Summer Mass Transportation in the Beibu Gulf

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Abstract. We establish a three dimensional current field using Mike3 Flow Model in the Beibu Gulf. The accuracy is verified by comparing the current data with the measured data of an offshore oil platform. We calculate the wind-tide coupled current by adding the daily mean wind field. On this basis and decoupling the Particle Tracking Model, a water exchange matrix is built. After doing the Lagrange particle tracking experiment, we get the tracking of the particle, the water renewal rate, mass transport paths and the average water residence time (ART) of each part of the matrix as well as the Gulf. The most active part in the Beibu Gulf is the southern border and the ART is 11.74 days. Subsequently, the ART of the Qiongzhou Strait is 16.15 days. However, the most inactive part is the coast of the Guangxi Province, and the ART is 79days. For the whole gulf, the ART is 77.88 days.

Introduction

The Beibu Gulf is surrounded by Hainan, Guangdong, Guangxi, and Vietnam, which is public waters between China and Vietnam. The gulf is located in the northwest of South China Sea continental shelf and it is the biggest marginal sea of the northwest Pacific. In general, the east border is the line between the Lingao corner of Hainan Island and the Denglou corner of Leizhou Peninsula, and the south border is the line between Yongling of Vietnam and the town of Yinggehai in Hainan Island [1](see Fig.1). The bathymetry of the gulf is flat and the isobaths is roughly parallel to the coastline. The average depth is 46 meters and the deepest point is 90 meters [2][3].

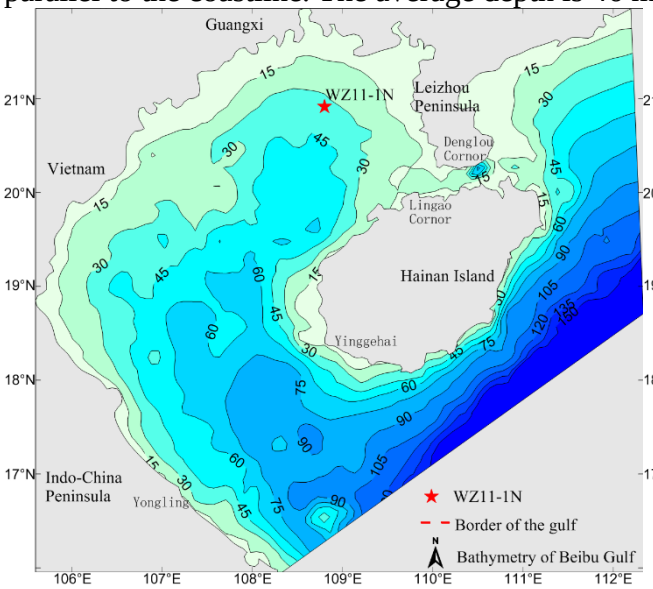

Fig.1 bathymetry of the Beibu Gulf

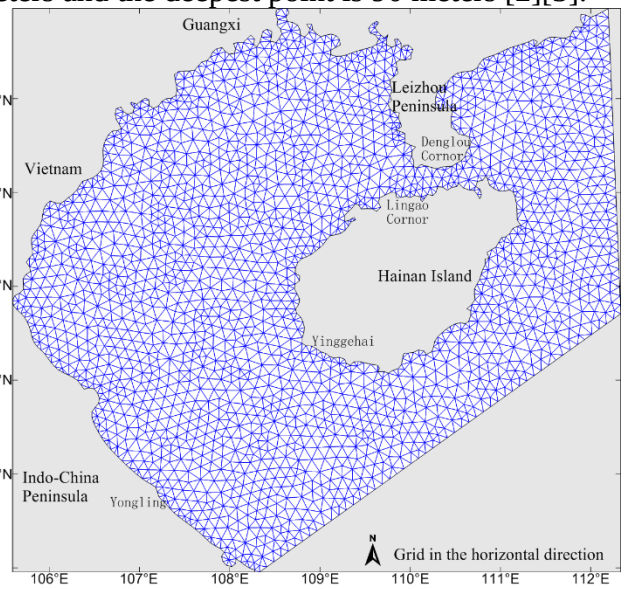

Fig.2 grid of the computational domain

Model setup

The computational domain is from 105.5°E to 112.8°E and from 16°N to 22°N, which covers the whole Beibu Gulf. The open boundary is set 170km away from the border of the gulf. The coastline and the bathymetry are fetched from sea chart of the PLA's general headquarter, with scale bar of

1:1000000. The bathygraphic map is shown in Fig.1. Depths that are greater than 150m are unifying colored and the deepest point is 1231m. The time step in the model is set up as 0.1second to 20seconds, and the output time step is 1 hour. Subdivide the computation domain with unstructured grid in the horizontal direction, then 4256 cells and 2425 points with 6000 to 8000 meters' grid spacing are got (see Fig.2). 30 sigma layers are divided in vertical [4].

Using well verified surface elevation and current as the initial state of the seawater motion, this model is warm booted and calculated for 3 months. Forcing on the open boundary is elevation forecasted by the global tidal model TPXO 7.2 [5], which is set up to soft start in 3600 seconds.

