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Global ocean simulation with INM-IO eddy-resolving model

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This poster participates in
OSP
Outstanding Student Poster Contest

Abstract

World Ocean numerical model with eddy-resolving 1/10 degree horizontal resolution and 49 vertical levels was developed in the Institute of Numerical Mathematics and P.P.Shirshov Institute of Oceanology of the Russian Academy of Sciences. It is used to study intra- and inter-annual variability of the World Ocean.

Recently two sets of numerical experiments were carried out. In the first set of numerical simulations atmospheric conditions were defined by the normal annual cycle, in accordance with the terms of the international experiment CORE-I [1]. The second numerical simulation was a hindcast experiment forced by ERA40 global atmosphere and surface conditions reanalysis data covering 43 years from 1958 to 2000.

Model description and parameters

Basis: *model is based on the system of three-dimensional primitive equations of ocean dynamics.*
Solution: *a numerical method is based on the separation of solutions to barotropic and baroclinic components. Differential equations are approximated using the finite volume method. In the horizontal plane, the equations are solved in an arbitrary orthogonal coordinate system.*
Coordinates and resolution: *tripolar system of coordinates, z-coordinate vertical grid, 1/10 degree resolution on horizontal scale, 49 vertical levels.*
Sub models: *sea-ice thermodynamics model [2], atmospheric boundary layer model [3].*
Initial conditions: *WOA 2001 data, no motion*

Experiments	Normal annual cycle run	Hindcast 1958 – 2000 run
Atmosphere forcing	CORE I normal annual cycle data	ERA 40 reanalysis data
Vertical mixing	Munk-Anderson parameterization	KPP scheme with turbulent bottom boundary layer
Horizontal mixing	Laplace viscosity: 500 **m^2**/s Laplace diffusivity: 100 **m^2**/s	Biharmonic viscocity: – 0.35 x 10^9 **m^4/s** Laplace diffusivity: 100 **m^2**/s
Topography	Accurate ETOPO5 interpolation	Smooth ETOPO5 interpolation (Fig 1. below)

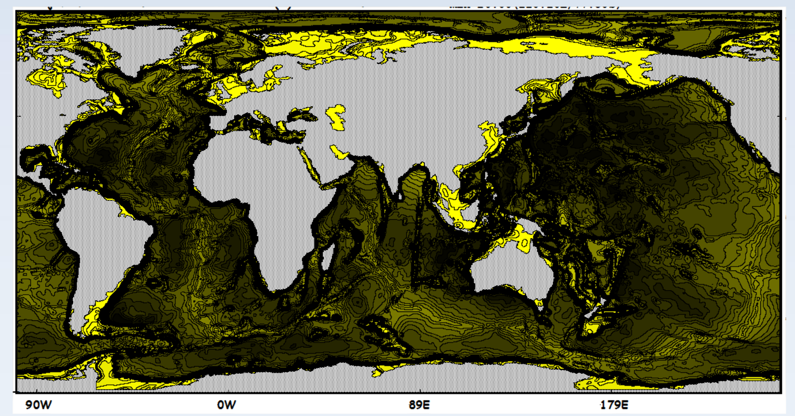
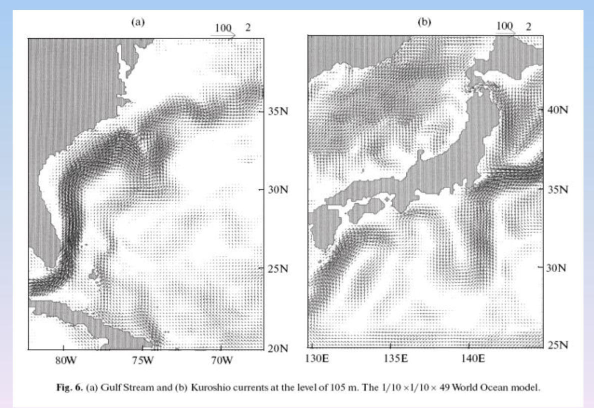


