Methane Measurements Using Portable Fourier Transform Spectrometers in the Greater Toronto Area

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Abstract

The Greater Toronto Area (GTA, pop. 6.4 million) is the populous city in Canada, thus accurately quantifying GHG emissions from the GTA is an important step towards meeting Canada's commitments to reduce its Greenhouse gas emissions. Mitigation of methane (CH4) emissions is of particular importance when setting the country's policy measures to meet the GHG reduction goal since it can be economically advantageous. In this study, a methane emission inventory with a high spatial resolution was prepared using individual facility reports gathered for each municipality in the GTA. Measurements using portable Fourier Transform Spectrometers (FTS), are then used to monitor CH4 levels in the GTA continuously. Four FTS instruments were installed in different locations in the city in line with the most frequent wind directions based on historical observations. High peak events were investigated and with measurements of tracer concentrations and wind data, the emissions from the city were estimated. At the end, we investigated how the results could be used to improve the existing emission inventory.

Environment and Climate Change Canada

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The GTA Emissions Project

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Abstract

- A facility based emission inventory for the GTA is introduced
- Used mobile in-situ measurements to validate facility emissions
- Used stationary in-situ measurements to validate local emissions
- Used total column measurements to validate city emissions

A Facility based methane emission inventory

Facility Level and Area Methane Emissions for the GTA (FLAME-GTA) lists all point sources and area sources of CH_4 to construct an inventory with a high spatial resolution.

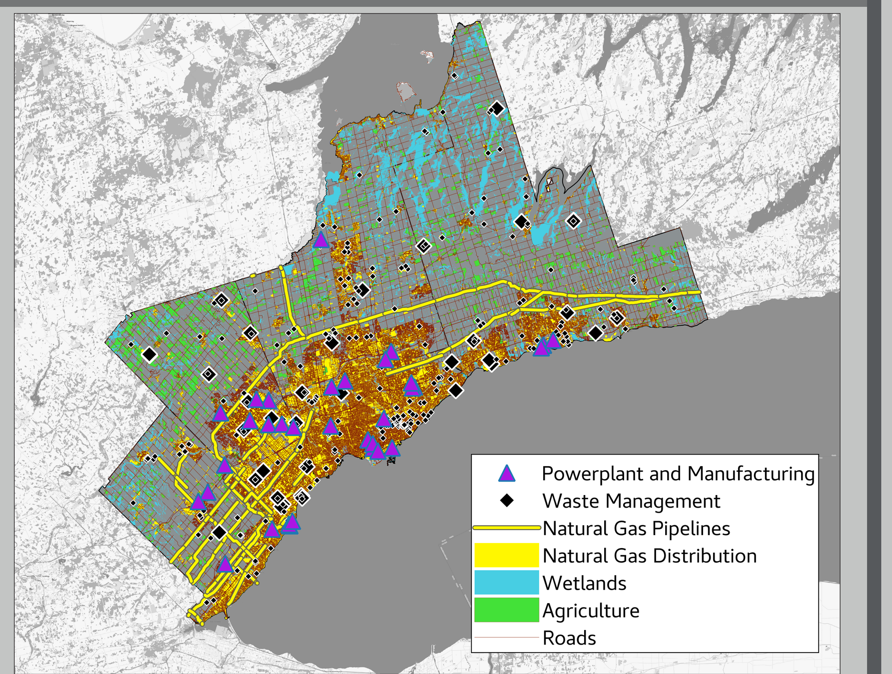

Figure 1: Emission categories and their geographical span used in FLAME-GTA.

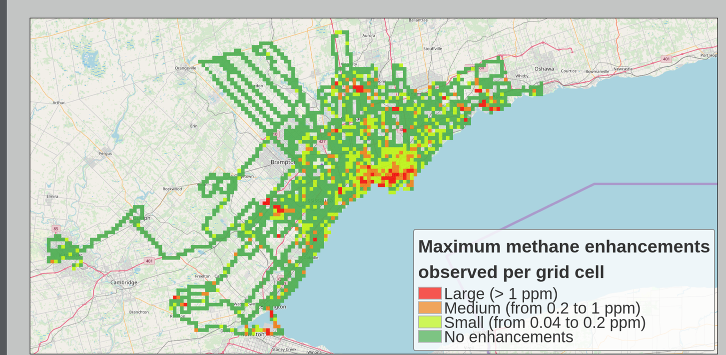

Figure 2: Maximum surface CH_4 concentrations measured by mobile instruments in the GTA (2017-2019)

Emission values are revised by circling the facilities with the mobile instrument. Seasonal variability is studied by repeating measurements at different times of the year. Figure 2 suggests CH_4 emissions are highly localized in the city.

