Greenhouse Gas Measurements Program

Advancing Greenhouse Gas Emissions (GHG) Measurement Tools and Standards

Partners: Jet Propulsion Lab., Penn State, Purdue Univ., Univ. of Colorado/CIRES, Earth Networks, Stony Brook University, University of Notre Dame, Arizona State Univ., Northern Arizona Univ., NOAA – GMD, Boston Univ., Scripps Inst. of Oceanography (SIO), University of California - San Diego, California Institute of Technology (Caltech), California Air Resources Board (CARB), University of California – Riverside, Southern California AQMD, Univ. of Michigan, Lawrence Berkeley National Lab (LBNL), Univ. of California – Irvine, Atmospheric Environmental Research (AER), Univ. of Maryland, Maryland Department of the Environment (MDE), etc., etc.

& MORE!!

National Institute of Standards and Technology
U.S. Department of Commerce

Kim Mueller, PhD
Greenhouse Gas Measurements Program
National Institute of Standards and Technology

Outline:

- Program overview including description of NIST urban testbeds
- Testbed research & development milestones
- Considerations for translating research & development into standards/services
- Example of service
- Other service considerations
- Need for data, method development (translation into emissions or proxies**) and validation

NIST's Urban GHG Testbed System (urban laboratories)

Goal: develop & demonstrate urban GHG flux measurement methods. Accurate, spatially-specific GHG emissions estimates can inform *science-based decision-making*.

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)

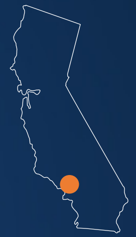
5 public & private actors +

Three urban testbeds 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.

