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Sea Level Rise and the Impact for the Port

Muhammad Zikra,[a,*], Kriyo Sambodho,[a] and Defian Naturezza,[b]

[a)]*Department of Ocean Engineering, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*
[b)]*Operational Research Laboratory, Department of Ocean Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia*

*Corresponding author: mzikro@oe.its.ac.id

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ABSTRACT

The problems in port infrastructures related with climate change, especially sea level rise, have continued to receive a high level of attention. Knowledge of climate change should become a major interest for engineer, stakeholders, and decision makers or the port authorities in port industry for developing mitigation and adaptation strategies in the future. The objective of this paper is to measure sea level change in the Indonesian sea from satellite altimetry. In this study, satellite altimetry mission of Jason-2 are used to obtain altimetry data from NOAA server databse. These data are processed by using software Basic Radar Altimetry Toolbox (BRAT). Analysis of sea level change is done for 4 years period from 2009 to 2012 in 4 locations, which are Medan, Pemangkat, Ambon, and Manokwari. The results showed that the highest sea level rise is in Manokwari 14.10 mm/year, and the lowest is in Ambon with trend of sea level rise 1.17 mm/year.

KEY WORDS: *Sea Level Rise; Satellite Altimetry; JASON-2; Port; BRAT*

1.0 INTRODUCTION

Indonesia is known as one of the largest archipelagic country in the world. The Indonesian seas are four times greater than its land area. Indonesia also located in strategic position locates in the cross road of East-West and North-South shipping route. Sea transportation as one element in the transportation system plays key roles in servicing and promoting the economic growth in Indonesia.

Ports as main elements of sea transportation are important infrastructure for supporting economic development in Indonesia. Until 2011, Indonesia has more 1031 public ports and special ports and wharfs, where 111 public ports to be managed commercially by four Indonesian Port Corporations, PT Pelabuhan Indonesia (PELINDO) I, II, III and IV in order to improve effectiveness and efficiency of public port management.

As the largest archipelago nation in the world, Indonesia is one of the countries that are most vulnerable to the negative impacts of climate change. Generally, the global climate change will affect public and private transportation in coastal areas through sea level rise, intensity of rainfall that will increase the risk of floods, increased frequency of extreme wave climate or storm events [1]. One of the largest threats of climate change to the Port is known the increase of the sea surface level.

In general, the increase in sea level provides a huge potential threat to Indonesia areas which is an archipelagic country with many islands and ports as main element of sea transportation as seen in Figure 1. In 2050, sea level rise due to global warming is projected to reach 35-40 cm relative to year 2000. Based on these projections, the maximum sea level rise in Indonesia can reach up to 80-175 cm in 2100 [2]. At this magnitude of rise, many ports will face inundation in the future.

Based on that fact, this phenomenon requires further study in order to find out how much sea level rise is occurred in Indonesia waters. Because an accurate estimation of sea level data is difficult to obtain due to the lack of consistent data recording in Indonesia territory. Added, conventional observation methods such as using survey vessels and in situ observations with tide gauge are not an effective and efficient for a very large water area in Indonesia. Therefore, to overcome this problem the satellite altimetry is used to measure the sea level change from space. Analysis of sea level change is done for 4 years period from 2009 to 2012 in Indonesia seas. This kind of information is important for better understanding when and how to implement adaptation and mitigation strategies for port development in the future related to sea level change phenomena.

