Numerical Study on water exchange between the Bohai Sea and the Yellow Sea

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The Bohai Sea (BS) is the largest inner sea of China, with the average depth of 18 m and total area of 77,000 km^2 (Fig.1). The Yellow River discharges into south part of the BS. The Bohai Strait is the only passage to the Yellow Sea (YS) and the water exchange between the BS and the YS is thought to be weak. Here in this paper the water exchange between the BS and the YS is simulated using POM (Princeton Ocean Model). The model has a resolution of 1/18 degree in latitude and longitude and 20 layers in vertical (Fig.2). The major difference between our simulation and previous numerical studies is the treatment of the Yellow River and the open boundary conditions. In this paper the Yellow River is directly considered in the model, so we can analyze the influence of the Yellow River discharge on the current field in the BS. Furthermore, the model domain includes the YS and the East China Sea (ECS) so that the open boundary is far from the BS. On the open boundary, the results of a nested ocean model (Guo *et al.*, 2003) are employed as the open boundary conditions. By this way, we can reduce the artificial error resulting from the given open boundary conditions in a regional model, and the model is fit to deal with the problem of water exchange between the BS and the YS.

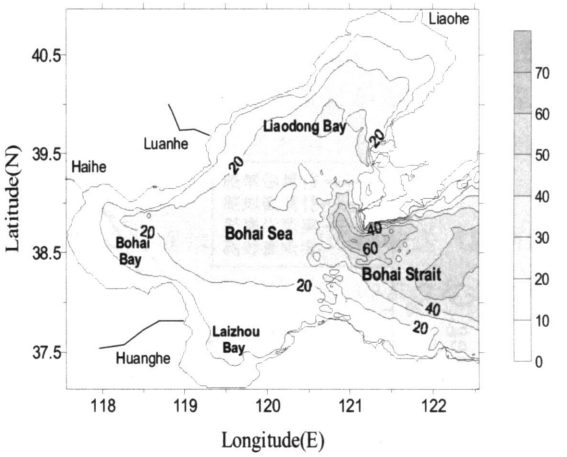

Fig.1 topography of the Bohai Sea

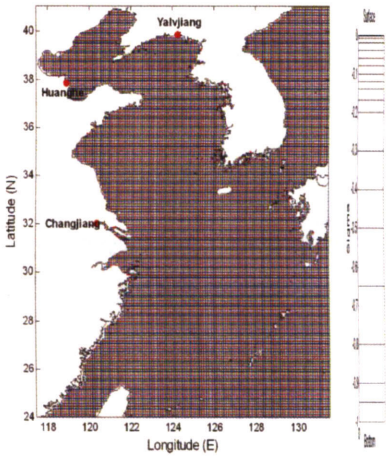

Fig.2 Domain area and model grid

The model is initialized with the nested ocean model's results and forced by 4 major tidal constituents (M2, S2, K1 and O1), monthly averaged ERS wind stress (1991-1998), monthly Levitus SST (1994), monthly net heatflux, evaporation and precipitation (Da Silva, 1994), and monthly NCEP air pressure (1948-2004). Six major rivers, including the Yellow River, the Changjiang River and the Yalu River, are considered in the model. The model was run for 2 years and the results from second year's run were analyzed.

The model succeeds to simulate the distribution and seasonal variation of water temperature, salinity and current field in the BS. Especially for the Yellow River plume, there is good agreement between the simulation result and observation (Fig.3). We can see that in summer Yellow River plume flows northeastward, in winter the fresh water located in the southeast corner of the Laizhou Bay, and in spring and autumn the fresh water located in the southwest corner of the Laizhou Bay.

