International Journal of Engineering & Technology, 7 (4.35) (2018) 248-253

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Determination of the Most Significant Fault Parameters for Manila Trench Earthquake Tsunami

A. F. Aziz[1]*, N. H. Mardi[2], M. A. Malek[3], W. K. Tan[4], S. Y. Teh[5]

[1]Civil Engineering Dept. College of Engineering, Universiti Tenaga Nasional, 43000, Kajang, Selangor, Malaysia.
[2]Institute of Power Energy (IPE), Universiti Tenaga Nasional, 43000, Kajang, Selangor, Malaysia.
[3]School of Mathematical Sciences, Sunway University, Bandar Sunway, 47500 Subang Jaya, Selangor, Malaysia.
[4]School of Mathematical Sciences, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia.
**Corresponding author E-mail: afifaziz51@gmail.com*

Abstract

Manila Trench subduction zone is capable to produce high magnitude of earthquake event that can generate a deadliest tsunami disaster. The 2006 tsunami source workshop conducted by United States Geological Survey (USGS) had classified Manila Trench as the most hazardous potential earthquake generated tsunami source in South China Sea. The giant megathrust rupture from Manila Trench has the ability to create an earthquake as powerful as the Great Tohoku tsunami in 2011 and the Indian Ocean tsunami in 2004. This technical paper aims to review the fault parameters used by different researchers in investigating the possibility of tsunami occurrences generated from Manila Trench earthquake to the coastal areas of Terengganu, Malaysia which is located within the vicinity of South China Sea. The selected fault parameters were simulated by using TUNA model in order to study the potential effects of Manila Trench earthquake induced tsunami. The outcomes of the simulation are the wave height and wave arrival time. At the end of this technical paper, an intensive approach is implemented to select the most significant fault parameters that create the potential worst-case tsunami scenario towards Terengganu coastal areas in terms of the highest and fastest first wave arrived.

Keywords: *South China Sea; Manila Trench; Earthquake tsunami; TUNA-M2*

1. Introduction

Tsunami is a hazardous natural coastal disaster impacting coastline areas and generally generated by natural events such as seaquakes, submarine landslides, volcanic eruptions and possibly caused by meteorites impact. The most typical tsunami events are induced by earthquakes that generate abrupt movements on the tectonic plate. The earthquake activities can generate a series of waves over a few meters high, striking the coastline areas in a period of a few hours. This phenomenon happened many times over the last couple of years and can occur at any time in the near future. This study focuses on the tsunami that is caused by earthquake activities from Manila Trench and its impacts toward Terengganu coastal regions. Terengganu is situated in the east-coast of Peninsular Malaysia and is bordered by Kelantan and Pahang in the northwest and southwest respectively. The east side of Terengganu is bordered by the South China Sea. Terengganu is a state with a long coastline and located with several offshore islands, making it popular for tourism industries which captivate beachgoers and snorkelers because of their picture-perfect beaches. Other than that, fishing and agriculture also are the important industries in Terengganu. Now, the petroleum and gas industry have become the main industry in Terengganu after the oil and gas were explored off the coastline in relatively recent past.

There are various aspects of tsunami being studied by researchers all over the world. The formation of tsunami has three main phases which are generation, propagation and run-up plus inundation. In this paper, the generation and propagation phases are being studied by simulating the earthquake induced tsunami from Manila Trench source. The simulation is done by using TUNA-M2 (Tsunami-tracking Utilities and Application) model which is developed in Malaysia. The fault parameters which acted as the source control in TUNA-M2 model are needed in order to generate the initial condition of tsunami source. In this study, the Okada Source Model is used for generating the initial tsunami source with the involvement of parameters such as focal depth, rake angle, dip angle and strike angle. This paper reviews the fault parameters used by previous researchers in investigating the tsunami generated from Manila Trench earthquake. Then, the selected fault parameters were simulated by using TUNA-M2 model in order to study the potential effects of Manila Trench earthquake tsunami towards Terengganu coastal areas. Each fault parameters have their own characteristics. At the end of this study, an intensive approach is implemented to determine the most significant fault parameters that create the potential worst-case tsunami scenario towards Malaysia offshore areas in terms of the highest and fastest first wave arrived. Future studies on simulation of tsunami generated from Manila Trench earthquake will be performed by utilizing the most significant fault parameters.

