

Creating an emissions map for benzene based on fossil fuel CO₂ emissions: "HESTIA Benzene"

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Using Tracers to Understand Specific fossil fuel CO₂ sectors

- The most robust tracer of fossil fuel CO₂ is radiocarbon (¹⁴CO₂)
- However, ¹⁴CO₂ → Provides total fossil fuel CO₂ (CO_{2ff}) but does not provide specific source information
- Emissions models such as HESTIA and VULCAN → estimate sector emissions → validated by measurements
- We attempt to create emissions maps for other species to assess if sectoral emissions of a tracer can be used as a proxy for a specific CO_{2ff} sector

MILLER ET AL.: THE ¹⁴CO₂ AND ANTHROPOGENIC TRACE GASES

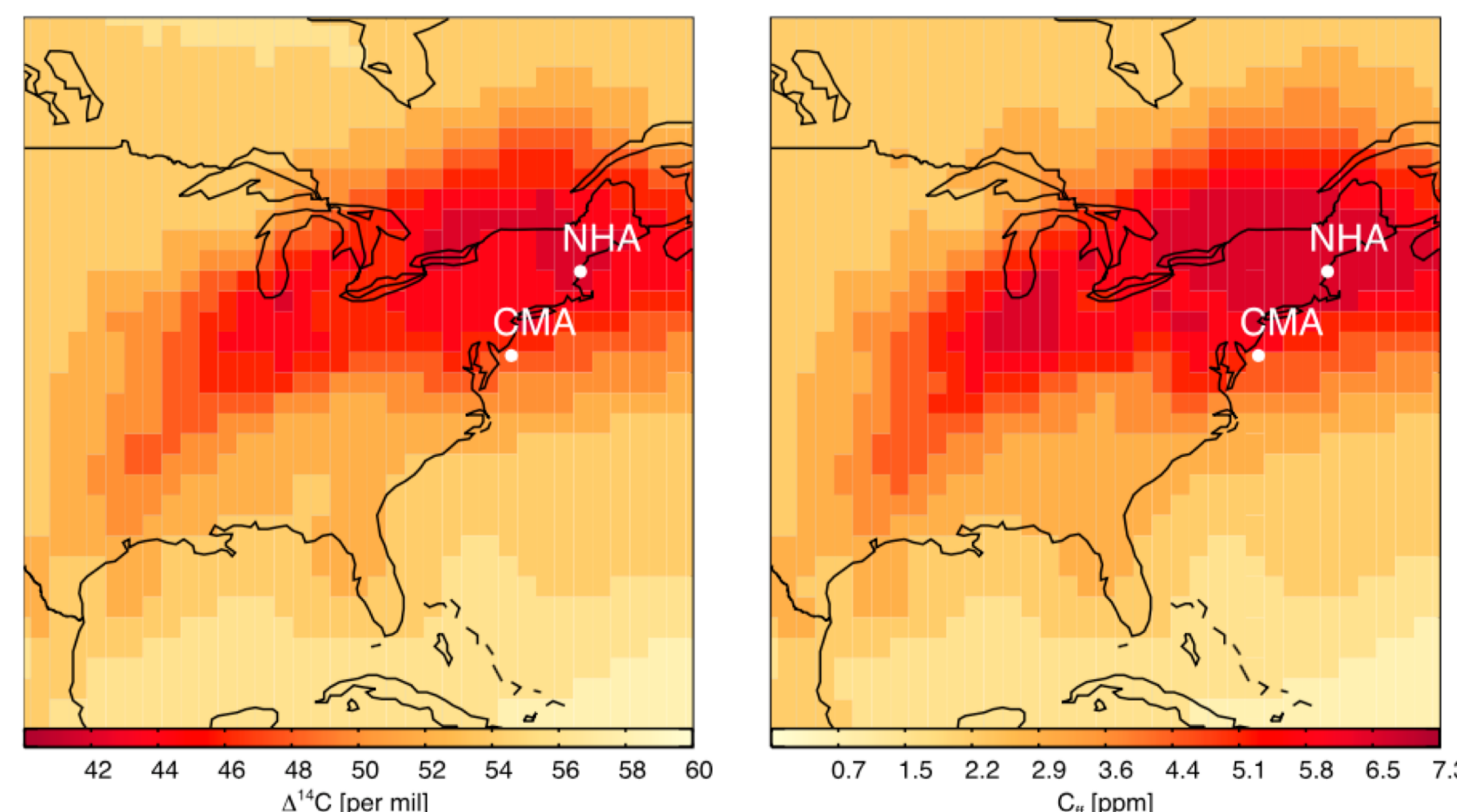
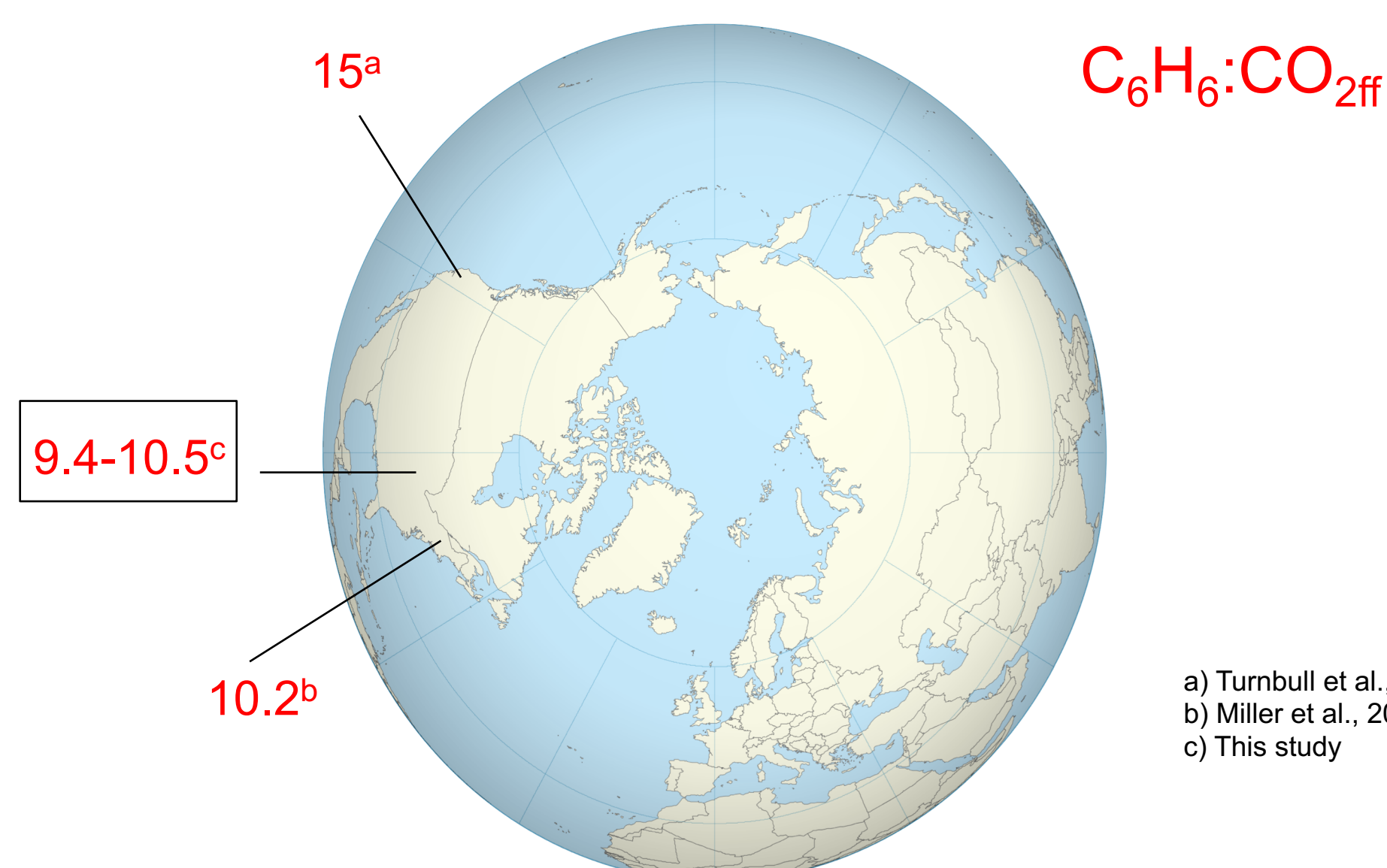


Figure 1: From Miller et al. (2012). Example of how ¹⁴CO₂ is an excellent proxy for fossil fuel CO₂. The colors are inverted on the right color bar to show a depleted ¹⁴CO₂ signal is highly correlated with fossil fuel CO₂.

