

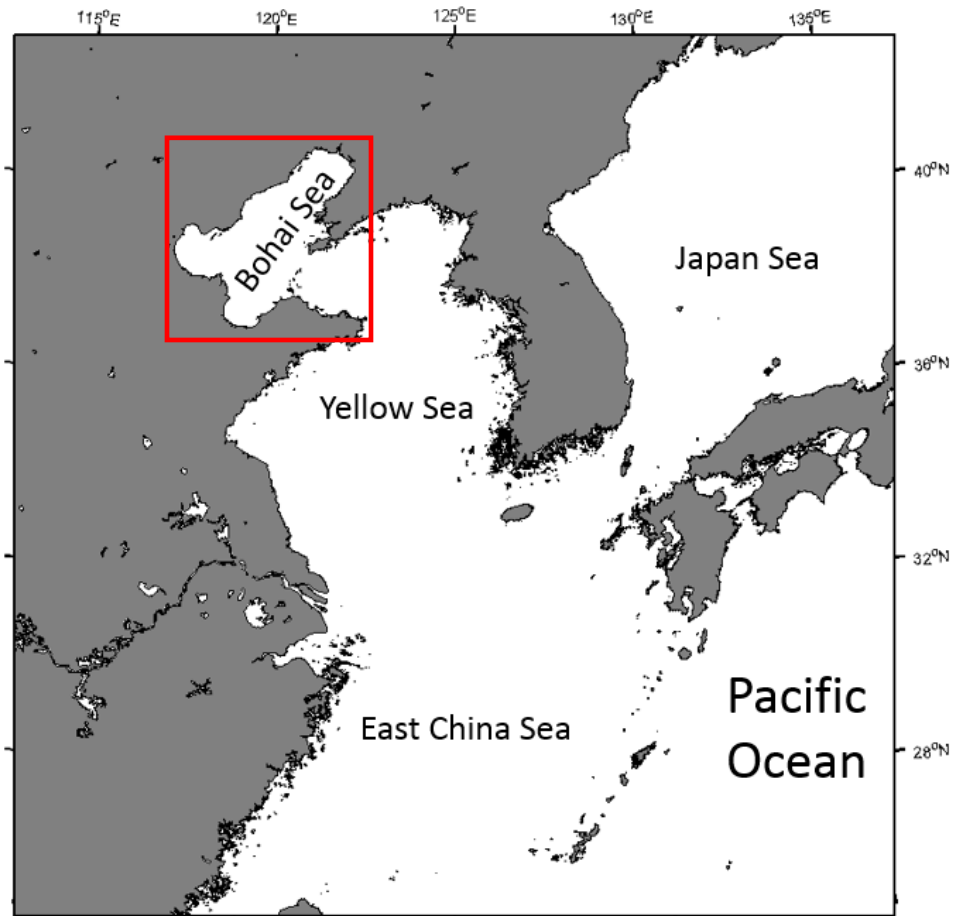
Analysis on the pattern and formation dynamics of the summertime
coastal circulation system in the western Bohai Sea

Chuanxi Xing

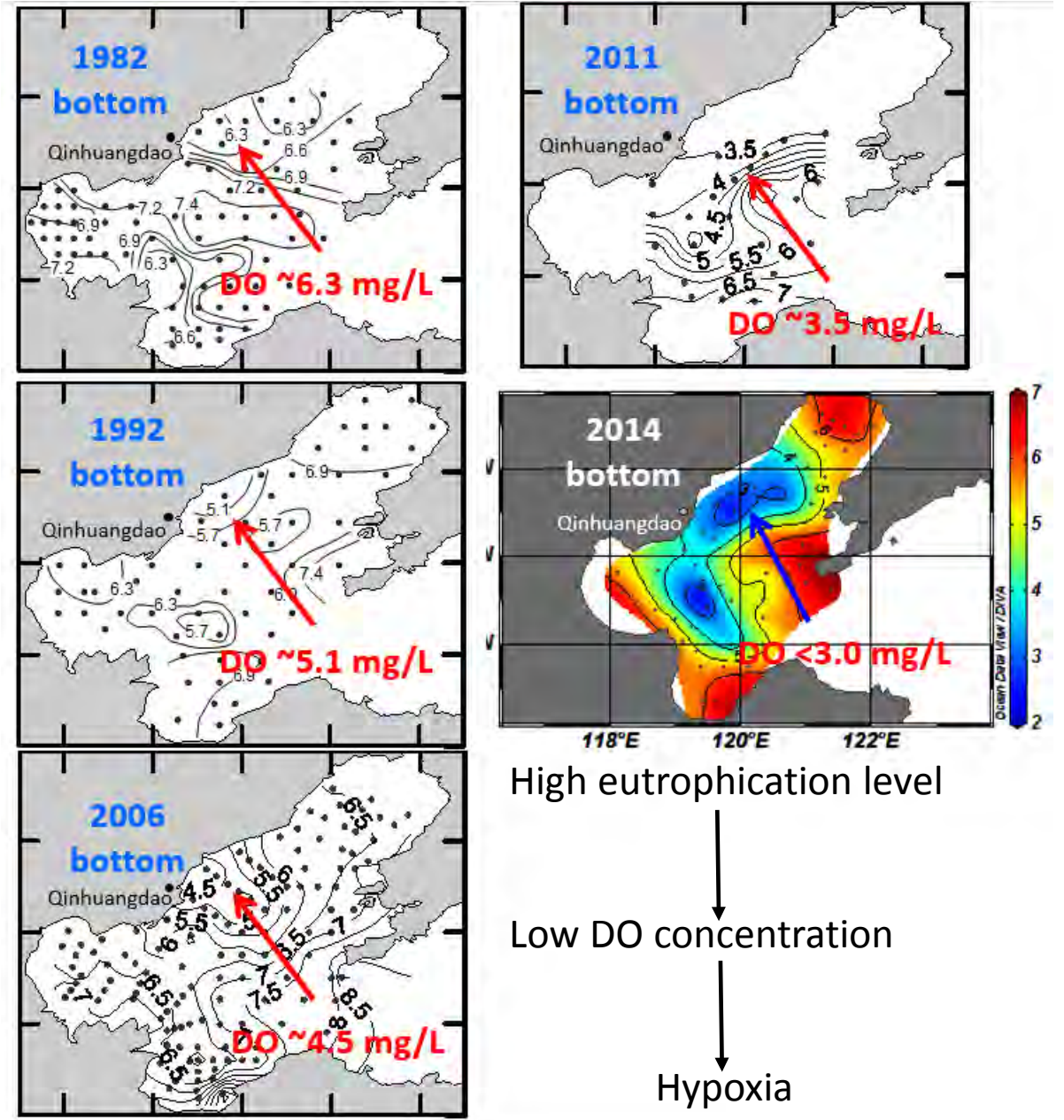
National Marine Environment Monitoring Center
State Oceanic Administration, P.R. China

