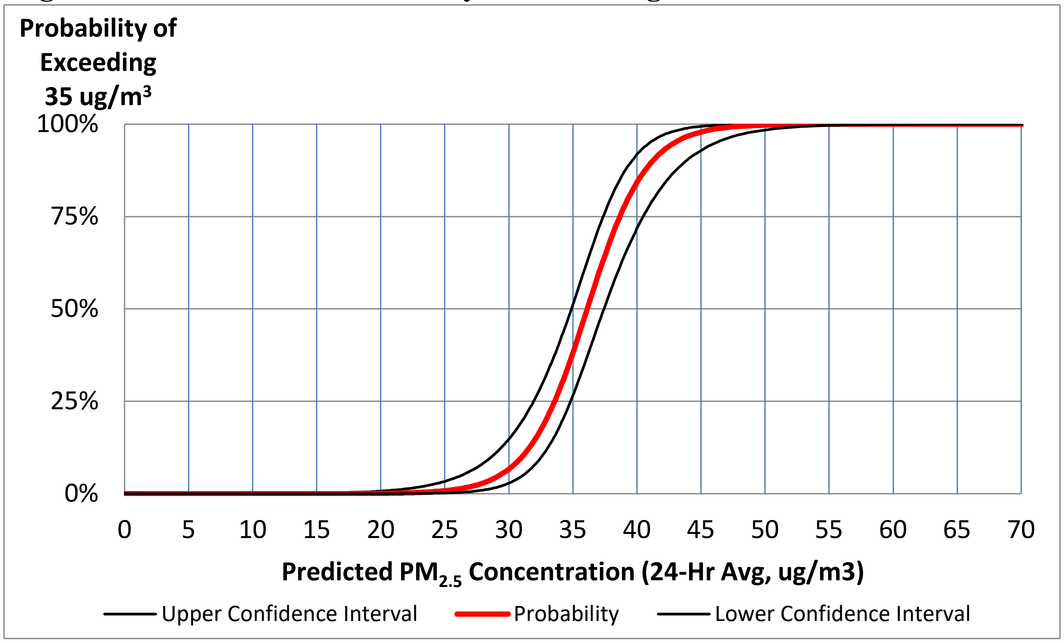
A similar level of performance is seen in the predictive model for Hurst Rd in North Pole. As Figure 3 shows, the observed 24-hour average $PM_{2.5}$ concentrations are essentially equal on average to the predictions of the Hurst Rd model. There is a scatter of ± 8% in the predictions compared to ± 9% for the NCore model.

Figure 3. North Pole: Accuracy of Predictive Model for Hurst Rd



As Figure 4 shows, the switching curve for its prediction of exceedances displays a small upward bias. A predicted value of 36 µg/m^3 is needed to have a 50:50 chance that an exceedance will occur. The sensitivity of prediction is also good. At a predicted concentration of 30 µg/m^3, there is a 7 percent chance that an exceedance will occur, while at a prediction of 40 μg/m^3 there is an 84 percent chance of exceedance.

Figure 4. North Pole: Probability of Exceeding the 24-Hour $PM_{2.5}$ Standard



North Pole has substantially higher $PM_{2.5}$ concentrations than NCORE and many more days when the 24-hour standard is exceeded. Nevertheless, the predictive performance of the Hurst Rd model is excellent (see Table 2, next page). It was correct on 99% of days when no exceedance was predicted (a 1% rate for errors of omission) and on 91% of days when an exceedance was predicted (a 9% rate for errors of commission). Of the 137 days on which an exceedance actually occurred, the Hurst model predicted an exceedance for 129 days or 94% of the time. As for the NCORE model, this is excellent performance as the basis for issuing advisories.

2.2 Use of Alert Model in a Subsequent Winter

The foregoing discussion examined the performance of the predictive models in the most favorable circumstances: the predicted $PM_{2.5}$ concentrations are based on the meteorology that actually occurred using the dataset on which the statistical models were estimated. This level cannot be achieved in the real world when the Alert Model is used in a subsequent winter. Instead, it will be applied in circumstances where behavioral factors may have changed (e.g., due to changes in the price of wood versus home heating oil) and the meteorological conditions are forecast, but not known.

