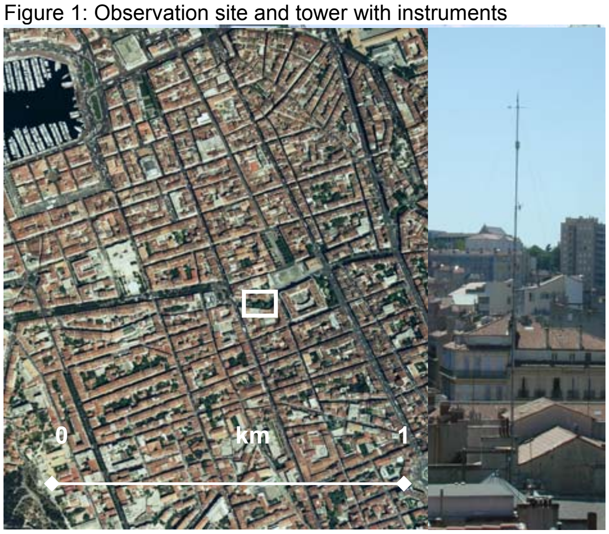
3.2 LOCAL-SCALE SURFACE FLUX MEASUREMENTS AT A DOWNTOWN SITE IN MARSEILLE DURING THE ESCOMPTE FIELD CAMPAIGN.

C.S.B. Grimmond*[1], J. Salmond[2], B. D. Offerle[1] and T. R. Oke[2]
[1] Indiana University, Bloomington, IN, [2]University of British Columbia, Vancouver, B.C.

1. INTRODUCTION*

Local-scale fluxes (of heat, mass, momentum and carbon dioxide) were measured at a downtown (central city) site as part of the ESCOMPTE project (Cros *et al.* 2002) conducted in Marseille, France during June and July 2001. These data provide information on surface fluxes in a highly urbanized area (low vegetation cover, tall roughness elements; Fig. 1), under a wide range of wind conditions. Flux data were collected at two levels to evaluate the effect of measurement height.

Figure 1: Observation site and tower with instruments



2. METHODS

2.1 *Site*

The site, centered on the Cour d'Appel Administrative (CAA, E10), located at 43.29°N 5.38°E (70 m asl), is a dense commercial and residential area with buildings 4-6 stories in height. A Hilomast NX30 pneumatic tower was installed on the roof of the CAA (base of the tower was 20.7 m above ground level). The tower was located in the path of a large aperture scintillometer; fluxes measured at the tower can be compared with those measured along the scintillometer path (Lagouarde *et al.* 2002).

2.2 Instrumentation, data acquisition and processing

The methods used to acquire and process the data are described in Grimmond *et al.* (2002). Equipment was mounted at multiple levels (L) on the tower (Table 1). The tower was operated at two heights (Up and Down), depending on wind conditions. Thus the two eddy covariance (EC) systems operated at two sets of heights above ground level (Table 2).

Table 1: Instrumentation used at the CAA (E10) site

Variable	Instrument	Model	Level
u, v, w, u*, Q_H, T, τ	Sonic anemometer	RM Young 81000	1,2
CO_2, H_20	IRGA	Licor-7500	1,2
K↓,K↑,L↓,L↑, Q*	Radiometer	Kipp &Zonen CNR1	2
T	Thermocouple	Omega T-type 36 awg	9x
T,RH	T/RH sensor	Vaisala HMP35C Gill radiation shield	2
Surface moisture		Weiss-type	
Surface T	IRT	Everest, various	

Table 2: Heights at which EC equipment was operated

	L1	L2	z_{L1}/z_H	z_{l2}/z_H
Up	43.9 m (U1)	37.9 m (U2)	1.83	1.58
Down	34.6 m (D1)	28.5 m (D2)	1.44	1.18

3. RESULTS

3. 1 *Roughness parameters*

Average building heights based on a ground survey of the site are ~24 m. Vegetation is largely contained within the urban canyons. Thus zero-plane displacement length (z_d), based on rule-of-thumb estimates (z_d = 0.7 z_H) (Grimmond & Oke 1999a), would be expected to be ~17 m.