2. Fault Parameters of the Manila Trench

The 2006 tsunami source workshop conducted by United States Geological Survey (USGS) had identified three subduction zones, the Manila Trench, the Ryukyu Trench and the North Sulawesi Trench, that physically could harm countries within South China Sea vicinity [1]. The Manila Trench, also called the Manila subduction zone, has been categorized as the largest and hazardous seaquake generated tsunami source in South China Sea compared to other sources [2]. The length of Manila Trench is about 1000 km, beginning from the north of Palawan, Philippine, expands to the north along the Western edge of Luzon and completely stops in Taiwan as shown in Figure 1 [2]. The giant megathrust rupture from Manila Trench is able to create an earthquake with the moment magnitude that could reach Mw: 9.0 which is as powerful as the Great Tohoku tsunami in 2011 and the Indian Ocean tsunami in 2004 [3]. The violent tsunami wave with leading elevation crest is expected to travel away through South China Sea towards Hong Kong, Vietnam, China, Taiwan, Thailand, Singapore and Malaysia [4].

The tsunami disaster induced by the Manila Trench earthquake has been studied extensively with varying perspectives on the fault parameters to develop the potential worst-case scenario. USGS suggested that there are six fault segments existed along Manila Trench based on the trench azimuth and the fault geometries [5]. The fault parameters included are the longitude and latitude of each segments, length of segments, strike angle, dip angle and rake angle [1]. In some researches carried out to investigate the impact of tsunami generated from Manila Trench source, there are authors suggested that the Manila Trench megathrust length is adequate to develop a Mw: 9.3 tsunami-genic earthquake [5][6], while other researchers decided to use the moment magnitude of Mw: 9.0 as the worst-case scenario [3][4].

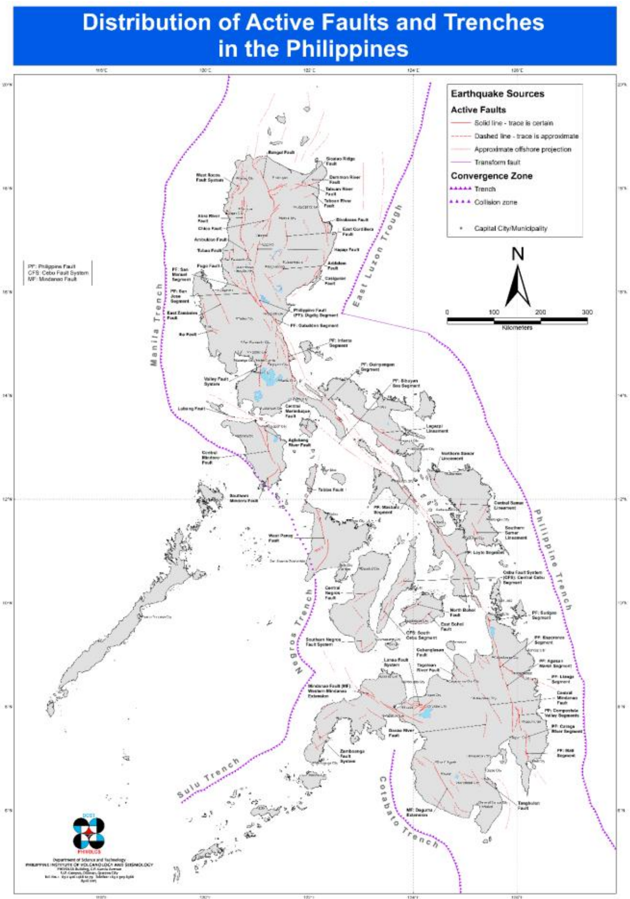

Fig 1: Distribution of active faults and trenches in Philippines [8]

