Paper Number: 1616

Using near real-time single frequency GPS network monitor deep seated landslides in active mountain belts

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Deep seated landslides or deep-seated gravitational slope deformations (DSGSD) are voluminous, short travelling and slow moving failures that generally occur in mountainous environment with great topographic relief. In sub-tropic environment such as Taiwan, great topography with heavy rainfalls during summer, deep-seated landslides are sometimes transformed into fast movement catastrophic landslide. The catastrophic Hsiaolin landslide that caused 450 casualties induced by 2009 Typhoon Morakot is one of the famous examples that transformed from DSGSD in the island of Taiwan. After the Hsiaolin landslide, over 3000 sites of DSGSD have been identified from airborne LiDAR derived 1 m resolution Digital Elevation Model (DEM) according to the slow movement landslide topography. Therefore, how to develop an economics and efficient approach to monitor the activity of these deep-seated landslides becomes an urgent task for the landslide mitigation plane of the island.

In this study, we demonstrate that a near real-time surface displacement monitoring system can be an economic and valid approach to monitor the activity of deep-seated landslides. The system contains 6 to 8 single frequency GPS receivers and a rainfall gauge. In the system all the received data is transferred to a data process centre via 3G wireless networks. The data are processed into standard receiver independent exchange format (RINEX) with defined epoch length for the following post-positioning processes. Broadcast or precise ephemerides are retrieved from the International GNSS Service (IGS) web site. The Bernese GNSS Software developed by the Astronomical Institute of the University of Bern (AIUB) is utilized for the high-precision multi-GNSS data processing. After that, the positioning results will be stored in an on-line database and displayed via a webpage. An agent program built for this system, which will automatically operate over each selected epoch, manages the whole workflow. The positioning result via Internet provides real time displacement information of all sites for further applications, such as activity monitoring and early-warning evaluation.

The current operating procedures require huge observation data to estimate proper error model parameters for the carrier phase positioning. Final positioning accuracy will increase with more redundant observation data, which resulting a longer period of signal collection. Higher sampling rate (depends on the capability of hardware) of the receiver and the utilization of multi-constellation Global Navigation Satellite Systems (GNSSs, use all four satellite systems: BeiDou, Galileo, GLONASS and GPS) will significantly improve the system. Displacement data of stable sites shows a deviation of 5-mm in horizontal and 15-mm in vertical with 1-Hour epoch from 1-Hz rate receivers in the field. The accuracy can be raised to 1-mm in horizontal and 3-mm in vertical with 1-Day epoch under the same conditions.

After installation of the monitoring system at 20 deep-seated landslides, there is no catastrophic failure has been recorded. However, during the heavy on the summer, several mm to tens of cm displacement are commonly observed at some sites. Additionally, both stick slip and stable sliding behaviour along the sliding plane can be observed in the recording data.