Analysis of Sea Level Changes in Balikpapan Bay as Basic Data for Strategic Planning the New Capital City of the Republic of Indonesia

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Abstract. Studies from various sectors are needed regarding the plan to move the capital city of the Republic of Indonesia from Jakarta to Penajam Paser Utara. The aquatic ecosystem that needs attention is Balikpapan Bay which is located in the vicinity of these activities. One of the factors that influences this is global warming. Therefore, it is necessary to analyze the variability and trend of sea level rise in front of Balikpapan Bay. The first mode of Empirical Orthogonal Function (EOF) shows that sea level around Balikpapan Bay has a strong correlation with the Multivariate ENSO Index (MEI). This indicates that the sea level in the area is predominantly influenced by ENSO. A strong correlation between the first principal component and MEI was found to be around -0.85 in Balikpapan Bay (significance level> 95%). Based on sea level anomaly data for the last 20 years, sea level in Balikpapan has increased with a linear trend of 5.4mm / year, with a decreasing trend due to El Niño and an increasing trend due to La Niña.

1. Introduction

Planning for the development of the new capital city of the Republic of Indonesia has been initiated since the establishment of the area in Penajam Paser Utara, East Kalimantan as a replacement for the capital city of Jakarta as the current capital city ([5], [9]). Good planning is needed so that the unfavorable conditions, which are happening in Jakarta at the moment, are expected not to happen in the future in the area of Penajam Paser Utara. Penajam Paser Utara is located in the north-west part of Balikpapan Bay. The waters of Balikapapan Bay, which are semi-closed and are the estuary of several rivers, are influenced by the mass of fresh water and sea water mass from the Makassar Strait ([4], [8]) Environmental change can occur due to global climatic factors as well as an increasing environmental burden due to the large increase in population. This paper will discuss about global climate change that can affect sea level rise in the sea around Balikpapan Bay. One of the parameters is the change in sea surface temperature and its effect on sea level rise. The rise in sea levels can be triggered by climate variability that occurs in a region, such as El Niño-Southern Oscillation (ENSO). El Niño causes a global mean sea level rise and La Niña causes a global mean sea level decrease [1]. During the era of altimetry, a strong El Niño occurred in 1997/1998 which caused the global mean sea level to rise about 20 mm ([2], [7]). In the Western Pacific including east Indonesia and Makassar Strait, El Niño causes a mean sea level decrease and La Niña makes sea levels rise [10].

