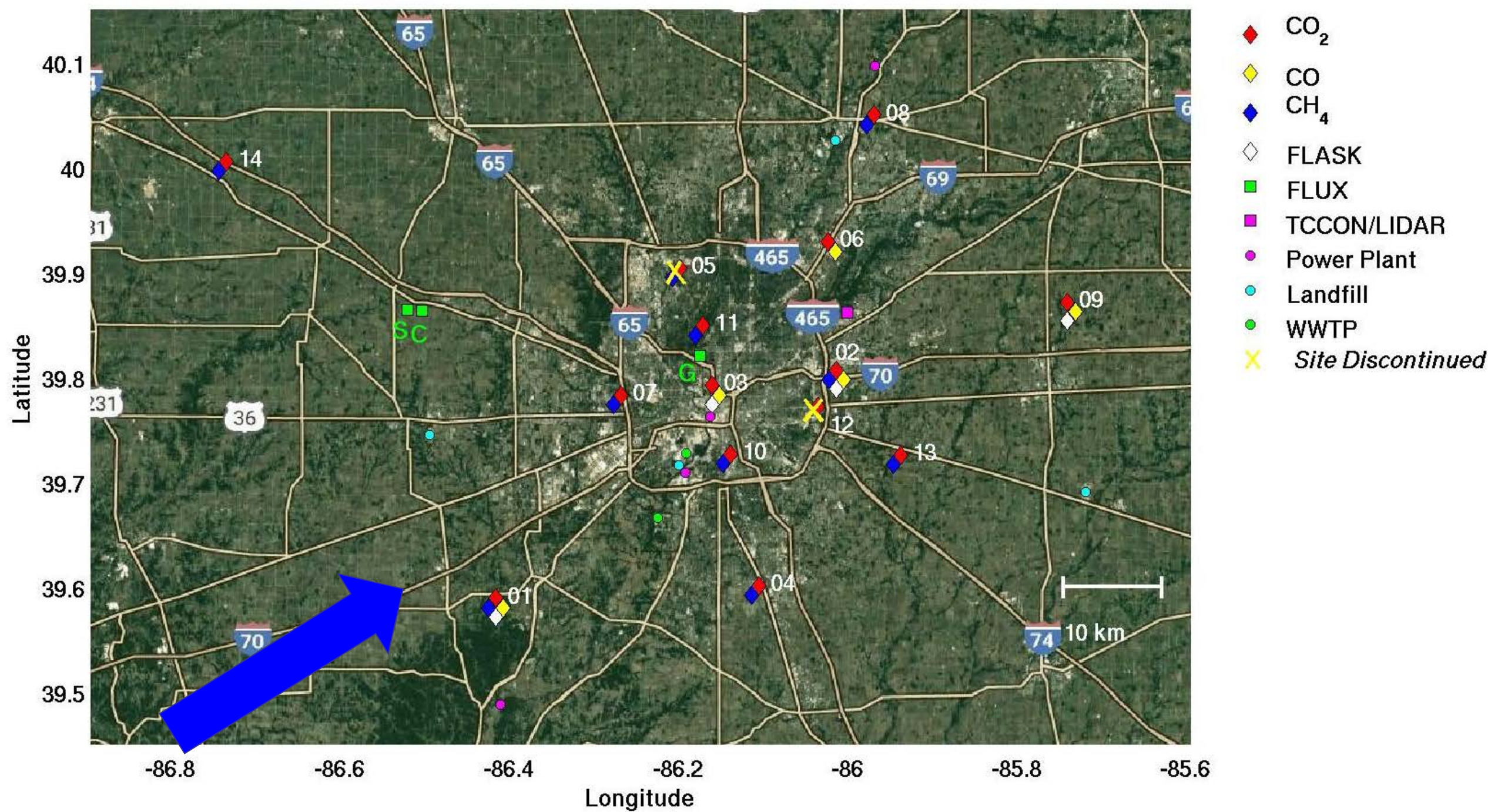


# Investigating Hydrocarbon Tracers for Anthropogenic CO<sub>2</sub> at Indianapolis, IN USA

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## The INFLUX Experiment: Monitoring Urban Emissions