z_d was calculated using the turbulence data from the sonic anemometers and the temperature variance method (TVM) of Rotach (1994). Following the approach of Grimmond *et al.* (1998), turbulence data were stratified by wind direction (into 30° sectors) and analyzed independently for all four measurement heights (§2.2) for unstable conditions (z/L < -0.2). Estimates of z_d around the tower range from 24.5 to 28.5 m. Consistent with the results of Rotach (1994), the lower measurement heights (L2) yields better estimates. A representative average z_d for the site from this method is 26 m. Similar to the findings of Grimmond *et al.* (1998), this estimate is high than the rule-of-thumb estimates.

Given a z_d of 17 or 26 m and the log-law (eqn. 5 Grimmond *et al.* 1998), a reasonable estimate of z_0 for the site is ~ 1 m.

3.2 *Heat Fluxes*

Energy balance fluxes are presented for a six day period of intensive observations (IOP/POI 2) (Fig. 2). The tower was in the "Up" position for this period. In this instrument configuration, the fluxes were very similar between the two levels. The turbulent sensible heat flux is the dominant means of heat transfer away from the surface during the middle of the day. As expected, given the absence of vegetation cover at this site and the dry conditions encountered in the measurement period, the latent heat fluxes are very small (Fig. 2). The storage

* *Corresponding author*: Sue Grimmond, Geography, IU, Bloomington, IN 47405; e-mail: grimmon@indiana.edu

heat flux (ΔQ_S) is calculated here as the residual in the energy balance, so it also accumulates the net flux from the measurement errors and the neglected terms (Grimmond and Oke 1999b). As found in other urban areas (Grimmond and Oke 1999b), ΔQ_S peaks before solar noon and the flux becomes negative a couple hours before the net all-wave radiation (Q*). Heat storage at this site is being studied in more detail (Roberts *et al.* 2002).

Figure 2: Energy balance fluxes observed at the upper level (L1) during IOP/POI 2 (172-177)

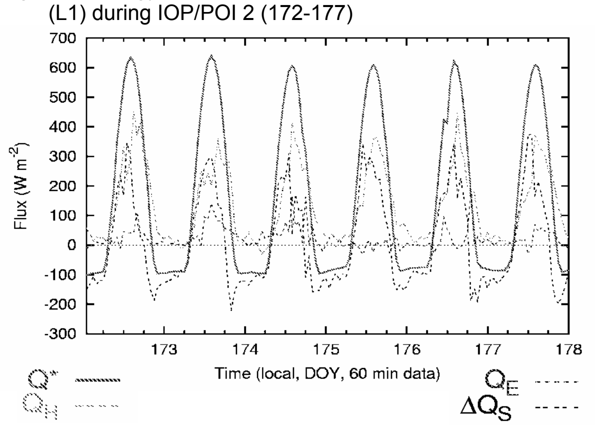
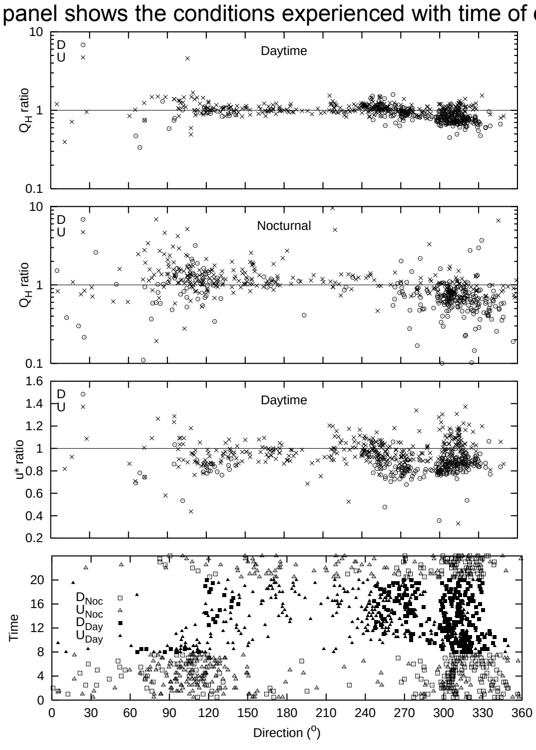


Figure 3: Ratio of sensible heat flux (Q_H) and friction velocity (u*) observed at the two levels (Lower/ Upper) when the tower was "Up" (U) and "Down" (D). The Q_H ratios are distinguished for daytime and nocturnal periods. Data are plotted against wind direction. Lowest panel shows the conditions experienced with time of day.

