Waves Induce Sediment Transport at Coastal Region of Timbulsloko Demak

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Abstract. Waves have variation of length and period. This influenced by seasonal variation. Impacts of seasonal variation related to wave is playing important roles in sediment transport mechanism and coastal changes. This condition not only treats coastal area but also decreases economic capacity of community. This research aim to determine different seasonal based on Indonesia Northwest-Northeast monsoon and Southeast-Southwest monsoon and theirs relation to sediment transport. Area of study is suffered by 938.73 H of abrasion. Conducted by CERC methods, transforming BMKG Ahmad Yani wind database (2005-2015) into wave's data of seasonal variation and using field measurement recorded by ADCP. Definitely, maximum speed of wind is reached at 23 knots from December to February, wind direction predominantly from North West direction. Range of significant Wave Height (Hs) all season is 24.66-30.32 cm and Significant Wave period (Ts) count at 3.64-3.78 sec. Net of sediment volume annual 72,353.40 m^3year^{-1} and sediment movement pattern is forwarding from west to east direction. Correlation between breaking waves and sediment transport is linier.

Keywords: Wind, Waves, Sediment Transport, Timbulsloko, Demak

1. Introduction

The changing of coastal area has influenced by several factors. It has regularly affected by natural mechanism and has rapidly received human activities. One of natural factor which has influencing coastal area is sediment transport. In fact, measuring the mechanism of displacement some sediment from one to the other area is possible and reliable [1]. The movement of sediment has been basically triggered by breaking wave. Breaking wave and decreasing of bathymetries will be followed by unstable peak of wave and turbulence of current has been delivered sediment along coastal area [2]. The breaking wave which has been existed in surf zone will be transporting sediment along coastal area. On the other hand, location near equator or low latitude area is depending on seasonal aspect because this factor has been affected of waves [3]. Indonesia has two major seasons depend on rainfall. There are four part condition regularly which known as northwest-northeast monsoon, first transitional season, southeast-southwest monsoon and the second transitional season [4]. The differences of wavelength and wave height are influenced by seasonal variation. Studying of characteristics of waves is basically important because it is dealing with understanding the foundation and determining the amount of wave. The sophisticated information is compulsory because it can estimate the changed coastal area in present frame and predict its evolution in the future [5]. This research had been aimed to determine sediment transport relied on different seasonal condition because of Indonesia monsoon.

2. Methodology

2.1. Area of Study
The massive of coastal change mainly in abrasion of Demak Resident reach 938.73 H furthermore it considered as secondly ranking of abrasion in coastal area along Pantai Laut Utara (PANTURA) after Brebes[6]. The highest abrasion has been deconstructed village area of Timbulsloko and the community not only suffered by this condition but also loosed their ponds as major income [7]. Area of study had focused in coastal area of Demak area which has borderline with Semarang at west side and Jepara at east side. There are directly in front of Java Sea. All situations of area which had been discussed depict on Figure 1.