The average air pressure in the Beibu Gulf is between 1010 and 1011 hPa, and the value is between 1002 and 1004 hPa in summer. In this paper, the air pressure will setup as a constant, whose value is 1003 hPa. The wind forcing data are download from the reanalyzed meteorology data from 1979 to now on ECMWF. The space resolution of the wind field data is 0.125°×0.125° and the temporal resolution is 4 times per day [6].

Model verification

We collect the measured tidal current and elevation data of the offshore oil platform called WZ11-1N (see Fig.1) during 14/6/2007 and 21/6/2007. By comparing the simulating current data to the measured data (see Fig.3, Fig.4 and Fig.5), we can verify the accuracy of the model.

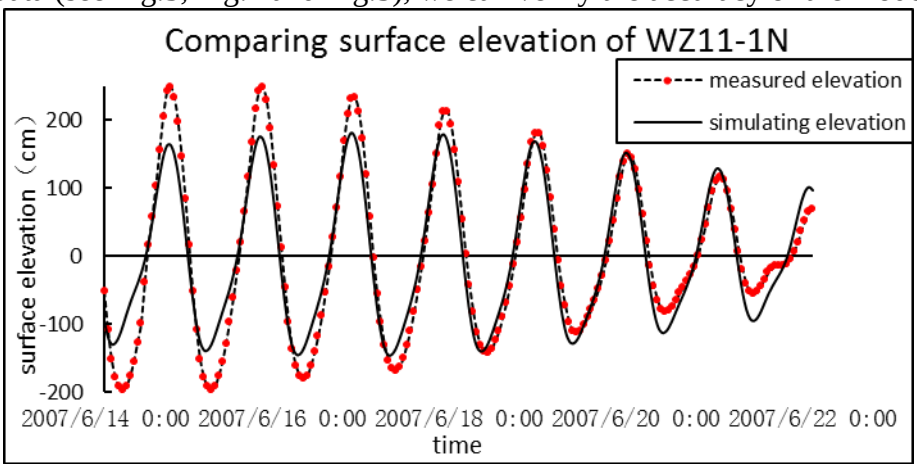

Fig.3 comparing surface elevation of WZ11-1N

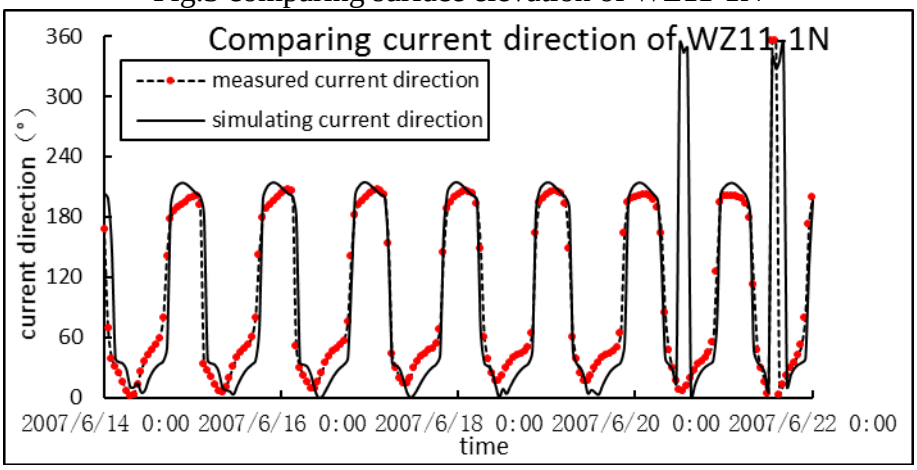

Fig.4 comparing current direction of WZ11-1N

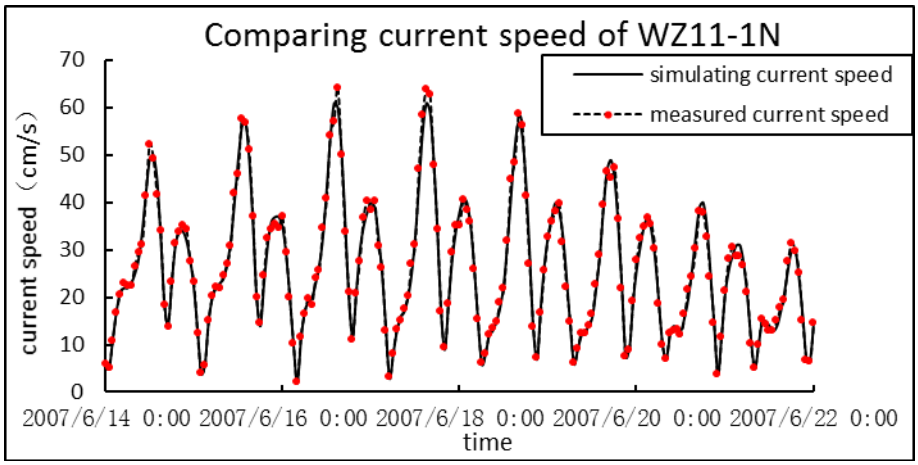

Fig.5 comparing current speed of WZ11-1N

After comparing the simulating data and the measured data, we can draw a conclusion that the model is well setup and could reflect the real current in the Beibu Gulf.

