Numerical simulation for tides and tidal currents in the Bohai Sea

--Yellow River Estuary

Gao Jia[1], Chen Xueen[1] , Yu Huaming[1]

(1.Ocean University of China)

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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

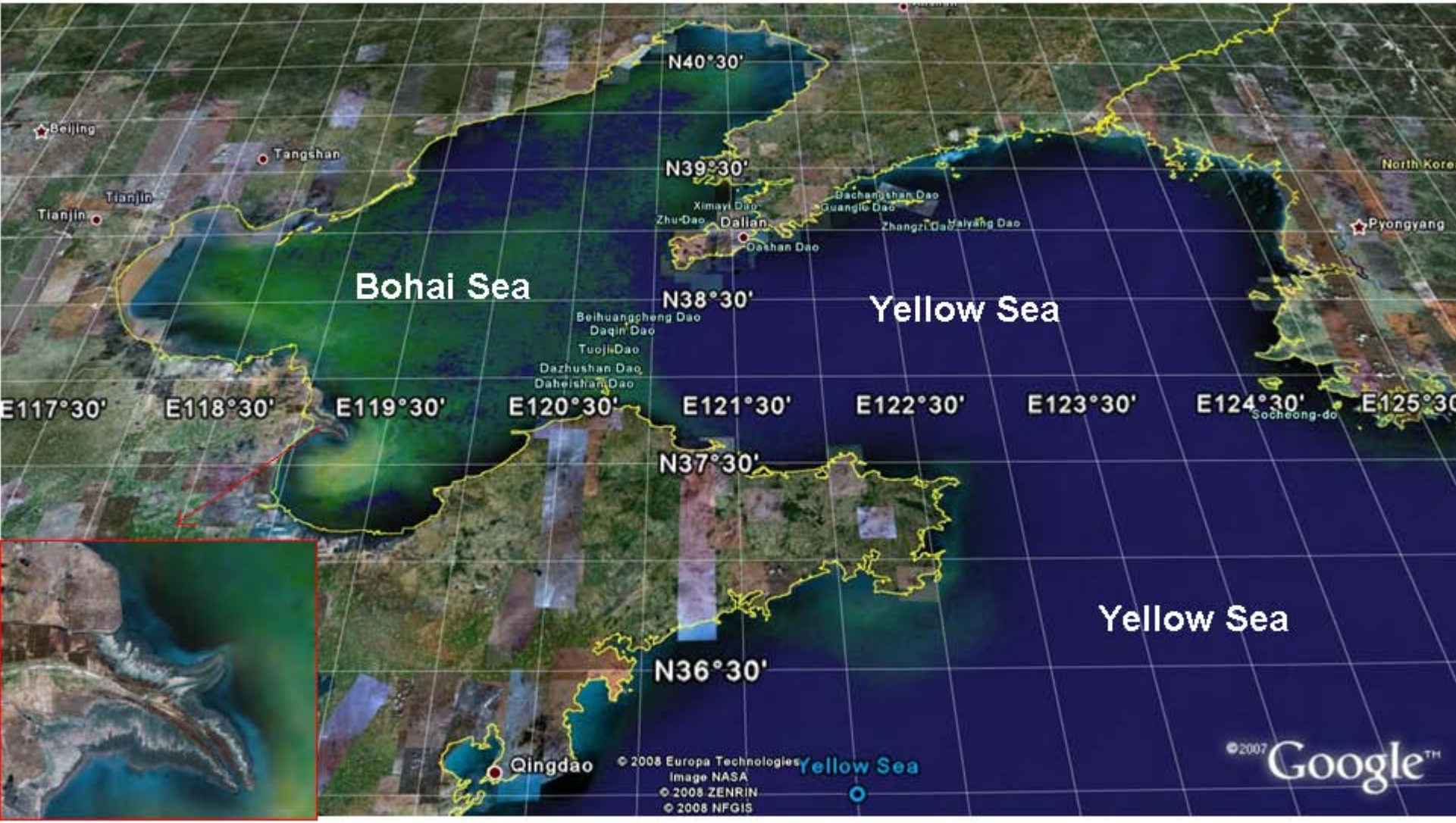


Fig. 1 the locality of the Bohai Sea

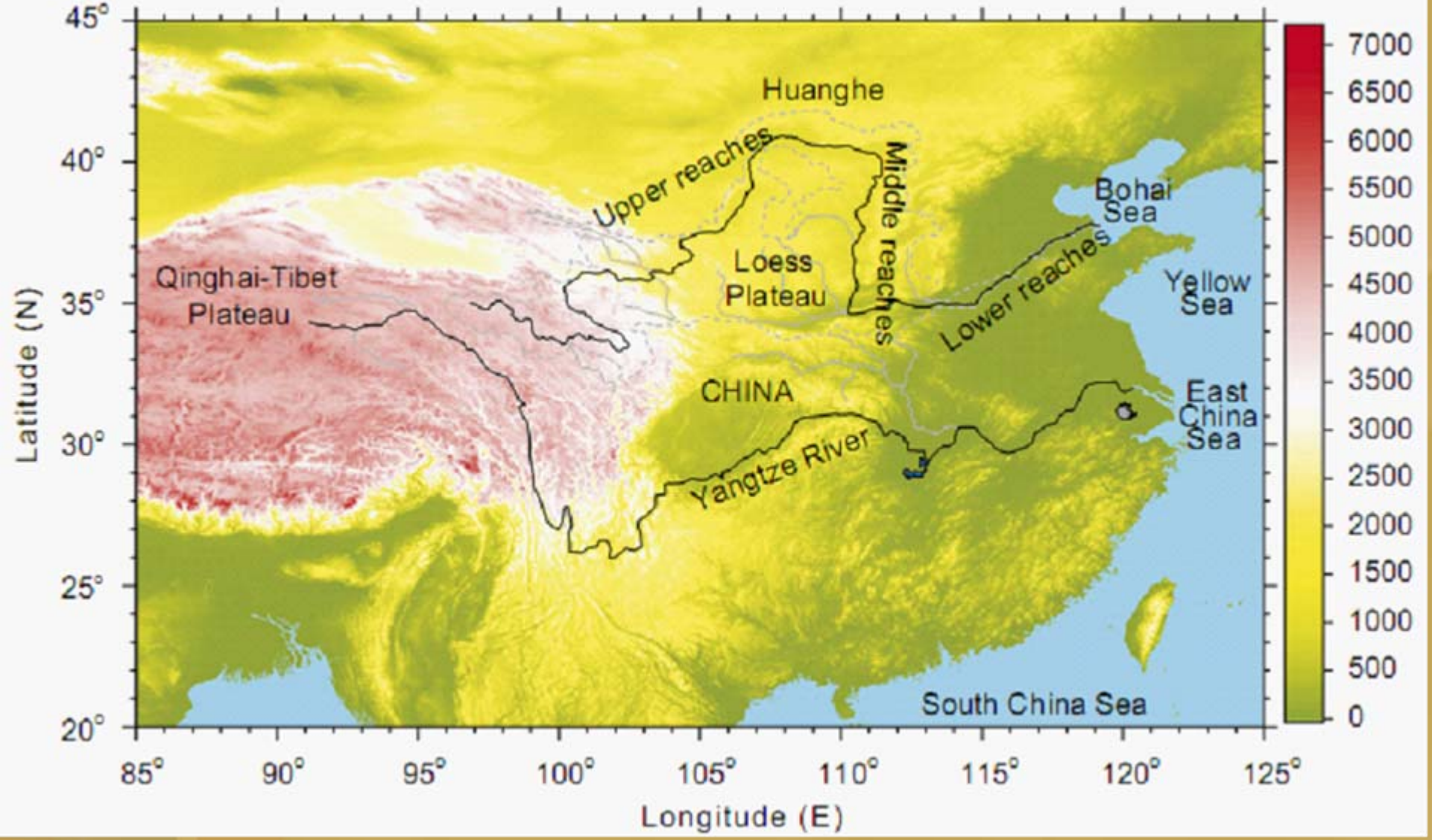


Fig.2 Index map of the Yellow River and its river basin.
The Yellow River,originating from the high Qinghai-Tibet Plateau(a plateau with the highest altitude in the world),is one of the major contributors of fluvial sediment to the oceans.

