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Quantification of glacial and ground surface velocities from repeat terrestrial LiDAR scans

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Repeat terrestrial LiDAR scans of moving surfaces (e.g. around faults, glaciers, mass movements, etc.) collected at different times offer the opportunity to quantify surface velocities in high resolution. This study presents a new approach for quantifying surface velocities from remote sensing data. Emphasis is placed on the interpretation of terrestrial LiDAR grid point cloud (GPC) data, but the technique presented is also applicable to other (RASTER) remote sensing datasets. The method used consists of investigating two or more temporally variable GPCs referred as a raw and displaced/deformed scans. A user-defined grid is defined on the raw and deformed scans and the center point of each grid is identified. A search window size is determined for comparison between the two scans. Elevations in both scans are then converted to a reference elevation and a normalized cross correlation is applied between the images for pattern recognition. The focal points of the raw image and correlated deformed location are used to prepare an affine transformation for that grid. This procedure is applied on all the grids to prepare the spatial distribution of the affine transformation. Finally, the affine transformation is extended to calculate the horizontal components of surface deformation. These components are used to prepare the spatial distribution of the displacement distance and angle between each grid on each scan. The routine was applied to a series of synthetic (test) datasets and to repeat LiDAR scans (ILRIS-LR) of the Rhone glacier, Switzerland collected in August 2011. Results from the synthetic tests indicate the approach provides a robust reconstruction of spatially non-uniform velocity fields on scans with different surface characteristics. For the Rhone glacier data both temporal and spatial variations in surface velocities were recovered across a large portion of the glacier at centimeter scale. Temporal variations in the glacier surface velocity were resolved from scans collected multiple times a day over the course of a week.