Comparison with existing grided inventories

GTA CH_4 emissions based on global scale and national scale grided inventories (EDGAR4.2 and ECCC) with a spatial resolution of 0.1×0.1 degrees suggests discrepancies with FLAME inventory:

Category	FLAME	ECCC	EDGAR
Agricultural	5.92	7.79	5.55
Landfill	64.75	119.21	45.13
Mobile	1.00	1.50	0.40
Upstream oil and gas	0	0.24	10.85
Industrial Sources and Natural Gas	12.35	13.90	51.27
Total	84.02	142.65	113.20

Table 1: Estimated GTA CH_4 emissions (Gg/yr) by each inventory

Spatial distribution of the emission inventories

In addition to the discrepancies in total emissions and category emissions, the spatial distribution of the emission inventories are also significantly different. FLAME inventory suggests more disperse emissions compared to the other two inventories. Average TROPOMI satellite measurements are included for qualitative comparison.

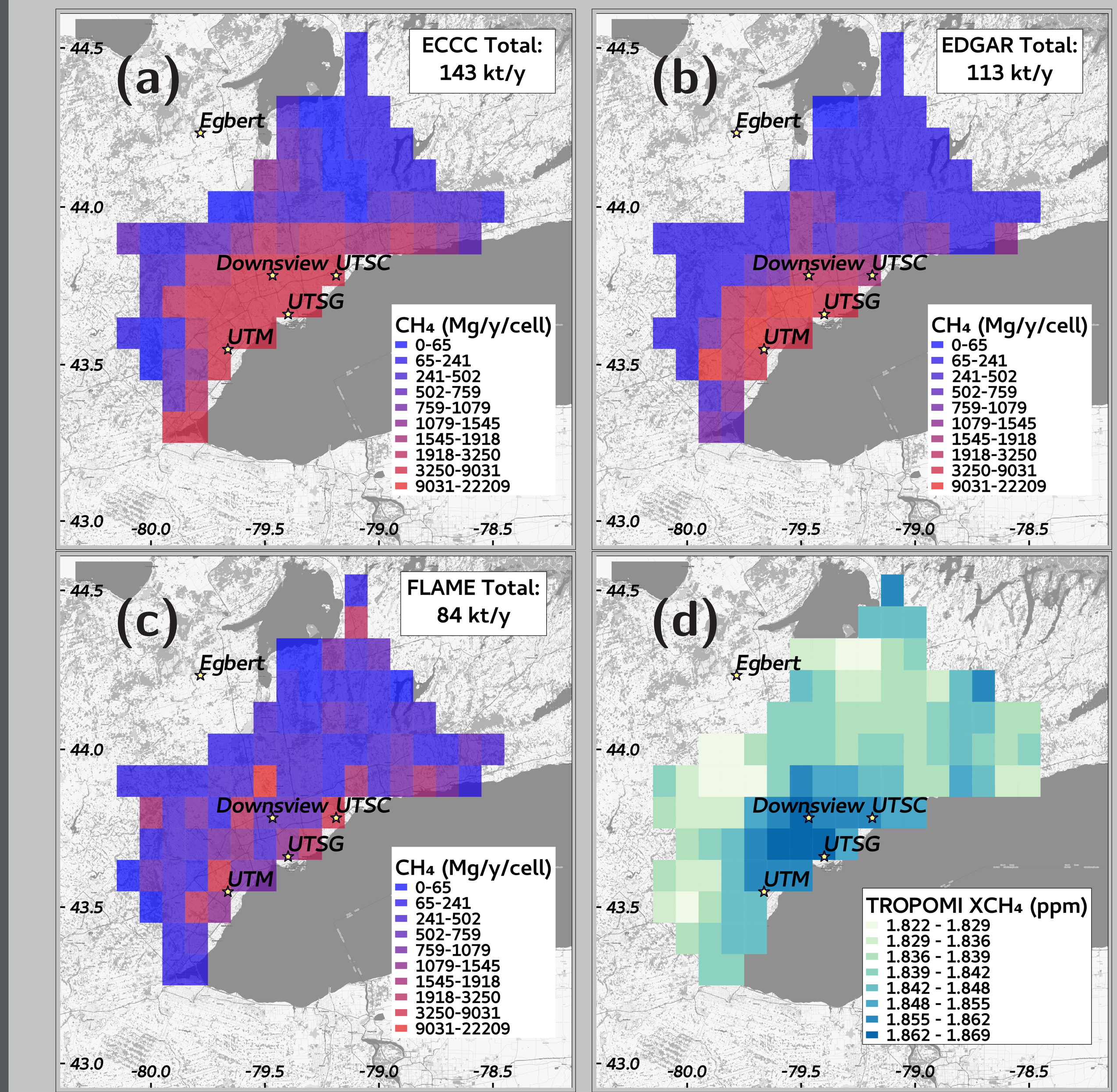

Figure 3: (a)ECCC,(b)EDGAR and (c) FLAME emission distribution and (d) average Tropomi XCH_4 measurements on the 0.1 × 0.1 degree grid.

