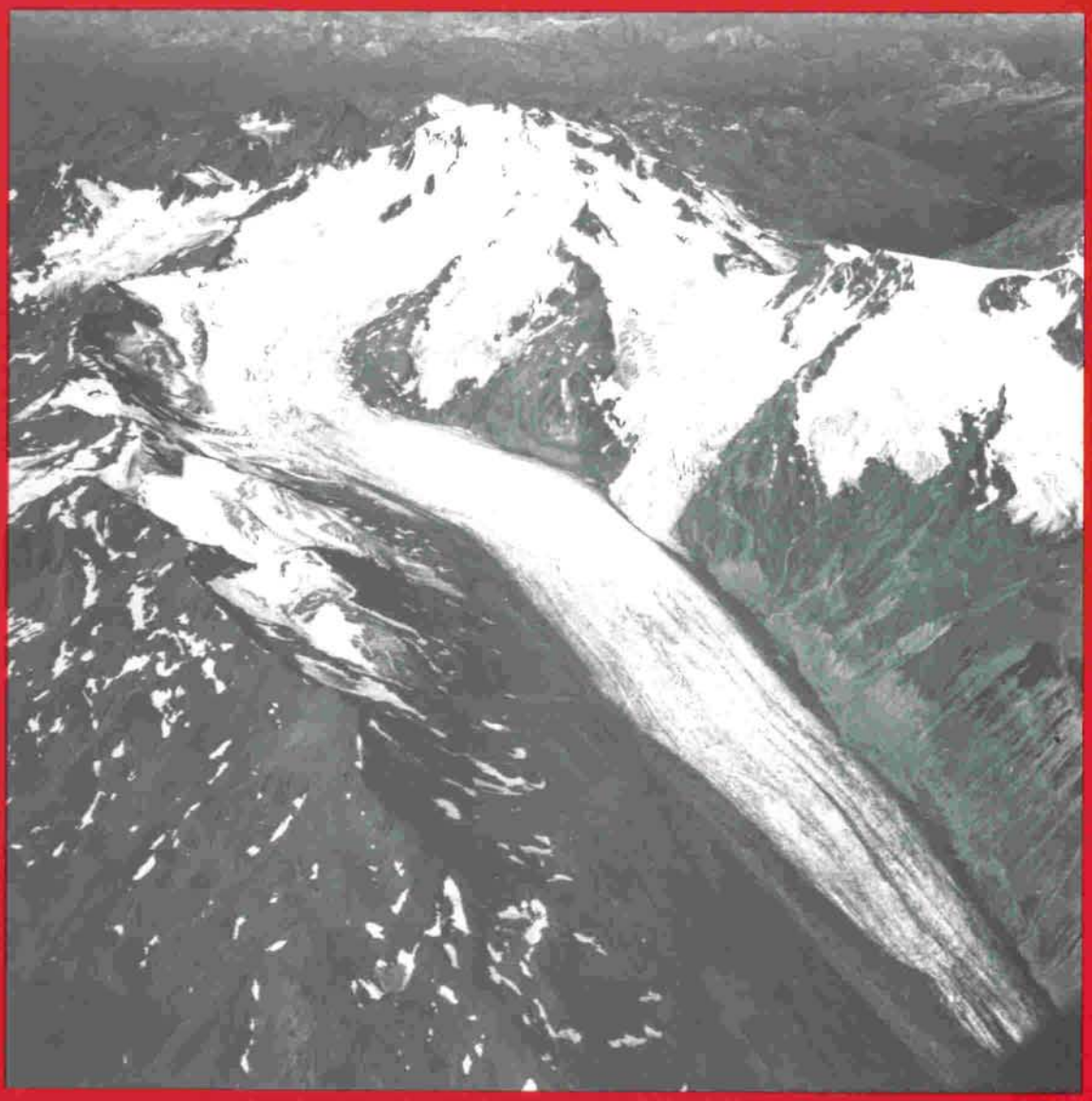
GLACIER MASS BALANCE BULLETIN

Bulletin No. 2 (1990 - 1991)

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
1993

GLACIER MASS BALANCE BULLETIN

Bulletin No. 2 (1990 - 1991)

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

Compiled by the World Glacier Monitoring Service

Edited by

Wilfried Haeberli, Eveline Herren and Martin Hoelzle

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

IAHS (ICSI) - UNEP - UNESCO
1993

Printed by

Kunz Druck + Co. AG
CH - 9053 Teufen AR
Switzerland

The cover picture shows Hintereisferner in Austria, where one of the longest and most complete investigations on Alpine glacier mass balances exists. Photo taken by G. Patzelt on 21 Aug. 1989.

PREFACE

Climate system monitoring makes use of natural phenomena which indicate energy fluxes, ranges of natural variability, rates of change and acceleration tendencies. Observed glacier fluctuations contribute important information about such aspects. As a good approximation, glacier mass balance may be expressed as the energy required for the melting or freezing related to ice thickness changes. The energy flux thus calculated can be compared with the estimated anthropogenic greenhouse forcing. In fact, mountain glaciers are highly sensitive, natural, large-scale and representative indicators for the energy balance at the earth's surface in remote polar or high-altitude areas, which are only marginally affected by direct industrial activity. In addition, pronounced filter, memory and enhancement functions are related to latent heat exchange, the persistence over long time-intervals of the perennial ice masses and the positive feed-backs related to the surface albedo or the mass balance/altitude relation. As a consequence, glacier signals are a valuable element of early detection strategies for dealing with possible man-induced climate change.

Glacier fluctuations reconstructed for historical and Holocene time periods from direct measurements, old paintings, written sources, moraines, pollen analysis, tree-ring investigation, etc. indicate that glacier extent in many mountain regions may have varied over the past millennia within a range defined by the extremes of the maximum Little Ice Age advance and today's reduced stage, respectively. As indicated by spectacular losses in glacier length, the general shrinkage of mountain glaciers during the 20th century is a major reflection of the fact that rapid secular change in the energy balance of the earth's surface is taking place on a global scale. The average rate of this change as deduced from glacier mass losses (a few decimetres ice depth per year) is broadly consistent with the estimated anthropogenic greenhouse forcing (2 - 3 W/m^2). Hence it appears that the situation is evolving at a high rate towards or even beyond the "warm" limit of natural Holocene variability. In this situation, directly measured glacier mass balances belong to the key indicators for assessing possible trends of continuation or acceleration.

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), which is 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 present Glacier Mass Balance Bulletin (MBB) is the second issue of a long-term series of publications. It is designed to speed up and facilitate access to information concerning glacier mass balances by reporting measured values from selected reference glaciers at 2-year intervals. The results of glacier mass balance measurements are made more easily understandable for non-specialists through the use of graphic presentations rather than purely numerical data. The Glacier Mass Balance Bulletin complements the publication series, "Fluctuations of Glaciers", 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 fast 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 Fluctuations series.

The following series of reports on the variations of glaciers in space and time were already published by the World Glacier Monitoring Service and its predecessor, the Permanent Service on the Fluctuations of Glaciers:

- 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)

- Glacier Mass Balance Bulletin No. 1, 1988-1989 (W. Haeberli / E. Herren)

Vol. 6, Fluctuations of Glaciers 1985 - 1990, is now being printed; publication and distribution is planned for early 1993.

The second bulletin reports the results for the balance years 1989/90 and 1990/91. It is planned to make available the complete set of earlier mass balance data used to compile the present bulletin in the first issue of another, less regularly appearing publication series: the "World Glacier Monitoring - Updates and Assessments". The third Glacier Mass Balance Bulletin will cover the years 1991/92 and 1992/93.

Zurich, December 1992

Wilfried Haeberli
Director
World Glacier Monitoring Service

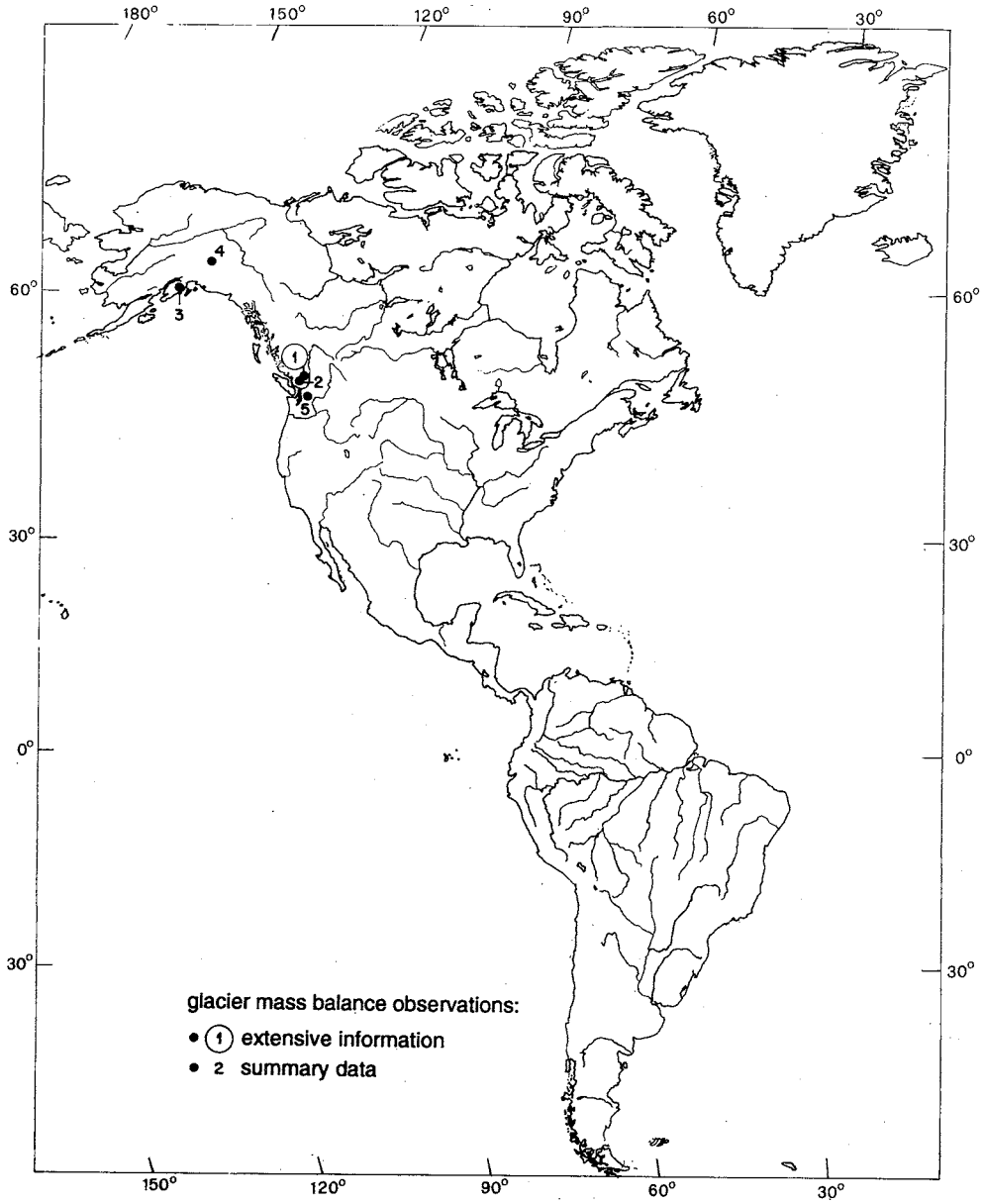
CONTENTS

1. INTRODUCTION

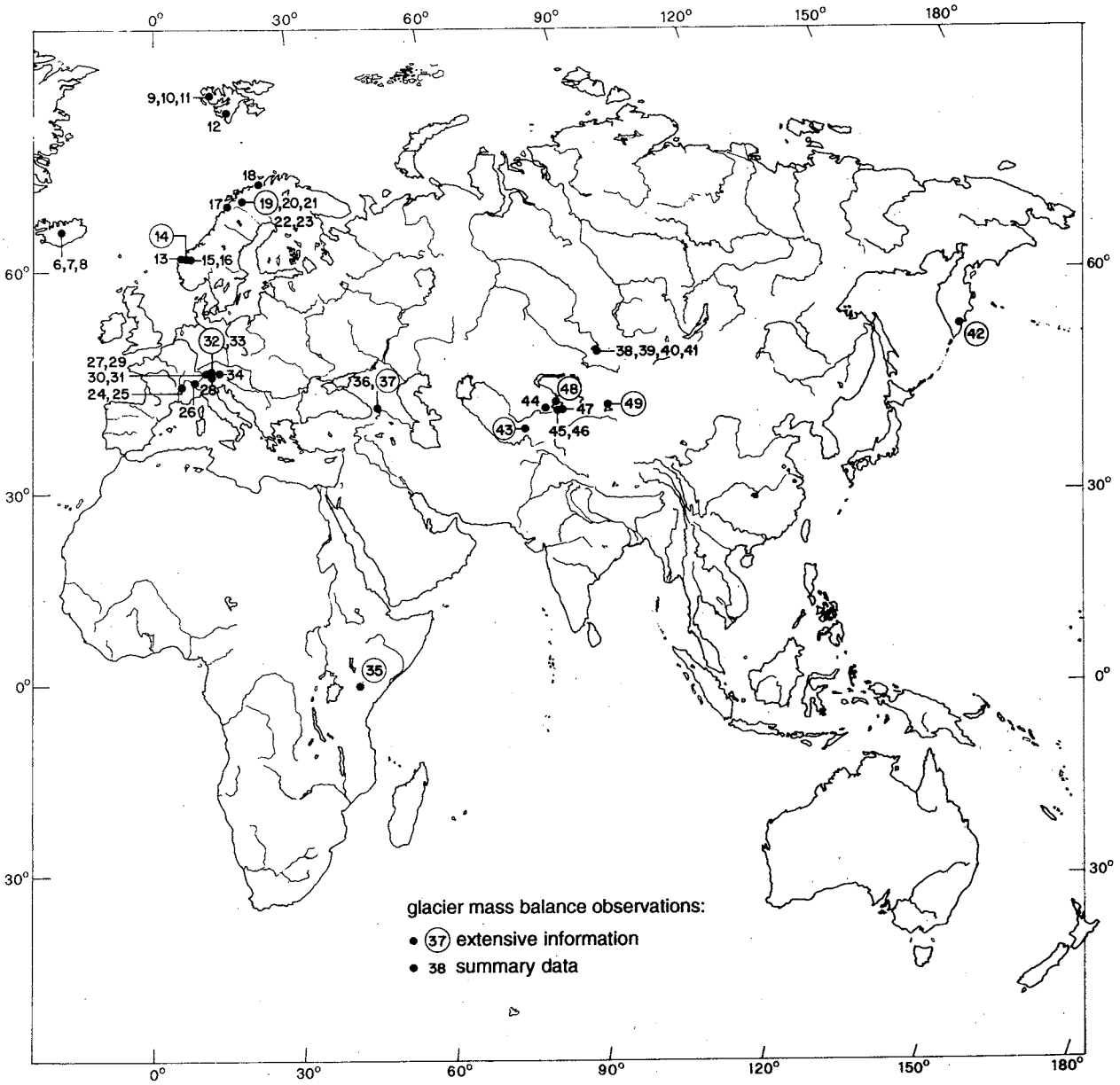
Two main categories of data - summary information and extensive information - are being reported in the Glacier Mass Balance Bulletin. Summary information on specific balance, cumulative specific balance, accumulation area ratio and equilibrium line altitude is given for 49 glaciers. Such information 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). Some glacier names in the former USSR changed. The old names are given in brackets.

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	Wolverine	USA	N Cascades Mtns.	48° 22' N	121° 03' W
4	Gulkana	USA (Alaska)	Kenai Mtns. Alaska	60° 24' N	148° 55' W
5	South Cascade	USA (Alaska)	Alaska Range	63° 15' N	145° 25' W
6	Hofsjökull North	Iceland	Central Iceland	64° 57' N	18° 55' W
7	Hofsjökull East	Iceland	Central Iceland	64° 40' N	18° 35' W
8	Hofsjökull Southwest	Iceland	Central Iceland	64° 43' N	19° 03' W
9	Austre Brøggerbreen	Svalbard	N-Spitsbergen	78° 53' N	11° 50' E
10	Midtre Lovénbreen	Svalbard	N-Spitsbergen	78° 53' N	12° 04' E
11	Kongsvegen	Svalbard	N-Spitsbergen	78° 50' N	12° 59' E
12	Hansbreen	Svalbard	S-Spitsbergen	77° 05' N	15° 40' E
13	Ålfotbreen	Norway	South Norway	61° 45' N	5° 39' E
14	Nigardsbreen	Norway	South Norway	61° 43' N	7° 08' E
15	Storbreen	Norway	South Norway	61° 34' N	8° 08' E
16	Gråsubreen	Norway	South Norway	61° 39' N	8° 36' E
17	Engabreen	Norway	North Norway	66° 39' N	13° 51' E
18	Langfjordjøkulen	Norway	North Norway	70° 07' N	21° 45' E
19	Storglaciären	Sweden	North Sweden	67° 54' N	18° 34' E
20	Rabots glaciär	Sweden	North Sweden	67° 54' N	18° 33' E
21	Tarfalaglaciären	Sweden	North Sweden	67° 56' N	18° 39' E
22	Riukojietna	Sweden	North Sweden	68° 05' N	18° 05' E
23	Mårmaglaciären	Sweden	North Sweden	68° 05' N	18° 41' E
24	Sarennes	France	Alps	45° 07' N	6° 10' E
25	Saint Sorlin	France	Alps	45° 11' N	6° 10' E
26	Gries	Switzerland	Alps	46° 26' N	8° 20' E
27	Silvretta	Switzerland	Alps	46° 51' N	10° 05' E



No.	Glacier Name	Country	Location	Coordinates	
28	Careser	Italy	Alps	46° 27' N	10° 42' E
29	Jamtalferner	Austria	Alps	46° 42' N	10° 10' E
30	Ochsentalergletscher	Austria	Alps	46° 51' N	10° 06' E
31	Vermuntgletscher	Austria	Alps	46° 51' N	10° 08' E
32	Hintereisferner	Austria	Alps	46° 48' N	10° 46' E
33	Kesselwandferner	Austria	Alps	46° 50' N	10° 48' E
34	Sonnblickkees	Austria	Alps	47° 08' N	12° 36' E
35	Lewis	Kenya	Mount Kenya	0° 09' S	37° 18' E
36	Garabashi	Russia	Caucasus	43° 18' N	42° 28' E
37	Djankuat	Russia	Caucasus	43° 12' N	42° 46' E
38	Maliy Aktru	Russia	Altai	50° 05' N	87° 45' E
39	Leviy Aktru	Russia	Altai	50° 05' N	87° 41' E



No.	Glacier Name	Country	Location	Coordinates	
40	Praviy Aktru	Russia	Altai	50° 05' N	87° 44' E
41	No. 125 (Vodopadniy)	Russia	Altai	50° 06' N	87° 42' E
42	Kozelskiy	Russia	Kamchatka	53° 14' N	158° 49' E
43	Abramov	Tadjikistan	Pamir-Alai	39° 39' N	71° 38' E
44	Golubin	Kirghizstan	Tien Shan	42° 27' N	74° 30' E
45	Suyok Zapadniy (West. Suyok)	Kirghizstan	Tien Shan	41° 47' N	77° 45' E
46	No. 131	Kirghizstan	Tien Shan	41° 53' N	77° 41' E
47	Kara-Batkak (Karabatkak)	Kirghizstan	Tien Shan	42° 08' N	78° 16' E
48	Ts. Tuyuksuyskiy (Tuyuksu)	Kasakhstan	Tien Shan	43° 03' N	77° 05' E
49	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 1989/90 and 1990/91 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 corresponding graphs (AAR and ELA, respectively, versus specific net balance) are given in Chapter 3, but only for the glaciers with extensive information.

