Coupled Physical-Ecosystem Model in the Bering-Chukchi Seas

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In December 2002, our project was approved to use ES to simulate the coupled physical-ecosystem model in the polar and subpolar ocean. This project is a joint project between the FRSGC and IARC, University of Alaska. We have conducted our simulations in various platforms: T3E, IBM, SX6/ES. The physical model includes an ocean circulation model (MOM3 and MITgcm) and a sea ice model with both thermodynamics and dynamics of plastic-viscous rheology (Wang et al. 2002). The ecosystem model includes nine-compartment NPZD (Nutrient, Phytoplankton, Zooplankton, Detritus) model for the polar and subpolar oceans (Wang et al. 2003). The initial simulation is presented and the future simulations are outlined.

Keywords: coupled physical-ecosystem model, polar and subpolar oceans, ocean circulation model, MOM3, MITgcm, sea-ice model, plastic-viscous rheology, NPZD.

1. Introduction

There have been efforts in investigating Arctic ice-ocean system using a limited domain (Semtner 1976; Hibler and Bryan 1987; Oberhuber 1993; Flemming and Semtner 1991; Hakkinen and Mellor, 1990) with the North Atlantic Ocean and Pacific Ocean excluded. These limited region models decouple the Arctic ice-ocean system with the North Atlantic circulation system and the Pacific system, with the decadal oscillators excluded (Mysak et al. 1990; Ikeda 1990; Ikeda et al. 2001), although the interannual and decadal variability of the ice-ocean system may be driven by the atmospheric forcing within the Arctic Ocean.

The ocean model can be categorized into three groups in terms of vertical coordinates: z-coordinate-based models, sigma-coordinate-based models, and isopynal-coordinate models. Sea ice models are based on two types of rheologies: viscous-plastic (VP), and elastic-viscous-plastic (EVP), with isotropic property because large scale sea ice dynamics is considered. An Arctic Ocean Models Intercomparison Project (AOMIP) has been conducted to compare variety of parameters and physical processes under the same forcing as much as possible, but with different, stand-alone configurations, resolutions, couplings, techniques, and coordinates (Proshutinsky et al. 2001). The resolution of these models are generally from 30km-100km. Thus, a much higher resolution model is required to achieve a better understanding of the Arctic changes from mesoscale to large-scale variability.

The PhEcoM is a new ecosystem model being developed by Wang et al. (2003), which has 9-compartment system, suitable for polar and subpolar oceans (Eslinger et al. 2001). We will apply this model to the Bering-Chukchi Seas as first step. The northern North Pacific, particularly the Bering Sea and the Gulf of Alaska, is one of the most productive regions in the world in fisheries, mammals, birds, and other species. Its ecosystem environment and productivity have significant impacts on economy of neighboring countries such as the USA, Canada, Russia, and Japan. The northern North Pacific ecosystem is not only an indicator of the changing climate, but also a component (biosphere) which interacts with other components such as atmosphere, oceanography, and cryosphere in the whole climate system. Thus, the present research efforts are consistent with the FRSGC missions.

2. Simulation Results

2.1. Ocean Model-MITgcm

The present model resolution is 0.2×0.4 degrees for the North Pacific Ocean with a localized stretched resolution in the Bering-Chukchi Seas and the Gulf of Alaska being about 4.5-km resolution, which is eddy-resolving. The global model simulation is very encouraging (Fig. 1). Figure 1 shows the world ocean major current system such as the Kuroshi, The Gulf stream, the Circumpolar Current. A close look of the northern North Pacific Ocean indicates mesoscale eddy and meandering (Fig. 2). Figure 2 shows the surface circulation of the North Pacific Ocean including the highest productivity regions such as the Bering Sea and the Gulf of