Yellow River Sediment Bulletin

	2007	multi-year average	
Water discharge	204	313.3	$\times 10^8\ m^3$
sediment discharge	1.47	7.78	$\times 10^8$ ton
mean sediment concentration	7.21	24.8	kg/m^3

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 : >1.6km

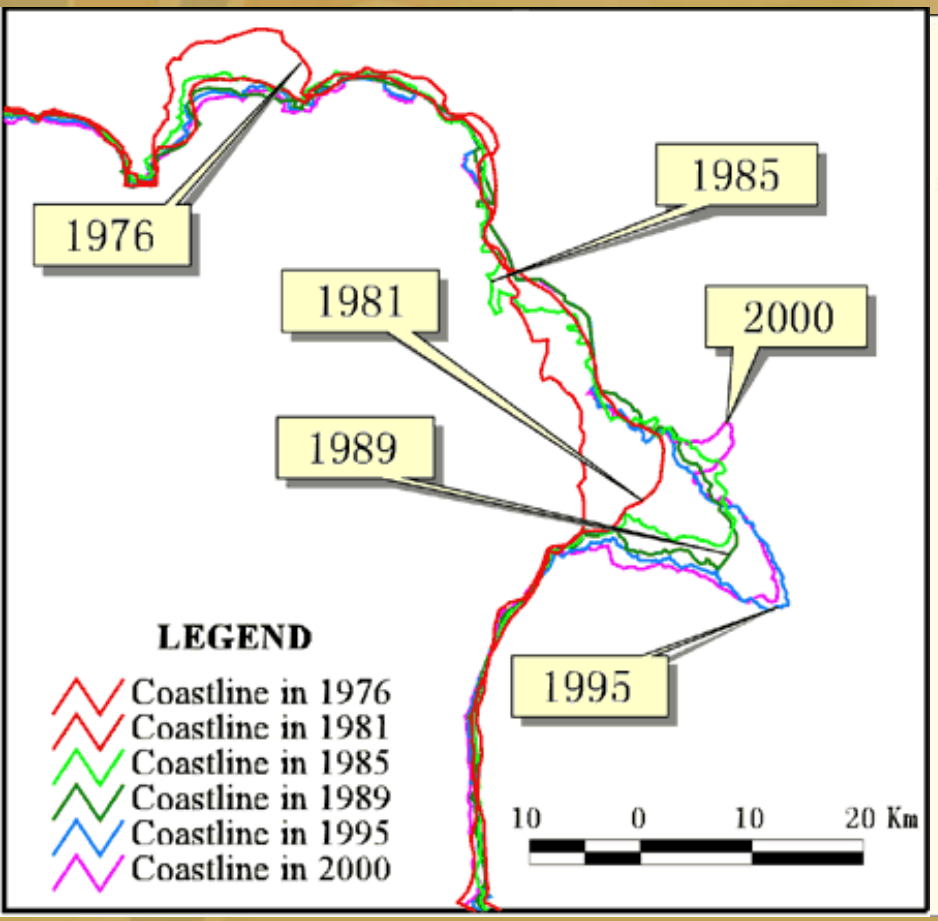


Fig.4 River course and coastline changes of the Yellow River

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 Costal Ocean Model

- 3-Dimensional
- Unstructured Grid
- free-surface
- primitive equation
- Finite-Volume Costal Ocean Model, which combines the best attributes of finite-difference methods for simple discrete coding and computational efficiency and finite-element methods for geometric flexibility.

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

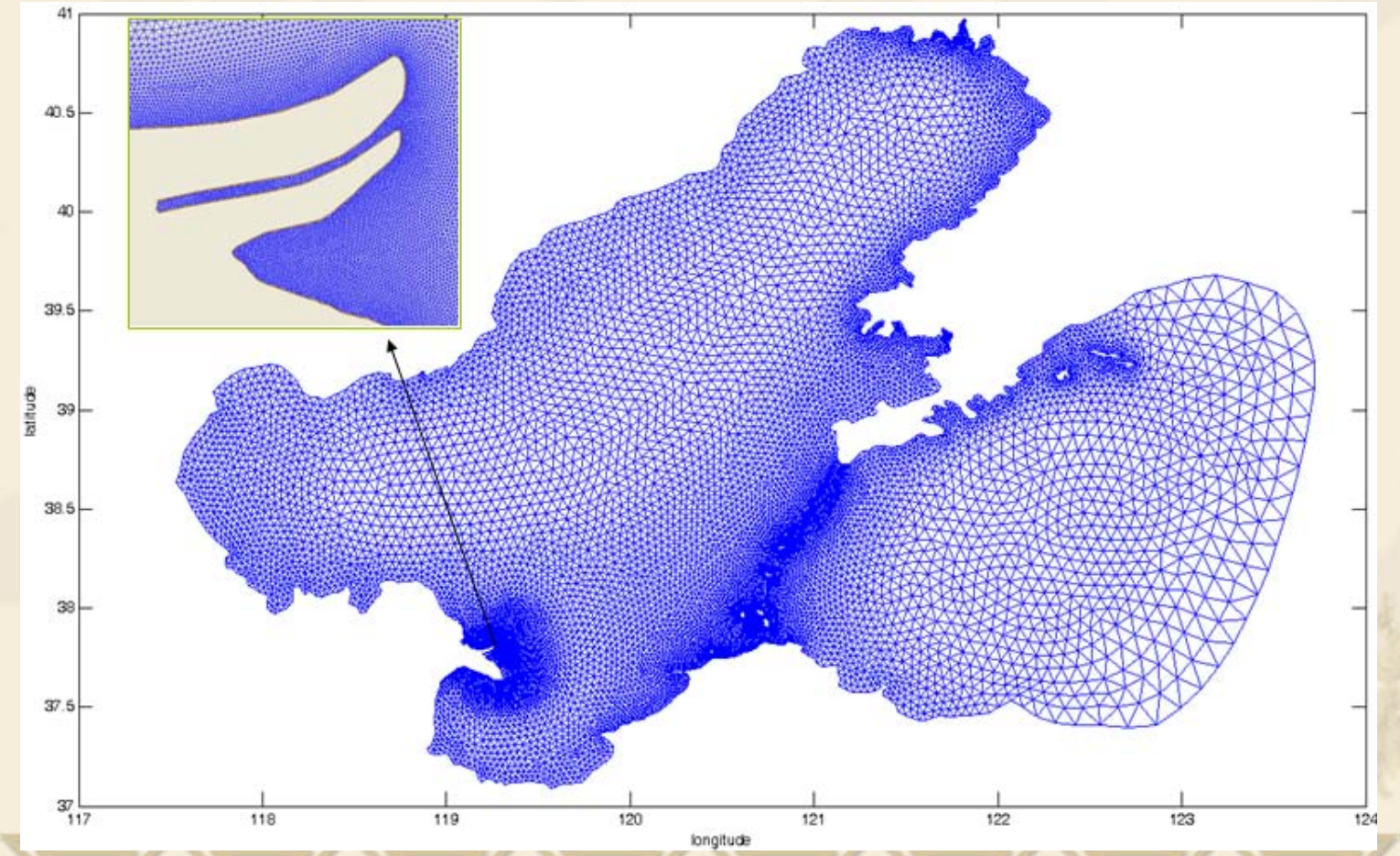


Fig.5 triangular grids in caculation area

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 tempreture and salinity of the Yellow River Runoff are taken as constant, 23.5℃ and 0 psu respectively.

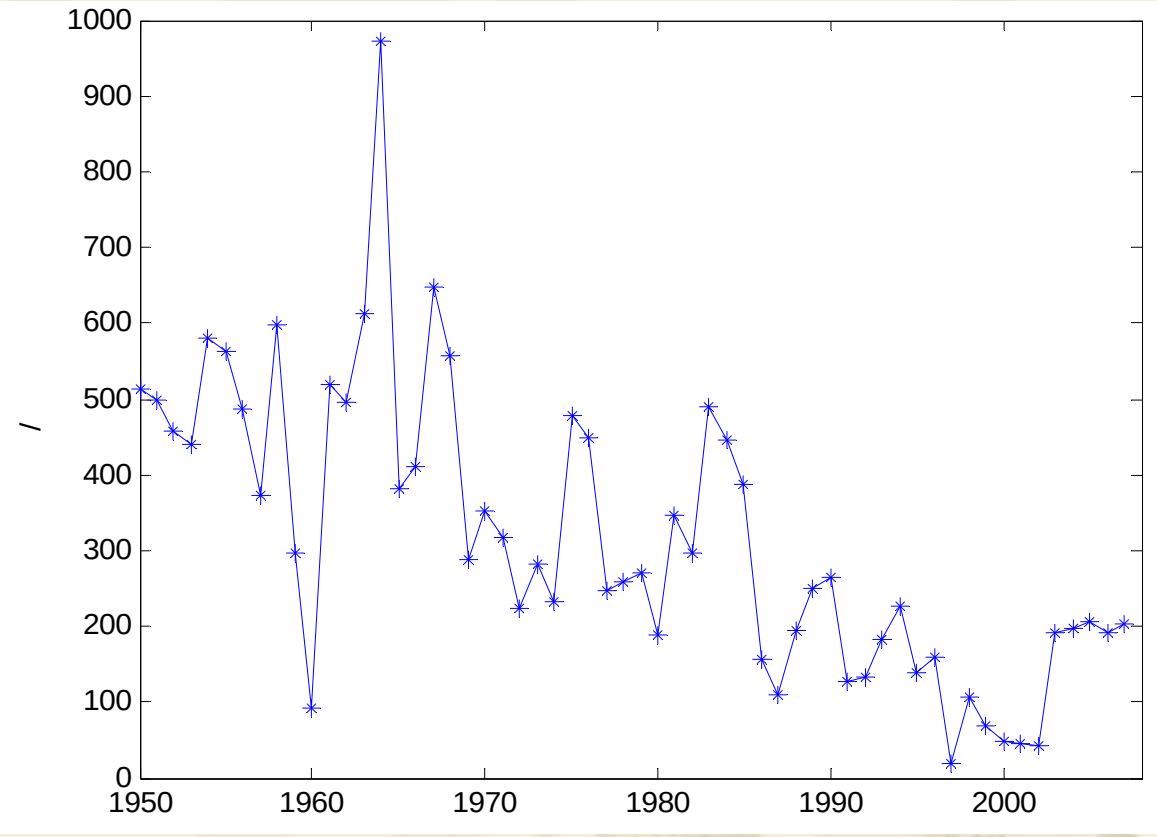
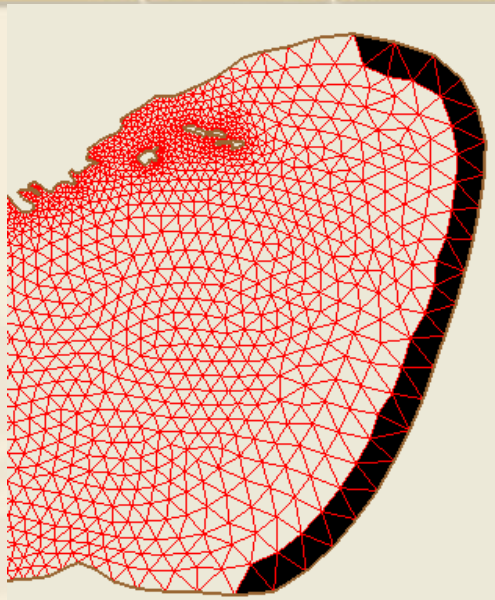


