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Impacts of Climate Change on Mountain Geosystems in Eastern Canada: Multiscale and Multidisciplinary Approach

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Mid-altitude, mid-latitude mountains are complex environments owing to their Pleistocene glacial heritage, the importance of geomorphic processes on the steep slopes, and the climatic conditions that are often close to periglacial. These factors, along with the fragmentation of the alpine habitats in eastern Canada, enhance the sensitivity of these geosystems to recent climate change with complex responses based on the interactions between the geosphere, the atmosphere, and the biosphere. Unfortunately, very few examples are available in the scientific literature concerning mid-altitude mountains and research in alpine areas of northeastern America has been poorly coordinated, with minimal communication among researchers, and it has rarely been multidisciplinary. In order to address the aforementioned gap, here we report a multi-proxy reconstruction of the effects of the ongoing climate change in the Chic-Choc Mountains, mainly based on: 1) the recent evolution of the marginal permafrost body on the Mount Jacques-Cartier – the highest summit; 2) the changes in the structure of alpine vegetation over the last decades; and 3) the quantification of sediment fluxes related to various hillslope processes for the last centuries. Our results suggest a rapid degradation of the permafrost, from a geothermal record for 1977-2014 from a 29 m deep borehole, associated with warmer winter temperatures and snowpack distribution. For this permafrost body already close to the thawing point, if the warming trend continues as predicted by climate simulations, the complete disappearance of this southernmost marginal permafrost in Quebec could occur around 2040-50. Although the alpine treeline appears stable since 1975, the diachronic analysis of aerial photos nevertheless shows densification and colonization of the shrub vegetation (+5%) and a decrease in bare soil (-1.5%) in alpine areas during the last 30 years. In spite of the short-term observations in the field (30 years), the annual resolution of the dendrochronology and its temporal limit ($\sim$150 years in the area), and the low-resolution of 14C dating, the reconstructed events related to hillslope processes clearly indicate an increase of sediment fluxes in the last millennium for scree slopes, debris flow cones and alluvial fans investigated. Because hillslope processes are generally related to specific storm and weather factors at various spatiotemporal scales, they appear sensitive to climate change. Finally, these results testify the sensitivity of mountain environments to current and future climate change, hence the need to develop relevant multidisciplinary approaches.