Detection and Quantification of Atmospheric Boundary Layer Greenhouse Gas Dry Mole Fraction Enhancements from Urban Emissions: Results from INFLUX

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Goals of the Indianapolis Flux Experiment (INFLUX)

- Develop and assess methods of quantifying greenhouse gas emissions at the *urban scale*, using Indianapolis as a test bed.
- In particular:
  - Determine whole-city emissions of CO_2 and CH_4 (P-17 Alexie Heimburger)
  - Calculate emissions of CO_2 (and CH_4) at 1 km^2 spatial resolution and ~weekly temporal resolution across the city
  - Distinguish biogenic vs. anthropogenic sources of CO_2 (P-14 Kai Wu)
  - Quantify and reduce uncertainty in urban emissions estimates

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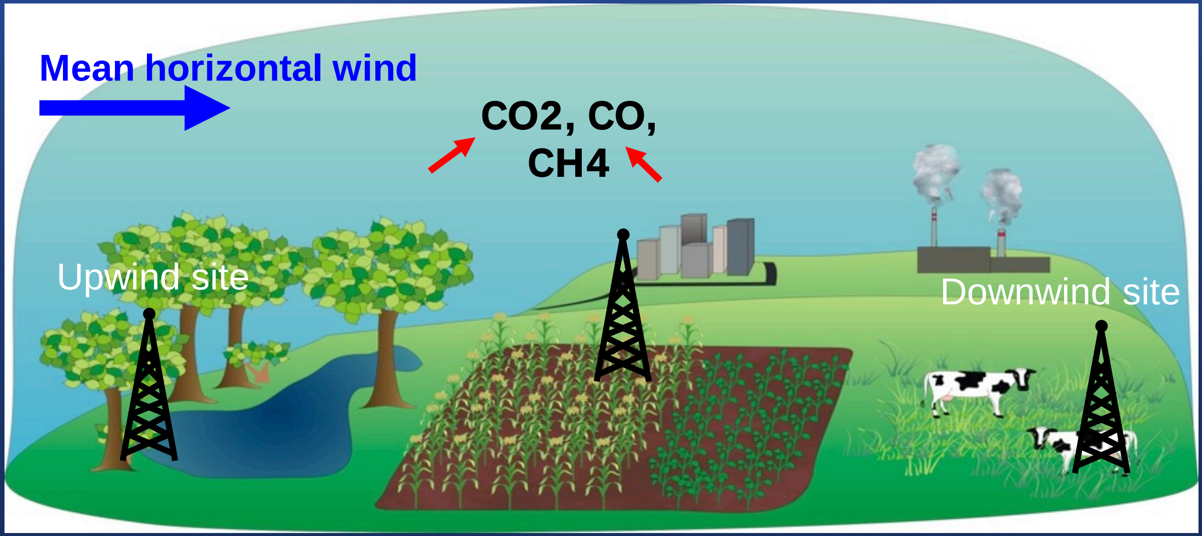
INFLUX: Urban scale emissions

- Compare to "Bottom-up" inventories which use economic data and emissions factors
- Atmospheric methods have the potential to provide independent emissions estimates
- ***"Urban box model"***
  1. Measure GHG concentrations upwind and downwind of a source
  2. Model atmospheric transport (backward)
  3. Optimize emissions by minimizing the difference between modeled and observed GHG concentrations