Fig.6 the discharge of Yellow River Runoff from 1950 to 2007

outer sea open boundary condition



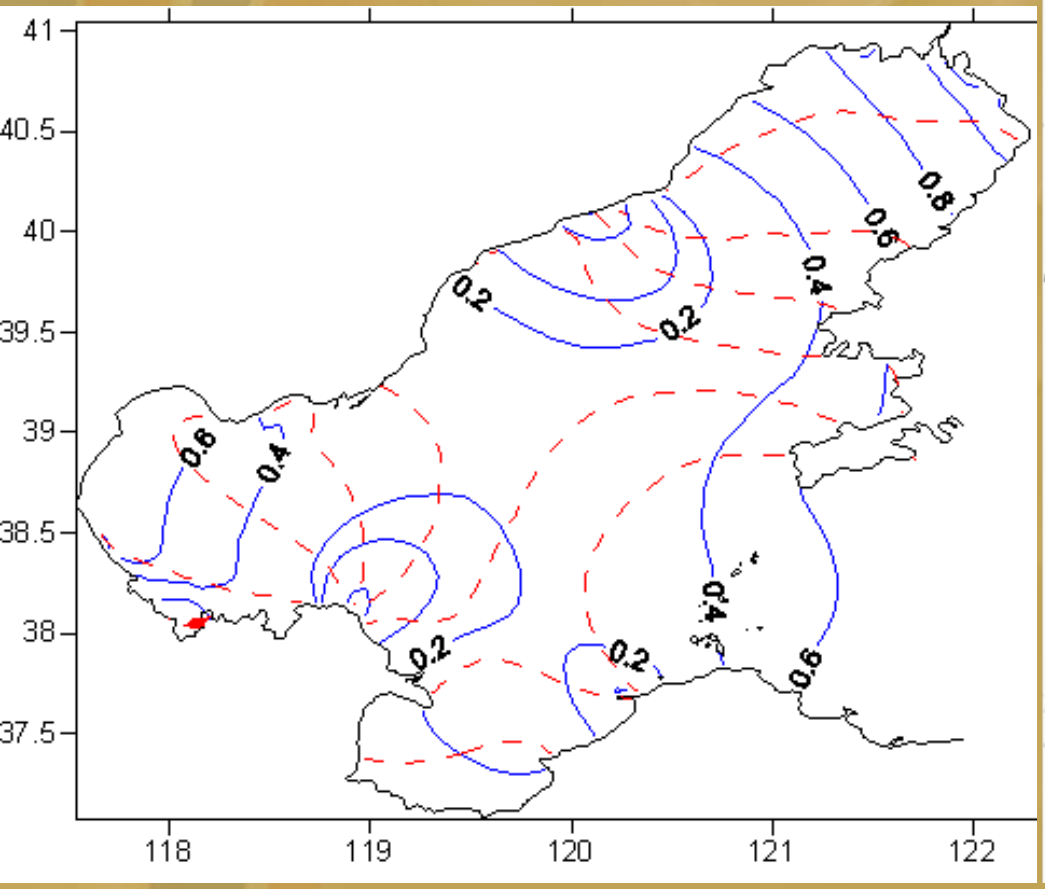
- 180km east to the Bohai Strait
- 22 nodes, 14.8 km
- M2，S2，N2，K1，O1，P1(I use six main tides to predict the water elevation to drive the model.)
- tempreture and salinity, constant : 23℃,32psu

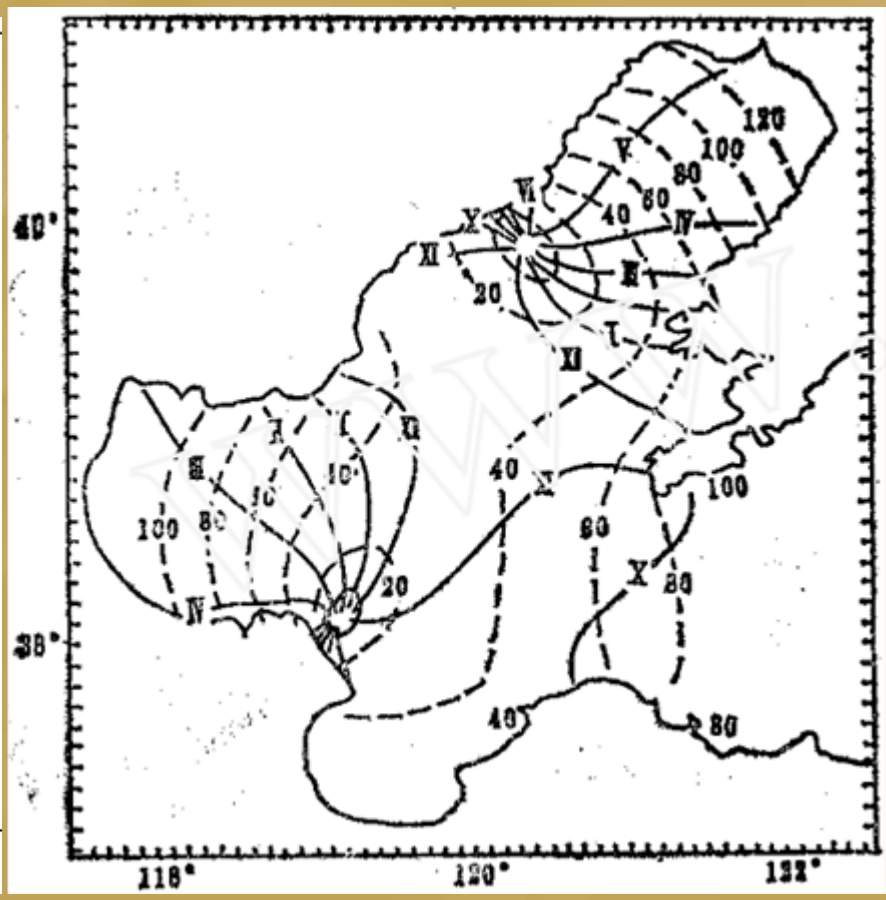
3 Results Analyzing

- 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)

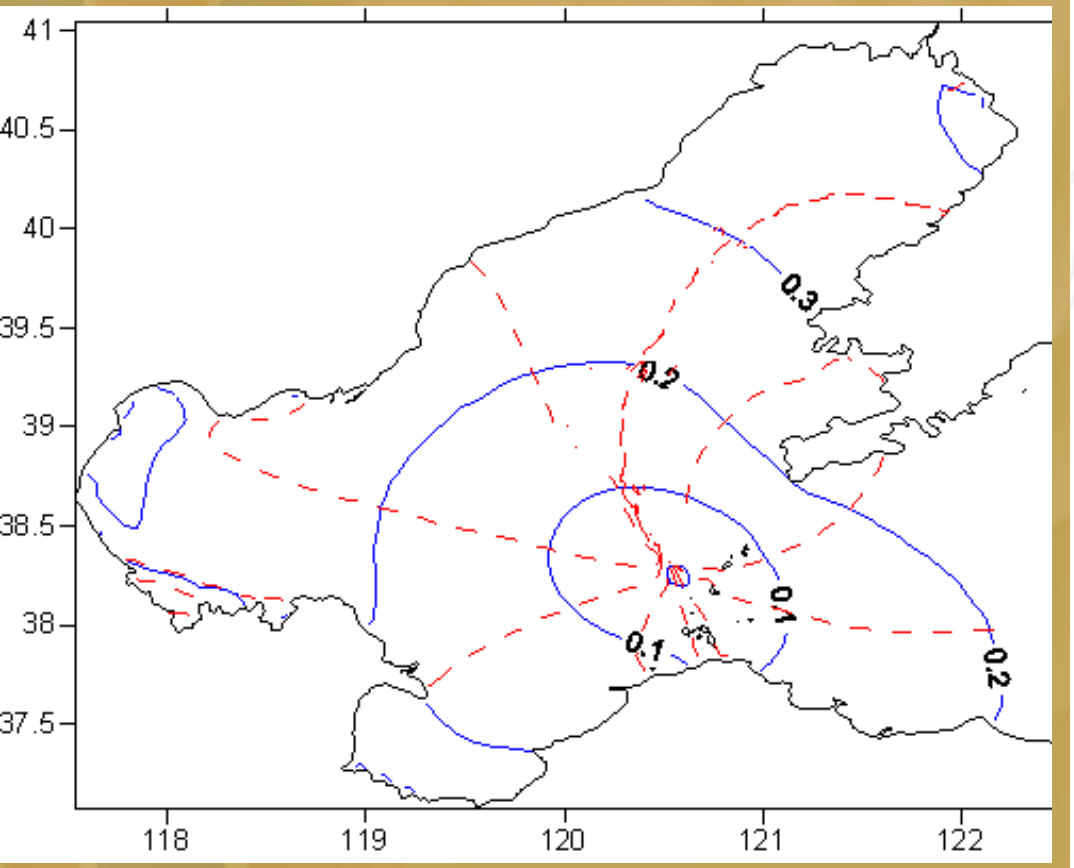
Red lines:co-phase lines (°)

