Range and Standard of Yang Dongfang Spatial Water Temperature Variation Angle I. Spatial Water Temperature Model Calculation

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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 studies the rise, decline and changing process of water temperature in the surface and bottom waters. The findings show that in the spatial changing process from May to August, then to October, the temperature in the surface water exhibits valley to peak line, then to the growth line and exhibits drop line to growth line in the bottom water from the bay inside to the waters of bay and to the outside waters. Based on the definition and model of Yang Dongfang spatial water temperature variation angle, the computerization result indicates that from May to August, the range of Yang Dongfang spatial water temperature variation angle from the water inside of the bay to the water around the bay mouth in the surface water is -0.57° to 0.57°, and it is 0.00° to 13.49° in the water from bay mouth to the outside, which are 0.00° to 6.27° and -4.00° to 0.00° in the bottom water, respectively.

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 cools the marine water. Through the effect of water body, the cooling flows to the seabed as well [1-10]. Utilizing the investigation materials in May, August and October of 1979, this paper set up the definition and model of the Yang Dongfang spatial water temperature variation angle, which helped to 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 446km² 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].

3. Results

3.1 The definition and model of Yang Dongfang spatial water temperature variation angle
Taken the space as x-axis, water temperature as y-axis, there is a forming XOY plane. Space x changes from x₁ to x₂ and water temperature y changes from y₁ to y₂. Thus, on the plane XOY, the water temperature y changes along the straight line formed by the surface points A (x₁, y₁) and B (x₂, y₂), of which the slope is as follows

\[ k_{AB} = \frac{y_2 - y_1}{x_2 - x_1} \]  

(1)

The intersection angle made by the line and x-axis is as follows

\[ \alpha_{AB} = \arctan k_{AB} \]  

(2)

It is called Yang Dongfang spatial water temperature variation angle, of which the range is -90° < \( \alpha_{AB} \) < 90°.

3.2 The range and standards of Yang Dongfang spatial water temperature angle
Through the changing process of Yang Dongfang spatial water temperature variation angle (figure 2), this paper determines the changing degree of the water temperature varying with space and standards of variation degree.

When 0° < \( \alpha_{AB} \) < 90°, the water temperature rises with space. Meanwhile, the larger the Yang
Dongfang spatial water temperature variation angle is in the interval $(0°, 90°)$, the faster the water temperature rises with space. The smaller the Yang Dongfang spatial water temperature variation angle is in the interval $(0°, 90°)$, the slower the water temperature rises with space. When $\alpha_{AB} = 45°$, this angle is called standard rising angle of Yang Dongfang spatial water temperature. At this time, the water temperature rises in standard with space.

When $0° < \alpha_{AB} < 30°$, this angle is called a slow rising angle of Yang Dongfang spatial water temperature. At this time, the water temperature rises slowly with space.

When $30° < \alpha_{AB} < 45°$, this angle is called a slower rising angle of Yang Dongfang spatial water temperature. At this time, the water temperature rises slower with space.

When $45° < \alpha_{AB} < 60°$, this angle is called a faster rising angle of Yang Dongfang spatial water temperature. At this time, the water temperature rises faster with space.

When $60° < \alpha_{AB} < 90°$, this angle is called a fast rising angle of Yang Dongfang spatial water temperature. At this time, the water temperature rises fast with space.

When $-90° < \alpha_{AB} < 0°$, the water temperature declines with space. In addition, the larger the Yang Dongfang spatial water temperature variation angle is in the interval $(-90°, 0°)$, the slower the water temperature declines with space. The smaller the Yang Dongfang spatial water temperature variation angle is in the interval $(0°, 90°)$, the faster the water temperature declines with space.

When $\alpha_{AB} = -45°$, this angle is called standard drop angle of Yang Dongfang spatial water temperature. At this time, the water temperature declines in standard with space.

When $-30° < \alpha_{AB} < 0°$, this angle is called slow drop angle of Yang Dongfang spatial water temperature. At this time, the water temperature declines very slowly with space.

When $-45° < \alpha_{AB} < -30°$, this angle is called slower drop angle of Yang Dongfang spatial water temperature. At this time, the water temperature declines slowly with space.

When $-60° < \alpha_{AB} < -45°$, this angle is called faster drop angle of Yang Dongfang spatial water temperature. At this time, the water temperature declines faster with space.

When $-90° < \alpha_{AB} < -60°$, this angle is called fast drop angle of Yang Dongfang spatial water temperature. At this time, the water temperature declines very fast with space.

