TSUNAMI EARLY WARNING SYSTEM IN MALAYSIA

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ABSTRACT

This study is on how to make the database for tsunami forecast using the tsunami simulation, retrieve and apply it to the Tsunami Early Warning System messages. Firstly, we searched the seismicity around Malaysia and found out the tsunamigenic earthquakes by comparing the earthquake event with the tsunami record. The earthquake events shallower than 100 km and trench area were considered the potential tsunami source. The most appropriate forecast points were determined by setting up and examining candidates along the coast of Malaysia, each of which has 4-minutes, 10-minutes, 20-minutes distance from the coast and they were with the 10-minutes intervals along the coast. Later, magnitude and depth interval are set up by considering the historical events. The magnitude intervals are 6.6, 7.2, 7.8, and 8.4, and depth intervals are 30 km, 50 km, 70 km and 90 km. The tsunami simulation is run for all the set up tsunami source and the result of tsunami height and travel time for all the forecast points are input into the database. The location of tsunami source is calculated using interpolation or extrapolation.

Keywords: Forecast point, Travel time, Tsunami height, tsunami simulation.

INTRODUCTION

After the 26 December 2004 tsunami disaster, Malaysian government has decided to set up the national tsunami early warning system to provide early warning on tsunami that are generated from subduction zone area such as Indian Ocean, South China Sea, Sulu Sea and Pacific Ocean. The tsunami warning system consists of sub-system that provides real-time monitoring, alert seismic and tsunami activities.

EARLY WARNING SYSTEM PROCEDURE

Tsunamigenic Earthquake Locations

Earthquake events can be searched through the internet. The earthquake event was searched through the Global CMT Catalog Search for the years from 1976 until 2007 (present) from the internet (http://www.globalcmt.org/CMTsearch.html). The magnitude was set up from 6.0 to 10 and the depth from 0 to 100 km to determine the location of tsunamigenic earthquakes. The depth and magnitude were set based on the historical event. Comparison is made with other search data from National Geophysical Data Center (NGDC) Tsunami Event Database (http://www.ngdc.noaa.gov/seg/hazard/tsu_db.shtml) and Integrated Tsunami Database (WinITDB). The NGDC Tsunami Event Database and Integrated Tsunami

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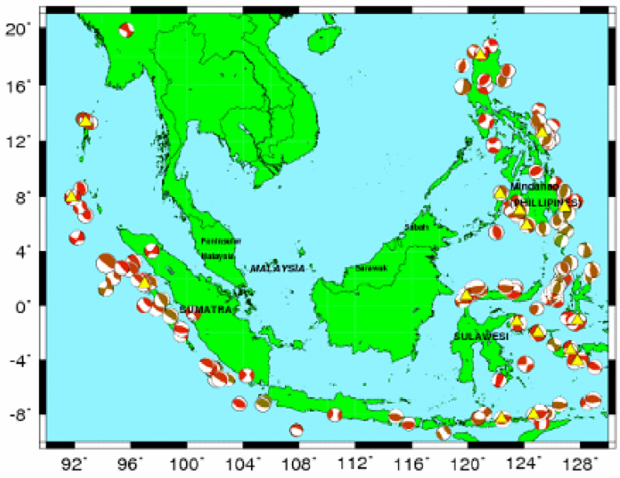
Database have much wider data from the year -2000 until 2007 and from -1628 until 2005, respectively. Thus, neither of the databases gave any information on the fault parameters.
Therefore, this source of data were compared in the time of event, location and also depth to Global CMT Catalog Search that has given the fault parameters that match each other to determine the tsunamigenic earthquake event around Malaysia (Figure 1).

Surface Deformation

The dislocation theory was introduced by Steketee (1958) and also by Rongved and Frasier (1958). All the papers revealed that the effect of earth curvature is negligible for the shallow events at distances of less than 20°, but the vertical layering or lateral inhomogeneity can sometimes cause effects on the deformation fields Okada (1985). Earthquake generates tsunamis when the sea floor deforms and vertically displaces the underlying water of the equilibrium position. The factor which determines the initial size of tsunami is the amount of vertical seafloor displacement determined by the magnitude of earthquake, depth and fault plane mechanism.

