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Slope deformations in high-mountain regions as observed by InSAR: Examples from the Cordillera Blanca, Peru

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Steep topography, the world's highest concentration of tropical glaciers, numerous glacial lakes and strong seismic activity combined with a densely populated valley bottom in the Rio Santa basin characterize the Cordillera Blanca in Peru. Besides glacier-related processes, a variety of landslide types and processes is present outside the glaciated areas, favoured by the steep terrain, geological conditions, sparse vegetation, intense precipitation, and strong seismicity. This combination of high hazard potentials and vulnerabilities results in a long list of natural disasters.

Information on surface displacements is very valuable for early detection of emerging hazard potentials and their assessment. Interferometric processing of SAR data (InSAR) provides the possibility to remotely detect different types of surface displacement processes, also in remote locations where no other monitoring data are available. This contribution, developed under the ESA-funded S:GLA:MO project (sglamo.gamma-rs.ch), shows the potential of InSAR products for hazard assessments and glaciological investigations in high-mountain regions. We present a selection of different surface displacements as observed in the Cordillera Blanca based on InSAR data:

- a landslide zone near the Rampac Grande village, where in 2009 a landslide caused casualties and property loss;
- a landslide at the entry of the Santa Cruz Valley, northern Cordillera Blanca, where the displacement history could be reconstructed over five years;
- surface displacements at the interior moraine slopes surrounding Laguna Palcacocha, a major glacier lake above the city of Huaraz, which are compared to and complemented by geophysical investigations in the field;
- surface displacements at the moraine damming Laguna Safuna Alta, a glacier lake in the northern part of the Cordillera Blanca;
- glacier velocities across the entire Cordillera Blanca, revealing ice flow velocities of more than 200 m yr-1 at certain locations at the end of the dry period.

Data archives of spaceborne SAR sensors such as ERS-1/2, ENVISAT, ALOS PALSAR-1/2, TerraSAR-X, Radarsat-2 and Sentinel-1 provide information reaching back to the 1990ies, allowing for detection and analysis of both current and past processes. Environmental conditions in the Peruvian Andes are particularly favourable for InSAR analyses, with an extended period of mostly cloud-free conditions during austral winter (dry season), sparse vegetation cover and only very limited snow coverage, factors that in other regions often limit the potential of this technology.

This contribution shows the potential of InSAR products, providing unique information on slope deformations and surface displacements as identified as an important information source for integrative hazard assessments and glaciological investigations in high-mountain regions. In particular in combination with field investigations this technology is very powerful, not only for hazard research, but for other types of applications related to surface displacements and terrain deformations. In regions like the Cordillera Blanca, where a variety of potentially hazardous and interacting processes are present, often under conditions beyond historical evidences, such data products provide invaluable information for hazard assessments, early detection of hazard potentials, and a basis for prioritization and decision-making by the authorities.