Capturing the urban plume using aircraft observations

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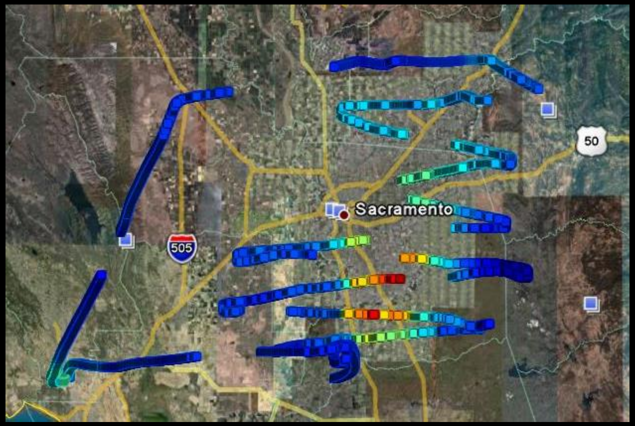
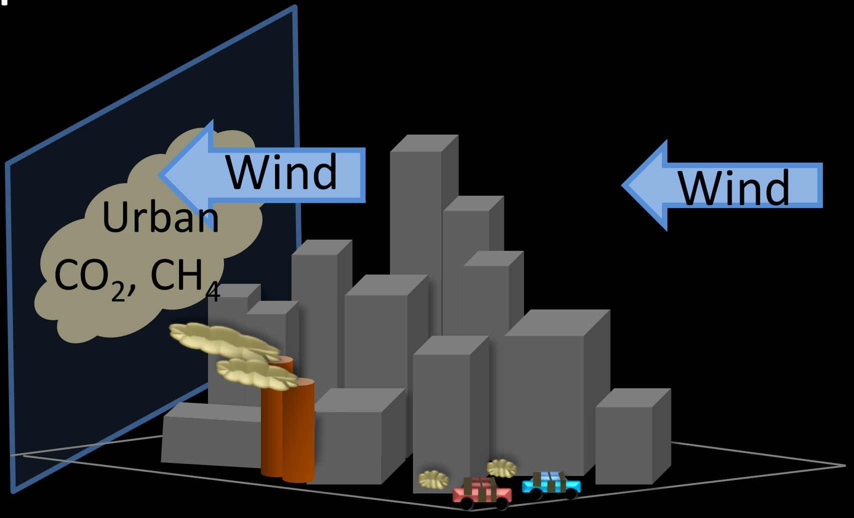
Advantages of the aircraft

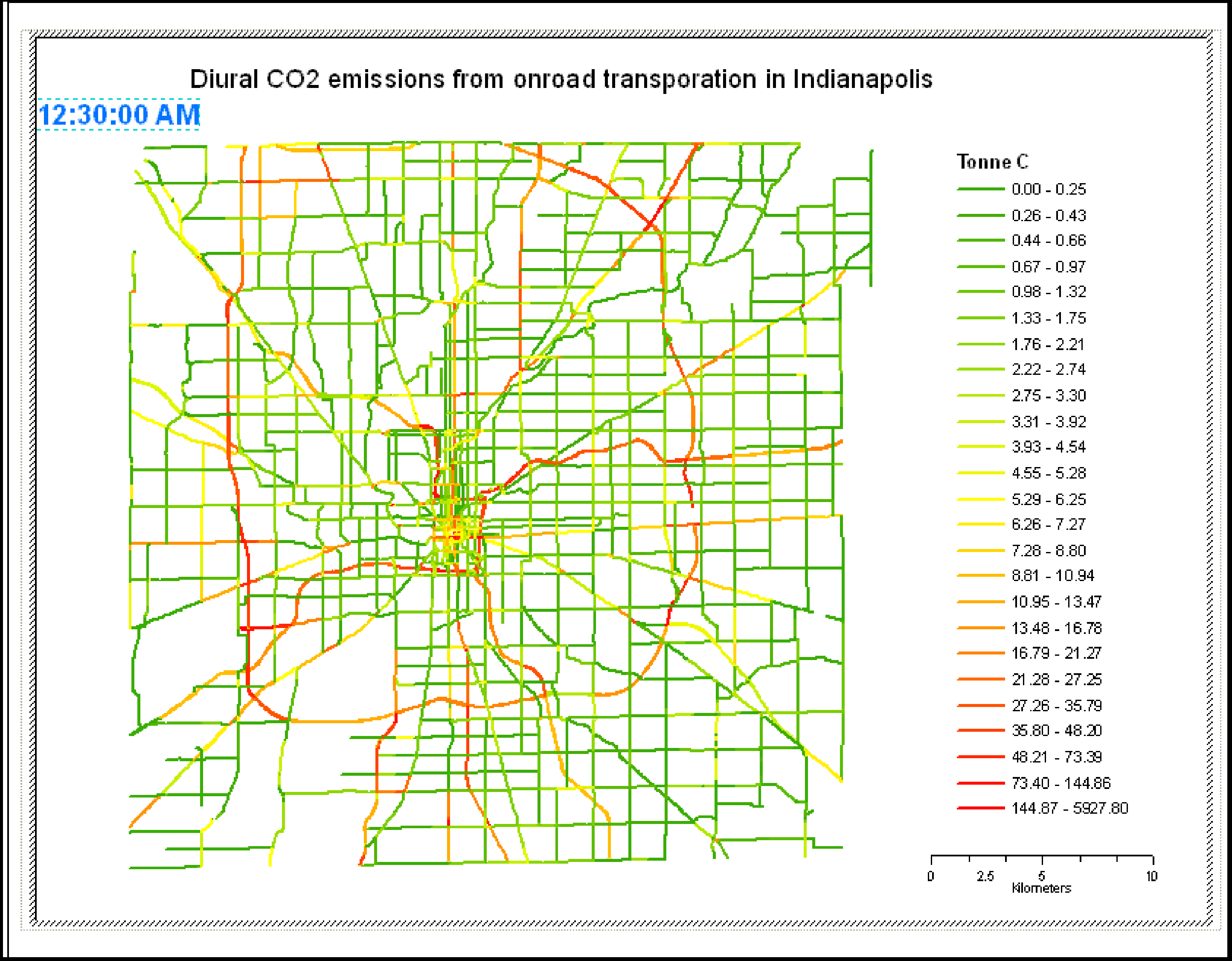
- Aircraft are an efficient way to survey an urban plume of greenhouse gases above and below the boundary layer.
- Aircraft allow exploration of point sources that may not be easily identified by ground-based measurements of greenhouse gases.
- Aircraft wind, temperature and RH measurements can be used to evaluate transport models.



