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Urban greenhouse gas mole fraction in-situ measurements: Results from the Indianapolis Flux Experiment (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
  - Measure 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
  - Quantify and reduce uncertainty in urban emissions estimates
  - Determine monitoring system requirements for achieving a given uncertainty threshold

Questions:

- ❑ Are these methods viable for policy and management applications?
- ❑ What additional research is needed to make these methods useful for policy and management applications?

Methods and their characteristics:

- ❑ Atmospheric budgets

  All emissions are captured, but identifying individual sources is challenging.
  - Aircraft measurements

    Cover space very well, poor spatial resolution, provide snapshots in time.
  - Tower-based measurements

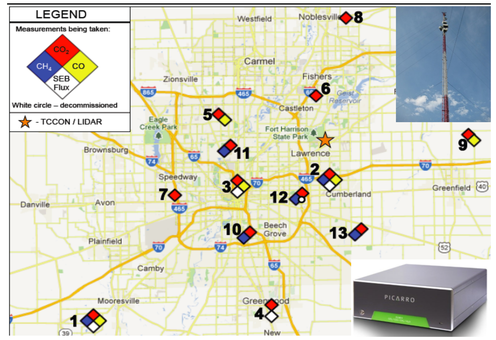
    Can provide continuous emissions estimates for years, spatial domain and resolution a function of the measurement network.
- ❑ "Bottom-up" inventories
  - Economic data and emissions factors

    Rich source of data regarding types of emissions and spatial distributions of emission. Prone to missing sources. Temporal resolution is limited.

Atmospheric measurement of greenhouse gas (GHG) emissions:

- ❑ Measure GHG concentrations upwind and downwind of a source.
- ❑ Measure atmospheric transport (wind, mixing depth).
- ❑ Estimate GHG emissions needed to explain the observed difference in GHG concentrations.

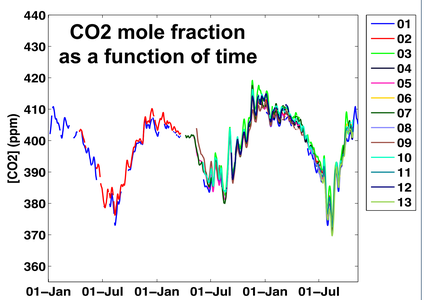
Tower-Based Measurement of GHG Mole Fractions
INFLUX Tower Network



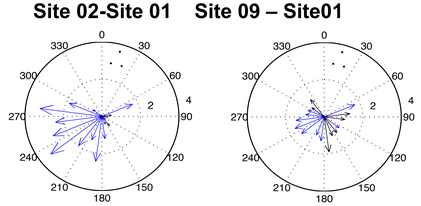
Picarro CRDS sensors; NOAA automated flask samplers; eddy covariance and radiative flux sensors

Site	Description	Sample heights (m AGL)
Site 01	Background	10/40/121
Site 02	East	10/40/136
Site 03	Downtown	10/20/40/54
Site 04	South	60
Site 05	NorthWest	125
Site 06	NorthEast	39
Site 07	West	58
Site 08	NorthEast (20 km from I-465)	41
Site 09	East (30 km from I-465)	10/40/70/130
Site 10	South	40
Site 11	North	130
Site 13	SouthEast (10 km from I-465)	87

Shown to the right is the afternoon averaged CO2 mole fraction for the INFLUX tower sites for January 2012 – September 2013, with 21-day smoothing applied. Both the seasonal and synoptic cycles are evident, as is coherence between the sites. Overall, Site 03 (downtown) measures the largest CO2, and Site 01 the smallest (background site).



Jan – April AFTERNOON CO2 (ppm) as a function of wind direction
Site 02-Site 01 Site 09 – Site01



Eastern edge of city - background
Average over all wind dir: 1.5 ppm
Downwind of city: 2.4 ppm
** Arrows point to sources

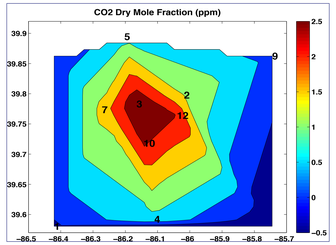
Site 30 km east of edge of city - background site
Average over all wind dir: 0.3 ppm
Downwind of city: 1.1 ppm
** Black: Site 01 larger than Site 09

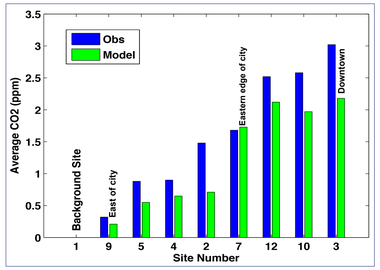
Shown on the far left is the difference in CO2 between Site 02 (eastern edge of the city) and Site 01 (background) as a function of wind direction; the mean is 1.5 ppm over all wind directions. When Site 02 is downwind of the city the average is 2.4 ppm. Shown just to the left is the difference between Site 09 and Site 01. the mean is only 0.3 ppm over all wind directions, but is 1.1 ppm when Site 09 is downwind of the city. The urban plume is thus detectable at this distance, and Site 09 may be appropriate as a background site, depending on wind direction.

Spatial Structure of Urban CO_2

Average [CO_2] Above Background Site

Miles et al, in prep
1 Jan – 1 April 2013 afternoon daily data

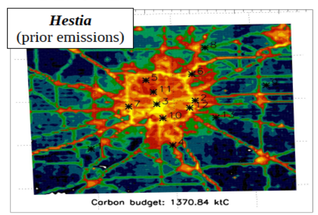




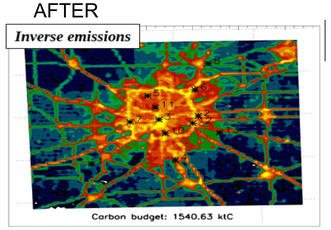
- Model results using mesoscale atmospheric model and a "bottom-up" emissions estimate (Hestia for 2002)
- Model results and observations are in agreement in terms of site ordering, indicating calculated footprints are reasonable
- Observations are 25% higher than modeled values, on average
- *The discrepancy suggests an underestimate in the "bottom-up" emissions estimate*

Atmospheric inverse flux estimate:

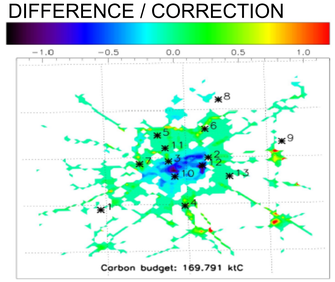
BEFORE



AFTER



DIFFERENCE / CORRECTION



Increment (posterior minus prior emissions) from reference inversion configuration (in ktC) for the period Oct 6th to Nov 30th, 2012.

- Posterior emissions are 1541 ktC, whereas the prior emissions are 1371 ktC.
- Spatial structure of the model-data difference reveals the spatial pattern of emissions corrections.
- Corrections can be computed continuously in time, detecting changes in emissions over time.

Lauvaux et al, in prep

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- ❑ http://influx.psu.edu

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