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Preliminary Analysis of Surface Circulation off the Minjiang River Estuary near the Southwestern East China Sea

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Abstract. Better understanding the surface circulation in the marine environment is pertinent to the preparedness of pollution response and maritime safety. In the spring of 2012, two GPS surface drifters were deployed off the Minjiang River Estuary to study the surface circulation near the southwestern East China Sea. One drifter followed the China Coastal Current and the other one joined the Taiwan Warm Current. Classical harmonic analysis technique was employed to analyse the current velocities derived from the trajectories of these two drifters. M2 tidal component is dominant in the tidal current spectrum. The residual currents obtained from these 2 drifters agree very well with the previous studies.

1. Introduction

Hypoxia in the East China Sea (ECS) has been referred to as the one of the largest low-oxygen areas in the world [1]. The hypoxia is aggravated by the increasing eutrophication, the frequent algal blooms and global warming in coastal and estuarine regions. The frequent hypoxia incidents and the expanding of its distribution have seriously damaged to the ocean organisms, even the whole ecosystem. In addition to the Yangtze River, the coastal waters near the Minjiang River have been faced by huge stress from anthropogenic activities and population growth along the Fujian coast [2]. Although the priority work is to cut off the land-based sources of ocean pollution [3], a better understanding of the surface circulation will be beneficial to proper response to the pollution accidents if happened.

It has long been recognized that the cold China Coastal Current (CCC) or ZheMin Coastal Current encountered the Taiwan Warm Current (TWC) in the western Taiwan Strait [4]-[6]. Several reports involved with the circulation and tidal residual currents near the Zhejiang-Fujian coast in the western ECS have been published [7]-[10]. However, these studies focused mostly upon the seas in the Zhejiang Province, with little emphasis in the vicinity of Fujian, especially near the seas close to the Minjiang River estuary (Figure 1). Since the oceanic region near this estuary is a traditional fishing ground for both Chinese and Taiwanese fishermen, the knowledge of surface circulation is pertinent to the ecosystem and the maritime safety.

The primary objective of this article is to gain some insight into the sea surface circulation near the Minjiang River estuary by employing the current velocities derived from the trajectories of satellite-tracked drifters. The outline of this paper is as follows. Section 2 presents the methodology used in this study. Results and discussion are shown in the section 3, and section 4 gives the conclusion.

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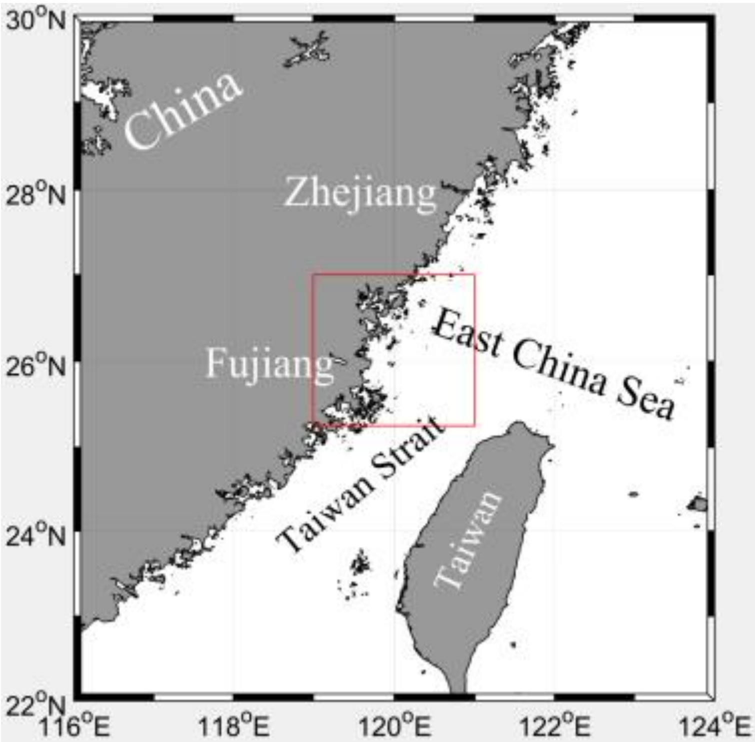


Figure 1. The map indicating the study area (red box) and the surrounding seas. It is located near the northwestern Taiwan Strait and southwestern East China Sea. The detailed topography of the study region will be shown later.