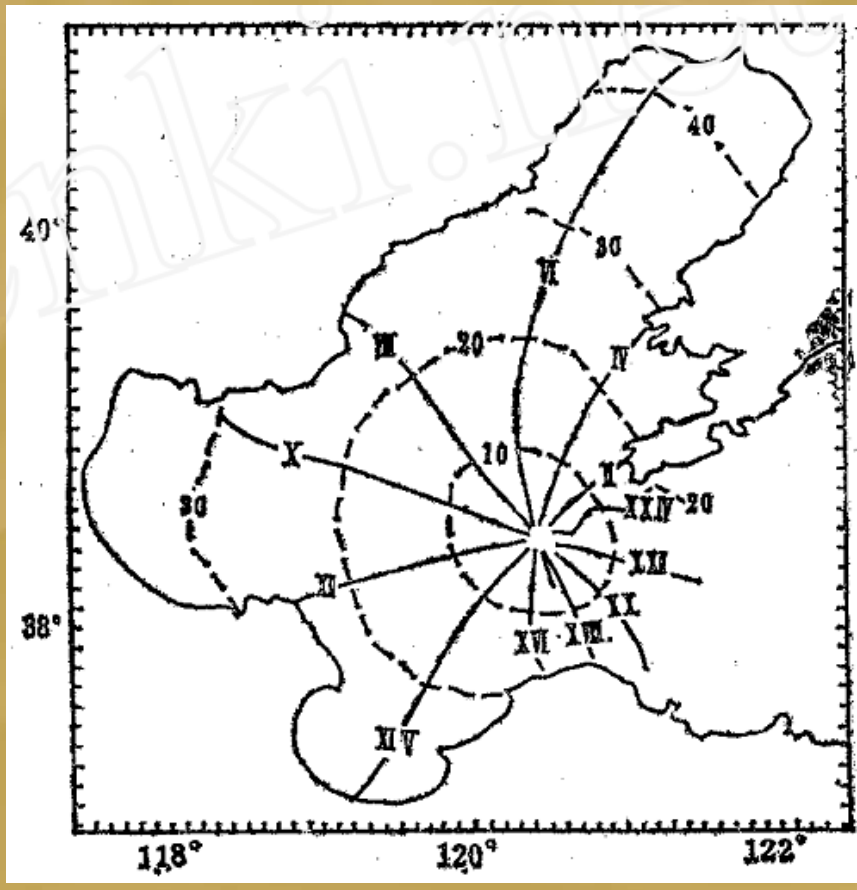
Zhang Zhanhai,1994

dashed lines: co-amplitude ines (cm)

Real lines: co-phase lines (°)

Cotidal chart of K1





Model result

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Zhang Zhanhai,1994

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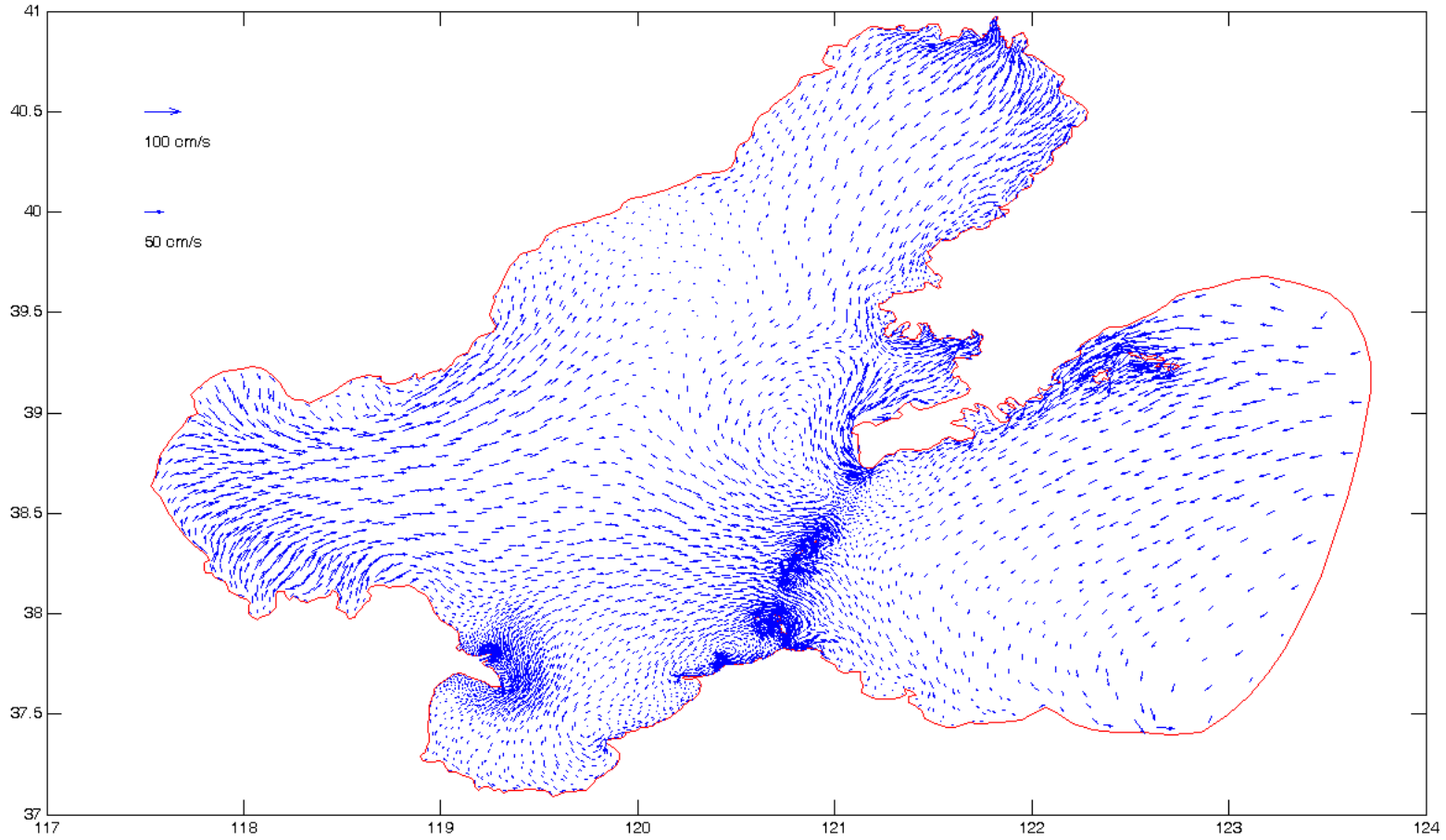
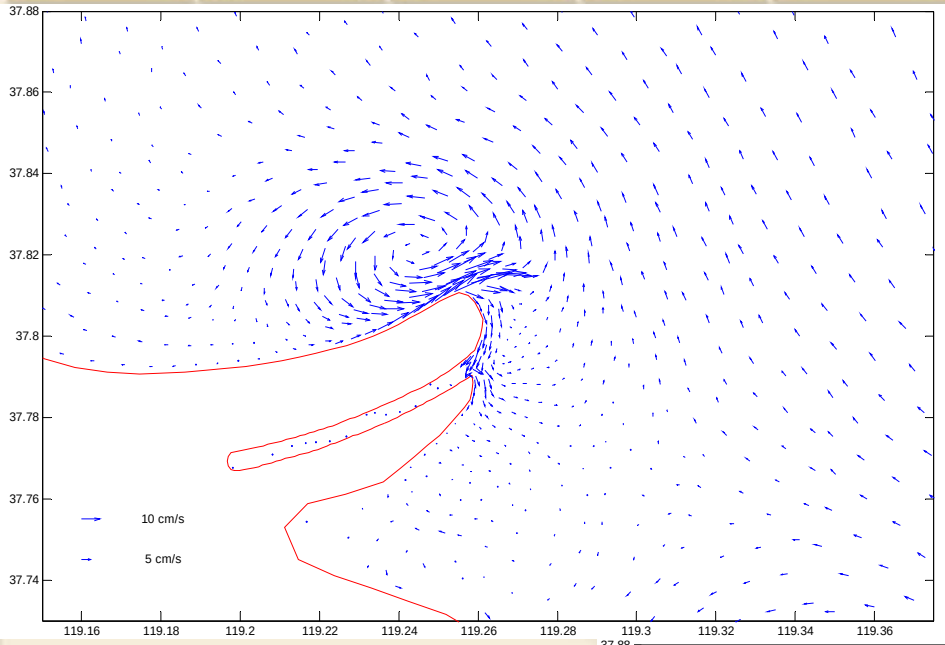