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".

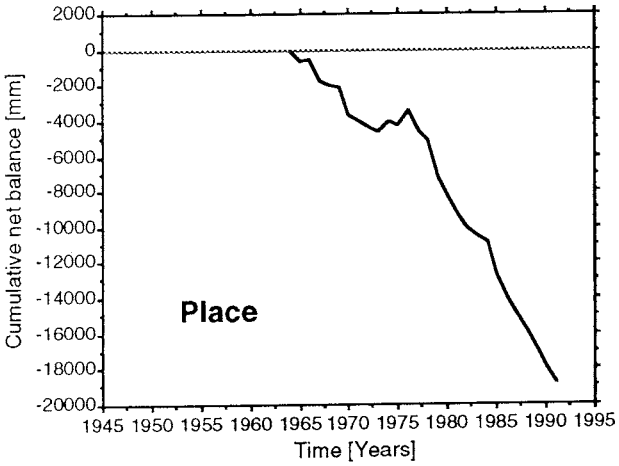
2.1 SUMMARY TABLE (NET BALANCE, ELA, ELA_0, AAR, AAR_0)

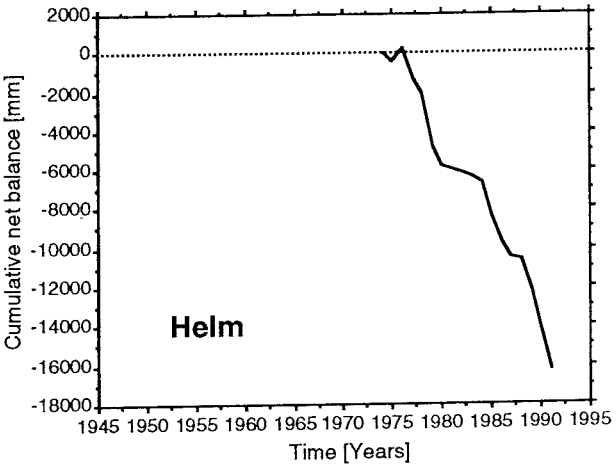
Glacier [1]		Country	b_{90} [mm]	b_{91} [mm]	ELA_{90} [m a.s.l.]	ELA_{91} [m a.s.l.]	ELA_0 [m a.s.l.]	AAR_{90} [%]	AAR_{91} [%]	AAR_0 [%]
Place	(1965)	Canada	- 938	- 990	2290	2280	2078	21	23	50
Helm	(1975)	Canada	-1790	-2239	2179 [2]	2138	2035	0	8	35
Wolverine	(1966)	USA-Alaska	-2510	- 410	1400	1230	1157	18	58	61
Gulkana	(1966)	USA-Alaska	- 600	- 110	1780	1710	1725	58	65	63
South Cascade	(1953)	USA	- 700	- 100	1870	1850		70	80	
Hofsjökull North	(1988)	Iceland	- 600	-1410	1330	1485		38	19	
Hofsjökull East	(1989)	Iceland	+ 110	- 990	1170	1235		53	45	
Hofsjökull Southwest	(1990)	Iceland	- 680	-1490	1305	1335		34	29	
Austre Brøggerbreen	(1967)	Svalbard	- 660	+ 130	500	275	273	8	58	56
Midtre Lovénbreen	(1968)	Svalbard	- 510	+ 100	450	265	295	19	68	60
Kongsvegen	(1987)	Svalbard	- 300	+ 430	580	450		50	73	
Hansbreen	(1989)	Svalbard	- 900	- 280	370	280		32	62	
Ålfotbreen	(1963)	Norway	+1790	+ 790	990	1035	1199	97	94	55
Nigardsbreen	(1962)	Norway	+1770	+ 200	1430	1510	1564	83	73	59
Storbreen	(1949)	Norway	+1250	- 150	1530	1740	1706	92	57	61
Gråsubreen	(1962)	Norway	+ 730	- 520	<1850 [3]	2195	2130	100	10	33
Engabreen	(1970)	Norway	+ 850	+ 690	1020	1090	1167	84	75	57
Langfjordjøkulen	(1989)	Norway	- 400	+ 80	780	680		53	67	
Storglaciären	(1946)	Sweden	+ 590	+ 170	1495	1460	1461	60	47	46
Rabots glaciär	(1982)	Sweden	- 40	- 216	1378	1370	1359	47	48	53
Tarfalaglaciären	(1986)	Sweden	+ 50	+ 160	1500			54	73	
Riukojietna	(1986)	Sweden	+ 210	+ 80	1300	1350		82	60	
Mårmaglaciären	(1990)	Sweden	- 120	- 200	1615	1640		26	25	
Sarennes	(1949)	France	-2140	-1360						
Saint Sorlin	(1959)	France	-1400	-1270						
Gries	(1962)	Switzerland	-1890	-1480	3401 [2]	3401 [2]	2837	0	0	58
Silvretta	(1960)	Switzerland	- 530	-1130	2869	3032	2764	33	5	54
Careser	(1967)	Italy	-1580	-1730	3420 [2]	3463 [2]	3094	0	0	50
Jamtalferner	(1990)	Austria	- 426	-1439	2900	>3200 [2]		32	10	
Ochsentalergletscher	(1991)	Austria		- 705		2920			42	
Vermuntgletscher	(1991)	Austria		-1490		>3140 [2]			3	
Hintereisferner	(1953)	Austria	- 995	-1325	3115	3260	2919	32	18	66
Kesselwandferner	(1953)	Austria	- 242	- 849	3130	>3500 [2]		60	21	
Sonnblickkees	(1959)	Austria	- 561	- 818	2855	2885	2740	32	22	60
Lewis [4]	(1979)	Kenya	-1010	- 810	>5000 [2]	>5000 [2]		0	0	
Garabashi	(1987)	Russia	+ 90	- 30	3780	3850		65	54	
Djankuat	(1968)	Russia	+ 340	- 310	3180	3240	3191	63	55	60
Maliy Aktru	(1962)	Russia	+ 70		3160		3126 [5]	43		71 [5]
Leviy Aktru	(1977)	Russia	+ 150		3140		3154 [5]	61		59 [5]
Praviy Aktru	(1980)	Russia	+ 70		3160		3143 [5]	45		48 [5]
No. 125	(1977)	Russia	+ 150		3160		3190 [5]	73		64 [5]
Kozelskiy	(1973)	Russia	-1280	+ 460	1700	1280	1299	37	67	52
Abramov	(1968)	Tadjikistan	- 540	- 420	4220	4242	4152	46	46	59
Golubin	(1969)	Kirghizstan	- 760	- 722	3900	3850	3808	52	63	74
Suyok Zapadniy	(1989)	Kirghizstan	- 676	- 527	4300	4300		22	22	
No. 131	(1985)	Kirghizstan	- 282	- 502	4200	4200		37	37	
Kara-Batkak	(1957)	Kirghizstan	- 778	- 398	3850	3900	3991	54	51	51
Ts. Tuyuksuyskiy	(1957)	Kasakhstan	- 960	-1100	3885	3950	3742	28	22	53
Urumqihe S. No. 1	(1959)	China	+ 52	- 706	3959	4130	4024	71	31	55

1) Numbers in brackets behind the glacier names indicate the beginning of continuous mass balance records.
2) Above glacier maximum elevation.
3) Below glacier minimum elevation.
4) Note that the balance year here starts in March of the year indicated.
5) Only values till 1990 included.

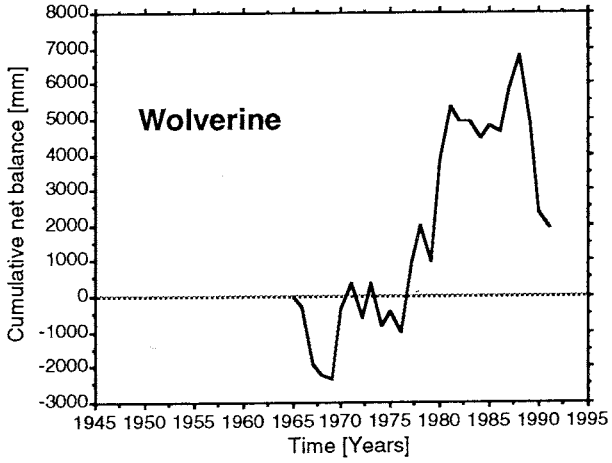
2.2 CUMULATIVE SPECIFIC NET BALANCES

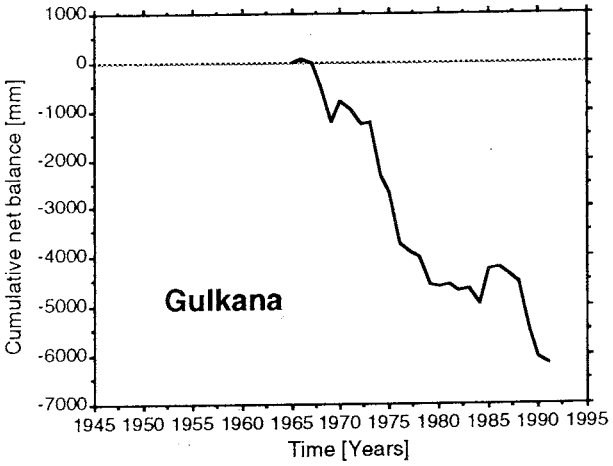
CANADA:

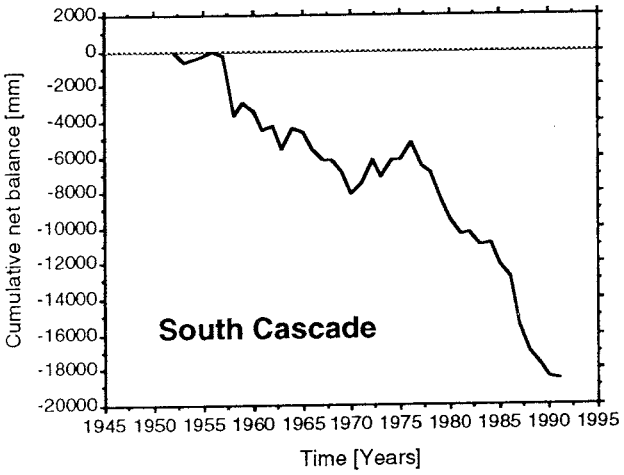




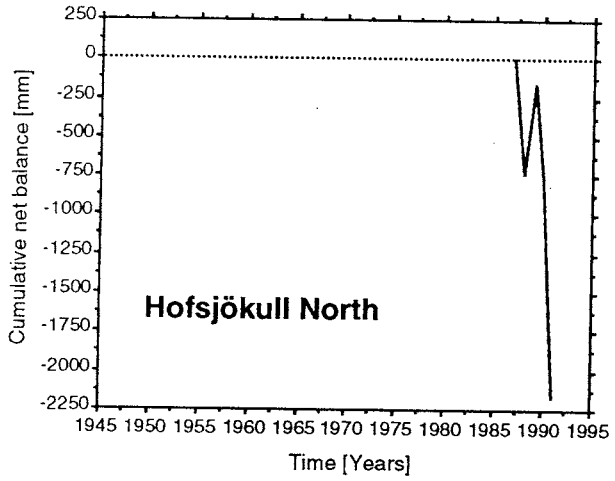
USA:

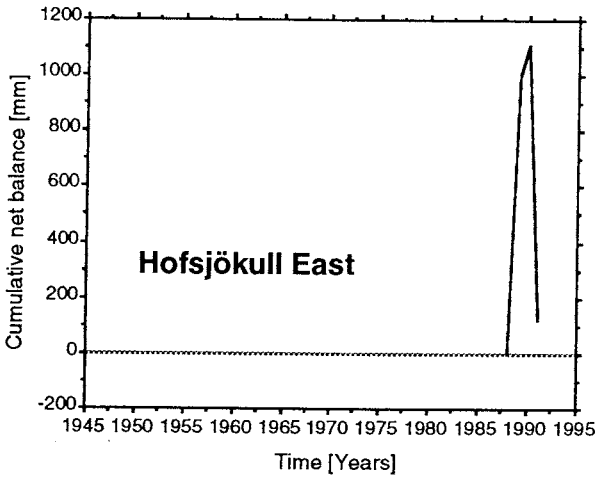


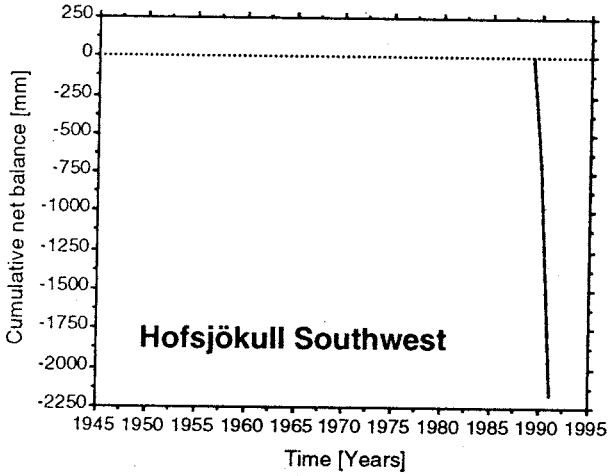




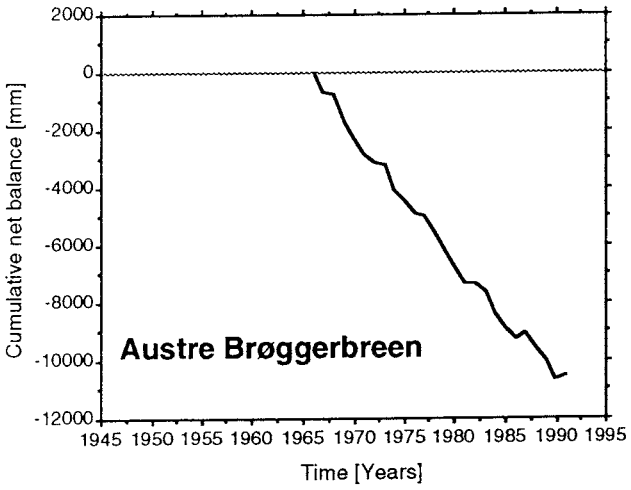
ICELAND:

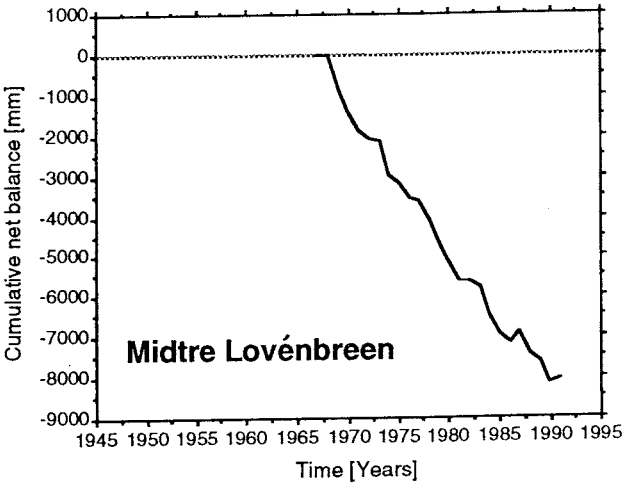

Hofsjökull North
Cumulative net balance [mm]
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

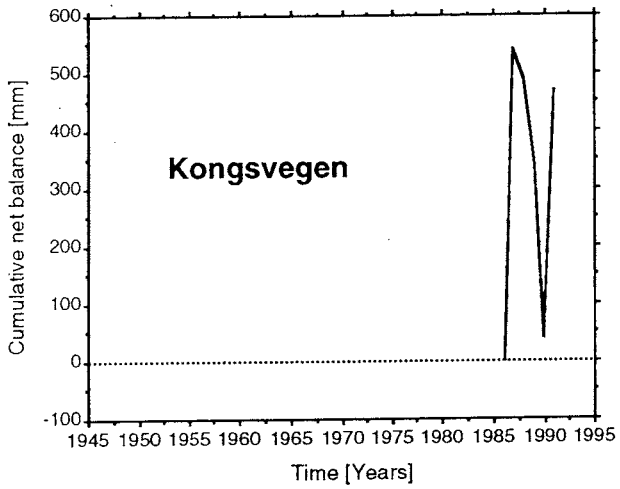

Hofsjökull East
Cumulative net balance [mm]
1200
1000
800
600
400
200
0
-200
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

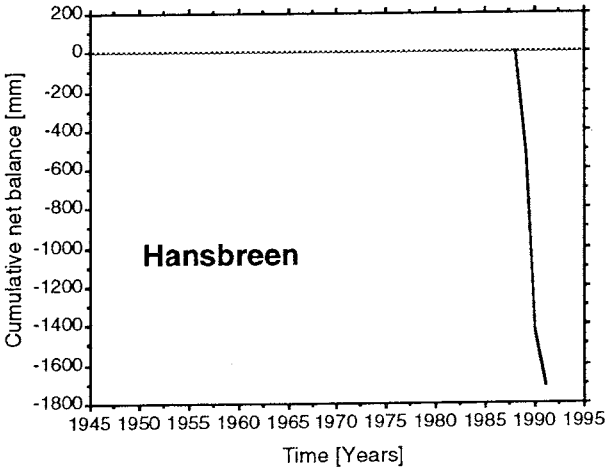

Hofsjökull Southwest
Cumulative net balance [mm]
250
0
-250
-500
-750
-1000
-1250
-1500
-1750
-2000
-2250
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

