Mobile Meteorological Measurements during the 2015 Toronto Games

PanAm/ParaPanAm Legacy Workshop – January 12, 2017

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Western

WESTERN GEOGRAPHY

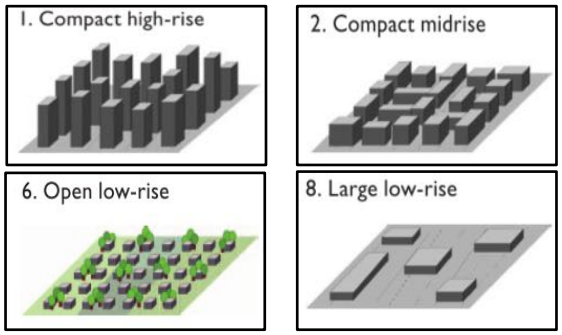
Overview

- A total of 23 vehicle traverses were completed between July 7th – July 29th, 2015 and targeted hot summer daytime conditions when human health is at greatest risk.
- Measured meteorological variables include: air temperature, relative humidity, surface temperature, and incoming shortwave and longwave radiation. A GPS was also included in the instrumentation.

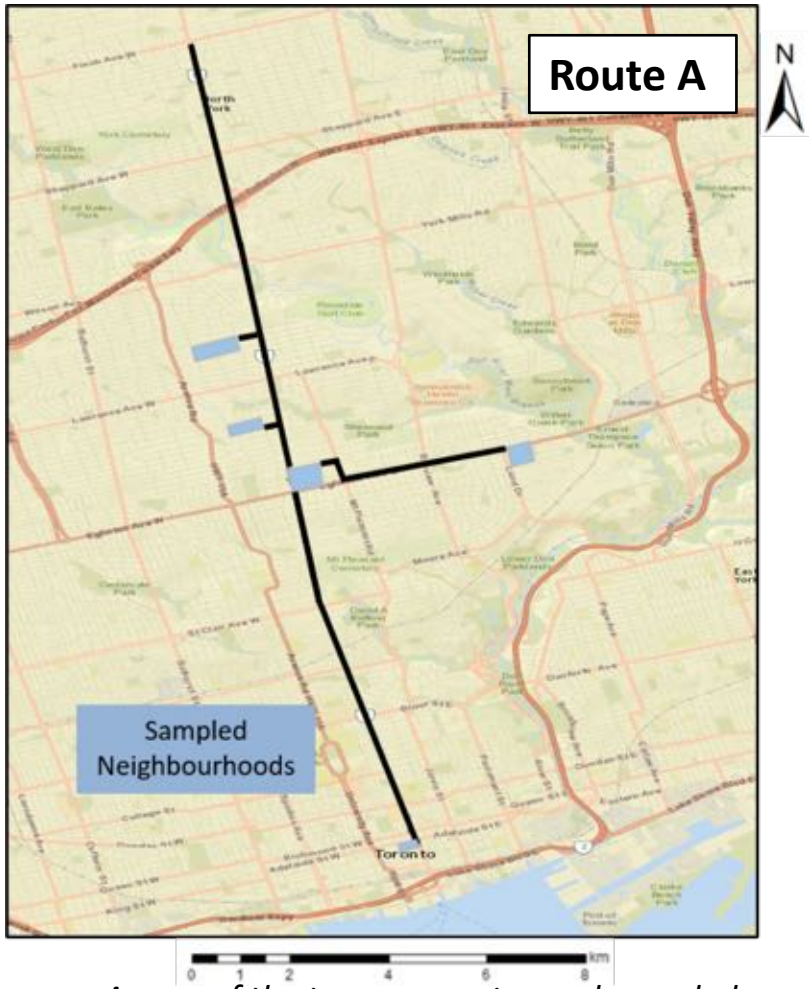
A photograph of our vehicle alongside an AMMOS (Environment Canada)

Overview cont'd

- 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].
- The Urban Heat Island (UHI) was also investigated under clear night conditions.



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



A map of the traverse routes and sampled neighbourhoods.

Summary of Vehicle Traverses

Traverse Date	Start Time	End Time	(°C)	Route	Weather Conditions
Jul-07	11:12 AM	2:14 PM	27.9	A	Slightly overcast, hot, humid, light winds.
Jul-08	12:43 PM	3:05 PM	21.9	A	Sunny, minor cloud coverage, light winds.
Jul-09	12:43 PM	2:55 PM	22.2	A	Overcast, light winds.
Jul-09	3:17 PM	5:49 PM	23.1	A	Overcast, moderate winds.
Jul-10	2:50 PM	5:57 PM	27.1	A	Mainly sunny with minor cloud coverage, light winds.
Jul-11	9:48 AM	11:50 AM	26.2	A	Clear skies, light winds.
Jul-11	1:14 PM	3:26 PM	28.2	A	Hot, clear skies.
Jul-11	9:12 PM	11:58 PM	25.0	A	Clear skies.
Jul-12	12:44 AM	4:00 AM	21.8	A	Clear skies.
Jul-12	2:58 PM	5:26 PM	28.8	A	Hot, humid, slightly overcast.
Jul-13	1:04 PM	3:42 PM	28.7	A	Hot, humid, slightly overcast.
Jul-16	1:26 PM	4:25 PM	23.1	A	Mostly clear skies with minor thin clouds.
Jul-19	1:03 AM	2:30 AM	25.3	A	Humid, minor cloud coverage.

Night Traverse

Summary of Vehicle Traverses

$\overline{T}_{air}$ > 30 °C
Night Traverse

Traverse Date	Start Time	End Time	(°C)	Route	Weather Conditions
Jul-19	1:07 PM	3:00 PM	31.1	A	Overcast, hot, humid, moderate winds.
Jul-20	1:34 PM	4:03 PM	29.0	B	Overcast, hot, moderate winds.
Jul-22	1:47 PM	4:15 PM	26.0	B	Relatively clear skies, strong winds.
Jul-23	1:39 PM	4:29 PM	26.9	B	Mainly clear skies, moderate winds.
Jul-24	1:49 PM	3:52 PM	28.6	B	Hot, overcast, light winds.
Jul-24	5:12 PM	7:09 PM	28.4	B	Hot, overcast, light winds.
Jul-28	4:00 PM	9:38 PM	31.3	UHI	Heat warning issued, light winds.
Jul-29	1:15 AM	4:19 AM	24.5	UHI	Hot, clear skies, light winds.
Jul-29	1:20 PM	3:51 PM	32.4	B	Hot, minor cloud coverage, moderate winds.
Jul-29	4:49 PM	7:00 PM	30.8	B	Hot, overcast, moderate winds

- **UHI - Joint traverses conducted with EC on July 28th and 29th**
- **Heat warning issued on July 28th**

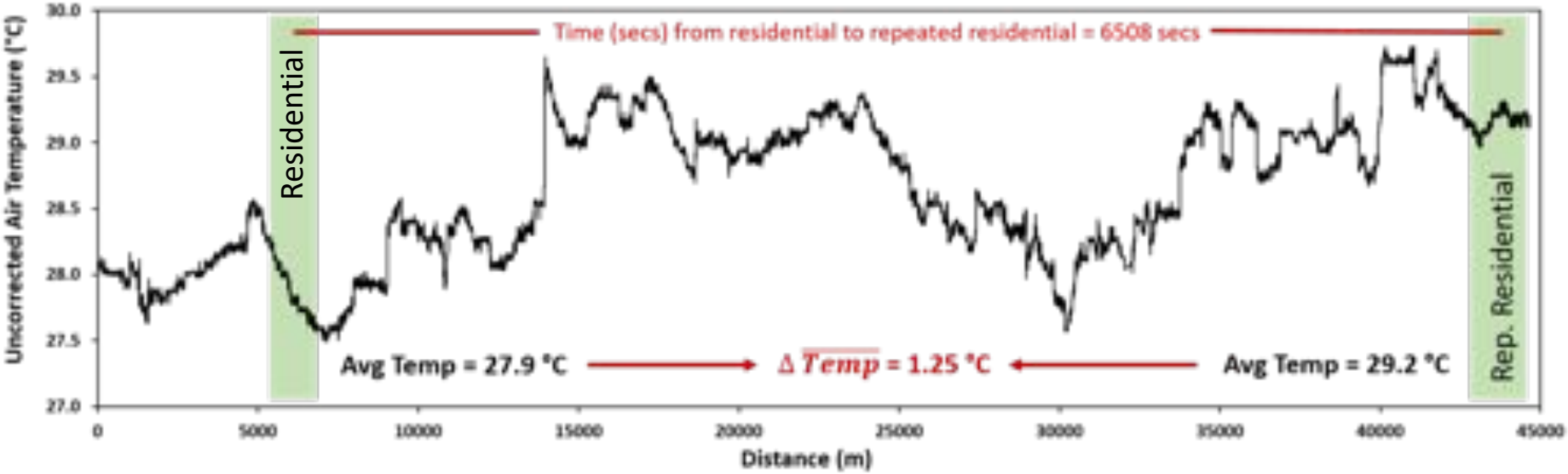
Research Questions

1. What are the microclimate differences between select urban neighbourhoods?
    - ➢ This presentation will examine differences in air temperature.

