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Dynamics of Alpine rock glaciers in the context of global warming

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Several Alpine rock glaciers exhibit increasing creep velocities since about 1990. The question arises how to explain this phenomenon within the context of global warming. Our study is focused on three active rock glaciers in the Eastern Alps, where information on the dynamics is derived from the comparison of maps and aerial photographs and GPS measurements. The internal structure of these rock glaciers was explored by geophysical methods (GPR, refraction seismology and gravimetry). Comprehensive geological, geomorphological, and hydrological studies were also carried out. The three studied examples are Reichenkar (Stubai Alps), Ölgrube, and Kaiserberg (Ötztal Alps) rock glaciers. The source areas of these rock glaciers are situated at altitudes of 2700 to 2800 m a.s.l. The fronts of the tongues extend down to elevations of 2300 - 2600 m.a.s.l. Their total areas vary between 0,22- 0,27 km^2, the maximum thickness measures 30 - 50 m. The creep velocities of the Ölgrube and Reichenkar rock glaciers increased during the last decades from 1,0 - 1,8 m/year to 1,5 - 3,1 m/year, whereas the creep velocity of Kaiserberg rock glacier did not change significantly.

Models of the internal structures of the rock glaciers were derived from integrated geophysical studies (thickness and density of the boulder layer, thickness and boulder-content of the ice core). On the basis of these geophysical models and the rheology of ice the observed creep velocities were successfully modelled. During the last decades the thickness and inclination, and therefore the internal states of stress of the rock glaciers did not change significantly. Therefore, the increase in creep velocity is assumed be a consequence of either higher internal deformation due to higher temperature, or of higher basal sliding due to higher pore water pressure. Support for the theory that higher internal deformation of the ice core due to higher temperatures

caused the velocity increase comes from the observation that the P-wave velocities of the accelerating rock glaciers (Reichenkar, ∼3300 m/s; Ölgrube, ∼3600m/s) are below the P-wave velocity of pure ice (3750 m/s), and the P-wave velocity of the stationary rock glacier (Kaiserberg, ∼3900m/s) is above. A P-wave velocity below the velocity of pure ice indicates reduction of the solid (frozen) contacts between ice and boulders within the ice core and formation of a water film along these contacts.