GLACIER MASS BALANCE BULLETIN

Bulletin No. 1 (1988 - 1989)

A contribution to the
Global Environment Monitoring System (GEMS)
and the
International Hydrological Programme

Compiled by the World Glacier Monitoring Service

IAHS (ICSI) - UNEP - UNESCO
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Edited by

Wilfried Haeberli and Eveline Herren

Laboratory of Hydraulics, Hydrology and Glaciology
Swiss Federal Institute of Technology (ETH)
Zurich

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The cover picture shows Storglaciären in Sweden, where the world's longest series of continuous mass balance measurements based on the direct glaciological method is available.

PREFACE

Fluctuations of glaciers are caused by changes in the climate system. They also strongly affect regional hydrology of mountain areas as well as the world's sea level. The general shrinkage of mountain glaciers following the end of the Little Ice Age is a major reflection of the fact that rapid secular changes in the energy balance of the earth surface are taking place at a global scale. This glacier signal of atmospheric warming not only concerns the recent past but may also be considered to be one of the key parameters for early detection of possible man-induced warming in the near future. Within the complex chain of processes linking climate and glaciers, glacier mass balances are most directly related to changes in atmospheric conditions. They are therefore of special interest in view of climatic trends which could exceed the band-width of historical variations within the coming years and decades.

As a contribution to the Global Environment Monitoring System (GEMS) of the United Nations Environment Programme (UNEP) and the International Hydrological Programme (IHP) of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the World Glacier Monitoring Service (WGMS) of the International Commission on Snow and Ice (ICSI/IAHS) as one of the permanent services of the Federation of Astronomical, Geophysical and Data Analysis Services (FAGS/ICSU) collects and publishes worldwide standardized glacier data. The following series of reports on the variations of glaciers in space and time are already published:

- Fluctuations of Glaciers 1959 - 1965 (Vol. 1, P. Kasser)
- Fluctuations of Glaciers 1965 - 1970 (Vol. 2, P. Kasser)
- Fluctuations of Glaciers 1970 - 1975 (Vol. 3, F. Müller)
- Fluctuations of Glaciers 1975 - 1980 (Vol. 4, W. Haeberli)
- Fluctuations of Glaciers 1980 - 1985 (Vol. 5, W. Haeberli / P. Müller)

- World Glacier Inventory - Status 1988 (W. Haeberli / H. Bösch / K. Scherler / G. Østrem / C.C. Wallén)

Vol. 6, Fluctuations of Glaciers 1985 - 1990, is now being prepared; publication and distribution is planned for winter 1992/93.

The present Glacier Mass Balance Bulletin (MBB) compiled by the World Glacier Monitoring Service with the help of its national correspondents is the first issue of a long-planned series of publications. Based on recommendations by an ICSI working group consisting of M. Kuhn (Austria, chairman), W. Haeberli (Switzerland, WGMS representative), L. Reynaud (France) and B. Wold (Norway), the new bulletin is designed to speed up and facilitate access to information concerning glacier mass balances by reporting measured values from selected reference glaciers at a 2-yearly interval. In addition, the results of glacier mass balance measurements are made more easily understandable through the use of graphic presentations rather than purely numerical data. Thus, the Glacier Mass Balance Bulletin complements the Fluctuations series, where the full collection of digital data including the more numerous observations of glacier length variation can be found. It should be kept in mind also that this first and somewhat preliminary reporting of mass balance measurements may require slight corrections and updates at a later time. Corrected and updated information can be found in the MBBs to follow as well as in the Fluctuations series.

The first bulletin reports the results for the balance years 1987/88 and 1988/89. The complete set of earlier mass balance data used to compile the present bulletin will soon be made available in the first issue of another, less regularly appearing publication series: the "World Glacier Monitoring - Updates and Assessments". In particular, the still unpublished data for the balance years 1985/86 and 1986/87 will be presented there as well as in Vol. 6 of the Fluctuations series. The second Glacier Mass Balance Bulletin will cover the years 1989/90 and 1990/91.

Zurich, March 1991

Wilfried Haeberli
Director
World Glacier Monitoring Service

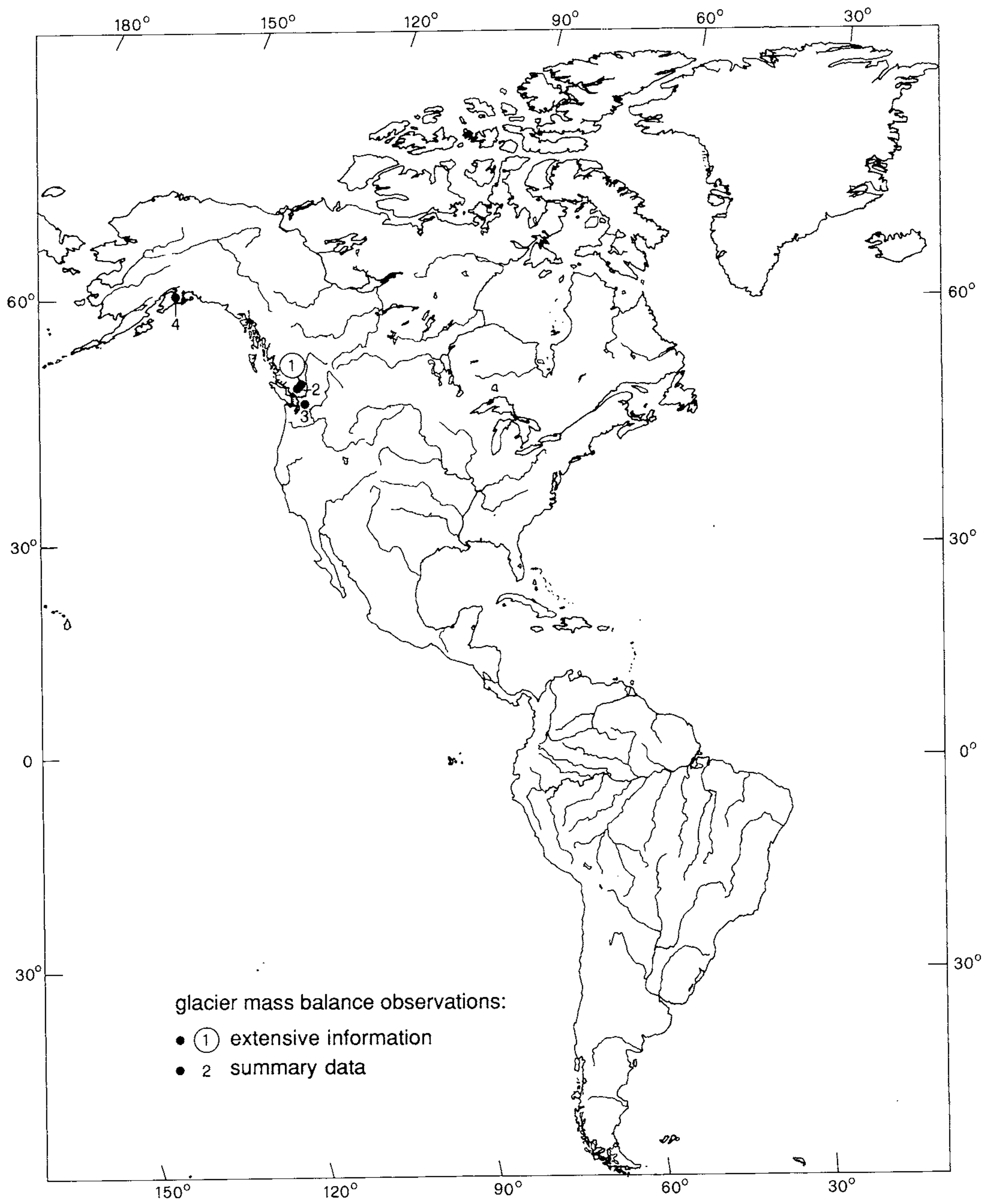
CONTENTS

1. INTRODUCTION

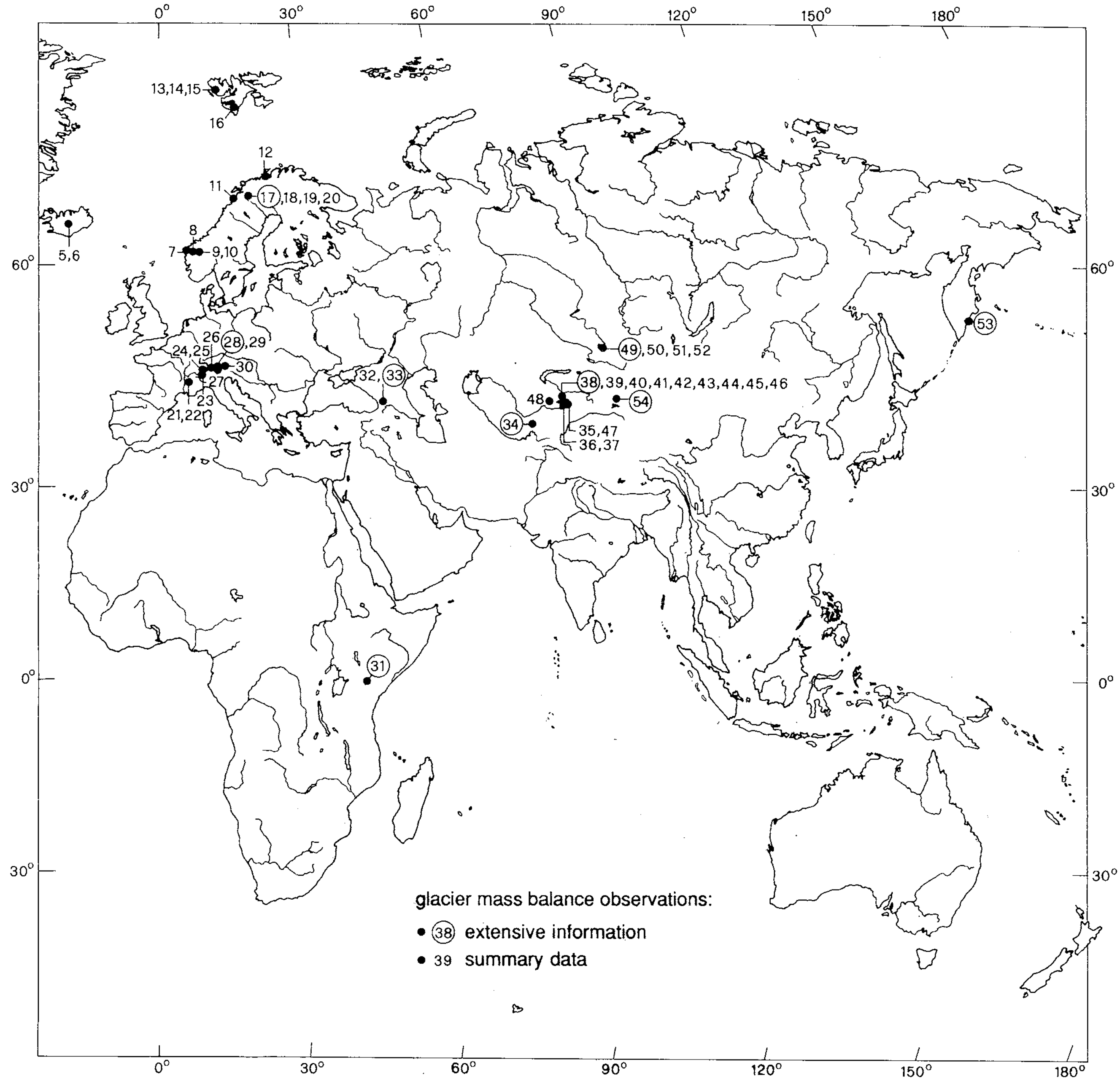
Two main categories of data - summary information and extensive information - are being reported in the Glacier Mass Balance Bulletin. Summary information on specific balance, cumulative specific balance, accumulation area ratio and equilibrium line altitude is given for 54 glaciers. Such information gives a regional overview. In addition, extensive information such as balance maps, balance/altitude diagrams, relations between accumulation area ratios, equilibrium line altitudes and balance, as well as a short explanatory text with a photograph, are presented for 10 selected glaciers with existing long and complete series of direct glaciological measurements. These long time series based on high density networks of stakes and firn pits are especially valuable for analyzing processes of mass and energy exchange at glacier/atmosphere interfaces and, hence, for interpreting climate/glacier relations.

The glaciers are marked on the following world map (next pages).

No.	Glacier Name	Country	Location	Coordinates	
1	Place	Canada	Coast Mtns.	50° 26' N	122° 36' W
2	Helm	Canada	Coast Mtns.	49° 58' N	123° 00' W
3	South Cascade	USA	N Cascades Mtns.	48° 22' N	121° 03' W
4	Wolverine	USA (Alaska)	Kenai Mtns. Alaska	60° 24' N	148° 55' W
5	Hofsjökull North	Iceland	Central Iceland	64° 57' N	18° 55' W
6	Hofsjökull East	Iceland	Central Iceland	64° 40' N	18° 35' W
7	Austre Brøggerbreen	N-Spitsbergen	Svalbard	78° 53' N	11° 50' E
8	Midtre Lovénbreen	N-Spitsbergen	Svalbard	78° 53' N	12° 04' E
9	Kongsvegen	N-Spitsbergen	Svalbard	78° 50' N	13° E
10	Hansbreen	N-Spitsbergen	Svalbard	77° 05' N	15° 40' E
11	Ålfotbreen	Norway	South Norway	61° 45' N	5° 39' E
12	Nigardsbreen	Norway	South Norway	61° 43' N	7° 08' E
13	Storbreen	Norway	South Norway	61° 34' N	8° 08' E
14	Gråsubreen	Norway	South Norway	61° 39' N	8° 36' E
15	Engabreen	Norway	North Norway	66° 39' N	13° 51' E
16	Langfjordjøkulen	Norway	North Norway	70° 07' N	21° 45' E
17	Storglaciären	Sweden	North Sweden	67° 54' N	18° 34' E
18	Rabots glaciär	Sweden	North Sweden	67° 54' N	18° 33' E
19	Tarfalaglaciären	Sweden	North Sweden	67° 56' N	18° 39' E
20	Riukojietna	Sweden	North Sweden	68° 05' N	18° 05' E
21	Sarennes	France	Alps	45° 07' N	6° 10' E
22	Saint Sorlin	France	Alps	45° 11' N	6° 10' E
23	Gries	Switzerland	Alps	46° 26' N	8° 20' E
24	Limmern	Switzerland	Alps	46° 49' N	8° 59' E
25	Plattalva	Switzerland	Alps	46° 50' N	8° 59' E
26	Silvretta	Switzerland	Alps	46° 51' N	10° 05' E
27	Careser	Italy	Alps	46° 27' N	10° 42' E



No.	Glacier Name	Country	Location	Coordinates	
28	Hintereisferner	Austria	Alps	46° 48' N	10° 46' E
29	Kesselwandferner	Austria	Alps	46° 50' N	10° 48' E
30	Sonnblickkees	Austria	Alps	47° 08' N	12° 36' E
31	Lewis	Kenya	Mount Kenya	0° 09' S	37° 18' E
32	Garabashi	USSR	Caucasus	43° 12' N	42° 30' E
33	Djankuat	USSR	Caucasus	43° 12' N	42° 46' E
34	Abramov	USSR	Pamir-Alai	39° 40' N	71° 30' E
35	Karabatkak	USSR	Tien Shan	42° 08' N	78° 16' E
36	No. 131	USSR	Tien Shan	41° 53' N	77° 41' E
37	West. Suyok	USSR	Tien Shan	41° 47' N	77° 45' E
38	Tuyuksu	USSR	Tien Shan	43° 00' N	77° 06' E
39	Igly Tuyuksu	USSR	Tien Shan	43° 00' N	77° 06' E
40	Molodyozhniy	USSR	Tien Shan	43° 00' N	77° 06' E



No.	Glacier Name	Country	Location	Coordinates	
41	Kosmodemyanskaya	USSR	Tien Shan	43° 00' N	77° 06' E
42	Partizan	USSR	Tien Shan	43° 00' N	77° 06' E
43	Ordzhonikidze	USSR	Tien Shan	43° 00' N	77° 06' E
44	Mayakovskiy	USSR	Tien Shan	43° 00' N	77° 06' E
45	Mametova	USSR	Tien Shan	43° 00' N	77° 06' E
46	Visyachie 1-2	USSR	Tien Shan	43° 00' N	77° 06' E
47	Sary-Tor	USSR	Tien Shan	41° 50' N	78° 11' E
48	Golubin	USSR	Tien Shan	42° 27' N	74° 30' E
49	Maliy Aktru	USSR	Altai	50° 05' N	87° 45' E
50	Leviy Aktru	USSR	Altai	50° 05' N	87° 41' E
51	Praviy Aktru	USSR	Altai	50° 05' N	87° 44' E
52	Vodopadniy	USSR	Altai	≈ 50° 01' N	≈ 87° 47' E
53	Kozelskiy	USSR	Kamchatka	53° 14' N	158° 49' E
54	Urumqihe S. No. 1	China	Tien Shan	43° 05' N	86° 49' E

2. SUMMARY DATA

Specific net balance (b), equilibrium line altitude (ELA) and accumulation area ratio (AAR) of all glaciers from the balance years 1987/88 and 1988/89 are presented in Part 2.1. The AAR values are given as integer values only.

Values for ELA_0 and AAR_0 are given in addition. They represent the calculated ELA and AAR values for a zero net balance, i.e. a hypothetical steady state. All values since the beginning of mass balance measurements were used for this calculation on each glacier. Minimum sample size for regression was defined as 6 ELA or AAR values. Reconstructed values were excluded from statistical regression. Some of the observed glaciers can entirely become ablation or accumulation areas in extreme years. Corresponding AAR values of 0 or 100% as well as ELA values outside the altitude range of the observed glaciers were excluded, too, in the calculation of AAR_0 and ELA_0 values.

The graphs in the second part of this chapter (2.2) present the development of cumulative specific net balance over the whole observation period for each glacier where two or more net balances were calculated.

The complete data set used to calculate the ELA_0 and the AAR_0 values and which forms the basis of the cumulative specific net balance graphs will be made available in the first issue of the new publication series "World Glacier Monitoring - Updates and Assessments".

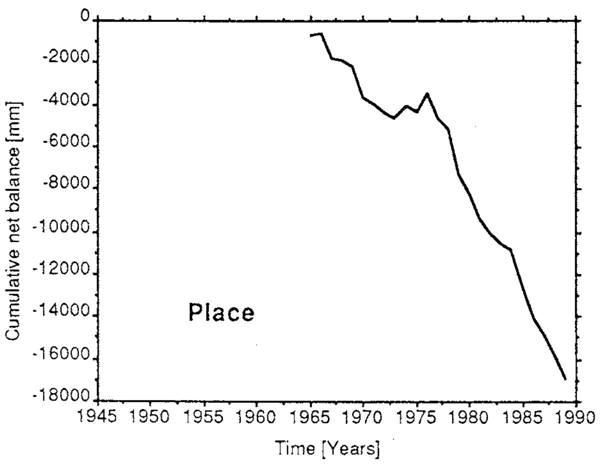
2.1 SUMMARY TABLE (NET BALANCE, ELA, ELA_0, AAR, AAR_0)

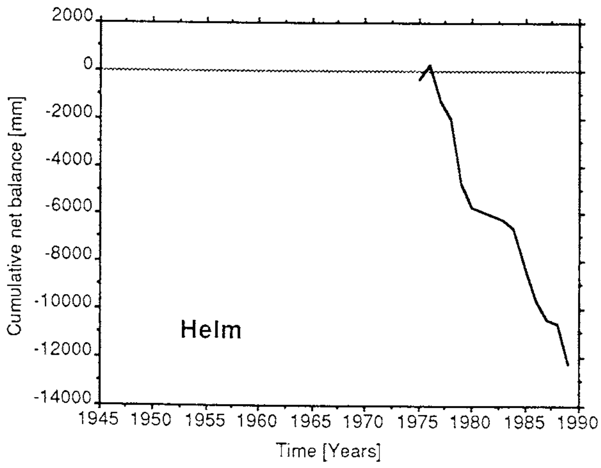
Glacier	Country	b_{88} [mm]	b_{89} [mm]	ELA_{88} [m a.s.l.]	ELA_{89} [m a.s.l.]	ELA_0 [m a.s.l.]	AAR_{88} [%]	AAR_{89} [%]	AAR_0 [%]
Place	Canada	- 969	-1040	2300	2250	2079	25	18	50
Helm	Canada	- 150	-1670	2100	2150	2027	7	6	37
South Cascade	USA	-1640	- 710						
Wolverine	USA-Alaska	-1400	-1800	1370	1440		26	13	
Hofsjökull North	Iceland	- 740	580				39	58	
Hofsjökull East	Iceland		1000		1020			70	
Austre Brøggerbreen	N-Spitsbergen	- 520	- 450	440	440	265	15	15	58
Midtre Lovénbreen	N-Spitsbergen	- 490	- 240	425	375	295	27	41	59
Kongsvegen	N-Spitsbergen	- 50	- 150	525	570		63	53	
Hansbreen	N-Spitsbergen		- 530		325			45	
Ålfotbreen	Norway	-2480	2930	>1380	1030	1203	0	94	54
Nigardsbreen	Norway	- 890	3470	1660	1175	1564	37	94	58
Storbreen	Norway	- 950	1200	1970	1550	1703	6	90	62
Gråsubreen	Norway	- 580	450	2195		2128	10	65	34
Engabreen	Norway	-1790	3170	1400	890	1168	7	93	56
Langfjordjøkulen	Norway		- 570		825			53	
Storglaciären	Sweden	- 840	1240	1564	1374	1458	27	66	46
Rabots glaciär	Sweden	-1050	460	1540	1335	1364	13	60	51
Tarfalaglaciären	Sweden	-1290	1230	1730	1390		0	100	
Riukojietna	Sweden	- 910	890	1525	1150		0	100	
Sarennes	France	- 690	-2590						
Saint Sorlin	France	310	-2490						
Gries	Switzerland	- 950	-1020	3120	3140	2832	7	6	56
Limmern	Switzerland	-220	- 308	2780	2770	2695	42	44	51
Plattalva	Switzerland	-310	- 750	2850	2890	2751	23	13	53
Silvretta	Switzerland	-210	- 400	2780	2907	2756	51	25	55
Careser	Italy	-1010	- 820	3398[1]	3275	3094	0	3	50
Hintereisferner	Austria	- 945	- 637	3130	3080	2920	29	38	66
Kesselwandferner	Austria	- 265	- 151	3150	3120	3101	56	66	72
Sonnblickkees	Austria	- 711	252	2875	2715	2739	26	75	60
Lewis[2]	Kenya	-2030	770	>5000	(4730)		0	85	
Garabashi	USSR	270	- 90	3660	3830		74	60	
Djankuat	USSR	520	40	3090	3170	3189	74	66	60
Abramov	USSR	- 10	- 220	4170	4200	4151	56	50	59
Karabatkak	USSR	- 456	- 396	3950	3900		46	52	
No. 131	USSR	- 712	- 354		4200			37	
West. Suyok	USSR		- 499		4300			23	
Tuyuksu	USSR	- 610	- 460	3835	3825	3742	35	37	53
Igly Tuyuksu	USSR	- 600	- 460						
Molodyozhniy	USSR	- 760	- 590						
Kosmodemyanskaya	USSR	- 350	- 220						
Partizan	USSR	160	260						
Ordzhonikidze	USSR	- 300	- 180						
Mayakovskiy	USSR	- 210	- 100						
Mametova	USSR	- 630	- 430						
Visyachie 1-2	USSR	- 490	- 390						
Sary-Tor	USSR	- 453	- 167	4340	4260		27	37	
Golubin	USSR	- 432	- 422	3870	3870	3788	67	67	76
Maliy Aktru	USSR	470	220	3040	3150	3125	83	76	71
Leviy Aktru	USSR	370	30	3070	3180	3153	66	58	59
Praviy Aktru	USSR	310	190	3050	3060	3139	62	61	48
Vodopadniy	USSR	160	100	3130	3160	3190	77	73	64
Kozelskiy	USSR	-1940	- 740	1300	1470	1251	6	24	51
Urumqihe S. No. 1	China	- 642	106	4080	3976	4027	36	66	55

1) above glacier maximum elevation.
2) Note that the balance year here is from March to March and therefore starts half a year earlier than on the other glaciers.

2.2 CUMULATIVE SPECIFIC NET BALANCES

CANADA:





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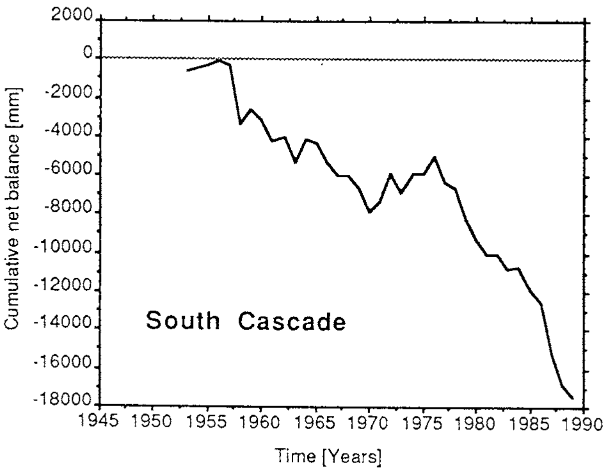

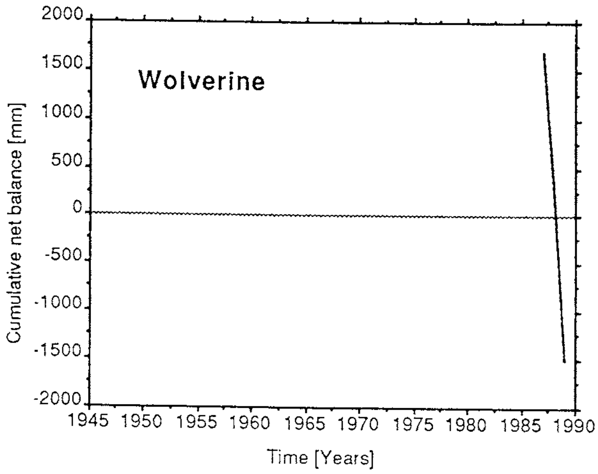

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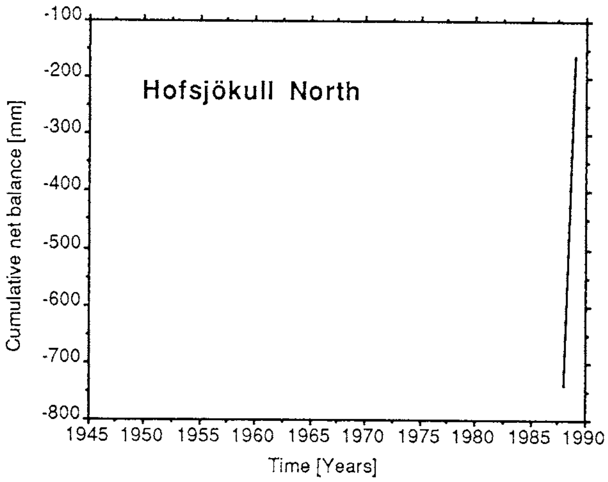

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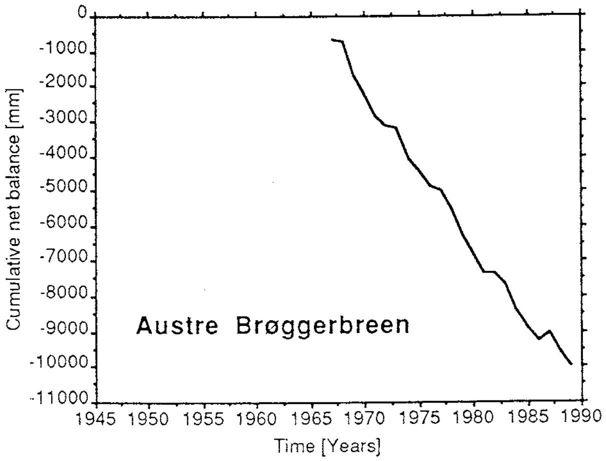

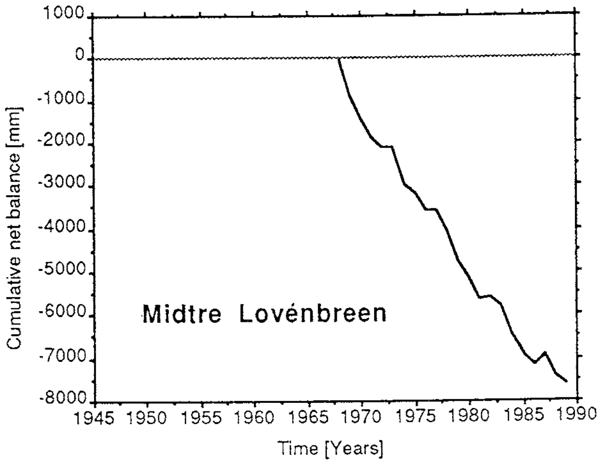

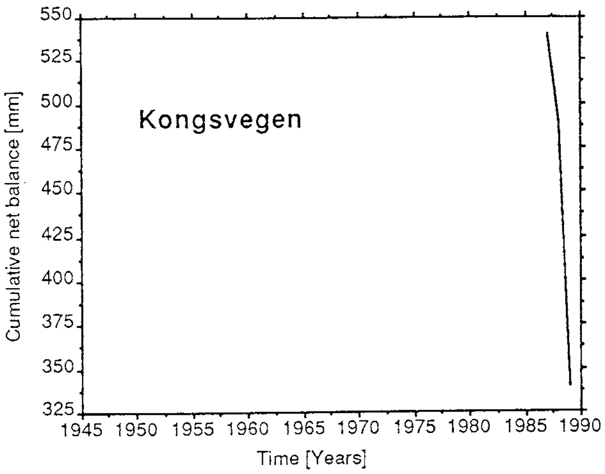

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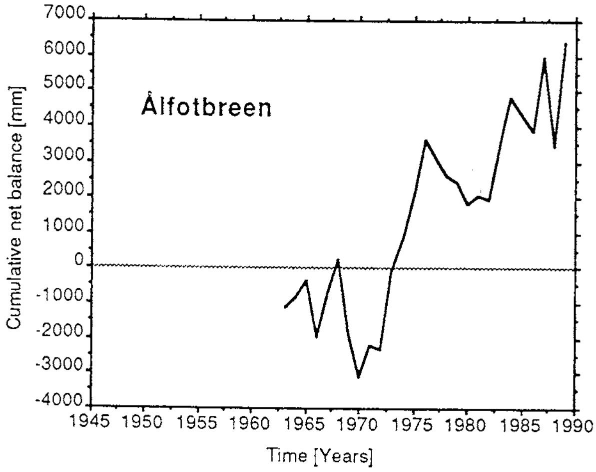
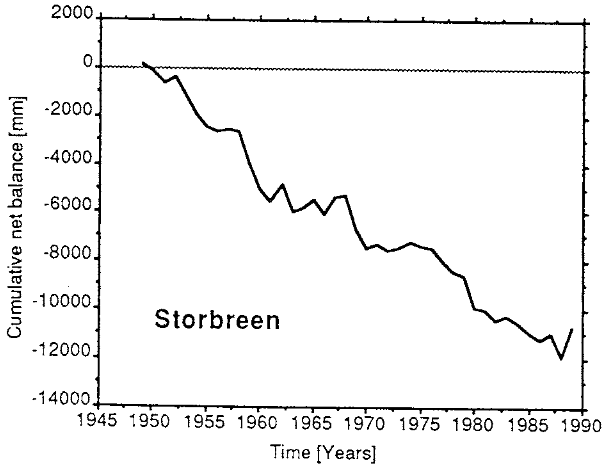

