A PROTOTYPE OF WEB-APPLICATION FOR TSUNAMI DATABASE ALONG SOUTHERN JAVA ISLAND COASTLINE

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ABSTRACT

Development of tsunami database system along coastline area of southern Sumatra, Java and Bali islands was presented in this study. This was performed in three stages, there are: (1) applying tsunami numerical simulation; (2) constructing a database; and (3) retrieving tsunami heights and arrival times from the database for assembling tsunami warning message. First stage was conducted by employing TUNAMI-N2 and TTT software for 1 real case and 28 artificial cases (with 4 depths of 0, 20, 40 and 60 km; and 3 different magnitudes of 7.0, 7.5, and 8.0), to obtain tsunami heights and arrival times on 56 coastal points. The results of tsunami heights at the coasts were considered applying Green's law at 50 m sea depth of forecast points. Then, a web application system using Apache web server, MySQL relational database and PHP programming language, were used to perform the second and third stages. The tsunami database which was successfully constructed in this study consists of 338 tables, and is divided into 3 parts: coastal point table, hypocenter table and simulation data table. Relation between the tables in the database based on the primary key from each table is a '*one to many*' type. The system retrieves tsunami heights and arrival times from the database and assembles warning messages. For retrieving methods, simple and interpolation techniques, are used. Lastly, it was found that the web application was effective for developing tsunami warning system.

Keywords: Tsunami database, Numerical simulation, Web application.

INTRODUCTION

The occurrence of the Great Sumatra earthquake followed by a devastating tsunami which struck the Indian Ocean region killing more than 230,000 peoples, has renewed Indonesian awareness of the importance of tsunami countermeasures. In order to protect people from tsunami disaster, the Indonesian government launched a project of the Indonesian Tsunami Early Warning System (InaTEWS). The primary task of InaTEWS is to issue reliable tsunami warnings with minimum false-alarm. In order to support it, the development of a pre-calculated tsunami is very significant in issuance of the tsunami warning. According to it, the main objective of this study is to construct a model of tsunami database. Secondary objective is to study the procedure of interpolation techniques using retrieving methods from the database and its application in study area considering the occurrence of tsunami in the future.

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THEORY AND METHODOLOGY

Tsunami Numerical Simulation

The main purpose of tsunami simulation is to calculate the tsunami heights and its arrival times. Tsunami are commonly referred as long waves, therefore, they are usually modeled mathematically using a depth-averaged approximation of the Navier-Stokes equations referred as “shallow-water wave theory”. In this study I use the shallow water theory with Coriolis effect and bottom friction omitted, which are described by Satake (1995). This theory will be solved numerically by applying the leap-frog staggered finite difference method (Satake, 2002). I used the TUNAMI-N2 numerical simulation software which was developed by Disaster Control Research Center of Tohoku University, Japan (Imamura, 2006) to obtain tsunami heights at the target points (forecast and coastal points). In this study, the dimension of computation area was set as 901 grid points and 601 grid points for longitude and latitude direction, respectively. This computation area covered study area from 5.0°S-15.0°S and 102.0°E-117.0°E. The time step of 0.5 s is set to satisfy the stability (CFL) condition. The total calculation time was set to three hours for the completion of the simulation at all the coastal points. To obtain tsunami arrival times I used Tsunami Travel Times (TTT) software which was originally developed by Dr. Paul Wessel from Geoware (http://www.geoware-online.com). In this study I first estimate tsunami heights at forecast points by tsunami simulation, then estimate tsunami heights at coastal point by applying the Green’s law to them.

Bathymetry Data

In this study, I use bathymetry data from the General Bathymetric Chart of the Oceans (GEBCO) with resolution of 1 arc minute that is almost equal to 1850 m. The study area is shown in Figure 1 with source points (SP), forecast points (FP) and coastal points (CP).

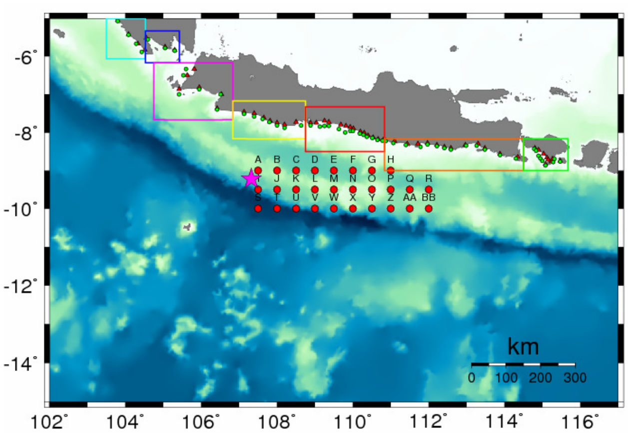

Figure 1. Bathymetry data of study area. Red dots show the source points (30 points) and green dots show forecast points (56 points) and red triangles show coastal points (56 points). Star shows epicenter of the 2006 Pangandaran tsunami. Each small colored rectangle (light blue, blue, magenta, yellow, red, orange and green) shows the area indicating coastal block area.

