Addressing Disaster Risk Reduction by Analyzing Sea Level Rise in the Aceh Waters

Addressing Disaster Risk Reduction by Analyzing Sea Level Rise in the Aceh Waters

Ichsan Setiawan[1,2], Yopi Ilhamsyah[1,3], Edy Miswar[1], Muhammad Irham[1*]

[1]Dept. of Marine Sciences, Faculty of Marine and Fisheries, Syiah Kuala University, Banda Aceh Indonesia 23111
[2]Center for Marine and Fisheries, Syiah Kuala University, Banda Aceh Indonesia 23111
[3]Applied Climatology, Graduate School of Bogor Agricultural University, Bogor Indonesia 16680

[*]Corresponding author: irham@unsyiah.ac.id

Abstract. Eustatic changes produce changing on global sea levels, such as changes in water volume in the oceans world. This change indirectly affects the balance of water and land and it is very harmful for the archipelago countries which one of them is Indonesia. The two most important effects are the temperature and mass of water stored on land and sea as fresh water in rivers, lakes, glaciers, polar ice caps, and sea ice. Therefore the purpose of this study is to see how far the sea level changes in Aceh waters in relation to disaster risk reduction. To achieve this goal, the method used is to analyze the record of sea level data in the waters of Aceh during the last 25 years. The analysis of sea surface change data in Aceh shows that there has been a linear increase in sea level since 2008 in parallel with the rise in temperature so that it is expected to lose ground in some areas of the Aceh coast**.**

1. Introduction

Sea Level Rise is a phenomenon of rising sea levels as a result of climate change which is an important issue today. Moreover for Indonesia, the archipelagic country has +18.110 islands and coastline along the 108,000 km. The results of the Intergovernmental Panel on Climate Change (IPCC) investigation estimated that within 100 years starting from 2000 the sea level would rise as high as 15-90 cm with a 48 cm height increase certainty. In Indonesia alone, a projected sea level rise of that magnitude would result in loss of land due to sea level rise of 30120 km^2 in 2050 and 90260 km^2 in 2100 [1-3].

Coastal region which is the boundary between land and sea make it as a sufficiently potential area of disaster where most of the people of Indonesia live along this area. This area is socially inhabited by more than 110 million people or about 60% of the population of Indonesia. Temperature changes cause the physical condition of the atmosphere to become more unstable and cause anomalies of long-lasting weather parameters that cause climate change potentially to have sea level rise.

The previous research in Aceh water related to this research such as tidal dynamic, wave, climate change, and coastal morphology surveyed [4-12] have shown the tendency of sea level rise. None of the topics, however, address the disaster risk reduction associated with the sea water dynamic in Aceh water. Therefore in this study will be discussed how to overcome disaster risk reduction by analyzing sea level rise in Aceh Waters. This is done with the intention of ensuring that early evaluation of the sea level rise impact on coastal areas will be used as a reference in adaptation strategy to reduce

disaster risk [1-3]. The purpose of this study is to see how far the sea level changes in Aceh waters in relation to disaster risk reduction.

2. The Methods of the Research

The sea level anomaly data was extracted from NASA's MEaSUREs program under NASA Sea Level Portal that is available at https://sealevel.nasa.gov/data-analysis-tool. The data originate from satellite altimetry of TOPEX/Poseidon, Jason-1, Jason-2, and Jason-3. It is monthly gridded data with the spatial resolution of 1/6 degree. The data range between January 1993 and June 2017. In the present study, we analyze the cumulative changing of the sea level in the western, northern, and southern Aceh Waters.

3. Results and Discussion

Figure 1 shows the changes in monthly average sea level at three stations of Aceh water. These three stations represent the northern coastal areas (Bireuen), the west coast (Lhoknga) and the south Coast (Calang). The result of sea level anomaly trend shows that for the last 25 years there is a tendency of sea level rise up, where significant increases began in 2008. It appears that over the past 25 years sea level in Aceh waters has risen by approximately 4 cm which indicates that there is an increase of 0.16 cm per year. The increase in water level is in line with the estimated world sea level rise trend as reported by NOAA (National Oceanic and Atmospheric Administration) and CSIRO (Commonwealth Scientific and Industrial Research Organization) (Figure 2).

