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Modeling the circulation and sediment transport in the Beibu Gulf

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Abstract

Water circulation and sediment transport in the Beibu Gulf are important for its environmental protection and resource exploitation. By employing the Regional Ocean Modeling System (ROMS), we studied the seasonal variation of circulation, sediment transport and long-term morphological evolution in the Beibu Gulf. The simulation results show that the circulation induced by tide and wind is cyclonic both in winter and summer in the gulf and that the wind-driven circulation is stronger in winter than that in summer. The sediment concentration is higher in the Qiongzhou Strait, west of the Hainan Island and the coast of Vietnam and the Leizhou Peninsula. The sediment is transported westwards in winter and eastwards in summer in the Qiongzhou Strait. The west entrance of the Qiongzhou Strait is dominated by westward transport all the year round. The sediment discharged by rivers is deposited near the river mouths. The simulated result demonstrates that the sediment transport is mainly controlled by tidal induced bottom resuspension in the Beibu Gulf. Four characteristics are summarized for the distribution patterns of erosion and deposition. (1) The erosion and deposition are insignificant in most area of the gulf. (2) Sediment deposition is more significant in the mouths of Qiongzhou Strait. (3) The erosion is observed in the seabed of Qiongzhou Strait. (4) Erosion and deposition occur alternatively in the west of Hainan Island.

Key words: Beibu Gulf, circulation, sediment transport, Regional Ocean Modeling System (ROMS)

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1 Introduction

The Beibu Gulf is of great importance in that it is a pivot location geographically for large-scale circulation, mass transport and environmental health in the South China Sea. The gulf receives freshwater discharges from the Red, Fangcheng, Qinjiang, Nanliu and Changhua Rivers as well as some small rivers. Under the influence of the monsoon climate, the runoff of these rivers is higher in summer and lower in winter. According to early survey of the Beibu Gulf that was conducted by China and Vietnam in 1960s (Liu, 1964), the circulation in the gulf is anti-cyclonic in summer and reversed in winter. In contrast, the latest investigation show that circulation is cyclonic in the gulf over the whole year (Xia et al., 2001; Manh and Yanagi, 2000; Zu, 2005; Wu et al., 2008; Gao et al., 2013; Ding et al., 2013). By constructing a high-resolution prognostic model, Gao et al. (2013) demonstrated that the circulation is anti-cyclonic in summer, and changes into a cyclonic one from fall to next spring. However, Ding et al. (2013) investigated the role of wind forcing in the seasonal variations of circulation in the gulf, and concluded that the circulation in the northern gulf is cyclonic in both winter and summer. In addition, Hu et al. (2003) noted two high kinetic energy zones in the Qiongzhou Strait and off the western coast of Hainan Island, which are important in mass transport. Huang et al. (2008) studied the seasonal variations of sea surface turbidity in the gulf by utilized the MODIS imagery, and revealed the high monthly averaged turbidity in the Qiongzhou Strait and the west coast of Hainan Island.

In contrast to the most numerous studies that are mainly focused on the hydrodynamics, nevertheless, few investigations have been conducted for the sediment transport and morphological evolution of the gulf. Van Maren (2007) claimed that the sediment from Red River is mostly deposited within 10 km of the river mouth. Using the grain size trend analysis, Ma et al. (2010) demonstrated the existence of distinct converging centers of sediment transport in the west entrance of the Qiongzhou Strait and the west coast of Hainan Island. Ma et al. (2014) applied high-resolution multibeam bathymetric data to study sand ridge mobility and sediment transport in the Dongfang coast. Their results showed that the morphology of the sand ridges are mainly

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controlled by finite water depth, daily reciprocal currents, changes in sand supply and the interaction between dunes. The mechanism of sediment transport in the Beibu Gulf is still poorly understood.

In this study, we attempt to examine the characteristics of circulation and then simulate the sediment transport and morphological evolution pattern in the Beibu Gulf with a regional ocean model. Hopefully, the results from this study will put forward our understanding about the sediment transport in the gulf.

2 Models

2.1 *Model description and setting*

The Beibu Gulf, with a water depth less than 100 m, is a semi-closed embayment adjacent to the northwest of the South China Sea (SCS). Water in the gulf exchanges that in SCS through the mouth of the gulf and the Qiongzhou Strait (Fig. 1).This study is performed with the Regional Ocean Modeling System (ROMS), which solves finite-difference approximations of the Reynolds averaged Navier-Stokes equations (Hedström, 2012). ROMS is a state-of-the-art numerical model, which is constructed on the basis of free-surface, hydrostatic and Boussinesq primitive equations and involves a horizontal curvilinear Arakawa C grid and vertical stretched terrain-following coordinates (Shchepetkin and McWilliams, 2005; Warner et al., 2008). We adopted the quadratic bottom stress formulation and Mellor-Yamada 2.5 turbulence scheme (Mellor and Yamada, 1982).

In order to investigate the sediment transport in the gulf, ROMS version 3.7 is utilized. The domain of our model is located within 13°–25°N in latitude and 105°–118°E in longitude, which is discretized into a total of 213×272 horizontal grids. The model grid has ten vertical layers, and a horizontal resolution varies from ~2 km within the Beibu Gulf to ~10 km out of the gulf. The horizontal resolution is about 1 km around the Qiongzhou Strait. The depth was derived from ETOPO1 (http://www.ngdc.noaa.gov/mgg/global/global.html), with a minimum value of –2 m. The monthly mean temperature and salinity were obtained from World Ocean Atlas 2009 (https://www.nodc.noaa.gov/OC5/WOA09 pr_woa09.html), while the wind field and heat flux were gained from Comprehensive Ocean-Atmosphere Data Set (http:// iridl.ldeo.Columbia.edu/SOURCES/.COADS/). As being derived from the Oregon State Tidal Prediction Software TPXO8.0, tidal boundary conditions were imposed at the south and east boundaries of the domain. Eight tidal constituents (K_1, O_1, P_1, Q_1, M_2, S_2, N_2, and K_2) were used to force the model. In addition, we adopted the monthly mean freshwater discharge as the same with Gao et al. (2013). We used the ROMS sediment routines (Warner et al., 2008) to simulate the sediment transport in the gulf. Monthly mean suspended sediment load were adopted at the Nanliu River and Changhua River (Yang et al., 2013), while annual means were used at other rivers given the unavailability of detailed data (Wang, 2012). The gradient condition for sediment concentration was utilized at open boundaries. For the sake of simplicity, we used a single sediment grain size of 63 μm. In this study, the critical shear stresses for erosion and deposition were set as constant values of 0.12 N/m^2, and the sediment settling velocity was set as 1×10^{-4} m/s.