Until now, there is still no study conducted in reviewing the Manila Trench fault parameters proposed by different researchers and analyzed its tsunami impact towards the east-coast of Peninsular Malaysia coastal areas. However, this study is implemented as an approach to determine the most significant fault parameters among the reviewed fault parameters, that create the potential worst-case tsunami scenario impacting the coastal areas located at the east-coast of Peninsular Malaysia. TUNA-M2 model is used to simulate the Manila Trench earthquake tsunami developed from different fault parameters with the moment magnitude of Mw: 9.3 proposed by Liu et al. [2], Nguyen et al. [6] and Mardi et al. [7] and Mw: 9.35 proposed by Wu and Huang [5]. This study only considered the Manila Trench earthquake source with six fault segments and utilized the rake angle of 90˚ to indicate the potential worst-case scenario.

2.1. The Manila Trench Fault Parameters Proposed by Liu.

The six fault segments parameters as indicated by Kirby et al. [1] was used in this study. For each fault segment, the strike and dip angles assigned were the same as suggested in the USGS Tsunami Source Workshop. In consideration of generating the potential worst-case scenario tsunami source, the rake angle of every segment was assumed 90˚ to develop maximum seafloor deformation [2]. The focal depth was assumed 15 km as it is familiar to be noticed in many major seismic activities in this region [2]. The width of every fault segment was identified by estimating the width from several past tsunami events by referring the National Earthquake Information Center (NEIC) database. This is because the true fault width can only be determined after an earthquake event [2].

In 1999, an earthquake with moment magnitude, Mw: 7.3 occurred at Manila Trench and with this vital data, the width of fault segment was estimated as 34 km [2]. Besides that, an alternative way was used in obtaining the fault width by using the empirical formula established by Wells and Coppersmith [9]. From the calculations, the width for every fault segment varies slightly, so the average width of 35 km for all the six segments is used. The dislocations were then calculated by using these following equations:

$$M_o = \mu DLW \tag{1}$$

$$M_w = \frac{2}{3}\log_{10} M_o - 10.7 \tag{2}$$

where M_o is the scalar moment of an earthquake, $\mu = 3.0 \times 10^{10}\ N/M$ is the rigidity of earth mantle, W is the fault width, L is the fault length, D is the dislocation, and M_w is the moment magnitude of an earthquake.

The moment magnitude used by Liu et al. [2] was Mw: 8.0, this study however decided to simulate the tsunami generated by earthquake with moment magnitude of Mw: 9.3 as the potential worst-case scenario. Hence the new dislocation at each segment were calculated by using Equations (1) and (2). The modified fault parameters are shown in Table 1.

2.2. The Manila Trench Fault Parameters Proposed by Wu and Huang.

In 2009, Wu and Huang suggested the worst-case scenario fault parameters for Manila Trench after referring the hypothetical fault geometry from three largest historical tsunami-genic earthquakes [5][6]. The potential worst-case scenario parameters for the source model from Manila Trench had been suggested to be generated by the earthquake moment magnitude of Mw: 9.35 with the fault width of 200 km, the fault length of 990 km, the focal depth of 40 km and the dislocation of 20 km. The fault parameters including the longitude, latitude, length, dip angle and strike angle of every fault segment followed the suggestion made by the USGS Tsunami Source Workshop. The rake angle for every fault plane is assumed to be 90° in order to indicate the potential worst-case scenario for the tsunami event as it generates maximum seafloor deformation [1]. The strike angle had been slightly modified by adjusting the sub-fault orientation in order to make it close to the reality [5]. The finalized potential worst-case scenario source model suggested by Wu and Huang [5] is shown in Table 2. Wu and Huang [5] used the same values of the dislocation, width, rake angle and focal depth for all the six fault segments.

