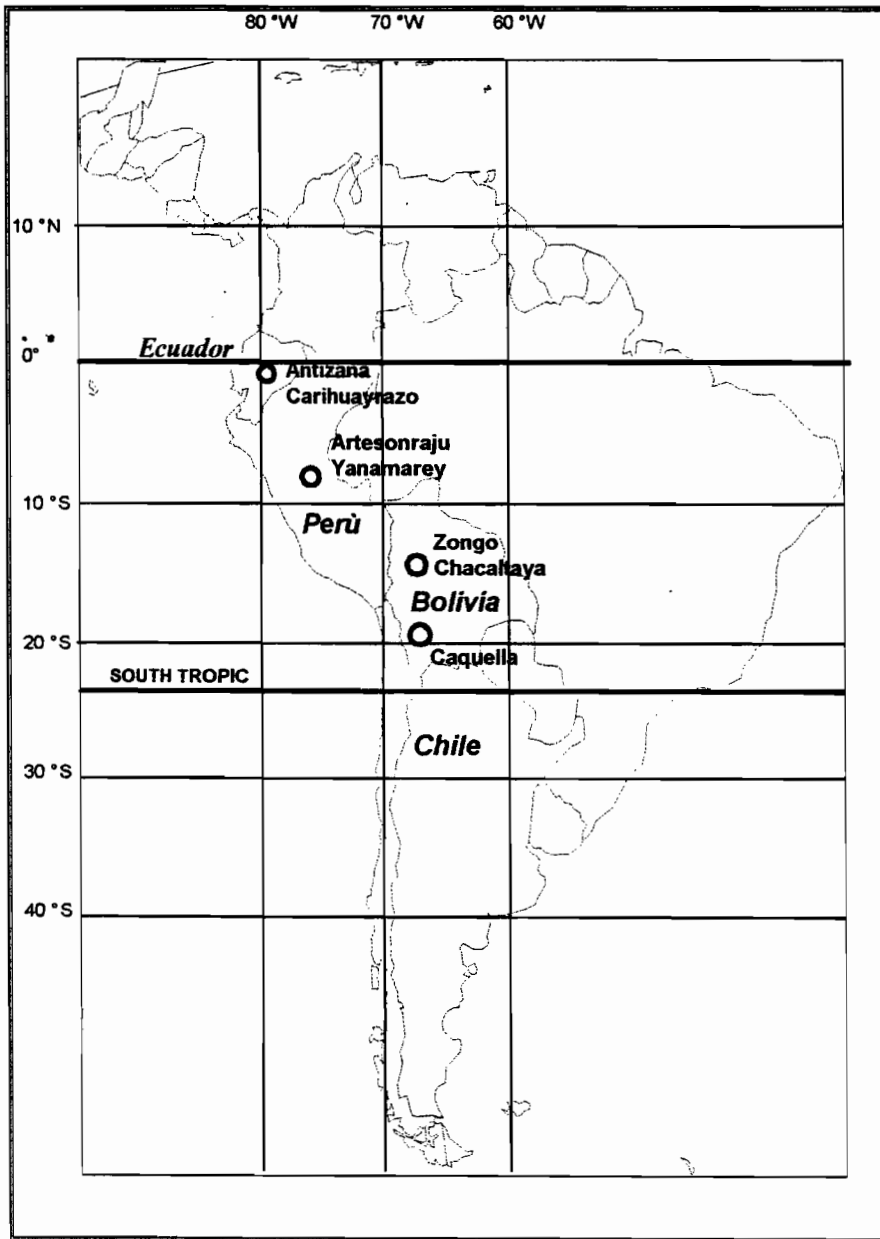


ORSTOM - IHH - EMAAP-Q - INAMHI
SENAMHI - EPN
LA PAZ - QUITO

Programme **NGT** (Neiges & Glaciers Tropicaux)

WORLD GLACIER MONITORING SERVICE
EXTENSIVE INFORMATION ABOUT
THE GLACIERS OF BOLIVIA and ECUADOR

1995-1997



Map of monitored glaciers in the Central Andes (by ORSTOM and partners)
Caquella (South Bolivia) is a rock glacier

THE NGT'S NETWORK OF MONITORED GLACIERS THROUGHOUT THE CENTRAL ANDES

NGT : Neiges & Glaciers Tropicaux (Nieves y Glaciares Tropicales)

Name	Location	Coordinates elevation surface	Specific Net Balance	Hydrological Balance	Topographic survey	Geophysical soundings	Meteorological survey (4)	Historical reconstruction
<i>Zongo (1)</i>	Cordillera Real Bolivia	16°21'S 68°10'W 6000-4800 m 2.100 km ²	17 stakes (month survey) 4 pits Drilling at 5500m	limnimetric station at 4860 m	Terminus oscillation and stake velocity (every year)	Radar 1995	1) classical at 4770 m and 5150 m 2) energetic balance at 5150 and 5550 m	Photogrametrical restitution since 1948
<i>Chacaltaya (2)</i>	Cordillera Real Bolivia	16°21'S 68°07'W 5375-5123 m 0.082 km ²	13 stakes (month survey) 3 pits	limnimetric station at 4750 m	Surface, contour evolution and stake velocity (every year)	Sismic refraction (1997) Radar (1995)	classical at 5240 m (40 years data of temperature and precipitation)	Topographic survey of the external moraine (XIXth century). Photogrametrical restitution since 1940
<i>Antizana 15α (3)</i>	Volcan Antizana Ecuador	0°30' S 78°08'W 5758-4800 m 0.353 km ²	20 stakes (month survey) 4 pits Drilling at the top	limnimetric station at 4500 m	Terminus oscillation and stake velocity (every year)		1) classical at 3900 m 2) energetic balance at 5100m.	Photogrametric restitution (in process)

(1) Monitored since September 1991 (ORSTOM, IHH, COBEE : La Paz, Bolivia)

(2) Monitored since September 1991 (ORSTOM, IHH : La Paz, Bolivia)

(3) Monitored since June 1994 (ORSTOM, EMAAP-Q, EPN)

(4) « Classical » involves air temperature under screen and precipitation (rain gauges).

« Energetical balance » includes air temperature, ground temperature, moisture, radiation balance and wind.

1. BOLIVIA

1.1. ZONGO GLACIER

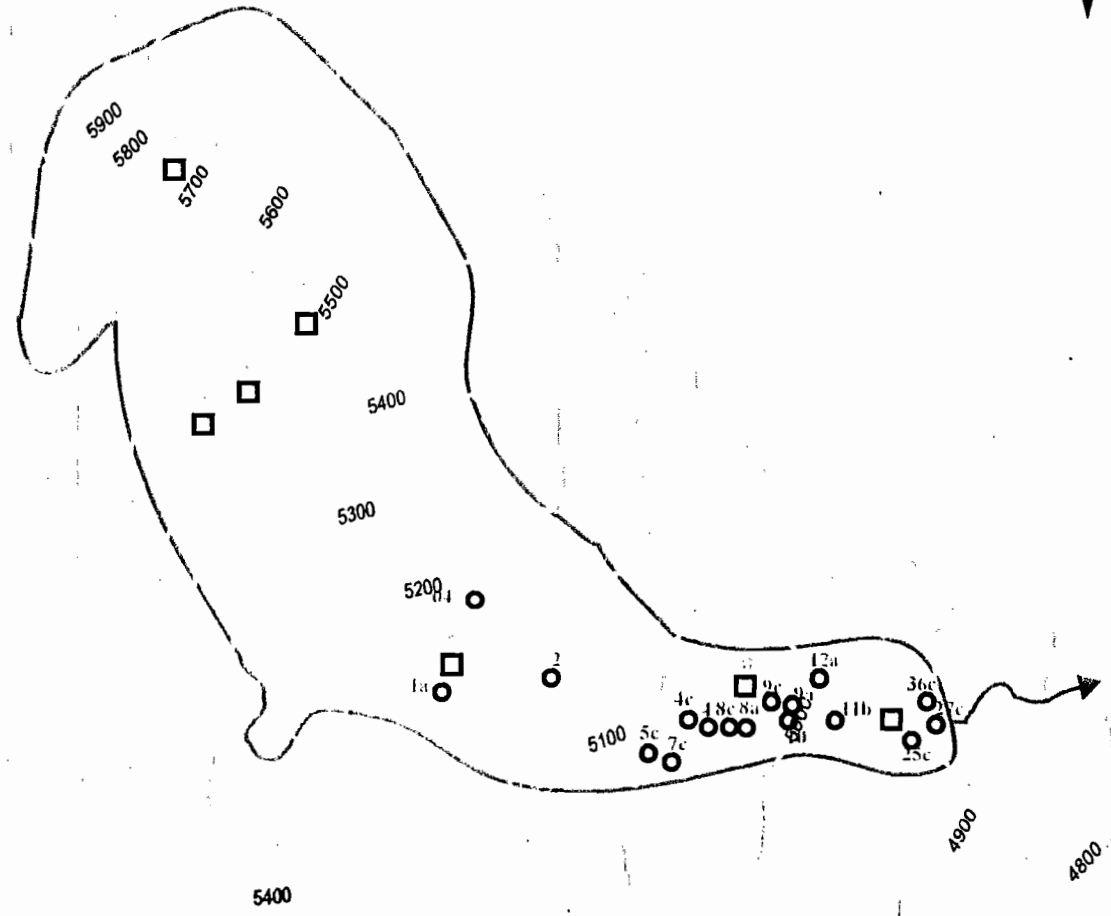
Zongo (16°S, 68°W) is a small valley-type glacier located North-East of La Paz city, at the head of an important hydraulic system which supplies power to the city. It is a 3 km long glacier, between 4900 and 6000 m asl and its surface extends to 2.1 km². Exposition is South in the upper part and East in the lower tongue. Mean temperature at the ELA₀ (5250 m asl) is - 1.5°C (directly measured). Mean precipitation at the Plataforma was about 900 mm/year (± 200 mm) during the 20 last years. Ablation is concentrated during the wet summer season (October-April) and presents a clear peak in October-December, before the precipitation maximum.

