The analysis of High Frequency (HF) Radar data for the investigation of surface residual current in the upper Gulf of Thailand

Siraporn Tong-u-dom[1], Anukul Buranapratheprat[1] and Akihiko Morimoto[2]
[1]Department of Aquatic Science, Faculty of Science, Burapha University, Thailand
[2]Center for Marine Environmental Studies (CMES), Ehime University, Japan

Introduction

The current data from High Frequency (HF) Radar system installed on the coastline are derived from the signal reflected from the sea surface. The resulted data are composed of several factors, such as tide, wind, discharge and sea level differences. The measured instantaneous current at any given time needs to be filtered to obtain the residual current, which is very useful for tracking changes in marine environment such as seasonal circulation and material transport. The Radar system responds to water movement near the sea surface which is mostly influenced by wind in the case of residual current. Therefore, it is useful for tracking material transport such as oil slick and floating plankton. Thailand by GISTDA has installed HF Radar systems in some coastal hot spots including the upper Gulf of Thailand (UGoT) since 2012. Because UGoT is important in the sense that there is a problem with eutrophication and severe hypoxia, the information of residual circulation becomes crucial to understand those phenomena. We therefore investigate the seasonal variations of residual surface circulation in UGoT based on HF Radar data.

Procedure

In this study, we analyses residual surface current in UGoT (Figure 1) form hourly surface current data in 2014 detected by HF Radar. All the data are officially provided by GISTDA, Thailand. The coverage area of the data is almost entire UGoT with spatial resolution of 2 km in both latitudinal and longitudinal spacing. Hourly data have been pre-processed to remove poor quality data. It is based on the quality flag that come with raw data, standard deviation and covariation values of u and v current components. High quality data with Flag 0, standard deviation of u and v less than 4 and 6, respectively, and covariance between both components less than 8 are selected for further analysis. Harmonic analysis based on leasedsquare method written in FORTRAN code is applied to extract amplitudes and phases of 8 tidal constituents namely M2, S2, O1, K1, Q1, P1, K2 and N2. Tidal current is simulated from extracted tidal components and then subtracted from hourly Radar data to get the residual value of circulation. Wind data from European Centre for Medium-Range Weather Forecasts (ECMWF) are used for the discussion about seasonal patterns of the surface current.

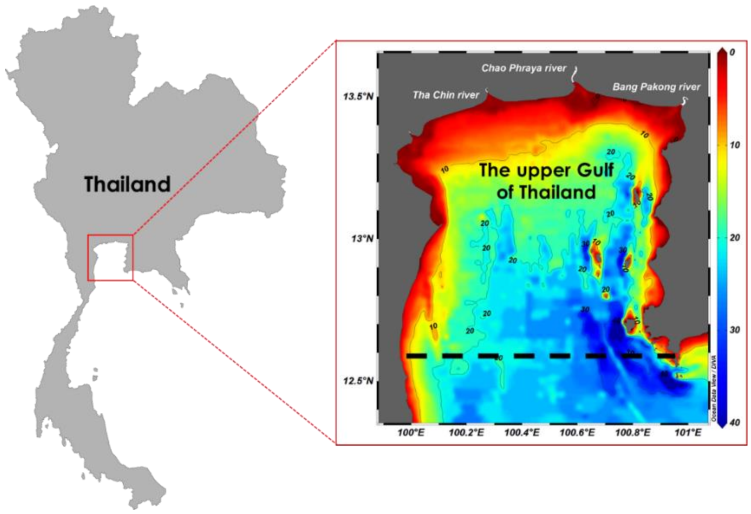

Figure 1 The upper Gulf of Thailand showing water depth in meter.

Table 1 Amplitudes of u and v current components, based on harmonic analysis, of 8 tidal constituents averaged over the study area

Tidal Constituents	u - Current Amp (cm)	v - Current Amp (cm)
M2	4.03	16.88
S2	2.18	8.88
O1	2.22	7.06
K1	3.31	12.07
Q1	0.44	1.03
P1	1.21	4.69
K2	0.85	2.78
N2	0.72	2.90

Results

The extracted 8 tidal constituent amplitudes from raw current data average over the whole study area are shown in Table 1. The resulted amplitudes suggest that current in north-south direction (v) be more dominant than that in east-west direction (u). The most influential tidal constituent in the area, considered from the tidal amplitudes, is M2 followed by K1. The ratios of diurnal to semi-diurnal components, (K1+O1)/(M2+S2), of 0.79 and 0.74 for u and v components, respectively, imply that mixed semi-diurnal tide is dominant over the area.

