2013 Lower Fraser Valley Air Quality Monitoring Report

Fraser Valley Regional District

metrovancouver

SERVICES AND SOLUTIONS FOR A LIVABLE REGION

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Cover Photo: Laurie Bates-Frymel

Summary

This annual report summarizes the air quality monitoring data collected by the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2013 and describes the air quality monitoring activities and programs conducted during the year. The main focus is to report on the state of ambient (outdoor) air quality in the LFV.

LFV Air Quality Monitoring Network

The LFV Air Quality Monitoring Network includes 27 air quality monitoring stations located from Horseshoe Bay in West Vancouver to Hope. Metro Vancouver operates 22 stations in Metro Vancouver, as well as 5 stations in the Fraser Valley Regional District (FVRD) in partnership with the FVRD.

Air quality and weather data from all but one station are collected automatically on a continuous basis, transmitted to Metro Vancouver's Head Office in Burnaby, and stored in an electronic database. The data are then used to communicate air pollutant information to the public, such as through air quality health index values.

Air quality monitoring stations are located throughout the LFV to provide an understanding of the air quality levels that residents are exposed to most of the time. This report shows how these levels have varied throughout the region in 2013 and how these levels have changed over time. Trends in air quality measured by the Air Quality Monitoring Network are used to evaluate the effectiveness of pollutant emission reduction actions undertaken as part of Metro Vancouver's Integrated Air Quality and Greenhouse Gas Management Plan.

Specialized Air Quality Monitoring

In addition to the fixed monitoring network stations, Metro Vancouver deploys portable air quality stations and instruments to conduct specialized monitoring studies. Specialized studies typically investigate suspected problem areas (or "hot spots") at the local, neighbourhood or community level. In 2013, Metro Vancouver supported an air quality and coal dust monitoring study in partnership with the Corporation of Delta.

Also in early 2013, a new Mobile Air Monitoring Unit (MAMU) became operational, replacing the previous MAMU that had reached the end of its useful service after operating throughout the LFV for nearly 25 years.

Visual Air Quality

Visual air quality (sometimes referred to as visibility or haze) can become degraded in the LFV, causing local views to become partially obscured. Haze may have different characteristics depending on where it occurs. In much of Metro Vancouver, especially the more urbanized areas to the west, haze can have a brownish appearance. Nitrogen dioxide from transportation sources contributes to this colouration. Further east in the LFV, impaired visibility is often associated with a white haze caused by small particles ($PM_{2.5}$) in the air that scatter light.

Monitoring is conducted to assess visual air quality and includes measurements of ammonia, $PM_{2.5}$ and particle constituents (for example, particulate nitrate, particulate sulphate, elemental carbon and organic carbon) and light scattering. Nine automated digital cameras are also operated throughout the LFV to record views along specific lines of sight. By examining photographs alongside the pollutant measurements, visibility impairment can be related to pollution concentrations and their sources. The data collected provide important information for a multi-agency initiative to develop a visual air quality management strategy for the LFV.

Pollutants Monitored

Pollutants are emitted to the air from a variety of human activities and natural phenomena. Once airborne, the resulting pollutant concentrations are dependent on several factors, including the weather, topography and chemical reactions in the atmosphere.

Common air contaminants, including ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter, are widely monitored throughout the network. Particulate matter is composed of very small particles that remain suspended in the air. They are further distinguished by their size, which is measured in units of a millionth of a metre (or micrometre).

Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored at stations throughout the LFV.

Other pollutants less widely monitored in the network include ammonia, volatile organic compounds (VOC), and total reduced sulphur compounds (TRS).

Priority Pollutants

Research indicates that adverse health effects can occur at the air contaminant concentrations measured in the LFV. Health experts have identified exposure to ozone and particulate matter as being associated with the most serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. $PM_{2.5}$ particles are small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Long-term exposure to these pollutants can aggravate existing heart and lung diseases and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail and non-road engines. These particles ("diesel PM") are believed to contribute significantly to the health effects described above. Instrumentation for $PM_{2.5}$ measurement is in operation that can be used to estimate the proportion of particles that originate from diesel engines.

Air Quality Health Index (AQHI)

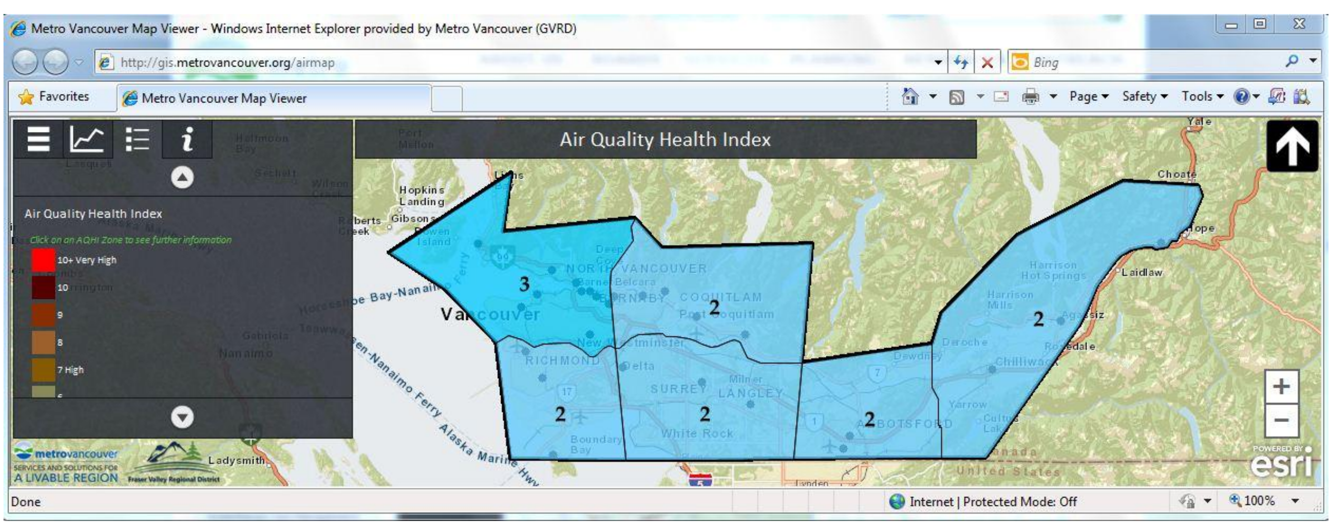
The Air Quality Health Index (AQHI), developed by Environment Canada and Health Canada, has been in use since 2008. The AQHI communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change. The AQHI is calculated every hour using monitoring data from stations in the LFV.

Current AQHI levels in the LFV as well as the AQHI forecasts (for today, tonight and tomorrow) and additional information about the AQHI are available at:

www.airmap.ca (shown below)
www.airhealth.ca
www.bcairquality.ca/readings

Air Quality Objectives and Standards

Several pollutant-specific air quality objectives and standards are used as benchmarks to characterize air quality. They include Metro Vancouver and provincial ambient air quality objectives, and the new federal Canadian Ambient Air Quality Standards (for ozone and particulate matter) which replace the previous Canada-Wide Standards. As part of the 2005 Air Quality Management Plan, health-based ambient air quality objectives were set for ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO), based on a review of the most stringent objectives of other jurisdictions.



In 2009, the provincial government established air quality objectives for $PM_{2.5}$. The 24-hour objective is numerically the same as Metro Vancouver's objective, however compliance with Metro Vancouver's objective requires no exceedances while the provincial objective allows for some exceedances each year.

The province's annual objective of 8 micrograms per cubic metre and annual planning goal of 6 micrograms per cubic metre are more stringent than the annual objective previously set by Metro Vancouver in 2005.

In the October 2011 Integrated Air Quality and Greenhouse Gas Management Plan, Metro Vancouver tightened its annual objectives for $PM_{2.5}$ aligning them with those set by the province in 2009 as well as adopting a one hour ozone objective of 82 parts per billion.

The federal Canadian Ambient Air Quality Standards (CAAQS) will be established as objectives under Canadian Environmental Protection Act 1999, and will replace existing Canada-Wide Standards for ozone and fine particulate prior to 2015.

Air Quality Advisories

Periods of degraded air quality can occur in the LFV for several reasons, such as summertime smog during hot weather or smoke from forest fires. Air quality advisories are issued to the public when air quality has deteriorated or is predicted to deteriorate significantly within the LFV. In the last ten years, the number of days when air quality advisories were in place ranged from zero to as many as ten days annually. No air quality advisories were issued in 2013.

Regional Long-Term Trends

Long-term *regional* trends in air quality are the trends observed within the LFV as a whole. They are determined by averaging measurements from several stations distributed throughout the LFV.

Figures S1 to S4 show the average concentrations and the short-term peak concentrations of four common air contaminants for the last two decades.

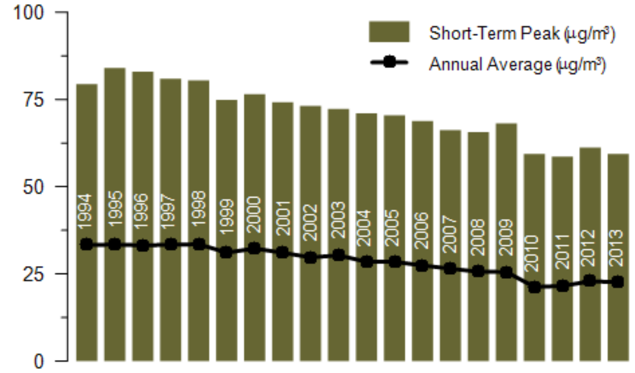


Figure S1: Nitrogen Dioxide Trend

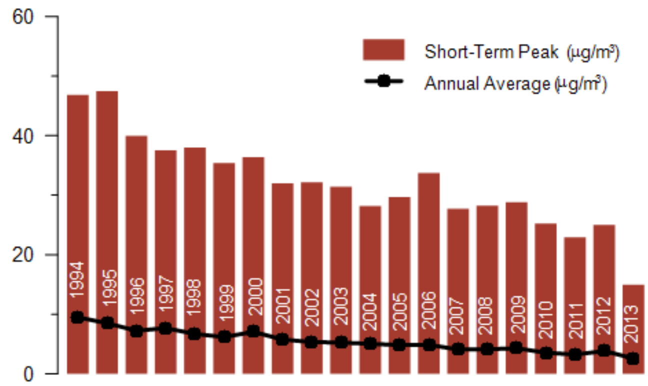


Figure S2: Sulphur Dioxide Trend

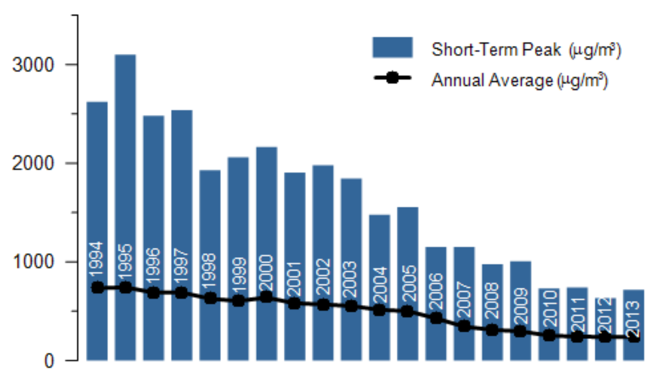


Figure S3: Carbon Monoxide Trend

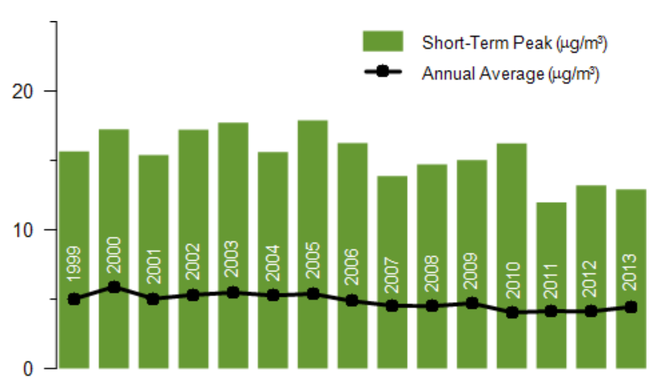


Figure S4: Particulate Matter ($PM_{2.5}$) Trend

Average concentrations represent the ambient concentrations that the region experiences most of the time. Short-term peak concentrations show the relatively infrequent higher concentrations experienced for short periods (on the scale of one hour to one day). Specific locations may have experienced trends that differ slightly from the regional picture.

Improvements have been made over the last two decades for most pollutants, including carbon monoxide (CO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and particulate matter ($PM_{2.5}$). Both short-term peak and average concentrations have declined since the early nineties for all these pollutants.

Despite significant population growth in the region over the same time period, emission reductions across a variety of sectors have brought about these improvements. Improved vehicle emission standards and the AirCare program are largely responsible for lower carbon monoxide (CO) and nitrogen dioxide (NO_2) levels.

Reduced sulphur in marine, on-road and off-road fuels, the shutdown of two refineries in Metro Vancouver and reduced emissions from the cement industry have led to the measured improvements in sulphur dioxide (SO_2) levels. Emission reductions from light duty and heavy duty vehicles, wood products sectors, and petroleum refining have contributed to the decline in $PM_{2.5}$ levels.

The regional $PM_{2.5}$ trends since 1999, when continuous $PM_{2.5}$ monitoring became prevalent throughout the LFV, are illustrated in Figure S4. These data also indicate that peak $PM_{2.5}$ levels have been relatively constant in recent years, although with some year-to-year variability. Figure S5 shows long-term $PM_{2.5}$ trends from a single monitoring station with a long record of non-continuous filter-based monitoring at the Port Moody station.

For ozone, the same improvements seen for other pollutants have not been observed. In contrast, average regional ozone levels (Figure S6) have shown a slight increasing trend. Research suggests that background ozone concentrations are rising and are one reason for the observed increase in average levels.

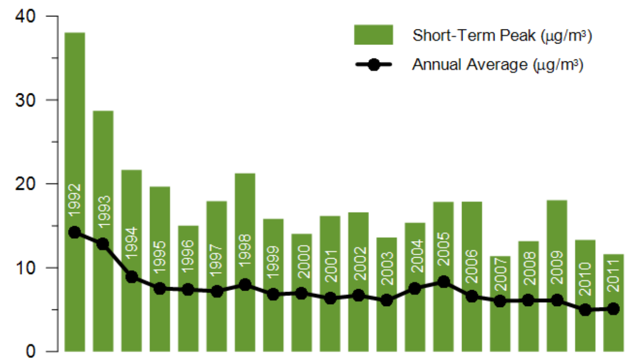


Figure S5: Port Moody $PM_{2.5}$ Trends

Regionally averaged short-term peak ozone trends are shown in Figure S6 and display year to year variability. The severity of peak ozone episodes greatly diminished in the 1980s, however short-term peak ozone levels have been mainly unchanged during the last two decades, despite large reductions in emissions of pollutants that contribute to ozone formation.

On-going research indicates that the highest ozone levels are occurring in the eastern parts of the LFV and that the location of the maximum has shifted eastward over time. A study led by UBC researchers was completed in 2011 to better understand ozone in the LFV and to suggest the most effective strategies to help reduce ozone levels. Findings from this study along with other research have informed a Regional Ground-Level Ozone Strategy to reduce emissions of ozone precursors and ground-level ozone concentrations.

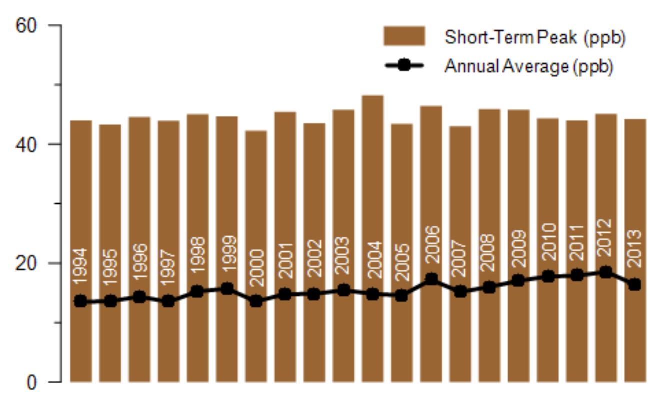


Figure S6: Ozone Trends

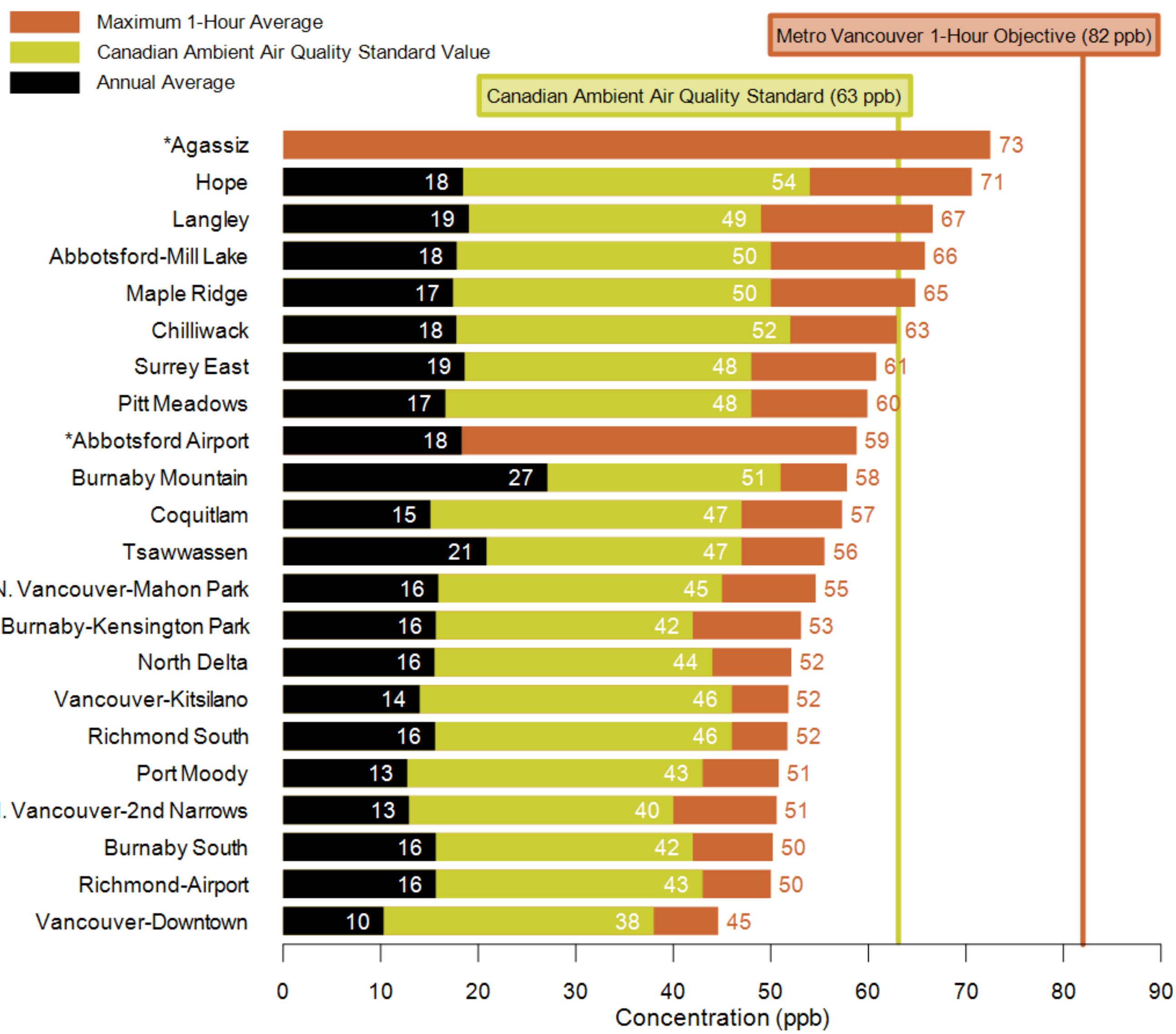
Ground-Level Ozone – 2013

Monitoring results for all ozone monitoring stations with sufficient data requirements in 2013 are shown in Figure S7. The data show that peak ozone levels, as measured by the Canadian Ambient Air Quality Standard and maximum 1-hour average values, occurred in the eastern parts of Metro Vancouver and in the FVRD during sunny and hot weather.

In 2013 the Canadian Ambient Air Quality Standard for ozone was met at all monitoring stations. Metro Vancouver's 1-hour objective and 8-hour objective (not shown) were also met in 2013. No air quality advisories were issued in 2013.

Ground-level ozone is a secondary pollutant formed in the air from other contaminants such as nitrogen oxides (NO_X) and volatile organic compounds (VOC). The highest concentrations of ozone occur during hot sunny weather.

NO_X emissions are dominated by transportation sources, with nearly 80% of emissions coming from cars, trucks, marine vessels, and non-road engines. VOC are emitted from natural sources (e.g., trees and vegetation), cars, light trucks, and solvents found in industrial, commercial and consumer products.



*Data completeness criteria were not met at these stations. The Agassiz station started operation in June 2013 and Abbotsford-Airport station was relocated in June 2012.

Figure S7: Ozone (O_3) 2013.

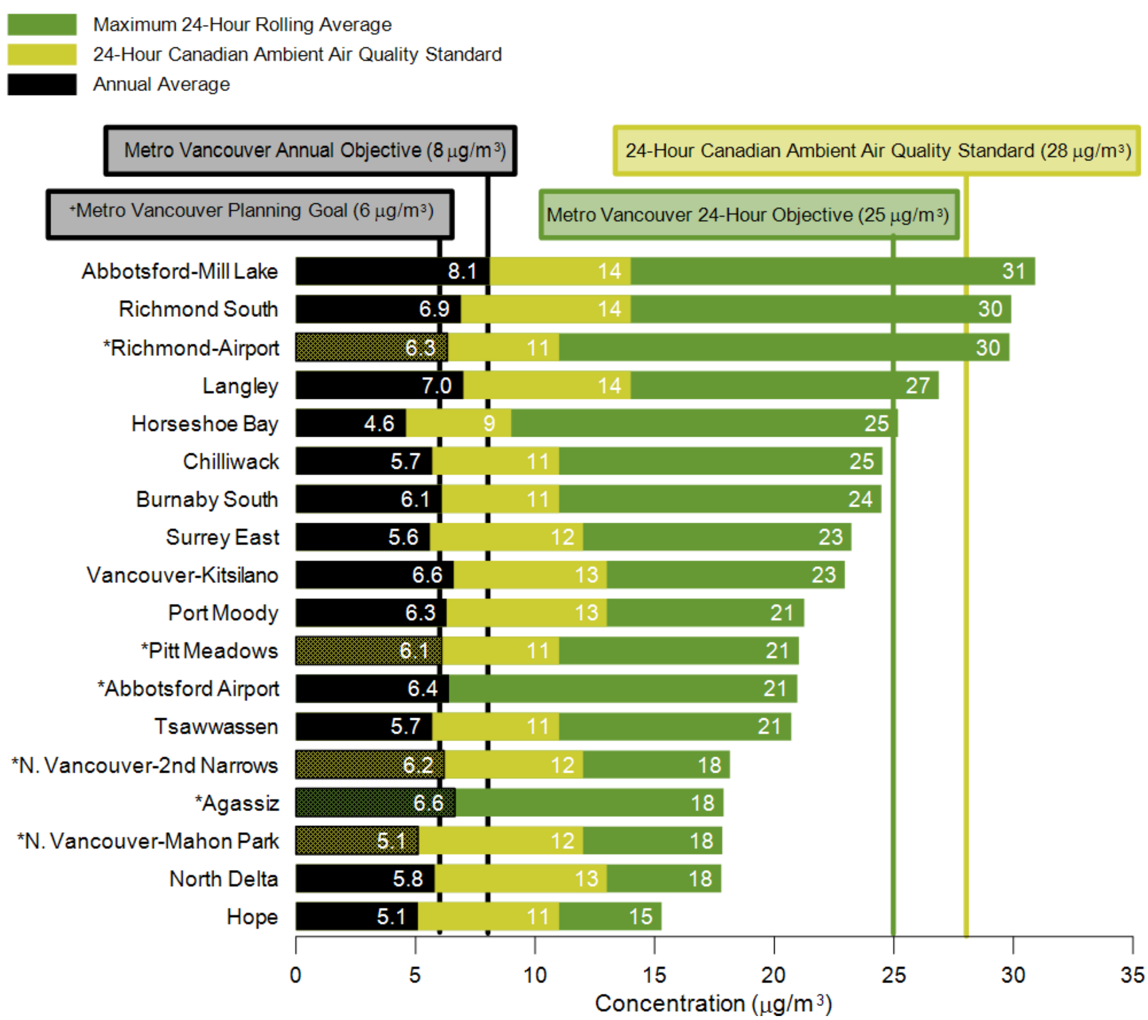
Fine Particulate Matter ($PM_{2.5}$) – 2013

Monitoring results for all $PM_{2.5}$ monitoring stations with sufficient data requirements are shown in Figure S8. The Canadian Ambient Air Quality Standard values for two stations are not shown in Figure S8 because the data are incomplete for the year.

All stations were well below (i.e., better than) the Canadian Ambient Air Quality Standard for $PM_{2.5}$. All stations were below the Metro Vancouver annual objective of 8 µg/m^3 with the exception of Abbotsford-Mill Lake. Metro Vancouver's 24-hour $PM_{2.5}$ objective was exceeded at five stations in 2013. Exceedances occurred during three separate periods on January 20-22, October 19-20 and November 25-26.

Fine particulate matter ($PM_{2.5}$) emissions are dominated by transportation, wood and natural gas heating, and industrial sources. $PM_{2.5}$ is also formed by reactions of nitrogen oxides (NO_X) and sulphur dioxide (SO_2) with ammonia in the air. $PM_{2.5}$ produced in this manner is called secondary $PM_{2.5}$ and accounts for a significant portion of $PM_{2.5}$ in summer.

Elevated levels of regional $PM_{2.5}$ can occur when high pressure weather systems are present. Typically experienced in the summer, 2013 had three occurrences of high pressure systems which contributed to $PM_{2.5}$ exceedances in the fall and winter. During these times regional and local emissions sources combined with stagnant atmospheric conditions led to elevated PM levels.



*Data completeness criteria were not met at these stations and annual averages were calculated from all available data for the year.
+Metro Vancouver's Planning Goal of 6 µg/m^3 is a longer term aspirational target to support continuous improvement.

Figure S8: Fine Particulate Matter ($PM_{2.5}$) 2013.

Sulphur Dioxide – 2013

Monitoring results for all sulphur dioxide (SO_2) monitoring stations in 2013 are shown in Figure S9. Sulphur dioxide levels were below the annual objective at all stations in 2013.

Hourly and 24-hour rolling average SO_2 concentrations were below Metro Vancouver objectives at all stations except Burnaby-Capitol Hill. The hourly objective was exceeded at the Burnaby-Capitol Hill station for a total of 2 hours during January 20 and 21. The 24-hour objective was exceeded at this station for a total of 3 hours on January 21. It is thought that the exceedances were caused by a combination of poor dispersion conditions along with emissions from marine vessels and the Chevron refinery. During this time there were stagnant weather conditions which limited dispersion.

Sulphur dioxide is formed primarily by the combustion of fossil fuels containing sulphur. The largest sources in the LFV are marine vessels (mainly ocean-going vessels) and the petroleum products industry. As a result, the highest sulphur dioxide levels are typically measured near the Burrard Inlet area. Away from the Burrard Inlet area, sulphur dioxide levels are considerably lower.

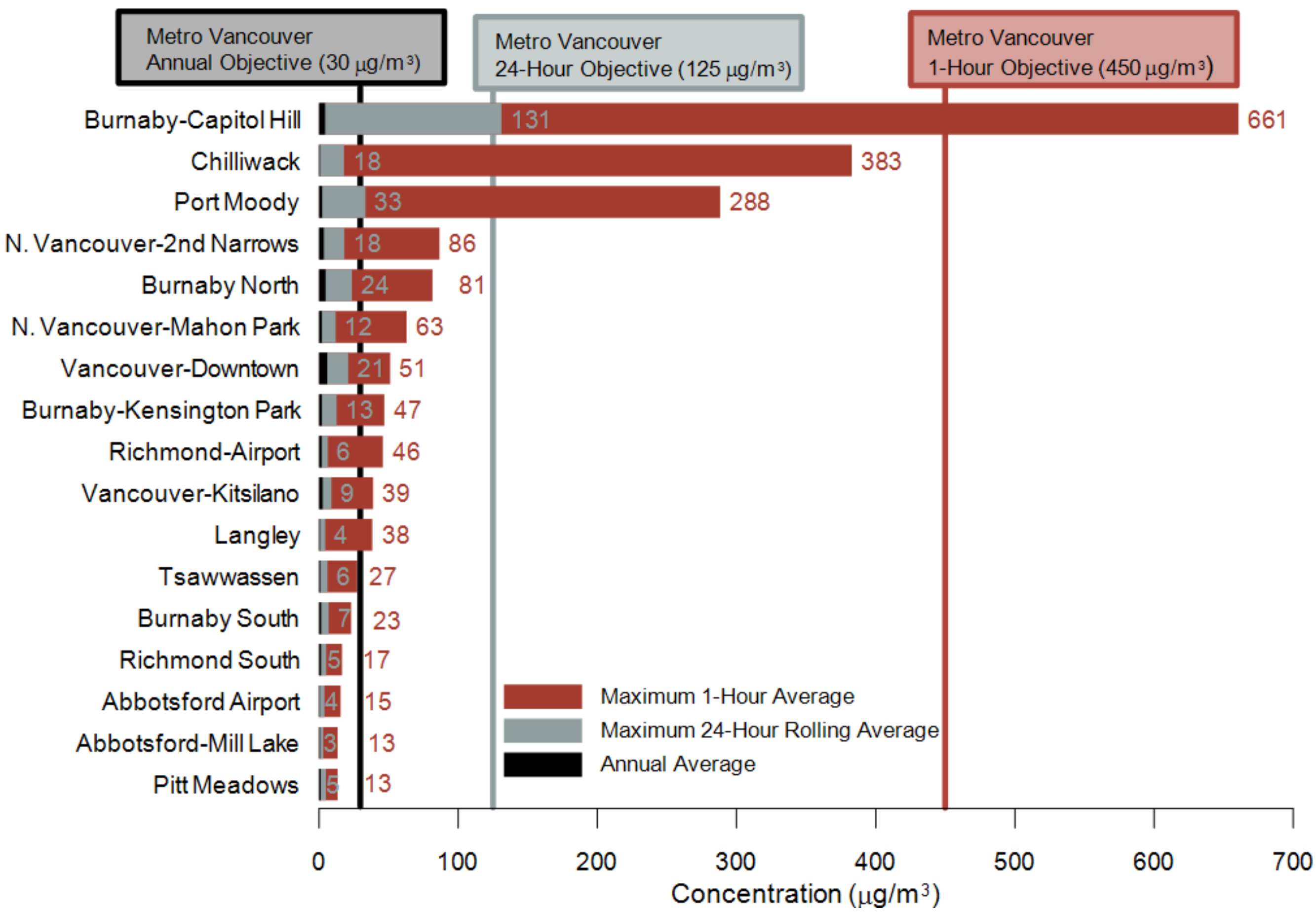
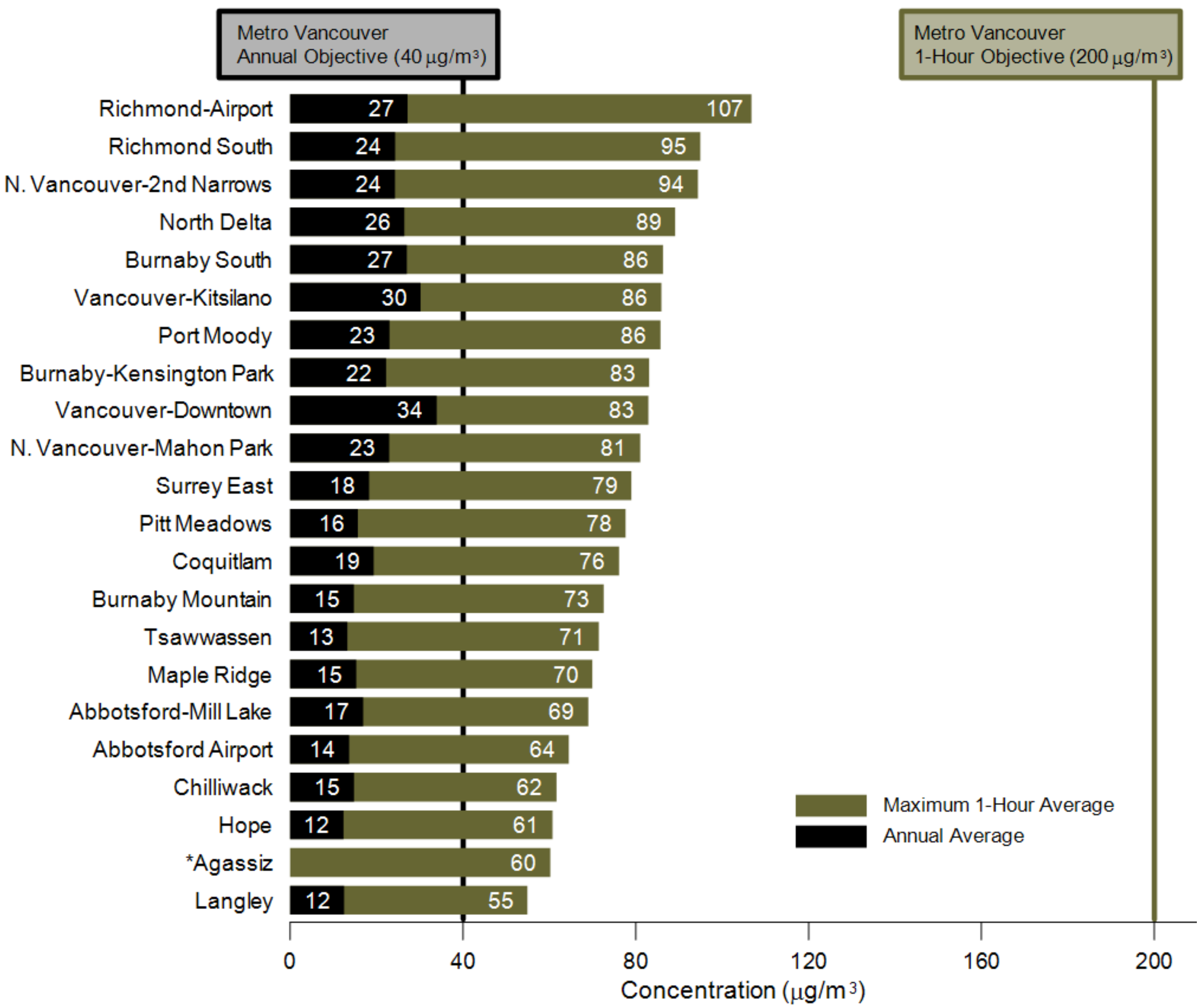


Figure S9: Sulphur Dioxide (SO_2) 2013.

Nitrogen Dioxide – 2013

Results for nitrogen dioxide (NO_2) monitoring in 2013 are shown in Figure S10. All stations experienced nitrogen dioxide levels that were below Metro Vancouver's 1-hour objective. Annual averages were also below Metro Vancouver's annual objective at all stations with sufficient data completeness. In 2013, as in past years, the highest average nitrogen dioxide levels were measured in downtown Vancouver, in a dense urban environment close to a busy street.

As nitrogen dioxide emissions are dominated by transportation sources, the highest average nitrogen dioxide concentrations are measured in the more densely trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.



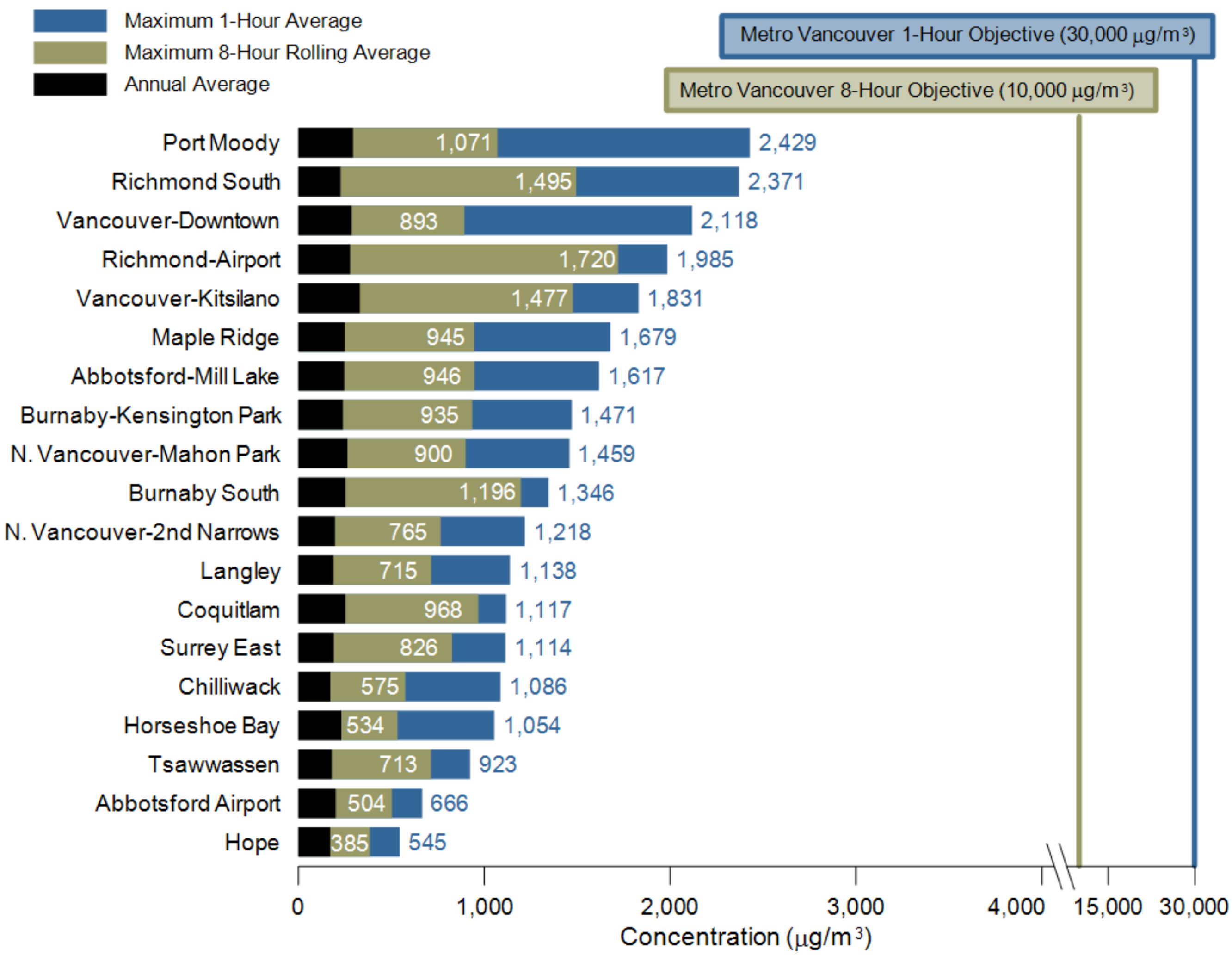
*Data completeness criteria were not met at this station.

Figure S10: Nitrogen Dioxide (NO_2) 2013.

Carbon Monoxide – 2013

Carbon monoxide (CO) monitoring results for 2013 are shown in Figure S11. Carbon monoxide levels were all well below the relevant Metro Vancouver air quality objectives at all stations throughout the LFV. The principle source of carbon monoxide continues to be emissions from motor vehicles.

Higher concentrations generally occur close to major roads during peak traffic periods. Like nitrogen dioxide, the highest average carbon monoxide concentrations are measured in the more densely trafficked areas and near busy roads. Lower concentrations are observed where these influences are less pronounced, such as the suburban and rural parts of Metro Vancouver and the FVRD.



Note: The scale is broken in the x-axis between 4,000 and 10,000 µg/m³. The highest concentration measured is almost ten times less than the objective.

Figure S11: Carbon Monoxide (CO) 2013.

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List of Acronyms

AQHI	Air Quality Health Index
BIALAQS	Burrard Inlet Area Local Air Quality Study
BC	Black Carbon
BCVCC	BC Visibility Coordinating Committee
CCME	Canadian Council of Ministers of the Environment
CAAQS	Canadian Ambient Air Quality Standard
CO	Carbon Monoxide
FEM	Federal Equivalent Method
FVRD	Fraser Valley Regional District
LFV	Lower Fraser Valley
MAMU	Mobile Air Monitoring Unit
NAPS	National Air Pollution Surveillance
NO_X	Nitrogen oxides
NO_2	Nitrogen dioxide
NO	Nitric oxide
NH_3	Ammonia
O_3	Ozone
PM	Particulate matter
PM_{10}	Inhalable particulate matter (particles smaller than 10 micrometres in diameter)
$PM_{2.5}$	Fine particulate matter (particles smaller than 2.5 micrometres in diameter)
SO_X	Sulphur oxides
SO_2	Sulphur dioxide
THC	Total hydrocarbons
TRS	Total reduced sulphur compounds
VOC	Volatile organic compounds

Section A – Introduction

This report summarizes data collected from air quality stations in the Lower Fraser Valley (LFV) Air Quality Monitoring Network in 2013 and describes the air quality monitoring activities and programs conducted during the year. The focus is to report on the state of ambient (outdoor) air quality in the LFV.

Metro Vancouver maintains one of the most comprehensive air quality networks in North America serving a population of 2.6 million with 27 air quality stations located from Horseshoe Bay in West Vancouver to Hope in 2013. Pollutants monitored by the network include both gases and particulate matter. Common air contaminants include ozone (O_3), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter. These are all widely monitored throughout the network.

Particulate matter consists of very small solid and liquid material suspended in the air. This air pollutant is characterized by size and measured in units of a millionth of a metre, or micrometre (µm). Particles with a diameter smaller than 10 micrometres are referred to as inhalable particulate (PM_{10}), while those smaller than 2.5 micrometres are termed fine particulate ($PM_{2.5}$). Both PM_{10} and $PM_{2.5}$ concentrations are monitored throughout the LFV.

Other pollutants monitored by the network include ammonia, volatile organic compounds (VOC), odourous total reduced sulphur compounds (TRS). Additional information Metro Vancouver collects to help monitor air quality conditions includes weather (meteorological) data and images recording visual air quality conditions (visibility).

Priority Pollutants

Research indicates that adverse health effects can occur at air quality levels commonly measured in the LFV. Health experts have identified exposure to ozone and particulate matter as being associated with the most serious health effects. Ozone is a strong oxidant that can irritate the eyes, nose and throat, and reduce lung function. Fine particulate ($PM_{2.5}$) is small enough to be breathed deeply into the lungs, resulting in impacts to both respiratory and cardiovascular systems. Long-term exposure to these pollutants can aggravate existing heart and lung diseases and lead to premature mortality.

Of particular concern is $PM_{2.5}$ that is emitted from diesel fuel combustion in car, truck, marine, rail and non-road engines. These particles, called diesel PM, are carcinogenic and believed to contribute significantly to health effects. Instrumentation for $PM_{2.5}$ measurement is in operation that can be used to estimate the proportion of particles that originate from diesel engines.

Air Quality Advisories

Periods of degraded air quality can occur in the LFV for several reasons, such as summertime smog during hot weather, smoke from forest fires and winter inversions preventing dispersion of emitted air contaminants. In cooperation with partner agencies, including the Fraser Valley Regional District, Vancouver Coastal Health Authority, Fraser Health Authority, Environment Canada and the B.C. Ministry of Environment, Metro Vancouver operates an air quality advisory program.

Air quality advisories are issued to the public when air quality has deteriorated or is forecast to deteriorate significantly within the LFV. Typically air quality advisories are issued when a pollutant exceeds or is predicted to exceed an air quality objective or standard at more than one monitoring location.

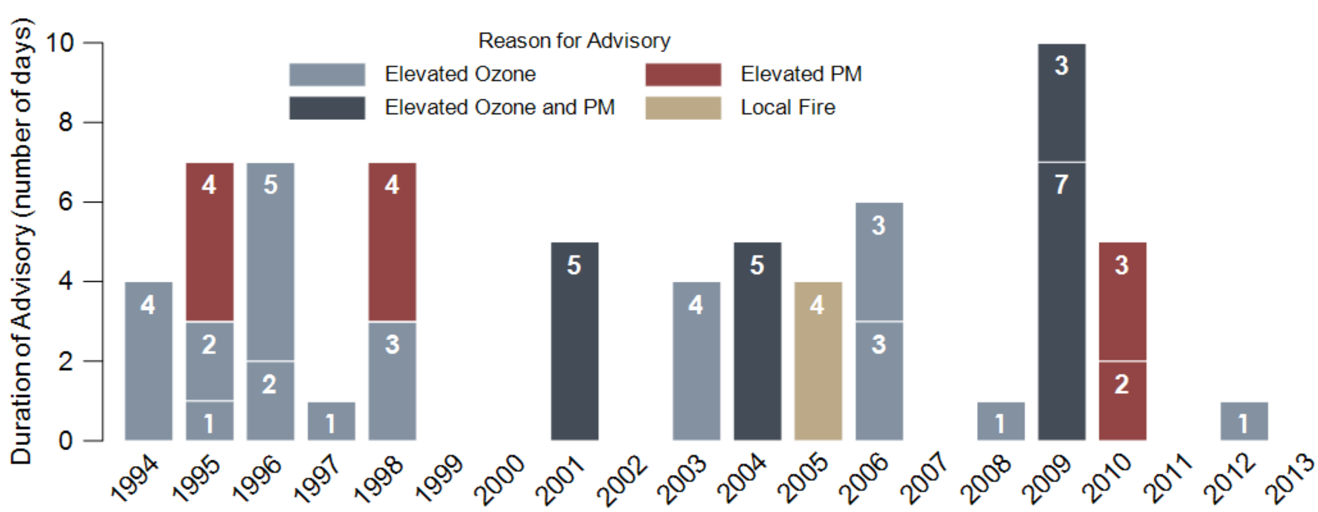
In the last ten years, the number of days on which air quality advisories were in place has ranged from zero to ten days annually. Shown in Figure 1 is the number of days the LFV was under an advisory. The total number of advisory days is shown as a bar while the number of consecutive days of an advisory period is given by the number in white.

