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Kinematic Insights from Optical Feature Tracking on Rock Glaciers in the Kazakh Tien Shan: Understanding Sub-Landform Scale Patterns of Rock Glacier Flow

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Rock glaciers exhibit complex and heterogenous dynamics, which are expressed in their pattern of surface flow; these surface kinematics provide insights into the processes taking place within the rock glacier system. Remote sensing methods using optical and radar imagery to detect movement are well established and have been widely applied at different spatial and temporal scales. However, the sub-landform scale is often overlooked despite considerable flow heterogeneity observed within individual rock glaciers. Feature tracking methods are suited to investigating kinematic detail as they are able to measure vector direction as well as magnitude, allowing them to identify complex and non-linear patterns of flow. This compliments widely used SAR interferometric methods which accurately detect slow displacements but don't account for flow direction.

Here we show how optical imagery can be used to investigate rock glacier kinematics at the sub-landform scale. The study focuses on 18 rock glaciers in the Kazakh Tien Shan. This region hosts numerous large, complex rock glacier landforms, many of which are part of larger systems composed of small, retreating normal glaciers, moraines and downwasting debris zones. These rock glaciers are an important and interconnected component of the deglaciating environment and are likely to be hydrologically significant stores of ice in the Tien Shan region.

Rock glacier velocities have been measured using an intensity based cross correlation algorithm implemented in Python, with adaptable pre and post processing steps that enable the best results to be achieved on different types of optical imagery. The results from Pleiades, Planet and Sentinel image pairs taken from 2016 onwards are compared to investigate how source image resolution and sensor type impact the spatial patterns detected. High resolution Pleiades imagery provides the most detailed results, however, lower resolution Sentinel and Planet imagery is also able to detect sub-landform scale variations in flow. Over a 7-year time interval Sentinel imagery identifies flow velocities comparable to those derived from high-resolution imagery across the 18 rock glaciers investigated. Planet imagery performed the worst of the three data sources, highlighting the importance of image quality as well as resolution for intensity-based image matching

methods. There is considerable variability in the mean, maximum and range of velocities detected between the landforms investigated. Rock glacier flow is heterogenous at both intra and inter landform scales, this is related to local topography but is also likely to be dependent on rock glacier internal structure and the distribution of material input.