J13.1 **CARBON DIOXIDE FLUXES IN TWO SUBURBAN NEIGHBORHOODS IN VANCOUVER, CANADA**

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1. INTRODUCTION

At the local scale, carbon dioxide fluxes from the urban surface are a complex response from various sources of anthropogenic and biogenic CO_2 sources and sinks. In urban areas, vegetation and soils may also be extensively managed (e.g. irrigation, fertilization), further altering the urban carbon balance relative to rural areas. Knowledge of the various sources and sinks of CO_2 could have important urban planning applications and assist decision-makers with sustainable growth policies in the context of global climate change mitigation and adaptation.

The objectives of this research are 1) to present preliminary local-scale CO_2 flux (F_c) measurements from two contrasting suburban sites and a rural reference station in Vancouver, BC, Canada and 2) compare these preliminary measurements to F_c observations from other cities.

2. SITE DESCRIPTION

During July and August 2008, energy and CO_2 fluxes were measured at two suburban Vancouver neighborhoods and at a rural reference location. These measurements were part of the Environmental Prediction in Canadian Cities (EPiCC) network (Voogt et al. 2009, same conference). The two suburban neighborhoods ('Vancouver-Sunset' and 'Vancouver-Oakridge') are both primarily composed of 1-2 storey family residences but have contrasting building and vegetation densities (Table 1). The two neighborhoods are approximately 4 km apart and the rural site ('Westham Island') is an unmanaged grass field located approximately 16 km south of Vancouver (Christen et al. 2009, same conference).

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Precipitation in Vancouver is concentrated in winter (annual average total 1199 mm) and temperatures are mild (annual average daily high 13.7 C, average daily low 6.5 C). Summers are typically dominated by high-pressure systems that bring clear skies and warm temperatures. Daily land-sea circulation systems result in westerly winds during the day and weaker easterly breezes at night. During the study period July – August 2008, average temperature was 19 C and there was 57 mm of precipitation.

Table 1. Vancouver F_c study site neighborhood characteristics.

	Sunset	Oakridge
Measurement Height	28 m	29 m
Building plan area fraction	21%	23%
Vegetation plan area fraction	44%	56%
Plan area fraction impervious ground	35%	21%
Homes / ha	19	9

3. PRELIMINARY RESULTS

F_c was observed continuously at both urban and the rural sites simultaneously using eddy-covariance methods. All sites measured three dimensional wind vector (Campbell Scientific CSAT-3d sonic anemometer) and CO_2 concentrations (Li-COR 7500 open path infrared gas analyzer) at 20 Hz. Fluxes were calculated in 30-minute periods and corrections for density and water vapor fluctuations were applied (Webb et al., 1980). Data presented here are from non-rainy conditions during July – August 2008 and no gap-filling procedures were used.

During the study period both suburban sites were a CO_2 source for most of the day (Figure 1). The more vegetated Oakridge neighborhood showed slight net CO_2 uptake during a few mid-day hours, while the Sunset neighborhood had positive F_c all day. Sunset F_c is highest from 0700 – 1000 LST, presumably due to predominantly Easterly winds that included a source area with higher emissions from traffic. The rural site showed net uptake during the day and positive F_c from soil and above-ground respiration and anthropogenic sources at night.

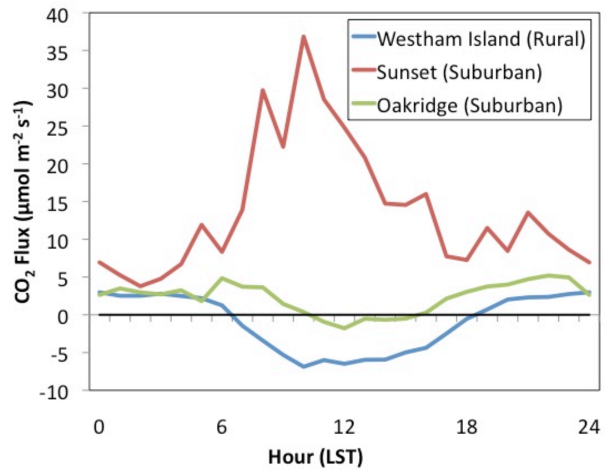

Figure 1. Ensemble mean F_c during July – August 2008, all wind directions included.

