Real-time monitoring of crustal deformation using large GPS networks - GEONET's potential as a natural hazards mitigation system

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Dense regional GPS geodetic networks have been successfully established to monitor crustal deformation and associated natural hazards. Procedures for early warning and rapid damage assessment, which are especially important in heavily populated areas, however, have, in most cases, not yet been fully incorporated into the data analysis of these networks.

The GPS Earth Observation Network System (GEONET) consists of an analysis center and an array of about 1200 GPS stations that cover the entire country with an average spacing of about 20 km. Most sites sample at 1 Hz and transmit the measurements in real time to the analysis center. Using GEONET data from the time of the Tokachi-Oki earthquake (September 26, 2003) and the Niigata-Chuetsu Earthquake (October 23, 2004) as test cases, this study focuses on a real-time applicable bootstrapping method to determine accurate absolute static and dynamic station motion. For this method we divide 523 stations from the northeastern part of Japan into 54 clusters; each cluster consists of 11 stations one of which is shared with the neighboring cluster. For each cluster, we calculate instantaneous baseline components for all stations of that cluster, using the Geodetics RTD software. Based on absolute (ITRF) coordinates of stations from clusters sufficiently remote from the epicenter we adjust the components of the shared stations and by means of the computed baselines then for all stations. This method thus yields absolute (ITRF) motion of stations within the epicentral region in real time.

Using instantaneous position solutions from the day before the earthquake and comparing them to daily positions, we quantify error propagation introduced by our method. We find that for the sequence of 54 clusters spanning about 1300 km, RMS errors approximately triple from the initial to the final cluster. Instantaneous coordinate accuracy is about 5 cm in the horizontal and 30 cm in the vertical, compared to the known ITRF coordinates of the stations. Theoretically this sequence can be extended to cover the entire Japanese archipelago keeping the above error rate. We conclude that coherent instantaneous (horizontal) position changes detected by a dense GPS network (like GEONET) could be used as part of an early warning system for mitigating natural hazards.