Understanding Urban Carbon Flux Quantification Information Systems

SOCCR2 and beyond

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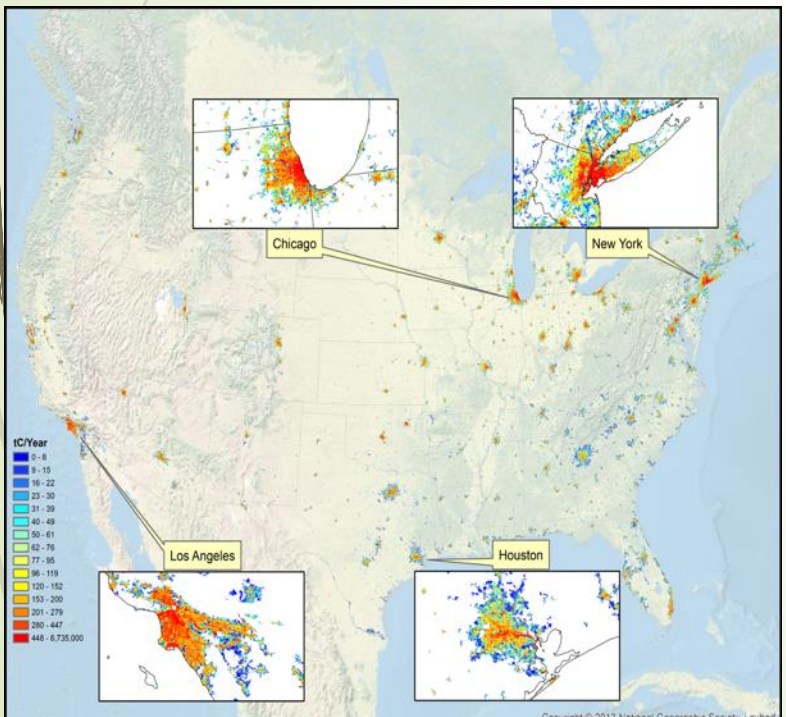
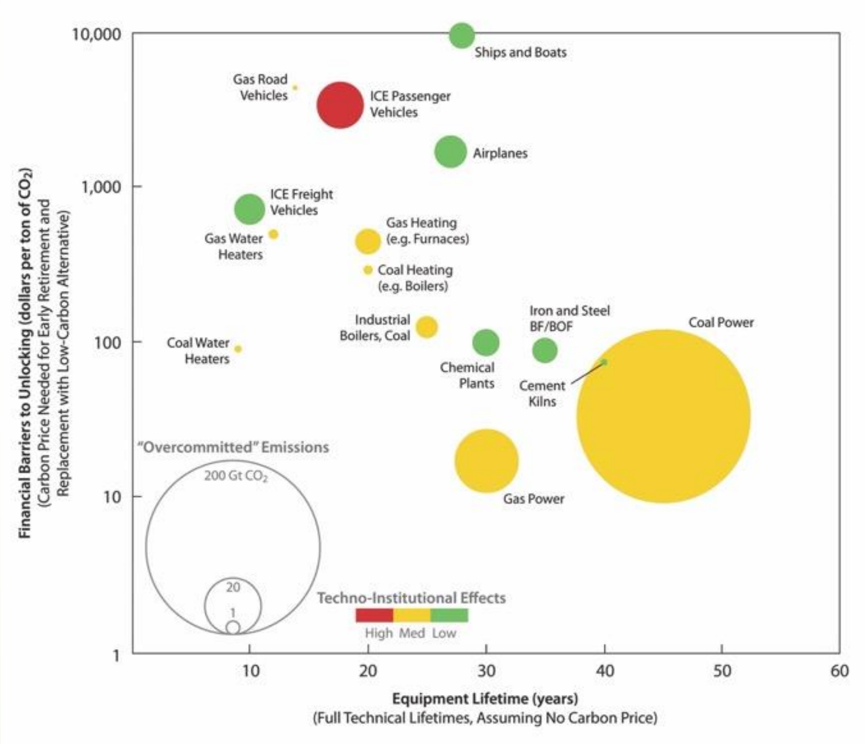
The Urban Share

- Urban areas in North America are the **<u>primary source</u>** of anthropogenic carbon emissions, with cities responsible for a large proportion of ***direct*** emissions. These areas are also ***indirect sources*** of carbon through the emissions embedded in goods and services produced outside city boundaries for consumption by urban dwellers (medium confidence, likely).



Emission “drivers”

Many **<u>societal factors</u>** drive urban carbon emissions, but the **urban built environment** and the regulations and policies shaping **urban form** (e.g., land-use) and **technology** (e.g., modes of transportation) play crucial roles. Such societal drivers can ***lock in*** dependence on fossil fuels in the absence of major technological, institutional, and behavioral change. Some fossil fuel–related infrastructure can have lifetimes up to 50 years (high confidence).



Key Findings continued

- Key <u>**challenges**</u> for urban carbon flux studies are ***observational design***, ***integration***, ***uncertainty*** quantification, and ***reconciliation*** of the multiple carbon flux approaches to detect trends and inform emissions mitigation efforts (medium confidence, likely).
- Improvements in **air quality** and **human health** and the reduction of the **urban heat island** are important **co-benefits** of urban carbon emissions mitigation (very likely, high confidence).

