5.02 MODELLED AGGREGATED TURBULENT FLUXES COMPARED TO URBAN TURBULENCE MEASUREMENTS AT DIFFERENT HEIGHTS

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INTRODUCTION

During recent years a broad and not yet settled discussion on the parameterisation of the complex layer structure of the atmosphere over urban areas is taking place. This topic is extremely important for the understanding of meteorological measurements in urban areas and has large implication in running and testing meso-scale meteorological and air pollution models over cities.

The concept of a blending height used over forested areas and a method to derive aggregated fluxes is described by Gryning and Batchvarova, (1999) and Batchvarova et al. (2001). The blending height concept was suggested by Gryning and Batchvarova (2002) to use for urban areas at the COST715 Workshop in Zürich 2001 (Rotach et al, 2002). The blending height approach requires information on the character and size of different land cover patches – in urban areas called neighbourhoods. The essential assumption is that the convective boundary layer over a non-homogeneous area develops as a result of aggregated turbulent forcing.

We discuss in this study the blending height concept in relation to the urban areas and show connections between near surface measurements and aggregated heat fluxes for a sub-urban area.

The mixed layer overlooks a very large area or in other words has a large foot print. In this study the aggregated fluxes that controls the development of the mixed layer height are determined by inverting a model for the prediction of the growth of the mixed layer height – knowing from measurements the development of the mixed layer height, the aggregated heat flux of the upwind area can be estimated. The required information for use of the method can be derived from wind speed and temperature profiles obtained by radio soundings when performed frequently enough to provide a reasonably detailed structure of the mixed-layer development. Alternatively data from remote sensing techniques like combined wind profiler and radio acoustic sounding systems can be used.

THE SOFIA EXPERIMENT

Data drawn from a recent urban boundary layer experiment (September/October 2003) in Sofia Bulgaria, that comprised high resolution boundary layer radio soundings to determine the mixing height and mixed layer growth and measurements with sonic anemometers at two heights in a sub-urban area of the city of Sofia are used for the analysis. The two sonic anemometers and a fast hygrometer were mounted on the research tower of NIMH at 20 and 40 m height agl (above ground level) and 10 and 30 m above roof, respectively on booms 4 m away of the tower in direction west, Figure 1.

The Sofia Experiment is a result of the collaboration within working group 1 of COST 715 and a project on Turbulence measurements for urban boundary layer research. It was initiated between the IAC-ETH Zürich and NIMH, Bulgaria and two related institutions from Skopjie, Macedonia, namely the Meteorological and Hydrological Service and the Republic Enterprise for Urban Planning.

RESULTS OF MEASUREMENTS

The site is typical for Eastern European large cities suburbs constituted of different by size and configuration blocks of apartments and vast open areas between them, Figure 2. The values of the turbulence parameters at both measuring levels were found to show typical urban features. The kinematic heat and momentum fluxes and the standard deviations of lateral (σ_v) and vertical (σ_w) fluctuations of the atmospheric turbulence are 5-15 % bigger at 40 m compared to 20 m agl, Figure 3. This result is in agreement with other experiments, which found the momentum flux and the standard deviations to increase with height within the roughness sub-layer (e.g. the BUBBLE experiment, Rotach et al, 2004.

Figure 1. The meteorological tower with sonic anemometers and a Krypton hygrometer

Figure 2. View from the tower to the west

High resolution radio soundings were performed with Vaisala equipment of NIMH and radiosondes provided by the project. Typical convective conditions were chosen for the campaign when 7 soundings per day were performed providing data for the growth of the mixed layer with 2 hours time interval. Five days with such conditions were identified in the period 18 September – 8 October 2003, and the analysis for two of them (29 September and 1 October) is shown here, Figure 4.

Following the understanding of aggregation of fluxes over heterogeneous areas, (Gryning and Batchvarova, 1999 and Batchvarova et al, 2001) the observed convective boundary layer was considered forced by the blended thermal and mechanical fluxes over the area. The measuring site (NIMH) is in the south east part of the city and the urban characteristics for it are spread over 3 km to south and East, about 10 km to north and about 20 km to the west. Depending on wind direction, the aggregated fluxes represent different percentage of urban and rural conditions, Figures 5 and 6.

