ANALYSIS OF SEA SURFACE HEIGHT ANOMALY CHARACTERISTICS BASED ON SATELLITE ALTIMETRY DATA (CASE STUDY: SEAS SURROUNDING JAVA ISLAND)

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Abstract. Sea surface height anomaly is a oceanographic parameter that has spatial and temporal variability. This paper aims to determine the characters of sea surface height anomaly in the south and north seas of Java Island. To find these characters, a descriptive analysis of monthly anomaly data is performed spatially, zonally and temporally. Based on satellite altimetry data from 1993 to 2010, the analysis shows that the average of sea surface height anomaly varies, ranging from -15 cm to 15 cm. Spatially and zonally, there are three patterns that can be concidered as sea surface height anomaly characteristics: anomaly is higher in coastal areas than in open seas, anomaly is lower in coastal areas than in open seas and anomaly in coastal area is almost the same as in open seas. The first and second patterns occur in the south and north seas of Java Island. The third pattern occurs simultaneously in south and north seas of Java Island. Characteristics of temporal anomaly have a sinusoidal pattern in south and north seas of Java Island.

Keywords: *Altimetry, Zonal, Anomaly, Characteristics and Sea Surface Height*

1 INTRODUCTION

Indonesia is a maritime continent, about 70 percent of its territory consists of water and flanked by two great oceans; Indian and Pacific Ocean. The very vast oceanic zone has great potential and influence on various sectors of human life. Those potentials and influences should be studied and identified for public welfare. An understanding of oceanic physical dynamic or circulation through data analysis can be used to improve human welfare (Dwi, 2010). Adequate availability of temporal and spatial data from oceanographic parameters are required in research activities.

The presence of satellite altimetry becomes the appropriate solution in meeting both regional and global needs of oceanographic data (Handoko, 2004). The analysed data generated from satellite altimetry shows pictures of the occurring processes of ocean dynamics and the factors or parameters that are dominant in the ocean dynamics (Digby, 1999). Nowadays, there are several satellite altimetry used to monitor or observe global water/sea like Jason-2, Cryosat-2, Saral and HY-2A (Hai Yang). Previous satellite altimetry: GeoSat, Topex/ Poseidon, GFO (GeoSat Follow On) and Jason-1. Each satellite performs measurements with different orbits and references and establishes the track density or trajectory. Thus, the obtained satellite data can complement each other to generate data with optimal spatial and temporal coverage. Satellite altimetry in monitoring ocean dynamics produces some oceanographic parameters: sea surface height temperature, chlorophyll-a, sea surface height, salinity, sea surface height currents and waves. These parameters can be used as indicator of the various phenomena that occur at the sea. Sea surface height temperature is an indicator of weather/climate phenomena *(La Nina, El Nino* and *Dipole Mode)*. The previously mentioned parameters of the ocean can also be used to determine potential fishing area. In addition to these functions, sea surface height has an important role as indicator of climate change phenomena in global and regional scale (Susanto *et al.*, 2001). As a result of global warming and polar ice melting, ocean water volume increases so that the sea surface height rises.

One of oceanographic parameters associated with physical dynamics that are discussed in this study are sea surface height anomaly. Sea surface height anomaly is the magnitude of the deviation on the average sea surface height condition (Steward, 2008). Sea surface height is the distance between the sea surfaces to the reference ellipsoid. With the availability of satellite altimetry data from remote sensing technology monitoring, analysis of sea surface height anomaly on seas surrounding Java Island can be done. The purpose of this study is to compare the characteristics of sea surface height anomalies spatially (different areas) and temporally (different time). Teh obtained characteristics of sea surface height anomaly can be used to determine the upwelling zone. Upwelling zones is a potential reservoir for fishing operations.

2 METHOD

This study used sea surface height anomaly data from combined (*merged*) monitoring of multiple satellite altimetry: Topex/Poseidon, Jason-1, Envisat, Jason-2 and Cryosat-2. The data has a spatial resolution of 0.33 ° x 0.33 ° and monthly temporal. The data used in the analysis are from 1993 to 2010. The data sources can be found at ftp://aviso.oceanobs.com/pub/seadatanet/. The study area is the south and north sea of Java Island with zonal boundary from longitude: E 105.33 ° to 114.67 ° and meridional boundary of latitude: S 3.42 ° to 12.01 °. Four points are determined for temporal analysis: location A (107.2 ° E, 5.2 ° S) and location B (112.5 ° E, 5.9 ° S) in north sea, and location C (106, 2 ° E, 8.7 ° S) and the location of D (112.5 ° E, 9.2 ° S) in south sea. Selection of the study points is based on representative of closed waters in north and open waters in south (Figure 2-1).

