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Data Sources and Methods for the Ground-Level Ozone and Fine Particulate Matter Air Quality Indicators

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1 Introduction

The national, regional and local air quality indicators are all part of the Canadian Environmental Sustainability Indicators (CESI) (http://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=En&n=47F48106-1) program, which provides data and information to track Canada's performance on key environmental sustainability issues.

Air quality indicators report on ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$). These indicators are intended as state/condition indicators to inform policy-makers, decision-makers and the public as to whether progress is being made towards improving ambient air quality.

2 Description and rationale of the ground-level ozone and fine particulate matter air quality indicators

2.1 Description

Air quality indicators track the average of ambient concentrations of ground-level ozone (O_3) and particulate matter ($PM_{2.5}$) during the warm season (April 1 to September 30). The air quality indicators are population-weighted; that is, when national and regional averages are compiled, ambient concentration measurements are weighted by the population attributed to a monitoring station.

The O_3 indicator is based on the highest 8-hour daily average concentration in parts per billion (ppb), while the $PM_{2.5}$ indicator is based on the 24-hour average daily concentration in micrograms per cubic metre ($\mu g/m^3$).

Since the adverse health effects of air pollution (e.g. cardiovascular and respiratory effects) can be observed even at low levels of exposure, especially for O_3 and $PM_{2.5}$, the calculation of air indicators are based on seasonal average concentrations rather than on maximum or peak concentrations. During the warm season, events of peak pollutant concentrations are rather sporadic and so the seasonal average of daily concentrations provides a better measure of cumulative exposure.

The air quality indicators consider O_3 and $PM_{2.5}$ concentrations during the warm season (April 1 to September 30). Meteorological conditions during these months tend to favour the formation of ground-level O_3. While fine particulate matter is usually a concern year around, challenges with instrument variability in cold weather are preventing effective all-year measurements of $PM_{2.5}$ for the purpose of these indicators. The current implementation of new particulate matter monitors in the National Air Pollution Surveillance (NAPS) (http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=5C0D33CF-1) network will help resolve this issue in the future.

2.2 Rationale

O_3 and $PM_{2.5}$ pollutants are key components of smog and two of the most widespread air pollutants to which people are exposed.

Other methods exist to report on O_3 and $PM_{2.5}$ concentrations, usually with different purposes and often providing different results. For example, the Canada-wide Standard (CWS) for ozone, based on the three-year average of the annual fourth-highest daily maximum eight-hour concentration, focuses on the effects of acute (short-term) exposure to peak air pollution rather than trying to approximate cumulative human exposure to O_3 and $PM_{2.5}$ over time, which is what the CESI air quality indicators do.

2.3 Changes since last report

The time series data completeness criteria were slightly modified for ozone. Eight stations were added for the calculation of the national and regional ozone indicators, as they now meet time series data completeness criteria. Three new stations were also added for $PM_{2.5}$ and two were removed because they no longer meet the time series data completeness criteria.

Table 1: New and removed monitoring stations for O_3 and $PM_{2.5}$

NEW STATIONS			
$PM_{2.5}$ Stations		O_3 Stations	
NAPS ID	Note	NAPS ID	Note
41301	combined with 41302	40501	
60708	combined with 60709	50203	combined with 50204
102301	combined with 102303	50306	combined with 50308
		50309	combined with 50310
		53301	
		100119	combined with 100120
		102001	
		102701	
REMOVED STATIONS			
$PM_{2.5}$ Stations		O_3 Stations	
NAPS ID	Note	NAPS ID	Note
51202			
100307			

New population statistics were used to do the population weighting for the stations included in the calculation of the national and regional air quality indicators for O_3 and $PM_{2.5}$. These statistics are 2011 updates from Statistics Canada's Census of Population (http://www12.statcan.gc.ca/census-recensement/index-eng.cfm).

The Lower Fraser Valley region is not used anymore and has been replaced by the British Columbia region for O_3 and $PM_{2.5}$.

3 Data

3.1 Data source

Air quality monitoring stations are located across Canada and are managed by the provinces, territories, some regional governments and Environment Canada. Almost all stations collecting ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$) data are under the National Air Pollution Surveillance (NAPS) (http://www.ec.gc.ca/rnspa-naps/default.asp?lang=En&n=5C0D33CF-1) program, a cooperative arrangement among the federal government and its provincial, territorial and regional government partners (http://www.ec.gc.ca/rnspa-naps/Default.asp?lang=En&n=31258671-1), an arrangement that has existed since 1969. The goal of the NAPS program is to provide accurate, long-term air quality data of a uniform standard throughout Canada and to store the data collected in the Canada-wide air quality database.[1]

[1] Other parameters measured through NAPS include sulphur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2), nitric oxide (NO), nitrogen oxides (NO_X), particulates less than 10 µm in aerodynamic diameter (PM_{10}), volatile organic compounds (VOC), metals and a variety of semi-volatile organic compounds.

The Canada-wide air quality database also includes ground-level ozone data information from the Canadian Air and Precipitation Monitoring Network (CAPMoN) (http://www.ec.gc.ca/rs-mn/default.asp?lang=En&n=752CE271-1), operated by Environment Canada. The CAPMoN stations were established for research purposes and to monitor air pollution outside urban areas.

Population data used for the population-weighted calculations were taken from the Census of Population (http://www12.statcan.gc.ca/census-recensement/index-eng.cfm) and the annual population updates compiled by Statistics Canada.

3.2 Spatial coverage

Air quality monitoring stations are spread across the country, but are more concentrated in urban areas. Monitoring stations used to calculate the air quality indicators are located in areas where most Canadians live, work and play.

The $PM_{2.5}$ and O_3 air quality indicators are provided by region. The following table lists the regions used. Refer to Appendix A for the full list of stations used to calculate the national and regional indicators.

