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Historic Climate Trends & Future Projections in Huron County



Photos by Maitland Valley Conservation Authority

The Corporation of the County of Huron | Climate Change & Energy

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1. Introduction

The following document provides a summary of the historic trends and future climatic changes that are projected to occur in Huron County. This information will be integral to the development of a climate adaptation plan, as it will provide the context for which priority areas are identified. Due to the geographic expanse of the County, one centralized location (Clinton, Ontario) was chosen for this analysis. All climate projections were obtained from ClimateData.ca (CRIM, 2019), unless otherwise stated.

In order to understand the climate trends in Huron County, the following analysis has been organized by climate variables. Each of the variables is briefly defined, followed by an analysis of the observed trends and future projections by reference period and emission scenario (further explained in Table 1 and 2). All definitions have been adapted from ClimateData.ca (CRIM, 2019) and the Climate Atlas of Canada (PCC, 2019). Each variable is expressed as a range of values (ie. the average minimum and maximum expected for a given time period), and a median (ie. the average of the median values within each range). To provide additional context, climate projections were also researched and summarized within the broader context of Canada (Appendix 1).

Table 1. Reference periods as adapted from CRIM (2019) and ICLEI (2014).

Name of Period	General Period of Reference	Specific Years of Reference
Baseline or Historic	1960s	1951-1980
Baseline or Historic	1990s	1981-2010
Near Term	2020s	2011-2040
Mid-Century	2050s	2041-2070
Late- or End of Century	2080s	2071-2100

Table 2. Emissions scenarios and representative concentration pathways (RCPs), as defined by ClimateData.ca, and originally denoted by the IPCC's 5th Assessment Report (IPCC, 2014).

Emissions Scenario	RCP	Characteristics
Low emissions scenario	RCP 2.6	• Assumes that greenhouse gas emissions will continue to increase until mid-century and then decline significantly • Referred to as a "peak and decline" scenario • Level of emissions required to ensure the success of the Paris Agreement

Emissions Scenario	RCP	Characteristics
Moderate emissions scenario	RCP 4.5 or 6.0	• Assumes that greenhouse gas emissions will continue to increase (more slowly than they are today) until mid-century and then stabilize towards the end of the century • Described as the “stabilization pathway” • This pathway results in the second-lowest level of global warming
High emissions scenario	RCP 8.5	• Assumes that greenhouse gas emissions will continue to increase at approximately the same rate as they are today • Described as the “business as usual” scenario • This pathway results in the most severe global warming and climate change

2. Climate Variables: Temperature

2.1 Mean Temperature

The mean temperature is the average temperature over a given period of time and is usually obtained by averaging the daily maximum and minimum temperatures. As the below data indicates, temperatures are rising in Huron County, and are projected to continue increasing under all emissions scenarios. If emissions continue to intensify, Huron County could expect an average annual temperature of 13°C (a 6-degree increase from historic levels) by 2100.

Table 1. Historic changes in mean temperature (°C) for Clinton, Ontario.

Parameter	1960s	1990s
Median	6.9	7.7
Range	6.0-7.9	6.9-8.7

Table 2. Projected changes in mean temperature (°C) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	8.8	9.4	9.4
Range	7.7-10.0	8.2-10.7	8.2-10.7

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	8.9	10.1	10.7
Range	7.9-10.0	8.7-11.4	9.2-12.1

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	9.0	11.0	13.1
Range	7.9-10.1	9.8-12.2	11.4-14.9

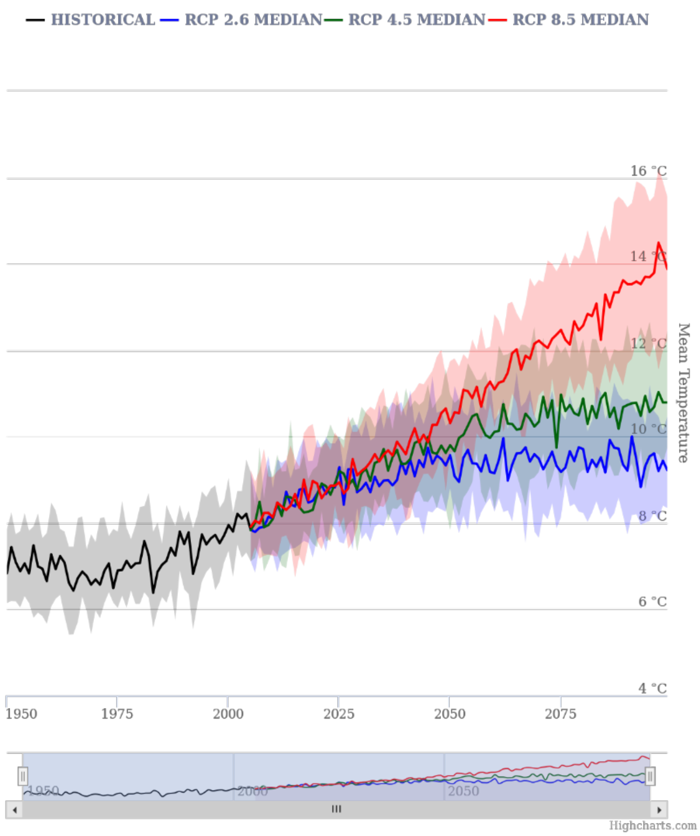

Figure 1. Projections of mean temperature (°C) in Clinton, Ontario under future emissions scenarios.

2.2 Minimum Temperature

The minimum temperature represents the average lowest temperature for a given time period and is derived by averaging all the daily minimum temperatures. The below data shows that minimum temperatures have risen in Huron County, and could see an increase of over 5 degrees by the end of this century.

Table 3. Historic changes in minimum temperature (°C) for Clinton, Ontario.

Parameter	1960s	1990s
Median	2.3	3.2
Range	1.4-3.3	2.3-4.1

Table 4. Projected changes in minimum temperature (°C) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	4.2	4.8	4.8
Range	3.1-5.3	3.7-6.1	3.7-6.1

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	4.3	5.4	6.0
Range	3.3-5.4	4.2-6.8	4.7-7.4

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	4.5	6.4	8.4
Range	3.4-5.5	5.3-7.6	7.0-10.3

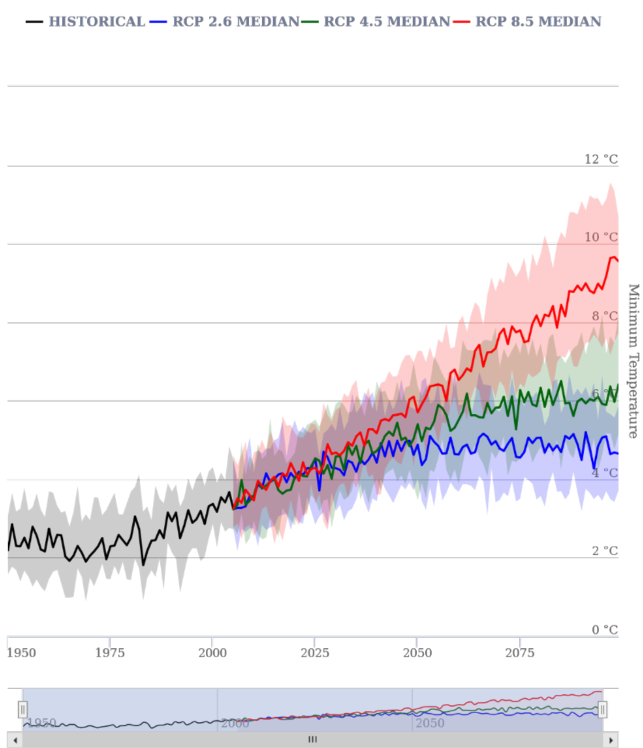

Figure 2. Projections of minimum temperature (°C) in Clinton, Ontario under future emissions scenarios.

2.3 Maximum Temperature

The maximum temperature represents the average highest temperature for a given time period and is derived by averaging all the daily maximum temperatures. The trends indicate that the maximum temperature has increased in Huron County, and it is projected to further increase by over 5 degrees by 2100.

Table 5. Historic changes in maximum temperature (°C) for Clinton, Ontario.

