ABSTRACT: A computational scheme for an improved level-3 closure turbulence model is proposed and its performance is examined to simulate the wind field structure above the urbanized surface (city) in the atmospheric boundary layer (ABL). In the present model, two new ingredients are employed: 1) an updated expression for the pressure-strain correlation, 2) an updated expression for the pressure-temperature correlation. The turbulent momentum and scalar fluxes are determined by the full explicit algebraic expressions which are derived from the closed transport equations for turbulent fluxes and simplified using the weak-equilibrium assumption and symbolic algebra. Closure is achieved by solving the evolution equations for the turbulent kinetic energy, its dissipation rate and scalar variance (the three-parametric turbulence model). This improved mesoscale model is able to reproduce the most important features of a wind field above the city.

KEYWORDS: Turbulence, Urban boundary layer, modeling.
The dependent variables in (1)-(5) are the mean flow velocities $U$, $V$, and $W$, in $x$, $y$, and $z$ directions, respectively, the mean pressure $P$, the mean departure $\Theta$ from a reference temperature $T_0$, $D_U$, $D_V$, $D_W$ here represents the forces (e.g., frictional force, drag force etc.) and $D_\Theta$ denotes the impact of the sensible heat fluxes from the ‘solid’ surfaces (ground or buildings) on the potential temperature budget. The parametric quantities in (1)-(5) include the acceleration of gravity $g$ (9.8 ms$^{-2}$), the Coriolis parameter $f$ (0.8×10$^{-4}$ at latitude 35$^\circ$N), the volumetric expansion rate of air $\beta$ (3.53×10$^{-3}$ К$^{-1}$), and mean air density $\rho$ (1.25 kgm$^{-3}$). The lower case terms $u$, $v$, $w$, and $\theta$ represent time dependent deviations from their respective mean values, and their products in (1)-(5) give the turbulent Reynolds stresses and heat fluxes. They are modeled by the full explicit anisotropic algebraic expressions which are obtained from the differential closed transport equations for turbulent fluxes by simplifications of the last up to the system of algebraic equations using the weak-equilibrium assumption. The obtained system of the algebraic turbulent fluxes equations is solved using symbolic algebra. For closure of expressions for the turbulent momentum and scalar fluxes the three-parametric turbulence model is used [3]. The turbulent fluxes expressions here are not resulted because of their bulkiness.

3 NUMERICAL TEST
A 2D numerical test is carried out. The size of computational domain is 6×120 km with the resolution of 1 km. The topography is flat with a 10-km wide city surrounded by a rural area. In the model, urban heat island effects are specified by the urban-rural temperature difference. The horizontal gradient of temperature between air above the city and air above the rural area generates a thermal circulation which depends on a variety of factors including the morphology of urban canopy layer. Therefore, the urban roughness parameterization has been incorporated in the improved mesoscale model (Fig. 1). The meteorological initial conditions are a geostrophic wind from the west of 1, 3 and 5 m s$^{-1}$, an atmospheric thermal stratification equal to 3.5 K km$^{-1}$ in potential temperature. The ground temperature is specified as $\Theta(x,0,t) = 6\sin(\pi t/43200)$, where $t$ is the current time in seconds. This is the only nonstationary boundary condition of the problem which models the 24-hour cycle of solar heating of the Earth’s surface.

3.1 Momentum
A vertical profile of the local $u_{\kappa i}$ (defined as $\sqrt{\left((uw(z))^2 + (vw(z))^2\right)}$) with the measurements
data is presented in Figure 2. Above the roughness sublayer the urban (day and night for both
gostrrophic wind speeds) simulations show a region where $u_{z1}$ is nearly constant with height.

![Figure 1](image1.png)

**Figure 1.** The concept incorporated of urban canopy layer. The thick line on abscissa between 45 km and 55 km indicates the city location.

The vertical profiles computed by the improved model show a good agreement with the measurements data.

![Figure 2](image2.png)

**Figure 2.** Vertical profiles of the local velocity friction $u_{z1}$

![Figure 3](image3.png)

**Figure 3.** Vertical profiles of the ratio between the local $u_{z1}$ to the mean wind speed.

![Figure 4](image4.png)

**Figure 4.** Comparison between computed and observed scaled averaged integrated vertical turbulent velocity variance.
3.2 Turbulent statistic

Figure 4 show the vertical distribution of the computed scaled frictional velocity, standard variation of vertical wind velocity component with observational data, is averaged from all computations for a 24-hr period and plotted against scaled heights, with $Z_{hl}$ the building canopy height.

3.3 Impact on the dispersion of passive tracer

The passive tracer is emitted in the city at ground level with a time variation typical of traffic emissions characterized by high values in a morning and low values during night hours in order to reproduce realistic profiles. The concentrations computed by the model at the lowest level in the centre of the urban area are plotted in Fig. 5. They show the impact of the city on pollutant dispersion. As it is possible to see in Fig. 5 the concentration distribution of pollutant near the surface reaches of a local maximum at distance of 10 km downwind from the city. Such an effect can be connected with the character of thermal circulation in this area (Fig. 6).

![Figure 5. Passive tracer concentration $C/C_{max}$ at the lowest level at 07 LST of the first day of modeling (•) and at 13 LST the second day of modeling (●), as function of horizontal distance.](image)

![Figure 6. A vector field of horizontal wind speed and isotachs of the mean vertical wind speed at 13 LST (second day of modeling).](image)

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5 REFERENCES