On this occasion, various factors affect the volume and mass of the oceans that result in long-term changes in the sea level rise. This condition can be related to two influencing factors, namely sea temperature rise (because the volume of water depends on temperature) and sea mass change where water stored on land and sea as fresh water in rivers, lakes, glaciers, polar ice caps, and sea ice. This condition occurs due to the dominant influence of thermal expansion so that the volume of seawater increases. On a long time scale, changes in the shape of the ocean and the distribution of terrestrial will affect the sea level (Figure 3). The sea-surface temperature anomaly Bireuen Station is larger than Calang Station. In general, this is in line with the Sea level anomaly which is also larger than Bireuen Station than Calang Station.

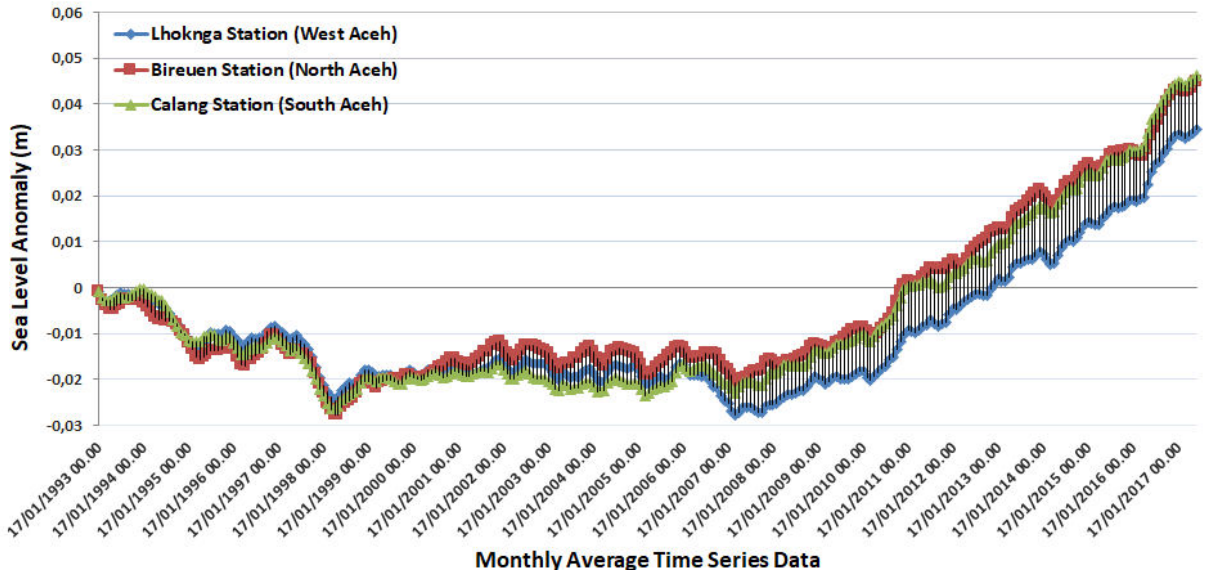

Figure 1. Sea level anomaly of the Aceh Waters (in meters).

The rise of sea level of 1.6 mm per year in the waters of Aceh requires us to rethink to anticipate the possibility of an unwanted disaster. Therefore, adaptation strategy management is a strategy that must be applied to anticipate the bad possibility that will happen. Consequently, the implementation of

disaster risk management to anticipate the possibility of adverse consequences of sea level rise from the analysis results obtained need to be immediately implemented.