Fig.1 Smooth ETOPO5 interpolation

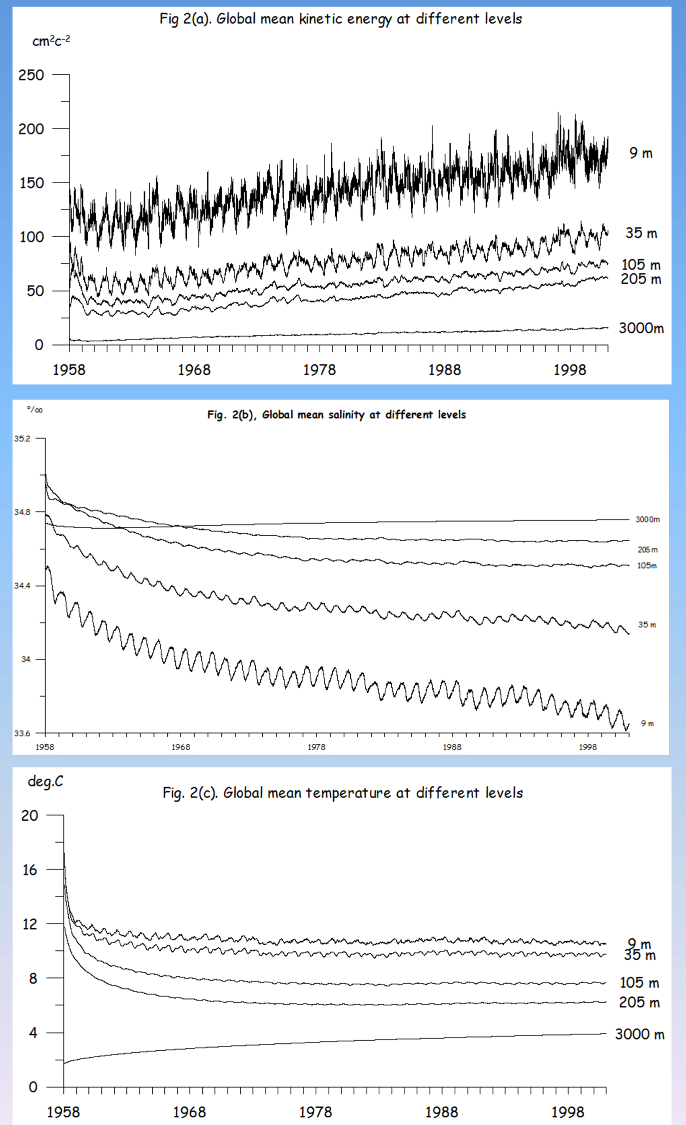
Main currents of the World Ocean

One of the aims of developing a high resolution ocean model is to achieve a more accurate reproduction of spatial–temporal characteristics of narrow boundary currents of the World Ocean. In the Atlantic Ocean, a resolution of 1/10° is a necessary condition for the correct reproduction of the region where the Gulf Stream separates from the shelf slope. According to the results (Maltrud, McClean, 2005), a realistic separation of Gulf Stream from the shelf is not reproduced automatically. Our model reproduces dynamics of the Gulf Stream sufficiently realistically (Fig. 6a).

According to the observation data, it is well known that the Kuroshio separates from the shelf near 37° N (Fig. 6b). In the model the current separates from the shelf by 1° to the North on average. The model solution shows a considerable variability of the current with the formation of strong anticyclonic meanders along the Japanese Islands.



Mean characteristics for the hindcast 1958 – 2001 run



The temporal dependence of average kinetic energy shown in Fig. 2(a) demonstrates how the model solution attains the quasiperiodic regime with a legibly pronounced seasonal variability. Together with this, one can observe a slow increase of average energy which means that after few decades of integration water circulation in the ocean still remains far from being established. At fig.2(b) and fig.2(c) average salinity and temperature values are shown on the same levels. Freshening of water near the surface is caused by water disbalance: precipitation rate is bigger than evaporation rate, and mean sea surface level is fixed artificially.

Meridional characteristics: overturning circulation and heat transport

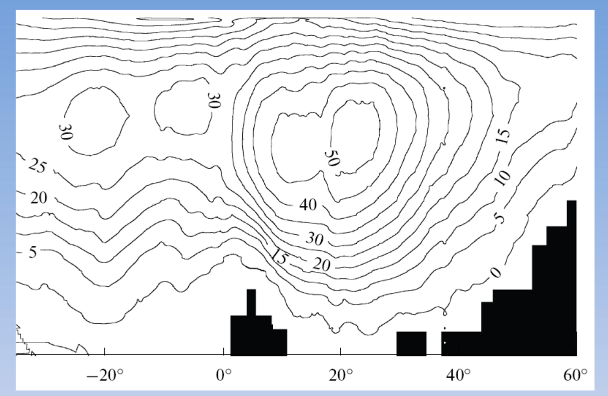


Fig.3 MOC in the Atlantic Ocean

The annual average meridional circulation in the Atlantic Ocean is shown in Fig. 3. It mainly covers the wind transfer of water from the South to the North in the upper layer of the ocean and the downwelling in the Northern Atlantic. The value of meridional transfer reaches the maximum of 50 Sv at 20° N, 2000 m.

