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Topographic and ground-ice controls on shallow landslides in Arctic permafrost

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Arctic landscapes are experiencing enhanced permafrost thaw due to a rapidly warming climate. More frequent extreme summer temperatures and rainfall events drive heat quicker and deeper into ice-rich permafrost soils. Higher heat fluxes increase the active layer depth and facilitate rapid thawing of ground-ice, resulting in more vigorous hillslope surface processes such as shallow permafrost landslides called active layer detachments (ALDs). Such increase in the rate of surface processes threaten Arctic infrastructure and are an important mechanism for delivering sediment, organic carbon, and other nutrients to Arctic rivers and lakes. However, little is currently known about the topographic controls and ground-ice conditions needed to generate ALDs on Arctic hillslopes. We used satellite imagery to map 150 ALDs in a 100 square kilometre study area of the Brooks Range, Alaska. We compared the distribution of ALDs to the drainage network to determine any topographic constraints. Our topographic results show that the majority of mapped ALDs are coincident with the drainage network, suggesting that they initiate in areas of topographic convergence. However, not all of the drainage network experienced ALD failures suggesting an additional mechanistic control on ALD intimation. We then modified a two-dimensional slope stability model to assess the temporal and spatial impact of excess pore-pressures generated by thawing ice lenses on slope stability. Our analysis shows that if ice lenses are too small or have low relative connectivity the slope remains stable. However, the conditions required to initiate ALDs is the rapid thawing of highly concentrated ground ice at depth. Therefore, we suggest that future ALD potential may be better understood through field measurements of ground ice distribution on Arctic hillslopes.