Microclimate Variability of Select Toronto Neighbourhoods

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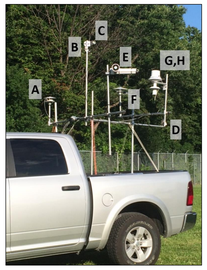
Project Overview

- Mobile measurements using vehicle mounted sensors *(see below)* were conducted to measure near-surface meteorological conditions within the City of Toronto.
- Measured variables include: air temperature, relative humidity, surface temperature, and incoming shortwave and longwave radiation.



A photograph of our vehicle alongside an AMMOS (Env. Canada).

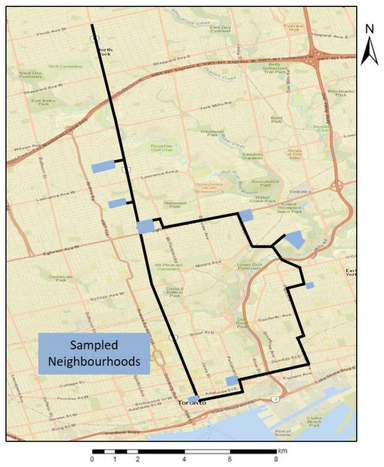
Diagram (left): A- pyrgeometer, B C D- infrared thermometers, E- fine-wire thermistor, F- pyranometer, G- temperature & relative humidity probe, H- fine-wire (type-T) thermocouple, Not shown- Garmin GPS.

Research Questions

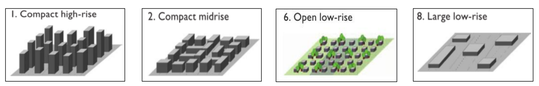
1. What is the canyon air temperature variability between select urban neighbourhoods?
2. Identified as 'high-risk' neighbourhoods by Toronto Public Health (TPH), do the Thorncliffe Park and Moss Park neighbourhoods show higher average air temperatures compared to other urban neighbourhoods?

Sampling Strategy

- Two traverse routes, A and B, sampled select urban neighbourhoods defined by contrasting surface characteristics through the use of the Local Climate Zone scheme[1].
- Sampling dates targeted hot summer daytime conditions when human health is at greatest risk. The Urban Heat Island (UHI) was also investigated under clear night conditions.



A map of the combined traverse routes and sampled neighbourhoods.



Examples of the LCZs sampled in this study[1].

Sample Results

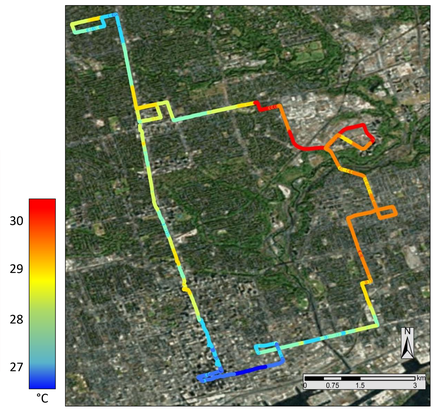
A total of 23 vehicle traverses were completed between July 7th – July 29th, 2015. Shown below are sample air temperature results from an early afternoon traverse and a nighttime traverse. All temperature data are corrected to remove linear heating/cooling during the period of the traverse[2,3].

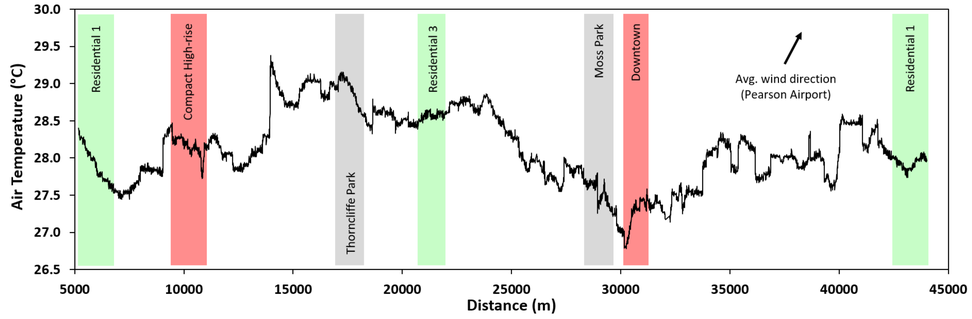
Early Afternoon

Date: July 24th — **Avg. T_{air}** = 28.0 °C
Start time: 1:49 PM (EDT) — **Max. T_{air}** = 29.7 °C
End Time: 3:52 PM (EDT) — **Min. T_{air}** = 26.8 °C

Figure *(right)*: Corrected traverse air temperatures plotted spatially and superimposed on a satellite image of Toronto.

