

SOME CIRCULATION FEATURES DURING SOUTH-WEST MONSOON IN SOUTHERN VIETNAM'S WATERS

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ABSTRACT: This paper presents some circulation features during South-West (SW) monsoon in Southern Vietnam's waters. The data were collected from different projects which were carried out by the Institute of Oceanography in recent years. Study results show that during SW monsoon the current mostly flows from the south to the north by wind action, and it is the period of high Mekong river discharge. These conditions are the main causes of Mekong river water spreading to the Central Vietnam upwelling area. Measured data during August and September 2009 indicate that Mekong River water spreads up to about 80 km to 100 km offshore, inclining in the northern part of Mekong river mouth region towards the upwelling area. The extent of river water spreading is directly proportional to the Mekong river discharge and SW monsoon intensity. This phenomenon is significant feature for assessment of the ecological-environmental effects on the upwelling area.

Keywords: Current, Mekong river, upwelling, ecological-environmental, monsoon.

INTRODUCTION

Circulation pattern in Southern Vietnam's waters is driven mostly by the East Asian monsoon, tidal regime and extreme events such as typhoon, coastal flood,... The main oceanographic features are the "westward intensification effect" during North-East (NE) monsoon, and upwelling phenomenon during SW monsoon, the dispersion of Mekong river waters to the Eastern Vietnam Sea. These oceanographic processes have effected ecosystem and marine biological resources in the studied area. The circulation system in the Eastern Vietnam Sea has been studied by several researchers; especially, Shaw and Chao (1994) [1] used 3D circulation model to study the surface circulation, Pohlmann (1987) [2] developed a 3D circulation model. Dinh Van Uu (2011) [3] has developed a forecasting model system on hydrodynamic processes.

Herein, the features of strong cold current system flowing from the north to south the during NE monsoon and upwelling phenomenon during SW monsoon in studied area were presented. In South Vietnam waters the remarkable study conducted by Hein et al., (2013) [4] focused on the feature of inter-annual variability of upwelling off the Southern Vietnam's coast and its relation to nutrient dynamics, that by Hein et al., (2013) [5] focused on the sediment dynamics in the region of Mekong river water influence. The main meteo-hydrological features were studied by Le Dinh Mau et al., (2011) [6]. However, most of above study results were based on numerical model whereas this study result is mainly based on observation data which were carried out by the Institute of Oceanography (IO) in recent years under the international cooperation project between Vietnam and Germany (2003-2009). The content of this paper focuses on the

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ship. Circulation system in upwelling area were computed by HAMSOM model (Hamburg Shelf Ocean Model) which was developed by Hamburg University (<https://csdms.colorado.edu/wiki/Model:HAMSOM>) [4]. The reference to estimate the influence of fresh water on the sea was based on the NAGA Expedition Report “The physical oceanography of the Gulf of Thailand” by Robinson in 1974 [7].

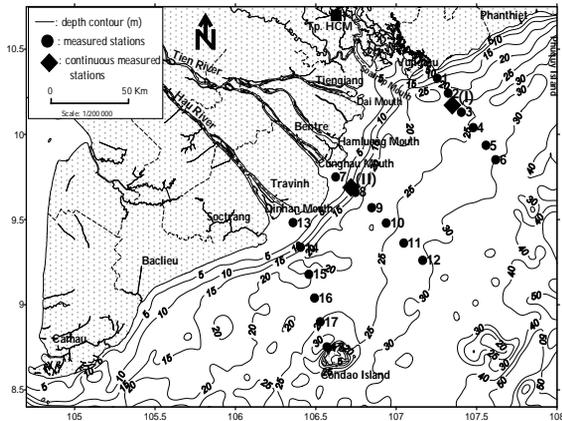


Fig. 2c. Measured stations of cruises 9/2009 and 4/2010

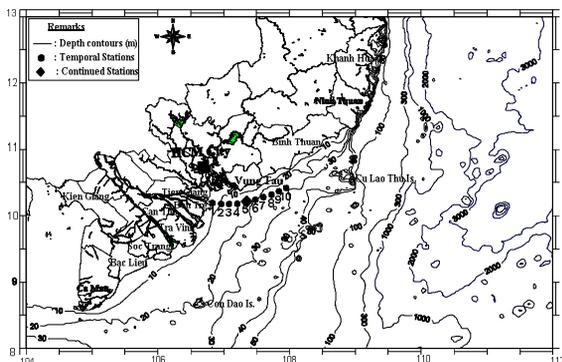


Fig. 2d. Measured stations of cruise 8/2009

STUDY RESULTS

Features of natural conditions along Southern Vietnam’s Coast

Geo-morphological features

The northern coast of studied area (Nha Trang to Vung Tau) is lying in NE-SW direction, it means the coastline direction is parallel with two main monsoonal wind