SVALBARD:

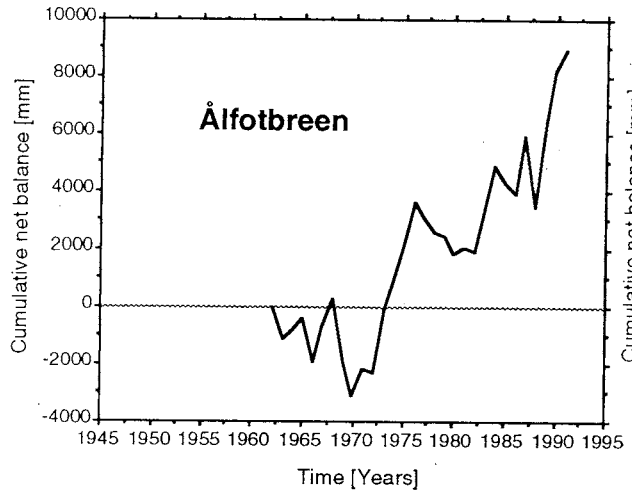

Austre Brøggerbreen
Cumulative net balance [mm]
2000
0
-2000
-4000
-6000
-8000
-10000
-12000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

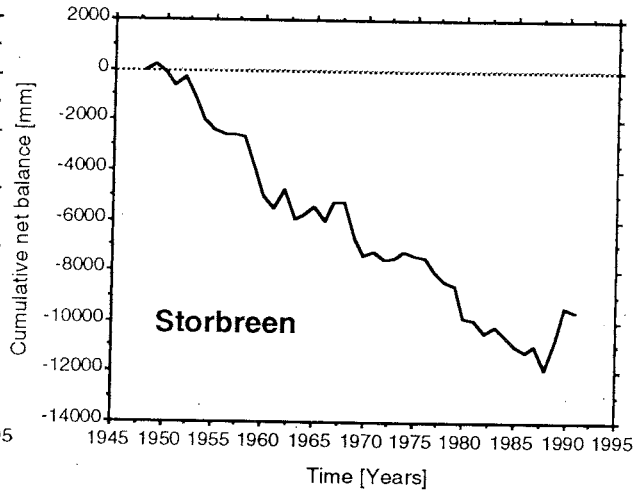

Midtre Lovénbreen
Cumulative net balance [mm]
1000
0
-1000
-2000
-3000
-4000
-5000
-6000
-7000
-8000
-9000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

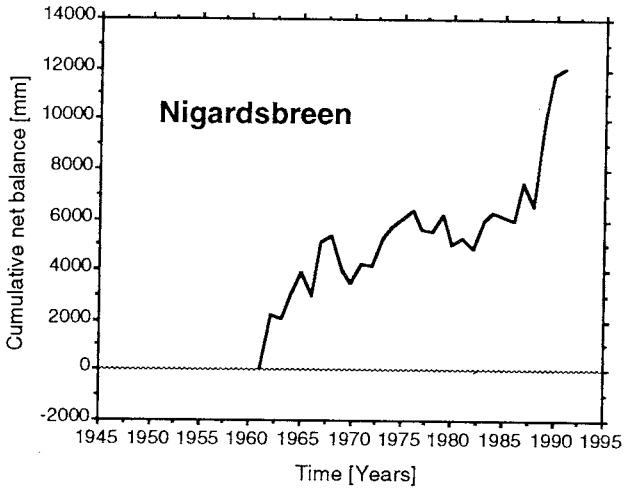

Kongsvegen
Cumulative net balance [mm]
600
500
400
300
200
100
0
-100
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

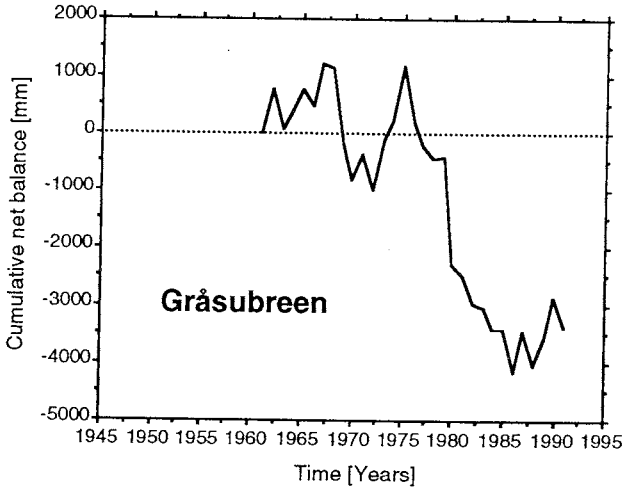

Hansbreen
Cumulative net balance [mm]
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

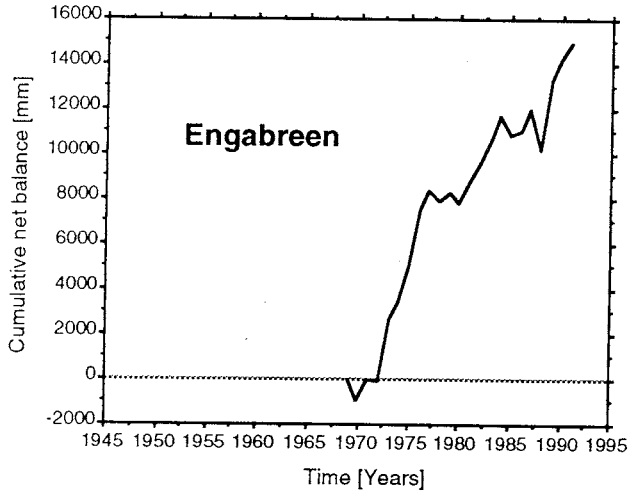
NORWAY:

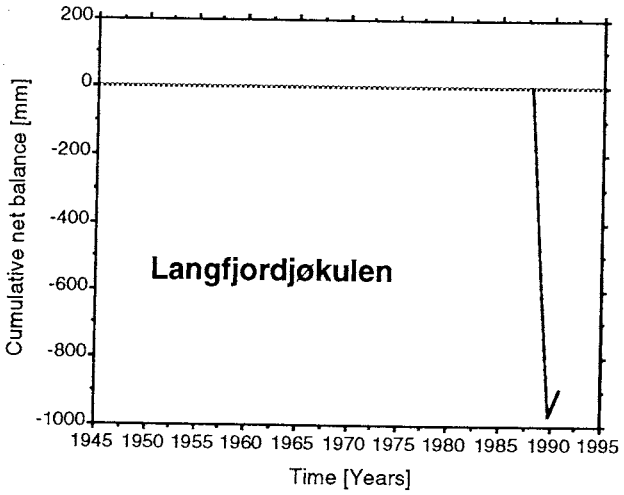

Ålfotbreen
Cumulative net balance [mm]
Time [Years]


Storbreen
Cumulative net balance [mm]
Time [Years]

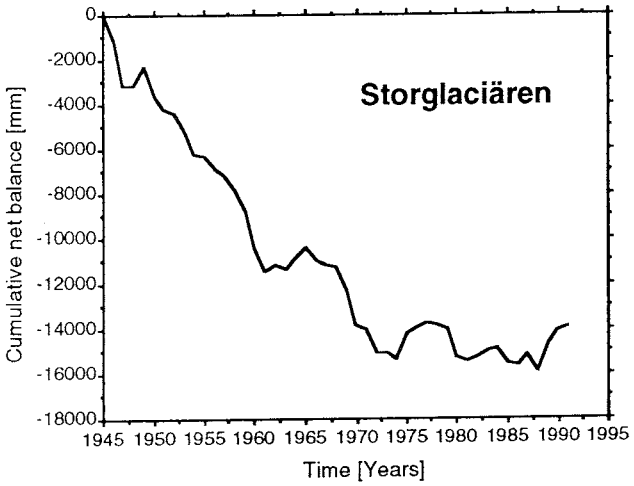

Nigardsbreen
Cumulative net balance [mm]
Time [Years]

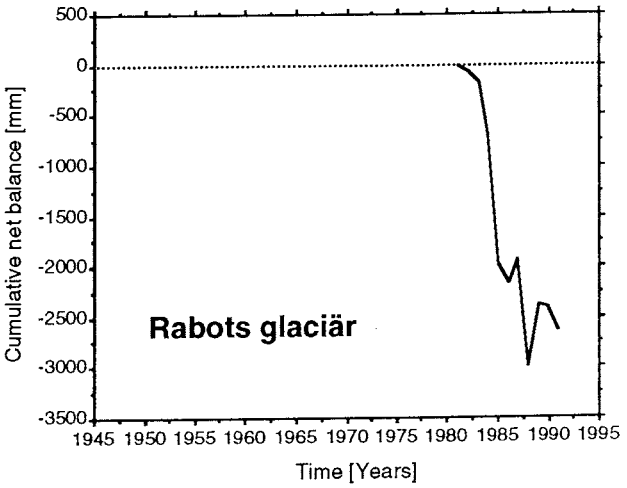

Gråsubreen
Cumulative net balance [mm]
Time [Years]

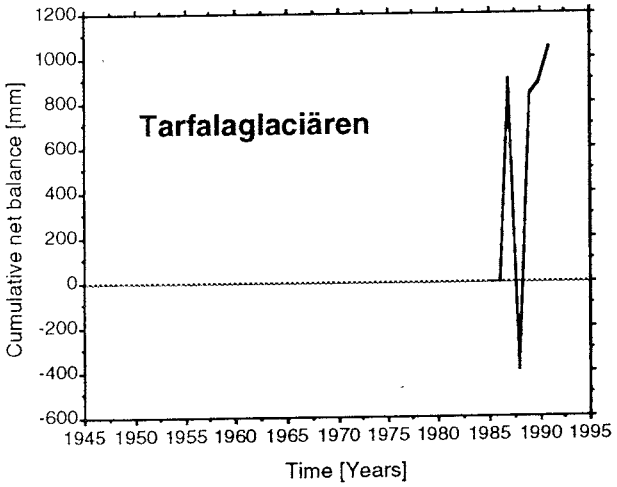

Engabreen
Cumulative net balance [mm]
Time [Years]

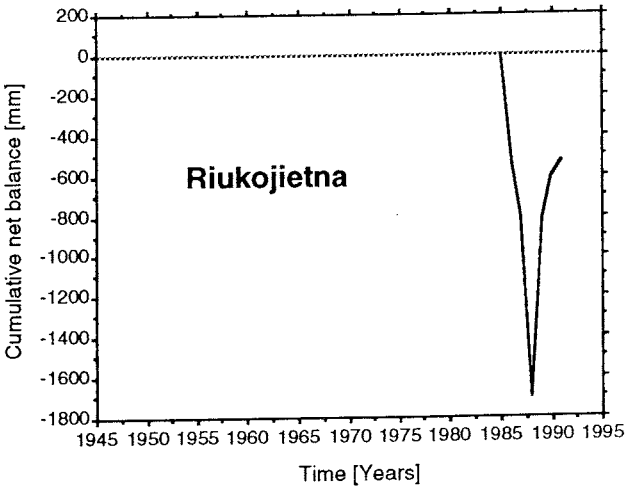

Langfjordjøkulen
Cumulative net balance [mm]
Time [Years]

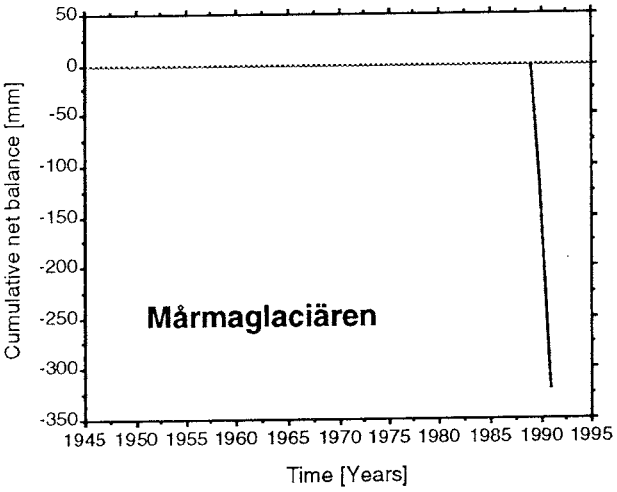
SWEDEN:


Storglaciären
Cumulative net balance [mm]
0
-2000
-4000
-6000
-8000
-10000
-12000
-14000
-16000
-18000
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

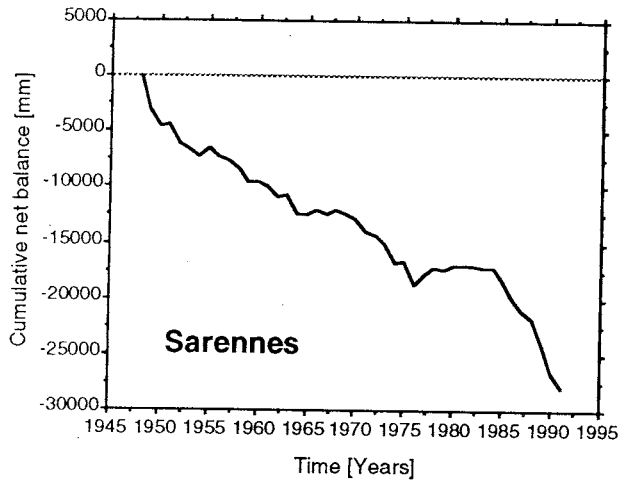

Rabots glaciär
Cumulative net balance [mm]
500
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

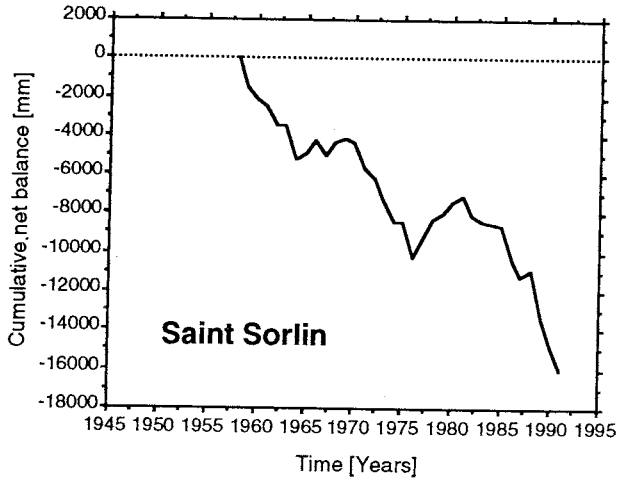

Tarfalaglaciären
Cumulative net balance [mm]
1200
1000
800
600
400
200
0
-200
-400
-600
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]


Riukojietna
Cumulative net balance [mm]
200
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

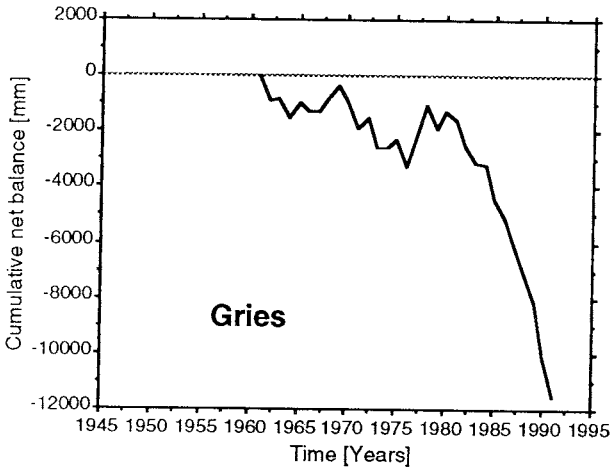

Mårmaglaciären
Cumulative net balance [mm]
50
0
-50
-100
-150
-200
-250
-300
-350
1945 1950 1955 1960 1965 1970 1975 1980 1985 1990 1995
Time [Years]

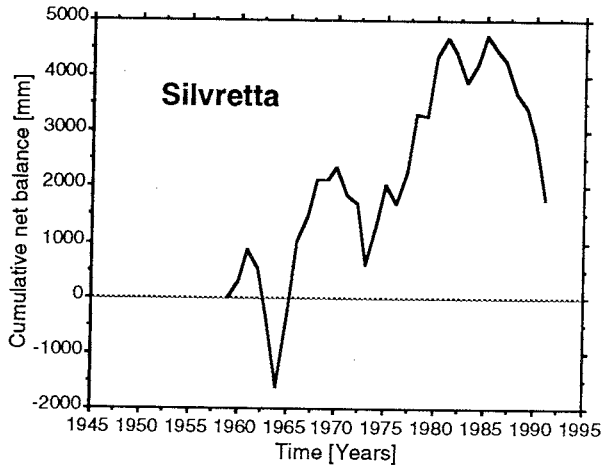
FRANCE:



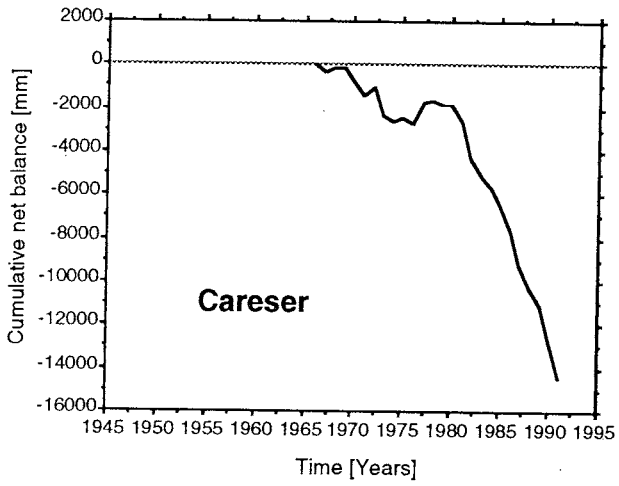


SWITZERLAND:

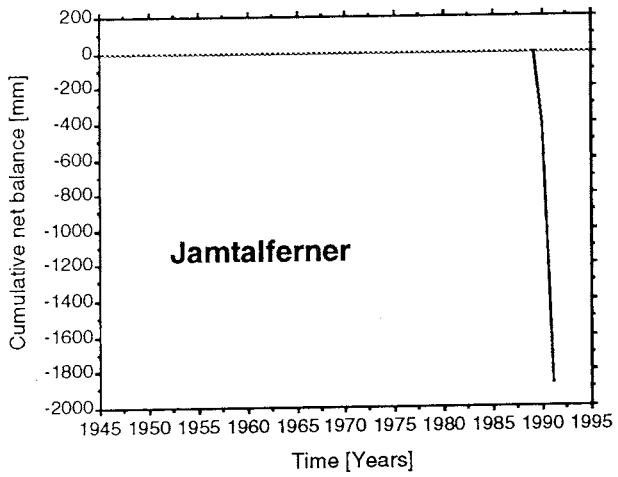


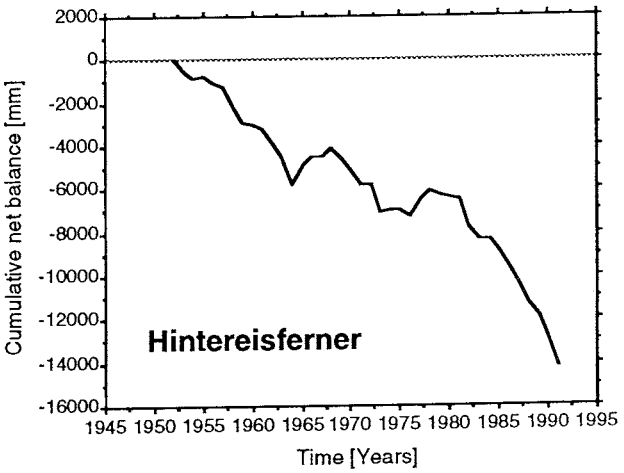


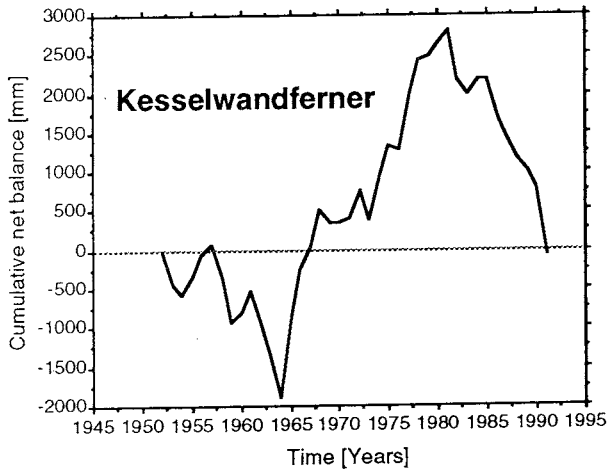
ITALY:

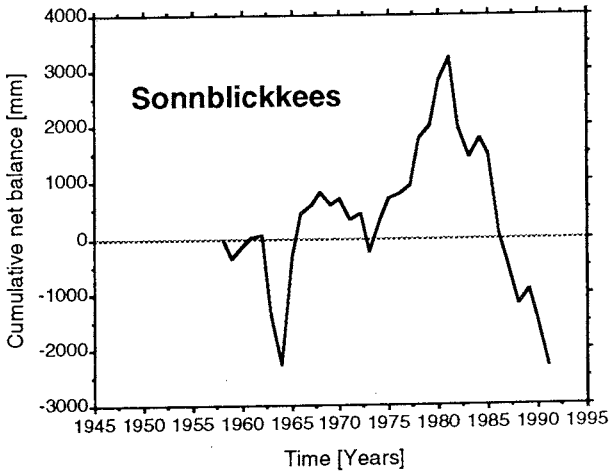


AUSTRIA:

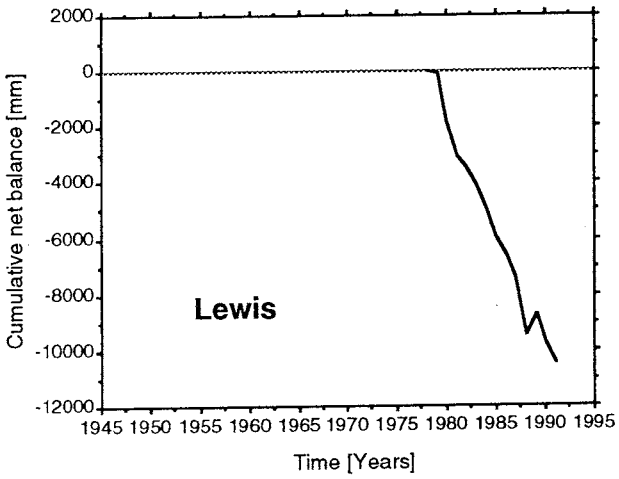




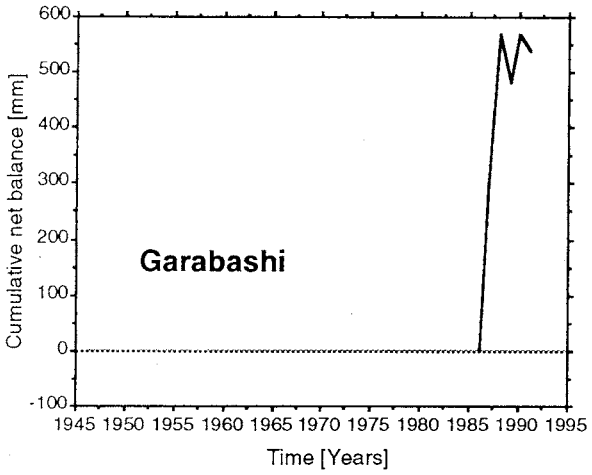


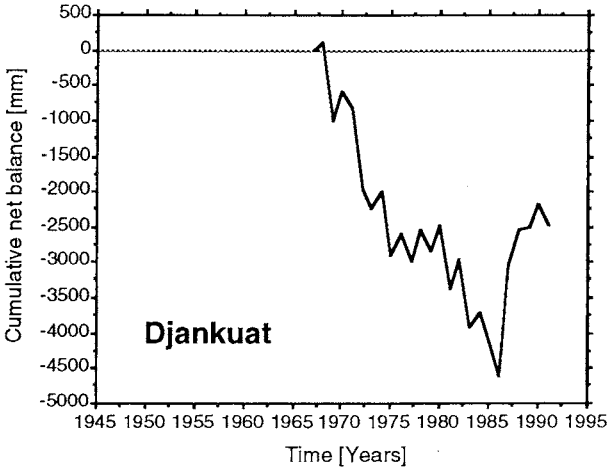


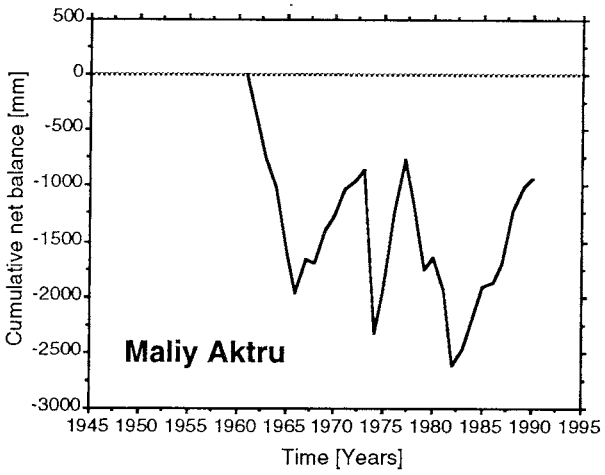
KENYA:

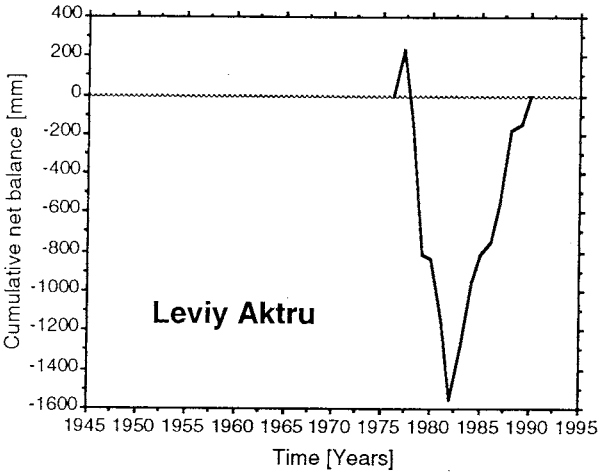


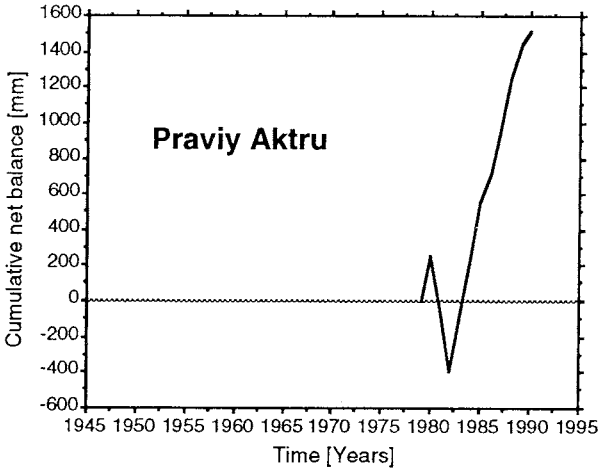
RUSSIA:

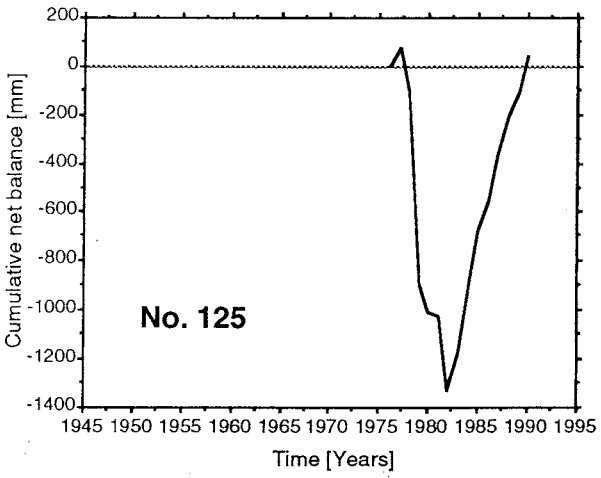

Garabashi
Cumulative net balance [mm]
Time [Years]


Djankuat
Cumulative net balance [mm]
Time [Years]

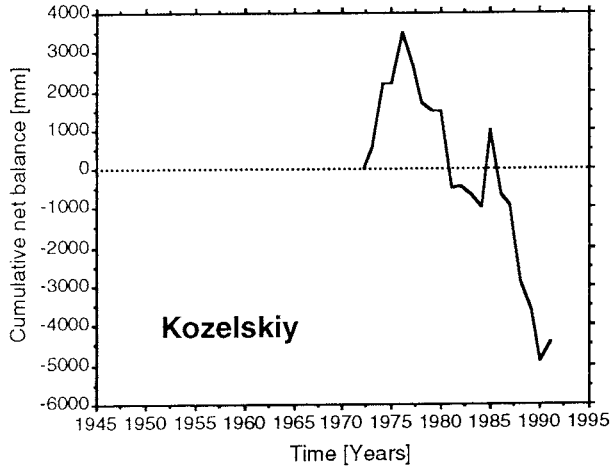

Maliy Aktru
Cumulative net balance [mm]
Time [Years]


Leviy Aktru
Cumulative net balance [mm]
Time [Years]

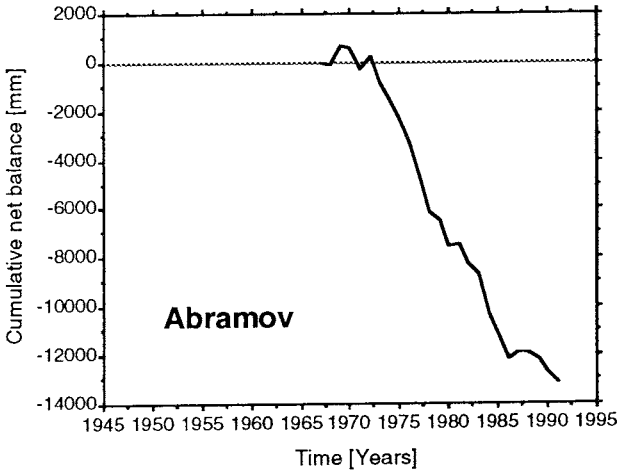

Praviy Aktru
Cumulative net balance [mm]
Time [Years]


No. 125
Cumulative net balance [mm]
Time [Years]

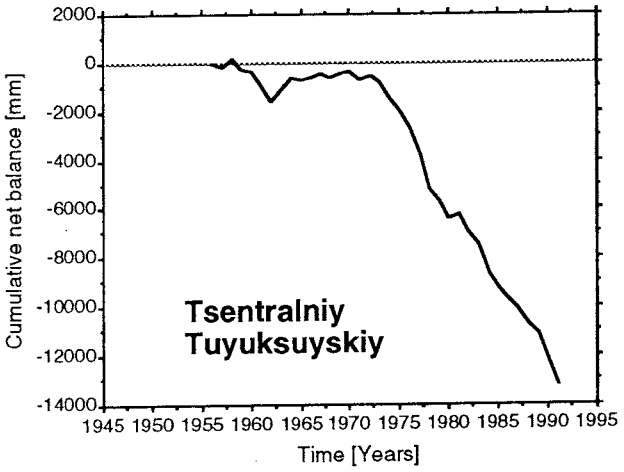
RUSSIA:



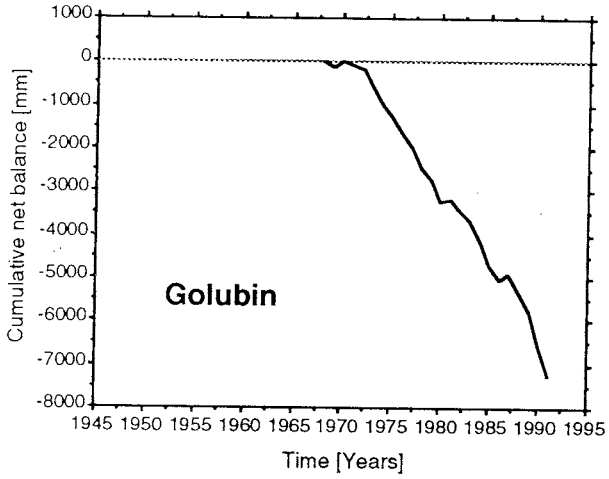
TADJIKISTAN:

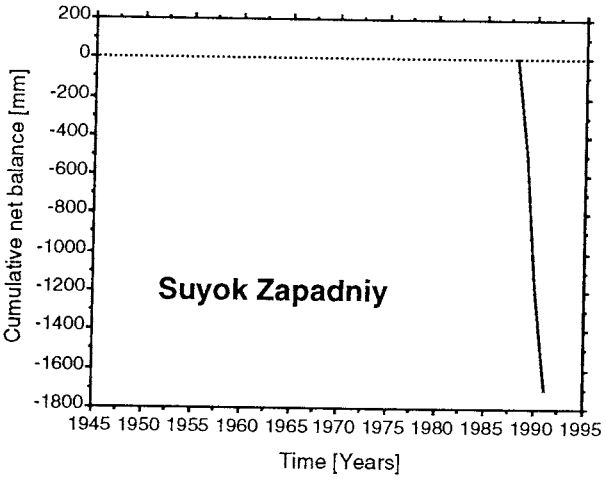


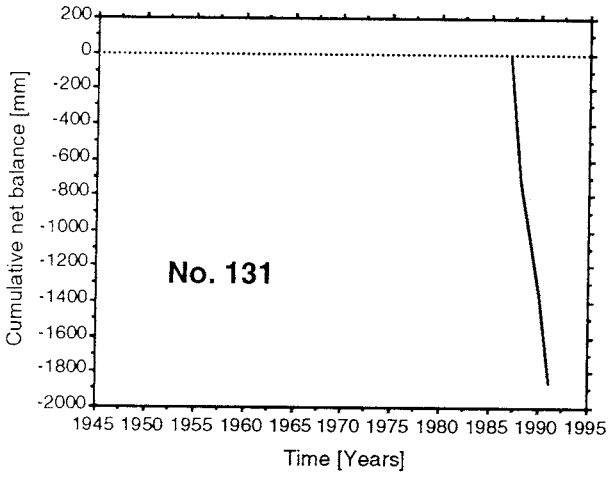
KASAKHSTAN:

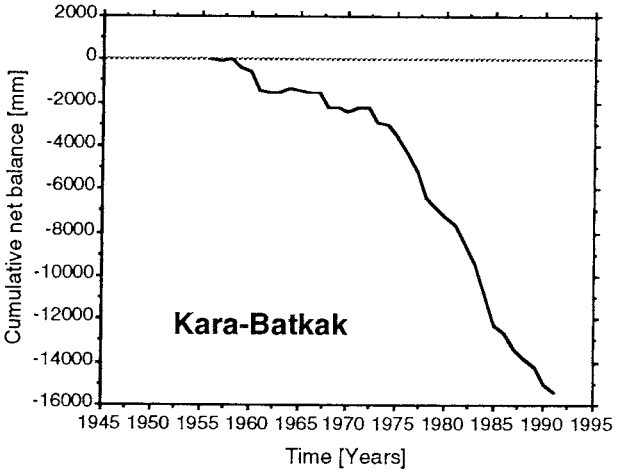


KIRGHIZSTAN:

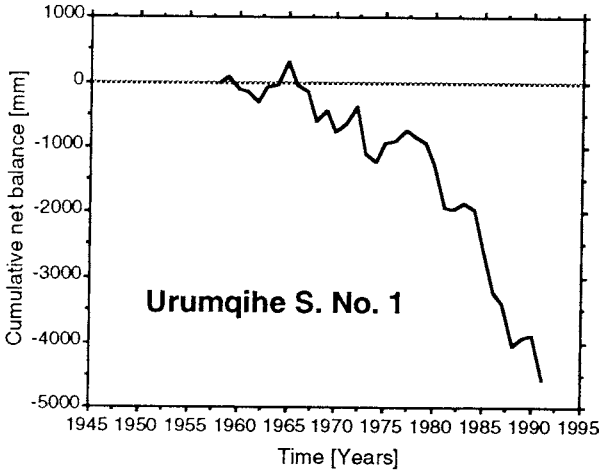








CHINA:



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 the entire glacier where possible is also included.

Three maps are presented for each glacier. The first one, a topographic map, shows the stake and snow pit network. This network is basically 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 1990/91. The second and third maps are balance maps from the years 1989/90 and 1990/91 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. Such regressions were used to determine the AAR_0 and ELA_0 values (cf. Chapter 2). The points from the two reported balance years (1989/90, 1990/91) are specially marked in the plots.