Table 2: Regions used for regional air quality indicators

Region Code	Region
ATL	Atlantic Canada
SQC	Southern Quebec
SON	Southern Ontario
PNO	Prairies and northern Ontario
BCO	British Columbia

3.3 Temporal coverage

The air quality indicators for O_3 and $PM_{2.5}$ were calculated for the following time series.

Table 3: Time series range for air quality indicators

Air Pollutants	Time series
$PM_{2.5}$	2000–2010
O_3	1990–2010

Although minute-by-minute data are recorded, only hourly average readings are transmitted.

3.4 Data completeness

The monitoring stations do not all have the same time series of data available, nor have they all been operating continuously since 1990 or 2000 for $PM_{2.5}$. There are a number of reasons for this, including short-term technical problems, the commissioning or decommissioning of stations, and incomplete records from some stations. However, these short data gaps have little effect on long-term averages at individual stations.

3.5 Data quality

Agencies contributing to the NAPS network perform routine audits, and all strive to adhere to established quality assurance and quality control (QA/QC) standards laid out in Table 4. Environment Canada conducts a national audit program to ensure consistency between jurisdictions across Canada.

The data quality objective (DQO) for ground-level ozone measurement accuracy is ± 10% and the DQO for $PM_{2.5}$ measurement accuracy is ± 20%.[2]

Table 4: Data quality objectives and specifications for O_3 and $PM_{2.5}$

Parameter	O_3	$PM_{2.5}$
Accuracy	±10%	± 20%
Precision	< 10%	< 10%
Completeness	> 75%	> 75%
Comparability	Traceable to primary standard	Reference method
Averaging period	Hourly	24 hours
Measurement cycle	Year-round	Year-round

3.6 Data timeliness

There is a two-year lag from the last day of a year's data collection to the date on which that year's indicator is published. This lag is due to several intertwining factors, including the link of the air quality indicators with other environmental sustainability indicators, raw data verification, compilation at the national level from all partners, analysis, review and reporting. The data used in this report was subject to quality assurance and quality control procedures to ensure that they adhere to the guidelines followed by Environment Canada and its partners.

4 Methods

The $PM_{2.5}$ and O_3 air quality indicators are calculated based on definitions established by the National Round Table on the Economy and the Environment (NRTEE 2003).

4.1 Calculation of air quality concentrations

Data collection and QA/QC

The data are taken from the Canada-wide air quality database. The data are validated using automated and manual procedures. Data from monitoring network organizations are converted to a compatible format and then entered in the Canada-wide air quality database. Although the data have been validated by the monitoring organization, quality control and assurance procedures outlined by the United States Environmental Protection Agency (U.S. EPA) are also undertaken. The originating agency must confirm data automatically (or manually flag data) before they are stored in the Canada-wide air quality database.

[2] Canadian Council of the Ministers of the Environment (CCME) (2011) Ambient Air Monitoring Protocol for $PM_{2.5}$ and Ozone. Canada-wide Standards for Particulate Matter and Ozone. Available from: www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf.

Data completeness (yearly criteria)

Yearly criteria are used to select stations that have enough hourly and daily measures to be included in the air quality indicators.

In calculating the ground-level ozone (O_3) indicator, a station is included only when

- each 8-hour period has data for at least 6 hours;
- each day has data for at least 18 hours; and
- each warm-season period (April 1 to September 30 = 183 days) has data for at least 75% of the days (i.e. minimum of 138 days of data).

In calculating the fine particulate matter ($PM_{2.5}$) indicator, a station is included only when

- each day has data for at least 18 hours; and
- each of the two quarters (April to June and July to September) has data for at least 75% of the days (i.e. minimum of 69 days of data per quarter).

In 2010, 196 ground-level ozone and 174 $PM_{2.5}$ monitoring stations satisfied the yearly data requirements and were used to calculate the annual air quality indicators.

Monitoring station concentrations calculations

After the yearly criteria have been applied, the O_3 and $PM_{2.5}$ concentrations can be calculated for the selected stations.

For O_3, the daily maximum 8-hour average concentration is calculated in parts per billion (ppb). There are 24 consecutive 8-hour averages (8-hour rolls) that can be possibly calculated for each day. The daily maximum 8-hour average concentration for a given day is the highest of the 24 possible 8-hour averages computed for that day. See Figure 1 for an illustration of the 8-hour averages.

Figure 1: Calculation of the ground-level ozone daily maximum 8-hour average concentration (in parts per billion)

Day	Hour	Hourly data (ppb)	8-hour moving average (ppb)	Daily maximum (ppb)
1	12 AM	44		
	1 AM	45		
	2 AM	46		
	3 AM	47		
	4 AM	47		
	5 AM	47		
	6 AM	46		
	7 AM	44	46	
	8 AM	41	45	
	9 AM	36	44	
	10 AM	34	43	
	11 AM	33	41	
	12 PM	35	40	
	1 PM	33	38	
	2 PM	30	36	
	3 PM	29	34	
	4 PM	29	32	
	5 PM	32	32	46
	6 PM	33	32	
	7 PM	32	32	
	8 PM	32	31	
	9 PM	34	31	
	10 PM	32	32	
	11 PM	30	32	
2	12 AM	31	32	
	1 AM	35	32	
	2 AM	36	33	
	3 AM	35	33	
	4 AM	34	33	
	5 AM	32	33	
	6 AM	30	33	

The warm-season average of ground-level ozone concentrations is the average of the highest daily maximum 8-hour average concentrations during the period from April 1 to September 30.

The warm-season average value for a given $PM_{2.5}$ monitor is the average of the 24-hour average daily concentrations during the period from April 1 to September 30. The daily value for $PM_{2.5}$ refers to the 24-hour average concentration of $PM_{2.5}$ measured from midnight to midnight. Calculations are done using 1990 to 2010 for O_3, and 2000 to 2010 for $PM_{2.5}$. Each station is then assessed to see if sufficient yearly data are available for time series.

