# The Dynamics of Sea Surface Height and Geostrophic Current in the Arafura Sea

**Umaroh[1,2], Sutrisno Anggoro[1], Muslim[1]**
[1]Department of Marine Sciences, Faculty of Fisheries and Marine Sciences, Diponegoro University, Jl. Prof. H. Soedharto, SH, Tembalang Semarang. 50275
[2]Indonesian Agency for Meteorological, Climatological, and Geophysics

Email address: umaroh@bmkg.go.id

**Abstract**. The aim of this research is to analyze the dynamics of sea surface height and geostrophic current in relation to upwelling and downwelling phenomenon. The climatic factor such as monsoon are also calculated to understand dynamic of all parameters. The location of this research is in the waters of Arafura Sea waters. The data used in this research include sea surface height anomaly and geostrophic current. The method used in this research is done by analyzing the relation of sea surface height and geostrophic current with the eddy current flow. Spatial and temporal analysis using Surfer will be used in this research to visualize the parameters. The result showed that the upwelling (downwelling) phenomenon occurs when the geostrophic current rotate with the cyclonic (anticyclonic) flow followed by higher (lower) sea surface height. The upwelling event mostly occurred during the Southeast Monsoon and downwelling event mostly occurred during Second Transitional Monsoon until Northwest Monsoon.

Keywords: sea surface height, geostrophic current, eddy, upwelling, downwelling

## 1. Introduction

Arafura Sea is located in the eastern part of Indonesia, bordered with the Banda Sea in the north, the Torres Strait in the east, the northern waters of Australia in the south, and the Banda Sea and the Timor Sea in the west. The Arafura sea is part of Sahul Shelf-shaped and semi-closed waters with an average depth of about 30-90 meters and small part of the area has a depth of >3000 meters [1].

The circulation and dynamic of sea water always occur continuously, the circulation exists both on the surface and in the deep. One of the circulation is sea current flow [2]. The general circulation of surface currents in Arafura waters is affected by the northwest and southeast monsoon cycle which changes periodically every year. This causes seasonal changes in oceanographic parameters including density, temperature, and salinity were also influenced by the flow of river water [3]. These waters also be the pathways of Indonesian Through Flow (ITF) which is the water mass flow from the Pacific Ocean to the Indian Ocean passing through the Indonesian seas seasonally in the Arafura Sea causing changes in the sea surface temperature.

Geostrophic current is current that occur due to geostrophic balance. This current is the result of the difference between the horizontal pressure gradient on the moving water mass and is balanced by the Coriolis force [4]. This current is related to the slope of (slope) of higher sea surface with lower one formed by the Ekman transport and is offset by the Coriolis force [5]. Therefore, this current movement is related to sea surface height. Other factor which play role in geostrophic current circulation is

Indonesian Through Flow [6,7]. The characteristic of the current is significantly needed to be known, especially for the fishery sector (vertical current or upwelling) and for planning sector, such as tackling of sea contamination (horizontal current surface) [8].

Research on the geostrophic flow variability has widely determined, but for the Arafura Sea region is still relatively rare. The sea surface and surface geostrophic variations were determined in the Sunda Strait. They found that seasonal variations in the Sunda Strait sea surface height caused a monsoon [9]. The research of geostrophic currents seasonal variation in the waters of the Arafura -Timor found that the dynamics of the surface geostrophic currents in the waters of the Arafura -Timor occur due to changes sea surface height due to the monsoon each season [10]. The results of these two studies stated that the monsoon (monsoon) greatly affects the variability of geostrophic currents. The anomaly characteristic of sea surface high in special terms and temporal on the northern waters and southern of Java island [11].