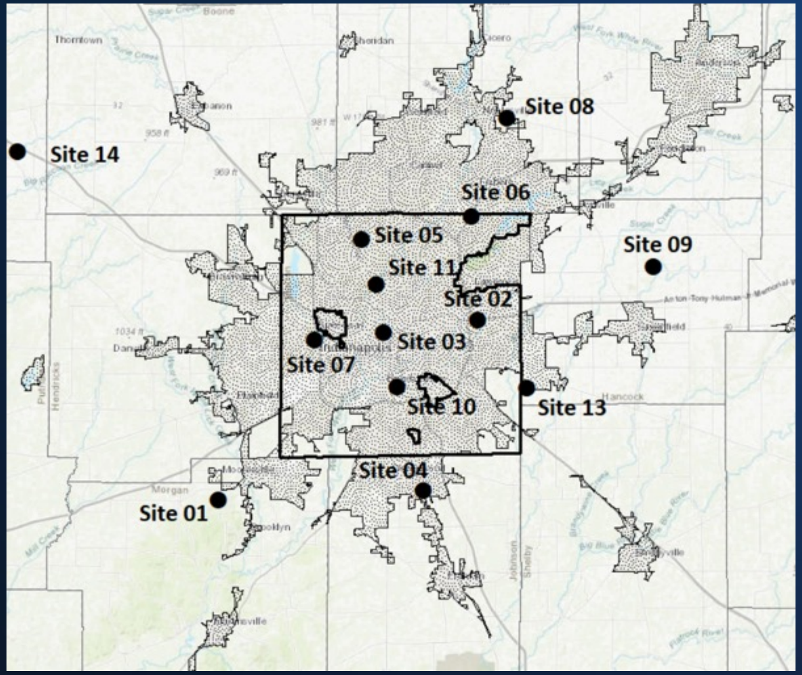
NIST’s Three Urban Testbeds

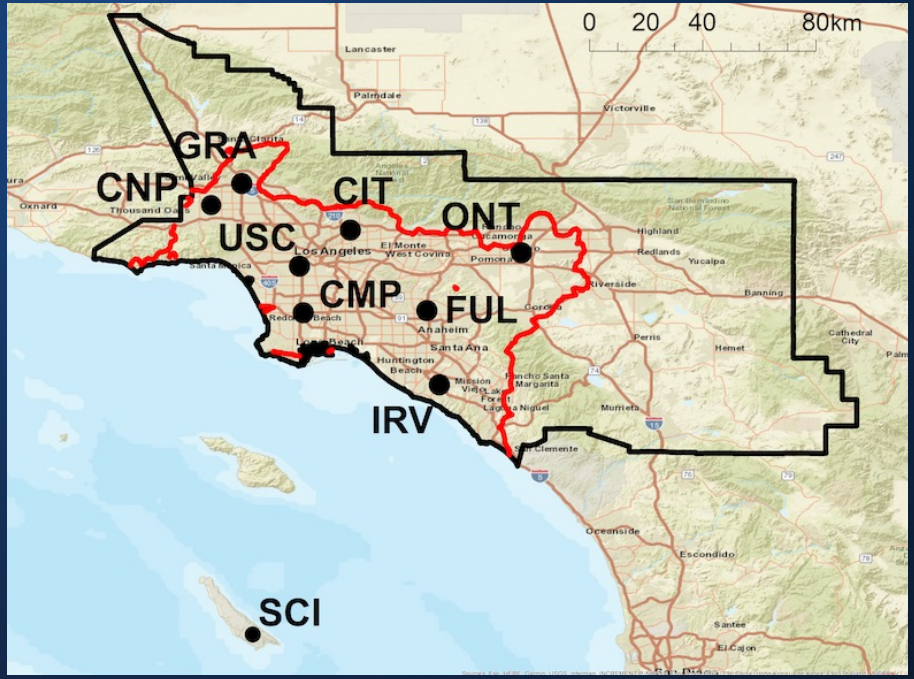
Indianapolis

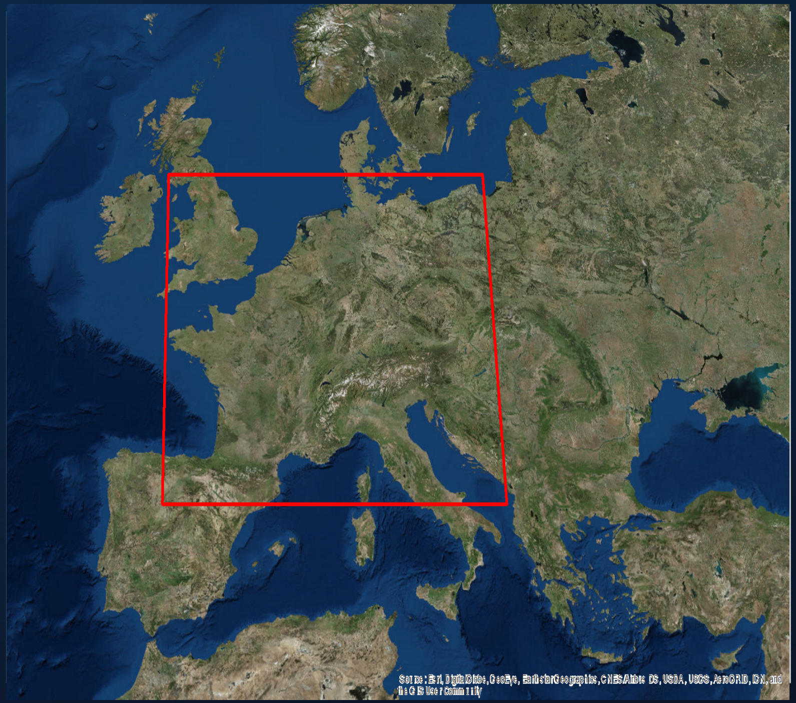
Los Angeles Megacity



Northeast Corridor



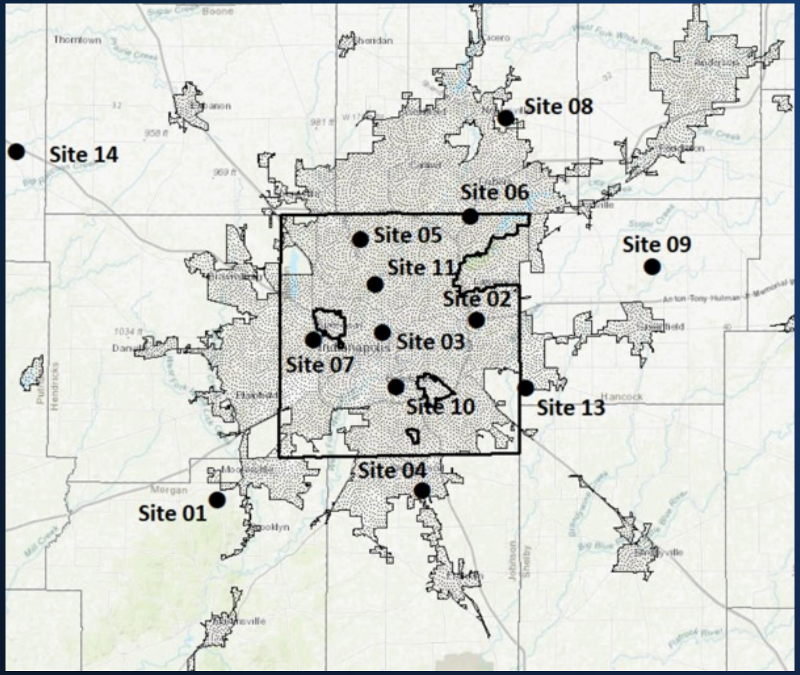




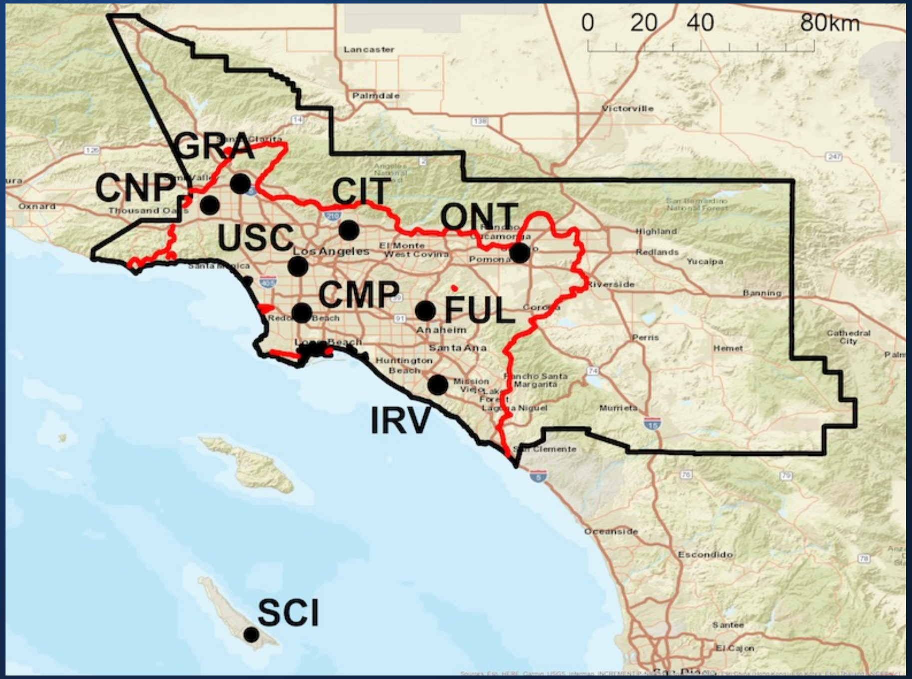
Backbone is a set of in-situ tower networks

NIST's Three Urban Testbeds

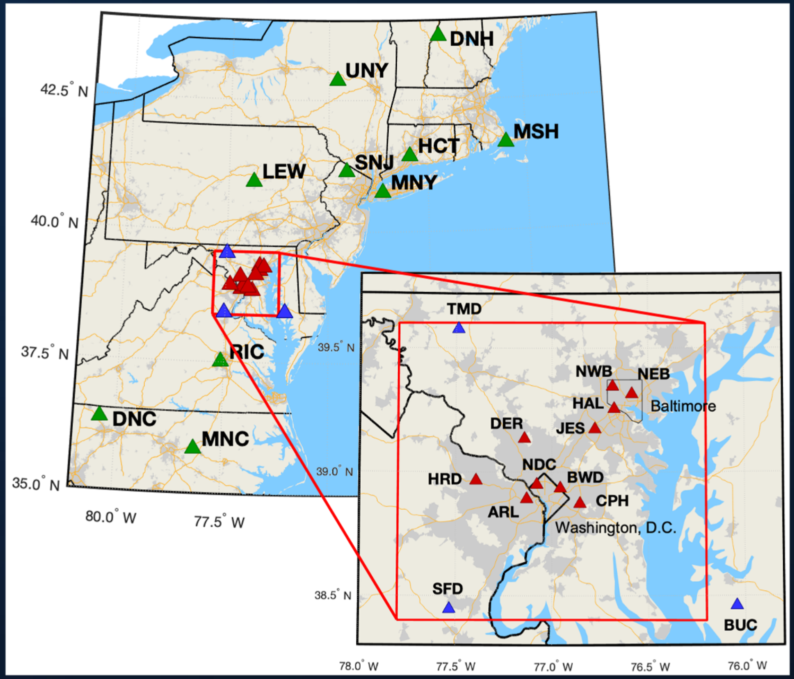
Indianapolis



Los Angeles Megacity



Northeast Corridor



Backbone is a set of in-situ tower networks

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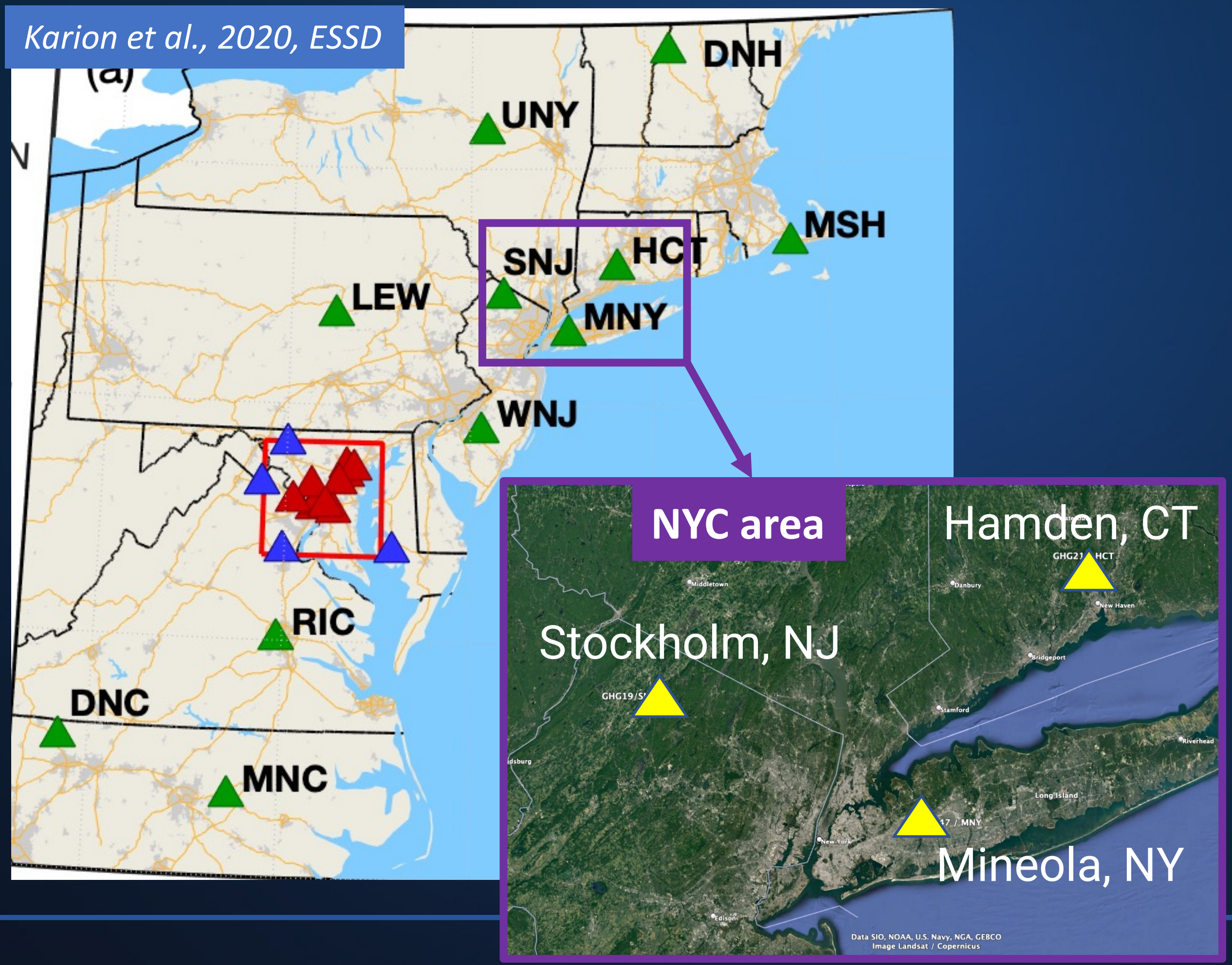
Complementary Observations