Other anthropogenic gasses: possible CO_{2ff} tracers

- A correlate tracer may be used to predict CO_{2ff} when ¹⁴CO₂ is not available
- Previous studies → Considered CO, SF₆, VOC's, Halo-carbons
- Correlate Tracers → Co-emitted or co-located → Co-emitted most desirable
- At Indianapolis → besides CO, benzene (C₆H₆) is best correlated → has specific emission sectors

Previous studies have looked at C₆H₆ to CO_{2ff}



a) Turnbull et al., 2015
b) Miller et al., 2012
c) This study

Figure 2: Other studies in the northern hemisphere that have measured C₆H₆ to CO_{2ff}. Red text indicates C₆H₆:CO_{2ff}. The boxed values are this study.

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. We use the data collected at INFLUX to assess how well we can create "tracer maps" using inventory based C₆H₆ and fossil fuel CO₂

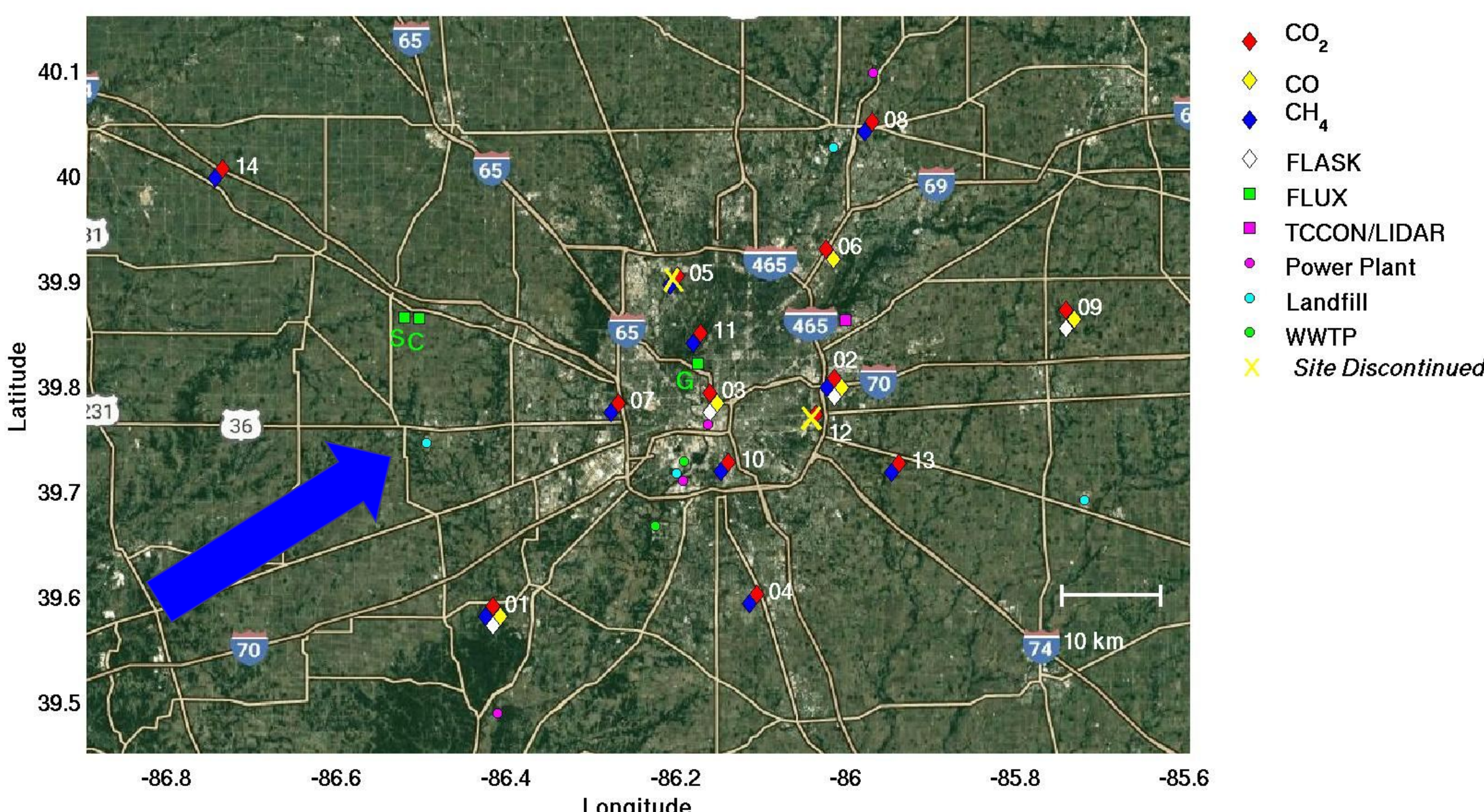


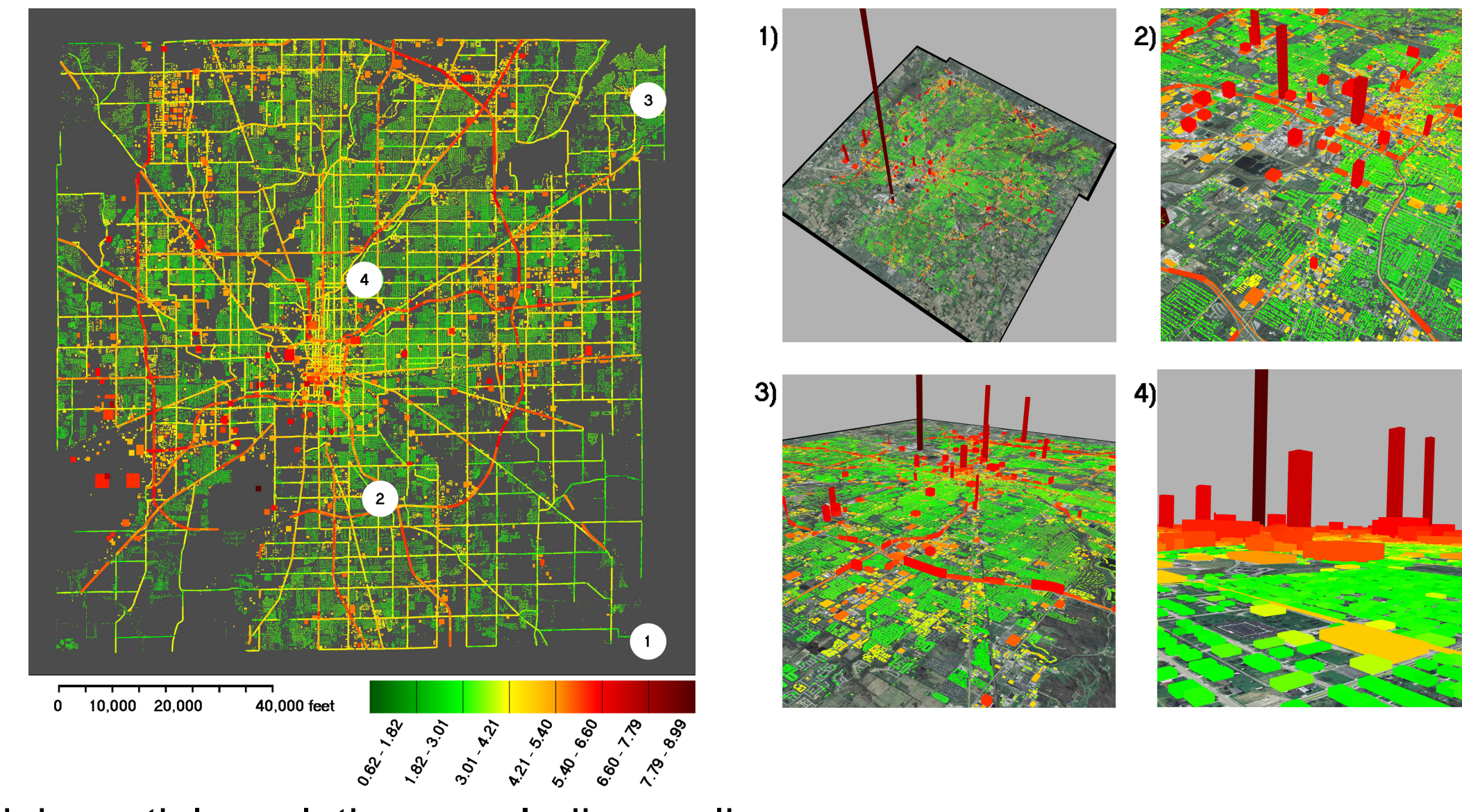
Figure 3: Map of Indianapolis INFLUX project tower locations. Legend and symbols designate measurements made at each site. Arrow indicates dominant wind direction

