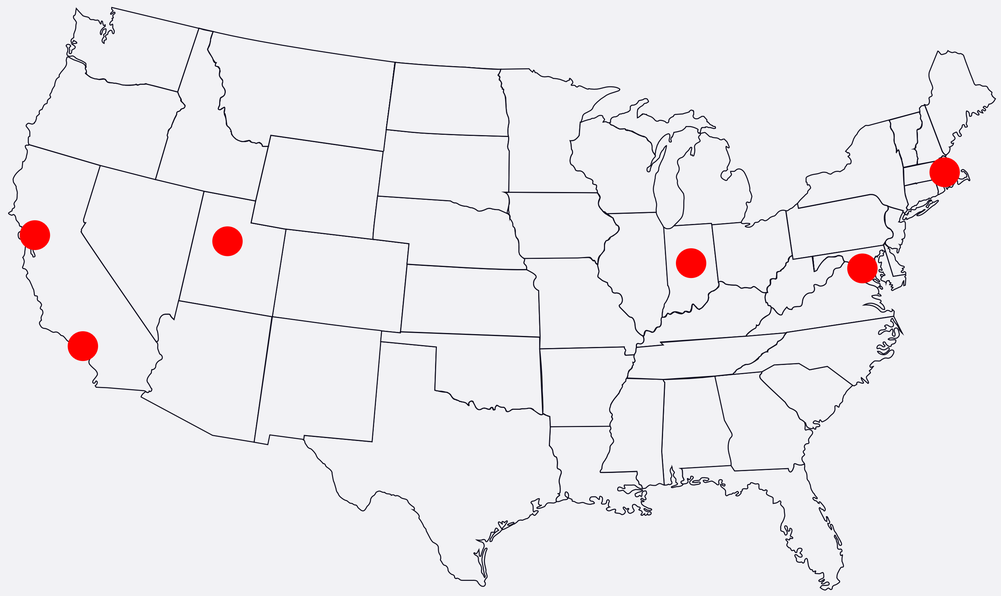


Summary of Assets in Different Cities

Boston, Indianapolis (INFLUX), Los Angeles (LA Megacities), Baltimore/Washington DC (NEC B/W), Salt Lake City, San Francisco

11/06/2017

Greenhouse Gas Measurements Program,
Special Programs Office

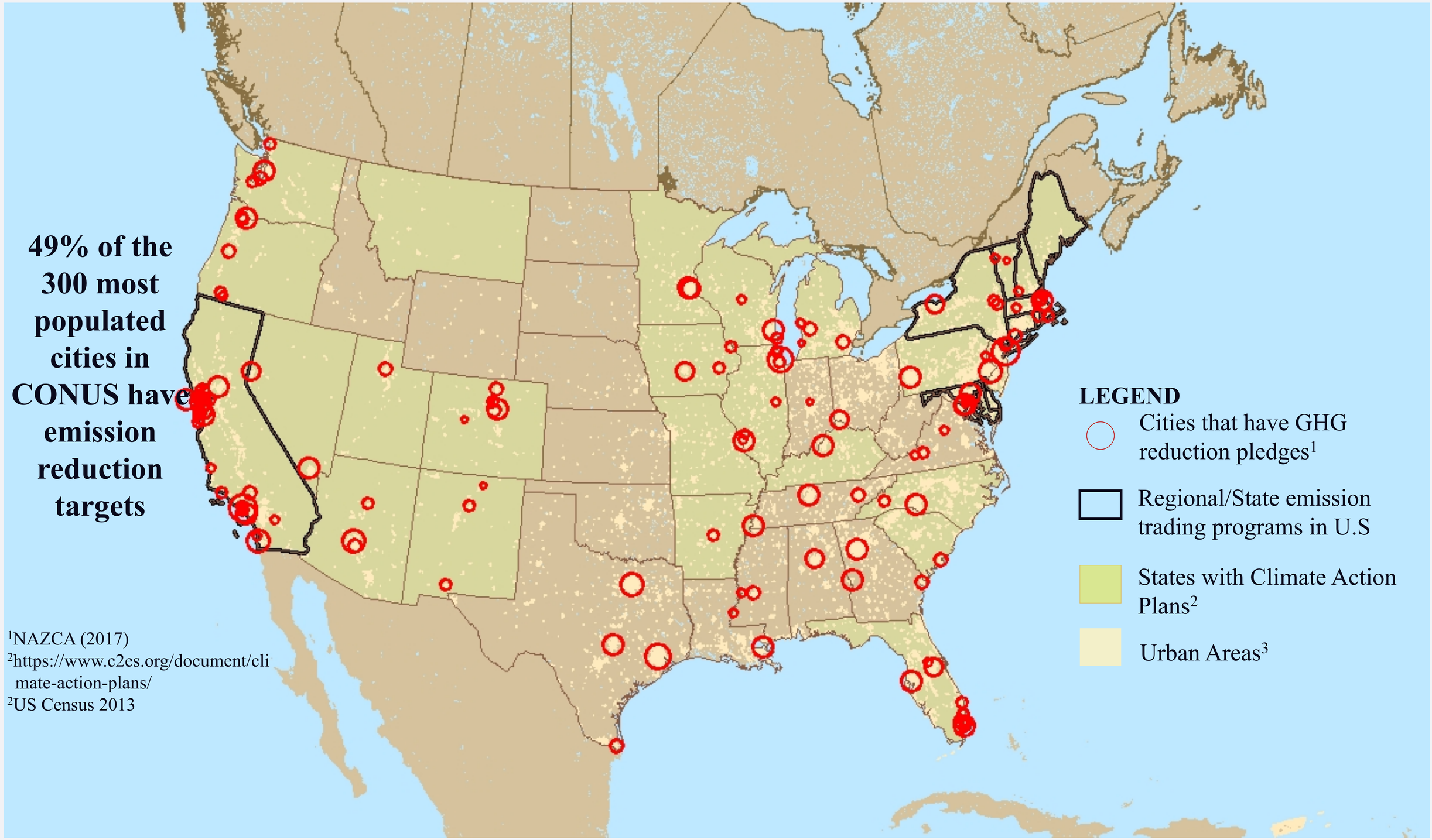
NIST

Why cities?

ADAM ROGERS SCIENCE 09.19.17 06:00 AM

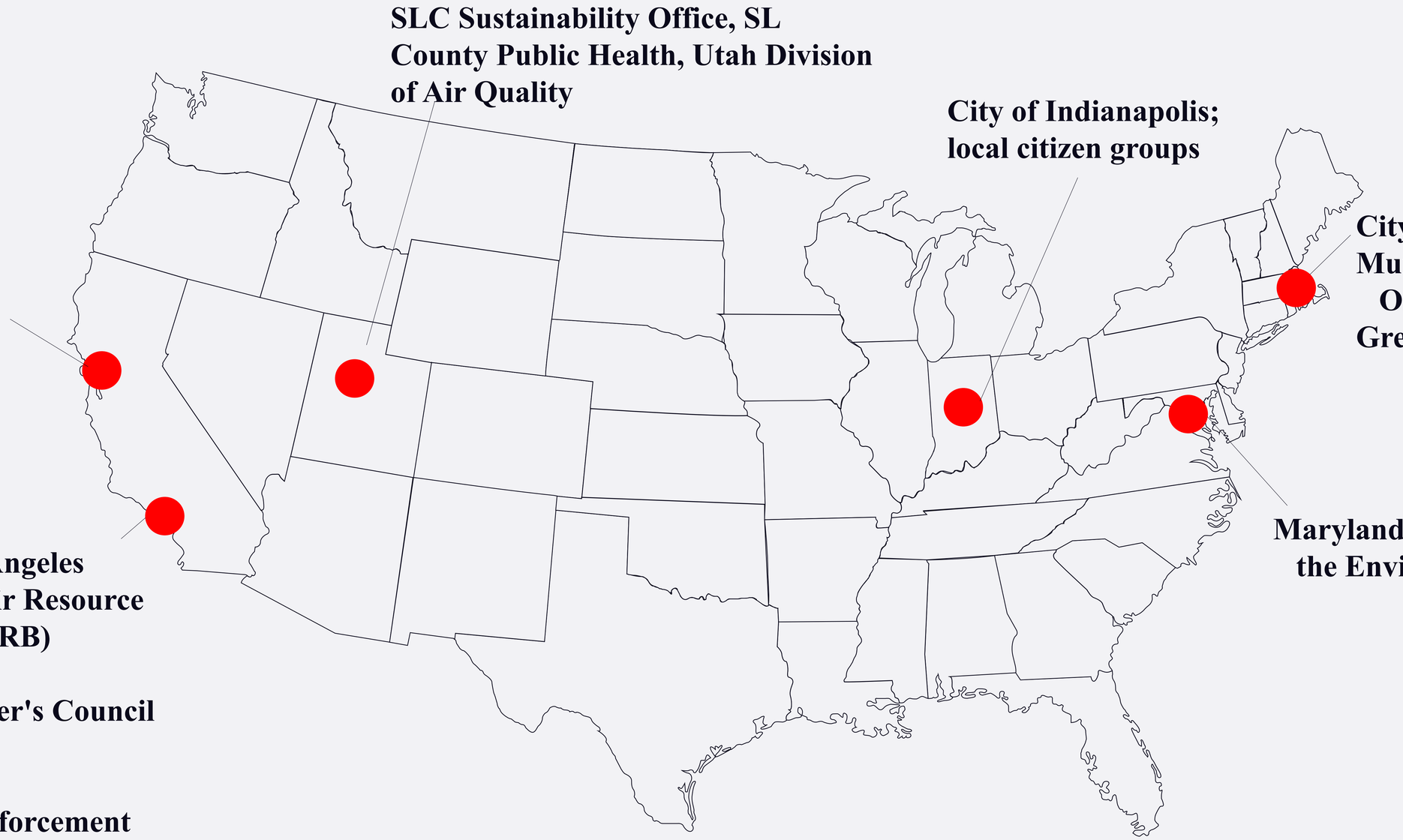
CITIES TURN TO OTHER CITIES FOR HELP FIGHTING CLIMATE CHANGE

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



[1]NAZCA (2017)
[2]https://www.c2es.org/document/climate-action-plans/
[2]US Census 2013

“Demand” for Localized GHG Emission Information ex. stakeholders

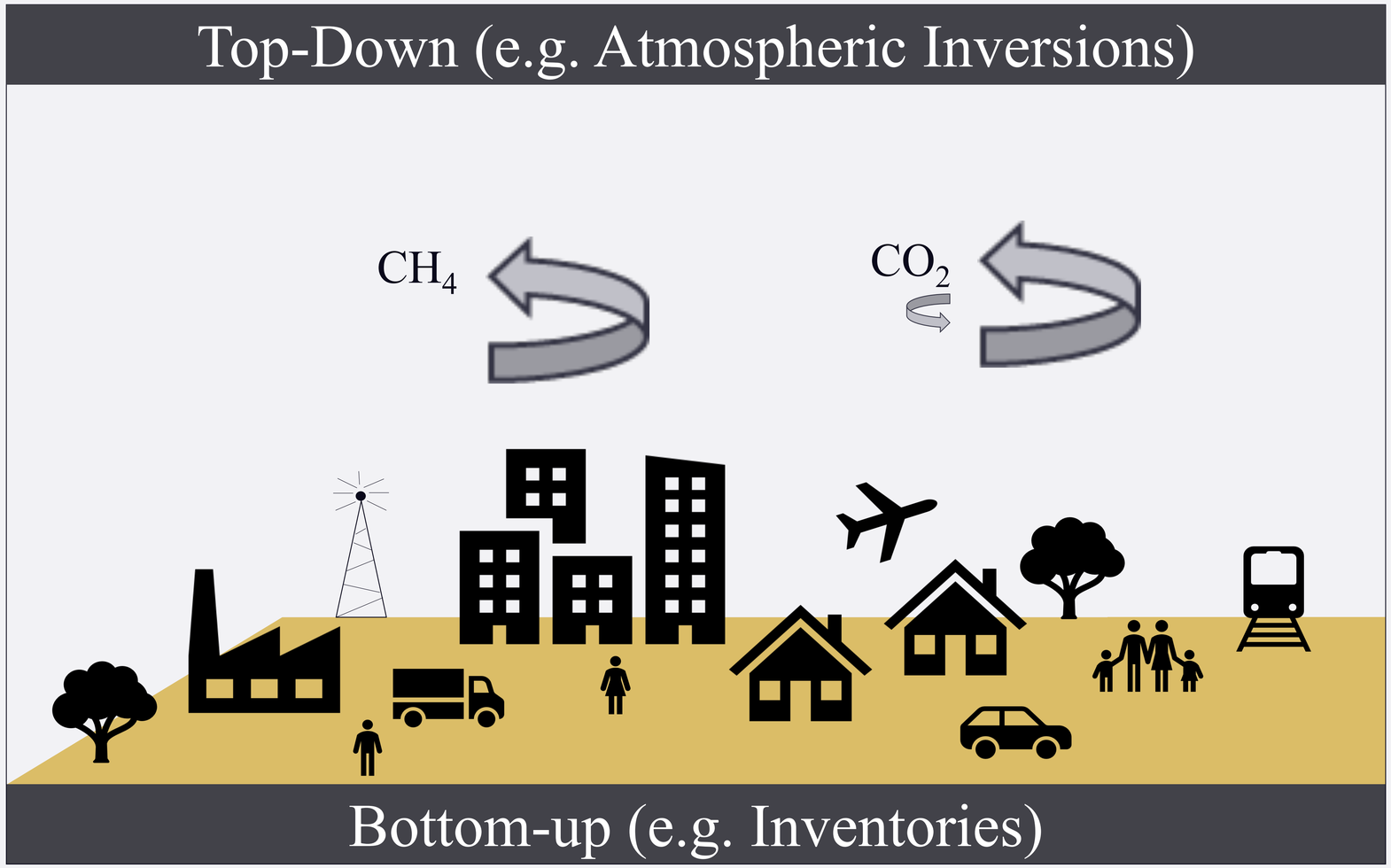


Ex.
City of Los Angeles
California Air Resource Board (CARB)
SoCal Gas
Milk Producer's Council
BA-AMQD
SC-AMQD
LA Local Enforcement Agency

Complementary Methods
@ urban scale

Atmospheric observations contain integrated emission signal from a city

“Accounting” methods use all available information on activities that produce GHG emissions



