

# The summer Bohai Sea hydrological environment analysis

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**Abstract.** The Bohai Sea is a nearly closed shallow sea which goes deep into china mainland, it has a supper shallow water shelf properties. The research about the Bohai Sea environment must consider the wind, tide, temperature and salinity. The fixed point observed temperature, salinity and current data were analysed. The results show that the Bohai Sea is regular half-day tidal current trend, and the tidal current trend is the substantially reciprocating flow properties. The reciprocating flow direction within the bay is trend towards the bay's direction; the rest is trend towards the sea shore. During the observation, the current direction is stable and the current rate is small at all fixed points, with a good correlation with wind. Thereinto the Liaodong Bay has a clockwise circulation and the Laizhou Bay flows substantially clockwise either, which consistent with the historical trend observation. One fixed point in the Bohai Bay flows different trend compared with the historical observation. The Bohai Sea surface temperature is slightly lower than that in August of the calendar year; salinity has a decreased trend compared to historical statistics.

## 1. Foreword

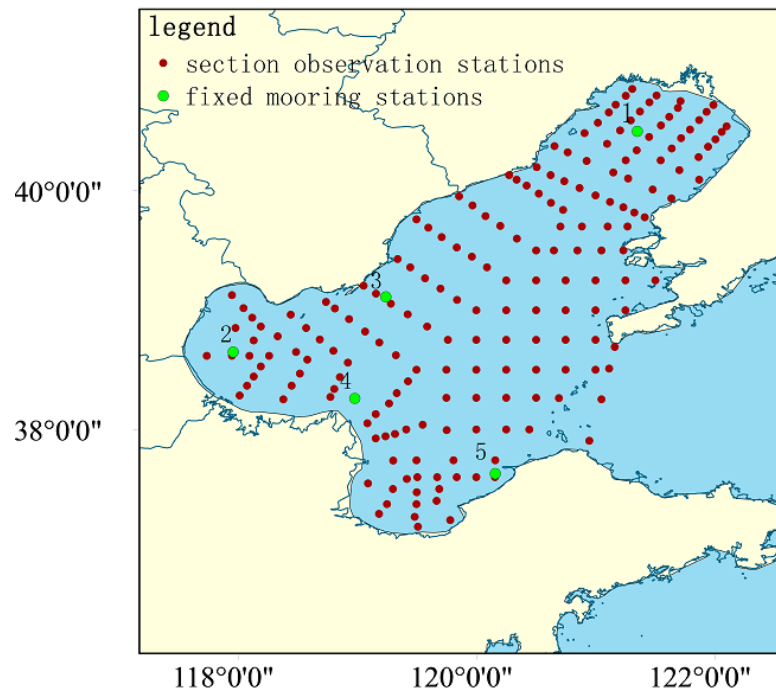
Bohai Sea is a nearly closed shallow sea which penetrate deeply into China mainland [1], it belongs to ultra-shallow continental shelf properties, it's response forcing factor is relatively short, the circulation dynamics studies about the Bohai Sea must consider the combined effects of wind、tide、heat and salt [2]. In September 2003, State Oceanic Administration organized and implemented a marine synthesized survey and evaluation [3]. Its investigation ranges includes the Bohai Sea. This paper use this survey data to analyze the summer Bohai Sea hydrological environment.

## 2. Data Source

Data this article refer to are derived from marine synthesized survey and evaluation, summer physical oceanographic survey. Survey area is the Bohai Sea west of the Bohai Strait.

Observation includes section observation and fixed moorings observation. Section observation contain 188 stations, time ranges from July 2006 to August 2006, and observation elements include station information、water depth, temperature, salinity and turbidity. The interlayer spacing is 1meter. There are 4 fixed moorings stations, time ranges from July to September 2006, observation elements mainly are currents, and the interlayer spacing is 1 meter. Figure 1 is observation station distribution image.





**Figure 1.** Observation station distribution image

### 3. Data Processing

Quality control the temperature and salinity data for use, quality control methods include reasonable inspection, range inspection, latitude and longitude reasonable inspection, spike inspection, landing inspection, gradient test, speed test, climatology inspection, constant test, stability test, level inverted repeat inspection. Test out erroneous data and annotate QC mark.

