CLIMATE AND SPACE SCIENCES AND ENGINEERING
UNIVERSITY OF MICHIGAN

Estimating Urban Methane Emissions from Space.

Can we quantify and track urban methane emissions from space?
And can we do so without a transport model?

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Evaluating urban methane emissions from space using TROPOMI methane and carbon monoxide observations

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Special Issue: Remote sensing of greenhouse gas emissions

Why Urban Methane?

- Atmospheric studies consistently show higher than inventoried urban methane emissions

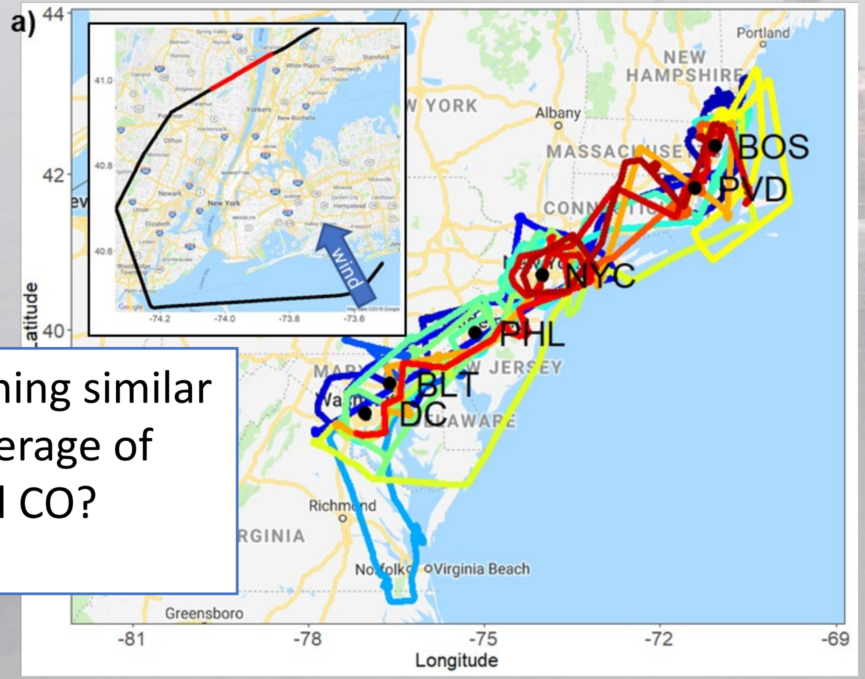
- Limited number of cities
- Limited coverage of seasons
- Are results extensible?
- Are there lessons for mitigation actions?

Table 3.7. Studies quantifying methane emissions from urban centers.

