Development of a High Resolution Global Ocean Model for Prediction of Marine Environment Changes

Background

From 2002, CRIEPI has investigated global warming in collaboration with NCAR, Los Alamos National Laboratory (DOE, USA) and Kyushu University, which is supported by the " project for sustainable coexistence of human, nature and earth" of the ministry of education, culture, sports, science and technology. Using the "Earth Simulator", global warming under atmospheric CO_2 stabilization scenarios is predicted over several hundred years by a moderate resolution climate model based on the NCAR atmosphere-ocean coupled model. However, the mixing effect of meso-scale eddy * such as meandering of the Kuroshio current cannot be reproduced in the moderate resolution climate model where the horizontal resolution of the ocean model is about 100km. A high-resolution ocean model should be needed to clarify the impact on the local ocean by global warming.

Objectives

To develop a high-resolution global ocean model to investigate detailed global warming impact in regional oceans.

Principal Results

1. Development of a high-resolution ocean model on the Earth Simulator

The original code of ocean model POP (Parallel Ocean Program) cannot demonstrate its high computational efficiency on the "Earth Simulator", because the model was developed for a scalar-massive parallel machine. A high-resolution model with the horizontal resolution of 10km and vertical levels of 40 is improved in vector code and communication between processor and node to obtain high computational speed, finally working on 80 nodes (640 processors). The North Pole is sifted onto Hudson Bay to prevent the computational singular point in the north hemisphere.

2. Reproduction of the present ocean

The horizontal mixing scheme of the momentum, temperature and salinity is improved to better representation of meandering of the Kuroshio current and meso-scale eddy. The high-resolution model well reproduced the present ocean as follows.

(1) The radius of a meso-scale eddy decreases in high latitude due to the effect of earth rotation. In the high-resolution model, the effect of meso-scale eddy is considered over entire ocean, which makes it possible to calculate Equatorial currents driven by the trade wind and western boundary current (such as Kuroshio and Gulf Stream) and Antarctic circum-polar current.

(2) Kuroshio is calculated on the average, overshoots to northward at separation point in the moderate resolution model of climate simulation. Meandering of the Kuroshio current, Kuroshio extension, Tsushima current in Japan Sea, Oyashio and its front can be computed in the high-resolution model.

(3) The current system around Japan is well reproduced. The volume transport of Tokara Strait (south off Kyushu), Izu section calculated by the high-resolution model quantitatively agrees with the estimated volume by the observation.

Future Developments

The high-resolution model might not be applied for long time integration, because of its huge computational resource and time. The model is very effective to study the impact of global warming in detail, in time slice prediction using the computed results of climate prediction as boundary conditions.

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Reference

Maruyama et al: FY2002 and FY2003 research reports on the "development high-resolution atmosphere-ocean coupled model", U99304 (June,2003), V99041 (June,2004), in Japanese

* : In the ocean, many cyclonic and anti-cyclonic eddies exist as same as in the atmosphere. The radius of such meso-scale eddy is about 100km, and one order smaller than the eddies in the atmosphere. The high-resolution ocean model is needed to simulate the eddy directly.