Fig.11 tidal current in the Bohai Sea

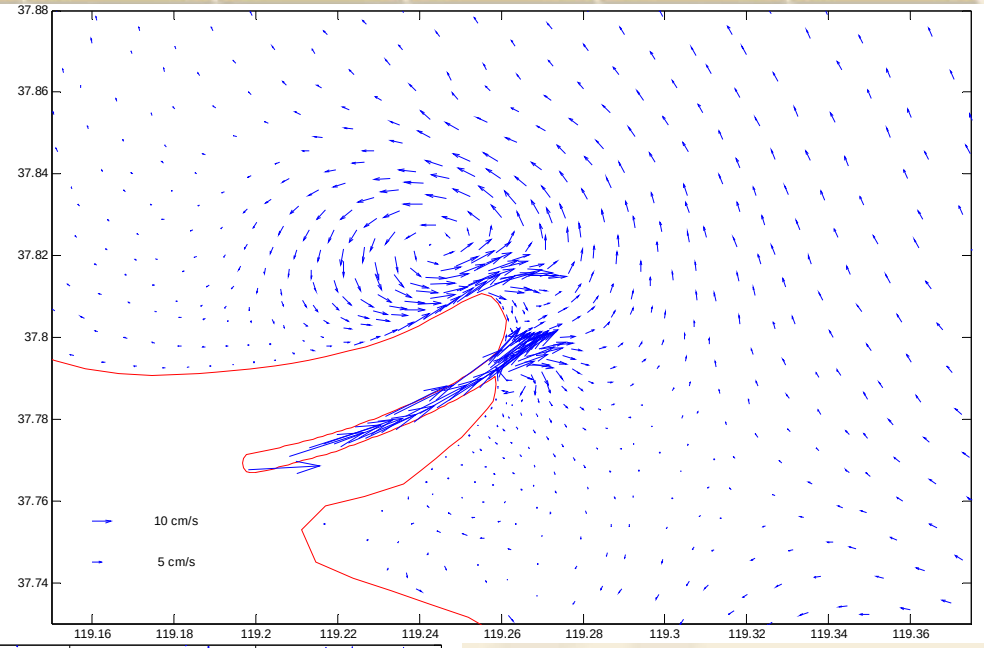
Tidal Current outside Yellow River Estuary