Quality control the current data for use, mainly for range test, peak test, continuity inspection, gradient inspection and any more. Test out erroneous data and annotate QC mark.

### 4. Current Characteristics

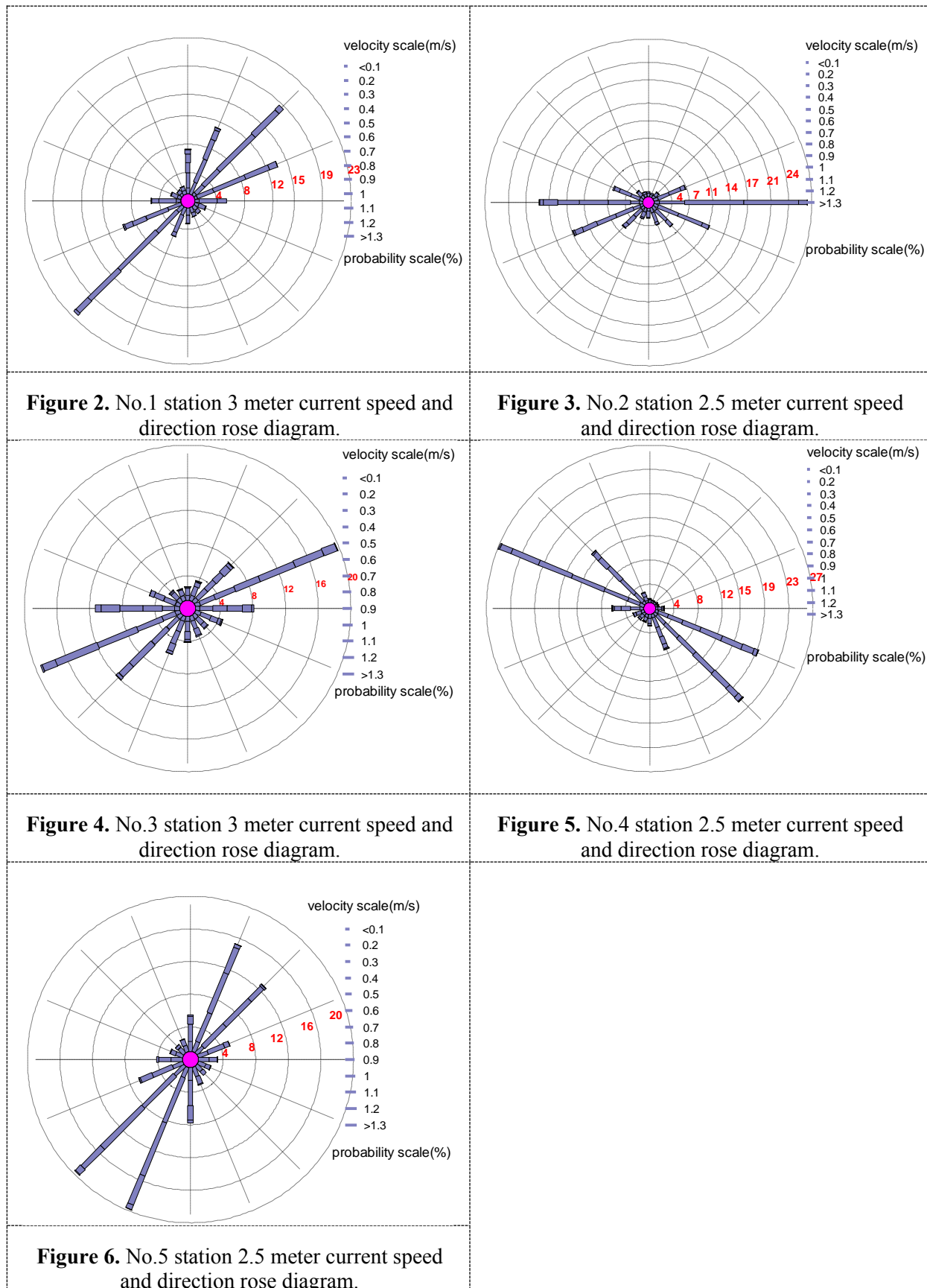
Fixed mooring station referred to as No.1-No.5 stations.

