Range and Standard of Yang Dongfang Spatial Water Temperature Variation Angle II. Spatial Water Temperature Model Application

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Abstract: According to the investigation materials in the water field of Jiaozhou Bay in May, August and October 1979, this paper studied the rise, decline and changing process of water temperature in the surface and bottom waters. Based on the definition and model of Yang Dongfang spatial water temperature variation angle, the results indicated that in the waters from inside of the bay mouth to the around from May to October, the range interval of the Yang Dongfang water temperature variation angle is 1.14° in the surface and 6.27° in the bottom when heated is the surface of a water body; from the waters in the bay mouth to the waters outside, the range interval of the Yang Dongfang water temperature variation angle is 13.49° in the surface and 4.00° in the bottom when cooled is the surface of a water body, which displays the changing process of the water temperature when heated or cooled is a water body.

1. Introduction
Along with the rise of the temperature in spring, sun heats the marine water and the heat is delivered to the seabed through the effect of water body. In autumn, the temperature declines and the wind cool the marine water. Through the effect of water body, the cooling flows to the seabed as well. Therefore, studying the delivering process of the heat energy in the water is of great important \cite{1-10}. Utilizing the investigation materials in May, August and October of 1979, this paper exhibited the sources of heat and cooling energy in the water temperature and its spatial changes of delivering quantity through the change of water temperature in the surface and bottom waters of the bay mouth in Jiaozhou Bay, which helped provide scientific basis for the research on horizontal and vertical delivery of heat and cooling energy in waters.

2. Investigation water fields, materials and methods

2.1 Natural environment in Jiaozhou Bay
Jiaozhou Bay is located in the south of Shandong Peninsula, ranging in 120°04’-120°23’E, 35°58’-36°18’N. Bounded by Tuan Island and Xuejiao Island, connecting to the Yellow Sea. With the
area of 446km$^2$ and average depth of 7m, it is a typical semi-enclosed bay. There are more than 10 rivers flow to the sea, of which the Dagu River, the Yang River, and some rivers in the urban of Qingdao such as Haipo River, Licun River and Loushan River, are the rivers with large runoff and sediment concentration. These rivers are ephemeral streams with obviously seasonal hydrological characteristics [11, 12].

2.2 Materials and methods
The investigation materials about the water temperature in the water bodies of Jiaozhou Bay in May, August and October of 1979 applied in this study are offered by the North China Sea Environmental Monitoring Center of State Oceanic Administration. In May, August and October, setting three stations to take water samples from the surface and bottom respectively: H34, H35, H36 (as shown in figure 1). Based on the water depth to take samples:
- Taking from surface and bottom layer, where the depth > 10m;
- Taking from surface layer only, where the depth < 10m.
This investigation method conforms to the national standards, and is recorded in *The Specification for Marine Monitoring (1991)* [13].

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

3. Results and Discussions
In May and August, it appears that the surface waters inside of the bay mouth transfer water heat to the marine waters in the bay mouth of Jiaozhou Bay and that the waters outside of the bay mouth transfer water heat to the marine waters in the bay mouth in October. Along with the changes of space, it is easily to quantify the rise or drop degree of water temperature on the basis of Yang Dongfang spatial water temperature angle proposed by the author, no matter how the water temperature is rising or declining.

3.1 The rise and drop of water temperature in May
From the waters inside of the bay mouth to the around, water temperature in the surface is declining and Yang Dongfang spatial water temperature angle is -0.57°. When -30°<$\alpha_{AB}$<0°, the angle is Yang Dongfang slow drop angle. At this time, the water temperature in the surface drops slowly with the spatial changes. It indicates that as the depth increases, the quantity of heat is slowly declining from the waters inside of bay mouth to the waters around although the sun can heat the surface water directly.

From the waters around the bay mouth to the waters outside, water temperature in the surface keeps
unchanged and Yang Dongfang spatial water temperature angle is 0.00°. When $\alpha_{AB} = 0°$, it is called that Yang Dongfang spatial water temperature angle is zero. At this time, the water temperature keeps unchanged. It indicates that the heat almost does not transfer from the waters in the bay mouth to the waters outside.

From the waters inside of the bay mouth to the around, water temperature keeps unchanged in the bottom waters. Yang Dongfang spatial water temperature variation angle is 0.00°. When $\alpha_{AB} = 0°$, it is called that Yang Dongfang spatial water temperature variation angle is zero. At this time, water temperature in the bottom keeps unchanged, which indicates that there is almost no heat transmission from surface to bottom although the sun can directly heat the surface water.