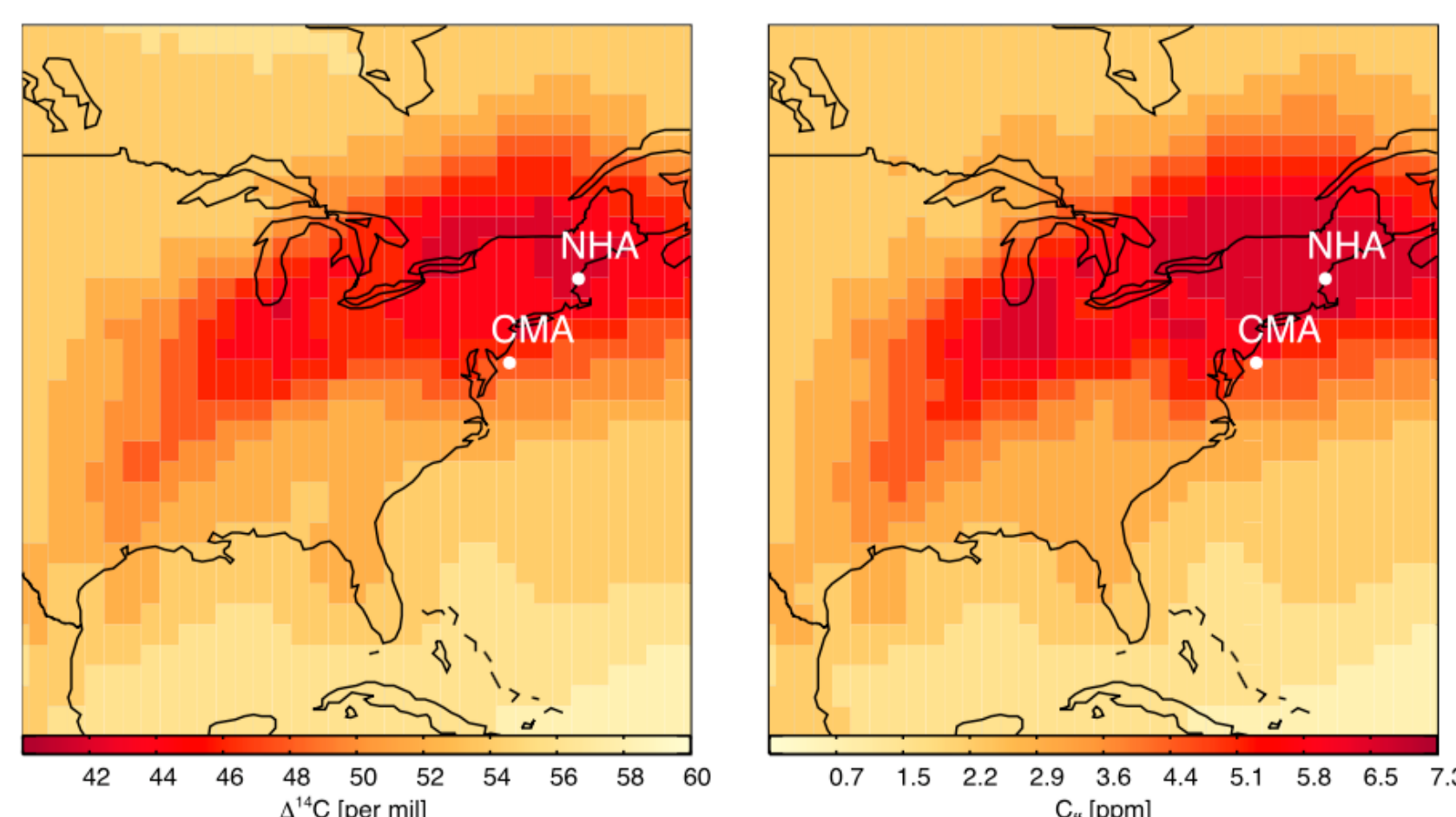
The Indianapolis flux project, (INFLUX), is a collaborative effort to assess and develop methods to determine greenhouse gas emissions from an urban environment. As part of the experiment, multiple trace gasses are being measured insitu as well as in flasks



**Figure 1:** Map of Indianapolis FLUX project tower locations. Legend and symbols designate measurements made at each site. Arrow indicates dominant wind direction