According to previous research, by observe to the course of current geostrophic resultant could be established the eddy current phenomenon observed from current vortex which formed [12]. This things is appropriate to previous research that in the southern hemisphere, eddy current with cyclonic rotation is dealing with upwelling event and anti-cyclonic rotation is dealing with downwelling event [12,13]. Mesoscale eddies is current of motion circling cause of heavy current, held more than a week to a couple of months, the condition held cause an eddies rotation could happen for 10-30 days [14]. The research of potential fishing zone can executed by combine the analysis between eddies current with anomaly high current surface.

Because the location of the waters is strategically influenced by the monsoon which blows periodically throughout the year, it is necessary to conduct a research on the dynamics of sea levels and currents geostrophic in the Arafura Sea to understand the dynamics or characteristics of the distribution of high sea surface height anomaly. This research aimed to determine the parameter condition spatially and temporally to finally analyze the upwelling / downwelling event in the Arafura Sea.

## 2. Material and Methods

### *2.1. Study Area*

The Arafura Sea, lies in the west of the Pacific Ocean and overlies the continental shelf between Australia and Indonesia (Papua). The study area was restricted to the area of 5°S – 15°S and 124°E – 141°E (Figure 1).

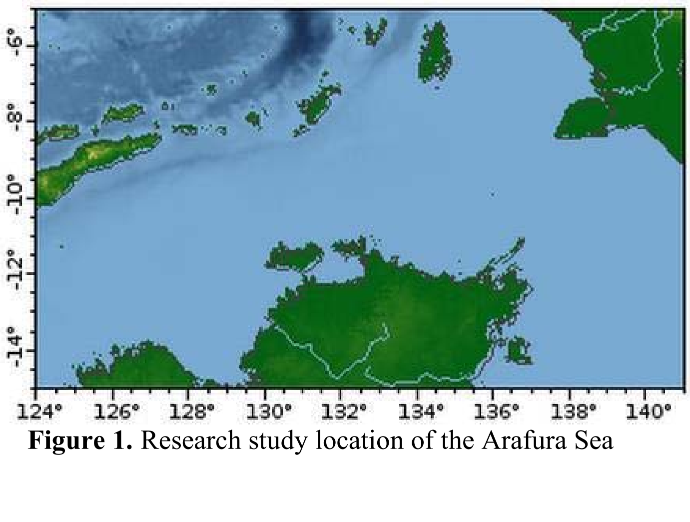


**Figure 1.** Research study location of the Arafura Sea

### *2.2. Data and Methods*

Data used in this research were monthly geostrophic currents and sea surface height anomaly along 20-year period from January 1996 to December 2015. Geostrophic currents data and sea surface height anomaly used in this research is an altimetry satellite data. All data were in NetCDF Format (.nc) and extracted using ODV (Ocean Data View) then plotted using Surfer Software.

Data processing procedure begins by calculating the monthly average of sea level anomaly parameters as well as the direction and speed of geostrophic currents are used in accordance with the data period to look at the general condition (normal) of these parameters in the Arafura Sea. After that, we calculated the average value of those parameters during monsoonal periods, namely: the Northwest Monsoon (December to February / DJF), the First Transitional Monsoon (March to May / MAM), the Southeast Monsoon (June to August / JJA), and the Second Transitional Monsoon (September to November / SON). The results of the calculation will be plotted in the form of two-dimensional (longitude-latitude) with Surfer software.

Furthermore, based on the results of the mapping, geostrophic flow pattern overlaid with sea surface height anomaly. Both of these parameters are combined into a single image (composite data) to make it easier to analyze the eddy currents as well as an indication of upwelling and downwelling event in the Arafura Sea.

## 3. Results and Discussion

The monthly composite of sea surface height and geostrophic current in the Arafura Sea have been determined. The upwelling event supposedly occurred in the area with cyclonic eddy and lower sea surface height. The downwelling event supposedly occurred in the area with anti-cyclonic eddy and higher sea surface height. In this research, we focused only on the eddy-induced upwelling and downwelling event. The upwelling event in the figures is shown in the red circle area and the downwelling event in the black circle area. We used the anomaly of sea surface height and geostrophic current to determine their variability during monsoonal periods.