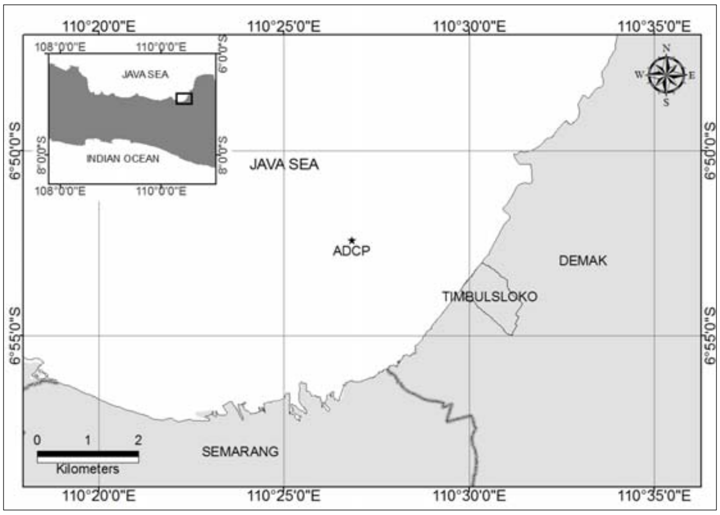


Figure 1. Area of Study

2.2. Collected Waves Field Data
The precedent procedures of data collecting was conducted by Wave Recorder Sontek Argonaut Type Xr 750 MHz particularly this instrument is highly recommended because this instrument is used more than two decades to measure waves and current [8]. The instrument was mounted at 6.89°S and 110.45°E position and staggered in 9.6 m water depth. Data of waves and current had been collected during 3-10 June 2016, sampling rate per 10 minutes were recording height and periods of waves, speed and direction of current.

2.3. Collected Wind Data
The obligatory in this research is assessment wind data which has information of speed and direction. These had been retrieving from BMKG Ahmad Yani 2005-2015 synoptic data which has enclosed by OGIMET. Wind data produce windrose graph. Transforming wind to wave in further processing of its value can generate measured longshore current and sediment transport known as methods of SMB [9].

2.4. Assessment of transforming Wind to Wave

Wind database ten years was divided into four season classification West monsoon (December, January, February); transitional season I (March, April, May) East monsoon (June, July, August) and transitional season II (September, October and November).

2.5. Measuring of Generated Wave and Sediment transport

Method to determine wind data convey into transport sediment speed along breaker zone and its volume using empirical equation [10]. The resuming formulas are followed by equation through (1) until (10).

Wind data transform to waves (Height and Period) are calculating sequentially wind stress factor (UA), wind speed (UW).

$$U_A = 0.71 U_W^{1.23} \quad (1)$$

$$U_W = R_L U_L \quad (2)$$

Waves which have happened at offshore determine wavelength (L_0), when they approach shoreline the refraction (Kr) and shoaling (Ks) are reforming of new height of waves (H). These formulas present at (3) and (4) equation.

$$L_0 = 1.56T^2 \quad (3)$$

$$H = H_0 K_r K_s \quad (4)$$

Determining of breaking wave height and depth of breaking wave followed by equation (5) and (6)

$$\frac{H_b}{H_0'} = \frac{1}{3{,}3(H_0'/L_0)^{1/3}} \quad (5)$$

$$\frac{d_b}{H_b} = 1.28 \quad (6)$$

Mainly discussed on this study is sediment transport which has speed of longshore current along coastline (7) and volume of annual transport sediment (9) and daily (10) complete equation formulated are shown bellow.

$$\mathrm{V} = 1{,}17(gHb)^{1/2} \sin\alpha_b \cos\alpha_b \quad (7)$$

$$\mathrm{P_1^n} = \frac{\rho g}{8} \mathrm{H_b}^2 \mathrm{C_b} \sin\alpha_b \cos\alpha_b \quad (8)$$

$$\mathrm{Qs} = 1290\mathrm{P1}(\mathrm{m^3/year}) \quad (9)$$

$$\mathrm{Qs} = 3{,}543\mathrm{P1}(\mathrm{m^3/day}) \quad (10)$$

3. Result and Discussion

3.1. Waves Height and Period among field measurement

Simultaneous recorded data of waves during seven days at offshore area by instrument ADCP are presented on Figure 2. Wave's height fluctuation generates differentiation between highly and lowest height of its. The highest peak which reached 31.5 cm had happened after more than 24 hours of deployment and slowly decreased. On the day three until the end of time period of data collection wave's height more stable than before. Waves Height Significant is 13.7 cm. Waves period represented by Tmin; Tmax and Ts were 3.6 sec, 6.3 sec and 4.04 sec. Long waves is 25.46 m assisted by equation (3). Wave's classification is transitional and ratio of depth and long wave (d/L) is 0.38.