Plot *(below):* A spatial series plot of air temperature highlighting the microscale variability. This plot represents a structural trend seen in 9 of 11 early afternoon traverses, where the highest average temperatures are observed in Thorncliffe Park (and the shopping centre) and the lowest observed temperatures are experienced downtown.



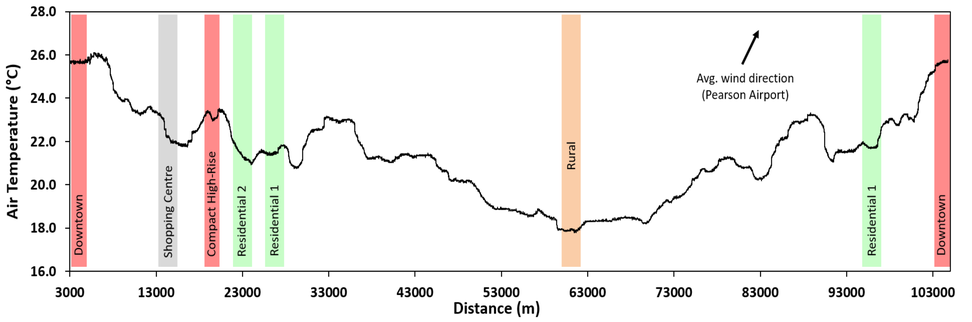


Nighttime

Date: July 12th — **Avg. T_{air}** = 22.1 °C
Start time: 12:44 AM (EDT) — **Max. T_{air}** = 26.3 °C
End Time: 4:00 AM (EDT) — **Min. T_{air}** = 17.8 °C

Figure *(left)*: Corrected traverse air temperatures plotted spatially and superimposed on a satellite image of Toronto.

Plot *(below):* A spatial series plot of air temperature measuring the UHI effect. On this night, the UHI magnitude was ~8 °C (UHI magnitude = $Tair_{Downtown} - Tair_{Rural}$).

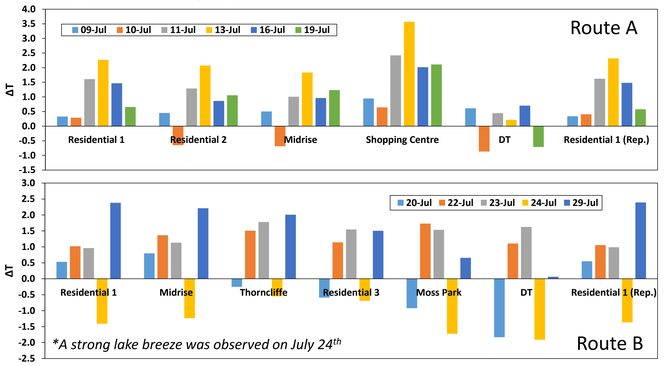


Neighbourhood Comparisons

- In order to compare neighbourhood averages of air temperature on different dates, a UHI value (ΔT, °C) was calculated for each neighbourhood.

$$\Delta\hat{T}_{t,(Ne-R)} = \hat{T}_{t,Ne} - T_{t,R}$$

where $\Delta\hat{T}_{t,(Ne-R)}$ is the calculated average UHI value , $\hat{T}_{t,Ne}$ is the average air temperature within a neighbourhood, and $T_{t,R}$ represents the rural reference air temperature (Claremont station).



The above bar plots suggest that replicate mobile sampling over different dates show similar differences in average air temperature between neighbourhoods.

Preliminary Conclusions

1. Replicate sampling of both routes proved to show similar temperature trends.
2. Thorncliffe Park and the shopping centre (with a high degree of impermeable surface cover and minor vegetation) show the highest early afternoon air temperatures. This supports TPH's 'high-risk' assessment for Thorncliffe Park.
3. Downtown experiences the coolest canyon air temperatures on average, likely a result of urban canyon shading from high-rise buildings and advection of cooler air from Lake Ontario.
4. Average air temperatures during nighttime traverses show larger inter-neighbourhood differences than daytime traverses.

Future Work

1. Expand analysis to include other measured meteorological variables to more thoroughly characterize the microclimates of each neighbourhood.
2. Compare mobile measurements to 3D GEM-LAM modeled outputs.
   - Does the model show similar microclimate differences between neighbourhoods?
   - Is there significant sub-pixel scale meteorological variability not being captured?

Acknowledgements

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References

1 - Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society, 93*(12), 1879–1900.
2 - Tsin, P.k., Knudby, A., Krayenhoff, E.S., Ho, H.C., Brauer., & Henderson, S.B. (2016). Microscale mobile monitoring of urban air temperature. *Urban Climate, 18,* 58-72.
3 - Leconte, F., Bouyer, J., Claverie, R., & Pétrissans, M. (2015). Using Local Climate Zone scheme for UHI assessment: Evaluation of the method using mobile measurements. *Building and Environment, 83,* 39-49.