### *3.1. Variability of Sea Surface Height and Geostrophic Current during Northwest Monsoon (DJF)*

During Northwest Monsoon, the anomaly of sea surface height ranged 0-0.32 meters. The area with lower sea surface height occurred in the western Arafura Sea, with the lowest area was in the south-western Arafura Sea. This low area mostly exhibited the cyclonic eddy event. Thus, in this research, those conditions represent the upwelling event (red circles). The area with the higher sea surface height occurred in the eastern Arafura Sea, with the highest area was along the eastern Arafura Sea during January until February. This highest area mostly exhibited the anticyclonic event. Thus, in this research, those conditions represent the downwelling event (black circles).

In December, the upwelling event occurred in the centre area of Arafura Sea and in the north Timor Sea, while the downwelling event occurred in the northeast and southeast Arafura Sea (Figure 2). These conditions were occurred until January. In February, the upwelling event was decreasing but the upwelling event was more than the downwelling event. In general, during the Northwest Monsoon, the upwelling event occurred mostly in the west Arafura Sea.

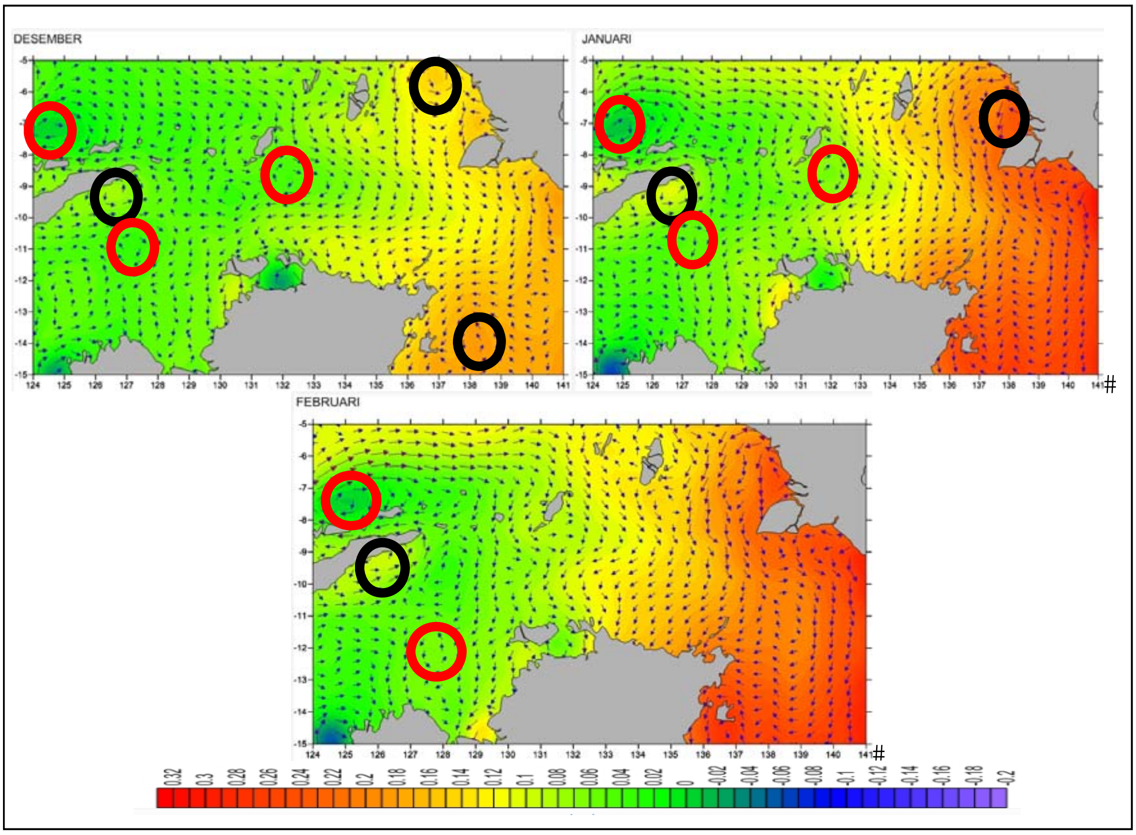


**Figure 2.** The composite of sea surface height and geostrophic current anomaly during the Northwest Monsoon (December-January-February). Red circles represent cyclonic eddy event (upwelling event) and black circles represent anti cyclonic eddy event (downwelling event).

