USING ATMOSPHERIC IN SITU MOBILE MEASUREMENTS TO MONITOR URBAN METHANE EMISSIONS IN THE GREATER TORONTO AREA (GTA)

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Methane emissions from urban areas

- **Urban areas** account for 37 to 49% of global GHGs emissions (Seto et al, 2014). Reducing **methane** emissions is an important short-term climate change mitigation option because of its relatively **short atmospheric lifetime** (≈ 9 years) and its **radiative forcing** (GWP of 28 to 36 over 100 years).
- **Urban methane sources** include fugitive emissions from **natural gas** distribution network, management and treatment of solid and liquid **waste**, **agriculture**, **wetlands**, and **transportation**.
- It is imperative to develop **unique mitigation strategies** for each city by identifying the location and source strength of all methane sources.
- Several studies in US cities have highlighted the contribution of natural gas distribution systems to the total methane emissions.

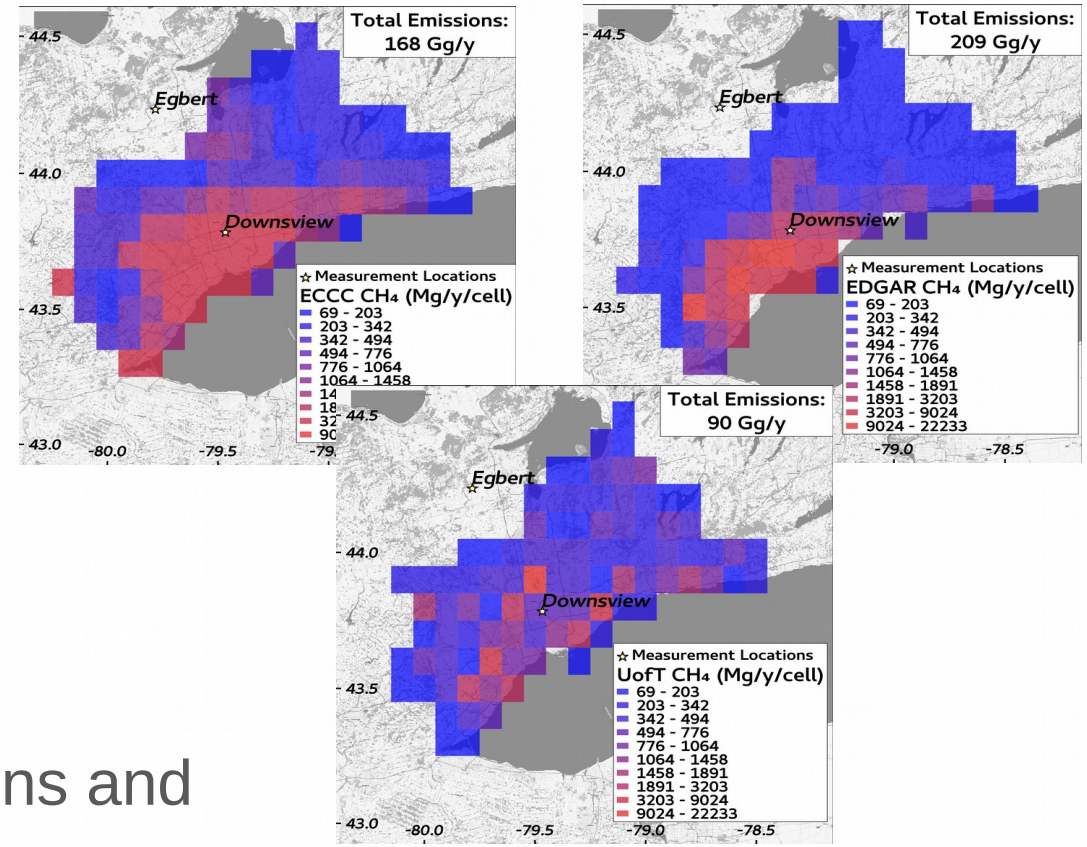
Knowledge of GTA methane emissions

The GTA is the largest metroplitan area in Canada with a population of 6 million inhabitants. **Three Inventories are** available for the GTA:

- EDGAR
- Environement and Climate Change Canada
- FLAME-GTA: a Facility Level and Area Methane

Emissions inventory developed by University of Toronto (https://dataverse.scholarsportal.info/dataset.xhtml?persistentId=doi:10.5683/SP2/HTNDSO)

➢ Different estimate of the total methane emissions and different spatial distribution.



