CO_2 sources and sinks in urban and suburban areas of a northern mid-latitude city

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Why choose this paper

Long-term observational studies reporting on the annual and seasonal variation of net CO2 exchanges as well as on the environmental drivers that can affect CO2 fluxes are still lacking, especially regarding the role of the vegetation in urban environments.

Outline

- **Background**
- **Objectives**
- **Method**
- **Results and interpretation**
- **Conclusions**
- **Implications for my research**

1. Background

1.1 importance of Urban climate

Urban environments can modify the local climate and are net CO_2 emitters which in turn can affect the global C cycle and public health.

Increasing attention is being focused on understanding the exchanges of heat , mass and momentum over cities.

1.2 Montreal

the second largest city in Canada

climate : humid continental climate

features :detached family suburban homes on grass and tree-covered lots ,row housing with narrow alleyways; coupled with the wide range of environmental conditions.

1.3 problem statement

Calibration and validation of atmospheric dispersion models are limited by the small number of observational studies available in the literature.

EPiCC research network provide observations of turbulent exchanges and surface to a Soil-Vegetation-Atmosphere Transfer model.

2. Objectives

- to quantify the net CO_2 exchanges of the three sites on daily to annual time scales;
- to estimate the vehicular traffic CO_2 emissions;
- to determine the response of CO_2 fluxes to temperature and light levels within each site;
- to determine the response of CO_2 fluxes to directional surface cover fractions.

3. Method

3.1 Site description

Table 1
Site characteristics.

	URB	SUB	AGR[a]
Latitude, Longitude (°)	45.547 N, 73.592 W	45.501 N, 73.811 W	45.328 N, 74.165 W
Land-use	Residential	Residential	Agricultural
Thermal climate zone[b]	Compact housing	Treed regular housing	Cropped fields
ρ_{pop} – population density (inh. km^{-2})	8400[c]	2400 (3150)[d]	–
z_H – mean building height[e] (m)	7.9	6.4	–
z_{TT} – mean tall tree height[f] (m)	13.0	13.8	–
z_M – measurement height (m)	25	25	2[g] or 5[h]
Surface cover fractions (%)[e]			
λ_I – impervious (pavement)	44	37	0
λ_P – built (roofs)	27	12	0
λ_V – vegetation (grass and trees)	29	50	100
grass	3	30	100
trees	26	20	0

3.2 Instrumentation

eddy covariance system:

sonic anemometer-thermometer , open-path infra-red gas analyser ;
Datalogger (CR5000 at URB and SUB , CR1000 at AGR).

four-component radiometer

Platinum resistance thermometer

3.3 Calculation of turbulent fluxes

F_{CO_2}: calculated from block averages over 30 min time periods.

Data select : Half-hours between 12:00 and 15:00 ;

(ZM -ZD)/L < 0.1 (ZD =0.7ZH, L -- Obukhov length) ;

relative stationarity < 30% .

3.4 Data analysis

Measurements: from November 1st 2007 to October 1st 2009

nighttime and daytime FCO_2 available: AGR---29 and 41%，
SUB ---47 and 45%,
URB--- 37 and 35%.

CO_2 fluxes to light levels as influenced by photosynthesis

$$F_{CO_2} = \frac{\alpha \cdot F_{MAX} \cdot K_{in}}{\alpha \cdot K_{in} + F_{MAX}} - R_D \quad (1)$$

α : the apparent light use efficiency (mmol CO_2 w^{-1} s^{-1}) ,

F_{MAX} : the asymptotic value of FCO_2 with respect to K_{in} (mmol m^{-2} s^{-1}),

R_D: the daytime respiration rate (mmol m^{-2} s^{-1}).

3.5 Vehicular traffic CO2 emissions

$$E_{VT} = pvDVD \cdot N_V \cdot F_t \cdot \rho_{pop} \cdot EF \quad (2)$$

pvDVD : per vehicle daily vehicle distance (km $vehicle^{-1}$ day^{-1}),

N_V : the number of vehicle per person (vehicles $person^{-1}$),

F_t : the fraction of daily traffic per hour (day $hour^{-1}$),

ρ_{pop} : hourly population density ($personm^{-2}$)

EF: the emission factor corresponding to the amount of CO_2 released per vehicle per distance travelled (µmol CO_2 km^{-1}).