### *3.2. Variability of Sea Surface Height and Geostrophic Current during First Transitional Monsoon (MAM)*

During First Transitional Monsoon, the anomaly of sea surface height ranged -0.1 - 0.32 meters. This sea surface height anomaly value was lower than the value during the Northwest Monsoon. The area with lower sea surface height mostly occurred in the western Arafura Sea, but the lowest area occurred in the south-eastern area in May (Figure 3). The area with the higher sea surface height mostly occurred in the north-eastern Arafura Sea, with the highest area was along the eastern Arafura Sea in March.

The unique condition was occurred during April-May (Figure 3). In April, the upwelling event tended to occur in the south Arafura Sea. This condition was a proof that upwelling event moved from north area to the south area during this First Transitional Monsoon. In May, the lowest area was in the eastern Arafura Sea, and the highest area was in the western Arafura Sea. In general, during the First Transitional Monsoon, the upwelling event occurred mostly in the southern Arafura Sea.

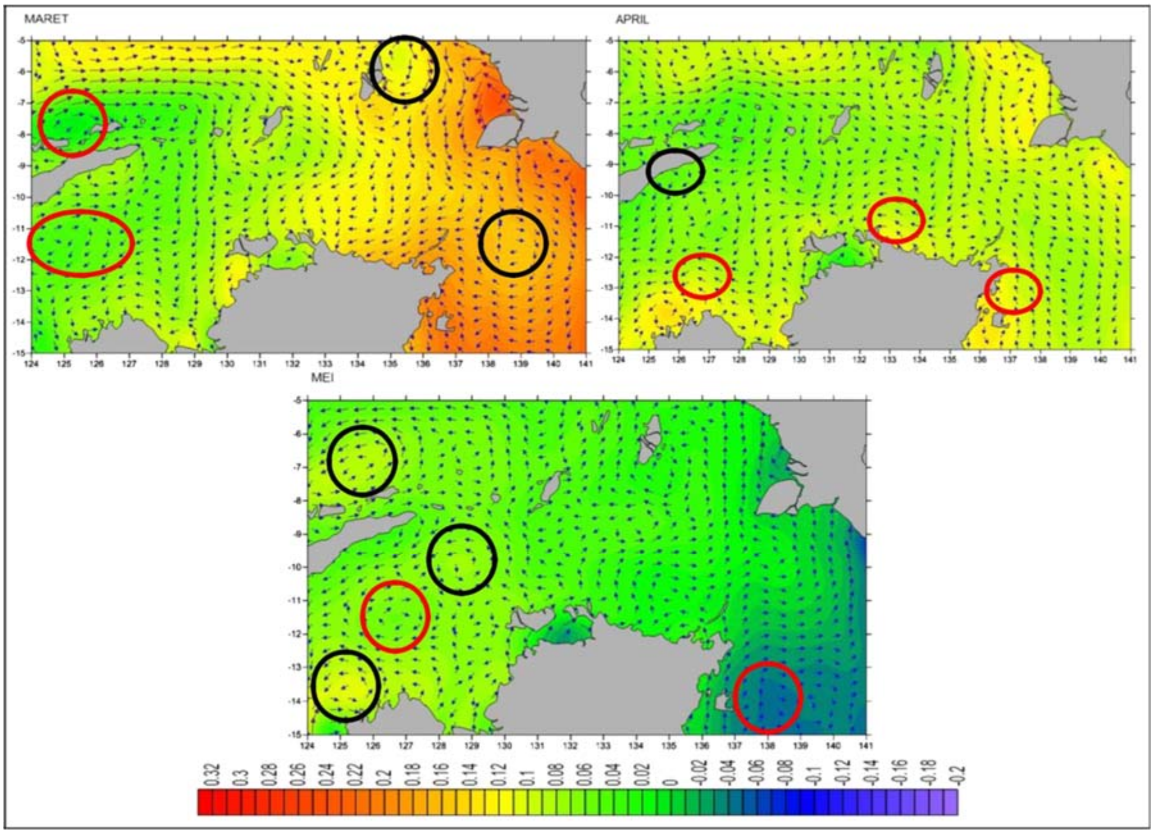


**Figure 3.** The composite of sea surface height and geostrophic current anomaly during the First Transitional Monsoon (March-April-May). Red circles represent cyclonic eddy event (upwelling event) and black circles represent anti cyclonic eddy event (downwelling event).

### *3.3. Variability of Sea Surface Height and Geostrophic Current during Southeast Monsoon (JJA)*

During the Southeast Monsoon, the anomaly of sea surface height ranged -0.2 - 0.14 meters. This sea surface height anomaly value was the lowest compared by the other Monsoonal periods. The area with shallower sea surface height mostly occurred in the eastern Arafura Sea, with the lowest area was in eastern Arafura Sea. This was the opposite of the condition during Northwest Monsoon. The area with the higher sea surface height mostly occurred in the western Arafura Sea, with the deepest area was in the western Arafura Sea in June.

The sea surface height anomaly in the western Arafura Sea exhibit lower value than the other areas. This condition was caused by the water mass flow from east to the west during Southeast Monsoon. Based on Figure 4, the upwelling event mostly occurred during this Southeast Monsoon, compared with other monsoonal periods. The upwelling event occurred in the centre area and extended to the southern Arafura Sea. The downwelling event occurred in some area beside the upwelling area.

