Taking the Red Bay as an Example to Study the Numerical Simulation Method for the Thermal Drainage along the East Coast of Guangdong Province

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Abstract. In view of the characteristics of the current in the east coast of Guangdong Province, based on the hydrological observation in the summer and winter in red bay, a two-dimensional ocean current mathematical model based on triangular meshes is established. Using the prediction results of the South China Sea regional circulation as the boundary conditions, the numerical simulation of the ocean current and the temperature drainage is carried out in the Red Bay. Because of the seasonal difference in current and the heat exchange parameters, the current and thermal drainage in summer and winter is predicted. The influence range and influence degree of summer and winter thermal drainage are compared and analysed. This method is more suitable for the prediction of current and temperature drainage along the east coast of Guangdong Province.

1. Introduction
In recent years, the construction of coastal power plants is increasing. In the Red Bay, the Taiping Ling nuclear power plant and Haifeng thermal power plant are to be built. Red Bay is in the north of the South China Sea, which is a semi closed bay, located on the east coast of Guangdong. As we all know, the sea current in the South China Sea is more complex [1], which is very different from other waters dominated by the tidal current.

The full tide hydrology test of the four seasons was carried out in the Red Bay Area in 2015[2]. The observed results show that the characteristics of the current flow are in accordance with the characteristics of the coastal current in East Guangdong. The flow direction of the East Guangdong coastal flow changes with the monsoon. The general characteristics are: the southwest monsoon is prevalent in summer, and the flow direction is drifting in the northeast, and the northeast monsoon is prevailing in winter, and the flow is changed to the southwest [3]. Its main driving mechanism is the strong wind stress formed by the wind field and the coastal terrain [4].

In view of the above features, based on the current mathematical model of summer and winter in the Red Bay, the prediction of thermal drainage in summer and winter is carried out. The influence range and influence degree of summer and winter thermal drainage are compared and analysed.

2. Numerical simulation method

2.1. Two dimensional hydrodynamic and water quality model
The paper uses the method of MIKE21 Flow Model hydrodynamic numerical simulation which is a general numerical modelling system for the simulation of water levels and flows in estuaries, bays and coastal areas. It simulates unsteady two dimensional flows in one layer (vertically homogeneous) fluids and has been applied in a large number of studies.

2.2 Model setting
(1) Settings of computational domain and grid
The computational range of the model is about 81km*66km. The calculation range and water depth of the model are shown in Figure 1. Figure 2 is grid diagram which have 51978 nodes in the area. The nodes are divided into 26653 non overlapping triangular units. The minimum space step length is 20m, the maximum space step is about 2km, and the time step is automatically adjusted from 0.01-20s.

Water depth and offshore boundary, according to the charts produced by the Ministry of People's Liberation Army Navy, is consistent with water depth data of "Tianwei Jiao to Great Kunshan".

(2) Settings of boundary condition
The open boundary of this study is extracted from the prediction results of the regional circulation of the South China Sea [5]. Because of the flow in the Red Bay is complex. In addition to tidal influence factors, but also by the circulation and coastal current effects induced by the local topography. Therefore, the model only considering the power flow is not consistent with the dynamic characteristics of the sea area. The South China Sea Regional Circulation prediction model takes account of the comprehensive factors such as monsoon, temperature and salinity. As an open boundary, it can accurately simulate the current in the Red Bay Sea area.

3. Model verification and analysis of the results of ocean current calculation

3.1 Model verification
To test the reliability of the model, according to the above information and given conditions, compare the measured results and calculation results of the tidal level, flow velocity and flow direction for each measured station. As the article length is limited, we omitted the verifying curve of model validation [5].

The verification of the two-dimensional model is precise. The calculation results of the model are in agreement with the change trend of the actual measurement. The current model is a good reflection of the flow in the Red Bay.

3.2 Simulating analysis of the ocean current
Figure 3 to Figure 4 is the flood tide in summer. During the flood tide at spring tide of summer, the current flows from the north to the west of the Red Bay. The current flows westward along the
coastline and finally from the west side of the bay to the west. During the ebb tide at spring tide of summer, the current flows from the southwest to the Red Bay. The flow runout of the Red Bay along the east coast line. The flow direction of calculation is consistent with the measurement. It can be seen from the velocity distribution, the velocity distribution is the same during the flood tide and the neap tide in summer. The velocity in the Red Bay is less than the outside of the Bay. The eastern velocity is slightly larger than the West. The calculated results are also in accordance with the distribution trend of the measured values. During the flood tide at neap tide of summer, the current flows from the west to the Red Bay. The current flows eastward along the coastline and finally from the east side of the bay to the east. The flow direction of the flood tide is the same as the ebb tide. The velocity distribution is the same. The velocity in the Red Bay is less than the outside of the Bay. The eastern velocity is slightly larger than the West. The calculated results are also in accordance with the distribution trend of the measured values.

Figure 5 to Figure 6 is the flood tide in winter. During the spring tide, the current flows to the northwest from the east side of the bay. The water flows southwest to the outside of the Bay. The currents in the bay present anti-clockwise rotation. During the neap tide, the current flows to the northeast from the west side of the bay. The water flows southeast to the outside of the Bay. The currents in the bay present clockwise rotation.

From the above calculation results, the Red Bay flow field calculated by the simulation is consistent with the measured results. The calculation method of this model is reasonable and feasible.