4. Results and Interpretation

4.1 Tower footprints and spatial heterogeneity

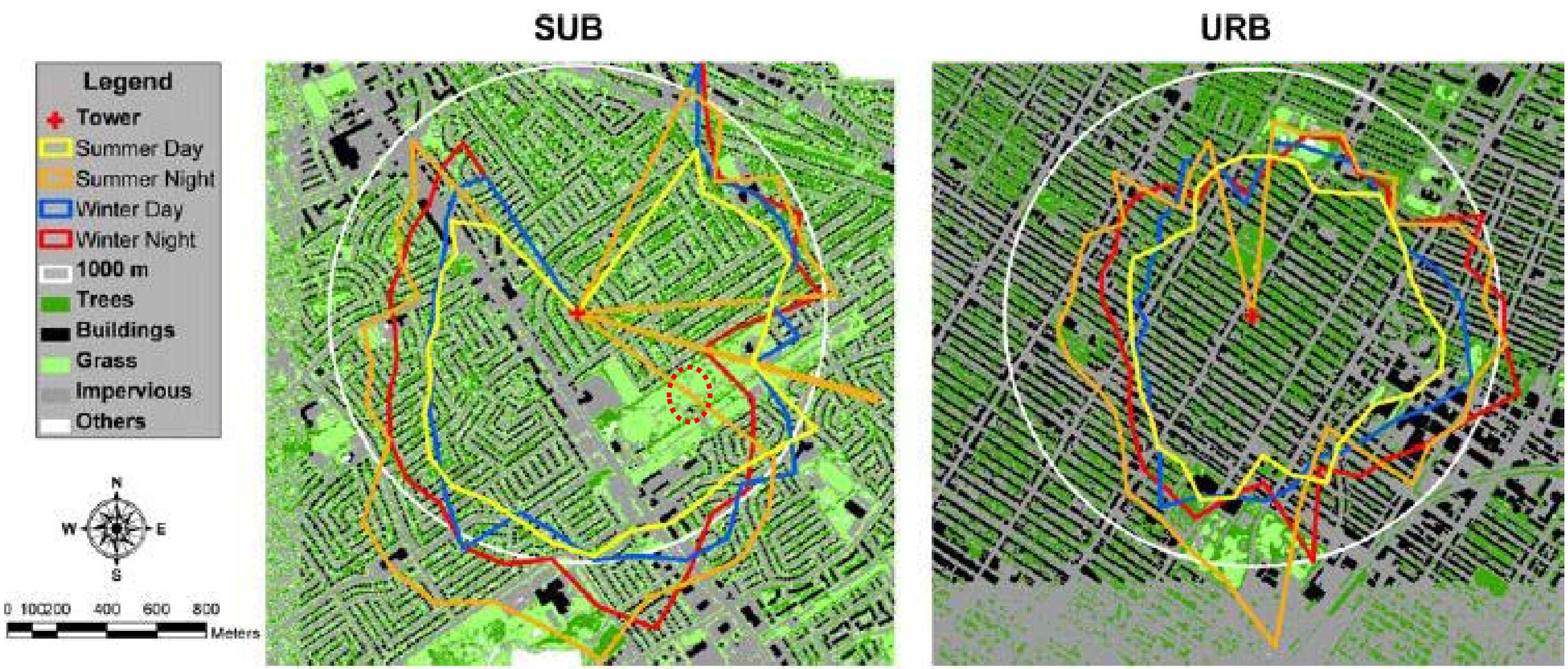


Fig. 1 Surface covers and footprint length for SUB (left) and URB (right). Footprint length was calculated for each available data point and binned over 36, 10 sectors around the towers using June to August (summer) and December to March (winter) data. Footprint length of zero indicates that no data point were available for that particular bin. Nighttime is defined as Kin < 5 W m^{-2}. Note that the building layer does not extend to the whole extent of the displayed map at both SUB and URB.

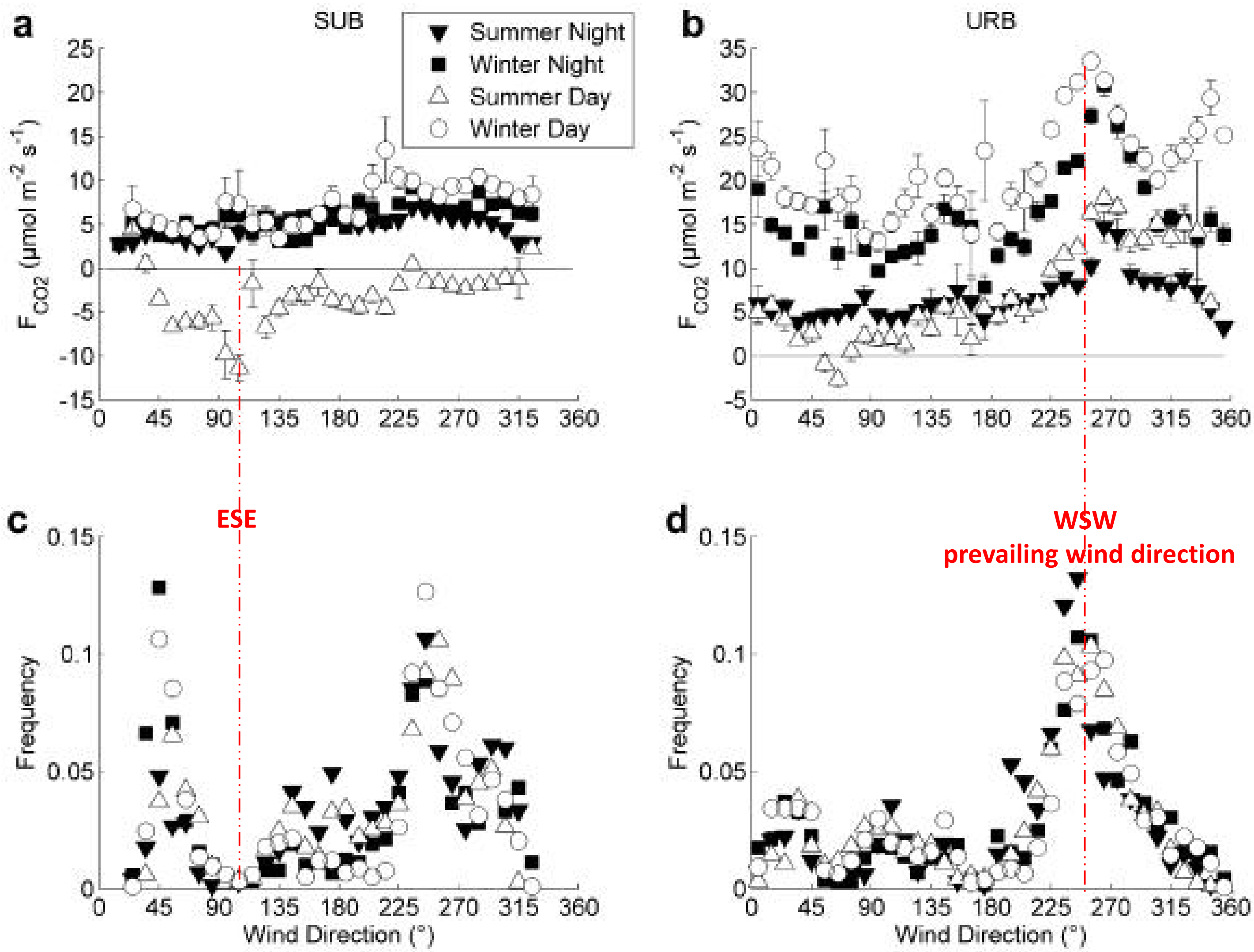


Fig. 2 CO2 flux (FCO2 , a, b) and frequency of occurrence (c, d) for 36, 10 sectors around SUB (a, c) and URB (b, d) towers. Winter and summer include data from December to March and June to August, respectively. Binned FCO2 values ± 1 standard error (2 < n < 194) are presented. Nighttime is defined as Kin < 5 W m^{-2}.