2. Identified as ‘high-risk’ neighbourhoods by Toronto Public Health (TPH), do the Thorncliffe Park and Moss Park neighbourhoods show warmer air temperatures compared to other urban neighbourhoods?

Applying Air Temperature Correction

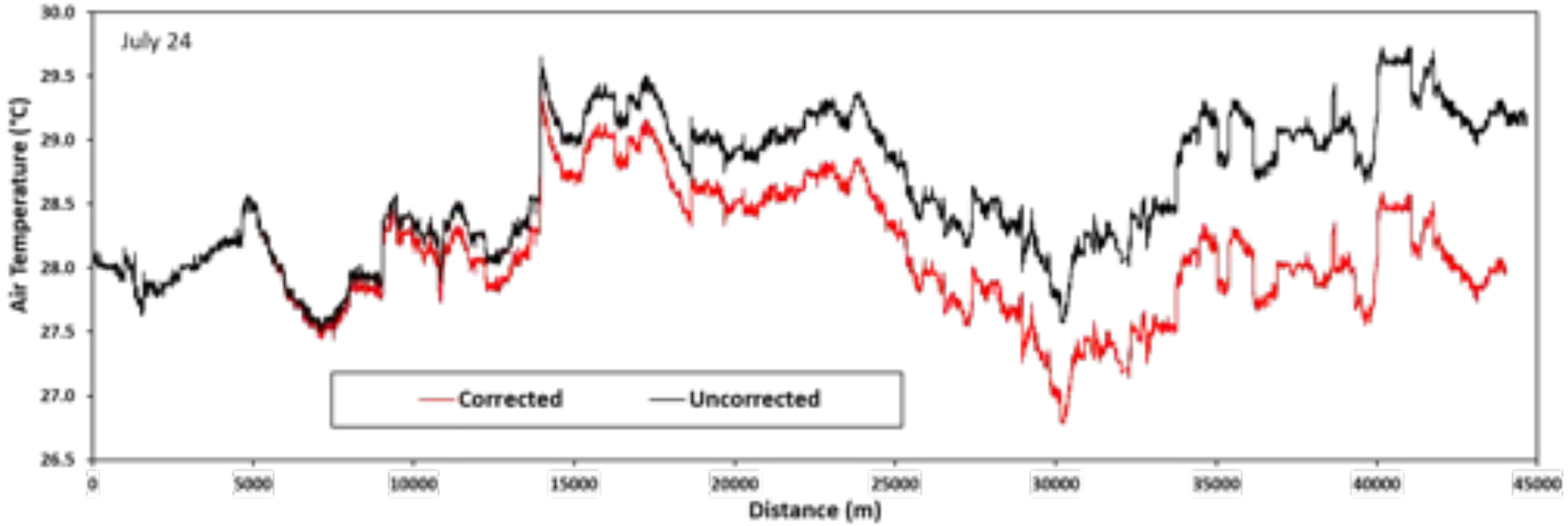
To account for heating/cooling during the period of a traverse, a linear time-correction scheme is applied.



$$Correction\ Factor(CF) = -1 \times \frac{\Delta \overline{Temp}_{\,end-start\ location}}{Time}$$

$$Tair_{corr} = Tair_{orig} + CF * Time$$

Corrected versus Uncorrected T_{air}

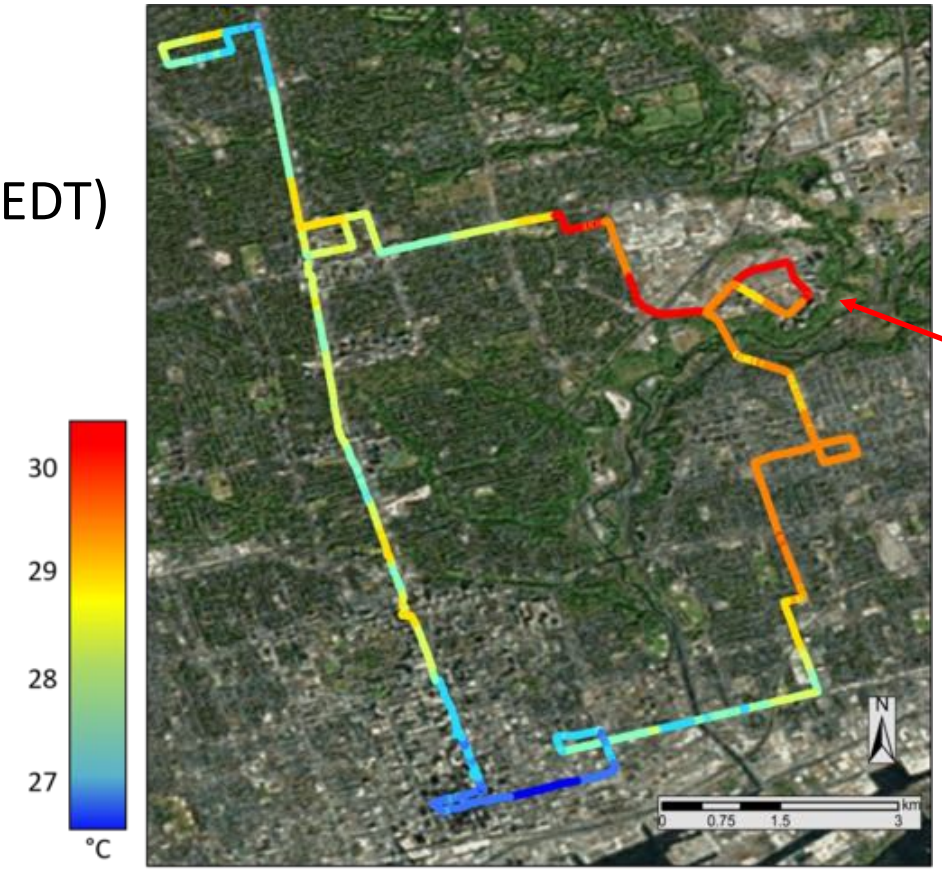


Represents a correction of ~1.25°C that occurred during the traverse duration.

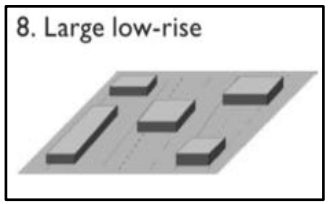
Sample Results - Afternoon Traverse

July 24th

Time: 1:49 PM (EDT)



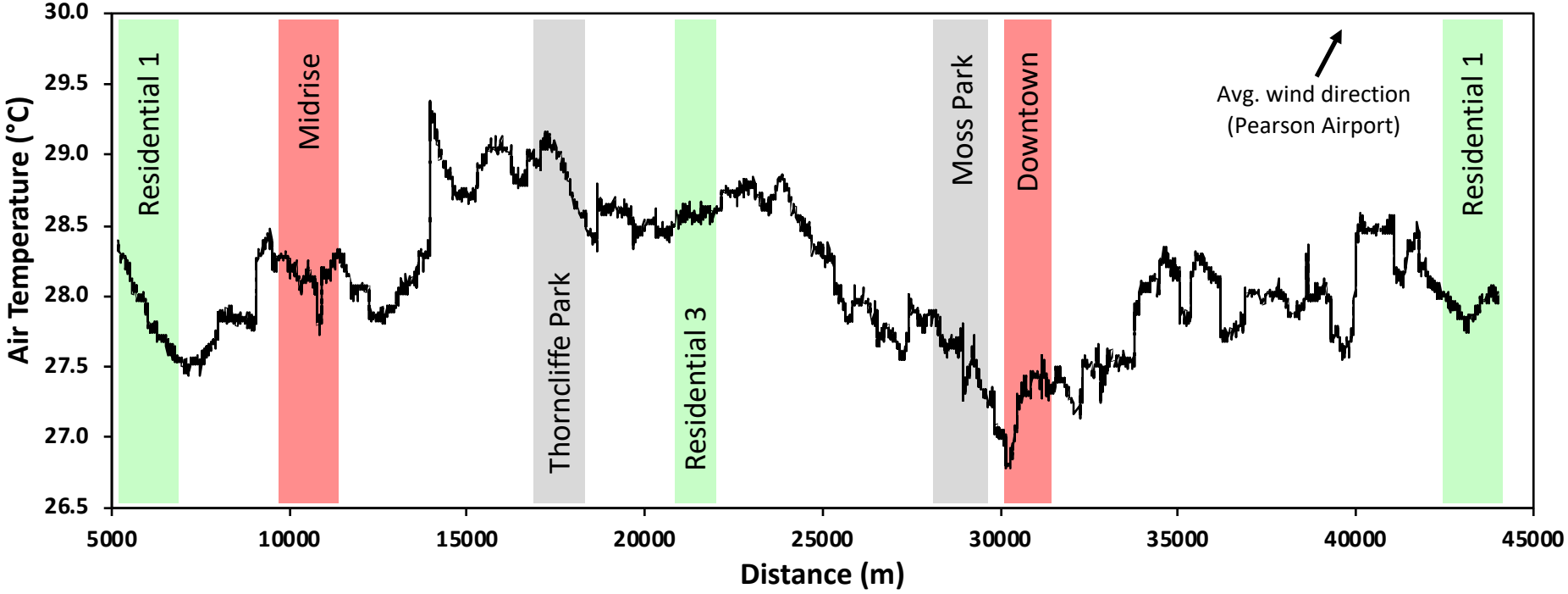
Thorncliffe Park



Corrected traverse air temperatures plotted spatially and superimposed on a satellite image of Toronto.

