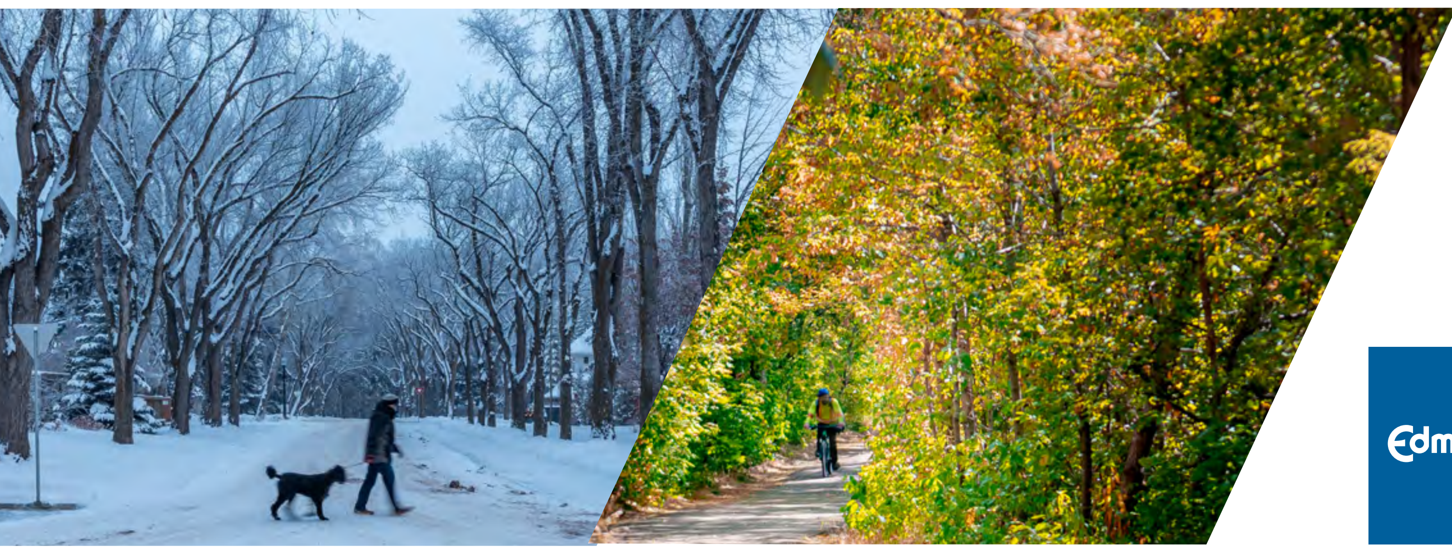
Understanding Edmonton's Changing Climate 2025:

Observed Climate Trends



Understanding Edmonton's Changing Climate 2025: Observed Climate Trends

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DIRECTOR OF ENVIRONMENT AND CLIMATE RESILIENCE

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Executive Summary

Understanding Edmonton's Changing Climate 2025: Observed Climate Trends provides a clear, science-based account of how Edmonton's climate is shifting and why it matters. Developed to support evidence-based decision-making across sectors, this assessment identifies the following key trends: rising temperatures, declining cold extremes, worsening air quality during wildfire season, and shifting precipitation patterns. These changes carry far-reaching implications, including effects on City operations, infrastructure resilience, ecosystems, and public health. Every fraction of a degree of additional warming compounds risks across multiple systems. The findings presented in this report should inform the next generation of climate adaptation and mitigation strategies tailored specifically to Edmonton's unique challenges and opportunities.

Rapid Warming

Edmonton is warming faster than the global average. Since 1885, the city's mean annual temperature has increased by 2.3°C, with winter temperatures rising by over 4°C. This warming has been especially rapid in the last two decades, with 2023 recorded as the warmest year in Edmonton's history. Summers are hotter, nights are warmer, and extreme heat events are longer and more frequent, increasing cooling demands and public health risks. At the same time, extreme cold events have sharply declined, signaling a new thermal regime that could challenge infrastructure, ecosystems, and emergency response systems.

Rising Risks from Air Pollution and Wildfires

While Edmonton's long-term air quality has remained relatively stable, episodic events, especially wildfire smoke during summer months, have caused spikes in exposure to harmful air pollutants such as fine particulate matter ($PM_{2.5}$). In 2023 alone, the city experienced 34 high-risk air quality days, the worst year on record. Although nitrogen dioxide levels have declined, likely due to cleaner vehicles and regulations, ozone levels are rising, indicating evolving atmospheric chemistry. Fine particulate matter remains highly variable, with wildfires now a dominant and unpredictable driver of air pollution.

Drier Climate, Greater Uncertainty

Edmonton is also experiencing a drying trend. Annual average precipitation has declined by 14 per cent, with winter precipitation dropping 31 per cent relative to the 1961–1990 baseline. Summer and fall seasons have become noticeably drier, likely increasing drought risk, wildfire vulnerability, and pressure on water resources. While extreme rainfall events still occur, prolonged dry spells, especially during the growing season, are reshaping conditions for agriculture, ecosystems, and water supply systems.

A Science-Based Call to Action

The findings presented in this report are clear: climate change is not a future threat—it is a present reality in Edmonton. Rising temperatures, declining precipitation, and worsening air quality trends demand urgent and sustained action. These changes, while consistent with global and national trends, are unfolding locally in ways that are deeply shaped by Edmonton's geography, infrastructure, and social systems.

This report establishes a scientific foundation to guide effective, equitable, and forward-looking responses. The information presented is intended to support future integration into corporate planning and decision-making. It also calls for ongoing scientific updates, the integration of Indigenous knowledge, and the application of a climate equity lens to ensure that all communities, especially the most vulnerable, are protected and empowered.

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Introduction

Edmonton has long been recognized as a leader in transparent climate reporting, committed to advancing understanding of environmental and climate issues. The City of Edmonton believes that climate action starts with climate knowledge.

Edmonton was proud to host the inaugural CitiesIPCC Cities and Climate Change Science Conference in 2018, where the Edmonton Declaration was created. This Declaration stands as a powerful call for cities worldwide to prioritize scientific research and data when crafting ambitious climate action plans.

To understand how to effectively address greenhouse gas emissions reductions and adapt to changing climate impacts, decision-makers need the best available science, evidence and information. Climate change presents a long-term, multi-disciplinary challenge, and requires multiple sources of different types of information and data to understand the impact of City of Edmonton's decisions.

EDMONTON DECLARATION COMMITMENT

Over 3,400 municipalities across North America, including the City of Edmonton, have endorsed the Edmonton Declaration under the Global Covenant of Mayors for Climate and Energy, which includes a commitment to:

"COMMIT TO AND CALL UPON all national, other subnational and local governments to establish formal, science-based policy and decision-making processes within their organizations"

— Edmonton Declaration, 2018

Purpose of the Report

This report provides a scientific foundation to help the City of Edmonton, interested parties, and the public understand how Edmonton's climate is changing and why it matters. The report translates complex climate science into meaningful, locally relevant insights, offering a clear, evidence-based understanding of observed changes and the emerging challenges the city must prepare for to ensure future resilience.

Developed by the City of Edmonton's Environment and Climate Resilience Section, this assessment synthesizes a wide range of climate data and scientific studies to tell the story of Edmonton's changing climate. While the report draws on advanced scientific sources, historical climate observations, and publicly available assessments, it presents findings in a way that is accessible and relevant to Edmonton's unique environmental and community context.

Edmonton is already experiencing measurable climate shifts consistent with global trends: rising temperatures, altered precipitation patterns, and more frequent extreme weather events. These changes are reshaping City operations, infrastructure, ecosystems, and public health risks.

Given Edmonton's unique geography, economy, and urban development patterns, a localized scientific approach ensures that climate risks and opportunities are assessed meaningfully. While national and global reports provide valuable context, Edmonton-specific climate science enables precision in designing resilient infrastructure, safeguarding services, and preparing the community for future conditions.

The scientific consensus, as reflected in the IPCC Sixth Assessment Report (IPCC, 2021), confirms that climate change is primarily driven by human activities. Global agreements such as the Paris Agreement aim to limit warming to well below 2°C—and preferably 1.5°C—to reduce the risks of irreversible climate impacts (UNFCCC, 2015). Importantly, Edmonton's climate is warming faster than the global average, amplifying the urgency for informed, locally grounded action.

The need for rapid emissions reductions and resilience planning is critical, as every fraction of a degree of additional warming increases risks across multiple systems. Further detail on climate science, key definitions, and global agreements is provided in Appendix: Foundations Behind Understanding Edmonton's Changing Climate.

Climate Equity, Inclusion, and Gender-Based Analysis Plus (GBA+)

Climate change does not affect all communities and individuals equally. Vulnerability to climate impacts varies significantly based on intersecting social, economic, cultural, and demographic factors, including gender, income, age, Indigeneity, newcomer status, disability, and housing security.

Applying a Gender-Based Analysis Plus (GBA+) lens recognizes that multiple identity factors influence how individuals experience environmental risks, access resources, and recover from climate-related disruptions. For example, vulnerable populations may be disproportionately affected by extreme heat, poor air quality, or infrastructure service interruptions, and may face greater systemic barriers to resilience and recovery.

This assessment acknowledges the critical role of equity in shaping climate impacts and responses. While the current report is primarily scientific in scope, it provides a foundation for future work that will further integrate social vulnerability assessments, Indigenous knowledge, and equitable adaptation planning to ensure that climate resilience-building efforts are inclusive, just, and reflect the needs of all Edmontonians. This initial scientific report, while foundational, may not fully capture the diverse range of climate impacts and perspectives across all Edmonton communities due to varying social, economic, and demographic factors.

ACKNOWLEDGING INDIGENOUS KNOWLEDGE SYSTEMS

Indigenous people have long-standing relationships with the land, waters, and ecosystems that are grounded in distinct knowledge systems. Traditional Ecological Knowledge (TEK) connects Indigenous ways of knowing with ecological processes, supporting environmental stewardship and sustainable land use practices that have persisted for generations. TEK offers unique insights into ecosystem connectivity, resilience, and change — perspectives that are often overlooked or underrepresented in Western scientific traditions.

Under the directives of The City Plan and the City's Indigenous Framework, the City of Edmonton is committed to integrating Indigenous values and knowledge into environmental management and stewardship. Respecting and incorporating Indigenous knowledge is critical to achieving a more holistic understanding of climate impacts and solutions.

This report recognizes that Indigenous knowledge and Western science offer complementary perspectives. While this current assessment is based primarily on Western scientific methods, it acknowledges that integrating Indigenous knowledge alongside scientific approaches will strengthen future work, leading to more effective, culturally appropriate, and sustainable responses to climate change in the Edmonton region.

City of Edmonton's Leadership in Climate Action

The City of Edmonton has emerged as a leader in climate action within Canada. Through initiatives such as the Community Energy Transition Strategy and the Climate Resilient Edmonton: Adaptation Strategy, Edmonton has committed to ambitious mitigation and adaptation goals—including community-wide net zero greenhouse-gas emissions by 2050 and a corporate emissions neutral target by 2040.

Edmonton's climate actions support strengthening resilience while supporting sustainable growth and community well-being. This report focuses on the scientific foundation of Edmonton's climate change and does not provide details on the specific actions taken under the City's climate strategies.

Importance of this Assessment

The Edmonton region faces a range of climate risks and shifts in seasonal patterns, including rising temperatures, more frequent and intense heat waves, milder winters, shifting seasonal precipitation, extreme rainfall events, wildland fires and smoke, and damaging hailstorms. Without action, these impacts are likely to intensify, placing growing pressure on Edmonton's infrastructure, natural systems, and the essential services that support residents' well-being (City of Edmonton, 2018). By identifying and understanding these risks now, the City of Edmonton can proactively plan and implement measures that support a safer, more climate-resilient future for the Edmonton region.

A localized, science-based assessment is essential because it translates global climate knowledge into actionable insights that can inform the City of Edmonton's planning and decision-making. While global and national assessments provide important context, they cannot capture the unique geographic, ecological, and urban characteristics that shape Edmonton's specific climate risks. Edmonton's warming trend surpasses the global average, emphasizing the local impacts of climate change. The city's physical setting — including land use, vegetation cover, and urban form — also influences how global changes manifest locally.

Localized climate science enables the City to assess how climate change will affect municipal operations, critical infrastructure, and community services. This level of detail is necessary to guide everything from stormwater design standards and heat mitigation strategies to emergency management and long-term planning. The more precise the information, the better the City can prepare and allocate resources where they are most needed.

City of Edmonton Climate Ambitions

CONNECTEDMONTON	EDMONTON CITY PLAN	EDMONTON'S COMMUITY ENERGY TRANSITION STRATEGY	CLIMATE RESILIENT EDMONTON
Climate Resilience Goal: Edmonton is a city transitioning to a low-carbon future, has clean air and water and is adapting to a changing climate.	Includes targets to achieve a total community wide carbon budget of 135 megatonnes and Net per-person greenhouse gas emissions are zero.	Outlines the path for Edmonton to transition to a low carbon city.	Adaptation Strategy and Action Plan outlines the path for Edmonton to be prepared for and respond to anticipated climate change impacts.
Sets the direction for Edmonton's future	Sets the strategic direction for the way Edmonton grows, its land use, its mobility systems, open spaces, employment and social networks.	Provides the path for how we achieve the transformational change to a low carbon city that is adapting to a changing climate as outlined in ConnectEdmonton and City Plan.	

Structure of the Report

TEMPERATURE IN EDMONTON

This section presents detailed analyses of historical temperature records, including annual and seasonal trends. It explores changes in temperature, including seasonal shifts, increases in extreme heat events, and declines in extreme cold. The section also explores the Urban Heat Island (UHI) effect, which contributes to elevated temperatures in densely built-up areas. To contextualize year-to-year variability, large-scale atmospheric patterns—such as El Niño and the Pacific Decadal Oscillation (PDO)—are also discussed.

AIR QUALITY IN EDMONTON

This section evaluates the trends and seasonal patterns in three key air quality parameters—nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter ($PM_{2.5}$)—and their implications for the Air Quality Health Index (AQHI) in Edmonton. It explores how air quality is influenced by climate-driven events such as wildfire smoke, along with urban factors like temperature inversions and traffic emissions. The section also highlights associated public health risks.

PRECIPITATION IN EDMONTON

This section evaluates long-term and seasonal changes in precipitation across Edmonton, including shifts in annual and seasonal totals, as well as the frequency of extreme wet and dry events.

APPENDIX: FOUNDATIONS BEHIND UNDERSTANDING EDMONTON'S CHANGING CLIMATE

The appendix provides the purpose, scope, and methods of this assessment, detailing the scientific frameworks, definitions, and data sources that underpin the findings presented throughout the report.

To support reader ease, where appropriate, sections and subsections begin with a summary in bold, dark blue font highlighting key insights. The report also includes Climate Brief: Key Insights to Know pages, which provide simplified, accessible overviews of the main content for a general audience.

Evolution and Future Updates

This assessment marks an important milestone and represents the first in a series of complimentary reports aimed at deepening understanding of historical climate trends, observed impacts, progress, and potential future conditions in Edmonton. This report is the first iteration and is intended to serve as a foundation for ongoing updates, refinements, and expansions as new scientific information, local data, and modeling capabilities emerge.

The City of Edmonton recognizes that climate science is dynamic, and that continuous learning and improving is needed and must be based on the best available science, research, and evidence

This cycle of continuous learning and improvement ensures that the City of Edmonton's climate science foundation remains relevant, evidence-based, and responsive to new challenges and opportunities. Embedding this assessment within a broader cycle of monitoring, research, and policy evaluation will strengthen the City's ability to proactively manage climate risks and support long-term community resilience. The City of Edmonton is committed to ongoing improvement to ensure our knowledge remains at the forefront, empowering Edmontonians to boldly face challenges and seize opportunities, strengthening our resilience and securing a vibrant future for all.

Climate Brief: Key Insights to Know

How Edmonton's Climate is Already Changing

Edmonton's climate has changed in clear and measurable ways. Temperatures have increased, snowfall patterns have changed, and certain weather events are happening more often. The climate today is not the same one that earlier generations in the city experienced. This Climate Brief summarizes key findings of this full assessment, which draws on local weather records and scientific data to show how Edmonton's climate has already changed. It highlights real, observed changes that are already affecting daily life in the city, including transportation, infrastructure performance, and health and safety during extreme weather.

EDMONTON IS WARMER THAN BEFORE

» **Edmonton's climate has become warmer over time.** Over the past 140 years, the city's average temperature has risen by 2.3°C [Fig. 2.1; 2.2], which is more than twice the global average increase over the same period.

» **From 2001 to 2024, only two years—2009 and 2019—were cooler than the 1961–1990 baseline.** This means that 92 per cent of recent years were warmer than the baseline [Fig. 2.3].

» **Warming has occurred in all seasons, but winter temperatures have increased the most.** Spring, summer, and fall have also become noticeably warmer [Fig. 2.4].

» **There are now more 'very hot days' in summer,** with temperatures reaching 32°C or higher, occurring more often than in the past [Fig. 2.13]. These conditions can be dangerous, especially for young children, older adults, marginalized individuals and people with certain health conditions.

» **Air conditioning demand has also increased sharply,** with cooling needs now far higher than in previous decades [Fig. 2.6].

» **Extreme heat events have become longer and more intense,** with years like 2021 and 2024 seeing record-breaking heatwaves [Fig. 2.9].

» **Winters are no longer as cold as they once were.** Although extremely cold days still occur, they are becoming less frequent, and long stretches of deep cold are now rare due to the overall warming trend [Fig. 2.14].

» **In 2023, Edmonton recorded its warmest year ever,** with annual temperatures reaching 2.8°C above the long-term average.

» **Built-up urban areas tend to stay warmer at night** due to the urban heat island effect—a phenomenon in which buildings, pavement, and other infrastructure absorb and retain heat, causing cities to be warmer than surrounding rural areas. This increases heatwave risk in some neighbourhoods [Fig. 2.17].

Climate Brief: Key Insights to Know

SMOKE AND AIR POLLUTION

- **Although Edmonton's overall air quality has remained fairly stable since 2010, wildfires and winter temperature inversions can cause poor air quality days to occur.**
- **In recent years, wildfire smoke has become a major cause of summer air pollution.**
- **In 2023, Edmonton recorded 34 high-risk air quality days,** the most on record, with 24 of those days linked to wildfire smoke [Fig. 3.4].
- **In winter, cold air can trap pollution** (especially from traffic and home heating) near the ground. These events, known as temperature inversions, lead to a buildup of harmful pollutants such as nitrogen dioxide (NO_2) and fine particulate matter (PM2.5), increasing their concentration in air.
- **Hot weather can also worsen air pollution** by increasing levels of ground-level ozone, which affects lung and heart health.
- **The number of smoke days and heat-related pollution spikes has grown in recent years.**
- **While poor air quality affects everyone,** it is especially harmful to children, seniors, people with respiratory conditions such as asthma and marginalized individuals.

PRECIPITATION IS BECOMING LESS RELIABLE

- **Over the past three decades, Edmonton has received less precipitation overall** compared to the past [Fig. 4.1].
- **Annual precipitation has declined by about 14 per cent,** with winter showing the largest drop (31 per cent, mostly due to reduced snowfall.
- **Summer and fall have also become noticeably drier** [Fig. 4.3], with growing implications for water availability during key growing periods.
- **Although heavy rain and snow events still happen, dry years are now more common than wet ones.**
- **Seven of Edmonton's 12 driest years on record have occurred since 2000,** and the city has seen more long stretches without rain, especially in spring and summer.
- **Shifting precipitation patterns add pressure on water resources.**

2.0 Temperature in Edmonton

Building a brighter future for Edmonton begins with understanding how the climate is changing. Examining long-term climate trends creates an opportunity, not just to reflect on what has shifted, but to act with foresight and purpose. This understanding supports the development of strategies that strengthen resilience, protect public health and infrastructure, and create a more sustainable, livable city. By learning from the past, it becomes possible to shape a future where Edmonton can adapt and thrive in the face of environmental change.

This section provides critical context for interpreting future climate projections, by establishing a data-driven baseline of how Edmonton's climate has already changed, supporting a more informed and confident approach to adaptation. The findings serve not only as a record of past change, but also as a foundation for forward-looking decisions that enhance resilience, protect quality of life, and strengthen environmental stability across sectors.

To support this analysis, it is essential to clarify a few key terms used in this assessment. For the purposes of this report, climate is understood as the long-term statistical description of weather patterns, including the mean, variability, and extremes of key atmospheric variables such as temperature and precipitation—typically observed over a 30-year averaging period. This definition follows the standards set by Environment and Climate Change Canada (ECCC), who describe climate as "the historical record and description of average daily and seasonal weather events that help describe a region," with statistics "generally drawn over several decades" (ECCC, 2024a). It also incorporates the Intergovernmental Panel on Climate Change (IPCC)'s more technical framing of climate as "the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years" (IPCC, 2018).

In contrast, the term weather in this report refers to the atmospheric conditions at a specific time and place, including variables like temperature and precipitation. It is understood that weather changes over short timescales, such as hours or days, and is inherently more variable and immediate. As defined by ECCC, weather is "the state of the atmosphere at a specific time. It is the short term or instantaneous variations of the atmosphere, as opposed to the long term, or climatic changes" (ECCC, 2024a).

2.1 Global and National Temperature Trends

Global temperatures have risen by 1.09°C since pre-industrial times, with 2024 being the warmest year on record at 1.55°C above pre-industrial level. Canada is warming at more than twice the global rate, with a 2.1°C increase since 1948 and record highs in 2023 and 2024. This trend, driven by human-caused emissions, is intensifying heat waves, wildfires, health risks, and infrastructure damage.

The IPCC states, "global surface temperature has increased by 1.09 [0.95 to 1.20]°C from 1850–1900 to 2011–2020" (IPCC, 2021). The global average surface temperature has continuously warmed since 1880[1] (IPCC, 2013), especially at an unprecedented rapid rate since the mid-20th century mainly due to human activities superimposed on natural variability (Wuebbles et al., 2017; Eum et al., 2023).

According to the World Meteorological Organization (WMO), 2024 was the warmest year on record, with global average surface temperature reaching 1.55°C (with a margin of uncertainty of ± 0.13 °C) above the mid-19th century average (1850–1900) (WMO, 2025). Both 2023 and 2024 were record-breaking warm years, reaching 1.43 °C and 1.55 °C above the pre-industrial period respectively. These unprecedented temperatures were driven by multiple factors, including unusually warm ocean waters and a strong El Niño event, compounded by the ongoing long-term trend of human-induced global warming (ClimateData.ca, 2025b).

2024 was the warmest year on record globally.

Canada's climate is also experiencing notable warming. According to preliminary data from ECCC, the national average temperature for 2024 was 3.0°C above the 1961–1990 baseline (defined as the mean over the 1961–1990 reference period). "This makes it tied as the warmest

1 The year 1880 is significant as it marks the advent of modern global temperature record-keeping (NASA, 2024).

year since nationwide recording began in 1948, matching the previous record of 3.0°C set in 2010" (ECCC, 2025b). In Canada, annual average temperatures across the country have fluctuated over the 1948–2024 period. Apart from 1996 and 2004, temperature departures above the baseline average have been observed in the previous three decades. The linear trend indicates that annual average temperatures across the nation have warmed up by 2.1°C over the past 77 years, highlighting the ongoing impact of climate change across the country (ECCC, 2025b). The national average temperature for 2023 was 2.8°C higher than the 1961–1990 reference period, reflecting a persistent warming trend (ECCC, 2024c). The record high temperatures in 2023 and 2024 were accompanied by heat waves across Canada attributed to climate change (ClimateData.ca, 2025b).

Temperature serves as a key indicator of climate change, primarily driven by greenhouse gas (GHG) emissions from human activities, leading to warming in the lower atmosphere. The primary sources of global GHG emissions include fossil fuel combustion for energy and transportation, industrial activities, deforestation, and agricultural practices. The primary anthropogenic GHGs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (IPCC, 2021). Carbon dioxide is predominantly emitted through the burning of fossil fuels and land-use changes, such as deforestation. Methane emissions largely originate from livestock production, landfill decomposition, and natural gas extraction, while nitrous oxide emissions are mainly associated with the use of synthetic fertilizers in agriculture. These gases contribute to warming by enhancing the greenhouse effect, trapping heat in the lower atmosphere and driving significant changes in the global climate system (IPCC, 2021).

Rising temperatures have widespread implications on Canadians, affecting agriculture, infrastructure, human health, water availability, and ecosystem stability (ECCC, 2024c).

The increasing frequency and intensity of heat waves pose significant health risks, particularly for vulnerable populations, while also driving up residential and building cooling costs and heightening the risk of food and waterborne illnesses. Additionally, warmer temperatures facilitate the spread of forest and agricultural pests into new regions, as well as disease vectors like ticks. Hotter and drier conditions further elevate the risks of droughts and wildfires. In Canada's North, the consequences of higher temperatures are particularly severe, with challenges including infrastructure damage from permafrost thaw, unpredictable sea ice conditions, and shorter winter road seasons. As temperature changes continue, most sectors of the Canadian economy will face growing adaptation challenges to mitigate these impacts (ECCC, 2024c).

2.2 Long-Term Warming Trends in Edmonton (1885–2024)

Edmonton has warmed by 2.3°C since pre-1900—over double the global average—with the greatest increases seen in winter (4.1°C) and nighttime summer temperatures. Since 2000, 92 per cent of years have been warmer than the historical baseline (1961–1990). 2023 was the warmest year on record for Edmonton. Extreme heat events, tropical nights, and cooling demand have all intensified, with 2021 and 2024 recording the longest and hottest heat waves. Extreme cold events have declined in both frequency and intensity, consistent with national warming trends, though isolated cold snaps still occur due to atmospheric variability and circulation patterns. These events do not reflect a reversal of Edmonton's long-term warming. Although atmospheric patterns like El Niño and the PDO contribute to short-term variability, Edmonton's persistent long-term warming trend appears to be primarily driven by human activity.

2.2.1 ANNUAL TEMPERATURE CHANGE

Understanding Edmonton's long-term warming trends requires examining temperature data through different analyses. By using different visualizations, this section shows how the city's climate has changed over time. Figures 2.1, 2.2 and 2.3 highlight the persistence, magnitude, and variability of temperature trends, offering a richer context for interpreting the data.

Figure 2.1 illustrates the trend in Edmonton's annual average temperatures from 1885–2024 using a 'warming stripes' visualization. Each stripe represents one year, with cooler colors (blues) indicating years with temperatures below the 1961–1990 average of 3.6°C, and warmer colors (reds) indicating years above this baseline. The progression from blue to red stripes highlights the steady increase in Edmonton's annual average temperatures, particularly over recent decades.

Long-term temperature records for Edmonton reveal an upward trend in mean annual temperatures, aligning with broader global climate patterns. Historical data (Figure 2.2) indicate that Edmonton's average temperatures have risen over the past century. Although year-to-year variability is observed globally, driven by natural factors such as volcanic activity and solar fluctuations, the overall trendline points to a general warming (Bush and Lemmen, 2019). This pattern aligns with scientific understanding, which attributes global climate change largely to human activities, including greenhouse gas emissions from fossil fuels and deforestation (IPCC, 2021). The observed increase in Edmonton's temperatures suggests a shift in baseline conditions (the historical average climate values), likely influenced by these anthropogenic factors.