From the waters around the bay mouth to the waters outside, water temperature in the bottom declines and Yang Dongfang spatial water temperature variation angle is -3.43°. When $-30° < \alpha_{AB} < 0°$, this angle is called Yang Dongfang spatial water temperature slow drop angle. At this time, water temperature drops slowly with the spatial changes. It indicates that as the depth increases, the water temperature in the surface waters declines slowly, and the heat decreases very slowly from the waters around the bay mouth to the waters outside.

3.2 The rise and drop of water temperature in August
From the waters inside of the bay mouth to the around, water temperature in the surface is increasing and Yang Dongfang spatial water temperature angle is 0.57°. When $0° < \alpha_{AB} < 30°$, the angle is called Yang Dongfang slow rise angle. At this time, the water temperature in the surface rises slowly with the spatial changes. It indicates that the quantity of heat is slowly increasing to a high level from the waters inside of bay mouth to the waters around because the sun can heat the surface water directly.

From the waters around the bay mouth to the waters outside, water temperature in the surface keeps unchanged and Yang Dongfang spatial water temperature variation angle is 0.00°. When $\alpha_{AB} = 0°$, it is called that Yang Dongfang spatial water temperature variation angle is zero. At this time, the water temperature keeps unchanged with the spatial changes. It indicates that as the depth increases, the quantity of heat in the surface waters almost keeps unchanged from bay mouth to the outside.

From the waters inside of the bay mouth to the around, water temperature increases in the bottom waters. Yang Dongfang spatial water temperature variation angle is 0.00°. When $\alpha_{AB} = 0°$, it is called that Yang Dongfang spatial water temperature variation angle is zero. At this time, water temperature in the bottom keeps unchanged, which indicates that there is almost no heat transmission from surface to bottom although the sun can directly heat the surface water.

From the waters around the bay mouth to the waters outside, water temperature in the bottom declines and Yang Dongfang spatial water temperature variation angle is -4.00°. When $-30° < \alpha_{AB} < 0°$, this angle is called Yang Dongfang spatial water temperature slow drop angle. At this time, water temperature drops slowly with the spatial changes. It indicates that as the depth increases, the water temperature in the surface and bottom waters declines slowly, and the heat decreases very slowly to a low level.

3.3 The rise and drop of water temperature in October
From the waters inside of the bay mouth to the around, water temperature in the surface is increasing and Yang Dongfang spatial water temperature angle is 0.57°. When $0° < \alpha_{AB} < 30°$, the angle is called Yang Dongfang slow rise angle. At this time, the water temperature in the surface rises slowly with the spatial changes. It indicates that in October, the quantity of heat is slowly increasing to a low level from the waters inside of bay mouth to the waters around because of heating by the sun directly.

From the waters around the bay mouth to the waters outside, water temperature in the surface keeps unchanged and Yang Dongfang spatial water temperature variation angle is 0.00°. When $\alpha_{AB} = 0°$, it is called that Yang Dongfang spatial water temperature variation angle is zero. At this time, the water temperature keeps unchanged with the spatial changes. It indicates that as the depth increases, the quantity of heat in the surface waters almost keeps unchanged from bay mouth to the outside.

From the waters inside of the bay mouth to the around, water temperature increases in the bottom
waters. Yang Dongfang spatial water temperature variation angle is 6.27°. When 0°<α_{AB}<30°, it is called Yang Dongfang spatial water temperature slow rise angle. At this time, water temperature in the bottom rises slowly, which indicates that the quantity of heat increases slowly to a low level from surface to bottom due to the sun can directly heat the surface water.

From the waters around the bay mouth to the waters outside, water temperature in the bottom keeps unchanged and Yang Dongfang spatial water temperature variation angle is 0.00°. when α_{AB}=0°, it is called that Yang Dongfang spatial water temperature variation angle is zero. At this time, water temperature keeps unchanged with the spatial changes. It indicates that as the depth increases, the water temperature in the bottom waters keeps unchanged, and there is almost no heat transmission.

