

CO₂-Urban Synthesis and Analysis (CO₂-USA) Project & Report from Initial Workshop

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NIST, November 6th~7th, 2017

Motivation



NASA Earth Observatory/NOAA NGDC

- **Urban areas are responsible for significant quantities of carbon emissions**
- **Increased population residing in cities**
- **Understanding *how much, where, and why* a particular city emits carbon remain scientific goals**
- **Cities have emerged as leading players in reducing greenhouse gas emissions**

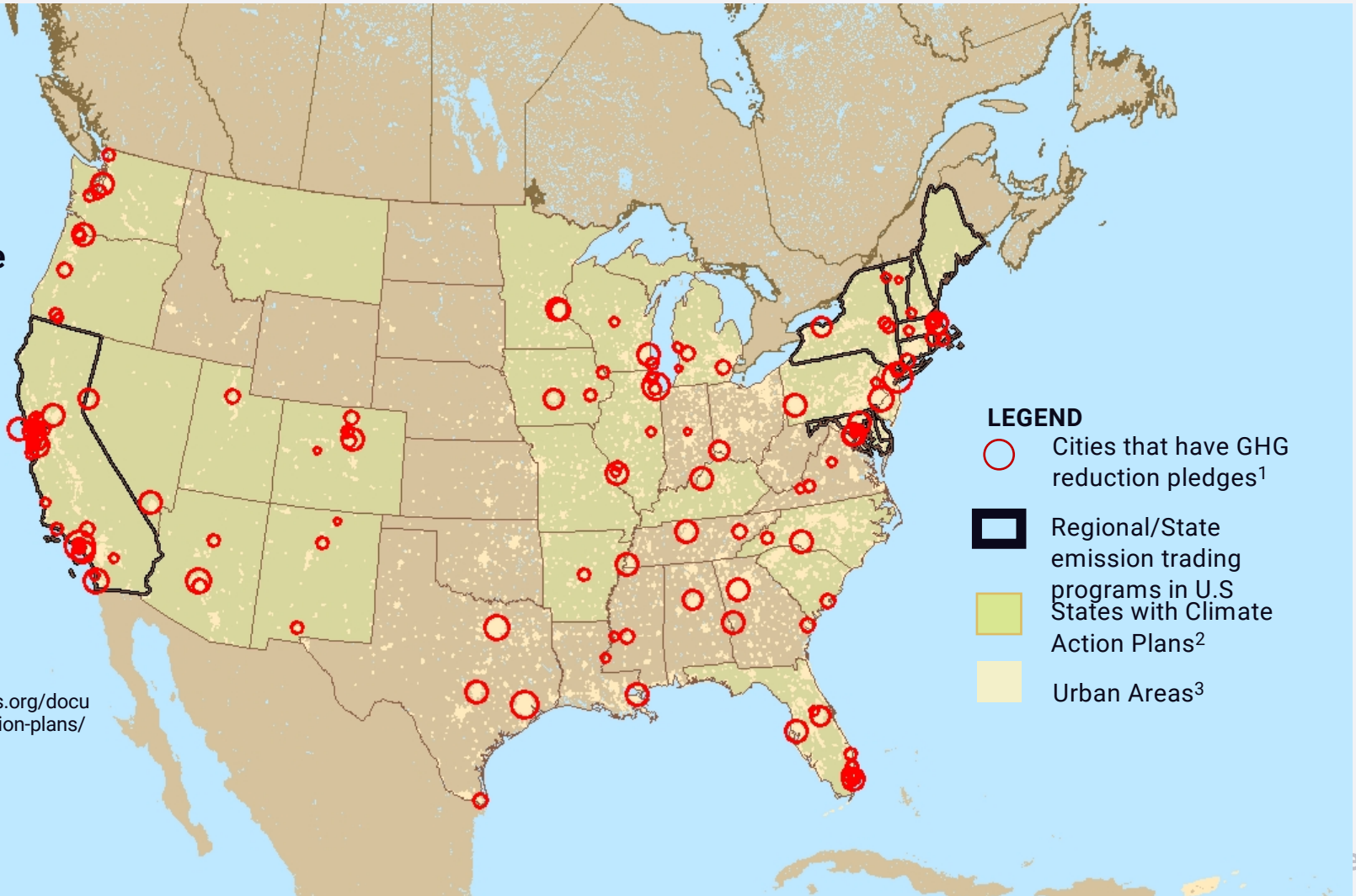
“Demand” for Localized GHG Emission Information ex. GHG mitigation policies/pledges

49% of the 300 most populated cities in CONUS have emission reduction targets

¹NAZCA (2017)

²<https://www.c2es.org/document/climate-action-plans/>

³US Census 2013



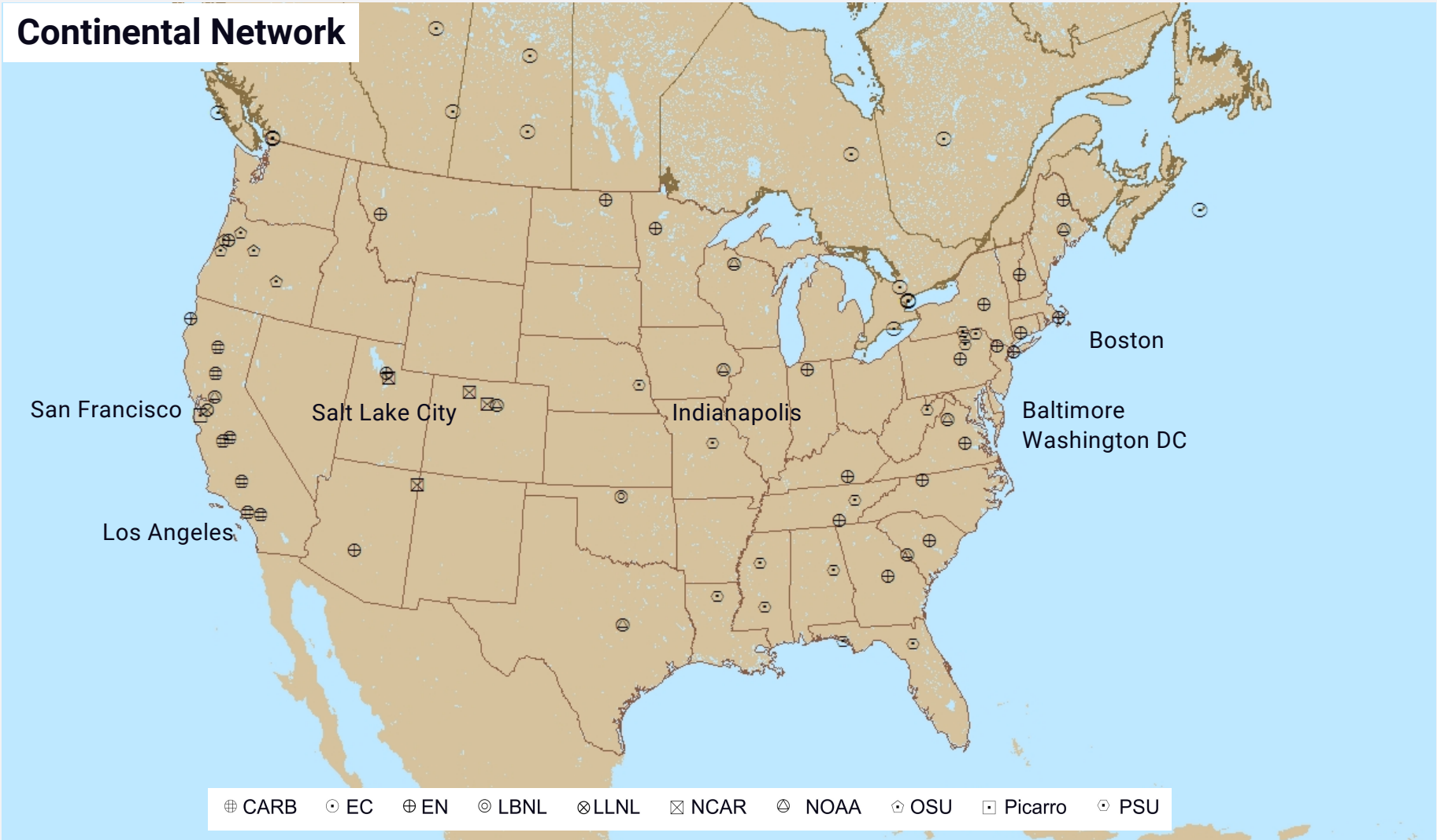
(from Kim Mueller)

Data Expansion

ex. in-situ obs. for top-down models



Continental Network



(from Kim Mueller)