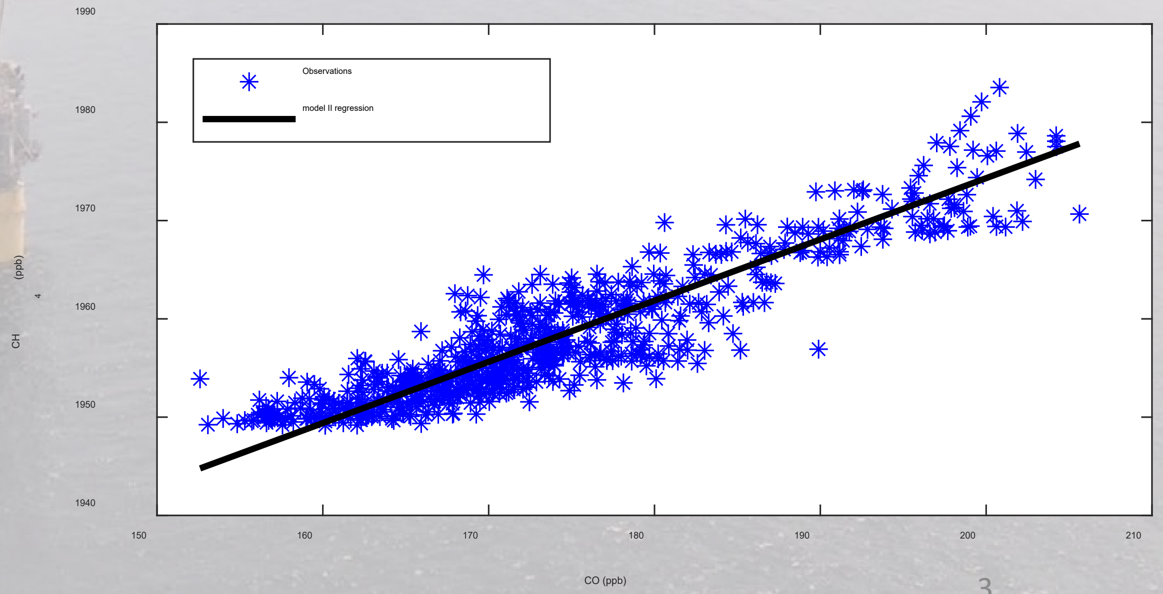
Location(s)	Approach	Study
Washington, D.C. Baltimore, MD	Two airborne platforms	Lopez-Coto et al. 2020
Washington, D.C. Baltimore, MD	Tower measurements and modeling	Huang et al. 2019
Washington, D.C. Baltimore, MD Philadelphia, PA New York, NY Providence, RI Boston, MA	Aircraft observations downwind of each city	Plant et al. 2019
Washington, D.C. Baltimore, MD	Aircraft measurements and grab samples for methane:ethane ratios	Ren et al. 2018
Indianapolis, IN	Aircraft mass balance to measure urban emissions	Heimburger et al. 2017
Los Angeles, CA	Ground-based stationary sites	Verhulst et al. 2017
Indianapolis, IN	Aircraft and tower measurements	Davis et al. 2017
Indianapolis, IN	Process-based estimation of emissions compared to atmospheric estimates	Lamb et al. 2016
San Francisco Bay area, CA	Flask samples or continuous monitoring at five locations; tracers used for source apportioning	Jeong et al. 2016
Boston, MA	Atmospheric transport modeling	McKain et al. 2015
Indianapolis, IN	Aircraft mass-balance approach	Cambaliza et al. 2015

East Coast Outflow (ECO) Aircraft Campaign

- Previous Work: "Large Fugitive Methane Emissions From Urban Centers Along the U.S. East Coast" (Plant et al., GRL, 2019, https://doi.org/10.1029/2019GL082635)
  - Most extensive study of urban methane emissions
  - Used CH_4:CO correlations to study CH4 emissions (urban emissions mix and are correlated in urban plume even though not co-emitted)



Can we do something similar with the daily coverage of TROPOMI CH_4 and CO?



