# The INFLUX Project: Toward Improved Capabilities in Urban-Area Scale Greenhouse Gas Flux Measurements

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# Developing Legislation du Jour:

## The American Power Act

AMERICAN POWER ACT

## SHORT SUMMARY

The American Power Act will transform our economy, set us on the path toward energy independence and improve the quality of the air we breathe. It will create millions of good jobs that cannot be shipped abroad and it will launch America into a position of leadership in the global clean energy economy.

Our approach sets an achievable national pollution reduction target and refunds the money raised right back to American consumers and American businesses. This is not a plan that enriches Wall Street speculators. And this is certainly not a plan to grow the government. It is a plan that creates jobs and sets us on a course toward energy independence and economic resurgence. It is time for Democrats, Republicans and Independents to come together to pass legislation that will create American jobs and achieve energy security, while reducing carbon pollution by 17 percent in 2020 and by over 80 percent in 2050. Our plan is based on five simple principles:

**We need reliable methods to measure area-wide greenhouse gas emission fluxes.**

# INFLUX

**Project goals (NIST Proposal)**
**"The uncertainty in area/regional greenhouse gas (i.e. $CO_2$ and $CH_4$) flux measurements can be ±20% or better, and this uncertainty can be constrained and defined through improved measurement techniques, comparison to inventory data, and use of carbon isotope ratio data."**

**Modified, to date:**
- Separation of $CO_2$ff, $CO_2$r
- Comparison of top-down with bottom-up emission estimates.
- Quantification of uncertainties.

Secondary goals
- Use emission ratios to quantify fluxes of other trace gases, e.g. CO, halocarbons.
- Identify and characterize point sources, esp. for $CH_4$.
- Utilize results to improve bottom-up inventories ($CO_2$ff, CO etc).

## Approach

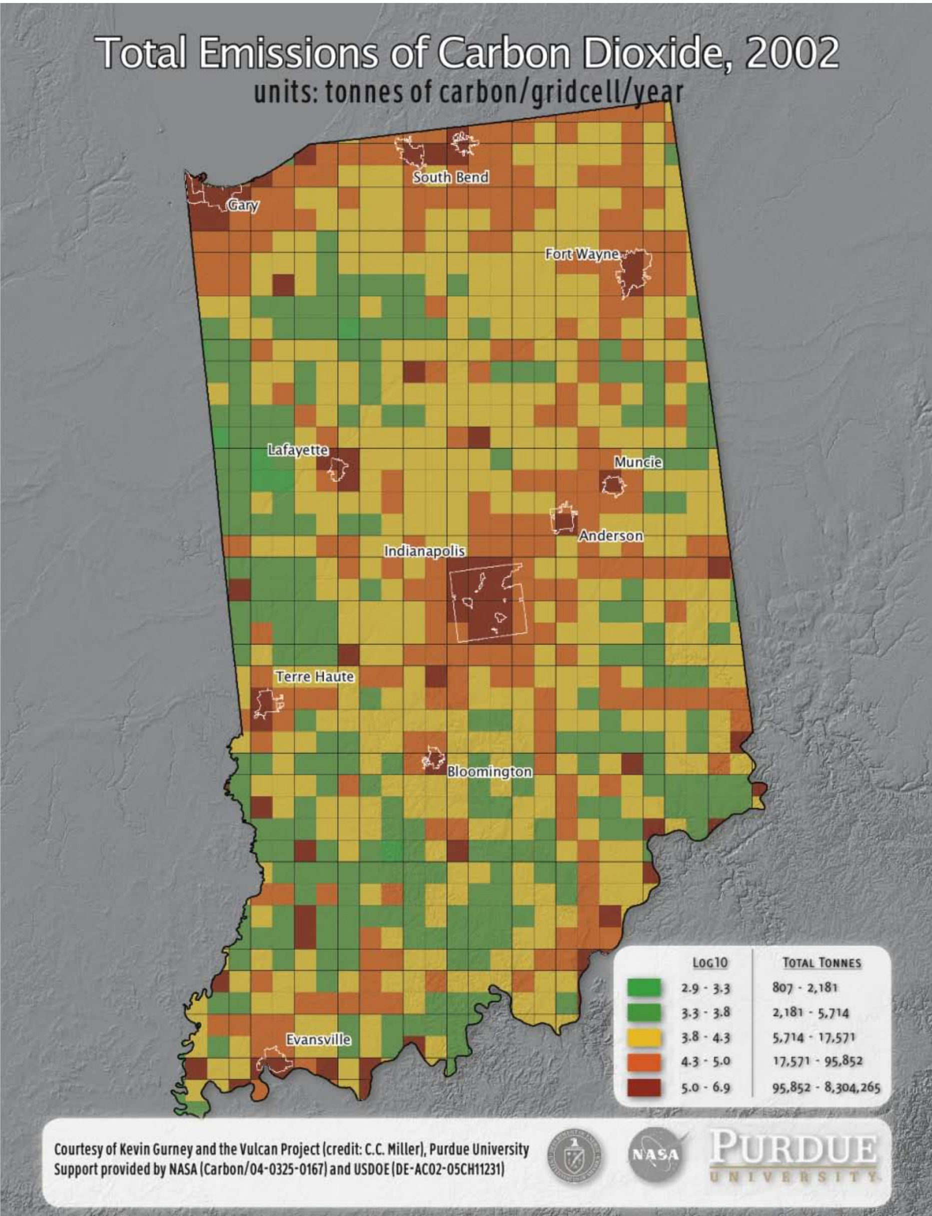
**Multiple simultaneous approaches to measure $CO_2$ and $CH_4$ fluxes.**