RESULTS OF MODELLING

In Figure 7 the comparison of measured and aggregated sensible heat fluxes is presented. On day of year 272, 29 September the aggregated and measure values are close, suggesting that blended fluxes are representing urban conditions at western and north-western weak winds, Figure 7. On day of year 274, 1 October the aggregated fluxes are smaller than the measured. The wind is easterly and thus leading to the conclusion that for that day the large rural areas upwind are also influencing the blended values, while the tower remains within the roughness sub-layer of the urban atmosphere.

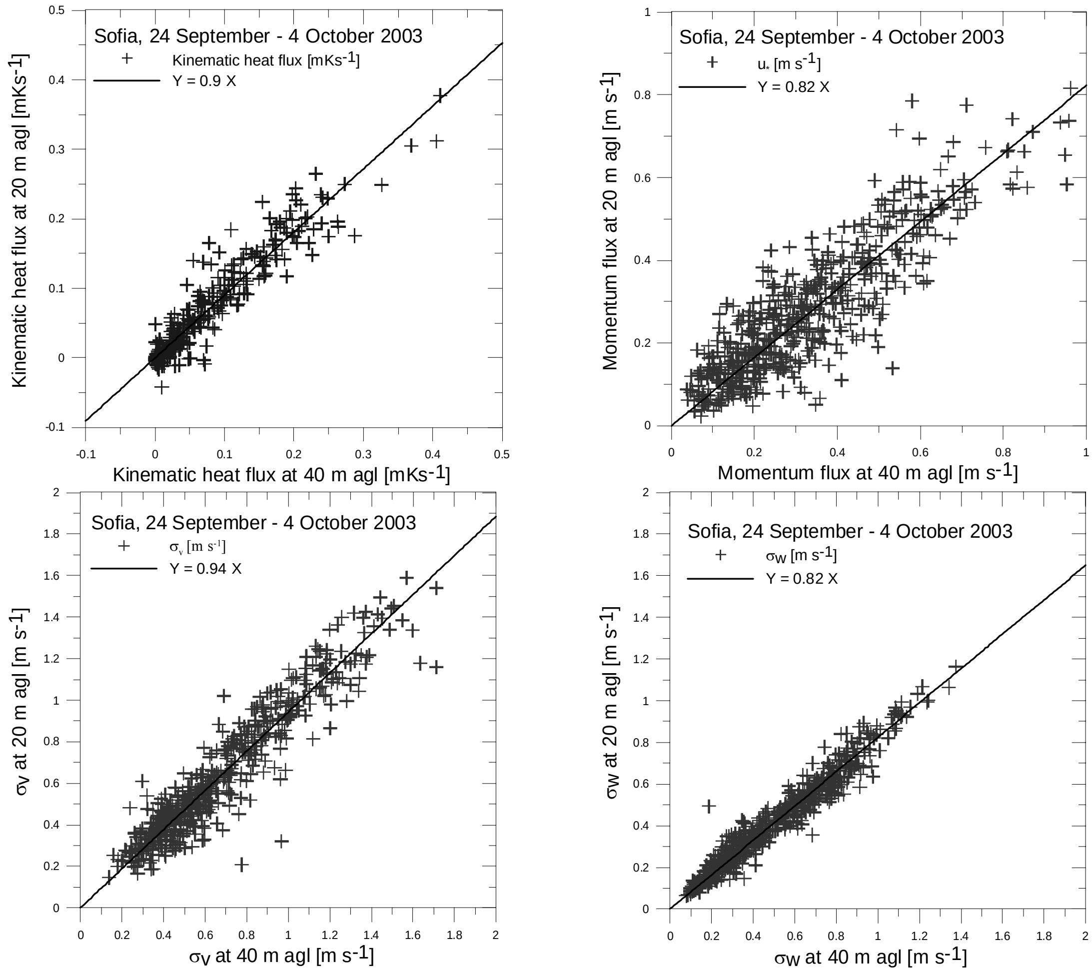

Figure 3. Turbulence parameters at both levels: kinematic heat flux (left-up), momentum flux (right-up), standard deviation for lateral (left-down) and vertical (right-down) wind component.