PICES, 2016
San Diego

The Bohai Sea and its problems



Semi-enclosed marginal sea of Pacific Ocean

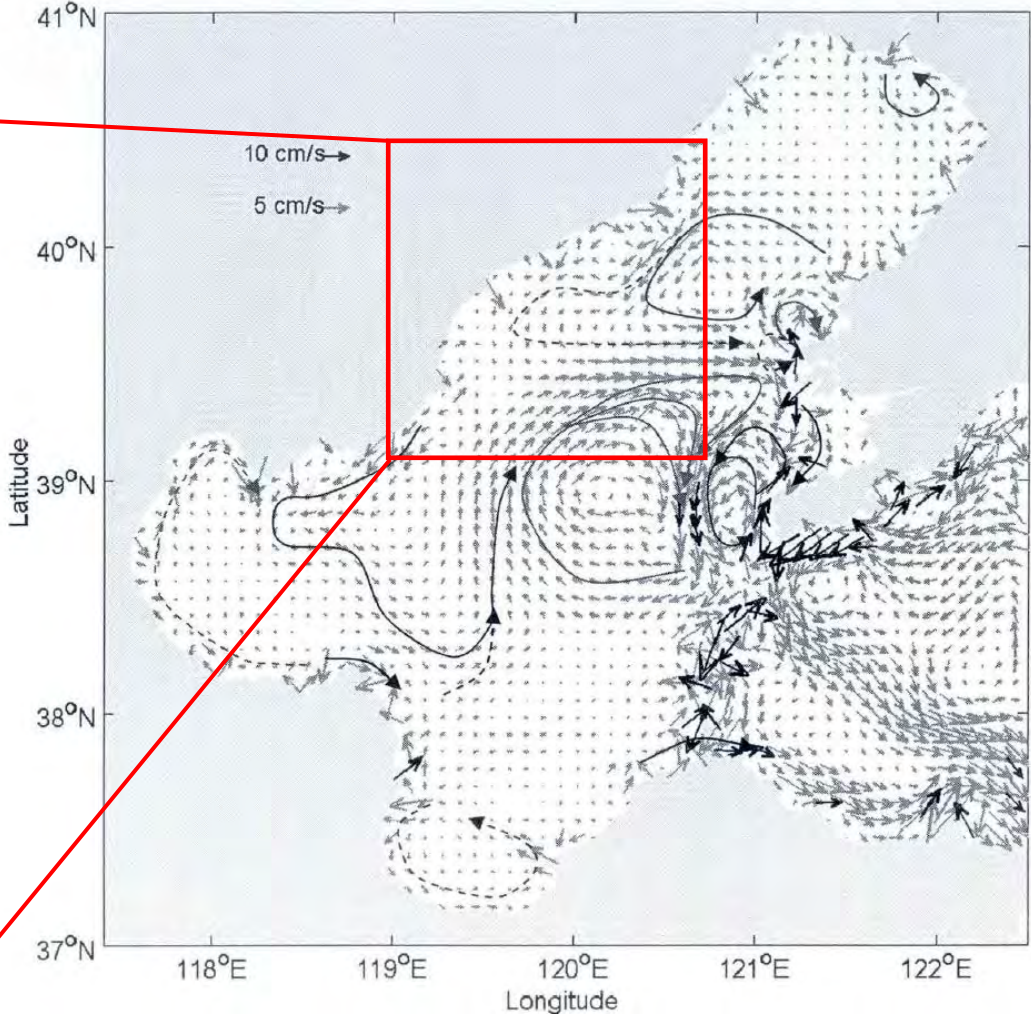


Summertime bottom DO concentration from historical records

The Bohai Sea and its problems

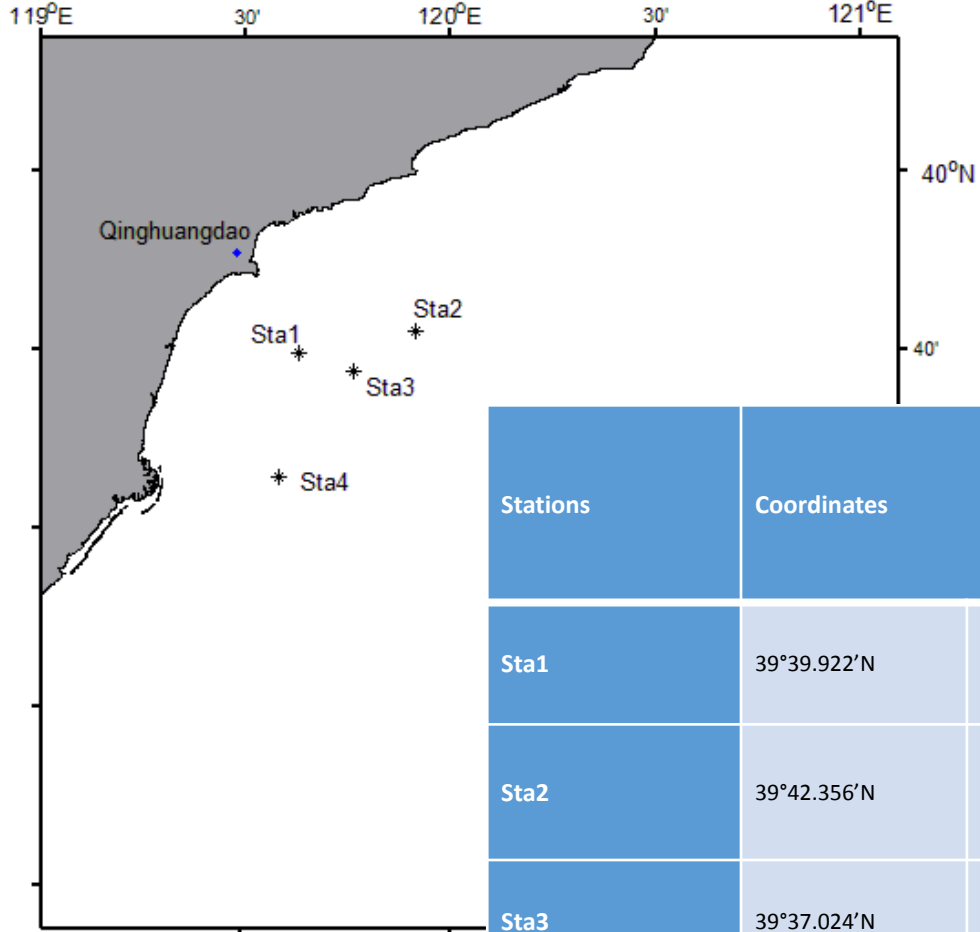


Satellite images of surface chlorophyll concentration in 2010
(light color denotes higher concentration)



The summertime circulation of the Bohai Sea
(vertically integrated values from Bi (2013))

Current observation



Four ADCP-equipped seabed based current observation systems are deployed in the Qinghuangdao coastal area.

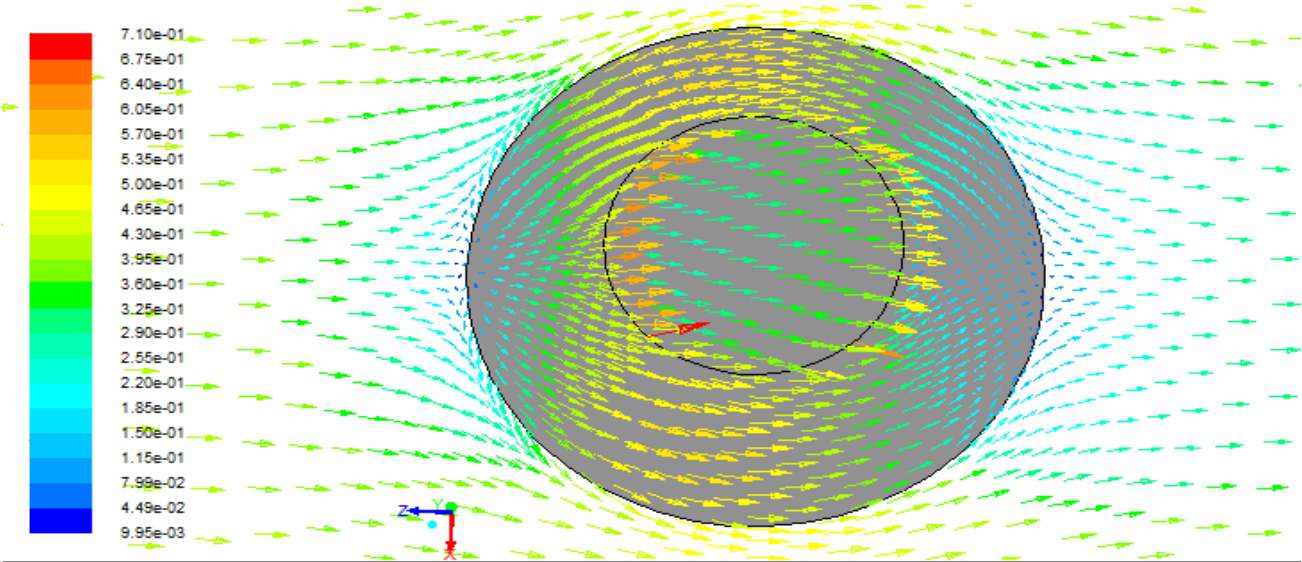
Stations	Coordinates		Depth (m) / Resolution (m)	Observation time (GMT)	Observation frequency	Observed parameters
Sta1	39°39.922'N	119°37.873'E	15/ 1	02.09 04:30 -26.09 07:40	10min	Current /Depth
Sta2	39°42.356'N	119°54.960'E	21/ 1	02.09 01:27 -26.09 02:57	10min	Current /Depth
Sta3	39°37.024'N	119°45.92'E	19/ 0.5	02.09 03:00 -26.09 03:00	10min	Current /Depth
Sta4	39°25.933'N	119°34.941'E	18/ 0.98	02.09 06:50 -26.09 10:10	10min	Current /Depth