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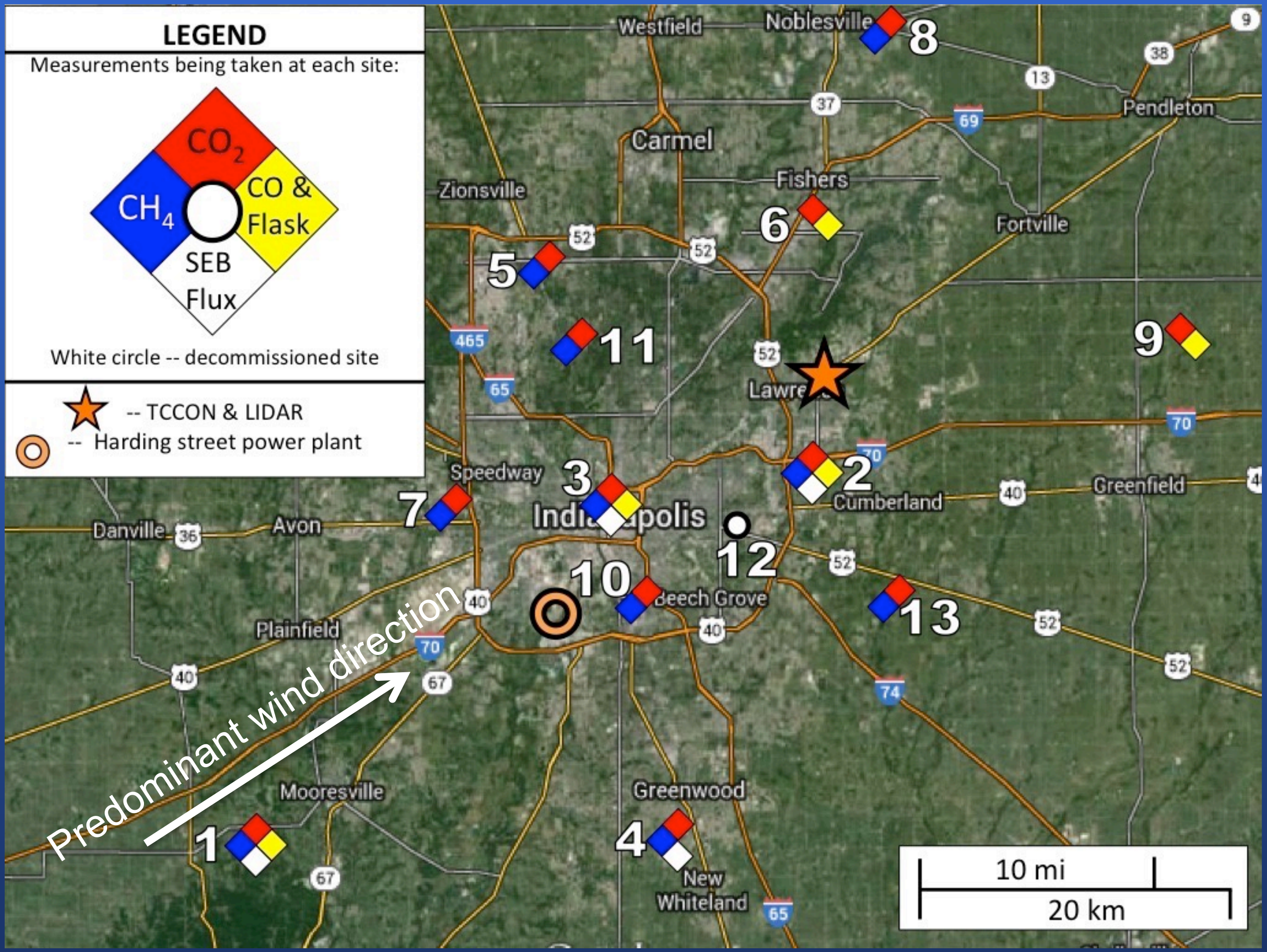
INFLUX Measurement Network



- Picarro sensors on communications towers 39-136 m AGL
- 12 measuring CO2, 10 with CH4, and 5 with CO
- *NOAA automated flask samplers*
- *NOAA Doppler LIDAR*
- *Eddy flux at 4 towers*
- *Flights (~monthly) with CO2, CH4, and flask sampler*
- *TCCON-FTS for 4 months (Sept-Dec 2012)*

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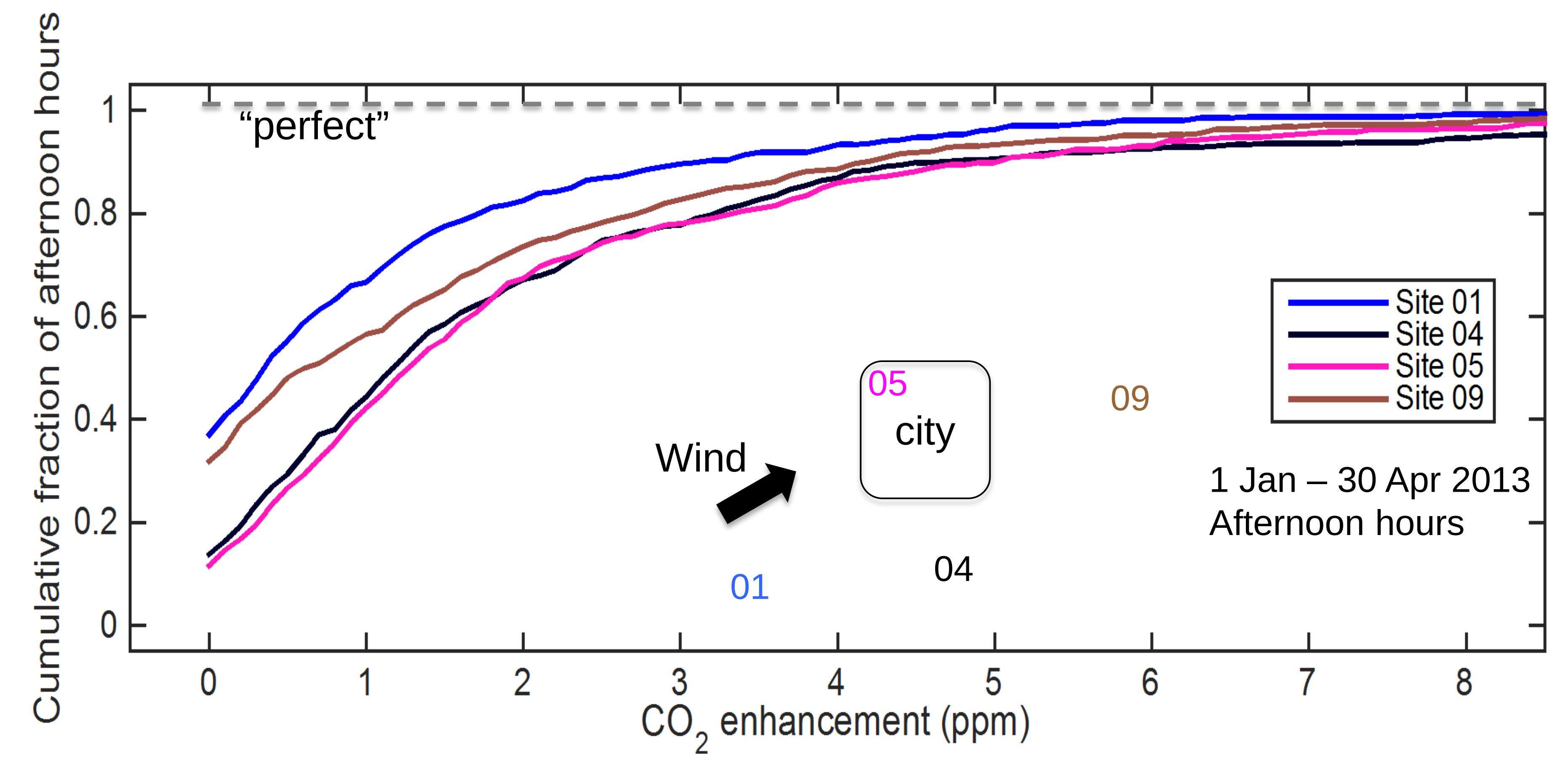
Evaluation of potential background sites: INFLUX in-situ CO_2 observations



