Study on the Diagnostics and Projection of Ecosystem Change Associated with Global Change

Project Representative

Michio J. Kishi — Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology

Authors

Yasuhiro Yamanaka[*1,2], Akio Ishida[*1], Yoshikazu Sasai[*1], Maki Noguchi Aita[*1], Taketo Hashioka[*1], Hiroshi Sumata[*2] and Takafumi Hirata[*2]

*1 Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology

*2 Faculty of Environmental Earth Science, Hokkaido University

In this project we will improve the ability to simulate the present status of ocean climate and ecosystems and clarify effects of climate variability on marine biogeochemical cycles and ecosystems by using multiple ocean general circulation models (GCMs) with multiple ecosystem models including marine biogeochemical cycles. Taking advantage of our high-resolution general circulation model, we have investigated the impact of fine scale physical variability on the marine ecosystem and found that cyclonic eddies affected approx. 20% of biological production in the Kuroshio Extension region. We also have developed an advanced ecosystem model including some key biogeochemical processes, e.g., optimal nutrient uptake kinetics of phytoplankton, iron cycle and aggregation processes for sinking particles. The new model is used for an international project on model intercomparison "The MARine Ecosystem Model Intercomparison Project (MAREMIP)". We have also begun developing a model including stable isotope compositions of carbon and nitrogen to simulate the trophic position of consumers in the food web.

Keywords: Ecosystem, Biogeochemical Cycles, Global Change, Ocean General Circulation Model

1. High resolution modeling of biogeochemical cycles and ecosystems

This study has made progress by using a high resolution model, the Ocean general circulation model For the Earth Simulator (OFES) including a simple ecosystem model (Nutrient-Phytoplankton-Zooplankton-Detritus, or NPZD type), with a horizontal resolution of 0.1 degrees. Using the OFES-NPZD model, we have published scientific results on the effects of the mesoscale eddies on the marine ecosystem in the Kuroshio Extension (KE) region [1]. The model reproduces high chlorophyll concentration corresponding to low sea surface height (SSH) associated with cyclonic eddies (Fig. 1), because the cyclonic eddies lift nutrient-rich water into the euphotic zone. The number of the cyclonic eddies and area-averaged surface chlorophyll concentration within the cyclonic eddies are shown in Fig. 2. On average two cyclonic eddies per year are detached to the south of the KE jet and they propagate westward. The area-averaged surface chlorophyll concentration within the cyclonic eddies is considerably higher (by two to seven times) than that outside the eddies (Fig. 2b, c). This gives an indication of the impact of the eddies on the overall chlorophyll concentration. The cyclonic eddies contribute about 20% of the area averaged surface chlorophyll concentration in this region.

2. Process modeling in marine ecosystems

Using a 3-D marine ecosystem model NEMURO (North pacific Ecosystem Model for Understanding Regional Oceanography), we published scientific results on the projection of marine ecosystems under global warming climate [2]. Maximum biomass during the spring bloom under global warming climate is found to occur 10 to 20 days earlier than under the pre-industrial climate. A study on the impact of global warming on Japanese common squid in the Sea of Japan was also published [3].

To improve the ability of the model to simulate marine ecosystems, we have advanced the model formulation for nutrient uptake by phytoplankton based on physiological acclimation. The optimal uptake kinetics describes observed nitrate uptake rates over wide ranges of nutrient concentrations better than the widely applied classical Michaelis-Menten equation [2]. We also improved the particles sinking process to simulate the dependence of aggregation on the size of particles. The iron cycle in the model is also revised. Implementing these