Model sensitivity tests have been implemented to examine the model results corresponding to changes in these parameters. In spite of the high variety of the magnitudes, the general sediment transport pattern and seabed evolution are not much too sensitive to the choices of these parameters, though the magnitudes vary a lot. Other parameters were identified from the literature (Harris et al., 2008). The simple setting could not reflect the real world completely (Yu et al., 2012). Nevertheless, our aim is to capture the essential pattern of sediment transport in the gulf in the first step, serving as a primarily tentative study to grasp a good understanding of the sediment transport regime. Further refinement of the model setting is still undergoing.

To identify the roles of tide, wind and freshwater discharge in the sediment transport of the Beibu Gulf, we performed four model cases by controlling the variants. In Cases 1 and 2, the

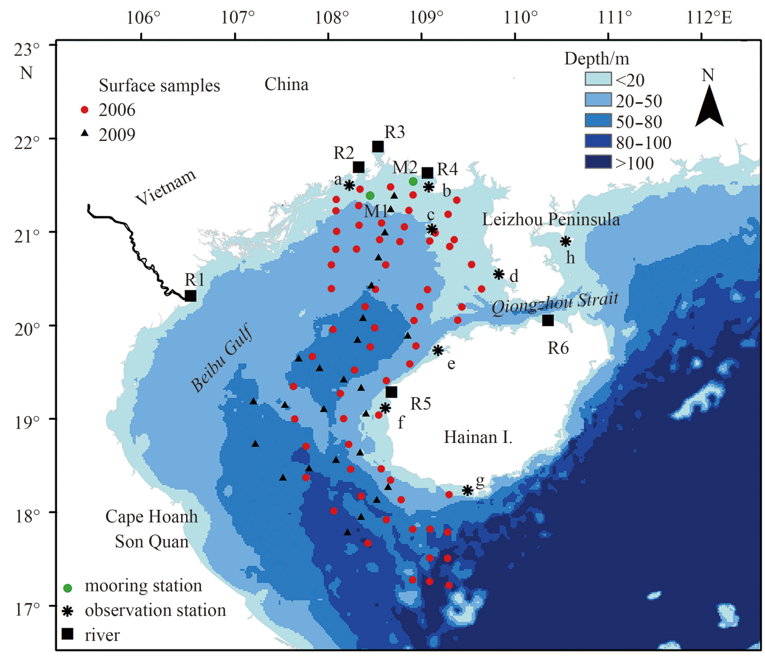

Fig. 1. Map of the Beibu Gulf, bathymetric contours are shown at 30-m intervals. Eight observation stations a–h include Bailongwei, Beihai, Weizhou Island, Wushi, Yangpu, Dongfang, Sanya, and Naozhou Island, respectively. Six rivers R1–R6 include the Red, Fangcheng, Qinjiang, Nanliu, Changhua, and Nandu Rivers, respectively. M1 and M2 are two mooring stations.

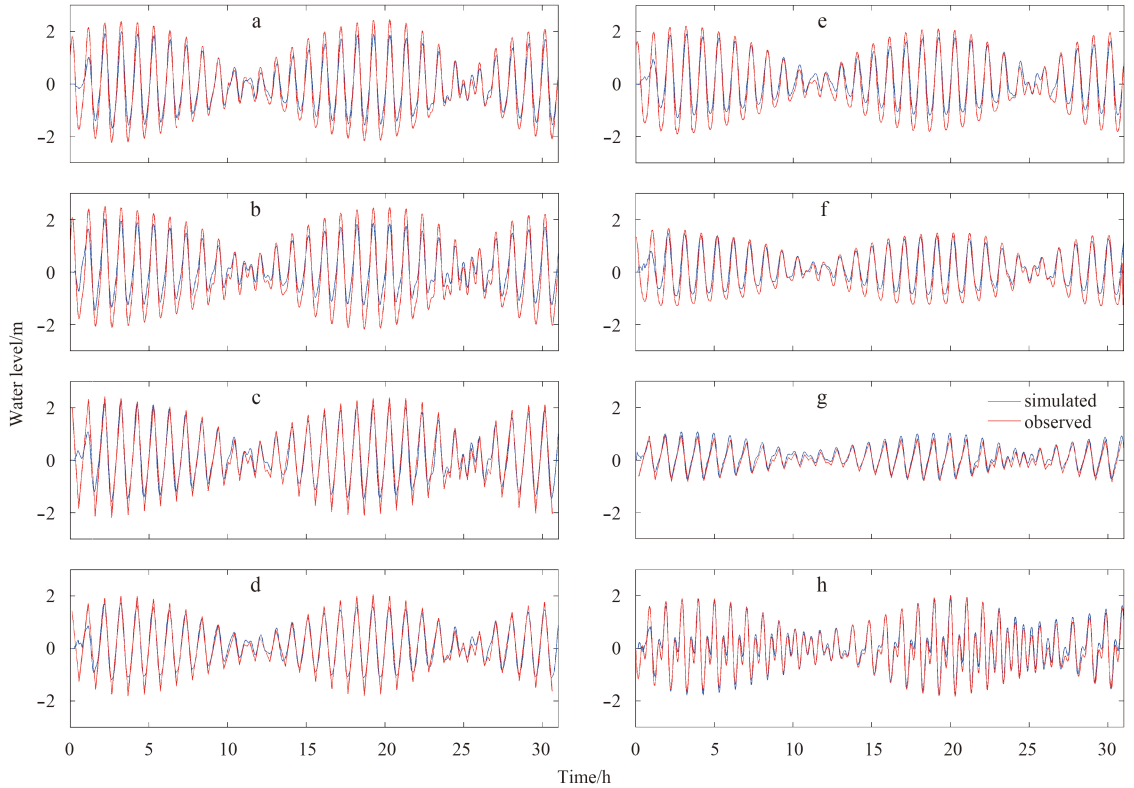

Fig. 2. Time series of water level. The blue lines show simulated, and the red lines show observed.