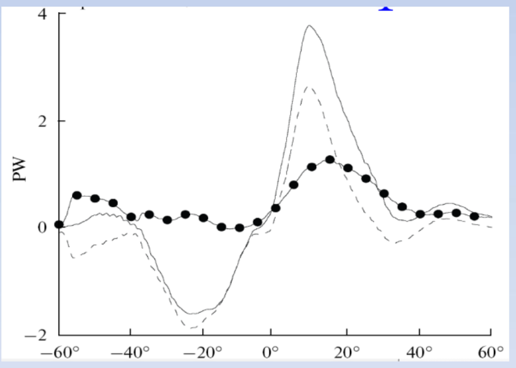


Fig.4 MHT . World Ocean (solid), Indo-Pacific (dashed), Atlantic Ocean (dots).

Meridional heat transport by ocean currents averaged over the sixth year of integration in CORE I run is shown in Fig. 4. In the Atlantic Ocean one can see the known antisymmetry of the heat flow with respect to the equator. The transport to the North is maximal at 20° N (about 1PW).

Seasonal variability in CORE I run

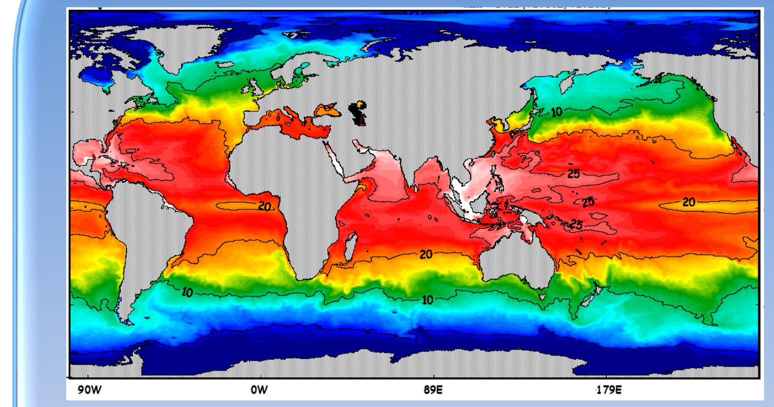


Fig. 5(a) Average sea surface temperature in July

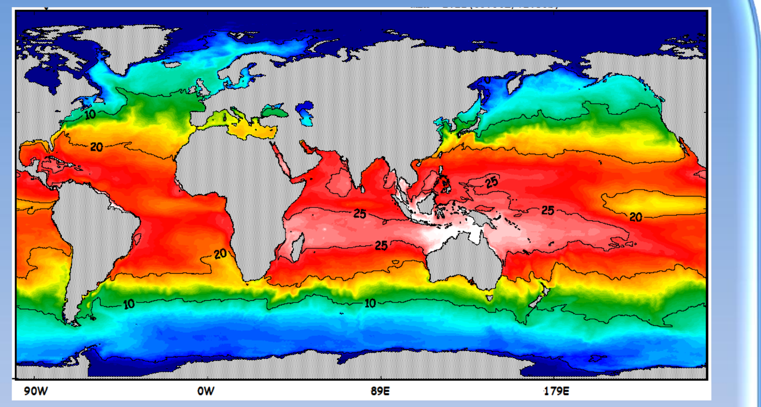


Fig.5(b) Average sea surface temperature in January

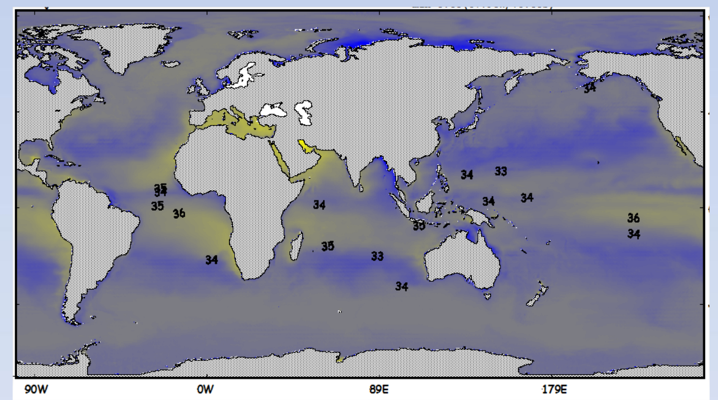


Fig.5(c) Average sea surface salinity in July

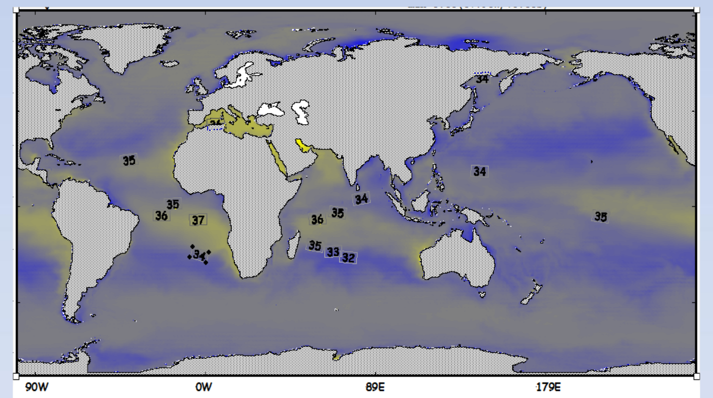
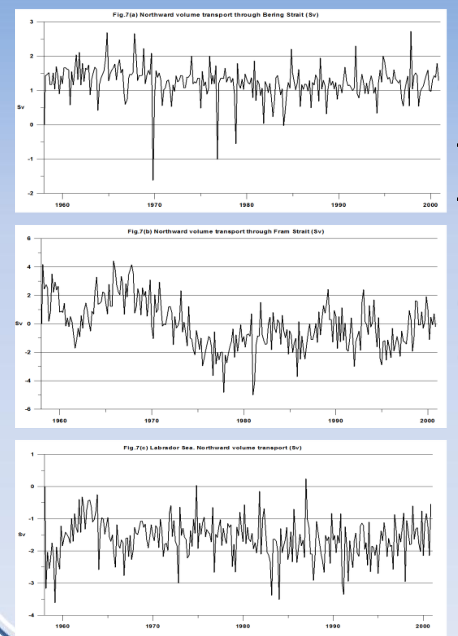
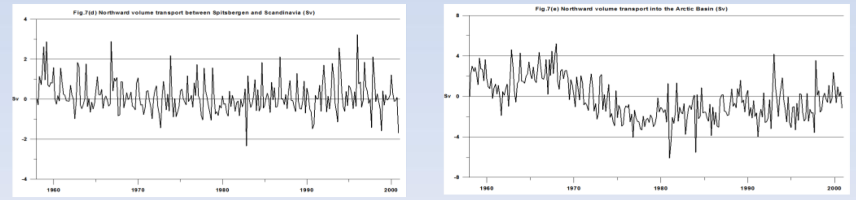


Fig.5(d) Average sea surface salinity in January

Inter-annual variability of Arctic water inflow in the hindcast 1958-2001 simulation



There are four key regions where waters flow in and out of Arctic Basin: Bering Strait, Fram Strait, Labrador Sea region and area between Spitsbergen and Scandinavia. Strong inter-annual variability of inflows in each of these regions causes significant variability of the total inflow and water balance in the Arctic Basin.



Discussion

High resolution models of the global ocean can be applied for studying large scale circulation and can be applied for estimating regional processes too. Some examples of these applications have been presented.

CORE I normal annual cycle and 1958 – 2001 numerical simulations are significant first step in the creation of an eddy resolving model of the World Ocean. In our model, an increase in the kinetic energy is observed during the whole period of integration, which points to an imbalance of the solution. So our next step is to pay attention to the processes and parameters of the model that determine the global energy and heat balances , this are the keys to solve this problem.

References

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Acknowledgements

Authors are grateful to Academician Artem Sarkisovich Sarkisyan. This study was supported by the Russian Foundation for Basic Research and by the Program of Fundamental Research of the Presidium of the Russian Academy of Sciences. Numerical simulations were done on the Lomonosov supercomputer in Moscow State University and on the MVS100k supercomputer of the Interdepartmental Supercomputer Center of the Russian Academy of Sciences.