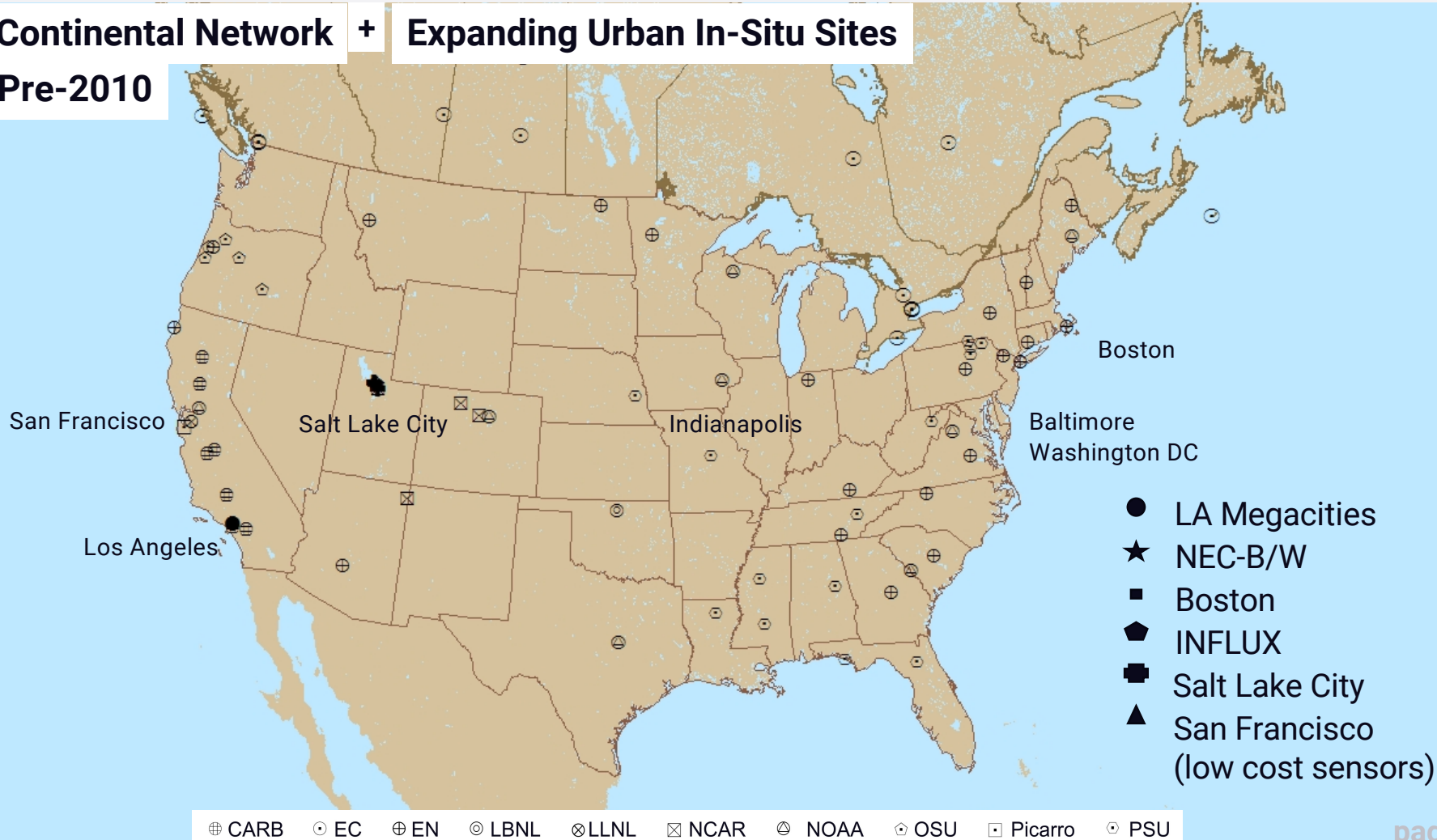
Data Expansion

ex. in-situ obs. for top-down models



Continental Network + Expanding Urban In-Situ Sites

Pre-2010



(from Kim Mueller)

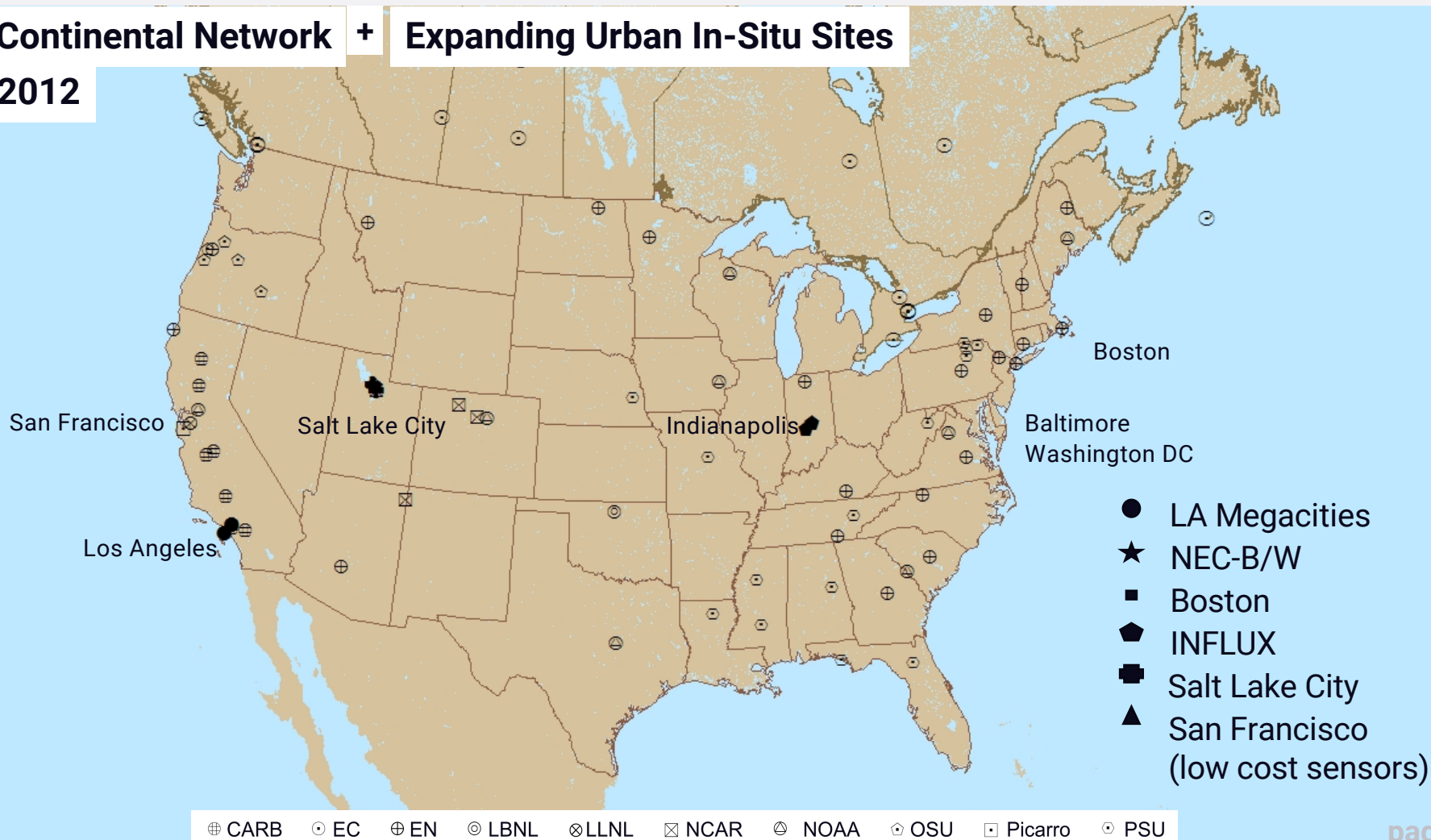
Data Expansion

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Continental Network + Expanding Urban In-Situ Sites

2012



(from Kim Mueller)

