The Definition, Equation and Application of the Varied Water Temperature Heat

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Abstract: Based on water exchange, the horizontal and vertical variation of water temperature heat were proposed by the author, and their definitions and equations were determined in this paper. According to the water temperature of Jiaozhou Bay in May, August and October of 1979, the horizontal and vertical variation of water temperature heat at surface and bottom were calculated. Besides, the corresponding diagrams were obtained. The horizontal variation showed that in May, August and October, from inside waters to bay mouth, then to outside waters, the horizontal decrease amount of water temperature heat reached 0.05-0.82% at surface and 0.00-7.62% at bottom, less than 1.00%. Even in the hottest season, it was less than 12.00%. Hence, spatially and temporally, when waters exchanged at surface and bottom, the heat loss was low. In this way, the heat could be transported for long distance. The vertical variation showed that in inside waters, the vertical decrease amount at surface and bottom reached 13.27% in summer, but 2.47-3.45% in spring and autumn. Whereas, in bay mouth, it reached 13.59% in summer and 1.66% in spring. It became vertical increase amount of 0.05% in autumn. In outside waters, from spring to summer, further to autumn, the vertical decrease amount decreased from 9.91% to 6.32%, further to 0.00%, respectively.

1. Introduction
Ocean plays an important role in climate regulation [1-10]. The study on nearshore water temperature variation and high-temperature waters is conductive to protecting ocean environment and maintaining the sustainable development of ecology. This paper, based on water temperature of Jiaozhou Bay in 1979, studied the vertical distribution and horizontal variation of water temperature at surface and bottom in inside waters, bay mouth and outside waters. Therefore, the author put forward the horizontal and vertical variation of water temperature heat, and determined their definition and equations, which provides scientific reference for the studies on horizontal and vertical variation of water temperature 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. 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](image)

3. Results

In Jiaozhou Bay, through exchanges of inside waters and outside waters in bay mouth, the concentration of materials continuously decreased [14-16]. In the same way, the heat of water temperature also varied. Hence, it was point source with a higher value of heat.

After the exchange of waters, the heat transported by ocean was substantial. It was necessary to determine its horizontal increase amount, which is divided into absolutely and relatively one, or its horizontal decrease amount, also including absolutely and relatively one.

The heat exchange caused by vortex motion and mixing of water temperature in vertical direction was great, resulting the new distribution vertically and variation of water temperature in each vertical layer [1]. The vertical increase amount and vertical decrease amount required to be determined, including absolutely and relatively amount, respectively.

**The definitions and equations of horizontal variation of water temperature heat** At surface waters of bay mouth, suppose water temperature heat was A in inside waters, B in bay mouth, and C in outside waters.

From inside waters to bay mouth, the absolutely horizontal decrease amount was D>0 and relatively horizontal increase amount was E. When D<0, the absolutely increase amount was -D>0 and corresponding relatively one was E (1).

\[ D = A - B, \quad E = \frac{|A - B|}{\max(A, B)} \]  

From bay mouth to outside waters, the absolutely horizontal decrease amount was F>0 and relatively horizontal increase amount was G. When F<0, the absolutely increase amount was -F>0 and corresponding relatively one was G (2).

\[ F = B - C, \quad G = \frac{|B - C|}{\max(B, C)} \]

At bottom waters of bay mouth, suppose water temperature heat was a in inside waters, b in bay mouth, and c in outside waters.
From inside waters to bay mouth, the absolutely horizontal decrease amount was $d>0$ and relatively horizontal increase amount was $e$. When $d<0$, the absolutely increase amount was $-d>0$ and corresponding relatively one was $e$. (3).

$$d=a-b, \quad e=|a-b|/\max(a,b) \quad (3)$$

From bay mouth to outside waters, the absolutely horizontal decrease amount was $f>0$ and relatively horizontal increase amount was $g$. When $f<0$, the absolutely increase amount was $-f>0$ and corresponding relatively one was $g$ (4).

$$f=b-c, \quad g=|b-c|/\max(b,c) \quad (4)$$

The definitions and equations of vertical variation of water temperature heat In outside waters, suppose water temperature heat was $A$ at surface and $a$ at bottom. Suppose the site was $n$, from surface to bottom, the vertical decrease amount was $V_{na}>0$, and relatively one was $V_{nr}$. When $V_{na}<0$, the absolutely vertical increase was $-V_{na}>0$, and when $V_{na}<0$, the relatively one was $-V_{nr}$. It was indicated in (5).

$$V_{na}=A-a, \quad V_{nr}=|A-a|/\max(A,a) \quad (5)$$

The horizontal variation at surface and bottom Suppose the waters from inside waters to bay mouth was from $A$ to $B$, and from $B$ to $C$ was from bay mouth to outside waters. The horizontal variation of water temperature heat disclosed its variation at surface and bottom.

