NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE | Institute of Catastrophe Risk Management

Evaluation of Natural Catastrophe Impact on the Pearl River Delta (PRD) Region – Earthquake Risk

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ABSTRACT

Guangdong Province including the Pearl River Delta (PRD) region is one of the major economic centers in China, which accounts for 11% of China's total GDP. Although Guangdong is located in low-to-moderate seismicity regions, seismic risk should be an important concern due to its strong economy, dense population and huge infrastructure investment. Based on historical records, this region has experienced several notable earthquakes, including the 1918 Shantou Earthquake with a moment magnitude of 7.3. Therefore, it is necessary to accurately assess the seismic hazard, especially the maximum shaking intensities that could occur. In this ICRM study, a historical earthquake catalogue including recent earthquakes is first compiled. Then the worst-case scenario affecting this region is identified. Finally, under this deterministic earthquake scenario, the corresponding hazard maps, including peak ground acceleration (PGA) and spectral acceleration at 0.3 second (Sa(0.3s)) maps, are generated based on ground motion prediction equations with or without effects of local site conditions. These resulting hazard maps are key components for further seismic risk evaluation analyses in this region.

INTRODUCTION

Evaluation of seismic hazard for metropolitan areas especially in Asia has become increasingly important due to the concentration of exposures resulting from their dense population and rapid economic growth. For instance, the 2015 Gorkha Nepal earthquake with a moment magnitude (M_w) of 7.8, caused a catastrophe with more than 8,500 deaths and about USD 10 billion economic loss (Goda et al. 2015). Recent seismic hazard analyses for metropolitan areas such as Metro Manila, Singapore, and Istanbul have been reported (e.g., Miura et al. 2008, Bal et al. 2010, Du and Pan 2017).

Guangdong Province including the Pearl River Delta (PRD) region is an area where the seismic hazard need to be well studied. Covering a territory of about 20,600 square kilometers, the PRD region comprises the urban districts of Hong Kong, Shenzhen, Dongguan, Macau, and Guangzhou, and is home to over 100 million inhabitants. The region is one of China's main economic centers, with an estimated GDP of USD 690 billion. Guangdong Province generates 11% of China GDP (largest provincial economy for 26 consecutive years), and realizes 26% of China's international trade. It has 9 cities (out of 21 prefecture-level cities in Guangdong) including 2 of the 4 Tier-1 cities of China - Guangzhou and Shenzhen.

Although the PRD area is generally classified as a low-to-moderate seismicity zone, the seismic risk cannot be neglected. In the 2010 seismic design code of China, the bedrock peak ground acceleration (PGA) values for major cities in the PRD area are listed in the range of 0.1-0.2 g for a return period of 475 years (10% probability of exceedance in 50 years). More importantly, as shown in Figure 1, a large portion of Guangdong lies over the various periods of sediment formation consisting of clay, silts, and sand layers. The time-average shear wave velocity in the top 30 m (V_{s30}) map estimated by U.S. Geological Survey (USGS) is shown in Figure 2, from which it is seen that the central PRD part has V_{s30} values lower than 300 m/s, classified as ground types C and D based on Eurocode 8 (2004). Therefore, significant site effects could be expected in the PRD area. Thus the aim of this work is to identify the worst-case earthquake scenario in Guangdong Province, and generate the corresponding seismic hazard maps to support seismic risk analysis.

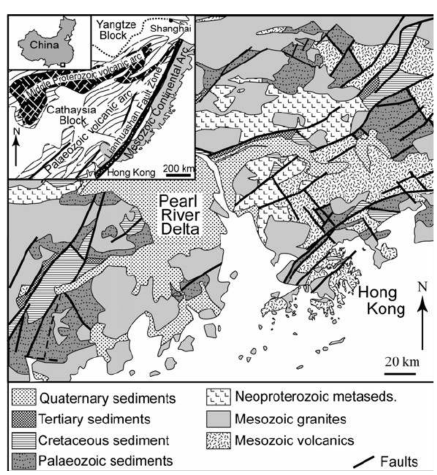

Figure 1. Geological map of the PRD region (Shaw et al. 2010).

