GLACIERS TROPICAUX ET VARIABILITÉ CLIMATIQUE

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GLACIER RECESSION ON MOUNT KENYA IN THE CONTEXT OF THE GLOBAL TROPICS

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Abstract

Glaciers began to retreat around the mid 1800's in the Ecuadorian Andes and New Guinea, but only towards the end of the 19th century in East Africa. Here the onset of the ice recession as well as the drop of lake levels were due to a change in the hydroclimatic conditions caused by circulation changes in the Indian Ocean sector. Pertinent to the onset of glacier retreat was a reduction of cloudiness accompanying the decrease of precipitation. Subsequently, a gradual warming and an increase in atmospheric humidity became the more prevalent forcings. The ice wastage appears accentuated in all of the tropics during the past two decades.

Key words: *Glacier, Kenya, recession, warming.*

RETROCESO DE LOS GLACIARES DEL MONTE KENYA EN EL CONTEXTO GLOBAL DE LOS TRÓPICOS

Resumen

El retroceso de los glaciares empezó, en los Andes del Ecuador y en Nueva Guinea, a mediados del siglo XIX más o menos, y sólo a fines de este siglo en África del Este. En esta zona, tanto el principio del retroceso de los glaciares como el descenso del nivel de los lagos, han sido provocados por un cambio de las condiciones hidroclimáticas debido a cambios en el sector del Oceáno Índico. Una reducción de la nubosidad acompañada por una disminución de las precipitaciones tuvieron el rol más importante en el proceso de desglaciación. Después, el progresivo recalentamiento y el aumento de la humedad atmosférica fueron los factores dominantes. La desglaciación es un fenómeno que se accentuó en todo el Trópico durante los dos últimos decenios.

Palabras claves: *Glaciar, Kenya, retroceso, recalentamiento.*

LE RECUL DES GLACIERS DU MONT KENYA DANS LE CONTEXTE GLOBAL DES TROPIQUES

Résumé

Les glaciers ont commencé leur retrait autour de la moitié du XIXème siècle dans les Andes équatoriales et en Nouvelle-Guinée, mais il faut attendre la fin du XIXème siècle pour les voir entamer leur recul en Afrique de l'Est. Dans cette région, la déglaciation, comme la baisse du niveau des lacs, est due à des changements hydroclimatiques survenant à la suite de modifications de la circulation atmosphérique dans l'Océan Indien. La diminution des surfaces englacées est attribuée à une réduction de la nébulosité accompagnée d'une baisse des précipitations. Par la suite, un réchauffement progressif et une augmentation de l'humidité atmosphérique sont devenus les facteurs dominants. La déglaciation tend à s'accentuer sous tous les Tropiques depuis deux décennies.

Mots-clés : *Glacier, Kenya, recul, réchauffement.*

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INTRODUCTION

Glaciers in the high mountains of the tropics are receiving increased attention in the context of global change and for their role in the regional water budget. Drawing on published results, the present note sketches the evolution of the tropical cryosphere since the past century with focus on the glaciers of Mount Kenya. Section 1 reviews the development in the three equatorial glacier regions, section 2 summarizes the history of ice retreat on Mount Kenya; the climatic causes of glacier recession are considered in section 3, and a synthesis is offered in section 4.

1. RETREAT OF TROPICAL GLACIERS

Glaciers near the Equator still exist in three regions of the World, namely the South American Andes, New Guinea, and East Africa. In all three of the these regions glaciers have been retreating since the 19th century, but with remarkable differences in the onset of the ice recession.

The Central Ecuadorian Andes (Hastenrath, 1981) merit particular attention, because they have in the course of the past half millenium been visited more frequently than any other tropical high mountain region, and because there are in close proximity numerous peaks with a range of summit elevations, so that reports of the presence or absence of perennial snow offer definitive information on the equilibrium line altitude (ELA). The evaluation of the historical sources (Hastenrath, 1981) indicates a rise of the ELA since the middle of the 19th century.

