NUMERICAL MODELING ANALYSIS FOR TSUNAMI HAZARD ASSESMENT IN WEST COAST OF SOUTHERN THAILAND

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ABSTRACT

This study is intended to know the tsunami effect on the west coast of southern Thailand from potential fault locations in and around Andaman Sea. Four cases of fault were simulated as the tsunami source models. TUNAMI code (TUNAMI-N2) used to compute tsunami propagation in the ocean. For large area (region 1), tsunami was computed using GEBCO 1 arc minute bathymetry by the linear theory in spherical coordinate system with Coriolis force. Finer spatial bathymetry grids resample from GEBCO, 15, 5 and 1.67 arcs second in small area, were used in regions 2, 3 and 4 and the tsunami propagation was computed by the non-linear theory in Cartesian coordinate system with bottom friction term. Calculated tsunami heights and travel times were obtained at following output points namely: two existing DART buoys, eight existing tide gauges, four TMD planning tide gauges and forty assumed tide gauges.

The results of Case 1 from linear long wave numerical model have shown that tsunami wave heights were larger than observed data. The results of the non-linear long wave numerical model demonstrated a good agreement with the observed data for tsunami heights and travel times.

The results of numerical simulations have shown that the Thai DART buoy is useful to indicate a generation of tsunami. Tsunami arrived at the Thai DART buoy in Cases 1, 2 and 3 before the other tide gauges. This result can be used to improve accuracy of tsunami warning system for preventing false alarm. Moreover, maximum tsunami heights were larger in the Phangnga and Phuket provinces then integrated countermeasures and city planning must be set up to prevent communities along coastal line.

Keywords: Tsunami simulation, Potential earthquakes, Southern Thailand.

INTRODUCTION

The 2004 Indian Ocean tsunami has made us understand more about the characteristics of tsunami. As the Indian Ocean tsunami occurred in technology age, new information and physical data of tsunami image were observed from satellite altimeters, water level recorded by coastal tide gauge stations around Indian Ocean, tsunami inundation and run-up height measured by field survey including waveforms recorded by many seismographs. However, lack of tsunami early warning system, countermeasures and knowledge caused severe damages along the Indian Ocean coast.

Historical record of tsunami event in Thailand is unclear because there is no evidence of Paleo-Tsunami and effect of tsunami. Some villages have legends related to tsunami events. Morgan people who roam freely from one island to another of the Andaman Sea have been keeping their legend that they must escape to high ground when abnormal sea drag appeared. It is said that Morgan people survived from the Indian Ocean tsunami on 26th December 2004.

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METHOD OF COMPUTATION FOR TSUNAMI HAZARD ASSESSMENT

To simulate tsunami propagation in the open sea, we used a linear equation to describe a shallow-water wave on the spherical earth with the Coriolis force, and to simulate tsunami in the coastal zone and the inundation area, we used a non-linear equation in a Cartesian coordinate system for a shallow-water wave with bottom frictions (Goto et al., 2007).

Target Area

We selected wider coarse grid area for far-field tsunami simulation. The position started from latitude 0º N to 25ºN and longitude from 75ºE to 110ºE. This area was called region 1 with bathymetry data from GEBCO (General Bathymetric Chart of the Oceans) and spatial grid size of 1 arc minute. Computation domains in region 1 were 2101 x 1501 grid points and the temporal grid size was set to 1.5 s which satisfied a C.F.L. stability condition and the computation time was 12 hours. Computation domains in region 2 was 825 x 905 grid points which covered area between latitude 5º59’00”N to 9º45’15”N and longitude 96º29’00”E to 99 º55’15”E with a finer spatial grid size of 15 arc seconds.

Region 3 with a finer spatial grid size of 5 arc seconds covered the area between latitude 7º45’25”N to 8º12’39”N and longitude 97º59’55”E to 98 º20’00”E, and had 241 x 325 grid points. Region 4 with the finest spatial grid size of 1.67 arc seconds in this study focused on Kamala and Patong beach in Phuket province and covered the area between latitude 7º50’58”N to 8º00’00”N and longitude 98º5’28”E to 98º19’00”E with 487 x 325 grid points. Non-linear long wave model with bottom friction term was used in region 2, 3, and 4. The coverage areas of region 1, 2, 3 and 4 are shown in Figure 1.