Table 1: The finalized fault parameters of Manila Trench by Liu et al. [2]

Fault	Lon. (degree)	Lat. (degree)	Length (km)	Width (km)	Strike (degree)	Dip (degree)	Rake (degree)	Focal depth (km)	Dislocation (m)
E1	120.5	20.2	160	35	10	10	90	15	595.24
E2	119.8	18.7	180	35	35	20	90	15	529.10
E3	119.3	17	240	35	359	28	90	15	396.83
E4	119.2	15.1	170	35	3	20	90	15	560.22
E5	119.6	13.7	140	35	320	22	90	15	680.27
E6	120.5	12.9	100	35	293	26	90	15	952.38

Table 2: The finalized fault parameters of Manila Trench by Wu and Huang [5]

Fault	Lon. (degree)	Lat. (degree)	Length (km)	Width (km)	Strike (degree)	Dip (degree)	Rake (degree)	Focal depth (km)	Dislocation (m)
E1	120.5	20.2	160	200	354	10	90	40	20
E2	119.8	18.7	180	200	22	20	90	40	20
E3	119.3	17	240	200	2	28	90	40	20
E4	119.2	15.1	170	200	356	20	90	40	20
E5	119.6	13.7	140	200	344	22	90	40	20
E6	120.5	12.9	100	200	331	26	90	40	20

Table 3: The finalized fault parameters by Nguyen et al. [6]

Fault	Lon. (degree)	Lat. (degree)	Length (km)	Width (km)	Strike (degree)	Dip (degree)	Rake (degree)	Focal depth (km)	Dislocation (m)
E1	120.5	20.2	190	120	354	10	90	30	25
E2	119.8	18.7	250	160	22	20	90	30	40
E3	119.3	17	220	160	2	28	90	30	40
E4	119.2	15.1	170	90	356	20	90	30	28
E5	119.6	13.7	140	110	344	22	90	30	12
E6	120.5	12.9	95	80	331	26	90	30	5

Table 4: The finalized fault parameters of Manila Trench by Mardi et al. [7]

Fault	Lon. (degree)	Lat. (degree)	Length (km)	Width (km)	Strike (degree)	Dip (degree)	Rake (degree)	Focal depth (km)	Dislocation (m)
E1	120.5	20.2	160	71	10	10	90	15	293.43
E2	119.8	18.7	180	71	35	20	90	15	260.82
E3	119.3	17	240	71	359	28	90	15	195.62
E4	119.2	15.1	170	71	3	20	90	15	276.17
E5	119.6	13.7	140	71	320	22	90	15	335.35
E6	120.5	12.9	100	71	293	26	90	15	469.48

2.3. The Manila Trench Fault Parameters Proposed by Nguyen.

By incorporating the two source models introduced by Megawati et al. [3] and Wu and Huang [5], Nguyen et al. [6] designed a potential worst-case scenario source model with moment magnitude Mw: 9.3. The six fault segments geometry imitated in this study with some modifications made to obtain the fit shape and size of each segment [6]. The strike and dip angles of each fault segment were appointed in accordance with the values suggested by Wu and Huang [5] while the dislocation for every segment were referred to the values introduced by Megawati et al. [3]. The rake angle was assumed to be 90˚ to indicate the potential worst-case scenario. The focal depths used in this study were 30 km. The length and width of each fault segment were computed by utilizing the established Wells and Coppersmith empirical relationships [9]. The procedure taken to define the potential worst-case scenario fault parameters was shown in their research paper [6]. Table 3 shows the finalized worst-case scenario source model with moment magnitude Mw: 9.3 proposed by Nguyen et al. [6]. As can be seen, the length of fault segments was different with values identified in USGS Tsunami Source Workshop and each fault width varies slightly.

2.4. The Manila Trench Fault Parameters Proposed by Mardi.

In 2016, the study done by Mardi et al. [7] used the six divided fault segments as suggested by the 2006 USGS Tsunami Source Workshop, utilizing the Papazachos et al. [10] empirical equations to determine the width of fault segments. The values calculated for each fault segment width are ranging from 53 km to 88 km. For simplicity, the average value which is 71 km was chosen as the fault width for every segment.

The Equations (1) and (2) are used to determine the dislocation for each fault segment to be used in this study. The finalized fault parameters for the earthquake with moment magnitude Mw: 9.3 is shown in Table 4. In this study, all the fault parameters used were the same as proposed by Liu et al. [2] except for the fault segment width and dislocation.