4.2 Seasonal variation of CO2 fluxes

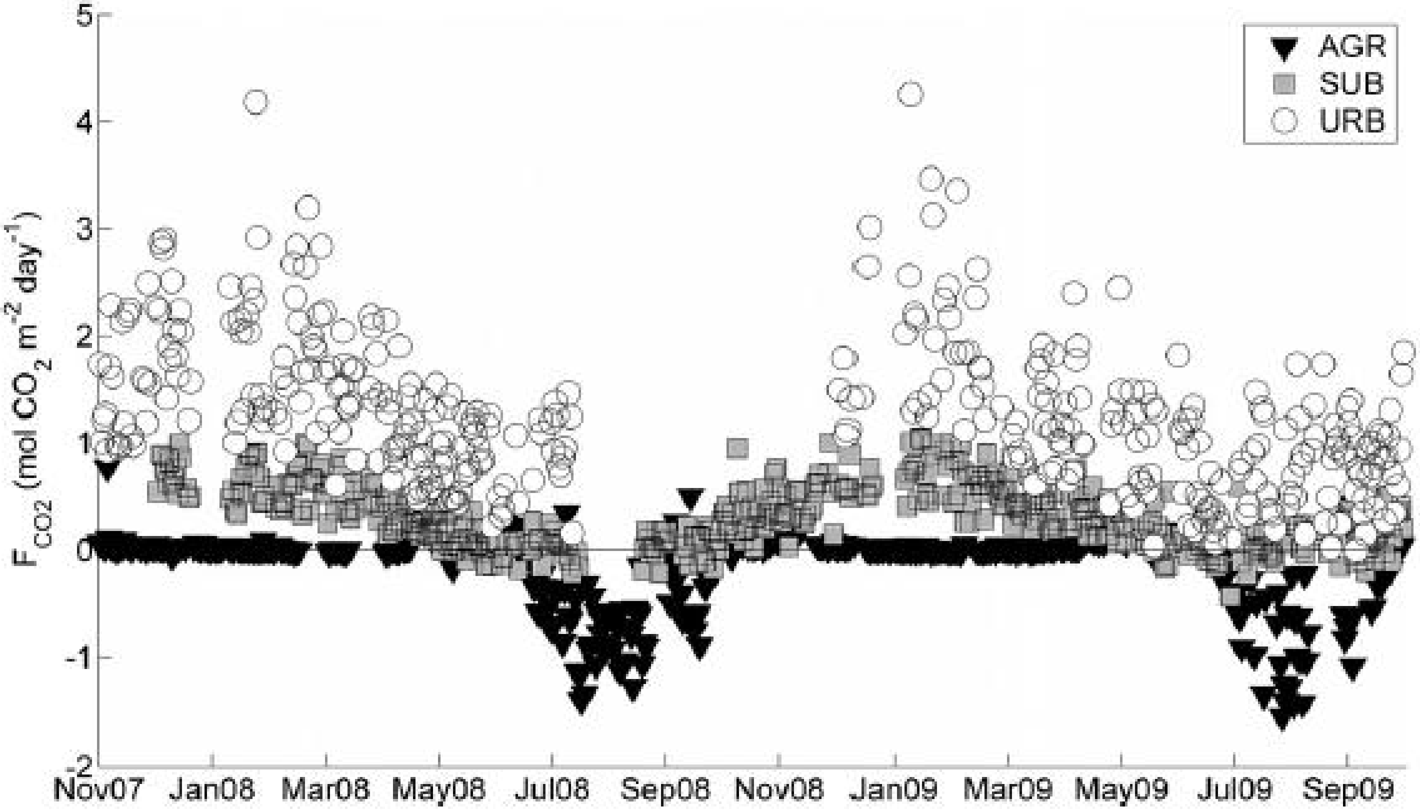


Fig. 3 Time series of total daily CO2 flux (F_{CO2}) over the study period

F_{CO2}:greater emissions during cold season and increased with urbanisation; influenced by vegetation(urbanisation ↑,CO2 uptake↓).