**Focus on Indianapolis, due to existing measurement and Vulcan data, and regional and topographical characteristics**

1. Aircraft-based flux measurements for both $CO_2$ and $CH_4$. Good snapshot for comparisons, and for hunting the "missing" $CH_4$, not good for integrated averages.
2. Tower-based fluxes. Good for averages
3. $^{14}C$ measurements, both towers and aircraft. Great complement to direct methods.
4. Vulcan/Hestia modeling.
   A bottom line. How to leverage these measurements to enable development of a better model/data fusion product.
5. Regional modeling/inverse analysis–WRF-CHEM-aircraft and towers

**Field measurement period is Fall 2010 – Summer 2012**

## Aircraft Approach



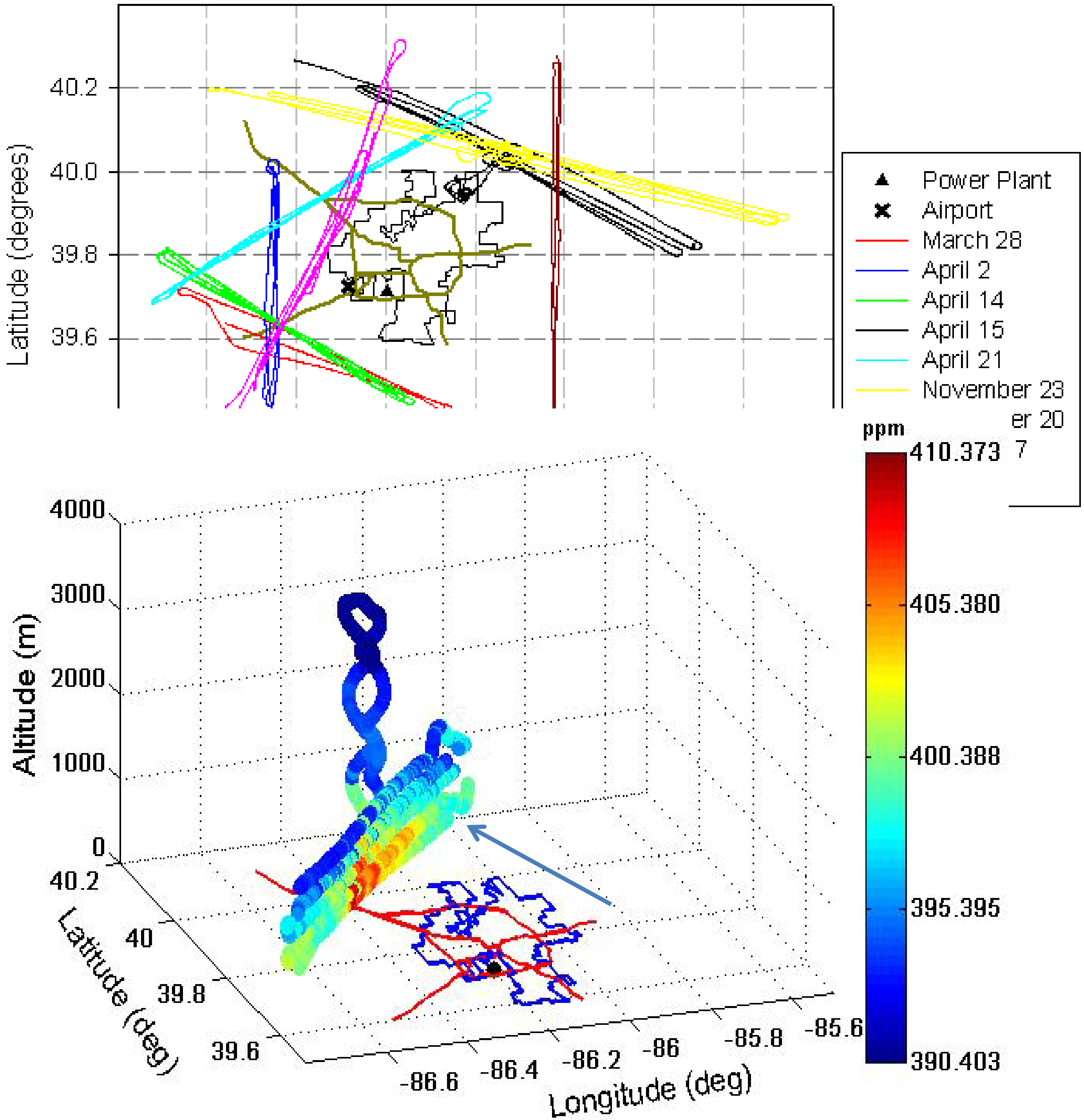

## Use of ALAR


## Mass Balance Approach

$$F = \frac{\int_0^{z_i} \int_{-x}^{x} \left[ \left( \frac{[C]_{ij} - \overline{[C]_b}}{1 \times 10^a} \right) \times n_{d\,ij} \times U_{\perp ij} \right] dx\, dz}{A_{city}}$$

$$\overline{[C]_b} = \frac{\sum [C_{ij}]_{edge}}{n}$$

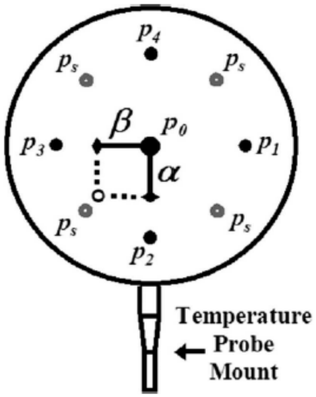
$$n_{d\,ij} = \frac{P_{ij} V}{R T_{ij}}$$