Ålfotbreen
Cumulative net balance [mm]
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Storbreen
Cumulative net balance [mm]
2000
0
-2000
-4000
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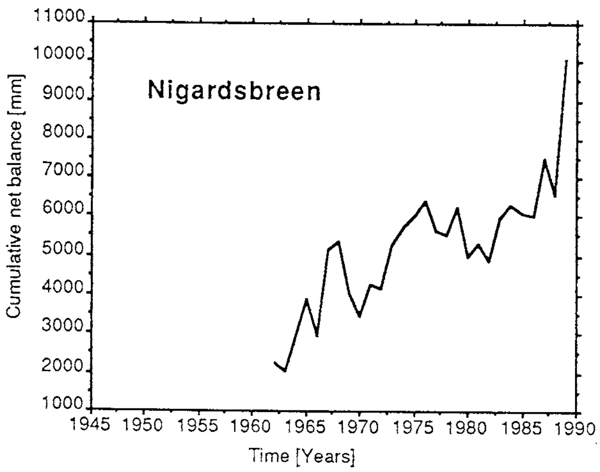
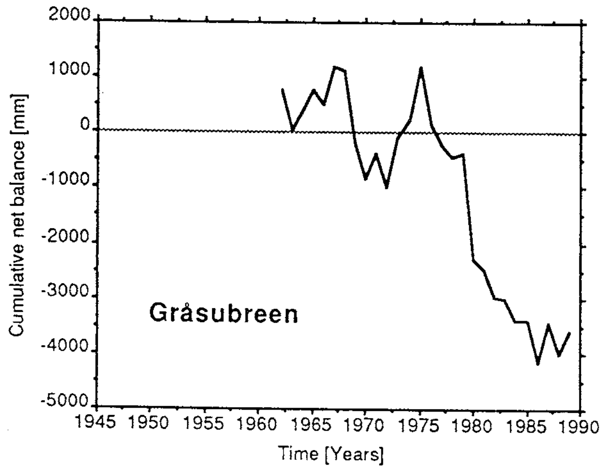
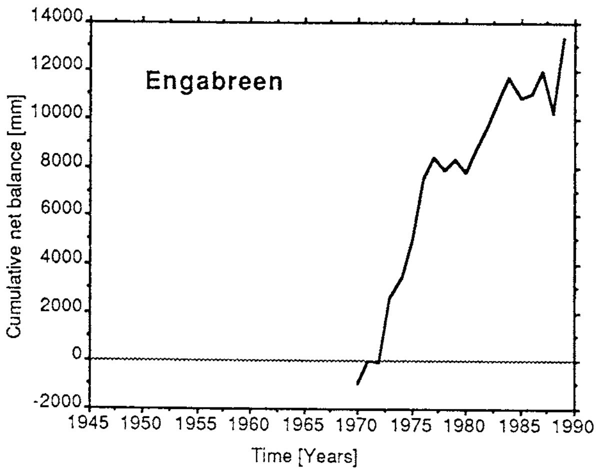
-8000
-10000
-12000
-14000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Nigardsbreen
Cumulative net balance [mm]
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Gråsubreen
Cumulative net balance [mm]
2000
1000
0
-1000
-2000
-3000
-4000
-5000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Engabreen
Cumulative net balance [mm]
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12000
10000
8000
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4000
2000
0
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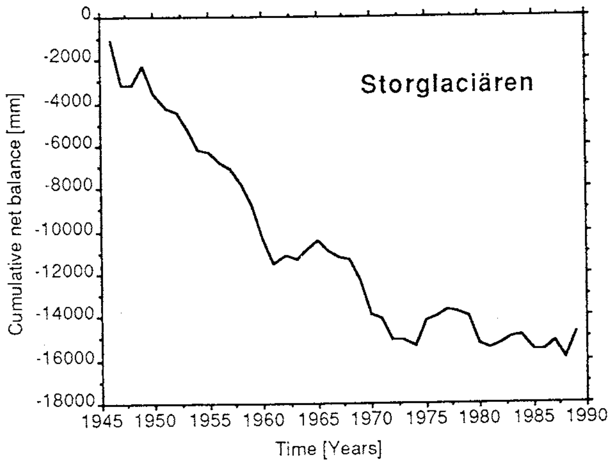
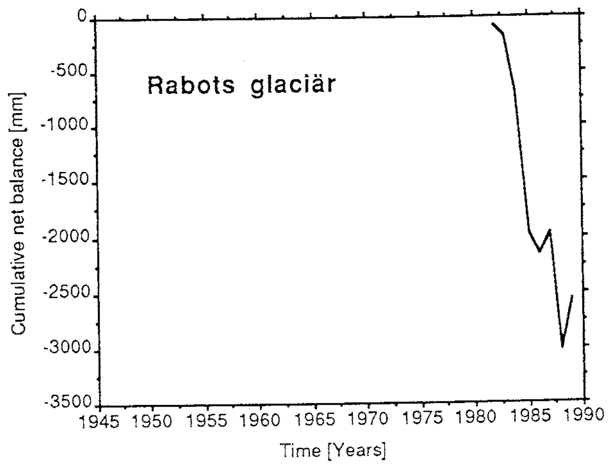
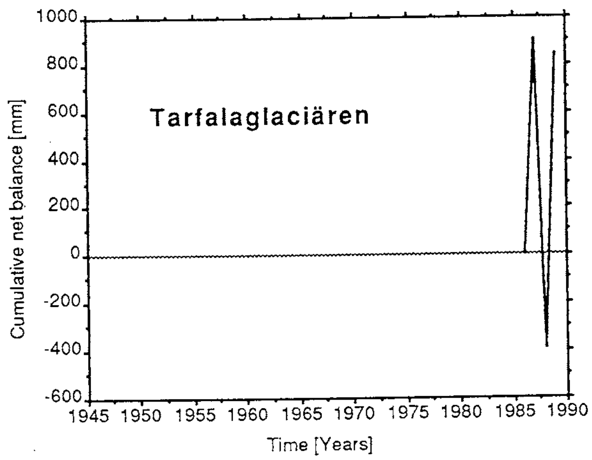
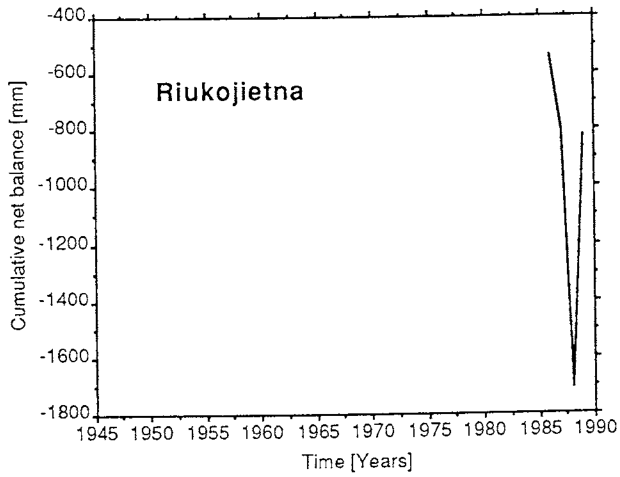
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

SWEDEN:









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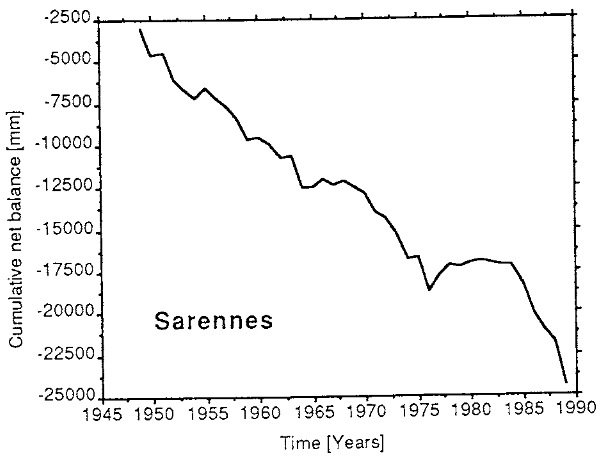

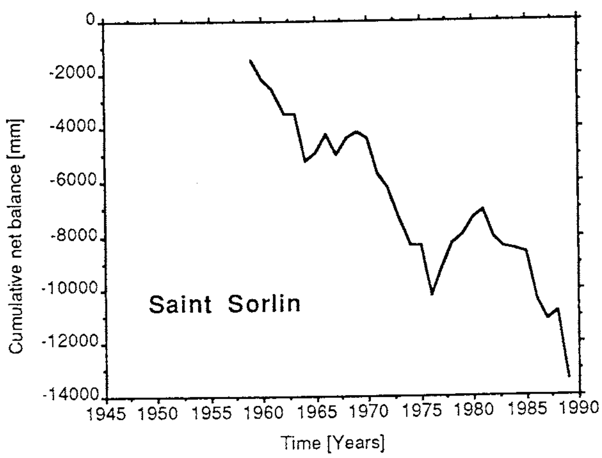

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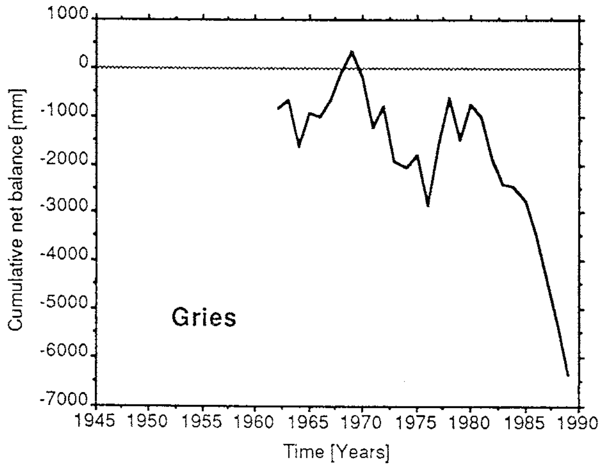

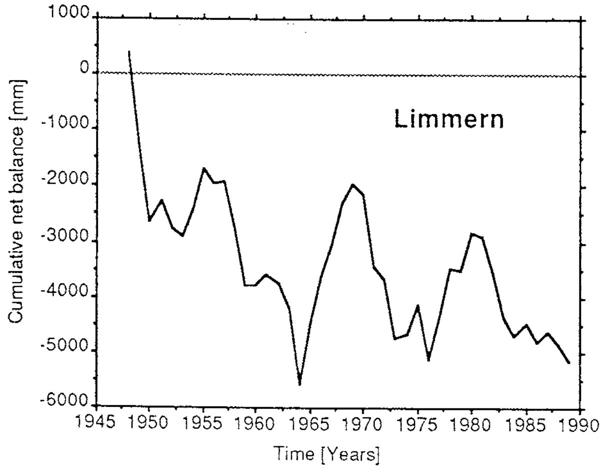

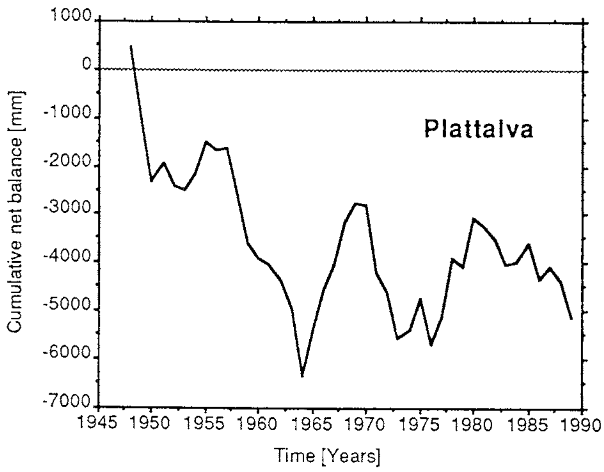

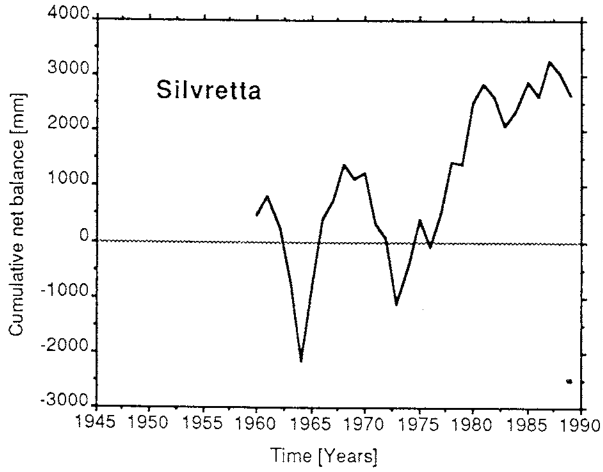

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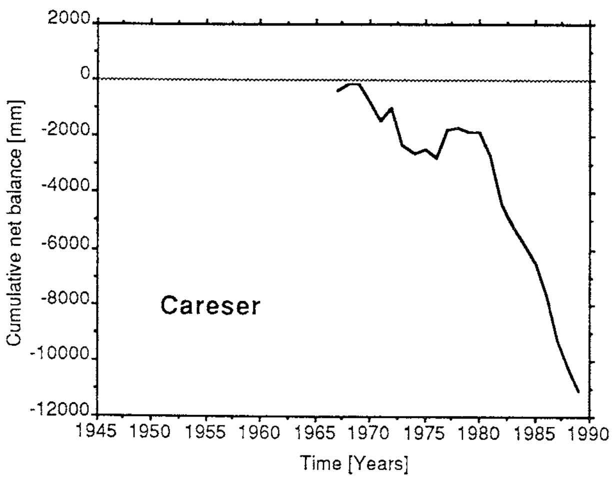
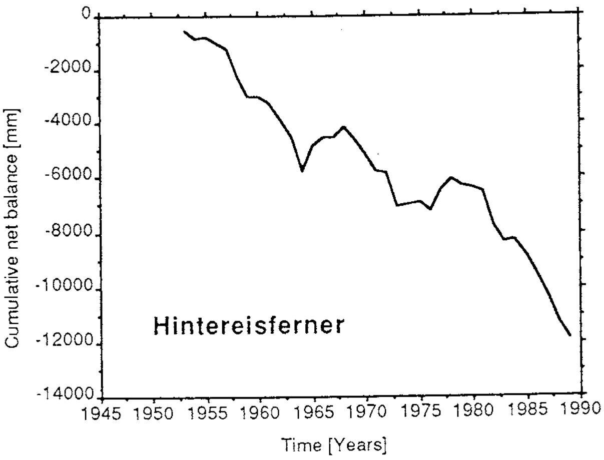
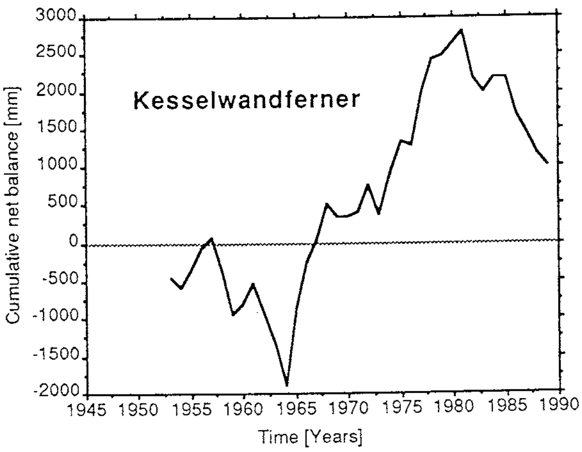
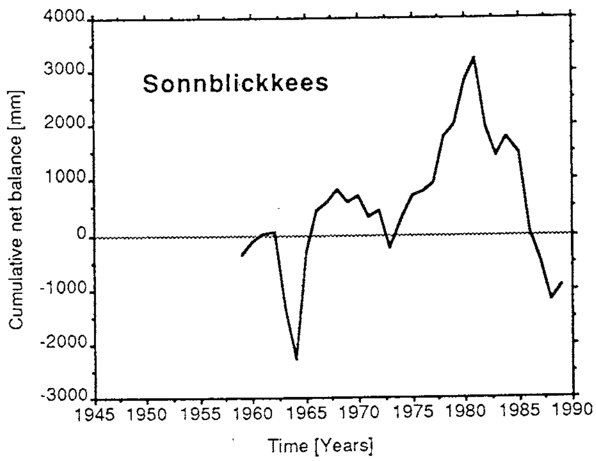


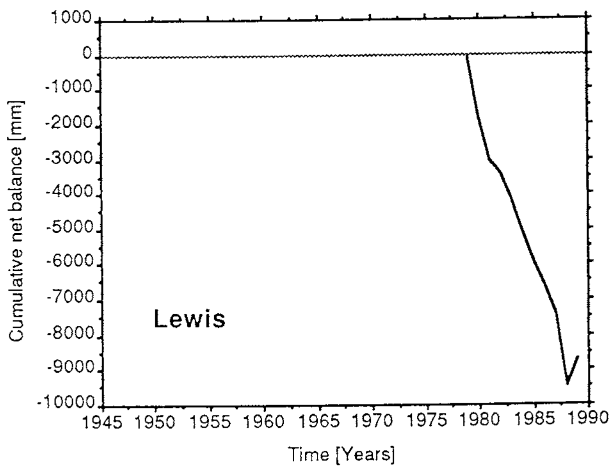
AUSTRIA:



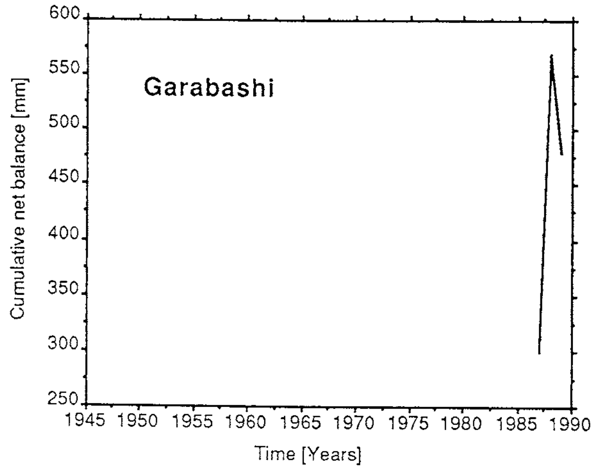


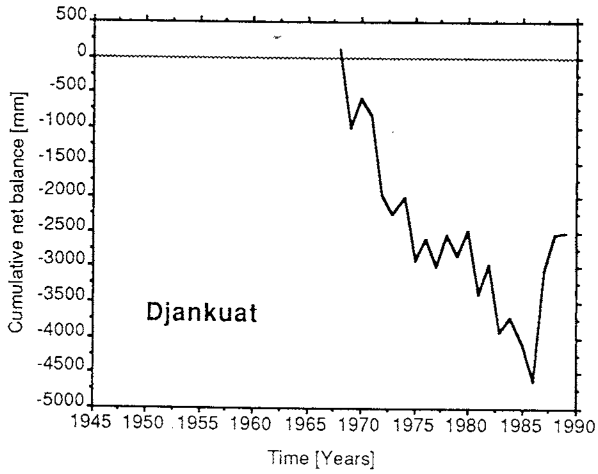


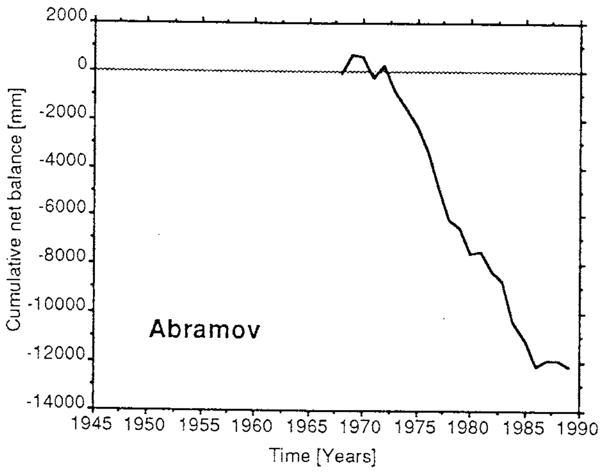
KENYA:

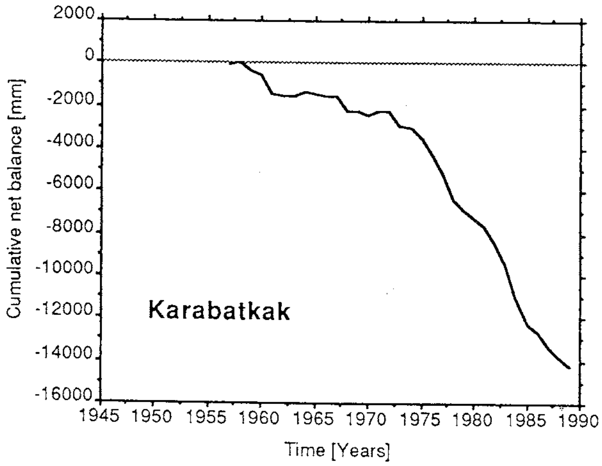


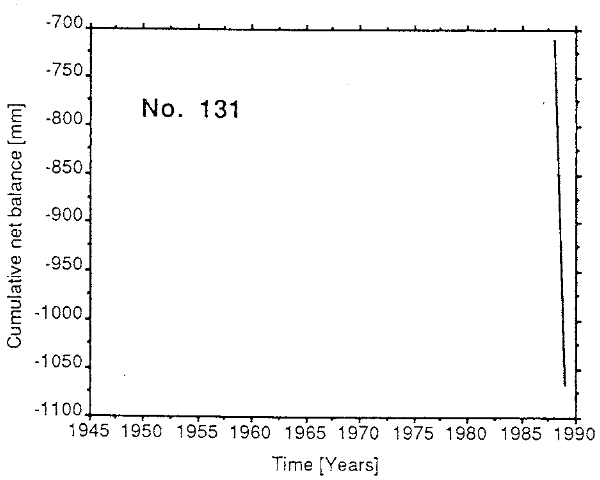
USSR:


Garabashi
Cumulative net balance [mm]
600
550
500
450
400
350
300
250
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

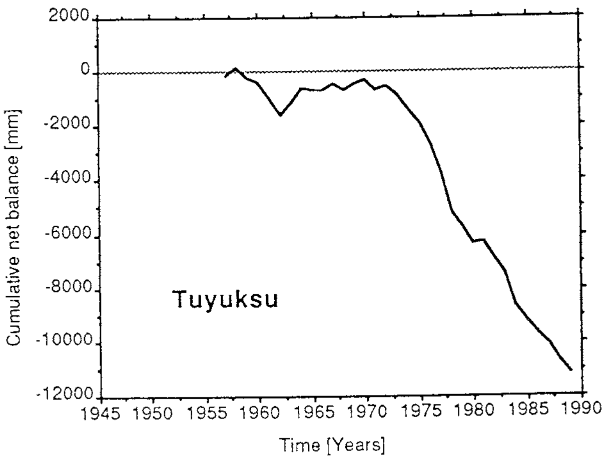

Djankuat
Cumulative net balance [mm]
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
-5000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

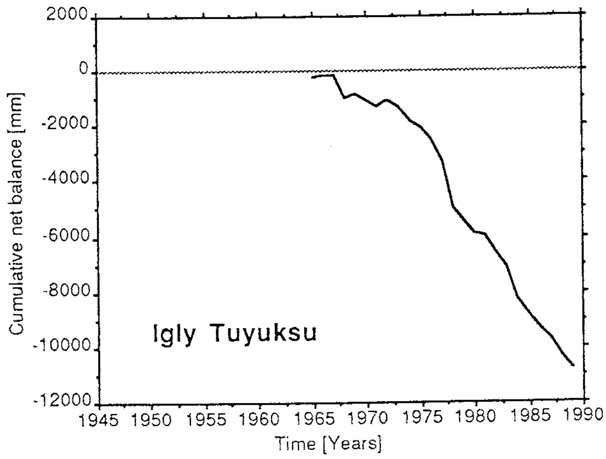

Abramov
Cumulative net balance [mm]
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

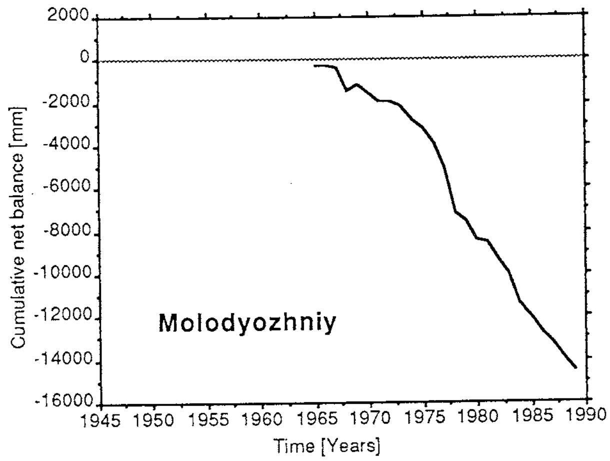

Karabatkak
Cumulative net balance [mm]
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

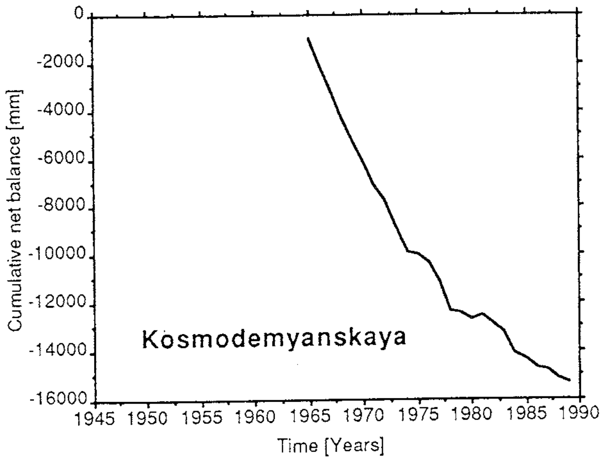

No. 131
Cumulative net balance [mm]
-700
-750
-800
-850
-900
-950
-1000
-1050
-1100
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

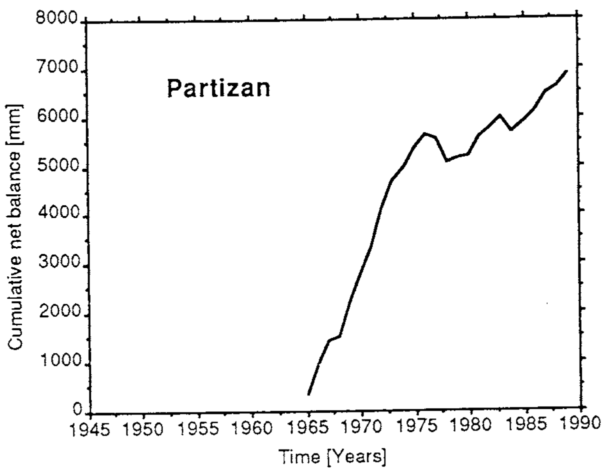
USSR:

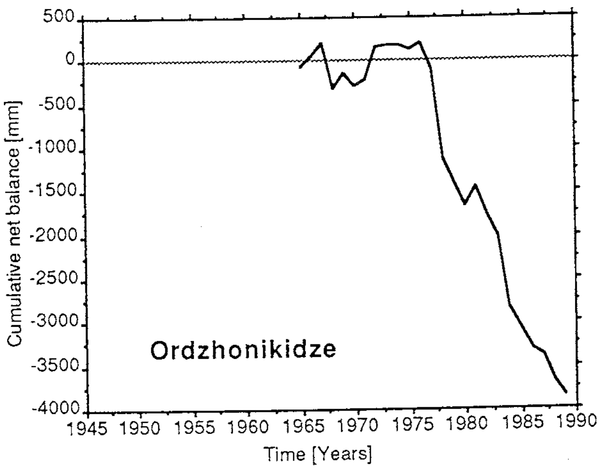

2000
0
-2000
-4000
-6000
-8000
-10000
-12000
Cumulative net balance [mm]
Tuyuksu
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


2000
0
-2000
-4000
-6000
-8000
-10000
-12000
Cumulative net balance [mm]
Igly Tuyuksu
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

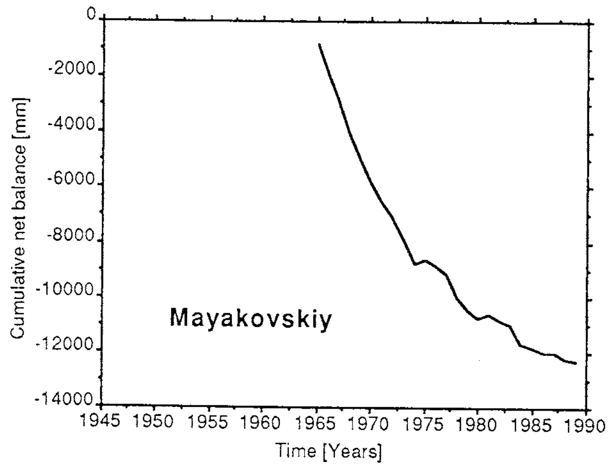

2000
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
Cumulative net balance [mm]
Molodyozhniy
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

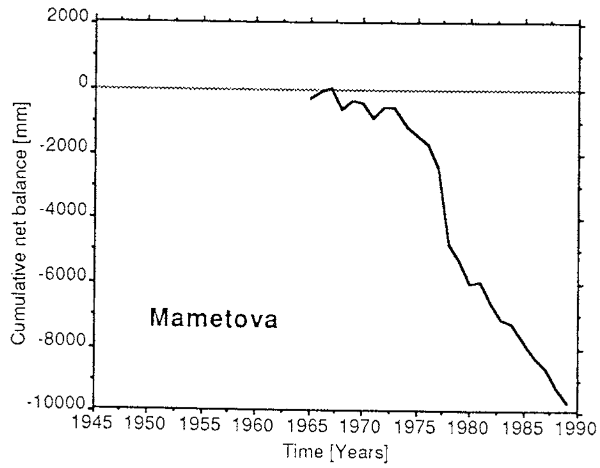

0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
Cumulative net balance [mm]
Kosmodemyanskaya
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

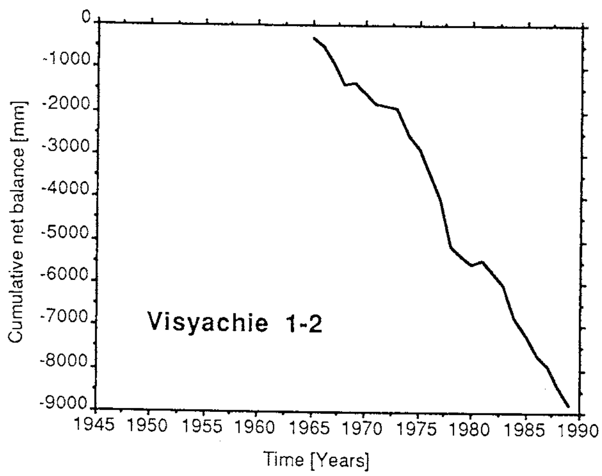

8000
7000
6000
5000
4000
3000
2000
1000
0
Cumulative net balance [mm]
Partizan
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