4. Numerical simulation and comparative analysis of thermal drainage in summer and winter

4.1 Construction of power plant in Red Bay
The Guangdong Taiping Ling nuclear power plant and the Haifeng power plant are to be built in the Red Bay. The Guangdong Taiping Ling nuclear power project plans to build 2 million kilowatt class
nuclear power units. The circulating water system of the power plant uses a direct current water supply system. The power plant uses the sea water around the site as a cooling water source. The circulating cooling water of the power plant is 130 m$^3$/s, and the temperature of the extraction and drainage is 7.83 degrees centigrade.

At the northeast direction of the Taiping Ling nuclear power plant, about 7km is the site of the Haifeng power plant. The Haifeng power plant plans to build 2 million kilowatt units, with a cooling water amount of 72m$^3$/s and a 7.5 centigrade temperature of the water intake and drainage. The geographical location and sensitive target map of the project is shown in Figure 7 and Figure8.

4.2 Analysis of temperature rise in summer and its influence on the marine environment

Figure 7 is the maximum temperature rise envelope of the whole tide in summer, and table 1 is the largest distribution of the influence of summer temperature rise. It can be seen from the chart and table that the thermal drainage of the Taiping Ling power plant in Guangdong mainly spread along the northeast and southwest. The range of temperature rise is mainly around the water distribution near the drain. The maximum temperature rise above 1°C in summer is about 77.6ha.

The main influence of temperature drainage in Haifeng thermal power plant is near the shore, and the direction of diffusion is South-North. The range of temperature rise is mainly around the water distribution near the drain. The maximum temperature rise above 1°C in summer is about 335.2ha. The maximum temperature rise in the ecological red line area is 0.76°C.

Table 1. Thermal drainage discharge environmental impact analysis on water environment in summer.

| The spatial distribution of temperature rise | The maximum possible impact area of different temperature rise (ha) |
|--------------------------------------------|---------------------------------------------------------------|
|                                           | ≥4.0°C ≥3.0°C ≥2.0°C ≥1.0°C                                  |
| Taiping Ling nuclear power plant           | --- --- 6.2 77.6                                             |
| Haifeng thermal power plant                | 1.4 12.9 170.4 335.2                                         |

4.3 Analysis of temperature rise in winter and its influence on the marine environment

Figure 8 is the maximum temperature rise envelope of the whole tide in winter, and table 2 is the largest distribution of the influence of winter temperature rise. It can be seen from the chart and table that the thermal drainage of the Taiping Ling power plant in Guangdong mainly spread along the northeast and southwest. The range of temperature rise is mainly around the water distribution near the drain. The maximum temperature rise above 2°C in winter is about 27.0ha. The maximum temperature rise above 3°C in winter is about 1.4ha, and the maximum temperature rise above 4°C is about 0.4ha.

The main influence of temperature drainage in Haifeng thermal power plant is near the shore, and the direction of diffusion is South-North. The range of temperature rise is mainly around the water distribution near the drain. The maximum temperature rise above 2°C in winter is about 455.9ha. The maximum temperature rise above 3°C in winter is about 173.1ha, and the maximum temperature rise above 4°C is about 128.6ha.

Table 2. Thermal drainage discharge environmental impact analysis on water environment in winter.

| The spatial distribution of temperature rise | The maximum possible impact area of different temperature rise (ha) |
|--------------------------------------------|---------------------------------------------------------------|
|                                           | ≥4.0°C ≥3.0°C ≥2.0°C                                        |
| Taiping Ling nuclear power plant           | 0.4 1.4 27.0                                               |
| Haifeng thermal power plant                | 128.6 173.1 455.9                                          |
4.4 **Comparison and analysis of the effects of thermal drainage in winter and summer**

To sum up, the thermal drainage of the power plant in the Red Bay is mainly influenced by the wind and the current. The diffusion region and morphology of the thermal drainage are basically consistent with the characteristics of the sea current.

Because of the large difference of sea current in summer and winter and the different parameters of heat diffusion, the difference of temperature rise range in summer and winter is also great. The temperature rise range of the power plant in the Red Bay is larger than that in summer, and the difference of the diffusion direction is little. According to the standard of Water Quality of Sea Water (GB 3097-1997), the temperature rise in summer is controlled by 1°C in summer, and the temperature
rise in winter is controlled by 2°C. The environmental impact of thermal emission from power plants should be taken into consideration in summer and winter. We should evaluate its impact on the marine environment in accordance with the corresponding evaluation criteria.

5. Summary

Through the numerical simulation of the sea current and thermal drainage in Red Bay, the following conclusions are obtained:

- The flow patterns in the Red Bay are very different in summer and winter. We also found this rule in the process of research in Daya Bay and DapengBay[6][7]. Measurements and calculations should be taken into consideration in different seasons (at least in summer and winter) and in different tidal types.
- The open boundary of the two-dimensional numerical simulation of the Red Bay is reasonable, which is provided by the results of the prediction of the South China Sea Regional Circulation. This method is also suitable for other regions along the east coast of Guangdong Province, such as Daya Bay, Dapeng Bay and Jieshi Bay etc.
- The diffusion region and morphology of the thermal drainage are basically consistent with the characteristics of the sea current.
- The environmental impact of thermal emission from power plants should be taken into consideration in summer and winter. We should evaluate its impact on the marine environment in accordance with the corresponding evaluation criteria.

6. References

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