Credit: Nasrin Mostafavi Pak

Mobile analytical platforms

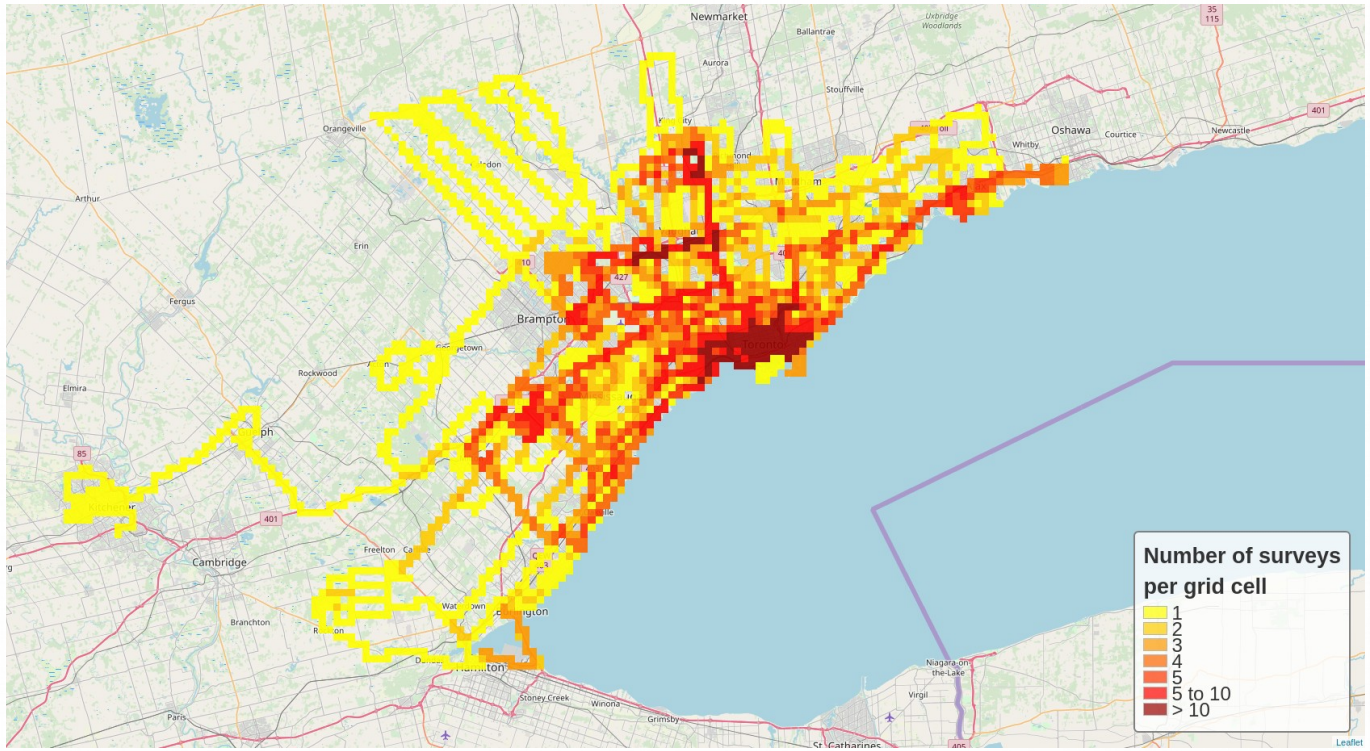
Two mobile platforms deployed in the GTA with:

- **High precision gas analyzer** providing continuous measurements of CH4.
- **Weather station** measuring wind speed and wind direction.
- **GPS** recording coordinates during the campaigns.

Summary of surveys

Between May 2018 and August 2019:

		Total	Bike	Car
2018	Distance (km)	3,703	732	2,971
	Number of surveys	41	27	14
2019	Distance (km)	2,741	1,007	1,734
	Number of surveys	36	29	7



