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URBAN ECOSYSTEM-ATMOSPHERE EXCHANGE OF CARBON DIOXIDE

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1. INTRODUCTION

The Earth's surface is covered with a mosaic of ecosystems. Urban ecosystems are a rapidly growing component of this mosaic. Nationally, urban areas are 27% tree covered and have tripled in size over the past 40 years (Dwyer et al. 2000). Within this ecosystem are the bulk of anthropogenic carbon dioxide (CO_2) emissions, but also a substantial vegetative sink, benefiting from a CO_2 rich atmosphere, nitrogen fertilization, and a longer, warmer growing season.

Although quantifying urban ecosystem-atmosphere CO_2 flux (Fc) is essential to understanding the carbon cycle, programs involving continuous measurement of Fc have only recently begun (Grimmond et al. 2002). Urban ecosystem-atmosphere measurements present difficult challenges to conventional eddy covariance measurements conducted over other ecosystems worldwide (Baldocchi et al. 2001). However, some approaches as described in Grimmond et al. (2002) offer promise in providing methods which lead to representative measurements of surface-atmosphere exchanges of mass and energy.

We report selected preliminary measurements from a long-term study of urban ecosystem-atmosphere exchange of CO_2 conducted in the Denver urban area.

2. METHODS

The study site is situated on nearly level terrain (39^o, 41' latitude, 105^o, 01' longitude, 1606m elevation) in Englewood, Colorado, 10 km south of Denver's urban center and well within urban development. A 0.5km wide area of commercial and light manufacturing buildings exists along a north-south axis through the site. Surrounding areas are residential, extending several kilometers in all directions. Commercial and residential buildings are 5-10 m in height. As typical of urban canopies, friction velocities are higher than experienced over vegetation (0.5-0.8 ms^{-1} for 3-6ms^{-1} winds).

Fc, which we also refer to as net ecosystem exchange, is calculated from the sum of: turbulent flux (covariance of vertical velocity and CO_2 fluctuations) plus the advective flux (due to horizontal and vertical gradients in concentration or wind velocity) plus the change in storage of CO_2 in the air column with time.

Turbulent flux measurements began in June 2001 using eddy covariance sensors deployed at 70m from a 120m tall, decommissioned A.M. radio broadcast tower. The relative contributions of advective flux to Fc can be determined from differences between measurements at 70m and a second level of eddy covariance sensors installed February 2002 at 100m, following methods in Bakwin et al. 1998. Eddy covariance sensors include tri-axis sonic anemometers (CSAT3, Campbell Scientific, Inc., Logan,UT), an open-path infrared gas analyzer (IRGA) (Auble and Myers, 1990 and Li7500, LiCor Inc., Lincoln, Ne), and a krypton hygrometer (Campbell Scientific, Inc.). Signals were recorded at 10Hz by a data logger (23x micrologger, Campbell Scientific) over 30 minute periods (increased to 1 hour periods later in the study) and saved to compact discs for post-processing. Fluxes were computed as described in Anderson and Farrar (2001).

Change in storage of CO_2 in the air column have been measured, based on sampling air from 6 levels (120, 100, 70, 50, 30, 15m) continuously since February 2002. CO_2 concentration is determined using an IRGA (Li6262, LiCor Inc.). Ancillary measurements include net (Q*7, REBS, Pullman, WA) and solar radiation (Li190, LiCor Inc.).

A preliminary assessment of CO_2 source strength due to vehicular emissions in the flux footprint of the tower was made as follows. Hourly traffic data (traffic count and vehicle type) of major area roads was obtained from the Colorado Department of Transportation. Traffic count was multiplied by CO_2 emissions per vehicular mile traveled as determined from national averages (EPA, 2000). Emissions from commercial and residential (assumed negligible in summer) sources were have not be included at this time.