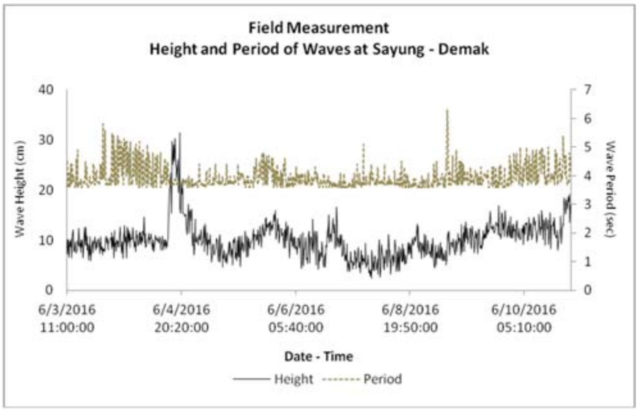
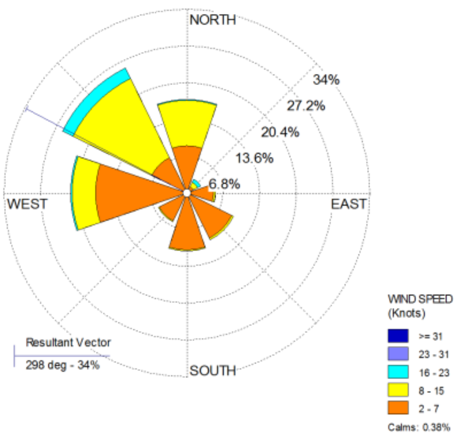


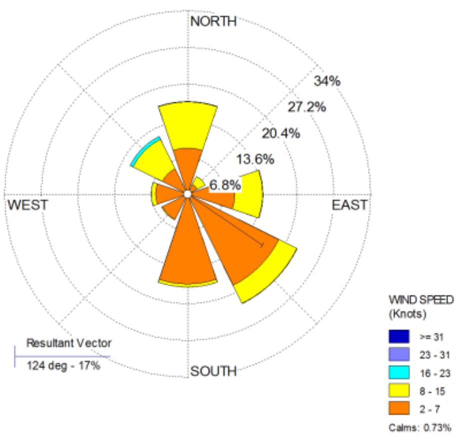
Figure 2. Field measurement of wave height and period recorded by ADCP

3.2. Wind Speed and Direction Plot

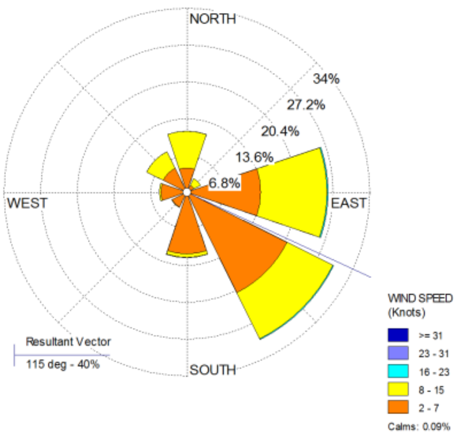
As mention above (sec 3.3) stated that there are four divided seasonal in ten years wind data. Figure 3 is represented all of seasonal variation and dominant of wave direction. At season of Northwest-northeast monsoon wind mostly originated at northwest contrary to Southeast-southwest monsoon wind directly opposite its directions. In transitional I and II wind were relatively coming from all direction.



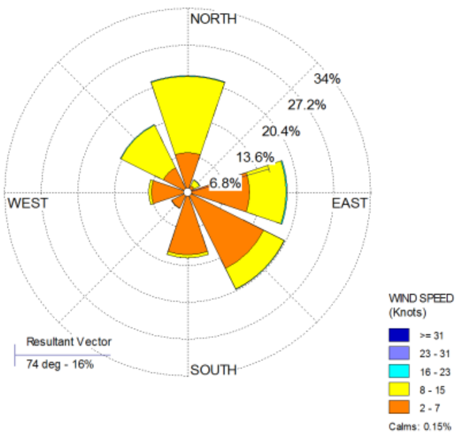
West monsoon



Transitional season I



East monsoon



Transitional season II

Figure 3. Wind speed and direction ten years (2005-2015) relied on varieties of seasonal condition

Plotting of wind called windrose proves that the value of speed in December, January and February is higher than other months, dominant wind force had been received from northwest direction and maximum wind speed velocity is 23 knot. Wind blowing on March until May come from two directions even though at northwest wind speed more than 16 knot still exists. It highly considerable at east monsoon wind forced from east direction with dominant velocity range is 8-15 knot. Uniformly speed at class 8-15 knot has happened at all season. Blowing wind circulate from north direction is highly occurring from September to November with velocity of wind at class 8-15 knot.