Modeling Emissions

- We need to obtain initial estimates for for C₆H₆ and CO_{2ff}
 - CO_{2ff} emissions from the VULCAN product
 - C₆H₆ emissions from EPA National Emissions Inventory (NEI) 2014
- Obtain sector based C₆H₆:CO_{2ff}

CO_{2ff}: Hestia and VULCAN

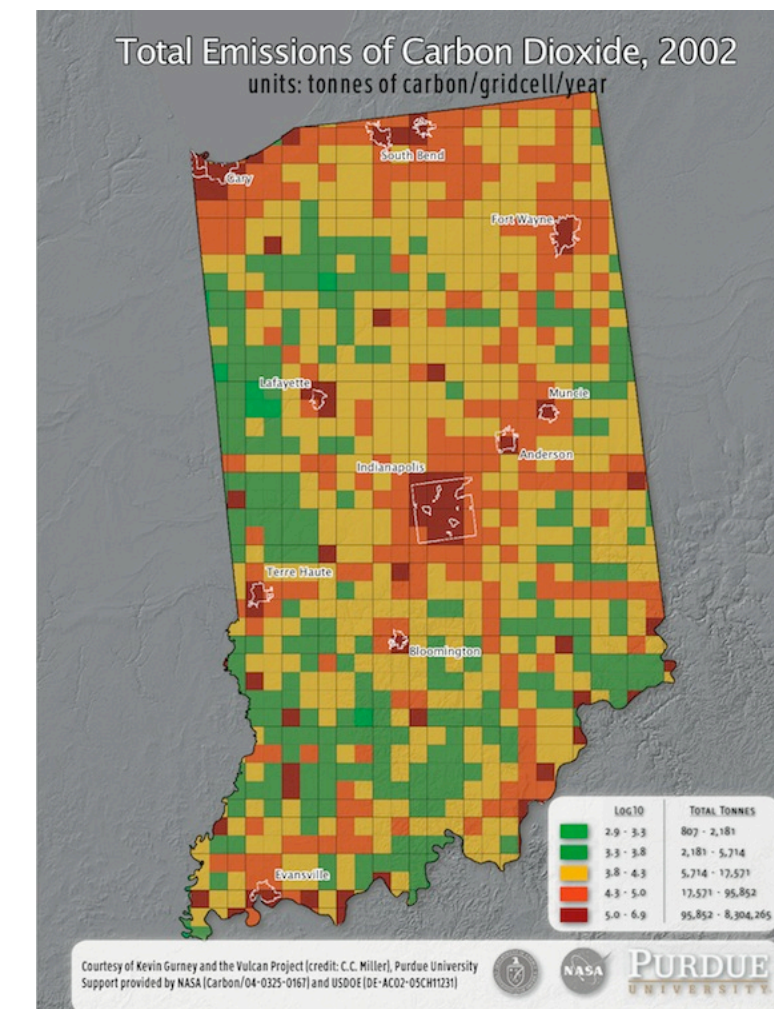
Hestia



- 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-Benzene

- Create R_{C₆H₆:CO_{2ff}} for 8 Hestia Sectors
- Apply Hestia Benzene to WRF footprints for each tower site at Indianapolis
- Create "receptors" → Simulations of the towers

$$\frac{x_{C_6H_6}(NEI\ 2014)}{x_{CO_2ff}(VULCAN)} * Hestia_{CO_2ff} = Hestia\ Benzene$$

Hestia Benzene * WRF Tower Footprints = Benzene Receptors (Simulated Towers)