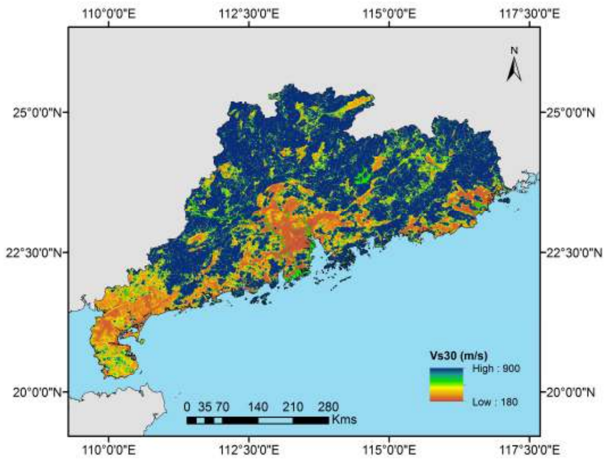

Figure 2. The V_{s30} map of Guangdong Province (USGS, 2017).

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Plate Tectonics and Fault Zones

Since the PRD region is not located at the edge of the plates, earthquakes and volcanoes are less frequent, and geologically such a region is referred to as a passive continental margin. The PRD area is located near the south-eastern margin of the Eurasian Plate, which is situated about 500-700 km away from the nearest plate boundary of the Philippines Ocean Plate. It is generally agreed that the PRD area is located in low-to-moderate seismicity zone, and a devastating large-size earthquake is less likely.

The Guangdong Engineering Earthquake Resistance Research Institute in its 2010 seismic hazard assessment report (GEERRI 2010) described the regional fault zones in detail as shown in Figure 3. The active faults are shown as red lines in this figure. In the PRD area, the main faults consist of three parts (GEERRI 2010): (i) dominant northeast (NE) trending faults; (ii) east of northeast (ENE) trending faults; and (iii) northwest (NW) trending faults. The NE trending faults are especially concentrated in the offshore region. Among these fault classes, the faults striking NE are more likely to create strike-slip moment and therefore have a higher possibility to generate large earthquakes. Historical large earthquakes occurred mostly near Shantou and Nanao, including the magnitude 7.3 Shantou earthquake in 1918, where the NW striking faults intersect the ENE trending faults to extend up to nearly 200 - 600 km on the surface intermittently (GEO 2015), as is shown in Figure 3.

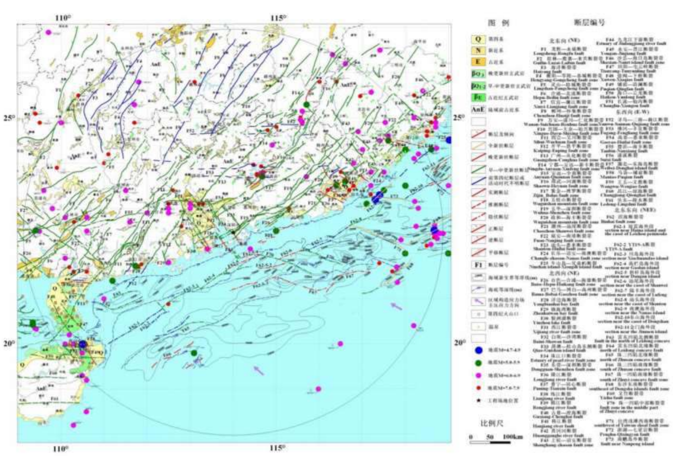

Figure 3. Tectonic structure of PRD Region (GEERRI 2010). In this plot, the thin lines denote the active faults within the PRD region, and the points denote the historical earthquakes with various magnitude size.

Data Collection and Historical Earthquakes

In developing our historical earthquake catalogue, the search parameters for earthquakes are mostly from and within the coordinates 15°N to 27°N and 105°E to 125°E. Since no single catalogue source is complete on its own, events are compiled from various available sources and from reports of historical earthquakes. Since the available catalogue sources can have different time-spans of available data, sources are combined to overcome gaps and missing earthquakes. The sources from which these data catalogues are derived are the China Earthquake Administration, the Guangdong Engineering Earthquake Resistance Research Institute, and the Seismological Bureau of Guangdong Province.