- Enhancement: defined as difference between each potential background site and the INFLUX minimum for that hour
- Site 01 is the best overall background site
- Also Site 09 (when the wind is from the SE)

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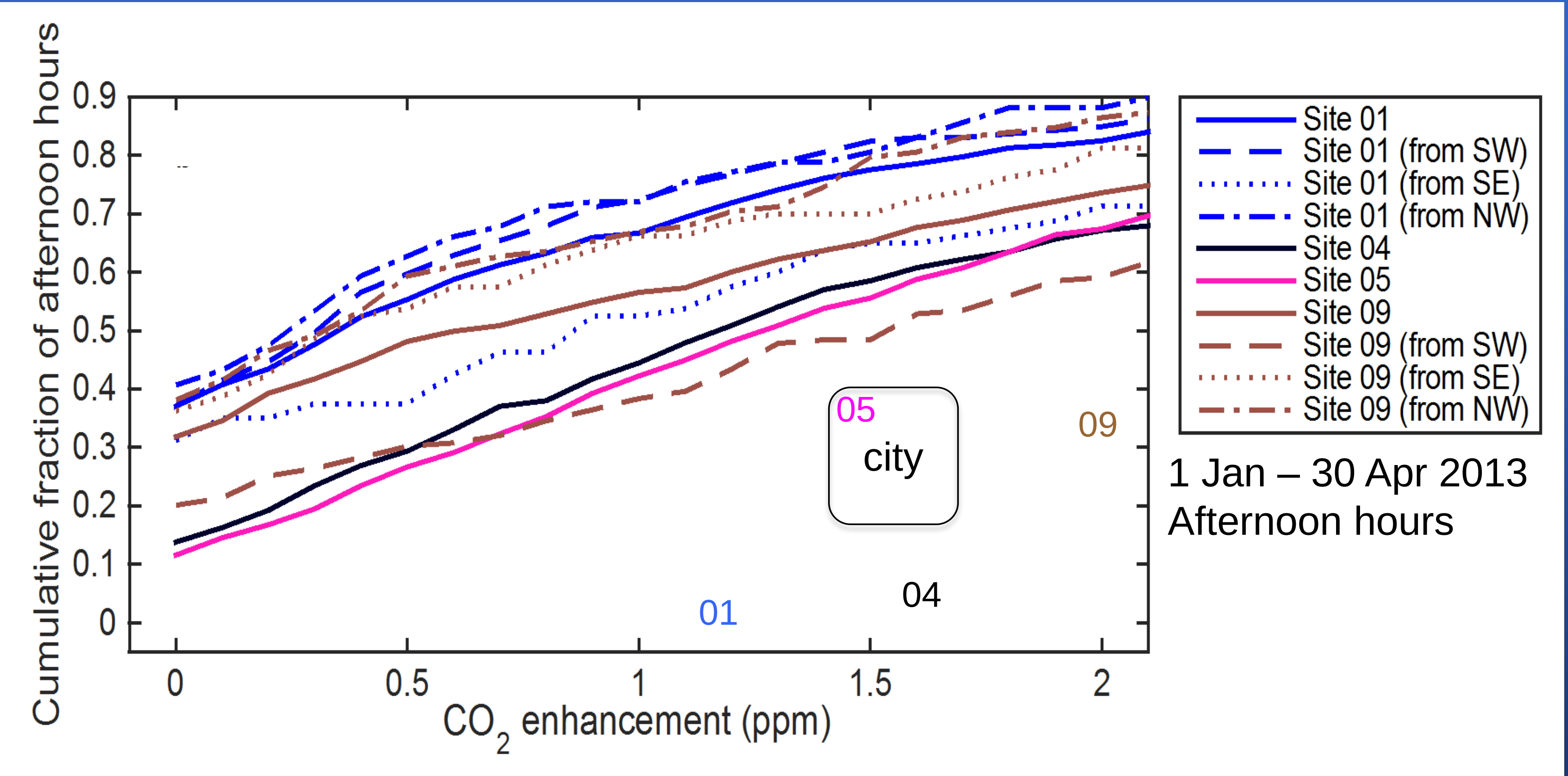
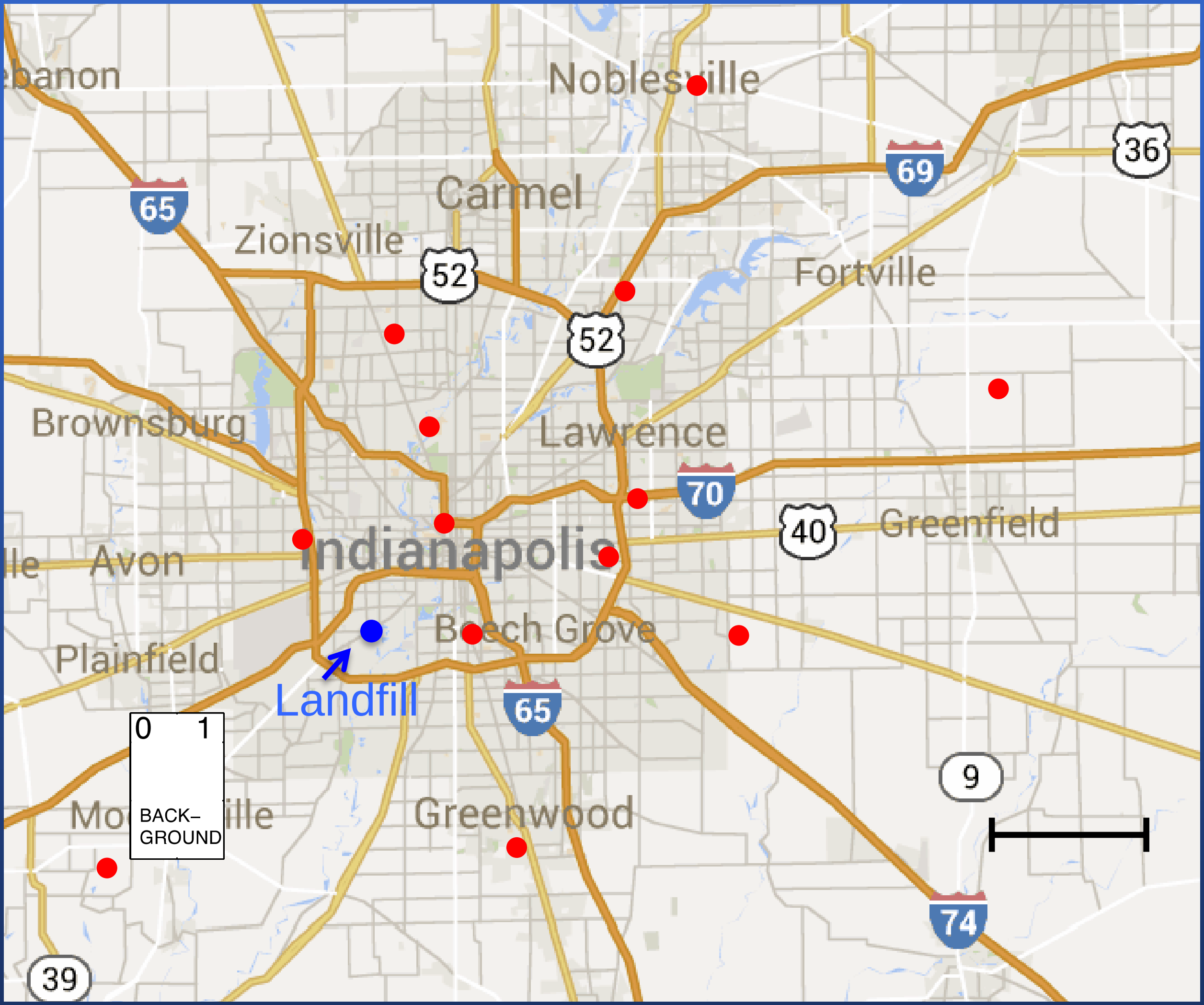
Evaluation of potential background sites: INFLUX in-situ CO_2 observations



1 Jan – 30 Apr 2013
Afternoon hours

- Enhancement: defined as difference between each potential background site and the INFLUX minimum for that hour
- Site 01 is the best overall background site
- Also Site 09 (when the wind is from the NW/SE)

Spatial structure of urban CH_4: observed



- Observed CH_4: afternoon values, averaged Oct – Dec 2013
- Ranges from 5 ppb at Site 13 (10 km east of the city) to 21 ppb at Site 10 (near the landfill).
- Miles et al., in prep

