Improving and Assessing Aircraft-based Greenhouse Gas Emission Rate Measurements for the city of Indianapolis (INFLUX project)

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Motivations :

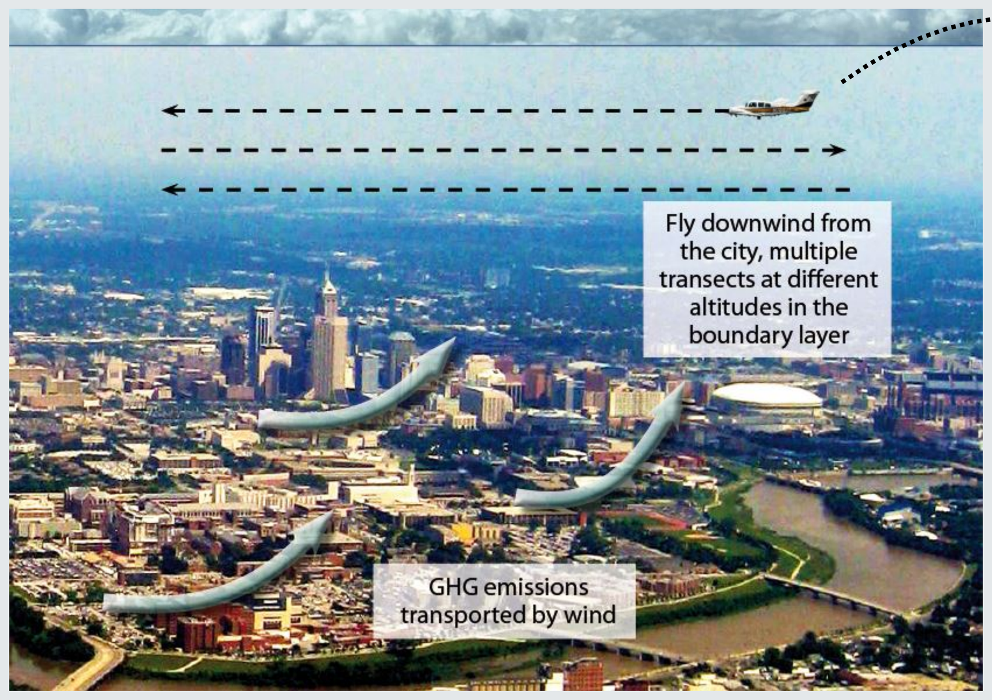
To achieve current greenhouse gas reduction targets established in the U.S. (reducing CO_2 emissions to 17% below 2005 levels, by 2020) and elsewhere, coherent and effective strategies in mitigating atmospheric carbon emissions must be implemented in the next decades. A challenge for international agreements is the ability to ensure that such emissions reductions are "measurable", "reportable", and "verifiable" and mitigation efforts accurately quantifiable. Approaches to manage greenhouse gas emissions must focus on urban environments since ~74% of CO_2 emissions worldwide will be from cities. However, recent studies suggest that carbon emission estimates at urban levels are significantly uncertain (~50 to >100%).

Successful implementation of climate change mitigation strategies thus requires a good understanding of uncertainties of the strengths of greenhouse gas sources and sinks, that depend on multiple factors. There is a critical need for accurate measurements and inventories of greenhouse gas emissions, as well as for approaches development to evaluate the uncertainties of these measurements.

Goals:

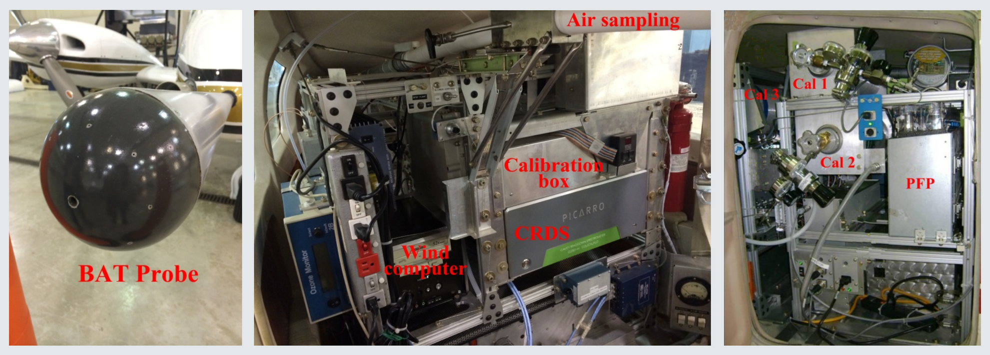
The Indianapolis Flux Experiment project (INFLUX) was established to develop, assess and improve top-down and bottom-up approaches for quantifying urban greenhouse gas emissions from the test case city, Indianapolis.

