Development of the parallel algorithm for advection analysis in the local sea

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1 Introduction

The research of Computational Fluid Dynamics (CFD) advances rapidly as the computer develops in recent years, and is used to elucidate a flow and the phenomenon with a flow in a wide field of the science and engineering. Especially, it often apply to the case that is to be not able to reproduce experimentally or is difficult to measure such as the environmental assessment, etc.. The oceanic phenomenon which is the theme of this study affect with the man society like the fishery etc. from the earliest times very much, and the observation for it has been continued as for, but it is difficult to understand the all phenomen in the ocean by the observation because the its scale is large. CFD is useful for the analysis of a oceanic phenomenon that is difficult to measure like this, and useful for a lot of fields in the geographical fluid dynamics.

There are a variety of space-scale and an elementary process included in it of oceanic phenomenon, and to what scale you pay attention, the way to estimate is different. It would be seen that there are many techniques for various scales, like ocean large circulation model using analytical technique by G. Veronis et al. at 60's, POM that is three-dimensional model and developed by the Princeton university in recent years, which are the model intended for the ocean of the earth scale and the several researches are been carrying out into the closing sea areas or the estuary in the Tokyo bay, the Osaka bay, and the Setouchi sea, etc.. On the other hand, surverying internal report, especially the Osaka bay is researched actively in the environmental assessment for the Kansai International Airport construction. There are the research by Horie et al. and ODEM which adopeted three dimension multi-layer model developed by Nakatsuzi et al..

However, a local area like the Japan Sea or the Japanese neighboring waters such as the land shelf and the coast region, which can be called the middle scale of the previous, is not analyzed still so much. Becouse, about the a local area, the scale of numerical calculation might grow further than that about the Osaka bay etc.. Especially in comparison with the Pacific Ocean, Japane Sea is closing sea area, and its structure is complex. The observation data about this is also a little.

Well, Russian ship "Nakhodka" sank in the Tottori Pref. offing of the Japan Sea in January 1997. And the accident that the heavy oil which spilled is washed to the seaside of Japan Sea occurred. It reached eight prefectures including Mikuni Beach in Fukui Pref. where the bow was washed, and the big disaster was broken out. It was able to be understood early where the ship sunk and how the oil spilled in this disaster, but it is very difficult to forecast the oil washing to the seaside of Japanese coast accurately. Because the numerical analysis is intended for Japan Sea was not done in the past. In addition, as it was necessary to take effective correspondence in a limited time, accurate presumption for passage was needed in a short time.

Then, we target "Japan Sea" as "Local ocean" in the title in this research. And, we aim at below, we would like to costruct the basic ocean model on the computer which became a base to predict the drift for the broken oceanic pollution like the oil spilled disaster and develop a suitable parallel algorithm for this ocean model, and we plan to speed up the calculation. As numerical calculation for the entire of Japan Sea have not been carried out yet, it must necessary to elucidate a whole its image for understanding the structure. In addition, constructing the Japan Sea model, it becomes possible to forecast the drift wherever the accident occurs.

2 Modeling and Parallelization

Modeling Japan Sea, we would like to use the assumption and the approximation below, the sea water is incompressible, the hydrostatic pressure approximation, approximation of Boussinesq , the flow is constructed from the baroclinic flow by an internal mode and from barotropic flow by an external mode, and we takes the influence of the wind into consideration. And so, we obtain the Navier-Stokes's equation, the diffusion equation of temperature and salinity from consevation of mass, momentum, temperature and salinity as a basic equation system. It was discretized by using the leap-frog method and the baroclinic flow was solved explicitly. We would like to solve the barotropic flow by introducing the sream function into the barotropic flow, discretizeit by the nine point difference in the spase, and use the pre-conditioned CG method.

Next, We have developed Japan Sea model by using this ocean model, and we experimented on the reserve including the verification of the model by 1PE on J90 manufactured by Cray Co. Ltd.. We used elevation data ETOPO5 which United States NGDC was making public. As a result, the influence of the Coriolis force and geographical features in the Japan Sea, etc. were able to be expressed well. However, when we constructed Japan Sea model with the grid resolution of 2km at which we aimed at first, it turned out that the used memory consumed a very large amount of 2.2GB and computing time of about

96 hours at CPU time by the time integration for one day. Then, after we considered this problem, we concluded to parallelize for the improvement of the calculation speed, and to introduce the nesting method for saving of memory use and the construction of a ocean model efficiently. At first we solve the region by rough resolution, catch the more partial region with fine resolution, and put the result as a boundary condition. With nesting method, we will be able to obtain a detailed result of aimed partial region. We can calculate efficiently by repeatedly solving a small model.

We used the domain decomposition to make to the parallel, which was a general technique, and parallelized the step where the baroclinic flow was solved explicitly (It is called a parallel region). The grid point row of the same latitude with a certain width is made a group by dividing this model with the data structure of three dimensions along the direction of latitude. Each processor is allocated this group, and a parallel region is executed by the multitask. We used MPI for impremeting a parallel code. The performance experiment which used a hexahedron model was done on T3E manufactured by Gray Co.Ltd., and we obtained speed-up ratio is 7.55 at 16PE.

3 Experience and discussion

We costructed the ocean model with quadruple grid resolution of the target resolution on the assumption of nesting method, experiment and considerate with this. When an external factor was only a Coriolis force, and the temperature distribution was given, meso-scale eddy because of geographical features was seen.

Next step, we set the boundary condition in the Tsushima islands west water service, and the reproduction of the Tsushima current was tried. it was seen that the current flowed into the southern part of the Japan Sea, the front was formed, the current flowed into the Toyama bay, but Tsushima current prime branch which went north according to the Japan Islands was not able to be reproduced. We thought that the purpose of this is to adopt constant for the eddy viscosity coefficient. The turbulent of the subgrid scale could not be expressed because of this constant.

In addition, we examined the influence of the wind. The influence of the sea surface static on the flow is few at velocity of the wind 5m/s level, but the flow was under control by the drift current when the wind became 10m/s . Moreover, the settling situation deteriorated at the stage where the strem function is solved because an external factor such as the currents was taken for this Japan Sea model, number of iteration increased, and computing time had grown.

4 Concluding remarks

We thought that it is only at the stage where a primitive numerical model of Japan Sea is constructed on the computer at the time. In addition, it will be necessary to work on the accuracy improvement of the model and the speed-up of the calculation in the future. There are reproduction of a real current or the cold water mass movement

by the introduction of a turbulen t model (for instance, coefficient of viscosity of SGS), impremen tting nesting, and an accuracy impro vemen t by the application of remotesensing, impremen tation of estimate to drift, etc. as the former. The latter is parallelization of pre-conditiond CG metho d that is worked out by serial pro cessing now