Edmonton's Annual Average Temperature (1885–2024)

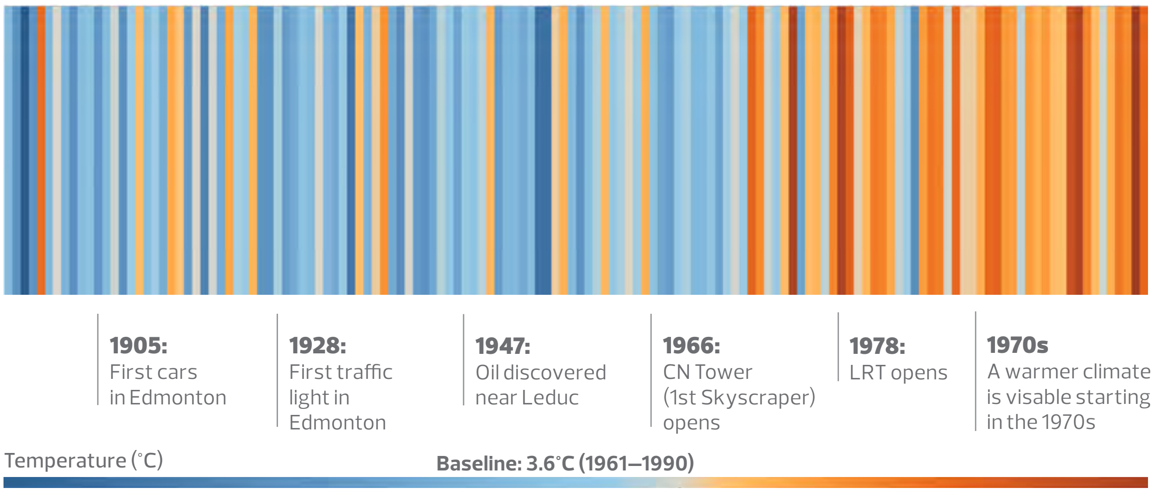


Figure 2.1: Edmonton's annual average temperature (Warming Stripes), 1885 to 2024.

Edmonton's 140-Year Annual Average Temperature: 1885–2024

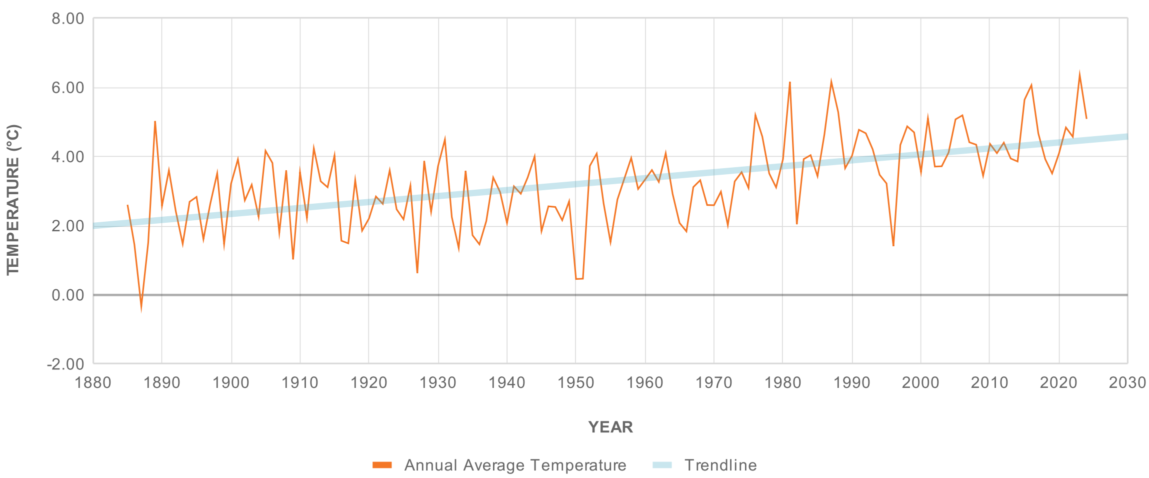


Figure 2.2: Annual average temperature trend in Edmonton, 1885–2024.

From 1885 to 2024, Edmonton's annual average temperature has increased at a rate of approximately 0.17°C per decade. This observed local trend aligns with broader global climate patterns that demonstrate a long-term warming trend, including periods of accelerated warming in recent decades.

According to the IPCC's Sixth Assessment Report (AR6), global mean surface temperature has increased by 0.99°C from pre-1900 to the first two decades of the 21st century (2001–2020) and by 1.09°C from pre-1900 to 2011–2020 (Arias et al., 2021).

Edmonton's mean temperature has risen by 2.3°C from pre-1900 to the recent 15 years. This indicates that Edmonton's warming trend surpasses the global average, emphasizing the local impacts of climate change.

The accelerated rate of warming observed in Edmonton is consistent with broader patterns across high northern latitudes. One key driver is the presence of climate feedback mechanisms, such as the loss of snow and ice cover, which reduces the Earth's albedo (surface reflectivity). As more solar radiation is absorbed by darker, exposed surfaces, rather than reflected away, this reinforces additional warming—a feedback loop well-known in Arctic and sub-Arctic environments (Bush and Lemmen, 2019).

In addition, Edmonton's inland continental position, far from the moderating influence of oceans, contributes to pronounced temperature extremes and seasonal variability (Oliver, 2005). Without the thermal buffering effect of oceans, inland areas tend to experience hotter summers and colder winters, which further amplifies the local impacts of climate change. These geographic and climatic features help explain why Canada, including Edmonton, is experiencing more rapid warming than the global average (Bush and Lemmen, 2019).

A comparison of Edmonton's yearly average temperatures to the historical baseline period (1961–1990) reveals how the city's temperature has shifted over time (Figure 2.3). During this period (1961–1990), the mean temperature was 3.6°C and this period is widely used as a standard reference in climate studies, as it provides a consistent benchmark for assessing long-term temperature changes. This baseline is recognized by international organizations like the World Meteorological Organization (WMO, 2024) and commonly utilized in national assessments, such as the ECCC's (ECCC, 2024c) reports, to compare annual temperature departures from historical norms.

Annual Average Temperature Departures in Edmonton

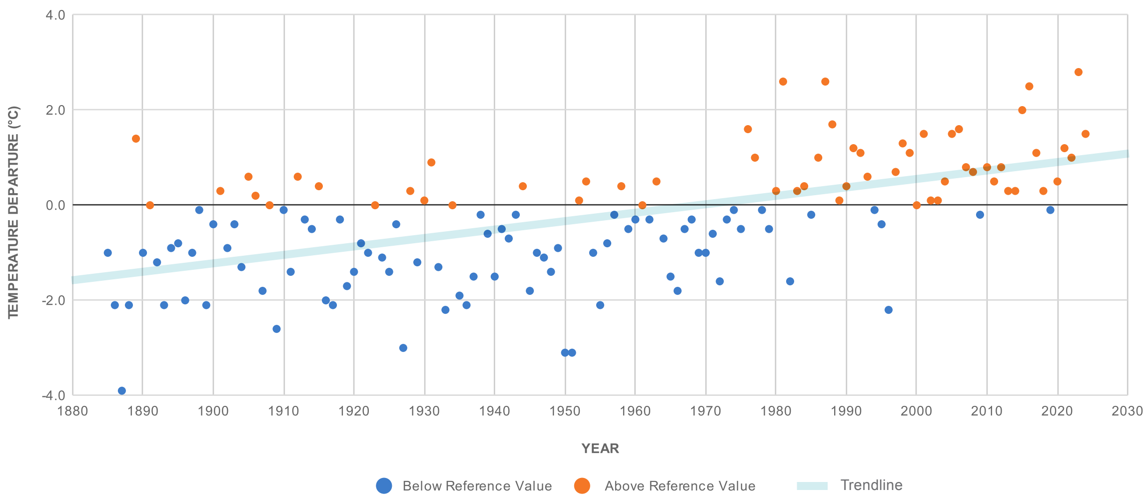


Figure 2.3: Annual average temperature departures from the 1961–1990 baseline in Edmonton, 1885–2024

Figure 2.3 shows the annual average temperature departures from the 1961–1990 baseline. Red dots represent years warmer than the baseline, while blue dots indicate cooler years. These temperature departures are calculated by subtracting the baseline mean temperature (3.6°C) from each year's annual average temperature, showing how each year deviates from the historical norm.

In recent decades, the majority of years have exceeded this baseline, indicating a warming trend. From 2001 to 2024, only two years (2009 and 2019) recorded annual temperatures slightly below the baseline. The remaining 22 years (92 per cent) were warmer, showing a clear departure from historical norms. The linear trendline (Figure 2.3) also highlights a gradual and persistent increase in temperatures over time.

From 2001 to 2024, 92 per cent of years were warmer than the historical baseline—showing a clear departure from historical norms.

2023 was the warmest year on record for Edmonton

In 2023, Edmonton recorded its warmest year on record, with the annual average temperature reaching 2.8°C above the baseline. This is in line with national trends, as Canada also experienced significant warming in 2023, which was one of the warmest years since 1948, registering 2.8°C above the 1961–1990 reference period (ECCC, 2024c).

KEY OBSERVATIONS

Warming Over the Years: Over the last 140 years, Edmonton's mean temperature has risen by 2.3°C from pre-1900 to the recent 15 years. This rate of warming is more than double the global average of approximately 1.1°C over the same timeframe (IPCC, 2021), indicating that Edmonton is experiencing a faster-than-global warming trend.

Comparison with Canada: This warming pattern in Edmonton is consistent with regional and national observations. Canada as a whole has experienced a 2.1°C increase in temperature from 1948 to 2024 (ECCC, 2025b), reflecting the broader impact of rising greenhouse gas concentrations on the country's climate. Notably, "Canada is warming faster than the world as a whole — at more than twice the global rate— and the Canadian Arctic is warming even faster — at about three times the global rate" (Bush and Lemmen, 2019).

Temperature Departures: Analysis of Edmonton's annual temperature departures relative to the 1961–1990 baseline reveals that between 2001 and 2024, only two years were colder than the baseline average, while the remaining years experienced above-average temperatures (Figure 2.3).

Notable Warm Years: Three of the five warmest years recorded in Edmonton have occurred within the past decade (2023, 2016 and 2015). Six out of the 10 warmest years recorded in Edmonton have occurred in 2001–2024 (Figure 2.3).

Edmonton has experienced warming trends over recent decades, consistent with patterns observed across Canada and other regions influenced by similar atmospheric and geographic factors. Global warming is driven by increased concentrations of greenhouse gases from human activities, including fossil fuel combustion and land use changes. These changes have contributed to a warmer and less predictable climate in Edmonton, affecting seasonal temperature patterns and highlighting the importance of monitoring and adaptation to build resilience (Bush and Lemmen, 2019; ECCC, 2024c).

2.2.2 SEASONAL TEMPERATURE CHANGE

From 1885 to 2024, Edmonton has experienced warming across all four seasons (Figure 2.4), indicating the impacts of broader climate change on regional temperatures (Climate Central, 2024). The seasons follow ECCC delineations and are defined as winter (December of the previous year, January and February), spring (March, April and May), summer (June, July and August), and fall (September, October and November) (ECCC, 2024c).

Seasonal temperature departures for Edmonton from the 1961–1990 baseline over the long term are illustrated in Figure 2.4. Positive departures indicate warmer-than-average seasons, while negative departures indicate cooler-than-average seasons.

Seasonal Average Temperature Departures in Edmonton

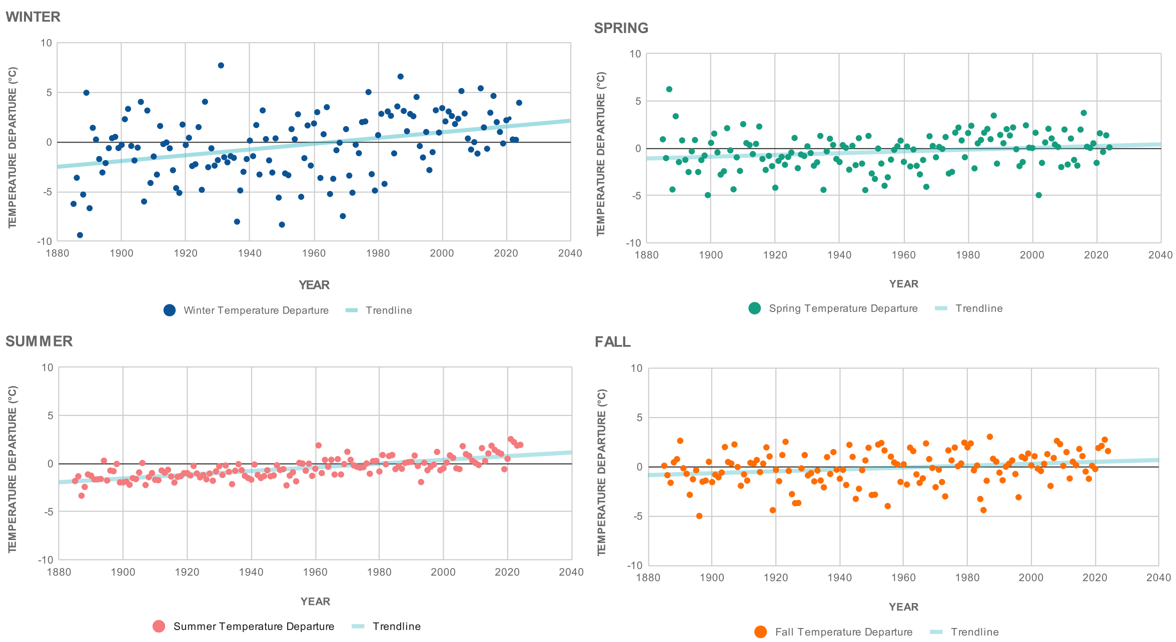


Figure 2.4: Seasonal average temperature departures from the 1961–1990 baseline in Edmonton, 1885–2024.

An analysis of seasonal temperature data indicates warming trends, with the magnitude of increase varying by season.

In Edmonton, winter has the most pronounced warming, with an average increase of 4.1°C over the past 140 years, equivalent to an increase of approximately 0.3°C per decade (Figure 2.4)

This increase in winter temperatures suggests that Edmonton's winters are becoming milder, with some of the warmest winters on record occurring in recent years.

The average spring temperature in Edmonton rose by 1.3°C over the same period, at an average rate of 0.1°C per decade (Figure 2.4). While this warming trend is less pronounced than winter's, the steady increase suggests a shift toward earlier and potentially warmer springs.

Summer temperatures in Edmonton have increased by approximately 2.7°C since 1885, at a rate of 0.2°C per decade (Figure 2.4). This long-term warming trend not only implies hotter average summers but also increases the likelihood and severity of extreme heat events, such as heat waves. The rise in both mean summer temperatures and the frequency of extreme heat days illustrates the broader shift in Edmonton's climate towards warmer and more intense summer conditions.

Similar to spring, fall has warmed by a total of 1.3°C, with an average increase of 0.1°C per decade (Figure 2.4). This seasonal shift suggests a delay in the onset of colder temperatures.

Summer 2021 was the warmest summer on record in Edmonton

Summer 2021, marked the warmest summer on record, followed by 2022 and 2024, with the seasonal average temperatures 2.0°C to 2.5°C above the baseline values. 2023 recorded one of the warmest summers and falls in Edmonton's history, with temperatures well above the baseline. It is also worth noting that eight out of the 10 warmest summers occurred in the recent two decades.

Edmonton's temperature records over the last 140 years reveal year-to-year variation in winter, spring, and fall (Figure 2.4). However, summer is characterized with less temperature fluctuation and a warming trend, largely due to increasingly high nighttime temperatures. Both of these observations can have significant implications for public health and energy use.

Nationwide, Canada has observed warmer and more humid summer nights between 1948 and 2016, with the nighttime temperatures increasing by 1.3°C over the 69 years (ClimateData.ca, 2024a). Furthermore, the IPCC AR6 reports states that despite substantial spatial and seasonal variations, strong evidence indicates a very likely increase in the intensity and frequency of hot extremes for North America (IPCC, 2021).

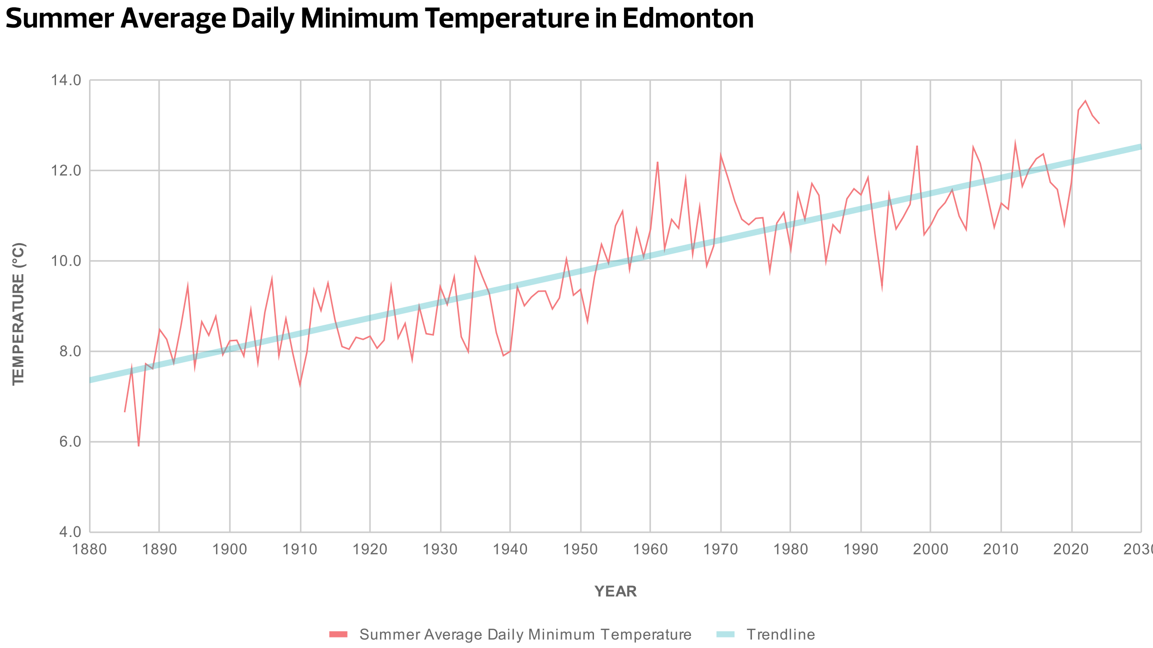


Figure 2.5: Summer average daily minimum temperature in Edmonton, 1885–2024.

The change in average daily minimum temperatures during summer (June, July, and August) shows that summer nighttime temperatures have increased at a rate of 0.35°C per decade, considerably higher than the warming rate of average summer temperatures (0.2°C per decade) (Figure 2.5). Between 1885 and 1952, most years recorded average summer nighttime minimum temperature between 8°C and 10°C. From 1953 to 2024, this range shifted upward to 10°C to 12°C, with the average summer nighttime minimum temperature in the most recent four years (2021–2024) reaching 13°C to 13.5°C. A more detailed discussion on the intensity and frequency of tropical nights is provided in Section 2.2.4.2 of this report.

2.2.3 COOLING DEGREE DAYS

Rising temperatures typically lead to increased energy demanding methods of air conditioning (UNICEF, 2024). Cooling Degree Days (CDD) measure the amount of air conditioning required to maintain comfortable conditions in a building, calculated as the cumulative number of degrees Celsius above a threshold value (18°C is commonly used) (CAC, 2025). Annual CDD is the sum of the number of degrees Celsius by which each day's mean temperature exceeds 18°C in a year.

Annual Cooling Degree Days in Edmonton

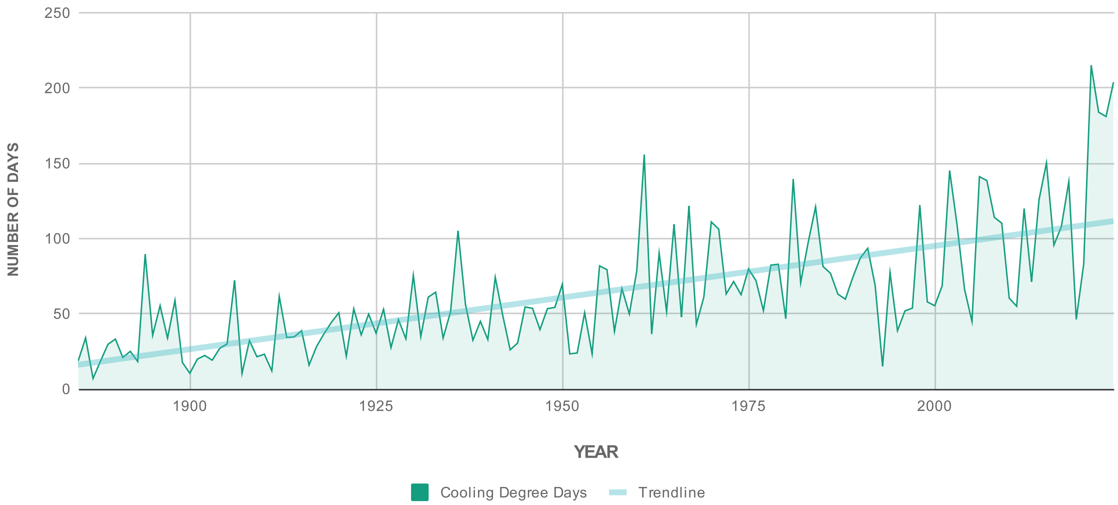


Figure 2.6: Annual Cooling Degree Days in Edmonton, 1885–2024.

Edmonton's Cooling Degree Days (CDD) have risen from 33 annually before 1900 to 122 annually since 2010 (Figure 2.6).

In Edmonton, 2021 and 2024 both exceeded 200 Cooling Degree Days, representing the highest cooling demands on record

Of the 15 years with over 120 CDDs between 1885 and 2024, 10 have occurred in the last 25 years. Similarly, five of the six years with over 150 CDDs also fall within this recent quarter-century, highlighting a strong upward trend.

Further aggregation analysis of annual average CDDs reveals a substantial increase in cooling demand over the years, as shown in Figure 2.7, when Edmonton's annual Cooling Degree Days are examined in 25-year periods.

Annual Average Cooling Degree Days by 25-year Period in Edmonton

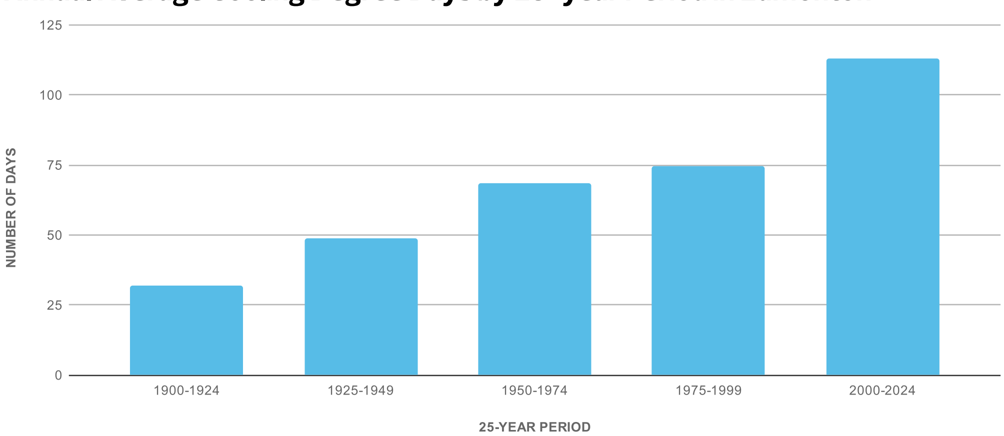


Figure 2.7: Annual average Cooling Degree Days by 25-year periods in Edmonton, 1885–2024.

2.2.4 EXTREME TEMPERATURE EVENTS IN EDMONTON

2.2.4.1 Heat Waves

Extreme heat events, commonly known as "heat waves," affect many regions across Canada (Health Canada, 2024), including Edmonton. A heat wave generally refers to an extended period of unusually high temperatures. In this report, a heat wave is defined as two or more consecutive days with maximum daytime temperatures of at least 29°C and minimum nighttime temperatures of 14°C or higher. This aligns with ECCC's heat warning criteria for Edmonton region (ECCC, 2024d; ECCC, 2025c). Accordingly, heat wave days in this report refer to days in the heat wave events meeting the defined temperature thresholds based on observed weather data. However, it is important to note that not all events meeting these temperature thresholds necessarily triggered official heat warnings, as ECCC may also consider additional factors. This section examines key characteristics of heat waves in Edmonton, including their frequency, intensity, and duration.

Annual Number of Heat Wave Days in Edmonton

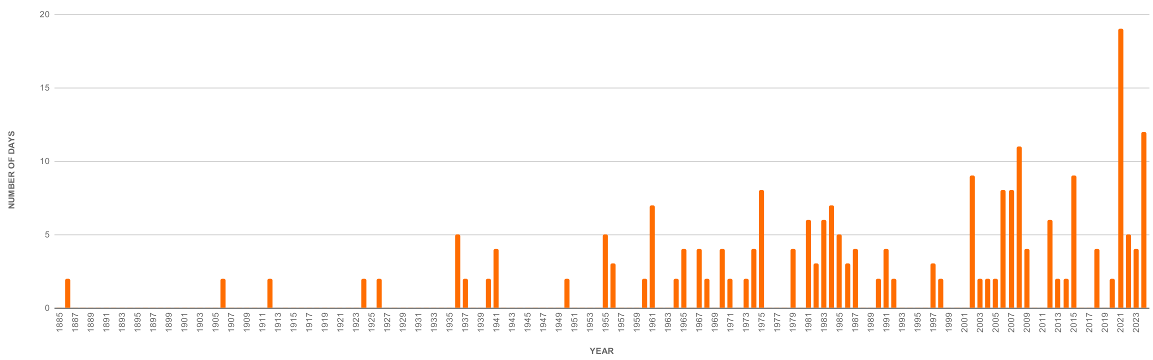


Figure 2.8: Annual number of heat wave days in Edmonton, 1885–2024.

Figure 2.8 illustrates the fluctuating patterns of extreme heat in Edmonton from 1885 to 2024 by analyzing the annual number of heat wave days. Heat wave days fluctuate notably from year to year, with periods of low or no heat wave activity interspersed with years of heightened frequency. For example, certain years such as 2002, 2008, 2015, 2021, and 2024, experienced a higher number of heat wave days (nine or more), while others recorded fewer or none. This reflects the influence of broader climate variability and atmospheric patterns.

In Edmonton, 2021 recorded the highest number of heat wave days (19 days) on record, and 2024 follows 2021 with 12 heat wave days, indicating the frequency of extreme heat events has been increasing in recent years.

The intensity of heat wave events from 1885 to 2024 provides additional insight into the changing characteristics of extreme heat in Edmonton. Examining the maximum temperatures recorded during these events can help better understand how the severity of heat waves has evolved over time.

Recent heat wave periods have also reached record maximum temperatures.

Importantly, five out of the eight years with daily maximum temperatures reaching 34.5°C or higher have occurred within the past 20 years (2006, 2008, 2018, 2021 and 2024).

Heat waves have not only become more frequent and intense but are also lasting longer in recent years. Analysis of the annual maximum length of heat waves from 1885 to 2024, indicates heat wave duration is increasing (Figure 2.9).

