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Induced stress changes and associated fracture development as a result of deglaciation on the Zugspitzplatt, SE Germany

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Bedrock stresses in alpine regions result from the combined effects of exhumation, tectonics, topography, inelastic strain (e.g. fault displacement and fracture formation), and external loading. Gravitational loading by glacial ice can significantly affect near-surface stress magnitudes, although the nature of this effect and it's impact on stress distributions and bedrock fracturing is strongly dependent on the stress history of the bedrock landscape. We assess the effects of recent (post-Little Ice Age , ∼1850 AD) and future deglaciation on bedrock stresses in the region of the Zugspitzplatt, a glaciated plateau surrounded by 1500 m high bedrock walls in SE Germany. We address this by undertaking a 2-D elasto-plastic finite element method analysis of stress changes and fracture propagation due to repeated glacial – interglacial cycles. Our model is initialised with upper crustal stresses in equilibrium with bedrock strength and regional tectonics, and we then simulate two cycles of major Pleistocene glaciation and deglaciation in order to dissipate stress concentrations and incorporate path-dependent effects of glacial loading on the landscape. We then simulate a final glacial cycle, and remove 1 m of bedrock to approximate glacial erosion across the topography. Finally, ice levels are reduced in accordance with known late-glacial and recent ice retreat, allowing us to compare relative stress changes and predicted patterns of fracture propagation to observed fracture distributions on the Zugspitzplatt.
Model results compare favourably to observed fracture patterns, and indicate the plateau is likely to be undergoing N-S extension as a result of deglaciation, with a strong reduction of horizontal stress magnitudes beneath the present-day Schneeferner glacier. As each glacial cycle has a similar effect on the plateau, it is likely that surficial stresses are slightly tensile, and each cycle of deglaciation produces additional sub-vertical tensile fractures, which are then exploited by the karst groundwater system. Here we show how stress histories and brittle deformation in near-surface stress models can provide a better understanding of long-term rock slope evolution and failure as well as karst co-evolution in Alpine Environments.