Time series criteria for O_3 and $PM_{2.5}$

To be included in the national and regional indicators, stations should have enough years of data available and no large data gap should exist at the beginning or end of the time series. The criteria for the time series are as follows:

- For the 1990–2010 O_3 time series, each station must have data that satisfy the yearly criteria described above for at least 16 of the 21 years.
- For the 2000–2010 $PM_{2.5}$ time series, each station should have data that satisfy the yearly criteria described above for at least 8 of the 11 years.
- $PM_{2.5}$ stations missing more than 2 consecutive years at the start or end of the time series are excluded to avoid using data from stations commissioned or decommissioned during the beginning or end of the period.
- O_3 stations are excluded if more than 3 consecutive missing years are encountered.

Imputation

Certain stations do not always have measurements for all the years. Hence, if they do not meet the time series criteria, they are excluded from the national and regional indicators. However, certain monitoring stations are located close to each other. Data from neighbouring stations have been used to supplement missing data and produce time series that meet the time series criteria.

Table 5: Stations grouped together in the O_3 air quality indicator

NAPS ID	Province	City	Years
50203 50204	QUEBEC	GATINEAU	1990–1996 1997–2010
50306 50308	QUEBEC	QUÉBEC	1990–1997 1999–2010
50309 50310	QUEBEC	QUÉBEC	1991–2005 2006–2010
60302 60303	ONTARIO	KINGSTON	1990–2005 2007–2010
60403 60429	ONTARIO	TORONTO	1990–2000 2001–2010
60415 60432 60434	ONTARIO	MISSISSAUGUA	1990–2003 2005–2007 2008–2010
60424 60433	ONTARIO	TORONTO	1991–2002 2003–2010
60607 60609	ONTARIO	SUDBURY	1990–2003 2005–2010
60707 60709	ONTARIO	SAULT STE. MARIE	1990–2003 2004–2010
60807 60809	ONTARIO	THUNDER BAY	1990–2003 2004–2010
60901 60903	ONTARIO	LONDON	1990–1994 1996-2010
61602 61603	ONTARIO	OAKVILLE	1990–2002 2004–2010
61701	ONTARIO	OSHAWA	1990–2004

NAPS ID	Province	City	Years
61702			2006–2010
62701 65301	ONTARIO	LONG POINT PORT STANLEY	1990–2001 2003–2010
63201 65101	ONTARIO	STOUFFVILLE NEWMARKET	1990–2003 2004–2010
80209 80211	SASKATCHEWAN	SASKATOON	1991–1992 1993–2010
90227 90228	ALBERTA	CALGARY	1990–2007 2008–2010
100119 100120	BRITISH COLUMBIA	METRO VAN – BURNABY	1995–2010 1990–1994
101001 101002 101003	BRITISH COLUMBIA	METRO VAN – ABBOTSFORD	1990–1991 1992–1998 1999–2010
101201 101202	BRITISH COLUMBIA	METRO VAN – PITT MEADOWS	1990–1995 1998–2010

Table 6: Stations grouped together in the $PM_{2.5}$ air quality indicator

NAPS ID	Province	City	Years
41301 41302	NEW BRUNSWICK	BATHURST	2000–2002 2005–2010
60403 60429	ONTARIO	TORONTO	2000 2001–2010
60415 60432 60434	ONTARIO	MISSISSAUGUA	2000–2003 2004–2007 2008–2010
60424 60433	ONTARIO	TORONTO	2000–2002 2003–2010
60708 60709	ONTARIO	SAULT STE. MARIE	2000–2001 2004–2010
61701 61702	ONTARIO	OSHAWA	2000–2004 2005–2010
90227 90228	ALBERTA	CALGARY	2000–2007 2008, 2010
102301 102303	BRITISH COLUMBIA	POWELL RIVER	2000–2007 2010

Exclusion criteria

The locations of certain stations in the NAPS network are not always ideal for O_3 or $PM_{2.5}$ monitoring purposes. For instance, certain stations have been placed in areas to measure the effects of stationary or mobile sources, including emissions from industrial plants and vehicular traffic. These stations do not represent community-wide air pollutant levels and, therefore, data from these stations have not been included in the O_3 and $PM_{2.5}$ air quality indicators. Certain monitoring stations have been excluded, even though they met the time series and yearly criteria, because of additional factors such as high NO_X scavenging[3] and the location of a station at a high elevation.

Table 7: NAPS network monitoring stations excluded from the national and regional indicators

STATION ID	PROVINCE	CITY	ADDRESS
O_3 (NO_X scavenging)			
50109	QC	MONTRÉAL	2495 DUNCAN / DÉCARIE, MT-ROYAL
50115	QC	MONTRÉAL	1001 BOUL DE MAISONNEUVE OUEST
100112	BC	METRO VAN – VANCOUVER	ROBSON / HORNBY
100121	BC	METRO VAN – VANCOUVER	75 RIVERSIDE DR. N. VANCOUVER

Selection of $PM_{2.5}$ data for multiple technology records
Different sampling methods are used in the NAPS network to measure ambient $PM_{2.5}$ concentrations:

- tapered element oscillating microbalance (TEOM)
- TEOM with the Filter Dynamics Measurement System (FDMS)
- Met-One Beta Attenuation Mass (BAM)

New sampling instruments that are approved by the U.S. EPA as Class III federal equivalent methods (FEMs) such as the TEOM-FDMS and Met-One BAM are being deployed across the NAPS network to replace older instruments that have been found to lose a portion of the $PM_{2.5}$ mass. Duplication of measurements exists for certain stations as the new technology is being deployed. Therefore, more than two records that use multiple sampling methods can be found for some stations in a given year.