Annual Maximum Duration of Heat Waves in Edmonton

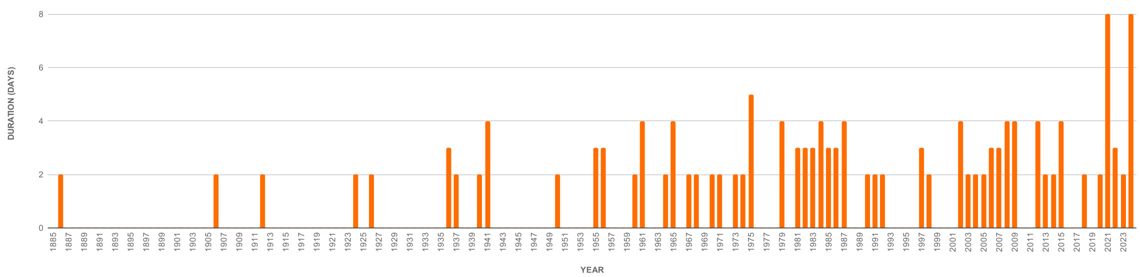


Figure 2.9: Annual maximum duration of heat waves (in days) in Edmonton, 1885–2024

Both 2021 and 2024 recorded the longest heat waves on record in Edmonton, each lasting eight consecutive days (Figure 2.9). While these events may reflect short-term variability or anomalous years, they align with broader warming trends and increasing heat wave frequency and intensity in recent decades. When considered in this context, such extended events may indicate an emerging trend toward longer and more severe heat waves. Continued monitoring is essential to determine whether these are isolated occurrences or part of a longer-term shift. Notably, of the 14 years that recorded heat waves lasting four days or more, half occurred in the 21st century. The persistence of these conditions appears to be consistent with observed warming patterns, which may contribute to an increased potential for extended heat events in the future.

Canada's rapid warming (Box 2.1) places Edmonton in a region experiencing heightened climate impacts, contributing to the increased frequency, intensity, and duration of extreme heat events. To further investigate this, heat wave events were summarized and compared across 25-year periods, beginning in 1900. The only recorded heat wave event before 1900 occurred in 1886.

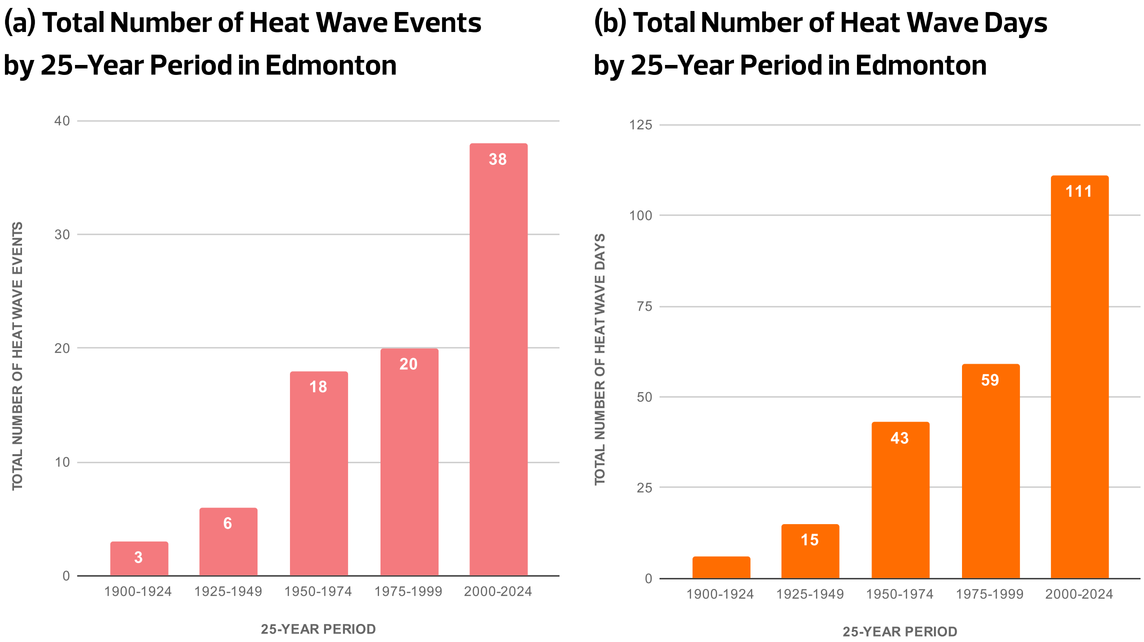


Figure 2.10: (a) Total number of heat wave events and (b) total number of heat wave days by 25-year period in Edmonton, 1900–2024.

The total number of heat wave events (Figure 2.10a) represent heat wave frequency, while the cumulative number of days within those heat waves (Figure 2.10b) reflects both frequency and duration. Between 2000 and 2024, a total of 38 heat waves including 111 days were observed, which equals to the total counts of heat events but exceeds the total number of heat wave days from the previous half century (1950–1999).

The heat wave in June 2021 recorded a peak temperature of 37°C, marking the second-highest temperature in Edmonton's history, following June 1937 when a daily high temperature of 37.2°C was observed.

Furthermore, the average heat wave duration has increased from two days in the early years to 2.9 days (111 heat wave days in 38 events) in the most recent quarter-century. This period also experienced the longest heat waves on record, reaching eight days in both 2021 and 2024.

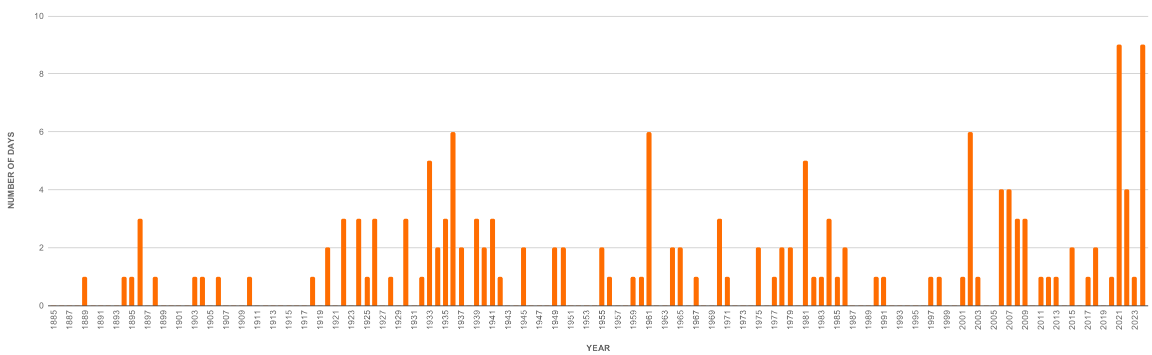
Climate change can increase the frequency and severity of extreme heat events, not only making heat waves more common but also altering the atmospheric patterns that drive them. For instance, heat waves may last longer in one location when high-pressure systems move more slowly, maintaining elevated temperatures over a region for an extended period (IPCC, 2021). Additionally, the occurrence of 'heat domes', where high-pressure systems trap heat over a region, has become more frequent and intense under warming conditions (Chen et al., 2023). These phenomena are pertinent to Alberta's recent heat wave trends (CER, 2021), where extended high-temperature events, such as the eight-day heat waves in 2021 in Edmonton, may reflect broader patterns of climate-driven extreme heat.

2.2.4.2 Extremely Hot Days and Tropical Nights

Extremely high temperatures pose significant risks to both human life and ecosystems, potentially resulting in severe consequences such as heat stroke, dehydration, and respiratory problems (WHO, 2024a). To assess the frequency of extreme heat over the past 140 years, this section analyzes two key climate indicators: the number of days with maximum temperatures at or above 32°C and 34°C (CAC, 2025).

Unlike heat wave events, which have thresholds for daily high and low temperatures and last two days or longer, extremely hot days are defined based on the maximum temperature on a single day. In addition, the occurrence of tropical nights, defined in this report as days when minimum nighttime temperatures remain at or above 18°C or 20°C, is analyzed as an important indicator of persistent heat. Hot days become particularly hazardous when nighttime temperatures fail to provide relief (ClimateData.ca, 2024b).

(a) Annual Number of Extremely Hot Days at 32°C or Higher in Edmonton



(b) Annual Number of Extremely Hot Days at 34°C or Higher in Edmonton

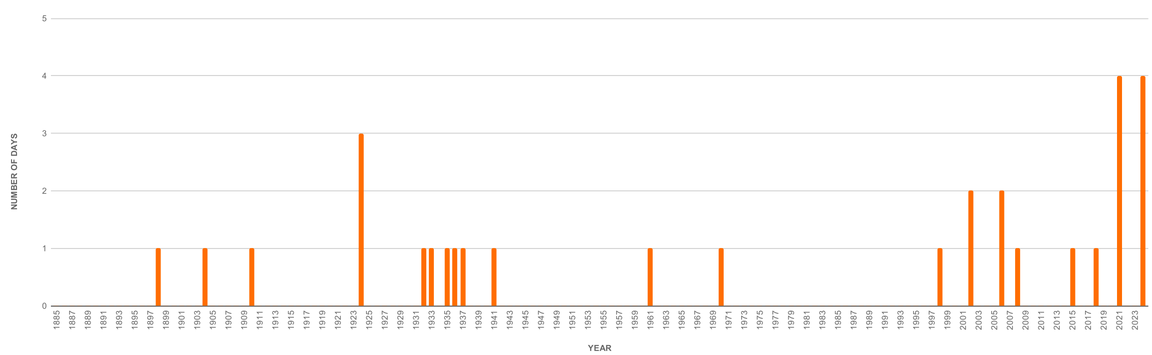
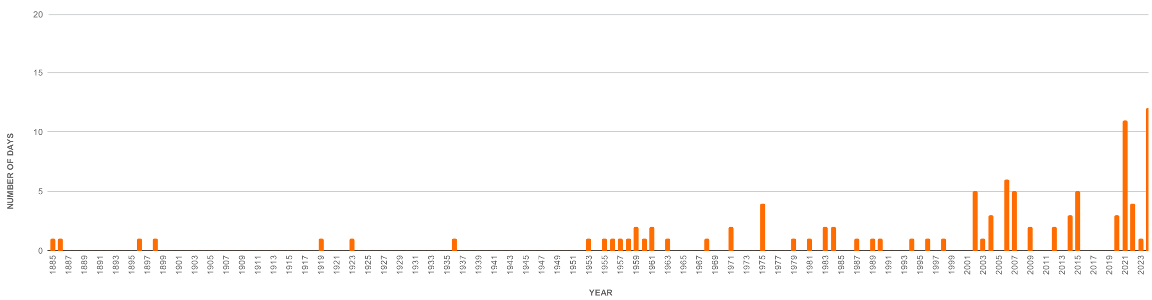


Figure 2.11: Annual number of extremely hot days based on temperature thresholds of (a) 32°C or higher and (b) 34°C or higher, in Edmonton, 1885–2024.

The annual number of extremely hot days in Edmonton from 1885 to 2024, is shown in Figure 2.11. These days are defined as those reaching daily high temperatures of 32°C or higher (Figure 2.11a) and 34°C or higher (Figure 2.11b).

Among the five years that recorded six or more such days with temperatures reaching or exceeding 32°C (1936, 1961, 2002, 2021, and 2024), three occurred in the most recent quarter-century (i.e. the past 25 years). The years 2021 and 2024 each recorded nine days at or above 32°C, including four days reaching at least 34°C, setting a record for the most extremely hot days observed in Edmonton.

(a) Annual Number of Tropical Nights at 18°C or Higher in Edmonton



(b) Annual Number of Tropical Nights at 20°C or Higher in Edmonton

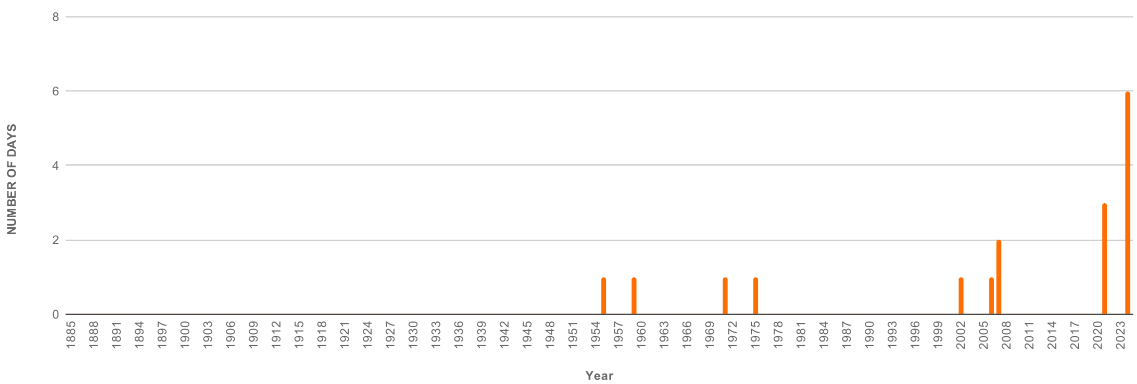


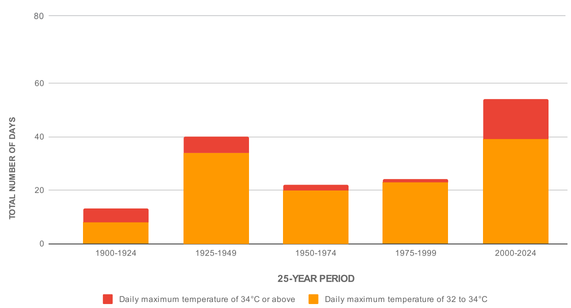
Figure 2.12: Annual number of tropical nights with minimum temperatures of (a) 18°C or higher and (b) 20°C or higher, in Edmonton, 1885–2024.

As shown in Figure 2.12, tropical nights have become more frequent in recent years. Prior to 1900, only four nights with minimum temperatures above 18°C were recorded. In contrast, the past 15 years have seen 41 such nights. Historically, most years experienced no tropical nights. Since 2000, six years have recorded more than five tropical nights individually. Notably, 2021 and 2024 set new records with 11 and 12 tropical nights, respectively, including three and six nights exceeding 20°C. This increase in both frequency and intensity of tropical nights poses a growing health risk to vulnerable and sensitive populations such as elderly adults, individuals with pre-existing health conditions, and those without access to adequate cooling. Prolonged warm nights hinder the body's ability to recover from daytime heat and can significantly increase the risk of heat stress and other heat-related illnesses (ClimateData.ca, 2024b).

To gain further insights into long-term patterns of extreme daytime and nighttime temperatures, historical data on extremely hot days and tropical nights was aggregated into 25-year periods (Figure 2.13).

The total number of extremely hot days (Figure 2.13a) and tropical nights (Figure 2.13b) for each quarter-century is summarized using defined temperature thresholds. In the most recent quarter-century (2000–2024), Edmonton recorded 54 days with daily maximum temperatures of 32°C or higher, including 15 days reaching or exceeding 34°C. During the same period, there were 63 tropical nights (defined as nights with a minimum temperature of 18°C or higher), of which 13 exceeded 20°C. This trend reflects a significant reduction in overnight cooling and an increased risk of heat stress. The frequency of both extremely hot days and tropical nights in 2000–2024 is markedly higher than in any previous 25-year period.

(a) Total Number of Extremely Hot Days by 25-Year Period in Edmonton



(b) Total Number of Tropical Nights by 25-Year Period in Edmonton

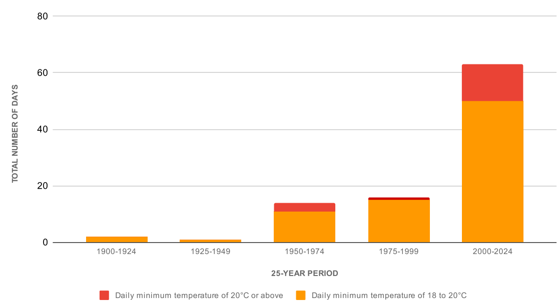


Figure 2.13: Total number of (a) extremely hot days and (b) tropical nights by 25-year period in Edmonton, 1900–2024.

2.2.4.3 Cold Extremes

Extreme cold events in Edmonton are identified based on the criteria set by ECCC. According to ECCC, extreme cold warnings for Alberta are issued when the temperature or wind chill is expected to reach -40°C or lower for a minimum duration of two hours. This threshold is primarily intended for short-term public safety alerts rather than long-term climate trend analysis.

In this study, thresholds of -30°C and -35°C were selected to support a more comprehensive analysis of extreme cold events over time. These thresholds capture very cold days that, while not always reaching -40°C warning level, still have considerable implications for public health and environmental systems. Additionally, wind chill values are derived metrics and are not consistently available in historical daily climate records. Therefore, minimum daily air temperature provides a more reliable and continuous indicator of cold extremes from 1885 to 2024.

In this report, for the analysis of very cold days, extreme cold is defined as days when the minimum temperature falls to -30°C or lower, with a subset of those days reaching –35°C or lower (Figure 2.14).

Annual Number of Very Cold Days in Edmonton

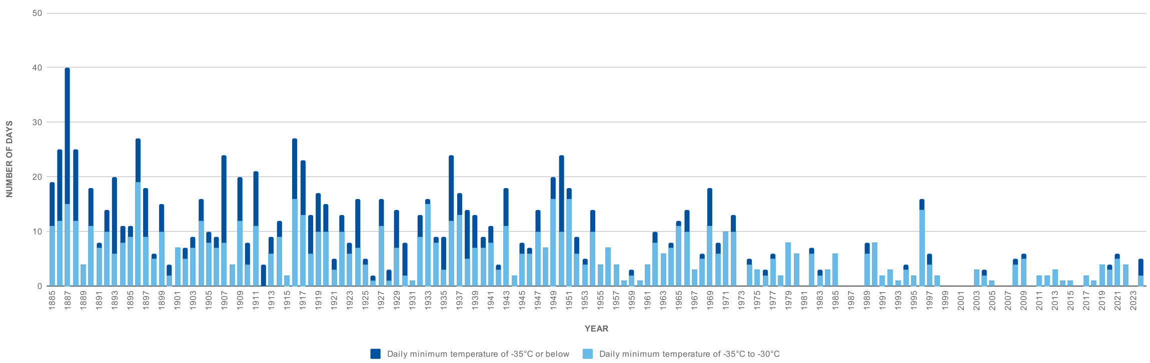


Figure 2.14: Annual number of very cold days in Edmonton, 1885–2024.

The annual number of very cold days is based on daily minimum temperatures, with dark blue bars representing days at or below -35°C and light blue bars representing days with minimum temperatures between -30°C and -35°C (Figure 2.14). The frequency of very cold days was highest prior to 1950 and has decreased gradually over time. Between 1970 and 2024, there were 14 years in which Edmonton recorded no days colder than -30°C.

A quarter-century analysis of extremely cold temperatures reveals a clear downward trend in the frequency of very cold days (Figure 2.15).

Total Number of Very Cold Days by 25-Year Period in Edmonton

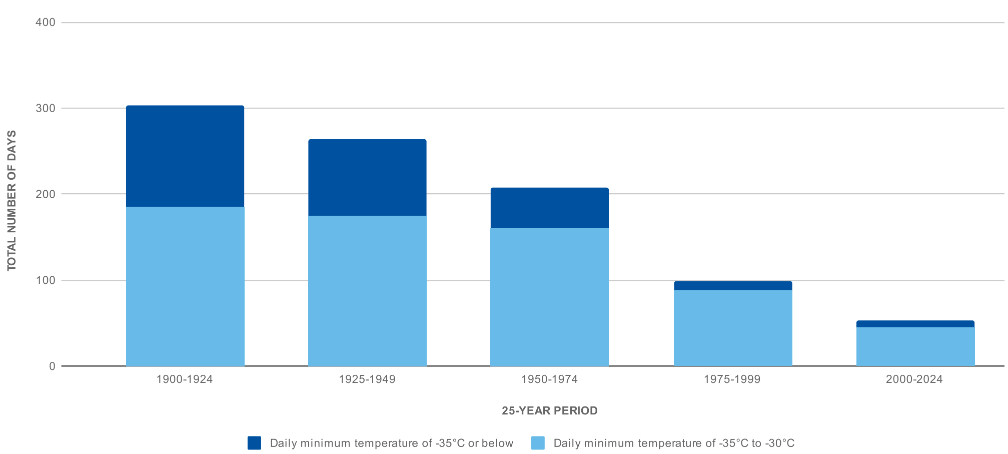


Figure 2.15: Total number of very cold days by 25-year period in Edmonton, 1900–2024.

While Edmonton continues to experience occasional and isolated extreme cold events, these occurrences are increasingly understood as part of complex interactions between Arctic warming and atmospheric circulation dynamics, particularly disruptions to the polar vortex (Overland and Wang, 2019; Cohen et al., 2024). The polar vortex is a large area of low-pressure and cold air encircling the Arctic, generally held in place by the polar jet stream. Recent studies have shown that Arctic amplification—the intensified warming of the Arctic relative to global averages—can influence atmospheric pressure patterns and destabilize the stratospheric polar vortex, increasing the likelihood of cold-air outbreaks into mid-latitudes regions (Cohen et al., 2024).

Temporary breakdowns or displacements of the polar vortex can allow Arctic air to surge southward into the Prairies. These events highlight the role of natural atmospheric variability within the broader context of ongoing regional warming.

There is strong scientific consensus that human activities—primarily the burning of fossil fuels—are causing the Earth to warm, with the Arctic warming at two to three times the global rate (Miller et al., 2013; Meredith et al., 2019; Bush and Lemmen, 2019; ClimateData.ca, 2024c). This overarching warming trend has led to an increase in extreme heat events globally, which now outnumber cold snaps. However, cold snaps still punctuate the general warming trend, particularly in northern temperate regions like North America. These cold snaps, although less frequent and generally not setting new records for cold, can bring temperatures that are significantly below seasonal averages and have considerable effects on human health, energy consumption, and transportation systems (ClimateData.ca, 2024c).

In Edmonton, broader climate change patterns are already reflected in observable shifts in winter conditions. Recent assessments suggest that changes are occurring not only in temperature trends but also in the overall characteristics and seasonal dynamics of winter. The city has experienced a reduction in the number of cold days (Figure 2.14), consistent with a general trend toward shorter and milder winters observed in several Canadian cities (Climate Central, 2024). These changes may influence snow cover, freeze-thaw cycles, and the timing of seasonal transitions. According to Climate Central, Edmonton now experiences an average of four winter days per year with minimum temperatures above 0°C, three of which are attributed to human-induced climate change (Climate Central, 2024). These results represent averages over the past decade (2014–2023). While Edmonton remains among the colder major cities in Canada, these findings indicate a measurable local signal of winter warming, with potential implications for infrastructure, ecosystems, and climate adaptation planning.

While the long-term trend in Edmonton shows a decline in extreme cold days, episodic cold snaps remain possible due to dynamic atmospheric processes.

2.2.5 INFLUENCE OF NATURAL ATMOSPHERIC PATTERNS

Edmonton's climate is likely influenced by large-scale natural oscillations, notably the El Niño–Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), which are known to drive year-to-year and decadal variability in temperature across western Canada (Shabbar and Khandekar, 1996; Bonsal et al., 2001). ENSO, in particular, is associated with episodes of unusually high sea-surface temperatures in the equatorial eastern Pacific, which arise from large-scale fluctuations in surface air pressure between the western and eastern tropical Pacific (Moran and Morgan, 1997). These ocean–atmosphere interactions result in atmospheric oscillations that can influence weather patterns far beyond the tropics.

ENSO's effects appear to include contributing to positive surface temperature anomalies across western Canada and the northwestern United States (Khandekar, 2000). During El Niño winters, an amplified high-pressure ridge often develops over western North America, inhibiting Arctic air outbreaks and contributing to warmer-than-normal conditions from the Yukon through the Prairies. Conversely, La Niña episodes are typically associated with colder winter anomalies in Alberta and surrounding areas due to a southward displacement of the jet stream, which allows more frequent Arctic air incursions (Shabbar and Khandekar, 1996). It is hypothesized that these patterns may contribute to observed winter temperature variability in Edmonton, although more localized attribution remains limited in the literature. Their influence generally diminishes by spring.

The PDO, a multi-decadal oscillation in North Pacific ocean–atmosphere conditions, appears to influence climate over longer timeframes. It typically persists for 20–30 years in either a "warm" (positive) or "cool" (negative) phase. Positive PDO phases have been associated with milder winters across western Canada, while negative phases are linked to increased cold-air surges (Bonsal et al., 2001). When El Niño events coincide with positive PDO conditions, especially warm winters have been observed in parts of western North America, potentially due to reinforcing circulation patterns. The mid-1970s shift to a positive PDO phase, along with a rise in El Niño frequency, coincided with relatively greater winter and spring warming in western North America, including parts of Alberta (Bonsal and Shabbar, 2011).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El Niño and melting snow causing warmer Alberta temperatures

Tuesday saw a record high in Edmonton of 12 C

Stephanie Cram · CBC News · Posted: Jan 30, 2024 3:15 PM MST | Last Updated: January 30, 2024

This time of year, Edmonton typically sees an average high of -6 C, but temperatures climbed to 10 C on Sunday, a huge jump from the -37.7 C the city experienced two weeks earlier. (Scott Neufeld/CBC)


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No-snow November: El Niño could mean a warm and dry winter for Edmonton

Thankfully, drought in November is not too much of a concern to farmers

Stephanie Cram · CBC News · Posted: Nov 25, 2023 6:00 AM MST | Last Updated: November 25, 2023

Skyline view from Northeast Edmonton on Nov. 24, 2023, with no snow on the ground. Environment Canada says that because of El Niño, this winter could be drier and warmer than normal. (David Bajer/CBC)

Although such oscillations introduce important short-term and decadal variability, they are unlikely to fully explain the persistent long-term warming trends observed in recent decades. Large-scale atmospheric oscillations—including ENSO, the North Atlantic Oscillation (NAO), and the Arctic Oscillation (AO)—may account for some variability and potentially a portion of observed warming trends at the hemispheric scale (Khandekar, 2000), but not the sustained upward trajectory in temperatures over decades. Canadian studies suggest that these natural modes modulate the spatial pattern and timing of warming, but are insufficient to account for its magnitude and duration (Vincent et al., 2015).

Canada's Changing Climate Report (Bush and Lemmen, 2019) concludes that while both natural variability and human influence have played roles in observed warming, it is very likely that anthropogenic factors are the dominant cause of long-term warming across Canada. The report discusses that from 1948 to 2016, the annual average temperature in Canada increased by approximately 1.7°C, with even greater increases in the Prairie provinces and during winter months. These changes are greater than what would be expected from internal variability alone.

Overall, while ENSO, PDO, and other large-scale atmospheric oscillations likely influence short-term and seasonal climate variability in Edmonton, they do not account for the persistent warming observed in recent decades. Regional and national scientific assessments consistently suggest that Edmonton's long-term temperature increase is occurring within the broader context of anthropogenic climate change, with natural variability serving a secondary, modulating role. Further research may help clarify the specific influence of these oscillations on local temperature trends.

2.3 Urban Heat Island (UHI) Effect in Edmonton

Urban Heat Island effects in Edmonton are shaped by the city's high-latitude location, land use patterns, and seasonal climate variability, resulting in UHI dynamics that are distinct from other major Canadian cities. While Edmonton shows its highest UHI intensity during winter nights, due to heat retention in built environments, the greatest potential for climate and health impacts likely occurs in summer, when daytime and nighttime UHI compound elevated ambient temperatures. Satellite-based analyses confirm urban hotspots in downtown and industrial zones, while vegetated zones and large water bodies provide localized cooling.

UHIs are a climate phenomenon where urban areas experience significantly higher temperatures compared to nearby rural regions (Welegedara et al., 2023). This temperature difference—referred to as UHI intensity—results from a combination of land cover changes, human activity, and urban infrastructure. Impermeable surfaces such as asphalt, concrete, and buildings absorb and retain more solar radiation, especially when composed of low-albedo materials that reflect less sunlight. The reduction of vegetation further exacerbates this effect by limiting natural cooling processes like shading and evapotranspiration (Welegedara et al., 2023).

While UHIs can intensify heat-related risks during summer—by increasing temperatures, stressing energy systems, and reducing comfort in urban settings, their significance varies by season. For example, in winter, Edmonton's elevated nighttime UHI may mitigate extreme cold exposure rather than increase risk. Thus, the most intense UHI does not always result in the most severe impacts, emphasizing the need to interpret UHI effects in context, accounting for both seasonal conditions and climate vulnerabilities.