2. Methodology

2.1. GPS Surface Drifter

We need a drifter to be used in the nearshore environment with time scales of several days as suggested by Johnson *et al.* [11]. A compact, low-cost GPS drifter was designed as in Figure 2. It is a plastic tube with 9-cm diameter and 87-cm of length with batteries and one GPS receiver inside, connected with a 15-m wire with 3 holey-socks at 12-m, 13-m, and 14-m respectively, and with a 1.5-kg anchor at the end of the wire. When deployed into the sea, 36-cm of the tube is above the sea surface and 41-cm in the water. The temporal resolution of the received GPS signals is set to be 1-min. As pointed out by Zeng *et al.* [9] that the boundary between the CCC and TWC is located at the 50-m isobath off the China coast. Hence, we deployed 2 drifters in May 24 and June 9 of 2012 respectively in the west and east of the 50-m isobath. The one deployed in May is denoted by ‘M’ and the other one denoted by ‘J’. The duration of drifter M is 05/24-30, and J is 06/6-20. However, from 07:00 of June 11 to 15:00 of June 12, GPS signals of J were not received for unknown reasons. The data before 15:00 of June 12 were not further analysed except showing it trajectory.

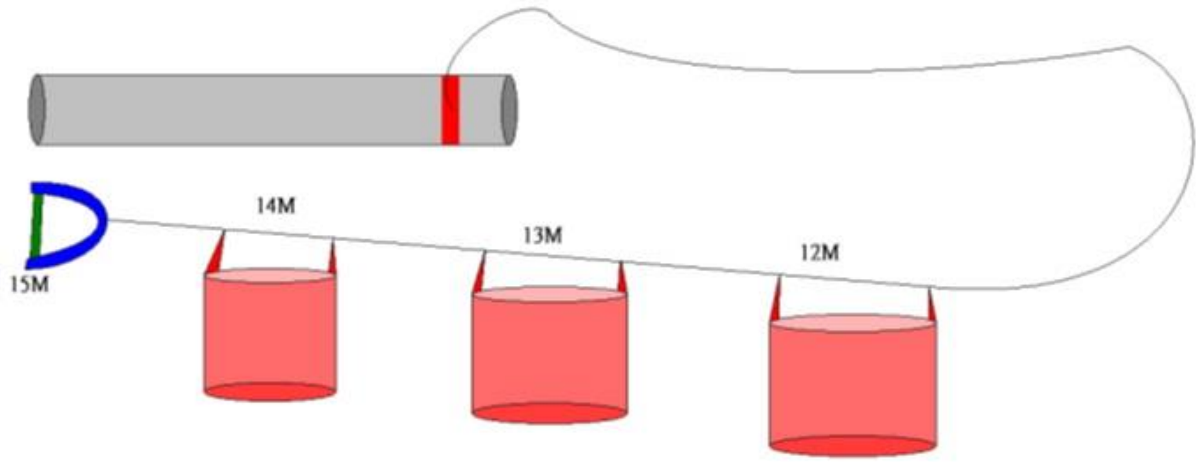


Figure 2. The configuration of the surface drifter employed in this study.

