Improved hydrodynamical scheme of the turbulence description

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The quantitative description of the turbulence is one of the problems in the current prediction of the large and mesoscale atmospheric processes. The prediction schemes use the equations of resolved scales of hydrodynamic variables and subgrid simulation model of turbulence characteristics for unresolved scales.

The most popular hydrodynamic description of atmospheric turbulence is based on the Level-3 and Level-2.5 model according to the classification of Mellor-Yamada [5,6]. The difference between these two models is that the Level-3 model uses two transport equations for turbulent kinetic energy (TKE) and temperature variance while the Level-2.5 includes only the transport equation for TKE and algebraic expressions for all second-moments of the fluctuations of variables. The greatest weakness of the hydrodynamic schemes based on Level-3 and Level-2.5 models is that they are constructed by using the conception of master length scale. This scale is calculated by the empirical expression, it's for example the formulae of Blackadar-Deardorff [4,6].

We developed the hydrodynamic model with two transport equation closure TKE and dissipation rate which was used for reconstruction internal structure of atmospheric boundary layer from operational data of Hydrometeorological Center of Russia. The arguments in favor of using this hydrodynamic model is shown [1,2].

The proposal improvement is the Level-3 model but the transport equation of dissipation rate is applied instead of the transport equation of the temperature variance. The expression for length scale is constructed by using the formulae of Kolmogorov-Prandtl (KP) with the predicted turbulence characteristics (TKE and dissipation rate). The obtained results show that less turbulent energy is transferred to the smallest eddies and dissipation decreases faster than $(TKE)^{\frac{3}{2}}$ when the stratification parameter increases. Therefore the value of length scale decreases if the stratification is unstable and increases when the stratification becomes stable [3,4]. In improved scheme the algebraic expressions for the second moments are transformed by using KP formulae for length scale. This value fits the balance described by TKE transport equation. The pressure-velocity and pressure- temperature correlations are also included in the algebraic expressions as it recommended in [4]. So the all components of the turbulent fluxes of momentum and heat are obtained. These fluxes are inserted in the equations for components of mean velocity and mean potential temperature in the prediction model.

The developed hydrodynamic scheme is also used for modeling the transport and diffusion of hazardous releases and can be applied for creation of an operational tool for real-time air pollution monitoring. For solution this problem the developed scheme is used to calculate the coefficients of turbulence, which are involved in the equation of turbulent diffusion of the pollutants. The calculation of the turbulence coefficients is based on the obtained algebraic expression of the second moments. The obtained expression of the turbulence coefficients has the same form as KP formulae but it includes the stability functions, which are depended from TKE, dissipation rate, the wind shear and the potential temperature gradient. The calculated and defined in [4] stability functions are different because the calculated ones don't require the empirical expression for length scale. So the proposed algorithm is more physically well-grounded than the constant values of the proportionality coefficient in KP expression [1] .

The improvement allows to include the scheme for description of the turbulent exchange on the whole calculation domain of forecast model.
The application of developed scheme for turbulence description to the forecast models and pollution modeling gets better the quality of weather prediction and ecological monitoring.

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