

Weather, Impacts and Trends in 2023:

Report for the City of London

Dr. David Sills, Dr. James Voogt and Dr. Gregory Kopp
Western University, London, Ontario, Canada

30 Nov 2023

Executive Summary

This brief report was undertaken to assist the City of London in further implementing their Climate Emergency Action Plan. It describes notable severe and extreme weather-related events that occurred in 2023 in the local, provincial, national and global contexts (up to the end of November). The report also attempts to put these events into historical context and discusses available trend information.

The year 2023 was the warmest on record globally, accompanied by the warmest July on record globally and record wildfires across Canada in terms of area burned (by a wide margin). The latest 30-year climate normal data showed that London continues to warm slightly, with notably higher minimum temperatures and an increasing number of days reaching 30°C or more.

Globally and across Canada, there has been a notable increase in short-term rainfall accumulations, particularly in association with thunderstorm event. Though such an increase has yet to be reliably recorded for London and area, a flash flood event in August affecting nearby areas to south and west of London showed that extreme precipitation can have significant impacts, including flooded basements and fields, washed out roads and a major highway, a state of emergency and even a fatality.

The weather in London did seem to lurch from one extreme to the other in 2023, at least as far as precipitation. Flooding rains in April were followed by a rare May drought, then a very wet July. While London experienced record or near record warmth in the shoulder seasons, the summer was marked by a lack of intense heat –the month of August experienced no 30°C days. A CBC study of temperatures in peoples' homes in several cities across Canada, including Windsor, showed that hazardous conditions can still occur even when outdoor conditions remain below official warning thresholds, a reminder of the important urban scale variations in climate that exist and for the need to provide adaptation measures for people and infrastructure. Wind-wise, it was an unremarkable year – perhaps more quiet than usual and part of a long-term decline in warm-season high wind events in the area.

Focus: London and Area

London and surrounding municipalities were affected by severe and climatologically extreme weather in 2023, though fortunately not to the extent of a number of other regions of Canada. The following sections provide overviews for local precipitation, local wind and local temperature.

Local Precipitation

It was a story of flooding and drought in London and area in 2023. Heavy spring rainfall at the end of March and beginning of April led to flooded basements in parts of London and the Thames River rising to the point that some homeless encampments were washed away. This led to a search and rescue operation but fortunately there were no casualties [1].

Then in May, London experienced an extremely rare drought, with only 17% of normal precipitation. This was followed by a much wetter than normal July where precipitation was 260% of normal, including 80 mm on July 2nd alone [2].

But the most significant rainfall event in the area occurred on August 23 as multiple intense thunderstorms moved from northwest to southeast ahead of a stalled warm front. The areas that experienced flooding rains stretched from Warwick Township to Glencoe to Dutton (Fig. 1). Environment Canada said approx. 135 mm fell during this one-in-100-year event, though multiple sources in Warwick Township (where a state of emergency was

declared) reported unofficial totals near 175 mm. Multiple roads were closed in the Township, and the Ontario Provincial Police closed Highway 402 between Exit 44 and Exit 52 for more than 12 hours. There were also numerous reports of basement flooding across the region [3].

Unfortunately, there was one fatality related to this storm. A transport truck driver was killed after his vehicle fell into a washed-out section of Dundonald Road near Glencoe. The OPP reported numerous other vehicle crashes due to the flooding in Middlesex and Lambton Counties [3].

While extreme precipitation events are expected to increase in the future, the observational record for London has not yet shown robust evidence of an upward trend in short-duration rainfall extremes. Fig. 2 shows the long-term trends in annual maxima at various rainfall durations (5 minutes to 24 hours), updated for 2023. While there are suggestions of weak upward trends from 10 to 30 minutes, and weak downward trends from 6 to 24 hours, none of the trends have statistical significance. A similar lack of robust trends has been the situation for Canada as a whole up until as recently as 2022 [4], due in part to high regional variability. However, a new national analysis with updated data is now able to show that, while there is still large variability across the country, Canada as a whole is experiencing an increase in precipitation intensity for the shortest sub-hourly to hourly timescales (5-min to 2-h durations) [5].

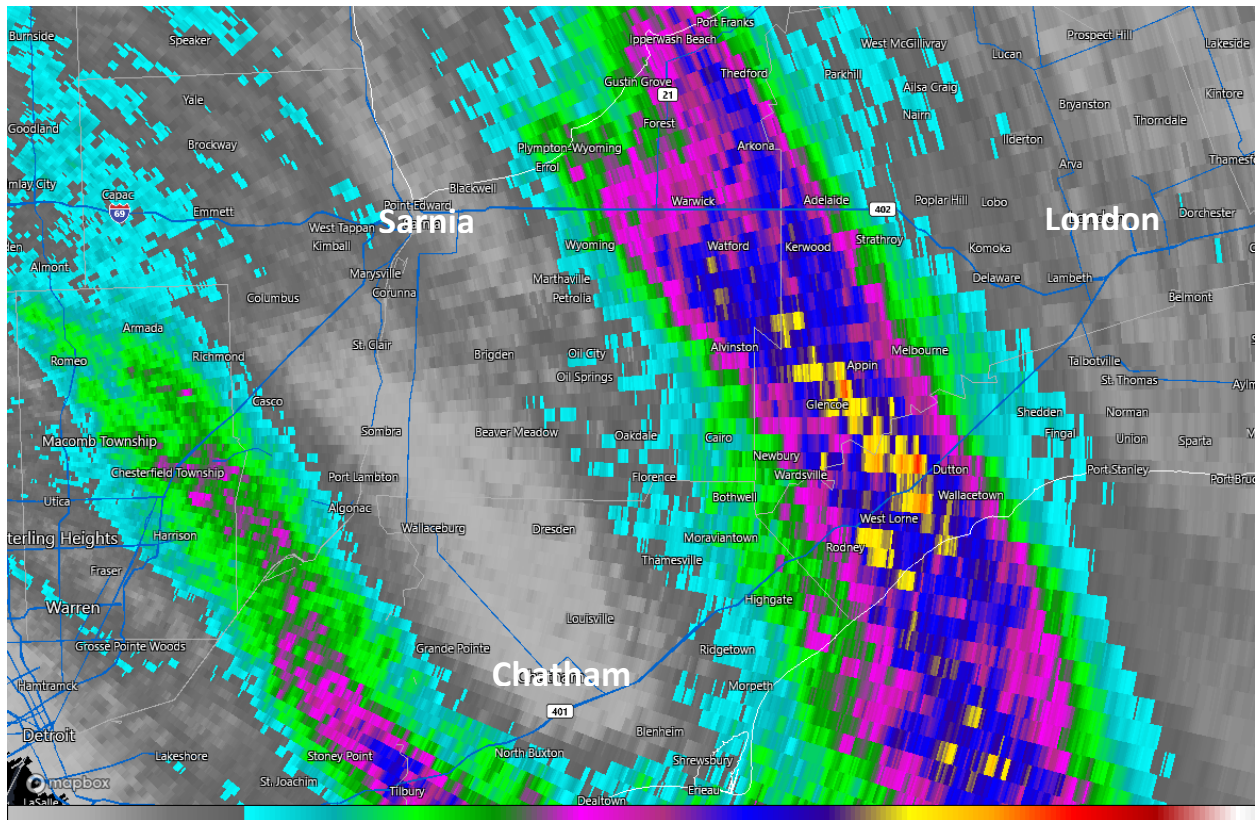


Figure 1. Map of storm total rainfall accumulations as of 10 pm EDT on August 23rd from the nearby DTX radar north of Detroit, MI. The map shows radar-estimated accumulation of 112 mm at Warwick Township, 156 mm at Glencoe and 158 mm near Dutton (Source: Northern Tornadoes Project).

Local Wind

While there was only one severe wind gust recorded at London Airport in 2023 (March 25, 91 km/h), there were a number of weak tornadoes and downbursts recorded in the area by the Northern Tornadoes Project (Fig. 3).

The first tornado of the year in Ontario occurred on June 13 at Talbotville (near St. Thomas) where an EFO tornado damaged trees and a restaurant. A second tornado from that day formed at Beachville (near Ingersoll) and was assigned a default EFO rating since no damage was associated.