Parameter	1960s	1990s
Median	11.5	12.4
Range	10.5-12.6	11.4-13.3

Table 6. Projected changes in maximum temperature (°C) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	13.4	14.0	14.0
Range	12.2-14.6	12.7-15.3	12.7-15.3

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	13.6	14.7	15.3
Range	12.4-14.8	13.2-16.1	13.7-16.8

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	13.6	15.6	17.7
Range	12.4-14.8	14.2-16.9	15.9-19.5

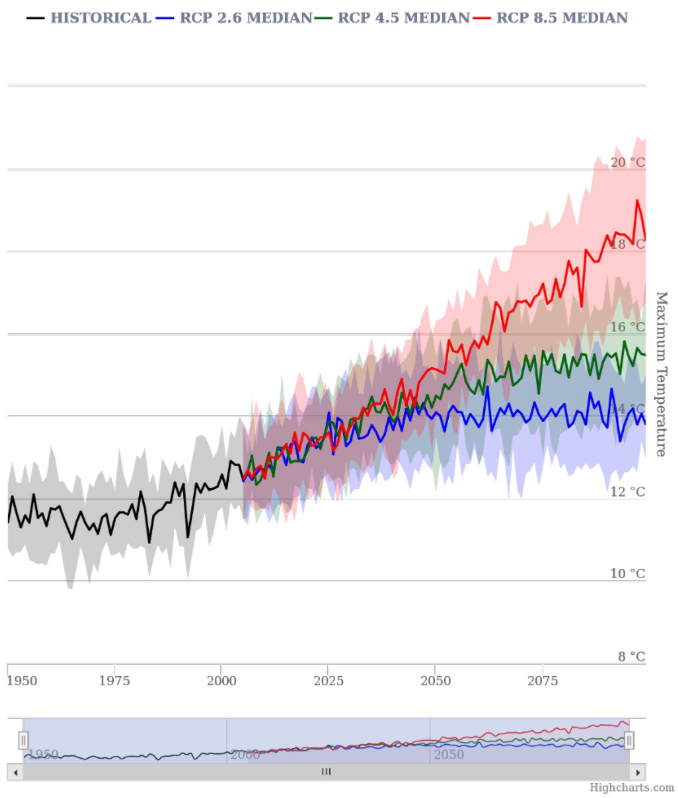

Figure 3. Projections of maximum temperature (°C) in Clinton, Ontario under future emissions scenarios.

2.4 Hottest Day

Hottest days refer to the highest maximum temperature value within a given period of time. The data indicates that the temperature of the hottest day is increasing in Huron County. By the end of this century, the hottest day could exceed 40 degrees, representing an almost 10-degree increase from historic levels.

Table 7. Historic changes in the hottest day (°C) for Clinton, Ontario.

Parameter	1960s	1990s
Median	31.9	32.8
Range	30.2-33.9	31.3-34.7

Table 8. Projected changes in the hottest day (°C) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	34.1	34.5	34.5
Range	32.2-36.3	32.5-36.9	32.4-36.8

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	34.2	35.2	36.2
Range	32.1-36.7	33.1-37.6	33.9-38.9

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	34.2	36.3	38.8
Range	32.1-36.7	34.2-38.8	36.0-41.7

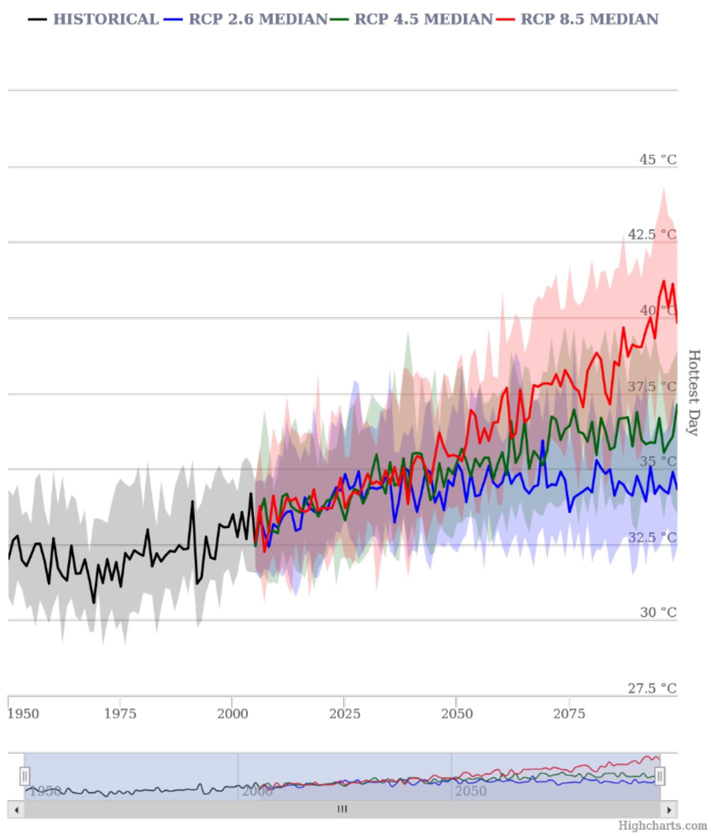

Figure 4. Projections of the hottest day (°C) in Clinton, Ontario under future emissions scenarios.

2.5 Coldest Day

Coldest days represent the lowest minimum temperature value within a given period of time. The below data indicates that the coldest day is getting warmer in Huron County. Under a high emissions scenario, the coldest day is projected to increase by almost 10 degrees by late century.

Table 9. Historic changes in the coldest day (°C) for Clinton, Ontario.

Parameter	1960s	1990s
Median	-23.1	-21.7
Range	-27.5-19.5	-25.7-18.2

Table 10. Projected changes in the coldest day (°C) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	-19.9	-18.9	-18.6
Range	-24.1-16.0	-23.3-14.5	-23.0-14.6

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	-20.0	-17.6	-16.5
Range	-24.3-16.4	-21.5-13.1	-20.7-12.0

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	-19.3	-16.1	-12.2
Range	-23.5-15.7	-20.1-12.2	-16.9-7.7

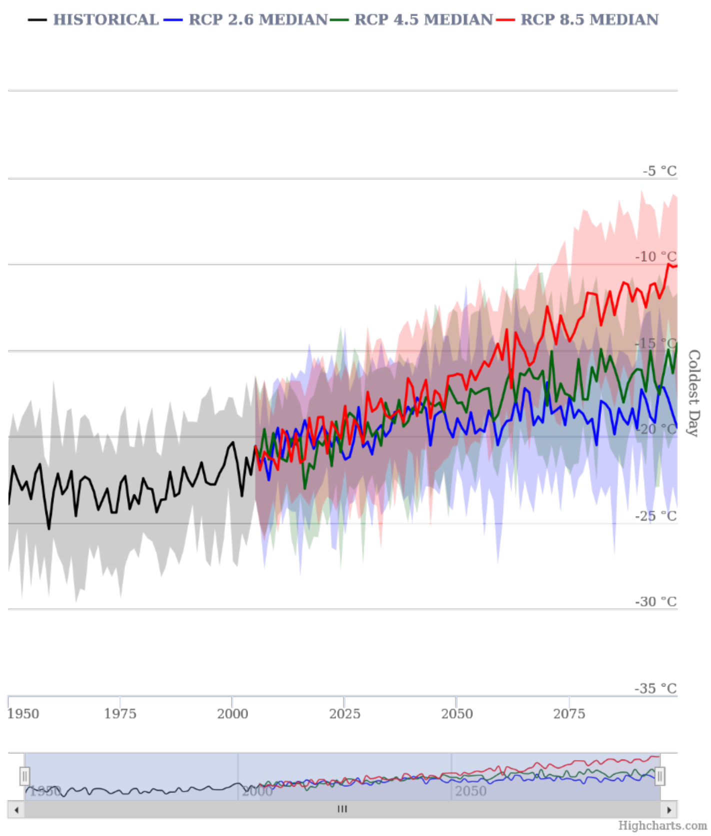

Figure 5. Projections of the coldest day (°C) in Clinton, Ontario under future emissions scenarios.