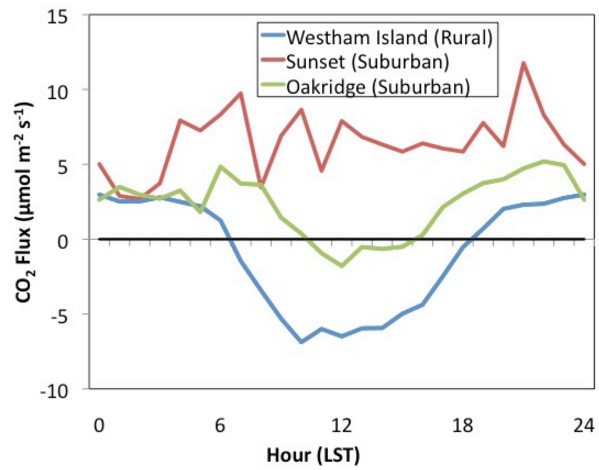

Figure 3. Ensemble mean F_c during July – August 2008 with Sunset F_c from wind directions 135° – 225° excluded.

Wind direction has a strong influence on measured F_c at the Sunset site (Figure 2). Highest fluxes are observed when winds are from 165°, the direction of a busy intersection approximately 200 m from the tower. When measurements from this wind sector (135°-225°) are removed, observations are more representative of a suburban residential area and F_c at Vancouver-Sunset is significantly lower, though still positive throughout the day (Figure 3).

Photosynthetic active radiation, which is a fraction of short-wave irradiance (K↓), is a strong control on CO_2 uptake by vegetation through photosynthesis. In an urban area, the relationship between solar radiation and CO_2 exchange is less clear than in rural areas due to anthropogenic sources of CO_2 (Figure 4). At the Westham Island rural site, there is good agreement between K↓ and F_c and some light saturation effects are observed. K↓ is a better predictor of F_c at the Oakridge neighborhood than Sunset because of the greater fraction of vegetation cover (Table 1).

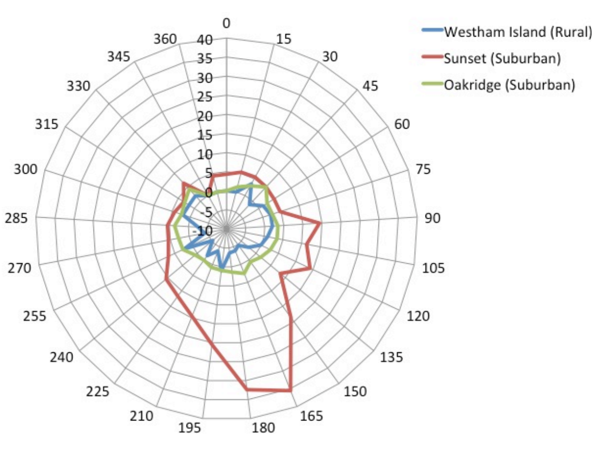

Figure 2. F_c by wind direction for day and night. Numbers at the outside edge of the circle indicate wind direction (degrees), radial numbers are F_c (μmol m^{-2} s^{-2}).

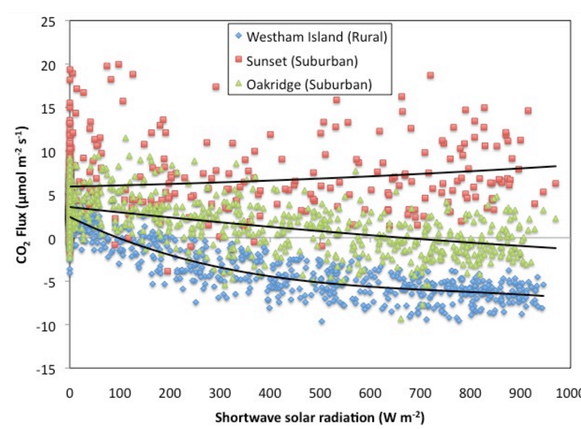

Figure 4. Shortwave solar radiation and F_c during July – August 2008. Fitted 3rd order polynomial curves are shown for each site: Westham Island r^2=0.87, Oakridge r^2=0.31, Sunset r^2=0.03.

