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Sea Level Fluctuations and Rates in the Kenjeran Coast, Surabaya and Its Surroundings

Viv Djanat Prasita[1], Nur Asyiah Agustina[2], Supartono[3]

[1]Department of Oceanography, Faculty of Engineering and Marine Science, Hang Tuah University, 60111, Surabaya, Indonesia

[2,3]Department of Marine Engineering, Faculty of Engineering and Marine Science, Hang Tuah University, 60111, Surabaya, Indonesia

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Corresponding Author: **Viv Djanat Prasita**

ABSTRACT

Kenjeran is one of the famous tourist areas in the city of Surabaya with a population of 7,021 people, most of which are concentrated in the coastal area. The coastal area of Surabaya is an area that is affected by sea level rise. Therefore, the purpose of this study was to determine the types of tides that exist in the Kenjeran Region of Surabaya and how much sea level fluctuations and the rate of sea level rise were using real time tidal data for 2014-2021 and Altrimetry satellite data in the period 2002-2021. The analytical method for tidal calculations was the Admiralty calculation and other method was linear regresion method. Based on the results of processing and calculating the tidal type data in the Kenjeran Region, it was classified as a mixed tidal type tend to the double daily tidal type. The new finding was that the fluctuation values of each data were very different. However, there was a similar pattern of relationship between data obtained from BIG and Altimetry satellites in the period 2014-2021 and 2002-2021, namely the trend of increasing MSL rate based on monthly and annual data. In altimetry satellite data, the differences in sea level rates that occured in the Kenjeran Region in the span of 7 years and 20 years showed a significant difference.

KEYWORDS: Fluctuation, mean sea level, tides

I. INTRODUCTION

Global warming at this time is estimated to increase sea surface temperatures so that the polar ice caps melt, and result in global sea level rise. According to IPCC, 2018, Global mean sea level (GMSL) was increasing with a probability of 99% to 100%. Abdulateef and Naheem (2021) also explained that global mean sea level rise was attributed to thermal expansion of water bodies and melting of glaciers, while regional sea level rise was caused by tidal interactions. This effect of sea level rise had several negative impacts on the environment that appear to have affected human life.

Tides were rhythmic fluctuations (movements up and down) of sea level due to the attraction of objects in the sky, especially the moon and sun, to the mass of sea water on earth. The moon and sun exert a gravitational force on the earth whose magnitude depends on the mass of the objects that attract each other. The mass of the moon is much smaller than the mass of the sun, but because it is much closer to the earth, the effect of the moon's attraction on the earth is greater than the effect of the sun's attraction. The attraction of the moon which affects the tides is 2.2 times greater than the attraction of the sun. Tides in Indonesia are divided into several types, which are influenced by topography and territorial boundaries in a waters. Calculation of Mean Sea Level (MSL) is important to study because tidal fluctuations are needed as indicators in various human activities, one of which is as a reference in planning, managing coastal areas and building coastal structures and tides are also one of the causes of sea level rise (Mahatmawati, et al., 2009).

The potential impact of sea level rise on densely populated islands, lowlands and coastal areas indicated that this was an urgent problem that requires deep-rooted countermeasures (Mucova, et al., 2021). Handiani, et al., 2019 explained that the issue of sea level rise due to global warming was a separate threat to coastal areas in Indonesia. The city of Surabaya, especially the coastal area of North Surabaya, was identified as an area that was prone to waterlogging from overflows of river and channel water discharge during the rainy season and tidal flooding due to the impact of rising sea levels. Global sea level rise would affect coastal areas, which provide a number of benefits for the tourism sector (Ritphring, et al., 2021). By looking at the conditions and impacts of sea level rise in the city of Surabaya, it would directly affect the lowland areas located in the coastal area.

Therefore, the restriction area that would be reviewed further was focused on the coastal area (Prasita and Kisnarti, 2013).

In the Surabaya City Spatial Plan for 2014-2030 regarding policies and strategies for determining spatial patterns, one of the steps to minimize risk and reduce disaster vulnerability was to manage areas prone to natural disasters such as areas prone to tidal waves, tidal flood prone areas through identification of risk levels, areas prone to natural disasters. According to Arini, et al. (2018), the Tanjung Perak Maritime BMKG estimated that every year the Surabaya Coastal Area experiences tidal flooding and in one year there were about 4 to 5 times the danger of flooding above the average sea level (Mean Sea Level). This was the urgency of doing this research.

Currently, sea level rise is very interesting to discuss because of its potential impact on existing residents in coastal areas and islands. In Indonesia, about 65% of the population live on the coast. Therefore, the impact of sea level rise was very influential on housing and livelihoods. Livelihoods were related to several sectors, including: fisheries and marine, transportation/ports, marine tourism. Surabaya was part of the lowlands with an average height of 3-6 meters above sea level (Prasita and Kisnarti, 2013). The eastern part of Surabaya is a coastal area that has the potential to be affected by sea level rise, even though this area has small wind and wave conditions (Prasita, 2022).

Tidal data used in this study were primary data and secondary data. Primary data were real-time data taken directly from field observations. This real-time tidal data was obtained from the Geospatial Information Agency (BIG) for 2014-2021. BIG is one of the Non-Ministerial Government Institutions (LPNK) and was born to replace the National Survey and Mapping Coordinating Board (BAKOSURTANAL). Implementation of basic geospatial information which includes data collection, processing, data and information storage, and use of basic geospatial information. BIG itself has built and managed 159 tidal stations distributed throughout Indonesia in 2019 (BIG, 2021). Measurement of sea level has actually been done for a long time. According to Wau, et al., 2022, the measurement of sea level rise was carried out using tides. However, nowadays, with the development of technology, the measurement of sea level can be done in various ways, one of which is using satellite imagery. From this satellite image, various data can be recorded. In this study, secondary tidal data used were obtained from Altimetry satellite imagery. Satellite altimetery observation processing was developed over the last few decades to generate new and unprecedented observational datasets of sea surface anomalies (SLAs) and geostrophic velocity anomalies in the subpolar ocean (Mati, 2022).