In this case, length, width and displacement of fault plane were determined from magnitude using empirical formula. Meanwhile, the strike is set to be parallel to the trench, considering that most of the earthquakes happen along the trench: the dip is 45° and slip is 90°. The dip and slip were set at these values because it is the worst case scenario of tsunami. The location of the hypocenter and source rupture is assumed to be in the middle of the fault plane.



Tsunamigenic earthquake event

Figure 1 Location of tsunamigenic earthquake events.

Bathymetry data

In this study, the bathymetry and topography data of ETOPO2 (2-minute grid interval) were downloaded from the internet (http://www.ndgc.noaa.gov/mgg/global/global.html). The ETOPO2 bathymetry data grid was derived from the satellite altimetry observations and gravity data were combined with shipboard echo-sounding measurements Smith and Sandwell (1997). Using the bathymetry data, the map from 10°S to 25°N latitude and 90°E to 130°E longitude was drawn to determine the sea depth around Malaysia.

Forecast Point and Source Point

Forecast point is the point that is set up near the coast for estimation of tsunami height and arrival time. The criteria are to set up as close to the coast and also considering the bathymetry of the coastal area. Firstly, the forecast point were set up at 10-minute ≈18.5 km from the coast with 10-minute intervals. In other cases, forecast points were set up as follows:

1) Near the coast 4-minute ≈ 7.4 km;
2) Far from the coast 20-minute ≈ 37 km; and
3) Between the original forecast points along the coastal area.

The simulation is run for all the forecast points (Figure 2). The source point was set up near the trench and along the coast of the Philippines. The source concentrated in the middle area of the Philippines Islands and southern Philippines (Mindanao) and also around the Moluca Sea, along the trench. It was set up according to grid size. The strike was set parallel to the trench in this area because it gives a great impact on the area east of Malaysia (Sabah).

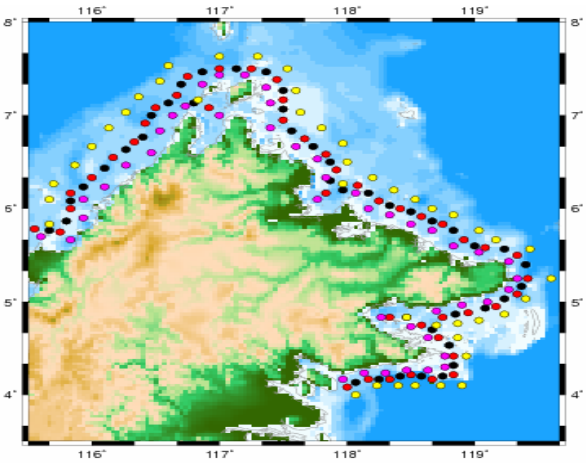


Figure 2 Location of 4-type forecast point

Notation:
- 20-minute ≈ 37 km
- 10-minute ≈ 18.5 km
- Between the 10-minute
- 4-minute ≈ 7.4 km;

Magnitude and Depth interval

The magnitude and depth interval were set. From the historical events, there hasn't been any tsunamigenic earthquake at the depth below 10 km. The interval for magnitude was set considering that minimal magnitude of the most destructive events is M6.3 and the maximum is M9.1. In this case the M9.0 was not set because the determination of Magnitude 9 would take longer time (3000 sec free oscillations).

Tsunami Simulation (Application)

In this simulation, the JMA simulation program is applied and this consists of the fault parameter calculation, seafloor deformation and simulation program. The simulation program was carried out considering the bottom friction and using the non-linear term.