directions (NE and SW monsoons). The coast can again be divided into several sections by headlands which form bay with the mouth in SE direction. The shelf has a relative slope with the depth contour of 200 m lying at distance of about 100 km offshore. Almost all the rivers are short, suspended matter concentrations are relatively low.

Southern part (Vung Tau - Ca Mau) with main feature being the coastline is also lying in NE-SW direction. The coast can be divided into several parts by different estuaries. The shelf is relatively less sloping compared with that of the northern part, with the depth contour of 30 m lying at distance of ≈ 100 km offshore. Suspended matter concentration from the Mekong river is relatively high.

Meteo-hydrological conditions

Distribution feature of SW monsoon wind in the studied area is shown in fig. 3.

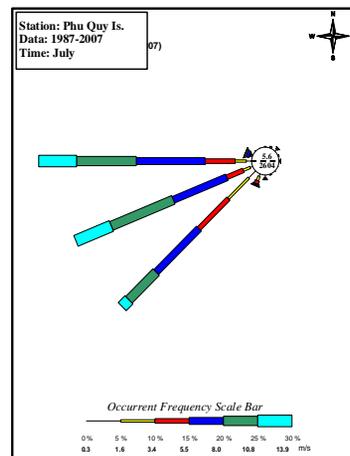


Fig. 3. Wind rose diagram at Phu Quy station in July (1987-2007)

The data in fig. 3 show the distribution of wind velocity and direction at Phu Quy station (offshore region of studied area) which indicate that during SW monsoon the wind direction is in the sector from SW to W.

Typhoons in the studied coast mostly occur from October to December, especially in November. The coast from Binh Thuan to Ca Mau is less affected by typhoons. The occurrence of typhoons is delayed from the

northern part (November) to southern part (December) of the studied area.

The tidal regime along the studied coast is from irregular diurnal tide in the northern part to irregular semi-diurnal tide in the southern part. Mean high tide amplitude is approximately 1 m along northern coast (Nha Trang - Vung Tau), and about 2 m along southern coast (Vung Tau - Ca Mau).

Mekong river discharge

Mekong river in Vietnam is divided into two main branches that are Hau and Tien rivers. River discharge data (from 1998 to

2007) at two branches were collected (My Thuan station on Tien river; Can Tho station on Hau river). Analysis results show that the variations of monthly river discharge at two stations are similar to the maximum value in September and the minimum value in March and April (fig 4a, 4b). In the flood season (July - December) the discharge ranges from 4,000 m³/s to 15,800 m³/s, in the dry season (January - June) the discharge value is less than 4,000 m³/s for each station. The minimum value of discharge was 760 m³/s in April 2004 at Can Tho station and 800 m³/s in March 2005 at My Thuan station.

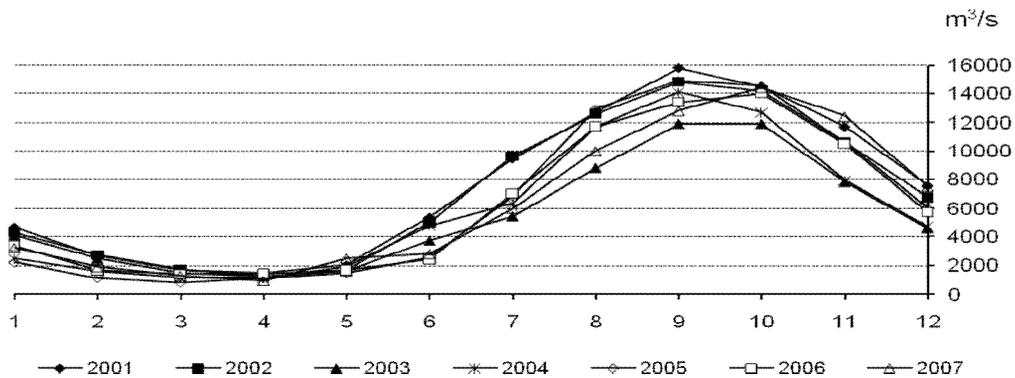


Fig. 4a. Variation of monthly river discharge at My Thuan station from 2001 to 2007 (Vertical axis: River discharge(m³/s); Horizontal axis: Months)