The glaciers in the Irian Jaya part of New Guinea have not been reached until early in the 20th century. However, based on a numerical modeling experiment, Allison & Kruss (1977) concluded that the climatic forcing of the ice retreat began around the middle of the 19th century. Recent visits to this remote mountain region indicate an accelerated ice shrinkage over the past two decades (Allison & Peterson 1989; Quarles van Ufford, 1996), concordant with other regions.

In contrast to the South American Andes and New Guinea, the glaciers of East Africa began to recede only at the end of the 19th century, an issue to be discussed in section 3.

2. CHANGES OF MOUNT KENYA'S GLACIERS

Figure 1 and Table 1 provide an orientation on the glaciers of Mount Kenya. Remarkable is the largest ice extent in the southeastern sector of the mountain, both at the turn of the century and recently. This is due to the precipitation distribution, with largest amounts to the Southeast.

The variations in ice cover are summarized in Table 1, compiled from information in a series of earlier publications (Hastenrath, 1984; 1991; Kruss & Hastenrath, 1987; Hastenrath *et al.*, 1989; Rostom & Hastenrath, 1994). The progressive shrinkage is further illustrated in Fig. 2, for the largest ice body on the mountain, the Lewis Glacier, and for the mountain as a whole. The ice-covered area decreased to less than a third in the course of this century. During 1963-1987 the glaciers thinned uniformly by about 14 m, whereas during 1987-1993 the average decrease in thickness amounted to 5 m.

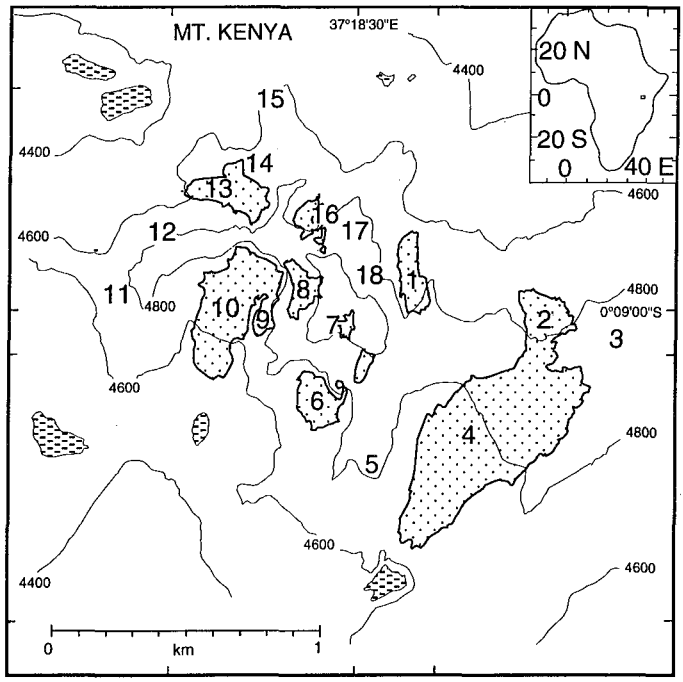

Fig. 1 - Orientation map of Mount Kenya's glaciers in 1987. Large numbers refer t › Table 1. Height contours are at 200 m intervals. Inset map in upper right corner shows location of Mount Kenya within Africa.

Table 1 - Area changes of the glaciers on Mount Kenya, in 10^3 m^2 (ref. Fig. 1).

Glacier		1899	1947	1963	1987	1993
1	Krapf	85	43	43	23	21
2	Gregory	290	94	91	45	35
3	Kolbe	100	0	0	0	0
4	Lewis	603	400	351	243	203
5	Melhuish	-	5	5	0	0
6	Darwin	90	40	42	26	23
7	Diamond	-	7	6	3	3
8	Forel	-	37	25	16	15
9	Heim	-	25	18	16	15
10	Tyndall	165	101	90	78	65
11	Barlow	6	0	0	0	0
12	NW Pigott	5	0	0	0	0
13	Cesar	100	49	40	24	18
14	Joseph	63	34	25	10	6
15	Peter	2	0	0	0	0
16	Northey	50	39	29	11	9
17	Mackinder	2	0	0	0	0
18	Arthur	2	0	0	0	0
	Total	1563	874	765	495	413