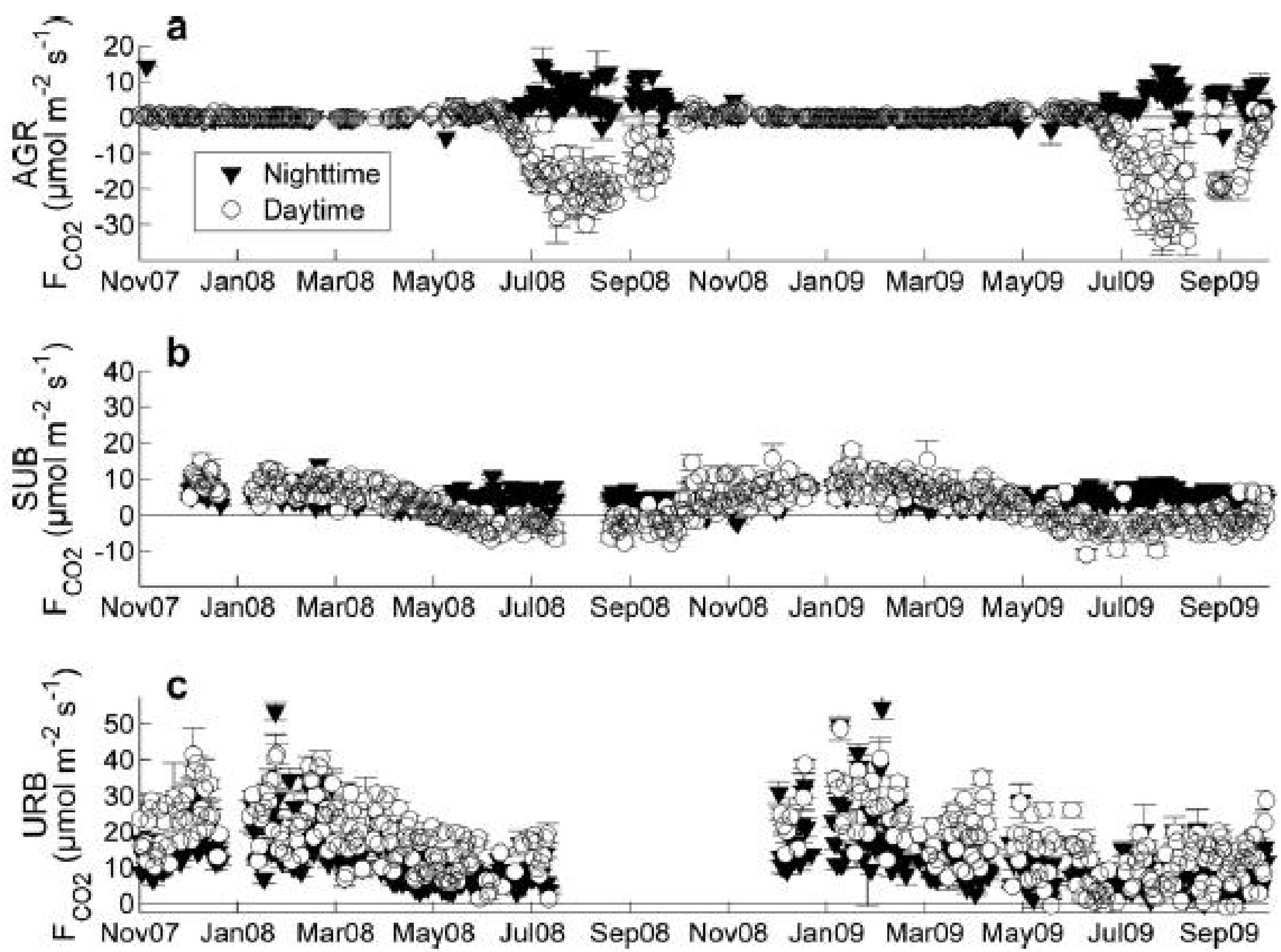


Fig. 4 Time series of mean daily nighttime and daytime CO2 flux (F_{CO2}) over the study period at AGR (a), SUB (b) and URB (c). Error bars correspond to one standard error (n > 10) is presented.

FCO2

AGR: cold season ≈0;warm season(daytime<0,nighttime>0)
SUB: cold season >0;warm season(daytime<0,nighttime>0)
URB: cold and warm season >0;

