The NIST Greenhouse Gas Urban Testbed System

A. Karion, S. Ghosh, I. Lopez Coto, K. Mueller, T. Boyle, J. Whetstone
National Institute of Standards and Technology, Gaithersburg, MD
With many academic & private partners

1. NIST Urban Testbeds

The NIST urban testbed program consists of three urban greenhouse gas (GHG) measurement projects designed to develop and test methods for emissions estimation in urban regions: Indianapolis (INFLUX, influx.psu.edu), Los Angeles, (megacities.jpl.nasa.gov), and the Northeast Corridor (NEC). Here we present an overview and plans for the project.

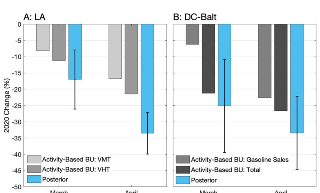
Right: Locations of urban GHG studies (NIST and other)

2. NIST's Urban Tower Networks

- Tower-based observation networks have been established by partners (Penn State, Earth networks, and Scripps Institution of Oceanography) in all three urban testbeds.
- Carbon dioxide (CO_2), methane, and carbon monoxide observations are made continuously using high-precision instruments calibrated to WMO scales.
- Data is made publicly available (at data.nist.gov and datacommons.psu.edu).
- Many tower sites also have equipment to collect whole air samples using NOAA/GML flasks that are measured for many additional gas species, and isotopes including radiocarbon (w/ GNS science).

Yadav et al. estimated decrease in CO_2 emissions due to lockdown, and attributed the decline using traffic & fuel sales data.

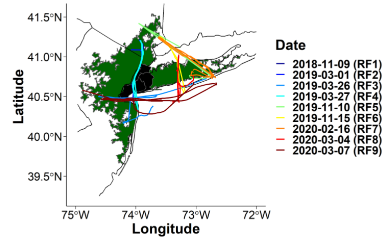
In this case we were successful in using activity information to isolate and attribute the changes due to the lockdown, by looking at the variability in activity associated with CO_2 emissions.



Decrease in CO_2 emissions from LA (left) and Washington/Baltimore (right) determined from atmospheric inversion modeling using tower network data. (Yadav et al., 2021)

3. Airborne sampling

- 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.*

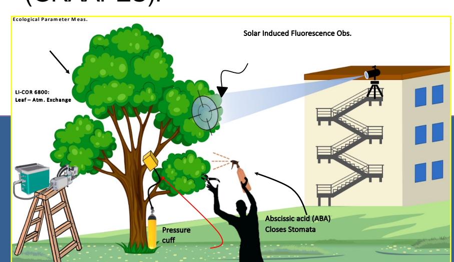


Stonybrook U./Purdue U. flight tracks used for GHG flux estimation. Figure from Hajny et al, 2022.

Refs: Lopez-Coto et al., ES&T (2020, 2022), Pitt et al., Elementa (2021), Ren et al., JGR (2018); Balashov et al., ACP (2019), Hajny et al., Elementa (2022).

4. 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, UMD.
- Planning deployment of low-cost CO_2 & AQ sensors; HALO (wind Lidar system); Mini-MPL for PBL depth.
- 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: GReenhouse gas And Air Pollutant Emissions System (GRAAPES).

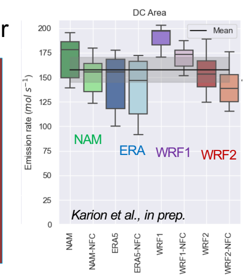


Schematic of SIF testbed (NIST FOREST project), courtesy D. Allen & L. Hutyra

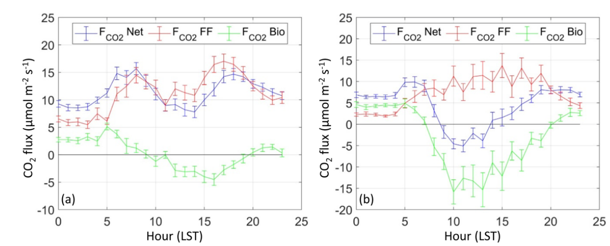
5. Challenges in top-down methods

1. Emissions variability
2. Background and Transport Error

- Top-down estimates of methane emissions in Washington DC (left) and Baltimore, MD (right) using tower observations and 8 different transport model configurations (based on 4 meteorological models) in an atmospheric inversion.
- Box plots contain monthly emissions estimates over 6 months, so variability within each configuration includes temporal variability.
- We can test weather models against observations (of wind speed, PBL, etc) to help better understand these differences.



3. Sectoral attribution
   - Making total emissions estimates relevant to policy makers requires isolating source of emissions and attributing to economic sectors.
   - E.g., biogenic vs. fossil CO_2



$^{14}CO_2$ and CO measurements were recently used to partition total CO_2 fluxes measured by an urban flux tower in Indianapolis (Wu et al., ERL, 2022).

Ethane and methane isotopes have also been used successfully to partition methane emissions from fossil and non-fossil sources.

6. Successes and challenges

- Trend detection
- Anomaly detection
- Whole city emissions
- Weekly / Monthly time scales
- Near-real-time answers
- Sectoral information
- Different platforms have different strengths

- Do we have consistency between methods (including transport)?
- How can we sample to correctly determine mean emissions at different temporal scales?
- What is the uncertainty in our ability to isolate our signal (i.e., relative to background) and in our transport model?
- How to attribute emissions across sectors? (and reduce uncertainty)

https://www.nist.gov/topics/greenhouse-gas-measurements/urban-test-beds

For more information, please contact Anna.Karion@nist.gov.

BIPM/WMO Metrology for Climate Action
26-30 September 2022