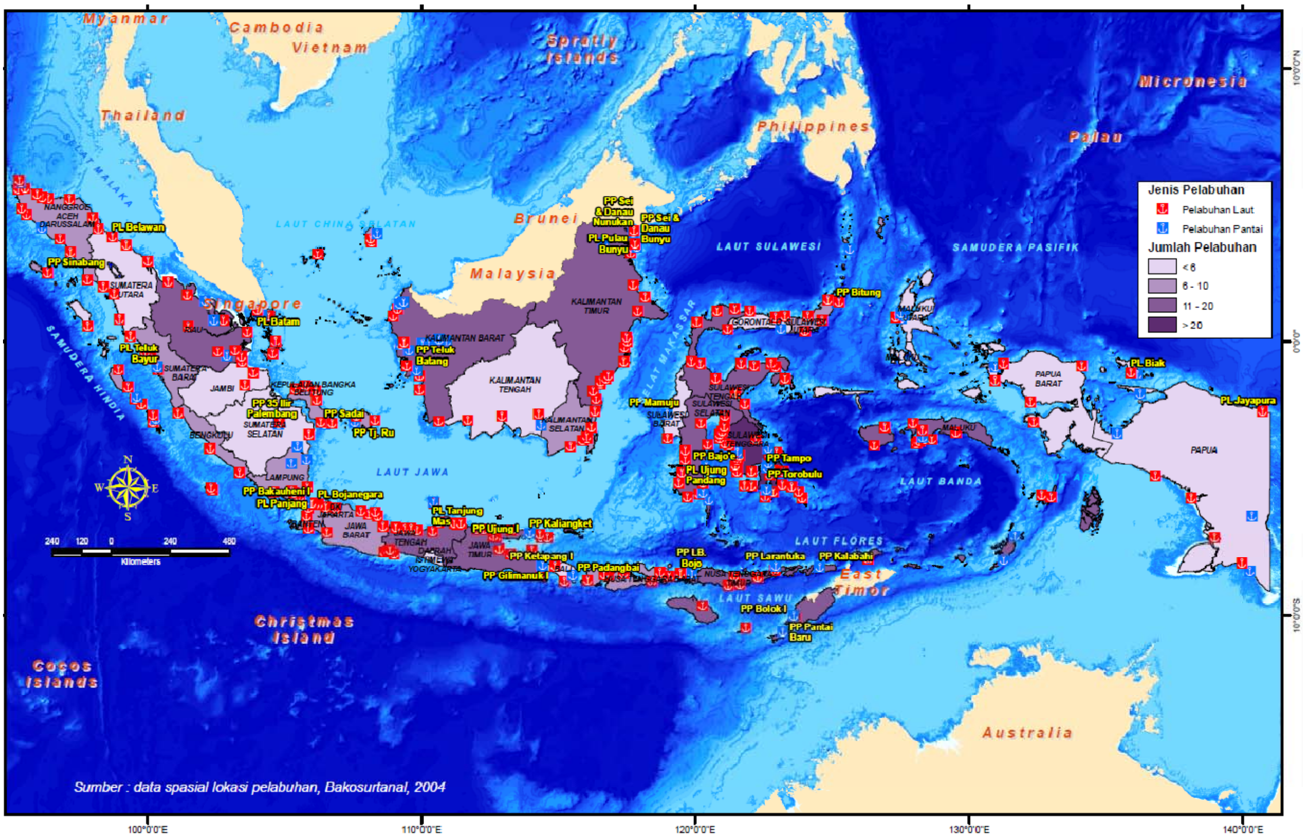


Figure 1: Ports location around Indonesia seas. (Bokosurtanal, 2004)

2.0 SEA LEVEL TREND USING ALTIMETRY SATELLITE

Now days, there are several remote sensing technologies that can monitor the condition of the oceans continuously. Satellite altimeter technology is one of technique to monitor sea level change. During the past two decades, observations from satellite altimeters have demonstrated dramatic descriptions of sea level variability with higher spatial resolution than the traditional tide gauges [4]. High accuracy radar altimeter missions are uniquely capable to globally and continuously observe the ocean for better understanding long term changes of ocean circulation [5].

