XXI ICTAM, 15–21 August 2004, Warsaw, Poland

JOINT URBAN 2003 SURFACE ENERGY BUDGET MEASUREMENTS AND ANALYSIS

J.E. Holeman, M. Princevac, S. Grossman-Clarke, S.M. Lee, H.J.S Fernando, R. Calhoun
EFDP, Department of Mechanical and Aerospace Eng., Arizona State University, AZ 85287, USA

Summary Understanding of the surface energy balance is a critical component of the correct modeling of flow in an urban environment. During the Joint Urban 2003 field campaign, extensive data were collected of the components of the surface energy. These data were analysed in an attempt to close the surface energy budget and to gain an understanding of energy partition.

INTRODUCTION

Research on air flow in urban environments is of considerable importance. Since much of humanity lives in urban settings, it is vitally important from the point of view of public safety to understand the mechanisms through which pollution and other contaminants disperse therein. The Joint Urban 2003 (JU 2003) field campaign was conducted from late June through early August in 2003 to provide data needed to increase our understanding of urban meteorology and dispersion [1, 2]. One of the important aspects that was studied by our group during JU 2003 was the efficacy of current surface energy budget schemes used in meso-scale meteorological models. The surface energy is what drives many of the flows in urban environments [3, 4], and it has been demostrated that surface energy parameterizations of the popular mesoscale meteorological model MM5 needs improvement [5]. During JU 2003, the our group fielded a suite of instruments in order to measure the dominant components of the surface energy budget in a grassy city park located in a suburban area.

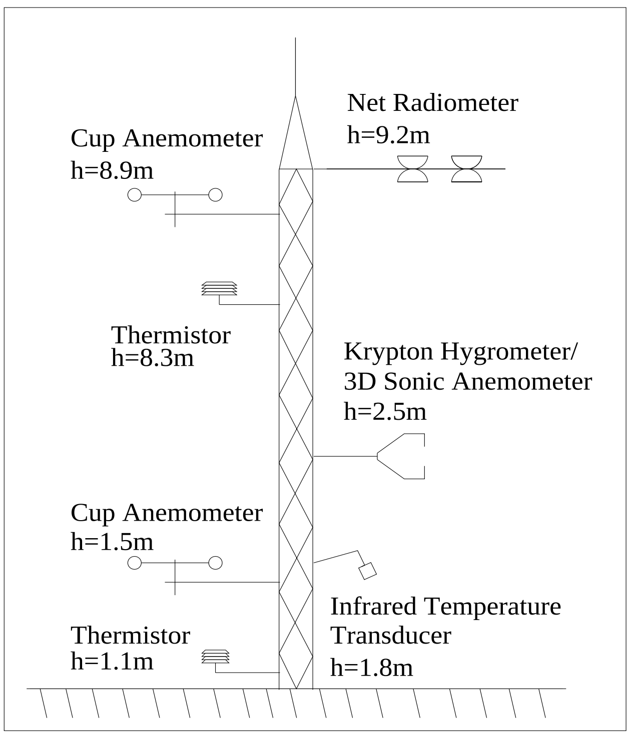

Figure 1: Meteorological Tower Instruments used to measure atmospheric surface energy budget components.

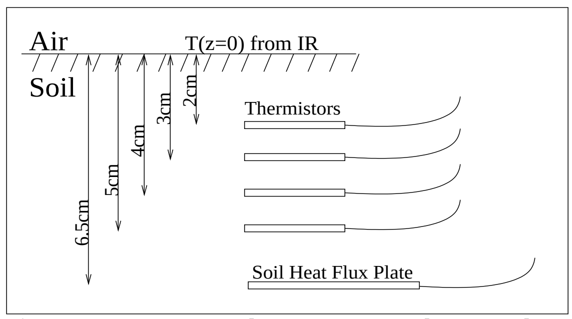

Figure 2: Sensors used to measure underground components of the surface energy budget.

