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Non-linear flow law of rockglacier creep determined from geomorphological observations: A case study from the Murtèl rockglacier (Engadin, SE Switzerland)

Marcel Frehner (1), Dominik Amschwand (1), and Isabelle Gärtner-Roer (2)

(1) Geological Institute, ETH Zurich, Switzerland (marcel.frehner@erdw.ethz.ch), (2) Department of Geography, University of Zurich, Switzerland

Rockglaciers consist of unconsolidated rock fragments (silt/sand–rock boulders) with interstitial ice; hence their creep behavior (i.e., rheology) may deviate from the simple and well-known flow-laws for pure ice. Here we constrain the non-linear viscous flow law that governs rockglacier creep based on geomorphological observations. We use the Murtèl rockglacier (upper Engadin valley, SE Switzerland) as a case study, for which high-resolution digital elevation models (DEM), time-lapse borehole deformation data, and geophysical soundings exist that reveal the exterior and interior architecture and dynamics of the landform.

Rockglaciers often feature a prominent furrow-and-ridge topography. For the Murtèl rockglacier, Frehner et al. (2015) reproduced the wavelength, amplitude, and distribution of the furrow-and-ridge morphology using a linear viscous (Newtonian) flow model. Arenson et al. (2002) presented borehole deformation data, which highlight the basal shear zone at about 30 m depth and a curved deformation profile above the shear zone. Similarly, the furrow-and-ridge morphology also exhibits a curved geometry in map view. Hence, the surface morphology and the borehole deformation data together describe a curved 3D geometry, which is close to, but not quite parabolic.

We use a high-resolution DEM to quantify the curved geometry of the Murtèl furrow-and-ridge morphology. We then calculate theoretical 3D flow geometries using different non-linear viscous flow laws. By comparing them to the measured curved 3D geometry (i.e., both surface morphology and borehole deformation data), we can determine the most adequate flow-law that fits the natural data best. Linear viscous models result in perfectly parabolic flow geometries; non-linear creep leads to localized deformation at the sides and bottom of the rockglacier while the deformation in the interior and top are less intense. In other words, non-linear creep results in non-parabolic flow geometries.

Both the linear (power-law exponent, n=1) and strongly non-linear models (n=10) do not match the measured data well. However, the moderately non-linear models (n=2–3) match the data quite well indicating that the creep of the Murtèl rockglacier is governed by a moderately non-linear viscous flow law with a power-law exponent close to the one of pure ice.

Our results are crucial for improving existing numerical models of rockglacier flow that currently use simplified (i.e., linear viscous) flow-laws.

References:

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