This study used descriptive data analysis method. To know the characteristics of sea surface height anomaly spatially, monthly mean of the same months during the observation period are calculated (Sudjana, 2005). Then, the average zonal anomaly for each month are calculated. Mean zonal value is averaging values at a latitude to the pixel values of all the longitude (Isawaki, 1998). Mean zonal value is analyzed to determine the characteristics based on different latitude. Analysis of temporal sea surface height anomaly characteristics is done based on the time series of the four assessment places, two locations in the north (location A and B) and two locations in the south (locations C and D).

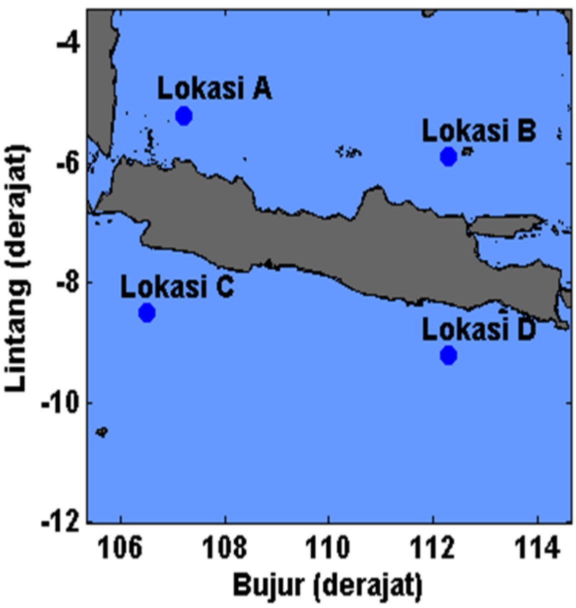

Figure 2-1: Area of research study and four assessment points/locations (A, B, C and D)

3 RESULTS AND DISCUSSION

Based on the analysis conducted on monthly data of sea surface heights anomaly from 1993 to 2008, the monthly mean of sea surface height anomaly from January to December are presented in Figure 3-1. Figure 3-1 shows the monthly mean scale of sea surface height anomaly with anomalous values ranging from -15 cm to 15 cm. The results show that in January, February, March, November and December, at south sea, the anomalies in the coastal areas is higher than in the open seas to the south. In coastal areas, the anomalous value is up to 15 cm, while at open sea, the value is smaller. There are two factors that cause it. The influence of the dynamic circulation of the Indian Ocean and the westerlies that occur in these months. These factors reinforce each other because of both's west to east directions cause the mass of seawater pushed into the south coast. This causes the sea surface height anomaly on the south coast becomes higher. The distribution of anomalies in the north sea is different from the south. Anomalies in the coastal areas are lower, and going north, the anomaly increases. This is due to the influence of westerlies that drive seawater masses from the north coast to the east and lower the anomaly on the north coast. In June and October, it shows that the anomaly in the south, especially in the coastal areas, is lower than that on the open seas. This is caused by the easterlies occuring from June to October. The winds blow from east to west, pushing the mass of seawater from the south coast to the open sea. The influence of the Indian Ocean dynamic circulation becomes weakened or non-existent because of the dominance of the easterlies. This incident resulted in the lowering of sea surface height anomaly on the south coast. Meanwhile, in the northern part, the anomaly is higher on coastal areas and lower on open seas. Easterlies push seawater masses from open seas towards the north coast so that the anomaly becomes higher. In April and May, the anomaly distribution seems different than the distribution characteristics that have been described. The distribution of anomaly on the south seas between the coast area and the open sea is almost equal. On the north seas, the anomalous value is almost spatially the same. This is presumably due to the influence of irregular wind direction in the transitional period of March-April-May.

