JST Basic Research Programs

C R E S T

(Core Research for Evolutional Science and Technology)

Annual Report for Research Work in the fiscal year 2006

Research Area :

High Performance Computing for Multi-scale and Multi-physics Phenomena

Research Theme :

Marine Environmental Simulation for Future Projection of Marine Ecosystems

Name of Research Director, Belonging and Title:

Yasuhiro Yamanaka (Hokkaido University, Faculty of Environmental Earth Science, Associate Professor)

§1. Outline of Research Work

We will develop simulation techniques by integrating the models for marine ecosystem and biogeochemical processes developed in various fundamental fields of ocean science in order to investigate the impacts of global warming and ocean acidification on marine ecosystems and fisheries resources. To examine the detailed contribution of various processes and the relationships among them, we will develop and improve the ecosystem models of different complexity as part of our integrated model. We will also develop two types of models. One is an online model in which both biogeochemical tracer distributions and physical fields such as currents and hydrography are computed simultaneously. The other is an offline model in which only biogeochemical tracer distributions are computed using the physical fields computed in advance with Ocean General Circulation Models (OGCMs). Using the model we will conduct historical experiments reproducing the observed biomass from pre-industrial to present states and future projection experiments (from present to 100 years in the future) based on the IPCC carbon dioxide emission scenario (e.g., A1B). This study is characterized by domestic and international collaborations in various fields in aiming for establishment of future projection techniques by integrating the individual models.

§2. Content of Research Work

To clarify the effect of global warming and ocean acidification associated with the increase in atmospheric carbon dioxide level year by year, we will develop and improve an integrated marine ecosystem and fish resource model. Using this model we will also conduct historical experiments reproducing the observed biomass from pre-industrial to present states and future projection experiments (from present to 100 years in the future). To examine the detailed contribution of various processes and the relationships among them, we will use ecosystem models of different complexity as part of our integrated model. We will develop a key technique (called off-line method), an independent calculation of biogeochemical tracer distributions from Ocean General Circulation Models (OGCMs) in which we calculate the physical fields such as current fields and distributions of temperature and salinity. We will also calculate using the on-line method, which simultaneously calculates both biogeochemical tracer distributions and physical fields. We will develop an integrated model using both off-line and on-line methods. Our project, has the following three stages of development:

[1] Improve our basic technology for developing an integrated ocean ecosystem and fish resource model,

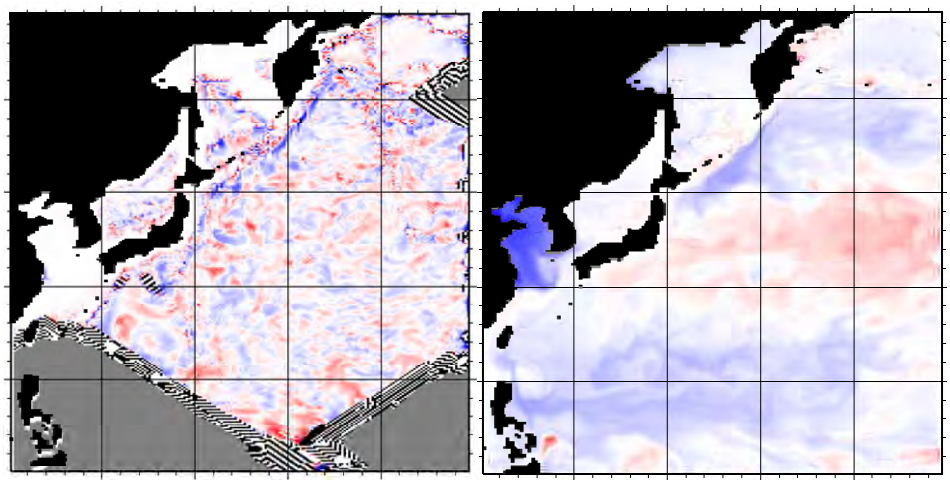
[2] develop an integrated ocean ecosystem and fish resource model,

[3] simulate historical and future projection experiments.

In this fiscal year, we have developed the technique for our off-line method and improved individual sub-models (parts of the integrated model).

[1-1] Development of the technique for the off-line method

The offline method is based on tracer equations that are developed by extracting the corresponding routines from the ocean general circulation model and coding the source program. In fiscal year 2006, Hashioka (Yamanaka Group) developed the offline method for the western North Pacific Ocean with 1/4x1/6 degrees spatial resolution based on the COCO (CCSR Ocean Component Model developed at Center for Climate System Research, University of Tokyo). It is feasible now to integrate the model equations for ideal tracer (conserved in advection-diffusion process) for more than several years. Therefore, seasonal simulation of ocean ecosystems is feasible. Masuda also has been developing another offline model based on the OFES (OGCM for the Earth Simulator