We have been quantifying the emission rates for CO_2 and CH_4 from the city of Indianapolis since 2008, and more recently for CO, using an aircraft-based mass balance approach (mass balance experiment, MBE). Our main goal is to dramatically improve the method overall uncertainty from the previous estimate of 50% (Cambaliza et al., 2014). To achieve our goal, our efforts are focused on improvements to the MBE design, and on improvements and assessment of the method precision.



Flight design:

For each flight experiment, one set of downwind flights are flown to characterize both the background trace gas concentrations (from the edges of transects, which don't receive city's plume) and the concentrations within the urban plume from Indianapolis. One upwind transect is also flown to check possible contamination upwind from Indianapolis.



Instrumentation in the airplane

ALAR

***A**irborne **L**aboratory for **A**tmospheric **R**esearch*

Equipped with:

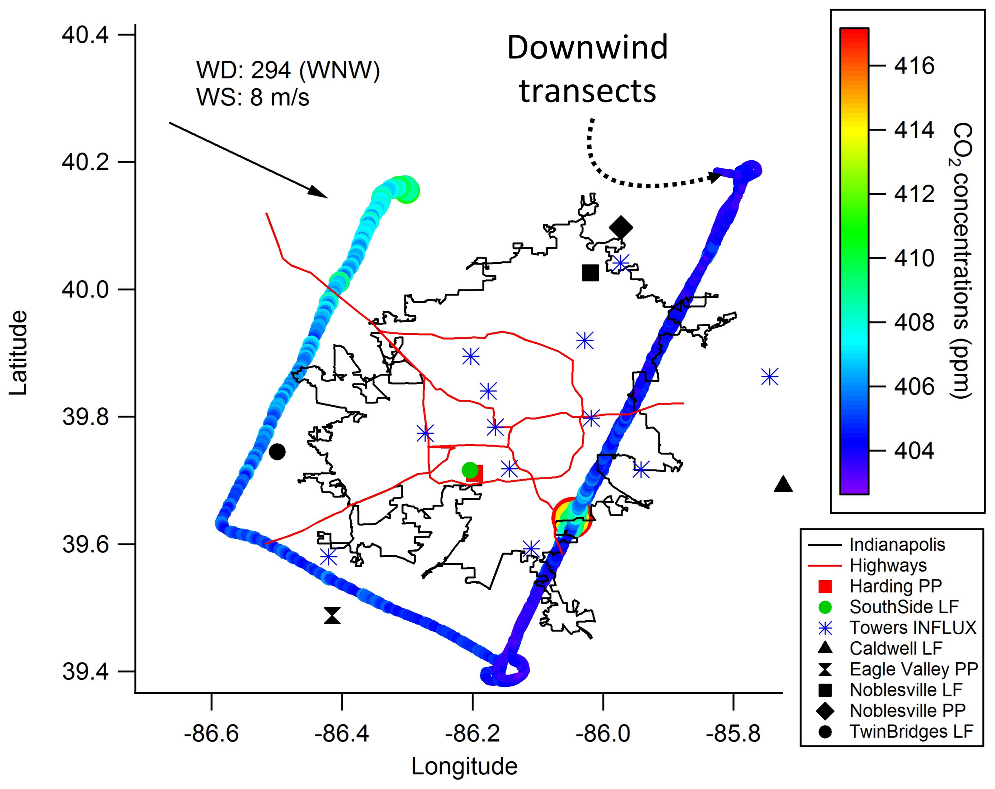
(a) a Best Air Turbulence (BAT) probe and an onboard Global Positioning System/Inertial Navigation System (GPS/INS) used to collect 50 Hz measurements of the three dimensional wind vector as well as static pressure and temperature,

(b) a Picarro cavity ring-down spectrometry system (CRDS), a in-flight CO_2/CH_4 calibration system and three NOAA/ESRL reference cylinders for in-situ, real-time CO_2, CH_4, CO and H_2O measurements (0.5 Hz),

(c) a programmable flask package system (PFP) for discrete ambient air sampling

Flight design:

We performed an intensive field campaign over Indianapolis. During 4 weeks in Nov-Dec 2014, we flew a similar flight path for 9 "replicate" MBEs: one upwind transect, to investigate point source pollution inflow into the city, and a set of downwind transects (3-5 depending on the boundary layer height observed the day of the experiment) at one downwind distance from the city for the flux calculation.