Key Findings continued

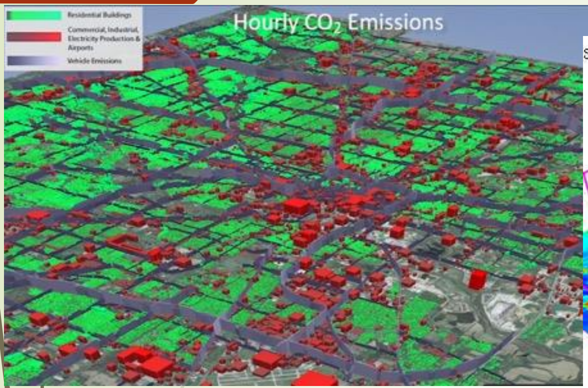
- Urban **methane** (CH_4) emissions have been poorly characterized, but the combination of **improved instrumentation, modeling tools, and heightened interest** in the problem is defining the range of emissions rates and source composition as well as highlighting infrastructure characteristics that affect CH_4 emissions (medium confidence).
- Urban areas are important sites for policy- and decision making that shape carbon fluxes and mitigation. However, cities also are **constrained** by other **levels of government**, variations in their sources of **authority and autonomy**, capacity, competing **local priorities**, and available fiscal **resources** (high confidence).

Ongoing work in many NA cities

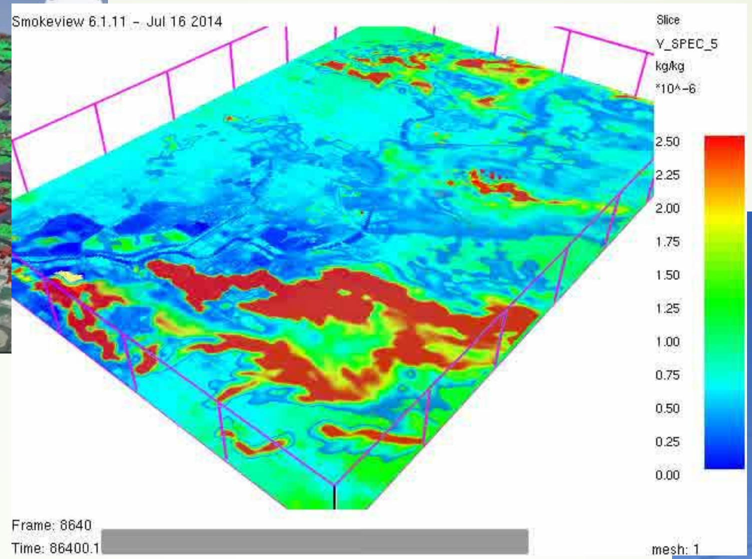
Table 4.1. Scientifically Based Urban Carbon Estimation Studies in North American Cities

Domain	Framework, Scope, Boundary[a]	Estimation Technique[b]	Sectors Estimated[c]	References	Notes[d]
Indianapolis, IN	In-boundary	Direct flux, activity-EF, and fuel statistics; airborne eddy flux measurement; isotopic atmospheric measurement; tmospheric inversion	All FF	Cambaliza et al. (2014); Gurney et al. (2012, 2017); Lauvaux et al. (2016); Turnbull et al. (2015)	Much of the work is space and time explicit; atmospheric monitoring includes $^{14}CO_2$, CO, and CH_4
Toronto, Canada	Life cycle (scopes 1, 2)	Activity-EF	Residential	Kennedy et al. (2009); VandeWeghe and Kennedy (2007)	Annual and census tract
Los Angeles, CA	In-boundary; embedded in buildings	Atmospheric measurement; activity-EF	All FF; on-road transportation; buildings	Feng et al. (2016); Kort et al. (2012); Newman et al. (2016); Pincetl et al. (2014); Porse et al. (2016); Reyna and Chester (2015); Wong et al. (2016); Wunch et al. (2009)	Some work is space and time explicit; atmospheric monitoring includes $^{14}CO_2$, CO, and CH_4
Salt Lake City, UT	In-boundary; consumption	Atmospheric measurement; direct flux, activity-EF, and fuel statistics; forest growth modeling and eddy flux measurement	All FF; biosphere	Kennedy et al. (2009); McKain et al. (2012); Pataki et al. (2006, 2009); Patarasuk et al. (2016)	Some work is space and time explicit
Baltimore, MD	In-boundary	Eddy flux measurement	All FF; biosphere	Crawford et al. (2011)	
Denver, Boulder, Fort Collins, and Arvada, CO; Portland, OR; Seattle, WA; Minneapolis, MN; Austin, TX	Hybrid life cycle (scopes 1, 2, 3)	Activity-EF	All FF	Hillman and Ramaswami (2010)	Addition of scope 3 emissions increased total footprint by 47%
New York City, NY; Denver; Los Angeles; Toronto; Chicago, IL	Scopes 1, 2, 3	Activity-EF, fuel statistics, and downscaling	Excludes some scope 3 emissions	Kennedy et al. (2009, 2010, 2014)	
Boston, MA; Seattle; New York City; Toronto	Scope 1, 2 (some scope 3 included); scope 1 in lowland area	Activity-EF, fuel statistics and downscaling; flux chambers and remote sensing	Excludes some sectors; biosphere carbon stock change	Hutyra et al. (2011); Kennedy et al. (2012)	
Boston	In-boundary	Activity-EF; atmospheric monitoring; atmospheric monitoring and inversion	Onroad; pipeline leak; biosphere respiration	Brondfield et al. (2012); Decina et al. (2016); McKain et al. (2015); Phillips et al. (2013)	Some work is space and time explicit; includes some CH_4
Washington, D.C.; New York City; Toronto	Scope 1	Activity-EF and fuel statistics	All greenhouse gases	Dodman (2009)	Mixture of methods from multiple sources
Chicago				Grimmond et al. (2002)	
Mexico City	In-boundary	Eddy flux measurement; Activity-EF	All FF, biosphere; onroad	Chavez-Baeza and Sheinbaum-Pardo (2014); Velasco and Roth (2010); Velasco et al. (2005, 2009)	Footprint of single monitoring location; whole-city inventory
Halifax, Canada	Scope 1, 2	Activity-EF	Buildings, transportation	Wilson et al. (2013)	Spatially explicit
Pittsburgh, PA	Scope 1, 2	Activity-EF, fuel statistics, and downscaling	Residential, commercial, industrial, and transportation	Hoesly et al. (2012)	
Phoenix, AZ	In-boundary	Activity-EF and soil chamber	Onroad, electricity production, airport and aircraft	Koerner and Klopatek (2002)	
Vancouver, Canada	In-boundary	Eddy flux measurement	All FF, biosphere	Crawford and Christen (2014)	
Vancouver, Edmonton, Winnipeg, Toronto, Montreal, and Halifax, Canada	Scopes 1, 2	Activity-EF	Residential building stock	Mohareb and Mohareb (2014)	
20 U.S. cities	In-boundary; consumption; hybrid	Activity-EF	All energy related	Ramaswami and Chavez (2013)	