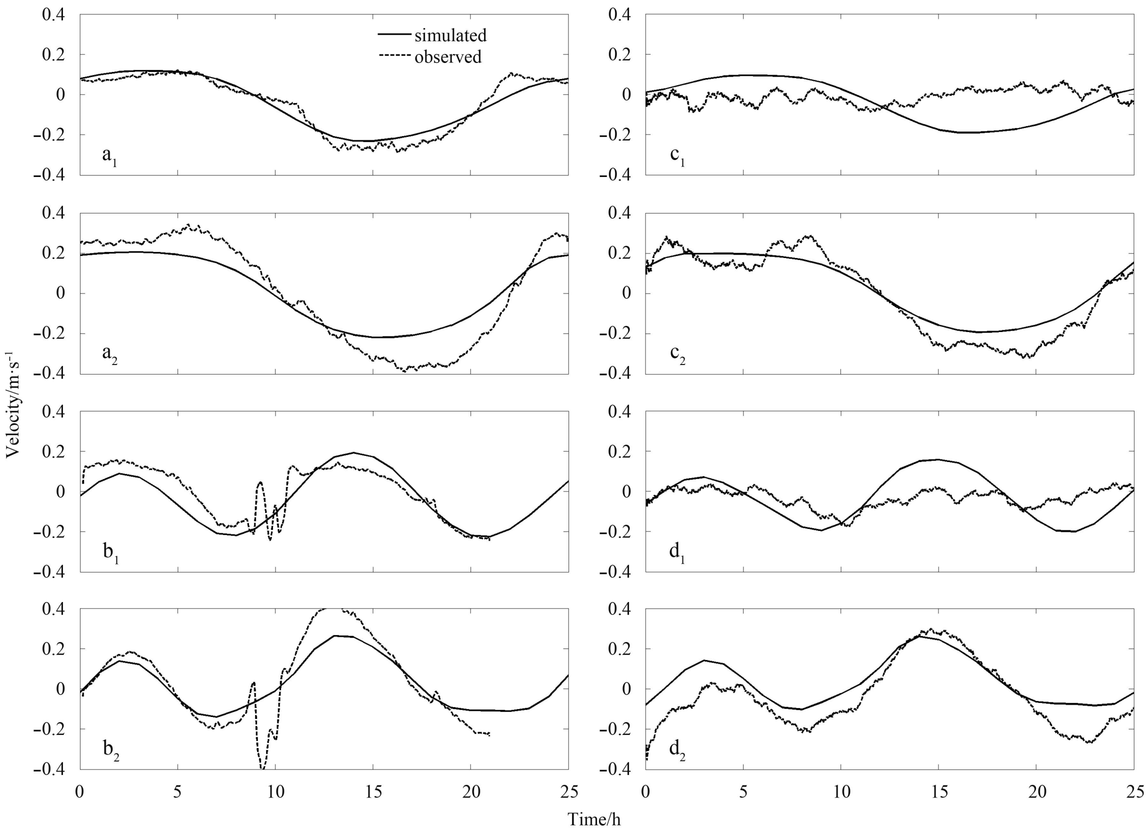

Fig. 3. The vertically mean velocity of simulated and observed comparison in two mooring stations. The start time is 12:00 on April 11, 2007 for a and c, while the start time is 12:00 on April 16, 2007 for b and d. Subscripts 1 and 2 represent the u and v components of velocity. The solid lines show simulated, and the dashed lines show observed.

model was driven by tidal forcing and monthly averaged wind forcing alone, respectively. In Case 3, the model was driven by the two factors in combination. In Case 4, the model was driven by all the impacting factors, including tide, wind and river discharge. In all the cases, the models were run in the baroclinic mode. It should be mentioned that the influence of heart flux in generating circulation is so small as to be neglected in the model. It took 36 days to run the model in Cases 1, 2 and 3, respectively, whereas 360 days in Case 4.

2.2 *Model verification*

The following steps are performed to guarantee the reliability of the model to simulate the hydrodynamics and sediment transport in the gulf. First, we ran the model considering merely tidal forcing in January 2007. The simulated water levels (Fig. 2) were compared to the observations at eight stations around the Beibu Gulf (Fig. 1). Although the model under estimates water level in some observation stations (a, b, d, and f), the good consistence between the simulated tidal phases and the observations demonstrated the accountability of the model. The underestimation of tidal range may be attributed to the inaccuracy of water depth around the observation stations. Noticeably, the modeling results are highly consistent with the observations on the stations of Sanya and Naozhou Island (g and h), in terms of both the amplitudes and the phases.

In order to validate the modeling results of velocity, the model with a combination of wind and tidal forcing is operated. Several field measurements were taken by Guangzhou Marine Geological Survey in April 2007. The locations of mooring stations (M1 and M2) are shown in Fig. 1. The simulated mean velocity turns out to correspond well to the observation in M1 (Figs 3a and b). Although the u component of the simulated velocity deviates from the observed in M2, the v component of the velocity follows the observed (Figs 3c and d) well. As the v component is larger than the u component at M2, the good match between the model and the observations at v component is not surprising. It is more difficult for the model to reproduce the water velocity, which is influenced by a variety of factors. The model results in our cases indicate that the fundamental hydrodynamic characteristics could be constrained well by the model.

3 Results

3.1 *The hydrodynamics*

3.1.1 *The characteristics of tidal dynamics*

The amplitudes and phases of the principal tidal constituents were obtained with the T_Tide Harmonic Analysis Toolbox for