Several steps are taken by DEC to maximize the performance of the Alert Model in such circumstances. First, a calibration analysis is conducted in November once elevated $PM_{2.5}$ concentrations begin to be observed. The analysis compares the model's $PM_{2.5}$ predictions to what was actually experienced in the new winter to date. If predictions are found to deviate from

Table 2. Accuracy in Predicting Exceedances of 24-Hour $PM_{2.5}$ Standard.
(5 Winters from 2017-18 through 2022-23. Hurst Site in North Pole.)

	Number of Days	Percentage	Result
No Exceedance Predicted by Model	623		
$PM_{2.5} < 35\ \mu g/m^3$	615	99%	Correct Prediction
Did Exceed	8	1%	Error of Omission
Exceedance Predicted	142		
$PM_{2.5} \geq 35\ \mu g/m^3$	129	91%	Correct Prediction
Did not Exceed	13	9%	Error of Commission

the accumulated experience (whether high or low), calibration factors are developed and input to the model to scale the underlying predictive equations to be better estimators for the current winter. The calibration exercise can be repeated at any time if there are indications of a misfit between predicted and observed concentrations. This work minimizes the error that could otherwise be caused by changes in consumer behavior.

Although they can be issued whenever needed, air advisories typically are issued at 2 pm in the afternoon, so that the prohibition on solid fuel use becomes effective by 5 pm, and may run either overnight to the next morning or for a 24-hour period. The former may be done early or late in the winter when a surface inversion is forecast to set up overnight, but to break down the next afternoon. The latter is more common throughout the winter and is done whenever meteorological conditions are expected to sustain a surface inversion through a 24-hour period.

By necessity, DEC staff must work with weather forecasts and without the benefit of knowing the meteorological conditions that actually will occur. The staff member primarily responsible for issuing air advisories is a meteorologist who has long experience in using met forecasts to guide operational decisions not only from his work at DEC but also during his prior military career. His practice is to exercise each of the several met forecasts available to the Alert Model to look for consensus or divergence in the met outlook. He may also consult outside sources of information on the synoptic (regional) weather patterns.

These weather forecasts are available to the Alert Model:

- The National Blend of Models, which is the flagship product of the National Weather Service (NWS) derived from a mix of US and foreign weather model forecasts.
- The Global Forecast System (GSF), which is the US global weather model.

- The North American Model (NAM), which represents North American at a finer spatial resolution than GFS.
- The zonal forecast prepared by the Fairbanks NWS Forecast Office.

All of the forecasts are individually tailored for Fairbanks or North Pole. For the first three, the forecasts are specific to Fairbanks International Airport (for Fairbanks) and Eielson Air Force Base (for North Pole), while the last is tailored to the NCORE and Hurst Rd monitor locations.

Weather conditions are inherently variable and not possible to predict with complete confidence. In much of the winter, weather conditions are sufficiently adverse that one can be confident of elevated concentrations; the uncertainty involves how high concentrations will go. In other circumstances, the uncertainty may be related to when a break in adverse conditions will occur, for example by the passage of a storm front, and cause a drop in concentrations. In a few cases, the uncertainty may be related to whether air flows will penetrate to the surface to influence the inversion, such as the decoupling of northerly airflows over the downtown area or the southerly Chinook winds that originate at the Alaska Range. Such uncertainties introduce the chance of error in the advisory process, whether of omission or commission, that cannot be completely avoided.

Human behavior can also contribute to error, particularly around the major holidays. Increased time spent at home during holidays and increased use of fireplaces and wood stoves for comfort can temporarily increase particulate emissions and $PM_{2.5}$ concentrations above what the predictive models would indicate. Fireworks during New Years is another example. Efforts have been made in the past to incorporate adjustments to the predictive models for major holidays, but without much success. The impact of holiday-related wood-use changes has not proven to be consistent year to year and firework displays may or may not influence recorded $PM_{2.5}$ concentrations depending on whether and where they are held.

3. DEC Advisories in Winter 2022-23

To complement the discussion of the Alert Model's predictive accuracy, this section examines the air advisories issued in Winter 2022-23 and contrasts them to the $PM_{2.5}$ concentrations that occurred. The discussion provides context on the levels of $PM_{2.5}$ that are experienced in Fairbanks and North Pole and insight into the complexity of managing the advisory program.