2.2. Method of Analysis

Wang *et al.* [12] analyzed more than 10 cruises of shipboard ADCP observations in the Taiwan Strait and concluded the current field in the strait is dominant by the M2 semidiurnal tidal current. As a result, the first step of analysis here is to assess the tidal contribution to the surface circulation. Poulain [13] recently studied the tidal currents measured by surface drifters in the Adriatic Sea. The harmonic analysis technique was applied to the drifter velocities using the least-squares method and the T_Tide MATLAB package [14] for comparison purpose. The results obtained from the 2 methods agree very well so that we decide to adopt the T_Tide package to analyse our drifter velocities. This software performs classical harmonic analysis using as many as 68 constituents, accounts for unresolved constituents using nodal corrections, and computes the Greenwich phase with nodal corrections applied to amplitude and phase relative to center time. It also estimates confidence intervals for the analysed components.

3. Results and Discussion

Figure 3 illustrates the trajectories of these 2 drifters. M was deployed west of the 50-m isobath, flowing southward with counter-clockwise traveling northward in the beginning and then turning toward southwest. However, J, deployed southeast of M, was moving northward with similar counter-clockwise pattern as M. When it approached the Dongyin island, it was blocked and circulated around the island and then also turned to the southwest.

Figures 4 and 5 present the original, tidal and residual speed of E-W and N-S components of current velocities derived from the trajectories of these 2 drifters respectively. The east-west tidal current is about 0.4 m/s, about twice of the north-south component. After deducting the tidal contributions, the residual currents were very weak and variable for both drifters. In sum, the mean residual current of M drifter is about 0.17 m/s, and that of J drifter is about 0.05 m/s. Compared with the observation work done by Zeng *et al.* [9], the mean current velocity of CCC is 0.24 m/s which is consistent with our measurement because their observations were conducted during winter, the northeast monsoon is stronger then and thus stronger residual current. For TWC, the mean current velocities obtained by Zeng *et al.* [9] are 0.03~0.09 m/s, which also agrees very well with the value of 0.05 m/s derived from the J drifter.

The tidal constituents of current velocity obtained from the J drifter are shown in Figure 6. As indicated in the figure, M2 constituent is dominant for both components, which is consistent with the work by Wang *et al.* [12]. However, the magnitude of tidal current in our study region seems to be smaller than those in the Taiwan Strait. Since the results of M drifter are similar and for the sake of brevity, we do not present the tidal information of M drifter here.