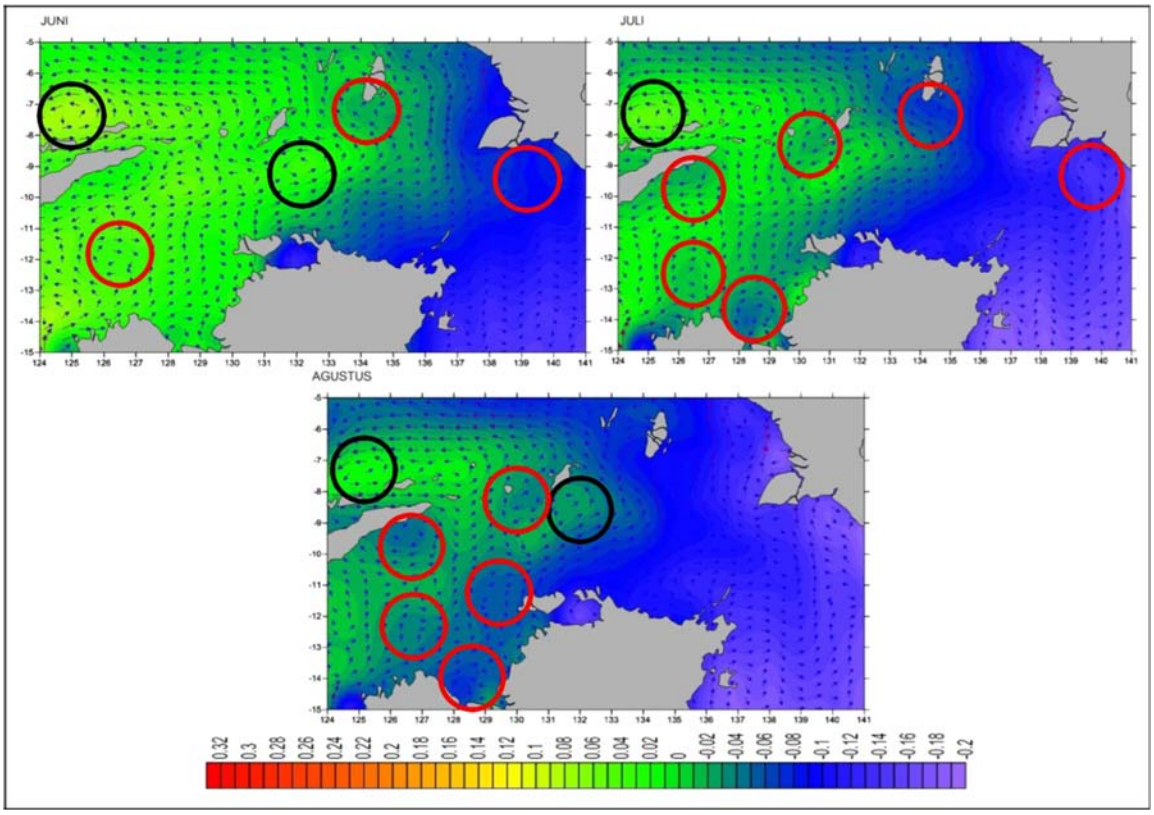


**Figure 4.** The composite of sea surface height and geostrophic current anomaly during the Southeast Monsoon (June – July- August). Red circles represent cyclonic eddy event (upwelling event) and black circles represent anti cyclonic eddy event (downwelling event).

*3.4. Variability of Sea Surface Height and Geostrophic Current during the Second Transitional Monsoon (SON)*

During the Second Transitional Monsoon, the anomaly of sea surface height seemed to increase, compared with the Southeast Monsoon. The lowest sea surface height area mostly occurred in the eastern Arafura Sea, with the lowest area was in eastern Arafura Sea. The area with the higher sea surface height mostly occurred in the western Arafura Sea during October and in the southeastern Arafura Sea in November.

Based on Figure 4, in September, the area with shallower sea surface height was almost the same with the condition during the Southeast Monsoon, but the sea surface height anomaly was in higher value. In October, the sea surface height anomaly was in the higher value and the upwelling event only occurred in the closed area near the island Melville of Australia. The downwelling event mostly occurred during this time.