The seabed based observation systems



Seabed based observation platform for multipurposes

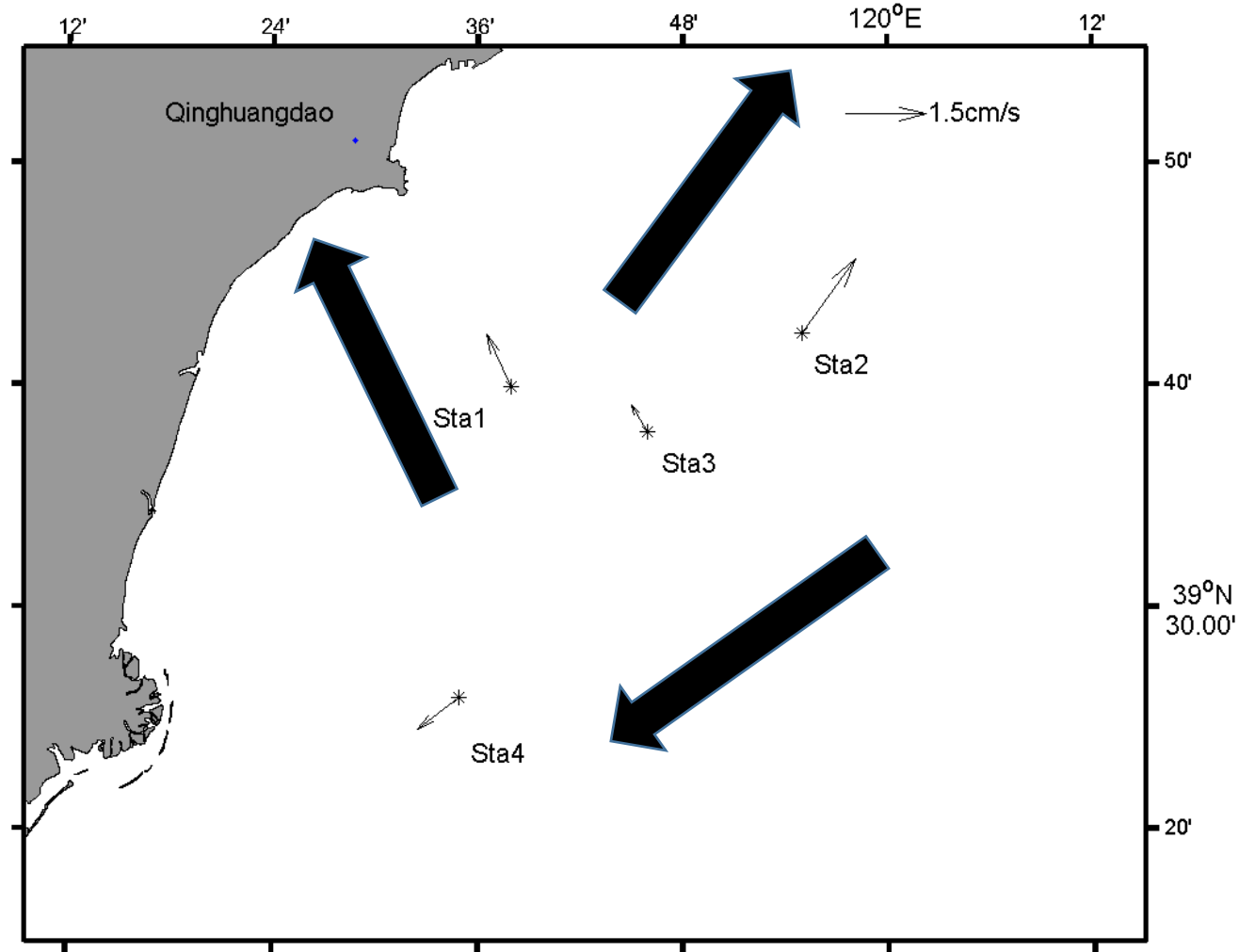
- Platforms for multipurposes
- Anti-trawler design, reliable



Simulation result of stress field when the platform is attacked by trawler

Current observation

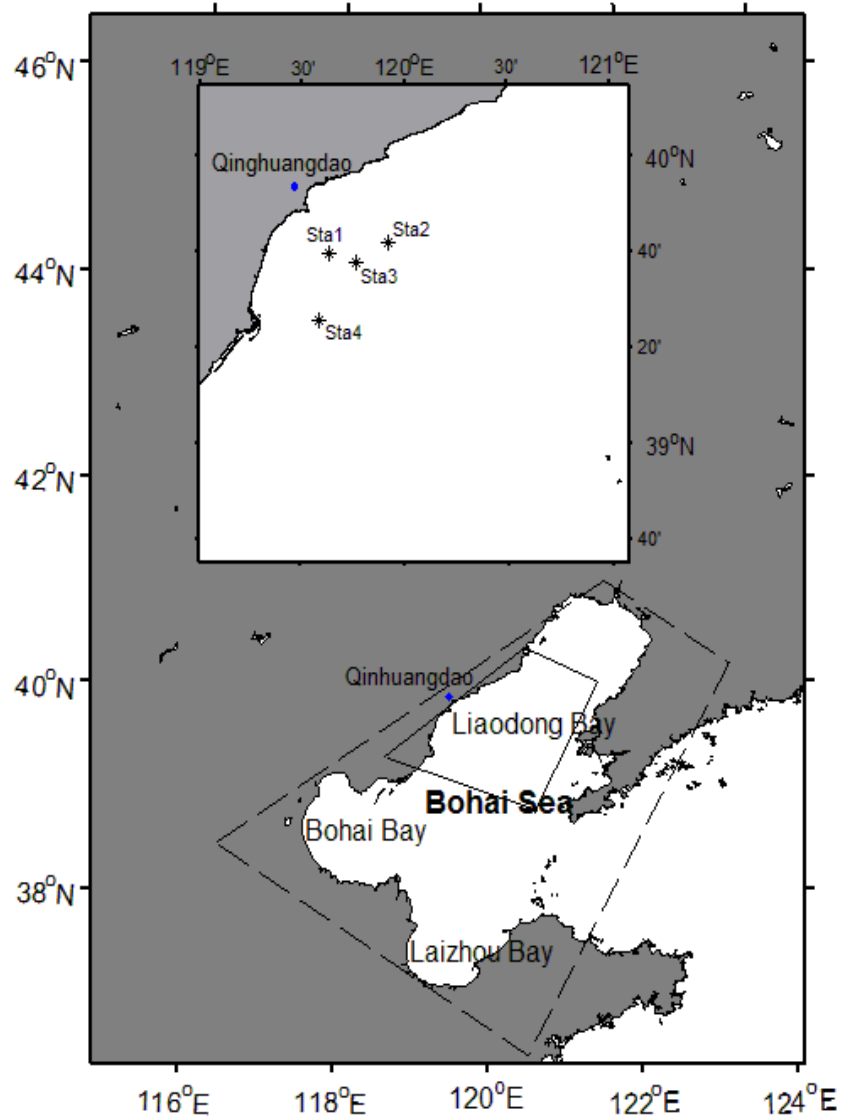
- The residual current is weak and is one magnitude less than the tidal current.
- The residual currents at Sta1, Sta2, and Sta3 move principally northward, whereas the residual current at Sta4 moves southward.
- The coastal circulation system seems to form a clockwise eddy.
- The water body piles up along Qinhuangdao coast through Sta1 and Sta3 and then dissipates in the north through Sta2 and in the south through Sta4.



The residual currents of the four stations derived from observations

Model setups

- Regional Ocean Modelling System (ROMS) is applied.
- Qinhuangdao current simulation is embedded into the Bohai current simulation.