- 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

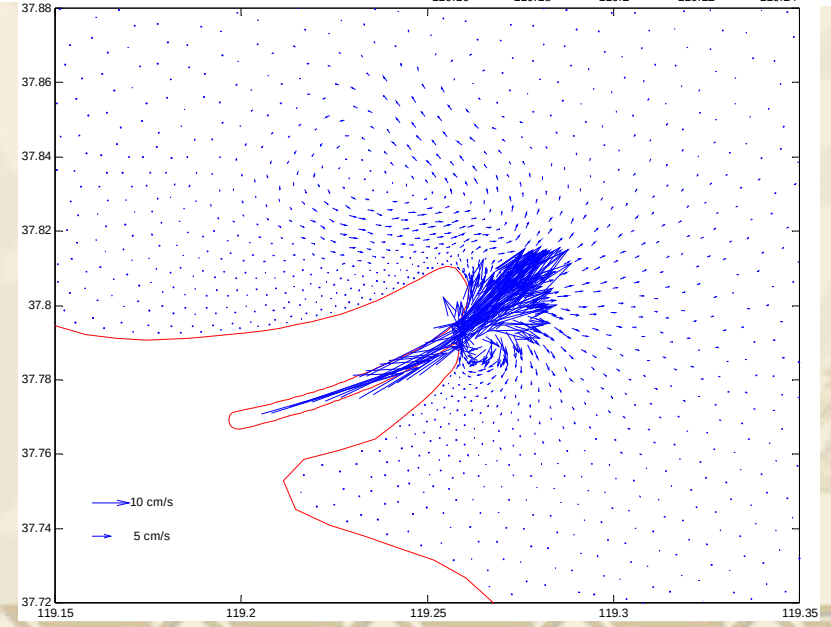


Without runoff



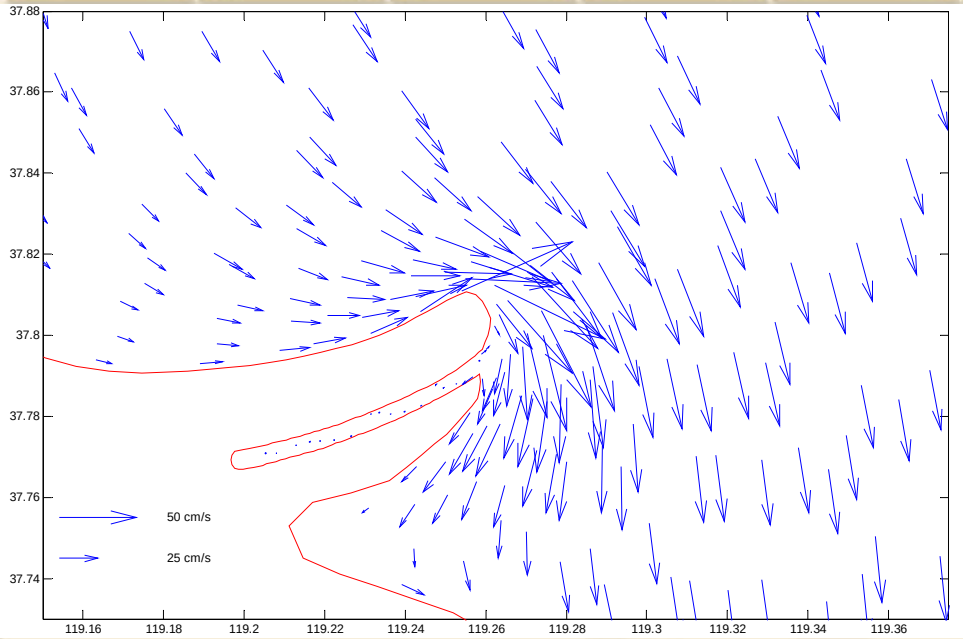
With runoff

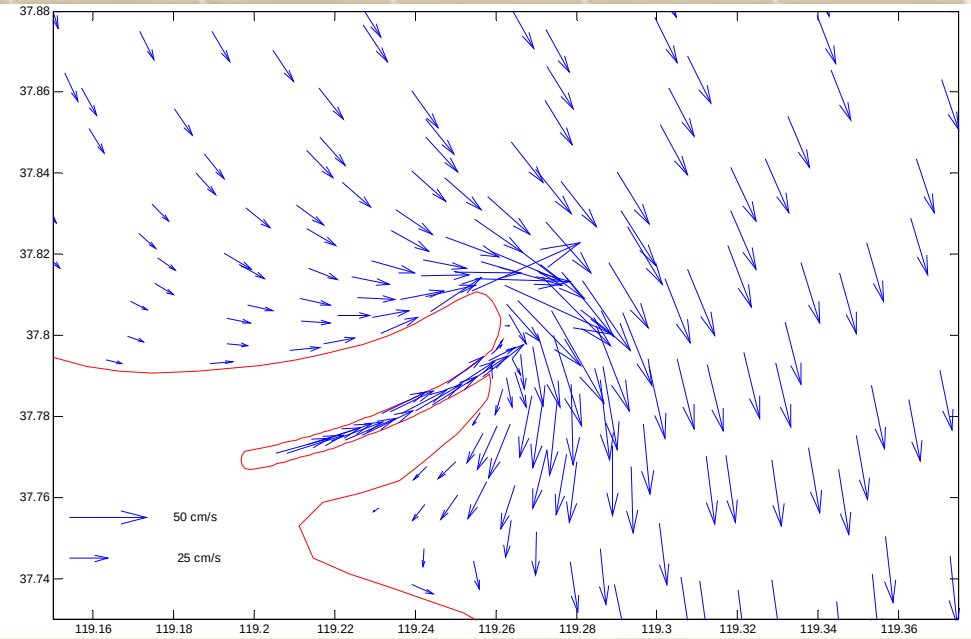
Maximum:15cm/s



difference

Tidal current at fastest flood moment

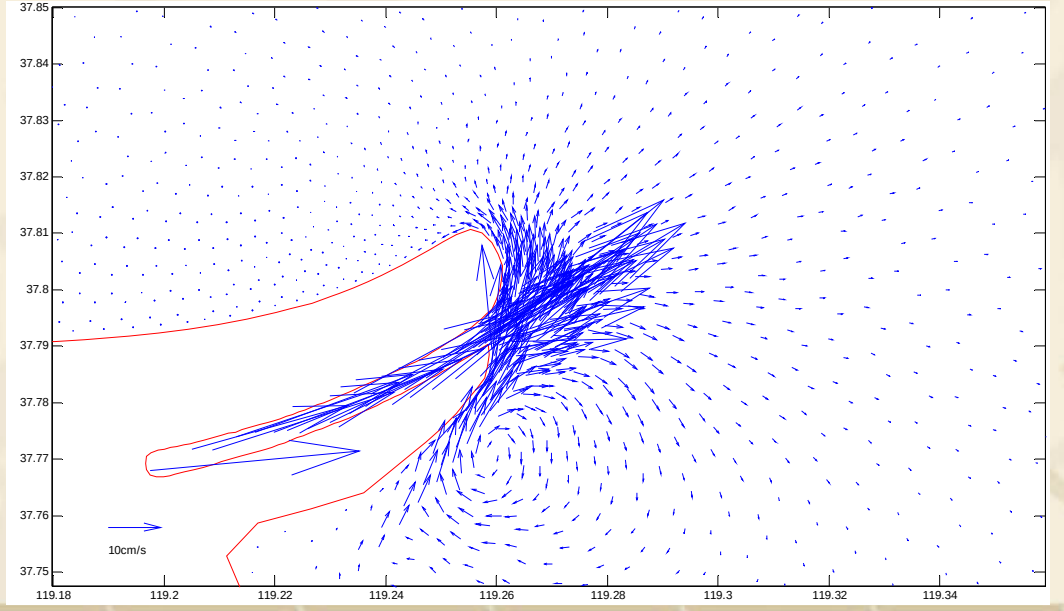




Without runoff

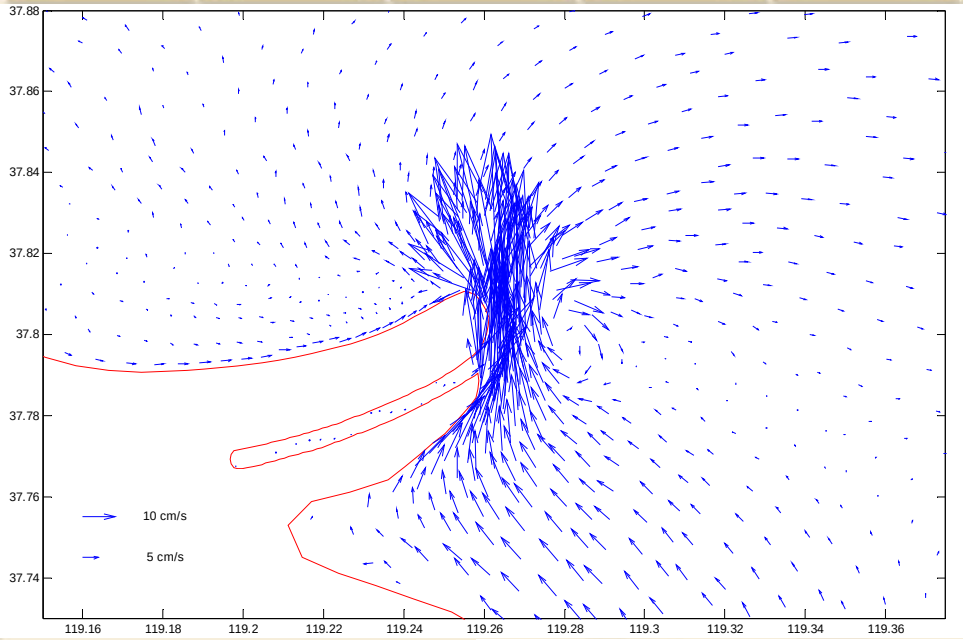
With runoff

Maximum:80cm/s

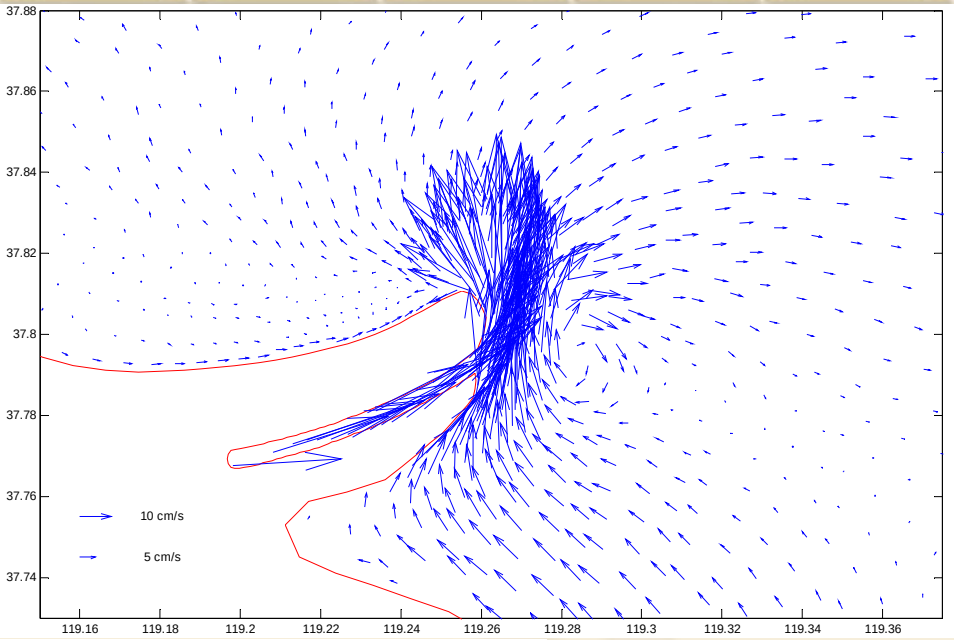


difference

Tidal current at high water stand moment

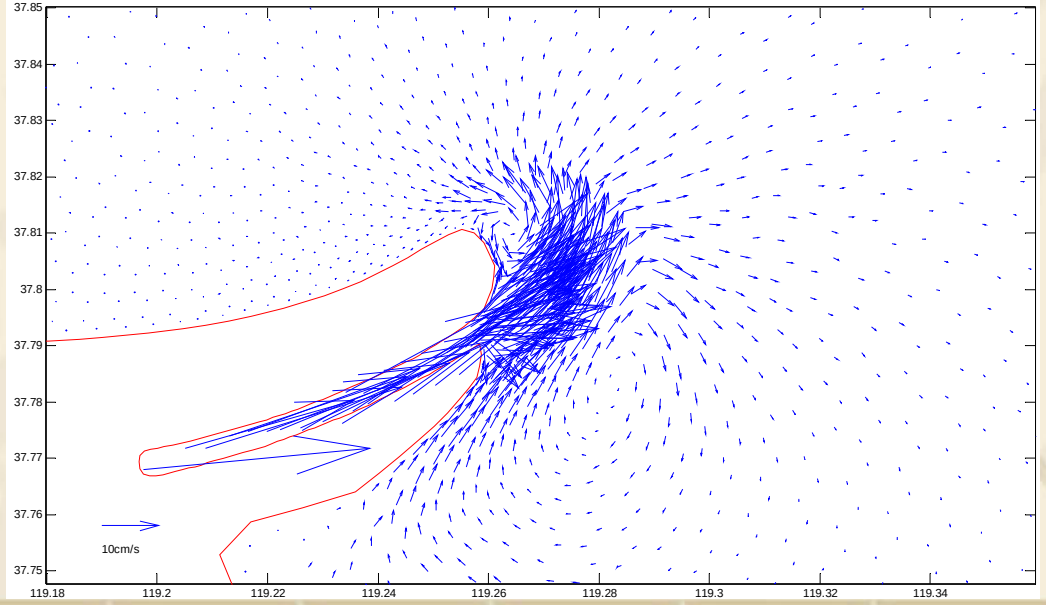


