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INFLUX: Tower-based greenhouse gas measurements and flux estimates in an urban environment

http://influx.psu.edu

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INFLUX (INdianapolis FLUX Experiment)

Independent verification of anthropogenic greenhouse gas emissions is an emerging need as legislation to regulate greenhouse gas emissions becomes increasingly likely. As part of the INFLUX project, CO2, CH4 and CO mixing ratios are measured using wavelength-scanned cavity ringdown spectroscopy (Picarro, Inc.) at two towers surrounding Indianapolis, IN, with expansion underway to a network of twelve sensors, including 14CO2 flask sampling. Sampling was initiated in October of 2010 and is planned to

Objective: To develop and assess methods of quantifying greenhouse gas emissons at the urban scale, using Indianapolis as the test site.

Project Goals:

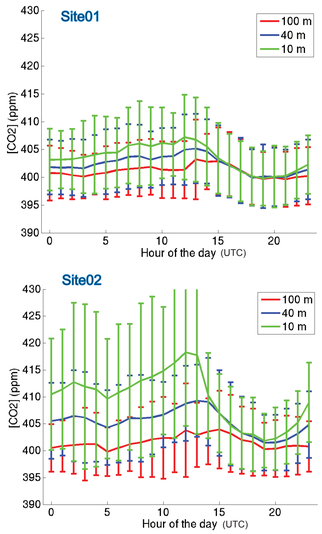
- Develop improved approaches for measurement of urban-scale greenhouse gas emission fluxes
- Compare top-down emission estimates from aircraft and tower-based measurements with bottom-up emission estimates from Hestia for Indianapolis
- Quantify uncertainties in the flux estimates

The Hestia Project

The Hestia Project builds on Vulcan, which quantified fossil fuel CO2 in the United States at 10 km (and finer) spatial resolution and hourly temporal resolution for the year 2002. Hestia will refine this to the urban landscape scale, and the greater Indianapolis region is the test case. The Hestia inventory is a *data product*. It is based on a number of data sources but relies to a great extent on data collected by the EPA through the Clean Air Act legislation. The large volume of data used to construct the inventory data product relies to a great extent on the QA/QC procedures and integrity of the EPA data and models.

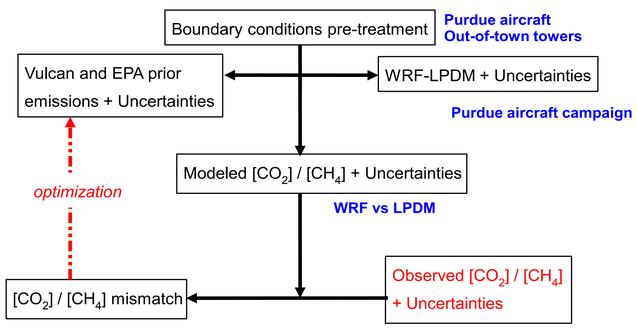
Composited diurnal cycles

Shown to the right are composites of the diurnal cycle of CO2 mixing ratio at the two sites on days which were well-mixed during Nov 2010. In lieu of heat flux as a discriminator of well-mixed conditions, we used a threshold based on the difference in mixing ratio between the three levels. While both sites exhibited a clear diurnal cycle, the difference between the levels is larger at the urban site. The difference between the 10 and 100+ m AGL levels is 15 ppm at its maximum for Site02.