The four EFO downbursts all occurred with severe storms on July 20 and were documented at Dorchester, Port Burwell, Alvinston and Wardsville. One injury resulted from the downburst at Port Burwell. Otherwise, minor structural damage, snapped and uprooted trees, and crop damage were reported. The same storms caused minor tree and hail damage in southern parts of London [6].

In general, it has been found that London has experienced a long-term decline in high-speed wind events (exclusive of tornadoes), particularly for the March through September period [7].

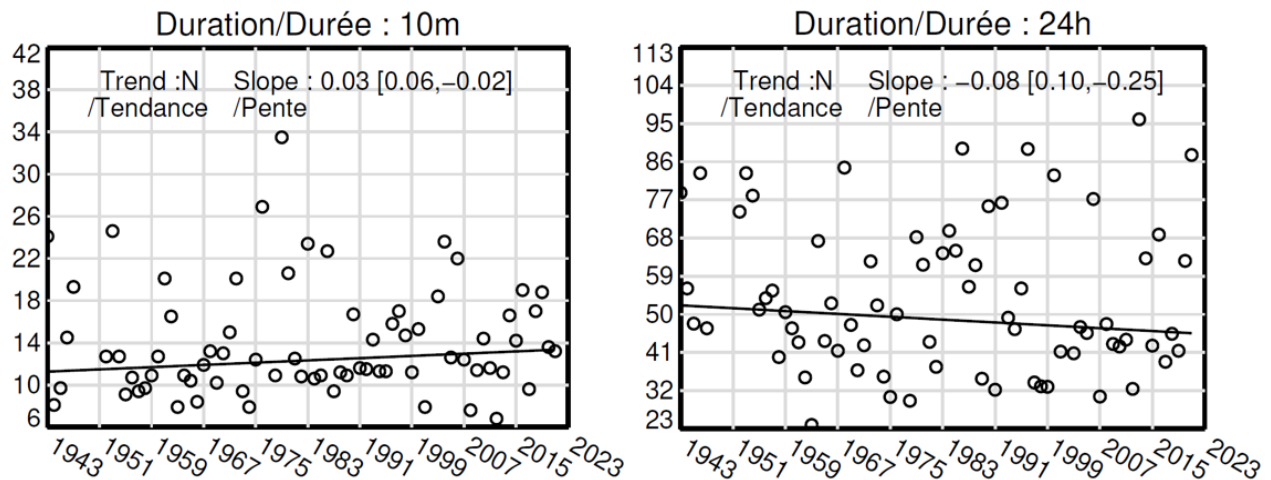


Figure 2. Trends in the annual maximum rainfall accumulation for 10-minute and 24-hour durations at the London International Airport climate station, updated for 2023. The amounts in mm are on the y-axis and the years are on the x-axis. Individual points represent the annual maximum in that year. The trend line for the 10-minute duration is slightly rising while for the 24-hour duration is slightly falling. However, neither trend has statistical significance, so there is low confidence that an actual trend exists (Source: Environment and Climate Change Canada).

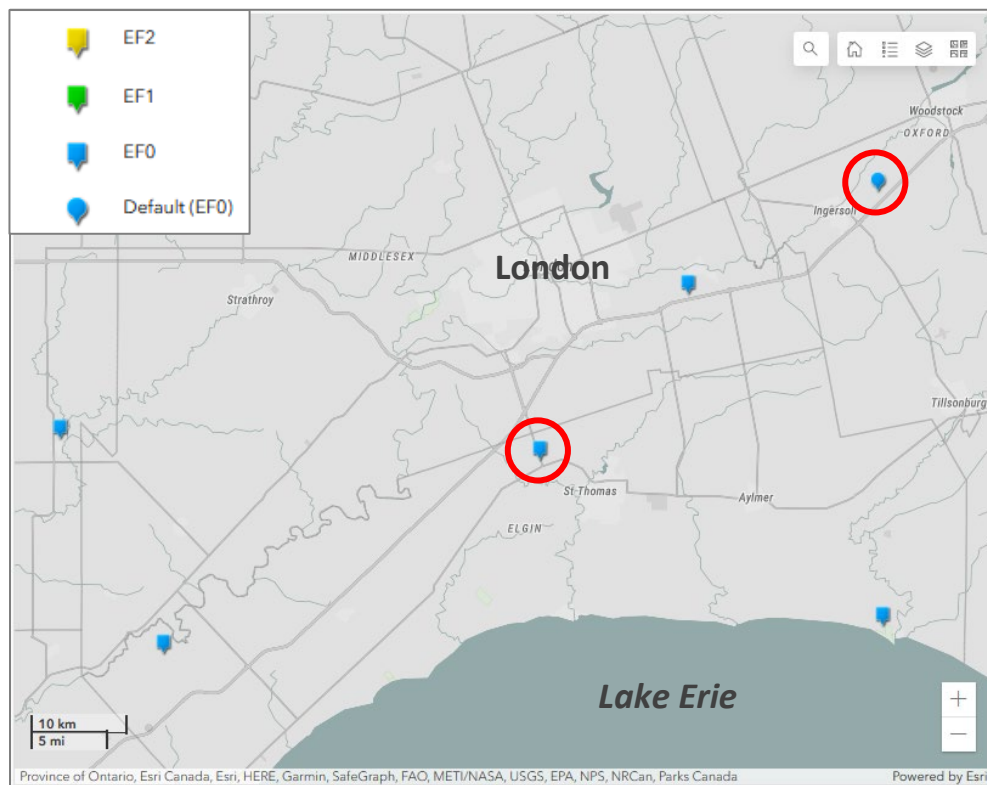


Figure 3. Map showing the locations of the two EF0 tornadoes (circled) and four EF0 downbursts that affected London and area in 2023, with pin colours and shapes indicating the EF rating (Source: Northern Tornadoes Project [Dashboard](#)).

Local Temperature

Fig. 4 plots air temperatures recorded at the London International Airport. It combines the reported daily maximum (red solid line), minimum (blue solid line) and average (black solid line) together with the long-term average maximum (red dotted line) and average minimum (blue dotted line) temperature for that station and day. The open dark red and light blue symbols are the maximum and minimum recorded air temperature for the period 1941-2023 (Jan – Oct) or 1940-2023 (Nov - Dec) at the station on that day. On a month-by-month basis, January was characterized by temperatures well above normal with only the last few days of the month falling to normal or below normal temperatures. February began and ended with a few cold days but in between temperatures were consistently above normal with a 12-day period where the daytime high was always above the normal average maximum temperature.

The maximum daytime high of 15°C on February 15, 2023 set a new daytime high for that date. March had mostly near normal temperatures, with April showing more cold and warm anomalies; the daytime average temperature exceeded the long term daytime *maximum* temperature for six consecutive days. For three of these days, air temperatures were 27°C or above, and missed setting a new record on April 14 and 15 by only 0.1 and 0.2°C respectively. May began relatively cool, but experienced periods of warmth near mid-month and at

the end of the month daytime maximum temperatures were close to or above 30°C, which when combined with the hot start to June, just missed the definition of a 'heatwave'. July and August temperatures were mostly near normal with a few cooler periods in August near the start and end of the month where the daily minimum temperature was substantially less than the long term mean daily temperature. Unusually, there were no days with maximum temperatures above 30°C for London in August. The fall had several warm periods: in September, London experienced a period of warm daytime temperatures where the daytime maximum temperature exceeded the long-term average maximum for a week at the start of the month. The beginning of October was also anomalously warm with daytime maximum air temperatures coming within a few tenths of a degree of the record for London on October 3 and 4 and in the later part of the month the daily maximum temperature exceeded the record by over 0.5°C.

To date in 2023, there have been three instances of 2023 equaling or exceeding the maximum recorded air temperature in the record: February 15, June 2, and October 27. There were no instances of daytime minimum air temperatures lower than those recorded over the ~80 year record of comparison. There have been 59 days in 2023 where the mean daytime temperature has been greater than the mean daytime maximum temperature¹.

¹ The daily mean maximum and mean minimum temperatures are only available from the London Intl Airport station, which has a period of record 1941-

2002. This limits comparisons of daily maximum temperatures given the warming experienced in the most recent 20 years.

No heat waves were recorded in London in 2023, based on the definition of a heat wave as three consecutive days where the temperature is 30°C or greater. There were three instances of 2 consecutive days with temperatures exceeding the threshold.