Early Afternoon

A spatial series plot of corrected 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 area) and the lowest observed temperatures are experienced downtown.

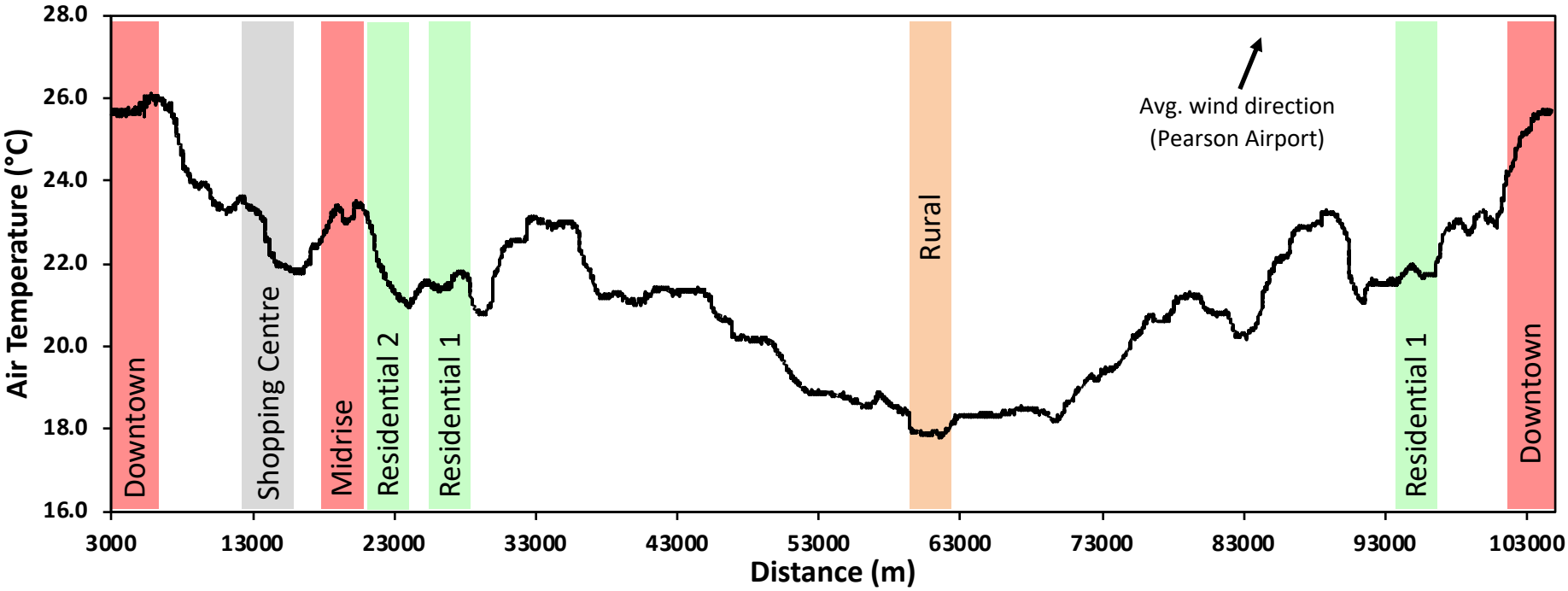
Nighttime Traverse

July 12th
Time:
12:44 PM (EDT)

King Rd.

Corrected traverse air temperatures plotted spatially and superimposed on a satellite image of Toronto.

Nighttime



A spatial series plot of air temperature examining the UHI effect.

On this night, the UHI magnitude was ~8 °C
(UHI magnitude = $Tair_{Downtown} - Tair_{Rural}$).

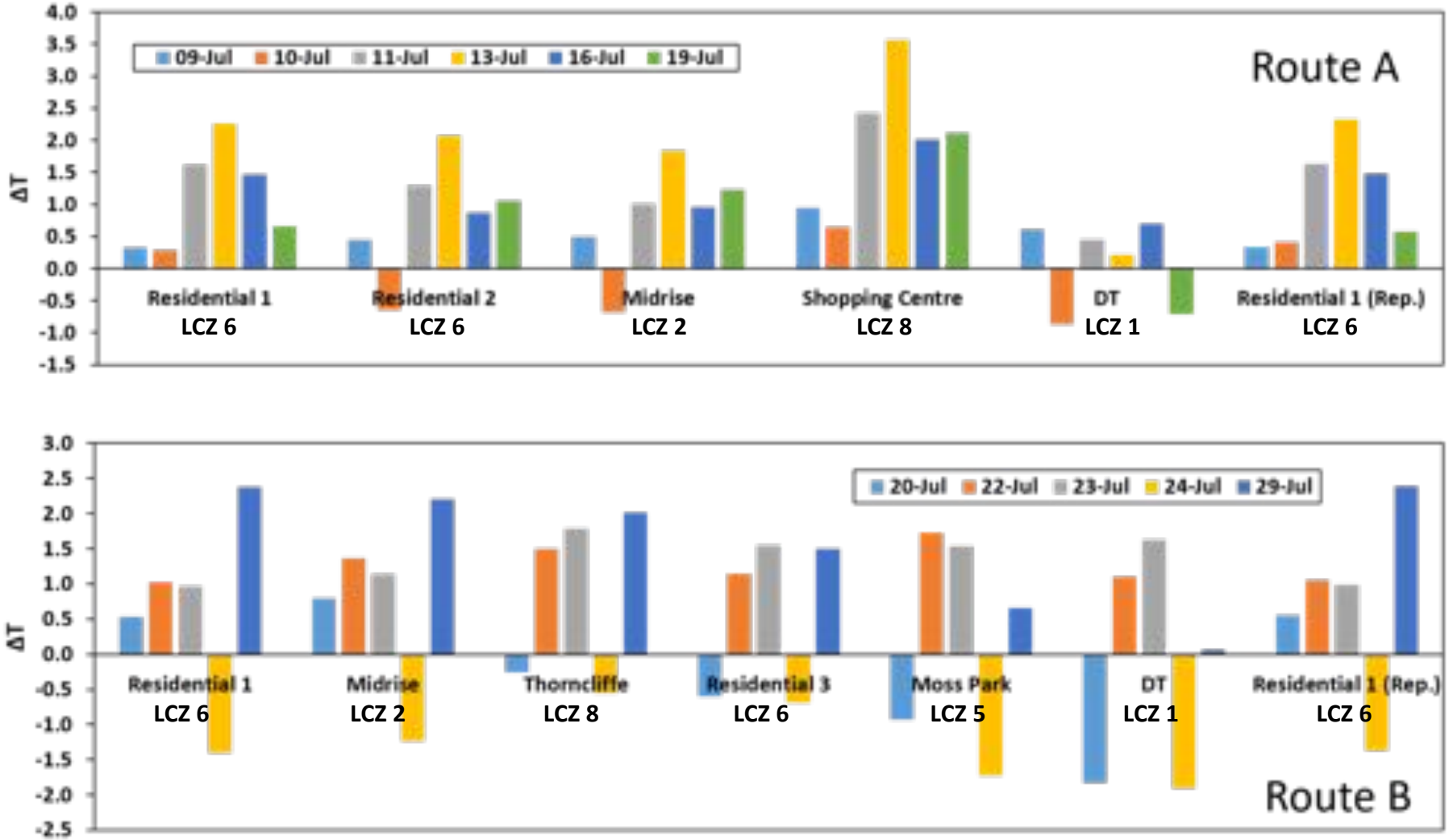
Neighbourhood Comparisons

- In order to compare neighbourhood averages of air temperature on different dates, a ΔT value (°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 value, $\hat{T}_{t,Ne}$ is the average air temperature within a neighbourhood, and $T_{t,R}$ represents the rural reference air temperature (ATMOS Claremont).

