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The Climatic Characteristics of surface salinity distribution in the East China Sea from 1981 to 2010

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Abstract: Choosing the surface salinity from SODA database during 1981 to 2010, the climatic distribution characteristics of surface salinity at the continental shelf of the East China Sea for the new 30-year climate reference period (1981-2010) were analyzed, to lay the foundation for further study of climate change. The results showed that: (1) The average salinity of the surface layer in the study area increased gradually from the Yangtze River estuary to the southeast. The isoline has a circular distribution near the Yangtze River estuary, and it is generally northeast-southwest in other sea areas of the study area; (2) In the inter-monthly change, the highest salinity in March is 27.38psu; the 5-8 month is the low salinity season, and the lowest salinity in August is 22.30psu; September-December is the season of salinity rise; (3) The annual amplitude of salinity has two regional changes: the largest positive center is located in the northeast of the Yangtze River estuary, the largest negative center is located in the waters near Hangzhou Bay south of the Yangtze River estuary.

1. Introduction

The 30 years during 1981 to 2010 is a new benchmark for the climate change research proposed by the Climatological Committee of the World Meteorological Organization (WMO) in 2015 (https://www.wmo.int/pages/mediacentre/press_releases/pr_997_en.html) for a comparative study of climate change.

The ocean is an important part of the climate system. Salinity is one of the most basic parameters of the physical and chemical characteristics of seawater. Salinity has closely related to all phenomena in the ocean. Ocean salinity change is one of the important indicators of climate change.

The East China Sea is one of the marginal seas of Pacific Ocean. Near the mainland coast of the East China Sea, there are several stable currents, such as, warm current from Taiwan Strait, Tsushima current, fresh water from the Yangtze River, and coastal flows in the north of the Yangtze River. These currents will have a profound impact on the salinity structure in research area, thus affect the climate of China and East Asia.

The predecessors have studied the surface salinity of the East China Sea. However, most of the researches have focused on the Kuroshio in the East China Sea or some typical sections, paying more attention to the characteristic changes of surface salinity in winter and summer seasons^[1-3], lacking study on the climatic characteristics of the surface salinity of the East China Sea during the new climate base period.

In this paper, we used the data from SODA to analyze the annual distribution characteristics and monthly variation of sea surface salinity of the East China Sea.



2. Data

The newer SODA database is “SODA-2.2.4” monthly average data, which is a reanalysis data by the University of Maryland (UMD) and Texas A&M University (TAMU) [4]. The local terrain data comes from the 1-Minute Gridded Global Relief Data (ETOPO1) [5], which released by the National Geophysical Data Center (NGDC).

3. Research areas and methods

The area with the latitude 21.25-33.25°N and longitude 116.25-127.25°E, has been selected to study, it mainly includes the continental shelf of the East China Sea

Extracting data of surface salinity of 1981-2010 from SODA database, to calculate salinity in annually average and monthly average for 30 years at each point, to analyze the distribution characteristics of surface salinity in annual and monthly variation.

4. Structure of the surface salinity distribution

4.1 Average salinity distribution characteristics at the surface for 1981-2010

The annually average salinity distribution at the surface for 30 years during 1981-2010, is showed at Fig 1, where the spacing of the equal salt lines is 0.25 psu.

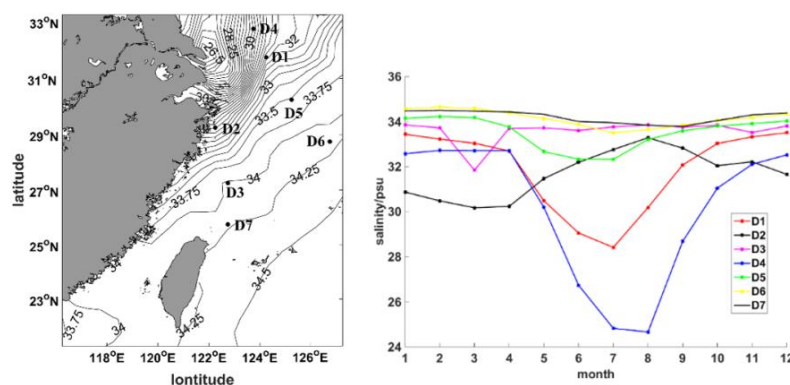


Fig .1. The structure of surface salinity climatic state in the study area from 1981 to 2010(left);

