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# Spatial aspects of vulnerability and risk resulting from snow avalanches

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Mountain regions provide a significant proportion of areas used for human settlements, economic purpose, and recreation. Simultaneously, due to steep vertical gradients mountain areas are prone to mass movement processes. The intersection of such processes with areas used by human action turns them into hazards. In particular in arctic regions, which show a greater susceptibility to disturbances than many landscapes, considerable efforts have been undertaken in recent decades to reduce the adverse effects of mountain hazards. The concept of risk supplemented the traditional engineering approaches of technical mitigation since the 1990s to comprehensively manage these threats, and to develop strategies for a sustainable use of these areas. The concept of risk is based on a mathematical combination of hazards and consequences, but is static over time. However, three major dynamic systems interact in the field of mountain hazard risk management: the physical environment, which includes hazardous events; the social and demographic characteristics of the communities that experience them; and the values at risk such as buildings, roads, and other components of the built environment. These dynamics have not sufficiently been taken into account so far in natural hazard risk management, in particular with respect to industrialised artic regions.
Within the city of Kirovsk, Kola Peninsula, Russian Federation, these dynamics were assessed by taking snow avalanche risk as an example. The test site is exposed to multiple avalanche tracks with repeated releases during individual winter seasons, endangering the built environment and any kind of infrastructure lines. The aim was to contribute to the development of a spatial risk model for mountain regions on different temporal scales. The spatial characteristics of the long-term avalanche risk, as a result of the evolution of the built environment, was analysed on an annual as well as inter-annual level. This long-term development was superimposed by short-term fluctuations due to the spatiotemporal movement of people and mobile values into and within areas endangered by avalanche hazards. As a result, individual system dynamics and the evolution of the entire risk system were specifically assessed. Furthermore, insights in spatiotemporal aspects of vulnerability of elements at risk exposed to snow avalanches were gained. The overall purpose of the study was to develop concepts and methods for an enhanced natural hazard risk management applicable in mountain regions.