The 2 last net balances were very contrasted : 1995-96 was negative, with a very strong ablation in October 1995 (1000 mm at 5150 m asl), while 1996-97 was positive (the most positive of the 1991-97 serie), marked by extensive precipitation occurrence from September to May. During the 2 years, 2 types of South Oscillation (SO) situations have occurred in the Pacific : in 1995-96, the SO index was low (a warm-type event), while in 1996-97, the SO index was high (a short cold-type event).

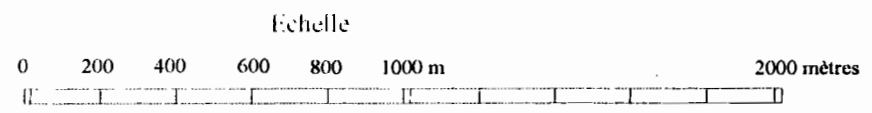
REFERENCE

Berton, P., Wagnon, P., Francou, B., Pouyaud, B., Baldivieso, H., 1997. Mesure météorologiques, hydrologiques et glaciologiques sur le glacier de Zongo. Année hydrologique 1995-1996. *Rapports ORSTOM*, 55, La Paz, Bolivie : 119 p.

6000
HUAYNA POTOSI
6088 m amsl



- balise
- sondage



GENERAL INFORMATION ABOUT ZONGO GLACIER

years	B_n (1)	ΣB_n (2)	P (3)	A (4)	Q (5)	ELA (6)	AAR (7)	Term. (8)
	mm	mm	mm	mm	mm	m	%	m
1991-92	-900	-900	920	1820	2240	5500	39	-12.3
1992-93	+516	-384	1060	544	1180	5050	88	+1.1
1993-94	-88	-472	850	938	1590	5250	64	-10.2
1994-95	-703	-1175	850	1553	2130	5450	44	-6.4
1995-96	-675	-1850	867	1542	2293	5425	47	-11.8
1996-97	+797	-1053	1068	271		5075	89	-15.6
AVG	-175		935	1110				

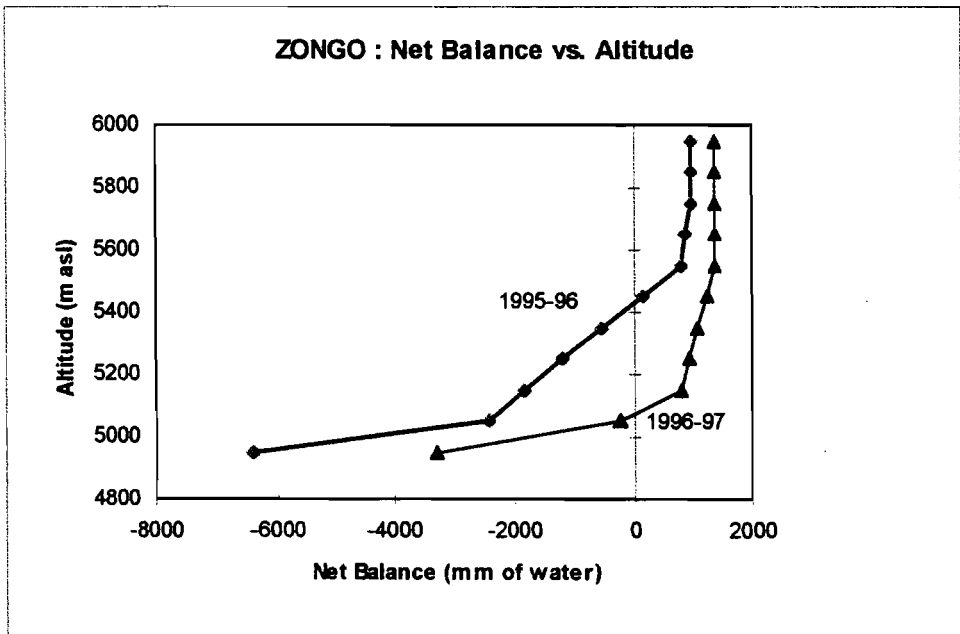
- (1) specific net balance
- (2) cumulated (1)
- (3) precipitation near the glacier
- (4) specific ablation [$A = P - B_n$]
- (5) specific runoff
- (6) Equilibrium Line Altitude
- (7) Accumulation Area Ratio
- (8) movement of the terminus

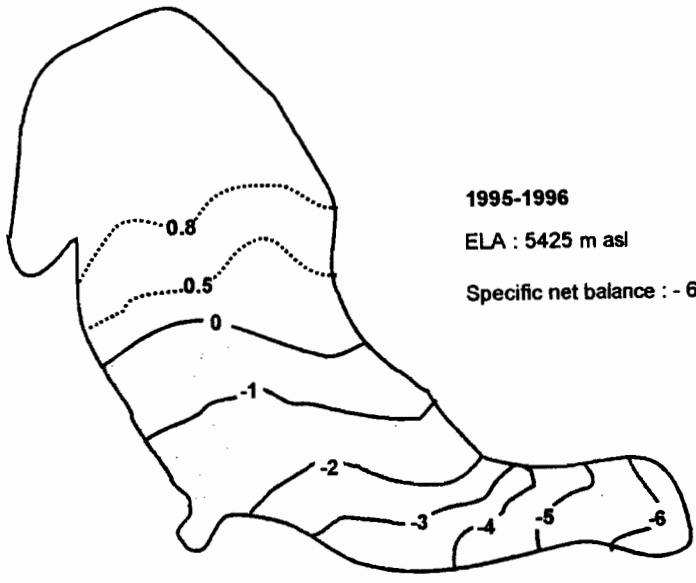
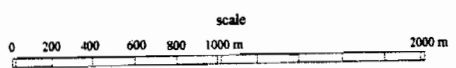
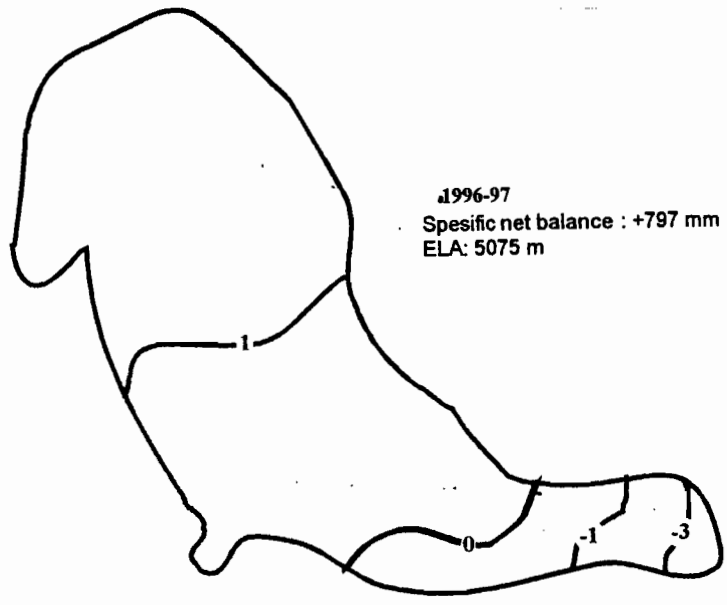
IMPORTANT NOTE

Due to application of a new topography on this glacier, which has implicated to lower the former altitude range by 50 m., we have calculated new values for the period 1991-95. The values presented here are definitive. Thus, the values issued before are not valid.