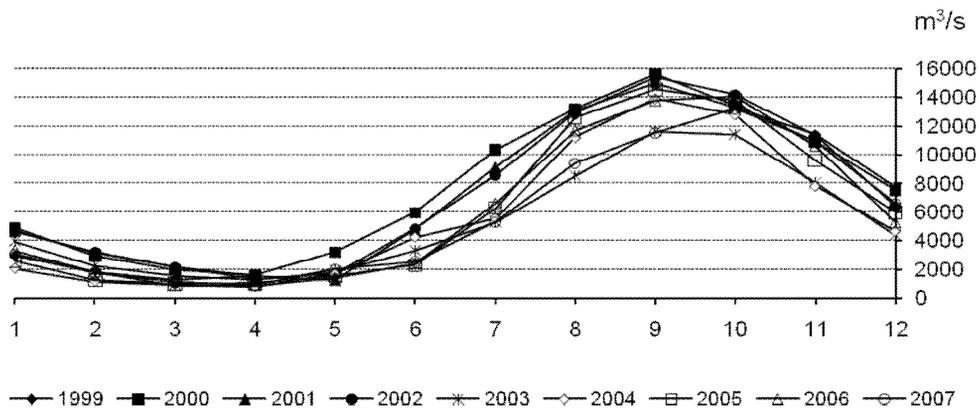


Fig. 4b. Variation of monthly river discharge at Can Tho station from 1999 to 2007 (Vertical axis: River discharge; Horizontal axis: Months)

Circulation features and upwelling phenomenon in Southern Vietnam’s waters

Upwelling phenomenon

Using HAMSOM model [4] to simulate the circulation in order to analyze the upwelling processes in the studied area, the modeled results are illustrated in fig. 5a. The study

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results show that during SW monsoon the northern part of studied area (from Nha Trang to Vung Tau) is in upwelling region with the

center being Ninh Thuan's waters. This result is according to satellite data (fig. 5b).

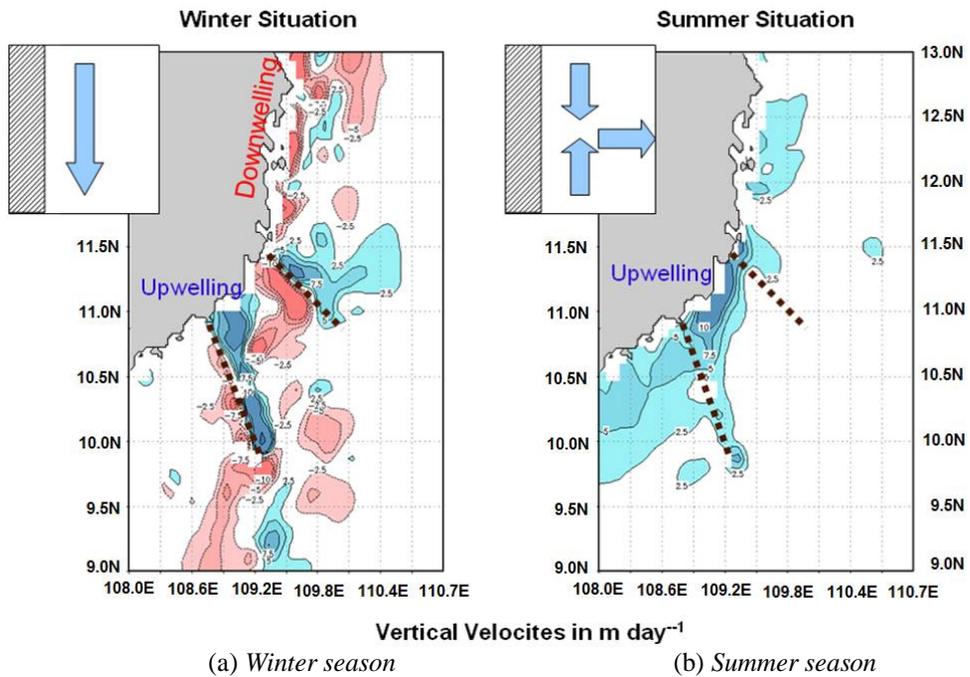


Fig. 5a. Computed vertical velocity during NE and SW monsoons (Blue color indicates upwelling; Red color indicates down welling)