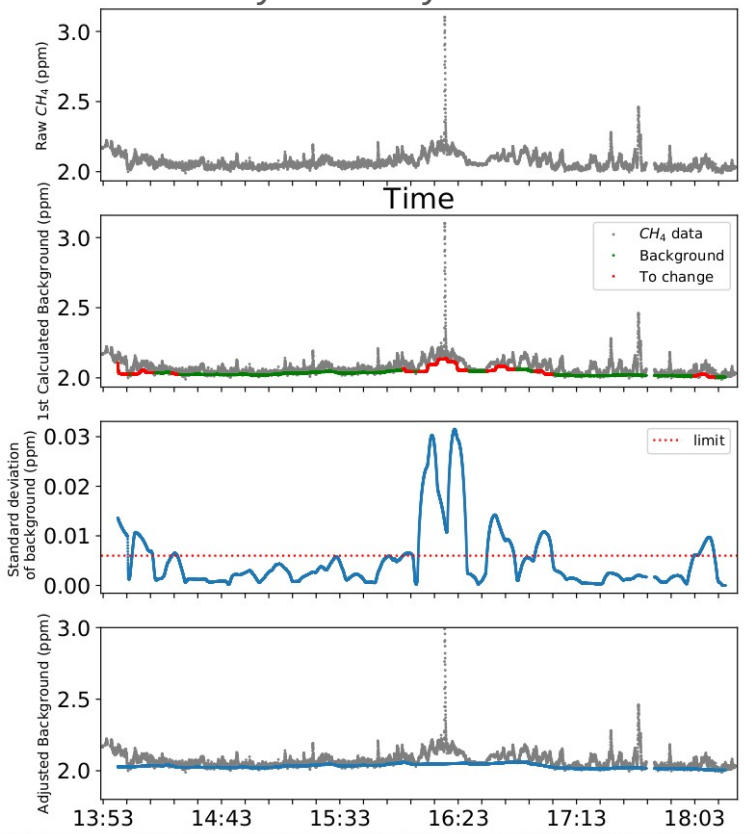
Detection of methane enhancements

The objective of our surveys is to detect enhancements of methane concentrations above background.

The background concentrations estimated using a two-step process to take into account its spatio-temporal variability:

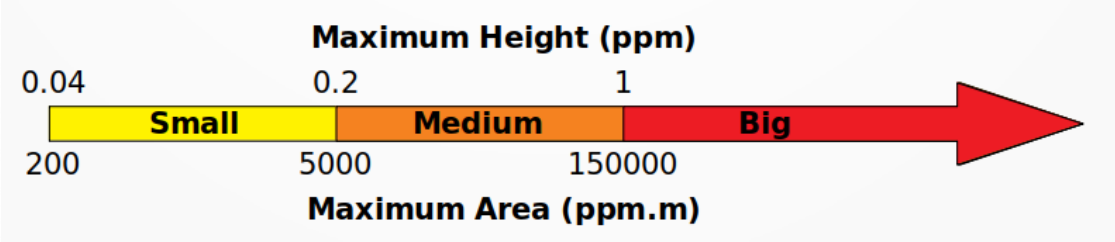
1. First estimate of the background concentrations calculated as the fifth percentile of a moving window (2nd graph).
2. Application of a filter using the background standard deviation to take into account errors associated with larger (3rd and 4th graphs).

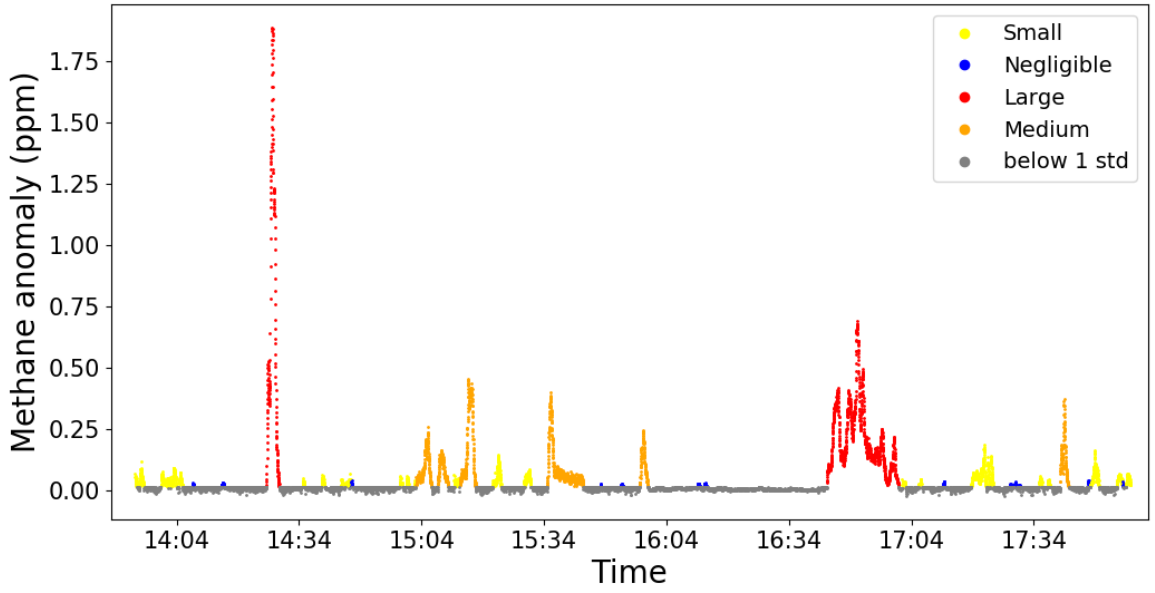
Credit: Emily Knuckey & Juliette Lavoie



Detection of methane enhancements

Once background concentrations are subtracted, methane enhancements are classified into 3 categories depending on their maximum height and their area:



