D-4.1 Coastal Current and Mass Transport in the Arabian Gulf

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Abstract The currents and mass transports in the Arabian Gulf are investigated with analysis of the oceanographic data and numerical models. Accoding to the seasonal variation of sea water temperature and salinity, It is found that sea waters of high salinity in the inner part of the gulf, which is produced by the extreme evaporation in winter season, sinks and flows out to the Strait of Hormuz in as a bottom current. With numerical models, we simulate 2-amphidromic system of semi-diurnal tides and 1-amphidromic system of diurnal tides. And also we calculate the wind-driven currents of both a stratified sea and a vertically well-mixed sea.

Using the wind-driven currens and tidal currents calculated numerically reffered to above, we construct a system to calculate the drift of floating materials. This program is designed to work in a notebook-type personal computer, so as to be able to calculate the path of the floating materials, including oil, in anywhere.

Key Words the Arabian Gulf, Water Mass, Tidal Current, Wind-driven Current

1. Introduction

Oil spill by the Gulf War occured in Jan., 1991, were estimated about 4 million barrels, which is the largest amount in the world. Although the Arabian Gulf is one of the most important commercial water ways in the world, the number of oceanographic surveys is very small. Then, oceanographic studies of the gulf are necessary to prevent oil spill disasters.

Tides and Tidal currents are not so weak, although the Arabian Gulf is a semi-enclosed sea connecting only through the Strait of Hormuz to the Indian Ocean. And the gulf is a source of the high saline sea waters to the Indian Ocean. Therefore, the oceanographic study on the gulf is significant for both the region itself and the global environment.

2. Reseach Objective

For the sake of the presavation of the marine environment and the prevention of the oil spill disaster in the Arabian Gulf, we investigate the seasonal variations of water properties and circulations in the gulf, and examine the characteristics of tidal currents and wind-driven currens with numerical models.

3. Analysis of the Oceanographic Data

We analyse the oceanographic data in the Arabian Gulf. Fig.1 shows the T-S diagram of 10m-layer and 50m-layer in 4 regions, the head(A), the center potion(B), the entrance(C), and the outside(D) of the gulf. The domains enclosed with solid lines denote the ranges of temperature-salinity in winter(Dec.~Feb.), and the domains enclosed in dotted lines denote those in summer(June~Aug.). One of the most remarkable features is that salinity of 50m-layer in summer is higher than that in winter, in the center potion and the entrance of the gulf. This fact suggests that the exceedingly high saline sea waters at the head of the gulf, produced by the extreme evaporation in winter, sink and flow out as a deep current.

