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

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Using multiple ocean general circulation models (GCMs) with multiple ecosystem models including marine biogeochemical cycles, we will improve the ability to simulate the present status of ocean climate and ecosystems and clarify effects of climate change on marine biogeochemical cycles and ecosystems. Taking advantage of our high-resolution general circulation model, we have investigated ecosystem variability associated with fine scale ocean variability such as eddies and meanders. Using more complex ecosystem models, we have performed a hindcast experiment for an international project on model intercomparison "The MARine Ecosystem Model Intercomparison Project (MAREMIP)".

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

1. High resolution biogeochemical cycles and ecosystem modeling

We have made progress in studies using a super 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, cooperating with researchers in the project "Understanding and Forecasting High-Impact Phenomena in the Atmosphere and Ocean" (project representative: Wataru Ohfuchi). We also have developed a chemical tracer (CFC: chlorofluorocarbon) model by coupling with the Ocean Ice general circulation model For the Earth Simulator (OIFES). Using the OIFES-CFC model, we are executing the numerical experiments with different horizontal resolution (0.25 and 0.5 degrees) to investigate the dependence of the simulated results on the model spatial resolution.

Using our high-resolution general circulation model, we have analyzed the processes of ecosystem variability in the Kuroshio Extension (KE) region and tracer transport in the Arabian Sea as described below. We also have published studies on the impact of ocean carbon sequestration and redistribution of injected CO_2 [3, 5].

The KE has the highest eddy variability in the North Pacific. Frontal disturbance of the KE causes mesoscale eddies, which increase local biological production. The OFES-NPZD model reproduces the high eddy variability and the westward propagation of sea surface height anomaly (SSHA) in the KE along zonal band of 32–34N (Fig. 1). The model high surface chlorophyll corresponds to low SSHA, because cyclonic eddies lift nutrient-rich water into the euphotic zone and maintain the high productivity in the subsurface layer. In fall, some of cyclonic eddies combine with other cyclonic eddies from the subarctic region (high nutrient water) and the biological productivity in the subsurface layer is high. Vertical velocity plays an important role in supplying nutrients near the KE meander.

In the intermediate waters of the Arabian Sea, low oxygen water persists throughout a wide depth range. The outflow from the Red Sea through the Gulf of Aden is considered to play a strong role in determining the properties of these intermediate waters. We conducted an idealized tracer experiment using the current velocities from OFES to investigate the role of current variability and eddies in spreading of the Red Sea Water. Figure 2 shows time sequences of the tracer, whose source term is set in the Gulf of Aden; this tracer is spread widely to the northeast and southwest along the Somali coast in the western Arabian Sea. This suggests that the water from the Red Sea may play an important role in the intermediate depths in the western region of the Arabian Sea.