Neighbourhood Results



Neighbourhood Ranks

1 = hottest

Route A

	Residential 1 (LCZ 6)	Residential 2 (LCZ 6)	Midrise (LCZ 2)	Shopping Centre (LCZ 8)	DT (LCZ 1)	Residential 1 (Rep.) (LCZ 6)
09-Jul	6	4	3	1	2	5
10-Jul	3	4	5	1	6	2
11-Jul	3	4	5	1	6	2
13-Jul	3	4	5	1	6	2
16-Jul	3	5	4	1	6	2
19-Jul	4	3	2	1	6	5
Avg. Rank	**3.7**	**4.0**	**4.0**	**1**	**5.3**	**3.0**

Route B

	Residential 1 (LCZ 6)	Midrise (LCZ 2)	Thorncliffe (LCZ 8)	Residential 3 (LCZ 6)	Moss Park (LCZ 5)	DT (LCZ 1)	Residential 1 (Rep.) (LCZ 6)
20-Jul	3	1	4	5	6	7	2
22-Jul	7	3	2	4	1	6	5
23-Jul	7	5	1	3	4	2	6
24-Jul	5	3	1	2	6	7	4
29-Jul	2	3	4	5	6	7	1
Avg. Rank	**4.8**	**3.0**	**2.4**	**3.8**	**4.6**	**5.8**	**3.6**

Conclusions

1. Replicate sampling of both routes shows similar spatial air temperature trends.

2. Consistent air temperatures differences are observed between neighbourhoods.

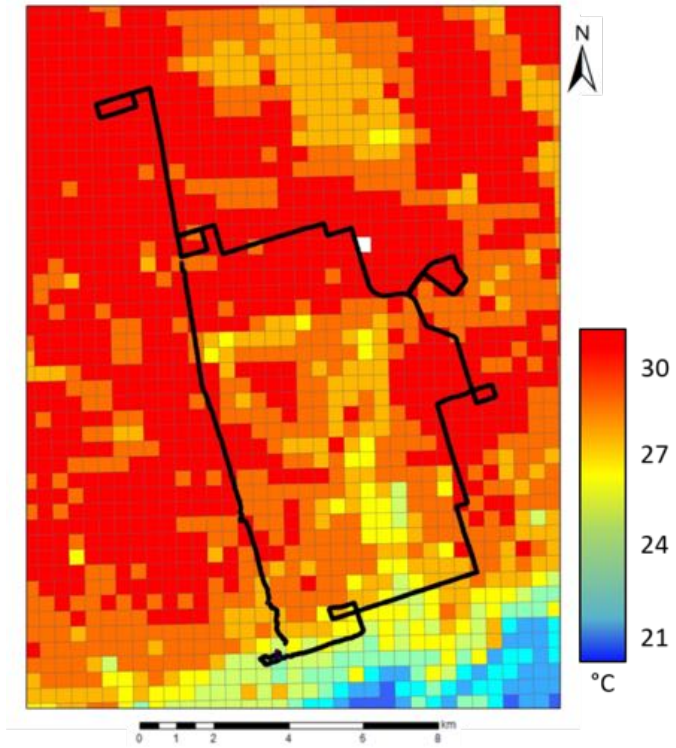
3. Of the two TPH ‘high-risk’ neighbourhoods, Thorncliffe Park is consistently ranked one of the warmest neighbourhoods while Moss Park typically ranks lower.

4. Downtown experiences the coolest canyon air temperatures on average during the early afternoon and is reversed during the nighttime.

Future Work

1. Expand analysis to include humidity and surface temperatures to more thoroughly characterize the microclimates of each neighbourhood and to calculate human thermal comfort indices.

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?



An example of GEM-LAM output with Route B overlaid.

References

- Stewart, I. D., & Oke, T. R. (2012). Local climate zones for urban temperature studies. *Bulletin of the American Meteorological Society*, *93*(12), 1879–1900.

2015 Pan/ParaPan Am Games

AMMOS Mobile Measurements

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Environment Canada Environnement Canada

Canada

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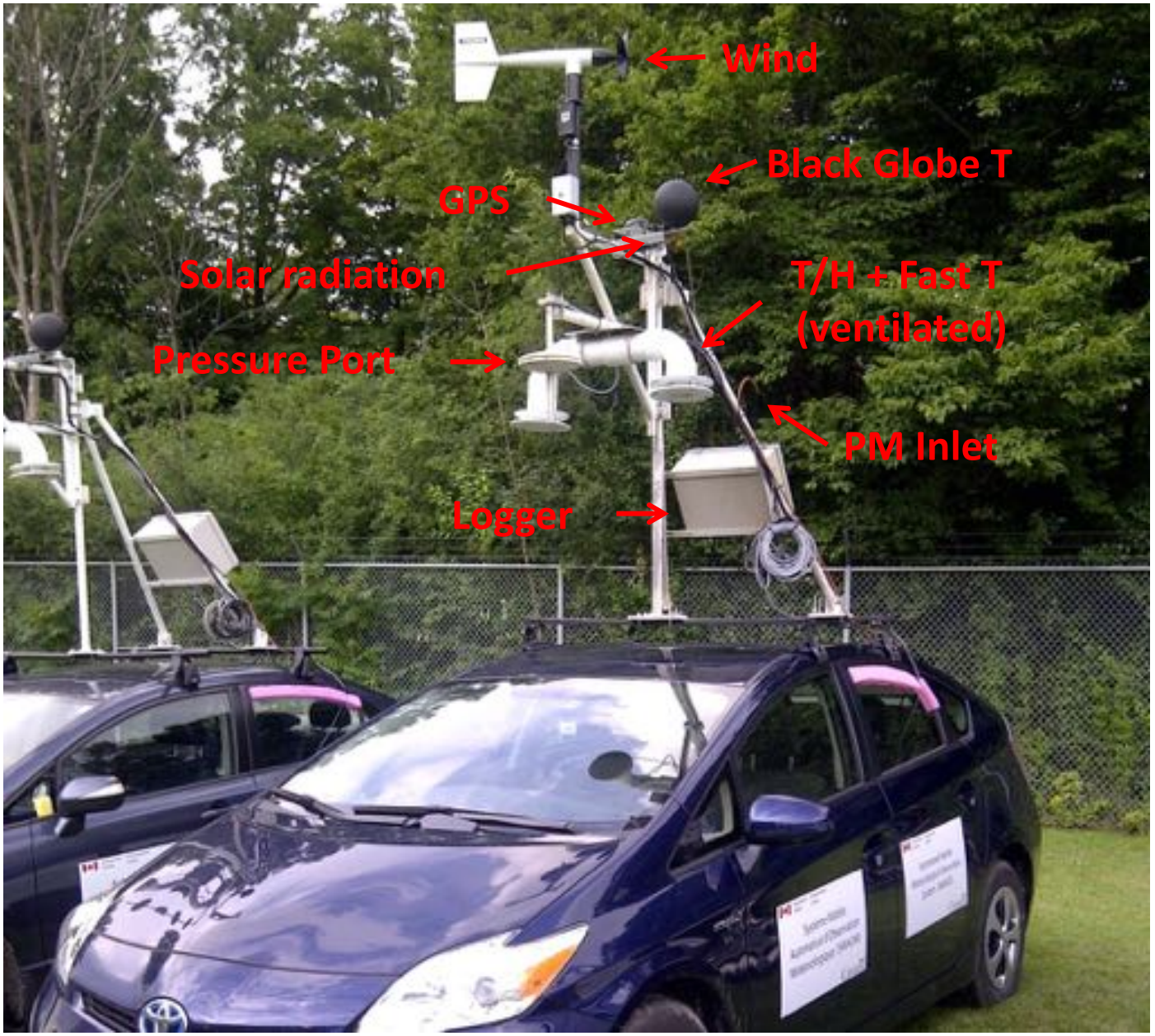
Joan Klaassen (MSC PA-HQ)
Supriya Singh (UofT student)
Jennifer Murphy (UofT)

