The turbulence characteristics of the pollutant diffusion in the oceanic boundary layer

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We considered the diffusion process when the distribution of pollutant concentrations depended on the transport, diffusion and removal processes of the substances. So the quantitative description of the components of transport velocity vector, turbulence parameters and the deposition is the necessary part of the environmental pollution control. In [Shnaydman V., Tarnopolsky A.,1999] the conception of anthropogenic forcing on the oceanic coastal area was formulated. The conception divided the pollution space on local and distant zones in dependence on the distance from the source. In these zones the Lagrangian and Eulerian descriptions were used. Both approaches required the turbulence closure. Restoring the three-dimensional hydrophysical structure of the coastal shallow-water area showed that the usually used turbulence closure schemes had to be essentially improved [Shnaydman V., Le Thi Quynh, 2000].

The main deficiencies of popular closure schemes came from using only one transport equation for turbulent kinetic energy, single master length calculated by the empirical formulae, the boundary layer approximation, the crude parameterization for the pressure-velocity and pressure-temperature correlations [Cheng Y, et al,2002].

Shnaydman V. [2002,2004] proposed to use the Kolmogorov-Prandtl and Smagorinsky-Lilly expressions as it was usually done but with essential improvement of the turbulence closure scheme.

The developed turbulence closure scheme described the three-dimension, non-local turbulence coefficients of oceanic boundary layer which were insert in the diffusion equation of pollutant concentration. These coefficients were obtained for vertical and horizontal turbulent mixing by using the two-equation parameterization scheme which involved the turbulent kinetic energy and dissipation rate equations. The developed model avoided the main deficiencies of usually used parameterization schemes.

The model included the forcing influence of the surface wind on the creation of the drift geostrophic currents and their contribution in the formation of the turbulent exchange in the oceanic shallow-water zone. The improved description of the interaction between atmospheric boundary layer and oceanic surface was applied. The atmospheric turbulent momentum flux was divided on two parts, one was responsible for development of the drift currents, another created the wind waves. The kinetic turbulent energy flux from the atmosphere to oceanic eddies by the collapse of the surface waves and the formation of the intensive dissipation oceanic surface layer was taken into account.

The important feature of developed model was the numerical algorithm of the solution of nonlinear turbulence closure equations. The finite difference equations are obtained by using the forward-differencing scheme for integration in time (first-order accurate), the central differences for advective terms (second-order accurate) and centered-in-space differences for the turbulent terms (second-order accurate).

The semi-implicit numerical integration method was used. The implicit treatment was concerned the vertical turbulent exchange terms in turbulent kinetic energy and dissipation rate equations. This treatment required the small vertical spacing only to resolve the internal structure of boundary layer without drastically reducing the time step as it would be done by explicit scheme. The use of centered-in-vertical implicit scheme allowed to apply the factorization method for getting the turbulence parameters. The linear finite-difference forms of turbulence closure equations are constructed and the criteria of advective and diffusive stability and positive numerical solution are fulfilled.

The model described the more full mechanisms of turbulent mixing in the oceanic boundary layer and improved the input turbulence parameters for the diffusion equation used for the calculation of the pollutant concentrations.

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