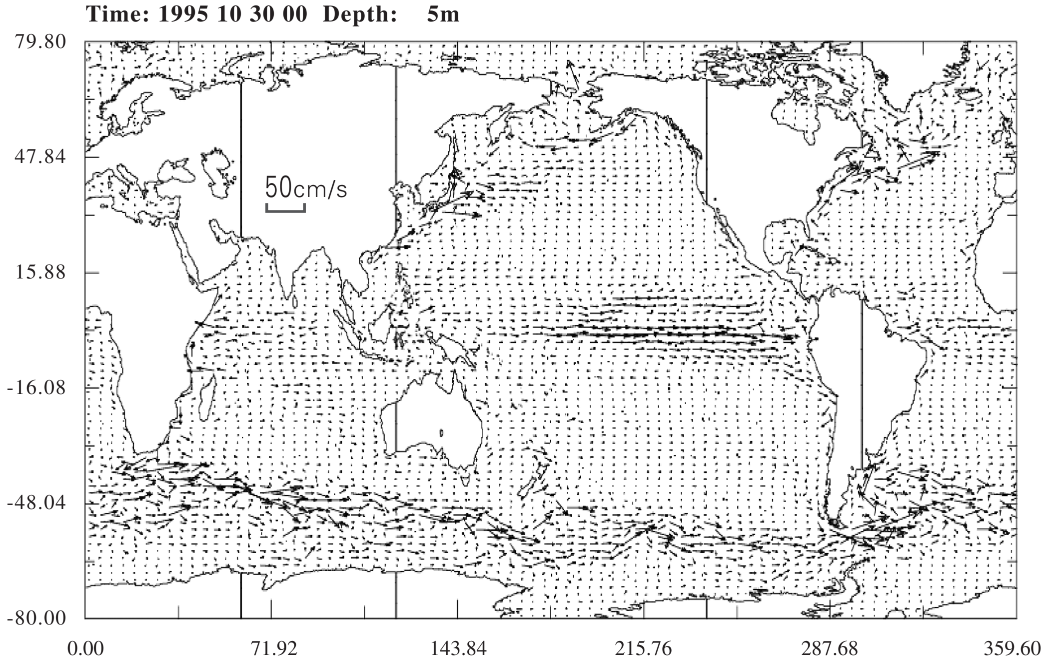

Fig. 1 The surface current simulated by the global MITgcm in the IBM and SX6/ES.

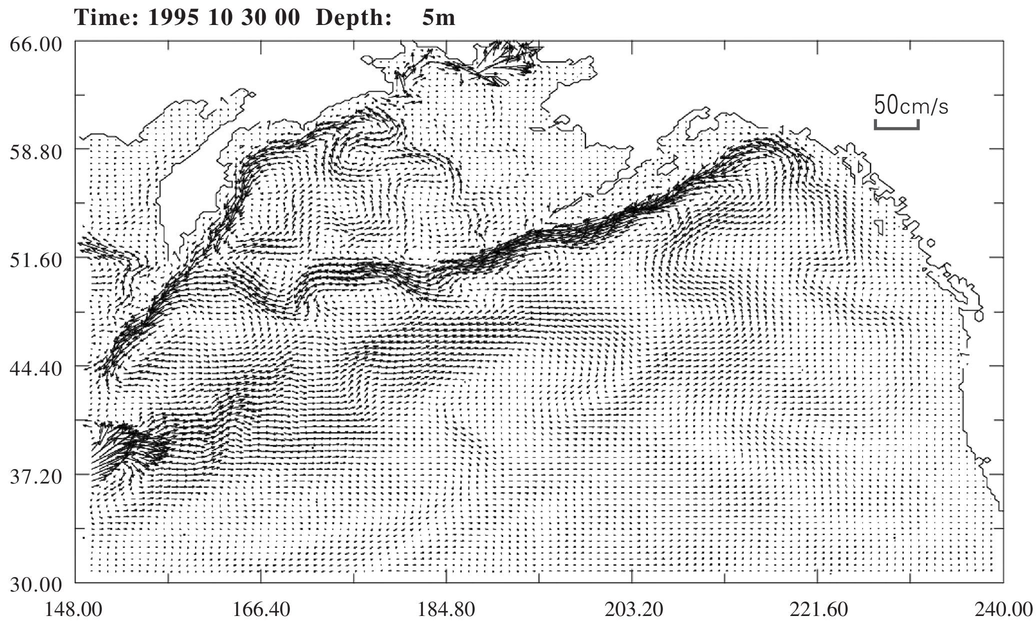

Fig. 2 Surface current of North Pacific from global MITgcm model.

Alaska. The Kuroshio, Oyashio, Alaska Stream, Alaska Current, Bering Sea Slope Current are clearly reproduced.

2.2. Ecosystem Model

The ecosystem model was run under daily forcing from a buoy mooring in the southeastern Bering Sea shelf. The simulation was conducted for 1999 and 2000 using a 3m vertical resolution. Figure 3 shows the time-depth section of ocean temperature, diatom, and nitrate-nitrite during the spring bloom. We realize that the Bering Sea spring blooms depend on ocean temperature and water stratification. The vertical resolution is 3-m in the ecosystem model, while the ocean model has only 6-m resolution, which may be insufficient for resolving the upper mixed layer.

3. Summary and Future Efforts

The need of high speed supercomputer such as ES is clearly clarified. Because both ocean dynamics and ecosystem dynamics require sufficient high resolution in both vertical and horizontal directions. The high resolution sea ice-ocean model needsa great deal of CPU time, storage, and pre-/post-processing data input and output. Thus, we will continue to utilize ES to conduct our simulations toward our long-term goals. The following is our proposed schedules:

Short-term plan:

April 2003 – March 2004: implement MITgcm/MOM3 in a fine (2km) resolution, and fine (3m in the vertical) 3D ecosystem model.

April 2004 – March 2005: numerical simulations of all the components in for interannual and decadal simulations

Long-term plan:

April 2005 onward: a high resolution, coupled ice-ocean-biogeochemical model should be available for studying the Arctic and peripheral seas' short-term and long-term climate change and interactions/interrelationships in these three systems: ice, ocean and ecosystem.