#### 4.1. Primary current direction frequency in fixed mooring station

The following table (Table 1) shows the frequency primary current direction appears at fixed mooring stations, including primary rising trend and frequency; primary falling trend and frequency. Wherein the primary rising trend of No.1 station point to the Liaodong Bay seashore, the primary falling trend point to estuary as shown in Figure 2. No.2 station is similar to No.1 station, rising trend point to the Bohai Bay seashore while falling trend point to estuary (see Figure 3). As shown in Figure 4, 5, and 6, the primary rising and falling trend of No.3, No.4, No.5 station all parallel the seashore.

**Table 1.** Primary current direction frequency

Station number	Primary rising trend	Frequency	Primary falling trend	Frequency
1	northeast and east- northeast	40-47%	southwest and southwest-west	30-39%
2	west-southwest and west	30-37%	east and east-southeast	36.5-43.5%
3	southwest and west-southwest	39-48.8%	northeast and east-northeast	25.8-35%
4	west-northwest and northwest	35-40.5%	east-southeast and southeast	37.8-39.6%
5	south-southwest and southwest	37.5-47.8%	north-northeast and northeast	22.3-29.4%



#### 4.2. Frequency of each current speed levels in fixed mooring station

The following table (Table 2) lists the highest frequency current speed in every fixed mooring station. From the table we can know the current speed dimension is not large. The highest frequency current speed at deeper layers is larger than surface layer at some stations.

**Table 2.** Highest frequency current speed

Station number	Highest frequency speed at surface	Frequency	Highest frequency speed at 5 meter	Frequency	Highest frequency speed at bottom	Frequency
1	10-19cm/s	30%	10-19cm/s	27.6%	10-19cm/s	31%
2	20-29cm/s	29.9%	30-39cm/s	23.8%	20-29cm/s	19.2%.
3	20-29cm/s	21.5%	30-39cm/s	21.3%	30-39cm/s	28.3%
4	20-29cm/s	18.7%	40-49cm/s	15.5%	10-19cm/s	14%
5	10-19cm/s	35.8%	20-29cm/s	28%	20-29cm/s	24.1%

#### 4.3. Maximum velocity of rising and falling tidal current at fixed mooring station

The maximum surface rising tidal current speed ranges from 45 cm/s to 73cm/s, thereinto No.2 station is maximum and No. 5 station is minimum. The direction in No. 1 station is 50°, point to northeast, These from No.2 to No. 5 stations are 217°-295°.

The maximum surface falling tidal current speed ranges from 44cm/s to 82cm/s, wherein No.4 station is maximum and No.5 station is minimum. The direction in No. 1 station is 227°, those from No.2 to No.5 stations are 34°-127°.

#### 4.4. Fixed mooring station tidal current character

Tidal current usually refers to the seawater flow caused by the rise and fall of the astronomical tide. Tidal current character is divided by the following formula:

$$K = \frac{W_{K_1} + W_{O_1}}{W_{M_2}}$$

Where  $W_{K_1}$ 、 $W_{O_1}$ 、 $W_{M_2}$  respectively are tidal ellipse semi-major axis of  $K_1$ 、 $O_1$  and  $M_2$  partial tides. If  $K \leq 0.5$  for regular semidiurnal tidal current; if  $0.5 < K \leq 2.0$  for irregular semidiurnal tidal current; If  $K > 2.0$  as the case may date as regular diurnal tidal current or irregular diurnal tidal current.

According to this formula, tidal current character criterion  $K$  of every depth of five fixed mooring stations is calculated.  $K$  value is shown in the following table (Table 3). These five fixed mooring station in addition to 5th station is irregular semidiurnal tidal current character, the rest are all regular semidiurnal tidal current properties.

**Table 3.** Tidal current character

Station number	Water depth rang (m)	K value range	Tidal current character
1	3-15	0.34-0.46	regular semidiurnal
2	3.5-10.5	0.34-0.39	regular semidiurnal
3	3-10	0.67-0.71	irregular semidiurnal
4	2.5-16.5	0.35-0.44	regular semidiurnal
5	2.5-11.5	0.80-1.08	irregular semidiurnal