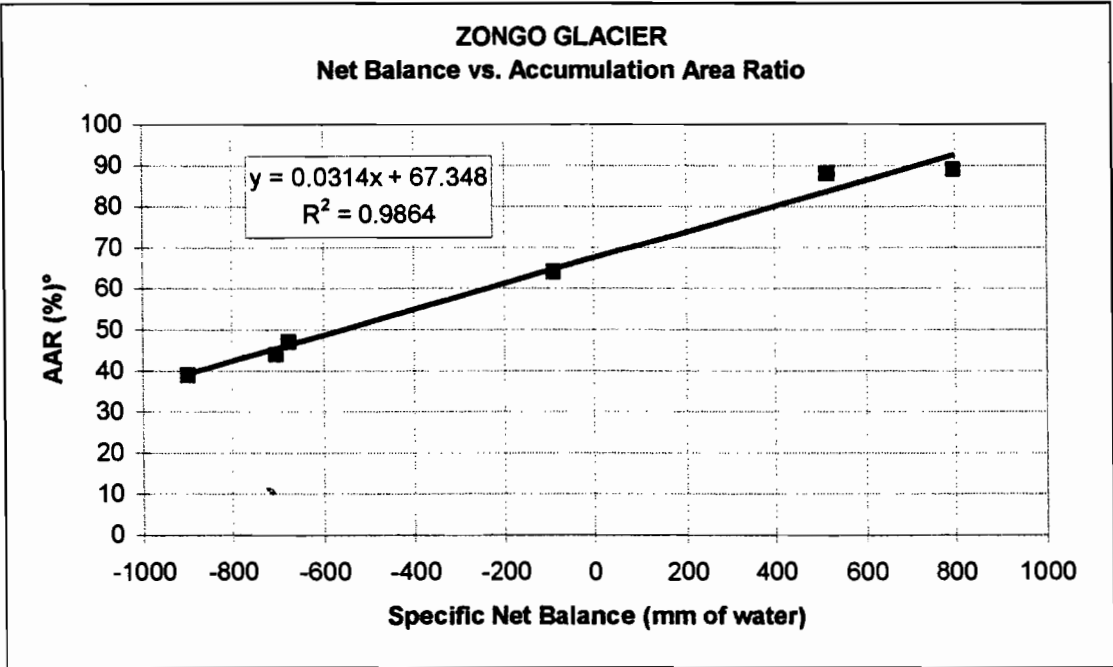
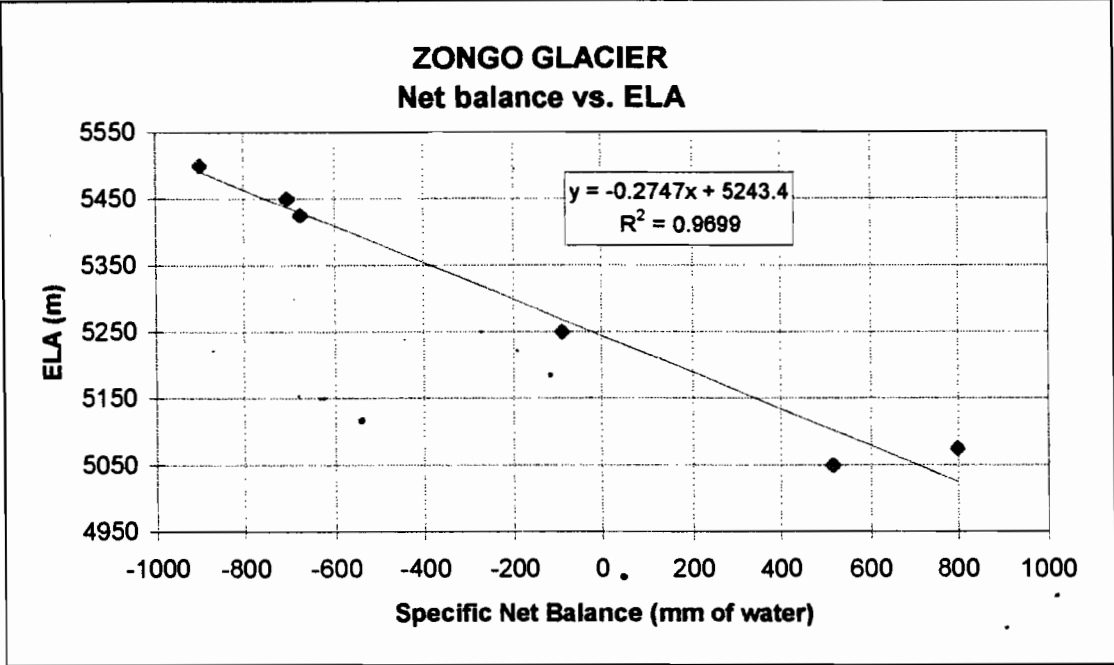
NET BALANCE vs. ALTITUDE

altitude	91-92	92-93	93-94	94-95	95-96	96-97
4950	-3265	-3265	-5403	-6680	-6420	-3291
5050	-2976	101	-1123	-2820	-2416	-231
5150	-2330	358	-140	-1640	-1830	768
5250	-1640	497	11	-1080	-1175	918
5350	-950	635	162	-530	-521	1068
5450	-267	774	313	-25	133	1218
5550	420	913	464	580	788	1371
5650	569	1148	747	980	848	1371
5750	571	1239	832	970	965	1371
5850	571	1239	832	970	965	1371
5950	571	1239	832	970	965	1371





NET BALANCE vs. ELA and AAR



1.2. CHACALTAYA GLACIER (CORDILLERA REAL)

Chacaltaya is a little glacier located at 20 km NE of the La Paz city. Its altitude range is 252 m, between 5375 and 5123 m asl. Its length and its maximum width total 584 and 234 m respectively. Its area extended to 0.0821 km² in August 1996.

As many small-size glaciers of the region, Chacaltaya plays an important role in the water resources of La Paz and the Altiplano. Since 1991, the net balance is estimated from a network of 6 stakes situated on the left part of the glacier. In 1996, we have extended this network to the whole glacier surface. The stakes are read every month.

