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Numerical Simulation of Tidal Current in Majishan Sea Area of Zhoushan Based on SCHISM

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Abstract. Based on the SCHISM ocean model, this paper constructs a numerical model of the Majishan sea area in Shengsi County, Zhoushan City, and numerically simulates the tidal and tidal current conditions in the sea area. The non-structural triangular elements are used to construct the high-precision nearshore terrain to accurately simulate the tidal and tidal conditions. Yearly measured tidal current data. Have a deeper understanding of the tidal currents in the Majishan sea area of Zhoushan. The results show that the Majishan sea area of Zhoushan belongs to regular shallow sea currents dominated by recurrent currents. In the actual measurement, the speed of the rising and falling tides varies, and the maximum and average flow speeds are both the high tide is greater than the medium tide and the small tide. The tidal changes are mainly controlled by the forward waves of the East China Sea, and the direction of the current is basically the same as the direction of the rising and falling tides.

Keywords. Numerical simulation, schism, tide, tide current

1. Introduction

The archipelago area has a complex coastline, numerous islands, narrow waterways and rugged undersea topography, making it one of the most complex geographic areas in the ocean. The complex topography, tides and currents in the archipelago together build a complex dynamic system [1].

Ocean numerical simulation began in the 1960s and 1970s. It is a new and practical simulation technology that combines fluid mechanics, storm surge dynamics, sediment dynamics, and computational mathematics. As a basis, combined with specific related engineering technologies, a certain physical process is simulated using mathematical models. Compared with the physical model, the numerical model has the advantages of economy and practicality, short establishment period, high accuracy, easy modification, etc., and is not limited by the size of the project. It has been widely used in various coastal, estuarine dynamics, ocean dynamics and other issues.

The international research on the trend model started around the 1960s, when Philips put forward the concept of R coordinate transformation [2]. The current three-dimensional tidal current model is relatively mature and is often used to simulate the

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characteristics of tidal currents [3] and storm surges [4] in coastal areas such as bay areas and estuaries. This is also used to study the transport of sediment and pollutants. And the movement mechanism provides the power base. In the past few decades, based on some observational data [5-7], or numerical model results [8-11], many researchers have studied the tidal characteristics of the Zhoushan Islands, but no researchers have targeted Majishan. Carry out high-precision ocean numerical simulation in the sea area to study the characteristics of local tidal currents.

With the improvement of computer performance and the innovation of observation methods in recent decades, the accuracy of regional ocean simulation has gradually improved. Majishan Port Area is located in the southern part of Shengsi County, Zhoushan City, Zhejiang Province. It is one of the important transit terminals in the Zhoushan Archipelago New Area. It conducts high-precision tidal and current numerical simulations in the Majishan sea area to understand local tidal and current conditions to ensure the safety of ships entering the port. Offshore safety is important.

2. Numerical Simulation

SCHISM [12] is an unstructured grid-based modeling system developed on the basis of the SELFE (Semi-implicit Eulerian-Lagrangian Finite Element) [13] model, which aims to simulate streams, lakes, rivers, Multi-scale 3D baroclinic circulation in estuaries, continental shelves, oceans, etc. It uses semi-implicit finite element and finite volume methods based on the Eulerian-Lagrangian algorithm to solve Navier-Stokes equations to simulate various physical and biological processes. Conservation of mass is implemented through a finite volume transmission algorithm. The SCHISM model has modules that simulate ocean circulation, tsunami hazards, wave-current interaction, storm surge, sediment transportation, ecology, biogeochemistry, water quality, and oil spills [14].

