3.4 EVALUATING PARAMETERIZATION OF ANTHROPOGENIC HEAT RELEASE IN URBAN LAND SURFACE SCHEME FROM FIELD MEASUREMENTS AND ENERGY CONSUMPTION INVENTORY OVER TOULOUSE DURING CAPITOUL.

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1. INTRODUCTION

The anthropogenic heat releases (Q_F) are additional sources of energy in urban areas that must be taken into account in surface schemes dedicated to these areas. The Q_F term has been studied with different methodology. The first one is based on energy consumption inventory (Sailor and Lu, 2004). This methodology gives access to statistical values of Q_F over large urban areas. It is very difficult to assess real-time spatio-temporal variability of Q_F with this methodology. The second methodology is based on measurements of components of the surface energy balance (SEB) (Pigeon et al., 2004, Offerle et al., 2005). This methodology can give access to the diurnal temporal variability but is limited for evaluation of spatial variability of Q_F. It is based on estimation of residual and has the inconvenient to accumulate all errors of measurement of the other terms of the SEB.

In the surface schemes dedicated to urban areas, the different sources of Q_F are differently integrated. The traffic and industrial releases are an additional source of sensible heat flux (Q_H) and latent heat flux (Q_{LE}). The domestic heating which varies with season can be parameterized. The objective of this paper is to evaluate this parameterization in the TEB scheme (Masson, 2000) against the CAPITOUL dataset. The CAPITOUL project (Masson et al., 2004) is focused on the study of the SEB of the centre of the city of Toulouse (France) over a whole year period (field campaign from February 2004 to February 2005) and its consequences on the urban boundary layer. Both methodologies of estimation of Q_F were applied in the CAPITOUL project.

2. ESTIMATION OF ANTHROPOGENIC HEAT FROM MEASUREMENTS

In the old core of Toulouse, a 30 m tower was set up on a terrace roof and instrumented with a 3D sonic anemometer, a Licor 7500 (water vapour and carbon dioxide) and a CNR1 (four components of the radiation budget). Turbulent fluxes of sensible heat (Q_H) and latent heat (Q_{LE}) are computed with the eddy-correlation technique. The residual of measurements is computed as: $R=Q^*-(Q_H+Q_{LE})$. Considering the surface energy balance drawn by Oke (1988) and neglecting the advection effects, $R=\Delta Q_S-Q_F$ where ΔQ_S is the storage inside the urban canopy. This term has been computed for daily period over the whole year of the campaign (Figure 1). The daily residual presents a seasonal evolution. It has negative values during end of winter 2004 and winter 2005. During summer the residual can be negative or positive but with lower absolute values. The negative values observed during winter time indicates that the mean residual over one day period is mainly driven by opposite of Q_F. On the contrary, the strongest positive values indicate that R can be driven by positive storage during warmer period. It can be the case during a few days when the climatic conditions evolves from a overcast period to a period with strong solar forcing.

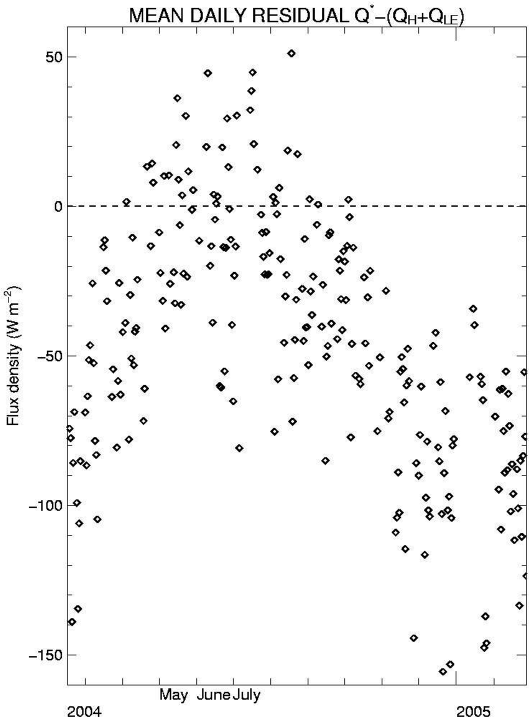

Figure 1: Mean daily residual ($Q^*-(Q_H+Q_{LE})$) for one year period. This term represents opposite of daily anthropogenic heat releases

The residual is very well correlated with the air temperature as can be seen on Figure 2 with a correlation of 0.77 over the whole year period.