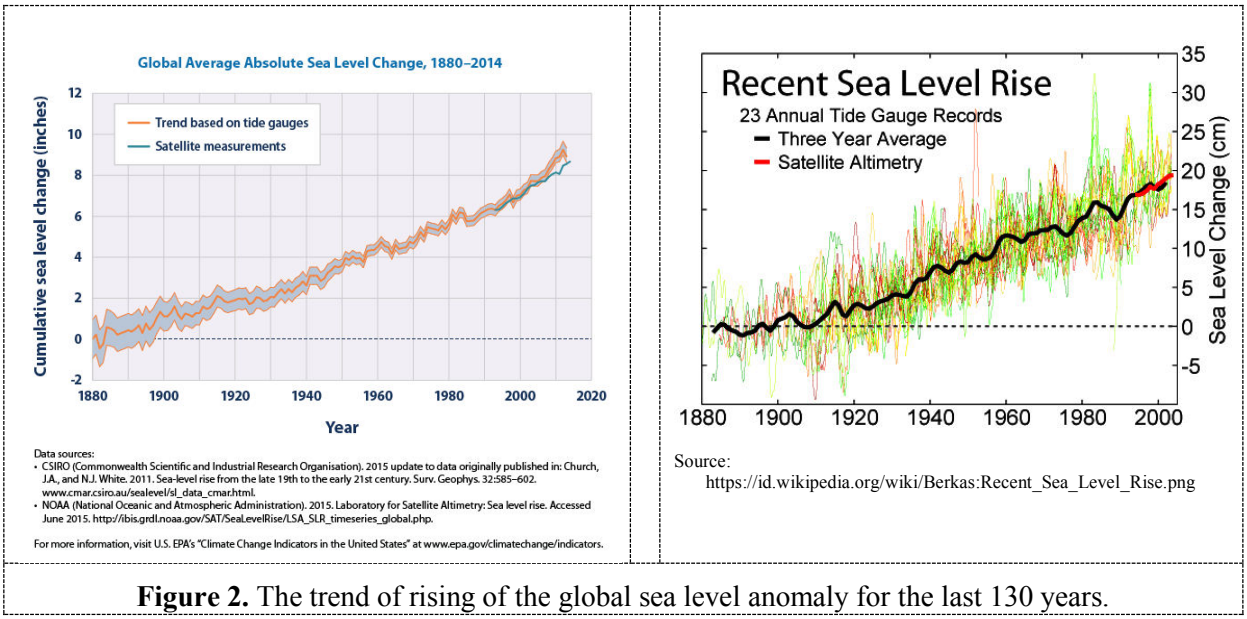

Figure 2. The trend of rising of the global sea level anomaly for the last 130 years.

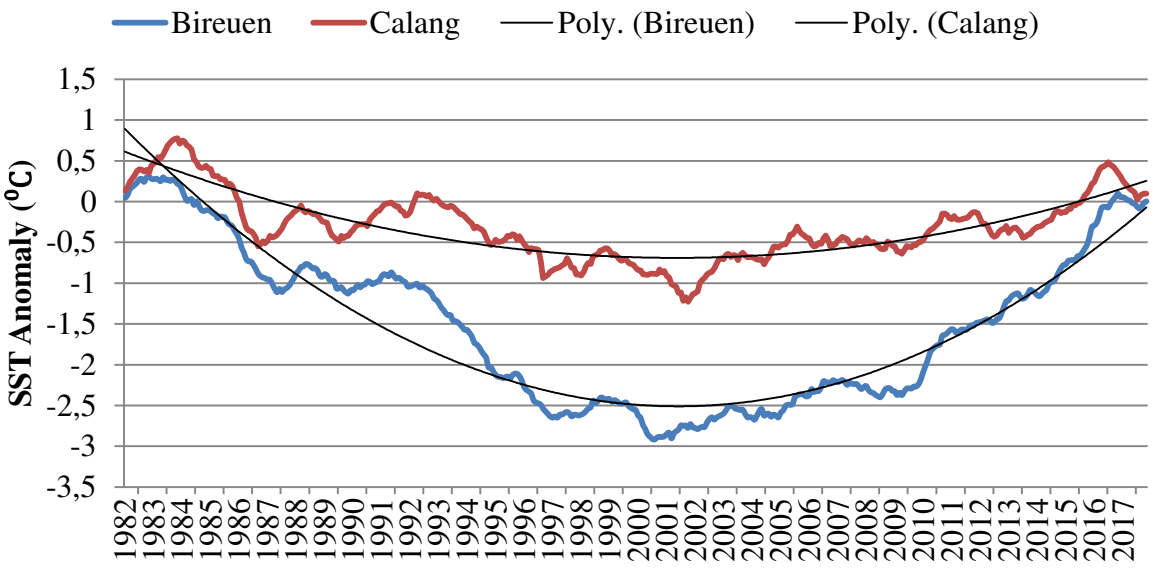

Figure 3. Sea-surface temperature anomaly (in centigrade).

