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THREE-DIMENSIONAL CIRCULATION MODEL DRIVEN BY WIND, DENSITY, AND TIDAL FORCE FOR ECOSYSTEM ANALYSIS OF COASTAL SEAS

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Foreword

The Center for Global Environmental Research (CGER), an organ of the National Institute for Environmental Studies of the Environment Agency of Japan, was established in October 1990 to contribute broadly to the scientific understanding of global change, and to the elucidation of and solution for our pressing environmental problems. CGER conducts environmental research from interdisciplinary, multi-agency, and international perspective, provides research support facilities such as a supercomputer and databases, and offers its own data from long-term monitoring of the global environment.

In March 1992, CGER installed a supercomputer system (NEC SX-3, Model 14) and in March 1997, CGER replaced this model with a newer supercomputer (NEC model SX-4/32) to facilitate research on global change. The system is open to environmental researchers worldwide. Proposed research programs are evaluated by the Supercomputer Steering Committee which consists of leading scientists in climate modeling, atmospheric chemistry, oceanic circulation, and computer science. After project approval, authorization for system usage is provided. In 1996 and 1997, several research proposals were designated as priority research and allocated larger shares of computer resources.

The CGER supercomputer monograph report Vol.5. is a report of priority research of CGER's supercomputer. The report covers the Three-dimensional Circulatoin Model Driven by Wind, Density, and Tidal Force for Ecosystem Analysis of Coastal Seas.

We hope this report provides you with useful information on the global environmental research conducted on our supercomputer. In order to promote the exchange of ideas and opinions amongst all the science fraternity utilizing this supercomputer, and to fully represent existing opinions, the Research Integration Section of CGER will greatly appreciate any comments or suggestions.

February 1999

Yohichi Gohshi
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Preface

The Center for Global Environmental Research (CGER) of the National Institute for Environmental Studies (NIES) of the Environment Agency of Japan provides research support facilities such as a supercomputer and databases for global environmental research activities.

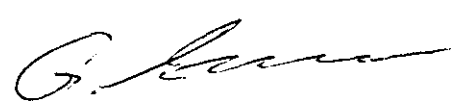
CGER's supercomputer is open to researchers internationally for any global environmental research applications. Users need to be authorized for such usage every fiscal year. CGER is responsible for efficient allocation of supercomputer resources for each research subject, such as CPU time and memory, sufficient for the research plans recommended by the Supercomputer Steering Committee, consisting of scientists.

NIES's Environmental Information Center (EIC) manages routine operations of the supercomputer system. This system is operated with close and cordial communications between users and the managing staff, including daily consultation by the engineers.

This CGER supercomputer monograph is the fifth publication to disseminate research progress achieved by the users of the supercomputer facilities set up by CGER. The system's CPU time and memory were fully occupied in fiscal years 1996 and 1997(from April 1996 to March 1998), demonstrating that the needs of researchers for this facility have been very high and that users from national research institutes and universities have fully utilized the system. We provided high-priority resource allocation to the group which studies on the Three-Dimensional Circulation Model Driven by Wind, Density, and Tidal Force for Ecosystem Analysis of Coastal Seas, in consideration of their prospective contribution to international frontier research activities.

We hope this publication contributes to further progress in global change research and efforts for global environmental conservation.

February 1999



Gen Inoue
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THREE-DIMENSIONAL CIRCULATION MODEL DRIVEN BY WIND, DENSITY, AND TIDAL FORCE FOR ECOSYSTEM ANALYSIS OF COASTAL SEAS

1. Introduction

Coastal seas are receiving a great deal of attention due to the increasing use of their resources. Escalating demands for coastal development have directed both governments and industries to investigate the basic mechanisms that govern water circulation in coastal seas. Knowledge of this circulation is useful for environmental management and conservation of marine ecosystems.

The movement of water in a coastal sea is driven by such factors as freshwater discharge from rivers, tidal excitation, intrusion of warm and highly saline ocean water at the mouth of bays, heat transfer, and wind stress at the surface of the water. The ecosystem in Tokyo Bay is strongly influenced by these complex factors. Thus, it is essential to analyze the water circulation there. To simulate this system, we used a 3-dimensional numerical circulation model developed originally by Blumberg and Mellor (1983, 1987), which is able to deal with stratified flows occurring on a time scale of 30 days and spatial scales of 1 to 100 km. The model was extended by Blumberg and Goodrich (1990) to include river segments as a domain of calculation up to the point at which tidal effects are minimal. This is a major difference between the two models, and the latter model is more favorable for simulating circulation in a bay with significant freshwater impact from rivers.

2. Model Description

Here we provide a relatively detailed description of a numerical circulation model called the Princeton Ocean Model (POM; Blumberg and Mellor, 1983). The model belongs to that class of models in which model realism is an important goal and mesoscale phenomena are addressed, that is, activities that are 1 to 100 km long and; 30-day time scales are commonly observed in estuaries and coastal waters (Beardsley and Boicourt, 1981). It is envisioned that the model ultimately will be used as part of a coastal sea-forecasting program. The model is 3-dimensional, incorporating a turbulence closure model to provide realistic parameterization of the vertical mixing processes. The prognostic variables are the three components of velocity, temperature, salinity, turbulence kinetic energy, and macroscale turbulence . The momentum equations are nonlinear and incorporate a variable Coriolis parameter. Prognostic equations governing the thermodynamic quantities, temperature and salinity account for water mass variations brought about by highly time-dependent coastal upwelling processes as well as horizontal advective processes. Free surface elevation is also calculated prognostically, with only some sacrifice in computational time so that tides and storm surge events can also be simulated. This is accomplished by use of a mode-splitting technique whereby the volume transport and vertical velocity shear are solved separately. Other variables include density, vertical eddy viscosity, and vertical eddy diffusivity. The model also accommodates realistic coastline geometry and bottom topography.

The model's performance has been tested in a variety of applications (Blumberg and Mellor, 1979a, b, 1980, 1981a, b, 1983; Blumberg, 1997), including simulation of the tides in Chesapeake Bay, simulation of coastal circulation off Long Island, New York, and a computation of the general circulation in the Middle Atlantic and South Atlantic bights and in the Gulf of Mexico. The grid spacings have ranged from 1 to 50 km in these applications.