Satellite altimetry is one of the satellite technologies that is currently widely used as a method for monitoring the dynamics of the Earth. The advantages of this method are: 1) measurement range/area that covers almost the entire surface of the Earth or is global, 2) continuous satellite missions resulting in long data periods, 3) measurement accuracy that is constantly increasing, and 4) data that is easily accessible (free). Based on their orbital periods, various altimetry satellite systems can be classified into past, current, and future altimetry satellite missions. On the Aviso website, it is stated that until now there have been 12 altimetry satellite missions, one of which is the Jason-2 satellite mission. The Jason-2 satellite was launched in 2008 with a mission to observe sea level globally. The Jason-2 altimetry satellite is an extension of the Topex/Poseidon and Jason-1 missions (Khasanah et al., 2017).

Seeing the importance of sea level rise information for coastal area management and the differences in the data obtained, the purpose of this study was to determine the types of tides in the Kenjeran area of Surabaya and the sea level fluctuations and the rate of sea level rise with using in situ and satellite tidal data.

II. MATERIALS AND METHODS

The research location was as shown in Figure 1, namely in the Kenjeran Region, Surabaya, East Java. The primary data for tidal observations was taken directly by BIG and secondary data was downloaded from the results of the Altimetry Satellite. The observations made by BIG were at the Surabaya station with the station code SRBY, located at the PT. PAL, Semampir, Ujung, Surabaya with coordinates 07.20006° South Latitude and 112.7406° East Longitude. While the tidal data recording from the Altimetry satellite image was located at coordinates 7,225° South Latitude and 112.875° East Longitude.

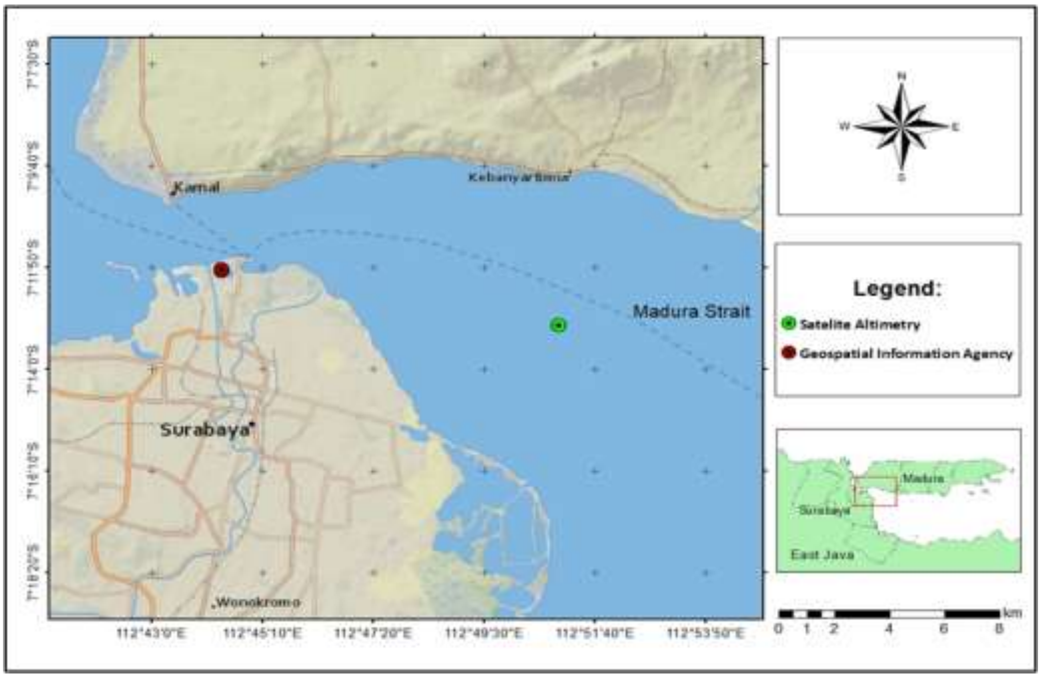

Figure 1. Tidal Observation Location Map

The flowchart of this research was shown in Figure 2. Data were collected from two different sources, namely: data from BIG and data from Altimetry satellites. The calculation of the harmonic constant was calculated from one month from the BIG data to determine the type of tide in the Surabaya area. Analysis of annual data in 2014-2021 and 2002-2021 from these two data sources was used to determine the annual rate of sea level rise, both 7 years and 20 years.

The data used in this research include: Field data (in situ) of tides obtained by recording conducted by the Geospatial Information Agency (BIG) in 2014-2021. The location of the station and the Bench Mark (BM point) owned by BIG which is at PT. PAL was shown in Figure 3.

Figure 2. Flowchart of Sea Level Rise Research in Kenjeran Surabaya

Figure 3. Building Location of Tidal Observation Station and BM Point in Surabaya

Tidal data obtained from Altimetry Satellite imagery for 2002-2021 can be accessed through the website https://www.aviso.altimetry.fr. The technique of recording data on altimetry satellites was an extraterrestrial sea level observation technique. The altimetry satellite was equipped with a radar pulse transmitter, a sensitive radar pulse receiver, and a high-accuracy clock. At the time of data acquisition, the altimetry radar carried by the satellite emited pulses of electromagnetic waves to the sea surface. The pulse was reflected back by the sea surface and received back by the satellite (Khasanah et al., 2017).

A. Tidal Harmonic Constants

The tidal harmonic constants are divided into three, namely the mid-day component, the daily component and the long-period component. Due to the periodic nature of the tides, it can be predicted. To predict the tides, data on the amplitude and phase difference of each component of the tidal generator are needed. The main components of tides consist of the mid-day and daily components. However, due to the interaction with the shape (morphology) of the coast and the superposition between the main component tidal waves, new tidal components were formed (Suyarso, 1989 in Mahatmawati et al., 2019).

The admiralty method is a tidal calculation method used to calculate two components/harmonic constants, namely amplitude and phase difference. The process of calculating the Admiralty method is calculated with the help of tables, where for the time of observation that is not tabled, an approach and interpolation with the help of tables must be made. The process of calculating the harmonic analysis of the Admiralty method is carried out by developing a formula system calculation with the help of Excel software, which will produce the prices of several parameters that are tabled so that the calculations in this method will be efficient and have high accuracy and are flexible for any time (Mahatmawati, et al., 2009).