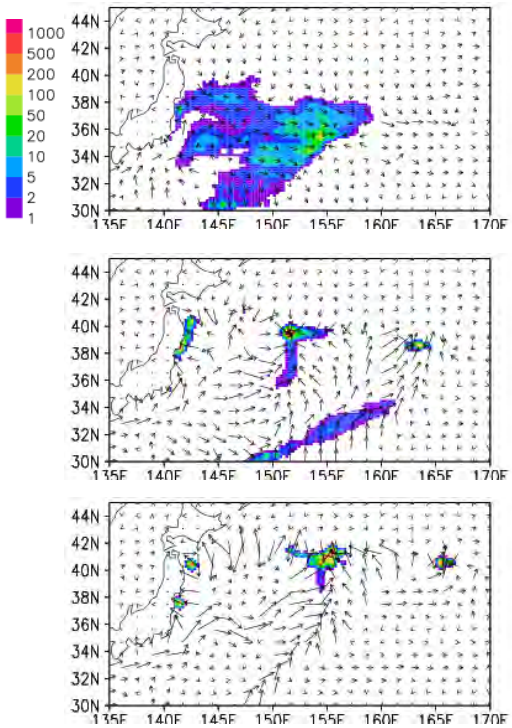


Concentrations of the idealized tracer. The regions in blue (red) represent -1% lower (+1% higher) than the initial concentration that should be conserved. In grey region, numerical instability occurs. The left panel shows the result using the original code in the COCO model (10 days run). The right shows the result from the revised version improved in lateral/bottom boundary conditions and adopted vertical diffusions instead of convective adjustments (1 year run). The result after the improvements exhibits natural change in concentrations due to surface precipitation/evaporation and river runoff (diluted in Yellow Sea and concentrated in the Kuroshio and its extension region due to evaporation).

developed at the Earth Simulator Center/JAMSTEC). Time integration of an ideal tracer for about three months is feasible, although the treatment of vertical diffusion is still under development.

[1-2] Improvement of individual model

The objectives are to check the detailed contributions of various processes and the relationship among them by intercomparison of ecosystem models of different complexity, each embedded into our integrated model, and also to evaluate the optimum level of complexity according to each research purpose. In this fiscal year, we have developed and improved three ocean ecosystem models: NPZD (Nutrient-Phytoplankton- Zooplankton-Detritus), NEMURO (North pacific Ecosystem Model Used for Regional Oceanography), and eNEMURO (extended NEMURO). Comparison between a box model and observed data at two observation sites east of Japan (one in the subarctic region, the other is in the subtropical region) has been performed through collaboration with Yoshie (research collaborator). Yamanaka developed common source code to allow sharing models among our research groups for this study. As for the fishery resources model based on NEMURO.FISH, a simple Population Dynamics Model was combined with a two-dimensional model including ocean current and fish swimming processes by Shido in order to combine the Bioenergetics Model for saury (a small pelagic fish) into the integrated model.



Population number density of saury, i.e., individual numbers per $1x10^4 km^2$ (top: April, middle: June, bottom: August). This is the case in which the initial 10,000 individual saury is conserved under the assumption of no mortality. Arrows represent the sum of ocean current and swimming speed by saury itself. The results exhibit that saury moves toward high zooplankton region.

Research collaborations:

To discuss international research collaboration, Yamanaka, Ishida, and Sasai held a meeting in March 2007 with James Orr (Marine Environment Laboratories, IAEA), who is a leading scientist in the field of oceanic acidification. Dr. Orr and we have progressed ocean carbon cycle modeling research in the international project OCMIP. At the meeting we were informed that scientists from 28 research laboratories of 10 nations are planning to submit a proposal for a European Project for Ocean Acidification (EPOCA, 1.1 billion yen for four years, about 30% for modeling studies) in

June 2007. The proposal is expected to be supported with high probability; it includes laboratory experiments, shipboard observations, and modeling concerning oceanic acidification. As requested by the leading scientist of EPOCA, Yamanaka sent a letter of support to represent that he would like to collaborate with the EPOCA project if it is funded. Hashioka stayed for about two months and Yamanaka visited at the laboratory of Dr. Corinne Le Quere (East Anglia University). As a result, we have obtained access to the ecosystem model PlankTOM5 which she has developed .We plan to conduct intercomparison studies using PlankTOM5 and our model.

The Intergovernmental Panel on Climate Change (IPCC) reported "Increasing atmospheric carbon dioxide concentrations lead to increasing acidification of the ocean. Projections give reductions in average global surface ocean pH of between 0.14 and 0.35 units over the 21st century." in the 4th assessment report released in February 2007. Since then society has paid still more attention to oceanic acidification.

Two research projects related with this CREST have been established in Japan. One is supported by the Global Environment Research Fund (Ministry of the Environment), and the other is the 21st Century Climate Change Prediction Innovation Program (Ministry of Education, Culture, Sports, Science and Technology). These projects will enable us to evaluate the future projection of ecosystems and fisheries with global warming by using the marine environmental simulation model being developed through CREST. Yoshie (research collaborator) and Yamanaka also have started research collaboration with the project "Development of techniques for evaluation of and countermeasures for influences of global warming on agriculture, forestry and fisheries" in which they will develop the eNEMURO model.

These research collaborations (listed above) make the integrated model and simulation techniques being developed in this CREST project even more important.

§3. Formation of Research Work

Yasuhiro Yamanaka

[1] Fundamental techniques for development of the integrated marine ecosystems and fishery model.

[1-1] Development of the offline technique based on the COCO model and its evaluation

[1-2] Improvements of individual models

Akio Ishida

[1] Fundamental techniques for development of the integrated marine ecosystems and fisheries model.

[1-1] Development of the offline technique based on the OFES model and its evaluation

[1-2] Improvements of individual models

§4. Publication of Research Results

（4－1） Publication of Thesis (The original Work)

① Number of Publications (0 times-Domestic, 0 times-International)

（4－2） Patent Application

① Cumulative Number

1) Patent Applications in the fiscal year 2006 (Domestic- 0 Cases, Oversea- 0 Cases)

2) Cumulative number of Patent Applications for the research period of CREST (Domestic- 0 Cases, Oversea- 0 Cases)

3) Details for this fiscal year

a) Domestic Application (0 cases)
Oversea Application (0 Cases)