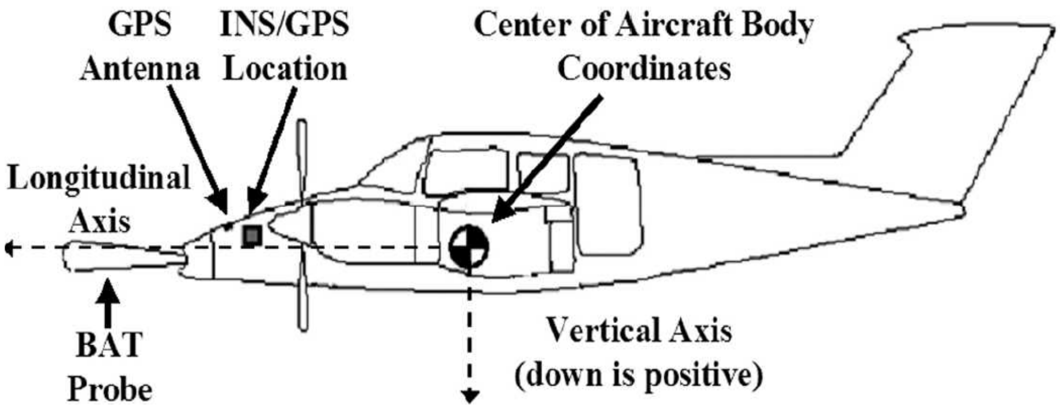
Latitude (degrees)
40.2
40.0
39.8
39.6
Power Plant
Airport
March 28
April 2
April 14
April 15
April 21
November 23
ppm
410.373
405.380
400.388
395.395
390.403
Altitude (m)
4000
3000
2000
1000
0
Latitude (deg)
40.2
40
39.8
39.6
Longitude (deg)
-86.6
-86.4
-86.2
-86
-85.8
-85.6