Source Points

The source point is defined as a center of the fault that could generate tsunami. In this study, a real case source point and artificial ones are used. For the real case, I use the 2006 Pangandaran tsunami (9.222°S, 107.320°E, M_w = 7.7 at 8:19:28 UTC according to USGS). According to the Global CMT solution, the focal mechanism of main shock of earthquake shows strike = 289°, dip angle = 10° and slip angle = 95°. According to Fujii and Satake (2006), the source area is divided into 10 subfaults that cover the aftershock area with the depth of 3 km in the shallow part and 11.7 km in the deep part. All the subfaults have same parameters of focal mechanism with the mainshock.

For the artificial cases, I select 28 source points in the Indian Ocean in front of Java island. For each source point, I use single segment which has the same assumption for fault parameter with strike of 285°. For dip and slip angle, I considered the severest case for tsunami generation and set them to 45° and 90°, respectively. By using these data, I set the depths into 4 scenarios (0, 20, 40 and 60 km) and magnitude into 3 scenarios (7, 7.5 and 8). Then, tsunami simulations were carried out for 337 cases in total including 336 artificial cases and 1 real case.

RESULT OF TSUNAMI SIMULATION

Based on the tsunami simulation results of 336 artificial cases and 1 real case using TUNAMI-N2 software, I will discuss several cases for the sample analysis.

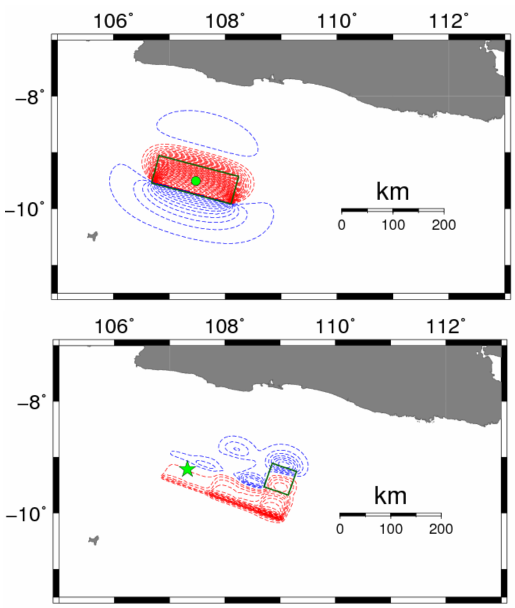

Figure 2. Comparison of fault deformation areas between the artificial case of source point I (top) and the real case of the 2006 Pangandaran tsunami (bottom).

Comparison of tsunami waveforms at coastal area obtained from the simulation between the real case and the nearest artificial source points shows that the tsunami heights of the real case mostly equal to the artificial ones, and arrival times are mostly earlier especially on the central Java coasts. These phenomena appear to be due to the difference of tsunami source area between two cases. Tsunami source area of the real case mostly extends to south-eastern part from the epicenter (main shock) of the real case closely to the central Java coasts like shown in Figure 2. Figure 2 also shows the subsided area of initial sea level displacement of the real case is huge in north-eastern direction, while the subsided area of point I is small for the same direction. This explanation is clarifying why the first arrivals of tsunami for the real case in the central Java coasts mostly subsided while the artificial one is uplifted. Even with those differences in waveforms between the real case and the artificial case, there seems no fatal discrepancy in tsunami heights, but more investigation is needed for arrival times. That indicates validity to use simple rectangular fault model for the artificial cases instead of using realistic but complicated fault model to obtain tsunami heights.

Figure 3 shows the comparison of the tsunami heights at coastal points which were obtained by applying Green's Law to the tsunami heights at different depth of forecast points. Based on this graph, we can find that the tsunami heights obtained at coastal point by applying Green's law are almost the same or do not vary significantly among different bathymetry depths of forecast point. Therefore, considering the complexity of coastal bathymetry along the study area, I decided to use the sea depth of 50 m for forecast points in the tsunami simulations.

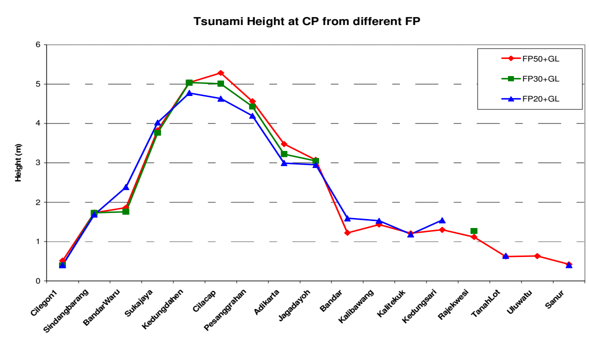

Figure 3. Comparison of tsunami heights at coastal points obtained by applying Green's law to the heights at the forecast points with different depths (source point C with depth of 0 km and magnitude of 8.0).