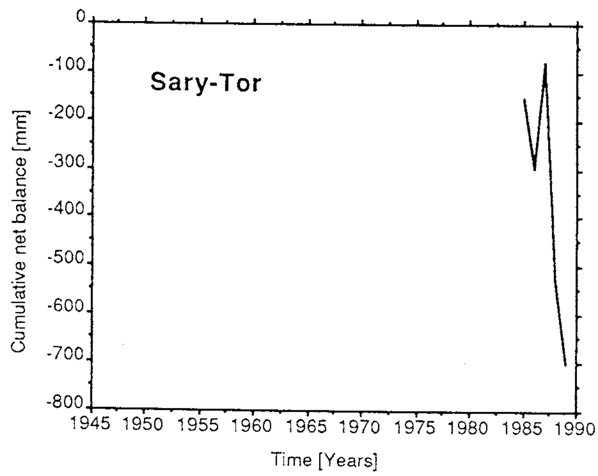

500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
Cumulative net balance [mm]
Ordzhonikidze
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

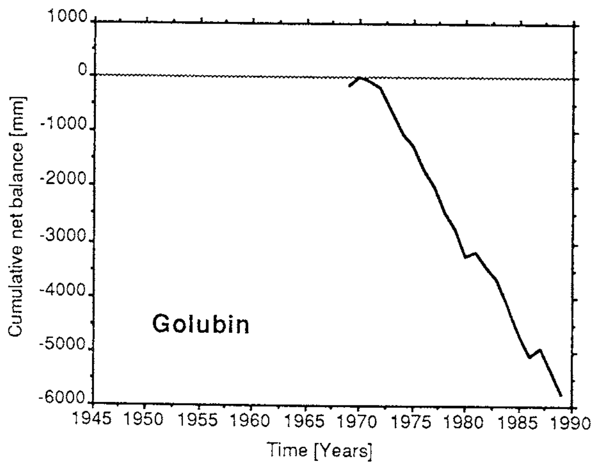
USSR:

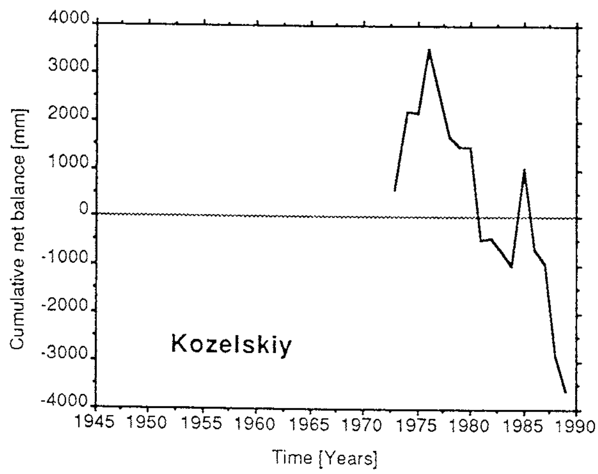

Mayakovskiy
Cumulative net balance [mm]
Time [Years]


Mametova
Cumulative net balance [mm]
Time [Years]

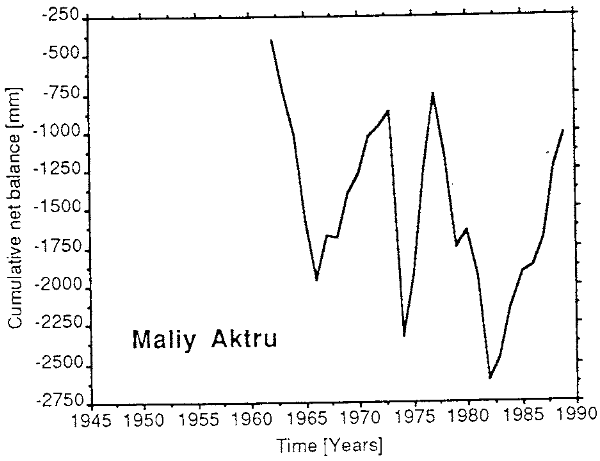

Visyachie 1-2
Cumulative net balance [mm]
Time [Years]

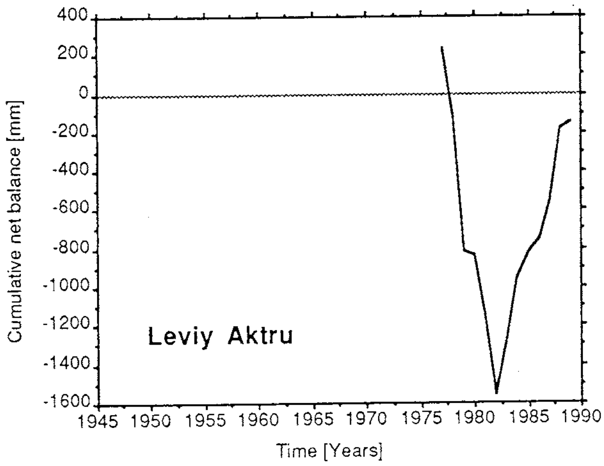

Sary-Tor
Cumulative net balance [mm]
Time [Years]

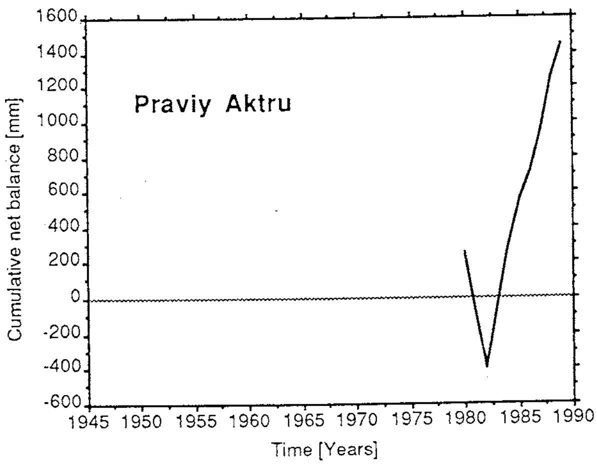

Golubin
Cumulative net balance [mm]
Time [Years]

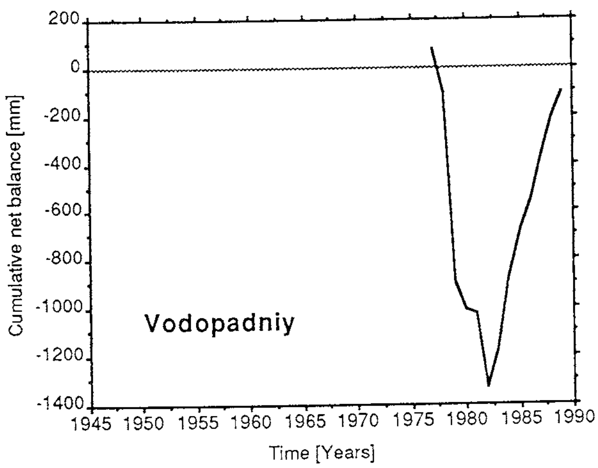

Kozelskiy
Cumulative net balance [mm]
Time [Years]

USSR:

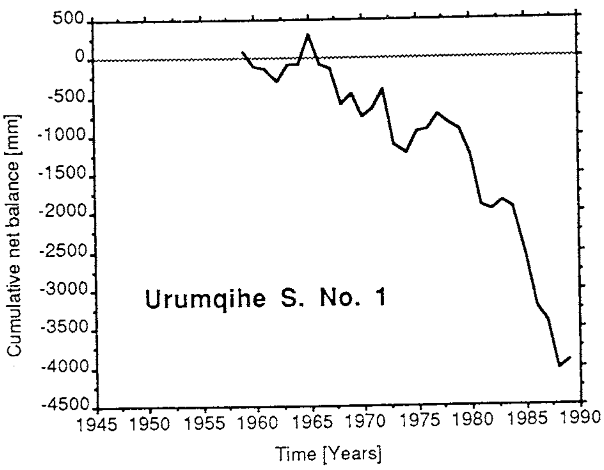

Maliy Aktru
Cumulative net balance [mm]
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
-2500
-2750
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Leviy Aktru
Cumulative net balance [mm]
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Praviy Aktru
Cumulative net balance [mm]
1600
1400
1200
1000
800
600
400
200
0
-200
-400
-600
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]


Vodopadniy
Cumulative net balance [mm]
200
0
-200
-400
-600
-800
-1000
-1200
-1400
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

CHINA:


Urumqihe S. No. 1
Cumulative net balance [mm]
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
-4000
-4500
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990
Time [Years]

3. EXTENSIVE INFORMATION

More detailed information about selected glaciers (no more than one glacier per mountain range), with long and complete series of direct glaciological mass balance measurments are presented here, in addition to the summary information contained in the previous chapter. In order to facilitate comparison between the individual glaciers, the material - text, maps, graphs and tables - submitted by the principal investigators was standardized and rearranged. The final version of the data presentation was then revised by the investigators again.

The text gives general information followed by brief comments on the two reported balance years. General information concerns basic geographic, geometric, climatic and glaciological characteristics of the observed glaciers which may help with the interpretation of climate/glacier- relations. An oblique photograph showing as far as possible the entire glacier is given also.

Three maps are presented from each glacier. The first one, a topographic map, shows the stake and snow pit network. This network is more or less the same from one year to another on most glaciers. In cases with differences between the two reported years, the second one was chosen, i.e. the network from the year 1988/89. The second and third map are balance maps of the years 1987/88 and 1988/89 respectively, illustrating the pattern of ablation and accumulation distribution. The accuracy of such balance maps depends on the density of the observational network, the complexity of the mass balance distribution and the experience of the local investigators.

A graph of mass balance versus altitude is given for both reported years. The relation between mass balance and altitude or the mass balance gradient is an important parameter in climate/glacier relationships, representing the climatic sensitivity of a glacier and constituting the main forcing function of glacier flow over long time intervals. Therefore, the mass balance gradient near the equilibrium line is often called the activity index of a glacier.

The last two graphs show the relation between the specific net balance and the accumulation area ratio (AAR) and the equilibrium line altitude (ELA) for the whole observation period. The regression equation is given at the top of both diagrams. The AAR regression equation is calculated by integer values only (in percent). AAR values of 0 or 100% as well as corresponding ELA values outside the altitude range of the observed glaciers were excluded in the regression analysis.

3.1 PLACE (CANADA)

COORDINATES: 50°26' N / 122°36' W

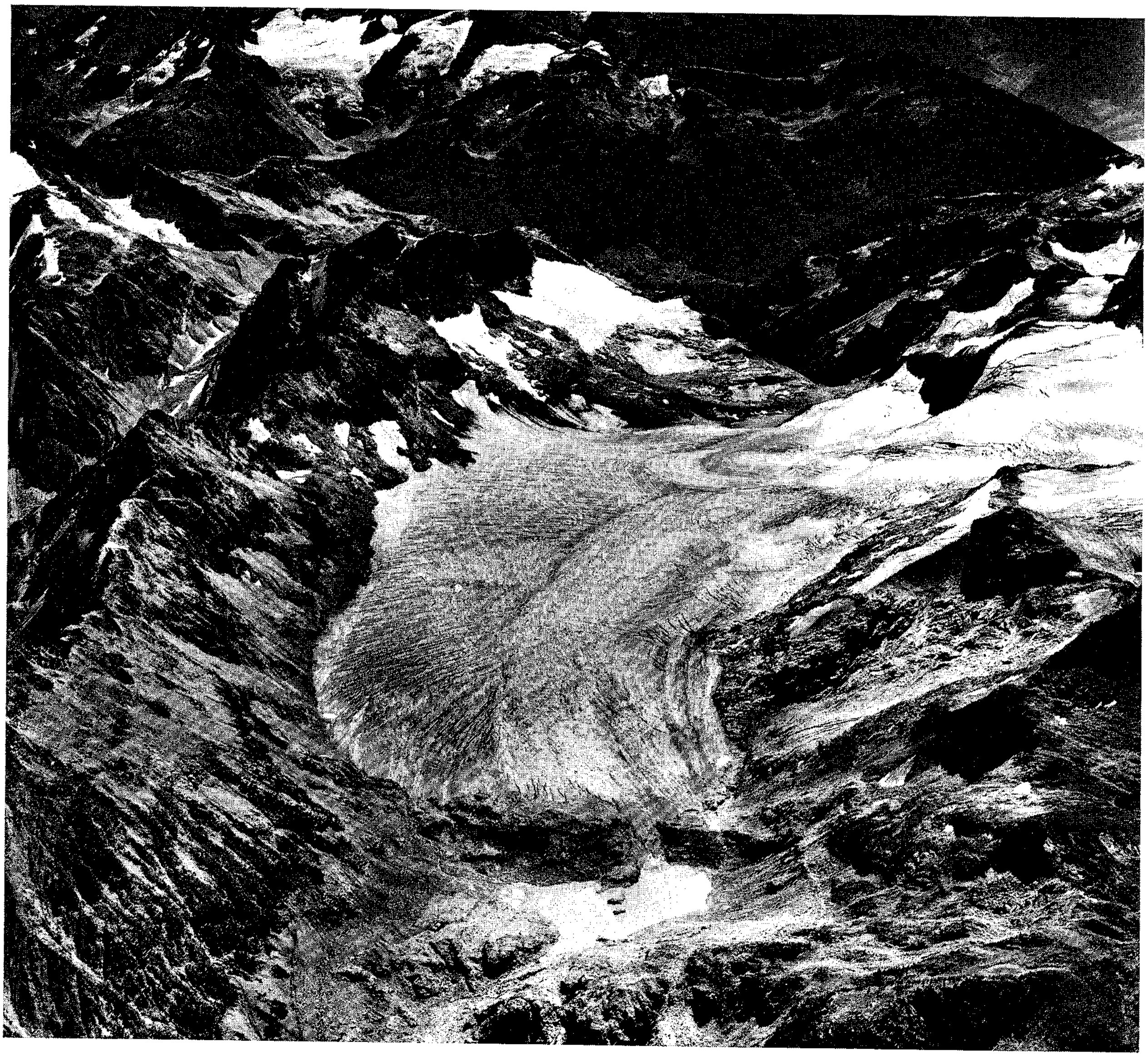
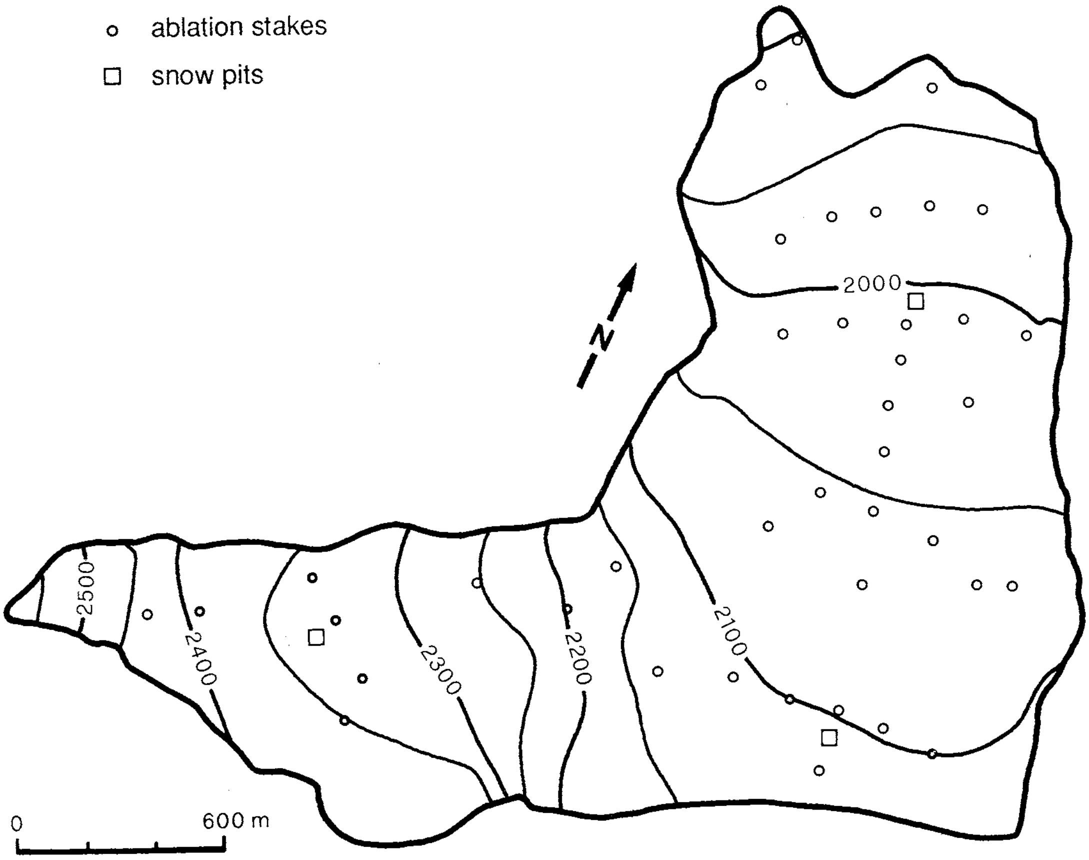


Photo taken by R.M. Krimmel on 5. September 1990.

The valley-type glacier is located in the southern Coast Mountain Range of Western Canada and extends from about 2,602 to roughly 1,870 m a.s.l. Its surface area is 3.70 km^2 and the exposure is NE to NW. Estimates of annual mean air temperature at the equilibrium line of the glacier (around 2,310 m a.s.l.) and average annual precipitation are not available so far. The glacier is thought to be temperate. Periglacial permafrost features of unknown activity exist on ridges surrounding the glacier but are not widespread.

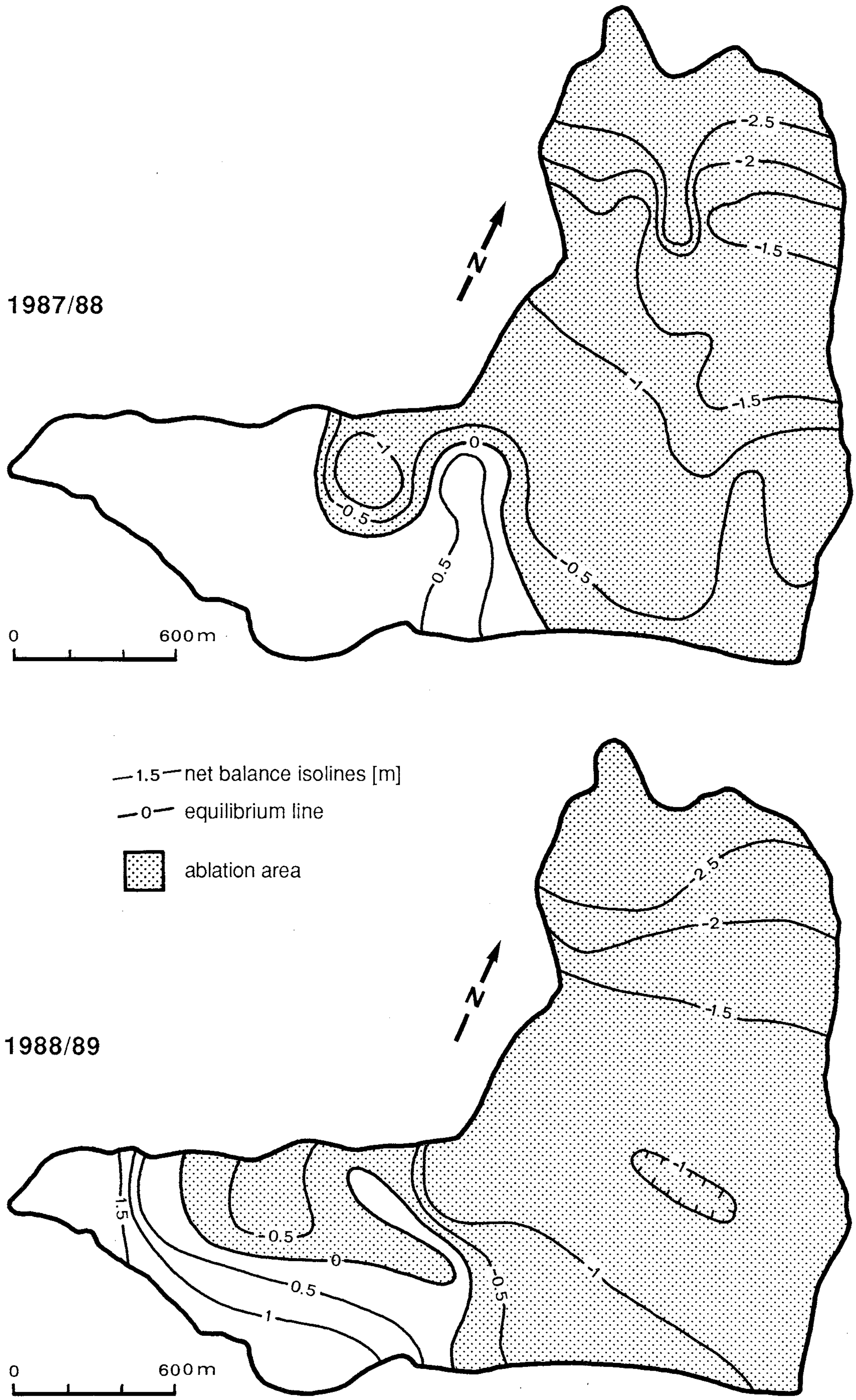
The two reported balance years were nearly identical with net mass losses of 0.97 m water equivalent in 1987/88 and 1.01 m in 1988/89. Both years showed slightly below average winter accumulation and near average summer ablation.

3.1.1 Topography and observational network

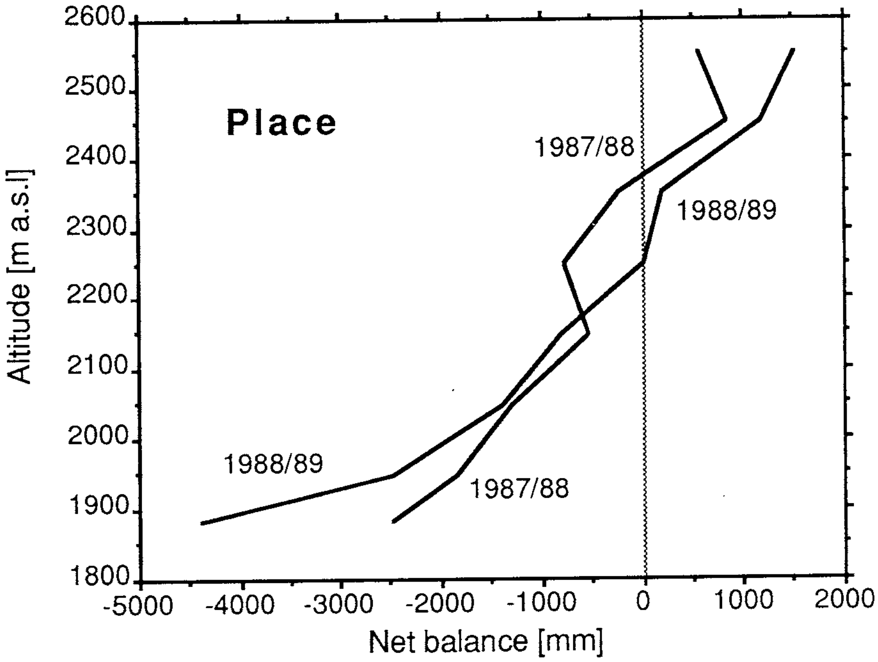


Place (CANADA)

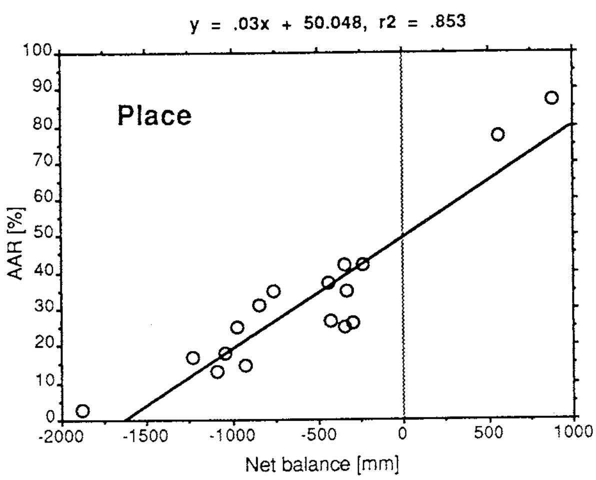
3.1.2 Net balance maps 1987/88 and 1988/89

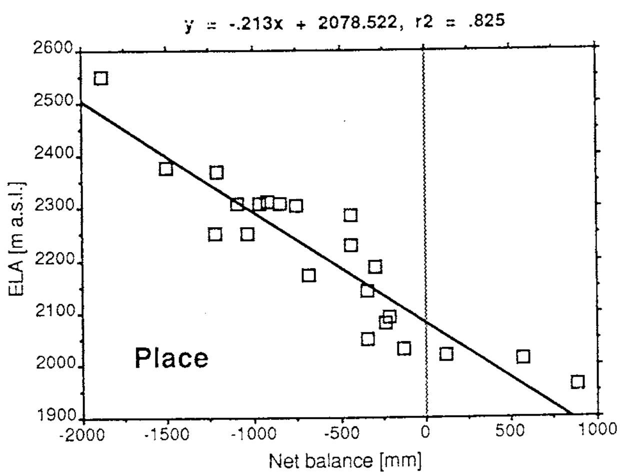


3.1.3 Net balance versus altitude (1987/88 and 1988/89)



3.1.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.2 STORGLACIÄREN (SWEDEN)

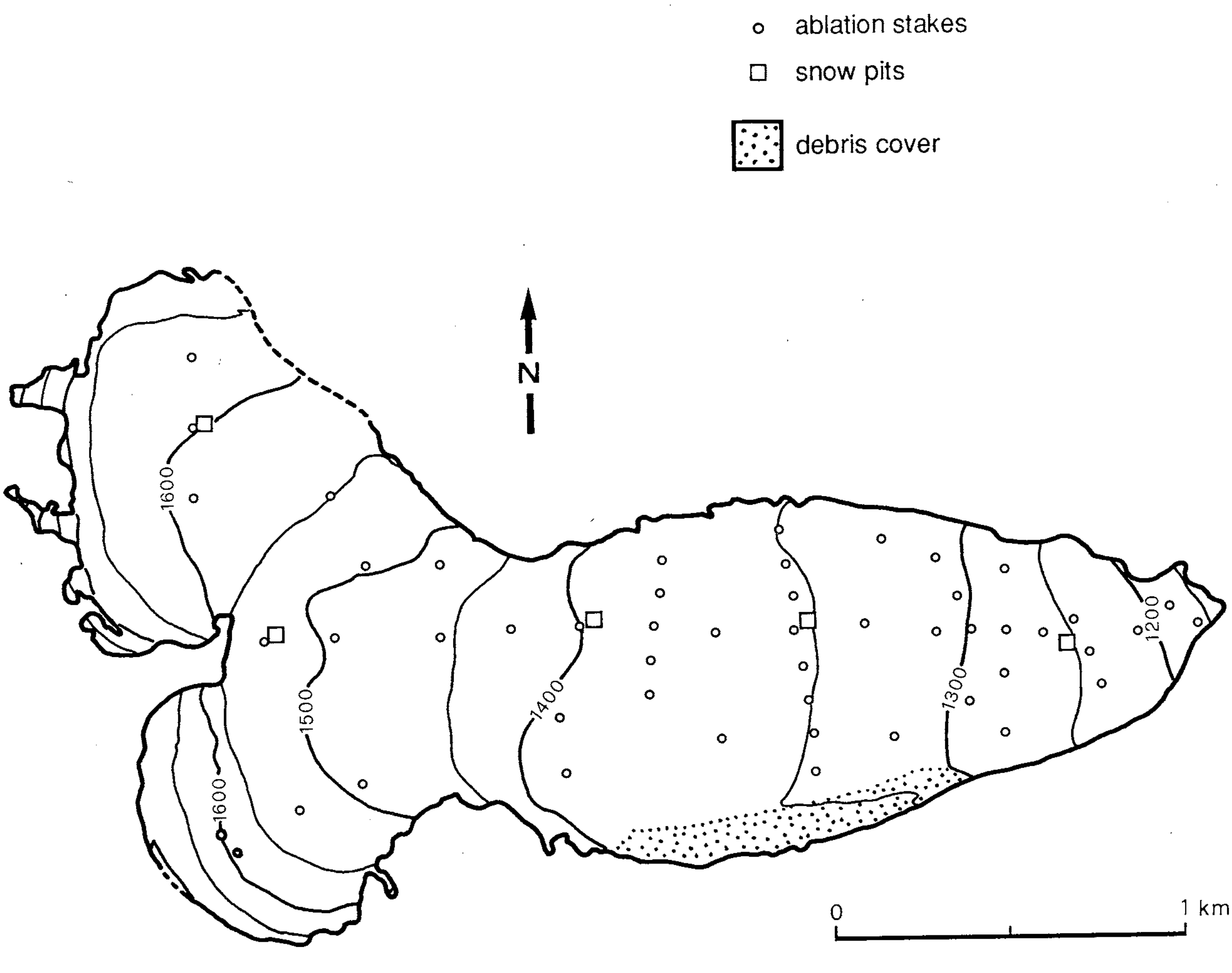
COORDINATES: 67° 54' N / 18° 34' E

Photo taken by P. Holmlund in August 1987.

Storglaciären in the Kebnekaise Mountains, Northern Sweden, is a small valley-type glacier with a divided accumulation area and a smooth longitudinal profile. It is exposed to the E, maximum and minimum elevations are 1,750 and 1,130 m a.s.l. and its surface area is 3.12 km^2 . Annual mean air temperature at the equilibrium line of the glacier (around 1,500 m a.s.l.) is about -6° C. The glacier is mainly temperate with a cold surface layer in its lower parts and ends in discontinuous permafrost. Average annual precipitation is about 1,000 mm at the nearby Tarfala Research Station.