The data were analyzed using the 29-day Admiralty method so that the final result was known components of tidal induction in the Kenjeran area of Surabaya which were used to determine the value of MSL, LLWL, HHWL and types of tides. The amplitude value (A) was used to determine the Formzahl value (F) to obtain the tidal type at the research site (Westplat, et al., 2017). The results of the admiralty method processing were 9 (nine) main tidal constants, namely: M2, S2, N2, K1, O1, M4, MS4, K2 and P1. The next process, to determine the type of sea tide, Formzahl numbers can be used, namely by calculating the Formzahl number calculation formula according to (Fitriana et al., 2022) with equation 1 as follows:

$$F = \frac{A(K_1) + A(O_1)}{A(M_2) + A(S_2)} \quad [1]$$

Where, F is the formzahl number, A(K1) the amplitude of the tidal generating element K1, A(O1) the amplitude of the tidal generating element O1, A(M2) the amplitude of the tidal generating element M2, A(S2) the amplitude of the tidal generating element tidal generator S2. While the other constants are N2: Harmonic constant which is affected by changes in the distance of the moon, K2: Harmonic constant which is affected by changes in the distance of the sun, O1: Harmonic constant which is affected by the declination of the moon, P1: Harmonic constant which is influenced by declination of the sun K1: Harmonic constant which is affected by the declination of the sun affected by the declination of the sun and the moon M4: Harmonic constants affected by multiple effects MS4: Harmonic constants affected by the interaction between M2 and S2.

Where the results of the F value will determine the type of tide, with the classification according to the F value resulting from the calculation of equation 2 above, the classification is in accordance with Table I as follows:

Table I. Tidal Classification

Formzahl Number	**Tidal Types**
$0 < F \leq 0{,}25$	Semidiurnal Tides
$0{,}25 < F \leq 1{,}5$	Mixed tend to Semidiurnal Tides
$1{,}5 < F \leq 3$	Mixed tend to Diurnal Tides
$F > 3$	Diurnal Tides

B. Sea Level Fluctuation Chart

Tidal data obtained from BIG at Surabaya station in 2014–2021, had been processed to produce monthly MSL values which were then averaged annually for 7 years, resulting in annual MSL values in 2014-2021. Monthly and yearly MSL values were displayed in tabular form to make it easier to see the resulting value and in graphical form to see annual sea level rise fluctuations.

C. Method of Analysis of Sea Level Rise Rate

The rate of sea level rise was obtained based on the value of MSL (Mean Sea Level) tidal data recorded by the Surabaya measurement station BIG from 2014-2021 and tidal data that has been downloaded from the Altimetry Satellite from

2002-2021 which was analyzed using a simple statistical regression method with Microsoft Excel software.

The daily tidal data was processed so that the monthly MSL value was obtained, then the monthly MSL value was averaged to produce the MSL value every year (Shalsabilla, et al., 2022). Next, the difference in the MSL value calculated each year which was then averaged so as to get the results of the annual rate of sea level rise based on tidal data from 2014-2021. Monthly and annual MSL values were presented in the form of tables and graphs in time series so that changes in the position of sea level were seen within a period of 7 years.

Trend analysis was carried out to determine the sea level rise that occured. The data included in this analysis were data that has been calculated using the admiralty method, data that had been processed into a graph using Microsoft Excel (Kisnarti and Prasita, 2014). To found out the sea level rise that occured, observational data were used in comparison of data obtained from BIG and satellites in 2014-2021 as well as comparison of trends over a period of 7 years and 20 years.

III. RESULTS AND DISCUSSION

A. Tidal Harmonic Constant

The results of the calculation of the tidal harmonic constant using the admiralty method and the tide chart in July 2021 are shown in Table II.

Table II. Calculation of the tidal harmonic constant

	S0	M2	S2	N2	K1	K2	O1	M4	MS4	P1
H	123,83	36,69	113,11	-0,32	60,31	30,54	26,35	,62	5,16	19,9
g°	-	298,32	322,48	106,17	209,98	322,48	137,36	30,82	75,71	569,98

The Formzhal value was obtained from the calculation of the tidal harmonic constant, namely the components AK1, AO1, AM2 and AS2. AK1 constant amplitude; AO1 and AM2; AS2 which was worth 60.31; 26.35 and 36.69; 113.11. The results of the amplitude of this constant produced a Formzhal (F) value of 0.58 in the Kenjeran area of Surabaya, as shown in Table 1, the Formzhal number with a range of 0.25> F F < 1.50 was included in the category of mixed tidal type with a daily trend. Double. In one day there were two high tides and two low tides with very different heights and periods.

The hourly chart showed that fluctuations in one day have two highs and lows, however, fluctuations in the highest and lowest tides occur around 03.00-14.00, while at 17.00-23.00 the fluctuations in tides and lows were not as significant as shown in Figure 4.