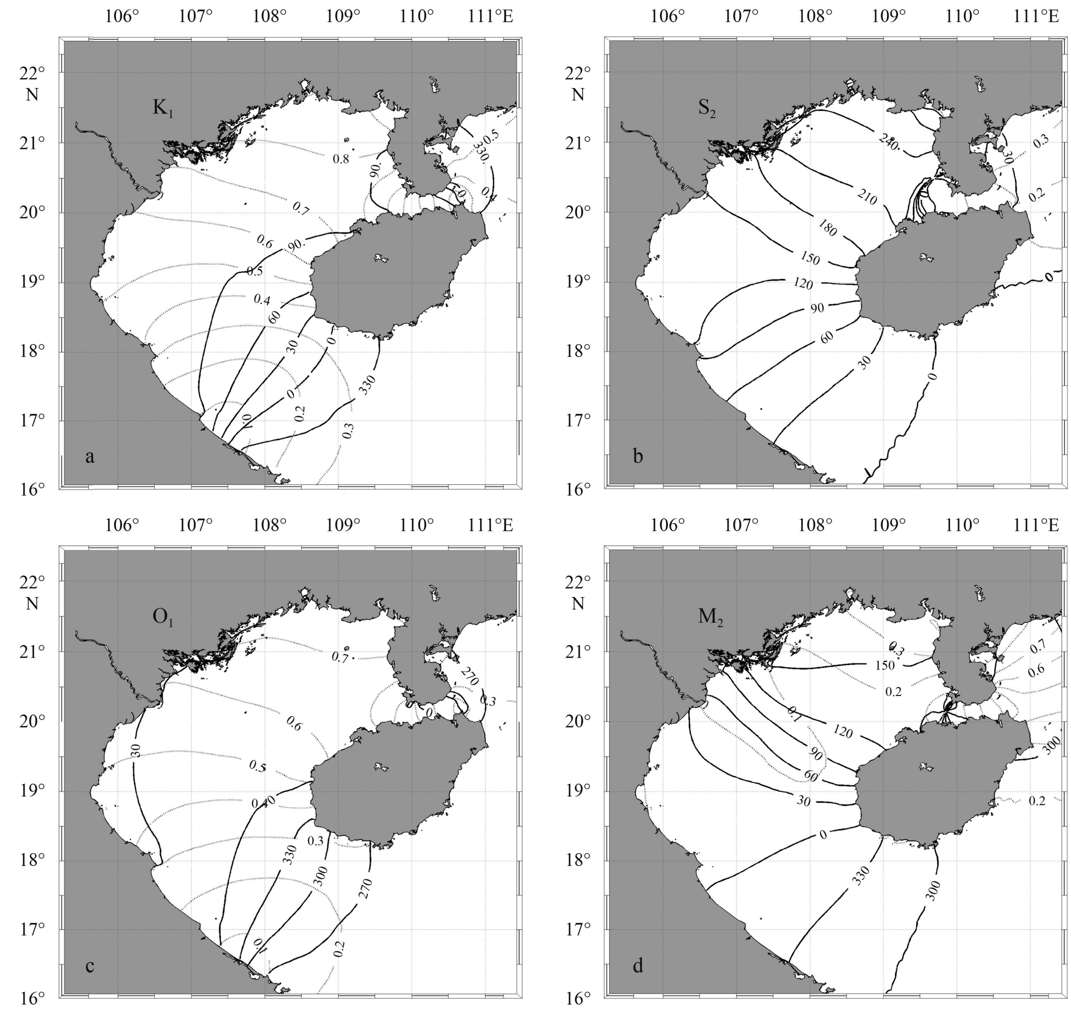

Fig. 4. The co-tidal charts of K_1, O_1, S_2 and M_2 produced by the model in the Beibu Gulf. The solid lines show co-phases (°) and the dashed lines show co-amplitudes (m).

Case 1. The modeling results of co-tidal charts of K_1, O_1, M_2 and S_2 are displayed in Fig. 4. The model results show that there is a degenerated amphidromic system for both O_1 and K_1 at the mouth of the Beibu Gulf close to the Vietnam coast, in fair agreement with the results in Fang et al. (1999) and Chen et al. (2009). Both the co-phases of K_1 and O_1 rotate anti-clockwise. The amplitudes of K_1 and O_1 range similarly from ~0.1 m at the mouth of the gulf to over 0.8 m at the head of the gulf.

The amplitude of S_2 is smaller than 0.1 m in the gulf, while the phase of S_2 changes from 0° to 240°. The amplitude of M_2 ranges from ~0.1 m to ~0.4 m in the gulf. The phase of M_2 ranges from 330° to 150°. These results are basically consistent with those found by Fang et al. (1999) and Chen et al. (2009). The diurnal components grow significantly owing to the resonance with the inherent frequency in the gulf (Chen et al., 2009). The amplitude of M_2 and S_2 are smaller than both K_1 and O_1, thus, diurnal tides dominate the gulf (Gao et al., 2013).

To understand the tidal residual current in the Beibu Gulf, we calculated the depth and time averaged velocity in Case 1 (Fig. 5a). The result demonstrates that there is a large cyclonic circulation in the north of the gulf, which is comparable to the results of Zhao et al. (2010), Zu (2005) and Minh et al. (2014). There exist some gyres resulting from the interacting of the southwestward current in the middle of the gulf and the northeastward current along the coast of Vietnam. The magnitude of the residual current is smaller than 0.05 m/s in most part of the Beibu Gulf. Two areas with relatively strong circulation are discovered in the Qiongzhou Strait and southwest of the Hainan Island. We enlarge the zone in the Qiongzhou Strait (Fig. 5b) to constrain the pattern of residual current. The tidal residual current turns out mainly westward in the Qiongzhou Strait. However, there is an obvious difference between the south and north coast of the strait. The residual current is westward on the north coast and eastward on the south coast owing to the tidal rectification (Loder, 1980; Chen and Beardsley, 1995). There are several anti-cyclonic or cyclonic eddies along the south and north coasts of the strait. The mechanism of gyre is consistent with that found by Neill (2008), Yang and Wang (2013). The strongest residual current in the strait is ~0.3 m/s. These results are consistent with Shi et al. (2002), Chen et al. (2009) and Minh et al. (2014).

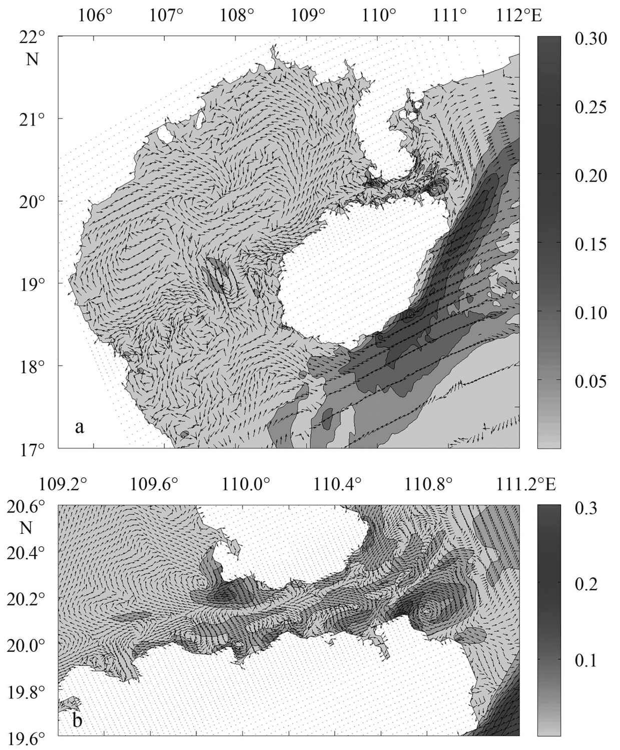

Fig. 5. The tidal residual current in the Beibu Gulf. The arrow symbol shows the direction of current and the gray bar shows the magnitude of current (m/s).

