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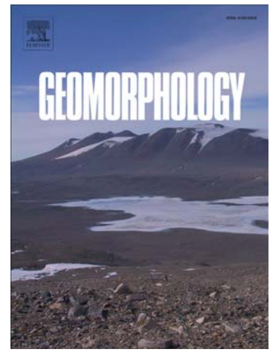

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Modeling rockfall frequency and bounce height from three-dimensional simulation process models and growth disturbances in submontane broadleaved trees

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Abstract

The use of dynamic computational methods has become indispensable for the assessment of rockfall hazards and the quantification of uncertainties. Although a substantial number of models with various degrees of complexity has become available over the past few years, models have only rarely been parameterized against observations, especially because long-term records of rockfalls have proven to be scarce and typically incomplete. On forested slopes, tree-ring analyses may help to fill this gap, as they have been shown to provide annually resolved data on past rockfall activity over long periods. In this paper, a total of 1495 rockfall scars recorded on the stem surface of 1004 trees have been studied at a site in the Vercors massif (French Alps) to calibrate the 3D process based simulation model RockyFor3D. Uncertainties related to the choice of parameters accounting for energy dissipation and surface roughness have been investigated in detail. Because of the lack of reliable data, these parameters typically are estimated based on expert judgments, despite the fact that they have significant impacts on runout distances and bounce height. We demonstrate that slight variations in roughness can indeed strongly affect the performance of runout modeling and that the decreasing downward gradient, observed in field data, is properly reproduced only if reduced roughness (<10 cm) enables blocks to reach the distal parts of the study plot. With respect to the height of impacts, our results also reveal that differences between simulations and observations can indeed be minimized if softer soil types are preferred during simulation, as they typically limit bouncing. We conclude that field-based dendrogeomorphic approaches represent an