VARIATIONS OF THE LEWIS AND GREGORY GLACIERS, MOUNT KENYA, 1990-1993

With 1 figure, 2 tables and 1 supplement (II)

STEFAN HASTENRATH, RAOUF S. ROSTOM, and WALLIS F. HIME

Zusammenfassung: Veränderungen des Lewis und des Gregory Gletschers am Mount Kenya 1990-1993

Vom Lewis und Gregory Gletscher am Mount Kenya wird eine Karte im Maßstab 1:2500 vorgelegt, die auf Luftbildaufnahmen vom 9. September 1993 zurückgeht. Im Vergleich mit Aufnahmen vom März 1990 dokumentiert diese Karte den Gletscherrückgang zu Beginn der 90er Jahre. Während der Zeitspanne von 3½ Jahren wich der Lewis Gletscher 25 m zurück und verlor 11% seiner Fläche bzw. 34% seines Volumens. Gleichzeitig zog sich der Gregory Gletscher um 30 m zurück und verlor 37% seiner Fläche und einen beträchtlichen Teil seines Volumens.

1 Introduction

For the past two decades the glaciers of Mount Kenya have been studied with particular attention to problems of climate-cryosphere interactions and climate change (HASTENRATH 1984, 1991, 1992), building on work of the previous generation (CHARNLEY 1959; Forschungsunternehmen Nepal-Himalaya 1967). These studies were also a contribution to monitoring and documentation efforts at the international level (World Glacier Monitoring Service of IASH-ICSI-UNEP-UNESCO 1993 a, b). As part of this project, the largest ice body on the mountain, the Lewis Glacier, and the contiguous Gregory Glacier were mapped at four-year intervals and at scale 1:2,500. These maps were successively published in this journal (CAUKWELL a. HASTENRATH 1977, 1982; HASTENRATH a. CAUKWELL 1979, 1987; HASTENRATH a. ROSTOM 1990), as were glacier mappings for the mountain as a whole at scale 1:5,000 (HASTENRATH et al. 1989; ROSTOM a. HASTENRATH 1994). The present communication brings this long-term effort to an interim closure.

2 The mappings

Surveys were flown by Photomap (Kenya) Ltd. on 1 March 1990 at 22,000 feet, and on 9 September 1993 at about 20,500 feet. Stereo-plotting was performed at the University of Nairobi by the same photogrammetrist, on the Wild A-8 Stereo Autograph. The 1993 map was compiled from the stereo pair 3099 and 3101, where the glaciers occupied a central portion in the model. The ground control points were as for the 1990 map (HASTENRATH a. ROSTOM 1990) and are listed in Table 1. The residuals on these points gave a RMS of ± 1.6 m in height and 0.2 mm in plan (1:2,500). These figures were adequate to map the glaciers at scale 1:2,500 with contour interval of 5 m. On 9 September 1993 the Lewis and Gregory Glaciers were covered by fresh snow, which obliterated some crevasses as well as the ice edge in some places.

3 Changes in ice thickness

The enclosed map at scale 1:2,500 for 9 September 1993 extends the documentation established by our earlier mappings of the Lewis and Gregory Glaciers and allows comparison with the 1 March 1990 date. On this basis, the changes in ice thickness from 1 March 1990 to 9 September 1993 have been evaluated at scale 1:2,500. This was done digitally, with co-registering of control points and using a 2,5 m grid. Topography differences of 1993 minus 1990 were calculated not only for the ice but also for a 50 m wide perimeter around the glaciers, and on this basis

Table 1: Control points used in mapping
Kontrollpunkte der Kartierung

Points	Coordinates South-North	Coordinates West-East	Elevation (m)
L 2	1,450.4	3,210.6	4,797.2
L 3	1,791.8	2,884.0	4,792.7
Lenana	1,847.9	3,622.1	4,985.0
Melhuish	1,630.6	2,742.2	4,876.5
S 3	1,206.3	2,745.5	4,600.6
Thomson	2,031.0	3,159.7	4,955.1
Gregory	2,261.3	3,303.1	4,693.5

