Greenhouse Gas and Short-Lived Pollutants Measured Via Research Aircraft over New York City during AGES+ in July 2023

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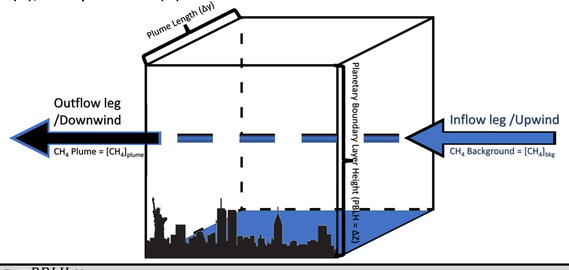
Intro

Greenhouse gas emissions are important metrics to help cities (1) assess and mitigate their environmental impact, (2) contribute to global climate goals, and (3) create sustainable urban development. As part of the AGES+ Summer 2023 aircraft campaigns, the UMD Cessna 402B aircraft conducted eight research flights in the New York City Long Island Sound (NYC-LIS) region during July 2023. The aircraft sampled trace gases including O_3, NO_2, NO, NOy, HCHO, C_2H_6, CH_4, CO_2, CO, H_2O, and VOCs, and measured aerosol optical properties (scattering, absorption, and black carbon). The primary objectives of the campaign were to: (1) quantify urban greenhouse gas emissions and (2) study the chemical and dynamic properties that lead to photochemical smog events at land-bay interface - which will be examined in future studies.

Figure 1 (top): UMD Research Cessna 402B with a red box highlighting the (bottom) "candy cane" inlet, Aerosol inlet and met (T/RH) sensors

Methods

- We conducted eight research flights in July of 2023 including four flights on New York Ozone exceedance days (July 11, 12, and 28). When possible, flights were coordinated with the NOAA twin otter CUPiDs campaign and the NASA GIII Aeromma campaign for a richer data set on chemical and physical properties.
- New York City and Long Island methane emission rates were determined from four aircraft-based mass balance experiments (July 12, 26, 27, and 28). To calculate the methane emission rate (CH_4 ER equation below), I validated the inflow and outflow legs with 10hr HYSPLIT forward- and back- trajectories, interpolated plume edges for background CH_4 concentrations ($[CH4]_{bkg}$) and determined the Planetary Boundary Layer Height (PBLH) from vertical profiles. Emission uncertainties were assessed through a propagation error analysis involving seven variables: mixed layer height (MLH), methane concentration (ΔC), wind speed (WS), wind direction (WD), groundspeed (GS), temperature (T), and pressure (P).



$$CH_4\ ER = \iint_{z_o=surface;y_o}^{z_1=PBLH;y_1} \left([CH_4]_{plume} - [CH_4]_{bkg}\right) * WS_{\perp} * (GS * \Delta T) * N(P,T)\, dy\, dz$$

Results

- July 2023 New York City/Long Island methane emission rate was 35.5± 5.5 tons CH_4/hour. The emission rate is ~25% lower than that found in NYC in a 2018 NOAA Aircraft campaign, which yielded 47.7 ± 7.9 tons CH_4/hour (Plant et al, 2019).
- July 2023 methane emission rates are more than double from 2020 US EPA 0.1ºx0.1º grided emission rate (18.0 tons CH_4/hour) (Maasakkers et al, 2023)

Table 1: July 2023 flight data used for mass balance analysis and methane emission rates.

Methane Mass Balance Emission Rates for Four Flight Days in July 2023

Flight Date	PBLH (m)	No. of Outflow legs (Altitude Range)	$\bar{U}$ (m/s)	U stdev (m/s)	CH4 bkg (ppb)	CH4 ER (tn/hr)	Uncertainty (tn/hr)
7/12/2023	2100	8 (440-810m)	4.5	1.0	2044.3	30.1	±7.5
7/26/2023	1950	3 (408-715 m)	5.9	1.1	2050.8	25.4	±1.5
7/27/2023	2050	3 (470-760 m)	12.1	1.9	2065.9	45.5	±4.4
7/28/2023	1900	3 (450-800 m)	3.8	0.8	2035.5	41.1	±8.7
July 2023 Methane Emission Rate Estimate						**35.5**	**±5.5**

Are **Methane** emissions **Declining in New York City?**

Scan for a link to the poster and more information about the presenter

Table 2: Percentile analysis for 10s smoothed trace gases (CO_2, CH_4, C_2H_6, CO, NO, NOy, and O_3) measured on 8 flight in July 2023 constrained to the boundary layer and the NYC-LIS domain.