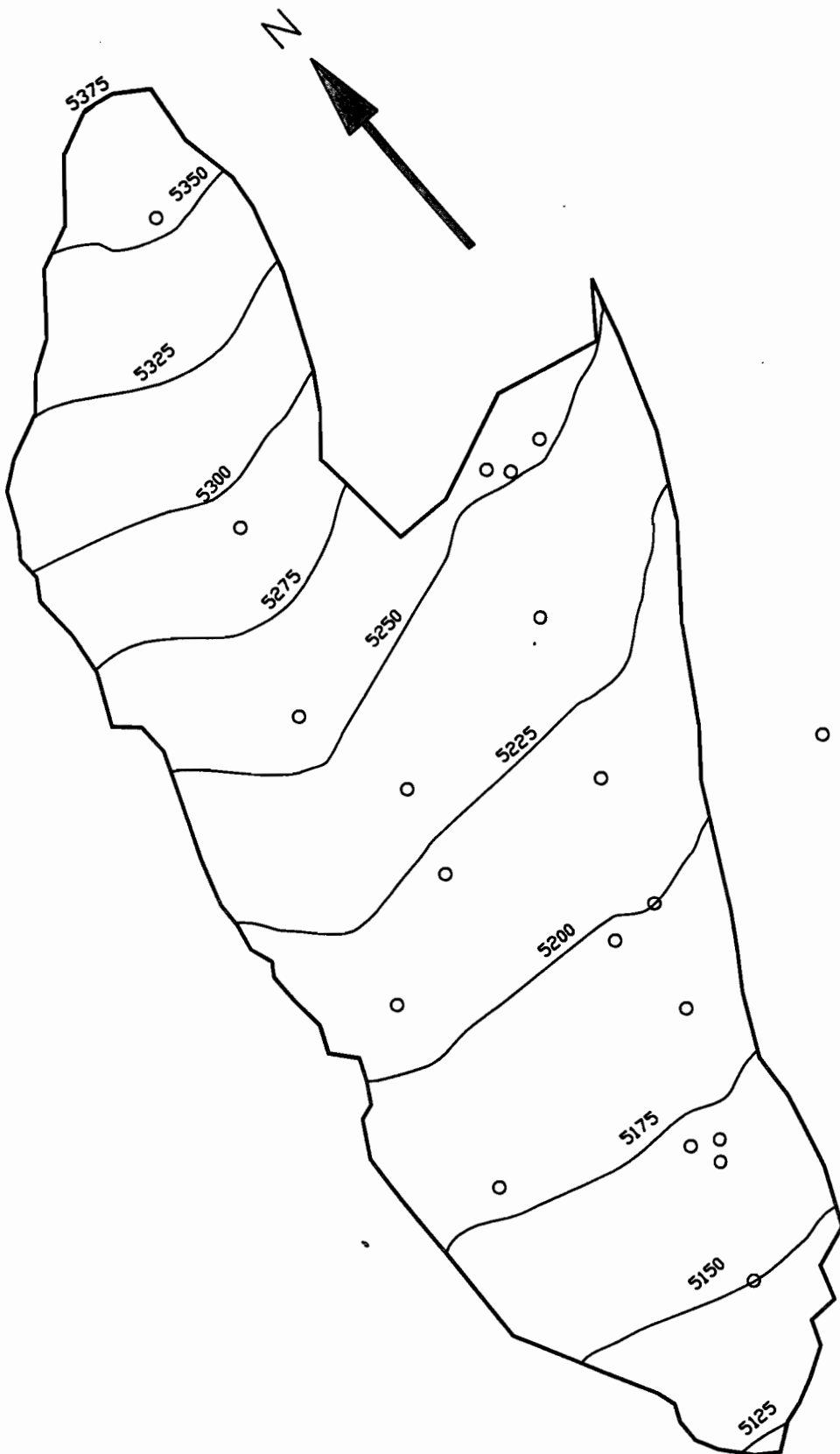
A topographic survey is effected every year since 1991 in September, which allows an estimation of the surface evolution and the surface velocity. In 1997, measurements by seismic refraction have made possible to determine the bedrock depth and to estimate the total volume of the glacier (703 372 m³ of ice). The maximum depth is estimated to 20 m.

The glacier has probably reached its maximum historical extension in the period 1840-1860. From this maximum, the surface loss has been estimated to be 84% in 1996. A dramatic acceleration of retreat is noted from the beginning of the 1980's, as recorded on all the monitored glaciers of the Central Andes. The surface loss is estimated to 52% between 1982 and 1996. Strong negative net balances are generally measured, particularly during the ENSO events of the Pacific. During the 1991-1997 period, the cumulated net balances appear to be negative (-5972 mm of we) and this evolution can be related in part with the constant negative South Oscillation in the Pacific (excepted in 1996-97). By extrapolation of the present tendency, it can be assumed that the glacier might disappear completely in the two next decades.

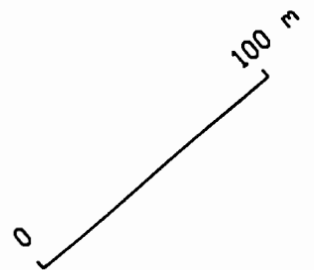
The net balances of the 2 last cycles were characterized by contrasted situation : 1. 1995-96 was very negative (ENSO context), due to very high ablation rates recorded in October (800 mm of we) and a net balance which never has been positive during the wet season ; 2. 1996-97 was more equilibrated (positive South Oscillation), but the long accumulation period (December-April) did not compensated the high ablation rates of the beginning of the cycle (September-October).

REFERENCE

Francou, B., Ramirez, E., Mendoza, J., Guereca, J., Miranda, G. and Noriega, L., 1998. El Glaciar de Chacaltaya (Cordillera real, Bolivia). Investigaciones Glaciológicas (1991-1997). *Informe ORSTOM, 56, La Paz, Bolivia.*



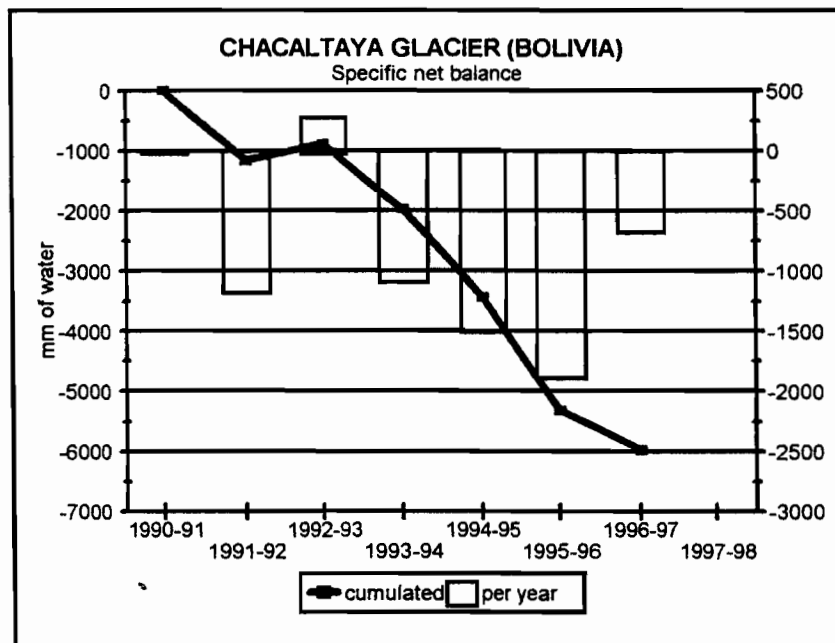
○ ablation stakes



GENERAL INFORMATION ABOUT CHACALTAYA GLACIER

year	B _n (1)	ΣB _n (2)	A (3)	ELA (4)	AAR (5)	Prec. (6)	Frente (7)	Frente (8)
1991-92	-1166	-1166		5371	0		-5.0	-5.0
1992-93	277	-889		5180	83		-4.7	-9.7
1993-94	-1080	-1969	1790	5359	3	710	-4.6	-14.3
1994-95	-1470	-3439	2160	5368	2	690	-17.6	-31.9
1995-96	-1874	-5313	2489	5454	0	615	-24.4	-56.3
1996-97	-659	-5972	1459	5322	10	800	0	-56.3

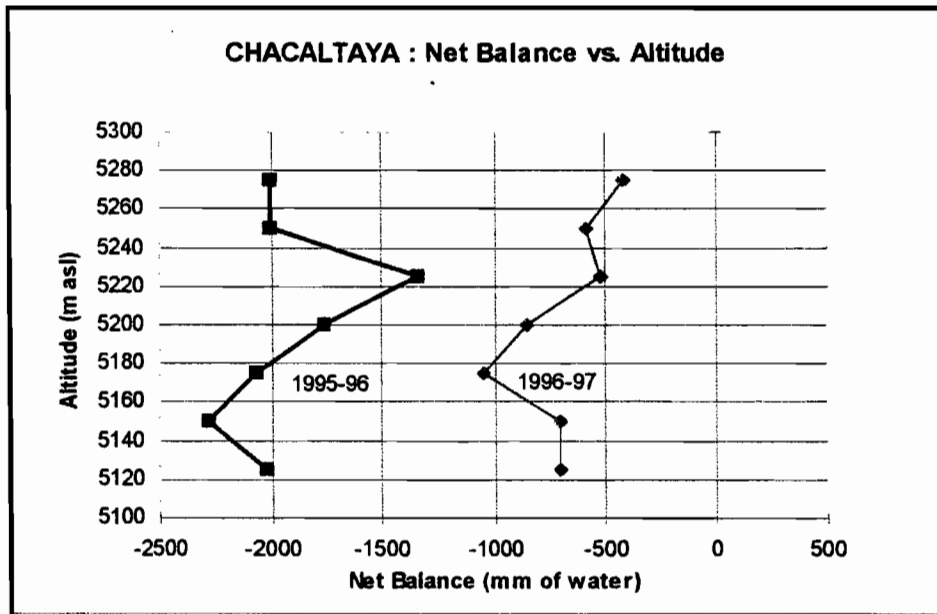
1. specific net balance (mm of we)
2. ΣB_n : cumulated (1)
3. specific ablation (A) : A = P - B_n (mm of we)
4. Equilibrium Line Altitude (m asl)
5. Accumulation Area Ratio (%)
6. precipitation (P) near the glacier (P7) (mm).
7. movement of the terminus (m).
8. cumulated (7)