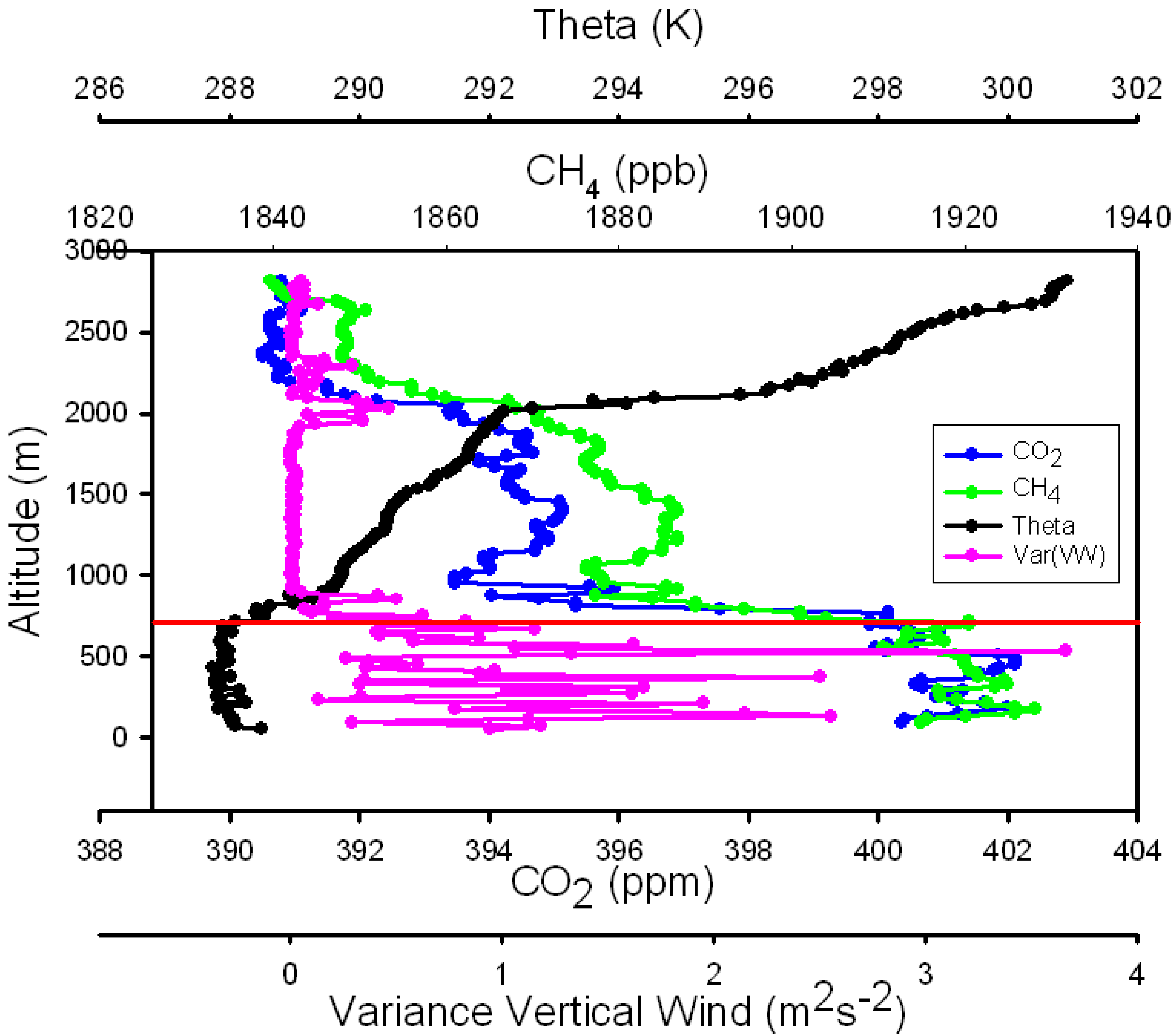
# The BAT probe

- Temperature and pressure (50hz)
- BAT probe winds determined to be in error, EDAS (Eta Data Assimilation System) 40-km forecast winds used as replacement
- GPS/INS position/navigation (50hz)




see Garman et al. (2006; 2008)

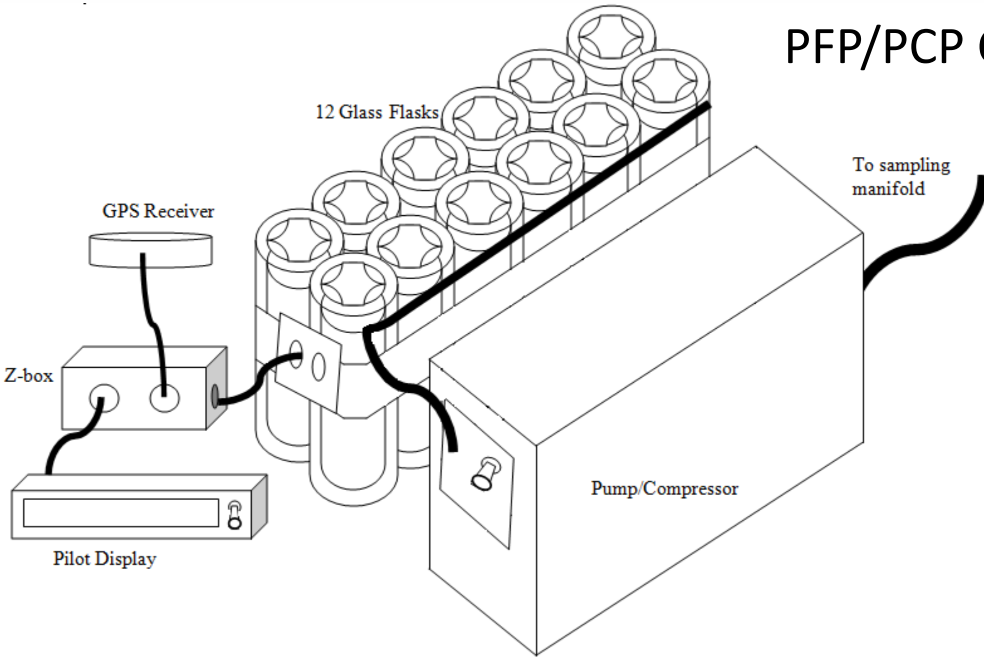



Theta (K)
286
288
290
292
294
296
298
300
302
CH4 (ppb)
1820
1840
1860
1880
1900
1920
1940
3000
2500
2000
1500
1000
500
0
Altitude (m)
CO2
CH4
Theta
Var(VW)
388
390
392
394
396
398
400
402
404
CO2 (ppm)
0
1
2
3
4
Variance Vertical Wind (m2s-2)