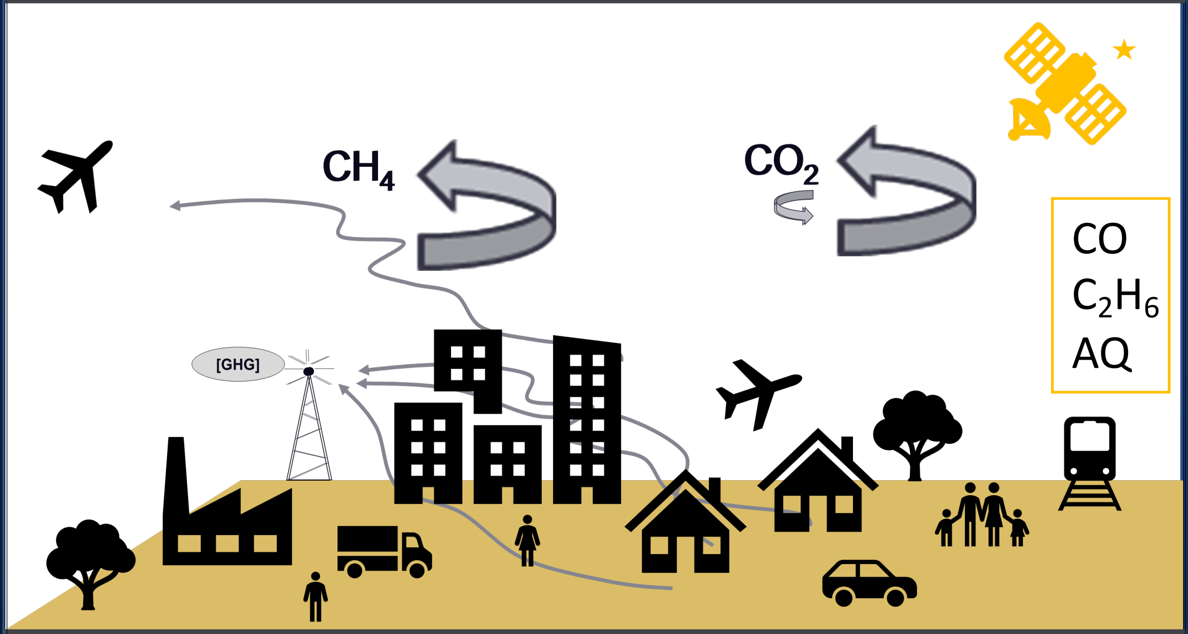
Northeast Corridor



- High-accuracy CO_2 / CH_4 / CO reported on WMO scales (in-situ, aircraft, mobile - planned)
- Integration with other tower networks (NOAA, PSU, Environment Canada, Harvard/Boston, other partners)
- Include regional non-urban sites to characterize background (inflow) conditions
- NOAA/GML flasks for $^{14}CO_2$ & other gases at 5 sites
- Stack flow measurements improvement for improving powerplant CEMS emissions (demonstration ongoing collab with EPRI)
- Airborne turbulence measurements (Stonybrook U.) and high-resolution tracer modeling around powerplants using WRF-LES.
- Planned landfill emissions monitoring activity in Maryland, collaborating with EPA, MDE, UMD.
- Planned deployment of low-cost CO_2 & AQ sensors.
- SIF-Biosphere testbed (FOREST project) on NIST campus in Maryland, collab. w/ BU, Bowdoin & others.

Measurement Methods for GHG Emission Quantification

Atmospheric Information



Assumed Emissions Information

Estimated Urban Emissions

★ 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

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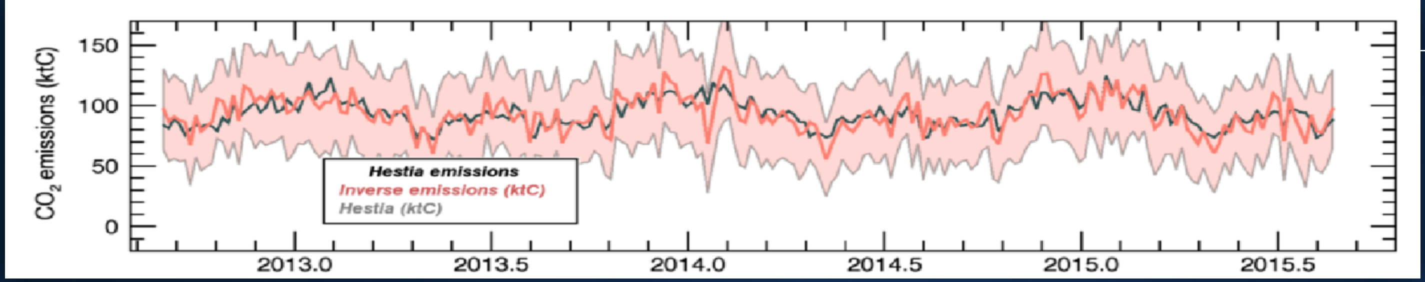
Whole City CO_2 Emissions: Annual/sub-annual

Indianapolis

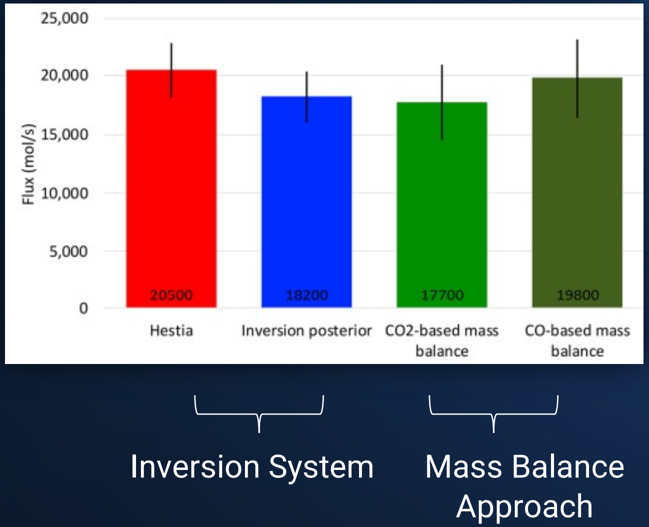


T. Lauvaux, ES&T, 2020

Convergence between "best" emission information and inversion system estimates:
Corrected intentional offset of "best" emissions information by +15% and system corrected by -14.2%.