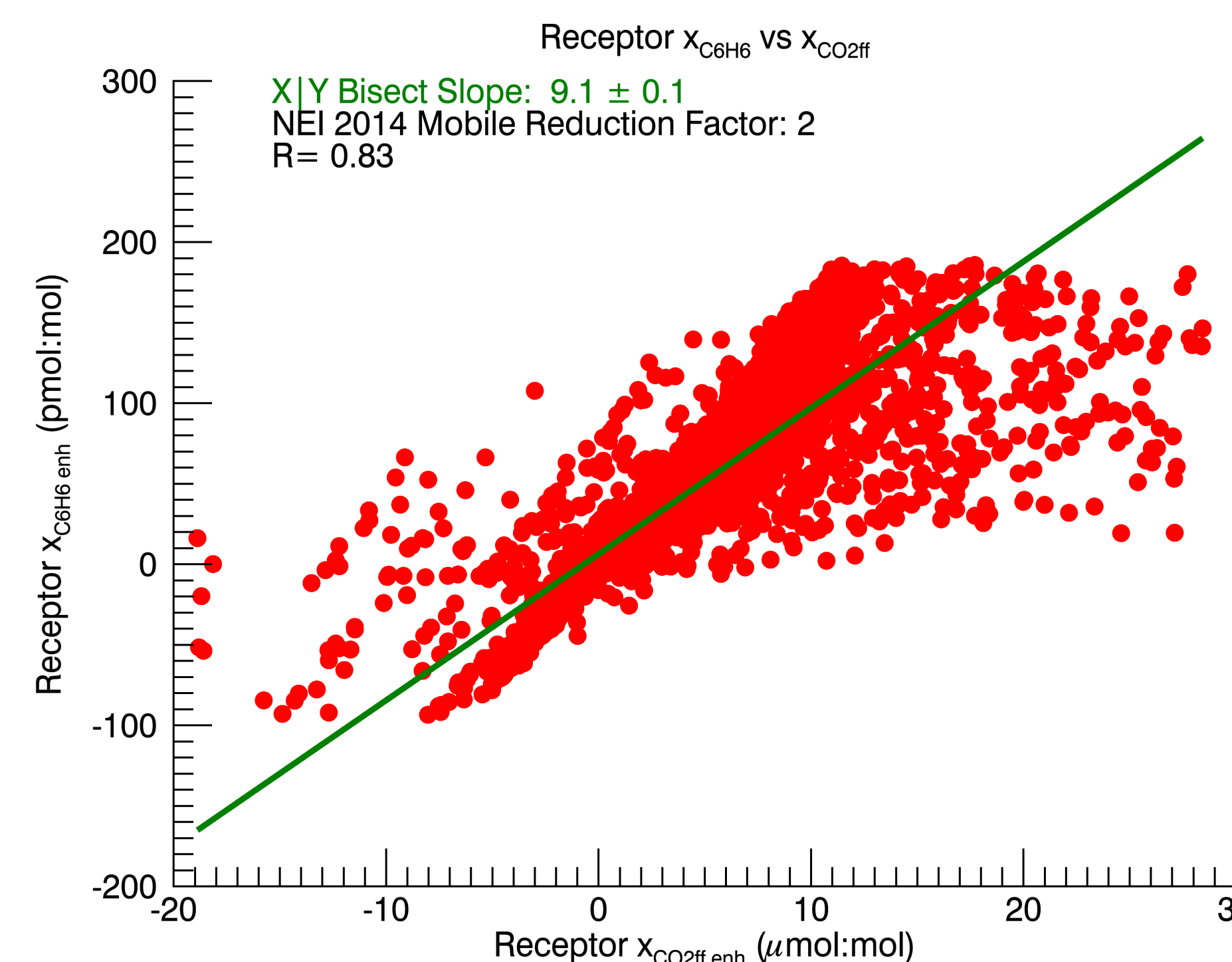


Figure 4: Scatter plot of receptor benzene vs receptor CO_{2ff} at all towers in Indianapolis from September 2012 – December 2013. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line. The EPA NEI 2014 mobile benzene emissions were reduced by a factor of 2 in order to better match the tower results. This reduction is consistent with prior work assessing EPA C₆H₆ emissions estimates

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Acknowledgements

Tim Newberger, Natasha Miles, Scott Richardson, Doug Martins, Alexie Heimberger, Maria Obiminda Cambaliza, Paul Shepson, Bill Callahan, Amanda Long, Ben Michalak, Ken Davis, and James Whelstone

Comparing Hestia Benzene to Measurements

Measured C₆H₆

- Emitted from anthropogenic processes
 - Large signal from on-road and off-road vehicles
 - Petroleum Operations
- Non-combustion sources
- Possible large source sectors: Painting/manufacturing and Rail → not confirmed