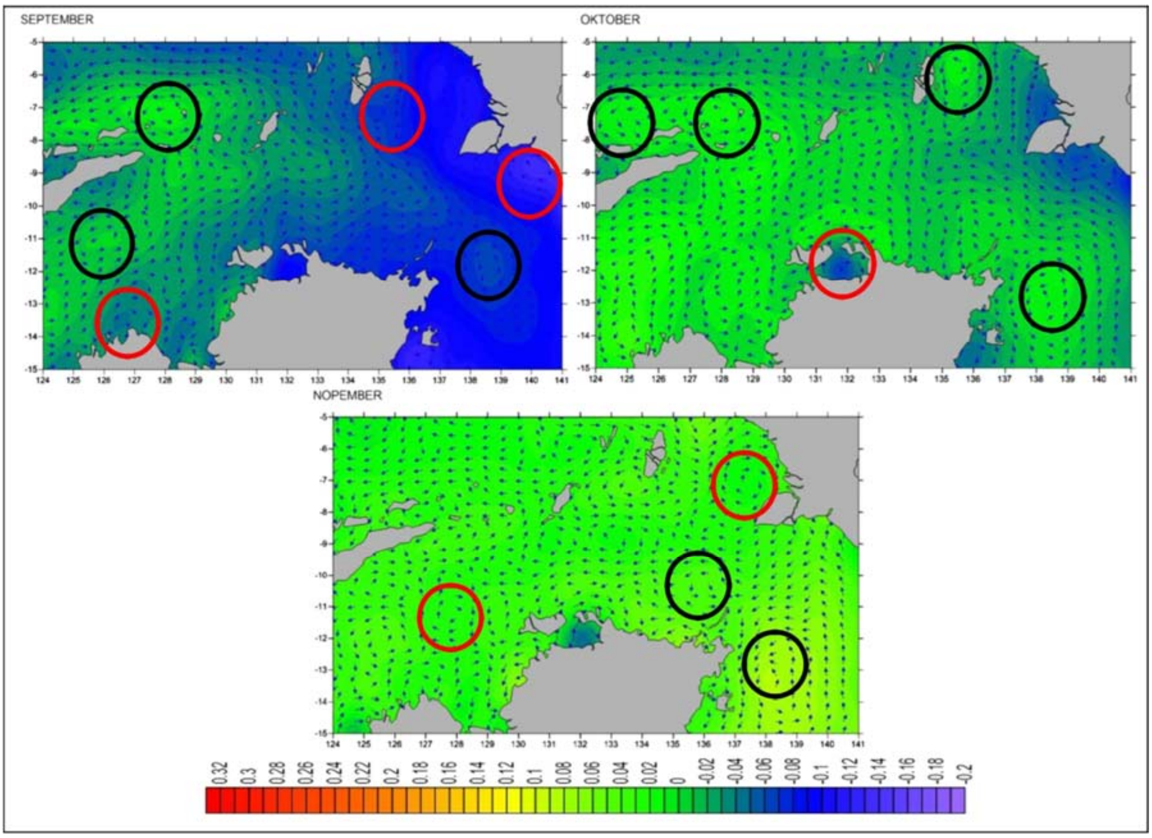


**Figure 5.** The composite of sea surface height and geostrophic current anomaly during the Second Transitional Monsoon (September – October- November). Red circles represent cyclonic eddy event (upwelling event) and black circles represent anti cyclonic eddy event (downwelling event).

*3.5. Temporal Analysis of Sea Surface Height and Geostrophic Current in the Arafura Sea*

Based on the monthly sea surface height anomaly in the Arafura Sea (Figure 6), it can be seen that the negative anomaly occurred from June until October, meanwhile the positive anomaly occurred from November until May. The negative sea surface height anomaly characterized the upwelling event, and the positive sea surface height anomaly characterized the downwelling event. This condition is dealing with the upwelling and downwelling event described spatially.

