Fifty years Time-integration of Global Eddy-resolving Simulation

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1. Introduction

The key elements that determine the basic properties of the general circulations of the world ocean are nonlinear scale interactions between mesoscale eddies and basin scale circulations. The Earth Simulator enables us to perform eddy-resolving simulations on the global domain to assess simulated eddy-dynamics together with the phenomenological validations of our numerical experiments. In order to pursue this goal, we have developed a high-resolution MOM3-based OGCM code (OFES) optimized for the Earth Simulator. We have executed a fifty-year time integration of the global eddy simulation.

2. Model setting and tuning

The computational domain covers a near-global region extending from 75 ° S to 75 ° N. The horizontal resolution and the number of vertical levels we employed are 0.1 degree and 54 respectively. The model was spun up from annual mean temperature and salinity fields (WOA98) without motion. The surface fluxes are specified from monthly mean NCEP re-analyses data in addition to a surface salinity restoring to climatological value. To suppress grid-scale noises, we introduced a scale-selective damping of Bi-harmonic type and employed KPP scheme for the vertical mixing.

To attain high performance of our eddy resolving code, a number of different optimization techniques have been utilized considering distinctive characteristics of the Earth Simulator. After intensive vectorization of the code, we have done an optimal parallelization taking the characteristics of inter- and intra-node communications into account. The computational domain on the sphere is divided into zonal strips bounded by four latitude circles and the number of PE employed is 1500 (188 nodes). The parallel efficiency and vector ratio of our code are 99.52% and 99.87% respectively and one model-year simulation has been completed in seven hours.

3. Results

Simulated annual mean sea surface height distribution is shown in Figure 1. We can clearly see that, in consistent with a simple geostrophic relation, the SSH in the subtropics is higher than that in the sub-polar region and the lowest SSH appears in the southern flank of the strong Antarctic Circumpolar Current. A zonal band of lower SSH can be noticed along 7°N in the Pacific, which corresponds to the boundary between the North Equatorial Current and the North Equatorial Countercurrent. Therefore, we can say that the basin-wide pattern of the mean SSH field is simulated well.

Smith et al. (2000) suggest that the distribution of eddy activity becomes realistic compare to that derived observation data with increasing horizontal grid spacing. Fig.2 shows the root-mean-square variation of the simulated SSH anomaly. The variability maxima appear in the western boundary current regions such as the Kuroshio/Kuroshio Extension, the Gulf Stream/the North Atlantic Current, the Malvinas Current and the Agulhas Current and around the Antarctic Circumpolar Current. Fairly high variability regions are also seen along 20N and 6N in the western Pacific. Locations of these high variability regions are observationally confirmed by the satellite altimetry (Le Traon and Orgor, 1988).

The snapshot of the sea surface height and the velocity field (Fig.3) suggests that the model reproduces the several eddies, so-called Agulhas Rings shed at the Agulhas retroflection. The scale of the simulated Agulhas Rings is close to the observation. The high resolution of the model contributes to resolve mesoscale eddies.

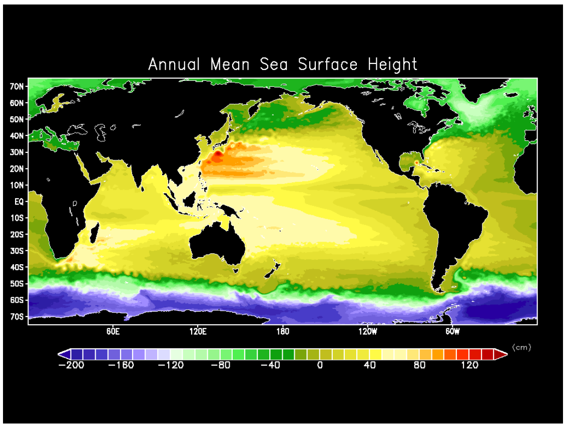

Fig.1 Simulated annual mean sea surface height.

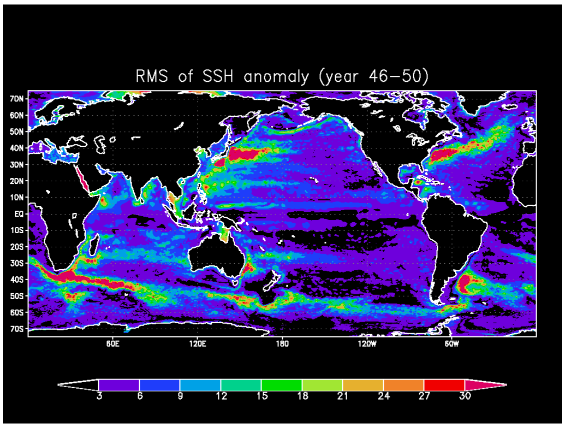

Fig.2 Root-mean-square variation of sea surface height.

It is well known that in low-resolution simulations the Kuroshio tends to overshoot to the north and the resulting separation point turns out to be quite unrealistic. The composite of the simulated monthly mean Kuroshio paths during the year 46 is shown in Fig.4. The Kuroshio separates with right latitude and the Kuroshio Extension bifurcates into two branches. Observation (Mizuno and White, 1983) suggested that the bifurcated Kuroshio Extension is controlled by the bottom topography.

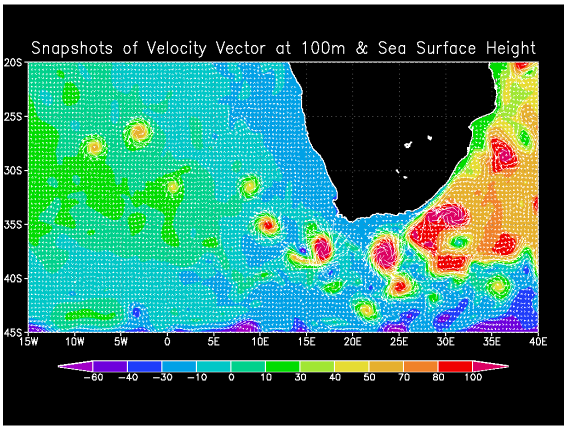

Fig.3 Snapshot of sea surface height and velocity velocity vector at 100m.

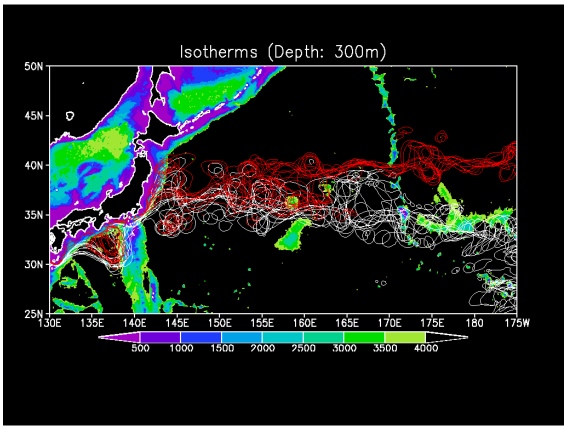

Fig.4 Monthly-mean Kuroshio Current paths as defined by the 14℃(Black) and 10℃(red) isotherm at 300m depth, superimposed upon bathymetry.

4. Summary

A quick look at the simulated result tells that the overall characteristics of oceanic fields are quite realistic. The hi-resolution of the model contributes to resolve the fine structure such as the mesoscale eddies, which encourages us to extend our investigation further on variety of topics.

Reference

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