Unfortunately, no extensive information could be obtained on Maliy Aktru glacier. The data presented for Nigardsbreen were collected during the final stage of preparation for printing in order to fill this gap. The prevailing conditions for Nigardsbreen are far more humid than for Storglaciären, the other Scandinavian glacier contained in this chapter, and illustrate a sharply contrasting evolution (mass increase) during recent years.

3.1 PLACE (CANADA)

COORDINATES: 50°26' N / 122°36' W

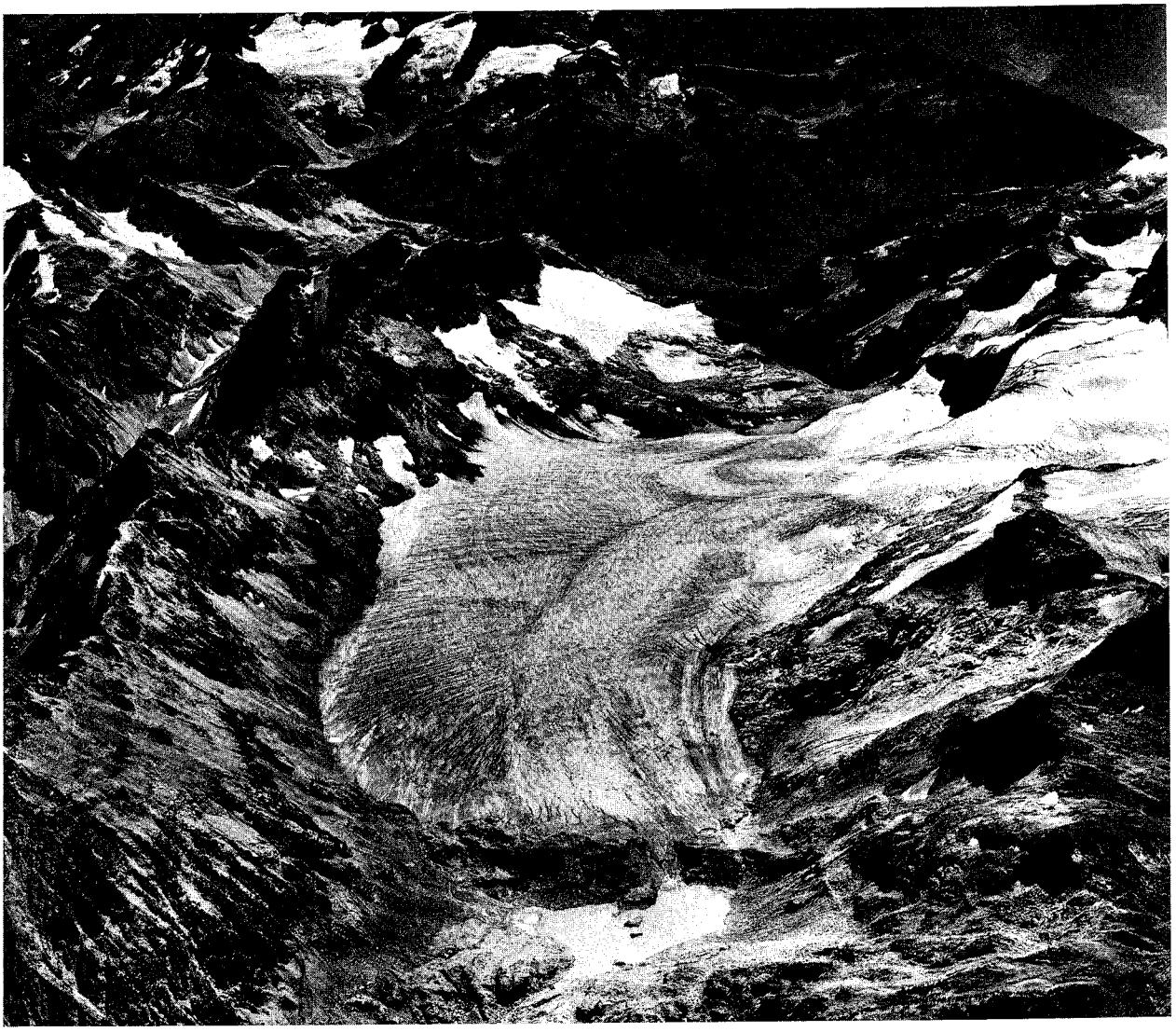
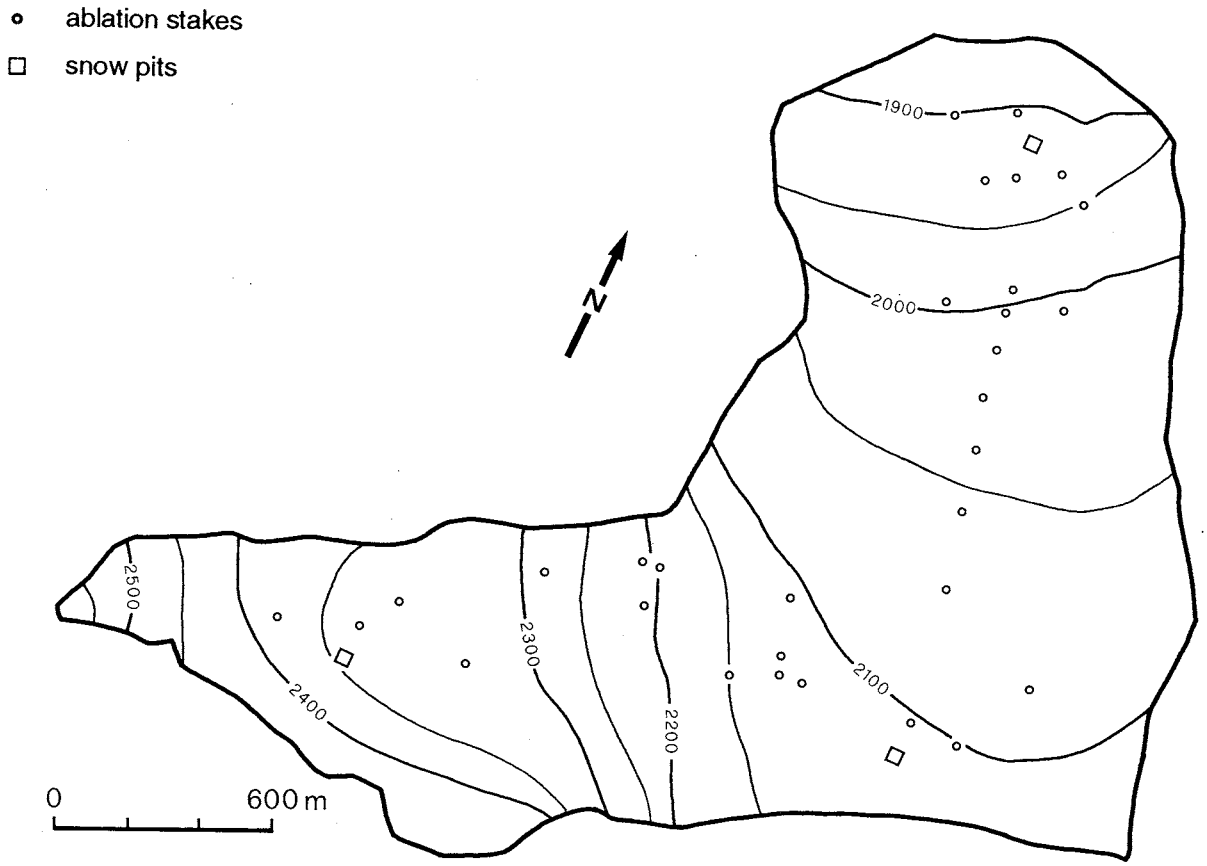


Photo taken by R.M. Krimmel on 5 September 1990.

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 3.44 km^2 and exposure is from NE to NW. Estimates of annual mean air temperature at the equilibrium line of the glacier (around 2,300 m a.s.l.) and average annual precipitation are not available so far, although the data have been collected. The glacier is thought to be temperate. Periglacial permafrost features of unknown activity exist on ridges surrounding the glacier, but are not widespread.

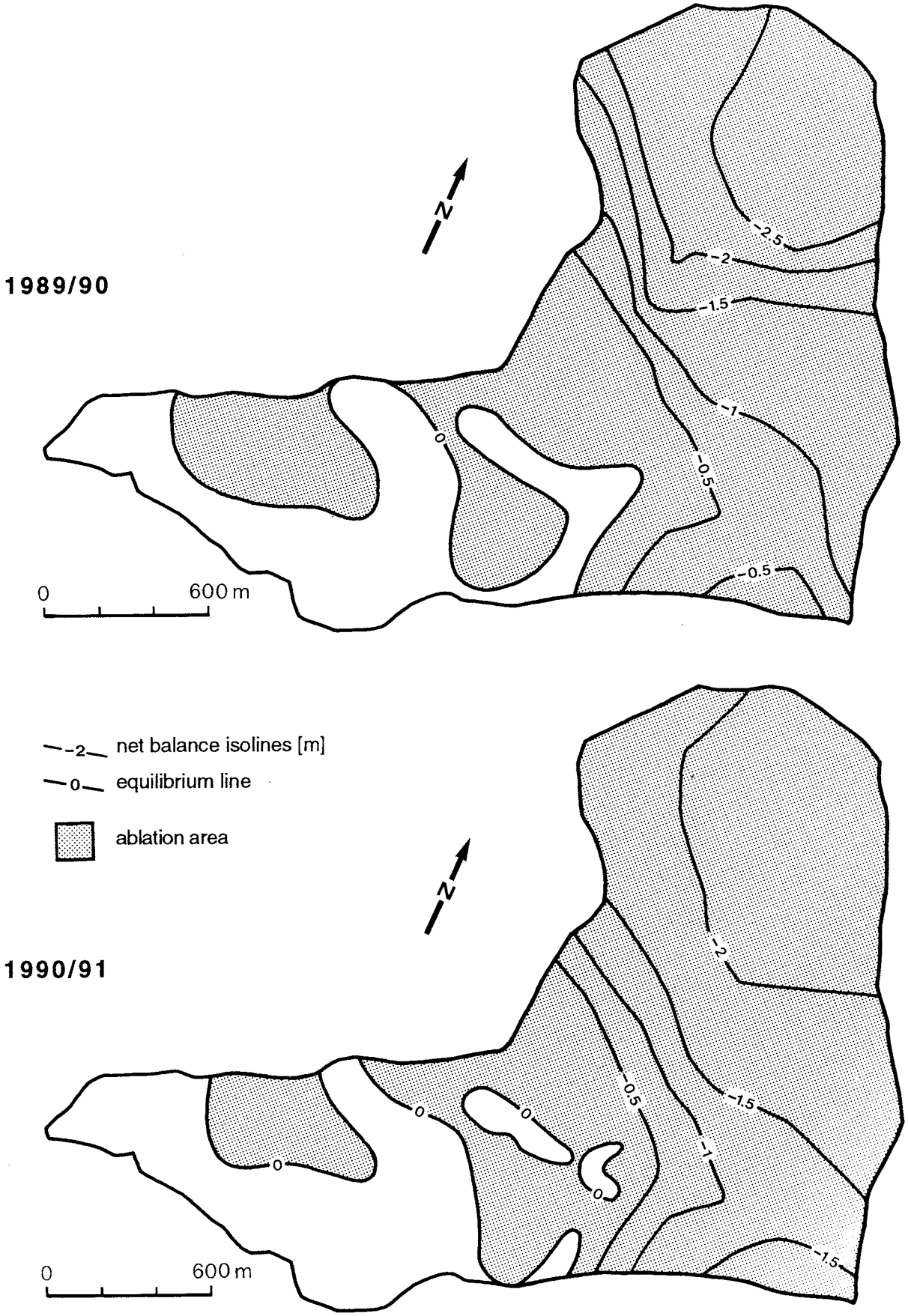
The two reported balance years are similar with net mass losses of 0.94 m water equivalent in 1989/90 and of 0.99 m in 1990/91. The first year (1989/90) showed less winter accumulation and average summer ablation, while the second year (1990/91) had more winter accumulation but greater summer ablation due to an extended period of warm sunny weather. During August 1991, several exceptionally warm rainstorms occurred causing extreme melt and snowline rise.

3.1.1 Topography and observational network

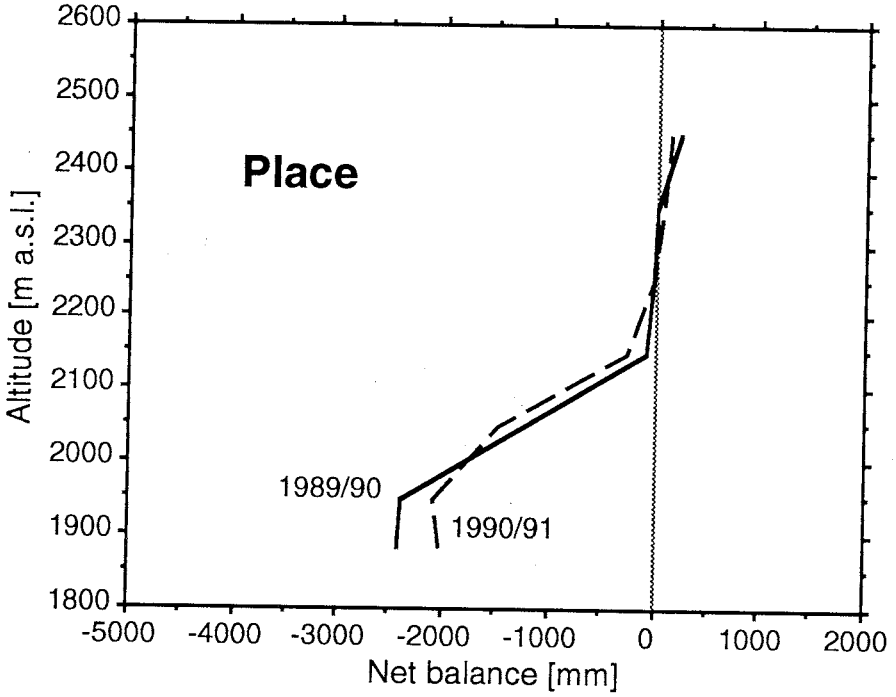


Place (CANADA)

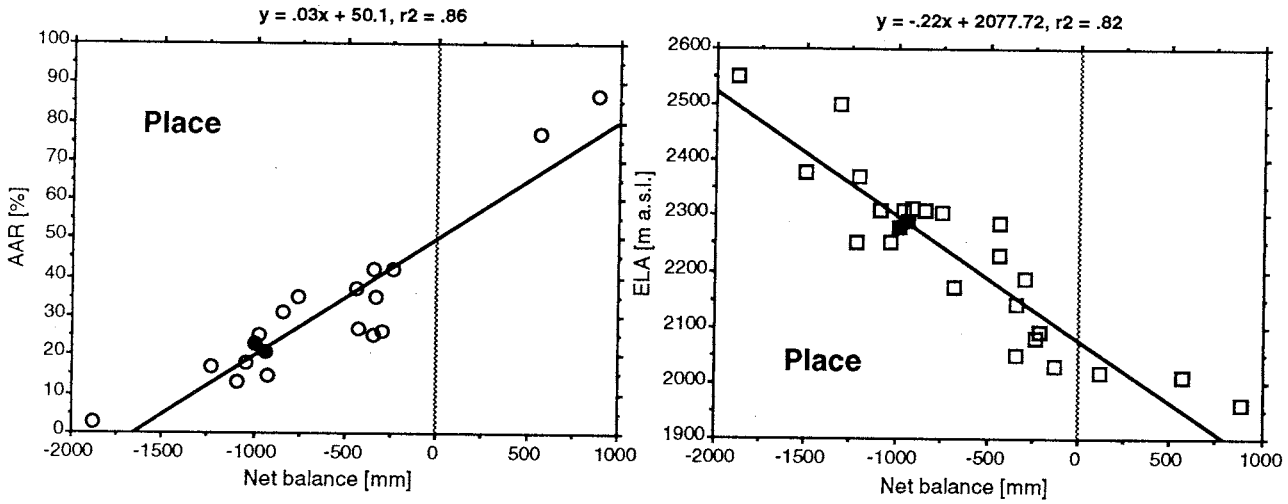
3.1.2 Net balance maps 1989/90 and 1990/91



3.1.3 Net balance versus altitude (1989/90 and 1990/91)



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



3.2 NIGARDSBREEN (NORWAY)

COORDINATES: 61° 43' N / 7° 08' E

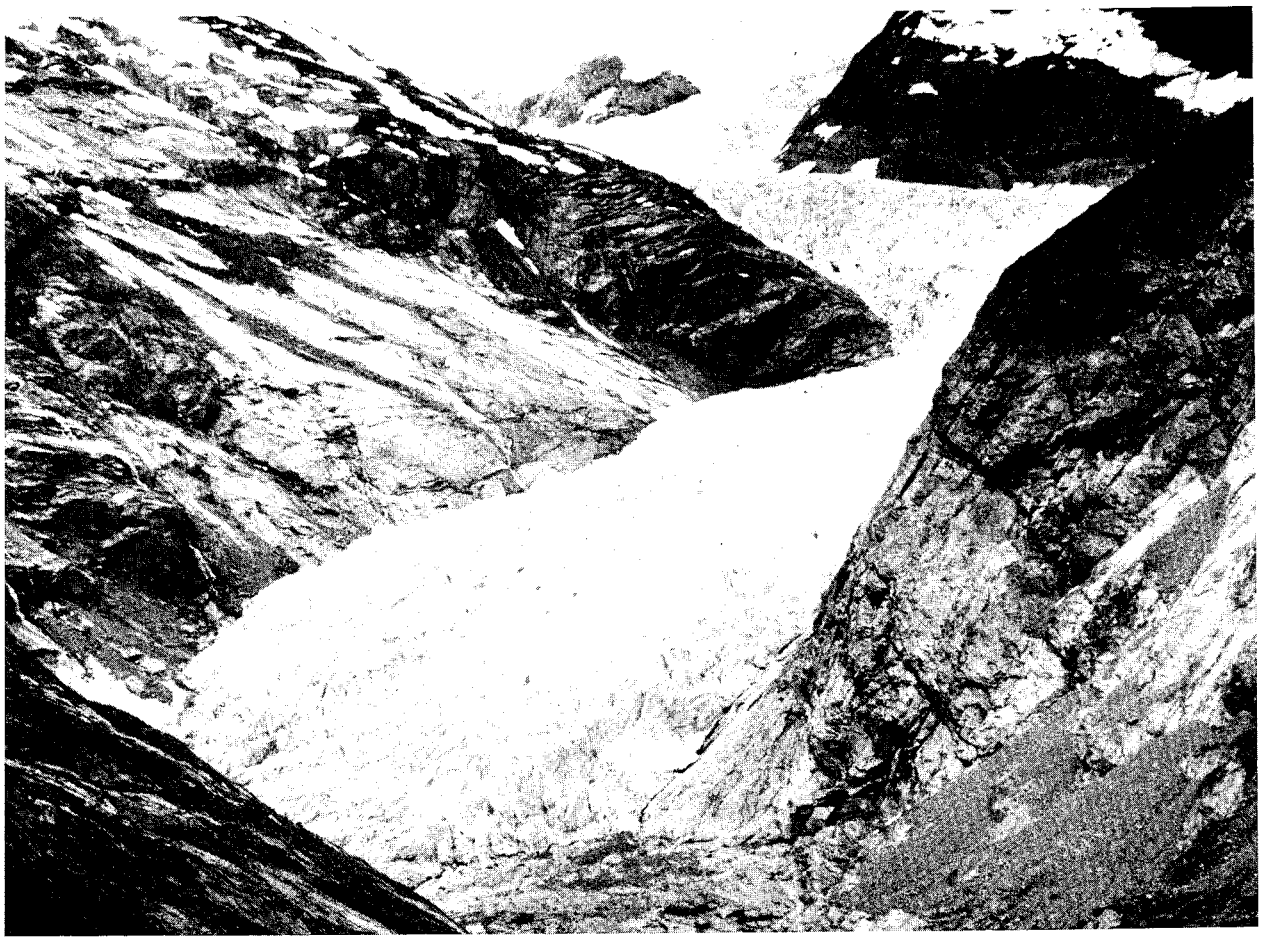


Photo taken by B. Wold on 17 June 1987.

