HIGH WAVE AND COASTAL INUNDATION IN SOUTH OF JAVA AND WEST OF SUMATERA (CASE STUDIES ON 7-10 JUNE 2016)

GELOMBANG TINGGI DAN BANJIR ROB DI WILAYAH PESISIR SELATAN JAWA DAN BARAT SUMATERA (STUDI KASUS TANGGAL 7 – 10 JUNI 2016)

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ABSTRACT

The high wave and spring tide occurred on June 7 to 10, 2016 had led to storm tide and coastal inundation at a number of coastal areas in south of Java and west of Sumatera, this incident caused substantial losses to coastal communities. The aim of this study is to understand the cause of storm tide, so it can be serve as a strategic contribution to assess, evaluate and mitigate the impact. The output of Wavewatch-III (WW3) model and Aviso Altimetry indicates the occurrence high wave in Indian Ocean reach more than 6 meters, this wave triggered by high wind speed around the Mascarene high event in Western Australia. Further analysis based on the output resulted by WW3 showed that the extreme wave in west Sumatera and south of Java (7-10 June, 2016) was dominated by swell waves generated by Mascarene High superposed with the highest diurnal tide as well as sea surface height anomaly, triggers the storm tide that consequentially costed more damaging impact in the south of Java and west of Sumatera.

Keywords: High Wave, tide, Coastal Inundation, Wavewatch-III, Mascarene High

ABSTRAK

Gelombang tinggi dan pasang air laut yang terjadi pada tanggal 7 -10 Juni 2016 menyebabkan sejumlah wilayah pesisir di selatan Jawa dan Barat Sumatera mengalami gelombang pasang dan banjir rob, yang mengakibatkan kerugian cukup besar bagi masyarakat pesisir. Kajian ini bertujuan untuk mengetahui penyebab terjadinya gelombang pasang tersebut, sehingga dapat bermanfaat sebagai evaluasi dan mitigasi kedepan. Data luaran model Wavewatch-III (WW3) dan Aviso-Satellite altimetry menunjukkan adanya gelombang tinggi lebih dari 6 meter di Samudera Hindia yang dipicu oleh angin kencang di sekitar wilayah kejadian *Mascarene High* di sebelah barat Australia. Analisis lebih lanjut berdasarkan output yang dihasilkan oleh WW3 menunjukkan bahwa gelombang ekstrim di selatan Jawa dan barat Sumatera (tanggal 7 – 10 Juni 2016) lebih didominasi oleh swell yang dihasilkan oleh kejadian Mascarene High. Terjadinya swell ini bersuperposisi dengan pasang tertinggi dan anomali tinggi muka laut, sehingga mengakibtkan terjadinya gelombang pasang dan banjir rob yang cukup merusak di sejumlah pesisir selatan Jawa dan barat Sumatera.

Kata kunci: Gelombang tinggi, Pasang Surut, Banjir rob, Wavewatch-III, *Mascarene High*

1. Introduction

Asian and Australian monsoon passed through Indonesia and move the opposite direction of each other periodically every six months [1]. During the Asian Monsoon period, particularly in December, January and February, the average wave height is high enough for most of the North region Equator Indonesia, such as in the South China Sea, Strait Karimata. And the contrary, the peak wave height in Indonesian waters, especially near the Indian Ocean, both in the south and north of the equator, occurred in June, July and August at the period of the Australian monsoon [2,3].

High waves threaten safety and cause much losses. It constrains activities of coastal communities and fishermen. High waves also cause interference to

coastal communities and fishing activities.It also cause delays in inter-island transportation and defer logistic distribution including material support, to small islands. It, in turn, impacts on food shortage, contribute to high inflation rate, and disrupt development activities. High waves definitely affect various activities at sea. Therefore, marine meteorological information services (marine meteorological services), in addition to the information the wind, information concerning waves become one of the important parts of information that must be present in every type of marine meteorological information [4]. This information is certainly very important for the maritime sector, including safety of shipping, development of coastal areas, defense and ship design [3]. The occurrence of extreme waves can be discerned either from the statistical point of view or its consequence thereof. In terms of statistics, extreme events are usually rare, the impact is, however, huge for the surrounding environment, especially activities in the impacted coastal areas [5].

The tidal wave that occurred on 7 to 10 of June 2016 has caused coastal inundation and flood at a number of coastal areas of Indonesia.National Disaster Management Agency (BNPB) released that a number of coastal areas in Indonesia experienced a tidal flood due to high tides, causing losses and disrupt community activities in the coastal areas, particularly in the west of Sumatra, north and south of Java's coasts [6].