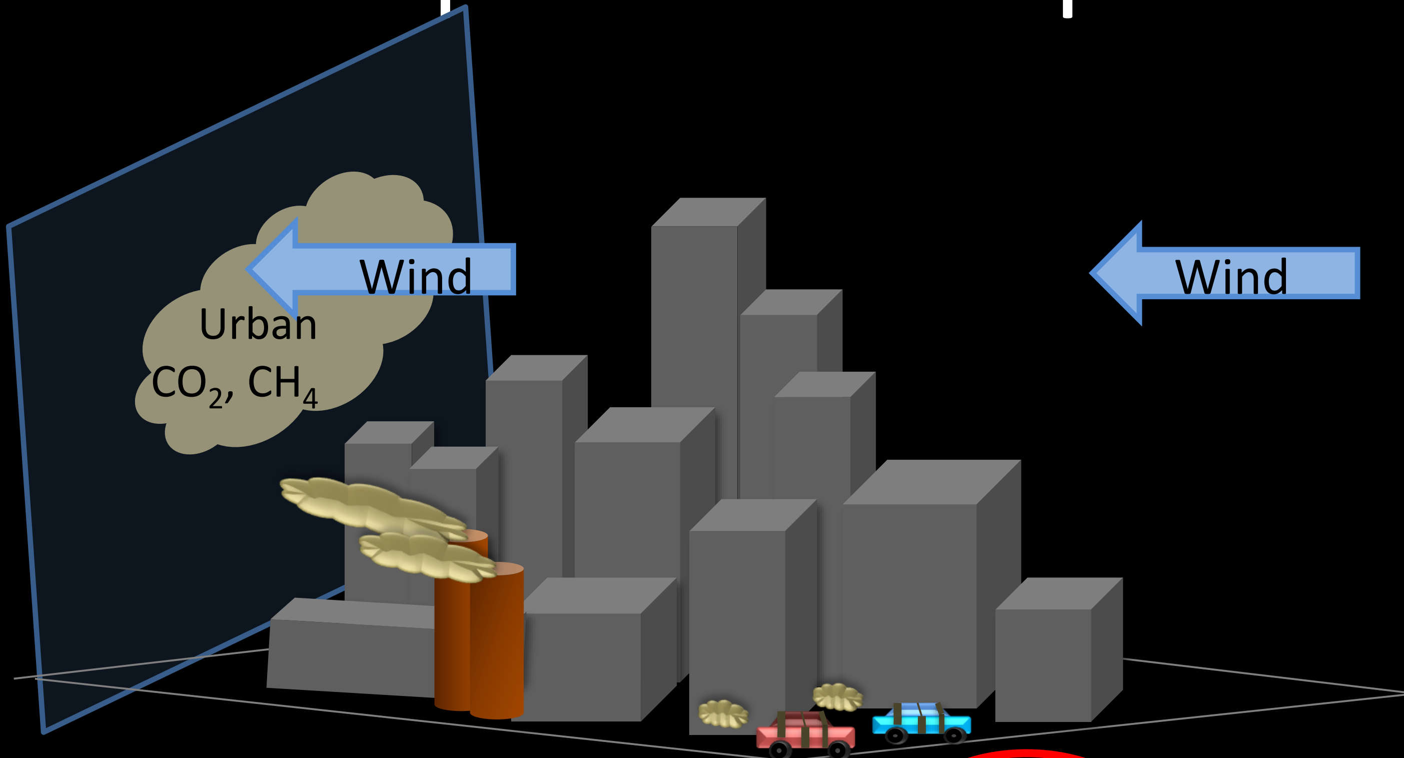


Disadvantage of the aircraft

Seasonal, weekly and diurnal variability make it impossible to use only aircraft



Indianapolis FLUX experiment



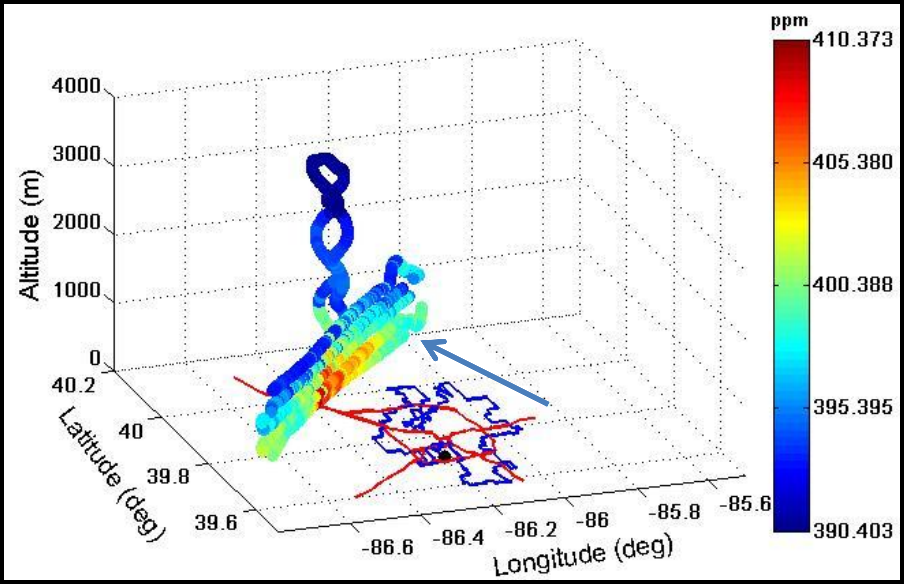
$$F = \frac{\int_0^{z_i}\int_{-x}^{x}\left[\left(\frac{[C]_{ij}-\overline{[C]}_b}{1\times10^a}\right)\times n_{d_{ij}}\times U_{\perp_{ij}}\right]dx\,dz}{A_{city}}$$