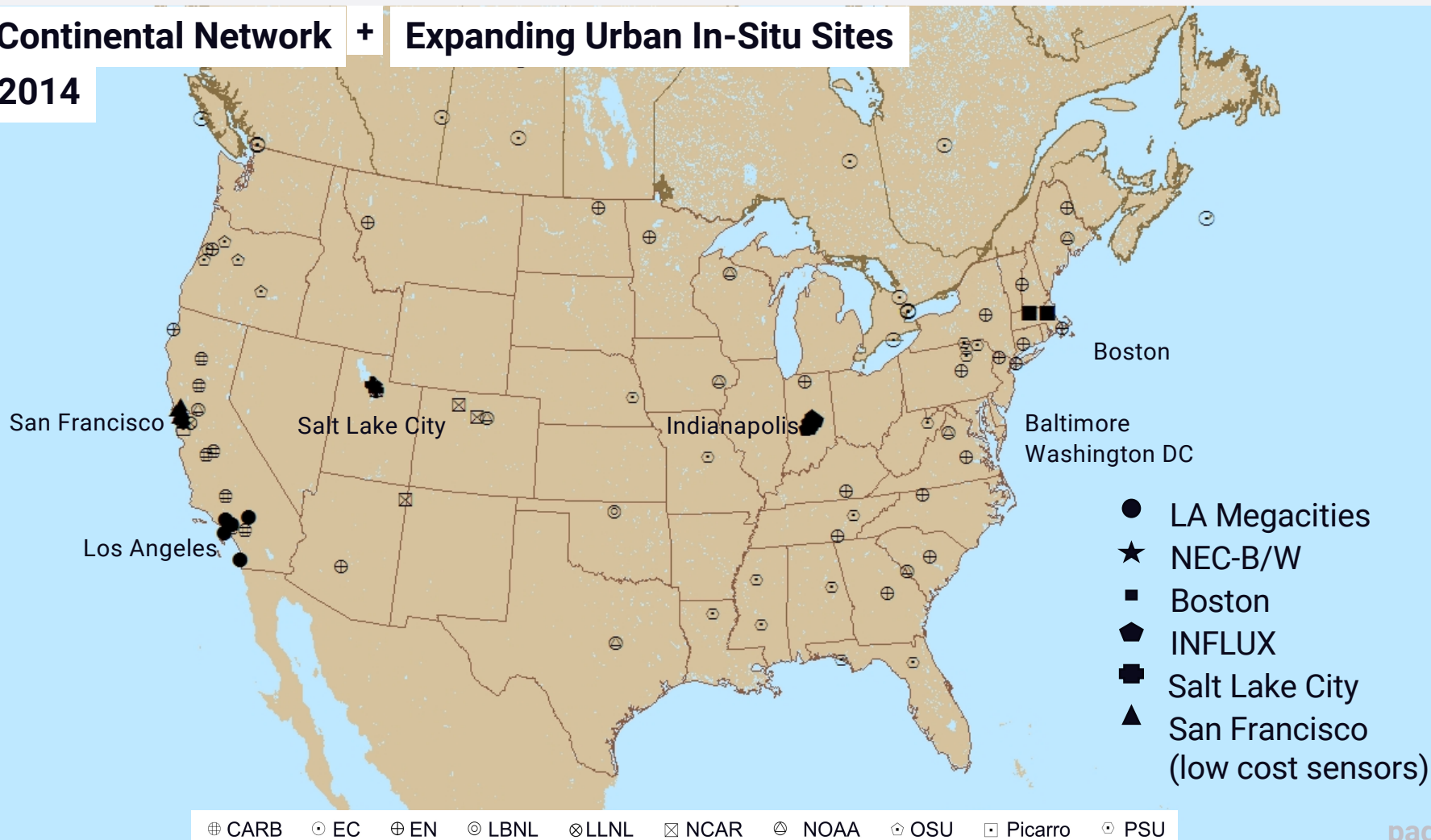
Data Expansion

ex. in-situ obs. for top-down models



Continental Network + Expanding Urban In-Situ Sites

2014



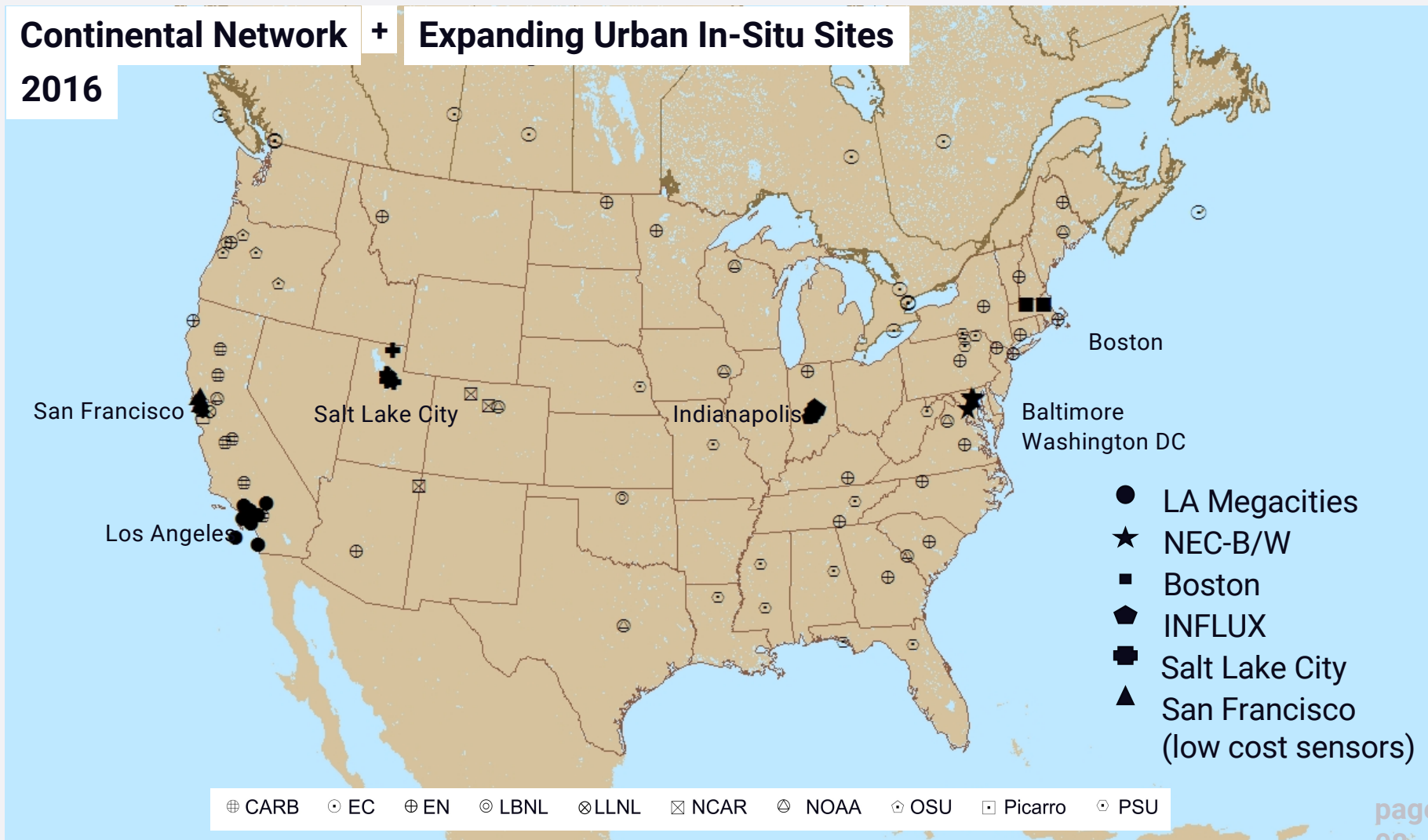
(from Kim Mueller)

Data Expansion

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Continental Network + Expanding Urban In-Situ Sites

2016



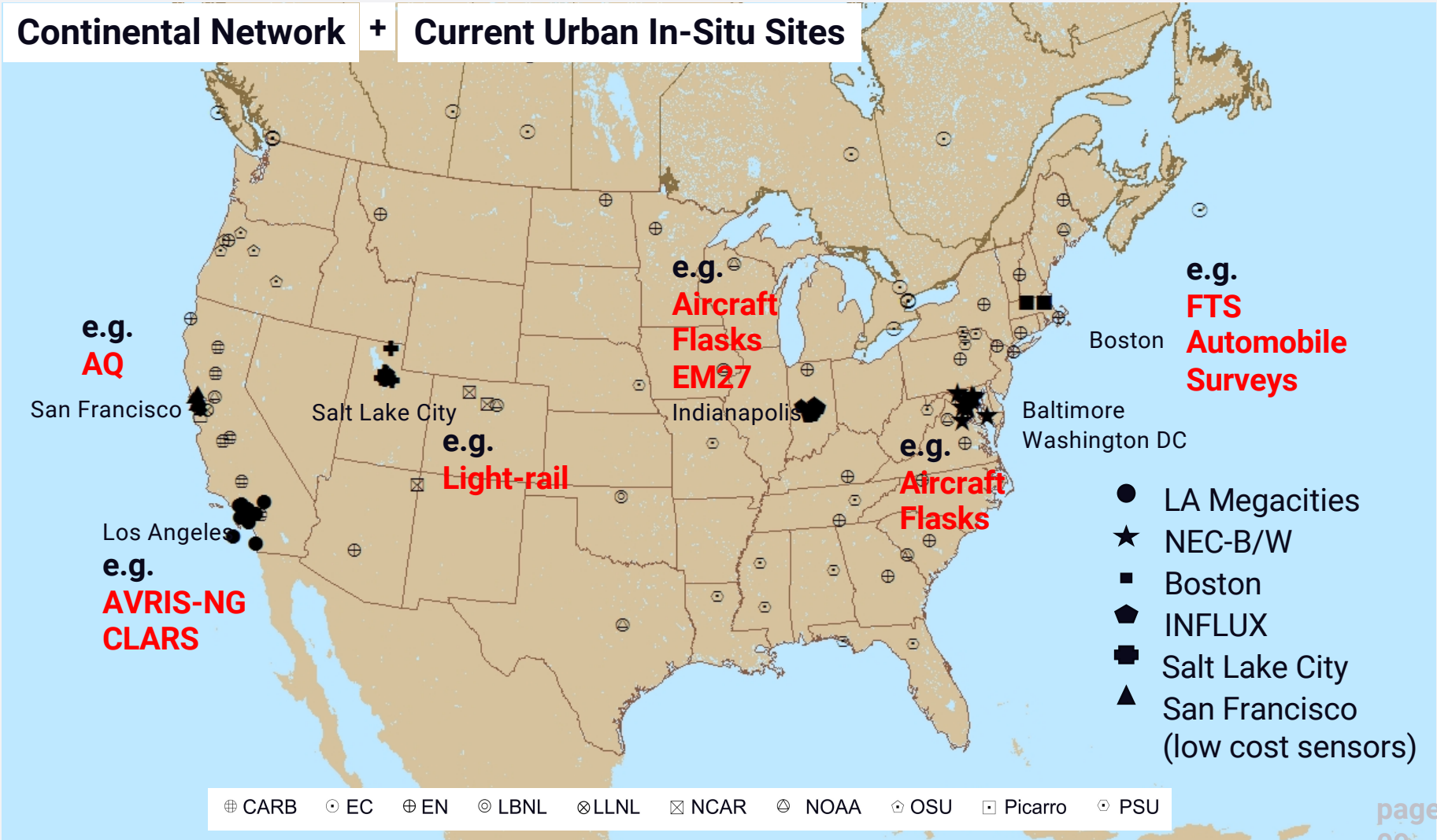
(from Kim Mueller)

Data Expansion

ex. in-situ obs. for top-down models

Many other measurements!