We note that the characterization of temperatures for London here are limited to the London International Airport, where monitored conditions are not necessarily representative of those experienced in the more highly urbanized parts of the city. Urban enhancement of temperature is typical, especially at night in the summer under clear skies and light winds and leads to an urban heat island (UHI) effect. On an annual basis, the enhancement of air temperature may be around 1-2°C in the most built-up part of the city [8]. Fig. 3 includes the mean daily temperature of a station located in a developed part of the Western University campus. Averaged over 2023 to date it is 1.0°C warmer than the airport. During select weather conditions that favour UHI formation, the enhancement at night may be 6-8°C at night in the most developed parts of a medium sized, North American city; daytime increases are much smaller, perhaps only a degree or two [8].

Fig. 5 shows an example of an urban heat island cross section through London. Variations in temperature coincide with the most intensely urbanized locations of the city – high amounts of impervious surfaces, lack of vegetation and tall buildings provide the greatest increase in the night time air temperature increase. The spatial patterns of heat remain largely constant through time, but the relative heat island magnitude is influenced strongly by weather conditions.

On this particular night, with weather conditions favourable to development of an urban heat island, a temperature difference of approximately 5°C is present between downtown London and the rural areas to the east of the city.

Areas of relative warmth in Fig. 5 include downtown (point 2) and near Argyle Mall (point 6). Areas near rivers or larger patches of tree canopy or open areas (points 1, 3, 4 and 7) in the urban area are relatively cool. Point 5 represents a neighbourhood temperature in the Argyle neighbourhood, close to the East Lions Community Centre that contrasts with the cool Kiwanis Park (point 4). Outside the rural area, temperatures are cooler and are impacted by vegetation, with point 9 likely influenced by the nearby golf club, and on this clear and very calm night, small areas of cold air that collect in lower lying parts of the landscape. Where there is development and reduced vegetation cover such as near the Trails End Market, temperatures warm slightly (point 10).

Increases in the number of tall buildings in downtown London are expected to contribute to enhancements of night time temperature in the core area. Development of new urban lands will also contribute to temperature increases; these are most easily seen in increased surface temperatures that accompany the loss of vegetation and exposed bare dry surfaces during the construction phase.

Both airport and intra-urban air temperatures provide a representation of the *outdoor* air temperature. However, most urban residents spend a large fraction of

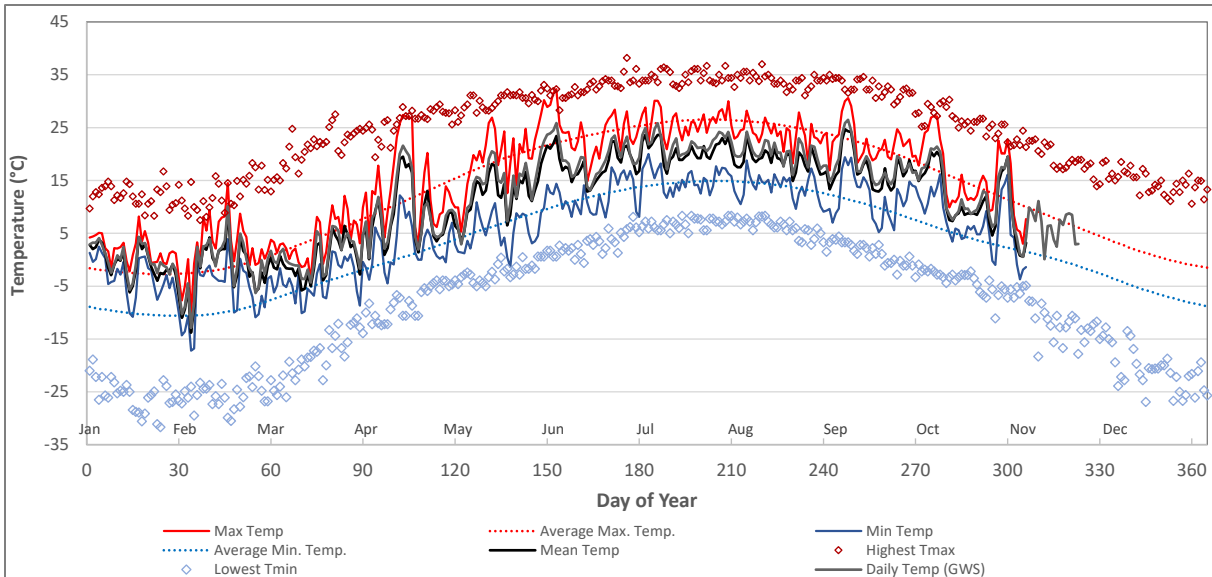


Figure 4. Air temperature data for 2023 recorded at the London International Airport station with comparisons to the long-term average maximum and minimum temperatures and the lowest and highest temperatures available from the period of record, which is 77 years. The mean daily temperature from a non-standard station operated by the Department of Geography and Environment near the Social Science Centre on campus is also shown to represent a station with urban influence in the signal. (Source data from ECCC and the Department of Geography and Environment, Western University).

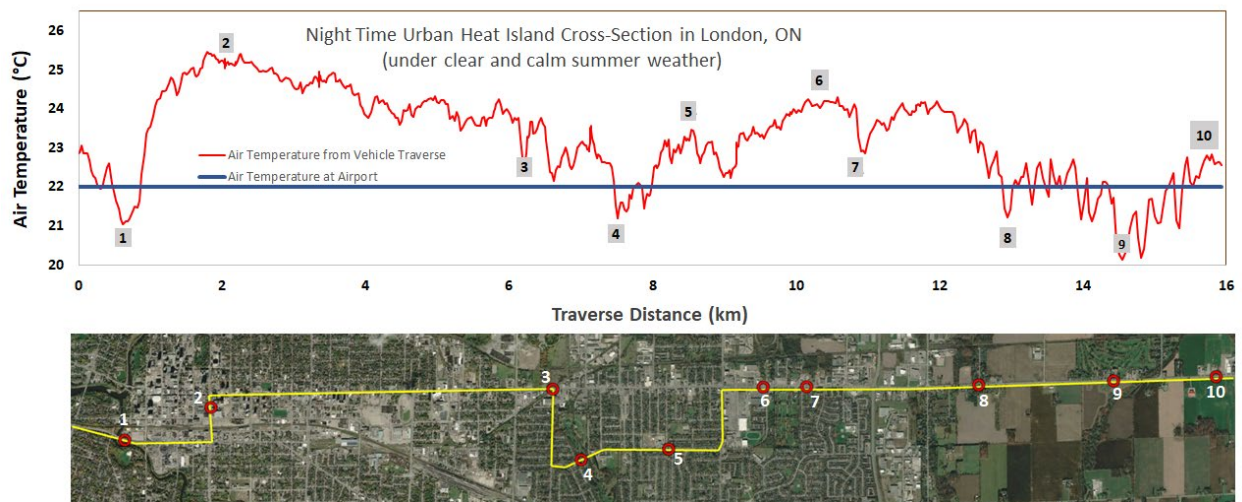


Figure 5. Air temperature measured from a night time vehicle traverse (red line) on July 22, 2022 just after mid-night from central London to east of the airport illustrating intra-urban scale variability of temperature. The thick blue horizontal line represents the temperature measured at the London airport. Locations represent: 1, Horton St E at Thames River; 2: Wellington St / King St; 3: Dundas St / Hale St; 4: Wavell St / Kiwanis Park; 5: Wavell St near East Lions Community Centre; 6: Dundas just east of Argyle Mall; 7: Dundas at Forest Lawn Cemetery; 8: Dundas St / Kostis Ave; 9: Dundas St / Maple Ridge Golf Club; 10: Dundas St / Trails End Market.

their time indoors, where conditions can differ substantially. Fig. 6 illustrates the indoor and outdoor temperatures for a house in Windsor monitored by CBC as part of their Urban Heat Project during the summer of 2023. A threshold of 26°C is also shown; it represents the maximum indoor temperature considered safe for sustained exposure. Also shown is a heat index, or 'apparent temperature' that provides a measure of the heat (or thermal comfort) the human body feels. It incorporates the effects of multiple environmental variables including humidity, effective wind speed, atmospheric humidity, activity rate, clothing resistance to heat and moisture transfer and others [9]. A simplified regression approach can be used to estimate the heat index from the original model results [10]. Despite relatively moderate outdoor temperatures, there is a significant increment to the indoor temperatures, that are frequently above the 26°C threshold known to be relevant to human health. For residents exposed to such conditions who are unable to effectively lower their indoor temperatures, provision of cooler outdoor spaces in the urban environment, such as parks and cooling centres can be important, even when the outdoor conditions do not reach typical heat warning threshold values.