Air Quality Trends

Improvements have been made in air quality over the last two decades for most pollutants, including nitrogen dioxide (NO_2), carbon monoxide (CO), sulphur dioxide (SO_2), volatile organic compounds (VOC) and fine particulate matter ($PM_{2.5}$). Despite significant population growth in the region over the same time period, emission reductions across a variety of sectors have brought about these improvements. The population increased in Metro Vancouver and the FVRD by nearly 50% from 1991 to 2011, from approximately 1.8 million to 2.7 million residents.

The long-term regional trends for ground-level ozone show a different story. Long-term trends of peak ozone concentrations show yearly variability with levels currently lower than those experienced in the 1980s. Short-term or "peak" levels have been largely unchanged over the last fifteen to twenty years. Average concentrations of ground-level ozone however have increased over the same period.

Trends in air pollutants are discussed further by pollutant in Section D.



Notes:

- Trigger levels for advisories have changed over the years; care must be taken when interpreting advisory trends.
- The advisory in 2005 was the result of a large fire in Burns Bog.

Figure 1: Number of days of air quality advisories in the LFV.

Air Quality Health Index (AQHI)

The national health-based Air Quality Health Index (AQHI), developed by Environment Canada and Health Canada, has been in use since 2008. The AQHI communicates the health risks associated with a mix of air pollutants to the public and provides guidance on how individuals can adjust their exposure and physical activities as air pollution levels change.

The AQHI is calculated every hour using monitoring data from stations in the LFV. Current AQHI levels in the LFV, AQHI forecasts (for *today*, *tonight*, and *tomorrow*) and additional information about the AQHI are available at:

www.airmap.ca (shown below)
www.airhealth.ca
www.bcairquality.ca

Environment Canada's Weatheroffice forecast web pages also publish the AQHI.

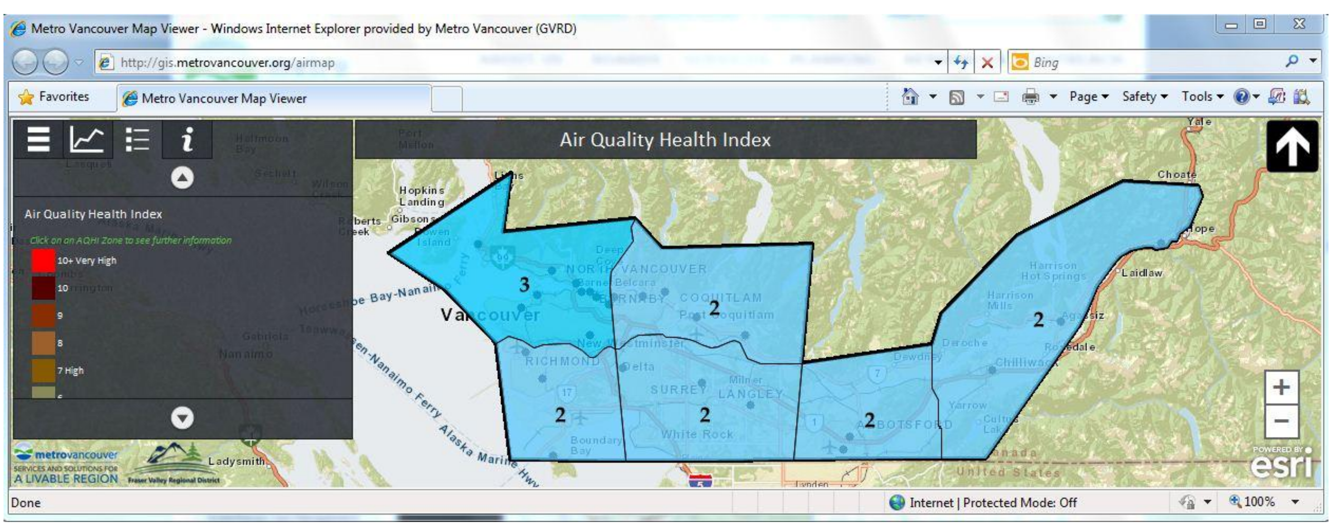
Visual Air Quality

Degraded air quality can cause views to be partially or fully obscured by haze at times in the LFV. This is referred to as visual air quality impairment.

The appearance of haze is affected by the nature of the air pollutants causing it. For example, in more urbanized areas in the west, haze may have a brownish colour. Nitrogen dioxide emissions from transportation sources contribute to this brown appearance. Further east in the LFV, a white haze can sometimes be observed as a result of small particles in the air ($PM_{2.5}$) scattering light. Secondary $PM_{2.5}$, such as that formed by reactions of NO_X and SO_2 with ammonia, contributes to this haze. Smoke and windblown dust and soil particles can also affect visual air quality at times.

In 2013, nine automated digital cameras in six locations were used to record visual air quality conditions. Images from the cameras show views along specific lines-of-sight with recognizable topographical features at known distances. The images are archived for various uses such as:

- relating air contaminant measurements to visual range under a variety of air quality and meteorological conditions;
- assessing public perception of the range of visual air quality conditions found in the LFV;
- developing visual air quality measurement metrics.



Images from each location were also available online in near-real time through: www.clearairbc.ca

Characterization of air contaminants in the LFV is being used to develop a quantitative assessment of visual air quality. Data collected in 2013 as part of the visual air quality monitoring program include measurements of nitrogen dioxide and $PM_{2.5}$, measurements of the constituents of particulate matter (for example particulate nitrate, particulate sulphate, elemental carbon and organic carbon) and light scattering.

Data collected in the visual air quality monitoring network provide important information to a multi-agency initiative to develop a visual air quality management strategy for the LFV. Visual air quality is further discussed in Section F.

Air Quality Measurements

The LFV Air Quality Monitoring Network primarily employs continuous monitors which provide data in real-time every minute of the day. The network also contains specialized air quality monitors that sample the air non-continuously. Non-continuous 24-hour (daily) samples are collected on filters and/or in canisters every sixth or twelfth day depending on the site. The sampling is scheduled in accordance with the National Air Pollution Surveillance (NAPS) program. After sample collection, filters and canisters are analyzed in a federal laboratory to determine pollutant concentrations.

Non-continuous samples of Volatile Organic Compounds (VOC) are collected at seven sites throughout the LFV. VOC refers to a group of organic chemicals. A large number of chemicals are included in this group but each individual chemical is generally present at relatively low concentrations in air compared to other common air contaminants.

Non-continuous particulate samples are collected at four monitoring stations in the LFV where pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for three of these stations (Port Moody, Burnaby South and Abbotsford Airport).

Chemicals contained in $PM_{2.5}$ and VOC samples are identified and quantified at a federal laboratory. These data can then be used to help determine the emission sources contributing to the contaminants in the air.

Non-continuous measurements are discussed in Section E.

Section B – Air Quality Objectives and Standards

Several air quality objectives and standards are used as benchmarks to characterize air quality including the federal Canadian Ambient Air Quality Standards (CAAQS), and Metro Vancouver's ambient air quality objectives. Metro Vancouver's ambient air quality objectives are shown in Table 1. The objective or standard is achieved if the ambient concentration is lower than (i.e., better than) the objective.

The federal Canadian Ambient Air Quality Standards (CAAQS) will be established as objectives under Canadian Environmental Protection Act 1999, and will replace the existing Canada-Wide Standards. Standards for fine particulate matter and ground-level ozone have been developed and were published to the Canada Gazette in May 2013. The new CAAQS are to be implemented by 2015 for particulate matter (PM) and ozone (O_3). These set specific limits for $PM_{2.5}$ and O_3 based on concentrations averaged over a three year period.

The CAAQS for $PM_{2.5}$ is a value that is calculated by taking an annual 98th percentile value using daily averages, averaged over three consecutive years. Achievement of the $PM_{2.5}$ CAAQS is attained when the CAAQS value is below 28 µg/m^3.

The CAAQS for ozone is a value that is calculated by the 4th highest annual 8-hour daily maximum, averaged over three consecutive years. Achievement of the ozone CAAQS is attained when the CAAQS value is below 63 ppb.

In October 2005, as part of the Air Quality Management Plan, Metro Vancouver adopted health-based ambient air quality objectives for ozone (O_3), particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and carbon monoxide (CO). Metro Vancouver's $PM_{2.5}$ objectives adopted in 2005 were established in advance of any provincial objectives.

An objective or standard is achieved if the ambient concentration is lower than (i.e., better than) the objective.

In April 2009 the provincial government established new air quality objectives for $PM_{2.5}$. The province's annual target of eight micrograms per cubic metre (µg/m^3) and annual planning goal of six micrograms per cubic metre for $PM_{2.5}$ were more stringent than the annual objective previously set by Metro Vancouver in 2005.

In the October 2011 Integrated Air Quality and Greenhouse Gas Management Plan, Metro Vancouver tightened its annual objectives for $PM_{2.5}$, aligning them with those set by the province in 2009 as well as adopting a one hour ozone objective of 82 parts per billion.

Metro Vancouver's 24-hour $PM_{2.5}$ objective of 25 µg/m^3 is numerically the same as the province, but compliance with Metro Vancouver's objective requires that there are no exceedances and is applied as a rolling average. In addition to the $PM_{2.5}$ annual objective of eight micrograms per cubic metre, the $PM_{2.5}$ annual planning goal of six is a longer term aspirational target to support continuous improvement.

Several of Metro Vancouver's objectives are intended to be compared with *rolling averages*. A *rolling average* is an average that is calculated by averaging the concentrations from a number of previous consecutive hours. For example, a 24-hour rolling average is calculated by averaging the concentrations measured during the previous 24 hours. A 24-hour rolling average is calculated for each hour of the day. Similarly an 8-hour rolling average is calculated by averaging the concentrations from the previous 8 hours.

Table 1: Metro Vancouver's ambient air quality objectives.

Contaminant	**Averaging Period**	**Units**	
		µg/m^3	**ppb**
Carbon monoxide	1-hour	30,000	26,500
	8-hour	10,000	8,800
Nitrogen dioxide	1-hour	200	107
	Annual	40	22
Sulphur dioxide	1-hour	450	174
	24-hour	125	48
	Annual	30	12
Ozone	1-hour	160	82
	8-hour	126	65
Inhalable particulate matter (PM_{10})	24-hour	50	
	Annual	20	
Fine particulate matter ($PM_{2.5}$)	24-hour	25	
	Annual	8 (6)*	
Total reduced sulphur	1-hour (acceptable)	14	10
	1-hour (desirable)	7	5

Note: The 8-hour and 24-hour objectives are intended to be compared against concentrations calculated as a rolling average.

*Metro Vancouver's Planning Goal of 6 µg/m^3 is a longer term aspirational target to support continuous improvement.

Section C – Lower Fraser Valley Air Quality Monitoring Network

Metro Vancouver operates the LFV Air Quality Monitoring Network which consists of air quality monitoring sites located between Horseshoe Bay in West Vancouver and Hope. The locations of the monitoring stations operated in 2013 are shown in Figure 2 while the pollutants and meteorology measured at each station are identified in Table 2.

In 2013, there were 27 fixed air quality monitoring stations in the network which includes 22 stations located in Metro Vancouver and 5 stations located in the FVRD. There are also 2 stations in Metro Vancouver that provide only weather data. Air quality and weather data are collected automatically on a continuous basis, transmitted to Metro Vancouver's head office in Burnaby, and stored in a database. The data are then used to provide information to the public through the AQHI, Metro Vancouver's website, the BC air quality website, and reports. At one of the fixed stations (White Rock) particulate matter is sampled throughout the year on a defined periodic schedule. These non-continuous data are not collected automatically to the database.

Many pollutants measured are discussed in this report with a focus on common air contaminants: particulate matter (PM_{10} and $PM_{2.5}$), ozone (O_3), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2).

Comparisons of measured levels of these air contaminants with federal, provincial and Metro Vancouver air quality objectives and standards and an assessment of regional trends are provided in Section D. The locations of SO_2, O_3, NO_2 and $PM_{2.5}$ monitoring in 2013 are shown in Figures 3 to 6.

Portable equipment was used to carry out short-term air quality monitoring studies (specialized studies) in 2013. The equipment employed in specialized studies includes Metro Vancouver's Mobile Air Monitoring Unit (MAMU) which is capable of monitoring gaseous and particulate pollutants in the same way as fixed monitoring stations. Specialized studies and other monitoring activities undertaken are described in Sections G, H and I.

Real-time data from the LFV Air Quality Monitoring Network can be accessed on Metro Vancouver's website at: www.airmap.ca

Additional information on the LFV Air Quality Monitoring Network is available in the report "Station Information: Lower Fraser Valley Air Quality Monitoring Network" at:

www.metrovancouver.org/about/publications/Publications/LowerFraserValleyAirQualityMonitoringNetwork2012StationInformation.pdf

Network Changes

Every year there are ongoing enhancements to stations and equipment that occur throughout the air quality monitoring network.

Network improvement highlights for 2013 included the establishment of a new Mobile Air Monitoring Unit (MAMU), transition to improved $PM_{2.5}$ monitoring technology, and ongoing work to expand the monitoring network in the FVRD.

Improvements and changes to the network are necessary to adapt to changes in population, land-use and demographics.

Changes to the network in 2013 include:

- Starting in January 2013 all $PM_{2.5}$ monitoring stations began reporting data from continuous particulate monitors that are designated by the U.S. Environmental Protection Agency as being a Federal Equivalent Method (FEM) for $PM_{2.5}$ measurement. Previous $PM_{2.5}$ TEOMs were retired at all stations with the exception of five stations where the TEOMs will continue to operate side by side with the FEM to allow long-term trending. The new FEM monitors have the ability to measure a portion of particulates not previously measured. See infographic:

  www.metrovancouver.org/services/air/Documents/AirInfographic.pdf

- Work continued to establish a new monitoring station in Mission in partnership with the FVRD.

- The new Agassiz (T44) station became operational in June 2013. The station, which monitors ground-level ozone, fine particulate matter, nitrogen oxides and meteorology will provide important information on air quality for the Agassiz community and improve our understanding of how pollutants form and move around the region.

- The new Mobile Air Monitoring Unit (MAMU) became operational in April 2013 (shown on front cover) replacing the previous MAMU that had reached the end of its useful service after operating throughout the LFV for nearly 25 years.

- Improvements to meteorological observations continued with the addition of relative humidity instrumentation at Burnaby-Kensington Park (T4), North Delta (T13), and North Vancouver-Mahon Park (T26).

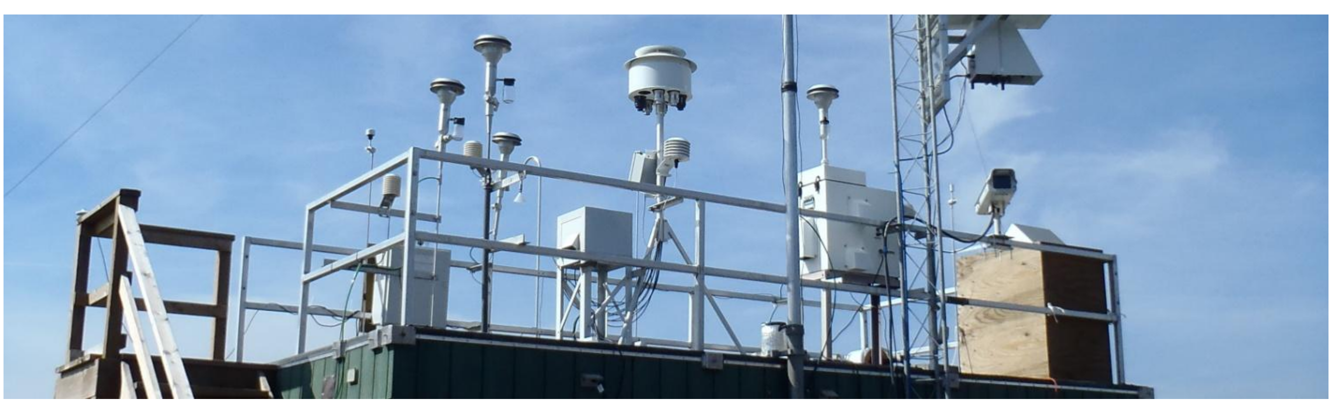


Figure 2: Lower Fraser Valley air quality monitoring network, 2013.

Table 2: Air quality monitoring network, 2013.

Stations		Air Quality Monitors														Meteorology					
		Continuous											Non-Continuous								
		Gases							Particulate Matter												
ID	Name	SO_2	TRS	NO_2	CO	O_3	THC	NH_3	PM_{10}	$PM_{2.5}$	CARB	NEPH	VOC	SP	D	Wind	T_{air}	SR	RH	BP	Precip
T1	Vancouver-Downtown	√		√	√	√															
T2	Vancouver-Kitsilano	√		√	√	√				√						√	√		√	√	√
T4	Burnaby-Kensington Park	√	√	√	√	√			√	√						√	√		√		
T6	N. Vancouver-2nd Narrows	√		√	√	√				√	√					√					
T9	Port Moody	√	√	√	√	√			√	√	√		√		√	√	√	√	√		√
T12	Chilliwack	√		√	√	√		√	√	√	√	√	√			√	√	√	√	√	√
T13	North Delta			√		√				√						√	√		√		√
T14	Burnaby Mountain			√		√										√	√		√		√
T15	Surrey East			√	√	√				√						√	√				√
T17	Richmond South	√		√	√	√				√						√	√		√		√
T18	Burnaby South	√		√	√	√			√	√	√	√	√	√	√	√	√		√	√	√
T20	Pitt Meadows	√		√		√				√						√	√		√	√	√
T22	Burnaby-Burmount		√				√						√			√	√				
T23	Burnaby-Capitol Hill	√	√													√	√		√		
T24	Burnaby North	√	√				√		√				√			√	√		√		√
T26	N. Vancouver-Mahon Park	√		√	√	√				√						√	√	√	√	√	√
T27	Langley	√		√	√	√			√	√						√	√		√	√	√
T29	Hope			√	√	√			√	√						√	√		√		√
T30	Maple Ridge			√	√	√										√	√		√		√
T31	Richmond-Airport	√		√	√	√			√	√	√	√	√			√	√	√	√	√	√
T32	Coquitlam			√	√	√										√	√	√	√	√	√
T33	Abbotsford-Mill Lake	√		√	√	√		√	√	√						√	√		√		√
T35	Horseshoe Bay				√					√						√	√		√		√
T37	Alex Fraser Bridge															√	√		√		
T38	Annacis Island															√	√		√		√
T39	Tsawwassen	√		√	√	√				√						√	√		√	√	√
T44	Agassiz			√		√				√						√	√		√		√
T45	Abbotsford Airport	√		√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√
#20	White Rock														√						
Total Monitoring Units		**17**	**5**	**22**	**19**	**22**	**2**	**3**	**10**	**19**	**6**	**4**	**7**	**2**	**4**	**27**	**26**	**6**	**24**	**10**	**22**

SO_2 = sulphur dioxide; TRS = total reduced sulphur; NO_2 = nitrogen dioxide; CO = carbon monoxide; O_3 = ozone; THC = total hydrocarbon; NH_3 = ammonia; PM_{10} = inhalable particulate matter;

$PM_{2.5}$ = fine particulate matter; NEPH = particulate light scattering; VOC = volatile organic compounds; SP = particulate speciation; D = dichotomous particulate; CARB = Carbon.

Wind = wind speed and wind direction; T_{air} = air temperature; SR = incoming solar radiation; RH = relative humidity; BP = barometric pressure; Precip = precipitation.

√ = monitored at this location.

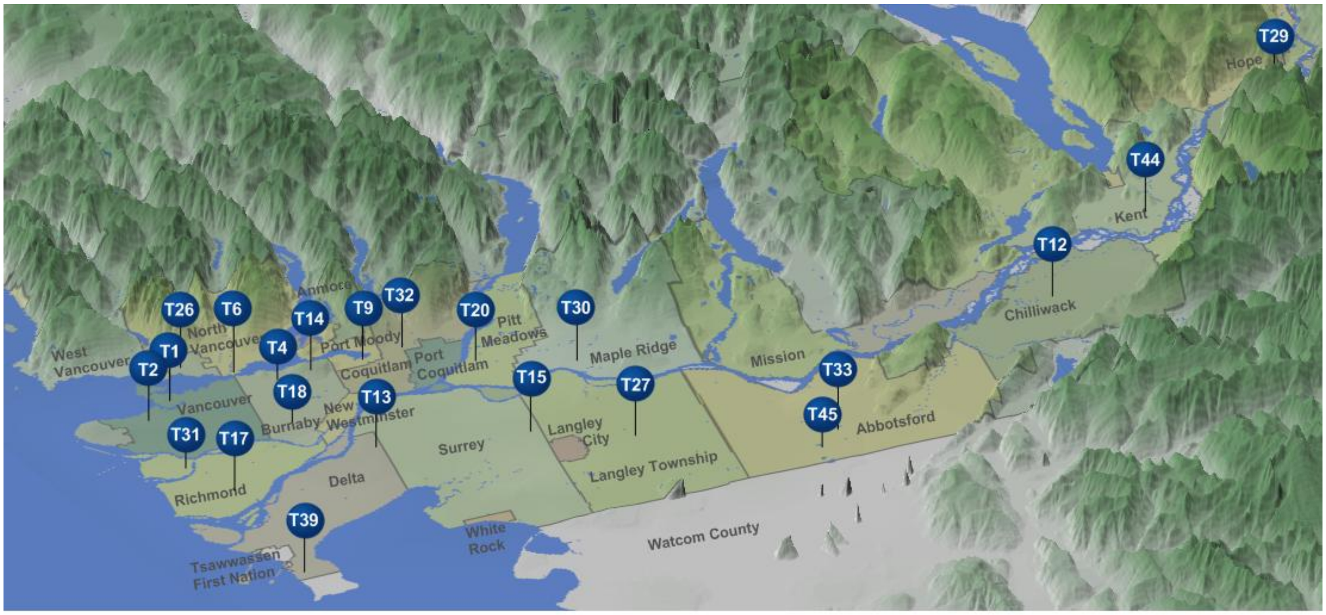


Figure 3: Ground-level ozone monitoring stations, 2013.

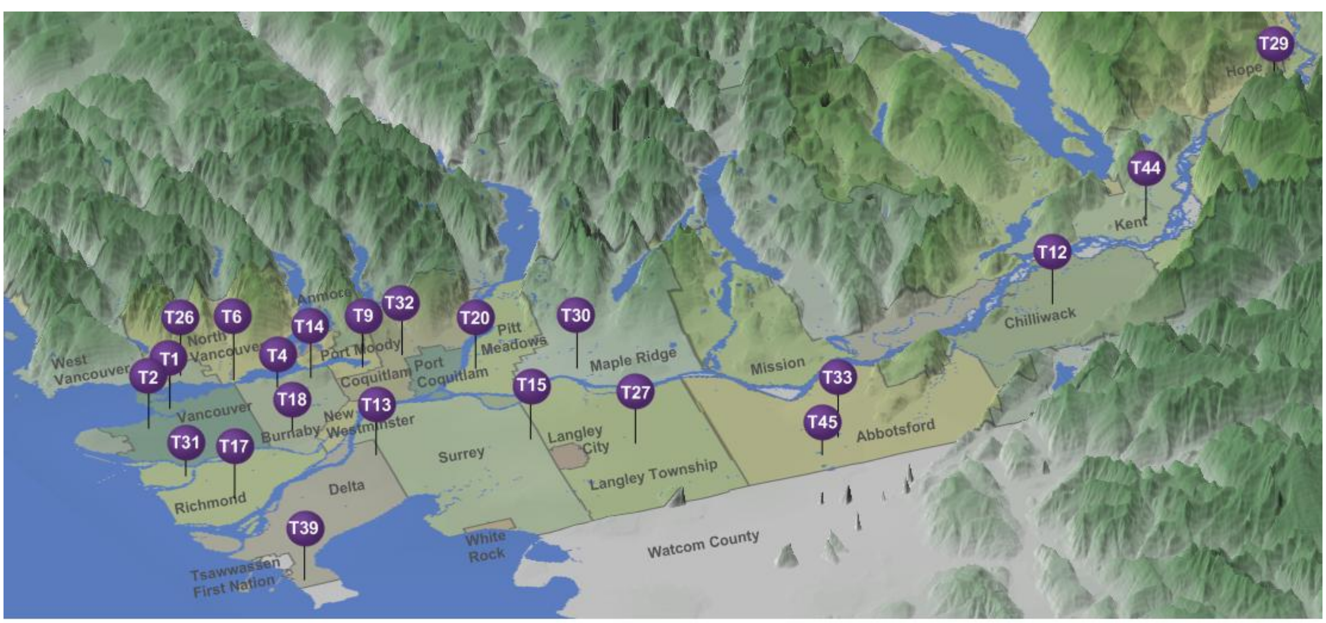


Figure 4: Nitrogen dioxide monitoring stations, 2013.

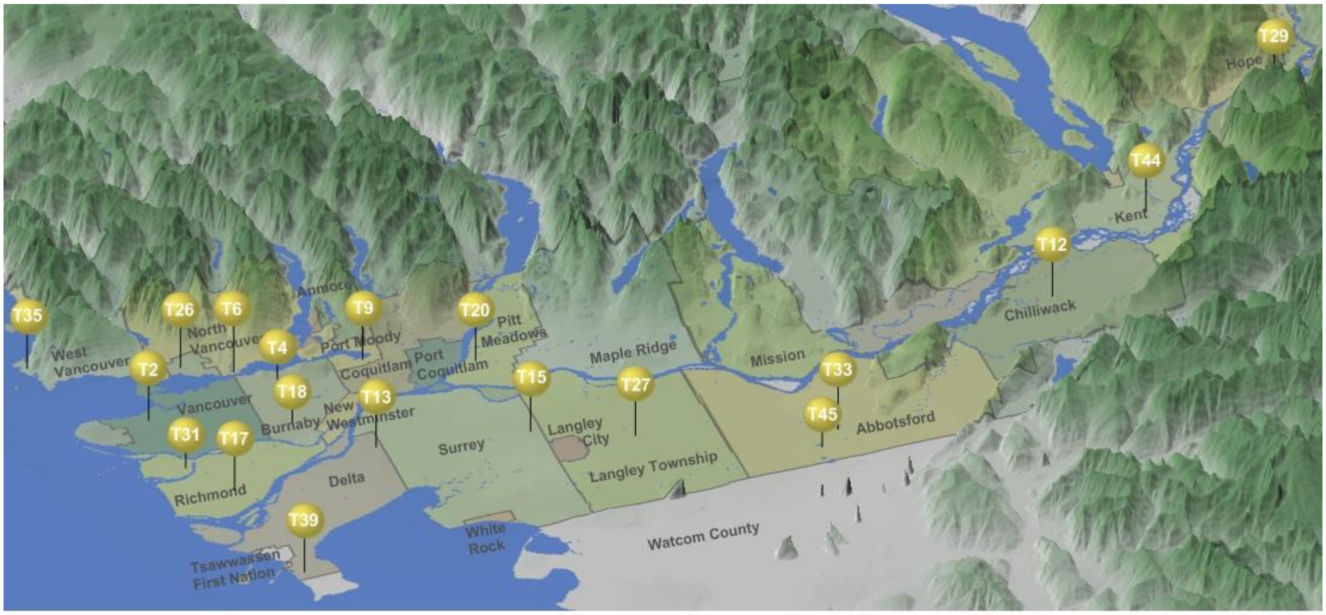


Figure 5: Fine particulate ($PM_{2.5}$) monitoring stations, 2013.

Figure 6: Sulphur dioxide monitoring stations, 2013.

Section D – Continuous Pollutant Measurements

Sulphur Dioxide (SO_2)

Characteristics

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour. It reacts in the air to form acidic substances such as sulphuric acid and sulphate particles.

Brief exposure to high concentrations of SO_2 and its by-products can irritate the upper respiratory tract and aggravate existing cardiac and respiratory disease in humans. Long-term exposure may increase the risk of developing chronic respiratory disease.

The environmental effects of SO_2 and its reactive products have been studied for many years. These compounds can cause damage to vegetation and buildings, they play a role in the formation of acid rain and they may affect the natural balance of waterways and soils. Sulphur oxides (SO_X) including SO_2 can also combine with other air contaminants to form the fine particulates ($PM_{2.5}$) that are thought to be one of the contributing factors in the degradation of visual air quality in the region.

Sources

Sulphur dioxide is emitted when fossil fuels containing sulphur are burned. The largest source of SO_2 emissions in the region is the marine sector, mostly ocean-going vessels. The major industrial source of SO_2 in this region is an oil refinery located in the Burrard Inlet area. Other significant sources contributing to the measured ambient SO_2 concentrations include non-road engines, industry, heating and transportation (motor vehicles, aircraft and trains).

Local SO_2 emissions are low relative to cities of similar size because natural gas, rather than coal or oil, is used in almost all residential, commercial and industrial heating in the region.

Monitoring Results

Sulphur dioxide levels measured in 2013 are shown in Figure 7. Figure 7 displays the value of the maximum 1-hour and 24-hour rolling average as well as the annual average for each SO_2 monitoring location. The same values are represented spatially in Figures 8, 9 and 10.

Average SO_2 levels were below the Metro Vancouver annual objective (30 $\mu g/m^3$) with relatively low levels of less than 6 $\mu g/m^3$ recorded at all stations.

Sulphur dioxide is more prevalent near the Burrard Inlet area as a result of emissions from ocean-going vessels and an oil refinery.

Hourly and 24-hour rolling average SO_2 concentrations were below Metro Vancouver objectives at all stations except Burnaby-Capitol Hill. The hourly objective was exceeded at the Burnaby-Capitol Hill station for a total of 2 hours during January 20 and 21. The 24-hour objective was exceeded at this station for a total of 3 hours on January 21. It is thought that the exceedances were caused by a combination of poor dispersion conditions along with emissions from marine vessels and the Chevron refinery. During this time there were stagnant meteorological conditions which limited dispersion.

The highest levels of SO_2 are typically measured in the north-west (Figures 8, 9 and 10), particularly close to the dominant sources of SO_2 emissions (i.e., marine vessels, port areas and an oil refinery) in the Burrard Inlet area.

Figures 11 and 12 show the seasonal trend of SO_2 with the monthly average shown in Figure 11 and the highest 1-hour concentration from each month shown in Figure 12. In both figures, concentrations from six selected stations are shown alongside the range of concentrations measured at all stations (shown as a grey band). There is little or no discernible trend in SO_2 concentrations throughout the year. The Downtown-Vancouver station experienced the highest average concentrations through most of the year while the highest 1-hour measurements were recorded at Burnaby-Capitol Hill in January, Port Moody in June and Chilliwack in August. Typically Chilliwack experiences low levels of SO_2, however on August 17 local emissions from an air show were detected.

The values in Tables 3 and 4 represent the frequency distribution or count of how many hourly and 24-hour rolling average measurements were in the specified ranges, respectively. It can be seen that stations located near the Burrard Inlet area experience a greater occurrence of higher concentrations compared with areas away from the Inlet.

A series of diurnal plots are shown in Figure 13 for each SO_2 monitoring station. The plots demonstrate the differences between weekdays and weekends along with differences between summer and winter. Stations located away from Burrard Inlet show little diurnal variation while stations located near the inlet show trends indicative of local emission sources.

Both North Vancouver stations, N. Vancouver-2nd Narrows and N. Vancouver-Mahon Park, measured a single winter peak around noon and both morning and evening peaks in summer. These two stations located close to Burrard Inlet are thought to be mainly influenced by emissions from ocean-going vessels.

The Burnaby-Capitol Hill station shows peak SO_2 concentrations during the morning and evening periods when mixing layer depth is reduced and dispersion is limited. Measurements of SO_2 at this station are influenced by its proximity to the oil refinery.

A distinct peak is displayed at Port Moody which is thought to be the result of a one day event on June 22 when a large Centennial festival was celebrated. On this day a car show and parade terminated near the station and food vendors were also located close to the monitoring station. During this event other pollutants were also elevated including CO, $PM_{2.5}$, PM_{10} and BC.

The Chilliwack station typically measures low concentrations of SO_2. However, in 2013 local emissions associated with an air show were measured on August 17. It is thought that emissions from aircraft and/or pyrotechnics contributed to elevated SO_2 levels on that day. The photo below shows visible smoke captured by the visibility camera during the air show the evening of August 17.

The long-term SO_2 trends in the LFV are shown in Figures 14 and 15. The annual average trend is given in Figure 14 with the short-term peak trend given in Figure 15 for the last two decades. The yearly variation can be attributed in part to meteorological variability while the major long-term changes in air quality are mainly a result of changes in emissions.

Long-term trends provide information to help assess the impact of emission reduction efforts, policy changes and technology advances. For example, emissions of SO_2 declined during the early 1990s due to reduced sulphur content in on-road fuels, the shutdown of several refineries, and reduced emissions from the cement industry. In recent years measurements of both the annual short-term peak (99^{th} percentile of the 1-hour values) and the annual average are markedly lower than they were in the early 1990s.

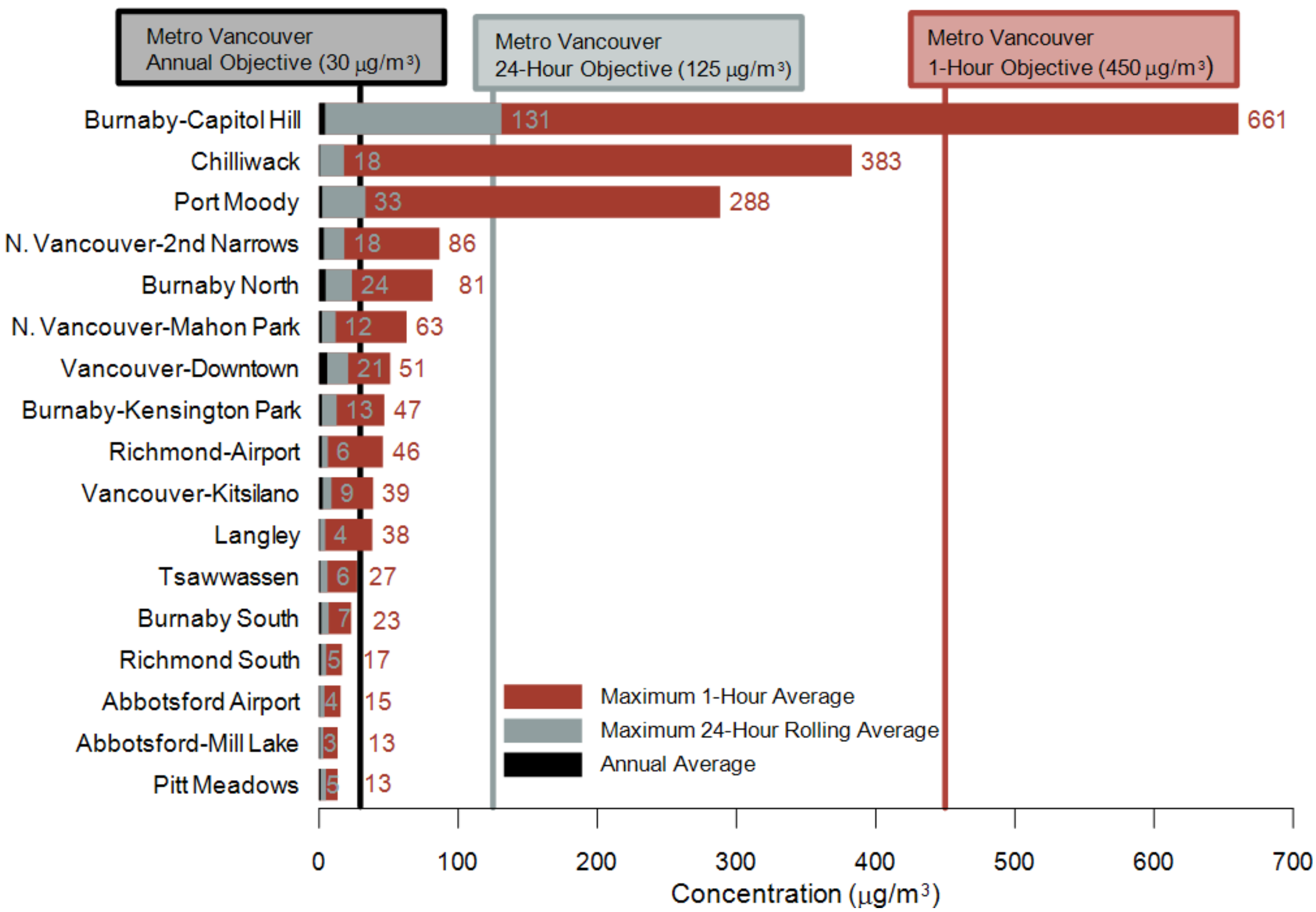


Figure 7: Sulphur dioxide monitoring, 2013.

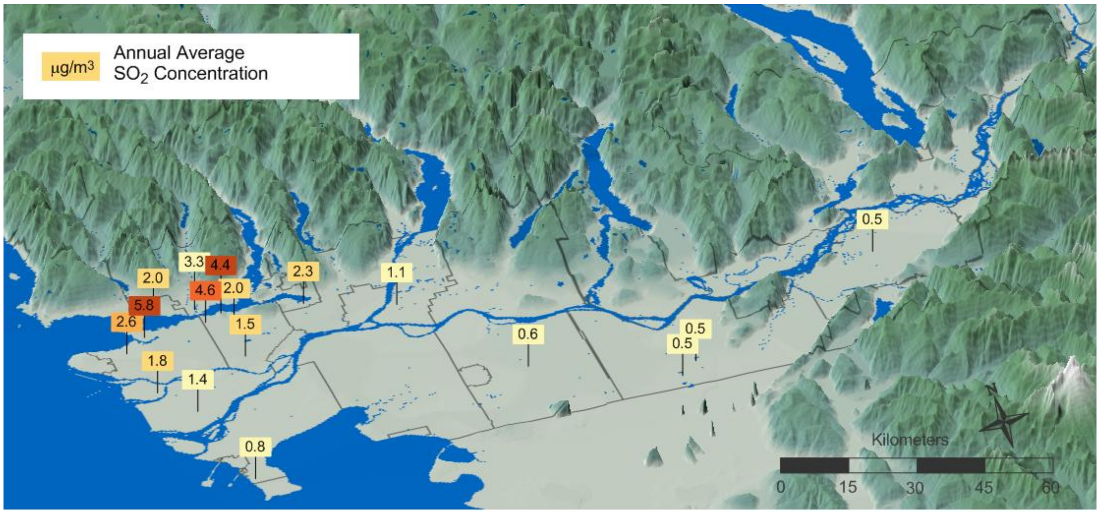


Figure 8: Annual average sulphur dioxide in the LFV, 2013.

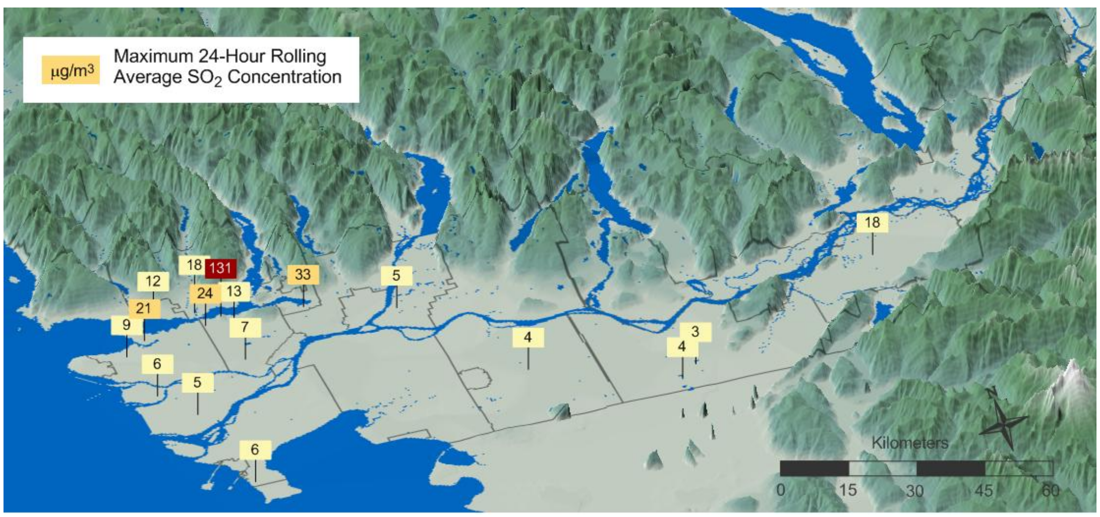


Figure 9: Short-term peak (maximum 24-hour) sulphur dioxide in the LFV, 2013.

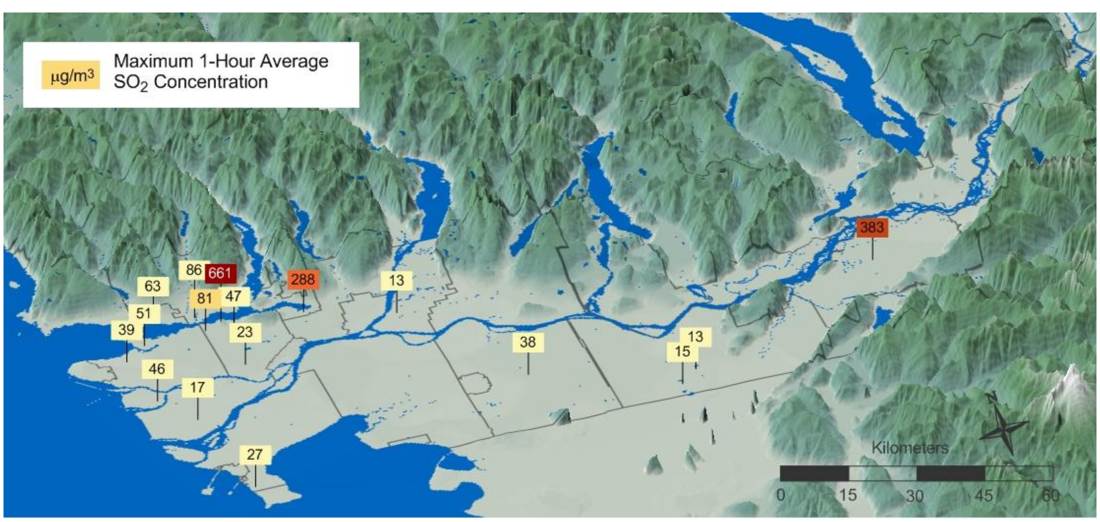


Figure 10: Short-term peak (maximum 1-hour) sulphur dioxide in the LFV, 2013.

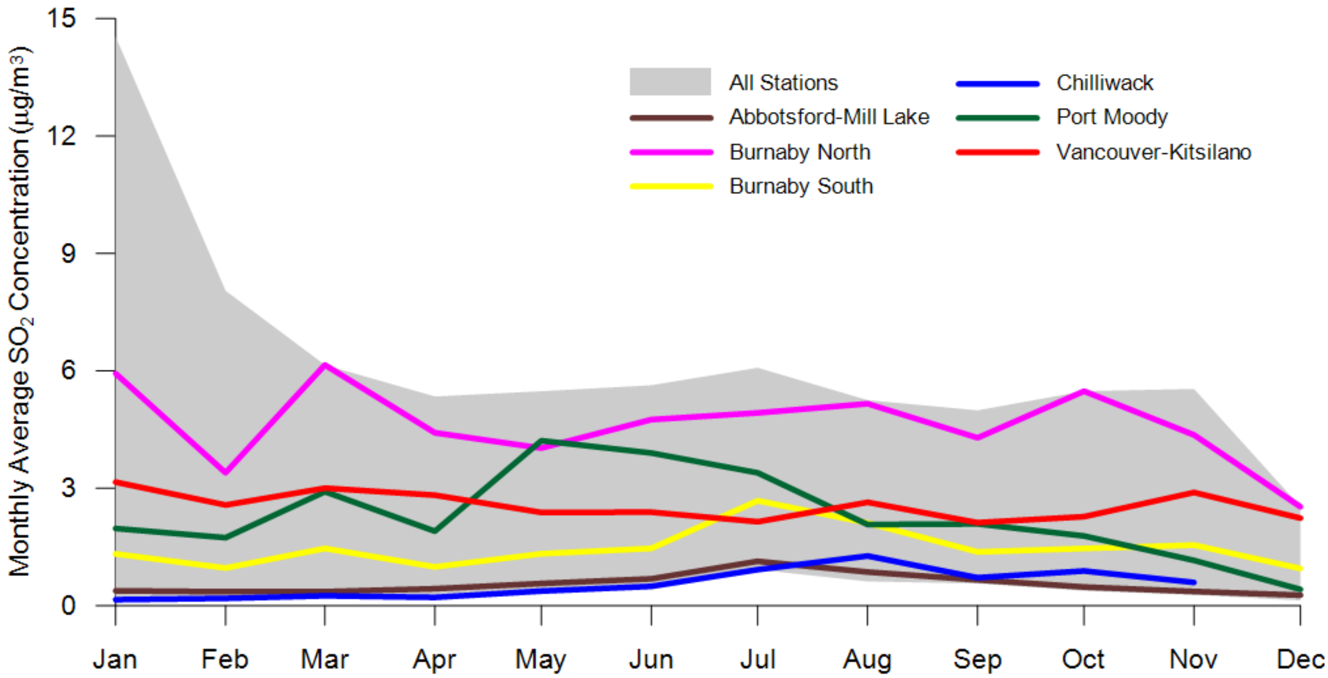


Figure 11: Monthly average sulphur dioxide, 2013.