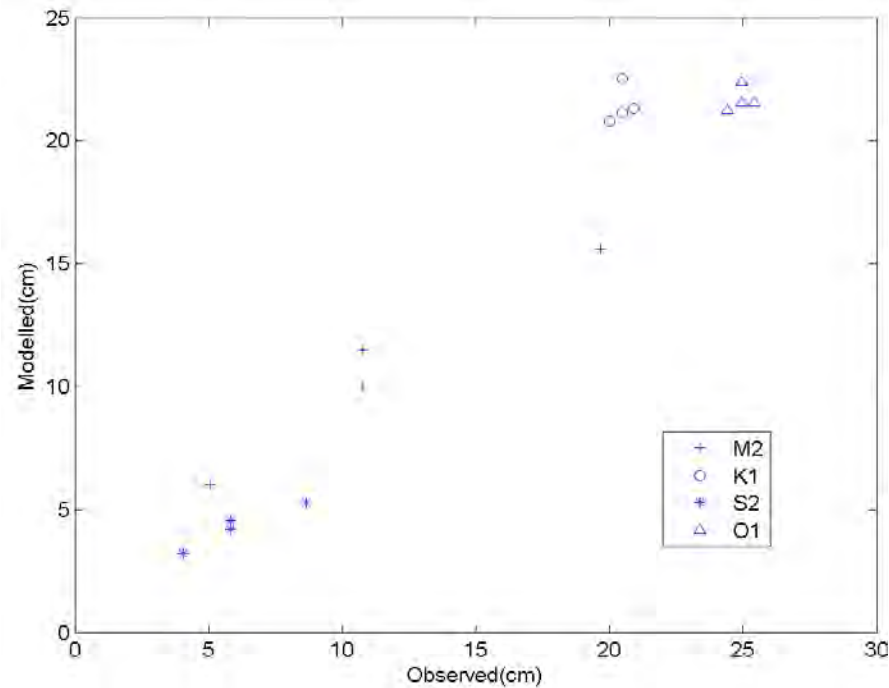


The model domains of Bohai current simulation and Qinhuangdao current simulation

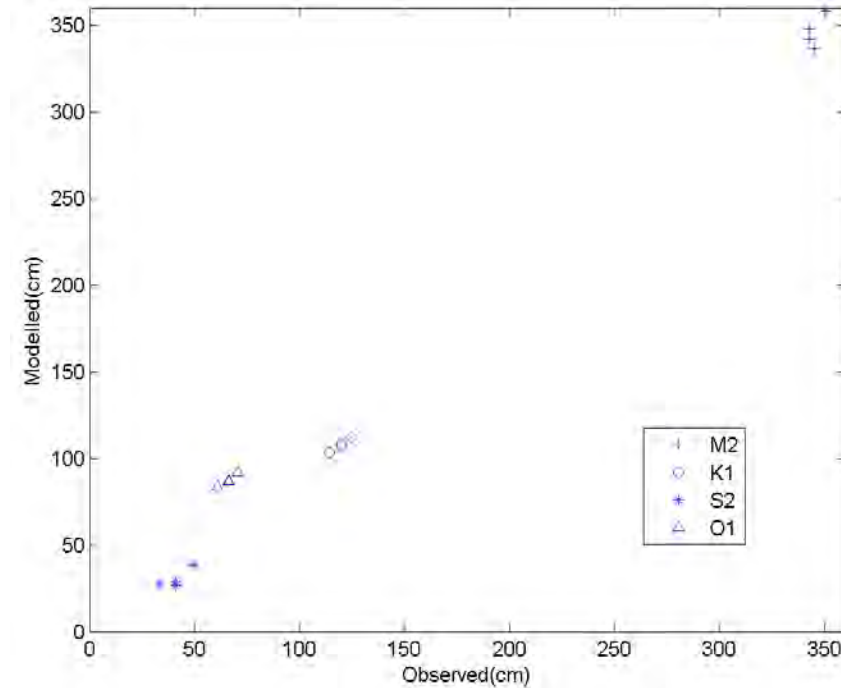
		Bohai current simulation	Qinhuangdao current simulation
Horizontal resolution		0.98 n.mile × 1.48 n.mile	0.32 n.mile × 0.44 n.mile
Initialization condition	Temp.	multi-year hydrologic atlas (Chen, 1992)	multi-year hydrologic atlas (Chen, 1992)
	Salt.		
Surface boundary conditions	Air temp.	NCEP/NCAR Reanalysis Monthly Mean Data (Kalnay et al., 1996)	NCEP/NCAR Reanalysis Monthly Mean Data (Kalnay et al., 1996)
	Pressure		
	Shortwave, longwave radiation		
	Relative humidity		
	Wind		
Lateral open boundary conditions	Tidal elevation	OSU Tidal Prediction Software (Egbert and Erofeeva, 2002)	Bohai current simulation
	Current velocity	None	Bohai current simulation

Input data of Bohai current simulation and Qinhuangdao current simulation

Model results of Qinhuangdao current simulation



(a)

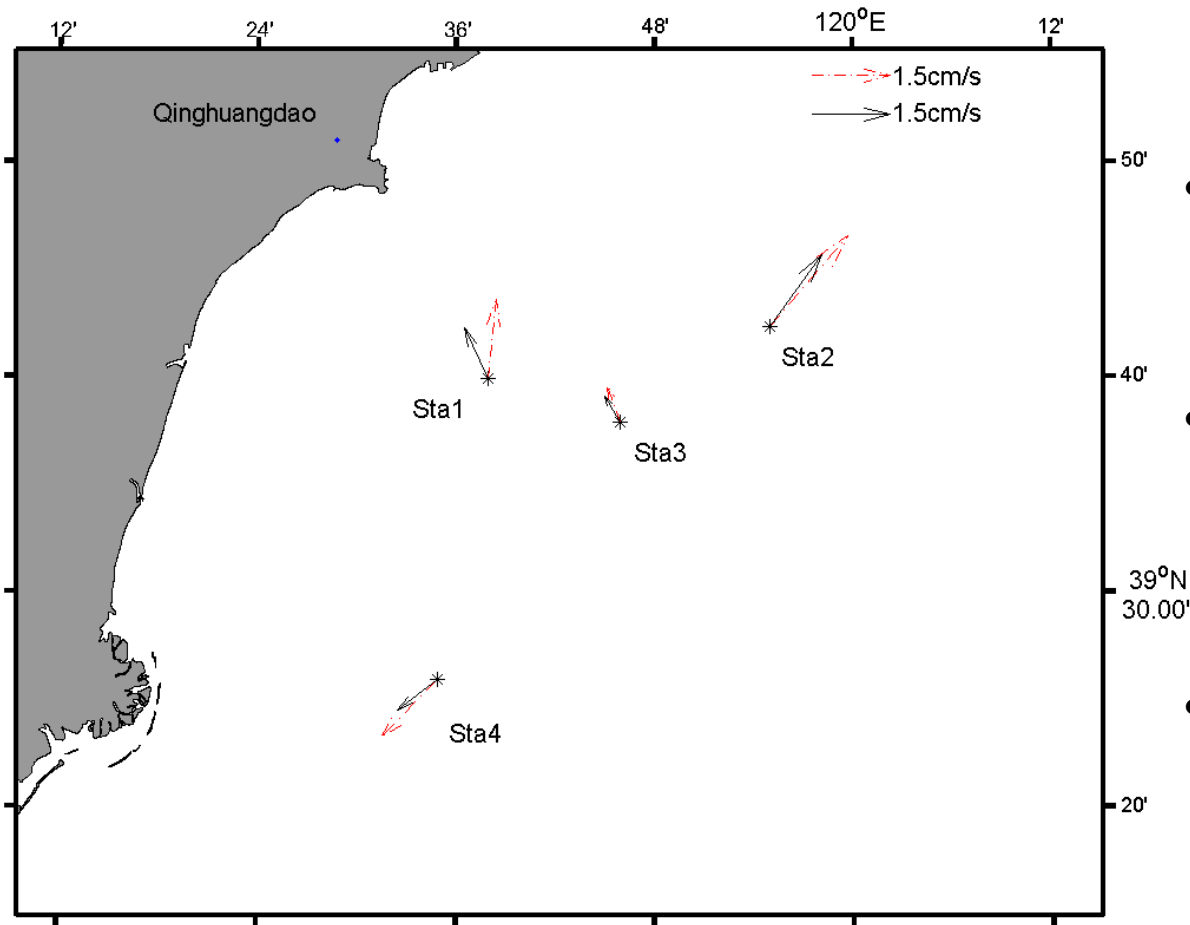


(b)

Harmonic constant comparison between observations and simulation results at four tidal constituents, (a) amplitude (cm), (b) phase (degree).

- The simulation results are generally consistent with the observations.
- K1 and O1 tidal constituents dominate, whereas M2 tidal constituent is less dominant. An amphidromic point of M2 tidal constituent exists in the Qinhuangdao coastal area (Chen, 1992).