The recently released 1991-2020 climate normals provide an additional time period to assess the longer term climate conditions for London. A climate normal is defined as a 30-year period over which arithmetic calculations are completed to provide a description of the average climate conditions at a site and to remove year-to-year variability in the data [11]. ECCC normal

calculations follow the standards set by the World Meteorological Organization (WMO) and use 30-year periods (NP = normal period) that are updated at the end of every decade. Climate normals have been produced by ECCC for every decade since the 1940s. The London International Airport station climate normal for temperature are shown in Fig. 7. Over the past three normal periods, the daily average air temperature has increased by 0.3 – 0.4°C/NP with the minimum air temperature increasing slightly more (0.4°C/NP) than the maximum air temperature (0.27°C/NP). Over the available record of 6 normals periods, the air temperature showed a small decrease from 1941-1970 to 1961-1990 followed by a warming trend (Fig. 8). The daily average, maximum and minimum temperatures for the last two normal periods are warmer than all previous periods.

Degree Days are calculated from the difference in temperature of the daily mean temperature above or below a given threshold temperature, where each difference in degree is a 'degree day'. A threshold of 18°C is used to characterize the demand for heating (for degree delays below the threshold) and cooling energy (for degree days above the threshold) in buildings. These are referred to as heating and cooling degree days respectively. Over the available climate normal periods, the HDD have decreased from an annual value of over 4100 in 1951-1980 to less than 3900 in the most recent period. At the same time CDD have increased by approximately 20 in each of the last two climate normal periods (Fig. 8). These reflect the expected reduction in demand for winter-season

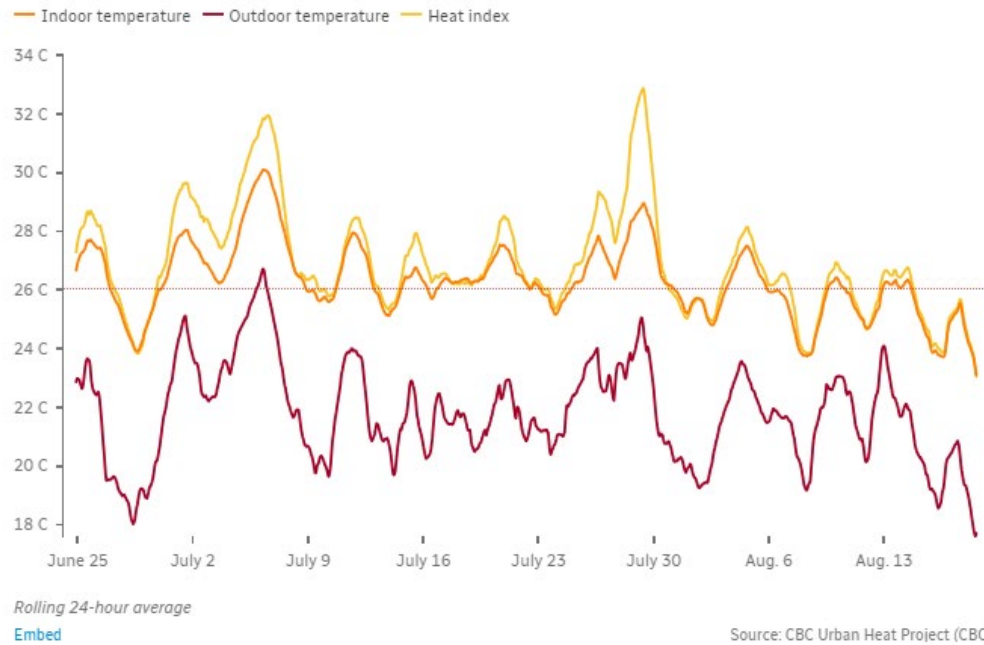


Figure 6. Air temperature measured indoors and outdoors in a house in Windsor as part of a CBC project tracking heat. The 26°C temperature threshold is a maximum indoor temperature commonly considered as safe for sustained exposure. Also shown is a heat index used by the US National Weather Service, which represents a “feels like” temperature to the human body. (Source: CBC Urban Heat Project).

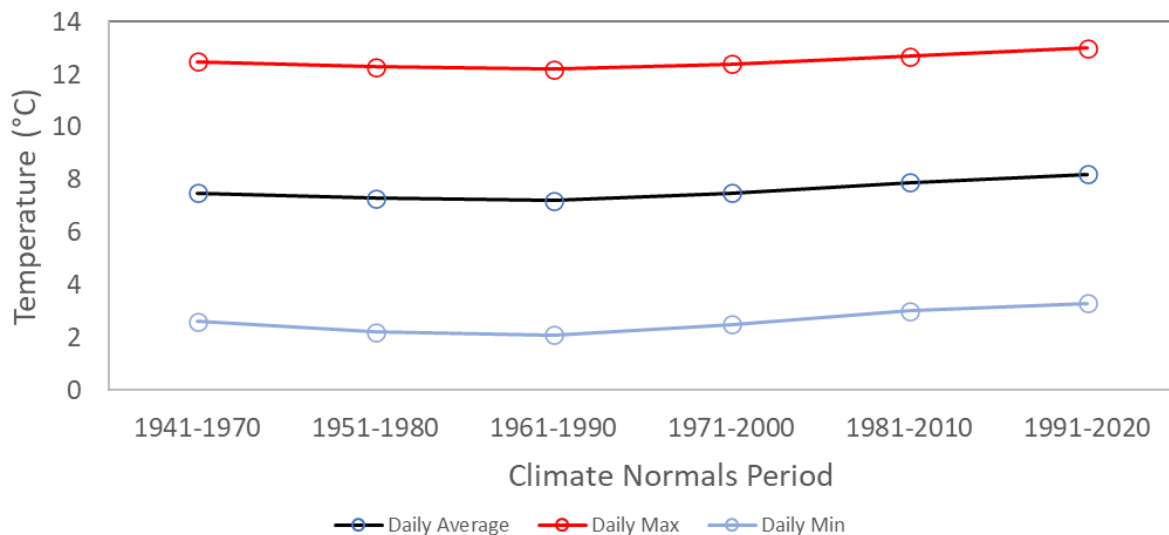


Figure 7. Climate normals for London ON over the past six decades (Source data from ECCC).

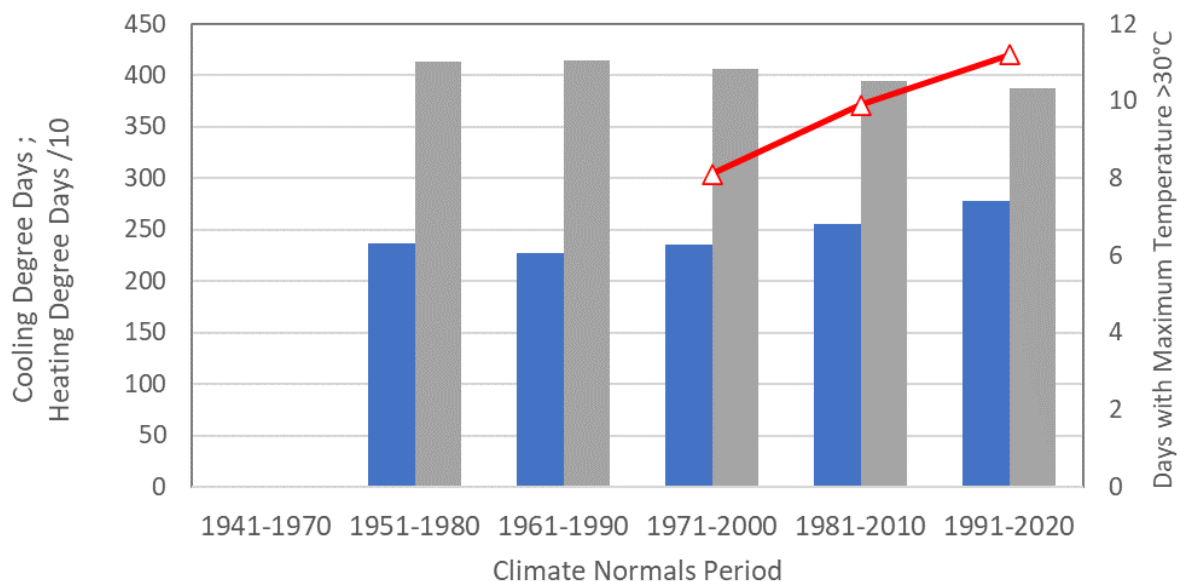


Figure 8. Cooling (blue) and Heating (grey) Degree Days along with the number of days (red triangles) with maximum daytime temperature exceeding 30°C (Source data from ECCC).

heating and increase in cooling demand for summer associated with large-scale climate warming.

