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Response of rockglacier creep to surface temperature variations: models, observations, consequences

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Beside its thermal characteristics creeping mountain permafrost is substantially defined by its kinematics. Due to the - in general considerable - ice content of such rockglaciers, their dynamics respond sensitive to climate forcing. Questions arise how rockglaciers react to the current or recent climatic changes, and what the further consequences of such reactions could be. As one step in this contribution, we compile globally observed rockglacier speeds as a function of mean annual air temperature. In fact, air temperature can be statistically identified as a major factor determining rockglacier speed. The remaining scatter clearly points to other influences such as slope, solids content, thickness or liquid water. In a next step, we summarize current monitoring results on rockglacier speed. A surprisingly large number of Alpine rockglaciers show an increase in speed since recent years. This large number points to other than solely local influences, but rather to some regional-scale impact such as the observed increase in air temperatures. Using an one-dimensional thermo-mechanically coupled numerical model we simulate the potential response of rockglacier creep to a change in surface temperature. It turns out that variations in temperature could indeed affect rockglacier creep in the currently observed order of magnitude. Other influences, however, clearly act as well. Among these, the occurrence and complex influence of liquid water in the frozen debris might be the most important for permafrost close to 0 $^{\circ}$C, though difficult to model. Our monitoring and modelling work clearly shows that rockglaciers close to 0 deg C ground temperature creep in general faster than colder ones. Furthermore, our findings suggest that the creep of permafrost close to 0 deg C is more sensitive to thermal forcing than colder one. From this, we conclude that increasing rockglacier temperatures may lead to a marked, but both spatially and temporally highly variable speed-up, before a significant loss of ice content by melt-out is able to reduce the deformation rate of the frozen mass towards its entire deactivation. By means of three scenarios, we finally exemplify the possible consequences of an increase in rockglacier temperature and subsequent acceleration: (1) increasing sensitivity of rockglacier creep to seasonal influences, (2) activation of so far stable frozen debris slopes, and (3) landslides from rockglaciers.