

# Condition of Environment – Air Indicators

## Data Analysis/Visualization Methodology

### 1 NO<sub>2</sub>, SO<sub>2</sub>, O<sub>3</sub>, and PM<sub>2.5</sub> Indicators

#### 1.1 Data Source

Data used in the data analysis and visualization is from Alberta’s long-term air quality monitoring network, which is publicly available through the Alberta Air Data Warehouse at <https://www.alberta.ca/access-air-data>.

##### 1.1.1 Limitations of the Dataset

The spatial coverage of the current long-term monitoring network is concentrated in central and northeastern Alberta and the majority of stations are located in/near communities. Therefore, data is not available for all parts of the province. The types and number of monitoring stations used for each indicator are given below:

- **NO<sub>2</sub>**: 60 monitoring stations met completeness criteria for annual average and peak NO<sub>2</sub> in 2023.
  - 36 Community monitoring stations, 12 Regional monitoring stations, and 12 Near Industrial Facility monitoring stations.
- **O<sub>3</sub>**: 46 monitoring stations met completeness criteria for annual average and peak O<sub>3</sub> in 2023.
  - 34 Community monitoring stations, 9 Regional monitoring stations, and 3 Near Industrial Facility monitoring stations.
- **PM<sub>2.5</sub>**: 51 monitoring stations met completeness criteria for annual average and peak PM<sub>2.5</sub> in 2023.
  - 34 Community monitoring stations, 9 Regional monitoring stations, and 8 Near Industrial Facility monitoring stations.
- **SO<sub>2</sub>**: 66 monitoring stations met completeness criteria for annual average and peak SO<sub>2</sub> in 2023.
  - 32 Community monitoring stations, 14 Regional monitoring stations, 17 Near Industrial Facility monitoring stations, and 3 Local Issues monitoring stations.

#### 1.2 Annual Average and Peak Metric Calculations

The annual average and peak metrics for the indicators were calculated for each continuous ambient air monitoring station in Alberta’s long-term air monitoring network using the statistical forms shown in Table 1. All indicator metrics, except O<sub>3</sub> annual average, are derived from the Canadian Ambient Air Quality Standards (CAAQS) metrics and follow the calculation methodology detailed in the Guidance Documents for each pollutant published by the Canadian Council of Ministers of Environment (CCME) (CCME, 2012; 2020a; 2020b; 2021).

Table 1: Statistical form for the annual average and peak metrics for each pollutant.

Metric	Parameter	Statistical Form
Annual Average	NO <sub>2</sub>	annual average of all valid hourly data in a year
	SO <sub>2</sub>	annual average of all valid hourly data in a year
	PM <sub>2.5</sub>	annual average of all valid daily average values in a year
	O <sub>3</sub>	Annual average of all valid daily maximum 8-hour rolling average concentrations
Peak	NO <sub>2</sub>	annual 98 <sup>th</sup> percentile of the daily maximum 1-hour average concentrations
	SO <sub>2</sub>	annual 99 <sup>th</sup> percentile of the daily maximum 1-hour average concentrations
	PM <sub>2.5</sub>	annual 98 <sup>th</sup> percentile of the daily 24-hour average concentrations
	O <sub>3</sub>	annual 4 <sup>th</sup> highest daily maximum 8-hour rolling average concentrations