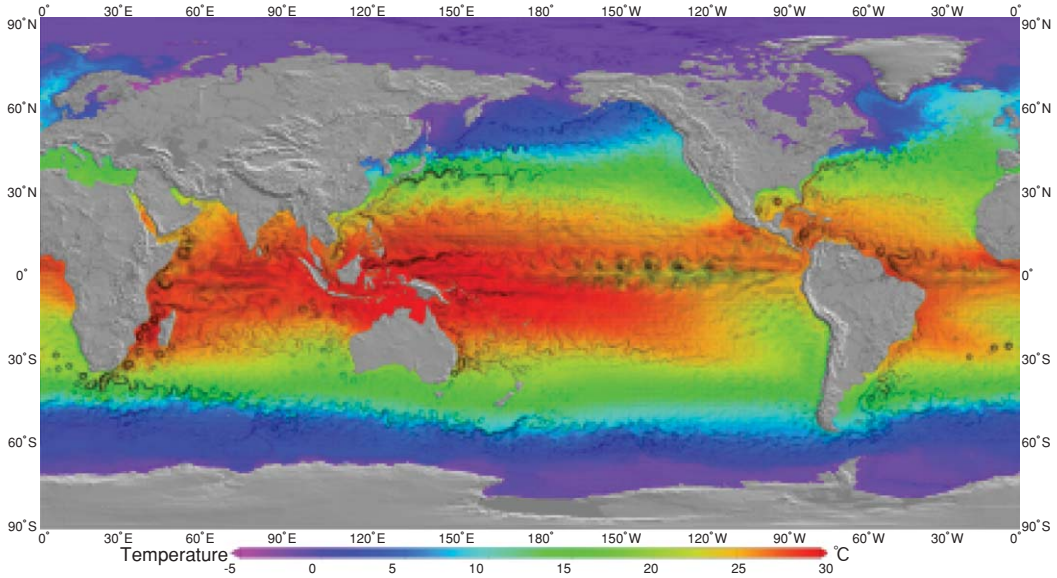

Fig.1 Sea Surface Temperature and Currents Calculated by the High-resolution Global Ocean Model

The high-resolution model of 10km horizontal resolution well calculates Equatorial currents driven by the trade wind and western boundary current (such as Kuroshio and Gulf Stream) and Antarctic circum-polar current.

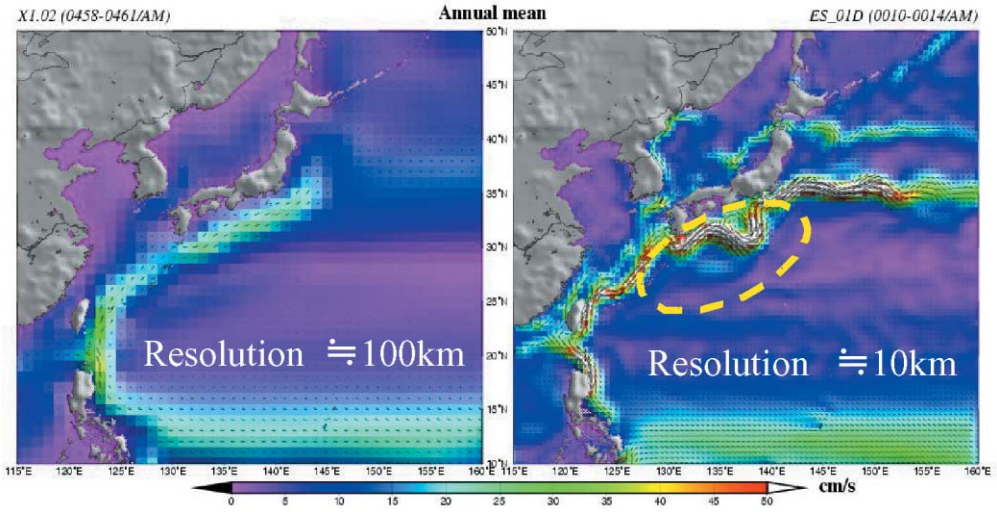

Fig.2 Currents around Japan Calculated by the High-resolution Global Ocean Model

Kuroshio is calculated on the average, overshoots to northward at separation point in the moderate resolution model of climate simulation (left). Meandering of the Kuroshio current, Kuroshio extension, Tsushima current in Japan Sea, Oyashio and its front can be computed in the high-resolution model (Right).

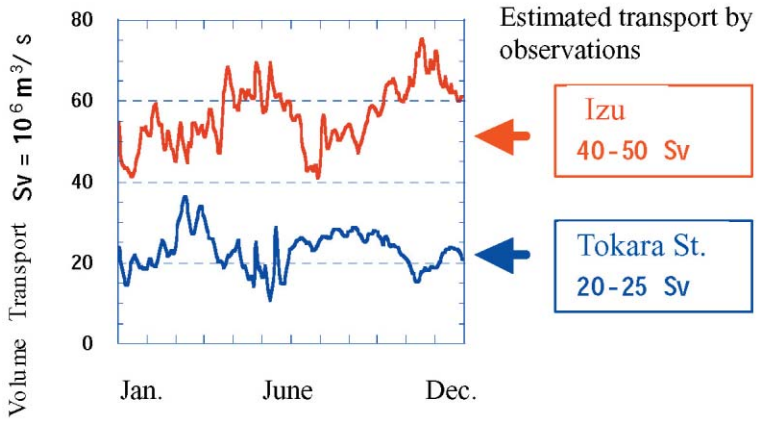

Fig.3 Calculated Volume Transport of Kuroshio

The current system around Japan is well reproduced. The volume transport of Tokara Strait (south off Kyushu), Izu section calculated by the high-resolution model quantitatively agrees with the estimated volume by the observation (□:right in fig.).