One implication of the result presented here is the caution needed when applying measurements based pre-processors in urban areas. In the case of 1 October the use of the turbulence measurement for estimation of the mixing height with the use of a meteorological pre-processor will give a much deeper mixed layer than is actually observed. In such way air pollution concentrations could be under-predicted. The representativeness of measuring sites is wind direction dependant. The same considerations are valid if mesoscale model results are compared to measurements. The area over which the modelled parameters are averaged can be different from the one represented by measurements. Considering the representativeness of airport stations for urban meteorological and air pollution studies is therefore a complex issue.

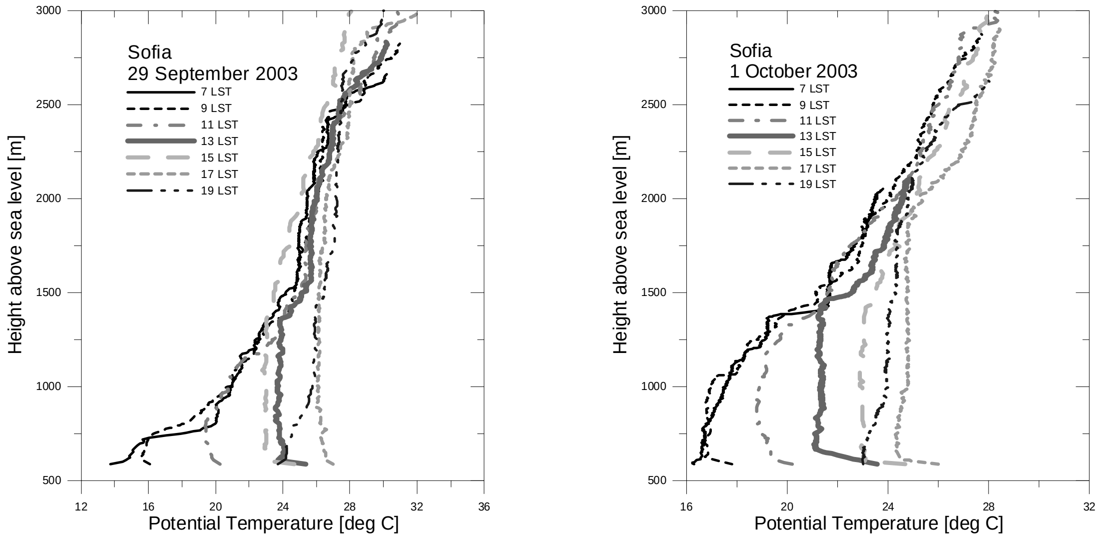

Figure 4. Potential temperature from radio soundings at day of year 272, 29 September 2003 (left) and day of year274, 1 October 2003 (right).

