ABSTRACT

In this study, an effective three-dimensional numerical model is used for the simulation of both barotropic and baroclinic processes across river-to-ocean scales. The governing equations of the model are based on the hydrodynamic equations and coupled with scalar transport equations. An unstructured grid system is adopted for better fitting of the river banks and coastal shorelines, and the staggered definition for different variables is used to avoid chaos accumulated error. Consistent finite volume schemes are adopted to assure mass as well as volume conservation. A semi-implicit Eulerian-Lagrangian algorithm is used to solve the shallow water equations for enhancing computational efficiency. The model was applied to the Danshuei River estuarine system and its adjacent coastal sea, including its three major tributaries: the Tahan Stream, the Hsintien Stream, and the Keelung River. Comparisons between elevations of surface water for both the observed and the predicted results appear to be well. Real time simulations of river plumes were compared with satellite images on the dates during high river flow conditions when the turbid river waters are detectable from space. It is noted that the swaying trend of the model predicted river plume is consistent with the satellite image, which delineates the extent of turbid river water under the high river flow condition obtained on corresponding day.

KEY WORDS: barotropic flow; baroclinic flow; 3D numerical model; Eulerian-Lagrangian algorithm.

INTRODUCTION

One major anthropogenic impact on the aquatic environment is through the discharge of waste materials by human activities on the land. Once discharged into a water body, these materials are transported around by the water flows and, at the same time, subjected to biogeochemical transformation. To understand, evaluate, and mitigate the harmful impacts of these discharged materials, it is essential to integrate all significant processes active in the water body. For an overall impact evaluation, simulated components should include hydrodynamics, nutrient dynamics, and primary production, benthic processes and benthic ecology, suspended sediment transport, toxic substance transport and fate, etc. Since there are so many and complex mechanisms occurred in the estuary area, so the topic is focused on some investigations induced through hydrodynamic and transport processes which were simulated by a 3D numerical model in this paper.

Barotropic flows in estuaries and coastal seas include tidal flow, river discharge, topographic currents, and the interaction among them. River plume is an important feature of the coastal sea around a river mouth. It is a manifestation of the spatial distributions of freshwater and its associated land-derived materials. It plays an important role in the ecological conditions in the coastal area. The characteristics of a river plume are constantly varying with the phase of tide, the magnitude of freshwater discharge, and the meteorological conditions. Baroclinic flow in estuaries and coastal seas is formally induced by the lateral variation in density. As the tidial flow is strong enough than the river discharge, the salt water then is transported into the river leading to a well-defined salt wedge with the higher density. A mixing process occurs between saltwater and fresh water, and leads to density current flow.

FORMULATION OF PHYSICAL MODEL

A number of three-dimensional hydrodynamic models are available for adaptation. Since there is more flexibility for the model applied with the “unstructured” grid to fit better the complex geometry of a natural water body. The finite-volume, unstructured-grid models have been becoming the state-of-the-art three-dimensional surface flow models. This type of models also employs Lagrangian backtracking to simulate the advection term, which relaxes the stability constraint to allow for larger time step in numerical computations. One such model named ELCIRC (Eulerian-Lagrangian CIRCulation model, Zhang et al., 2004) was developed with close cooperation with the modeling group in the Virginia Institute of Marine Science (VIMS), the College of William and Mary, USA.

Governing Equation

ELCIRC is a model designed for the effective three-dimensional