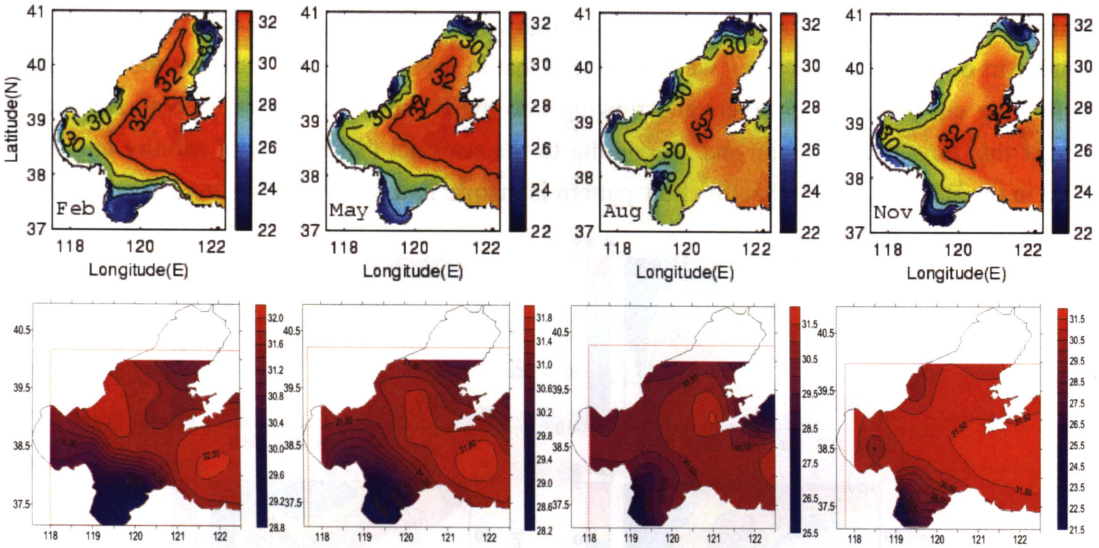

Fig.3 Seasonal distribution of salinity simulated (upper panel) and observed (lower layer)

Model result shows that the monsoonal wind makes current flow into the BS in the first half year, and flow out in the second half year (Fig.4); the peak water flux could be 4000 m^3/s. As a result, sea level in the BS is high in summer and low in winter (Fig.5). Accompanying with thermal expansion effect, sea level in the BS has a seasonal variation of about 50 cm.

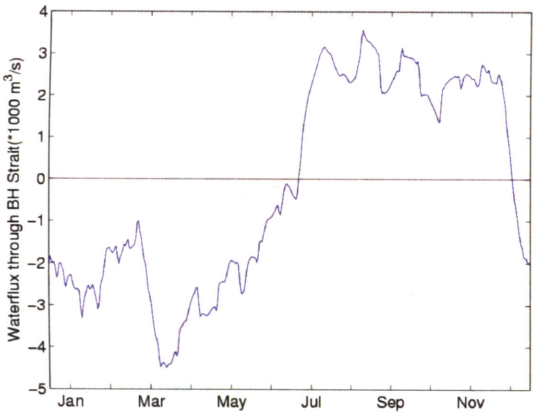

Fig.4 Net water flux through the Bohai Strait.
Positive means flowing out of the BS.
Negative means flowing into the BS.

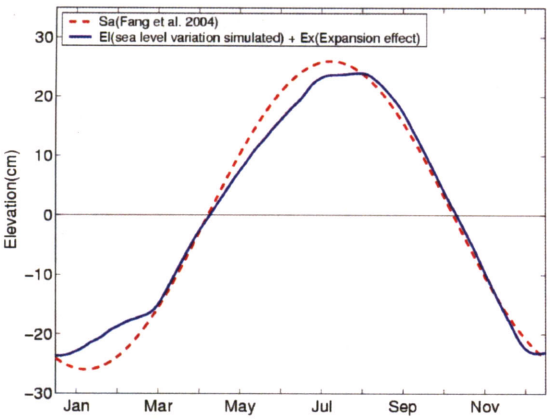

Fig.5 Variation of average sea level in the BS during a year.
Blue line is the model result plus expansion effect.
Red line is the observation result from T/P data.

Current through the Bohai Strait, in most time of the year, is "north-in and south-out" (Fig.6). However, in spring, there is also outflow in the lower layers in south part of the strait.

Several case studies were conducted to study the tidal residual current, wind-driven current and density-induced current through the Bohai Strait (Fig.7). The result shows that tidal residual current induces a "north-in and south-out" flow pattern through the strait. The inflow is strong and located in a small area of north part of the strait; the outflow is weak and located in the large other area.

