Spatial Trends in Ground-level Ozone in the Greater Toronto Area

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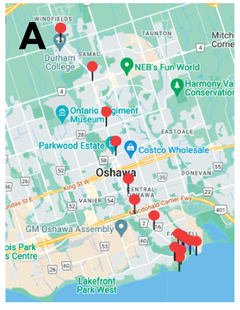
Introduction

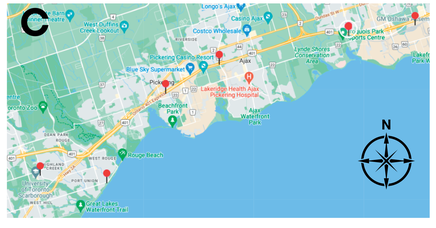
- Ground-level or tropospheric ozone (O_3) is a pollutant from precursors of NO_2 and VOCs[1]
- Modeling and measurements suggest lake-breeze circulation increases O_3 over the surface of the Great Lakes and nearby land[2]
- Previous study reported a **lake-edge removal effect:** negative-linear relationship between O_3 concentration and distance to shore (<500m from Lake Ontario) due to lake-breeze circulation[3]
- This project aimed to investigate if this phenomenon is seen in urban Toronto and surrounding suburban Greater Toronto Area (GTA) environments.

Hypothesis

1. O_3 concentration decreases away from Lake Ontario shoreline in urban and suburban environments.
2. O_3 concentration increases east to west moving into the city of Toronto from suburan areas.

Method





- O_3 measured using Aeroqual 500 handheld monitor throughout Jun-Aug 2022 between 2-7 pm EST on non-raining days.
- Average five values at 1 min intervals
- Wind speeds measured using a AOPUTTRIVER 816B handheld anemometer and wind direction using a digital compass.
- Measurements compared with provincial Ontario air quality monitoring data in Oshawa and the four Toronto stations

Figure 1. Measurement sites in in Oshawa (A), Toronto (B) and along the GO train line from Oshawa to Scarborough (C). Base map taken from Google Maps.

Results

A: Oshawa

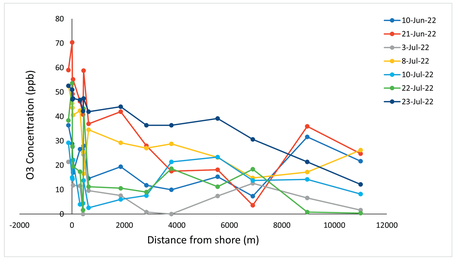


Figure 2. Line graph of average O3 (ppb) in relation to corresponding distance from the shore of Lake Ontario on seven separate days in Oshawa.

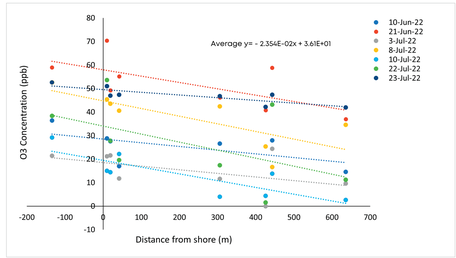


Figure 3. Scatter plot of average O3 (ppb) to distance from the shore of Lake Ontario (<1000m) with linear regression in Oshawa.

B: Toronto

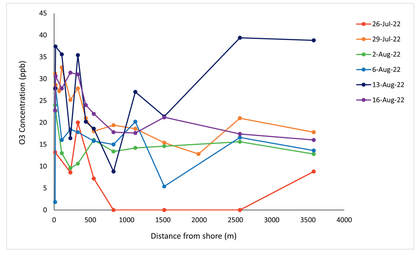


Figure 4. Line graph of average O3 (ppb) in to corresponding distance from the shore (m) of Lake Ontario in downtown Toronto.

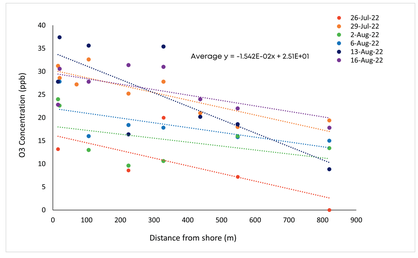


Figure 5. Scatter plot of average O3 (ppb) to distance from the shore of Lake Ontario (<1000m) with linear regression in downtown Toronto.

- Linear relationship observed <1 km from Lake Ontario in both Oshawa and Toronto
  - Stronger relationship in Oshawa
- The average slope was -0.0235 ppb/m in Oshawa and -0.0154 ppb/m in Toronto.
- Beyond 1 km ozone levels rebound to regional levels, typically lower than near shore.
- Daily variation in ozone captured, e.g. Jun 21st, 2022 high ozone warning issued.

