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A Nested OGCM Simulations with Restart Dataset
--Strategy for Simulating Fine Structures of Circulation for NW Pacific

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1. INTRODUCTION

Laboratory for Coastal and Ocean Dynamics Studies at SungKyunKwan University and Department of Physical Oceanography, Institute of Oceanology, Chinese Academy of Sciences has been working on cooperative studies on ocean circulation. At initial stages we have used GFDL/MOM for simulating global ocean with 1° , 1/2° in diagnostic manner and independent 1/3° resolution model for northern Pacific(Wei *et al*, 2000). At the present stages with a NSFC (Natural Science Foundation of China) and KOSEF (Korea Science and Engineering Foundation) jointly supported program, we are continuing OGCM studies focussing on East Asian Marginal Seas(EAMS). In the present paper we will briefly describe the preliminary results from nested OGCM simulations using GFDL/MOM (version 2.0 and 3.0) and NCAR/NCOM. We also have attempted to use the CR(control run) simulation results from regionally refined, NCAR/CSM (Choi *et al*, 2000) for making restart dataset for these nested models to avoid lengthy integration for spin up. The computing systems we used are LINUX-based alpha CPU warewolf clusters and multiple CPU based TRUE64UNIX system for accommodating parallel MPI operation of models. Some of future strategy for our ocean simulation is also briefly presented and discussed.

2. APPROACH METHOD

There are four kinds of models what we used--MOM1.1, MOM2.0, MOM3.0, and NCAR/NCOM. All of these models are based on Kirk Bryan(1969)'s work. As described by Bryan, the equations consist of the Navier-Stokes equations subject to the Boussinesq,hydrostatic,and rigid lid approximations along with a nonlinear equation of state which couples two active tracers, temperature and salinity to the fluid velocity.

But for MOM3.0, there is a main development, which is, not only rigid lid method, but also free surface method are considered. That means we can establish the rigid lid model or free surface model based on MOM3.0. Much of the foundations for the free surface approach in MOM were established by Blumberg and Meller (1987), Killworth *et al.* (1991) and Dukowicz and Smith (1994). MOM's free surface is completely documented in the paper of Griffies, Pacanowski, Schmidt, and Balaji (2000).

The governing equations described by Bryan (1969) were already discussed at the previous paper (Wei *et al.*, 2000). We do not want to discuss it here again.

Our interest is the circulation of the EAMS, which

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includes the East China seas, South China Sea, and Japan/East Sea. To study the circulation of this region, people often just run small region model giving the inflow and outflow around the open boundary. It is valuable to represent the current system of the region. But, because it depends on the inflow and outflow which is prescribed by the modeller,some people will suspect the result of this kind of model. Therefore, we use the global model, which covers world oceans and does not need open boundary conditions, to study world ocean circulation, especially the EAMS.

At initial stage, we established some diagnostic models, global ocean models with 1° , 1/2° , and North Pacific ocean model with 1/3° . These models were driven by Hellerman and Rosenstein(1983)'s wind stress, and Levitus(1994)' temperature and salinity with the real topography. This kind of diagnostic model is not traditional diagnostic model, it is called Robust Diagnostic model (Sarmiento and Bryan, 1982). From these diagnostic models, we reproduced the general circulation of the world oceans. Especially, the basic patterns of the general circulation of EAMS were reasonably well reproduced, though Fujio *et al.*(1991, 1992) and Semtner *et al.*(1988,1992) have not resolved marginal seas adequately because of their coarse resolution of the model grids. We have also analyzed the water, heat and salt transport crossing some representative sections (Wei *et al.* 2000), and we found that the results are reliable comparing with the some observations and other numerical results.

At the present stage, we start the prognostic study for EAMS using global model. We are presently setting up six models for this aim, the first one is nested model based on MOM2.0 initialed by Levitus (1994)'s hydrographic data set. The second on is similar with the first one but initialed by the restart data from the CR(control run) simulation results from regionally refined, NCAR/CSM (Choi *et al*, 2000). The third one is free surface model based on MOM3.0 initialed by Levitus(1994)' hydrographic data set. And the fourth one is similar with the third one but initialed by the CR simulated results(Choi *et al*, 2000). All of these six models are nested model with 1/6° resolution at EAMS with 3° background resolution. The last two models are based on NCAR/NCOM, one is initialed by Levitus (1994)' hydrographic data set, and another one is initialed by CR's results (Choi *et al*, 2000). The horizontal resolution is 1/3° for EAMS with 2.4° background resolution.