Urban emissions over Indianapolis: CO2 and CH4

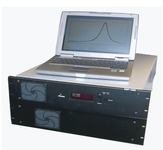
The inverse system framework



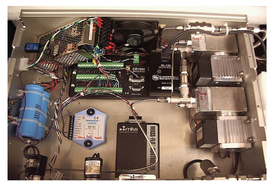
Model configuration

WRF-CHEM simulation, 10 km resolution, 1000 km x 1000 km
Meteo drivers: NCEP/ETA-NAM 40 km
PBL scheme: MYNN 2.5 TKE
LPDM model (Uliasz et al, 1995): particle model, based on TKE param, using wind, T, P, and TKE from WRF
Inversion: 2 km resolution, analytical method, weekly to daily time step
Prior fluxes: Vulcan CO2 inventories, CH4/CO inventories from NOAA
Boundary conditions: fossil fuel component from CarbonTracker
Additional information from 14CO2 and CO

INFLUX measurements

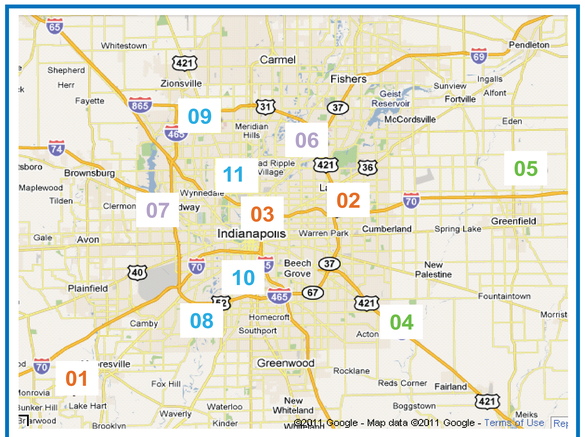


Penn State University: Currently, continuous measurements using co-located instruments (CO2/H2O and CO2/CO/CH4) are made at two sites. When the expansion is fully installed, there will be 11 sites. Wavelength-scanned cavity ringdown spectroscopy (Picarro, Inc.) is used. In this poster, we focus on these tower-based measurements and corresponding model results.



NOAA: Flasks, filled preferentially when the wind direction is such that Site 02 is downwind of Site 01, measure the following: CO2, CO, CH4, 14CO2, 13CO2, N2O, SF6,H2, and a suite of halocarbons and hydrocarbons. By utilizing intermittent flask measurements of 14CO2 and correlating those with continuously measured CO, we will separate fossil fuel CO2 sources from ecological sources and sinks.

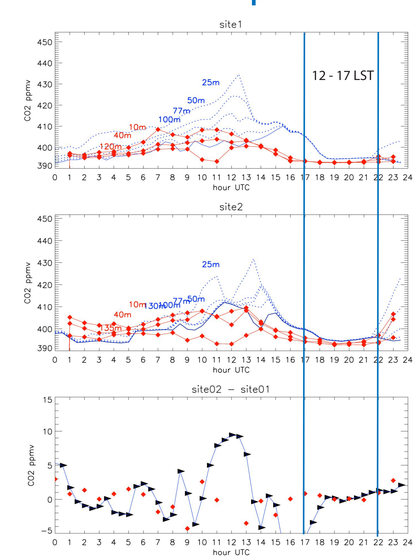
Purdue University: ALAR aircraft flights, beginning in fall 2010, will measure CO2/CH4/H2O continuously, as well as sampling flasks and measuring meteorological data. Two types of flights will be utlized: mass balance and source characterization.



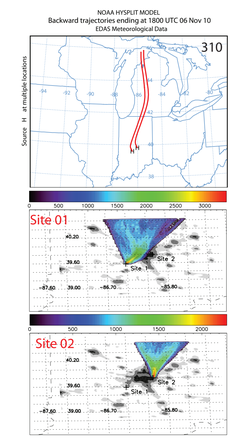
Currently deployed
Site 01: CO2/CH4/CO, Flasks, Profile, "Rural"
Site 02: CO2/CH4/CO, Flasks, Profile, "Urban"

Additional sites planned
Site 03: CO2/CO, CO2/CH4, Flasks, "Downtown"
Sites 04 and 09: CO2/CO, Flasks
Sites 06 and 07: CO2/CH4
Sites 05, 08, 10, and 11: CO2