For the national and regional air quality indicators, the measurements using the TEOM method are preferred over measurements using BAM or FDMS methods to ensure consistency and comparability, given that the TEOM has been the most widely used continuous sampling method in the NAPS network. The following table lists the stations with new sampling equipment and the year the equipment was used for reporting ambient air data. The NEW TECH column identifies the year in which the new technology was implemented. As a rule, the TEOM measurements were used when two or more technologies were available in a given year.

[3] "NO_X" is a term applied to the sum of nitric oxide and nitrogen dioxide (NO plus NO_2) as a chemical family. Reversible conversion of one of these nitrogen oxides to the other is common in the atmosphere, in a reaction usually involving ground-level ozone. Operational networks actually measure NO and NO_X, with NO_2 computed as a difference. At the low concentrations typical of rural areas, NO_X makes a net positive contribution to photochemical ozone formation, but at the higher concentrations typical of urban centres, the balance is shifted to ozone consumption, so that higher transportation emissions can decrease ozone locally. This phenomenon is referred to as NO_X scavenging.

Table 8: Stations with new sampling technologies in the $PM_{2.5}$ air quality indicator

NAPS ID	PROVINCE	CITY	TYPE	NEW TECH
10102	NEWFOUNDLAND	ST. JOHN'S	TEOM	BAM 2010
40103	NEW BRUNSWICK	FREDERICTON	TEOM	BAM 2008 +
40203	NEW BRUNSWICK	SAINT JOHN	TEOM	BAM 2007+
40302	NEW BRUNSWICK	MONCTON	TEOM	BAM 2008+
40901	NEW BRUNSWICK	ST. ANDREWS	TEOM	BAM 2008+
41302	NEW BRUNSWICK	BATHURST	TEOM	BAM 2008+
50105	QUEBEC	MONTRÉAL	TEOM	FDMS 2008+
50110	QUEBEC	MONTRÉAL	TEOM	FDMS 2008+
50126	QUEBEC	MONTRÉAL	TEOM	FDMS 2009+
50128	QUEBEC	MONTRÉAL	TEOM	FDMS 2008+
50129	QUEBEC	MONTRÉAL	TEOM	FDMS 2008+
50131	QUEBEC	MONTRÉAL	TEOM	FDMS 2008+
50308	QUEBEC	QUÉBEC	TEOM	BAM 2010
50801	QUEBEC	TROIS-RIVIÈRES	TEOM	BAM 2009+
54401	QUEBEC	SAINT-ANICET	TEOM	BAM 2008+
54501	QUEBEC	L'ASSOMPTION	TEOM	BAM 2008+
55301	QUEBEC	SAINT-JEAN-SUR-RICHELIEU	TEOM	BAM 2008+
80110	SASKATCHEWAN	REGINA	TEOM	BAM 2010
90130	ALBERTA	EDMONTON	TEOM	FDMS 2010
90228	ALBERTA	CALGARY	TEOM	FDMS 2010
90302	ALBERTA	RED DEER	TEOM	FDMS 2010
100304	BRITISH COLUMBIA	VICTORIA	TEOM	BAM 2010

4.2 Population weighting

The air quality indicators are calculated using a population-weighted approach, weighting the annual warm-season average values of monitoring stations across Canada. Monitoring stations are scattered from coast to coast, in different areas with different population densities. Therefore, proportionally adjusting air pollution levels measured at a monitoring station based on the size of the population residing near the station provides a surrogate estimate of exposure to ground-level ozone (O_3) and fine particulate matter ($PM_{2.5}$).

An annual population-weighted concentration level was calculated for each year by estimating the number of people living within a 40-km radius of each monitoring station, hence assigning each monitoring station a weight relative to its population. The population-weighted concentration level for each year (E_{year}) is calculated by multiplying the population (P) of a monitoring station by the average warm-season ambient level (C) of O_3 or $PM_{2.5}$ measured at that station.

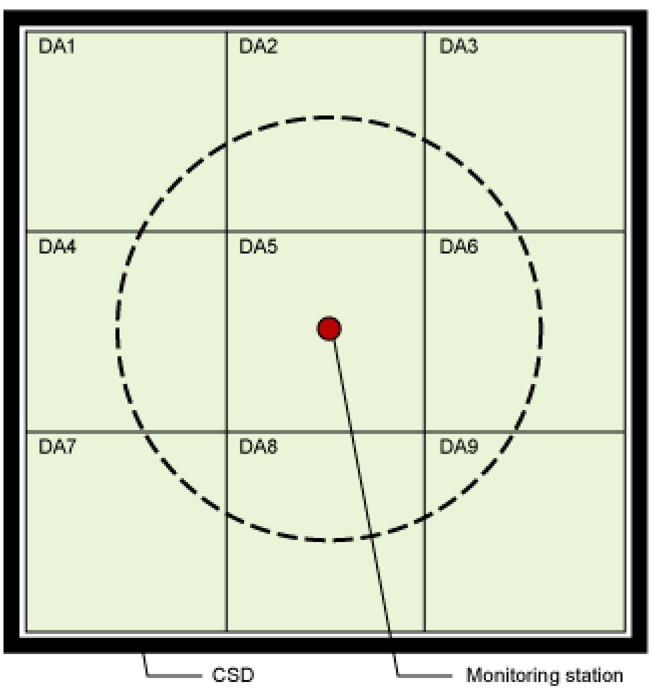
For example, P_n in the equation below represents the population within a 40-km radius of station (n) for a specific year and C_n is the average warm-season concentration level at station (n) during the same year. The products for each monitoring station are then added together and collectively divided by the sum of the total population, which is the sum of population counts of all the monitoring stations.

$$E_{year} = \frac{\Sigma (P_n \, x \, C_n)}{\Sigma \, P_n}$$

Estimating population weights

The estimation of population weights for each monitoring station relies on data from the latest Census of Population down to the dissemination area (DA) level and, for non-census years, the yearly population estimates for each census subdivision (CSD) provided by Statistics Canada. Each CSD is made up of several DAs and, in non-census years, the population of each DA is estimated using the annual population estimates of each corresponding CSD.
Since the boundaries of DAs do not always fit precisely with the boundaries of the 40-km radius circles around the monitoring stations used for the air quality indicators, the population in each circle is estimated based on the proportion of the area of DAs. Figure 2 presents a conceptual framework for estimating the population in a circular area around a monitoring station.

