Eddy covariance measurements of trace gases and energy fluxes from an urban district of Mexico City

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Introduction

In the MCMA-2003 field study we demonstrated the feasibility of the micrometeorological techniques to measure fluxes of CO_2 (Velasco et al., 2005a) and VOCs (Velasco et al., 2005b) in an urban environment. Micrometeorological techniques, such as eddy covariance are ideal because the flux measurements include all major and minor emission sources from a determined area, hence, they are a valuable tool for evaluating and improving emission inventories.

One of our objectives for 2006 was to verify the representativeness of the 2003 flux measurements in terms of the magnitude, composition, and overall distribution of urban emissions. We deployed a new flux system in a busy district surrounded by congested avenues close to the center of the city (SIMAT site) during 25 days of March 2006 as part of the MILAGRO campaign.

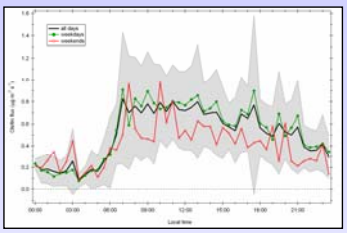
For this study we extended the number of species using diverse instruments coupled with different micrometeorological methods. This poster presents preliminary results of fluxes calculated by eddy covariance (olefins, CO_2, and energy), disjunct eddy covariance (toluene, C_2-benzenes, benzene and methanol), a modified gradient method (CO) and disjunct eddy accumulation (selected VOCs).

Eddy Covariance (EC)

The fluxes of trace gases (F_x) were calculated as the covariance between the instantaneous deviations of the vertical wind velocity (w') and the gas concentration (c_x') from their 30 minute mean:

$$F_x = \overline{w'c_x'} = \frac{1}{t_2 - t_1}\int_{t_1}^{t_2} w'(t)c'(t)dt$$

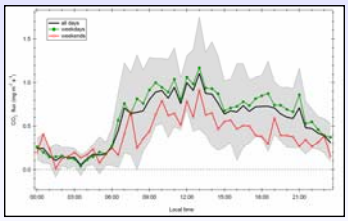
Olefins



The olefins were measured by a Fast Isoprene Sensor (Hills Scientific, Inc.) calibrated with a propylene standard.

Olefin fluxes ranged from essentially zero to 1.5 μg m^{-2} s^{-1}, with an average of 0.51 μg m^{-2} s^{-1}, 42% higher than the average observed in 2003. The diurnal pattern was constant during the entire study, but on average, weekday fluxes were 36% higher than on weekends.

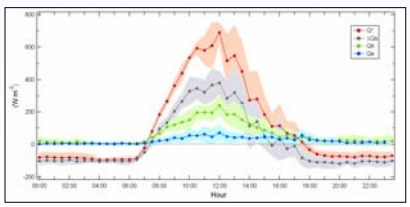
CO_2



The CO_2 was measured by an open-path infrared gas analyzer (IRGA) model OP-2 (ADC BioScientific, Ltd.)

The monitored urban site showed to be a net source of CO_2, with a diurnal average of 0.51 mg m^{-2} s^{-1}, 24% higher than the average measured in 2003. The effects of reduced traffic on weekends produced a reduction of 39% for the average diurnal weekend flux compared to weekdays.

Energy balance



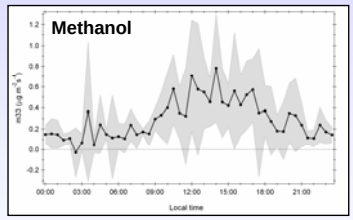
The sensible (Qh) and latent (Qe) heats were measured by eddy covariance, the net radiation (Q*) by a net radiometer, and the storage heat (ΔQs) was obtained as the residual of the measured energy components (ΔQs = Q* - (Qh + Qe)). During the daytime (Q^* >0) ΔQs contributed 50% to Q^*, Qh 37% and Qe 13%.

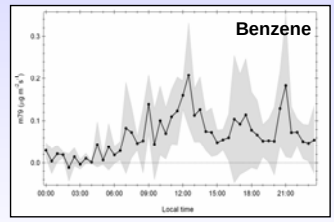
Disjunct Eddy Covariance (DEC)

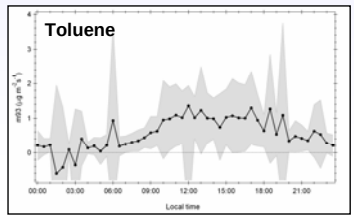
The DEC employs instantaneous measurements, but with slower frequency compared to the EC method. The flux is calculated as an average of a smaller subset of samples:

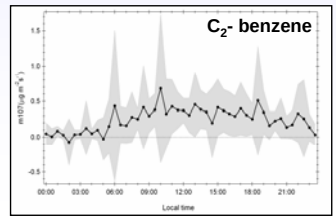
$$F_x = \overline{w'C'} = \frac{1}{N}\sum_{i=1}^{N} w'(t_i)c'(t_i)$$

DEC fluxes of toluene, benzene, C_2-benzenes and methanol were measured by a Proton Reaction Mass Spectrometer (PTR-MS) during 16 days of the campaign. Overall, fluxes showed consistent diurnal patterns, similar to the patterns observed in 2003, but with higher magnitudes. Methanol flux was 26% higher, C2-benzenes 70% and toluene 100% higher than fluxes in 2003. These differences were likely due to increased traffic congestion at the 2006 site. However, the toluene difference was due to the application of a toluene based resin to the sidewalks near the tower during the measurement campaign.









Summary

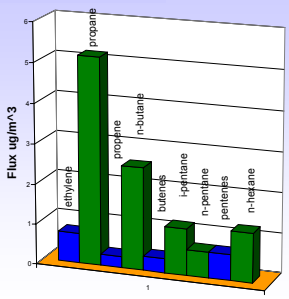
- The implementation of a flux tower at the SIMAT site was successful.
- Clear anthropogenic signatures of concentrations and fluxes were observed.
- The diurnal patterns of both, concentrations and fluxes of olefins and CO_2 were similar to those observed in 2003, but with higher magnitudes. These differences were due to the different characteristics of the monitored site rather than an increment of the emissions in a period of 3 years.
- Valuable turbulent data and energy fluxes were obtained.
- The energy balance distribution and radiative parameters observed are similar to distributions and parameters reported for other urban sites.

Disjunct Eddy Accumulation (DEA)

In DEA method, updrafts and downdrafts are detected with the sonic anemometer and air is sampled during the up/down draft into two up/down canisters at proportional volumes to the strength of the up/down draft. The flux is calculated from the measured vertical wind velocities and concentrations. W and C are the overall means during the sampling period. Sample analyses were done by GC-FID.

$$F_x = \left(w'c_x'\right)_{up} - \left(w'c_x'\right)_{down} - WC$$

Weekly average fluxes for a series of alkanes and alkenes show that alkane fluxes are 6 times higher than alkene fluxes, which is in good agreement with the current emissions inventory of Mexico City.



Flux averages for March 14-20, 2006

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References

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- Velasco et al., 2005b. Measurements of urban VOC fluxes. Geophysical Research Letters, 32, doi:10.1029/2005GL023356.

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