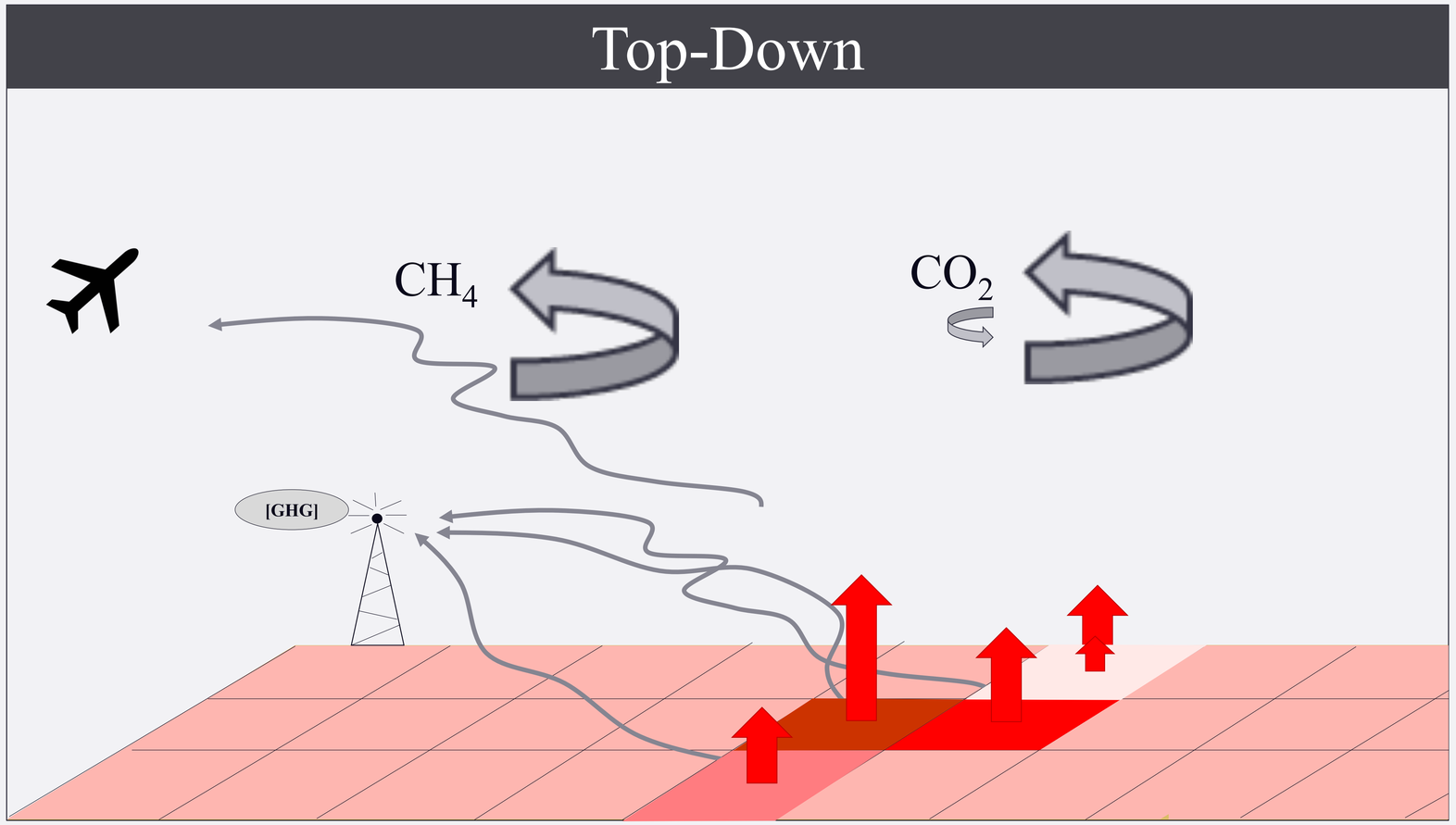
NIST

Bottom Up
ex. inventories

$$CO_2 \text{ or } CH_4 \text{ Emissions} = \underbrace{\text{Activity Data}}_{\text{(e.g. \# of building, fuel sales, etc.)}} \times \underbrace{\text{Emission Factors}}_{\text{(parameter that converts to emissions)}}$$

Top Down

ex. atmospheric inversions or mass balance methods



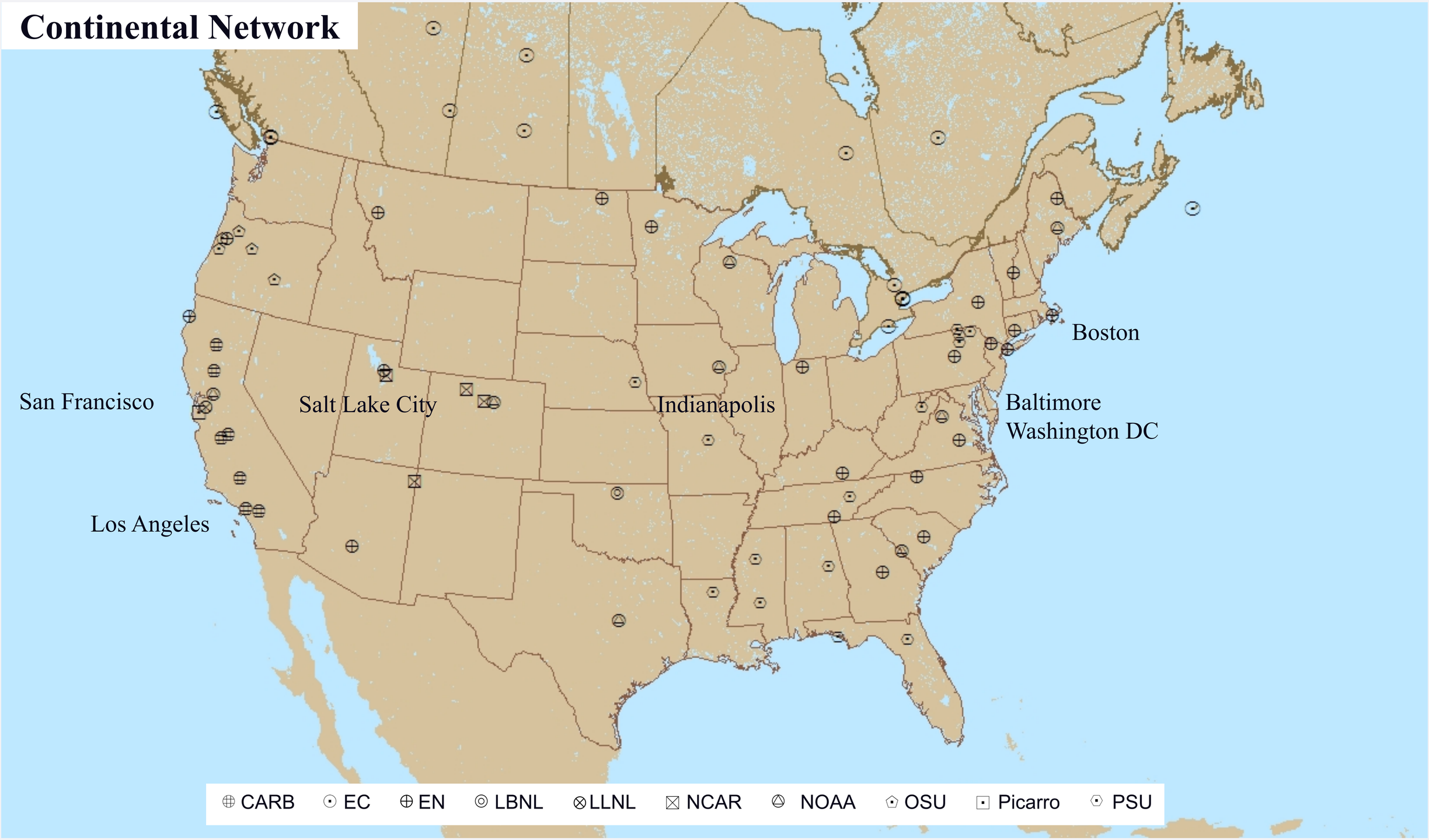
Mass Balance

Atmospheric Inversions

Require some understanding of atmospheric transport/dispersion modeling
(& removal of background and biospheric components from observations)

Data Expansion

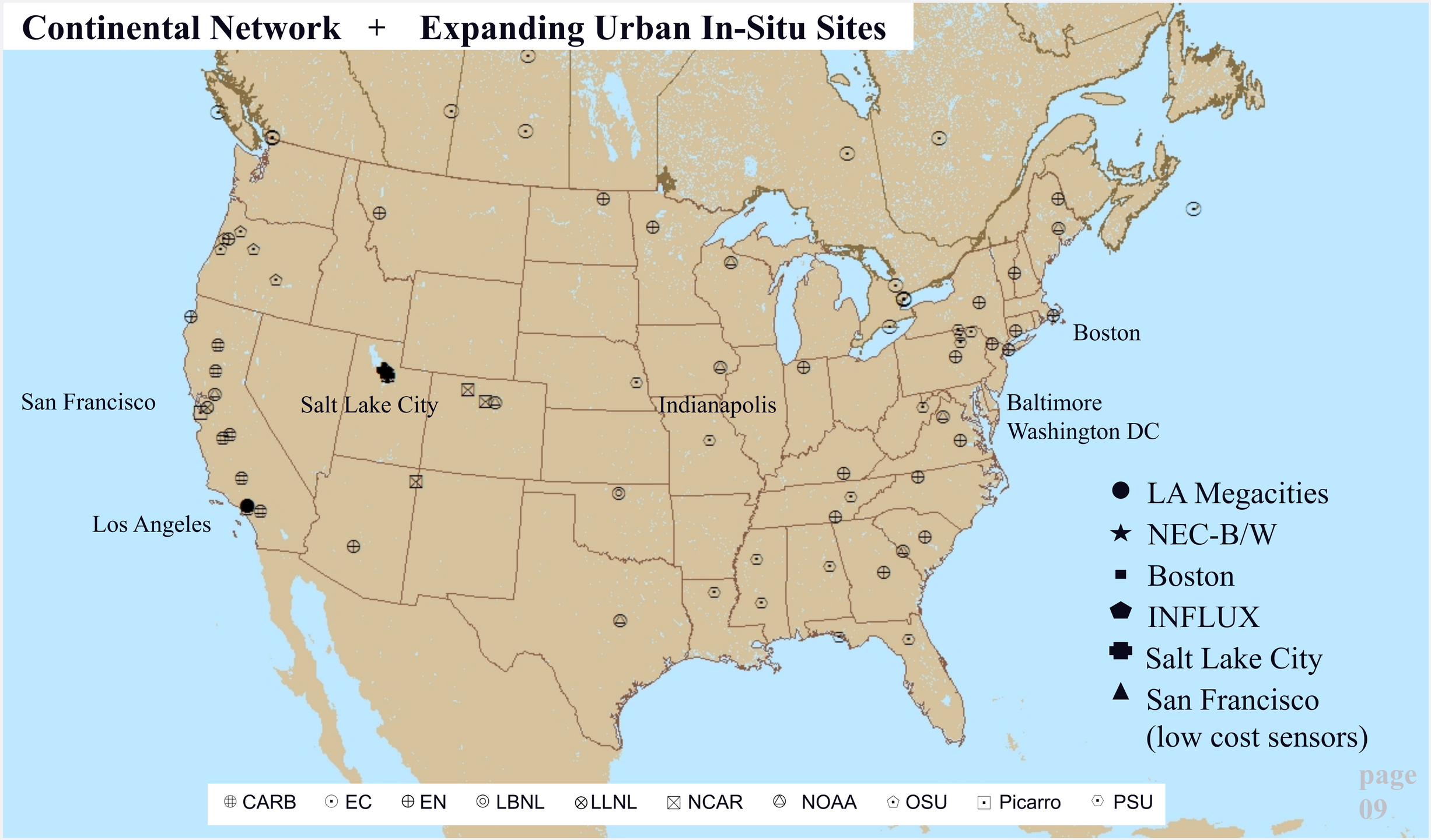
ex. in-situ obs. for top-down models



Data Expansion

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

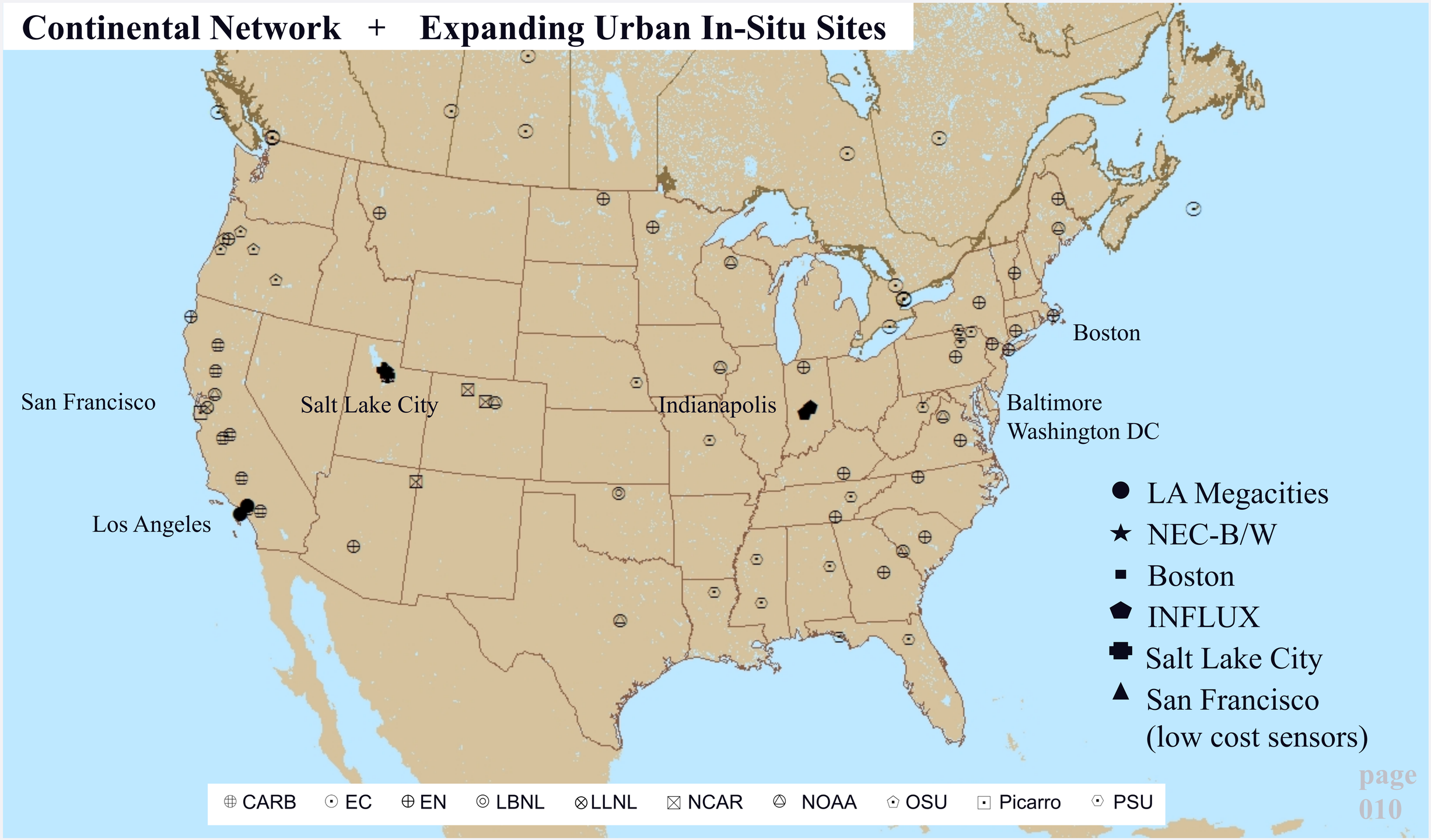
Continental Network + Expanding Urban In-Situ Sites



