Tsunami Hazard Modeling Based on its Appropriate Source for mitigation in Padang, Indonesia

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1. Introduction

In Sumatra forc arc region; recent tectonic activities in the region started at 2000 when a 7.9Mw earthquake occured on 4 June 2000, then 2002 with 7.3Mw, continued in 2004 with 9.3 Mw in northern Sumatra. This stressed other structure nearby, caused 8.7 Mw earthquake in 2005. The megathrust series continues in 2007 with 8.5Mw and 7.9Mw in twelve hours in southern part. Then consecutively, a 7.0 Mw earthquake occured in Mentawai Island in 2008, and 7.6Mw in 2009 near Pariaman district coast. The latest was claimed 1,117 casualties. Referring to historical record in the region, energy after 1797 and 1883 earthquake is not completely released by above series. The seismic gap still has potential to produce a mega thrust earthquake with magnitude between 8.6 – 8.9Mw (Natawidjaja, 2009). Then, a reliable worstcase scenario of earthquake and tsunami for disaster mitigation purpose should be determined.

2. Objectives

Several scenarios proposed from geological perspectives. However, for disaster mitigation purposes, a reliable worstcase scenario in term of impact is needed. In this paper, firstly we review some available tsunami source scenarios in Padang region and determine the worst in term of arrival time and observed tsunami wave height at given tide gauges. We are then modeled respective scenario with two type of topographic data in order to asses worst inundation parameter such inundation length and flow depth. This is tend to propose the methodology and its limitation to predict the worst inundation zone. Finally, we propose the appropriate source and methodology on tsunami hazard modeling in Padang, Indonesia.

3. Methodology

Available tsunami source model calculated using Okada theory (Okada, 1985). The detail of each scenario is given below,

Table1. Fault parameters of existing scenarios

ID	Source Model	Fault Numbe	Disloc (m)	Length (km)	Width (km)	Strike	Dip	Slip	Depth (km)
		1	0.5	20.0	20.0	325.0	13.0	75.0	85.0
		2	0.9	20.0	20.0	325.0	13.0	75.0	85.0
		...	...	...	...	...	...	...	...
a	Natawidjaja	348	3.1	20.0	20.0	325.0	13.0	75.0	58.0
		1	0.3	20.0	20.0	325.0	13.0	75.0	85.0
		2	0.6	20.0	20.0	325.0	13.0	75.0	85.0
		...	...	...	...	...	...	...	...
b	Chlieh	348	2.1	20.0	20.0	325.0	13.0	75.0	58.0
c	Aydan	1	6	450	117	325.0	13.0	75.0	10.0
d	Tobita	1	7	370	125	325.0	13.0	75.0	10.0

For case of scenario (c) (Aydan, 2008) and (d) (Tobita, 2007), we only got information about potential magnitude and the preditiction of fault length. Then, an empirical relation from Papazachos (Papazachos, 2004) was used to determine the fault dimension and dislocation from its predicted magnitude. Other parameter was assumed likely as the fault characteristic in the region. We got different estimation for fault dimension for (c) and (d) case. For example, we got only 395 km fault length in (c) case, while it suggest a 450 km faulth length in the reference. We got 446 km fault length in (d) case, while it suggest only 370 km fault length in the proposal. An adjustment for this parameter is performed to satisfied the referred papers.

We put three tide gauge in Padang coast at 5m depth which are placed on Parupuk Tabing coast (Padang old airport), Purus (central city) and Teluk Bayur. One tide gauge placed in Painan at 11m depth (Figure1). We compute tsunami arrival time and maximum wave height by using TUNAMI model and GEBCO data with 30 arc second accuracy.

