Aircraft Measurements of Air Pollutants and Greenhouse Gases in the Mid-Atlantic States

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Motivation

- Mid-Atlantic states occasionally experience severe air smog in summer.
- Urban greenhouse gas (GHG) emissions contribute to the majority (~70%) of the anthropogenic GHG emissions.
- Quantification of urban greenhouse gas (GHG) emissions is important for establishing scientifically sound and cost-effective policies for mitigating GHGs.

Measurements

GPS Position (Lat, Long, Altitude)

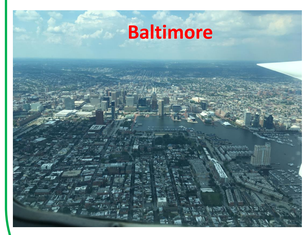
Met (T, RH, P, wind speed/direction)

Trace gases:

- O_3: UV Absorption, modified TECO
- SO_2: Pulsed Fluorescence, modified TECO
- $CH_4/CO_2/CO/H_2O$: Cavity Ringdown, Picarro
- NO_2: Cavity Ring Down, Los Gatos
- NO: Chemiluminescence, modified TECO
- VOCs: grab canisters/GC-FID

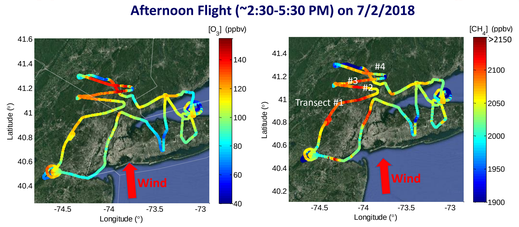
Aerosol Optical Properties:

- Scattering: b_{scat} (@450, 550, 700 nm), Nephelometer
- Absorption: b_{ap} (565 nm), PSAP
- Black Carbon: Aethalometer



A Typical Air Quality & Mass Balance Flight

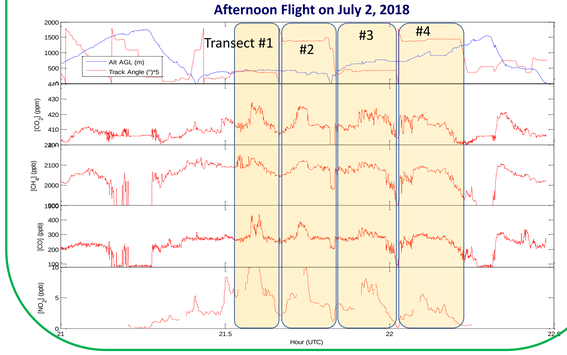
Afternoon Flight (~2:30-5:30 PM) on 7/2/2018



- Ozone and CH_4 plume downwind of NYC.

Time series of Alt, Ozone, CO_2, CH_4, and CO

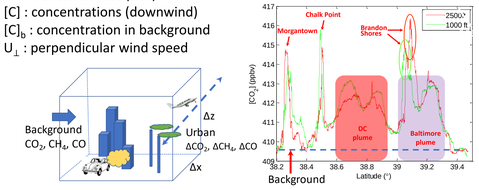
Afternoon Flight on July 2, 2018



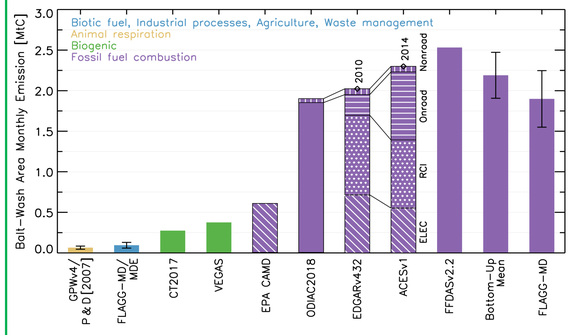
Mass Balance Approach

$$E.R._{CH_4} = \int_0^{z_i} \int_{-x}^{+x} ([C] - [C]_b) \times U_\perp \, dx dz$$

E. R. : emission rate (flux)
[C] : concentrations (downwind)
$[C]_b$: concentration in background
$U_\perp$: perpendicular wind speed



CO_2 Emissions from Washington, DC/Baltimore



Emission Rates (E. R.) based on Mass Balance

July 2, 2018 (NYC urban center)