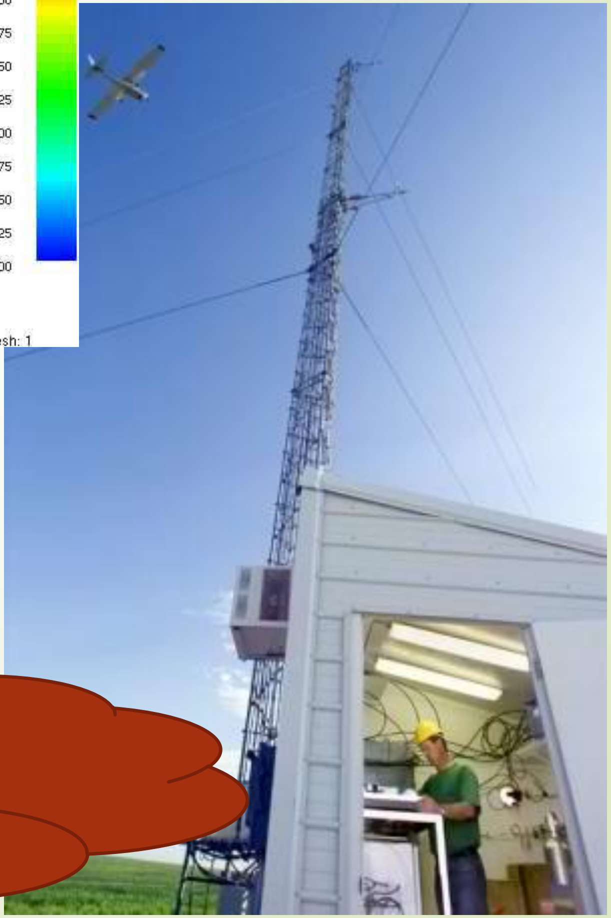
Urban emission quantification architecture



