ERRORS IN REGIONAL MODEL SIMULATION OF TEMPERATURE AND WIND PROFILES IN RURAL AND URBAN ATMOSPHERIC BOUNDARY LAYER

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Abstract

Comparison of mesoscale model WRF forecasts and remote measurements of temperature and wind speed in ABL in Moscow megapolis is made. Long term measurements of wind profiles, carried out by acoustic sounding, and temperature, measured by microwave profilers MTP-5 provide information for statistical analysis of model errors. Forecasts were made using different parametrisations of ABL. Observation data obtained by co-working of IAP RAS, MSU and Hydrometcentre of Russia.
The statistical estimations of forecasts deviations in description of temperature and wind profiles are calculated. Main limitations of commonly used parametrisations of ABL are noted. Developed method of comparison with remote measurements provide opportunity to estimate influence of different model options on the forecast. Optimal model configuration for best results in the particular region can be made on the base of the developed method.

Key words: numeric models, remote sensing, statistical estimations

1. INTRODUCTION

The vertical structure of the atmospheric boundary layer (ABL) has considerable influence on meteorological and environmental issues. It affects near-surface pollutant concentrations, the vertical profiles of mean wind velocity, and the turbulent vertical exchange of momentum, heat, moisture. Key parameters in describing the ABL are its height and its dynamical and thermal structure.
The ABL description in numeric weather prediction models still has errors, especially under stable conditions. Hence there is need to compare mesoscale model results with observations to understand the model limitations as well as their strengths. Comparison of model data with observations is useful for choosing appropriate model configuration including parameterizations of physical processes and time and spatial resolution. At other hand parameters of urban area can be determined by observations for their following use in numeric weather prediction models.
In this study the ABL schemes implemented in mesoscale model WRF are evaluated against remote measurements of temperature and wind speed in ABL in Moscow megapolis

2. MODEL DESCRIPTION

The NWP model chosen for this research is the Weather Research and Forecast model version 3.0.1 (WRF, Skamarock et al., 2008). It has a number of options for various physics processes. ABL. This study was focused on ABL description in WRF. We choose the Mellor-Yamada-Janjic (MYJ) scheme in WRF (Janjic, 2002), which is designed to simulate turbulence for both stable and unstable conditions, has undergone extensive evaluations in research and operations. This scheme was ound to be the best choice during prior model testing. Other physics for these WRF experiments include the Dudhia radiation scheme and the MM5 five-layer soil scheme for surface fluxes. Table 1 shows the model options used in this study. The initial and boundary conditions were taken from NCEP FNL archive data (http://www.ncep.noaa.gov/) with the spatial resolution of 0.5˚ by 0.5º and the temporal resolution of six hours.

Table 1

Atmospheric process	Parameterization
Microphysics	Ferrier scheme
Longwave radiation	RRTM scheme
Short wave radiation	MM5 scheme (Dudhia)
Surface layer	Monin-Obuhov similarity theory
	Mellor-Yamada-Janjic
Land-surface model	5-layer thermal diffusion
Planetary boundary layer	Yonsei University (YSU)
	Mellor-Yamada-Janjic (MYJ)
Cumulus	Not used

The domain covers ~200 X 200 km, has a horizontal resolution of 2 km and is centered over the Moscow city (Figure 1). This area has remarkable urban–rural difference and include all available points of height ABL measurements in its central part. Vertical resolution is 41 layers, about 15 levels are within the lowest 1 km. The very fine vertical resolution near the surface is designed to resolve ABL structure and processes.
The WRF configuration described above is run daily over July 2005, August and February 2007 during period for 60 h, beginning at 0000 UTC. The time step is 10 s. with model output at intervals of 30 min.