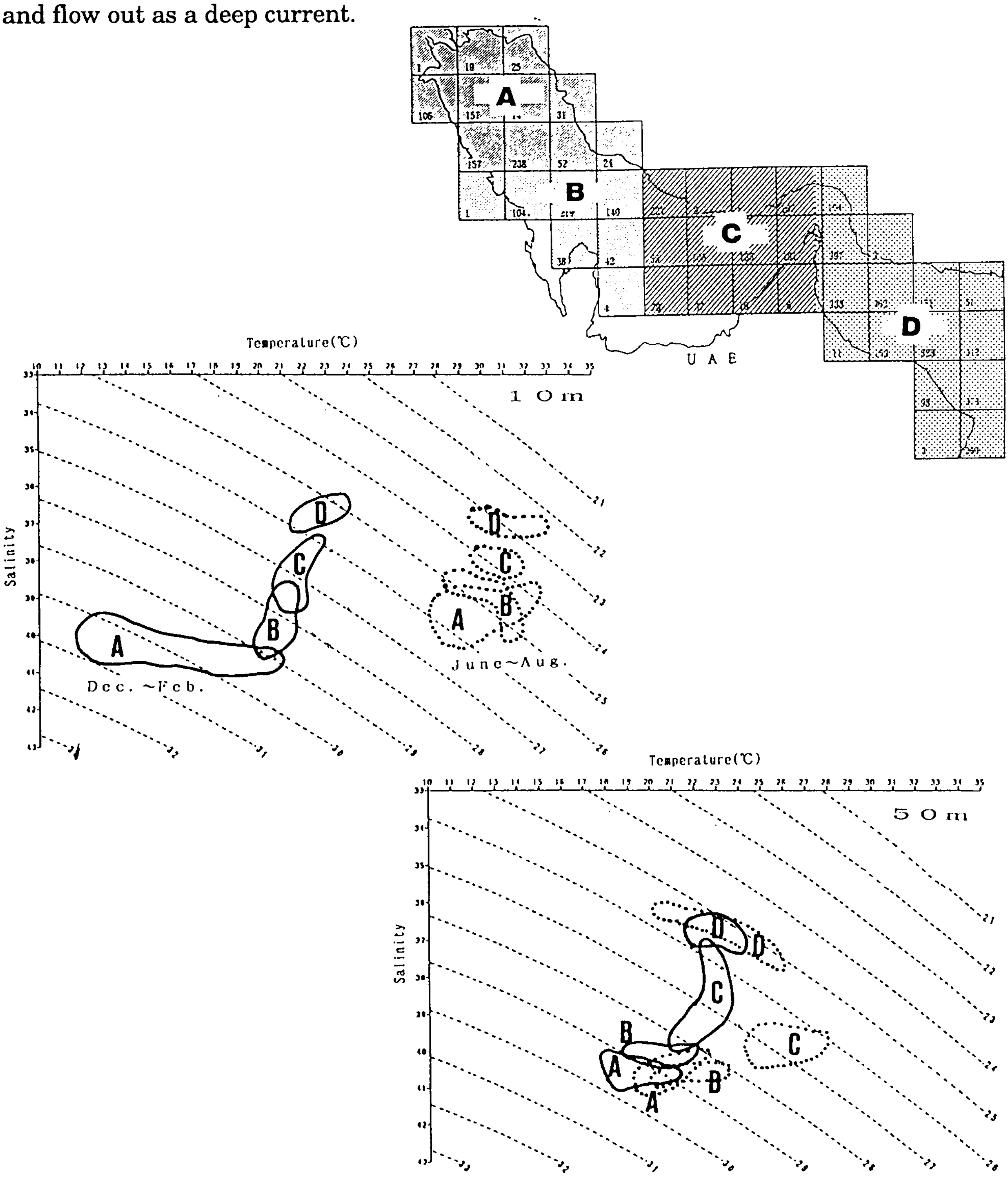

Fig.1

4. Tides and Tidal Currents

We develop a 2-dimensional numerical model to investigate the characteristics of tides and tidal currents. The model contains realistic geometry and bathymetry of the Arabian Gulf and the mesh size is 10' x 10'. Tides of 4 constituents(M2, S2, K1, O1) are given at the mouth of the Gulf of Oman.

In the Arabian Gulf, semi-diurnal tides have two amphidromic points, one at the head of the gulf and the other in the southern potion, and diurnal tides have an amphidromic point which exists in the center of the gulf, as shown in Fig.2. Tidal waves rotate cyclonically around these amphidromic points. Generally speaking, tidal currents are strong near amphidromic points, so diurnal tidal currents are strong in the center of the gulf, and semi-diurnal tidal currents are strong at the head and in the soutern potion of the gulf. M2 tidal current reaches about 0.4 knot at the head of the gulf. K1 tidal current exceeds 0.3 knot near the center of gulf.

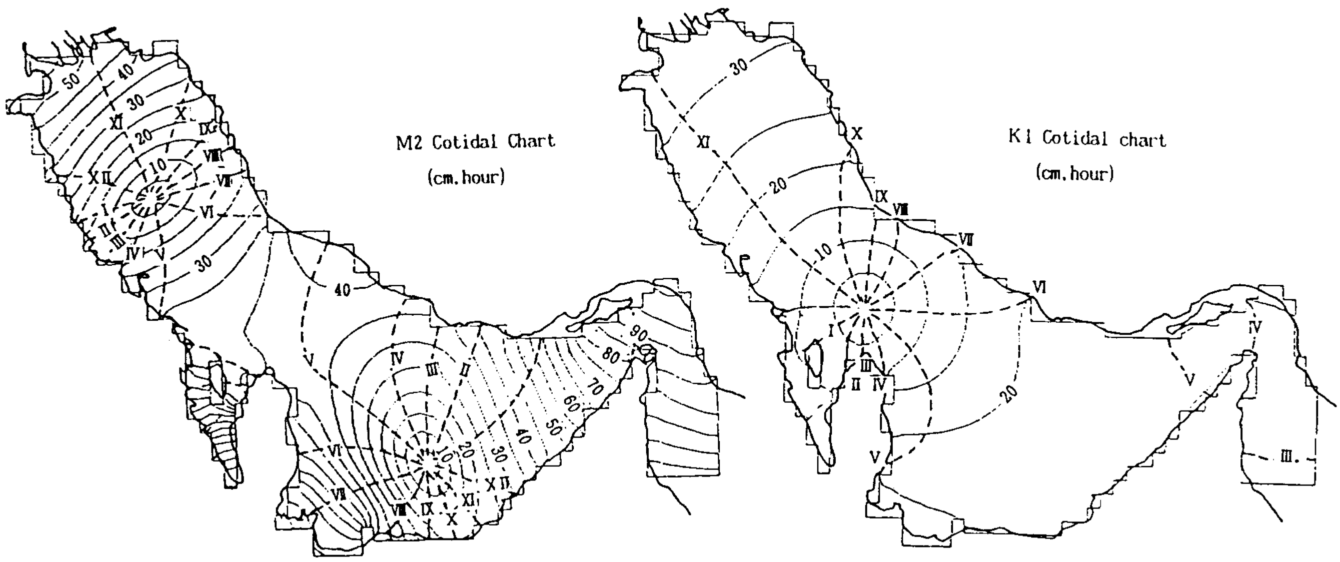

Fig.2

5. Wind-driven Currents

We develop a 3-dimensional numerical model to investigate wind-driven currents in the Arabian Gulf. The model is a 6-level model and the thicknesses of 6 levels are, in descending order, 2m, 8m, 10m, 10m, 20m, and to the sea bottom. The mesh size is 10km x 10km. The model basin is closed at the mouth of the Gulf of Oman and the boundary condition is slippery.