3. Tsunami Propagation Model

Tsunami propagation models are developed to prepare the coastal communities which are exposed to tsunami risk and to provide near real-time projection while tsunamis propagate through the open ocean and before reaching the coastline. There are several tsunami numerical models available to perform tsunami numerical simulation. In 2015, Ren et al. [11] conducted a research to study the Manila Trench earthquake tsunami with moment magnitude of Mw: 8.0 and the worst-case scenario (Mw: 9.3) by using the weakly dispersive model (FUNWAVE). However, this study utilized TUNA model to perform tsunami simulation from Manila Trench by using fault parameters proposed by Liu et al. [2], Wu and Huang [5], Nguyen et al. [6], and Mardi et al. [7]. TUNA is developed by the research team from Universiti Sains Malaysia (USM) to simulate a complete tsunami process with three different modules, generation (GE), propagation (M2) and, run-up and inundation (RP). In this paper, TUNA-GE, which is based on the

Okada formulation, was utilized to simulate the initial tsunami wave induced by various earthquake sources, while TUNA-M2, which solves the linear shallow water equations, was used to simulate the tsunami wave propagation across deep ocean. In future work, high-resolution topographic and bathymetric data will be obtained from relevant governmental agencies to simulate the run-up and inundation phase by utilizing TUNA-RP module.

TUNA model is a validated model since the tsunami results recorded from TUNA model signified satisfying performance and fine correlation when it was matched with the results simulated from a well-established model COMCOT and on-site survey data [12]. Mardi et al. [13] chose TUNA model to perform tsunami numerical simulation in their research due to the consistency and computational efficiency when compared to other tsunami models such as COMCOT, TUNAMI, MOST, and ANN Tsunami Forecast. Based on literature review, several tsunami events at Andaman Sea [12], Indian Ocean [14] and South China Sea [15] [16] had been investigated by using TUNA model. In this study, the outcomes from TUNA-M2 model will provide an approximation of Manila Trench tsunami waves height and waves arrival time towards the study area in Terengganu, Malaysia.

TUNA model applies the Okada model to generate the initial tsunami wave height induced by an earthquake and utilizes the shallow water equation (SWE) to simulate wave propagation. TUNA is a two-dimensional model which solves the linear SWE as the governing equation in accordance with the proposal made by Intergovernmental Oceanography Commission (IOC) [17]. Since the wavelength of tsunami wave is large and the wave height is much smaller than the depth of ocean, so SWE is genuine to be used for the analysis of tsunami wave. This condition can be applied for tsunami propagations occurred within the South China Sea and the Andaman Sea. The SWE is solved in TUNA-M2 model by applying explicit finite difference with staggered grids. Equations (3) to (5) presented the equations of SWE:

$$\frac{\partial_{\eta}}{\partial_{t}}+\frac{\partial_{M}}{\partial_{x}}+\frac{\partial_{N}}{\partial_{y}}=0 \tag{3}$$

$$\frac{\partial_{M}}{\partial_{t}}+\frac{\partial}{\partial_{x}}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial_{y}}\left(\frac{MN}{D}\right)+gD\frac{\partial_{\eta}}{\partial_{x}}+\frac{gn^2}{g^{7/8}}M\sqrt{M^2+N^2}=0 \tag{4}$$

$$\frac{\partial_{N}}{\partial_{t}}+\frac{\partial}{\partial_{x}}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial_{y}}\left(\frac{N^2}{D}\right)+gD\frac{\partial_{\eta}}{\partial_{y}}+\frac{gn^2}{g^{7/8}}N\sqrt{M^2+N^2}=0 \tag{5}$$

Here, n $(s/m^{1/3})$ symbolizes the Manning's roughness coefficient, g (m/s²) indicates the gravitational acceleration constant, M (m²/s) and N (m²/s) represent the horizontal discharged fluxes in the x- and y-direction respectively, which then related to velocities u (m/s) and v (m/s) as stated in Equations (6) and (7), η (m) symbolizes the vertical free surface displacement measured from mean sea level (MSL), h (m) indicates the water depth below MSL, and D (m) = $h+\eta$ represents the total water depth.