Data Expansion

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

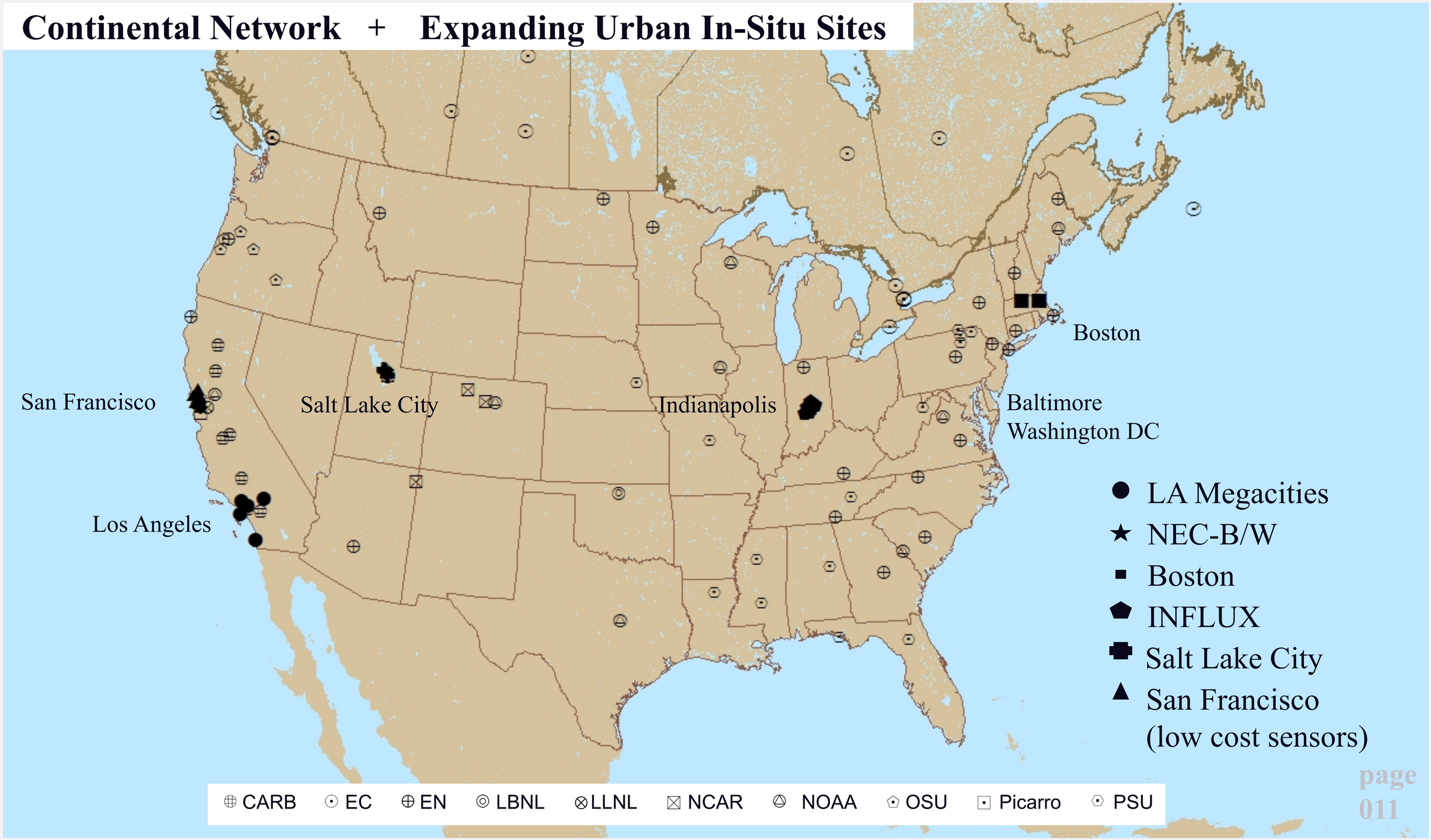
Continental Network + Expanding Urban In-Situ Sites



Data Expansion

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

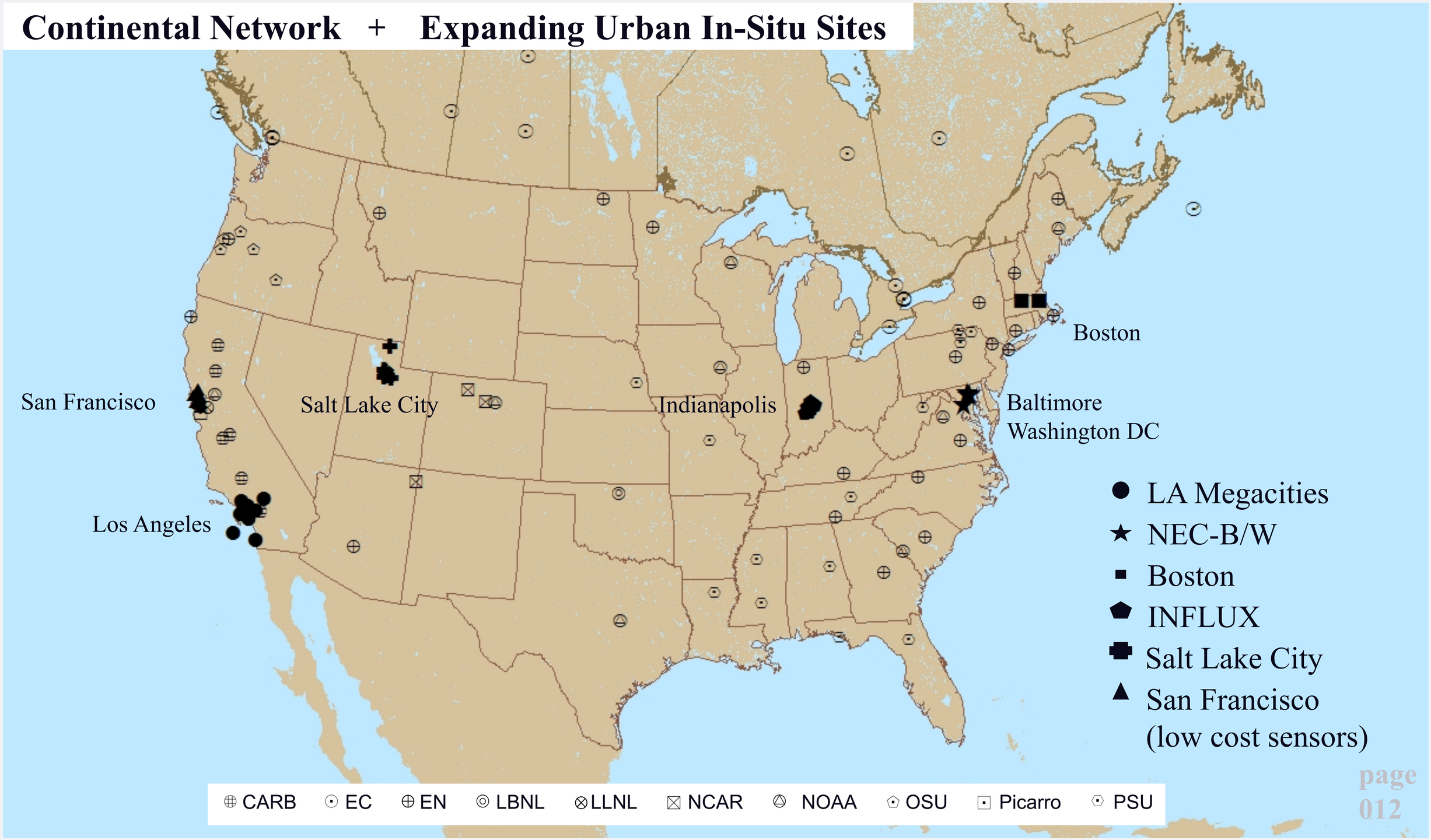
Continental Network + Expanding Urban In-Situ Sites



Data Expansion

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

Continental Network + Expanding Urban In-Situ Sites

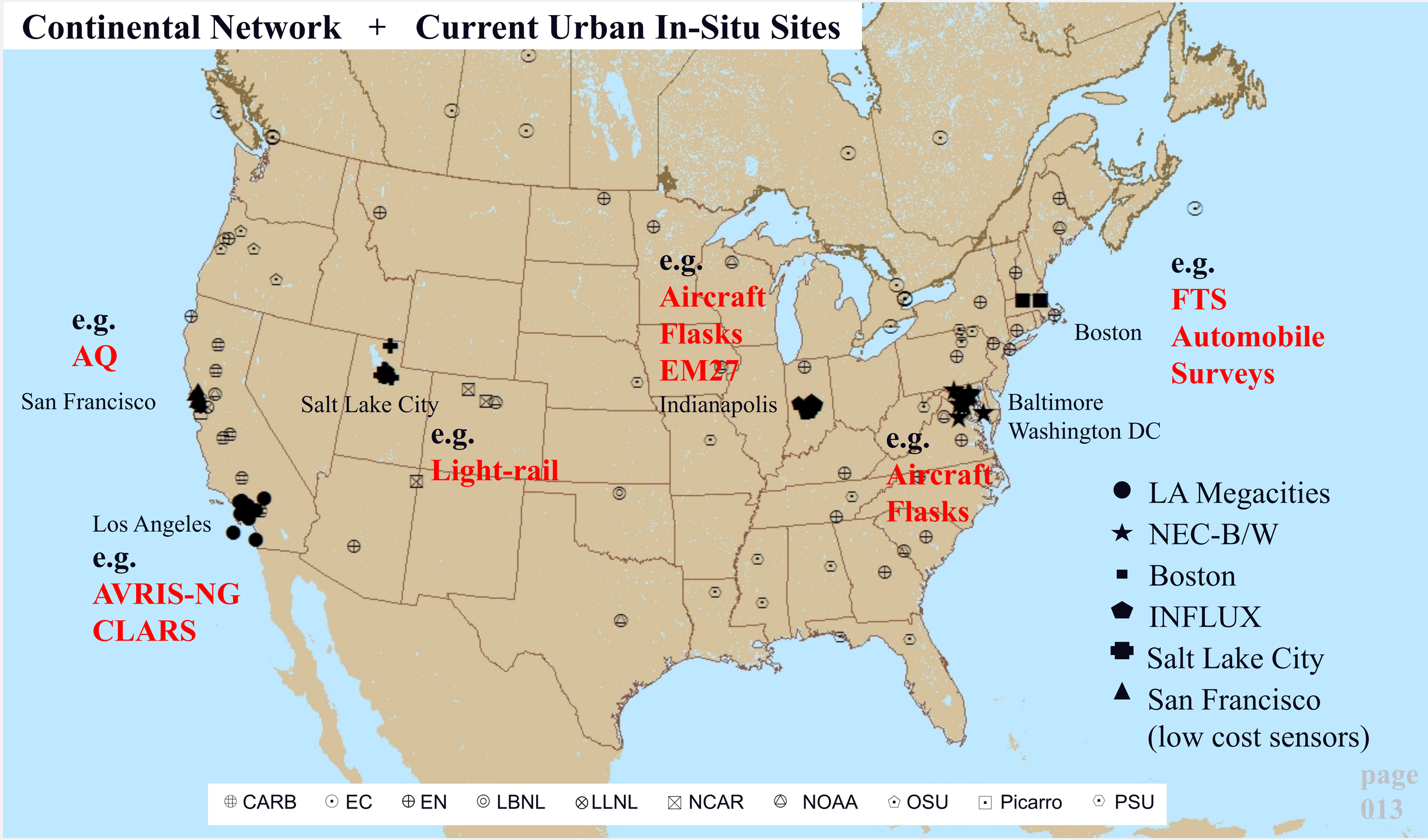


Data Expansion

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

Many other measurements!

Continental Network + Current Urban In-Situ Sites



Data Expansion
ex. inventories

Global/Continental

FFDAS (CO_2)[1]: (1997-2011 @~10km, hourly)
ODIAC (CO_2)[2]: (2000-2017 @~1km, hourly)

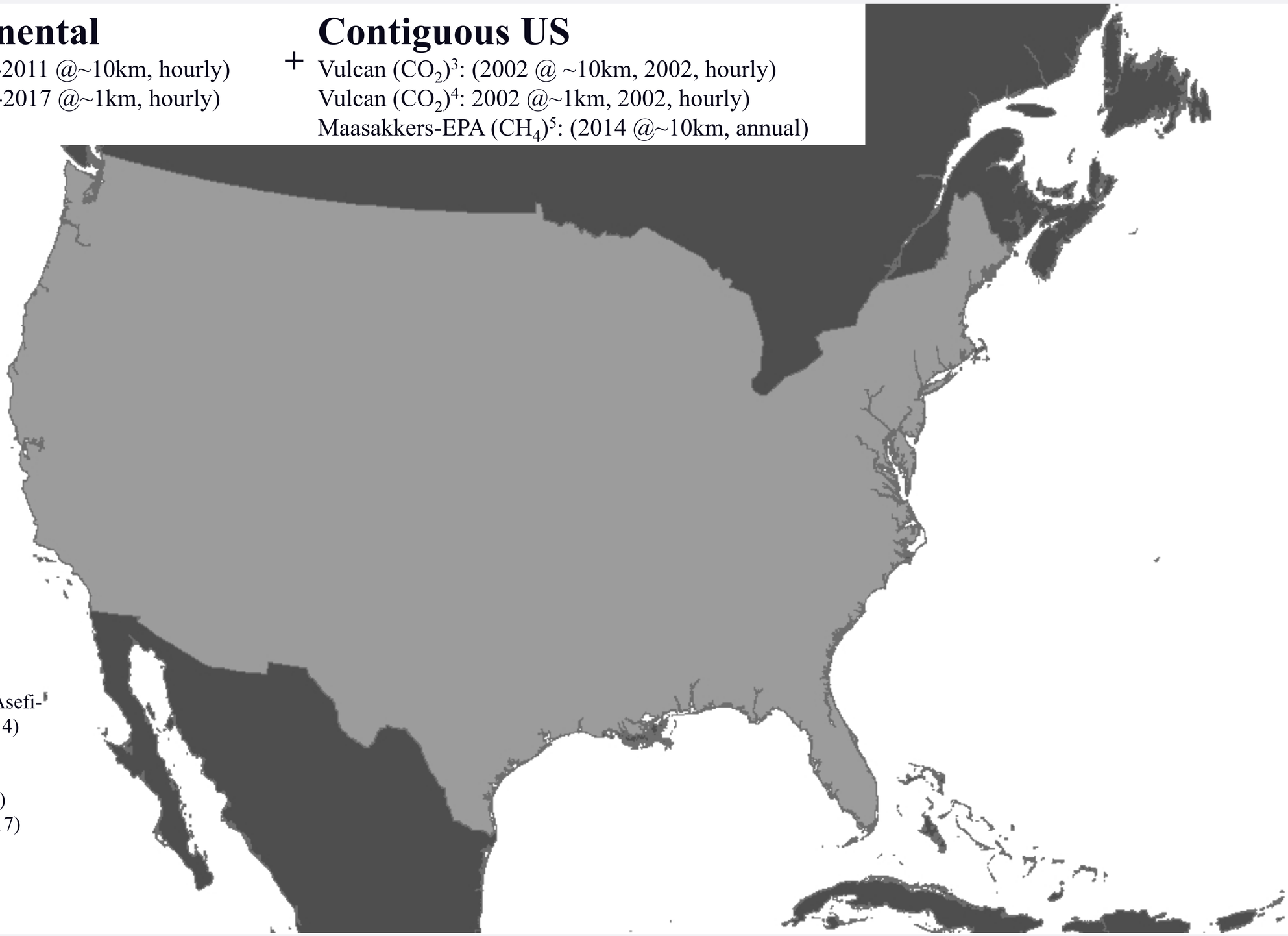
[1]Rayner et al. (2010), Asefi-Najafabady et al. (2014)
[2]Oda et al. (2017)

