A simple description of turbulent transport in a stratified shear flow devoted to the simulation of thermohydrodinamics of inland waters

D. Gladskikh [1, 2], I. Soustova [1], Yu. Troitskaya [1], S. Zilitinkevich [3, 4]

[1] Institute of Applied Physics of the Russian Academy of Sciences, Nizhny Novgorod, Russia

[2] Nizhny Novgorod State Technical University n.a. R.E. Alekseev, Russia

[3] Finnish Meteorological Institute, Helsinki, Finland

[4] Lobachevsky State University of Nizhni Novgorod, Russia

By now, the role of inland water bodies in the processes of general circulation of the atmosphere, the ocean and land, their thermohydrodynamic and biological properties in weather forecasts, and also in climate change has been established. There are classifications of physico-mathematical models of inland water objects both in terms of spatial detailing and in terms of the described processes. 3D and 2D mathematical simulation, widely used in ocean models, is practically not used for lakes and water reservois due to the large computational resources required for these models. The most popular are one-dimensional (vertical) ones that have computational simplicity and acceptable accuracy of temperature, heat fluxes, flow velocity reproduction.

The basis of physico-mathematical simulation of thermodynamics and hydrodynamics of inland waters is RANS (Reynolds-averaged Navier–Stokes equations**)** [1]. Since this system contains unknown quantities (turbulent flows), it is necessary to involve additional hypotheses for its closure. Practically significant is the so-called κ-ε model based on the equations for the kinetic energy of turbulence κ and its dissipation rate ε. In this case, the system of Reynolds equations for the means is closed using gradient hypotheses with turbulent exchange coefficients proportional to the coefficient of turbulent viscosity. The ratio of the coefficient of turbulent viscosity to the coefficient of thermal diffusivity (the turbulent Prandtl number, Pr_T) is assumed to be constant. This, in particular, limits the description of the known effect associated with the existence of turbulence for large Richardson numbers *Ri*. At the same time, both laboratory and field measurements demonstrate the dependence of the Prandtl number on the Richardson number. In this connection, special attention in the simulation of the thermohydrodynamic regime of inland water bodies is paid to stratification and, in particular, to its role in the processes of turbulent mixing, thermocline dynamics, etc. Recently, modernized approaches to the description of geophysical turbulence, taking into account stable and unstable stratification and internal waves, are actively developing.

Authors propose geophysical turbulence models that take into account the two-sided transformation of the kinetic and potential energies of turbulent pulsations, which allow calculating, in particular, the Prandtl number dependence on the gradient Richardson number. In this paper, we present a parametrization of the turbulent exchange coefficient for the κ-ε model in order to take into account stratification in calculating the thermohydrodynamic regimes of inland water bodies.

The work was partly supported by Russian Science Foundation project 15-17-20009 and RFBR project 18-05-00292

References

[1] Monin A.S., Yaglom A.M. Statistical Fluid Mechanics: v. 1 / Moscow: Nauka, 1965. - p. 640.