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Fluctuation patterns of groundwater levels in Tokyo caused by the Great East Japan Earthquake

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The hourly groundwater levels have been observed at 42 sites in Tokyo Metropolis since 1952. The Great East Japan Earthquake occurred at 14:46 JST on March 11, 2011. It was the strongest earthquake on record with a magnitude of 9.0 (Mw) and large fluctuations of unconfined and confined groundwater levels were observed at 102 observation wells in Tokyo, around 400 km away from the epicenter. Abrupt rises and sharp drawdowns of groundwater levels were observed right after the earthquake for most of the wells, although some did not show a change.

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 unconfined and confined groundwater levels caused by the Great East Japan Earthquake. 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. The optimal number of clusters was selected by the Davies-Bouldin index (DBI) using the k-means algorithm. Using the optimal number of cluster, a final fine-tuning cluster analysis was carried out by Ward's method.

As a result, the fluctuation patterns of the confined and unconfined groundwater level were classified into eight clusters. Abrupt rising patterns in unconfined groundwater level were identified as an independent cluster. For the confined groundwater levels, drawdown just after the earthquake occurred about 90% of the wells, which is caused by the pressure release derived from crustal expansion. The most common fluctuation pattern after the drawdown is an increasing tendency of groundwater level, which is mainly caused by decreasing groundwater pumping rate due to the blackout. Groundwater level rising just after the earthquake especially for unconfined groundwater was caused by the phenomenon of liquefaction. In addition, the spatial characteristics and the causes of these patterns were also investigated.

It is very important to understand this fluctuation correctly, not only for developing countermeasures for land subsidence and liquefaction, but also for water resource management.
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