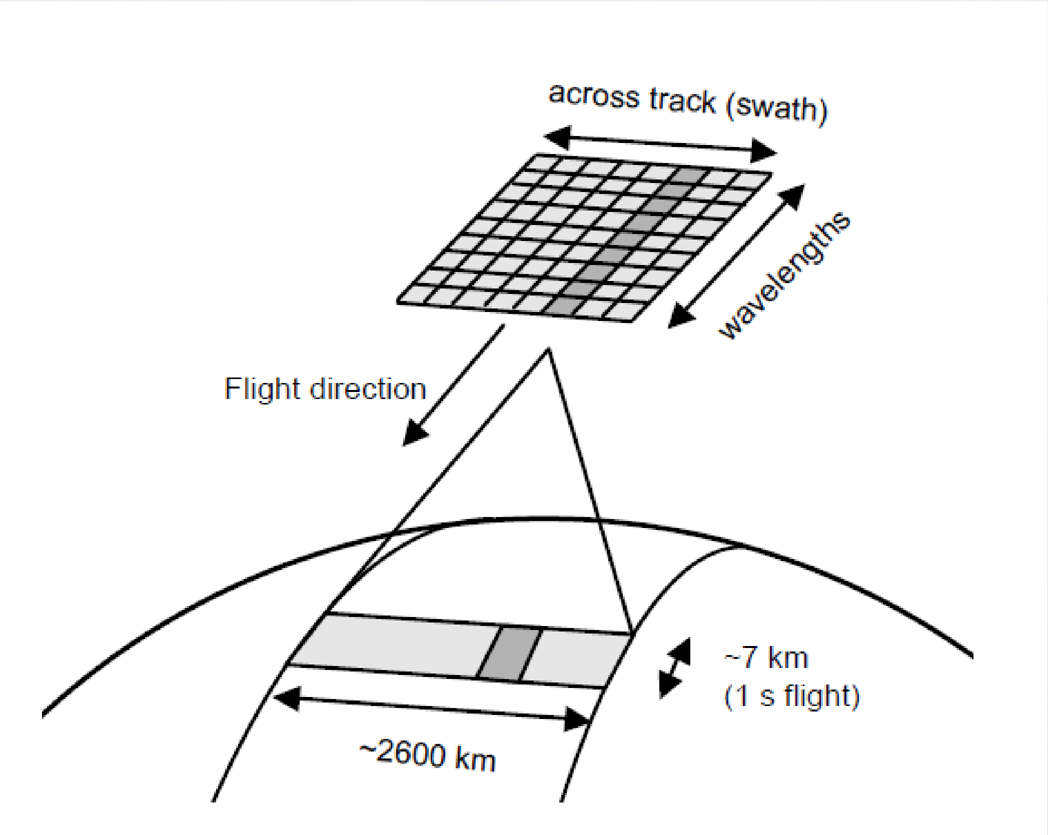
TROPOMI (TROPOspheric Monitoring Instrument)

- Passive Spectrometer with 4 different detectors (8-band):
  - UV (270 – 320 nm)
  - UV-visible (320 - 490 nm)
  - Near Infrared (710 – 770 nm)
  - Shortwave Infrared (2314 – 2382 nm)

- High spatial resolution and daily global coverage

- This work: Using L2 methane (CH4) and carbon monoxide (CO) products
  - Retrievals based on SWIR observations → same geographic grid

- Access to the urban scale
  - Borsdorff et al., 2018 & 2019 [CO]
  - Lama et al., 2020 [CO, NO_2]

