An Investigation of Precipitation Trends in the Greater Toronto Hamilton Area

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Introduction

- The Greater Toronto Hamilton Area (GTHA) shown in Figure 2, lies in Southern Ontario Canada and is compromised largely of growing urban environments.
- The urbanization of Toronto and changes in climate have lead to an increase in the mean temperature of Toronto and the surrounding area.
- Rainfall in the GTHA is greatly impacted by the presence of Lake Ontario
- An increase in precipitation in the GTHA could lead to more frequent flooding and damage of infrastructure.

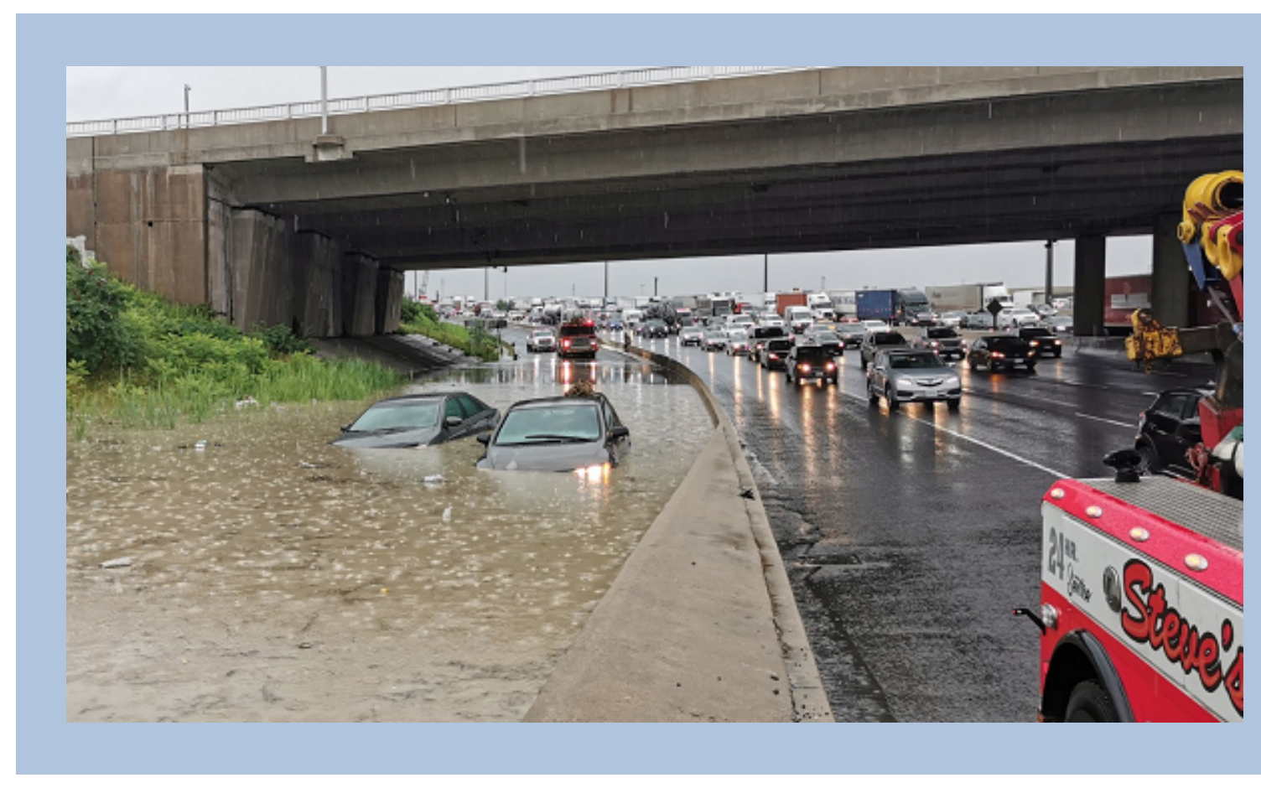
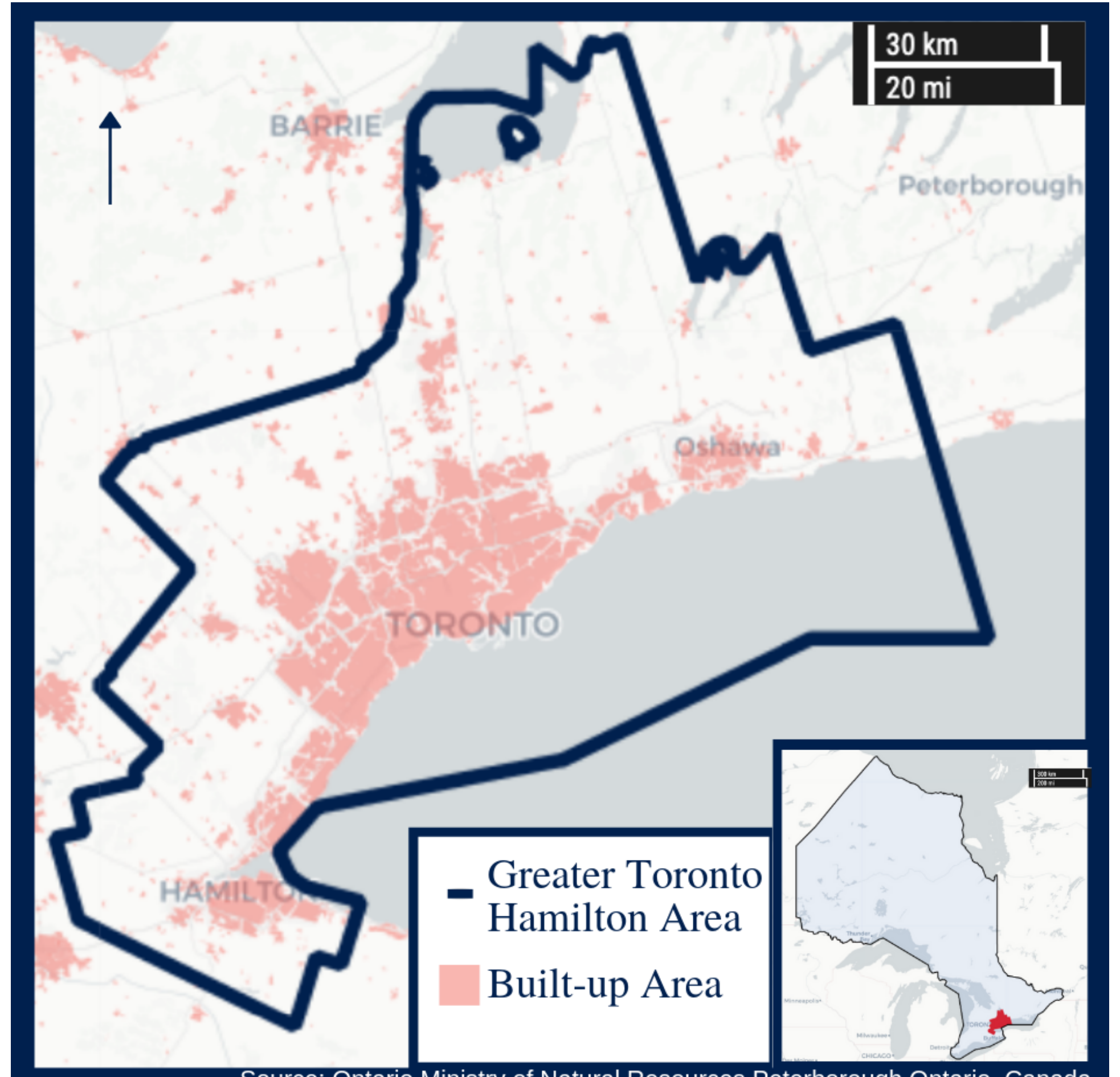


Figure 1: Massive flooding on the Islington exit of the 401 highway through Toronto on July 17th 2019. [1]



Source: Ontario Ministry of Natural Resources Peterborough Ontario, Canada

Figure 2: The GTHA's location in Ontario, Canada, with the red areas marking the built-up locations in Ontario. Meaning the areas where the linear frequency of structures is above 10 per 500m. The data comes from the Ontario Geo spatial data exchange at the Ministry of Natural Resources. [2]