3. EXPERIMENTS

At the present stage, as described above, we set up six prognostic global nested models to study EAMS's general circulation. The surface forcing of these models is interpolated from Hellerman and Rosenstein (1983)'s wind stress. And surface heat flux and salt flux are from GFDL and NCAR. At the sea surface boundary, we also restore Levitus (1994)' SST and SSS into the models. The topography is taken from DBDB5 data set (National Geophysical Data Center, Boulder, Colorado).

The details of the models are shown in table 1.

Table 1. The information of the models

Model	Resolution	Initial field	Basic Model
M1	1/6°(3°)	Levitus	MOM2.0
M2	1/6°(3°)	CR	MOM2.0
M3	1/6°(3°)	Levitus	MOM3.0
M4	1/6°(3°)	CR	MOM3.0
M5	1/3°(2.4°)	Levitus	NCOM
M6	1/3°(2.4°)	CR	NCOM

Note: For the resolution, the value inside parentheses is background resolution.

For M1 to M4, the water volume is divided into 15 levels (see table 2).

Table 2. Depths and Thickness of Model Levels

Level	Thickness(cm)	Depth of T-grid(cm)
1	2500	1250
2	2500	3750
3	2500	6250
4	2500	8750
5	3462	11250
6	7232	15674
7	14467	25715
8	24581	44609
9	36754	74876
10	50000	118116
11	63246	174876
12	75419	244609
13	85533	325715
14	92768	415674
15	96538	511250

For M5 and M6, the water volume is divided into 45 levels.

The model grid structures of the models from M1 to M4 are same (see fig.1 and 2). Fig.1 is for whole region, and fig.2 is for EAMS.

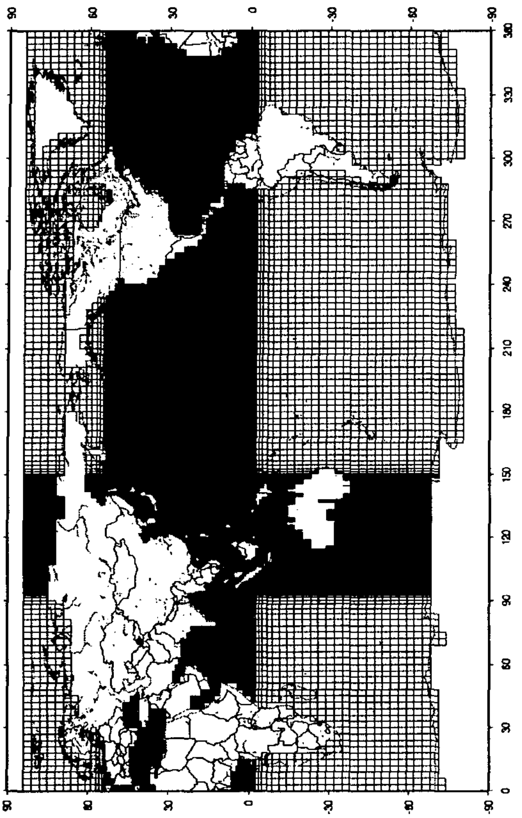

Fig.1 The grid of the model (whole region)

All the forcing data are monthly mean, and they are time interpolated to the model time step.

4. PRELIMINARY RESULTS

Limited to the length of the present paper, we just give some preliminary results of M1. As the main results, we give the transport stream function and the upper ocean velocity fields of EAMS in the winter (January) and summer (August).

Fig.3 shows the simulated stream function (in Sv, $1\mathrm{Sv}=10^6\mathrm{m}^3/\mathrm{s}$) of EAMS in wintertime (January), and fig.4 shows the one in summertime (August).

