Satellite and terrestrial radar interferometry and applications to the monitoring of the deformation of glaciers, rock glaciers and landslides

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Abstract

Repeat-pass Interferometric Synthetic Aperture Radar (InSAR) is a powerful technique for mapping land surface deformation from space at fine spatial resolution over large areas. Displacement is derived from the measurement of the phase difference of the signals acquired by two satellite SAR acquisitions after compensation of the topographic effects with use of an external Digital Elevation Model. Major advantages of this technique are the wide area coverage, the high sensitivity to surface displacement (centimetres to millimetres), and the availability since 1991 of a large archive of satellite acquisitions with repeat-cycles on the order of one month. Despite limitations due to vegetation cover, the special SAR viewing geometry, atmospheric artefacts, and snow cover, short-baseline interferograms are successfully applied in alpine areas for the mapping and monitoring of glaciers, rockglaciers and landslides.
The application of InSAR is limited by temporal and geometric decorrelation and inhomogeneities in the tropospheric path delay. In Persistent Scatterer Interferometry (PSI) differential SAR interferometry is applied only on selected pixels that do exhibit a point-target scattering behavior and are persistent over an extended observation time period. Through the use of many SAR scenes, errors resulting from atmospheric artefacts are reduced and a higher accuracy can be achieved. Over urban areas with numerous man-made structures or in regions where rocks or single infrastructures (e.g. houses, power line masts) scattered outside cities and villages are visible, it is therefore possible to estimate the progressive deformation of the terrain at millimetre accuracy. In mountainous regions the number of persistent scatterers is limited by the sparse urbanization, the large forest cover, and areas of shadow and layover. A significant improvement was possible in recent years with the use of the new generation of satellite SAR sensors characterized by a higher spatial resolution and a shorter revisiting time.

Besides satellite sensors, terrestrial instruments are in use for a variety of geoscientific applications. A terrestrial radar interferometer (TRI) compliments satellite SAR data in time and space, allowing the measurement of additional displacement vectors and velocity classes. In contrast to the satellite based method a TRI is more flexible with respect to the choice of the instrument position, the area covered, and the time interval between observations. The GAMMA Portable Radar Interferometer (GPRI) was developed and manufactured in-house by GAMMA Remote Sensing. The GPRI can operate over distances up to about 10 km and

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scans can be taken in less than one minute to allow for near real-time monitoring. On the other hand, it is also suited to map and monitor slower movements by coming back to the same site after days, weeks or months. The basic principles used to determine displacements with TRI are the same as for satellite InSAR and similarly there is the potential to measure displacements with millimetre accuracy.

In this contribution we review the radar-interferometric monitoring techniques applied to detect and quantify the surface displacement of glaciers, rock glaciers and landslides and show selected results obtained with the various satellite and terrestrial sensors of different spatial resolution and acquisition time intervals to highlight the potential of a synergistic use of the two techniques.