Lessons Learned:
3% to 5% changes over 1 to 3 years can be quantified using inversion system approach

Challenges:
Important to assess incoming airflow
Assessing sectoral emissions requires further constraint



J. Turnbull, ES&T, 2019

Agreement among different methods:
±7% agreement on whole city emissions
Previous estimates – 30% to 50% differences

Lessons Learned:
Mass balance may be viable (less expensive) approaches to ascertain whole-city emissions

Challenges:
Mass-Balance provides only snap-shot
Important to assess "footprint" of the aircraft obs.

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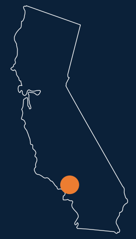
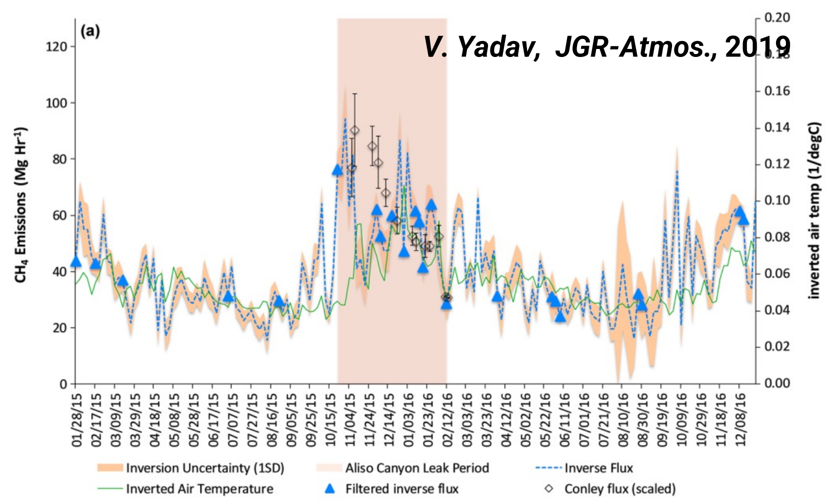
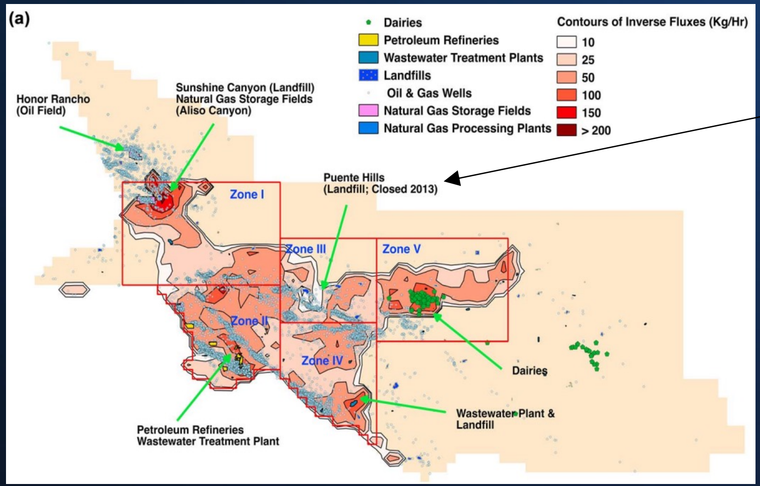
Whole/sub-city CH_4 Emissions: Annual/sub-annual

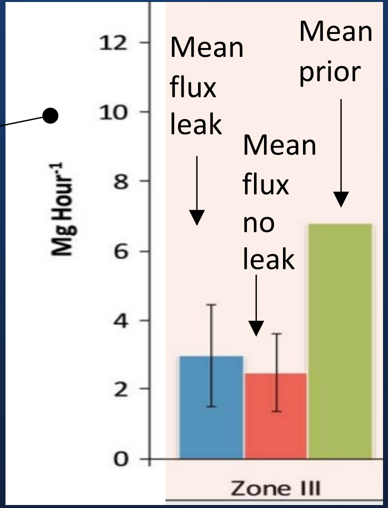
Los Angeles Megacity





Estimates reflect anomalies and seasonal demand for natural gas:
Detect CH_4 emissions changes due to Aliso Canyon NG leak and closure of Puente Hills landfill using in-situ observations from urban network in traditional Bayesian inversion



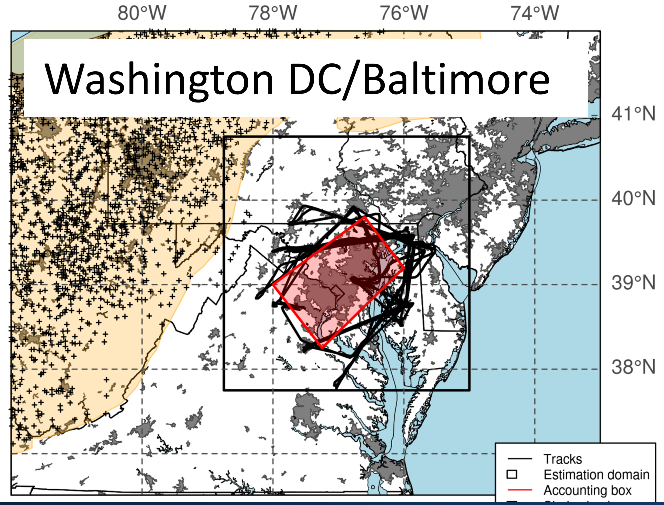


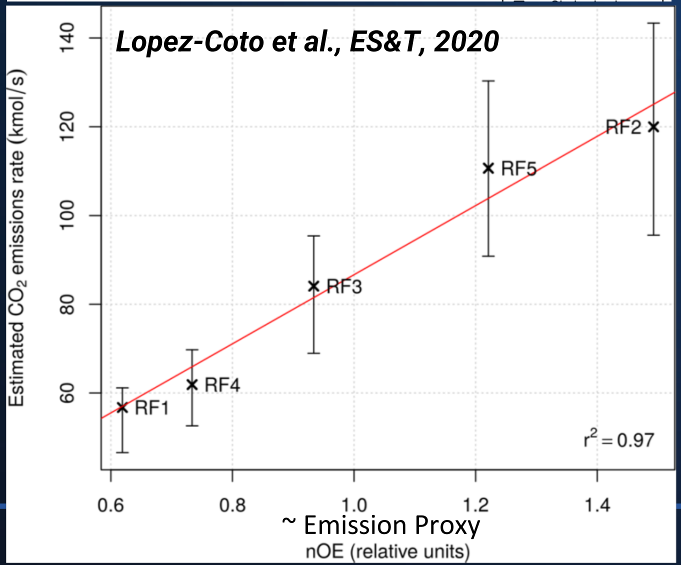
Lessons Learned:
Detect CH_4 emissions due to Aliso Canyon NG leak and Puente Hills landfill
Can assess areas and times that are best constrained by observations to help interpret emission estimates

Challenges:
Attribution of seasonal fluctuations to “leaks” or “behind the meter” requires more data or targeted observational studies
Need additional metrics to assess the sensitivity of estimates to inversion

Whole-city CO_2 & CO Emissions: Inter-annual/annual

Northeast Corridor

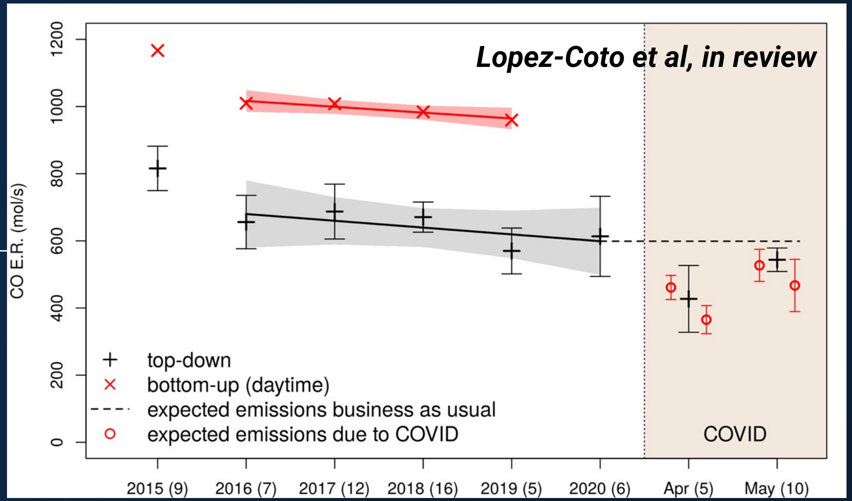




Estimates yield variability consistent with an emission proxy:
Time/location-specific activity data (powerplant emissions and traffic counts) along with met/disp. explained variability of CO_2 daily estimates