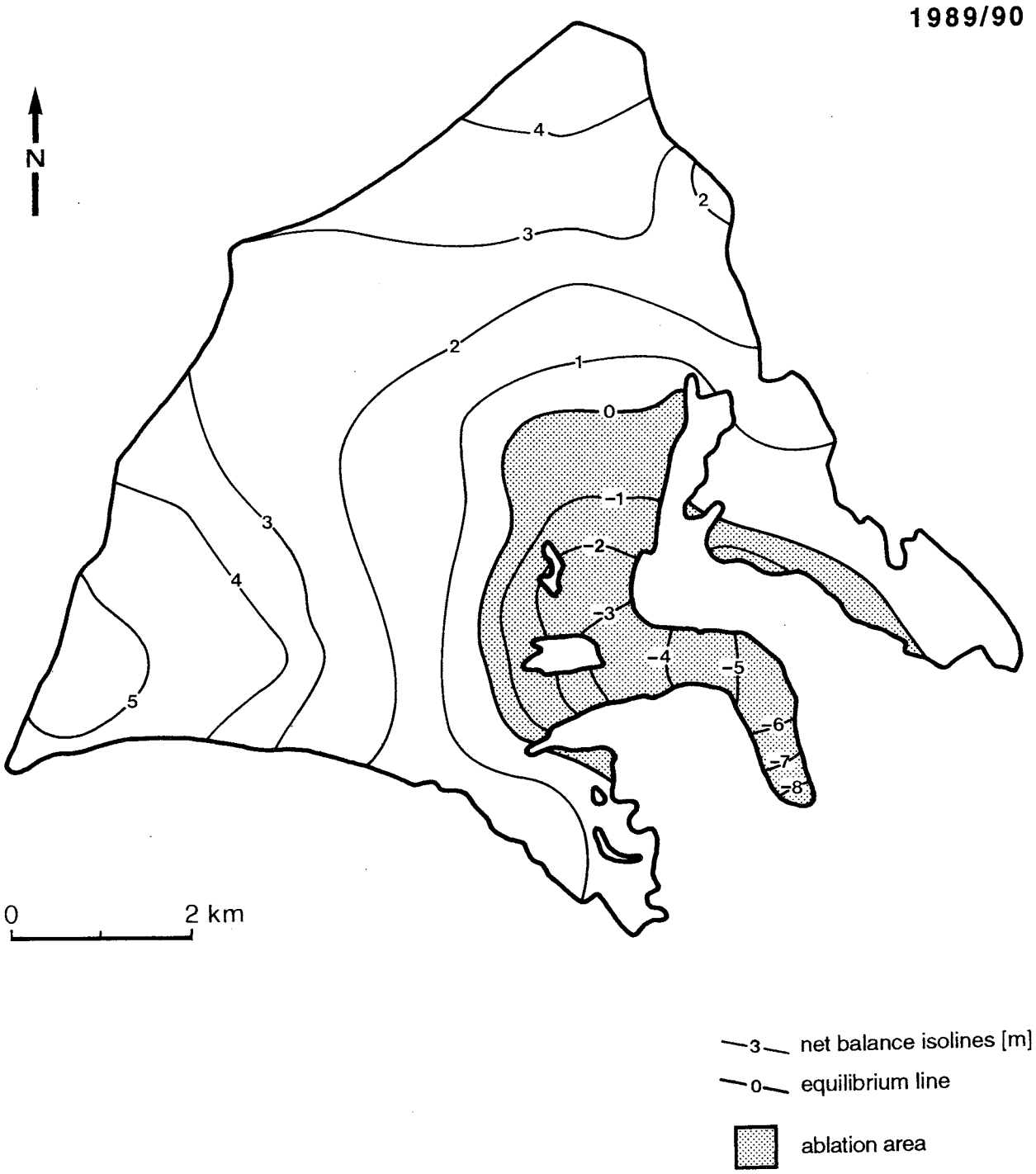
Nigardsbreen is an outlet glacier on the east side of Jostedalsbreen in the central part of southern Norway. The wide accumulation area discharges into a narrow tongue, both being generally exposed to SE. Surface area is 48.2 km^2 and reaches from a highest point of 1,950 m a.s.l. to a minimum elevation of approximately 350 m a.s.l. The equilibrium line of the glacier is commonly found near 1,550 m a.s.l. where the mean annual air temperature can be estimated at some -3° C. The glacier is assumed to be entirely temperate and the periglacial area to be predominantly free of permafrost. Average annual precipitation for the 1961-90 period at the nearby Bjørkehaug station at 324 m a.s.l. is 1,380 mm. The stake network for the direct glaciological measurements recently has been reduced based on the past experience with more extended observations. Photogrammetric mapping at a scale of 1:20,000 was carried out for the years 1964, 1974 and 1984.

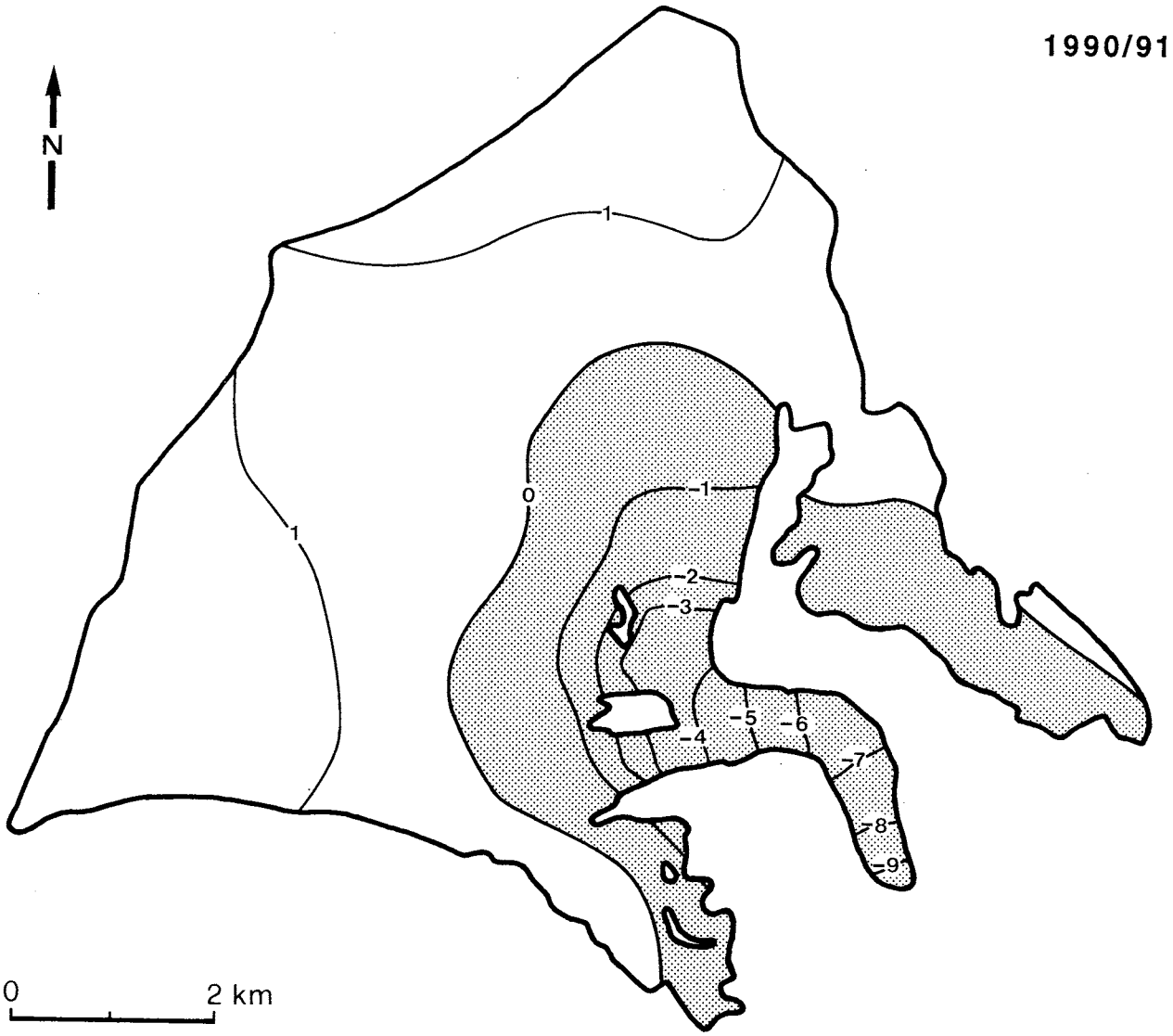
The balance year 1989/90 was strongly positive with a mass gain of 1.77 m water equivalent, which was caused mainly by high winter accumulation (50 % higher than the long-term average) and by slightly below-average summer melting. The balance year 1990/91 was close to normal with a small mass gain of 0.20 m water equivalent. Both winter and summer balance remained somewhat below the long-term averages.

3.2.1 Topography and observational network

Nigardsbreen (NORWAY)

3.2.2 Net balance maps 1989/90 and 1990/91





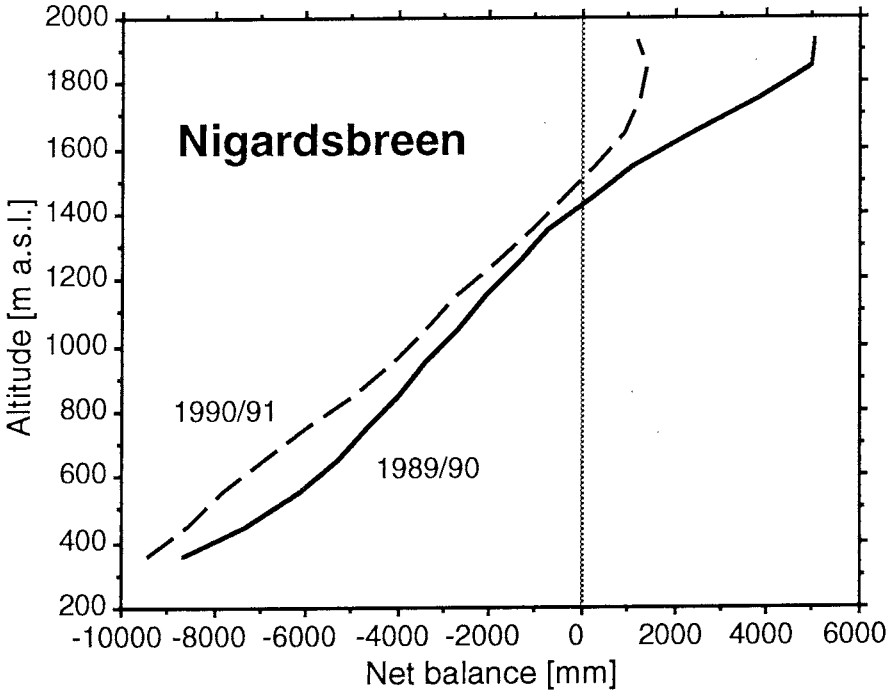
—3— net balance isolines [m]

—0— equilibrium line

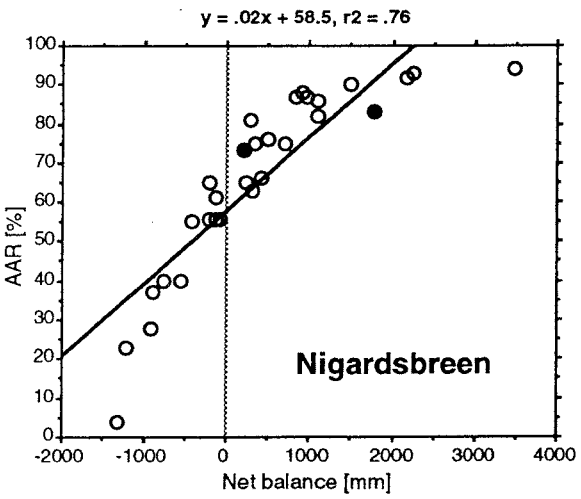
ablation area

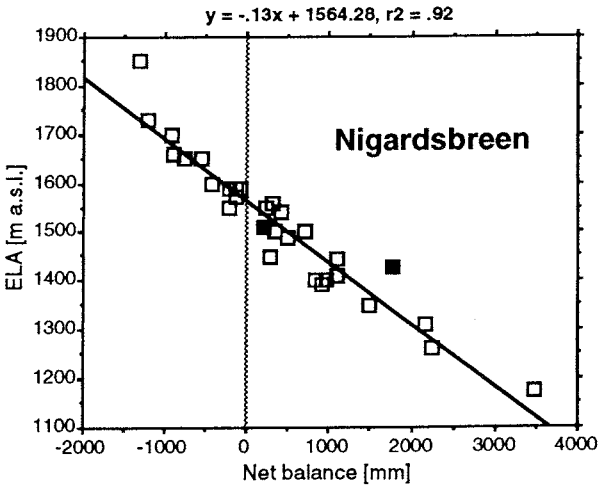
Nigardsbreen (NORWAY)