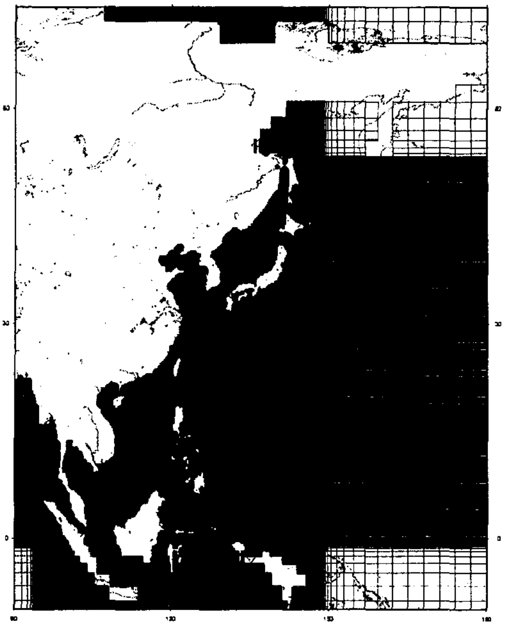

Fig.2 The grid of the model (for EAMS)

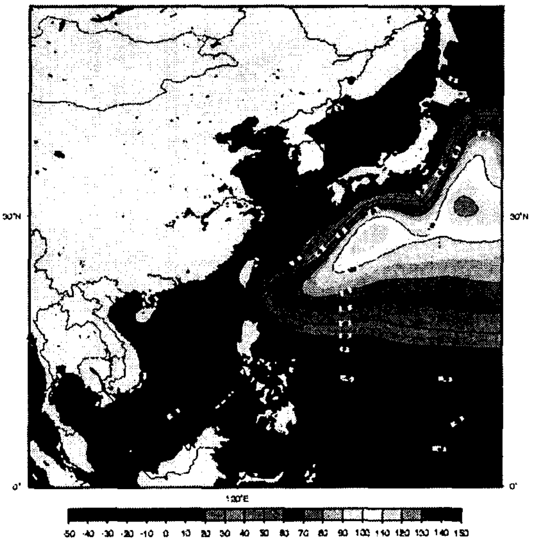

Fig.3 The model-produced transport stream function (in Sv) in wintertime (January)

From Fig.3 and 4, we can see the main structure of the circulation of EAMS. The western boundary current is strengthened and thus more realistic, comparing with Fujio (1992)'s result and the result of our previous works. It predicts that the model with finer resolution can represent the western boundary current better than coarser resolution model. And for the South China sea, more detailed current structures are reproduced.

Fig.5 and 6 show the model-produced upper ocean currents of the EAMS in the wintertime and summertime respectively.

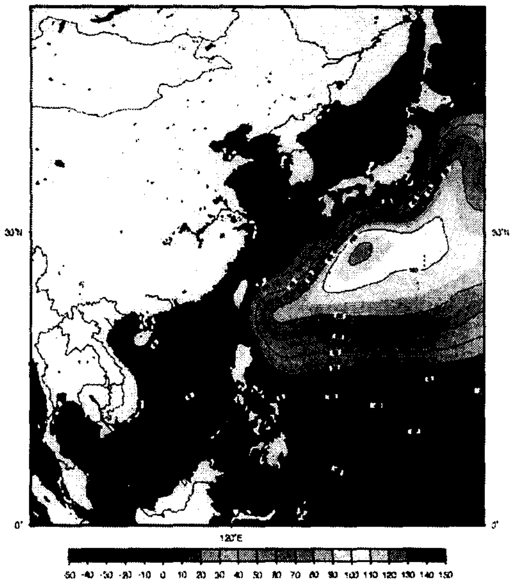

Fig.4 The model-produced transport stream function (in Sv) in summertime (August)

Because the model resolution is so fine, if we draw the current figure with every grid, the figure will be very unclear, that means we can not get the details from the figures. Therefore, we draw the current vectors every two grids, it makes the figures very clear.

From the two figures, we can find that, the Kuroshio, Taiwan-Tsushima-Tsugaru Warm Current System (T-T-T WCS) (Fang, *et al.* 1991), SCS Southern Anticyclonic Gyre in summertime, SE Vietnam Off-shore Current in summertime, SCS Southern Cyclonic Gyre in wintertime and Guangdong coastal current (Fang, *et al.* 1998) are reproduced reasonably well.

