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MODELLING OF URBAN EFFECTS OVER THE CITY OF BASEL (SWITZERLAND) AS A PART OF THE BUBBLE PROJECT

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Abstract

The aim of BUBBLE (Basel UrBan Boundary Layer Experiment) is to investigate the exchange processes near the urban surface, as well as the flow in the upper part of the Urban Boundary Layer (UBL), using surface and remote sensing instrumentation on one hand, and a mesoscale meteorological model on the other hand. An urban parameterization scheme is implemented in a mesoscale model in order to take into account the typical effects of a city on the surface exchange fluxes and on the atmospheric flow fields near the ground. Firstly the urban module is being tested offline on a single column. The validation of the module is made with measurements in a street canyon (IOP of BUBBLE in the city of Basel, June-July 2002). In a second step, three dimensional simulations will be performed on two nested grids centered over the city of Basel. Several atmospheric parameters, as wind, temperature or turbulence flows, will be compared with measurements in and above the street canyon, as well as over rural areas, in order to validate the urban parametrization scheme.

Key words: urban meteorology, urban surface exchange parameterization, mesoscale model

1. INTRODUCTION

A city, by its characteristical roughness height (z_0) and temperature evolution, has a strong impact on the structure of the Planetary Boundary Layer (PBL). The involved processes can be induced by mechanical (turbulence induced by the buildings, where z_0 is higher than for a rural landscape) or thermal (radiation trapping in the street canyons) effects. Due to the complexity of the atmospheric phenomena, mesoscale numerical models are the most appropriate tools to represent the flow field. Two scales are involved in this problematic : an urban scale of few kilometers, with particular "urban effects", and a meso-scale of few hundreds of kilometers representing the flow fields of the mesoscale circulation. The dynamical model must be able to represent these two scales in the most accurate way. For that purpose an urban module (Martilli et al., 2002) representing the city as a combination of several urban classes, characterized by the size of the street canyon and of the buildings (roof, wall) is implemented in a mesoscale model (Clappier et al., 1996), and is thus able to take into account the sink of momentum over the entire height of the buildings, as well as the shadowing and the radiation trapping effects, which are commonly neglected.

Figure 1: The tower in Basel with measurement setup for the IOP of BUBBLE (June-July 2002).

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The first step of this contribution is the validation of the urban parameterization scheme in Basel (Chapter 2), using a simplified version of the mesoscale model running offline and on a single column. The validation is made with comparison of the simulation results with the measurements taken from a tower in a street canyon (see Figure 1).

In a second step, the three dimensional mesoscale model including the above tested urban parameterization will be run over the region of Basel, on two nested grid with a resolution of 1 by 1 km for the smaller grid. The validation of the model is made using measurements at different sites, representing different landuse properties (urban, suburban, rural).

2. OFFLINE SIMULATIONS IN THE STREET CANYON

The simulations are performed with a simplified version of the model running on a single column, in order to test the urban module offline. The boundary conditions at the top of the street canyon are taken from measurements on the tower at a level corresponding to the first layer of the model above the top of the buildings (see Figure 2). The model calculates fluxes and meteorological variables from this point down to the ground. The calculation and validation is applied to the part of the PBL called the Urban Roughness Sublayer, which is defined as the first layer of the PBL and includes the urban canopy. This layer is therefore the crucial place for the influence of an urbanized area on the PBL structure.