In Edmonton, the UHI effect is most pronounced in densely populated areas with limited green space—defined here as areas with natural or semi-natural vegetation such as parks, treed boulevards, vegetated open spaces, and community gardens. During heat waves, the UHI effect can exacerbate temperature extremes, with heightened implications for public health and energy infrastructure (Welegedara et al., 2023; Duan et al., 2024).

While the Urban Heat Island (UHI) effect contributes to localized warming in specific urban areas, Edmonton's overall warming trend is not solely—or even primarily—due to urban growth. Long-term temperature increases observed across the Edmonton region reflect broader climatic changes driven largely by greenhouse gas emissions and global climate dynamics. UHI intensifies warming within city boundaries, but it does not explain the magnitude or persistence of Edmonton's regional warming trend.

Recent analyses using MODIS Land Surface Temperature (LST) data from 2021 provide further insights into Edmonton's UHI dynamics (Duan et al., 2024). Understanding Edmonton's UHI requires examining its land use and land cover characteristics. The city's urban areas are predominantly built-up and are surrounded by croplands, vegetated zones, and the river valley, which serve as natural cooling areas. The contrast between Edmonton's urban areas (signified by built-up areas in red) and its surrounding natural and rural zones, based on 2021 data, is illustrated in Figure 2.16.

Land Use and Land Cover Map of Edmonton

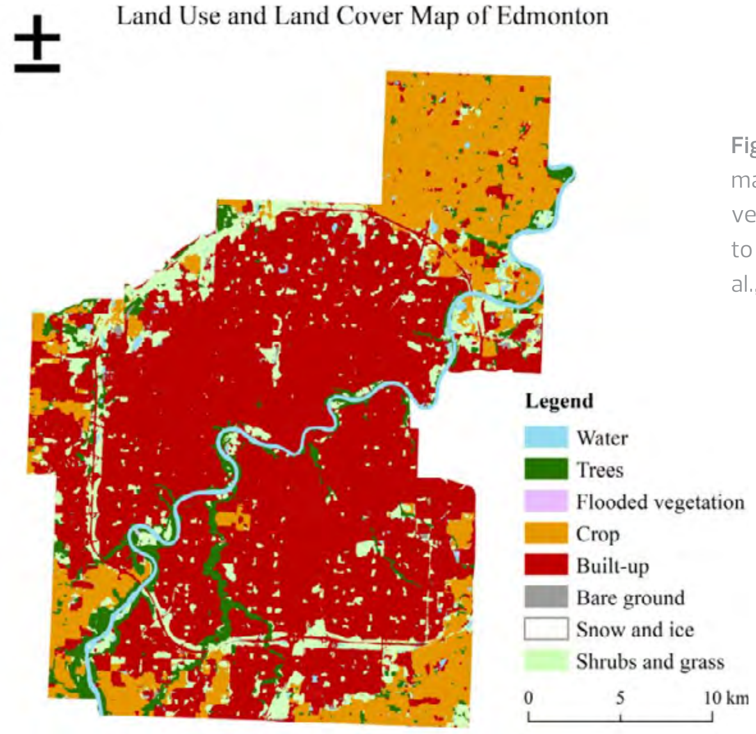


Figure 2.16: Land Use and Land Cover map of Edmonton, highlighting urban, vegetated, and cropland areas relevant to UHI patterns (Illustration by Duan et al., 2024).

Edmonton's UHI intensity shows notable seasonal and diurnal patterns. During the winter months, daytime UHI intensity is relatively low at -1.29°C, as the colder temperatures in surrounding rural areas offset urban warming. However, nighttime UHI intensity increases significantly to 2.86°C, primarily due to heat retention in built-up areas, which release stored heat during longer winter nights (Duan et al., 2024). This highlights the role of urban infrastructure in contributing to nighttime warming.

Seasonal patterns further reveal urban heat sinks in vegetated zones and along the river valley during winter days, contrasting with persistent warming patterns in the urban areas during nighttime throughout the year. Warmer urban areas are consistently evident in both daytime and nighttime maps across all seasons, while areas near the river valley remain cooler due to vegetation (Figure 2.17). Notably, Edmonton experiences its highest maximum daytime UHI intensity during the winter months likely influenced by snow-covered vegetated surfaces and limited solar reflection (Duan et al., 2024). However, the most critical UHI-related risks emerge in summer, when elevated baseline temperatures are compounded by both daytime and nighttime UHI effects. These compounding factors can significantly intensify heat waves, heightening public health risks and straining infrastructure (Zhao et al., 2018; Ejiagha et a., 2022).

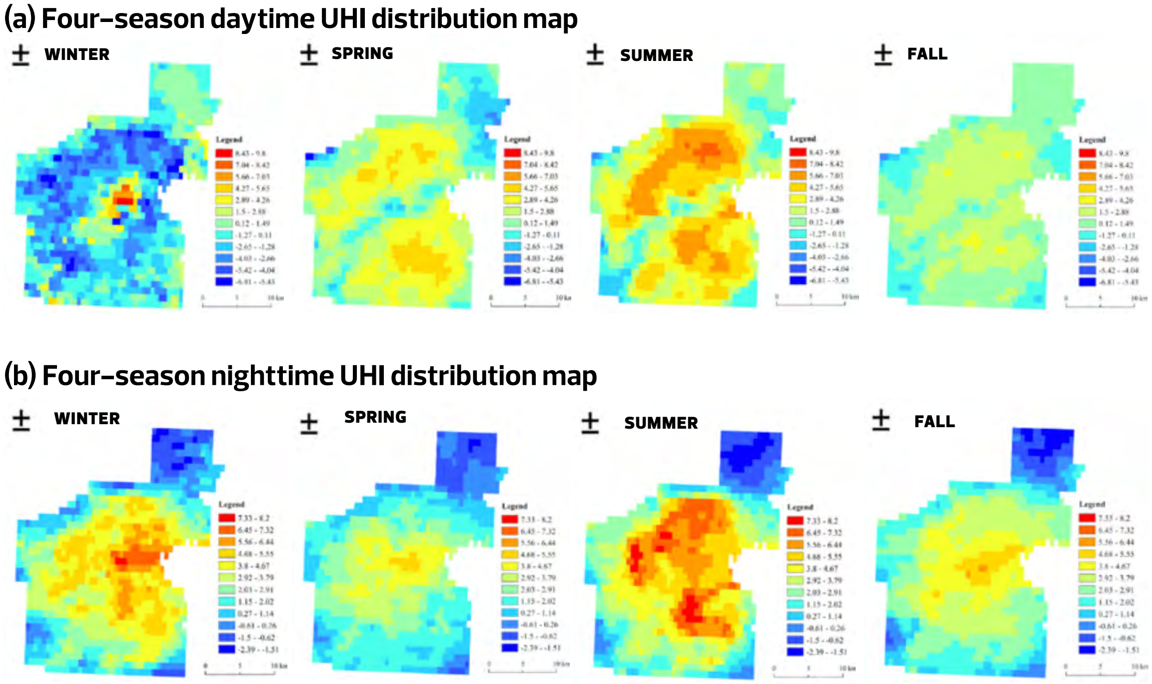


Figure 2.17: Four-season Urban Heat Island (UHI) intensity distribution maps for Edmonton, showing (a) daytime and (b) nighttime patterns (Illustration by Duan et al., 2024).

The spatial distribution of UHI in Edmonton reveals the role of urbanization in shaping temperature dynamics. High UHI intensities are concentrated in downtown Edmonton and industrial areas, where impermeable surfaces such as roads and buildings dominate. These urban areas experience greater heat retention compared to areas near the river valley and other vegetated zones, which benefit from the cooling effects of water bodies and vegetation. These green spaces significantly lower surface temperatures, providing natural relief from UHI effects (Duan et al., 2024).

Land use also plays a pivotal role in Edmonton's UHI intensity. Built-up areas consistently exhibit the highest daytime surface temperatures due to the heat-absorbing properties of impermeable surfaces. In contrast, vegetated areas—particularly croplands and tree-covered regions—as well as large water bodies act as natural cooling zones by moderating surface temperatures. These findings highlight the importance of preserving and expanding green spaces to mitigate urban heat and enhance thermal comfort in the city (Duan et al., 2024).

Edmonton's UHI effect is distinct from other Canadian cities, with more pronounced nighttime warming due to its high-latitude location.

Compared to other major Canadian cities such as Vancouver and Toronto, Edmonton's UHI dynamics are distinct. Situated at a high latitude, Edmonton displays unique UHI characteristics shaped by its geographical location, seasonal climate, and diverse land use patterns. While Vancouver and Toronto are characterized by prominent daytime UHI effects—partly shaped by the moderating influence of nearby large water bodies— Edmonton's nighttime UHI intensity

is more pronounced. This unique trend is attributed to Edmonton's high-latitude location, which leads to extended winter nights and increased heat retention in urban areas. Additionally, Edmonton experiences significant seasonal variability in UHI patterns, with heat sinks in green spaces during winter days juxtaposed against nighttime warming in built-up zones (Duan et al., 2024).

The contrast with other cities shows the importance of Edmonton's specific geographic and climatic context in shaping its UHI effects. These insights are vital for tailoring mitigation strategies that account for local conditions, such as increasing tree cover, reducing impermeable surfaces, and protecting green spaces in high-UHI areas like downtown (Duan et al., 2024).

3.0 Air Quality in Edmonton

Edmonton is part of an airshed currently classified at the "orange" management level under the Canadian Ambient Air Quality Standards (CAAQS). This status reflects pollutant levels that are elevated enough to warrant management plans but not yet exceed national thresholds. Within this context, air quality in Edmonton has remained relatively stable between 2010 and 2024. This stability suggests that conditions have not worsened, even amid growing urban activity and increasing climate pressures. Episodes of poor air quality are driven primarily by winter inversions and summer wildfire smoke, rather than persistent urban emissions. Nitrogen dioxide (NO_2) levels have declined overall but continue to peak during traffic rush hours. Ozone (O_3) concentrations have risen and show clear midday peaks linked to photochemical processes. Fine particulate matter ($PM_{2.5}$) remains highly variable, with spikes during wildfire events and atmospheric inversions, but no clear long-term trend.

Air quality, defined as the condition of air in the surrounding environment, is essential for both human and ecosystem health (ECCC, 2017a). It relates to the concentration of air pollutants present in the atmosphere that may affect human health or the natural environment. Air pollution can negatively impact environmental systems and pose serious health risks, particularly for vulnerable populations such as older adults, young children, and individuals with pre-existing respiratory conditions (ECCC, 2017a).

The World Health Organization identifies outdoor air pollution as one of the most significant global environmental health risks, affecting populations worldwide (WHO, 2024b; ECCC, 2017a). Pollutants such as ground-level ozone (O_3), acidifying compounds, and heavy metals not only harm human health but also affect soil, water, crops, and wildlife. Some air pollutants—like short-lived climate pollutants—further contribute to climate change, amplifying their environmental and socioeconomic impacts (ECCC, 2017a).

To place these findings in a broader policy and regulatory context, the Canadian Ambient Air Quality Standards (CAAQS) provide a benchmark for air quality management across Canada. According to the Alberta Air Zones Report (2020–2022), the North Saskatchewan Air Zone, which includes the Edmonton Metropolitan Region, remains within the orange management level for $PM_{2.5}$, NO_2, and O_3. This designation indicates that the air zone is either exceeding the standards or is at risk of doing so in the near future and requires proactive management actions (Brown et al., 2025). However, analysis of Edmonton-specific monitoring stations shows that the city met the 2023 CAAQS thresholds for all three pollutants—$PM_{2.5}$ (after exclusion of wildfire data), NO_2, and O_3—based on the most recent three-year average. These findings highlight the importance of distinguishing between episodic and anthropogenic pollution sources and reinforce the need for targeted emission reduction strategies alongside emergency response planning for natural events like wildfires.

The following sections provide an overview of air quality trends and key emission sources in Edmonton, based on findings from a recent study conducted for the City of Edmonton by the Alberta Capital Airshed (McCullum, 2025).

3.1 Air Quality Indices

This section evaluates the trends in three key air quality parameters—nitrogen dioxide (NO_2), ozone (O_3), and fine particulate matter ($PM_{2.5}$)—and their implications for the Air Quality Health Index (AQHI) in Edmonton. Evaluated data was collected from 2010 to 2024 by four monitoring stations across the city (Edmonton Woodcroft, Edmonton McCauley, Edmonton Lendrum, and Edmonton East). Monthly averages, followed by the 98th percentile of these parameters, were analyzed to identify significant patterns over time, reflecting both broad-scale trends and episodic events for the three parameters and AQHI (Figure 3.1). Mean trends reflect broader, long-term changes in air quality, while the 98th percentile trends provide insight into the behaviour of extreme pollution events.

Mean Monthly Air Quality Trends in Edmonton

(a) **(b)**

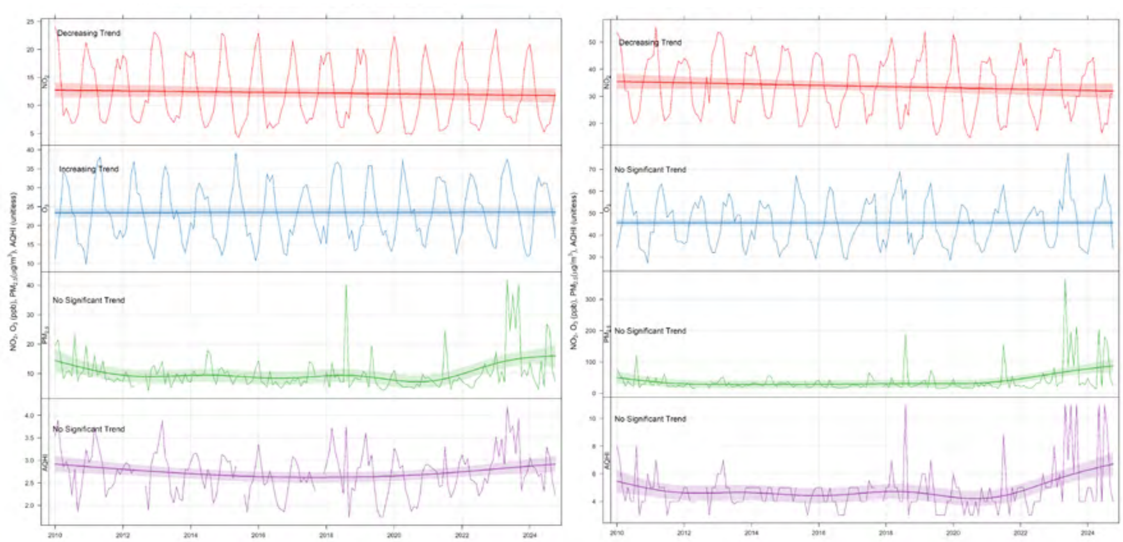


Figure 3.1: (a) Monthly mean and (b) 98th percentile trends for three key air pollutants and the Air Quality Health Index (AQHI) in Edmonton, 2010–2024.

NITROGEN DIOXIDE (NO_2)

Mean monthly NO_2 levels show a decreasing trend between 2010 to 2024 with strong statistical evidence of decline (Seasonal Mann-Kendall test, $z = -3.6126$, p-value = 0.00030), indicating an overall improvement in air quality related to this pollutant. The 98th percentile data also shows a statistically significant decreasing trend ($z = -3.8605$, p-value =0.00011), suggesting that even the highest NO_2 concentrations have declined over time. Together, these findings indicate

that reductions in NO_2 emissions are influencing both average and peak levels. This reduction likely reflects the effectiveness of improved emissions control technologies at key sources, influenced by advancements in vehicle technology, industrial regulations, and cleaner energy practices however no source-specific attribution analysis has been conducted for Edmonton. As such, while these technologies are expected to contribute to observed improvements, the exact contributions of various sectors (e.g., transportation vs. industrial sources) remain unquantified locally. (GoA, 2025b).

OZONE (O_3)

Mean monthly O_3 levels show an increasing trend between 2010–2024 ($z = 3.2934$, p-value $= 0.00099$), likely influenced by reductions in NO_2 emissions. Changes in nitrogen oxide concentrations over time may also play a role, as they can both promote and suppress ozone concentration, depending on pollution levels and meteorological conditions (GoA, 2025b). Nitrogen dioxide acts as a scavenger for ozone, and its reduction in the atmosphere can lead to higher average O_3 levels.

However, 98th percentile data shows no significant trend ($z = 0.4682$, p-value $= 0.6397$), indicating that extreme ozone levels are not increasing significantly, even though average levels are rising. The increasing trend in mean O_3 may reflect broader environmental changes, while the absence of a trend in the 98th percentile suggests that extreme ozone events have not become more frequent or severe and remain stable.

PARTICULATE MATTER ($PM_{2.5}$)

Mean monthly $PM_{2.5}$ levels show no significant trend between 2010 and 2024 ($z = -1.5702$, p-value = 0.1164), with occasional spikes that coincide with episodic events such as increased wildfire activity and wintertime temperature inversion. The 98th percentile data also shows no significant trend ($z = 0$, p-value = 1), but displays high variability and sharp peaks likely associated with extreme events. Both metrics indicate a lack of consistent long-term trend; however, the 98th percentile highlights episodic high-concentration events which may not strongly affect the mean.

AIR QUALITY HEALTH INDEX (AQHI)

The Air Quality Health Index, or AQHI, is a scale from 1 to 10 that communicates the health risk associated with local air quality. It is particularly useful for individuals more sensitive to air pollution such as children, the elderly, and those with pre-existing health conditions by providing real-time guidance on outdoor activity. The higher the AQHI value, the greater the potential health risk and the need to take appropriate precautions (GoA, 2025c).

The AQHI, calculated using NO_2, O_3, and $PM_{2.5}$, demonstrates no significant trend in mean monthly values between 2010 and 2024 ($z = -0.415$, p-value = 0.678). The 98th percentile data also shows no significant trend ($z = 0.0661$, p-value = 0.9473), suggesting that extreme AQHI levels—such as those observed during high pollution events—have not shown a consistent change over the period evaluated. Together, these metrics indicate that while air quality remains variable, there is no clear indication of an increase in the frequency or severity of extreme AQHI events based on the 2010–2024 monthly data.

KEY OBSERVATIONS IN AIR QUALITY TRENDS:

The consistent decline in NO_2 levels likely reflects effective emission reduction measures across Edmonton, with source-specific attribution analysis required to identify the specific causes.

Rising mean ozone levels point to changing atmospheric chemistry, likely driven by reductions in NO_2 and broader environmental changes, though extreme events remain stable.

$PM_{2.5}$ levels are characterized by high variability due to episodic events, such as wildfires and wintertime inversions, which can lead to short-term but severe air quality impacts without significantly influencing long-term averages.

3.1.1 TEMPORAL AND NORMALIZED PATTERNS IN AIR QUALITY PARAMETERS

To better understand the trends in Edmonton's air quality, an additional analysis was conducted by normalizing the data for NO_2, O_3, $PM_{2.5}$, and AQHI (Figure 3.2). The purpose of normalizing is to highlight relative variations in each metric over time (hourly, monthly, or weekly) without being influenced by absolute concentration differences between pollutants. The normalization process highlighted relative variations in these parameters over time (hourly, monthly, and weekly) while minimizing the influence of absolute concentration differences. This analysis uses the same data set covering the 2010–2024 period. This approach is particularly effective when working with parameters measured on vastly different scales, such as NO_2 in parts per billion (ppb), $PM_{2.5}$ in micrograms per cubic meter (µg/m^3), and the AQHI as a unitless index. By normalizing the data, patterns and trends became more apparent, enabling easier comparisons.

Normalized Temporal Air Quality Patterns in Edmonton

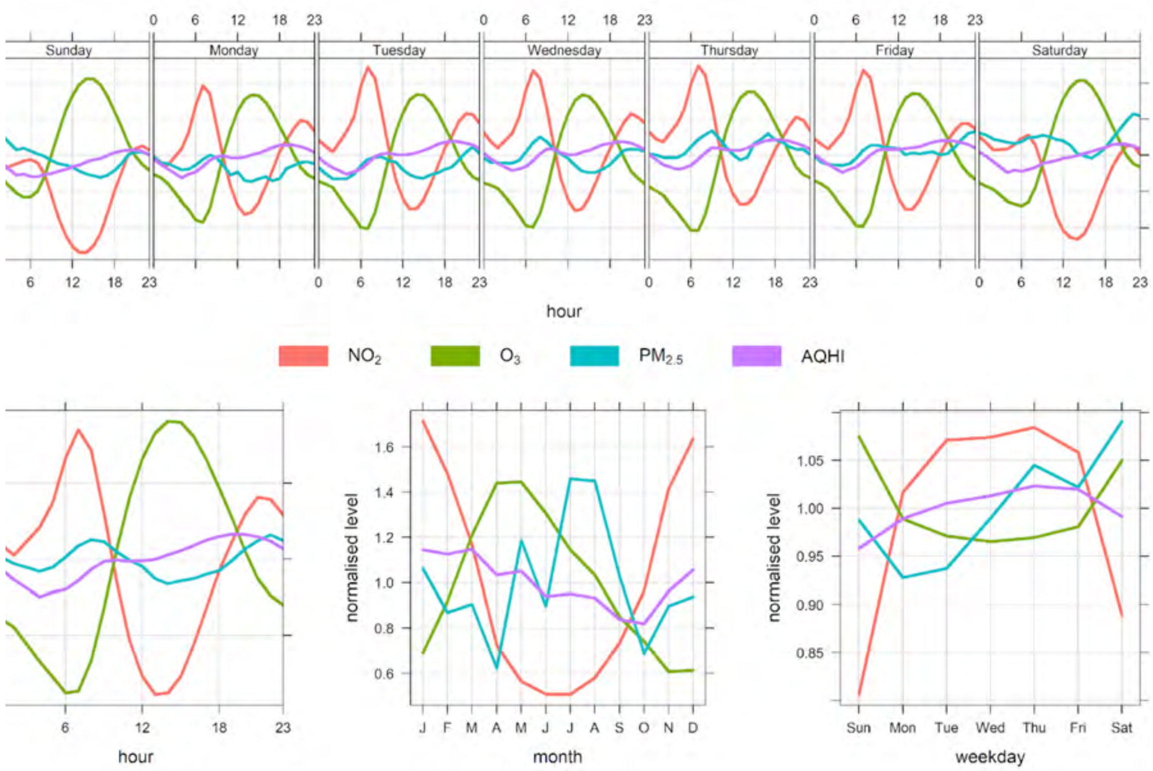


Figure 3.2: Normalized patterns of NO_2, O_3, $PM_{2.5}$ and AQHI in Edmonton.

Analysis of daily patterns offers insight into contributing causal mechanisms (Figure 3.2). NO_2 exhibited peaks during morning (7–9 AM) and evening (6–9 PM) rush hours, a reflection of emissions from vehicular traffic. In contrast, O_3 levels peaked around midday due to photochemical reactions driven by sunlight and decreased at night in the absence of sunlight. $PM_{2.5}$ displayed relatively stable levels throughout the day, with slight increases during evening hours. These increases may be attributed to a combination of factors, including residential heating, the use of local fire pits, evening traffic, possible industrial emissions, and meteorological influences such as localized wind patterns or temperature inversions that hinder pollutant dispersion. However no source attribution has been completed to define the contribution of these potential sources. Meanwhile, AQHI showed relatively stable daily behavior, as it reflects the combined effects of NO_2, O_3, and $PM_{2.5}$.

Monthly patterns provided further insights into seasonal variations (Figure 3.2). NO_2 concentrations were highest during the winter months, particularly from November to February, likely due to low atmospheric ceilings and temperature inversions trapping pollutants near the surface and increased emissions from vehicle idling and residential heating (Britannica, 2020). In contrast, O_3 concentrations peaked in the spring months, from April to July, as warmer temperatures and sunlight promote ozone formation. $PM_{2.5}$ displayed a dual pattern, with spikes during summer months, likely due to wildfires and agricultural burning, and a secondary peak during winter, possibly influenced by inversions and heating-related emissions. The AQHI reflected the combined seasonal behaviors of its component pollutants, showing variability that aligned with these trends.

Weekly patterns showed further differentiation among the pollutants. NO_2 levels were higher during weekdays, consistent with traffic patterns, and dropped significantly on weekends, reflecting reduced commuting and vehicular activity. O_3 levels, on the other hand, remained more consistent across the week but showed a slight increase on weekends, likely due to reduced NO_2 scavenging. $PM_{2.5}$ and AQHI demonstrated minimal variation throughout the week, suggesting they were less influenced by weekly activity cycles and more by longer-term or episodic factors.

To further understand the patterns in the data, the analysis was repeated without normalization to visualize the temporal patterns using actual concentration values (Figure 3.3). This approach retains the absolute values of each parameter, providing important context about real-world exposure levels and their magnitude. When multiple pollutants exhibit similar temporal patterns, this may indicate shared sources (e.g., traffic emissions), similar atmospheric behavior, or common meteorological influences. Conversely, when patterns differ—such as one pollutant peaking in the morning and another in the afternoon—it can highlight differences in source timing, chemical transformation processes (e.g., ozone formation), or dispersion characteristics. This distinction helps to better interpret the drivers behind observed air quality dynamics and supports targeted mitigation efforts.

Daily patterns in absolute terms showed NO_2 concentrations peaking at approximately 30 ppb during rush hours—morning (around 7–9 AM) and evening (around 6–9 PM), while O_3 reached values between 30 and 40 ppb around midday (Figure 3.3). $PM_{2.5}$ levels generally remained below 15 $\mu g/m^3$. AQHI values stayed low and stable, mostly below 3.

Weekly patterns in absolute terms mirrored those in the normalized analysis, with NO_2 levels clearly higher on weekdays compared to weekends, O_3 slightly elevated on weekends, likely due to reduced NO_2 scavenging, and $PM_{2.5}$ and AQHI remaining relatively stable across the week.

Monthly patterns highlighted that NO_2 concentrations were highest during winter, exceeding 20 ppb, and lowest in summer. O_3 exhibited peaks in spring months, exceeding 30 ppb, while $PM_{2.5}$ levels showed modest baseline concentrations with occasional spikes above 15 μg/m^3 during wildfire events in summer months. AQHI values remained predominantly low.