There are several terminologies related with flood that occurs in the coastal area, including coastal flooding, tidal wave, and coastal inundation. World Meteorological Organization (WMO) names this phenomenon as coastal inundation [7], referring an inundation at the coastal area which is affected by meteorological, hydrology and/or oceanography factors. Northern of Java coastal communities are more familiar with the so-called coastal inundation phenomenon. This coastal inundation term used to distinguish flood coming from the sea as well as flood caused by overflowing river due to excessive rainfall. Unlike the case faced by communities live in the west coast of Sumatra, south of Jawa and Nusa Tenggara Timur (NTT), they refer the flood as a tidal wave.

The occurrence of tidal wave and coastal inundation in 7 till 10 June 2016 has resulted substantial losses, particularly for impacted coastal communities. Bearing in the objective to mitigate of the impact, the above mentioned phenomena is analysed and assessed.

2. Methods

Observation and measurement data at the ocean used to be very limited and, if any, is rarely continuous. Providing a more complete data, in addition to the available observation and measurement data, the wave hind-cast is also being explored based on estimated wind speed and direction [8].

In this report, data resulted from numerical simulated WW3 has been used to analysis the phenomena. WW3 is a third generation wave model developed at NOAA/NCEP, however, differs from its predecessors in many important points such as the governing equations, the model structure, the numerical methods and the physical parameterizations [9]. The parameters assessed covers wave height (Hs), Swell, Wind Sea, and wind that occurred from 7 to 10 June 2016 for every 12 hours (00 UTC and 12 UTC) [10].

Both wind data at 10 meters height with resolution 0,5°(≈55,5 km) compiled by GFS (Global Forecasting System) from National Center for Environmental Prediction (NCEP), NOAA[11], and ETOPO's bathymetry with resolution 1' (≈ 1,85 x 1,85 km) from US *Geological Survey* (USGS)[12] has been used as inputs for WW3. Parameterization used in the modelling and its validation referred to the research of Ramdhani (2015) [13].

The analysis on high wave and coastal inundation in the coastal area in the west of Sumatera and Southern part of Java was conducted based on the wave, sea surface anomaly of the Aviso-Satellite Altimetry [14], and tide gauge data at Cilacap (7.75 ° S - 109 ° E) from Geospatial Information Agency (BIG) to represent the tides in southern coast of Java in period June 2015 and June 2016 [15].

3. Result and Discussion

Extreme high wave as happened on 8 June 2016 in the coastal area in the western part of Sumatera was once occurred on 17 to 19 May 2007. The incidence has induced wave reached 3 to 6 meters height along the western part of Sumatera coast, southern part of Java, till Nusa Tenggara[16]. Construing that phenomena based on the output of numerically simulated wave using WW3, Habibie M.N. et al [16] found that the tidal wave at that period, other than caused by superposition of the low and high tides, there was also due to swell.

In the range of 7 till 10 June 2016, the increasing sea surface has inundated northern as well as southern parts of Java coasts. The happening of which was at the same period of new moon. The position of the moon, sun and earth was in conjunction that induced a spring tide, the phenomenon of when a gap between the high tide and the low ones is maximum. This event is actually a normal cycle that happens every month. However, analyzing the sea level from tide gauge data

at Cilacap (by comparing with the same astronomic phases tides data before and after the events), it indicates an increase of high water level (HWL) and low water level (LWL) during the time span of inundation events (Figure 1). The larger graphic shows the sea level at the same astronomic tide phases in May, June, and July, 2016 and the insert shows the emphasis on June 6-10 as a reference. This suggests that there is another triggering factor to the increase of sea level (Figure 1).

Nevertheless, this event is actually a normal cycle that happens every month. Sea level rise that occurred on June 7 to 10, 2016 can be seen from the positive anomalies of the Sea Surface Height in several Indonesian waters with a variation of 20-30 cm, among others, in the west of Sumatra, in the middle section of Malacca Strait, nothern and soither parts of Java coast, and southern part of Bali, this condition is higher when compared with sea level rise on 7-10, June 2015 (Figure 2).

