The Range and Standards of Yang Dongfang Temporal Water Temperature Variation Angle Ⅰ. Model Calculation

Dongfang Yang¹,², a, Haixia Li¹, Haoyuan Ren¹, Sivakumar Manickam³, Dong Yang¹
¹Accountancy School, Xijing University, Xi’an 710123, China;
²North China Sea Environmental Monitoring Center, SOA, Qingdao 266033, China;
³Department of Chemical and Environmental Engineering, Faculty of Science and Engineering, University of Nottingham Malaysia, Kuala Lumpur 43500, Malaysia
²dongyang_dfyang@126.com

Abstract: According to the investigation materials about water bodies of Jiaozhou Bay in May, August and October 1979, this paper studies the changing process of water temperature in the surface and bottom waters. The findings show that from May to August and then to October, water temperature in the waters from inside of bay mouth to the outside forms a peak line over the time. From May to August and then to October, water temperature changes from the lowest to the highest and then drops to a relatively higher level. Based on the definition and model of Yang Dongfang temporal water temperature variation angle, the results indicate that in the water bodies of inside, around and outside of bay mouth, the Yang Dongfang temporal water temperature variation angles in the surface layer range in 75.86°-78.84° from May to August, and in 70.41°-77.28° from August to October. While in the bottom layer, Yang Dongfang temporal water temperature variation angle ranges in 75.47°-75.61° from May to August, and in 63.99°-71.27° from August to October.

1. Introduction
Along with the rise of air temperature in spring, the quantity of heat heated by the sun is delivered to the seabed through water bodies. Similarly, along with the decline of air temperature in autumn, the quantity of cold cooled by the wind is delivered to the seabed through water bodies. Therefore, it is important to study the transmission process of heat in water bodies [1-10]. Based on the investigation materials about water temperature in Jiaozhou Bay in May, August and October 1979 and the definition and model of Yang Dongfang temporal water temperature variation angle, which provides a scientific basis for the research on vertical and horizontal transmission process in water bodies.

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, and 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 and Discussion

3.1 The definition and model of Yang Dongfang temporal water temperature variation angle
Taking time as x-axis, water temperature as y-axis, forming an 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:

\[ k_{AB} = \frac{y_2 - y_1}{|x_2 - x_1|} \] (1)

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

\[ \alpha_{AB} = \arctan k_{AB} \] (2)

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

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

When \(0^\circ < \alpha_{AB} < 90^\circ\), the water temperature rises with time. Meanwhile, the larger the Yang Dongfang temporal water temperature variation angle is in the interval \(0^\circ, 90^\circ\), the faster the water temperature rises over time. The smaller the Yang Dongfang temporal water temperature variation angle is in the interval \(0^\circ, 90^\circ\), the slower the water temperature rises over time.

When \(\alpha_{AB} = 45^\circ\), this angle is called standard rising angle of Yang Dongfang temporal water temperature. At this time, the water temperature rises in standard over time.

When \(0^\circ < \alpha_{AB} < 30^\circ\), this angle is called a slow rising angle of Yang Dongfang temporal water temperature. At this time, the water temperature rises slowly over time.

When \(30^\circ < \alpha_{AB} < 45^\circ\), this angle is called a slower rising angle of Yang Dongfang temporal water temperature.
temperature. At this time, the water temperature rises slower over time.

When $45^\circ < \alpha_{AB} < 60^\circ$, this angle is called a faster rising angle of Yang Dongfang temporal water temperature. At this time, the water temperature rises faster over time.

When $60^\circ < \alpha_{AB} < 90^\circ$, this angle is called a fast rising angle of Yang Dongfang temporal water temperature. At this time, the water temperature rises fast over time.

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

When $\alpha_{AB} = -45^\circ$, this angle is called standard drop angle of Yang Dongfang temporal water temperature. At this time, the water temperature declines in standard over time.

When $-30^\circ < \alpha_{AB} < 0^\circ$, this angle is called slow drop angle of Yang Dongfang temporal water temperature. At this time, the water temperature declines very slowly over time.

