NUMERICAL SIMULATION OF TSUNAMI FOR SCENARIO EARTHQUAKES ALONG THE MYANMAR (BURMA) SUBDUCTION ZONE

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ABSTRACT

We performed tsunami simulations for the tsunami hazard assessment along the coastline of Myanmar. We considered four scenario earthquakes along the Burma (Myanmar) subduction zone, eastern margin of the Indian Plate, with the same depth range of the fault and different locations. Dip angles are determined based on the high-resolution hypocenter distributions along the Burma (Myanmar) subduction zone. We used 8 tide gauge stations and 42 assumed stations along the Bangladesh and Myanmar coasts as output points. To examine the maximum heights and travel times of tsunami at all output points, we performed numerical simulations by using TUNAMI-N2 with GEBCO 1 arc-minute grid size bathymetry data.

The case A source is located on the subduction interface on land and near the Bangladesh coast and the maximum tsunami heights generated by this source are less than 1.0 m in the Bangladesh coast and are less than 0.1 m in the Myanmar coast. The case B source is also mainly located on the subduction interface on land. The maximum tsunami heights of the case B are less than 1.0 m in the Bangladesh coast and are less than 0.5 m in the Myanmar coast. The case C source is located on subduction interface beneath the sea, located in the Rakhine coast, western part of Myanmar. For this case, the maximum tsunami height of 3.261 m is calculated at TG23 station, located in the Rakhine coast, and the height is less than 2.0 m along the Ayeyarwady delta region. The case D source is located in the Andaman trench near the Ayeyarwady delta region. The maximum tsunami heights of the case D are less than 1.0 m along the Ayeyarwady delta region. The case D source cannot generate a great tsunami because the fault system is almost strike-slip fault.

Keywords: Tsunami, Numerical simulation, Assessment.

1. INTRODUCTION

Myanmar is one of earthquake prone countries in the world because of its location in active Alpide-Himalayan seismic belt. According to historical record of tsunami, the Arakan earthquake occurred on 2 April, 1762, 250 years ago which had generated tsunami and the wave arrived at the Rakhine coast, western part of Myanmar. Myanmar experienced the tsunami effect caused by the Sumatra earthquake. After the 2004 Sumatra earthquake, some researchers predicated the possibility of the occurrence of a tsunamigenic earthquake from the northern part of the Andaman trench to the Bay of Bengal (Cummins, 2007). Therefore, Myanmar coastline regions are unsafe for the predicted tsunamigenic earthquake. Although historical record is poor in this region, we study about some scenario earthquakes through numerical simulation to mitigate the tsunami hazard disaster to local people along the coast and around the Bay of Bengal and Andaman Sea.

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2. DATA AND METHOD OF COMPUTATION

2.1 Bathymetry Data

Accurate bathymetric data is necessary for simulation of tsunami propagation. We use the General Bathymetric Chart of the Oceans (GEBCO) bathymetry data in this study, which is available from the website (http://ngdc.noaa.gov/mgg/gebco). The interval of grid space used in this study is 1 arc-minute (1844.20 m and 1774.49 m in longitude and latitude direction, respectively).

2.2 Tsunami Simulation

We obtained the tsunami maximum heights and tsunami travel times at the coastal output points from the numerical results the tsunami propagation for all cases. For tsunami calculation based on the non-liner shallow water equations with bottom friction terms, we used TUNAMI-N2 code developed by the Disaster Control Research Center (DCRC) of the Tohoku University, Japan (Imamura et al., 2006; Koshimura, 2010).

2.3 Source Parameters of Scenario Earthquakes

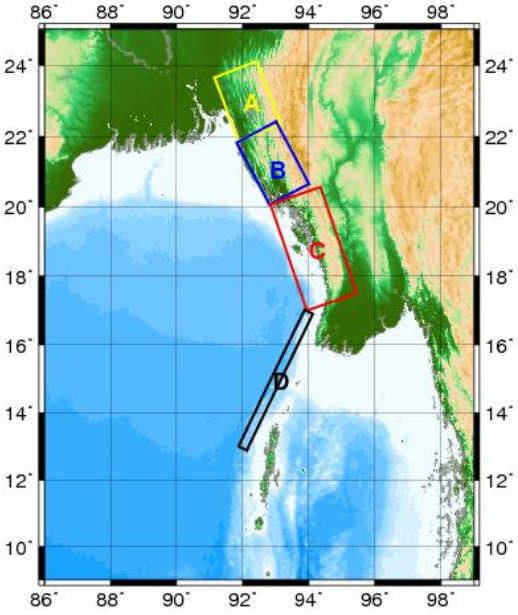

Figure 1. Four scenario earthquakes along the Burma (Myanmar) subduction zone.