2.1. Model Set

The SCHISM model is used to simulate the tide wave of Majishan. The model simulation range is from 120.4^{o}E to 124.5^{o}E in longitude and 28.3^{o}N-34.3^{o}N in latitude.Model grid and water depth as figure 1. In order to maximize the grid accuracy of the Majishan region, the grid density is 20m, the average precision of the density is 35m, and the boundary distance is 10km. There are 132087 unstructured triangular grids in the model area and 68560 grid points. The model is divided into six layers. The model adopts cold start, that is, when the model starts, the flow velocity and water level in the simulation area are all 0, regardless of sea surface forcing, fresh water input, and changes in wind and heat flux. The open sea borders astronomical tides. 8 astronomical component tides (M2, S2, K2, O2, K1, O1, P1, Q1) are used, interpolated from the global tide harmonic constant results to the open boundary grid points to give the model simulation time from June 21, 2015 A total of 40 days ended on July 30, with a time step of 120s. In order to stabilize the model data, only the 30-day data after the model data was used for research and analysis. The seabed topography data is the electronic chart water depth data provided by the Maritime Safety Administration of the People's Republic of China. The initial temperature is 20 degrees Celsius and the initial salinity is 35. Regardless of wind speed and other influences, a barotropic tide model is constructed.

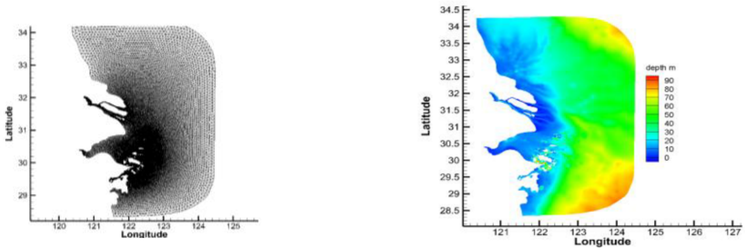

Figure 1. Image from model grid and water depth.

2.2. Model Verification

The calculation results of the model use the hydrological and sediment test data of the surrounding sea area of the third phase of the Majishan Port in July 2015 to verify the tide level, velocity, and flow direction. The tide level data is collected from four stations, Luchao Port (K1), Xiaoyangshan (K2), Xiaohengshan (K3), and Majishan Temporary Tide Station (K4). Set up 2 measuring stations, located in the sea area west of Maji Mountain.

2.2.1. Tide Verification

The data sequence of the four tide gauge stations used in this article is from July 1, 2015 to July 23, 2015. This article verifies the tide level during the spring, mid-tide, and neap tide during this period (figure 2~ figure 5). From the verification curve, the calculated value of the tide level during the large, medium and period is basically consistent with the actual measured value. The calculated value of the tide level during the neap tide is slightly different from the actual measured value. The model calculation result has high accuracy and can be reflected well. Changes in tide levels of large, medium and small tides. The locations of tide gauge stations are shown in table 1.

Table 1. Tide station.

Station	Latitude	Longitude	Time
Luchao Port (K1)	30°50′24″	121°50′42″	
Xiaoyangshan (K2)	30°32′00″	122°16′00″	Spring tide: July 01-02, 2015; July 17-July 18
Xiaohengshan (K3)	30°38′22.14″	122°02′24.25″	Mid-tide: July 05th-July 06th, 2015;
Majishan Temporary Tide Station (K4)	30°41′26.59″	122°25′16.55″	Neap tide: July 8th-July 9th, 2015.

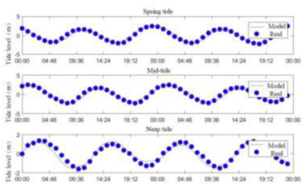

Figure 2. K1 station tide verification.

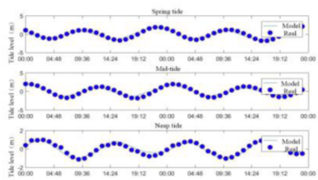

Figure 3. K2 station tide verification.

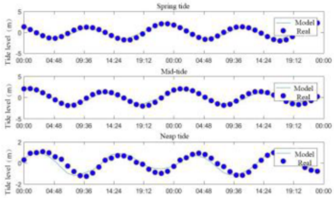

Figure 4. K3 station tide level verification.

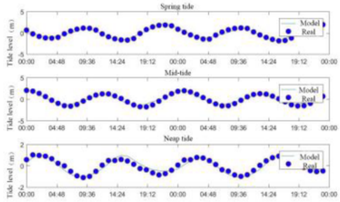

Figure 5. K4 station tide verification.