Monthly variation of surface average salinity at 7 feature points for the 30 years (right)

In the continental shelf of the East China Sea, the distribution of salinity is roughly between 26.25 and 34.25psu, and the salinity value increases from the Yangtze River estuary toward the southeast. The lowest salinity is in the range of 26-26.25psu, and the lowest salinity zone is mainly distributed in 122°E, 30-33.25°N, where is near the Yangtze River estuary. There is a sub-low value center near 116.25°E and 22°N, and the salinity value ranges from 33.5 to 33.75psu. The high value of salinity ranges from 34 to 34.25psu, and its distribution is located in the northeast of the Taiwan Strait until the sea near 127.25°E and 29.75°N. It is similar to the northeast-southwest trend and presents a wide-band high-salt area.

The trend of the isohaline can be clearly divided into two forms at the continental shelf of the East China Sea: One is that the isohaline is approximately annularly distributed around the Yangtze River estuary; in the region of 121.75-124°E, the distribution of the isohaline runs north-south along the coast. Another is that from about 124°E toward the east, the isohaline begins to show a northeast-southwest trend, and the slope of the isohaline in the latitude and longitude grid is about 1.

4.2 Monthly variation of surface salinity distribution

In order to further explore the monthly variation of surface salinity in the continental shelf of the East China Sea, the mean, maximum and minimum variation curves for different months averaging 1981-2010 are plotted, showing the monthly salinity of the entire study. The period of change is shown in figure 2.

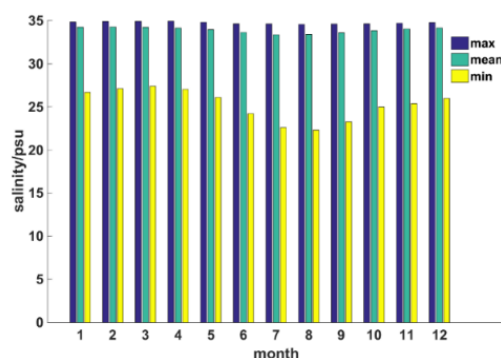


Fig. 2. Histogram of monthly variation of surface salinity in 30 years

It can be seen from the Fig 2, that there is a significant circulation in the monthly variation curve of surface salinity in the study area. The minimum salinity showed significantly a peak and a valley, the peak appears in March at 27.38psu, and the valley appears in August at 22.30psu. It suggests that the lowest salinity is in August, the highest in March, and the remaining months were transitional at the surface of the study area.

Here, the distribution of the average salinity at the surface in March and August is plotted, as shown in fig 3. The spacing of the equal salt lines is 0.25 psu.

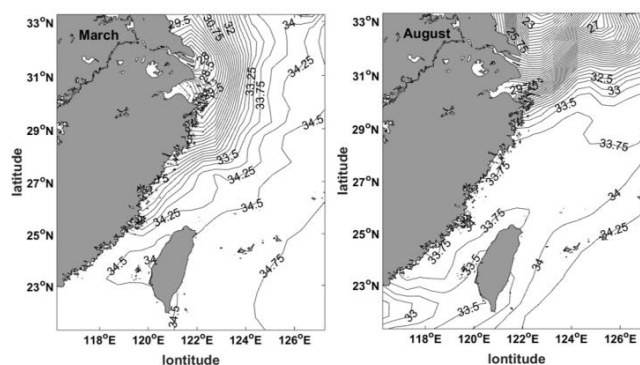


Fig .3. Research area and the distribution of average salinity in the study area in March and August

Combined the diagram in Fig 3, it can be seen:

In August, the surface salinity at the entire East China Sea continental shelf is roughly between 22.30 and 34.46psu. The lowest salinity is not located in the Yangtze River estuary, but in the northeastern part of the Yangtze River estuary, around 123.75°E and 33.25°N,. The highest salinity appeared on the side of the East China Sea continental shelf adjacent to the Kuroshio area. The isohaline distribution is gradually thinned from the Yangtze River estuary to the northwest Pacific Ocean. Among them, the isohaline at the Yangtze River estuary distributed circularly. However, from the continental shelf to the Kuroshio area of the East China Sea, the isohaline are generally northeast-southwest trend.