Data Expansion
ex. inventories

Global/Continental
FFDAS (CO_2)[1]: (1997-2011 @~10km, hourly)
ODIAC (CO_2)[2]: (2000-2017 @~1km, hourly)

\+

Contiguous US
Vulcan (CO_2)[3]: (2002 @ ~10km, 2002, hourly)
Vulcan (CO_2)[4]: 2002 @~1km, 2002, hourly)
Maasakkers-EPA (CH_4)[5]: (2014 @~10km, annual)



[1]Rayner et al. (2010), Asefi-Najafabady et al. (2014)
[2]Oda et al. (2017)
[3]Gurney et al. (2009)
[4]Gurney et al. (in prep.)
[5]Maasakkers et al. (2017)

Data Expansion
ex. inventories

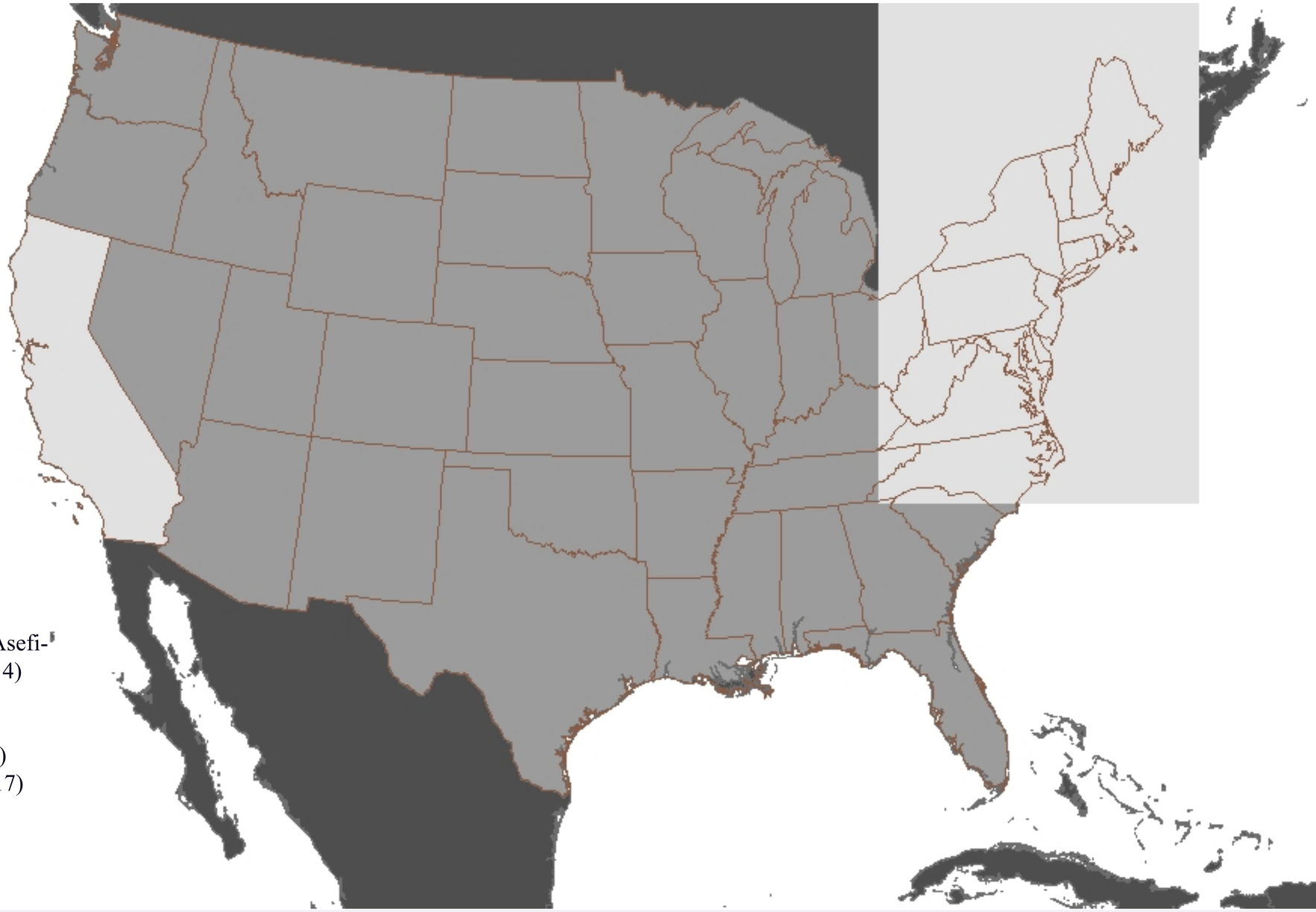
Global/Continental
FFDAS (CO_2)[1]: (1997-2011 @~10km, hourly)
ODIAC (CO_2)[2]: (2000-2017 @~1km, hourly)

+

Contiguous US
Vulcan (CO_2)[3]: (2002 @ ~10km, 2002, hourly)
Vulcan (CO_2)[4]: 2002 @~1km, 2002, hourly)
Maasakkers-EPA (CH_4)[5]: (2014 @~10km, annual)

+

Regional/State
CALGEM (CH_4)[6]: (2011 @~10km, annual)
ACES (CO_2)[7]: (2014 @1km, 2013-2014 hourly)



[1]Rayner et al. (2010), Asefi-Najafabady et al. (2014)
[2]Oda et al. (2017)
[3]Gurney et al. (2009)
[4]Gurney et al. (in prep.)
[5]Maasakkers et al. (2017)
[6]Jeong et al. (2012a)
[7]Gately et al. (2017)

Data Expansion
ex. inventories

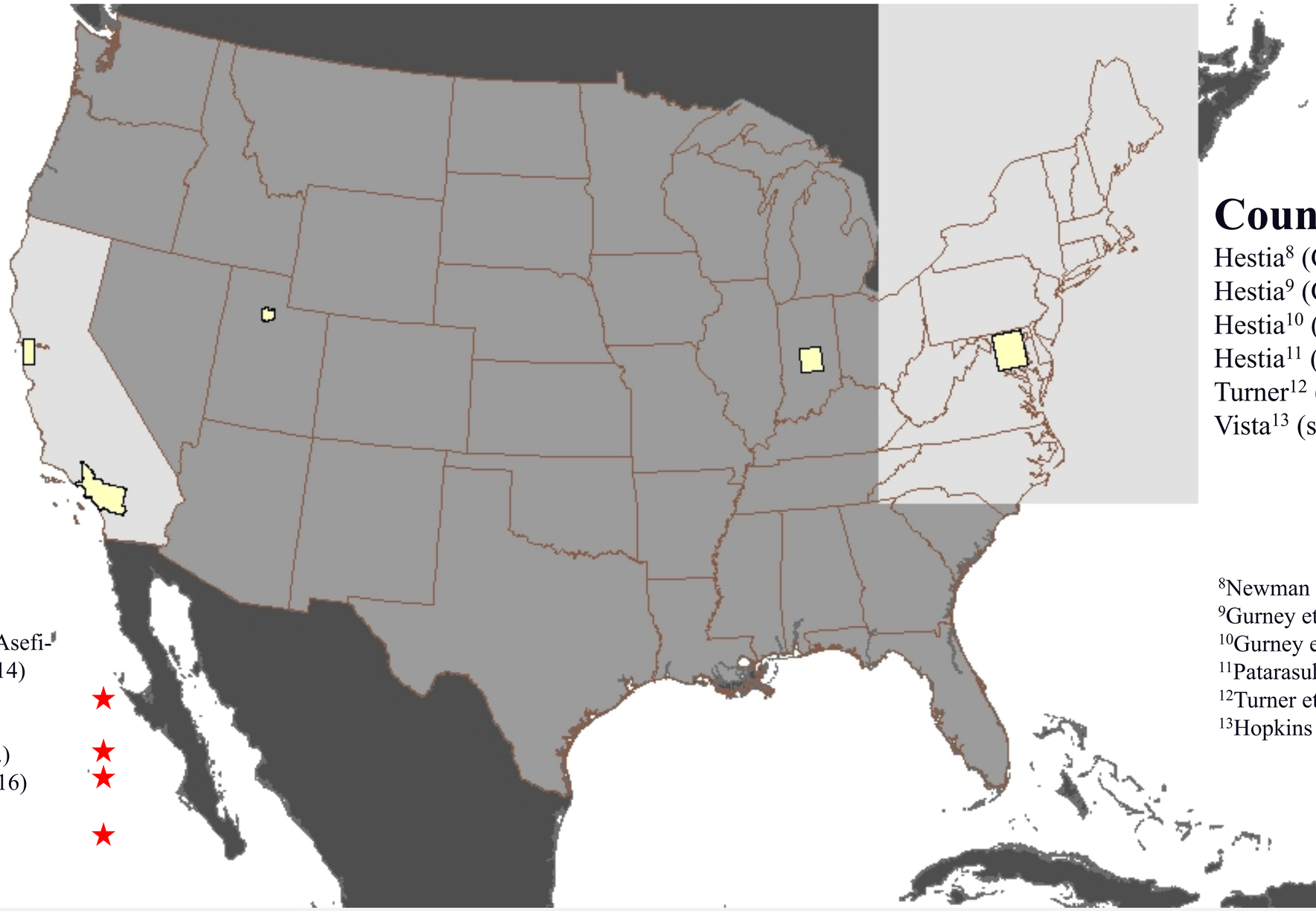
Global/Continental
FFDAS (CO_2)[1]: (1997-2011 @~10km, hourly)
ODIAC (CO_2)[2]: (2000-2017 @~1km, hourly)

\+

Contiguous US
Vulcan (CO_2)[3]: (2002 @ ~10km, hourly)
Vulcan (CO_2)[4]: (2010-2015 @~1km, hourly)
Maasakkers-EPA (CH_4)[5]: (2014 @~10km, annual)

\+

Regional/State
CALGEM (CH_4)[6]: (2011 @~10km, annual)
ACES (CO_2)[7]: (2014 @1km, 2013-2014 hourly)

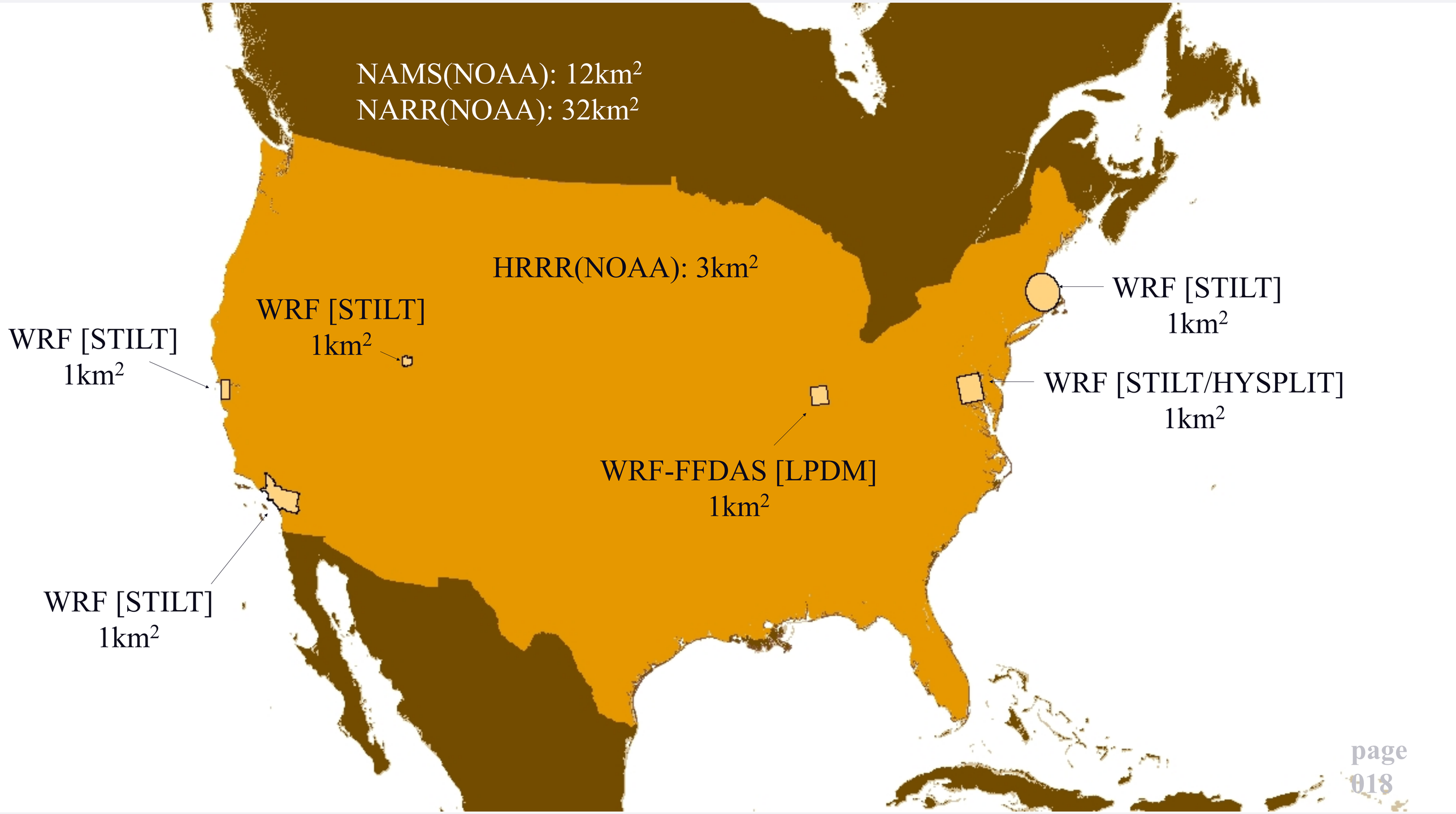


Counties/Cities
Hestia[8] (CO_2, LA Megacities)
Hestia[9] (CO_2, INFLUX)
Hestia[10] (CO_2, NEC-B/W)
Hestia[11] (CO_2, Salt Lake City)
Turner[12] (CO_2, San Francisco)
Vista[13] (soon CH_4, LA Megacities)