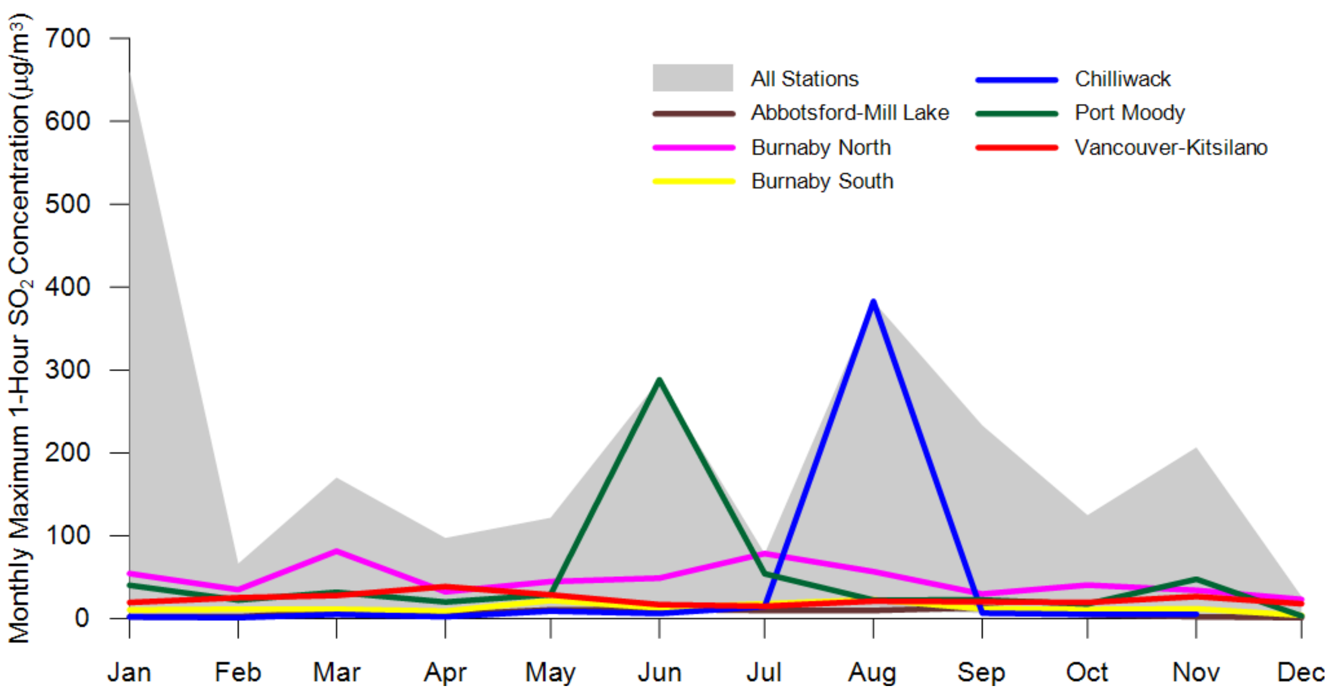


Figure 12: Monthly short-term peak sulphur dioxide, 2013.

Table 3: Frequency distribution of hourly sulphur dioxide, 2013.

SO_2 Conc. ($\mu g/m^3$)	Vancouver-Downtown	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Richmond-Airport	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport
0 to 35	8092	8609	8507	8543	8291	8366	8495	8591	8182	8463	8580	8607	8468	8601	8514	8397	8421
35 to 70	20	1	2	18	5					77	18	2	1	1			
70 to 105				1						31	2						
105 to 140					1					11							
140 to 175										7							
175 to 210										7							
210 to 245										4							
245 to 280					1					2							
280 to 315					1					1							
315 to 350										2							
350 to 385						1											
385 to 420																	
420 to 455										1							
455 to 490																	
490 to 525																	
525 to 560										1							
560 to 595																	
595 to 630																	
630 to 665										1							
>=665																	
Missing	648	150	251	198	461	393	265	169	578	152	160	151	291	158	246	363	339
Data Completeness	93%	98%	97%	98%	95%	96%	97%	98%	93%	98%	98%	98%	97%	98%	97%	96%	96%

Table 4: Frequency distribution of 24-hour rolling average sulphur dioxide, 2013.

SO_2 Concentration ($\mu g/m^3$)	Vancouver-Downtown	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	Richmond South	Burnaby South	Pitt Meadows	Burnaby-Capitol Hill	Burnaby North	N. Vancouver-Mahon Park	Langley	Richmond-Airport	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport
0 to 7	5725	8634	8554	7970	7994	8495	8633	8738	8293	7595	7130	8619	8564	8743	8646	8504	8556
7 to 14	2298	108	118	655	381					709	1485	119					
14 to 21	177			62	15	24				166	81						
21 to 28					1					67	24						
28 to 35					22					31							
35 to 42										39							
42 to 49										18							
49 to 56										6							
56 to 63										14							
63 to 70										11							
70 to 77										2							
77 to 84										1							
84 to 91										1							
91 to 98										19							
98 to 105										5							
105 to 112										9							
112 to 119										4							
119 to 126										2							
126 to 133										3							
>=133																	
Missing	560	18	88	73	347	241	127	22	467	58	40	22	196	17	114	256	204
Data Completeness	94%	100%	99%	99%	96%	97%	99%	100%	95%	99%	100%	100%	98%	100%	99%	97%	98%

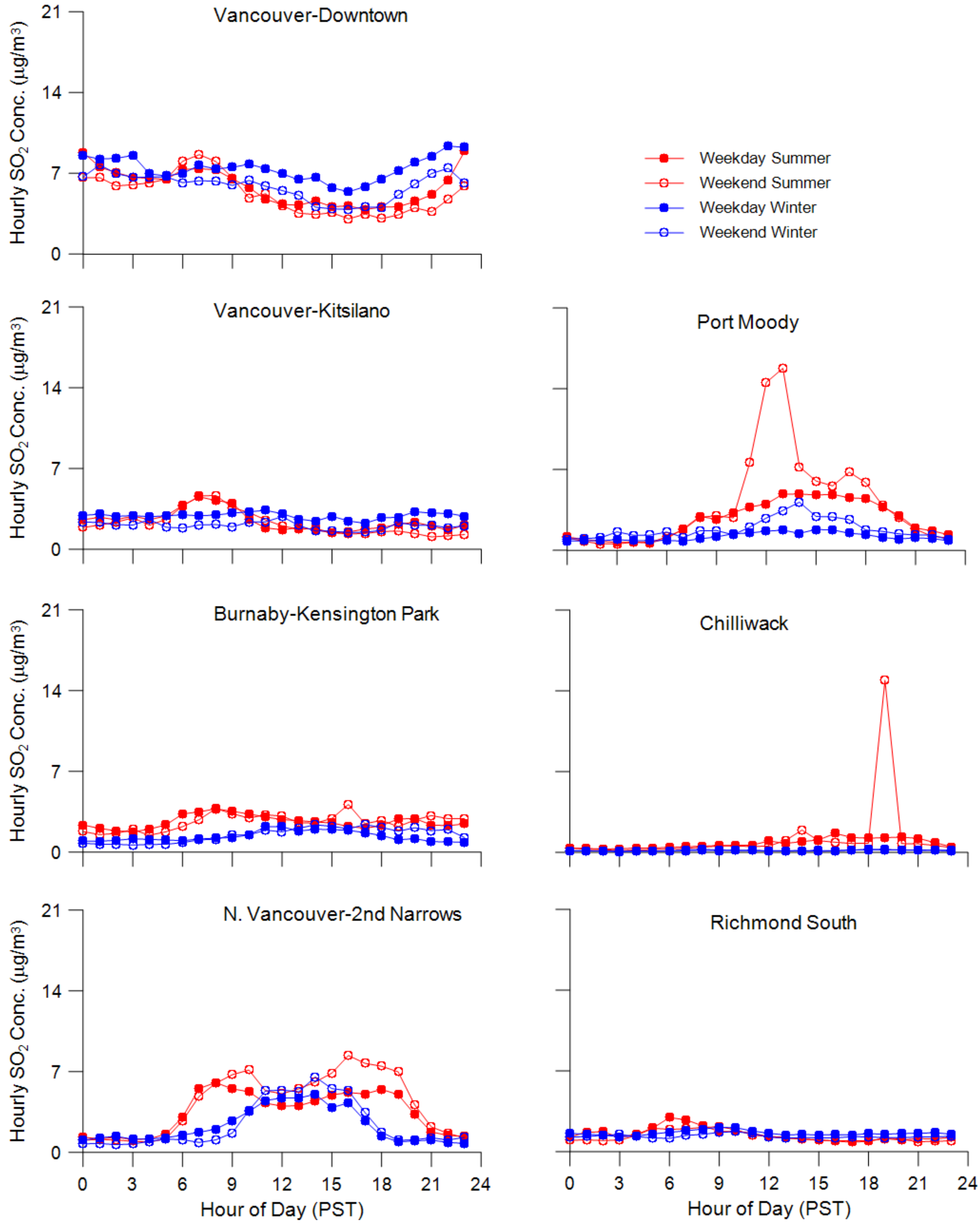


Figure 13: Diurnal trends sulphur dioxide, 2013.

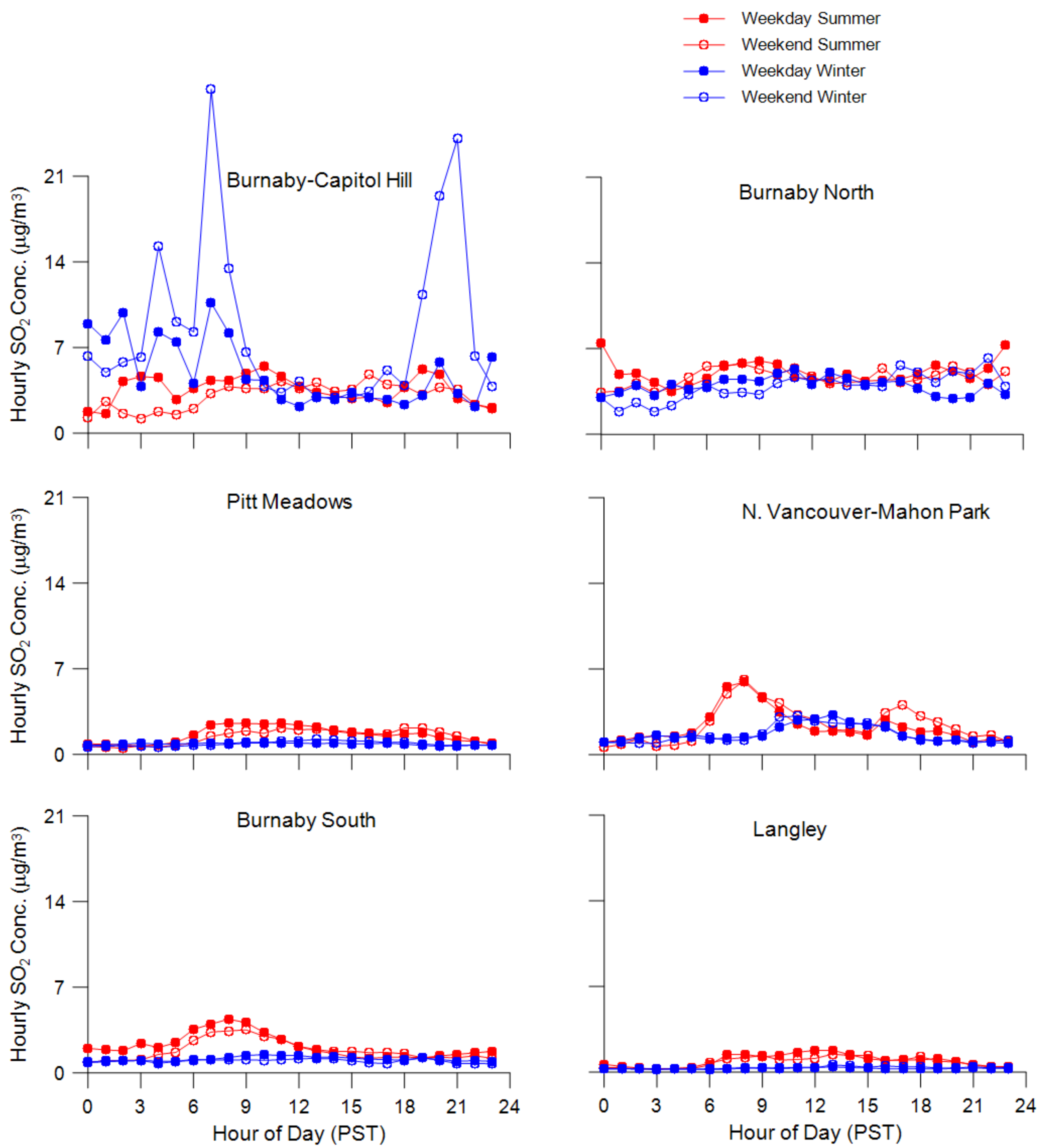


Figure 13: Cont. diurnal trends sulphur dioxide, 2013.

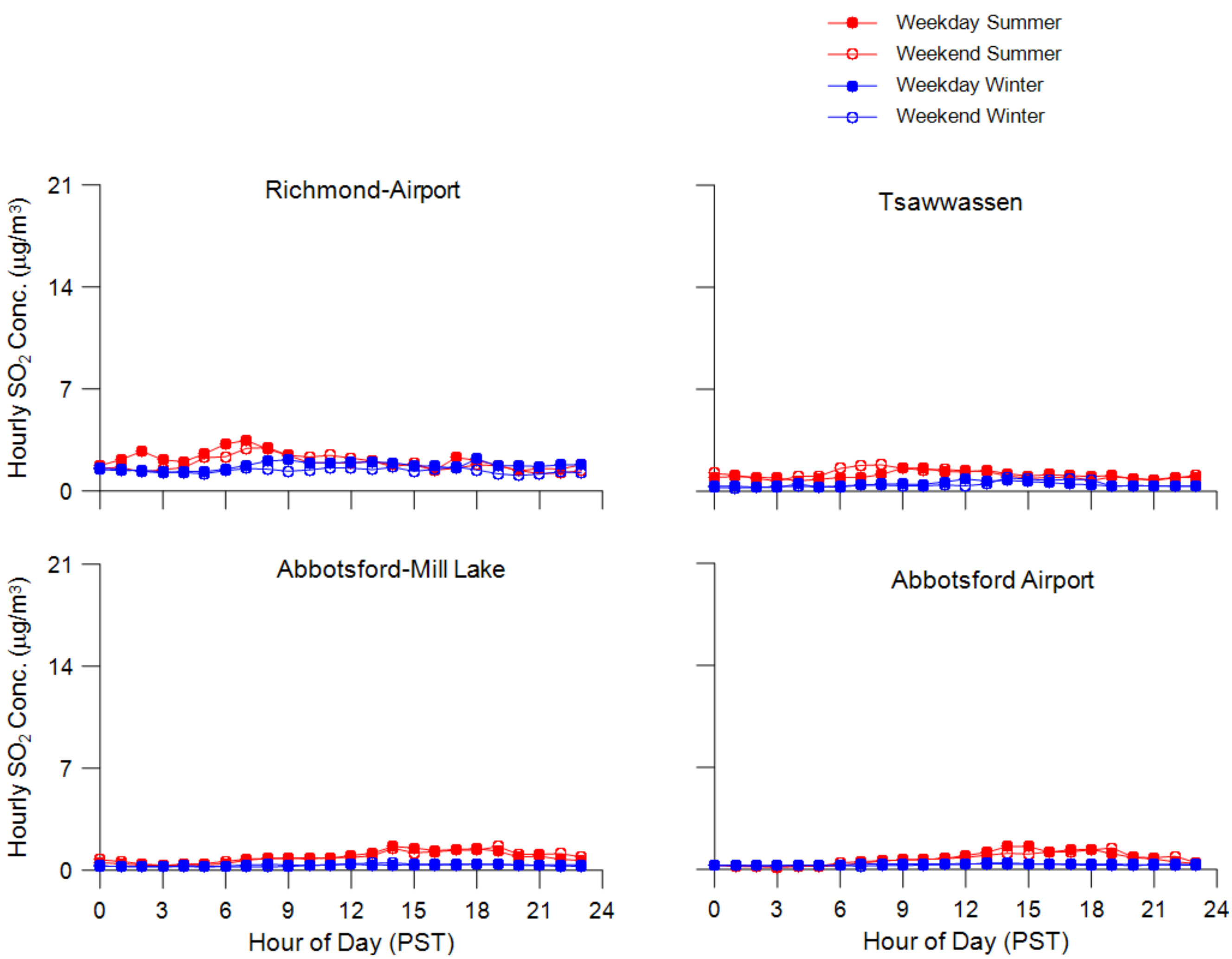


Figure 13: Cont. diurnal trends sulphur dioxide, 2013.

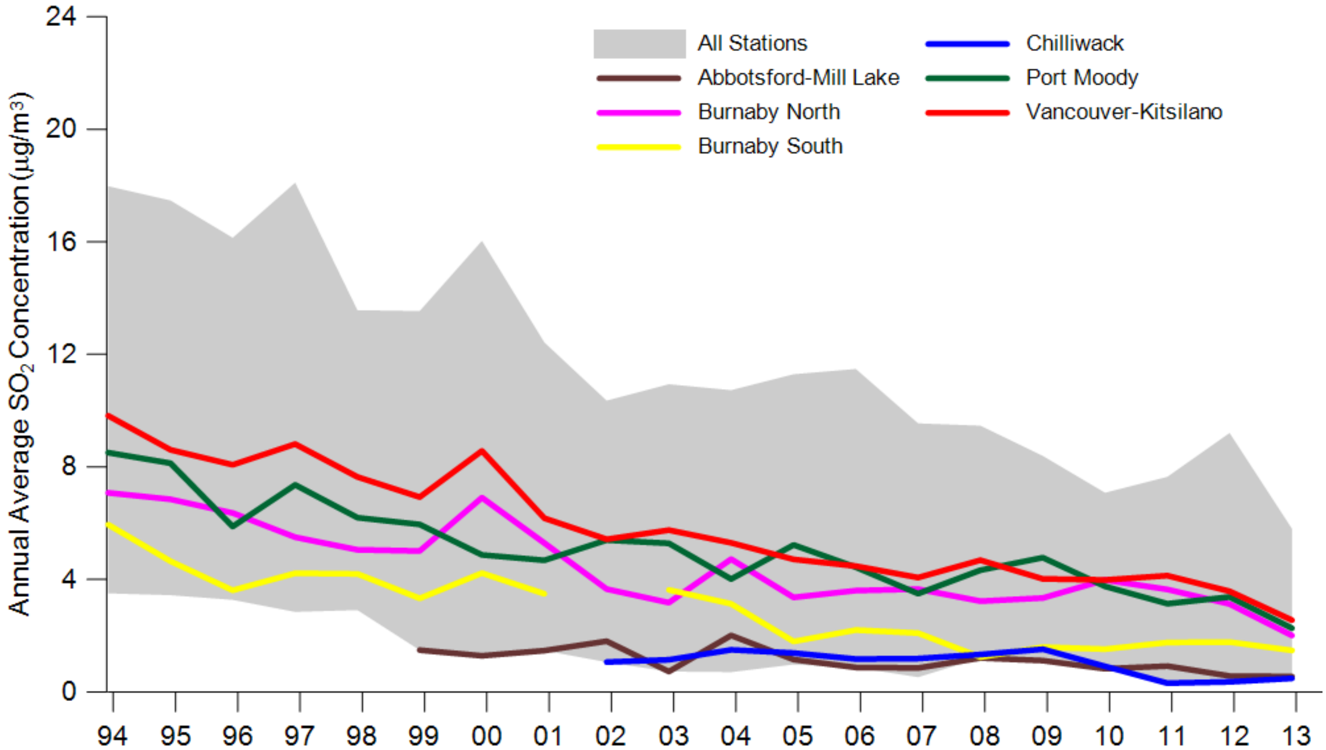


Figure 14: Annual sulphur dioxide trend, 1994 to 2013.

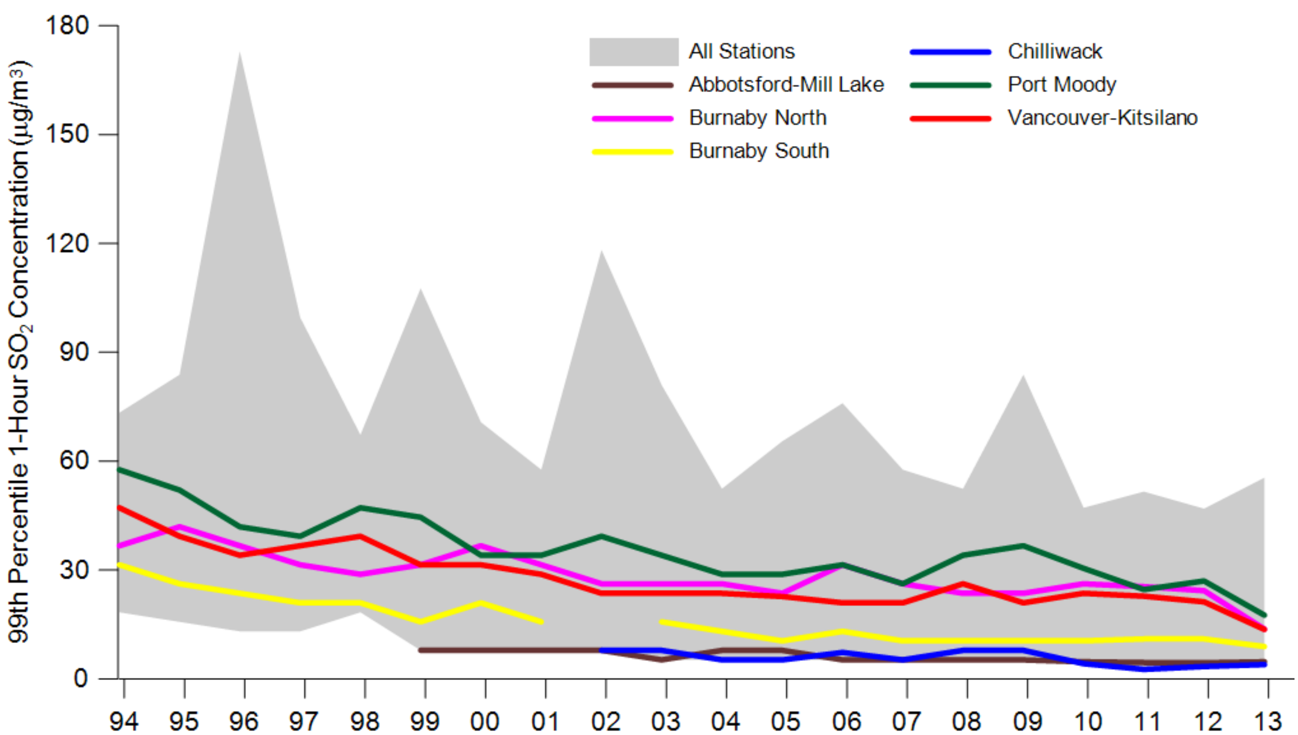


Figure 15: Short-term peak sulphur dioxide trend, 1994 to 2013.

Nitrogen Dioxide (NO_2)

Characteristics

Of all the different oxides of nitrogen (NO_X), nitric oxide (NO) and nitrogen dioxide (NO_2) are of most concern in ambient air quality. Both are produced by the high temperature combustion of fossil fuels, and are collectively referred to as NO_X. Nitric oxide generally predominates in combustion emissions but rapidly undergoes chemical reactions in the atmosphere to produce NO_2.

Nitrogen dioxide is a reddish-brown gas with a pungent, irritating odour. It has been implicated in acute and chronic respiratory disease and in the creation of acid rain. It also plays a major role in ozone formation, and as a precursor to secondary particulate formation ($PM_{2.5}$), both of which can affect visual air quality in the region.

Sources

Common NO_X sources include boilers, building heating systems and internal combustion engines. In the LFV, transportation sources account for approximately 63% of NO_X emissions, with stationary and area sources contributing the remainder.

Monitoring Results

Figure 16 shows NO_2 monitoring levels in 2013, while Figures 17 and 18 shows the same values spatially.

All 1-hour NO_2 concentrations continued to be below Metro Vancouver objective at all times in 2013. Average levels for the year were also below Metro Vancouver's annual objective.

Emissions affecting NO_2 concentrations are dominated by transportation sources. The dominance of traffic influencing NO_2 is evident when reviewing the locations of the highest concentrations. The highest concentrations are measured in more densely trafficked areas near busy roads. Lower concentrations were observed where traffic influences were less pronounced, such as the eastern parts of Metro Vancouver and in the FVRD.

The seasonal trend for NO_2 in 2013 is demonstrated by plotting monthly averages in Figure 19 and the monthly maximum 1-hour concentrations in Figure 20. Overall, NO_2 concentrations were higher in the winter and lower in the summer. This seasonal trend is typical of the region and is the result of lower atmospheric mixing heights in winter along with increased traffic and residential, commercial and industrial heating.

The frequency distribution of hourly concentrations measured in 2013 is given in Table 5.

The majority of nitrogen oxides are from transportation sources such as cars, trucks, rail, planes and ships.

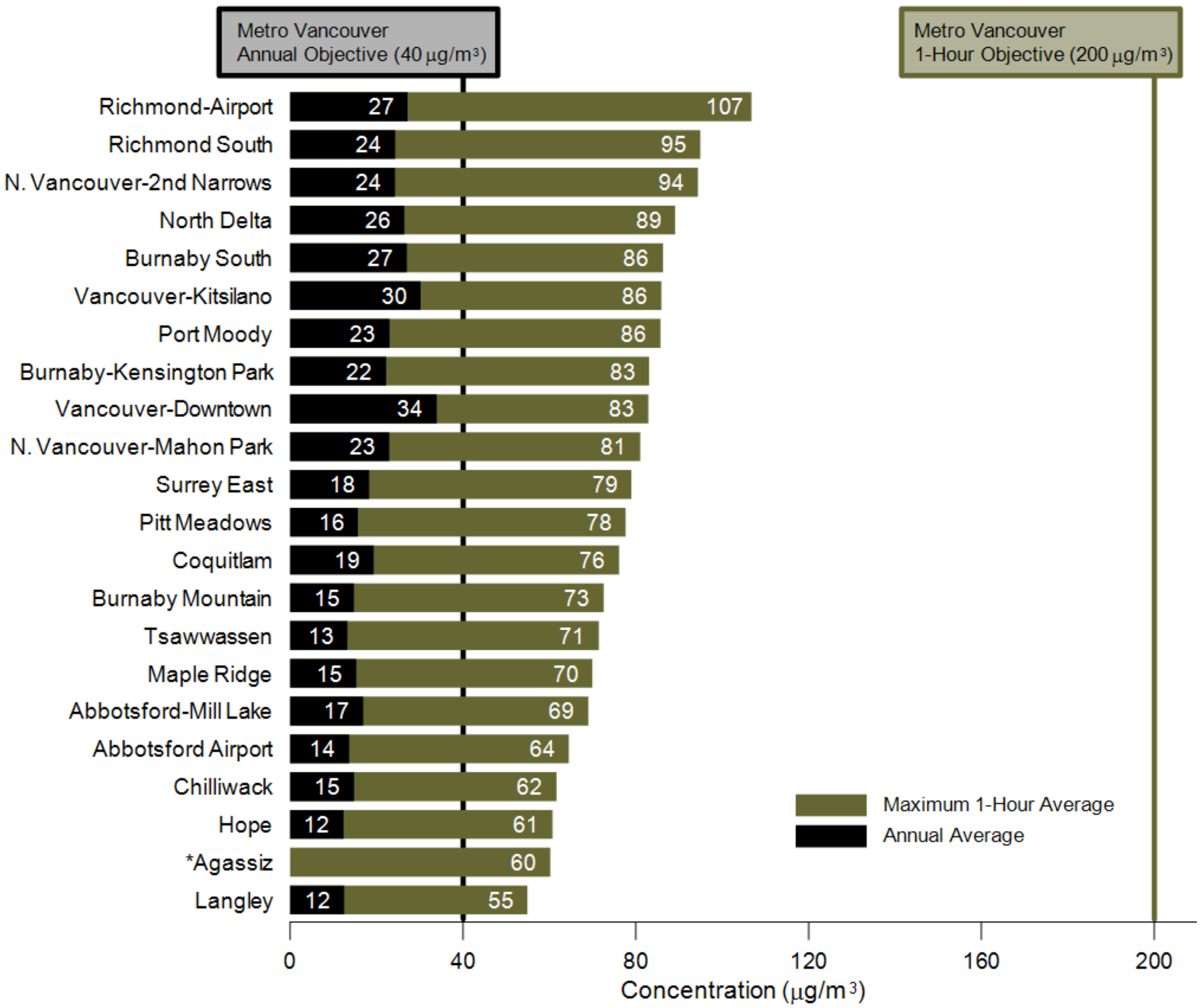
These sources play a large role in ozone formation in the summer, which can lead to an air quality advisory.

A series of diurnal plots are shown in Figure 21 for each station that monitors NO_2. The plots demonstrate the differences between weekdays and weekends along with differences between summer and winter. Most stations exhibit higher concentrations on weekdays compared with weekends and show a peak in the morning along with a peak in the afternoon. Higher concentrations correspond relatively well with traffic volume patterns.

North Vancouver-2nd Narrows shows a slightly different trend than most, with a sharp increase in the early morning hours of winter weekdays. In the summer there is a peak in the evenings. The North Vancouver-2nd Narrows station is situated in an active industrial area within half a kilometre from a large emitter of NOx in the region (a chemical plant), and a major roadway.

The long-term NO_2 trends are shown in Figures 22 and 23. The annual average trend is given in Figure 22 with the short-term peak trend given in Figure 23 for the last two decades.

The trend for average and peak (99th percentile of 1-hour) concentrations continued to decline, showing constant improvement in NO_2 levels since the early 1990's. Long-term changes in air quality can be attributed to changes in emissions while the yearly variation is likely attributable to meteorological variability. The improvements in the long-term trends shown here are thought to be largely due to improved vehicle emission standards and the AirCare program.



*Data completeness criteria were not met at this station.

Figure 16: Nitrogen dioxide monitoring, 2013.

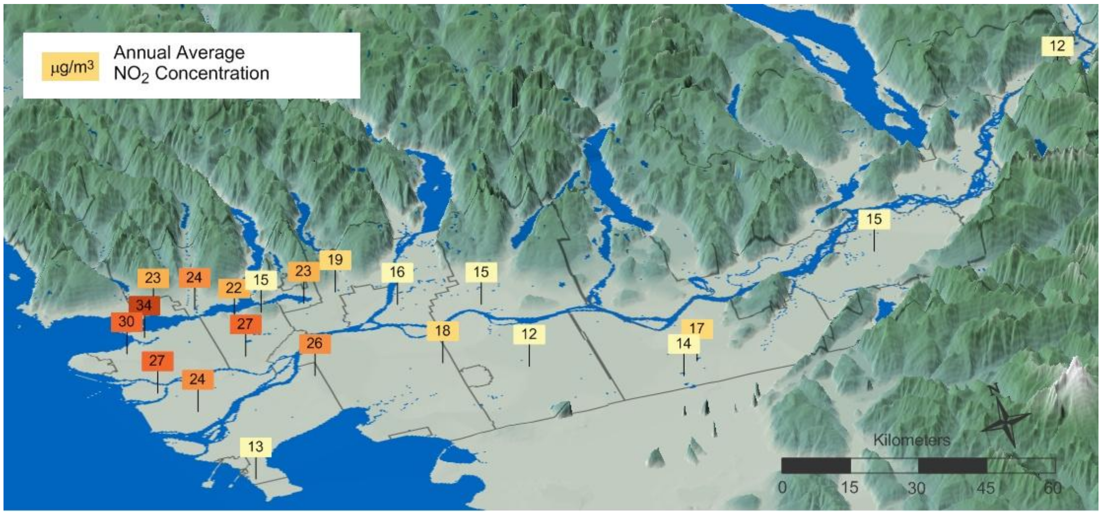


Figure 17: Annual average nitrogen dioxide in the LFV, 2013.

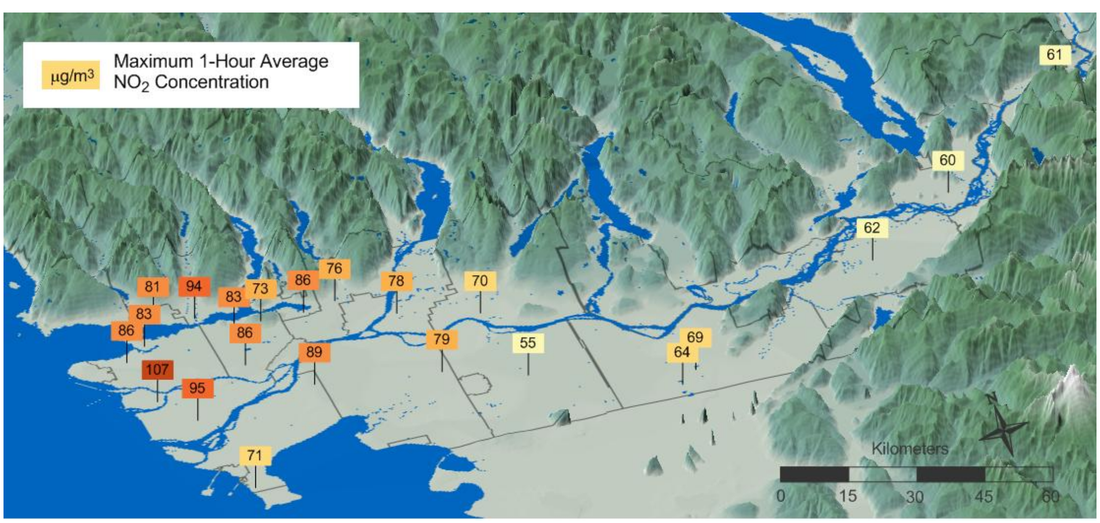


Figure 18: Short-term peak (maximum 1-hour) nitrogen dioxide in the LFV, 2013.

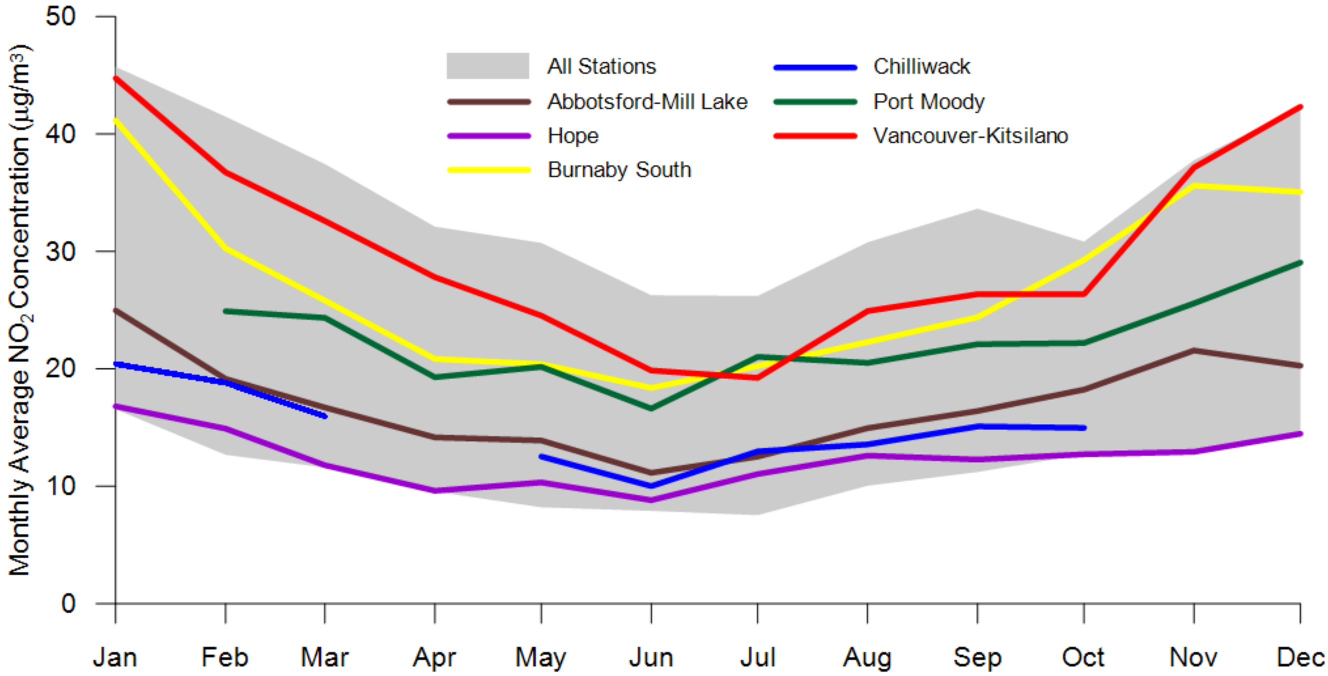


Figure 19: Monthly average nitrogen dioxide, 2013.

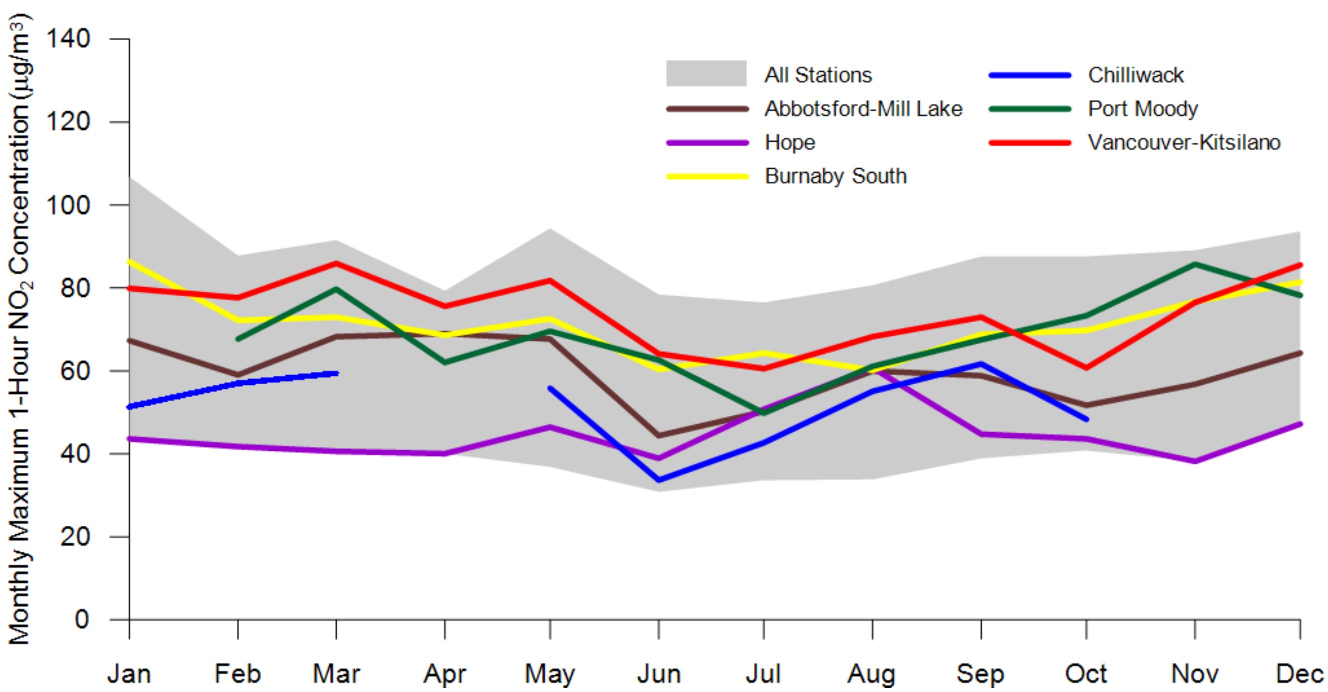


Figure 20: Monthly short-term peak nitrogen dioxide, 2013.

Table 5: Frequency distribution of hourly nitrogen dioxide, 2013.

NO_2 Conc. ($\mu g/m^3$)	Vancouver-Downtown	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport
0 to 6	8	554	361	123	223	1300	280	1383	1067	1013	136	1802	540	2177	2251	1142	652	705	1014	2678	2015
6 to 12	256	1017	1552	1141	1348	2337	1575	2613	2322	1463	1039	2068	1546	2847	2641	2812	1339	2046	2426	2459	2384
12 to 18	784	888	1756	1889	1641	1690	1393	2042	1642	1218	1508	1628	1609	1607	1691	1901	1221	1809	1699	1199	1646
18 to 24	1162	968	1623	1669	1551	1140	1127	1200	1200	1026	1458	1203	1363	916	1033	1181	1088	1393	1242	824	1140
24 to 30	1348	983	1188	1366	1345	695	1033	593	873	883	1297	820	1148	459	552	723	955	1062	872	578	701
30 to 36	1367	990	823	1005	995	343	884	307	563	823	1019	475	856	308	217	395	849	680	516	388	320
36 to 42	1281	965	507	646	523	152	798	164	410	669	824	258	645	133	101	215	673	435	246	252	165
42 to 48	1025	779	322	336	314	60	559	107	218	535	542	122	404	40	27	96	584	240	140	122	51
48 to 54	699	620	182	182	152	18	414	50	126	390	347	65	254	18	6	42	438	96	70	55	14
54 to 60	376	413	84	113	80	10	227	25	74	246	209	24	132	5	2	14	335	42	45	20	3
60 to 66	172	234	40	65	32	1	126	9	34	130	119	27	57		1	4	216	20	17	13	1
66 to 72	65	107	30	30	13		78	7	21	61	54	5	21			2	110	7	6	2	
72 to 78	21	48	7	17	4		60	2	7	27	27	5	5				64	4			
78 to 84	7	24	4	9	2		25		1	9	10		3				26				
84 to 90		2		3	2		4			2	2						15				
90 to 96				1						1							5				
96 to 102																	2				
102 to 108																	1				
>=108																					
Missing	189	168	281	165	535	1014	177	258	202	264	169	258	177	250	238	233	187	221	467	170	320
Data Completeness	98%	98%	97%	98%	94%	88%	98%	97%	98%	97%	98%	97%	98%	97%	97%	97%	98%	98%	95%	98%	96%

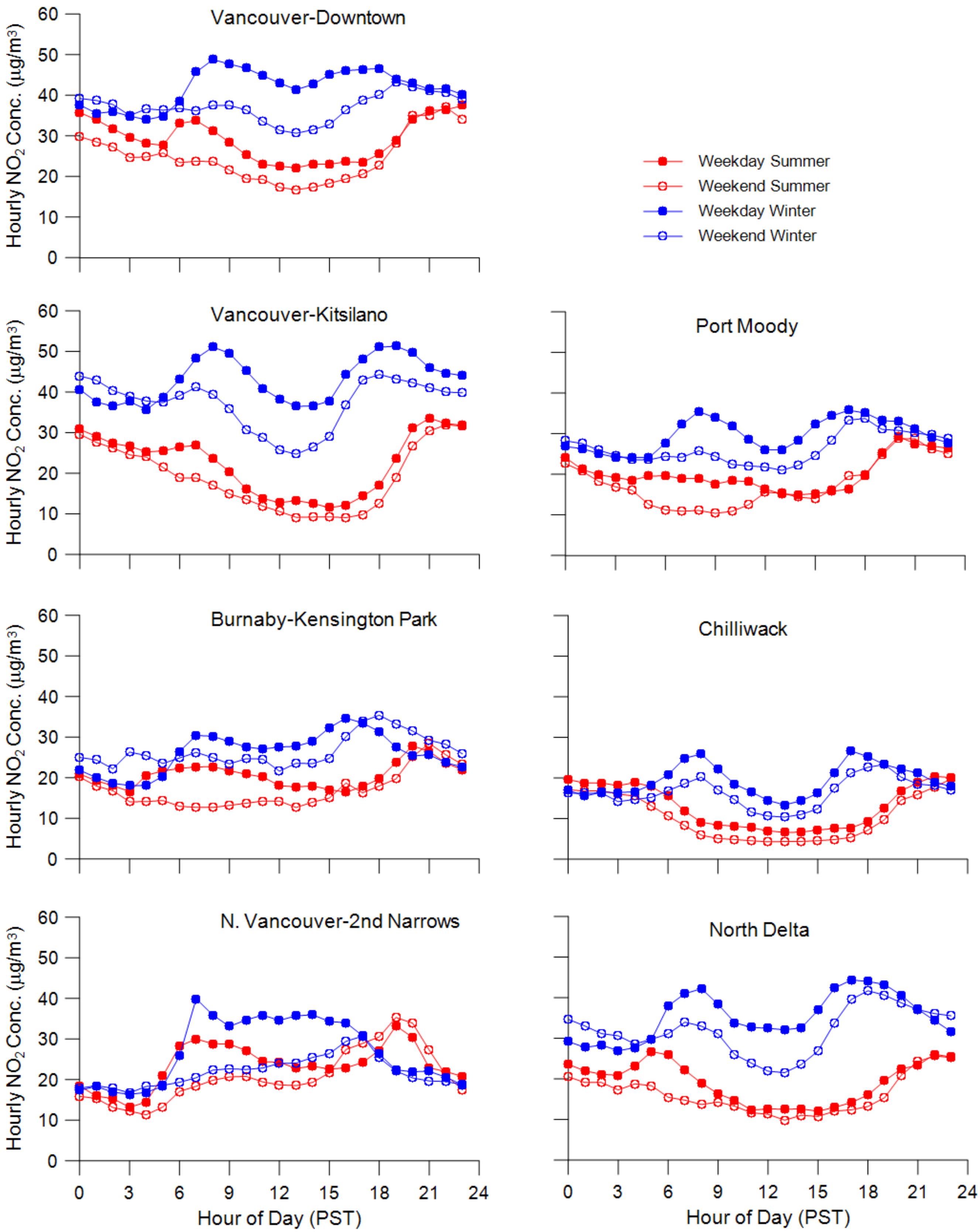


Figure 21: Diurnal trends nitrogen dioxide, 2013.

