A numerical study on the seasonal variation of Yellow River plume path in the Bohai Sea

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Introduction

The Bohai Sea (Fig.1) is the largest inner sea of China, and the Yellow River is the largest river that discharges into the Bohai Sea. In the past several decades, both the course (Fig.2) and the runoff of Yelllow River (Fig.3) dramatically changed, which is thought to have a significant influence on the hydrodynamic environment in the Bohai Sea, so does the water exchange between the Bohai Sea and the outer Yellow Sea. As the first step to study this influence, in this paper we investigated the seasonal behavior of Yellow River plume in the Bohai Sea with a numerical model.

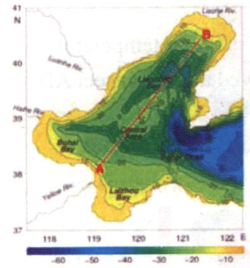

Fig.1 Topography of the BS

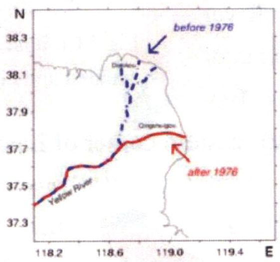

Fig.2 Yellow River course

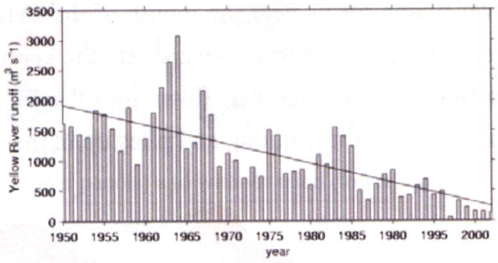

Fig.3 Variation of annual averaged Yellow River runoff from 1950 to 2002

Model configuration

The model used in this paper is Princeton Ocean Model (POM). The model has a resolution of 1/18 degree in both zonal and meridian directions and 20 layers in vertical. The model domain (Fig.4) includes not only the Bohai Sea, but also the Yellow Sea and the East China Sea, which allow us to avoid the problems related to the open boundary conditions in a regional ocean model. The results of a nested ocean general current model (Guo et al., 2003) and four leading tidal constituents are given along the open boundary. On the surface, the model is forced by monthly averaged forcing including wind stress, sea surface temperature, net heat flux, evaporation, precipitation and air pressure. Six major rivers in the model domain, including the Yellow River and the Changjiang River, are considered in the model. The model is initialized with the nested ocean model's results and run for 4 years. The results from last year's run are analyzed.

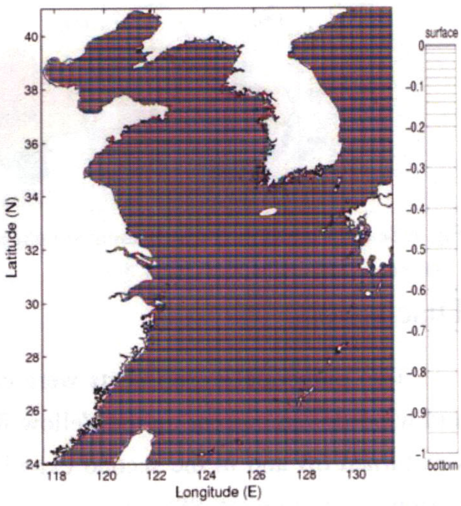

Fig.4 Model domain

Results

The model well simulated the seasonal variation of water temperature, salinity and current field in the Bohai Sea. The model results are consistent with observations. From the model results we note that seawater in the Bohai Sea is well-mixed in autumn and winter, and thermocline exists in the other two seasons (Fig.5).

Fig.6 shows the seasonal variation of sea surface salinity (SSS) simulated and observed. The model results show some common characteristics with observation, that is, the center of the low-salinity water is located in the south-eastern corner of Laizhou Bay in winter, and located in the south-western corner in spring and autumn. In summer the low-salinity area extends northeastward into the central area of the Bohai Sea.

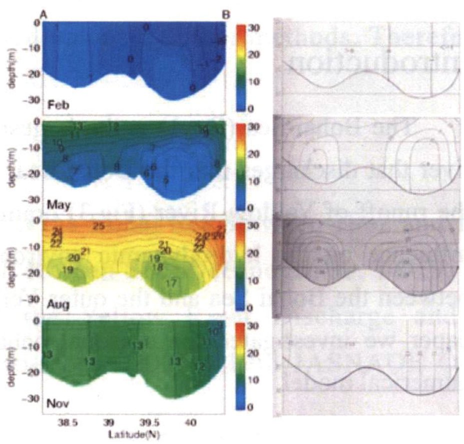

Fig.5 Comparison of water temperature simulated and observed along transect AB

The distribution of SSS reveals the Yellow River plume path. The seasonal variation of Yellow River plume path could be concluded as follow: the Yellow River plume forms near the mouth of the Yellow River in spring, spreads northeastward into the central area of the Bohai Sea in summer, flows into the Laizhou Bay along the coast in autumn, and piles up in the south-eastern corner of Laizhou Bay in winter.