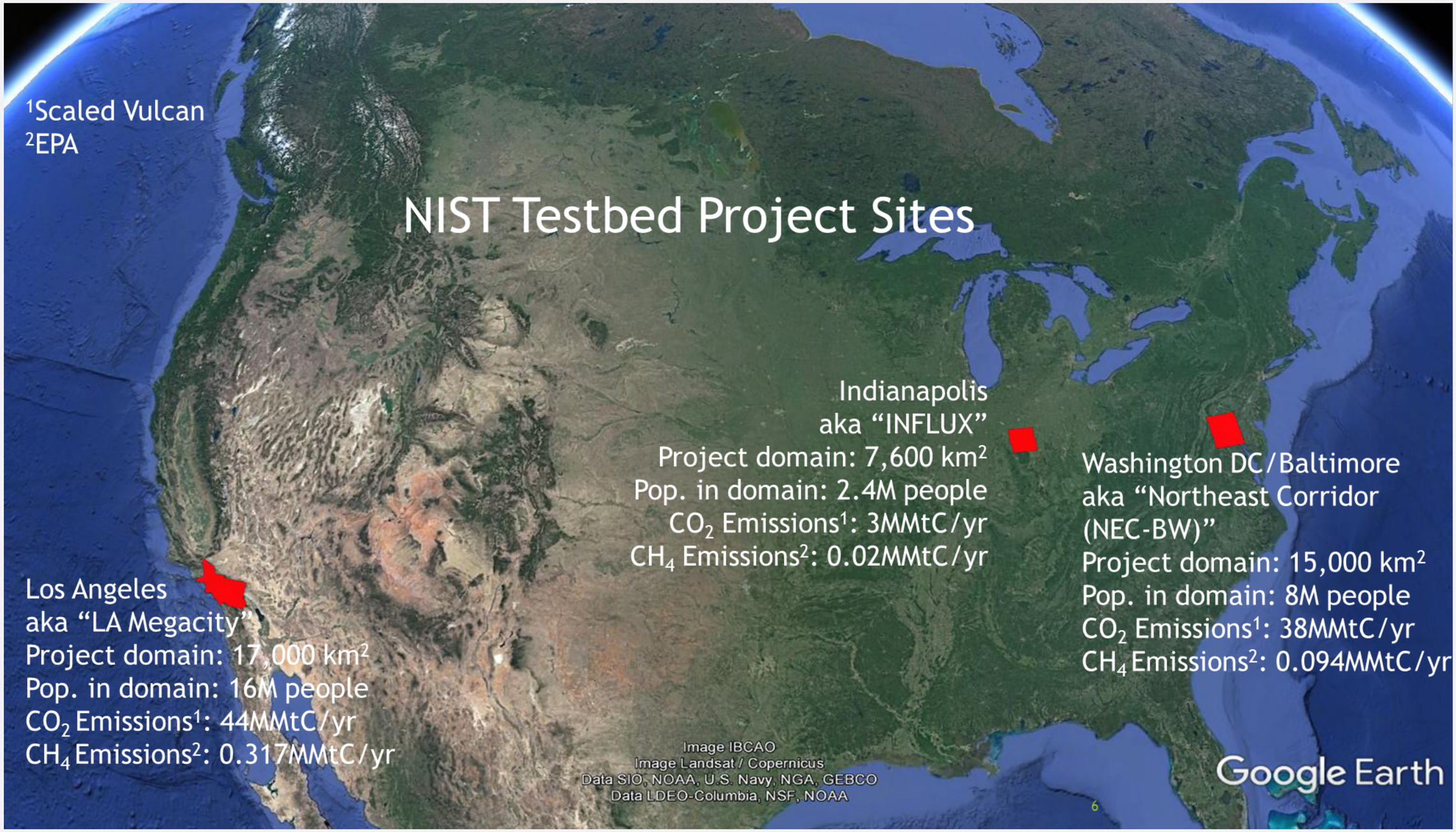
[1]Rayner et al. (2010), Asefi-Najafabady et al. (2014)
[2]Oda et al. (2017)
[3]Gurney et al. (2009)
[4]Gurney et al. (in prep.)
[5]Maasakkers et al. (2016)
[6]Jeong et al. (2012a)
[7]Gately et al. (2017)

[8]Newman et al. (2016)
[9]Gurney et al. (2012)
[10]Gurney et al. (in prep)
[11]Patarasuk et al. (2016)
[12]Turner et al. (2016)
[13]Hopkins et al. (in review)

Data Expansion
ex. meteorological models



Urban “Testbeds” → city laboratories
ex. NIST Urban Testbed sites



Urban "Testbeds"
principal investigators

INFLUX

Ken Davis
Penn State University

Thomas Lauvaux
Penn State University

Paul Shepson
Purdue University

Jocelyn Turnbull
CU/NOAA/GNS

LA Megacity

Riley Duren
JPL

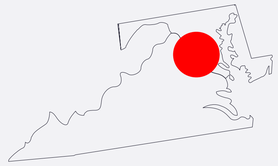
Chip Miller
JPL

Ralph Keeling
SIO

Ray Weiss
SIO

Kevin Gurney
Arizona State University

NEC-BW

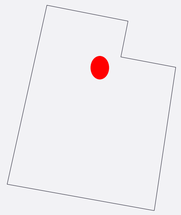


Anna Karion
NIST

Russ Dickerson
University of Maryland

Urban “Testbeds”
principal investigators

Salt Lake City



John Lin

University of Utah

Jim Ehleringer

University of Utah

Kevin Gurney

Arizona State University

Boston

Lucy Hutyra

Boston University

Steve Wofsy

Harvard University

Thomas Nehrkorn

AER

San Francisco

Ron Cohen

University of California Berkeley

Urban "Testbeds"
project teams

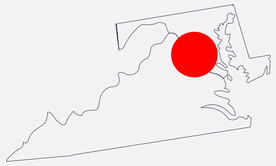
INFLUX

- **Institutions:**
  - Penn State University
  - Purdue University
  - U. Colorado/CIRES
  - Earth Networks
  - Arizona State University
  - NOAA – ESRL
  - Washington State University
  - Boston University
- **Funding: NIST, NOAA**

LA Megacity

- **Institutions:**
  - NASA - JPL
  - Scripps Inst. of Oceanography (SIO), University of California - San Diego
  - Earth Networks
  - California Institute of Technology (CalTech)
  - California Air Resource Board (CARB)
  - NOAA - ESRL
  - Arizona State University
  - University of California – Riverside, Southern California AQMD
  - University of Michigan
  - Lawrence Berkeley National Lab (LBNL)
  - University of California - Irvine
  - Atmospheric Environmental Research (AER)
- **Funding: NIST, NASA, NOAA, CARB, & Keck Institute for Space Sciences**

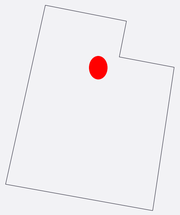
NEC-BW



- **Institutions:**
  - University of Maryland
  - Earth Networks
  - NOAA – ARL & ESRL
  - Arizona State University
  - Boston University
  - Purdue University
  - Maryland Department of the Environment (MDE)
  - University of Michigan
- **Funding: NIST, NOAA, MDE**

Urban “Testbeds” project teams

Salt Lake City



- **Institutions:**
  - University of Utah
  - Arizona State University
- **Funding: NSF, DOE, NOAA**

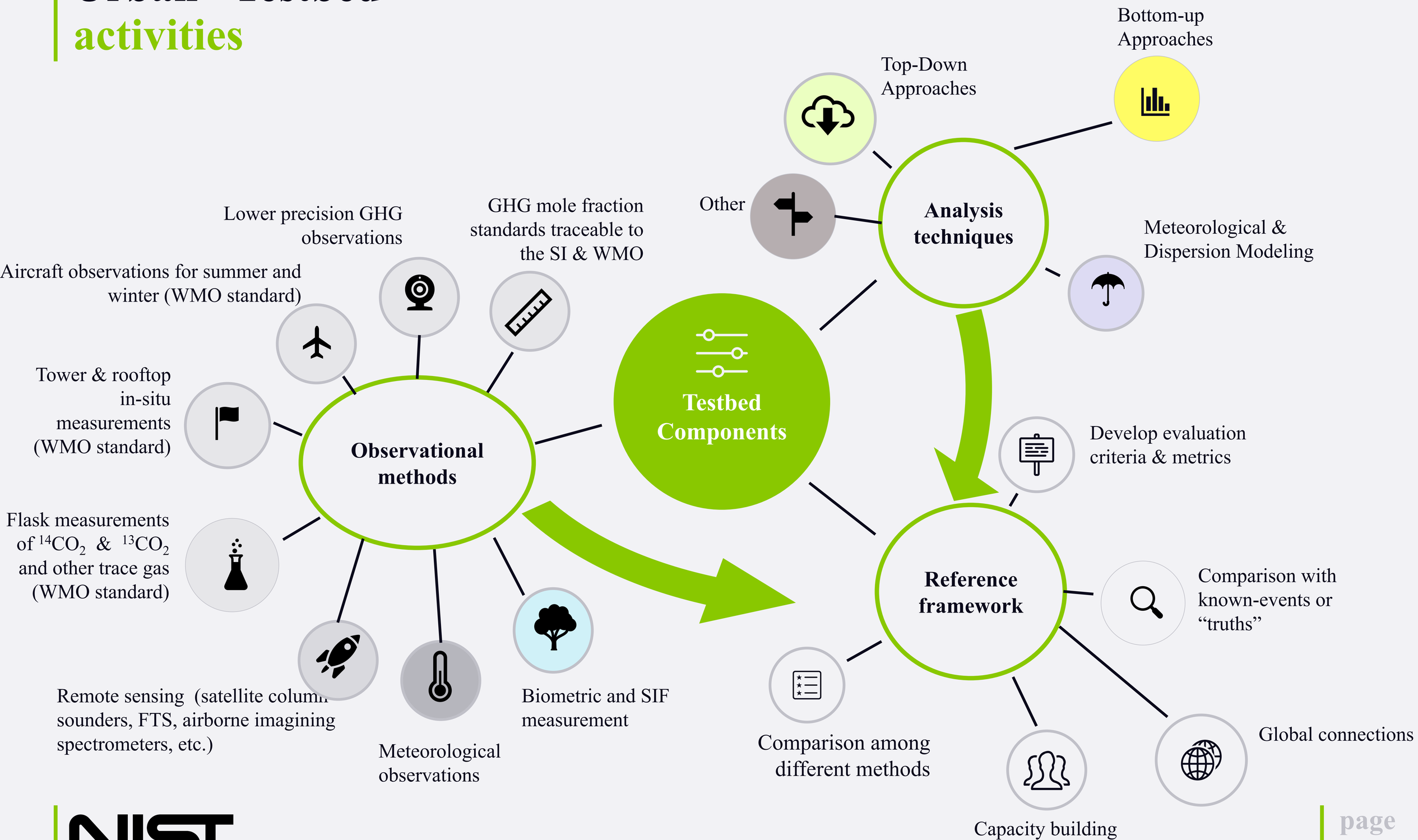
Boston

- **Institutions:**
  - Boston University
  - Harvard University
  - Atmospheric Environmental Research (AER)
  - University of Massachusetts (Boston)
- **Funding: Boston University, Harvard University, NSF, NASA, NOAA**

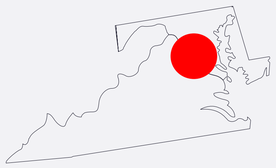
San Francisco

- **Institutions:**
  - University of California - Berkeley
- **Funding: NSF, UC- Berkeley, Koret Foundation, BAAQMD**

Urban “Testbed” activities



Overcoming Challenges
ex. analysis domains



Differences in time, spatial extent, etc. How to reconcile?

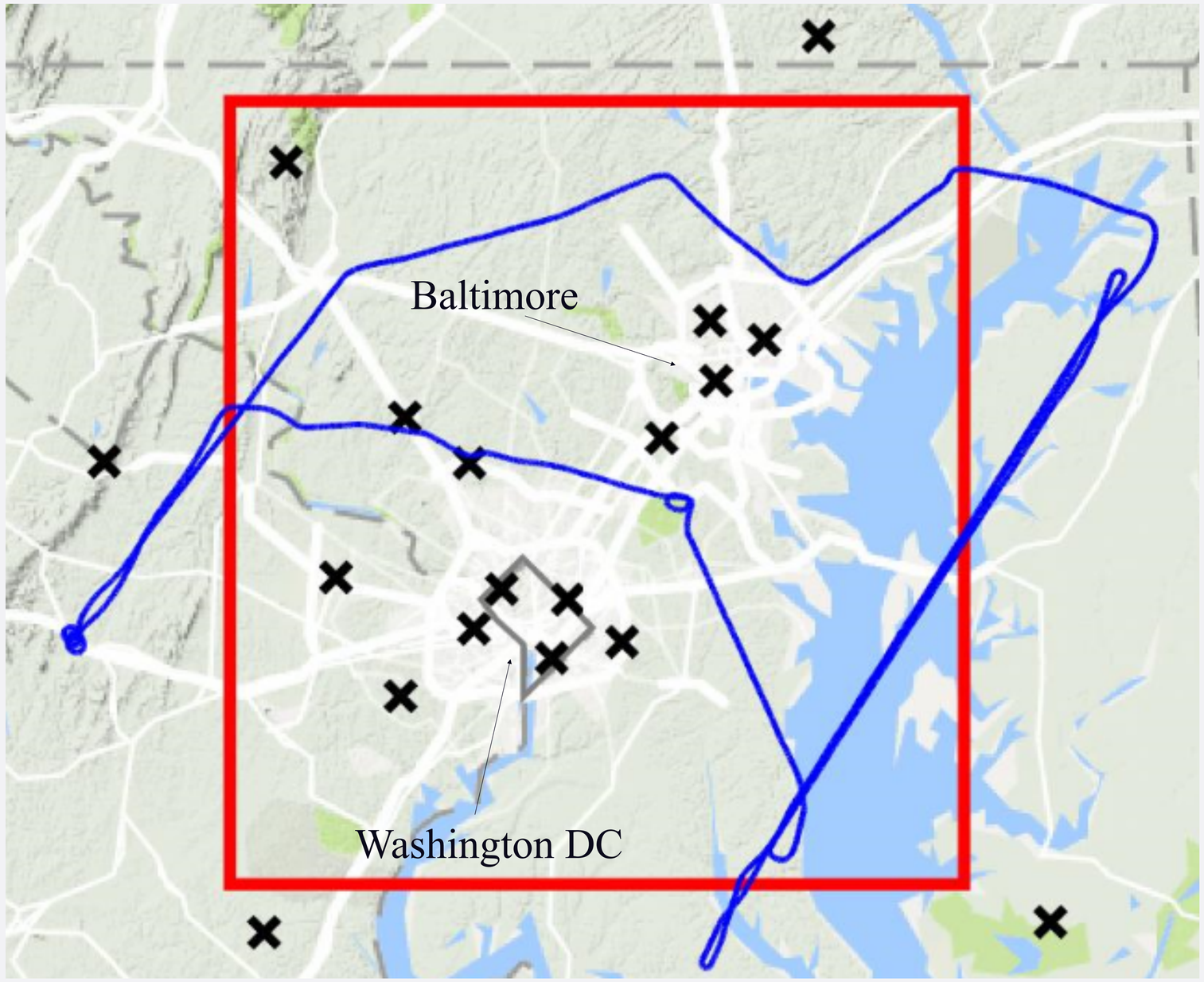
Legend:

Inversion flux domain

In-situ tower locations (planned and installed)

