The snow depth distribution in complex terrain is of great importance for hydrological applications and commonly investigated with regard to spatial heterogeneities and roughness characteristics. In general, snow deposition and snow redistribution tend to smooth out rugged, alpine topography on intermediate length scales if it is observed on seasonal time scales. Thus, the roughness of the snow surface evolves in time and must be addressed as a dynamic phenomenon with special emphasis on the underlying topography. Involved mechanisms of snow deposition and redistribution are both fluctuating in space and time. It seems therefore natural to pursue a stochastic description which captures the main ingredients phenomenologically. To this end we conduct Monte Carlo simulations of the growing snow surface using a discrete growth model with random deposition and surface relaxations. In order to explicitly account for the effect of underlying topography, our simulations are based on real three-dimensional surface profiles from experimental data. We focus on spatial domains of a few hundred meters and measure time in units of the spatially averaged snow depth. This allows comparability of different sites by avoiding the drawbacks of physical time related to the temporally discontinuous and random occurrence of natural precipitation events. Model simulations are compared to experimental laser scanning data of snow depth at the Wannengrat field site in Davos, Switzerland. Potentials and limitations of this novel approach are quantitatively revealed by the analysis of snow depth distributions.