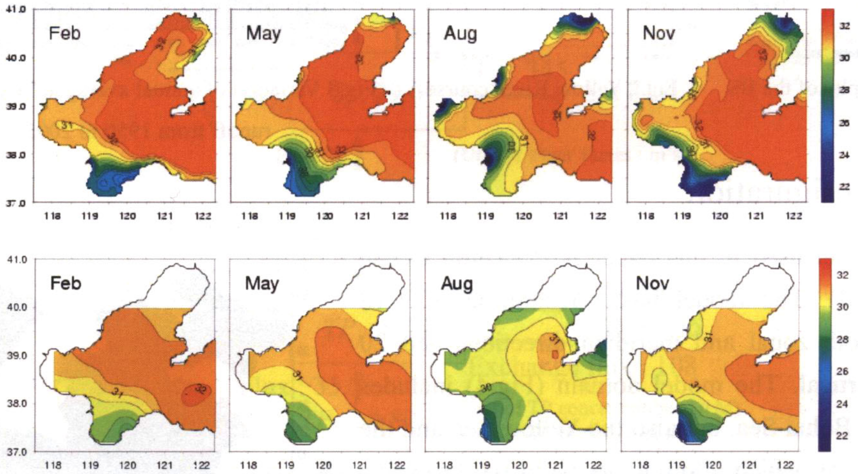

Fig. 6 Sea surface salinity distribution: simulated (upper panels) and observed (lower panels, Liu et al. 2003).

Discussion

Two numerical experiments were carried out to study the influence of tidal residual current and wind-driven current on the Yellow River plume path. In the first experiment the tidal current was turned off and in the second experiment the wind force was turned off. In the first case the seasonal variation of SSS is shown in the upper panels of Fig.7. Compared with Fig.6, the low-salinity area extending northeastward in summer disappears in this case; however, in winter the low-salinity water moves farther eastward. This could be explained by the tidal residual current (Fig.8). In the Bohai Sea, tidal residual current forms a clockwise circle in the central area and the Laizhou Bay. This current pattern drives buoyant water flowing northeastward in summer and prevents it moving out of the Bohai Sea along the south coast in winter. In the second experiment the wind force was turned off and the seasonal variation of SSS in the Bohai Sea is shown in the lower panel of Fig.6. In this case, the plume path almost does not vary with time, except that the shape of the plume varies with river runoff. So we can conclude that both tidal residual current and wind-driven current contribute to the northeastward extension of low-salinity water in summer. In Addition, wind-driven current makes the center of the buoyant water appear in the south-eastern corner of the Laizhou Bay in winter, and tidal residual current prevents buoyant water flowing out of the Bohai Sea along the south coast.

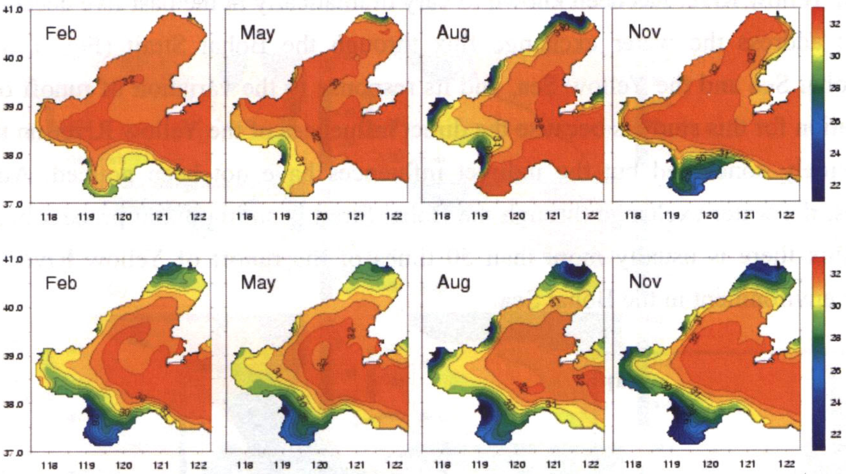

Fig. 7 Sea surface salinity distribution in the cases without tide (upper panels) and without wind (lower panels).

Conclusions

1) The Yellow River plume forms near the mouth of Yellow River in spring, spreads northeastward into the central area of the Bohai Sea in summer, flows into the Laizhou Bay along the coast in autumn, and piles up in the south-eastern corner of Laizhou Bay in winter.

2) Tidal residual current and wind-driven current both contribute to the northeastward extension of low-salinity water in summer. Additionally, wind-driven current makes the center of the buoyant water appear in the south-eastern corner of the Laizhou Bay in winter, and tidal residual current prevents buoyant water flowing out of the Bohai Sea in winter.

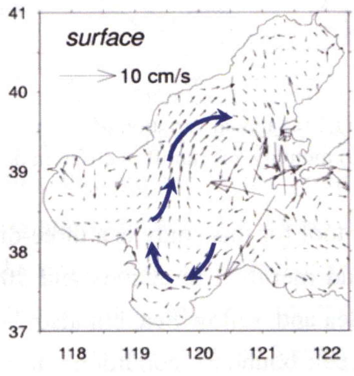

Fig.8 Tidal residual current in the BS (surface layer)