Continental Network + Current Urban In-Situ Sites



(from Kim Mueller)

Assets in Different Cities

		Boston	Indianapolis	Los Angeles	Salt Lake City	San Francisco	Washington DC/Baltimore
GHG Observations	In-situ mixing ratio	~10 sites (CO ₂ , CH ₄ , CO) since 2012*	12 sites (CO ₂ , CH ₄ , CO) since 2012	14 sites (CO ₂ , CH ₄ , CO, N ₂ O) first one in 2012; 2 planned	9 sites (first one established in 2001)	50 low cost sensor sites (CO ₂ , CO, NO, NO ₂ , O ₃ , PM10)	9 sites (CO ₂ , CH ₄) first one in 2015; 7 planned; aircraft campaigns
	Flasks	episodic	5 sites (¹⁴ CO ₂ & trace gases) since 2010	3 sites (¹⁴ CO ₂ & trace gases) 2014-2017; MWO since 2010 (¹⁴ CO ₂ & trace gases) with 2012-2014 gaps	δ ¹³ CO ₂ stable isotope flasks at 1 site since 2002	-	3 planned at tower sites (¹⁴ CO ₂ & trace gases)
	Column Carbon Observations	FTS	TCCON, 2012; EM27 May, 2016	TCCON since 2012	-	-	-
	Radiocarbon	-	-	-	Radiocarbon in tree rings, leaves	-	-
	Other	automobile surveys of CO ₂ and CH ₄	Automobile surveys, 500km of road data, 2012-2014; CO ₂ Lidar (JPL, Goddard, and Langley)	CLARS since 2010; AVRIS-ng, AVRIS-C & HyTES (CO ₂ , CH ₄ , NO ₂ , NH ₃ - retrievals not robust yet) since 2012	Continuous light rail transects since Dec 2014; mobile lab surveys	PANDORA since 2017 (column O ₃ and NO ₂)	Planned network of low-cost sensors
Meteorological Observations	Surface stations		Met. observations from 2–4 sites since 2013	ASOS stations; 5 radar wind profilers	25 research-grade meteorological sites	BAAQMD maintains stations in vicinity including 6 Picarro CO ₂	Met observations at most in-situ sites; METAR and ASOS
	Radiosondes		-	-	Regular NWS launches at KSLC airport (00 and 12 UTC)	-	Regular NWS launches at Sterling, VA (00 and 12 UTC)
	Profilers	MiniMPL	HRDL/HALO Doppler LIDAR since 2013	MiniMPL & Ceilometer (CalTech) since 2012; AQMD wind LIDAR since 2016	Ceilometer, sodar, radiometer, lidar (deployed during IOPs)	Ceilometer	Ceilometer at Sterling and UMBC; MiniMPL at UMBC, GSFC and Sigma Space Corp
Land cover and biospheric observations		Lidar, extensive field plots, hi res land cover	-	-	Lidar survey	-	Plot level SIF measurements on NIST campus since 2017

Main Objectives of CO₂-USA

- Leverage existing scientific infrastructure and investments in GHG work over the past few years
- Quantify & understand similarities/differences in CO₂ and CH₄ fluxes across cities
- Foster a community of urban carbon cycle researchers and generate collaborative studies
- Engage stakeholders to link them with data, syntheses, and insights into urban emissions



Thanks To:

NOAA Climate Program Office's Atmospheric Chemistry, Carbon Cycle, and Climate program for funding this project



NIST for hosting this workshop and for providing travel and logistical support



Workshop Website

EVENTS

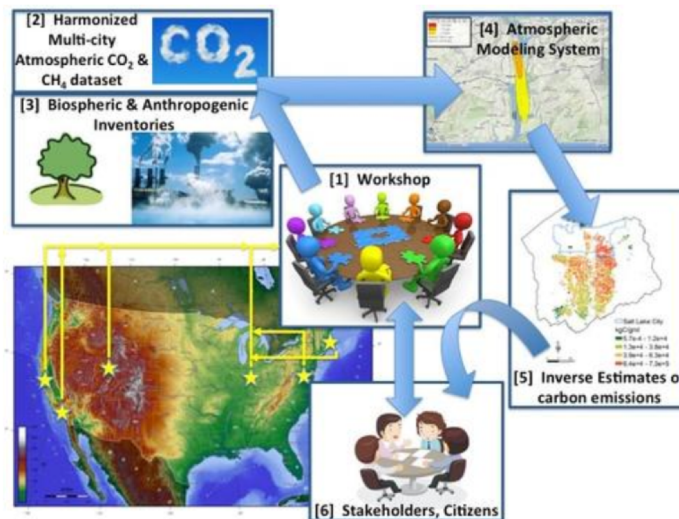
CO2 Urban Synthesis and Analysis (USA) Network Workshop

Purpose: Launch a collaborative network of researcher and stakeholders facilitating collaboration and information exchange concerning best practices and approaches to urban greenhouse gas measurements, data, and estimation results.

Planning Team: John Lin, Lucy Hutyra, James Whetstone, & Tamae Wong

Participants:

1. Scientists leading urban-scale CO₂ & CH₄ flux measurements using bottom-up and topdown methods;
2. Regulators and policymakers interested in integrating scientific observations into their greenhouse gas reporting systems;



WORKSHOP

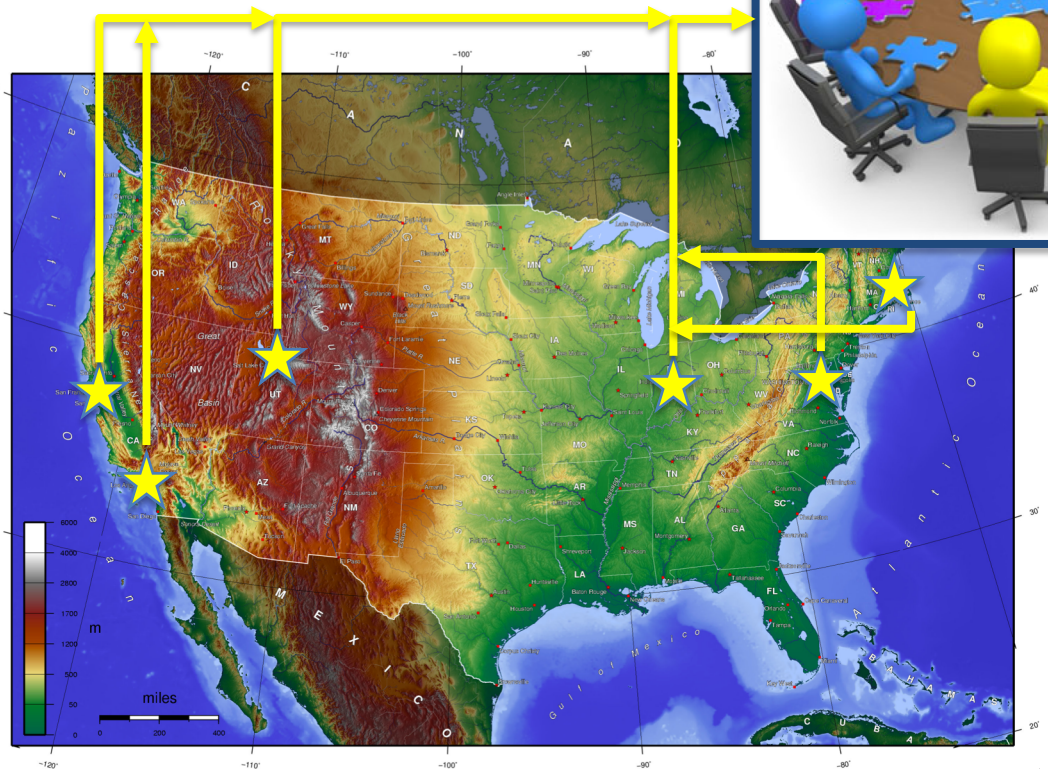
November 06, 2017 to November 07, 2017

NIST, 100 Bureau Drive, Gaithersburg, Maryland 20899 (Portrait Room)

Registration has closed. We are offering a webinar Option. The Webinar/BlueJeans information is available upon request from [Tamae Wong](#). Please contact her no later than Friday November 3rd by 12:00pm EDT.

All attendees must be pre-registered to gain entry to the NIST campus. Photo identification must be presented at the main gate to be admitted to the conference. International

[1] Workshop



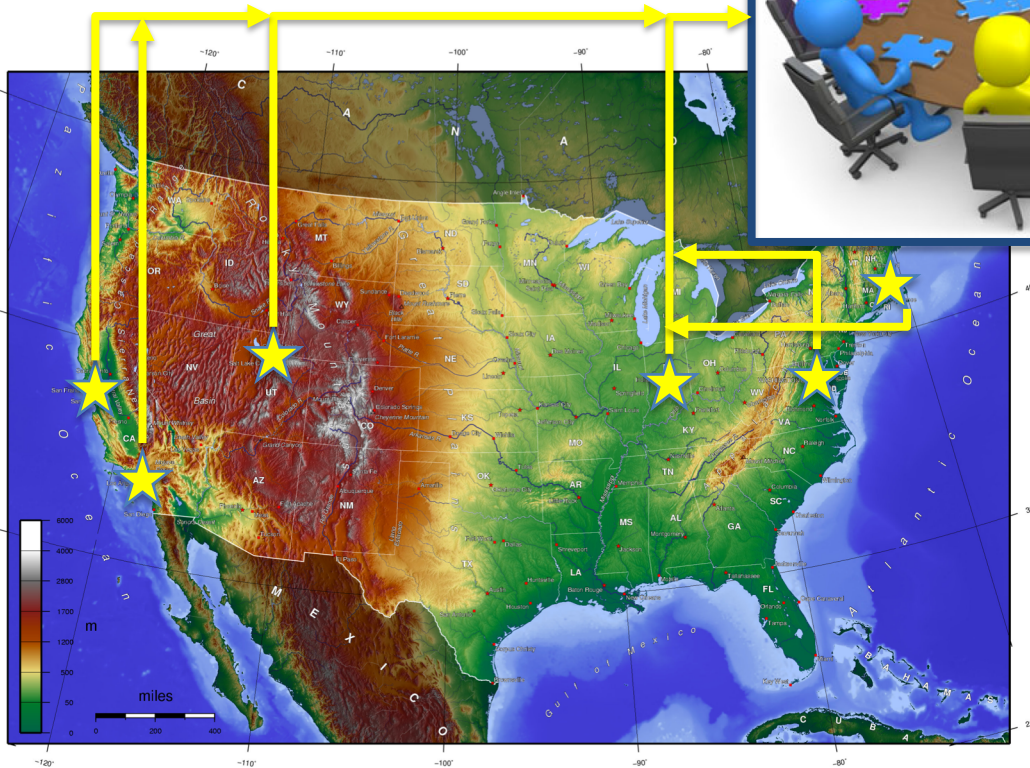
**[2] Harmonized
Multi-city
Atmospheric CO₂ &
CH₄ dataset**