EC *AMMOS* Mobile Mesonet Stations

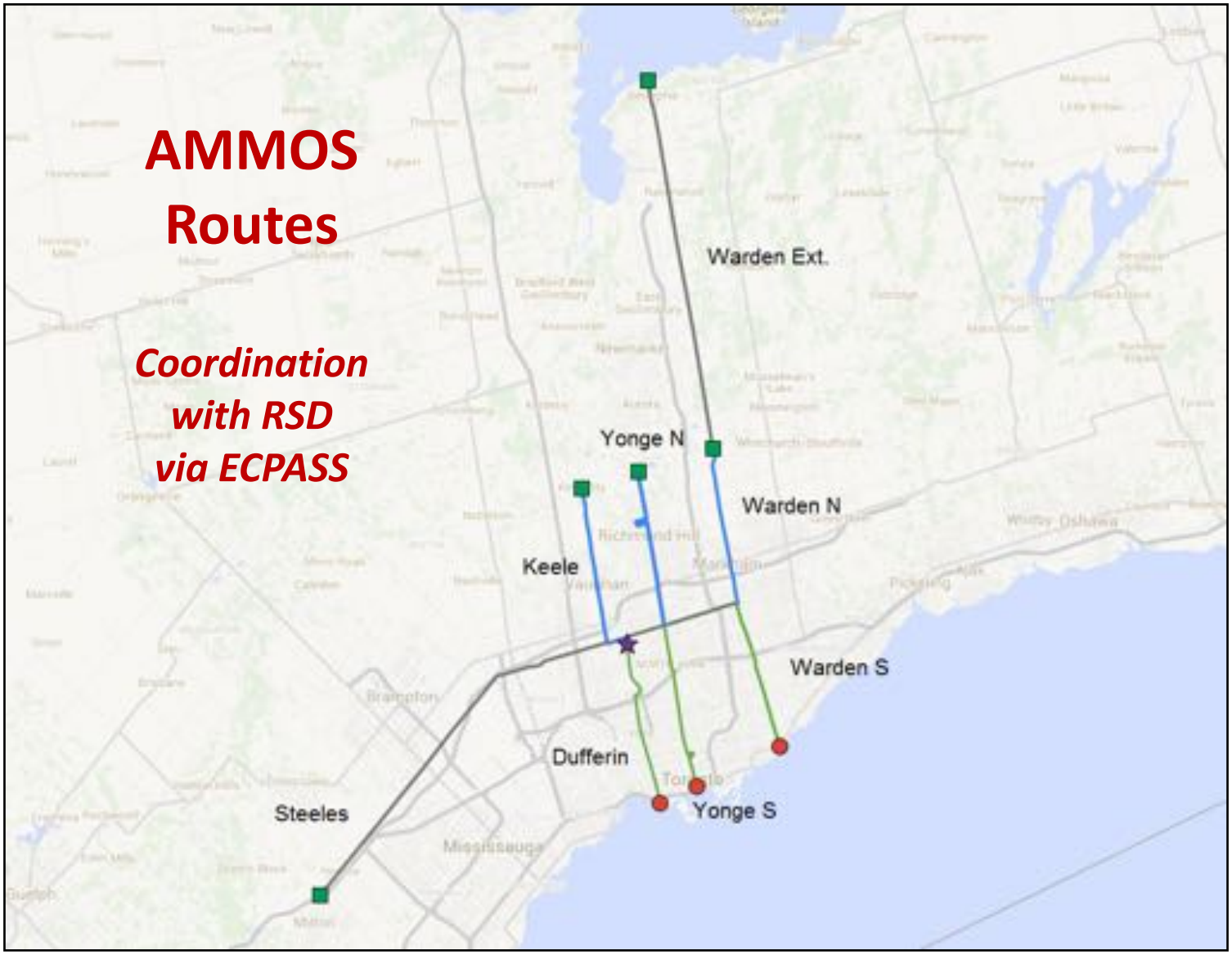
Strategy – sample lake-breeze fronts, gust fronts, heat stress, urban heat island effects, and air quality

- Meteorology sensors
- Two particulate matter sensors + AirSence AQ (experimental)

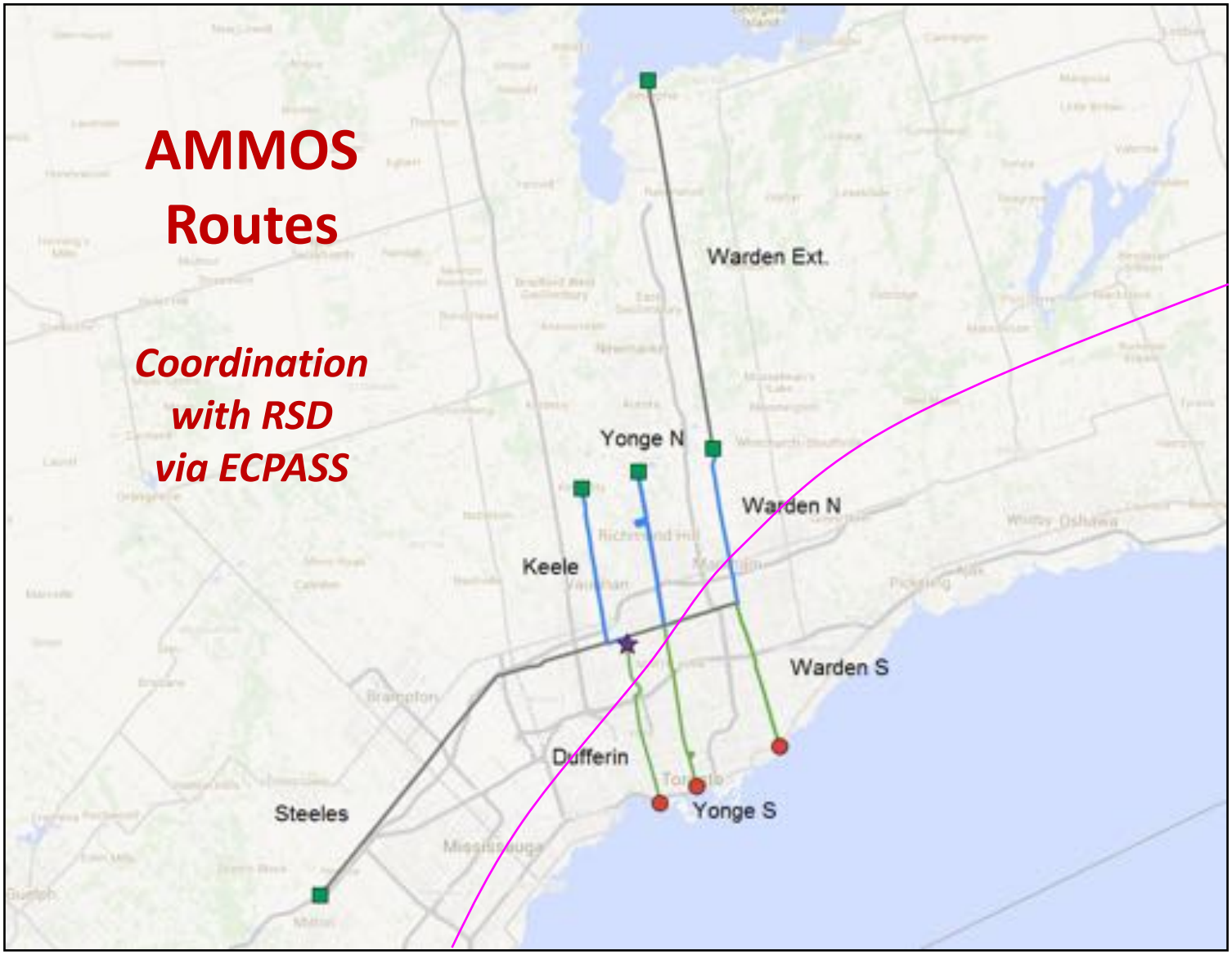
EC *AMMOS* Mobile Mesonet Stations



EC *AMMOS* Mobile Mesonet Stations



EC *AMMOS* Mobile Mesonet Stations



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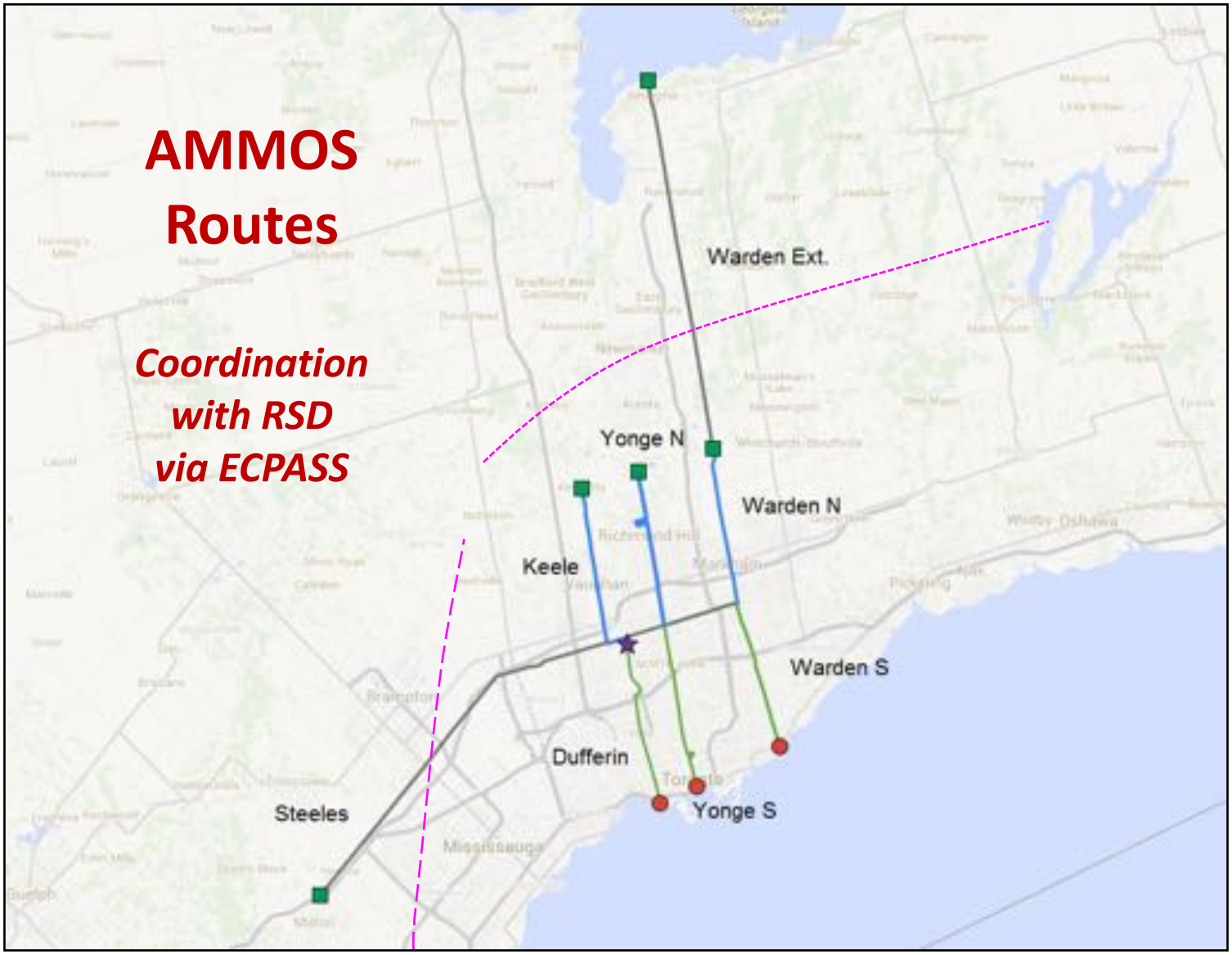

