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Quaternary glaciation of the central Gangdise Mountains and glacier change of the Gangdise Mountains since the Little Ice Age

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The Gangdise Mountains of southern Tibet are located in a transition zone to the Indian Monsoon-dominated Himalaya and to the south of the Westerly-dominated Qangtang Plateau. Constraining the timing and extent of paleo-glaciations is of great importance when attempting to understand regional climatic changes and can also help to improve the understanding of any predictions of future glacial changes. The glacial history of the Gangdise Mountains is not yet clear. We investigated the glaciation history in the Lopu Kangri area of the central Gangdise Range using ^{10}Be exposure dating. Glacial events were constrained to 0.19 ± 0.04 ka to 0.30 ± 0.09 ka (Little Ice Age, LIA), 1.68 ± 0.16 to 2.75 ± 0.26 ka (Neoglacial), and 19.91 ± 1.8 ka (global Last Glacial Maximum, gLGM). A glacial event at 23.07 to 29.15 ka was also constrained. In addition, we found glacial events of >51.1 ± 4.6 and >297.6 ± 3.0 ka in this region.

In this study, we mapped 4188 contemporary glaciers and reconstructed 1216 LIA areas of glacial coverage in the Gangdise Mountains to the north of the Himalaya using Google Earth satellite imagery. We estimated their paleoglacial areas and equilibrium line altitudes (ELAs) based on the toe-to-headwall altitude ratio (THAR) method. Results show that most glaciers are small (<1 km^2), with slope/hanging glaciers the most common (2844 out of 4188 glaciers), while valley glaciers have the greatest coverage (1009.0 km^{2}out of a total area of 1723.7 km^2). Contemporary glaciers have retreated significantly since the LIA, with reductions in length of between 5.5% and 94.7% (mean glacier length 696 m; mean reduction in length 41.7%) and reductions in glacier area of between 4.1% and 94.9% (mean glacier area 0.42 km^2; mean reduction in area 44.8%). These reductions have occurred under different local climatic and topographic conditions. The contemporary ELA ranges from 5516 to 6337 m asl; the LIA ELA ranged from 5476 to 6329 m asl. Contemporary and LIA ELA values rise from southeast to northwest. As a general rule, the rise in the ELA value decreases from the eastern to the central Gangdise Mountains and then increases westward, with a mean ELA rise of 45 m. Multiple regression models suggest that 46.8% of the glacier area loss can be explained by glacier elevation, area, and slope. However, only 15.5% of the rise in ELA values can be explained by glacial geometric, topographic, or locational parameters. The spatial pattern of modern ELA values in this region appears inversely related to precipitation, which decreases from southeast to northwest, implying that precipitation is one of the key controls of ELAs. This is also consistent with results from elsewhere in High Asia. In contrast to the Gangdise Mountains' eastern and western sectors, glaciers in the central sector have undergone less change, i.e., in terms of reductions in length, area loss, and rises in ELA. Topography can of course also influence glacial change by creating shielding and/or rainshadow effects and by affecting local temperatures.