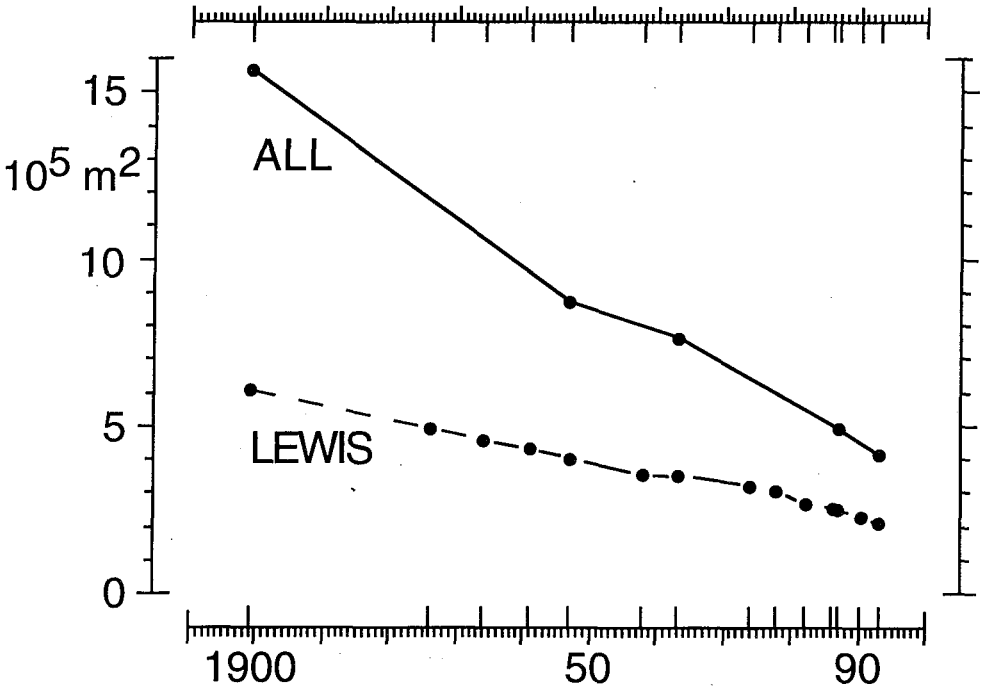

Fig. 2 - Variations of ice covered area, in 10^5 m^2; Lewis Glacier dashed, and all glaciers solid line.

The history of terminus retreat of Lewis Glacier could be reconstructed in considerable detail. This historical record along with measurements of net balance, ice surface flow velocity, and of bedrock topography, served as input to a numerical modeling experiment. From this, Kruss (1983) inferred an onset of climatic forcing from about 1880 to the turn of the century and onset of terminus retreat from the innermost large moraine of Lewis Glacier at 1890.

3. CLIMATIC FORCINGS

The onset of glacier recession on Mount Kenya must be seen in the context of the drastic drop in the water level of East African lakes from high stands up to 1880 and low stands after 1900 (Hastenrath, 1984; Kruss, 1983). The reduction of cloudiness accompanying the decrease in precipitation is of primary importance for the surface radiation budget of the glaciers.

In response to this first climatic forcing the glaciers of Mount Kenya could have stabilized in the early decades of the 20th century. By then a warming was underway, concentrated in the 1920's, which caused further retreat of the glaciers. However, the prevalent role of the forcing involving cloudiness and solar radiation changes is still evident from an evaluation over the period 1899 to 1963 (Kruss & Hastenrath, 1987).

Progressing further in time, an evaluation for the period 1963 to 1987 (Hastenrath & Kruss, 1992) showed that the diverse topographic shading of the various glaciers, and hence

cloudiness and solar radiation forcing, no longer dominated the ice wastage. Indeed, over this time span, the ice thickness decreased uniformly by about 14 m for all glaciers, regardless of topographic location. A sensitivity analysis indicated that warming alone would be insufficient to account for the observed ice wastage, and that a slight increase in atmospheric humidity was instrumental in this context.