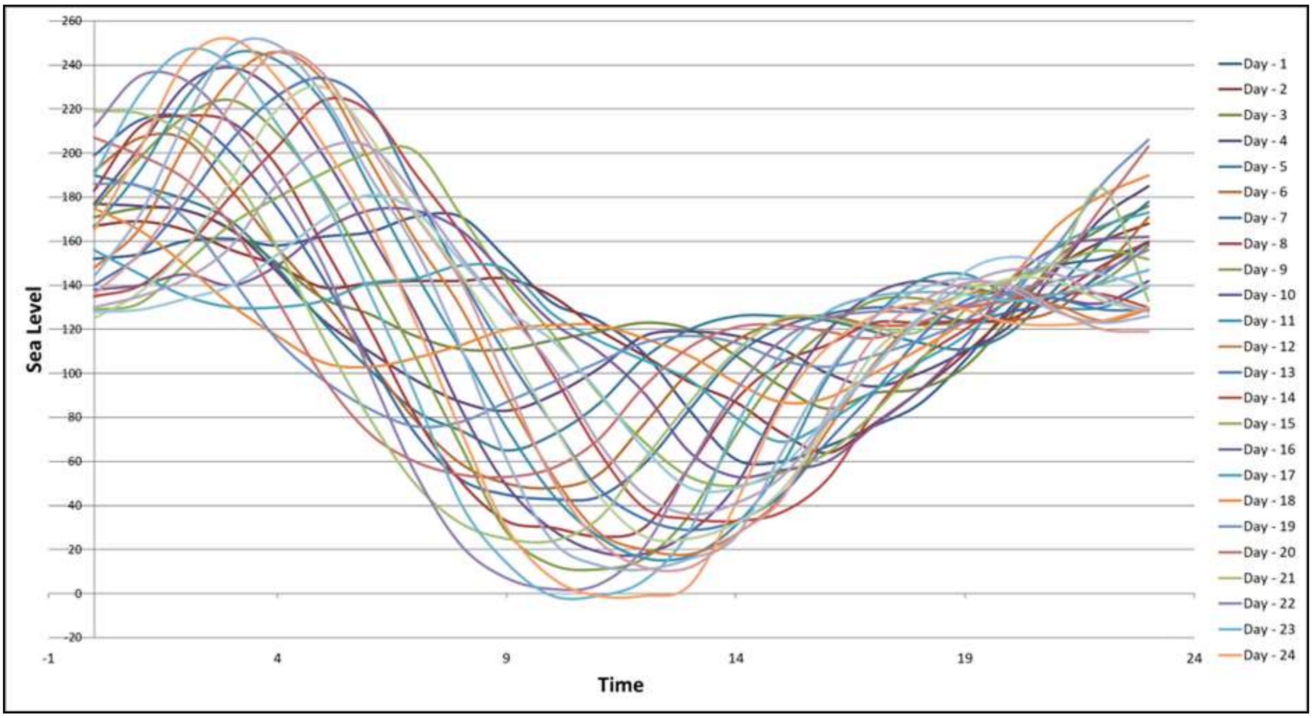

Figure 4. Hourly Tidal Chart for Surabaya Waters in July 2021

Graph Daily fluctuations very clearly showed that the tides in the Kenjeran Region occured twice, with high tides and low tides, with different levels of fluctuation. This was shown in Figure 5.

The highest value or HHWL of tidal fluctuations in July reached 252 cm while the lowest value or LLWL reached -1 cm which occurred on July 24, 2021 with the MSL position value of 123.83 cm.

B. BIG tidal fluctuations in 2014-2021

The processed monthly and annual MSL values were presented in Table III. and it was seen that the monthly and annual MSL values tended to fluctuate. From the average annual value obtained, it can be seen that the MSL value in the Kenjeran Coast Region has increased in 2016 and continues to increase starting in 2020 and there were also decreases such as in 2015 and 2018. The highest MSL value occurred in 2021 with an average The monthly MSL was 120.91 cm.

The resulting monthly MSL fluctuations in the Kenjeran Region were also presented in a graphical form as shown in Figure 6 so that an increasing trend of MSL value of 0.1046 cm was seen every year for a period of 7 years during 2014-2021. The highest value or HHWL of tidal fluctuations in July reached 132.73 cm in 2016 while the lowest value or LLWL reached 99.63 cm which occurred in 2019 with an annual MSL position value of 112.60 cm.

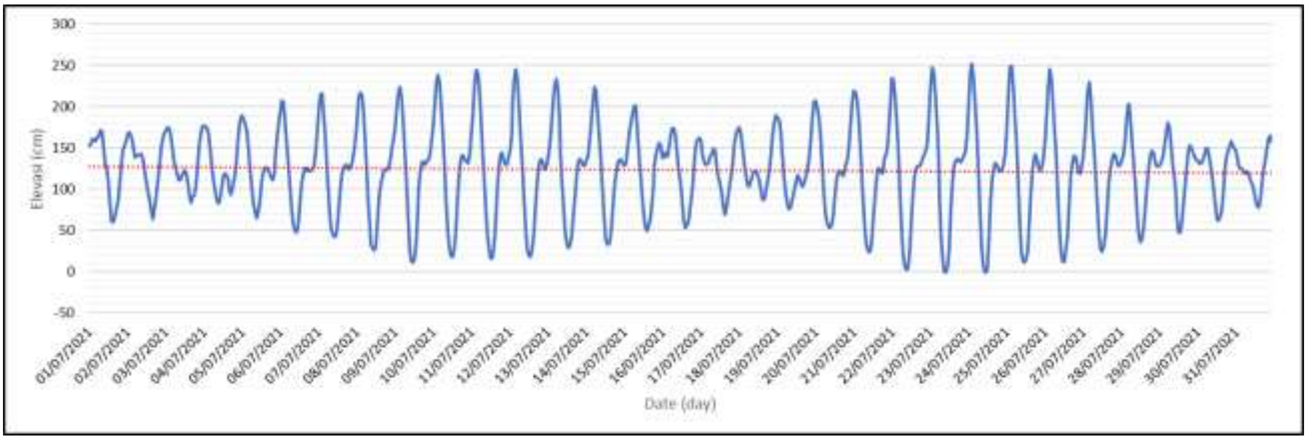

Figure 5. Daily Tidal Chart for Surabaya Waters in July 2021

Table III. Monthly and yearly MSL values from BIG Data

Month/Year	2014	2015	2016	2018	2019	2020	2021
January	121,03	117,40	103,98	113,33	99,63	105,62	122,76
February	105,15	105,28	106,91	104,93	106,64	105,48	116,18
March	104,92	106,53	105,47	103,35	102,56	110,24	116,32
April	109,28	110,70	112,81	109,18	113,85	114,57	121,26
May	117,71	116,01	122,05	114,42	116,20	124,22	121,96
June	117,34	112,17	132,73	110,75	113,84	127,45	127,18
July	115,09	108,03	125,89	106,00	110,07	119,42	123,67
August	110,34	105,45	119,66	111,86	106,33	115,25	117,44
September	104,67	101,35	122,14	100,55	103,85	114,82	116,65
October	103,84	102,08	124,60	101,32	103,18	117,51	114,38
November	107,02	104,01	125,11	103,08	100,05	119,79	126,62
December	113,41	103,81	127,99	103,32	100,18	122,57	126,45
MSL	**110,82**	**107,73**	**119,11**	**106,84**	**106,36**	**116,41**	**120,91**

