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An open-source Python package for DEM generation and landslide volume estimation based on Sentinel-1 imagery

Lorena Abad[1], Daniel Hölbling[1], Zahra Dabiri[1], and Benjamin Robson[2]
[1]University of Salzburg, Department of Geoinformatics - Z_GIS, Salzburg, Austria (lorena.abad@plus.ac.at)
[2]University of Bergen, Department of Earth Science, Bergen, Norway

Landslide assessments require timely, accurate and comprehensive information, where Earth observation (EO) data such as optical and radar satellite imagery has played an important role. Volume estimates are important to understand landslide characteristics and (post-failure) behaviour. Pre- and post-event digital elevation model (DEM) differencing is a suitable method to estimate landslide volumes remotely, leveraging EO techniques. However, high costs for commercial DEM products, limited temporal and spatial coverage and resolution, or insufficient accuracy hamper the potential of this method. Sentinel-1 synthetic aperture radar (SAR) data from the European Union's Earth observation programme Copernicus opens the opportunity to leverage free EO data to generate multi-temporal topographic datasets.

With the project *SliDEM* (Assessing the suitability of DEMs derived from Sentinel-1 for landslide volume estimation) we explore the potential of Sentinel-1 for the generation of DEMs for landslide assessment. Therefore, we develop a semi-automated and transferable workflow available through an open-source Python package. The package consists of different modules to 1) query Sentinel-1 image pairs that match a given geographical and temporal extent, and based on perpendicular and temporal baseline thresholds; 2) download and archive only suitable Sentinel-1 image pairs; 3) produce DEMs using interferometric SAR (InSAR) techniques available in the open-source Sentinel Application Platform (SNAP), as well as performing necessary post-processing such as terrain correction and co-registration; 4) perform DEM differencing of pre- and post-event DEMs to quantify landslide volumes; and 5) assess the accuracy and validate the DEMs and volume estimates against reference data.

We evaluate and validate our workflow in terms of reliability, performance, reproducibility, and transferability over several major landslides in Austria and Norway. We distribute our work within a Docker container, which allows the usage of the *SliDEM* python package along with all its software dependencies in a structured and convenient way, reducing usability problems related to software versioning. The *SliDEM* workflow represents an important contribution to the field of natural hazard research by developing an open-source, low-cost, transferable, and semi-

automated method for DEM generation and landslide volume estimation.