3.1.2 *The wind-driven current in winter and summer*

In Case 2, we calculated the wind-driven current in January and July, respectively. The result illustrates that there is a cyclonic circulation in winter and anti-cyclonic one in summer (Fig. 6). The wind is mainly southwestern in summer and northeastern in winter, and it is relatively strong in winter (Chen et al., 2009). In winter (Fig. 6a), the northeastern wind generates a westward flow in the Qiongzhou Strait. The flow divides into two branches at the west mouth of the strait: one flowing northwest along the coast and subsequently turning southwest along the coast of Vietnam, the other flowing southwest along the west coast of Hainan Island. One current enters the gulf along the south coast of Hainan Island from the gulf mouth and joins with the southwest current from the west coast of Hainan Island at approximately 19°N. The combined current turns west until the coast of Vietnam at about 20°N. The current then turns southeast along the coast of Viet-

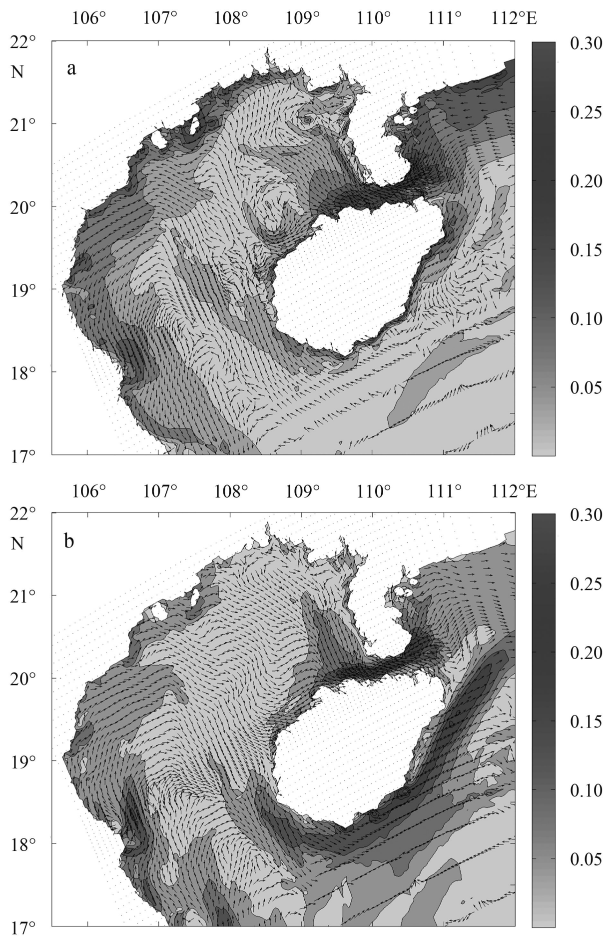

Fig. 6. The wind-driven monthly and vertically averaged current in January (a) and July (b). The arrow symbol shows the direction of current and the gray bar shows the magnitude of current (m/s).

nam, and flow out of the gulf. In summer (Fig. 6b), the southwestern wind generates a northward flow near the coast of Vietnam. The northward flow separates into two branches at about 20°N, with one turning eastward till the west coast of Hainan Island, and the other continuously flowing northward along the coast before turning eastward and entering the Qiongzhou Strait. The current along the west coast of Hainan separates into two branches at approximately 19°N, with one flowing northeastward and entering the Qiongzhou Strait and the other turning southeastward to flowing out of the gulf. The resulting vertically averaged current indicated an anti-cyclonic circulation in the Beibu Gulf, in consistence with Ding et al. (2013).

3.1.3 *The circulation driven by tide and wind*

In Case 3, we obtained the residual currents in January and July, which represents the circulation in winter and summer, respectively. The buoyancy-driven flow by salinity and temperature gradient in terms of the vertically averaged flow is considered negligible (Ding et al., 2013). The depth and temporally averaged velocity in winter (Fig. 7a) illustrate a large cyclonic circulation in the Beibu Gulf. At the mouth of the gulf, a current flows into the gulf along the south coast of Hainan Island and flows out along Vietnam coast in winter. The currents form an anti-cyclonic circulation in the northeastern Gulf. The current moves westwards in the Qiongzhou Strait (Fig. 7a) before separating into two branches. One of the branches traverses the gulf from the Qiongzhou Strait to Cape Hoanh Son Quan (Fig. 1) along the coast, while the other flows towards the southwest along the west coast of Hainan Island. These two currents from south coast and west coast of Hainan Island conjoint on 19°N. The intensity of the current is relatively strong on the coast of Vietnam and in the Qiongzhou Strait, in correspondence to the findings by Gao et al. (2013). The depth and temporally averaged current in summer are shown in Fig. 7b. A current enters the gulf and flows northwest along the south coast of Vietnam and flows out of the south coast of Hainan Island in summer. There also exists a large cyclonic circulation in the Beibu Gulf. The current is northward along the coast of Vietnam and turns eastward close to 20.5°N. There is a northward current at the mouth of the gulf which comes from the SCS. However, the current divides into two branches on the west coast of Hainan Island. One of the branches flows northward along the coast of Hainan Island and subsequently to the west side of the Qiongzhou Strait, where this current is further bifurcated into two branches. One flows eastward into the strait, while the other flows northwestwards along the coast of Leizhou Peninsula. The northwestward branch turns westward along the coast until joining the eastward current at 20.5°N.