In March, the surface salinity of the entire East China Sea continental shelf was between 27.38 and 34.45psu. The lowest salinity was at the Yangtze River estuary, and the highest salinity was also found in the Kuroshio waters adjacent to the East China Sea. The isohaline gradually becomes sparsely from the vicinity of the Yangtze River estuary, and is distributed in a ring shape near the estuary of the Yangtze River. The isohaline near the Kuroshio area of the East China Sea is northeast-southwest trend.

4.3 Annual variation characteristics of surface salinity distribution

In order to highlight the regional differences in the seasonal variation of surface salinity in the study area, the average salinity in March and August is subtracted, and the annual amplitude of the surface salinity at each point is obtained, as shown in fig 4.

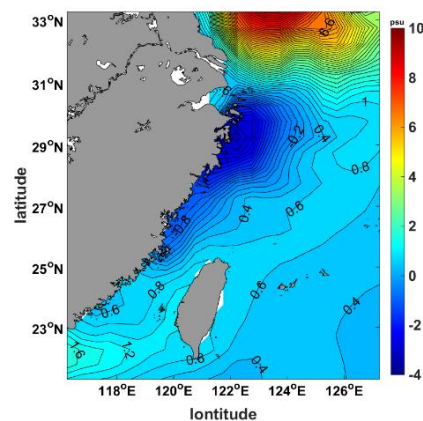


Fig .4. Annual variation of surface salinity in the research area

From the Fig 4, the annual variation of salinity in the two regions is 2-15 times of the normal variation of the study area.

The positive center with the largest annual variation of salinity appears in the northeastern part of the Yangtze River estuary, which is near 123.75°E and 33.25°N, with a value of 9.52psu. It indicates that the sea salinity of this area in August is much lower than that in March, which may be related to the northeast direction of the Yangtze River dilute water and low salt water tongue in summer ^[6].

In the vicinity of 122°E and 29°N, the maximum negative center of salinity annual variation is close to -3psu, indicating that the surface salinity at August is higher than at March, which is obviously different from other areas. The predecessors ^[6] found that due to the southward flow of the Yangtze River dilute water in the winter, but in the spring (May), the Yangtze River dilute the water to the northeast, which prevented the northern Jiangsu coast current going toward south, caused the sea salinity along the coast in this region lower than in summer.

In order to visually analyze the spatial difference of the monthly variation of salinity, the value of the month is subtracted from the previous month at each point, and the monthly distribution of the salinity difference between March and August is showed in Fig 5.

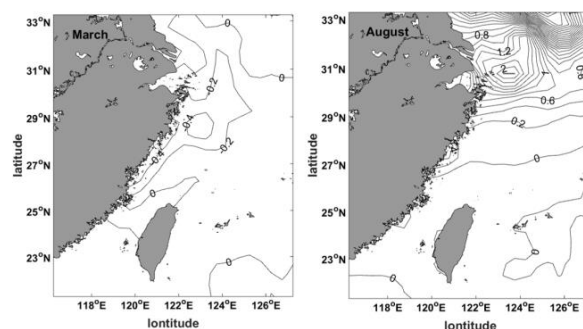


Fig .5. Distribution of salinity difference between March and August in the study area

From Fig 5, it can be seen that the inter-monthly spatial variation of salinity in August is the largest, with a range of -3.4-2.2psu, which represents an obvious monthly variation of the surface salinity value from July to August. The largest negative value of salinity difference occurs near 126°E and 33.25°N, that is, the area near the Korean Strait; the largest positive value appears at 124°E and 30.75°N, which is the eastern part of the Yangtze River estuary.

The smallest monthly difference of salinity in the study area is at March, and the range of the monthly salinity difference is -0.5-0.2psu. The largest negative difference in salinity occurs near 123°E and 28.25°N, which is the southern part of Hangzhou Bay; the largest positive value appears in the Yangtze River.