Lessons Learned:
Powerplant and vehicular emissions (e.g., during rush hours) are a large source of daily variability

Challenges:
Understanding how the variability of the emissions sources effects the mean results
Knowing where/when to sampling variable sources

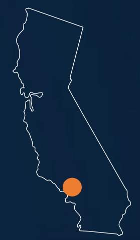


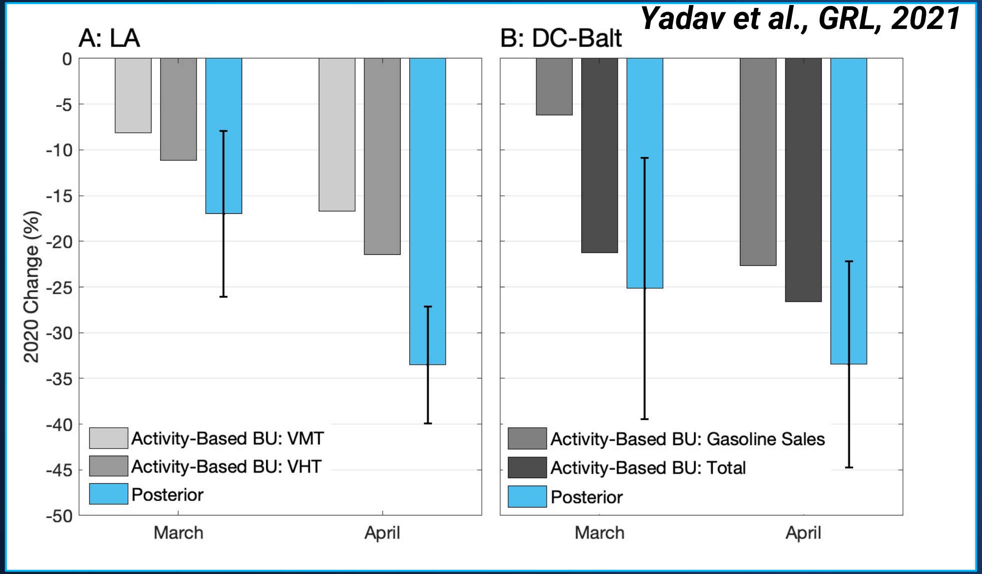
Aircraft campaigns can quantify trends and detect anomalies:
~70 aircraft campaigns over 6 years using a Bayesian inversion detected decreasing CO trends and drops in emissions during behavioral shifts per COVID-19

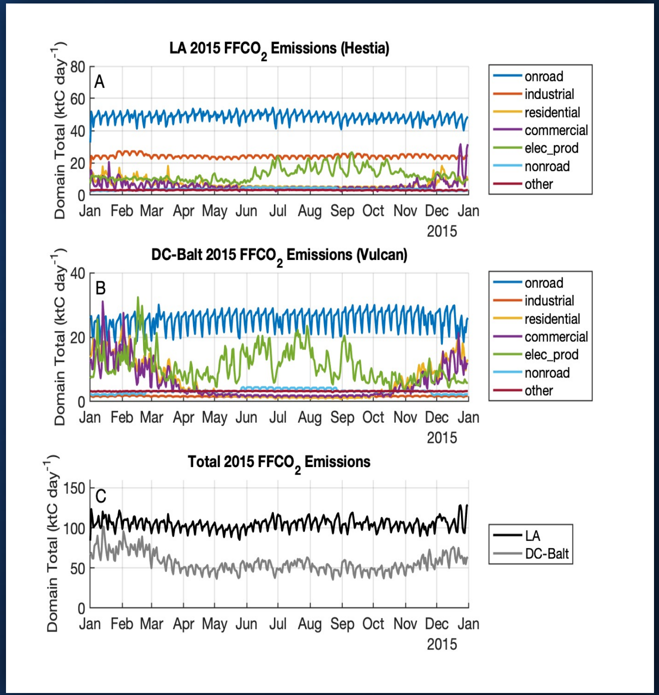
Lessons Learned:
Improvements in car efficiencies can be observed using atmospheric measurements

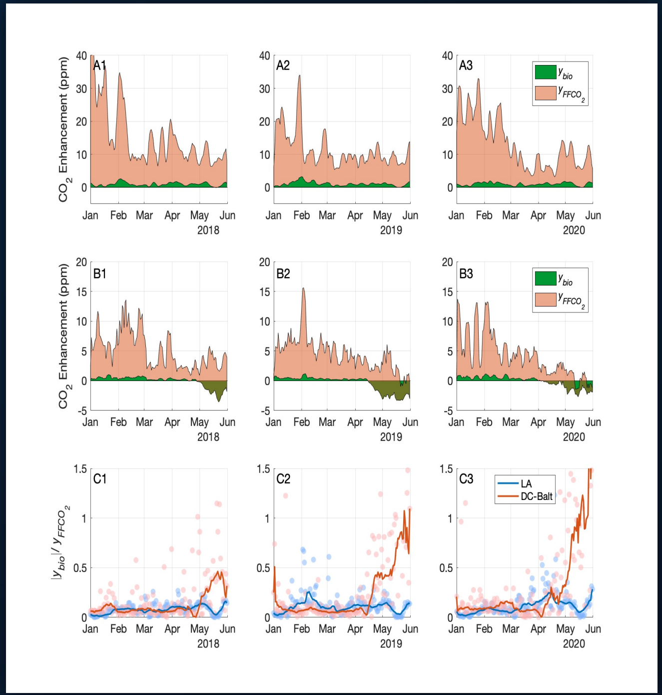
Challenges:
GHGs like CH_4 (unknown proxies) or CO_2 (growing season) are more difficult

Multi-City CO_2 Whole-city: Sub-annual

Los Angeles Megacity  **+** **Northeast Corridor** 







↓

Urban in-situ networks estimate similar relative reductions in 2 different metropolitan areas associated with COVID-19:
LA: Mar 17% +/- 9%; Apr 34% +/- 6%
Baltimore-Washington DC: Mar 25% +/- 14%; Apr 33% +/- 11%

Lessons Learned:
Understanding emission sub-annual variability key for interpreting relative reduction.

Challenges:
Properly representing biosphere during “spring-out” and incoming air important for anomaly detection in places like Baltimore-Washington DC. City-level data may not be available

Lessons Learned: NIST’s Urban GHG Testbed System

- Accounting/understanding variability matters!
  - Need observations and activity data that reflect underlying emission variability or can bias results
- Representation matters!
  - Use footprint type methods to ensure that sampling strategy addresses objective
- Incoming airflow (aka the background/inflow problem) can be a serious issue!
- Essential to model biogenic emissions at fine spatial and temporal scales!
- Still have work to do for sectoral attribution!

Need to understand “lessons learned” to translate measurements and measurement methods into science-based information for decision-making (aka *services*)

NIST Mission: promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life

Research & Development
Methods
Measurements
Standards
Etc.

Framework
Voluntary
Regulatory
Connected to other frameworks

Relevance (Services/Science-based information)
City-stakeholders
Etc.