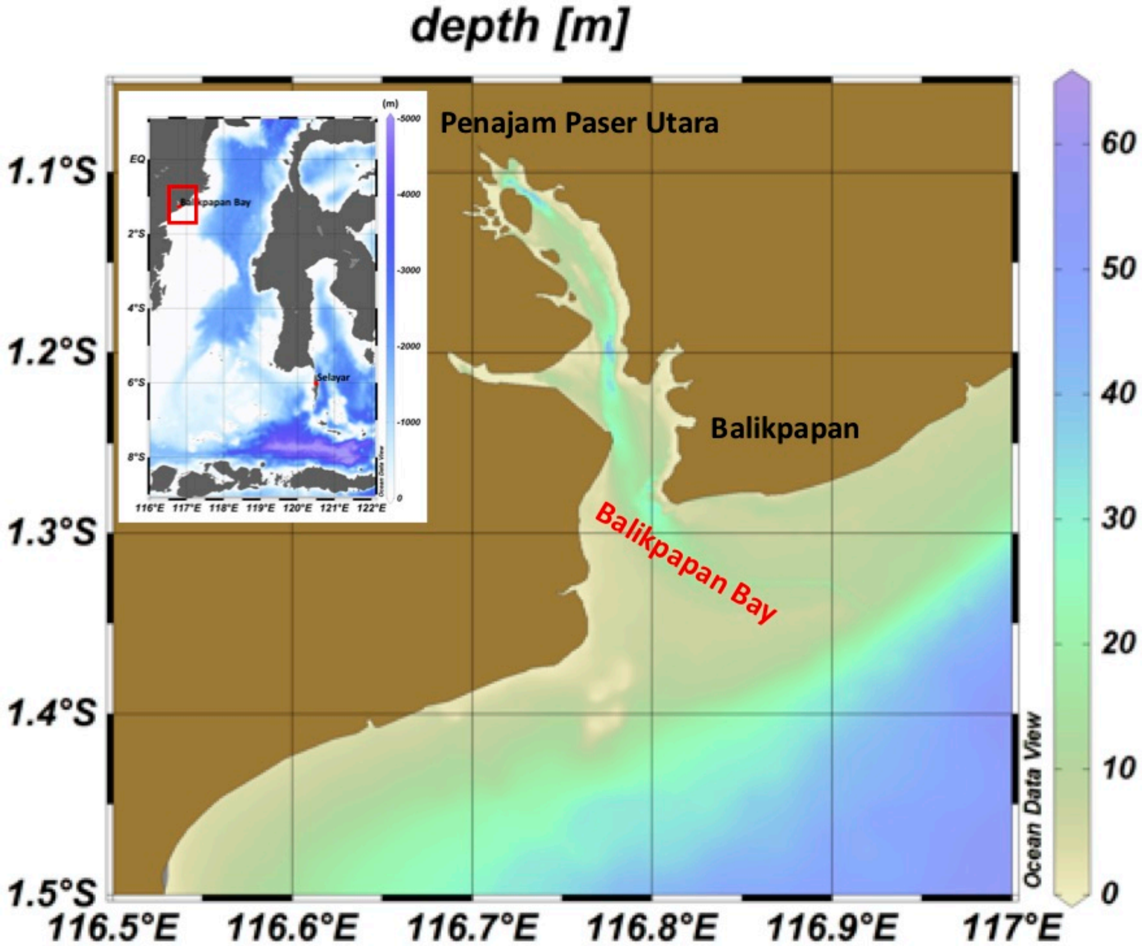

Figure 1. Research Location of Balikpapan Bay and Surroundings

2. Materials and Methods

The Mean Sea Level Anomaly (MSLA) data from multi-satellites (HY-2A, Saral/AltiKa, Cryosat-2, Topex/Poseidon (T/P), Jason-1, Jason-2, Envisat, ERS-1, and ERS-2 ([14] and [15])) was used. The mean sea level anomaly data used in this research was Delayed Time Mean Sea Level Anomaly (DT-MSLA), from January 1993 until December 2012, with a Cartesian grid of 1/4° × 1/4°. When analyzing the effect of ENSO on sea level rise, the 13 months low pass filter to remove seasonal variation has been done [12]. Multivariate ENSO Index (MEI) was used to indicate ENSO [13]. The MEI data was defined based on six atmospheric and sea variables along the tropical Pacific [11], which were: sea level pressure

(P), zonal wind surface (U), meridional wind surface (V), sea surface temperature (S), atmosphere surface temperature (A), and cloud (C).

Data was processed using the Empirical Orthogonal Function (EOF, also known as Principal Component Analysis). With EOF, data is transformed into a linearly independent set of data consisting of variables that have variations from the largest to the smallest (Preisendorfer, 1988 in [7]). The equation for sea level anomaly using EOF is shown by Equation 1.

$$H(x, y, t) = \sum_{i=1}^{N} U(x, y)\alpha(t) \quad (1)$$

$H(x, y, t)$ shows sea level anomaly in a specific position and time, $U(x, y)$ shows spatial pattern, $\alpha(t)$ shows temporal amplitude, i is an EOF mode, and N is the number of EOF mode [6]. The analysis of EOF can be calculated using Singular Value Decomposition (SVD). The SVD equation is shown by Equation 2.

$$D = USV^T \quad (2)$$

U is defined as in the previous equation, S is a diagonal matrix that contains singular value from D and V in Equation 2 shows the temporal Eigen-mode. SV^T can be written as $\alpha(t)$ in Equation 2.1. The Spatial component will have the same unit as sea level data, and temporal component (principal component) will be normalized [7]. Before using SVD, spatial and temporal mean from the data were removed as in [3]. The purpose of removing spatial and temporal mean is to delete spatial effect such as gyre, front, and temporal variations.

3. Results and Discussion

The anomaly data for the mean sea level that has been filtered for 13 months (low pass filter) shows an increase in sea level at a rate of 5.4 mm / year in Balikpapan Bay (Figure 2). Based on the graph below, it can be seen that the rate of sea level is related with the climate variability of the El Niño-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The correlation of mean sea level anomaly with ENSO is -0.85 and still with PDO of -0.74. During a strong El Niño in 1997-1998 there was a decrease in sea level by 120 mm and during a strong La Niña in 2010-2011 there was an increase in sea level of 180 mm.

The results of Principal Component (PC) in the first mode show that the anomaly in the water level is influenced by ENSO with a correlation of -0.83. During El Niño the sea level has decreased as in 1997-1998, while during La Niña the water has increased.