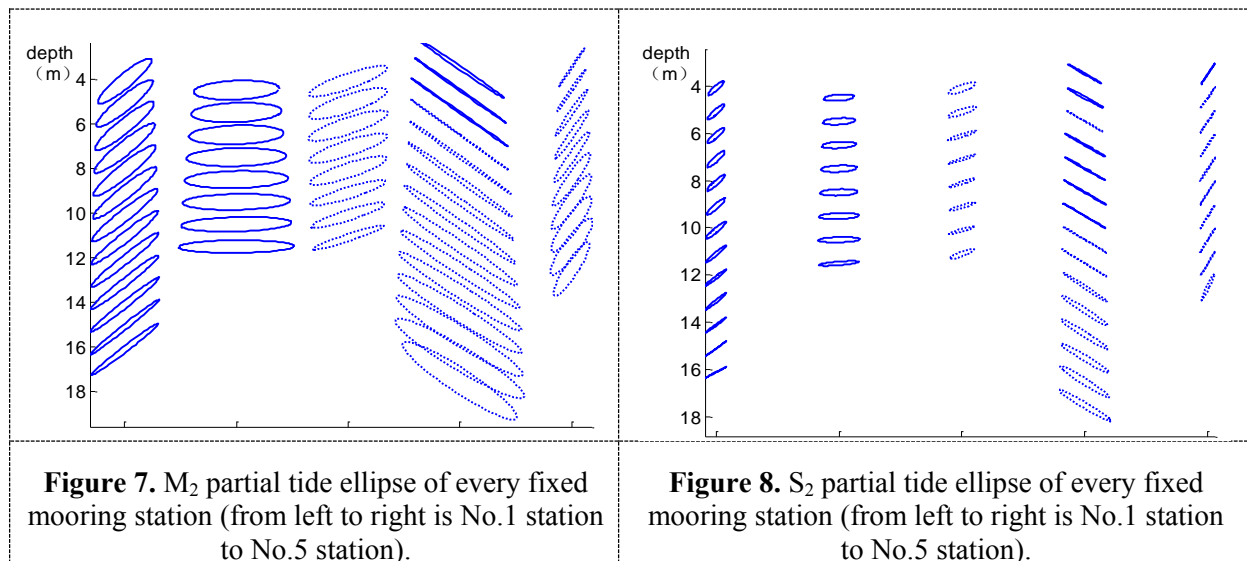
#### 4.5. Fixed mooring station tidal current trend form

Tidal current trend form depends on the ellipse elements of main partial tides in the sea. By the tidal current character analysis showed above we know that the trend of five fixed mooring stations are semidiurnal tidal current character, so the trend form of main semidiurnal tide ( $M_2$  and  $S_2$ ) could represent the tidal current trend form of this sea.

The parameter reflecting the trend form of tidal current is rotating rate (also known as ellipticity), its value is the ratio of minor axis and major axis of the ellipse of this partial tide, which sign has the difference of "+", "-", positive sign denotes that the partial tidal current rotates counterclockwise, negative sign means clockwise rotation.

As shown in Figure 7 and Figure 8, No.1 station and No.2 station all layers are counterclockwise rotation, No.3 station and No.5 station all layers substantially rotate clockwise, No.4 station surface layer is counterclockwise rotation, deeper clockwise.

Rotation ellipse of partial tide  $M_2$  and  $S_2$  manifest strong reciprocating current properties, major axis of these two partial tides are consistent. Wherein the rising tidal current direction of No 1 station point to seashore, falling tidal current direction point to Liaodong Bay mouth; Rising tidal current direction of No.2 station also point to seashore and falling tidal current direction point to Bohai Bay mouth; Since No.3、4 and 5 stations are not located within the Bay, and close to the shore, so the direction of the reciprocating current parallel the seashore. Compare to section 4.1 current direction frequency, semidiurnal partial tide rotation ellipse represent the same direction with primary current direction. This shows that tidal current plays important role in current in Bohai Sea.



#### 4.6. Residual current analysis in observation period

The residual current this article refers to is the sum of the various flow after deducting the tidal current from the measured flow, The following figure (Figure 9) shows residual current of every layer of every fixed mooring station during the investigation. Seen from the figure, during the observation No.1 station all layers are flowing northeast except 15 meter layer, wherein the 12 m-15 m layer flow rate are greater than 7cm/s, the flow rate of the other layers is smaller. No2 station all layers substantially are flowing southward, flow rate is less than 5cm/s. No 3 station all layers are flowing southwest, flow rates are small in addition to 10 meter layer. No.4 station several surface layers are flowing southward, deeper layers turn to the westward start from 10 meter, all layers' flow rate are small in addition to bottom layer. No 5 station all layers are flowing southwest, the velocity of the bottom layer is larger and the rest layers is small. On the whole, during the observation period, in addition to No.4 station the residual current have a turn at 10 meter layer, that of the rest stations are

stable and the flow rate is smallish. A point worth noting is that residual current at the bottom layer are larger than at the upper layer of each station. Which agree with Jiang WSH[4] measured the C11 station in Bohai Bay.