C: Oshawa to Scarborough

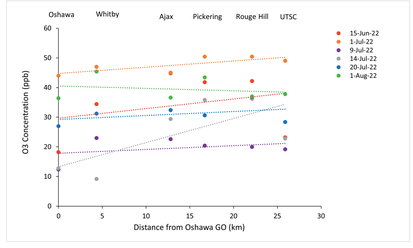


Figure 6. Scatter plot of average O3 (ppb) to distance from Oshawa GO station (m) with linear regression.

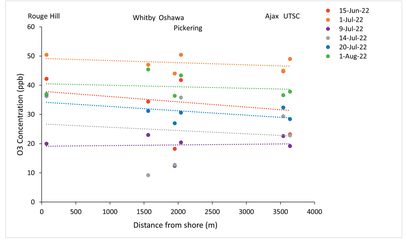


Figure 7. Scatter plot of average O3 (ppb) to distance from the shore of Lake Ontario (<1000m) with linear regression.

- Small increase in ozone moving east to west from Oshawa to Scarborough
- No obvious relationship between ozone and dependence on distance to shore regionally.
- Data from Oshawa and Toronto provincial air quality sites show similar trends in average daily ozone and hourly ozone

Local Environment & Mechanism

- Lake-breeze circulation was observed (figure 8)
  - Afternoon winds most commonly from the direction of the lake, secondary from the west (see arrows)
  - Higher ozone in more western points (red circle) to eastern points (white circle) at similar distances from lake
- No obvious impact on ozone concentration by wind speed (figure 9)

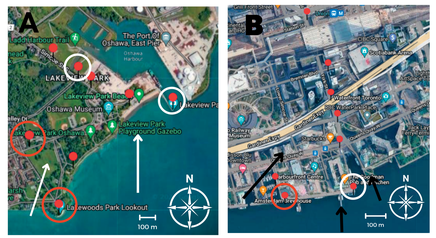


Figure 8. Measurement sites in in Oshawa (A) and Toronto (B) within 1 km from Google Maps satellite view. Arrows indicate wind direction.

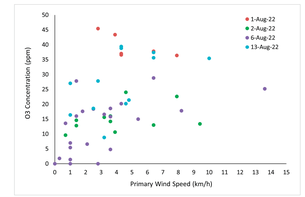


Figure 9. Scatter plot of average O3 (ppb) to wind speed (km/h) .

- Vegetation may be involved in ozone removal processes
  - Slopes decrease from rural (-0.0376 ppb/m Sandbanks National Park)[3], suburban (-0.0235 ppb/m Oshawa) and urban (-0.0154 ppb/m Toronto)
  - Decrease of ozone within forest canopy (**forest-edge effect**) observed in previous studies[4]

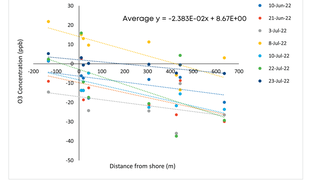


Figure 10. Scatter plot of absolute difference from Oshawa station O3 (ppb) to distance from shore (m) . O3 concentration = measured O3 - Oshawa station at same time of day. Linear regression applied to O3 values of Oshawa station when measured time fell within the hour.

- Adjusting for time of day on ozone concentration did not alter the observed trend (figure 10)

Conclusion & Future Directions

- Lake-edge removal effect of ozone observed in both Toronto and Oshawa within 1km of the Lake Ontario
- Regional ozone levels similar throughout the Greater Toronto Area (GTA).
- Future investigations should look into whether elevated ozone levels occur over the lake and confirmation of the mechanisms behind this observation.

References

1. Finlayson-Pitts, B. J., & Pitts, J. N. (1993). Atmospheric Chemistry of Tropospheric Ozone Formation: Scientific and Regulatory Implications. Air & Waste, 43(8), 1091–1100. https://doi.org/10.1080/1073161X.1993.10467187
2. Levy, I., Makar, P. A., Sills, D., Zhang, J., Hayden, K. L., Mihele, C., Narayan, J., Moran, M. D., Sjostedt, S., & Brook, J. (2010). Unraveling the complex local-scale flows influencing ozone patterns in the southern Great Lakes of North America. Atmospheric Chemistry and Physics, 10(22), 10895–10915. https://doi.org/10.5194/acp-10-10895-2010
3. Blanchard, D., & Aherne, J. (2019). Spatiotemporal variation in summer ground-level ozone in the Sandbanks Provincial Park, Ontario. Atmospheric Pollution Research, 10(3), 931–940. https://doi.org/10.1016/j.apr.2019.01.001
4. Karlsson, P. E., Hansson, M., Höglund, H. O., & Pleijel, H. (2006). Ozone concentration gradients and wind conditions in Norway spruce (Picea abies) forests in Sweden. Atmospheric Environment, 40(9), 1610–1618. https://doi.org/10.1016/j.atmosenv.2005.11.009