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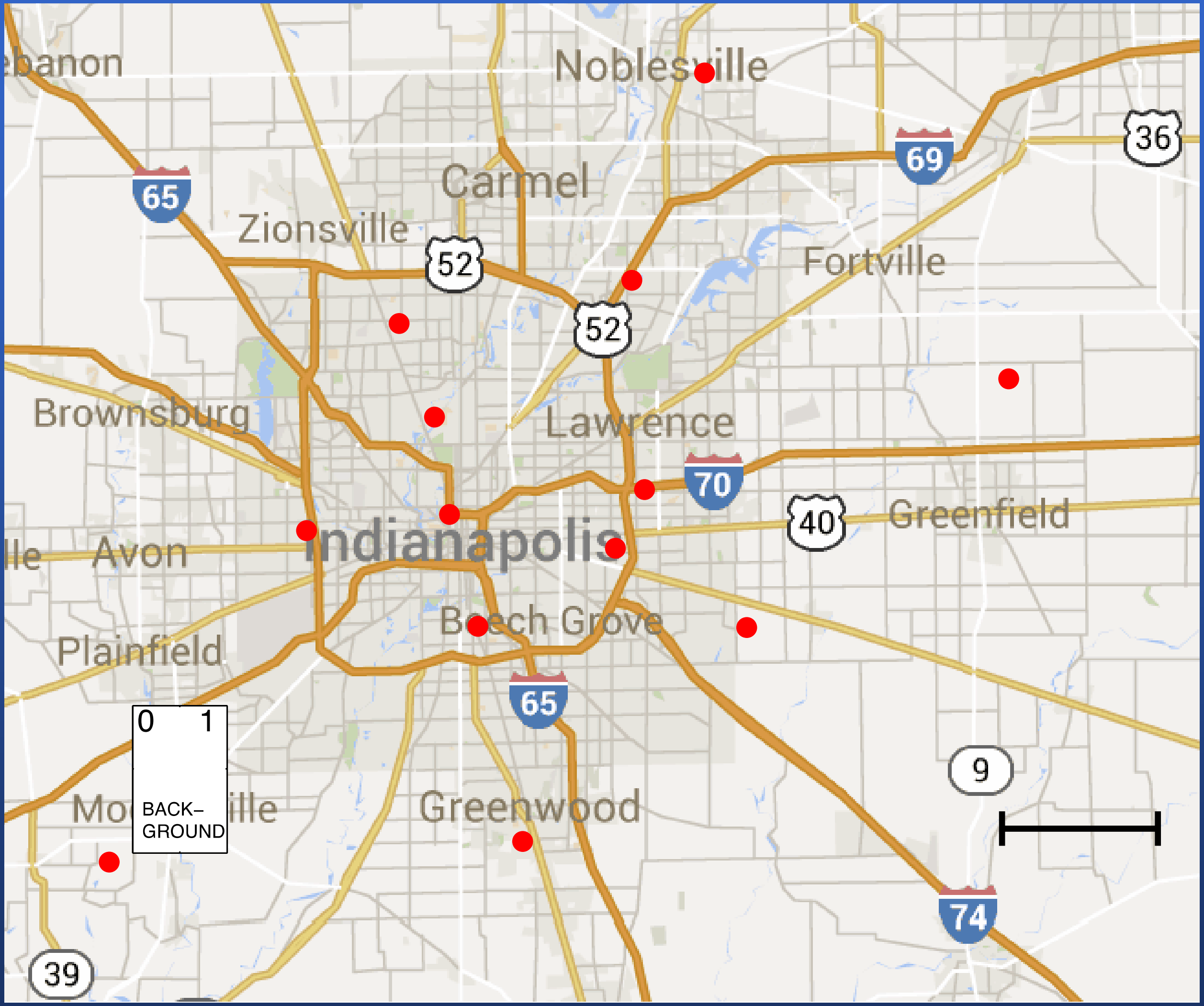
Spatial structure of urban CO: observed



- Observed CO: afternoon values, averaged Jan-April 2013
- Ranges from 6 ppb at Site 09 (24 km downwind of the edge of the city), to 29 ppb at Site 03 (downtown).
- Miles et al., in prep

