NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

Greenhouse Gas Measurements Program

Advancing Greenhouse Gas Emissions (GHG) Measurement Tools and Standards

Kim Mueller
Ages Workshop
September 2022

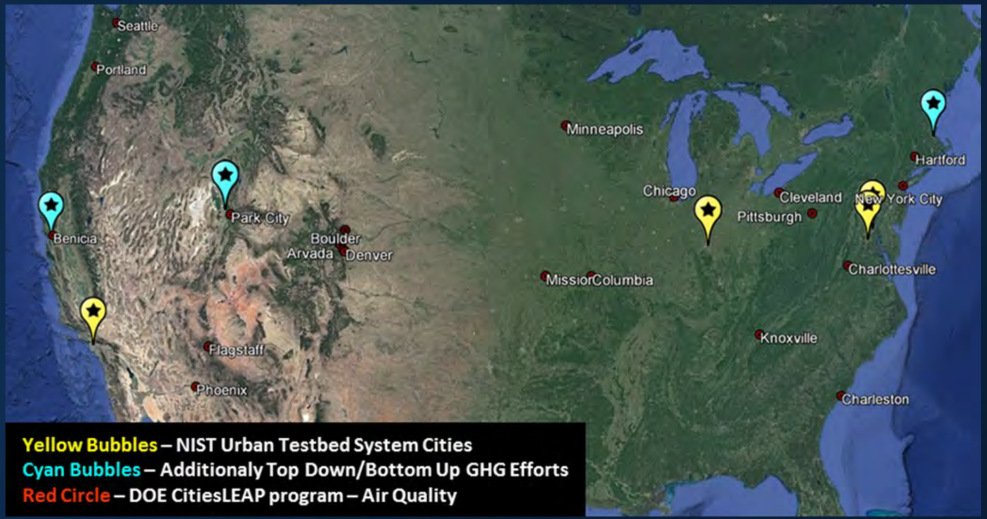
NIST's Greenhouse Gas Measurement Program

Purpose: Develop internationally recognized standards enabling reliable, accurate, traceable, and spatio-temporally resolved Greenhouse Gas (GHG) emission data to support effective mitigation actions and science-based policy decisions.

Components:

- Urban GHG Measurements Testbed System, Tools, and Methods
- Stationary or Point Source Emission Metrology (advanced smokestack Continuous Emissions Monitoring, aka CEMs, technology)
- Measurement Tools, Standards and Reference Data
- Satellite Calibration and Atmospheric Carbonaceous Aerosols Measurements & Standards
- International Documentary Standards Development for Urban GHG Flux Measurements

Project Component: NIST's Urban GHG Testbed System



Objective: To develop & demonstrate urban GHG flux measurement methods.

2010

The initial testbed

Indianapolis Flux Experiment (INFLUX)

9 public & private actors +

2013

2nd testbed

LA Megacities Project

12 public, non-govt., & private actors +

2014

Latest testbed

Northeast Corridor/Baltimore - Washington (NEC/BW)

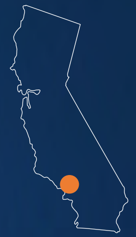
5 public & private actors +

NIST established three urban testbeds (Indianapolis, Los Angeles, and Washington/Baltimore). These are collaborative multi-institution projects (including federal agencies, universities, and the private sector), combining atmospheric measurements and analysis to estimate urban GHG emissions and related uncertainties.