When $-45^\circ < \alpha_{AB} < -30^\circ$, this angle is called slower drop angle of Yang Dongfang temporal water temperature. At this time, the water temperature declines slowly over time.

When $-60^\circ < \alpha_{AB} < -45^\circ$, this angle is called faster drop angle of Yang Dongfang temporal water temperature. At this time, the water temperature declines faster over time.

When $-90^\circ < \alpha_{AB} < -60^\circ$, this angle is called fast drop angle of Yang Dongfang temporal water temperature. At this time, the water temperature declines very fast over time.

Thus, giving a quantitative description and standard on the change of water temperature varying over time when it ranges within $-90^\circ < \alpha_{AB} < 90^\circ$.

3.3 The changes of water temperature in the surface layer

Station H36 locates inside waters of the bay mouth, station 35 in the waters of bay mouth, and H34 outside waters of bay mouth. In May, August and October, water temperature changes in both surface and bottom layers along with the changes of time (figure 1).

In May, the water temperature in the surface waters inside of bay mouth changes from the lowest $12.10^\circ \text{C}$, then rises gradually to the highest $27.12^\circ \text{C}$ in August. After that, it gradually declines to a relatively higher figure $18.25^\circ \text{C}$ in October. Thus, the changing process of water temperature forms a peak line (figure 3). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.

In the surface water bodies around bay mouth, the water temperature changes from the lowest $12.00^\circ \text{C}$ in May, then rises gradually to the highest $27.21^\circ \text{C}$ in August. After that, it gradually declines to a relatively higher figure $18.38^\circ \text{C}$ in October. Thus, the changing process of water temperature forms a peak line (figure 4). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.
In the surface water bodies outside of bay mouth, the water temperature changes from the lowest figure 12.10°C in May, then rises gradually to the highest figure 24.02°C in August. After that, it gradually declines to a relatively higher figure 18.39°C in October. Thus, the changing process of water temperature forms a peak line (figure 5). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.

![Fig.5 The change process of water temperature at the surface and bottom outside the bay mouth](image)

### 3.4 The changes of water temperature in the bottom layer

Station H36 locates inside waters of the bay mouth, station 35 in the waters of bay mouth, and H34 outside waters of bay mouth. In May, August and October, water temperature changes in both surface and bottom layers along with the changes of time (figure 1).

In May, the water temperature in the bottom waters inside of bay mouth changes from the lowest figure 11.80°C, then rises gradually to the highest figure 23.52°C in August. After that, it gradually declines to a relatively higher figure 17.62°C in October. Thus, the changing process of water temperature in the bottom layer forms a peak line (figure 3). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.

In the bottom water bodies around bay mouth, the water temperature changes from the lowest figure 11.80°C in May, then rises gradually to the highest figure 23.51°C in August. After that, it gradually declines to a relatively higher figure 18.39°C in October. Thus, the changing process of water temperature forms a peak line (figure 4). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.

In the bottom water bodies outside of bay mouth, the water temperature changes from the lowest figure 10.90°C in May, then rises gradually to the highest figure 22.50°C in August. After that, it gradually declines to a relatively higher figure 18.39°C in October. Thus, the changing process of water temperature forms a peak line (figure 5). The waters temperature changes from lowest to highest then to a relatively high level in the period from May to August then to October.

In the water bodies inside of bay mouth, around the bay mouth and outside of bay mouth, the water temperature in surface and bottom all forms a peak line from May to August and then to October. At the same time, the peak value in surface water bodies is greater than it in bottom water bodies. Meanwhile, the values of water temperature are almost same at the starting point of May and ending point of October.

### 3.5 Yang Dongfang temporal water temperature variation angle in the waters inside of bay mouth

Taking time as x-axis, and the water temperature in the waters inside of bay mouth as y-axis, the water temperature in the surface layer from May to August changes along with the line made by points A (5,12.10) and B (8,27.12). The slope of the line is $k_{AB}=5.00$ and the intersection angle made by the line and x-axis: $\alpha_{AB}=\text{Yang Dongfang temporal water temperature variation angle }=78.69°$. From August to October, the water temperature changes along with the line made by points B (8,27.12) and C (10,18.25). The slope of the line is $k_{BC}=-4.43$ and the intersection angle made by the line and x-axis: $\alpha_{BC}=\text{Yang Dongfang temporal water temperature variation angle }=-77.28°$ (Tab. 1).