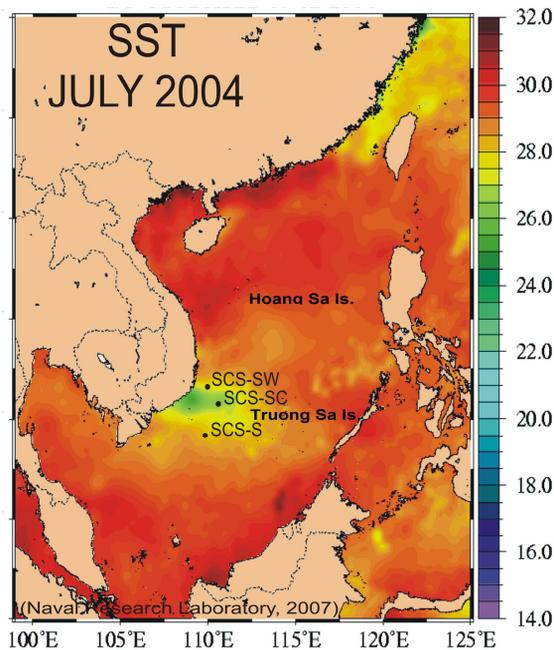


Fig. 5b. Satellite image showing the upwelling phenomenon in South Vietnam waters [8]

Circulation features in Southern Vietnam's waters

Base on measured data from different projects carried out in the recent years, we have

the current pattern for SW monsoon period (fig. 6). It indicates that during SW monsoon the current flows from the south to the north. That means the Mekong river waters can spread to upwelling area.