As a data standard, the earthquake information in each catalogue source consists of the date, time, coordinates of the earthquake epicentre, depth, and magnitude, though in some catalogues additional information is present. The combined earthquake catalogue covers the time from year 1067 up to 31 July 2016 inclusive. The catalogues consist of different types of earthquakes (e.g., M_w, M_s, and M_L), and the empirical relationships proposed by Wells and Coppersmith (1994) are used for converting the different magnitude forms to M_w. The overall seismicity plot of the study area with respect to different magnitude bins is shown in Figure 4.

An extensive seismicity analysis performed indicated that the 1918 strike-slip Shantou event (M_w=7.3) can be identified as the worst-case earthquake scenario, due to its capability of producing larger stronger motions in this area. Therefore, the next step is to determine the credible ground motion intensity map subjected to this scenario, which will be illustrated in next section.

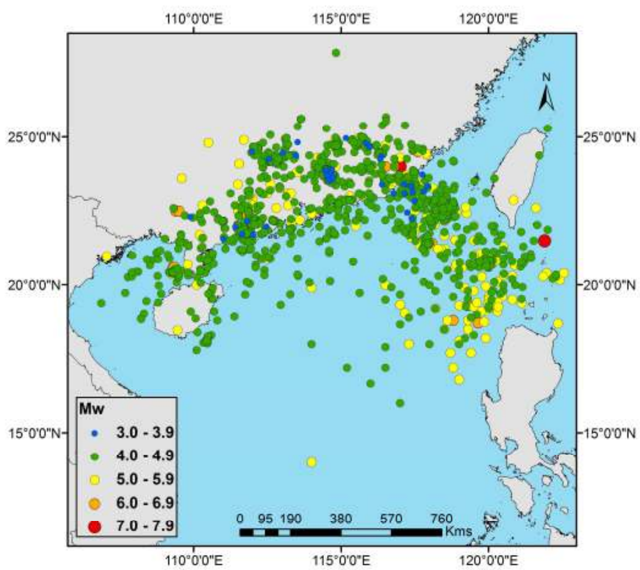

Figure 4. Historical earthquakes collected. The empirical relationships proposed by Wells and Coppersmith (1994) were used to covert the different magnitude types (i.e., M_s, and M_L) into M_w.

Table 1. Source parameters used for the deterministic earthquake scenario

M_w	Depth (km)	Strike (º)	Dip (º)
7.3	10	44	60
Epicentre (lat)	Epicentre (long)	Upper Depth (km)	Lower Depth (km)
23.613	116.828	2	17

Generation of Ground Motion Intensity Maps

OpenQuake Software

OpenQuake is an open-source, accessible software for earthquake hazard and risk modelling developed by the Global Earthquake Model (GEM) community (Pagani et al. 2014). To run the hazard engine implemented in OpenQuake, three kinds of input parameters are needed: (i) seismic source parameters for source modelling; (ii) a set of ground motion prediction equations; and (iii) geological information such as V_{s30} map to quantify the site amplification effect. In this study, the source parameters for the 1918 Shantou earthquake are listed in Table 1. The globally applicable NGA-West2 ground motion prediction equation developed by Chiou and Youngs (2014) is used to predict the surface response spectrum, and the V_{s30} map shown in Figure 2 is used to account for the site effects.

Ground Motion Intensity Maps

Figures 5(a) and 5(b) show the median prediction maps of PGA and S_a(0.3s) at rock sites (V_{s30}=760 m/s), respectively as computed based on the OpenQuake engine. The highest PGA and S_a(0.3s) values are 1.543 g and 5.436 g, respectively. As expected, the higher intensity values can be observed at the neighboring region of the fault area, such as Shantou, Jieyang, and Chaozhou cities.