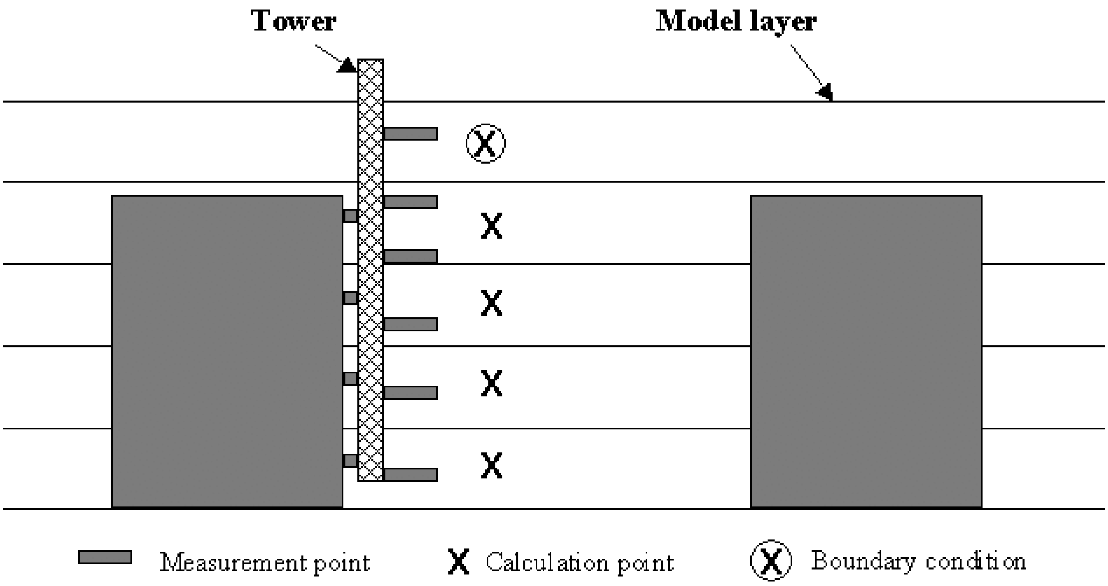

Figure 2: The offline model running on a single column in the Urban Roughness Sublayer and the measurements setup.

The parameters for the city and building shape needed as input for the model are set to realistic conditions representing the urban area of Basel where the measurements were taken (dense urban, mainly residential 3 to 4 storey buildings in blocks, flat commercial and light industrial buildings in the backyards, data taken from the online data bank on the BUBBLE website).

In order to test the urban module, and to quantify its impact on the meteorological modeling, three different simulations are carried out. The first simulation uses the urban surface exchange parameterization, with a percentage of rural areas set to 20% (which represents the BUBBLE measurement site). The second simulation considers a 100% rural soil coverage, while the third simulation represents the traditional less detailed approach used in mesoscale models to represent urban surfaces (modification of the roughness length and the soil thermal capacity). The period of the simulation extends from the 25th of June to the 16th of July 2002, and corresponds to the second half of the IOP in the frame of BUBBLE. The results of these three simulations are compared with measurements taken during the IOP from the tower of Figure 1.

The daily profile of the potential temperature in the street canyon is fairly well represented by the urban module (see Figure 3). At nighttime, the rural and the traditional simulation are not able to represent the heat storage near the ground, whereas the urban simulation indicates a temperature at the ground very close to the measurements (and 4-5 °C higher than the rural and the traditional simulations at 0000 LT), and is thus able to represent the nocturnal Heat Island Effect over an urban area. During daytime, the shape of the profile obtained by the urban simulation is in better agreement with the measured profile, but with a shift of 1-2 °C (profile at 1200 and 1800 LT).

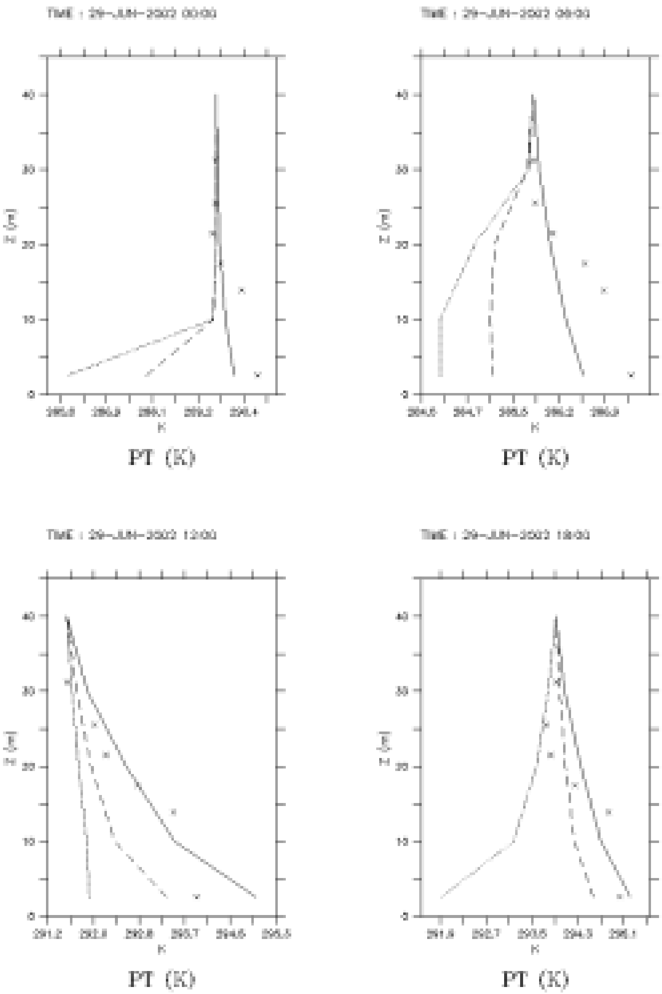

Figure 3: Daily evolution of the potential temperature in the street canyon for the urban simulation (solid line), the rural simulation (dashed line), the traditional urban parameterization (dotted line) and the measurements in the street canyon (crosses).