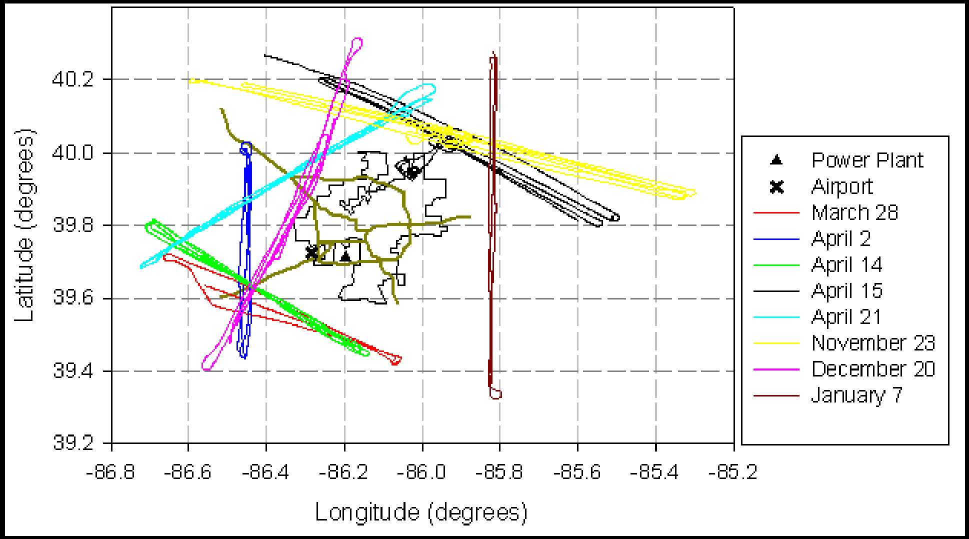
ΔCO_2 **Transport**

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

$$n_{d_{ij}} = \frac{P_{ij}V}{RT_{ij}}$$

Indianapolis



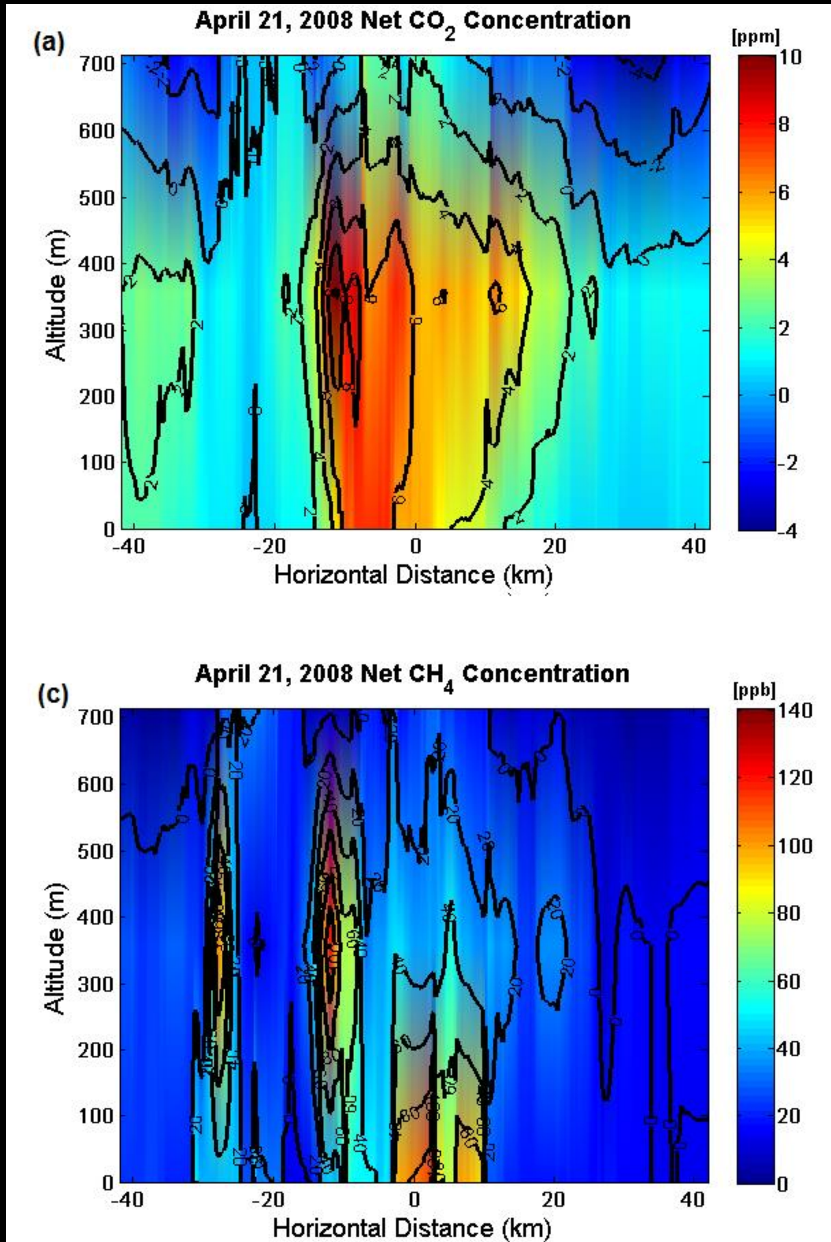


- March 28, 2008
- April 2, 2008
- April 14, 2008
- April 15, 2008
- April 21, 2008
- November 23, 2008
- December 20, 2008
- January 7, 2009

- Upwind and downwind legs to flights
- Upwind legs wasted too much time
- Better to fly outside plume on downwind legs

CO_2

CH_4



Indianapolis

April 21, 2008

CO_2 measurements clearly indicate that there is a signal of 10 ppm.

Methane measurements show likely point sources.

- Important constraint on plume dispersion
- Suggest mean back trajectory

Mays et al 2009

Date	CO_2 Flux (µmole/m²s)	CH_4 Flux (µmole/m²s)	Vulcan C Flux (µmole/m²s)
March 28	9.02 +/- 0.80	0.0063 +/-0.0011	17.45
April 2	7.89 +/- 0.66	0.068 +/- 0.0016	18.70
April 14	24.36 +/- 1.05	0.13 +/- 0.0041	15.87
April 15	51.86 +/- 0.83	0.16 +/- 0.0044	15.10
April 21	5.93 +/- 0.48	0.22 +/- 0.0036	15.5
Nov 23	6.60 +/- 2.77	0.071 +/- 0.010	12.36
Mean +/- 1σ	***17.61 +/- 18.14***	***0.11 +/- 0.076***	***15.83 +/- 2.17***

INFLUX 1

Strengths:

- Background and urban signal for CO_2 and CH_4 signal was easily detectable and well defined.

Weakness:

- Unclear what part of the plume was due to respiration/photosynthesis and what part was due to fossil fuel.
- Transport was not well known and led to large errors in CO_2

Sacramento Study

New Assets

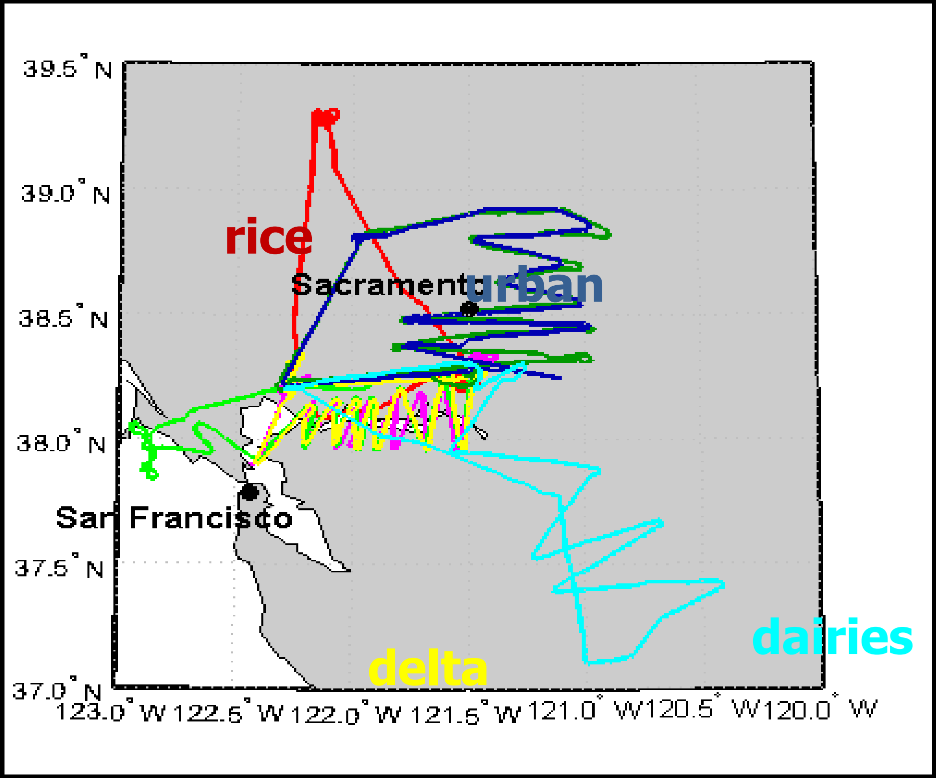
Cessna 165

12 flask package

Walnut Grove Tower

- The ability to Sampling for $^{14}CO_2$
- The ability to make continuous measurements at a tower
- Focus on understanding point sources

Flight map
exploring point sources



Mission Focus:
To understand and identify point sources that might effect measurements around the Walnut Grove Tower (WGC)

Posters:
Anna Karion (I – 196)
Jocelyn Turnbull (I – 203)