During the hottest periods of the year, increased use of air conditioning can lead to an additional warming effect on outdoor air temperatures in the more densely developed parts of the city, augmenting the urban heat island. This effect is known as a *positive feedback effect*, where the use of ‘positive’ indicates an additional change in the direction of the original change.

Superimposed on Fig. 8 is the number of days with maximum temperature above 30°C for the past three normal periods. Days meeting this threshold are likely to cause thermal discomfort in the population. This measure has risen over the past three normal periods (as shown by the red line joining the plotted triangles) by over 35% with the latest normal period indicating 11.2

days. In 2023 to date for London, there have been 8 days that meet the threshold.

Focus: Ontario and Quebec

Precipitation, Wind and Fire

As has been the case over the past 5 years, severe and extreme weather events have hit eastern Ontario and southern Quebec particularly hard and often straddled the provincial border. Thus, these provinces will be grouped together here rather than just focusing on Ontario alone.

The first such example is the early April ice storm that hit eastern Ontario and southern Quebec, with the greatest impacts in the Ottawa and Montreal regions. Freezing rain and strong winds resulted in catastrophic impacts to trees and power lines, with up to 1.3M people losing power and hundreds of millions of dollars in insured losses. It was the worst power outage in Quebec since the

1998 ice storm. There were two fatalities associated with storm, one in each province, both caused by trees falling [12]. Ottawa was also affected by excessive precipitation on August 10th when a severe thunderstorm produced flash flooding.

There were 37 tornadoes in southern Ontario and southern Quebec (Fig. 9), roughly half of all tornadoes in Canada in 2023, as documented by the Northern Tornadoes Project. However, all of these tornadoes were weak – causing EF0 to EF1 damage. In 2022, there were 5 EF2 tornadoes across this region, and in 2021 there were 12. Three locations with multiple

weak tornadoes over the summer were Ottawa, Windsor and the Tweed area (see Fig. 9).

Thunderstorms with hail are not uncommon in southern Ontario, but some storms from this past summer produced hail that can be considered climatologically extreme. On July 20th, baseball-sized hail was documented at Courtright and Amherstburg, with tennis ball-sized at Cottam ([2], [13]).

On July 28th, up to tennis ball-sized hail fell in the Ottawa region associated with a storm for which an ‘extreme’ thunderstorm warning was issued [2]. This is a new,

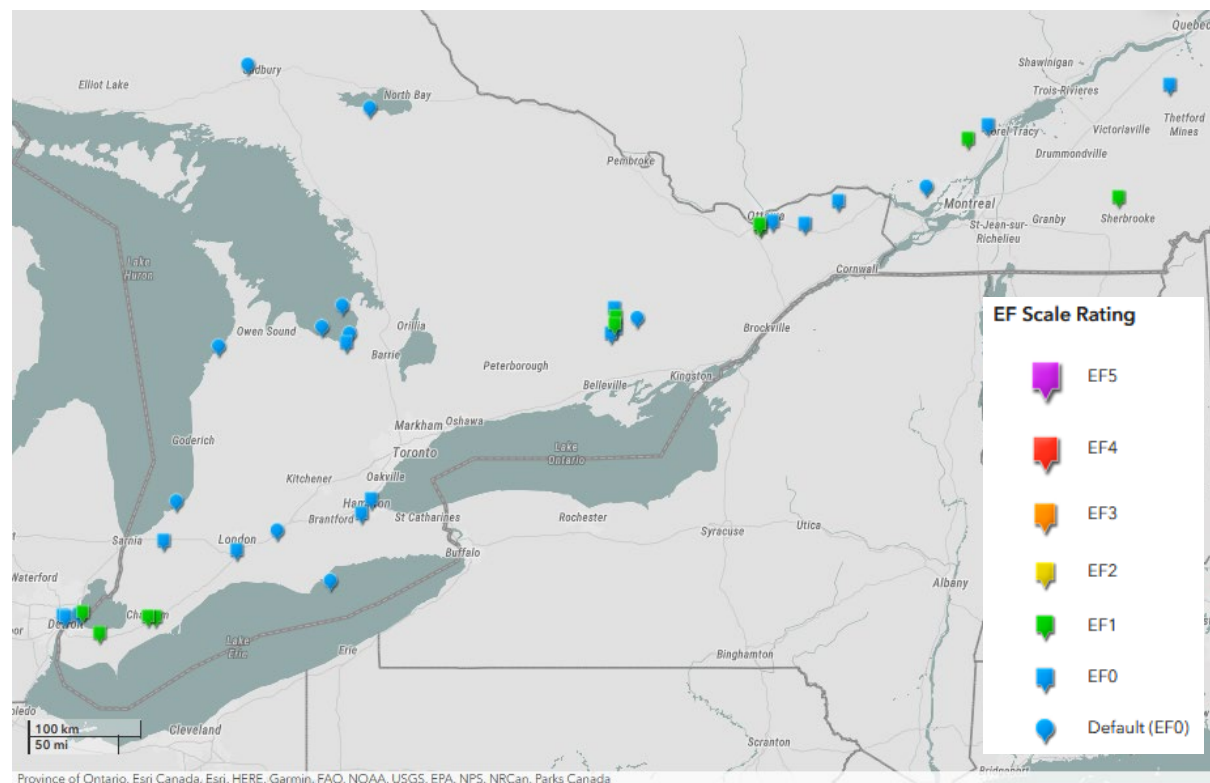


Figure 9. Map showing the locations of tornadoes in southern Ontario and southern Quebec over the 2023 season, with pin colours indicating the EF rating (Source: Northern Tornadoes Project [Dashboard](#)).

broadcast-intrusive type of warning for thunderstorms that are capable of producing hail to 7 cm and/or winds to 130 km/h, and was first used in 2022 for the May 21st derecho.

On August 12th, a hail storm struck the Port Bolster / Pefferlaw area southeast of Lake Simcoe. The wind-driven hailstones, some larger than baseballs, caused enough damage to homes that the Northern Hail Project conducted a damage survey there.

The wildfires that devastated parts of heavily forested central Quebec were investigated by World Weather Attribution, an international scientific collaboration that studies the influence of climate change on extreme weather events. The organization concluded that climate change made peak fire weather like that experienced in Quebec in 2023 twice as likely and 20% more intense. It also estimated that fire seasons of this severity are at least severe times more likely due to climate change [14].

Temperature and Air Quality

The most striking of the monthly temperature anomalies provided by MSC-ON for Ontario is January where temperatures Ontario-wide and in the bordering provinces and states were well above normal (Fig. 10). In April, a province wide warm event was experienced with particularly warm temperatures in southern Ontario with Oakville reaching 31°C [2].

May and June provincial temperature anomalies were mostly near normal except in the northwest part of the province where conditions were relatively warm. July temperatures for most of the province were

near normal [2], despite other parts of Canada, North America and the globe experiencing record heat.

The cool periods noted for August in London were also widespread in southern Ontario; the MSC noted that for Toronto, such conditions had not been experienced in over a decade [2]. Provincially, September was warmer than normal and the heat event experienced in London near the beginning of the month was experienced province-wide (including many regions with high humidex values) and numerous record high temperatures were set.

Ontario and Quebec were anomalously warm in October, with province wide heat events in the first and last weeks of the month. During this period the unusual warmth saw daytime minimum temperatures that were warmer than the average daily maximum temperature in the southern part of the province [2].

Smoke associated with wildfires in north-eastern Ontario and Quebec impacted southern Ontario during the latter part of the first week and into the second week of June and again into the third week of June. While London fared relatively better than locations to our east and north, PM_{2.5} readings were high, especially the evening/night of June 6/7 with values for multiple hours above 70 µg m⁻³ and midnight on June 8 with a value above 100 µg m⁻³.

