Evaluation of coseismic groundwater changes caused by the 2003 Tokachi-oki earthquake

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Many hydrological changes were caused in and around Hokkaido, Japan by the 2003 Tokachi-oki earthquake (M8.0), which was a typical inter-plate thrust earthquake. We will mainly discuss the coseismic hydrological changes and compare them to coseismic volumetric strain changes calculated from the fault model in this presentation.

The 2003 Tokachi-oki earthquake occurred off the southeast coast of Hokkaido, Japan on 26 September 2003. The epicenter, depth and magnitude of the earthquake were 41.7617° N and 144.0783° E, 42km and M8.0, respectively. It is the latest gigantic inter-plate thrust earthquake in Japan. Unfortunately there was neither crustal deformation nor groundwater change related to the pre-slip or preseismic sliding in and around the focal region before the main shock. Based on the result, Nishimura et al.(2004) concluded that there was no pre-slip larger than M 6.0 in the focal region.

In Hokkaido, coseismic steps in groundwater level or discharge rate at thirty-two observation wells and at an undersea coal mine were detected (Fig.1). Depths of the screens of the thirty-two wells range 24 – 1488m and all those groundwaters are confined. Most of the changes in the groundwater levels or discharge rates can be explained as a poroelastic response to the earthquake-induced volumetric strain changes inferred from a fault model determined by dense static GPS observation (Geographical Survey Institute, 2003). In the same region there was also similar inter-plate thrust earthquake (M 8.2) in 1952, which was named the 1952 Tokachi-oki earthquake. There were also many coseismic changes in the groundwater level but they can not be so well explained by the volumetric strain changes as the case of the 2003 Tokachi-oki earthquake. This is because the responses of unconfined groundwater, which is not sensitive to volumetric strain changes, were included in them. Smaller coseismic persistent groundwater level changes associated with the 2003 Tokachi-oki earthquake were also detected at ten of the forty-two observation stations in Honshu, Japan, some of which are located about 1,000 km away from the epicenter (Sato et al., 2004). Seven of the ten changes can be also explained as a poroelastic response to the earthquake-induced volumetric strain changes.

These analyzed only the distribution of signs (increases and decreases) of the coseismic changes (Fig.1). Therefore we also checked amplitudes of the coseismic changes in Hokkaido. Fistly, we estimated strain sensitivity of the groundwater level from observed tidal groundwater level changes and theoretical tidal volumetric strain changes. Next we calculated coseismic groundwater level changes from the strain sensitivity and theoretical coseismic strain change from the fault model. Finally we compared them to the observed ones. Unfortunately such quantitative analysis can be carried out only at 7 wells in Hokkaido at present. At two of the 7 wells, the calculated coseismic groundwater level changes coincided well with the observed ones. At the two wells, the relationship between the groundwater-level changes and volumetric strain changes is also consistent with that in the past four large earthquakes (M > 7.5) in and around Hokkaido in 1993-1994. However the condition which is needed for such simple poro-elastic coseismic responses remains unknown.

References

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Fig.1

Distribution of the signs (solid circle or square: increase, open circle or square: decrease) of the coseismic changes in groundwater level or discharge rate related to the 2003 Tokachi-oki earthquake. A hatched square indicates the fault model of the 2003-Tokachi-oki earthquake by the Geographical Survey Institute (2003). Contours denote the coseismic volumetric strain changes at the depth of 500m calculated from the fault model. Positive and negative values denote extension and contraction, respectively. This figure is modified from Akita and Matsumoto (2004) and Sato et al.(2004).