In May, August and October, at surface, from inside waters to bay mouth, further to outside waters, the surface heat of water temperature greatly varied, which could be calculated and shown in Table 1 by (1) and (2).

| Time    | Waters | $V_{na}$ | $V_{nr}$ |
|---------|--------|----------|----------|
| May     | Inside| 0.30     | 0.0247   | 2.47%    |

In the same way, the variation at bottom also could be calculated and shown in Table 2 by (3) and (4).

| Time    | Waters | $d$      | $e$      | $g$      |
|---------|--------|----------|----------|----------|
| May     |        | 0.00     | 0.0000   | 0.00%    |
| August  |        | 0.01     | 0.00084  | 0.04%    |
| October |        | -0.77    | 0.0418   | 4.18%    |

| Time    | Waters | $f$      | $g$      |
|---------|--------|----------|----------|
| May     |        | 0.90     | 0.0762   | 7.62%    |
| August  |        | 1.01     | 0.0429   | 4.29%    |
| October |        | 0.00     | 0.0000   | 0.00%    |

Vertical variation The vertical variation of water temperature heat disclosed the vertical decrease and increase amount at surface and bottom.

Similarly, the vertical decrease and increase amount of water temperature heat at surface and bottom were calculated and shown in Table 3 by (5).

| Time    | Waters    | $V_{na}$ | $V_{nr}$ | $V_{nr}$ |
|---------|-----------|----------|----------|----------|
| May     | Inside    | 0.30     | 0.0247   | 2.47%    |
4. Discussion

4.1 The variation of water temperature heat
Water temperature heat varied when it was transported. Its horizontal variation disclosed the horizontal decrease and increase amount, and the variation at surface and bottom displayed the vertical decrease and increase amount. Thus, according to definitions and equations of horizontal and vertical variation, the waters effect of water temperature heat was quantified. In this way, the water temperature heat was also quantified in the transportation.

4.2 The horizontal and vertical variation of water temperature heat
In May, August and October, from inside waters to bay mouth, further to outside waters, the water temperature heat at surface could be calculated and shown in Table 1 by (1) and (2), the variation at bottom also could be calculated and shown in Table 2 by (3) and (4), and the vertical decrease and increase amount of water temperature heat at surface and bottom were calculated and shown in Table 3 by (5).

|          | Bay mouth | August | October |
|----------|-----------|--------|---------|
|          |           |        |         |
|          | Inside waters | Bay mouth | Outside waters |
|          | 0.20 | 0.166 | 1.66% |
|          | 1.20 | 0.0991 | 9.91% |
| August   | 3.60 | 0.1327 | 13.27% |
| Bay mouth| 3.70 | 0.1359 | 13.59% |
| October  | 1.52 | 0.0632 | 6.32% |
| Inside waters | 0.63 | 0.0345 | 3.45% |
| Bay mouth | -0.01 | 0.0005 | 0.05% |
| Outside waters | 0.00 | 0.00 | 0.00% |

In May, the horizontal decrease amount at surface reached 0.82% from inside waters to bay mouth and from outside waters to bay mouth. The horizontal decrease amount at bottom was 0.00% from inside waters to bay mouth and that at surface was 7.62% from bay mouth to outside waters. In addition, vertical decrease amount at surface and bottom reached 1.66-2.47% in inside waters and bay mouth, and 9.91% in outside waters(Fig.2).

In August, the horizontal decrease amount at surface reached 0.33% from bay mouth to inside waters and 0.33% from bay mouth to outside waters. The horizontal decrease amount at bottom was 0.04% from inside waters to bay mouth and that at surface was 4.29% from bay mouth to outside waters. In addition, vertical decrease amount at surface and bottom reached 13.27-13.59% in inside waters and bay mouth, and 6.32% in outside waters(Fig.3).

In October, the horizontal decrease amount at surface reached 0.70% from bay mouth to inside waters and 0.05% from outside waters to bay mouth. The horizontal decrease amount at bottom was 4.18% from bay mouth to inside waters and that at surface was 0.00% from bay mouth to outside waters. In addition, vertical decrease amount at surface and bottom reached 0.00-3.45% in inside waters and outside waters, and 0.05% in bay mouth(Fig.4).
In short, in May, August and October, the absolutely horizontal variation at surface and bottom was 0.00–3.19°C, and the relatively one was 0.00–11.72%. The vertical decrease amount at surface and bottom was 0.00–3.70°C, and the relatively one was 0.00–13.59%. The vertical increase amount at surface and bottom was 0.01°C, and the relatively one was 0.05%.