2.6 Very Hot Days

Very hot days refer to the number of days when the daily maximum temperature is greater than 30°C. This indicator is commonly used to measure the likelihood of heat-related health effects during summer months. As represented below, the number of very hot days has increased in Huron County and is projected to continue increasing under all emissions scenarios. If emissions continue to rise, Huron County could experience over 30 more hot days each year.

Table 11. Historic changes in the number of days exceeding 30°C for Clinton, Ontario.

Parameter	1960s	1990s
Median	5.6	9.7
Range	1.1-13.8	3.6-21.1

Table 12. Projected changes in the number of days exceeding 30°C for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	17.5	23.0	22.1
Range	7.4-32.3	9.0-39.8	9.3-39.6

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	19.5	29.6	35.9
Range	7.8-34.4	13.6-47.1	18.8-58.7

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	19.6	40.9	67.9
Range	8.6-34.4	23.6-59.9	44.1-91.0

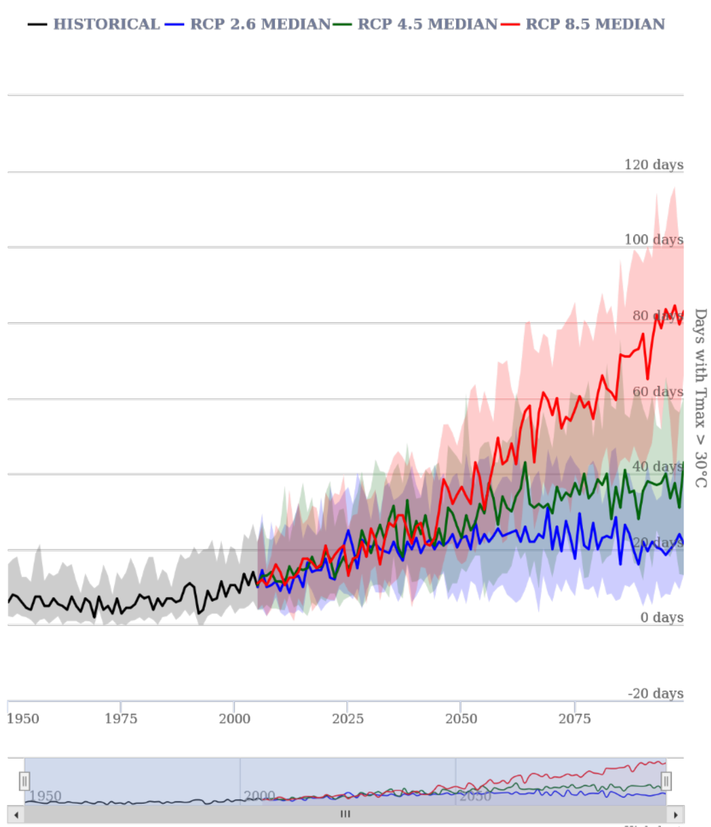

Figure 6. Projections of very hot days in Clinton, Ontario under future emissions scenarios.

2.7 Heat Waves

Heat waves are defined as a period of at least 3 consecutive days with temperatures above 30°C. Two parameters are of importance when analyzing this variable, including the average number of heat waves expected in a year, as well as the average number of days the heat wave is projected to last. Similar to very hot days, this indicator is commonly used to determine the likelihood of heat-related health effects.

The following data was obtained from the Climate Atlas of Canada (PCC, 2019). Due to variations in climate models, this data is representative of the Kitchener region and is expressed as median values.

The data indicates that historically, this area has experienced on average 1 heat wave a year, lasting approximately 2 days. Under future emissions scenarios, the frequency and duration of heat waves is projected to increase. By late century, Huron County could experience 7 heat waves a year, each of which has the potential to persist for 9 days.

Table 13. Historic changes in the average number and length of heat waves for Kitchener, Ontario.

Parameter	1960s	1990s
Number	0.9	1.1
Length	2.2	2.0

Table 14. Projected changes in the average number and length of heat waves in Kitchener, Ontario.

A. RCP 4.5

Parameter	2020s	2050s	2080s
Number	2.9	4.4	5.1
Length	4.1	5.1	5.8

B. RCP 8.5

Parameter	2020s	2050s	2080s
Number	3.0	5.4	7.0
Length	4.4	6.3	9.1

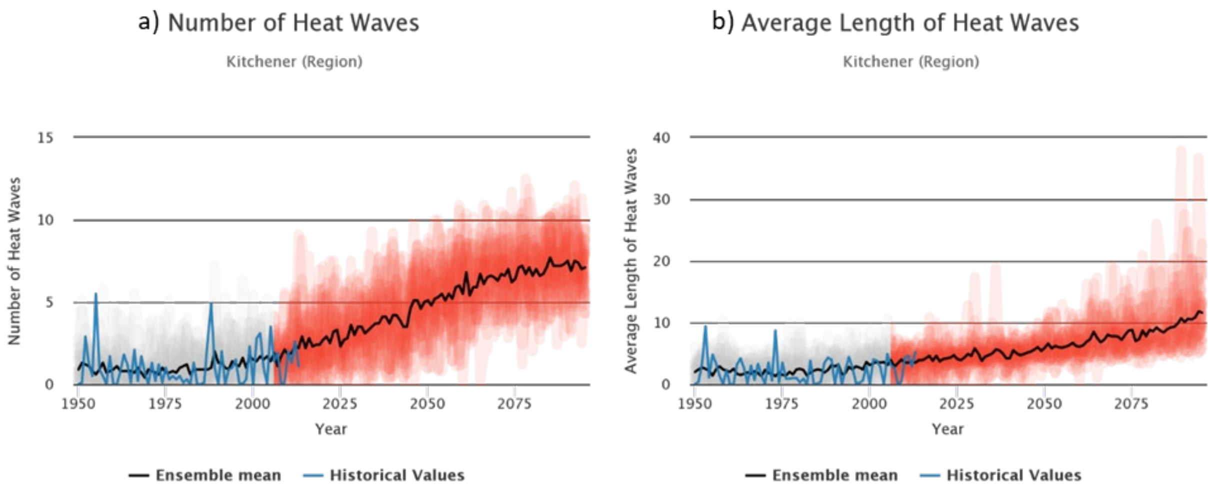

Figure 7. Projections of the average number (a) and length (b) of heat waves under future-emissions scenarios in Kitchener, Ontario.

3. Climate Variables: Precipitation

3.1 Total Precipitation

Total precipitation is the total amount of precipitation (including rain and snow) accumulated over a given period of time. Precipitation is commonly measured over the span of a year and referred to as the annual or total precipitation. For Huron County, total precipitation has increased since the 1960s, and it is projected to increase by over 100 mm by the end of the century.

Table 1. Historic changes in total precipitation (mm) for Clinton, Ontario.

Parameter	1960s	1990s
Median	960.7	978.0
Range	830.8-1103.2	834.4-1119.0

Table 2. Projected changes in total precipitation (mm) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	1006.0	871.8	1163.5
Range	871.8-1163.5	871.4-864.7	864.7-1207.6

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	1009.3	1058.4	1034.2
Range	879.0-1173.1	888.7-1212.4	878.8-1203.4

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	1016.1	1043.6	1087.0
Range	862.4-1165.7	883.0-1230.5	917.2-1278.1

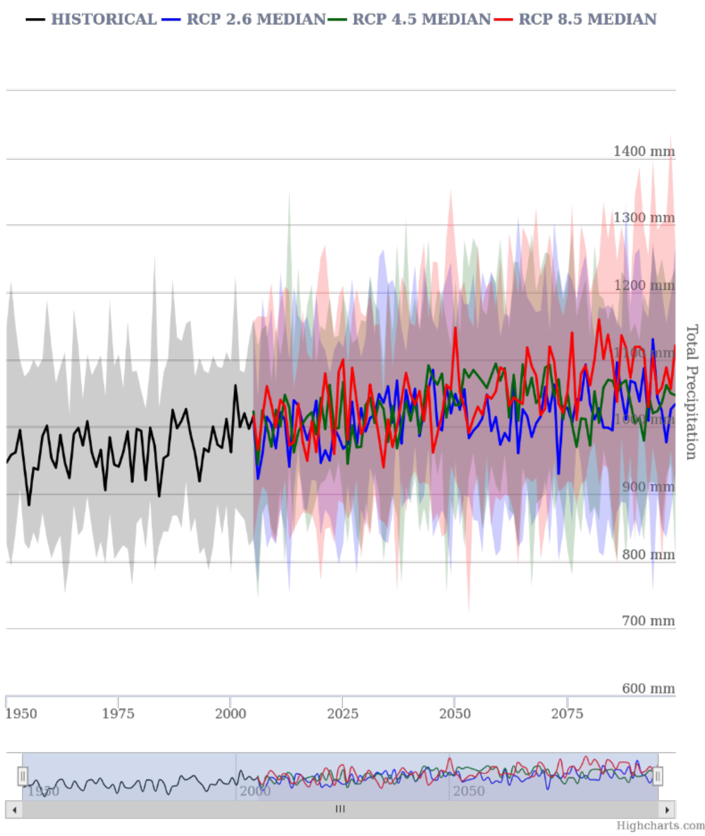

Figure 1. Projections of total precipitation (mm) in Clinton, Ontario under future emissions scenarios.