The night of June 27/28 saw the worst absolute concentration, which exceeded 200 µg m⁻³ for 5 hours with a maximum hourly value of 240 µg m⁻³. Inspection of the

hourly PM2.5 readings² suggest that June 5-9, 16, 27, 28 and 30 likely exceeded the 24-hour Ambient Air Quality Criteria of $27 \mu\text{g m}^{-3}$. The smoke brings with it air quality and health concerns, but also may have acted to limit daytime maximum air temperatures.

Focus: Across Canada

A unifying climate event that affected Canada from coast to coast (and far beyond) in 2023 was a record wildfire season in terms of burned area, and the resulting wildfire smoke.

As shown in Fig. 11, the burned area in 2023 was extreme relative to past years, and unprecedented in documented history. Of course, the conditions required for extreme wildfire occurrence – prolonged heat and drought – were also prevalent across much of the forested areas of Canada. There were also a number of notable climate events in provinces and territories outside of Ontario.

West Coast

A large portion of BC experienced severe to extreme drought in 2023, including almost the entire coastal area and Vancouver Island – referred to as unprecedented [15]. BC experienced a heat emergency in mid-August, with some temperatures in the interior reaching over 40°C. Even an October ‘atmospheric river’ event couldn’t put much of a dent in the precipitation deficit across the coastal region, and experts warned that the drought could persist into 2024 and may even reflect a new reality for BC [16].

Prairies

Across the Prairie provinces, while fires raged in the north, severe storms occurred with less than typical frequency in the south. For example, Saskatchewan – it’s southern regions long thought to be a tornado hotspot in Canada – recorded just one tornado. As documented by the Northern Tornadoes Project, it was an EF1 tornado near Regina with a path length less than 1 km.

Even though the tornado season across the Prairies was relatively quiet, there was still one climatologically extreme event – an EF4 tornado at Didsbury, AB on Canada Day. With an estimated maximum wind speed of 275 km/h, a path length of 15.3 km and maximum path width of 620 m, it was by far the strongest wind event in Canada in 2023. Historically, only 0.3% of tornadoes in Canada have produced F4/EF4 damage.

East Coast

That Maritime provinces, and Nova Scotia in particular, experienced severe and extreme weather that residents there are not accustomed to. It was the most destructive wildfire season documented in Nova Scotia, with over 25,000 hectares burned and 200 homes destroyed [17]. That province also experienced significant flooding caused by an ‘atmospheric river’ on July 23rd that dropped more than 250 mm on the hardest-hit areas, leading to significant damage to infrastructure, flooding of homes and businesses, and a state of emergency declaration. Insured losses reached over \$170M [18]. Tragically, it also caused four

² Data as presented at <https://www.airqualityontario.com/history/station.php>

[?stationid=15026](#). These data are preliminary data not yet checked by the province.

fatalities. The Maritimes were also hit by the post-tropical remnants of Hurricane Lee, with trees and power lines felled by winds gusting to 120 km/h and storm surge-related flooding in some coastal areas. Thankfully, this storm was not nearly as damaging as 2022's devastating Hurricane Fiona.

Around the Globe

Year to date results from NOAA [19] show that the first 9 months of 2023 rank as the warmest year to date with a 99% likelihood that 2023 will rank as the warmest year on record. The months of June, July, August, September and most recently October 2023 have all set records as the warmest month in comparison to the same month for the available period of record [20].

Overall, the summer of 2023 (meteorological summer is defined as the months June, July and August) was also the warmest on record in terms of global temperatures (and also the warmest summer in North America). July 2023 was the hottest month on record (174 years; Fig. 12 and 13) and August 2023 the second hottest. The July globally average near-surface air temperature was 1.12°C higher than average

with notable warming occurring in parts of North Africa, South America, the Antarctic Peninsula and northwestern and northeastern North America (Fig. 13). Multiple regions in the Northern Hemisphere experienced heatwave conditions [20]. Many areas over the oceans experienced higher air temperatures – anomalously warm sea surface temperatures (SST) in the North Atlantic and developing El Niño in the equatorial eastern Pacific helped drive the warmth (Fig. 14). Record low sea ice concentration around Antarctica has also been recently reported [23]. In September, NOAA reported that record-warmth covered 20% of the world's surface, the highest percentage of any month since records for this statistic began in 1951 [19] and the monthly temperature anomalies in comparison to those from 1940 onwards demonstrate the globally anomalous warmth over the past 5 months (Fig. 15).

Recognizing the importance of climate change to cities, the IPCC has begun the process of nominating experts to draft the special report on climate change and cities that is planned as part of the AR7 cycle.

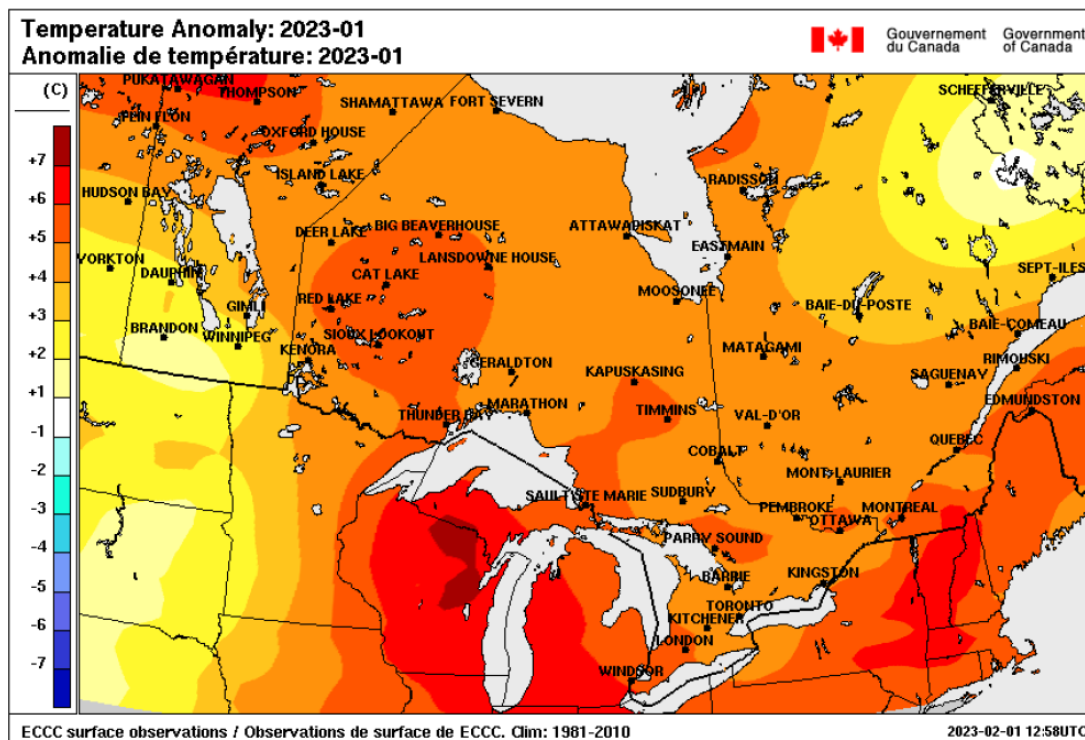


Figure 10. Monthly air temperature anomaly for January 2023 across Ontario and neighbouring regions (Source: MSC-ON Media Bulletin – Feb 1, 2023).