Residual surface current data are computed by subtracting tidal current simulated based on harmonic analysis using extracted tidal constituents from the raw HF Radar data. Monthly residual current fields are generated to investigate their seasonal variations. The current in 4 months including March, July, September and December 2014 are chosen to represented as the inter-monsoon period from the northeast to the southwest monsoon (1^{st} inter-monsoon), the southwest monsoon, the inter-monsoon period from the southwest to the northeast monsoon (2^{nd} inter-monsoon) and the northeast monsoon, respectively, shown in Figure 2. Monthly wind averaged over UGoT area, shown in Figure 3, is used to support the discussion on the monthly surface current variation.

Seasonal variations in wind and surface current are clearly seen. Their seasonal patterns change in clockwise direction. Wind and surface current direct from the south during the 1^{st} inter-monsoon (March) then change to be flowing from the southwest during the southwest monsoon (July). Current pattern in the southern part of UGoT directs eastward or in the right hand side of surface wind, which may be related to the Coriolis effect. Averaged circulation directs southeastward, and weak and complex current in most area is observed during the 2^{nd} inter-monsoon period (September) because wind direction in this season is unstable. Surface current near the Chaopraya River mouth, however, is strong which may be resulted from large river discharge that generates density driven current in this wet period. Strong southwest current over the gulf area develops during the northeast monsoon (December). Most current flows out of the gulf in this time different from other times in which most currents flow into the bay.

Comparison between overall averaged surface wind and current in Figure 3 clearly shows the relationship in their directions. Surface current bends to the east of wind direction during the southwest monsoon and to the west of wind direction during the northeast monsoon. This may be resulted from the response of surface current to the shape of the gulf. Northeastward flow during the southwest monsoon bends to the east after approaching the northern coast while southwestward flow during the northeast monsoon bends to the south after approaching the west coast. It is also noticed that surface current during the northeast monsoon is stronger than that during the southwest monsoon while current magnitude between both seasons are not much different. This is also related to the position of coastline and seasonal current direction.