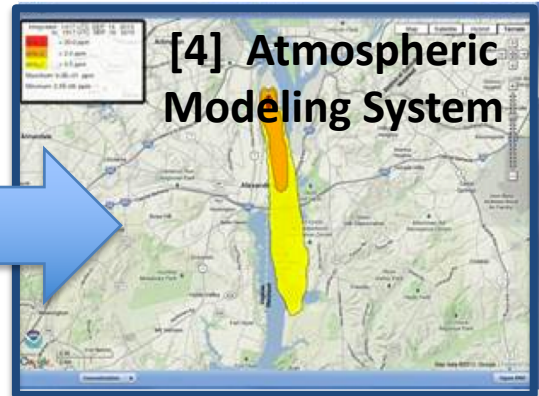
**[3] Biospheric & Anthropogenic
Inventories**



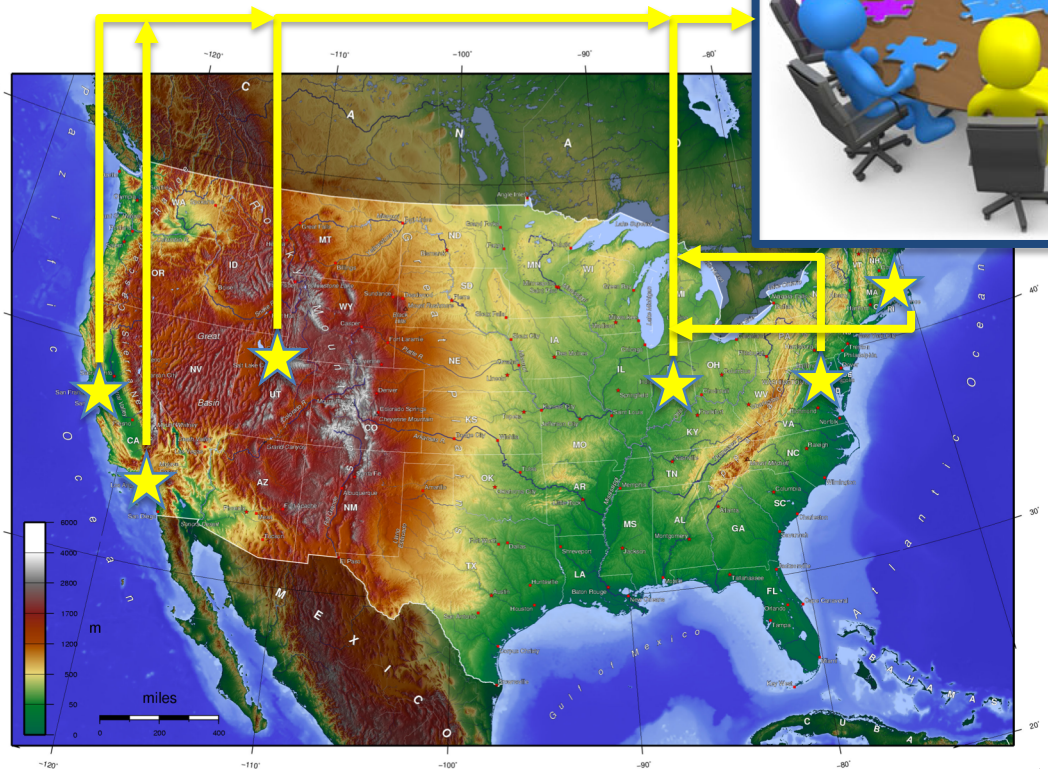
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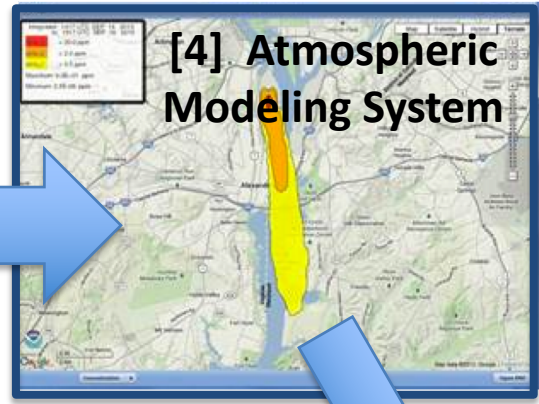
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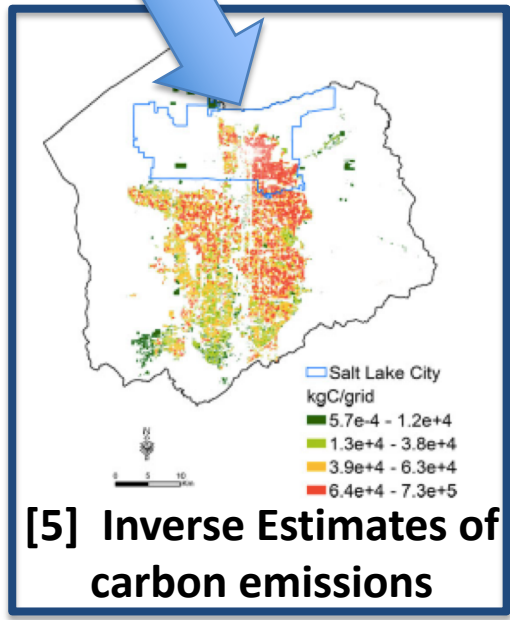
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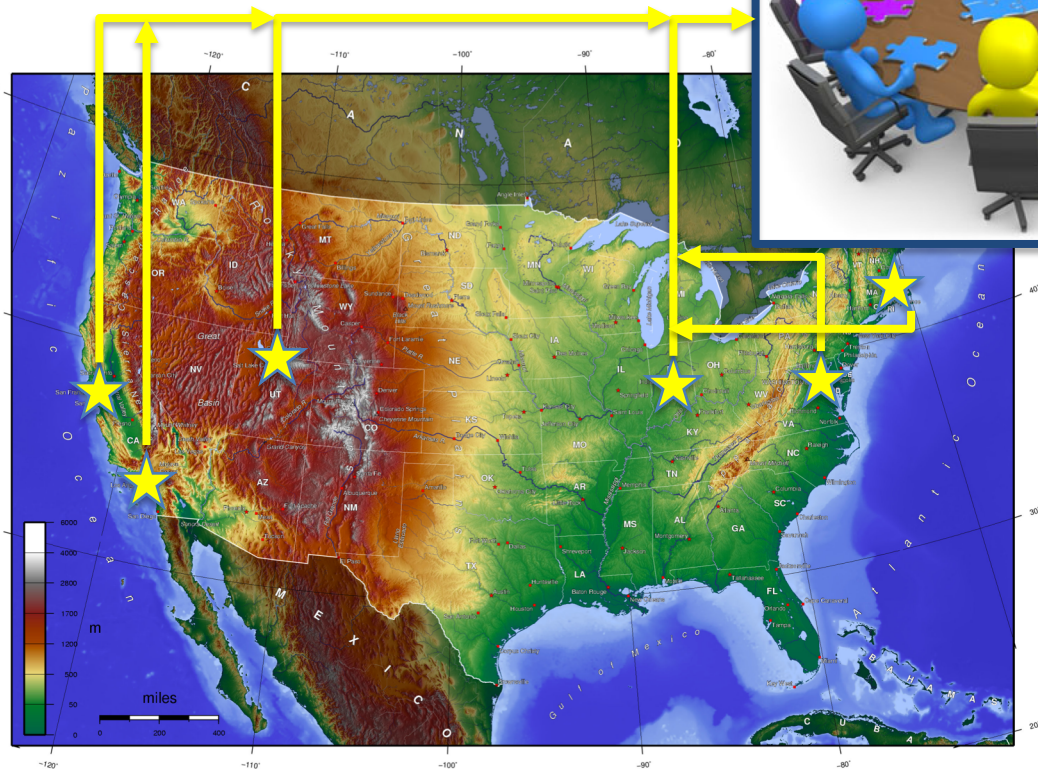
[4] Atmospheric
Modeling System