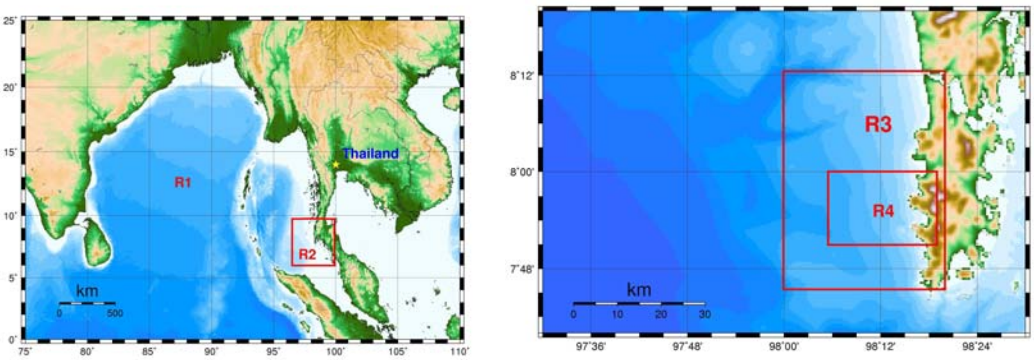

Figure 1. Computation area for numerical model regions 1, 2 (left) and regions 3, 4 (right).

Target Points

We calculated tsunami heights and travel times at 54 stations including the Thai DART buoy station and the Indonesia DART buoy station. Eight tide gauge stations are presented. Within these tide gauges, Taphaonoi and Tarutao tide gauge stations were operated by Hydrographic Department Royal Thai Navy. Ranong, Kuraburi, Krabi, and Kantang tide gauge stations were operated by Marine Department of Thailand. At four tide gauge

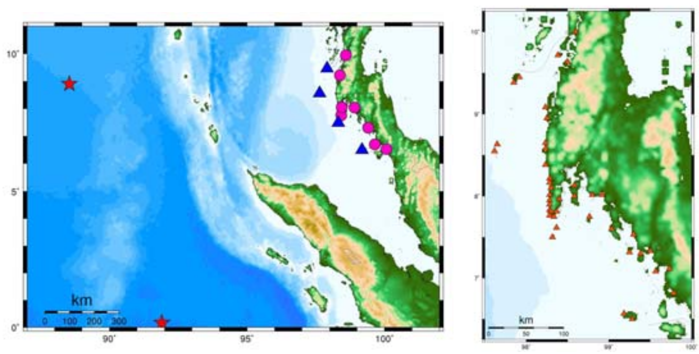

Figure 2. Locations of DART buoys (red stars), existing tide gauge stations (pink circles), and TMD planned installation tide gauge stations (blue triangles). Locations of virtual tide gauge stations (red triangles) along the west coast of southern Thailand.

stations the installation is underway by Thai Meteorological Department. Another tide gauge stations assumed along west coast of southern Thailand near the famous beaches and important residential areas in the provinces. Locations of all tide gauge stations are shown in Figures 2.

Source Model in Andaman Sea

Fault parameters such as fault mechanism, location, and magnitude of earthquake are significant to make generation of tsunami. Tsunami power is related to volume of water change which depends on fault parameters of earthquake. We considered fault locations around Andaman Sea which potentially generate tsunami along Sunda trench and Burma ridge. The source models include 4 cases namely; Case 1 is real tsunami case of the 2004 Sumatra Indian Ocean tsunami in which fault model parameter from DCRC (Disaster Control Research Center, Tohoku University, Japan) were used. Magnitude for this event was estimated to be 9.3 and its fault was divided into 6 sub faults. For second case, we considered height potential seismic gap in north Andaman Sea and the fault area was located from northern part of Andaman Island along Sunda trench. The empirical formula introduced by Papazachos et al. (2004) was used to the estimate fault parameters for an assumed magnitude of 9.0.

The Same earthquake magnitude of 9.0 was used in Case 3. Location of fault along trench line in western side of Andaman Island was similar to that of Fujii and Satake (2007). For Case 4, historical earthquake records were used to provide fault parameters and assumed magnitude was 7.5 in central Andaman Sea. Mechanism of fault was different from the other cases because it was categorized in normal fault. All the fault parameters for four cases are shown in Table 1.