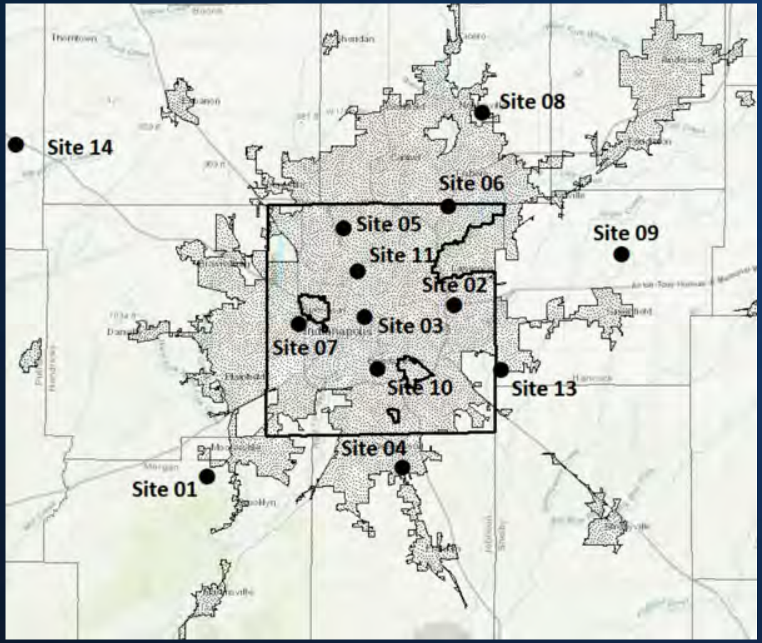
NIST's Three Urban Testbeds

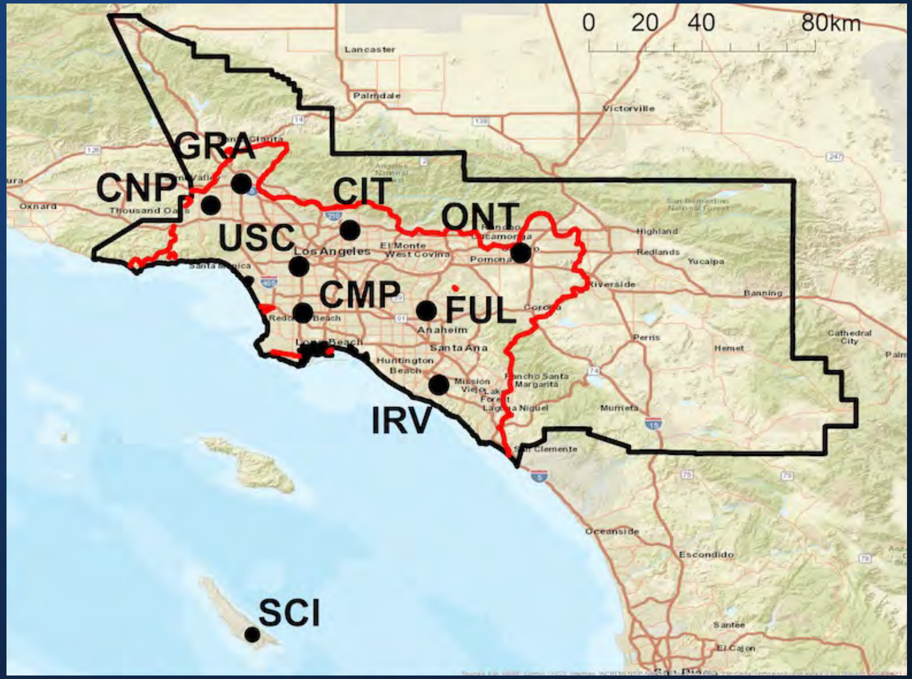
Indianapolis

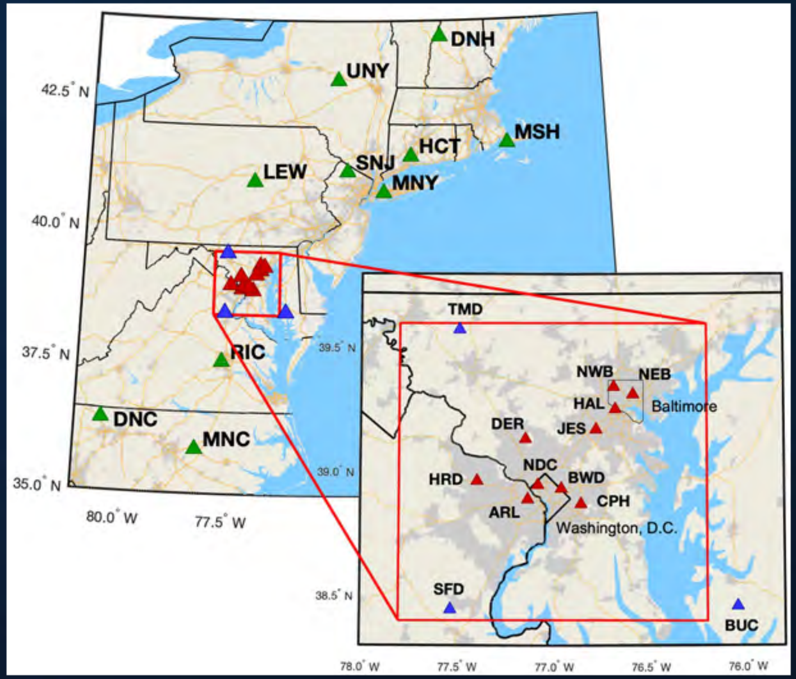
Los Angeles Megacity



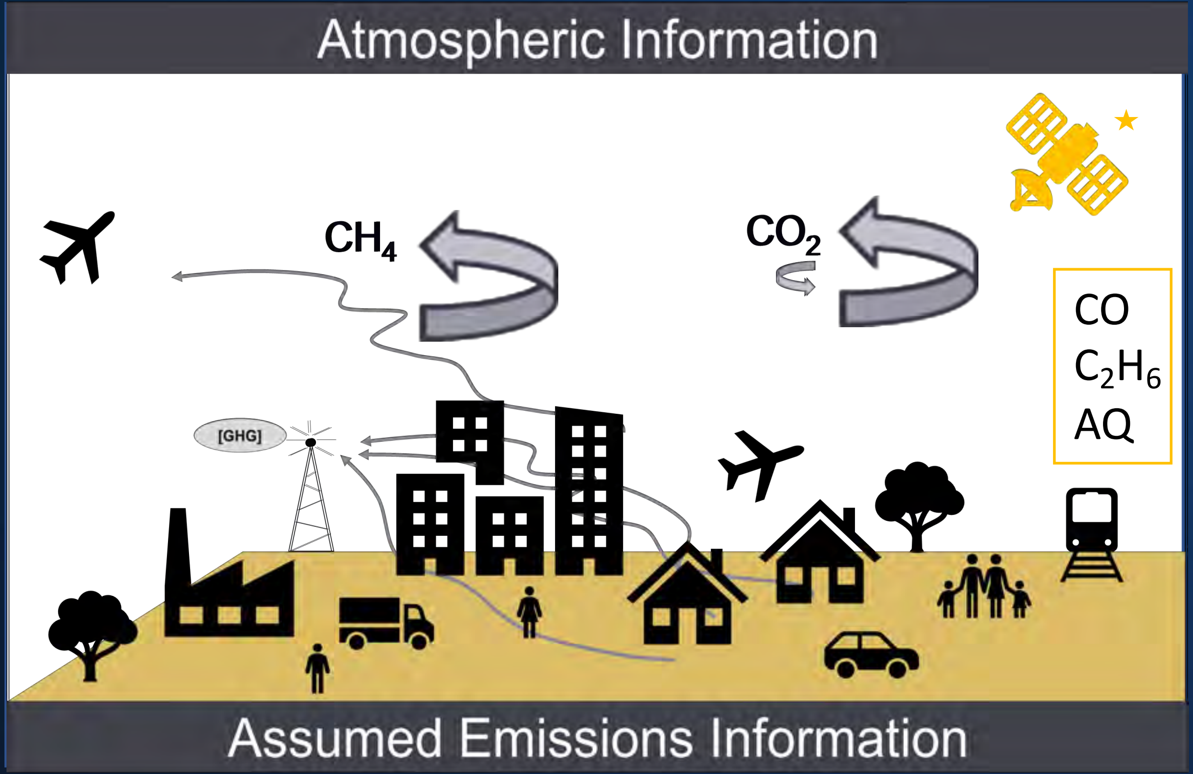
Northeast Corridor