→ Human active increase F_{CO2}

4.3 Diurnal variation of CO2 fluxes

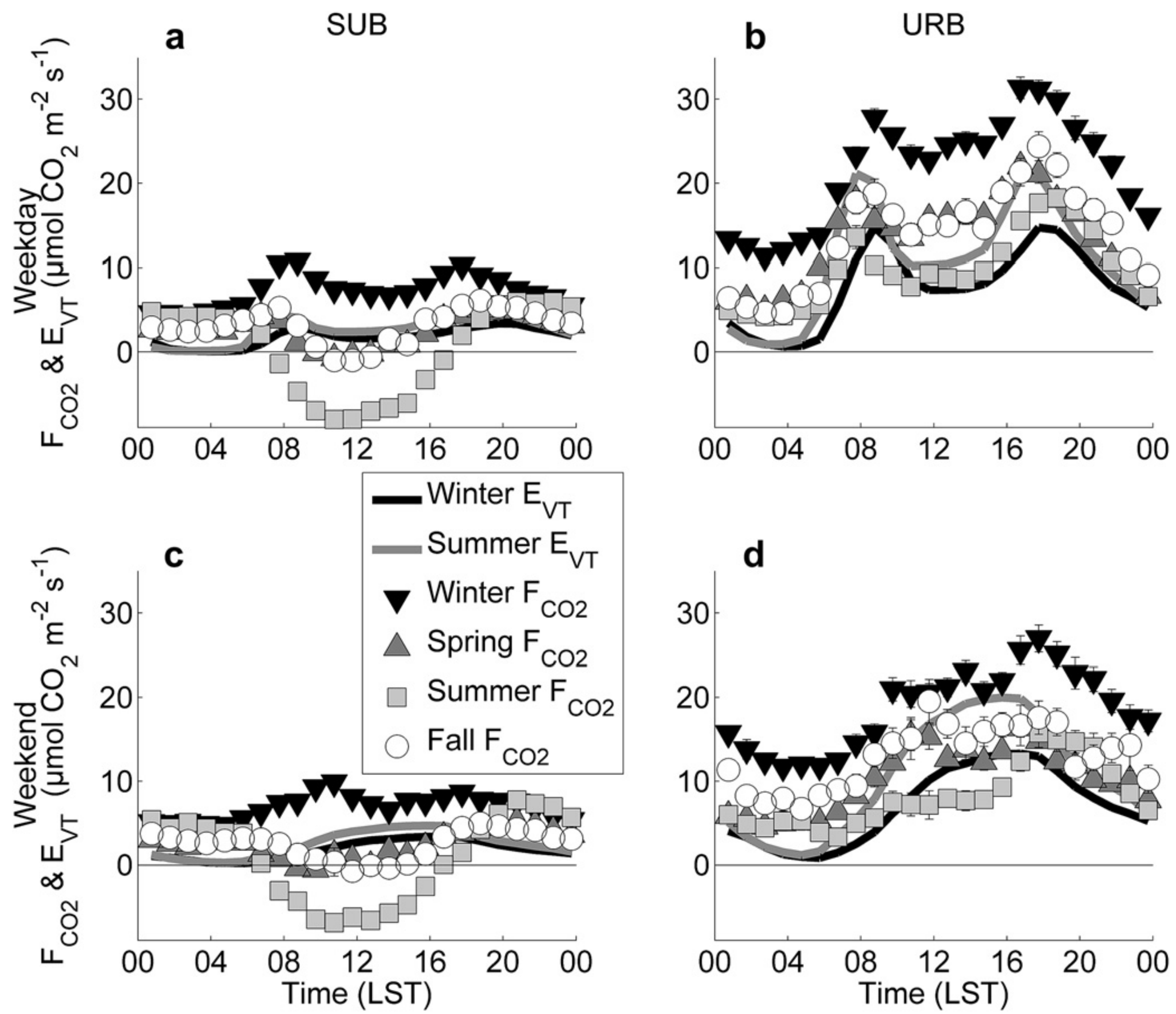


Fig. 5 Weekday (a, b) and weekend (c, d) diurnal profiles of CO_2 flux (F_{CO2}) for SUB (a, c) and URB (b, d). Winter and summer vehicular traffic CO_2 emissions (E_{VT}) are also presented. Winter corresponds to December-March, spring to April-May, summer to June-August, and fall to September-November. Hourly means ±1 standard error are presented.

Table 2. Linear regression parameters (±1 standard error) of nighttime (Kin < 5 W m^{-2}) and daytime CO_2 flux against built (λ_P), and vegetation (λ_V) cover fractions for summer (June-August) months.

Surface Cover	Season	Time of Day	Slope	Intercept	r^2	n
λ_P	Summer	Nighttime	8.3 ± 1.5	3.4 ± 0.3	0.28	77
		Daytime	83.4 ± 5.8	-18.3 ± 1.1	0.76	68
λ_V	Summer	Nighttime	-3.2 ± 0.6	6.4 ± 0.4	0.27	77
		Daytime	-30.8 ± 2.4	10.6 ± 1.5	0.72	68

Vehicular traffic , vegetation play important role in diurnal variation of CO2 fluxes ; fuel combustion for heating affect the FCO2 in cold season.

4.4 Vehicular traffic CO2 emissions

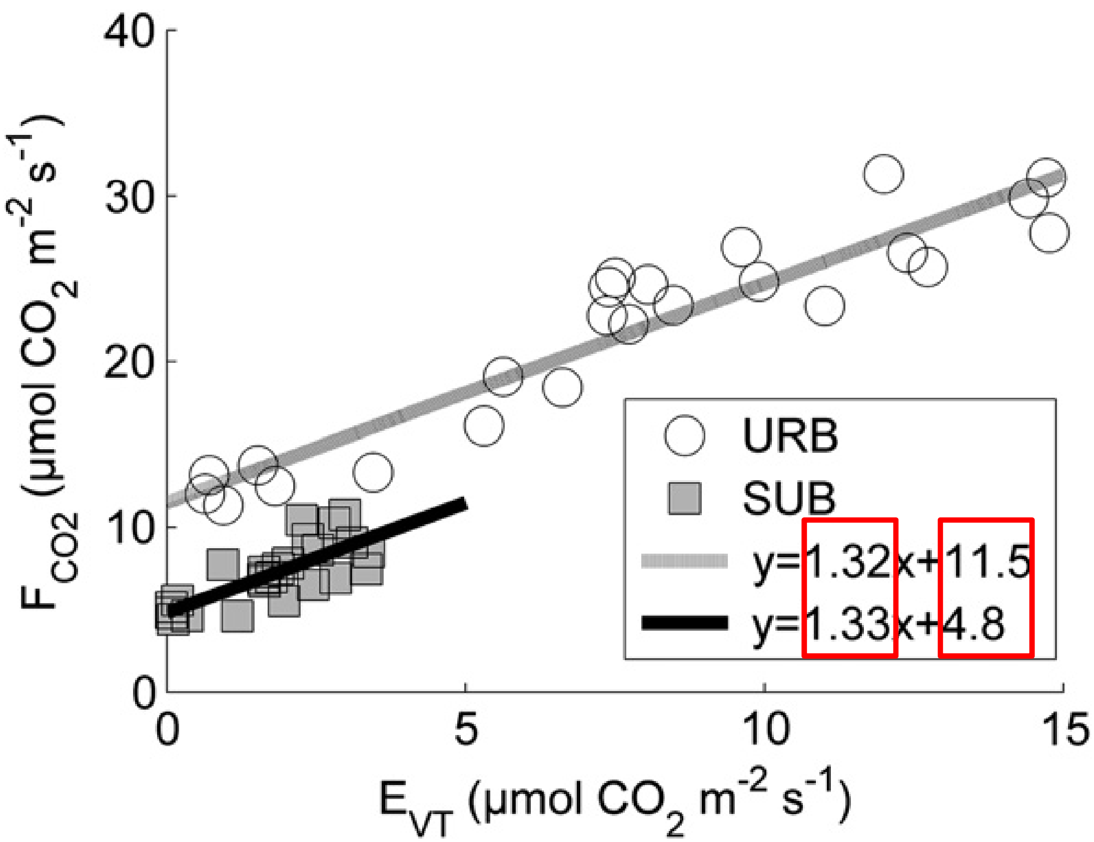


Fig. 6 CO2 flux (FCO2) against vehicular traffic CO2 emissions (EVT) using winter (December-March) data. Half-hourly values ±1 standard error (n > 10) are presented for weekdays only.