[1] Workshop



[5] Inverse Estimates of
carbon emissions



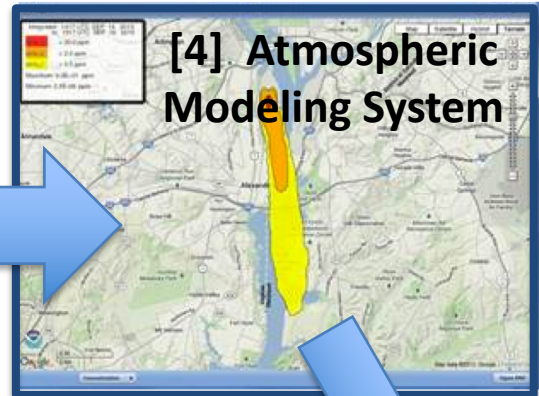
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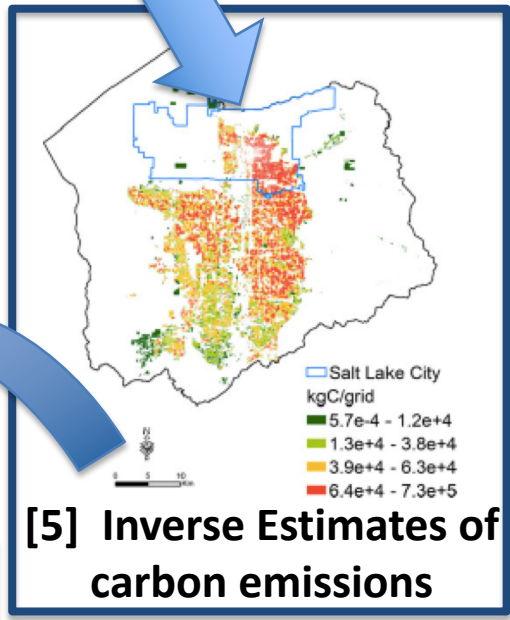
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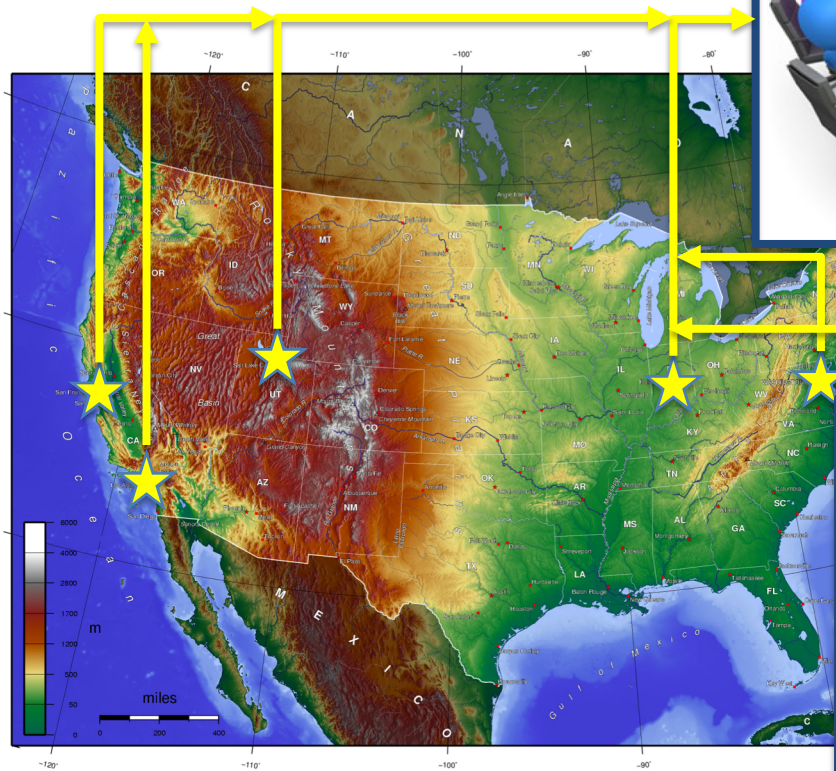
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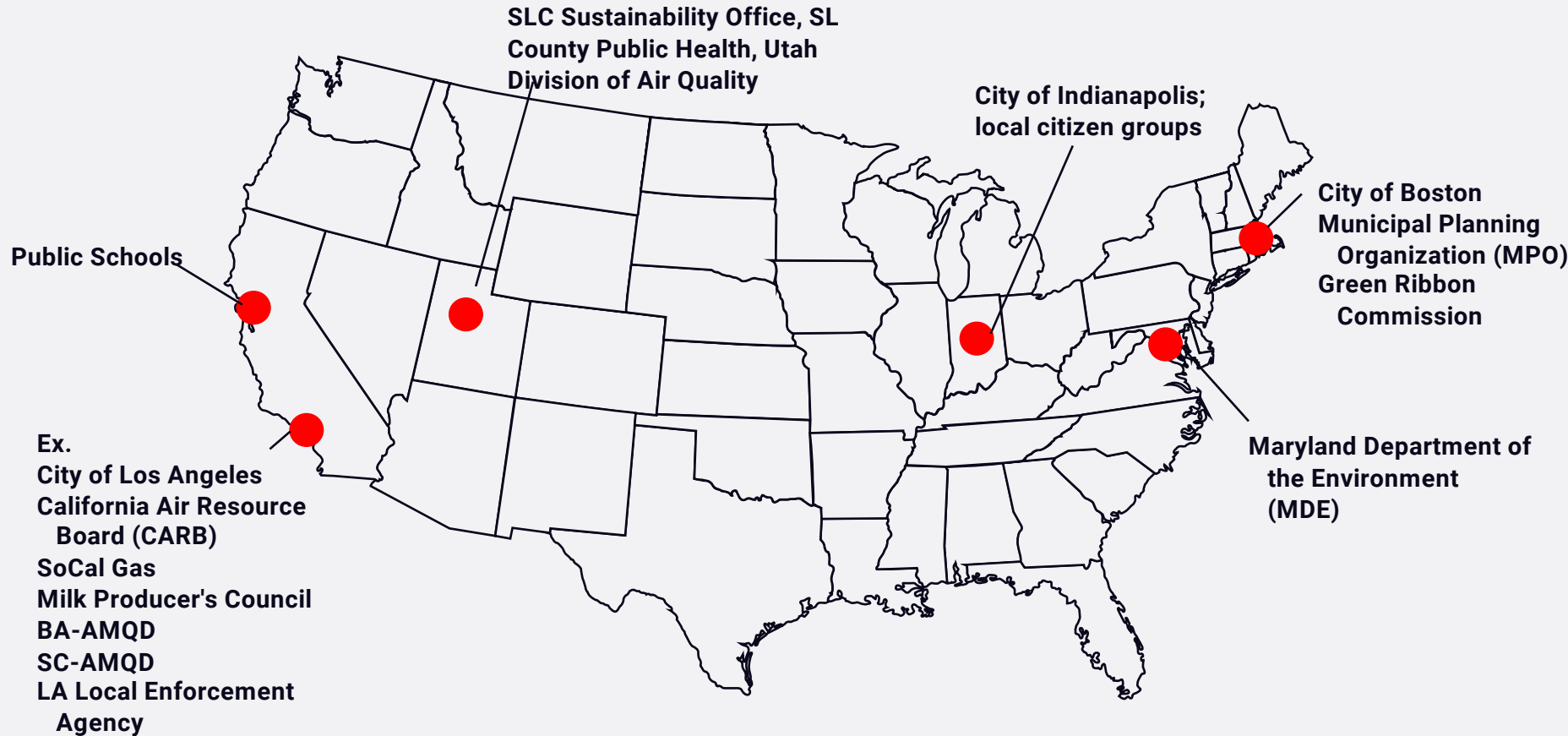
[6] Stakeholders, Citizens



Salt Lake City
kgC/grid
5.7e+4 - 1.2e+4
1.3e+4 - 3.8e+4
3.9e+4 - 6.3e+4
6.4e+4 - 7.3e+5

Stakeholder Engagement

“Demand” for Localized GHG Emission Information **ex. stakeholders**



Importance of Co-benefits of GHG Reductions for Stakeholders

- Improved air quality
- Healthier living (e.g., more walking/biking from reduced driving)

Value to Cities from Community's Scientific Research

- Retrospective: Assessment of economic/social values of reduction efforts.
- Diagnostic & Prognostic: Mitigation guidance-estimated impacts, prioritization and cost/benefit
- Trend Detection
- Policy Relevant timescales
- Evaluation of scope 1 inventory
- Hot spots/attribution - bias & knowledge gaps
- Value of carbon sinks

Issue of Uncertainties for Stakeholders

Do stakeholders care about uncertainties?

Or more about BIASES or hotspots?

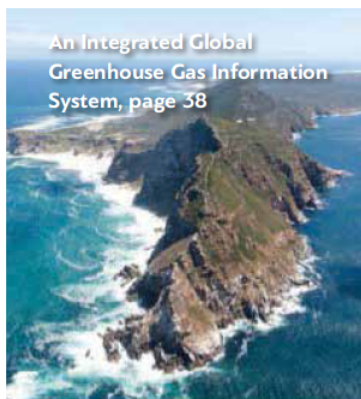
If biases, then CONSISTENT bias for trend detection instead of continually improving methods, such that introduce “jumps” in estimates?