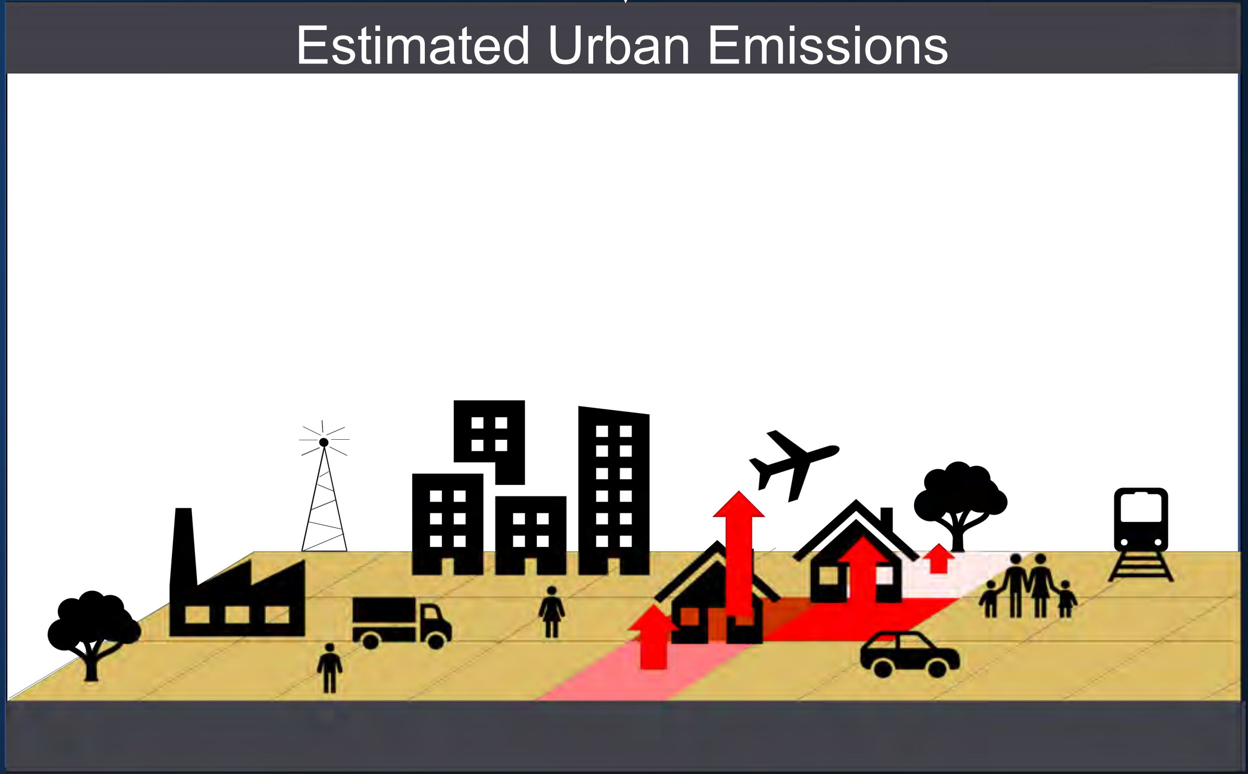






Measurement Methods for GHG Emission Quantification





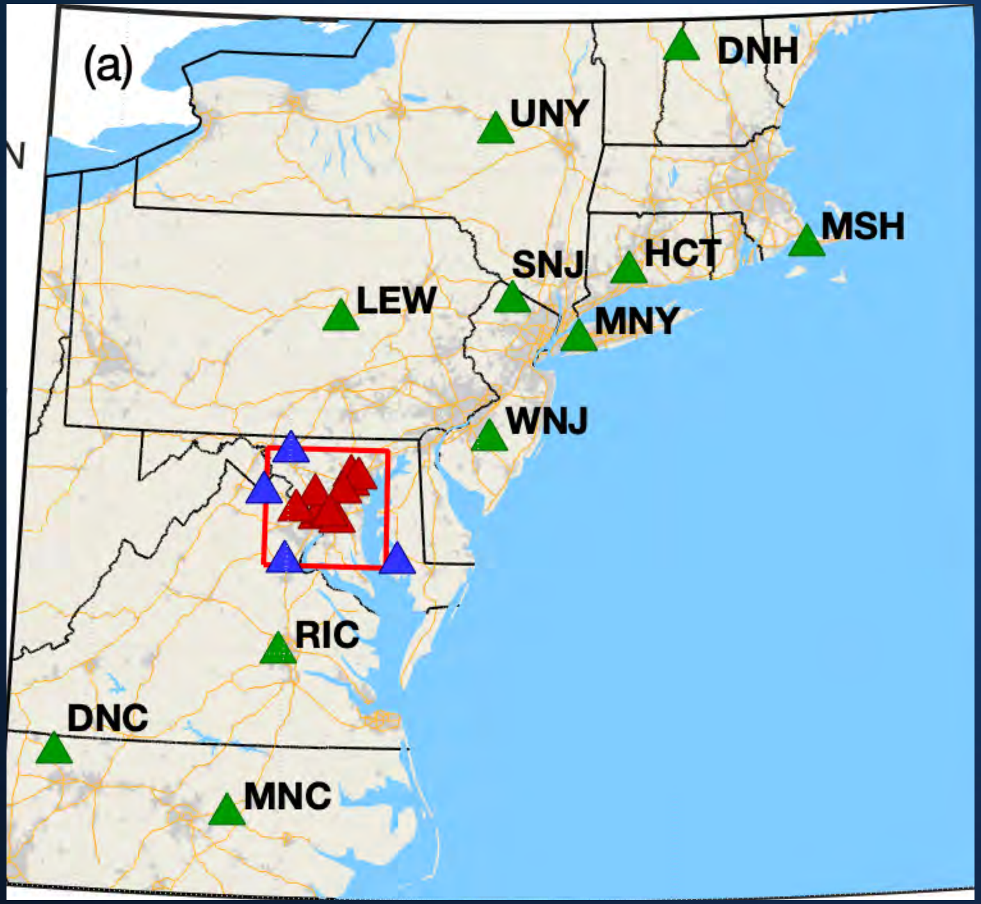
★ Future Objective
Tropomi, OCO-3 (SAMS), GeoCARB, etc.

Correlates to help with source apportionment

