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Impact of the Great East Japan Earthquake on the Groundwater Levels in Tokyo

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1. Background

Whole Japanese Archipelago is in serious peril of severe earthquakes as witnessed in the past, because it is situated in the Circum-Pacific Seismic Zone, one of the major seismic zones caused by the plate tectonics. Many Southeast Asian countries as well as North and South American countries facing the Pacific Ocean are also located in the same seismic zone. Most of the megacities not only in Japan but also Southeast Asian countries are located on the alluvial plains where the ground is very soft and especially vulnerable for groundwater related disasters like landslides and liquefactions. Since groundwater is a crucial water resource for most of the cities around the world, it is very important as the first step to understand and evaluate the impact of a huge earthquake on the groundwater levels not only for developing disaster risk deduction countermeasures for land subsidence and liquefaction, but also for water resource risk management. However, so far, almost no such studies have been carried out mainly because no densely distributed groundwater level observations were available at a short time interval when a large earthquake occurred.

2. Facts

The Great East Japan Earthquake occurred at 14:46 JST on March 11, 2011, which was the strongest earthquake on record in Japan (the 4th biggest in the world) with a magnitude of 9.0 (Mw). More than 18,000 people were sacrificed or missing by the earthquake mostly by Tsunami generated by it. In Tokyo Metropolis, the hourly groundwater levels have been observed at 42 sites sine 1952 in order to mainly monitor the land subsidence situation. When the Great East Japan Earthquake occurred, large fluctuations of confined and unconfined groundwater levels were observed at 102 observation wells in Tokyo, although Tokyo is located around 400 km away from the epicenter. Interestingly, either abrupt rise or sharp drawdown of groundwater level was observed right after the earthquake for most of the wells, although some did not show a change. After abrupt rise or drawdown, the groundwater levels fluctuate during the month as one of the three typical patterns : keeping the rise or drawdown, recovering gradually to the original level, and over recovering more than the original level.

3. Objectives

Under the above background and facts, in this study, taking full advantage of the unique rare case data from the dense groundwater monitoring network in Tokyo, we investigate the fluctuation patterns of groundwater levels caused by the Great East Japan Earthquake.

4. Methods

The groundwater level data used in this study consist of one month time series in March 2011 with one-hour interval. The fluctuation patterns of groundwater levels caused by the earthquake were identified using Self-Organizing Maps (SOM). The SOM developed by Kohonen, can project high-dimensional, complex target data onto a two-dimensional regularly arranged map in proportion to the degree of properties. In general, the objective of the SOM application is to obtain useful and informative reference vectors. These vectors can be acquired after iterative updates through the training of the SOM. Design of the SOM structure, selection of a proper initialization method, and data transformation methods were carried out in the SOM application process. The reference vectors obtained from the SOM application were fine-tuned using cluster analysis methods.

5. Results and Conclusion

The fluctuation patterns of the groundwater level were classified into eight clusters. Either abrupt rise or sharp drawdown pattern was identified right after the earthquake for most of the wells. Abrupt rise pattern was typical for the unconfined groundwater levels. For the confined groundwater levels, sharp drawdown just after the earthquake occurred about 90% of the wells, which is inferred as the result of the pressure release derived from crustal expansion. Groundwater level rising just after the earthquake especially for unconfined groundwater may be caused by the phenomenon of liquefaction. The most common fluctuation pattern is the sharp drawdown followed by the rising tendency, which is mainly caused by decreased groundwater pumping rate due to the planned blackout by Tokyo Metropolitan Government.

The major lesson is that quite a few patterns could happen by a huge earthquake for the groundwater level change even in a small urban alluvial plain, which is never found before. In other words, we found for the first time (maybe in the world) the specific impacts on the fluctuation of groundwater levels in an urban alluvial plain.

Keywords: Earthquake, Self-Organizing Maps, groundwater level, fluctuation pattern, clustering