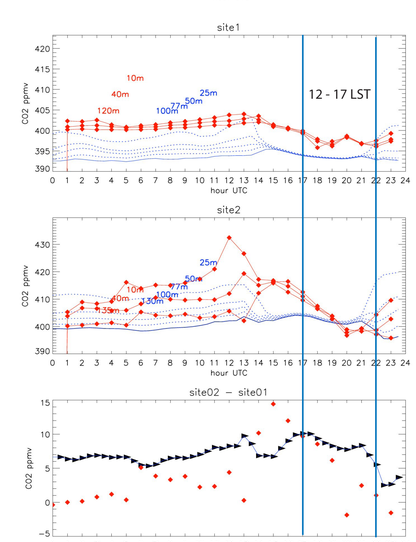
Model-data comparisons: CO2 mixing ratio



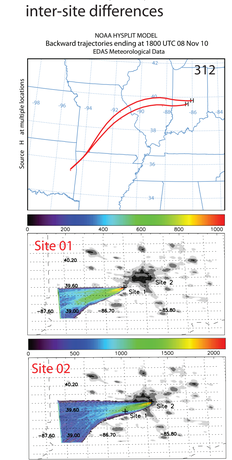
DOY 310 (6 Nov 2010)
Example: small daytime inter-site differences



Shown to the left are observations / forward model CO2 mixing ratio comparisons for a day in which the daytime inter-site difference was relatively small (2 - 3 ppm). During the daytime, there is good model-data agreement at both of the sites. The model mixing is delayed somewhat in the morning, however, and the model is more stratified than indicated by the data. The HYSPLIT trajectories and modeled footprints indicate winds coming from the north; thus both sites captured relatively rural air and the inter-site difference was low.



DOY 312 (8 Nov 2010)
Example: large daytime inter-site differences



Shown to the left are observations / forward model CO2 mixing ratio comparisons for a day in which the daytime inter-site difference was relatively large (up to 10 ppm). While there are noteable model-data differences, even during the daytime, the magnitude of the inter-site difference is similar between the model and the data. The HYSPLIT trajectories and modeled footprints indiacate that the wind was from the west. Site02 captured the urban signal and Site01 the background signal; thus the inter-site difference was large.

Why Indianapolis?

Indianapolis is a medium-sized city, with fossil fuel CO2 emissions of ~3.4 MtC yr-1, providing a large enough signal to be readily detectable in the atmosphere.

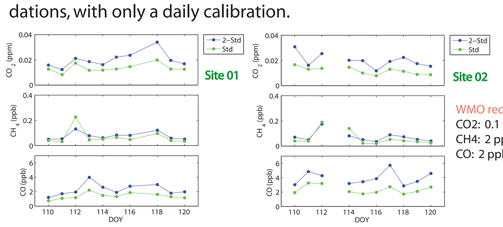
Indianapolis is located far from any other metropolitan areas, so the signal from Indianapolis can be isolated with relative ease.

The terrain is flat, making the meteorology relatively simple.

The Hestia bottom-up fossil fuel CO2 inventory product for Indianapolis is the highest resolution emission inventory available for any city in the world, allowing comparison of the bottom-up and top-down methods, to evaluate and improve uncertainties in both.

Field testing of CO2/CH4/CO instruments

In addition to daily calibrations, we tested a separate tank hourly, in order to assess zero drift magnitudes. The hourly tank is treated as an unknown. Then we calculated the daily standard deviation for each instrument. The precision, even for CO, appears to be sufficient to meet the WMO recommendations, with only a daily calibration.



WMO recommendations
CO2: 0.1 ppm
CH4: 2 ppb
CO: 2 ppb (5 ppb for urban)

Shown to the right is a comparison of two instruments co-located at Site 01. The multi-species instrument is dried, but the CO2-only instrument is not (a water vapor correction is applied). The two instruments have independent calibration tanks. The difference is -0.13+-0.03 ppm. There is no apparent dependence on [CO2], time, or [H2O].