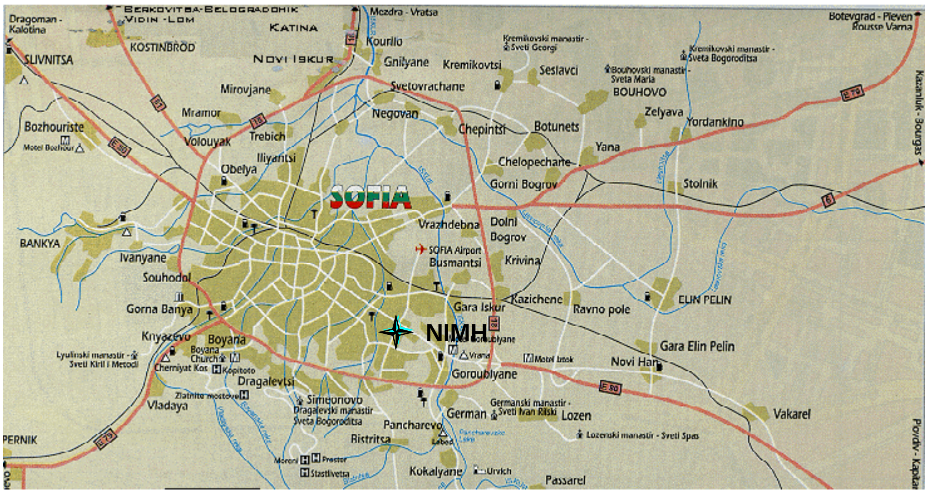

Figure 5. Map of Sofia and close rural areas (56 by 28 km approximately). The Position of NIMH is marked.

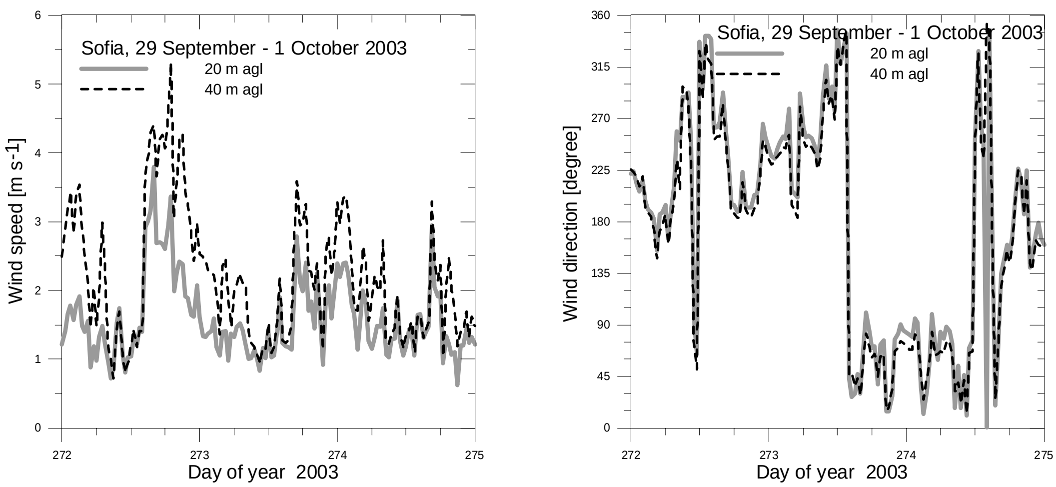

Figure 6. Wind speed and direction from sonic measurements.

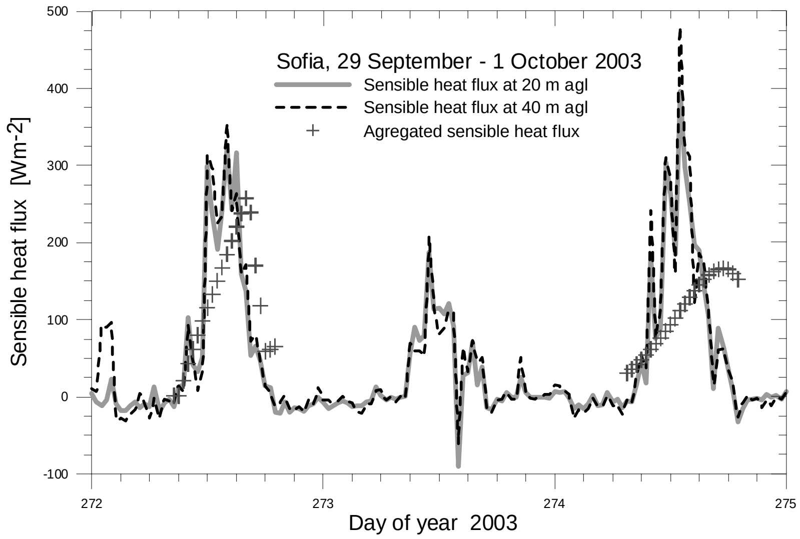

Figure 7. Sensible heat flux measured at the tower and aggregated following Gryning and Batchvarova, 1999.

ACKNOWLEDGEMENTS

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