Figure 2: Conceptual diagram, estimating the population around a monitoring station



Note: The large square with a dark boundary line in Figure 2 represents a census subdivision (CSD) containing 9 dissemination areas (DA1 to DA9) presented as small squares. The dashed circle represents a conceptual circular area (40-km radius) around a monitoring station. The contribution of each DA to the population in the circle is based on area-proportion, that is to say, the percentage of the area of each DA that falls in the circle. For example, DA5 contributes all its population, while DA2 contributes approximately half of its population to the population of the circle. The percentage of the area of each DA in relation to the circle is constant throughout the entire time frame used in the calculation of the indicators. The percentage of the population of each DA to the overall population of its CSD is, however, updated once every census year, on a five-year cycle, when new census data then become available. In non-census years, the latest census data are used as the basis for deriving the degree to which each DA contributes to the population of a CSD (as a percentage), using Statistics Canada's yearly population estimates for each CSD.

National and regional indicators

In total, 91 ground-level ozone and 66 $PM_{2.5}$ monitoring stations satisfied the data requirements and were included in the national air quality indicators.

Table 9: Number of stations selected for the O_3 and $PM_{2.5}$ regional air quality indicators

Region	$PM_{2.5}$	O_3
Atlantic Canada	6	7
Southern Quebec	11	25
Southern Ontario	23	31
Prairies and northern Ontario	13	13
British Columbia	13	15

Local indicators

Local data of the 2010 warm-season O_3 and $PM_{2.5}$ are also presented in the CESI interactive map (http://maps-cartes.ec.gc.ca/indicators-indicateurs/default.aspx?lang=en). These snapshots are average concentrations obtained from all the monitoring stations across Canada that have satisfied the 2010 yearly criteria.

4.3 Statistical analysis

Non-parametric statistics tests were conducted to detect the presence of a linear trend and determine its magnitude. The standard *Mann-Kendall trend test* was used to detect the presence and direction (positive or negative) of a linear trend between the annual average pollutant concentrations (O_3 and $PM_{2.5}$) and time at the 90% confidence level. The *Sen's pairwise slope method* was also used to test the presence of a linear trend at the 90% confidence level and to estimate the slope between pollutant concentrations and time. The Mann-Kendall and the Sen's methods were applied to the annual average warm-season population-weighted concentration levels for O_3 (1990–2010) and $PM_{2.5}$ (2000–2010) data. A trend is reported when both the Mann-Kendall and Sen's tests indicate the presence of a trend at the 90% confidence level.

Tables 10 and 11 present the rate of change per year for the national and regional O_3 and $PM_{2.5}$ indicators, estimated with the Sen's method. The units for O_3 and $PM_{2.5}$ are expressed in percent change based on the median of the 1990–2010 for O_3 and the median of the 2000-2010 time series for $PM_{2.5}$.

Table 10: Rate of change per year for the national and regional O_3 air quality indicators, 1990 to 2010

O_3 indicator	Number	Median	90% lower	90% upper

	of stations	rate of change per year	confidence interval	confidence interval
	Number	%	%	%
National	91	0.48	0.10	0.87
Atlantic Canada	7	**	-	-
Southern Quebec	25	**	-	-
Southern Ontario	31	0.56	0.12	1.17
Prairies and northern Ontario	13	0.56	0.01	0.94
British Columbia	15	0.30	0.04	0.63

*** Indicates that the Mann-Kendall or Sen's method failed to reject the no-trend hypothesis at the 90% confidence level.*

Table 11: Rate of change per year for the national and regional $PM_{2.5}$ air quality indicators, 2000 to 2010

$PM_{2.5}$ indicator	Number of stations	Median rate of change per year	90% lower confidence interval	90% upper confidence interval
	Number	%	%	%
National	66	**	-	-
Atlantic Canada	6	**	-	-
Southern Quebec	11	**	-	-
Southern Ontario	23	-3.18	-5.06	-1.83
Prairies	13	**	-	-
British Columbia	13	**	-	-

*** Indicates that the Mann-Kendall or Sen's method failed to reject the no-trend hypothesis at the 90% confidence level.*

Based on a 90% confidence interval, test results presented a statistically significant trend for the O_3 indicator at the national level, in southern Ontario, in the Prairies and northern Ontario, in British Columbia, and for the $PM_{2.5}$ indicator in southern Ontario. The no-trend hypothesis could not be rejected for all other national and regional time series. Results of the tests are available in Appendix B.

5 Caveats and limitations

Measurement error: While instrument measurement error is inevitable, Environment Canada and its provincial partners have deployed quality control and quality assurance procedures for monitoring instruments to ensure that sources of measurement error are controlled and minimized. The data quality objectives for accuracy are ± 10% for ozone and ± 20% for fine particulate matter. For more information, consult the National Air Pollution Surveillance Network Quality Assurance and Quality Control Guidelines (www.etc-cte.ec.gc.ca/publications/naps/NAPSQAQC.pdf) from Environment Canada and the Ambient air monitoring protocol for $PM_{2.5}$ and ozone (http://www.ccme.ca/assets/pdf/pm_oz_cws_monitoring_protocol_pn1456_e.pdf) from the Canadian Council of Ministers of the Environment (CCME).