Sea Level Anomaly

Sea Level Anomaly (SLA), also referred to as residual sea surface, is defined as the sea surface height (SSH) minus geophysical surface and geophysical effect, namely tidal and inverse barometer [5]. Geophysical surface in this case can be either the geoids or Mean Sea Surface (MSS). SLA is calculated using the formula

$$SLA = SSH - MSS - Correction \qquad (1)$$

where Sea Surface Height (SSH) is calculated by subtracting the corrected range from the Altitude, which is [5]:

$$SSH = Altitude - Corrected\ Range \qquad (2)$$

Sea Surface Height (SSH) in the equation 2 still contains the effects of short-period variations such as tidal. Furthermore, these effects should be eliminated so that the phenomenon of sea level rise can be seen through the temporal analysis. Based on this, SLA was used to observe the phenomenon of sea level rise, because these effects have been eliminated in SLA data. The SLA contains information about real changes in ocean topography related to ocean currents, dynamic response to atmospheric pressure, differences between tides and the tide models, differences between the mean sea surface model and the true mean sea surface, unmodelled or mismodeled measurements effects and orbit errors.

SLA calculation is performed to obtain an average value of SLA per month at each observation point. In one month there were ± 3 cycles, monthly calculation is performed to get a definite value that will be used to analyze sea level rise phenomenon per year, for 4 years of observation (from 2009 to 2012) at each observation points.

3.0 DATA

In this research, we use GDR (Geophysical Data Record) data that obtained from Jason-2 satellite for period 2009-2012 which passed Indonesian waters. Cycle data which is used in this paper after selection is ranging from 018-165 cycles.

This data were obtained from NOAA server (http://data.nodc.noaa.gov/jason2/gdr/gdr site). These data will be used to calculate Sea Level Anomaly (SLA) for the analysis of sea level rise. There are 4 observation points deployed along the trajectory following the Jason-2 orbits that pass through the territory of Indonesia as seen in Figure 2 and 3.

Figure 2: Observation points in Indonesian waters.

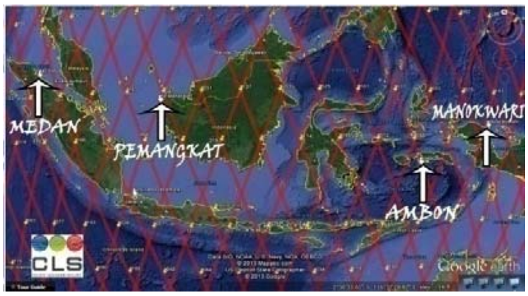


Figure 3: Jason-2 orbits track

4.0 RESULT AND DISCUSSION

Trend of Sea Level Rise

In this study, Geophysical Data Record (GDR) data that obtained from altimetry mission of Jason-2 are processed and controlled by using software BRAT. In the BRAT, data that are not in accordance with proper reference will be automatically removed. Only data those are really appropriate with the reference which can be processed using this software. GDR data products are fully validated data and generated every 30 days [5]. GDR files contain sea surface height, ocean surface wind speed, significant wave height information and all required corrections. All files are available in NetCDF format.

For this study, GDR data will be used as an input in software BRAT to calculate Sea Level Anomaly (SLA). SLA images and graphics will be displayed for each observation point as well as a whole area. The output example of BRAT for SLA analysis is given in Figure 4. Then SLA calculation is performed to obtain an average value of SLA per month at each observation point. Figure 5 shows the averaged SLA results for every observation points during 4 years of observation period. Then, linear trend analysis was conducted to determine the existence of the phenomenon of sea level rise on the data SLA Jason-2 satellite for the period 2009-2012 as shown in Figure 5.

