Development of High-Resolution Pacific Ocean Circulation Model

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ABSTRACT

A Pacific Ocean circulation model based on the RIAM Ocean Model (RIAMOM) with 1/6° and 1/12° horizontal resolution successfully reproduced the peculiar circulation structures of the Pacific Ocean. The volume transports of model agree very well with the results of observations in the northwestern Pacific Ocean. Also our model successfully reproduced the observed structures of the northeastward Ryukyu Current with a subsurface core at 500 ~ 600 m. A possible mechanism for the subsurface current core of the Ryukyu Current is proposed focusing on the blocking effect of the Ryukyu Island Chain.

1. INTRODUCTION

Ocean General Circulation models (OGCMs) have become major tools for the study of the ocean circulation and water masses. However, the great expense of running OGCMs has hindered the developments by limiting the number of calculations and by prohibiting the use of reasonable resolution for satisfying physical requirements. In recent years, the introduction of fast vector processing supercomputers has enabled high-resolution models of the ocean to be developed. These have led to a significant improvement in out ability to represent and understand the ocean circulation and water masses. Therefore supercomputing capabilities are constantly increasing and are at the point whereby numerical basin-scale and even global ocean models can be run at sufficiently high vertical and horizontal resolution to be 뱁ddy-resolving? (horizontal resolutions of 5 ? 10 km and 40 ? 50 vertical levels) rather than 뱁ddy permitting? (horizontal resolutions of 35 ? 40 km and 20 ? 30 vertical levels) scales.

In this study, the usefulness of high-resolution ocean simulations are evaluated focusing on the enhanced regional features of Pacific Ocean circulations manifested in 뱁ddy-resolving? ocean simulation carried out on the Earth Simulator which is the fastest supercomputer in the world in 2002-2004.

2. MODEL

RIAMOM (RIAM Ocean Model) used in this study is the primitive general ocean circulation model with a free surface, which is developed by Lee and Yoon (1994) at

Research Institute for Applied Mechanics (RIAM). The model covers from 95°E to 70° W in longitude and from 50°S to 65°N in latitude. The horizontal grid intervals are 1/6° and 1/12° in both latitudinal and longitudinal directions and vertical layers are 70 levels. The model is integrated from a state of rest with annual mean temperature and salinity distribution by World Ocean Atlas (WOA) 94 (Levitus, 1994), and forced by National Centers for Environment Predictions (NCEP) wind stress climatology during the period from 1979 to 2001.

3. RESULT

To examine the effects of the high resolution model in more detail, we compared the model and the observation results of Hawaii - Tahiti Shuttle Experiment (Wyrtki and Kilonsky, 1984) in the equatorial region. Fig. 1 shows the zonal velocity, temperature and salinity distributions along 155°W for the observation, 1/6° model and 1/12° model results, respectively. The peculiar feature of zonal flow observed in equatorial region is very well simulated by the 1/6° and 1/12° models. Especially, the small scale motion of alternate east-west flow below 200 m in this region is well simulated by 1/12° model rather than 1/6° model due to better horizontal resolution.