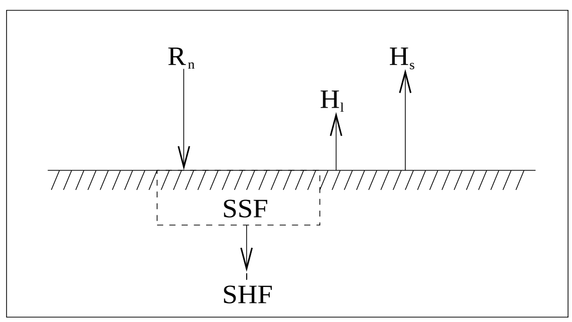

Figure 3: Schematic of the components of the surface energy budget: net raditaion(R_n), sensible heat flux(H_s), latent heat flux(H_l), soil heat flux(SHF), and soil heat storage flux(SSF)

PRELIMINARY RESULTS

Two days in mid-July were chosen for analysis, considering their relatively cloud-free skies on those days. If the assumption of a vertical, one dimensional system is correct, various componants of the surface energy budget (see Figure 3) are expected to be in balance. The net radiometer used is able to measure the shortwave(R_s) and longwave radiation(R_l) both facing up and down. The net radiation present at the Earth's surface is $R_n = R_{l\downarrow} + R_s^{\downarrow} - R_l^{\uparrow} - R_s^{\uparrow}$(Figure 4). The part of the energy, R_n, which is transferred to the atmosphere does so by one of two processes: the sensible heat, and through the evaporation of water into the air, the latent heat. These were measured by turbulent flux instruments near the ground. The sonic anemometer and fine wire thermocouple are used to measure the covariance between vertical velocity (w) and temperature (T), $\overline{w'T'}$ (where $\cdot'$ terms indicate a fluctuation, based on one minute averages). The sensible heat flux is then

$H_s = c_p \rho \overline{w'T'}$, where c_p and ρ are the specific heat at constant pressure and the density, respectively, of dry air. The sonic anemometer is used with a Krypton hygrometer to measure the covariance between vertical velocity (w) and water vapor density (q), $\overline{w'q'}$. Latent heat flux is $H_l = L_v \overline{w'q'}$, where L_v is the latent heat of vaporization (Figure 5). In order to close the energy budget, it is also necessary to measure the heat flux through the bottom of the control surface for the soil layer (SHF) as well as the storage in the control volume (SSF). SHF was measured by a heat flux plate located at a depth of 6.5cm. Integrating the temperature profile of the soil yields energy storage per unit area. Differentiating this with respect to time produces the net flux required to heat or cool the upper soil layer: Soil Storage Flux (SSF) $= \frac{d}{dt}\int_{depth}^{0} c\rho_s T(z)dz$, where c is the specific heat of the soil, ρ_s is the soil density, and $T(z)$ is the temperature profile (Figure 6). The sum $H_s + H_l + SHF + SSF$ is the quantity that should balance the net radiation, R_n. Comparing these quantities as in Figure 7, we see consistancy between the two curves. This is an indication that the measured quantities indeed do a good job of characterizing the surface energy budget in this suburban park. Further, it appears that the assumption of a vertical, one dimensional system may be adequate to describe the surface energy budget at this experiment site.