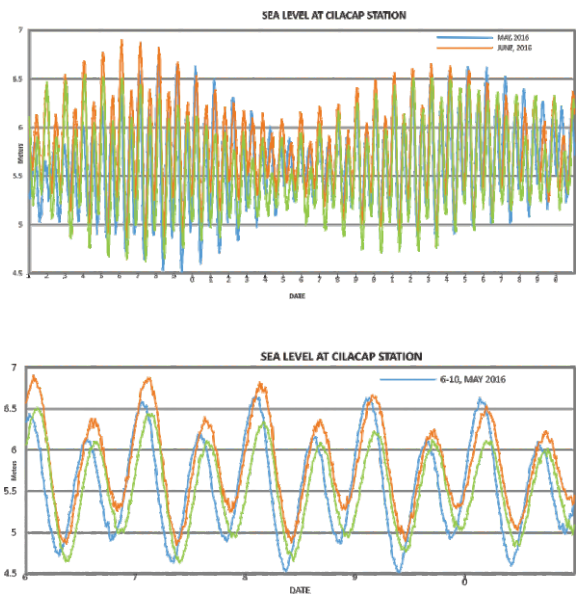

Figure 1. Sea level at Cilacap from the tide gauge of BIG, period May, June, and July [15].

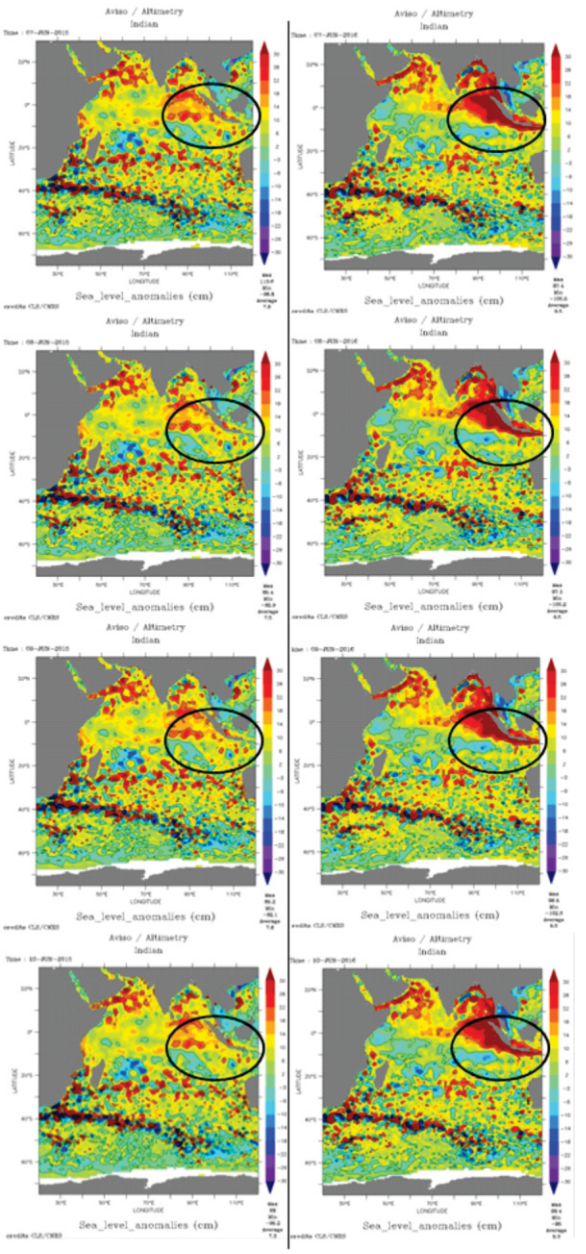

Figure 2. Aviso-Satellite altimetry data of sea level rise anomalies, (a) 7-10 June 2015 and (b) 7-10 June 2016 [14].

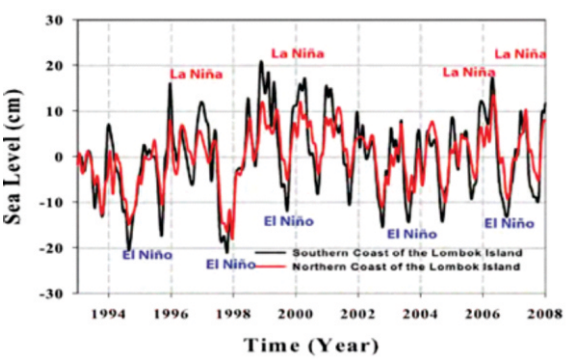

Figure 3. Time series of Sea Surfsce Height in the northern and southern part of Lombok and Sumbawa Islands as correlated with El Niño and La Niña [17].