3.2.3 Net balance versus altitude (1989/90 and 1990/91)



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





3.3 STORGLACIÄREN (SWEDEN)

COORDINATES: 67° 54' N / 18° 34' E

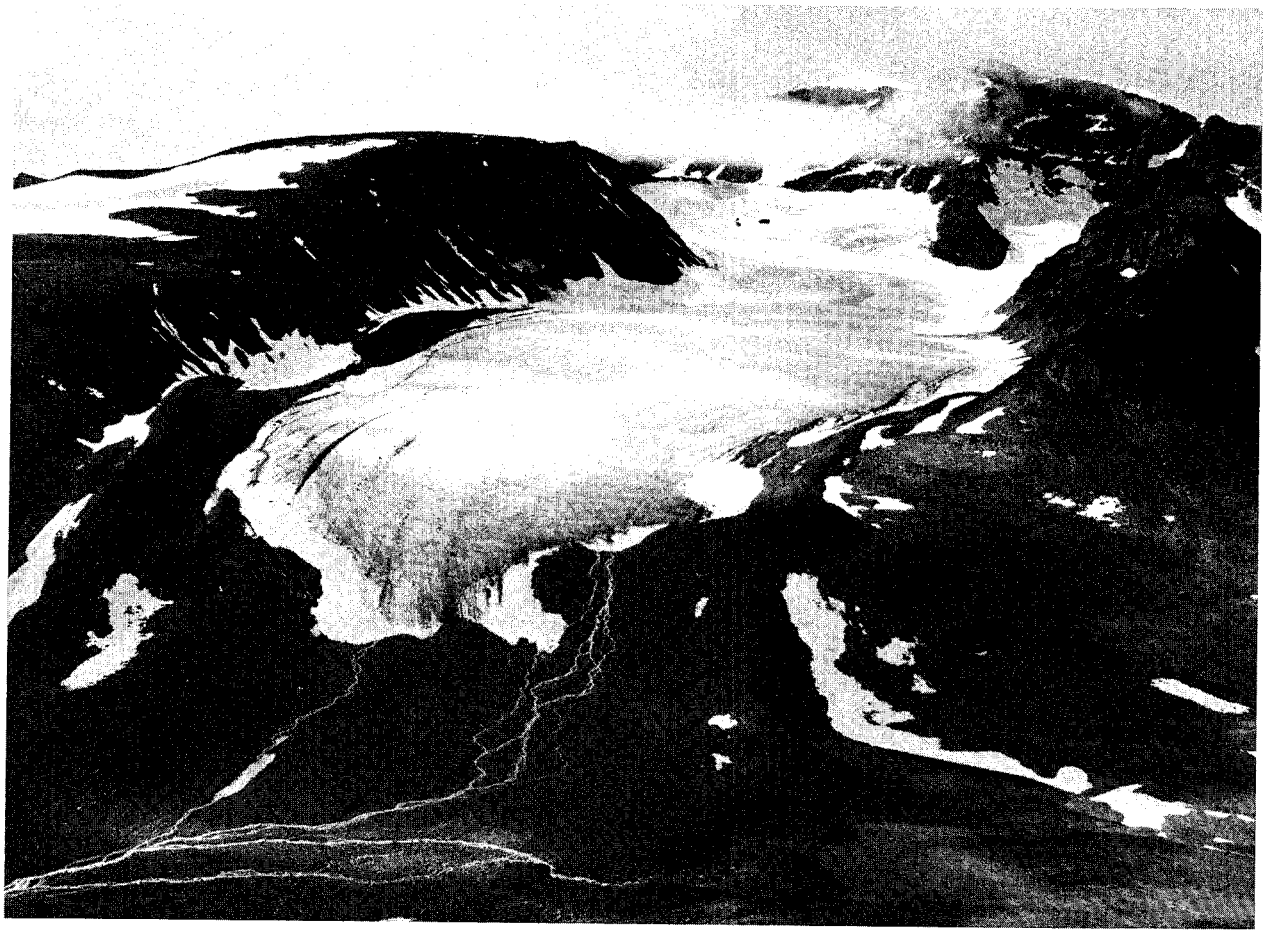
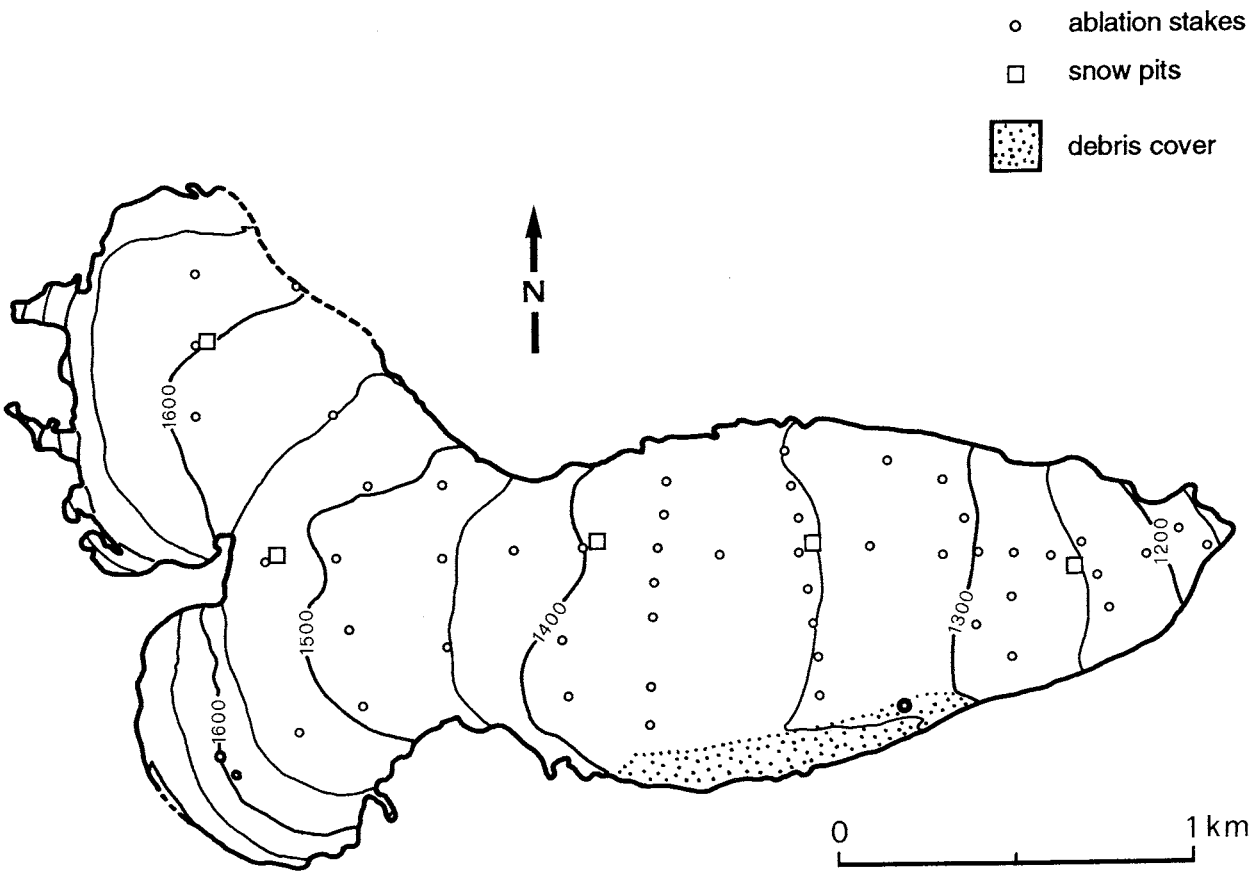


Photo taken by P. Holmlund in August 1987.

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.

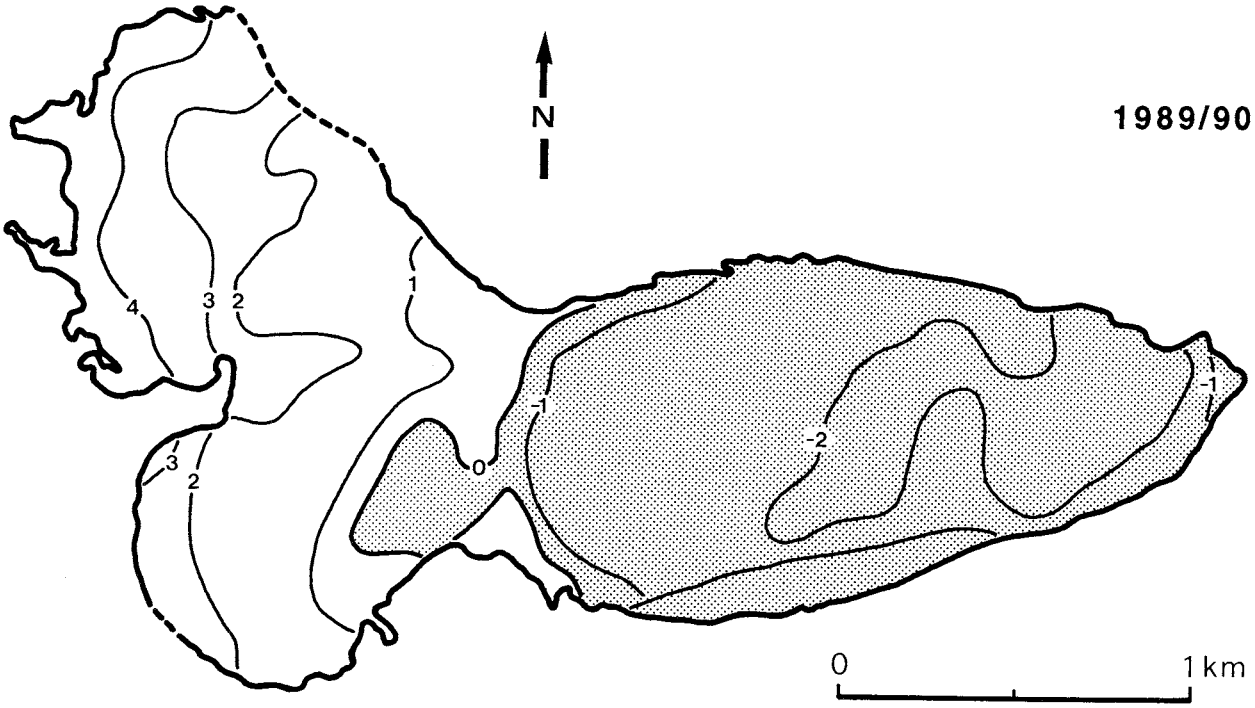
The accumulation for 1989/90 (2.26 m water equivalent) is the second highest rate measured since 1946, when the mass balance record was initiated (the highest rate was measured during the previous mass balance year 1988/89). The summer of 1990 was normal in most respects and the ablation rate differed only by a few percent from the mean since 1946. As a consequence, the glacier experienced a net mass gain of 0.59 m water equivalent during the 1989/90 balance year. The following accumulation period 1990/91 gave a value of 1.68 m water equivalent, which is close to the average. The summer of 1991 was slightly cooler than the previous one, resulting in a net mass gain of 0.17 m water equivalent at the end of the year.

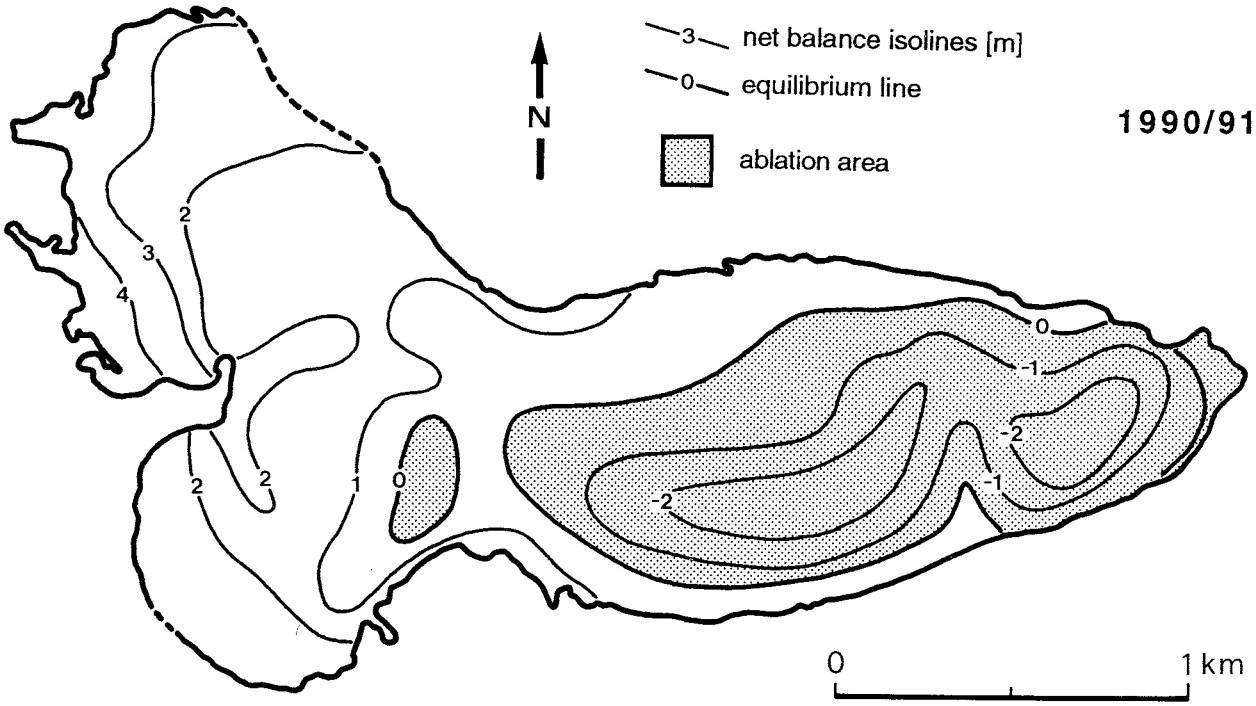
3.3.1 Topography and observational network



Storglaciären (SWEDEN)

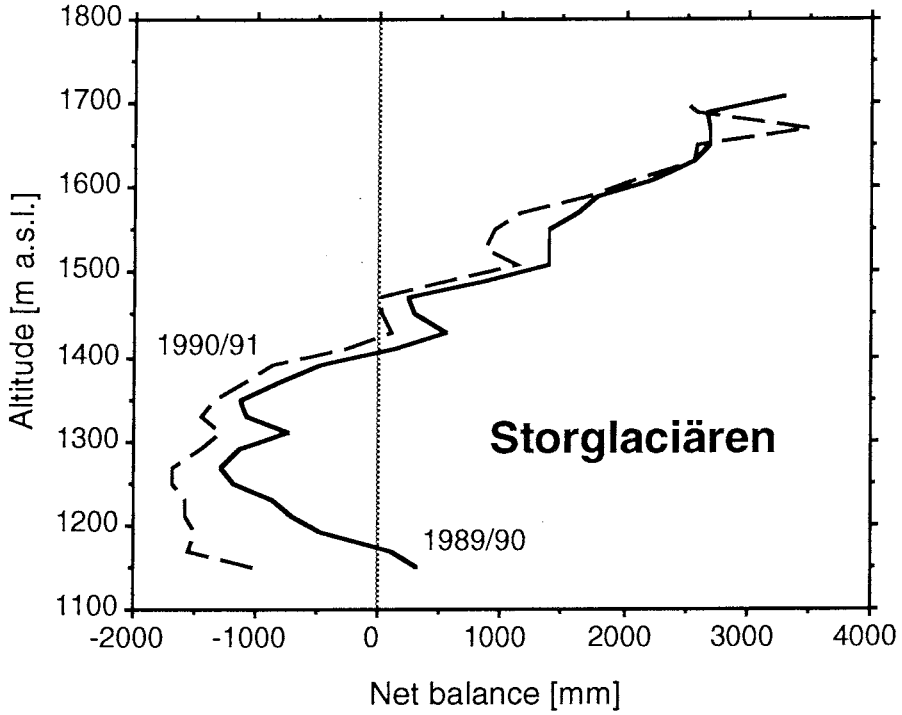
3.3.2 Net balance maps 1989/90 and 1990/91



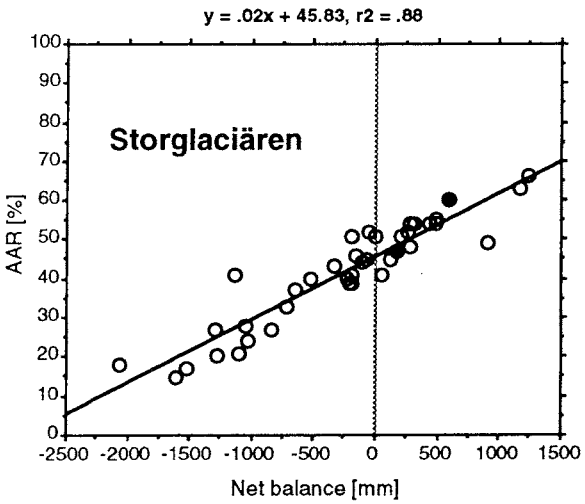


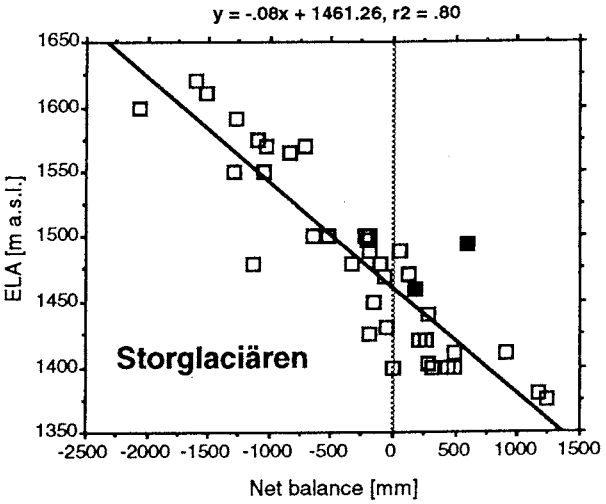
Storglaciären (SWEDEN)

3.3.3 Net balance versus altitude (1989/90 and 1990/91)



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





3.4 HINTEREISFERNER (AUSTRIA)

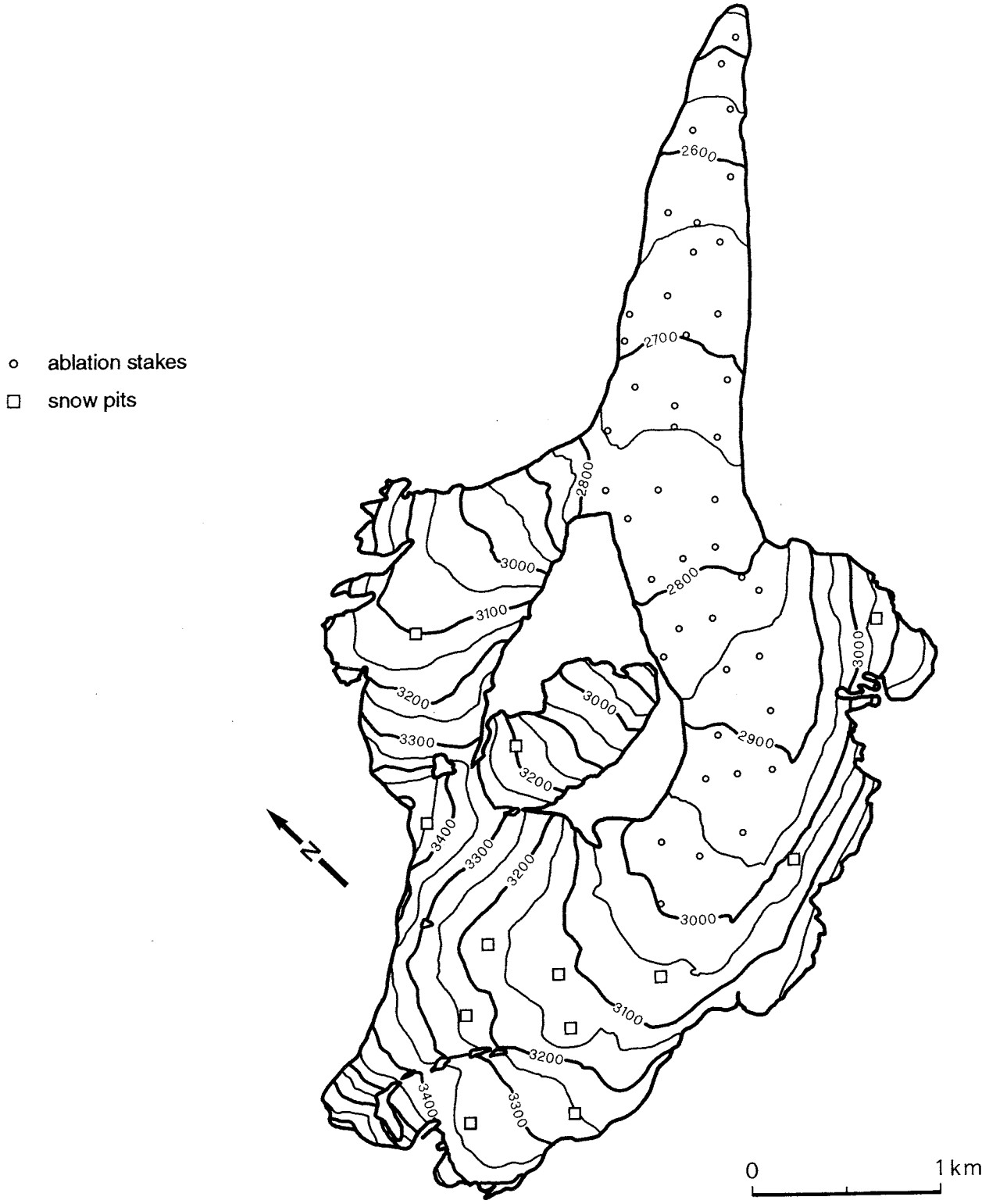
COORDINATES 46° 48' N / 10° 46' E

Photo taken by G. Patzelt on 21 September 1989.

