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Detecting local-scale to large-scale climate change in the tropics from glacier recession on Kilimanjaro (East Africa): observations, proxies, and numerical models

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The mass balance of a glacier represents the most direct (but, basically, local) link between glacier behavior and climate forcing. To learn more about glacier-climate interactions on Kilimanjaro, we maintain automatic weather stations in the glacierized summit area between 5700 and 5900 m above sea level. This provides us with a rare opportunity to derive climate change in the mid-troposphere, a region with a lack of climate data. All results so far (based on meteorological measurements and mass balance modeling) underline the importance of solid precipitation for these glaciers. In agreement with lowland proxy data, the retreating glaciers therefore most probably indicate a shift from relatively wet to relatively dry conditions. However, Kilimanjaro is the highest free-standing mountain in the world, so its summit area is a unique sample point in the free atmosphere. Hence, we are also in the position to explore the potential of glacier response to climate change at scales beyond local or regional. The large-scale climate link is investigated by experiments with a coupled atmosphere-ocean general circulation model (AOGCM). These experiments show a drastic change in moisture supply from the Indian Ocean into East Africa between the 19th and 20th century, which provides the framework for changed precipitation conditions over the glaciers. The large-scale flow, however, is known to be strongly modified by high mountains such as Kilimanjaro. Mesoscale experiments with a numerical atmospheric model therefore complement our study. Results reveal that – as the moisture structure and stability of approaching air masses change – precipitation does not change uniformly with altitude but the shape of the vertical profile of precipitation on the slopes of Kilimanjaro is altered. The impacts of this finding on the glaciers are discussed. In summary, this study demonstrates how the use of atmospheric- and climate-science methods may add value to local-scale mass balance studies, and that tropical climate change at high altitude is enhanced compared to lower elevations.