both sites showed similar regression slopes ; URB's intercepts>2*SUB's intercepts , why?

the background CO2 emissions

4.5 Response of FCO2 to environmental factors

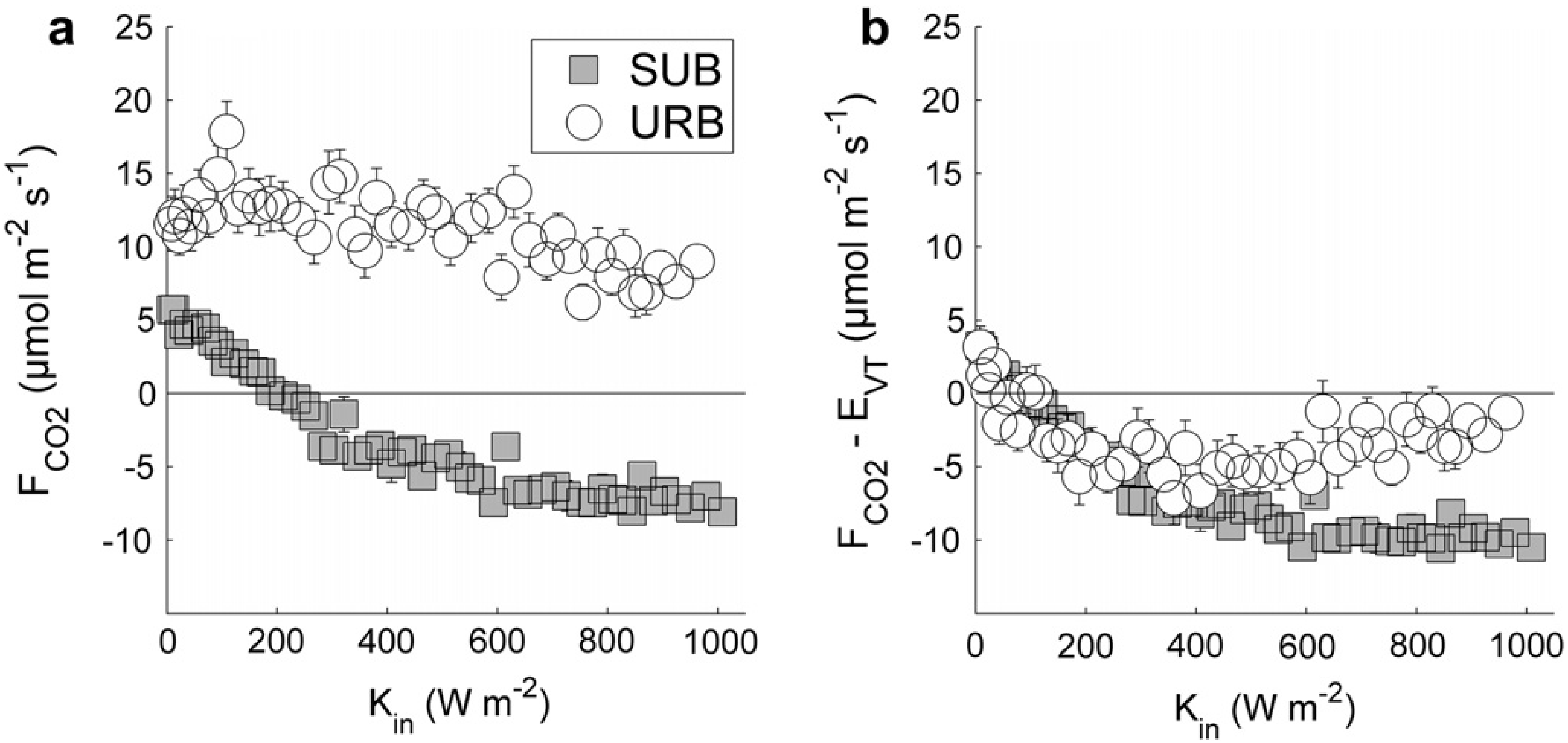


Fig. 7 CO_2 flux (F_{CO2}) with (a) and without (b) vehicular traffic CO_2 emissions (E_{VT}) against incoming shortwave radiation (Kin). Summer (June-August), weekday data are presented . Binned values ±1 standard error (n=30) are presented.

SUB ,responsive to K_{in} in summer (very similar to natural ecosystems);
URB, no significant relationship between FCO2 and K_{in}.

