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The potential of UAV technology for monitoring rock glacier kinematics: Examples from the Western Swiss Alps.

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Active rock glaciers are unique geomorphological landforms resulting from the creep of mountain permafrost, with superficial rates of movement ranging from few cm a^{-1} to few m a^{-1}. They correspond to aggregations of debris and ice with tongue-shape or lobate form. Regular monitoring of active rock glaciers can be achieved by different means, such as repeated terrestrial geodetic surveys, laser scanning, time-lapse cameras or UAV flights. Repeated UAV surveys can bring new insights about the rock glacier surface changes and current destabilisation phases. Due to the very-high spatial resolution obtained by UAV systems, small rock sizes (i.e. tens of cm) can be tracked, and further detailed analysis can be exploited, such as the rotational movements of rock groups and compression patterns. However, studies that combine an assessment of the quality and accuracy based on concomitant in situ measurements remain unusual. In this case, the validation of remote sensing measurements remains troublesome due to logistical constrains caused by steep slopes over unstable terrain and high surface velocities. To overcome this, we provide the first results after two years of terrestrial geodetic and UAV surveys from slow and fast rock glaciers in the Valais Alps, Switzerland. We focus on the UAV survey design and the Structure from Motion (SfM) workflow used to process and obtain very-high resolution datasets, such as cloud points, Digital Elevation Models (DEM) and orthophotomosaics. Common processing practices, including imagery orthorectification, co-registration and feature tracking algorithms are performed to derive rock glacier surface displacements, which are extensively validated using ground information from terrestrial geodetic surveys. Preliminary, comparisons between coincident terrestrial geodetic surveys and UAV-derived velocities revealed a good agreement, underlining the potential to study rock glacier kinematics completely from UAV surveys.