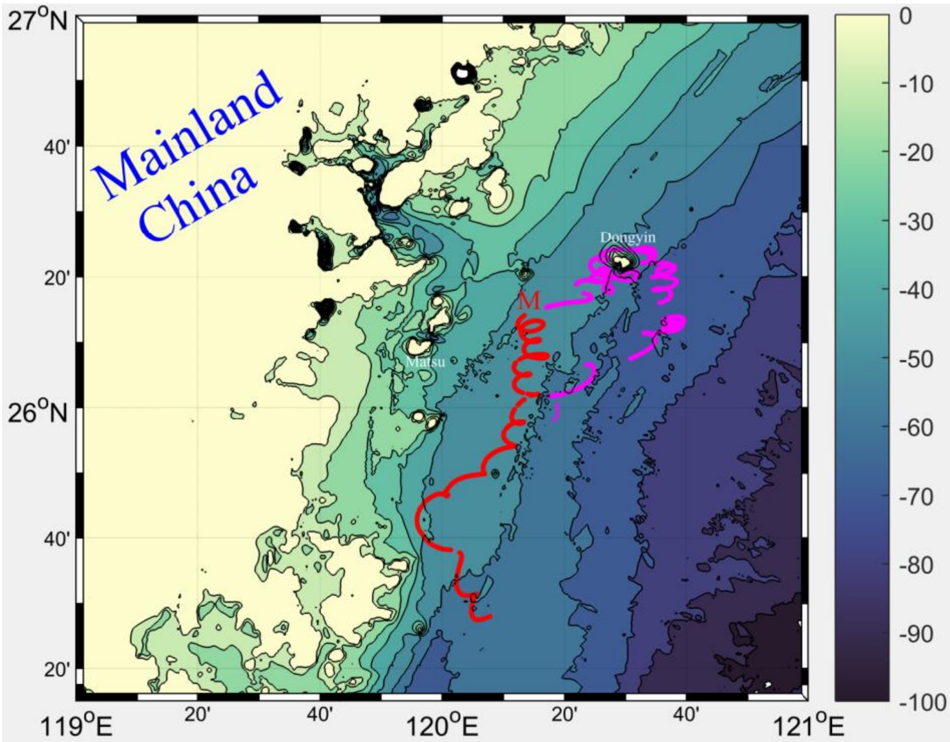
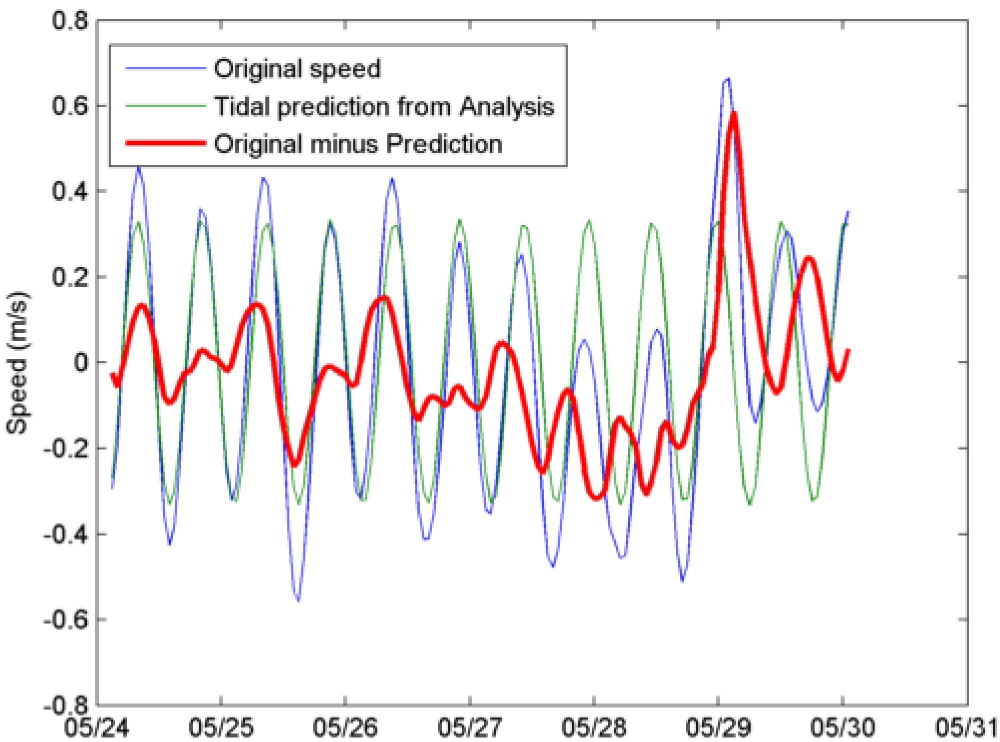


Figure 3. The trajectories of the two drifters. The track of the M is represented by red, and J is denoted by pink. The locations of the letters are the locations of deployment. The color bar at the right indicates the depth (in meters) associated with the colors in the image.