Temporal Air Quality Patterns in Edmonton

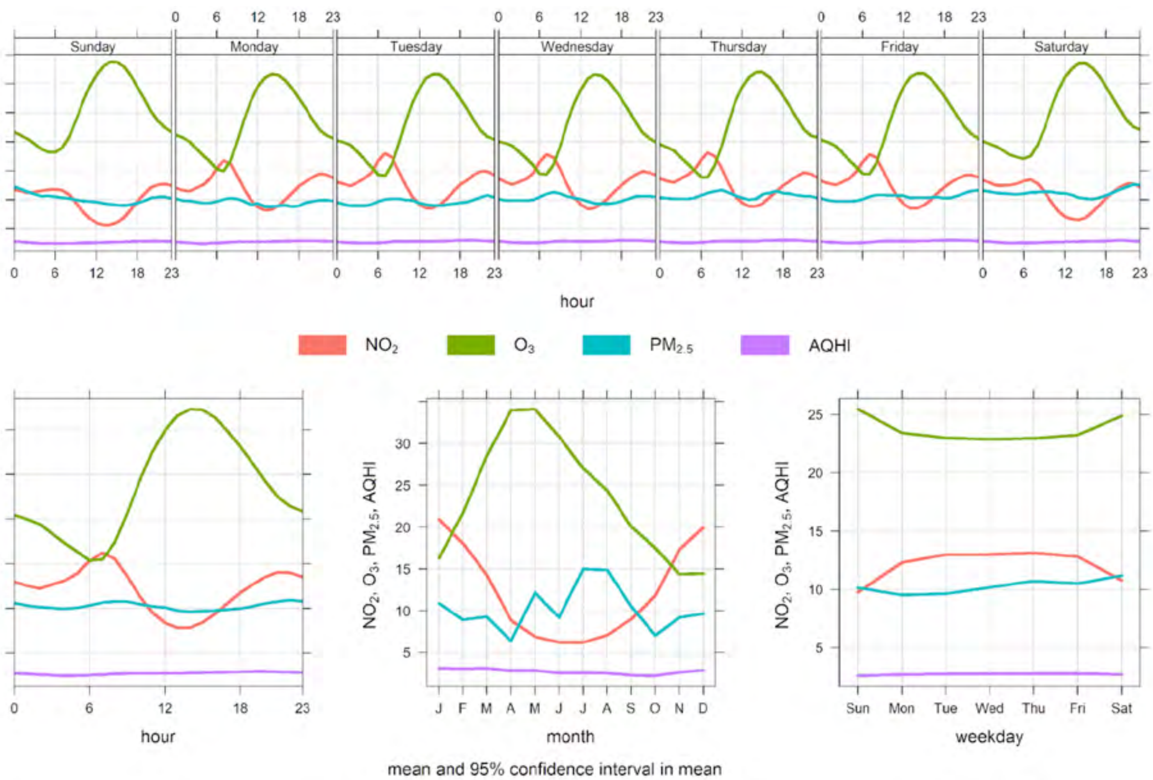


Figure 3.3: Temporal patterns of NO_2, O_3, $PM_{2.5}$ and AQHI in Edmonton.

The combined insights from normalized (Figure 3.2) and absolute (Figure 3.3) data highlight several key trends. Traffic-related emissions (reflected in NO_2) and photochemical reactions (driving O_3 levels) dominate daily variations, while $PM_{2.5}$ and AQHI appear to be less influenced by daily activities and exhibit more stable daily patterns. Seasonal trends show that NO_2 is highest in winter, O_3 peaks in spring, and $PM_{2.5}$ shows episodic spikes in spring and summer (due to wildfires) and winter (due to atmospheric temperature inversions and localized heating-related emissions). Weekly variations underline the influence of human activity, with NO_2 and O_3 showing distinct weekday–weekend differences likely driven by traffic patterns and photochemical processes, while $PM_{2.5}$ and AQHI remain relatively stable across the week.

This analysis provides a comprehensive understanding of Edmonton's air quality dynamics between 2010–2024, highlighting both broad-scale trends and the impact of episodic pollution events. The temporal trends observed offer valuable insights for interpreting air quality data and informing mitigation strategies to address Edmonton's unique air quality challenges.

A comparative analysis of air quality parameters—NO_2, O_3, and $PM_{2.5}$— across monitoring stations in Alberta, including four stations in Edmonton for 2023 showed NO_2 concentrations were notably higher in urban centers such as Edmonton, driven by transportation, home heating, and industrial emissions, with Edmonton's stations ranking among the top 10 in the province. In contrast, O_3 concentrations were lower in urban areas due to the scavenging effect of NO_2, where elevated NO_2 suppresses O_3 formation (Brown et al., 2025). As a result, two of Edmonton's stations were within the bottom 10, and all four ranked in the bottom 20 for O_3 levels. $PM_{2.5}$ concentrations, influenced by episodic wildfire events, displayed a different pattern, with three of Edmonton's stations ranking among the top 20 in the province. A notable north-to-south gradient in $PM_{2.5}$ levels was observed, reflecting wildfire activity across Canada in 2023. These contrasting spatial patterns highlight the unique drivers of NO_2, O_3, and $PM_{2.5}$ concentrations, with NO_2 and O_3 influenced by urbanization and atmospheric chemistry, while $PM_{2.5}$ is predominantly affected by episodic events like wildfires and atmospheric inversions.

3.2 Seasonal Variation in Pollutant Levels

A comprehensive analysis of seasonal variations in pollutant levels was conducted using data from 2010 to 2024. To visualize these patterns, calendar plots were developed to display daily variations in AQHI (Figure 3.4), $PM_{2.5}$ (Figure 3.5), NO_2 (Figure 3.6) and O_3 (Figure 3.7). These calendar plots use a color scale to display daily values throughout the year, providing an intuitive visual summary of seasonal and episodic patterns in air quality. High and very high levels are prominently highlighted in red, making these plots an effective communication tool for interpreting complex temporal dynamics. They are particularly useful for identifying:

- $PM_{2.5}$ peaks during wildfire seasons (typically May–August) and wintertime temperature inversions (Britannica, 2020).
- NO_2 elevations in colder months (November–February), associated with home heating and transportation (Britannica, 2020).
- O_3 increases in spring and early summer, driven by photochemical processes under high sunlight conditions (GoA, 2025b).
- AQHI spikes, which often align with the above seasonal pollutant trends.

These plots complement the previous trend analyses by visually reinforcing the seasonality and variability of Edmonton's air quality.

Air Quality Health Index (AQHI) in Edmonton (2010–2024)

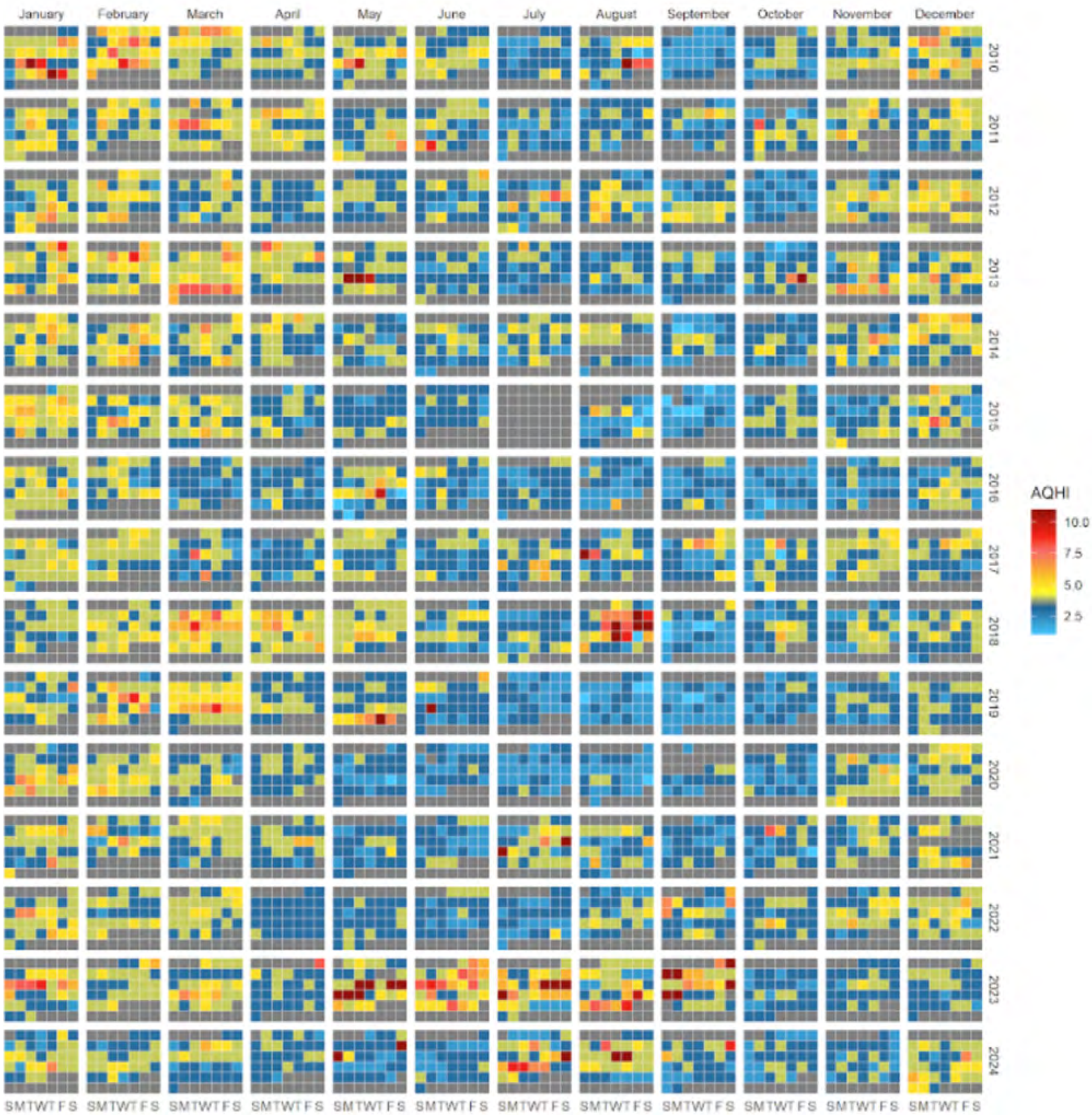


Figure 3.4: Calendar plot of the daily maximum AQHI values in Edmonton, 2010–2024.

Fine Particulate Matter ($PM_{2.5}$) Levels in Edmonton (2010–2024)

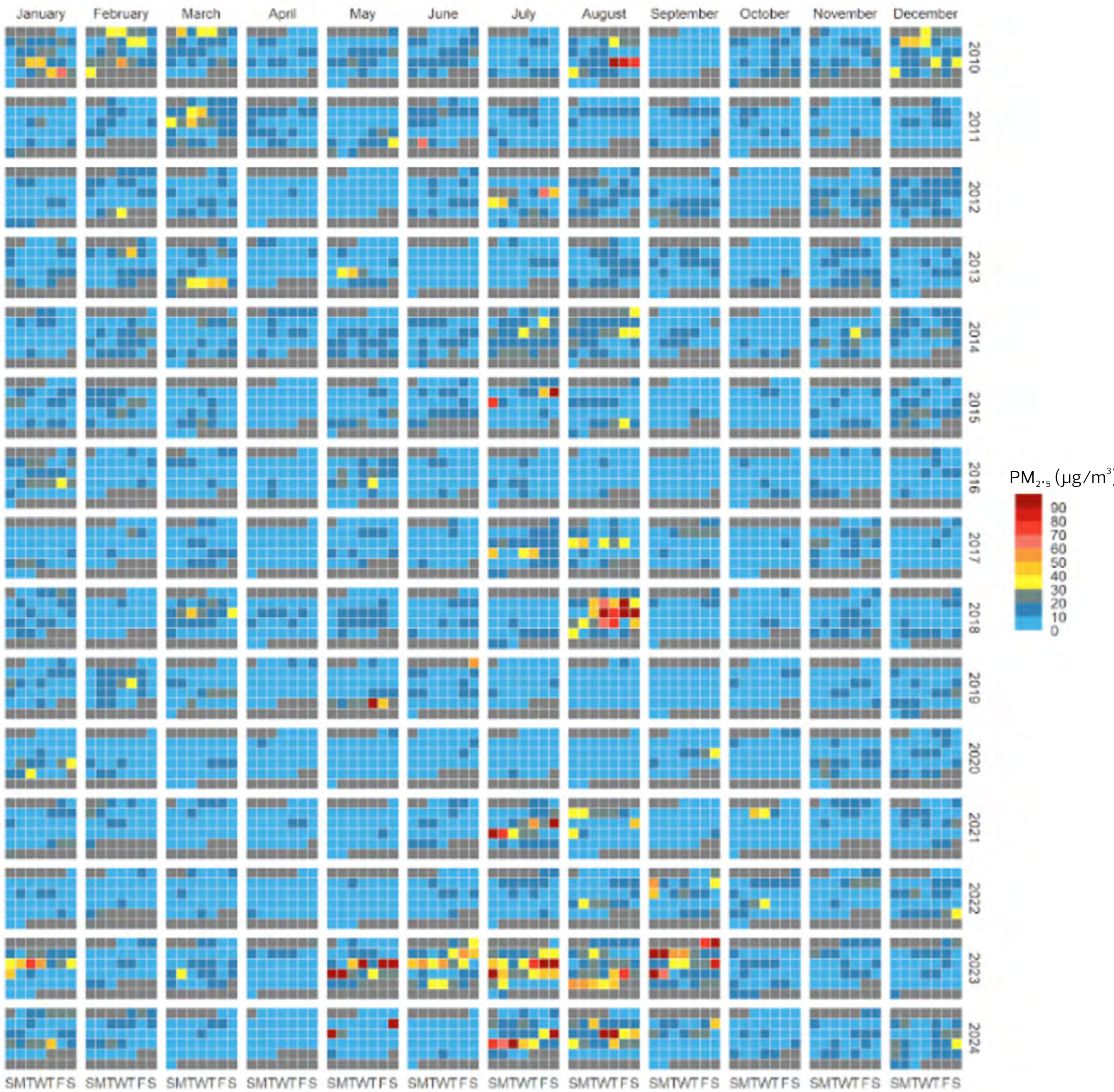


Figure 3.5: Calendar plot of daily maximum $PM_{2.5}$ concentrations in Edmonton, 2010–2024.

Nitrogen Dioxide (NO_2) Levels in Edmonton (2010–2024)

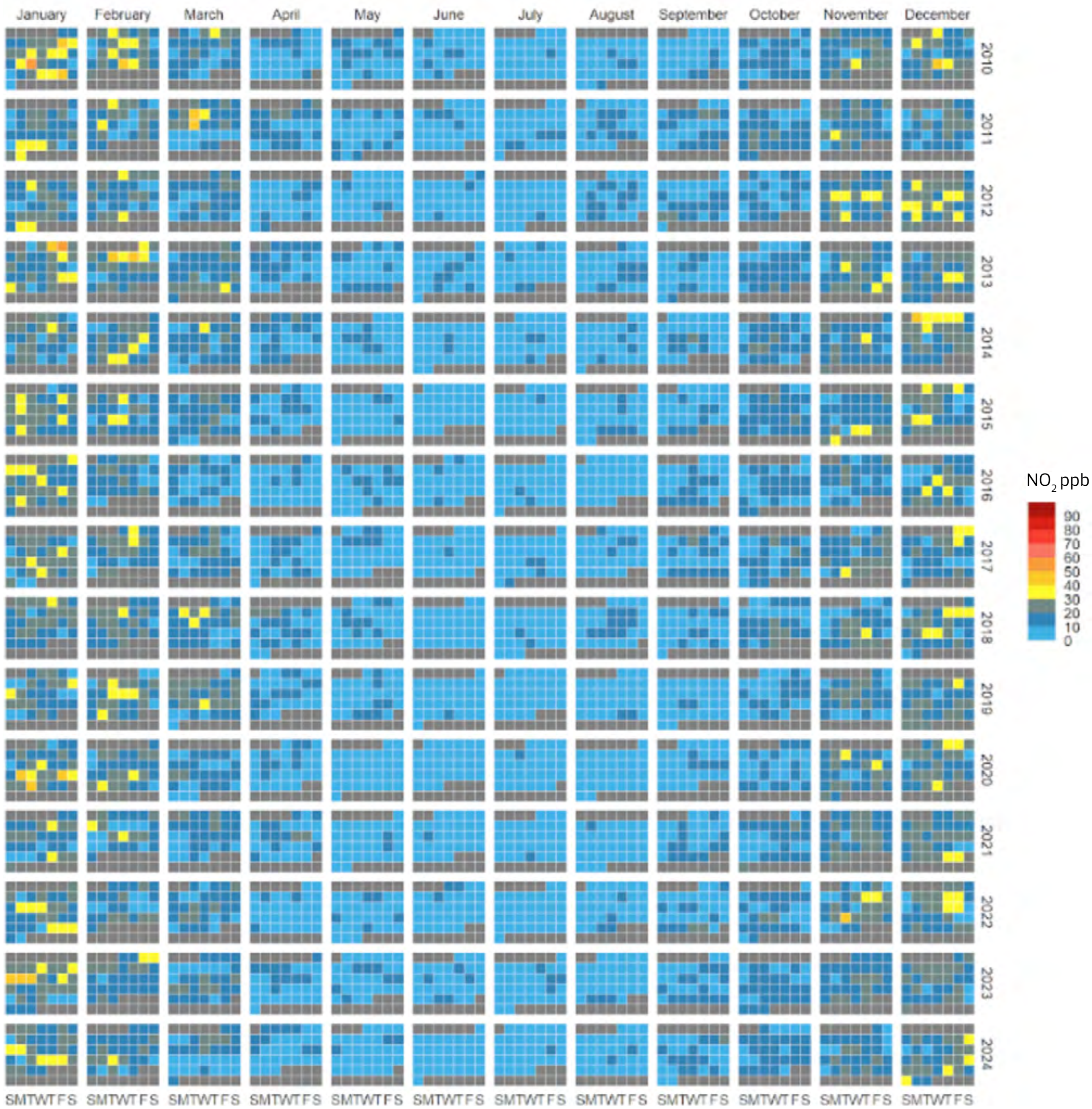


Figure 3.6: Calendar plot of daily maximum NO_2 concentrations in Edmonton, 2010–2024.

Ozone (O_3) Levels in Edmonton (2010–2024)

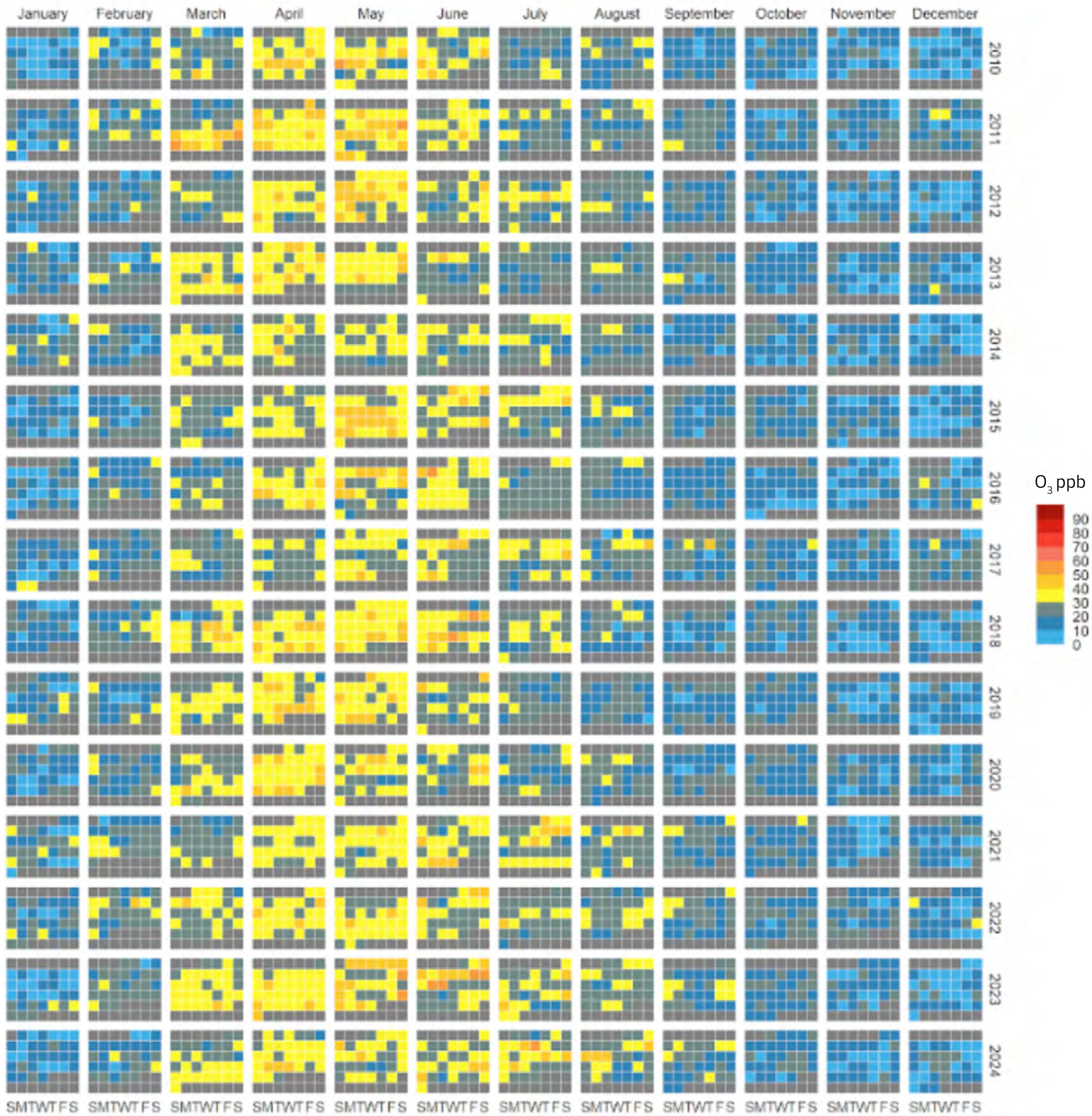
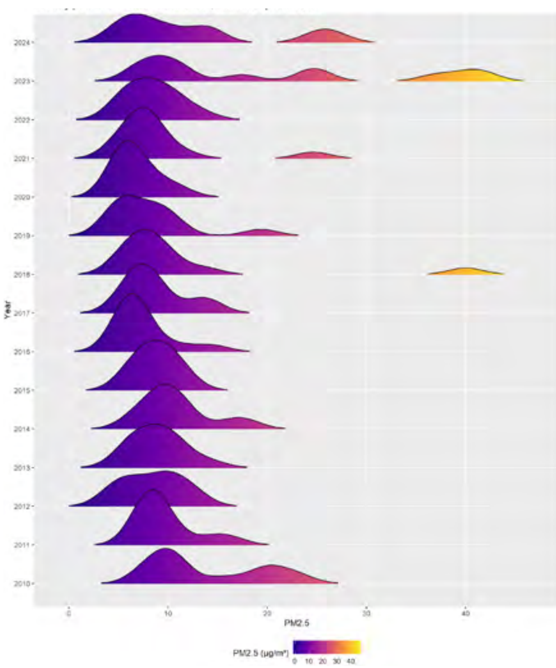


Figure 3.7: Calendar plot of daily maximum O_3 concentrations in Edmonton, 2010–2024.

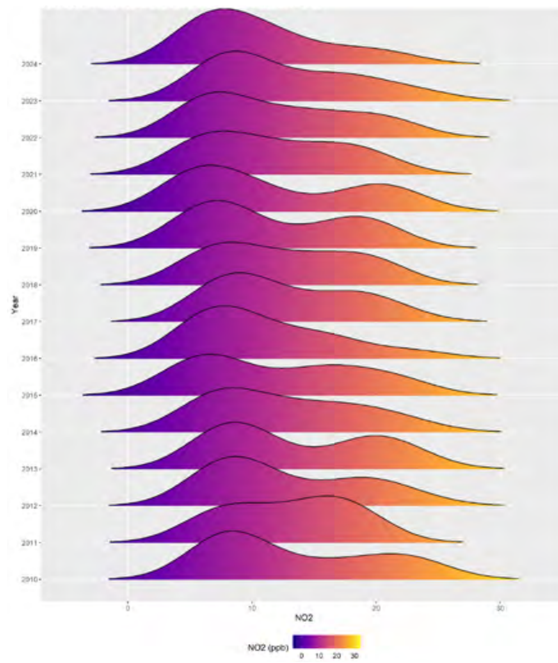
3.2.1 LONG-TERM EVOLUTION OF SEASONAL PATTERNS

A deeper analysis using ridge plots (Figure 3.8) provided additional insights into the evolving seasonal patterns of $PM_{2.5}$, NO_2, O_3, and AQHI in Edmonton over 2010–2024. Notably, $PM_{2.5}$ distributions in years with significant wildfire activity, such as 2018 and 2023, exhibited clear bimodal spikes, reflecting the acute air quality impacts of these events. In contrast, earlier years (2010–2015) generally displayed lower and tighter distributions, highlighting a concerning trend of increasing wildfire-driven pollution in more recent years.

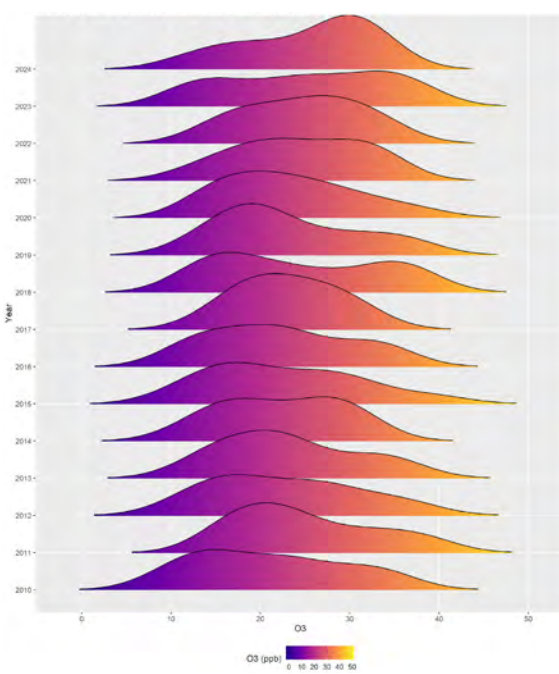
Monthly pattern of $PM_{2.5}$ in Edmonton



Monthly Pattern of NO_2 in Edmonton



Monthly pattern of O_3 in Edmonton



Monthly pattern of AQHI in Edmonton

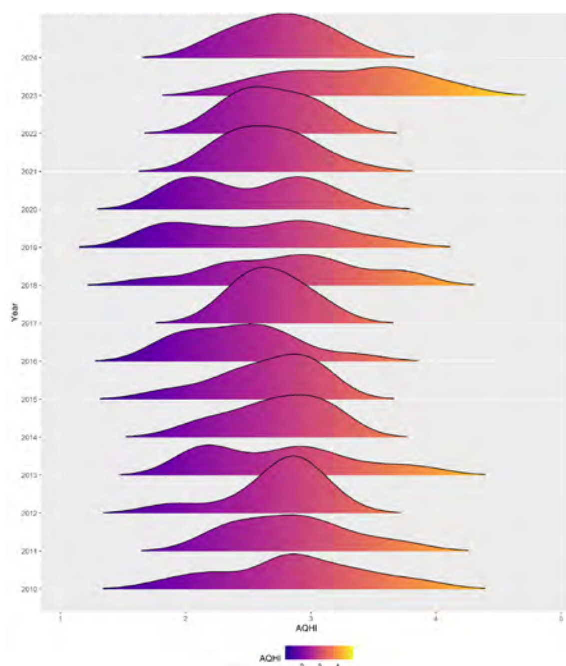


Figure 3.8: Annual ridge plots of monthly $PM_{2.5}$, NO_2, O_3, and AQHI in Edmonton, 2010–2024.

NO_2 trends revealed higher concentrations in earlier years, followed by a gradual decrease over time. This reduction aligns with the introduction of enhanced vehicular emission controls and industrial regulations, however no formal source attribution has been completed to confirm the specific cause of these reductions. The stabilization of NO_2 peaks around 10–20 ppb, along with reduced tail distributions in recent years, may reflect more consistent emission patterns from key sources.

O_3 levels, conversely, showed a slight increase over the study period, with broader and higher peaks in recent years. This trend is consistent with the photochemical dynamics of ozone, where reduced NO_2 emissions lead to less scavenging and therefore higher ozone formation. The broader spread of O_3 in some years may also indicate the compounded influence of summer wildfires, which contribute to higher ozone formation during peak sunlight months.

The AQHI distributions remained relatively stable across the years, with most values clustering at the lower end, indicating generally good air quality. However, recent years (2023–2024) displayed a modest shift towards higher AQHI values, correlating with the increased frequency and intensity of wildfire events. This trend highlights the episodic but significant impacts of extreme events on Edmonton's air quality, a critical consideration in the context of ongoing climate change.