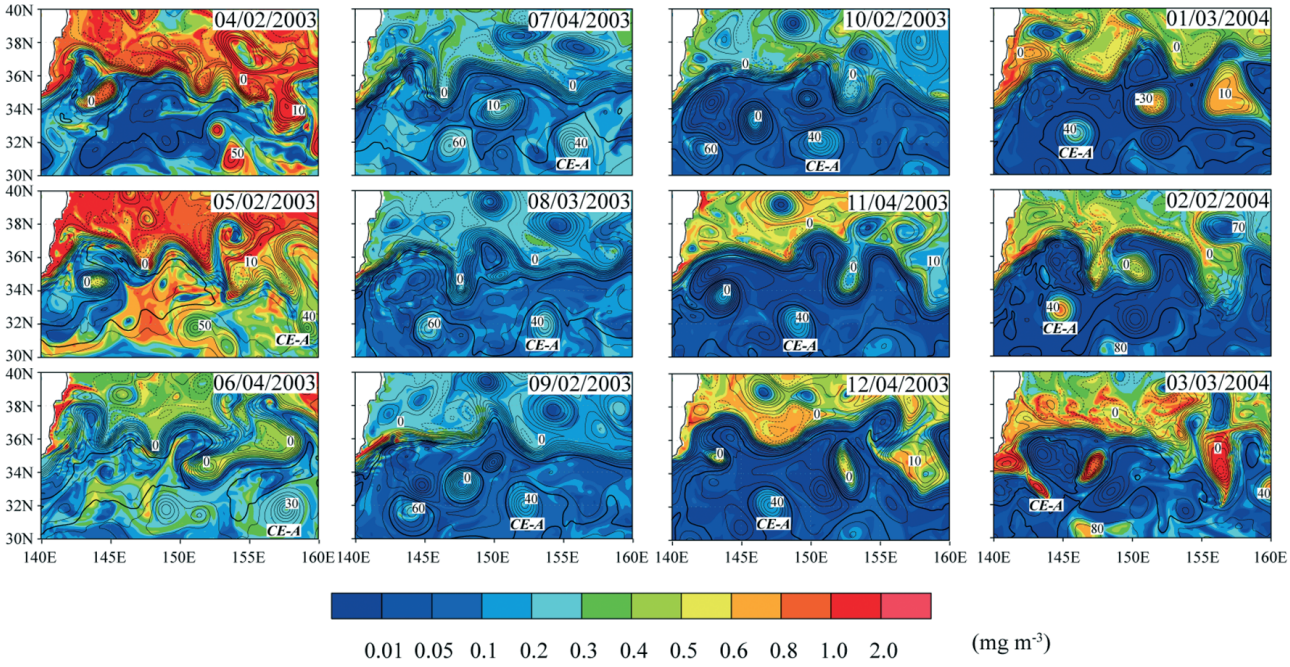

Fig. 1 Snapshots of surface Chlorophyll-a (color) and SSH (contour) from April 2003 to March 2004. In spring, the chlorophyll concentration reaches its highest value (2.0 mg m^{-3}) for the year, especially in the subpolar region and cyclonic eddies in the subtropical region. The high chlorophyll (0.8-1.0 mg m^{-3}) associated with the cyclonic eddies is at the same level as in the subpolar region.

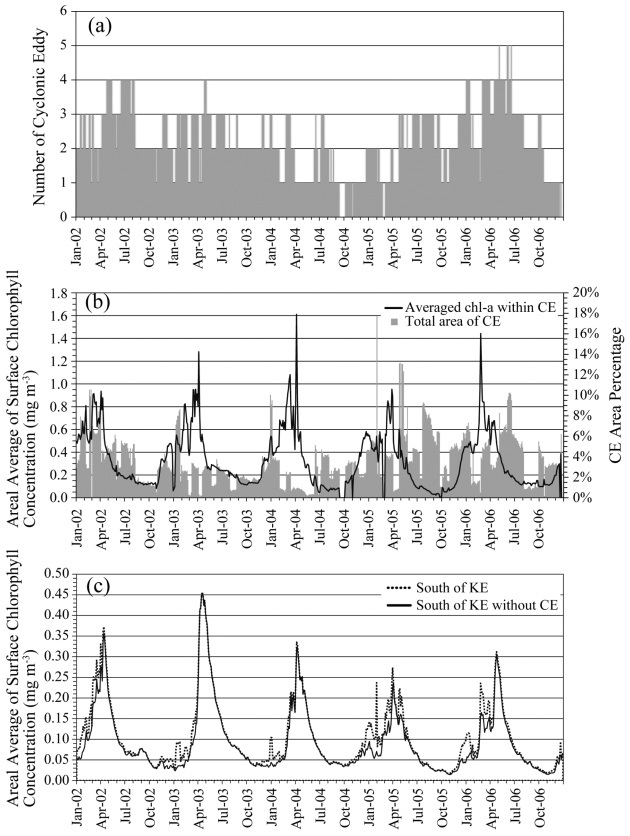

Fig. 2 (a) Number of cyclonic eddies (CEs) produced in the model, (b) areal average of the surface chlorophyll concentration within CEs (black line) and total surface area of CEs (grey bar), (c) the areal average of the surface chlorophyll concentration south of the KE jet (dashed line) and without CEs area (solid line).