An Integrated Global Greenhouse Gas Information System (IG³IS)

by Phil DeCola¹ and WMO Secretariat²

New Edition of the International Cloud Atlas



An Integrated Global
Greenhouse Gas Information
System, page 38



The Evolution of
Climate Science: A
Personal View from
Julia Slingo, page 16

Objective 1 – support of national GHG emission inventories

Objective 2 - Detection and quantification of fugitive methane emissions

Objective 3 - Estimation and attribution of megacities emissions

Linkage to International Efforts

Secure | <https://citiesipcc.org>

CITIES
2018 CONFERENCE
IPCC

ABOUT ▾ CONFERENCE PROGRAMME ▾ GET INVOLVED ▾ HOST CITY: EDMONTON ▾ BEYOND THE CONFERENCE ▾
MEDIA ▾



Cities & Climate Change Science Conference

MARCH 5 - 7, 2018
EDMONTON, ALBERTA, CANADA



<https://citiesipcc.org/en/conference-programme/preliminary-programme>



Greenhouse Gases Data Resource Registry

A Collaboration of GHG Research Organizations

SEARCH FOR RESOURCES

ADD YOUR RESOURCE

Find GHG Resources

This system allows for the registration of resources, bridging the gap between existing resources and the end users. The Greenhouse Gases Data Resource Registry functions as a centrally located service, making the registered information available for research to the global community.

This is being developed at the National Institute of Standards and Technology (NIST) and is made available to collect information from the global community. Please do not enter any proprietary data into this system.

<https://ghgr.nist.gov/>

(from Gretchen Greene, NIST)

Home Page

Services

Search for resources

Add your resource

Login

Help

Contact

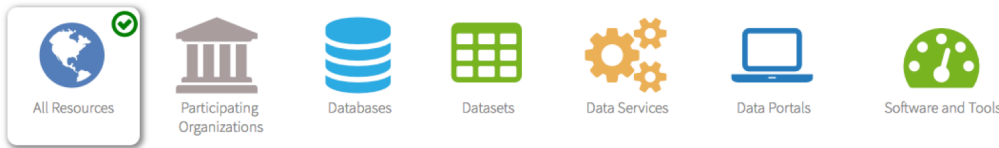
Greenhouse Gas Registry



Greenhouse Gases Data Resource Registry

Search for Resources

methane



Search criteria used (Clear all):

5 results

Resource Type:

RESOURCE TYPE:

- Database (3)
- Dataset (2)
- Document (0)
- Organization (0)
- Portal (0)
- Service (0)
- Software (0)

SECTOR AREA:

DATA COLLECTION METHOD:

GREENHOUSE GAS:

SOURCE CATEGORY:

STATE NAME:

AVAILABILITY:

TYPE OF MEDIA AVAILABLE:

Boston Regional Atmospheric Measurement Network: Methane Emissions from Natural Gas Infrastructure and Use in the Urban Region of Boston, Massachusetts

Harvard Dataverse
Home: [10.7910/DVN/28530](https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/28530)
Subject keyword(s): atmospheric; methane; greenhouse; gas; emissions; urban;
Archival datasets associated with with the paper McKain K, et al. (2015), including: continuous atmospheric methane and ethane concentration observations, and inventories of methane emissions by source type and natural gas consumption. (2014-12-29)

In-situ tower atmospheric measurements of carbon dioxide, methane and carbon monoxide mole fraction for the Indianapolis Flux (INFLUX) project, Indianapolis, IN, USA.

Data Commons, PSU
Home: [10.18113/D37G6P](https://datacommons.org/dataset/10.18113/D37G6P)
Subject keyword(s): mole fractions; aircraft
CO₂, CH₄, and CO mixing ratios

Inventory of U.S. Greenhouse Gas Emissions and Sinks

EPA/GHGRP
Home: <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks>
Since 1990s, inventory of U.S. Greenhouse Gas Emissions and Sinks is prepared by EPA. The annual report provides total greenhouse gas emissions for man-made sources. The gases covered by the Inventory include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. The Inventory a... show more

Vista-LA

Distributed Active Archive Center (ORNL)
Home: https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1525
Subject keyword(s): CH₄, inventory
Maps of methane emitting infrastructure with plans to add in emissions in the future

University of Utah Atmospheric Trace gas and Air Quality

University of Utah
Home: <https://air.utah.edu/>
Subject keyword(s): Carbon dioxide, Methane, greenhouse gas, air quality
Greenhouse gas and air quality measurements

<https://ghgr.nist.gov/>

(from Gretchen Greene, NIST)

Working Groups

1. Data Synthesis Working Group

Goal: shared dataset of observed CO₂ plus CH₄ (where available) and associated tracers in multiple U.S. cities (and potentially beyond)

Working group defining:

- Data format
- Reporting of standards and calibrations
- QA/QC
- Data archive location (likely Oak Ridge DAAC)
- Fair use policy
- Ancillary datasets
 - Aircraft and ground-based surveys
 - Meteorology
 - Satellite
 - Inventories

Working Groups

2. Atmospheric Transport Working Group

Goal: evaluate atmospheric simulations alongside meteorological observations

Potentially leveraging NOAA-ARL's HYSPLIT-based modeling system (see later slides), that allows

- 1) Multiple meteorological fields
- 2) Tracer release datasets to evaluate dispersion

3. Atmospheric Inversion Working Group

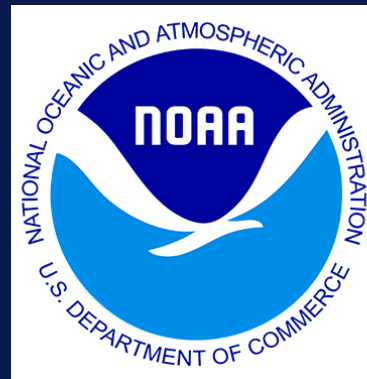
Goal: compare different atmospheric inversions techniques and results in different cities

CO₂-USA ARL Modeling System Updates

Chris Loughner – University of Maryland / NOAA
ARL

Ariel Stein – NOAA ARL

John Lin – University of Utah



Introduction

- **Goal:**
 - Apply model to estimate carbon emissions and trends in different U.S. cities
- **1st Step:**
 - Construct an atmospheric modeling system that is scalable and transferable between cities
 - Enhance HYSPLIT with STILT routines
 - Compile urban/suburban scale datasets for testing updated HYSPLIT model
 - Host benchmark scenarios for future testing of model updates and model inter-comparisons
- **Benefits of HYSPLIT modeling system updates:**
 - Enhance HYSPLIT's capabilities
 - Host and maintain STILT routines with HYSPLIT code that will continue to be updated with the state of the science
 - Provide testing platform to evaluate and examine model similarities and differences to other Lagrangian models / model options. Testing platform can also be used to test inversion techniques to estimate source strength and location.



meteorological input files

- Pre-processors for many different meteorological models and gridded analysis/reanalysis datasets (WRF, RAMS, MM5, ECMWF, GALWEM, MERRA, ERA interim, ERA5) to convert data to the ARL format, in addition to the archives of existing NOAA models and analysis/reanalysis (NAM, HRRR, GFS, SREF, NARR, GDAS, NCEP/NCAR reanalysis).
- ARL new WRF simulation
 - Resolution: 27 km (216 E->W, 174 S->N, 33 vertical from surface to 100mb)
 - Timeframe: 1980-2016 with plans to continue through 2017 and beyond
 - Domain covers all of CONUS
 - Model configured to obtain optimal transport results; not temperature
 - Some STILT specific optional inputs are available (mass conserving winds available, but no convection variables)
 - Converted to ARL formatted files and is publically available
- Future ARL WRF simulation
 - Resolution: 9 km, nested down from the 27 km domain described above
 - All STILT optional inputs will be available
 - Will be converted to ARL formatted files and made publically available



Model Evaluation System

Data Archive of Tracer Experiments and Meteorology (DATEM)

- **Approach**

- Meteorology

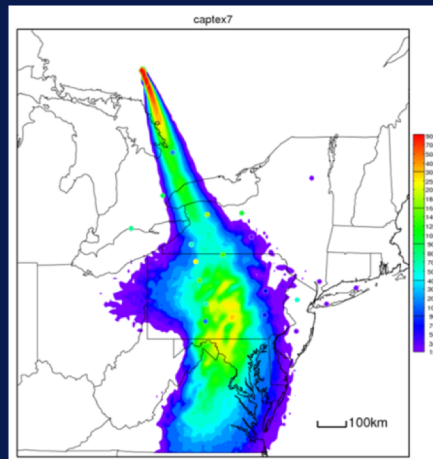
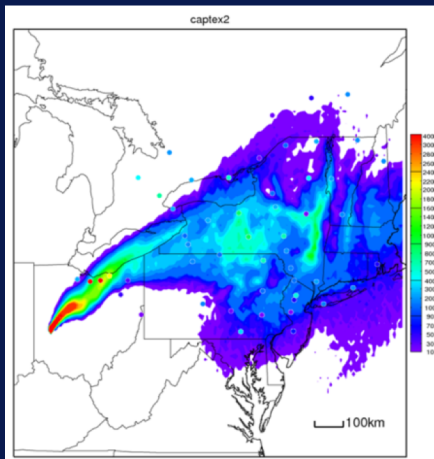
- North American Regional Reanalysis (NARR)
- WRF runs

- Common statistical evaluation protocols

- **Accomplishments**

- Web access to run HYSPLIT for each experiment
- Standardized model change testing in conjunction with version control

- **Cross Appalachian Tracer Experiment (CAPTEX)**
Dayton, OH, and Sudbury, ONT, Sep., Oct., 1983
- **Atlantic Coast Unique Regional Atmospheric Tracer Experiment (ACURATE)**, Savannah River Plant, SC, Spring 1982 – Summer 1983
- **Across North America Tracer Experiment (ANATEX)**, Glasgow, MT, and St. Cloud, MN, January through March 1987
- **Oklahoma Tracer Experiment**, Norman, OK, July, 08 1980
- **Metropolitan Tracer Experiment (METREX)**, Washington, DC, January – December 1984
- **European Tracer Experiment (ETEX)**, Rennes, France, October 23, 1994
- **Savannah River Plant Experiment**, Aiken, SC, Aug. 1975 through Sep. 1977
- **Atmospheric Studies in Complex Terrain (ASCOT)**, California, September 12-25, 1980
- **Colorado Springs Tracer Experiment (COSTEX)**, October 18, 21, 23, 2010
- **Sagebrush, Idaho, 2013**
- **Aliso Canyon well blowout, 2015**
- **Tracers of opportunity (e.g. SO₂ flight data)**