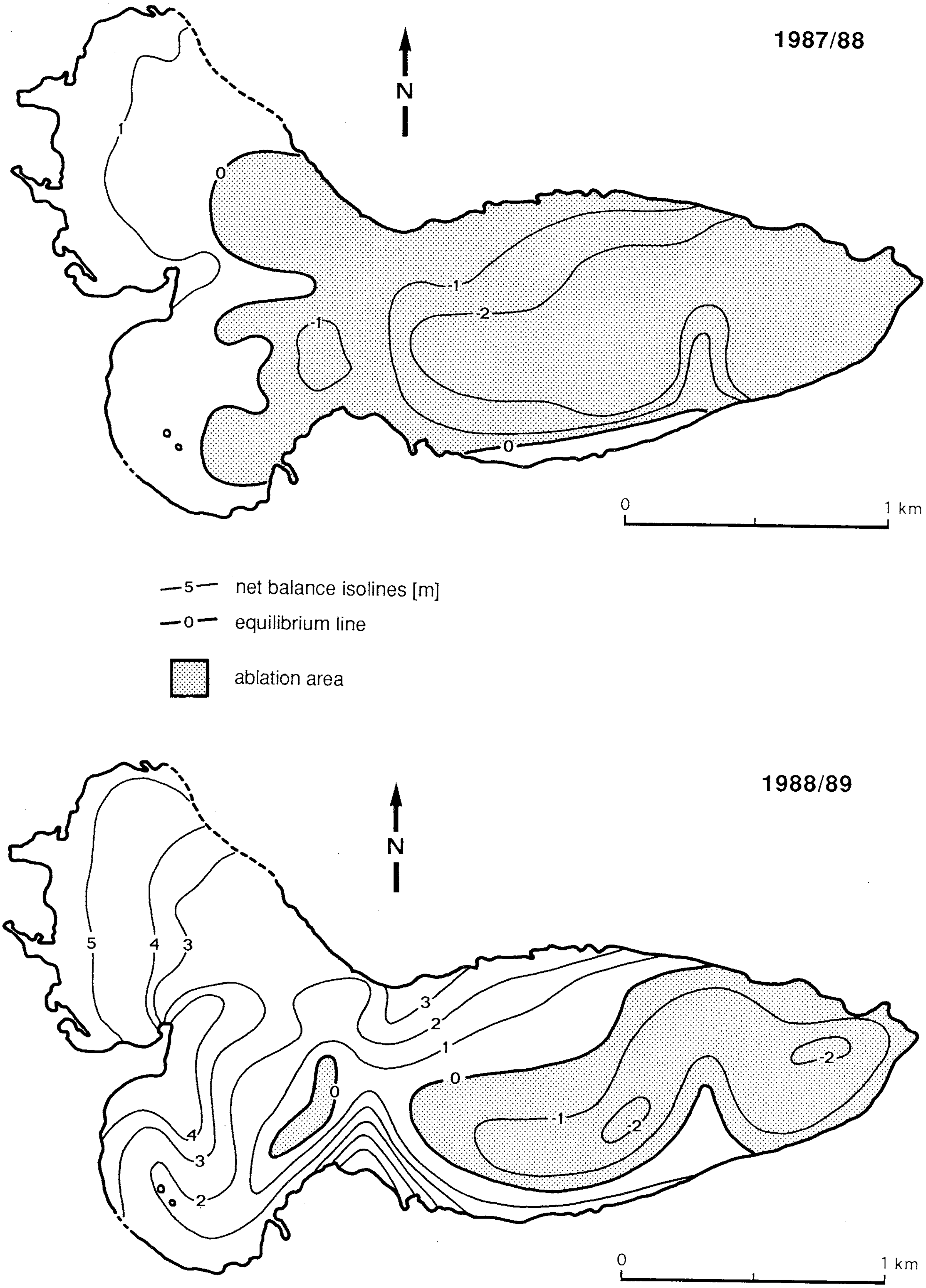
The balance year 1987/88 was strongly negative with a net mass loss of 0.84 m water equivalent which was mainly caused by high rates of melting during summer, accumulation having been a few percent higher than average. The balance year 1988/89 was the opposite with the largest net mass gain ever recorded since the beginning of the measurements in 1946 (1.24 m water equivalent); the winter balance was roughly 100% higher than normal while the summer balance was close to average.

3.2.1 Topography and observational network

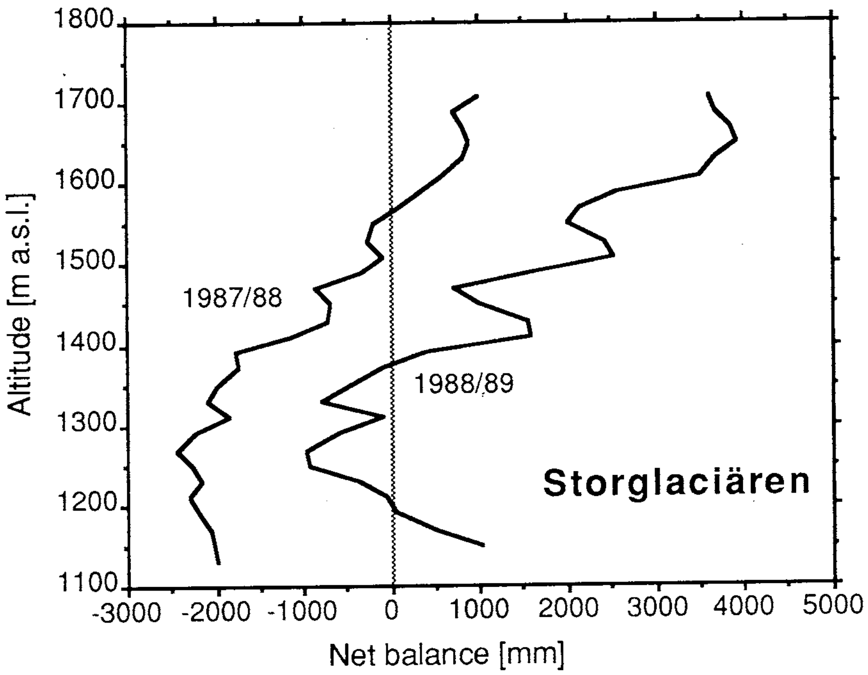


Storglaciären (SWEDEN)

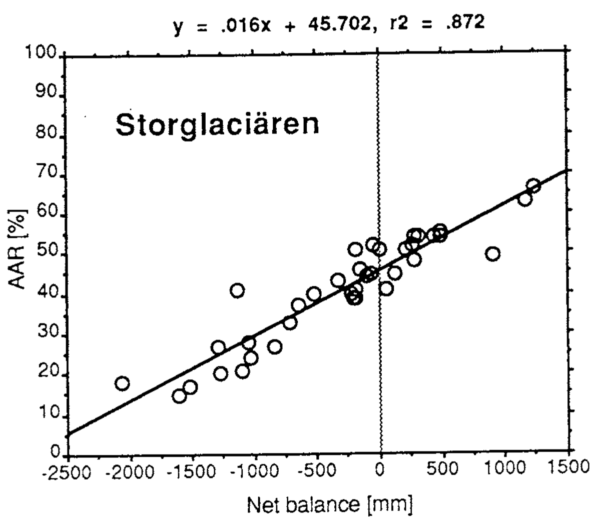
3.2.2 Net balance maps 1987/88 and 1988/89

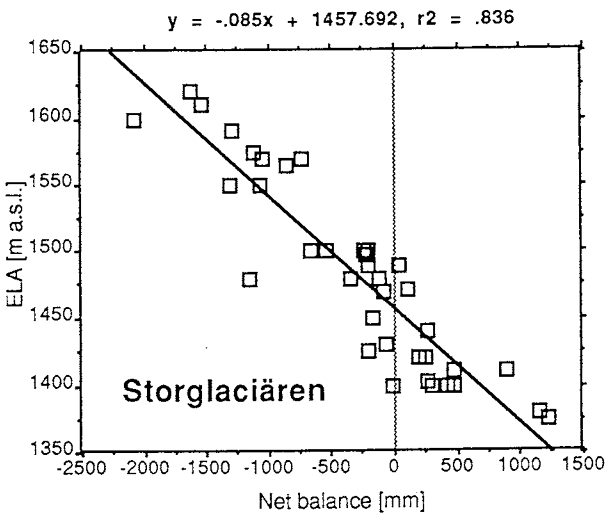


3.2.3 Net balance versus altitude (1987/88 and 1988/89)



3.2.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.3 HINTEREISFERNER (AUSTRIA)

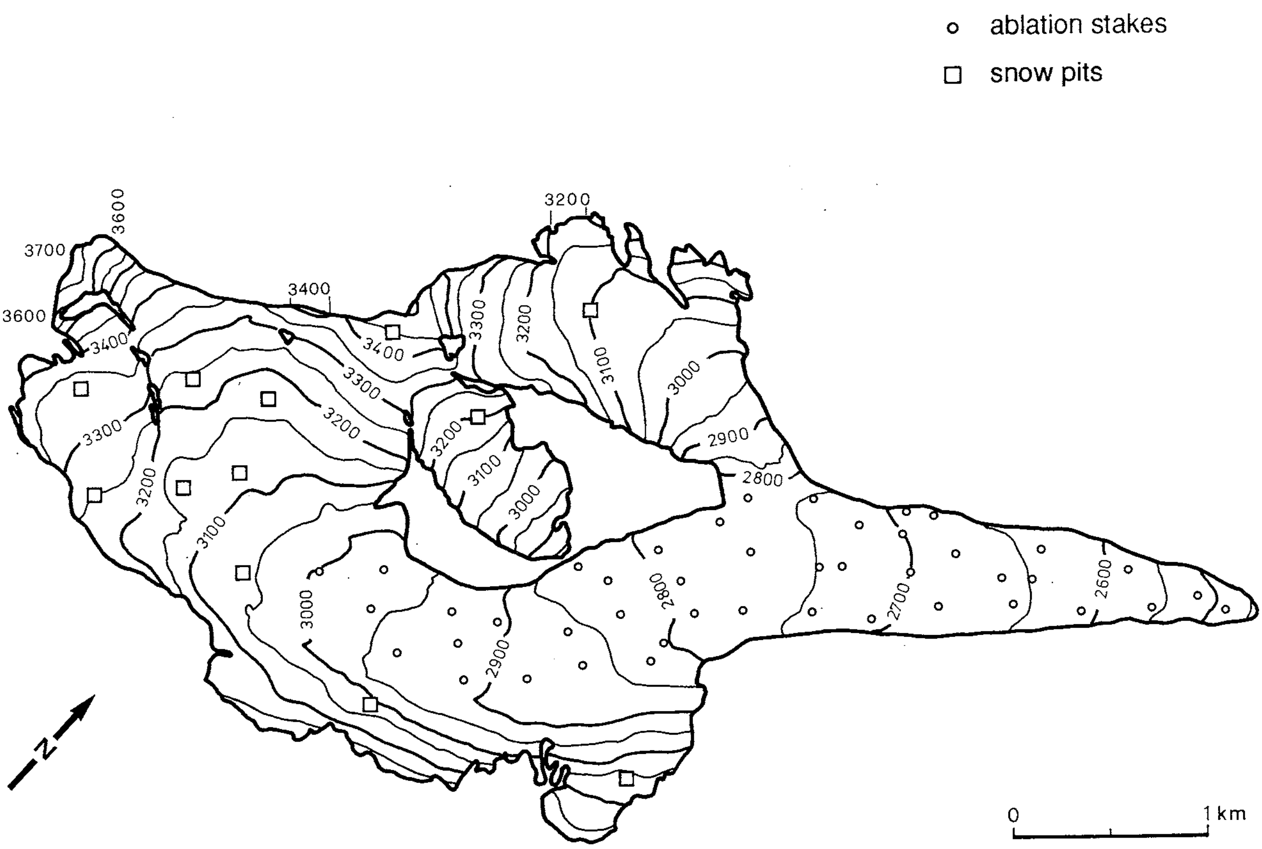
COORDINATES 46° 48' N / 10° 46' E

Photo taken by G. Kaser in September 1981.

The valley-type glacier is located at the southern end of the Oetztal within the relatively dry interior zone of the Alps and extends from 3,720 to 2,450 m a.s.l. Its surface area is 9.70 km^2 and the exposure is E to NE. Annual mean air temperature at the equilibrium line of the glacier (around 3,100 m a.s.l. in the two years reported) is -5 to -6° C. The glacier is temperate in the accumulation area and has a cold surface layer in the upper parts of the ablation area. Periglacial permafrost is assumed to be discontinuous and probably occurs mainly on the orographic right slopes of the glacier. Average annual precipitation as measured at 2,970 m a.s.l. is about 1,450 mm. A 1:10,000 topographic map of the glacier in 1979 can be found in Vol. 4 of the Fluctuations of Glaciers.

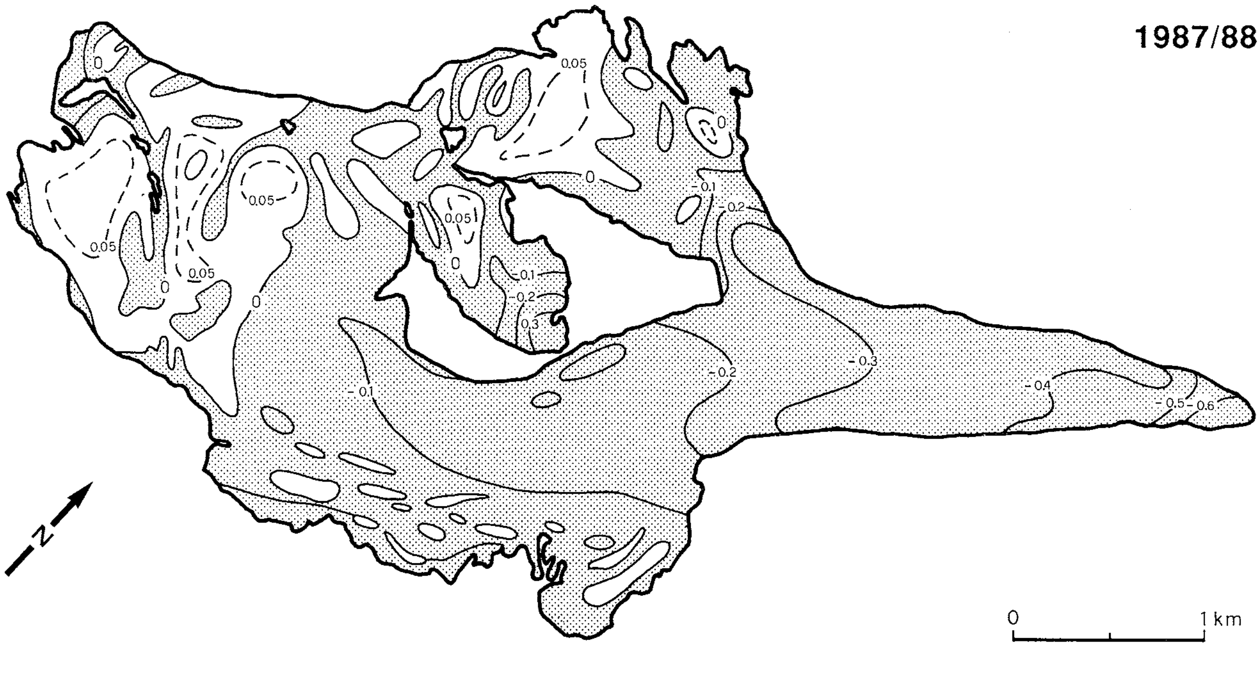
The two reported (fixed-date) balance years were both strongly negative. 1987/88 with a net mass loss of 0.95 m water equivalent had average winter precipitation but was too dry (10%) and too warm (0.8° C) in summer. A pronounced Sahara dust fall on 7 May lowered the albedo and, in addition, summer snowfalls were lacking. 1988/89 had average climate values. The negative balance of 0.64 m water equivalent can be explained by continuing ablation in October 1988, three dust falls in spring 1989 and again lacking summer snowfalls.

3.3.1 Topography and observational network



Hintereisferner (AUSTRIA)

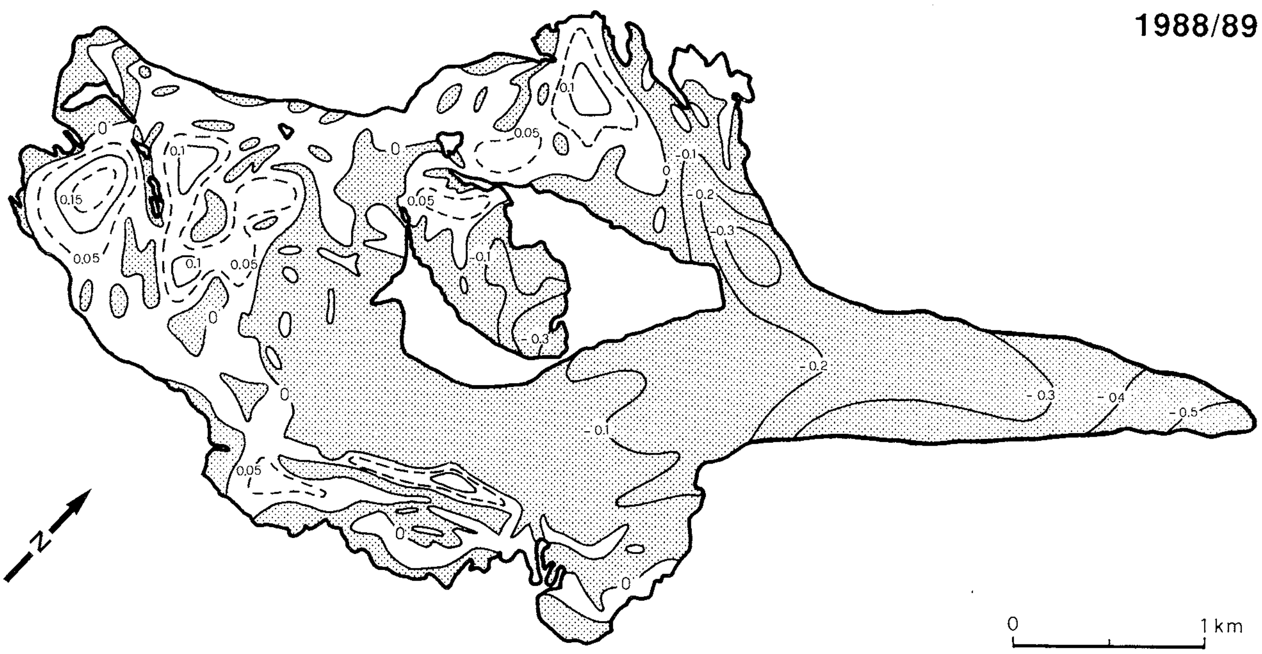
3.3.2 Net balance maps 1987/88 and 1988/89



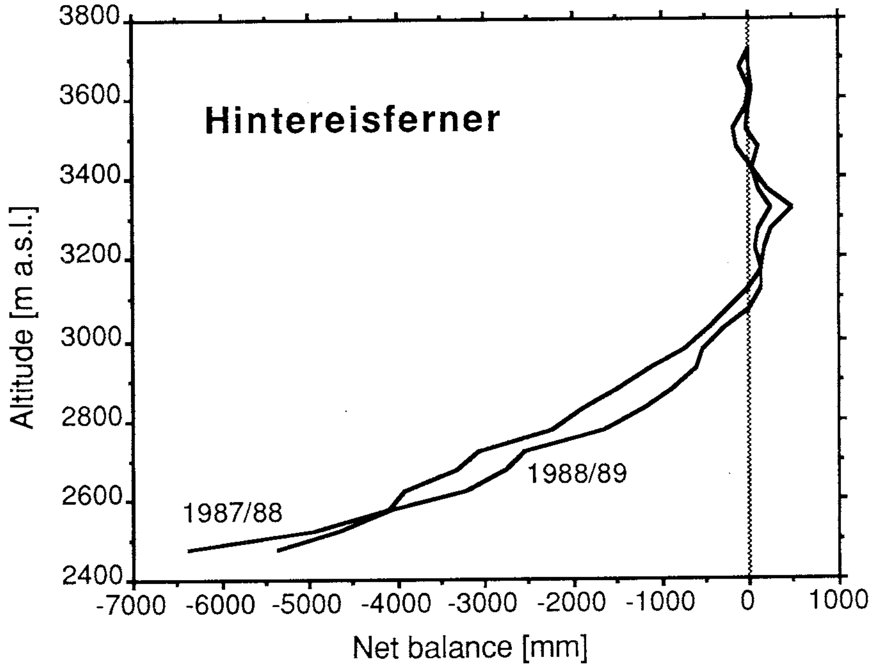
— 0.1 — net balance isolines [m]

— 0 — equilibrium line

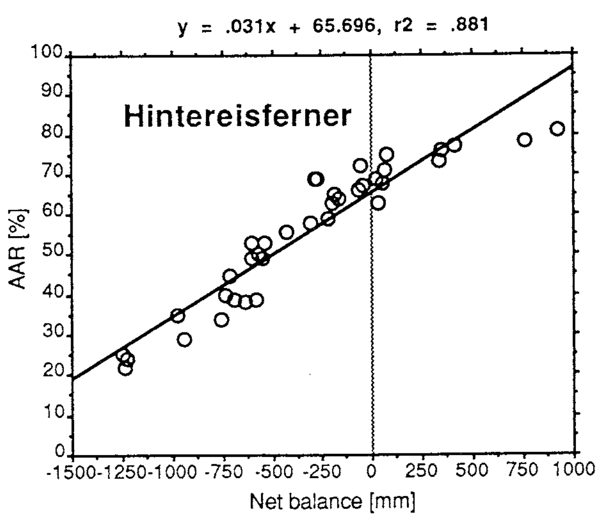
ablation area

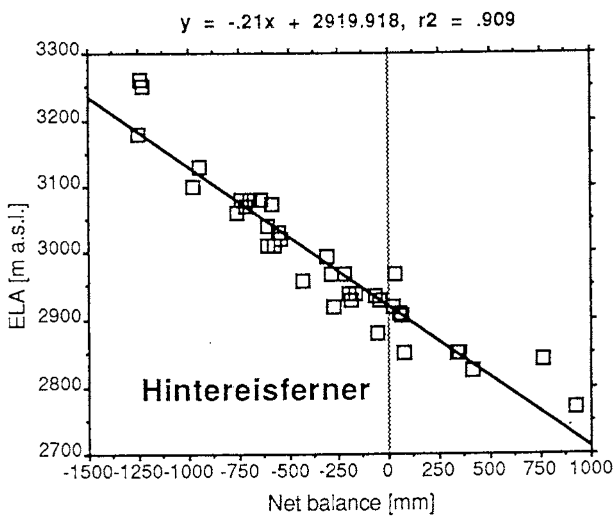


3.3.3 Net balance versus altitude (1987/88 and 1988/89)



3.3.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.4 LEWIS (KENYA)

COORDINATES: 00° 09' S / 37° 18' E

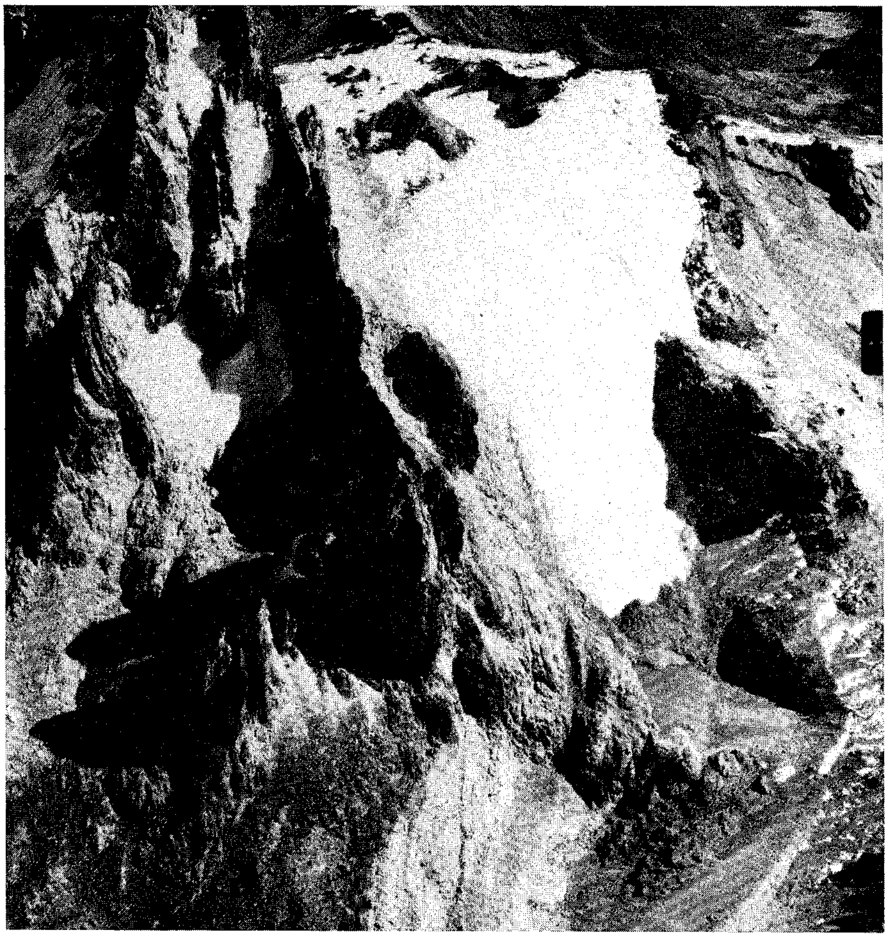
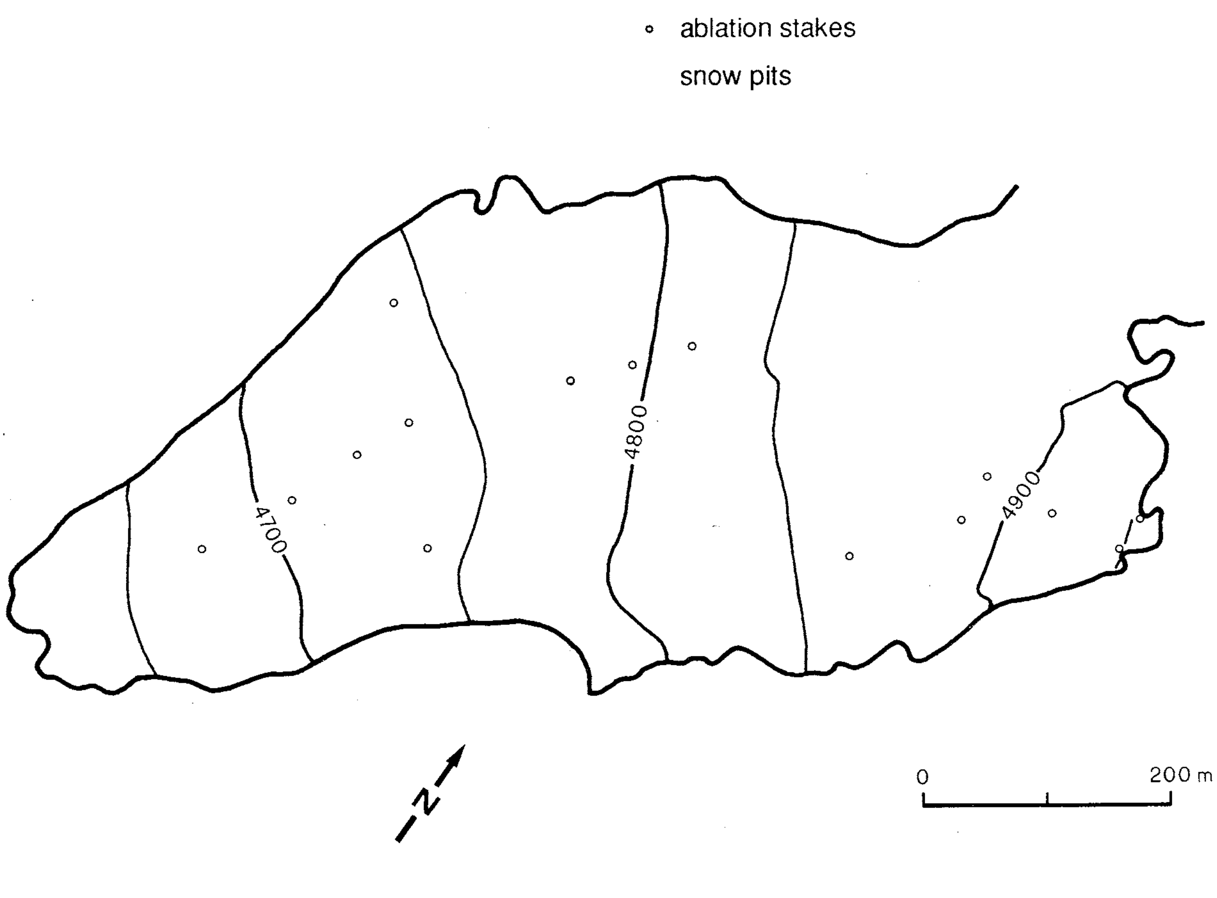


Photo taken in the mid-1980s; courtesy of Photomap (K) Ltd.

This largest glacier on Mount Kenya is located less than 20 km to the south of the Equator at elevations between 4,600 and 5,000 m a.s.l. It has a surface area of 0.25 km^2 and is exposed to the SW. Annual mean air temperature at the equilibrium line of the glacier (around 4,700 to 4,800 m a.s.l.) is 0 to -1° C. The glacier is assumed to be temperate, and periglacial areas to be free of permafrost. Average annual precipitation measured on a rock ridge ("Austrian Hut") next to the glacier was about 700 mm during the 12 past years of predominantly negative balances. However, years of zero balance are characterized by annual precipitation of about 1,000 mm. Ablation is substantial throughout the year and the seasons of minimum precipitation are January/February and July/August. The applicability of mid-latitude glaciological terminology to this tropical glacier is limited: for instance, the balance year starts in March rather than boreal autumn. For various of the years monitored since 1978, the entire glacier acted as "ablation area". A 1:5,000 topographic map of the glacier and its forefield in 1983 can be found in Vol. 5 of the Fluctuations of Glaciers.

March 1987 to March 1988 was a dry year with a strong mass loss of 2.03 m water equivalent on the glacier. The balance year March 1988 to March 1989 featured abundant snowfall, resulting in a remarkably large mass gain of 0.77 m water equivalent.