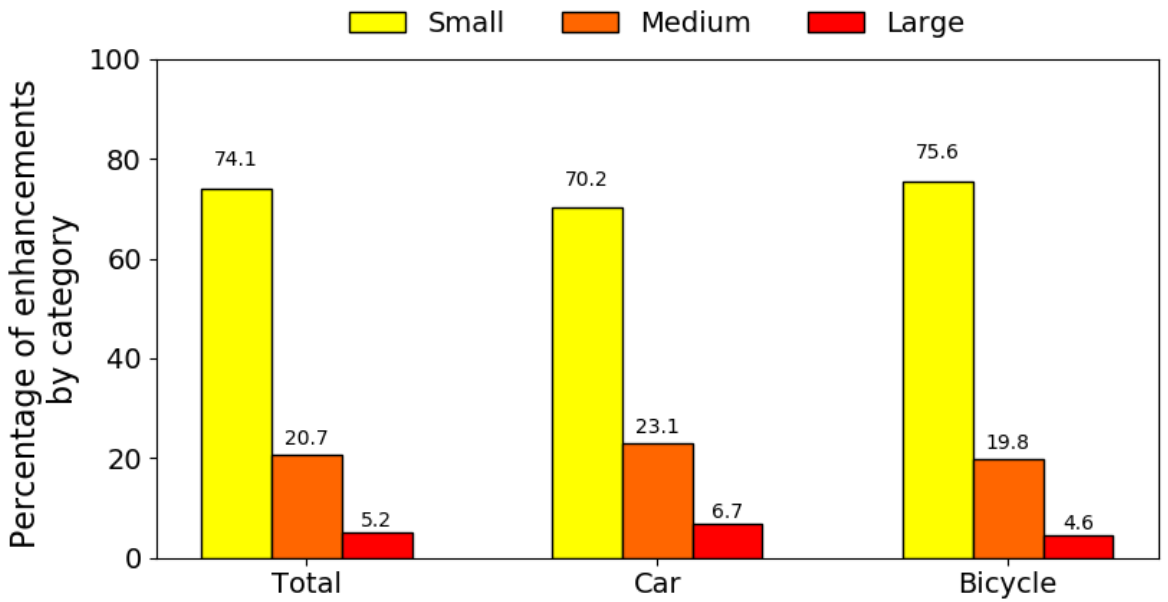


Between May 2018 and August 2019, a total of **2083 enhancements** were observed.

Detection of methane enhancements

Measurements were carried out during both daytime and nighttime, enhancements are normalized to take into account the effect of the boundary layer height:

- Scaling factors between different atmospheric stability estimated using a Gaussian model.

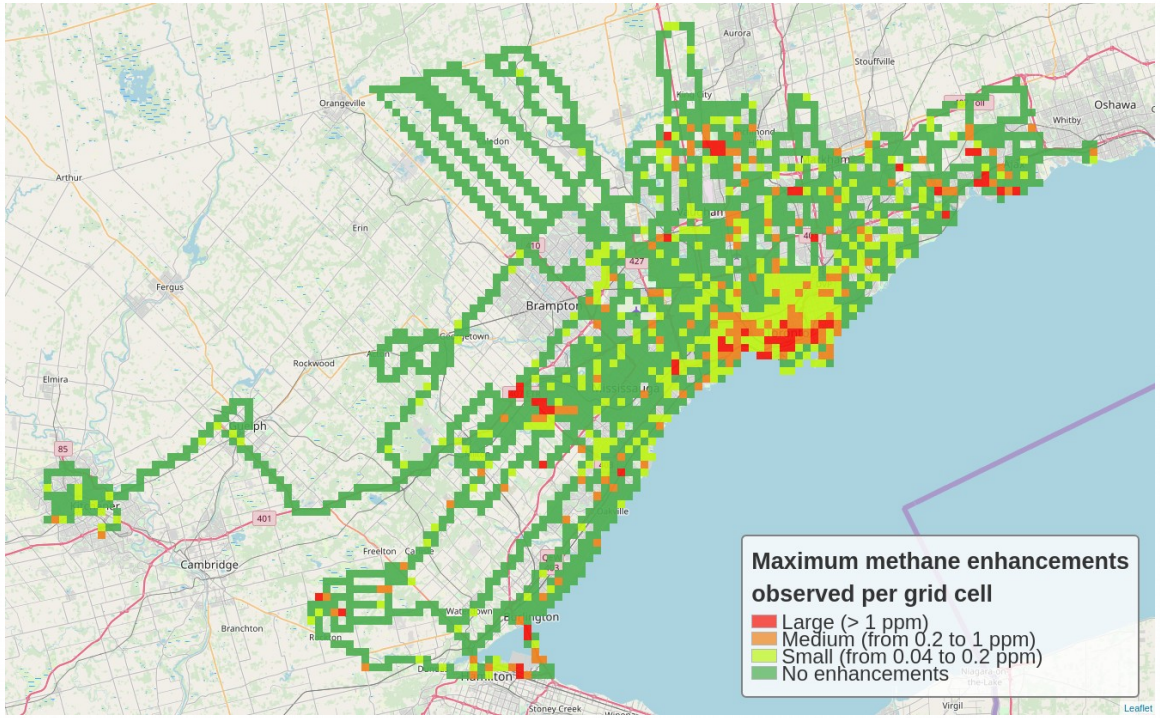


Distribution of methane enhancements

- Observed enhancements are gathered into 1 km x 1 km grid cells and we look at the maximum enhancement of methane in each cell.

