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Long-Term Subcentimeter-Accuracy Landslide Monitoring Using a Cost-Effective Global Navigation Satellite System Rover Network: Case Study

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Abstract : Precise landslide monitoring with differential global navigation satellite system (GNSS) is well known, but technical or economic reasons limit its application by geotechnical companies. This study demonstrates the reliability and the usefulness of Geomon (Infrasurvey Sàrl, Switzerland), a stand-alone and cost-effective rover network. The system permits deploying up to 15 rovers, plus one reference station for differential GNSS. A dedicated radio communication links all the modules to a base station, where an embedded computer automatically provides all the relative positions (L1 phase, open-source RTKLib software) and populates an Internet server. Each measure also contains information from an internal inclinometer, battery level, and position quality indices. Contrary to standard GNSS survey systems, which suffer from a limited number of beacons that must be placed in areas with good GSM signal, Geomon offers greater flexibility and permits a real overview of the whole landslide with good spatial resolution. Each module is powered with solar panels, ensuring autonomous long-term recordings. In this study, we have tested the system on several sites in the Swiss mountains, setting up to 7 rovers per site, for an 18 month-long survey. The aim was to assess the robustness and the accuracy of the system in different environmental conditions. In one case, we ran forced blind tests (vertical movements of a given amplitude) and compared various session parameters (duration from 10 to 90 minutes). Then the other cases were a survey of real landslides sites using fixed optimized parameters. Sub centimetric-accuracy with few outliers was obtained using the best parameters (session duration of 60 minutes, baseline 1 km or less), with the noise level on the horizontal component half that of the vertical one. The performance (percent of aborting solutions, outliers) was reduced with sessions shorter than 30 minutes. The environment also had a strong influence on the percent of aborting solutions (ambiguity search problem), due to multiple reflections or satellites obstructed by trees and mountains. The length of the baseline (distance reference-rover, single baseline processing) reduced the accuracy above 1 km but had no significant effect below this limit. In critical weather conditions, the system's robustness was limited: snow, avalanche, and frost-covered some rovers, including the antenna and vertically oriented solar panels, leading to data interruption; and strong wind damaged a reference station. The possibility of changing the sessions' parameters remotely was very useful. In conclusion, the rover network tested provided the foreseen sub-centimetric-accuracy while providing a dense spatial resolution landslide survey. The ease of implementation and the fully automatic long-term survey were timesaving. Performance strongly depends on surrounding conditions, but short pre-measures should allow moving a rover to a better final placement. The system offers a promising hazard mitigation technique. Improvements could include data post-processing for alerts and automatic modification of the duration and numbers of sessions based on battery level and rover displacement velocity.

Keywords : GNSS, GSM, landslide, long-term, network, solar, spatial resolution, sub-centimeter.
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