14.8 SENSIBLE HEAT FLUX ESTIMATED OVER THE CITY OF MARSEILLE, USING A LAS SCINTILLOMETER

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1. INTRODUCTION

The interest of large aperture scintillometry (LAS) to estimate spatially-averaged sensible heat flux has been largely demonstrated for homogeneous surfaces (McAneney et al., 1995, De Bruin et al., 1995) and recently confirmed for composite ones (Lagouarde et al., 2002). Measurements can also be performed over areas with gentle topography provided an 'equivalent height' of the optical path is defined (Chehbouni et al., 2000 ; Meijninger et De Bruin, 2000). Less work has been done over cities (Kanda et al., 1999). LAS measurements performed over the city center of Marseille during the ESCOMPTE experiment (http://medias.obs-mip.fr/escompte) are presented. The objectives were twofold : validation of the method and characterization of the spatial variability of H over a urban area.

2. THEORY

Scintillometers provide path-averaged measurements of the structure parameter for refractive index C_N^2, according to a weighing function W(u) which follows a bell-shape curve (Wang et al., 1978) :

$$C_N^2 = \int_0^1 C_N^2(u)\ W(u)\ du \qquad (1)$$

u is the normalized distance along the pathlength. The structure parameter for temperature C_T^2 can be derived from C_N^2 as :

$$C_T^2 = C_N^2\ [T_a^2/(\gamma P)]^2\ (1 + 0.03/\beta)^{-2} \qquad (2)$$

β is the Bowen ratio, P the atmospheric pressure (Pa), T_a the air temperature (K); $\gamma = 7.9\ 10^{-7}$ K Pa^{-1}. C_N^2 and C_T^2 are in m$^{-2/3}$ and K^2 m$^{-2/3}$.

For unstable atmospheric conditions, the sensible heat flux H can be estimated as:

$$H = \rho\ c_p\ b\ Z\ (g/T_a)^{1/2}\ (C_T^2)^{3/4} \qquad (3)$$

with b = 0.57 (De Bruin et al., 1995), g = 9.81 ms^{-2}, ρ and c_p density and heat capacity of air. Z = z-d, z and d being the optical path and displacement heights above the ground respectively. According to Kohsiek (1982), (3) applies down to $-Z/L > 0.02$. In the case of topography, Z must be replaced by an equivalent height Z_{eq} to compute the spatially-averaged flux directly from the measurement of C_N^2 performed by the scintillometer:

$$(z - d)_{eq} = \left[\int_0^1 (z_u - d_u)^{-4/3}\ W(u)\ du \right]^{-3/4} \qquad (4)$$

z_u and d_u being the beam height above ground and the displacement height at normalized distance u.

3. EXPERIMENTAL SETUP

Two LAS (built by the Meteorology and Air Quality Group, Wageningen Univ., Netherlands) were installed over Marseille city center between June 12th and July 10th 2001. They have a 0.152 m diameter and operate at 0.93 µm. Output values were sampled at 1 Hz and averaged over 15 minute time steps. Transmitters and receivers were placed on

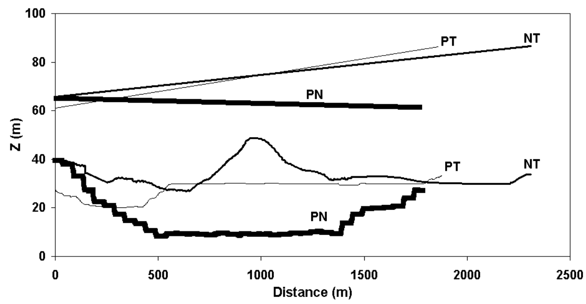

Figure 1: ground topography and position of the optical beam for the 3 paths.

terraces of 3 buildings (Paradis and Nedelec, and Timone Hospital referred to as P, N and T in what follows) at 34.0, 26.1 et 53.1 m above ground. The pathlengths were 1785, 1878 and 2308 m for PN, PT

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and NT respectively. The surface is rather homogeneous (dense mixture of old buildings 15-20m high and narrow streets in all directions). A digital map provided both ground topography (Fig. 1) and building height h_b at 50 m spatial resolution. Measurements of energy budget (radiation, turbulent fluxes by eddy correlation technique) were also performed using a mast (at 44m above ground in most cases) situated on the PN pathlength.

4. RESULTS

4.1 Validation

The displacement height was taken as $d = h_b$ all over the city to remain consitent with its only determination at the central mast site. A comparison between scintillometer derived and eddy correlation measured sensible heat flux is given in Figure 2. Further processing is likely to decrease the noise on the latter (integration over 30 minute time steps instead 15 minutes). Nevertheless the agreement is quite good. It remains the same for the whole experiment. We can notice that unstable conditions prevail during nightime.

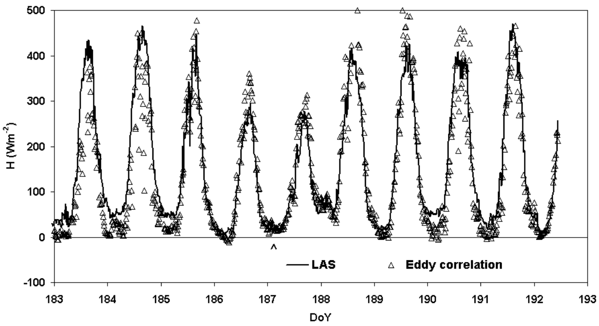

Figure 2: validation of scintillometer derived sensible heat flux against eddy correlation measurements.

4.2 Spatial variability of H

A comparison between LAS retrieved flux for the 3 pathlenghts revealed a rather good homogeneity of H above the city. The fluxes corresponding to the path closest to the coast and parallel were provided systematically greater values by about 15% than for the two other paths situated more inland. Further work involving spectral analysis (Irvine et al., 2002) and footprint modelling is presently being done with the scope of explaining these differences.

5. DISCUSSION

The practical interest of LAS over cities is confirmed. Nevertheless we must point out the fact the results are particularly good because atmospheric conditions were most of the time very unstable. Closer to neutrality, an independent estimation of the friction velocity should be introduced (McAneney et al., 1995). The case of stable conditions has not been addressed here, and remains at the time being a research challenge. Because of spatial integration performed, LAS may provides reliable fluxes over much shorter time steps than eddy-correlation, and finally appears as a low-cost competitive method.

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