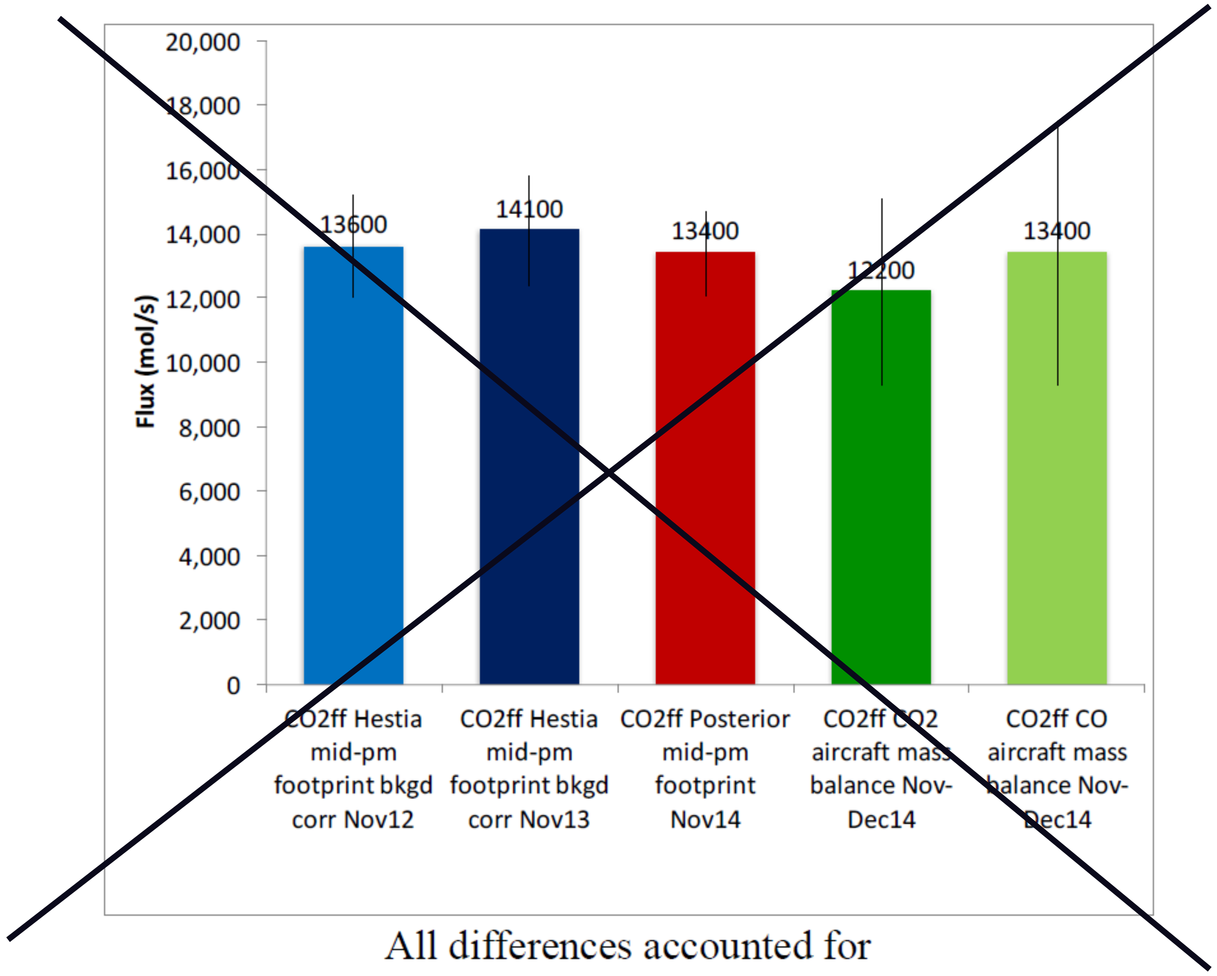
Univ. of Maryland flight track

Mass Balance vs. Inversion Estimation Domains

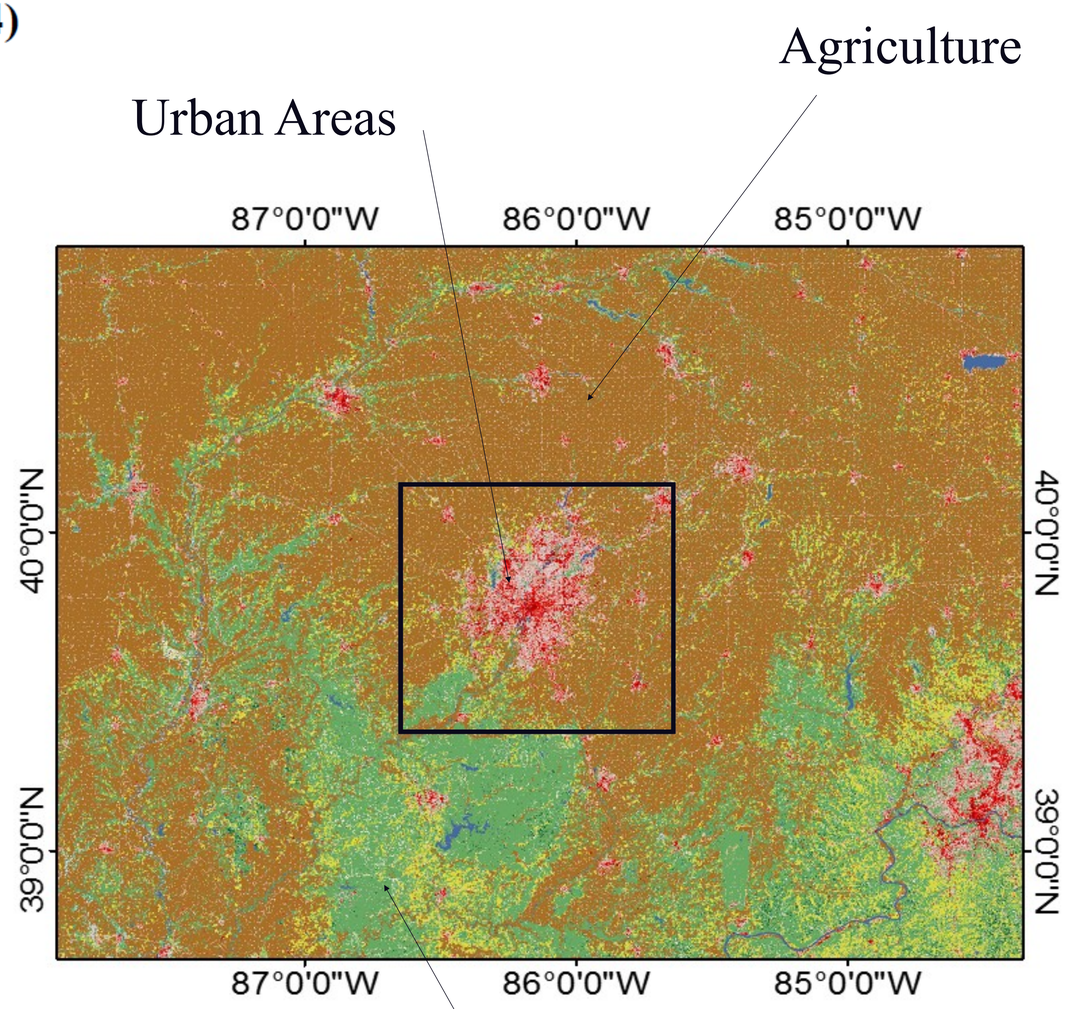


Overcoming Challenges
ex. analysis domains

INFLUX Inversion System: Evaluation / Comparison (November 2014)



All differences accounted for
Excellent agreement across top-down and bottom-up methods



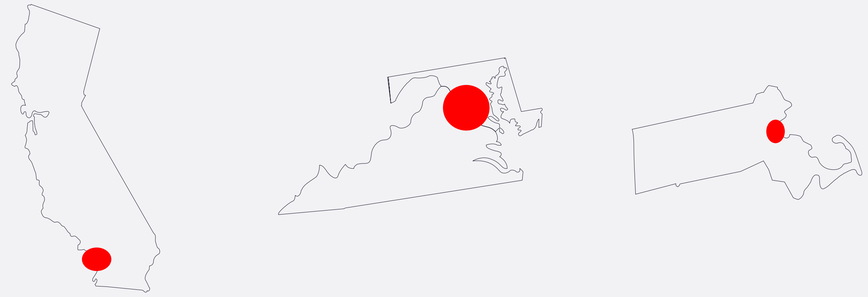
Total Flux: 13,300 mols/s ±6%

Turnbull et al., in prep.

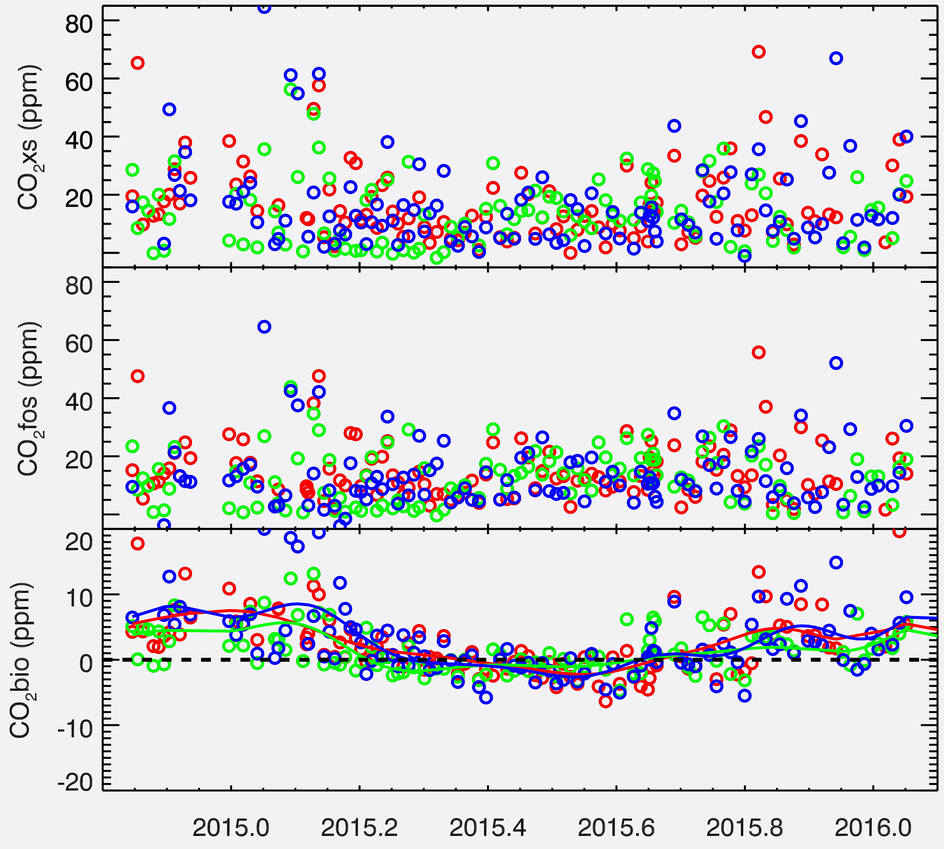
Winter

Summer?
(active biosphere makes things challenging)

Overcoming Challenges
ex. understanding urban biosphere



Top Down:

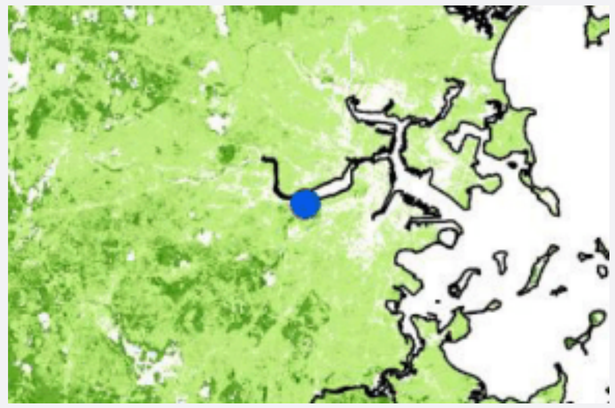


In Los Angeles, biospheric contribution to total CO_2 is substantial

(Miller et al., in prep)

Bottom Up

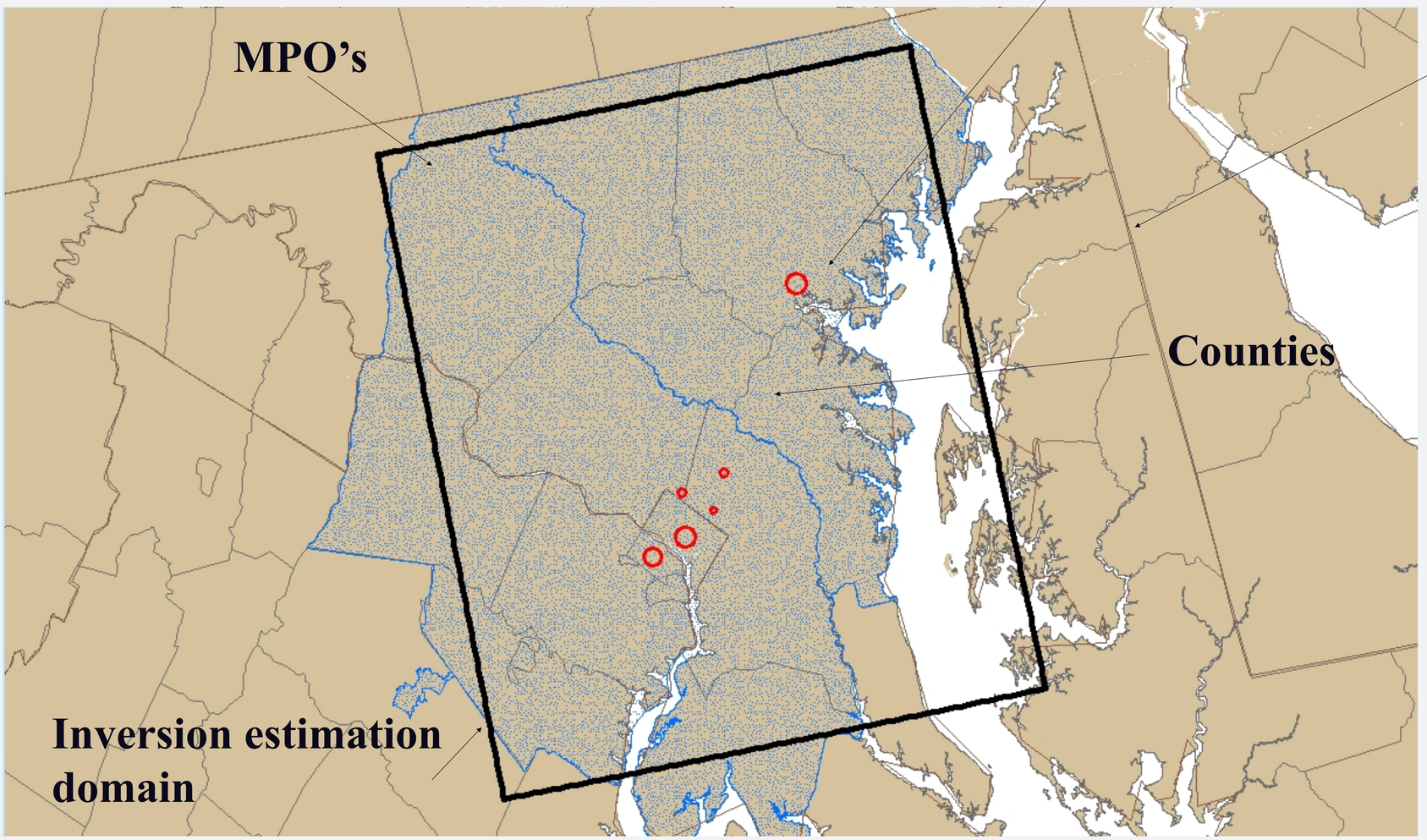
Respiration and photosynthesis operate differently in urban biosphere