Voluntary City-pledges/Mitigation Planning & Evaluation

Allocating emissions by type/sector using common protocol (e.g., GPC)

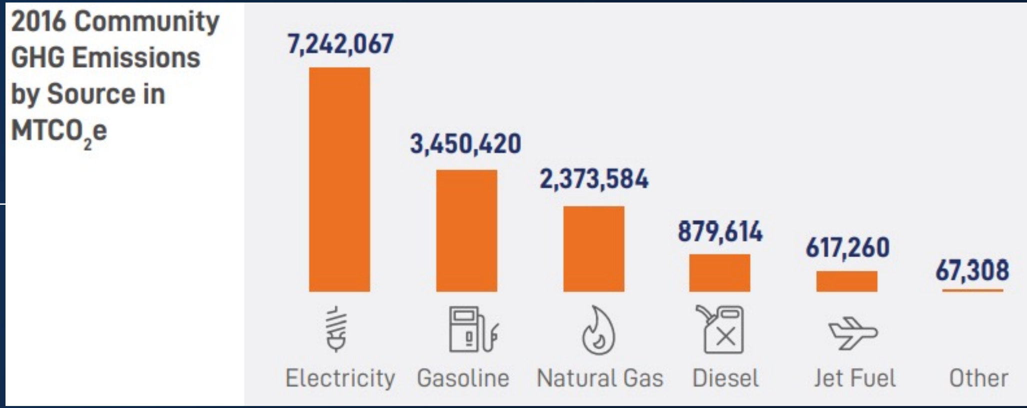
Scope 1
(Direct/Production-based)
- Facilities
- In-boundary transportation
- Onsite landfills
- Other

Scope 2
- Purchased Electricity
- Purchased Heating
- Purchased Cooling

Scope 3
(Indirect/Consumption-based)
- Out-of-boundary transportation
- Waste

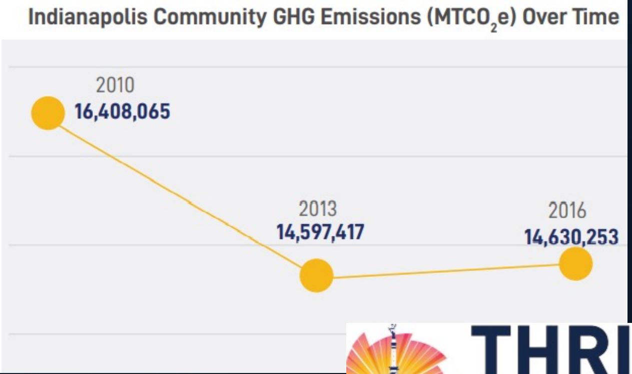
Not necessarily independent

Climate action plan (CAP, *Thrive 2019*)



Pledge – Indianapolis aims to reduce emissions to net zero by 2050 (*Thrive 2019*)

