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Hypsometry and the distribution of high-alpine lakes in the European Alps

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Climate change strongly affects alpine landscapes. Cold-climate processes shape the terrain in a typical way and ice-free overdeepenings in cirques and glacial valleys as well as different types of moraines favor the formation of lakes. These water bodies act as sediment sinks and high-alpine water storage but may also favor outburst and flooding events. Glacier retreat worldwide is associated with an increasing number and size of high-alpine lakes which implies a concurrent expansion of sediment retention and natural hazard potential. Rising temperatures are regarded to be the major cause for this development, but other factors such as the distribution of area over elevation and glacier erosional and depositional dynamics may play an important role as well. While models of ice flow and glacial erosion are employed to understand the impact of glaciers on mountain landscapes, comprehensive datasets and analyses on the distribution of existing high-alpine lakes are lacking.

In this study we present an exhaustive database of natural lakes in the European Alps and analyze lake distribution with respect to hypsometry. We find that the distribution of lake number and lake area over elevation only weakly coincides with hypsometry. Unsurprisingly, largest lakes are often tectonically influenced and located at the fringe of the mountain range and in prominent inter-montane basins. With increasing elevation, however, the number of lakes, lake area and total area decrease until a local minimum is reached around the equilibrium line latitude (ELA) of the last glacial maximum (LGM). Above the LGM ELA, total area further decreases, but lake number and area increase again. A local maximum in lake area coincides with an absolute maximum in lake number between the ELAs of the LGM and the little ice age around 2500 m. We conclude that glacial erosional and depositional dynamics control the distribution and size of high-alpine lakes and thus demand for exceptional attention when predicting future lake development.