Numerical Modeling Approach of an OTEC Thermal Discharges in Coastal Waters of Kosrae, Micronesia

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ABSTRACT

In this study we try to identify the mixing and dispersion characteristics of thermal discharges in coastal waters of Kosrae, Micronesia to consider their physical properties using a field observation and a three-dimensional numerical modeling with FVCOM (Finite Volume Coastal Ocean Model). A FVCOM and HYCOM (Hybrid Coordinate Ocean Model) data was used to predict the plume behavior of thermal discharges in coastal waters of Kosrae, Micronesia. The elevation, current, temperature and salinity boundary conditions on the open boundary and thermal effluents at the specific boundary are considered in this study. Various turbulence models have been applied in the numerical model to assess the accuracy of turbulence models in predicting the effluent discharges in OTEC outfalls.

The model successfully reproduced well known the plume behavior in coastal waters of Kosrae, Micronesia. These works illustrate the challenging nature of OTEC environmental studies.

KEY WORDS: Ocean Thermal Energy Conversion, Finite-Volume Coastal Ocean Model

INTRODUCTION

Due to the effect of several factors such as tides, waves, winds, river discharges, thermal effluents etc., the mixing characteristics of OTEC (Ocean Thermal Energy Conversion) thermal plume is much complicated. Thermal discharge from industrial outfalls is categorized into two major classes based on their density. First class is the effluent that has a higher density than that of the ambient water body and is hence defined as negatively buoyant jet. The second class is the effluent that has a lower density than that of the ambient water body and is hence defined as a positively buoyant jet. Negatively/Positively buoyant jets are found in various ocean and environmental engineering projects. Coastal discharge produces buoyancy-driven flow (large-scale plumes and coastal currents) in coastal ocean regions. When buoyant coastal discharge is released into a coastal region occupied by saltier and more dense oceanic water, potential energy becomes available to drive thermohaline currents, where strong lateral entrainment and vertical mixing occur. Often the dynamical structure of the spreading low-salinity water over the coastal region is referred to as a coastal plume.

Recently, observations and model studies of large-scale buoyant plumes show three major types for the horizontal distribution of density (Garvine, 2001). Type 1 represents the typical coastal freshwater plume of observations. The buoyant discharge turns right in the northern hemisphere (toward downshelf) under earth rotation at its source. Type 2 is common in many numerical model studies. Most of the buoyant water at the inlet turns left (upshelf) along the coast to form a continuously growing intrusion. Type 3 turns right but exhibits a massive anticyclonic bulge which grows with time; its coastal current is weak and carries a small fraction of the inlet fresh water or buoyancy flux.

Studies of the temporal and spatial structures of a coastal plume are of considerable interest not only because of their influences on the physical processes of the coastal circulation but also because of their close relationship to coastal ecosystem and environmental pollution problems.

The circulation characteristics of coastal waters, especially, estuarine inner bay which have variable topography and coast line are much complicated. To explain and simulate the coastal estuarine circulation, it is necessary to develop the three-dimensional ocean model in coastal waters (Kim, 2003; Kim, 2006).

In this study, we will provide and describe the results of numerical experiment designed to understand the change of the hydrodynamic conditions with emphasis on the impact of the density-driven current followed by the thermal effluent.

MATERIALS AND METHOD

1) FVCOM

We have developed a 3-D unstructured-grid, free-surface, primitive equation, Finite-Volume Coastal Ocean circulation Model (called FVCOM) (Chen et al., 2006) (Fig. 1). Unlike the differential form used in finite-difference and finite-element models, FVCOM discretizes the integral form of the governing equations. Since these integral equations can be solved numerically by flux calculation (like those used in the finite-difference method) over an arbitrarily sized triangular mesh (like those used in the finite-element method), the finite-volume approach is better suited to guarantee mass conservation in both the individual control element and the entire computational domain. From a technical