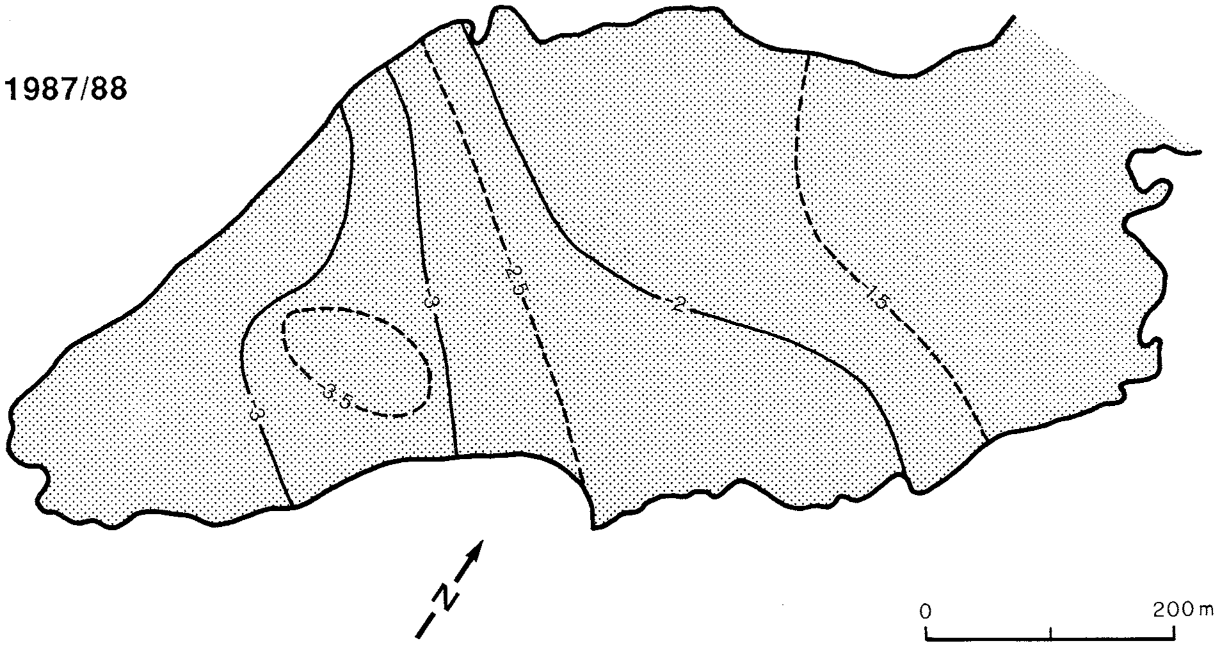
3.4.1 Topography and observational network



Lewis (KENYA)

3.4.2 Net balance maps 1987/88 and 1988/89

1987/88

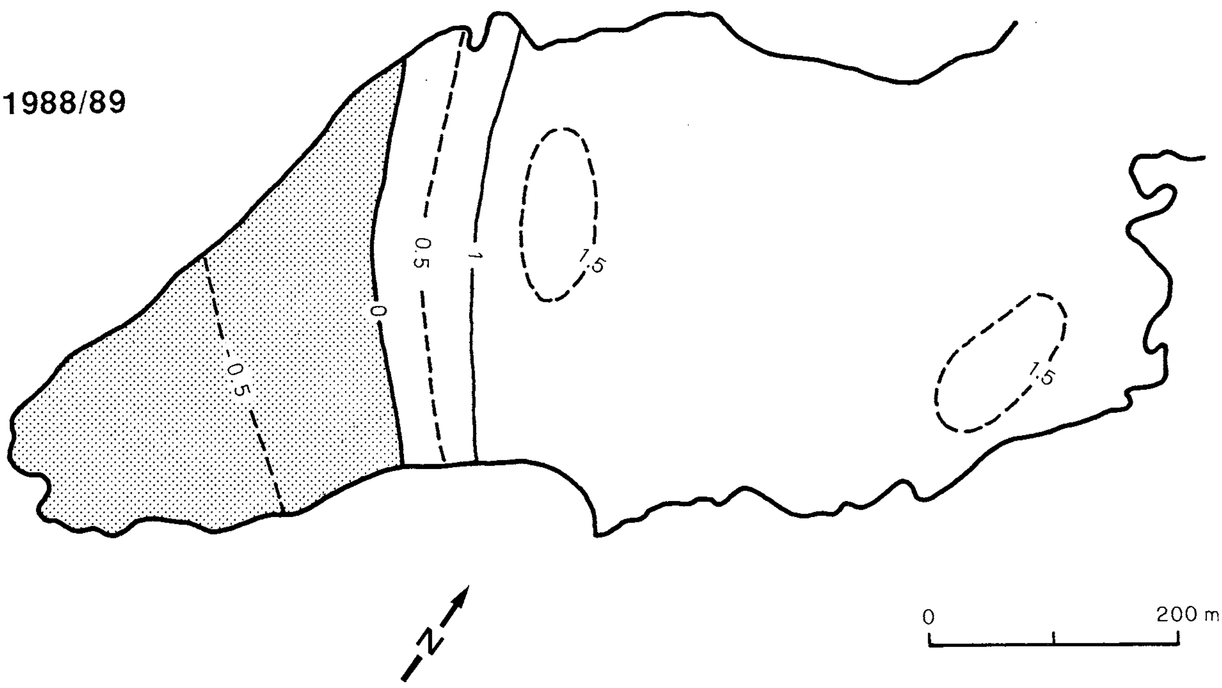


—1.5— net balance isolines [m]

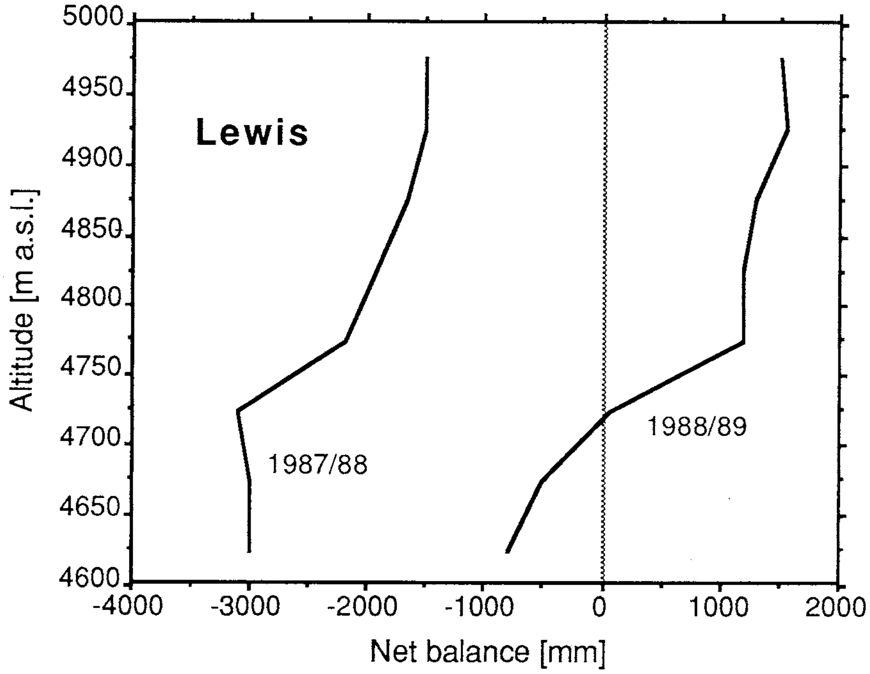
—0— equilibrium line

ablation area

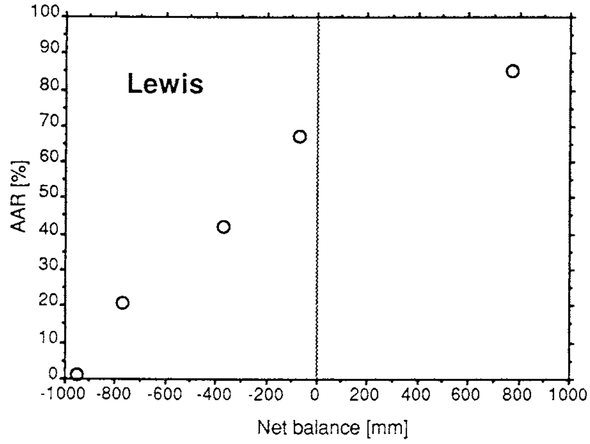
1988/89

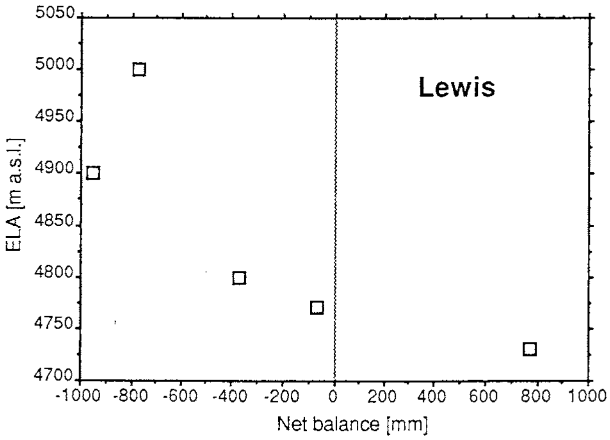


3.4.3 Net balance versus altitude (1987/88 and 1988/89)



3.4.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.5 DJANKUAT (USSR)

COORDINATES: 43° 12' N / 42° 46' E

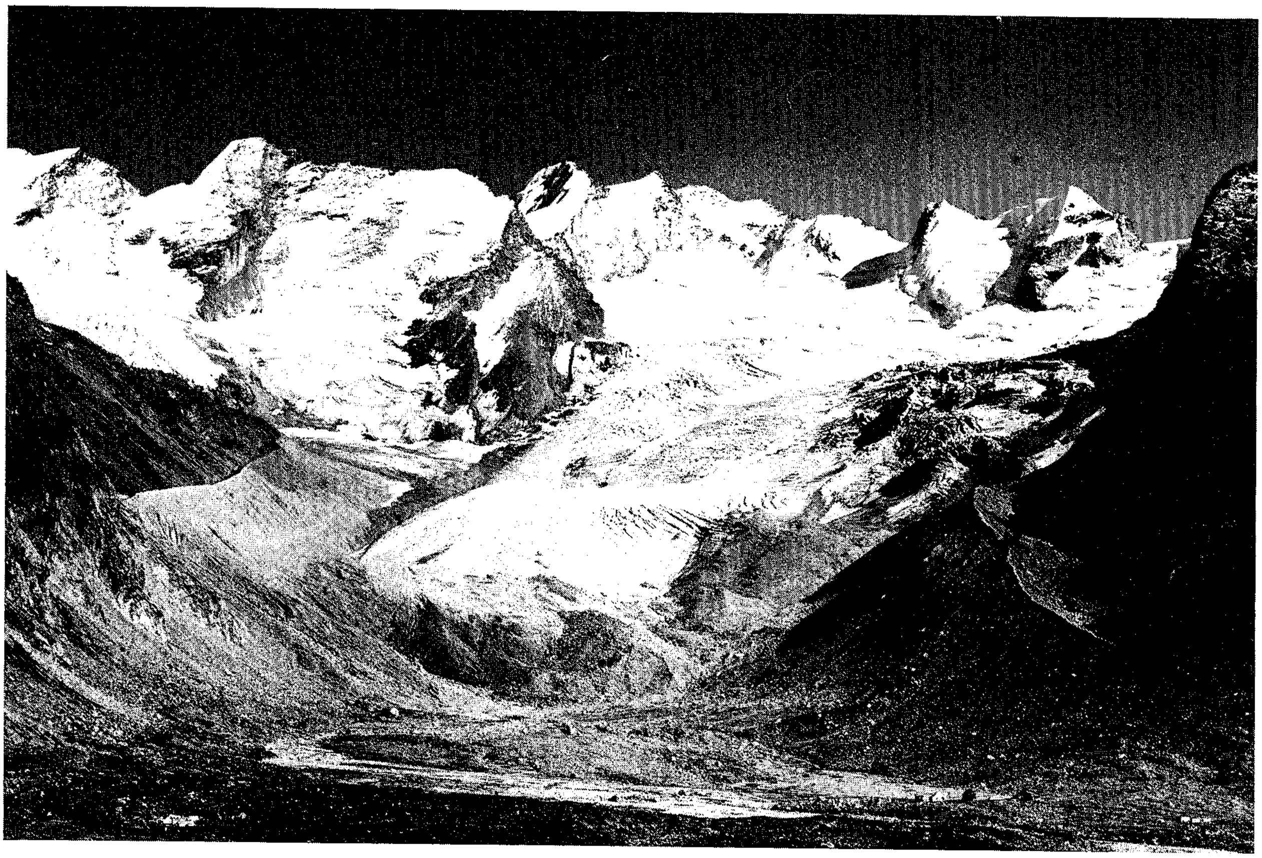
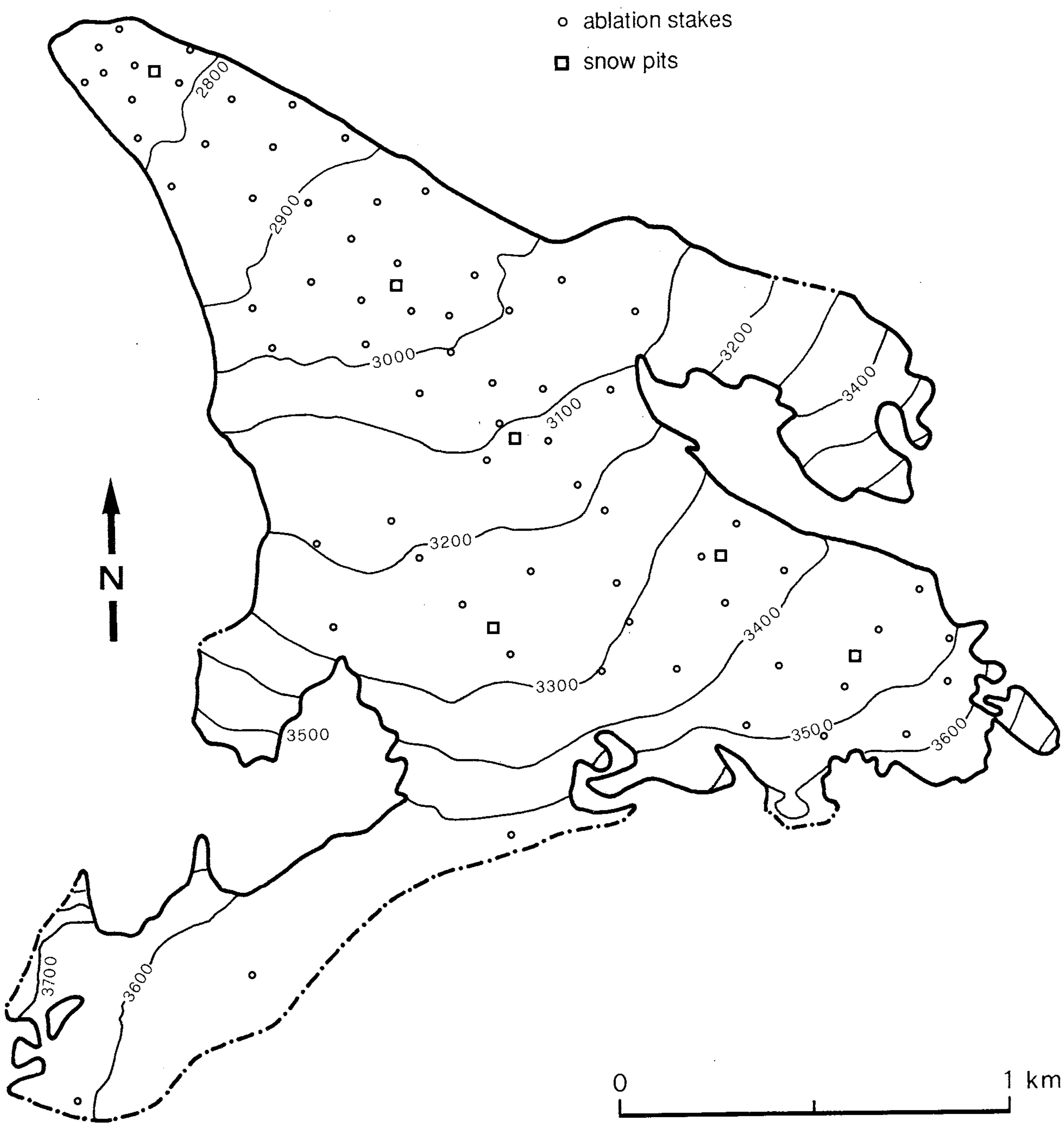


Photo taken by Ye. A. Zolotaryov and V. V. Popovnin in September 1985.

The valley-type glacier is located on the northern slope of the central section of the main Caucasus Ridge and extends from 3,990 to 2,650 m a.s.l. Its surface area is 3.13 km^2 and the exposure is NW. Mean annual air temperature at the equilibrium line of the glacier at about 3,200 m a.s.l. is -3 to -4.5° C and the glacier is temperate. Periglacial permafrost is assumed to be highly discontinuous. Average annual precipitation as measured near the snout is about 1,100 to 1,200 mm but roughly three times that amount at the equilibrium line. Three 1:10,000 topographic maps depicting the glacier in 1968, 1974 and 1984 exist at the Moscow State University but are not yet published. The peculiarity of the glacier is the migration of the ice divide on the firn plateau of the crest zone, redistributing mass flux between adjacent slopes of the Main Caucasus Ridge.

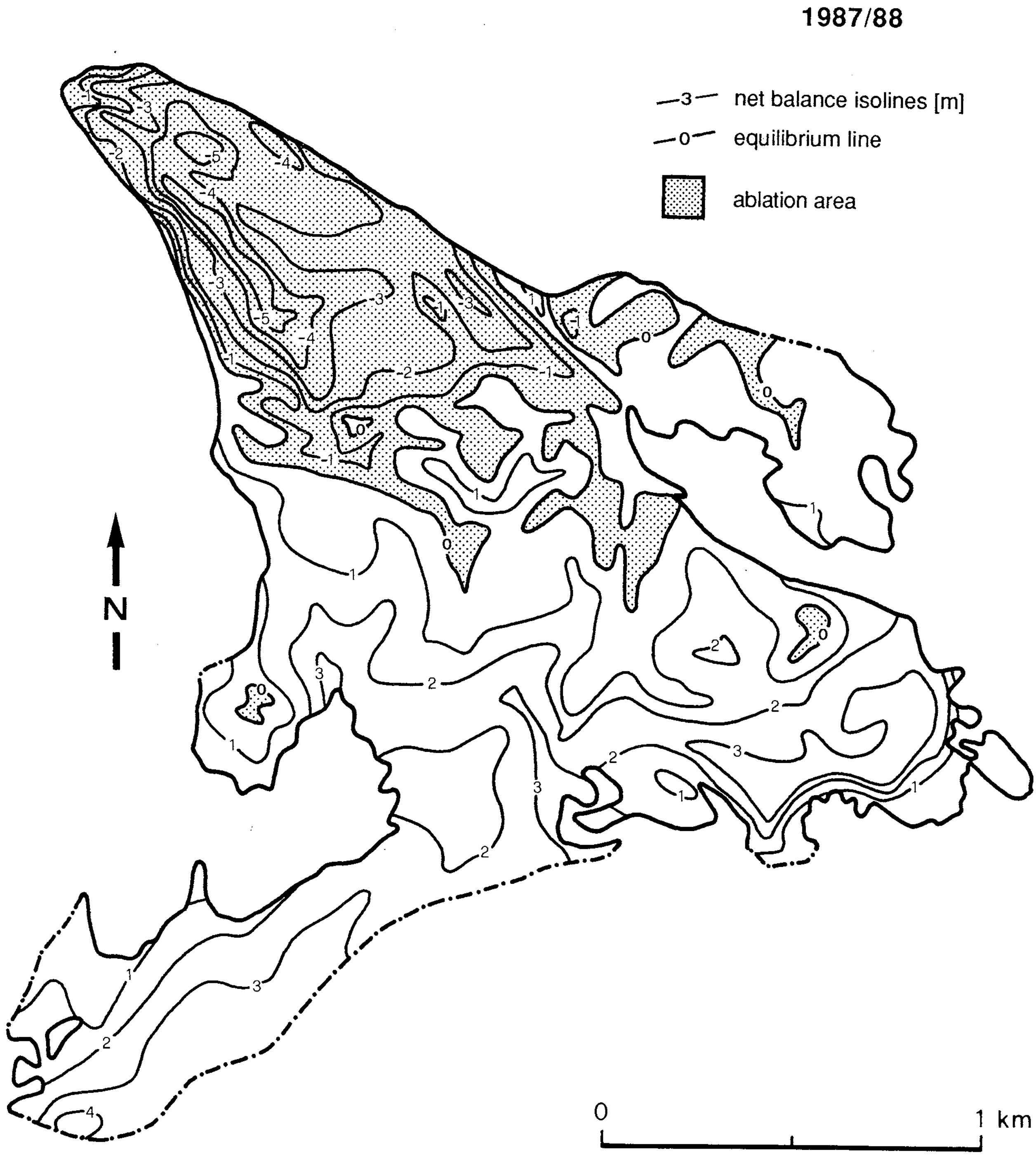
Winter accumulation was 16% above average in 1987/88 and 11% in 1988/89. The summer season was cool in 1987/88 but rather warm in 1988/89. As a result, the glacier had a mass gain of 0.52 m water equivalent in 1987/88 and, with a small mass gain of 0.04 m water equivalent, it was near a state of zero balance in 1988/89.

3.5.1 Topography and observational network

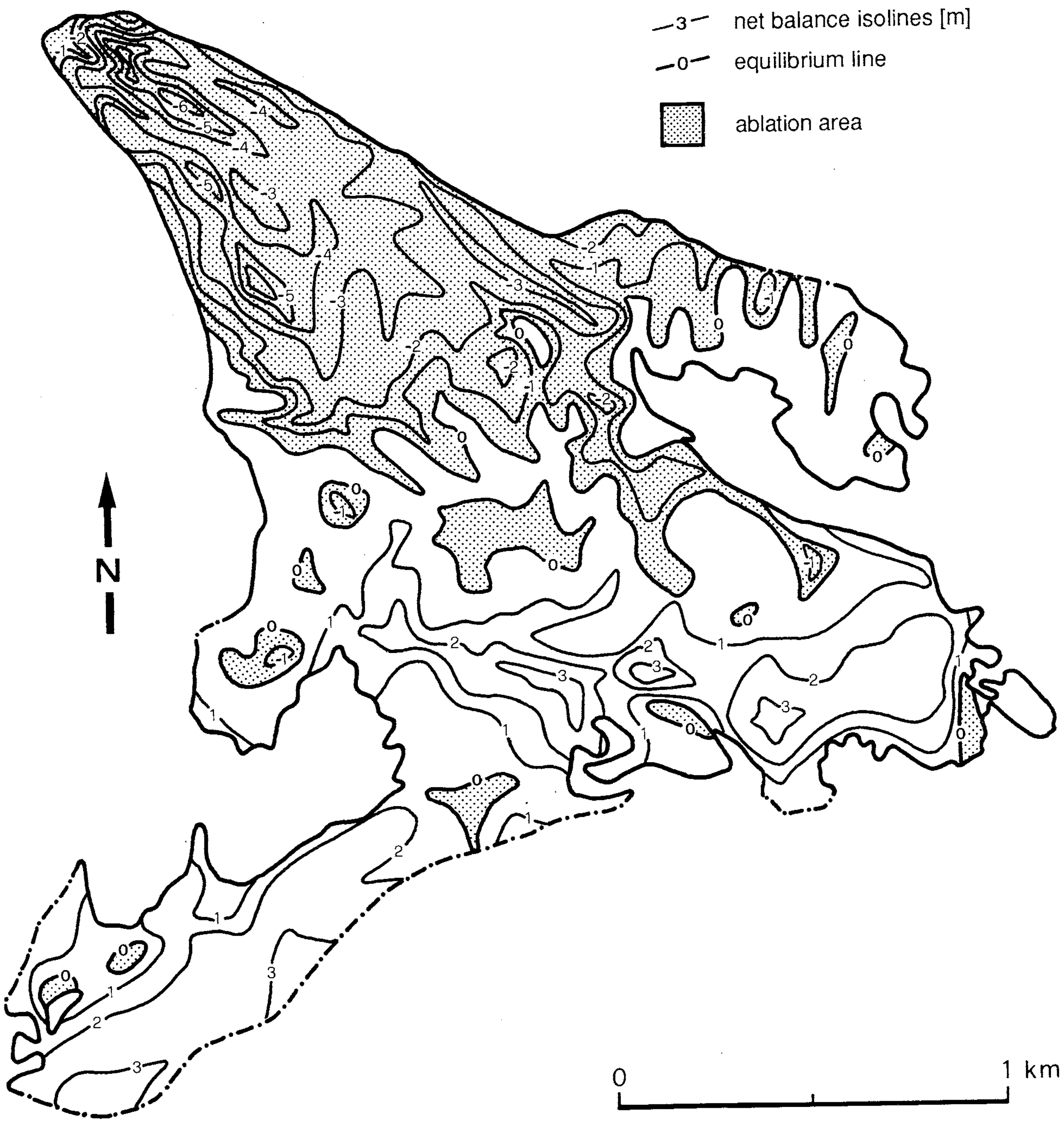


Djankuat (USSR)

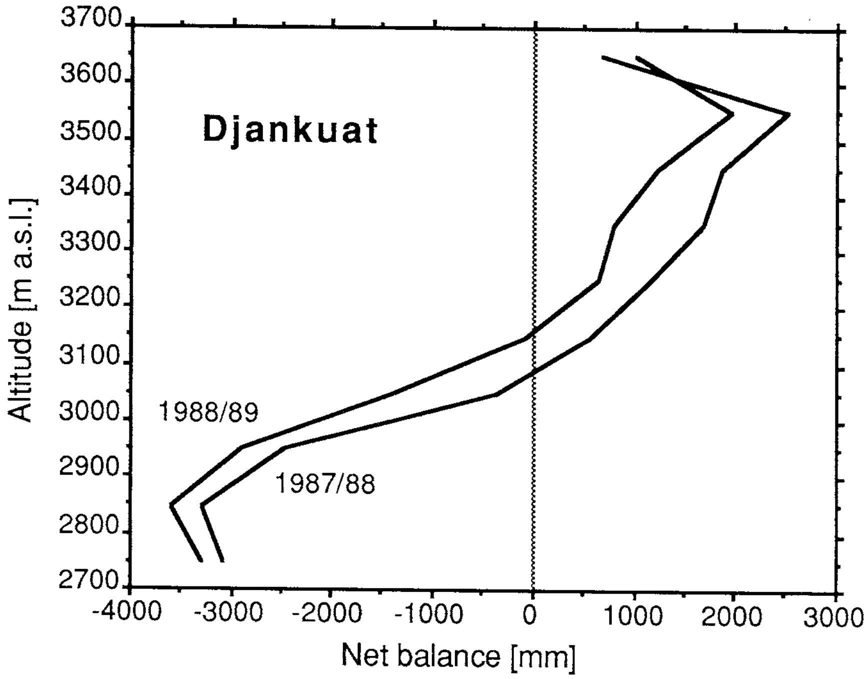
3.5.2 Net balance maps 1987/88 and 1988/89



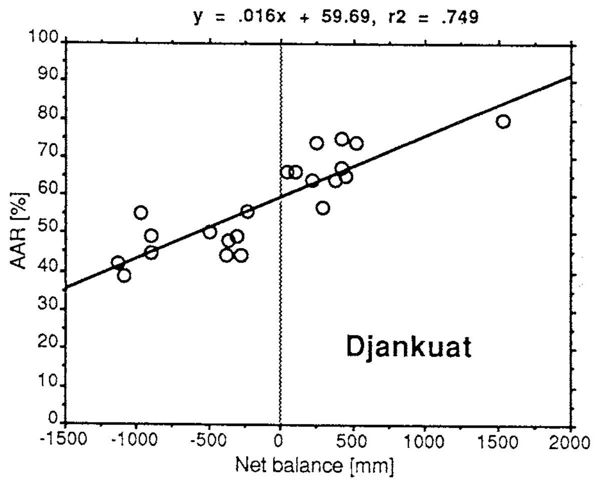
1988/89

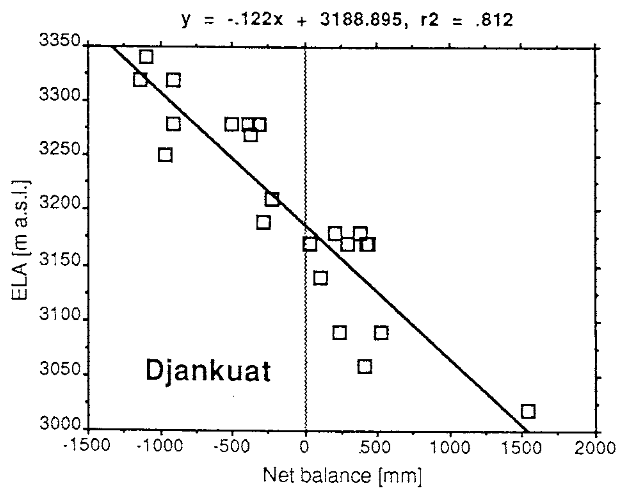

net balance isolines [m]
equilibrium line
ablation area
N
0
1 km

3.5.3 Net balance versus altitude (1987/88 and 1988/89)



3.5.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.6 ABRAMOV (USSR)

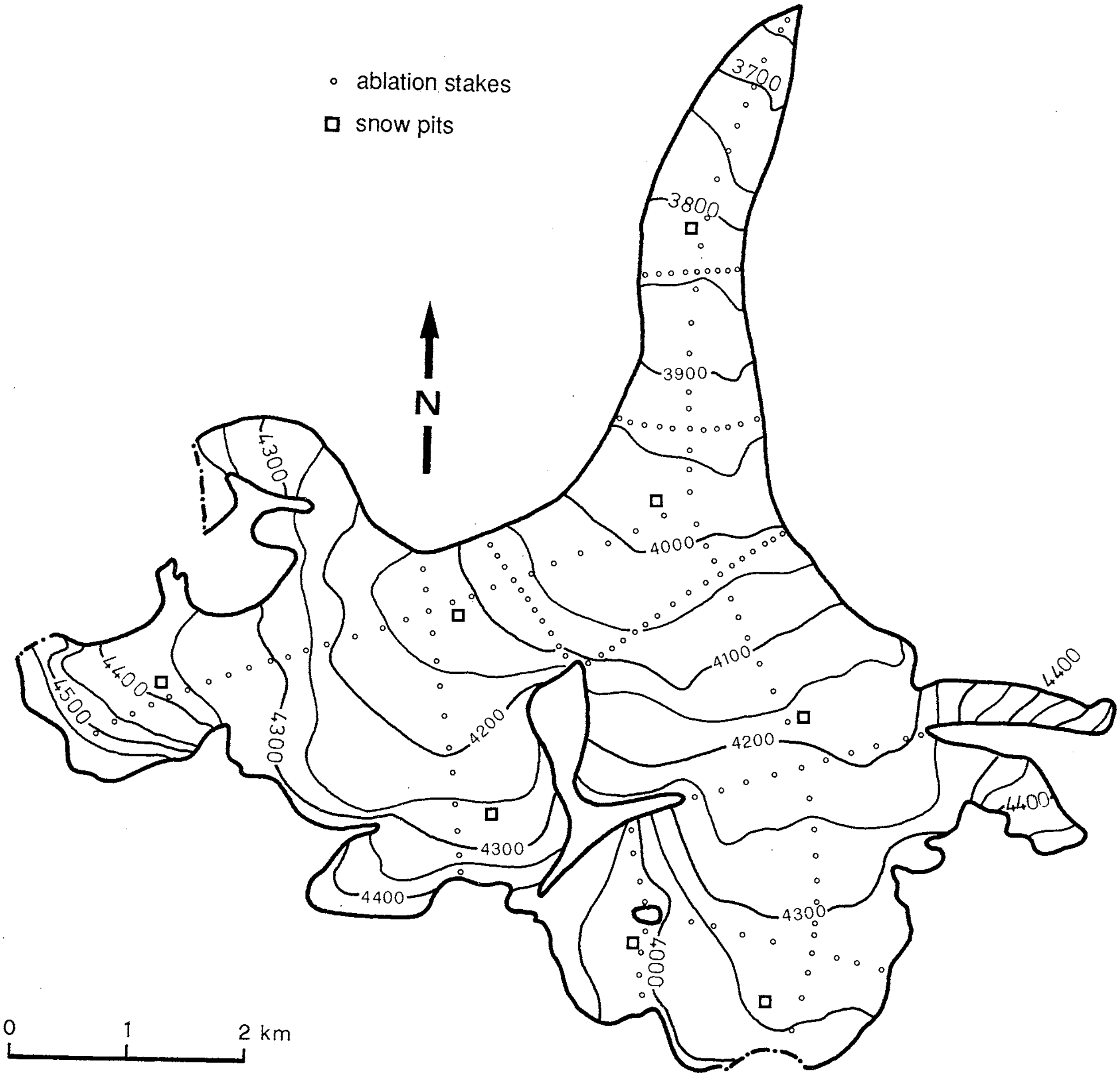
COORDINATES: 43° 00' N / 77° 06' E

Photo taken by G.M. Kamnyanskiy in 1978.