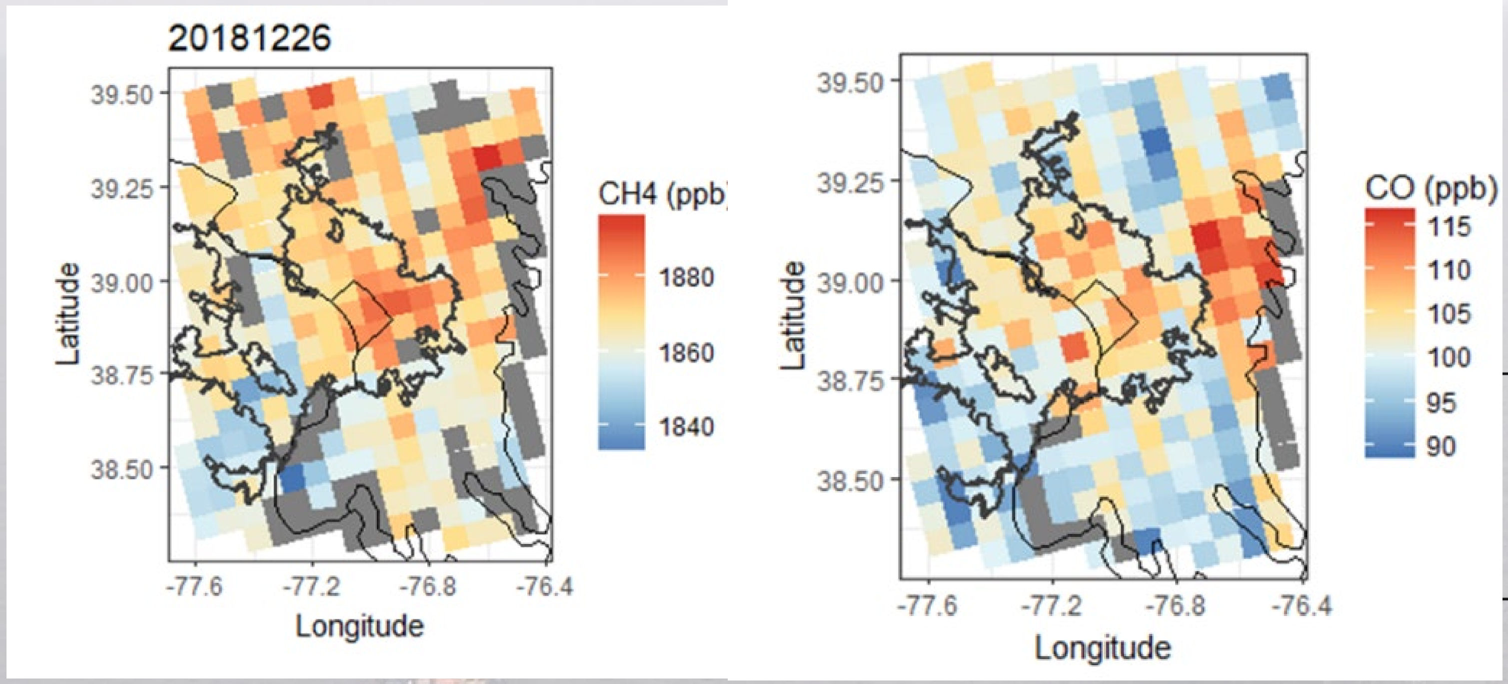


Source: S5P L2 PUM Carbon Monoxide

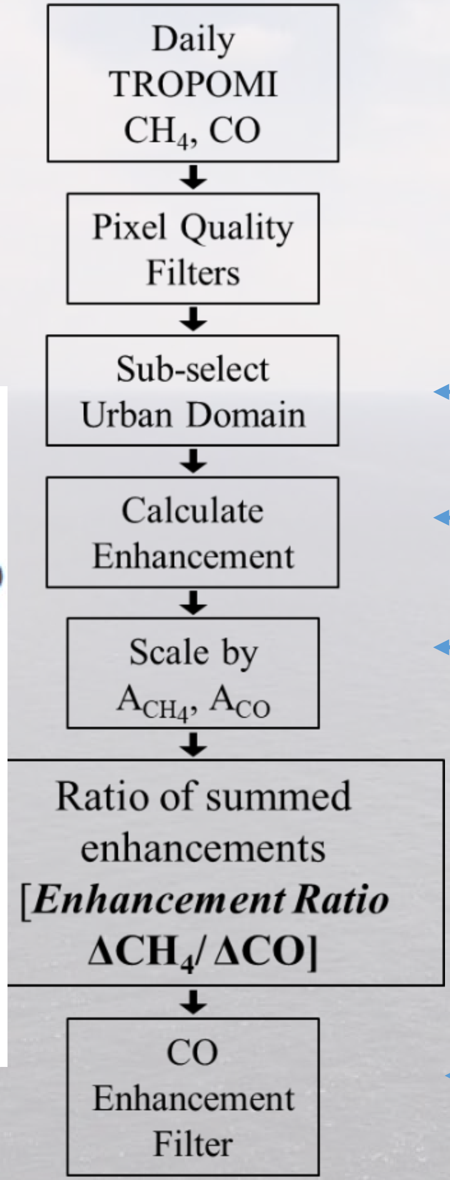
Urban Tracer:Tracer Analysis from Space

- Previous Work from space:
  - Silva et al., 2013: GOSAT, MOPITT retrievals CO_2:CO in megacities
  - Lama et al., 2020: TROPOMI NO_2:CO combustion in cities
  - All gases with co-located emissions, retrievals averaged across many days
- This Work:
  - CH_4, CO sources not co-emitted
  - Calculate *daily* urban $\Delta CH_4/\Delta CO$
  - Leverage existing CO emission estimates (inventories) to generate urban CH4 emission rates.
  - Expand our study of urban CH_4 to three additional cities in the U.S.