Model results of Qinguangdao current simulation

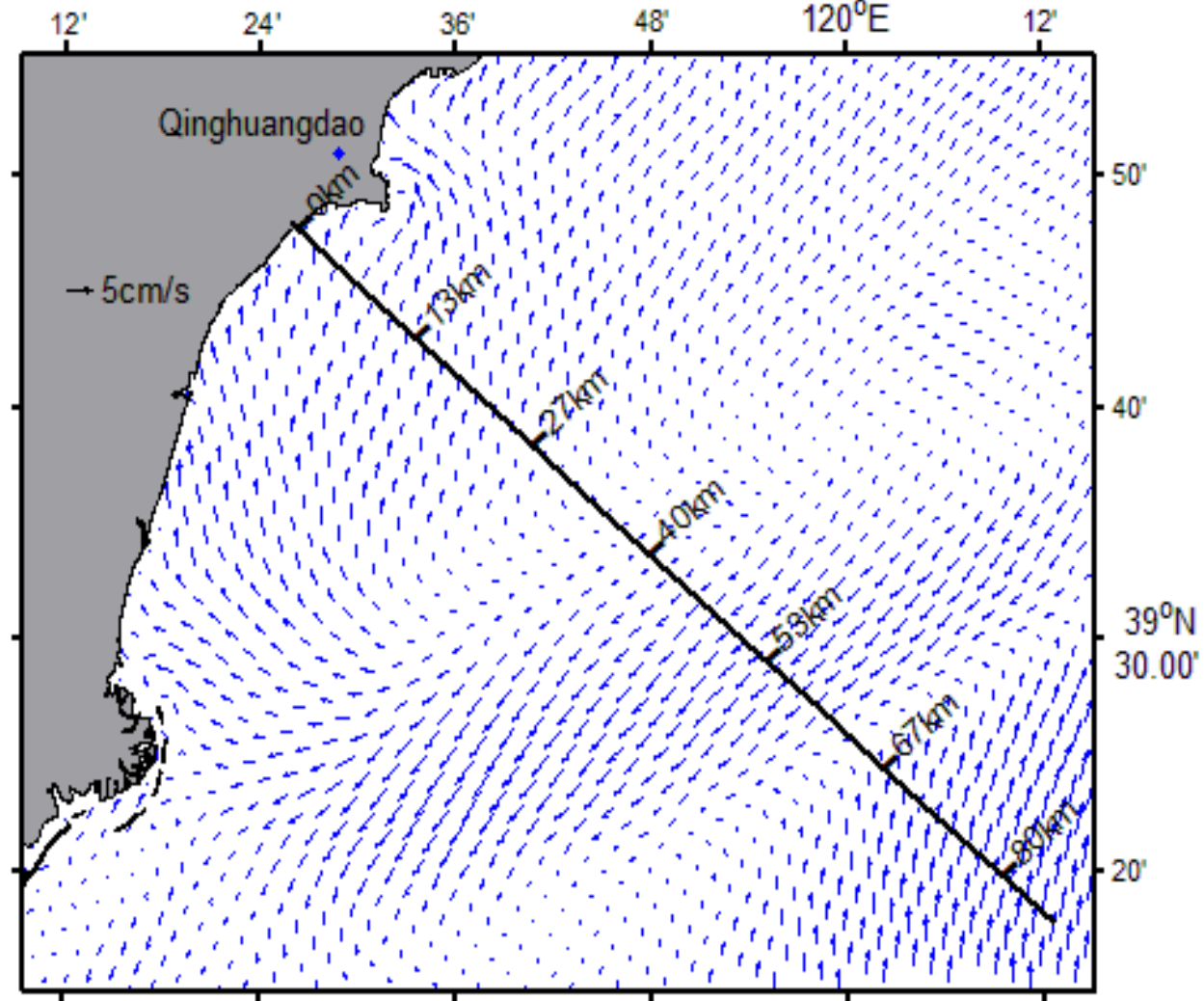


- The directions of the model results at Sta2, Sta3 and Sta4 are basically well consistent with the observations.
- The deviation of the current direction at Sta1 between the model results and observations is larger, but the model results also show northward and shoreward current direction at Sta1.
- The velocities of the model results and observations agree well.

The residual currents the four stations derived from observations (black solid arrow) and model results (red dashed arrow).

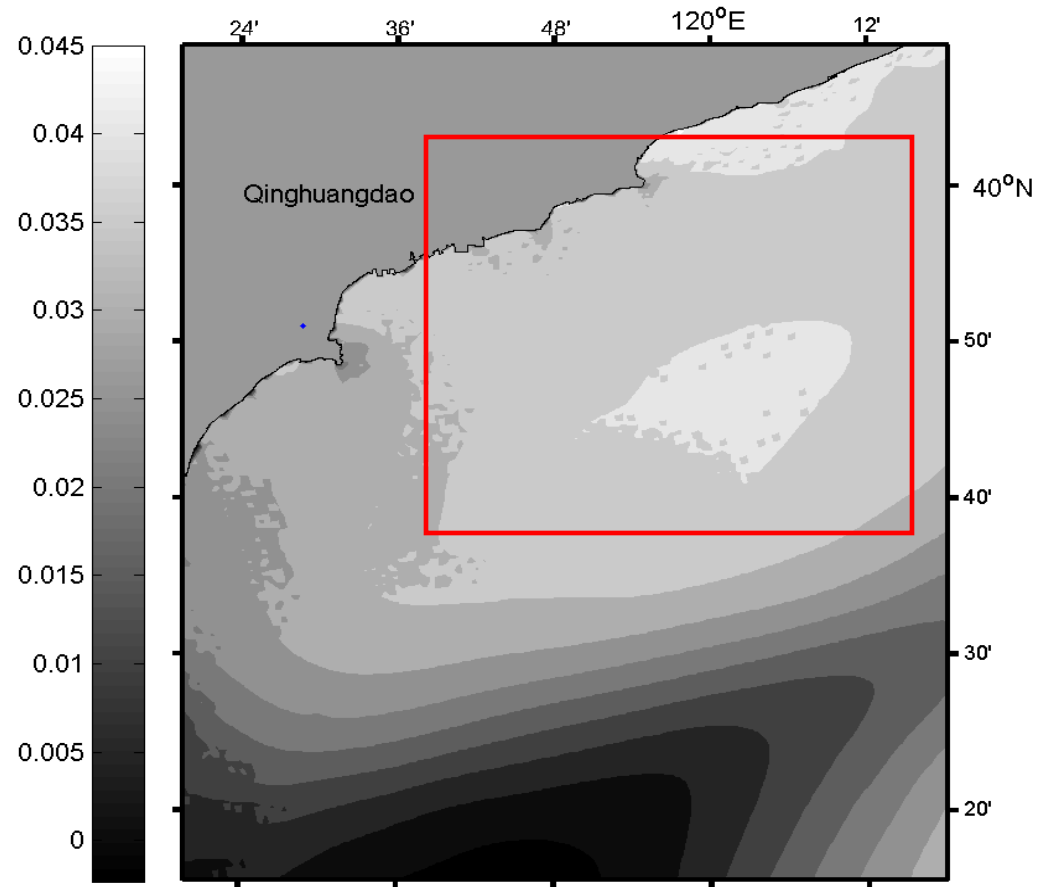
Model results of Qinhuangdao current simulation

- From coast to 27km, the currents flow northward with the stronger velocities occurring near the coast.
- From 40km to 65km, the current velocities are southward.
- The northward currents near the coast and southward currents off the coast forms an eddy-shaped circulation.



The circulation system in the Qinhuangdao coastal area from model results.

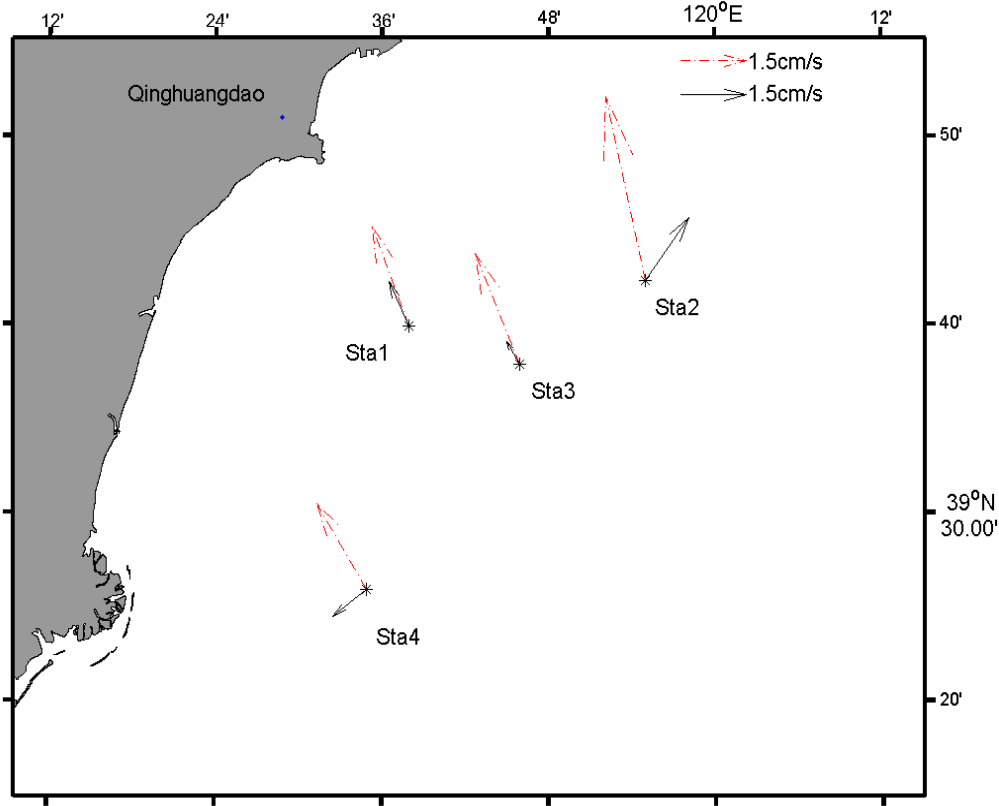
Model results of Qinhuangdao current simulation