The valley-type glacier of the Amudarya river basin is located in the Southern Alai Range and extends from 4,960 to 3,625 m a.s.l. Its surface area is 26.21 km^2 and the exposure is N. Annual mean air temperature at the equilibrium line of the glacier (around 4,200 m a.s.l.) is -6.5 to -8° C. The glacier has a temperate accumulation zone but cold ice near the surface of the ablation area. Periglacial permafrost is probably discontinuous. Average annual precipitation as measured at 3,840 m a.s.l. is about 750 mm. A 1:25,000 topographic map of the glacier is still unpublished.

In 1987/88 with a zero mass balance, the glacier received about 40% above average precipitation and underwent strong melting during the warm summer. In 1988/89, precipitation was normal and the summer relatively cool, leading to a small net mass loss of 0.22 m water equivalent.

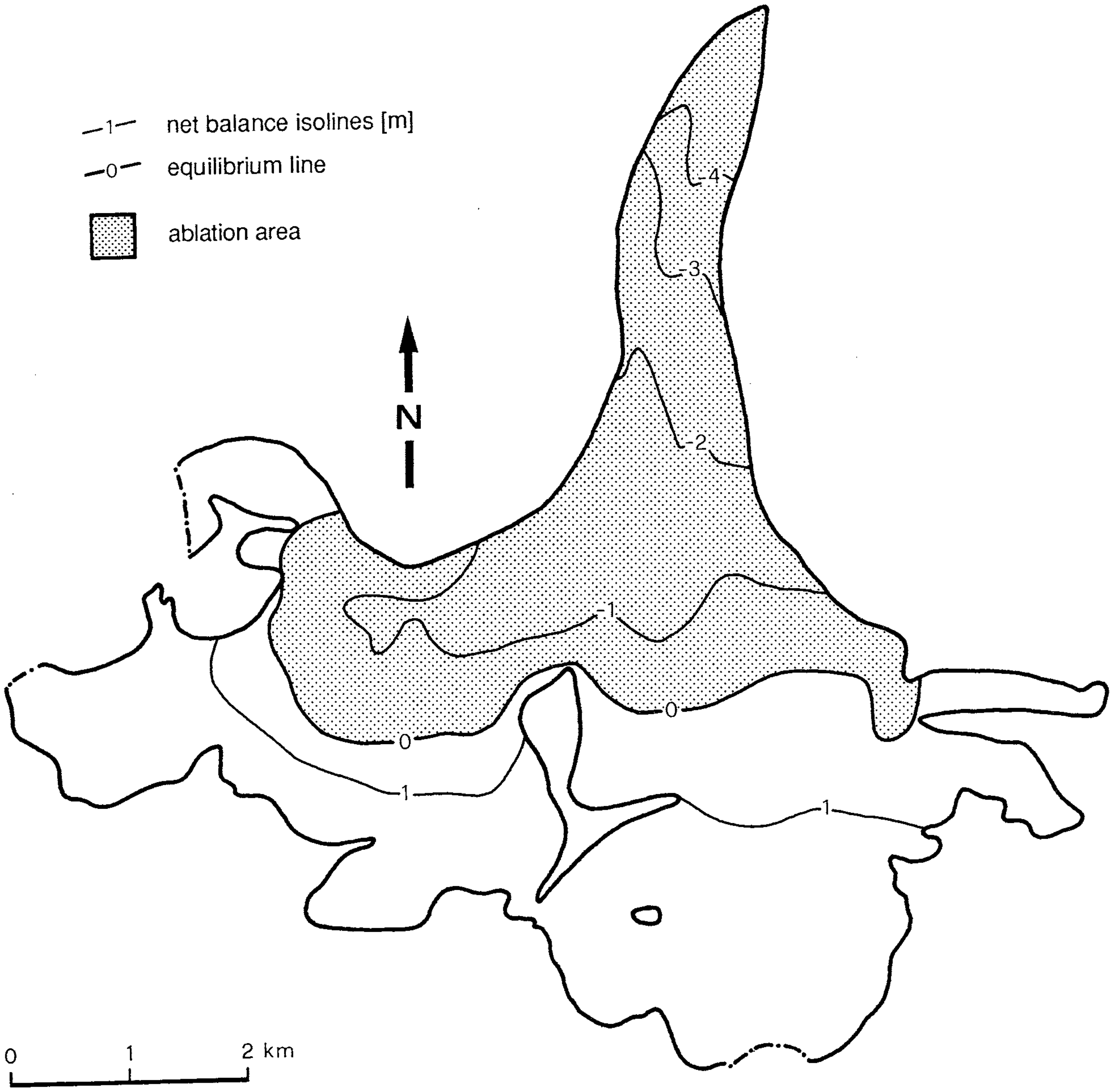
3.6.1 Topography and observational network



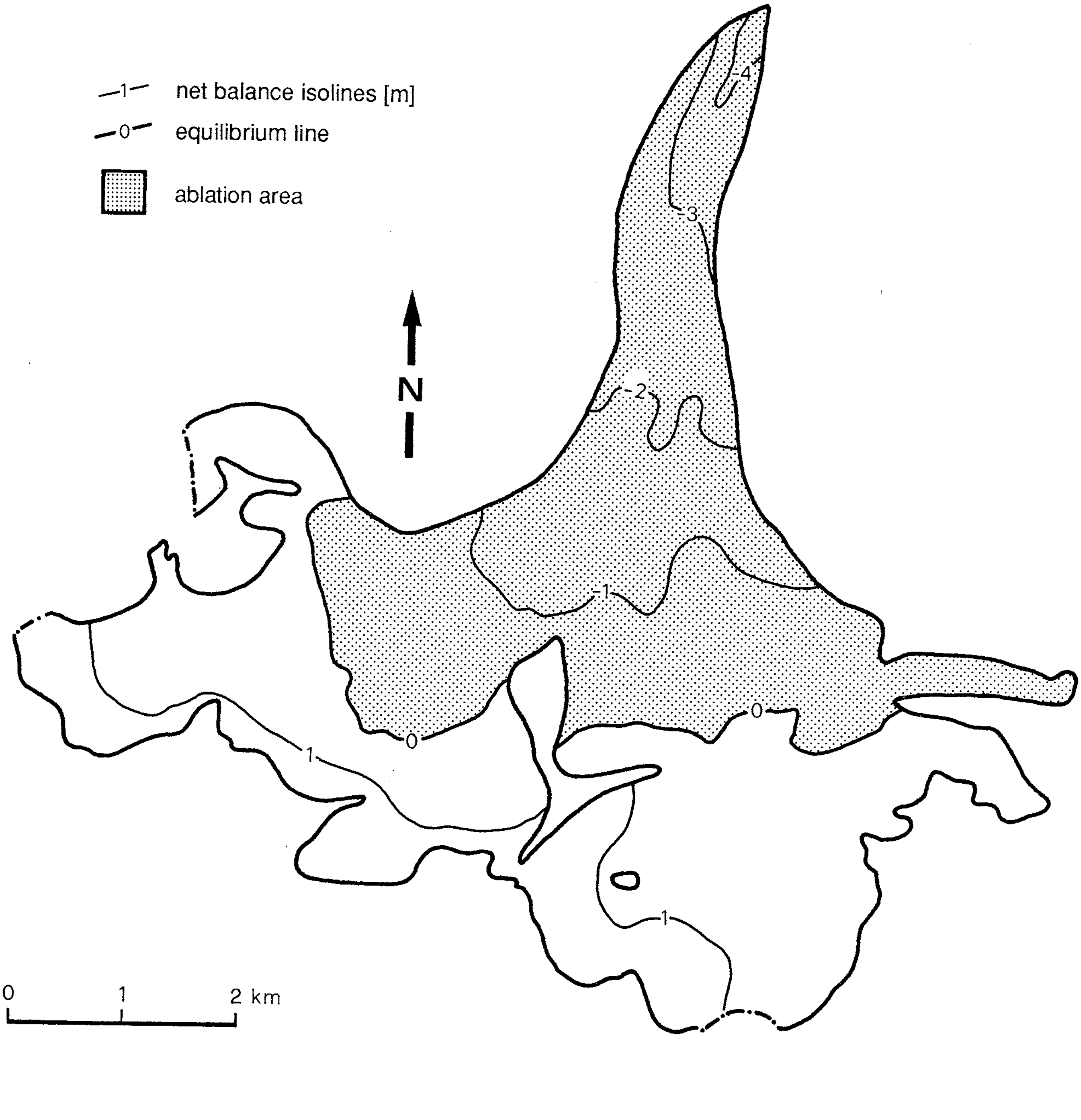
Abramov (USSR)

3.6.2 Net balance maps 1987/88 and 1988/89

1987/88

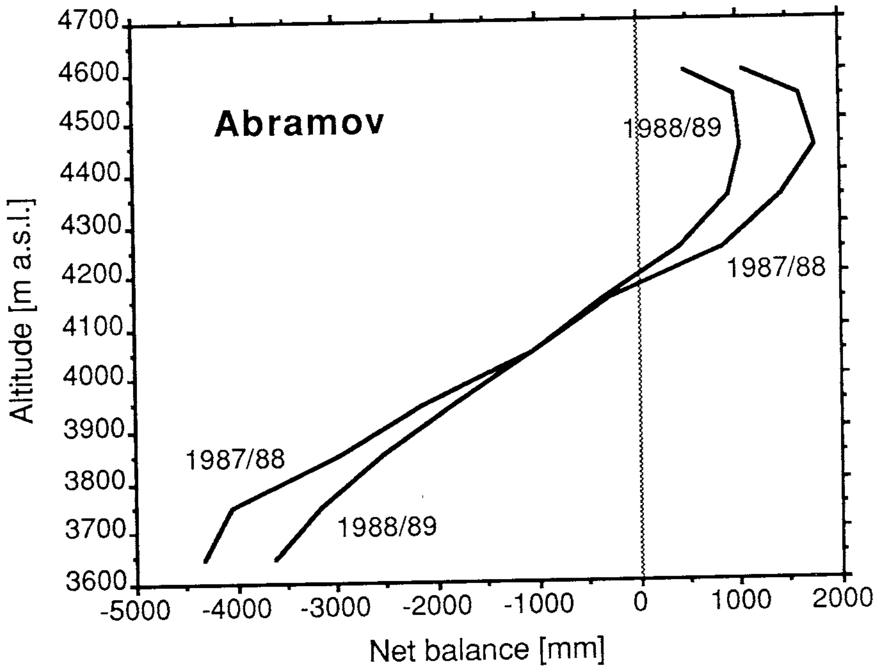


1988/89

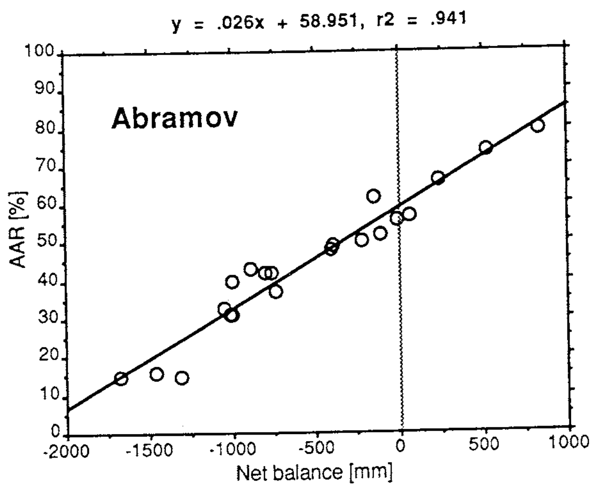


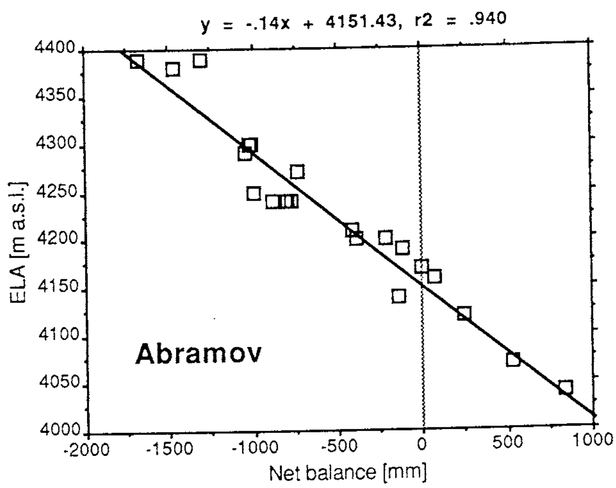
net balance isolines [m]
equilibrium line
ablation area
N
-4
-3
-2
-1
0
0
1
1
0 1 2 km

3.6.3 Net balance versus altitude (1987/88 and 1988/89)



3.6.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.7 TUYUKSU (USSR)

COORDINATES: 43° 00' N / 77° 06' E

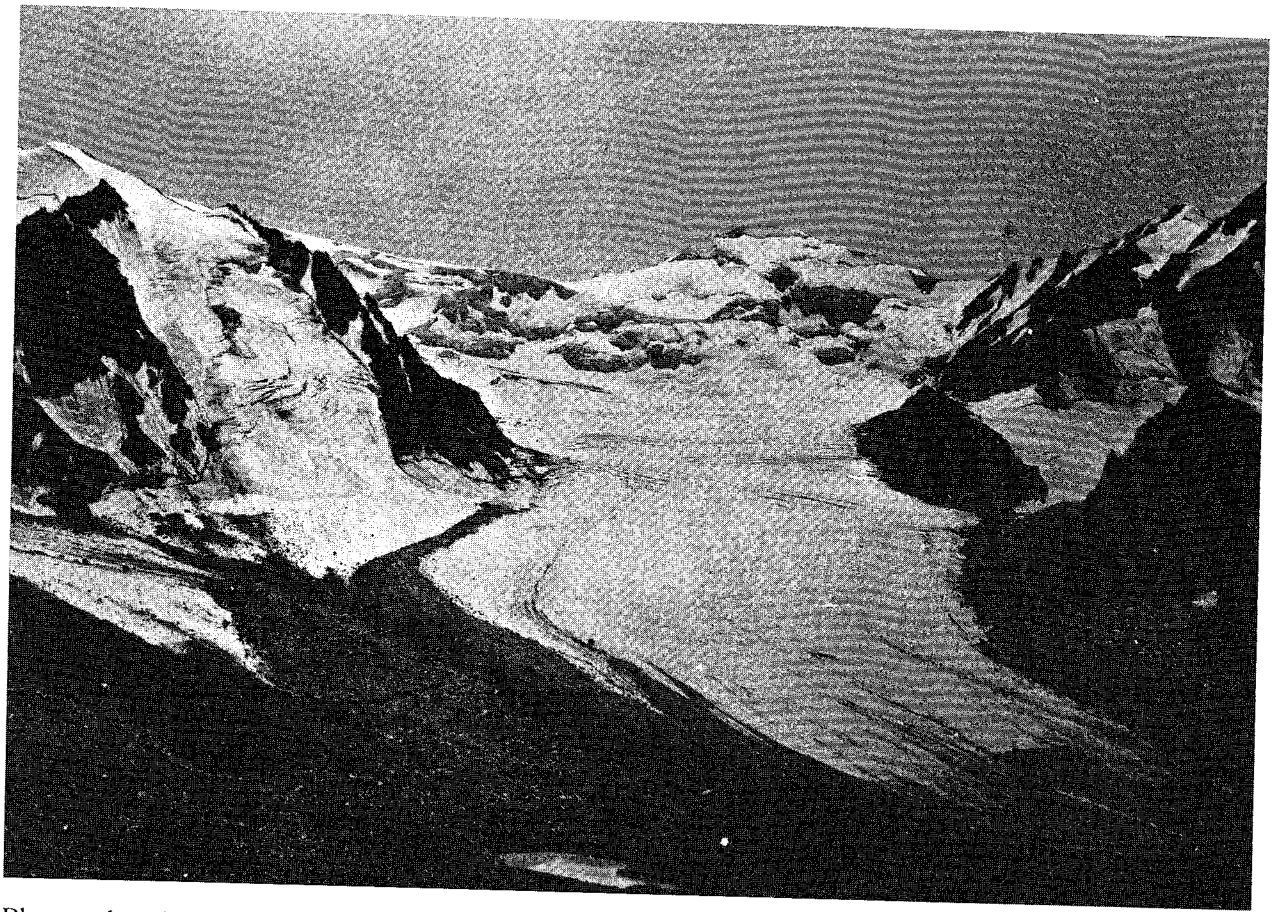
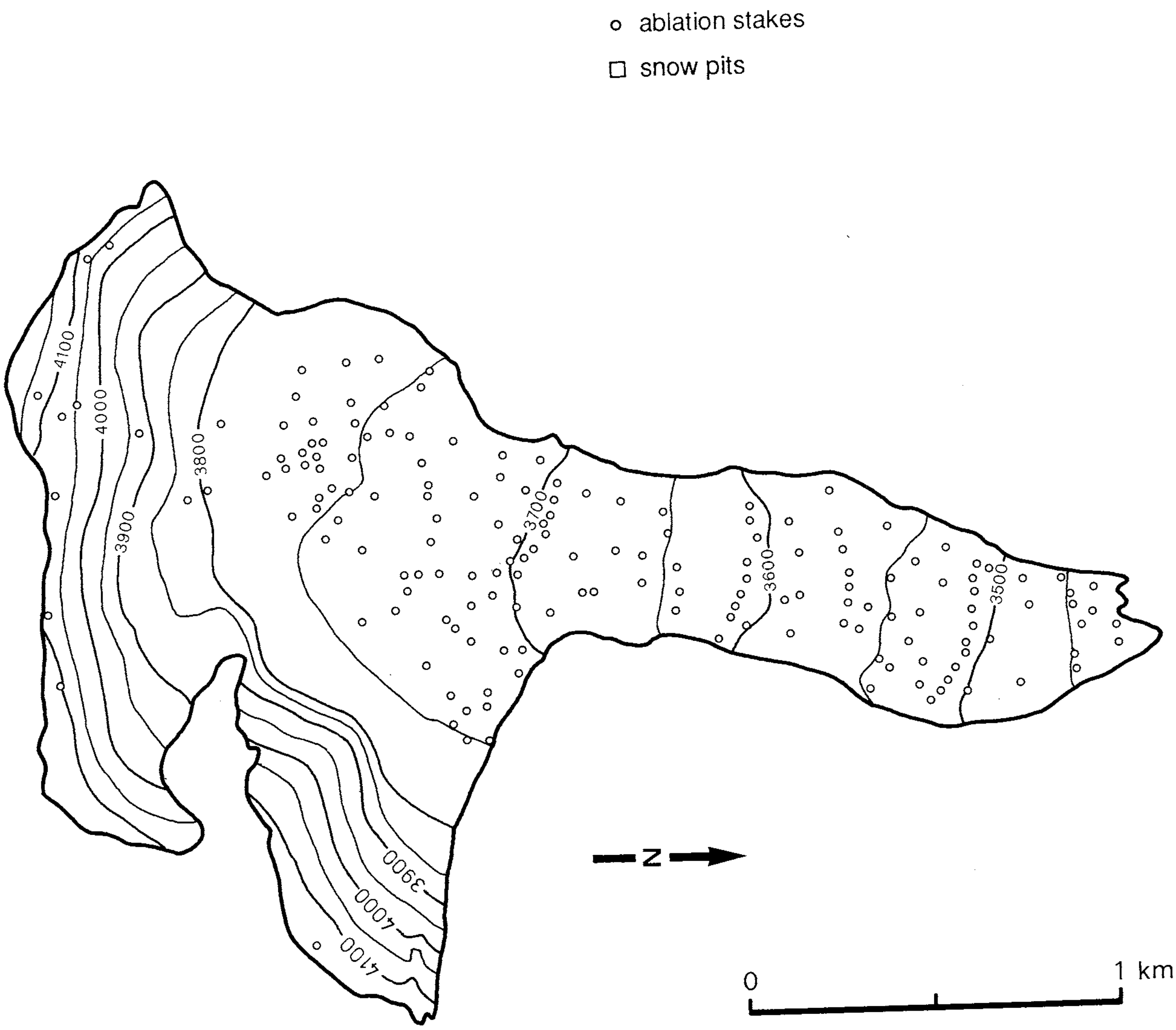


Photo taken by K.G. Makarevich in August 1970.

The valley-type glacier in the Zailiyskiy Alatau Range of the USSR Tien Shan is also called Tsentralniy Tuyuksu Glacier. It extends from 4,220 to 3,400 m a.s.l and has a surface area of 3.02 km^2 with the exposure being to the N. Annual mean air temperature at the equilibrium line of the glacier (around 3,800 m a.s.l.) is -6 to -7° C. The predominantly cold glacier is surrounded by continuous permafrost and reaches melting temperatures over parts of the bed. Average annual precipitation as measured with a great number of precipitation gauges is about 1,000 mm in the glacier belt. Ablation processes play the key role for the mass balance of this continental-type glacier with considerable winter accumulation (roughly 50% of annual precipitation).

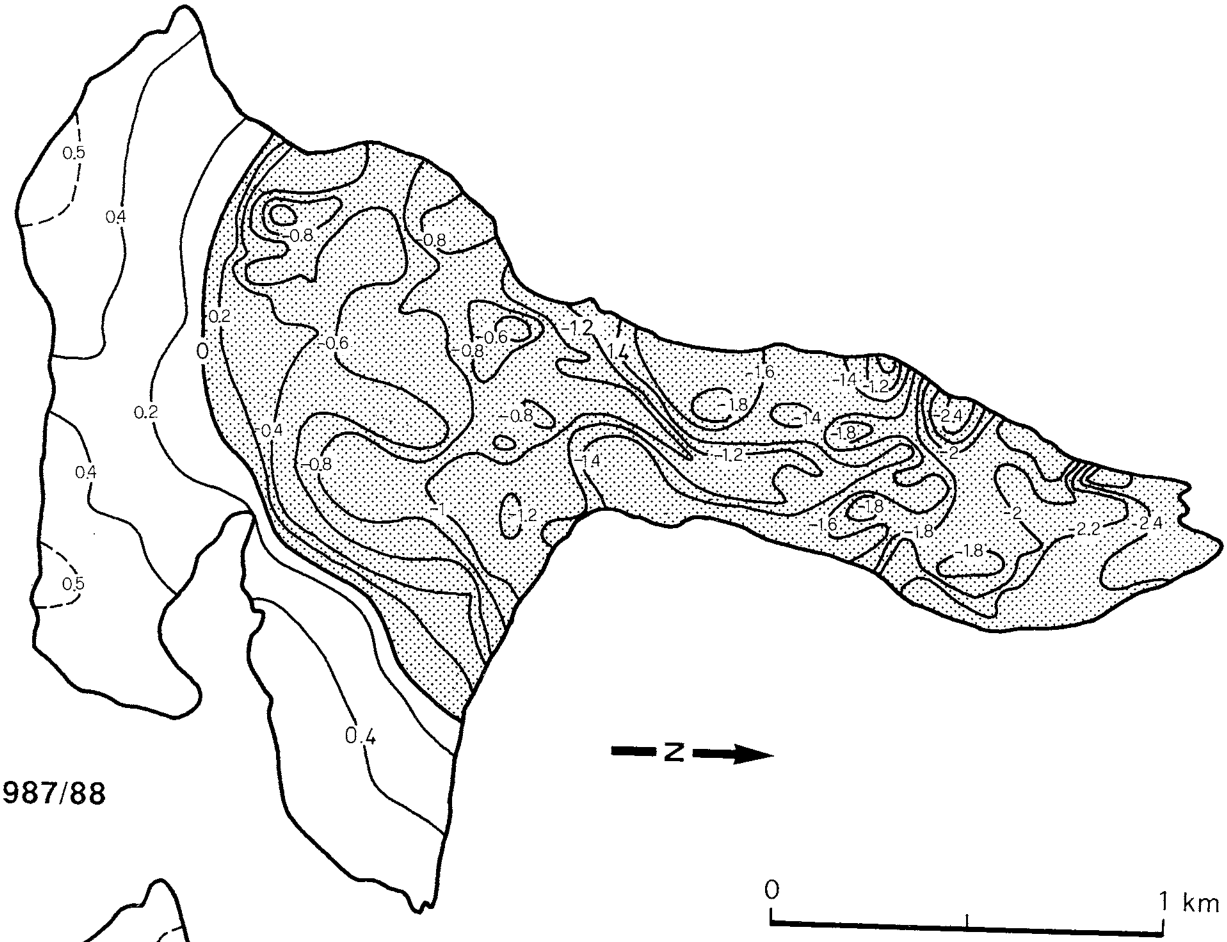
The two reported mass balances were both clearly negative. 1987/88 with a net mass loss of 0.61 m water equivalent had high precipitation but also warm summer temperatures. Winter accumulation and summer ablation were both weaker in 1988/89 than the year before, resulting in a net mass loss of 0.46 m water equivalent.

3.7.1 Topography and observational network



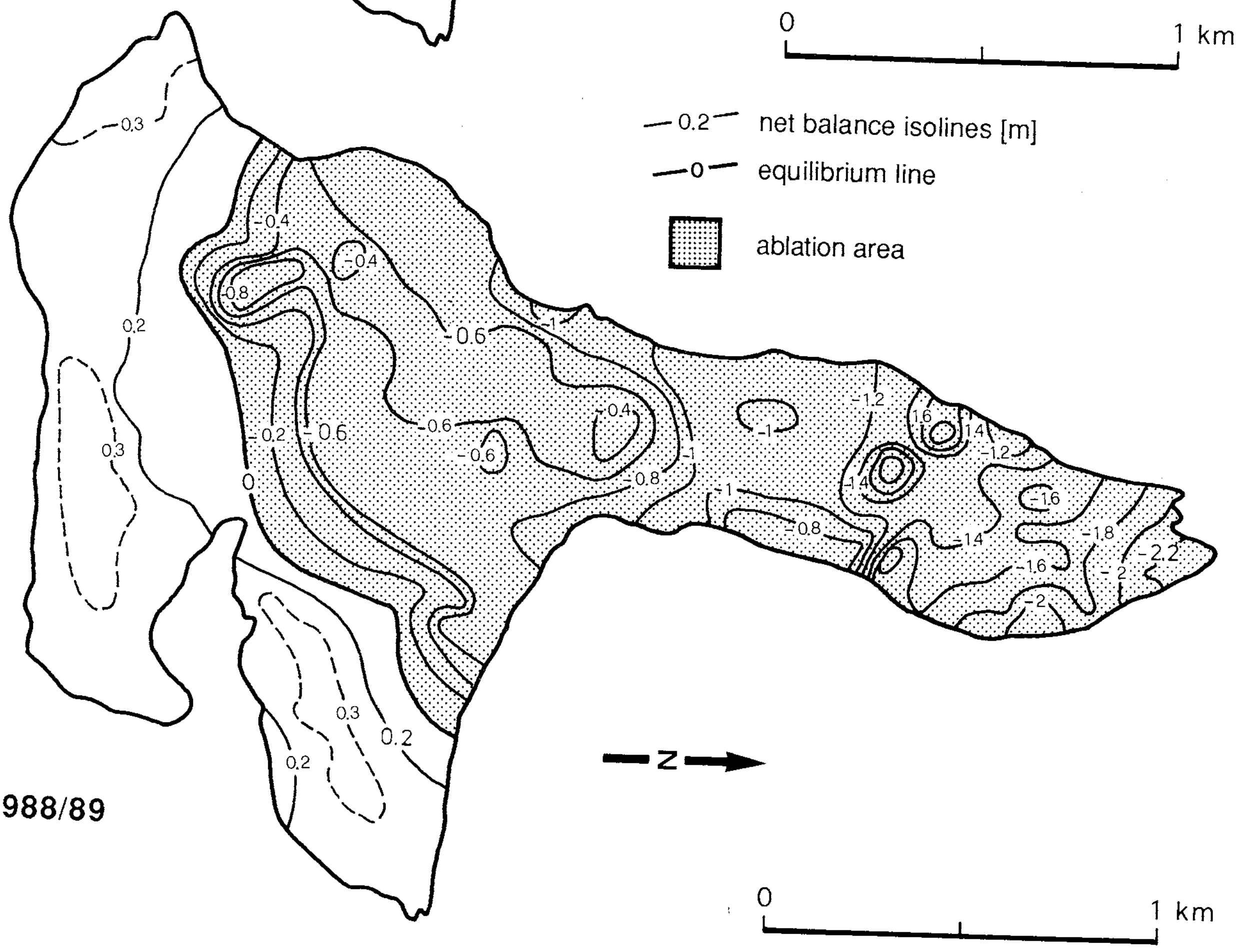
Tuyuksu (USSR)