## Using Tracers To Identify Fossil Fuel CO<sub>2</sub>

MILLER ET AL.: THE <sup>14</sup>CO<sub>2</sub> AND ANTHROPOGENIC TRACE GASES



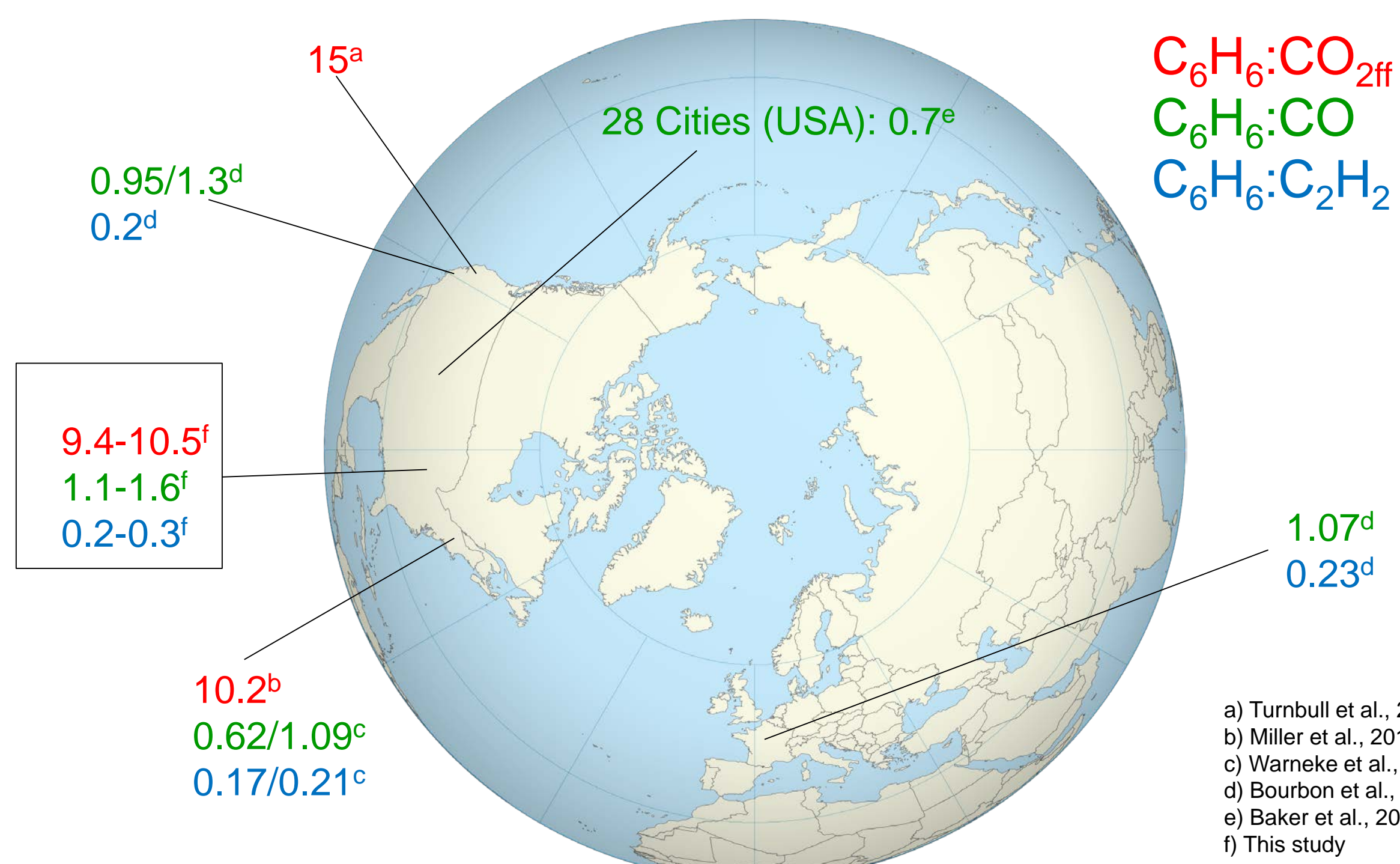
**Figure 2:** From Miller et al. (2012). Figure shows modeled fossil fuel produced CO<sub>2</sub> and <sup>14</sup>CO<sub>2</sub>. The colors are inverted on the right color bar to show a depleted <sup>14</sup>CO<sub>2</sub> signal is highly correlated with fossil fuel CO<sub>2</sub>.

- Carbon 14 → a robust measure of fossil fuel CO<sub>2</sub>
- However → difficult and expensive to measure

## Other anthropogenic gasses: possible CO<sub>2</sub> tracers

- Previous studies → Considered CO, SF<sub>6</sub>, VOC's, Halo-carbons
- Correlate Tracers → Co-emitted or co-located → Co-emitted most desirable
- At Indianapolis → Benzene, CO, and Acetylene are the most correlated
- All species → Imperfect