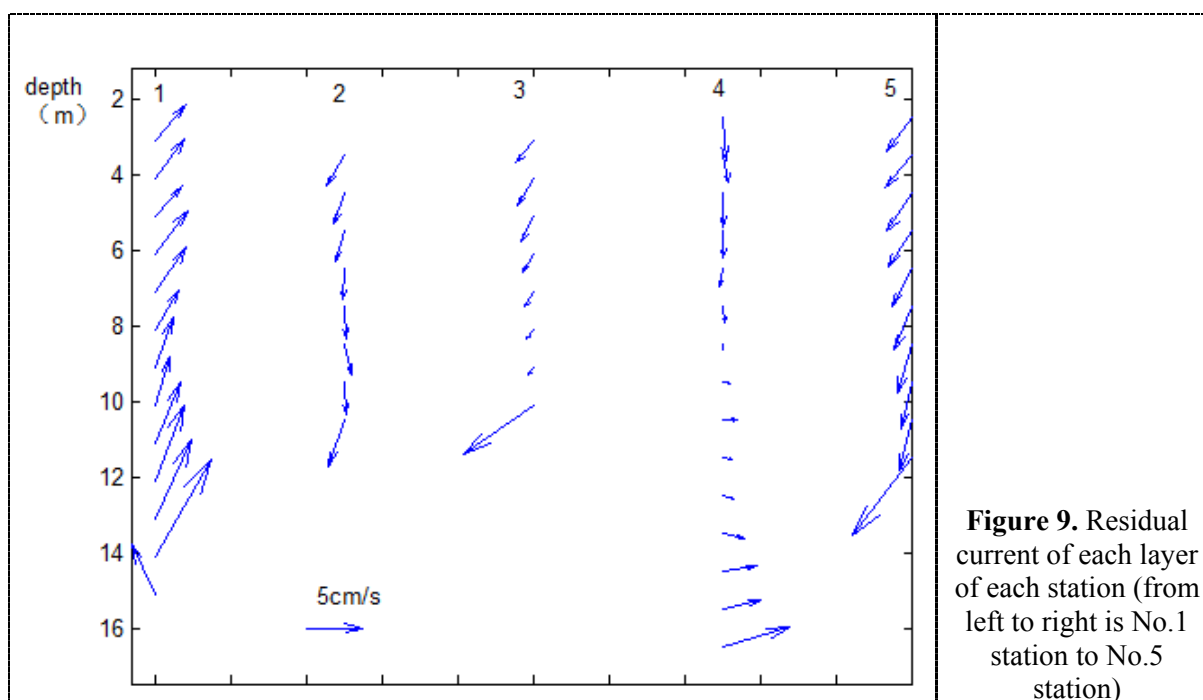
Compared with previous research results, the surface residual current within the Liaodong Bay (No.1 station) corroborates the viewpoint of Zhao BR[5], who considered that it is clockwise residual current in Liaodong Bay.

Jiang WSH[4,6] launched artificial jellyfish in Bohai Bay and the whole Bohai Sea in summer 1993 and summer 2000, the analysis concluded that the bottom residual current in Bohai is basically less than 5cm/s, the results of this paper show that the bottom residual current in Bohai Sea is mostly about 5cm/s or larger.

Jiang WSH considered that there was an anticlockwise circulation in north Liaodong Bay, and there was a clockwise circulation in Bohai Bay. However, further analysis revealed that the migration of bottom artificial jellyfish didn't fully reflect the direction of circulation, even reversed the trend in some stations. The result of this paper is different with his result, residual current shows up clockwise trend in Liaodong Bay, and there exists an anticlockwise residual current in Bohai Bay.

The residual current direction within Bohai Bay (No.2 station) is anticlockwise, which is different with one clockwise trend of the double current loop structure analysed by Zhao BR[5], we infer it is maybe the influence of wind.