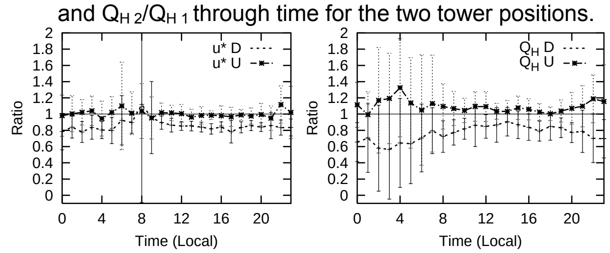


Local-scale measurements normally need to be at heights at least 2 z_H to ensure they are in the inertial sub-layer (e.g. Grimmond and Oke 1999a). However, wind tunnel studies indicate that the spacing (W) of the buildings also is important (e.g. Raupach *et al.* 1980).

Observations of Q_H and u* from the two levels were compared when the tower was Up and Down (Table 2). Here we ratio the Lower/Upper sensor data and stratify the data by tower position, time of day, and wind direction (Fig. 3). When the tower is fully extended (Up), during the day the Q_H ratio is close to 1 (Figs. 3, 4); i.e. fluxes from both levels of EC instruments on the tower are similar. This suggests both are in the inertial sub-layer. Given the close spacing of the buildings (Fig. 1), measurement heights at this site of > 1.5 z_H seem appropriate. When the tower is down, the lower EC system measures smaller fluxes (ratios are less than one). In this configuration the instruments are at heights < 1.5 z_H and differences with height are observed. These differences are greater at night. Similar results are found for both Q_H and u*.

These results reiterate the importance of ensuring that instruments are located at sufficient height above the roughness elements to ensure that representative observations at the local-scale are taken.

Figure 4: Mean and standard deviation of ratio of $u*_2/ u*_1$ and $Q_{H\,2}/Q_{H\,1}$ through time for the two tower positions.



4. Acknowledgements. Funding provided by NSF, Météo-France, ESCOMPTE, NSERC, & CFCAS. We thank: CAA, C. Walsh, P. Jackson, S. Roberts, S. Scott, F. Cropley, J. Voogt, C. Souch, J. Noilhan, V. Masson, A. Lemonsu, J.-P. Lagouarde, and M. Irvine.

5 .References:

Cros, B. *et al*. 2002: The ESCOMPTE field experiment. *Preprints 4th Symposium of Urban Environment*. P4.2

Grimmond C.S.B. *et al*. 1998: Aerodynamic roughness of urban areas derived from wind observations. *B-LM,* **89**, 1-24.

-- & T.R. Oke 1999a: Aerodyn. properties of urban areas derived from analysis of surface form. *JAM,* **38**,1262–92.

-- & -- 1999b: Heat storage in urban areas: observations and evaluation of a simple model. *JAM*, **38**, 922-940.

-- & -- 2002: Turbulent heat fluxes in urban areas: Observations & local-scale urban meteorological parameterization scheme (LUMPS). *JAM, in press.*

Grimmond C.S.B. *et al*. 2002: Observations of local-scale heat, water, momentum and CO_2 fluxes at Cub Hill, Baltimore, *4th Symp. Urban Environment*. 10.6

Lagouarde, J.-P. *et al*. 2002: Sensible heat flux estimated over the city of Marseille, using a LAS scintillometer. *4th Symposium of Urban Environment.* 14.8

Raupach M.R. *et al*. 1980: *B-LM*, **18**,373-397.

Roberts, S.M. et al. 2002: Heat storage in a European central city environment, *4th Symp. Urban Env.,* 9.4

Rotach, M. 1994: Determination of the zero plane displacement in an urban environment *B-LM,* **67**, 187-193.