Figure 4 shows the comparison of tsunami heights from the source point R. From this figure we can see that the application of the Green's law gives relatively higher tsunami heights at coasts than those directly obtained from tsunami simulation. But these results are relatively more stable than the results obtained directly from tsunami simulation. This may be because of not so accurate sea depth data of GEBCO near coasts and choose grid of 1 arc minute, since the complexity of bathymetry of the shallow coastal area could considerably affect the tsunami simulation. Although this result needs further investigation, it gives us good judgement for application of Green's law in the tsunami warning scope.

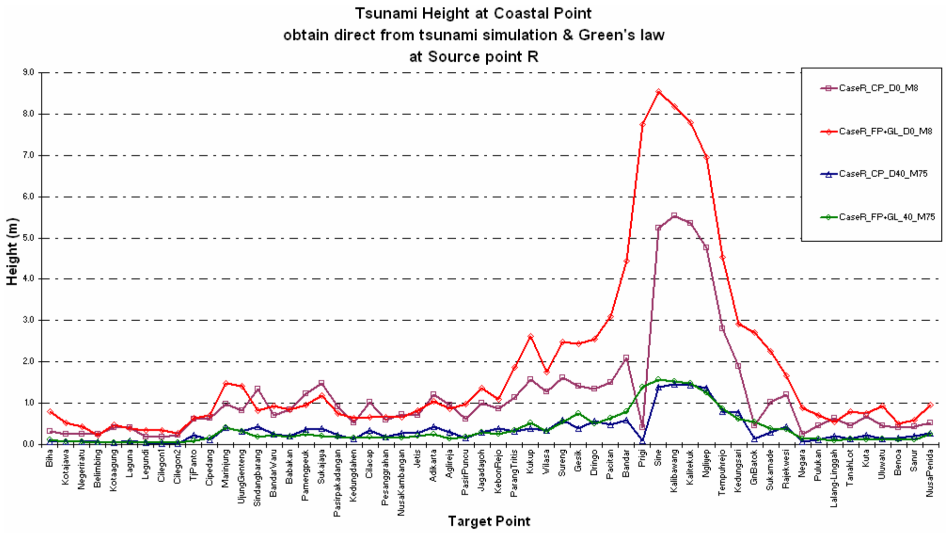

Figure 4. Comparison of tsunami heights obtained directly from simulation and by applying Green's law to heights at FPs for source point R with the same depth and magnitude.

TSUNAMI DATABASE AND WARNING INFORMATION

For establishment of reliable and robust tsunami database, the selection of the database and systems will be important. In this study I adopted a system for developing web application to construct tsunami database and applied retrieve method to it. In this study I used Apache 2.2.8 for web server and MySQL5.0.51 for relational database. PHP 5.2.5 was used in this study as middleware scripting language to connect the server and the database.

Construction of Database

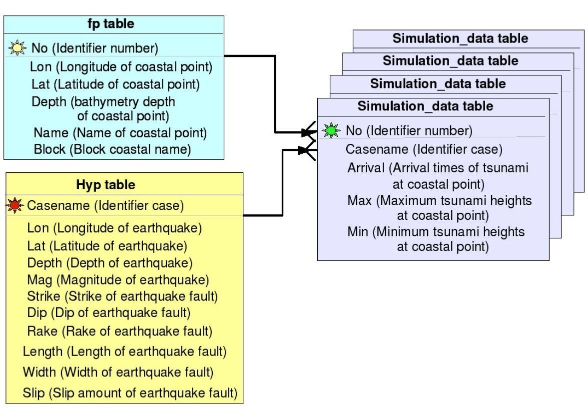

Figure 5. Architecture of tsunami database.

In this study, the tsunami database which I constructed consisted of 3 main parts: 1 coastal point table (fp table), 1 hypocenter table (hyp table) and 336 simulation data tables. I also constructed several temporary tables considering their applications to retrieve from the database. The architecture and relationship between tables of this database are shown in Figure 5. SQL commands were used to make table structure and to insert the tsunami simulation results into the tables.

Retrieving from Database

The next important step to perform database method is to explore how quickly and precisely retrieve tsunami heights and arrival times from the database. In this study I used 2 methods namely simple and interpolation method. These methods are performed by a combination of PHP scripting language and SQL syntax commands. PHP scripting language chooses the most appropriate data from database which match the real earthquake. This combination also makes earthquake and tsunami information message.

Simple method seeks simulation data whose epicenter is located in the nearest horizontal distance to the real earthquake. As for magnitude and depth, this method uses the closest element for outputs. For arrival times, considering the tsunami warning, this method will seek the arrival times from the nearest element to the hypocenter.