3.4 The variation of water temperature in the waters from inside of bay mouth to the bay mouth
From May to October, the water temperature in the surface water from inside of bay mouth to the bay mouth changes from decline to rise and the corresponding variation range is -0.57-0.57°. In the surface waters, Yand Dongfang spatial water temperature angle transfers from slow drop angle to slow rise angle. In this period, the water temperature in the surface changes from dropping slowly to rising slowly. Meanwhile, the water temperature in the bottom changes from keeping unchanged to rising slowly, and the Yang Dongfang spatial water temperature variation angle ranges within 0.00-6.27°. The corresponding Yang Dongfang spatial water temperature angle transfers from constant angle to slow rise angle. The water temperature changes from constant to slow rising.

The range of Yang Dongfang spatial water temperature variation angle in the surface layer is less than the range in the bottom, which indicates that the water temperature rises much slowly in the surface than in the bottom. The range interval of the water temperature variation angle in the surface is 1.14°while 6.27°in the bottom, which indicates that the rising degree of water temperature in the surface layer is smaller than it in the bottom layer. That is to say, from May to October, the rising degree is smaller in the surface layer while larger in the bottom. It reveals that the rising degree of water temperature is consistent in the surface waters when the sun heats different water areas at the same time. However, when the heat is delivered to the bottom waters through the water bodies, the water temperature rises faster in the bottom.

3.5 The variation of water temperature in the waters from bay mouth to the outside
From May to October, the water temperature in the surface water from bay mouth to the outside changes from keeping constant to decline and then to keep constant, and the corresponding variation range is 0.00--13.49°. In the surface waters, Yand Dongfang spatial water temperature angle transfers from constant angle to slow drop angle and then to constant angle. In this period, the water temperature in the surface changes from unchanged to dropping slowly then to constant. Meanwhile, the water temperature in the bottom changes from dropping slowly to keeping constant, and the Yang Dongfang spatial water temperature variation angle ranges within -4.00-0.00°. The corresponding Yang Dongfang spatial water temperature angle transfers from slow drop angle to constant angle. The water temperature changes from dropping slowly to constant.

The range of Yang Dongfang spatial water temperature variation angle in the surface layer is larger than the range in the bottom, which indicates that the water temperature drops much slowly in the surface than in the bottom. The range interval of the water temperature variation angle in the surface is 13.49°while 4.00°in the bottom, which indicates that the rising degree of water temperature in the surface layer is larger than it in the bottom layer. That is to say, from May to October, the dropping degree is larger in the surface layer while smaller in the bottom. It reveals that the dropping degree of water temperature is larger in the surface waters when the wind cools different water areas at the same time. However, when the cooling energy is delivered to the bottom waters through the water bodies, the water temperature drops slowly in the bottom.

3.6 Water temperature variation process in water bodies
When heated or cooled is the surface of water bodies, water temperature will rise or decline. After the
effect of vertical water bodies, the eddy turbulence in the vertical direction will result in the heat exchange between surface and bottom waters, which will lead to the rise or decline of the water temperature in the bottom.

From May to October, it displays the variation process of heating the surface waters from inside of bay mouth to the bay mouth, and the variation process of cooling the surface waters from the bay mouth to the outside.

When heated is the surface of a water body, the variation interval of Yang Dongfang water temperature variation angle is 1.14° in the surface layer, while it is 6.27° in the bottom. It shows that the changing degree of the rising of water temperature in the surface is smaller than it in the bottom. In the surface, the sun heats various water bodies at the same time while the rising degree of water temperature is the same. In the bottom, heat is delivered to the bottom through water bodies so the rising of water temperature is much faster.

When cooled is the surface of a water body, the variation interval of Yang Dongfang water temperature variation angle is 13.49° in the surface layer, while it is 4.00° in the bottom. It shows that the changing degree of the decline of water temperature in the surface is larger than it in the bottom. In the surface, the wind cools various water bodies at the same time when the rising degree of water temperature drops much. In the bottom, the cooling energy is delivered to the bottom through water bodies where the drop of water temperature is smaller.

4. Conclusion

Taken is the space as x-axis and water temperature as y-axis, calculating the results following based on the definition and model of Yang Dongfang spatial water temperature variation angle.

From May to October, it displays the changing process of heating the surface of a water body from waters inside of bay mouth to the waters around, and the process of cooling the surface of a water body from the waters in bay mouth to the outside. When heated is the surface of a water body, the range of Yang Dongfang spatial water temperature variation angle is 1.14°, but 6.27° in the bottom of water body. When cooled is the surface of a water body, the range of Yang Dongfang spatial water temperature variation angle is 13.49°, but 4.00° in the bottom of water body, which exhibits the variation process of water temperature in water bodies.

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