3.2 Maximum 1-Day Total Precipitation

Maximum 1-day total precipitation is a measure of the largest precipitation total on a single day. This indicator is particularly useful for analyzing the localized impacts of heavy rain events, including flooding and runoff. The data indicates that the maximum 1-day total precipitation in Huron County is projected to increase slightly under future scenarios, with a potential 7 mm increase by 2100.

Table 3. Historic changes in maximum 1-day total precipitation (mm) for Clinton, Ontario.

Parameter	1960s	1990s
Median	36.4	37.7
Range	27.2-54.1	26.8-58.5

Table 4. Projected changes in maximum 1-day total precipitation (mm) for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	37.9	39.3	39.3
Range	28.3-60.6	28.2-61.4	28.7-63.0

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	38.5	40.7	39.9
Range	28.4-60.7	29.7-62.0	29.0-62.5

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	38.7	41.2	44.6
Range	27.3-62.6	30.1-62.5	30.8-71.3

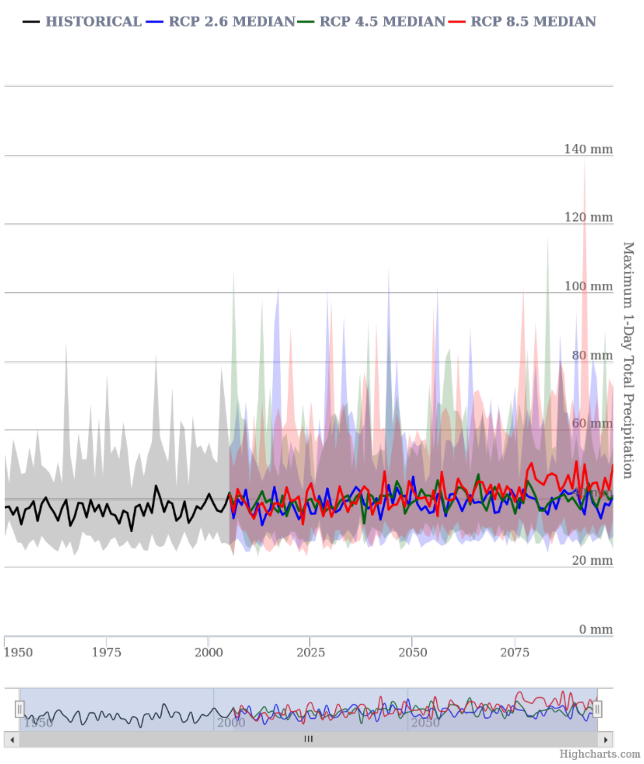

Figure 2. Projections of maximum 1-day total precipitation (mm) in Clinton, Ontario under future emissions scenarios.

3.3 Wet Days

Wet days represent the number of days with daily precipitation totals exceeding 10 or 20 mm. These days are also referred to as heavy precipitation days, and similar to the previous variable are useful for determining risks associated with heavy rain events. This variable is separated by differing intensities as the enormity of future projections depends on the historic rainfall of a given location. For example, some areas rarely experience 10 mm of rain, while others commonly exceed this threshold.

In regards to wet days in Huron County, it appears that both intensities have experienced slight increases over the baseline period, with historically fewer days of precipitation exceeding 20 mm. Under future emissions scenarios, the number of wet days are projected to increase by over 10 days with 10 mm and almost 3 days with 20 mm, by the end of the century.

Table 5. Historic changes in the number of wet days over 10 and 20 mm for Clinton, Ontario.

A. 10 mm

Parameter	1960s	1990s
Median	26.1	26.4
Range	20.2-33.0	21.0-33.3

B. 20 mm

Parameter	1960s	1990s
Median	5.4	5.5
Range	2.9-8.4	2.6-8.8

Table 6. Projected changes in wet days over 10 mm for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	28.3	28.9	29.5
Range	21.7-35.6	21.7-37.3	21.6-37.4

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	28.4	30.4	29.3
Range	21.6-35.5	23.1-38.0	22.2-37.1

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	28.5	38.0	37.1
Range	21.7-36.0	22.8-38.2	24.7-39.5

Table 7. Projected changes in wet days over 20 mm for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	6.1	6.6	6.6
Range	3.4-9.8	3.6-10.6	3.6-10.6

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	6.3	7.0	7.0
Range	3.4-9.8	4.1-10.8	3.8-10.8

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	6.5	7.2	8.2
Range	3.2-10.0	3.9-11.2	4.6-12.3

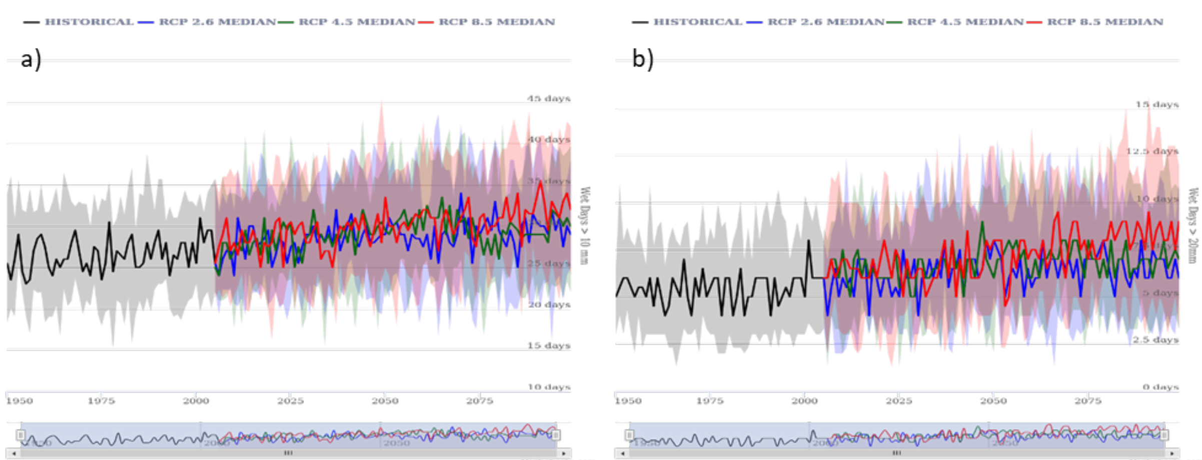

Figure 3. Projections of wet days over 10 (a) and 20 mm (b) in Clinton, Ontario under future emissions scenarios.

4. Climate Variables: Other Parameters

4.1 Frost Days

Frost days refer to the number of days with daily minimum temperatures less than 0°C, which indicates when conditions are below freezing. This is useful as it represents the duration and intensity of winter, which ultimately may affect growing season and other factors related to everyday life (ie. human health, transportation, and outdoor activities).

The below data indicates that the number of frost days in Huron County are decreasing, and are projected to decrease by almost half by late century under a high emissions scenario.

Table 1. Historic changes in the number of frost days for Clinton, Ontario.