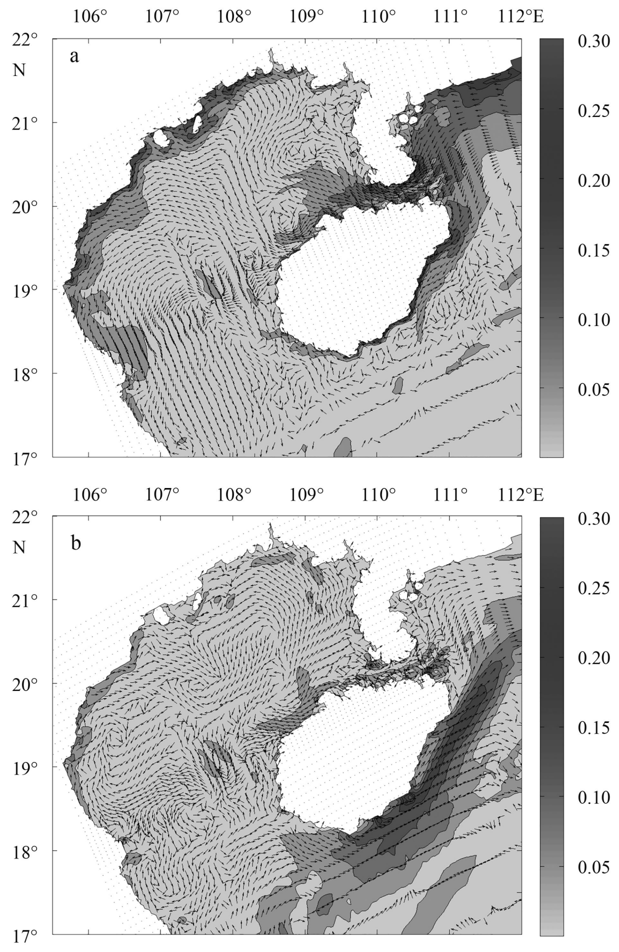

Fig. 7. The monthly and vertically averaged circulation in January (a) and July (b). The arrow symbol shows the direction of current and the gray bar shows the magnitude of current (m/s).

In summary, the modeling results reveal that the circulation induced by tide and wind is cyclonic in both winter and summer in the gulf. The wind-driven circulations are stronger in winter than those in summer. The current in the Qiongzhou Strait moves from east to west in winter whereas reversely in summer. Compared with the tide-induced residual current (Fig. 5) and the wind-driven current (Fig. 6), we conclude that the wind driven circulation is the strongest in winter. The circulation is cyclonic in summer as a likely result of the tidal residual current rather than the inflow from the Qiongzhou Strait. Further evidence is needed to explore the mechanism for summer circulation.

3.2 *The suspended sediment concentrations in winter and summer*

We calculated the depth and time averaged suspended sediment concentration in Case 4. The results (Figs 8a and b) indicate a low sediment concentration in most part of the Beibu Gulf and a negligible sediment concentration along the coast of Vietnam. The sediment concentration is discovered to become higher in the Qiongzhou Strait, west of the Hainan Island, and the Leizhou Peninsula. River sediment in the simulation is confined close to the river mouths, with only a small fraction being able to be transported to the gulf. The sediment transport flux turns out the largest in the Qiongzhou Strait owing to the strengthened current (Fig. 7). The sediment concentration is ~0.02–0.08 kg/m^3 in the Qiongzhou Strait, which is comparable to the magnitude calculated by Li and Ke (2000). The sediment concentration is found higher in winter than in summer, presumably due to the stronger circulation in winter. The spatial distribution of the sediment concentration is consistent with the monthly averaged surface turbidity, as obtained from remote sensing data (Huang et al., 2008). The results (Figs 8c and d) in Case 3 are similar to that those in Case 4. It should be noted that the sediment is transported westwards in winter in the Qiongzhou Strait and reversely in summer. In Case 2, the sediment concentration is very small (not shown). It is found that high sediment concentration (Fig. 8e) is closely related to high mean tidal kinetic energy (Hu et al., 2003) in the Beibu Gulf in Case 1. Compared the results in Figs 8a, b and e, we conclude that the tidal forcing dominates the sediment transport in the Beibu Gulf.

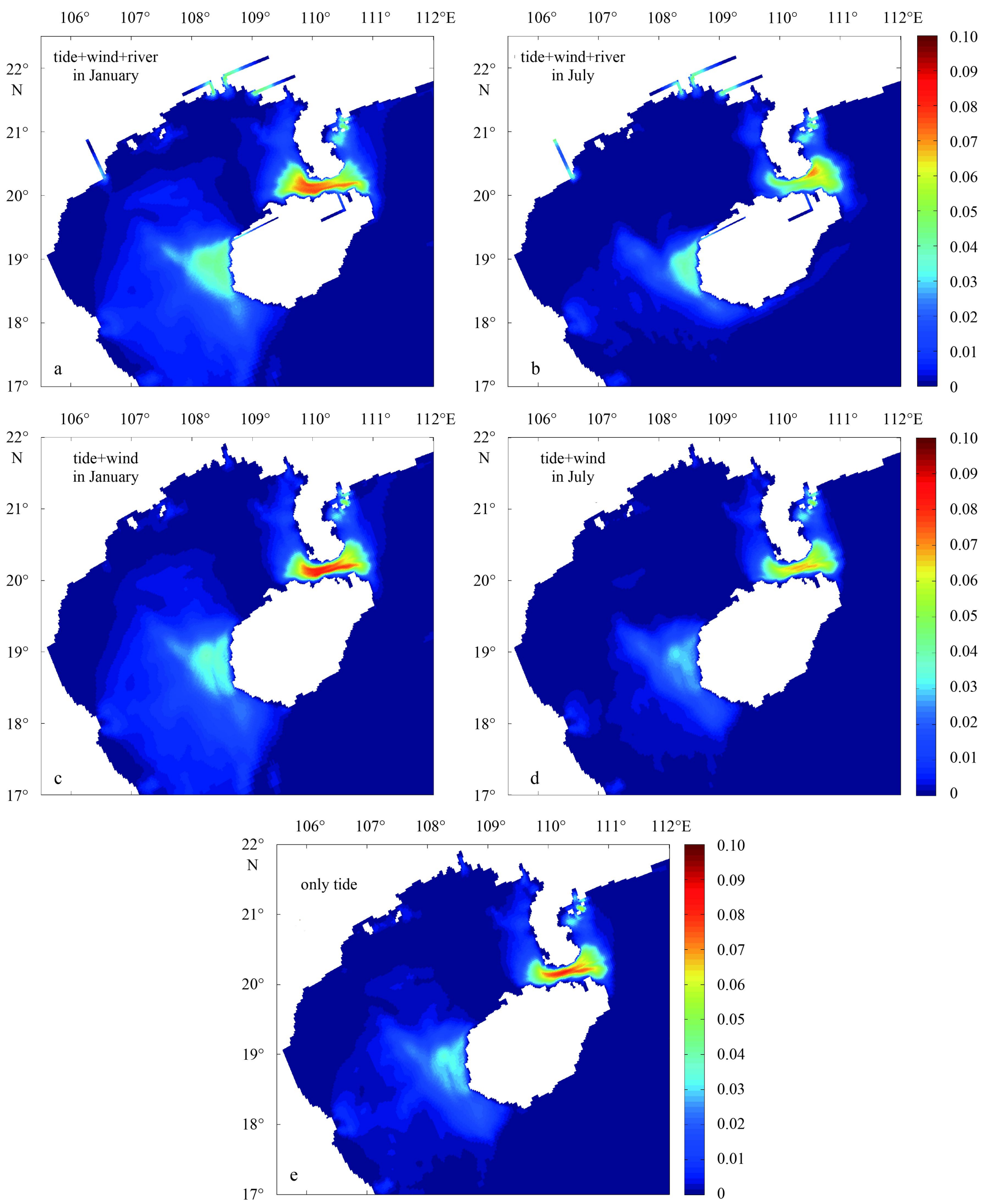

Fig. 8. Depth and time averaged sediment concentration. The color bars show the magnitude of concentration (kg/m^3).

