Waste Technology (WasTech)
Journal homepage: http://ejournal.undip.ac.id/index.php/wastech
An International Journal

Monthly Variation Characteristics of Wave Height In North Sulawesi

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Abstract - *Indonesia is a maritime country which most of the territory is ocean, where many people have activities at sea. Information about variations and characteristics of wave height in some region is very important to support safety and efficiency of the activity. The purpose of the research is to know and analysis the characteristics of the monthly variations of wave height in the water of North Sulawesi. The data used in this study is surface wind that processed into Windwaves-05 wave model. This model calculates wave height based on energy from surface wind that blows above sea surface. The research results showed that variations of sea waves in the waters of North Sulawesi generally are closely related to the monsoon wind patterns that occur in Indonesia. When Asian west monsoon in November to April, the average wave height in the waters of North Sulawesi is higher than wave height at Australian east monsoon in May to October. The highest average wave occurred in January with maximum wave height to 3.5 m and lowest average wave occurred in October with a maximum height to 1.25 m. Generally, the average wave height in the waters which bordering the ocean is higher than the waters close to all major islands.*

Keywords *– Wave Height, Surface wind, Monsoon, North Sulawesi.*
Submission: January 22, 2017 Correction: April 12, 2017 Accepted: April 20, 2017
Doi: http://dx.doi.org/10.12777/wastech.5.1.21-26
[How to cite this article: Fadlan, A., Aror, R.D., Sugianto, D.N., Zainur, M. (2017). Monthly Variation Characteristics of Wave Height In North Sulawesi. *Waste Technology, 5*(1), 21-26. doi: http://dx.doi.org/10.12777/wastech.5.1.21-26]

1. Introduction

Indonesia is a maritime country where many people have a variety of activities at seasuch as fishing and shipping. This becomes an important part in the lives of the people of Indonesia. Under these conditions, the various activities undertaken in oceans are very vulnerable to any changes in conditions that occur in marine waters. Ocean waves are one of the parameters that have a major influence on the activity at the sea(Kurniawan*et al.*, 2012), which can affect the activity of efficiency and safety at the sea.

The ocean waves are generally arises because of the factor of force generators at sea. The wind factor is the most dominant in the formation of a wave(Sugianto, 2009; Azis, 2006), although there are still other factors that may cause waves such as earthquake that caused a tsunami wave (Nichols *and* Williams, 2009), the eruption of volcanic mount and the influence of ship movements(Nining, 2002).

In climatological, most parts of Indonesia include North Sulawesi waters affected by monsoon (Tjasyono, 2008). Monsoon activity not only affects the weather and climate in Indonesia, but in general the monsoon activity also affects wave height in all Indonesian waters(KurniawandanKhotimah, 2015; Kurniawan*et al*., 2011).As a result of these influences, some regions in Indonesia is prone to high waves, especially the areas are directly adjacent to the ocean(Kurniawan*et al*., 2012), such as North Sulawesi region which directly adjacent to the Pacific Ocean.

Studies on wave conditions that containing information monthly variation of wave height in the waters of North Sulawesi indispensableas a reference for the needs of societyand the interests of government activitiesin

carrying out the trade, shipping, fisheries, tourism, security and the research. The purpose of this study was to determine the characteristicsand monthly variations of waves in the waters of North Sulawesi. This research is expected to be a reference in the estimation of wave conditions in the waters of North Sulawesiand may be preliminary information for the perpetrators of the activities in these waters.

2. Materials and Methods

This research is located in North Sulawesi waters that are in a position: 8°N – 4° Sand 116°E – 132°E (Figure 1). This location is the location of the work area and the responsibility of the Maritime Meteorology Station Bitungin conveying the marine meteorological information to the public.In this research sites, the waters around North Sulawesi is divided into small areas to make it easier to analyze and inform the condition of ocean waves (Table 1)