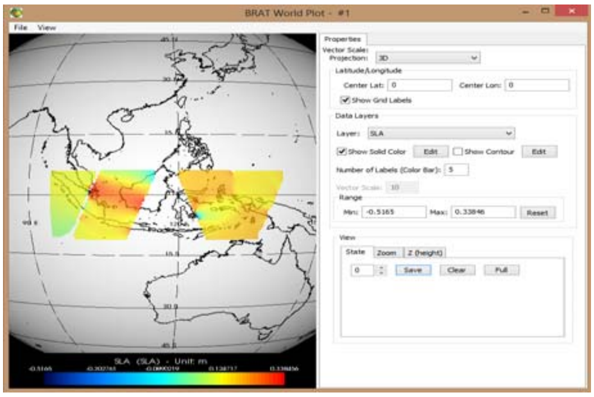
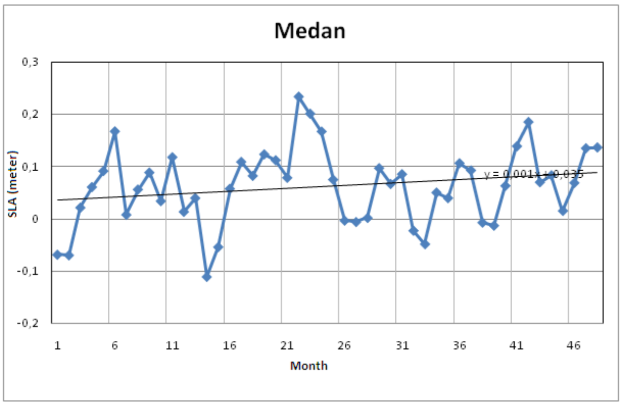
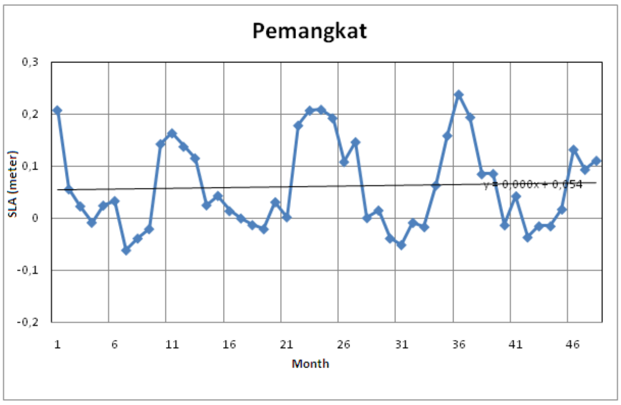


Figure 4: SLA for November 2011





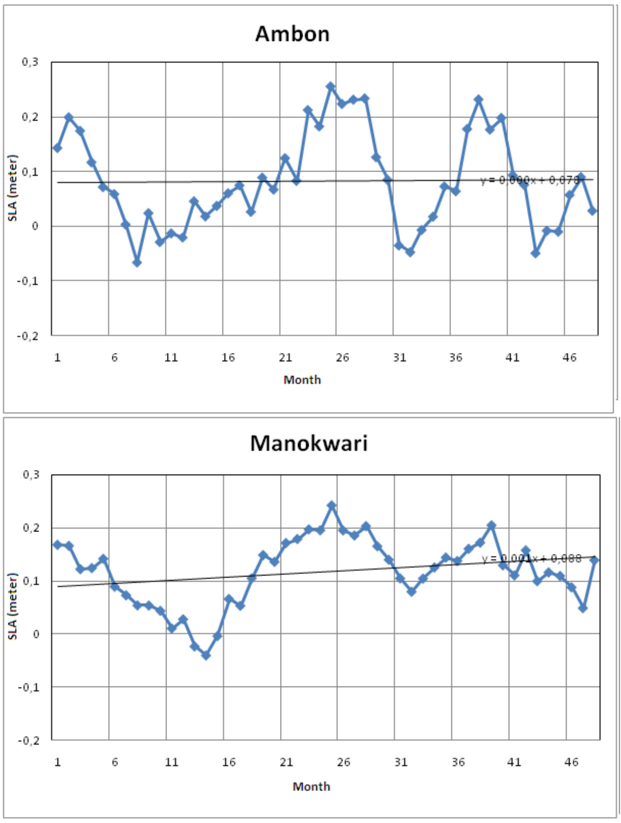


Figure 5: Trend analysis of sea level rise

From the trends of analysis of 4 observation points, indicated that there were increased trend of sea level in Indonesian seas as shown in Table 1. The highest trend of sea level rise is 14.10 mm/year at Manokwari (North West Papua) and the lowest is in Ambon with trend of sea level rise 1.17 mm/year.