Laizhou Bay (No.5 station) residual current flows substantially in a clockwise trend, which supports the viewpoint of Zhao BR[5].



**Figure 9.** Residual current of each layer of each station (from left to right is No.1 station to No.5 station)

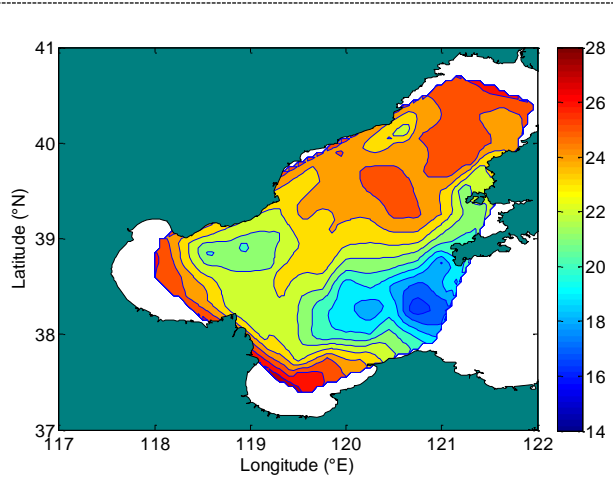
## 5. Thermohaline characteristics analysis

### 5.1. Seawater temperature plane distribution characteristic

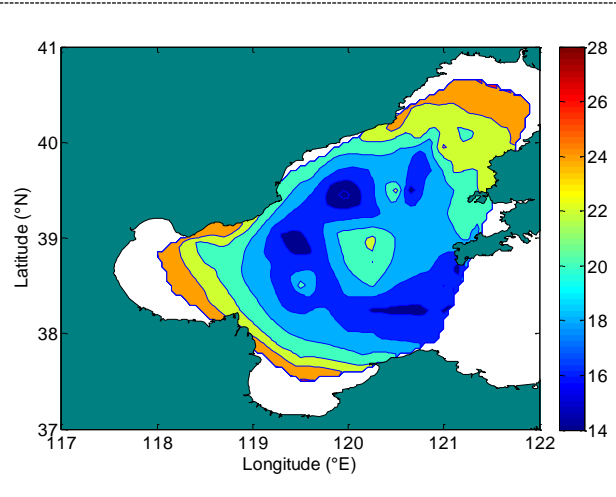
As shown in Figure 10, the surface temperature distribution situation of the Bohai Sea in summer is that temperature is high along the coast, there present a low-temperature region near the Bohai Strait, and it extends to the direction of the Bohai Bay. With the depth increase, temperature decrease, and the scope of the cold water zone gradually expand. The average surface temperature is 23.58°C.

Sea surface temperature is lower consider to August plane temperature distribution over the years analysed by He XM[7].

The temperature distribution at 5 meter layer 、 10 meter layer (see Figure 11) and bottom layer is consistent with the temperature distribution measured in summer 2006 which is analysed by Song WP[8].