$$M=u\left(h+\eta\right)=uD \tag{6}$$

$$N=v\left(h+\eta\right)=vD \tag{7}$$

In this paper, a computational domain is bordered by 100˚E to 125˚E in longitude and 0˚N to 25˚N in latitude within a square shape with grid dimension of 1851×1851 and grid size of 1500 m is used. A 180 km length of study area boundary covering the entire coastline of Terengganu, Malaysia is selected for the simulation purpose. The Manila Trench tsunami wave is expected to propagate towards Terengganu east boundary. The study domain stated as A and Terengganu east boundary are shown in Figure 2 and Figure 3.

Fig. 2: Study domain (A)

Fig. 3: Terengganu east boundary

4. Results and Discussion

In this paper, the tsunami source recognized is induced by a megathrust earthquake from Manila Trench of moment magnitude Mw: 9.3 which are considered as the possible worst-case scenario by four literatures stated in section 2. The result for tsunami wave height and arrival time is obtained when the earliest wave peak arrives at the Terengganu east boundary. Based on the results obtained from the simulation of tsunami by utilizing TUNA-M2 model, the tsunami wave height and wave arrival time were identified for each scenario. The maximum and minimum of tsunami wave height and arrival time that reached the Terengganu east boundary were clarified in terms of range as shown in Table 5. As observed, the fault parameters suggested by Mardi et al. [7] provide the highest range of tsunami wave height from 2.70 m to 4.65 m followed by Liu et al. [2] with the wave height range of 2.33 m to 4.00 m. The third highest range of wave height is contributed by the Nguyen et al. [6] fault parameters with the range of 0.45 m to

0.55 m while the lowest wave height range, 0.35 m to 0.50 m is coming from the fault parameters proposed by Wu and Huang [5]. In terms of arrival time, the tsunami wave expected to hit Terengganu east boundary is ranging from 8.90 h to 9.40 h for the combination of all scenarios. Based on the results, the tsunami generated by Manila Trench earthquake will arrive Terengganu offshore approximately within 9 hours after the generation phase. Based on the result summarized in Table 5, the tsunami from Liu et al. [2] is expected to be the earliest wave to reach Terengganu east boundary followed by fault parameters suggested by Mardi et al. [7], Wu and Huang [5] and Nguyen et al. [6].

Table 5: Tsunami wave height range and arrival time range results

Fault Parameters	Wave Height Range (m)	Wave Arrival Time Range (h)
Liu et al. [2]	2.33 – 4.00	8.90 – 9.07
Wu and Huang [5]	0.35 – 0.50	9.10 – 9.25
Nguyen et al. [6]	0.45 – 0.55	9.16 – 9.40
Mardi et al. [7]	2.70 – 4.65	8.92 – 9.08

Then, the maximum wave height for each scenario are determined and plotted in graph. Figure 4 displays the tsunami wave height versus wave arrival time graph for the maximum wave height of each fault parameters analyzed in this paper. According to the results, the waves can be seen starting to propagate approximately about 9 hours for all four scenarios. The highest maximum first wave peak height is contributed by fault parameters proposed by Mardi et al. [7] which is 4.65 m. The second highest wave height goes to fault parameters from Liu et al. [2] with 4.00 m and followed by Nguyen et al. [6] and Wu and Huang [5] with a very low wave height compared to other fault parameters which are 0.55 m and 0.50 m respectively. This is due to the low value of dislocations set by Wu and Huang [5] and Nguyen et al. [6] compared to Liu et al. [2] and Mardi et al. [7] which were using Equations (1) and (2) in determining the dislocations for every fault segment.