PURDUE UNIVERSITY

# Portable Flask Package (PFP)

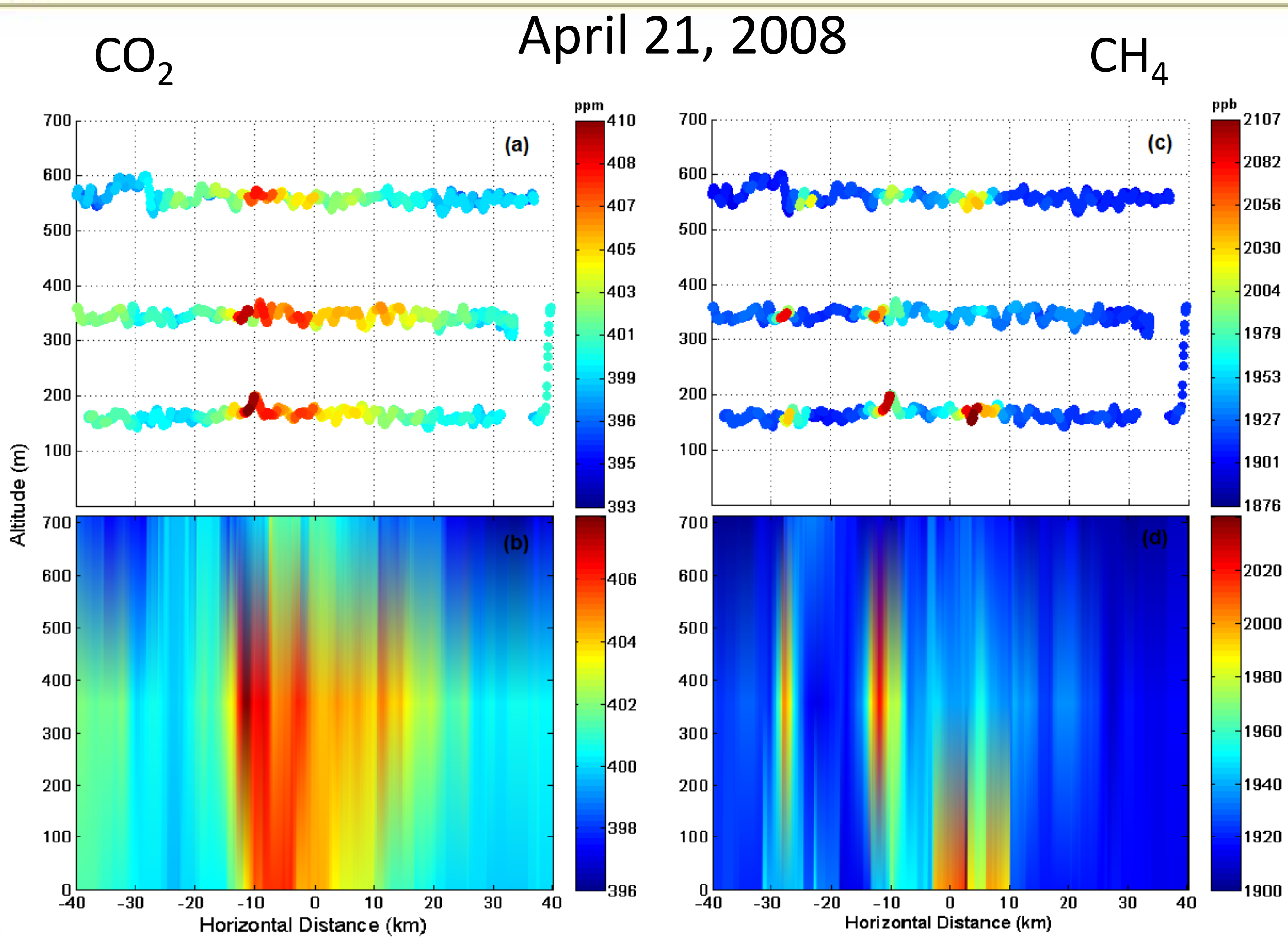
## PFP/PCP Components




## PFP/PCP Installation

- 12 or 24 Flasks per flight
- $CO_2$, CO, $CH_4$, $SF_6$, $H_2$, $N_2O$, halocarbons, and $^{14}C$ of $CO_2$
- Flasks taken at pilot/scientist discretion
- Filled during times of flat/level flight