To apply the interpolation method, firstly the four cases surrounding the epicenter of the real earthquake will be searched in the database. Each case has 2 different magnitudes and 2 different depths. Totally there exist 16 cases used for the interpolation. In order to obtain tsunami heights for the actual hypocenter, the linear method will be used in horizontal interpolation for 4 cases surrounding the hypocenter. I performed logarithm method to obtain coefficients for magnitude and depth interpolations following the JMA's rules. For estimation of arrival times of tsunami at coastal area, the method will seek the earliest case among the data which were used for the interpolation.

Tsunami Warning Information

Based on JMA (2007), in this study the tsunami warning messages are divided into 3 stages of warning. *The first warning* message consists of data about the recent earthquake that occurred and the earliest arrival time and the highest tsunami height at each estimated coastal block which will be affected. Besides this the information in the warning also includes criteria of warning for each coastal block and name list of the coastal area affected within coastal blocks. *The second warning* message clarifies the details of arrival time and tsunami height at each coastal area within coastal block which were affected. *The third warning* message is about cancellation of tsunami warning information or downgrading or upgrading on the coastal blocks warning criteria. In this study, tsunami warning message was developed by utilizing PHP scripting language integrated with the application of retrieving method in the web application framework. The flowchart of web application used in this study is shown in Figure 6.

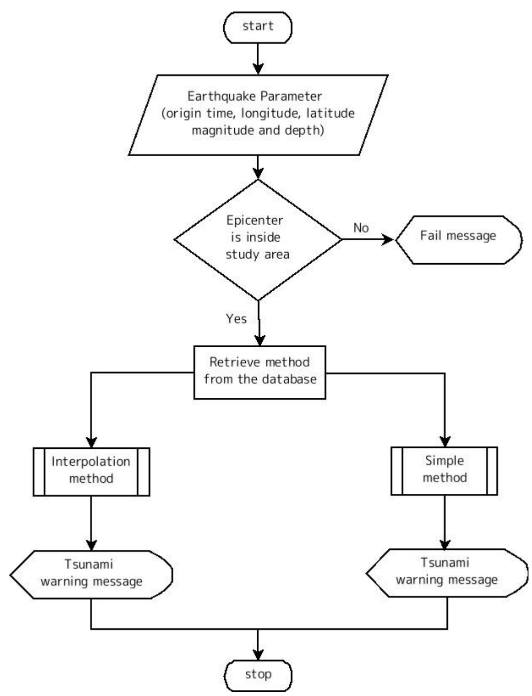

Figure 6. Flowchart of web application.

CONCLUSIONS

In this study, a prototype of tsunami database developed and retrieving methods were used for web application. The source points in the study area are combinations of 1 real case (The 2006 Pangandaran tsunami) and 28 artificial cases with 4 different depths and 3 different magnitudes (totally 337 cases). I considered tectonics setting of study area and the severest case of tsunami occurrence for initial conditions for numerical tsunami simulation.

The tsunami simulation was conducted by using TUNAMI-N2 numerical simulation software from DCRC and TTT software from Geoware. From these simulations I obtained the tsunami heights and estimated arrival times at target points along the study area which consist of 56 forecast and 56 coastal points. I investigated the exact location of forecast points in the offshore area for applying Green's law, and I decided to locate the forecast points in the 50 m depth of bathymetry in the ocean in front of coastal points.

Tsunami simulation result shows that comparison of tsunami waveforms between the real case and the artificial case closest to it had a strong similarity in tsunami heights, but had differences in arrival times due to the differences of fault deformation area for the two cases. Also I found consistency between the tsunami heights at the coast obtained by applying the Green's law and those obtained directly from tsunami simulation. These results show that the setting of artificial cases is acceptable for constructing tsunami database.

Then, the results of tsunami simulation were stored in the database by utilizing web application system. This system consists of Apache 2.2.8 for web server, MySQL 5.0.51 for relational database and PHP 5.2.5 for middleware scripting language. The tsunami database which was successfully constructed in this study consists of 337 tables, and is divided into 3 parts: coastal point table, hypocenter table and simulation data table. Relation between tables in the database based on the primary key from each table has type of '*one to many*'. Here, I also succeeded in applying the retrieving method to search the data from the database. The methods I used are simple and interpolation. These methods are easy to apply, but are not so precise due to the lack of bathymetry data I used. So, the accuracy of tsunami heights and arrival times should be increased by using finer bathymetry data. The next stage in this study was to assemble tsunami warning message. The design of tsunami warning message also must be simple and apprehensible by people. Although, I couldn't finish to completing all the tsunami warning message perfectly like the format I designed, this study verified the ability of web application system for developing tsunami warning system. However, there are still needs for further research and improvement to increase utilizing the web application in tsunami warning system.

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