In this study, we considered the four sources of scenario earthquakes for the tsunami simulation along the Burma (Myanmar) subduction zone (Figure 1). Firstly, we measured the starting and ending points of the fault (fault length) and then the strike angle is calculated from the trench alignment. Dip angle was assumed based on the cross-section of relocated earthquakes along the Burma Plate from the study by Hurukawa et al. (2010). The rake angle was determined using the plate motion direction of the Indian Plate with respect to the Burma Plate. The bottom depth of fault was assumed to be 30 km for all cases. The fault width was calculated by the equation; $W = 30km/\sin\delta$, where δ is dip angle for each source. The magnitude and slip amount were calculated by using the Papazachos et al. (2004) scaling law for all cases. Table 1 shows the parameters of fault setting for all cases and the initial conditions of the seafloor deformation are shown in Figure 2.

Table 1. Source parameters of four scenario earthquakes along the Burma (Myanmar) subduction zone

Scenarios	M	Length (km)	Width (km)	Top depth of fault (km)	Bottom depth of fault (km)	Dip (°)	Strike (°)	Rake (°)	Slip amount (m)	Latitude ° N	Longitude ° E
Case A	8.5	210.054	144.3	0	30	12	339	124	4.51	21.8823	91.875
Case B	8.5	221.338	144.3	0	30	12	332	118	4.68	20.0588	92.8125
Case C	8.9	358.794	172.811	0	30	10	341	127	7.67	17.00	93.9375
Case D	8.3	495.048	42.427	0	30	45	26	172	3.43	13.00	91.875

M = Magnitude of the scenario earthquake

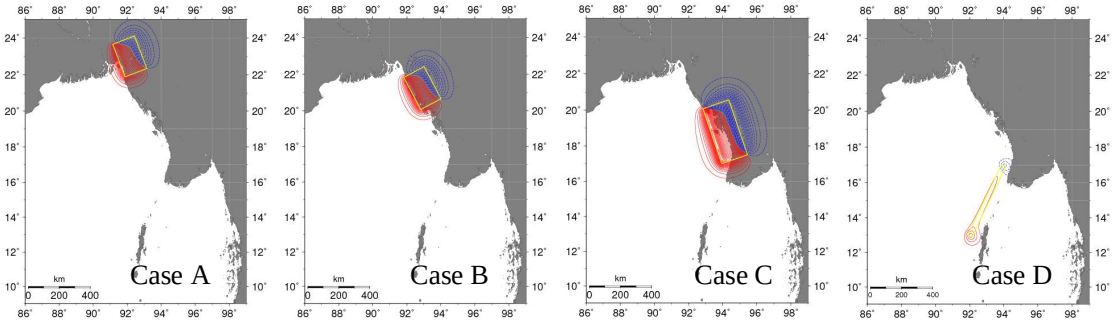

Figure 2. Seafloor deformations as the initial condition of case A, B, C and D. Yellow rectangles are the fault areas. Red and blue lines represent the uplift and subsidence, respectively, with the contour interval of 0.1 m.

