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Temporal patterns of glacial lake evolution in high-mountain environments

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Lakes forming at the front of retreating glaciers are characteristic features of high-mountain areas in a warming climate. Typically, lakes shift from the proglacial phase (lake is in direct contact with glacier) to a glacier-detached (no direct contact) and finally to a non-glacial phase (lake catchment is completely deglaciated) of lake evolution. Apart from changing glacier-lake interactions, each stage is characterized by particular features of lake growth, and by the lake's susceptibility to sudden drainage (lake outburst flood). While this concept appears to be valid globally, some mountain areas are rich in dynamically evolving proglacial lakes, while in others most lakes have already shifted to the glacier-detached or even non-glacial phase. In the present contribution we (i) explore and quantify the history of glacial lake formation and evolution over the past up to 70 years; (ii) assess the current situation of selected contrasting mountain areas (eastern and western European Alps, southern and northern Pamir, Cordillera Blanca); and (iii) link the patterns of lake evolution to the prevailing topographic and glaciological characteristics in order to improve the understanding of high-mountain geoenvironmental change.

In the eastern Alps we identify only very few lakes in the proglacial stage. While many lakes appeared and dynamically evolved until the 1980s between 2550 m and 2800 m asl, most of them have lost glacier contact until the 2000s, whereas very few new proglacial lakes appeared at the same time. Even though a similar trend is observed in the higher western Alps, a more dynamic glacial lake evolution is observed there. The arid southern Pamir is characterized by a high number of proglacial lakes, mainly around 4500 m asl. There is strong evidence that glacial lake evolution is, after a highly dynamic phase between the 1970s and approx. 2000, decelerating. Few proglacial lakes exist in the higher and more humid, heavily glacierized northern Pamir, even though there is some evidence for a the recent trend of lake formation and growth. The tropical Cordillera Blanca displays a high, but gradually decreasing share of proglacial lakes. A significant shift of lake elevation was observed: tmost lakes were situated between 4250 m and 4600 m asl in 1950s, while almost half of the lakes are currently situated above 4600 m asl, confirming post-LIA climate change forcing.

We attempt to explain the observed trends by investigating the relation of the timing of lake evolution with an interplay of the broad-scale elevational patterns of glaciers and topography, and the local conditions. The findings will assist in anticipating possible future patterns of lake evolution at different scales, relevant for lake outburst risks and water management issues.