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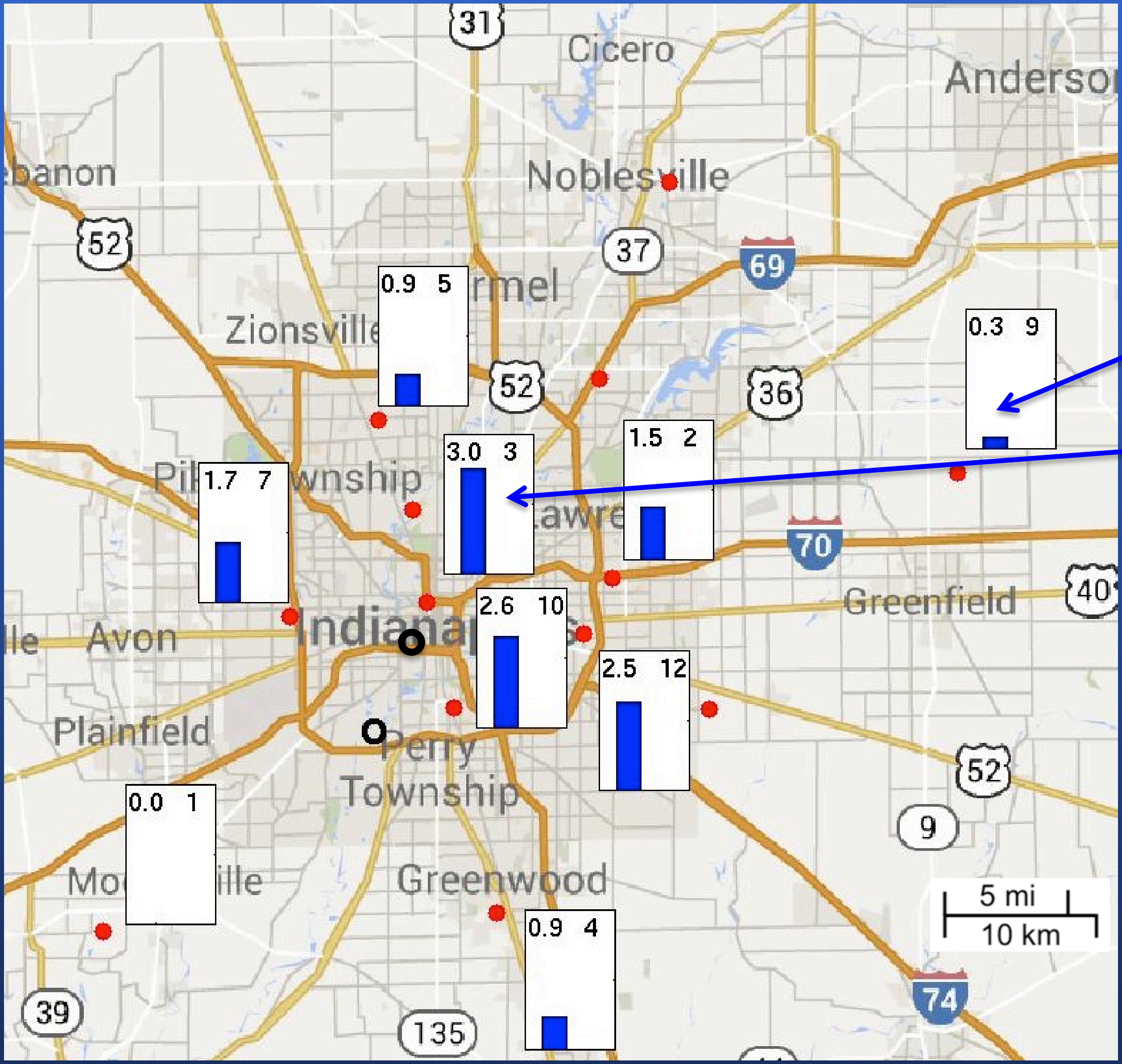
Spatial structure of urban CO_2: observed



- Observed CO_2: afternoon values, averaged Jan-April 2013
- Site 09: 0.3 ppm larger than Site 01
- Site 03: larger [CO_2] by 3 ppm
- Miles et al., in prep

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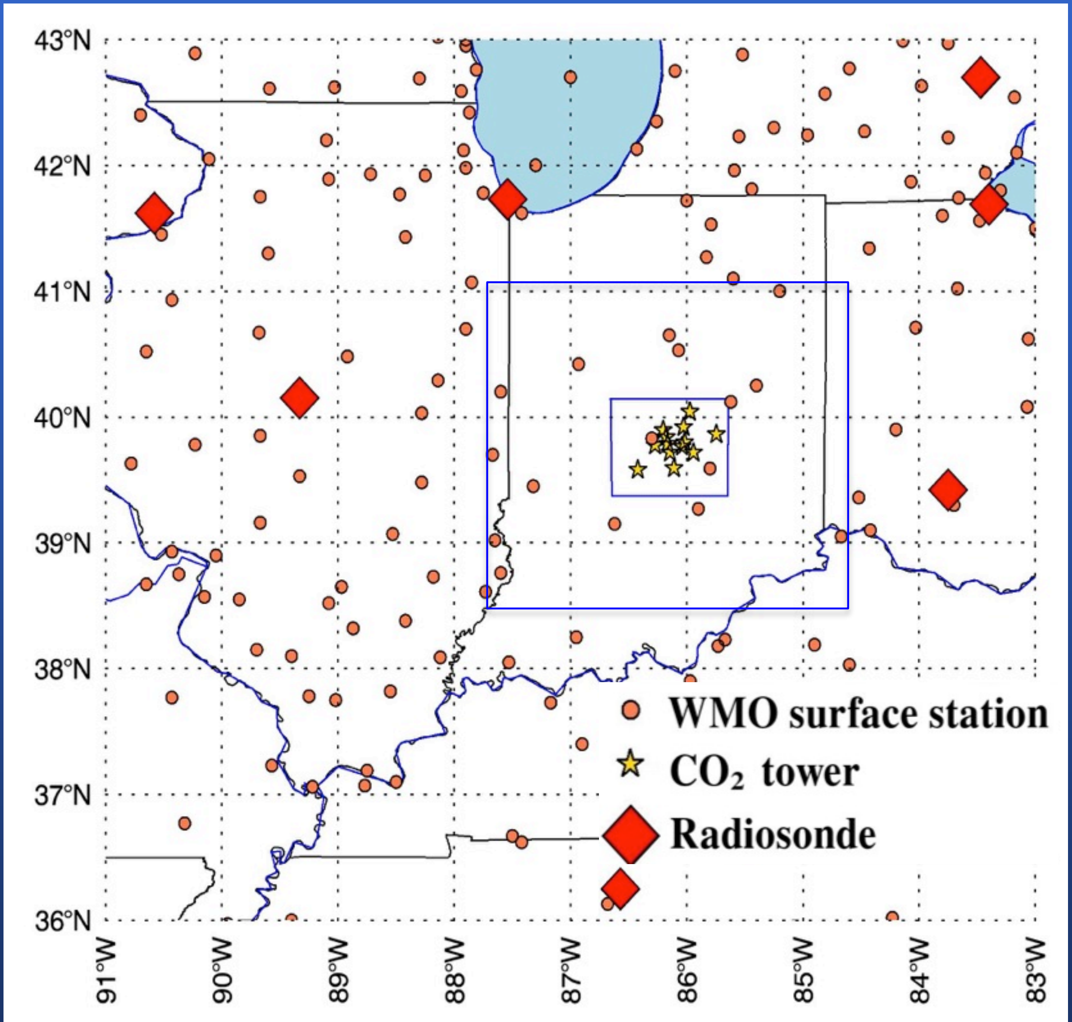
High resolution inverse modeling