Parameter	1960s	1990s
Median	147.1	138.5
Range	134.4-161.4	120.5-153.6

Table 2. Projected changes in the number of frost days for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	125.5	117.6	117.4
Range	106.2-141.1	96.2-134.7	97.0-136.4

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	124.1	108.8	99.2
Range	103.9-140.2	87.3-127.8	77.4-120.9

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	123.8	97.1	74.2
Range	103.6-141.7	74.6-118.4	42.6-100.1

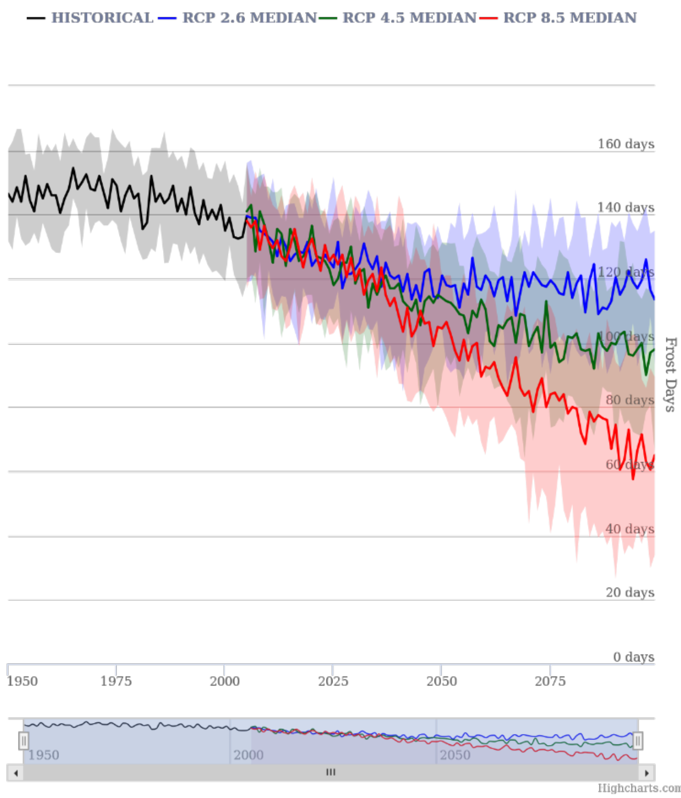

Figure 1. Projections of the number of frost days in Clinton, Ontario under future emissions scenarios.

4.2 Cooling Degree Days

Cooling degree days (CDD) are equal to the number of degrees a given day's mean temperature is above 18°C. For example, a daily mean temperature of 21°C would result in a CDD value of 3. CDDs are useful as they provide an indication of the amount of air conditioning that may be required to maintain comfortable indoor temperatures during warmer months. Furthermore, an increase in CDD values implies rising temperatures, which may have implications on energy demand and human health.

For Huron County, the below data indicates that CDDs have risen over the baseline period, which suggests a rise in mean temperatures during summer months. Under all emissions scenarios, CDDs are projected to increase, with the potential for this value to triple by late century.

Table 3. Historic changes in cooling degree days for Clinton, Ontario.

Parameter	1960s	1990s
Median	191.4	257.1
Range	132.2-276.0	180.5-343.9

Table 4. Projected changes in cooling degree days for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	339.6	393.0	387.2
Range	248.1-460.5	274.0-530.8	274.6-520.3

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	349.2	446.3	508.8
Range	243.8-471.8	314.0-610.2	371.3-717.5

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	366.4	568.3	835.1
Range	258.3-479.3	427.2-731.7	628.1-1094.0

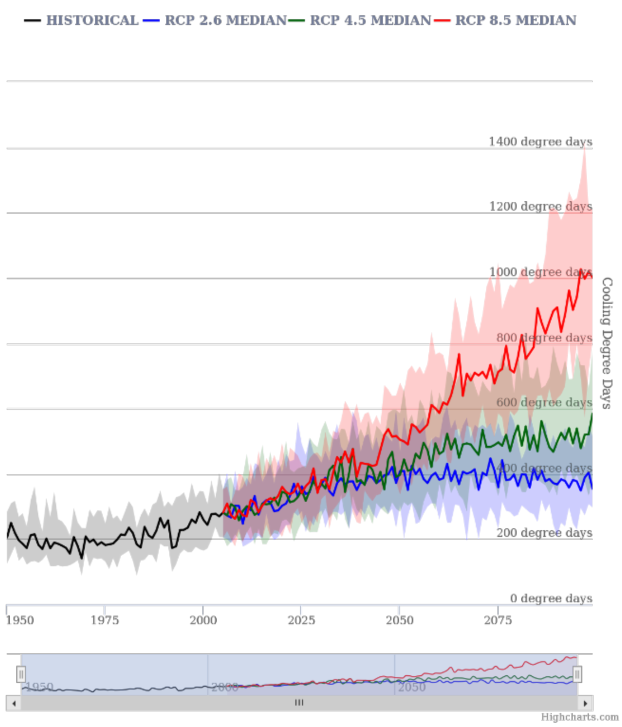

Figure 2. Projections of cooling degree days in Clinton, Ontario under future emissions scenarios.

4.3 Heating Degree Days

Heating degree days (HDD) are equal to the number of degrees a given day's mean temperature is below 17°C. For example, a daily mean temperature of 12°C would accrue a HDD value of 5. HDDs are useful as they provide an indication of the amount of heating that may be required to maintain comfortable indoor temperatures during colder months. A decrease in HDD values is indicative of shorter and less severe winters.

For Huron County, the below data indicates that HDDs have decreased over the baseline period, which suggests a rise in mean temperatures during winter months. This trend is projected to continue under all future emissions scenarios.

Table 5. Historic changes in heating degree days for Clinton, Ontario.

Parameter	1960s	1990s
Median	3919.8	3702.1
Range	3613.1-4223.5	3373.2-3970.8

Table 6. Projected changes in heating degree days for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	3406.0	3248.8	3239.1
Range	3062.2-3746.5	2878.6-3591.5	2860.5-3601.8

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	3386.4	3088.1	2937.2
Range	3037.6-3700.9	2688.9-3438.0	2546.6-3312.1

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	3344.6	2881.4	2411.0
Range	3004.9-3695.3	2510.9-3215.3	1972.8-2809.6

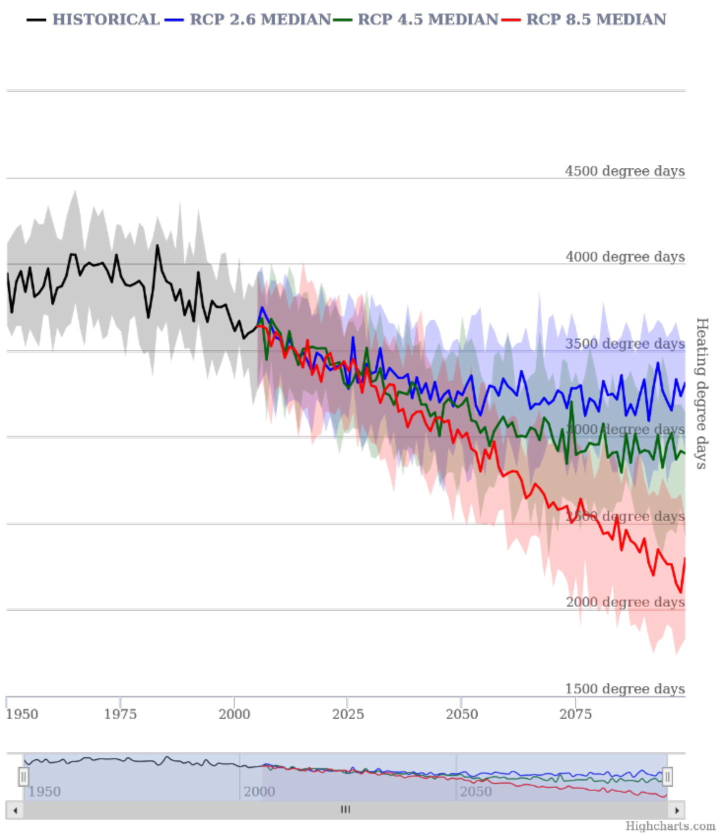

Figure 3. Projections of heating degree days in Clinton, Ontario under future emissions scenarios.

4.4 Growing Degree Days

Growing degree days (GDD) provide an index of the amount of heat available for the growth and maturation of plants and insects. Various base temperatures (or thresholds) are used to analyze GDDs, as different organisms require varying amounts of heat to thrive. GDDs accumulate when the daily mean temperature is above the specified threshold. A threshold of 5°C is often used to assess the growth of canola and forage crops, while 10°C is more appropriate for corn and beans. This indicator is particularly useful when assessing future risks to agriculture.