Through vertical transmission, water temperature passes through the surface water bodies to the
bottom. Thus, the changes of water temperature in the bottom from May to August follow the line made by points a (5,11.80) and b (8,23.52), with the slope $k_{ab}=3.90$. The intersection angle made by the line and x-axis is $\alpha_{ab}=\text{Yang Dongfang temporal water temperature variation angle }=75.61^\circ$. The changes of water temperature in the bottom from August to October follow the line made by points b (8,23.52) and c (10,17.62), with the slope $k_{bc}=-2.95$. The intersection angle made by the line and x-axis is $\alpha_{bc}=\text{Yang Dongfang temporal water temperature variation angle }=-71.27^\circ$ (Tab. 1).

3.6 Yang Dongfang temporal water temperature variation angle in the waters around bay mouth

Taking time as x-axis, and the water temperature in the waters around bay mouth as y-axis, the water temperature in the surface layer from May to August changes along with the line made by points A (5,12.00) and B (8,27.21). The slope of the line is $k_{AB}=5.07$ and the intersection angle made by the line and x-axis: $\alpha_{AB}=\text{Yang Dongfang temporal water temperature variation angle }=78.84^\circ$. From August to October, the water temperature changes along with the line made by points B (8,27.21) and C (10,18.38). The slope of the line is $k_{BC}=-4.41$ and the intersection angle made by the line and x-axis: $\alpha_{BC}=\text{Yang Dongfang temporal water temperature variation angle }=-77.22^\circ$ (Tab. 1).

Through vertical transmission, water temperature passes through the surface water bodies to the bottom. Thus, the changes of water temperature in the bottom from May to August follow the line made by points a (5,11.80) and b (8,23.51), with the slope $k_{ab}=3.90$. The intersection angle made by the line and x-axis is $\alpha_{ab}=\text{Yang Dongfang temporal water temperature variation angle }=75.61^\circ$. The changes of water temperature in the bottom from August to October follow the line made by points b (8,23.51) and c (10,18.39), with the slope $k_{bc}=-2.56$. The intersection angle made by the line and x-axis is $\alpha_{bc}=\text{Yang Dongfang temporal water temperature variation angle }=-68.66^\circ$ (Tab. 1).

3.7 Yang Dongfang temporal water temperature variation angle in the waters outside of bay mouth

Taking time as x-axis, and the water temperature in the waters outside of bay mouth as y-axis, the water temperature in the surface layer from May to August changes along with the line made by points A (5,12.10) and B (8,24.02). The slope of the line is $k_{AB}=3.97$ and the intersection angle made by the line and x-axis: $\alpha_{AB}=\text{Yang Dongfang temporal water temperature variation angle }=75.86^\circ$. From August to October, the water temperature changes along with the line made by points B (8,24.02) and C (10,18.39). The slope of the line is $k_{BC}=-2.81$ and the intersection angle made by the line and x-axis: $\alpha_{BC}=\text{Yang Dongfang temporal water temperature variation angle }=-70.41^\circ$ (Tab. 1).

Through vertical transmission, water temperature passes through the surface water bodies to the bottom. Thus, the changes of water temperature in the bottom from May to August follow the line made by points a (5,10.90) and b (8,22.50), with the slope $k_{ab}=3.86$. The intersection angle made by the line and x-axis is $\alpha_{ab}=\text{Yang Dongfang temporal water temperature variation angle }=75.47^\circ$. The changes of water temperature in the bottom from August to October follow the line made by points b (8,22.50) and c (10,18.39), with the slope $k_{bc}=-2.05$. The intersection angle made by the line and x-axis is $\alpha_{bc}=\text{Yang Dongfang temporal water temperature variation angle }=-63.99^\circ$ (Tab. 1).