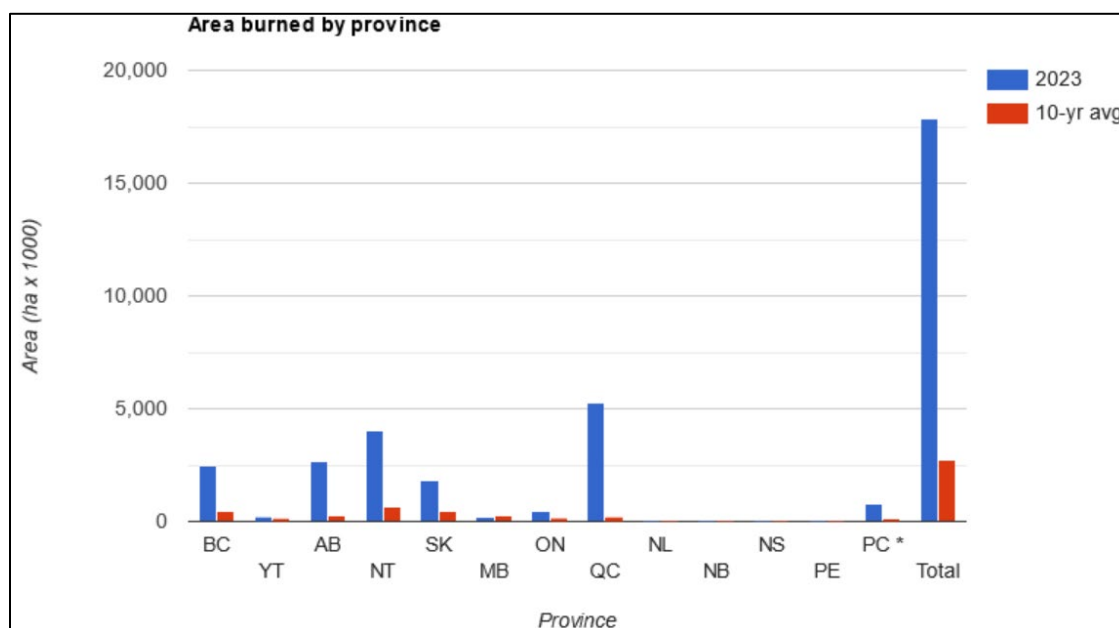


Figure 11. Chart showing the area burned by wildfires in each province and territory, for both the last 10 years and for the year 2023 (Source: Canadian Wildland Fire Information System / Natural Resources Canada).

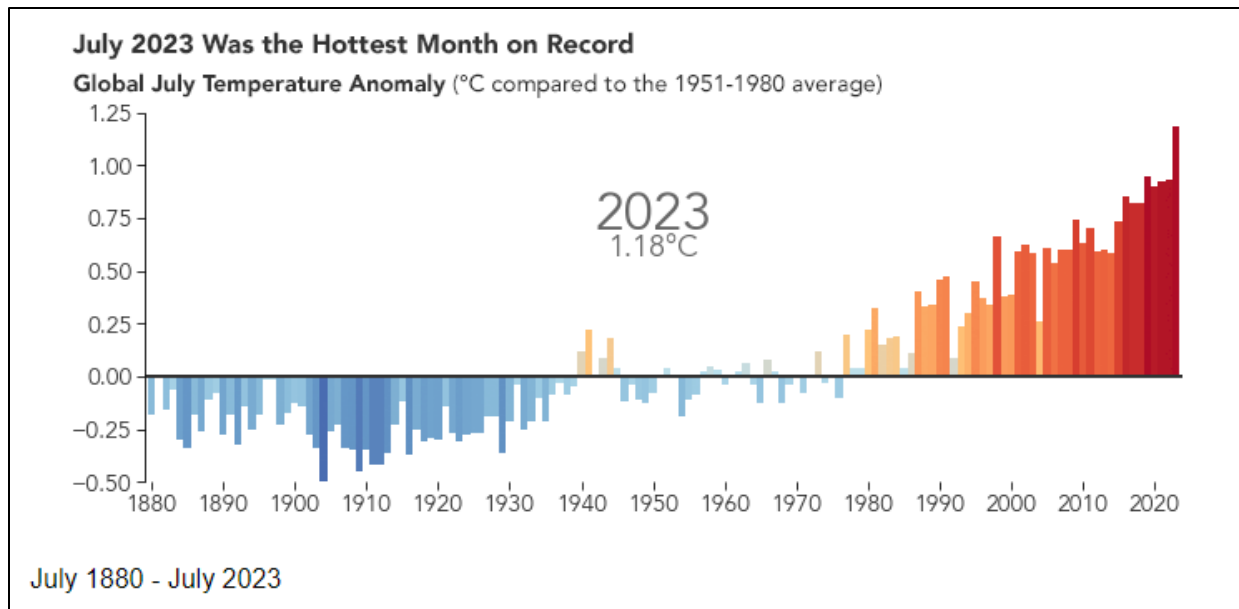


Figure 12. July global surface air temperature anomalies 1880-2023 (Source: NASA Earth Observatory).

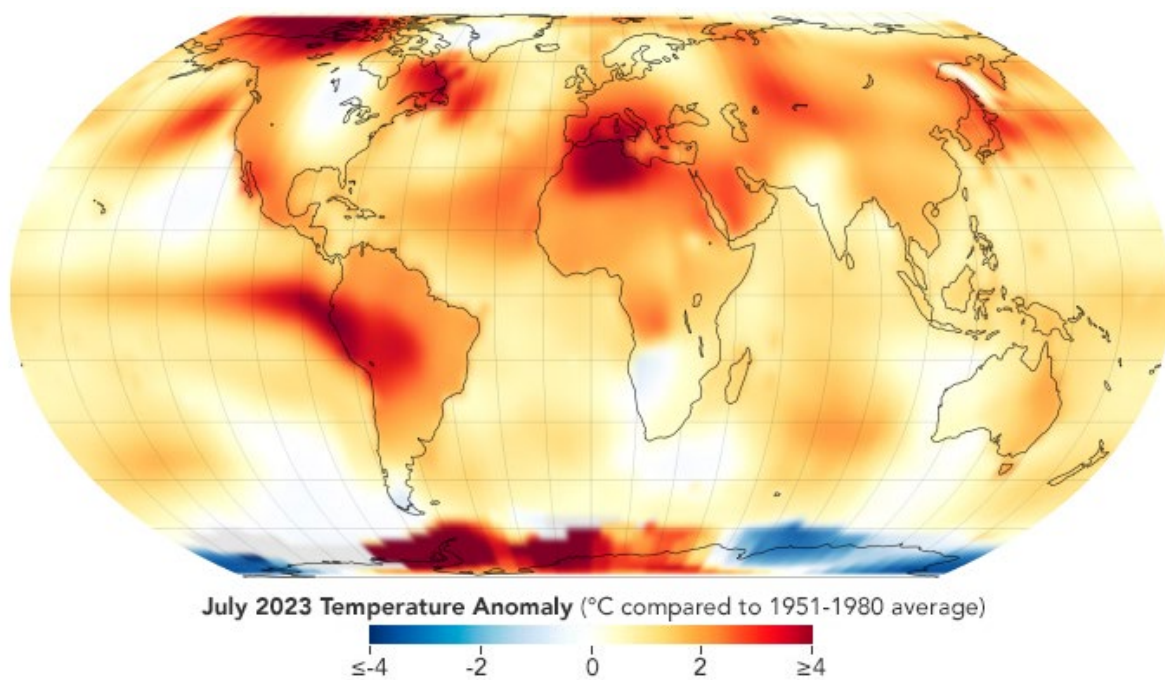


Figure 13. July surface air temperature anomaly (Source: NASA Earth Observatory [21]).

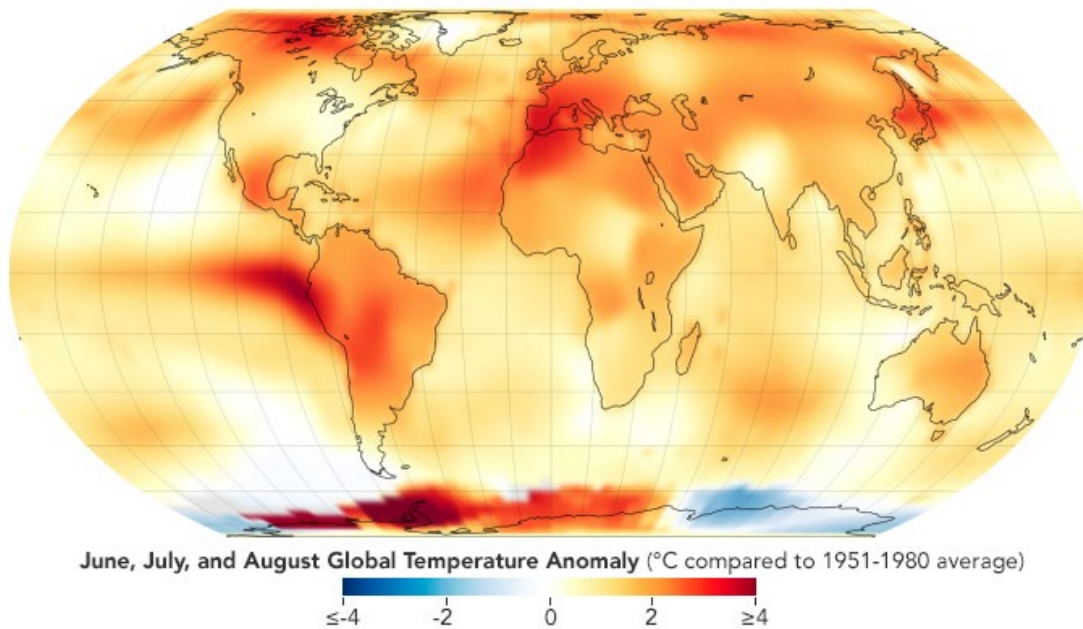


Figure 14. Meteorological summer (June, July and August) global surface air temperature anomaly compared to the 1951-1980 average. (Source: NASA Earth Observatory [22]).

