The Transport Direction and Variation Process of Water Temperature Heat at Surface

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Abstract: According to the water temperature of Jiaozhou Bay in May, August and October of 1979, based on its horizontal and vertical variation, and the difference between water temperature at surface and bottom, the impact of the transport amount and time of water temperature heat on its variation at surface and bottom and regional variation was studied. The results showed that in May, from northeastern to northern nearshore waters, water temperature reached high as 15.30-16.50 \(^\circ\)C, which began to rise from inside waters to bay mouth, and to outside waters. In August, from eastern to northern nearshore waters, it reached high as 28.09-28.70 \(^\circ\)C, which began to rise in same order. In October, in eastern nearshore waters, it was as high as 18.39\(^\circ\)C, which began to increase from outside waters to bay mouth, and to inside waters. Regionally, from inside waters to bay mouth and outside waters, the minus of water temperature at surface and bottom showed that when it was transported to Jiaozhou Bay, it first reached the surface, then rapidly and constantly to sea floor, showing the variation of water temperature at surface and bottom. Spatially, water temperature at surface caused low heat and slow increase along with the horizontal and vertical gradients in May, high heat and rapid increase in August and heat and increase in October. Besides, the homogeneous layer was formed in outside waters vertically from surface and bottom. In bay mouth, water temperature at bottom was slightly higher than that at surface, whereas, in inside waters, it was opposite. Therefore, the temporal and spatial variation displayed the variation of water temperature at surface along with horizontal and vertical gradients. In addition, the modelling diagram was proposed and the transport direction and variation process of water temperature heat at surface were clarified.

1. Introduction

Human activities cause the rise of atmospheric temperature, which influences the ocean waters. Water temperature heat is transported to sea floor through waters effect. Hence, the study on the transport of water temperature heat in waters, especially from surface to sea floor [1-10]. Based on the water temperature of Jiaozhou Bay in May, August and October of 1979, according to its horizontal and vertical variation, the temporal and spatial variation of source and transport amount of water temperature were displayed by the minus of water temperature at surface and bottom, providing scientific reference for the study on the horizontal and vertical transport of water temperature heat at surface and bottom.
2. Study area and data collection

Study area. Jiaozhou Bay, located in southern Shandong Peninsula, is a typical semi-closed bay. The geographical location is 120°04′-120°23′E, 35°58′-36°18′N. Bounded by the line connecting Tuandao Cape and Xuejiadao Island, it connects with Yellow Sea, covering an area of about 446km², with the average depth of about 7m. There are dozens of rivers reaching the ocean in Jiaozhou Bay, among of which, the rivers with a larger volume of runoff and sand content include Dagu River, Yang River, Haibo River in Qingdao, Licun River, Loushan River and so on. These rivers are seasonal streams, and hydrological characteristics vary seasonally [11, 12].

Data collection. The materials about water temperature in Jiaozhou Bay waters in May, August and October of 1979 was provided by North China Sea Environment Monitoring Center, State Oceanic Administration. In May and October, 3 sites were established for sampling in Jiaozhou Bay: H34, H35 and H36, shown in Figure 1. Samplings were performed for three times in May, August and October in 1979, respectively. According to the depth of water, sampling and survey were conducted (surface and bottom layers were sampled when the depth of water is more than 10m, but just surface layer when less than 10m). The survey on water temperature of Jiaozhou Bay waters was in accordance with national standard method, which was included in The Specification for Marine Monitoring (1991) [13].

![Fig. 1 Investigation sites in Jiaozhou Bay](image1)

![Fig. 2 Water temperature distribution at surface in Jiaozhou Bay in May 1979](image2)

3. Results

3.1 The horizontal distribution at surface

In May, from northeastern to northern nearshore waters, the water temperature reached high as 15.30-16.50 °C, forming the high-temperature area in northern nearshore waters and a series of parallel lines
from northern to southern bay with different gradients. The water temperature decreased from the high temperature of 15.30-16.50 °C in the center to 12.00-12.10 °C in inside waters, bay mouth and outside waters of southern bay(Fig. 2).

In August, from eastern to northern nearshore waters, the water temperature reached high as 28.09-28.70 °C, forming the high-temperature area in eastern and northern nearshore waters and a series of parallel lines from the center to bay mouth with different gradients. The water temperature decreased from the high temperature of 28.09-28.70 °C in the center to 27.12-27.21 °C in bay mouth and 24.02 °C in outside waters(Fig. 3).

In October, in eastern nearshore waters outside the bay, the water temperature reached high as 18.39℃, forming the high-temperature area in eastern nearshore waters and a series of parallel lines with different gradients. The water temperature decreased from the high temperature of 18.39℃ in the center to 18.25-18.28℃ in inside waters and 16.21℃ in northern waters inside the bay(Fig.4).

Site H36 was established in inside waters, H35 in bay mouth and H34 in outside waters.

In May, August and October, in site H34, H35 and H36, the minus of water temperature between surface and bottom layers was -0.01-3.70°C, indicating that the heat at surface and bottom was similar and also different.