Ambient $PM_{2.5}$ concentrations are officially measured using the Federal Reference Method (FRM), in which a sample air stream is drawn through a fabric filter for 24 hours and then subsequently weighed in a laboratory. The FRM measurements are the basis for determining whether the 24-hour standard of 35 $\mu g/m^3$ has been exceeded and are used here to indicate the $PM_{2.5}$ levels that are experienced in Fairbanks and North Pole. Although nominally taken every day, there are days in which the FRM measurement was not taken, was incomplete or otherwise not valid.

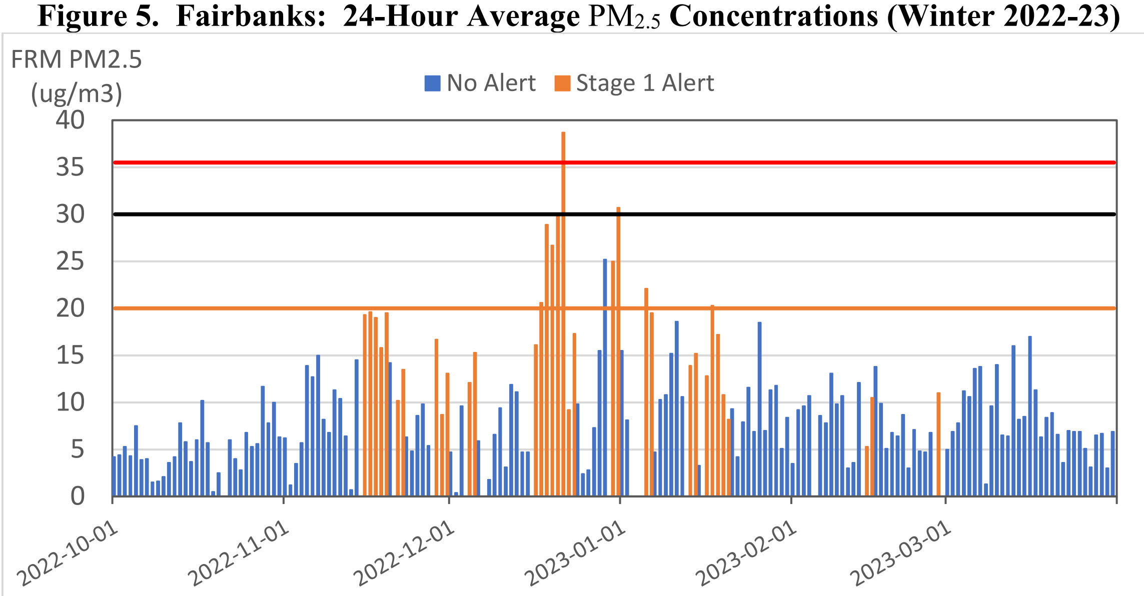
Because they are the only near-real time indicator of $PM_{2.5}$ concentrations, hourly BAM values are also used in the discussion. BAM values are the only information on $PM_{2.5}$ concentrations known to the public and to DEC air quality staff when advisories are issued. BAM values will differ from the official daily FRM values, although they can be correlated to the FRM with some confidence. Because the discussion uses both FRM and BAM data, the type of $PM_{2.5}$ value is clearly labeled in the exhibits.

A Stage 1 Alert is issued when concentrations are expected to range between 20 and 30 μg/m^3, while a Stage 2 Alert is issued when concentrations are expected to exceed 30 μg/m^3. EPA classifies air quality as "good" when concentrations do not exceed 50% of the applicable standard or 17.5 μg/m^3 for $PM_{2.5}$. Air quality is classified as "moderate" when the concentrations range from 50 to 100% of the standard and "unhealthy for sensitive groups" when 100 to 150% of the standard. Stage 1 advisories air issued when concentrations may reach as much as 85% of the standard, a level sometimes termed "high moderate". Stage 2 advisories are issued when concentrations are expected to exceed 85% of the standard on a sustained basis and be in excess of the standard for periods of time and, thus, be unhealthy for some people.

