

Thermal and Dynamical Urban Effects of Saint-Petersburg Metropolitan Area – Winter Case Study

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ABSTRACT

A city can strongly modify the structure of atmospheric boundary layer. The urban areas have significant influence on the meteorological processes and atmospheric flow, its turbulence regime, microclimate, and, accordingly modify the transport, dispersion, and deposition of atmospheric pollutions within these areas. In this study, the spatial and temporal variability of meteorological fields due to influence of the thermal and dynamical effects of the metropolitan area was estimated on example of the city of St. Petersburg (Russia). The selected case study is associated with the winter period. Dependence of these fields on the temporal variability of meteorological variables (wind at 10 m and air temperature at 2 m) in the lower surface layer was estimated as a function of modified parameters – roughness, anthropogenic heat flux, and albedo.

Introduction

It is known that the boundary layer in the urban areas has a complex structure due to multiple contributions of different parameters, including changes in roughness, fluxes, etc. All these effects can be included to some extent into meteorological models (Baklanov et al., 2009; Mahura et al., 2009). Since measurements cannot reflect completely a complexity of urban areas, the modeling could be a way to examine effects of the urban areas on various meteorological variables.

The aim of study is to evaluate effects of urbanization of the High Resolution Limited Area Model (HIRLAM) used in numerical weather prediction (NWP) on simulated meteorological fields.

The specific objectives include following:

- To modify the meteorological model and apply with different urbanization parameters;
- To evaluate the diurnal cycle variability of meteorological parameters comparing two types of runs: without and with modifications;
- To estimate the possible impact of the metropolitan area on meteorological fields.

Model and MetroData

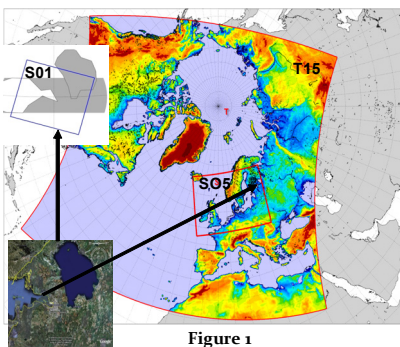


Figure 1
Modeling domains.

As NWP model a research version of the Environment - High Resolution Limited Area Model (Enviro-HIRLAM; Korsholm et al., 2008; Korsholm, 2009) was used in simulations. The chosen domain called –S01 (Fig 1), with St. Petersburg Metropolitan area in the domain center, extending with 144 vs. 170 grids along latitude vs. longitude, with a horizontal resolution of 1.4 km, and having 40 vertical levels. This model was run with modified land use and climate generation files. The meteorological fields' simulations were driven using initial and boundary conditions from operational NWP HIRLAM models of lower resolutions (at first, 15 km, and then – 5 km).

Results

The winter period of 29 Jan – 1 Feb 2009, characterized by dominating low wind conditions and prevailing strong deep inversion and isothermal layers, was chosen for evaluation of the thermal and dynamical effects of the St. Petersburg metropolitan area.

For selected specific dates several independent runs were done for: no modifications in scheme (Control run) and modified run. In the later, the combined effects of the anthropogenic heat flux, AHF (ranging from 50 up to 200 W/m²), urban roughness, R, parameter of 2 m, and albedo, A, increased were included (Fig 2).

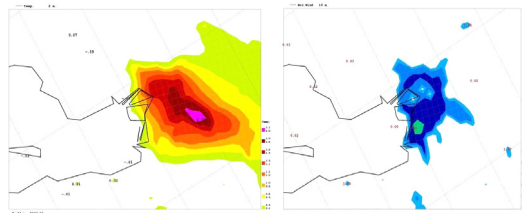


Figure 2
Difference plots (between outputs of the NWP Control vs. A+R+AHF module runs for the (left) air temperature at 2 m and (right) wind velocity at 10 m at 00 UTCs on 29 January 2009.

The differences between the control vs. urbanized runs over the metropolitan area were the following:
wind velocity at 10 m - up to 2 m/s (with a maximum of 2.9 m/s at nighttime), and
air temperature at 2 m - more than 1°C (with a maximum of 2.7°C at nighttime as well).

The simulation results were compared with observations at urban/sub-urban locations (synoptical stations): St. Petersburg (Fig 3), Sosnovo, Ozerki, Oranienbaum, Belogorka, Shlisselburg, Vyborg, Kronshadt, Volosovo (Fig 4).

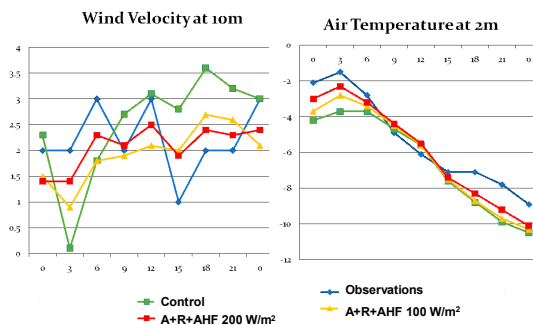
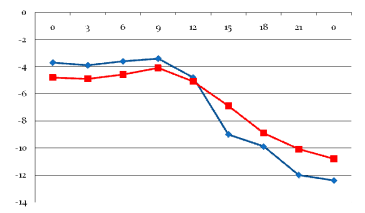


Figure 3
Diurnal variability during 29 January 2009 for the (left) wind velocity at 10 m and (right) air temperature at 2 m for the control and modified runs vs. observational data.

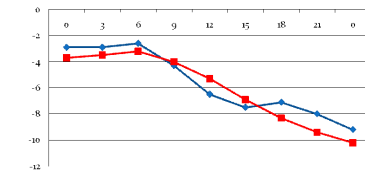
For the suburban station, the modification including the improved roughness and anthropogenic heat flux showed a better fit observational data compared with all other runs.

Volosovo



Modified run

Kronshadt



Observations

Figure 4

Diurnal variability during 29 January 2009 for the air temperature at 2 m for the Volosovo (top) and Kronshadt (bottom) stations for modified run vs. observational data.

Conclusions

- ❖ The inclusion of urban related parameters can significantly improve the forecasted meteorological fields for urban areas;
- ❖ Results of the combined urban effects have underlined significant role of non-linear effects

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