Estimate progress and update plans

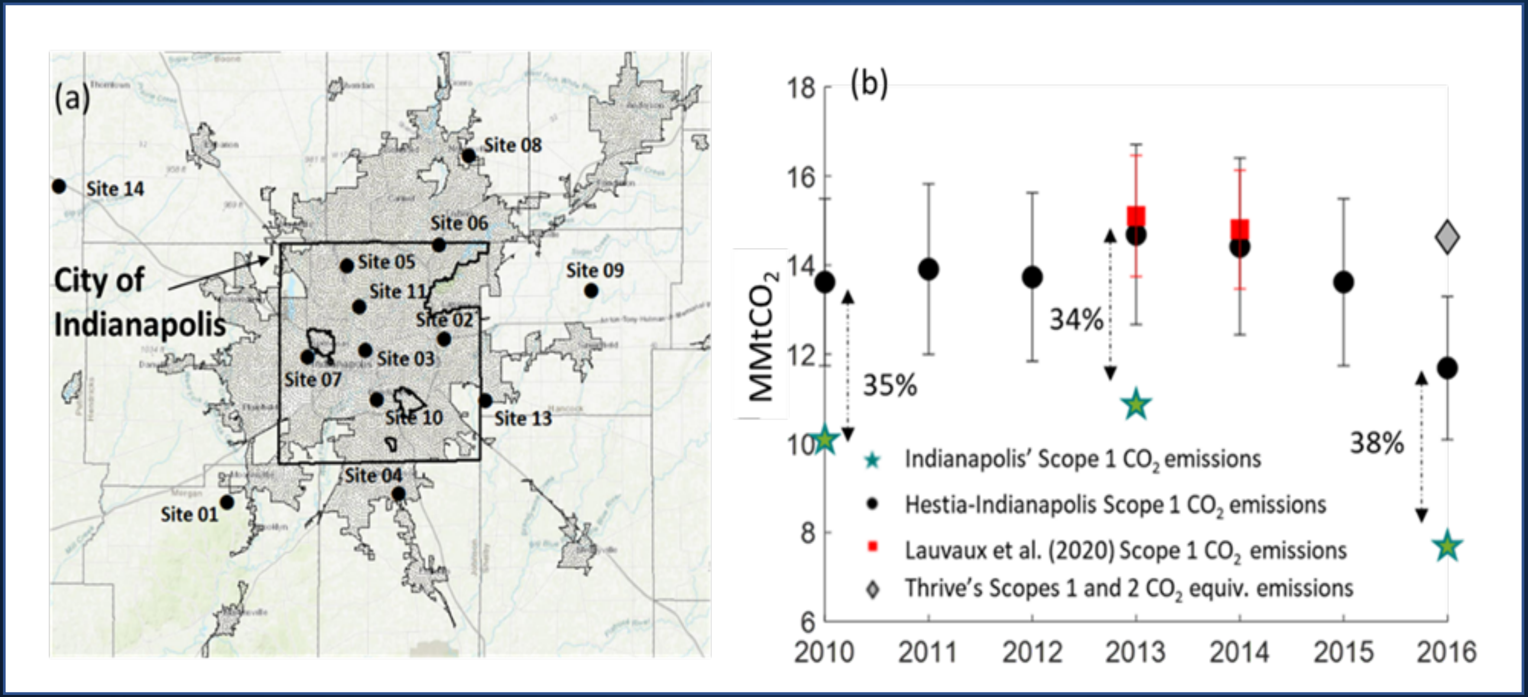


THRIVE INDIANAPOLIS
Annual Report 2020

National Institute of Standards and Technology
U.S. Department of Commerce

Whole City CO_2 Emissions: Annual/sub-annual Revisited …

Indianapolis

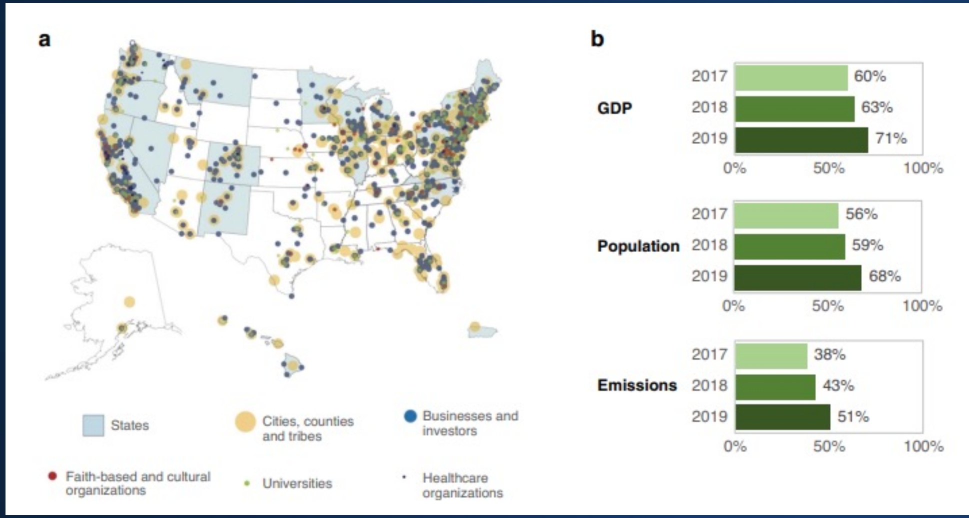


K. Mueller, ERL, 2021

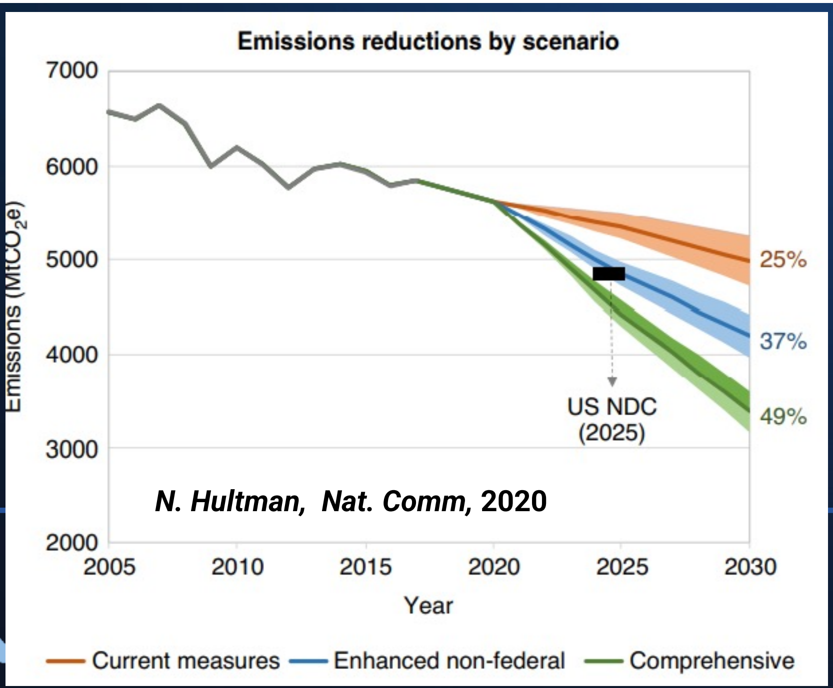
- Isolated Scope 1 CO_2 emissions from Indianapolis' GHG inventory (non-negligible)
- We scooped out the emissions for the City of Indianapolis from the inversion system and compared to the Hestia emission product – ascertain agreement (~3%)
- Compare city's reported estimates

- City reports Scope 1 emissions that are ~35% lower than both the inversion and Hestia
- Trends ok but overall difference make a difference if goal is net-zero
- Lots of assumptions, lack of transparency, value choices

Sub-national Mitigation Planning & Evaluation



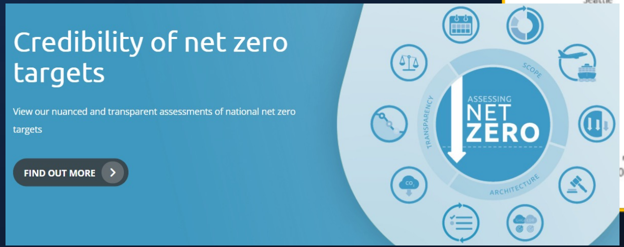
The group of U.S. coalitions of non-federal actors making commitments to climate goals is large, growing, and globally significant

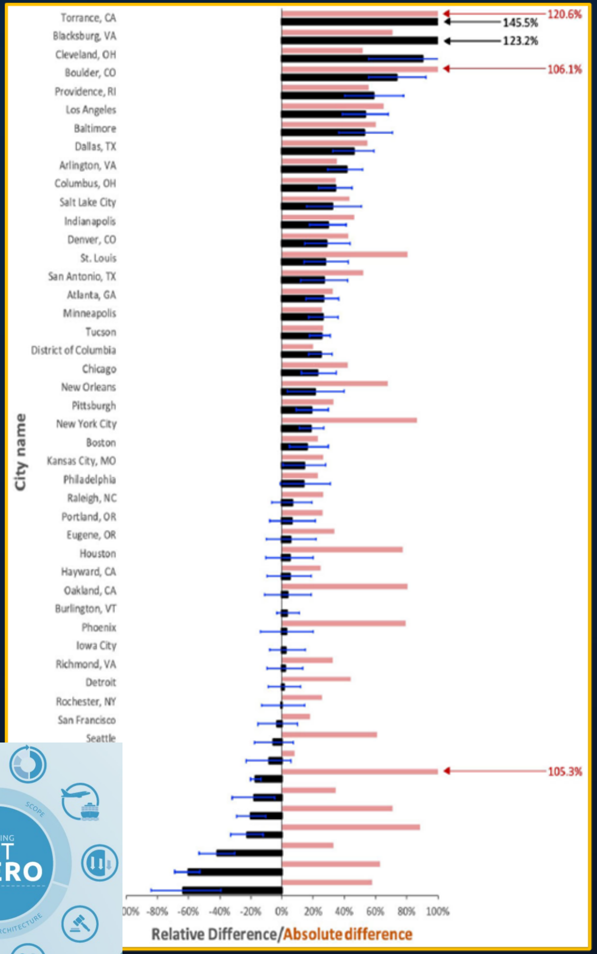


N. Hultman, Nat. Comm, 2020

Rapidly expanded bottom-up action could reduce U.S. emissions significantly

Climate Action Tracker





K. Gurney, Nat. Comm., 2021

Unclear if action is really happening → very ambitious reduction goals (aka net-zero 2050)

U.S. Policy Levers and the aggregate …

Buildings Federal, State, City	Appliances
	Energy Efficiency → (ex. city building; building ordinances)
	Building Retrofits
	Inspections (targeted list) → (city inspectors)
	Demolition → (cities)
	Zoning
Transportation Federal, States, Cities	Mandates/Standards
	EV incentives
	Light Duty Vehicle phaseout (incentives)
	Improve technology
	Zoning for EV charging stations
	Establish multi-modes of travel
Landuse Federal, State, City	Establish green spaces (zoning)
	Plant trees
	Composting
	Parks/designated places (via Zoning)

Other:
Purchasing (ex. electricity or goods and services)
City Tax

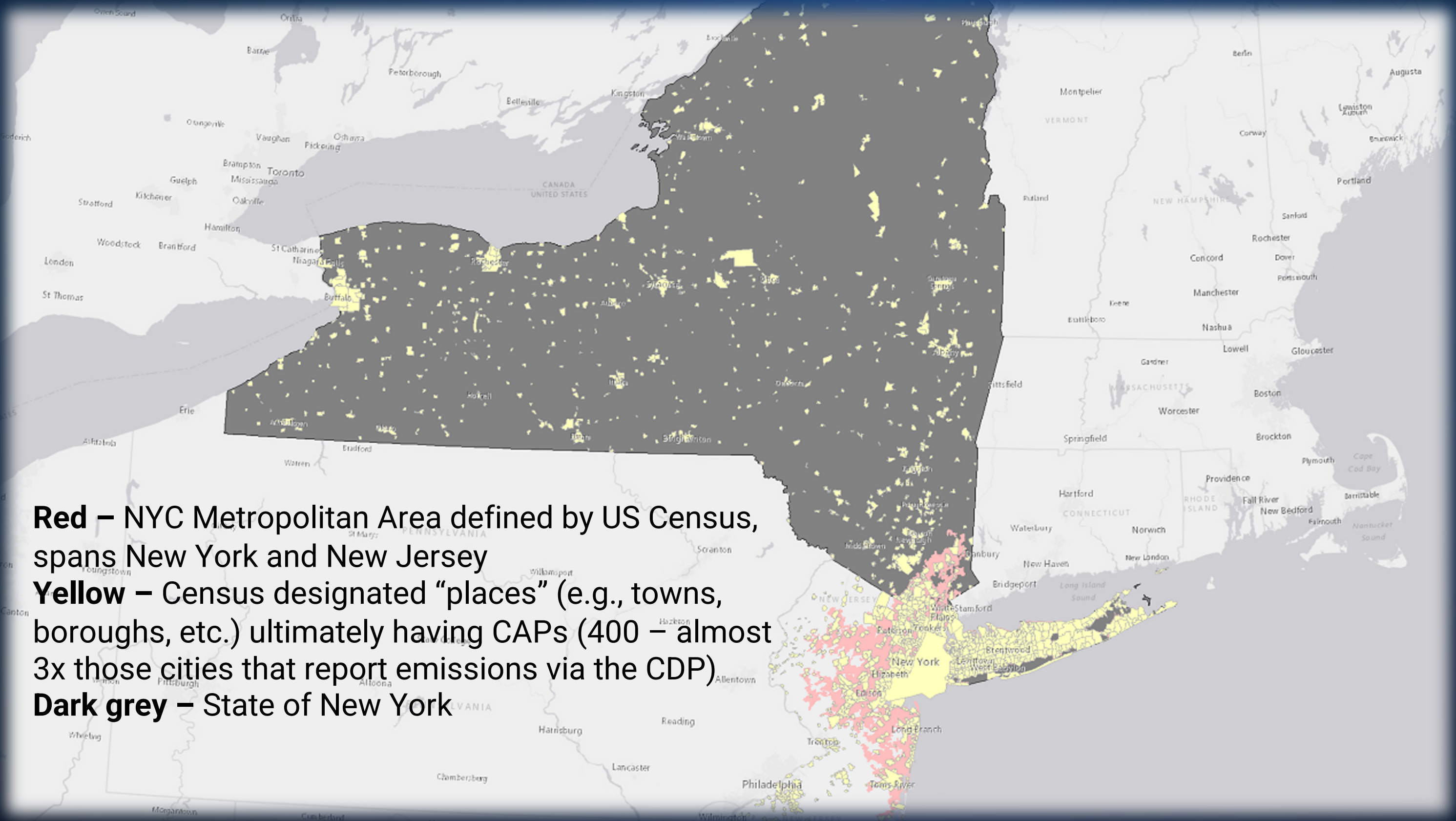
Soft Policy Levers:
Climate leadership
Socialization of climate problem