5. DISCUSSION

As described above, it is known that the fine resolution model is valuable to represent the current system of EAMS. At the Fujio, *et al.*(1991,1992)'s study and our previous works, the resolutions of the models were coarse, so that the western boundary current was not represented well, as well as some small scale eddies are not represented at all.

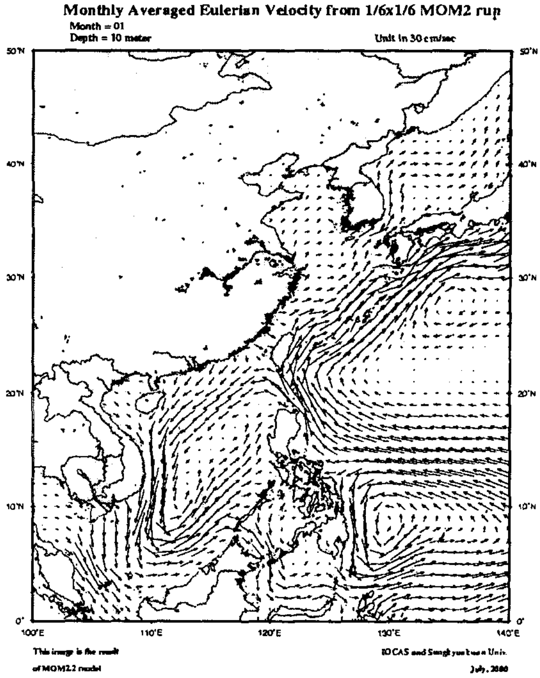

Fig.5 The model-produced upper ocean circulation of EAMS in wintertime (January)

At the present study, since the Kuroshio is represented rather well, but it still has some unreasonable shortages. For example, the wintertime surface currents of Kuroshio are not strong enough. This problem may be caused by the coarser heat flux and salt flux data, SST and SSS restored into the model.

The current system of the East China Seas is not represented well. The Yellow sea warm current and the current system of Bohai sea are not represented at the present study. It also may be caused by the coarser hydrographic data at the local region.

The current system of South China sea and T-T-T warm current system are represented well at the present study. It is inspiring to us, because it is not reported that global model reproduced the current systems in the region until now.

6. FURTHER WORKS

It is just a beginning stage for us to study the circulation of EAMS using global model. We have taken some advances already, but there are still many works that we need to do.

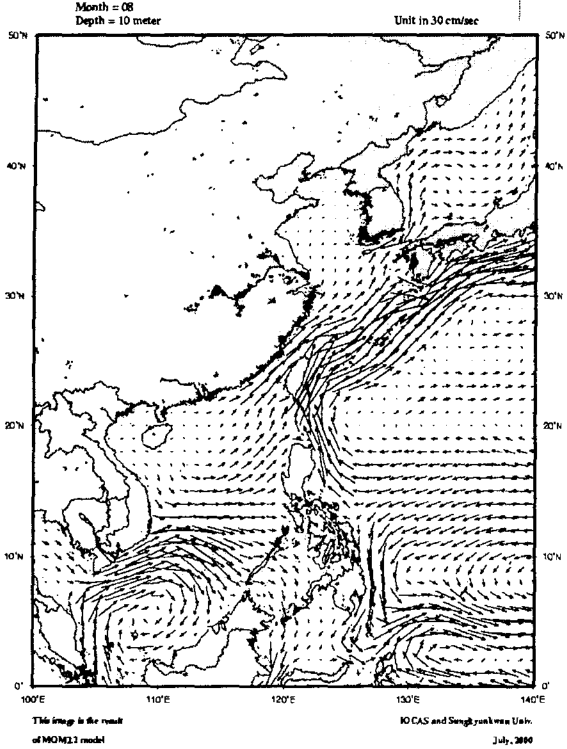

Fig.6 As fig.5 but of summertime (August)

We are continuing this kind of work with a NSFC (Natural Science Foundation of China) and KOSEF (Korea Science and Engineering Foundation) jointly supported program. We are running the six models described above. We believe that we can get some valuable ideas with comparing the results of these models what make us know the dynamic mechanism of the current system of EAMS. And then we will do more numerical simulation studies to uncover the dynamic mechanism of the current system of EAMS.

