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Proposal of Real-time Monitoring System of Strong Earthquake Motion and Tsunami based on GPS

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[1]GPS Solutions

We propose a real-time monitoring system for strong earthquake motion and tsunami based on GPS with real-time data streaming. The system makes it possible to monitor real-time crustal deformation and tsunamis with latency of a second. The GPS coordinate solutions help to improve the accuracy of fault model of strong earthquake and tsunami model which is needed to issue urgent and accurate warnings as soon as possible after the occurrence of strong earthquakes.

Fast and accurate estimation of the magnitude of the 2011 Tohoku earthquake was difficult because seismometers were saturated with strong motion of the seismic wave of the earthquake (Wright et al., 2011). High-rate (1Hz or more) GPS observations have been used as complementary observation to the seismometer for strong earthquakes (i.e., Miyazaki et al., 2004). In Japan, we have a dense GPS network called GEONET deployed by GSI, and it stream 1-Hz data in real-time. However, the current operational processing system focuses only on near real-time processing (latency of several hours or more) or post-processing.

We demonstrated that our GPS processing system based on precise point positioning (PPP) strategy with the RTNet software (developed by GPS Solutions and Hitachi Zosen) succeeded to detect seismic wave and deformation of crust with real-time in the event of the 2011 off the Pacific Coast of Tohoku Earthquake with real-time streaming data of GEONET (http://rtgps.com/rtnet_pppar_honshu hereafter rtgps site). In an additional experiment with post-processing of GEONET 1Hz data in real-time mode (satellite orbit and clock were estimated in real-time by the Veripos APEX system), we showed that we could detect propagation of seismic waves for the earthquake (see rtgps site).

The tsunami induced by the earthquake inflicted significant damage in the port cities along the coast of the Pacific ocean in Tohoku. We processed GPS buoy data at Hiratsuka-oki operated by Tokyo university with RTNet and APEX, and showed that coincide motion of buoy with the arrival of seismic waves and the subsequent tsunami wave signal (see rtgps site). The facts suggest that we can monitor tsunami signal with real-time with PPP strategy based on real-time satellite products and if real-time communication between GPS processing system and buoy were available.

Based on the facts above, we propose (1) real-time monitoring system of motion and deformation of crust, and (2) GPS buoy network in the off-shore and corresponding real-time monitoring system. Both systems would mitigate disaster due to earthquake and tsunami for future strong earthquakes.

(1) There are multiple services which provide real-time satellite orbit and clock based on global GPS (GNSS) networks. Such products are superior to corrections from regional networks because multiple reference station in the regional network could move or fail during strong earthquakes. Currently, an accuracy of a few cm in the horizontal and better than 10 cm in the vertical component, is achievable with the products. The system is also helpful to monitor ongoing slow slip.

PPP-AR (PPP with ambiguity resolution, Mervart et al., 2008) can provide more accurate coordinate solutions. For this application we propose to process multiple networks of reference stations to avoid offset due to movement of coordinate of the reference stations during earthquakes. We plan to demonstrate the proposed system in rtgps site in the near future.

(2) We need to deploy tsunami GPS buoy system in more off-shore of about 100-200km (currently 20 km) from the coast to allow for more time for evacuation. We propose that the GPS buoy system is used as multi-purpose observing system during periods without tsunami. One application is water vapor monitoring based on tropospheric delay processed in GPS for weather forecast. Another one is GPS wave observation for fisheries and ocean engineering. The systems could be deployed for all nations which need such monitoring systems.

Keywords: GPS, Real-time, Earthquake, Tsunami, PPP, Monitoring