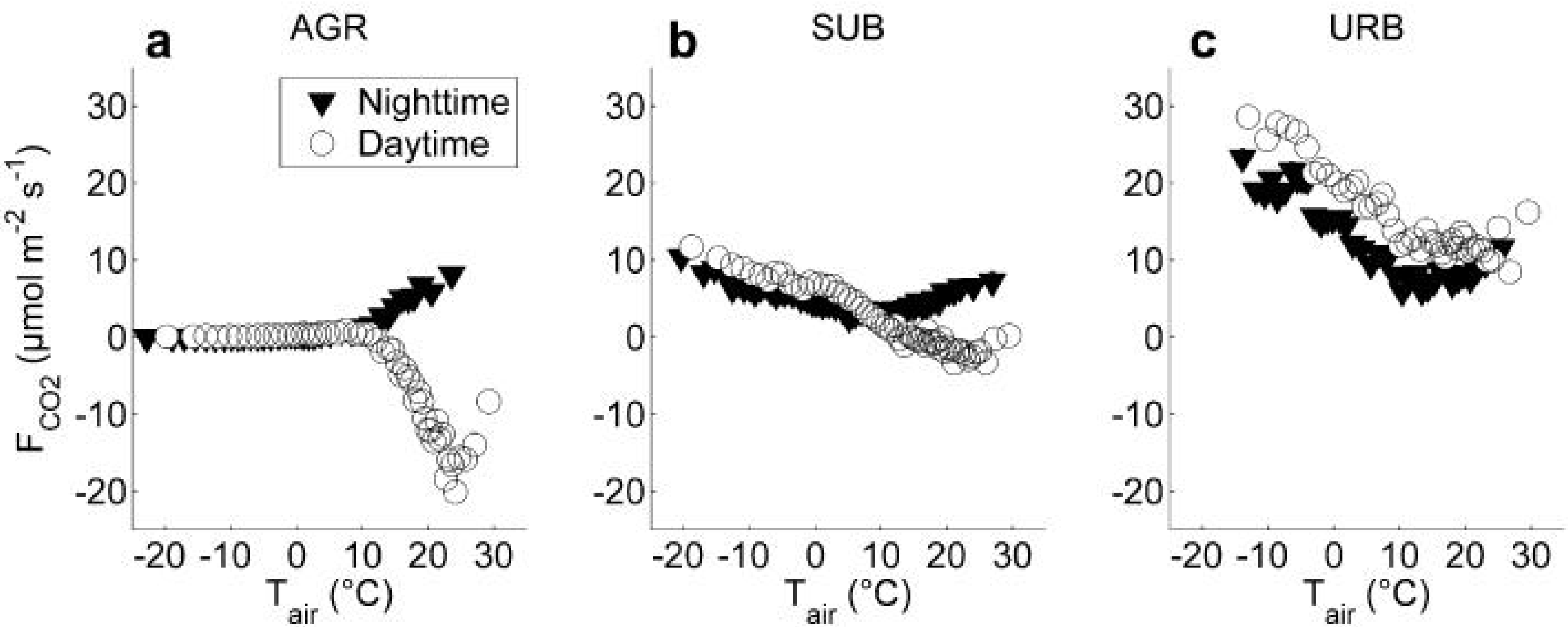


Fig. 8 Nighttime and daytime CO2 flux (F_{CO_2}) against air temperature (T_{air}) from AGR (a), SUB (b) and URB (c). Binned values ±1 standard error (n =150) are presented. Nighttime is defined as Kin < 5 W m^{-2}.

Table 3. Estimates (with 95% confidence bounds) of light response curve parameters (eq. (1)) for SUB using CO2 flux (F_{CO_2}) with and without vehicular traffic CO2 emissions (E_{VT}).Summer (June-August), daytime (Kin ≥5 W m^{-2}) half-hourly data points were separated in AM (time of day < 1300) and PM periods, all years altogether.

	Time of Day	α ($\times 10^{-2}$) (μmol CO_2 W^{-1} s^{-1})	F_{MAX} (μmol m^{-2} s^{-1})	R_D (μmol m^{-2} s^{-1})	r^2	n
F_{CO_2}	AM	−7.3 (−9.6,−4.9)	−19.3 (−20.8,−17.8)	6.6 (5.3, 7.9)	0.50	784
	PM	−3.6 (−4.6,−2.7)	−22.6 (−26.0,−19.1)	6.5 (5.7, 7.3)	0.56	826
$F_{CO_2}-E_{VT}$	AM	−12.6 (−16.4,−8.8)	−20.8 (−22.1,−19.5)	6.6 (5.2, 8.0)	0.55	784
	PM	−3.4 (−4.4,−2.4)	−17.8 (−20.3,−15.2)	1.6 (0.8, 2.4)	0.50	826

4.6 Annual net CO_2 exchanges

Table 4. F_{CO_2} of different urban residential areas

CITY	**FCO2(t ha^{-1} year^{-1})**
Melbourne	85
Mexico City	128
Tokyo	100
Copenhagen	125

AGR was an annual net CO_2 sink of 2 t CO_2 ha^{-1} while SUB and URB were annual sources of 52 and 204 t CO_2ha^{-1}