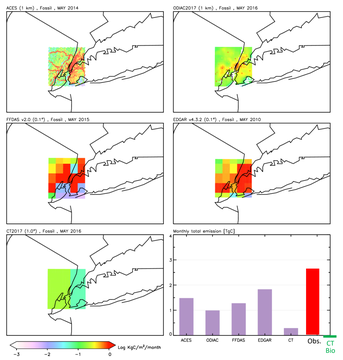
Transect #	CO_2 E. R. (mol/s)	CH_4 E. R. (mol/s)	CO E. R. (mol/s)	NO_2 E. R. (mol/s)
1	75,300	222	488	--
2	62,300	260	397	24.3
3	65,700	523	567	28.4
4	85,110	668	489	21.9
Mean	74,700	418	481	24.9

Comparison with CO_2 Emission Models

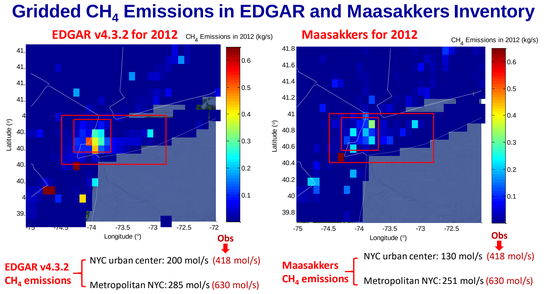
(NYC urban center — corresponding to the flight on July 2, 2018)

Fossil-Fuel CO_2 emission models:

- ACES (1 km, v1) July 2014
- ODIAC (1 km, v2017) July 2016
- FFDAS (0.1°, v2.0) July 2015
- EDGAR (0.1°, v4.3.2) July 2012
- CarbonTracker (1°, CT2017) July 2016



Gridded CH_4 Emissions in EDGAR and Maasakkers Inventory



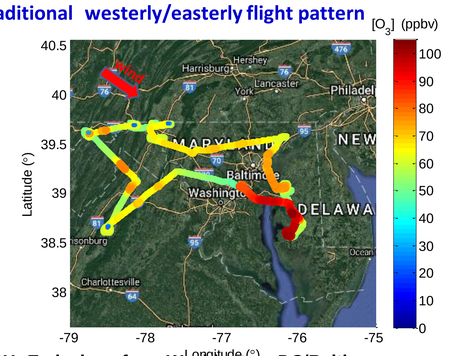
EDGAR v4.3.2 CH_4 emissions: NYC urban center: 200 mol/s (418 mol/s); Metropolitan NYC: 285 mol/s (630 mol/s)

Maasakkers CH_4 emissions: NYC urban center: 130 mol/s (418 mol/s); Metropolitan NYC: 251 mol/s (630 mol/s)

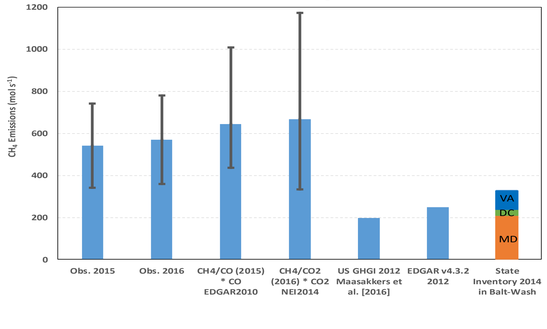
Results

Air Quality Flight in Maryland on 8 Sept. 2016

Traditional westerly/easterly flight pattern



CH_4 Emissions from Washington, DC/Baltimore



High $[CO_2]$ & $[CH_4]$ observed over the Sound and CT/RI coastal areas were associated with airflow passing NYC/NJ

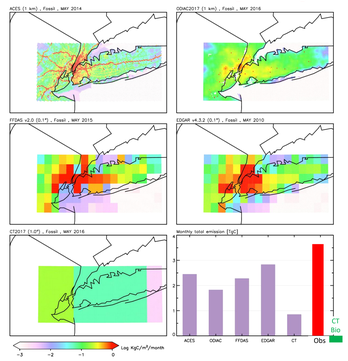
Emission Rates (E. R.) based on Mass Balance

May 18, 2017 (the Greater NYC Metro.)

