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THE SYNOPTIC DATA FOR ADAPTATION CLIMATE CHANGE IN SIDOARJO REGENCY EAST JAVA

Surya Hermawan
Civil Engineering Department, Petra Christian University, Surabaya 60236, Indonesia

Joko Purnomo
Civil Engineering Department, Petra Christian University, Surabaya 60236, Indonesia

Daniel Tjandra
Civil Engineering Department, Petra Christian University, Surabaya 60236, Indonesia

ABSTRACT

As the biggest archipelago country in the world, many places in Indonesia are potential for maritime economy industries but also suffered from negative impact of the global sea level rise. It was identified as one most contributing factors which is threatening Indonesia coastal water by coastal flood, including the research area where is in Sidoarjo Regency. To adopt the climate change, it is compulsory to have knowledge and technology along with data, unfortunately insufficient raw data in research area have identified as a major problem during years. The purpose of this research is to utilize synoptic data for coastal adaptation of climate changing design and construction. The data were collected from the National Oceanic and Atmospheric Administration (NOAA) for 16 years that will be processed into wind rose and fetch length. The outcomes are going to be obtained from the analysis of graphical and analytical calculations. The results prove that the using of synoptic data analysis give an accurate forecasting of maximum sea wave height at the research area in the range of 0.30 – 0.88 m, then it can be used to determine appropriate adaptation to the sea level rise due to global climate changing.

Key words: Climate changing, maritime economy, sea level rise, synoptic data

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1. INTRODUCTION

Based on United Nation Convention on the Law of the Sea (UNCLOS), Indonesia is one of the biggest maritime country with total ocean territory reaches 5.8 million km2, which consists of 3.2 million km2 sea territory and of 2.7 km2 exclusive economic zone (EEZ) [1].

The area excludes continental area. The area can be used to improve local citizen's prosperity, particularly for low-economic fishermen residing along the coastline.

(BNPB) Indonesia releases statistics that several residences suffer from coastal flood. This phenomenon corresponds to prediction claimed by Meteorology Climatology and Geophysics Agency—Badan Meteorologi Klimatologi dan Geofisika (BMKG) Indonesia that there were high sea waves. The impacted residences include Kulon Progo, Gunung Kidul, Bantul, Tasikmalaya, Pangandaran, Cilacap, Pekalongan, Purworejo, Wonogiri, Semarang, Pacitan, Banyuwangi, Jember, Trenggalek, Malang, Tulungagung, Lumajang, Gresik, Tuban, Surabaya, Pemekasan, Probolinggo, dan Jakarta [2–7]. Furthermore, in 2006, 13 residences along the north and south coastline of Java, i.e. Tuban, Probolinggo, Gresik, Jember, Tulungagung, Banyuwangi, Jember, Pacitan, Trenggalek, Malang, Lumajang, Pamekasan, and Blitar suffered from coastal flood. BPBD of East Java records as much as 10 hectares of plantation failed to crop. Also, access to Jokerto Beach submerged at 60 cm height, thus made the connection broken [8].

At the end of 2017, dozens of houses in Kupang Village, Jabon District, Sidoarjo, were submerged by coastal flood at 60-70 cm height. Local residence testified that the flood started submerging the area since Tuesday night, December 5. The water quickly filled the area and made the farmers could not save the fishponds as well as their belongings. Although the houses already submerged, the local citizens rejected to be evacuated [9].

Loss caused by the coastal flood was estimated around 5 billion rupiah because farmers could not harvest their fishes. Moreover, seaweed was also failed to crop and further caused delays in logistic delivery. The delays caused other problem in local household production due to the absence of raw materials.

Coastal flood is caused by several major factors, such as sea level rise, extreme tidal waves, sea waves' height, topographical and bathymetrical conditions [10–15]. Amongst the factors, sea waves' height will be covered thoroughly. This research employs synoptic data to predict maximum sea waves' height. The outcomes are expected become enrichment to better understand the sea level rise phenomenon as well as to figure out the optimal solution for the adaption against sea level rise as an impact of global climate change [16–18].