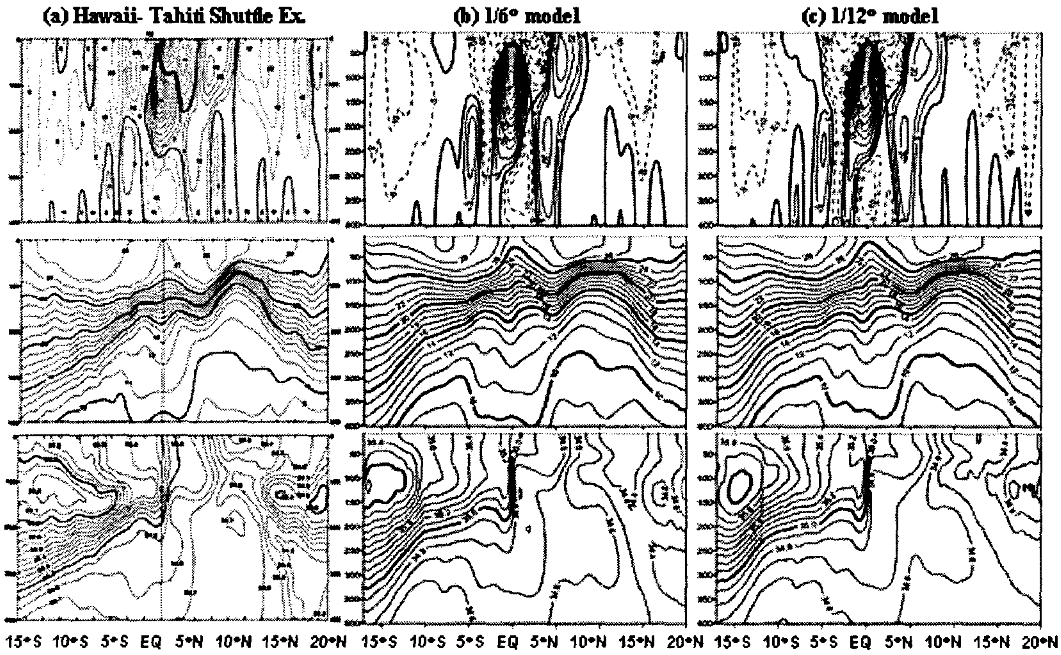

Fig.1 Cross-Section of the zonal-mean velocity, temperature and salinity in (a) Hawaii-Tahiti Shuttle Experiments and along 155°W (b) 1/6° model and (c) 1/12° model.

Kinetic energy (KE) field of annual mean current for 1/6° and 1/12° models are shown in Fig. 2. In this KE distribution, the KE is largest in the so-called strong current regions such as western boundary current region such as the Kuroshio and EAC region, the equatorial current region for the cases the value of KE exceeds 1000 cm^2/s^2. The areas of low KE less than 200 cm^2/s^2 extend over the interior region.

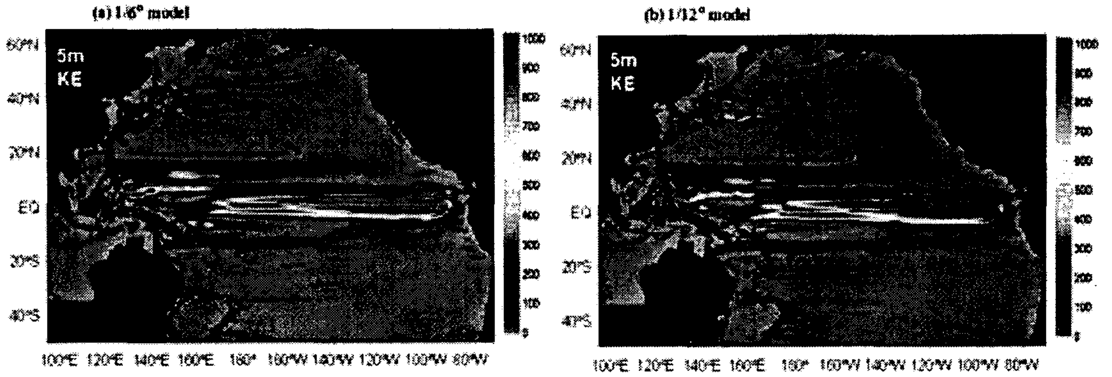

Fig. 2. Kinetic energy field at 5 m depth (a) 1/6? model and (b) 1/12? model.

Fig. 3 shows the Root-Mean-Square Deviation (RMSD) of sea surface height as derived from the 1/6° and 1/12° model simulation. It is seen that the model is capable producing the basic features of the sea level variabilities over many parts of the Pacific Ocean. In the North Pacific, strong sea level variabilities are evident near the Kuroshio region. Sea level variabilities are only evident in areas where there are strong mean currents such as the Equatorial current. In the western equatorial Pacific, strong sea level variabilities are seen in the Philippine Sea near 10°N ? 20°N and 120°E- 160°E. In the eastern equatorial Pacific, strong sea level variabilities are evident near the North Equatorial Countercurrent around 5°N ? 10°N.