Analysis I

- The oldest historical data for the GHTA dates back to 1840, and is taken from the 'Toronto Station' with station id 6158350
- The timespan covered by this station data for the GTHA is significantly larger than a number of other stations in the GHTA.
  - Larger time period gives better understanding of climatic trends.
  - This data was compared to station data from North York, which starts in the 1930's and agreement was found between the two sets for the time periods they both covered.
- The daily mean data was used to look at annual daily averages, and seasonal daily averages across a 160 year timespan as seen in figure 3.
  - Winter was considered to be December, January, February,
  - Summer was taken as June, July, August
- The temperature (3.a.) was shown to increase significantly with time.
  - Some sources show that urbanization in the GHTA has played a role in the increase in temperature, but global climate is also a culprit [4].However, further work will compare a non-urbanized area in the GTHA to verify this claim.
- The winter snowfall (3.b.) decreases, while this is of interest the significance of this trend requires further analysis.
- The rainfall for both winter (3.c.) and summer (3.d) shows a significantly slower decrease per year than the snowfall.

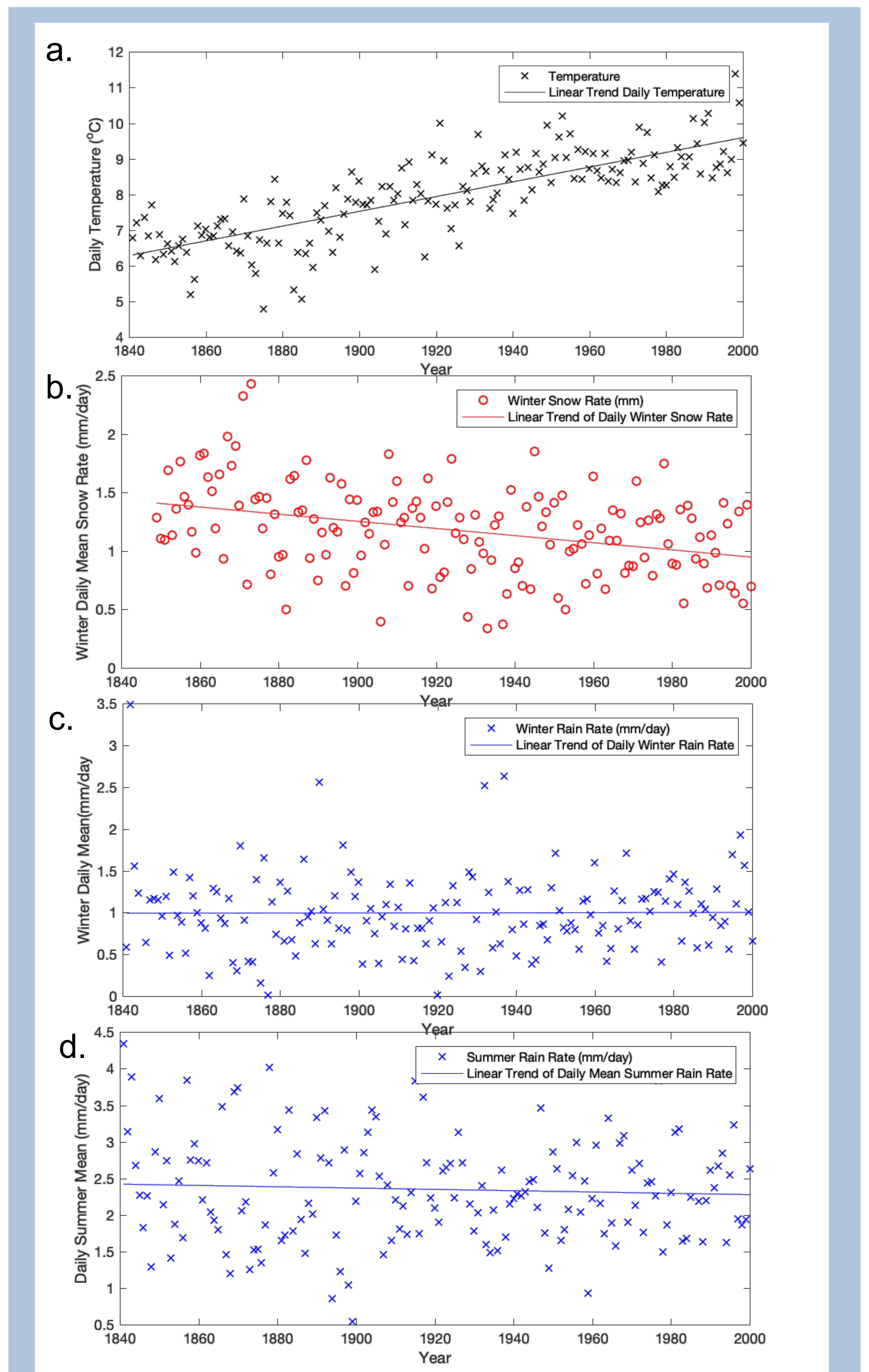


Figure 3: a) Mean Annual Daily Temperature, has a slope of 0.02°C/year with R^2 = 0.6, **b)** Mean daily snowfall rate in the winter decreases at a rate of 0.003 dailymm/year with an R^2 of 0.1, and the annual daily snowfall has a slope of -1x10^{-3} dailymm/year and R^2 of 1x10^{-1} **c)** Mean daily rainfall rate in the winter has a slope of 5x10^{-5} dailymm/year with R^2 of 3x10^{-5} and the annual daily rainfall rate of -5x10^{-4} dailymm/year with an R^2 of 5x10^{-3} , **d)** shows the summer mean daily rainfall rate and has a slope of -9x10^{-4} dailymm/year, and R^2 of 3x10^{-3} .

Analysis II

Moving window trend analysis was preformed to investigate the stationarity of the trends in precipitation In figure 4, the rainfall rate in the winter and summer months is investigated.

Initially the overall trend was compared to the trend from 1980 to 2000, next the slopes of the trendlines were taken starting at a different year up to 1990.