## Previous studies have looked at Benzene to CO<sub>2ff</sub>, CO and C<sub>2</sub>H<sub>2</sub> ratios



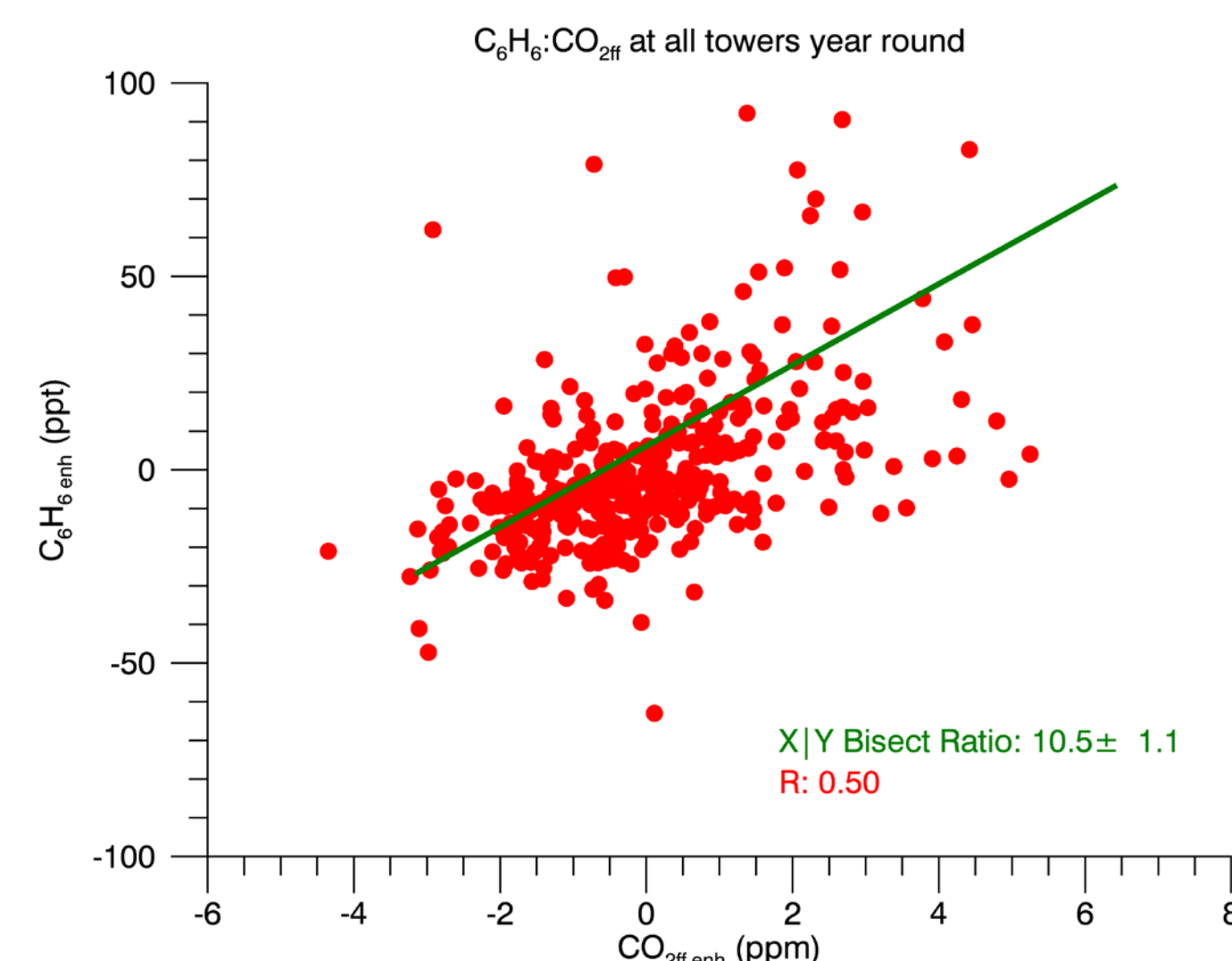
**Figure 3:** Other studies in the northern hemisphere that have measured benzene to CO<sub>2ff</sub>, CO, and Acetylene. Red text indicates C<sub>6</sub>H<sub>6</sub>:CO<sub>2ff</sub>, Green indicates C<sub>6</sub>H<sub>6</sub>:CO. Blue Indicates C<sub>6</sub>H<sub>6</sub>:C<sub>2</sub>H<sub>2</sub>. The boxed values are this study.

- INFLUX tower data → large scatter → natural variability
- Indianapolis Ratios → within the ranges of other cities around the US and Europe
- Suggests tower regressions are reasonable → Use C<sub>6</sub>H<sub>6</sub>:CO<sub>2ff</sub>, C<sub>6</sub>H<sub>6</sub>:CO