3.7.2 Net balance maps 1987/88 and 1988/89



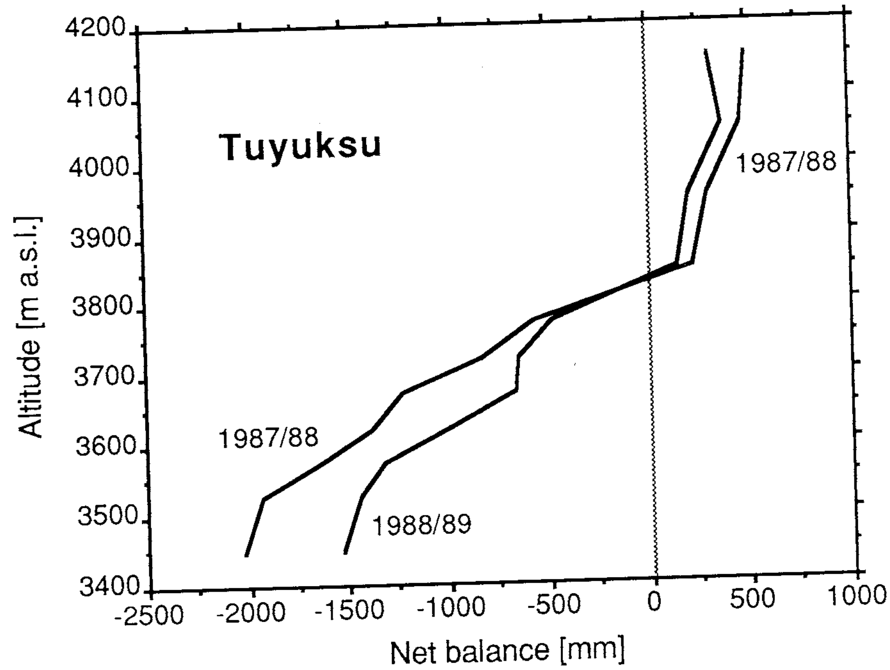
1987/88

— 0.2 — net balance isolines [m]
— 0 — equilibrium line
ablation area

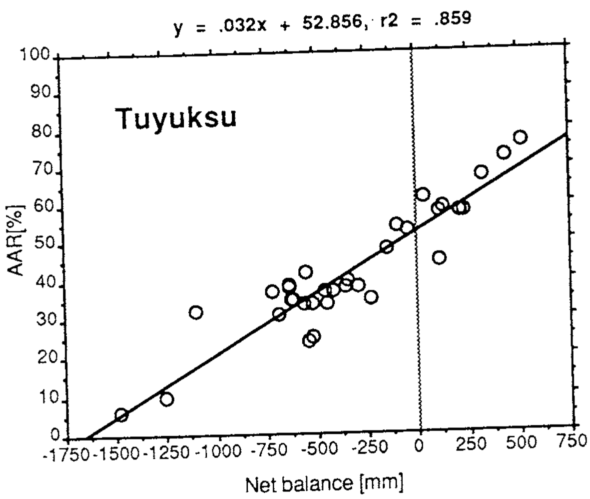


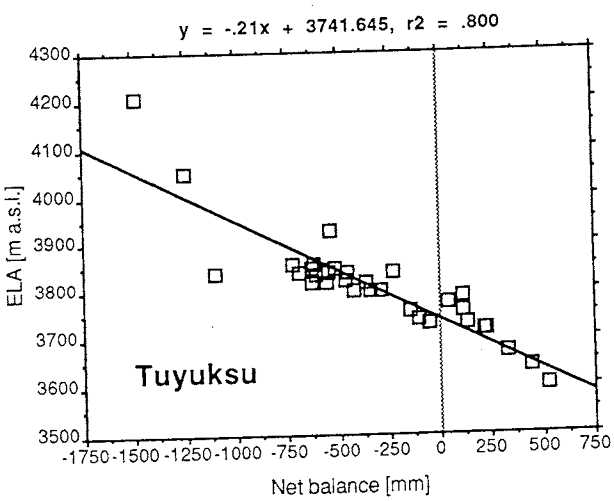
1988/89

3.7.3 Net balance versus altitude (1987/88 and 1988/89)



3.7.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.8 MALIY AKTRU (USSR)

COORDINATES: 50° 05' N / 87° 45' E

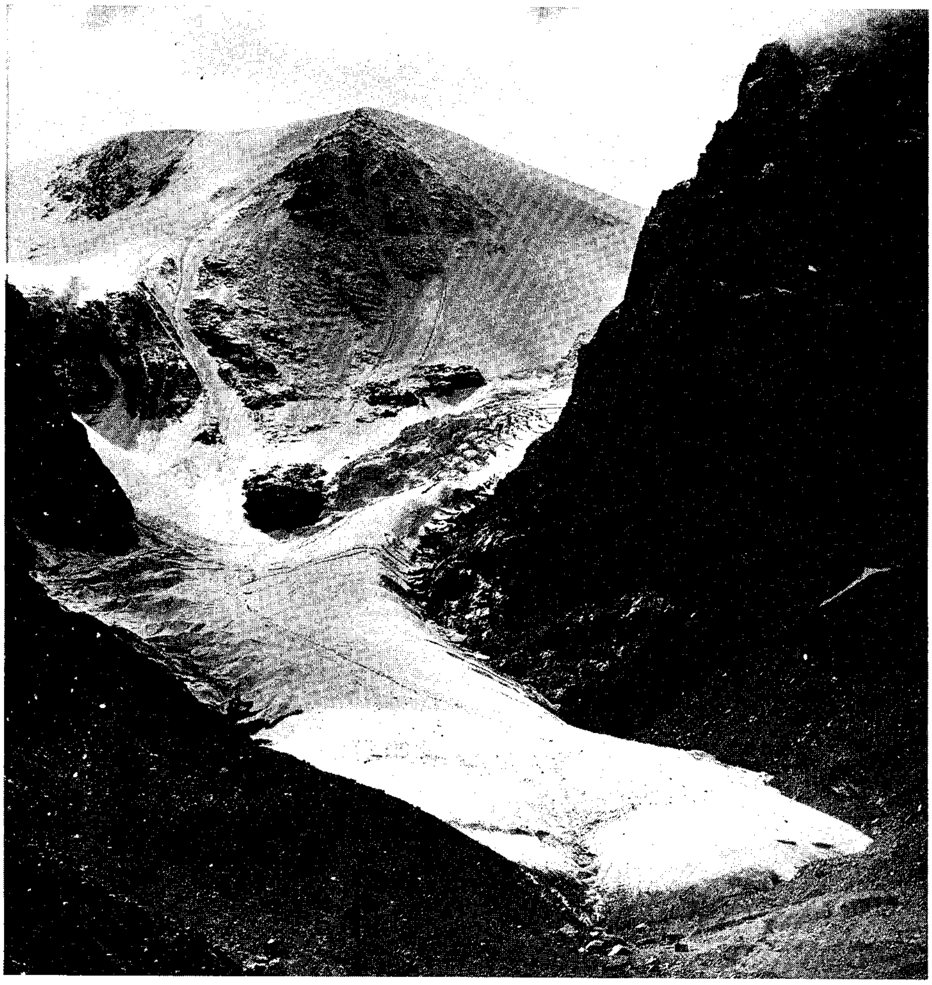
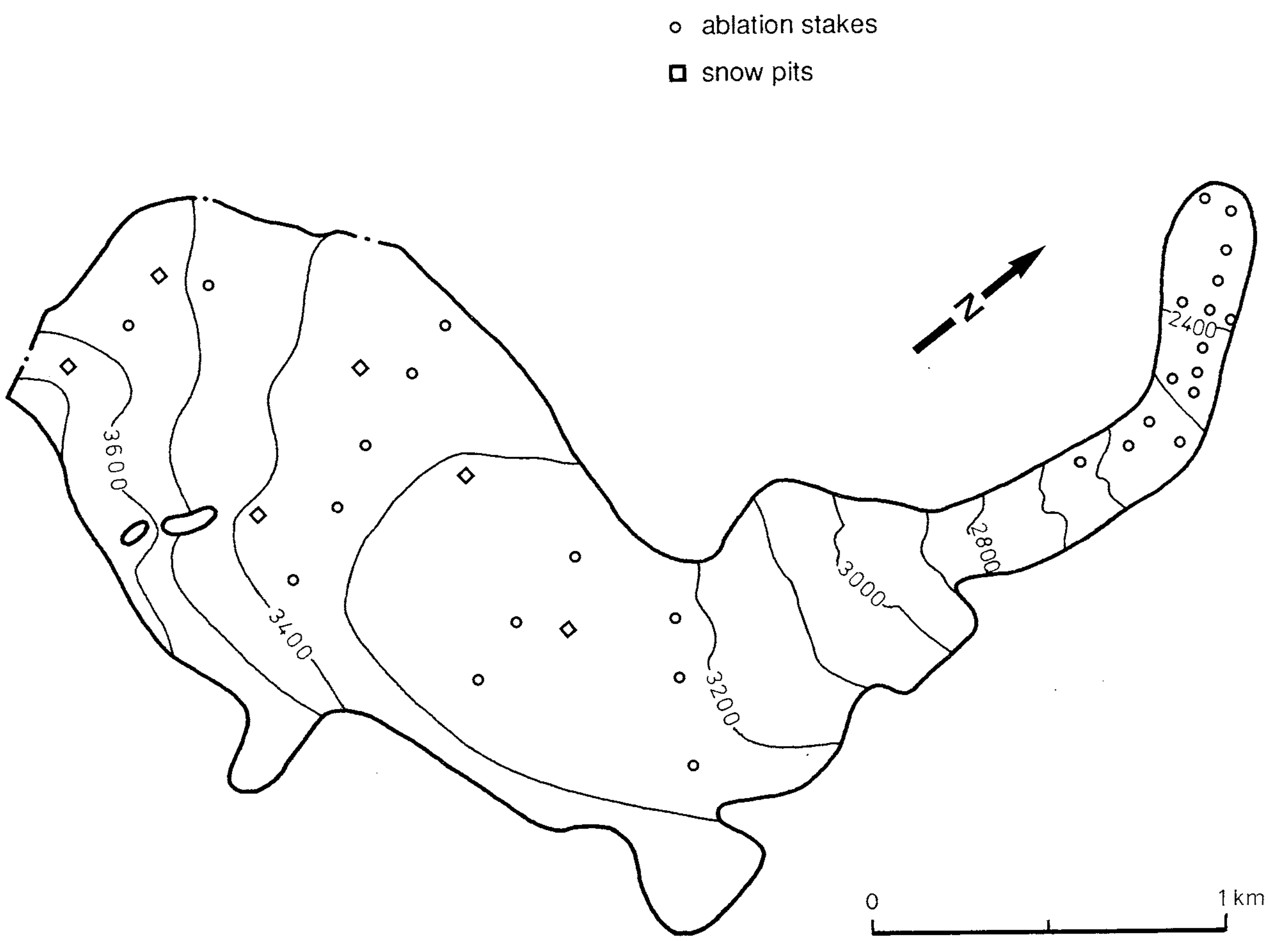


Photo taken by Yu. K. Narozhniy in July 1989.

The valley-type glacier is located on the northern slope of the North Chuyskiy Range of the USSR Altai Mountains. It extends from 3,714 to 2,224 m a.s.l. Its surface area is 2.86 km^2 and the exposure is E to N. Annual mean air temperature at the equilibrium line of the glacier (around 3,130 m a.s.l.) is -10 to -12° C. The glacier is polythermal and surrounded by continuous to discontinuous permafrost. Average annual precipitation as measured at 2,130 m a.s.l. is about 520 mm. Mass balances of four glaciers within the same basin are being determined.

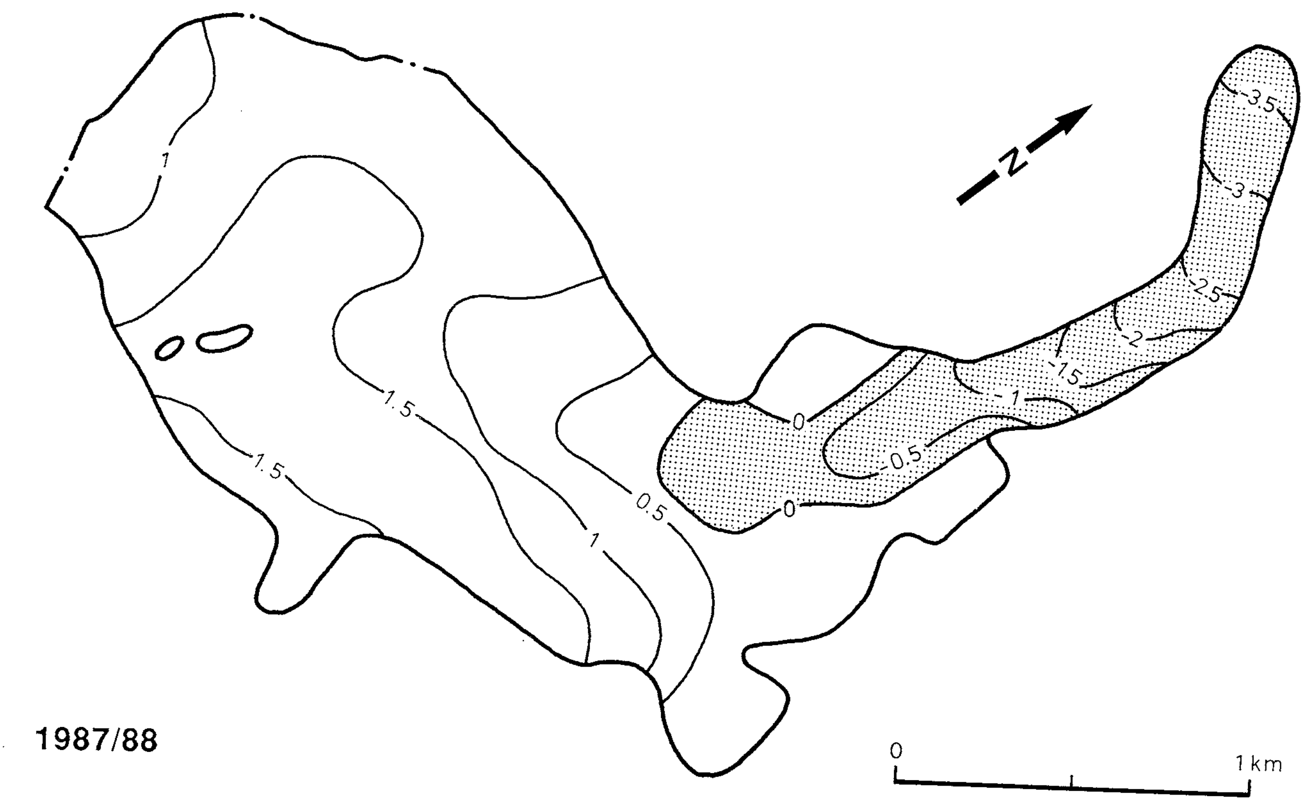
The growth tendency observed since 1982/83 continued with the two reported balance years. In 1987/88, summer mean air temperature was 1.3° C lower and annual precipitation roughly 25% higher than average, leading to a mass gain of 0.47 m water equivalent. The resulting total accumulation was 30% above normal and is without precedent for the entire investigation period. In addition, numerous snowfalls reduced melt rates during summer. 1988/89 had average precipitation values. The summer temperatures, however, were slightly below average causing a net mass gain of 0.22 m water equivalent. Since 1982/83, the glacier practically compensated for the mass losses in the years from 1978 - 1982.

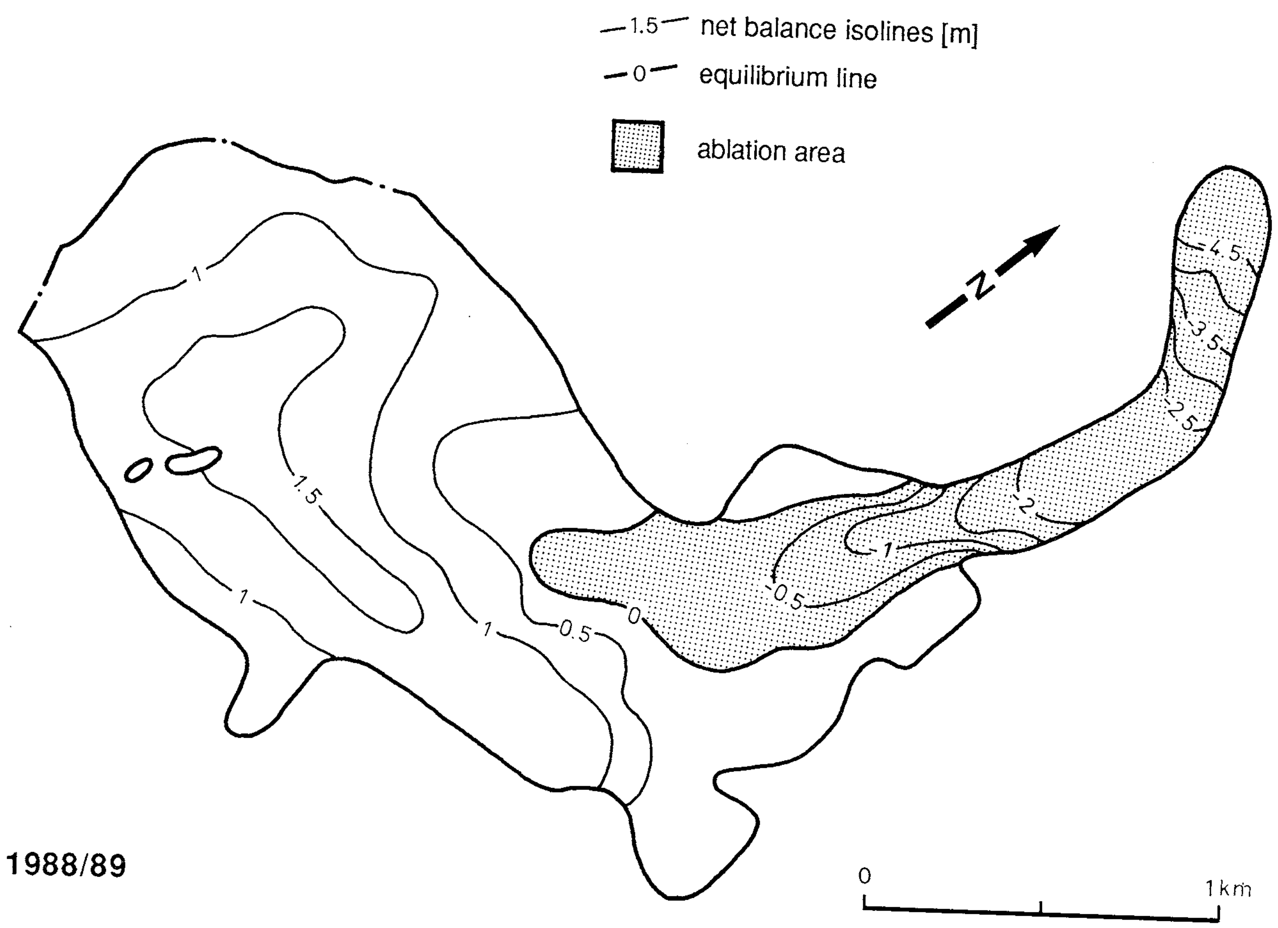
3.8.1 Topography and observational network



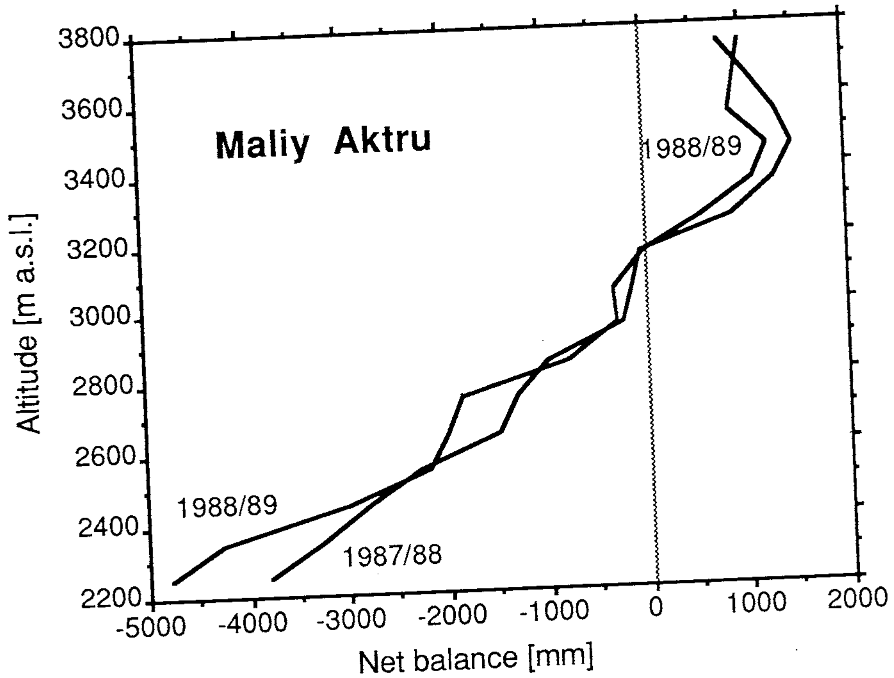
Maliy Aktru (USSR)

3.8.2 Net balance maps 1987/88 and 1988/89

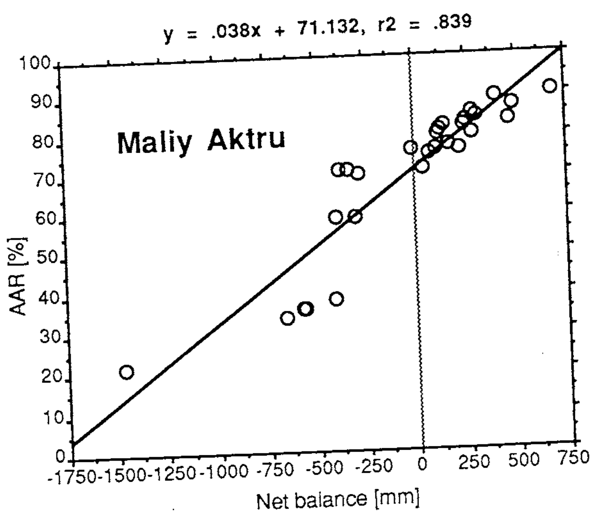


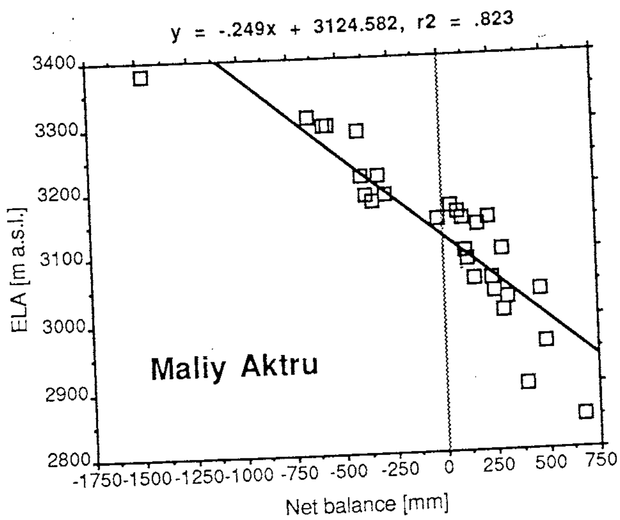


3.8.3 Net balance versus altitude (1987/88 and 1988/89)



3.8.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.9 KOZELSKIY (USSR)

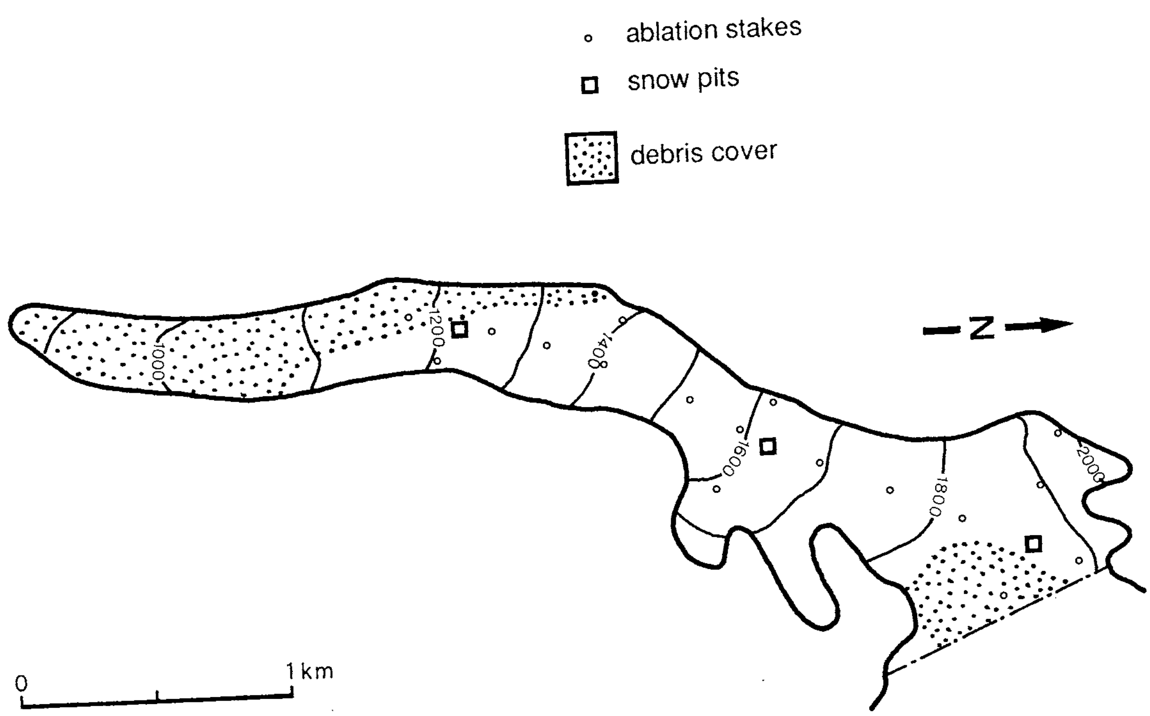
COORDINATES: 53° 14' N / 158° 49' E

Photo taken by Ya. D. Muravyov in September 1984.

The valley-type glacier is located on the eastern slope of Avachinskiy Volcano in the Vostochny Range of Kamchatka Peninsula and extends from 2,030 to 870 m a.s.l. Its surface area is 1.78 km^2 and the exposure is S. Annual mean air temperature at the equilibrium line of the glacier (around 1,590 m a.s.l.) is -5 to -6° C. The glacier is thought to be temperate, perhaps with a cold surface layer in the upper parts of the ablation area. Average annual precipitation as measured at 1,850 m a.s.l. is about 2,100 mm. A 1:25,000 topographic map of the glacier in 1975 is not yet published. The main peculiarities of the glacier are the sub-lengthwise orientation of the equilibrium line and a zone covered by volcanic ash in the upper reaches of the glacier, where mass balance remains zero.

The two reported balance years were both strongly negative. 1987/88 with a net mass loss of 1.95 m water equivalent was extremely unfavourable for the glacier with winter precipitation remaining about 25% below average and summer temperatures being among the highest during the 17 years of observation. In 1988/89, winter precipitation was 40% above average but summer temperatures were again very high. The resulting mass loss was 0.76 m water equivalent.

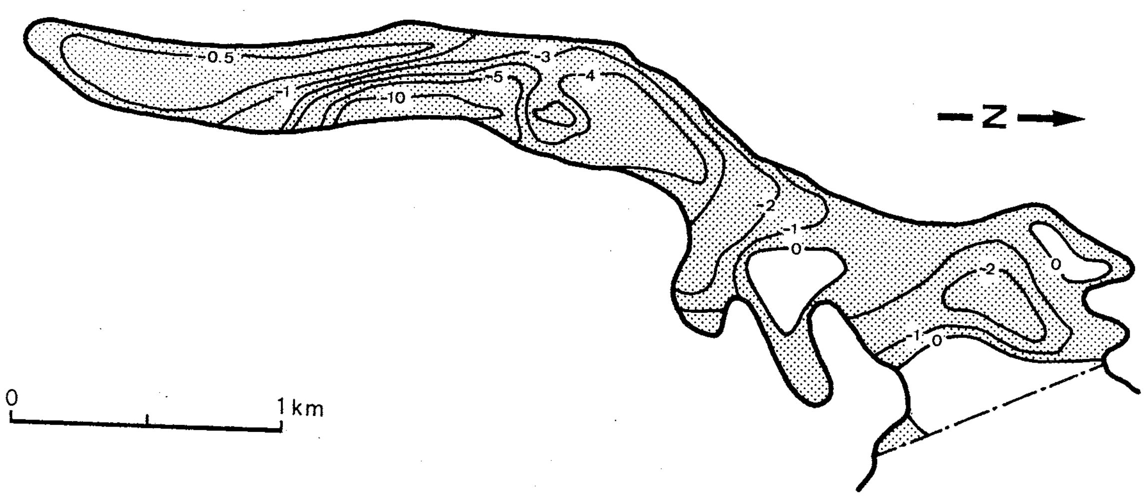
3.9.1 Topography and observational network



Kozelskiy (USSR)

3.9.2 Net balance maps 1987/88 and 1988/89

1987/88

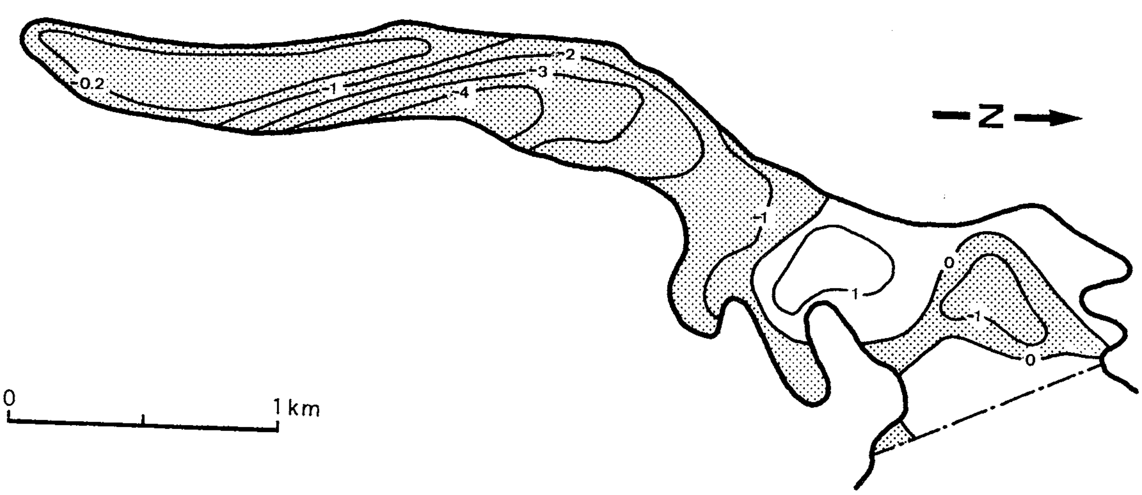


—1— net balance isolines [m]