2. MATERIAL AND METHOD

2.1. Location of Research Study

The selected research site covers three sub-villages, i.e. Tanjung Sari, Kalialo, and Tegalsari in Kupang Village, Jabon District, Sidoarjo Residence, East Java—Indonesia. There are the key locations at which the coastal flood occurred as depicted in Figure 1. The site is located at the estuary of Brantas River.

Figure 1 Location of the research

2.2. Synoptic Data

Synoptic data is known as a branch data simultaneously collected over a wide region for weather forecasting. The data is used in this research to estimate maximum sea waves' height for further deciding appropriate adaption strategy against global climate change. Table 1 shows an example of synoptic data containing wind data in one week recorded in February 2002. The data was obtained from nearest station to the research site, which is Juanda Station with World Meterological Organization (WMO) number 969350 and located at latitude S 07°22'38", longitude T 112°47'38". To predict the maximum sea waves' height, a 16 years wind data was taken.

To estimate the sea waves' height, comprehensive wind data provided by National Oceanic & Atmospheric Administration U.S. Department of Commerce (NOAA) from 2000-2016 is needed [19–24]. Beside the secondary data provided by NOAA, direct measure as primary data was also taken using Weather Station, which was installed facing north at 7°31'54" S, 112°49'19" E.

2.3. Sea Waves' Height

In predicting the sea waves' height two methods are used, i.e. analytical method via Sverdrup, Munk and Bretchneider (SMB method) equation as well as graphical method using waves' height predicting chart in Shore Protection Manual (SPM method) or Darby Shire Method (DSM method) [14]. SMB method is used to predict sea waves' height by transforming wind data into wave data. Graphical method can be used based on wind direction, duration as well as fetch length [14].

Table 1. Sample of one-week wind data

Day	1		2		3		4	
Hour	dd	df	dd	df	dd	df	dd	df
0	270	2.6	290	2.6	300	4.6	300	4.1
1	270	2.6	270	3.6	280	5.7	300	5.1
2	270	3.1	270	3.6	0	0.0	290	4.6
3	300	3.1	270	3.1	280	8.7	290	4.6
4	270	3.1	0	0.0	300	8.7	300	4.6
5	300	3.1	270	4.1	330	5.1	300	5.7
6	300	4.1	270	4.1	320	4.6	300	4.6
7	0	0.0	320	7.7	290	4.1	310	5.7
8	0	0.0	320	4.1	320	4.1	310	7.7
9	250	2.6	320	5.7	320	4.6	320	7.2
10	0	0.0	330	5.1	0	0.0	330	4.6
11	0	0.0	320	4.1	0	0.0	320	4.1
12	360	1.5	280	3.1	310	4.6	300	4.1
13	0	0.0	270	2.6	270	3.1	290	4.1
14	0	0.0	0	0.0	0	0.0	300	4.6
15	0	0.0	0	0.0	260	3.1	290	4.1
16	0	0.0	0	0.0	0	0.0	0	0.0
17	0	0.0	0	0.0	0	0.0	0	0.0
18	0	0.0	280	3.1	290	4.6	220	4.1
19	0	0.0	0	0.0	0	0.0	0	0.0
20	0	0.0	0	0.0	0	0.0	0	0.0
21	280	3.1	0	0.0	0	0.0	280	3.1
22	280	3.1	280	3.6	0	0.0	0	0.0
23	270	3.1	280	4.1	300	3.6	290	3.6

Table 1 Sample of one-week wind data (continue)

Day	5		6		7	
Hour	**dd**	**df**	**dd**	**df**	**dd**	**df**
0	300	4.1	290	4.1	290	5.7
1	300	4.6	280	4.6	280	5.7
2	0	0.0	300	5.7	280	5.7
3	300	5.7	300	5.1	300	9.8
4	0	0.0	300	5.7	300	8.7
5	330	5.7	290	8.2	280	5.7
6	330	5.7	330	9.3	300	8.2
7	320	4.6	0	0.0	290	8.2
8	330	4.1	270	4.6	300	8.7
9	310	5.7	0	0.0	300	8.7
10	0	0.0	0	0.0	310	7.7
11	280	4.1	290	5.7	0	0.0
12	240	4.6	310	7.2	300	4.6
13	270	4.6	310	5.7	300	7.2
14	280	3.1	290	3.1	300	5.7
15	280	3.1	280	3.1	0	0.0
16	270	4.1	0	0.0	280	3.1
17	300	3.1	0	0.0	0	0.0
18	290	3.1	270	3.6	290	4.6
19	320	3.1	0	0.0	0	0.0
20	280	4.1	0	0.0	0	0.0
21	290	3.1	270	3.1	270	4.6
22	280	3.6	0	0.0	280	4.6
23	280	4.1	290	4.6	280	3.1