2.4 Tide Gauge Stations

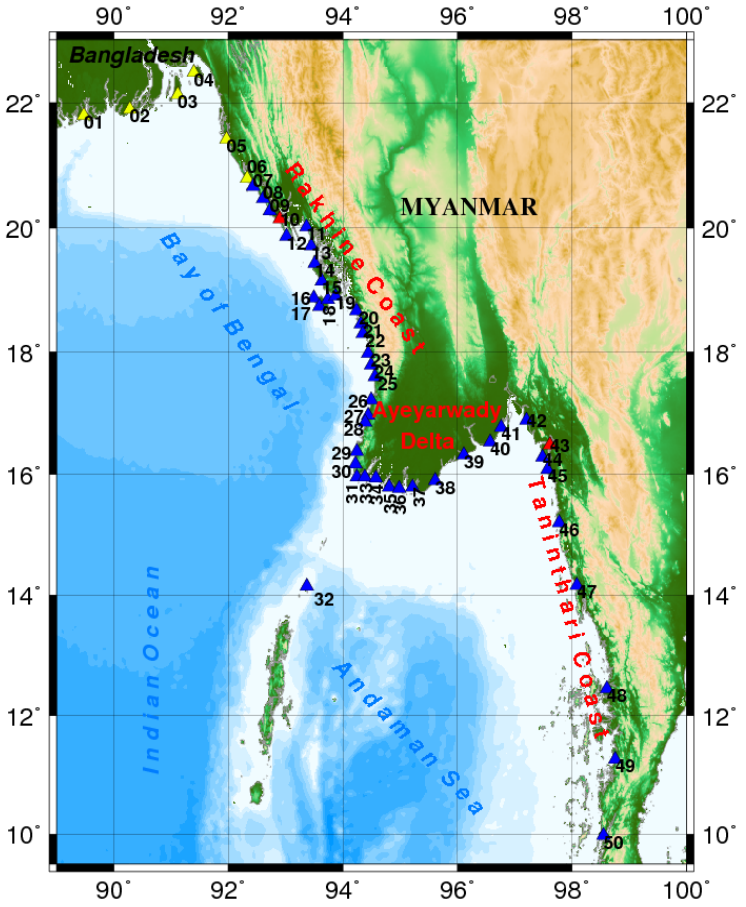

Figure 3. Existing and assumed tide gauge stations along the Bangladesh and Myanmar coasts. The yellow triangles indicate BIWTA's tide gauges along the Bangladesh coast. Red triangles are operated stations by Myanmar and blue triangles are assumed stations along the Myanmar coast.

We selected 50 tide gauge stations along the coast of Bangladesh and Myanmar as output points (Figure 3). These are selected to compute tsunami waveforms at target points, and to secure accuracy of tsunami wave height and arrival time for each point. 42 stations are assumed to be at coastlines in the Bay of Bengal and the Andaman Sea and two stations are operated by Myanmar; at Sittwe and at Mawlamyine (Moulmein) which are part of the Global Sea Level Observing System (GLOSS) of Intergovernmental Oceanographic Commission (IOC). 6 stations are operated by the Bangladesh Inland Water Transport Authority (BIWTA). These were taken from Sarker (2007). Some places of output points are highly dense in high population and tourist areas along the coastlines.

3. RESULTS AND DISCUSSION

3.1 Tsunami Heights

Tsunami heights are obtained from tsunami simulation at all tide gauge stations. We read the values of the tsunami heights at each tide gauge station every second until 720 min (12 hrs). The details of the maximum tsunami height at each output point of all cases are shown in Figure 4.

In the case A, the maximum tsunami height reached 0.614 m at Sandwip (TG04) and the second maximum tsunami height arrived 0.447 m at Char Changa (TG03), which are located at latitude of 22.48°N and longitude of 91.4°E, and latitude of 21.13°N and longitude of 91.12°E in the Bangladesh coast. For this case, the maximum tsunami height is less than 0.7 m in the Bangladesh coast and 0.1 m, the smallest tsunami height in the Myanmar coast.

In the case B, the maximum tsunami height reached 0.922 m at Cox's Bazar (TG05), which is located at the coordinate of 21.42°N and 91.97°E in the Bangladesh coast and the second maximum tsunami height reached 0.44 m at TG11 which is located at the coordinate of 20.0209°N and 93.3643°E in the coastline of Myanmar. Shahpuri Island (TG06), TG07, TG08, TG09 and Sittwe (TG10) have no tsunami wave according to the computation because these stations are at uplifted region side caused by deformation of the fault. However, we obtained the tsunami wave height near the stations.

In the case C, we obtained the maximum tsunami height of 3.261 m at TG23 which is located at latitude of 17.9759°N and longitude of 94.4404°E and the second maximum height of 2.761 m at TG21 which is located at latitude of 18.4557°N and longitude of 94.3117°E. In this case, the highest tsunami wave occurred along the Rakhine coast, western part of Myanmar. This case is the tsunami generated by the largest source in this study. In this case, TG14, TG15, TG19, TG24, TG26 and TG27 have also no tsunami wave such as the case B. The maximum tsunami height between 2 m and 3.5 m at 7 tide gauge stations and between 1 m and 2 m at 11 tide gauge stations along the Rakhine coast, western part of Myanmar and Ayeyarwady delta region.

In the case D, we obtained the maximum tsunami height of 0.853 m at TG28 and the second maximum height of 0.305 m at TG27 along the Ayeyarwady delta region, which are located at latitude of 16.8505°N and longitude of 94.389°E, and latitude of 16.9662°N and longitude of 94.4398°E respectively. The maximum tsunami height is less than 1.0 m along the Ayeyarwady delta region.

According to simulation, the maximum heights are less than 1 m in cases A, B and D. Therefore, we can say that characteristics of these events will be small in terms of damages on the coastlines of Bangladesh and Myanmar.