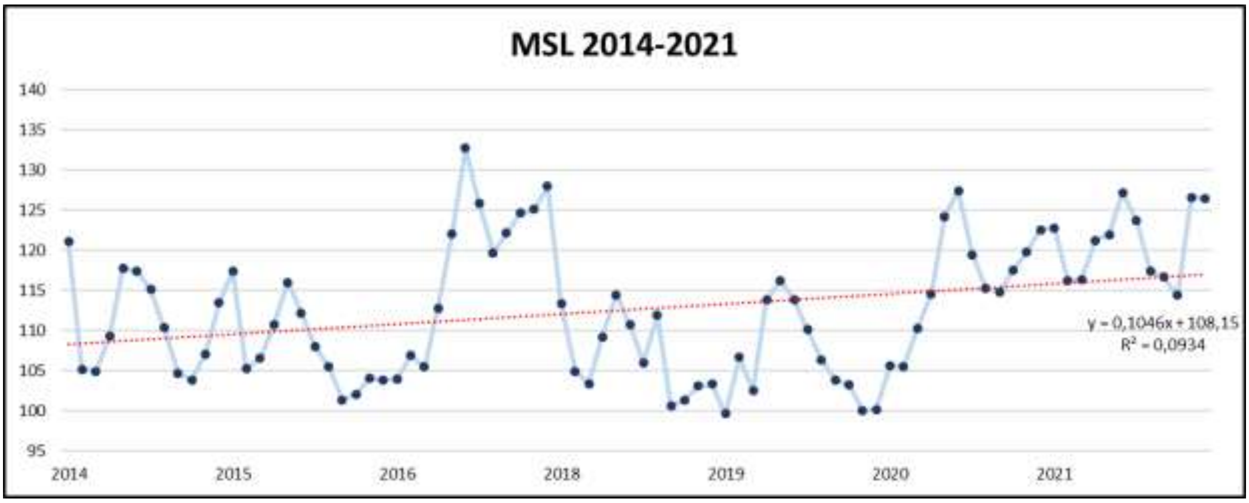

Figure 6. Monthly MSL Value Chart with In Situ Data

C. Altimetry Satellite Tidal Fluctuations in 2014-2021

The monthly and annual MSL values in Table IV also tend to fluctuate. From the annual average value obtained, it can be seen that the MSL value has increased and decreased every year. The increase in sea level rise occurred in 2016, 2020 to 2021. The highest MSL value occurred in 2021 with an average monthly MSL of 162.35 cm.

Table IV. Monthly and yearly MSL values from Satellite Altimetry

Month/Year	2014	2015	2016	2018	2019	2020	2021
January	104,00	176,35	38,90	158,96	47,38	1,50	205,60
February	66,93	15,38	28,52	82,55	-10,23	35,05	167,53
March	20,54	30,14	-8,78	58,40	54,53	16,88	120,72
April	56,90	58,53	61,48	115,86	118,54	68,85	186,88
May	95,10	141,73	135,00	147,25	167,90	144,78	182,46
June	101,40	64,08	256,78	88,63	96,20	138,90	242,38
July	62,60	-9,93	178,20	44,30	46,40	48,28	176,20
August	57,20	-43,38	145,54	9,35	14,43	71,18	131,74
September	1,30	-101,25	164,00	-27,88	-15,70	101,50	98,43
October	-7,35	-71,88	162,12	3,74	-44,50	74,65	104,38
November	49,83	-37,92	177,30	30,45	-2,80	104,28	205,40
December	124,10	32,15	174,18	64,50	-5,78	157,53	126,45
MSL	**61,05**	**21,17**	**126,10**	**64,68**	**38,86**	**80,28**	**162,35**

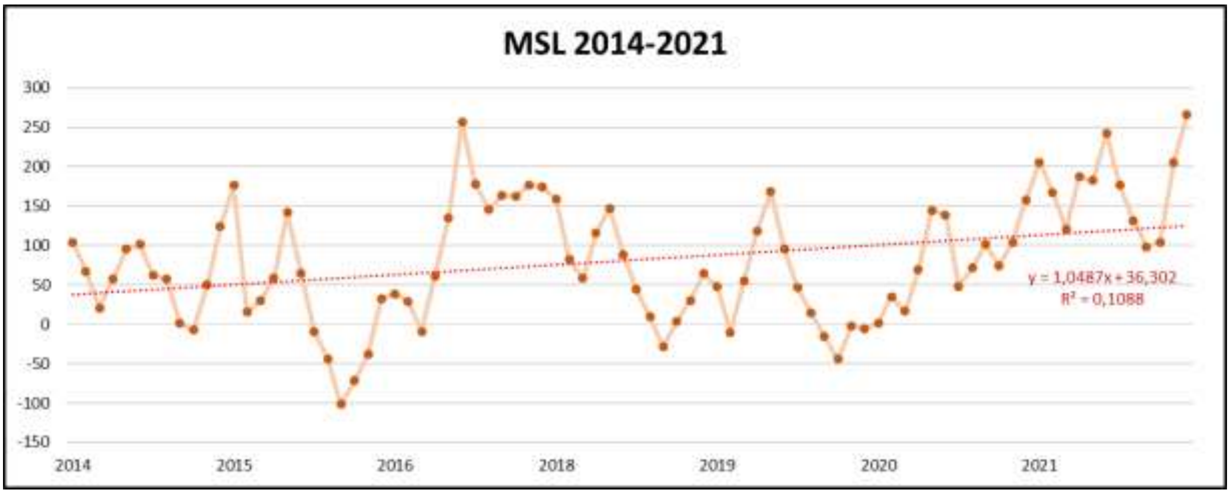

Figure 7. Monthly MSL Value Chart with Satellite Data

The results of processing from Excel, the monthly MSL value in the Kenjeran Coastal Area was presented in graphical form as in Figure 7. It can be seen that the trend of increasing the MSL value was 1.0487 cm every year for a period of 7 years during 2014-2021. The highest value or HHWL of tidal fluctuations in July reached 256 cm in 2016 while the lowest value or LLWL reached -101 cm which occurred in 2015 with an annual MSL position value of 79.21 cm.