It has long been widely reckoned that ENSO: El Niño and La Niña affects directly to the increase or decrease of sea surface height. Figure 3 shows the time series of sea surface height correlated with the occurrence of El Niño and La Niña for the period from 1993 until 2008. It is arguably that during El Niño period the sea surface height will drop by 20 cm below the normal level, whereas at La Niña period, it rises about 10 to 20 cm [17]. June 2016 was a transitional period of El Niño 2015 to La Niña 2016. In such period, the sea level tends to increase. It is caused by trade wind in the Pacific Ocean which getting stronger and brings the mass of water from the Equatorial Eastern Pacific and Central Pacific to the Equatroail western Pacific around north of New Guinea by called Warm pool. This incidence was marked by the movement of warm water pool in the Central Pacific to the Indonesian Archipelago. These conditions raise the gradient of sea level in Indonesian waters territory. The comparison of tides data in June 2015 and June 2016 at Cilacap (7.75 ° S - 109 ° E) shows the evidence that the sea level in June 2016 was higher than in June 2015 (Figure 4).

The combination of the above phenomena, namely the highest astronomical tide with positive anomalies and the high gradient of sea surface happened in some waters of Indonesia seems to correlate with the factor that triggers tidal flood disaster on 7 to 10 June 2016. In the same period, there was a storm tide in some coastal areas in the west of Sumatera and south of Java. The storm tide damaged the buildings at the impacted surrounding areas. Besides triggered by tidal flood above mentioned, the emergence of fairly extreme ocean wave in the range of 4 to 5 meter height seems to also contribute to the occurence of the storm tide.

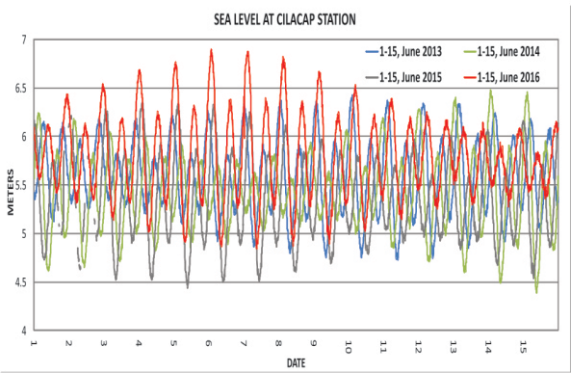

Figure 4. Sea level in Cilacap from the tide gauge of BIG in period June 2015 and June 2016[15].

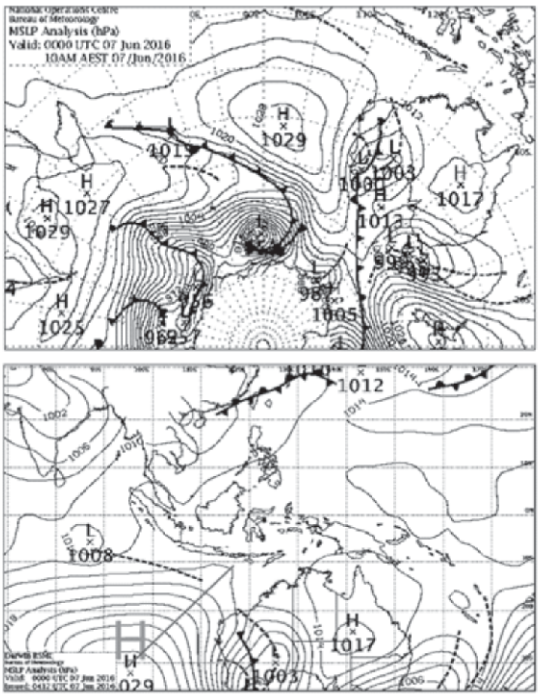

Figure 5. Mean Sea Level Pressure (MSLP) dated in June 7, 2016 at 00 hours UTC, Indian Ocean (top) [18], South East Asia / Western Pacific (bottom) (red: ridge of high pressure) [19].