3.3 *The sediment transport and deposit in Beibu Gulf*

The net erosion and deposition in the Beibu Gulf over a year (Case 4) is illustrated in Fig. 9a, in which the morphological factor took a value of 1.0. The erosion and deposition is insignificant in most of the gulf overall. High deposition rates occur near the western Hainan Island, the Qiongzhou Strait and the mouth of rivers. Erosion and deposition occurs alternatively in the west of Hainan Island, resulting in a stripped pattern of sedimentation/erosion. The modeling results indicate intense erosion or deposition near the capes of the Hainan Island coast and intense sedimentation at the mouth of the Qiongzhou Strait radically along with erosion on the sea bed in the strait. The sediment derived from rivers are not transported vary far; it is deposited near the river mouths.

In order to compare to the results in Case 4, the morphological factor was enhanced to 10 for Cases 1, 2 and 3. When the model is forced by only tide (Case 1), as shown in Fig. 9b, the modeling erosion and deposition are significant at the west of Hainan Island and the Qiongzhou Strait in consistence with Case 4. In Case 3 (Figs 9c and d), more sediment is exported out of the Qiongzhou Strait in winter and transported into the strait in summer, implying that the wind-driven current dominates the sediment transport in the Qiongzhou Strait. In order to validate the hypothesis, we exhibit the sea bed changes (Figs 9e and f) that are dependent on the wind alone (Case 2). The result shows that the wind-driven current only impact sediment transport in the Qiongzhou Strait, and transport sediment westward in winter and reverse in summer. Comparing these results with Figs 9a and b, the sediment transport and deposition/erosion patterns seem to be related to tidal forcing, rather than to wind on the southwestern coast of Hainan Island.

Generally, the simulated result demonstrates that the tide in-

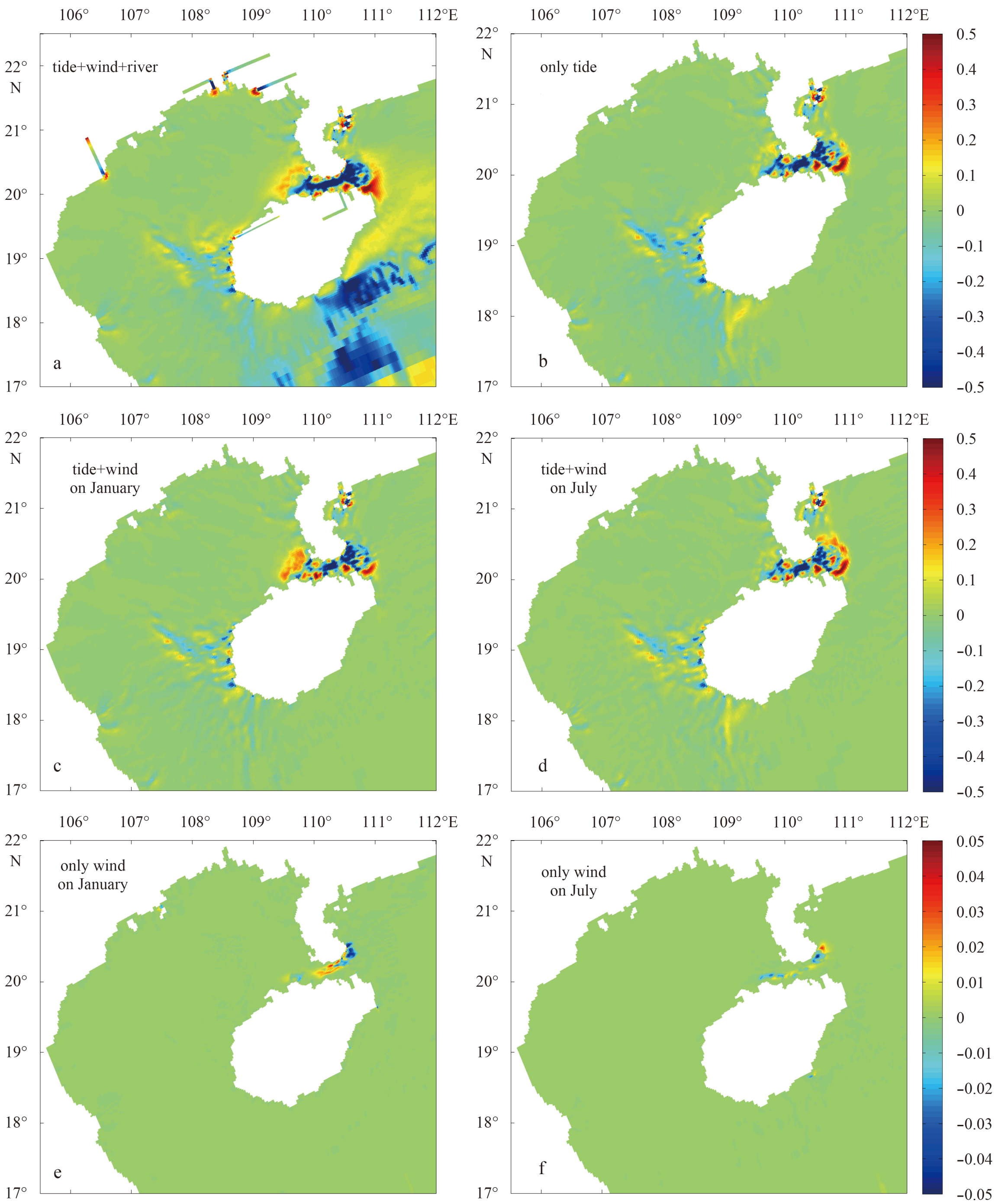

Fig. 9. Net erosion (blue) and deposition (red) calculated by mode (kg/m²).

duced bottom resuspension is the predominate the sediment transport in the Beibu Gulf, whereas the runoff and ambient current are secondary impacting factors.