To complete the results that have been obtained and reinforce the characteristics of sea surface height anomaly in the south and north (analysis based on the difference in latitude), averaging zonal anomaly values is carried. The results in Figure 3-2 show that the mean zonal of sea surface height anomaly has high variability based on latitude. Generally, latitude: 8^{o} to 9 ^{o}S (the sea near the southern part of the mainland), the mean anomalies value is high in January, February, March, November and December. By contrast, in the same position in June to October, mean anomalies has low value. While in latitude: 5 ^{o} to 6 ^{o} S (the waters near the northern part of the mainland) variability of sea surface height anomaly is lower than in the seas of the southern part.

Bima *et al.*, 2014, states that the monsoon system in southern seas of Indonesia is characterized by seasonal reversal of wind direction that causes a different movement pattern of water masses. Variability of sea surface height anomaly indicates that the *upwelling* and *downwelling* are stronger on the south sea than on the north one. This is presumably due to the influence of the geographical position of the two seas. The south sea is an open sea with influence from the Indian Ocean circulation while the north sea is located in a closed sea.

The analysis results of the mean spatial and the mean zonal show three patterns or characters of sea surface height anomaly. First, the anomaly is higher in coastal areas than in open seas. Second, the anomaly is lower in coastal areas than in open seas. Third, the anomaly in the coastal areas is almost the same as in the open seas. When the first pattern occurres in the south sea, the second pattern occures in the north sea and vice versa. The first and second patterns occur in pairs in the sea around the Java Island. Meanwhile, the third pattern occurs simultaneously in south and north sea.