3.3. Significant Wave Height (Hs) and Significant Wave Period (Ts)

Transforming wind-wave data was connected into parameter itself within empirical methods. Based on that experienced, Table 1 present number of waves height and waves period among seasonal time and related to field measurement. Recording ADCP instrument had settled in between east monsoon season (June, July and August). Significant wave height at all season circumstances was compared between one and each others. The value of Hs is ranging from 24.66 cm to 30.32 cm. The highest predominant Hs had happened in period West monsoon and circulating begins December. Non monsoon season appointed lowest value of significant wave height (Hs) than monsoon[11]. In fact, at East period Hs number is below than Transition II. Hs value decreased after West monsoon because the direction of wind suddenly predominant came from 124 degree or relative opposite with primarily condition. In reality, study area coastline onset 50^0 orientations from north direction.

The number of significant wave's period (Ts) ranging from 3.64 sec to 3.78 sec. Periods of wave among seasonal event proved that the highest Ts also had happened from December to January season linier with Hs number. Interesting value of significant wave's period was rarely different value. Figure 4 and Figure 5 depicted Hs and Ts value.

Table 1. Summary of wave height and wave period.

Time	Waves Height (cm)			Waves Period (sec)		
	Hmin	Hmax	Hs	Tmin	Tmax	Ts
West monsoon (December, January, February)	2.13	134.90	30.32	2.97	5.74	3.78
Transition I (March, April, May)	6.65	151.53	24.66	3.12	5.98	3.64
East monsoon (June, July, August)	2.13	110.36	26.01	2.97	5.36	3.68
Transition II (September, October, November)	2.13	140.73	28.34	2.97	5.83	3.74
ADCP 6/3/2016-6/10/2016	2.4	31.5	13.7	3.6	6.3	4.04

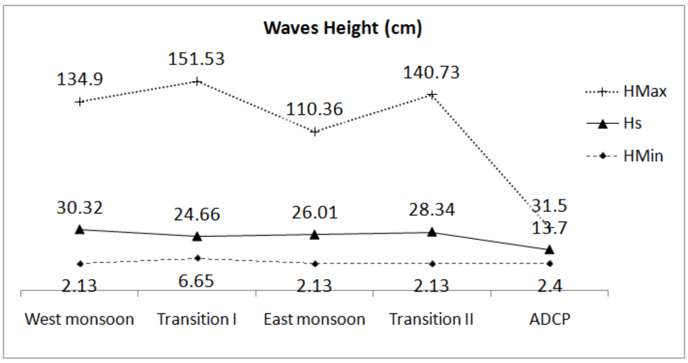


Figure 4. The number of wave's height (cm) among seasonal variation and field measurement

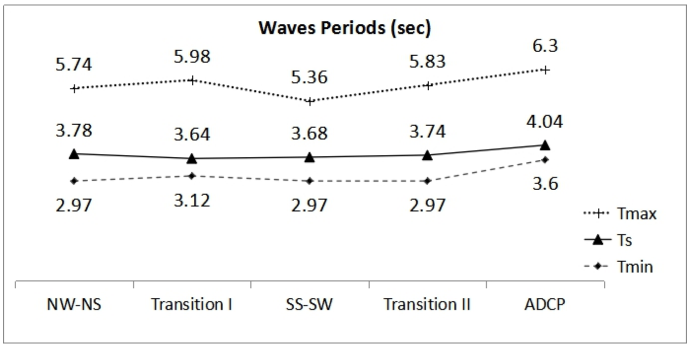


Figure 5. The number of wave's period (sec) among seasonal variation and field measurement

West monsoon period has the highest number of significant wave's based on calculation. Wave conveys the number of transport sediment because it influences breaking wave height and periods. Transported sediment is more massive when storming wind has happened and it will potential bring suspended sediment and reform area of coastal [12].