Transport model analysis

Measured data at Downsview (DOW) for Jan-Mar 2015-2016 was used to compare against Flexpart generated concentrations from each inventory.

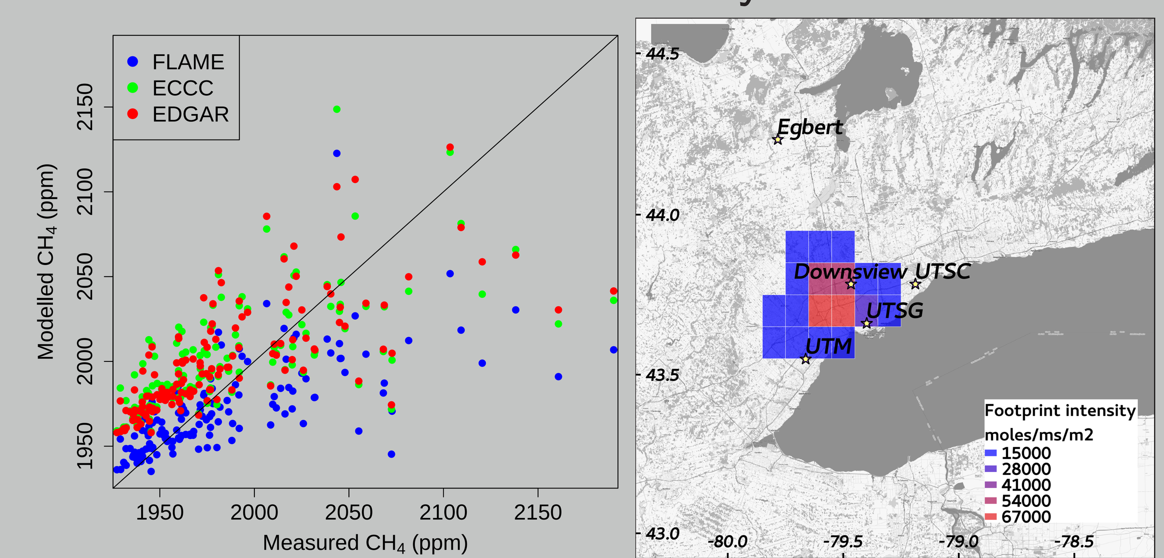

Figure 4: Left: FLEXPART predicted concentrations from the three inventories against the measured values. Right: Grid cells that contribute to 90% of CH_4 enhancements.

Total Column Measurements

Bruker EM27/SUN FTS instruments have been measuring CO_2, CH_4 and CO total column abundances in Toronto starting from 2017.The instruments were deployed at 4 different locations in summer 2019:

When the wind conditions were favorable, a XCH_4 enhancement of upto 20 ppb were observed at the downwind site compared to the upwind site. Those enhancements were often coincident with XCO_2 and/or XCO enhancements. Assuming the CO and CO_2 inventories have better accuracies than the CH_4 inventories, the ratio of the anomalies could be used to estimate CH_4 emissions as described by Wunch et al. 2009.