$\Delta CH_4/\Delta CO$ Enhancement Ratio Approach



Example for Washington, DC

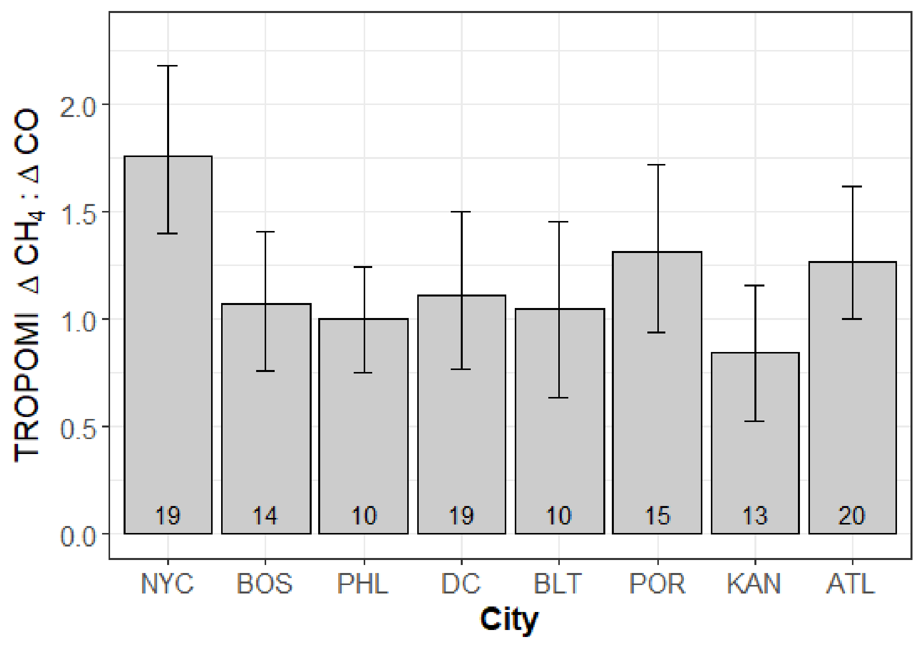


Investigated sensitivity in either data or model space – see paper for details

Compare Space-based and Aircraft Ratios

$\Delta CH_4/\Delta CO$ Scaling - to emissions

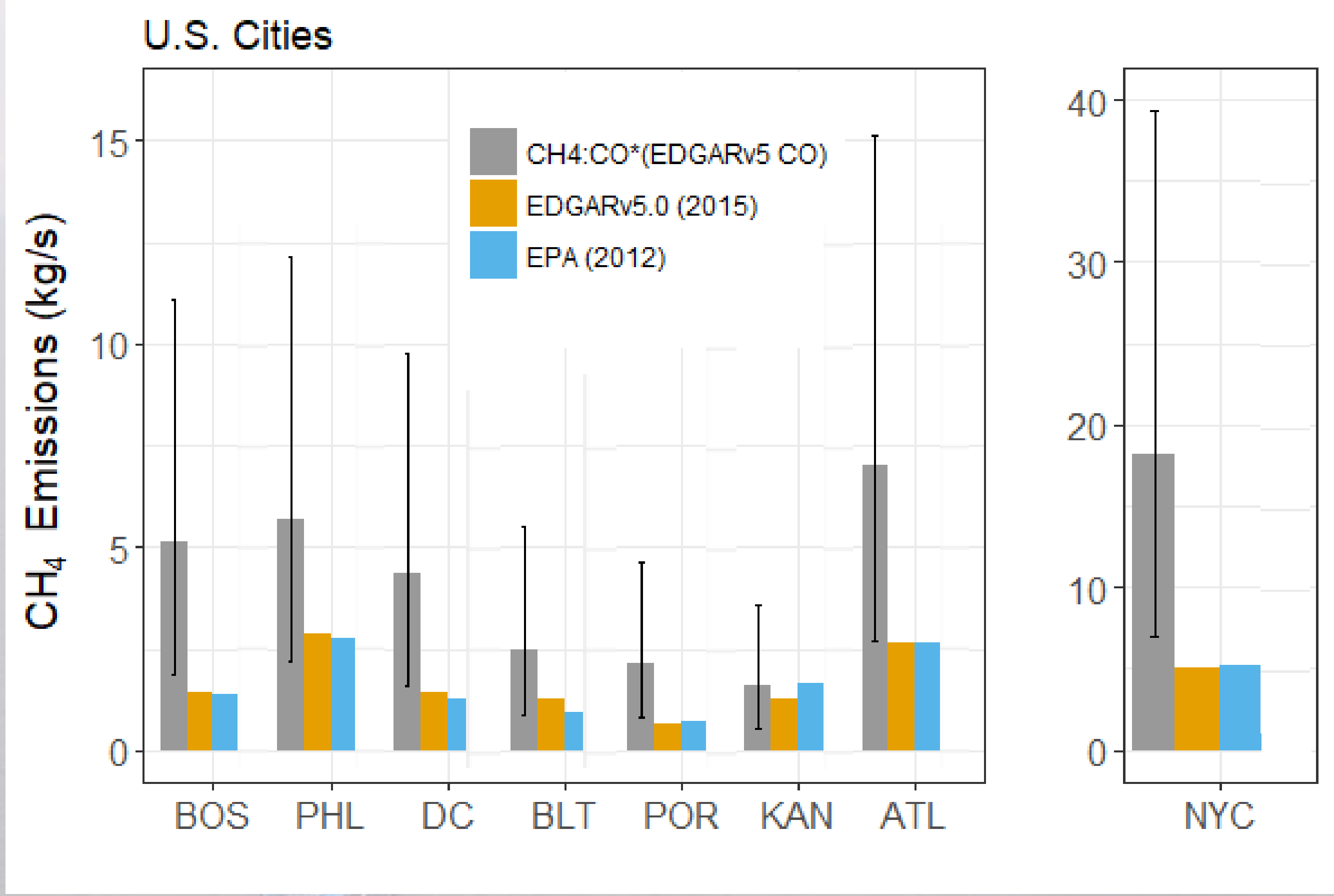
2019



City	EDGAR v5.0 CO Emission Rate (kg CO/s)
Atlanta, Georgia	2.9
Baltimore, Maryland	6.9
Boston, Massachusetts	8.4
District of Columbia	4.1
Kansas City, Missouri	9.6
Philadelphia, Pennsylvania	9.9
Portland, Oregon	3.3
New York, New York	18.1

$$E_{CH4}\left[\frac{kg\ CH_4}{s}\right] = \frac{\Delta CH_4}{\Delta CO} \cdot E_{CO}\left[\frac{kg\ CO}{s}\right] \cdot \frac{m_{CH_4}}{m_{CO}}$$

Independent natural gas correction matches satellite constraint



- East Coast (ECO) aircraft analysis (with simultaneous measurement of ethane) found natural gas (NG) was represented in the inventory by a factor of 8.8x.
- To explore if this same trend could possibly explain the discrepancy in other cities we scale the NG categories in the inventory (distribution, transmission) by 8.8 → pink bar
- NG scaling results in better agreement in most cities and does not change in cities where they was already good inventory-observation agreement (i.e. Kansas City, KAN)

Directions we are going

- Explore in more detail this approach in comparison to cities that are ‘well-observed’
- Develop approach for comparing and evaluating
- Extend approach to future space-based sensors
- Expanding to more cities (US and the world)

Delhi