Gurney et al., *Env. Sci. & Tech.*, 2012



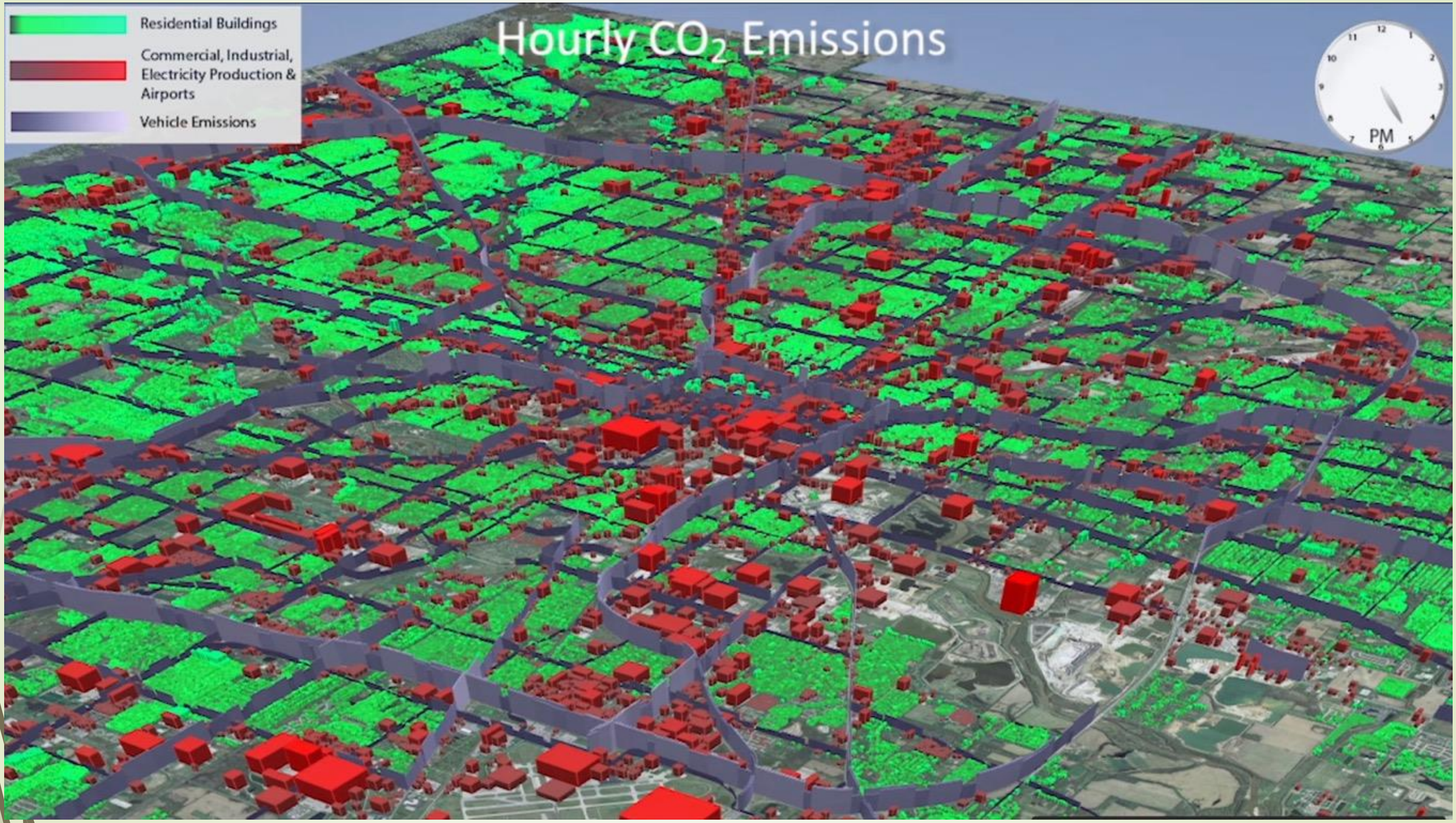
Shepson and Davis



1) Verification capability
2) Mitigation guidance
3) Questions on urban metabolism

Aiming for the knowledge gap
between whole-city inventories
and building-scale energy auditing

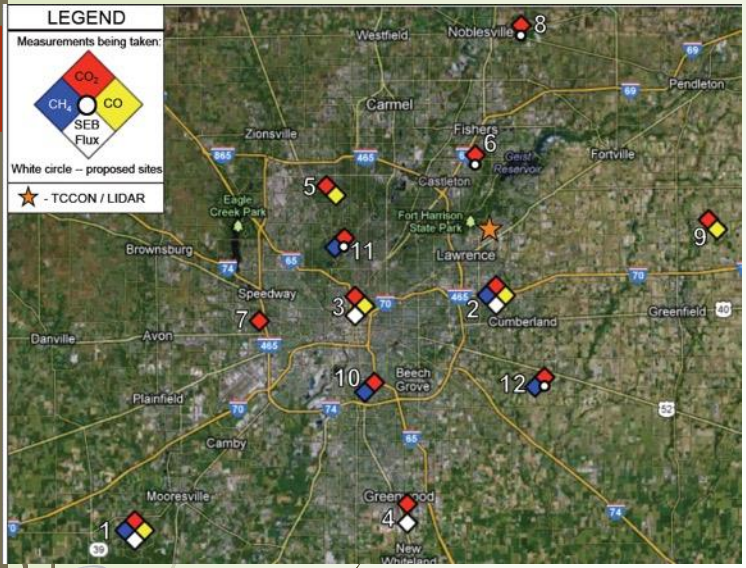
Hestia



Space, time, process

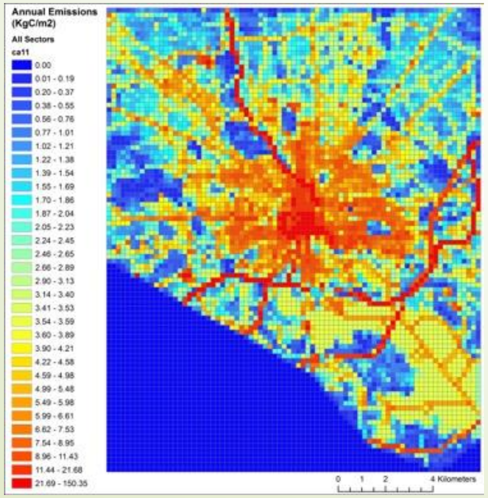
Nested within Vulcan (conserves mass)
Data mining from city operations (traffic data, tax assessment)

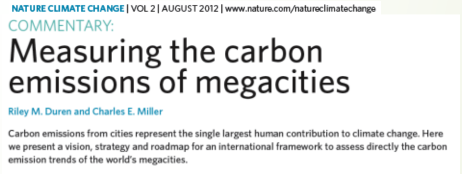
Multiple cities



Melbourne
Aukland
Paris
Sao Paulo

Boston via BU/Harvard




NATURE CLIMATE CHANGE | VOL 2 | AUGUST 2012 | www.nature.com/natureclimatechange

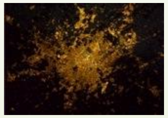
COMMENTARY:

Measuring the carbon emissions of megacities

Riley M. Duren and Charles E. Miller

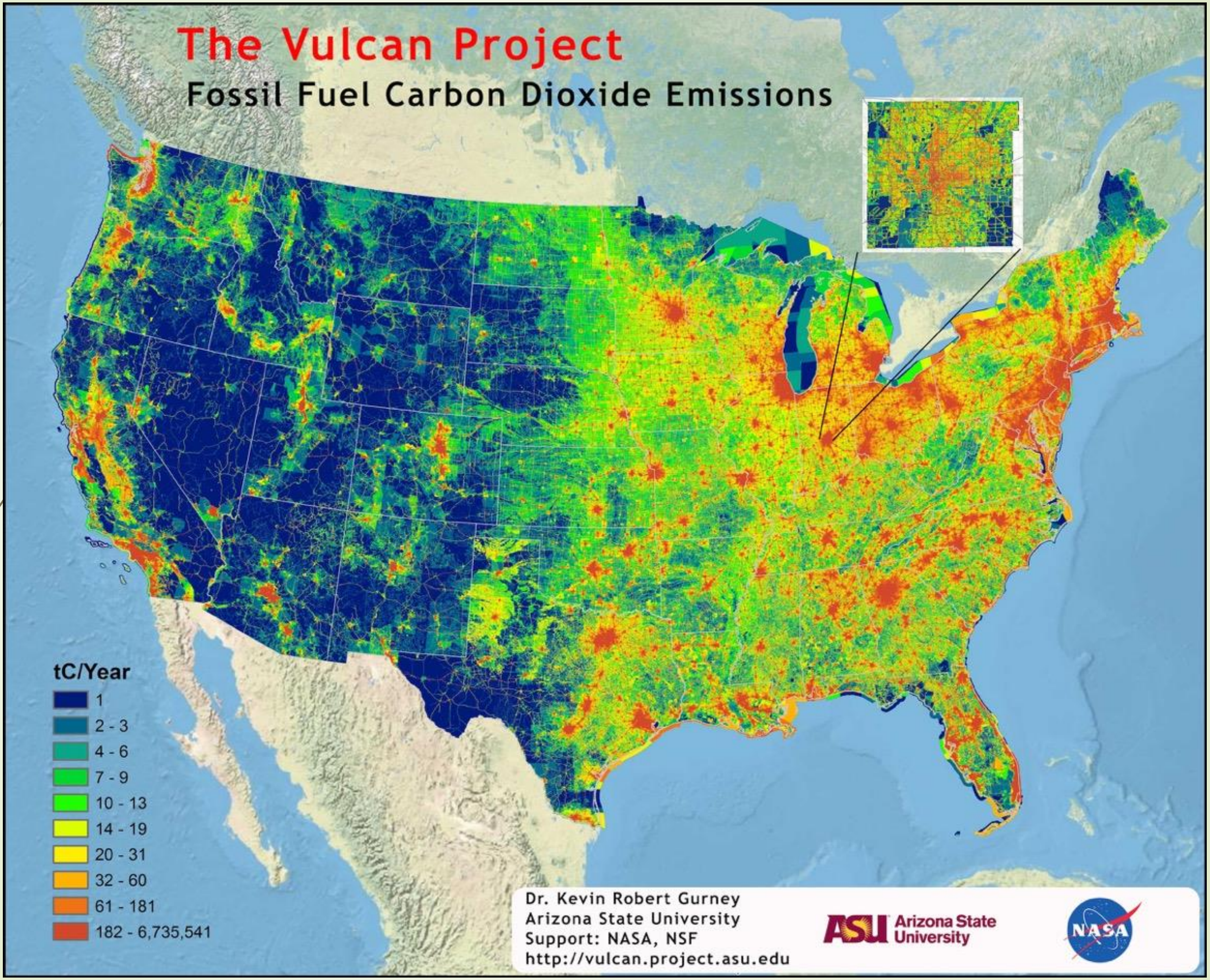
Carbon emissions from cities represent the single largest human contribution to climate change. Here we present a vision, strategy and roadmap for an international framework to assess directly the carbon emission trends of the world's megacities.