Table 2: The Lewis and Gregory Glaciers during 1990-1993
Lewis und Gregory Gletscher 1990-1993

	Lewis 1990	Lewis 1993	Lewis Δ	Gregory 1990	Gregory 1993	Gregory Δ
A [10^3 m]	230	205	25	63	40	23
h [m]	13.7	10.3	4.6	-	-	0.9
V [10^3 m^3]	3,170	2,393	1,064	-	-	57
L [m]	940	915	25	-	-	30
E [m]	4,620	4,620		4,708	4,720	

(A = area, h = average thickness, V = volume, L = length, E = terminus elevation in 1990 and 1993, Δ = changes over the 1990-1993 interval)

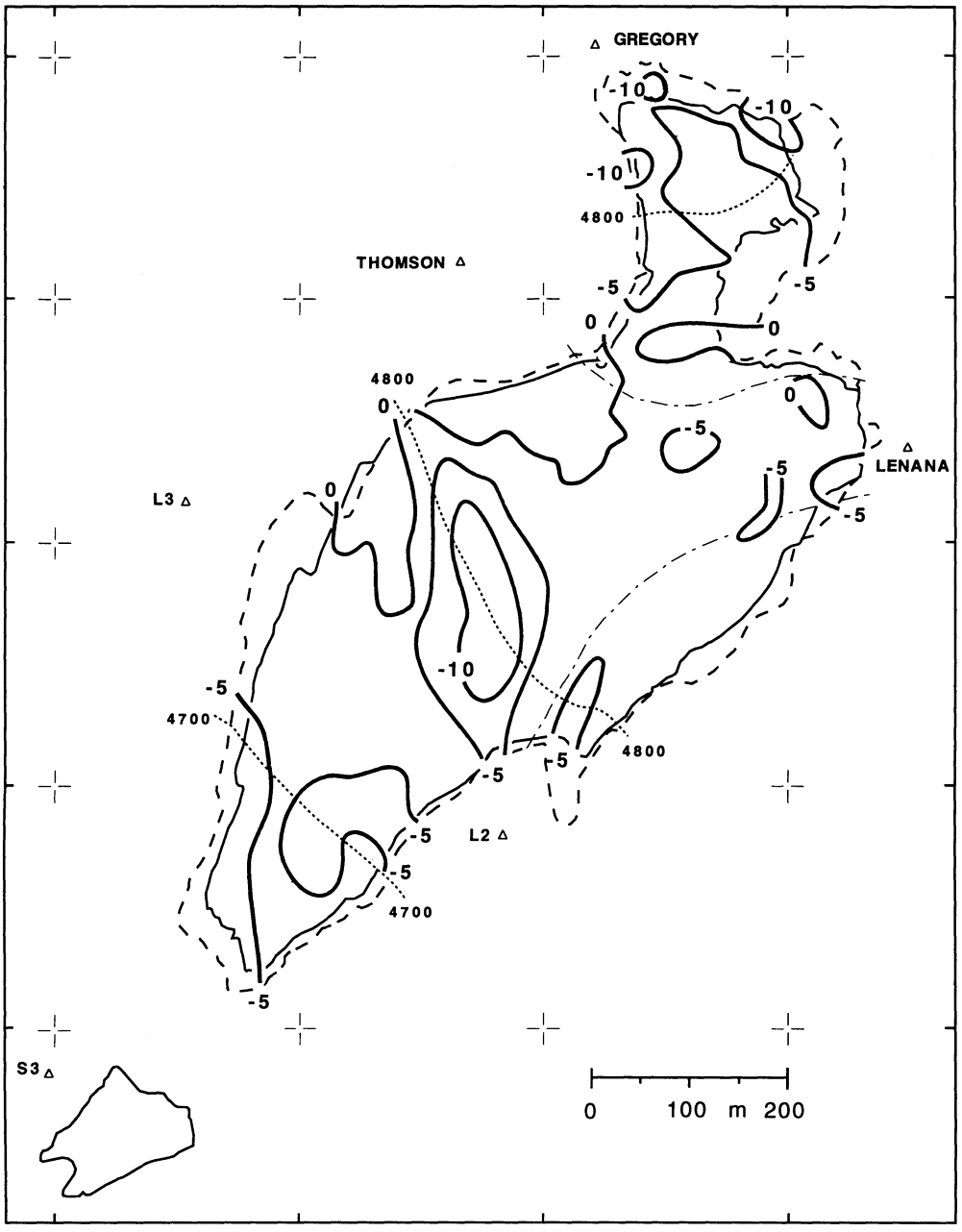

Fig. 1: Changes in ice thickness September 1993 minus March 1990
Ice rim in 1993 is shown as solid, and in 1990 as broken line. Dash-dotted lines indicate ice-flow divides to the eastern part of Lewis Glacier and to Gregory Glacier in the North, respectively. 1993 height contours are entered as dotted lines. Scale 1:7,500.

Veränderung der Eismächtigkeit September 1993 minus März 1990
Eisrand 1993 durchgehende, 1990 gestrichelte Linie. Strichpunktierte Linien markieren die Gletscherscheiden zum östlichen Lewis- bzw. zum nördlichen Gregory-Gletscher. Punktiert sind die Höhenlinien von 1993. Maßstab 1:7500

glacier thickness changes were adjusted according to apparent discrepancies in the surrounding rock topography.

The resulting map of ice thickness change is reproduced in Fig. 1 at scale 1:7,500, and evaluations for the Lewis and Gregory Glaciers separately are further

summarized in Table 2. Fig. 1 shows losses for all areas of the Lewis and Gregory glaciers. For the Lewis these were largest in the western lower portion and in a swath of relatively steep slope in the middle glacier. The Gregory suffered largest losses in its lower portion. There are also noticeable decreases in area. Quantitative evaluations are summarized in Table 2. Over this time span of 3.5 years, the Lewis Glacier has receded by 25 m, and has lost 11 percent of its area and 34 percent of its volume. Over the same time interval, the Gregory Glacier became 30 m shorter, lost 37 percent of its area, as well as substantial volume.

4 Crevasse pattern

The various earlier mappings mentioned above all show a zone of crevasses extending from Point Thomson towards the rock ridge West of Curling Pond, and this crevasse zone is also prominent on the 1993 map. The ice cliff in the upper glacier, oriented approximately from Southwest to Northeast, is found in similar position in both mappings.