- Weather Research and Forecasting model (WRF) : 9km/3km/1km (nested)

- Four Dimensional Data Assimilation (FDDA)

- Coupled to backward Lagrangian model (Uliasz et al., 1994)

- Kalman matrix inversion using Hestia 2013 emissions as a priori



Lauvaux et al., in prep

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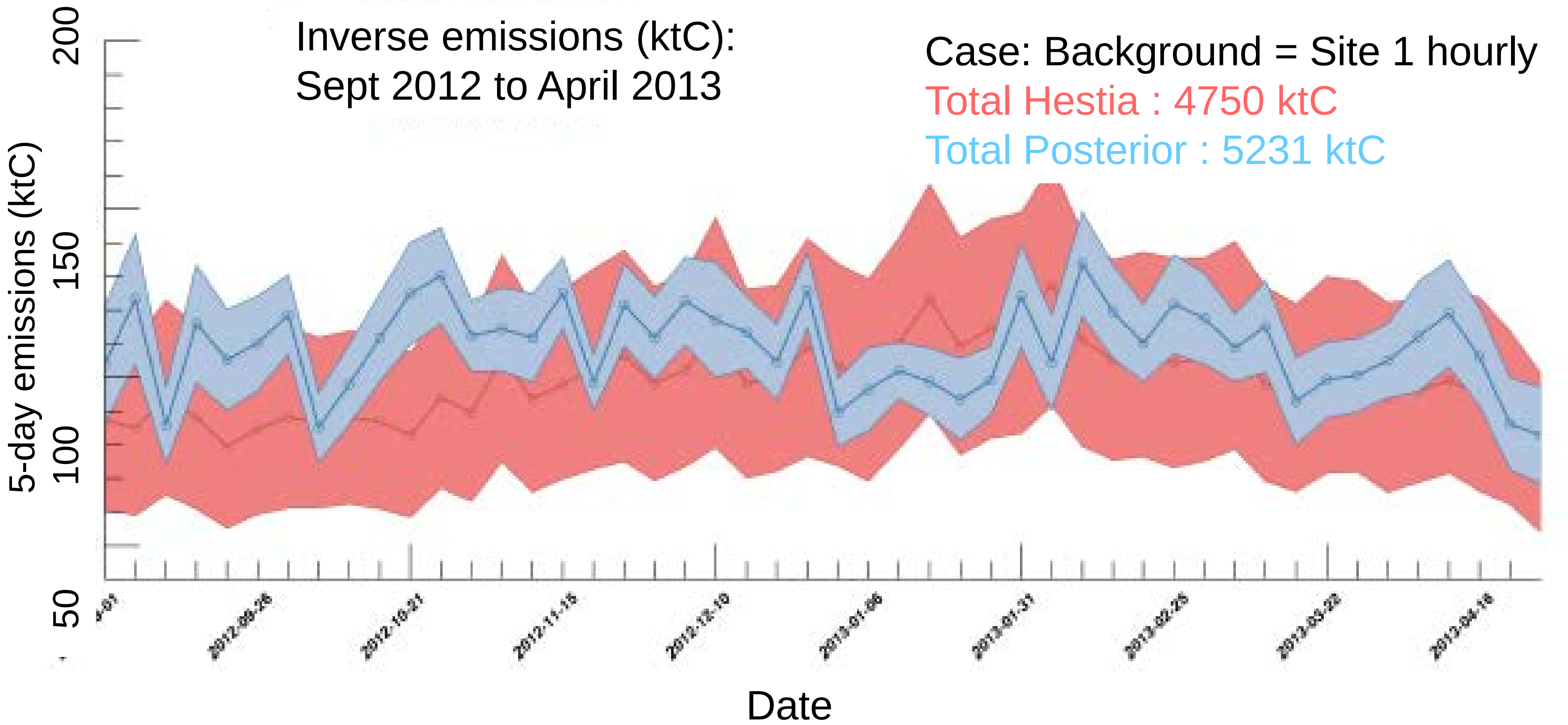
INFLUX: Urban scale inversion