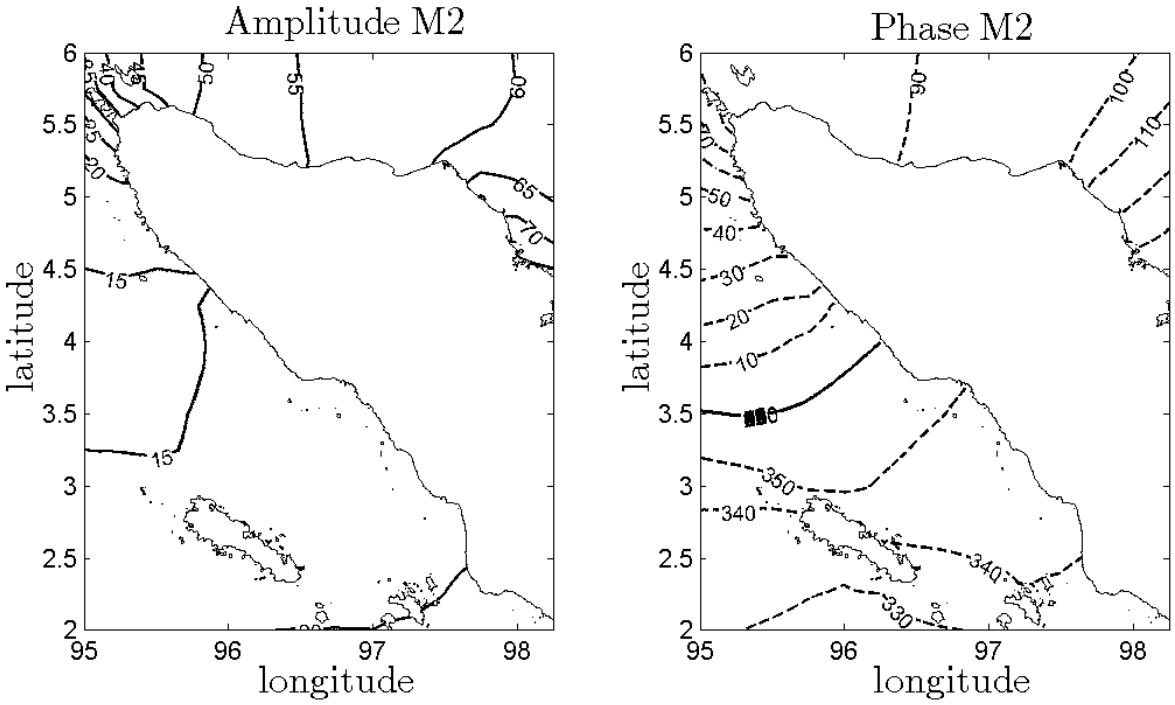

Figure 4. M2 Amplitude in centimeter and M2 Phase in degree.

Figure 4 shows the results of M2 Amplitude and M2 Phase [13]. Based on the amplitude result, the waters of North Aceh is greater than the West and South water. Figure 4 shows a close relation of amplitude and phase of Aceh water to the sea level rise data (Figure 1) which indicates that the sea level rise of North Aceh is larger compared to the West and South water. While the phase differences can be used to predict the mass flow patterns of water. The sea water movement is influenced by the difference between high to low tide.

Table 1. Tides harmonic component of Aceh waters

Location	M2		S2		K1		O1		Tide Type
	A (cm)	g (°)	A (cm)	g (°)	A (cm)	g (°)	A (cm)	g (°)	
Lhoknga	0.3023	81.36	0.1348	105.48	0.0944	208.33	0.0421	178.63	Mixed tide prevailing semidiurnal
Bireuen	0.4637	87.21	0.2075	119.54	0.1035	213.70	0.0437	181.73	Semidiurnal tide
Calang	0.1515	29.70	0.0748	51.64	0.0847	197.74	0.0432	170.39	Mixed tide prevailing semidiurnal

Table 1 shows the constant harmonic components of Lhoknga, Bireuen and Calang water. Based on these constants, the harmonic of semidiurnal tide and mixed tidal prevailing semidiurnal are found in Lhoknga and Calang water that represents west and south Aceh water. However, the Bireuen waters have the harmonic semidiurnal tide, which is located in the Malacca Strait. This location has a higher tidal elevation when compared to Lhoknga and Calang water which is directly opposite to the Indian

Ocean. The location and tidal height are basically very influential on sea level rise. Therefore, based on the sea level rise data in Figure 1, there is a greater increase in Bireuen water (northern waters) than Lhoknga and Calang waters (wester southern water).