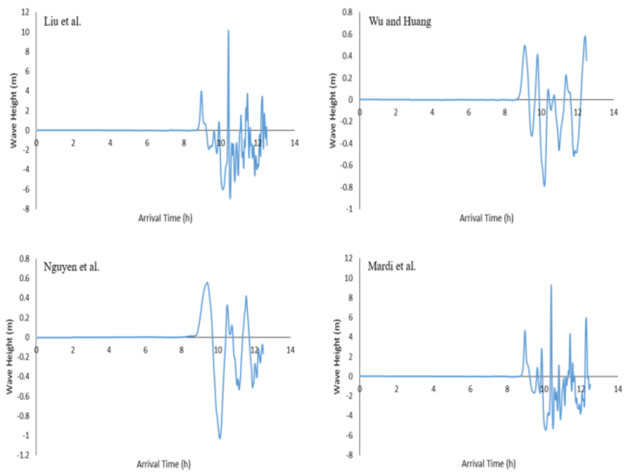

Fig. 4: The maximum tsunami wave height versus arrival time graph for each fault parameters.

Figure 5 shows the maximum wave height arrival time for every fault parameter. Based on the combination column and line chart, it shows that the arrival time for the highest maximum wave height (4.65 m) as proposed by Mardi et al. [7] is at 8.95 hours after the earthquake occurred. For maximum 4 m wave height as suggested by Liu et al. [2], the tsunami wave also will take 8.95 hours to travel from the epicenter to the Terengganu east boundary. The arrival time for tsunami wave generated by the fault parameters set by Nguyen et al. [6] is taking the longest time to reach Terengganu offshore with the approximate time of 9.35 h while Wu and Huang [5] fault parameters take about 9.1 h for the 0.5 m maximum wave height to arrive the boundary.

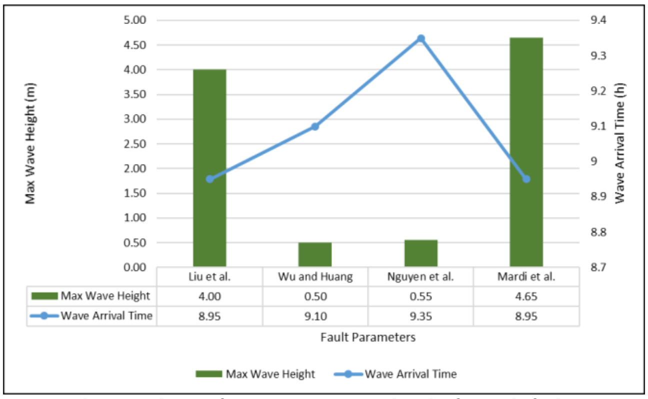

Fig. 5: The arrival time for maximum wave height for each fault parameters.

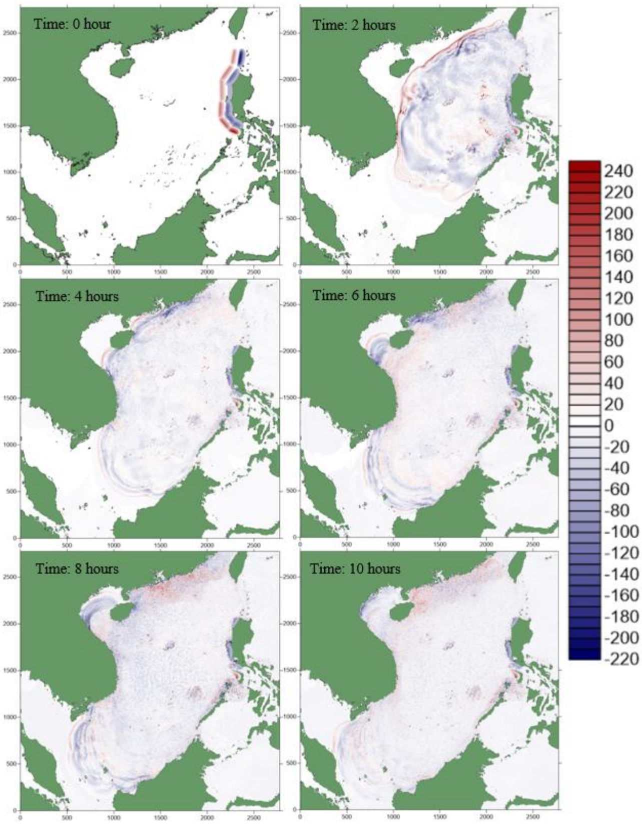

Fig. 6: Tsunami wave propagation time sequence from Manila Trench.