- The SSH in the northern part is higher than that in the southern part
- Higher SSH in the north is formed because the northward currents near the coast transport water north.
- The SSH distribution implies the clockwise coastal circulation is formed partially due to the sea level pressure compensation flow.

The Sea Surface Height (SSH) distribution from QCS in the Qinhuangdao coastal area (m).

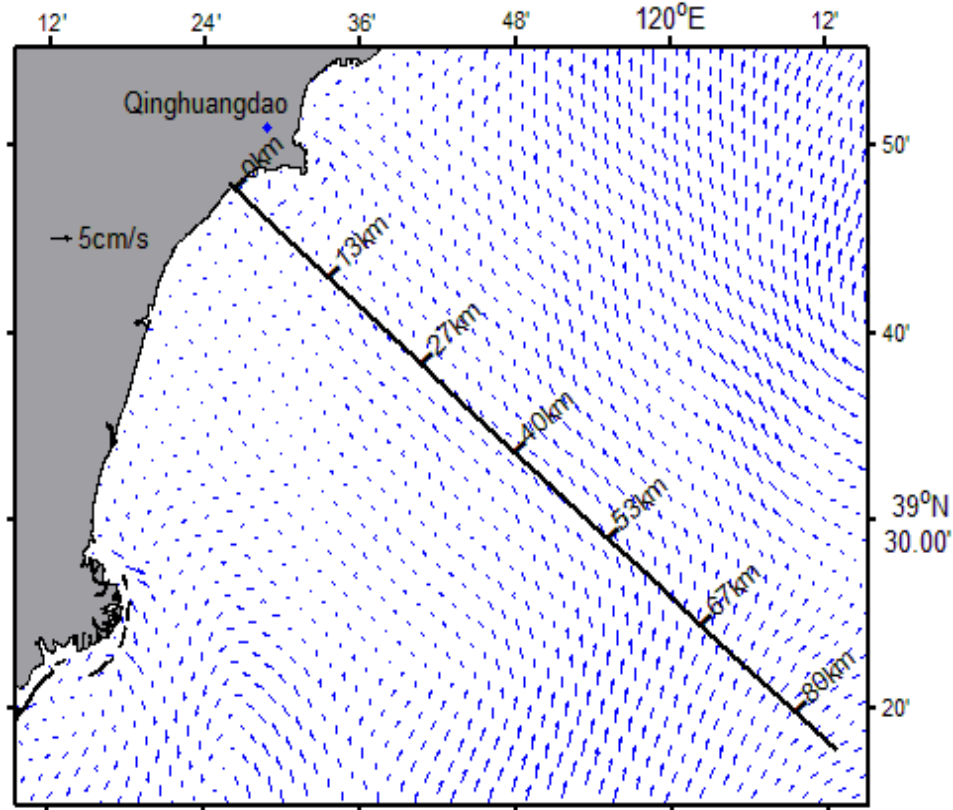
Sensitivity experiment: without wind



- The residual currents at the four stations all are shoreward.
- The residual current directions at Sta1 and Sta3 are well consistent with the observations, but the deviations at Sta2 and Sta4 are significant.

The residual currents the four stations derived from observations (black solid arrow) and model results (without wind, red dashed arrow).

Sensitivity experiment: without wind

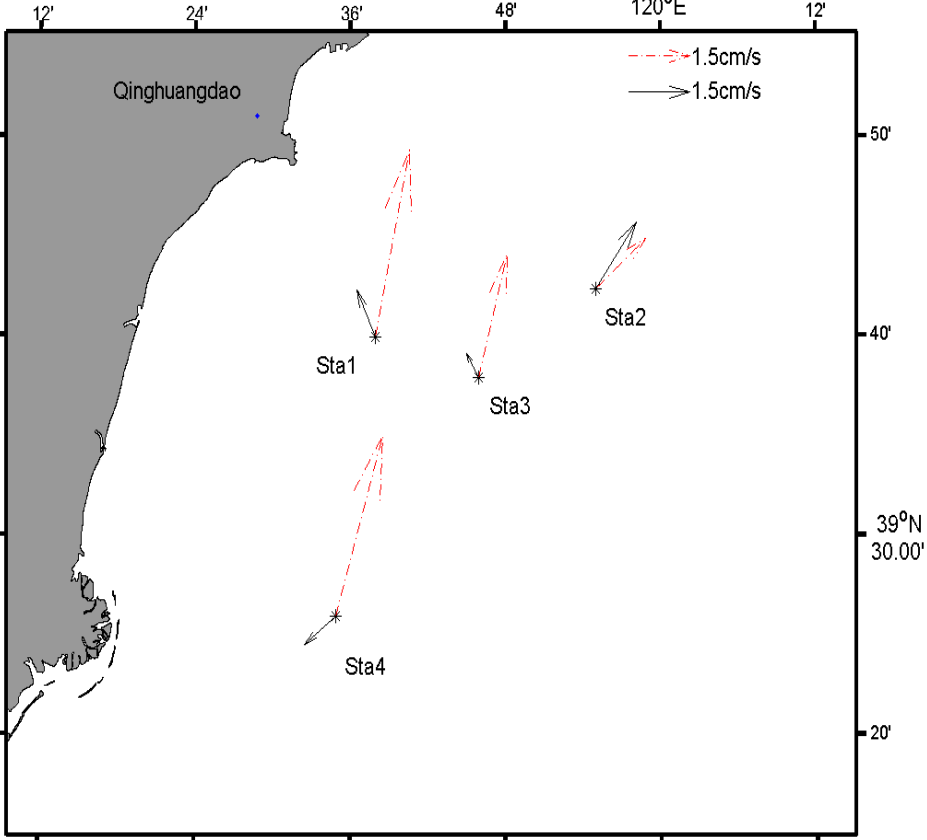


- Near the coast area, the residual currents are weaker compared to the regions 27 km away from the coast.
- The residual currents generally moves northward and shoreward.
- The model results show no eddy-shaped coastal current system.

The circulation system in the Qinghuangdao coastal area from model results (without wind).