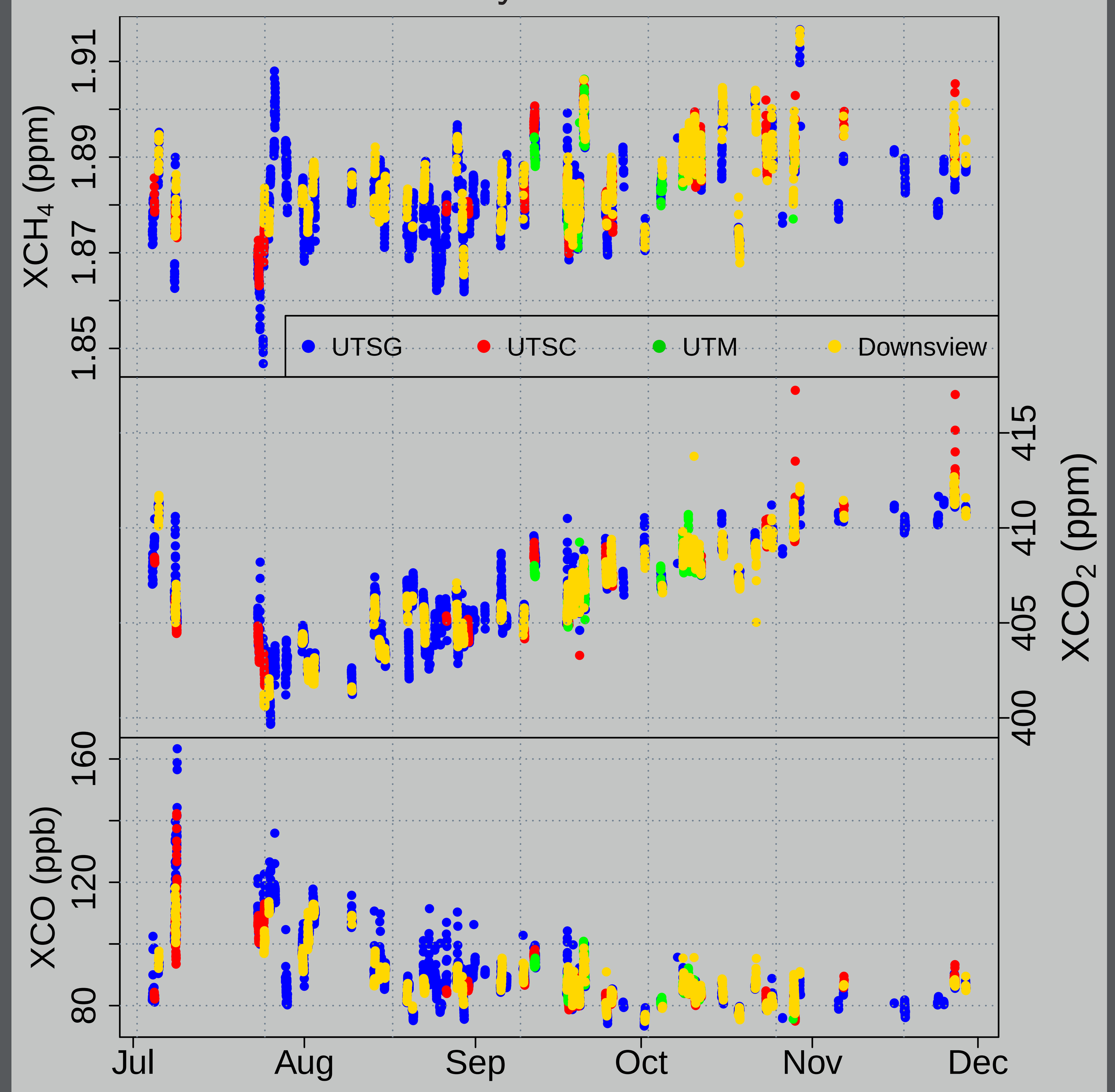

Figure 5: Timeseries of XCH_4 (top), XCO_2 (middle) and XCO (bottom) measured since July 2019 to present.

Emission estimates using enhancement ratios

To obtain dXGas values ten minute average XGas mole fractions measured at each site are subtracted from the values measured at the reference site (UTSG).