As discussed above, the onset of glacier recession in East Africa occurred distinctly later than in the other two equatorial glacier regions, and was a consequence of a drastic change of hydroclimatic conditions from a pre-1880 wetter regime to a distinctly drier environment after the turn of the century. This drastic location of the regional climate appears to have been due to an acceleration of the westerly surface winds along the Indian Ocean Equator in boreal autumn (Hastenrath & Larson, 1993).

4. CONCLUDING REMARKS

In this brief review of published work during the past two decades, attention was called to the remarkable diversity in the timing and nature of the climatic forcing of the tropical glacier recession. Glaciers began to retreat in the mid 1800's in the Andes and New Guinea, but only towards the end of the 19th century in East Africa. Here, the onset of glacier recession as well as the drop of the lake levels from pre-1880 high to post-1900 low stands was due to the drastic change of the hydroclimatic conditions resulting from an acceleration of the boreal autumn equatorial westerlies over the Indian Ocean. Most pertinent for the onset of the ice recession was a reduction of cloudiness accompanying the decrease in precipitation. In the 20th century, the prevalent climatic forcings were a gradual warming and then a slight increase of atmospheric humidity. Glaciers in all of the tropics appear to share an accentuated ice wastage over the two most recent decades.

Acknowledgments

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References Cited

ALLISON, I. & KRUSS, P. D., 1977 - Estimation of recent climatic change in Irian Jaya by numerical modeling of its tropical glaciers. *Arctic and Alpine Research*, **9**: 49-60.

ALLISON, I. & PETERSON, J., 1989 - Glaciers of Irian Jaya, Indonesia *in: Satellite image atlas of glaciers of the World.* (R. S. Williams and J. G. Ferrigno, eds.): H1-H20, U.S. Geological Surfey Professional Paper 1386.

HASTENRATH, S., 1981 - *The glaciation of the Ecuadorian Andes*, 166p., Rotterdam: Balkema.

HASTENRATH, S., 1984 - *The glaciers of equatorial East Africa.*, 353p., Boston, Lancaster: Reidel, Dordrecht.

HASTENRATH, S., 1991 - *Glaciological studies on Mount Kenya*, 1971-83-91, 104p., Madison: Department of Meteorology, University of Wisconsin.

HASTENRATH, S. & KRUSS, P. D., 1992 - The dramatic retreat of Mount Kenya's glaciers 1963-87: greenhouse forcing. *Annals Glaciology*, **16**: 127-133.

HASTENRATH, S. & LARSON, N., 1993 - Secular variation of circulation in the Indian Ocean and Western Pacific. *in: Proceedings of International Conference on Regional Environment and Climate Changes in East Asia*: 353-358, Nov-Dec 1993, Taipei, Taiwan.

HASTENRATH, S., ROSTOM, R. & CAUKWELL, R. A., 1989 - Variations of Mount Kenya glaciers 1963-87. *Erdkunde*, **43**: 203-210.

KRUSS, P. D., 1983 - Climatic change in East Africa: numerical modeling from the 100 years of terminus record of Lewis Glacier, Mount Kenya. *Zeitschrift für Gletscherkunde und Glazialgeologie*, **19**: 43-60.

KRUSS, P. D. & HASTENRATH, S., 1987 - The role of radiation geometry in the climate response of Mount Kenya's glaciers, part 1: horizontal reference surfaces. *Journal of Climatology*, **7**: 493-505.

QUARLES VAN UFFORD, A., 1996 - Recession of the equatorial Puncak Jaya glaciers, Irian Jaya (Western New Guinea), Indonesia. *Zeitschrift für Gletscherkunde und Glazialgeologic* (submitted).

ROSTOM, P. & HASTENRATH, S., 1994 - Variations of Mount Kenya's glaciers 1987-93. *Erdkunde*, **48**: 174-80.