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Dynamics of solifluction lobes in the Swiss Alps: A summary of 14-year monitoring

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Dynamics of stone-banked lobes was investigated by monitoring soil movements and environmental parameters with a variety of manual and automated techniques over 14 years (1994–2008) on a east-facing limestone slope in the Corviglia area, Upper Engadin. The monitored parameters include surface and subsurface soil movements, frost heave, soil temperature, moisture and snow depth. The entire slope lacks permafrost but experiences deep seasonal frost 1–2 m thick. Despite the same soil, lobes on the upper slope (mean gradient 20°) display pressure ridges on the tread and terminate in a high riser (<1 m), whereas lobes on the lower slope (mean gradient 10°) lack pressure ridges and terminate in a low riser (<0.5 m). The lower lobes undergo annual frost heave cycles with an average heave amount of 5 cm, as well as a few, small and irregular diurnal frost heave cycles. The surface debris shows homogeneous downslope displacement at a nearly constant rate of 4 cm/a and the uppermost 30−50 cm of the subsoil deforms downslope without a well-defined basal shear plane. The measured downslope displacement far exceeding the potential frost creep indicates the primary contribution of gelifluction, which operates on the lower lobes during thawing periods when the volumetric water content of soil exceeds the liquid limit (20%). Irrespective of interannual fluctuation in the seasonal frost depth, the rate, depth and timing of soil movement is nearly constant, which promotes the advance of lobes having similar morphology. The upper lobes are subject to slope failure and subsequent rapid mudflows, which happen locally during seasonal thawing. A superficial layer about 20 cm thick flows downslope by up to 2 m per event, inducing heterogeneous surface movements. The area escaping mudflow moves by slow gelifluction similar to that operating on the lower lobes. Prolonged moisture supply from a late-lying snow patch behind the upper lobes leads to supersaturation (25% vol.) of the thawed superficial soil, which far exceeds the liquid limit, in addition to the steeper slope favouring slope failure. The mudflow sediments pile up near the front, developing a lobe with a gentle surface and a high, steep frontal slope. Both gelifluction and mudflow recur annually during thawing periods, unless extraordinarily early and deep snow covers the ground until midsummer.