**Figure 10.** Temperature plane distribution in summer at 0 meter layer (unit: °C).

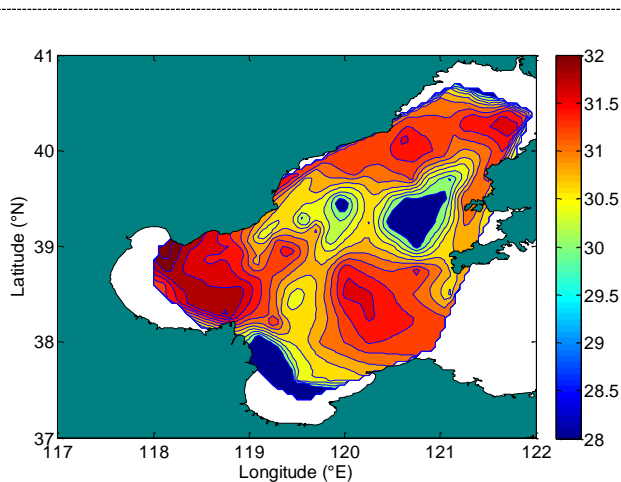


**Figure 11.** Temperature plane distribution in summer at 10 meter layer (unit: °C).

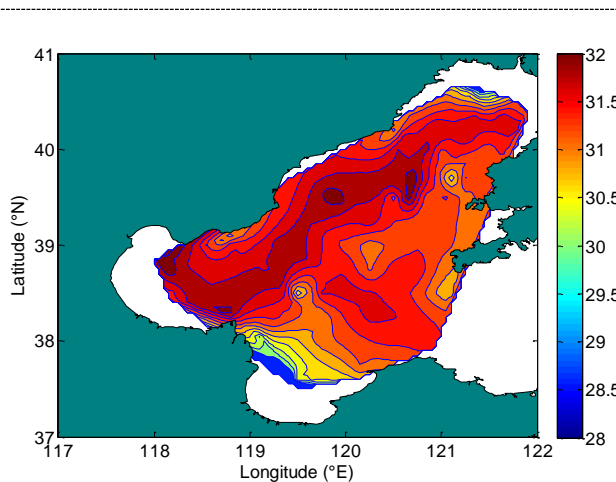
### 5.2. Salinity plane distribution characteristic

The surface salinity in summer as shown in Figure 12 has three high salinity areas and three low salinity areas, they cross each others, the Bohai Bay, middle of Liaodong Bay and the Bohai Strait are high salinity areas, the estuary of Liaodong Bay and middle of Bohai sea are low salinity areas. The high salinity areas under 10 meter (see Figure 13) represent herringbone. The salinity characteristic is consonant with that analyzed by Song WP [8].

The mean surface salinity is 30.93, lower than the mean surface salinity after 90 age analyzed by Bi CC [9].



**Figure 12.** Salinity plane distribution in summer at 0 meter layer.



**Figure 13.** Salinity plane distribution in summer at 10 meter layer.



## 6. Conclusion

The fixed point observed temperature and salinity, and current data which were quality controlled were analyzed. The results show that:

- The Bohai Sea is the regular half-day tidal current trend, and the tidal current trend is the substantially reciprocating flow properties.
- The reciprocating flow direction within the Bay is trend towards the Bay' s direction, the rest is trend towards the sea shore. During the observation, the current direction is stable and the current rate is small all fixed points, with a good correlation with wind. Thereinto the Liaodong Bay has a clockwise circulation, and the Laizhou Bay flows substantially clockwise either, which consistent with the historical trend observation. One fixed point in the Bohai Bay flows different trend compare with the historical observation.
- The Bohai Sea surface temperature is slightly lower than the in August of the calendar year, salinity has a decreased trend compared to historical statistics.

## References

- [1] Feng S Z, Li F Q and Li S J 1999 Introduction to ocean science *Higher Education Press* 434-435.
- [2] Li G S, Wang H L and Li B L 2005 Numerical simulation on the wind-driven and tide-induced lagrangian residual circulation and its seasonal spatial-temporal variations in the Bohai Sea *Geographical Research* **24**(3) 359-370.
- [3] Xu H F, Jiang B, Zhao S H M, Wu H, et al. 2011 Analysis of hydrological environment of Tianjin coast *Ocean Technology* **30**(2) 63-68.
- [4] Jiang W S H, Wang J Y, Zhao J Z 1997 An observation of current in BoHai Gulf and its analysis *Journal of Ocean University of QingDao* **27**(1) 23-32.
- [5] Zhao B R, Zhuang G W, Cao D M 1995 Circulation, tidal residual currents and their effects on the sedimentations in the Bohai Sea *Oceanologia Et Limnologia Sinica* **26**(5) 466-473.
- [6] Jiang W S H, Su J, Yang H, Zhang Y, et al. 2002 Therelation ship between SPM concentration and hydrodynamic condition in the Bohai Sea *Acta Oceanologica Sinica* **24**(1) 311-316.
- [7] He X M and Zhang Y K 1990 The temperature distribution characteristic and interannual variability of south central Bohai sea in spring, summer and autumn *Marine Forecasts* **7**(3) 44-50.
- [8] Song W P 2009 The Analysis of the structure of T-S and the current characteristics in Bohai Sea during winter and summer, QingDao *Ocean University of China*.
- [9] Bi C C, Bao X W, Wan K 2015 The effect of decadal salinity variation on circulation in the Bohai Sea *Periodical of Ocean University of China* **45**(1) 1-8.