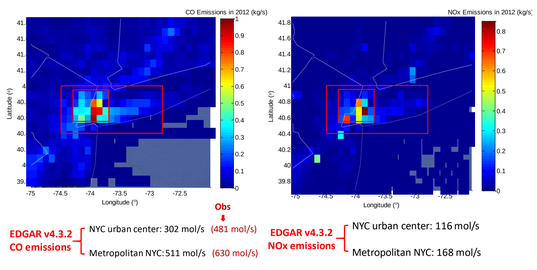
Transect #	CO_2 E. R. (mol/s)	CH_4 E. R. (mol/s)	CO E. R. (mol/s)	NO_2 E. R. (mol/s)
1	101,000	560	642	10.4
2	127,000	700	628	7.6
Mean	114,000	630	636	9.0

Comparison with CO_2 emission models

(Close up NYC Metropolitan Area — corresponding to the flight on May 18, 2017)



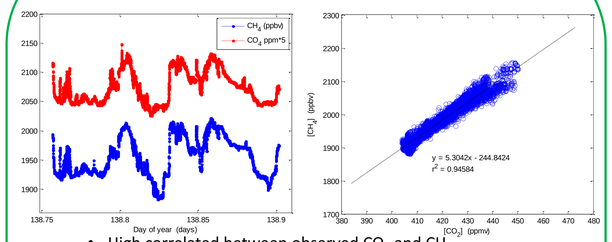
Gridded CO & NOx emissions in EDGAR v4.3.2 for 2012



EDGAR v4.3.2 CO emissions: NYC urban center: 302 mol/s (481 mol/s); Metropolitan NYC: 511 mol/s (630 mol/s)

EDGAR v4.3.2 NOx emissions: NYC urban center: 116 mol/s; Metropolitan NYC: 168 mol/s

CH_4 and CO_2 during the flight on May 18, 2017

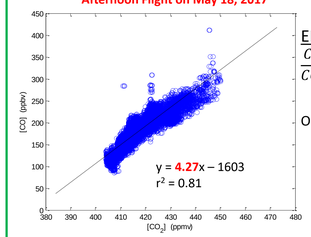


- High correlated between observed CO_2 and CH_4.
- Unlikly the same sources for CO_2 & CH_4, but likelythe sources are collocated.

We could use observed ratios to evaluate emission models.

Correlation among CO, CO_2 and CH_4

Afternoon Flight on May 18, 2017

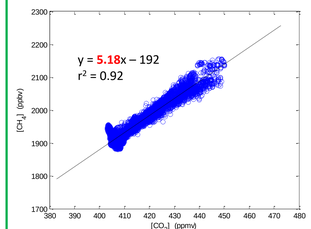


EDGAR v.4.3.2 for 2012

$\frac{CO\ E.R}{CO_2\ E.R} = 4.48$ ppb CO/ppmCO_2

Observed $\frac{\Delta[CO]}{\Delta[CO_2]} = 4.27$ ppb CO/ppmCO_2

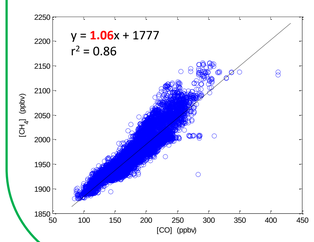
- EDGAR CO and CO_2 emissions may be good.



EDGAR v.4.3.2 for 2012

$\frac{CH_4\ E.R}{CO_2\ E.R} = 1.70$ ppbCH_4/ppmCO_2

Observed $\frac{\Delta[CH_4]}{\Delta[CO_2]} = 5.18$ ppb CH_4/ppmCO_2



EDGAR v.4.3.2 for 2012

$\frac{CH_4\ E.R}{CO\ E.R} = 0.38$ ppbCH_4/ppbCO

Observed $\frac{\Delta[CH_4]}{\Delta[CO]} = 1.06$ ppb CH_4/ppmCO

- EDGAR CH_4 emissions may be significantly underestimated for the NYC area.

Summary and Future Work

- Aircraft mass balance approach is a valuable tool for estimating urban GHG emission.
- CO & CO_2 emissions: obs. agree with emission models in general. The discrepancies may be explained by uncertainties in mass balance approach and emission models.
- The EDGAR Inventory may underestimate CH_4 emissions by a factor of 2-3.

Future work

- More flights will be conducted over Mid-Atlantic and NYC in the future to reduce uncertainties
- Biosphere CO_2 uptake/emissions and inversion modeling
- NO_2 (& NOy) emissions and compare to GEO-TASO and satellites

Acknowledgments