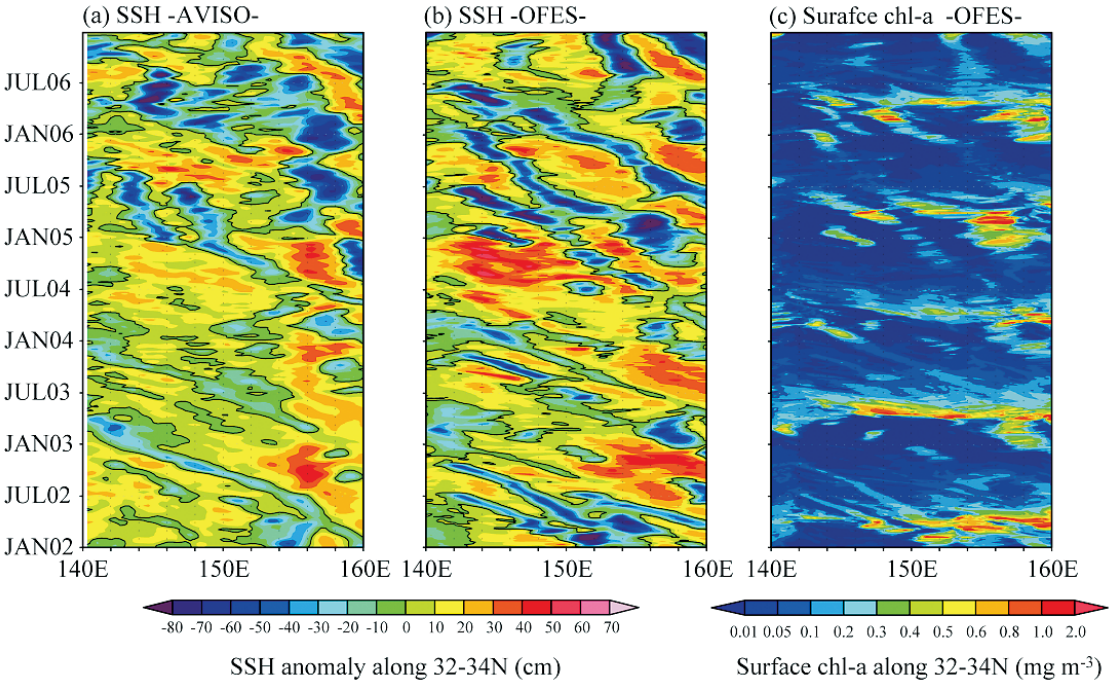

Fig. 1 Longitude-time diagrams of sea surface height anomaly (cm) along 32–34N from (a) AVISO (observed data) and (b) OFES and (c) OFES surface chlorophyll concentration (mg m^{-3}).

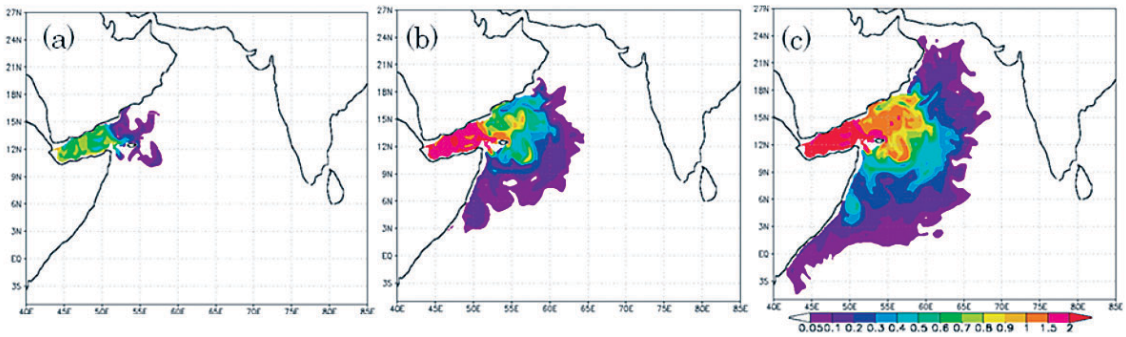

Fig. 2 Horizontal map of the idealized tracer concentrations at 600 m depth in year 1 (a), year 5 (b) and year 10 (c).

2. Activities using global 3-D ecosystem model NEMURO

Using a 3-D ecosystem model (COCO-NEMURO), which consists of the CCSR Ocean Component Model (COCO, developed by the Center for Climate System Research (CCSR), University of Tokyo) coupled with the North pacific Ecosystem Model Used for Regional Oceanography (NEMURO), we had conducted a historical experiment from 1760 to 2002. Some studies related with this model have been published or submitted [1, 2, 4]. We have also conducted experiments to investigate sensitivities of model performance to number of species of phytoplankton and zooplankton in the model.

In cooperation with other research groups, we have made progress in an international project on model intercomparison named "The MARine Ecosystem Model Intercomparison Project (MAREMIP)". The major scientific question in this project is "What are the main physical, chemical and biological processes that determine the global marine biomass, its regional distribution, its distribution among size classes and plankton groups, its organization in biological provinces, its internal and external fluxes, its variability, and its resilience to change?" The comparison will include basic properties, such as surface chlorophyll and the biomass of Plankton Functional Types (PFTs). Figure 3 shows the comparison of surface chlorophyll among the satellite data and model results. All models capture the general pattern of high chlorophyll regions, i.e., equatorial oceans, subarctic region in the North Pacific and Atlantic Oceans, and Southern Ocean, but the detailed distribution and peak values are different among the different models. Further analysis including temporal variability is being conducted in the project.