Graph 1: Example of flight path performed in Nov-Dec 2014 (Nov, 13th)

Flux calculation:

The flux of elements, which cross a two-dimensional plane, is calculated using the measured wind speed perpendicular to the plane and the difference between the city and background greenhouse gas concentration (downwind transects) (Eq. 1).

$$F_{ij} = \left([C]_{ij} - [C]_b\right) * U_{\perp ij} \qquad \text{Eq.1}$$

The flux is then interpolated (kriging) to locations where data were not recorded on the 2-D plane and integrated from the ground to the top of the boundary layer and on the downwind distance flown by the airplane (Eq. 2, Graph 2).

$$F_{integrated} = \int_0^{z_i} \int_{-x}^{+x} F_{ij}\, dx dz \qquad \text{Eq.2}$$

Date of flight	CO2 flux (mol/s)	CH4 flux (mol/s)	CO flux (mol/s)
Nov, 13th	13573	101	111
Nov, 14th	11734	54	119
Nov, 17th	15336	46	112
Nov, 19th	19192	173	83
Nov, 20th	13846	22	111
Nov, 21st	14036	50	101
Nov, 25th	14369	55	125
Dec, 1st	14006	45	100
Dec, 3rd	10227	16	62
Average	**14035**	**62**	**103**
Uncert.	*1526*	*30*	*15*

Table: Daily emission rates observed during the Nov-Dec 2014 field campaign

Acknowledgement:

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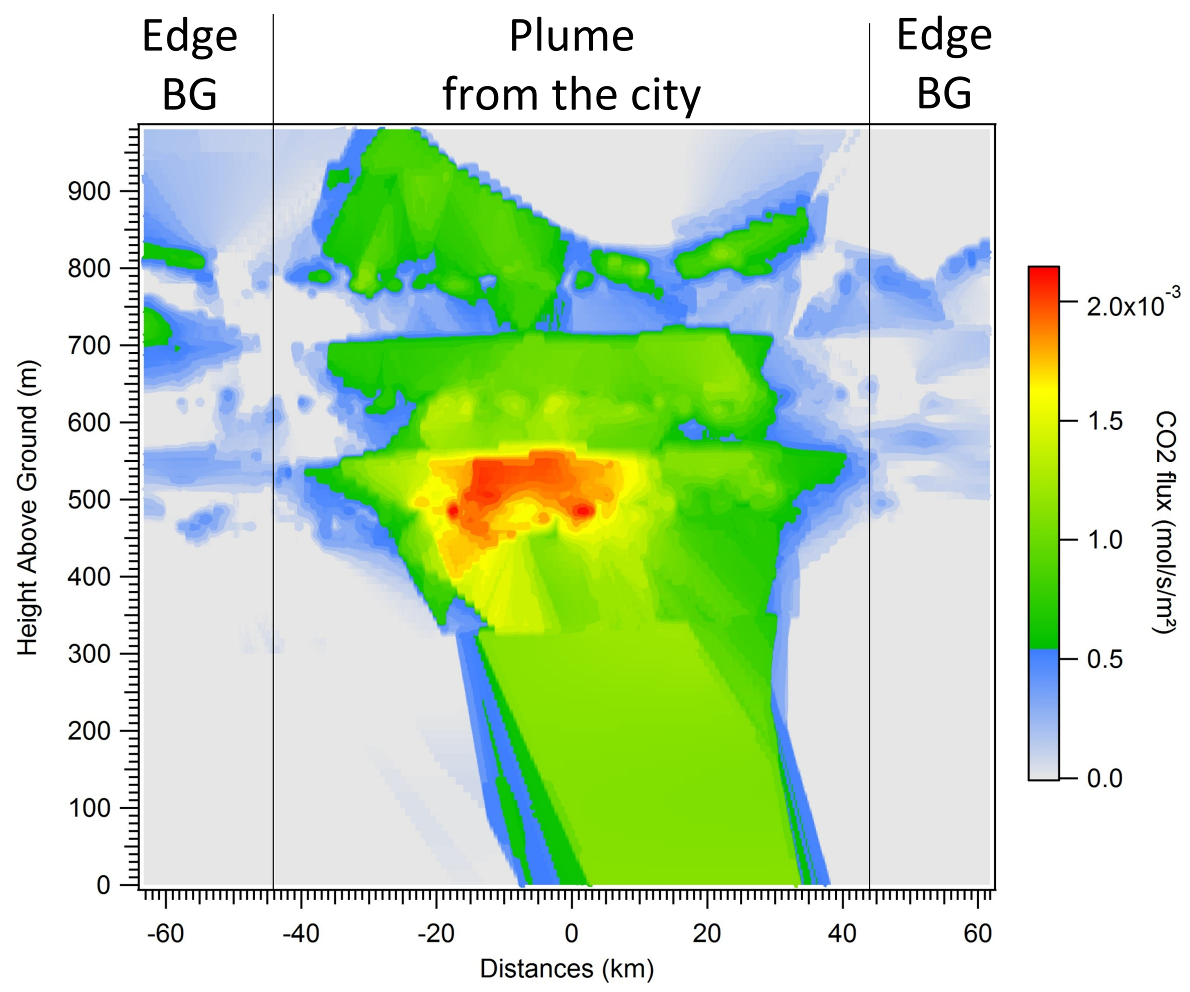
Results:

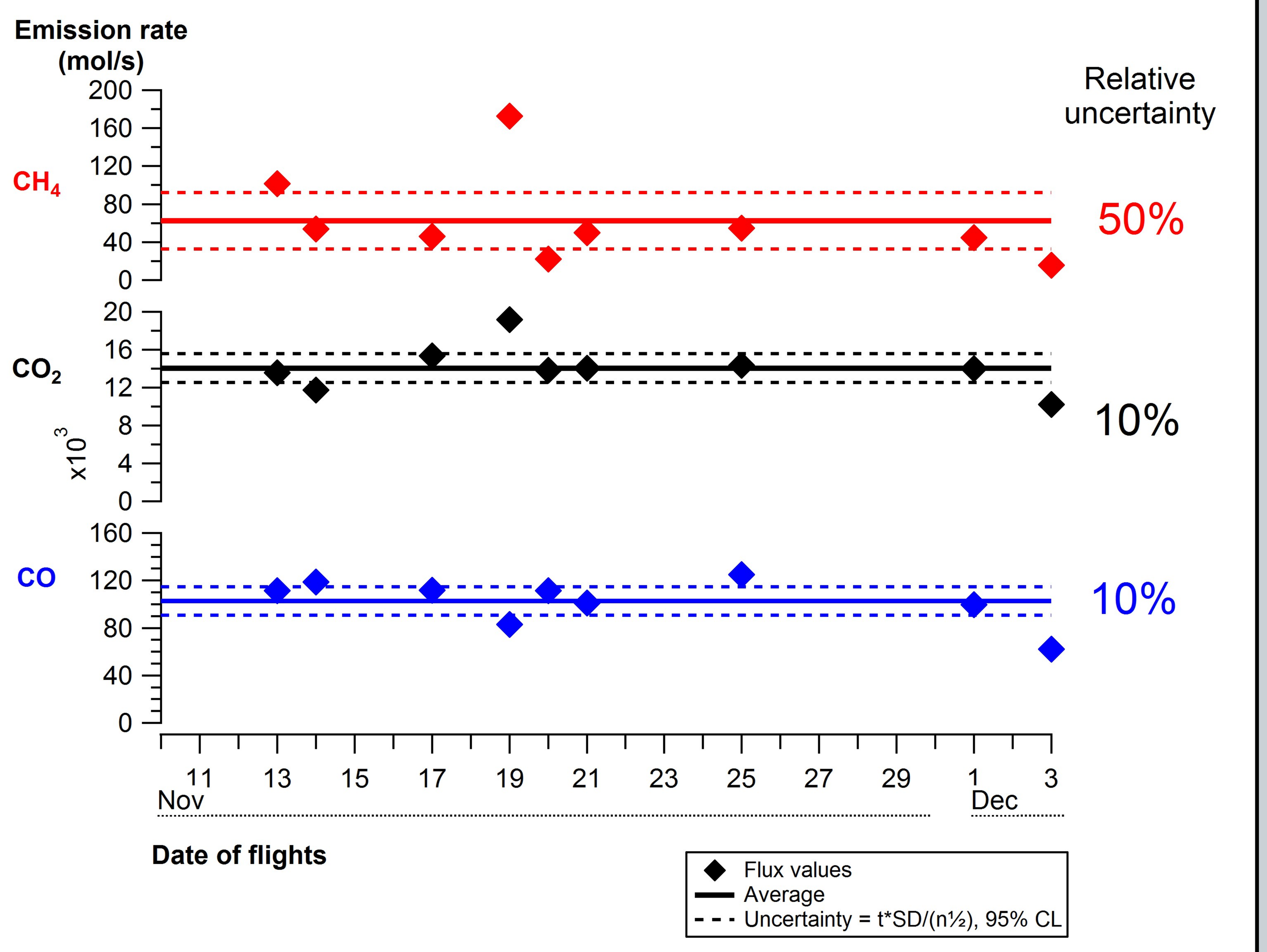
Fluxes for the 9 MBEs were averaged, **assuming constant total emission rate conditions** for the short period of time when the field campaign was running.



Graph 2: Example of observed CO_2 plume from Indianapolis (Nov, 10th)

Our results demonstrate that from averaging replicate aircraft mass balance experiments, it is possible to obtain an improved 95% C.L. for the mean determination equal to **±10% for CO_2 and CO.**

Uncertainty of CH_4 emission rates is equal to 50%, which might be explained by the variability of emission sources. CH_4 sources at Indianapolis are the Southside Landfill (responsible for ~33% of CH4 emissions) and the natural gas distribution system (~67%) (Cambaliza et al., 2015).



Graph 3: Daily flux values, average and uncertainties for the 9 MBEs performed in Nov-Dec 2014

References:

Cambaliza et al. (2014), doi:10.5194/acp-14-9029-2014

Cambaliza et al. (2015), doi: 10.12952/journal.elementa.000037