The comparison of other measured parameters which are also calculated by the model, such as the vertical kinematic heat flux (see Figure 4), is also of interest for the validation of the urban surface exchange parameterization. The shape of the profile of w'T' obtained by the urban simulation is different than the profile calculated with the traditional method. As it is more or less constant over the entire height of the street canyon in the traditional method (as prescribed by the surface layer theory, which doesn't hold in the Roughness Sublayer), it increases with height in the urban simulation. This trend is valid as well for nighttime as for daytime. The vertical heat flux is slightly negative during nighttime in the traditional simulation, while it is near zero or slightly positive in the urban simulation and in the measurements. This means that the cooling is smaller with the urban parameterization than with the traditional method, which is in agreement with the higher temperatures computed during nighttime with the urban module (see Figure 3).

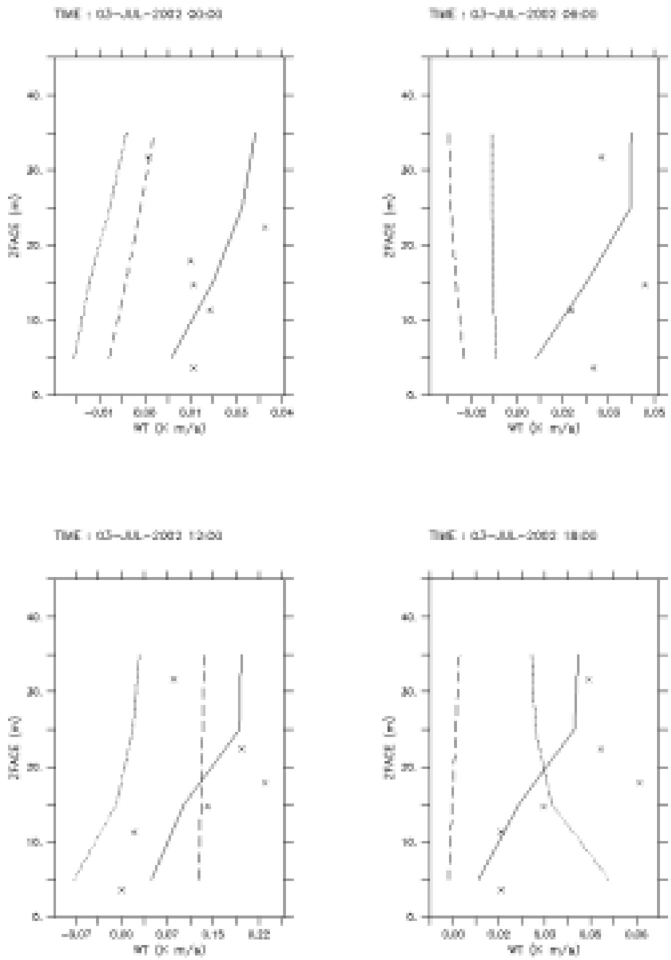

Figure 4: Daily evolution of the kinematic temperature flux in the vertical (w'T') in the street canyon for the urban simulation (solid line), the rural simulation (dashed line), the traditional urban parameterization (dotted line) and the measurements (crosses).

3. CONCLUSION AND PERSPECTIVE

A detailed urban surface exchange parameterization has been tested offline in a street canyon, and compared with simulations using traditional parameterization, and with measurements taken from a tower on an urban site. The comparison shows that the profile of meteorological variables and of exchange fluxes (sensible heat flux) obtained with the urban module fits better to the measurements than the simulation with the traditional parameterization. Especially the effect of Urban Heat Island is well captured by the module. Future work will be to analyze the impact of each input term of the module, in order to determine the most sensitive parameters, and eventually to improve the quality of the simulation. It is also planned to perform three dimensional simulations on the region of Basel, in order to validate the mesoscale model with the urban parameterization.

References

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