Percentile Analysis of Trace Gases in the Boundary Layer: NYC-LIS July 2023

	CO2 (ppm)				CH4 (ppm)				C2H6 (ppb)			
Flight Date	25%	Median	75%	90%	25%	Median	75%	90%	25%	Median	75%	90%
7/11/2023	401.1	405.8	408.0	410.5	2.02	2.04	2.05	2.06	4.4	5.3	5.6	5.8
7/12/2023 (am)	397.2	401.0	407.0	412.5	2.04	2.06	2.09	2.12	5.5	6.0	6.8	7.4
7/12/2023 (pm)	401.2	402.8	405.3	407.7	2.05	2.06	2.09	2.10	4.8	5.0	5.8	6.3
7/26/2023	402.4	404.4	410.3	413.2	2.06	2.07	2.08	2.09				
7/27/2023	410.5	412.1	413.8	415.4	2.07	2.08	2.08	2.09				
7/28/2023 (am)	418.6	421.7	425.8	431.2	2.05	2.06	2.09	2.13				
7/28/2023 (pm)	417.8	419.3	423.2	427.5	2.05	2.06	2.09	2.11	5.8	6.1	6.4	7.0
7/29/2023	417.3	422.8	425.5	428.5	2.04	2.08	2.09	2.11	5.6	6.2	7.0	7.3
	CO (ppb)				O3 (ppb)				NOy (ppb)			
Flight Date	25%	Median	75%	90%	25%	Median	75%	90%	25%	Median	75%	90%
7/11/2023	151.9	164.6	193.0	206.9	61.0	71.1	90.6	103.9				
7/12/2023 (am)	155.7	178.5	208.5	235.1	69.9	74.8	80.0	92.0	1.9	2.9	5.2	7.8
7/12/2023 (pm)	178.1	187.6	197.7	211.9	82.3	87.7	94.6	110.6	3.3	3.7	4.2	5.7
7/26/2023	259.2	274.7	301.5	310.6	76.3	80.3	95.3	103.5	3.0	3.7	6.6	7.6
7/27/2023	212.5	222.5	231.4	248.7	57.4	61.0	69.2	80.5	2.9	3.5	4.1	5.3
7/28/2023 (am)	184.8	199.8	222.5	251.6	55.4	60.9	66.8	77.3	2.4	3.3	5.7	9.1
7/28/2023 (pm)	197.3	205.5	231.7	258.2	74.6	83.1	97.4	114.1	3.8	4.3	5.9	7.3
7/29/2023	165.3	178.8	200.7	215.5	64.6	67.3	72.9	80.3	2.2	2.9	3.7	4.2

References:
Maasakkers, Joannes D., Erin E. McDuffie, Melissa P. Sulprizio, Candice Chen, Maggie Schultz, Lily Brunelle, Ryan Thrush, et al. "A Gridded Inventory of Annual 2012–2018 U.S. Anthropogenic Methane Emissions." *Environmental Science & Technology* 57, no. 43 (October 31, 2023): 16276–88. https://doi.org/10.1021/acs.est.3c05138.
Plant, Genevieve, Eric A. Kort, Cody Floerchinger, Alexander Gvakharia, Isaac Vimont, and Colm Sweeney. "Large Fugitive Methane Emissions From Urban Centers Along the U.S. East Coast." *Geophysical Research Letters* 46, no. 14 (July 28, 2019): 8500–8507. https://doi.org/10.1029/2019GL082635.