The below data indicates that GDDs for both base temperatures are on the rise, and they are projected to continue rising under all future emissions scenarios. Given the sensitivity of agriculture to climatic conditions, this could have implications for agricultural management in Huron County.

Table 5. Historic changes in growing degree days above 5 and 10°C for Clinton, Ontario.

A. 5°C

Parameter	1960s	1990s
Median	2024.6	2201.7
Range	1845.9-2231.3	2019.6-2392.4

B. 10°C

Parameter	1960s	1990s
Median	1121.2	1252.1
Range	974.9-1277.6	1106.4-1399.0

Table 6. Projected changes in growing degree days above 5°C for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	2420.6	2179.9	2669.3
Range	2179.9-2669.3	2283.4-2818.3	2276.1-2816.8

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	2445.5	2193.4	2679.8
Range	2193.4-2679.8	2379.3-2961.6	2497.7-3151.4

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	2460.1	2894.6	3417.1
Range	2216.3-2702.1	2619.3-3184.6	3020.6-3877.4

Table 7. Projected changes in growing degree days above 10°C for Clinton, Ontario, relative to the baseline.

A. RCP 2.6

Parameter	2020s	2050s	2080s
Median	1432.9	1525.2	1508.7
Range	1244.7-1621.1	1311.3-1744.0	1310.1-1734.5

B. RCP 4.5

Parameter	2020s	2050s	2080s
Median	1439.6	1627.5	1741.1
Range	1242.8-1645.9	1388.6-1864.2	1479.9-2023.4

C. RCP 8.5

Parameter	2020s	2050s	2080s
Median	1465.2	1813.3	2227.4
Range	1267.3-1657.1	1584.0-2048.3	1911.9-2593.0

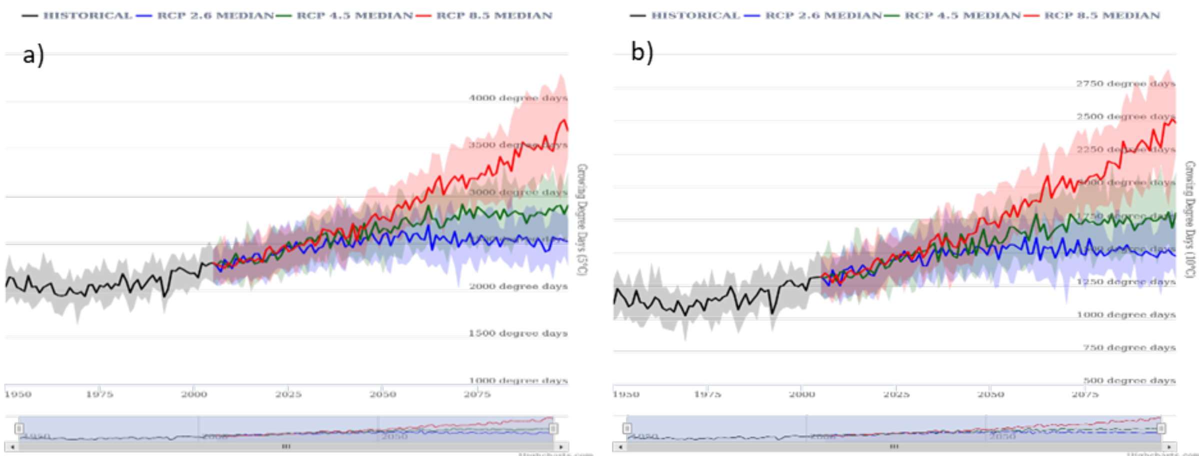

Figure 4. Projections of growing degree days above 5 (a) and 10°C (b) in Clinton, Ontario under future emissions scenarios.

4.5 Frost-Free Season

The frost-free season is the approximate length of the growing season, during which temperatures remain above freezing. An increase in the length of the frost-free season indicates a longer growing season, and consequently a shorter period of cold weather. This indicator is important to agricultural management and may be applicable to other activities, including transportation and road maintenance.

Similar to the analysis of heat waves, the following data was obtained from the Climate Atlas of Canada (PCC, 2019) and is representative of the Kitchener region. The data shows that historically, this region has had a frost-free season of approximately 150 days. Under future scenarios, the length of the frost-free season is projected to increase by almost 70 days by the end of the century.

Table 8. Historic changes in the frost-free season for Kitchener, Ontario.

Parameter	1960s	1990s
Median	147.6	155.3

Table 9. Projected changes in the frost-free season for Kitchener, Ontario.

Parameter	2020s	2050s	2080s
RCP 4.5 Median	176.7	189.3	196.0
RCP 8.5 Median	179.7	201.1	223.4

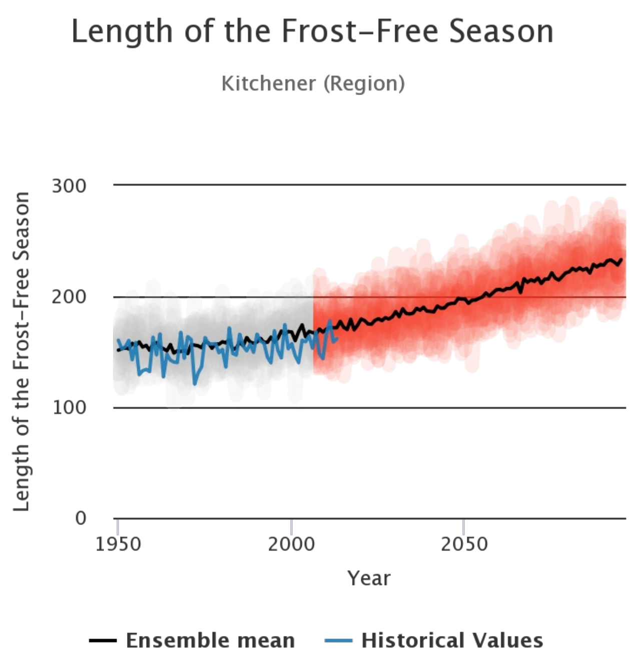

Figure 5. Projections of the frost-free season under future emissions scenarios in Kitchener, Ontario.

4.6 Lake Huron: Lake Levels, Lake Ice, & Other Projected Changes

Due to the County's proximity to Lake Huron, it is important to consider how climate change may impact the Great Lakes. Unfortunately, concrete predictions of lake conditions under future climate scenarios do not exist, as lake models are not readily incorporated into global climate simulations (Bush & Lemmen, 2019). This is partially a result of the Great Lakes having a large degree of natural variation, much of which is influenced by global atmospheric processes (Bush & Lemmen, 2019; GLISA, n.d.). Although limited, the research that has been done in this area may provide an indication of the future state of Lake Huron. This is important, as Lake Huron has an influence on local weather, and may impact the extent of some climatic changes in the area.

4.6.1 Lake Levels

It is possible that water levels in the Great Lakes could decline as a result of increased evaporation due to rising temperatures (Figure 5). It is projected that increases in precipitation could offset this decline in some regions, however this is not anticipated for Southern Ontario. Due to increasing temperatures, it is projected that Lake Michigan-Huron could experience a decrease of 1.7-3.9% in net basin supply by mid-century. This may result in a 0.1-0.5 m reduction in lake levels by 2050 (Bush & Lemmen, 2019).