Data completeness: An important amount of measurement data is not used due to data completeness criteria. The criteria for determining whether stations have sufficiently complete data for inclusion in indicator analyses are based on standard practices followed by a number of organizations, including the World Health Organization and the U.S. Environmental Protection Agency, as well as expert opinion. Even with the use of data completeness criteria, some gaps can be found in the air quality data.

$PM_{2.5}$ sampling equipment: Different sampling methods for measuring $PM_{2.5}$ are used in the NAPS network, so caution needs to be used when comparing results among stations and cities. $PM_{2.5}$ monitors based on newer technologies are being deployed across the NAPS network to replace older instruments that have been found to lose a portion of the $PM_{2.5}$ mass. So far, 22 of the 66 monitoring stations used in the calculation of this indicator were upgraded: 1 in 2007, 12 in 2008, 2 in 2009 and 7 in 2010. Caution should be used when interpreting $PM_{2.5}$ levels and trends, as measurements from these newer methods may not be directly comparable with data from the older instruments.

Regional groupings: The definitions of the regions used for reporting are not the same as those used in the 2006 and earlier releases of CESI. Accordingly, the "Quebec and eastern Ontario" region as presented in the earlier reports has been changed to include only stations that are in southern Quebec.

Population weighting: The population weighting method used in CESI assumes uniform concentrations of ground-level ozone and $PM_{2.5}$ within relatively arbitrary zones. These uniform concentrations therefore do not factor in prevailing winds and the location of major emissions sources.

6 References and further reading

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Appendix A

Table A: Air quality monitoring stations reported in CESI for the national and regional indicators

Legend and acronyms

COLUMN	DESCRIPTION
NAPS ID	Monitoring station NAPS identifier
PROV, CITY and ADDRESS	Location of monitoring station
$PM_{2.5}$	If not empty, the station contributes data to the time series trend analysis for fine particulate matter in the national indicator and regional indicator of the identified region.
O_3	If not empty, the station contributes data to the time series trend analysis for ground-level ozone in the national indicator and regional indicator of the identified region.
ACRONYMS	**DESCRIPTION**
ATL	Atlantic Region CESI regional indicator
SQC	Southern Quebec CESI regional indicator
SON	Southern Ontario CESI regional indicator
PRA	Prairies CESI regional indicator
PNO	Prairies and northern Ontario CESI regional indicator
BCO	British Columbia CESI regional indicator

Monitoring stations

NAPS ID	PROV	CITY	ADDRESS	$PM_{2.5}$	O_3
10102	NL	ST. JOHN'S	354 WATER STREET	ATL	ATL
30118	NS	HALIFAX	1657 BARRINGTON STREET		
30501	NS	KEJIMKUJIK	NATIONAL PARK		ATL
40103	NB	FREDERICTON	437 ABERDEEN STREET	ATL	
40203	NB	SAINT JOHN	MOUNTAIN ROAD	ATL	ATL
40302	NB	MONCTON	5 THANET STREET	ATL	
40401	NB	FUNDY NAT. PARK	HASTINGS TOWER		ATL
40501	NB	POINT LEPREAU	RECREATION AREA		ATL
40601	NB	CENTRAL BLISSVILLE	AIRPORT ROAD		ATL
40701	NB	NORTON	308 HWY 124		ATL
40901	NB	ST. ANDREWS	BRANDY COVE ROAD	ATL	
41302*	NB	BATHURST	1255 ROUGH WATERS DRIVE	ATL	
50102	QC	MONTRÉAL	BOUL. ROSEMONT		SQC
50103	QC	MONTRÉAL	1050 A, BOUL. SAINT-JEAN-BAPTISTE		SQC
50104	QC	MONTRÉAL	1125 RUE ONTARIO EST		SQC
50105	QC	MONTRÉAL	1212 RUE DRUMMOND	SQC	
50109	QC	MONTRÉAL	2495 DUNCAN / DÉCARIE, MT-ROYAL		
50110	QC	MONTRÉAL	11280 BOUL. PIE IX, MTL NORD	SQC	SQC
50113	QC	LAVAL	1160 BOUL PIE X		SQC
50116	QC	MONTRÉAL	3161 JOSEPH, VERDUN		SQC
50119	QC	LONGUEUIL	FACE AU 1819 RUE VICTORIA		SQC
50126	QC	MONTRÉAL	20965 CH. SAINTE-MARIE, STE-ANNE dB	SQC	
50128	QC	MONTRÉAL	90-A RUE HERVÉ-SAINT-MARTIN, DORVAL	SQC	