For 1991-97, the total loss of Chacaltaya is 6000 mm we (1000 mm year)

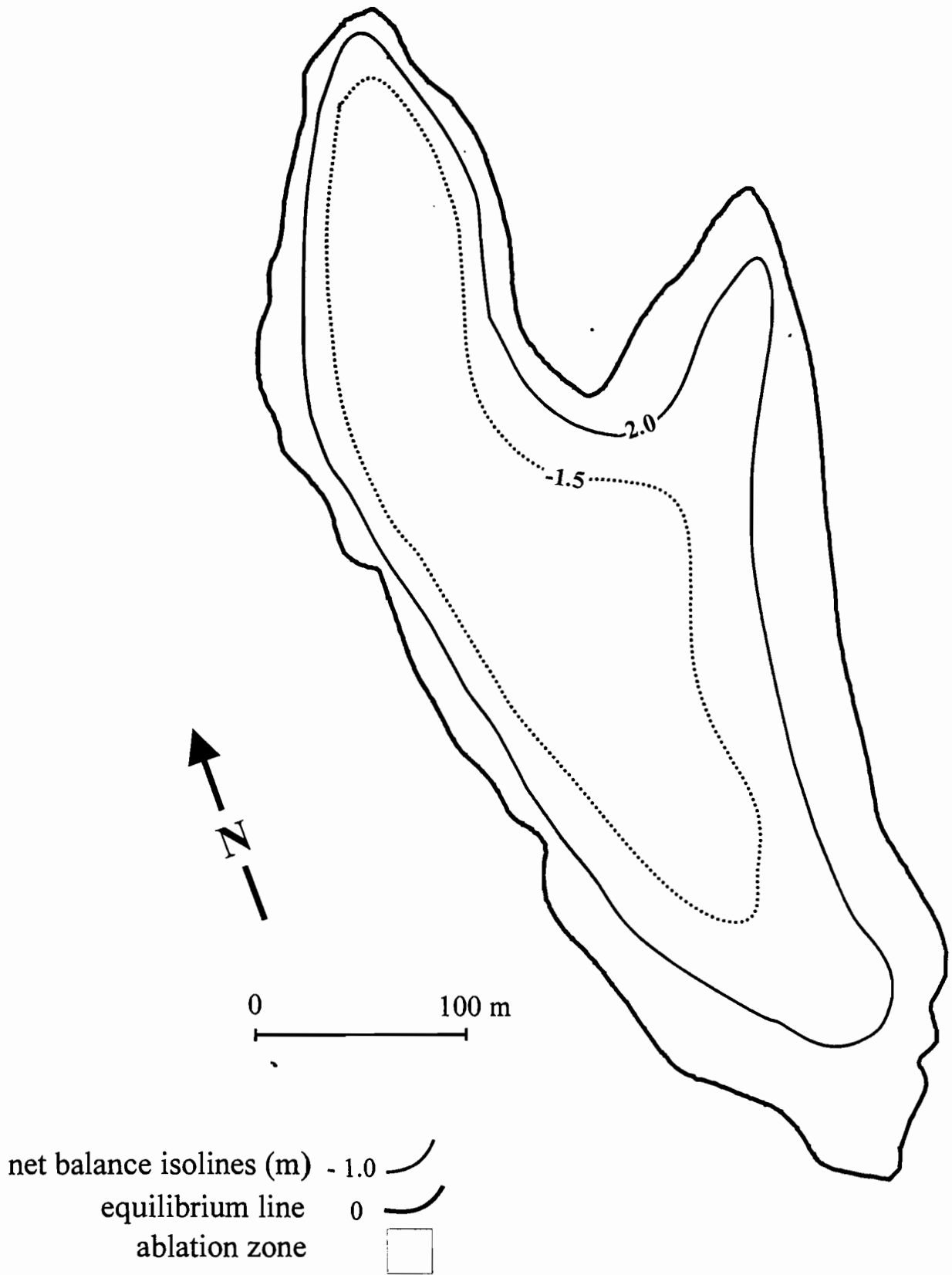
NET BALANCE vs. ALTITUDE

ALT.	95-96	96-97
5275	-2007	-420
5250	-2007	-577
5225	-1341	-519
5200	-1760	-852
5175	-2070	-1047
5150	-2271	-699
5125	-2025	-699



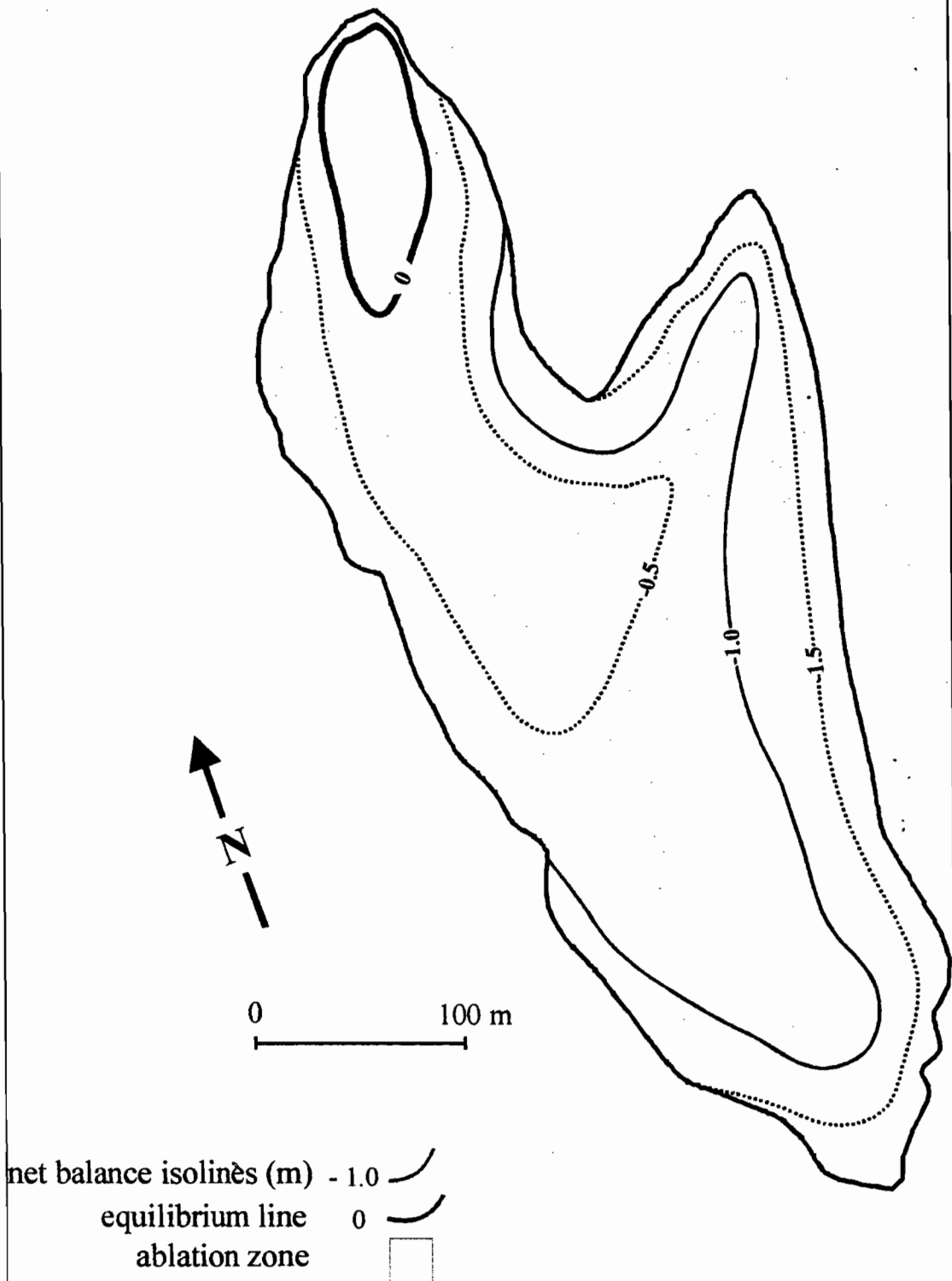
CHACALTAYA GLACIER (BOLIVIA)