Without runoff



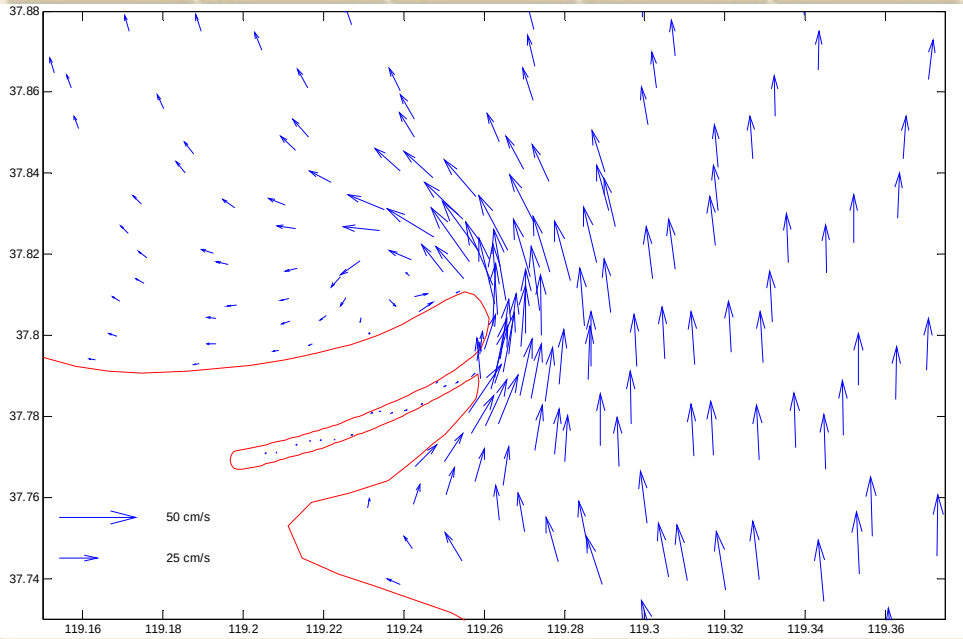
With runoff

Maximum:25cm/s



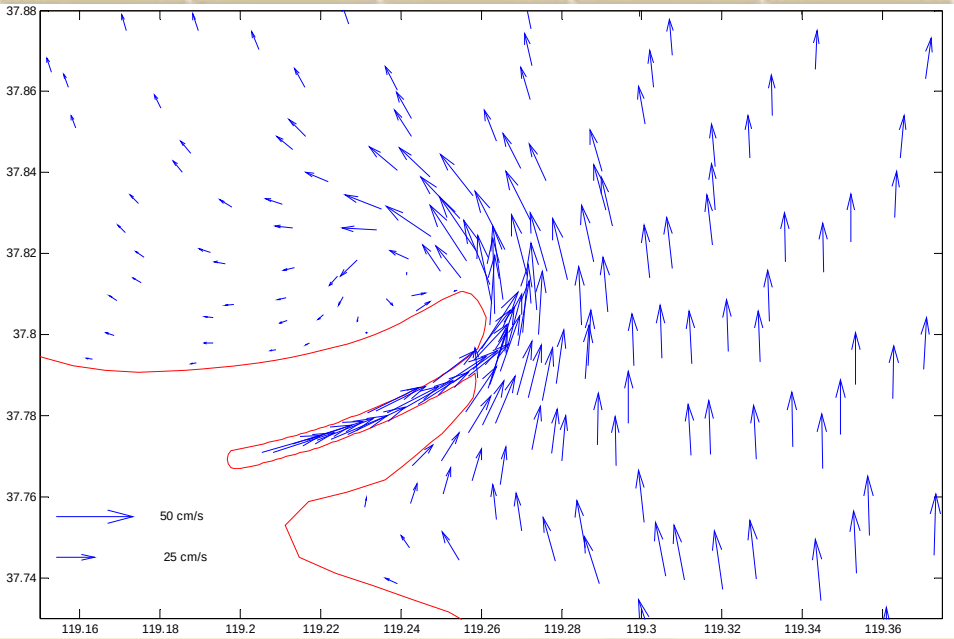
difference

Tidal current at fastest ebb moment

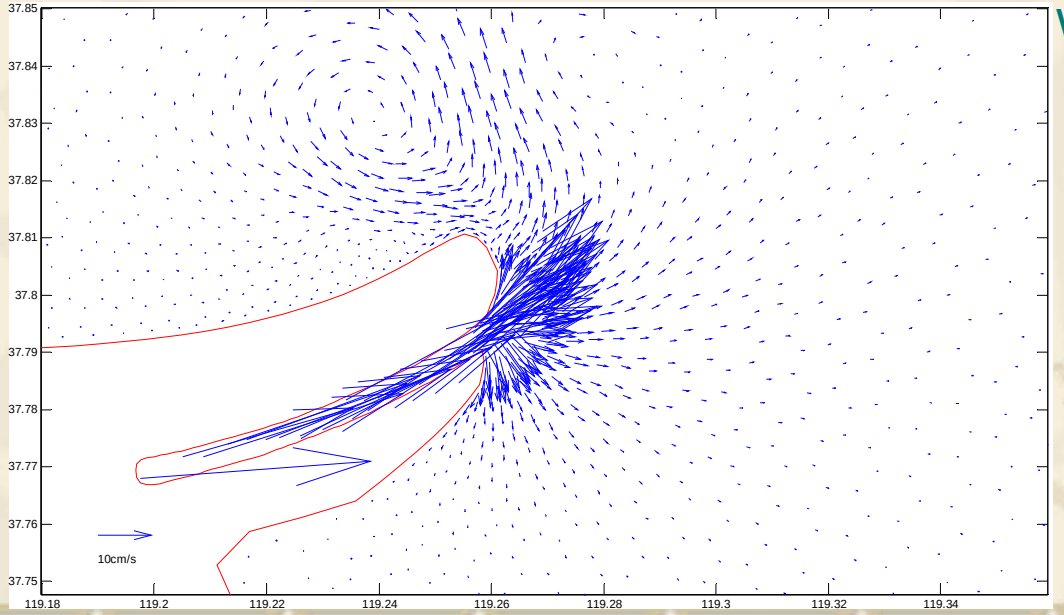


Without runoff

Maximum:70cm/s



With runoff



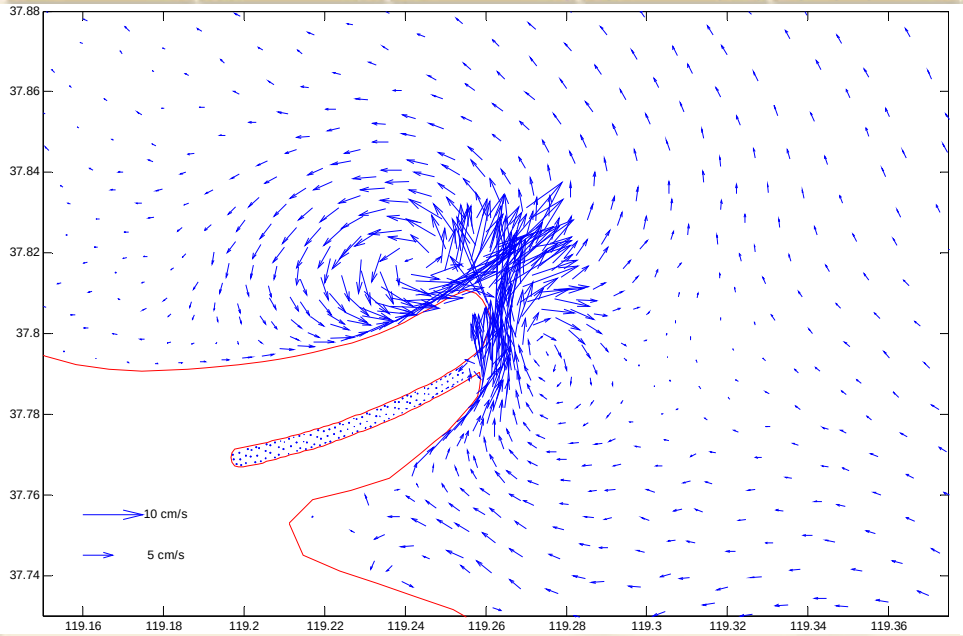
difference

Eulerian Residual Currents Outside Yellow River Estuary

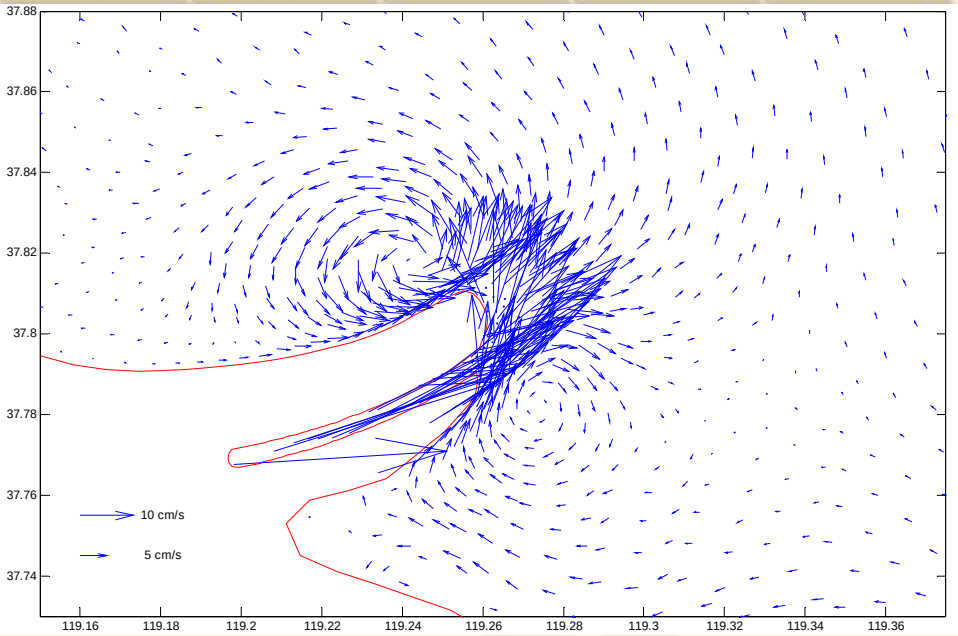
- Tide-induced Eulerian Residual Currents : calculated by averaging current vectors in M2 tidal periods.