- 78% of the surveyed grid cells do not present any enhancements.
- 14% presents small enhancements.
- 6% presents medium enhancements.
- 2% presents large enhancements.

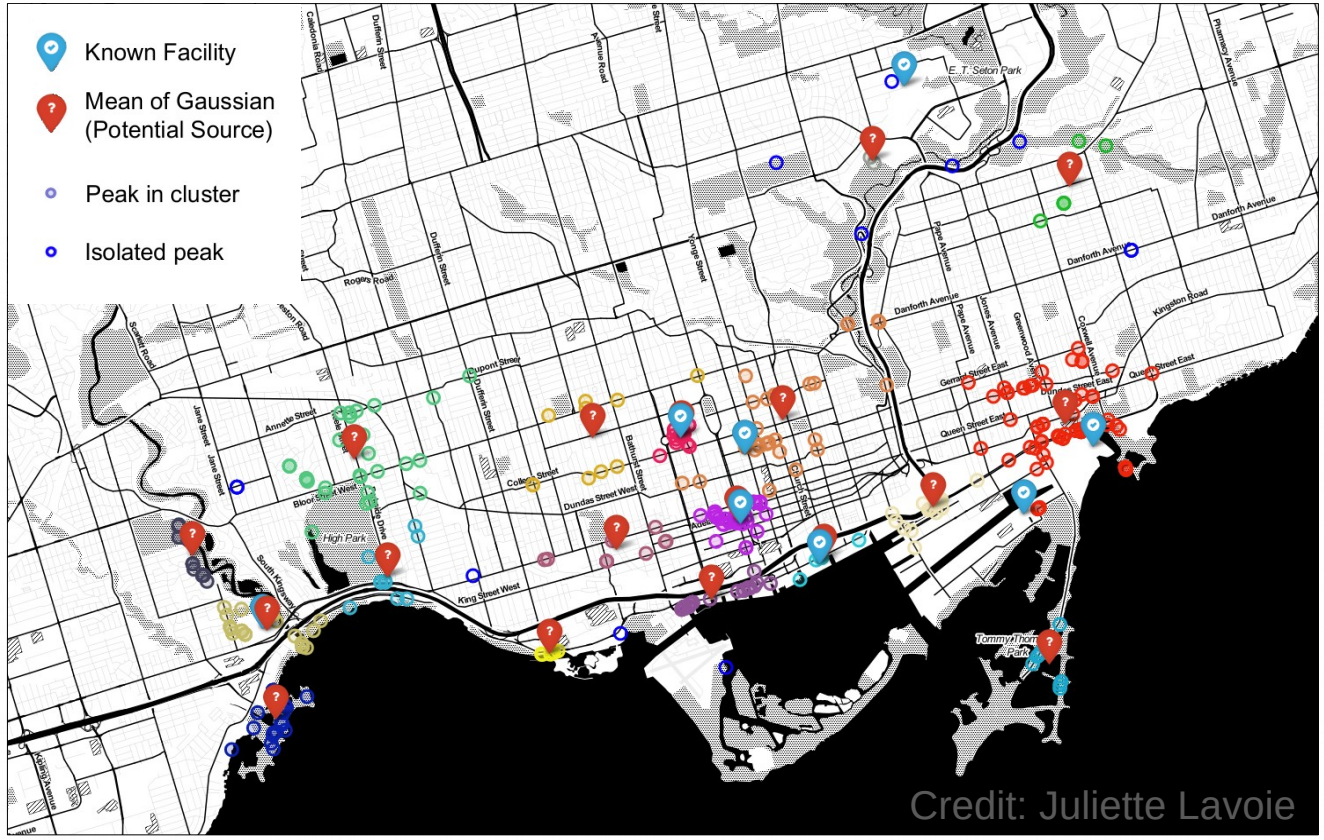
- Maximum enhancements distribution shows localized hot spots of methane.



Attribution of methane enhancements

Medium and big enhancements used in a **Gaussian Mixture Cluster Analysis** to find the location of important methane sources.