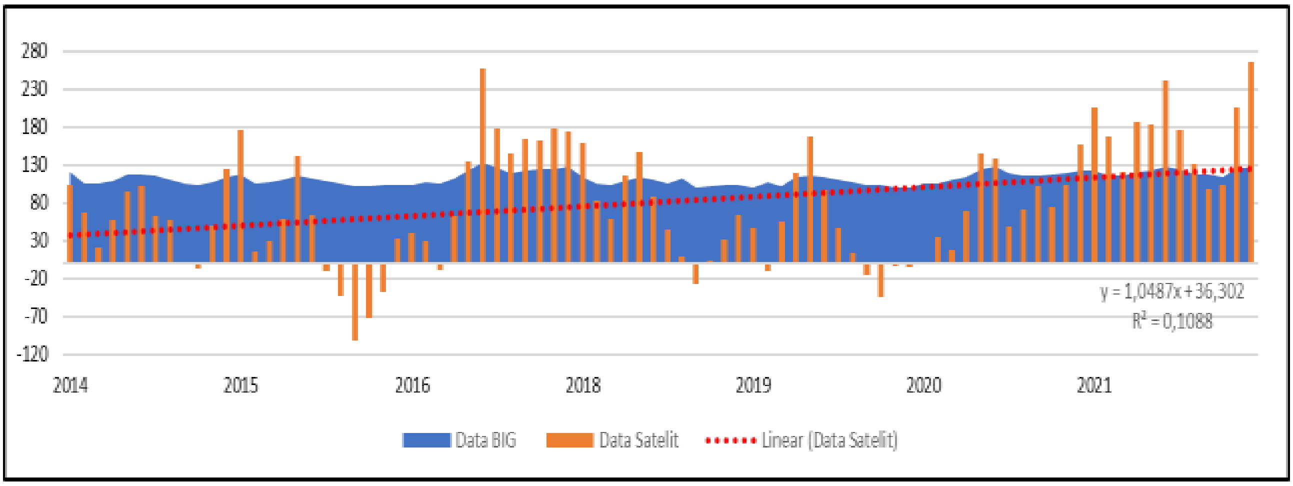

Figure 8. Graph of Comparison of MSL Value of BIG and Satellite Data in 7 years.

The graph above showed a comparison of sea level values obtained from BIG and Altimetry Satellites, which had different sea level values. This difference was due to the different points of observation, but it was observed in detail the monthly and annual sea level rise, the trend line showed a sea level rise. Where fluctuations during high tide and also low tide, both BIG and satellite data, both experience the same phase.

D. Rate of Sea Level Rise for 7 Years

The graph of the rate of sea level rise based on the annual MSL value was presented in Figure 9 and Figure 10. In addition, the results of the difference in the MSL value each year in 2016- 2021 which were averaged produce data on the rate of sea level rise which was presented in Table V.

The trend of the annual average sea level rise rate based on BIG data (Figure 9) following a linear pattern with the equation y = 0.8394 x - 1581 with R2 = 0.1307, where y = MSL (cm) and x = year, thus the rate of increase sea level in 1 year that was equal to 0.839 cm in a span of 7 years. While the trend of the annual average sea level rise based on Altimetry data (Figure 10) by following a linear pattern with the equation y = 9.6866 x - 19462 with R2 = 0.2344, where y = MSL (cm) and x = year, with Thus the rate of sea level rise in 1 year is 9.6866 cm in a span of 7 years.

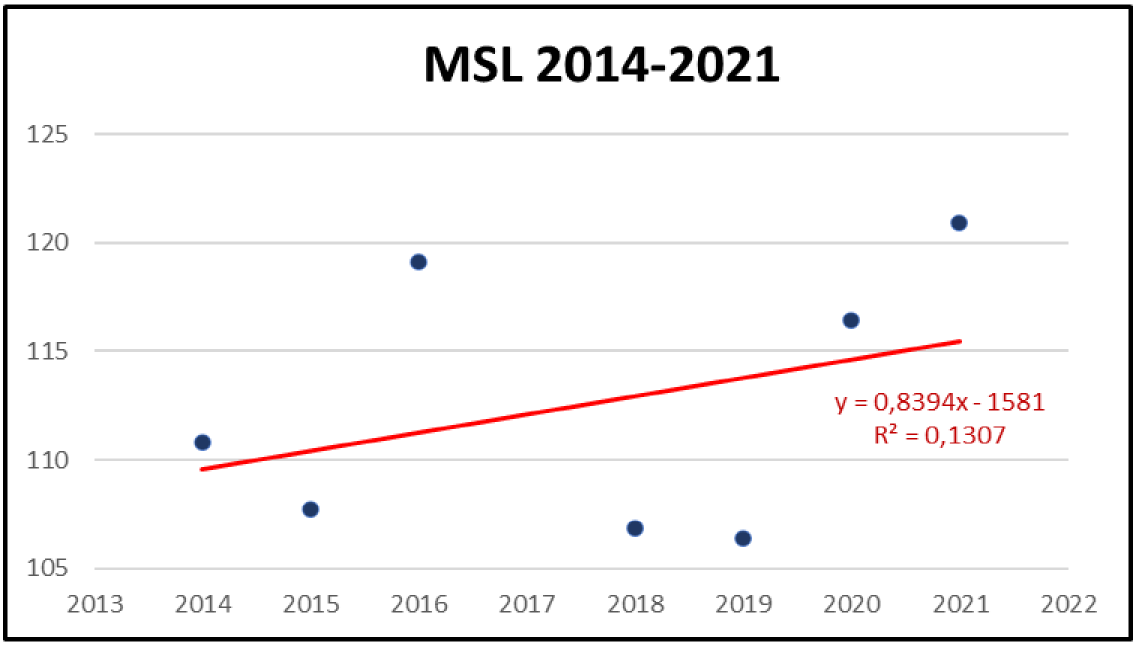

Figure 9. Rate of Sea Level Rise in 7 years based on BIG Data.

