Rapid coseismic displacement detection/estimation algorithm and its application to the 2011 Tohoku-Oki earthquake

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Real-time crustal deformation monitoring is extremely important for achieving rapid understanding of actual earthquake scales, because the measured permanent displacement directly gives us the true earthquake size (seismic moment, Mw) information. We have developed an algorithm to detect/estimate static ground displacements due to earthquake faulting from real-time kinematic GPS time series. Our algorithm identifies permanent displacements by monitoring the difference of a short-term average to a long-term average of the GPS time series [1]. We applied the algorithm to data obtained in the 2011 off the Pacific coast of Tohoku earthquake (Mw 9.0) to test the possibility of coseismic displacement detections, and further, we inverted the obtained displacement fields for a fault model. Estimated a fault model with Mw 8.7, which is close to the actual Mw of 9.0. We also applied the algorithm to data of aftershocks of the 2011 M9 earthquake. We succeed in detecting the coseismic step caused by Iwate-oki earthquake (March 11, 15:08 (JST), Mw 7.4) and Ibaraki-oki earthquake (March 11, 15:15 (JST), Mw 7.7). For the Ibaraki-oki earthquake, we evaluated the coseismic fault model estimation. The inversion estimated a fault model with Mw 7.7, which is same with the actual one determined by the seismic data [e.g. 2].

The false detection of the permanent displacement should avoid for reliable warning system. Based on the long-term varied baselines and different reference sites posterior processing, we estimated the false detection rate reached ˜0.25% with 4-sigma confidential limit in single baseline. This false detection rate is inadequate to work for practical use in dense GPS network (many baselines) such as GEONET. We improved permanent displacement detection algorithm for reduction of the false detection rate. In the improved algorithm, the earthquake occurrence is defined as all neighboring GPS sites must be detected the displacement including oneself. We applied the improved algorithm to actual data set. The false detection rate clearly decreases with our improved algorithm, which is little more than zero. When we can use the several reference sites for the RTK-GPS data processing and compared with each reference site result, the false detection rate will become almost zero. The improved algorithm is also useful for small displacement detection because the threshold value is possible to cut down to 2 or 3-sigma confidential limit.

[1] Ohta et al., JGR, 2012 [2] Hirose et al., EPS, 2011