### 1.2.1 Data completeness criteria used in the calculation of each metric:

- **NO<sub>2</sub>:**
  - Daily maximum = at least 75% valid hours in a day, except if the daily maximum based on the available hours exceeds 60 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the year and 60% in each quarter, except if the 98<sup>th</sup> percentile based on the available daily maximums exceeds 60 ppb, then the year is included.
  - Annual average = at least 75% valid hours in a year and 60% valid hours in each quarter, except if the annual average exceeds 17 ppb and at least 50% valid hours are available in each quarter.
- **SO<sub>2</sub>:**
  - Daily maximum = at least 75% valid hours in a day, except if the daily maximum based on the available hours exceeds 70 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the year and 60% in each quarter, except if the 98<sup>th</sup> percentile based on the available daily maximums exceeds 70 ppb, then the year is included.
  - Annual average = at least 75% valid hours in a year and 60% valid hours in each quarter, except if the annual average exceeds 5 ppb and at least 50% valid hours are available in each quarter.
- **PM<sub>2.5</sub>:**
  - Daily average = at least 75% valid hours in a day.
  - Peak value = at least 75% valid daily averages in a year and 60% in each quarter
  - Annual average = at least 75% valid daily averages in a year and 60% in each quarter.
- **O<sub>3</sub>:**
  - 8-hour rolling average = at least 75% of hours in 8-hour period.
  - Daily maximum = at least 75% of valid 8-hour rolling averages in a day, except if the daily maximum based on the available hours exceeds 62 ppb, then the daily maximum is retained in the calculation.
  - Peak value = at least 75% valid daily maximums in the combined 2<sup>nd</sup> and 3<sup>rd</sup> quarter of the year, except if the 4<sup>th</sup> highest value based on the available daily maximums exceeds 62 ppb, then the year is included.
  - Annual average = at least 75% valid daily maximums in the combined 2<sup>nd</sup> and 3<sup>rd</sup> quarter of the year.

## 1.3 Time Series Graphs

### 1.3.1 All Indicators

Provincial average = for each year, the annual average/peak concentration was averaged across all stations in the long-term air quality monitoring network that monitored a valid annual average/peak concentration.

10<sup>th</sup> and 90<sup>th</sup> percentiles = for each year, the 10<sup>th</sup> and 90<sup>th</sup> percentile in annual average/peak concentration across all stations in the long-term air quality monitoring network monitoring a valid metric were calculated.

Results for major population centres = The average concentration across all stations in a given large population centre (Calgary, Edmonton, Fort McMurray, Grande Prairie, Lethbridge, Medicine Hat, and Red Deer) was calculated to give one averaged concentration value for each city each year. All stations in the long-term air quality monitoring network within the municipal boundaries of the city were included in each spatial average.

### 1.3.2 For SO<sub>2</sub> Indicator only

The average concentration across each station type (Community, Near Industrial Facility, and Regional) were calculated to give one averaged concentration value for each station type each year. For more information on the monitoring station types see the "Five-year provincial air quality and deposition monitoring, evaluation and reporting (MER) plan (2021-2025)" (Aklilu, et al., 2021).

## 1.4 Trend Estimates

Trends in annual average/peak concentrations were estimated for each indicator using the openair package (Carslaw and Ropkins, 2012) in R (R Core Team, 2024) and TheilSen function therein. For information on this package and function, see the OpenAir user manual at [https://bookdown.org/david\\_carslaw/openair/](https://bookdown.org/david_carslaw/openair/). For NO<sub>2</sub>, SO<sub>2</sub>, and O<sub>3</sub>, trend estimates for the provincial average and large population centres were calculated beginning in 2000 or the earliest date with monitoring data using the annual average/peak concentration and required at least 10 years of data.

Trends in more recent years (2014-2023) for monthly average concentrations of NO<sub>2</sub>, SO<sub>2</sub>, and O<sub>3</sub> were estimated using the methodology outlined in Nunifu and Fu (2019). Two trend estimation approaches were used:

1. Non-parametric approach where the Theil-Sen and Mann-Kendall methods are used to estimate trend and test for significance.
2. Parametric approach where linear regression is used to estimate trend and the generalized autoregressive conditional heteroscedasticity (GARCH) method is used to estimate the standard error to test the null hypothesis that the estimated trend is not statistically significant.

The 10-year monthly average trend results are provided in the maps in Figures 1a and 1b on the NO<sub>2</sub> and SO<sub>2</sub> indicator webpages and Figure 1 on the O<sub>3</sub> indicator webpage. These results can be viewed for each station when the station's symbol is selected. The threshold to report a significant trend was a p-value <0.05.

## 1.5 Seasonal variation bar plots for PM<sub>2.5</sub> and O<sub>3</sub>

Monthly average concentration from each station monitoring during the year(s) included in the bar plot were included. The data completeness criteria for monthly average concentration calculation was at least 50% of hourly data available in a given month. The median value of the monthly average concentrations across all stations is represented by the bar in the plot, while the maximum value across all monthly average concentrations is shown with the whisker extending from the top of each bar.