Ex.: Ratio, Mass Balance, Atmospheric Inversions, etc.
(whole-city, inter-annual/annual/sub-annual, sub-city/city-block/facility, sectoral attribution, etc.)

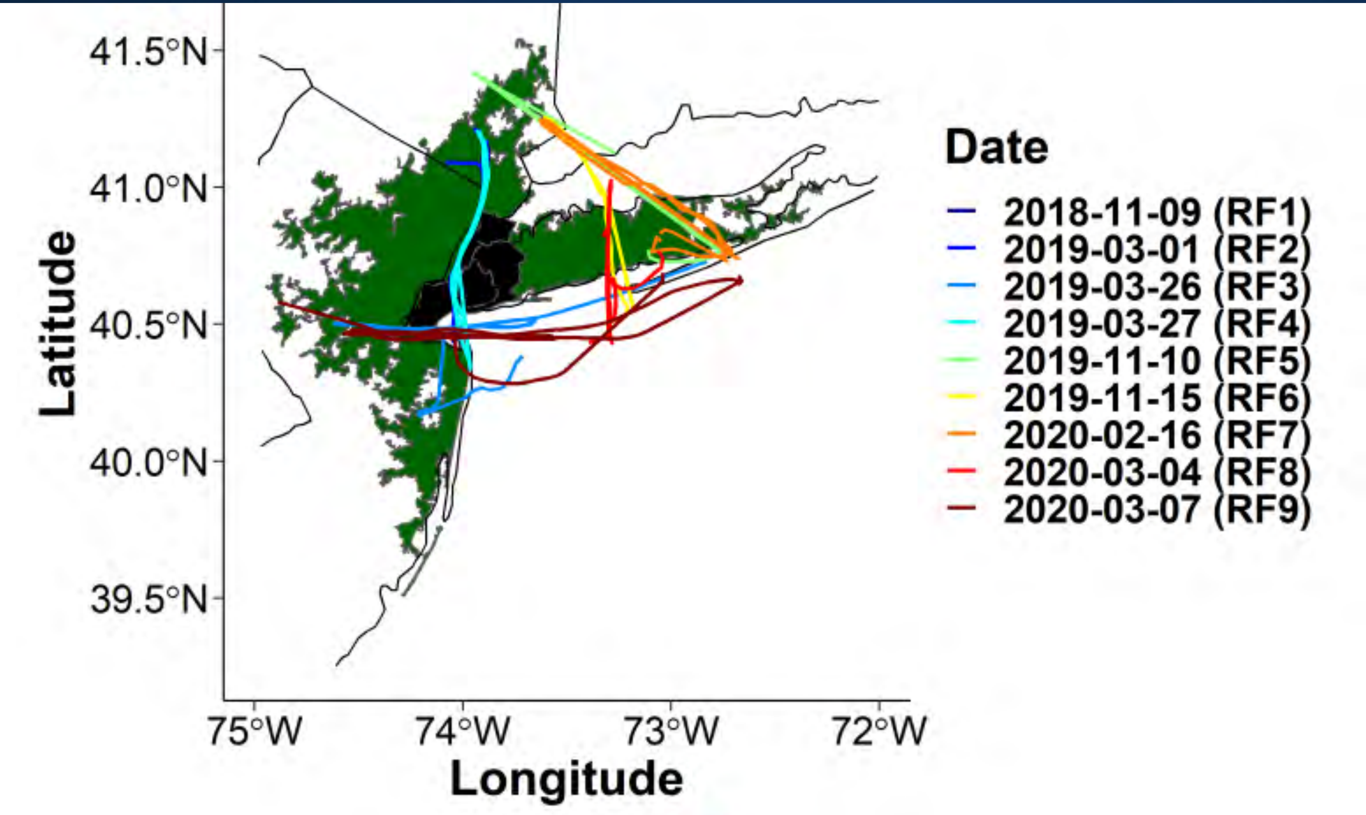
Tie into AQ assessment → recent and coordinated with NOAA, US EPA, and States

