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Patterns of reversible ground surface deformations in crystalline rock slopes

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Fractured rock-masses deform in response to changes in pore pressure. In alpine catchments, groundwater flow dynamics is generally dominated by strong recharge signal from snowmelt infiltration in spring / early summer and in early winter, and punctuated by large rainstorms in snow-free periods. In crystalline rock slopes, infiltration occurs along discontinuities, such as faults and joints. Under constant normal stress joint apertures increase non-linearly during pore pressure increase, increasing the volume of saturated rock masses and leading to surface deformation. The latter can be measured with high-resolution geodetic monitoring systems and remote sensing methods such as DInSAR.
In this work, we discuss temporal and spatial variations of reversible ground surface deformation measured in the Aletsch region, Switzerland. The study area is situated in the vicinity of the tongue of the Great Aletsch Glacier, central Swiss Alps, in the gneissic and granitic bedrock of the Aar massif. The valley (1550 to 2300 m.a.s.l.), is roughly oriented parallel to the main Alpine foliation (NE-SW) and to major fault zones. Total annual precipitation is less than 1 m/y, but snow depth frequently reaches 2 m during winter, with strong spatial variability. We use a network of 4 continuous Global Positioning System (cGPS) stations and 90 reflectors linked to 2 total stations (TPS), operating since 2014, to track deformation at millimetric to centimetric scale. We use weather and hydrological data from surrounding stations to estimate the timing of infiltration.
At some locations in our study area we observe peak-to-peak magnitude of seasonal deformation over 2 cm, whereas other areas show no significant seasonal deformation. Measured displacement vectors are generally oriented towards the valley center in spring, when deformation rates are the highest (>0.5 mm/d). The start of the high-rate of deformation period also varies spatially. The South-facing slope starts deforming around 20 days earlier than the North-facing slope. The vertical component of motion is generally smaller than the horizontal one, and often below the noise level. Finally, we discuss possible factors (e.g. topography and slope orientation, discontinuities' orientation and density, lithology, groundwater recharge magnitudes and durations) that might influence the spatial and temporal variations of reversible deformation on the slopes adjacent to the tongue of the Great Aletsch Glacier.