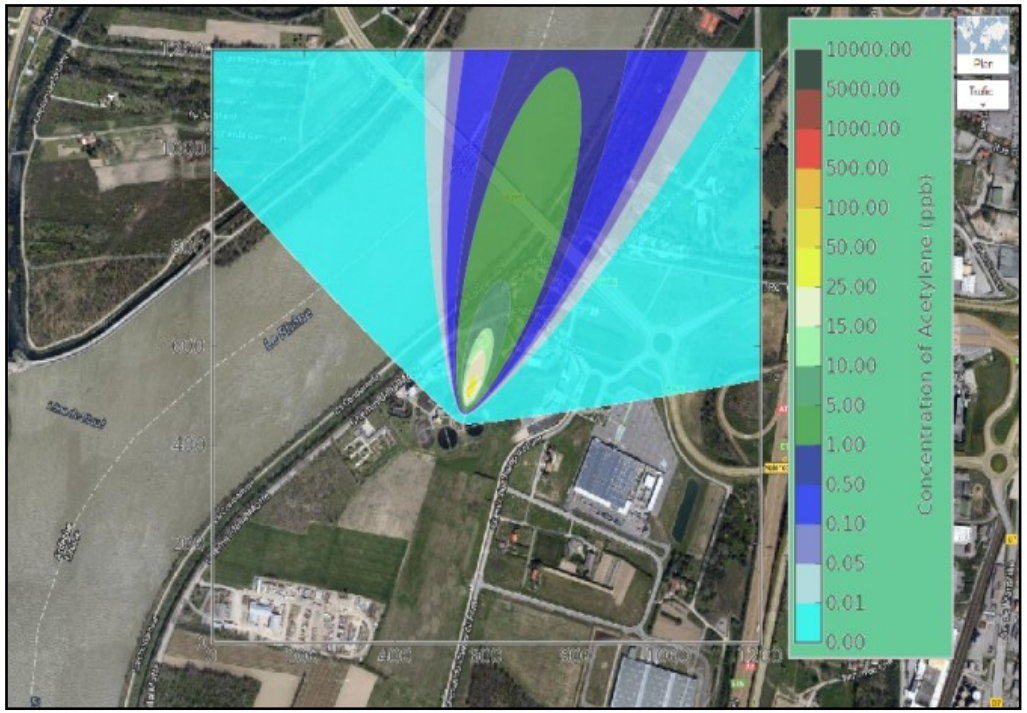
- Successfully locates 4 known sources.
- Limitations when sources are spatially close.



Quantification of methane emissions

Emissions from specific sites are estimated using our in situ measurements and a **Gaussian plume dispersion model**.

Tests on the sensitivity of this method to different parameters show that the selection of the stability class is the main source of uncertainty (66%), followed by wind direction (20%), wind speed (7%), and source location (5%).

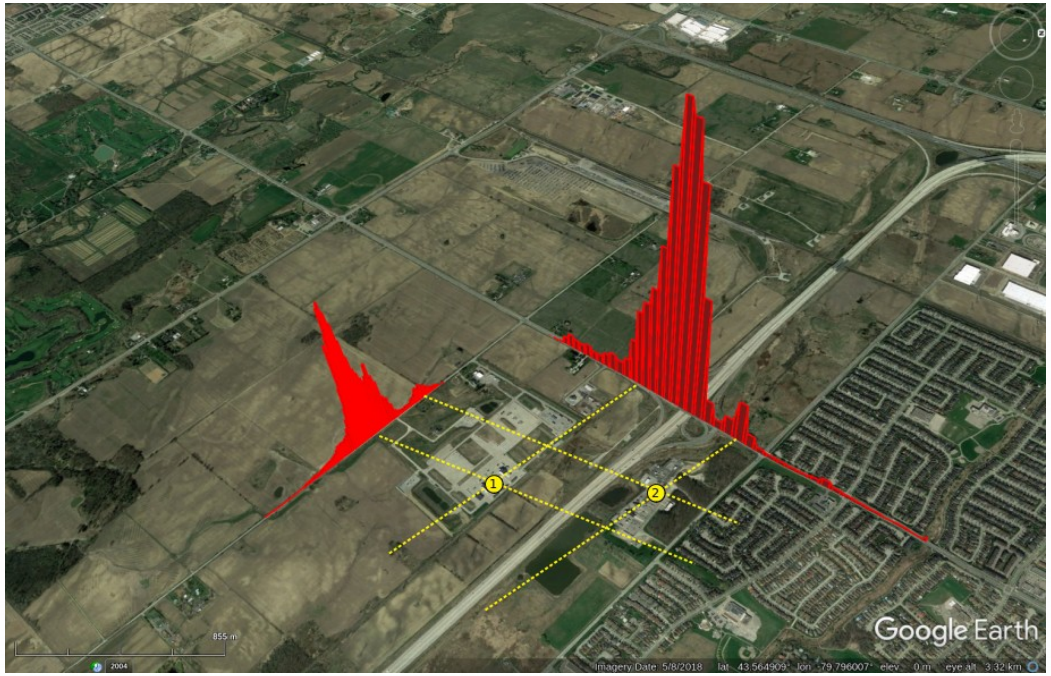


Quantification of methane emissions

Each site has been surveyed from 4 to 10 times under different wind conditions between May 2018 and August 2019.