## Benzene relative to CO<sub>2ff</sub>, CO, and Acetylene at Indianapolis

### Benzene

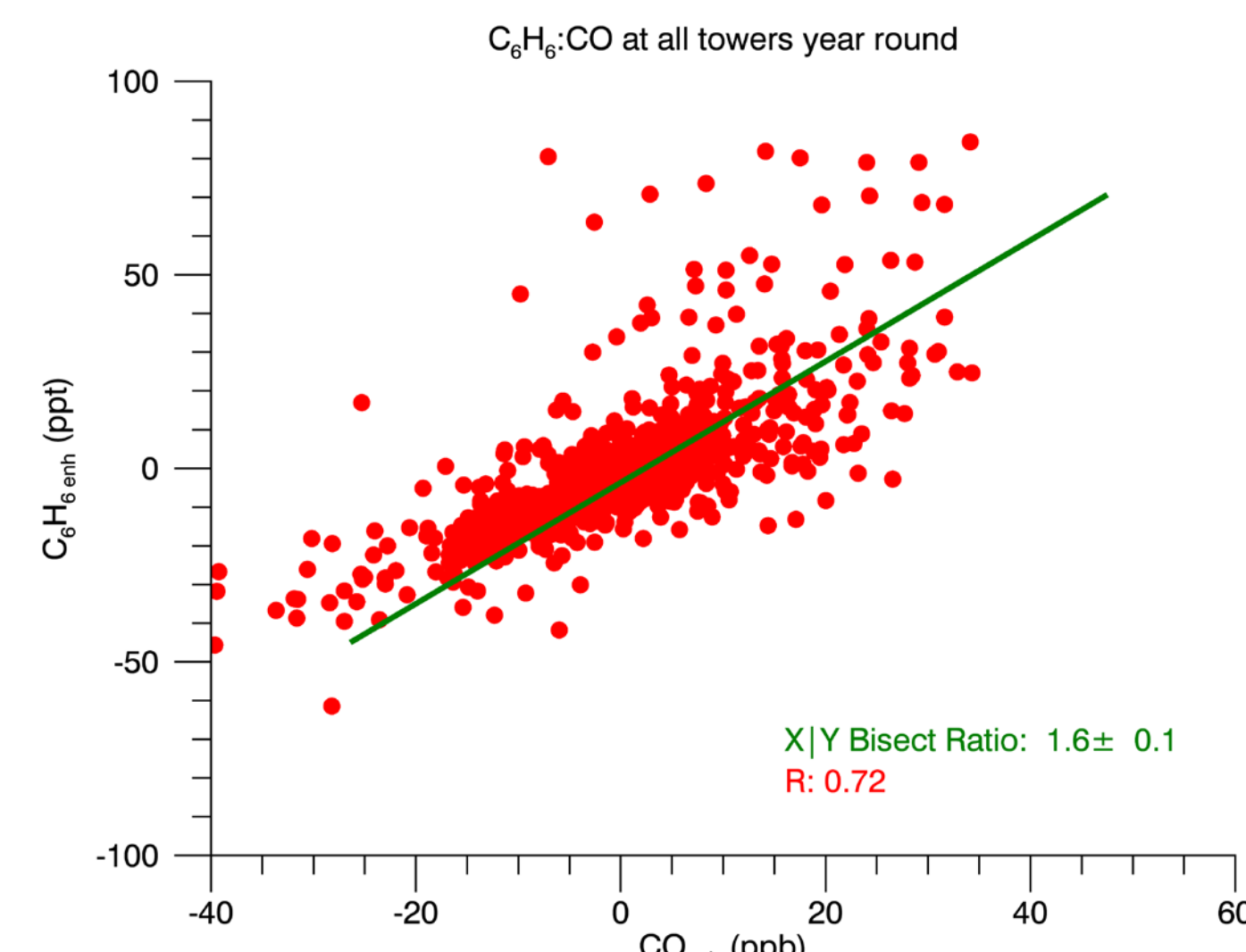
- Emitted from anthropogenic processes
  - Large signal from on-road and off-road vehicles
  - Petroleum Operations
- Non-combustion sources



**Figure 4:** Scatter plot of measured benzene vs measured fossil fuel CO<sub>2</sub> (derived from <sup>14</sup>CO<sub>2</sub>) at all towers in Indianapolis from 2010-2015. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line.

