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Development of auto-detection technique for coseismic displacement using RTK-GPS

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Detection of coseismic crustal deformation by Real-time Kinematic GPS (RTK-GPS) has been studied in the recent years [e.g., Nishimura et al., 2009, Blewitt et al., 2009]. The advantage of GPS time-series for earthquake related studies is that a GPS can directly detect displacement relative to a reference site or a reference frame. In contrast, if we try to derive displacement from seismometer, we need some integral operation and correction for sensitivity. Therefore GPS is a powerful tool to detect tsunami earthquakes, which are difficult for common seismometers to reveal its characteristics because of sensitivity limitation for the slow displacement. As the limitation of RTK-GPS, we can use only broadcast orbits or predicted ephemeris for estimation of site coordinates. The accuracy of estimated time-series is strongly dependent on the quality of ephemeris especially for long baseline analysis. However in the case of large inter-plate earthquakes occurring around Japan trench, we need the long-baseline RTK-GPS analysis because the coseismic displacement spreads over a wide area. It is necessary to evaluate an accuracy of RTK-GPS time series for long baseline in short-term (from hours to days) and to develop an automatic detection procedure for coseismic displacement using coordinate time series.
First, we examined the dependence of standard deviation (SD) on baseline length using data from the GEONET sites (42 sites). We used RTKLIB ver.2.3.0 [Takasu, 2009] for the analysis with the IGS Ultra-Rapid orbits. As a result, slight dependence of SD on baseline length was obtained as approximately 2 cm for horizontal components, and 8 cm for vertical ones for baselines of about 2 00 km. In comparison with the observed maximum horizontal displacement of about 5 cm for the 2 005 Miyagi-oki earthquake (M 7.2) [Miura et al., 2006], enough accuracy was achieved to detect coseismic displacement for horizontal component. In order to validate the response to the coseismic step, we analyzed the same GEONET data used by Ohta et al. (2008) with broadcast ephemeris before and after the 2008 Iwate-Miyagi Nairiku earthquake. In comparison with the coseisimc displacement from the kinematic precise point positioning analysis [Ohta et al., 2008], horizontal displacement coincides within 1-2 cm, while vertical one shows large discrepancy up to about 8 cm.
Second, we developed an algorithm for automatic detection procedure for coseismic displacement. We referred to the methods using short-term average (STA) and long-term average (LTA) [e.g., Matsumura et al., 1988], which is used for automatic detection of P-, S-, and later phases of seismic waves. Our method compares the absolute value of the difference of LTA and STA with the SD of the site coordinate within the time window for LTA. We assume that permanent displacement is detected if the former exceeds the later multiplied by a constant empirically determined for each baseline component. We also combined two kinds of weighting factor; formal errors, and 1 for ambiguity-fixed solution or 0.5 for ambiguity-free solution at each epoch. This algorithm was applied to the post-processing using 1 Hz GPS data obtained for a baseline between Akita and Sendai. We confirmed that it is capable to detect slow displacement with a rate of 2.7 cm/3 min, which is superimposed to the actual data to simulate a tsunami earthquake. However, the detection capability became worse when S/N was law. So, noise reduction of time-series together with refinement of the algorithm is a key to the improvement of this method.

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References:
Nishimura et al., JPGU, Abstract, S150-002, 2009; Blewitt et al., J. Geod., 83:335-343, 2009; Miura et al., EPS, 58, 1567-1572, 2006; Ohta et al., EPS, 60, 1197-1201, 2008; Matsumura et al., Rep. NRCDP, 41, 44-64, 1988