Each survey includes **multiple plume crossings** which sometimes correspond to hours of measurements.

The number and location of the main sources within a site are estimated by **triangulation**.

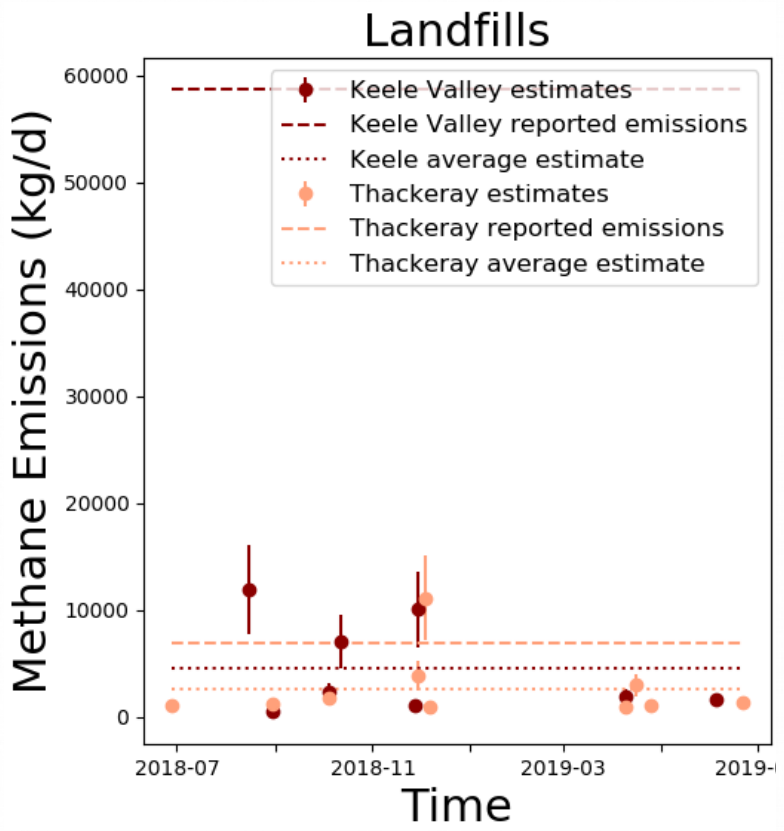


Waste sector

- Waste sector is the largest emitter of methane according to FLAME-GTA and contributes to **73%** of the total methane fugitive emissions.
- These emissions mostly come from old landfills among which:
  - - **Keele Valley landfill** (closed in 2002) has 28 million tonnes of accumulated waste and was Canada's largest landfill.
  - - **Thackeray landfill** (closed in 1978) stored about 2.2 million tonnes of waste.

Landfills

- Keele Valley was surveyed 8 times and has an estimated emissions between 600 and 11900 kg/d.
- Thackeray was surveyed 10 times and has an estimated emissions between 900 and 11100 kg/d.
- Estimates lower than reported emissions.
- No seasonal variability observed.



Natural gas sector

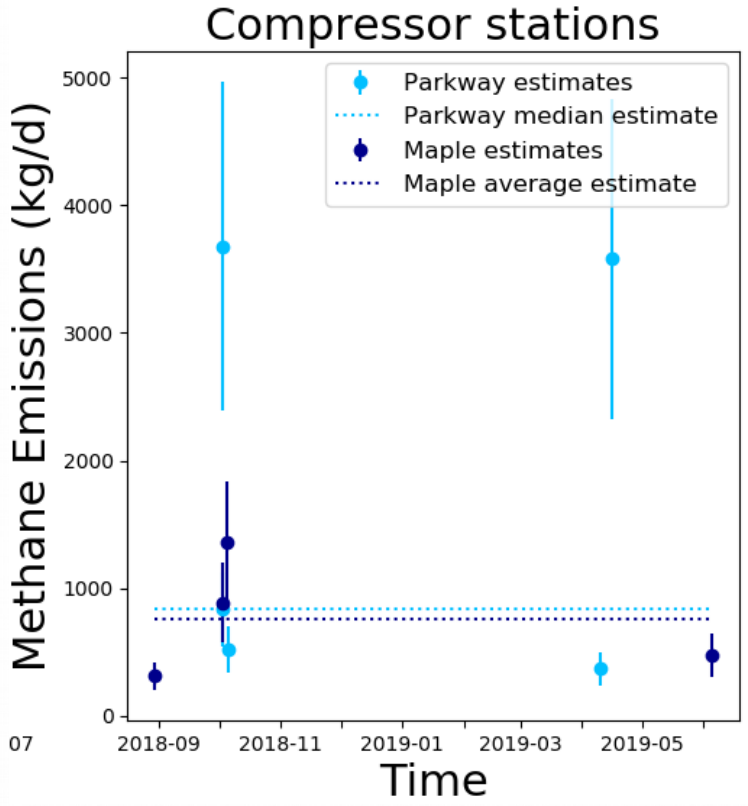
Natural gas sector is the second largest emitter of methane according to FLAME-GTA and contributes to **11%** of the total methane fugitive emissions.

