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Limits on the critical length of damage in weak snowpack layers from en-echelon slab fracture spacing observed during avalanche release

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We present simple estimates of the maximum possible critical length of damage or fracture in a weak snowpack layer required to maintain the propagation that leads to avalanche release, based on observations of 'en-echelon' slab fractures during avalanche release. These slab fractures may be preserved in situ if the slab does not slide down slope. The en-echelon fractures are spaced evenly, normally with one every one to ten metres or more. We consider a simple two-dimensional model of a slab and weak layer, with upslope fracture propagating the weak layer, and examine the relationship between the weak layer and en-echelon slab fractures. We assume that the slab fracture occurs in tension, and initiates at either the base or surface of the slab in the area of peak tensile stress at the tip of the weak layer fracture. We also assume that if at the time the slab is completely bisected by fracture the propagation in the weak layer will arrest spontaneously if it has not advanced beyond the critical length. In this scenario, en-echelon slab fractures may only form when the weak layer fracture repeatedly exceeds the critical length; otherwise, there could be only a single slab fracture. We estimate the position of the weak layer fracture at the time of slab bisection using the slab thickness and ratio between the fracture speeds in the weak layer and slab. We show that in the simple model en-echelon fractures only form if the slab thickness multiplied by the velocity ratio is greater than the critical length. Of course, the critical length must also be less than the en-echelon spacing. It follows that the first relationship must be valid independent of the occurrence of en-echelon fractures, although the speed ratio may be process-dependent and difficult to estimate. We use this method to calculate maximum critical lengths for propagation in actual avalanches with and without en echelon fractures, and discuss the implications for comparing competing propagation models. Furthermore, we discuss the possible applications to other cases of progressive basal failure and en-echelon fracturing, e.g. the ribbed flow bowls or so-called 'thumbprint' morphology which sometimes develops during landsliding in sensitive clay soils.