Urban Tower Network Data and Models



- Partnership with Earth Networks (LA/NEC), SIO/JPL (LA) and PSU (Indianapolis)
- High-accuracy CO_2 / CH_4 / CO concentrations reported on WMO scales
- Northeast Corridor:
  - High density in the DC/Baltimore area
  - Plans to extend to Philadelphia, NYC, Boston
- Include regional non-urban sites to characterize background conditions (i.e. incoming CO_2/CH_4 concentrations)
- NOAA/GML flasks for $^{14}CO_2$ & other gases to help characterize biosphere, attribute sources to economic sectors, etc.
- Emissions modeling (Hestia, Vulcan) & Biosphere modeling (VPRM) ongoing in all three
- Extensive atmospheric inverse modeling effort to estimate emissions of GHGs

Airborne sampling



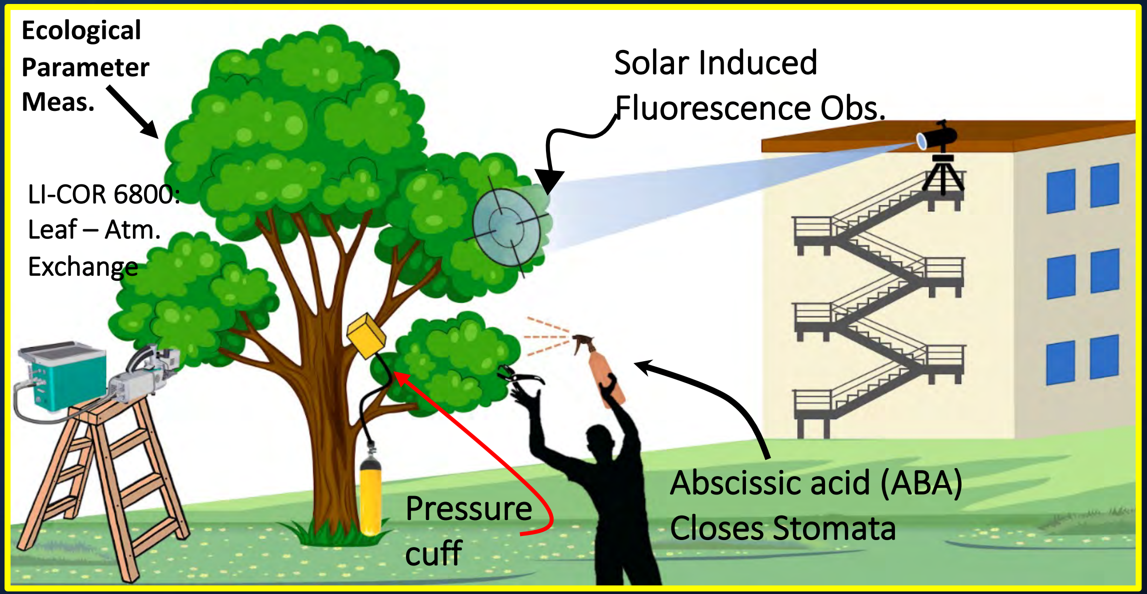
Stonybrook U./Purdue U. flight tracks used for GHG flux estimation. Figure from Hajny et al, (2022).

- University of Maryland, Purdue, & Stonybrook University conducting flight campaigns in Indianapolis, DC and NYC areas.
- Measurements of CO_2, CH_4; sometimes include CO, O_3, NO_2, & turbulence / meteorology
- Mass balance, scaling factor, and full model inversion analyses using flight GHG data.
- ***Flight campaigns will continue at regular intervals.***

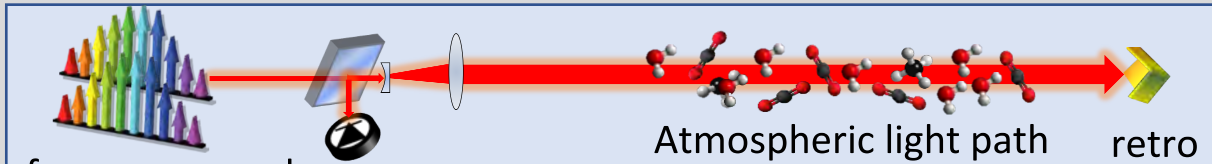
Refs: Lopez-Coto et al., ES&T (2020), Pitt et al., Elementa (2021), Ren et al., JGR (2018); Hanjy et al., Elementa (2022) & many more