Build modified urban biosphere models

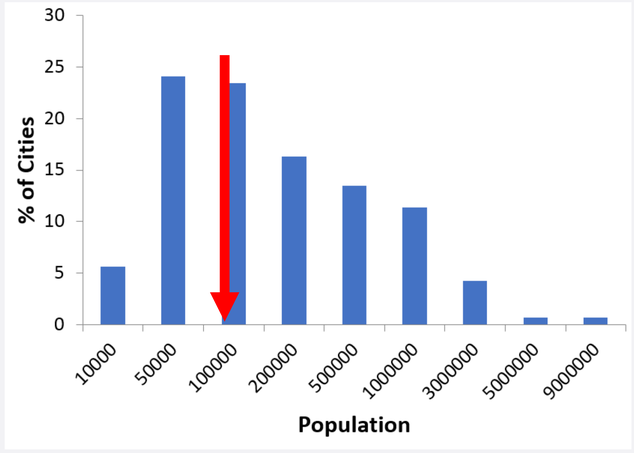
(Decina et al., 2016)
(Hardiman et al., 2017)

Overcoming Challenges
ex. “value proposition"



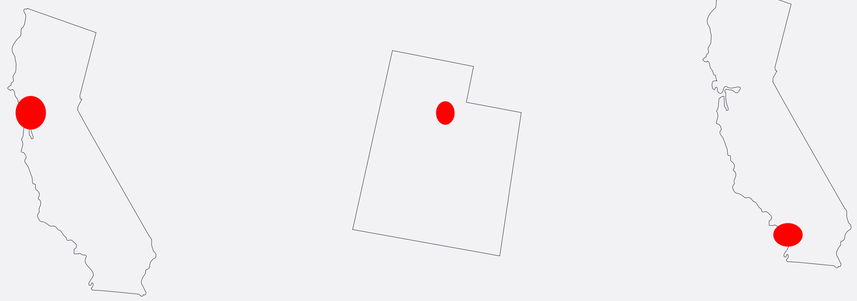
How do we bring our research/knowledge to various stakeholders who represent a variety of scales?

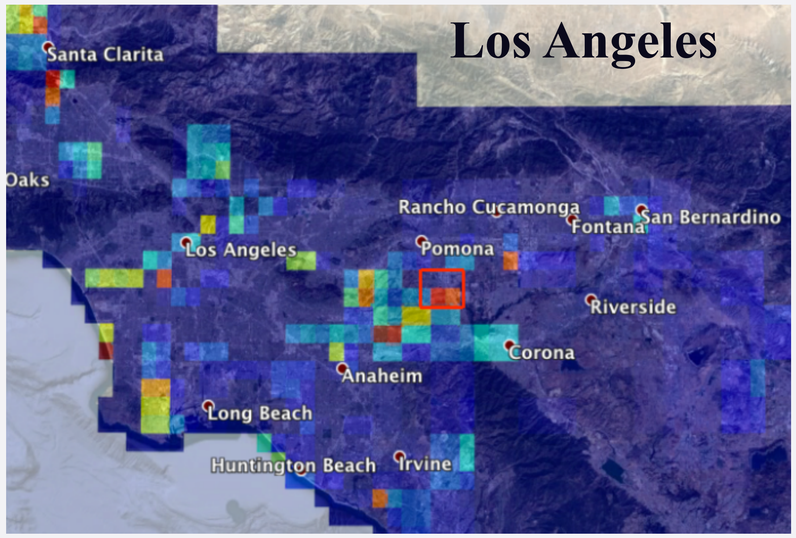
49% of 300 most populated cities in CONUS have emission reduction targets



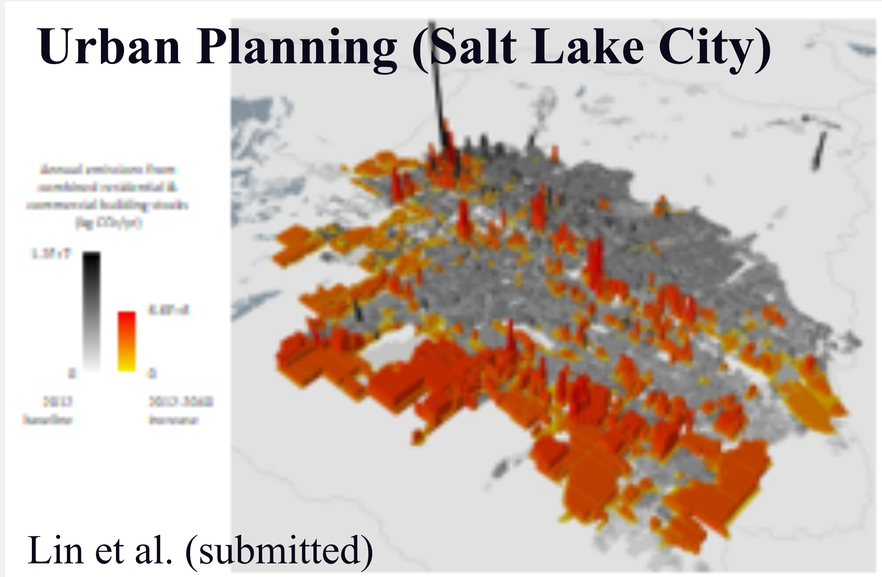
BUT median size of city with climate pledge is approx. 100K people!

Overcoming Challenges
ex. “value proposition"

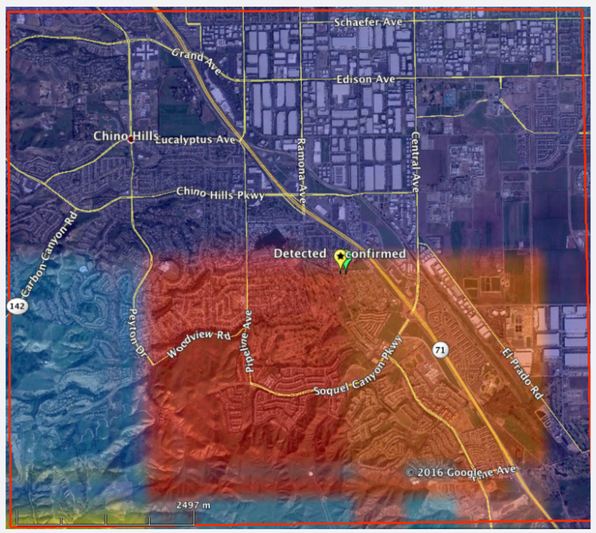




Pipeline Repair
LA Megacities Project

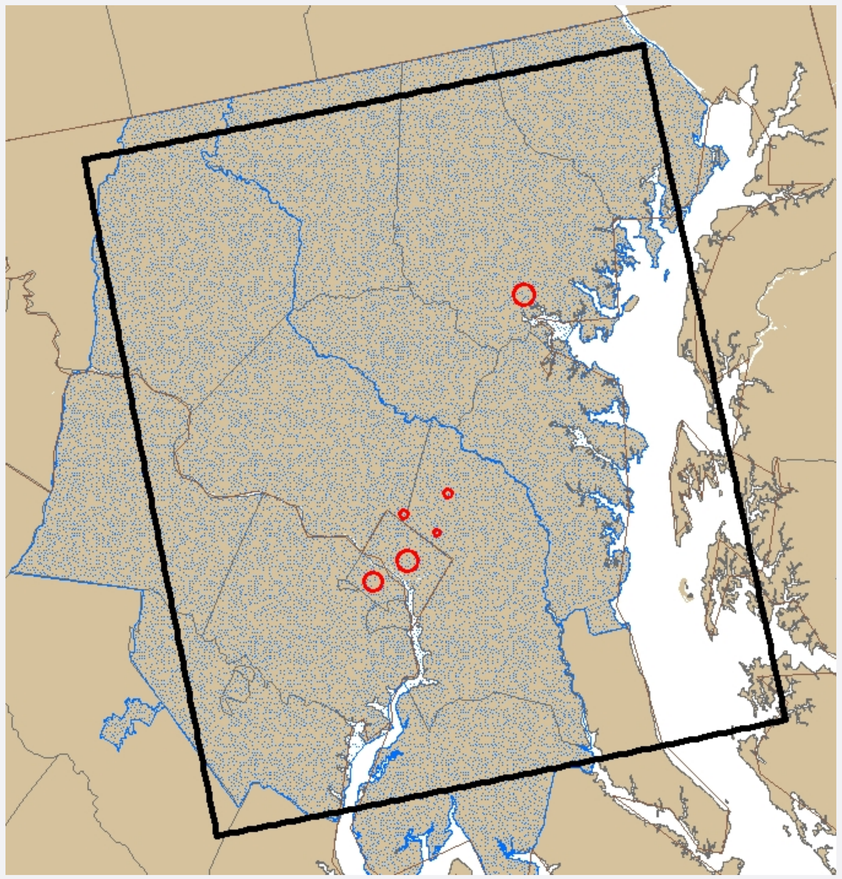


Lin et al. (submitted)



Sometimes a number starts a conversation (L. Sugar) …

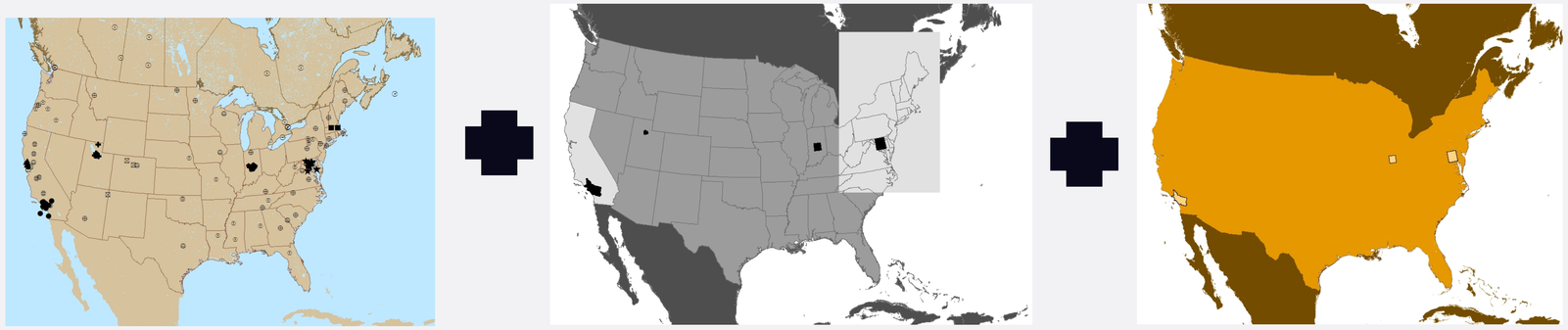
Remaining Challenge
ex. “value proposition"



Integrate from very “local” → city → “urban” → “regional” → US contiguous → continental?

Opportunities:

(1) Information: Observations, methods, etc.



(2) Stakeholders: States, cities, schools, citizen groups, industry, etc.

(3) Participants: U.S. Federal, states, research institutions, private sector (make sure to mention PG&E control release), international (?), etc.

Expand? Think about representative cities. What we will learn from the investment and what will be the value from the effort?

Urban “Testbed”
concluding remarks

- Still far from a mature field ....
- Collaborating, coordinating, and leveraging …
- Developing science, technology, and application in a rapidly changing landscape;
- Learning to find the value of our work to better interact with stakeholders;
- Method challenges;
  - How accurate do our models need to be?
  - Accounting for biosphere?
  - Representing background?
  - Defining “urban” and boundaries?
  - Etc.
- Taking advantage of lessons learned
- Expand to other cities?

Urban "Testbed"
papers

Indianapolis (INFLUX)

Elementa (as part of the Special Feature "Quantification of urban greenhouse gas emissions: The Indianapolis Flux experiment")

Turnbull et al., (in prep), Reconciling CO2 emission estimates from different methods in the dormant season for the Indianapolis Flux Experiment (INFLUX)

Lauvaux et al., (in prep), Multi-year high resolution atmospheric inversion of urban CO2 emissions of the Indianapolis Flux Experiment (INFLUX)

Gurney, K., J. Kiang, R. Patarasuk, D. O'Keefe, J. Huang, M. Hutchins, T. Lauvaux, J. Turnbull, P.B. Shepson (2017) Reconciling the differences between a bottom-up and inverse-estimated $FFCO_2$ emissions estimate in a large US urban area, Elem Sci Anth, 5: 44.

Heimburger, A.M.F., R.M. Harvey, P.B. Shepson, B.H. Stirm, C. Gore, J. Turnbull, M.O.L. Cambaliza, O.E. Salmon, A.-E.M. Kerlo, T.N. Lavoie, K.J. Davis, T. Lauvaux, A. Karion, C. Sweeney, W.A. Brewer, R.M. Hardesty, K.R. Gurney (2017) Assessing the optimized precision of the aircraft mass balance method for measurement of urban greenhouse gas emission rates through averaging. Elem Sci Anth, 5: 26

Lamb, B., M.O. Cambaliza, K. Davis, S. Edburg, T. Ferrara, C. Floerchinger, A. Heimburger, S. Herndon, T. Lavoie, T. Lauvaux, D. Lyon, N. Miles, K. Prasad, S. Richardson, J. Roscioli, O. Salmon, P. Shepson, B. Stirm, J. Whetstone (2016) Direct and indirect measurements and modeling of methane emissions in Indianapolis, IN, Environ. Sci. Technol., **50**(16), 8910–8917

Lauvaux, T., N.L. Miles, A. Deng, S.J. Richardson, M.O. Cambaliza, K.J. Davis, B. Gaudet, K.R. Gurney, J. Huang, D. O'Keeffe, Y. Song, A. Karion, T. Oda, R. Patarasuk, D. Sarmiento, P. Shepson, C. Sweeney, J. Turnbull, and K. Wu (2016) High resolution atmospheric inversion of urban CO2 emissions during the dormant season of the Indianapolis Flux Experiment (INFLUX), J. Geophys. Res., 121.

Turnbull, J. C., A. Zondervan, J. Kaiser, M. Norris, J. Dahl, W.T. Baisden, and S.J. Lehman: High-precision atmospheric 14CO2 measurement at the Rafter Radiocarbon Laboratory, Radiocarbon (2015), 57(3): 377 – 388.

Turnbull, J., C. Sweeney, A. Karion, T. Newberger, P. Tans, S. Lehman, K.J. Davis, N.L. Miles, S.J. Richardson, T. Lauvaux, M.O. Cambaliza, P. Shepson, K. Gurney, R. Patarasuk, A. Zondervan (2015) Towards quantification and source sector identification of fossil fuel CO_2 emissions from an urban area: Results from the INFLUX experiment. J. Geophys. Res. Atmos.

