The Influences of Yellow River Flow-Sediment Regulation Field Experiments on the Salinity in the Bohai Sea

Xinyan Mao[1], Wensheng Jiang[1], Peng Zhao[1], Huiwang Gao[2]

[1] Physical Oceanography Laboratory, Ocean University of China

[2] College of Environmental Science and Engineering, Ocean University of China

Introduction

The Bohai Sea consists of 5 parts: Liaodong Bay, Laizhou Bay, Bohai Bay, Bohai Strait, and central area. It is typically a shallow shelf sea, where the mean depth is only 18m, and the deepest place is at the Bohai Strait, not more than 80m.

The variation of salinity in the Bohai Sea is influenced by freshwater flux, including runoff, evaporation, and precipitation. Besides, the exchange with North Yellow Sea is also very important. In the last 20 years, the evaporation is more than annual-mean value (Lin, et al. 2001). It is reported by Wu that the mean salinity has increased from 28 to 30 in last 35 years before 2000, and North Yellow Sea water's strong intrusion often took place (Wu, et al. 2004).

Generally speaking, Yellow River (YR) runoff is the key factor to the salinity in the Bohai Sea, especially in the Laizhou Bay. Because of the booming economy and other anthropogenic influences, the runoff into the sea was less and less these years. All of the factors lead to the increasing salinity.

Since 2002, Yellow River Conservancy Commission (YRCC) has conducted a field experiment of flow-sediment regulation every year. The three schedules are, respectively, July 4^{th} -15^{th}, 2002; Sept. 6^{th} -18^{th}, 2003; June 19^{th} –July 13^{th}, 2004. The experiment's objective is to optimize the rebalance between flow and sediments released, transport the sediment into sea, and ultimately reduce lower reach's sedimentation.

Referred to Communique on Water Resources of Yellow River, due to the regulation experiments, the runoff measured at the YR mouth in 2003 and 2004 is about 200 hundred million cubic meters, 4 times more than that in 2001, 2002. Before the first experiment in 2002, runoff in non-flood season is less than 100 cubic meters per second. However, during the experiment, the flux could exceed 1000 cubic meters per second. In 2003, there was continuous precipitation from September to October, so the experiment was carried out then, and the maximum flux almost reached 2500 cubic meters per second.

With the more runoff, how will the salinity adjust itself? Would it begin decreasing or keep increasing? The problem could be studied by use of model simulation.

Model Configuration and Results

HAMSOM, Hamburg Shelf Ocean Model, is a three-dimension baroclinic model. The simulation range covers the Bohai Sea and part of North Yellow Sea. The open boundary is at the 122.5° E. In the simulation, we adopt the newest position of the YR mouth, at 37.8167° N, 119.2833° E.

In HAMSOM, grid-C is used. The horizontal resolution is 1 minute. In the vertical, it's divided into 10 layers: 3m, 6m, 9m, 12m, 15m, 18m, 23m, 28m, 38m, and 65m. The simulation period covers 4 years from 2001 to 2004, with 360s time step.

In the simulation, the atmospheric forcing data was downloaded from ECMWF

(European Center for Medium-range Weather Forecast), including 10m wind speed, 2m air temperature, 2m dewpoint temperature, sea level pressure and total cloud cover. The data is 4 times per day, respectively at 00:00, 06:00, 12:00, and 18:00. Besides, the used runoff data was digitized from two communiqués: Communique on River and Sediment of China, and Communique on Water Resources of Yellow River.

Figures, No.1 to No.15, are the contours of monthly mean sea surface salinity (SSS) in the Bohai Sea, with the same color bar. They show clearly that the salinity in 2003 and 2004 is less than before. The salty water from central area flows to Laizhou Bay along the south of Bohai bay. Besides, the freshwater from YR mainly extends to south, and influences the salinity of Laizhou bay, and has too little influence on the other part in the Bohai Sea. It flows out of the Bohai Strait along the south bank of the Laizhou Bay. This is related to the Bohai circulation: inflow from north of Bohai Strait, and then divide into two branches. One follows the upper clockwise track, and the other one follows the lower counterclockwise track, at last, outflow along south of Bohai Strait

In Fig.16, point A is near the YR mouth, and point B is in the Laizhou Bay. The time series of salinity at A and B shows intra-annual oscillation and inter-annual decreasing trend. Besides, there is a time lag of the occurrence of minimum SSS between these two points, one to three months. It validates the conclusion that YR freshwater mainly outflows along the south bank of Laizhou Bay.