Additional testbed activities

- Airborne turbulence measurements (Stonybrook U.) and high-resolution tracer modeling around powerplants using WRF-LES
- Planning landfill emissions monitoring activity in Maryland, collaborating with EPA, Maryland Dept. of Environment, Univ. of Maryland.
- Planning deployment of low-cost CO_2 & AQ sensors
- Eddy covariance flux towers (Penn State) in Indianapolis and in the Washington area to diagnose CO_2 and CH_4 fluxes in cities (including suburban vegetation) (Wu et al., 2022).
- SIF-Biosphere testbed (FOREST project) on NIST campus in Maryland, collab. w/ BU, Bowdoin & others. Goal to assess SIF measurements and linkage to GPP to improve biosphere modeling (Marrs et al., GRL)
- Bottom-up emissions modeling collaboration with NOAA/CSL: GReenhouse gas And Air Pollutant Emissions System.



Open-path dual-comb spectroscopy



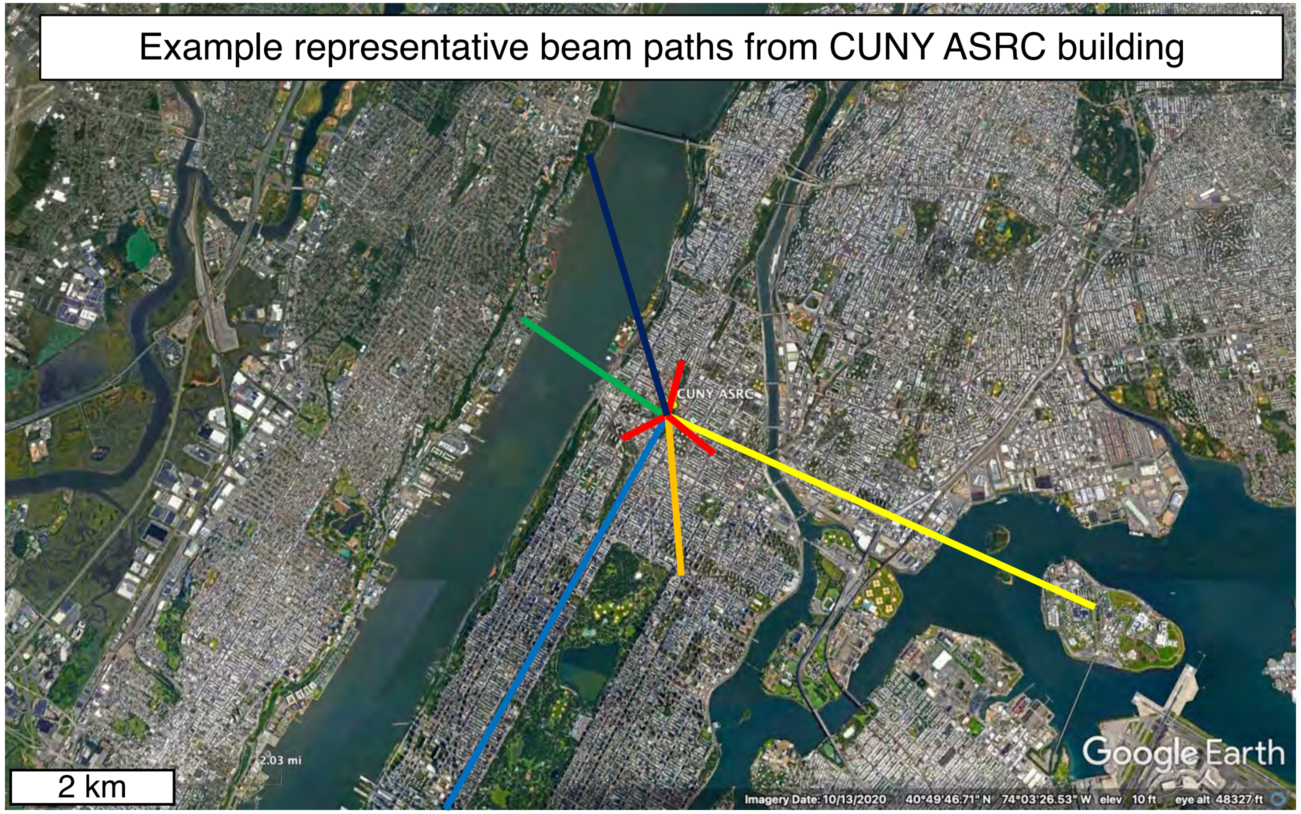
I Coddington Optica, 3, 414 (2016)
KC Cossel, Advances in Spectroscopic Monitoring of the Atmosphere, pp 27-93 (2021)

- ppb-level sensitivity, ~2 minute time resolution
- GHGs: CH_4, N_2O, CO_2
- H_2CO
- Tracers: C_2H_6, Other small VOCs
- HDO/H_2O (<10 per mil)

Goals:

- Characterize urban emissions of GHGs and spatial-temporal variability
- Use C_2H_6 to apportion thermogenic, biogenic sources of CH_4
- Look at other tracers for source apportionment
- Compare point and open-path measurements
- Look at sources of H_2CO and relationship to ozone formation

Please visit 4:30 Session: Instrument Team Presenters (GHG) for more info!