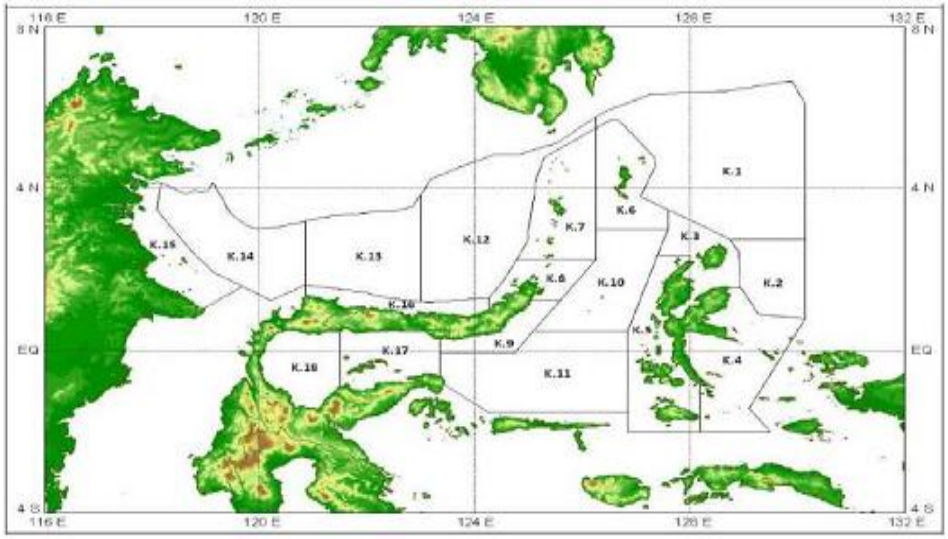

Figure 1. Area of study

Table 1.The list of areas in the study area in North Sulawesi

No	Name of Region	No	Name of Region
K.1	Pacific Ocean in North Halmahera	K.10	North of Maluku Sea
K.2	Halmahera Sea	K.11	South of Maluku Sea
K.3	North Waters of Halmahera	K.12	East of Sulawesi Sea
K.4	East Waters of Halmahera	K.13	Middle of Sulawesi Sea
K.5	East Waters Halmahera	K.14	West of Sulawesi Sea
K.6	Talaud Island Waters	K.15	Tarakan – TanjungRedep Waters
K.7	Sangihe Island Waters	K.16	North Waters of Sulawesi
K.8	Bitung – Manado Waters	K.17	Gulf Tomini in South of Gorontalo
K.9	South Waters of North Sulawesi	K.18	Gulf Tomini in North Poso

The collected data is the direction and wind speed of 10 meters in 2004-2014 periods with 1° x 1°resolution. The data is reanalysis data that collected from National Center for Environmental Prediction (NCEP) http://rda.ucar.edu/. Bathymetry data with 2 x 2 minute resolution was collected from *https://www.ngdc.noaa.gov*.

Sea wave height is obtained from the calculation using the wave model windwave-05. This model is a hydrodynamic model and calculates the waves caused by wind surface energy. The general equation used in wave forecasting models is the equation of wave energy transfer as follows:

$$\frac{\partial S}{\partial t} = -\nabla.\left(C_g S\right) + S_{in} + S_{nl} + S_{ds}$$

Where $S = S(f, \theta)$, the energy spectrum as a function of frequency and wave direction. t, is a function of period. C, is group velocity. Equation of $\nabla.\left(C_g S\right)$ is the change in energy during the propagation due to advection and refraction by seabed. S_{in} ischanges in energy due to wind, S_{nl} is changes in energy due to non-linear energy transfer between waves, and S_{ds} is energy lost due to friction seabed.

Several studies have validated this model by altimetrysatellite observations. The validation result has showed that Windwaves-05 model output with observations closer the level of correlation above 0.7 (KurniawandanKhotimah, 2015; Kurniawan*et al.*, 2013, Khotimah, 2012) .

Parameterization wave model was use wind data in 2004-2014 periods withthe resolution model run is 10x10 minutes. The output of the model used was the average maximum wave and surface wind. This is because the maximum wave can affect the activity of the activities at sea and as the basis for determining the extreme weather information for maritime weather information.

3. Results and discussion

Analysis of variation and characteristics of sea waves in the waters of North Sulawesibased on the monthly average in the period of 2004 – 2014. The overall results of the calculation of average surface winds and average wave height of models Windwave-05 are shown in Figures 2 and Figures 3.