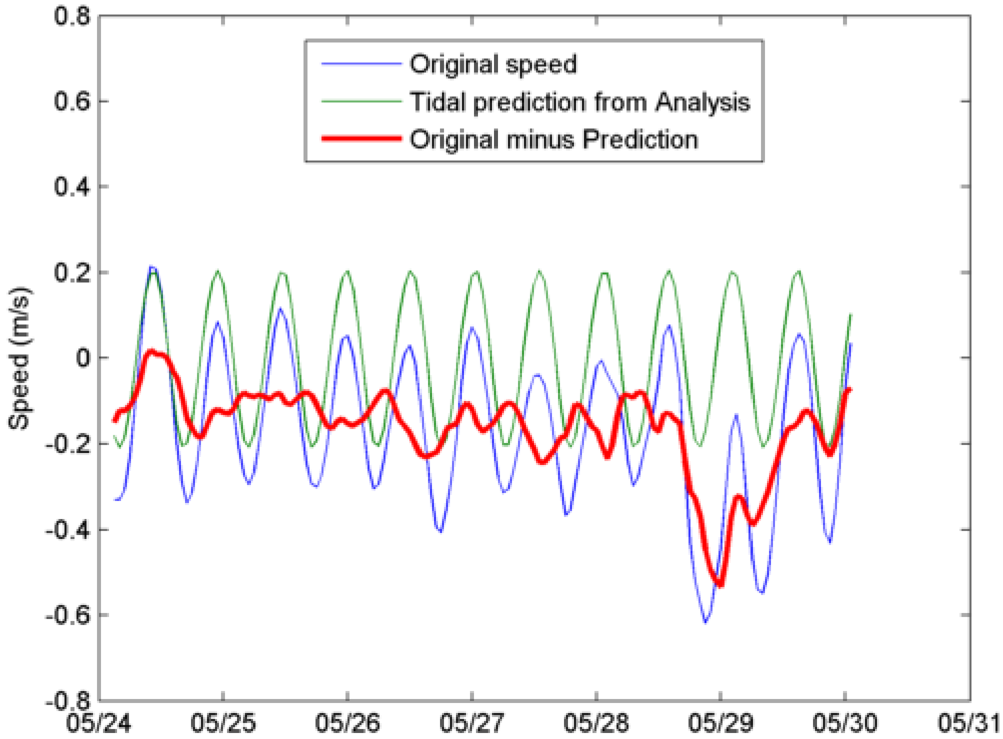
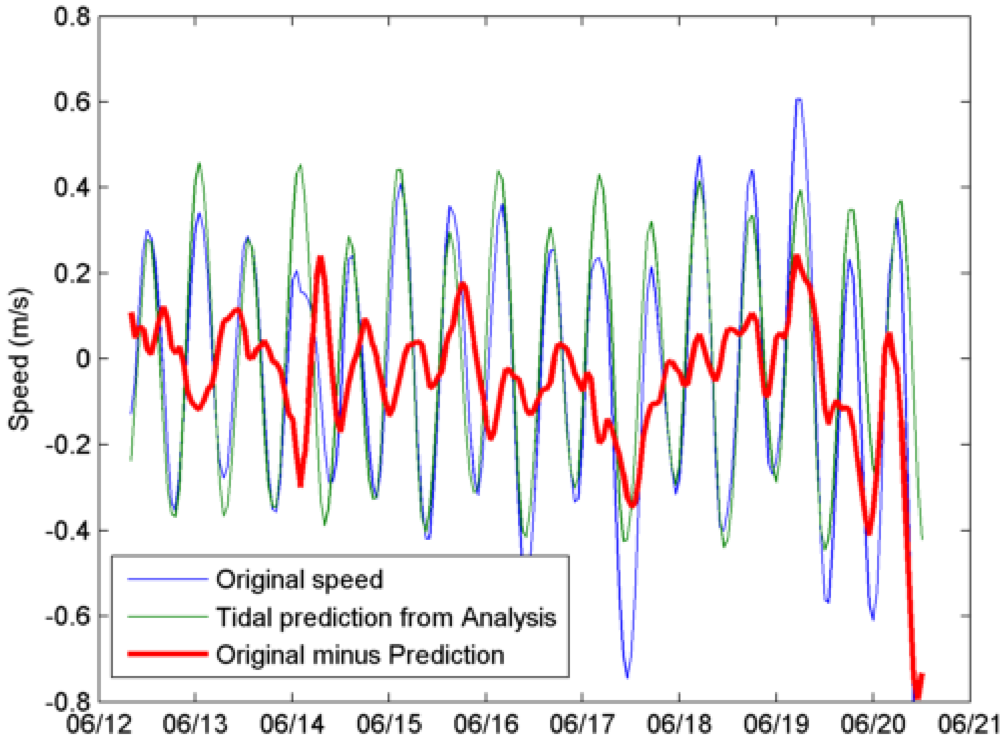


Figure 4. The results of harmonic analysis of current velocities derived from the M drifter. The original velocities are denoted by blue, the tidal currents from harmonic analysis are indicated by green, and the residual currents are red. The E-W component is shown in the upper panel, and the lower panel presents the N-S component.