Net balance map 1995-96

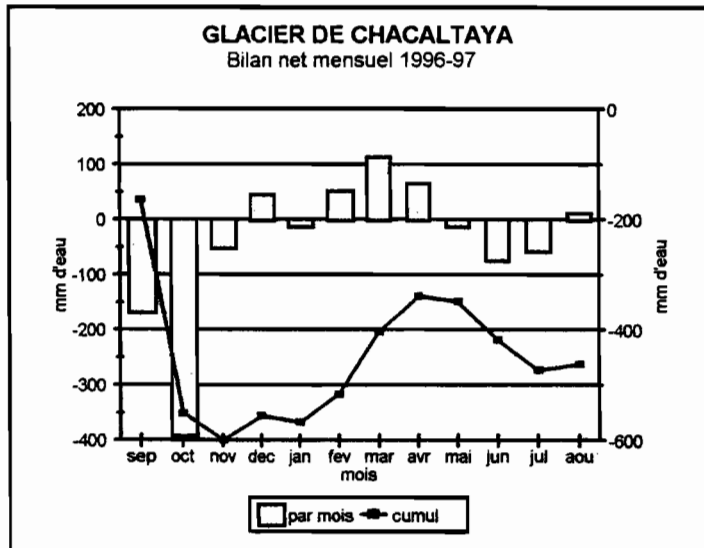
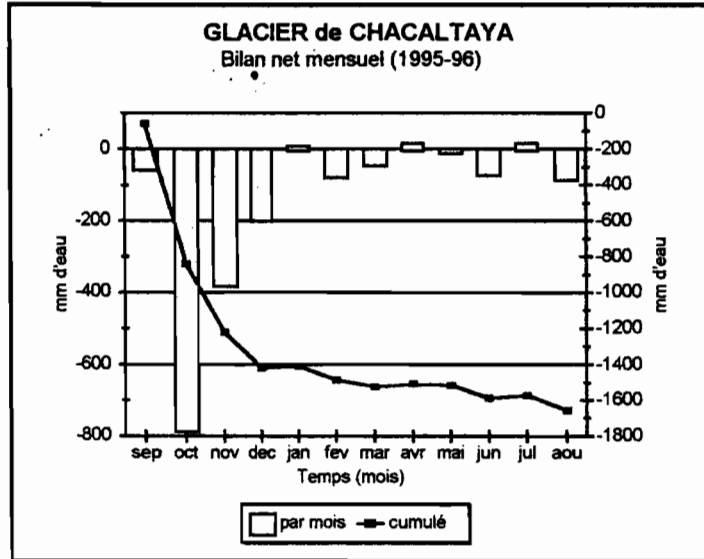


CHACALTAYA GLACIER (BOLIVIA)

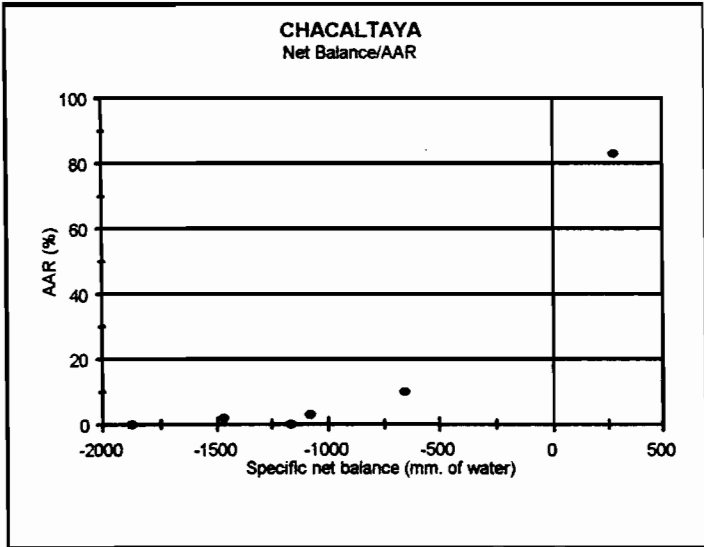
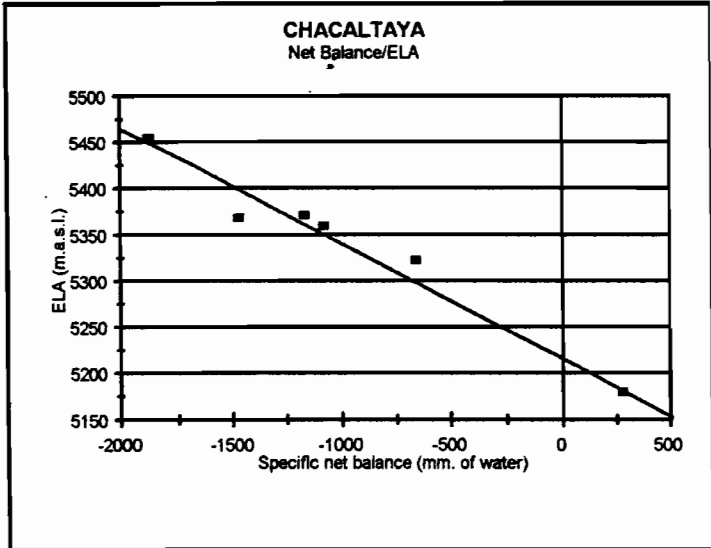
Net balance map 1996-97



NET BALANCE EVOLUTION AT MONTH SCALE (1995-1997)



NET BALANCE vs. ELA and AAR



2. ECUADOR

ANTIZANA 15α GLACIER (Antizana Volcano)

Antizana 15α glacier (0°28'30"S, 78°08'55"W) is a slope/ice cap glacier located 40 km East of the Quito city, at the head of an important hydraulic system which supplies water to the city. It is a 2.0 km long glacier, between 4800 and 5760 m asl and its surface extends to 0.353 km². Exposition is NW and the summit forms the extensive ice cap which covers the summit of Antizana. This volcano is considered as still active.