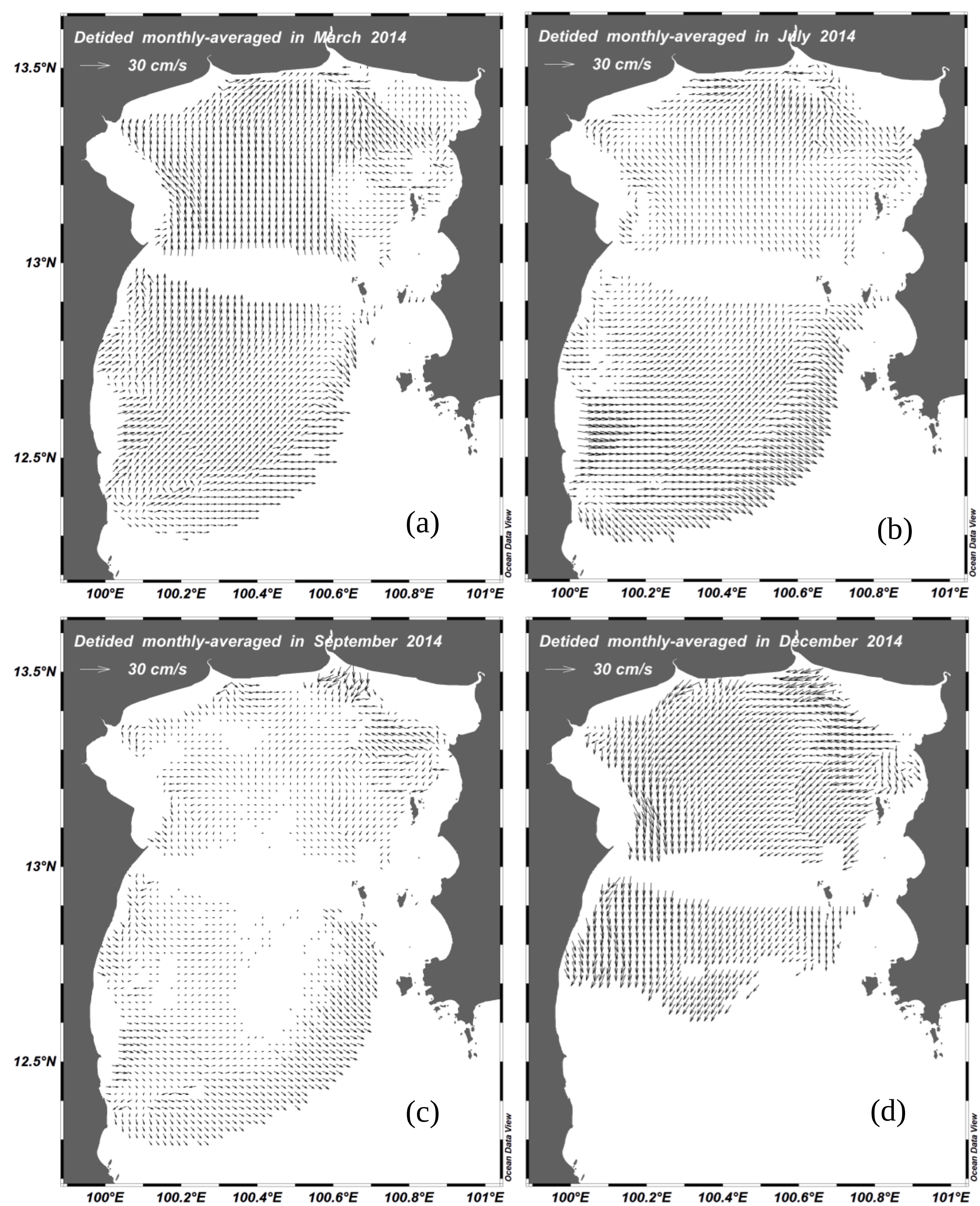

Figure 2 Monthly surface residual current derived from HF Radar data during the 1st inter-monsoon (a), the southwest monsoon (b), the 2nd inter-monsoon (c) and the northeast monsoon (d).

The current velocity will decrease as the water flows into the bay closer to the shallow water during the southwest monsoon. On the contrary, the current magnitude is high as the current flows offshore during the northeast monsoon. River discharge is not significant to the averaged velocity because its influence is high in just near the river mouths located in the northern region.

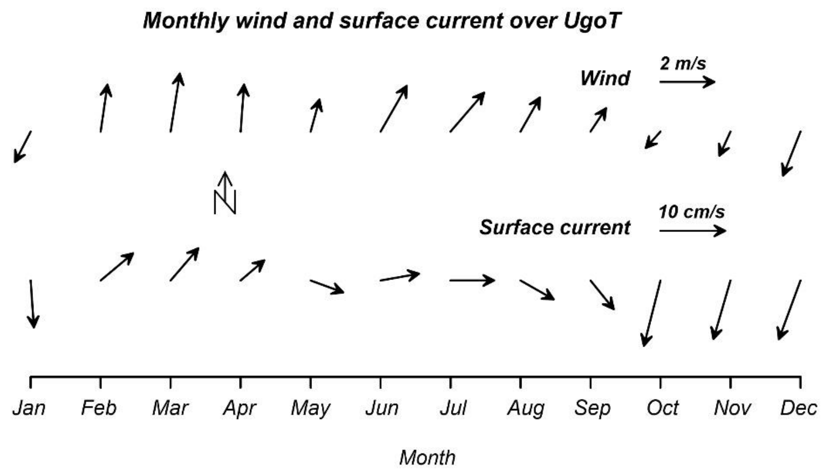

Figure 3 Monthly wind and surface current averaged over UGoT

Publication/conference presentation

Publication: It was planned to do in the near future on the title of "Seasonal variations in surface currents in the upper Gulf of Thailand revealed by High Frequency Radar"

Presentation: "Seasonal variations in surface currents in the upper Gulf of Thailand revealed by High Frequency Radar" in JSPS-CCore-RENSEA Third Joint Seminar on Coastal Ecosystems in Southeast Asia, 20–22 February 2019, Chulalongkorn University, Bangkok, Thailand

Perspectives in the future

We will clarify the patterns of the surface residual circulation in UGoT in some temporal time scales including daily, monthly and seasonal variations. By comparing with the results from numerical experiments, we will classify the influence of wind, tide and river discharge on surface circulation in each zone in UGoT. The information from the experiments will be very useful to understand the mechanism of material transport in this area.