4.3 The horizontal variation
In May, the horizontal decrease amount at surface reached 0.82% from inside waters and outside waters to bay mouth. In August, it was 0.33% from bay mouth to inside waters and 11.72% from bay mouth to outside waters. In October, it reached 0.70% from bay mouth to inside waters and 0.05% from outside waters to bay mouth.

Thus, except to the 11.72% in August from bay mouth to outside waters, its variation was 0.05–0.82%, which was low temporally and spatially, less than 1.00%. It indicated that at surface, the heat loss was very low. Thus, the heat could be transported farther when waters moved for long distance. In August, the horizontal decrease amount at surface reached 11.72%, showing that in the hottest season, it was still less than 12.00% in waters with high temperature, thus, the heat loss was low.

In May, the horizontal decrease amount at bottom was 0.00% from inside waters to bay mouth and 7.62% from bay mouth to outside waters. In August, it was 0.04% at bottom from inside waters to bay mouth and 4.29% at surface from bay mouth to outside waters. In October, it reached 4.18% at bottom from bay mouth to inside waters and 0.00% at surface from bay mouth to outside waters.

Thus, it was 0.00–7.62% at surface and bottom, which was low temporally and spatially, less than
8.00%. It indicated that at bottom, the heat loss was very low. Thus, the heat could be transported farther when waters moved for long distance.

The horizontal decrease amount at bottom was 0.00% from inside waters to bay mouth in May and 0.00% from bay mouth to outside waters in October. It indicated that temporally and spatially, at bottom, there was no heat loss. Thus, the heat could be transported farther when waters moved for long distance.

4.4 The vertical variation
In inside waters, vertical decrease amount at surface and bottom was 2.47% in May, 13.27% in August and 3.45% in October, showing that in summer, it was higher as 13.27% when waters moved downward and lower as 2.47-3.45% when waters moved upward.

In bay mouth, it was 1.66% in May, 13.59% in August and 0.05% in October, indicating that in summer, it was higher as 13.59% when waters moved downward and lower as 1.66% when waters moved upward in spring. In autumn, it was lower as 0.05% when waters moved downward and it became vertical increase amount when waters moved downward from August to October.

In outside waters, it was 9.91% in May, 6.32% in August and 0.00% in October, indicating that from May to August, then to October, it became lower when waters moved downward. Hence, it was largest in spring and smallest in summer and reached zero in autumn when the vortex motion mixing and convective mixing were strong, so that the temperature from ocean surface to bottom was uniform, forming homogeneous layer.

5. Conclusion
Based on water exchange, the horizontal and vertical variation of water temperature heat were proposed by the author, and their definitions and equations were determined in this paper. According to the water temperature of Jiaozhou Bay in May, August and October of 1979, the horizontal and vertical variation of water temperature heat at surface and bottom were calculated. Besides, the corresponding diagrams were obtained.

The horizontal variation at surface showed that, except to the 11.72% in August from bay mouth to outside waters, its variation was 0.05-0.82%, which was low temporally and spatially, less than 1.00%. It indicated that at surface, the heat loss was very low. Even in the hottest season, it was still less than 12.00%. Thus, the heat could be transported farther when waters moved for long distance.

The horizontal variation at bottom displayed that it was 0.00-7.62% at surface and bottom, which was low temporally and spatially, less than 8.00%. It indicated that at bottom, the heat loss was very low. Thus, the heat could be transported farther when waters moved for long distance.

The vertical variation at surface disclosed that in inside waters, in summer, it was higher as 13.27% when waters moved downward and lower as 2.47-3.45% when waters moved upward. In bay mouth, in summer, it was higher as 13.59% when waters moved downward and lower as 1.66% when waters moved upward in spring. In autumn, it was lower as 0.05% when waters moved downward and it became vertical increase amount when waters moved downward from August to October. In outside waters, from May to August, then to October, it became lower from 9.9% to 6.32%, then to 0.00% when waters moved downward. Hence, it was largest in spring and smallest in summer and reached zero in autumn when the vortex motion mixing and convective mixing were strong, so that the temperature from ocean surface to bottom was uniform, forming homogeneous layer.

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