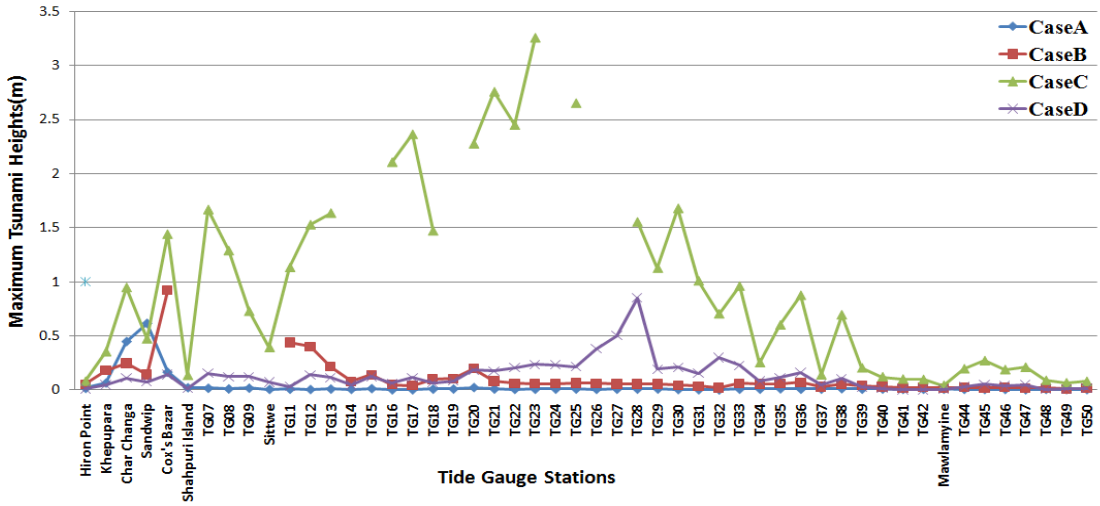

Figure 4. Maximum tsunami height at each output point of all sources. Blue curve, red, green and purple curves represent the maximum tsunami height of case A, B, C and D, respectively.

3.2 Tsunami Travel Times

Tsunami travel times were obtained from the results of tsunami waveforms for four scenario earthquakes at 50 tide gauge stations along the Bangladesh and Myanmar coasts as shown in Figure 5. Tsunami arrival times for case A, whose Magnitude is 8.5, calculated at all output points, indicate that the first waves arrived at Char Changa (TG03), Sandwip (TG04), Cox's Baza (TG05) and Shahupuri Island (TG06) in the Bangladesh coast and TG07 and TG08 along the Myanmar coast, respectively at 0 min. These stations are very close to the source. We obtained the result of the tsunami waves at TG09 to TG33 within 100 min except for TG20 (103.61 min) and in between 176 min and 186 min at the TG34 to TG36 stations located along Myanmar coast. The Andaman Sea, located between Ayeyarwady delta region and Taninthari coast (see Figure 3), is an area of shallow bathymetry. This explains the late tsunami arrivals (over 250 min) at the TG37 to TG50 stations located in this area as a process of the slow propagation of tsunami waves.

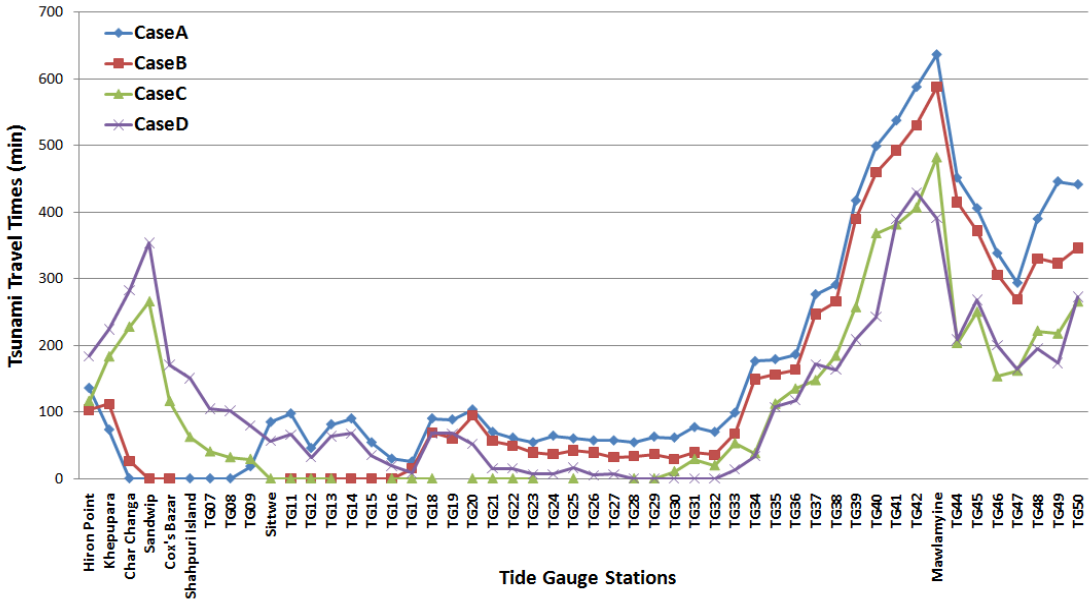

Figure 5. Tsunami arrival times estimated from waveforms at each output point of all sources.