Overall, the monthly difference in salinity is larger in summer and autumn, and smaller in winter and spring.

5. Monthly salinity variation at climate feature points

Depend on discussion above, the climate feature points for salinity distribution are selected (in Table 1), to detail analyze the monthly salinity variation at each point. From fig 5 (right), it can be seen that:

Table 1. 7 selected typical feature points

points	Latitude and longitude	Characteristic	Monthly variation of surface average salinity at 7 feature points
D1	124.25°E, 31.75°N	select this point to observe the salinity near the Yangtze River estuary. The inter-monthly changes can characterize the changes in the intensity and extent of the Yangtze River dilute water.	The second largest change in salinity is the D1. The monthly distribution curve of salinity shows a deep "V" shape, which approximates the symmetric distribution pattern with the axis of July.
D2	122.25°E, 29.25°N	there is a significant negative anomaly in the sea surface salinity here.	At the continental shelf area of the East China Sea, the monthly variation of salinity of D2 in the southern part of Hangzhou Bay is opposite to the D1、D4、D5、D6 and D7, and the monthly trend of the these points is basically the same: the salinity is low in summer and autumn (June-August), but higher in winter and spring.
D3	122.75°E, 27.25°N	the choice of this point is taken at the midpoint of D2 and D7	the monthly variation of salinity of D3 is similar to that of D2: the salinity of summer and autumn is higher than that of winter and spring, but the difference is that the annual salinity of D3 is much higher than D2 and D3 reaches the lowest annual salinity in March and the highest in August.
D4	123.75°E, 32.75°N	select this point to observe the northward shift and southward withdrawal of the Yangtze River dilute water tongue.	The lowest value of surface salinity is D4 which in the northern part of the Yangtze River estuary in August and the surface salinity of D4 has the largest monthly variation. The monthly distribution curve of salinity shows a slightly wide "V" shape, which is similar to the symmetric distribution pattern with the axis of July and August.
D5	125.25°E, 30.25°N	the two points are close to the PN section. These two points were chosen to analyze the change of surface salinity near the PN section.	D5, also located on the PN section, is closer to the Yangtze River estuary than D6, so the monthly variation of salinity is slightly larger. The salinity begins to decrease rapidly in April, reaching the lowest in July. As the Yangtze River dilute water tongue moved northward in August, salinity began to rise again.
D6	126.75°E, 28.75°N		Among the 7 feature points, the highest salinity of the surface is D6 and D7, the surface salinity curves of these two points are very consistent, and the highest salinity occurs in winter and spring.
D7	122.75°E, 25.75°N	this point was chosen to observe the effect of Kuroshio on the salinity of the surface waters in the continental shelf waters of the East China Sea.	

6. Conclusion

Using the monthly mean salinity data in the dataset of SODA-2.2.4 data, the distribution characteristics of the continental shelf of the East China Sea in the new 30-year climate base period and surface salinity climatic state were analyzed, and the following results were obtained:

1) The average salinity of the surface layer increases gradually from northwest to southeast in 30 years, and the lowest value area was mainly distributed near the Yangtze River estuary. In the East China Sea continental shelf, the annual variation of salinity in two regions is 2-15 times of the normal variation of the sea area; among them, the positive anomaly occurs in the northeastern part of the Yangtze River estuary and the negative anomaly is located at 122°E, 29 °N, which is closely related to the impact of the Yangtze River and the warm current of Taiwan.

2) In the inter-monthly variation of surface salinity in the study area for 30 years, the monthly salt lines are gradually thinning from east to south with the Yangtze River estuary as the center. The northerly Yangtze River estuary has the largest monthly variation of salinity and it is getting smaller and smaller in the southeast.

3) Among the 7 characteristic points, the maximum monthly variation of salinity value is at D4 in the northeastern part of the Yangtze River estuary, and the smallest changes are D6 and D7. It is worth noting that the surface salinity values of D2 and D3 in summer are higher than those in winter, but the salinity values of the remaining 5 points are lower in summer than in winter.

Acknowledgements

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