When $\alpha_{AB} = 0°$, the Yang Dongfang spatial water temperature variation angle is zero. At this time, the water temperature remains unchanged with space.

Thus, giving a quantitative description and standard on the change of water temperature varying with space when its changing range within $-90° < \alpha_{AB} < 90°$.

### 3.3 The distance among bay mouth, inside and outside of the bay mouth

Station H36 locates inside waters of the bay mouth, station 35 in the waters of bay mouth, and H34 outside waters of bay mouth.

| Station | Longitude | Latitude |
|---------|-----------|----------|
| H36     | 120.2344° | 36.0678° |
| H35     | 120.2683° | 36.0169° |
| H34     | 120.3833° | 36.0333° |

Calculate the distance between inside waters of bay mouth H36 and the waters of bay mouth H35.

Assuming the distance between H36 and H35 is $L_1$, calculate $L_1$ at the basis of $1′=1858m$

$L_1^2= [(120.2344-120.2683) \times 60 \times 1858]^2 + [(36.0678-36.0169) \times 60 \times 1858]^2$

$L_1=0.0611 \times 60 \times 1858=681.142(m)=6.81 \text{ (km)}$

Calculate the distance between the waters of bay mouth H35 and outside waters of bay mouth H34.

Assuming the distance between H35 and H34 is $L_2$, calculate $L_2$ at the basis of $1′=1858m$

$L_2^2= [(120.2683-120.3833) \times 60 \times 1858]^2 + [(36.0169-36.0333) \times 60 \times 1858]^2$

$L_2=0.1161 \times 60 \times 1858=1294.282(m)=12.94 \text{ (km)}$
3.4 The changes of water temperature in the surface layer

In May, August and October, the water temperature in the surface layer has changed along with the spatial variation from the waters inside of bay mouth to the waters around the bay mouth and then to the waters outside of the bay mouth (figure 1).

In May, the water temperature in the surface waters inside of bay mouth changes from a higher figure $12.10^\circ\text{C}$, to the lowest figure $12.00^\circ\text{C}$ in the waters of bay mouth, and then gradually increases to a higher figure $12.10^\circ\text{C}$ in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a valley line (figure 3). The waters change from inside of the bay mouth to the outside when the water temperature changes from a high value to the lowest and then to high.

![Fig.3 The change process of water temperature at the surface and bottom inside the bay mouth in May](image)

In August, the water temperature in the surface waters inside of bay mouth changes from a higher figure $27.12^\circ\text{C}$, to the highest figure $27.21^\circ\text{C}$ in the waters of bay mouth, and then gradually declines to the lowest figure $24.02^\circ\text{C}$ in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a peak line (figure 4). The waters change from inside of the bay mouth to the outside when the water temperature changes from a high value to the highest and then to lowest.

In October, the water temperature in the surface waters inside of bay mouth changes from the lowest figure $18.25^\circ\text{C}$, to a higher figure $18.38^\circ\text{C}$ in the waters of bay mouth, and then continues to increase to the highest figure $18.39^\circ\text{C}$ in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a growth line (figure 5). The waters change from inside of the bay mouth to the outside when the water temperature changes from the lowest value to the higher and then to highest.

![Fig.4 The change process of water temperature at the surface and bottom inside the bay mouth in August](image)

![Fig.5 The change process of water temperature at the surface and bottom inside the bay mouth in October](image)
The water temperature changing from inside water of the bay mouth to the water around the bay mouth then to the water outside forms a valley line in May, a peak line in August and a growth line in October. Thus, water temperature in the spatial changing process displays a change from valley line to peak line then to growth line from May to August then to October.

3.5 The changes of water temperature in the bottom layer
In May, August and October, the water temperature in the bottom layer has changed along with the spatial variation from the waters inside of bay mouth to the waters around the bay mouth and then to the waters outside of the bay mouth (figure 1).

In May, the water temperature in the bottom waters inside of bay mouth changes from a higher figure 11.80°C, remains 11.80°C unchanged in the waters of bay mouth, and then gradually declines to a lowest figure 10.90°C in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a drop line (figure 3). The waters change from inside of the bay mouth to the outside when the water temperature in the bottom layer remains unchanged then decreases.

In August, the water temperature in the bottom waters inside of bay mouth changes from a higher figure 23.52°C, to a lower figure 23.51°C in the waters of bay mouth, and then gradually declines to the lowest figure 22.50°C in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a drop line (figure 4). The waters change from inside of the bay mouth to the outside when the water temperature in bottom layer changes from a high value to the lowest.