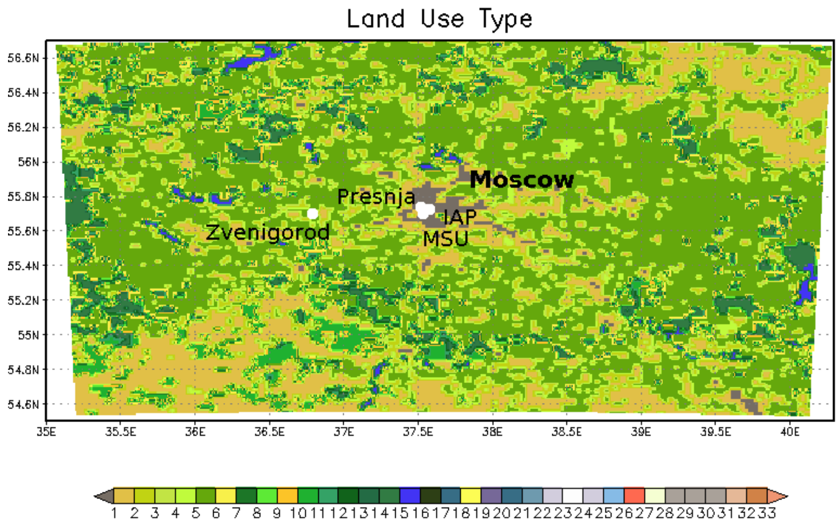

Figure 1: Model domain indicating land use type and points of measurements in ABL

3 OBSERVATION DATA

Wind measurements in Moscow are carried out by three-component mono-static Doppler sodars LATAN-3 developed at the Obukhov Institute of Atmospheric Physics (IAPh). Detailed description of this tool and its accuracy can be found in (Kouznetsov R.D., 2006). Two sodars are synchronously operated at two sites: on the roof of IAPh building in Moscow downtown and in Moscow State University (MSU) on the roof of Physics Faculty building in the south-west district of Moscow. Uninterrupted measurements are carried out since April 2005 (Yushkov V.P. et al., 2007).
Case study measurements were provided in rural area (near Zvenigorod 45 km south-west from Moscow) during July 2005.
ABL temperature profiles measurements are carried out by microwave temperature profiler MTP-5 (Kadygrov E.N. et al., 2003) in the center of Moscow in Hydrometcenre of Russia (Presnja). These tool was also used for mesurements in Zvenigorod in July 2005, July 2006 and since August 2008 till now in operational regime.

4. RESULTS

Moscow is example of a large city in the middle of Russian plain.
Temperature comparison of model and observation data shows their good agreement, mean absolute error in ABL is about 1-2 ºC, decreasing with height. It is interesting that forecast accuracy occurred to be almost the same for 24h and 48h forecasts. Error is smaller at daytime then at nighttime especially in lower part of ABL.
Fig. 2 shows monthly mean temperature profiles in Moscow according to observation and modeling. Temperature in winter is overestimated for 1 ºC at all heights in rural area and in the city higher 100 m. Mean surface temperature bias in Moscow is about 0 ºC, but temperature vertical gradient is much smaller in model data then observed.