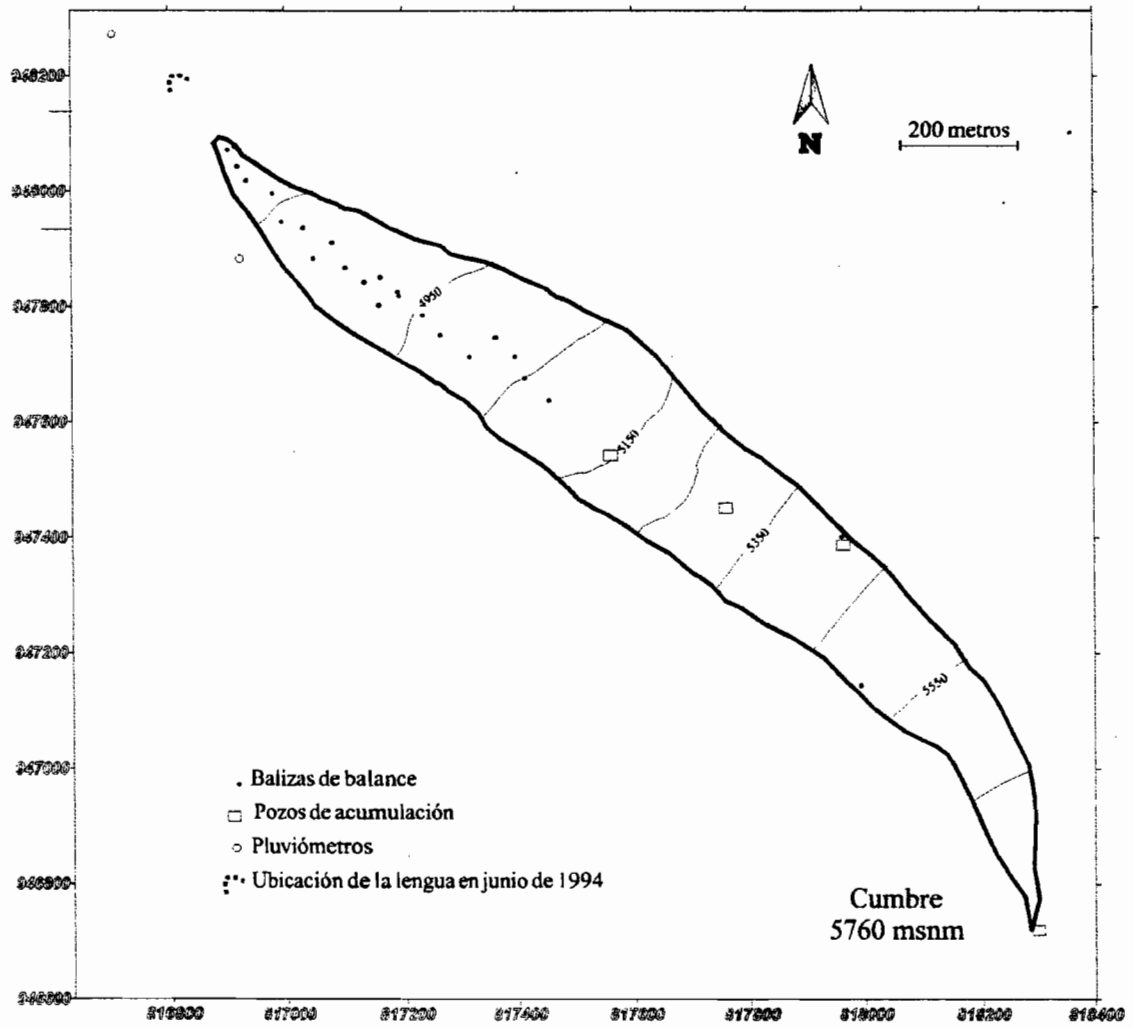
Mean temperature at the ELA₀ (probably between 5000-5100 m asl) is -0.5/-1°C and mean precipitation (3 years) near the glacier is 800 mm/year. Ablation occurs all the year round, with a maximum during the "little summer" of November-March. But the variability is important, depending of precipitation distribution, which is highly variable.

The 2 last balances were negative, particularly 1997, due to unusual warm temperature and irregular precipitation, a situation related to the strong ENSO event that has occurred in the Pacific from May. Since June 1994 to December 1997, the glacier terminus has retreated by 150 m.

REFERENCE

Hastenrath, S., 1981. Glaciation of Ecuadorian Andes. *A.A.Balkema, Rotterdam.*

Sémiond, H., Francou, B., Ayabaca, E., de la Cruz, A., Chango, R., 1998 : El Glaciar 15 del Antizana (Ecuador). Investigaciones glaciológicas 1994-1997. *Informe NGT-ORSTOM, Quito.*

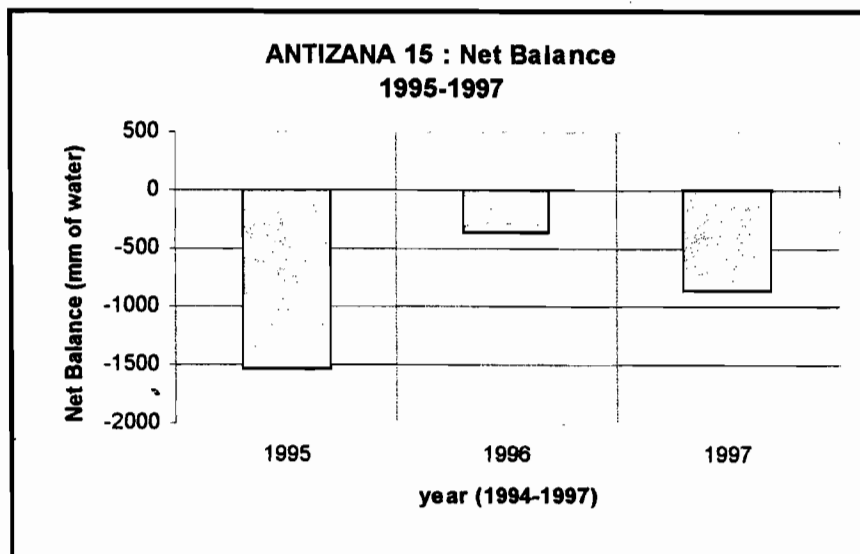


Map of Antizana 15α Glacier (1996)

GENERAL INFORMATION ABOUT ANTIZANA 15α GLACIER

Year (1)	B _n (2)	ΣB _n (3)	A (4)	B _{ter} (5)	B _{sum} (6)	ELA (7)	AAR (8)	Prec. (9)	Term. (10)
1995	-1543	-1543	2253	-7700	+654	5250	45	710	-28.2
1996	-359	-1802	1189	-4530	+826	5100	57	830	-27.4
1997	-864	-2466		-6831	+870	5130	50	-	-35.3

- (1) Hydrologic year (January-December)
- (2) Specific Net Balance (in mm of water)
- (3) Cumulated Specific Net Balance (in mm of water)
- (4) Specific ablation : $A = P - B_n$ (in mm of water)
- (5) Balance near the front (4800 m asl) (in mm of water)
- (6) Balance on the summit (5750 m asl) (in mm of water)
- (7) Equilibrium Line Altitude (in metres asl)
- (8) Accumulation Area Ratio (in %)
- (9) Precipitation near the glacier : $P = [(P_1 + P_2)/2]$ (in mm of water)
- (10) Movements of the terminus (in metres)



Total loss for the period : 2766 mm of we (822 mm year)