# Results - Kriging



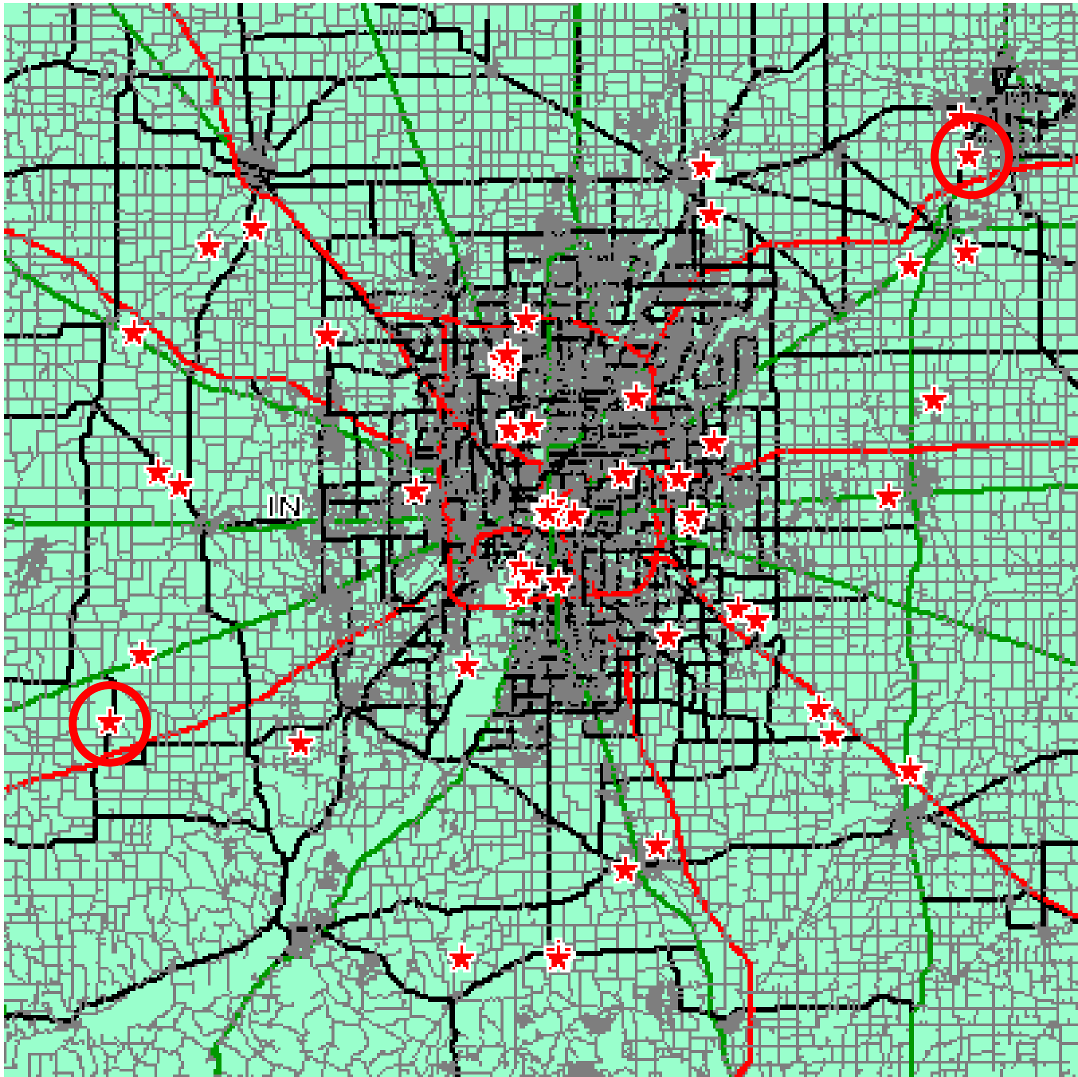

See Mays et al., 2009

# Tower measurements

- Upwind and downwind tower (+ 2 (or) more downwind/city center as funding permits)
- Tower overflights on a few occasions
- In situ: $CO_2$, $CH_4$ and CO
- Integrated sampling: Collect air over two week sampling period, only when met conditions meet certain criteria. Vary sampling rate with wind speed and/or pbl height. $CO_2$, $CH_4$, CO, $\Delta^{14}CO_2$, $\delta^{13}CO_2$, $SF_6$, $N_2O$, $H_2$. Halocarbons/hydrocarbons likely not possible.
- ?N “Grab” sample flasks: $CO_2$, $CH_4$, CO, $\Delta^{14}CO_2$, $\delta^{13}CO_2$, $SF_6$, $N_2O$, $H_2$, and a suite of halocarbons and hydrocarbons.
- We do not currently have met data defined; likely to have 2D sonics at both towers.
- We are looking into funding for at least 2 additional towers.

# INFLUX Tower Experimental Design

- Two methods to calculate flux from the measurements
  - Simple mass balance approach
    - But mixing state in BL is unknown
  - Inversions with WRF-CHEM