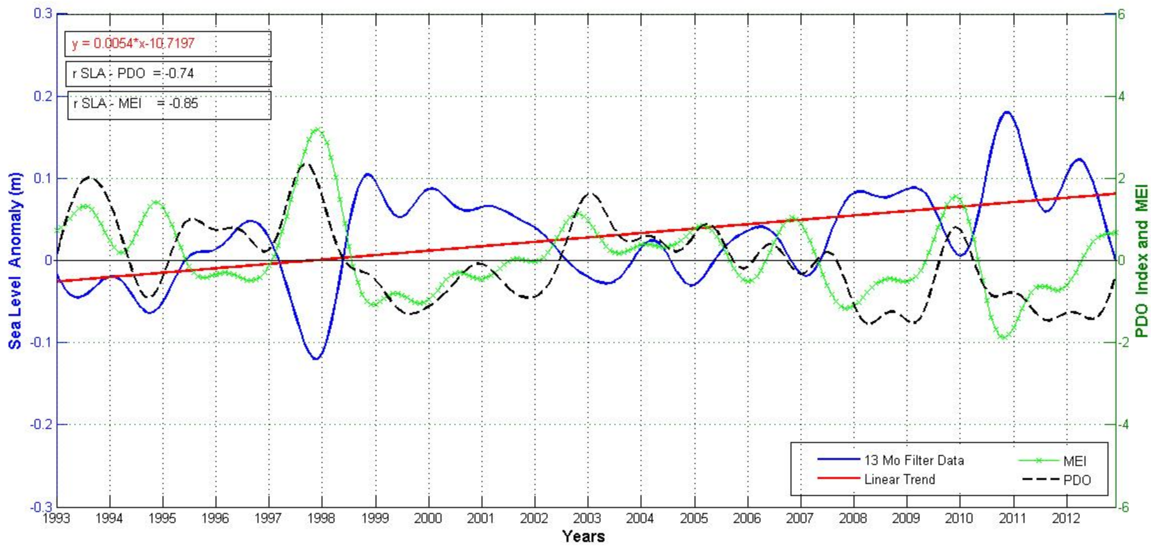

Figure 2. The average sea level anomaly of Balikpapan Bay in 1993-2012 and its connection with the Multivariate ENSO Index (MEI) and the Pacific Decadal Oscillation (PDO) Index.

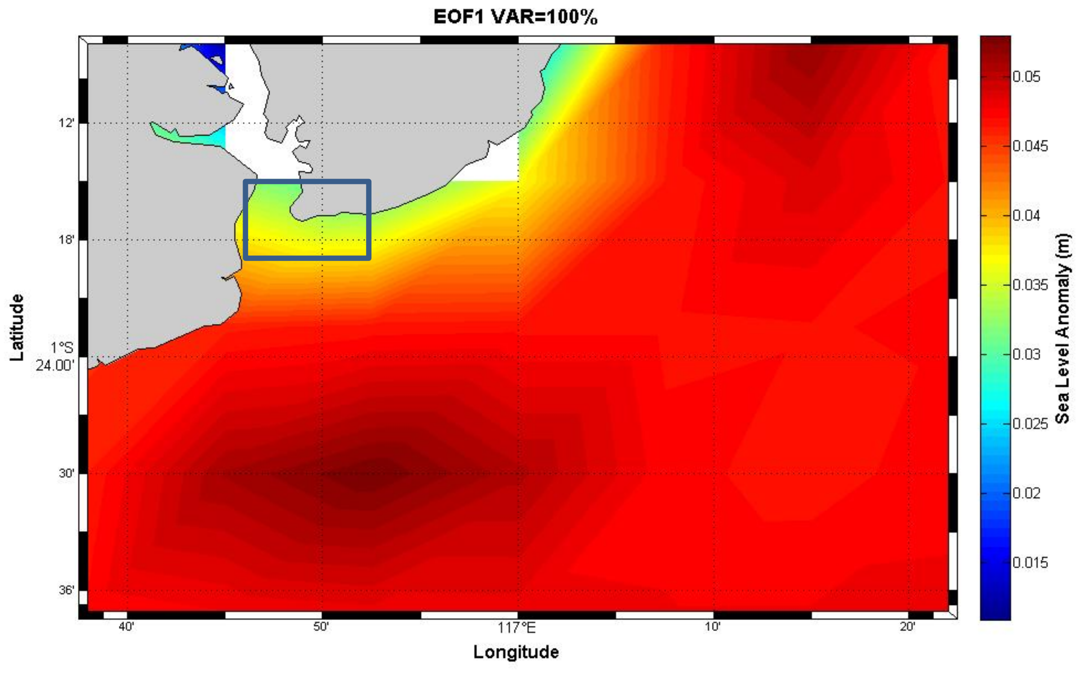

Figure 3. The first EOF mode of the mean sea level anomaly in 1993-2012 around Balikpapan Bay.