Firstly, the area of computation is determined by considering the continental effect and mount bed area. The area is 25°N to 10°S and 90°E to 130°E. The grid size was set from this as dx = 1,200 m and dy = 1,050 m. The grid size was set for each forecast point. The calculation time was set 8 hours for the area near east of Sabah. This is because of considering the reflection of the wave between the Philippines and east of Sabah and also surrounding area. The time step (dx) used by JMA is 3 second. This time step is actually for Japan case with 1-minute interval but it can be used also for the 2-minute interval as it follows the CFL conditions.

Result of the forecast point

In the below graph (Figure 3), a comparison was made for neighbouring forecast points by distance from the coast (4-minute, 10-minute and 20-minute). The first wave amplitude shows that the green and red lines are higher than the black line. This is because the depths of green and red lines are almost the same, while the depth of the black line. When near the coast depth becomes shallow the wave amplitude becomes higher for the black line. The graph shows that the red and black lines are higher than the green line in the second wave. Since both black and red lines (4-minute and 10-minute) were obtained from the forecast points near the coast the wave amplitude will be much higher than the other while the arrival time will be a little bit later than that of green line (20-minute) forecast point . We can see a quite similar pattern between the 10-minute and 4-minute forecast points.

Notation:
20-minute ≈ 37 km
10-minute ≈ 18.5 km
4-minute ≈ 7.4 km

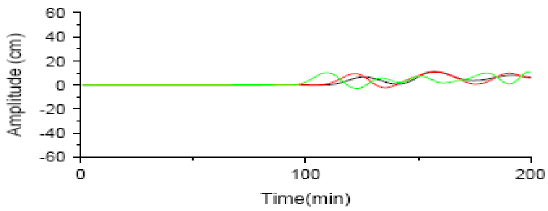


Figure 3 Comparison the three locations of forecast point – epicenter at Mindanao.

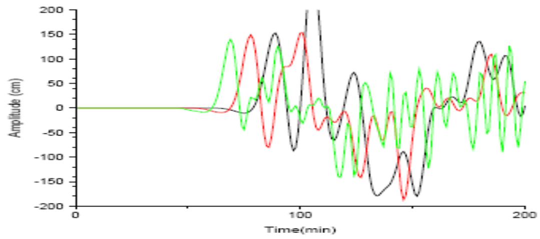
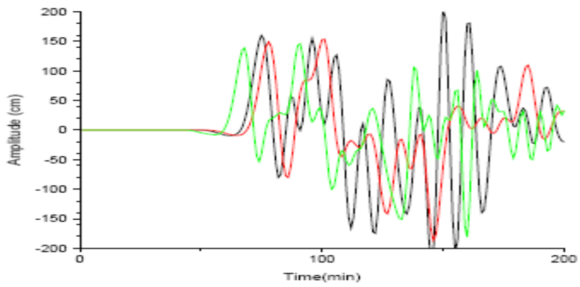


Figure 4 Comparison the forecast points of 4-minutes, 10-minutes and 20-minutes distance to the coast.

Meanwhile in Figure 4, which is for another forecast point set, the first wave amplitude shows almost the same height, and only the red and black lines are a little bit higher than the green line. The comparison shows a very clear difference of the wave amplitude in the second wave, where the black line which indicates 4-minute point from the coast is the highest among the 3 forecast points. This is because the wave amplitude becomes higher when it reaches near the coast, and the wave energy is converted to wave height. We compare the result of Figure 3 and Figure 4 and it makes quite the same result, therefore, the 4-minute to the coast was chosen.



Notation:
20-minute ≈ 37 km
10-minute ≈ 18.5 km
4-minute ≈ 7.4 km

Figure 5 Comparison among the location of forecast points with the 10-minutes interval along the coast.

In this case, we searched for the best forecast point location among the interval along the coast. The red and green lines indicate amplitude from two points with the interval of 10-minutes and the black lines is in the middle of them (Figure 5). The depth of these three forecast points is almost the same. Among the forecast points of each 10-minutes interval, the graphs (Figure 5) show quite similar pattern in the first and second wave amplitudes. The similarity in wave height was observed between the green and red lines, while the black line was much higher and not similar to the others for the rest of the wave amplitude. Therefore, 10-minute interval was considered to be enough.