Sacramento Valley

Urban Plume

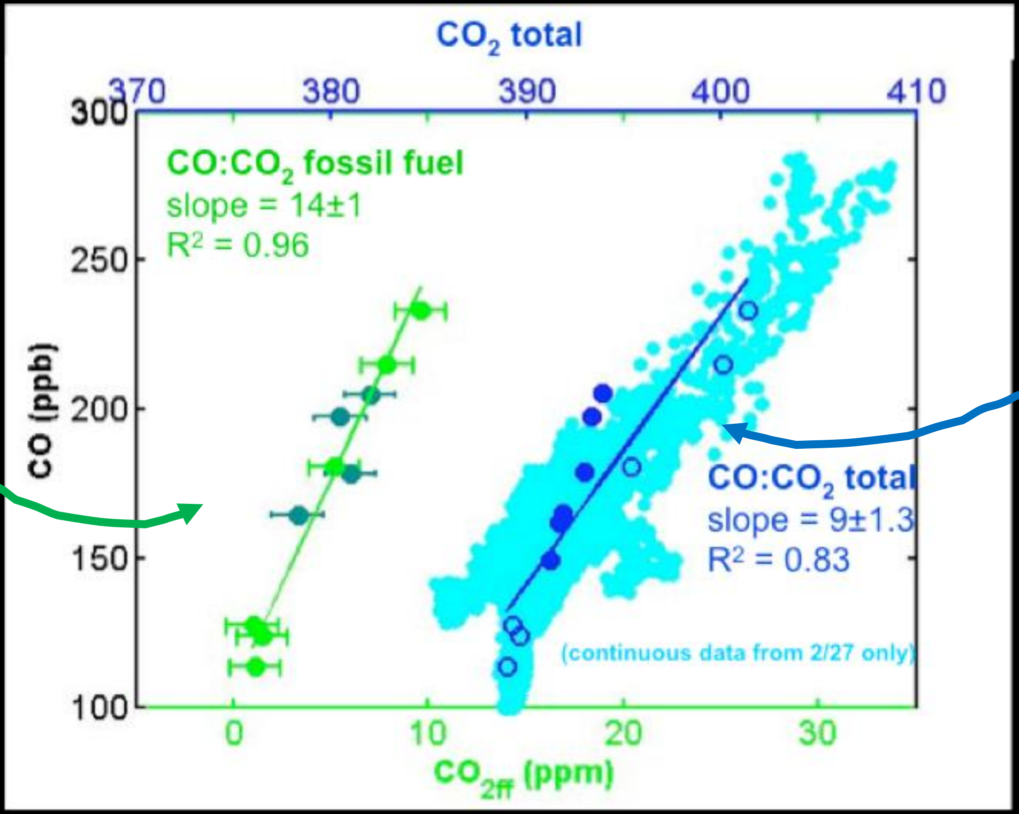
Marc Fischer, LBL

Sacramento Valley

Urban Plume – Natural respiration is important

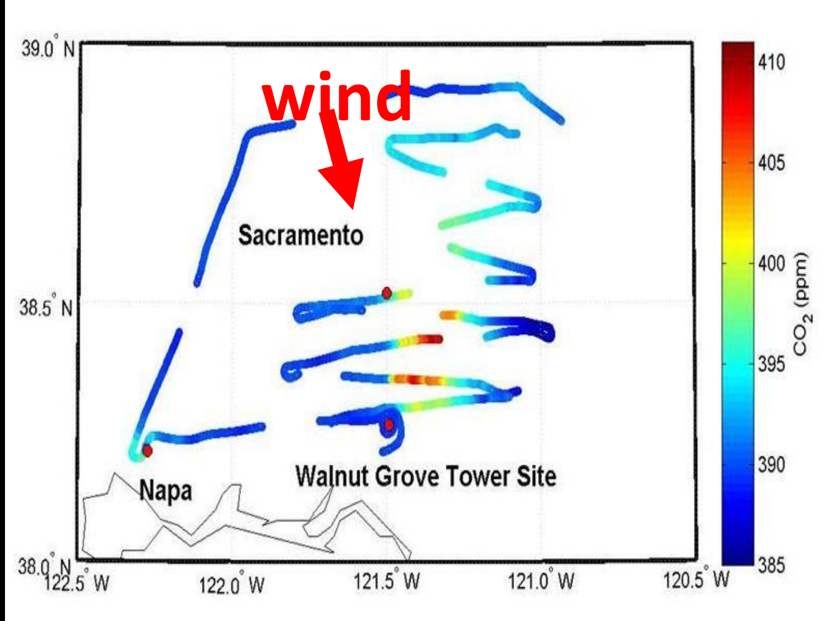
CO/C_{ff} = 14±1

CO/TCO_2= 9±1

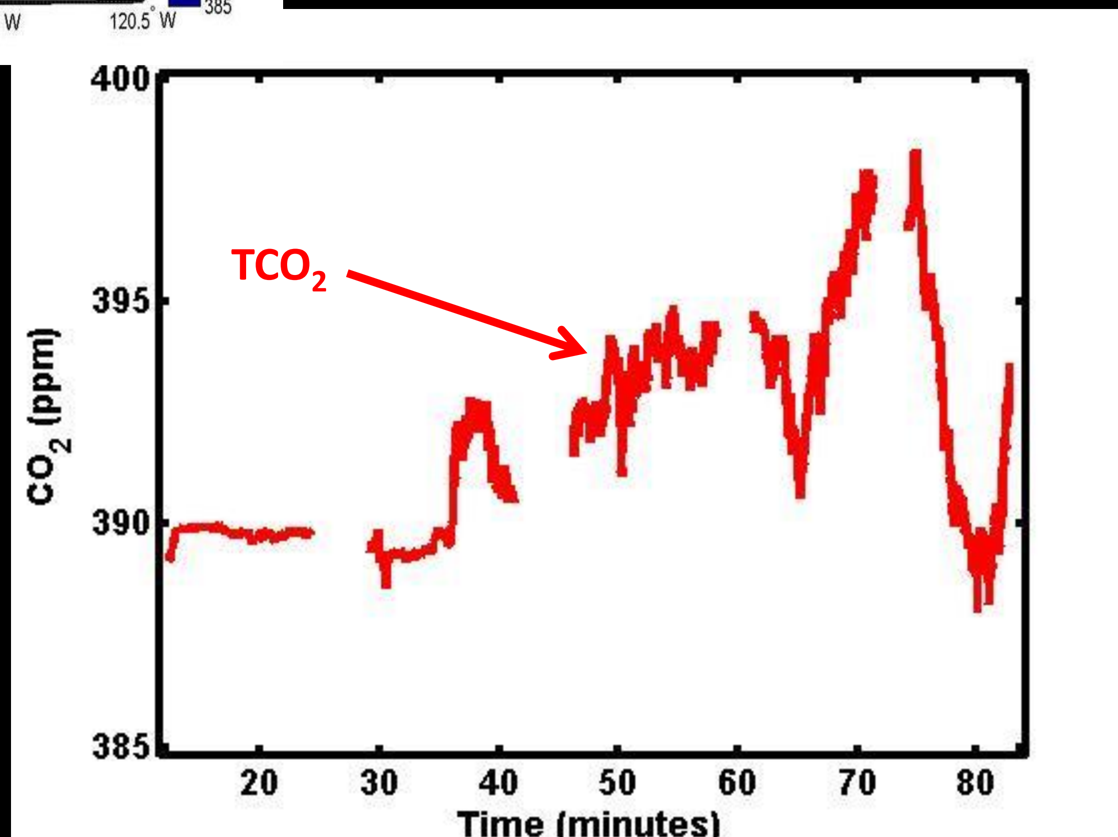


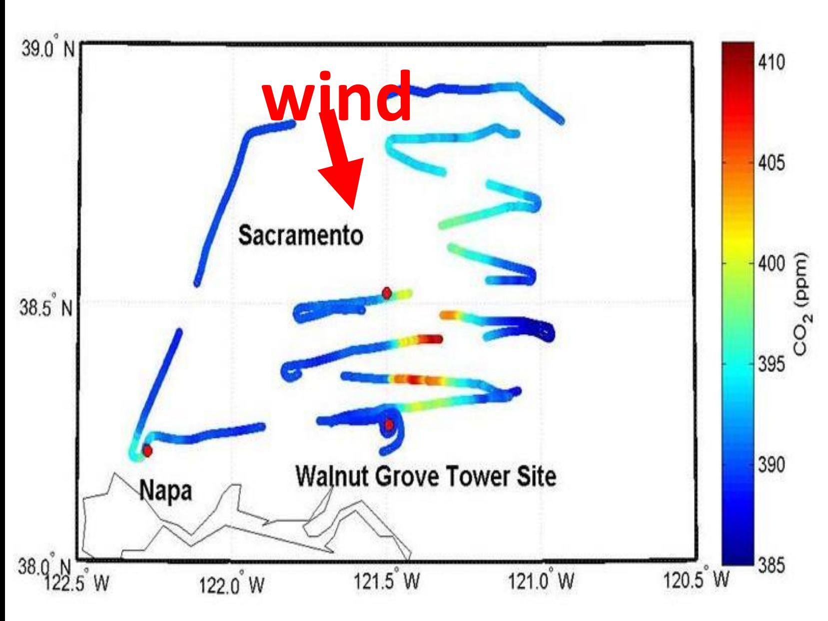
$$C_{ff} = \frac{C_{obs}(\Delta_{obs} - \Delta_{bg})}{\Delta_{ff} - \Delta_{bg}} - \frac{C_r(\Delta_r - \Delta_{bg})}{\Delta_{ff} - \Delta_{bg}}$$