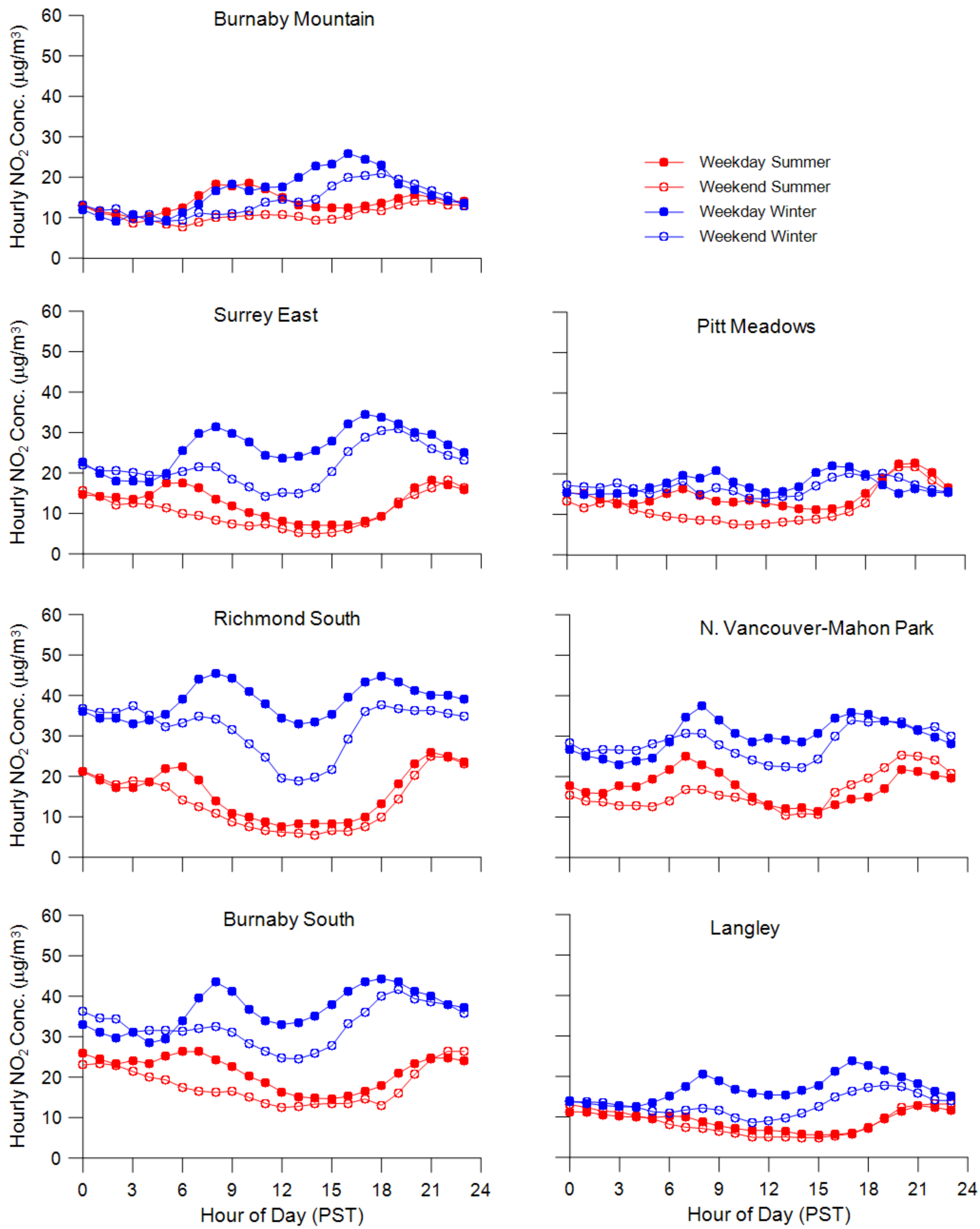


Figure 21: Cont. Diurnal trends nitrogen dioxide, 2013.

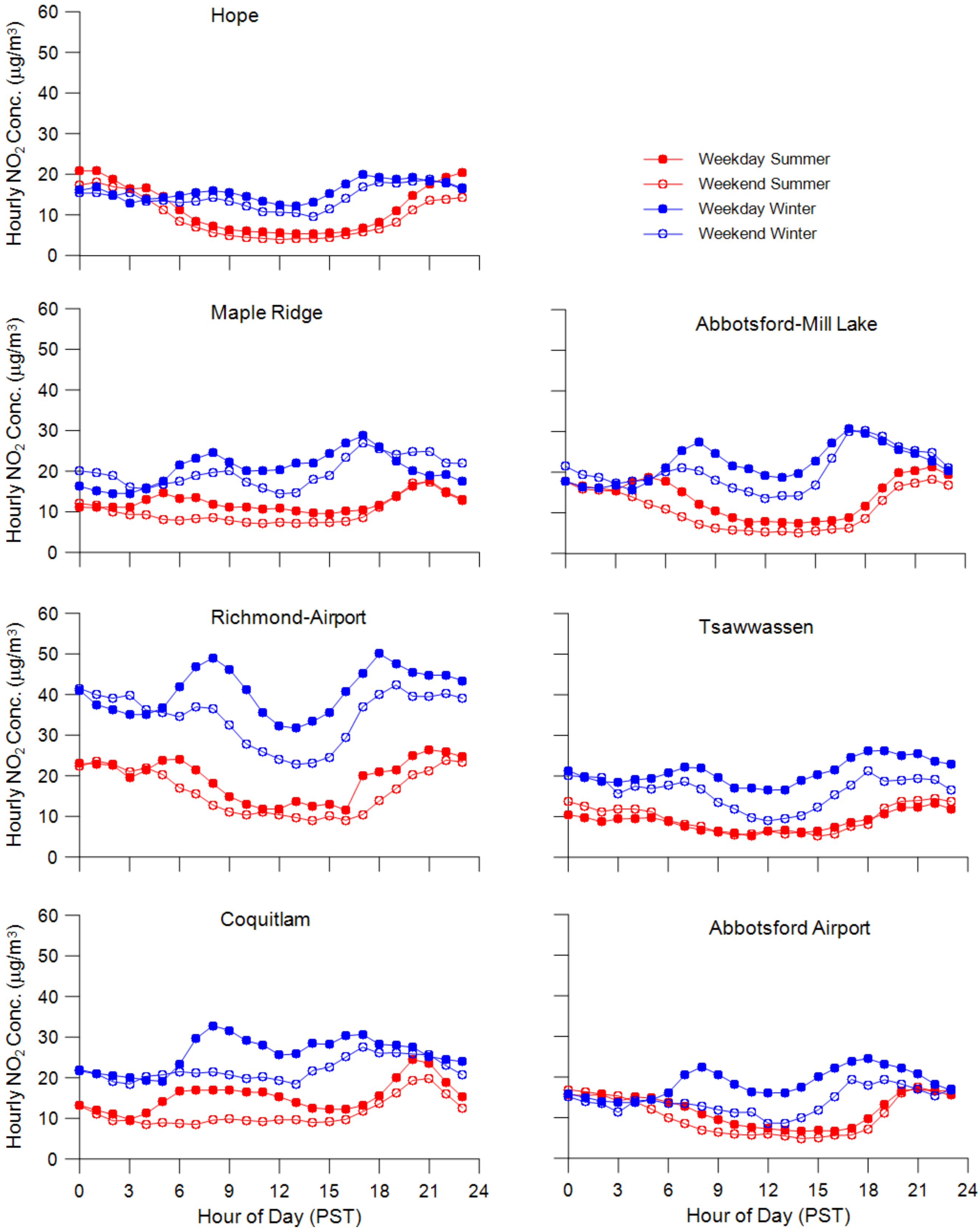


Figure 21: Cont. Diurnal trends nitrogen dioxide, 2013.

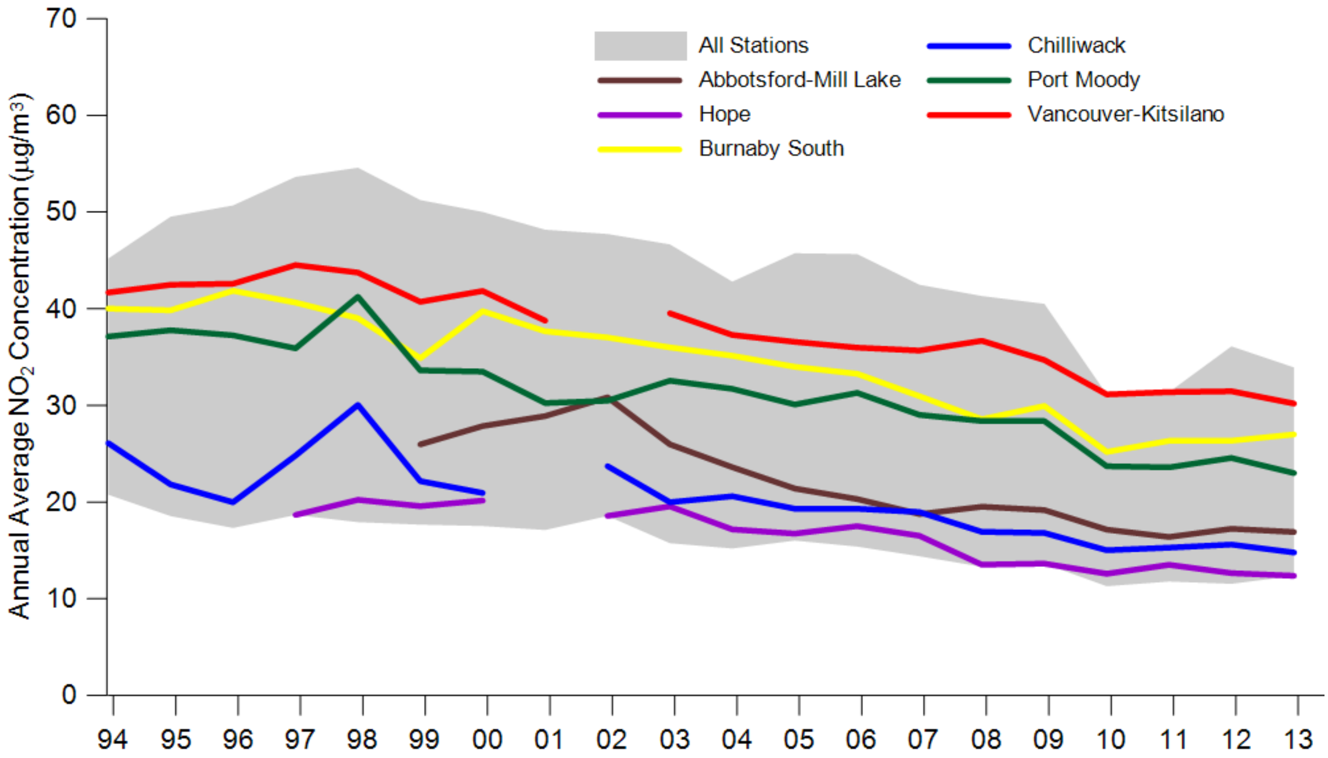


Figure 22: Annual nitrogen dioxide trend, 1994 to 2013.

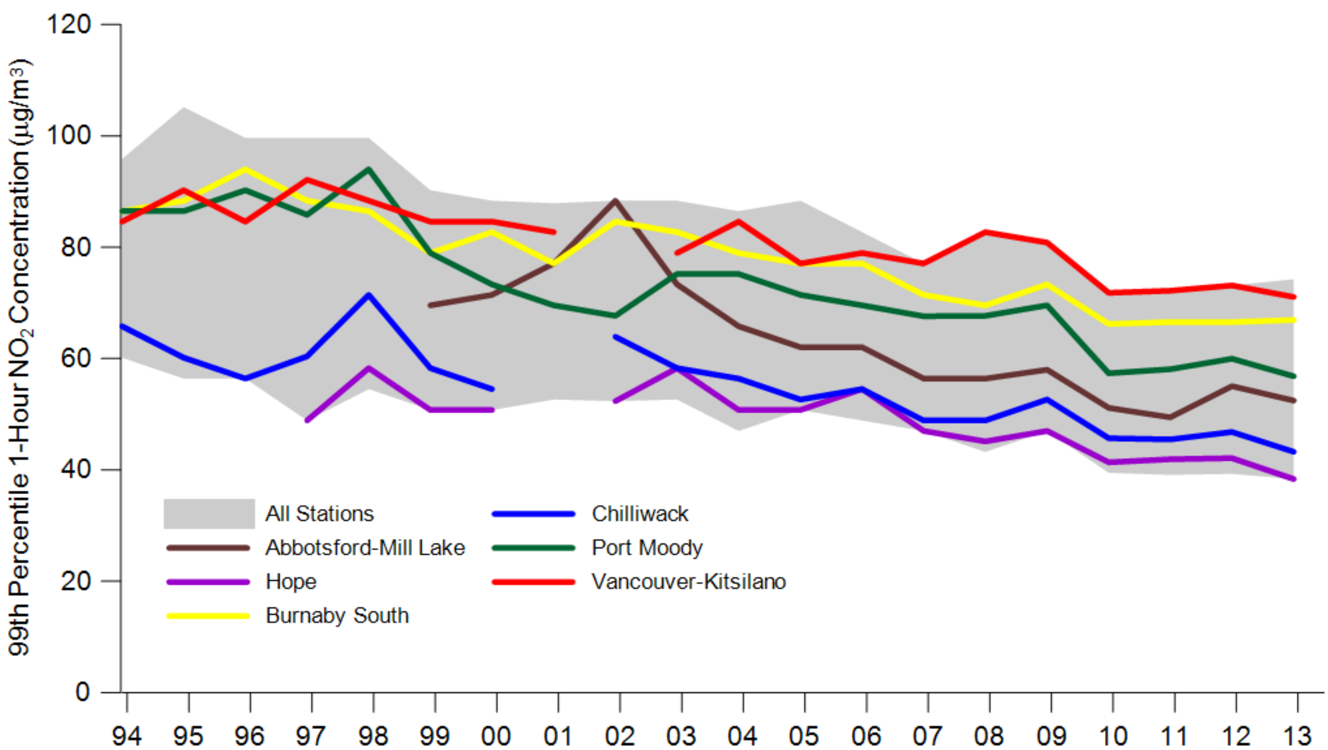


Figure 23: Short-term peak nitrogen dioxide trend, 1994 to 2013.

Carbon Monoxide (CO)

Characteristics

Carbon monoxide (CO) is a colourless, odourless and tasteless gas produced by the incomplete combustion of fuels containing carbon. It has a strong affinity for haemoglobin and thus reduces the ability of blood to transport oxygen. Long-term exposure to low concentrations may cause adverse effects in people suffering from cardiovascular disease.

Sources

Carbon monoxide is the most widely distributed and commonly occurring air pollutant. The principle sources are non-road engines and motor vehicles. In the LFV, over 94% comes from mobile sources which include cars, trucks, buses, planes, trains, ships and non-road engines. Other sources contributing to measured CO levels are building heating and commercial and industrial operations.

Monitoring Results

Figures 24 to 27 illustrate the results of CO monitoring for 2013. Figure 24 displays the value of the maximum 1-hour and 8-hour average as well as the annual average for each CO monitoring location. The same values are represented on maps in Figures 25, 26 and 27.

Measured carbon monoxide levels were well below Metro Vancouver's objectives at all stations throughout the LFV. The highest concentrations generally occurred in the west in highly urbanized areas that experience large volumes of traffic.

Average levels remained low throughout the LFV (less than 335 $\mu g/m^3$) with the lowest readings recorded at stations away from heavily trafficked areas.

The seasonal trends for CO in 2013 are plotted as monthly average and maximum 1-hour concentrations in Figures 28 and 29, respectively. Overall, average CO concentrations were higher in the winter compared with the summer. This seasonal trend is typical of the region and is the result of lower atmospheric mixing heights in winter along with increased traffic and residential, commercial and industrial heating. The highest 1-hour value was measured at Port Moody on June 22 during a large Centennial festival. The festival included a car show and parade that terminated near the station. During the event there were also food vendors located close to the station and other pollutants were also elevated including SO2, $PM_{2.5}$, PM_{10} and BC.

A series of diurnal plots are shown in Figure 30 for each station that monitors CO. Most stations exhibit higher winter concentrations on weekdays compared with weekends with many stations showing a large peak in the morning that corresponds relatively well with morning traffic patterns.

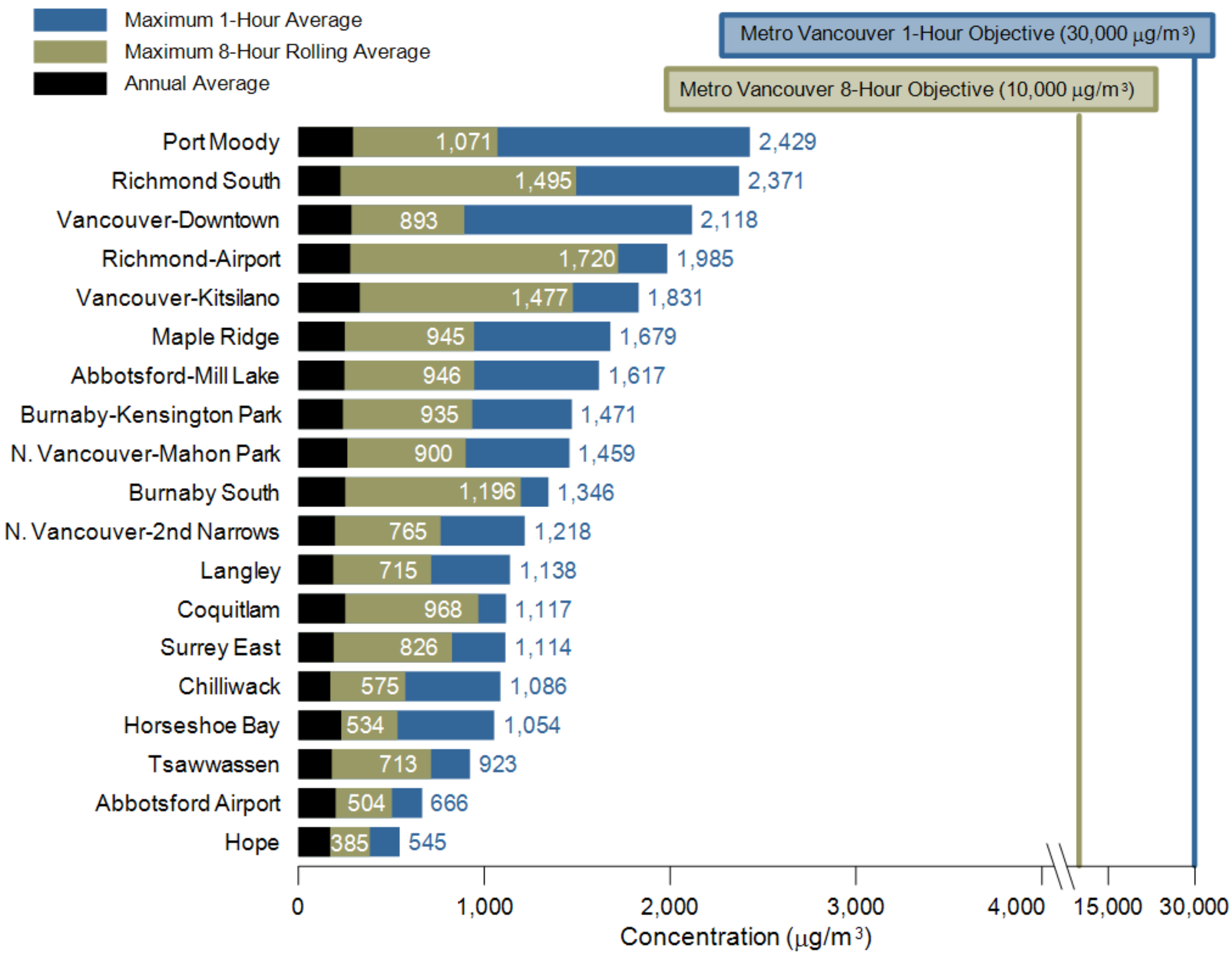
Stations that appear to be strongly influenced by CO emission sources such as traffic include Vancouver-Kitsilano, Richmond-South and Richmond-Airport where a well defined peak is evident in the mornings on weekdays during the winter.

In the summer diurnal trends are much less apparent, however two stations (Port Moody and Horseshoe Bay) show higher CO concentrations on weekends in the summer compared with other stations. At Port Moody the trend is thought to be a result of both the Centennial festival and the use of the Rocky Point Park parking lot and boat launch which is located close to the monitoring station. Weekend ferry traffic is thought to influence the Horseshoe Bay station.

With the majority of CO released from cars, trucks, buses and non-road engines, dramatic improvements have occurred in the last two decades due to improved vehicle emission standards and vehicle testing.

Figures 31 and 32 illustrate the long-term average and peak CO trends in the LFV, respectively. Some yearly variation is evident in the peak trends, however long-term changes in air quality are mainly attributed to changes in emissions. Both the average and the short-term peak (99th percentile of the 1-hour values) continued to show an improving trend downward.

In the LFV region, average levels have decreased dramatically since the early nineties. Declining CO concentrations are largely due to improved vehicle emission standards and the AirCare program.



Note: The scale is broken in the x-axis between 4,000 and 10,000 $\mu g/m^3$. The highest concentration measured is almost ten times less than the objective threshold.

Figure 24: Carbon monoxide monitoring, 2013.

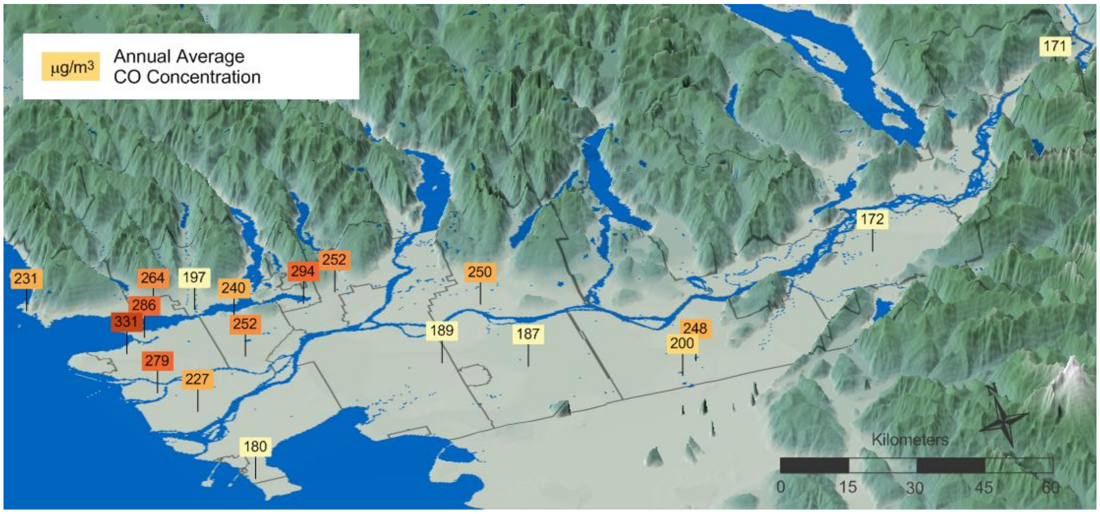


Figure 25: Annual average carbon monoxide in the LFV, 2013.

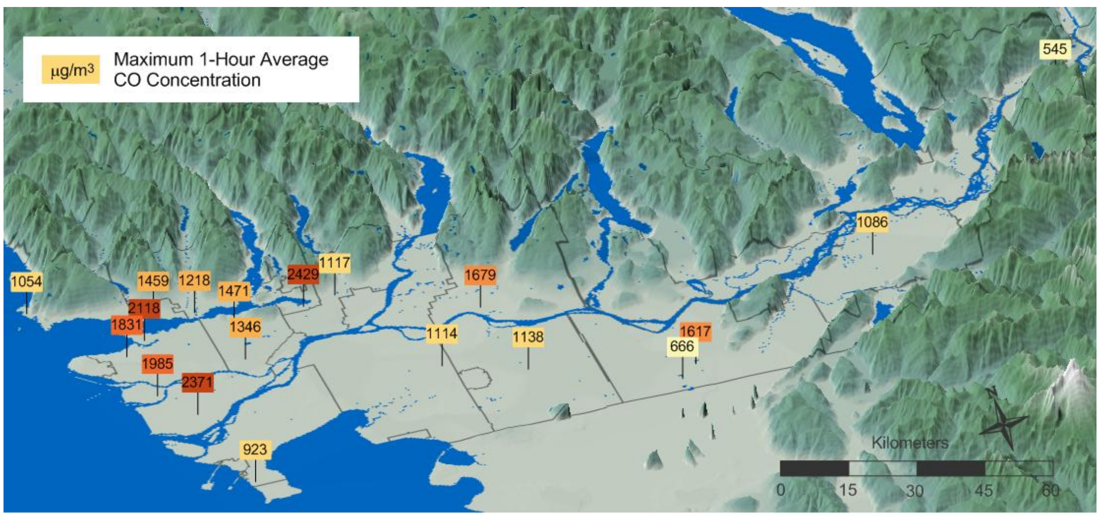


Figure 26: Short-term peak (maximum 1-hour) carbon monoxide in the LFV, 2013.

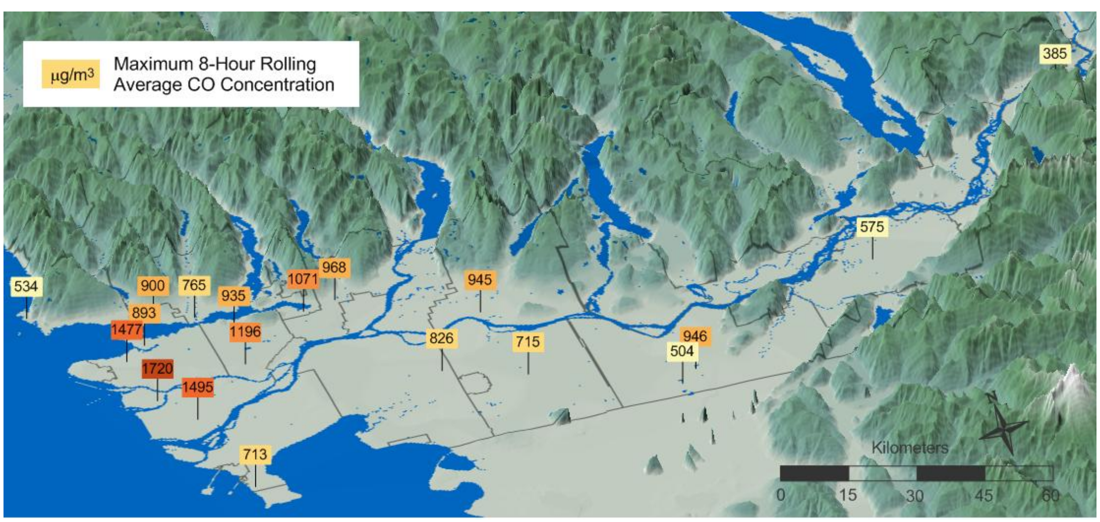


Figure 27: Short-term peak (maximum 8-hour) carbon monoxide in the LFV, 2013.

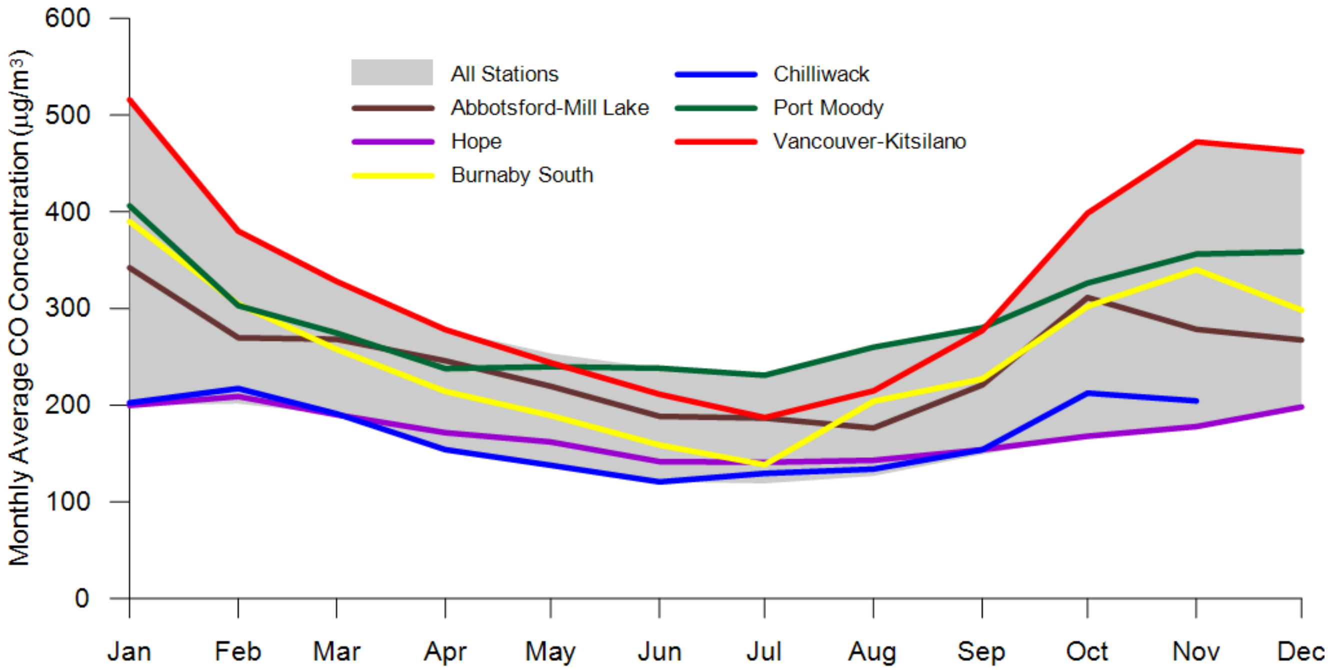


Figure 28: Monthly average carbon monoxide, 2013.

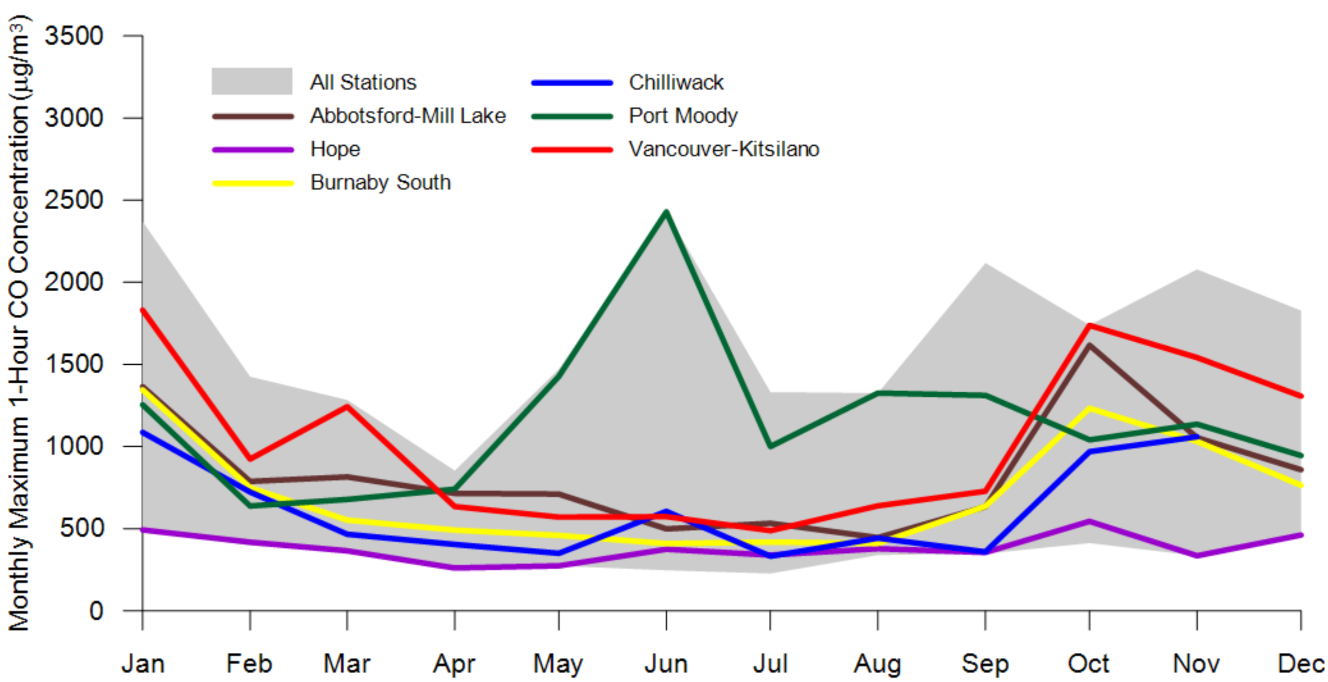


Figure 29: Monthly short-term peak carbon monoxide, 2013.

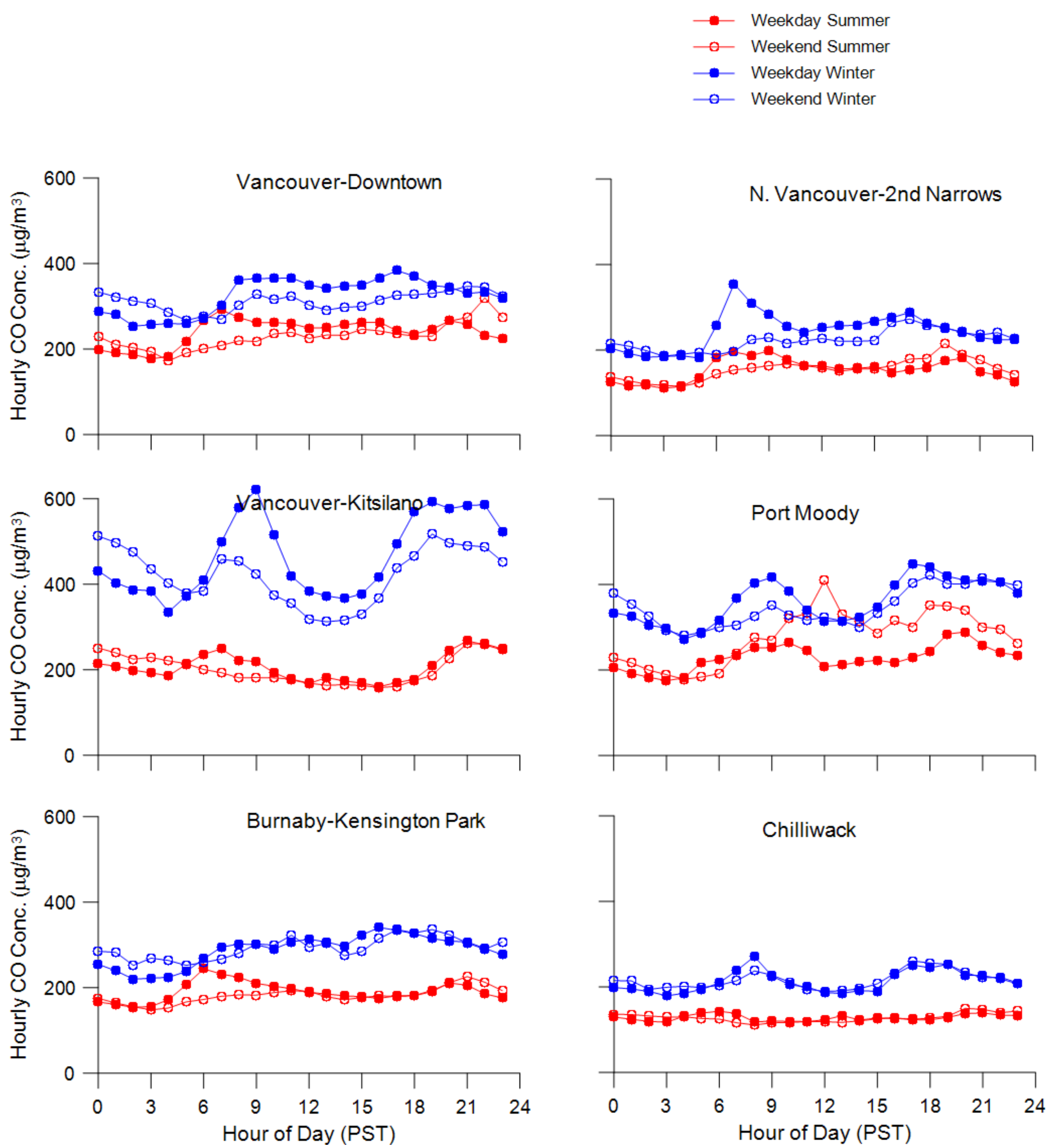


Figure 30: Diurnal trends carbon monoxide, 2013.

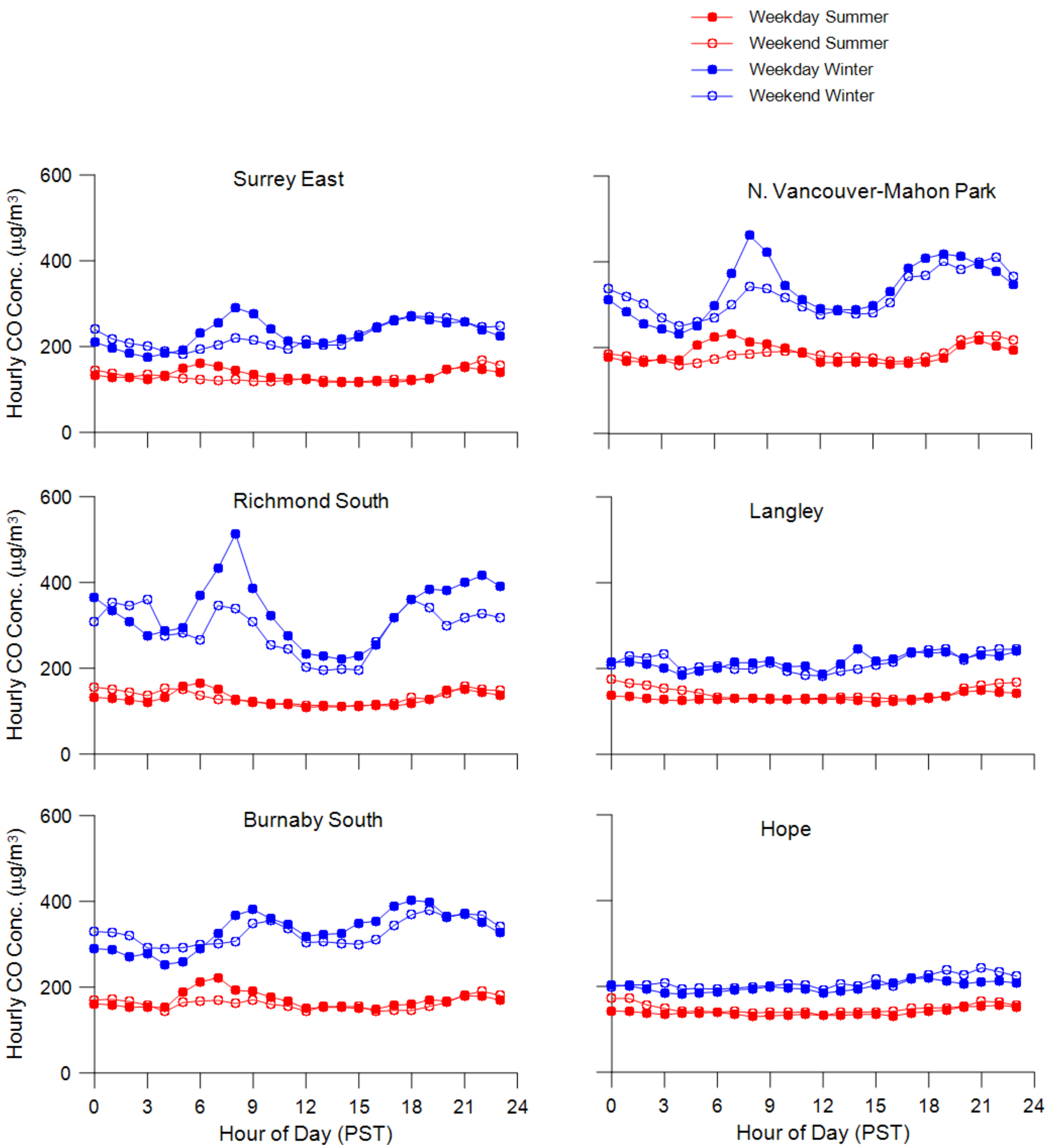


Figure 30: Cont. diurnal trends carbon monoxide, 2013.

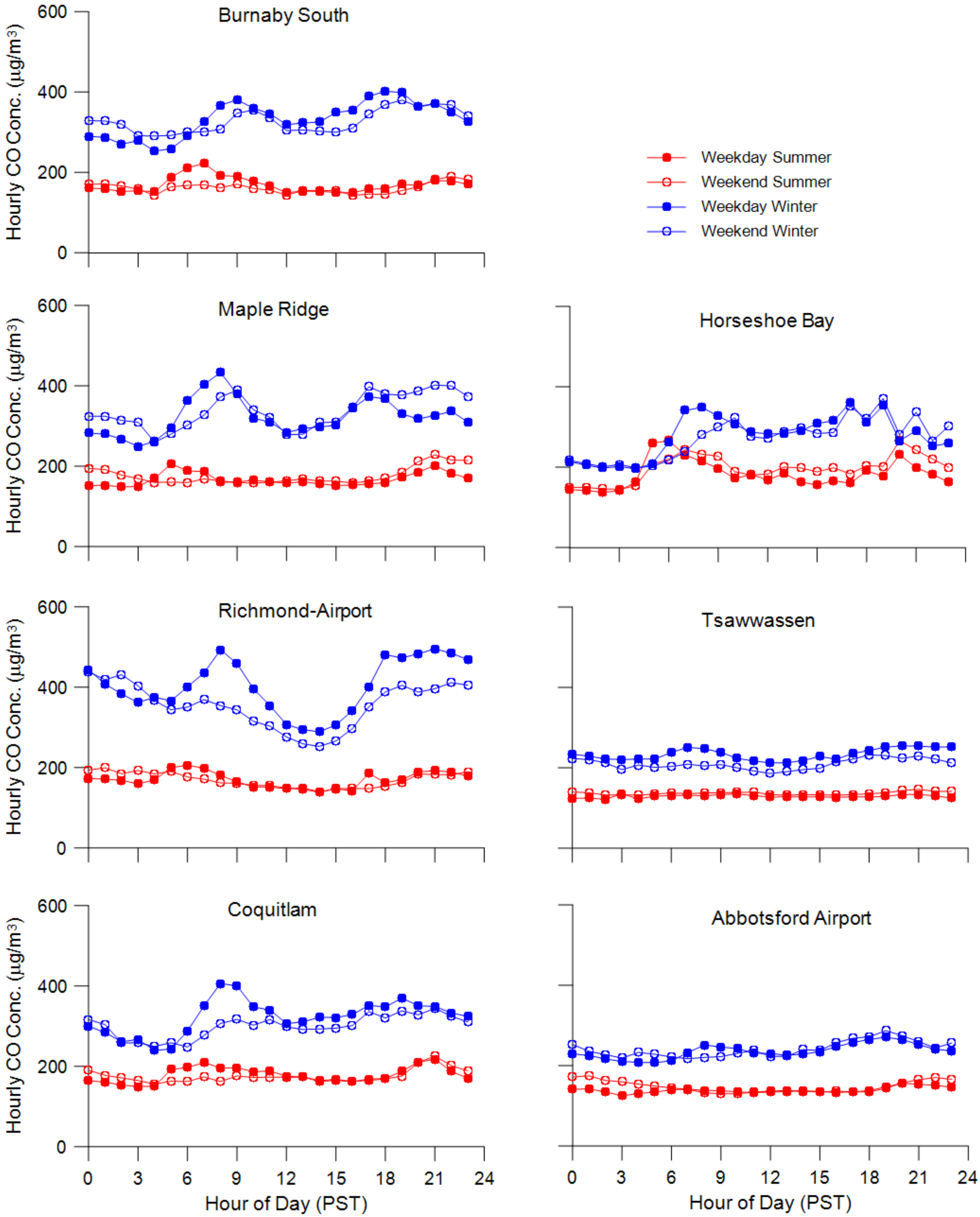


Figure 30: Cont. diurnal trends carbon monoxide, 2013.

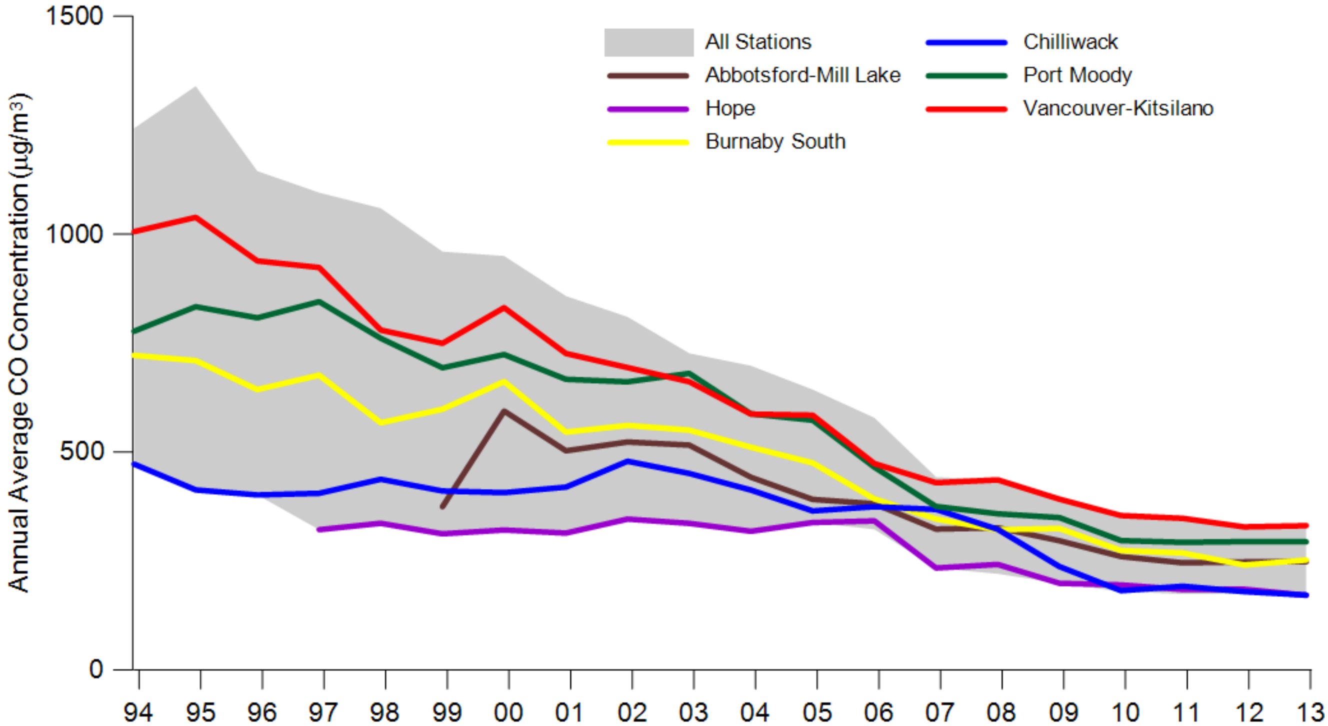


Figure 31: Annual carbon monoxide trend, 1994 to 2013.