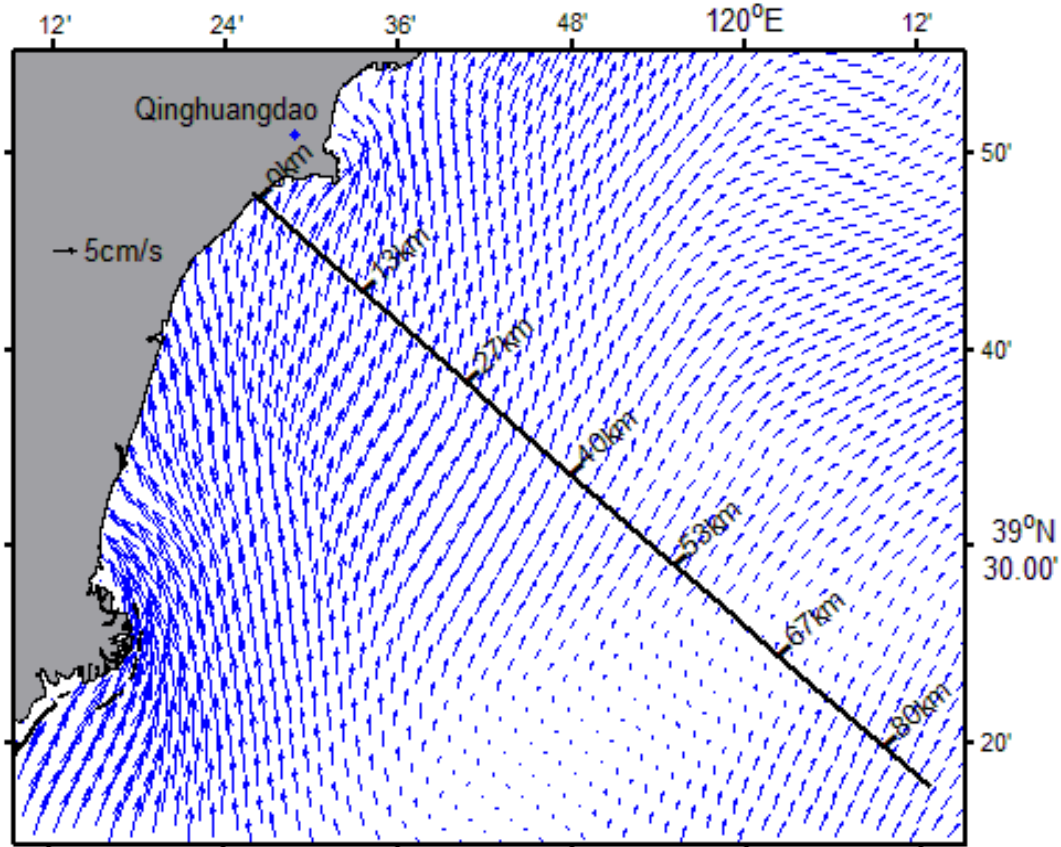
Sensitivity experiment: without tide

- The currents at the four stations all are northward.
- The current directions at all four stations are not consistent with the observations.



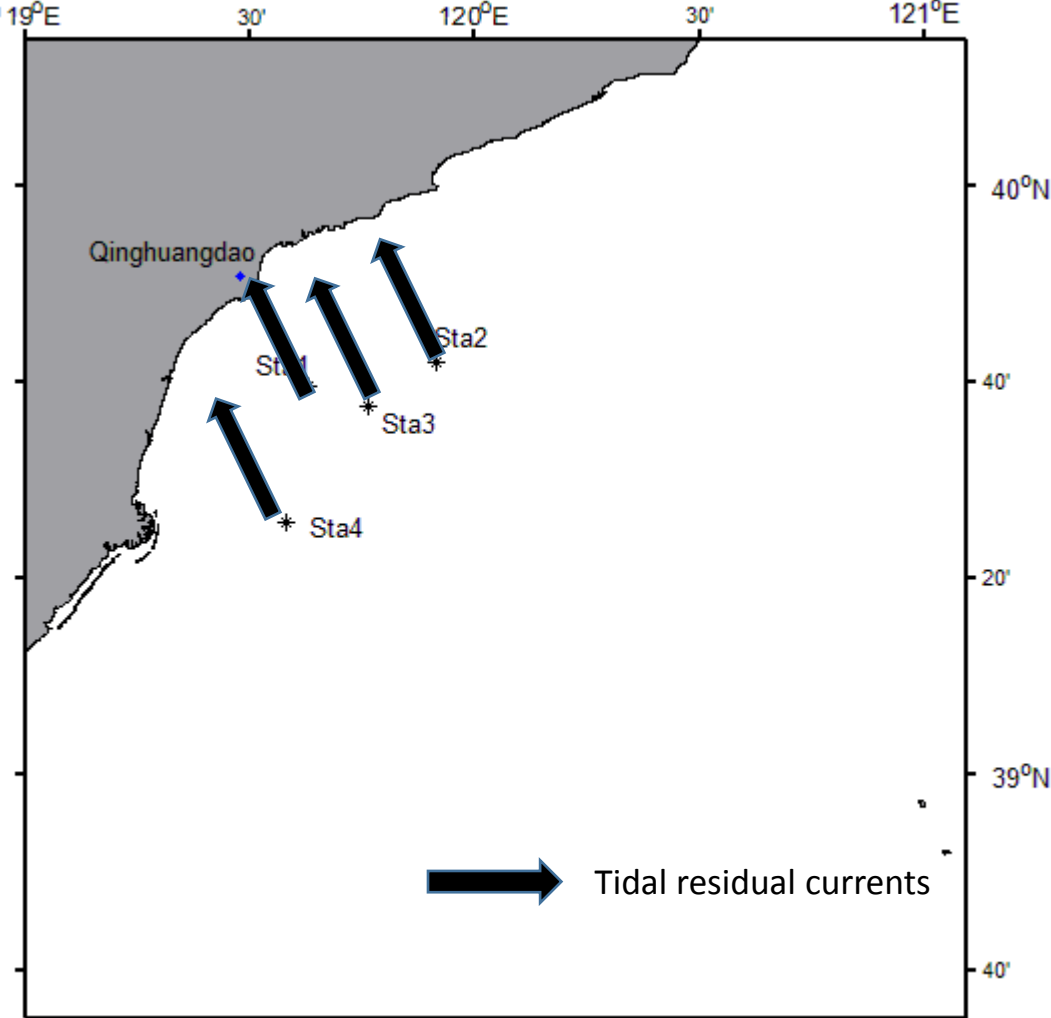
The residual currents the four stations derived from observations (black solid arrow) and currents from the model results (without tide, red dashed arrow).

Sensitivity experiment: without tide

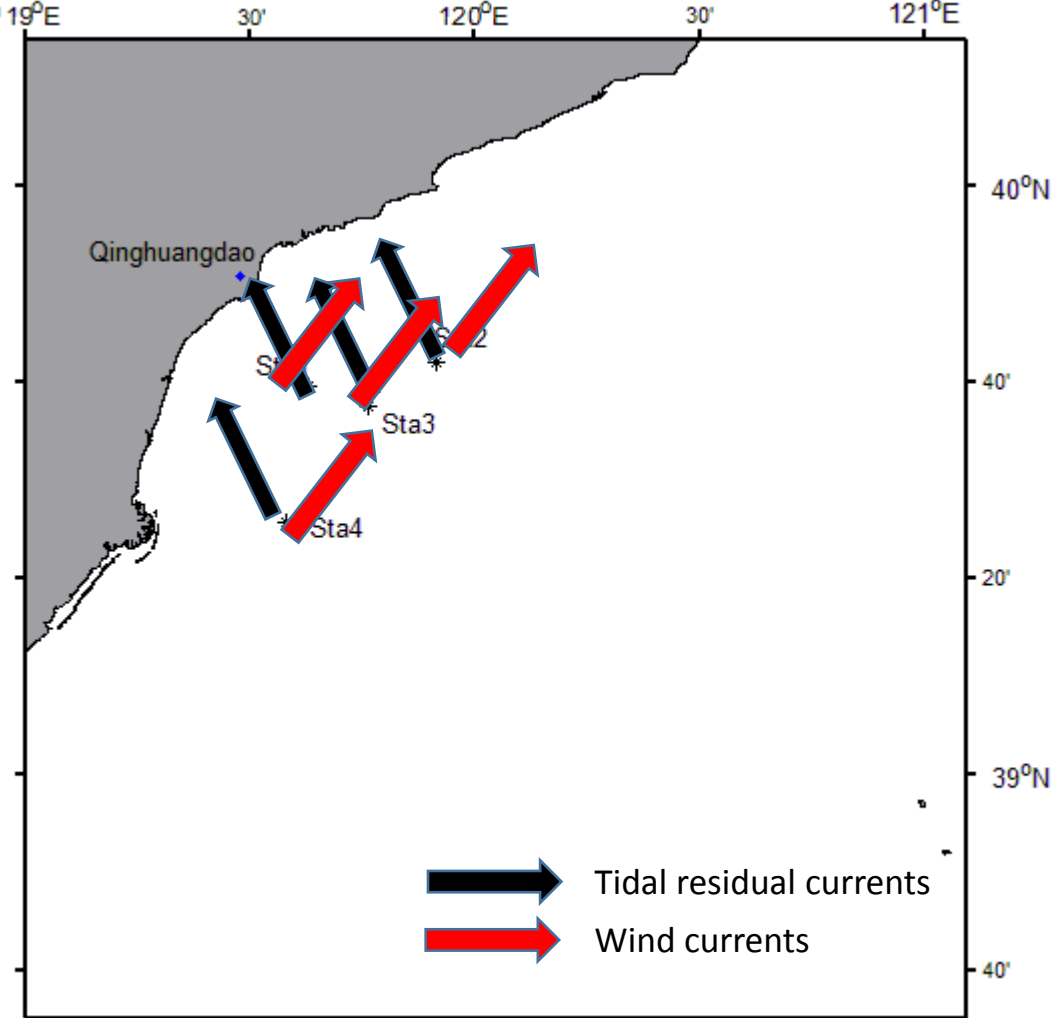


- Near the coast area, the currents are stronger comparing to the regions 40 km away from the coast.
- The residual currents moves northward and along the coastline.
- The model results show no eddy-shaped coastal current system.