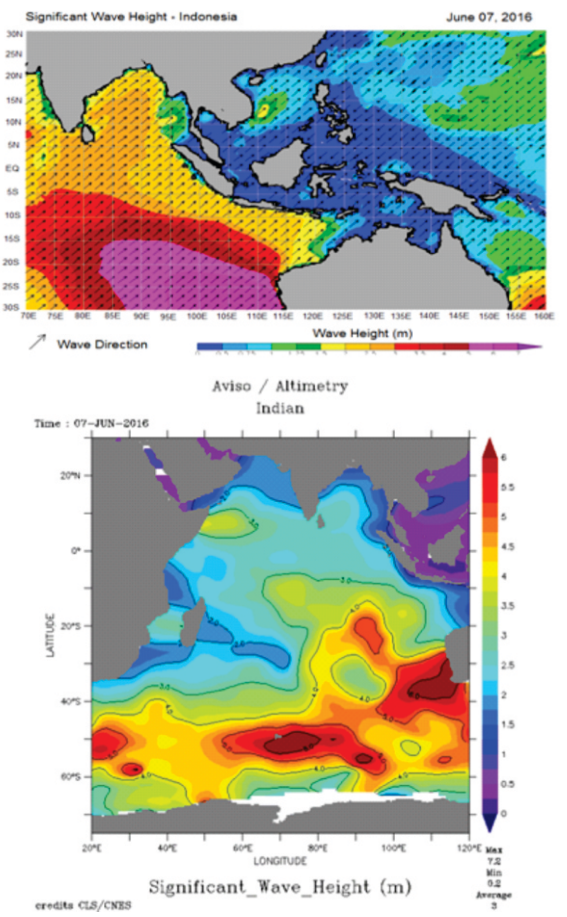

Figure 6. (a) Significant Wave Height in June 7, 2016, at 12:00 UTC[10], (b) Aviso-Satellite altimetry data of significant Wave Height in June 7, 2016[14].

The global air pressure characteristics shows a sub-tropical high pressure point known as Mascarene High at 30° S in the Indian Ocean in the western part of Australia (Figure 5). This phenomenon used to occur between the month of June and September. This 1029 HPa high pressure point has been identified since the date of June 7, 2016 and is getting stronger, moving eastward to the area southern part of Java. The surface wind around the Mascarane High reaches the speed of 25 - 30 knots, this triggered high speed wind and induced wave more than 6 meter height on 7 june 2016 at surrounding Mascarane High areas (Figure 6), and the swell waves generated from the Mascarene High event propagate reaching coastal area in West of Sumatera and South of Java, the swell event generated by the storm can propagate thousands of kilometers until the coastal region.

The WW3 seems to replicate effectively the pattern of the global wind characteristics. The speed of wind seems to getting stronger in the date of June 8, 2016 (Figure 7). Moreover, figure 7 also shows that in the western part of Sumatera and southern part of Java coasts, the wind speed from 7 till 10 June 2016 was dominated by south-easterly wind with the speed ranges from 5 - 10 knots.

Based on the output of the numerical model simulations WW3 in the period of 7 to June 10, 2016, the Hovmöller diagram (Figure 8) and Spatial map of Significant Wave Height (Figure 9) can be shown that the significant wave height in the southern part of Java coast reached 4 to 5 meters, whereas the wave height decreased in 10 June 2016.

Compared to the wind speed and direction condition in June 7 to 10, extreme waves that occur in the waters territory in the West of Sumatra and in the south of Java are more likely caused by the swell comes from Western Australia (Figure 10). Figure 11 clearly indicates that wind occured in June 7 - 10 unlikely affects the high waves in waters areas in the west of Sumatera and South of Java.

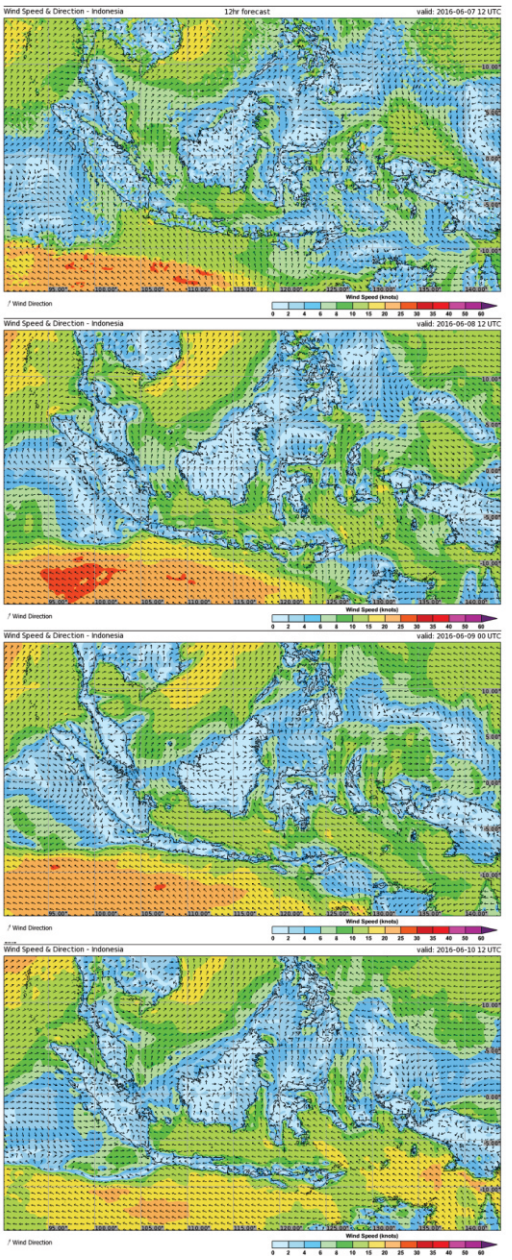

Figure 7. Surface Surface wind in period of June 7 to 10, 2016, at 12:00 UTC [10].