Fig17 and Fig18 are two comparisons between observation and model results. The first one was conducted in August 2002. The extending trend of fresh water is similar. However, the value difference is about 2 psu. It's probably related to not employing the evaporation data in the model, so the simulated salinity didn't reach the level of observation. From the observation of Sept. 2004, it could be seen clearly that there's some fresh area at the south of Laizhou Bay. So far, the source was not clear. Maybe it's from the YR fresh water, or from the Xiaoqinghe River's runoff, which wasn't taken into account when simulating.

Conclusions

There are several drawbacks in the simulation. Lack of evaporation and precipitation data made the salinity less that real value. Besides, it is known that the open boundary condition is very significant for simulating salinity. We have no high-quality data at the boundary, so it's impossible to simulate the intrusion of North Yellow Sea; also it is difficult to assure the simulation accuracy. Moreover, we considered too few rivers in the model, only Yellow River, no other rivers, which leads to not so good simulation in other area.

However, some conclusions could be obtained from the present simulation result. Firstly, the variation of YR runoff is important to the salinity in the Bohai Sea, especially in the Laizhou Bay. Secondly, the salty water of central area flows to Laizhou Bay along south of Bohai Bay, and fresh water from YR flows out of Bohai Strait along the south bank of Laizhou Bay. Thirdly, the salinity in the Laizhou Bay shows intra-annual oscillation, and inter-annual decreasing trend. Furthermore, its variation lags one to three months compared with the YR mouth. Fourthly, although there're certain differences, to some extent, the model result agrees well with the observation. Fifthly, the flow-sediment regulation experiments not only realize the initial objectives, but also bring more fresh water through the lower reach into the Laizhou Bay, and contribute a lot to decreasing the salinity there.

References

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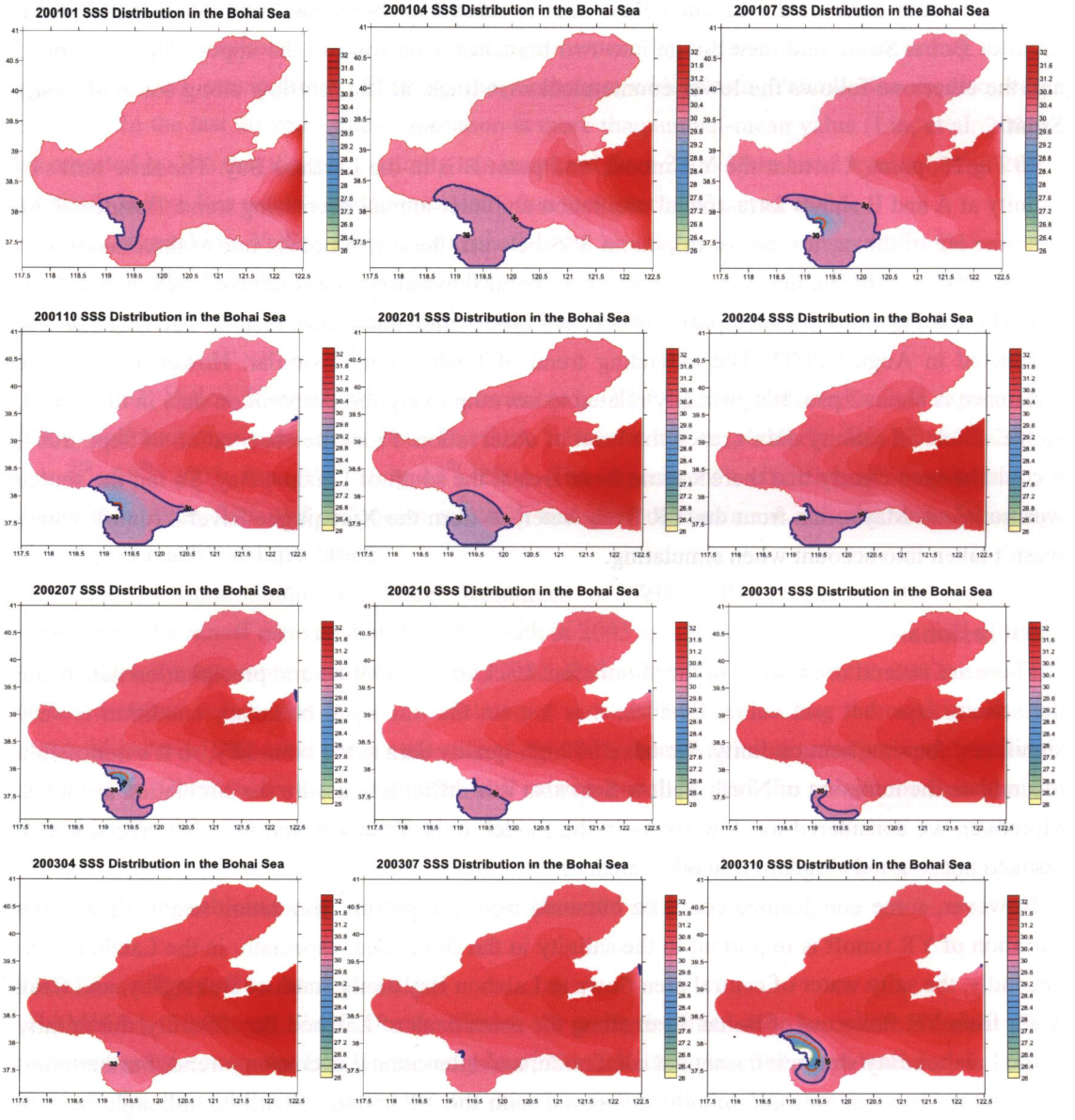
Wu Dexing, et al. Long-term variation characteristics of the salinity of the Bohai Sea and the probable leading factors Progress in Natural Science, 2004, 14(2)

