

The Evolution of Glacier Mass Balance Gradients under the Current Climate Change

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Glaciers variations are a unique observable expression of climate change. In several mountain ranges, rapid environmental changes are happening and cause an accelerating glacier mass loss since approximately the 1990s. The mass balance gradient of glaciers is both a good measure of glacier-climate interactions and an important representative of the climatic environment of glaciers. In the present study, the hypothesis that mass balance gradients are steepening during the last decades as a consequence of higher ablation rates and of an induced increase in accumulation rates that a warmer atmosphere could trigger is tested. 49 glaciers are selected from the WGMS database and their annual mass balance data series with elevation is downloaded for the period 1954-2017. Their ablation, glacier-wide and accumulation gradients are calculated by the slope of the linear regression line passing through the mass balance points. The detailed evolution curves and the linear evolution trends of these mass balance gradients are analyzed for glaciers individually, for the 49 selected glaciers together and for glaciers classified according to climatic and geometric parameters. As a result, a general steepening trend over the period is observed. The total linear increase in gradients is quantified to +10% for ablation gradients, +14% for glacier-wide gradients and +25% for accumulation gradients over a period of 50 years. The evolution is marked by a clear and rapid shift from smaller to steeper gradients between the mid-1980s and the mid-1990s for maritime and transitional glaciers and seems to have been triggered by the simultaneous increase in solar radiation known as “global brightening”. Continental glaciers have an earlier and longer steepening in glacier-wide and accumulation gradients probably triggered by warming air temperature. This increase is potentially related to a long-term warming induced increase in accumulation rates and would mark a climate regime shift in continental environments towards more maritime conditions. The observed important evolution differences between continental and maritime glaciers showed that the evolution of mass balance gradients is dependent on the climatic environment of glaciers. In addition, glaciers with different geometric parameters, particularly glaciers with different hypsometry and slope showed contrasted evolutions of their mass balance gradients. The observed high sensitivity of mass balance gradients to climatic changes points out that a better understanding of this complex relationship is necessary. It is particularly important in the current context of climate change and given the key role of mass balance gradients for glacier dynamics and glacier response time to climatic perturbations.

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