Tsunami arrival times for the case B, whose magnitude is 8.5, are also calculated at all tide gauge stations. At tide gauge stations of Sandwip (TG04) to TG16, first waves arrive at 0 min. Mawlamyine (TG43) station exists inside of a River. Therefore, tsunami waves reach later than other stations and tsunami travel times are calculated at 637.08 min (10.62 hrs) of case A, 588.09 min (9.80 hrs) of case B, 482.05 min (8.03 hrs) of case C and 391.01 min (6.52 hrs) of case D after the earthquakes origin time.

The case C has the magnitude of 8.9 and that is the largest one in this study. We also calculated tsunami travel times from waveforms at each tide gauge station. Tsunami waves arrived at 0 min at the tide gauge stations of Sittwe (TG10) to TG29 because those are very close to the source. For the remaining tide gauge stations in Bangladesh coast it took longer than 100 min at Hiron Point (TG01) to Cox's Bazar (TG05) and Shahpuri Island (TG06), at which the wave reaches at 62.26 min. As for the tide gauge stations in Myanmar coast, the first wave was calculated at 10 min to less than 60 min at TG07 to TG09 and TG30 to TG34, located in Rakhine coast and Ayeyarwady delta region. As for the remaining tide gauge stations of TG35 to TG50, located in Ayeyarwady delta region and Taninthari coast, tsunami waves reach there at more than 100 min.

The case D has the magnitude of 8.3 and we also computed tsunami arrival times from waveforms at each tide gauge station. Tsunami waves arrived between at 151 min and 354 min at the

coastal output points of Bangladesh. In Myanmar coast, the waves were calculated at 0 min at TG29 to TG32 that are very close to the source, and at less than 10 min at TG17, TG23, TG24, TG26 and TG27, between 10 min and 20 min at TG21, TG22, TG25 and TG33, and less than 35 min at TG12, TG15 and TG34, and more than 50 min at Sittwe (TG10), TG11, TG13, TG14, TG18, TG19 and TG20. The tsunami arrival times are very late (over 100 min) to reach the TG35 to TG50 stations located in the shallow water areas.

4. CONCLUSIONS

In order to understand the hazard assessment of tsunami, and we have worked with four scenario earthquakes along the Arakan and Andaman trenches, Burma (Myanmar) subduction zone, considering different locations of sources. The maximum tsunami heights and arrival times are derived from the tsunami simulation at each case.

The case A source is located on the subduction interface on land and near the Bangladesh coast. The case B source is also mainly located on the subduction interface on land. The case C source is located on subduction interface beneath the sea, located in the Rakhine coast, western part of Myanmar. The case D source is located in the Andaman trench near the Ayeyarwady delta region. The case D source is almost strike-slip fault.

According to the tsunami simulation, the maximum tsunami heights of case A, case B and case D along the Bangladesh and Myanmar coasts are less than 1 m. Especially, the maximum tsunami heights of case A are nearly 0.7 m in the Bangladesh coast and 0.1 m in the Myanmar coast. Therefore, we can conclude the sources of case A, case B and case D cannot generate a great tsunami.

For case C, the obtained maximum tsunami height is nearly 3.5 m. It is the highest one in this study (see Figure 4). The maximum waves were predicated in the Rakhine coast and the tsunami arrived at tide gauge stations at the same time of the earthquake occurrence. Therefore, there is not enough time to disseminate tsunami warning, especially for the residents of Rakhine coast, western part of Myanmar. The maximum tsunami height is 0.3 m in the Taninthari coast and 1.7 m in the Ayeyarwady delta region for the case C.

Rakhine coast is much closer to all the sources. Therefore tsunami arrival times for all the cases are earlier at Rakhine coast than at Ayeyarwady delta region and Taninthari coast. For some tide gauge stations along the Rakhine coast, arrival times of tsunami are 0 min or less than 100 min. Ayeyarwady delta region is closer than Taninthari coast to the source of the case D. Therefore, in this case, the waves reach to Ayeyarwady delta region earlier than to Taninthari coast.

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