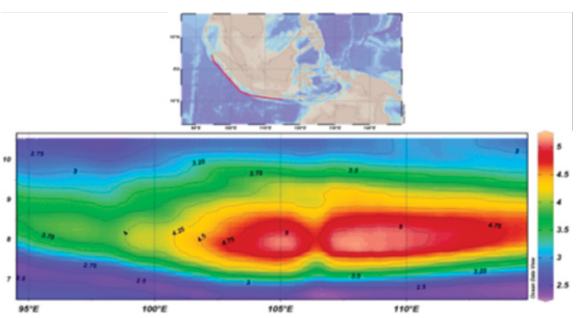

Figure 8. Hovmöller diagram of Significant Wave Height in period of June 7 to 10, 2016. (x axis is longitude, y axis is days and the color contour is Hs).

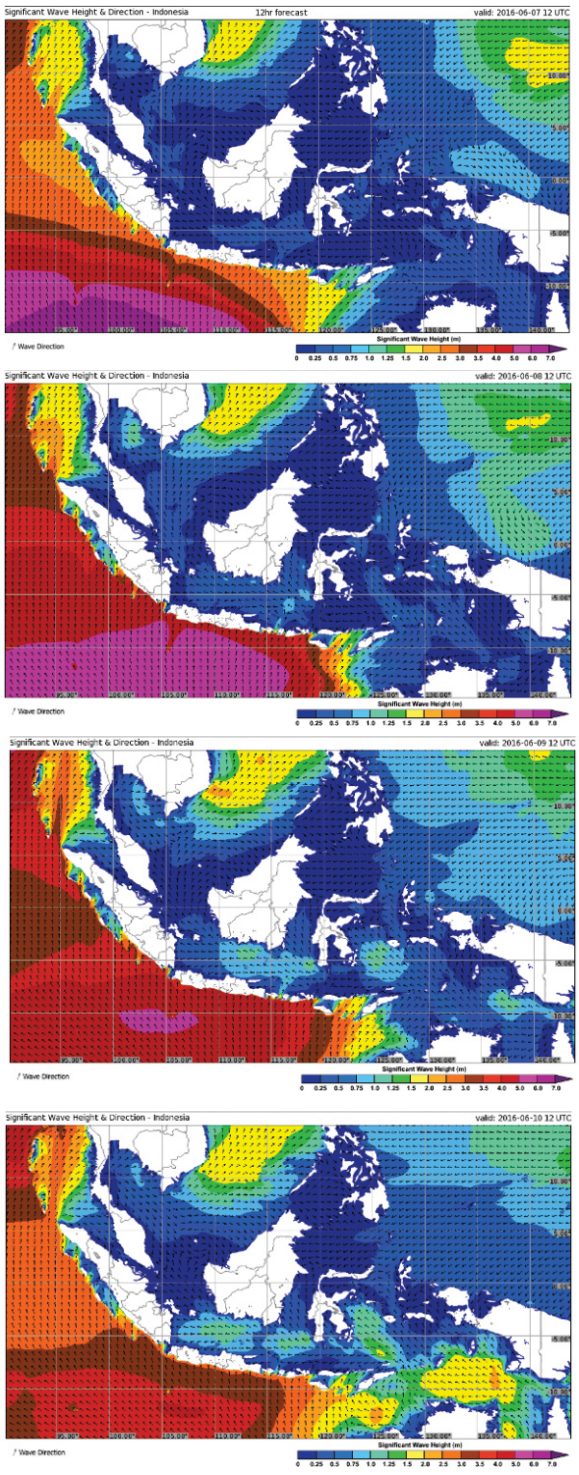

Figure 9. Significant Wave Height in period of June 7 to 10, 2016, at 12:00 UTC[10].