3.3 Influence of Wildfire Smoke on Air Quality

Wildfire smoke contributes to poor air quality in the Edmonton region. To understand the relationship between wildfire smoke and general ambient air quality, this section first examines the correlation between wildfire smoke hours and the Air Quality Health Index (AQHI), followed by a historical analysis of smoke hour data from 1963 to 2024. Figure 3.9 shows a calendar plot of days with AQHI values greater than six in Edmonton, 2010–2024.

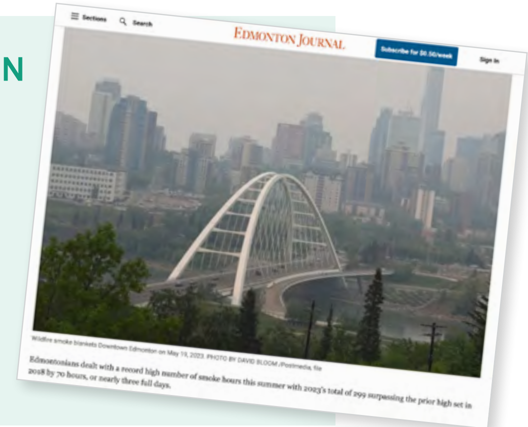
Wildfire smoke plays a pivotal role in shaping AQHI levels during the wildfire season.

To explore the relationship between wildfire smoke and air quality, the smoke hour data from 2010 to 2024 was correlated with AQHI values greater than six (indicating "high" or "very high" health risks) (Figure 3.10). The analysis revealed a strong seasonal overlap, with elevated AQHI values (7–10+) predominantly occurring during the same months as high smoke hour events, specifically from May to August. This seasonal alignment underscores the significant contribution of wildfire smoke to Edmonton's elevated AQHI levels during these months. Notably, the years 2018, 2021, 2023, and 2024 exhibited clusters of high smoke hours and corresponding spikes in AQHI values, further affirming the direct impact of wildfires on air quality.

2023: A YEAR OF POOR AIR QUALITY IN EDMONTON

In 2023, Edmonton experienced unprecedented levels of poor air quality, deterioration, making it the most severe year on record for short-term air pollution exposure:

- 34 days with AQHI greater than seven (high risk)
- 18 days with AQHI greater than 10 (very high risk)
- 24 smoke days, primarily attributed to regional wildfire activity



High AQHI values during winter months were not associated with smoke events but were instead linked to local emissions, such as NO_2 and $PM_{2.5}$ from urban sources, combined with poor atmospheric dispersion conditions due to temperature inversions. This distinction highlights the seasonal variability in AQHI drivers, with wildfire smoke dominating the summer months and urban emissions playing a more prominent role in winter.

AQHI 7 to 10+ in Edmonton

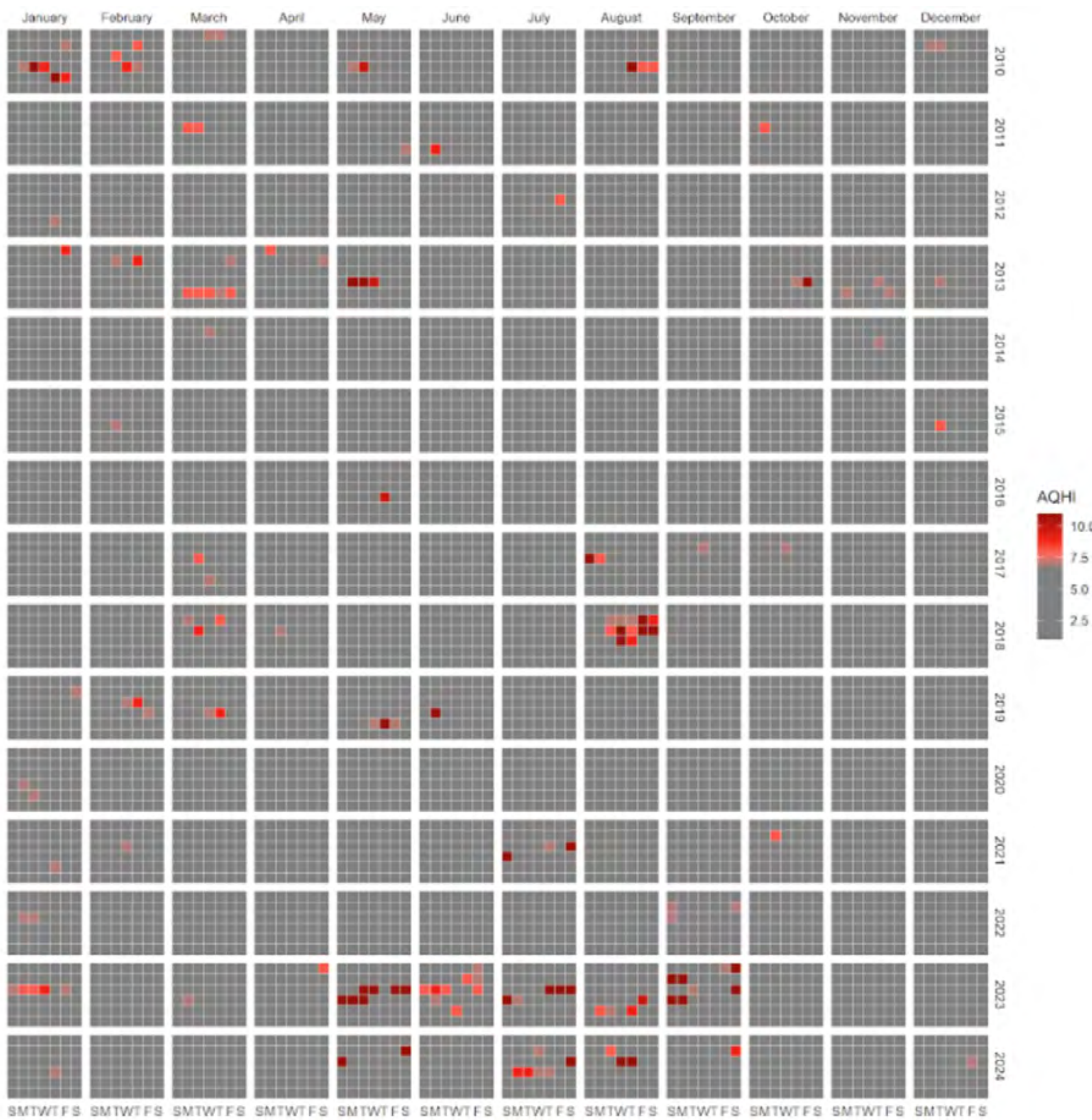


Figure 3.9: Calendar plot of days with AQHI values greater than six in Edmonton, 2010–2024.

A correlation analysis between smoke hours and elevated AQHI values (7–10+) yielded a correlation coefficient of 0.78 (Figure 3.10), suggesting a strong linear relationship between the presence of wildfire smoke and higher AQHI values. This result aligns with expectations, given the well-documented contribution of wildfire smoke to elevated $PM_{2.5}$ concentrations, which are a key driver of AQHI.

While the correlation does not imply causation, the findings strongly suggest that smoke is a significant factor in Edmonton's elevated AQHI levels during wildfire seasons. Further analysis of monthly data revealed strong positive correlations between smoke hours and elevated AQHI values during late spring, summer, and early fall (May—October). These months coincide with the peak wildfire season in Western Canada, reflecting the regional influence of wildfire activity on Edmonton's air quality. A further correlation analysis was conducted to identify counts of smoke hours and elevated AQHI hours (7–10+) (Figure 3.11).

Correlation Between Smoke Presence and AQHI Hours more than 6 in Edmonton

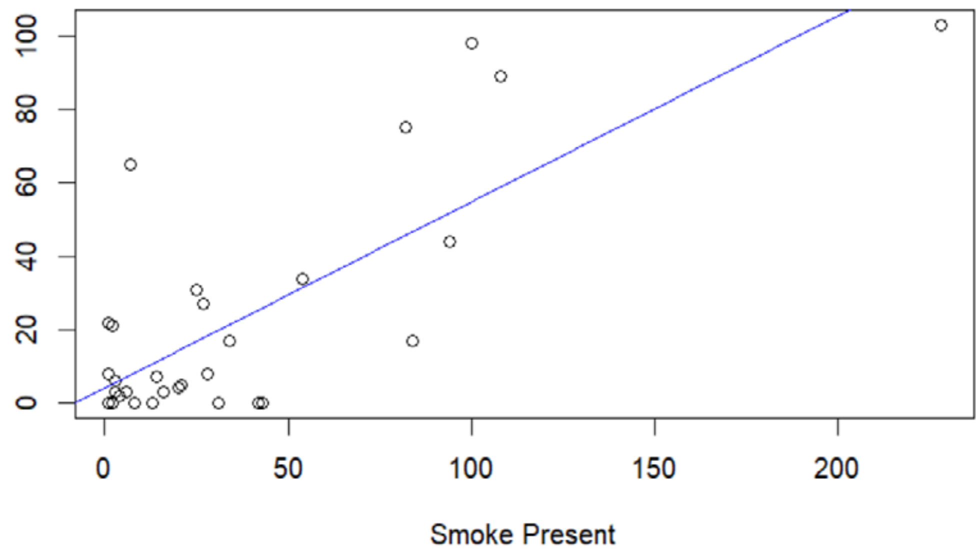


Figure 3.10: Correlation between smoke hours and elevated AQHI values in Edmonton.

Annual Comparison of Smoke Hours and AQHI Hours more than 6 in Edmonton

Figure 3.11: Annual comparison of smoke hours and elevated AQHI (greater than six) hours in Edmonton.

The monthly correlation analysis (Table 1) also highlighted some notable variations. Strong positive correlations were observed in May (0.902), July (0.778), August (0.835), September (0.993), and October (0.829), indicating that smoke presence during these months is closely associated with elevated AQHI values. These months also align with wildfire seasonality in Western Canada. In contrast, weak or negative correlations were observed in March (0.222) and June (-0.0843), suggesting that other pollution sources, such as local emissions, may dominate during these months. The absence of sufficient data for January, February, April, November, and December reflects the lack of significant wildfire activity during these months.

TABLE 1. Correlation analysis between monthly smoke hours and AQHI hours exceeding six in Edmonton.

MONTH	CORRELATION	NOTES
January	NA	no correlation
February	NA	no correlation
March	0.222	weak correlations
April	NA	no correlation
May	0.902	strong positive correlations, smoke and high AQHI
June	-0.0843	weak correlations
July	0.778	strong positive correlations, smoke and high AQHI
August	0.835	strong positive correlations, smoke and high AQHI
September	0.993	strong positive correlations, smoke and high AQHI
October	0.829	strong positive correlations, smoke and high AQHI
November	NA	no correlation
December	NA	no correlation

To provide historical context, calendar plots of smoke hours were analyzed for the period from 1963 to 2024 (Figure 3.12). These plots were split into four time periods to highlight changes in frequency and intensity over time: 1963–1978, 1979–1994, 1995–2009, and 2010–2024.

It is important to note that the smoke hour data is based on visual observations recorded by meteorological staff rather than direct instrument-based measurements. This distinction is essential when interpreting the data and its correlation with AQHI. Furthermore, the available data is dependent on the weather station and quality of the observations, therefore limited in coverage and only applicable to the point where the visibility observation was taken.

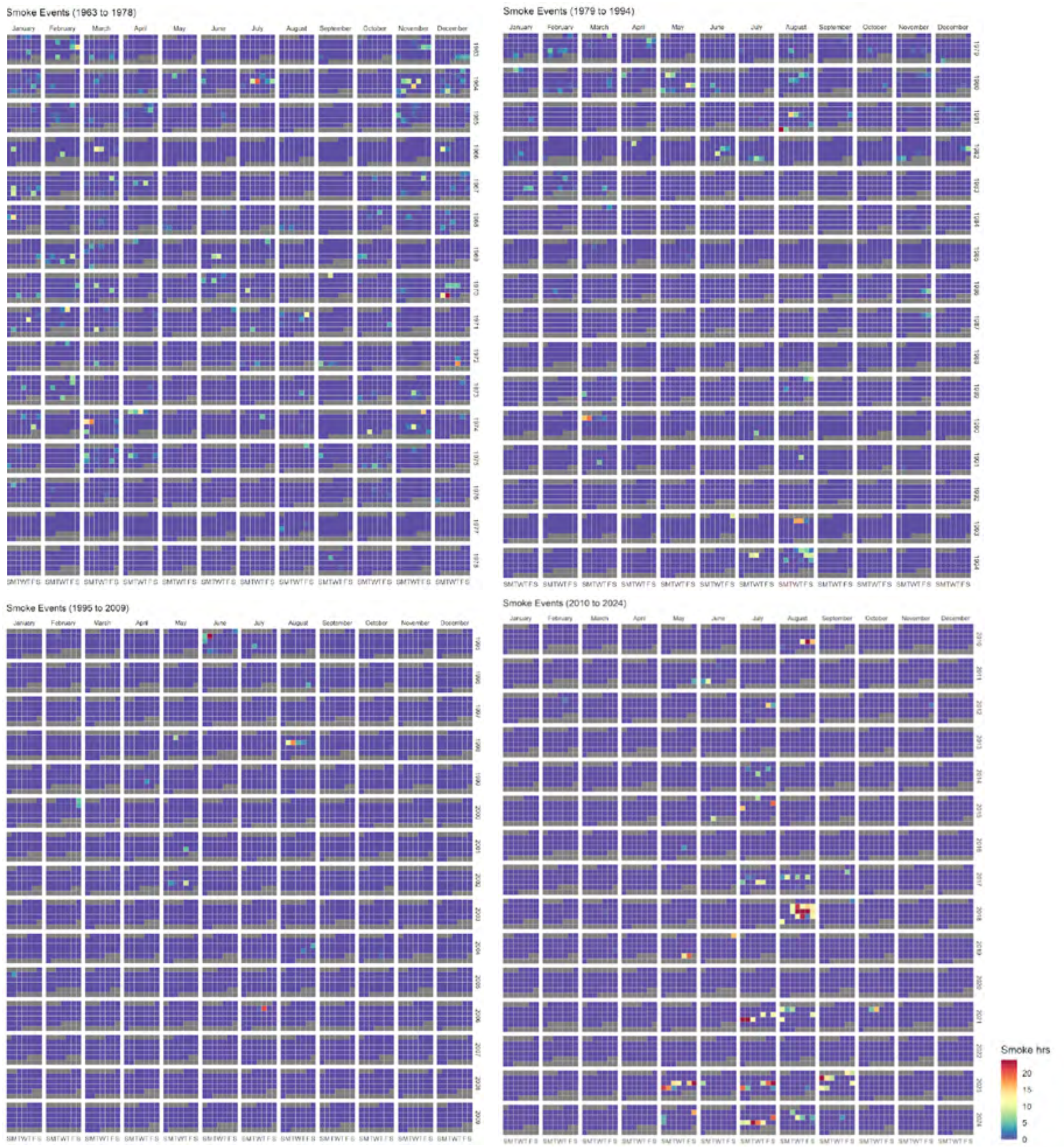


Figure 3.12: Calendar plots of smoke hours in Edmonton from 1963 to 2024.

From 1963 to 1978, smoke events appeared sporadically and of relatively low intensity, with fewer days experiencing high smoke hours. By the period of 1979 to 1994, smoke events showed a slight increase in both frequency and intensity, particularly during the late summer months of August. This pattern likely reflects the increasing occurrence of wildfires during this time. Between 1995 and 2009, smoke events were less frequent overall; however, isolated years with high-intensity smoke events emerged, primarily in July and August, suggesting specific notable wildfire years.

In the most recent period, from 2010 to 2024 (Figure 3.12), there is a noticeable increase in smoke hours, particularly during the wildfire season from June to August. This period also marks a shift in the wildfire season, with smoke events observed as early as May and as late as October in certain years. Key wildfire years, including 2018, 2021, 2023, and 2024, stand out due to prolonged and severe smoke hours, reflecting heightened wildfire activity across Western Canada. This sharp increase in smoke hours aligns with heightened wildfire activity across Western Canada, likely influenced by predicted climate change impacts, such as hotter, drier summers and an accumulation of fuel in the Boreal Forest, which amplify wildfire risks.

Overall, the analysis highlights the growing influence of wildfire smoke on Edmonton's air quality, with a strong seasonal and interannual variability driven by wildfire activity. The data illustrates that wildfire smoke plays a pivotal role in shaping AQHI levels during the wildfire season, with its impacts becoming increasingly pronounced in recent years due to climate change. This underscores the importance of targeted air quality management strategies and emergency response measures during wildfire-heavy periods to mitigate the health impacts of poor air quality in Edmonton.

3.4 Sources of Air Pollution

Understanding the sources of air pollutants is essential for effective air quality management. While ambient air quality measurements reflect pollutant concentrations in the atmosphere, they do not directly reveal the origin of those pollutants. In Edmonton, emissions result from a combination of local and regional human activities, with varying contributions depending on the pollutant and the time of year.

Although a complete, Edmonton-specific emissions inventory of all air pollutants is not yet available, this section identifies key emission sources using the best available spatial data, infrastructure maps, and broader provisional emission patterns along with relevant demographic and transportation metrics. The analysis includes both point sources—such as regulated industrial facilities—and nonpoint sources, which include vehicle traffic, residential heating, and wildfire smoke.

To explore point source emissions, a spatial map was developed including the locations of licensed emitters within Edmonton's municipal boundaries. These include facilities regulated under the Alberta Energy Regulator (AER), approval holders under the Environmental Protection and Enhancement Act (EPEA), and facilities required to report to the National Pollutant Release Inventory (NPRI). These stationary sources are associated primarily with industrial processes and represent significant contributors to gaseous pollutants such as nitrogen oxides (NO_x) and sulphur oxides (SO_x).

However, not all emissions come from stationary facilities. Nonpoint sources, such as transportation and home heating, are spread throughout the city and are harder to isolate. A road network map was developed using 2021 Census data (StatCan, 2022) to identify areas with high traffic volume. Vehicles are a known contributor to both nitrogen dioxide (NO_2) and fine particulate matter ($PM_{2.5}$), especially from exhaust and road dust.

Further insight into mobile source emissions was provided through the analysis of vehicle registration trends. A comparison of vehicle registrations in Edmonton from 2004 to 2023 indicates a rising trend over this period (Figure 3.13). This trend is juxtaposed with a gradual decline in measured NO_x concentrations over the same period. This observation suggests that although the number of vehicles has increased, improvements in fuel quality, cleaner engine technologies, and the implementation of stringent emissions standards for vehicles and engines may have contributed to controlling vehicle emissions (ECCC, 2017b). National analyses support this interpretation, indicating that the decline in NO_x emissions since 2000 is largely attributable to the progressive introduction of cleaner fuels and vehicle technologies (ECCC, 2023b).

Annual Trend of Vehicle Counts and Nitrogen Emissions in Edmonton

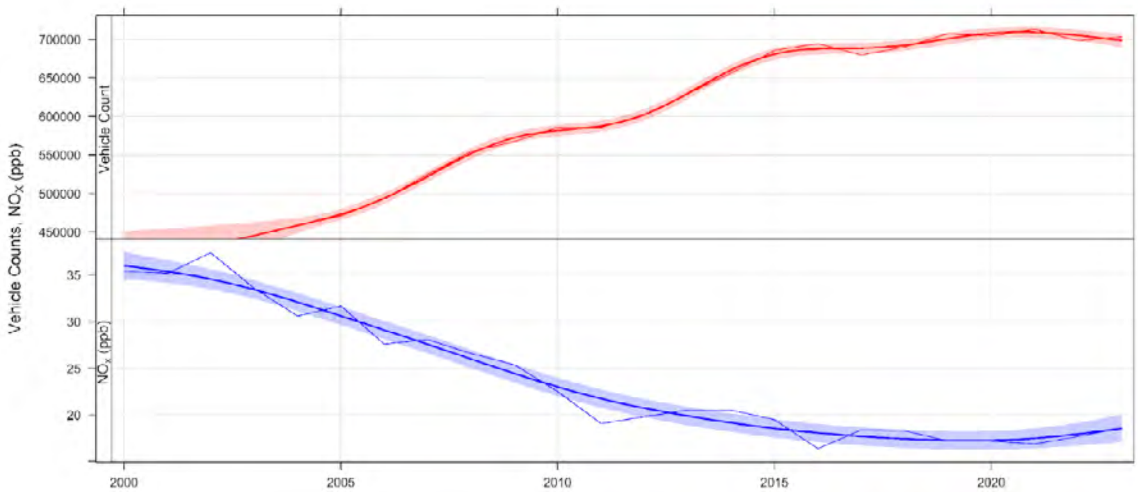


Figure 3.13: Annual trend in vehicle registrations and NO_x concentrations in the Edmonton region.

Population density also offers insights into other diffuse emissions, such as those from residential heating and daily commuting. Higher-density neighborhoods in the north, west, and south parts of Edmonton are associated with increased winter heating demand, which may contribute to localized emissions during colder months.

4.0 Precipitation in Edmonton

Annual and seasonal precipitation in Edmonton has declined over the past three decades, with a 14 per cent drop in annual average precipitation compared to the 1961–1990 baseline. Winter precipitation has decreased by 31 per cent, largely due to reduced snowfall, while summer and fall precipitation have declined by 15 per cent and 13 per cent respectively. This drying trend has increased the frequency of dry years and extreme dry spells, including longer consecutive dry days during the growing season. While extreme wet events still occur, the recent period has seen more years with below-average precipitation, raising concerns about drought risk and water resource pressures.

Precipitation, for the purpose of this report, is defined as any and all forms of water, liquid or solid, that falls from clouds and reaches the ground. This includes rain, freezing rain, drizzle, snow, ice pellets, and hail etc (ECCC, 2024a). Precipitation plays a critical role in Edmonton's environment, influencing water resources, agriculture, ecosystems, and infrastructure resilience. Understanding changes in precipitation patterns—both annual and seasonal—is essential for assessing potential risks such as droughts, floods, and shifting water availability (City of Edmonton, 2018). While this section focuses on long-term trends in total precipitation, the form precipitation takes (e.g., snow versus rain) also has important implications for water storage, runoff patterns, and drought resilience.

This section evaluates long-term and seasonal changes in precipitation across Edmonton, including changes in annual and seasonal totals, the frequency of extreme wet and dry events, and shifts in winter snowfall.

4.1 Annual Precipitation Trends

Substantial interannual variability is evident in Edmonton's annual precipitation from 1885 to 2024 (Figure 4.1). The inclusion of a 10-year moving average (black line) helps to smooth out the fluctuations in this interannual variability and reveals a downward trend in precipitation since the mid-1990s. Specifically, the moving average was generally above 400 mm between 1885 and the 1990s, but it has decreased in recent years, dropping below 400 mm. This reduction in precipitation could have important implications for water resources, agricultural practices, and the risk of drought in the Edmonton region.

Edmonton's 140-Year Annual Precipitation: 1885 – 2024

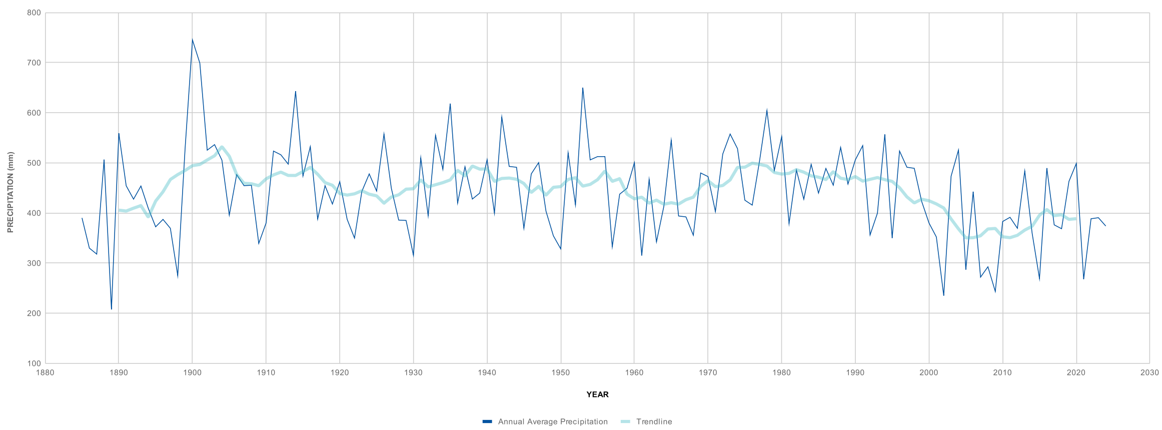


Figure 4.1: Annual average precipitation trend in Edmonton, 1885—2024.

The annual average precipitation departures in Edmonton, expressed as a percentage relative to the 1961—1990 reference value (461 mm) are presented in Figure 4.2. The green bars above the reference line represent years with precipitation exceeding the baseline, while the brown bars represent years with below-average precipitation.

Edmonton's 140-year precipitation data reveals interannual variability. Notably, in the last 25 years, only six years recorded above-average precipitation, while 19 fell below. Moreover, seven of the 12 driest years (defined as having precipitation 30 per cent below the baseline or less) have occurred in this recent period. 2002 and 2009 recorded the driest years since 1889, with annual precipitation around 240 mm, 45 per cent below the reference value.

Annual Average Precipitation Departures in Edmonton

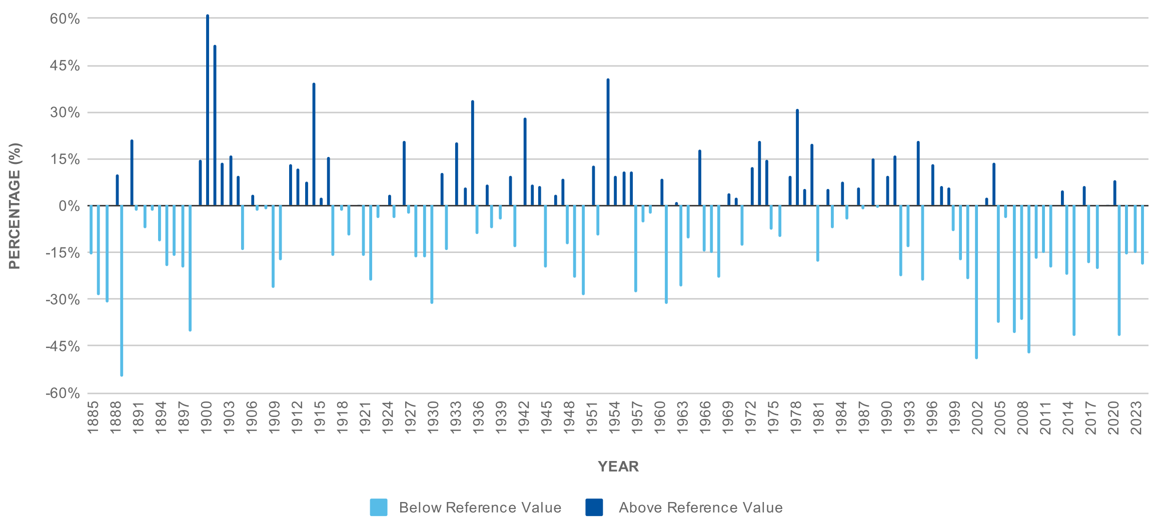


Figure 4.2: Annual average precipitation departures from the 1961–1990 baseline in Edmonton, 1885–2024.

4.2 Seasonal Precipitation Change

Seasonal precipitation patterns in Edmonton are essential to understand climate variability and long-term trends, with direct implications for water availability, agriculture, flood risks, and ecosystem health. Figure 4.3 shows average seasonal and annual precipitation across three periods: 1885–1960 (historical), 1961–1990 (baseline), and 1991–2024 (recent) in Edmonton.