Megacities Carbon Project



Vulcan

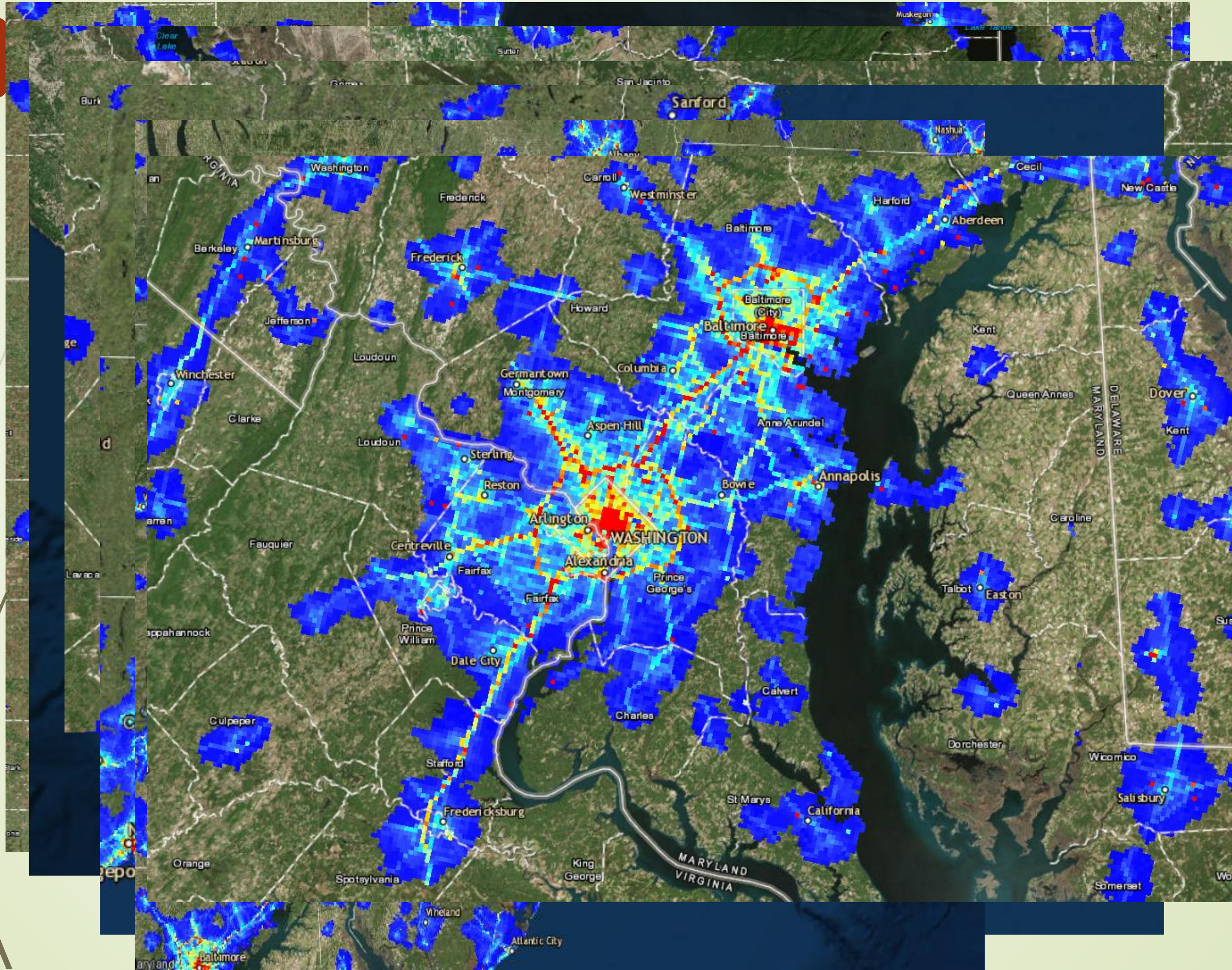
0.5 km x 0.5 km, hourly 2010-2015



Gurney et al., *Env. Sci & Tech*, 2009; 2019

Scope 1 AND scope 2 (working on scope

Urban examples

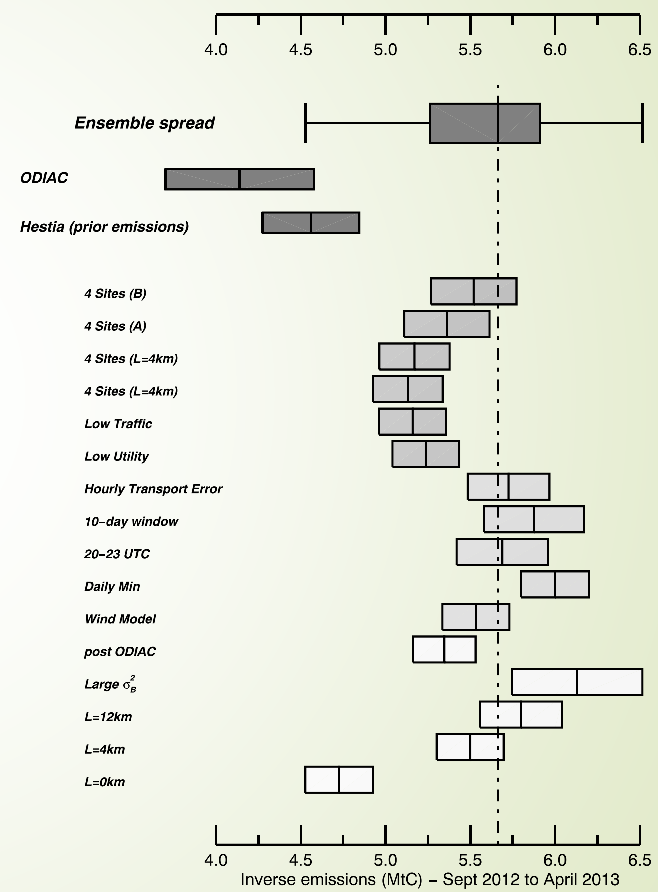


INFLUX inversion

Notes:

The inversion is NOT estimating the same thing as contained in the prior.

There is no inversion without a prior…..hence, there is no “independent” inversion.