Contact: Kevin Cossel, kevin.cossel@nist.gov

Successes and Future Efforts

Examples:

- Estimate whole city CO_2 emissions using measurements and estimation techniques.
  (~3% agreement among methods)
- Measure relative CO_2 emissions drawdown associated with COVID policies (Los Angeles & Baltimore/Washington DC).
- Measured atmospheric impact of decreasing vehicle emissions in (Baltimore/Washington DC).

Examples:

- Improve consistency among urban emissions measurement
- Fossil fuel source partitioning – e.g., ethane & methane isotopes
- Advanced uncertainty analyses on various modelling components
- Improvement in model components that have a large impact on emission estimation

Ex.

Geophysical Research Letters

RESEARCH LETTER

10.1029/2021GL092744

Special Section:
The COVID-19 pandemic: linking health, society and environment

Key Points:

- Atmospheric CO_2 observations can be used to detect the onset of the

The Impact of COVID-19 on CO_2 Emissions in the Los Angeles and Washington DC/Baltimore Metropolitan Areas

Vineet Yadav[1], Subhomoy Ghosh[2,3], Kimberly Mueller[3], Anna Karion[3], Geoffrey Roest[4], Sharon M. Gourdji[3], Israel Lopez-Coto[3], Kevin R. Gurney[4], Nicholas Parazoo[1], Kristal R. Verhulst[1], Jooil Kim[5], Steve Prinzivalli[6], Clayton Fain[6], Thomas Nehrkorn[7], Marikate Mountain[7], Ralph F. Keeling[5], Ray F. Weiss[5], Riley Duren[8], Charles E. Miller[1], and James Whetstone[3]

Estimated decrease in CO_2 emissions due to lockdown and attributed the decline using traffic & fuel sales data.

In this case we were successful in using activity information to isolate and attribute the changes due to the lockdown, by looking at the variability in activity associated with CO_2 emissions.

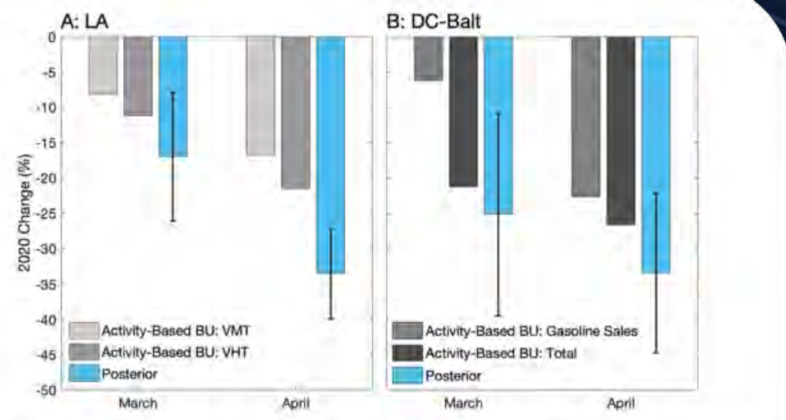


Figure 3. Changes in monthly mean emissions for April and March 2020 relative to 2018/2019 means for (a) LA and (b) DC-Balt. Blue bars represent the decrease estimated from the atmospheric inversion posteriors, with error bars representing the 95% CI. Various shades of gray bars represent the decrease for each month using different activity-based adjusted bottom-up totals, as indicated in the legend and described in the text.

AGES activities may help us "chip" at some challenges we have with GHG quantification methods using atmospheric data

Emissions Variability

- Sampling bias – need to consider spatial and temporal variability at different scales in model framework.
- Can also muddy the interpretation of results if underlying source sector variability is unknown.

Background & Transport Error

- Need to isolate concentration enhancement from domain of interest (e.g., determine background).
- **Transport model error affects results**.
- Can cause biases in results; error in both transport and background is often not random, can be seasonal.

Sectoral Attribution

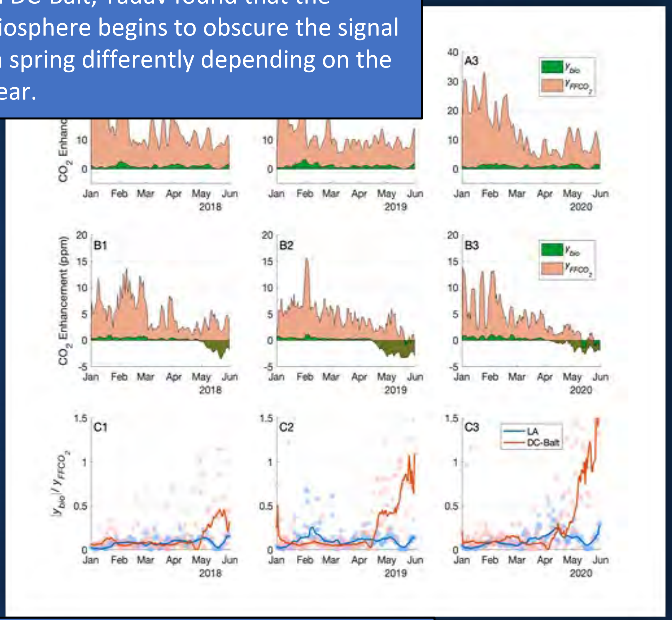
- Depending on goals of project – need to **isolate the sources from different sectors**.
- Could be different fossil sectors or **biogenic vs. fossil vs. "natural" fluxes (for CO_2 or CH_4).**