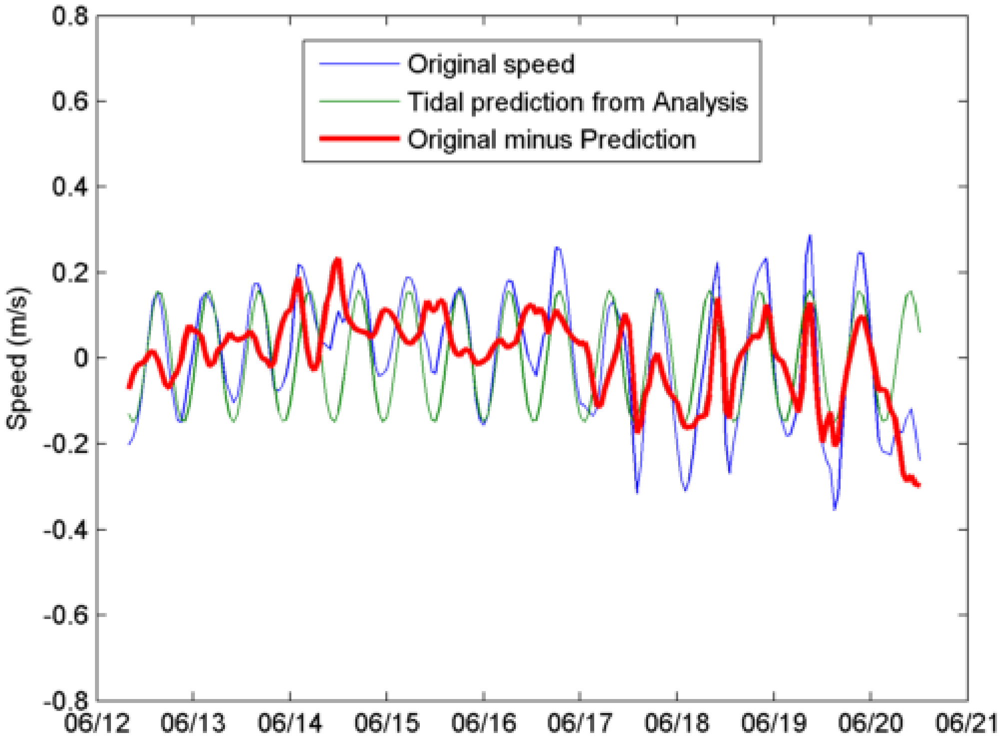
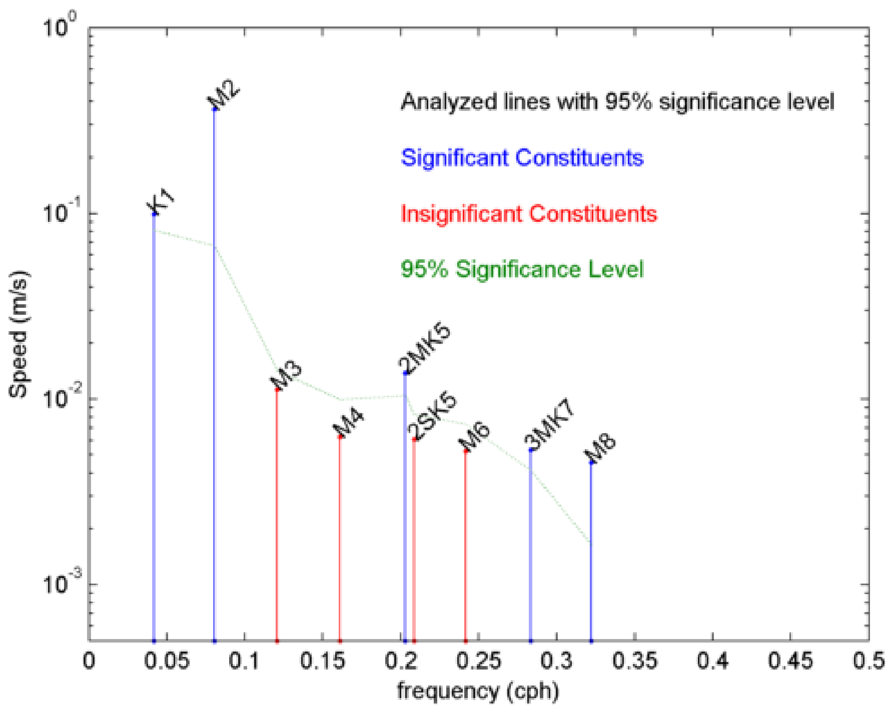


