# Condition of Environment – Air Indicators

Data Analysis/Visualization Methodology

## 1 $NO_2$, $SO_2$, $O_3$, and $PM_{2.5}$ 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-quality-and-deposition-data.aspx.

#### 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:

- **$NO_2$:** 61 monitoring stations met completeness criteria for annual average and peak $NO_2$ in 2021.
  - 35 Community monitoring stations, 14 Regional monitoring stations, and 12 Near Industrial Facility monitoring stations.
- **$O_3$:** 47 monitoring stations met completeness criteria for annual peak $O_3$ in 2021.
  - 32 Community monitoring stations, 12 Regional monitoring stations, and 3 Near Industrial Facility monitoring stations.
- **$PM_{2.5}$:** 50 monitoring stations met completeness criteria for annual average and peak $PM_{2.5}$ in 2021.
  - 32 Community monitoring stations, 11 Regional monitoring stations, and 7 Near Industrial Facility monitoring stations.
- **$SO_2$**: 65 monitoring stations met completeness criteria for annual average and peak $SO_2$ in 2021.
  - 31 Community monitoring stations, 16 Regional monitoring stations, 15 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. The indicator metrics are the same as are used for 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). $O_3$ only has a peak metric on the $O_3$ indicator webpage, just as there is only a peak metric for the $O_3$ CAAQS.

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

| Metric | Parameter | Statistical Form |
|---|---|---|
| Annual Average | $NO_2$ | annual average of all valid hourly data in a year |
| | $SO_2$ | annual average of all valid hourly data in a year |
| | $PM_{2.5}$ | annual average of all valid daily average values in a year |
| Peak | $NO_2$ | annual 98$^{th}$ percentile of the daily maximum 1-hour average concentrations |
| | $SO_2$ | annual 99$^{th}$ percentile of the daily maximum 1-hour average concentrations |
| | $PM_{2.5}$ | annual 98$^{th}$ percentile of the daily 24-hour average concentrations |
| | $O_3$ | annual 4$^{th}$ highest daily maximum 8-hour rolling average concentrations |

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

- **$NO_2$:**
  - 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$^{th}$ 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.

- **$SO_2$:**
- 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$^{th}$ 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.

- **$PM_{2.5}$:**
- 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.

- **$O_3$:**
- 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$^{nd}$ and 3$^{rd}$ quarter of the year, except if the 4$^{th}$ highest value based on the available daily maximums exceeds 62 ppb, then the year is included.

## 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$^{th}$ and 90$^{th}$ percentiles = for each year, the 10th and 90th 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 $SO_2$ 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, 2021) and TheilSen function therein. For information on this package and function, see the OpenAir user manual at https://bookdown.org/david_carslaw/openair/.

For $NO_2$, $SO_2$, and $O_3$, 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 (2012-2021) for $NO_2$ and $SO_2$ were estimated using monthly average concentrations for each monitoring station. The 10-year trend results are provided in the maps in Figures 1a and 1b on the $NO_2$ and $SO_2$ indicator webpages and can be viewed for each station when the station's symbol is selected. Data were deseasonalized and

autocorrelation was considered in the trend uncertainty estimates. A data completeness threshold of 75% was required when aggregating the data to monthly averages. Using this data completeness criteria resulted in missing data for some months. In such cases, the missing months could not exceed six months in a given year if the pattern of missing months was random and could not exceed four months in a year if they were consecutive months that were missing. The threshold to report a significant trend was a p-value <0.05.

### 1.5 Seasonal variation bar plots for $PM_{2.5}$ and $O_3$

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 (AAAQOs) 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 AAAQOs in effect in Alberta and used in this assessment, see the "Alberta Ambient Air Quality Objectives and Guidelines Summary" (AEP, 2019).

### 1.7 References


Aklilu, Y.A., Adams, C., Myrick, R.H., Wentworth, G., Tam, N. (2021). A five-year provincial air quality and deposition monitoring, evaluation and reporting plan (2021-2025). ISBN 978-1-4601-5167-9. Available at: https://open.alberta.ca/publications/five-year-provincial-air-quality-deposition-mer-plan-2021-2025.