2.2.2. Tide Current Verification

The fixed-point velocity and flow direction observations are equipped with 2 hydrological measurement points, and the full tide is observed for more than 26 hours in the large, medium and small tides respectively. The flow direction is measured based on the true north position, and the magnetic declination is corrected. This paper verifies the flow velocity of the surface layer and 0.6 layer during the high tide and mid-tide period (figure 7). From the verification curve, the surface layer and the 0.6 layer flow velocity during the high and medium tide the calculated value of the flow direction is basically consistent with the measured value. The calculation result of the model has high accuracy and can better respond to the change of the flow velocity of large and medium tides. The location distribution of each station is shown in table 2 and figure 6.

Table 2. Tide current station.

Station	Latitude	Longitude	Time
V1	30°41′17.31″	122°23′34.97″	Spring tide: July 01-02, 2015; July 17-July 18
V2	30°41′04.49″	122°23′37.85″	Mid-tide: July 05th-July 06th, 2015; Neap tide: July 8th-July 9th, 2015.

Figure 6. Tide current station.

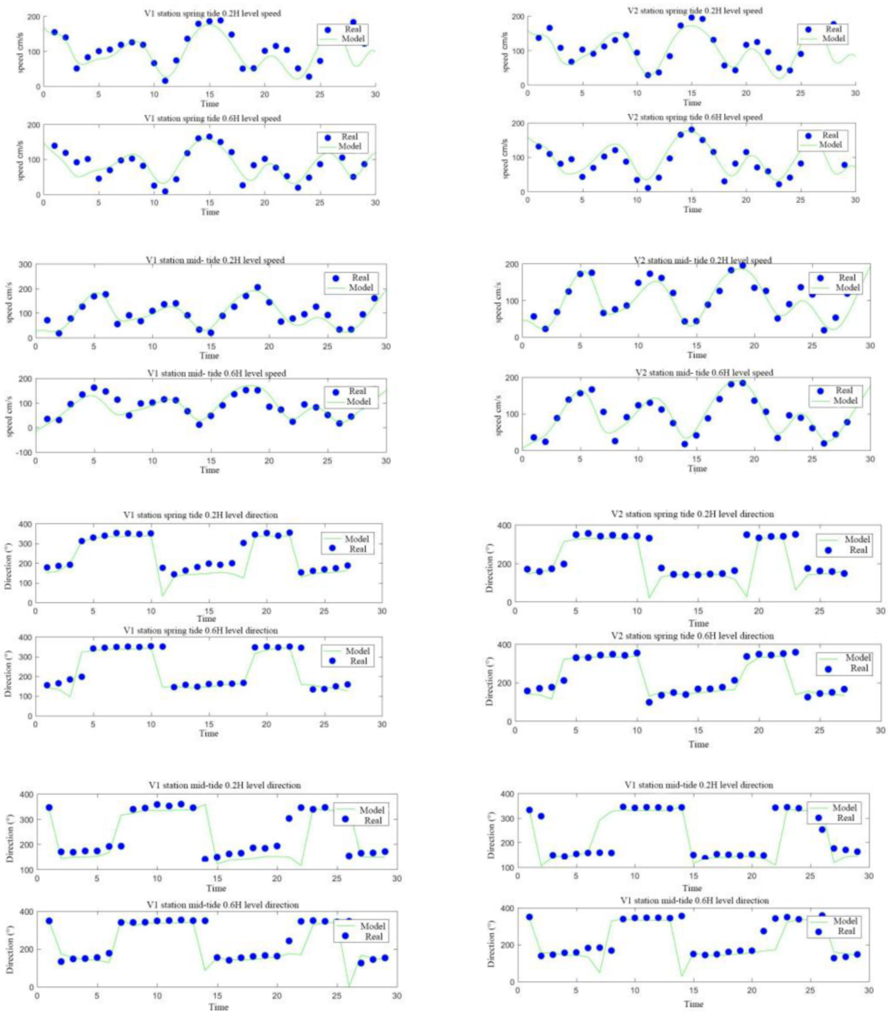

Figure 7. Speed station speed and direction verification.