3.4 *The grain size trend analysis*

We repeated surficial sediment sampling in the Beibu Gulf (Fig. 1): one is from 908-01-ST09 summer cruise (Ma et al., 2010) in 2006, and the other is from Guangzhou Marine Geological Survey in 2009. We used the grain size trend analysis model (Gao et al., 1991) to obtain the trends of sediment transport in the Beibu Gulf. Ma et al. (2010) assumed that the range for sorting coefficient is meaningful physically and that the semivariance range with respect to sorting can match currents and sediment transport information well. Accordingly, we used the semivariance range with respect to sorting as the characteristic distance. When only the surface samples in 2009 was adopted (Fig. 10a), a distinct converging center (a1) of sediment transport is revealed at the west coast of the Hainan Island. When using the two collected surface samples to analyze the trends of sediment transport in the gulf, we found two converging centers (b1 and b2) of sediment transport in the Beibu Gulf (Fig. 10b). The direction of net sediment transport is westward at the west entrance of the Qiongzhou Strait. The patterns are consistent with residual currents in the strait. The resultant estimation of net sediment trans-

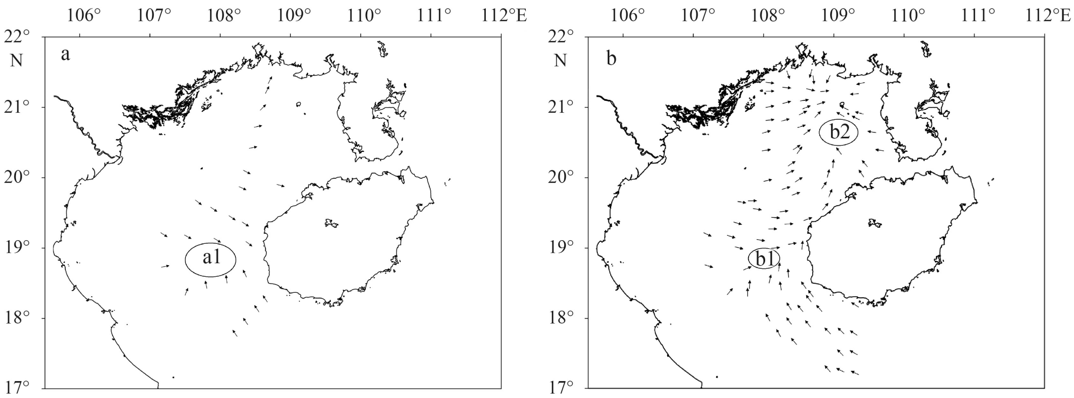

Fig. 10. The net sediment transport patterns after applying grain size trend analysis model. a. Grain size trend analysis only used the samples in 2009 and b. grain size trend analysis used the samples in 2006 and 2009.

port is consistent with the hydrodynamic properties in the Beibu Gulf.

4 Discussion

Despite the numerous studies that have been conducted about the circulation pattern in the gulf, there is still no consensus whether the circulation is cyclonic or anti-cyclonic in summer and the mechanism of the cyclonic circulation in summer remains unclear. Three prospective processes have been proposed to explain the occurrence of the cyclonic circulation in summer: the prevailing wind in summer (Manh and Yanagi, 2000; Gao et al., 2013), the density-effect (Xia et al., 2001; Zu, 2005) and the current in the Qiongzhou Strait (Wu et al., 2008; Ding et al., 2013). The modeling result supports that the cyclonic circulation in summer mainly results from the tidal residual current. Ding et al. (2013) proposed that the tidal current is more energetic in summer than in winter. Two controversial opinions exist about the moving direction of currents in the Qiongzhou Strait: one is a westward current for the whole year (Shi et al., 2002; Chen et al., 2009; Ding et al., 2013), the other supports a current that moves eastward in summer whereas westward during the rest of the year (Zhang et al., 2009; Gao et al., 2013). Our modeling result shows that the current in the Qiongzhou Strait is westward in winter and reversed in summer, in agreement with the second one as proposed by Zhang et al. (2009) and Gao et al. (2013). The model simulation was limited by the use of monthly mean wind and thus cannot account for the short-term variability of wind-driven current in the Qiongzhou Strait. Wind field data of High resolution will be needed to simulate the short-term variability in the future.

The modeling result demonstrates that there is a distinct area suffering erosion and deposition of high intensity in the west coast of the Hainan Island, which was verified by the grain size trend analysis (Fig. 10a). One explanation is that the large tidal kinetic energy induces a strong bottom resuspension. However, the modeling result does not exhibit a converging center at the west entrance of the Qiongzhou Strait (Fig. 10b). The monthly averaged surface turbidity (Huang et al., 2008) implies that there were no sediment concentration maxima at the west entrance of the Qiongzhou Strait. One explanation is that the sediment transport rate is small in the area and there is not sufficient time to form significant erosion and deposition during the study period.

Storm events may generate more sediment transport than that under normal conditions. The modeling result reveals no high sediment concentration along the coast of Vietnam, which is likely ascribed to the neglect of wave effect. Actually, the simplified utilization of one single sediment class in our model could be too rough to derive a perfect simulation of the real situations and further improvement is urgently needed in the future.

5 Conclusions

We employed the State-of-the-Art model (ROMS) to simulate the hydrodynamics and sediment transport in the Beibu Gulf. The simulation results indicate that the circulation induced by tide and wind is cyclonic in both winter and summer in the gulf. The wind-driven circulations are stronger in winter than those in summer. The current in the Qiongzhou Strait moves from east to west in winter, and reversed in summer. The cyclonic circulation in summer mainly results from the tidal residual current instead of the inflow from the Qiongzhou Strait. The current in the Qiongzhou Strait is affected significantly by the monsoon winds.

Erosion and deposition over a year is insignificant in most part of the gulf. The higher deposition is identified close the west of Hainan Island, the Qiongzhou Strait and the mouth of rivers. The modeling results demonstrate that the sediment is deposited in the mouth of the Qiongzhou Strait radially, while erosion undergoes in the sea bed of the strait. The sediment from rivers does not transport for a long distance before settling close to the river mouths.

The net sediment transport trend derived from the sediment grain size analysis demonstrates the existence of a distinct converging center at the west coast of Hainan Island. The sediment is transported westwards at the west entrance of the Qiongzhou Strait.

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