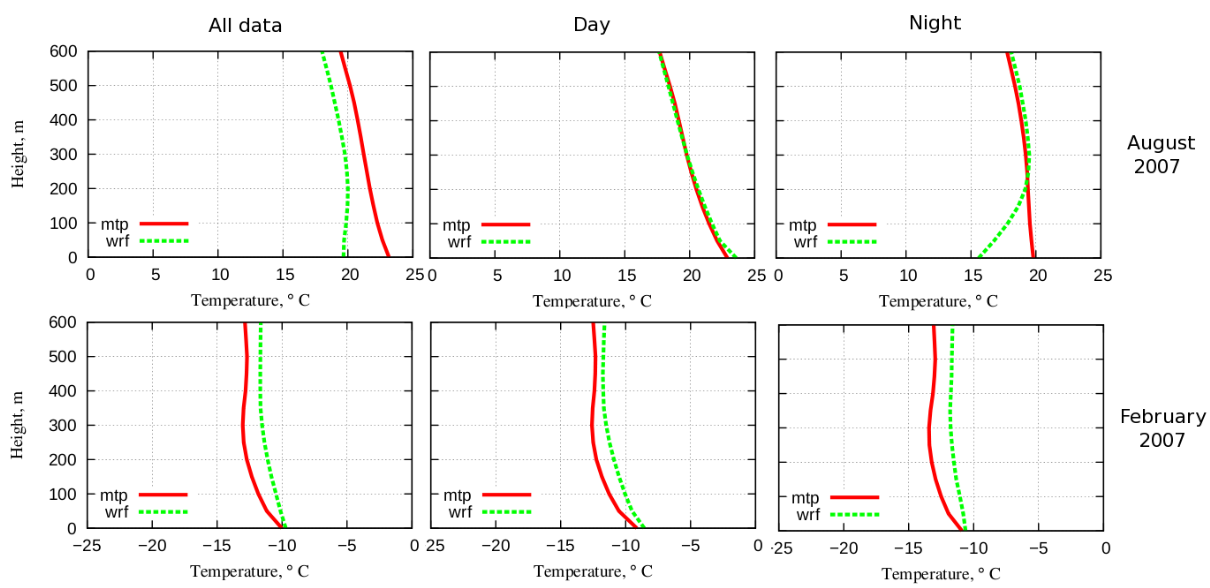

Figure 2: Monthly average temperature profiles obtained by model (wrf) and observation (mtp) data using all (left), diurnal (middle) and nocturnal (right) data in Moscow in August 2007 (top) and in February 2007 (bottom)

Temperature in summer is underestimated. In Moscow mean bias is close to 0 higher than 200 m, absolute error is less than 1 ºC. But temperature in the lowest part of ABL has large error especially at nighttime, where absolute error in august was 4 ºC.

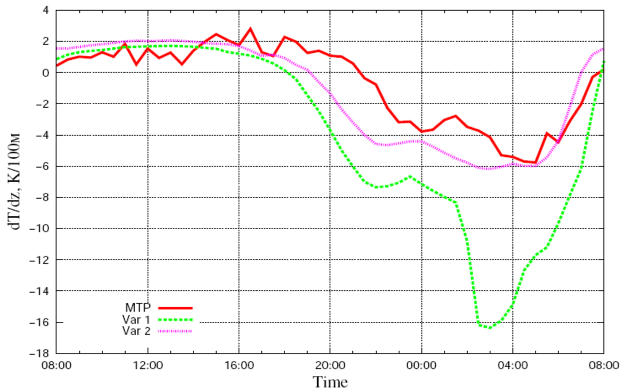

Figure 3: Vertical temperature gradient from 0 to 50 m in Zvenigorod obtained by mesurements (MTP) and model with different ABL parametrizations (YSU - Var 1 and MYJ - Var 2)

Surface vertical temperature gradient is larger in model data than observed. Some parameterizations lead to unrealistic large nocturnal inversions as can be seen at Fig. 3. At the same time model in other configuration shows good agreement with observed diurnal cycle of temperature gradient. Comparison of forecasted obtained with different process parameterizations allows to choose optimal model configuration for desired purpose.

A statistic analysis of model representation of inversions, stratification types was provided. Temperature lapse rate distributions were calculated. Model distributions in Moscow occurred to be wider and shifted to larger gradients then observed.

Wind forecast accuracy varies at different cases. Diurnal wind profiles are similar in model and observations, while nocturnal have significant differences. Wind up to 300 m is overestimated. Mean bias in wind speed is 1-2 m/s and constant with height. This is most significant at lowest heights where large wind speeds are rare, but on 200-300m bias can be up to 7-8 m/s. Fig. 4 show mean wind bias depending on height and time of day. It can be seen that diurnal bias is near zero and nocturnal is small in winter and about 2 m/s in summer with maximum near 100 m.