3.4. Sediment transport related to seasonal variation

Transforming wind-wave data was produced several parameter which play important roles to determine and describe the value of sediment transport. Table 2 shows different number among season. Arranging from west predominantly monsoon the number of annual sediment transport is outstanding because of its breaking wave deeper than others. Speed of longshore transport during December until two months later correlate to sediment transport.

During June until August the value of breaking wave height (Hb) and breaking wave depth (db) decreased because direction of wind come from relative south east to northwest must be consider at area of study is bordered by mainland. This condition influence of magnify of wind speed.

Table 2 Summary of breaking wave number on surfzone.

Season	α_0 (^{0})	Hb (m)	db (m)	αb (^{0})	Notation
West monsoon (December, January, February)	298	1.17	1.29	57.15	(-)
Transition I (March, April, May)	22.5	1.00	1.11	19.73	(+)
East monsoon (June, July, August)	75	0.77	0.85	48.56	(+)
Transition II (September, October, November)	320	0.92	1.02	33.01	(-)

Generally, all of seasonal variations prove their breaking wave height (Hb) and breaking wave depth (db) linier with speed of transport (V) and volume (Qs). During September-November phase the velocity of longshore current higher than next period but its high of breaking wave influence volume of sediment. If the breaking wave height and its depth increase, sediment transport number will be magnify. This kind of situation present on Table 3.

Sediment which has displaced based on calculated ten years data of wind shows the Nett of sediment volume is 72,353.40m3year-1 and predominantly moving forward from west to east direction. Timbulsloko located in near of Semarang Bay. Wave and current influence of stress of displacement particularly in coastal area with bay morphology [13].

Table 3 Summary of velocity of longshore current and sediment transport Net.

Season	V (ms^{-1})	Qs daily (m^3day^{-1})	Qs annual (m^3year^{-1})	Direction of displacement
West monsoon (December, January, February)	1.80	311.50	113,697.69	West-East
Transition I (March, April, May)	1.16	160.10	58,436.69	East-West
East monsoon (June, July, August)	1.60	149.21	54,461.12	East-West
Transition II (September, October, November)	1.61	196.04	71,553.51	West-East
Sediment Net		198.23	72,353.40	

On the other hand dominant factor which generate sediment transport is surf zone area. At this point breaking waves has been occurred and mixed some materials. Although there are several factors of properties of sediment, bathymetry, shape of wave and its properties, angle of coastal area [14]. Hence vegetation are play important roles in sediment net because it can support of increasing sediment when the thick of vegetation higher. Flux of sediment is related to its velocity [15].

4. Conclusion

Studies of sediment transport has been founded that during December until February in area of study held significant wave height and period based on condition which has speed of wind maximum velocity is 23 knot. Sediment transport which has transformed from wind to wave data and its connection with different seasonal variation was considering number of waves when it has slowly destructed. Based on this study, correlation between breaking waves and sediment transport is linier. Breaking wave is triggering sediment transport and it will be displaced sediment from one area depend on speed of transport along coastal area. Based on the study, different wave forming which had generated by wind results the variation number of longshore current and volume of sediment.

Necessity of studying sediment transport plays important roles because changing of coastal area will destruct not only morphological but also economical factors. Sediment transport as one of natural factor has rapidly effect in coastal area either abrasion or accretion. Focusing in area of study, after it has reliable database of sediment transport and its wave's properties, this study is recommend for the next management of coastal area must be prepare well plan and consider natural factors and their effects for coastal region and particularly communities who have been living and working in this area.

5. Acknowledgments

This acknowledge present for Centre of Education and Training Meteorology, Climatology and Geophysics (BMKG) which has encouraging scholarship at Master of Science Marine of Diponegoro University. Dr. Ita Widowati and Dr. Diah Permata Widjayanti in research collaboration with Wageningen University, Netherland. Lembaga Penelitian dan Pengabdian kepada Masyarakat (LPPM) and Pusat Unggulan Iptek (PUI). All collaborated colleagues in field studies and laboratory activity.

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