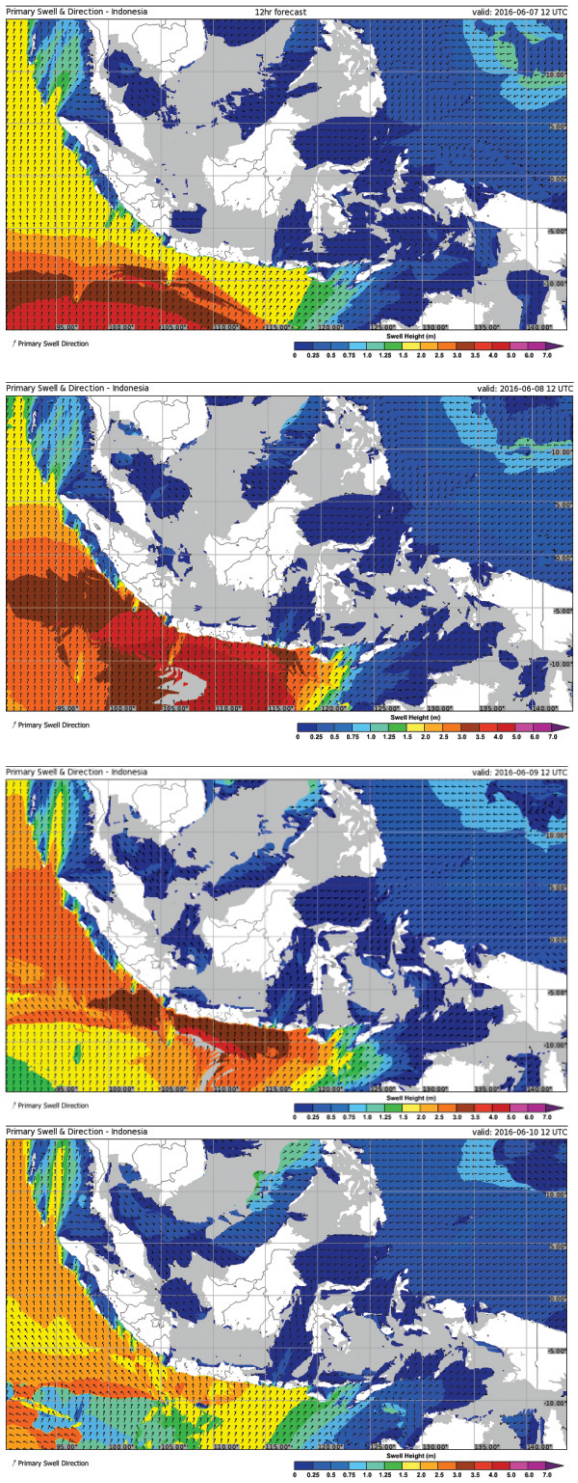

Figure 10. Swell in period of June 7 to 10, 2016, at 12:00 UTC [10].

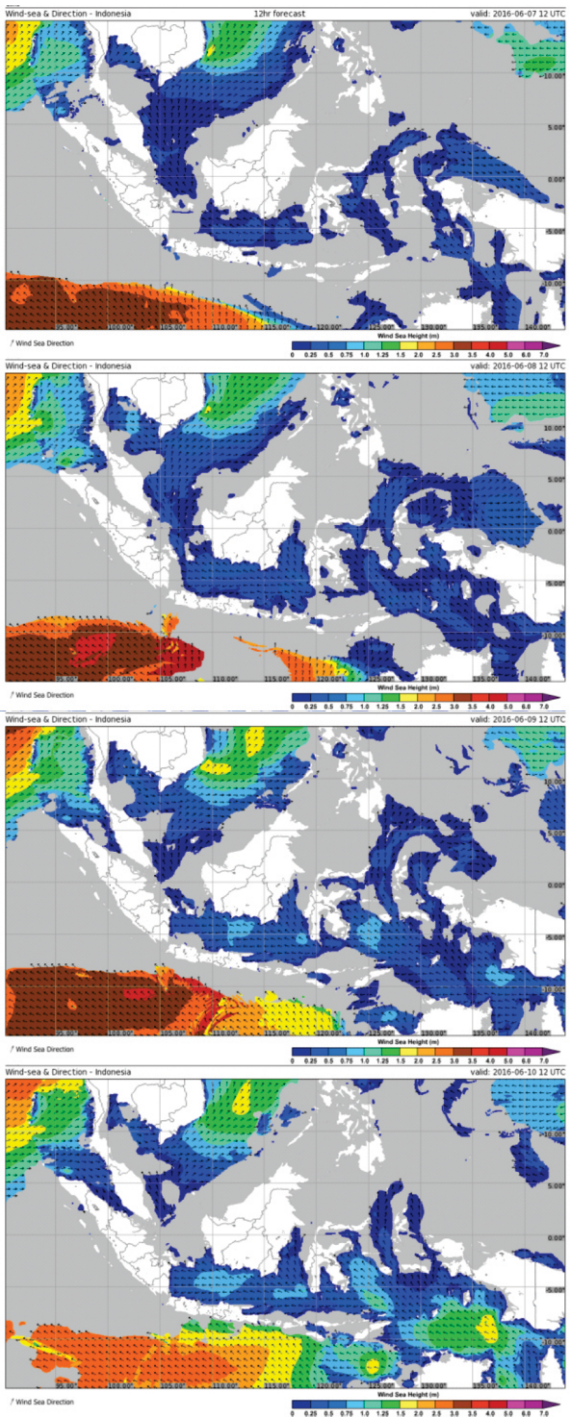

Figure 11. Windsea in in period of June 7 to 10, 2016, at 12:00 UTC [10].