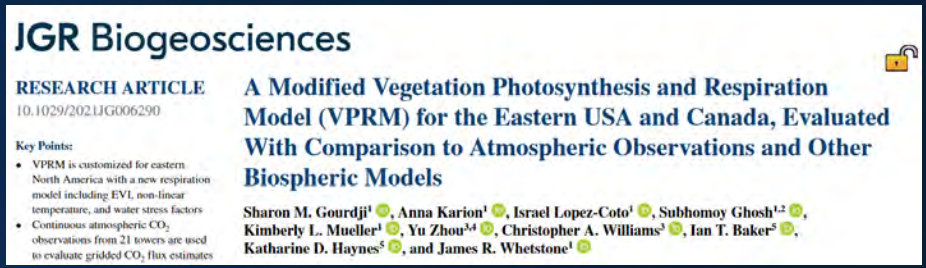
AGES activities may also help us leverage efforts

Emissions Variability

- Biogenic variability at the urban scale

In DC-Balt, Yadav found that the biosphere begins to obscure the signal in spring differently depending on the year.




JGR Biogeosciences

RESEARCH ARTICLE
10.1029/2021JG006290

A Modified Vegetation Photosynthesis and Respiration Model (VPRM) for the Eastern USA and Canada, Evaluated With Comparison to Atmospheric Observations and Other Biospheric Models

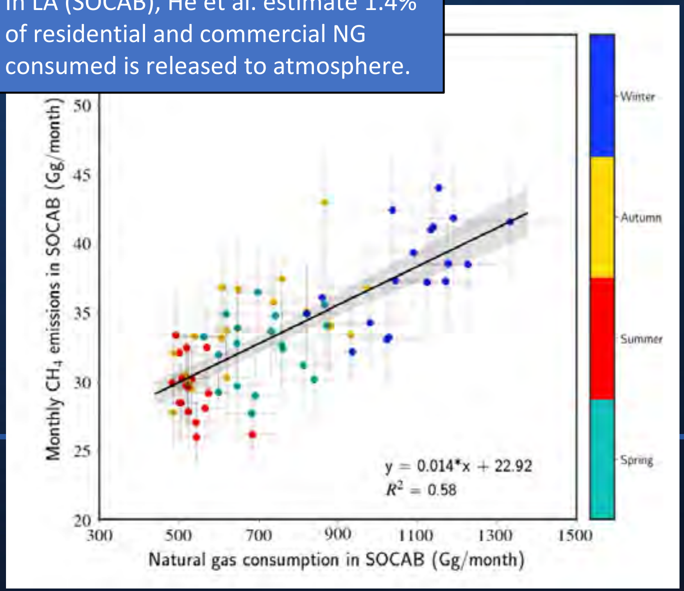
Sharon M. Gourdji[1], Anna Karion[1], Israel Lopez-Coto[1], Subhomoy Ghosh[1,2], Kimberly L. Mueller[1], Yu Zhou[3,4], Christopher A. Williams[3], Ian T. Baker[5], Katharine D. Haynes[5], and James R. Whetstone[1]

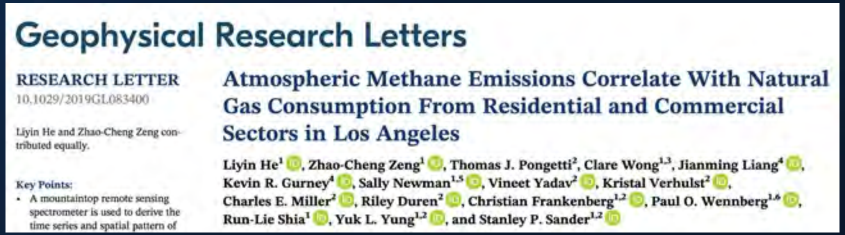
What types of activities planned to investigate urban biosphere?

Sectoral Attribution

- Thermogenic/Biogenic CH_4 partitioning;
- "Post/Pre" meter fugitive NG leaks

In LA (SOCAB), He et al. estimate 1.4% of residential and commercial NG consumed is released to atmosphere.




Geophysical Research Letters

RESEARCH LETTER
10.1029/2019GL083400

Atmospheric Methane Emissions Correlate With Natural Gas Consumption From Residential and Commercial Sectors in Los Angeles

Liyin He[1], Zhao-Cheng Zeng[1], Thomas J. Pongetti[2], Clare Wong[1,3], Jianming Liang[4], Kevin R. Gurney[4], Sally Newman[1,5], Vineet Yadav[2], Kristal Verhulst[2], Charles E. Miller[2], Riley Duren[2], Christian Frankenberg[1,2], Paul O. Wennberg[1,6], Run-Lie Shia[1], Yuk L. Yung[1,2], and Stanley P. Sander[1,2]

What types of activities planned to investigate VOC emissions that may be co-located with CH_4 emissions? Other proxy measurements planned?

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Thank You.

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NIST team: James Whetstone (director), David Allen, Tyler Boyle, Subhomoy Ghosh, Sharon Gourdji, Anna Karion, Israel Lopez-Coto, Hratch Semerjian, Tamae Wong

Please visit 4:30 Session Instrument Team Presenters (GHG)!!!