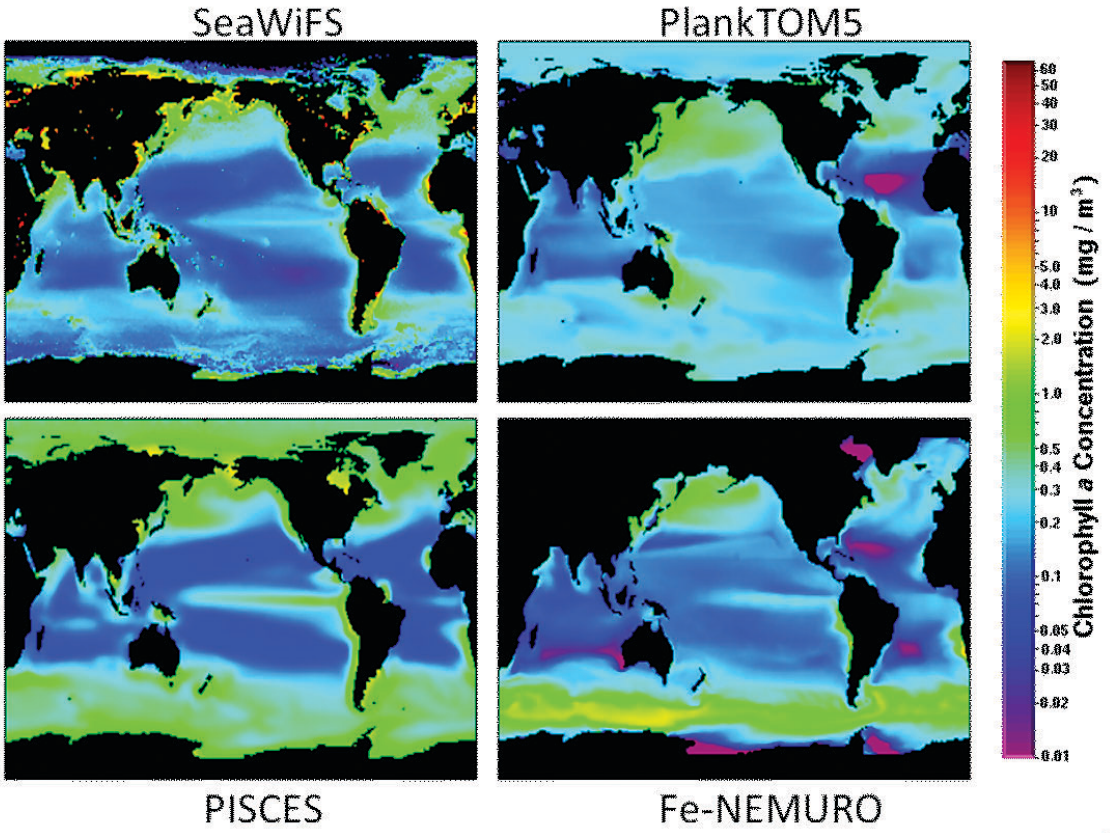

Fig. 3 Comparison of annual mean surface chlorophyll-a concentration (in units of mgChl m^{-3}) among the satellite observation (top left) and those simulated with the models.

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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生態系モデルを用いた実験結果の相互比較・解析を通じて、海洋環境の変化による生態系への影響や、海洋による二酸化炭素吸収量についての将来予測の高精度化を目指す。今年度は超高解像度の海洋大循環モデル(OFES, Ocean general circulation model For the Earth Simulator)に、比較的簡単な生態系モデル(NPZD, Nutrient-Phytoplankton-Zooplankton-Detritus)を結合させたモデルによる数値実験から、黒潮続流域での蛇行や渦変動によるクロロフィル変動や、インド洋での水塊輸送について解析した。また、海氷過程を含むOIFES (Ocean-Sea-Ice GCM for the Earth Simulator)にトレーサーを組み込んだ中解像度での計算を継続して実施した。さらに、複雑さの異なる生態系の過程を再現できるNEMUROモデル(North pacific Ecosystem Model Used for Regional Oceanography)を、海洋大循環モデルCOCO (CCSR Ocean Component Model)に結合させたモデルを用いて、国際的な海洋生態系モデル相互比較プロジェクト(MAREMIP: MARine Ecosystem Model Intercomparison Project)の計画に基づいて生態系変動再現実験(1996–2007)を実施した。その結果、年平均のChl-a濃度の再現性にモデル間で大きな相違はないが、季節変動のタイミングや生態系の構造(プランクトンの種構成など)に大きな違いがあることが明らかになった。

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