Measured CO_{2ff}

- Measured using ¹⁴CO₂
- Hestia CO₂ is in good agreement with measured CO_{2ff}

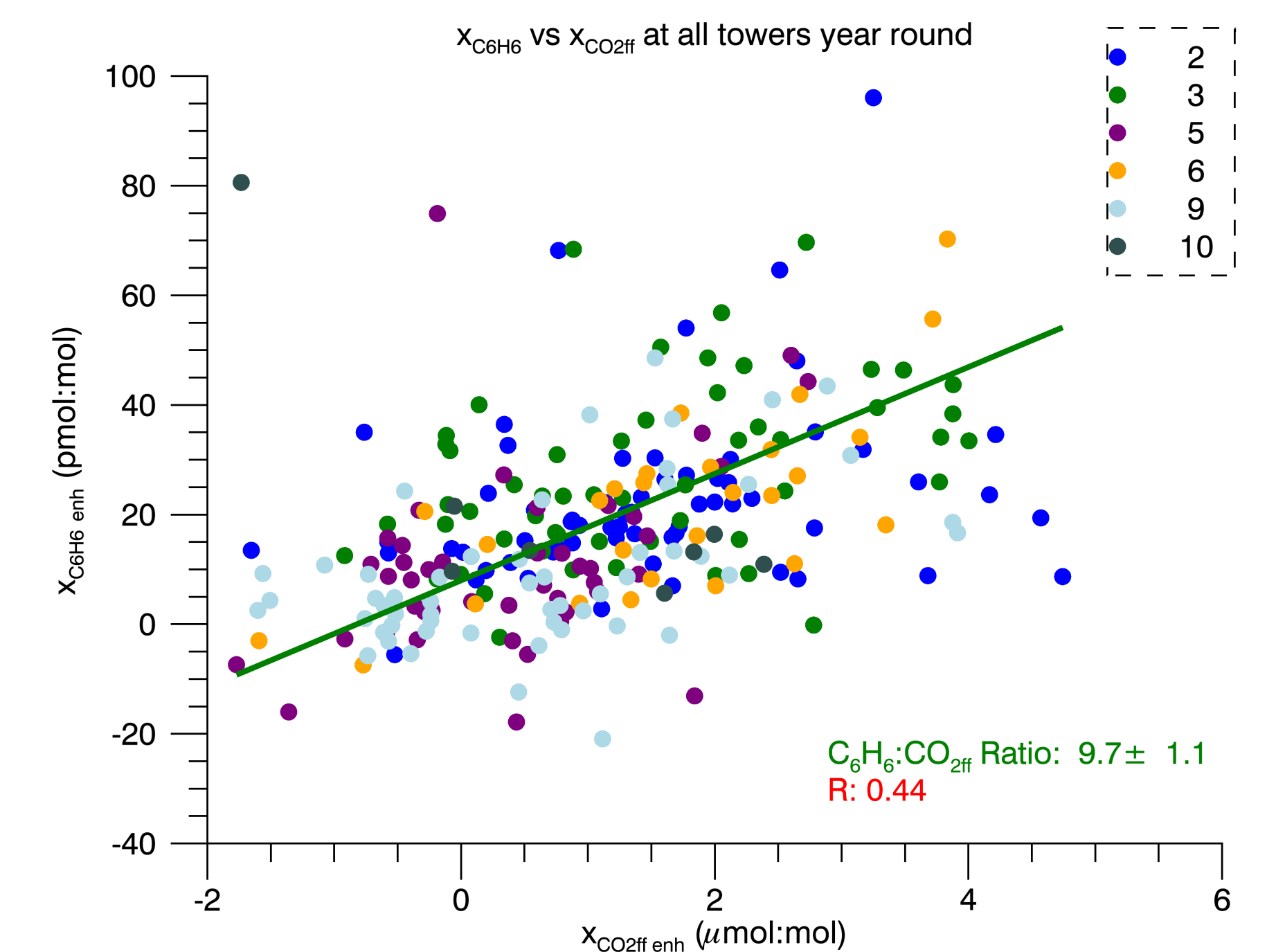


Figure 5: Scatter plot of measured benzene vs measured fossil fuel CO₂ (derived from ¹⁴CO₂) at all towers in Indianapolis from 2010-2015. R is the Pearson Correlation Coefficient, and does not reflect the goodness of fit for the X|Y bisector regression line. Towers are represented by their numbers (Figure 1) in the legend.