In some cases model represent such phenomena as low level jets. Fig. 5 shows wind speed at 9-10 July 2005 night

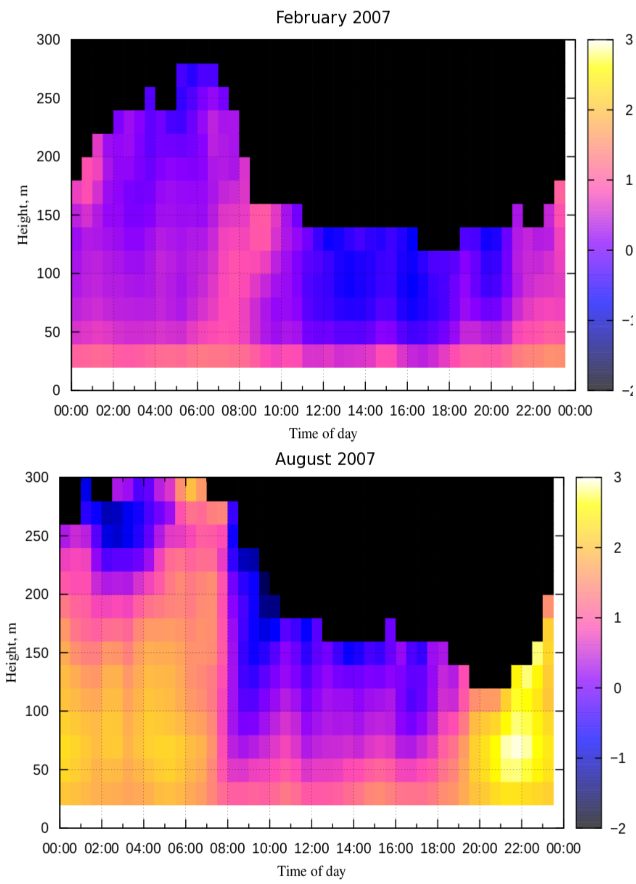

Figure 4: Mean wind bias depending on height and time of day in Moscow in February 2007 (top) and August 2007 (bottom)

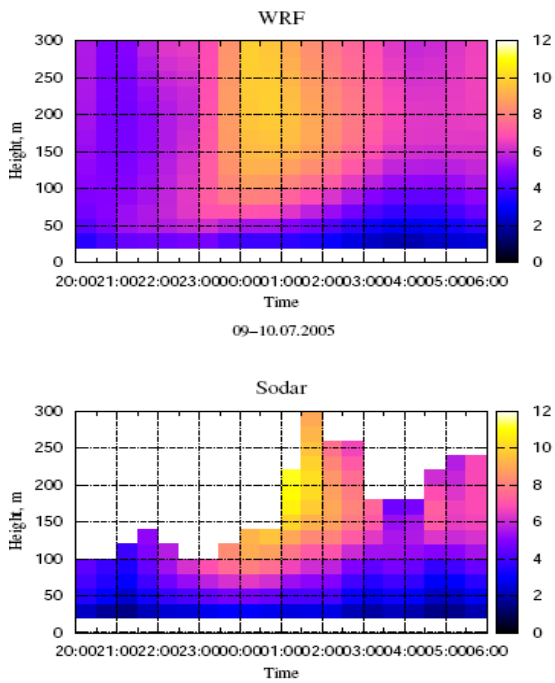

Figure 5: Wind speed depending on height and time 09 July 2005 in Zvenigorod in model data (top) and observations (bottom)

5. CONCLUSIONS

The main object of the investigation was to study accuracy of the model at various real conditions. t is necessary to use statistic methods for comparison with long-term measurements and following choice of parametrizations. Main limitations of commonly used parametrisations of ABL are noted for Moscow city. The role of ABL parametrization on model description of various phenomena was studied. The statistical estimations of forecasts deviations in description of temperature and wind profiles are calculated. Not all characteristics can be used for comparison due to their instability. Developed method of comparison with remote measurements might be used to provide opportunity to estimate influence of different model options on the forecast. Optimal model configuration in the particular region can be made on the base of statistic estimations. So that remote measurements can be used for improvement of ABL parameterizations in numeric weather prediction models.

Acknowledgments. This study was supported by Russian Foundation for Basic Research, projects nos. 07-05-13610, 08-05-00984, 07-08-00491 and 08-05-13545

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