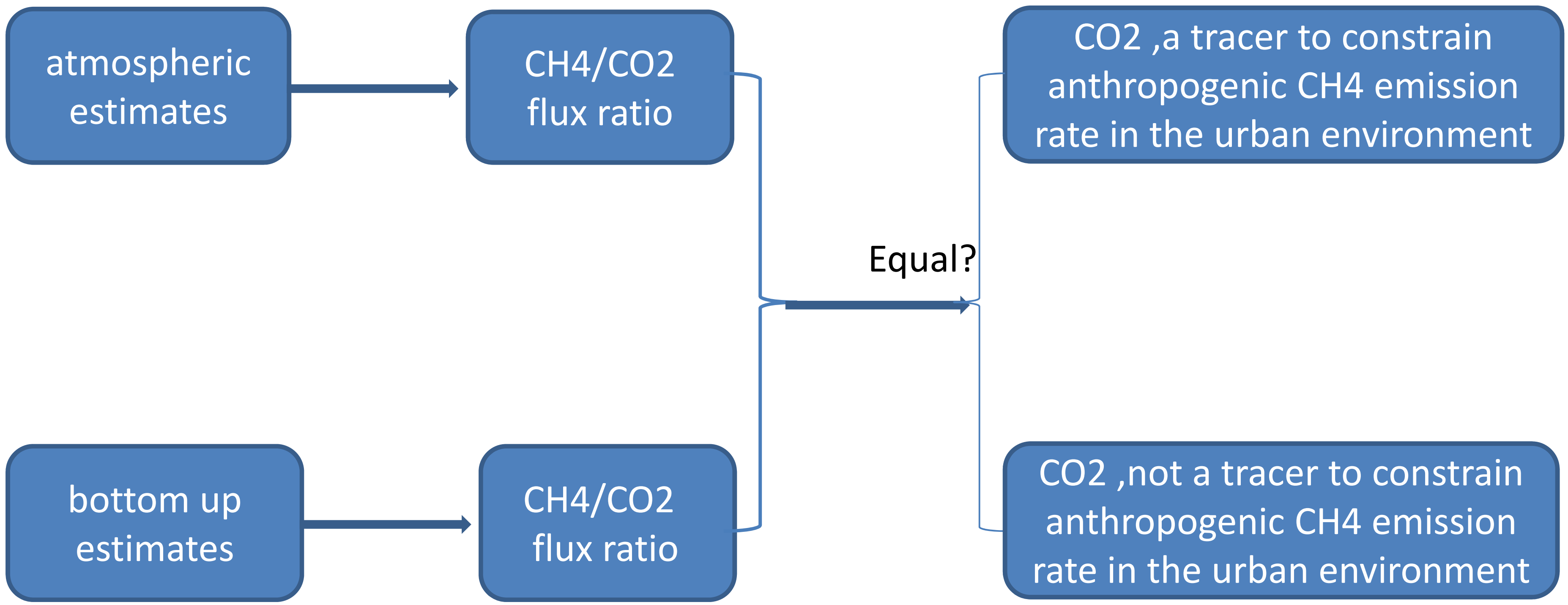
5. Conclusions

- Urban, a net source of CO_2 ;Suburban, a winter source and a summer daytime sink;

- Net CO_2 exchange affected by vehicular traffic, vegetation 、 fuel combustion for heating;

- The cold climate induced increased heating fuel .

6. Implications for my research



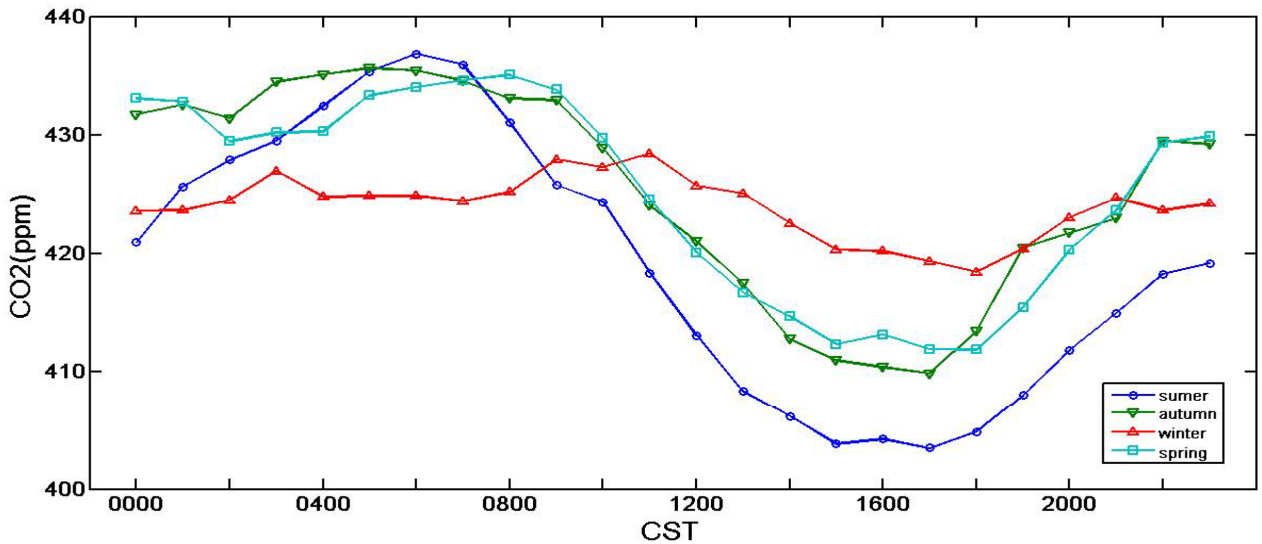
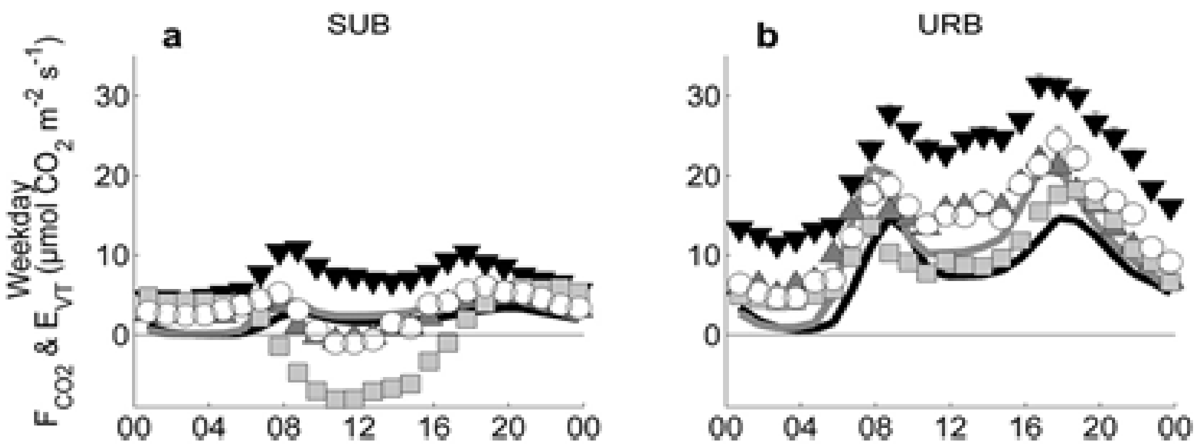


Fig.9 Diurnal composites of CH4 and CO2 concentrations for each of the four seasons



Compare to Fig.5

In my science piece ,the diurnal variation of CO2mixing ratio was mainly influenced by Boundary layer stability.

In this paper , the diurnal variation of CO2 was mainly influenced by Vehicular traffic.