Solifluction patterns arising from competition between gravity and cohesion

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Solifluction deformation style (rheology)

We know that soil moves as a result of freeze thaw and flow-like "gelifluction". However, soliflucting soil is a complex cohesive-granular-fluid mixture, and its rheology is largely unknown. It may behave similarly to a pseudoplastic fluid, especially over small scales (e.g., Harris et al., 2000; Roy et al., 2017; Deardorff and Dunn, 1985). In addition, it is complicated given the wide range of observed vertical velocity profiles, the high prevalence of contact angle instabilities, and the presence of liquid bridges.

Effective surface tension in solifluction

If fluid flow patterns result from surface tension, could an "effective" surface tension due to cohesive soil explain solifluction lobes? We have found evidence of effective surface tension in dry granular materials (Eisele et al., 1999; Breuer et al., 2000; Rowan et al., 2017) due to small cohesive forces between grains and soil vs. soils (Wyatt et al., 2017).

In addition to exhibiting similar pattern, solifluction lobes form near vegetation and dynamic characteristics of surface tension-directed control line fronts.

Solifluction lobes generally originate near liquid bridges (Eqs. 1).

$$ \text{Lobe wavelength} \propto \text{Contact angle}^{1/2} $$

Does field data agree with fluid theory/ experiments? It’s messy, but maybe...

As fluids flow downhill, their advancing contact angle-the angle at the very front of the flow-is determined by viscosity, velocity, and surface tension.

The wavelength of the contact line stability is also determined by viscosity, velocity, and surface tension. We can combine these to predict the relationship between wavelength and contact angle.

Field data from Norway

We empirically derived a high sensitivity threshold for the transition of well-developed soliflucting lobe patterns.

Value ranges:

- Mean wavelength: 2-60 m
- Contact angles: 10°-80°
- Dominant lobe pattern: 1-2 lobes/m

Example LiDAR profile shows bimodal lobe fronts.

OpenFOAM Fluid Modeling: Viscous flow + surface tension

We can use OpenFOAM to see if these patterns arise at large length scales relevant for solifluction. We can also play with different rheologies.

Preliminary large-scale model (viscous Newtonian fluid)