Urbanization in Atmospheric Modeling with High Spatial and Temporal Resolution

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Abstract
The large-eddy simulations (LES) employing the atmospheric model SUBMESO (derived from the Advanced Regional Prediction System model) coupled with the Soil Model for Sub-Meso scales Urbanized version (SM2-U), composed with 3 soil layers and a canopy layer were carried out during winter months (Dec, Jan, and Feb). The selected area of interest is the Copenhagen metropolitan area (island of Zealand). The land use classes, including related to urban areas, were derived from the CORINE dataset (based on 40 different types of surfaces over Europe, resolution of 250 m) providing a better representation of orography and identification of urban surface features. The selected modeling domain (118 x 124 grid points) has a resolution of 1.4 x 1.4 km.

For each grid cell, the classification is represented by 7 types of surfaces.

In our study, the SUBMESO-SM2-U model was run in a climatological mode with monthly typical averaged meteorological variables in the selected model domain. To perform such simulations, as input, a set of characteristics was extracted from the climate generation files produced for the HIRLAM model as well as from climatological data (city of Copenhagen and other cities located in the domain). The surface oriented data included also types of soil, vegetation above natural and artificial surfaces, water bodies and artificial surfaces, water table of water content related characteristics in different soil layers, etc. The meteorological oriented data included air temperature, direction and velocity components for wind, relative humidity, surface and sea surface temperatures, salinity, soil and deep soil water contents, pressure, roughness.

An analysis of the winter diurnal variability of the surface temperatures and fluxes was performed for different types of surfaces/covers and districts of the Copenhagen urban area.

Introduction
In urban areas, in contrast with rural areas, the urban boundary layer is more complex, and hence, it requires a special treatment. The surface energy balance in urban areas includes the storage, sensible, and latent heat fluxes, plus the anthropogenic heat flux. Experimental studies showed that within the city itself there are differences between different districts. The LES can be employed as a numerical substitute or research tool in studies of urban processes like radiative trapping inside the street canyon are parameterized by an effective albedo of the street. Energy and water budgets are performed for each type of surface in order to determine the heat and moisture fluxes to be set at the interface between canopy and atmosphere. The surface dynamical influence due to building walls; the lower box shows the modeled heat storage processes due to building walls; the lower box shows the modeled water transfer processes. The black brackets indicate the different possible tiles within one grid module. Precipitation is a model input while the net radiation is computed by the model from the incoming global and atmospheric radiation inputs (Fig 3 of Dupont et al., 2006a).

Land Use Classification, Urban Districts and its Characteristics
Land use covers/surfaces
- BARE — bare soil without vegetation;
- NAT — bare soil located between sparse vegetation elements;
- VEG — vegetation over bare soil;
- VEGA — vegetation over paved surfaces (trees on road side);
- ART — paved surfaces between sparse vegetation elements;
- BAT — building/roofs & walls;
- EUA — water surfaces.

Tab 1. Distribution of surface types and its characteristics (in %) in the model domain based on classification of the CORINE dataset (CORINE, 2000).

<table>
<thead>
<tr>
<th>Surface</th>
<th>Characteristic</th>
<th>CCI</th>
<th>CC/ HBD</th>
<th>BB</th>
<th>HBD</th>
<th>ICD</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>BARE</td>
<td></td>
<td>1.8</td>
<td>0.5</td>
<td>89.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>NAT</td>
<td></td>
<td>1.8</td>
<td>0.5</td>
<td>89.5</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>VEG</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>89.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>ART</td>
<td></td>
<td>0.5</td>
<td>0.5</td>
<td>89.5</td>
<td>0.5</td>
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<tr>
<td>BAT</td>
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<td>89.5</td>
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<tr>
<td>EUA</td>
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<td>0.5</td>
<td>89.5</td>
<td>0.5</td>
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<td>0.5</td>
</tr>
</tbody>
</table>

Urban Modeling

Fig. 3. Schematic representation of SM2-U: the upper box shows the processes modeled in the energy budget part, with a zoom on the insolation and heat storage processes due to building walls; the lower box shows the modeled water transfer processes. The black brackets indicate the different possible tiles within one grid module. Precipitation is a model input while the net radiation is computed by the model from the incoming global and atmospheric radiation inputs (Fig 3 of Dupont et al., 2006a).

Fig. 4. Schematic January surface temperature (deg K) simulated using SM2-U urban module for the Copenhagen metropolitan area (interpolated over 7 types of surfaces) at (left) 09:00, (middle) 13:00, and (right) 17:00 UTCs.

Results
Summary results are shown in Figs 5 and 6. During winter months, among different types of surfaces, the lowest net radiative flux is for artificial surfaces (abs. min. -69 W/m²) in Dec. For CC/HBD, on a diurnal cycle, this flux is negative during Dec-Jan, but beginning Feb it becomes positive between 09-13 h, moreover, a daily mean flux is the lowest (-47 W/m²) in Dec. For ICD, on a diurnal cycle, there are always periods showing positive flux, but duration of such periods is the shortest (09-14 h) during Dec-Jan compared with Feb; moreover, a daily mean flux is the lowest (-7 W/m²) in Dec.

The mean sensible heat flux, for CC/HBD is negative only in Dec-Jan reaching -33 W/m² at night, and it becomes positive in Feb between 8-9.5 h. For ICD, on a diurnal cycle, this flux is always negative only in Dec reaching -29 W/m² at night. For RD, the pattern is similar, although reaching higher values -32 W/m² in Dec. The monthly and diurnal cycle variability for RA grid cells show patterns very similar to RD.

Applicability
The results of this study are applicable for investigation of temporal and spatial variability of various meteorological and derived variables over urban areas, for improvements in the land use classification and climate generation properties, distinguishing and selection of types of urban districts and their properties, testing feasibility of NWP models performance over high resolution model domains, especially over the urbanized areas.

References