Water exchange matrix

We divide the Beibu Gulf into 6 sections including the Qiongzhou Strait (see Fig.6). 2508 particles well-distributed are released into the gulf according to the area of each section (see table.1)

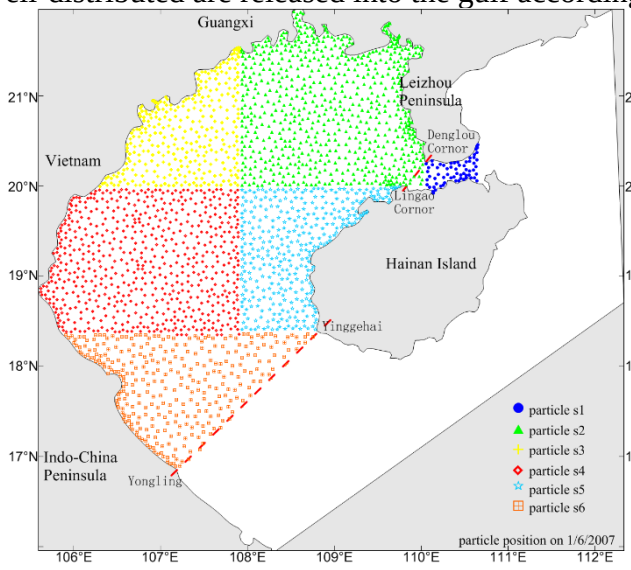

Fig.6 particle position on 1/6/2007

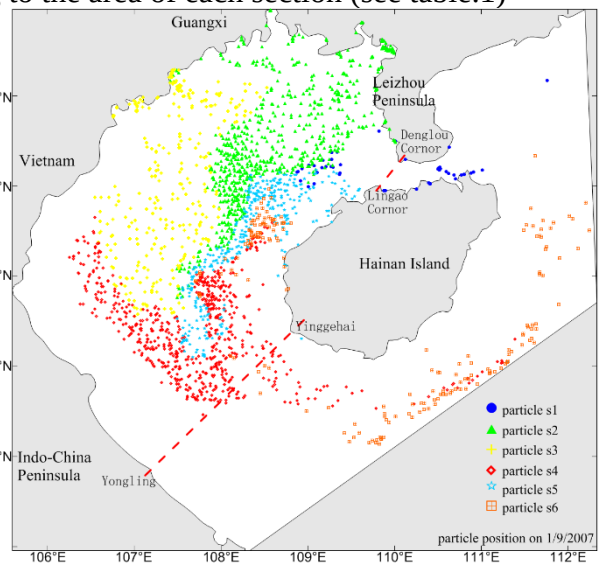

Fig.7 particle position on 1/9/2007

Table 1. particle number of each section

Particle names	s1	s2	s3	s4	s5	s6
Particle number	64	709	320	634	359	486

After simulating 3 months (see Fig.7), we get the tracking of the particles. Statistics position data list in table.2. We can figure that 58% of the total mass in the Qiongzhou Strait transport to the coast of Guangxi. 15% of the total mass in the Guangxi offshore area transport to the west of the Hainan Island. 45% of the total mass in the northern coastal area of Vietnam transport to the middle of the Beibu Gulf. 34% of the total mass in the middle of the gulf transport to the south exit of the gulf. 19% and 14% of the total mass in the west of the Hainan Island transport to the middle of the gulf and to the offshore area of Guangxi respectively. 85% of the total mass in the south exit of the gulf transport out of the gulf. As for the whole gulf, 2016 particles still stay in the Beibu Gulf, which is to say the mass transport in the Beibu Gulf is 19.61% in summer.

Table.2 water exchange matrix

Particle names	S1	S2	S3	S4	S5	S6	Irrelevant water	Out of domain
S1	0.15	0.58	0.02	0.00	0.00	0.00	0.17	0.08
S2	0.00	0.79	0.02	0.04	0.15	0.00	0.00	0.00
S3	0.00	0.09	0.44	0.45	0.02	0.00	0.00	0.00
S4	0.00	0.00	0.00	0.37	0.17	0.34	0.10	0.01
S5	0.00	0.14	0.00	0.19	0.59	0.08	0.00	0.00
S6	0.00	0.00	0.00	0.01	0.15	0.00	0.23	0.61

Average residence time (ART)

The ART stands for the time that water point needs to leave the research domain [7]. It can be described as the following formula, and we calculate the ART of every section (see Table.3):

$$\tau_\gamma = \int_0^\infty \xi \psi^*(\xi) d\xi$$

Table.3. the ART in each section

Section name	S1	S2	S3	S4	S5	S6	Whole Beibu Gulf
ART（day）	16.15	79.08	48.53	49.86	54.37	11.74	77.88

Conclusion

Particles influx into the Beibu Gulf from the Qiongzhou Strait, then flow along the Leizhou Peninsula. Particles in the northern part of the gulf seems to be an anti-clockwise motion, and the particles in the west part of Hainan Island have the trend of northing motion. In general, the mass transport tendency in the whole gulf is “entering from the north and leave at the south”.

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