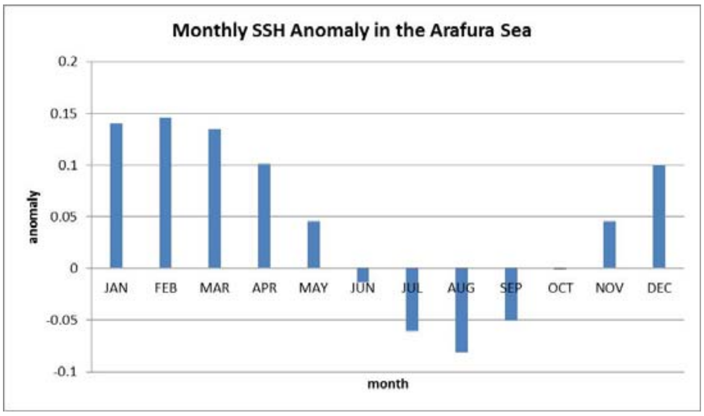


**Figure 6.** Monthly sea surface height anomaly in the Arafura sea

## 4. Conclusion

The sea surface height and geostrophic current anomaly can describe the upwelling and downwelling event. The upwelling event supposedly occurred in the area with low sea surface height with cyclonic eddy. The downwelling event supposedly occurred in the area with high sea surface height with anti-cyclonic eddy. The upwelling event mostly occurred during the Southeast Monsoon and downwelling event mostly occurred during Second Transitional Monsoon until Northwest Monsoon.

## 5. Acknowledgement

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