3.1 Fairbanks

Figure 5 shows the FRM-based 24-hour average $PM_{2.5}$ concentrations experienced during Winter 2022-23. Each day is colored based on whether a Stage 1 Alert was in effect for all or part of the day. Days without alert are colored in blue, while days with a Stage 1 Alert are in orange. No Stage 2 alerts were issued for Fairbanks that winter.

Figure 5. Fairbanks: 24-Hour Average $PM_{2.5}$ Concentrations (Winter 2022-23)



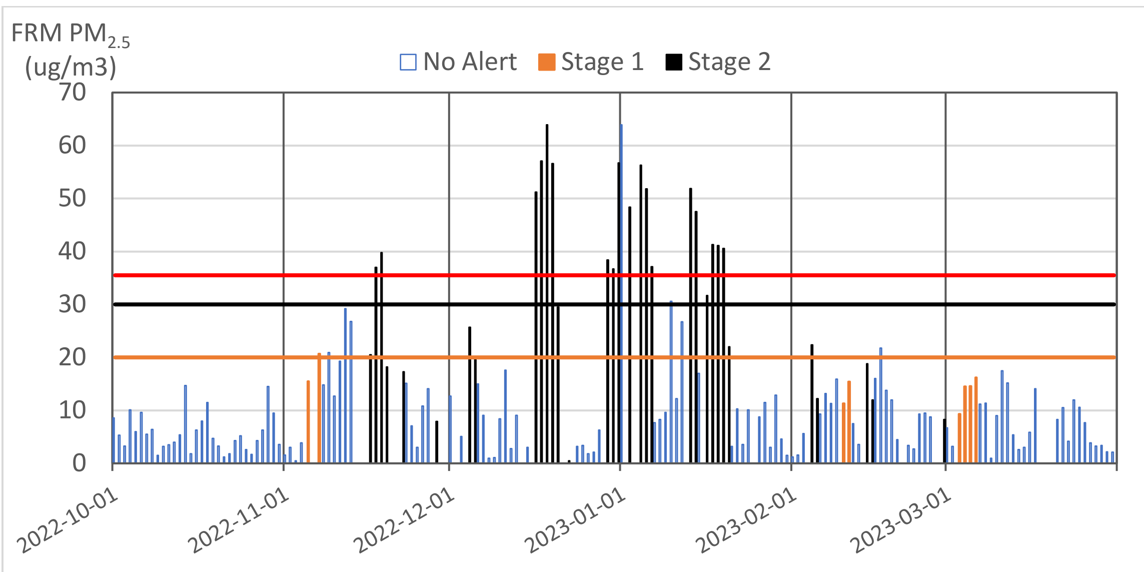
Of the many days without an advisory in effect at any time, only 3 days exceeded 17.5 μg/m^3 (as measured by the FRM) putting them into the realm of "moderate" air quality. Only 1 day exceeded the 20 μg/m^3 level for issuance of a Stage 1 alert. That one day appears simply to be a "miss" as will happen from time to time. Otherwise, the Advisory process performed well in differentiating days with good air quality from those with moderate or "high moderate" air quality.

A total of 33 days had a Stage 1 Alert in effect for all or part of the day. The partial restrictions on wood use were helpful in holding $PM_{2.5}$ concentrations to or below the 20 μg/m^3 level on most of those days. Starting December 16th, a period of severe weather led to Stage 1 Alerts for 8 consecutive days. $PM_{2.5}$ concentrations were held to ≤ 30 μg/m^3 on all but two days, with the winter's only exceedance of the 24-hour standard recorded on December 21st. In retrospect, the conditions of that day warranted a Stage 2 Alert, but neither the actual conditions nor the resulting FRM values were known to DEC in advance. Overall, these results indicate very good performance by the DEC advisory process under real-world conditions.

3.2 North Pole

A very different situation existed in North Pole during Winter 2022-23. $PM_{2.5}$ concentrations were much higher, many Stage 2 Alerts were issued, and a number of exceedances of the 24-hour standard occurred. Figure 6 demonstrates this using FRM data, with the days colored according to the air advisory in effect. Days without alert are colored in blue, while days with a Stage 1 Alert are in orange, and days with Stage 2 alerts are in black. Of the 182 days that winter, 11 had a Stage 1 Alert and 39 had a Stage 2 Alert for all or part of the day. In total, wood-burning restrictions were in effect on 50 of the 182 days (28%).

