Numerical simulation for tides and tidal currents in the Bohai Sea

--- Yellow River Estuary

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outline

- Introduction and background
- model configuration
- results analyzing
- Conclusions
The Bohai Sea located in 37°07′~41°N, 117°35′~121°10′E

Fig. 1 the locality of the Bohai Sea
The Yellow River, originating from the high Qinghai-Tibet Plateau (a plateau with the highest altitude in the world), is one of the major contributors of fluvial sediment to the oceans.
### Yellow River Sediment Bulletin

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>multi-year average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water discharge</td>
<td>204</td>
<td>313.3 × 10^8 m³</td>
</tr>
<tr>
<td>sediment discharge</td>
<td>1.47</td>
<td>7.78 × 10^8 ton</td>
</tr>
<tr>
<td>mean sediment concentration</td>
<td>7.21</td>
<td>24.8 kg/m³</td>
</tr>
</tbody>
</table>

**Fig.3 flow of the Yellow River into the Bohai Sea**
The coastline is changing dramatically.

Rate of the sand-spit extending into the sea
1976-1996: 0.98 km/a; 1996-2007: 1.10 km/a; 2005: >1.6 km
Question:

As the terrain, water and sediment conditions have changed so much. It’s necessary to simulate the hydrodynamic environment with latest data application.
Finite-Volume Coastal Ocean Model

- 3-Dimensional
- Unstructured Grid
- free-surface
- primitive equation

model configuration: Calculation Domain: 117°35′~121°10′E  37°07′~41° N
Node number: 13474  Element number: 25443
Finer resolution: 60 m  Coarser resolution: 14.8 km
External time step: 1s  ISPLIT: 6
Sigma layers number: 11

Fig. 5  triangular grids in caculation area
Open Boundary Conditions
The open boundary conditions include two parts, one is the outer sea, the other is Yellow River Discharge

- **Yellow River runoff**
  
  The discharge of Yellow River Runoff has a trend of minishing seen from the right figure. The average discharge of Yellow River from 2003 to 2007 is 626 m$^3$/s, here in the model I take 1238 m$^3$/s for flood season (June-October).

  The temperature and salinity of the Yellow River Runoff are taken as constant, 23.5°C and 0 psu respectively.

![Fig.6 the discharge of Yellow River Runoff from 1950 to 2007](image)
outer sea open boundary condition

- 180km east to the Bohai Strait
- 22 nodes, 14.8 km
- M2, S2, N2, K1, O1, P1 (I use six main tides to predict the water elevation to drive the model.)
- temperature and salinity, constant: 23°C, 32 psu
3 Results Analyzing

- cotidal charts for M2 and K1
- Tidal currents in the Bohai Sea
- Tidal currents outside Yellow River Estuary
- Residual currents outside Yellow River Estuary
- Yellow River Diluted Water
One kind of the model results: Water elevation of every node
Harmonic Analysis

Cotidal chart of M2

Model result
Blue lines: co-amplitude ines (cm)
Red lines: co-phase lines (°)

Zhang Zhanhai, 1994
dashed lines: co-amplitude ines (cm)
Real lines: co-phase lines (°)
Cotidal chart of K1

Model result
Blue lines: co-amplitude ines (cm)
Red lines: co-phase lines (°)

Zhang Zhanhai, 1994
dashed lines: co-amplitude ines (cm)
Real lines: co-phase lines (°)
Fig. 11 tidal current in the Bohai Sea
Tidal Current outside Yellow River Estuary

- Experiment 1: run the model with Yellow River Runoff
- Experiment 2: run the model without Yellow River Runoff
- Difference: residual current of Yellow River Runoff
Tidal current at low water stand moment

Maximum: 15 cm/s
Tidal current at fastest flood moment

Without runoff
Maximum: 80cm/s

With runoff

difference
Tidal current at high water stand moment

Without runoff

Maximum: 25 cm/s

With runoff

difference
Tidal current at fastest ebb moment

Without runoff
Maximum: 70 cm/s

With runoff
Eulerian Residual Currents Outside Yellow River Estuary

- Tide-induced Eulerian Residual Currents: calculated by averaging current vectors in M2 tidal periods.

- Residual Currents of Yellow River Runoff: difference between the two experiments
Tide-induced Residual Current

without runoff

with runoff

difference
Residual Current of Yellow River Runoff
Yellow River Diluted water

119.15 119.2 119.25 119.3 119.35 119.4

37.74 37.76 37.78 37.8 37.82 37.84 37.86 37.88

10 cm/s

5 cm/s
Conclusions of the study on the flow field outside the Yellow River Estuary

- Yellow River Runoff only has obvious effect on the area near the river estuary (10 kilometers from the estuary)
- Flow field was intensified by the river runoff
- Tide-induced residual current: two cells with opposite direction of rotation on either side of the sand-spit, left cyclonic and right anti-cyclonic
- Residual current of Yellow River Runoff
- Yellow River diluted water: northeast-east
Thanks!

Any questions?