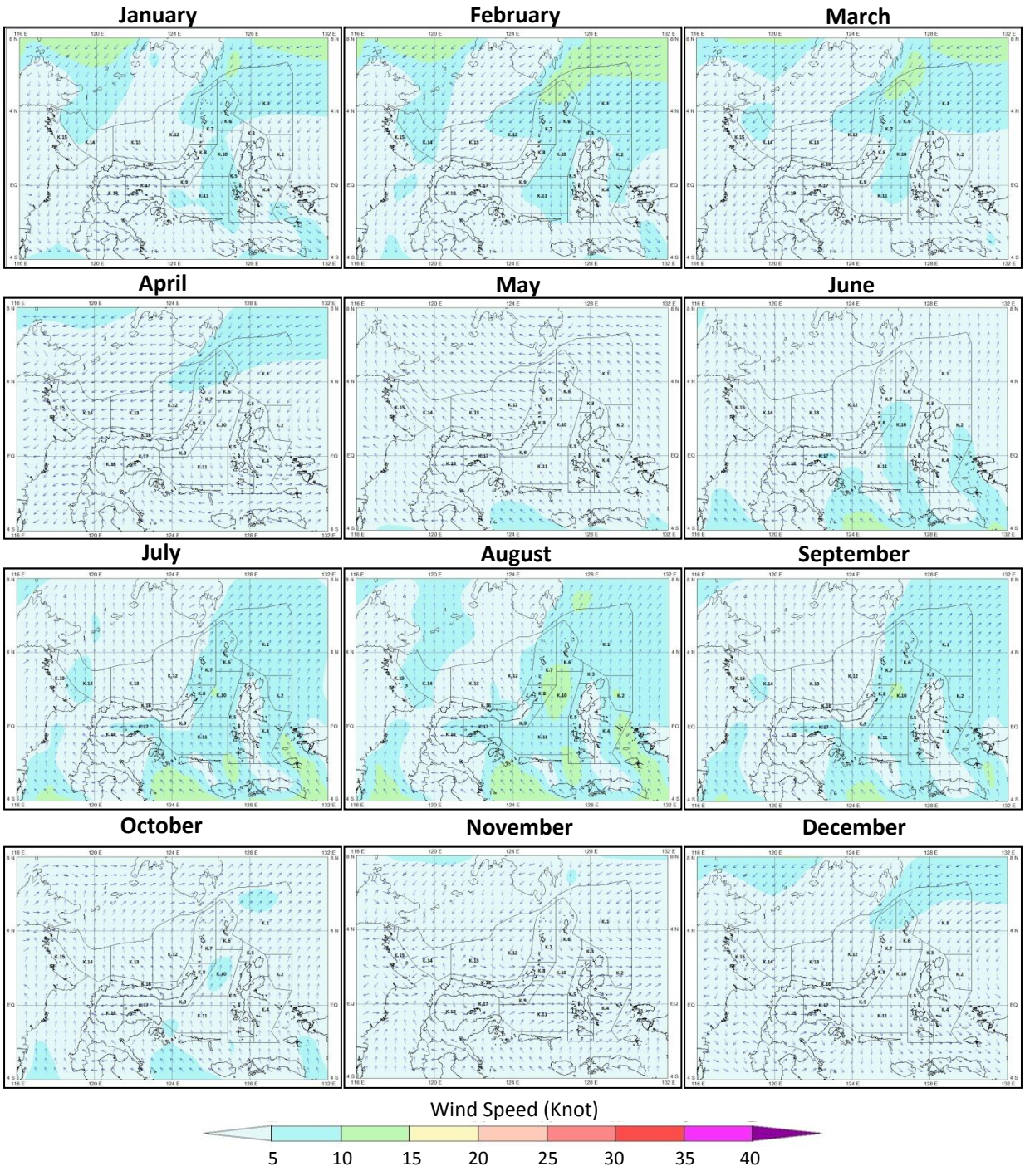

Figure 2.The average surface winds in the waters of North Sulawesi and surrounding