NAPS ID	PROV	CITY	ADDRESS	$PM_{2.5}$	O_3
50129	QC	MONTRÉAL	12400 WILFRID-OUELLETTE	SQC	
50131	QC	MONTRÉAL	3250 STE-CATHERINE EST	SQC	
50204*	QC	GATINEAU	255 ST-RÉDEMPTEUR, HULL		SQC
50307	QC	QUÉBEC	RUE JACQUES CARTIER		
50308*	QC	QUÉBEC	600 RUE DES SABLES	SQC	SQC
50310*	QC	QUÉBEC	1150 BOUL. RENÉ-LÉVESQUE O.		SQC
50801	QC	TROIS-RIVIÈRES	FACE AU 678 RUE HART	SQC	
51501	QC	ST. ZÉPHIRIN-DE-COURVAL	701 RANG SAINT-MICHEL		SQC
52001	QC	CHARETTE	AU NORD DU 170 2E RANG		SQC
52201	QC	SAINT-SIMON	DERRIÈRE LE 83, 4E RANG EST		SQC
52301	QC	SAINT-FAUSTIN-LAC-CARRÉ	CHEMIN DU LAC (CARIBOU)		SQC
52401	QC	LA PÊCHE	LAC PHILIPPE - MASHAM		SQC
53201	QC	LA DORÉ	ROUTE 167- LA DORÉ		SQC
53301	QC	DESCHAMBAULT	334, 3 E RANG - DESHAMBAULT		SQC
53501	QC	SAINT-FRANÇOIS	FACE AU 198, ROYALE ÎLE D'ORLÉANS		SQC
53601	QC	NOTRE-DAME-DU-ROSAIRE	RANG ST-LOUIS		SQC
53701	QC	ST-HILAIRE-DE-DORSET	RANG DORSET		SQC
53801	QC	TINGWICK	CHEMIN RADAR ET WARWICK		SQC
53901	QC	LAC-ÉDOUARD	DERRIÈRE L'HÔPITAL VILLAGE		SQC
54401	QC	SAINT-ANICET	1128 DE LA GUERRE	SQC	
54501	QC	L'ASSOMPTION	801 ST-ÉTIENNE/ROUTE 344	SQC	
54801	QC	STUKELY-SUD	CHEMIN MONTBEL		SQC
54901	QC	LA PATRIE	RANG PETIT CANADA OUEST		SQC
55001	QC	FERME NEUVE	215 4 IÈME RANG GRAVEL		SQC
55301	QC	SAINT-JEAN-SUR-RICHELIEU	FERME EXP., 1134 ROUTE 219	SQC	
60104	ON	OTTAWA	RIDEAU & WURTEMBURG	SON	SON
60204	ON	WINDSOR	467 UNIVERSITY AVE. WEST	SON	SON
60303	ON	KINGSTON	752 KING ST. WEST		SON
60429*	ON	TORONTO	1 ETONA COURT	SON	SON
60410	ON	TORONTO	LAWRENCE & KENNEDY		SON
60413	ON	TORONTO	ELMCREST ROAD		SON
60434*	ON	MISSISSAUGUA	3359 MISSISSAUGUA RD N	SON	SON
60421	ON	TORONTO	YONGE ST. & FINCH AVE.	SON	SON
60433*	ON	TORONTO	BAY & WELLESLEY	SON	SON
60428	ON	BRAMPTON	525 MAIN ST. N. BRAMPTON	SON	
60430	ON	TORONTO	125 RESOURCES ROAD	SON	
60512	ON	HAMILTON	ELGIN & KELLY	SON	SON
60513	ON	HAMILTON	VICKERS RD. & EAST 18TH. ST.	SON	SON
60609*	ON	SUDBURY	RAMSEY LAKE ROAD		SON
60709*	ON	SAULT STE. MARIE	443 NORTHERN AVE., SAULT COLLEGE	SON	SON
60809*	ON	THUNDER BAY	421 JAMES STREET SOUTH		SON
60903*	ON	LONDON	900 HIGHBURY AVENUE	SON	SON
61004	ON	SARNIA	FRONT ST. AT C.N. TRACKS	SON	SON
61104	ON	PETERBOROUGH	10 HOSPITAL DRIVE	SON	
61201	ON	CORNWALL	BEDFORD & THIRD ST.		SON
61302	ON	ST. CATHARINES	ARGYLE CRESCENT	SON	SON
61502	ON	KITCHENER	WEST AVE. & HOMEWOOD	SON	SON
61603*	ON	OAKVILLE	8TH LINE/GLENASHTON DR.; HALTON RESERVE		SON
61702*	ON	OSHAWA	2200 SIMCOE STREET NORTH	SON	SON
61802	ON	GUELPH	70 DIVISION STREET; EXHIBITION PARK	SON	SON

NAPS ID	PROV	CITY	ADDRESS	$PM_{2.5}$	O_3
62001	ON	NORTH BAY	CHIPPEWA ST.	SON	SON
62501	ON	TIVERTON	BRUCE NUCLEAR VISITOR CTR	SON	SON
62601	ON	SIMCOE	EXPERIMENTAL FARM	SON	SON
65301*	ON	PORT STANLEY	43665 DEXTER LINE		SON
63001	ON	BURLINGTON	HWY 2 & NORTH SHORE BLVD.	SON	SON
65101*	ON	NEWMARKET	EAGLE ST. & McCAFFREY RD.		SON
63301	ON	DORSET	HWY 117 & PAINT LAKE ROAD	SON	SON
64101	ON	ALGOMA	ALGOMA		SON
64401	ON	EGBERT	EGBERT		SON
64001	ON	EXP. LAKES AREA	EXP. LAKES AREA		PNO
70118	MB	WINNIPEG	299 SCOTIA ST.	PRA	PNO
70119	MB	WINNIPEG	65 ELLEN STREET	PRA	PNO
70203	MB	BRANDON	1430 VICTORIA AVENUE EAST		PNO
80110	SK	REGINA	2505 11TH. AVENUE	PRA	PNO
80211*	SK	SASKATOON	511 1ST AVENUE NORTH		PNO
90121	AB	EDMONTON	17 STREET & 105 AVENUE	PRA	PNO
90130	AB	EDMONTON	10255 - 104TH STREET	PRA	PNO
90218	AB	CALGARY	49 AVENUE & 15TH STREET S.E.		PNO
90222	AB	CALGARY	39 ST. & 29 AVE. N.W.		PNO
90228*	AB	CALGARY	620 7TH AVE SW	PRA	PNO
90302	AB	RED DEER	73 STREET & RIVERSIDE DRIVE	PRA	
90601	AB	FORT SASKATCHEWAN	9209A-96 AVE		PNO
90701	AB	FORT MCMURRAY	FRANKLIN AVENUE	PRA	PNO
90702	AB	FORT MCMURRAY	TIMBERLEA SUBDIVISION	PRA	
90801	AB	FORT MACKAY	MAIN STREET	PRA	
91201	AB	HIGHTOWER RIDGE	SE 11 54 2 W6	PRA	
91301	AB	TOMAHAWK	SE 2 51 6 W5	PRA	
91801	AB	FORT CHIPEWYAN	FORT CHIPEWYAN	PRA	
100110	BC	METRO VAN - BURNABY	6400 E. HASTINGS & KENSINGTON		BCO
100111	BC	METRO VAN - PORT MOODY	MOODY & ESPLANADE PORT MOODY		BCO
100118	BC	METRO VAN - VANCOUVER	2550 WEST 10TH AVENUE		BCO
100119*	BC	METRO VAN - BURNABY	5455 RUMBLE STREET		BCO
100125	BC	METRO VAN - DELTA	8544 116TH AVE. DELTA		BCO
100126	BC	METRO VAN - BURNABY	RING ROAD BURNABY		BCO
100127	BC	METRO VAN - SURREY	19000 & 72ND AVE. SURREY		BCO
100128	BC	METRO VAN - RICHMOND	WILLIAMS & ARAGON RICHMOND		BCO
100132	BC	METRO VAN - VANCOUVER	16TH ST. & JONES AVE NORTH VAN		BCO
100134	BC	METRO VAN - RICHMOND	3153 TEMPLETON STREET	BCO	
100202	BC	PRINCE GEORGE	1011 4TH AVENUE	BCO	
100304	BC	VICTORIA	923 TOPAZ	BCO	
100402	BC	KAMLOOPS	MAYFAIR STREET	BCO	
100701	BC	KELOWNA	3333 COLLEGE WAY	BCO	BCO
101003*	BC	METRO VAN - ABBOTSFORD	32995 BEVAN AVE.		BCO
101101	BC	METRO VAN-CHILLIWACK	46244 AIRPORT ROAD	BCO	BCO
101202*	BC	METRO VAN-PITT MEADOWS	18477 DEWDNY TRUNK	BCO	BCO
101701	BC	QUESNEL	585 CALLANAN STREET	BCO	
101702	BC	QUESNEL	950 MOUNTAIN ASH ROAD	BCO	
101704	BC	QUESNEL	CORRELIEU SCHOOL	BCO	
102001	BC	SATURNA	SATURNA		BCO

