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

Project Representative

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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 cyclonic eddies detached from the Kuroshio Extension on the marine ecosystem. We also have developed an advanced ecosystem model including some key biogeochemical processes, e.g., optimal nutrient uptake kinetics of phytoplankton. Using the new model we have performed hindcast experiments for an international project on model intercomparison "The MARine Ecosystem Model Intercomparison Project (MAREMIP)". We have also begun developing a marine ecosystem model for the Arctic Ocean to investigate the impact of climate change and sea ice decline on Arctic ecosystems.

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

1. High resolution modeling of biogeochemical cycles and ecosystems

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, we have investigated the effects of the mesoscale eddies on the marine ecosystem in the Kuroshio Extension (KE) region.

The model reproduces high chlorophyll concentration in the cyclonic eddies which are captured by satellite observations. The model also exhibits subsurface structures of chlorophyll and their seasonal variations [1]. Particularly interesting is that the subsurface chlorophyll in winter is high along the edge of the cyclonic eddies rather than in the centers. This is associated with deep mixed layer at the edge of the cyclonic eddies. Strong positive values of the vertical component of velocity around the edge of the eddy appear to contribute to the ring of high chlorophyll at depth. Comparison of the subsurface patterns of chlorophyll and velocity strongly suggests that both lateral and vertical advection influence primary production.

2. Process modeling in marine ecosystems

Based on the 3-D marine ecosystem model NEMURO (North pacific Ecosystem Model for Understanding Regional Oceanography), we have developed a new marine ecosystem model MEM (Marine Ecosystem Model coupled with OU Kinetics). 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 modified the plankton functional type (PFT) in the model to compare with satellite observations [3]. The particles sinking process and the iron cycle in the model are also revised. Implementing these new formulations and schemes in a 3-D model, we performed numerical experiments to investigate the performance of the new model with the offline version of the model [4].

In order to evaluate our marine ecosystem model (MEM) within Marine Ecosystem Model Intercomparison Project (MAREMIP), we conducted hindcast experiments for the period 1985-2009 using NCEP reanalysis data as an external forcing, and their results for the period 1998-2009 were compared with satellite observation. Figure 1 shows a linear trend of total chlorophyll-a (TChla), diatoms and smaller phytoplankton derived from the ecosystem model and satellite observation. For majority of ocean basins, a general agreement was found in terms of increase or decrease of TChla, Diatoms and smaller phytoplankton. A disagreement was also found in the South Atlantic for TChla and smaller phytoplankton, which is rather exceptional, however. We found that there are some trends over

recent years in phytoplankton community structure and they are regionally different.

To compare other spatio-temporal variation of phytoplankton community derived from the model and satellite observation, principal components were used as a comparison metric. The eigen vector of the 1st mode showed less temporal variation in all ocean basins (Fig. 2), thus the 1st mode was interpreted as a steady state of phytoplankton habitat. The eigen vector of the 2nd mode exhibited seasonality. The eigen vector of the 3rd mode also showed seasonality but inter-annual variability was superimposed for some ocean basins. A comparison of the eigen vectors derived from model and satellite showed that the fundamental features of phytoplankton dynamics were well reproduced by the model in each ocean basin, thus our model is useful for marine ecosystem analysis.

References

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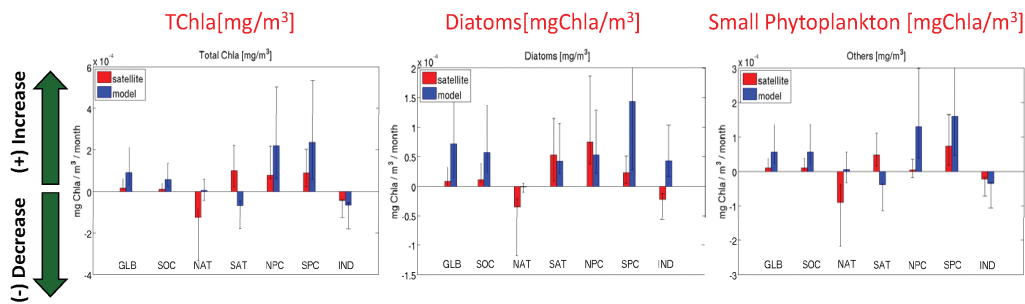[4] Sumata, H., T. Hashioka, T. Suzuki, N. Yoshie, T.

Fig. 1 Linear trends of total Chlorophyll-a (TChla), Diatoms and other small phytoplankton for each ocean basin; GLB (global ocean), SOC (Southern Ocean), NAT (North Atlantic), SAT (South Atlantic), NPC (North Pacific), SPC (South Pacific) and IND (Indian Ocean).
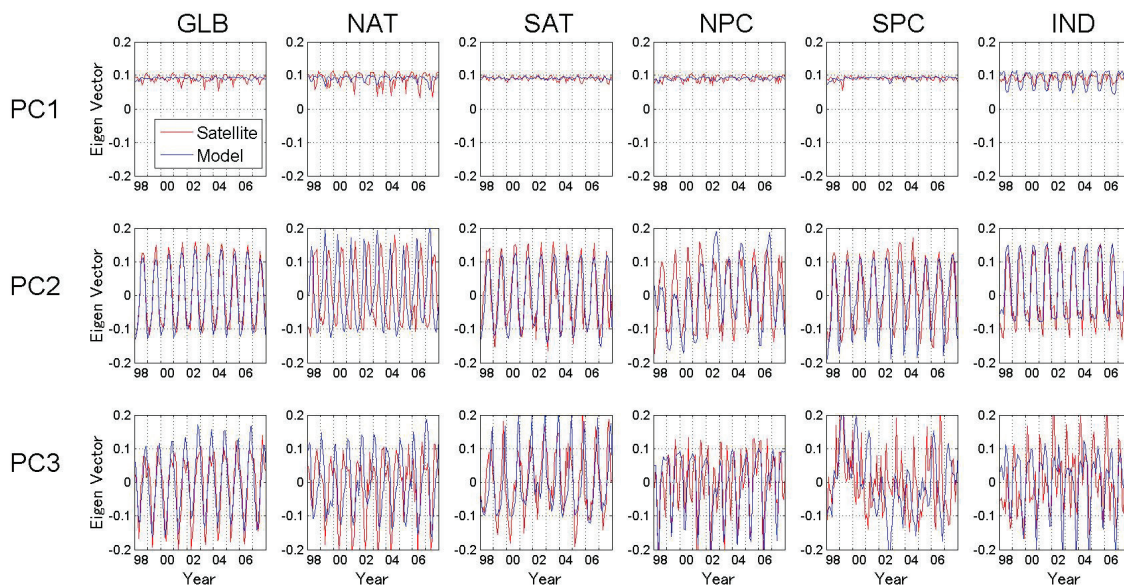

Fig. 2 Time series of the eigen vectors for spatial Principal Components (PC) for each ocean basin; Top row 1st PC (PC1), middle row 2nd PC (PC2), bottom row 3rd PC (PC3). From left to right; GLB (global ocean), SOC (Southern Ocean), NAT (North Atlantic), SAT (South Atlantic), NPC (North Pacific), SPC (South Pacific) and IND (Indian Ocean).

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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

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　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た、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、低気圧性渦に伴うクロロフィル構造の季節的な変化を議論した。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用いて、国際研究計画 MAREMIP（MARine Ecosystem Model Intercomparison Project）の Phase 1 に対応した実験を完了し、解析に着手した。さらに、北極海を対象とした 3 次元海洋生態系モデルの開発に着手した。

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，水産資源