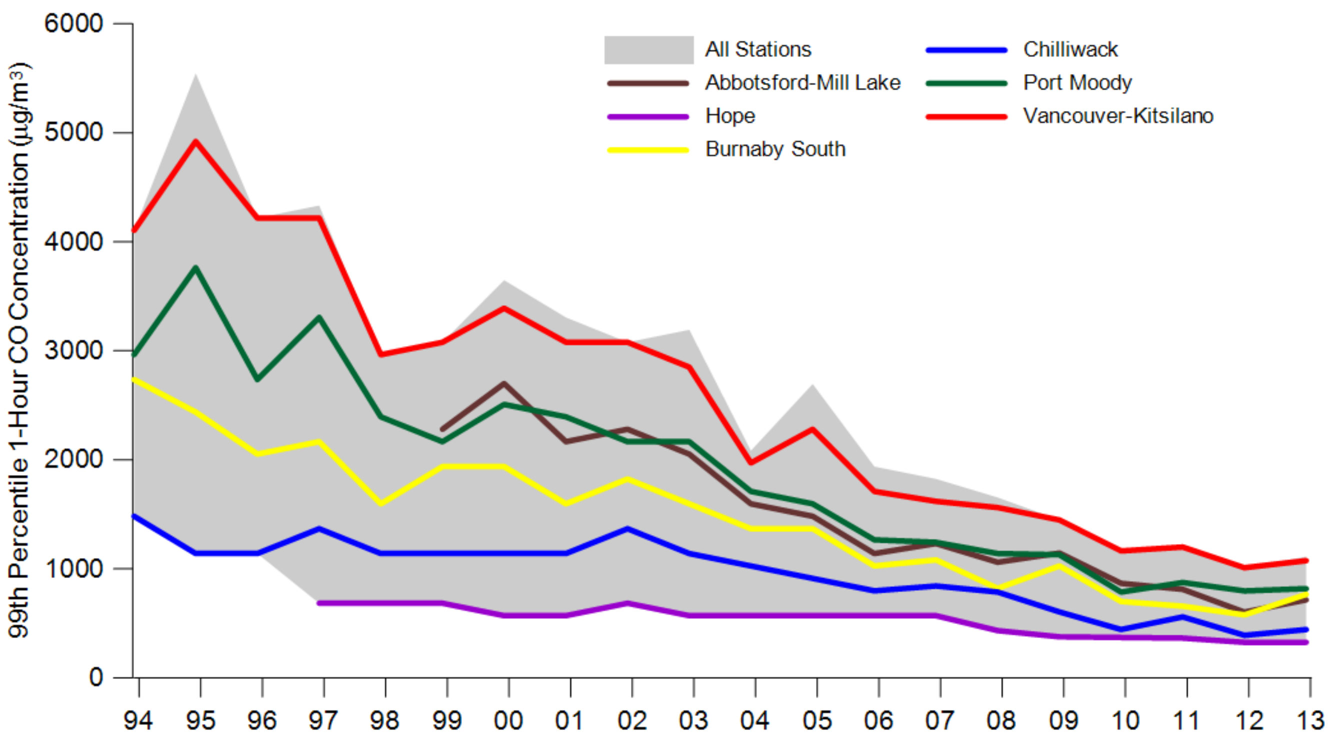


Figure 32: Short-term peak carbon monoxide trend, 1994 to 2013.

Ozone (O_3)

Characteristics

Ozone (O_3) is a reactive form of oxygen. It is a major pollutant formed when NO_X and reactive volatile organic compounds (VOC) react chemically in the presence of heat and sunlight. Sunlight plays a significant role in O_3 production and as such, local maximum O_3 concentrations are usually experienced during the summer.

Naturally occurring O_3 in the upper level of the atmosphere, known as the stratosphere, shields the surface from harmful ultraviolet radiation. However at ground level, O_3 is a major environmental and health concern. Ozone is a strong oxidant and can irritate the eyes, nose and throat as well as reduce lung function. High concentrations can also increase the susceptibility to respiratory disease and reduce crop yields.

Sources

Ozone is termed a secondary pollutant because it is not usually emitted directly into the air. Instead, it is formed from chemical reactions involving pollutants identified as precursors, including NO_X and reactive VOC. The levels of O_3 measured depend on the emissions of these precursor pollutants.

Nitrogen oxide (NO_X) emissions are dominated by transportation sources. About 63% of the emissions come from cars, trucks, ships, rail and planes. Other sources include non-road engines, boilers and building heating systems.

The main contributors to VOC emissions are chemical products use (industrial, commercial and consumer products such as paints, varnishes and solvents), natural sources (trees and vegetation), cars and light trucks and non-road engines.

The formation of O_3 occurs readily during hot and sunny weather conditions with peak levels observed in the summer. Under these conditions, the highest levels generally occur downwind of major precursor emissions such as in eastern parts of Metro Vancouver and in the FVRD.

Monitoring Results

Figures 33 and 34 illustrate the results of O_3 monitoring in 2013. The annual average and Canadian Ambient Air Quality Standard values are shown in Figure 33 while the maximum 1-hour and 8-hour averages are shown in Figure 34. These are shown spatially in Figures 35 to 38.

In 2013, there were no exceedances of the Canadian Ambient Air Quality Standard (CAAQS) nor the 1-hour and 8-hour Metro Vancouver Objectives. The Burnaby Mountain station measured the highest average ozone level which is typical given the station's high elevation on the top of Burnaby Mountain.

In 2013, there were no exceedances of the ground-level ozone Canadian Ambient Air Quality Standard nor the 1-hour and 8-hour Metro Vancouver Objectives.

It can be seen that the highest short-term concentrations occur in the eastern parts of Metro Vancouver and in the FVRD (Figures 36, 37 and 38). The lowest annual averages of O_3 (Figure 35) are seen to occur in highly urbanized areas due to O_3 scavenging. Ozone scavenging occurs in locations where higher levels of NO_x are found (e.g. urban areas or near busy roadways). In these areas, emissions containing NO_x, react very quickly with O_3 to form NO_2 (nitrogen dioxide) and O_2 (oxygen) thus decreasing O_3 concentrations.

The seasonal variation evident in Figures 39 and 40 is typical of historical ozone trends in the LFV with higher values in the spring and summer, and lower values during the fall and winter. Given that O_3 is created through photochemical reactions there is much greater production in the spring and summer with the presence of sunlight. Spring exhibits the highest average O_3 concentrations (Figure 39) while the highest short-term hourly concentrations (Figure 40) occur in the summer.

The frequency distribution for hourly and 8-hour rolling average concentrations is shown in Tables 6 and 7, respectively. The frequency distributions in these tables show how often various O_3 levels are reached. It can be seen that stations located in the eastern parts of Metro Vancouver and in the FVRD measured the greatest frequency of high O_3 concentrations.

A series of diurnal plots are shown in Figure 41 for each O_3 monitoring station. The diurnal plots illustrate the weekday/weekend differences along with summer/winter differences. Most of the stations exhibit similar diurnal trends.

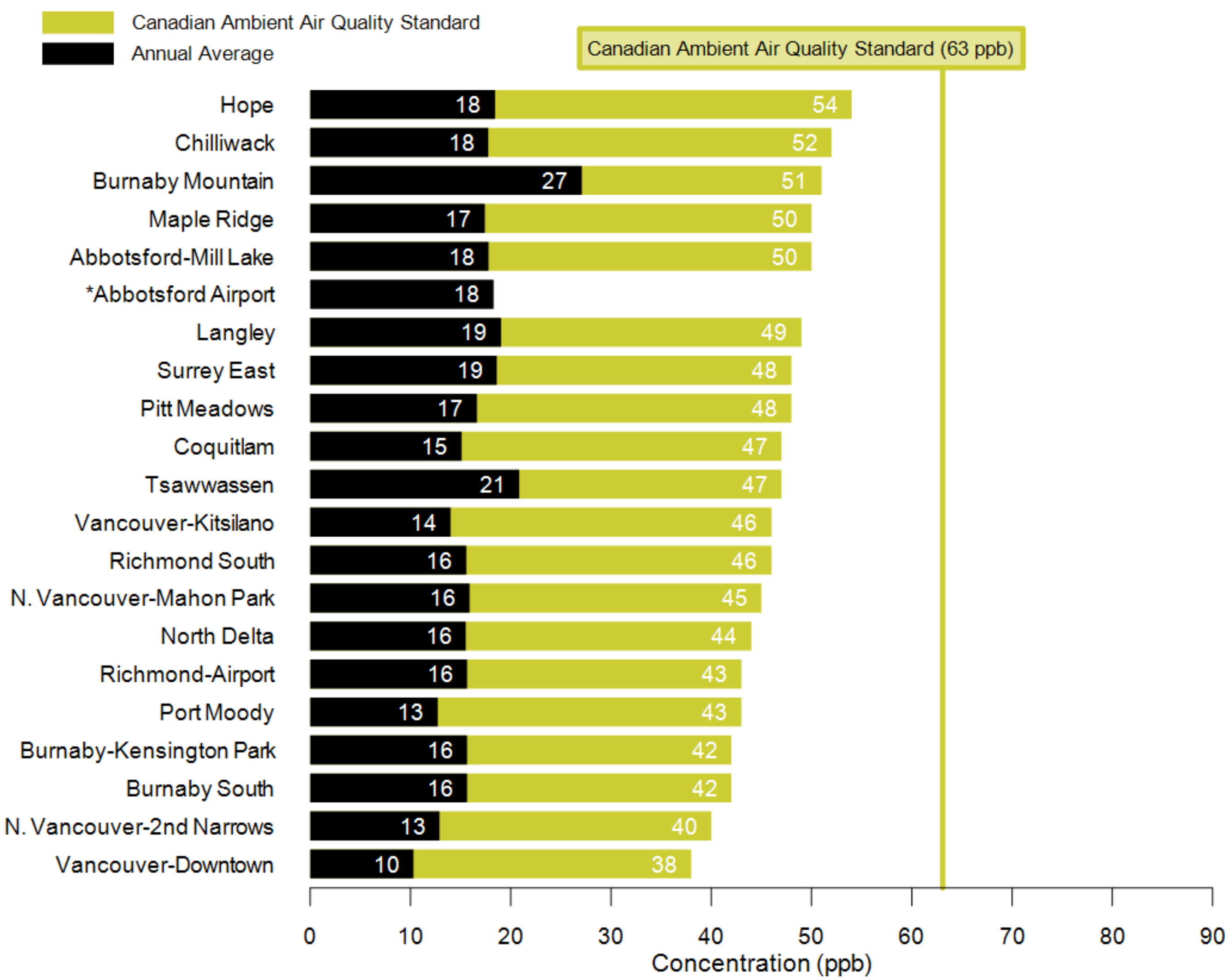
In the summer, O_3 concentrations are low through the night and begin increasing near sunrise with the highest (peak) concentration occurring in the afternoon. Examining the timing of the peak shows in general the stations in the west peak first while the stations in the east peak a few hours later with Hope typically experiencing the latest peak in the day. On very hot sunny days, typically during a summertime episode, the O_3 peak occurs later in the day. Winter shows a similar trend of an afternoon peak although it is greatly attenuated compared with the summer.

Most stations experienced greater ozone on weekends compared with weekdays in the summer. This is consistent with 2011 and 2012, when all stations experienced greater ozone on weekends.

Figure 42 illustrates the long-term annual average O_3 trend in the LFV. Annual O_3 levels have shown an upward trend since 1994. Research indicates that background ozone concentrations are rising and is one factor for the observed increase in average levels.

A short-term peak O_3 concentration trend (Figure 43) is less apparent. There are yearly differences, which are likely related to variability in meteorology, however there doesn't appear to be a trend in peak concentrations. Peak ozone levels have been mostly unchanged during the last fifteen to twenty years, despite significant reductions in ozone precursor pollutants over the same time period.

On-going research indicates that the highest ozone levels are occurring in the eastern parts of the LFV and that the location of the maximum has shifted eastward over time. A study led by UBC researchers was completed in 2011 to better understand ozone in the LFV and to suggest the most effective strategies to help reduce ozone levels. Findings from this study along with other research have informed a Regional Ground-Level Ozone Strategy to reduce emissions of ozone precursors and ground-level ozone concentrations.



* Data completeness criteria were not met at this station and therefore the Canadian Ambient Air Quality Standard value was not calculated.

Figure 33: Ground-level ozone monitoring (Annual and CAAQS), 2013.

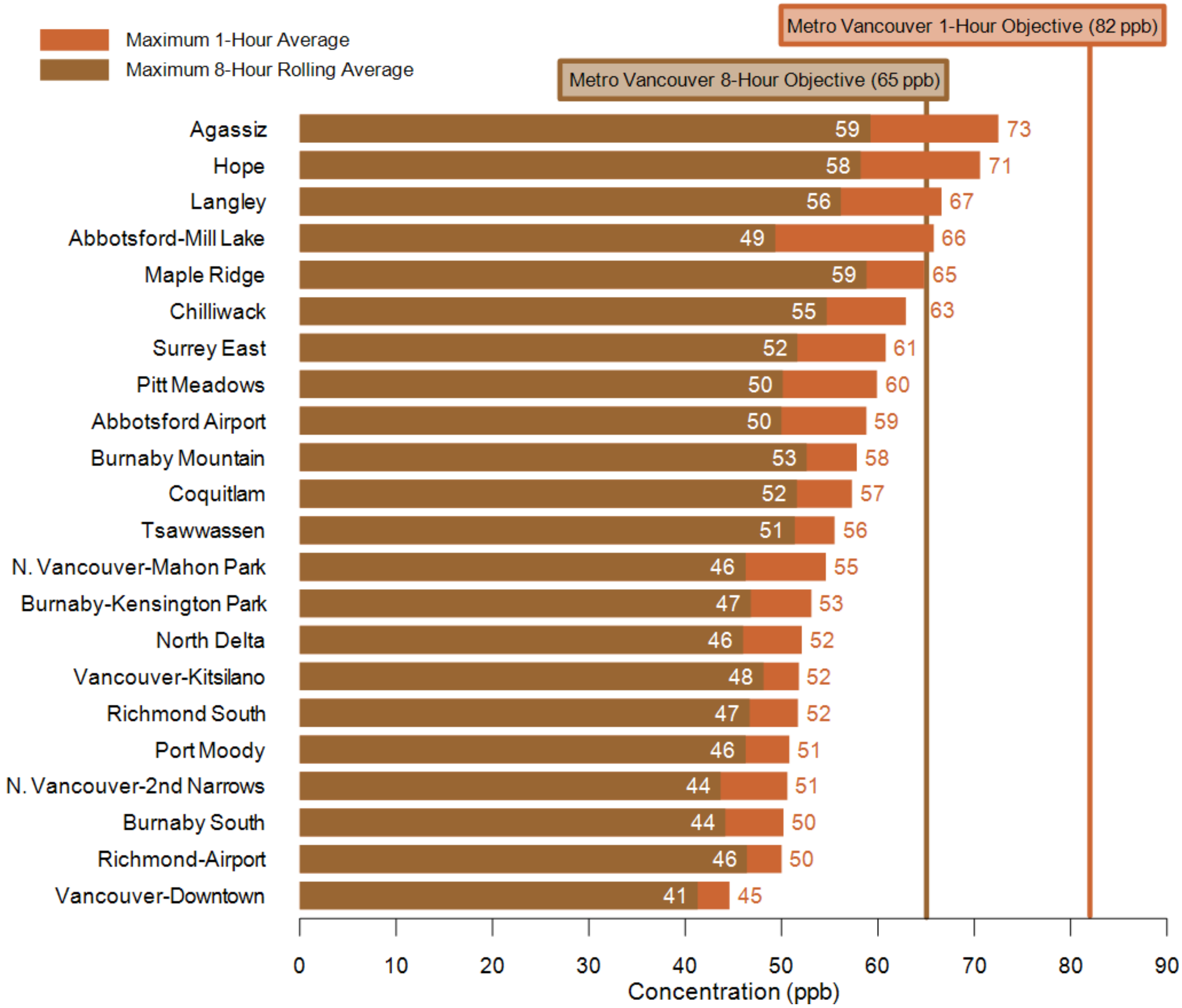


Figure 34: Ground-level ozone monitoring (1-hour and 8 hour), 2013.

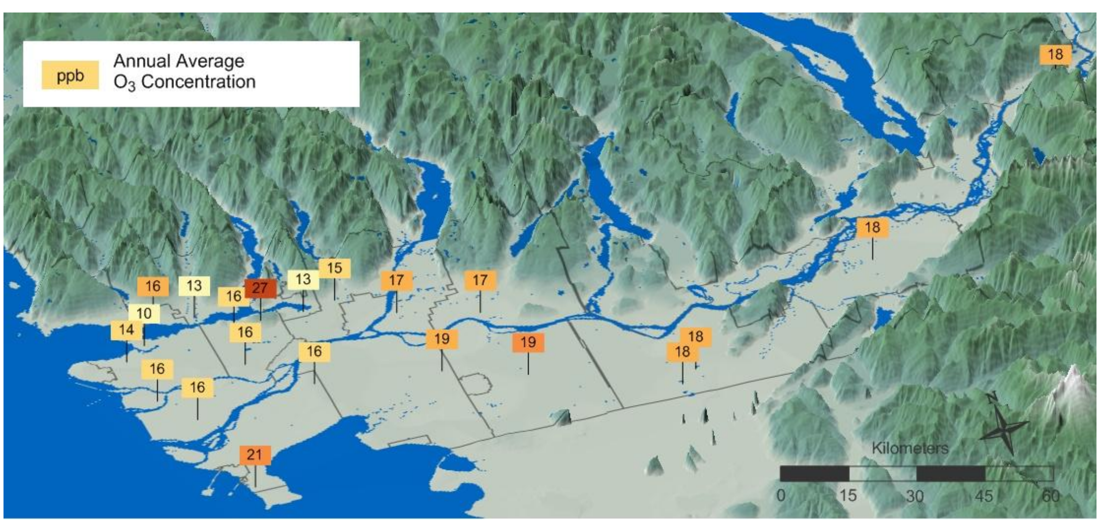


Figure 35: Annual average ozone in the LFV, 2013.

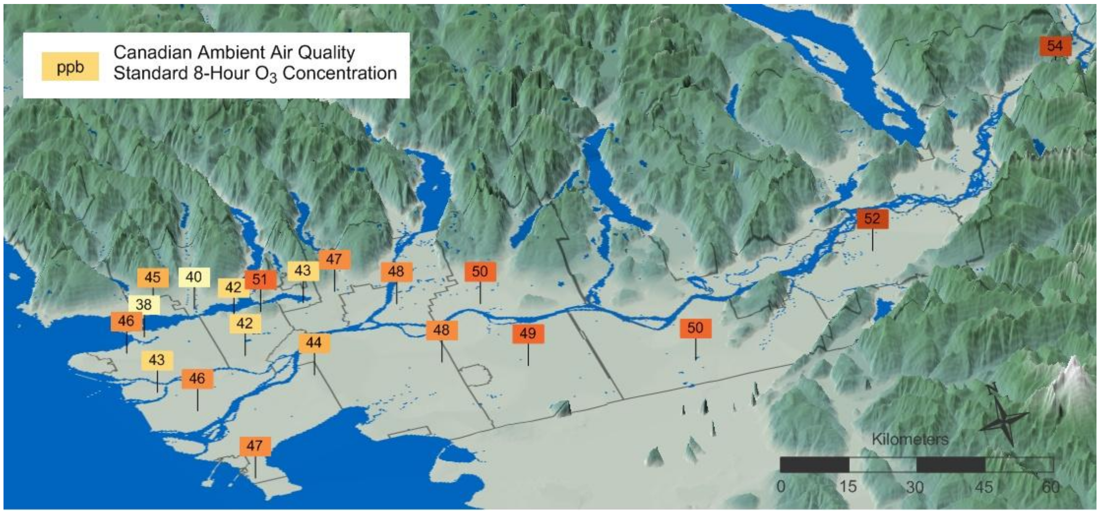


Figure 36: Canadian Ambient Air Quality Standard value for ozone in the LFV, 2013.

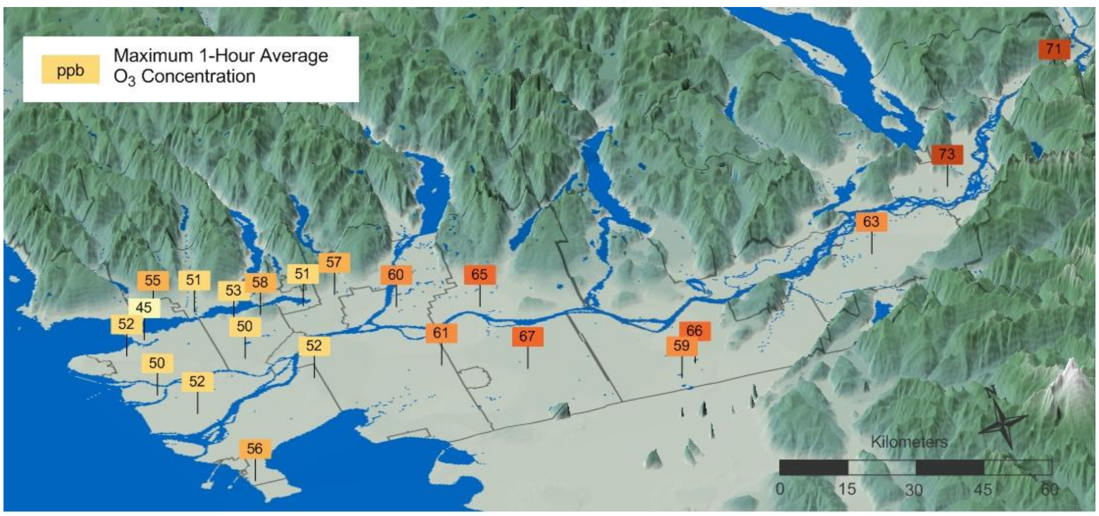


Figure 37: Short-term peak (maximum 1-hour) ozone in the LFV, 2013.

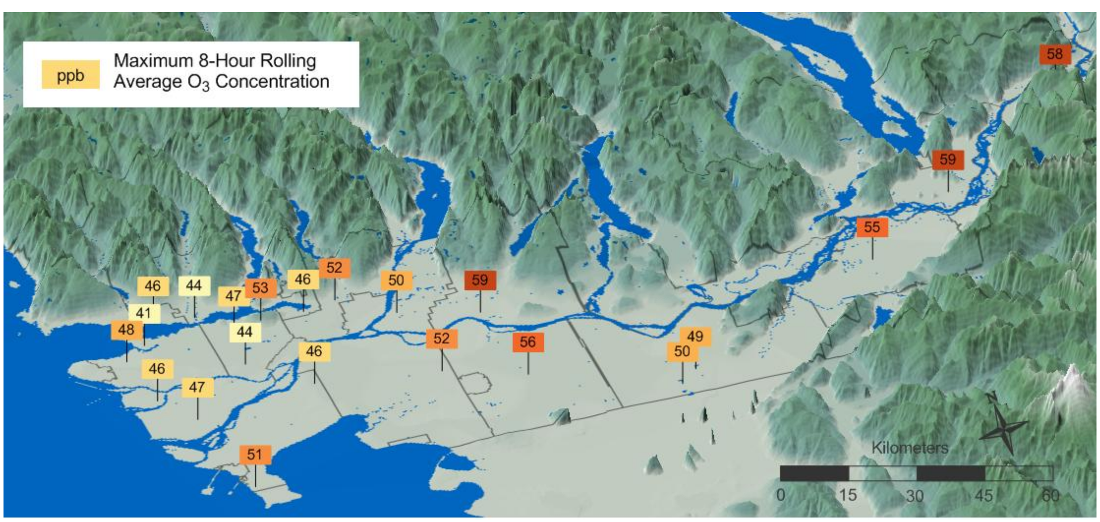


Figure 38: Short-term peak (maximum 8-hour) ozone in the LFV, 2013.

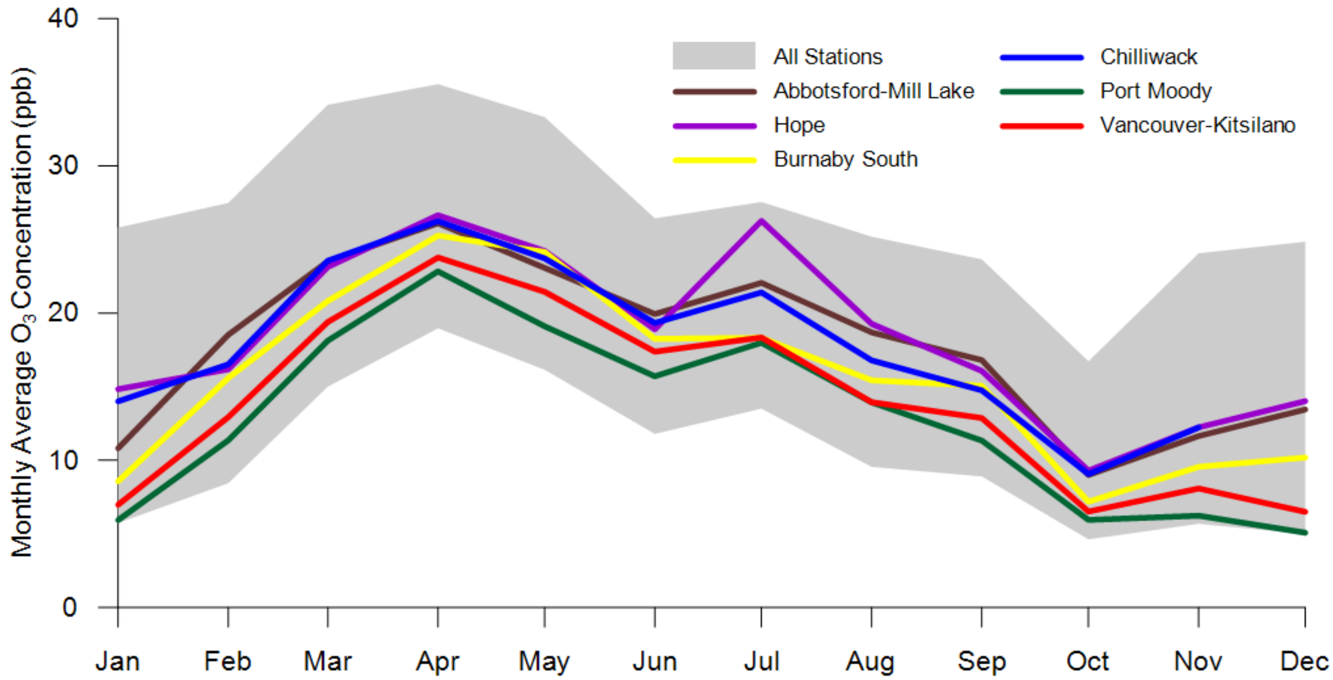


Figure 39: Monthly average ozone, 2013.

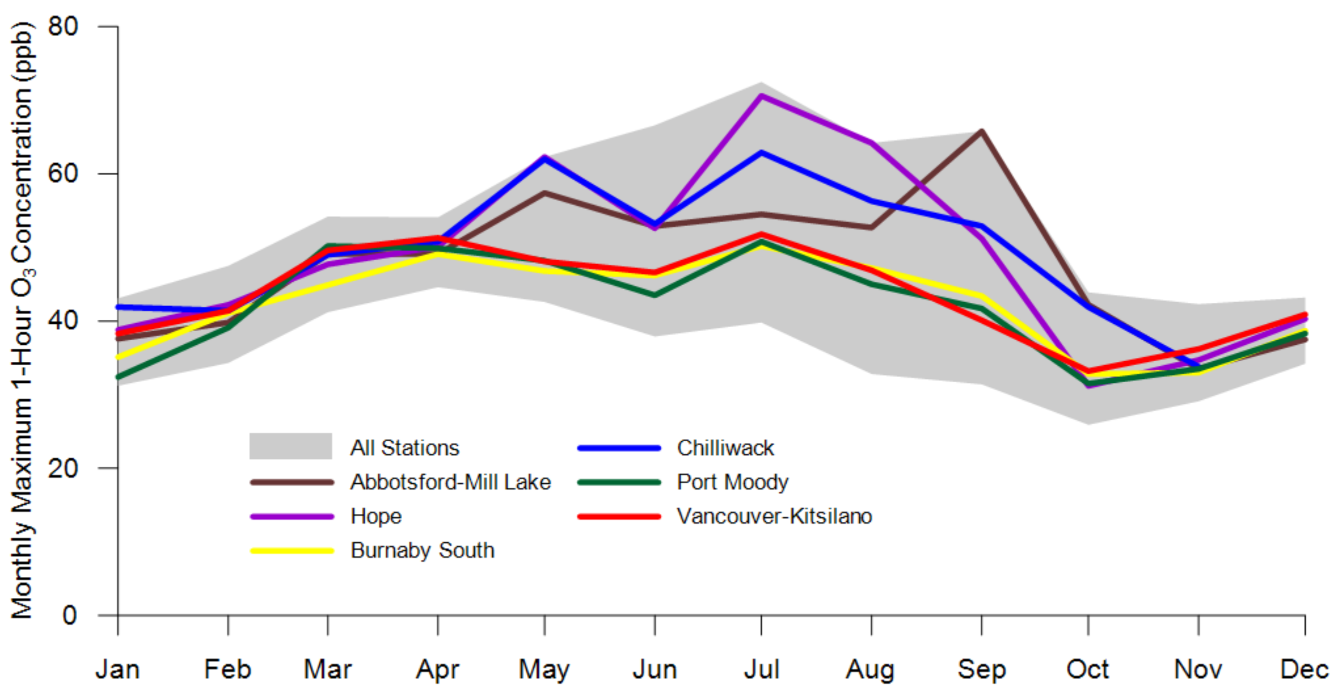


Figure 40: Monthly short-term peak ozone, 2013.

Table 6: Frequency distribution of hourly ozone, 2013.

O_3 Conc. (ppb)	Vancouver-Downtown	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport
0 to 4	3255	2748	1543	1950	2991	1628	1918	113	1330	2360	1663	2052	1744	1440	1680	1640	2007	2181	1548	808	1411
4 to 8	1300	969	998	1322	947	815	885	155	729	818	938	733	889	672	783	843	811	947	840	584	912
8 to 12	916	809	1092	1313	811	781	942	296	792	696	946	728	924	696	779	815	783	986	794	758	844
12 to 16	853	702	1010	1053	716	808	949	548	936	733	1013	865	1066	757	757	884	856	832	853	898	756
16 to 20	712	729	992	895	635	792	865	832	935	741	975	779	957	847	763	835	867	799	828	1001	827
20 to 24	545	597	881	741	569	828	867	1224	905	752	893	837	837	871	825	802	765	645	870	1023	819
24 to 28	426	578	723	553	605	748	731	1336	866	654	793	709	712	844	803	781	662	619	782	965	807
28 to 32	266	491	516	328	480	601	615	1341	686	658	586	654	567	760	670	635	588	551	679	827	753
32 to 36	195	388	365	243	351	511	405	1089	581	429	364	532	398	649	498	567	382	407	620	697	616
36 to 40	100	259	252	119	217	376	259	784	428	326	245	328	247	452	437	358	275	308	367	523	390
40 to 44	30	201	115	47	114	261	129	485	217	206	93	204	164	252	298	197	201	174	214	289	252
44 to 48	2	114	40	14	33	127	42	213	110	97	35	97	57	108	170	103	68	80	94	115	105
48 to 52		27	11	3	14	48	10	82	41	18	3	30	21	50	60	42	8	23	38	32	36
52 to 56			2			21	1	19	5			12	4	10	41	12		16	8	6	10
56 to 60						5		4	2			3		1	16	8		4	2		4
60 to 64						4			2					1	5	4					
64 to 68														3	3	2			1		
68 to 72															2						
>=72																					
Missing	160	148	220	179	277	406	142	239	195	272	213	197	173	347	170	232	487	188	222	234	218
Data Completeness	98%	98%	98%	98%	97%	95%	98%	97%	98%	97%	98%	98%	98%	96%	98%	97%	94%	98%	98%	97%	98%

Table 7: Frequency distribution of 8-hour rolling average ozone, 2013.

O_3 Conc. (ppb)	Vancouver-Downtown	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Burnaby Mountain	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Maple Ridge	Richmond-Airport	Coquitlam	Abbotsford-Mill Lake	Tsawwassen	Abbotsford Airport
0 to 3	2168	1759	951	1217	2085	819	1263	30	824	1496	1089	1331	1057	908	1006	1119	1187	1459	912	397	776
3 to 6	1324	950	779	1038	937	752	768	74	574	805	750	659	725	524	667	591	855	823	682	444	752
6 to 9	1099	892	746	1089	821	789	726	107	628	688	680	692	743	582	673	674	713	782	700	545	698
9 to 12	1007	772	944	1081	787	718	878	223	676	734	860	725	881	617	697	750	728	801	746	665	752
12 to 15	828	800	936	1020	738	765	857	334	802	754	934	780	936	702	754	783	818	839	743	666	733
15 to 18	685	666	928	923	643	725	798	480	763	709	872	691	884	711	684	771	745	750	765	813	718
18 to 21	512	609	840	750	582	650	752	767	796	668	856	671	819	734	667	717	753	703	753	850	676
21 to 24	374	528	719	568	530	714	690	1086	735	632	769	692	689	742	684	640	646	561	656	848	699
24 to 27	263	499	605	362	483	633	619	1198	731	552	663	647	637	697	648	663	524	530	675	836	753
27 to 30	170	367	463	277	374	509	523	1148	625	520	476	530	448	664	557	617	483	490	643	744	598
30 to 33	112	297	316	197	252	443	352	987	550	344	290	473	364	532	495	459	298	365	516	548	543
33 to 36	107	198	195	111	164	309	251	737	405	255	209	339	247	475	370	376	231	238	405	496	402
36 to 39	47	151	131	34	114	297	136	668	263	179	140	207	153	312	302	202	156	166	238	375	299
39 to 42	12	107	76	24	59	187	76	418	173	137	70	134	80	172	247	139	146	92	147	253	152
42 to 45		95	16	3	16	98	33	243	90	82	19	70	38	94	126	79	80	61	66	104	87
45 to 48		32	6		5	41	5	76	26	28		29	7	41	57	35	6	16	18	41	32
48 to 51		1				10		33	8			1		11	29	6		3	5	9	7
51 to 54						5		12	1					2	15	5		2		1	
54 to 57						2								2	8	1					
57 to 60															3	2					
>=60																					
Missing	52	37	109	66	170	294	33	139	90	177	83	89	52	238	71	131	391	79	90	125	83
Data Completeness	99%	100%	99%	99%	98%	97%	100%	98%	99%	98%	99%	99%	99%	97%	99%	99%	96%	99%	99%	99%	99%

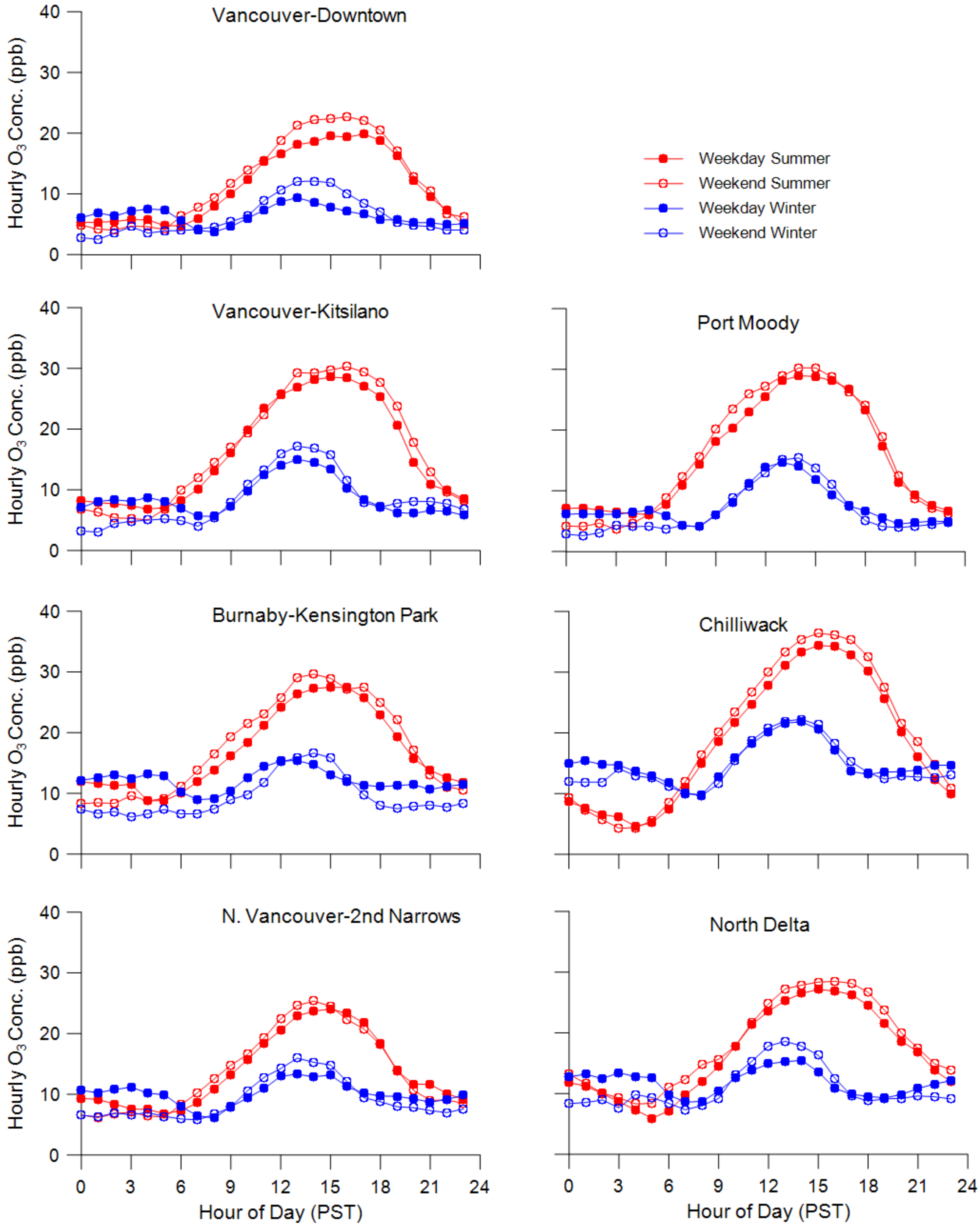


Figure 41: Diurnal trends ozone, 2013.

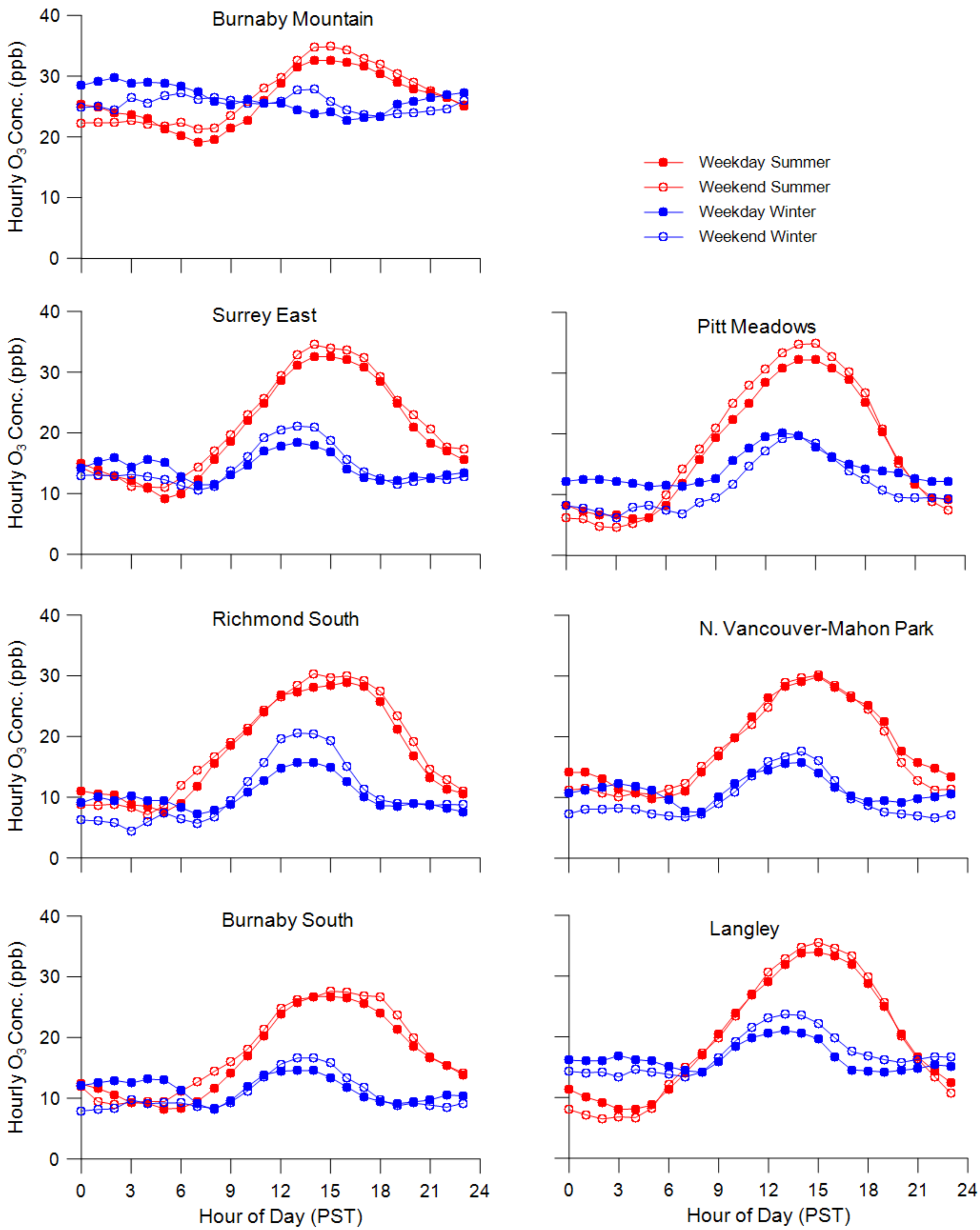


Figure 41: Cont. Diurnal trends ozone, 2013.

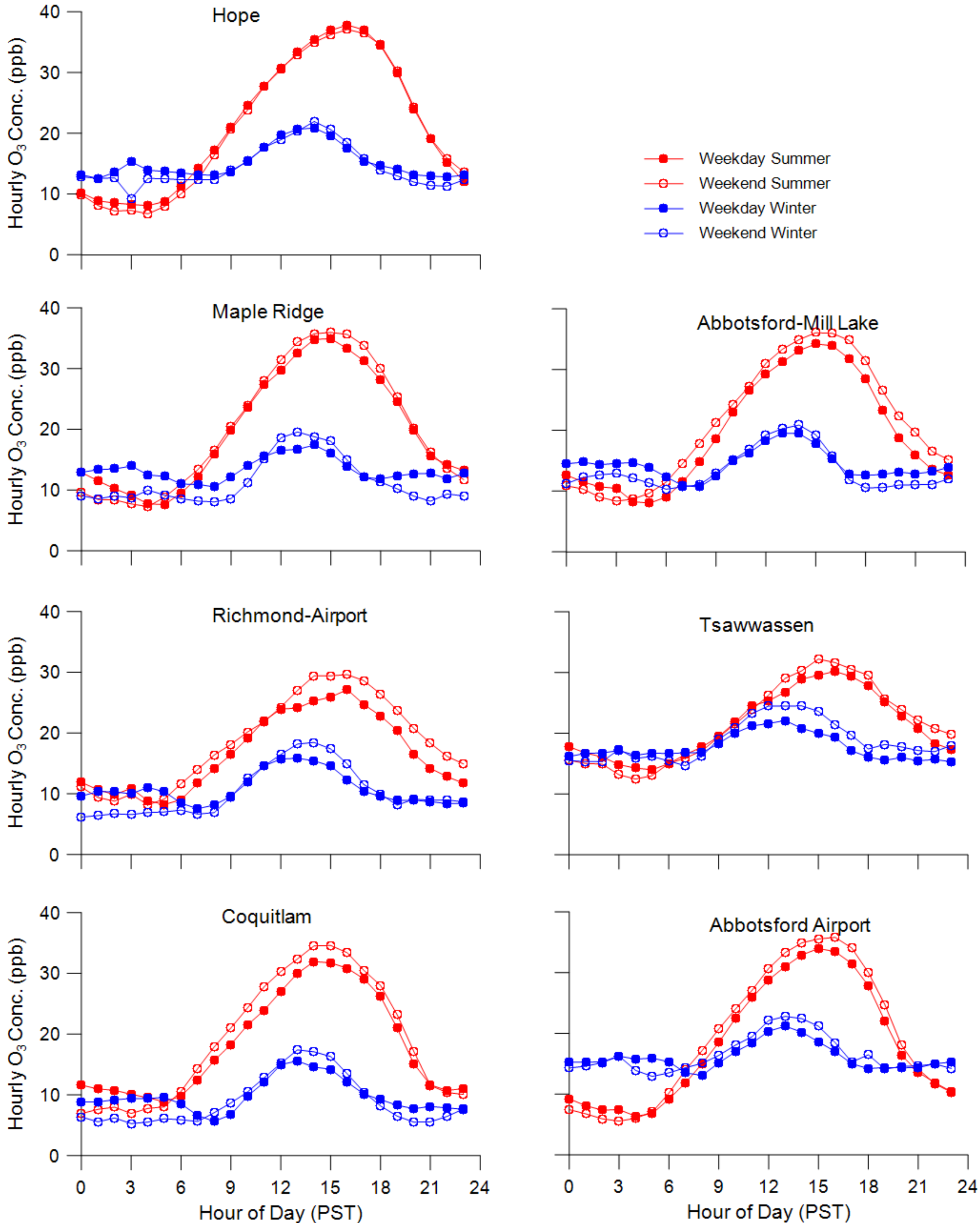


Figure 41: Cont. Diurnal trends ozone, 2013.