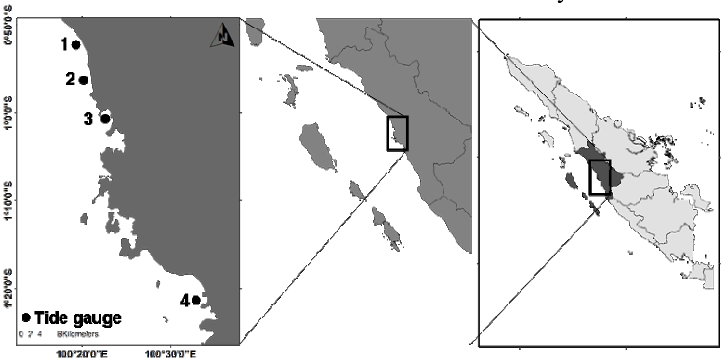

Figure1. Tide gauges position, (1) Parupuk tabing Village, (2) Purus Village, (3) Teluk Bayur Bay, (4) Painan

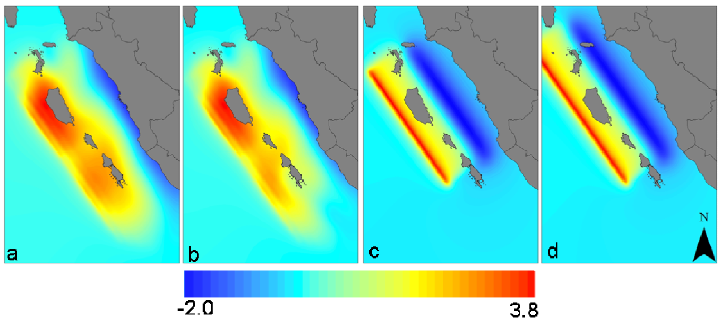

Figure2. Initial sea surface distribution of existing scenarios, (a) Chlieh scenario, (b) Natawidjaja scenario, (c) Tobita scenario, and (d) Aydan scenario

4. Result

For tsunami arrival time, we got an independent function of tsunami arrival time from its slip distribution or even from the magnitude (in correlation to its focal mechanism). A similar wave pattern in term of wave period and amplitude was got for single fault scenario (c and d case). Average arrival time in this case is 30.5 minute. For multi-slip scenario (a and b case), we got a slight different wave period and significant different on wave height. Average tsunami arrival time less then single scenario which only 21.2 minutes. Different fault dimension in single scenario is not make significant different on its arrival time. Comparing with other previous result in the region (Borero, 2006 and Mc.Closkey, 2007), multi slip scenario either it would be from scenario (a) or (b) showing a faster arrival time which is only 20 (+2) minutes in Padang area, and 22 minutes in Painan area. In the area of Padang coast, the highest tsunami wave height is given by the first wave of single fault scenario which reached up to 10 meters (Table2). Average maximum tsunami wave at given tide gauges by single fault is 9.5 meters, while multi fault scenario is 8.5 meter (a) and 6.5 meter (b).

Table2. Arrival time and maximum wave height observed at given tide gauges

ID	Source Model	Arrival Time (minute)				Wave height (meter)			
		(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
a	Chlieh	22.0	20.8	20.0	22.6	6.0	5.3	8.2	6.8
b	Natawidjaja	21.6	20.5	20.0	22.3	7.9	7.1	10.7	8.7
c	Tobita	30.6	29.6	29.8	31.8	8.7	9.1	10.1	10.2
d	Aydan	30.6	29.6	29.8	31.8	8.7	9.1	10.1	10.2

Next step is performing the inundation modeling with two kind of topographic data in order to analyze the worst inundation zone. Model domain is divided into 5 sub domain (Figure3). In order to fulfill the nested system requirement, a Kriging interpolation is performed to data in largest domain. This is directed to get a set of nested data without changing the original data in smallest domain. Overall domain cell size varies from 405 meter to 5 meter.