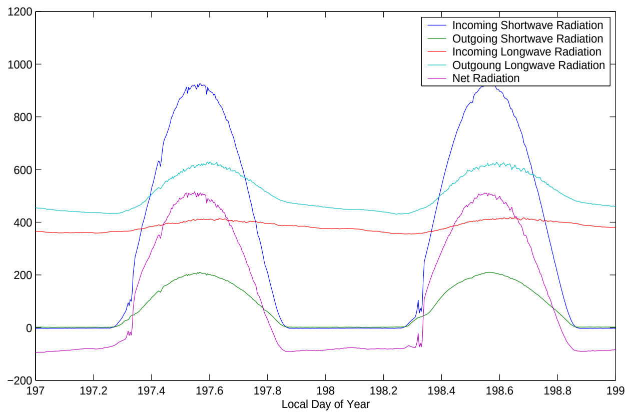

Figure 4: Radiative fluxes for July 16 and 17

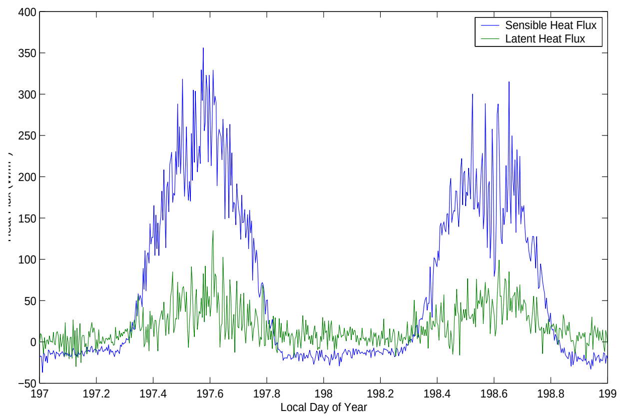

Figure 5: Sensible and latent heat fluxes for July 16 and 17

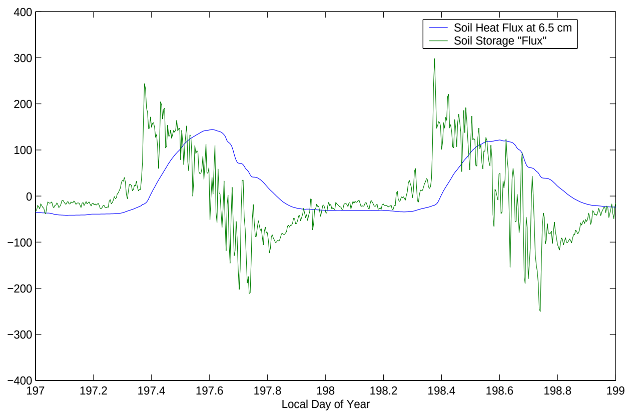

Figure 6: Soil heat fluxes for July 16 and 17

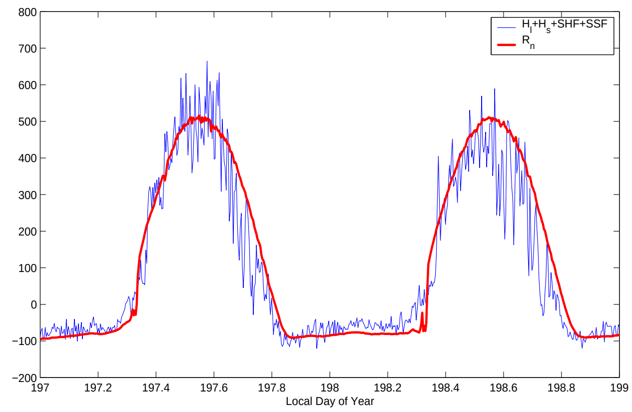

Figure 7: Comparison of H_s+H_l+SHF+SSF and R_n

ACKNOWLEDGEMENTS

Financial support of the Army Research Office and National Science Foundation is gratefully acknowledged.

References

[1] Joint Urban 2003, web site http://ju2003.pnl.gov/

[2] Joint Urban 2003 Atmospheric Dispersion Study, Oklahoma City, Jun-July 2003. Experimental Plan (available from http://ju2003.pnl.gov/study.html)

[3] Fernando H.J.S., S.M. Lee, J. Anderson, M. Princevac, E. Pardyjak and S. Grossman-Clarke: Urban Fluid Mechanics: Air Circulation and Contaminant Dispersion in Cities, *J. Env. Fluid Mech.* **1**: 107-164, 2001

[4] Grimmond C.S.B and T.R. Oke: Turbulent heat fluxes in urban areas: Observations and a Local-scale Urban Meteorological Parameterization Scheme (LUMPS), *J. Appl. Meteor.*, **41(7)**: 792-810, 2002

[5] Zehnder, J.A.: Simple Modifications to Improve Fifth-Generation Pennsylvania State University-National Center for Atmospheric Research Mesoscale Model Performance for the Phoenix, Arizona, Metropolitan Area, *J. Appl. Meteor.* **Vol. 41(9)**:971-979, 2002