Figures 6(a) and 6(b) show the median prediction maps of PGA and S_a(0.3s) by considering the realistic site conditions in PRD area, respectively. It can be seen that the hazard intensities in Figure 6 are consistently higher than those in Figure 5. This is not surprising due to the significant site amplification effects. However, the PGA and S_a(0.3s) values at the PRD area are generally smaller than 0.02 g and 0.05 g, respectively.

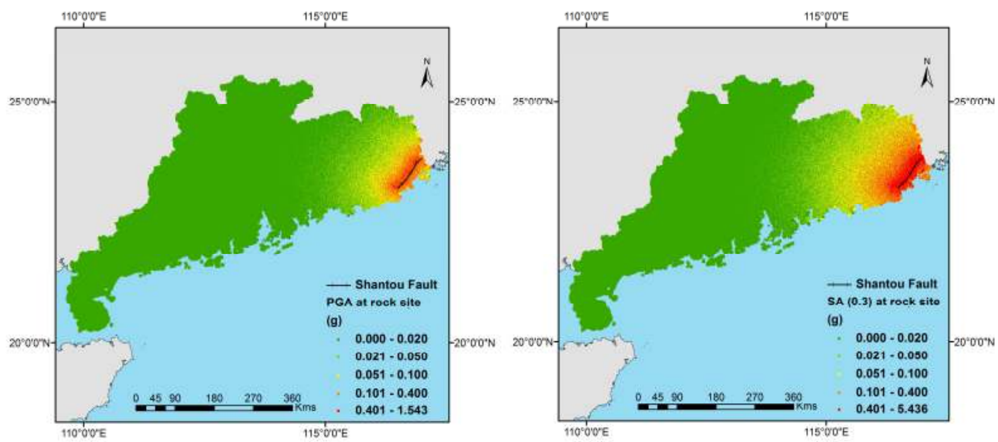

Figure 5. Generated (a) PGA and (b) S_a(0.3s) maps at rock sties of Guangdong Province for the 1918 Shantou (M_w=7.3) Earthquake.

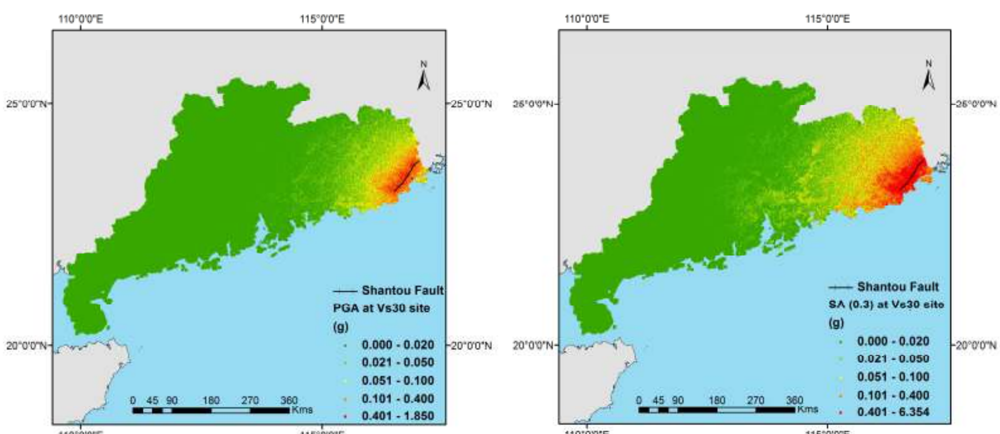

Figure 6. Generated surface (a) PGA and (b) S_a(0.3s) maps considering site conditions of Guangdong Province for the 1918 Shantou (M_w=7.3) Earthquake.

Conclusions

This work has identified the worst-case earthquake scenario affecting Guangdong Province, and developed the PGA and $S_a(0.3s)$ hazard maps under the 1918 Shantou M_w=7.3 scenario. It is anticipated that the high seismic hazard (PGA>0.2 g) could mostly occur in the eastern part of this province, whilst the seismic hazard for the PRD area is generally small (surface PGA<0.05 g). It is also observed that the site effect at the PRD area is noticeable. These results can then be further used to determine the seismic risk as well as its impact on this area.

Acknowledgments

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