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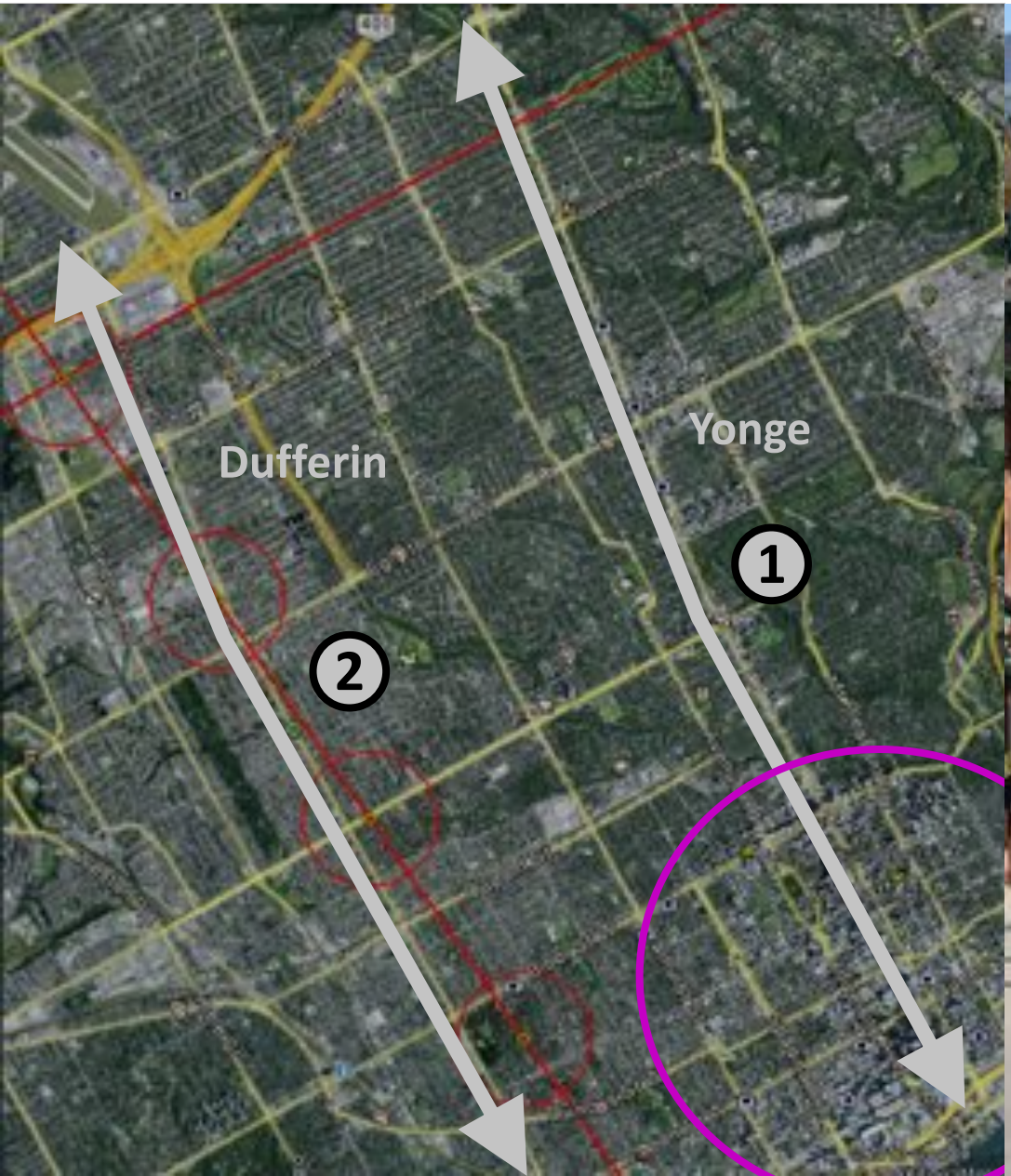
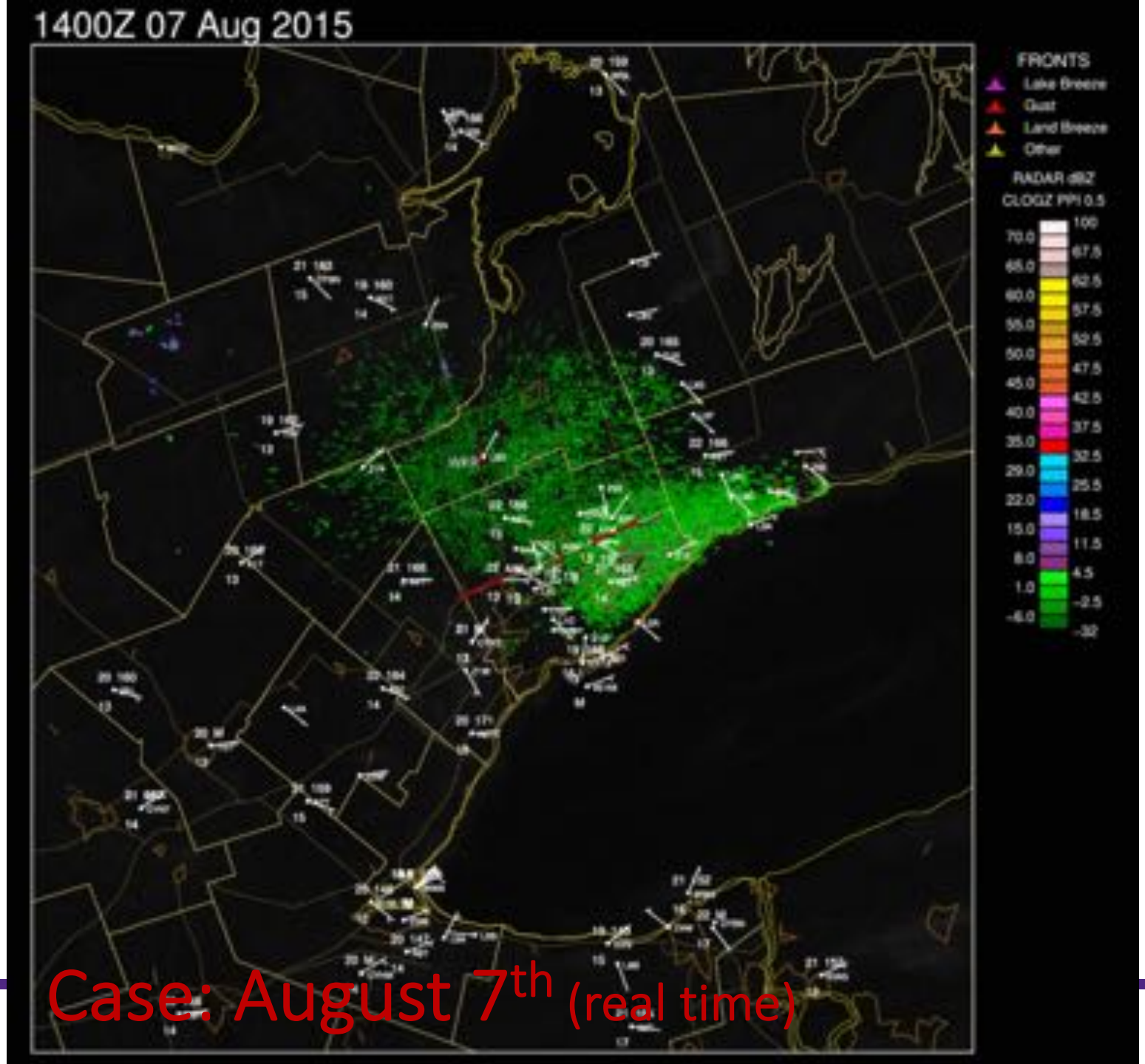