3. Results

The water flow in Shengsi sea area is relatively smooth, and the velocity is generally between 50cm/s~100cm/s. In the vicinity of Shengsi Island and Majishan Island, it is greatly affected by the topography, and the flow direction of the water changes accordingly. The flow velocity is small, and the high tide is affected. The flow resistance of Majishan Island in Shengsi, the northwest area, the flow velocity is small, the minimum can be about 10cm/s, and the flow velocity in the southeast area is also small at low tide. On the southwest side of Majishan Island, the flow velocity is relatively high, and the flow velocity can reach about 2m/s during the spring tide. High tide and ebb tide rapids field diagram as figures 8~9.

At the time of rapid rise, the flow velocity is higher on the south side of Majishan

Island, but due to the influence of the topography, the flow velocity on the west side of the island, side flow rate is small especially in the northerly area. The flow velocity is generally manifested as the largest spring tide and the smallest neap tide between tidal times, the largest in the vertical direction, the largest in the middle layer, and the smallest in the bottom layer. The residual current in the sea area of the port area is not large, and the direction of the residual current is similar to the direction of the maximum velocity.

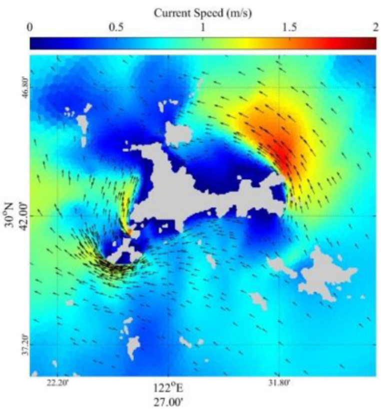

Figure 8. High tide rapids field diagram.

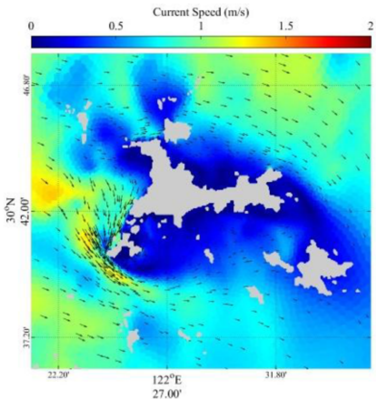

Figure 9. Ebb flow field diagram.

4. Conclusion

Based on the original data of the water depth, topography, hydrology and meteorology of the Majishan Port sea area, this paper uses the marine numerical model SCHISM to construct a three-dimensional tidal current numerical model of the study area, analyze the changes of the tidal field, and the basic conclusions are summarized as follows:

The tides in the sea area near Majishan Port are mainly controlled by the forward waves of the East China Sea, dominated by semi-diurnal tides. The shallow sea partial tide M4 has a small amplitude of about 3.7cm, and the shallow water influence coefficient HM4/HM2 is about 0.03. It is not necessary to consider the impact of shallow water tides. Generally speaking, the Majishan sea area is a regular semi-diurnal tidal current movement form dominated by reciprocating currents. The forward tide of the East China Sea enters the waters near Maji Mountain from the southeast through Huangzeyang to the west. After the tide wave entered the waters near Maji Mountain, the sea surface narrowed, the water depth became shallower, and the tide wave deformed due to obvious changes in the boundary. The tidal waves in the coastal waters are mainly standing waves, and there is a relatively consistent phase relationship between the tidal current and the tide level at each station. Generally speaking, during the high, medium and small tides, the maximum flow velocity of the rising and ebb tides occurs before the high and low tides1 -2 hours.

Establish a three-dimensional tidal current mathematical model based on the characteristics of the natural conditions and topography of the research sea area, and verify each model with measured data. The verification results are good, indicating that the established mathematical models can truly reflect the law of motion of the research sea tidal field.

Outlook:

This paper uses a three-dimensional tidal current numerical model to simulate the tidal current field in the sea area around Majishan Port, but does not use a mathematical model of wind, tidal current, and sediment coupling for simulation. Therefore, the following issues in this article need to be further studied.

(1) This paper does not have complete wave data. The three-dimensional tidal current simulation of Majishan Port does not consider wave factors. If conditions permit, the waves can be coupled with the original model.

(2) The wind pressure field is very important to improve the accuracy of numerical simulation, and further research is needed.

Acknowledgement

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