Turnbull et al. 2011

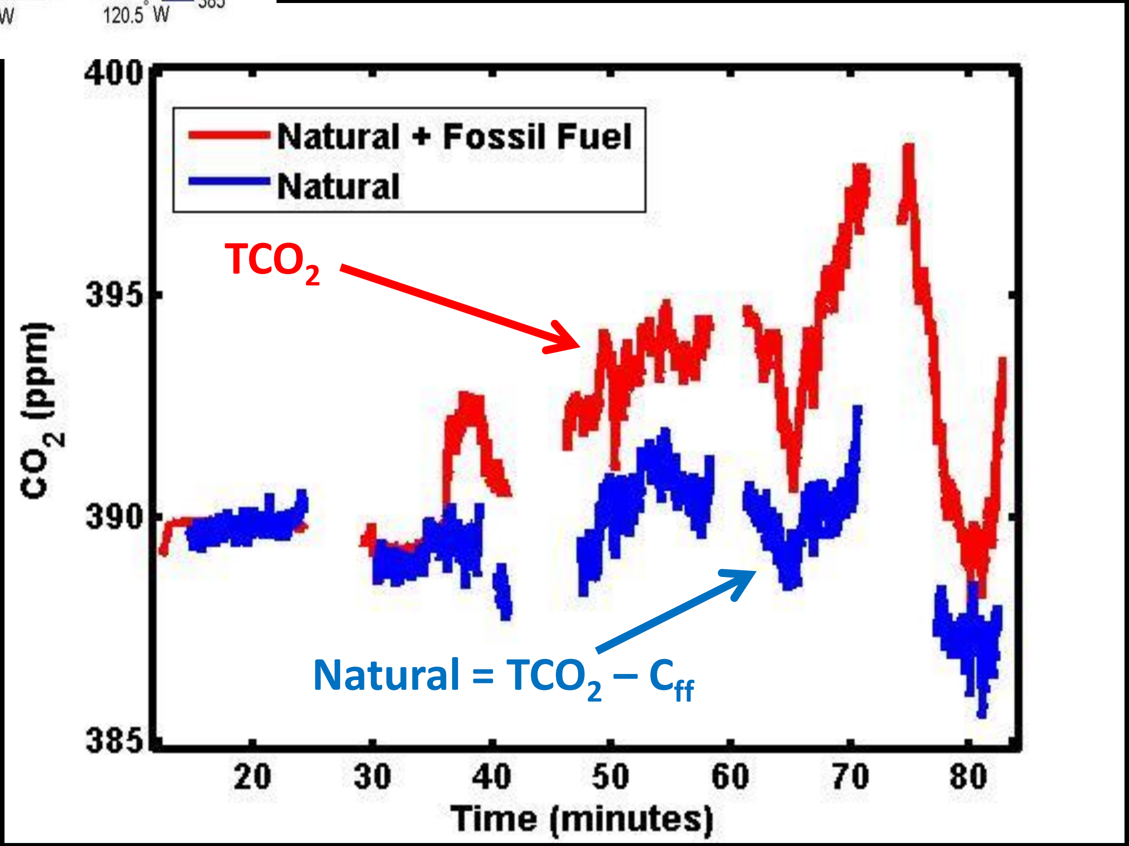

wind
Sacramento
Napa
Walnut Grove Tower Site
39.0° N
38.5° N
38.0° N
122.5° W
122.0° W
121.5° W
121.0° W
120.5° W
CO_2 (ppm)
410
405
400
395
390
385


N54R


TCO_2
CO_2 (ppm)
400
395
390
385
20
30
40
50
60
70
80
Time (minutes)

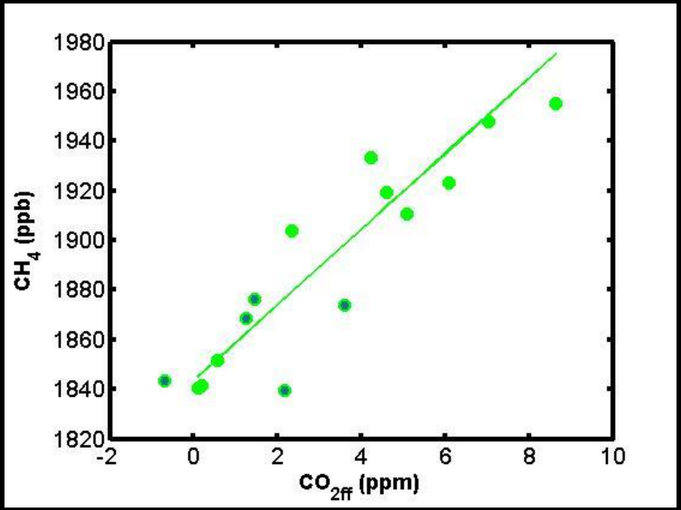


The variability in natural carbon suggests variability in uptake and respiration that correlates with the urban plume.

