Japan Geoscience Union Meeting 2015
(May 24th - 28th at Makuhari, Chiba, Japan)

HDS27-P01 Room:Convention Hall Time:May 27 18:15-19:30

A proper method of Mercalli intensity-based evacuation from tsunami

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Three national organizations in Chile cooperate for tsunami early warning operations. National Seismology Center, University of Chile (CSN) operates real-time seismic analysis, Hydrographic and Oceanographic Service of the Chilean Navy (SHOA) evaluates the necessity of tsunami alerts or alarms by using CSN data, and National Office of Emergency of the Interior Ministry (ONEMI) is the only responsible in disseminating warnings and prompting residents to evacuate directly. For example, after the Iquique earthquake on April 1, 2014 (moment magnitude (M_w) 8.2 by CSN), a tsunami warning was issued for all coastlines of mainland Chile, because tsunami forecast areas have not been defined in Chile yet. Another example is the case of the earthquake on July 13, 2014 (at 4:56 p.m. local time; local magnitude (M) 5.6 by CSN); based on the MSI reports from the coastal cities, ONEMI issued precautionary evacuation of the coastal edges of Iquique, but it was soon canceled. It is found that this false alarm likely was caused by an inadequate standard procudure of Mercalli Scale Intensity (MSI)-based.

This paper shows that deriving an empirical relationship among MSI, epicentral distance (Δ), and M enable us to optimize the parameters of MSI-based precautionary evacuation, so that consistency between TFC-based warnings and MSI-based evacuation is assured.

The Japan Meteorological Agency (JMA) began operation of a quantitative tsunami warning system in 1999 (Kamigaichi, 2011); TFCs were used from 1977 to 1999. The version used from 1987 to 1999 has three curves relating Δ and M, which were used as the thresholds between four tsunami warning categories (major tsunami, tsunami, tsunami advisory, and no tsunami).

After compiling data of the earthquake catalog by CSN, tsunami observation data by SHOA, and some additional tsunami numerical calculation, we can apply TFC. Then, an empirical equation among MSI, M_w, and Δ (*e.g.*, MSI = a M_w - b $\log_{10}\Delta$ + c, where a, b, and c are constants) can be derived from MSI data collected by ONEMI and an earthquake catalog by CSN. When the range of precautionary evacuation by MSI-based method is defined "within r(M) km from any coast city in which MSI is s or higher", parameters r(M) and degree s can be determined almost equivalent to the curves of thresholds used in the TFC method. If M and MSI at a coastal area in concern are available, MSI-based method can be applied just after the earthquake. Duration of strong shake or MSI at remote cites can substitute M.

This indicates that optimization of parameters of the MSI-based method for consistency to the TFC method is promising approach to improve the reliability of early tsunami warnings in Chile. This methodology could also be applicable to other countries. By the way, the issue of real-time measurement and acquisition of objective MSI can be solved by tsunami alarm equipment (Katsumata *et al*, in the same session).

Acknowledgements: This work is partly supported by SATREPS program by JICA and JST.

Keywords: Chile, early tsunami warning, instrumental Mercalli Scale Intensity, precautionary evacuation, tsunami forecast chart