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Investigating erosion and entrainment of snow avalanches using the material point method

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Erosion and entrainment are critical processes in gravity-driven mass flows like snow avalanches, as they can significantly change the flow mass and momentum and thus affect the flow dynamics. In snow avalanches, snow cover can be considerably eroded but only partially entrained into the flow. Differentiating erosion and entrainment gives more accurate prediction of the increased flow mass and offers information on eroded snow cover remaining on the slope, but is challenging in practice. This study investigates snow avalanche erosion and entrainment with the material point method, focusing on exploring various erosion mechanisms, differences in erosion and entrainment, and their possible influences on runout distance. By using different mechanical properties for the flowing snow, distinct erosion patterns are observed and the corresponding temporal evolutions of entrainment, erosion, and deposition in the erodible bed are examined. Erosion and entrainment require an appropriate combination of snow friction and cohesion of the bed. If cohesion and/or friction are too low, the bed will naturally be unstable. On the other hand, highly cohesive and frictional bed will prevent erosion. For intermediate values, erosion and entrainment can be notable, and the amount of eroded snow shows a clear negative correlation with snow friction and cohesion while the entrained snow does not demonstrate a strong tendency. Furthermore, the release and erodible bed lengths are varied to study their effect on erosion and entrainment propensity. It is found that the increase in the lengths of the release zone and erodible bed leads to more erosion and entrainment as expected, but not necessarily to a longer runout distance. In our simulations, the release and erodible bed lengths are positively and negatively correlated with the runout distance, respectively. This implies that the runout distance can have opposite trends with erosion and entrainment, which might be closely related to the energy change of the simulated avalanches from the outlet of the erodible bed to the final deposit. Our results shed more light into the erosion and entrainment mechanisms and may contribute to improve related parametrizations in large-scale avalanche dynamics models.