Annual average precipitation remained relatively stable between the historical period (456 mm) and the 1961–1990 baseline (461 mm). However, in the most recent period (1991–2024), annual average precipitation declined to 397 mm, a 14 per cent decrease compared to the baseline. This decline suggests an increased risk of drought conditions and water stress in the region (AAFC, 2025).

Average Seasonal and Annual Precipitation in Edmonton for Three Time Periods

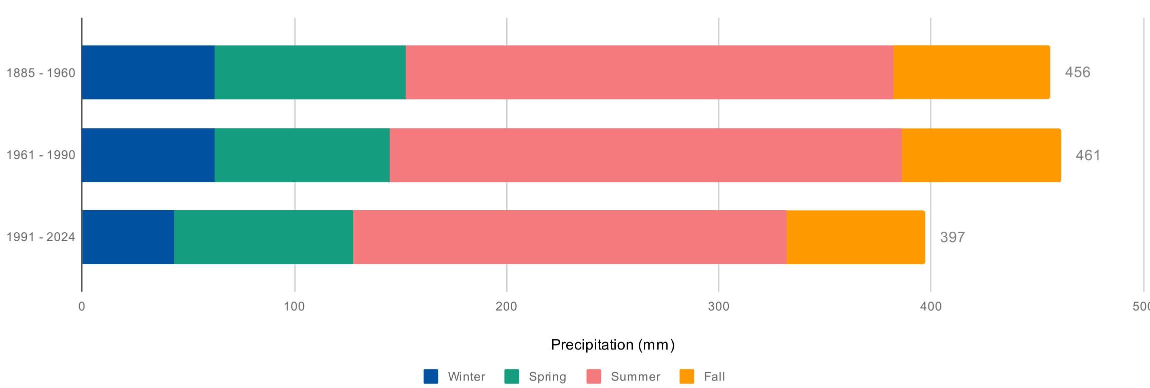


Figure 4.3: Average seasonal and annual precipitation for three periods (1885–1960, 1961–1990, and 1991–2024) in Edmonton.

The most pronounced decline in total precipitation has occurred during winter, with a 31 per cent decrease from the 1961–1990 baseline, largely due to reduced snowfall from warmer winters (Newton et al., 2021). Summer and fall precipitation have also declined by 15 per cent and 13 per cent, respectively, while spring precipitation has remained relatively stable. These seasonal shifts, likely influenced by climate variability and regional patterns, when combined with rising temperatures, considerably increase the risk of water shortages, severe drought, and wildfires.

Winter precipitation has decreased by 31 per cent from the 1961–1990 baseline.

Seasonal precipitation departures for Edmonton were analyzed from the 1961–1990 baseline over the long term (Figure 4.4). To calculate seasonal precipitation departures, monthly precipitation totals and normals were summed for each defined season: winter (December of the previous year, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November). Positive departures indicate wetter-than-average conditions, while negative values reflect drier-than-average seasons, compared to the baseline. This approach enables a season-by-season comparison of long-term trends relative to the historical norm.

Seasonal Average Precipitation Departures in Edmonton

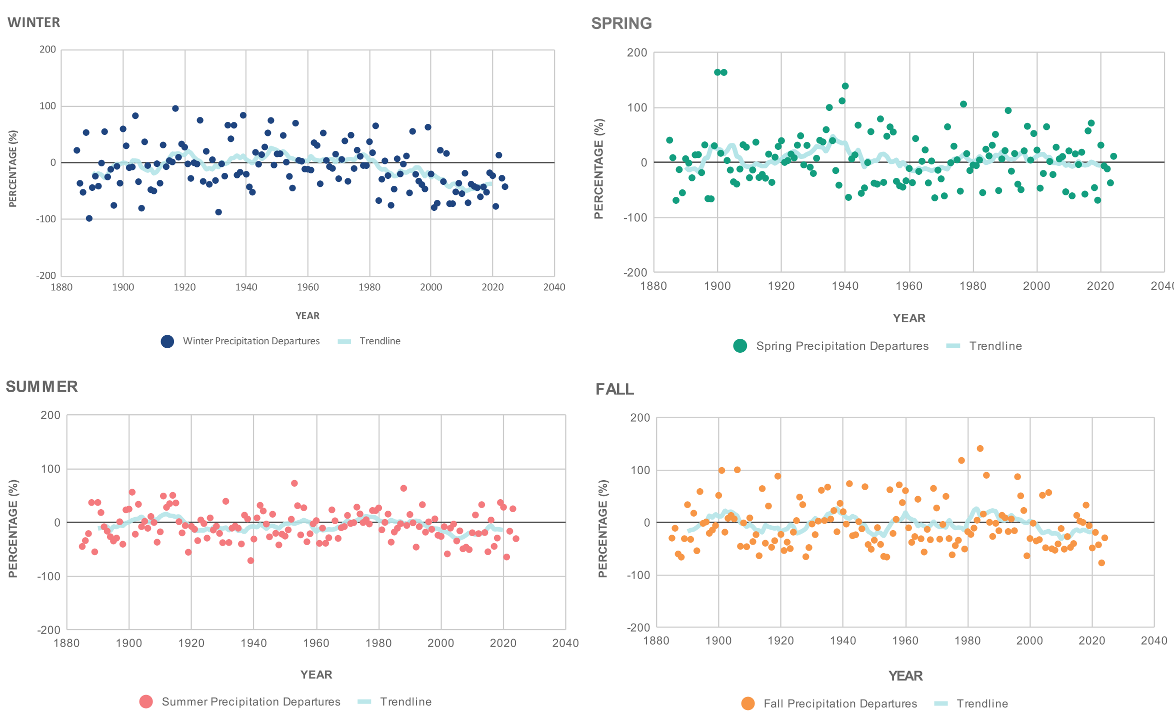


Figure 4.4: Seasonal average precipitation departures in Edmonton from the 1961–1990 baseline, 1885–2024.

Winter precipitation in Edmonton has shown a clear downward trend, with a 31 per cent decline from an average of 62 mm (1961–1990) to 43 mm (1991–2024). Notably, 22 of the past 25 winters were drier than the baseline, including six winters with precipitation at least 70 per cent below average.

Spring precipitation in Edmonton exhibits substantial year-to-year variability, ranging from under 30 mm to over 200 mm. Despite this wide range, average spring precipitation has remained close to the baseline, indicating no clear long-term trend for the season.

Edmonton's summers have become drier, with a 15 per cent reduction in average precipitation—from 241 mm (1961–1990) to 204 mm (1991–2024). This drying trend increases the risk of drought, wildfires, and increased stress on water resources. Furthermore, 19 of the last 25 summers were drier than the baseline period, and six of these rank among Edmonton's 10 driest summers on record.

2021 and 2002 stand out as the second and third driest summers, respectively.

Edmonton's fall precipitation has declined by 13 per cent—from 75 mm (1961–1990) to 65 mm (1991–2024). Seventy-six per cent of the past 25 falls were drier than average. 2023 was the driest fall on record, attributed to a prolonged summer and delayed onset of winter influenced by a strong El Niño (Amiri et al., 2024).

4.3 Extreme Precipitation Events

Precipitation plays a vital role in supporting human well-being and ecosystem health. Rainfall, snowfall, and snowmelt directly affect water availability for drinking, irrigation, and industrial use, while also influencing flood risk and habitat conditions. This section analyzes long-term trends in extreme precipitation events, focusing on three key indicators: wet days, maximum five-day precipitation, and consecutive dry days to examine extremely high and low precipitation events over the last 140 years.

4.3.1 WET DAYS AND HEAVY PRECIPITATION EVENTS

A wet day is defined in this report as a calendar day with at least 10 mm or more of precipitation (rain, sleet or snow). These heavy precipitation days can cause drainage problems, crop damage, and transportation disruptions.

Analysis shows that about 90 per cent of years between 1885 and 2024 recorded between five to 16 wet days annually (Figure 4.5). Wet days were more frequent in the early 20th century, particularly up to the 1940s, followed by a gradual decline from 1945 onward. The highest numbers of wet days in a year occurred in 1900 (23 days) and 1901 (19 days), while 1995 and 2009 each recorded just three wet days, the lowest on record.

Annual Number of Heavy Precipitation Days in Edmonton

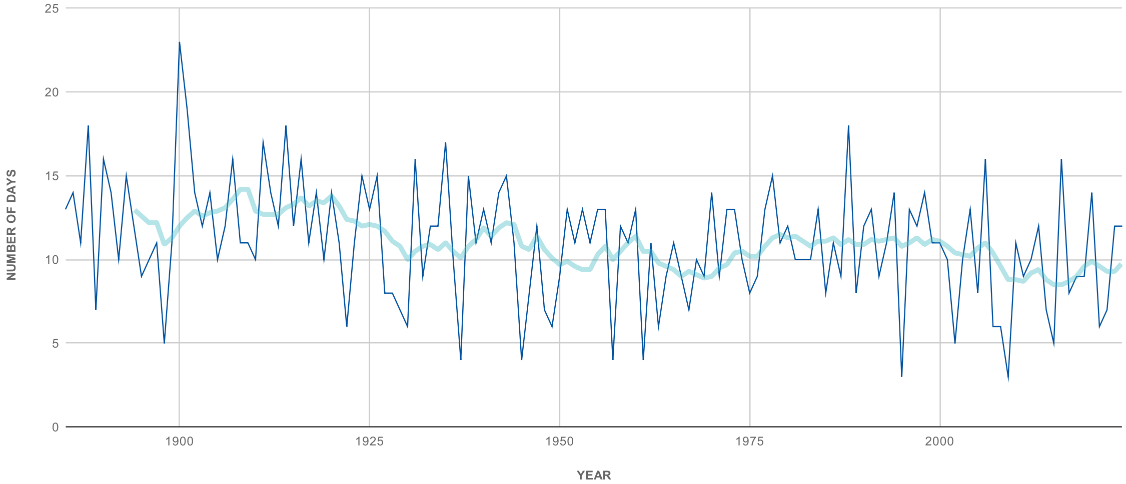


Figure 4.5: Annual number of heavy precipitation days (greater than or equal to 10mm) in Edmonton, 1885–2024.

The maximum five-day precipitation indicator measures the largest total precipitation recorded over any five consecutive days within a year. Figure 4.6 shows the yearly maximum five-day precipitation, along with a 10-year moving average line. The highest recorded five-day precipitation occurred in 1937 and 1953, both exceeding 150 mm and taking place in July.

Annual Maximum Five-Day Precipitation Totals in Edmonton

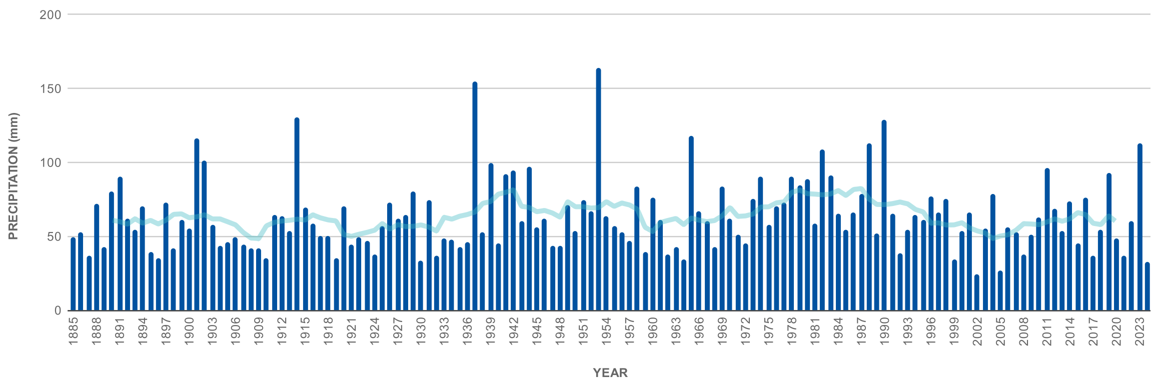


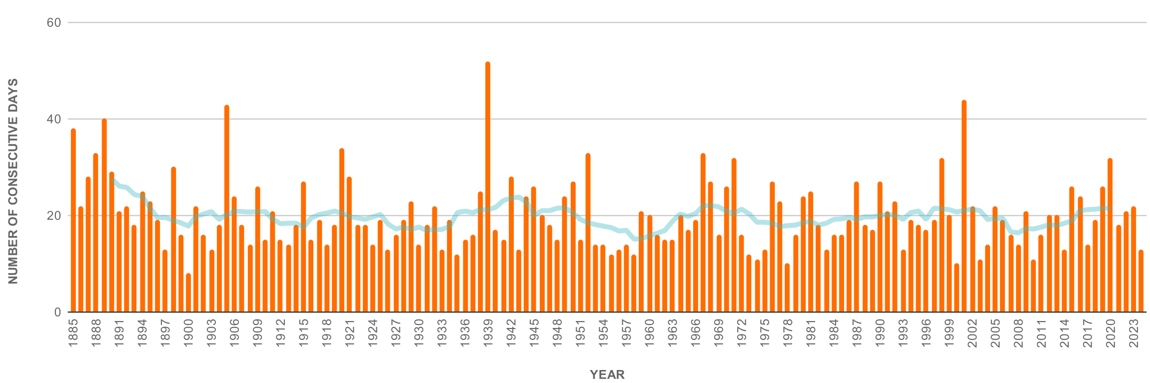
Figure 4.6: Annual maximum five-day precipitation totals in Edmonton, 1885–2024.

4.3.2 DRY DAYS

The maximum length of dry spell, also known as Consecutive Dry Days (CDD), represents the maximum number of consecutive days within a year during which daily precipitation is less than one mm (GoC, 2024). This analysis focuses on CDD values during the growing season, defined as April 1 to September 30 (Sushama et al., 2010), when prolonged dry periods can have considerable impacts on agriculture, ecosystems, and water resources.

Edmonton's longest growing-season dry spell occurred in 1939, lasting 52 consecutive days without significant precipitation from mid-July through September (Figure 4.7). The second-longest was in 2001, with 44 consecutive dry days from April to mid-May. Both substantially exceed the 1961–1990 baseline value of 19 days, underscoring the increasing potential for extended periods of water stress.

(a) Annual Maximum Consecutive Dry Days During the Growing Season in Edmonton



(b) Annual Number of Dry Spells Longer Than Five Days During the Growing Season in Edmonton

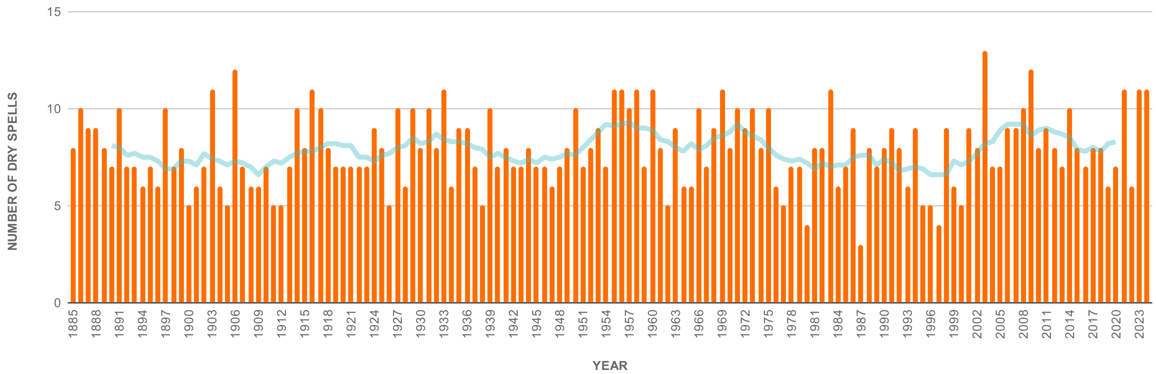


Figure 4.7: (a) Annual maximum consecutive dry days and (b) annual number of dry spells longer than five days during the growing season in Edmonton, 1885–2024.

Prolonged dry spells, defined here as six or more consecutive days with daily precipitation below one mm, have become increasingly common in recent years. Notably, 2003 experienced 13 such dry spells during the growing season alone (April 1 to September 30). In total, 15 years have recorded more than 10 extended dry spells, with five of these occurring in the most recent quarter-century.

This trend suggests an increasing likelihood of more frequent or prolonged dry periods, which may reduce the replenishment of soil moisture, surface water, and groundwater. Drought conditions can affect ecosystems and agriculture and may also increase the likelihood of forest fires.

References

AAFC. Agriculture and Agri-Food Canada. (2025). Canadian drought outlook. Retrieved March 31, 2025, from https://agriculture.canada.ca/en/agricultural-production/weather/canadian-drought-outlook

Amiri, A., Gumiere, S., & Bonakdari, H. (2024). White blanket, blue waters: Tracing El Niño footprints in Canada. International Journal of Applied Earth Observation and Geoinformation, 135, 104267. https://doi.org/10.1016/j.jag.2024.104267

Arias, P.A., N. Bellouin, E. Coppola, R.G. Jones, G. Krinner, J. Marotzke, V. Naik, M.D. Palmer, G.-K. Plattner, J. Rogelj, M. Rojas, J. Sillmann, T. Storelvmo, P.W. Thorne, B. Trewin, K. Achuta Rao, B. Adhikary, R.P. Allan, K. Armour, G. Bala, R. Barimalala, S. Berger, J.G. Canadell, C. Cassou, A. Cherchi, W. Collins, W.D. Collins, S.L. Connors, S. Corti, F. Cruz, F.J. Dentener, C. Dereczynski, A. Di Luca, A. Diongue Niang, F.J. Doblas-Reyes, A. Dosio, H. Douville, F. Engelbrecht, V. Eyring, E. Fischer, P. Forster, B. Fox-Kemper, J.S. Fuglestvedt, J.C. Fyfe, N.P. Gillett, L. Goldfarb, I. Gorodetskaya, J.M. Gutierrez, R. Hamdi, E. Hawkins, H.T. Hewitt, P. Hope, A.S. Islam, C. Jones, D.S. Kaufman, R.E. Kopp, Y. Kosaka, J. Kossin, S. Krakovska, J.-Y. Lee, J. Li, T. Mauritsen, T.K. Maycock, M. Meinshausen, S.-K. Min, P.M.S. Monteiro, T. Ngo-Duc, F. Otto, I. Pinto, A. Pirani, K. Raghavan, R. Ranasinghe, A.C. Ruane, L. Ruiz, J.-B. Sallée, B.H. Samset, S. Sathyendranath, S.I. Seneviratne, A.A. Sörensson, S. Szopa, I. Takayabu, A.-M. Tréguier, B. van den Hurk, R. Vautard, K. von Schuckmann, S. Zaehle, X. Zhang, and K. Zickfeld. (2021). Technical Summary. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 33-144, doi:10.1017/9781009157896.002

Bonsal, B. R., Shabbar, A., & Higuchi, K. (2001). Impacts of low-frequency variability modes on Canadian winter temperatures. International Journal of Climatology, 21(1), 95–108.

Bonsal, B., & Shabbar, A. (2011). Large-scale climate oscillations influencing Canada, 1900–2008. In Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 4. Canadian Councils of Resource Ministers.

Britannica. (2020). The Editors of Encyclopaedia Britannica. Temperature inversion. Encyclopedia Britannica. Retrieved April 1, 2025, from https://www.britannica.com/science/temperature-inversion

Brown, C., Duruisseau-Kuntz, R., Stanley, C., Tokarek, T., & Thi, A. (2025). Status of air quality in Alberta: Air zones report 2020–2022. Government of Alberta, Ministry of Environment and Protected Areas. https://open.alberta.ca/publications/alberta-air-zones-report

Bush, E., & Lemmen, D. S. (Eds.). (2019). Canada's changing climate report. Government of Canada. https://changingclimate.ca/CCCR2019/

C3S. Copernicus Climate Change Service. (2025). The 2024 Annual Climate Summary: Global Climate Highlights 2024. Retrieved March 26, 2025, from https://climate.copernicus.eu/global-climate-highlights-2024

C40 Cities. (2021). Why Cities Must 'Race to Zero'. Retrieved April 7, 2025, from https://www.c40.org/news/why-cities-must-race-to-zero/

CAC. Climate Atlas of Canada. (2025). Climate Variables. Prairie Climate Centre. Retrieved January 31, 2025, from https://climateatlas.ca/variables

CEIP. Clean Energy Improvement Program. (2025). Clean Energy Improvement Program (CEIP). Retrieved March 3, 2025, from https://www.edmonton.ca/city_government/environmental_stewardship/clean-energy-improvement-program-ceip

CER. Canada Energy Regulator. (2021). Market Snapshot: How the 2021 Summer Heat Dome Affected Electricity Demand in Western Canada. Retrieved March 30, 2025, from https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/market-snapshots/2021/market-snapshot-how-the-2021-summer-heat-dome-affected-electricity-demand-in-western-canada.html?=undefined&wbdisable=true

CER. Canada Energy Regulator. (2024). Provincial and Territorial Energy Profiles – Alberta. Retrieved April 7, 2025, from https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-alberta.html

Chen, Z., Lu, J., Chang, C. C., & et al. (2023). Projected increase in summer heat-dome-like stationary waves over Northwestern North America. npj Climate and Atmospheric Science, 6, 194. https://doi.org/10.1038/s41612-023-00511-2

City of Edmonton. (2018). Climate Resilient Edmonton: Adaptation Strategy and Action Plan. https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/climate-change-adaptation-strategy

City of Edmonton. (2020). The City Plan. https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/city-plan

City of Edmonton. (2021). Edmonton's Community Energy Transition Strategy and Action Plan. https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/energy-transition

City of Edmonton. (2022a). 2023–2026 Carbon Budget. https://www.edmonton.ca/sites/default/files/public-files/2023-2026CarbonBudget1.pdf

City of Edmonton. (2022b). Connected Edmonton: Strategic Plan 2019–2028. https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/connectedmonton

City of Edmonton. (2023). Corporate Business Plan 2023-2026. https://www.edmonton.ca/city_government/city_vision_and_strategic_plan/corporate-business-plan

City of Edmonton. (2024). Climate Strategies Annual Implementation Update 2024. https://www.edmonton.ca/city_government/facts_figures/videos-booklets-annual-report-environment

City of Edmonton. (2025). Change Homes for Climate. https://homes.changeforclimate.ca/

Climate Central. (2024). Lost winter: Above-freezing days added by climate change — Lost winter in Canada. Retrieved March 30, 2025, from https://www.climatecentral.org/report/lost-winter-days-2024

ClimateData.ca (2024a). Heat Waves and Climate Change. Retrieved March 6, 2025, from https://climatedata.ca/resource/heat-waves-and-climate-change/

ClimateData.ca. (2024b). All Variables. Retrieved March 6, 2025, from https://climatedata.ca/variable/

ClimateData.ca. (2024c). Cold snaps and Climate Change. Retrieved November 13, 2024, from https://climatedata.ca/resource/cold-snaps-and-climate-change/

ClimateData.ca. (2025a). Historical Weather Station Observations. Retrieved March 24, 2025, from https://climatedata.ca/resource/historical-weather-station-observations/

ClimateData.ca. (2025b). 2025 forecasted to rival 2024 for record-breaking heat. Retrieved March 27, 2025, from https://climatedata.ca/2025-forecasted-to-rival-2024-for-record-breaking-heat

Cohen, J., Francis, J. A., & Pfeiffer, K. (2024). Anomalous Arctic warming linked with severe winter weather in Northern Hemisphere continents. Communications Earth & Environment, 5, 557. https://doi.org/10.1038/s43247-024-01720-0

Duan, Y., Agrawal, S., Sanchez-Azofeifa, A., & Welegedara, N. (2024). Urban heat island effect in Canada: Insights from five major cities. SSRN. https://doi.org/10.2139/ssrn.4965331

ECCC and ClimateData.ca. (2025). Historical station data. Retrieved January 20, 2025, from https://climatedata.ca/download/#station-download

ECCC. Environment and Climate Change Canada. (2017a). About air quality. Government of Canada. Retrieved April 7, 2025, from https://www.canada.ca/en/environment-climate-change/services/air-pollution/research-science/about/air-quality-overview.html

ECCC. Environment and Climate Change Canada. (2017b). Canadian Environmental Protection Act: Fuel quality and vehicle and engine emissions. Government of Canada. Retrieved April 7, 2025, from https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/general-information/fact-sheets/fuel-quality-vehicle-engine-emissions.html

ECCC. Environment and Climate Change Canada. (2019). Canada's climate is warming twice as fast as global average. Government of Canada. https://www.canada.ca/en/environment-climate-change/news/2019/04/canadas-climate-is-warming-twice-as-fast-as-global-average.html

ECCC. Environment and Climate Change Canada. (2020). Climate change concepts. Government of Canada. Retrieved March 26, 2025, from https://www.canada.ca/en/environment-climate-change/services/climate-change/canadian-centre-climate-services/basics/concepts.html

ECCC. Environment and Climate Change Canada. (2023a). Emission reductions through greenhouse gas regulations — Environment and Climate Change Canada Report 5: Independent auditor's report. Government of Canada. https://www.oag-bvg.gc.ca/internet/docs/parl_cesd_202304_05_e.pdf

ECCC. Environment and Climate Change Canada. (2023b). Canadian Environmental Sustainability Indicators: Air pollutant emissions. Government of Canada. Retrieved April 7, 2025, from https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollutant-emissions.html

ECCC. Environment and Climate Change Canada. (2024a). Glossary. Government of Canada. Retrieved December 16, 2024, from https://climate.weather.gc.ca/glossary_e.html

ECCC. Environment and Climate Change Canada. (2024b). Canadian Environmental Sustainability Indicators: Greenhouse gas emissions. Government of Canada. Retrieved January 9, 2025, from https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html

ECCC. Environment and Climate Change Canada. (2024c). Canadian Environmental Sustainability Indicators: Temperature change in Canada. Government of Canada. https://www.canada.ca/content/dam/eccc/documents/pdf/cesindicators/temperature-change/2024/temperature-change-en.pdf

ECCC. Environment and Climate Change Canada. (2024d). Criteria for public weather alerts. Government of Canada. Retrieved April 7, 2025 from https://www.canada.ca/en/environment-climate-change/services/types-weather-forecasts-use/public/criteria-alerts.html

ECCC. Environment and Climate Change Canada. (2025a). National Inventory Report, 1990–2023: Greenhouse gas sources and sinks in Canada. Government of Canada. canada.ca/ghg-inventory

ECCC. Environment and Climate Change Canada. (2025b). Climate trends and variations bulletin – Annual 2024. Government of Canada. Retrieved April 7, 2025, from https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/climate-trends-variability/trends-variations/annual-2024-bulletin.html

ECCC. Environment and Climate Change Canada. (2025c). Canadian Environmental Sustainability Indicators: Extreme heat events. Government of Canada. Retrieved April 7, 2025, from www.canada.ca/en/environment-climate-change/services/environmental-indicators/extreme-heatevents.html

Ejiagha, I. R., Ahmed, M. R., Dewan, A., Gupta, A., Rangelova, E., & Hassan, Q. K. (2022). Urban warming of the two most populated cities in the Canadian province of Alberta, and its influencing factors. Sensors, 22(8), 2894. https://doi.org/10.3390/s22082894

Eum, H.-I., Fajardo, B., Tang, T., & Gupta, A. (2023). Potential changes in climate indices in Alberta under projected global warming of 1.5–5 °C. Journal of Hydrology: Regional Studies, 47, 101390. https://doi.org/10.1016/j.ejrh.2023.101390

GoA. Government of Alberta. (2025a). City of Edmonton Charter, 2018 Regulation. https://kings-printer.alberta.ca/documents/Regs/2018_039.pdf

GoA. Government of Alberta. (2025b). Condition of the environment – Air indicators. Retrieved March 30, 2025, from https://www.alberta.ca/condition-of-the-environment-air-indicators

GoA. Government of Alberta. (2025c). About the Air Quality Health Index. Retrieved March 30, 2025, from https://www.alberta.ca/about-the-air-quality-health-index

GoC. Government of Canada. (2024). Definitions of the core climate extreme indices (Climdex). Retrieved November 22, 2024, from https://climate-scenarios.canada.ca/?page=climdex-indices

Health Canada. (2024). Extreme heat. Government of Canada. Retrieved November 11, 2024, from https://www.canada.ca/en/health-canada/services/climate-change-health/extreme-heat.html

IPCC. Intergovernmental Panel on Climate Change. (2012). Glossary of terms. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564.