Table 1. Tsunami source parameters for scenario earthquakes in and around Andaman Sea

Parameter	Case 1						Case 2	Case 3	Case 4
Magnitude	9.3						9.0	9.0	7.5
Sub Fault	1	2	3	4	5	6	-	-	-
Length (km)	200	125	180	145	125	380	575.4	575.4	77.6
Width (km)	150	150	150	150	150	150	144.5	144.5	25.1
Displacement (m)	14	12.6	10	11	7	7	9.55	9.55	3.80
Depth (km)	10	10	10	10	10	10	3	3	35
Strike (º)	323	335	340	340	345	7	25	8	254
Dip (º)	15	15	15	15	15	15	10	10	56
Slip (º)	90	90	90	90	90	90	90	115	-90
Latitude (ºN)	3.03	4.48	5.51	7.14	8.47	9.63	11.8	8.60	10.95
Longitude (ºE)	94.90	93.82	93.30	92.74	92.28	91.97	91.0	91.64	95.05

RESULTS AND DISCUSSION

Scenario Case 1

The first tsunami wave that reached to the Thai DART buoy (by23401) took approximately 27.75 min after the earthquake. The wave was a positive wave with the maximum wave height of 1.055 m. Miang, TMD planning station (tmd007) was the second tide gauge station where the first tsunami wave arrived at approximate time of 62.25 min. Tsunami wave reached Miang station about 34.75 min later than the Thai DART buoy. Simulated tsunami travels time for all the stations are shown in Figure 3.

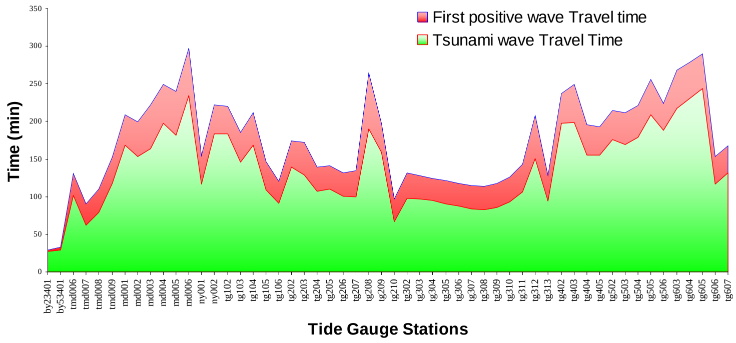

Figure 3. Tsunami travel times and first positive wave travel times (Case 1).

Tsunamis propagate in deep sea faster than in shallow sea. Therefore, waves reached the Thai DART buoy in deep water before they arriving at the other near shore tide gauges.

In this computation case, the maximum tsunami wave height in far-field model was 15.419 m at Kapoe Ranong stations (tg104) and in near-field model was 8.989 m at Khao-lak Phangnga station (tg204).

Tsunami heights and arrival times: comparison between observed data and numerical result

The 2004 Indian Ocean tsunami was observed at six tide gauge stations in Thailand. Tsunami waveforms comparisons between calculated data and observed data at existing tide gauges are shown in Figure 4. The results demonstrated that the tsunami of the far-field model reached to the Ranong, Kuraburi and Kantang stations earlier than the observed data, but the tsunami travel times from calculated data at Taphaonoi, Krabi and Tarutao stations are later than the observed data. For near-field model, earlier tsunami wave reached to the Kuaraburi, Taphanoi, amd Kantang stations before the observed data. However, simulated tsunami reached to the Krabi and Tarutao stations later than the observed data.