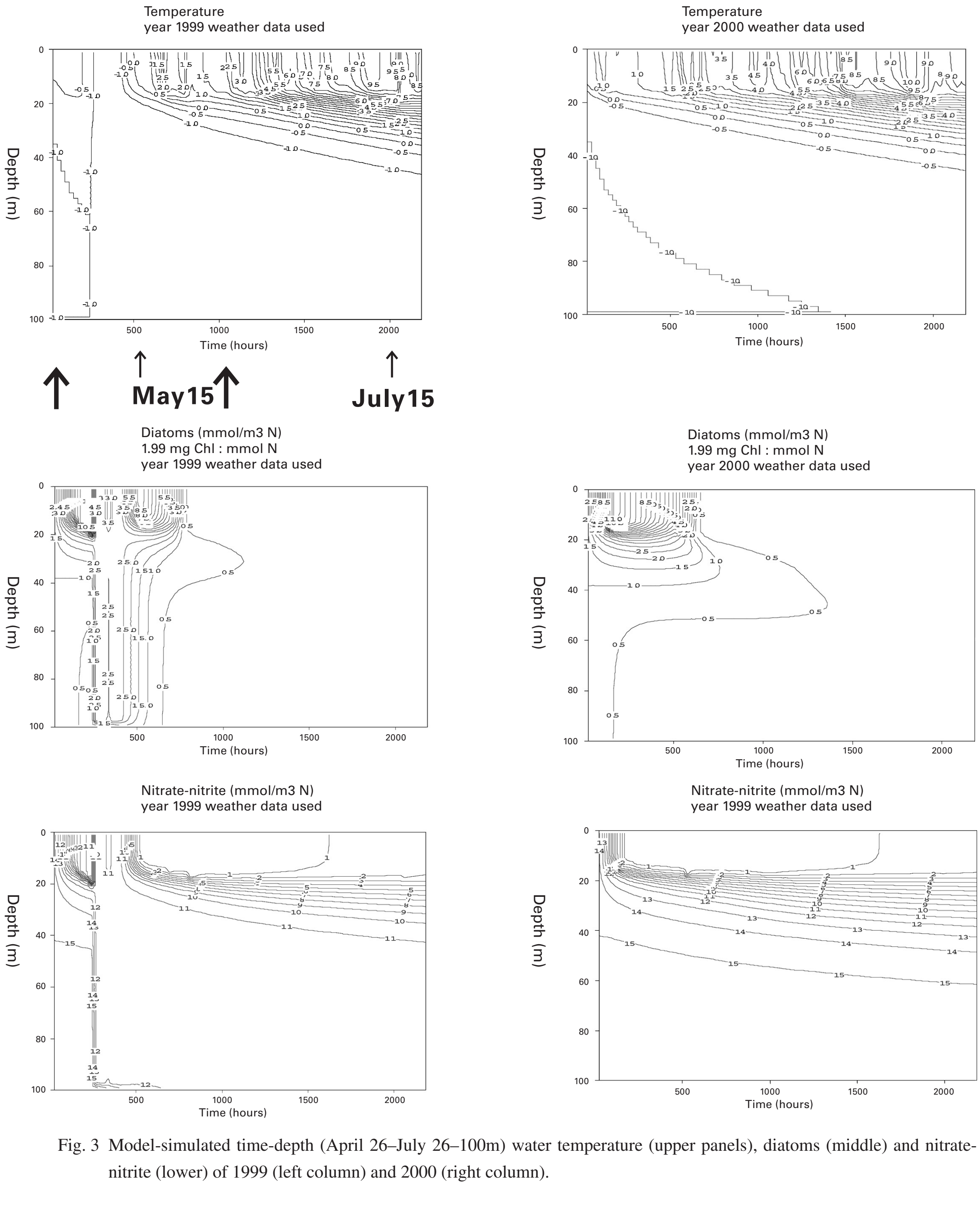

Fig. 3 Model-simulated time-depth (April 26–July 26–100m) water temperature (upper panels), diatoms (middle) and nitrate-nitrite (lower) of 1999 (left column) and 2000 (right column).

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本研究計画の課題である北極海とその周辺の海における物理生態系結合モデルは、昨年12月に平成14年度利用課題として追加採択された。本研究は、地球フロンティア研究システムとアラスカ大学に在る国際北極圏研究センターの共同計画である。我々は、この物理生態系モデルをCRAY T3E (272 CPUs, 69.6 GB, 230 GFLOP)とIBM SP(200 CPUs, 100 GB, 300 GFLOP)およびCRAY SX-6(8 CPUs, 64 GB, 64 GFLOP)の計算機上で数値シミュレーションを実行してきた。この物理生態系モデルの物理の部分は、海洋モデル(MOM3とMITgcm)と、熱力学と動力学の両方を含む海氷モデル(粘塑性流体)からなる(Wang et al. 2002)。一方、生態系の部分は、北極海とその周辺の海における合計9つの栄養分と植物プランクトンと動物プランクトンおよび排出物からなる(Wang et al. 2003)。本成果報告書では、研究の初期の数値計算結果と将来の数値計算計画を概説した。

キーワード：物理生態系結合モデル、北極海とその周辺の海、海洋モデル、MOM3、MITgcm、海氷モデル、
粘塑性流体、栄養分、植物プランクトン、動物プランクトン、排出物