Lauvaux et al., 2016

Bottom-up/top-down reconciliation

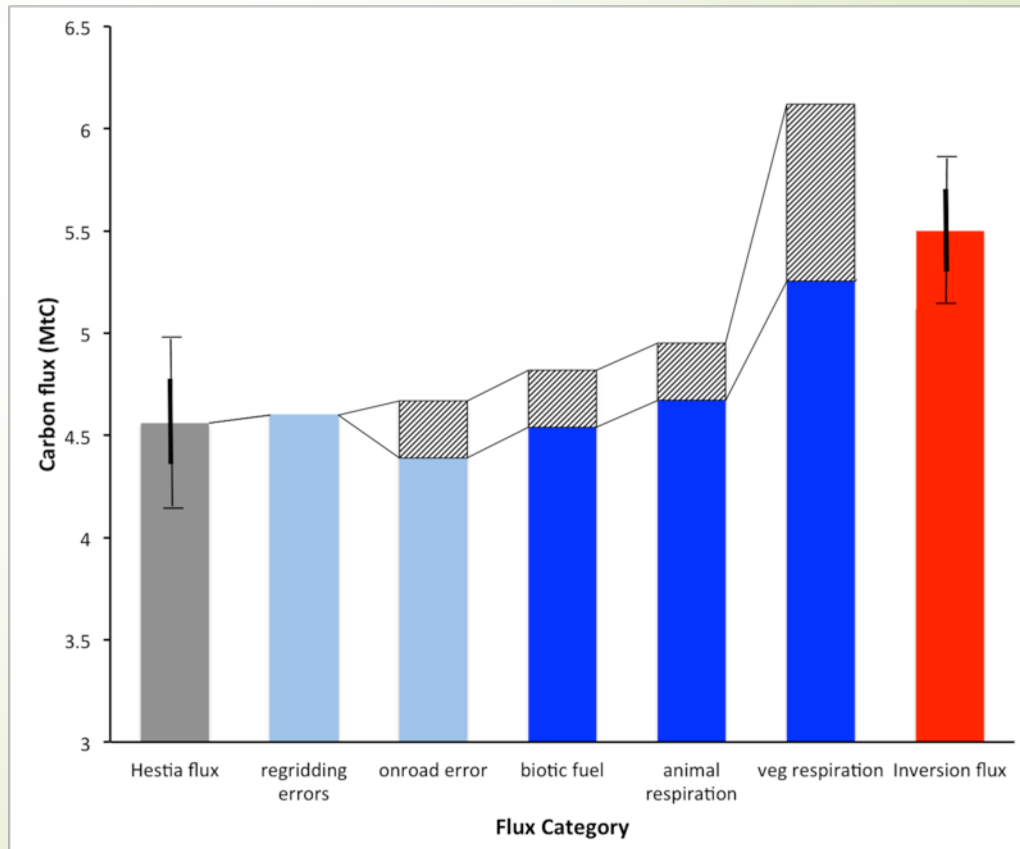
RESEARCH ARTICLE

Reconciling the differences between a bottom-up and inverse-estimated FFCO$_2$ emissions estimate in a large US urban area

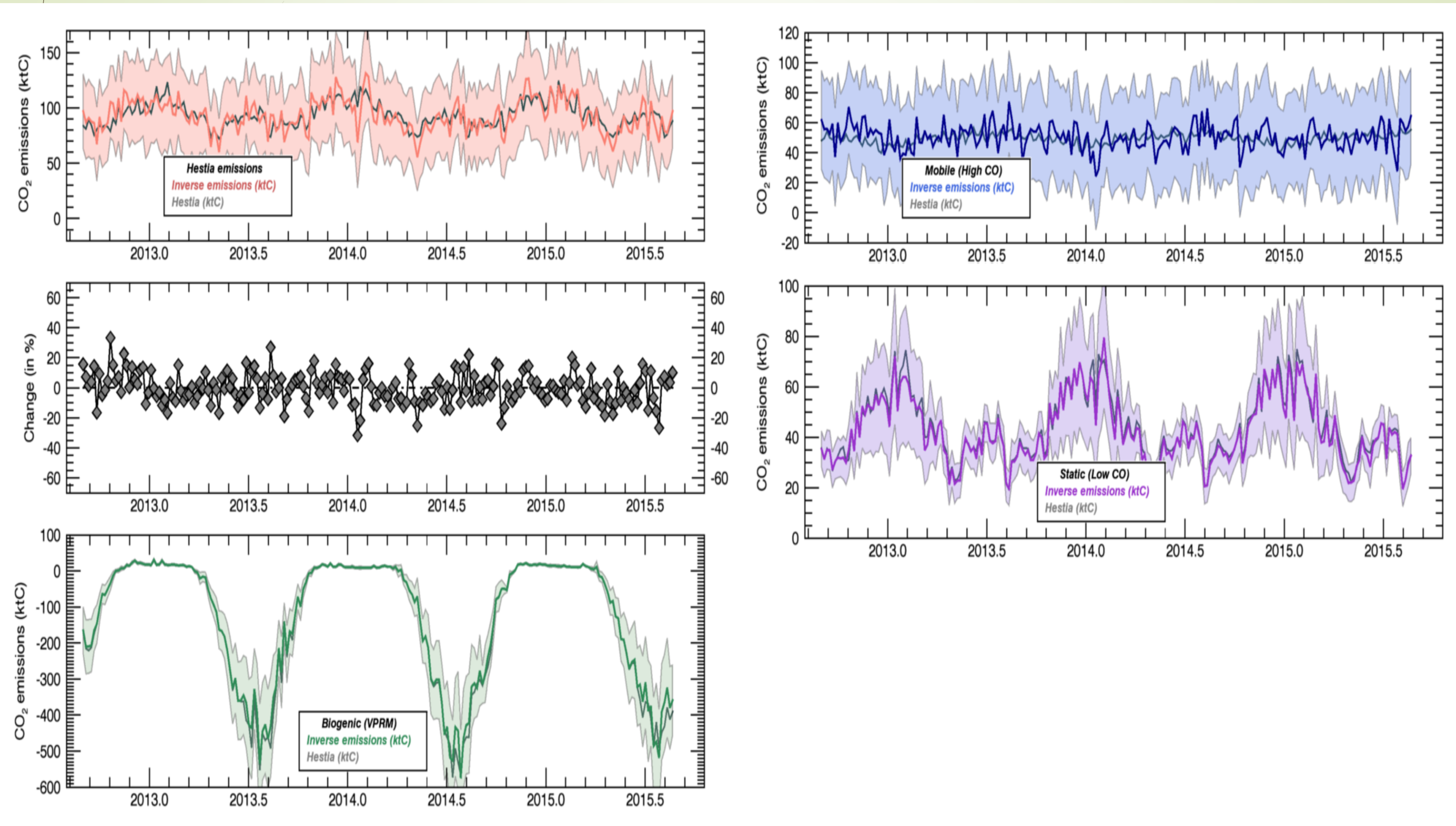
Kevin R. Gurney*, Jianming Liang*, Risa Patarasuk*, Darragh O'Keeffe*, Jianhua Huang*, Maya Hutchins*, Thomas Lauvaux†, Jocelyn C. Turnbull‡,§ and Paul B. Shepson‖