3. RESULTS

Since instrumentation required for advective flux and storage flux components have only recently been installed, we will only discuss data gathered from 70m during periods of well mixed conditions (near neutral to unstable stability). Also, in our preliminary analysis, due to the Li7500 IRGA's light sensitivity, we have selected periods of

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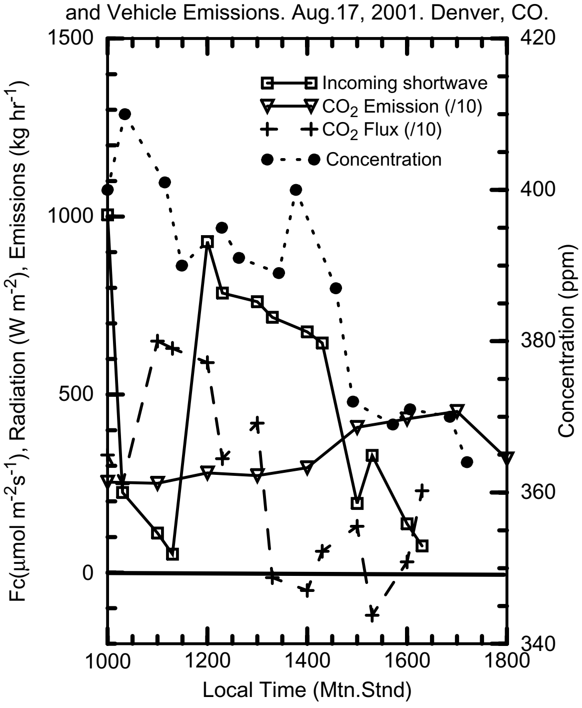
nearly constant incoming radiation after late summer when this sensor was employed.

During fall and winter, Fc ranged from about 10 to 40 μmol m^{-2} s^{-1} when the tower's footprint extended over mainly residential areas. Fc from other directions sometimes well exceeded this range, perhaps due to advection from strong near field sources, particularly under light winds.

In summer months, Fc was highly variable except during mid-morning to late afternoon hours when the surface layer is well mixed. Under these conditions, Fc was typically -5 to 20 μmol $m^{-2}s^{-1}$. A small downward flux, indicating net uptake of CO_2 by the urban ecosystem, often occurred by mid-afternoon, before the surge in afternoon rush-hour traffic. An example of this relation is seen in figure 1. Morning cloudiness was followed by afternoon clearing, as indicated by the increase in solar radiation. These conditions likely promoted both increased photosynthesis and increased thermal mixing of the surface layer during the afternoon. Under this scenario, CO_2 concentrations should decrease in the manner shown. Photosynthesis may have reduced Fc and reversed its sign, suggesting net uptake of CO_2 by the urban ecosystem at certain times in mid-afternoon. The increase in Fc late in the afternoon may be due to the increase in CO_2 emissions from traffic, overwhelming decreasing rates of photosynthesis as incoming radiation decreased.

Fig.1: Trends in Fc, Concentration, Solar Radiation, and Vehicle Emissions. Aug.17, 2001. Denver, CO.



4. CONCLUSIONS

Preliminary analysis indicates that the Denver urban ecosystem may be a small source of CO_2 during the growing season. Under certain conditions, this ecosystem can actually sequester substantial CO_2 to the extent that it can become a net sink over short periods of time during the growing season.

Analysis under way will improve preliminary flux estimates of CO_2 by including advection and change in storage flux components of Fc, determined from eddy covariance measurements at two heights and profile concentration data.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Anderson, D.E. and C.D. Farrar. 2001. Eddy covariance measurement of CO_2 flux to the atmosphere from an area of high volcanogenic emissions, Mammoth Mountain, CA. Chem. Geol. 1777: 31-42.

Auble, D. and T. Myers. 1992. An open-path, fast-response infrared absorption gas analyzer for H2O and CO_2. Bound. Lay. Meteorol. 59: 243-256.

Baldocchi, D., E. Falge, et al. 2001. FLUXNET: a tool to study the temporal and spatial variability of ecosystem scale carbon dioxide, water vapor, and energy flux densities. Bull. Amer. Meteorol. Soc. 82: 2415-2434.

Bakwin, P.S., P.P. Tans, D.F. Hurst, and C. Zhao. 1998. Measurements of CO_2 on very tall towers: Results of the NOAA/CMDL program. Tellus 50B: 401-415.

Dwyer, J.F., D.J. Nowak, M.H. Noble, and S.M. Sisinni. 2000. Connecting people with ecosystems in the 21st century: An assessment of our nation's urban forests. U.S. Forest Service Tech. Rpt.PNW-GTR-490.

Enviornmental Protection Agency 2000. Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-1998). EPA rept. #236-R-00-001.

Grimmond, C.S.B., T.King, F. Cropley, D.Nowak, and C. Souch. 2002. Local scale fluxes of carbon dioxide in urban environments: methodological challenges and results from Chicago. Environ. Poll. 116: 243-254.