Development of Possible Tsunami Exposure Estimation Module for Tsunami Disaster Response

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ABSTRACT: A GIS module to estimate possible tsunami exposure (PTE), population which would be exposed to tsunami hazard was developed. The module was applied to the Indian Ocean Tsunami Disaster, Dec. 26, 2004 and another tsunami which hit northern Sumatra in Mar. 28, 2005. As a result, it was shown that the estimated PTE is consistent with reported damage and that the module could assess the PTE due to the event with enough accuracy to get the big picture of the event.

Key Words: Indian Ocean Tsunami Disaster, Damage estimation, Coastal population

INTRODUCTION

In case of large scale disaster, it tends to require lots of time and re-sources to grasp total damage situation. In Indian Ocean Tsunami Disaster, Dec. 26, 2004, huge tsunami swept Indian Ocean rim countries such as Indonesia, Sri Lanka, India and Thailand as shown in Figure 1. 169,752 dead and 127,294 missing were reported as of Feb. 22, 2004. It took more than one month after the event occurred that the overview of the damage situation in the affected countries was revealed.

Delay of grasping damage situation leads delay and inefficiency of response and relief activities by affected countries, donor countries and NPOs. So, it is required to identify severely damaged areas in very early stage and then concentrate limited resources on those areas for getting de-tailed damage situation efficiently. In such first stage screening, grasping big picture of total damage is important rather than pursuing precise number. Especially, it tends to require more time for most of developing countries to grasp damage situation because of lack of disaster information and communication system and because of high vulnerability against natural disasters which cause larger damage with same extreme natural force com-pared with developed countries.

PTE estimation module we introduce in this paper is developed for screening severely damaged area. This module is applicable to tsunami disaster which occurred anywhere in the world with recent development of tsunami simulation technology and global demographic and topographic data-base.

All of these global database used in the module are available in public domain. This global applicability is an advantage of the module in applying it to the tsunami disaster which occurred in developing countries. In case of tsunami, the module receives maximum tsunami height simulated by tsunami researchers and calculates PTE in reasonable time. As a result, possible total affected population, affected population by countries and by regions and possible severely affected area can be published via Web-GIS.

Such information will help stakeholder countries and organizations to recognize the significance of the event and to know which country or area should be prioritized in relief activity. Sharing common view against the situation among the stakeholders will lead efficient coordination.

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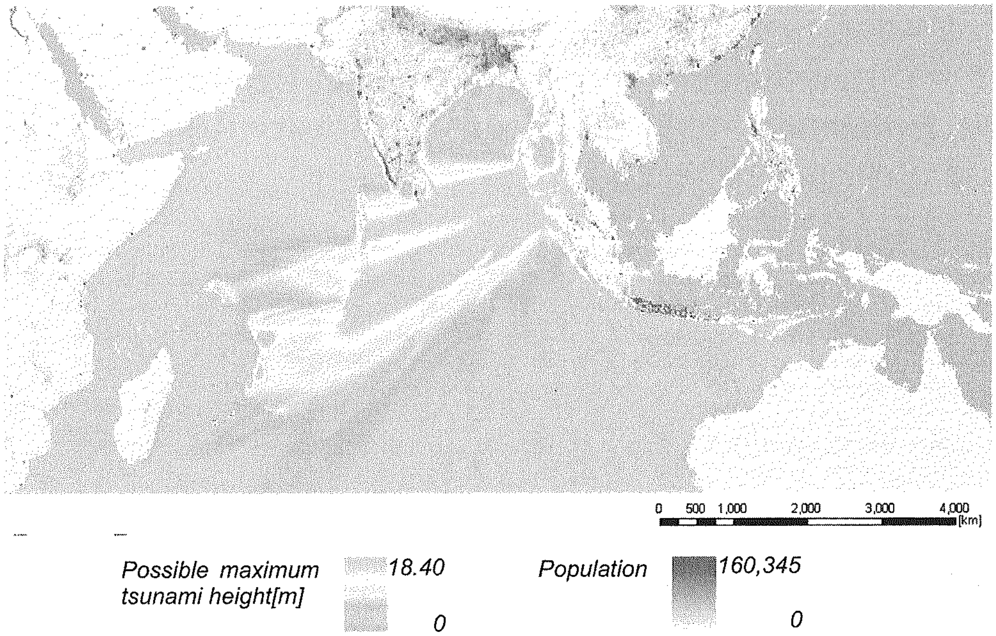

Figure 1. Possible maximum tsunami height of Indian Ocean tsunami ,Dec. 23, 2004 simulated by S. Koshimura, Tohoku Univ. (2'grid) and Population distribution of Indian Ocean rim countries based on Landscan2003, Oak Ridge National Laboratory (30"grid)
(LandScan Global Population Database. Oak Ridge, TN: Oak Ridge National Laboratory. Available at http://www.ornl.gov/gist/.)