### CO

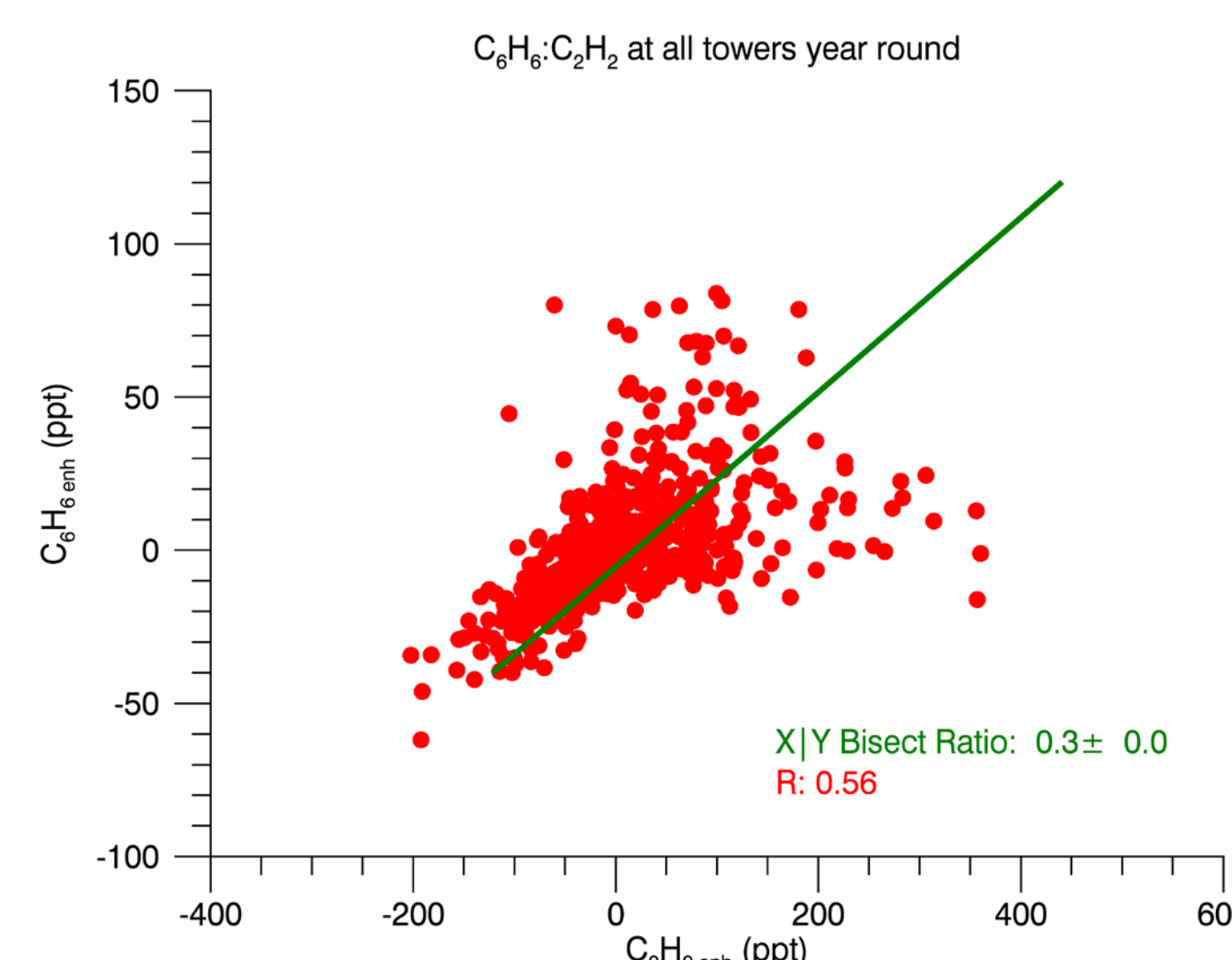
- Emitted from anthropogenic processes
  - Large signal from on-road and off-road vehicles
  - Incomplete combustion
  - Regulated → Catalytic removal
- Significant summer contribution from hydrocarbon oxidation
- Not exclusively anthropogenic



**Figure 5:** Scatter plot of measured benzene vs measured CO at all towers in Indianapolis from 2010-2015. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line.

### Acetylene

- Emitted from anthropogenic processes
  - Signal from on-road and off-road vehicles
  - Industrial Processes
- Non-combustion sources



**Figure 6:** Scatter plot of measured benzene vs measured acetylene at all towers in Indianapolis from 2010-2015. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line.

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<sup>6</sup>CIRES, University of Colorado, Boulder, CO

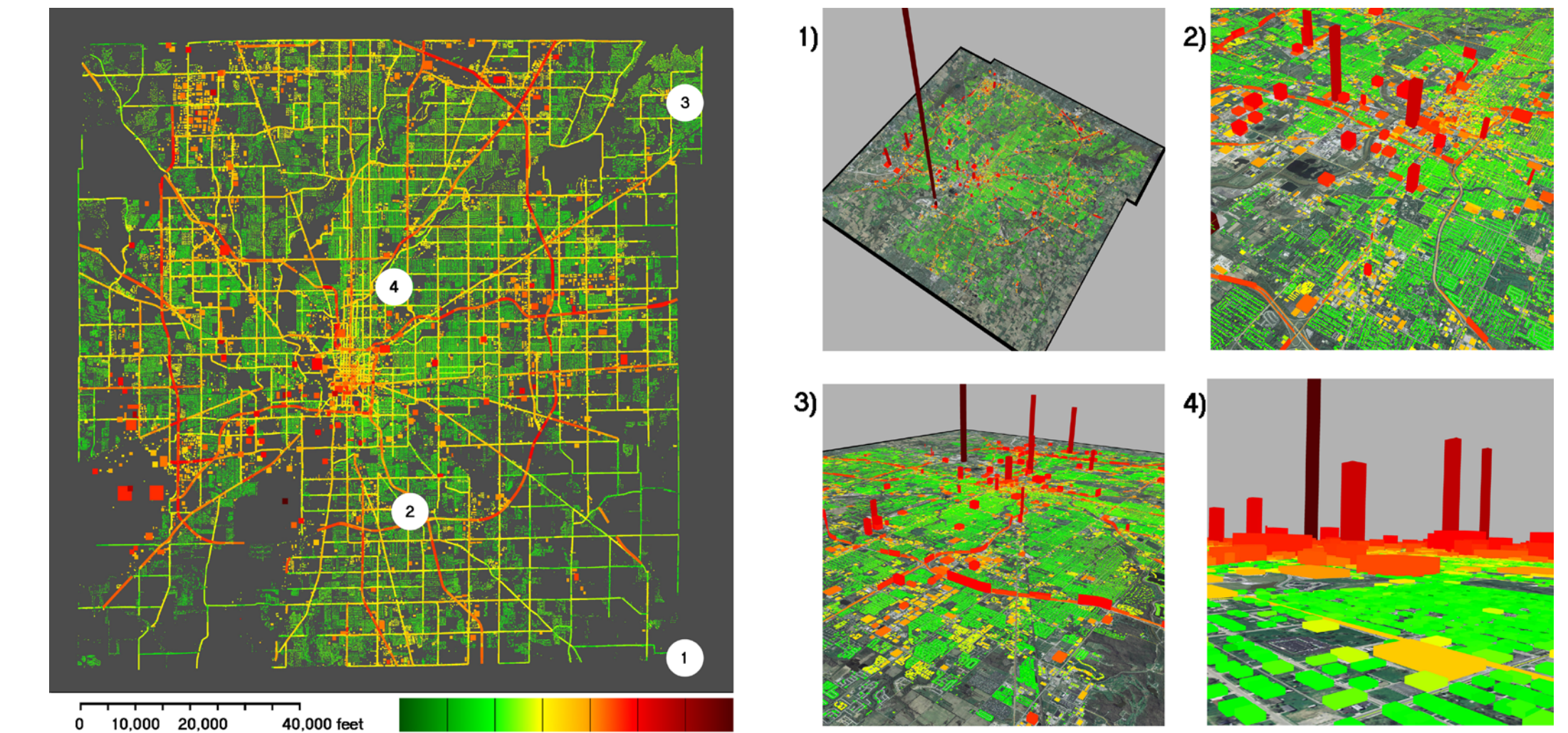
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## Modeling Emissions