*policy plans don't map to how cities report emissions

Policy Levers and the aggregate (multiple frameworks)

Neighborhood → City → State → Region → Federal → International

Business



Red – NYC Metropolitan Area defined by US Census, spans New York and New Jersey
Yellow – Census designated "places" (e.g., towns, boroughs, etc.) ultimately having CAPs (400 – almost 3x those cities that report emissions via the CDP)
Dark grey – State of New York

Cities' Other Important Role: Influencers (incentivizes actions) whose policies are eventually stitched into overarching federal and state action. Actions are further amplified when coordinated with business community.

Multiple Frameworks

Voluntary/Regulatory
(Reporting Emissions for jurisdictions)

Financial
(Green Financing/Reporting)

Standards Bodies and International Initiatives
(BIPM/WMO-IG3IS)

Complementary Regulatory Schemes
(Air Quality)

Private Sector

MORE!

NIST Mission: promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life

Data, Method Development & Validation (like testbed type systems)

Research & Development
Methods
Measurements
Etc.

Framework
Voluntary
Regulatory
Connected to other frameworks

Relevance (Services/Standards)
City-stakeholders
Etc.

Role of Satellites: Fine spatio-temporal information

Methane Watch

https://www.kayrros.com/methane-watch/

Glasgow Climate Pact: Focus on Sectors

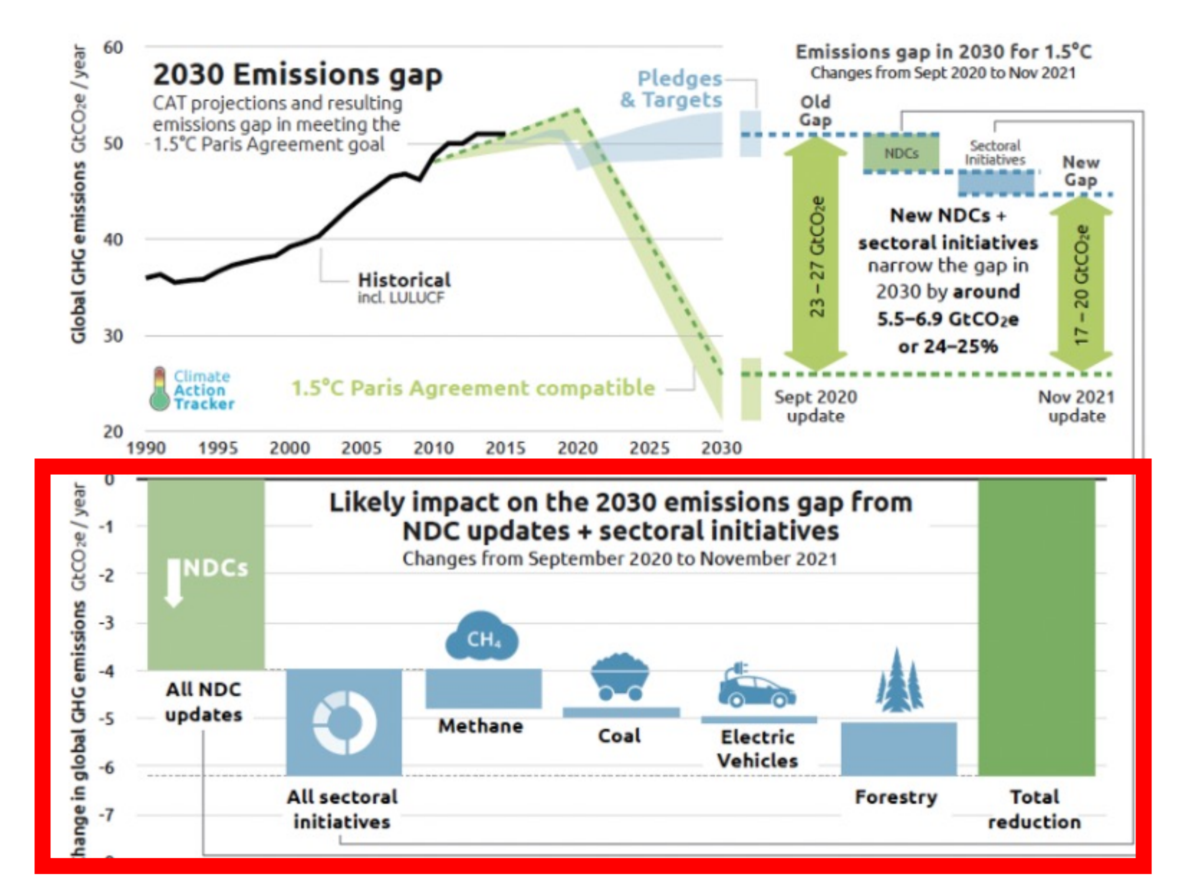


Figure 1 Potential of sectoral initiatives (methane, deforestation, coal exit, electric mobility) announced at COP26 to close the 2030 emissions gap in addition to new Glasgow NDC updates. Note: The likely emission reduction impact of updated NDCs ranges from 3.3 to 4.7 $GtCO_2e$ (15-17% of the 2030 emissions gap), displayed as the average of 4 $GtCO_2e$ above.

Climate Action Tracker

- Tools/measurements we are developing are applicable for evaluating progress for these initiatives
- Many sector initiatives will significantly alter city/state emissions and require spatial/temporally resolved emissions information
- Need more sector information at these scales

Our Challenge:

- Estimate and map emissions beyond Scope 1 → along business chains or through life cycles
- May require partnering with other experts either academic/government/private sector

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U.S. Department of Commerce

Some Collaborators ….

INFLUX

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Stony Brook/Purdue

Ken Davis
Penn State University

Thomas Lauvaux
LSCE and
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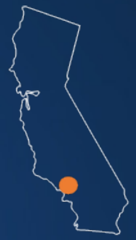
Jocelyn Turnbull
CU/NOAA/GNS

LA Megacity



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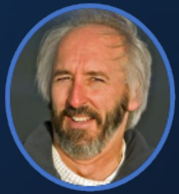
University of Maryland



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Thank You.

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