Wind-driven current shows different flow pattern in winter and summer. In winter, northwest wind prevails on the BS, as a result, wind-driven current flows into the BS through north part of the strait and flows out through south part of the strait; in summer, southeast wind prevails on the BS, as a result, current flows into the BS through south part of the strait and flows out through north part of the strait.

Density-induced current is strong in summer and weak in winter. In summer, the density-induced current flows into the BS through north part of the strait and flows out through south part of the strait. However, we also noticed that in the south part of the strait the flow pattern is flowing out in the upper layers and flowing into the BS in lower layers. In both summer and winter this flow pattern maintains. According to the seasonal distribution of salinity and current field in the BS, we can say that this flow pattern is mainly induced by the Yellow River plume.

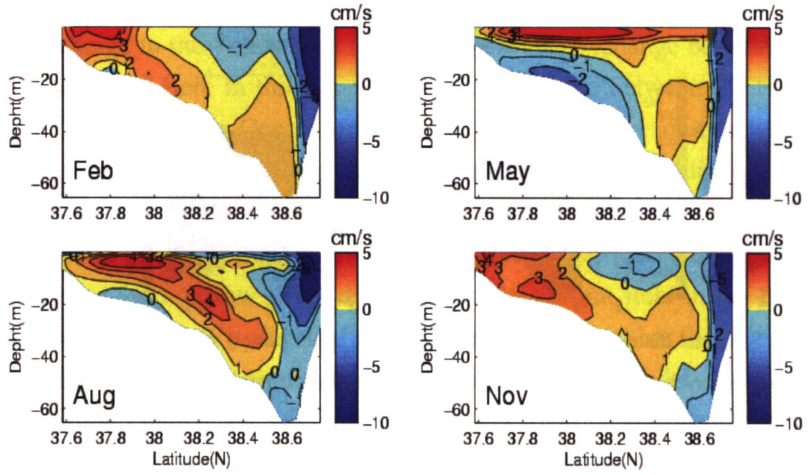

Fig.6 Seasonal current through the Bohai Strait. Positive means flowing out of the BS and negative means flowing into the BS.

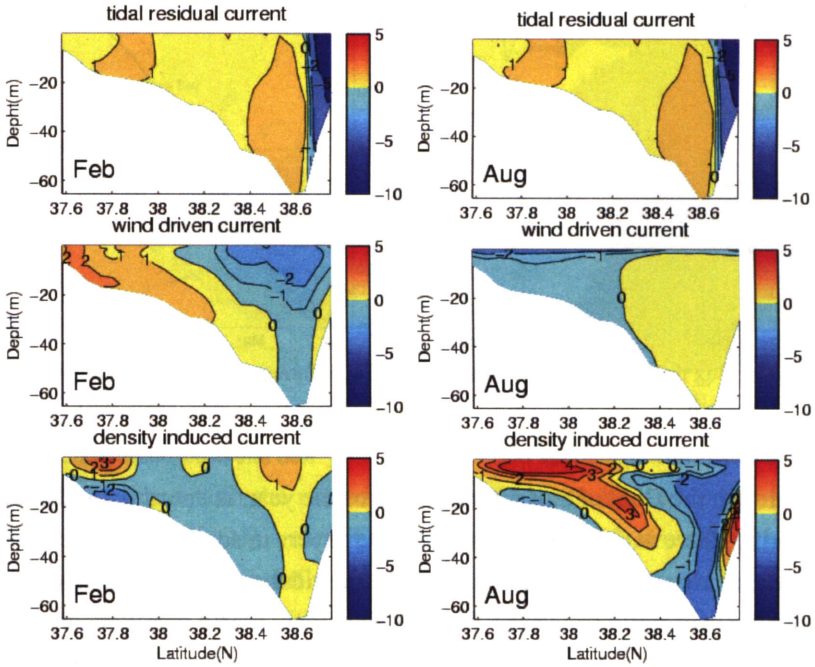

Fig.7 Tidal residual current, wind-driven current and density-induced current through the Bohai Strait in winter (Feb) and summer (Aug)