Figure 2. Installation of Geodetic Receiver and Weather Station in Tanjung Sari

Furthermore, wind speed data is transformed into wind rose to determine the dominant wind direction. After the direction is confirmed, wind at the nearest land can be obtained by transforming the existed wind data using shallow water equation.

$$H_s = 0.283 \tanh\left[0.53\left(\frac{gd}{U^2 a}\right)\right]^{3/4} \tanh\left[\frac{0.00565\left(\frac{gF}{U^2 a}\right)}{\tanh\left[0.53\left(\frac{gd}{U^2 a}\right)\right]^{3/4}}\right]\frac{U^2 a}{g} \quad (1)$$

Notes:

Hs = Wave Height (m)

F = Fetch length (km)

Ts = Period (second)
H = Depth (m)
UA = Duration of windspeed (m/second)

3. RESULTS

As can be seen in Table 2, the wind speed and direction data for 16 years' synoptic data at the research site with respect to Beaufort scale are provided. It also can be seen that as much as 68.2% of wind is categorized calm. Meanwhile, the result shows that 11.4% wind direction is east and 6.3% is west. Furthermore, maximum wind of 29-38 km/h, which is categorized as fresh, blows from north, east, south, and west.

Table 2 Wind speed and direction with respect to Beaufort scale

Wind Velocity (km/h)		Wind Direction (%) North	North East	East	South East
<1		68.227			
≥1	<6	1.036	1.774	8.988	4.132
≥6	<12	0.089	0.134	2.383	0.408
≥12	<20	0.005	0.001	0.009	0.001
≥20	<29	0.003	-	0.001	0.001
≥29	<39	0.001	-	0.001	-
Total		1.134	1.909	11.382	4.541

Table 2 Wind speed and direction with respect to Beaufort scale (continue)

Wind Velocity (km/h)		Wind Direction (%) South	South West	West	North West
<1		68.227			
<1	<6	1.873	1.985	5.795	2.031
<6	<12	0.048	0.033	0.508	0.506
<12	<20	-	-	0.011	0.013
<20	<29	-	0.001	0.002	-
<29	<39	0.001	-	0.002	-
Total		1.922	2.018	6.317	2.551

The determination of the Fetch length in the research area can be seen in Table 3, which shows that the total fetch length (x cos α) is 1694.5 km and total cosine is 13.5. Thus, the result of fetch length (x cos α) divide total cosine is 125.4 km.

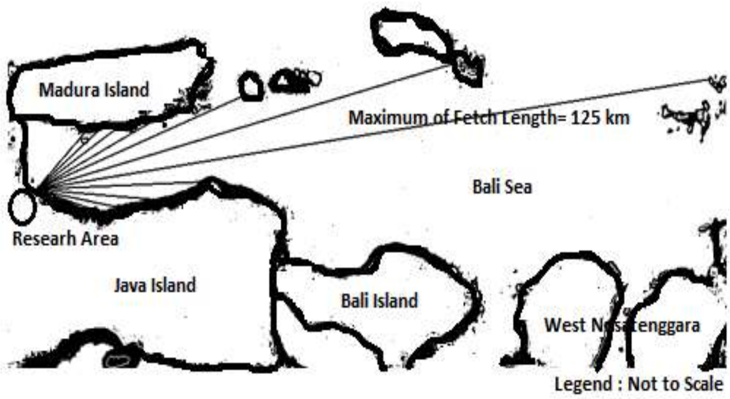

Figure 3. Fetch length of the research location

Table 3. Fetch length calculation

Angle (α)	**Cosine**	**X (km)**	**X.Cos(α)**
42	0.743	57.680	42.865
36	0.809	66.650	53.921
30	0.866	76.850	66.554
24	0.914	91.620	83.699
18	0.951	164.310	156.268
12	0.978	319.420	312.440
6	0.995	513.940	511.125
0	1.000	129.600	129.600
6	0.995	106.990	106.404
12	0.978	69.930	68.402
18	0.951	59.780	56.854
24	0.914	47.420	43.320
30	0.866	38.550	33.385
36	0.809	19.690	15.930
42	0.743	18.500	13.748
Total	13.511		1,694.514