Cambaliza, M.O.L., P.B. Shepson, J. Bogner, D.R. Caulton, B. Stirm, C. Sweeney, S.A. Montzka, K.R. Gurney, K. Spokas, O.E. Salmon, T.N. Lavoie, A. Hendricks, K. Mays, J. Turnbull, B.R. Miller, K. Davis, A. Karion, B. Moser, C. Miller, C. Obermeyer, J. Whetstone, K. Prasad, N. Miles, and S. Richardson (2014) Quantification and source apportionment of the methane emission flux from the city of Indianapolis, Elementa.

Cambaliza, M.O., P.B. Shepson, D. Caulton, B. Stirm, D. Samarov, K. Gurney, J. Turnbull, K.J. Davis, A. Possolo, A. Karion, C. Sweeney, B. Moser, A. Hendricks, T. Lauvaux, K. Mays, J. Whetstone, J. Huang, I. Razlivanov, N. Miles, and S.J. Richardson (2014) Assessment of uncertainties of an aircraft-based mass-balance approach for quantifying urban greenhouse gas emissions. Atmos. Chem. Phys., 14, 9029-9050.

Gurney, K.R., Razlivanov, I., Song, Y. Zhou, Y., Benes, B., M. Abdul-Massih (2012) Quantification of fossil fuel CO_2 at the building/street scale for a large US city, *Environmental Science and Technology*.

Turnbull, J., Guenther, D., Karion, A., Sweeney, C., Anderson, E., Andrews, A., Kofler, J., Miles, N., Newberger, T., Richardson, S., and Tans, P.: An integrated flask sample collection system for greenhouse gas measurements, Atmos. Meas. Tech., 5, 2321-2327, doi:10.5194/amt-5-2321-2012, 2012.

Urban “Testbed” papers

Boston

Decina, S., Templer, P.H., Hutyra, L.R., Gately, C.K., Rao, P. Variability, drivers, and effects of nitrogen deposition across an urban area: emerging patterns among human activities, the atmosphere and soils. Science of the Total Environment, 609: 1524-1534.

Gately, C.K., Hutyra, L.R., Peterson, S., Sue Wing, I. Urban Emissions Hotspots: Quantifying Vehicle Congestion and Air Pollution Using Mobile Phone GPS Data. Environmental Pollution, 229:496-504, 2017.

Hardiman, B., Wang, J., Hutyra, L.R., Gately, C., Getson, J., Friedl, M. Accounting for urban biogenic fluxes in regional carbon budgets. Science of the Total Environment, 592: 366-372, 2017.

Groffman, P.M., Cavender-Bares, J., Childers, D., Grimm, N.B., Grove, M., Hutyra, L.R., Pataki, D., Pickett, S., Pouyat, R., Rosi-Marshall, E., Ruddell, B. Moving towards a new Urban System Science, Ecosystems, 20: 38-43, 2017.

Wang, J.A., Hutyra, L.R., Li, D., Friedl, M.A. Gradients of atmospheric temperature and humidity controlled by local urban land use intensity in Boston. Journal of Applied Meteorology and Climatology, 56: 817-831, 2017.

Reinmann AB and LR Hutyra. Effects of forest fragmentation on carbon storage and uptake in an urbanizing landscape. Proceedings of the National Academy of Sciences of the United States of America, 114(1): 107-112, 2017.

Gurney, K.G., Romero-Lankao, P., Seto, K.C., Hutyra, L.R., Duren, R., Kennedy, C., Grimm, N.B., Ehleringer, J.R., Marcotullio, P., Hughes, S., Pincetl, S., Chester, M.V., Runfola, D.M., Feddema, J.J., Sperling, J. Track urban emissions on human scales. Nature525: 179-181, 2015.

McKain, K., Down, A., Raciti, S., Budney, J., Hutyra, L.R., Floerchinger, C., Herdon, S., Zahniser, M., Nehrkorn, T., Jackson, R.B., Phillips, N., Wofsy, S.C., Methane Emissions from Natural Gas in the Urban Region of Boston, Massachusetts. Proceedings of the National Academy of Sciences of the United States of America 112: 1941-1946, 2015.

Kittredge, D.B., Short, A., Hutyra, L.R., Foster, D.R., Getson, J.M., Landowner conservation awareness across a rural-to-urban gradient. Biological Conservation 184: 79-89, 2015.

Templer, P.H., Toll, J., Hutyra, L.R., Raciti, S.M., Nitrogen and Carbon Export from Urban Areas Through Removal and Export of Litterfall. Environmental Pollution 197: 256-261, 2015.

Rao, P., Hutyra, L.R., Raciti, S.M., Templer, P.H., Atmospheric nitrogen inputs and losses along an urbanization gradient in the Boston metropolitan region. Biogeochemistry121: 229-245, 2014.

Hutyra, L.R., Duren, R., Gurney, K., Grimm, N.B., Kort, E., Larson, E., Shrestha, G., Urbanization and the carbon cycle: Current capabilities and future outlook on observing and modeling urban carbon flows. Earth’s Future, 2(10): 473-495, 2014.

Romero-Lankao, P., Gurney, K., Seto, K.C., Chester, M., Duren, R.M., Hughes, S., Hutyra, L.R., Marcotullio, P., Baker, L., Grimm, N.B., Kennedy, C., Larson, E., Pincetl, S., Runfola, L., Sanches, L., Shrestha, G., Feddema, J.J., Sarzynski, A., Sperling, J., Stokes, E., A critical knowledge pathway to low-carbon, sustainable futures: Integrating understanding of urbanization, urban areas, and carbon. Earth’s Future, 2(10): 515-532, 2014.

Raciti, S.M., Hutyra, L.R., Newell, J.D. Mapping carbon storage in urban trees with multi-source remote sensing data: Relationships between biomass, land use, and demographics in Boston neighborhoods. Science of the Total Environment, 500-501: 73-83, 2014.

Rao, P., Hutyra, L.R., Raciti, S.M., Finzi, A.C., Field and remotely sensed measures of soil and vegetation carbon and nitrogen across an urbanization gradient in the Boston Metropolitan Area. Urban Ecosystems, 16: 593-616, 2013.

Briber, B.M., Hutyra, L.R., Dunn, A.L., Raciti, S.M., Munger, J.W., Variations in atmospheric CO_2 and carbon fluxes across a Boston, MA urban gradient. Land, 2(3): 304-327, 2013.

Gately, C.K., Hutyra, L.R., Sue Wing, I., Brondfield, M.N., A bottom-up approach to on-road CO_2 emissions estimate: Improved spatial accuracy and applications for regional planning. Environmental Science and Technology, 47(5), 2423–2430, 2013.

Phillips, N.G., Ackley, R. Crosson, E.R., Down, A., Hutyra, L.R., Brondfield, M., Karr, J.D., Zhao, K., Jackson, R.B., Mapping urban pipeline leaks: methane leaks across Boston. Environmental Pollution, 173: 1-4, 2013.

Seto, K.C., B. Güneralp, Hutyra, L.R., Global Forecasts of Urban Expansion to 2030 and Impacts on Biodiversity and Carbon Pools. Proceedings of the National Academy of Sciences of the United States of America, 109 (40): 16083-16088, 2012.

Brondfield, M.N., Hutyra, L.R., Gately, C., Raciti, S.M., Peterson, S.A. Modeling and validation of on-road CO_2 emissions inventories at the urban regional scale. Environmental Pollution, 170: 113-123, 2012.

Raciti, S.M., Hutyra, L.R., Rao, P., Finzi, A.C., Inconsistent definitions of “urban” result in different conclusions about the size of carbon and nitrogen stocks. Ecological Applications 22(3): 1015-1035, 2012.

Urban “Testbed” papers

Los Angeles (LA Megacities)

Yadav et. al (in prep)

Miller, J. et al. (in prep) Biospheric signature from Los Angeles as inferred by detla C14 observations.

Liyin, H., Z. Zeng, T. Pongetti, C. Wong, R.L. Shia, Y. Yung, S. Sander(in prep) Top-Down Attribution of Methane Emissions in the Los Angeles basin Using Remote Sensing Observations from CLARS

Gourdji, S., V. Yadav, A. Karion, K. Mueller, S. Conley, T. Ryerson, T. Nehrkorn, E.A. Kort, (submitted) Reducing the impact of transport model error in urban greenhouse gas inversion models using the Aliso Canyon natural gas leak as a natural tracer experiment, Environmental Research Letters.

Verhulst, K. R., Karion, A., Kim, J., Salameh, P. K., Keeling, R. F., Newman, S., Miller, J., Sloop, C., Pongetti, T., Rao, P., Wong, C., Hopkins, F. M., Yadav, V., Weiss, R. F., Duren, R. M., and Miller, C. E. (2017). Carbon dioxide and methane measurements from the Los Angeles Megacity Carbon Project – Part 1: calibration, urban enhancements, and uncertainty estimates, Atmos. Chem. Phys., 17, 8313-8341.

Viatte, C., Lauvaux, T., Hedelius, J. K., Parker, H., Chen, J., Jones, T., Franklin, J. E., Deng, A. J., Gaudet, B., Verhulst, K., Duren, R., Wunch, D., Roehl, C., Dubey, M. K., Wofsy, S., and Wennberg, P. O. (2017): Methane emissions from dairies in the Los Angeles Basin, Atmos. Chem. Phys., 17, 7509-7528, doi: 10.5194/acp-17-7509-2017. Ware, J., E. Kort, P. Decola, R. Duren (2016), Aerosol Lidar Observations of Atmospheric Mixing in Los Angeles: Climatology and Implications for Greenhouse Gas Observations, J. Geophys Res – A.

Newman, S., Xu, X., Gurney, K. R., Hsu, Y. K., Li, K. F., Jiang, X., Keeling, R., Feng, S., O'Keefe, D., Patarasuk, R., Wong, K. W., Rao, P., Fischer, M. L., and Yung, Y. L. (2016). Toward consistency between trends in bottom-up CO2 emissions and top-down atmospheric measurements in the Los Angeles megacity, Atmos. Chem. Phys., 16, 3843-3863,

Hopkins, F.M., S.E. Bush, J.R. Ehleringer, C.T. Lai, E.A. Kort, D.R. Blake, J.T. Randerson (2016). Spatial patterns and source attribution of urban methane in the Los Angeles Basin. J. Geophys Res- A.

Wong, K. W., Pongetti, T. J., Oda, T., Rao, P., Gurney, Kevin. R., Newman, S., Duren, R. M., Miller, C. E., Yung, Y. L., and Sander, S. P.: Monthly trends of methane emissions in Los Angeles

San Francisco

A.A. Shusterman, V. Teige, A.J. Turner, C. Newman, J. Kim, and R.C. Cohen (2016) The BErkeley Atmospheric CO_2 Observation Network: initial evaluation, Atmos. Chem. Phys.

A.J. Turner, A.A. Shusterman, B.C. McDonald, V. Teige, R.A. Harley and R.C. Cohen (2016), Network design for quantifying urban CO_2 emissions: Assessing tradeoffs between precision and network density, Atmos. Chem. Phys.

J. Kim, A.A. Shusterman, K.J. Lieschke, C. Newman and R.C. Cohen (2017) The BErkeley Atmospheric CO2 Observation Network: Field calibration and evaluation of low-cost air quality sensors, Atmos. Meas. Tech. Disc.

Urban “Testbed” papers

Washington DC, Baltimore (NEC-B/w)

Lopez-Coto, I., S. Ghosh, K. Prasad and J. Whetstone (2017) Tower-based greenhouse gas measurement network design—The National Institute of Standards and Technology North East Corridor Testbed. Advances in Atmospheric Sciences 34(9): 1095-1105.

Martin, C. R., N. Zeng, A. Karion, R.R. Dickerson, X. Ren, B.N. Turpie, and K.J. Weber (2017) Evaluation and environmental correction of ambient CO_2 measurements from a low-cost NDIR sensor, Atmos. Meas. Tech., 10, 2383-2395

Mueller K., V. Yadav, I. Lopez-Coto, A. Karion, S. Gourdji, C. Martin, J. Whetstone (in review) Siting background towers to characterize incoming air for urban GHG estimation: a case study in the Washington DC/Baltimore Area, Journal of Geophysical Research – Atmospheres.

Martin, C. N. Zheng, A. Karion, S. Ghosh, I. Lopez-Coto, K. Mueller, K. Gurney, T. Oda, K. Prasad, Y. Liu, R.R. Dickerson, and J. Whetstone (in prep) Evaluation of WRF-Chem Simulated Carbon Dioxide Transport and Emissions in the Baltimore/Washington Metropolitan Area.

Ahn, D. (in prep) Emissions of Carbon Dioxide from the Washington DC-Baltimore area: Results from FLAGG-MD aircraft campaign.

Salt Lake City

Bush, S. E., D. E. Pataki, and J. R. Ehleringer (2007), Sources of variation in delta C-13 of fossil fuel emissions in Salt Lake City, USA, Appl. Geochemistry, 22(4), 715–723.

Lin, J. C. et al. (n.d.), CO2 and carbon emissions from cities: linkages to air quality, socioeconomic activity and stakeholders in the Salt Lake City urban area, Bull. Am. Meteorol. Soc., Submitted.

McKain, K., S. C. Wofsy, T. Nehrkorn, J. Eluszkiewicz, and J. Ehleringer (2012), Assessment of ground-based atmospheric observations for verification of greenhouse gas emissions from an urban region, Proc. Natl. Acad. Sci., 109(22), 8423–8428.

Mitchell, L. E. et al. (n.d.), Long-term urban carbon dioxide observations reveal spatial and temporal dynamics related to urban form and growth, Proc. Natl. Acad. Sci., In Review.

Nehrkorn, T., J. Henderson, M. Leidner, M. Mountain, J. Eluszkiewicz, K. McKain, and S. Wofsy (2012), WRF Simulations of the Urban Circulation in the Salt Lake City Area for CO2 Modeling, J. Appl. Meteorol. Climatol., 52(2), 323–340, doi:10.1175/JAMC-D-12-061.1.

Pataki, D. E., D. R. Bowling, and J. R. Ehleringer (2003), Seasonal cycle of carbon dioxide and its isotopic composition in an urban atmosphere: Anthropogenic and biogenic effects, J. Geophys. Res., 108(D23), 4735, doi:10.1029/2003JD003865–4735, doi:10.1029/2.

Pataki, D. E., B. J. Tyler, R. E. Peterson, A. P. Nair, W. J. Steenburgh, and E. R. Pardyjak (2005), Can carbon dioxide be used as a tracer of urban atmospheric transport?, J. Geophys. Res., 110(D15).

Pataki, D. E., D. R. Bowling, J. R. Ehleringer, and J. M. Zobitz (2006), High resolution atmospheric monitoring of urban carbon dioxide sources, Geophys. Res. Lett., 33(L03813), doi:10.1029/225GL024822.

Patarasuk, R., K. R. Gurney, D. O’Keeffe, Y. Song, J. Huang, P. Rao, M. Buchert, J. C. Lin, D. Mendoza, and J. R. Ehleringer (2016), Urban high-resolution fossil fuel CO2 emissions quantification and exploration of emission drivers for potential policy applications, Urban Ecosyst., 1–27, doi:10.1007/s11252-016-0553-1.

Strong, C., C. Stwertka, D. R. Bowling, B. B. Stephens, and J. R. Ehleringer (2011), Urban carbon dioxide cycles within the Salt Lake Valley: A multiple-box model validated by observations, J. Geophys. Res., 116(D15), D15307, doi:10.1029/2011JD015693.