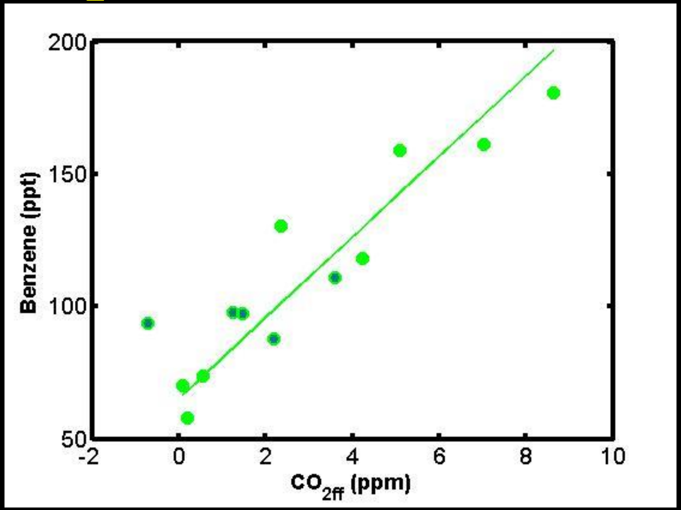


Fossil Fuel CO_2 v. Halocarbons

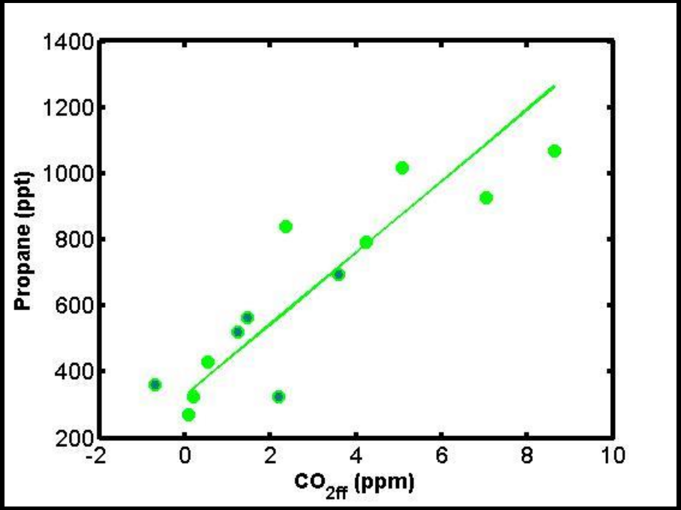
Proxies for $^{14}CO_2$



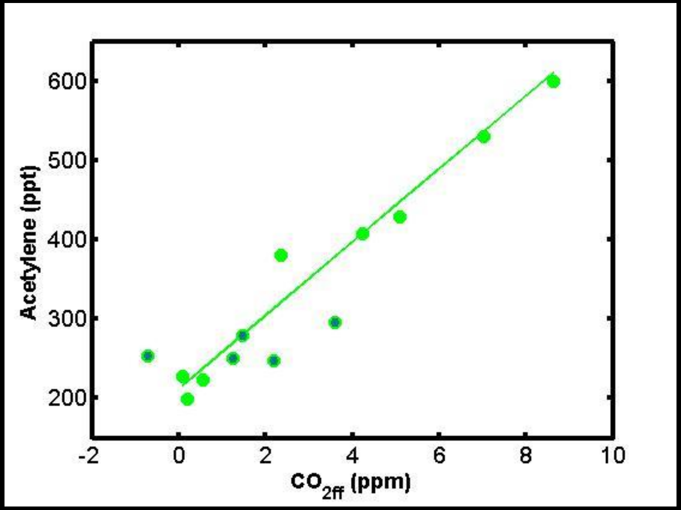
Methane



Benzene

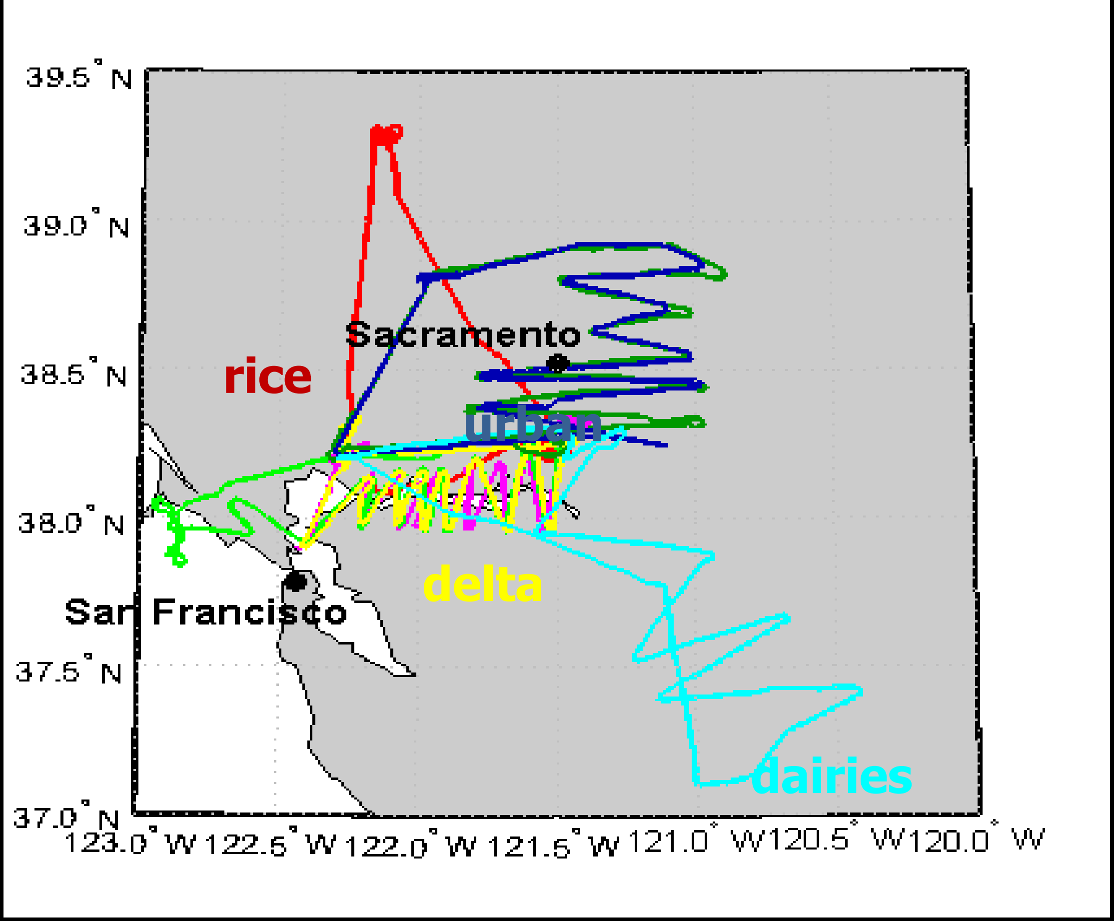


Propane



Acetylene

Flight map

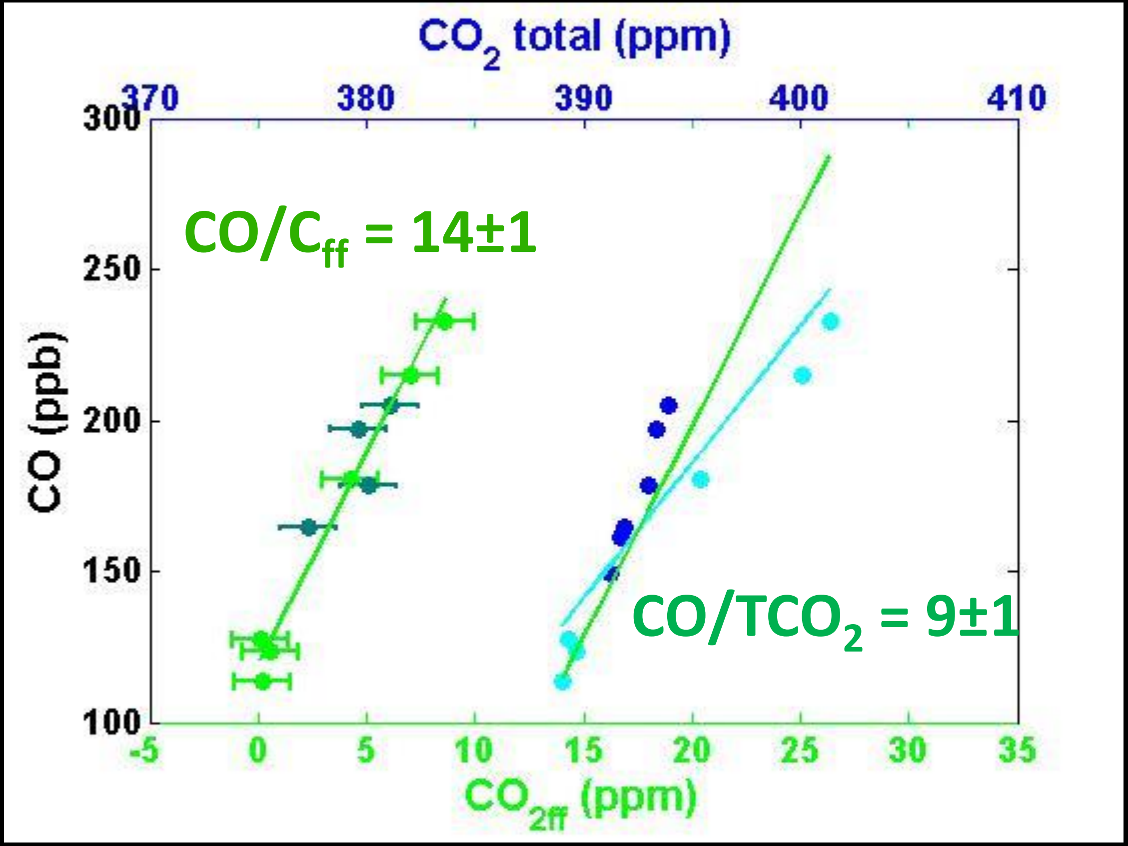


Delta Region:

To understand and identify point sources that might effect measurements around the Walnut Grove Tower (WGC)