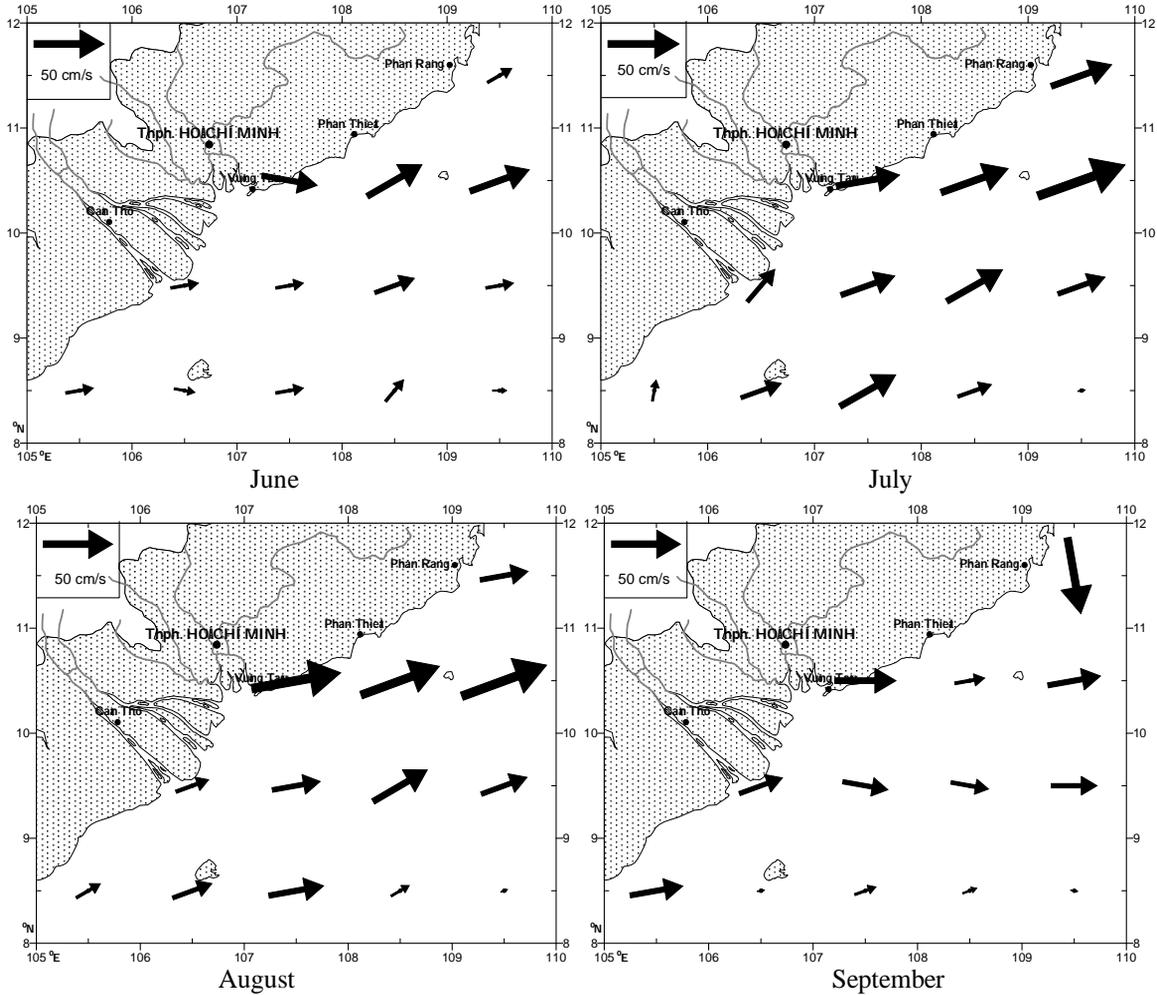


Fig. 6. Surface current pattern in SW monsoon

Spreading of Mekong river waters

Mekong river mouth and upwelling areas are the most important regions for economic development and environmental protection of Vietnam. This section presents the dispersion of Mekong river waters to the Eastern Vietnam Sea, especially to the upwelling area. Study results show that during SW monsoon season and high river discharge, the waters from Mekong river mouth region spread into the

upwelling area. In September 2009, the Mekong river waters with $S \leq 32$ psu spread up to 80 - 100 km offshore with the thickness of about 15 m (fig. 7a) and spread northwards to La Gi region (fig. 7b) with the thickness of about 10 m. During August 2009 an intrusion of Mekong river waters was observed on the Vung Tau transect with the thickness from the surface to the bottom (fig. 7c). Data from satellite images (fig. 7d) agreed with measured ones.

Comments:

The features of upwelling and Mekong river water spreading into the Eastern Vietnam Sea depend on the conditions of the western boundary current in the Eastern Vietnam Sea and on the Mekong river discharge.

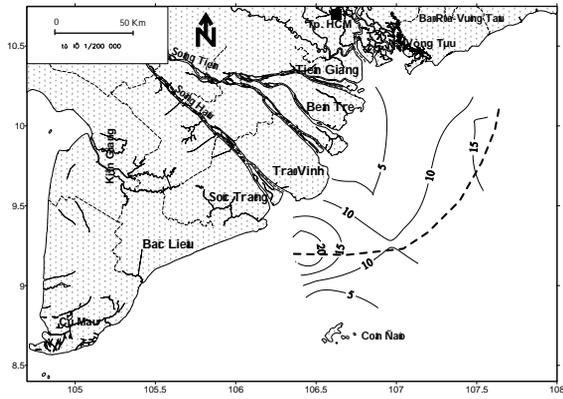


Fig. 7a. Distribution of the thickness (m) of Mekong river waters in September 2009 ($S \leq 32$ psu)

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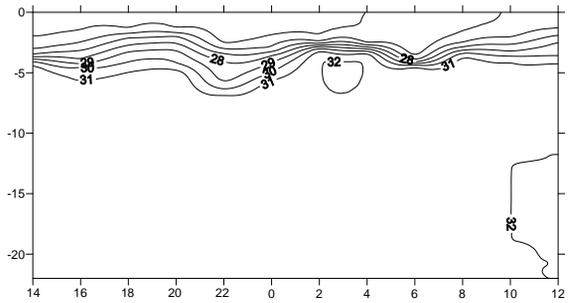


Fig. 7b. Distribution of salinity (psu) at anchored station (Vung Tau transect) during 14 h/19/8 - 12 h/20/8/2009 (Horizontal axis: times-h; vertical axis: water depth-m)