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

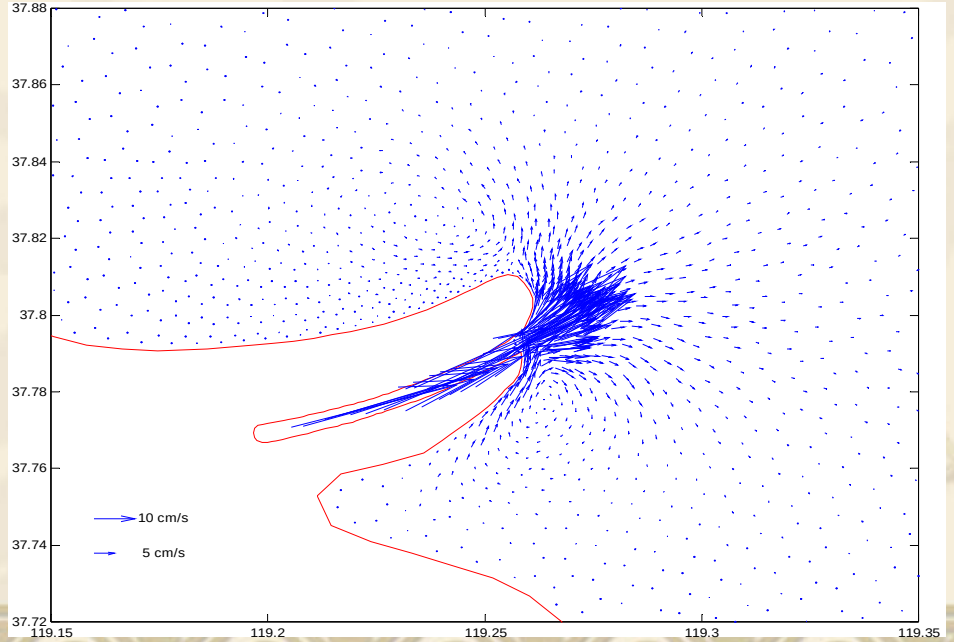
Tide-induced Residual Current



without runoff

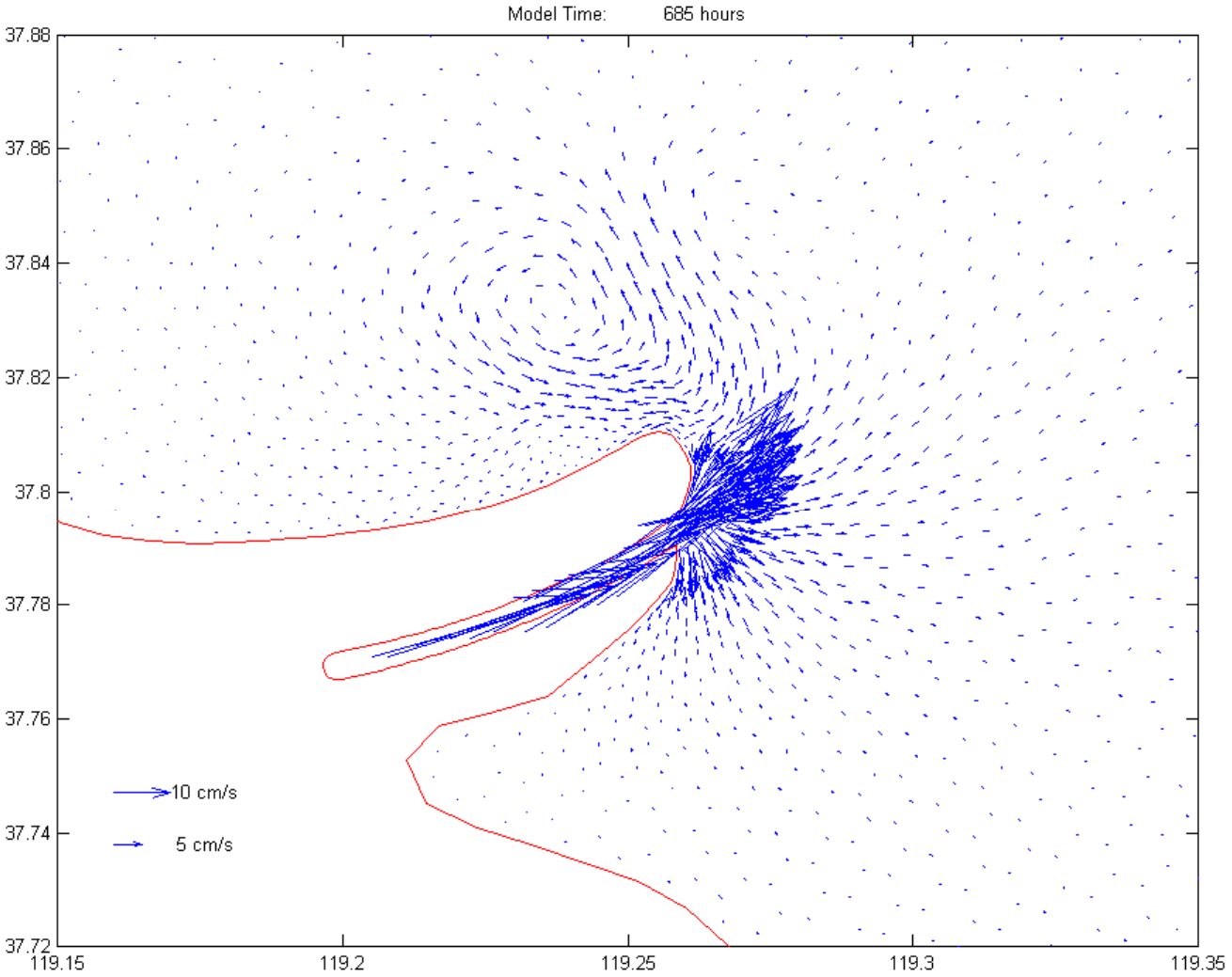


with runoff

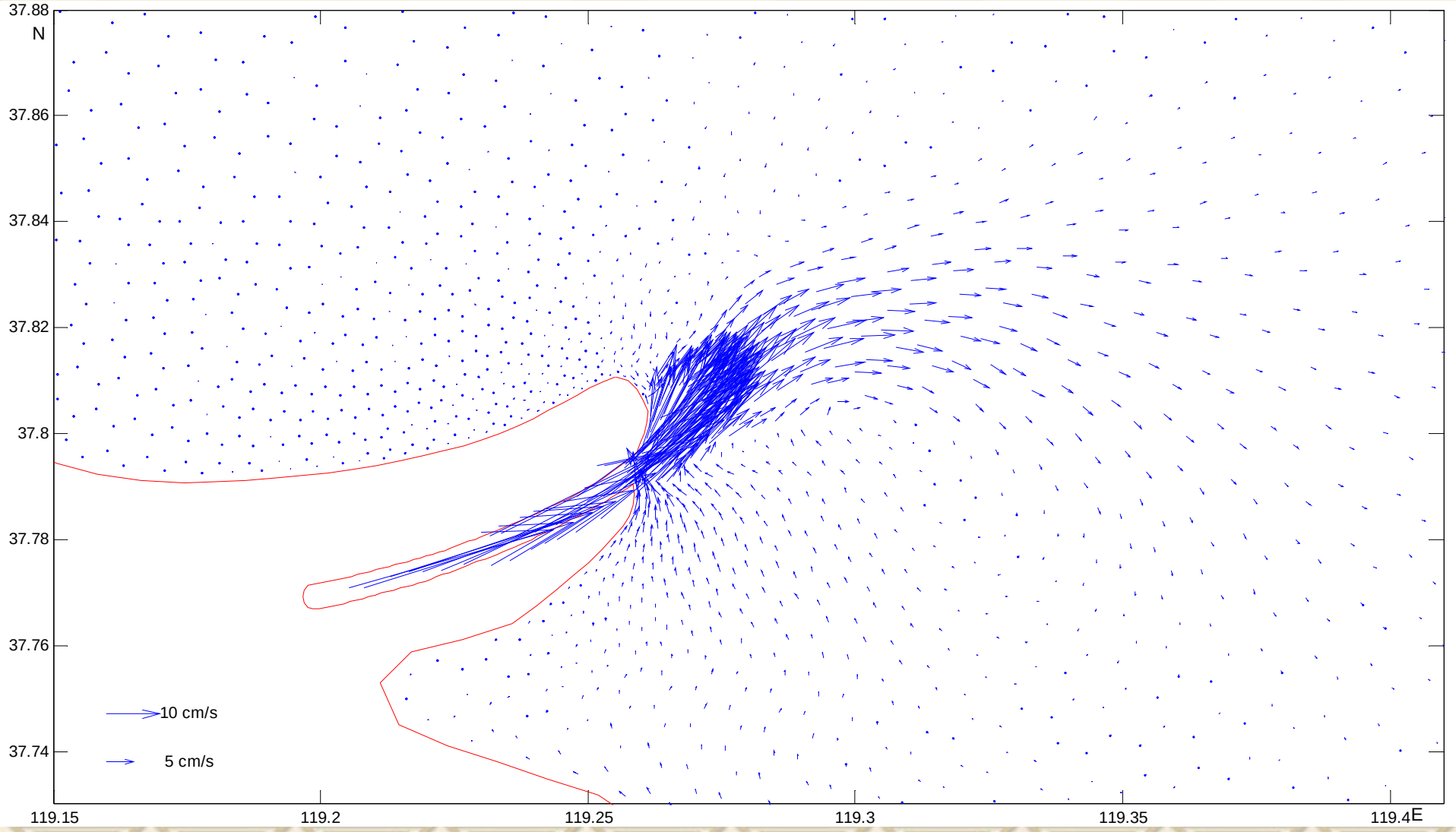


difference

Residual Current of Yellow River Runoff



Yellow River Diluted water



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

Any questions ?