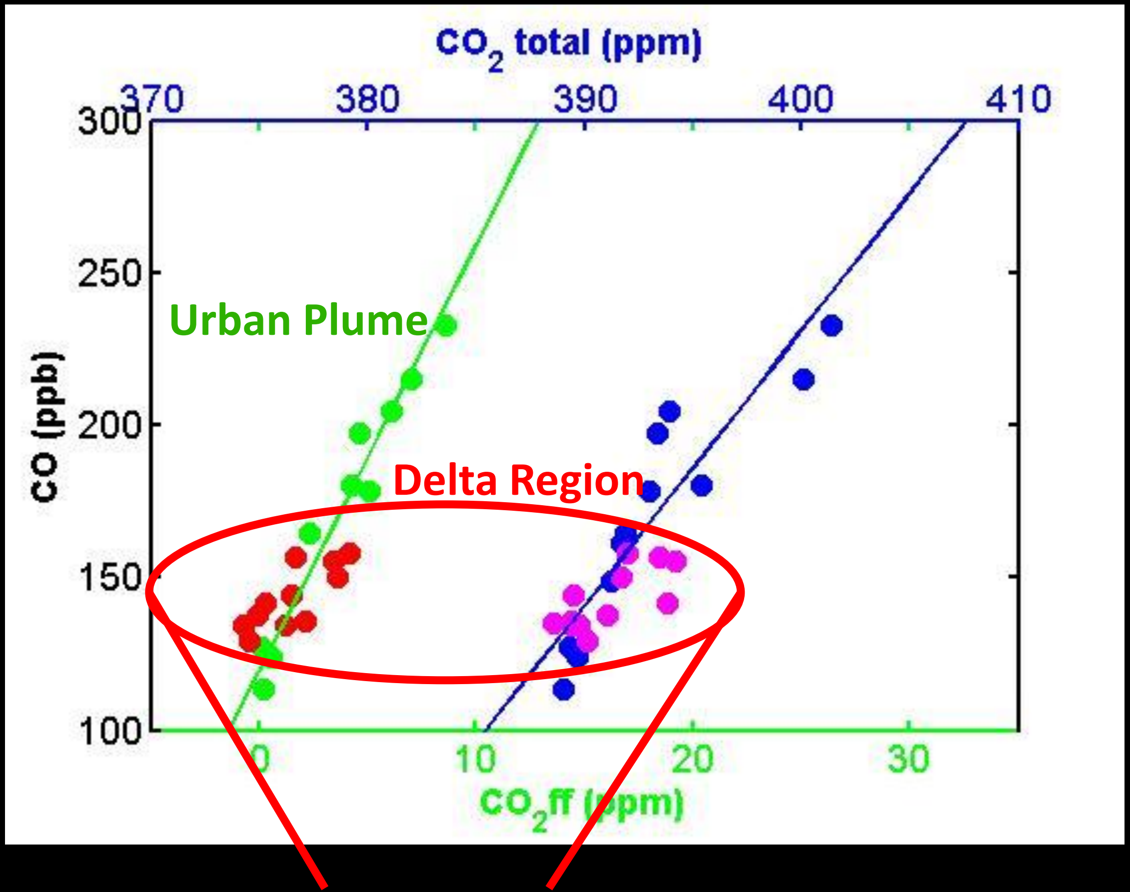
Sacramento Valley

Urban Plume



Sacramento Valley

Delta Region

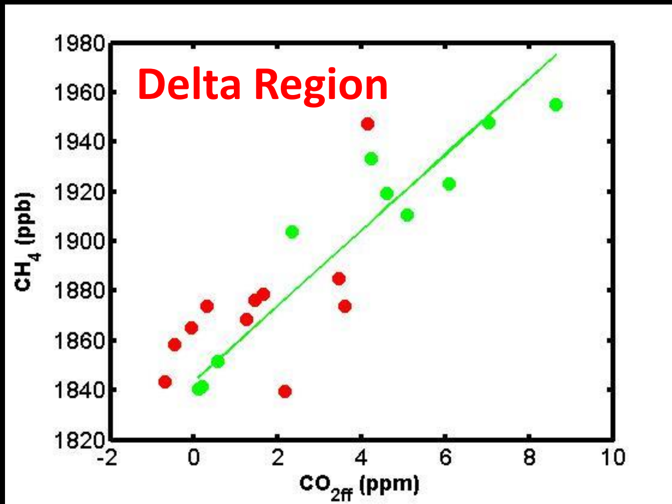


Delta Region shows less significant correlation with CO but in context of Urban plume the ratio of CO/C_{ff} are very consistent.

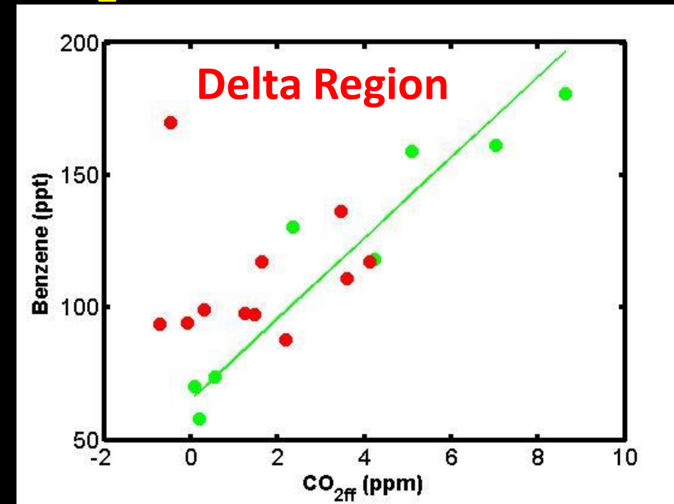
Karion et al. 2011

Fossil Fuel CO_2 v. Halocarbons

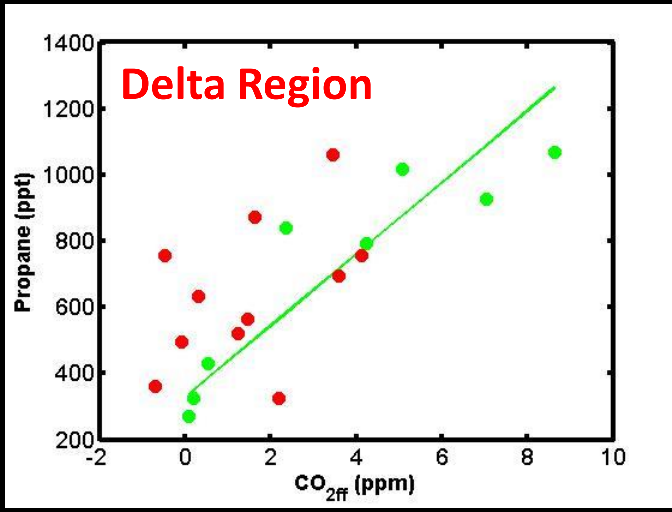
Proxies for $^{14}CO_2$



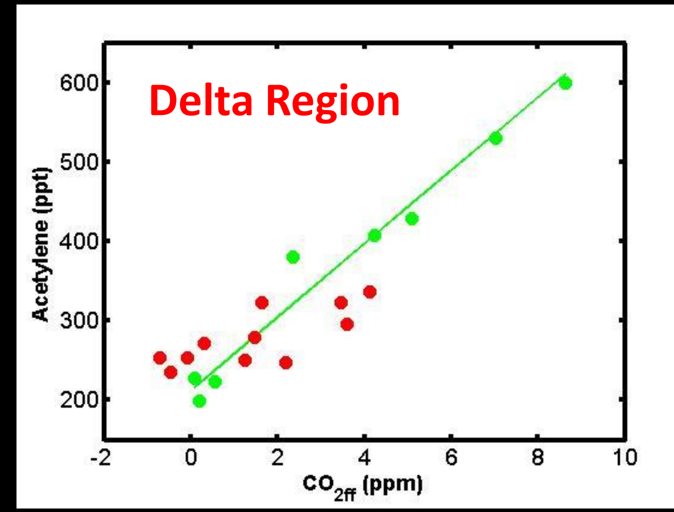
Methane



Benzene



Propane



Acetylene

INFLUX 2

Funded by NIST

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Thomas Lauvaux[2], Natasha Miles[2], Gabrielle Petron[3], Scott Richardson[2]
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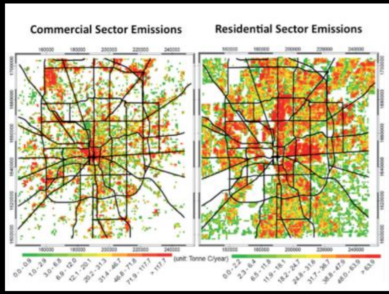
Merging Assets