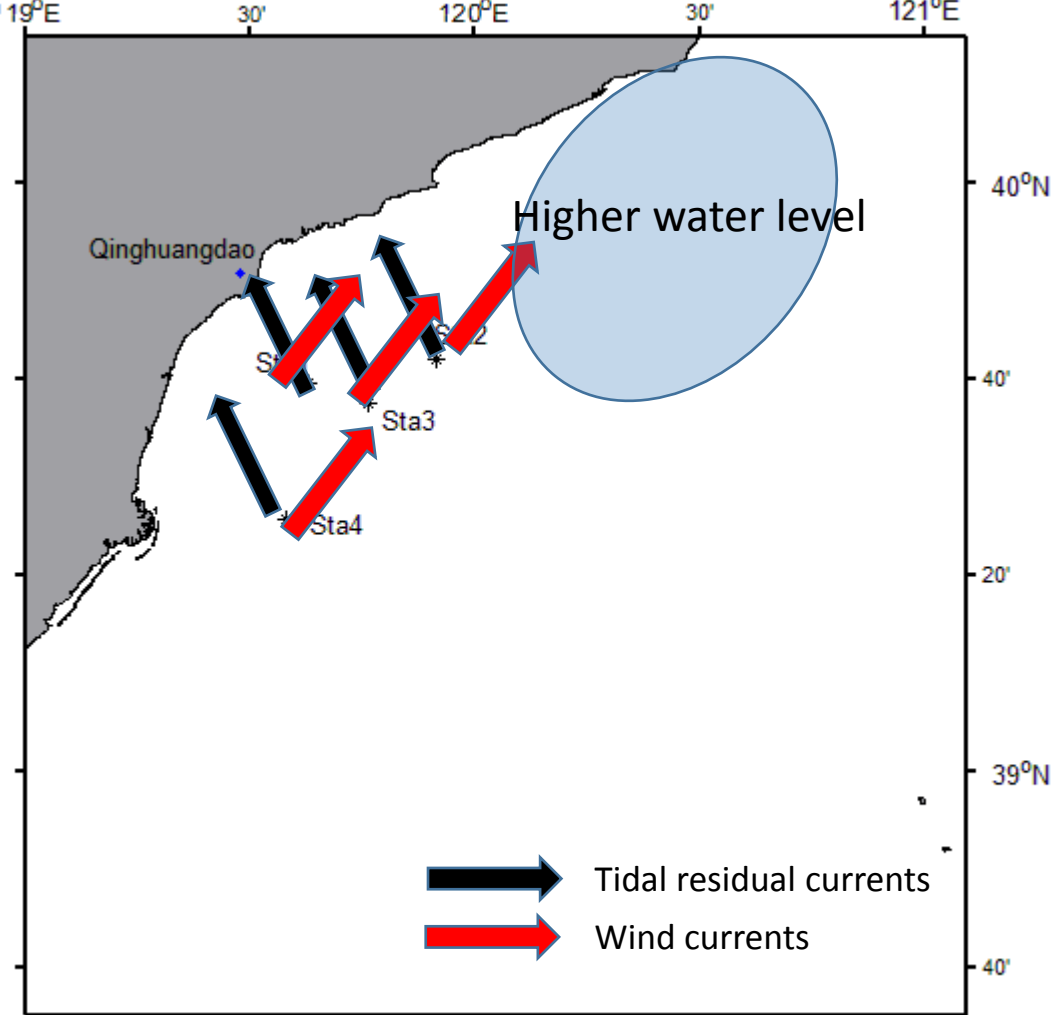
How the observed coastal circulation system forms?



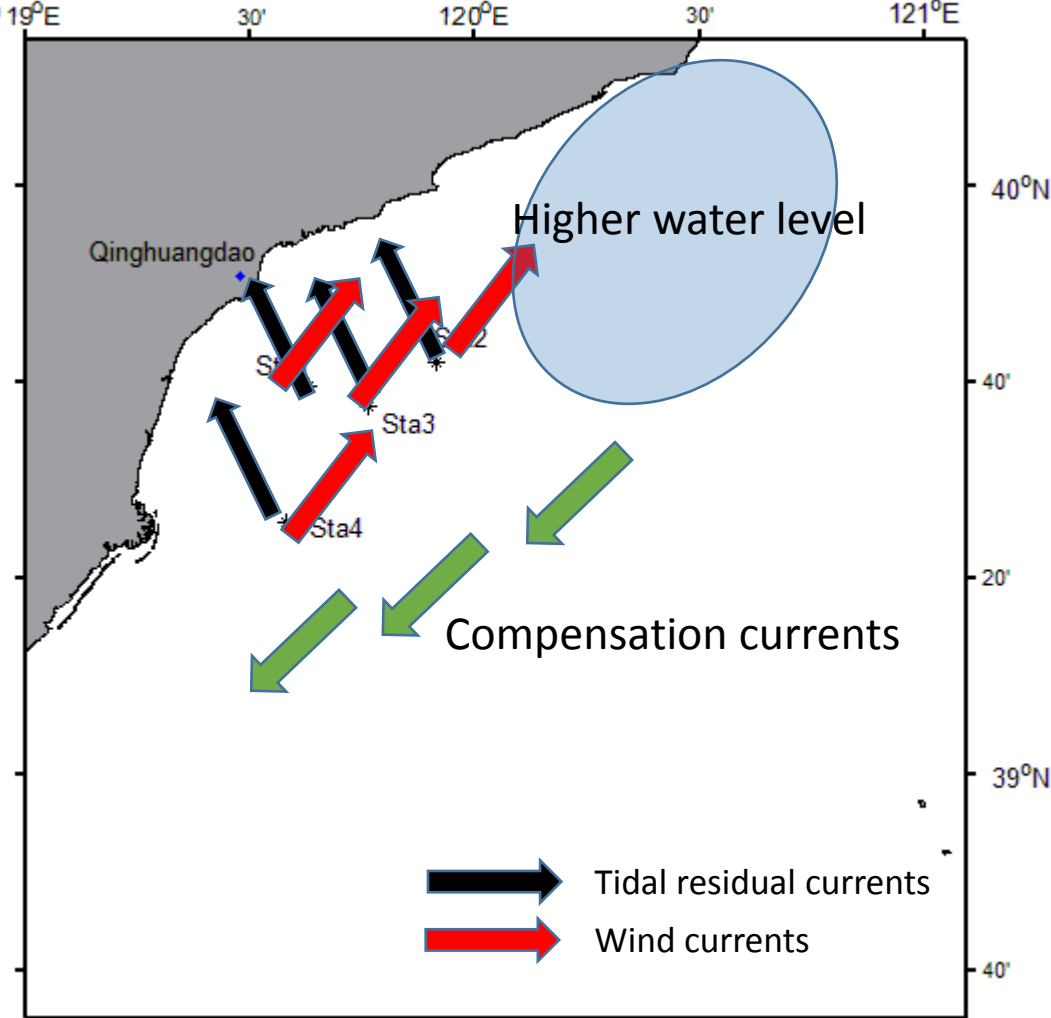
How the observed coastal circulation system forms?



How the observed coastal circulation system forms?



How the observed coastal circulation system forms?



Summary and outlook

- Sea-based observation systems provides efficient platforms to monitor the coastal circulation system. The high temporal resolution and long-term current observations are ideal for understanding the background hydrodynamic conditions.
- Numerical models are useful tools to explain the forming mechanisms of the coastal circulation system.
- Tide and wind are normally the main driving forces of the coastal circulation.

Summary and outlook

- The summertime coastal circulation system in the Qinhuangdao coastal area in the other years should be observed.
- No larger nutrients sources exists in the Qinhuangdao coast area, yet severe 'brown tide' events frequently happen in the this area. The nutrient transportation by coastal circulation system should be examined in the following study.

Thank you for attention

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