Figure 5. The same as Figure 3, but for the J drifter.



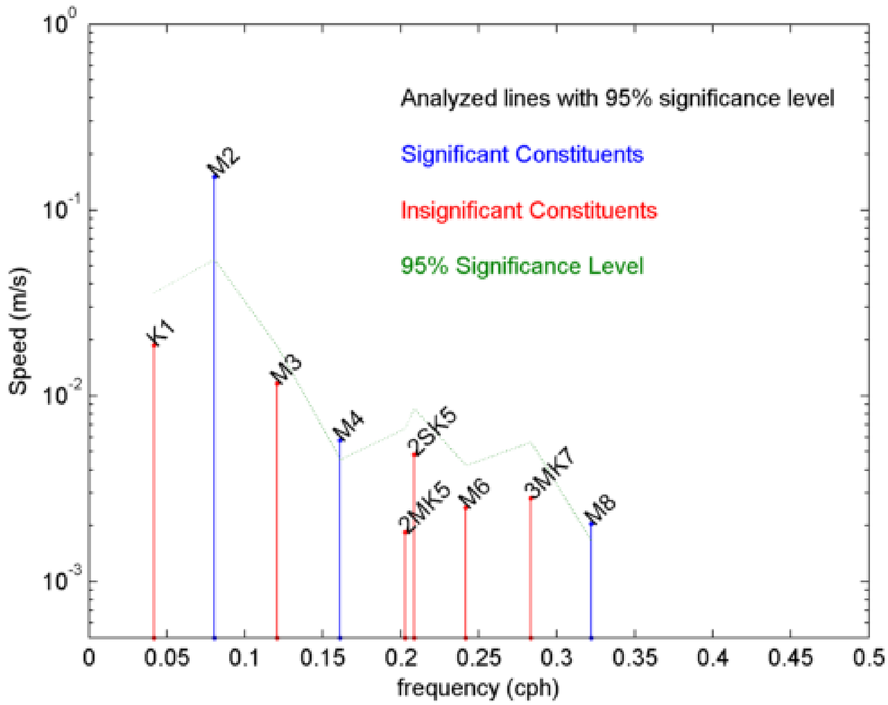


Figure 6. The tidal constituents obtained from harmonic analysis of current velocities derived from the J drifter. The upper panel is for the E-W component of the velocity, and the N-S component is shown in the lower panel.

4. Conclusion

Preliminary analysis of the surface circulation near the MinJiang River estuary in the spring of 2012 confirm the boundary of CCC and TWC to be located near the 50-m isobath. The current velocities derived from the 2 drifters deployed respectively reveal the characteristics of CCC and TWC near this region. The tidal current field is dominant by the M2 tidal constituent. Mean (residual) current of CCC flowed southward and TWC northward with weak and variable features.

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Acknowledgments

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