- Errors are significantly reduced after inversion, from 25% to 9% on average
- Posterior emissions higher Sept to mid Nov
- Total posterior emissions are 10% higher than Hestia

Lauvaux et al., in prep

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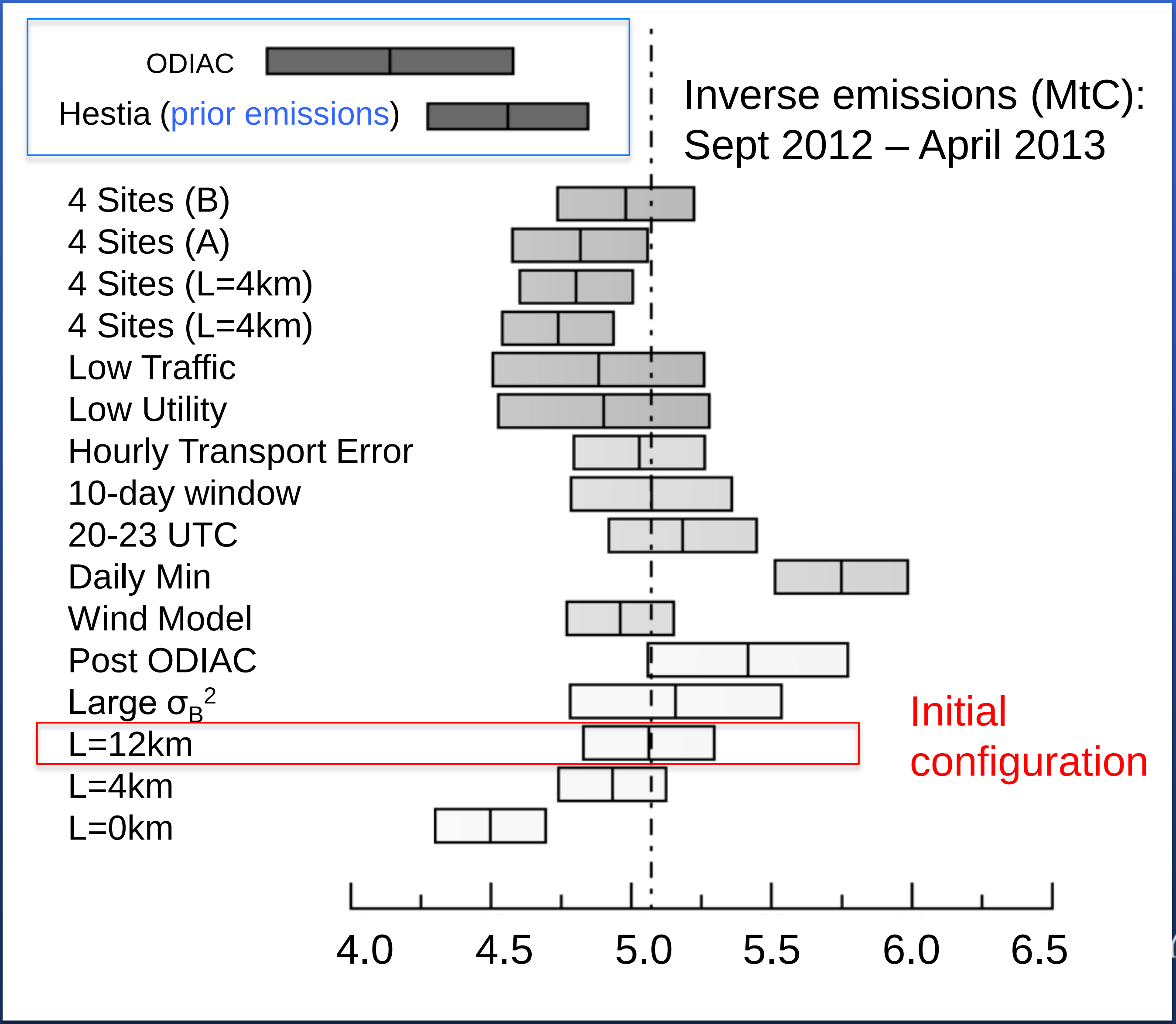
Inverse emission estimates using different inverse system configurations and prior emissions



Lauvaux et al., in prep

Conclusions

- Tower observations detect a clear urban signal in $CO_2/CH_4/CO$ (buried amid lots of synoptic "noise").
- Average afternoon dormant-season enhancements are as high as
  - 21 ppb CH_4
  - 28 ppb CO
  - 3.0 ppm CO_2
- The inverse emissions and Hestia are within 10% for the period Sept 2012 - April 2013. 16 different configurations with very different assumptions yield similar results.

Influx.psu.edu

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