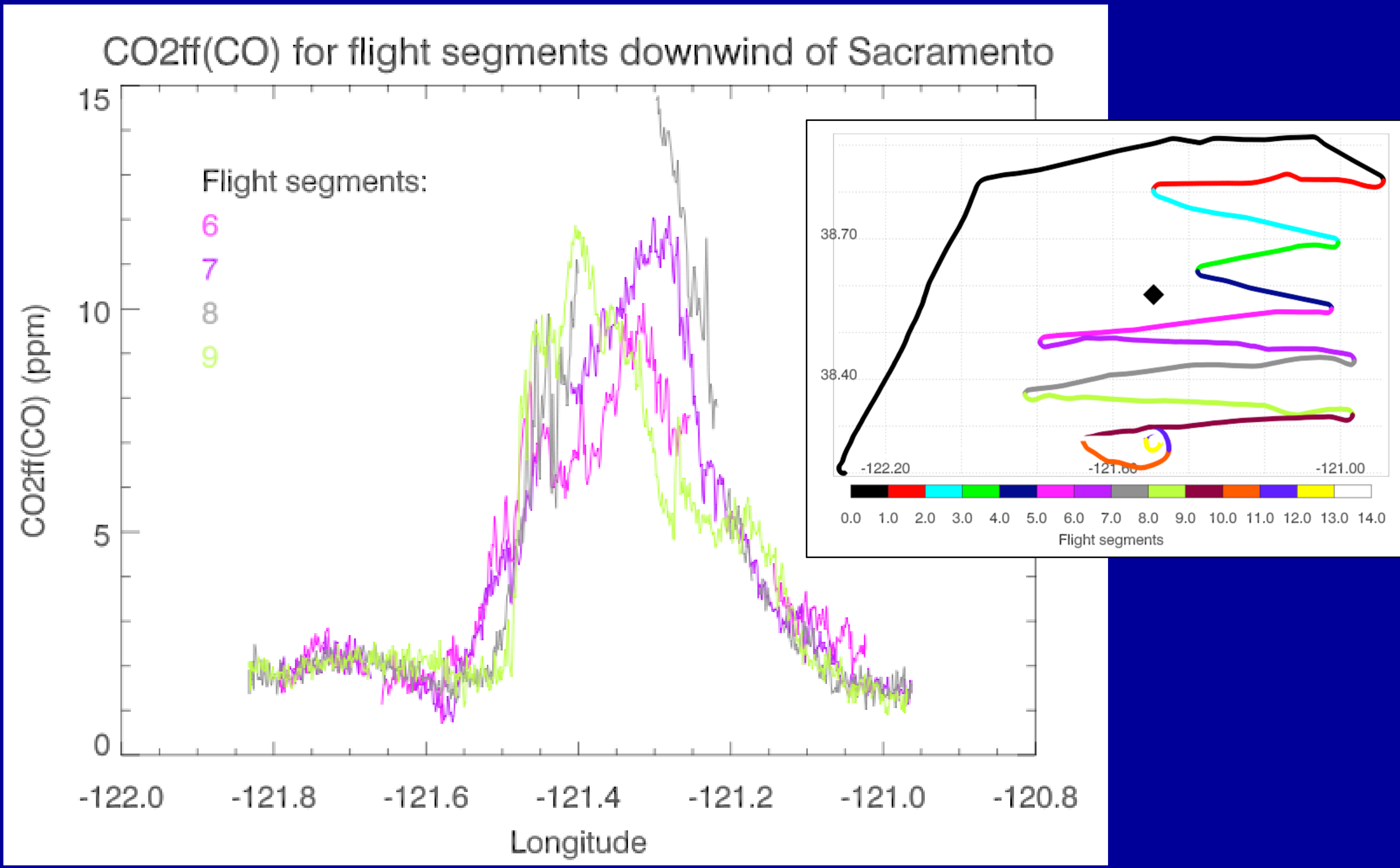



# $^{14}CO_2$ Measurements

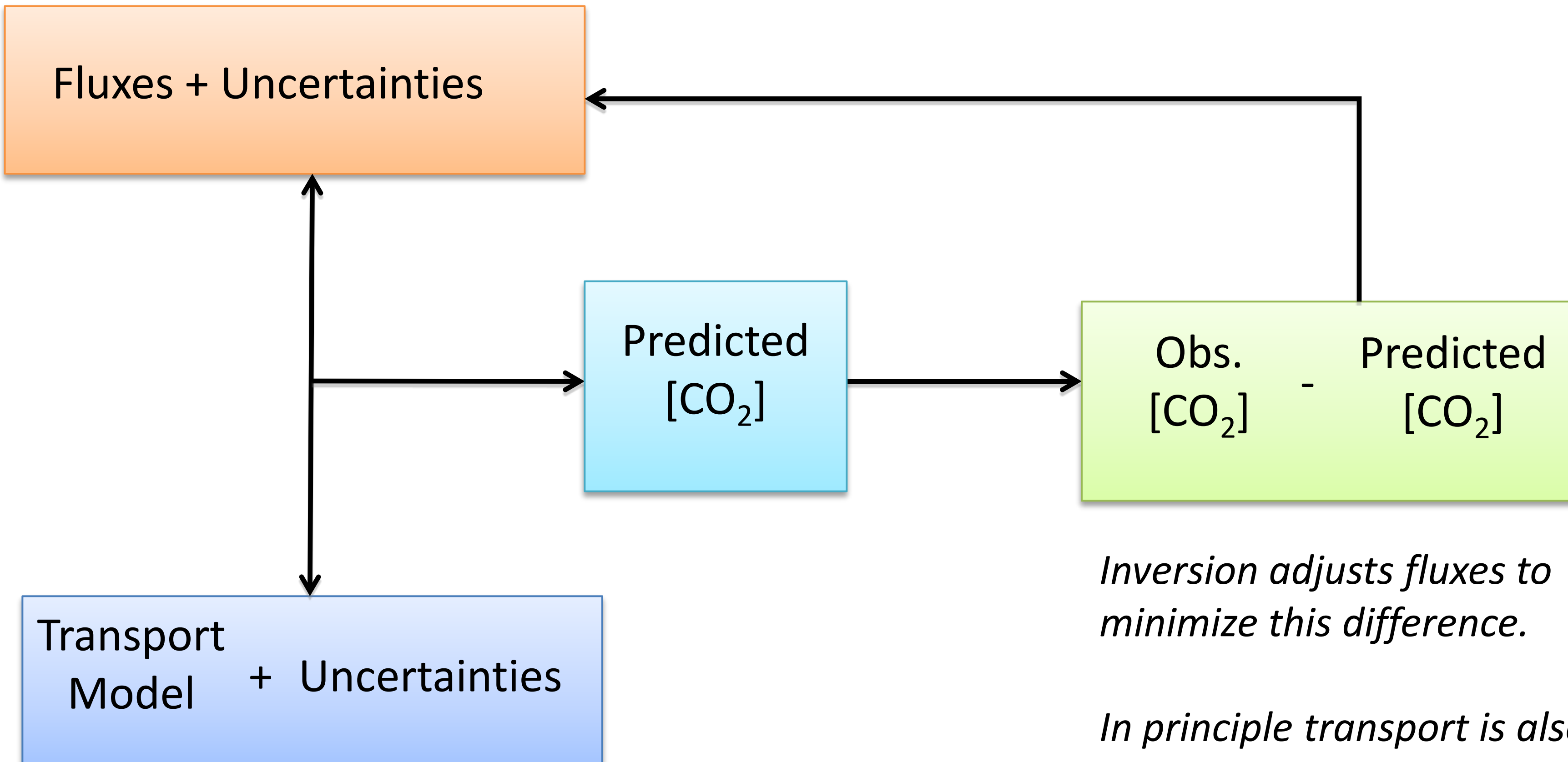
$$CO_{2ff} = \frac{CO_{2obs}\left(\Delta_{obs} - \Delta_{bg}\right)}{\Delta_{ff} - \Delta_{bg}} - \frac{CO_{2r}\left(\Delta_{r} - \Delta_{bg}\right)}{\Delta_{ff} - \Delta_{bg}}$$

- **We will do integrated (~biweekly) sampling at the towers, for specified wind directions/conditions. $^{14}CO_2$ measurements are expensive, and there is limited capacity. Aircraft samples will also be analyzed for $^{14}CO_2$. Analysis to be done by AMS.**
- **Integrated samples reduce the number of measurements, but still allow us to average over longer time periods (can average out some of the biases)**
- **We will also measure CO and obtain $CO_2$ff using known $CO/CO_2$ emission ratios.**

# Learning lessons from Sacramento 2009: $CO_2$ff from $\Delta^{14}CO_2$ and insitu CO (Turnbull, Fischer, Karion and Sweeney)