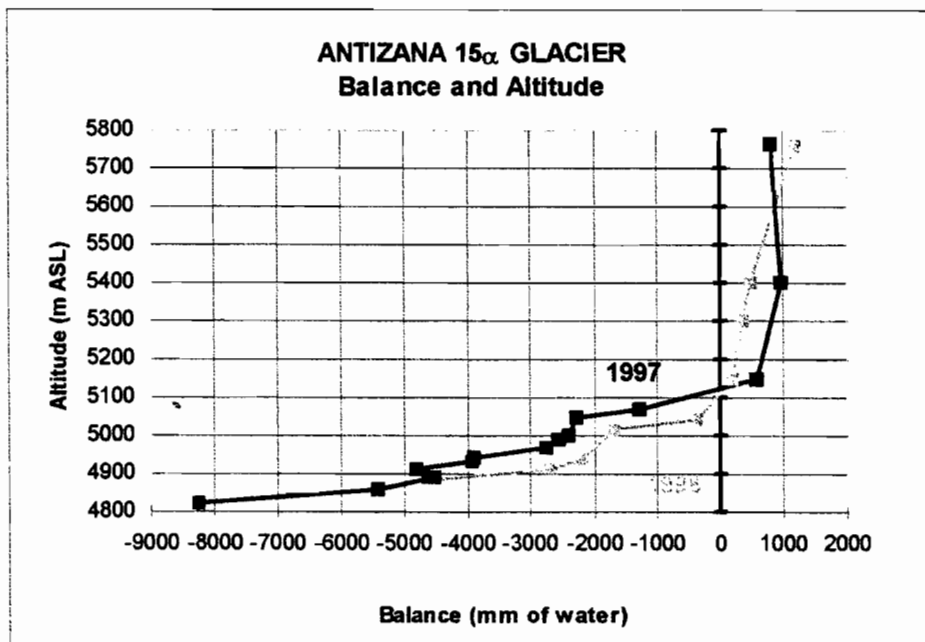
NET BALANCE vs. ALTITUDE

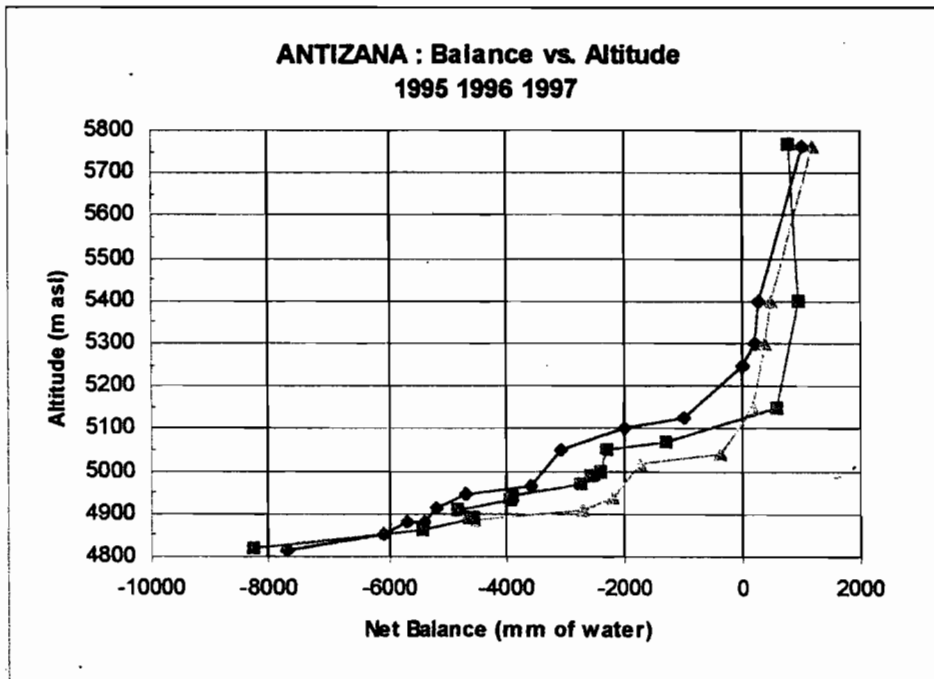
1995		1996		1997	
balance	alt.	balance	alt.	balance	alt.
1030	5760	1183	5760	780	5765
278	5400	468	5400	960	5400
200	5300	358	5300	564	5150
0	5250	186	5150	-1281	5070
-1000	5125	-380	5042	-2294	5050
-2000	5100	-1717	5016	-2410	5000
-3068	5048	-2207	4939	-2560	4990
-3584	4966	-2700	4910	-2745	4970
-4673	4948	-4532	4886	-3885	4940
-5179	4913			-3942	4930
-5385	4880			-4824	4910
-5686	4882			-4626	4890
-6098	4854			-4545	4890
-7703	4812			-5418	4860
				-8244	4820

ELA=5250

ELA=5100

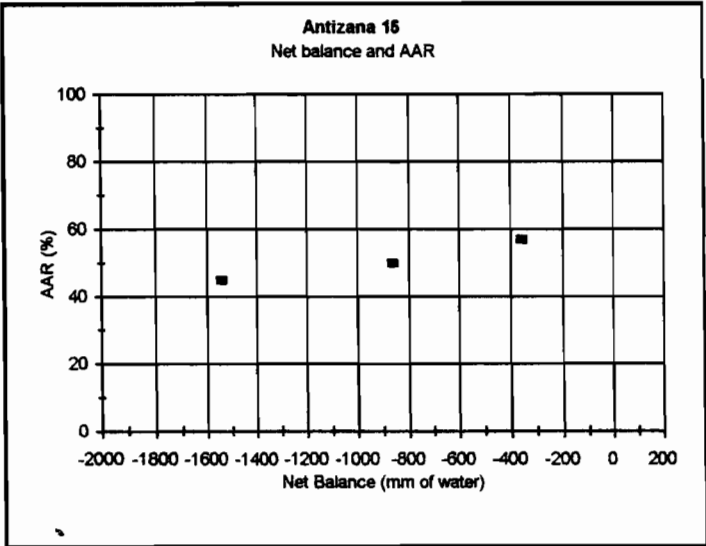
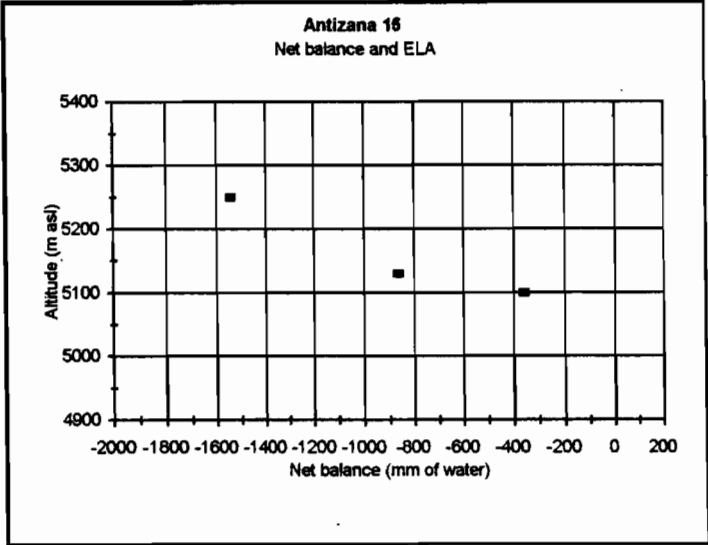
ELA=5130





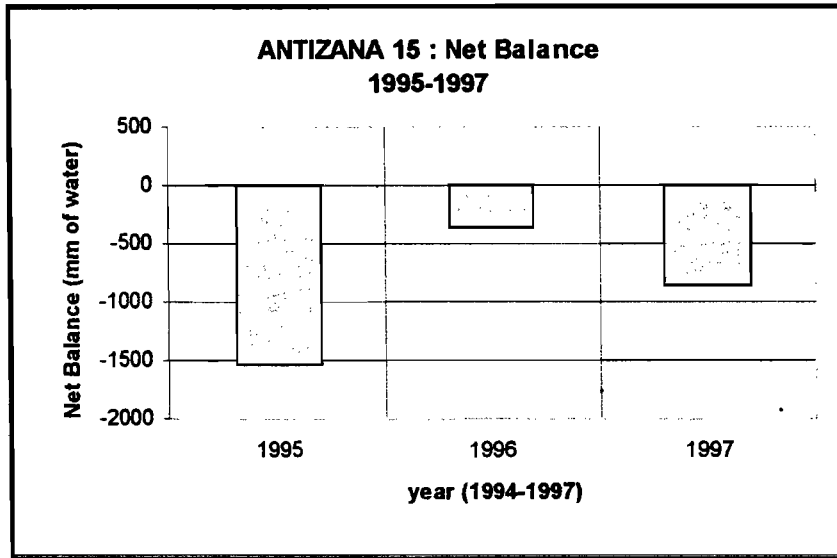
1995 (lozenge), 1996 (triangle), 1997 (square).
The 1995 cycle was corrected between 5100 and 5300 m asl using the mass balance linear model
(by extrapolation of 1996 and 1997 curves)

NET BALANCE vs. ELA and AAR

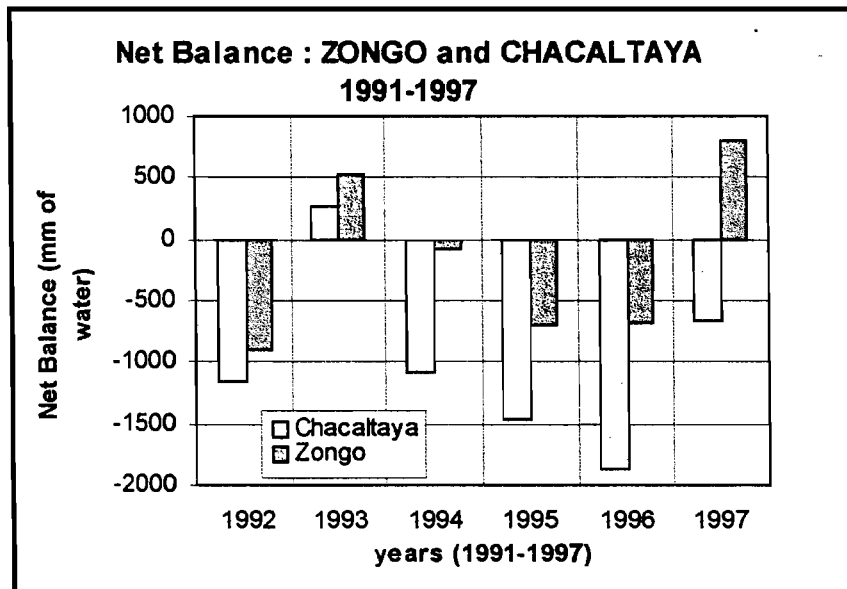


THE NET BALANCE

COMPARISON BETWEEN ZONGO, CHACALTAYA and ANTIZANA



Hydrologic year : January-December
Total loss for the 3 last years : 865 mm we



Hydrologic year : September-August
Total loss for the 3 last years :
Chacaltaya : 4000 mm we ; Zongo : 580 mm we

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