## 1.6 Comparison to Alberta's Ambient Air Quality Objectives

Comparison to Alberta's Ambient Air Quality Objectives (AAQOs) followed the rounding and comparison rules stipulated in Section 3.1.2 of the "Air Monitoring Directive Chapter 9: Reporting" (Alberta Environment and Parks [AEP], 2016). For a summary of the AAQOs in effect in Alberta and used in this assessment, see the "Alberta Ambient Air Quality Objectives and Guidelines 2024" (Alberta Environment and Protected Areas, 2024).

## 1.7 References

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- Carslaw DC, Ropkins K. (2012). "openair — An R package for air quality data analysis." *Environmental Modelling & Software*, 27–28(0), 52–61. ISSN 1364-8152, doi: 10.1016/j.envsoft.2011.09.008.
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R Core Team. (2024). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>.

## 2 Wildfire Smoke Indicator

### 2.1 Data Sources

#### 2.1.1 Wildfire Burn Area

Estimated wildfire burn area for Canadian jurisdictions (1990 to 2023) was accessed from the National Forestry Database at <http://doi.org/10.5281/zenodo.3690046>. Data for United States jurisdictions (2002 to 2023) was accessed from the National Interagency Fire Centre at <https://www.nifc.gov/fire-information/statistics>.

#### 2.1.2 Trend Estimates

Trends in annual area burned in Alberta were calculated beginning in 1990 using the openair package (Carslaw and Ropkins, 2012) in R (R Core Team, 2024) and TheilSen function therein. For information on this package and function, see the OpenAir user manual at [https://bookdown.org/david\\_carslaw/openair/](https://bookdown.org/david_carslaw/openair/). The threshold to report a significant trend was a p-value <0.05.

#### Limitations of the datasets:

- Different jurisdictions might vary in their reporting of area burned due to differences in land use, among others.
  - For example, Alberta reports area burned within the province's Forest Protection Area, while Saskatchewan reports area burned data under the Intensive Protection Zone.
- U.S. data from the National Interagency Fire Center is only available from 2002 onward. Additionally, U.S. data beyond 2018 does not include prescribed burns (which are not expected to be significant in size).

*Note: Megafires are fires greater than 40,500 ha, as defined by the U.S. Interagency Fire Center (National Geographic, 2023).*

#### 2.1.3 Wildfire Smoke Influenced Days

Data collected at select monitoring stations in Alberta are evaluated for wildfire smoke impact using multiple datasets:

- satellite imagery (<https://worldview.earthdata.nasa.gov/>);
- back trajectories (obtained from Environment Climate Change Canada);
- maps of past wildfires and smoke forecasts (<https://firesmoke.ca/>);
- time series analysis of PM<sub>2.5</sub>, other pollutants and meteorological variables; and
- information gathered throughout the year as part of the Air Quality Health Index and associated air quality advisories, and through communication with station operators.

This process identifies wildfire smoke with notable impact on PM<sub>2.5</sub> concentrations (daily average concentrations > 15 µg m<sup>-3</sup>); marginal impacts may not be recognized.

EPA has used this analysis to determine wildfire impacted days for select stations, chosen for this indicator to represent the areas of the province with air monitoring in place, going back as far as 2015.

#### Limitations of the dataset:

- Only days with daily average PM<sub>2.5</sub> concentration greater than 15 µg/m<sup>3</sup> were included in the identified wildfire smoke impacted days. There may be additional days with lower PM<sub>2.5</sub> concentrations that were impacted by wildfire smoke but not included in the results. For data showing total number of impacted days, only urban stations were included due to limited data in rural regions.
- Long-term air quality monitoring stations do not cover all regions of Alberta, therefore monitoring gaps may incorrectly suggest that wildfire smoke impacts do not occur in those areas.

## 2.2 References

Canadian Council of Forest Ministers - Conseil canadien des ministres des forêts. (2020). National Forestry Database - Base de données nationales des forêts - Canada (Version 2.0.0), Forest Fires. Natural Resources Canada – Ressources naturelles Canada. <http://doi.org/10.5281/zenodo.3690046>.

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