In October, the water temperature in the bottom waters inside of bay mouth changes from the lowest figure 17.62°C, to a higher figure 18.39°C in the waters of bay mouth, and then continues to remain unchanged in the waters outside of the bay mouth. Thus, the changing process of water temperature forms a growth line (figure 5). The waters change from inside of the bay mouth to the outside when the water temperature changes from the lowest value to the higher and then remains to the higher degree.

The water temperature changing from inside water of the bay mouth to the water around the bay mouth then to the water outside forms a drop line in May and August, and a growth line in October. Thus, water temperature in the spatial changing process displays a change from drop line to growth line from May to August then to October.

3.6 Yang Dongfang spatial water temperature variation angle in May
From the waters inside of the bay mouth to the waters around and then to the waters outside, taking space as x-axis, and the water temperature in May as y-axis. From the waters inside of bay mouth to the waters around the bay mouth, the water temperature in the surface layer in May changes along with the straight line \( L_1 = x_2 - x_1 \), made by points \((x_1,12.10)\) and \((x_2,12.00)\). The slope of the line is \( k_{AB} = -0.01 \) and the intersection angle made by the line and x-axis: \( \alpha_{AB} = \) Yang Dongfang water temperature variation angle \( =-0.57° \). From the waters around the bay mouth to the waters outside, the water temperature in May changes along with the straight line \( L_2 = x_2 - x_1 \), made by points \((x_1,12.00)\) and \((x_2,12.10)\). The slope of the line is \( k_{BC} = 0.00 \) and the intersection angle made by the line and x-axis: \( \alpha_{BC} = \) Yang Dongfang water temperature variation angle \( =0.00° \).

Through vertical transmission, water temperature passes through the surface water bodies to the bottom. Thus, the changes of water temperature in the bottom waters inside of the bay mouth to the around follow the straight line \( L_1 = x_2 - x_1 \), made by points \((x_1,11.80)\) and \((x_2,11.80)\), with the slope \( k_{ab} = 0.00 \). The intersection angle angle made by the line and x-axis is \( \alpha_{ab} = \) Yang Dongfang water temperature variation angle \( = 0.00° \). The changes of water temperature in the bottom from waters around the bay mouth to the outside follow the straight line \( L_2 = x_2 - x_1 \), made by points \((x_1,11.80)\) and \((x_2,10.90)\), with the slope \( k_{bc} = -0.06 \). The intersection angle angle made by the line and x-axis is \( \alpha_{bc} = \) Yang Dongfang water temperature variation angle \( = -3.43° \).

3.7 Yang Dongfang spatial water temperature variation angle in August
From the waters inside of the bay mouth to the waters around and then to the waters outside, taking
space as x-axis, and the water temperature in August as y-axis. From the waters inside of bay mouth to the waters around the bay mouth, the water temperature in the surface waters in August changes along with the straight line made by points A(x1,27.12) and B(x2,27.21). The slope of the line is kAB=0.01 and the intersection angle made by the line and x-axis: αAB= Yang Dongfang water temperature variation angle =0.57°. From the waters around the bay mouth to the waters outside, the water temperature in May changes along with the straight line made by points B(x1,27.21) and C(x2,24.02). The slope of the line is kBC=0.24 and the intersection angle made by the line and x-axis: αBC= Yang Dongfang water temperature variation angle =-13.49°.

Through vertical transmission, water temperature passes through the surface water bodies to the bottom. Thus, the changes of water temperature in the bottom from waters inside of the bay mouth to the around follow the straight line made by points a(x1,23.52) and b(x2,23.51), with the slope kab=0.00. The intersection angle angle made by the line and x-axis is αab=Yang Dongfang water temperature variation angle = 0.00°. The changes of water temperature in the bottom from waters around the bay mouth to the outside follow the straight line L2= x2-x1|, made by points b(x1,23.51) and c(x2,22.50), with the slope kbc=-0.07. The intersection angle angle made by the line and x-axis is αbc=Yang Dongfang water temperature variation angle = -4.00°.