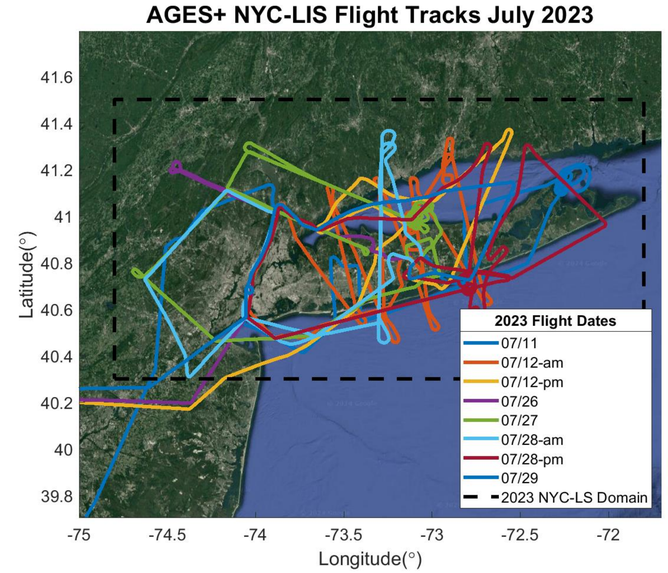


Figure 2 (above): Flight Tracks for 8 New York flights in July 2023 colored by flight date. NYC-LIS domain defined by the latitude range (40.3° -41.5°) and longitude range (-74.8° - -71.8°).

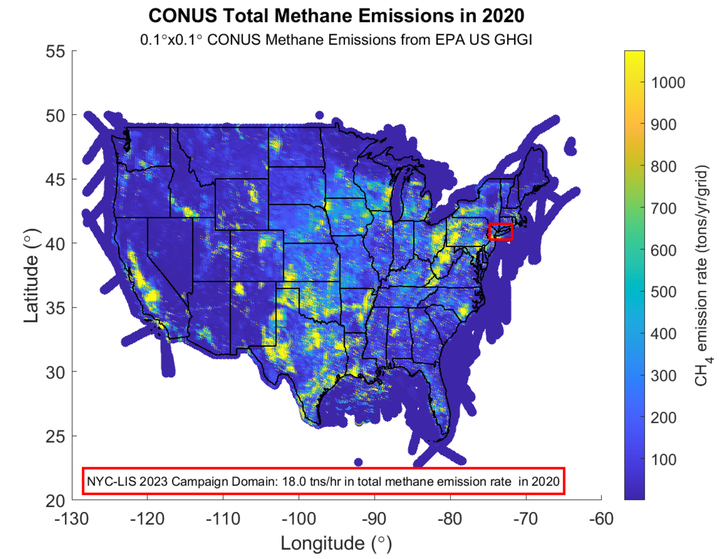


Figure 3 (above): CONUS plot of US EPA GHGI 2020 grided Methane emission rates. The NYC-LIS 2023 campaign domain is boxed in red. The total methane emission rate for the boxed domain was 18.0 tons CH_4 /hour.

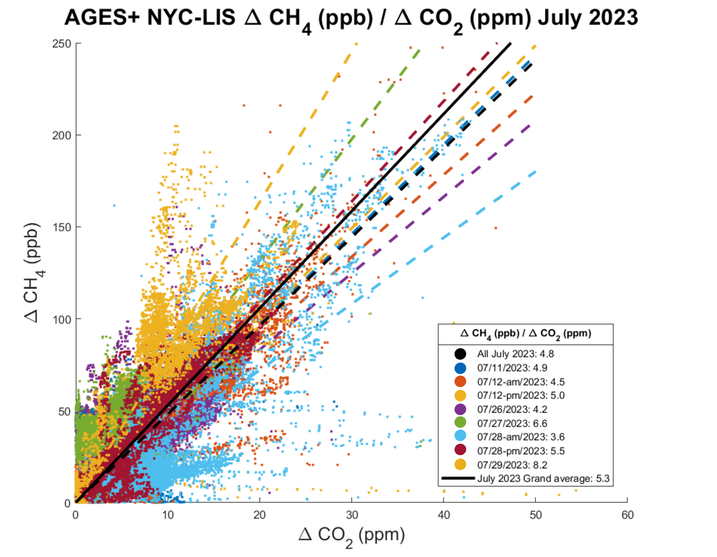


Figure 4: Examining the ratio of ΔCH_4 (ppb) to ΔCO_2 (ppm) relative to background concentrations estimated by the 5th percentile of each data set allows us to approximate CH_4 methane emissions from known CO_2 emissions, such as through the Emissions Database for Global Atmosphere Research (EDGAR v 8.0), which will be assessed in future work.