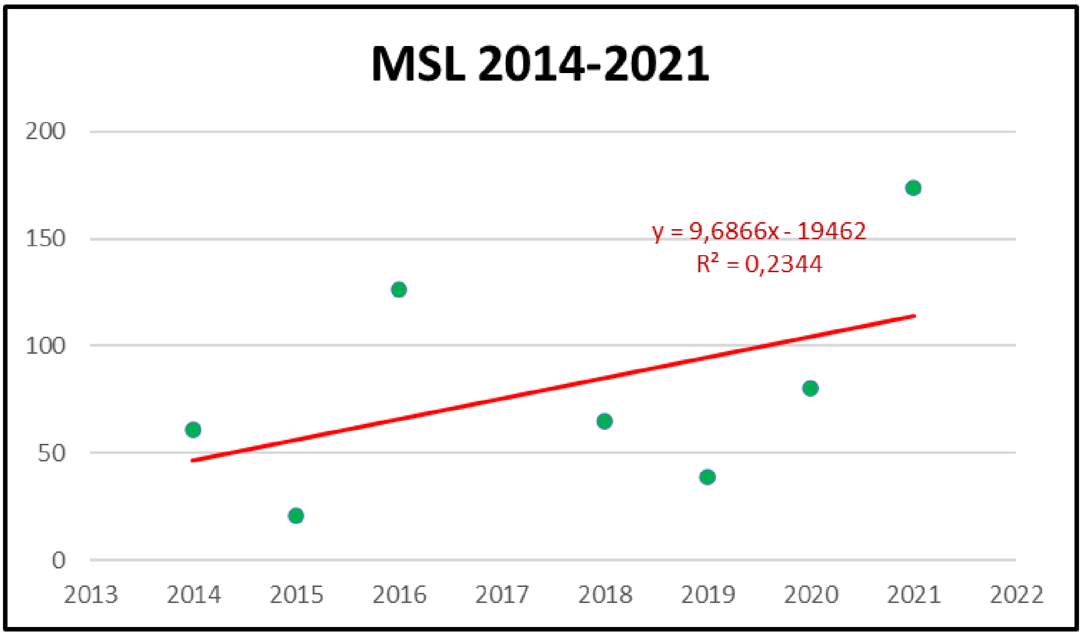

Figure 10. Rates of Sea Level Rise in 7 years based on Altimetry Data

In 2015-2016, the two data (BIG and Altimetry) experienced the highest difference from the monthly MSL reaching 11.38 cm and 104.94 cm, while in 2016-2018 the highest difference was -12.27 cm and -61.43 cm (Table V). This year was the lowest difference in a span of 7 years. Both of these data also experienced an increase again in 2020 and 2021 so that both these data experienced the same monthly and annual fluctuations.

Table V. Rates of Sea Level Rise 2014-2021

Years	Sea Level Rise Difference	
	BIG	**Altimetry**
2014-2015	-3,08	-39,88
2015-2016	11,38	104,94
2016-2018	-12,27	-61,43
2018-2019	-0,48	-25,81
2019-2020	10,05	41,42
2020-2021	4,49	93,69
Means/Year	1,68	18,82

E. 20 Years Sea Level Rise Rate

The rate of sea level rise was obtained based on the value of MSL (Mean Sea Level) tidal data from the Altimetry Satellite 2002-2021 which was analyzed using statistical methods. The processed monthly and annual MSL values. From the annual average value obtained, it can be seen that the MSL value had increased and decreased almost every year. The highest MSL value occurred in 2021 with an average monthly MSL of 162.35 cm.

The graph of tidal data analysis for the Kenjeran Region produced monthly MSL values for 20 years in the period 2002-2021. The resulting graph showed the trend of sea level rise which increased with a monthly average of 0.44 cm in one year. The highest value of MSL occurred in 2021 reaching 173.97 cm. While the lowest MSL value reached -6.49 cm in 2002.

The result of the difference in sea level rise per year within a period of 20 years showed that the level of difference was quite volatile. Where in 2015-2016 sea water experienced the highest difference from MSL reaching 104.94 cm, while in 2013-2014 the difference in MSL was -72.98 cm. This year was the lowest difference in a span of 20 years. These results were shown in Table VI.

Table VI. Rates of Sea Level Rise 2002-2021

Years	MSL Difference	Years	MSL Difference
2002-2003	9,41	2012-2013	27,67
2003-2004	12,63	2013-2014	-72,98
2004-2005	1,33	2014-2015	-39,88
2005-2006	-4,71	2015-2016	104,94
2006-2007	6,17	2016-2017	-30,45
2007-2008	65,40	2017-2018	-30,97
2008-2009	-20,10	2018-2019	-25,81
2009-2010	51,20	2019-2020	41,42
2010-2011	-23,85	2020-2021	93,69
2011-2012	15,37	2021-2020	-
Means/Year		9,50	

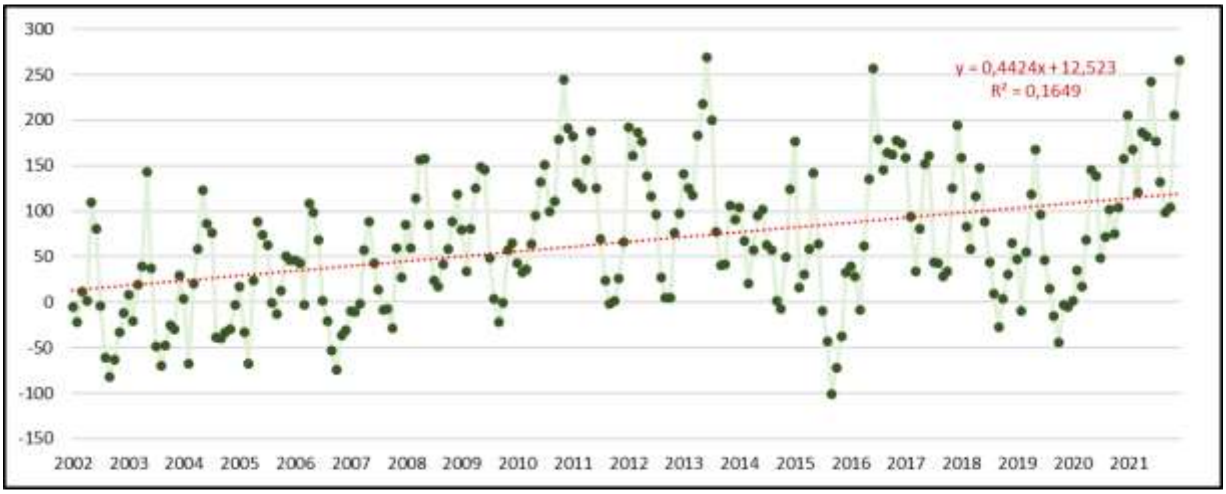

Figure 11. Graph of Monthly MSL Value Fluctuations Altimetry Satellite Data 2002-2021.