IPCC. Intergovernmental Panel on Climate Change. (2013). Climate change 2013: The physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M., Allen, S. K., Boschung, J., Nauels, A., Xia, Y., Bex, V., & Midgley, P. M. (Eds.)]. Cambridge University Press.

IPCC. Intergovernmental Panel on Climate Change. (2018). Annex I: Glossary [Matthews, J.B.R. (ed.)]. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 541-562, doi:10.1017/9781009157940.008.

IPCC. Intergovernmental Panel on Climate Change. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2391 pp. doi:10.1017/9781009157896.

IPCC. Intergovernmental Panel on Climate Change. (2022). Summary for Policymakers [P.R. Shukla, J. Skea, A. Reisinger, R. Slade, R. Fradera, M. Pathak, A. Al Khourdajie, M. Belkacemi, R. van Diemen, A. Hasija, G. Lisboa, S. Luz, J. Malley, D. McCollum, S. Some, P. Vyas, (eds.)]. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.001.

Khandekar, M. L. (2000). Trends and changes in extreme weather events: An assessment with focus on Alberta and Canadian Prairies. Alberta Environment.

Luqman, M., Rayner, P. J., & Gurney, K. R. (2023). On the impact of urbanisation on CO_2 emissions. npj Urban Sustainability, 3(6). https://doi.org/10.1038/s42949-023-00084-2

McCullum, K. (2025). Analysis of air quality in Edmonton. Consultant report prepared for the City of Edmonton on behalf of Alberta Capital Airshed.

Meredith, M., Sommerkorn, M., Cassotta, S., Derksen, C., Ekaykin, A., Hollowed, A., Kofinas, G., Mackintosh, A., Melbourne-Thomas, J., Muelbert, M. M. C., Ottersen, G., Pritchard, H., & Schuur, E. A. G. (2019). Polar regions. In H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, & N. M. Weyer (Eds.), IPCC special report on the ocean and cryosphere in a changing climate (pp. 203–320). https://www.ipcc.ch/srocc/

Miller, G. H., Lehman, S. J., Refsnider, K. A., Southon, J. R., & Zong, Y. (2013). Unprecedented recent summer warmth in Arctic Canada. Geophysical Research Letters, 40(23), 5745–5751. https://doi.org/10.1002/2013GL057188

Moran, J. M., & Morgan, M. D. (1997). Meteorology: The atmosphere and the science of weather (6th ed.). Prentice Hall.

NASA. National Aeronautics and Space Administration. (2024). Global temperature records: An overview. Goddard Institute for Space Studies (GISS). Retrieved December 29, 2024, from https://climate.nasa.gov/vital-signs/global-temperature/

NASA. National Aeronautics and Space Administration. (2025). Temperatures rising: NASA confirms 2024 warmest year on record. Retrieved January 20, 2025, from https://www.nasa.gov/news-release/temperatures-rising-nasa-confirms-2024-warmest-year-on-record/

Newton, B. W., Farjad, B., & Orwin, J. F. (2021). Spatial and temporal shifts in historic and future temperature and precipitation patterns related to snow accumulation and melt regimes in Alberta, Canada. Water, 13(8), 1013. https://doi.org/10.3390/w13081013

Oliver, J. E. (Ed.). (2005). Encyclopedia of world climatology. Springer. https://doi.org/10.1007/1-4020-3266-8

Overland, J. E., & Wang, M. (2019). Impact of the winter polar vortex on greater North America. International Journal of Climatology, 39, 5815–5821. https://doi.org/10.1002/joc.6174

Shabbar, A., & Khandekar, M. (1996). The impact of El Niño–Southern Oscillation on the temperature field over Canada. Atmosphere-Ocean, 34(2), 401–416.

StatCan. Statistics Canada. (2022). 2021 Census – Road network file. https://www12.statcan.gc.ca/census-recensement/2021/geo/sip-pis/rnf-frr/index2021-eng.cfm?year=21

Sushama, L., Khaliq, N., & Laprise, R. (2010). Dry spell characteristics over Canada in a changing climate as simulated by the Canadian RCM. Global and Planetary Change. 74(1), 1-14.

UNEP. United Nations Environment Programme. 2024. . Emissions Gap Report 2024: No more hot air ... please! With a massive gap between rhetoric and reality, countries draft new climate commitments. Nairobi. https://doi.org/10.59117/20.500.11822/46404

UNFCCC. United Nations Framework Convention on Climate Change. 1992. United Nations Framework Convention on Climate Change. https://unfccc.int/resource/docs/convkp/conveng.pdf

UNFCCC. United Nations Framework Convention on Climate Change. 2015. Paris Agreement. United Nations. https://unfccc.int/sites/default/files/english_paris_agreement.pdf

UNICEF. United Nations Children's Fund. (2024). The cooling dilemma amid climate change. Retrieved March 30, 2025, from https://www.unicef.org/innocenti/cooling-dilemma-amid-climate-change

Vincent, L. A., Zhang, X., Brown, R. D., Feng, Y., Mekis, É., Milewska, E. J., Wan, H., & Zhai, X. (2015). Observed trends in Canada's climate and influence of low-frequency variability modes. Journal of Climate, 28(11), 4545–4560.

Welegedara, N. P. Y., Agrawal, S. K., & Lotfi, G. (2023). Exploring spatiotemporal changes of the urban heat island effect in high-latitude cities at a neighbourhood level: A case of Edmonton, Canada. Sustainable Cities and Society, 90, 104403. https://doi.org/10.1016/j.scs.2023.104403

WHO. World Health Organization. (2024a). Heat and health. Retrieved March 30, 2025, from https://www.who.int/news-room/fact-sheets/detail/climate-change-heat-and-health

WHO. World Health Organization. (2024b). Ambient (outdoor) air pollution. Retrieved April 7, 2025, from https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

WMO. World Meteorological Organization. (2025). WMO confirms 2024 as warmest year on record at about 1.55°C above pre-industrial level. Retrieved March 22, 2025, from https://wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level

Wuebbles, D. J., Fahey, D. W., Hibbard, K. A., DeAngelo, B., Doherty, S., Hayhoe, K., Horton, R., Kossin, J. P., Taylor, P. C., Waple, A. M., & Yohe, C. P. (2017). Executive summary. In Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program. https://doi.org/10.7930/J0DJ5CTG

Zhao, L., Oppenheimer, M., Zhu, Q., Baldwin, J. W., Ebi, K. L., Bou-Zeid, E., Guan, K., & Liu, X. (2018). Interactions between urban heat islands and heat waves. Environmental Research Letters, 13(3), 034003. https://doi.org/10.1088/1748-9326/aa9f73

Appendix: Foundations Behind Understanding Edmonton's Changing Climate

Rationale and Scope

This appendix establishes the foundational context for Understanding Edmonton's Changing Climate by situating the assessment within the broader landscape of global and regional climate change, local and national policy responses, and the history of climate science in the Edmonton region. It introduces key concepts and methods pertinent to understanding Edmonton's climate, recent developments in local and regional climate science, and the general approach used to understand Edmonton's historical climate conditions. Together, these components provide a comprehensive background for understanding the specific climate challenges and opportunities facing the Edmonton region.

Foundations of Climate Science

This report evaluates existing scientific evidence relevant to a rapidly changing climate system, recognized internationally by leading scientists as predominantly influenced by human activities (IPCC, 2021). The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body responsible for assessing the science related to climate change. Its reports are widely regarded as the most comprehensive and authoritative sources of climate science, developed through contributions from thousands of leading experts across the globe and subject to rigorous peer review. These reports provide regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation. They also serve as a key input into international climate change negotiations.

Further, sustained changes across all major components of the climate system, including the atmosphere, land, and biosphere, are documented and widely available as evidence-based information from peer-reviewed research and leading climate organizations.

Edmonton's Climate in a Global Climate Context

Multiple lines of evidence — including the understanding of climate processes, paleoclimate reconstructions using ice cores and tree rings, instrumental records, and satellite observations — indicate that the recent large-scale global climatic changes are unprecedented in the context of human history (IPCC, 2021). For Edmonton, these changes have the potential to present long-term

challenges, including shifts in seasonal patterns, impacts on water resources, and increased risks from extreme events. The city is already experiencing climate shifts consistent with global trends, such as rising temperatures, altered precipitation patterns, and an increase in the frequency and intensity of extreme weather events. These changes, both gradual trends and acute events, have far-reaching implications across multiple systems. Shifting climate conditions are already affecting City operations, infrastructure, and service levels, while also posing growing risks to public health, ecosystems, and the local economy.

As global temperatures continue to rise, the decisions the City of Edmonton makes today about how the city is planned, built, and operated will define its resilience in the decades ahead. Climate pressures will place increasing strain on city assets such as buildings, roads, parks, and transportation networks, and challenge the delivery of essential services. Proactive, locally driven climate action can strengthen resilience, support economic growth, and improve the quality of life for Edmontonians.

Key Definitions of Climate Change and Related Terms

For the purpose of this report, climate refers to the long-term statistical description of weather patterns—specifically the average, variability, and extremes of key atmospheric variables such as temperature and precipitation. Unlike weather, which changes over short timescales (hours or days), climate reflects conditions observed over much longer periods, typically 30 years or more.

CLIMATE CHANGE

Climate change, as used in this report, refers to long-term changes in weather patterns—for example, an increase or decrease in extreme weather events such as hurricanes, droughts, or floods—occurring over time frames ranging from decades to millions of years.

This framing aligns with both national and international definitions. Environment and Climate Change Canada (ECCC) describes climate as "the historical record and description of average daily and seasonal weather events that help describe a region," with statistics "generally drawn over several decades" (ECCC, 2024a). The IPCC defines climate more technically as "the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years" (IPCC, 2018).

The IPCC defines climate change as "a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer" (IPCC, 2021). According to the IPCC, climate change can result from both natural processes such as solar cycles and volcanic eruptions, and human activities. Similarly, Environment and Climate Change Canada (ECCC) defines climate change as "a long-term shift in the average weather conditions of a region, such as its typical temperature, rainfall, and windiness" (ECCC, 2020).

The United Nations Framework Convention on Climate Change (UNFCCC) uses a narrower definition that attributes climate change specifically to human activity: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere" distinguishing it from natural climate variability (UNFCCC, 1992). In this report, the broader definitions from IPCC and ECCC are used to represent the full range of long-term shifts in climate patterns driven by both natural systems and human influence.

In addition to defining climate and climate change, this report also refers to several related concepts that are central to climate science and policy. Mitigation refers to efforts that aim to slow the pace of climate change by reducing or preventing the release of greenhouse gases into the atmosphere. These actions include transitioning to renewable energy, improving energy efficiency, and protecting carbon-absorbing ecosystems like forests and wetlands. Adaptation focuses on reducing the risks and negative impacts associated with climate change while embracing potential opportunities. It enables communities and ecosystems to prepare for and adjust to new climate conditions, such as increased flooding or prolonged heat waves. Resilience refers to the capacity of systems—natural, human, or built—to survive and thrive under changing conditions, maintaining essential functions in the face of disruptions brought about by climate impacts. Together, these approaches represent interconnected strategies to address both the causes and consequences of a changing climate.

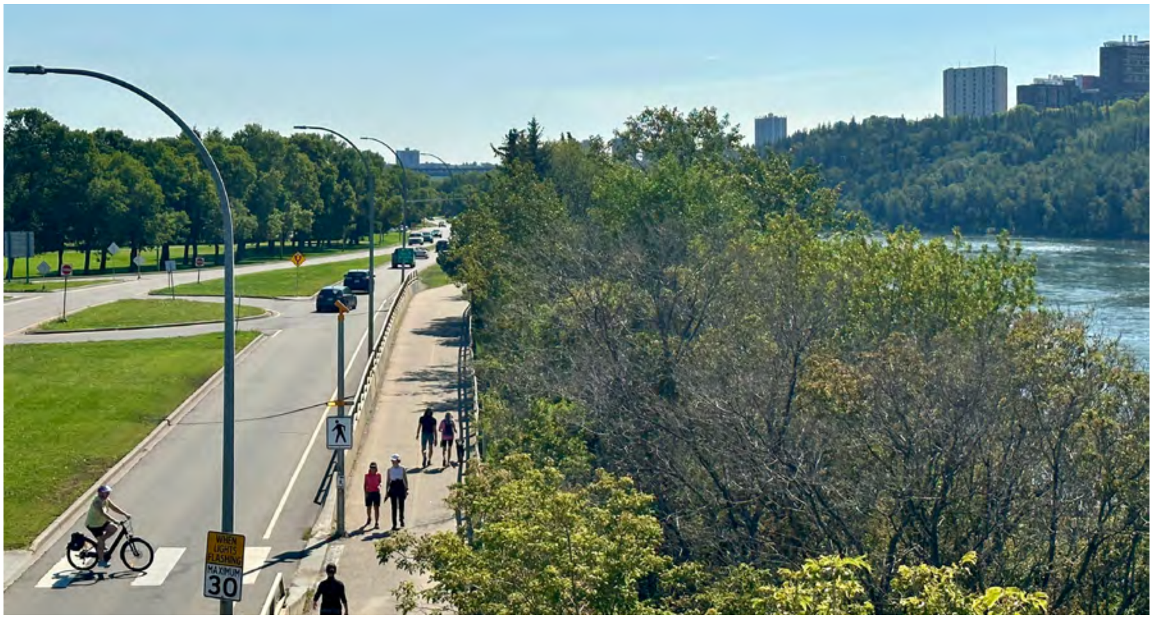
GLOBAL AGREEMENTS AND WARMING THRESHOLDS

The Paris Agreement, a legally binding international treaty on climate change adopted in 2015, established long-term objectives to keep the global average temperature rise well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels (UNFCCC, 2015). The Agreement commits participating countries to reduce greenhouse gas (GHG) emissions and adapt to climate change impacts, while encouraging nations to develop and communicate long-term low GHG emission development strategies. These temperature thresholds—2°C and 1.5°C—are informed by scientific evidence, including findings from the IPCC Sixth Assessment Report (AR6), which indicates that exceeding 2°C could lead to irreversible climate impacts—such as intensified heat waves, rising sea levels, and more frequent extreme weather events. The urgency of climate action cannot be overstated; every fraction of a degree matters, and changes in extremes and risks become larger with each increment of warming. Limiting global warming to below 1.5°C is expected to substantially reduce the risks from a changing climate, reducing costly losses and damages to infrastructure, livelihoods, and natural resources, and safeguarding the function of essential natural ecosystems (IPCC, 2021). Additionally, the Agreement seeks to achieve 'a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century' (UNFCCC, 2015).

Understanding these global thresholds is crucial, as they guide international climate policies, impact global security, and inform risk assessments across multiple sectors, including insurance, infrastructure planning, and market stability. However, meeting the commitments of the Paris Agreement remains challenging, and current global efforts are insufficient to avoid the most severe climate risks (UNEP, 2024). Notably, the past decade has seen an extraordinary streak of record-breaking temperatures, with each of the last ten years ranking among the warmest on record. In 2024, the global average temperature exceeded 1.5°C above pre-industrial levels for the first full calendar year, with average temperatures temporarily reaching 1.55°C to 1.60°C above pre-industrial levels (NASA, 2025; WMO, 2025; C3S, 2025). This marks a critical climate signal, emphasizing the need for urgent and collective global action. While short-term climate patterns such as the El Niño Southern Oscillation (ENSO) may influence year-to-year variability, human-induced climate change remains the dominant driver of long-term warming and the increasing frequency of extreme air and sea surface temperatures (C3S, 2025).

Projections suggest that even if all existing commitments made by countries under the Paris Agreement are fulfilled, global temperatures could rise by approximately 2.6°C by the end of the century (UNEP, 2024). This trajectory points toward more severe climate impacts, including intensified heat waves, rising sea levels, and increased frequency of extreme weather events. As temperatures rise further, the risks do not simply scale linearly, higher levels of warming introduce greater uncertainty, including the potential for cascading effects, such as the release of stored carbon from permafrost or forests. These processes could accelerate warming even further and trigger long-term, irreversible changes to the climate system (Bush and Lemmen, 2019). Many of these changes, once reached, would be effectively locked in for centuries (IPCC, 2021), making the window for meaningful intervention both narrow and urgent.

The IPCC emphasizes that limiting warming to 1.5°C requires global GHG emissions to peak before 2025 and then decline by 43 per cent by 2030, reaching net-zero around 2050 (IPCC, 2022).



Achieving this target demands not just a long-term vision, but continuous and progressing reductions. These reductions must occur alongside rapid and far-reaching transitions in energy production, land use, urban infrastructure, and industrial systems. Delaying action not only makes the transition more costly and difficult, but also allows the problem to grow larger and more challenging to solve.

While setting a 2050 net-zero target is important, it must be matched with near-term action. Global climate models already illustrate what kinds of emissions reductions are needed across all major sectors to limit warming. These scenarios identify the timing and scale of changes required — showing that emissions must peak immediately and decline rapidly to stay within the 1.5°C limit. Delays compress the timeline, increasing costs, technological hurdles, and social disruption. The longer emissions continue to rise, the harder it becomes to reach net-zero by 2050 without relying on uncertain or risky technologies.

Furthermore, delaying implementation increases the risk of crossing critical tipping points—thresholds in the climate system that, once passed, could trigger widespread and potentially irreversible impacts on both human societies and natural ecosystems.

CANADA'S CLIMATE COMMITMENTS AND ALBERTA'S ROLE

Canada, as a signatory to the Paris Agreement, submitted its Nationally Determined Contribution (NDC) in 2021, committing to reduce GHG emissions by 40–45 per cent below 2005 levels by 2030 (ECCC, 2025a). This represents a more ambitious target compared to the previous goal of a 30 per cent reduction by 2030 (ECCC, 2023a). This shift reflects growing recognition that global and national emissions reductions were not occurring at the pace required to limit warming to 1.5°C. Both the IPCC's Sixth Assessment Report (AR6) and Canada's National Inventory Report underscore this gap, highlighting the need for deeper and faster cuts (IPCC, 2021; ECCC, 2025a).

The updated target aims to recover lost ground and align with scientific guidance on the reductions required to reach net-zero emissions by 2050.

Canada has also set a long-term goal of achieving net-zero emissions by 2050, meaning that GHG emissions will be balanced by their removal from the atmosphere (ECCC, 2025a). However, the country faces a unique set of challenges in meeting its emissions targets. These include a strong economic reliance on fossil fuel extraction and production, a vast landmass and dispersed population that increase transportation and infrastructure demands, and a cold climate that drives higher energy use for heating. In addition, energy-intensive sectors such as mining and forestry remain vital to Canada's economy, making a swift transition more complex and costly.

Alberta, as a leading energy-producing province, plays a key role in Canada's emissions profile. While the oil and gas sector remains a major contributor to both the provincial economy and national greenhouse gas emissions (ECCC, 2024b), Alberta has made important strides in other areas. Notably, the province has completed a near-total phase-out of coal-fired electricity generation, resulting in significant emissions reductions from the power sector (CER, 2024). This example highlights both the complexities and opportunities in transitioning toward a lower-carbon economy in fossil fuel-dependent regions.

CITY OF EDMONTON'S ROLE IN CLIMATE ACTION

As the governing body of a rapidly growing metropolitan centre, the City of Edmonton plays a critical role in addressing climate change through both mitigation and adaptation. While climate action requires coordination across all levels of government, municipalities are uniquely positioned to implement effective, localized solutions. Globally, cities account for over 70 per cent of energy-related CO_2 emissions (Luqman et al., 2023), and urban areas—due to dense populations, concentrated infrastructure, and systemic inequalities—are especially vulnerable to climate impacts. At the same time, cities represent one of the greatest opportunities for climate leadership (C40 Cities, 2021).

The City of Edmonton has taken bold steps to lead on climate. It was one of the first municipalities in Canada to implement a carbon budget, directly linking municipal planning and spending to greenhouse gas reduction targets (City of Edmonton, 2022a). Initiatives such as the Clean Energy Improvement Program (CEIP, 2025) and Neighbouring for Climate have been recognized nationally for advancing community-scale climate action. The City has also invested in renewable energy, supported building retrofits, and integrated climate goals into key plans like The City Plan and the Community Energy Transition Strategy (City of Edmonton, 2024).

These efforts have been made possible by the ongoing support of the City Council, which has championed ambitious climate action through strategic funding, fostering partnerships, and enabling transformative policy development. Edmonton's approach is rooted in both local priorities and alignment with national and global emissions reduction targets, reinforcing the city's role as a climate leader in Canada.

Edmonton's climate strategies reflect this alignment. Edmonton's Community Energy Transition Strategy and Action Plan (City of Edmonton, 2021) and Climate Resilient Edmonton: Adaptation Strategy and Action Plan (City of Edmonton, 2018) integrate both global commitments and local priorities (i.e. contributing to Canada's federal climate commitments through local action). This multi-level governance approach ensures Edmonton's policies contribute to broader climate goals while addressing specific local risks such as urban heat islands, extreme weather events, and water scarcity.

Edmonton's Community Energy Transition Strategy and Action Plan, approved by City Council in April 2021, outlines several targets, including reducing community GHG emissions by 35 per cent by 2025 (relative to 2005 levels), 50 per cent by 2030, and achieving an emissions neutral community by 2050. The strategy also includes a target to achieve an emissions neutral corporation by 2040, ten years ahead of the community target. The strategy provides four main pathways for achieving these targets, including:

1. Renewable and Resilient Energy Transition
2. Low Carbon City and Transportation
3. Emissions Neutral Buildings
4. Nature Based Solutions and Carbon Capture

The Climate Resilient Edmonton: Adaptation Strategy and Action Plan, approved by City Council in December 2020, focuses on helping the city respond to the impacts of climate change and protect the community, infrastructure, and services. The Adaptation Strategy outlines the climate science and projections, identifies impacts and opportunities, and provides five pathways towards a climate resilient Edmonton:

1. Science and Evidence Based Decisions
2. Preparing for Changing Temperatures
3. Preparing for Changing Precipitation
4. Preparing for Changing Weather Extremes
5. Preparing for Changing Ecosystems

These strategies meet the requirements of the City of Edmonton Charter, 2018 Regulation (GoA, 2025a), which mandates both mitigation and adaptation plans. They also align with the strategic goal of Climate Resilience in ConnectEdmonton (City of Edmonton, 2022b), the Big City Move of Greener as we Grow in The City Plan (City of Edmonton, 2020), and Council's priority of Climate Action and Energy Transition as outlined in the Corporate Business Plan 2023–2026 (City of Edmonton, 2023).

To implement its climate-related policies—including C627 Climate Resilience Policy, which establishes clear governance and accountability for achieving a climate-resilient community and signals the City's leadership in climate solutions— the city has launched several key initiatives. These include expanding renewable energy integration, developing climate-resilient infrastructure, and fostering community-led sustainability programs (CEIP, 2025; City of Edmonton, 2025). By embedding scientific assessments into decision-making, the City ensures that its climate strategies remain evidence-based and adaptable to emerging challenges such as increased extreme weather events, shifting precipitation patterns, and rising temperatures.

Climate change is already influencing Edmonton's weather patterns, environmental conditions, economic stability, and public health. Without substantial global efforts to reduce GHG emissions, these impacts will persist and intensify, posing significant challenges for the city's resilience and sustainability. However, the City of Edmonton remains well-positioned to lead through innovative policies, building resilient infrastructure, and active community engagement. By aligning local climate action with national and global objectives, the City of Edmonton not only strengthens local resilience but also contributes meaningfully to broader efforts to address climate change (City of Edmonton, 2018).

In Edmonton, the development and communication of climate information are influenced by local values, including a strong sense of community, a commitment to environmental stewardship, and economic considerations tied to the region's dependence on oil and gas development and related industries. These values, as reflected in The City Plan (City of Edmonton, 2020) and Connect Edmonton (City of Edmonton, 2022b), shape how climate information is best conveyed. Effective climate communication must therefore be accessible, accurate, and locally relevant—addressing misconceptions, providing clear evidence, and engaging diverse audiences.

Methodology Used across the Report

This assessment of Edmonton's climate draws on a variety of high-quality data sources and analytical approaches to provide an accurate and comprehensive understanding of the local climate system. It synthesizes multiple lines of evidence—including observational records, reanalysis datasets, and peer-reviewed scientific literature focused on regional climate patterns—to establish a credible scientific foundation.

Advancements in climate observation technologies, combined with the extensive data collection efforts by ECCC, have significantly enhanced the ability to monitor local weather and climate. ECCC provides high-resolution data from local monitoring networks, including weather stations that track temperature, precipitation, and other atmospheric variables. Remote sensing systems and ECCC's extensive datasets support a robust understanding of Edmonton's climate, despite some limitations such as occasional gaps in data continuity and the impacts of recent global disruptions on monitoring systems (ClimateData.ca, 2025a).

Reanalysis datasets combine historical observations with climate models to create a comprehensive record of past climate conditions. For Edmonton, ECCC's historical climate data serves as a foundational input to these reanalyses, enabling consistent, spatially complete depictions of climate trends and variability. This approach helps fill observational gaps and improves the accuracy of modeled representations of Edmonton's historical climate.

In this report, the analysis of Edmonton's annual temperature and precipitation trends from 1885 to 2024 is based primarily on historical observations from weather stations located in the Edmonton City Centre and Blatchford area. To address gaps in the historical record and ensure continuity, supplementary data from other nearby stations—Edmonton Blatchford, Edmonton South Campus, and Edmonton Namao—were incorporated as needed. These datasets were carefully combined to construct a continuous and reliable long-term climate record. The data were sourced from ECCC through ClimateData.ca (ECCC and ClimateData.ca, 2025).

By integrating observational data, reanalysis tools, and scientific literature, this report provides a detailed and locally relevant assessment of Edmonton's historical climate. This information is essential for guiding local decision-making and policy development within the limits of municipal authority.

The data used throughout this report is drawn from reputable sources, including:

- Observational Records: Historical data from ECCC which includes regional weather stations used to assess long-term climate trends.
- Reanalysis Data[1]: Reconstructed datasets that merge observations with models to improve continuity and completeness.
- Attribution Studies: Scientific methods used to determine the extent to which human activities have contributed to observed climate trends in Edmonton.

This report takes inspiration from the structure and methodology of major international climate assessments—particularly the Intergovernmental Panel on Climate Change's Climate Change 2021: The Physical Science Basis (IPCC, 2021)—while tailoring the approach to Edmonton's unique environmental and socioeconomic context.

By bridging global scientific knowledge with local priorities, this assessment offers findings relevant to local policymakers, interested parties, and the public. Findings are grounded in traceable evidence, supported by clearly cited sources throughout the report.

1. Reanalysis data are long-term records of weather and ocean conditions—like temperature, wind, and ocean currents—created by combining past observations with modern weather forecasting models. These records use the same method throughout time to keep the data consistent. While this approach improves continuity, the data can still be affected by changes in how and where measurements were taken over the years (IPCC, 2012).

Understanding Edmonton's Changing Climate 2025:

Observed Climate Trends