new formulations and schemes in a 3-D model, we performed numerical experiments to investigate the performance of the new model. Using the new model we started a hindcast experiment for the MARine Ecosystem Model Intercomparison Project (MAREMIP) Phase 1. The offline version of the 3-D model developed in Hokkaido University [5] was transplanted on the Earth Simulator and tuned for long-term integration. We also started developing a model including stable isotope compositions of carbon and nitrogen to simulate the trophic position of consumers in the food web. Using the observed data in the northwestern North Pacific, we evaluated the trophic level and material flow related with the food habit of one key species in the Oyashio region.

References

[1] Sasai, Y., K. J. Richards, A. Ishida, H. Sasaki (2010): Effects of cyclonic mesoscale eddies on the marine ecosystem in the Kuroshio Extension region using an eddy-resolving coupled physical-biological model, Ocean Dynamics, DOI 10.1007/s10236-010-0264-8.

[2] Hashioka, T., T. Sakamoto, Y. Yamanaka (2009): Potential impact of global warming on North Pacific spring blooms projected by an eddy-permitting 3-D ocean ecosystem model, Geophysical Research Letters, 36, L20604, doi:10.1029/2009GL038912.

[3] Kishi, M. J., K. Nakajima, M. Fujii and T. Hashioka (2009): Environmental factors which affect growth of Japanese Common Squid, Todarodes pacificus, analyzed by a bioenergetics model coupled with a lower trophic

ecosystem model. Journal of Marine Systems, 78, 278-287.

[4] Smith, S. Lan, Y. Yamanaka, M. Pahlow and A. Oschlies (2009) Optimal uptake kinetics: physiological acclimation explains the pattern of nitrate uptake by phytoplankton in the ocean, Marine Ecology Progress Series, 384 Feature Article, p. 1-12.

[5] Sumata, H. T. Hashioka, T. Suzuki, N. Yoshie, T. Okunishi, M. N. Aita, T. T. Sakamoto, N. Okada and Y. Yamanaka (2010) Effect of eddy transport on the nutrient supply into the euphotic zone simulated in an eddy-permitting ocean ecosystem model, Journal of Marine Systems, doi:10.1016/j.jmarsys.2010.07.002.

地球環境変化に伴う生態系変動の診断と予測に関する研究

プロジェクト責任者

岸　　道郎　　海洋研究開発機構　地球環境変動領域

著者

山中　康裕 *1,2，石田　明生 *1，笹井　義一 *1，相田（野口）真希 *1，橋岡　豪人 *1，須股　　浩 *2，
平田　貴文 *2

*1　海洋研究開発機構　地球環境変動領域

*2　北海道大学　大学院地球環境科学研究科

本プロジェクトでは、空間解像度や複雑さの異なる複数の海洋生態系モデル、海洋大循環モデルを用いて、現在の気候条件における生態系変動再現実験、及び、温暖化気候における将来予測実験を通して、生態系の変動特性の定量化、生態系の将来予測、海域による海洋生態系の違いや卓越種の再現を目指した生態系モデル開発を実施する。今年度は高解像度海洋大循環・海洋生態系結合モデルを用いて、黒潮続流域における渦による海洋生態系へのインパクトを定量的に調べ、低気圧性渦が黒潮続流の南の生物量に約 20% 寄与していることを明らかとした。また、いくつかの鍵となる生物地球化学過程（植物プランクトンの栄養塩取り込み過程や鉄循環の導入、沈降粒子の凝集過程など）を導入した新モデルを開発し、中解像度の海洋大循環モデルに結合することで、国際研究計画 MAREMIP（MARine Ecosystem Model Intercomparison Project）の Phase 1 に対応して実験に着手した。さらに、オフライン版の 3 次元海洋生態系モデルの ES2 への移植、テスト計算を実施した。

キーワード:生態系, 物質循環, 気候変動, 高解像度海洋大循環モデル