Identification of fluctuation patterns of groundwater levels in Tokyo caused by the Great East Japan Earthquake using Self-Organizing Maps

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Abstract: 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 98 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.

Similarly, after the Great East Japan Earthquake, phenomena such as the rising or lowering of groundwater level, and increased amounts and rising temperatures of hot spring water were observed all over Japan (Itadera et al., 2011). However detailed analyses on the changes before and after the earthquake do not appear to have been published.

In this study, the fluctuation patterns of groundwater levels caused by the earthquake were identified using Self-Organizing Maps (SOM). The SOM, developed by Kohonen (2001), can project high-dimensional, complex target data onto a two-dimensional regularly arranged map in proportion to the degree of properties (Jin et al., 2011). 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. The SOM has also proven to be a powerful and effective data analysis tool in hydrological analyses.

As a result, the Great East japan Earthquake triggered the fluctuations of groundwater level in Tokyo. The fluctuation patterns of the confined and unconfined groundwater level could be classified into eight clusters. An increase after a short drawdown was a major pattern for the confined groundwater levels, whereas no change in pattern was observed for about 70% of the unconfined levels. The confined groundwater levels after the earthquake were classified into seven clusters. Abrupt rising patterns in unconfined groundwater level were classified into another cluster.

In addition, the spatial characteristics and the causes of these patterns were also investigated.

- The Great East Japan Earthquake triggered the fluctuations of groundwater level in Tokyo.
- For the confined groundwater level, drawdown just after the earthquake occurred about 90% of the wells, which is caused by the pressure release derived from crustal expansion.
- For the confined groundwater level, the most common fluctuation pattern is the drawdown followed by increasing tendency, which is mainly caused by decreasing groundwater pumping rate due to the blackout.
- Groundwater level rising just after the earthquake, it is appeared that abrupt rises of groundwater level just after the earthquake was caused by the similar of liquefaction.

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. Furthermore, evaluating the rapid fluctuation of groundwater level after the earthquake is effective to predict its influence on hydrologic cycle, and will be valuable for future research.

Keywords: *The Great East Japan Earthquake, Self-Organizing Maps, groundwater level, Tokyo*

1. INTRODUCTION

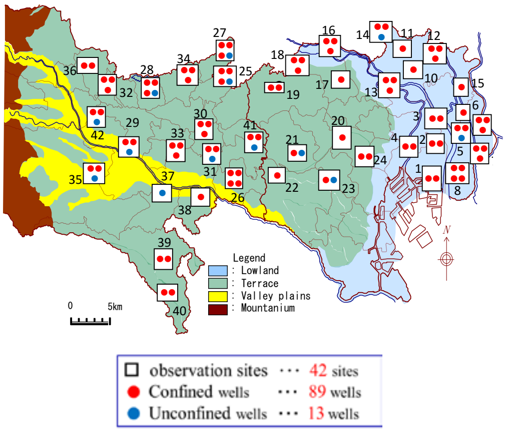
Groundwater observation wells have been bored in 42 sites in Tokyo Metropolis. Large fluctuations of groundwater levels were observed after the Great East Japan Earthquake at 102 observation wells in Tokyo.

2. STUDY AREA AND DATA USED

Fig. 1 shows the location of Tokyo, and Fig. 2 shows the locations and numbers of the groundwater level observation sites in the Tokyo Metropolitan area.

Using hourly observation data for the month of the Great East Japan Earthquake, the authors investigated the time-series behaviors of the groundwater level fluctuation and found that the earthquake caused changes. Some data are missing due to Tokyo Electric Power Co. Inc.'s planned blackouts. Therefore, input data are used from 98 wells (confined: 85, unconfined: 13) in 40 observation sites.

Figure 1. Tokyo location map



3. RESULTS AND DISCUSSION

In Fig. 3, the arrangement of the results of the pattern classification of eight clusters using SOM, as well as the number of observation wells in each node.

The decreasing trend patterns in confined groundwater levels after the earthquake were classified into seven clusters. The patterns showing no significant change were classified into three of these clusters. Abrupt rising patterns in unconfined groundwater level were classified into another cluster. For example, 80% of the patterns showing no significant change and sharp rising trends in unconfined observation wells are in Cluster 4 and Cluster 6.

The spatial characteristics and causes of these patterns were also investigated. The ground movements of Tokyo Metropolis which indicate movements of up to 407 mm to the east due to the earthquake. A decrease can be seen in the confined groundwater level following a swell in the crust due to the earthquake. Furthermore, a few unconfined observation wells show that the groundwater levels increased immediately following the earthquake which was caused by a phenomenon to liquefaction.

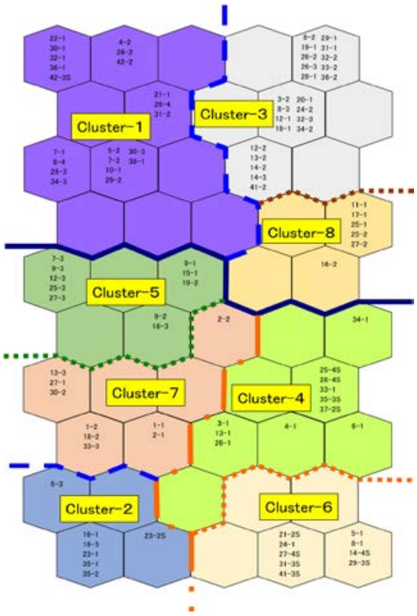


Figure 3. Pattern Classification using SOM and index of observation wells

4. CONCLUSION

The fluctuation patterns of the groundwater level could be classified into eight clusters. It became clear that the trend of groundwater level fluctuation could be shown more objectively and comprehensibility using SOM. Therefore, SOM analyses appears to be applicable in the field of groundwater observation.

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