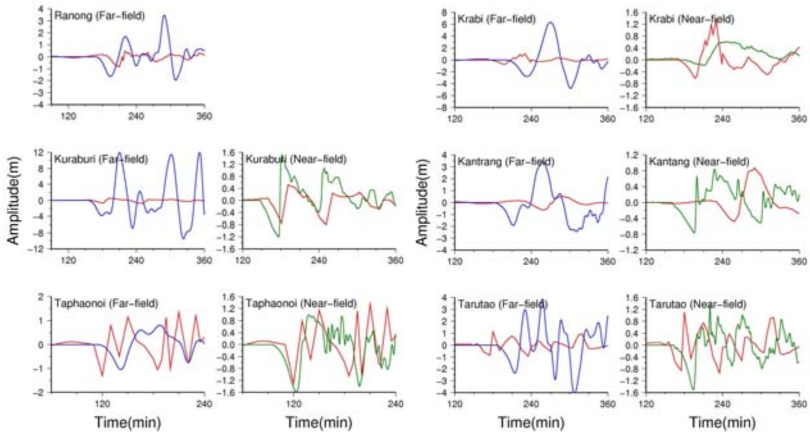

Figure 4. Synthetic waveforms from far-field model (blue colors) and near-field model (green colors) compared with observed tsunami waveforms (red colors) at existing Thai tide gauges for Case 1.

Large bathymetry grid size contains one value of the depth, but it will have different values when make a comparison with a finer grid size in the same area. When finer grid is used in one large grid area, the same area provides more detailed values. Tsunami waves which were computed by a non-linear model with a finer grid size and bottom friction terms traveled faster than linear model with larger grid size in a small region. Wave turned to viscosity in large grid size that resulted in smooth waveform shape in far-field model.

Tsunami heights computed from the far-field model gave over estimated results compared with the observed data. However, computation results have shown a good agreement with observed data in near-field simulation model. For tsunami propagation in the shallow water, where the depth is less than 50 m, bottom friction terms were included in model calculation. Selecting different Manning's roughness value for bottom friction terms can affect the computation result. The maximum tsunami height can be higher or lower than observed data as well as difference of tsunami arrival times. The results of the far-field model have shown that excluding bottom friction terms resulted over estimated tsunami heights compared with the observed data.

Scenario Case 2

Tsunami wave firstly reached to the Thai DART buoy about 38.5 min after the earthquake, which was 56.25 min earlier than the arrival at the second tide gauges, Miang, TMD planning station. The first wave that reached to the Thai DART buoy was a positive wave with the height up to 0.256 m. Tsunami wave reached to the Miang station at approximate time of 94.75 min with the maximum wave height of 0.519 m. Kho-khao Island in Phangnga (tg203) has 2.769 m maximum wave height from far-field model simulation, which was considered as the highest wave in Case 2. The result of the near-field model indicates the tsunami height of 1.311 m at Khao-lak. The maximum wave height distributions concentrate on Indian coastline and other sides as refracted to Myanmar coast.

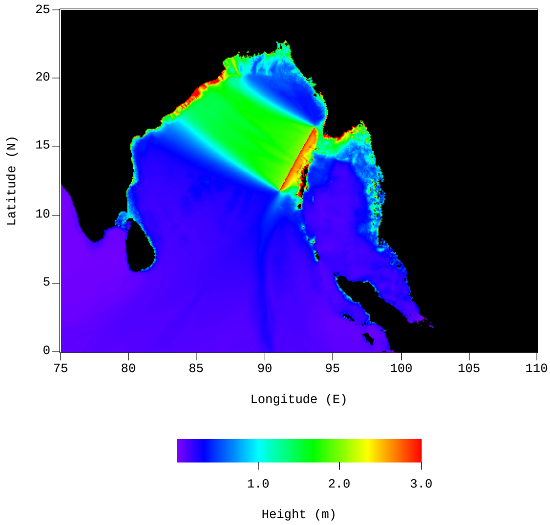

Figure 5. Maximum wave height distribution in Indian Ocean after 12 hours (Case 2).

Tsunami energy was perpendicular to the direction of the fault length. The initial wave was separated into two components and travelled to opposite directions. India is location perpendicular on the major axis of the fault caused the maximum wave height at the coastal line as shown in Figure 5. Tsunami wave can refract in both shallow and deep water. However, the effects of refraction would become prominent near the coast because of the rapid decrease of depth towards the shore. This is one of the reasons why tsunami energy was trapped in shallow water parts of Myanmar.

Scenario Case 3

Similarly to Case 1 and Case 2, tsunami wave reached to the Thai DART buoy firstly at approximate 30.5 min with positive wave and maximum wave height of 0.479 m. The second tsunami wave reached to the Miang station within about 73.75 min. The maximum wave height from the far-field tsunami model appeared at Ban-thap-lamu Phangnga (tg205) with a height of 7.24 m as shown in Figure 6. The result from the near-field model has shown the maximum height of 3.467 m at Kamala beach Phuket (tg305). The maximum wave height distribution shows energy concentration of India coastline and the opposite site, the north of west coast of the southern Thailand.