5 Concluding remarks

The recent re-mapping of Mount Kenya's glaciers at scale 1:5,000 gave the opportunity to map also the Lewis and Gregory Glaciers at scale 1:2,500 (Supplement II), to compare with a corresponding mapping of these two glaciers in March 1990. Over this time span, the Lewis Glacier lost 25 m in length, 25×10^3 m^2 in area, and $1{,}064 \times 10^3$ m^3 in volume, while the corresponding losses for the Gregory amounted to 30 m, 23×10^3 m^2, and 57×10^3 m^3, respectively. To compare the ice shrinkage rate with the late 1980's, the surface lowering for the Lewis was 3.1 ma^{-1} in 1986–90 as compared to 4.6 ma^{-1} in 1990–93; the corresponding rates for the Gregory being 5.3 and 0.9 ma^{-1}, respectively. These values indicate a sustained shrinkage during recent years. Based on our earlier mappings of surface and bedrock topographies of Lewis Glacier, the ice thickness at its maximum in the middle glacier is for 1993 estimated at less than 30 m. At that location, the ice has thinned by about 15 m from 1978 to 1993. Also, our monitoring of surface velocity indicates that the ice flow has become slow. Thus, under the recent conditions of the atmospheric environment and with no climatic change, remnants of the Lewis Glacier may survive into the earlier decades of the next millenium. Should the net balance deteriorate further, the demise of the glacier would be accelerated. Such indications of long-term evolutions are pertinent to the broader issues of "greenhouse effect" and global change. In the closer context of Mount Kenya, it is intended to evaluate the present results in analyses consistent with those reported for preceding 4-year intervals (Hastenrath 1989, 1992). In particular, spatial pattern of the ice thickness changes assessed here from successive topographic mappings shall be evaluated along with the continuous net-balance measurements of Lewis Glacier. This will extend the detailed documentation on the functioning of Lewis Glacier from 1978 to 1994 and bring this long-term glacier program to an interim juncture; no re-mapping of the Lewis and Gregory Glaciers is planned for the rest of the millenium.