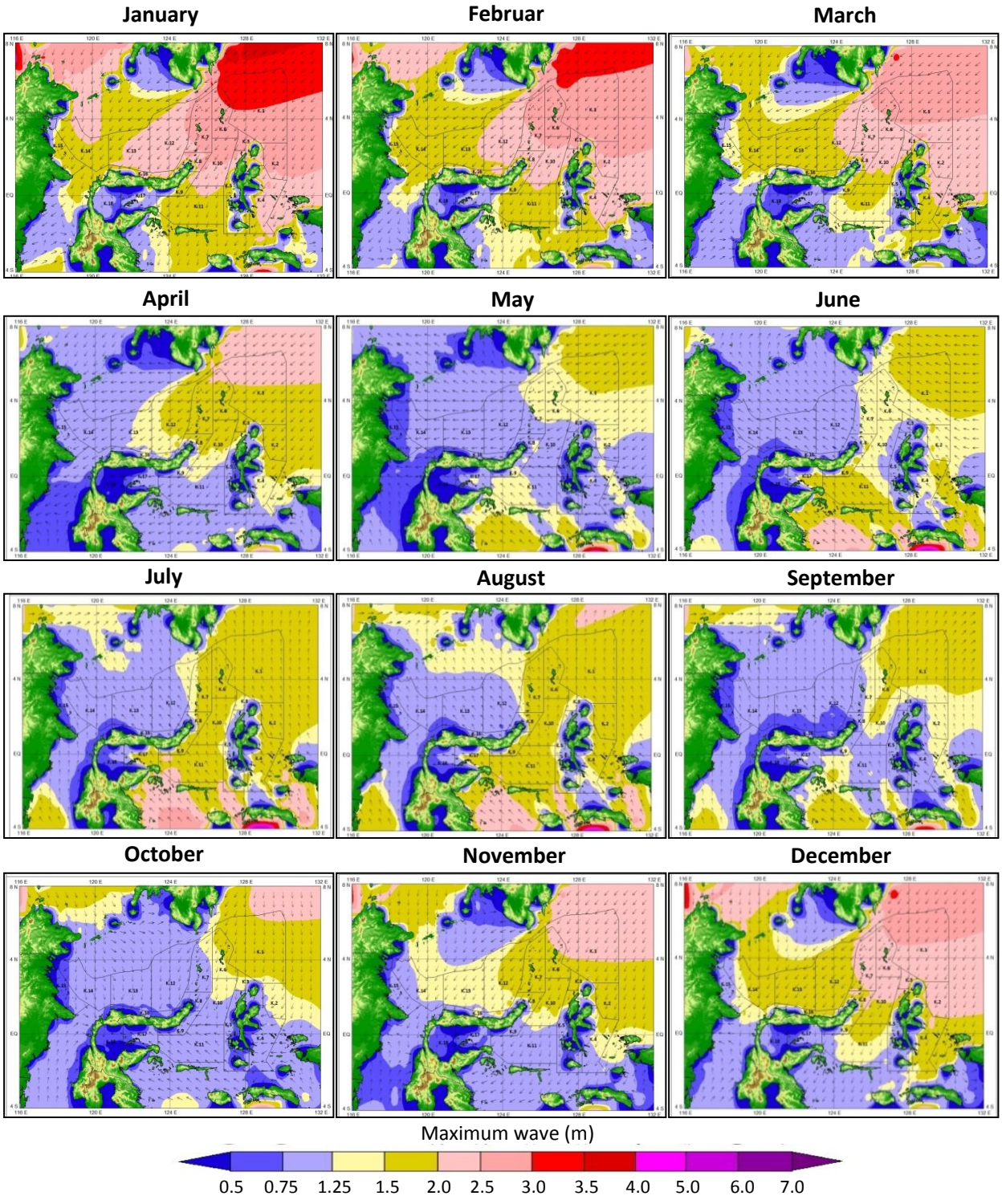

Figure 3.Average maximum wave in North Sulawesi and surrounding

Based on analysis of the average height of waves in the waters of North Sulawesi is found that high waves in the waters has a variety of characteristics depending on the condition of the season occurs. Based on the analysis of average wind blowing over the surface of the waters, in December-January-February (DJF) as the Asian monsoon,generally has the characteristics of wind direction from the northeast to the south. The wind moving over the waters had reached an average speed of 15 knots, particularly in the area directly adjacent to the Pacific Ocean. However, the average wind speed reduced to 10 knots when approaching land.

