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Mixing parametrizations for ocean climate modelling

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The algorithm is presented of splitting the total evolutionary equations for the turbulence kinetic energy (TKE) and turbulence dissipation frequency (TDF), which is used to parameterize the viscosity and diffusion coefficients in ocean circulation models. The turbulence model equations are split into the stages of transport-diffusion and generation-dissipation. For the generation-dissipation stage, the following schemes are implemented: the explicit-implicit numerical scheme, analytical solution and the asymptotic behavior of the analytical solutions. The experiments were performed with different mixing parameterizations for the modelling of Arctic and the Atlantic climate decadal variability with the eddy-permitting circulation model INMOM (Institute of Numerical Mathematics Ocean Model) using vertical grid refinement in the zone of fully developed turbulence.

The proposed model with the split equations for turbulence characteristics is similar to the contemporary differential turbulence models, concerning the physical formulations. At the same time, its algorithm has high enough computational efficiency. Parameterizations with using the split turbulence model make it possible to obtain more adequate structure of temperature and salinity at decadal timescales, compared to the simpler Pacanowski-Philander (PP) turbulence parameterization. Parameterizations with using analytical solution or numerical scheme at the generation-dissipation step of the turbulence model leads to better representation of ocean climate than the faster parameterization using the asymptotic behavior of the analytical solution. At the same time, the computational efficiency left almost unchanged relative to the simple PP parameterization. Usage of PP parametrization in the circulation model leads to realistic simulation of density and circulation with violation of T,S-relationships. This error is majorly avoided with using the proposed parameterizations containing the split turbulence model.

The high sensitivity of the eddy-permitting circulation model to the definition of mixing is revealed, which is associated with significant changes of density fields in the upper baroclinic ocean layer over the total considered area. For instance, usage of the turbulence parameterization instead of PP algorithm leads to increasing circulation velocity in the Gulf Stream and North Atlantic Current, as well as the subpolar cyclonic gyre in the North Atlantic and Beaufort Gyre in the Arctic basin are reproduced more realistically. Consideration of the Prandtl number as a function of the Richardson number significantly increases the modelling quality.

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