After the wind rose is obtained, the effective fetch length with respect to the dominant wind direction is evaluated. Based on Figure 3, the maximum effective fetch length is 125.4 km. The outcome is further presented in Table 3, which shows 16 years' data collection based on wind rose generated from 2000 until 2016. The analysis is further done via SMB and DSM method. It is also worth noting that the maximum wind speed is 34.96 knot in 2009. Finally, the sea waves' height evaluation is presented in Table 4.

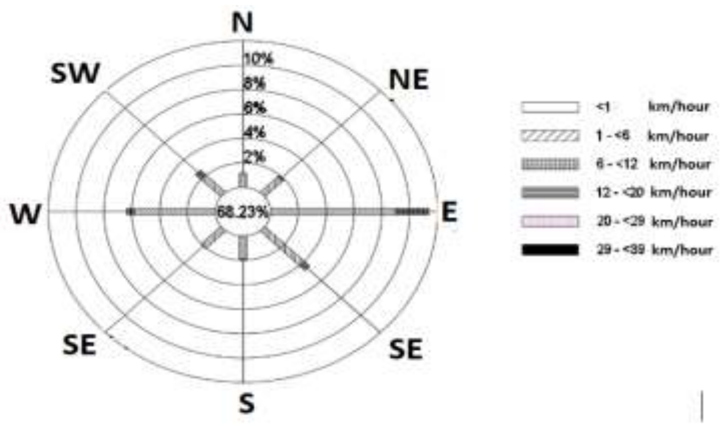

Figure 4 Windrose of the research area (2000-2016)

Table 4. Fetch length calculation

Years	**Waves' height (m)**		**Years**	**Waves' height (m)**	
	DSM	**SMB**		**DSM**	**SMB**
2000	0.290	0.305	2009	0.830	0.462
2001	0.320	0.316	2010	0.280	0.301
2002	0.740	0.453	2011	0.310	0.313
2003	0.310	0.313	2012	0.340	0.333
2004	0.840	0.468	2013	0.730	0.452
2005	0.880	0.475	2014	0.310	0.313
2006	0.500	0.389	2015	0.600	0.412
2007	0.360	0.335	2016	0.520	0.391
2008	0.450	0.351			

Regarding 16 years data recorded, the analysis results of analytic and graphical method show that the maximum sea wave height forecasting in the range of 0.280 to 0.880 m. Meanwhile, Table 5 shows the sea level rise is 15 mm/year. Thus, from the results, three scenarios can be considered, i.e. at high, best estimate, and low condition. The first scenario, i.e. high, has the highest impact to the research site. The results indicate that Kali Alo, Tegal Sari, and Tanjung Sari will be submerged in 50 years if first scenario occurs. In second scenario, most of fishponds in Kali Alo, Tegal Sari, and Tanjung Sari will be submerged in 50 to 80 years. If the second scenario occurs, i.e. best estimate, 2 m height embankment can be constructed to protect the site. Meanwhile, in third scenario, i.e. low, only a few areas of the site will be submerged in 50-80 years.

Table 5. Scenario of sea level rise

Scenario	**TW (cm)**	**SLR (cm)**	**WH (cm)**	**Total**	
				50 years (cm)	**80 years (cm)**
High	130	1,5	88	293	338
Best Estimate	40	1,2	60	160	196
Low	30	1,0	28	108	138

4. CONCLUSIONS

The results show that by using new method in this research, synoptic data can be used as adaptation planning and design against climate change. Furthermore, to provide three scenarios in predicting the sea level rise, data of tidal waves, sea waves' height, and sea level rise per year is needed.

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