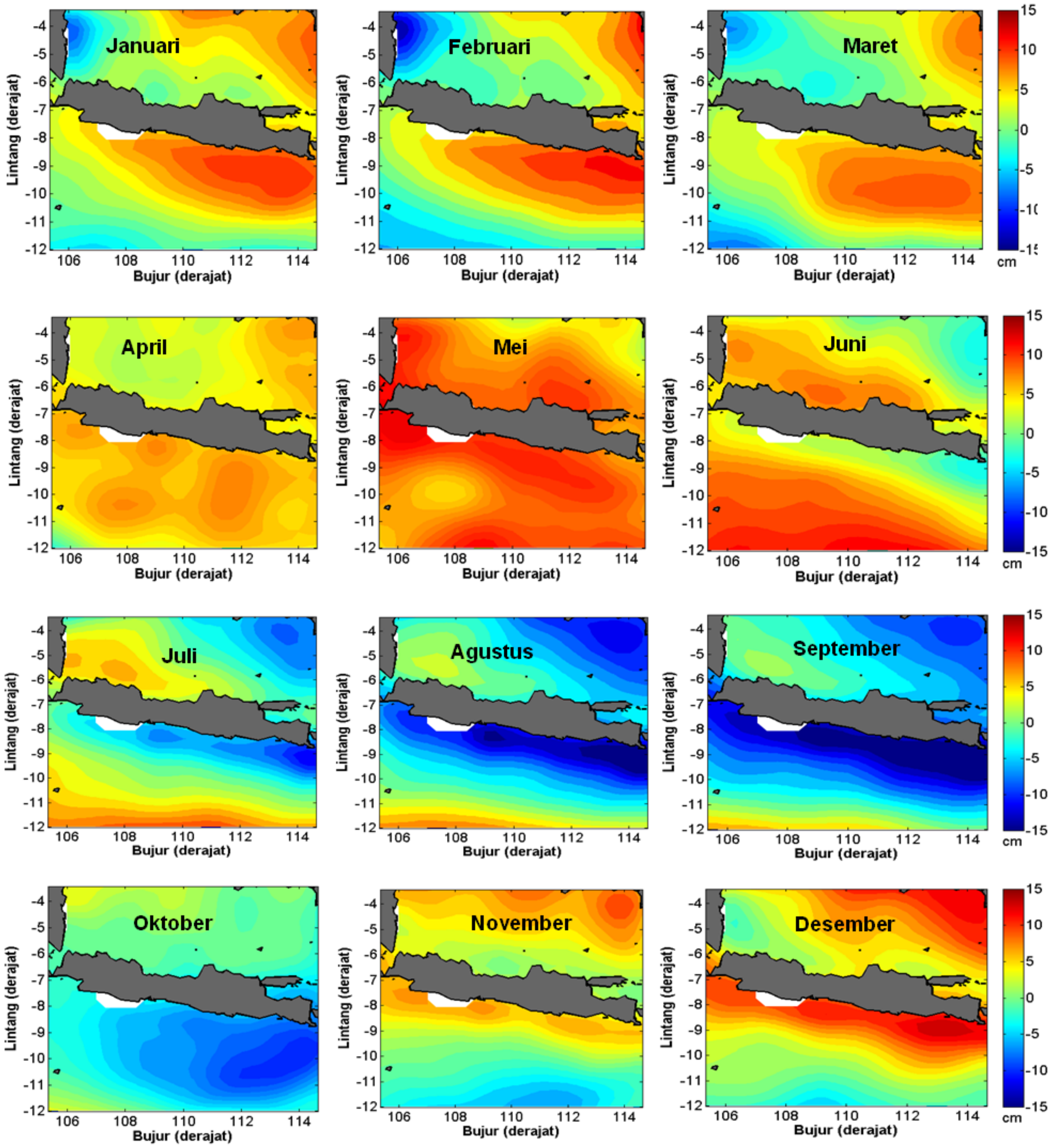

Figure 3-1: Monthly mean of sea surface height anomaly from January to December

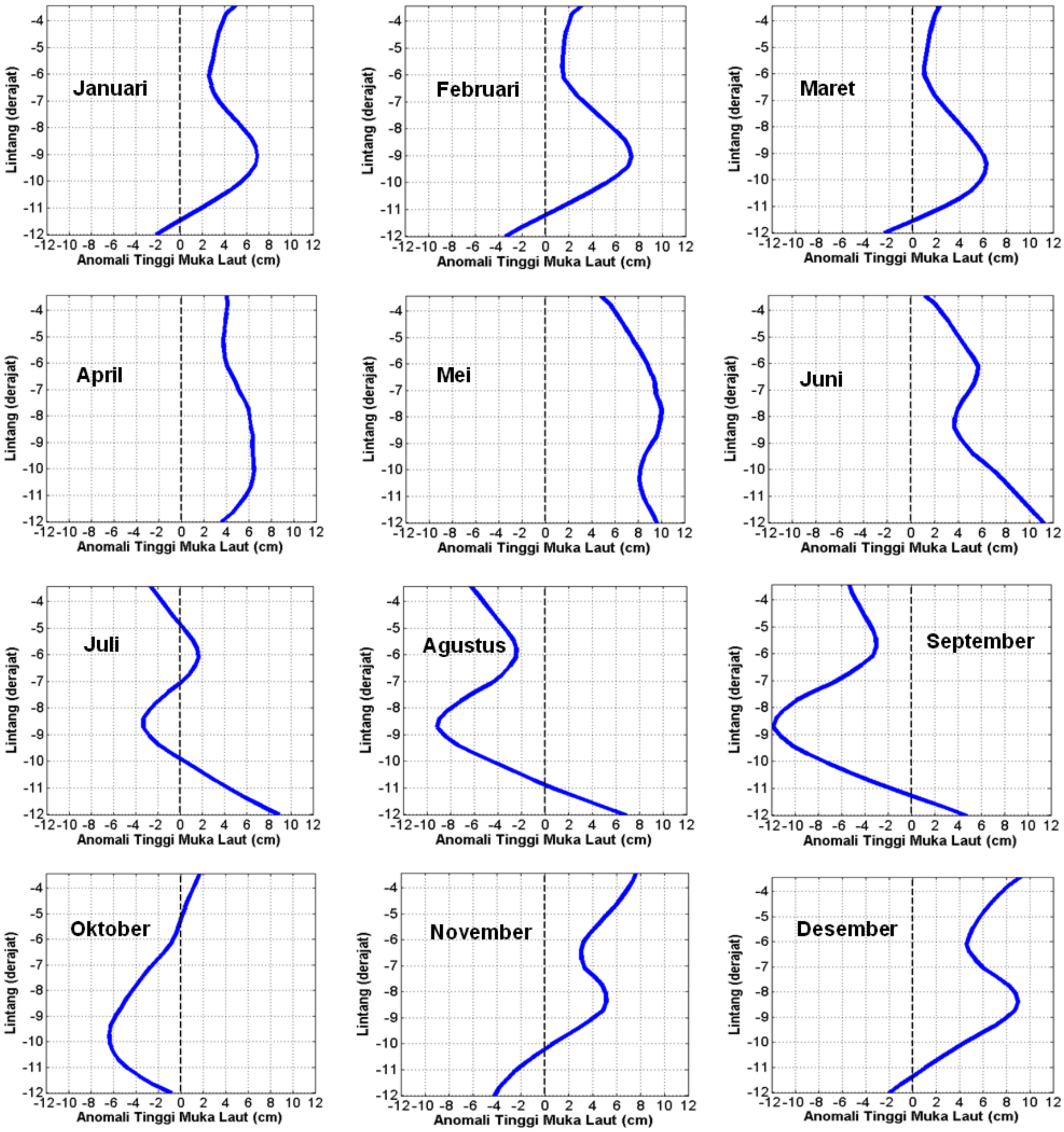

Figure 3-2: Average zonal anomalies in sea surface heights from January to December

To determine the temporal characteristics of sea surface height anomaly in the south and north sea of Java Island, time series of anomaly for four assessment points (Figure 3-3) are made. Figure 3-3 shows that the sea surface height anomaly declines slightly in January to March and increases in April to May. It appears that the anomaly maximum peak occurs in May. In June to September, the anomaly decreases significantly. The minimum condition of anomaly occurs in September at assesment point on south sea and in August/October at assesment point on north sea. In October to December, the anomaly increases. Judging from the form of time series on the four assesment points, sea surface height anomaly has the same trends or tendencies; sinusoidal pattern. It