As a conclusion, the interval was set around 10-minutes from one forecast point to another and the distance from the coast is 4-minutes. In this case, bay site is considered. It is because in the V-shape area and also bay area they give a big impact on tsunami height.

Retrieve data method

SQL Database

MySQL command is used to make tables from the simulation result. The simulation result was divided into (3) three tables under the name of "Tsunami" main table, that is, "FP" table, "Hyp" table and also "Simudata" table. FP table contains the number of forecast points, depth (m), latitude and longitude, meanwhile "Simudata" table contains the number of forecast points, arrival time(minutes), maximum height (cm), minimum height (cm) and "Hyp" table contains parameters information on longitude, latitude, magnitude, depth, strike, total station, total time, length, width, Us component, Ud component, Ut component, dip, rake and filename.

Interpolation

Surrounding hypocenter and centroid data

Each latitude, longitude and strike must be searched before making hyp table. On each of the four corners that have the same strike, centroid data are added as the grid data. The centroid data were not applied if there is different strike at each point and also there are only three corners. Later, Hyp table is used to seek the nearest centroid data by calculating distance. The magnitude and depth surrounding the input hypocenter at each four epicenter were searched by using interpolation logarithm. The coefficient for horizontal interpolation (location of latitude and longitude) is calculated by a linear method.

Database Search

There are two ways of database search that are "simple" database search and also "max risk method" database search. These two methods of search are based on the simulation data. The "simple" database search is used when there is not enough simulation data and too little to use interpolation method. This method searches for the nearest simulation point data to the epicenter. In the case of searching for the depth and magnitude, either way, it can use the interpolation method to get the database output or use the nearest element as a database output.

"Max risk method" database search is the other method used to calculate fault distance from magnitude of the earthquake. In this method the target area is within half length of the earthquake's fault distance. The search for maximum data at each forecast point within half length of the earthquake's fault distance and the maximum data will be the output database.

Issuance of Tsunami Warning

Issuance of the warning is very important for disaster mitigation. The warning must be clear and understandable by everyone. It must not confuse the public. Therefore, the warning format has been decided and it is divided into 3 stages of warning. The first message is for the information on the fastest arrival time and the highest tsunami height in the state area, including name of the coastal area affected. The second message gives more specification on each state coastal areas affected with arrival time and tsunami height. The third message is the downgrading and cancellation of state coastal areas.

DISCUSSION AND CONCLUSIONS

Firstly, the seismicity at the surrounding areas of Malaysia was investigated. Then, the historical earthquakes and tsunami events were searched. Locations of tsunamigenic earthquakes were determined by combination of these two kinds of events. In this search, the locations of tsunamigenic area were located at west of Sumatera, Andaman Island, Sulawesi and southern Philippines. Tsunami from these areas might propagate to Malaysian coast. Bathymetry data ETOPO2 are used to search the depth of the surrounding sea. Near the coastal area of Malaysia, the sea depth is shallow, less than 50m. We compared the result from the wave form data to check if it gives a good result for each shape of the coastal area according to the tsunami theory. The graph plotted shows that when the magnitude is larger the tsunami height becomes higher. This is because of the energy conservation, namely, when the wave approaches the coast, the depth becomes shallow and the kinetic energy of the wave is converted to height or potential energy. Meanwhile, the graph of tsunami height versus depth where the magnitude is constant indicates that the depth of deformation gives less impact on tsunami height if it becomes deeper. This result is consistent with the theory of tsunami.

Later, all the results of simulation were gathered and put in the database using MySQL in the form of table. In the program, interpolation and extrapolation method were used to determine location, magnitude and depth from the simulation epicenter point. This method is easy to use but not so accurate especially for extrapolation when the simulation epicenter point is far from the hypocenter. The result then is used to issue the warning.

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