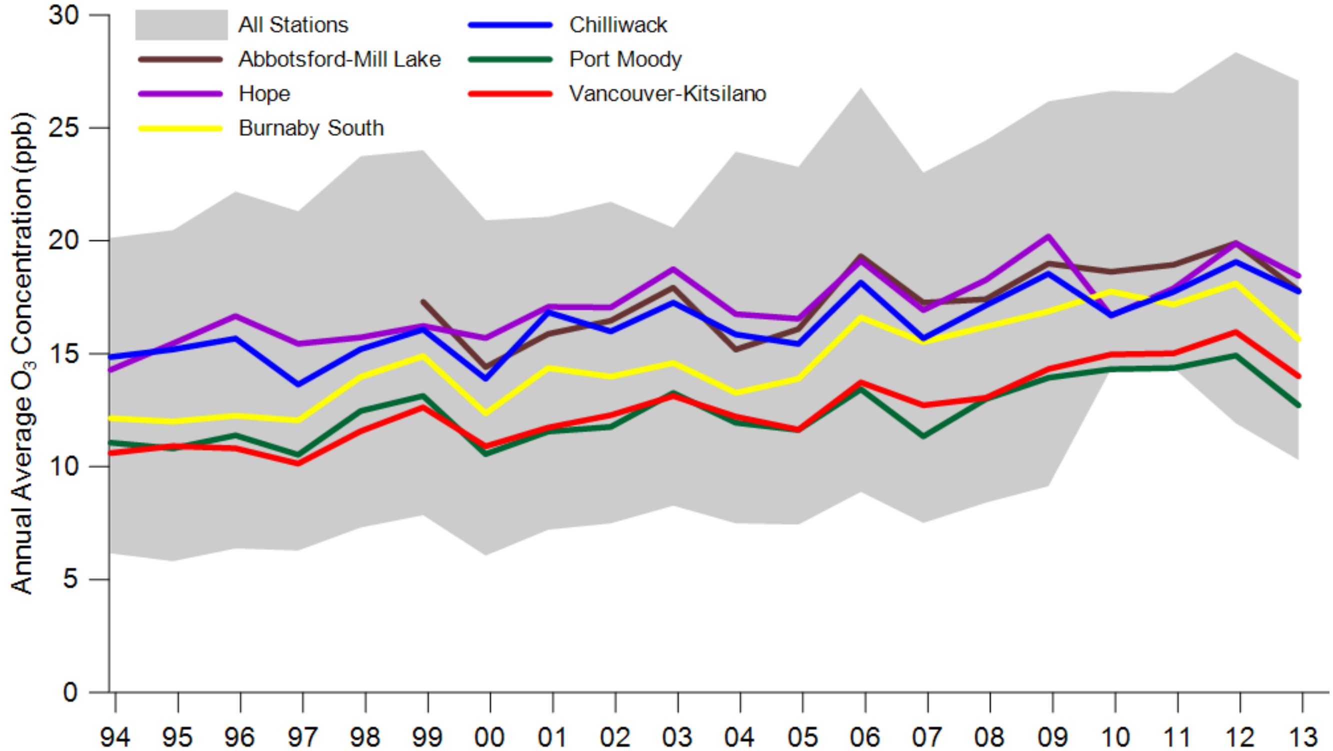


Figure 42: Annual ozone trend, 1994 to 2013.

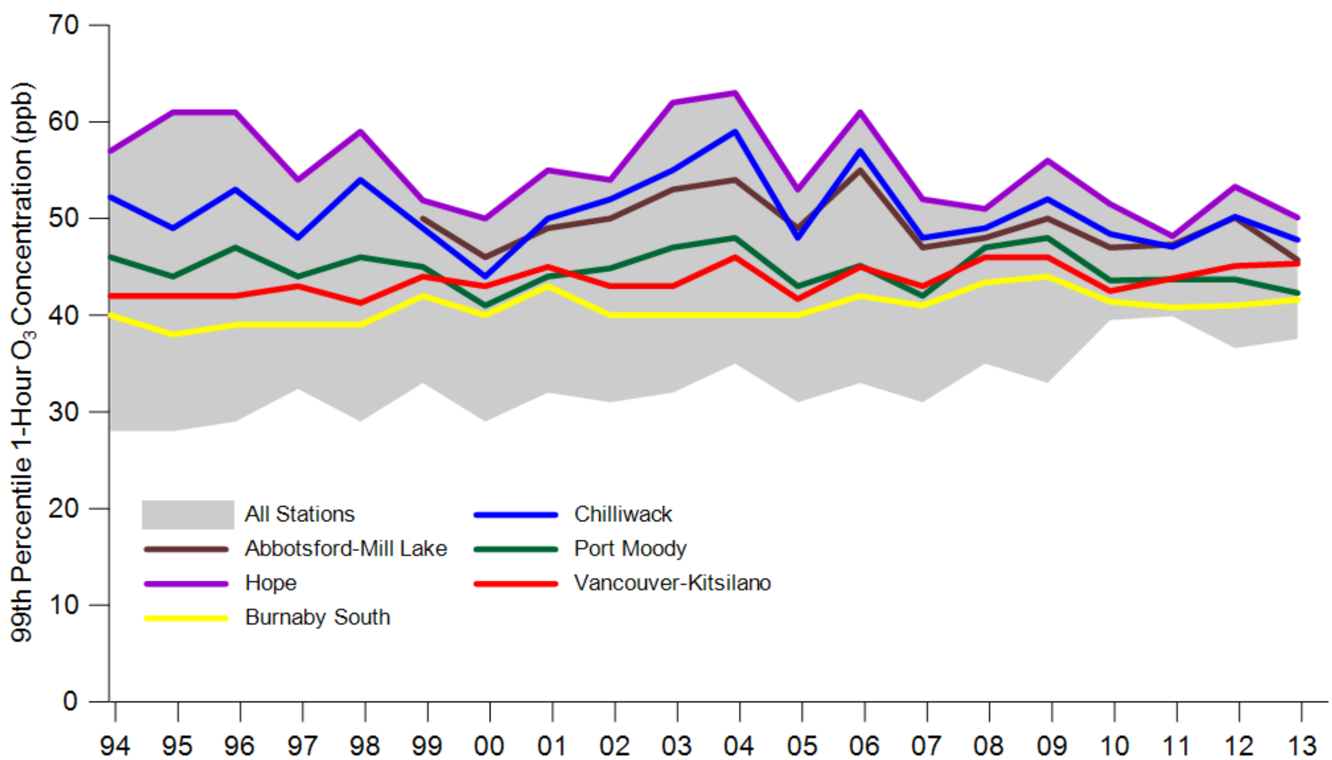


Figure 43: Short-term peak ozone trend, 1994 to 2013.

Fine Particulate ($PM_{2.5}$)

Characteristics

The term '$PM_{2.5}$' has been given to airborne particles with a diameter of 2.5 micrometres (μm) or less, also known as fine particulate. Particles of this size make up a fraction of PM_{10} (those particles with a diameter of 10 micrometres or less) which can vary with factors such as season and location. Within the LFV emissions of $PM_{2.5}$ represent approximately one-half of the PM_{10} emissions, which is a typical value for North American urban environments.

Given the very small size of these particles, they can penetrate into the finer structures of the lungs. As with inhalable particulate (PM_{10}), exposure to fine particulate ($PM_{2.5}$) can lead to both chronic and acute human health impacts, aggravate pulmonary or cardiovascular disease, increase symptoms in asthmatics and increase mortality. Fine particulate matter is considered by health experts to be an air pollutant of serious concern because of these health effects.

Fine particulate is also effective at scattering and absorbing visible light. In this role $PM_{2.5}$ contributes to regional haze and impaired visual air quality.

Sources

Emissions of $PM_{2.5}$ are dominated by heating, transportation, industrial sources and non-road engines. In addition to these local sources, $PM_{2.5}$ can be transported long distances in the air from sources such as large forest fires in other parts of western Canada, the US or more distant.

Scientific investigations in the LFV indicate that a considerable proportion of ambient $PM_{2.5}$ is also formed by reactions of NO_X and SO_2 with ammonia in the air (mainly from agricultural sources in the LFV). Fine particulate produced in this manner is called secondary $PM_{2.5}$ and accounts for a significant percentage of $PM_{2.5}$ in summer. Therefore, emissions of precursor gases of secondary $PM_{2.5}$ are also important sources in the region.

Monitoring Results

A major change in PM monitoring occurred in 2013 with the switch of monitoring technology for $PM_{2.5}$. Starting in January 2013 all $PM_{2.5}$ monitoring stations reported data from continuous particulate monitors that met the U.S. Environmental Protection Agency $PM_{2.5}$ Federal Equivalent Method (FEM). Previous $PM_{2.5}$ TEOM monitors were retired at all sites with the exception of five sites where the TEOMs will continue to operate side by side with the FEM monitors to allow longer term trend analysis and develop correlations between the two instrument types. The new FEM monitors have the ability to measure a portion of particulates not previously measured. For more information see:

http://www.metrovancouver.org/services/air/Documents/AirInfographic.pdf

The $PM_{2.5}$ annual average, maximum 24-hour rolling average and Canadian Ambient Air Quality Standard (CAAQS) values are shown in Figure 44 for 2013. The same values are shown spatially in Figures 45, 46 and 47, respectively.

Elevated levels of regional $PM_{2.5}$ can occur when high pressure weather systems are present. While typically experienced in the summer, 2013 had three occurrences of high pressure systems which contributed to $PM_{2.5}$ exceedances in the fall and winter.

All stations with sufficient data available to calculate a CAAQS value were found to be below the Standard. Canadian Ambient Air Quality Standard values for 2013 ranged from 9 to 14 μg/m^3. In order to calculate the three year metric, TEOM data was used for the years 2011 and 2012 while FEM data was used for the year 2013.

All stations were below the Metro Vancouver annual objective of 8 μg/m^3 with the exception of Abbotsford-Mill Lake. About half of the stations were above the planning goal of 6 μg/m^3. Metro Vancouver's planning goal is a longer term aspirational target to support continuous improvement.

There were several exceedances of Metro Vancouver's 24-hour $PM_{2.5}$ objective in 2013. Exceedances occurred at five stations during three separate periods in January, October and November. The objective was exceeded at the Langley station on January 20, the Horseshoe Bay station on January 22, the Abbotsford-Mill Lake station on October 19 and 20, and the Richmond South and Richmond-Airport stations on November 25 and 26.

During late January weather conditions were conducive to elevated PM due to stagnant conditions throughout the Pacific Northwest. A persistent high pressure weather system induced calm winds and limited dispersion.

In mid to late October another persistent high pressure weather system brought stagnant weather conditions that limited dispersion. $PM_{2.5}$ concentrations were elevated throughout the LFV during this time, but concentrations at the Abbotsford-Mill Lake station occasionally rose higher compared with other stations. Given the stagnant conditions it is likely that local or nearby emission sources were largely responsible.

In late November another persistent high pressure weather system limited dispersion throughout much of the LFV. $PM_{2.5}$ concentrations rose throughout the LFV, especially in the western part of the region. Richmond was the only municipality to observe exceedances of the 24-hour objective during this time. It is possible that smoke from forest fires located on Vancouver Island and in Washington State may also have contributed to the elevated $PM_{2.5}$

Table 8 gives the frequency distribution of $PM_{2.5}$ concentrations for the year. In 2013, Abbotsford-Mill Lake experienced the greatest frequency of higher $PM_{2.5}$ concentrations (> 25 μg/m^3) which was thought to be the result of local emission sources.

Seasonally, $PM_{2.5}$ levels are usually higher in the summer with the highest values typically experienced during the dry summer months (Figures 48 and 49), due to secondary formation of $PM_{2.5}$ and smoke from forest fires. However, in 2013 peak levels were seen in the fall and winter due to the timing of several high pressure weather systems.

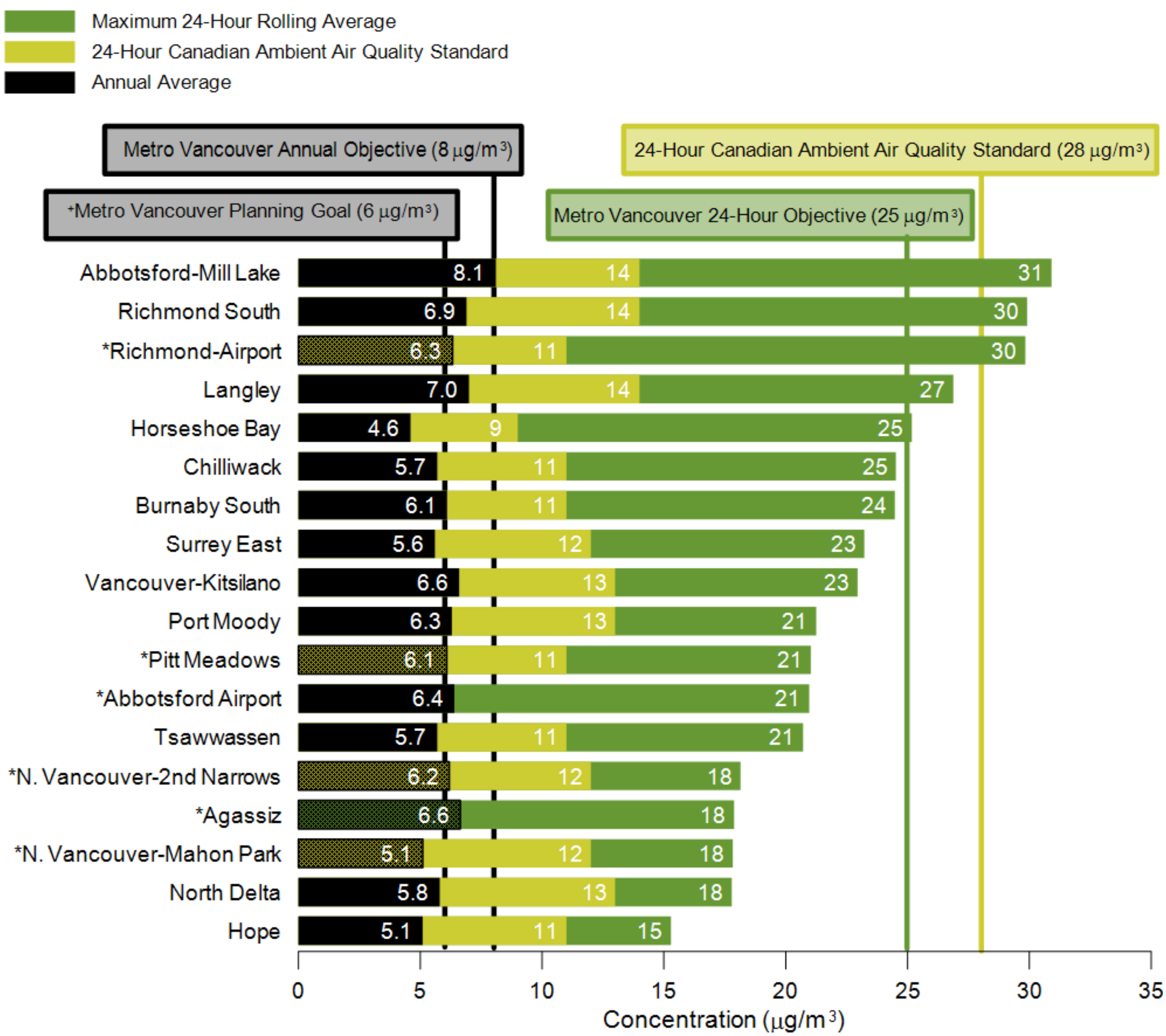
A series of diurnal plots are shown in Figure 50 for each $PM_{2.5}$ monitoring station. The summer exhibited little diurnal variation while the winter displayed higher $PM_{2.5}$ concentrations in the evenings compared with the daytime. The evenings in winter were likely elevated due to reduced atmospheric mixing depths coupled with regional and local emissions sources. Activities from a one day Centennial festival are evident in the Port Moody station data.

Figures 51 and 52 illustrate the long-term $PM_{2.5}$ trends in the LFV with the annual average and peak concentrations shown respectively. The short-term peak concentrations reflect the highest levels that occur, represented by the 99th percentile of the 24-hour rolling average for each year. Given that it will take several years to establish a long-term record of $PM_{2.5}$ with the new FEM monitor, both the TEOM and FEM data are shown together.

In Figures 51 and 52 the TEOM data is shown as solid lines with a gray band displaying the range of values from all TEOM stations, while the FEM data is shown as dotted lines with an orange band showing the range from all FEM stations.

It can be seen that the FEM monitor measures higher $PM_{2.5}$ concentrations compared to the TEOM monitor. Long-term trends of the TEOM data show that the year 2013 was not appreciably different than previous years. While the FEM data shows a step increase compared with the TEOM, this is a result of the FEM monitor's ability to measure particles not previously measured by the TEOM monitor.

The differences in peak trends from year to year are likely driven by meteorological variability and forest fire activities. Based on the TEOM data, the average long-term trend shows little variation. It will take several years to be able to establish and describe the long-term trend using data from the FEM monitor.



* Data completeness criteria were not met at these stations and therefore some of the values have not been shown.
+ Metro Vancouver's Planning Goal of 6 µg/m^3 is a longer term aspirational target to support continuous improvement.

Figure 44: Fine particulate ($PM_{2.5}$), 2013.

Figure 45: Annual average fine particulate ($PM_{2.5}$) in the LFV, 2013.

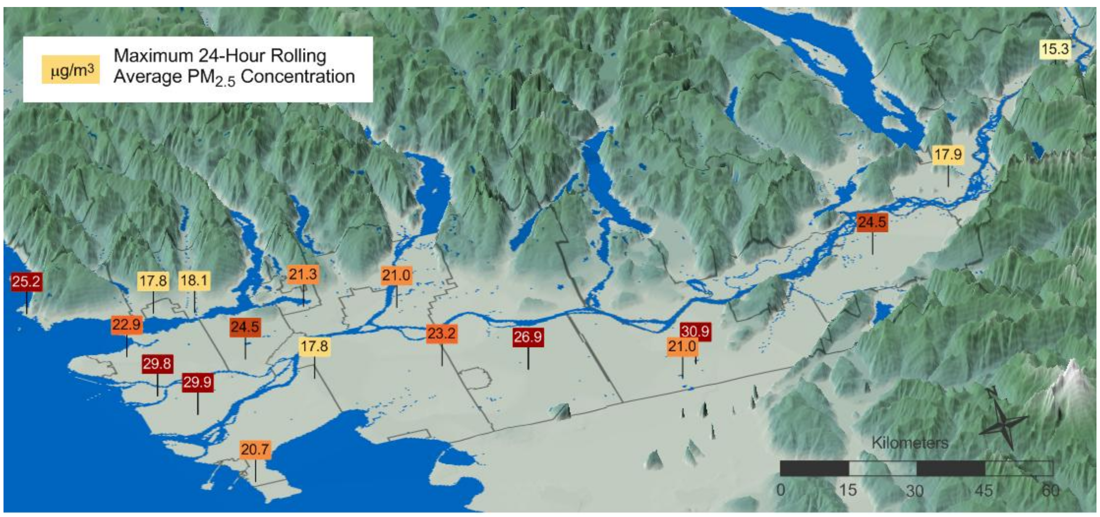


Figure 46: Short-term peak fine particulate ($PM_{2.5}$) in the LFV, 2013.

Figure 47: Canadian Ambient Air Quality Standard value for fine particulate ($PM_{2.5}$), 2013.

Table 8: Frequency distribution of 24-hour rolling average fine particulate ($PM_{2.5}$), 2013.

$PM_{2.5}$ Conc. ($\mu g/m^3$)	Vancouver-Kitsilano	Burnaby-Kensington Park	N. Vancouver-2nd Narrows	Port Moody	Chilliwack	North Delta	Surrey East	Richmond South	Burnaby South	Pitt Meadows	N. Vancouver-Mahon Park	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Horseshoe Bay	Tsawwassen	Abbotsford Airport
0 to 2	97	197	301	156	621	616	519	145	307	742	437	166	675	129	272	677	224	540
2 to 4	1774	951	1778	1832	2119	2016	2584	1997	2189	1808	2744	1717	2777	1888	993	3145	2761	1821
4 to 6	2555	1052	1979	2577	2449	2361	2547	2272	2428	1375	2445	2288	2509	2127	1767	2975	2782	2426
6 to 8	1804	1010	2042	1982	1682	1665	1463	1678	1894	1045	1367	1395	1330	1633	1693	1309	1404	1539
8 to 10	1152	456	972	952	1005	1035	574	893	886	755	510	797	777	838	1280	442	623	1037
10 to 12	562	211	402	538	450	399	322	557	547	535	366	469	400	407	776	110	448	707
12 to 14	209	68	242	263	159	246	275	333	315	359	117	382	110	180	569	10	194	343
14 to 16	155	7	126	99	40	107	201	185	98	177	19	360	26	158	463	8	210	195
16 to 18	82	5	56	22	34	30	73	190	27	71	10	144		64	280	10	48	78
18 to 20	57		3	27	16		5	72	11	11		57		29	123	4	14	22
20 to 22	7			10	6		9	55	6	15		55		17	23	2	9	12
22 to 24	5				11		8	6	6			16		5	21	4		
24 to 26					6			6	4			22		5	10	13		
26 to 28								7				4		7	6			
28 to 30								11						13	4			
30 to 32															10			
>=32																		
Missing	301	4803	859	302	162	285	180	353	42	1867	745	888	156	1260	470	51	43	40
Data Completeness	97%	45%	90%	97%	98%	97%	98%	96%	100%	79%	92%	90%	98%	86%	95%	99%	100%	100%

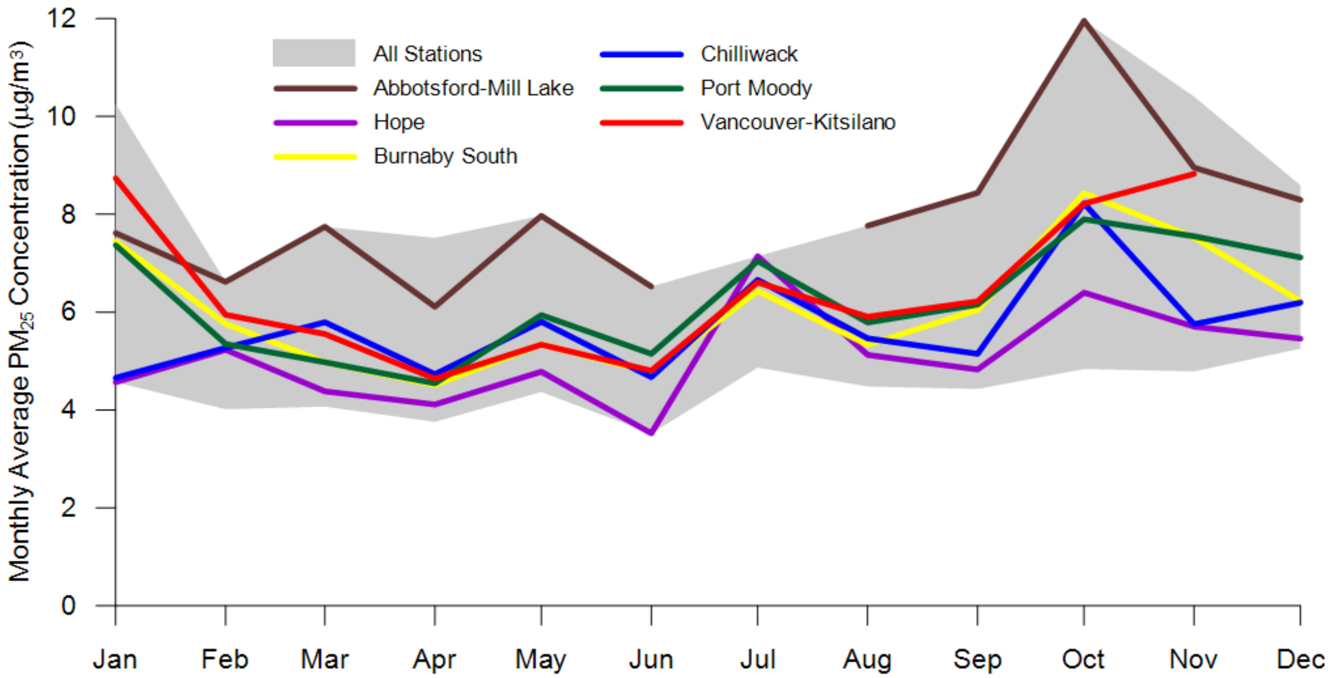


Figure 48: Monthly average fine particulate ($PM_{2.5}$), 2013.

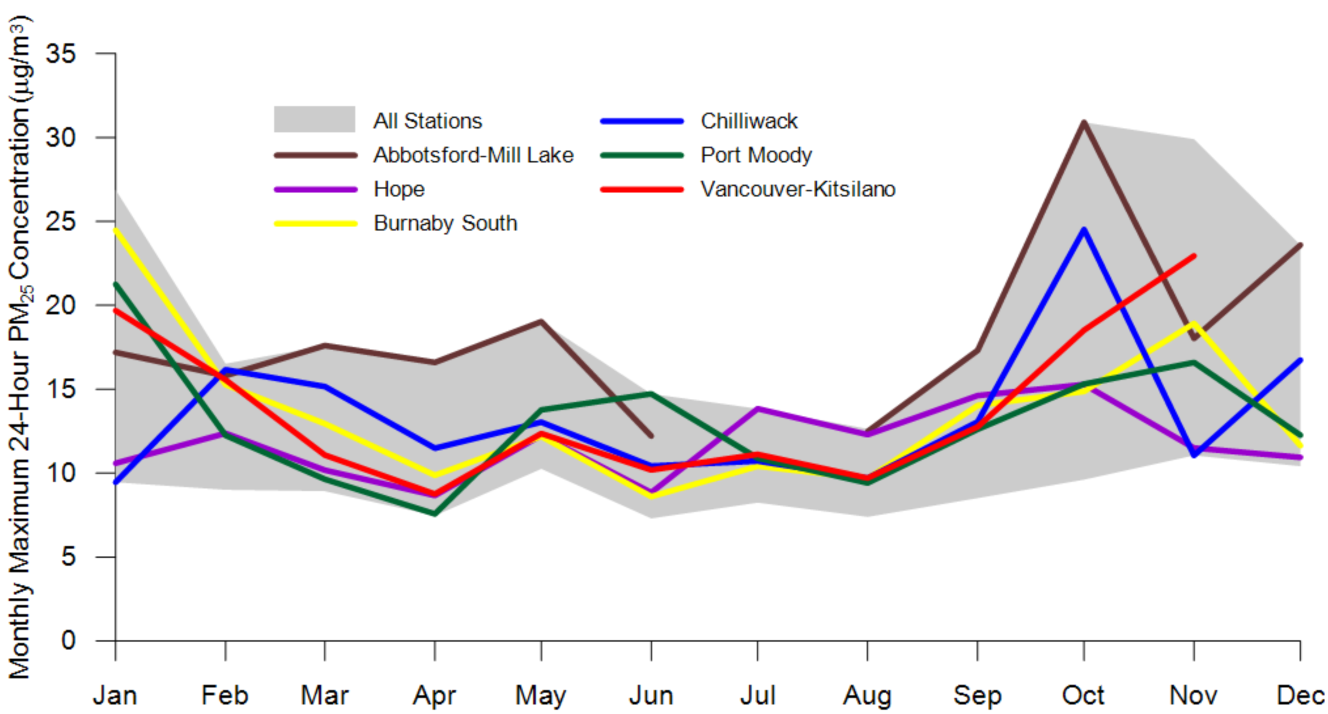
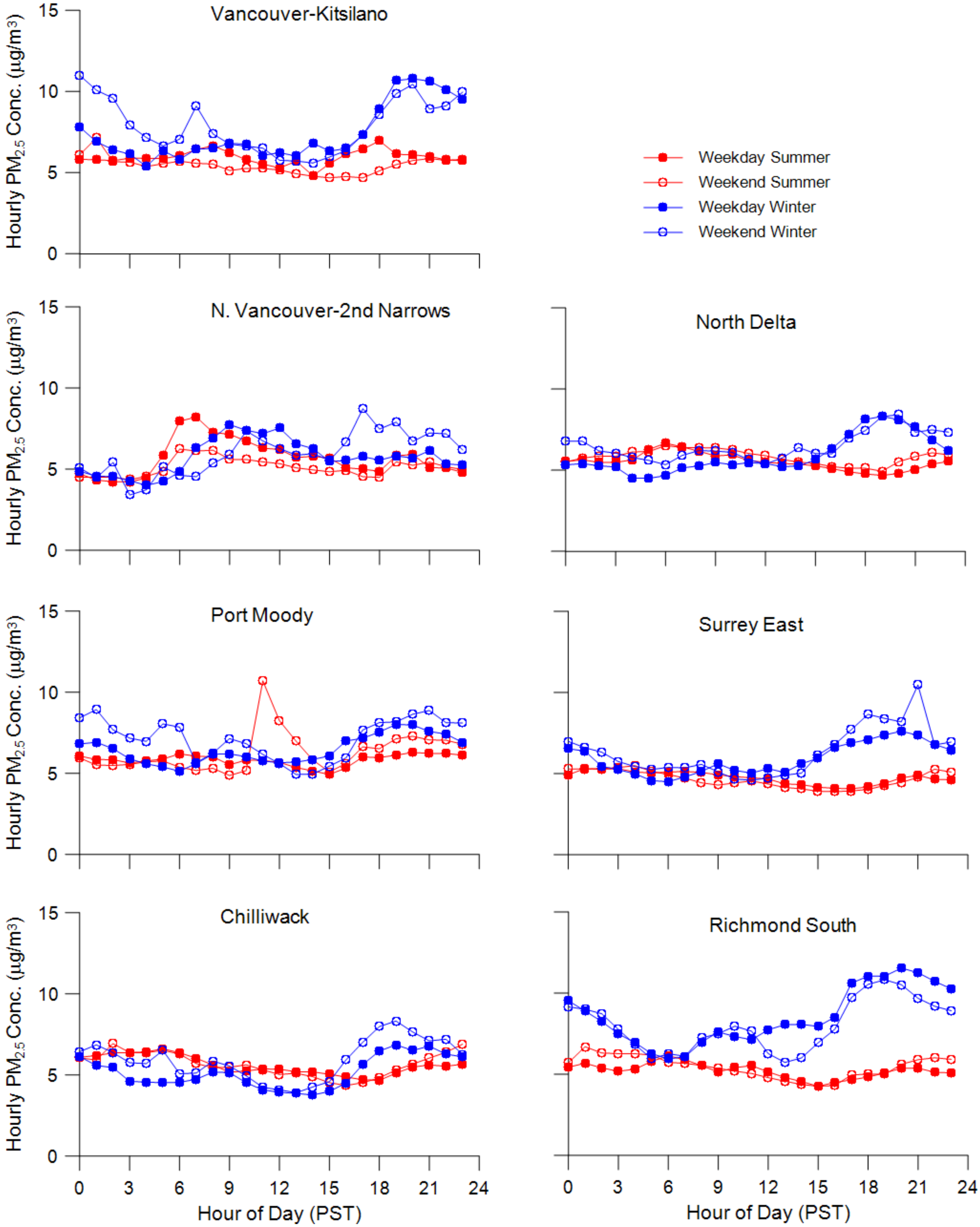
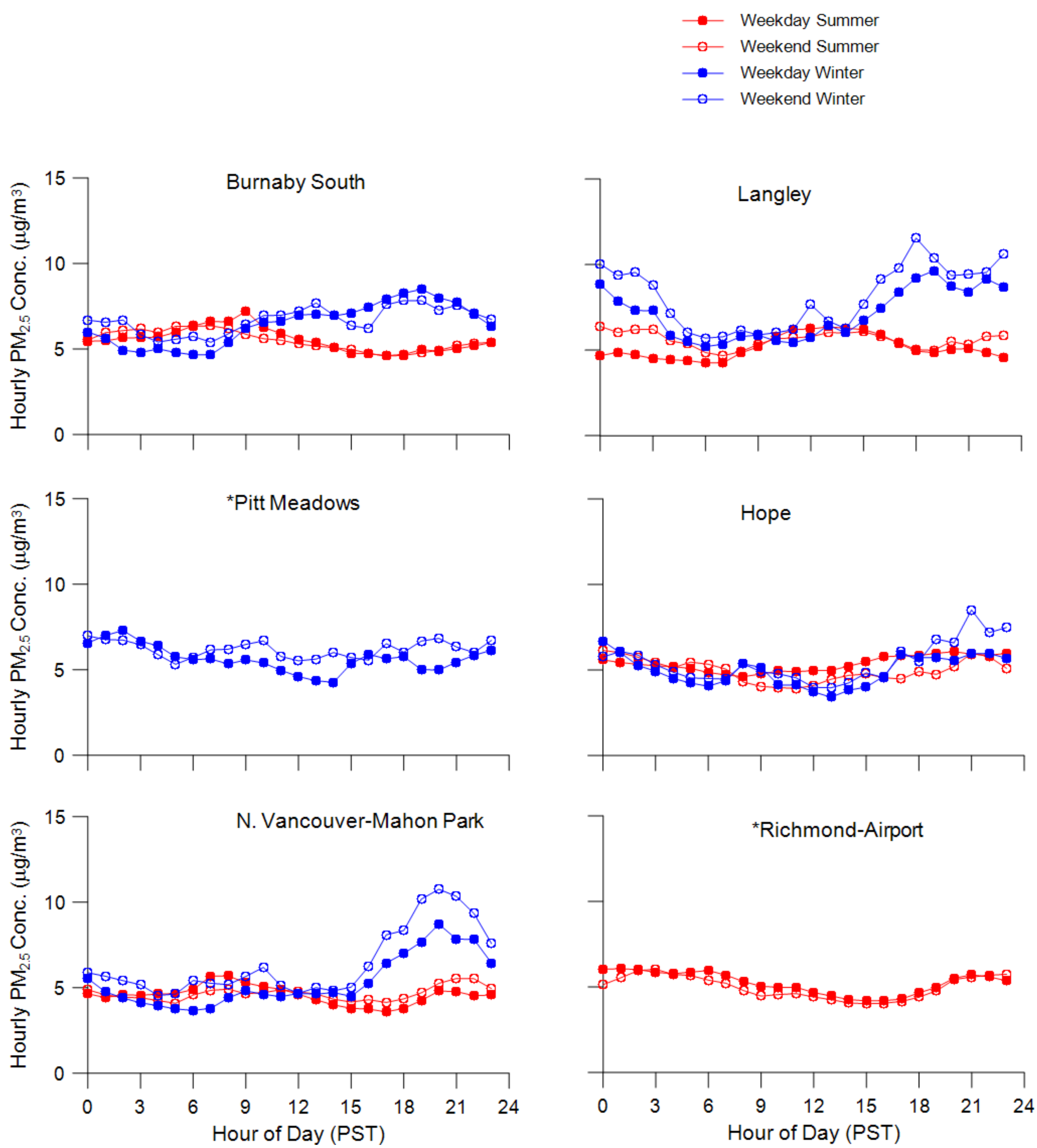


Figure 49: Monthly short-term peak fine particulate ($PM_{2.5}$), 2013.



*Data completeness requirements were not met at this site in winter.

Figure 50: Diurnal trends fine particulate ($PM_{2.5}$), 2013.



*Data completeness requirements were not met at this site.

Figure 50: Cont. Diurnal trends fine particulate ($PM_{2.5}$), 2013.

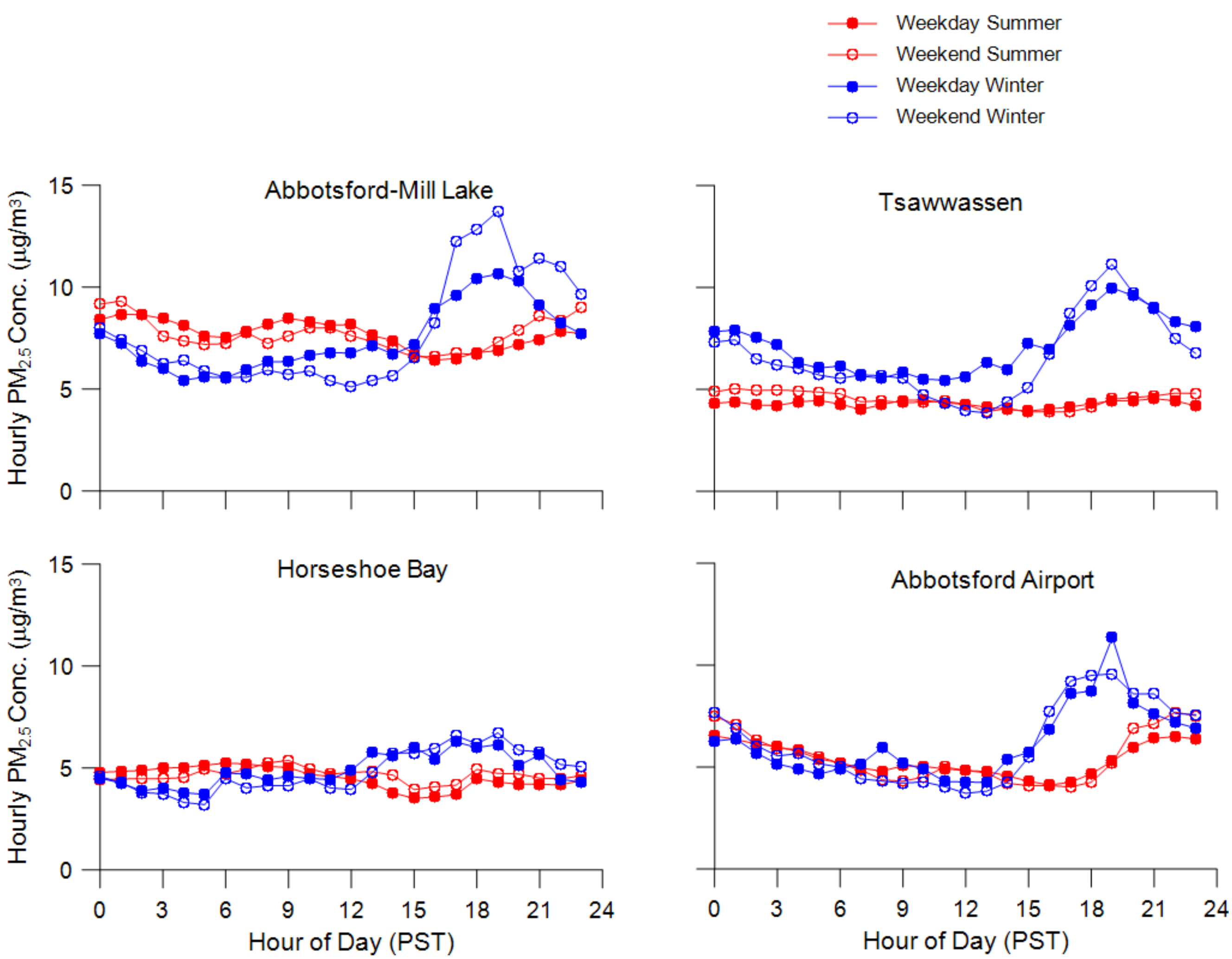


Figure 50: Cont. Diurnal trends fine particulate ($PM_{2.5}$), 2013.

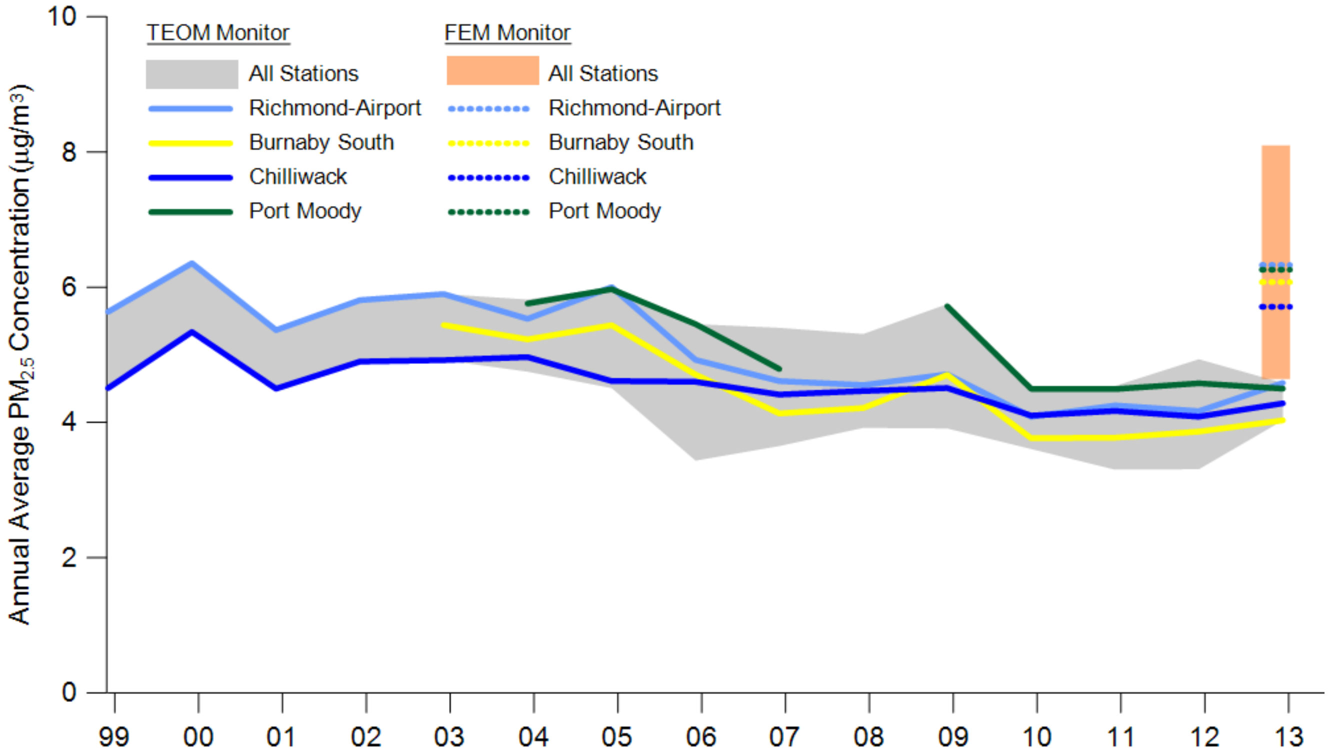


Figure 51: Annual fine particulate ($PM_{2.5}$) trend, 1999 to 2013.

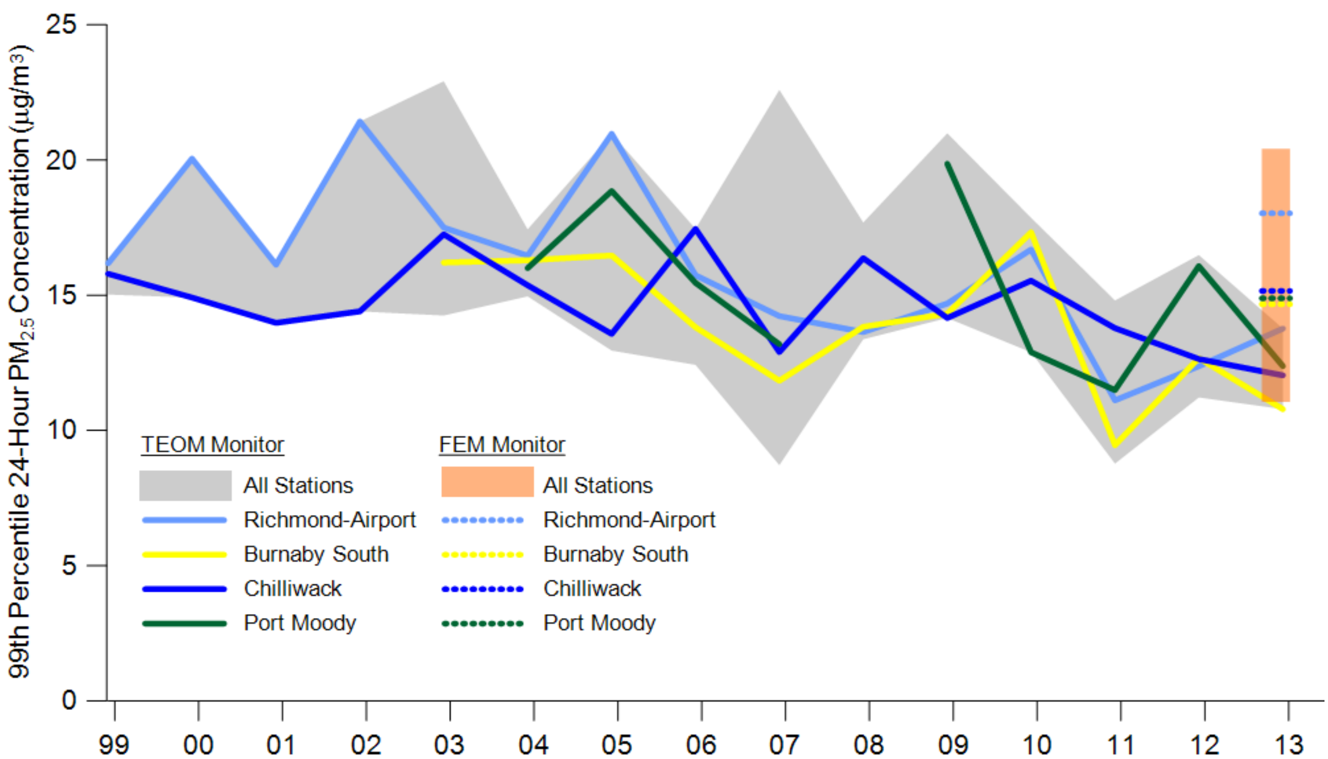


Figure 52: Short-term peak fine particulate ($PM_{2.5}$) trend, 1999 to 2013.

Inhalable Particulate (PM_{10})

Characteristics

The term 'PM_{10}' refers to airborne particles with a diameter of 10 micrometres (µm) or less. These particles are also known as inhalable particulate matter which, given their small size, can be inhaled and deposited in the lungs.