Based on the overall results of this study, due to the highest wave height range and the speed of arrival time to hit the Terengganu east boundary, it can be concluded that the tsunami wave generated from Manila Trench earthquake based on fault parameters proposed by Mardi et al. [7] is the most dangerous tsunami event. This is followed by the fault parameters proposed by Liu et al. [2], Nguyen et al. [6] and Wu and Huang [5]. It is also found that, the time taken for the tsunami wave to arrive Terengganu east boundary is approximately around 9 hours as the range for the wave arrival time is from 8.9 h to 9.4 h for the combination of all scenarios. Besides that, the values of wave heights obtained from Mardi et al. [7] and Liu et al. [2] fault parameters show significant differences when compared to the wave heights achieved from Nguyen et al. [6] and Wu and Huang [5]. Because of that, the fault parameters proposed by Mardi et al. [7] and Liu et al. [2] should be taken into account in conducting future study on the tsunami generated from Manila Trench earthquake towards Malaysia coastal regions. Figure 6 exhibits the tsunami wave propagation time sequence from Manila Trench earthquake source towards Terengganu east boundary from the simulation result of fault parameters proposed by Mardi et al. [7].

5. Conclusion

The simulation of tsunami induced from Manila Trench earthquake towards Terengganu coastal areas has been conducted by using TUNA-M2 model. This paper presented and compared four simulation results generated by the six fault segments Manila Trench earthquake source developed from fault parameters with the moment magnitude of Mw: 9.3 proposed by Liu et al. [2], Nguyen et al. [6] and Mardi et al. [7] and Mw: 9.35 proposed by Wu and Huang [5]. The outcomes of the simulation are the wave height and wave arrival time. The comparison shows that the tsunami waves generated based on the fault parameters proposed by Mardi et al. [7] created the highest wave height range from 2.7 m to 4.65 m when reaching the Terengganu east boundary and followed by the fault parameters proposed by Liu et al. [2], Nguyen et al. [6] and Wu and Huang [5]. The wave arrival time for tsunami from Manila Trench to hit the Terengganu offshore is approximately around 9 hours.

Based on the comparison that has been made, the fault parameters proposed by Mardi et al. [7] and Liu et al. [2] should be highlighted and taken into account in conducting future studies on the generation of tsunami from Manila Trench earthquake towards Malaysia coastal areas. For future analysis, the fault parameters for the simulation of Manila Trench tsunami-genic earthquake by using TUNA-M2 model should be set as follow:

a. The Manila Trench megathrust is divided into 6 fault segments as suggested by USGS.
b. The longitude and latitude of fault segments, length of fault segments, strike and dip angle are set as suggested by Kirby et al. [1].
c. The rake angle is assumed to be 90° to indicate the potential worst-case scenario for Manila Trench tsunami event as it generates maximum seafloor deformation.
d. The focal depth is assumed 15 km as it is familiar to be noticed in many major seismic activities in this region.
e. The width of fault segments is determined by using the empirical formula promoted by Papazachos et al. [10].
f. The dislocation of fault segments is calculated by using equations (1) and (2).

Further studies will be performed to investigate the tsunami generated by the Manila Trench earthquake and the impact towards Malaysia coastal areas as this research has not been explored extensively. The outcome would be the tsunami wave height, arrival time, wave run-up height and inundation distances. This study is vital and useful for coastal communities in order to raise public awareness on the possibility of tsunami occurrences and thereby reducing the destruction of property and preventing loss of life.

Acknowledgement

This research is financed by TNB Seeding Fund. Project code U-TG-CR-18-03: Institute of Power Energy (IPE), Universiti Tenaga Nasional. The authors intent to specify their sincere gratitude to 2017/18 UNITEN BOLD Scholarship for financial support of the study. The authors also would love to acknowledge Universiti Sains Malaysia (USM) for providing TUNA model and guidance in utilizing this model.

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