FOUR YEARS OF MONTHLY MASS BALANCE ON A TROPICAL GLACIER: THE ZONGO GLACIER, 16°S, CORDILLERA REAL, BOLIVIA

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INTRODUCTION

Recent studies have emphasised the extreme sensitivity of tropical glaciers to climatic changes (Hastenrath and Kruss 1992, Thompson 1992). It seems that the strong response of these glaciers to climatic forcing is partly due to specific seasonal patterns of accumulation and ablation (Francou et al.1995). The main accumulation and ablation occur during summer and an important part of the glacier surface is submitted to a predominant ablation regime the whole year round. Since 1991, a monitoring programme has been conducted on the Zongo Glacier, Bolivia, in order to study mass and hydrological balance. This monthly survey aims at understanding what the glacier response is to seasonal variability. In the Central Andes, the largest climatic variabilities are due to extreme phases of southern oscillation (ENSO events). The period from 1991 to 1995 was marked by a negative trend of the South Oscillation Index (SOI), particularly during the 1991-92 ENSO event. This paper presents a short synthesis of the principal results obtained during these four cycles from 1991 to 1995, with emphasis on the ablation variabilities on a monthly scale.

Mass balance is estimated from a stake network which extends to the ablation and accumulation zones. Regular measurements of snow accumulation and density in pits have completed the survey system. Six rain-gauges between 4,700m and 5,200m, and a limnimetric station near the glacier snout allow the estimation of hydrological balance.

MASS AND HYDROLOGICAL BALANCES

The following table presents the different characteristics of the 4 measured cycles.

Years	Bn (1)	P (2)	A (3)	Q (4)	ELA (5)
1991-92	-1.38	0.92	2.30	2.25	5300
1992-93	0.02	1.06	1.04	1.18	5100
1993-94	-0.73	0.85	1.58	1.56	5200
1994-95	(row to be completed with the data of August 1995)				

1) Specific net balance (m of water)
2) Precipitation near the glacier (4,880-5,200m) (m of water)
3) Specific ablation : A = P - Bn (m of water)
4) Specific runoff for a 2.1 km² glacier area (m of water)
5) Equilibrium Line Altitude (in masl)

Mass balance was negative, except during the 1992-93 cycle. This result is coherent with the trend of the last two decade as reconstructed from hydrological data by Ribstein et al. (1995). The 1991-92 cycle was marked by a significant loss in ice volume, which is generally recorded during ENSO cycles in the Central Andes.

From figures 1 and 2, it is possible to point out some general features. Ablation is always very strong early in summer (October-December), before the full precipitation season which extends normally from January to March. A second ablation peak is observed immediately after the humid months of April and May. The dry cold months (June-August) may be considered as a *steady state* period for the largest surface of the glacier. Neverthless, other features may be observed.

1) The ENSO year 1991-92 was characterised by a clear shrinkage of the accumulation period near the ELA (< 2 months); this year, as the others in general, it was observed that a deficit in the precipitation during the wet months is always associated with strong ablation rates, even at high altitudes (5,300-5,500m). This was observed in January 1994 and February 1995.

2) During the last two years, it was also possible to measure notable ablation rates during the dry season, particularly in August 1994 and July (and August) 1995.

CONCLUSIONS

1. The complexity of ablation and accumulation regimes in the tropics makes it necessary to survey glacier balance every month.

2. The intensity of ablation closely depends on the variability of precipitation distribution during summer; the high quantity of energy and humidity available between October and April explains the main peaks of runoff occuring during this period.

3. Ablation rates during the cold-dry season may be important, as shown by the last two cycles.

Energy balance measurements conducted on the glacier surface will make it possible to explain how climatic variability controls glacier behaviour, making these glaciers useful indicators of climatic change at low latitudes.

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Fig. 1 : Monthly mass balance at 5,200-5,100m (ELA position when mass balance is in equilibrium). Mean values of 7 representative stakes

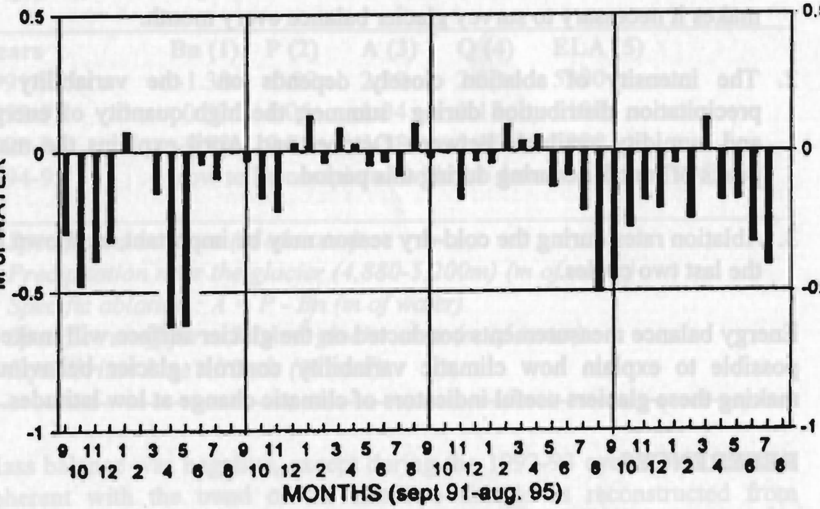

Fig. 2 : Month precipitation (average of 4 rain-gauges) and runoff during the 4 cycles 1991-95 *(1994-95 to be added in the definitive version of the paper)*