Snow and Ice on Kilimanjaro

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Kilimanjaro's bright summit mantle is among the mountain's most fascinating and distinctive attributes. The intrigue of equatorial snow and ice, appearing to float 5,000 m above the plains, has helped make Kilimanjaro one of the most enduring icons of Africa. In recent years there has been considerable discussion about the dwindling extent of snow and ice on the mountain, rekindling controversy over snow, ice, and climate on Kilimanjaro which erupted after the initial European 'discovery' of the snow cap by Johannes Rebmann in 1848. Then, for more than a decade, English Geographers dismissed and even ridiculed Rebmann's report of tropical snow. Today, as thousands of climbers experience snow on the mountain and witness the dramatic glaciers each year, controversy concerns their fate. Will the glaciers disappear and, if so, when? Will the seasonal blanket of snow also disappear with the glaciers, and what role does global climate change play in cryospheric changes underway at the summit?

Glaciers at the summit are a product of climatic conditions which no longer exist. At the time of Hans Meyer's first ascent in 1889, recession of the ice was probably already underway from an area of almost 20 km^2 (Osmaston, 1989), likely the glacier's greatest extent during the Holocene. Dramatic accounts of ice loss were a major theme of Kilimanjaro scientific literature throughout the 20th century, with their demise "within decades" predicted as early as 1900 (Meyer, 1900), and repeatedly thereafter; today only 2 km^2 of ice remains.

The morphology of Kilimanjaro's glaciers has remained quite uniform since early observations. Ice bodies within the summit crater feature near-horizontal surfaces with vertical walls and steplike features (see photo), while slope glaciers descend the mountain's south and west flanks. All regimes are strongly impacted by the frequency and magnitude of snowfall, which governs energy exchanges on both horizontal ice surfaces (Mölg and Hardy, 2004) and the slope glaciers (Cullen *et al.*, 2006). Today, as during Meyer's time when there was "hardly any snow on Kibo worth mentioning" during the dry season, the mass balance is negative. And although superimposed ice formation reduces mass loss on horizontal surfaces, evidence indicates that the current Northern Icefield surface is 50-200 years old.

Snowfall also governs energy exchanges on the flat, dark volcanic sand adjacent to the vertical ice walls. Retreat of these vertical walls, which accounts for much of the continuous decrease in areal extent of the glaciers, has been controlled by solar radiation (Hastenrath and Greischar, 1997; Mölg *et al.*, 2003). Still under investigation is to what extent the process is aided by energy transfer from the surrounding sand, by longwave radiation and sensible heat, during snow-free intervals.

Kilimanjaro glaciers received considerable attention by astute observers during the first half of the 20th century. Interest dwindled after IGY (1957-58), but was rekindled by cartographic documentation of ice recession by Hastenrath and Greischar in 1997. A new phase of Kilimanjaro glacier and climate research began in February 2000, involving ice-core drilling, aerial photography, and a program to measure modern climate and monitor the glaciers (Thompson *et al.*, 2002). Three automated weather stations now complement glacier observations, in a collaborative effort between the Universities of Massachusetts and Ohio State (USA), Innsbruck (Austria), and Otago (New Zealand), as well as the Tanzanian Meteorological Agency, and modeling efforts are underway at a variety of spatial scales (esp. Innsbruck and Otago personnel). These combined efforts are helping to develop better understandings of how climate variability impacts Kilimanjaro glaciers, and answering questions about the fate of snow and ice on the mountain.

References

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Kilimanjaro's Northern Icefield, illustrating vertical walls, dark crater surface, and patchy snowcover. Vertical height of the ice front shown is ~20 meters. Photograph by Douglas Hardy, UMass Geosciences.