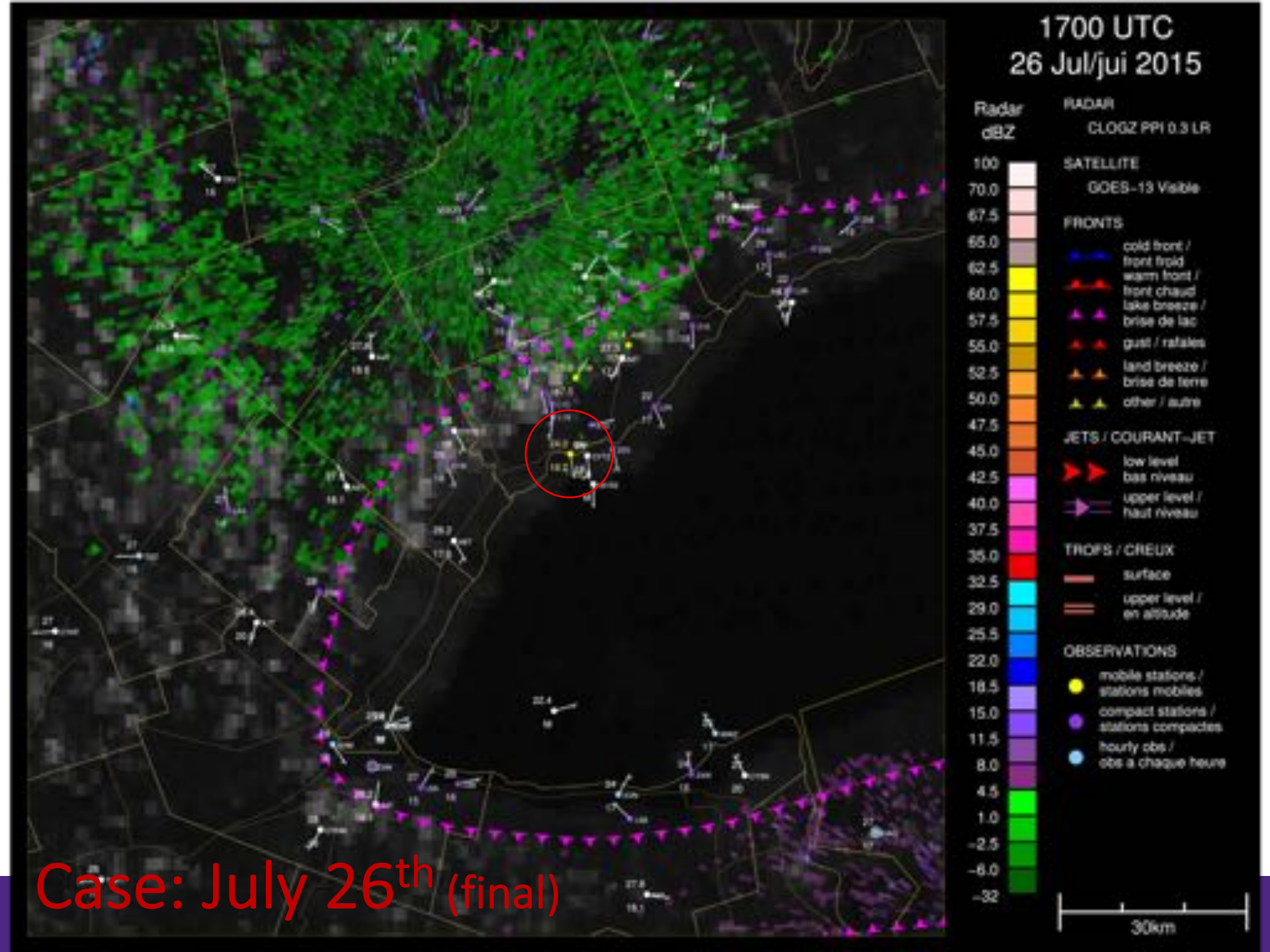
EC *AMMOS* Mobile Mesonet Stations

Coordinated measurements on hottest day of the summer

- Afternoon July 28th (ozone >90 ppb in lake air)
- Overnight July 29th (urban heat island – 27ºC vs 19ºC)

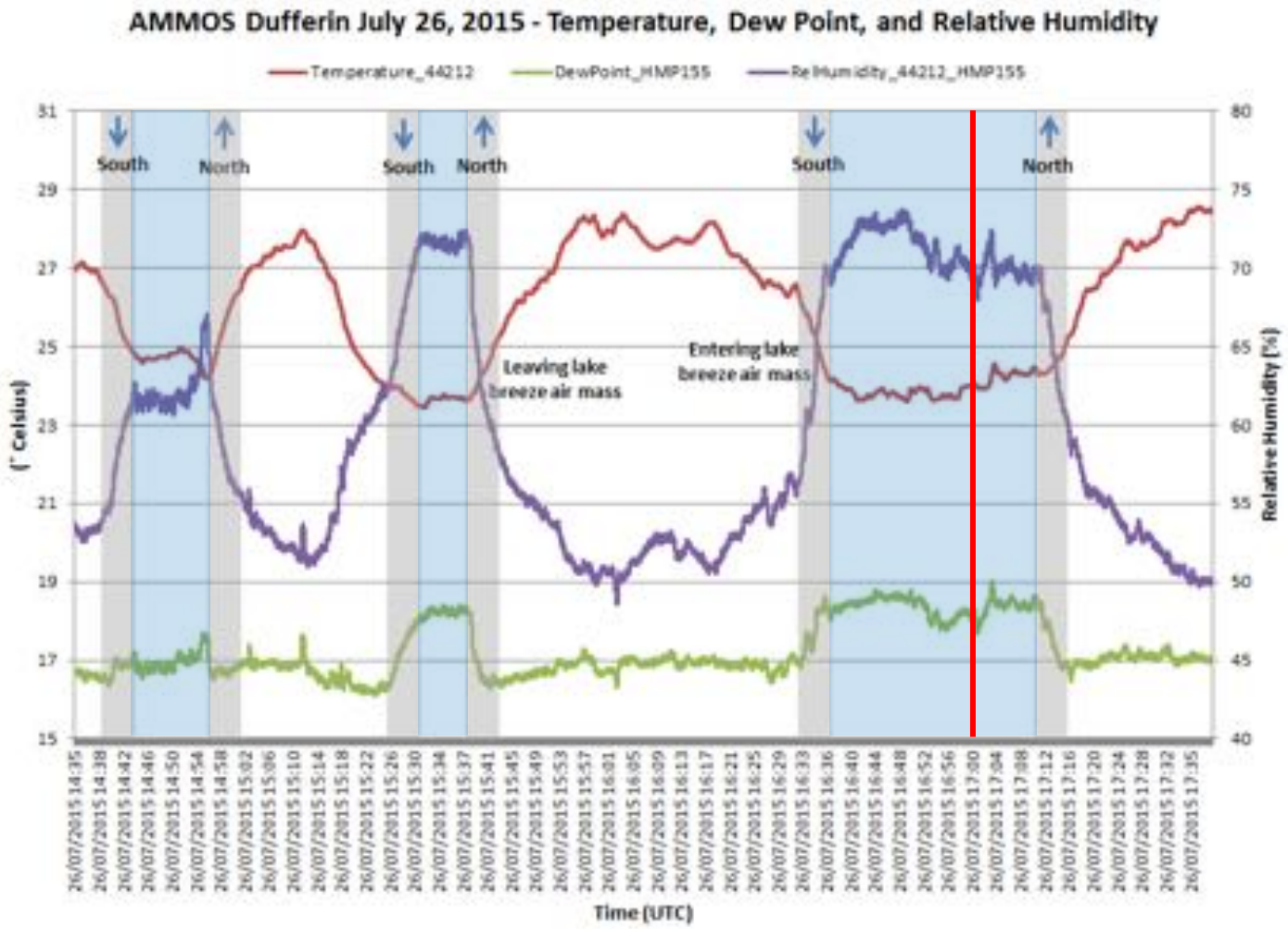
EC *AMMOS* Mobile Mesonet Stations


1400Z 07 Aug 2015
FRONTS
Lake Breeze
Gust
Land Breeze
Other
RADAR dBZ
CLOGZ PPI 0.5
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
29.0
22.0
15.0
8.0
1.0
-6.0
100
67.5
62.5
57.5
52.5
47.5
42.5
37.5
32.5
25.5
18.5
11.5
4.5
-2.5
-32
Case: August 7th (real time)