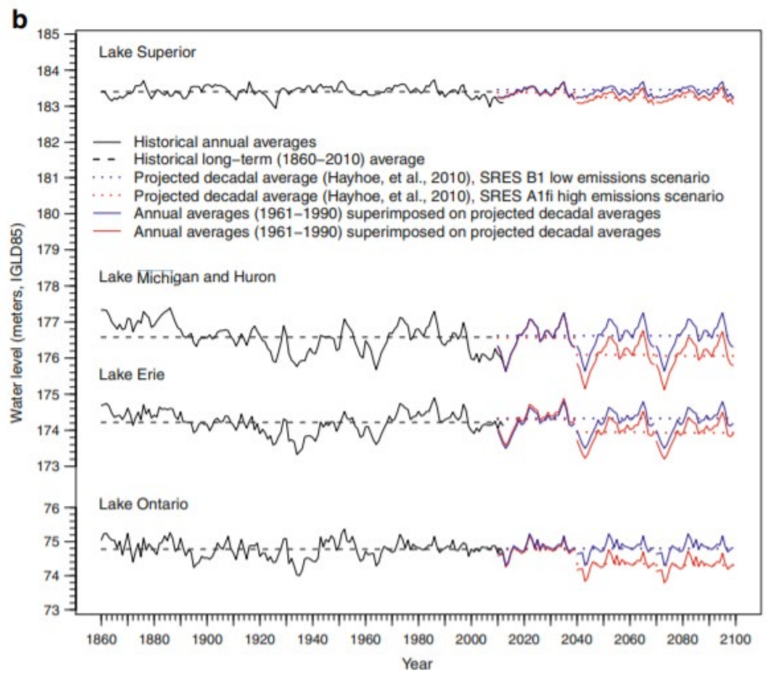

Figure 6. Forecasts of water levels in the Great Lakes under future emissions scenarios relative to historic averages. Figure adapted from Gronewold et al (2013).

4.6.2 Lake Ice & Temperature

Climate change has contributed to a decline in seasonal lake ice accumulation in the Great Lakes, and from 1973 to 2010, there was a 71% decrease in annual ice cover (Bush & Lemmen, 2019; GLISA, n.d.). This trend is anticipated to continue under future emissions scenarios, and by mid-century, it is projected that the duration of seasonal lake ice could decrease by 25-50 days. Furthermore, the seasonal thickness of the ice is predicted to decline by 10-50cm by 2050 (Bush & Lemmen, 2019).

Changes in the duration and extent of seasonal ice, combined with the influence of rising temperatures, have resulted in increased surface water temperatures in the Great Lakes (Austin & Colman, 2007). As a result, lake temperatures are rising at a faster rate than air temperatures (GLISA, n.d.). Under future emissions scenarios, it is projected that the maximum surface water temperature in Lake Huron (historically 19.7°C) could increase by over 1 degree in the near future and between 2-4 degrees by the end of the century (Trumpickas et al., 2007). This warming has been most evident in summer months within the Great Lakes, which is greatly influencing seasonal water cycles and ultimately leading to an increased period of summer stratification (Dobiesz & Lester, 2009; Trumpickas et al., 2009).

4.7 Storms & Extreme Events

As temperature and precipitation patterns transform under the influence of climate change, the frequency, duration, and intensity of weather events is expected to change. It is not yet known how the likelihood of extreme events will alter with climate change (Bush & Lemmen, 2019). However, the combination of climate projections and localized knowledge allows the intensity of extreme events to be inferred for Huron County. This is important as it provides an indication of anticipated future events, which ultimately enables better preparedness.

4.7.1 Extreme Events: Droughts & Flooding

With climate change, global hydrologic cycles are projected to intensify, consequently resulting in an increase in the intensity of hazards associated with wet and dry extremes (Council of Canadian Academies, 2019; Warren & Lemmen, 2014). At a global scale, atmospheric processes are also shifting, which has an influence on localized weather events. For example, the jet stream in the Northern Hemisphere is weakening. As a result, weather systems are moving more slowly and becoming “stuck in place”, which thereby allows undesirable events, such as heat waves and droughts, to persist (Beard & Jackson, 2019; Romanowsky et al., 2019).

In regards to temperature, it is projected that maximum temperature extremes will continue to increase under future emissions scenarios. This has the potential to lengthen the duration of dry spells, which could result in droughts. However, the intensity and duration of dry events is difficult to anticipate, as increased precipitation could offset these impacts in some areas (Bush & Lemmen, 2019).

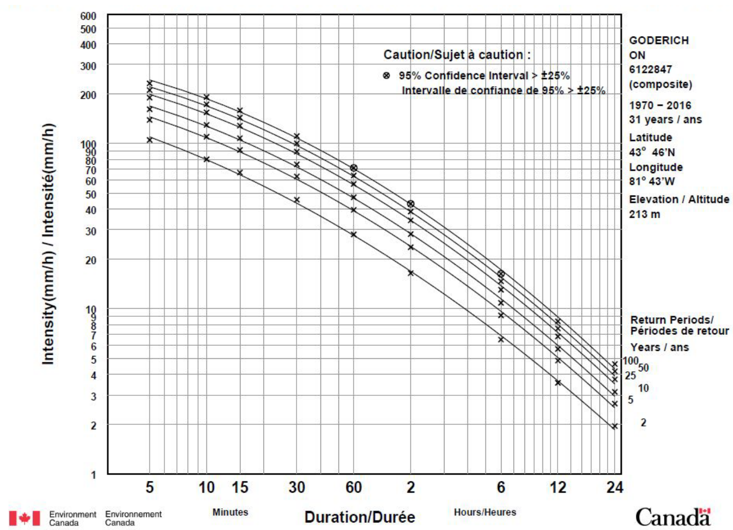

Figure 7. Intensity-duration-frequency (IDF) curve for Goderich, Ontario (CRIM, 2019).

In relation to precipitation, extreme rainfall events are projected to increase and have the potential to become twice as frequent by mid-century (Bush & Lemmen, 2019). It is likely that this will result in an increase in localized flood events. However, it is important to note that in Huron County, floods are not necessarily increasing in intensity or getting bigger. Rather, rain events are happening more quickly and exceeding the capacity of the natural environment to infiltrate precipitation (Beard & Jackson, 2019; Dickinson et al., 2018). Furthermore, the seasonal patterns of flooding are shifting due to an increase in rain-generated flooding, as well as changing freeze-thaw cycles. As a result, floods that historically occurred in the spring are happening earlier and persisting into other times of the year (Beard & Jackson, 2019; Bush & Lemmen, 2019; Dickinson et al., 2018).

The intensity-duration-frequency (IDF) curve for Goderich, Ontario has been included above (Figure 6). This data is particularly useful in preparing for future flood events, as it indicates the projected frequency of short-duration rainfall intensity (CRIM, 2019). This information is important for future adaptation efforts.

4.7.2 Ice & Snow Storms

Both ice and snow storms are projected to increase in frequency and intensity within Huron County. In regards to ice storms, warming winter temperatures and a shift in the ratio of precipitation from snow to rain present the ideal conditions for the development of ice events (Beard & Jackson, 2019; Bush & Lemmen, 2019). This is an important consideration in planning for climate change as ice events impact road maintenance, transportation, and other activities related to everyday life.

In regards to snowstorms, snowfall has increased in lake-effect areas due to a reduction in seasonal ice cover (Burnett et al., 2003; GLISA, n.d.; The Coastal Centre, 2008). As previously mentioned, a reduction in lake ice accumulation in winter months leads to increased water temperatures. When a cold air mass moves across warmer water, it encourages evaporation. The evaporated water ultimately leads to increased snowfall as this air mass reaches land. As lake ice continues to decline with climate change, the corresponding snowstorms are projected to increase in intensity (Burnett et al., 2003; The Coastal Centre, 2008).

In addition to the above, as winter temperatures warm they become more favourable for snow development. This is projected to further increase lake-effect snowfall as long as "winter air temperatures remain cold enough to produce snow". However, there is the potential for lake-effect snow events to "decrease significantly" by the end of this century, if climate change results in fewer days below freezing (Burnett et al., 2003).

4.7.3 Wind Events

The frequency and magnitude of wind gust events are projected to increase with climate change. As indicated below, compared to the historic averages (1994-2007), the frequency of wind gusts greater than 40 km/h are projected to increase by 10-20% and those greater than 70 km/h could increase by 20-40% by the end of the century (Cheng et al., 2012). This is important to consider in future adaptation planning, as high winds are detrimental to physical infrastructure and could pose risks to human health.

Table 10. Projected increase in the frequency of hourly wind gust events for the period of 2081-2100 in Ontario.

Wind Gusts	Projected Increase
> 28 km/h	10-15%
> 40 km/h	10-20%
> 70 km/h	20-40%

5. Summary

Table 1. Summary of future climate projections for Huron County.