4. Conclusion

The emergence of the phenomenon of the Mascarene high in west Australia lead fairly strong wind speeds around the region. These conditions affected the wave height varies between 6.0 - 8.0 meters. The waves are induced by Mascarene High propagates and causes swell that reaches 5 m height in the waters territory of the west of Sumatera and South of Java. The numerical simulated result using WW3 reemphasizes the hypothesis that the extreme wave occurred in the West of Sumatera and south of Java coast area, particularly in June 8, 2016, was dominated by swell as compare to merely waves. The condition was worsened due to superposition of spring tide and high gradient and sea surface height that triggered the storm tide in the coastal area of southern part of Java and western part of Sumatera.

Reference

[1] Ramage, C. S. (1971). *Monsoon Meteorology*. San Diego: Academic Press.

[2] Kurniawan, R., Habibie, M. N. & Permana, D. S. (2012). Study of High Wave Prone Areas Over Indonesian Waters. Jurnal Meteorologi dan Geofisika. 13(3), 201-212.

[3] Kurniawan, R.&Mia Khusnul Khotimah. (2015). Ocean Wave Characteristics In Indonesian WatersFor Sea Transportation Safety And Planning. Jurnal IPTEK, The Journal for Technology and Science. 26(1), 19-27.

[4] World Meteorolgical Organization (WMO). (2001). *Guide the marine Meteorological Services, Third edition,* WMO no.471. Secretariat of the World Meteorological Organisation, Geneva-Switzerland: Author.

[5] Garrett, C. & Muller, P. (2008). Extreme events. Suplement: Bulletin of American Meteorological Society.

[6] BNPB. 2016. The Indonesian Disaster Data and Information-DIBI. http://dibi.bnpb.go.id/.

[7] JCOMM. (2012). Coastal Inundation Forecasting Demonstration Project-Implementation Plan. Joint WMO – IOC Technical Commission For Oceanography And Marine Meteorology, JCOMM Technical Report No. 64.

[8] World Meteorological Organization (WMO). (1998). *Guide to Wave Forecasting and Analysis, WMO-No. 702*, Secretariat of the World Meteorological Organisation, Geneva-Switzerland: Author.

[9] NOAA - National Weather Service, Environmental Modeling Center, Wavewatch III Model. http://polar.ncep.noaa.gov/waves/wavewatch/

[10]BMKG Ina-Waves. http://peta-maritim.bmkg.go.id/2.0/peta_interaktif.php. accessed June 18th, 2016.

[11]National Center for Environmental Prediction (NCEP) – NOAA. https://www.mmm.ucar.edu/.

[12]US Geological Survey (USGS). (http://www.usgs.gov/

[13]Andri Ramdhani, 2015. Effects of tropical cyclone and the Madden-Julian Oscillation (MJO) to the high wave events in

Indonesian waters in parts. Doctoral Dissertation Study of Earth Sciences, Bandung Institute of Technology. AVISO Ocean Bulletin - Sea views

[14]. http://bulletin.aviso.oceanobs.com/html/produits/aviso/welcome_uk.php3). accessed June 18th, 2016.

[15]IOC. 2016, Sea Level Station Monitoring Facility. http://ioc-sealevelmonitoring.org/station.php?code=cili. accessed June 18th, 2016.

[16]Muhammad Najib Habibie, Donaldi Sukma Permana, Suratno. (2013). The Simulation Of Extreme Wave Due To Swell In Indonesia Using WAVEWATCH-III. Jurnal Meteorologi dan Geofisika. 14(2), 99-108.

[17]WWF Indonesia. *Kajian Risiko dan Adaptasi Terhadap Perubahan Iklim Pulau Lombok Provinsi Nusa Tenggara Barat Sektor Pesisir dan Laut*, http://awsassets.wwf.or.id/downloads/sektor_pesisir_dan_laut.pdf. accessed June 18th, 2016.

[18]Bereau of Meteorology (BOM), Australia Government. MSLP Analysis. http://www.bom.gov.au/cgi-bin/charts/charts.view.pl?idcode=IDX0033&file=IDX0033.201606070000.gif. accessed June 18th, 2016.

[19]Bureau of Meteorology (BOM), Australia Government. MSLP Analysis.. accessed June 18th, 2016.