Alberta Environment and Parks. (2016). Air Monitoring Directive Chapter 9: Reporting, ISBN: 978-1-4601-3198-5 (On-line Edition). Available at: https://open.alberta.ca/publications/air-monitoring-directive-2016.

Alberta Environment and Parks. (2019). Alberta Ambient Air Quality Objectives and Guidelines Summary. Available at: https://open.alberta.ca/publications/9781460134856.

Canadian Council of Ministers of the Environment. (2012). Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Fine Particulate Matter and Ozone, ISBN: 978-1-896997-91-9 PDF. Available at: https://ccme.ca/en/res/pn1483_gdad_eng-secured.pdf.

Canadian Council of Ministers of the Environment. (2020a). Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Nitrogen Dioxide, ISBN: 978-1-77202-061-8 PDF. Available at: https://ccme.ca/en/res/gdadforcaaqsfornitrogendioxide_en1.0.pdf.

Canadian Council of Ministers of the Environment. (2020b). Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Sulphur Dioxide, ISBN: 978-1-77202-063-2 PDF. Available at: https://ccme.ca/en/res/gdadforcaaqsforsulphurdioxide_en1.0.pdf.

Canadian Council of Ministers of the Environment. (2021). Guidance Document on Achievement Determination Canadian Ambient Air Quality Standards for Ozone, ISBN: 978-1-77202-067-0 PDF. Available at: https://ccme.ca/en/res/gdadforozonecaaqsen.pdf.

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.

R Core Team. (2021). 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 2021) was accessed from the National Forestry Database at http://doi.org/10.5281/zenodo.3690046. Data for United States jurisdictions (2002 to 2021) was accessed from the National Interagency Fire Centre at https://www.nifc.gov/fire-information/statistics.

**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).
- Wildfire burn data from the National Forestry Database (used in this indicator) are available up until 2021 as of the posting of this indicator.

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

### 2.1.2 Wildfire Smoke Influenced Days

As part of the annual Canadian Ambient Air Quality Standards (CAAQS) assessment, data collected at select monitoring stations in Alberta are evaluated for wildfire smoke impact using multiple datasets (Brown and Thi, 2022; CCME, 2019). Wildfire impacted days are identified using the following (as needed/appropriate):

- 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 $PM_{2.5}$, 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 $PM_{2.5}$ concentrations; marginal impacts may not be recognized.

If an initial assessment determines that a CAAQS reporting station is in the orange (management plan) or red (exceedance) level for $PM_{2.5}$, wildfire impacted days are identified for each year until the $98^{th}$ percentile of each year can be identified (according to the CAAQS metric calculation). Further analysis is conducted for the annual average CAAQS metric.

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 $PM_{2.5}$ concentration greater than 15 $\mu g/m^3$ were included in the identified wildfire smoke impacted days. There may be additional days with lower $PM_{2.5}$ 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


Brown, C., Thi, A. 2023. Status of Air Quality in Alberta: Air Zones Report 2019-2021. Government of Alberta, Ministry of Environment and Protected Areas. ISBN 978-1-4601-5851-7. Available at: https://open.alberta.ca/publications/alberta-air-zones-report.

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.

Canadian Council of Ministers of the Environment. (2019). Guidance Document on Transboundary Flows and Exceptional Events for Air Zone Management, ISBN: 978-1-77202-052-6 PDF, available at: https://ccme.ca/en/res/guidancedocumentontransboundaryflowsandexceptionalevents_secured.pdf.

Canadian Interagency Forest Fire Centre. (2020). Canada Report 2020. https://www.ciffc.ca/sites/default/files/2021-02/Canada_Report_2020_Final.pdf.

Hicke, J.A., S. Lucatello, L.D., Mortsch, J. Dawson, M. Domínguez Aguilar, C.A.F. Enquist, E.A. Gilmore, D.S. Gutzler, S. Harper, K. Holsman, E.B. Jewett, T.A. Kohler, and KA. Miller. (2022). North America. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1929–2042, doi:10.1017/9781009325844.016.

National Geographic. (2023). Accessed: November 2023. https://education.nationalgeographic.org/resource/megafire/.

National Interagency Fire Center. (2023). Accessed: March 2023. https://www.nifc.gov/fire-information/statistics.