shows the presence of factors that strongly influences the dynamics of sea surface height anomaly periodically; seasonal westerlies and easterlies which occur alternately in Indonesia.

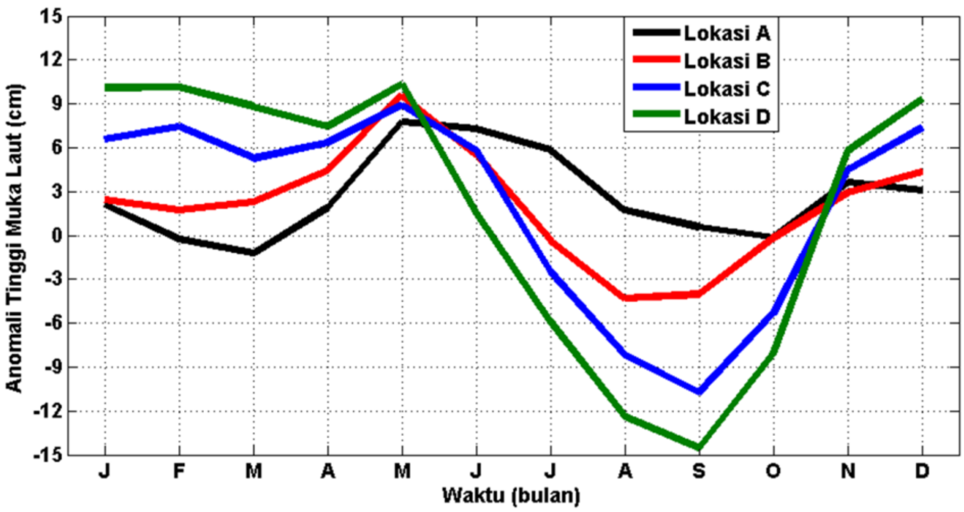

Figure 3-3: The time series of monthly sea surface height anomaly at four assesment locations (A, B, C and D)

4 CONCLUSION

Monthly sea surface height anomaly ranges from -15 cm to 15 cm. Spatially and zonally, there are three patterns or characteristic of sea surface height anomaly: the anomaly is higher in coastal areas than in open seas, the anomaly is lower in coastal areas than in open seas and anomaly in coastal area is almost the same as in open seas. The first and second patterns occur in the south and north seas of Java Island. The third pattern occurs simultaneously in south and north seas of Java Island. Characteristics of temporal anomaly have a sinusoidal pattern in south and north seas of Java Island.

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