PROBABILISTIC TSUNAMI HAZARD ASSESSMENTS WITH CONSIDERATION OF UNCERTAIN EARTHQUAKE CHARACTERISTICS

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INTRODUCTION

This study proposes a methodology to conduct probabilistic tsunami hazard assessments (PTHA) with consideration of uncertain earthquake characteristics. The methodology adopts a stochastic framework to model the earthquake slip and location as a random field and a random vector, respectively. The stochastic framework consists of three stages: (1) the definition of consistent probability properties for uncertain earthquake characteristics, (2) the generation of samples and (3) the uncertainty propagation. To complete each stage we follow the method recently proposed in Sepúlveda et al. (2017). We illustrate our PTHA methodology by assessing the tsunami hazard in Kao Hsiung and Hong Kong, with consideration of earthquakes in the Manila Trench.

METHODS

The PTHA solves the return period of the exceedance of a tsunami measure h_{crit}, by the expression,

$$T_R(h_{crit}) = \frac{1}{\sum_{M_W} \sum_{x_i} \lambda^{EQ}_{M_W,x_i} P_h(h > h_{crit}|M_W, x_i)}.$$

where $\lambda^{EQ}_{M_W,x_i}$ is the average rate of earthquakes of magnitude M_W occurring in the seismogenic zone x_i, and $P_h(h > h_{crit}|M_W, x_i)$ is the probability to exceed the tsunami measure h_{crit} given a M_W earthquake in x_i, with uncertain slip distribution and location. While the average rates $\lambda^{EQ}_{M_W,x_i}$ are estimated from site specific data and employing classic methodologies (e.g. Gutenberg & Richter, 1944), the probability of exceedance $P_h(h > h_{crit}|M_W, x_i)$ is determined by using our method proposed in Sepúlveda et al. (2017). First, the method considers the generation of consistent earthquake samples by means of a Karhunen Loeve (KL) expansion and a translation process (Grigoriu, 2012). Unlike existing methods, we preserve the original probability properties of the slip distribution and location, by avoiding post sampling treatments. Our method is tested in the framework of the present study. Fig.1a shows a Mw 9 earthquake sample in the northern segment (A) of Manila Trench. Second, the method uses a Stochastic Reduced Order model (SROM) (Grigoriu, 2012) to propagate uncertainties to tsunami responses. Analyses are conducted to measure the performance of SROM as compared with classic Monte Carlo simulations.

APPLICATION CASE

The PTHA with consideration of uncertain earthquakes is applied in Hong Kong and Kao Hsiung, South China Sea (Fig.1b). We study tsunamigenic earthquakes in three segments of Manila Trench (Fig.1a). The earthquake recurrences are estimated by adopting the Gutenberg-Richter model (Gutenberg & Richter, 1944) and using calibration data from the USGS earthquake catalog. Fig.1c shows the return periods of maximum tsunami amplitudes. Tsunamis in Kao Hsiung have amplitudes smaller than 2 m for return periods of 1,000 years. Tsunamis in Hong Kong, on the other hand, have amplitudes smaller than 1 m for return periods of 1,000 years. According to these results, other hazards may be more relevant than tsunamis from Manila Trench. As an extension of our study, we also analyze the relevance of the uncertainties of the probability properties defining earthquake uncertainties.

a) b) c)

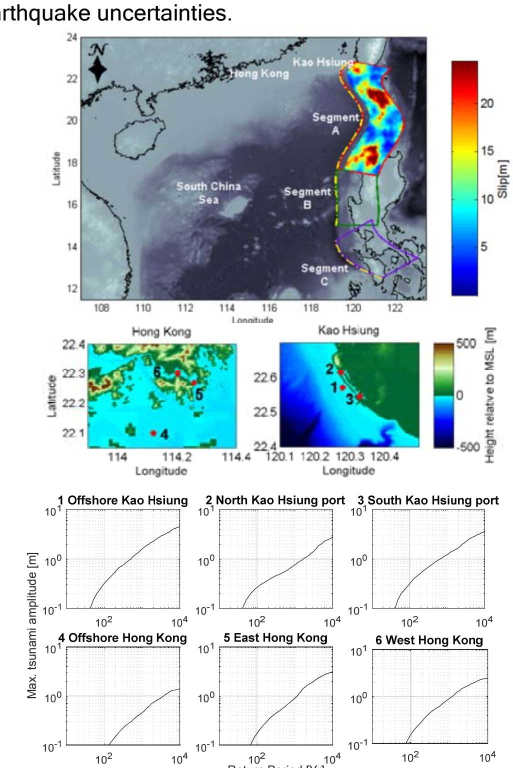

Figure 1 - a) Segmentation and earthquake sample, b) assessed locations, c) Return periods.

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