# Atmospheric Inversion



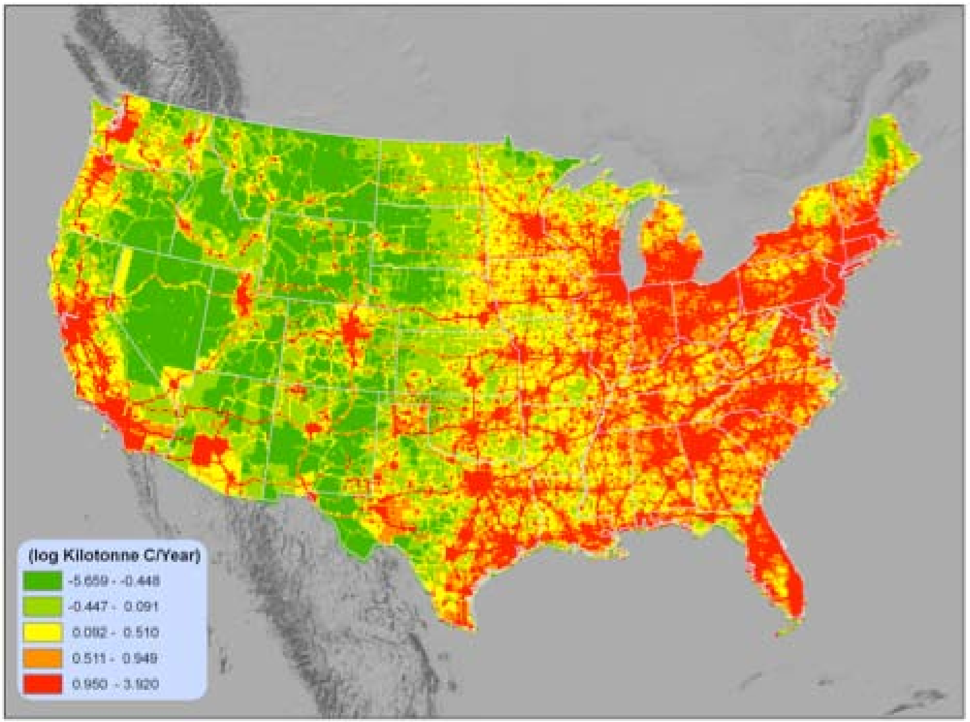

*Inversion adjusts fluxes to minimize this difference.*

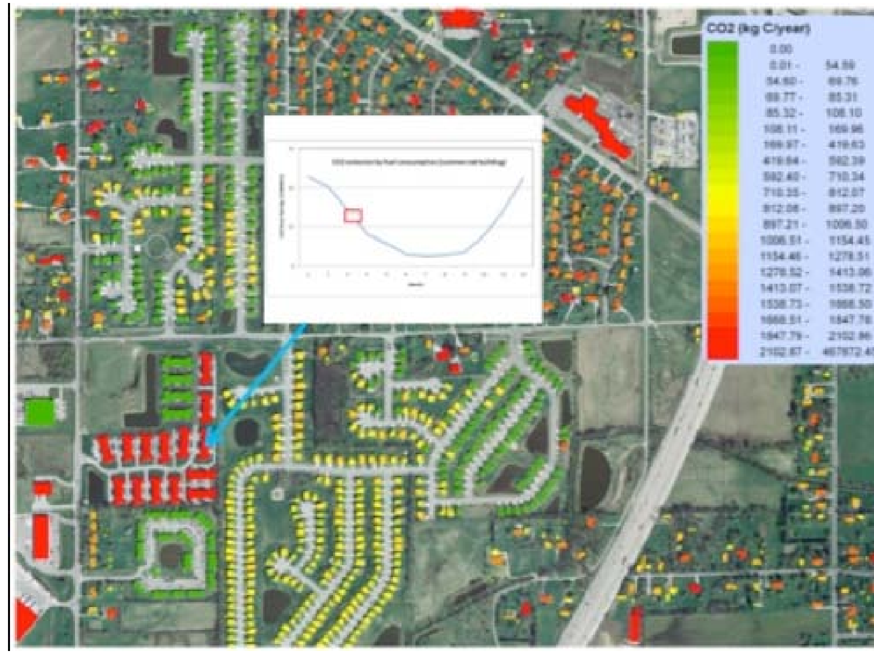
*In principle transport is also uncertain and could be adjusted as part of the minimization, but this is not done at present.*

# Unique challenges for a high resolution inversion of anthropogenic emissions

- High-resolution atmospheric transport is essential.
  - Mesoscale model (e.g. WRF) run at high resolution should suffice.
  - A mesonet of regional meteorological data, boundary layer depth data may be necessary to constraint atmospheric transport – assimilate into model.
- Multi-species inversion ($CO_2$, $^{14}CO_2$, CO) is likely to be necessary – more complex than $CO_2$ alone.
- Location of emissions are known fairly well – can be used as prior information.
- Treatment of boundary conditions will be important.  Utilize upwind observations when possible.

# Comparing to/informing the Vulcan Emission Inventory/Model




**Vulcan - hourly resolution for USA**

**Hestia – building level for Indianapolis**

- **See: Kevin Gurney/**
- **http://www.purdue.edu/eas/carbon/vulcan/index.php**

# What we don't have, but need

- Support for more towers, to ensure adequate coverage
- Winds and boundary layer information
  - -We have 3D winds and BL profiling on the aircraft, but of course this is sporadic
  - -Need acoustic sounders/LIDAR or the equivalent/better
- We do not yet have CO (except flasks) on the aircraft
- We would like a partnership with NOAA on this project


Please join the INFLUX Team!
Thank you!