Hestia compared to atmospheric CO_2 inversion (Lauvaux et al., 2016)

Biotic respiration prior to persistent ground freeze explains majority of difference



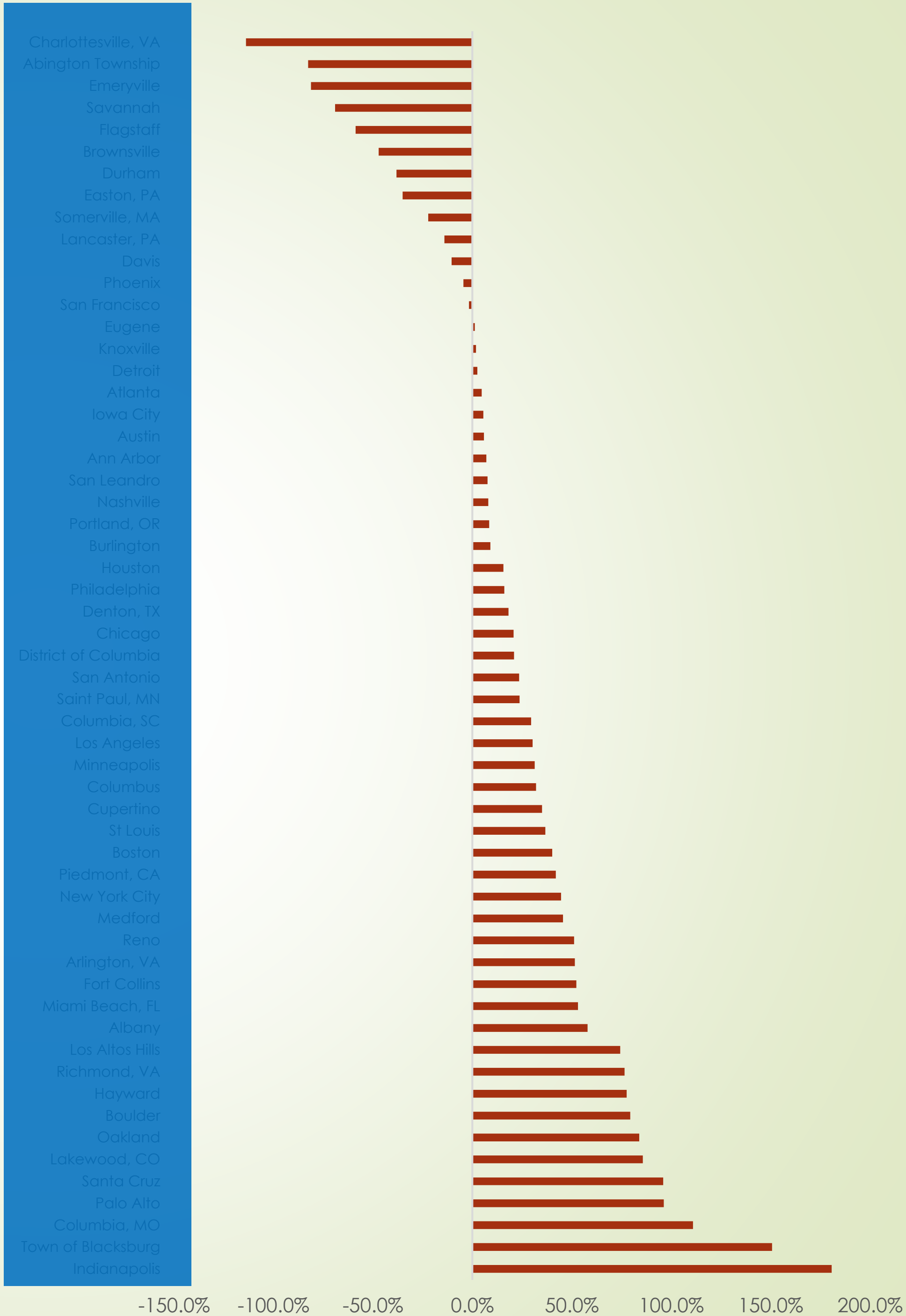
Reconciliation continued



Comparison to self-reported

The mean signed % difference: +24.0%

The mean absolute % difference: 44.3%



For 44 of the 57 cities, Vulcan estimates larger scope 1 $FFCO_2$ emissions

Thank you

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- AND – SOCCR2 chapter 4 co-authors (co-leads: Paty Romero-Lankao, Stephanie Pincetl)