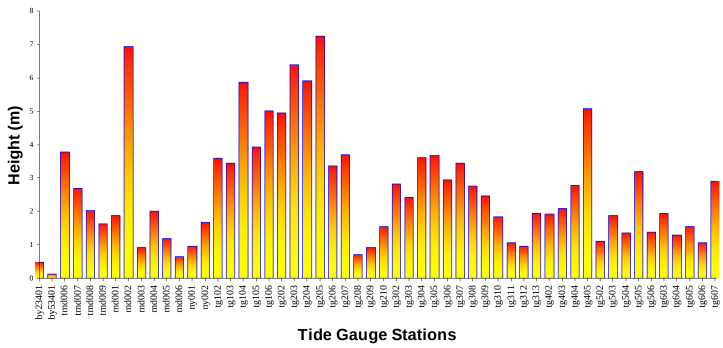

Figure 6. Maximum wave height in Case 3.

Scenario Case 4

The simulation results in this case were interesting because of the change of the first station's location. Tsunami wave arrived at the first station at Similan island station (tg210) in about 72 min, which was very close to 72.25 min, the arrival time at the Thai DART buoy. It took about 72.5 min to reach the third station (Miang station) as shown in Figure 7. The maximum wave height distribution is also interesting because tsunami energy was released along large stretches of the coastline in the Andaman Sea. The maximum wave height from the far-field model was 1.632 m at Kamala beach Phuket (tg305) and the wave height from the near-field model was 2.436 m at Naihan beach Phuket (tg309).

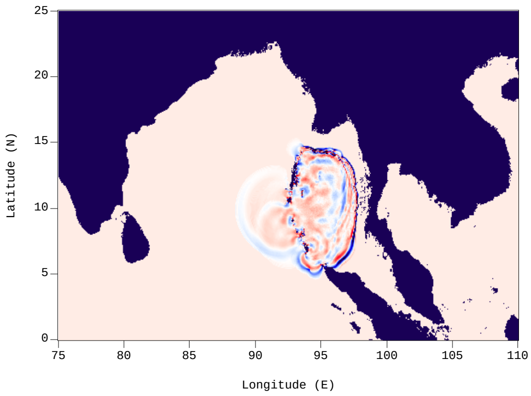

Figure 7. Snapshots of a tsunami wave in Case 4 at time of 72 min after the earthquake.

The tsunami waves in three cases (Case 1, 2, and 3) that reached to the Thai DART buoy at first were positive waves before they arrive at another tide gauges. However, tsunami wave in Case 4 reached to another tide gauge before the Thai DART buoys with negative wave.

The results of the four TMD planning tide gauge stations have indicated that tsunami wave reached Miang Phangnga station earlier than the other stations. The first waves of tsunami that reached to the four TMD planning tide gauge stations were negative in all the cases. The maximum wave height in Case 1 is larger than that in the other cases and the smallest maximum wave height was calculated in Case 4.

CONCLUSIONS

The results of TUNAMI model simulation with the sources around Andaman Sea have shown that the tsunami travel time and wave height in Case 1 gave good agreement with those from near-field model when a comparison was made with observed data. Scenario simulation Cases 1, 2, and 3 presented tsunami waves first reach to the Thai DART buoy before the other tide gauge stations. For TMD planning tide gauge, tsunami first arrived at Miang stations in all the cases.

Even if tsunami cannot be prevented or precisely predicted but damages can be reduce through undertaking various countermeasures and mitigation plans. Moreover, integrated measures are needed to take in to account the achievement of the mission. Adjusting integrated countermeasures must be considered for a suitable area with maximum efficiency. As the results of this study, tsunami heights were larger in Phangnga and Phuket provinces. Therefore, people who live in these areas and along coastal line should be protected from tsunami disaster by the government.

Because the simulated tsunamis reach to the Thai DART buoy at first as mentioned in the result, we can use the Thai DART buoy data as reference in order to assure generation of tsunami for preventing false alarm for tsunami early warning system. However, we must be careful about its use for some cases because in Case 4 the tsunami reached to some tide gauges before the Thai DART buoy.

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