### CO<sub>2ff</sub>: Hestia and VULCAN

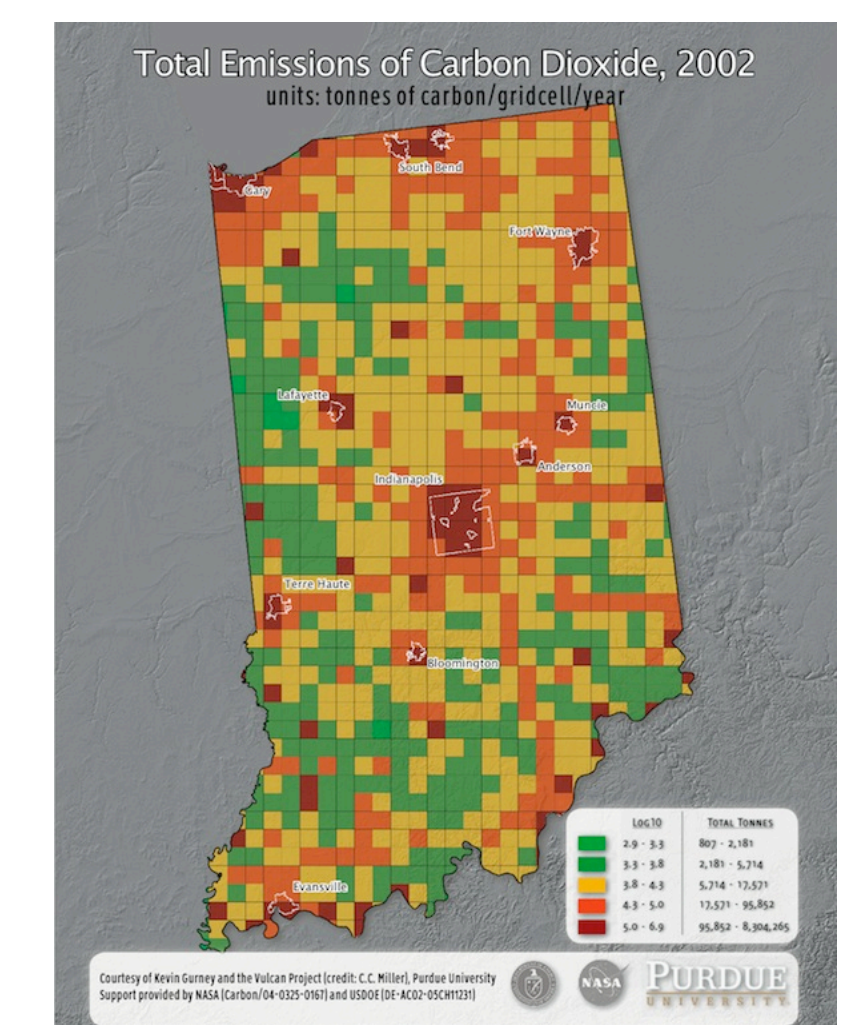
#### Hestia



- High spatial resolution over Indianapolis
- 8 Sectors: Airport, Commercial, Industrial, Mobile, Non-road, Residential, Utility, and Rail