In this paper, the PTE estimation process and data required in the process are described in chapter 2. Then, application of the module to Indian Ocean Tsunami Disaster, Dec. 26, 2004 and another tsunami which hit northern Sumatra in Mar. 28, 2005 is introduced and it is shown that the estimated PTE is consistent with reported damage and that the module could assess the PTE due to the event with enough accuracy to get the big picture of the event in chapter 3. Chapter 4 is concluding remarks.

PTE ESTIMATION MODULE

In this module, PTE is estimated in the process shown in Figure 2. The module was developed on ArcGIS. Input data are maximum tsunami height (MTH), population distribution and DEM. Output is PTE by MTH and by region or country.

Data required in the module

Maximum tsunami height (MTH) Any data provided in ArcGIS grid or ASCII format can be used. Ba-sically, MTH must be provided by numerical simulation from tsunami re-searchers. In our research group, MTH can be calculated on the basis of global bathymetry data provided in 2' grid by National Geophysical Data Center wherever tsunami occurs in the world.

Population Any data provided in ArcGIS grid or ASCII format can be used. Landscan provided from Oak Ridge National Laboratory is used as global population data with default setting (Figure 1).

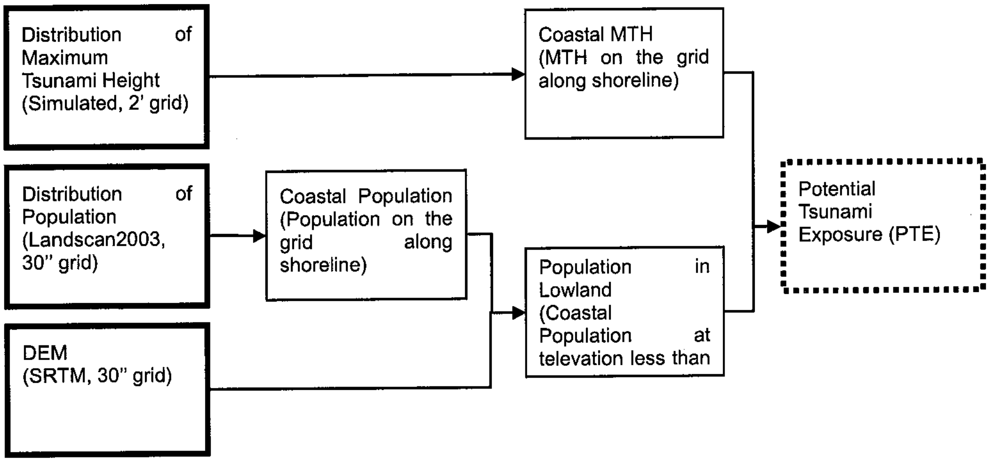

Figure 2. Potential tsunami exposure (PTE) estimation process flow

It is provided in 30" grid. Landscan data is not census based data. Reported total population within a political boundary is allocated in each grid considering land use, proximity to the major road, slope, and night-time city light. So, Landscan should be used to know gross configuration of population. If census based statistics in similar spatial resolution is available in the target region, it will lead more precise result.

DEM Any data provided in ArcGIS grid or ASCII format can be used. STRM30 provided from NASA is used as global topological data with de-fault setting. It is provided in 30" grid.

PTE estimation process
At first stage, coastal population grid and coastal MTH grid is extracted. Then, coastal population grid at elevation less than 30m is extracted by using DEM grid to avoid overestimate of coastal population which a tsunami can affect. Then, coastal population grid at elevation less than 30m is assigned to nearest coastal MTH grid. Finally, coastal population exposed to a certain MTH in a certain region is calculated.

In this process, whole population in 30" grid along shoreline is included in PTE without considering local topography. 30" is approximately 900m in low latitude area. So, this module may overestimate PTE in case that coastal area is mountainous or may underestimate PTE in case that there is large flat plane next to shoreline. How far a tsunami come to inland depends on local coastal topography. The process to evaluate coastal population which a tsunami can affect should be reviewed for further study.

ESTIMATION OF PTE IN ACTUAL TSUNAMI DISASTERS

PTE of Indian Ocean tsunami disaster, Dec. 26, 2004
PTE of Indian Ocean Tsunami Disaster (M9.0), Dec. 26, 2004 was estimated with PTE estimation module introduced in previous chapter. The result is shown in Table 1. Indonesia had largest coastal population in low-lands. It can be seen that Indonesia had larger PTE for MTH larger than 5m compared with other countries. On the other hand, India and Sri Lanka had larger PTE for MTH which ranges from 2m to 5m. As a whole, Indonesia had largest PTE among the affected 11 countries and India, Sri Lanka and Thailand followed. Compared with other countries, PTE of these four countries

were apparently dominant.

Reported number of dead and missing as of Feb. 22, 2005 (CNN) is shown at the bottom of Table 1. Indonesia had largest number of dead and missing (236,169) and Sri Lanka (35,672) , India (16,416) and Thailand (8,388) followed at that time. These numbers corresponded to 13.3%, 3%, 0.4% and 6.4% of PTE for MTH larger than 1m in each country, respectively. This result shows the vulnerability of Indonesia against tsunami is higher than other three countries.