3.8 Yang Dongfang spatial water temperature variation angle in October
From the waters inside of the bay mouth to the waters around and then to the waters outside, taken space as x-axis, and the water temperature in October as y-axis. From the waters inside of bay mouth to the waters around the bay mouth, the water temperature in the surface waters in August changes along with the straight line made by points A(x1,18.25) and B(x2,18.38). The slope of the line is kAB=0.01 and the intersection angle made by the line and x-axis: αAB= Yang Dongfang water temperature variation angle =0.57°. From the waters around the bay mouth to the waters outside, the water temperature in May changes along with the straight line made by points B(x1,18.38) and C(x2,18.39). The slope of the line is kBC=0.00 and the intersection angle made by the line and x-axis: αBC= Yang Dongfang water temperature variation angle =0.00°.

Through vertical transmission, water temperature passes through the surface water bodies to the bottom. Thus, the changes of water temperature in the bottom from waters inside of the bay mouth to the around follow the straight line made by points a(x1,17.62) and b(x2,18.39), with the slope kab=0.11. The intersection angle angle made by the line and x-axis is αab=Yang Dongfang water temperature variation angle = 6.27°. The changes of water temperature in the bottom from waters around the bay mouth to the outside follow the straight line made by points b(x1,18.39) and c(x2,18.39), with the slope kbc=0.00. The intersection angle angle made by the line and x-axis is αbc=Yang Dongfang water temperature variation angle = 0.00°.

| Water area | Water body | From waters inside of bay mouth to the bay mouth | Variation degree | From waters in the bay mouth to the outside | Variation degree |
|------------|------------|-------------------------------------------------|------------------|-------------------------------------------|------------------|
| May        | surface    | kAB=-0.01 αAB=-0.57 Slow drop angle              | kBC=0.00         | aBC=0.00 Keep unchanged                     |
|            | bottom     | kab=0.00 αab=0.00 Keep unchanged                 | kbc=-0.06        | αbc=-3.43 Slow drop angle                  |
| August     | surface    | kAB=0.01 αAB=0.57 Slow rise angle                | kBC=-0.24        | αBC=-13.49 Slow drop angle                 |
|            | bottom     | kAB=0.00 αAB=0.00 Remain unchanged               | kbc=-0.07        | αbc=-4.00 Slow drop angle                  |
| October    | surface    | kAB=0.01 αAB=0.57 Slow rise angle                | kBC=0.00         | αBC=0.00 Keep unchanged                     |
|            | bottom     | kAB=0.11 αAB=6.27 Slow rise angle                | kBC=0.00         | αBC=0.00 Keep unchanged                     |

4. Conclusion
From the waters inside of bay mouth to the around then to the outside, the water temperature in the surface waters forms a valley line in May, a peak line in August and a growth line in October. Thus,
the changing of water temperature varying with space displays the curve from valley line to peak line then to a growth line.

From the waters inside of bay mouth to the around then to the outside, the water temperature in the bottom waters forms a drop line in May and August and a growth line in October. Thus, the changing of water temperature varying with space displays the curve from drop line to growth line.

Taken 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.

In May, Yang Dongfang spatial water temperature variation angle in the surface waters from inside of bay mouth to the bay mouth is -0.57°, and 0.00° in the waters from bay mouth to the outside. In the bottom waters, Yang Dongfang spatial water temperature variation angle from inside of bay mouth to the bay mouth is 0.00°, and -3.43° in the waters from bay mouth to the outside.

In August, Yang Dongfang spatial water temperature variation angle in the surface waters from inside of bay mouth to the bay mouth is 0.57°, and 0.00° in the waters from bay mouth to the outside. In the bottom waters, Yang Dongfang spatial water temperature variation angle from inside of bay mouth to the bay mouth is 0.00°, and -4.00° in the waters from bay mouth to the outside.

In October, Yang Dongfang spatial water temperature variation angle in the surface waters from inside of bay mouth to the bay mouth is 0.57°, and 0.00° in the waters from bay mouth to the outside. In the bottom waters, Yang Dongfang spatial water temperature variation angle from inside of bay mouth to the bay mouth is 6.27°, and 0.00° in the waters from bay mouth to the outside.

From May to October, water temperature in the surface waters from inside of bay mouth to the bay mouth changes from decline to growth, and the range of Yang Dongfang spatial water temperature variation angle is -0.57-0.57°. Meanwhile, the water temperature in the bottom changes from constant to slow growth, and the Yang Dongfang water temperature variation angle ranges within 0.00-6.27°.

From May to October, water temperature in the surface waters from bay mouth to the outside changes from constant to decline, then to constant, and Yang Dongfang spatial water temperature variation angle ranges within 0.00-13.49°. Meanwhile, the water temperature in the bottom changes from drop slowly to constant, and the Yang Dongfang water temperature variation angle ranges within -4.00-0.00°.

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