| Water area              | Water body | From May to August | Variation degree | From August to October | Variation degree |
|------------------------|------------|--------------------|------------------|------------------------|------------------|
| Waters inside of bay mouth | surface    | $k_{AB}=5.00$      | $\alpha_{AB}=78.69$ fast rise angle | $k_{BC}=-4.43$       | $\alpha_{BC}=-77.28$ fast drop angle |
|                        | bottom     | $k_{ab}=3.90$     | $\alpha_{ab}=75.61$ fast rise angle | $k_{bc}=-2.95$       | $\alpha_{bc}=-71.27$ fast drop angle |
| Waters around bay mouth | surface    | $k_{AB}=5.07$      | $\alpha_{AB}=78.84$ fast rise angle | $k_{BC}=-4.41$       | $\alpha_{BC}=-77.22$ fast drop angle |
|                        | bottom     | $k_{ab}=3.90$     | $\alpha_{ab}=75.61$ fast rise angle | $k_{bc}=-2.56$       | $\alpha_{bc}=-68.66$ fast drop angle |
| Waters                 | surface    | $k_{AB}=3.97$      | $\alpha_{AB}=75.86$ fast rise | $k_{BC}=-2.81$       | $\alpha_{BC}=-70.41$ fast drop |

Table 1 Yang Dongfang temporal water temperature variation angle and degree
outside of bay mouth

|     | angle |     | angle |
|-----|-------|-----|-------|
|     | bottom |     | fast rise |     | fast drop |
|     | $k_{ab}=3.86$ | $\alpha_{ab}=75.47$ | $k_{bc}=-2.05$ | $\alpha_{bc}=-63.99$ |

4. Conclusion
In the waters inside of bay mouth to the around then to the outside, the water temperature in the surface and bottom waters forms a peak line from May to August then to October. Thus, from May to August then to October, the water temperature in the surface and bottom waters changes from the lowest to the highest then drops to a relatively high level.

From the waters inside of bay mouth to the around then to the outside, the water temperature in the surface and bottom layers both forms a peak line from May to August then to October. Meanwhile, the peak value in surface water bodies is greater than it in bottom water bodies. The values of water temperature are almost same at the starting point of May and ending point of October.

Taking time as $x$-axis, and the water temperature as $y$-axis, getting the calculation results based on the definition and model of Yang Dongfang temporal water temperature variation angle as follows:

In the surface waters inside of bay mouth, Yang Dongfang temporal water temperature variation angle is $78.69^\circ$ from May to August, and $-77.28^\circ$ from August to October. In the bottom, Yang Dongfang temporal water temperature variation angle is $75.61^\circ$ from May to August, and $-71.27^\circ$ from August to October.

In the surface waters around bay mouth, Yang Dongfang temporal water temperature variation angle is $78.84^\circ$ from May to August, and $-77.22^\circ$ from August to October. In the bottom, Yang Dongfang temporal water temperature variation angle is $75.61^\circ$ from May to August, and $-68.66^\circ$ from August to October.

In the surface waters outside of bay mouth, Yang Dongfang temporal water temperature variation angle is $75.86^\circ$ from May to August, and $-70.41^\circ$ from August to October. In the bottom, Yang Dongfang temporal water temperature variation angle is $75.47^\circ$ from May to August, and $-63.99^\circ$ from August to October.

From May to August, the water temperature in the surface waters inside, around and outside of bay mouth rises over time, and the corresponding Yang Dongfang temporal water temperature variation angle ranges in $75.86$-78.84$^\circ$. The water temperature in the bottom rises as well, of which the range of Yang Dongfang temporal water temperature variation angle is 75.47-75.61$^\circ$.

From August to October, the water temperature in the surface waters inside, around and outside of bay mouth drops over time, and the corresponding Yang Dongfang temporal water temperature variation angle ranges in $-70.41$-77.28$^\circ$. The water temperature in the bottom drops as well, of which the range of Yang Dongfang temporal water temperature variation angle is $-63.99$-$71.27^\circ$.

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