Exposure to PM_{10} can lead to both chronic and acute human health impacts, particularly pulmonary function. Inhalable particulate can aggravate existing pulmonary and cardiovascular disease, increase symptoms in asthmatics and increase mortality. High PM_{10} levels can also increase corrosion and soiling of materials, and may damage vegetation. The smaller particles also contribute to degraded visual air quality.

Sources

Inhalable particulate is emitted from a variety of sources with the largest contribution from road dust (35%). Road dust is made up of material that has been previously deposited on the road surface such as mud and dirt track-out, leaves, vehicle exhaust, tire debris, brake linings, and pavement wear. Traffic or wind re-suspends the road dust into the air. Other major contributors to PM_{10} are transportation, construction and demolition, residential wood heating, agriculture and industry. There are also natural sources of PM_{10} such as wind blown soil, forest fires, ocean spray and volcanic activity.

Monitoring Results

Figure 53 illustrates the PM_{10} monitoring in 2013, while Figures 54 and 55 shows the same values spatially. Annual averages at all stations were quite similar with each other, about half the Metro Vancouver annual objective.

The Metro Vancouver 24-hour objective was exceeded at the Abbotsford Airport station in 2013 on December 17. It is not known was caused elevated PM_{10} during this time, however it is thought to be caused by local emission sources.

Table 9 gives the frequency distribution of various PM_{10} concentrations for the year. It can be seen that Abbotsford Airport experienced the greatest frequency of high PM_{10} concentrations.

The seasonal trend of PM_{10} followed a pattern somewhat similar to the previous year with the highest average concentrations occurring during hot and dry periods of the summer (Figures 56). The seasonal peak PM_{10} trend (Figure 57) exhibited the highest levels in December.

A series of diurnal plots are shown in Figure 58 for each PM_{10} monitoring station. The plots show the differences between weekdays and weekends along with differences between summer and winter.

Improvements in PM_{10} concentrations have occurred in the last two decades, however one exceedance of PM_{10} occurred in the winter of 2013.

At most stations weekdays exhibit higher concentrations than weekends, likely the result of greater traffic volumes (road dust) and work related activities (outdoor burning, agricultural activities, industrial processes, etc.). The Port Moody station shows elevated levels during Centennial festival as described in the SO_2 and CO subsections. The peak from the December 17 event is clearly evident at the Abbotsford Airport station.

The long-term PM_{10} trends are shown in Figures 59 and 60 between the years 1994 to 2013. The annual average trend is given in Figure 59 with the short-term peak trend given in Figure 60.

The annual average PM_{10} trend (Figure 59) shows a general improvement in the last 20 years. The peak trend, represented by the 99^{th} percentile of the 24-hour rolling average in Figure 60, also shows a slight improvement. The large peak measured in 1998 was attributed to a dust storm in Asia with dust transported to the LFV. The 2005 peak was the result of a large fire in Burns Bog located in Delta.

Table 9: Frequency distribution of 24-hour rolling average inhalable particulate (PM_{10}), 2013.

PM_{10} Concentration ($\mu g/m^3$)	Burnaby-Kensington Park	Port Moody	Chilliwack	Burnaby South	Burnaby North	Langley	Hope	Richmond-Airport	Abbotsford-Mill Lake	Abbotsford Airport
0 to 4	106	81	93	123	58	82	209	26	104	242
4 to 8	2974	2160	2277	2340	2714	2138	3217	1584	2369	2261
8 to 12	2648	2906	2472	2967	2756	2589	3153	2758	2413	2762
12 to 16	1331	1840	1740	1517	1835	1635	1493	1829	1865	1951
16 to 20	447	759	840	396	732	632	436	692	906	1002
20 to 24	73	171	461	107	238	157	155	241	180	355
24 to 28	24	20	186	10	35	27		43	40	87
28 to 32			91	9				14	16	22
32 to 36			10					8		
36 to 40										
40 to 44										
44 to 48										
48 to 52										
52 to 56										
56 to 60										1
60 to 64										
64 to 68										22
68 to 72										1
>=72										
Missing	1157	823	590	1291	392	1500	97	1565	867	54
Data Completeness	87%	91%	93%	85%	96%	83%	99%	82%	90%	99%

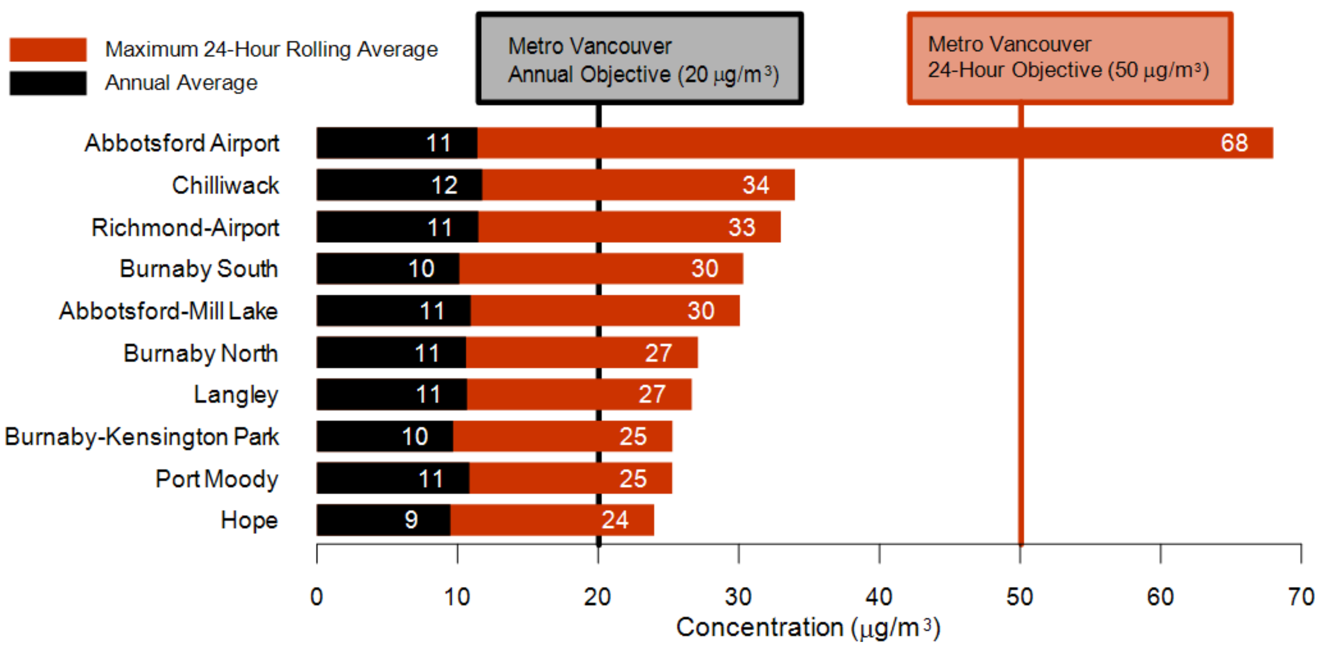


Figure 53: Inhalable particulate (PM_{10}) monitoring, 2013.

Figure 54: Annual average inhalable particulate (PM_{10}) in the LFV, 2013.

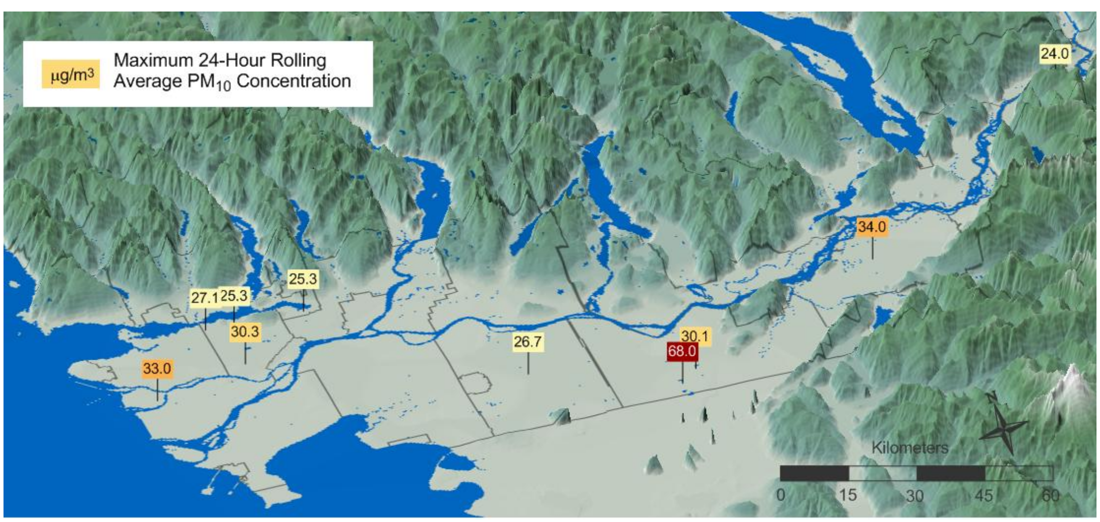


Figure 55: Short-term peak inhalable particulate (PM_{10}) in the LFV, 2013.

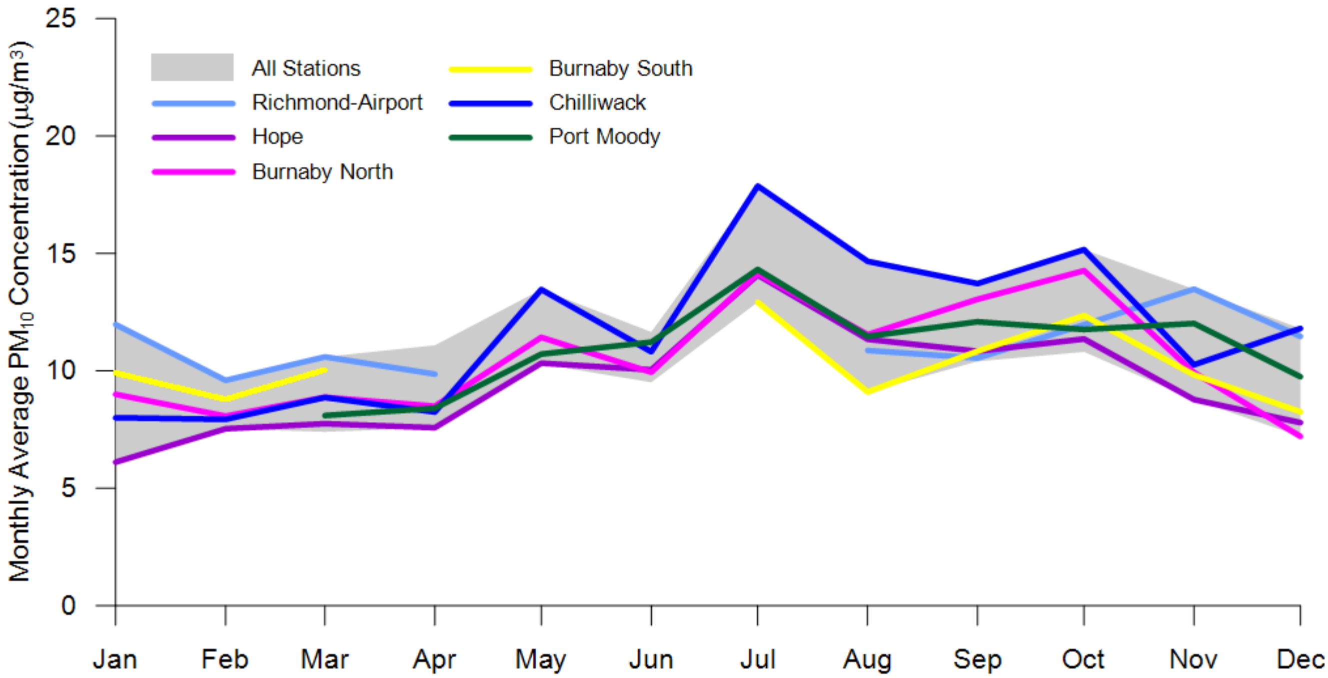


Figure 56: Monthly average inhalable particulate (PM_{10}), 2013.

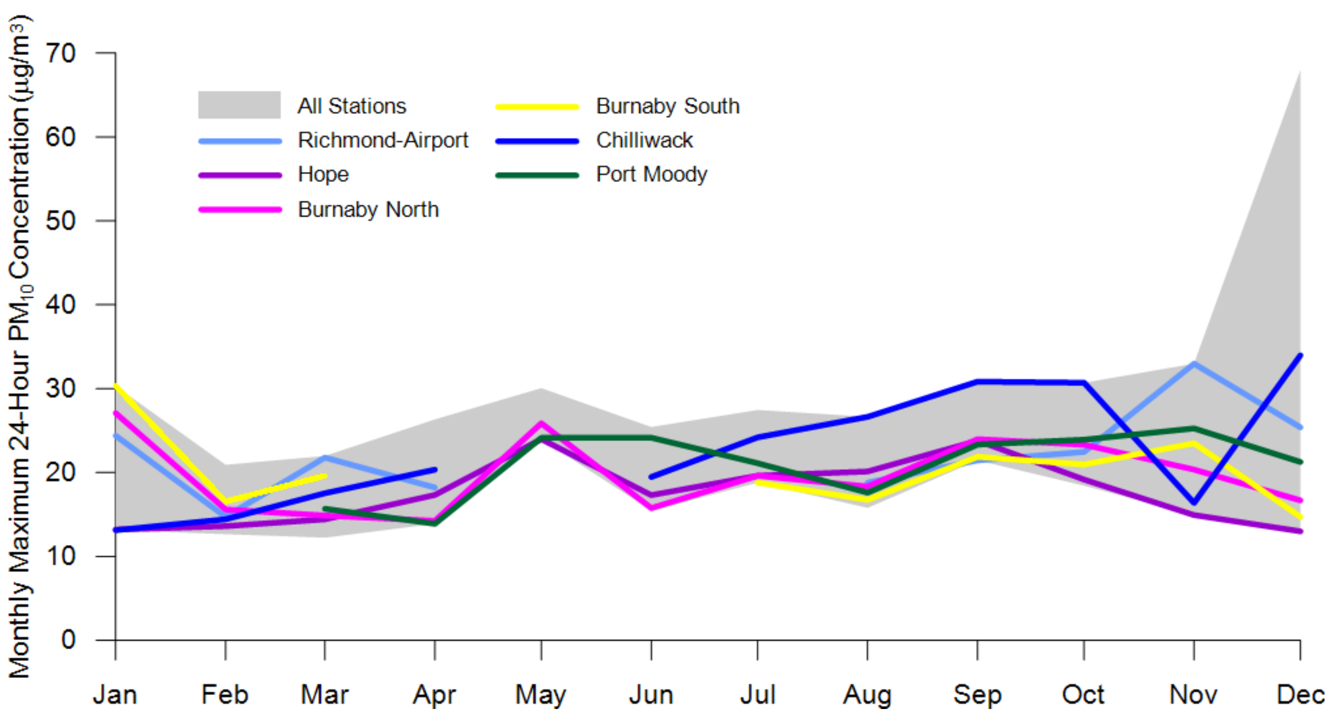
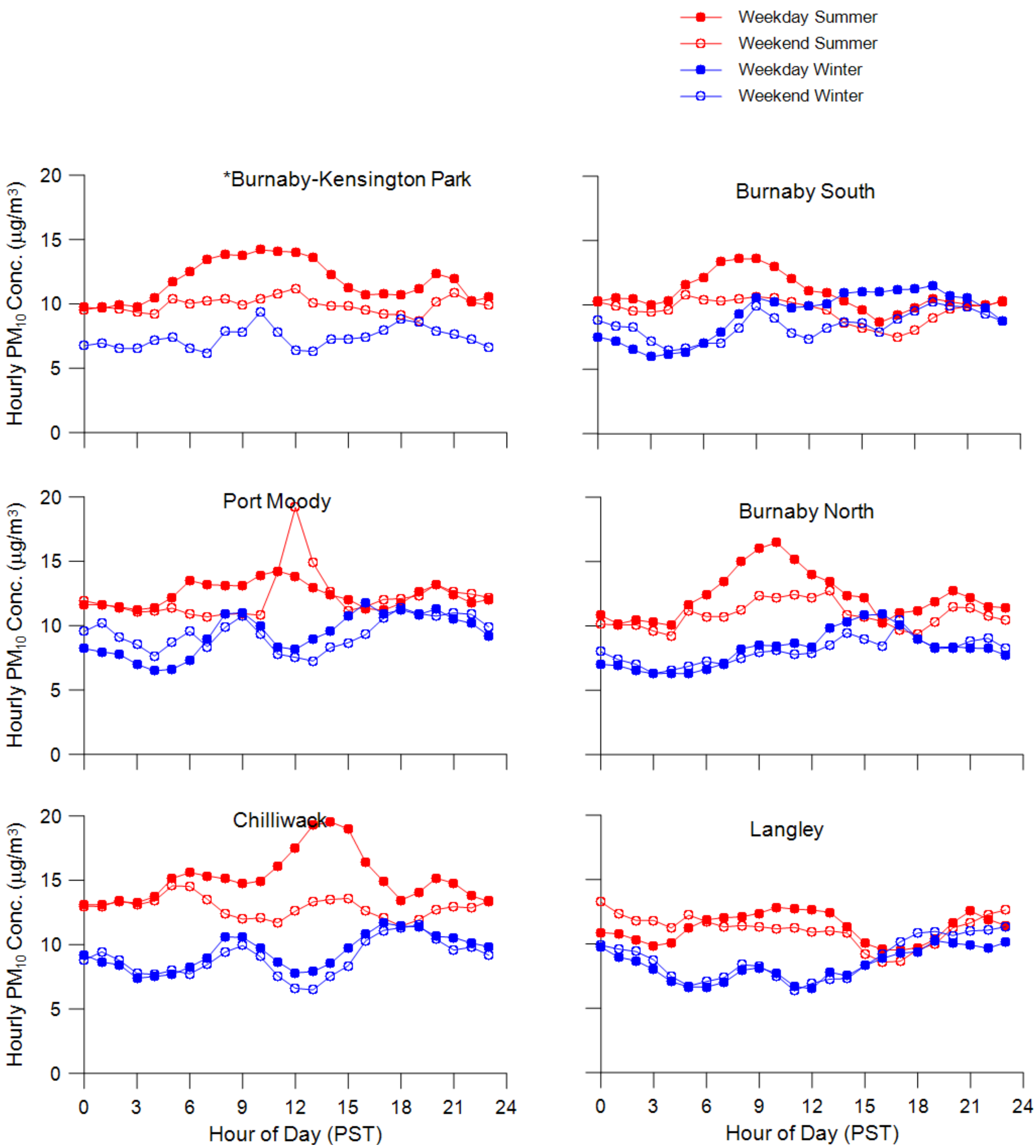
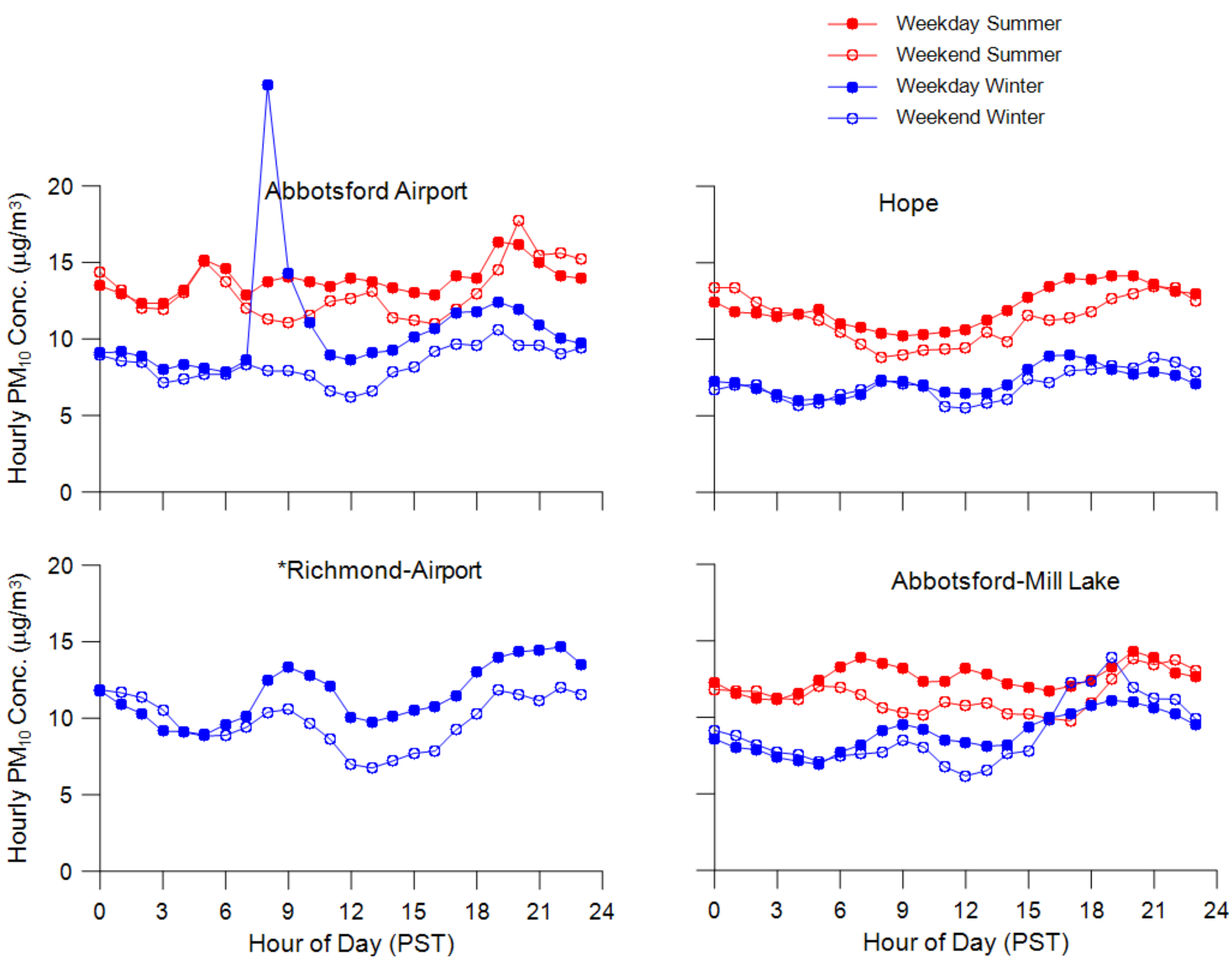


Figure 57: Monthly short-term peak inhalable particulate (PM_{10}), 2013.



*Data completeness requirements were not met at this site in winter.

Figure 58: Diurnal trends inhalable particulate (PM_{10}), 2013.



*Data completeness requirements were not met at this site in summer.

Figure 58: Cont. Diurnal trends inhalable particulate (PM_{10}), 2013.

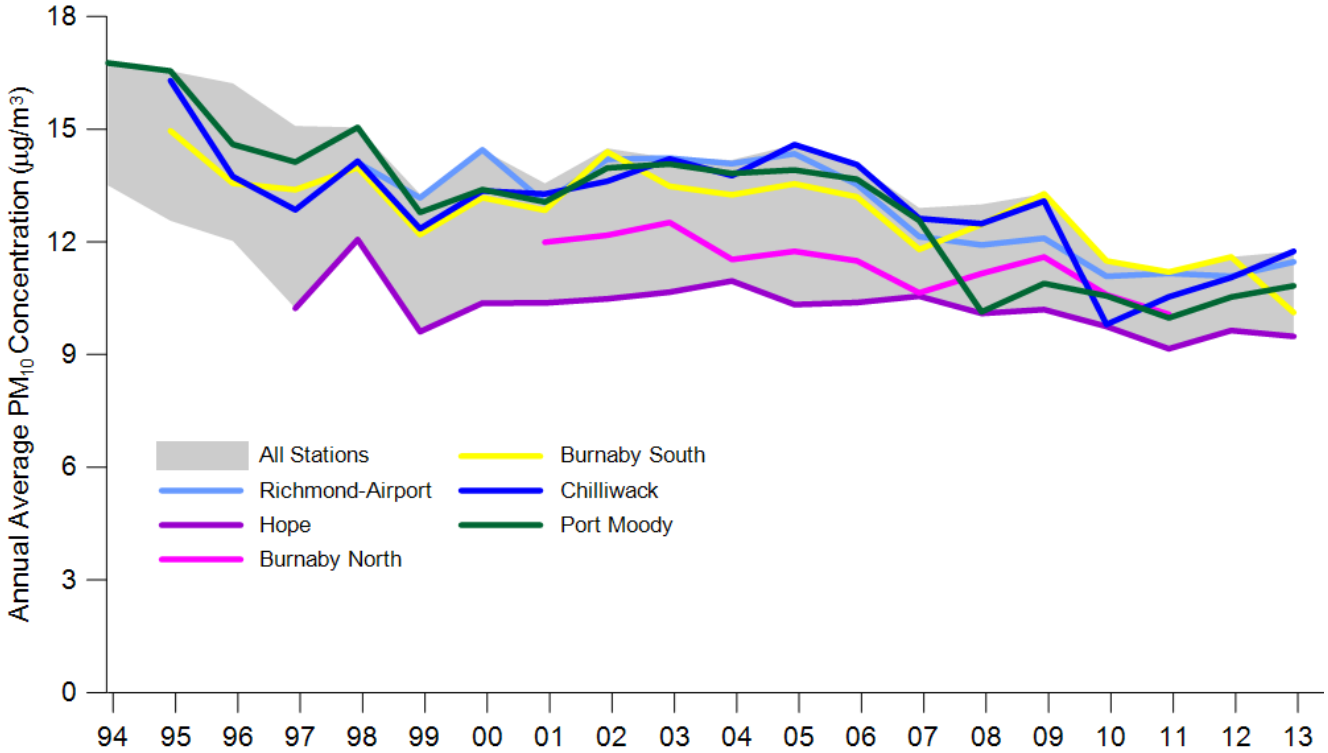


Figure 59: Annual average inhalable particulate (PM_{10}) trend, 1994 to 2013.

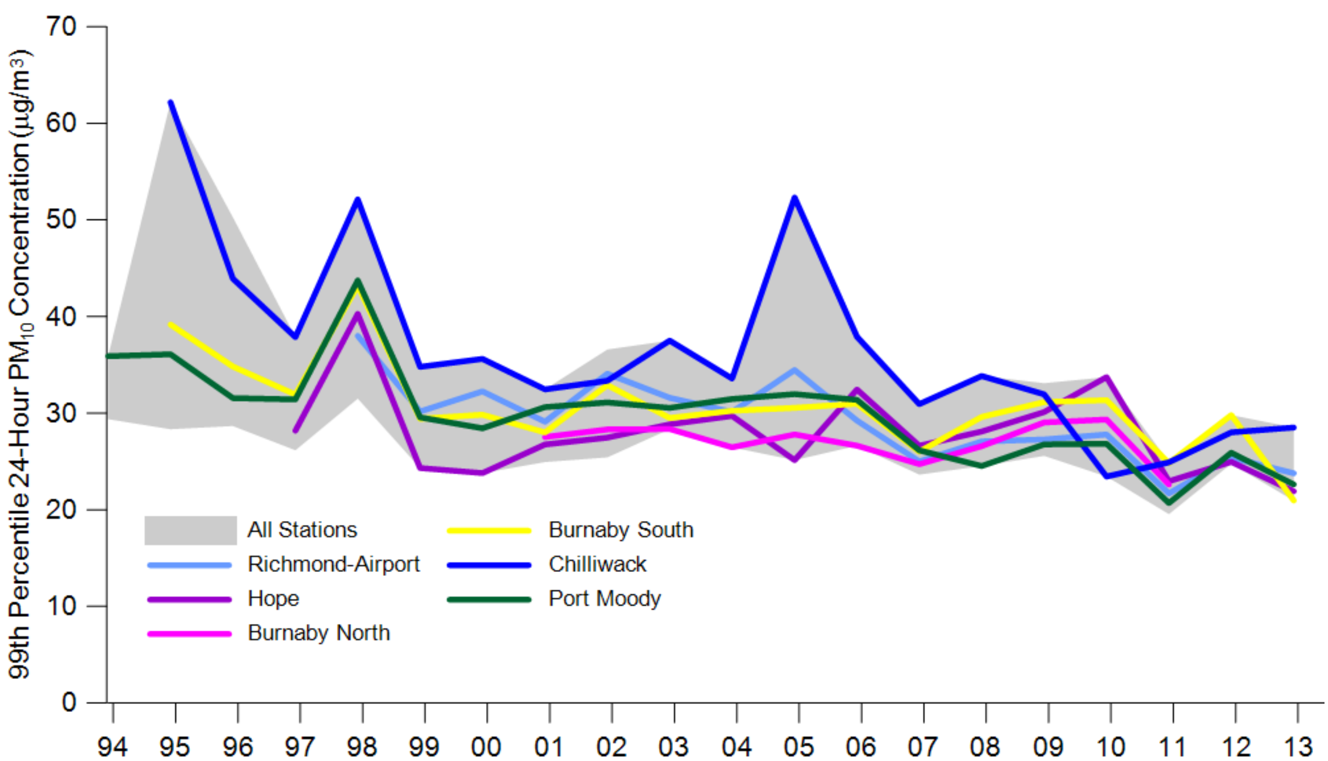


Figure 60: Short-term peak inhalable particulate (PM_{10}) trend, 1994 to 2013.

Black Carbon (BC)

Characteristics

Black carbon (BC) is carbonaceous material formed by the incomplete combustion of fossil fuels, biofuels, and biomass, and is emitted directly in the form of fine particles ($PM_{2.5}$). BC is a major component of "soot", a complex light-absorbing mixture that also contains some organic carbon.

The terms black carbon and soot are sometimes used interchangeably. Although BC has a very short residence time in the atmosphere (about a week), it is a strong absorber of solar radiation and can absorb much more energy than carbon dioxide (CO_2). As a result, BC is considered a "short-lived climate forcer". Black carbon contributes to the adverse impacts on human health, ecosystems, and visibility associated with fine particulate matter ($PM_{2.5}$).

Sources

Mobile sources are the largest contributors of BC emissions in the LFV, emitting over 80% of the BC emissions in the region. Non-road engines (primarily diesel fuelled), heavy duty vehicles, rail and marine vessels are significant sources of BC emissions. Other significant sources in the region are biomass burning operations, including agricultural burning, open and prescribed burning, wild fires and residential heating.

Monitoring Results

Figure 61 illustrates the results of continuous BC monitoring for 2013. Figure 61 displays the value of the maximum 1-hour and 24-hour average as well as the annual average for each BC monitoring location.

There are no provincial, federal or Metro Vancouver objectives for black carbon. The highest 1-hour average BC concentration occurred on June 22 in Port Moody as a result of the Centennial festival. The festival included a car show and parade that terminated near the station as well as food vendors operating in close proximity to the monitoring station. Other pollutants were also elevated at this station including SO_2, CO, $PM_{2.5}$ and PM_{10}.

In Figures 62 and 63 the seasonal trends for BC shows average values higher in January, October and November with the highest peak level occurring in June. Black carbon is generally greater on weekdays compared with weekends, shown in Figure 64. This trend is especially evident at the industrial station, North Vancouver – Second Narrows where large values of BC are seen on weekdays with smaller values experienced on weekends. The Centennial festival is evident in the Port Moody diurnal trend.

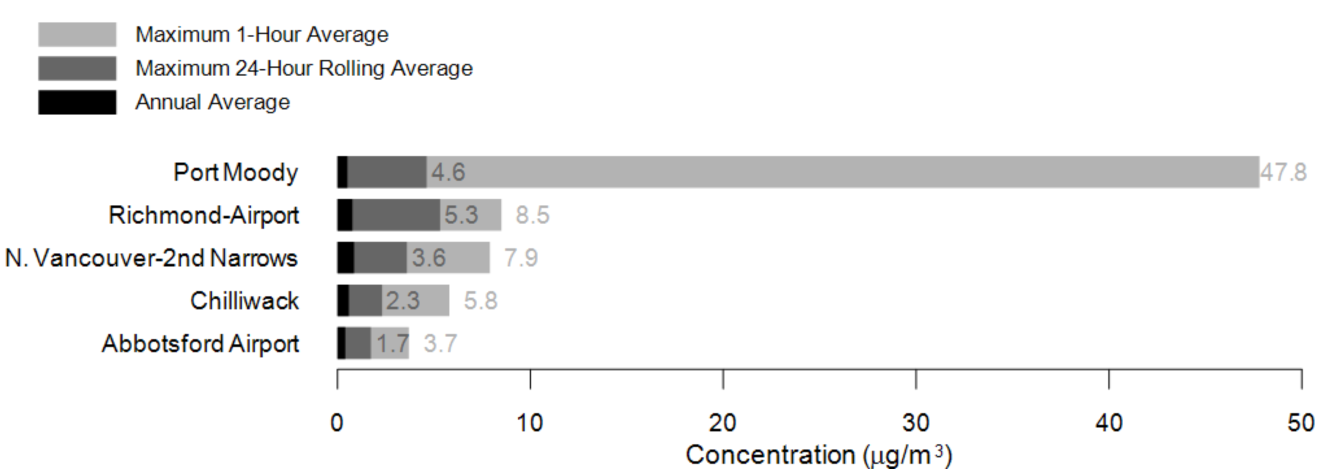


Figure 61: Black carbon monitoring, 2013.

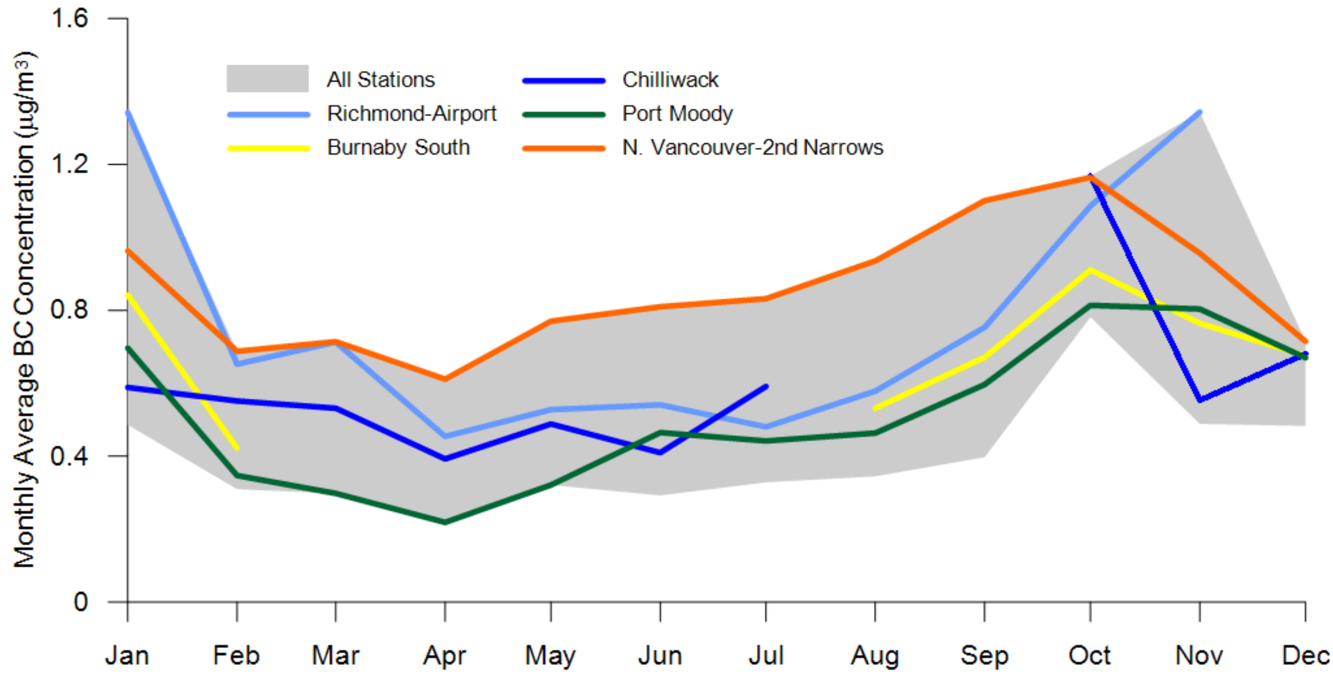


Figure 62: Monthly average black carbon, 2013.

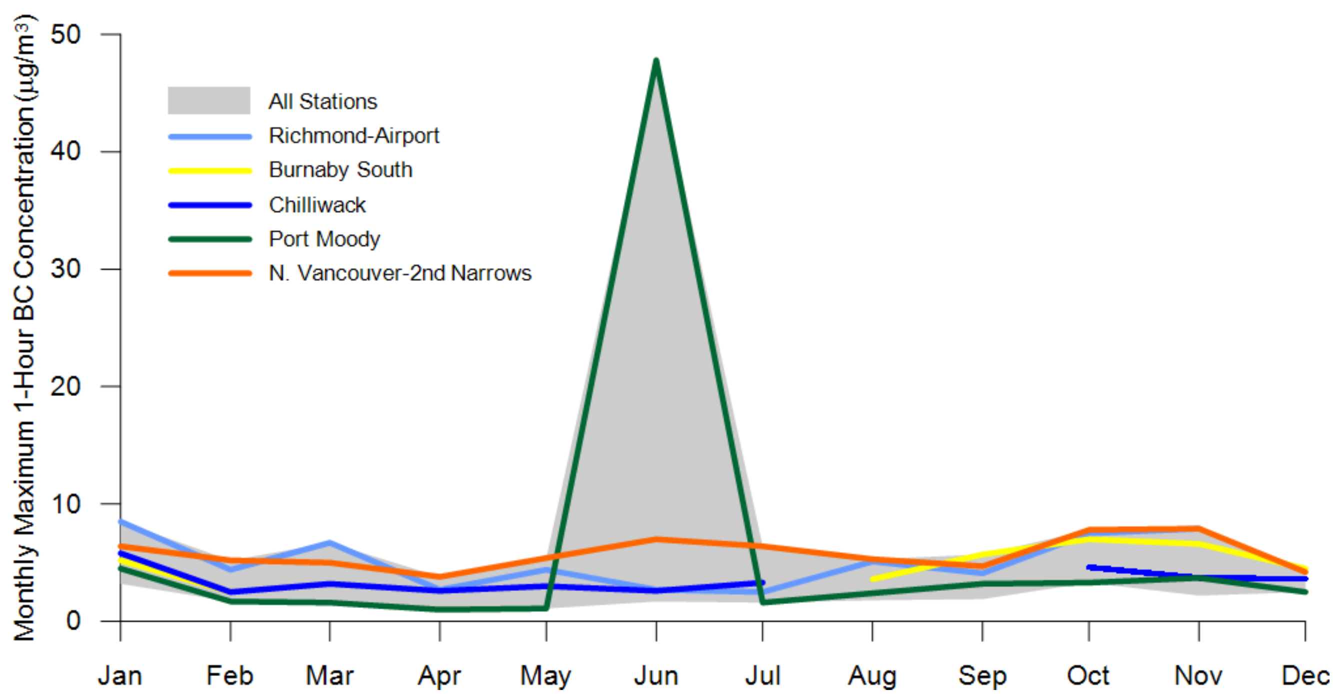
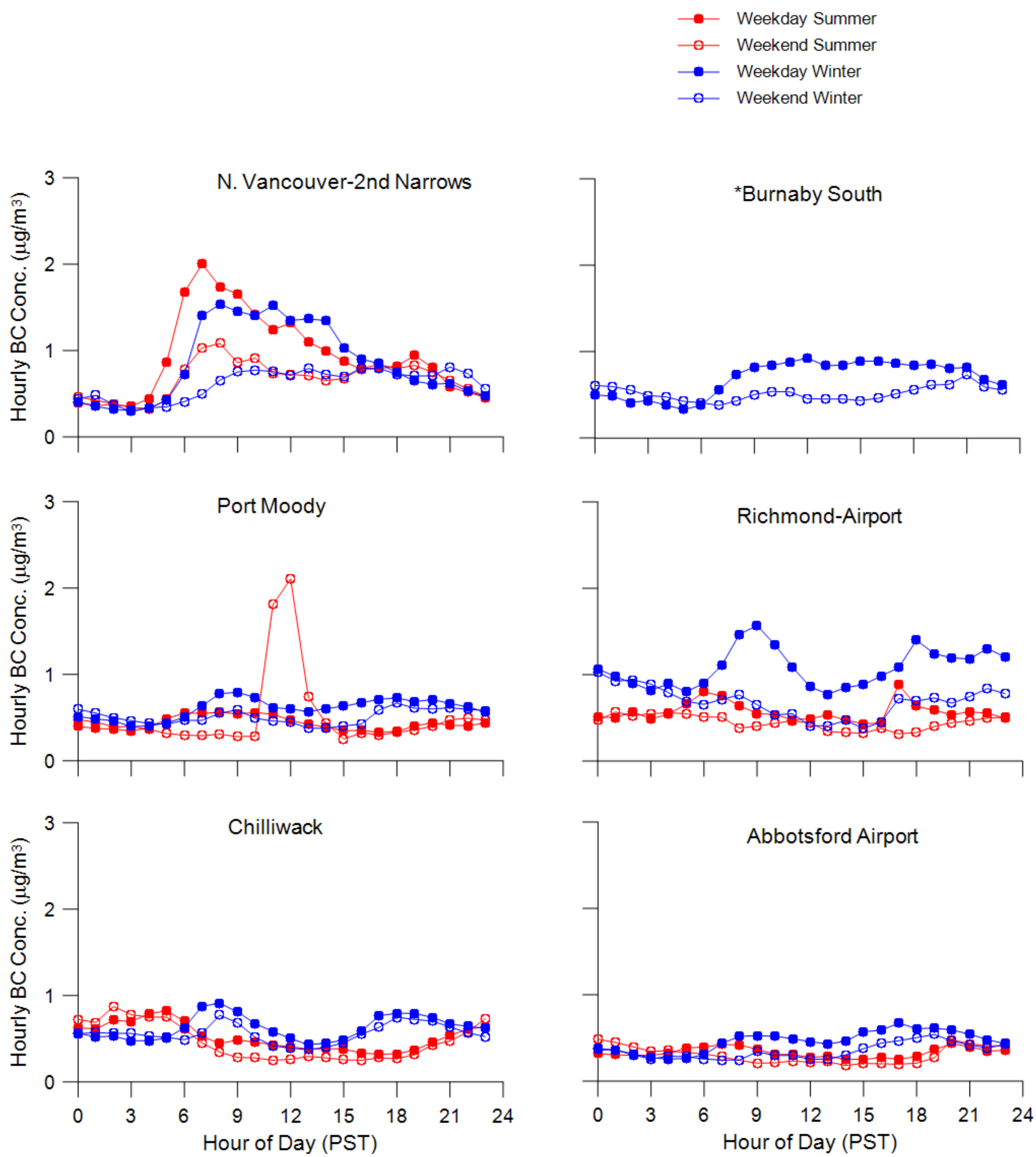


Figure 63: Monthly short-term peak black carbon, 2013.



*Data completeness requirements were not met at this site in summer.

Figure 64: Diurnal trends black carbon, 2013.

Total Reduced Sulphur (TRS)

Characteristics

Total reduced sulphur (TRS) compounds are a group of sulphurous compounds that occur naturally in swamps, bogs and marshes. They are also created by industrial sources such as pulp and paper mills, petroleum refineries and composting facilities. These compounds have offensive odours similar to rotten eggs or rotten cabbage, and at high concentrations can cause eye irritation and nausea in some people.

Sources

Most public complaints regarding these odours are associated with composting facilities and with the petroleum refining and distribution industry located along Burrard Inlet. A few periodic inquiries also occur as a result of natural emissions from such locations as Burns Bog in Delta.

Monitoring Results

Figure 65 illustrates the TRS measurements in 2013. Average levels continued to be near or below detectable limits. Peak levels during 2013, indicated by the maximum 1-hour value, exceeded the Desirable Objective for a total of 13 hours at Port Moody. The Acceptable Objective was not exceeded at any stations. The occurrences of elevated TRS are of a short duration and generally occurred during the night or early morning. The majority of exceedances occurred in the winter with a few in the summer and fall.

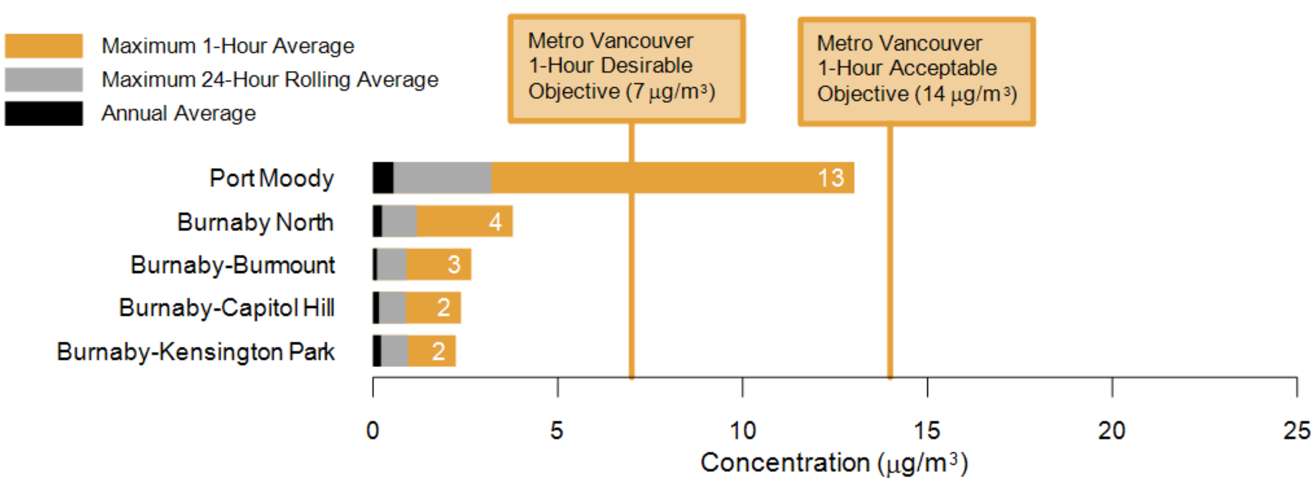


Figure 65: Total reduced sulphur monitoring, 2013.