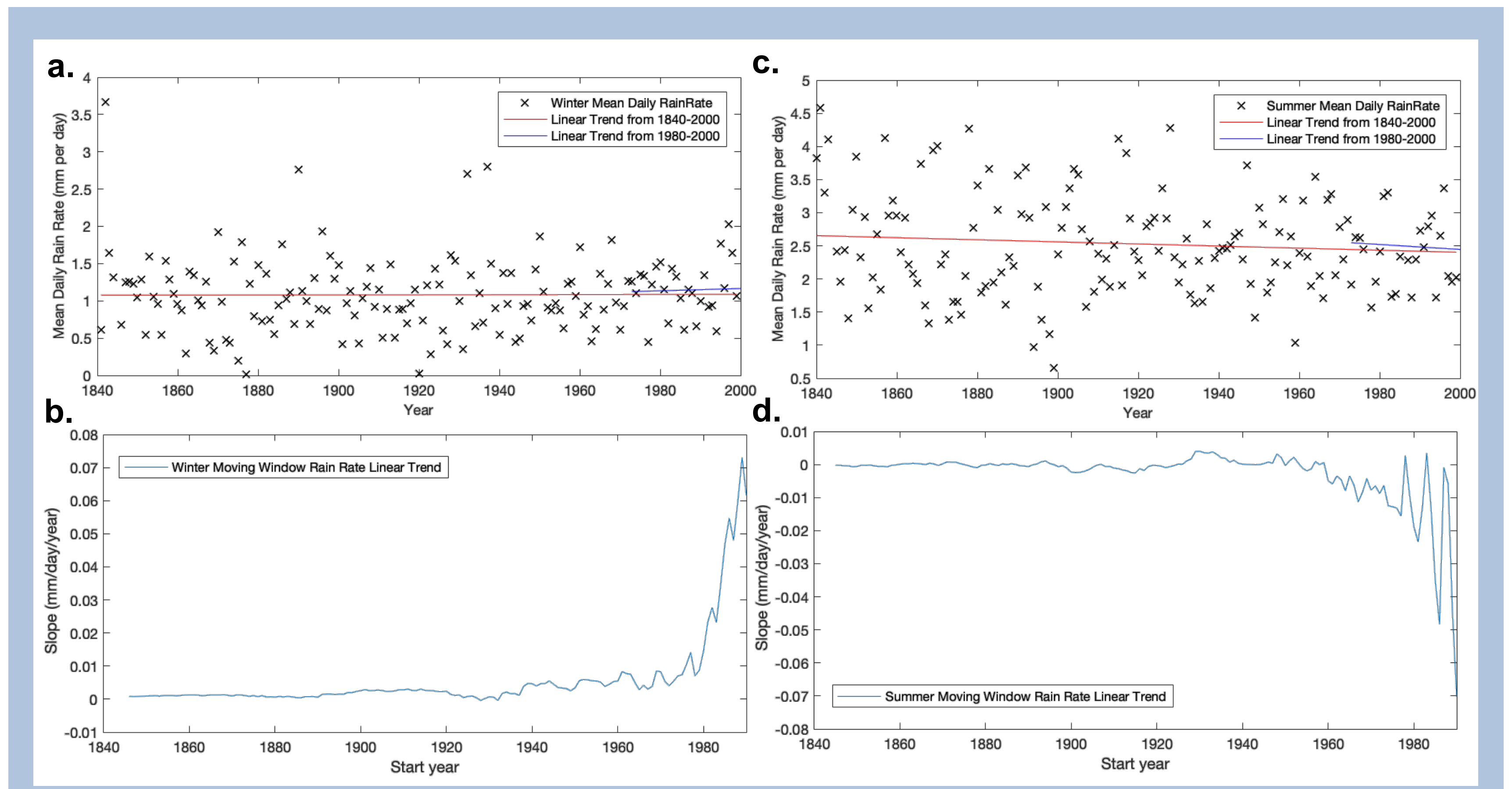


Figure 4: a) The winter daily rain rate with the linear trend from 1840-2000, and the linear trend from 1980 -2000 **b)** The winter moving window linear trend, note the x- axis indicates the start year of the trends and all the trends used the same end date of 2000, the last start date plotted is 1990 as at least 10 datapoint were used to generate the moving window trends . **c)** The summer daily rain rate with the linear trend from 1840-2000, and the linear trend from 1980 -2000 **d)** The summer moving window linear trends as a function of start year from 1840-1990, all trends used an end year of 2000.

- The winter rainfall data (4.a.)shows an overall linear trend of 7x10^{-5} compared to the linear trend beginning 1980 which is 2x10^{-3} . The increase in the linear trend is seen to begin in approximately the 1960s and indicates a non-stationary aspect of the data.
- The summer rainfall data (4.a.)shows an overall linear trend of -2x10^{-3} compared to the linear trend beginning 1980 which is -4x10^{-3} , suggesting there is a change in precipitation seasonally.

Conclusions

Rainfall in the GTHA is below the annual average in the winter and above the annual average in the summer. The appears largely consistent over the past 160 years while the snow fall is decreasing in the winter. The significance of these trends is still under investigation.

The moving window analysis shows the trend in rainfall may be non-stationary. The moving window slopes in rainfall for both the winter and summer shows a large change after 1960 compared to the slope with start years from 1840-1960.

Further research is being done into the significance of the trends in rain and snowfall.

- This includes a spectral analysis of the trend, to look at the significance of the trends, comparing synthetic datasets with the same underlying frequencies
- White noise analysis wherein the same data is reordered and the trends are compared

The maximum and minimum events are currently being analyzed through similar methods to the initial timeseries to determine if there has been an increase in large precipitation events that could result in flash flooding.

References & Acknowledgements

[1] Subra, S. (2019). Toronto flooding eastbound Islington ramp. [image] Available at: https://globalnews.ca/news/5503652/heavy-rain-toronto-environment-canada/ [Accessed 25 Jul. 2019].

[2] Built-up area and the GHTA boundary were sourced from the Ontario Geospatial Data exchange, the Ministry of Natural Resources.

[3] Weather Station data is taken from Environment and Climate Change Canada's historical data, for Toronto, station id 6158350.

[4] Mohsin, T. and Gough, W. (2009). Trend analysis of long-term temperature time series in the Greater Toronto Area (GTA). Theoretical and Applied Climatology, 101(3-4), pp.311-327.

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