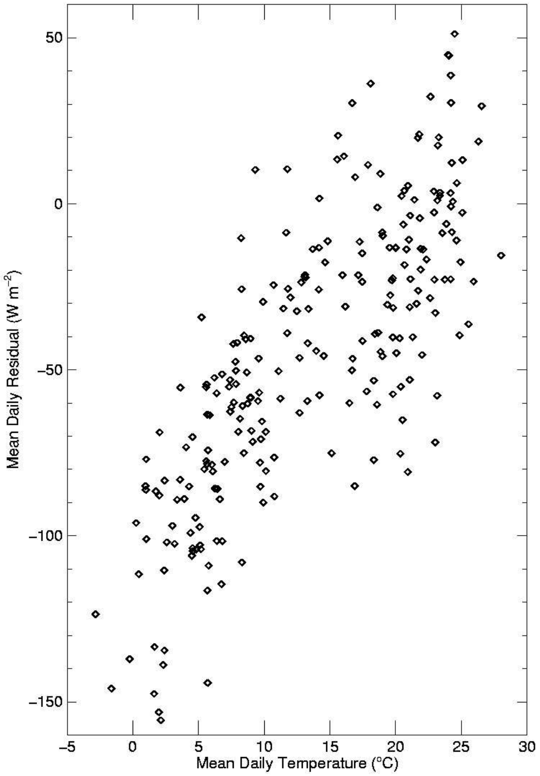

Figure 2: Variation of mean daily residual in function of mean air temperature. The correlation between the 2 signals is 0.77.

3. ESTIMATION OF ANTHROPOGENIC HEAT FROM INVENTORY

A database has been constituted to evaluate Q_F over the whole agglomeration. The original data are:

- annual mean of total daily traffic counting for all street sections with more than 2000 vehicles per day available in a Geographical Information System (GIS) and provided by the city administration,
- consumption factors of vehicles typical of urban areas provided by the COPERT program,
- electricity consumption around the measurement area and over 14 areas covering the whole agglomeration with a sampling rate of 10 minutes provided by the French national electricity company,
- annual mean of consumption of other source of energy (gas, fuel, wood) for the different types of housing provided by the regional observatory of energy,
- number of building of each type of housing in each district of the agglomeration (spatial resolution variable between a few hundreds of meters in the city centre to a few kilometres in suburbs), provided by the French national statistics administration.

The original data have been integrated in a GIS. The annual Q_F terms for an area of 500 m around the measurement site have been reported in Table 1 for the different sources (traffic, electricity, other sources) and compared with the mean annual residual of flux measurements (see section 1). On an annual basis, the observations are very comparable with the inventory data. On an annual basis, the mean residual of observations will not be affected by ΔQ_S which should be close to 0, otherwise the ground temperature would increase abnormally.

	Q_F traffic	Q_F elec-tricity	Q_F Other sources	Q_F All sources	Mean Res. Obs.
Mean Annual value (W m^{-2})	7	25	9	41	46

Table 1: Mean annual value of the different sources of anthropogenic heat and comparison with estimation with mean residual of observations

4. SIMULATION WITH TEB

4.1 *The Q_F term in TEB*

In the TEB model, three sources of anthropogenic heat releases are considered: the traffic, the industries and the domestic heating. To account for traffic and industries, 2 additional sources are added to Q_H (and Q_{LE}). These terms are prescribed by the user when preparing a simulation. Domestic heating is simulated by limiting the evolution of the internal temperature inside the building with a minimum value of 19°C. This internal temperature is used to compute the conduction trough the internal layer of walls or roof (Masson et al., 2002). In winter time the internal temperature generally remains steady and is warmer than inner walls or roof temperature. As a consequence the flux of heat between the internal building and the first layer of walls or roof is directed to the outside of the building and represents the domestic heating.

4.2 *Surface characteristics*

The city administration has let at our disposal a GIS describing the agglomeration. It is composed of maps of buildings (2D and 3D), streets, green parks. It also contains ortho-rectified aerial photography of the agglomeration at a spatial resolution of 0.25 m. This data set has been processed in order to retrieve the information useful for preparation of simulation with schemes like TEB. A grid covering the whole agglomeration with a resolution of 100 m has been constituted and contains:

- fraction occupied by buildings,
- fraction occupied by roads,
- fraction occupied by trees,
- fraction occupied by grass,
- height of buildings.

In order to perform a simulation of TEB comparable with observations from the tower, the characteristics of an area of 500 m around the tower has been prescribed to the model (Table 2).

Fraction of roofs	Fraction of roads	Fraction of trees	Fraction of grass	Building height (m)
0.50	0.42	0.06	0.02	14.9

Table 2: surface characteristics over 500 m radius area around measurement station

Walls and roofs are represented by three layers in TEB. Characteristics of these layer have been estimated from observations. Walls are constituted from red bricks of cooked soil of a depth of 0.3 m (3 layers of 0.1 m in TEB). Heat capacity of red brick is 1.5804 10^6 J m^{-3} K^{-1} and thermal conductivity is 1.15 W m^{-1} K^{-1}. The roofs are constituted of 3 different layers:

- two 0.025 m layers of red tiles also made with cooked soil with the same characteristics than the red bricks,
- a 0.03 m layer of wood whose heat capacity is 2.201 10^6 J m^{-3} K^{-1} and thermal conductivity is 0.2 W m^{-1} K^{-1}.