Ammonia (NH_3)

Characteristics

Ammonia (NH_3) can contribute to the formation of fine particles when chemical reactions occur between ammonia and other gases in the atmosphere including sulphur dioxide (SO_2) and nitrogen dioxide (NO_2). The resulting ammonium nitrate and ammonium sulphate particles are efficient at scattering light and can impair visual air quality with a white haze.

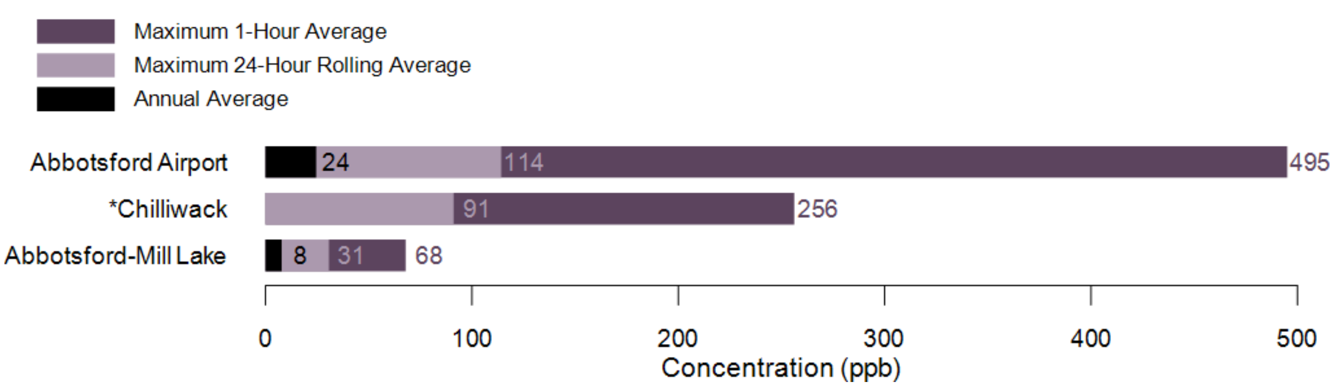
Sources

The largest contribution to ammonia in the LFV comes from the agriculture sector. The majority of ammonia emissions come from cattle, pig, and poultry housing, land spreading and storage of manure, and fertilizer application.

Monitoring Results

Continuous measurements of ammonia were made at three sites in the monitoring network in 2013. The 2013 data for two stations are presented in Figure 66, shown as the maximum 1-hour average, maximum 24-hour rolling average and annual average ammonia concentrations. Data collected at Chilliwack did not meet the data completeness criteria and an annual average was not calculated. There are no applicable objectives for ammonia.

Continuous measurements of ammonia began in 2005. Due to the relatively short period for which data are available, no clear year-to-year trend in ammonia is evident.



*Data completeness requirements were not met at this station.

Figure 66: Ammonia monitoring, 2013.

Section E – Non-Continuous Pollutant Measurements

Non-continuous samples are collected in accordance with the National Air Pollution Surveillance (NAPS) program. After collection, samples are transported to and analyzed in a federal laboratory in Ottawa to determine pollutant concentrations.

The process of obtaining results of non-continuous sampling from the federal laboratory can take considerable time. Results for 2013 are not yet available to Metro Vancouver, but will be included when available in a subsequent publication.

Particulate Sampling

Non-continuous 24-hour (daily) $PM_{2.5}$ and PM_{10} samples are collected on filters every sixth day depending on the site. Non-continuous particulate samples are collected at four monitoring stations in the LFV and pollutant concentrations are determined. A detailed analysis is conducted by the federal laboratory for three of these stations (Port Moody, Burnaby South and Abbotsford Airport).

Using specialized PM speciation instrumentation, additional detailed information about the chemical composition of $PM_{2.5}$ is obtained from two stations in the network (Burnaby South and Abbotsford Airport) as a result of analysis carried out by the federal NAPS program. From the 24-hour samples collected at these two sites, the various compounds that form $PM_{2.5}$ are identified.

Volatile Organic Compounds (VOC)

Volatile Organic Compounds (VOC) refers to a combination of organic chemicals. A large number of chemicals are included in this group but each individual material is generally present at relatively low concentrations in air compared to other common air contaminants. The gaseous VOC present in the air can originate from direct emissions and from volatilization (*i.e.* changing into the gas phase) of substances in the liquid or solid phase.

Locally, some VOC can be pollutants found in urban smog and are precursors of other contaminants present in smog such as ozone and fine particulates. Some materials in this class (*e.g.* carbon tetrachloride) can contribute to depletion of the stratospheric ozone layer and may contribute to climate change. Other VOC (*e.g.* benzene) can pose a human health risk.

Sources of VOC in Metro Vancouver include, but are not limited to emissions from the combustion of fossil fuels, industrial and residential solvents and paints, vegetation, agricultural activities, petroleum refineries, fuel-refilling facilities, the burning of wood and other vegetative materials, and large industrial facilities.

Under the Canadian Environmental Protection Act some VOC are included in the Toxic Substances List.

Emissions of some VOC are limited by permits and industry-specific regulations within Metro Vancouver.

Non-continuous 24-hour (daily) sampling of VOC is conducted every sixth or twelfth day on a national schedule. In 2013, VOC samples were collected at seven sites in the LFV. In cooperation with the federal National Air Pollution Surveillance (NAPS) program, canister sampling of VOC has been conducted in the LFV since 1988. Canisters sent to the federal laboratory are analyzed for up to 177 VOC. These data can then be used to help determine the emission sources contributing to contaminants in the air.

In addition to the canister sampling, continuous measurements of total hydrocarbons (THC) were made at two stations in 2013, Burnaby North (T24) and Burnaby-Burmount (T22) (results not shown). Both of these are adjacent to petroleum industry facilities.

Section F – Visual Air Quality Monitoring

Characteristics

When light between an object and the eye of an observer is scattered and/or absorbed by particles and gases in the air, views can look hazy or even be fully obscured. Visual air quality refers specifically to the effect air contaminants have on our ability to see through the atmosphere, or how clear the air is. The term does not refer to the effects of clouds, fog, rain or mist on a view.

Studies conducted in the region show that the major contributor to visual air quality impairment in the LFV is light scattering by $PM_{2.5}$.

Haze, or visual air quality impairment, may look noticeably different in different locations as it is dependent on the nature of the air contaminants present. In the more urbanized areas in the west of the LFV, haze can have a brownish colour. Nitrogen dioxide, emitted when fuels are burned from such sources as transportation, contributes to this brown appearance. Further east in the LFV, white haze caused by $PM_{2.5}$ may be observed. Windblown dust, soil, sea salt and smoke can also affect the appearance of haze.

Monitoring Program

To assess visual air quality impairment, Metro Vancouver, FVRD, and Environment Canada have jointly established a visual air quality monitoring network in the LFV. Continuous measurements of NO_2, $PM_{2.5}$, light scattering and absorption are being complemented by particulate speciation sampling and images of views along specific lines-of-sight. Measurements of air contaminants, views or both occur at seven locations in the LFV (Figure 67).

Light scattering measurements are made using nephelometers at four locations: Chilliwack, Abbotsford, Burnaby and Richmond. Aethalometers and nitrogen dioxide analyzers are also located at these sites and are used to characterize light absorption. Analysis of the data from the nephelometers, aethalometers and nitrogen dioxide analyzers indicates that scattering by particles has the most influence on average light extinction, and consequently visual air quality impairment.

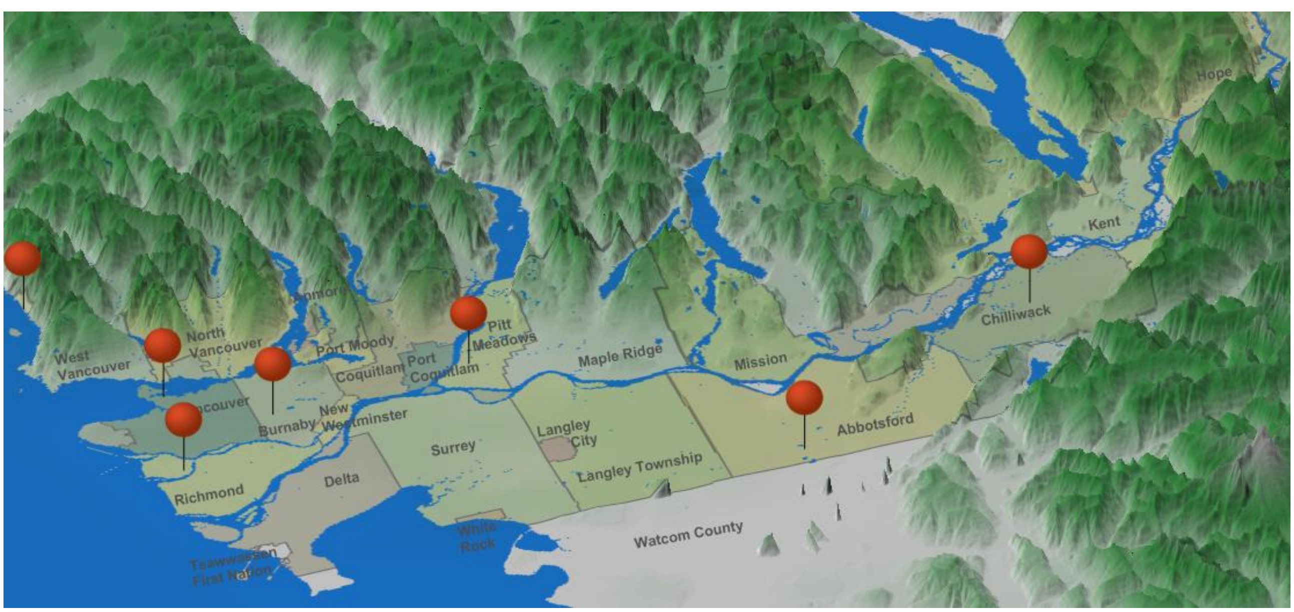


Figure 67: Visual air quality monitoring locations in the LFV, 2013.

Nine automated digital cameras are operated in six locations across Metro Vancouver and the FVRD: Chilliwack, Abbotsford, Pitt Meadows, Burnaby, Vancouver and Lions Bay. Images are captured at 10 or 30 minute intervals along specific lines-of-sight with recognizable topographical features at known distances. Examples showing a range of visual air quality conditions recorded by one of the cameras in Burnaby in 2013 are shown in Figure 68.

Near real-time images from the visual air quality monitoring cameras can be viewed through:

http://www.clearairbc.ca/community

Images from the cameras are used in conjunction with air contaminant data to relate the visual characteristics, such as the colour, clarity and definition of mountain ridges, of scenes from around the region to air contaminant concentrations and $PM_{2.5}$ composition. The information gathered by the visual air quality monitoring network is being used to further our understanding of visual air quality as part of a visual air quality pilot project for BC.

Pilot Project

The results of studies conducted in the LFV indicate that people perceive degraded visual air quality even at low air contaminant concentrations, less than Metro Vancouver's ambient air quality objectives for $PM_{2.5}$. To address the issue of visual air quality impairment, the BC Visibility Coordinating Committee (BCVCC) was established. Metro Vancouver is a partner with the FVRD, Environment Canada, Health Canada and BC Ministry of Environment in the BCVCC.

A pilot project is being conducted in the LFV by the BCVCC to develop a visual air quality management strategy for the region. As part of this pilot, improvements have been made to the visual air quality monitoring network to enhance public reporting of visual air quality. The causes and impacts of impaired visual air quality are also being determined:

- Air contaminant measurements and modelling tools are being used to identify how to reduce air contaminant concentrations to improve visual air quality.
- A visual air quality metric to measure and report visual air quality in the LFV is being tested.

Figure 68: Images of the view from Burnaby of downtown Vancouver and the North Shore mountains under a range of visual air quality conditions (Summer 2013).

Section G – Meteorological Measurements

Purpose

An understanding of meteorology is integral in understanding and forecasting air quality and visual air quality patterns. The state of the atmosphere determines how pollutants disperse and the resultant ground-level concentration. Meteorology is observed at LFV air quality monitoring network stations for several purposes:

- To allow for a characterization of meteorological patterns throughout the LFV.
- To assist with the linkage between pollutant emission sources and ambient concentrations.
- To provide data to be used as input in dispersion modelling.
- To provide real-time data to numerous agencies including Environment Canada, which are used for weather and air quality forecasting in the region.

It should be noted that the LFV network's primary purpose is for the collection of air quality measurements and secondary purpose is for meteorological observation. Attempts have been made to mount meteorological instruments so that spatially representative measurements are observed, however due to site restrictions at some stations, not all instruments are sited to capture spatially representative measurements.

Monitoring Program

Various meteorological parameters are observed as part of the LFV air quality monitoring network (see Section C Table 2).

Meteorological parameters observed in the network include:

- wind speed and direction
- air temperature
- relative humidity
- precipitation
- barometric pressure
- incoming solar radiation

Wind speed and direction observations allow for the characterization of pollutant transport and dispersion and are used to understand the relationships between pollutant sources and measurements at air quality monitoring stations.

Air temperature and incoming solar radiation measurements can be used to determine the potential for ozone formation during the summer. Ozone concentrations are dependent on sunshine to cause photochemical reactions among air pollutants. Higher air temperatures are necessary for these reactions to occur.

Humidity is important in the formation and growth of visibility reducing particles, and its measurement is a key to understanding the many factors responsible for visual air quality degradation.

Precipitation can wash pollutants out of the atmosphere and may help explain differences in air quality from one part of the region to another. In addition precipitation data are used by Metro Vancouver's Wastewater Collection and Watershed Management functions.

Meteorological Observations

Figure 69 shows the precipitation totals for 2013 at Lower Fraser Valley air quality monitoring network stations. The greatest precipitation was observed near the local mountains. Figure 70 displays the seasonal variation as observed by the LFV air quality network stations (shown as a blue band). Historical 30-year climate normals (1971-2000) obtained from Environment Canada are also shown in Figure 70 for Vancouver International Airport and Hope Airport.

Overall in 2013, precipitation amounts observed were slightly lower than previous years. Monthly precipitation was drier in July, October and December and slightly wetter in March and September.

Figure 71 illustrates the seasonal variation of air temperatures observed throughout the monitoring network stations. The hourly maximum and minimum, daily maximum and minimum, and average temperatures are given with the range in values shown as bands. Also shown in Figure 71 are the 30-year climate normals (1971-2000) for Environment Canada's Vancouver International Airport and Hope Airport stations.

The data collected in 2013 suggest that temperatures recorded in May, June and September were slightly warmer than the 30-year average. During these months higher averages and daily maximums were experienced compared with the climate normals. The highest air temperature was measured in June. November and December were slightly cooler than normal with slightly lower daily maximums compared with the climate normals.

Table 10 provides the average temperature along with the lowest and highest hourly air temperatures observed throughout the year. Air temperatures are milder near the water and exhibit a greater range inland. The highest hourly temperature in 2013 was 34.9°C observed at Chilliwack.

Wind patterns vary between stations as shown by the frequency distributions in Figure 72. The distributions are shown as a "wind rose", which is a bar chart in a polar format. The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 72 shows observed annual wind roses for selected stations including (in order of west to east): Horseshoe Bay, Richmond-Airport, Burnaby North, Pitt Meadows, Abbotsford Airport, Chilliwack, and Hope. The patterns shown during 2013 reflect the predominant winds in those areas. Richmond exhibits a predominant easterly wind with a smaller component from the west, and very little wind from either the north or south. Horseshoe Bay shows wind patterns aligned with Howe Sound with a strong north-south component.

The weather in 2013 included three persistent high pressure systems in the fall and winter resulting in a drier than normal October, November and December.

Burnaby North shows several northerly wind components along with a predominant east-north east component. This wind pattern is reflective of the North Shore mountain wind flows and drainage flow from Indian Arm. Pitt Meadows shows a somewhat similar pattern with predominant directions from the valleys of Pitt Lake and Alouette Lake. Abbotsford, Chilliwack and Hope experience similar wind flow patterns, with strong east-west components driven by the channelling of winds in the narrower portion of the Fraser Valley.

Figures 73 to 76 show wind roses for winter, summer, spring and fall, respectively. The contrast between winter and summer can be seen in Figures 73 and 74 with winds predominantly from the east in winter switching to southwest in summer. The more westerly flow seen in the summer is the development of a daytime sea breeze during anticyclonic (high pressure) weather.

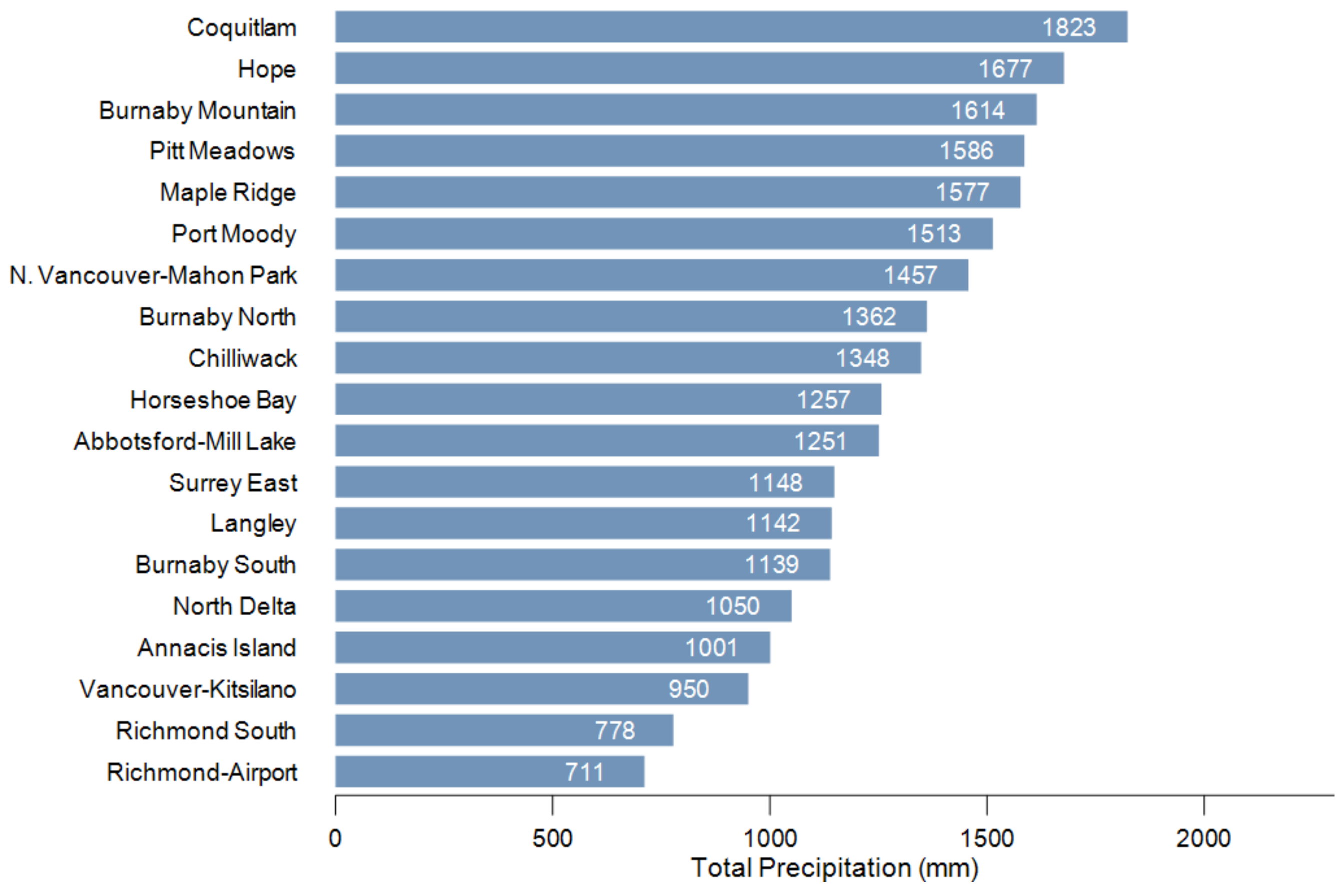
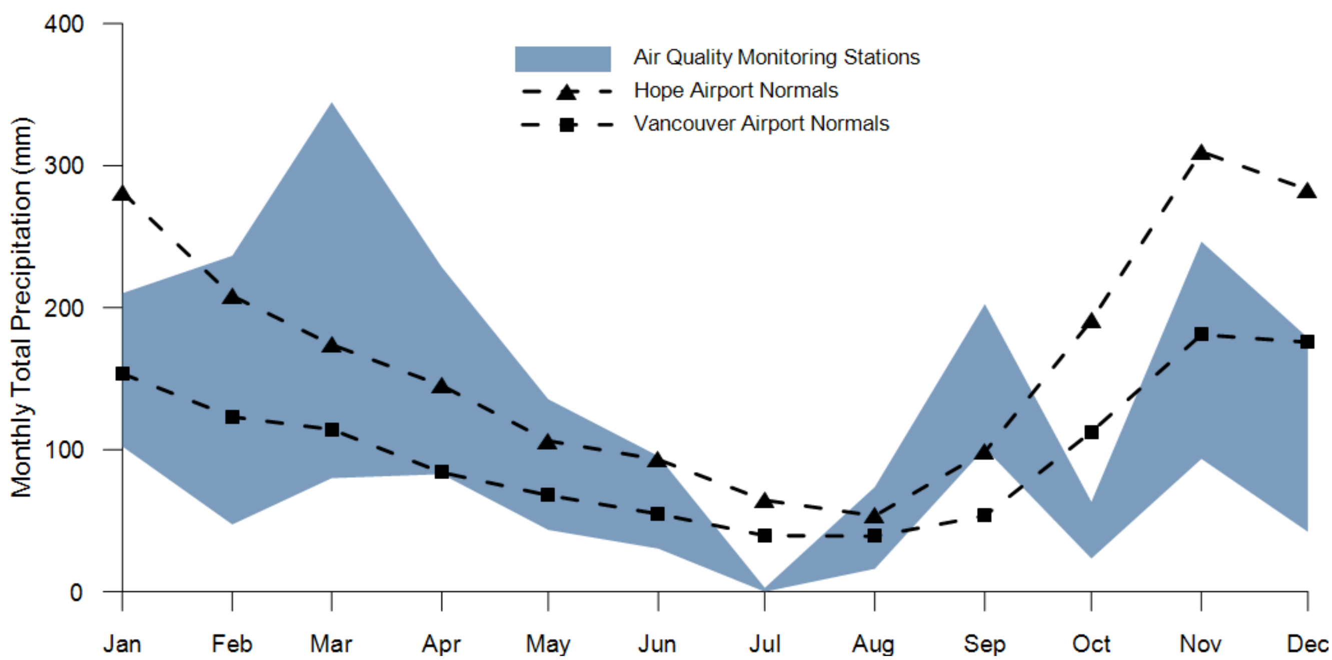
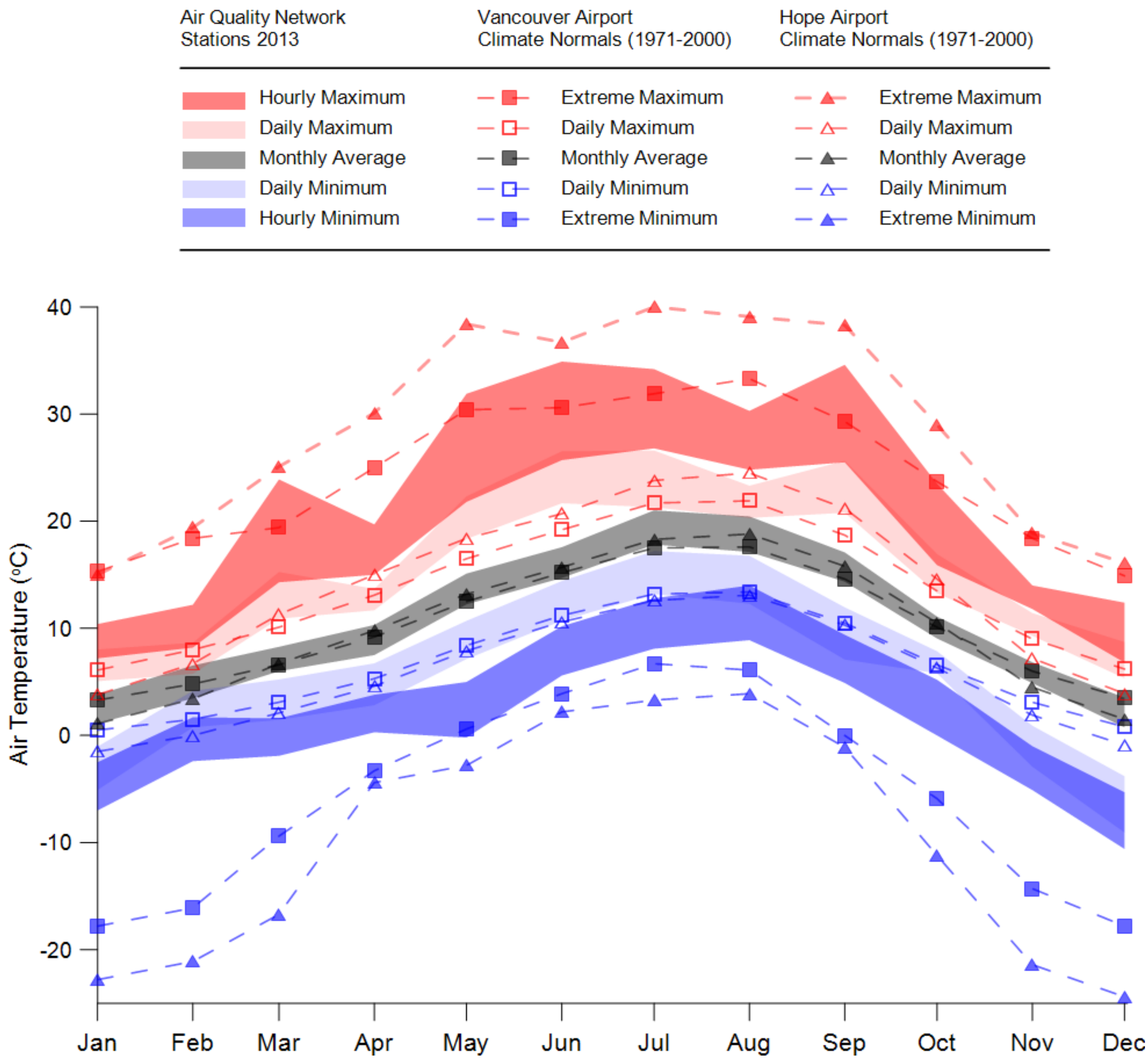


Figure 69: Precipitation totals in the LFV, 2013.



Note: The range of values observed at LFV air quality network stations are shown as a blue band and Environment Canada climate normals are shown as dotted lines.

Figure 70: Total monthly precipitation in the LFV, 2013.

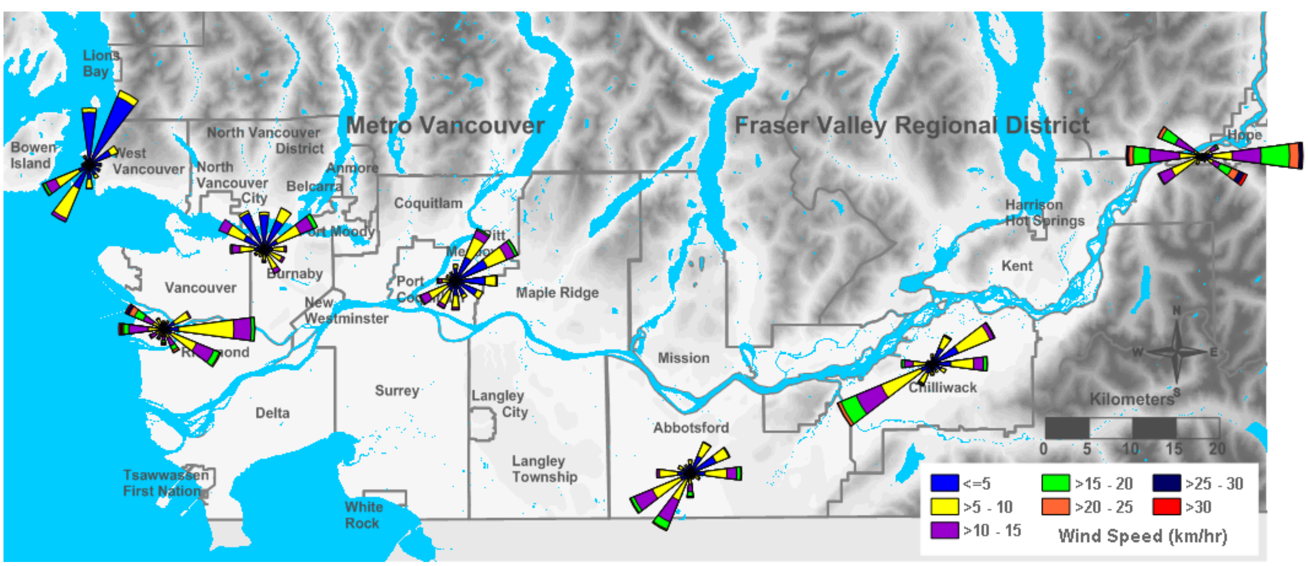


Note: LFV air quality network stations are shown as colour bands and Environment Canada 30-year climate normals are shown as dotted lines.

Figure 71: Monthly air temperatures in the LFV, 2013.

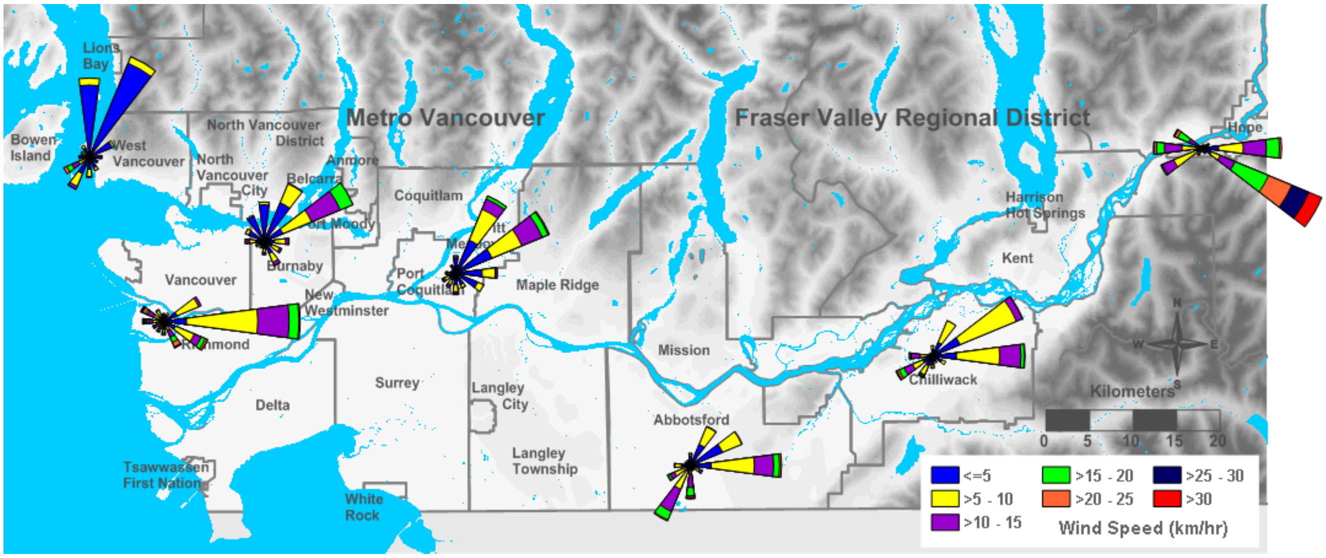
Table 10: Air temperature in LFV, 2013.

Station	Hourly Maximum (°C)	Hourly Minimum (°C)	Annual Average (°C)
Chilliwack	34.9	-9.1	11.4
Hope	34.6	-10.6	10.6
Maple Ridge	34.6	-9.3	10.7
Abbotsford Airport	34.3	-8.6	10.2
Pitt Meadows	34.1	-9.6	10.3
Abbotsford-Mill Lake	33.9	-8.5	10.7
Surrey East	32.6	-7.8	10.5
Langley	32.6	-8.3	10.1
Coquitlam	32.3	-7	10.9
Burnaby-Burmount	31.8	-7.2	10.9
North Delta	31.7	-7.4	10.2
Burnaby North	31.2	-6.8	10.6
Burnaby South	31.1	-5.3	10.7
Port Moody	30.8	-7.9	10.8
Burnaby-Kensington Park	30.7	-6.8	10.3
N. Vancouver-Mahon Park	30.7	-7.5	10.7
Burnaby-Capitol Hill	30.1	-7	9.8
Vancouver-Kitsilano	30.0	-6.9	10.9
Burnaby Mountain	30.0	-8.1	9.3
Annacis Island	30.0	-6.4	10.9
Richmond South	29.4	-8.2	11.2
Horseshoe Bay	28.6	-5.7	10.3
Richmond-Airport	28.1	-6.3	10.8
Tsawwassen	25.2	-6.3	10.6



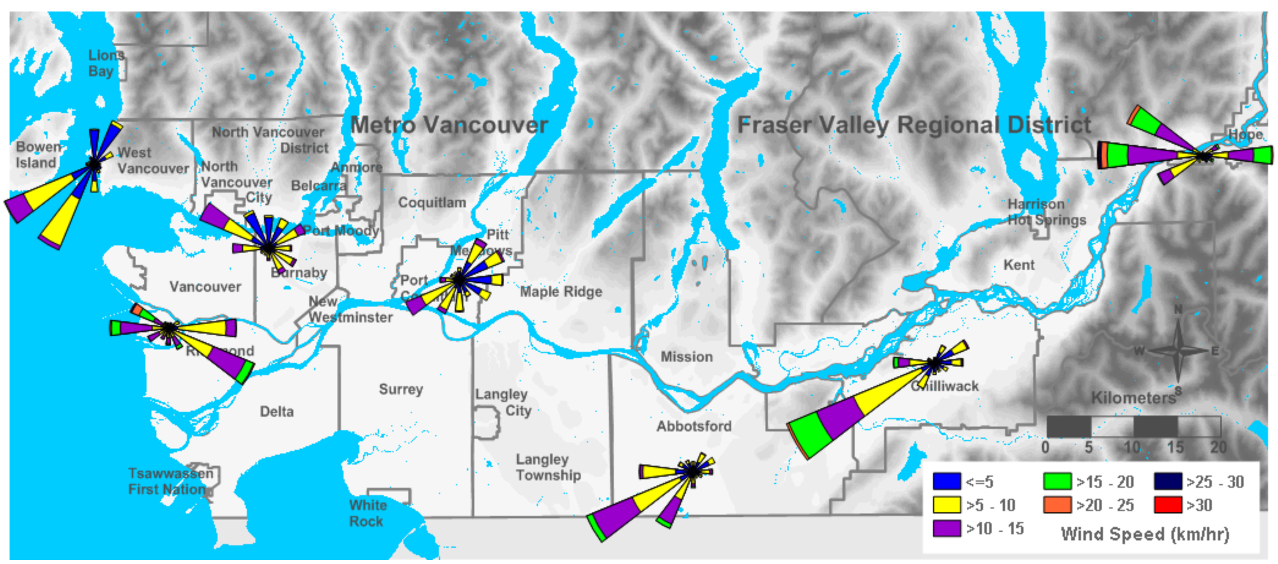
Note: The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 72: Selected annual wind roses throughout the LFV, 2013.



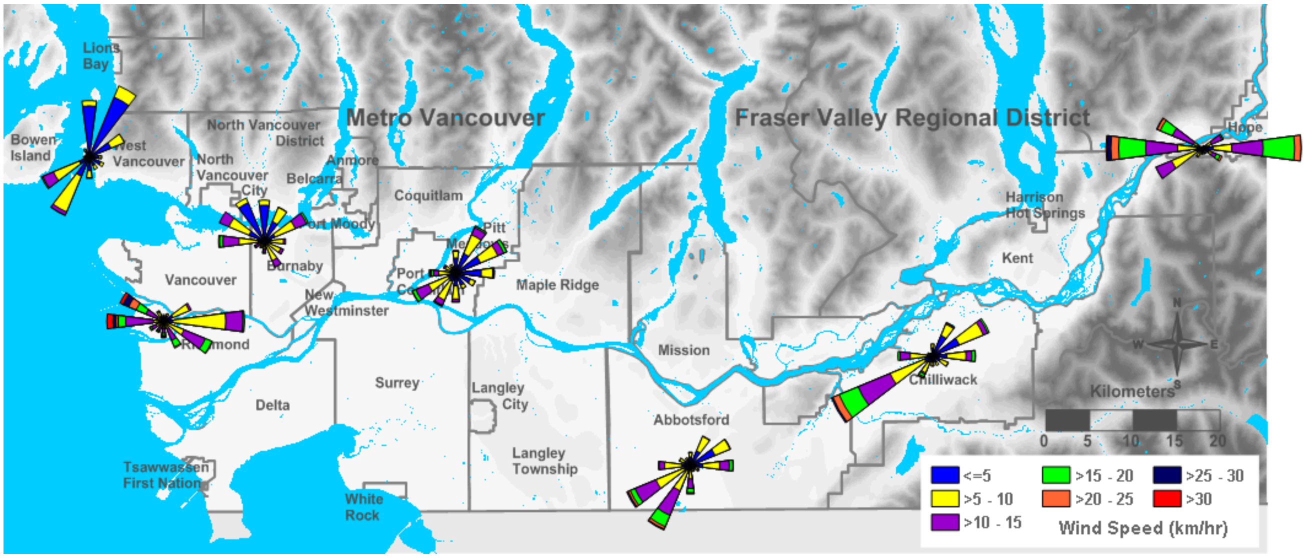
Note: The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 73: Winter (Dec 12, Jan 13, Feb 13) representative wind roses throughout the LFV, 2013.



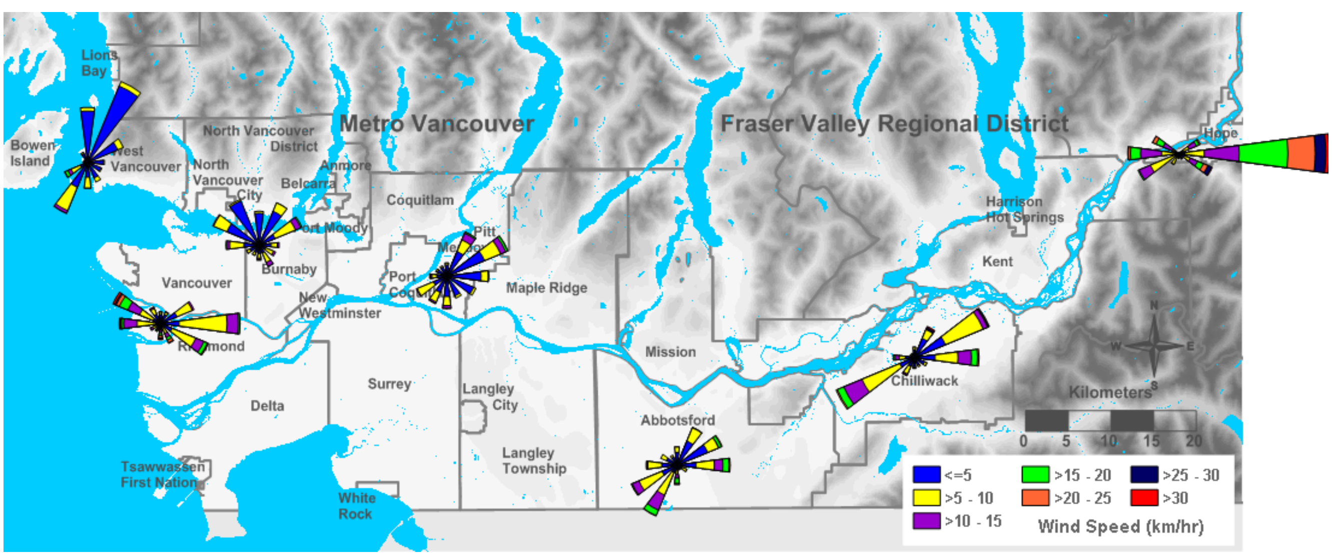
Note: The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 74: Summer (Jun, Jul, Aug) representative wind roses throughout the LFV, 2013.



Note: The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 75: Spring (Mar, Apr, May) representative wind roses throughout the LFV, 2013.



Note: The direction of the bar indicates the direction from which the wind is blowing, the colour indicates the wind speed class and the length of the bar indicates the frequency of occurrence.

Figure 76: Fall (Sep, Oct, Nov) representative wind roses throughout the LFV, 2013.

Section H – Specialized Monitoring Initiatives

Specialized air quality monitoring studies complement the fixed monitoring network. The studies typically allow for characterization of air quality at finer spatial scales, such as at the neighbourhood scale, and allow investigation of air quality problems on the local scale. The fixed monitoring network may not address local scale issues and therefore performing specialized local air quality studies is an important component to characterizing air quality in the LFV.

A Mobile Air Monitoring Unit (MAMU) that is capable of monitoring particulate and gaseous pollutants along with meteorology is utilized throughout the region to conduct specialized air quality studies. In addition to MAMU, Metro Vancouver utilizes small mobile units along with several portable air quality monitors.

A new Mobile Air Monitoring Unit (MAMU) became operational in April 2013 (shown below) replacing the previous MAMU that had reached the end of its useful service after operating throughout the LFV for nearly 25 years.

Specialized study activity in 2013 included a coal dustfall monitoring study and continued support of the background air quality station located in Ucluelet.

Metro Vancouver supported air quality and coal dustfall monitoring initiated by the Corporation of Delta in 2013. Monitoring was conducted in the summer for approximately four weeks where canisters were deployed along with concurrent sampling for airborne particulate at the Tsawwassen monitoring station. Filter samples were analyzed to identify coal particles in the airborne particulate.

In partnership with the BC Ministry of Environment and Environment Canada, Metro Vancouver continues to provide support for the West Coast Marine Boundary Layer Background Station located in Ucluelet on Vancouver Island. The background station, located at the Amphitrite lighthouse, is a remote station located to monitor background air quality in the lower atmosphere on the west coast of British Columbia. The station, established in 2010, will allow a more complete understanding of the effect of background air masses transported into British Columbia on local and regional air quality.

Section I – Monitoring Network Operations

Network History

Air monitoring in the region began in 1949, when the City of Vancouver established a dustfall monitoring network. Monitoring for total suspended particulate was added in later years. Following the Pollution Control Act (1967), provincial air quality programs initiated monitoring of dustfall and total suspended particulate in other areas of the region.

In 1972, provincial and municipal air quality responsibilities were transferred to Metro Vancouver, including operation of air quality monitoring programs. In 1998, a Memorandum of Understanding established cooperative management of the monitoring network by both Metro Vancouver and the Fraser Valley Regional District.

Continuous monitoring of gaseous pollutants began in 1972 under the auspices of the federal National Air Pollution Surveillance (NAPS) program. Several new stations were established to measure SO_2, O_3, CO, NO_X and VOC. Over the years, stations and equipment have been added or removed in response to changing air quality management priorities. Mobile Air Monitoring Units and portable instruments provide added flexibility to carry out measurements at many locations. Some monitoring is part of co-operative programs with industry and other governments.

Monitoring Network Partners

Several partners contribute to the on-going management and operation of the Lower Fraser Valley Air Quality Monitoring Network. The government partners include:

- Fraser Valley Regional District
- Environment Canada
- BC Ministry of Environment

Other monitoring network partnerships:

- The Vancouver International Airport Authority provides partial funding for the Vancouver International Airport station (T31).
- Chevron Canada Ltd. provides funding for the Burnaby North (T24) and Capitol Hill (T23) stations.
- BC Hydro provides funding for three network stations, including Port Moody (T9), Burnaby Mountain (T14) and Surrey East (T15).
- Kinder Morgan Canada provides funding for the Burnaby-Burmount (T22) station.
- Port Metro Vancouver provides funding for the Tsawwassen (T39) station in Delta which became fully operational in 2010.

Metro Vancouver continues to operate and maintain the monitoring stations and equipment, and to collect real-time data from the regional monitoring network on behalf of all partners.

Courtesy of City of Vancouver Archives (1924).

Federal Government

Metro Vancouver co-operates with the federal government by providing field services for three major nation-wide sampling programs under the National Air Pollution Surveillance (NAPS) program of Environment Canada.

- Canister sampling of VOC has been conducted in the LFV since 1988. The federal government supplies equipment and Metro Vancouver staff provide field exchange of canisters, calibration and routine maintenance. Exposed canisters are sent to the federal laboratory in Ottawa, for analysis of up to 177 VOC.
- A second program involves dichotomous particulate sampling at three sites. This long-term program samples PM at two size fractions: 10 to 2.5 μm (coarse), and under 2.5 μm (fine). Samples are collected every sixth day, and returned to Ottawa for detailed chemical analysis.
- In 2003 a $PM_{2.5}$ speciation sampling program was initiated. Particulate speciation samplers are operated at the Burnaby South and Abbotsford Airport stations. $PM_{2.5}$ samples are taken every sixth day in specially designed cartridges. The exposed samples are sent to the federal laboratory in Ottawa where they are analyzed for various particulate species.

Quality Assurance and Control

Air quality monitoring data is regularly reviewed and validated. Technicians perform weekly inspections and routine maintenance of the monitoring equipment and stations.

In addition, technicians perform major repairs to any instrument in the network, as required. Through the data acquisition system, technicians can check on instruments remotely prior site visits. This system also allows for calibration of the instruments either automatically or upon demand. Portable calibration equipment is used to evaluate instrument performance.

Continuous air quality monitors are subject to performance audits and multi-point calibration every fourth month. In addition, all other instruments and samplers in the network are subjected to annual and/or biannual calibrations. All reference materials and quality control procedures meet or exceed Environment Canada and/or U.S. Environmental Protection Agency requirements. Metro Vancouver coordinates quality assurance procedures and activities with both the provincial and federal government.

Database

Data from continuous air quality analyzers are transmitted to the central database using internet, phone lines and cellular links. Hourly averages for each monitor are calculated from the one minute data and stored in the database. For a measurement to be considered valid (and stored for further use), at least 75% of the relevant data must be available. Calibration data and instrument diagnostics are also retained by the data acquisition system.