In the region of the Arabian Gulf, northwestward winds dominate through the year. Then, we investigate the response of the gulf to constant northwestward winds.

We simulate two cases. one is the case of a stratified sea, which corresponds to the sea in winter, and the other is a sea of constant density which almost corresponds to the sea in summer. The currents of the surface layer of both two cases are shown in Fig.3. The resulsts are the almost same. For both case, the directions of the surface currents are southeastward or southward owing to the effect of the Coliolis' force.

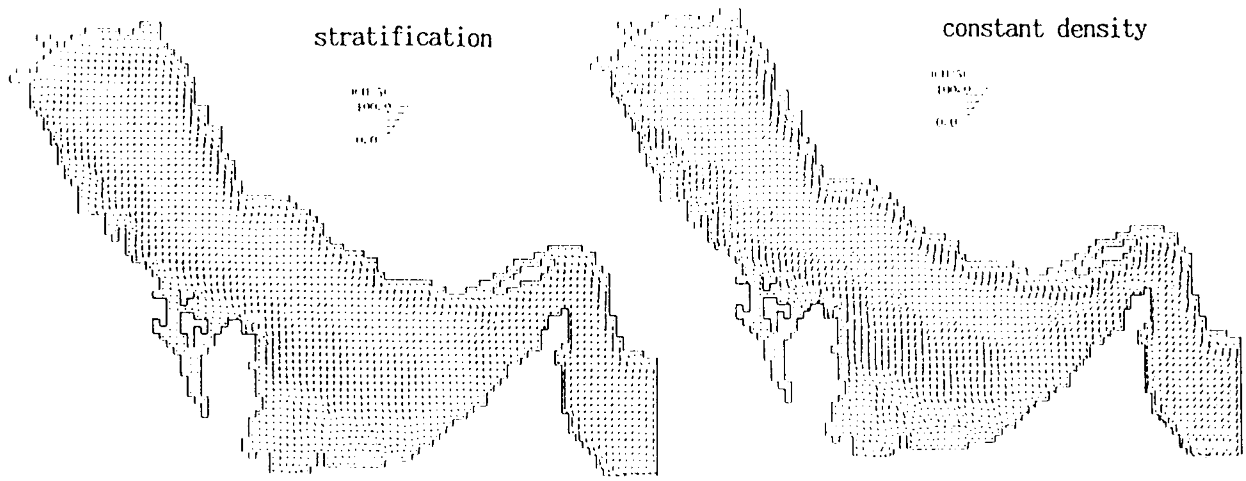

Fig.3

6. Simulation of oil spill Movement

We construct a program to calculate the drift of floating materials including, the oil spill, using the wind-driven currents and tidal currents calculated with the numerical models reffered to above. The program is designed to work in notebook-type personal computer.

An example of the simulation is shown in Fig.4. In this case, floating materials are released at 6 points and the paths of 15 days after the release are calculated under the condition of constant northwestward wind.

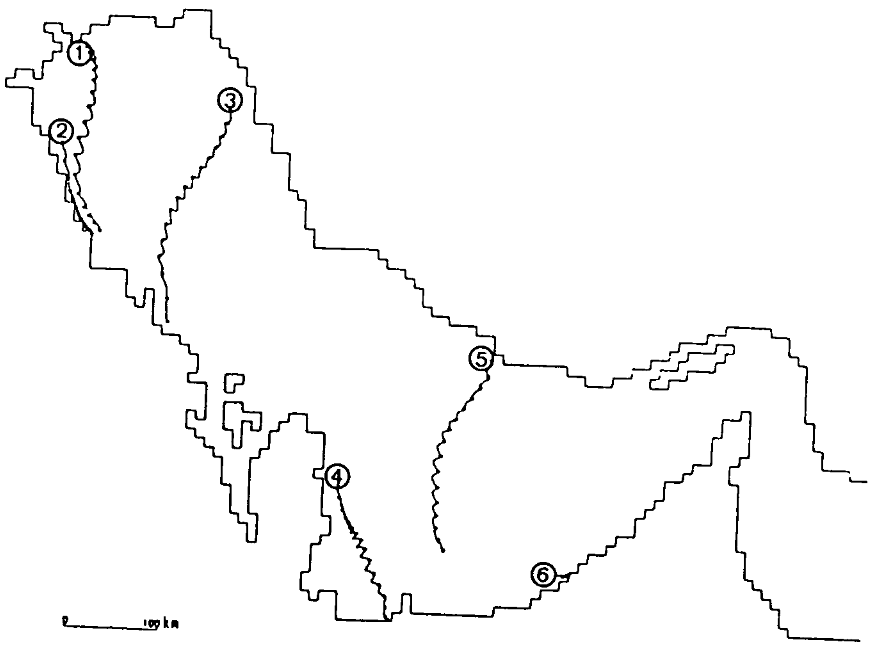

Fig.4