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A full free surface ocean general circulation model in sigma-coordinates for simulation of the World Ocean circulation and its variability

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A new version of the Institute of Numerical Mathematics ocean model (INMOM) is presented. The INMOM uses arbitrary orthogonal coordinates in horizontal space and isobathic sigma-coordinate in vertical direction. The previous version of the OGCM was used as the oceanic component of the IPCC climate system model INMCM (Institute of Numerical Mathematics Climate Model (Volodin et al, 2017). Besides, INMOM as the only sigma-model was used for simulations according to CORE-II scenario (Danabasoglu et al. 2014,2016). In general, INMOM results are comparable to ones of other OGCMs and were used for investigation of climatic variations in the North Atlantic (Gusev and Diansky 2014).

In the new INMOM version, the model equations are formulated in terms of full free surface with taking into account water budget variation. Tensor form of lateral viscosity operator is used, which is invariant to rotation. Isopycnal diffusion including Gent-McWilliams eddy-induced transport is used to parameterize lateral mixing. The two-equation turbulence model Mellor-Yamada level 2.5 is implemented for vertical mixing parameterization.

To simulate sea ice characteristics, the INMOM contains an embedded sea ice module consisting of thermodynamics, transport and dynamics components. The ice thermodynamics module is based on the assumption of quasi-stationarity (Yakovlev, 2009) in which temperatures at the ice and snow surfaces are computed diagnostically at a time step assuming linearity of temperature profiles inside each of the media. At the same time, there is no approximation of “levitating” ice, which makes it possible to take into account the full exchange of salt and fresh water between the ocean and sea ice and, therefore, conserve the total amount of salt in the total ice-snow-ocean system. The sea ice transport module is based on the MPDATA scheme (Smolarkiewicz, 2006) with nonlinear correction reducing the dissipative properties of the basic upwind scheme. The sea ice dynamics module is based on the elastic-viscous-plastic rheology (Hunke and Dukowicz, 1997) using the total time derivative of ice drift velocity.

The INMOM is adapted for simulations at multiprocessor systems with distributed memory using the hybrid MPI-OpenMP technology including procedures for reading from and writing to files, with loading processors close to uniform.

The INMOM is tested by reproducing World Ocean circulation and thermohaline characteristics. The used OGCM version is constructed in a curvilinear orthogonal coordinate system obtained through the conformal Moebius transformation of a geographic system. To avoid the problem of grid convergence near the North Geographical Pole, the “north” pole on the model grid is located to the point 90°E, 60°N, while the model “south” pole coincides with the South Geographical Pole. The model was integrated using datasets from the CORE database (Large and Yeager, 2009). The features of oceanic circulation and climate-forming characteristics are well reproduced and in agreement with other simulation results.

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