The consequecy of the condition of Aceh sea level for the previous 25 years, based on data and water dynamic of Aceh water, we can assume that the northern part of Aceh coastal area will likely to lose ground faster than western and southern part of Aceh. Therefore, the management strategy for disaster risk reduction will have to be the focus on the northern part of Aceh coast rather than soutern one. In a long run, Aceh coastal area will still losing ground due to sea level rise either northern part or western and southern part of Aceh and both of them should be evaluated yearly for disaster management strategy.

4. Conclusions

For the last 25 years, the rising sea level in Aceh has reached about 4 cm or an increase of 0.16 cm per year. This linear increase will plunge the coastal areas of Aceh. Therefore, a preliminary evaluation of sea level rise can be a management strategy for disaster risk reduction to be implemented in Aceh's coastal areas.

References

[1] Mimura N, Harasawa H (Eds) 2000 Data book of Sea-Level Rise 2000 *Centre for Global Environment Research* National Institute for Environmental Studies, Environmental Agency of Japan.

[2] Susandi A, Herlianti I, Tamamadin M 2008 *Impact of climate change on sea levels in the Banjarmasin* Region ITB [in Indonesian].

[3] Soenarno 2003 *Review of aspects of spatial planning in the management of sea and coastal areas* Delivered at the 43rd ITS Dies Natalies General Seminar [in Indonesian].

[4] Ilhamsyah Y, Fadli N, Setiawan I, Haridhi HA 2014 Notes: coral reef bleaching in Weh Island, Indonesia, a natural climate variability or global climate change impact? *AACL Bioflux* **7(6)** 508-515.

[5] Irham M, Fadhla Y, Setiawan I 2018 The spatial distribution of suspended sediment analysis along Krueng Cut River, Banda Aceh *IOP Conf. Ser.: Earth Environ. Sci.* **106** 012066 doi: 10.1088/1755-1315/106/1/012066.

[6] Irham M, Miswar E, Ilhamsyah Y, Setiawan I 2018 The northern tidal dynamic of Aceh waters: A 3D numerical model *IOP Conf. Ser.: Mater. Sci. Eng.* **352** 012043.

[7] Irham M, Setiawan I 2017 The study of flow resulting from wave on Lhonga beach, Aceh Besar *OmniAkuatika* **13(1)** 5-12.

[8] Irham M, Setiawan I 2018 The numerical model of the sediment distribution pattern at Lampulo National fisheries port *IOP Conf. Ser.: Earth Environ. Sci.* **106** 012067 doi: 10.1088/1755-1315/106/1/012067.

[9] Purnawan S, Mailala NA, Karina S, Muhammad, Setiawan I, Ilhamsyah Y 2018 The beach slopes and grain size distribution at Anoi Itam and Pasir Putih Beaches, Sabang City *IOP Conf. Ser.: Earth Environ. Sci.* **176** 012013 doi: https://doi.org/10.1088/1755-1315/176/1/012013.

[10] Purnawan S, Setiawan I, Haridhi HA, Irham M 2018 Granulometric analysis at Lampulo Fishing Port (LFP) substrate, Banda Aceh, Indonesia *IOP Conf. Ser.: Earth Environ. Sci.* **106** 012070 doi: 10.1088/1755-1315/106/1/012070.

[11] Setiawan I, Irham M 2018 Wave trajectory study on the coast of Lhoknga, Aceh Besar, Indonesia: a numerical model approach *Civil Engineering Dimension* **20(1)** 30-34.

[12] Setiawan I, Rizal S, Haditiar Y, Ilhamsyah Y, Purnawan S, Irham M, Yuni SM 2018 Study of Current Circulation in the Northern Waters of Aceh *IOP Conf.* Ser.: *Earth Environ. Sci.* **176** 012016 doi: 10.1088/1755-1315/176/1/012016.

[13] Egbert GD, Erofeeva SY 2002 Efficient inverse modeling of barotropic ocean tides *Journal of Atmospheric and Oceanic Technology* **19(2)** 183-204.

Acknowledgments
Authors express gratitude to the Research and Community Service Institutions of Syiah Kuala University for financial assistance under 'Associate Professor Research Grants', with contract number: 288/UN11/SP/PNBP/2018. We also thank to Syiah Kuala University through the facility support at Ocean Modelling Laboratory during the research.