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Solifluction patterns arising from competition between gravity and cohesion

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Arctic soil movement, accumulation and stability exert a first order control on the fate of permafrost carbon in the shallow subsurface and landscape response to climate change. A major component of periglacial soil motion is solifluction, in which soil moves as a result of frost heave and flow-like “gelifluction”. Because solifluction soil is a complex granular-fluid-ice mixture, its rheology and other material properties are largely unknown. However, solifluction commonly produces distinctive spatial patterns of terraces and lobes that have yet to be explained, but may help constrain solifluction processes. Here we take a closer look at these patterns in an effort to better understand material and climatic controls on solifluction. We find that the patterns are analogous to classic instabilities found at the interface between fluids and air—for example, paint dripping down a wall or icing flowing down a cake. Inspired by classic fluid mechanics theory, we hypothesize that solifluction patterns develop due to competition between gravitational and cohesive forces, where grain-scale soil cohesion and vegetation result in a bulk effective surface tension of the soil. We show that, to first order, calculations of lobe wavelengths based on these assumptions accurately predict solifluction wavelengths in the field. We also present high resolution DEM-derived data of solifluction wavelengths and morphology from dozens of highly patterned hillslopes in Norway to explore similarities and differences between solifluction lobes and their simpler fluid counterparts. This work leads us toward quantitative predictions of the presence or absence of solifluction patterns and their response to variation in material properties (e.g., vegetation, rock type, grain size) and climatic conditions (e.g., water content, active layer depth, variability in snow cover).