Table 1: Trend of sea level rise from 2009 to 2012

	Location	Trend (mm/year)
1	Medan	12.90
2	Pemangkat	3.52
3	Ambon	1.17
4	Manokwari	14.10

Potential Impact of Sea Level Rise

The 4th assessment report by the Intergovernmental Panel on Climate Change (IPCC) published in 2007 has warned that the warming of the earth's climate system is unequivocal. Global warming as a result of the effects of greenhouse gases, have an impact on rise in sea levels. IPCC (2007) reported that the sea level has risen by an average of 2.5 millimeters annually.

The past few years, have witnessed an increase in damage due to the extreme weather events in Asia or Indonesia itself. Coastal erosion, inundation of land, sedimentation, coastal flooding, and increased salinity are common problems that affect man-made infrastructure and ecosystems in coastal areas. Based on this study, there were increased trend of sea level in Indonesia, which make Indonesia particularly very vulnerable to sea level rise.

Even though, sea level rise would have no direct impact on navigation, but it would affect port infrastructure and port structure. Climate change could affect port environments in different of ways. Climate change will affect ports, depending on their geographic location and topographical area which the port is located. Ports that are located in low lying areas are sensitive to sea level rise, increased flooding, changes in the frequency and intensity of wind speed and increased storm surges.

Sea level rise may allow greater penetration of wave energy to the coastline and into port, causing increased coastal erosion in areas with a soft coastline. Increased sedimentation in harbors, inlets and channels will result in the need for more maintenance dredging to maintain exists access. Sea level rise also may reduce top clearance between ships and bridges due to a change in high and extreme sea levels.

Another potential impact on port structures include changes in overtopping and even stability of breakwaters due to increased force from wave action coupled with attack at a higher level on a structure due to sea level rise. The elevation at which the wave force attack a structure will increase the exposure of decks of wharfs and piers, which may increase the corrosion rate and the degradation of material designed for a particular range of sea level conditions.

The problems and potential impacts of sea level rise require serious attention from the scientific community, stakeholders, decision makers and the port authorities to take an active role to better understand when and how to implement proactive adaptation and mitigation strategies. With better data and information, especially the types of impacts that they can expect on their facilities, it can help the port assess their risk in the future. Because the data that ports typically use for planning purposes do not incorporate climate change forecasts.

5.0 CONCLUSION

In this study, the sea level change in the Indonesian seas was measured from satellite altimetry. Satellite altimetry mission of Jason-2 are used to obtain altimetry data from NOAA server databse. These data are processed by using software Basic Radar Altimetry Toolbox (BRAT). Analysis of sea level change is done for 4 years period from 2009 to 2012 in 4 locations, which are Medan, Pemangkat, Ambon, and Manokwari. The results showed that the highest sea level rise is in Manokwari 14.10 mm / year, and the lowest sea level rise is in Ambon at 1,175 mm / year. This kind of information is important to study the impact of sea level rise to the port infrastructures and perhaps strategy for adaptation and mitigation in the future.

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REFERENCES

1. Wirght, P. (2013). *Impact of climate change on ports and shipping*, MCCIP Science Review
2. ICCSR. (2003). *Basis Saintifik: Analisis dan Proyeksi Kenaikan Muka Air Laut dan Cuaca Ektrim*. Bappenas, Indonesia
3. Bokosurtanal (2004). *Data Spasial Lokasi Pelabuhan*. Jakarta
4. A. H. M., Din and K., Omar (2009) *Derivation of sea level anomaly using satellite altimeter*. In: Proceeding of 2009 East Asia Hydrographic Symposium & Exhibition (EAHSE), Kuala Lumpur.
5. AVISO. (2011). OSTM/*Jason-2 Products Handbook.* CNES, EUMETSAT, JPL, NOAA/NESDIS
6. ESA, and CNES. (2011). *Basic Radar Altimetry Toolbox v3.0 User Manual*. ESA, CNES.
7. IPCC. (2007). *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.