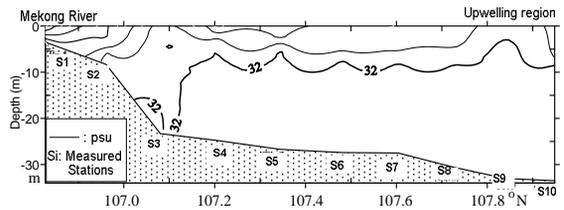


Fig. 7c. Distribution of salinity (psu) along the transect Dai Mouth - La Gi (8/2009)

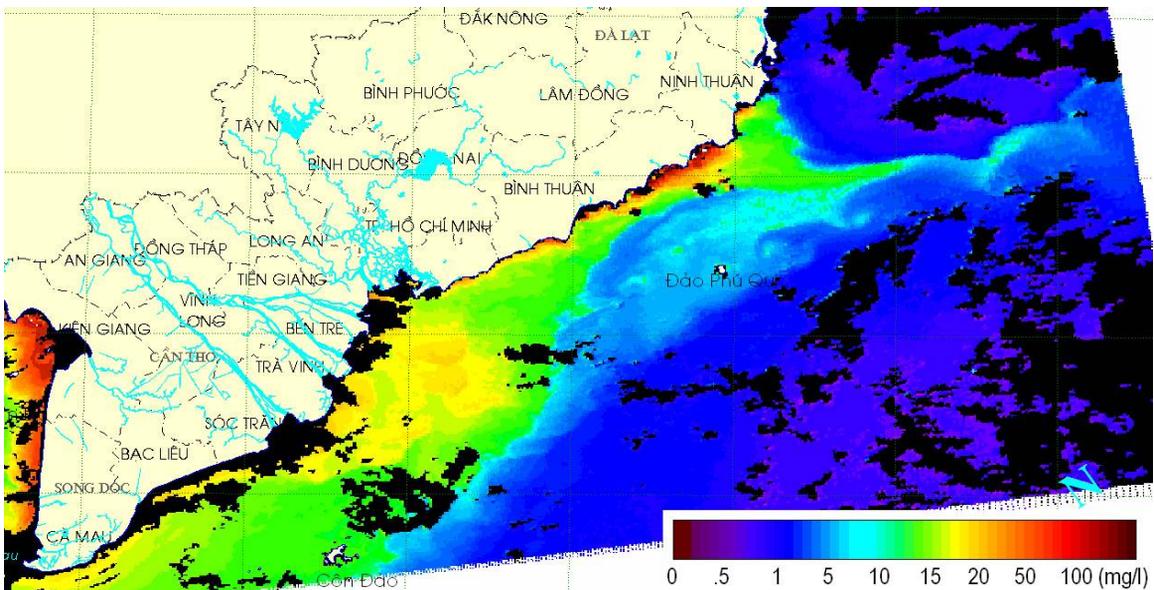


Fig. 7d. SPM concentration on 24/9/2009 (MODIS Image)

During the SW monsoon and high river discharge, Mekong river waters spread up to about 80 km to 100 km offshore, inclining to the northern part of the studied area towards the transect between Ke Ga headland and Phu Quy

island. The extent of Mekong river waters with characteristics of $S \leq 32$ psu in case of high river discharge and prevailing SW monsoonal wind can reach Phan Thiet and enter the Con Dao and Phu Quy island regions. The transect Phan Thiet

- Phu Quy marks the front of two water masses (upwelling and Mekong river waters) (fig.7d). In case of highest Mekong river discharge (10/2005), the river waters can reach as far as 200 km offshore. The thickness of Mekong river waters ($S \leq 32$ psu) at the transect Long Hai (off Vung Tau) is about 10 m.

CONCLUSIONS

The main hydrodynamic processes in Southern Vietnam's waters are driven by the monsoonal wind regime. Remarkable features are the region of strongest upwelling occurring in Ninh Thuan - Binh Thuan waters during the SW monsoon.

Measured data during August and September 2009 indicate that Mekong river waters ($S \leq 32$ psu) spread up to about 80 km to 100 km offshore, inclining to the northern part towards the transect between Ke Ga headland and Phu Quy island (upwelling area).

The extent of river water spreading is directly proportional to the Mekong river discharge and SW monsoon intensity. Spreading of Mekong river waters to the upwelling area is significant data for assessment of the ecological-environmental effects on the upwelling area.

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