4.3 *Simulation of a cold winter period*

A 9 days period from 20 to 28 February 2005 has been simulated with the a surface model using TEB to compute evolution of the urban system (roofs, walls, roads) and the ISBA model (Noihlan and Planton, 1989) for all other covers (here vegetation). The model is forced by the observations at the tower of incoming solar radiation, incoming infra-red radiation, air temperature, air pressure, specific humidity, wind, and precipitation. It computes then all other fluxes of the SEB. The selected period is characterized by an evolution from an overcast situation on the first day to more sunny days (Figure 3). The air temperature is low on average and no trend can be observed for the whole period. There are a few small rain events during the period. Daily cycle of SEB terms computed by the model and averaged over the period are presented on Figure 4 and compared with the observations from the tower. The first graph of Figure 4 represents the net radiation.

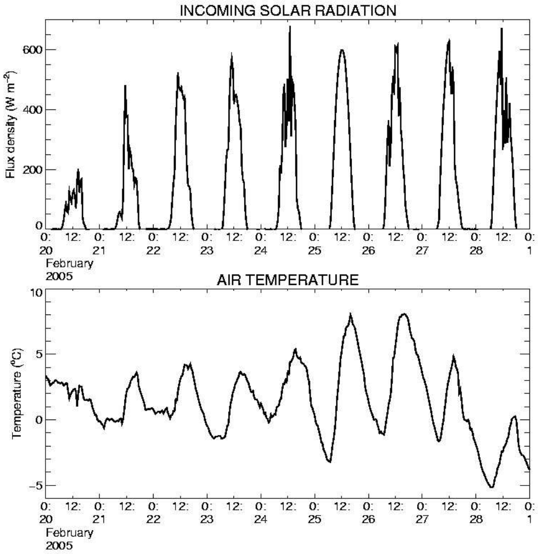

Figure 3: Incoming solar radiation and air temperature during the simulation period.

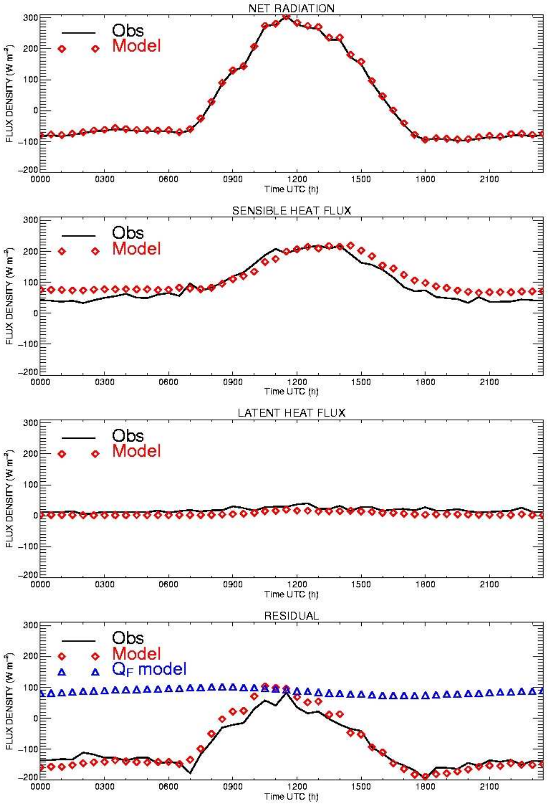

Figure 4: Comparison between simulation and observation for the different components of the energy balance. Mean diurnal cycle on the period 20-28 February 2005.

Observations and the simulation are very comparable for that term. The model has notably a good ability to compute the upward infra-red radiation at night which is the most dependant term with surface characteristics. The second graph represents the sensible flux. In red, the simulation has a tendency to overestimate Q_H at night of about 25 W m^{-2}. The third graph presents the latent heat flux comparison. Q_{LE} is very low during the period. However, small fluxes are present in both observations and simulation and correspond to rain events during the period. Finally the bottom graph of Figure 4 represents the residual for both observations and simulation and also Q_F (all source of energy) that has been computed from the simulation. The residual is globally well computed by the simulation. The Q_F term (blue triangle) presents a very smooth evolution which results from the cycle of storage of the solar energy by walls or roofs.

Residual from obs. (W m^{-2})	Residual from model (W m^{-2})	Q_F from model (W m^{-2})
-95	-92	87

Table 3: Mean value of residual from observations, residual from model and Q_F from model during the period of simulation (20-28 February 2005). Residual is defined as $R = \Delta Q_S - Q_F$.

The mean values of residual (observations and simulation) and Q_F over the period have been computed and are reported in Table 3. We can see that the model and the observations are close. The Q_F term computed from the model is slightly lower in absolute value but of the same order than the other.

5. CONCLUSION

The surface energy balance measured over the centre of a European city over a whole year indicates that the anthropogenic heat flux is a quantitative source of energy. This term can reach up to 150 W m^{-2} during winter period. It has been compared to inventory of energy consumption (traffic, electricity, etc…) and the results are very coherent. A simulation of cold winter period has been performed with the TEB-ISBA model and compared with observations. The model presents a good ability to simulate winter conditions. The Q_F term computed from the model is also coherent with observations.

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