Preliminary F_c results in Vancouver are within the range of other summertime urban F_c measurements from various cities worldwide (Figure 5). The Oakridge neighborhood has the second greatest CO_2 uptake during daylight hours while the Vancouver-Sunset neighborhood appears similar in magnitude to measurements in Melbourne (Coutts et al., 2006) and Tokyo (Moriwaki and Kanda, 2004).

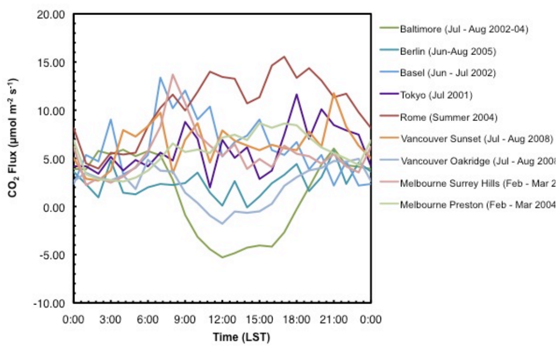

Figure 5. Summer averages of hourly F_c from other selected studies.

4. DISCUSSION

Carbon dioxide fluxes measured in suburban and urban areas are strongly controlled by traffic and household emissions, but vegetation uptake can be substantial in summertime. In order to model F_c and apply results more broadly to other neighborhoods and cities, careful consideration of the source area must be taken into account and a detailed surface database is needed.

(Sub)urban F_c is primarily a balance between emissions from vehicle traffic, human respiration, soil respiration, and home heating (e.g. wood or gas) and uptake by photosynthetic vegetation. Eddy covariance observations of F_c at the local-scale provide direct, top-down measurements of total CO_2 exchange from these components, but the relative importance of each of these factors is unknown. A bottom-up approach to measure the individual processes that contribute to F_c may be useful. Future work exploring the specific contributions of these components, in particular traffic and vegetation, to F_c is planned in Vancouver.

REFERENCES

Christen, A., B. Crawford, N. Goodwin, R. Tooke, N. Coops, C.S.B. Grimmond, T.R. Oke, J.A. Voogt. 'The EPiCC Vancouver Experiment: How do urban vegetation characteristics and garden irrigation control the local-scale energy balance?', same conference, paper 6.4

Coutts, A.M., J. Beringer, N.J. Tappa, 2007. Characterstics influencing the variability of urban CO2 fluxes in Melbourne, Australia. *Atmospheric Environment,* 41, 51-62.

Moriwaki R. and M. Kanda, Seasonal and diurnal fluxes of radiation, heat, water vapor, and carbon dioxide over a suburban area, *Journal of Applied Meteorology,* 43 (2004),1700–1710.

Vogt R., A. Christen, M.W. Rotach, M. Roth, A.N.V Satyanarayana. Temporal dynamics of Co2 fluxes and profiles over a Central European city. *Theoretical and Applied Climatology*, 84, 117-126

Voogt J.A., T.R. Oke, O. Bergeron, N.R. Goodwin, S. Leroyer, B.R. Crawford, E. Christensen, B.E. Nanni, R. Tooke, D. Van der Kamp, D. Aldred, S. Belair, F. Chagnon, A. Christen, N. Coops, J. Mailhot, I. McKendry, I.B. Strachan, J. Wang, M. Benjamin, S. Grimmond, A. Lemonsu, V. Masson (2009): 'The Environmental Prediction in Canadian Cities (EPiCC) network', same conference, paper J1.4

Webb, E.K., G.I. Pearman, and R. Leuning (1980). Correction of flux measurements for density effects due to heat and water vapour transfer. *Quarterly Journal of the Royal Meteorological Society*, 106, 85-100.

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