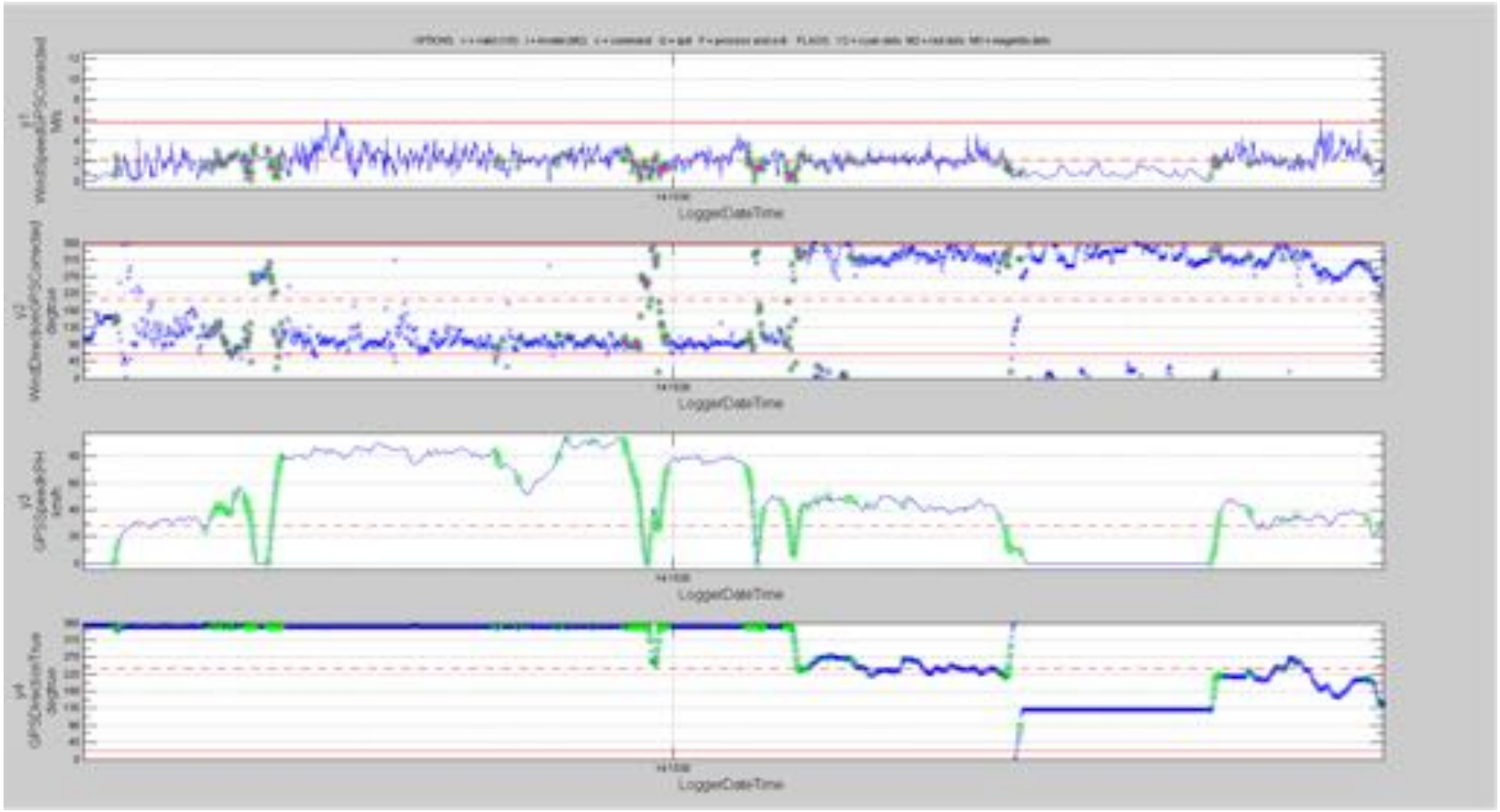
Case: July 26th (final)

Case: July 26th

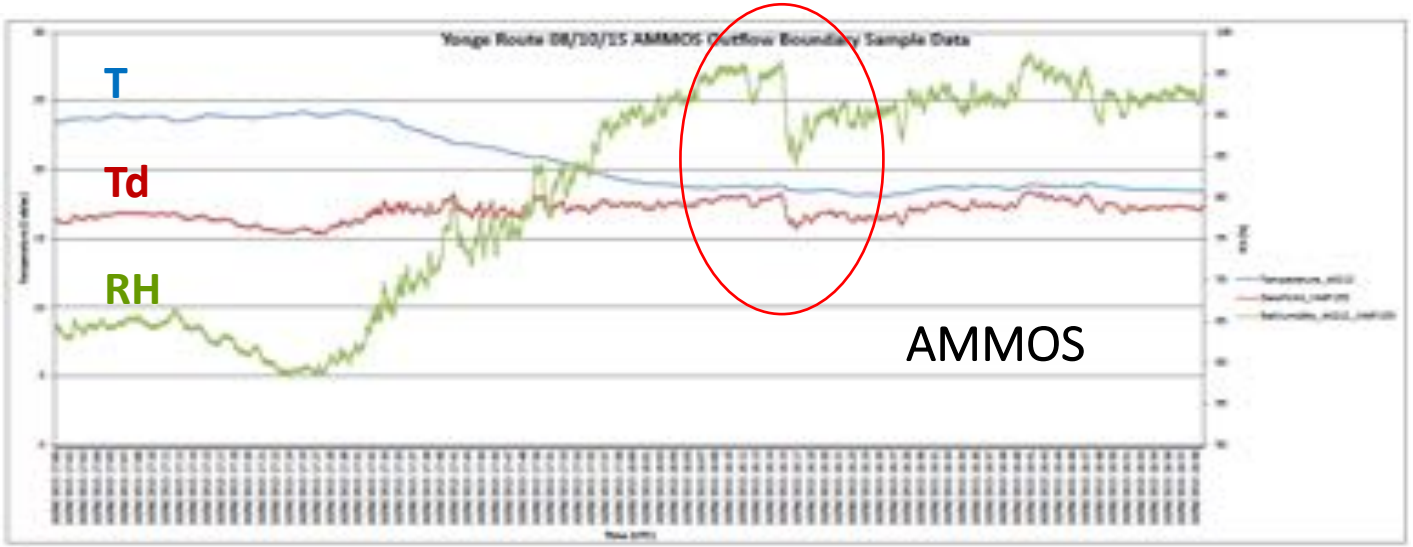


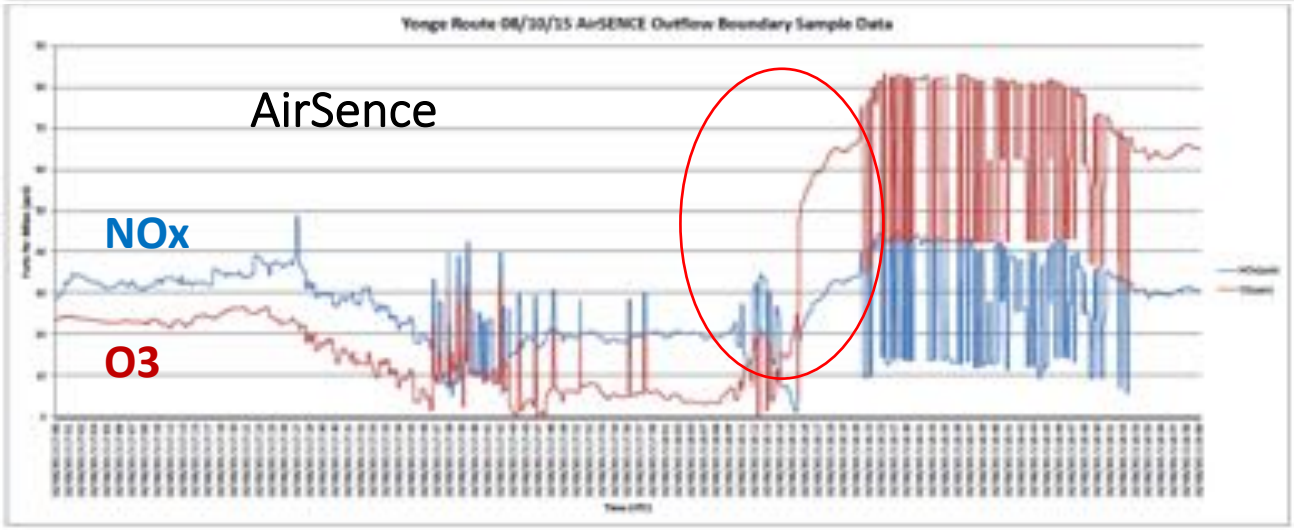
Quality Control - Met

QC tool developed with MATLAB



Quality Control - AQ





Status Summary

AMMOS

- 1-sec and 1-min data sets from all 3 mobile units now ready!
  - 22 days / nearly 10,000 km
  - 19 days with measurements in lake breezes
  - 207 Lake Ontario lake-breeze front traverses
  - 33 Lake Simcoe lake-breeze front traverses
  - 7 thunderstorm outflow boundary traverses
- Some remaining QC issues with wind data while mobile – investigating…

Future Work

AMMOS

- Publishing to GoC Open Data Portal under way
- Work with AQRD and UWO on data from coordinated runs
- Work on characterization of lake-breeze fronts
- QC for AQ data, and analysis