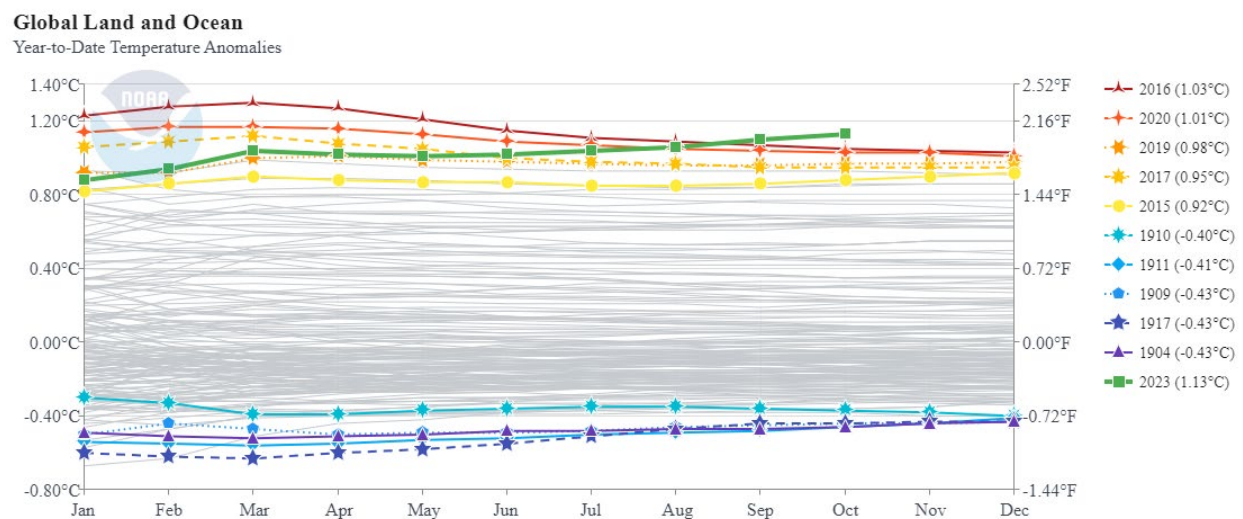


Figure 15. Global air temperature anomalies relative to the 1901-2000 average from 1850 to the present. The five warmest years, 5 coolest years and current year (green) are plotted in colour with all other years in light gray. (Source: National Centers for Environmental Information - NOAA [24]).

References

- [1] <https://london.ctvnews.ca/flooding-near-the-thames-river-leads-to-washed-away-homeless-encampments-1.6339601>
- [2] MSC-ON Media Bulletin, 2023: Weather Summary for Ontario (published monthly), Environment and Climate Change Canada.
- [3] <https://www.cbc.ca/news/canada/london/ontario-highway-buckles-transport-truck-driver-killed-1.6946037>
- [4] Bush, E., Bonsal, B., Derksen, C., Flato, G., Fyfe, J., Gillett, N., Greenan, B.J.W., James, T.S., Kirchmeier-Young, M., Mudryk, L., Zhang, X., 2022: Canada's Changing Climate Report in Light of the Latest Global Science Assessment. Government of Canada. Ottawa, ON. 37 p.
- [5] Cannon, A.J., D.-I. Jeong, and K.-H. Yau, 2023: Stronger Evidence for Increases in Sub-hourly to Daily Extreme Rainfall in Canada: Observed Trends and Links With Warming. Submitted manuscript.
- [6] <https://www.cbc.ca/news/canada/london/storms-across-london-ont-bring-damage-from-fallen-trees-and-large-hailstones-1.6913533>
- [7] Shah, L., C. A. Arnillas and G. B. Arhonditsis, 2022: Characterizing temporal trends of meteorological extremes in Southern and Central Ontario, Canada. *Weather and Climate Extremes*, **35**, <https://doi.org/10.1016/j.wace.2022.100411>.
- [8] Oke, T.R., G. Mills, A. Christen, J.A. Voogt, 2017: *Urban Climates*, Cambridge University Press, Cambridge UK, 525 p.
- [9] Steadman, R. G., 1979: The assessment of sultriness. Part I: A temperature–humidity index based on human physiology and clothing science. *J. Appl. Meteor.*, **18**, 861–873, [https://doi.org/10.1175/1520-0450\(1979\)018<0861:TAOSPI>2.0.CO;2](https://doi.org/10.1175/1520-0450(1979)018<0861:TAOSPI>2.0.CO;2).
- [10] Rothfusz, L. P., 1990: The heat index “equation” (or, more than you ever wanted to know about heat index). NWS Western Region Tech. Attachment 90-24, 3 pp., www.weather.gov/media/wrh/online_publications/TAs/ta9024.pdf.
- [11] ECCC 2023. Canadian Climate Normals 1991-2020. https://collaboration.cmc.ec.gc.ca/cmc/climate/Normals//Canadian_Climate_Normals_1991_2020_Calculation_Information.pdf. Environment Climate Change Canada | Date modified: 2023-09-05.
- [12] <https://www.reuters.com/world/americas/freezing-rain-canada-leaves-more-than-million-without-power-2023-04-06/>
- [13] <https://windsor.ctvnews.ca/biggest-hailstones-i-ve-ever-seen-intense-storm-rips-through-windsor-essex-1.6489512>
- [14] <https://www.worldweatherattribution.org/climate-change-more-than-doubled-the-likelihood-of-extreme-fire-weather-conditions-in-eastern-canada/>
- [15] <https://droughtmonitor.unl.edu/nadm/home/NADMBByArea.aspx?CA02>

[16] <https://bc.ctvnews.ca/b-c-preparing-for-new-reality-of-longer-more-widespread-droughts-minister-says-1.6560328>

[17] <https://www.cbc.ca/news/canada/nova-scotia/nova-scotia-most-devastating-wildfire-season-ever-1.7010205>

[18] <https://www.ibc.ca/news-insights/news/nova-scotia-flooding-causes-over-170-million-in-insured-damage>

[19] NOAA 2023 Global climate summary for September 2023. Published Oct.16, 2023
<https://www.climate.gov/news-features/understanding-climate/global-climate-summary-september-2023> Accessed: Nov 14, 2023

[20] CCCS 2023 Surface air temperature maps <https://climate.copernicus.eu/surface-air-temperature-maps>

[21] NASA Earth Observatory 2023. July 2023 Was the Hottest Month on Record.
<https://earthobservatory.nasa.gov/images/151699/july-2023-was-the-hottest-month-on-record#:~:text=July%202023%20was%200.24%C2%B0,waves%20in%20the%20Northern%20Hemispher.>
Accessed Nov. 4, 2023.

[22] NASA Earth Observatory 2023. NASA Announces Summer 2023 Hottest on Record
<https://earthobservatory.nasa.gov/images/151831/summer-2023-was-the-hottest-on-record>. Accessed Nov. 4, 2023.

[23] NSIDC 2023. Antarctic sets a record low maximum by a wide margin. Sept. 25, 2023.
<https://nsidc.org/arcticseaicenews/2023/09/antarctic-sets-a-record-low-maximum-by-wide-margin/>
Accessed Nov. 11, 2023.

[24] National Centers for Environmental Information – National Oceanic and Atmospheric Administration 2023. Global Haywoods. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/global/haywood/globe/land_ocean