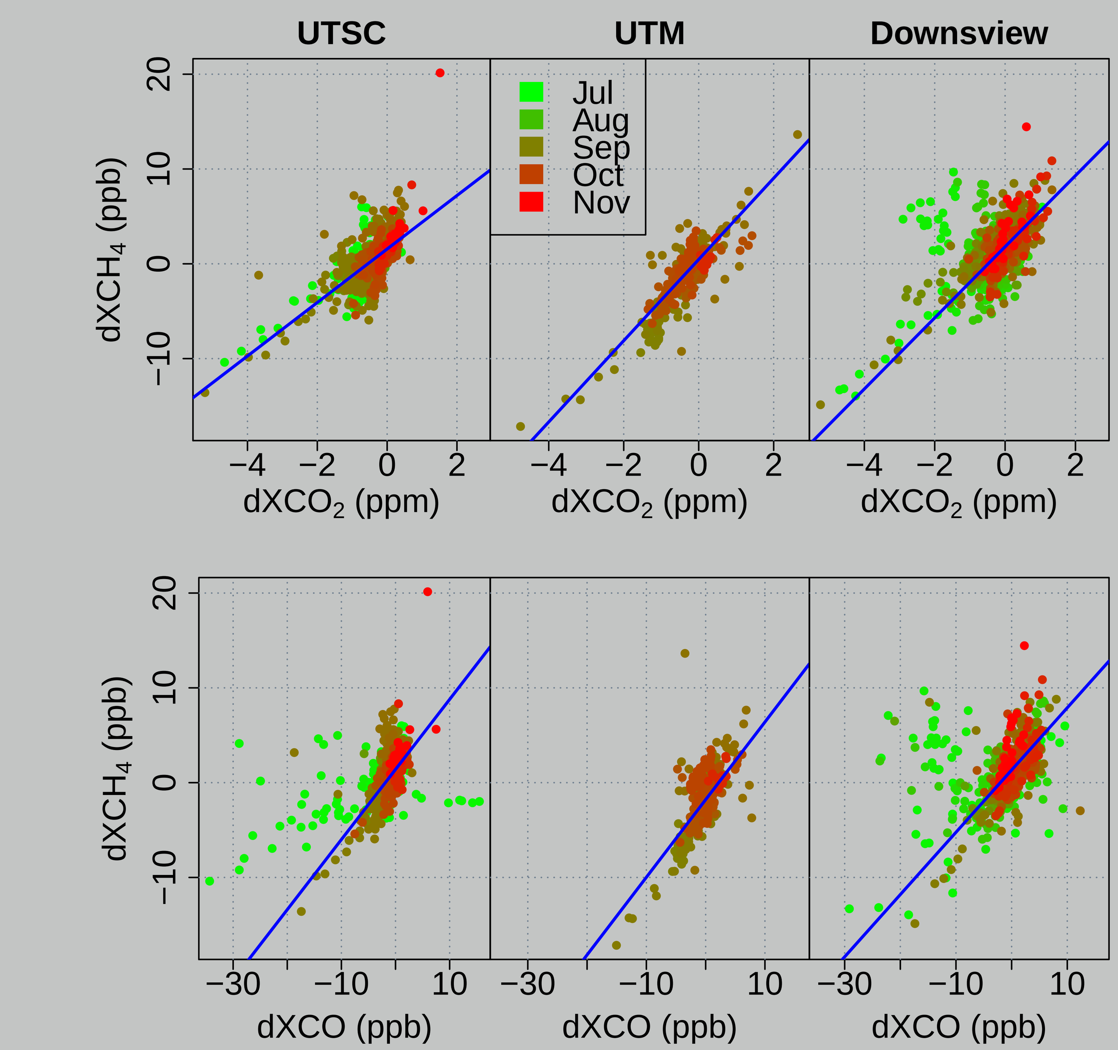

Figure 6: Correlations between $dXCH_4$ and $dXCO_2$ (top) and between $dXCH_4$ and dXCO(bottom).

Toronto CH_4 emissions are estimated based on EDGAR CO and CO_2 emissions and the corresponding anomaly ratio.

	Average anomaly ratio	CH_4 emission estimate	FLAME	EDGAR	ECCC
$dXCH_4/dXCO_2$	3.7 ± 0.6	19.9 ± 3.6	14.8	47.8	50.4
$dXCH_4/dXCO$	0.74 ± 0.22	40.4 ± 12	14.8	47.8	50.4

Table 2: Average anomaly ratios and corresponding estimated CH_4 emissions for the city of Toronto (Gg/yr)

Conlcusion

- Total column measurements are preferable to surface in-situ measurements to validate city scale emissions
- Significant discrepencies between CO and CO_2 based emissions
- The enhancement ratios for Toronto are similar to Boston [7]
- Once more data is collected, seasonal trends could be implemented in the emission inventory

References

[1] EDGAR v4.2, Emissions Database for Global Atmospheric Research, 2012
[2] Zhang et al., Canadian anthropogenic methane and ethane emissions: A regional air quality modeling perspective. Poster, 15th Community Modeling and Analysis System (CMAS) Conference, 2016
[3] Mostafavi Pak et al., Methane Emission Inventory for the Greater Toronto Area (GTA), Scholars Portal Dataverse, 2019, https://doi.org/10.5683/SP2/HTNDSO
[4] Copernicus Sentinel-5P (processed by ESA), TROPOMI Level 2 Methane Total Column products. Version 01. European Space Agency, 2019
[5] Wunch et al., Emissions of greenhouse gases from a North American megacity, Geophysical Research Letters 36.15, 2009
[6] EDGAR v4.3.2, Global Air Pollutant Emissions, 2018
[7] Plant et al., Large fugitive methane emissions from urban centers along the US East Coast., Geophysical research letters, 2019

http://www.atmosp.physics.utoronto.ca/GTA-Emissions/

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