Figure 6. North Pole: 24-Hour Average $PM_{2.5}$ Concentrations (Winter 2022-23)



Stage 1 Alerts were generally effective at holding $PM_{2.5}$ concentrations at or below 20 μg/m^3, although there are several instances in which concentrations rose into the 20 to 30 μg/m^3 range without a Stage 1 advisory being issued. There are 3 such days in November, although one barely reaches the level. There are 3 more in January and one in February. A major challenge in forecasting $PM_{2.5}$ levels in North Pole is that concentrations can build very rapidly when adverse meteorological conditions set up. If the Alert Model predicts that concentrations will approach but not reach 20 μg/m^3, the forecasted weather conditions need turn only slightly more severe to push actual concentrations above the 20 to 30 μg/m^3 range. All but one of the missed opportunities appear to be of this kind.

The larger number of Stage 2 Alert were associated with a range of $PM_{2.5}$ levels. Of the 39 days with Stage 2 Alerts in effect for all or part of the day, 24 of the days (62%) experienced $PM_{2.5}$ concentrations in excess of 30 μg/m^3 as measured by the BAM. The FRM data confirm concentrations above 30 μg/m^3 for 19 of those days and indicate that 18 days exceeded the 24-hour standard[1]. Of the remaining 15 days with Stage 2 Alerts in effect, the $PM_{2.5}$ concentrations experienced fell within the 20 to 30 μg/m^3 on 10 days and below 20 μg/m^3 on 5 days as measured by the BAM. The FRM data confirm that $PM_{2.5}$ concentrations we below the 30 μg/m^3 level for Stage 2 Alerts on 13 of the days. The Stage 2 Alert days with concentrations below 30 μg/m^3 reflect a mix of outcomes ranging the wood-burning restrictions holding down emissions and concentrations to errors of commission in which the adverse met conditions did not develop to the extent forecast.

Of the missed opportunities, one occurred on January 1st when the FRM recorded a 24-hour average of 63.9 μg/m^3. This level exceeds the 24-hour standard and is more than high enough to warrant a Stage 2 Alert. We believe this event to be the result of a New Year's fireworks display that was held close enough to the Hurst Rd monitor to exert a significant influence on measured concentrations. As has been explained, the Alert Model does not account for behavioral factors that may (or may not) occur on major holidays and does not provide a basis for issuing air advisories events (such as fireworks displays) that may have a temporary impact on air quality.

Given that meteorological conditions are only forecasts when air advisories are issued, it is not possible for the DEC program to operate without occasional "misses", whether they are errors of omission (not issuing an advisory when one later proves to be needed) or errors of commission (issuing an advisory that later proves not to be needed). This inherent difficulty is compounded by the tendency of $PM_{2.5}$ concentrations in North Pole to be highly volatile when adverse meteorological conditions set up and break down. We believe the results presented here indicate very good performance by the DEC advisory process under real-world conditions.

4. Summary

The AQ Alert Model is one tool used by DEC air quality staff to assess the need for advisories. It retrieves a range of meteorological observations and forecasts for both surface and upper-air conditions and uses statistical equations developed from past experience turn the meteorological information into predictions of $PM_{2.5}$ concentrations at the monitors. The performance assessment presented here shows that both the Alert Model and the DEC air advisory program perform well.

Judged against 5 winters of historical data from 2017-18 through 2022-23, the Alert Model predicts the 24-hour average $PM_{2.5}$ concentration accurately to within ±8-9 percent of the observed values and without bias when actual meteorology is known. During winter, it uses forecasts of meteorological conditions to predict $PM_{2.5}$ concentrations 1 to 3 days ahead. Comparison of the air advisories issued in Winter 2022-23 to FRM measurements show very good performance by the DEC advisory process under real-world conditions. The Alerts issued correspond closely with the $PM_{2.5}$ levels actually encountered and there were very few instances when levels were significantly under-estimated or an advisory was missed (should have been issued but was not).

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[1] Valid FRM data are not available for every day of the winter. Of the 24 days, 3 did not have a valid FRM measurement and 2 had FRM measurements below 30 ug/m3.