Acknowledgements

This study was supported by U.S. National Science Foundation Grant EAR-9217211. At the University of Nairobi, Samuel W. Kimani did the stereographic work, and at the University of Wisconsin, Dierk Polzin assisted with the data processing and graphics.

References

Caukwell, R.A. a. Hastenrath, S. (1977): A new map of Lewis Glacier, Mount Kenya. In: Erdkunde 31, 85–87.
- (1982): Variations of Lewis Glacier, Mount Kenya, 1978–82. In: Erdkunde 36, 299–303.
Charnley, F. (1959): Some observations on the glaciers of Mount Kenya. In: J. Glaciol. 3, 483–492.
Forschungsunternehmen Nepal-Himalaya (1967): Mount Kenya 1:5,000. Wien.
Hastenrath, S. (1984): The glaciers of equatorial East Africa. Dordrecht, Boston, London.
- (1989): Ice flow and mass changes of Lewis Glacier, Mount Kenya, East Africa: observations 1974–86, modeling, and predictions to the year 2000 A. D. In: J. Glacial. 35, 325–332.
- (1991): Glaciological studies on Mount Kenya, 1971–83–91. Department of Meteorology, University of Wisconsin.
- (1992): Ice-flow and mass changes of Lewis Glacier, Mount Kenya, East Africa, 1986–89: observations and modeling. In: J. Glaciol. 38, 36–42.
Hastenrath, S. a. Caukwell, R. A. (1979): Variations of Lewis Glacier, Mount Kenya, 1974–78. In: Erdkunde 33, 292–297.
- (1987): Variations of Lewis Glacier, Mount Kenya, 1982–86. In: Erdkunde 41, 37–41.
Hastenrath, S. a. Rostom, R. (1990): Variations of the Lewis and Gregory Glaciers, Mount Kenya, 1978–86–90. In: Erdkunde 44, 313–317.
Hastenrath, S., Rostom, R. a. Caukwell, R. A. (1989): Variations of Mount Kenya's glaciers, 1963–87. In: Erdkunde 43, 202–210.
Rostom, R. a. Hastenrath, S. (1994): Variations of the glaciers of Mount Kenya 1987–93. In: Erdkunde 48, 174–180.
World Glacier Monitoring Service of IASH-ICSI-UNEP-UNESCO (1993a): Fluctuations of glaciers 1985–90, vol. 6. ETH Zurich.
- (1993b): Glacier mass balance bulletin no. 2 (1989–91). ETH Zürich.

LEWIS GLACIER

Scale 1:2 500

Date of Photography 9 Sept. 1993

Nos. 3099–3101

GREGORY △(4693.5)

GREGORY GLACIER

THOMSON CROSS △(4958.1)

PT. LENANA △(4985.0)

L3 △(4792.7)

L E W I S

G L A C I E R

MELHUISH CROSS △(4878.1)

L2 △(4797.2)

M. C. K. Huts

L5 ×4623.5

S3 △(4600.6)

LEWIS TARN

Glacier edge

Principal crevasses

Ice cliffs

△ Survey stations used in mapping

● Net balance and motion stakes

○ Net balance stake, not surveyed

× Other surveyed point

0 50 100 150 200 m

Kartographie: S. Dohmen