Climate Variable	Summary of Projections
Temperature	• **Annual average temperatures** are rising in Huron County. From 1981-2010 the average temperature was 7.7°C. Temperatures are projected to increase to 9.0°C by the 2020s, 11.0°C by the 2050s, and 13.1°C by the 2080s. • Trends in **minimum and maximum temperatures** indicate that warming is occurring in all seasons, however it is projected to have the greatest impact on winter temperatures. • The number of **very hot days** (days above 30°C) are projected to increase and this will result in an increase in the frequency and duration of **heat waves**. Historically, Huron County has experienced 1 heat wave a year. This is projected to increase to 3 by the 2020s, 5 by the 2050s, and 7 by the 2080s. • The number of **frost-days** (days with daily minimum temperatures below 0°C) are projected to decrease from 139 days in the 1990s to 74 days by the end of the century. This indicates that winters are becoming shorter in Huron County.
Precipitation	• **Average precipitation totals** are projected to increase in Huron County. From 1981-2010 annual precipitation was 978 mm. This is projected to increase by 3.9% by the 2020s, 6.6% by the 2050s, and 11.0% by the 2080s. • Trends indicate that **maximum 1-day total precipitation** and **wet days** (days with 10-20 mm of precipitation) are projected to increase.
Lake Huron	• Research indicates that **lake levels** could decline by 0.1-0.5 m by mid-century, as a result of increased evaporation from rising temperatures. • Seasonal **lake ice** accumulation has declined by 71% from 1973 to 2010. It is projected that the extent and duration of lake ice will continue to decline with rising temperatures. • Surface **water temperatures** are projected to increase. Historically Lake Huron has an average maximum surface temperature of 19.7°C. This is projected to increase by 2-4 degrees by the end of the century.

Climate Variable	Summary of Projections
Extreme Events	• Projected increases in the intensity, frequency, and duration of **extreme rainfall events** could result in more localized flooding. • A reduction in the accumulation of seasonal lake ice in combination with rising temperatures is projected to increase the intensity of lake-effect **snow events**. • As a result of warming winter temperatures and a shift in the ratio of precipitation from snow to rain, it is projected that **ice storms** will become more frequent and severe in Huron County. • The frequency and magnitude of **wind gust events** are projected to increase by the end of the century.

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Note: the numbers following the references above corresponds with the information in Appendix 1.

7. Appendix

Appendix 1: Historic Climate Trends & Future Projections in Canada

Table 1. Summary of historic and projected climatic changes across Canada, with an emphasis on patterns specific to southern Ontario. The following table format has been adapted from Snover et al. (2007).[1]

Climate Variable	Expected Change	Specific Change & Reference Period(s)	Seasonal Patterns	Degree of Confidence	Additional Notes
Mean Temperature	Increase	-1950-2010: +1.5°C[2] (+1.7 1948-2016)[5] 1970-2000 baseline[3]: -2020s: +2.3°C -2050s: +4.1°C -2080s: +5.6°C	-Largest increases projected in summer[4] -Projected largest increases in winter[3]	High (virtually certain/likely)[5]	-Canada warming at twice the global rate[2] -Greater warming in night time temperatures, than day time[5]
Temperature extremes	Increase (in frequency & duration)	-1 in 20 year extreme hot day projected to become 1 in 5 year event by mid-century[2,4] -RCP 8.5: highest daily temperature currently attained 1 in 10 years, will become 2 year event by 2050[5] -Number of hot days (exceeding 30°C) +50 by 2100[5]	-Cold events decreasing, warm events increasing[2,4]	High (virtually certain)[5]	-Extreme minimum/cold temperatures increasing more rapidly than extreme warms/maximums[2,5] -Length, frequency, and/or intensity of warm spells projected to increase[4] -Extreme cold temperatures to become less frequent[5] -More cooling and less heating degree days[5]
Total Precipitation	Increase	-1950-2010: +16%[2] (+20% 1948-2012)[5] -RCP 2.6: +7% by 2100[5] -2080s: +20% under RCP 2.6[3] (24% projected by 2100)[5]	-Decline in summer & fall precipitation, increase in winter & spring, projected for Southern Canada[2,4,5]	Medium/high[5]	-Shifting ratio to more rain and less snow[2,5] -Decline in summer precipitation projected most strongly under RCP 8.5[5] -Over short-term, small (less than 10%) increase projected across all seasons -Median increase by ~7% per 1 degree warming in global temperature[5]

Climate Variable	Expected Change	Specific Change & Reference Period(s)	Seasonal Patterns	Degree of Confidence	Additional Notes
Heavy precipitation events	Increase	-RCP 8.5: Extreme precipitation with 20 year return period projected to become 1 in 10 year event by mid-century and 1 in 5 by 2100[5]	N/A	-Low: difficult to predict due to data availability, and also largely influenced by broader atmospheric & global cycles[2,5]	-Global hydrologic cycles expected to intensify resulting in increased intensity of wet & dry extremes, and associated hazards (ie. floods and drought)[2,4] -Rare extreme precipitation events projected to become twice as frequent by mid-century[4] -Daily extreme P projected to increase[5]
Flooding, droughts, and other extremes	Possible increase	-Increases in number of dry days and duration of dry spells expected under RCP 8.5[2] -Projected increases in extreme precipitation expected to increase likelihood of rain-generated flooding[5]	-Reduced dryness in winter & increased in summer[2]	- Low/medium: anthropogenic climate change has likely increased likelihood of extreme events, but must also consider we have increased our exposure to the effects of extremes[5]	-Linked to projected rises in temperature, but largely dependent on patterns of precipitation and whether increased precipitation will offset increased evaporation as a result of rising temperatures[5] -Snowmelt-related floods occurring earlier in year due to rising temperatures[5]
Growing season	Increase	-1948-2016: 15+ days[5]	N/A	High: largely dependent on temperature changes	-Due to warming temperatures, longer growing season is projected[5]
Frost days	Decrease	-1948-2016: -15 frost days[5] -1948-2016: -10 ice days[5] -RCP 2.5 (2031-2050): -10 frost days[5] -RCP 8.5 (2081-2100): -40 frost days[5]	N/A	High: largely dependent on temperature changes	

Climate Variable	Expected Change	Specific Change & Reference Period(s)	Seasonal Patterns	Degree of Confidence	Additional Notes
Snow & ice cover	Decrease	-Snow cover fraction has decreased 5-10% per decade since 1981[5] -Decline in seasonal snow accumulation of 5-10% projected per decade through to mid-century[5] -Continual snow loss projected under RCP 8.5[5]	-Decrease in seasonal duration and accumulation of snowfall and ice cover[4,5]	Medium/high[5]	-Projected decreases in snow cover fraction largest for Southern Canada, where temperature increases will result in less snowfall as a proportion of the total precipitation[5] -Later snow onset and earlier spring melt[5]
Lake ice cover	Decrease	-Duration of seasonal lake ice cover declined over past 50 years[5] -1973-2010: 71% decline in annual maximum ice cover for all great lakes[5] -Ice breakups projected 10-15 days earlier & freeze ups 5-15 days later by mid-century (for total reduction of 25-50 days)[5] -Mean seasonal maximum ice thickness projected to decrease 10-50cm by mid-century[5]	-Later ice formation in fall and earlier spring breakup has been trend in great lakes since 1971[5]	-Medium/high[5] **Changes in lake ice can be projected only indirectly, as lake models are not embedded within global climate models. Also more strongly linked to larger global processes, ie. ENSO[5]*	-Duration of lake ice expected to decrease[4]
Lake levels	Possible decrease	-No indication of long-term changes in lake levels[5] -Future levels may decline in southern Canada[5] -2041-2070: Projected decrease in net basin supply by 1.7-3.9% in Lake Michigan/Huron[5] -2050s: possible decrease of 0.1-0.5m[5]	-Great lakes have natural & large year-to-year fluctuations of less than 2m[5] -Increase in NBS in winter/spring and decrease in summer/fall	-Low: lack of monitoring and data availability **Also result of variability being significantly influenced by naturally occurring large-scale modes of climate variability[5]*	-Result of increased evaporation due to rising temperatures, but expected to be offset by increased precipitation in some areas[2] -Unsure if changes in duration of lake ice will effect temperatures[5] -Projected decline in southern Canada where increased evaporation may exceed increased precipitation -Smaller lakes more responsive to local climatic conditions[5]