#### VULCAN

- Low Resolution relative to Hestia
- EPA NEI County level Emissions Estimates → Similar resolution

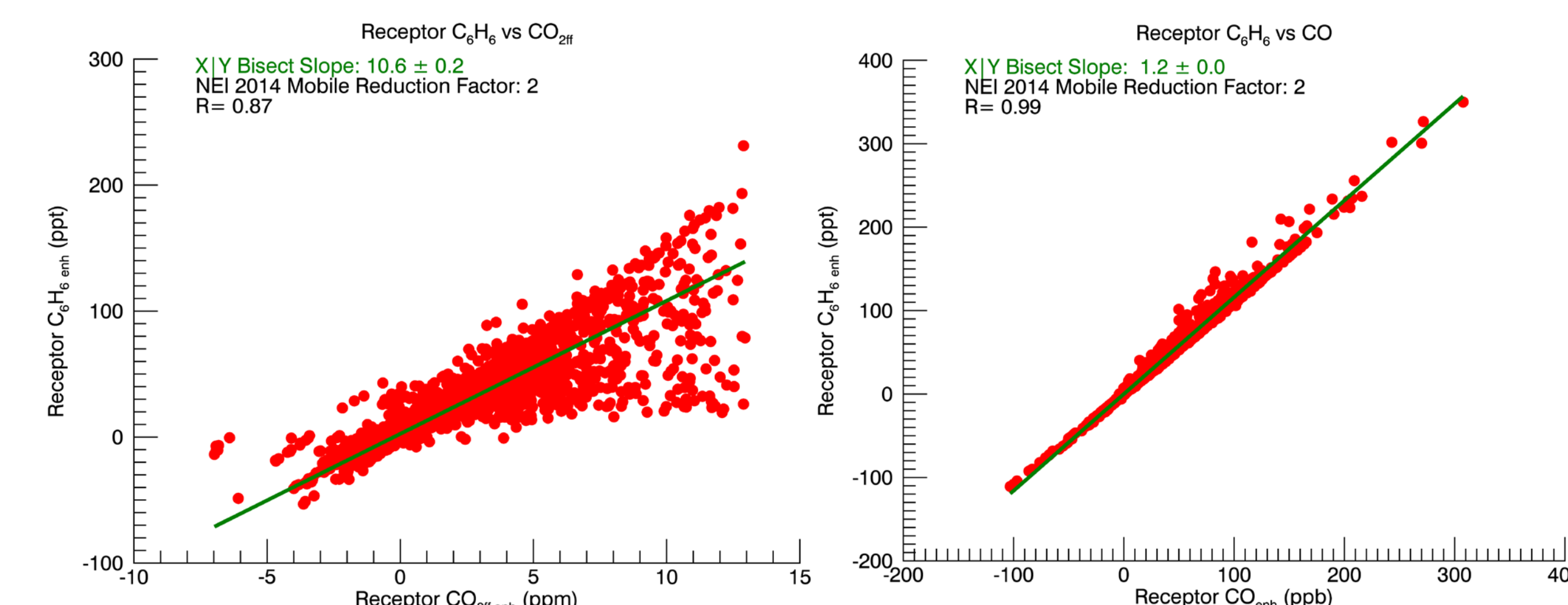


### Hestia-CO and Hestia-Benzene

- Use Vulcan estimates for CO<sub>2ff</sub>
- Benzene Emissions → EPA NEI 2014
- Create R<sub>C6H6:CO2ff</sub> for 8 Hestia Sectors
- Acetylene → not easily available in EPA NEI → future work

$$\frac{\text{pmol } C_6H_6 / CO(\text{NEI2014/2011})}{\mu\text{mol } CO_{2ff}(\text{VULCAN})} * \text{HESTIA} = \text{Hestia Benzene} / CO$$

$$\text{Hestia Benzene} / CO * \text{Tower Footprints} = \text{Hestia Benzene} / CO \text{ Receptors}$$



**Figure 7:** Scatter plot of receptor benzene vs receptor CO<sub>2ff</sub> and CO at all towers in Indianapolis from November 2012 – October 2013. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line. In both cases, the EPA NEI 2014 benzene emissions were reduced by a factor of 2 in order to better match the tower results.

## Summary

- INFLUX Tower data → High variability
- However, consistent with other studies
- Using Vulcan and EPA NEI 2014 → Inventory ratios
- Combined Inventory ratios and Hestia → "Hestia" product for Benzene and CO
- Using tower footprints → obtain modeled CO and Benzene at towers
- Modeled to Measured → reduce EPA Benzene estimates factor of 2
- Reduction is consistent with prior evaluations of EPA NEI