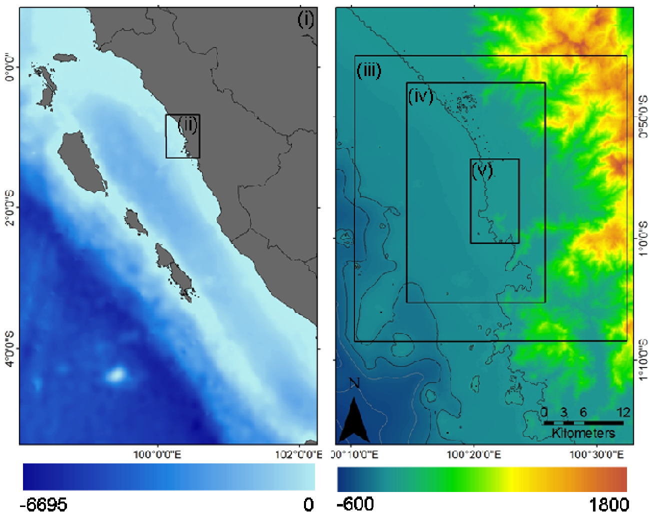

Figure3. Model domain in the nested system

We modeled the detail inundation in central part of Padang with two topographic models. First is using only topography data which is called as terrain model and the second is terrain model with building mask which called topographic model. Scenario (b) is used to model respective topographic condition.

5. Discussions

Scenario (c) and (d) (single fault) provides a higher tsunami wave height observed at given tide gauge. However, these scenarios have bigger arrival time compare with scenario (a) and (b) (multi slip). Nine minutes average time difference between single fault scenario and multi-slip scenario will be very important on designing the mitigation strategy. One meter different on wave height at given tide gauge between single fault scenario (c and d) and multi-slip scenario (b) should be assessed furthermore on its inundation pattern in order to check the influence of wave period on determining the inundation area.

Different topographic data has a significant influence on estimating the worst inundation zone, the result of inundation model gives such of comparison. Topographic model gives smaller inundation area then terrain model. The inundation pattern using surface model can show the real condition tsunami flow through the buildings, and undergo the resistance when it hits them. However, the assumption that all the building can survive against tsunami force may result an underestimate on tsunami inundation length due to the building resistance effect. In the other hand, the miss of topographic features to reduce the tsunami wave energy in terrain model can caused the calculation overestimated because no resistance factor acting on the flow beside the bottom friction with same manning condition.

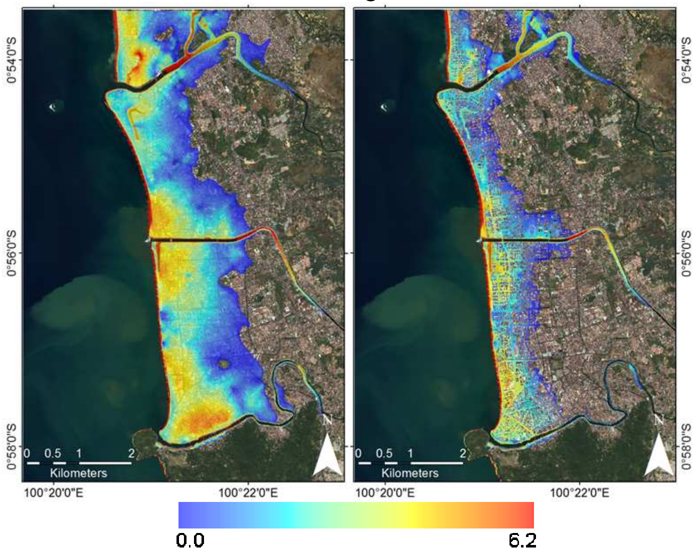

Figure4. Inundation area and flow depth (in meter) from terrain model (left) and topographic model (right)

6. Conclusions

Same dip, slip strike and depth on the fault mechanism in single fault scenario give an almost similar result on the parameter of wave period, height and arrival time. Slip distribution give a significant different on wave height but not significant in wave period.

Scenario (b) is the worst in term of arrival time, while scenario (c) and (d) are the worst in term of tsunami wave height at given tide gauges. Terrain model with same manning roughness gave the maximum inundation length and run up height. While using surface model can give the impression about flow characteristic through the buildings. In order to propose the most reliable worst case scenario for mitigation purposes, inundation pattern from single fault scenario is still needed to be performed in order to compare with above multi-slip result. A building fragility analysis due to tsunami force is needed to analyze the limitation of the surface model and also the reliability of terrain model.

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