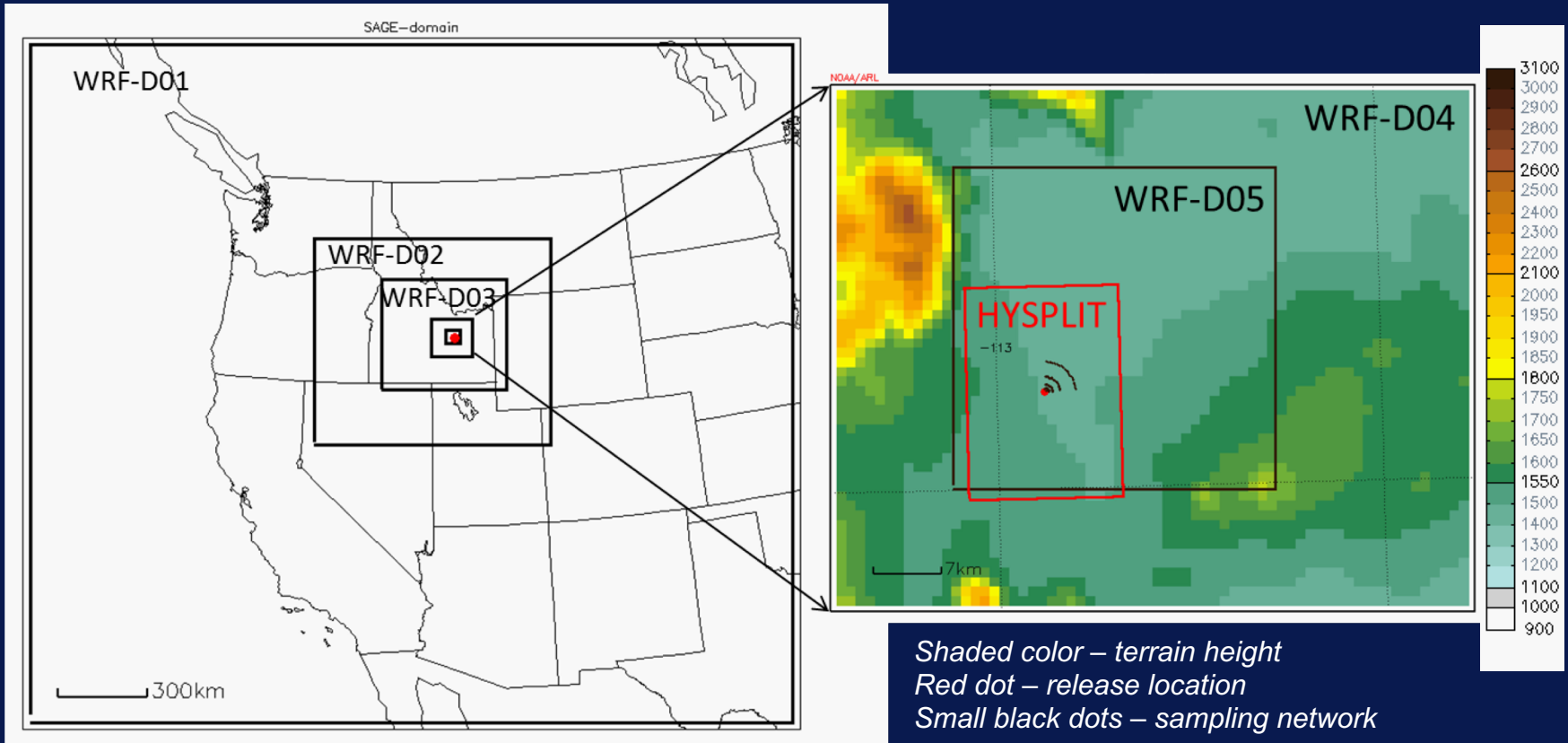
STILT

- Built from the HYSPLIT code
- Major STILT features not currently in HYSPLIT:
 - Mass conservation
 - Hanna Lagrangian timescale
 - Convection scheme that utilizes WRF convective fluxes
 - A more complex turbulence module that includes a reflection/transmission scheme for Gaussian turbulence. This preserves well-mixed distributions of particles moving across interfaces between step changes in turbulence parameters.
 - Account for transport errors by incorporating uncertainties in winds into the motion of air parcels

STILT features being incorporated into HYSPLIT

- Mass Conservation
 - Convection scheme
 - Hanna Lagrangian timescale
 - Complex turbulence module
 - Account for transport errors
-
- Allow for updated features to be modular

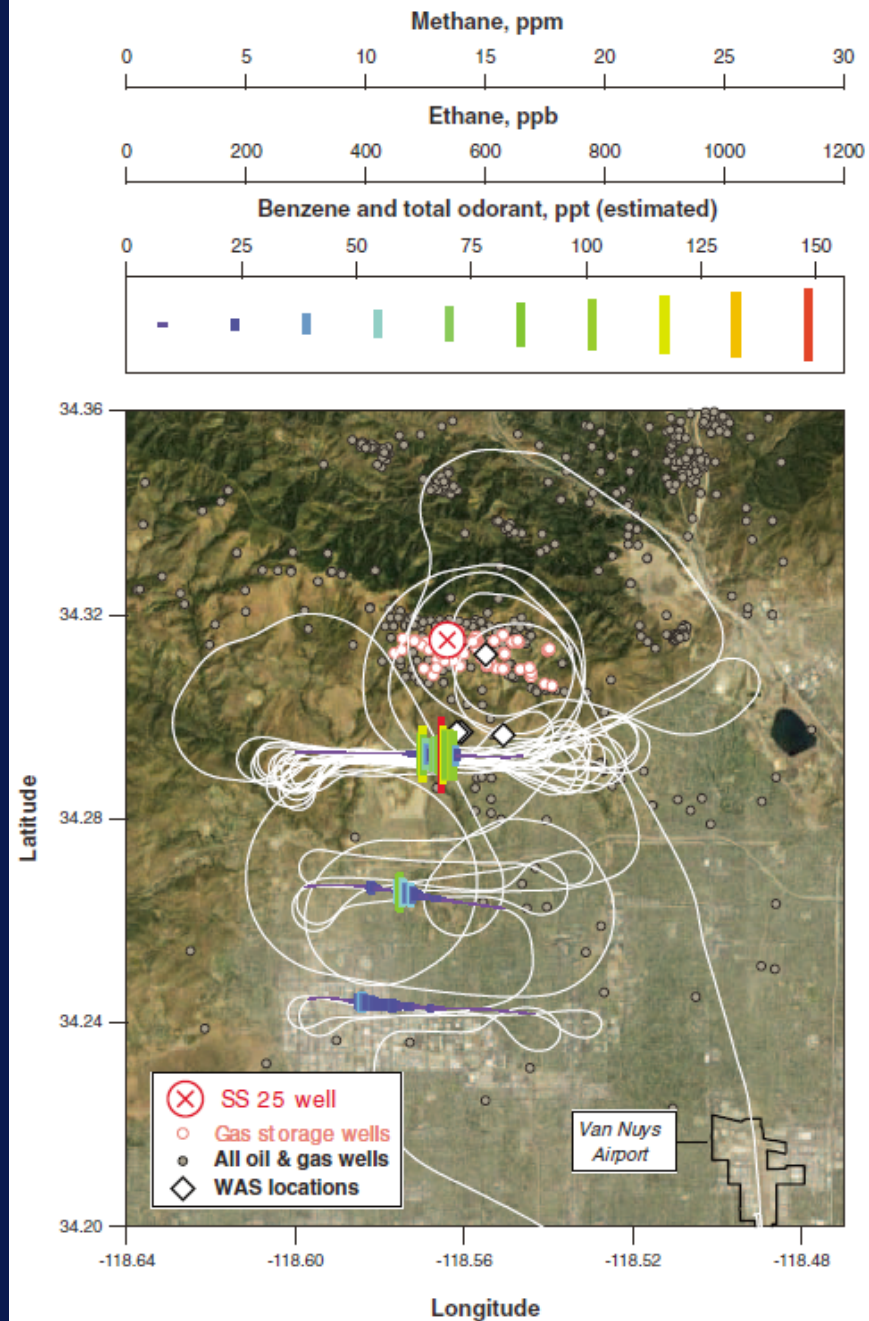
HYSPLIT simulation of Sagebrush experiment



- ❖ Horizontal grid: 27km, 9km, 3km, 1km and 333m
- ❖ Vertical coordinate: 33 layers with the 1st mid-layer at around 8m and 20 layers included below 850 hPa.
- ❖ Simulation period: 2013/10/07 00UTC – 10/08 00UTC

2015 Aliso Canyon blowout

- Large natural gas emissions released from a well blowout of connected to an underground storage facility
- 13 research aircraft flights sampled the plume
- Atmospheric leak rates up to 60 metric tons of methane and 4.5 metric tons of ethane per hour (Conley et al., 2016)



Tracers of Opportunity

- Observations downwind of an isolated source with known emissions rates
- Continuous Emissions Monitoring Systems (CEMS) measures actual emissions from stationary sources.

TEXAQS II

