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Corner reflector SAR interferometry as an element of a landslide early warning system

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The development of efficient and cost-effective landslide monitoring techniques is the central aim of the alpEWAS research project (www.alpewas.de). Within the scope of the project a terrestrial geosensor network on a landslide site in the Bavarian Alps has been set up, consisting of low cost GNSS with subcentimeter precision, time domain reflectometry (TDR) and video tacheometry (VTPS). To increase the spatial sampling, 16 low-cost Radar Corner Reflectors (CRs) were installed on the site in 2011. The CRs are to reflect radar signals back to the TerraSAR-X radar satellite, allowing for precise displacement measurements.
The subject of this study is the application of the CR SAR Interferometry (CRInSAR) technique, and the integration of the derived motion field into an early warning system for landslide monitoring based on terrestrial measurements. An accurate validation data set is realized independently of the monitoring network using millimeter precision GNSS and tacheometer measurements.

The 12 CRs from Astrium Geo-Information Services employed over the test site were specifically designed for TerraSAR-X satellite passes. They are made of concrete with integrated metal plates weighing about 80 to 100 kg. They are of triangular trihedral shape with minimal dimensions to obtain a Radar Cross Section 100 times stronger than that of the surrounding area. The concrete guarantees stability against harsh weather conditions, and robustness with respect to vandalism or theft. In addition, the Technical University of Munich (TUM) and the German Aerospace Center (DLR) installed another four CRs made entirely out of aluminum, with the TUM reflectors being of similar minimum size than the Astrium reflectors. Three CRs were placed on assumed stable ground outside the slope area and shall act as reference reflectors.

Since the installation date of most CRs (25/08/2011), TerraSAR-X HighResolution SpotLight data have been repeatedly acquired from ascending orbit over the test site with an incidence angle of 25.73°. The ascending orbit was chosen for the satellite to look on the backslope of the mountain, minimizing foreshortening effects. The datasets have a spatial resolution of about one meter and VV polarization, and have been processed with precise Scientific Orbits.

In a first step, the sub-pixel position of the CR, as well as its intensity are characterized. The phase values for each image are then extracted for each CR and a differential interferometric phase with respect to a single master is calculated using a Digital Elevation Model. These phases are then unwrapped in the temporal domain and transformed to displacements. The redundant displacement results stemming from the use of three different reference reflectors are adjusted and an error is estimated.
To integrate the result into the early warning system, datum corrections are necessary, as the InSAR displacement measurement is relative to the reference point(s) and reference time. In addition, the line-of-sight measurement is transformed with respect to coordinate system of the alpEWAS measurement system. Both the InSAR and terrestrial landslide movement measurements are then cross-checked with the validation high precision GNSS and tacheometer measurements.