This estimate includes **transmission along the pipelines**, the **distribution network**, and the **end use systems**.

Emissions from two gas compressor stations (**Maple** and **Parkway** stations) are studied. These emissions are included in the distribution network section in the FLAME-GTA inventory but no site-specific estimate is available.

Natural gas compressor stations

- Each site was surveyed 4 times.
- Average estimate of methane emissions around 800 kg/d for both sites.
- Observation of intermittent enhanced emission events for the Parkway compressor station with emissions around 3800 kg/d.



Keating Channel

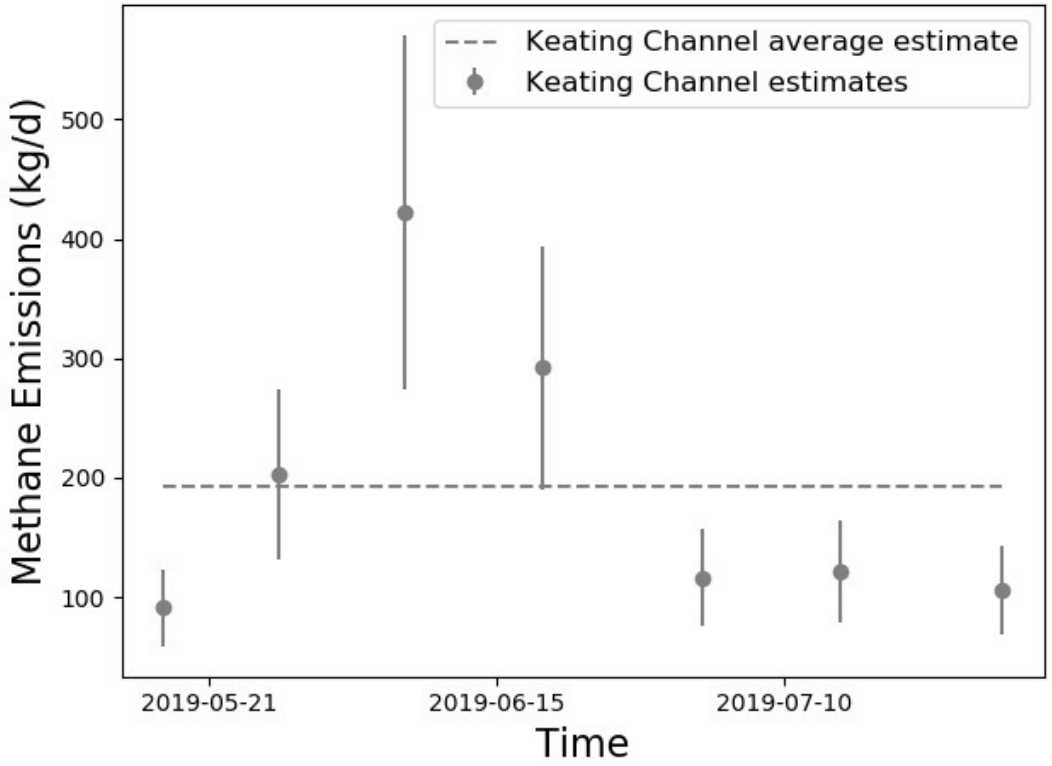
The Keating Channel is a waterway connecting the Don River to the Toronto Harbour on Lake Ontario.

Accumulation of floating debris which can be degraded under anaerobic conditions and produce methane.

Emissions not catalogued in the inventories.

Keating Channel

- Surveyed 7 times during summer 2019.
- Emissions estimated between 91 and 422 kg/d with an average estimate of 193 ± 114 kg/d.
- Estimates seem correlated with meteorological conditions: larger emissions after rainy weather in late May and early June washing organic matter into the channel.



Conclusions

- Mobile measurements with the bicycle and the car allows to consistently observe methane enhancements from given sources.
- Waste sector is confirmed to be the largest methane emitter of the GTA even though the reported emissions of most landfills seem to be overestimated.
- Leak indications are lower in Toronto compared with other US cities with aging infrastructure such as Boston.
- Gaussian Mixture Cluster Analysis is able to identifies known sources, locate unknown sources but presents limitations if sources are spatially close.
- Reliable quantification of methane emissions requires multiple site visits and plume crossings.
- Natural sources might emit more methane than expected in the GTA.