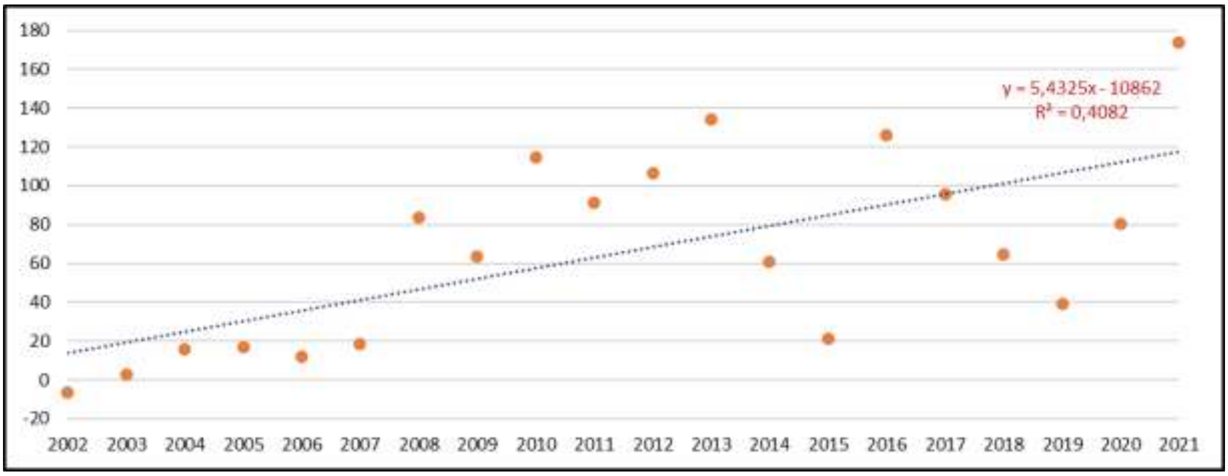

Figure 12. Sea Level Rise Rate in 20 Years

The trend of the annual average sea level rise in 20 years (Figure 12) following a linear pattern with the equation y = 5.4325 x – 10862 with R2 = 0.4082, where y = MSL (cm) and x = year, thus the rate of increase sea level in 1 year was 5.4325 cm in a span of 20 years.

In general, the position of sea level located in the Kenjeran area of Surabaya, as shown in Figure 12, the average sea level value or annual MSL obtained has increased every year. From data processing with a range of 2002-2021, the maximum annual average MSL value was obtained in 2021 which had a very high tide value than the previous year. Meanwhile, the minimum annual MSL value was obtained in 2002, with the tide value this year was very small compared to the following year.

The rate or trend of sea level rise (Tables V and VI) seem to have increased every year. This was evidenced that the graph of sea level rise based on the annual mean sea level (MSL) continues to increase. The rate or trend of sea level rise in this study was sourced from the annual MSL value obtained based on the average monthly MSL value during the period 2014- 2021 and 2002-2021. In a span of 7 years, the data from BIG produced a rate of sea level rise in 1 year which is 0.839cm, while the altimetry data showed the rate of sea level rise was 9.6866cm per year. In a span of 20 years the rate of sea level rise per year is 5.4325cm, where the average annual sea level rise is 0.27cm. Differences in sea level rates that occur in the Kenjeran Region in the span of 7 years and 20 years, show a significant difference. The rate or trend of sea level rise in this study is a value obtained purely from the annual mean sea level (MSL).

Previous research that examined sea level rise in Surabaya by Prasita and Kisnarti, 2012 in their research resulted that the tides in Surabaya waters were mixed tend to double daily with a formzhal value of 0.74 and the results of tidal calculations showed a sea level rise in Surabaya of 0. 7 cm/year. Previous research owned by Khasanah et al., 2007 resulted in an average sea level (MSL) reaching 12.38 cm/year, where the MSL value is quite far when compared to the results of this study, but the type of tide in the Surabaya area in this study is mixed double daily skew. Fitriana et al. 2022 also conducts research on sea level rise with the MSL result obtained is 1.1cm/year, with the Formzhal value obtained is 1.153, where this type of tide was the same as this study and several previous studies.

The trend value or trend of sea level rise generated in this study was an approach whose analysis is based only on the annual mean sea level (MSL) from tidal data measured in the field sourced from BIG in a 7 year period which was a the time that was categorized was short to find out the amount of increase or rate of sea level elevation that represents the waters.

IV. CONCLUSION

Admiralty's calculations showed that the Kenjeran Region had mixed types of mixed tides with a double daily trend (mixed type tend to semi-diurnal type), where in one day there were two high tides and two low tides with very different heights and periods.

Although the fluctuation values of each data were very different, there was a similar pattern of relationship between data obtained from BIG and Altimetry satellites in the period 2014- 2021 and 2002-2021. The trends of increasing MSL rate were based on monthly and annual data. The MSL value generated from the BIG results in the rate of sea level rise in 1 year, which was 0.839 cm and it on altimetry data was 9.6866cm per year. In a span of 20 years the rate of sea level rise per year is 5.4325cm, where the average annual sea level rise is 0.27cm. The difference in sea level that occurs in the Kenjeran Region in the span of 7 years and 20 years, showed a significant difference.

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