It can be said that countries which had larger PTE tend to have larger number of dead and missing. And also, it can be seen that dead and missing in a country got larger sharply when the country had PTE for MTH larger than 7m. Dead and missing was very limited when there is no PTE for MTH larger than 7m.

Table 1. Cumulative possible tsunami exposure due to Indian ocean tsunami disaster Dec. 26, 2004, by maximum tsunami height for Indian Ocean rim countries

MTH[m]	Indonesia	India	Thailand	Sri Lanka	Myanmar	Malaysia	Bangladesh
0	8,178,490	6,923,301	898,902	1,188,898	1,305,493	1,347,390	2,370,781
1	1,775,482	4,403,036	130,425	1,188,898	950,480	369,769	1,451,794
2	446,557	1,947,329	130,421	1,070,477	252,752	307,918	403,176
3	156,750	953,828	108,485	586,008	65,303	19,080	133,810
4	93,604	149,938	41,285	159,962	5,343	0	2,743
5	67,139	45,711	18,954	79,274	1,780	0	1,790
6	56,793	19,786	9,780	35,612	23	0	98
7	49,279	8,266	8,366	17,854	0	0	0
8	39,563	6,626	4,168	2,022	0	0	0
9	32,203	4,048	4,039	1,345	0	0	0
10	18,596	2,826	2,430	493	0	0	0
11	10,821	1,878	15	346	0	0	0
12	10,200	444	13	0	0	0	0
13	7,024	100	0	0	0	0	0
14	6,878	100	0	0	0	0	0
15	319	100	0	0	0	0	0
16	173	100	0	0	0	0	0
17	0	100	0	0	0	0	0
18	0	92	0	0	0	0	0
19	0	92	0	0	0	0	0
death	122,232	10,776	5,395	30,974	59	68	2
missing	113,937	5,640	2,993	4,698	0	0	0
death +missing	236,169	16,416	8,388	35,672	59	68	2

MTH[m]	Maldives	Somalia	Kenya	Tanzania	Seychelles	Australia	Total
0	328,164	420,947	552,882	1,092,660	19,173	75,347	24,702,428
1	328,164	387,148	520,322	1,025,921	17,299	245	12,548,983
2	268,382	245,536	224,134	330,940	8,947	0	5,636,569
3	139,998	1,412	360	2,893	0	0	2,167,927
4	0	6	0	0	0	0	452,881
5	0	0	0	0	0	0	214,648
6	0	0	0	0	0	0	122,092
7	0	0	0	0	0	0	83,765
8	0	0	0	0	0	0	52,379
9	0	0	0	0	0	0	41,635
10	0	0	0	0	0	0	24,345
11	0	0	0	0	0	0	13,060
12	0	0	0	0	0	0	10,657
13	0	0	0	0	0	0	7,124
14	0	0	0	0	0	0	6,978
15	0	0	0	0	0	0	419
16	0	0	0	0	0	0	273
17	0	0	0	0	0	0	100
18	0	0	0	0	0	0	92
19	0	0	0	0	0	0	92
death	82	150	1	10	3	0	169,752
missing	26	0	0	0	0	0	127,294
death +missing	108	150	1	10	3	0	297,046

PTE of tsunami disaster in Mar. 28, 2004

In Mar. 28, 2004, another large earthquake (M8.7) and tsunami occurred along the Sunda trench and hit northern Sumatra. Although the magnitude was considerably large and the source area was adjacent to that of the previous event, the damage was very limited. Indonesia had several hundred dead and missing. No damage was reported in other countries which were affected in the previous event.

We also applied the module to estimate the PTE of the event. As a result, it was clarified that only Indonesia had moderate PTE compared with the previous event. No country had PTE for MTH larger than 7m. It was confirmed the module could assess the PTE due to the event with enough accuracy to get the big picture of the event and within reasonable calculation time.

As a result of above-mentioned application, it can be said that PTE estimated by the module is reflecting actual damage situation as a whole. This result supports that PTE estimation module we developed can be used to get a big picture of tsunami disaster.

CONCLUSION

In this study, we developed PTE estimation module which is applicable globally. Then, we applied the module to Indian Ocean Tsunami Disaster, Dec. 26, 2004 and another tsunami which hit northern Sumatra in Mar. 28, 2005 to calculate the PTE of both events. As a result of examination of relationship between estimated PTE and actual damage, it is shown that the estimated PTE is consistent with reported damage and that the module could assess the PTE due to the event with enough accuracy to get the big picture of the event.

The module we introduced in this paper can be used not only in emergency response but also in risk analysis for possible tsunami disasters in future by preparing simulated MTH of future tsunami scenario as input data. To prepare for future tsunami disaster, risk evaluation against possible scenario is indispensable. But, the target area get larger, it is almost impossible to conduct detailed risk assessment for all target area. Since our module can provide gross configuration of risk due to future scenario, we can concentrate our resources on the high risk area for detailed assessment.

As mentioned in chapter 2, in the PTE estimation process, whole population in 30" grid along shoreline is included in PTE without considering local topography. How far a tsunami come to inland depends on local coastal topography. The process to evaluate coastal population which a tsunami can affect should be reviewed for further study.

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