Probabilistic tsunami hazard zonation in the coastal area of China

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Outlines

1 Background

2 Methodology and data

3 Case study

4 Results and Conclusions
1 Background

Before the Great Sumatra tsunami in 2004

Confused with storm surge

What is a Tsunami?
1 Background

After the Great Tohoku tsunami in 2011

- **Nuclear power plants in service:**
  - 3 bases, 15 units
  - Total capacity is 12.54 million kilowatts

- **Nuclear power plants under construction**
  - 11 sites, 26 units
  - Total capacity is 29.24 million kilowatts

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1 Background

Population density

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1 Background

Disposable income

Source: National Bureau of Statistics
2 Methodology and data

THE STEPS OF PSHA (Cornell, 1968)

Fault Source
STEP 1 Sources
Distributed Seismicity Source
SITE

STEP 2 Recurrence
Frequency
Magnitude

STEP 3 Attenuation
Ground Motion Level
Source-to-Site Distance

STEP 4 Hazard at Site
Probability of Exceedance
Ground Motion Level

OUR CONCEPTUAL PTHA FRAMEWORK

Submarine Fault Source
STEP 1 Sources
Submarine Landslide
Submarine Volcano
SITE

STEP 2 Recurrence
Frequency
Fault Displacement /Landslide Volume /Eruption Volume

STEP 3 Attenuation
Wave Height at Site
Source-to-Site Distance

STEP 4 Hazard at Site
Probability of Exceedance
Wave Height at Site

GMPEs

Numerical simulation

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2 Methodology and data

Step 1 Sources & Step 2 Recurrence

15 local sources
2 regional sources
2 Methodology and data

Regional sources

## 2 Methodology and data

### Fault geometry

<table>
<thead>
<tr>
<th>Manila</th>
<th>location</th>
<th>length (km)</th>
<th>width (km)</th>
<th>depth (km)</th>
<th>strike (°)</th>
<th>dip (°)</th>
<th>rake (°)</th>
<th>$M_u$</th>
<th>slip (m)</th>
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<tbody>
<tr>
<td>RM 1</td>
<td>119° 51’</td>
<td>21° 58’</td>
<td>210</td>
<td>82</td>
<td>20</td>
<td>350</td>
<td>14</td>
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<td>20° 06’</td>
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<td>16° 24’</td>
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<td>66</td>
<td>20</td>
<td>351</td>
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</table>
2 Methodology and data

Local sources

The 4th-generation national seismic zoning map: potential earthquake sources
2 Methodology and data

The data now is going to be updated from the new-generation zoning map.
2 Methodology and data

29 seismic belts, with $b$ and $\nu_4$ values
2 Methodology and data

Fault geometry

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<th>Sources</th>
<th>Node location</th>
<th>Strike (°)</th>
<th>Length (km)</th>
<th>$M_u$</th>
<th>Depth (km)</th>
<th>With (km)</th>
<th>Dip (°)</th>
<th>Rake (°)</th>
<th>Slip (m)</th>
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</table>

(Personal communication with Dr. Li)
2 Methodology and data

Step 3: Attenuation

PSHA

PTHA

\( P(\text{PGA} > 1 \mid m, r) \)

Target PGA

Mean prediction

Mean prediction +/- one standard deviation

Distance (km)

PGI (g)

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2 Methodology and data

Step 4: Hazard at site

\[
\lambda(IM > x) = \sum_{i=1}^{n_{\text{sources}}} \lambda(M_i > m_{\text{min}}) \sum_{j=1}^{n_M} \sum_{k=1}^{n_R} P(IM > x \mid m_j, r_k) P(M_i = m_j) P(R_i = r_k)
\]

PSHA

G-R relationship

Source location

\[
P(M = m_j) = F_{M}(m_{j+1}) - F_{M}(m_j)
\]

\[
F_{M}(m) = \frac{1 - 10^{-b(m - m_{\text{min}})}}{1 - 10^{-b(m_{\text{max}} - m_{\text{min}})}}, m_{\text{min}} < m < m_{\text{max}}
\]

G-R relationship

\[
\lambda(H > x) = \sum_{i=1}^{n_{\text{sources}}} \lambda(M_i > m_{\text{min}}) \sum_{j=1}^{n_M} \sum_{k=1}^{n_R} P(H > x \mid m_j) P(M_i = m_j)
\]

PTHA

G-R relationship

Numerical simulation

COMCOT

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3 Case study

Affected by 2 local sources and 1 regional source
2 Methodology and data

PSHA—GMPEs

PTHA—Simulated tsunami waves

Improve the method using Monte Carlo technique

(Abrahamson et al., 2008)
3 Case study

\[
\lambda(H > x) = \sum_{i=1}^{n_{\text{sources}}} \lambda(M_i > m_{\text{min}}) \sum_{j=1}^{n_M} \sum_{k=1}^{n_R} P(H > x | m_j) P(M_i = m_j)
\]

PTHA

G-R relationship

Numerical simulation

G-R relationship

COMCOT

Combined

Total: 200 scenarios

Cumulative distribution function (CDF)

Number of occurrence

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3 Case study

\[ M \propto L, W, D \]

Empirical relationship given by Papazachos et al. (2004)

\[ f(x \mid \mu, \sigma) = \frac{1}{\sqrt{2\pi}x\sigma} \exp\left(-\frac{(\log x - \mu)^2}{2\sigma^2}\right) \]

\[ \mu = -3.51 \]
\[ \sigma = 0.99 \]

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3 Case study

\[ P(H > x) = 1 - \prod_{l=1}^{N_{\text{sources}}} \{1 - P_l(H > x)\} \]
## Case study

<table>
<thead>
<tr>
<th>Wave height (m)</th>
<th>Probability of exceeding a given height</th>
<th>Return period (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>per year</td>
<td>per 10 years</td>
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<tr>
<td>0.1</td>
<td>8.49%</td>
<td>66.17%</td>
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<tr>
<td>0.2</td>
<td>5.52%</td>
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<td>0.3</td>
<td>3.86%</td>
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<td>0.4</td>
<td>2.81%</td>
<td>39.91%</td>
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<tr>
<td>0.5</td>
<td>2.09%</td>
<td>33.97%</td>
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<td>1.61%</td>
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<td>4.0</td>
<td>0.03%</td>
<td>1.69%</td>
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</table>

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4 Results and Conclusions

2 regional sources, 8 local sources, 640 scenarios
4 Results and Conclusions

- There is a high-risk level for tsunami hazard in the coastal area of East/South China Sea. It is strongly suggested to do more works about probabilistic tsunami hazard analysis (PTHA) in this area.
- The Monte Carlo technique can be effectively used in the PTHA work.
- With a reliable PTHA result, the delineation of potential tsunami sources should be scientifically debated and verified, much more reliable seismic parameters should be determined for these sources.
- The uncertainties about our PTHA results will be considered in a next step, including the seismic parameters, fault parameters, numerical computation, water depth, etc.
Remarks

Seismic station
Strong motion station

EEW system
- ~5000 stations
- 280 million dollars
Thank you