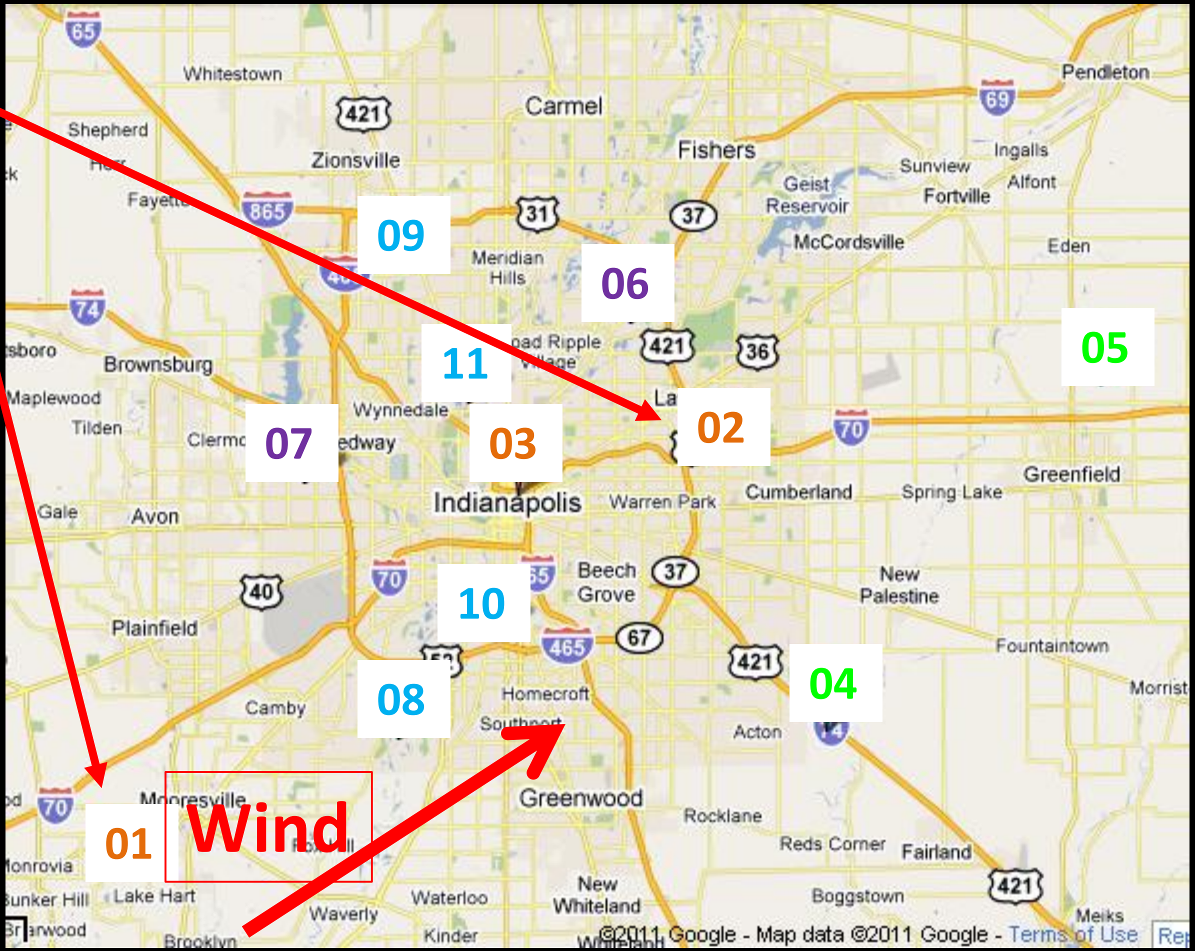
Combining models, inventories and multi – tracer atmospheric measurements

1. Aircraft-based measurements
   - CO_2, CH_4
   - 20 flights a year
2. Tower-based measurements
   - CO_2, CH_4 and CO
   - 11 towers (75 - 100m tall)
3. ^{14}C measurements, both towers and aircraft.
   - Includes $^{13}CH_4$, Halocarbons etc.
4. Regional modeling/inverse analysis–
   - WRF-CHEM- 2km x 60 levels (40 levels in BL).
5. Vulcan/Hestia modeling.
   - 10 km to building resolution for Indianapolis



- **Site 01: CO2/CH4/CO Flasks, PROFILE, "Rural"**
- **Site 02: CO2/CH4/CO Flasks, PROFILE, "Urban"**
- Site 03: CO2/CH4/CO (2 instruments) Flasks, PROFILE
- Site 04: CO2/CO, Flasks
- Site 05: CO2/CO, Flasks
- Site 06: CO2/CH4
- Site 07: CO2/CH4 PROFILE
- Site 08: CO2
- Site 09: CO2
- Site 10: CO2
- Site 11: CO2

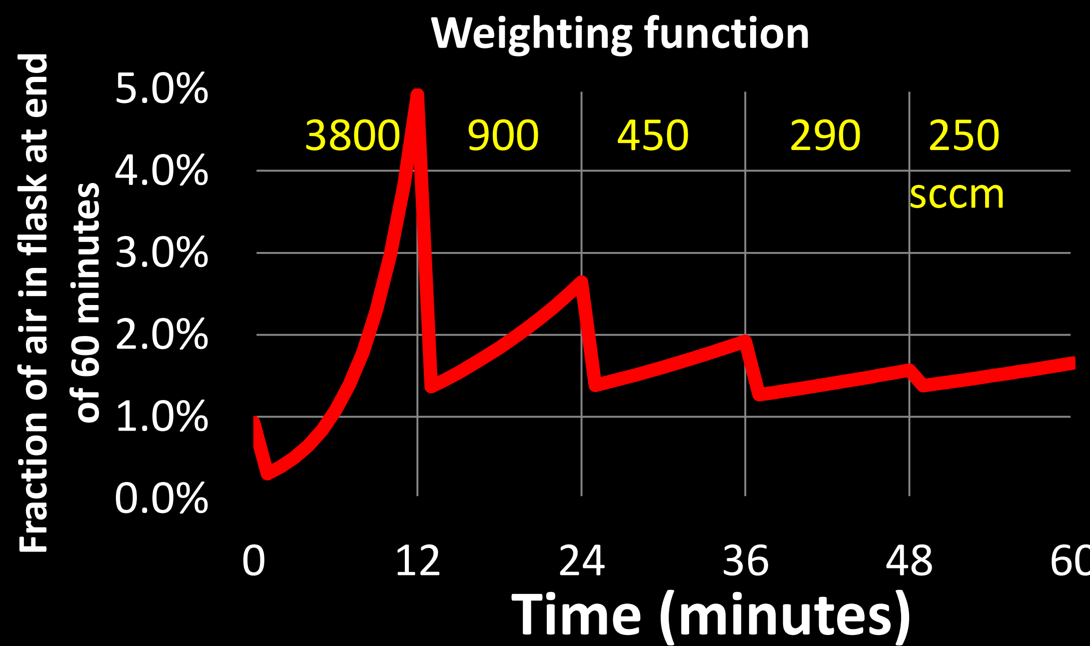
INFLUX 2 Tower Sites

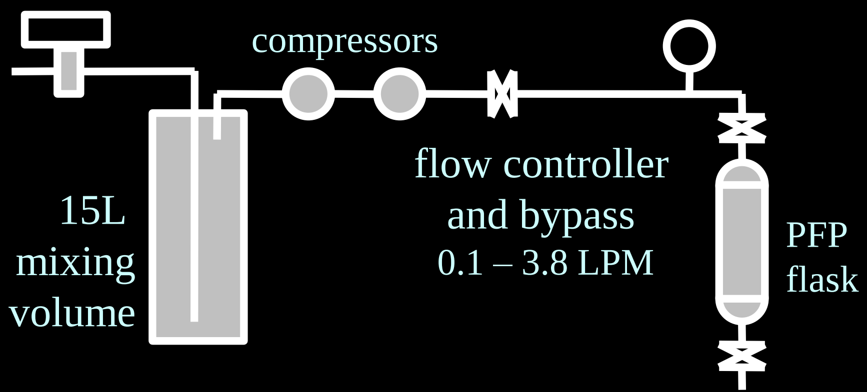


Combining measurements and Models

Integrating samples

- Reduce representation error by collecting a sample over similar time scales as the transport.
- Sample is collected over hour with varied flow rates to ensure that the air collected in the first minute has the same weight as the air collected in the last minute.





Conclusion

Aircraft play a critical role in measuring urban plumes for the following reasons:

- Ideal for identifying point sources
- Can provide synoptic picture of the urban plume
- Can provide validation for transport models which includes plume dispersion and boundary layer height.