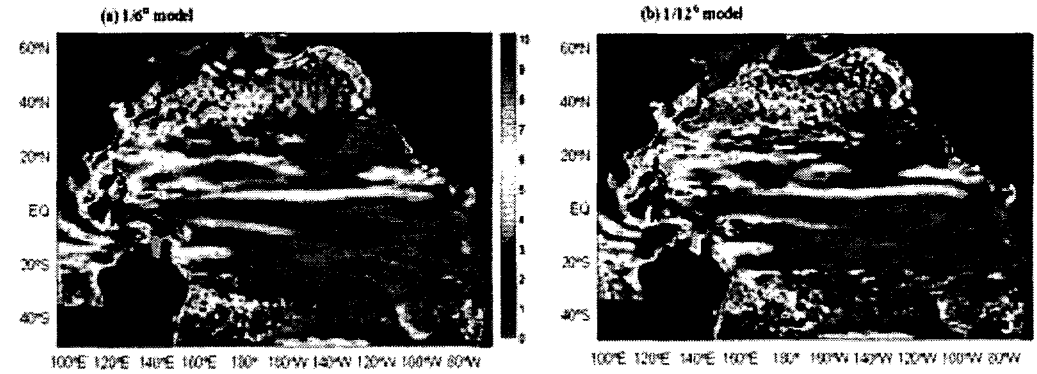

Fig. 3. RMSD of sea surface height for the (a) 1/6? model (b) 1/12? model

Historical hydrographic surveys show that the Kuroshio flowing along the East China Sea (hereafter, ECS) continental shelf flows out through the Tokara Strait and feeds the Kuroshio south of Japan. However, the volume transport through the Tokara Strait is only half (20 ~ 25 Sv) of that of the Kuroshio south of Japan (45 ~ 50 Sv) suggesting the existence of 뱧 missing component of the Kuroshio transport? somewhere. Many researchers have been thinking that there should be a northeastward current along the Pacific side of the Ryukyu Islands (hereafter, RI), which supplies the missing transport to the Kuroshio. However, until recent years, any currents with enough volume transport to supply the missing transport had not been detected along the Pacific side of the RI due to a unique current structure with a subsurface core and strong variability.

The stream function field of volume transport in Fig. 4 and the schematic view of the volume transport budget in Fig. 5 clarify the volume transport supply to the RC. The volume transport of the RC is about 5.7 Sv at its origin near the strait east of Taiwan and gradually increases to about 15.5 Sv at Okinawa and about 21.3 Sv at Amami-Ohshima. This increase of volume transport is compensated by a broad westward flow between 20캮 and 26캮 in the western Pacific Ocean.

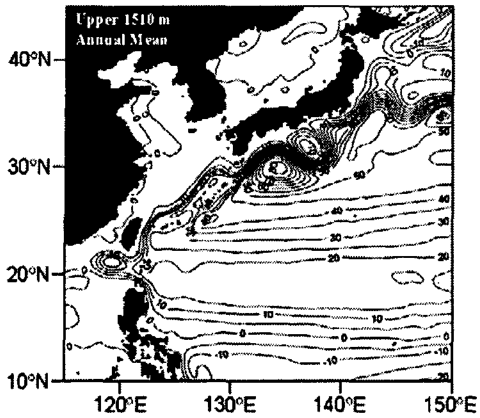

Fig. 4. Five-year mean volume transport stream function in the northwestern Pacific Ocean for the upper 1,510 m. The contour interval is 5 Sv.

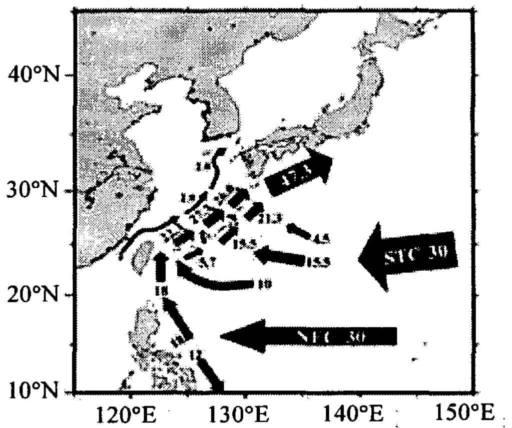

Fig. 5. Schematic view of volume transports in the northwestern Pacific Ocean based on the stream function in Figure 5

4. Conclusion

The lack of numerical resolution with Ocean General Circulation Models (OGCMs) has long been considered to be one of the major limiting factors in basin scale modeling. With high supercomputer resources it is possible to perform basin scale 뱲ddy-resolving? modeling. In this study, the high resolution Pacific Ocean model with 1/6° and 1/12° horizontal resolutions with 70 vertical levels are used to present an analysis of the salient features of the mean circulation and water masses in the Pacific Ocean. We have found that the simulation using high resolution Pacific Ocean model shows remarkable improvements in reproducing features of mean circulation and water masses.

REFERENCES

[1] Lee, H. C., and J. H. Yoon, 1994: On the free surface OGCM. *Proc. of fall meeting the Japan Oceanogr. Soc.*, pp. 225-226 (abstract).

[2] Levitus, S., R. Burgett, T. P. Boyer 1994: World Ocean Atlas 1994 Volume3: Salinity. NOAA Atlas NESDIS **3**, 99 pp.

[3] Levitus, S., T. P. Boyer 1994: World Ocean Atlas 1994 Volume4: Temperature. NOAA Atlas NESDIS **4**, 117 pp.

[4] Wyrtki, K., and B. Kilonsky, 1984: Mean water and current structure during the Hawaii-Tahiti Shuttle Experiments. *J. Phys. Oceanogr.* **14**, 242-254.