Figures

Fig.1-Fig.15 Contour of monthly mean SSS every three months from 2001.1 to 2004.7



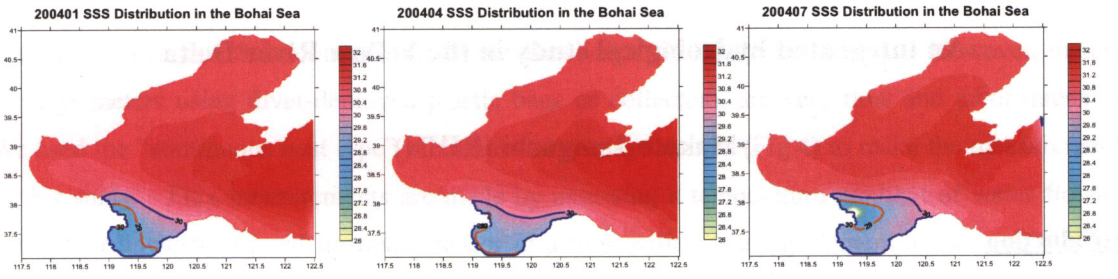


Fig.16 Time-series of SSS at point A and B

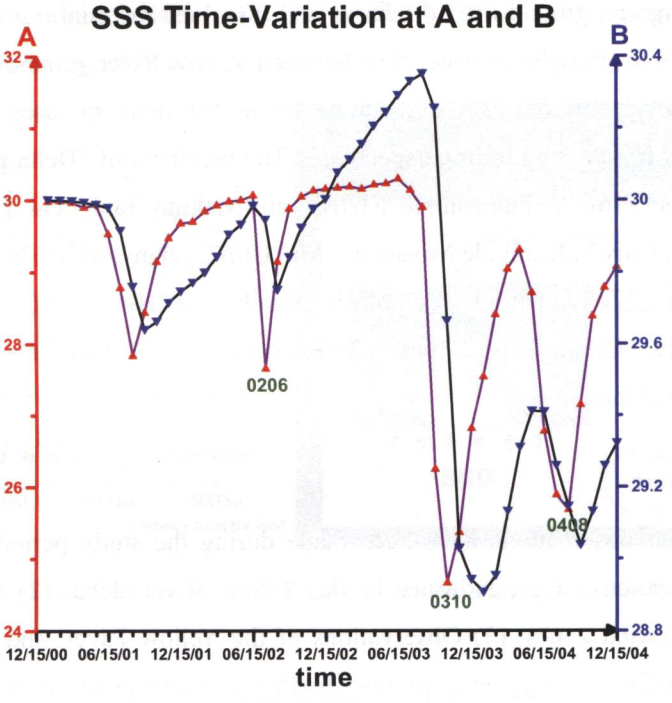


Fig.17 Comparison of 2002.8

Fig.18 Comparison of 2004.9