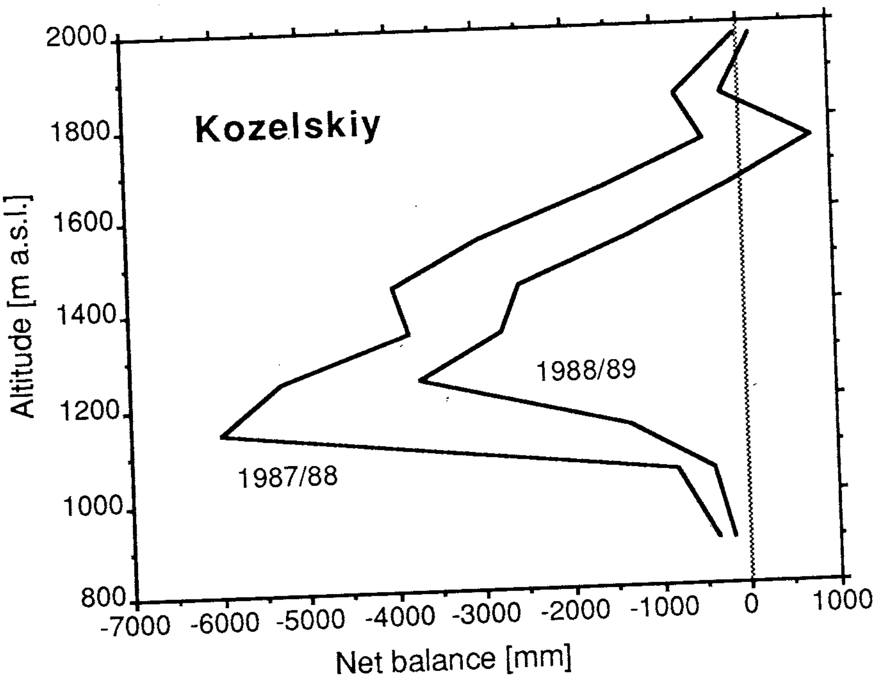
—0— equilibrium line

ablation area

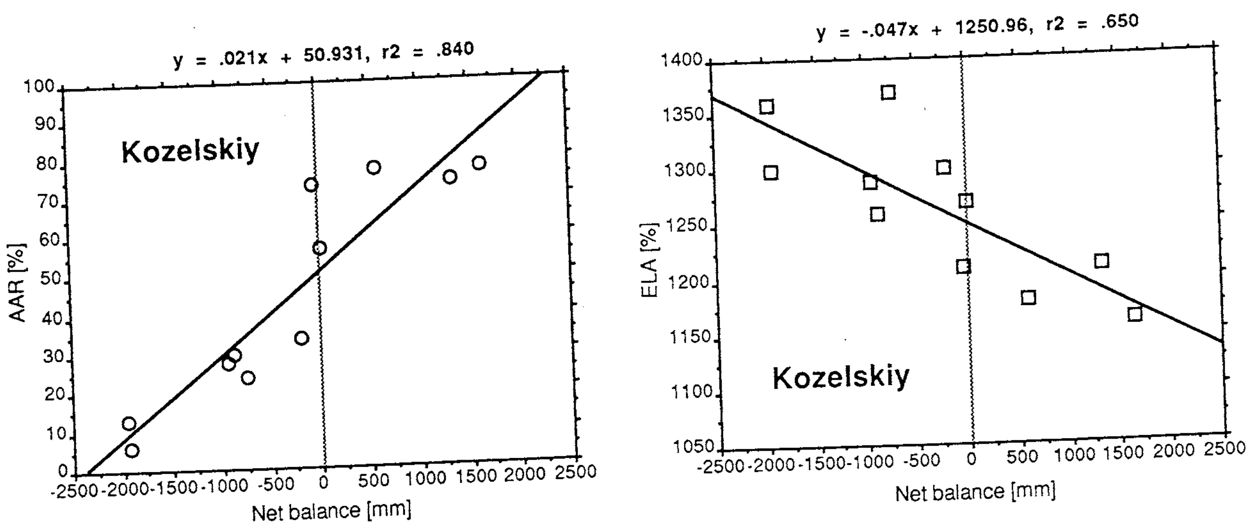
1988/89



3.9.3 Net balance versus altitude (1987/88 and 1988/89)



3.9.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period



3.10 URUMQIHE S. NO. 1 (CHINA)

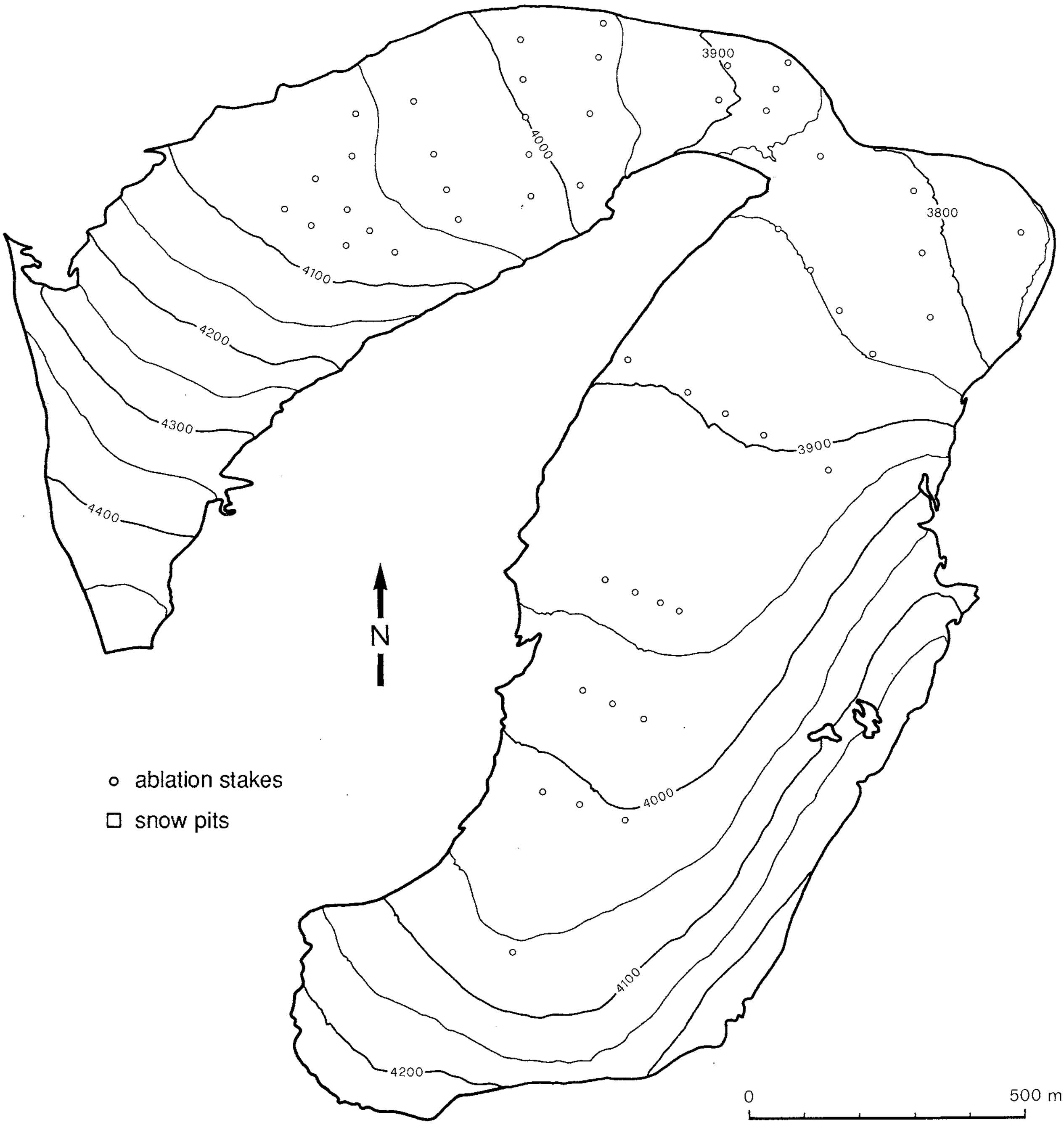
COORDINATES: 43° 05' N / 86° 49' E

Author and date of Photo not reported.

The so-called Glacier No. 1 in the headwaters of Urumqi River in the Chinese Tian Shan is a small valley-type glacier with a total surface area of 1.84 km^2 and consisting of two branches, both exposed to the NE. The highest and lowest points of the glacier are at 4,486 and 3,745 m a.s.l. Annual mean air temperature at the equilibrium line of the glacier (around 4,000 m a.s.l.) is -7 to -8° C. The predominantly cold glacier is surrounded by continuous permafrost but reaches melting temperatures over wide areas of the bed. Average annual precipitation measured at the nearby meteorological station is 400 to 500 mm at 3539 m a.s.l. and 600 to 700 mm at the glacier. Mass gain and ablation both predominantly take place during the warm season and the formation of superimposed ice on this continental-type glacier is important. A 1:5,000 topographic map of the glacier and its forefield in 1980 can be found in Vol. 5 of the Fluctuations of Glaciers.

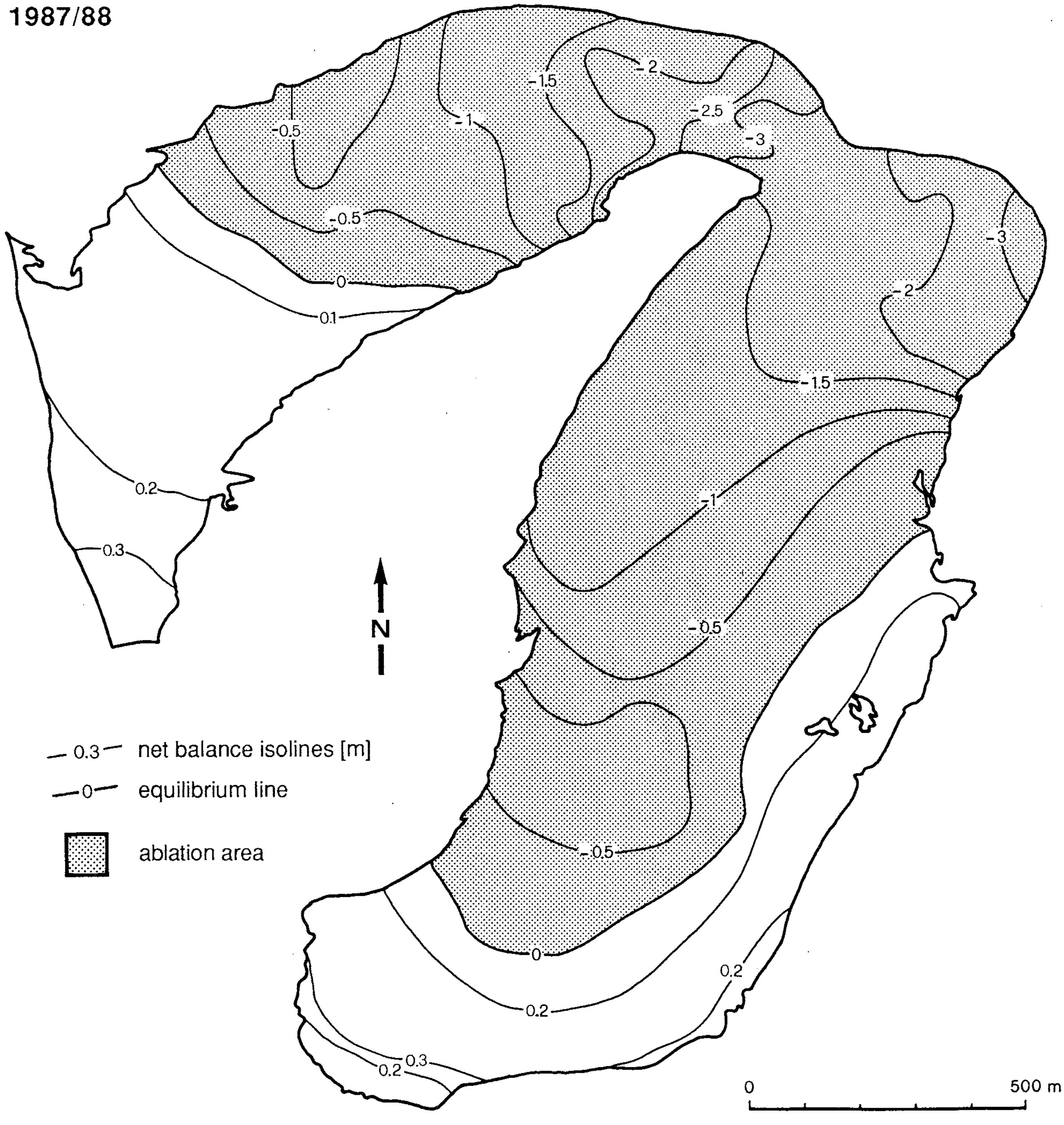
Precipitation in 1987/88 was average but temperature was too warm in summer. This resulted in a pronounced mass loss of 0.64 m water equivalent. The mass gain in 1988/89 is mainly a consequence of low summer temperatures and correspondingly weak ablation.

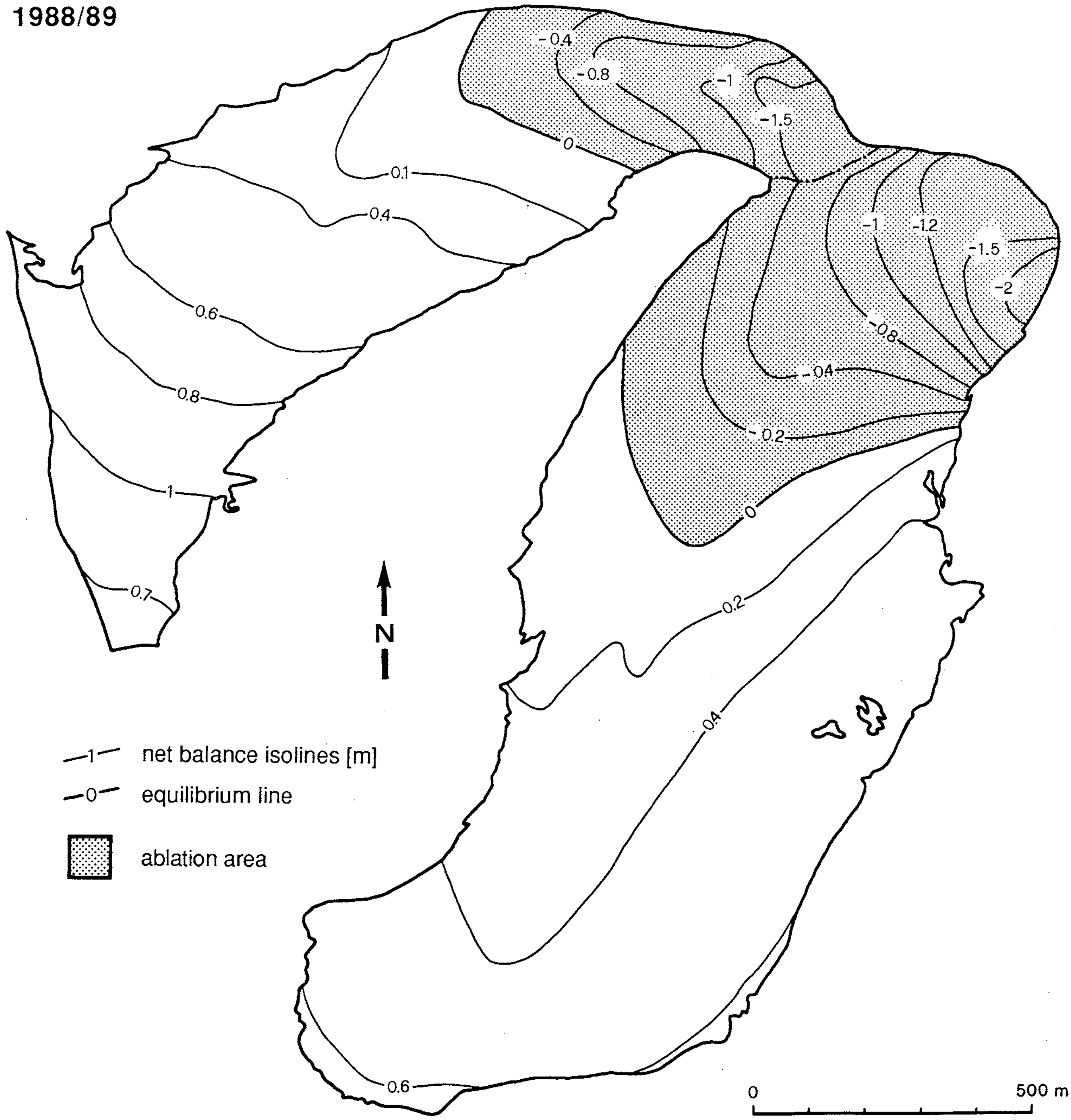
3.10.1 Topography and observational network



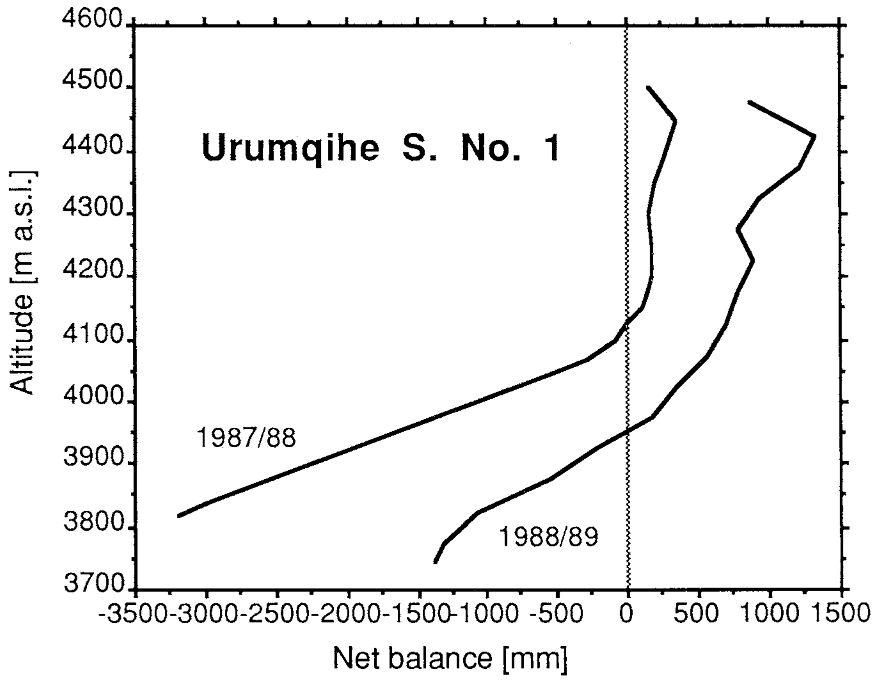
Urumqihe S. No. 1 (CHINA)

3.10.2 Net balance maps 1987/88 and 1988/89

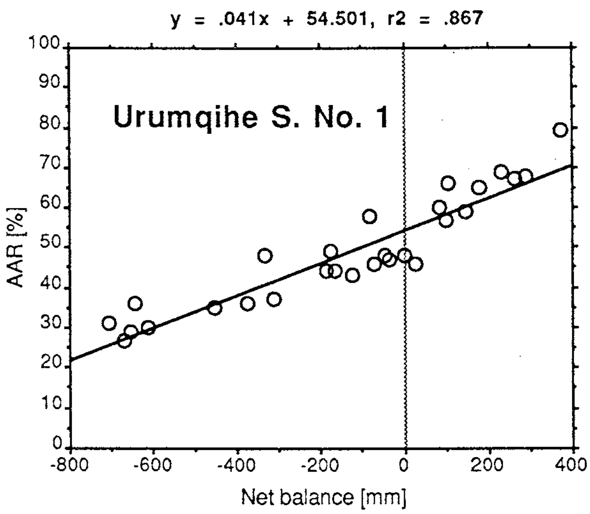


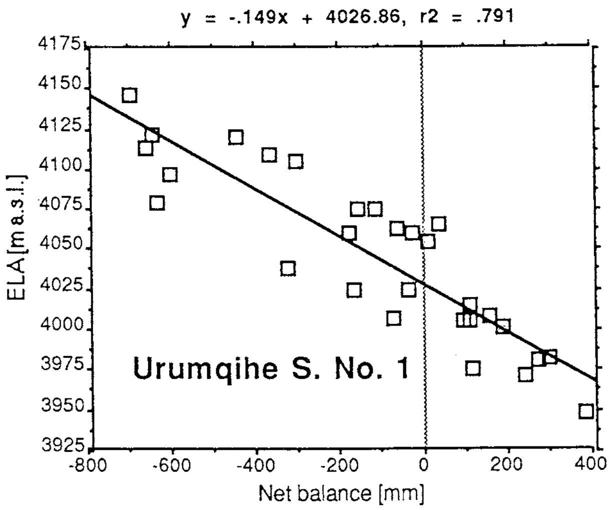

1988/89
-0.4
-0.8
-1
-1.5
0
0.1
0.4
0.6
0.8
1
0.7
-1
-1.2
-1.5
-2
-0.8
-0.4
-0.2
0
0.2
0.4
0.6
N
—1— net balance isolines [m]
—0— equilibrium line
ablation area
0
500 m

3.10.3 Net balance versus altitude (1987/88 and 1988/89)



3.10.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





4. FINAL REMARKS AND ACKNOWLEDGEMENTS

For 50 glaciers out of 54, mass balance values are available of both years 1987/88 and 1988/89. The corresponding results of this sample of 50 glaciers can be summarized as follows:

	1987/88	1988/89
mean specific net balance:	- 602 mm	- 57 mm
standard deviation:	± 652 mm	± 1138 mm
minimum value:	- 2480 mm	- 2590 mm
maximum value:	+ 520 mm	+ 3470 mm
range:	3000 mm	6060 mm
positive balances:	16 %	38 %

These values give a rough indication of northern hemisphere mass balances of mountain glaciers. Taking the two years together, the mean mass balance was negative by a few decimeters; this result resembles the secular average quite closely and shows a continuation of the long-term trend.

The wide range of reported balance values and the curves of cumulative mass balances (Chapter 2) indicate a remarkable variability in the state of health of mountain glaciers, with mass gains preferentially occurring in some humid coastal ranges (e.g. Norway). Such variability is, in fact, characteristic for the time period since about the middle of the 20th century and has replaced the almost uniform shrinking tendency of earlier decades. It not only reflects regional climatic variability but also marked differences in the sensitivity of the observed glaciers. This sensitivity has a local topographic component - the hypsographic distribution of glacier area with altitude - which can lead to pronounced differences in mass balance trends even within one and the same catchment (Hintereis- and Kesselwandferner in the Oetztal, the glaciers around Tsentralniy Tuyuksu in the Almatinka Basin, and the Aktru glaciers in the Altai Mountains). The climatic component of the sensitivity is the mass balance gradient or the relation between changes in balance and equilibrium line altitude, which leads to stronger reactions of maritime than of continental glaciers. Over long time intervals, however, local and regional differences tend to diminish or even to disappear. The photos of the 10 glaciers with extensive information show glaciers far within the moraines from the Little Ice Age. This phenomenon, which is characteristic for mountain glaciers all around the world, clearly illustrates that - at a secular time scale - the reported observations are just a short episode within a general trend of strong ice melt.

Completion of the present first Glacier Mass Balance Bulletin was made possible through the co-operation of the national correspondents to WGMS and the principal investigators on the various glaciers, as listed in the final chapter, 5. Thanks are also due to the other staff members of WGMS for their help and assistance, especially to Martin Hoelzle for management and statistical analysis of the data, to Werner Nobs for drawing the maps and, to Susan Braun for editing the English.

Funding was mainly through GEMS / UNEP and FAGS / ICSU. The contributors are prepared to help publishing forthcoming bulletins no later than one year after the termination of the second reported balance year. Drawing on the experience from the first issue, we hope to issue the second Glacier Mass Balance Bulletin in winter 1992/93. Suggestions for further improvement of the content and presentation of this new publication series are very welcome.

5. PRINCIPAL INVESTIGATORS AND NATIONAL CORRESPONDENTS

5.1 PRINCIPAL INVESTIGATORS

CANADA:	Place Helm	M. Brugman Hydrological Sciences Division National Hydrology Research Institute 11, Innovation Boulevard **CANADA - Saskatoon, Saskatchewan S7N 3H5**
USA:	South Cascade	R.M. Krimmel US Geological Survey Ice and Climate Project University of Puget Sound **USA - Tacoma, WA 98416**
	Wolverine	D. Trabant US Geological Survey Water Resources Division 800 Yukon Drive **USA - Fairbanks, Alaska 99775-5170**
ICELAND:	Hofsjökull North Hofsjökull East	O. Sigurdsson National Energy Authority Hydrological Survey Orkustofnun Grensasvegi 9 **ICELAND - 108 Reykjavik**
NORWAY:	Ålfotbreen Nigardsbreen Storbreen Gråsubreen Engabreen Langfjordjøkulen	B. Wold Norwegian Water Resources and Energy Administration Glacier Division P.O. Box 5091, Maj. **N - 0301 Oslo 3**
	Austre Brøggerbreen Midtre Lovénbreen Kongsvegen	J.O. Hagen Norwegian Polar Research Institute Postboks 158 **N - 1330 Oslo lufthavn**
	Hansbreen	J. Jania Silesian University Faculty of Earth Sciences Department of Karst Geomorphology ul. Mielczarskiego 60 **POLAND - 41-200 Sosnowiec**

SWEDEN:	Storglaciären Rabots glaciär Tarfalaglaciären Riukojietna	P. Holmlund and W. Karlén Department of Physical Geography University of Stockholm **S - 106 91 Stockholm**
FRANCE:	Sarennes Saint Sorlin	L. Reynaud Laboratory of Glaciology and Environmental (CNRS) Geophysics Domaine Universitaire Case Postale 96 **F - 38402 St-Martin-d'Héres, Cedex**
SWITZERLAND:	Gries Limmern Plattalva Silvretta	M. Aellen and M. Funk Laboratory of Hydraulics, Hydrology and Glaciology (VAW) Federal Institute of Technology ETH-Zentrum **CH - 8092 Zurich**
ITALY:	Careser	G. Zanon University of Padua Department of Gegraphy Via del Santo, 26 **I - 35123 Padua**
AUSTRIA:	Hintereisferner Kesselwandferner	G. Markl and M. Kuhn Institute of Meteorology and Geophysics University of Innsbruck Innrain 52 **A - 6020 Innsbruck**
	Sonnblickkees	H. Slupetzky Geographical Institute University of Salzburg Hellbrunnerstrasse 34 / III **A - 5020 Salzburg**
KENYA:	Lewis	S. Hastenrath Department of Meteorology University of Wisconsin-Madison 1225 West Dayton Street **USA - Madison, Wisconsin 53706**
USSR:	Garabashi	A.B. Bazhev, O.V. Rototayeva, I.F. Khmelevskoy Institute of Geography Academy of Sciences of the USSR Staromonetniy, 29 **USSR - 109017 Moscow**
	Djankuat	V.V. Popovnin Moscow State University Faculty of Geography Leninskiye Gory **USSR - 117899 Moscow**

	Abramov	G.M. Kamnyanskiy Midasian Hydrometeorological Research Institute SANIGMI Observatorskaya Str., 72 **USSR - 700052 Tashkent-52**
	Karabatkak No. 131 West. Suyok	A.N. Dikikh and E.K. Bakov Tien-Shan Physical Geography Research Station Kirghiz SSR Academy of Sciences Pionerskaya, 7 **USSR - Pokrovka, Issyk Kul Region**
	Tuyuksu Igly Tuyuksu Molodyozhniy Kosmodemyanskaya Partizan Ordzhonikidze Mayakovskiy Mametova Visyachie 1-2	K.G. Makarevich Institute of Geography Kazakh Academy of Sciences Pushkin Str., 99 **USSR - 480100 Alma Ata**
	Sary-Tor	S.N. Ushnurtsev Institute of Geography Academy of Sciences of the USSR Staromonetniy, 29 **USSR - 109017 Moscow**
	Golubin	A.A. Ermolov Kirgiz SSR Hydrometeorological Committee Karasuyskaya, 1 **USSR - 720403 Frunze**
	Maliy Aktru Leviy Aktru Praviy Aktru Vodopadniy	Yu. K. Narozhniy Tomsk State University Lenin Str., 36 **USSR - 634010 Tomsk-10**
	Kozelskiy	Ya. D. Muravyov Institute of Volcanology Academy of Sciences of the USSR Far East Research Center Piyp Boulevard, 9 **USSR - 683006 Petropavlovsk Kamchatskiy**
CHINA:	Urumqihe S. No. 1	Chaohai Liu Lanzhou Institute of Glaciology and Geocryology Chinese Academy of Sciences **CHINA - Lanzhou**

5.2 NATIONAL CORRESPONDENTS OF WGMS:

ARGENTINA:	L. Espizua Istituto Argentino de Nivologia IANIGLA/CONICET Casilla de Correo, 330 **ARGENTINA - 5500 Mendoza**
AUSTRALIA:	I. Allison University of Melbourne Antarctic Division Glaciology Section Earth Science Building **AUSTRALIA - Parkville Vic. 3052**
AUSTRIA:	G. Patzelt Institute for High Mountain Research University of Innsbruck Universitätsstrasse 4 **A - 6020 Innsbruck**
BOLIVIA:	E. Jordan Physical Geography Universität Vechta Driverstrasse 22 **D - 2848 Vechta** **GERMANY**
CANADA:	C.S. Ommanney Hydrological Sciences Division National Hydrology Research Institute 11, Innovation Boulevard **CANADA - Saskatoon, Saskatchewan S7N 3H5**
CHINA:	Yang Huyan Lanzhou Institute of Glaciology and Cryopedology Academia Sinica **CHINA - Lanzhou**
FRANCE:	L. Reynaud Laboratory of Glaciology and Environmental Geophysics (CNRS) Domaine Universitaire Case Postale 96 **F - 38402 St-Martin-d'Hères Cedex**
GERMANY:	O. Reinwarth Commission for Glaciology Bayerische Akademie der Wissenschaften Marstallplatz 8 **D - 8000 München 22**
GREENLAND:	A. Weidick Geological Survey of Greenland Øster Voldgade 10 **DENMARK - 1350 København K**

ICELAND:	O. Sigurdsson National Energy Authority Hydrological Survey Orkustofnun Grensasvegi 9 **ICELAND - 108 Reykjavik**
INDIA:	V.K. Raina Geological Survey of India 27, Jawaharlal Nehru Road **INDIA - Calcutta - 700 016**
ITALY:	G. Zanon University of Padua Department of Geography Via del Santo, 26 **I - 35100 Padua**
JAPAN:	K. Higuchi Water Research Institute Nagoya University Chikusa-Ku **JAPAN - Nagoya 464**
KENYA:	S. Hastenrath Department of Meteorology University of Wisconsin 1225 West Dayton Street **USA - Madison, Wisconsin 53706**
MEXICO:	H. Delgado-Granados Instituto de Geofisica Universidad Nacional Autonoma de Mexico Circuito Cientifico Ciudad Universitaria **MX - Coyoacan 04510 D.F.**
NEW ZEALAND:	T.J. Chinn Ministry of Works and Development P.O. Box 1479 **NZ - Christchurch**
NORWAY:	B. Wold Norwegian Water Resources and Energy Administration Glacier Division P.O. Box 5091, Maj. **N - 0301 Oslo 3**
PAKISTAN:	W. Kick Macheinerweg 35 **D - 8400 Regensburg** **GERMANY**
PERU:	M. Zamora C. Section of Glaciology and Lake Safety Electroperu Jr. Huaylas No. 143 **PERU - Huaraz / Ancash**

POLAND:
M. Klapa
Department of Hydrology and Meteorology of Tatra Mountains
ul. Sienkewicza 26c
PL - 34500 Zakopane

SPAIN:
E. Martinez de Pison
Department of Physical Geography
Universidad Autonoma
anto Blanco
E - Madrid 34

SWEDEN:
P. Holmlund
Departement of Physical Geography
University of Stockholm
S - 106 91 Stockholm

SWITZERLAND:
M. Aellen
Laboratory of Hydraulics, Hydrology and Glaciology (VAW)
Federal Institute of Technology
ETH-Zentrum
CH - 8092 Zurich

UNITED KINGDOM:
D. Collins
Department of Geography
University of Manchester
UK - Manchester M13 9PL

USA:
A. Fountain
US Geological Survey
P.O. Box 25046 / M.S. 412
Denver Federal Center
USA - Denver, Colorado 80225

USSR:
D.G. Tsvetkov
Academy of Sciences of the USSR
Soviet Geophysical Committee
Department of Glaciology
Staromonetny, 29
USSR - 109017 Moscow

VENEZUELA:
C. Schubert
Departamento de Ecologia
Instituto Venezolano de Investigaciones Cientificas
Ap. 21827
VENEZUELA - Caracas 1020A