The wave conditions in DJF showed that high waves may occur in the territorial waters of the north part of North Sulawesi, which includes the Celebes Sea, Manado-Bitung waters, Sangihe-Talaud island waters, Pacific Ocean north Halmahera, Northern Maluku Sea and Halmahera Sea with Average maximum waves reaching 2.0 to 3.5 m. North Sulawesi generally have a high potential for sizable waves in the monsoon Asiawhich indicates the frequency reaches 100% with a maximum height of waves reaches 3.5 m (Kurniawan andKhotimah, 2015). In DJF in the territorial waters of North Sulawesi, which is directly adjacent to the Pacific Ocean also has the absolute maximum height of up to 4.5 m (Rais and Yunita, 2016).

Wind generally moves from the southeast toward the north in June-July-August (JJA). This condition contrasts with the wind patterns during DJF. In JJA the active monsoon is Australian monsoon whit prevailing winds move from south to north. This condition causes the wind speed is quite strongin the southern waters of North Sulawesi, which reached 15 knots. As a result of the intensity of the wind is quite strong in the southern waters of North Sulawesi, the high waves generally occur in the Gulf of Tomini, the south waters of North Sulawesi, and the south of the Maluku Sea.

Maximum average of waves that can occur inthe Gulf of Tomini, the south waters of North Sulawesi, and the south of the Maluku Sea was reaches 1.5 – 2.5 m. In addition, the potential of the waves were quite high also persists inManado-Bitung waters, Northern Maluku Sea, Sangihe-Talaud island waters, and Pacific Ocean north Halmahera. However, when compared with the average waves in DJF, this average smaller than wave's condition in JJA. This is because the wind is moving in DJF coming from the Pacific Oceanand has the speed and extent of the influence of the broader so that the waves generated higher.

In North Sulawesi region, transitionseason occurred in March-April-May (MAM) and September-October-November (SON). This season, mostly to wind patterns that occur have an uncertaindirection.This condition occurs because the sun's position in the Equator that causing a pressure gradient to be small so as to make the wind direction uncertain with weaker speed. Under these conditions, high sea waves that form will also be lower than other season. Wave height generally ranges from 0.75 m around Sulawesi Sea, Manado-Bitung waters, Gulf of Tomini, Maluku Sea, while Sangihe-Talaud island waters and Pacific Ocean north Halmaher has waves reaching 2.0 m.

Duration component and persistence of the wind direction also affects the condition of the ocean waves. The longer and uniform wind that occurs in a water area, then the wave that will occur is also getting bigger (Kurniawan, 2011). It can occur because when the wind in the same direction, the energy generated by the wind will be collected and caused a wave of mutually reinforcing that occur in DJF and JJA. Different conditions occur in the transition season (MAM and SON). The wind not has consistent directionand mutually weakens. This condition makes the average wave height in Indonesian waters are generally lower than wave height condition in Australian monsoon and Asian monsoon. Another study also showed the average wave height in the Java Sea in February and August has a wave higher than in May (Hadikusumah, 2009).

In general, North Sulawesi and the surrounding areas are affected by the wind season (monsoon). In the westerly season (DJF), areas that have an average waveshigh generally occur in northwaters of North Sulawesi. In the easterly season (JJA), areas that have an average waveshigh generally occur in southwaters of North Sulawesi. This relates to fetch, speed and duration of the wind.However there are some areas of high waves are not unduly influenced by season. In this area have a fairly high wave heightthroughout the year. This region is Talaud island waters and Pacific Ocean waters in North Halmahera. This is due to both the area immediately adjacent to the Pacific Ocean. Different conditions occur in the Gulf of Tomini.These waters are in small areas and closed by the Sulawesi Island so high waves in these waters has always been low throughout the year.

4. Conclusions

Variations and characteristics of the wave in North Sulawesi and the surrounding waters are generally closely related to seasonal patterns that occur in Indonesia. During Asian monsoon (DJF) and Australian monsoons (JJA), the average wave height is higher than in the transitional seasons (MAM and SON). The average peak of the highest waves occurred in January in the north waters of North Sulawesi which reached 3.5 m. The lowest average of the waveshigh occur in October in the transitional seasons with wave height reached 1.25 m. The territorial waters directly adjacent to the Pacific Ocean such as Talaud island waters and Pacific Ocean waters in North Halmahera have a high average wave's height throughout the year.

Acknowledgments

Acknowledgements and awards are given to the Marine Meteorology Station Bitung with permission and assistance in processing the data in this study.

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