As one of the comparisons of the results in Balikpapan Bay, it can be seen the conditions south of the Makassar Strait, namely in the waters of Selayar Island. The sea level trend in Selayar is 5.8 mm / year. The correlation between sea level anomaly and ENSO is -0.83 (significance level> 95%) (Figure 4). Due to strong El Niño (1997/1998) the sea level fell by 120 mm and rose by 180 mm due to strong La

Niña (2010/2011) in Selayar waters. The trend of sea level decline due to El Niño is 7.5 mm /decade, and the increase due to La Niña is 65.7 mm /decade.

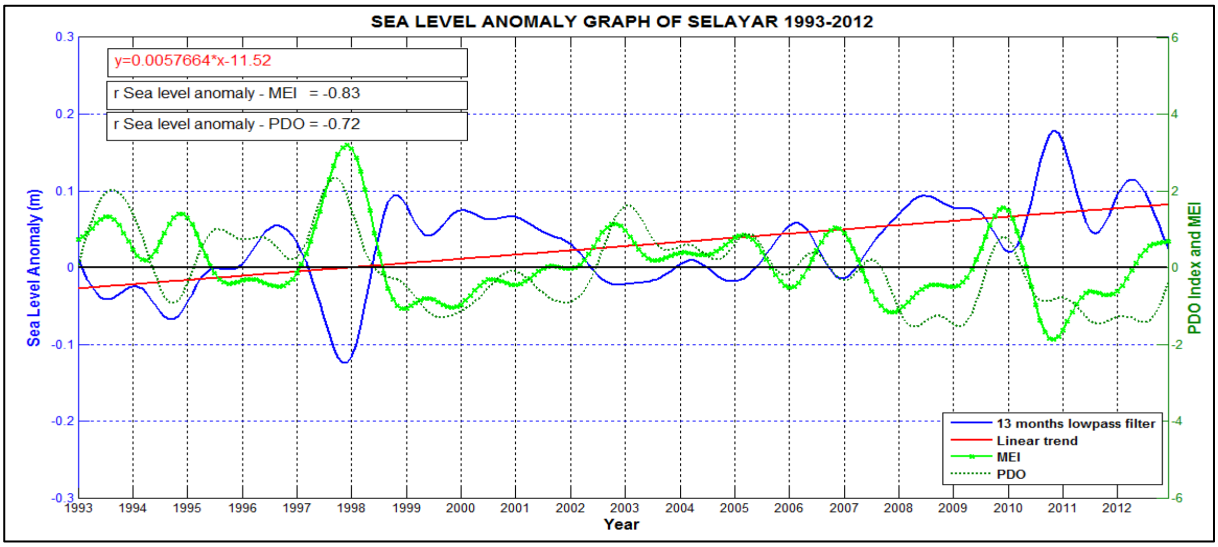

Figure 4. The average sea level anomaly of Selayar Island in 1993-2012 and its connection with the Multivariate ENSO Index (MEI) and the Pacific Decadal Oscillation (PDO) Index.

The first EOF mode indicates that the greatest variability affecting sea level is ENSO. The first mode has a variation of 99%. The correlation between PC1 and MEI is -0.81 without time lag (significance level > 95%), which means that sea level responds directly to ENSO events. The results of the amplitude spectrum calculation show that the amplitude peaks occur over a period of 10 years and 2.5 years.

4. Conclusion

Sea level variation has a strong relationship with ENSO on interannual and decade time scales; evidenced by the strong correlation between PC1 and MEI. There is a strong correlation between PC1 and MEI in Balikpapan Bay to Selayar Island or it can be said that along the Makassaar Strait without any time delay, which means that sea level is directly responded to by ENSO events. In the Balikpapan Bay, the sea level trend was 5.4 mm/year, while in Selayar island it is slightly higher, up to 5.8 mm/year. New national capital development should be considered the sea level rise for the long-term. We assume the natural condition in the whole Balikpapan Bay has a similar characteristic with the mouth section. Thus, along the Balikpapan Bay coast, including estuary and mangrove areas, sea-level rise will be affected with a rate of 5.4 mm/year. If Balikpapan Bay's natural changed, it should be higher the natural rate of sea-level rise.

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