NAPS ID	PROV	CITY	ADDRESS	$PM_{2.5}$	O_3
102102	BC	NANAIMO	280 LABIEUX ROAD	BCO	
102303*	BC	POWELL RIVER	6388 SUTHERLAND DRIVE	BCO	
102701	BC	WILLIAMS LAKE	1045 WESTERN AVENUE	BCO	BCO

* These stations were merged with past stations located nearby to respect data completeness criteria. See tables 5 and 6 for details.

Appendix B

Legend for tables B1 and B2

FIELD	DESCRIPTION
Time series	Names of the time series
First year	Starting year of each time series
Last year	Ending year of each time series
N	Number of annual values in the calculation excluding missing values
Test Z	If n is at least 10, the test statistic Z is displayed. The absolute value of Z is compared to the standard normal cumulative distribution to define if there is a trend or not at the selected level α of significance. A positive (negative) value of indicates an upward (downward) trend. If n is 9 or less, this cell is empty.
Significant	The smallest significance level ***α*** at which the test shows that the null hypothesis of no trend can be rejected. If n is 9 or less, the test is based on the S statistic and if n is at least 10, the test is based to the Z statistic (normal approximation). For the 4 tested significance levels, the following symbols are used in the template: *** if trend at α = 0.001 level of significance ** if trend at α = 0.01 level of significance * if trend at α = 0.05 level of significance + if trend at α = 0.1 level of significance If the cell is blank, the significance level is greater than 0.1
Q	The Sen's estimator for the true slope of linear trend, i.e. change per unit time period (in this case a year)
Qmin90	The lower limit of the 90% confidence interval of Q (α= 0.1)
Qmax90	The upper limit of the 90% confidence interval of Q (α= 0.1)
B	Estimate of the constant B in equation f(year)=Q*(year-first Data Year)+B for a linear trend
Bmin90	Estimate of the constant Bmin90 in equation f(year)=Qmin99*(year-first Data Year)+Bmin90 for 90% confidence level of linear trend
Bmax90	Estimate of the constant Bmax90 in equation f(year)=Qmax99*(year-first Data Year)+Bmax90 for 90% confidence level of linear trend

Trend Equation

f(year) = Q*(year-First Data Year) + B

Where First Data Year =

- 1990 for O_3
- 2000 for $PM_{2.5}$

Table B1. Mann-Kendall and Sen's tests results for O_3

STATISTICS	Ground-level Ozone (O_3)					
	NATIONAL	ATL	SQC	SON	PNO	BCO
First Year	1990	1990	1990	1990	1990	1990
Last Year	2010	2010	2010	2010	2010	2010
N	21	21	21	21	21	21
Test Z	1.96	0.51	1.42	2.14	1.66	2.02
Significant	**Yes ***	**No**	**No**	**Yes ***	**Yes +**	**Yes +**
Q	0.17			0.22	0.18	0.09
Qmin90	0.04			0.05	0.00	0.01
Qmax90	0.31			0.46	0.31	0.18
B	34.98			39.41	32.95	28.42
Bmin90	36.86			41.89	34.58	29.09
Bmax90	33.64			37.74	31.81	27.47

Table B2. Mann-Kendall and Sen's tests results for $PM_{2.5}$

STATISTICS	Fine particulate matter ($PM_{2.5}$)					
	NATIONAL	ATL	SQC	SON	PRA	BCO
First Year	2000	2000	2000	2000	2000	2000
Last Year	2010	2010	2010	2010	2010	2010
N		11	11	11	11	11
Test Z	-1.25	1.09	1.56	-2.49	1.40	-1.09
Significant	**No**	**No**	**No**	**Yes ***	**No**	**No**
Q				-0.35		
Qmin90				-0.57		
Qmax90				-0.21		
B				11.32		
Bmin90				12.59		
Bmax90				10,89		

www.ec.gc.ca

Additional information can be obtained at:
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