Limited glaciations, glacier modeling, and paleo-climatic implications for the Tibetan Plateau

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The Tibetan Plateau has a large number of mountain glaciers that yield meltwater for several of the largest Asian rivers. Recent studies of the timing and extent of past glacier expansions on the Tibetan Plateau have revealed regional variations in chronologies, but a common characteristic is that past glaciations were restricted to local mountain glaciers and ice-fields. Because glaciers are sensitive to climate change the paleo-glaciation record of the Tibetan Plateau can provide insights into paleo-climate. Here we present a study combining glacial geology and glacier modeling to constrain past climate shifts on the Tibetan Plateau in terms of temperature and precipitation. We have mapped the glacial geomorphology of several mountain ranges across the Tibetan Plateau that have contemporary glaciers and cosmogenic exposure dating constraints for the timing of past glaciations. A high resolution (< 500 x 500 m) higher-order glacier model has been calibrated against contemporary glacier coverage and was then run to reproduce paleo-glaciation targets based on the mapped glacial geomorphology. For each domain we ran the model with different boundary conditions; i.e. basal sliding on and off and varying temperature and precipitation. The model results indicate that glaciers on the Tibetan Plateau are generally more sensitive to temperature than precipitation. To expand present-day glaciers to paleo-glaciation targets requires extreme and unrealistic values of increased precipitation if the temperature is maintained at current conditions. Conversely, modest cooling is enough to reproduce paleo-glaciation targets even with substantially drier condition compared to present. The modeling indicates that the paleo-climate of the Tibetan Plateau was not much cooler than today during periods of glacial expansion, or that more substantial temperature depressions were offset by extreme aridity. Finally, the temperature sensitivity indicates that future warming might cause significant glacier reduction.