Comparing the modeled results to the tower data

- Monthly mean values used
 - Back trajectories → often wrong (by a small amount)
 - At Hestia resolution → one or two degree error in winds → change in sectoral influence
- Regression slope suggests that our C₆H₆:CO_{2ff} ratios are reasonable

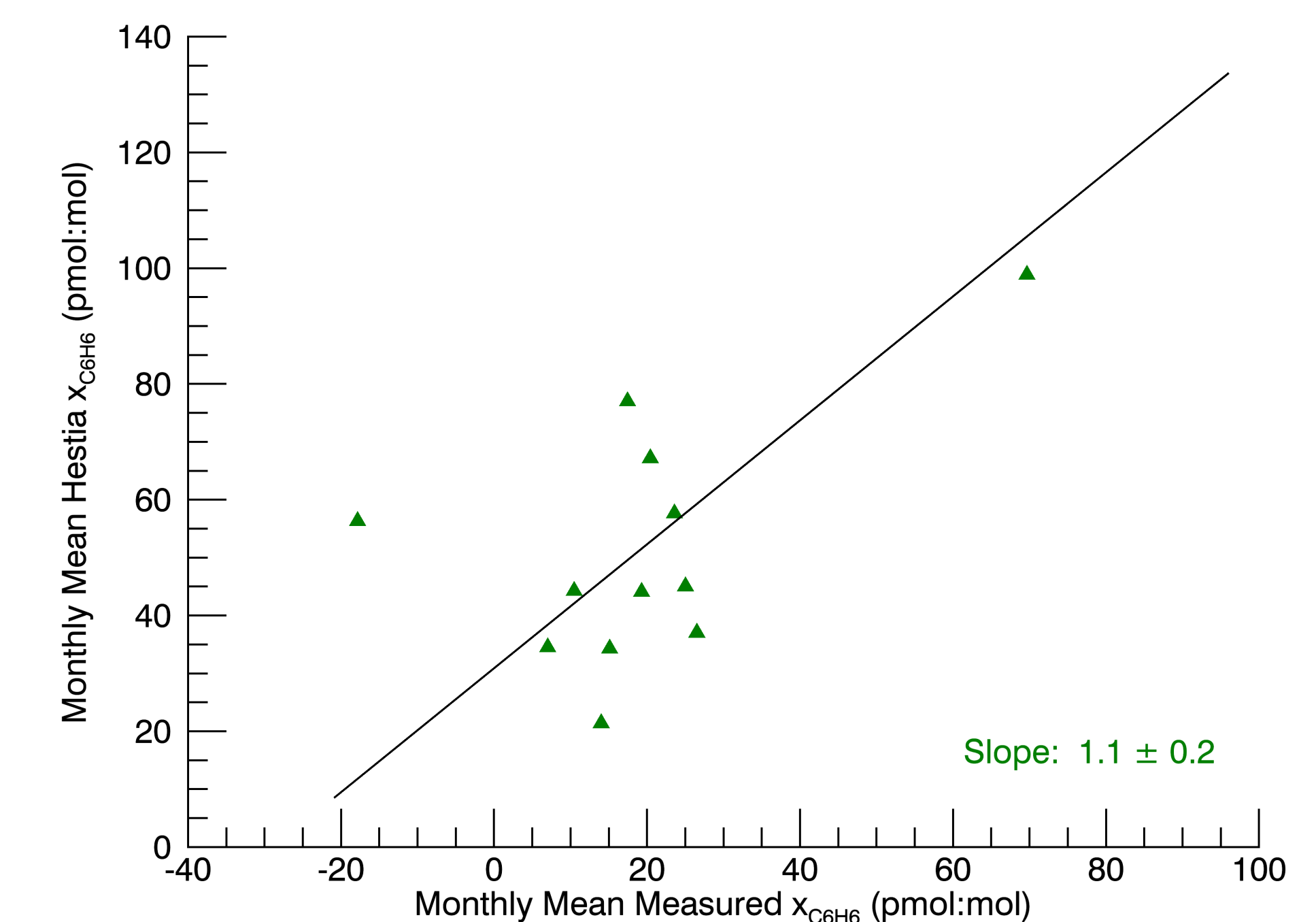


Figure 6: Scatter plot of monthly mean Hestia benzene vs measured benzene at all towers in Indianapolis from 9/2012-12/2013.

Conclusions and Future Work

- INFLUX Tower data → High variability
- However, consistent with other studies
- Using Vulcan and EPA NEI 2014 → Inventory ratios
- Combined Inventory ratios and Hestia → "Hestia" map for Benzene
- Using tower footprints → obtain modeled benzene at towers
- Modeled vs Measured → suggests this emissions map is reasonable
- Next steps:
 - Expand Hestia Benzene for longer period: 2012-2015
 - Investigate individual sectors more thoroughly
 - Assess the ability of Hestia Benzene to understand emissions