The minus was 0.20-1.20°C in May, 1.52-3.70°C in August and -0.01-0.63°C in October. In May and August, the values were positive in all three sites. Whereas, in October, the value was positive in H36, zero in H34 and negative in H35. The results are presented (Tab 1).
Tab.1 The minus of the water temperature between the surface and bottom layers in Jiaozhou bay mouth waters

| Site    | H36     | H35     | H34     |
|---------|---------|---------|---------|
| Month   |         |         |         |
| May     | Positive| Positive| Positive|
| August  | Positive| Positive| Positive|
| October | Positive| Negative| Zero    |

4. Discussion

4.1 The vertical variation
Due to the effect of vertical waters [14-16], the water temperature varied greatly through the waters. The heat exchange caused by the vortex motion mixing in vertical direction played an important role in distributing the heat of waters at surface and bottom in vertical surface. The direction of heat transport was decided by the vertical distribution of temperature. When the water temperature at upper surface was higher than that at lower surface, the heat was transported downward. Otherwise, it was transported upward. The exchange of heat between upper and lower surfaces inevitably caused the new distribution of water temperature in vertical direction and variation of temperature at each layer [1]. Thus, the vertical variation of water temperature could be determined after obtaining the variation of water temperature at surface and bottom.

4.2 The source of water temperature
The source of rising water temperature in inside waters, bay mouth and outside waters in May, August and October was studied in this paper.

In May, from northeastern to northern nearshore waters, water temperature reached high as 15.30-16.50 ℃, forming high-temperature area in northern nearshore waters and providing heat for inside waters, bay mouth and outside waters. It began to rise from inside waters to bay mouth, and to outside waters, respectively.

In August, from eastern to northern nearshore waters, it reached high as 28.09-28.70 ℃, forming high-temperature area in eastern and northern nearshore waters and providing heat for inside waters, bay mouth and outside waters. It began to rise in same order.

In October, in eastern nearshore waters, it was as high as 18.39℃, forming high-temperature area in eastern nearshore waters and providing heat for inside waters, bay mouth and outside waters. It began to increase from outside waters to bay mouth, and to inside waters, respectively.

4.3 The regional variation
Regionally, the minus of water temperature between surface and bottom layers were also different in inside waters, bay mouth and outside waters, which showed the variation of water temperature at surface and bottom. When water temperature heat was transported to Jiaozhou Bay, it reached the surface first, then rapidly and constantly to sea floor, showing its variation at surface and bottom (Tab 1).

4.4 The spatial variation
The spatial variation of water temperature heat was displayed according to different sources of water temperature heat.

In May, water temperature heat was from northeastern and northern nearshore waters, and water temperature was low. At surface, it decreased along with the gradients from inside waters to bay mouth then to outside waters. At the same time, it was transported vertically from surface to bottom layer, showing that the water temperature at surface was larger than that at bottom in three waters. It is presented in Figure 5. In this way, it brought low heat and slow increase along with horizontal gradients. Besides, it was transported vertically from surface to bottom layer. Thus, it caused low heat and slow increase along with vertical gradients.
In August, water temperature heat was from eastern and northern nearshore waters, and water temperature was low. At surface, it decreased along with the gradients from inside waters to bay mouth then to outside waters. At the same time, it was transported vertically from surface to bottom layer, showing that the water temperature at surface was larger than at bottom in three waters. It is presented in Figure 5. In this way, it brought high heat and rapid increase along with horizontal gradients. Besides, it was transported vertically from surface to bottom layer. Thus, it caused high heat and rapid increase along with vertical gradients.

In October, water temperature heat was from eastern nearshore waters. At surface, it decreased along with the gradients from outside waters to bay mouth then to inside waters. At the same time, it was transported vertically from surface to bottom layer. In outside waters, the water temperature at surface was consistent with that at bottom. It was less at surface layer in bay mouth and bottom layer in inside waters. It is presented in Figure 6. In this way, it brought heat and increase along with horizontal gradients. Besides, in outside waters, because of the arrival of autumn, the cold wind caused the vortex motion mixing of water temperature at surface and bottom in vertical direction. Impacted by heat exchange, the heat at surface was vertically consistent with that at bottom, vertically forming the homogeneous layer from surface to bottom layer. In bay mouth, before the heat exchange reached the bottom layer, there was a certain heat in bottom layer, thus, the water temperature of bottom layer was slightly higher than that at surface. In inside waters, heat exchange just began from surface layer, so the water temperature at surface was higher than that at bottom before it affected the waters.

5. Conclusion
The source of rising water temperature in inside waters, bay mouth and outside waters in May, August and October was determined in this paper.
In May, from northeastern to northern nearshore waters, water temperature reached high as 15.30-16.50 °C, providing heat for inside waters, bay mouth and outside waters. It began to rise from inside waters to bay mouth, and to outside waters, respectively.

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The spatial variation of water temperature heat was displayed according to different sources of water temperature heat.

In May, from inside waters to bay mouth then to outside waters, it brought low heat and slow increase along with horizontal gradients. Besides, it was transported vertically from surface to bottom layer. Thus, it caused low heat and slow increase along with vertical gradients.

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