There are some ideas for the further numerical study:

1. Set up finer resolution numerical model. We think finer resolution is more valuable on studying the current system of EAMS.
2. More reasonable local hydrographic data for the EAMS.
3. Using data assimilation to get more reasonable results. We can use satellitic data and coastal observation data to adjust the result of the model. At the first stage, the nudging method which is the simple assimilation method is good choice, because it is similar with the restoring method of the diagnostic and present model. The next stage, we can use the adjoint model to do the data assimilation, since it is rather difficult and requiring supercomputing powers. Our approach is to modeling the global ocean since it is a pathway to understand dynamics of EAMS in NW Pacific.

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References

Blumberg, A. F.and G. L. Mellor (1987): A description of a three-dimensional coastal ocean circulation model. *Three-Dimensional Coastal Ocean Models*. **Vol.4**, N. Heaps, Ed., American Geophysical Union. 208pp.

Bryan, K.(1969): A numerical method for the study of the circulation of the world ocean, *Journal of Computational Physics*, **4**, 347-376

Choi, B. H., Kim, D. H. and Kim, J. W.(2000): Steric sea level change due to global warming in the Northwestern Pacific ocean. Submitted to Geophysical Research Letters.

Dukowicz, J. K. and R. D. Smith (1994): Implicit free-surface method for the Bryan-Cox-Semtner ocean model. *J. Geophys. Res.*, **99**, 7991-8014.

Fang, G. *et al.* (1998): A survey of studies on the South China Sea upper ocean circulation. *Acta Oceanographica Taiwanica*, 37(1), 1-16.

Fang, G. *et al.* (1991): Water transport through the Taiwan Strait and the East China Sea measured with current meters. *Oceanography of Asian MarginalSeas(Ed.K.Takano), Elsevier, Holland,* 345-358.

Fujio, S. *et al.* (1992): World ocean circulation diagnostically derived from hydrographic and wind stress fields, *J. Geophys. Res.*, **97**,11163-11176

Griffies, S. M., P. R. Pacanowski, M. Schimidt, and V. Balaji (2000): The explicit free surface method in the GFDL modular ocean model. Submitted to Monthly Weather Review.

Hellerman, S., and Rosenstein, M. (1983): Normal monthly wind stress over the world ocen with error estimates, *Journal of Physical*

Oceanography, **13**,.1093- 1104.

Killworth, P. D., D. Stainforth, D.J. Webb, and S.M. Paterson(1991): The development of a free-surface Bryan-Cox-Semtner ocean model. *Journal of Physical Oceanography*, **21**, 1333-1348.

Levitus, S. and T. Boyer. 1994b. *World Ocean Atlas*. **Vol.4**: Temperature, 117pp., NOAA, Washington, D.C.

Levitus, S., R. Bugett, and T.Boyer. 1994d. *World Ocean Atla*. **Vol.** 3: Salinity, 100 pp., NOAA, Washington, D.C.

Sarmiento, J. L., and K. Bryan(1982): An ocean transport model for the North Atlantic, *J. Geophys. Res.*, **87**, 394-408

Semtner , A.J., and R. M. Chervin (1988): A simulation of the global ocean circulation with resolved eddies, *J. Geophys. Res.*, **93**, 15502-15522.

Semtner , A.J., Jr., and R. M. Chervin(1992): Ocean general circulation from a global eddy-resolving model, *J. Geophys. Res.*, **97**, 5493-5550

Zexun Wei, Byung Ho Choi, and Guohong Fang.(2000): Water, Heat and Salt Transports from Diagnostic World Ocean and North Pacific Circulation Models. Submit. to Lar me (the preceding of the 10th PAMS/JECSS)

Zexun Wei, Byung-Ho Choi and Guohong Fang(2000): Diagnostic study of the World-Ocean circulation, I Velocity field and Stream Function. Submitted to Oceanologia et Limnologia Sinica (in Chinese with English abstract).

Zexun Wei, Byung-Ho Choi and Guohong Fang(2000): Diagnostic study of the World-Ocean circulation, II Water, heat and salt transports. Submitted to Oceanologia et Limnologia Sinica (in Chinese with English abstract).