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 8.9 km^2 and the exposure is E to NE. Annual mean air temperature at the equilibrium line of the glacier (around 3,200 m a.s.l. in the two years reported) is -6 to -7 °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.

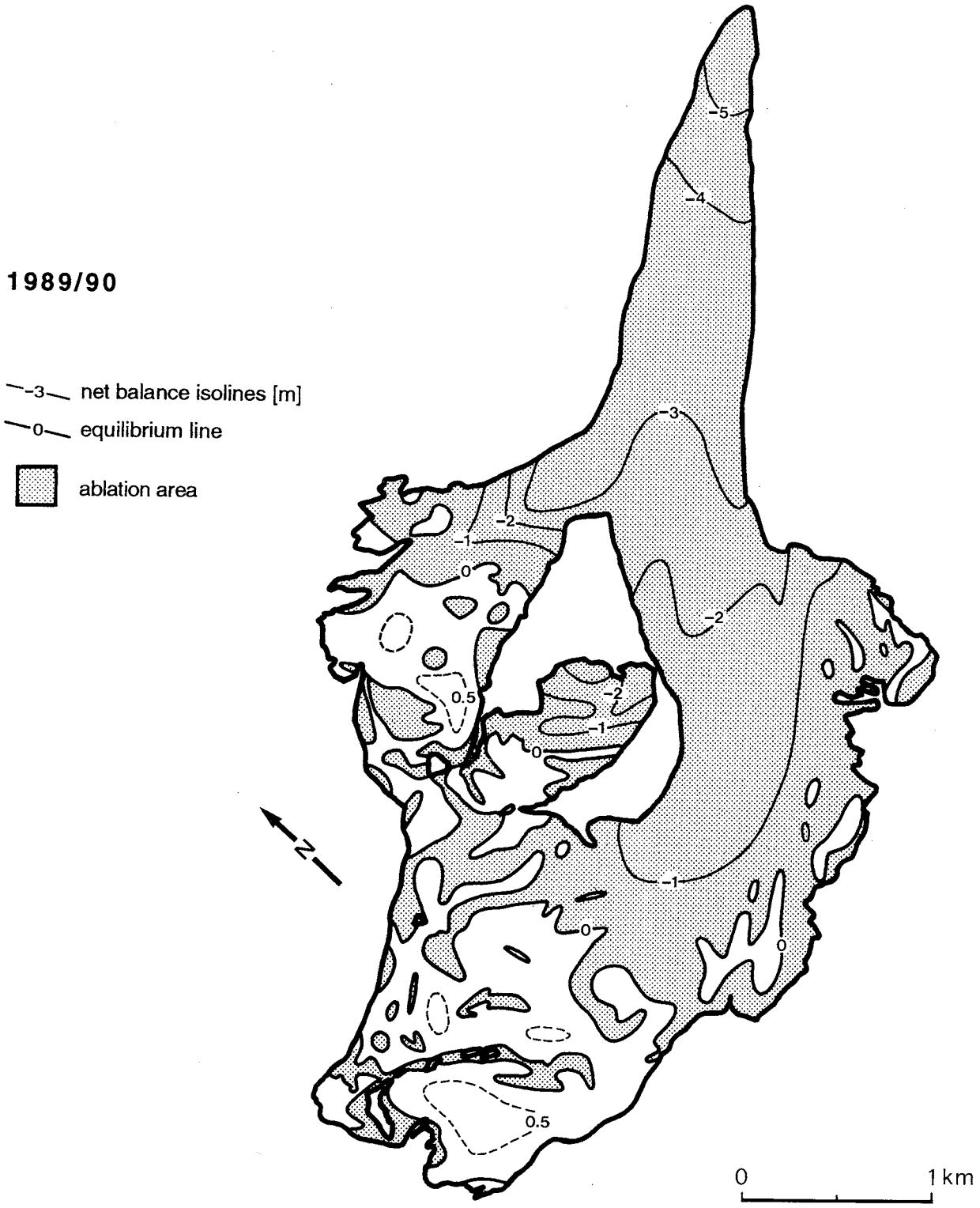
The fixed-date balances of the two reported years were both strongly negative. The year 1989/90 with a net mass loss of 1.00 m water equivalent had winter precipitation slightly below the average, but a very dry summer (73 % of the average May-to-September precipitation, no mid-summer snowfalls) with air temperatures 0.4 °C above the long-term mean). The balance of -1.33 m water equivalent in 1990/91 is the most negative on record, i.e., since 1952/53. It was associated with 90 % of the average winter precipitation, near the average summer temperatures but only 74 % of the average summer precipitation with a particular lack of summer snowfalls.

3.4.1 Topography and observational network

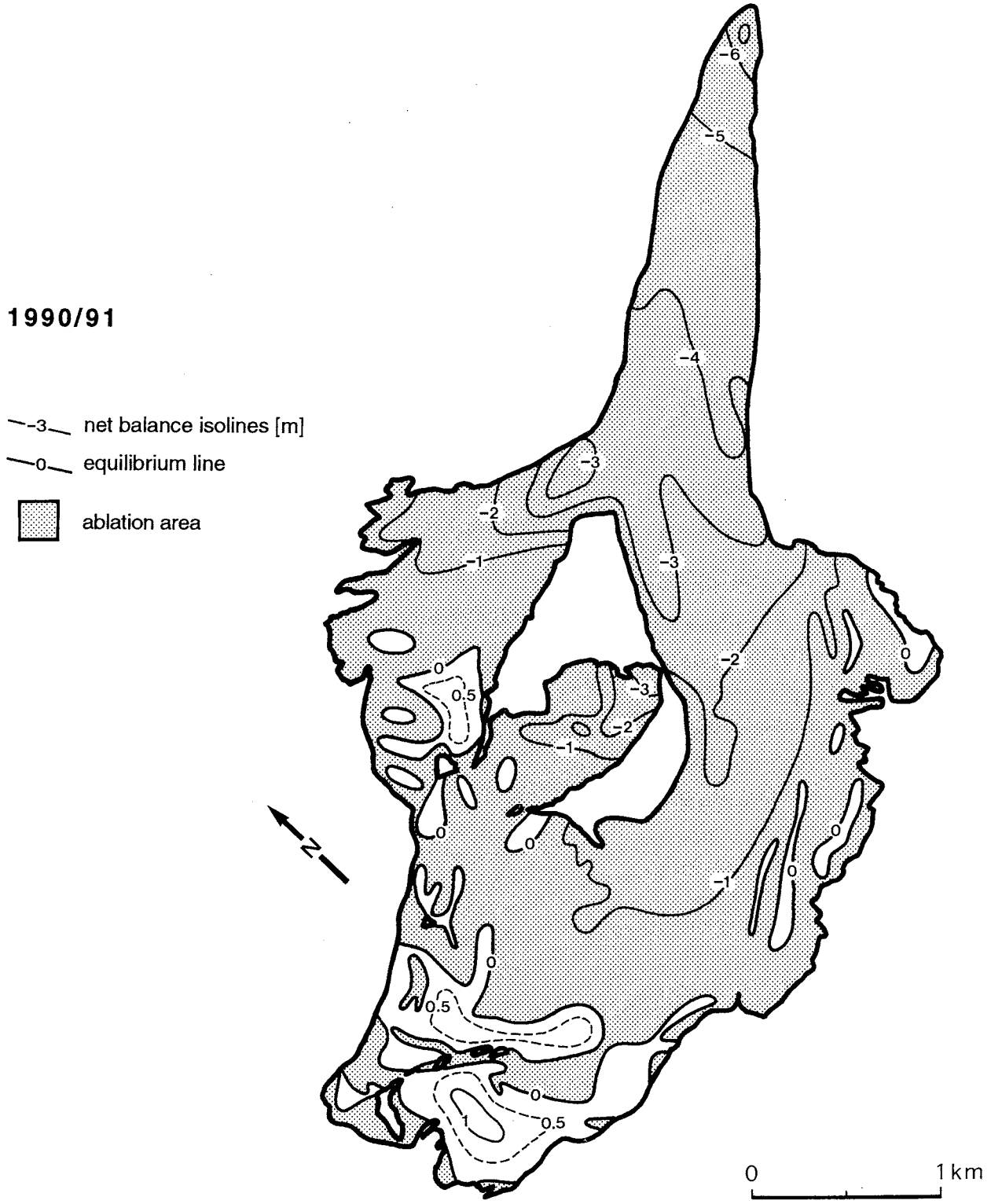


Hintereisferner (AUSTRIA)

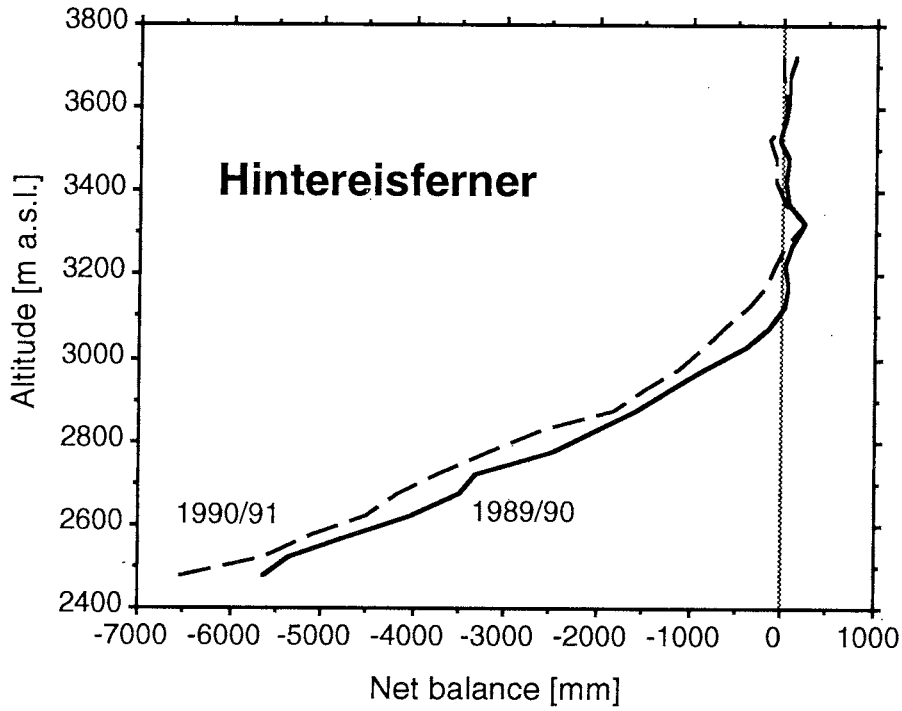
3.4.2 Net balance maps 1989/90 and 1990/91



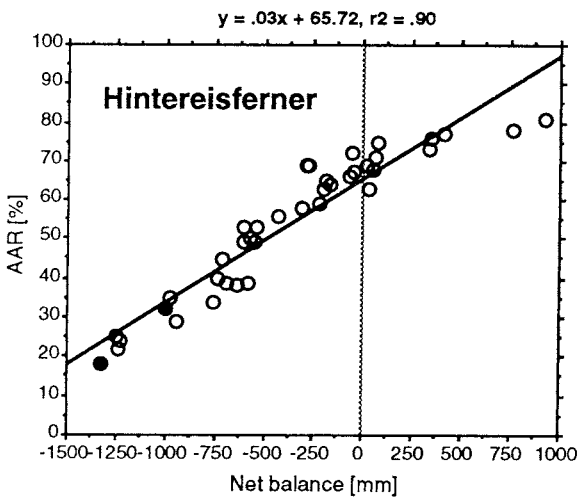
Hintereisferner (AUSTRIA)

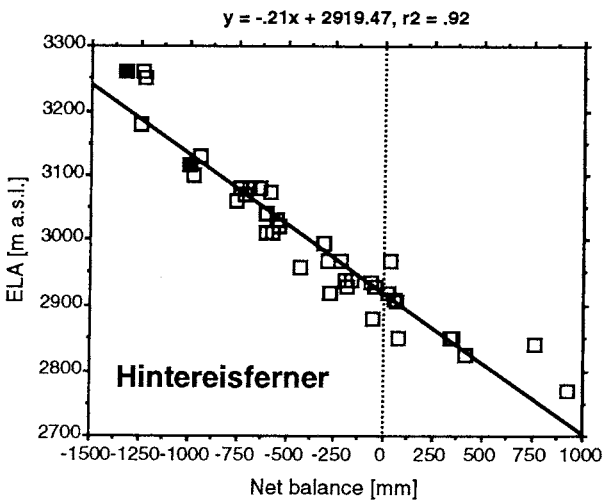

1990/91
-3 net balance isolines [m]
0 equilibrium line
ablation area
N
0
1 km

3.4.3 Net balance versus altitude (1989/90 and 1990/91)



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





3.5 LEWIS (KENYA)

COORDINATES: 00° 09' S / 37° 18' E

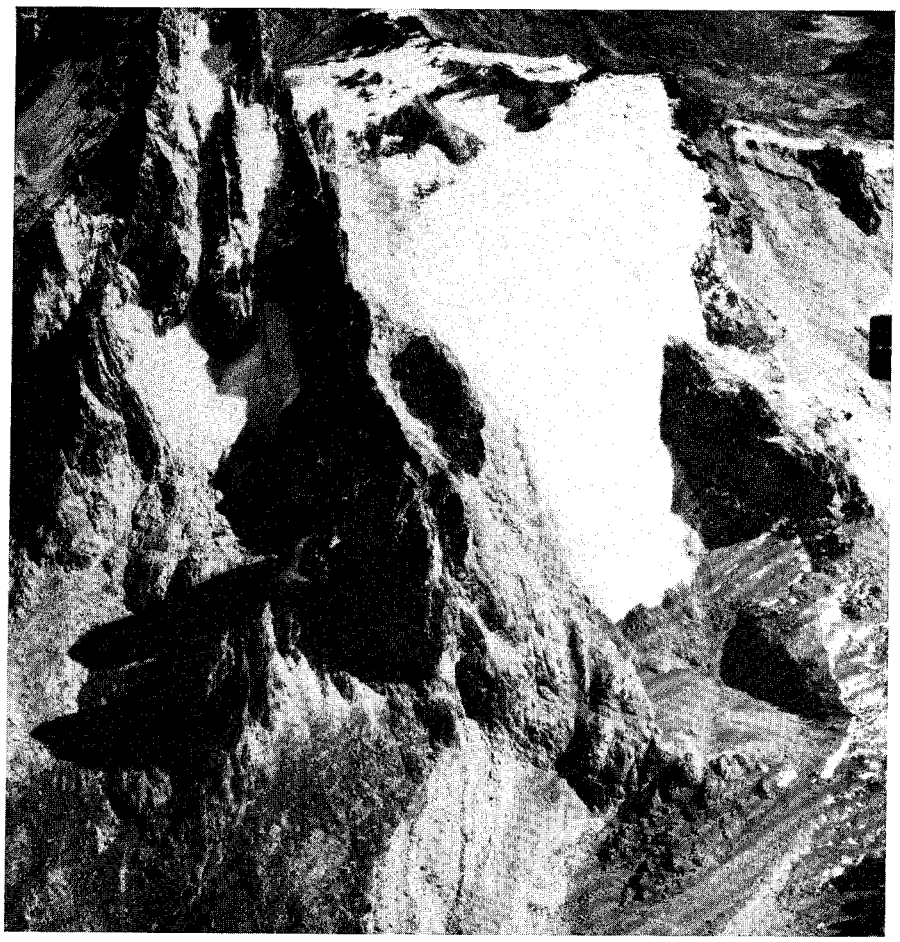


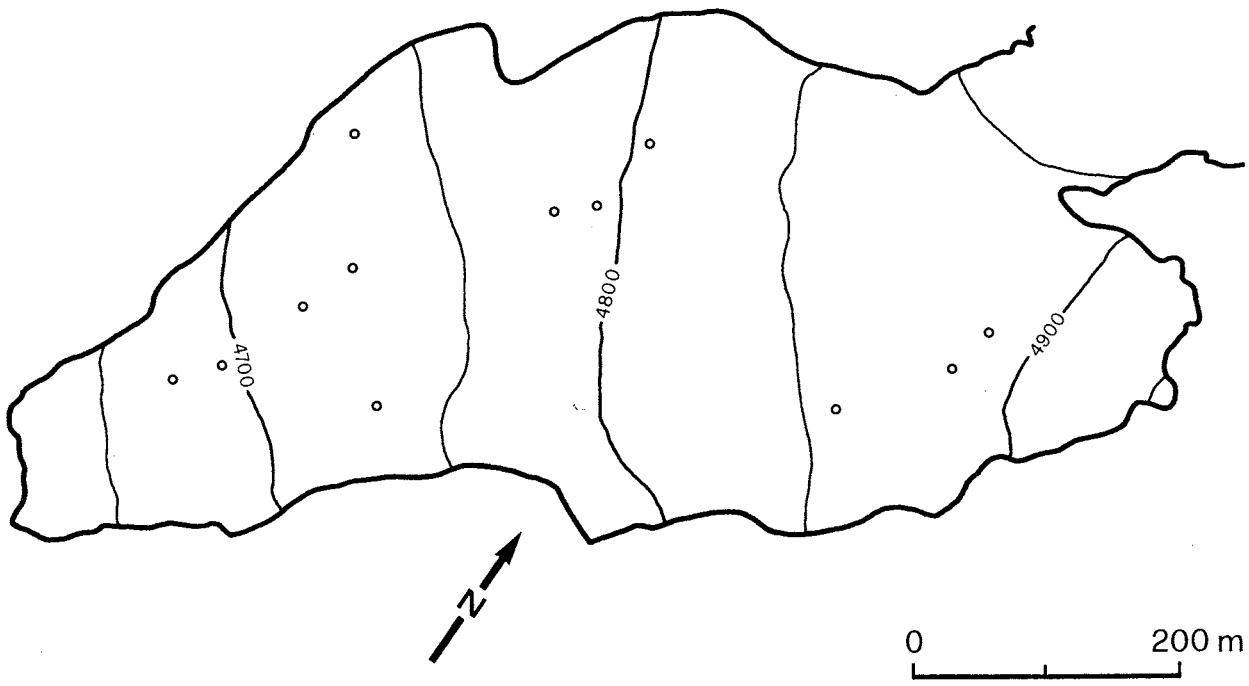
Photo taken in the mid-1980s; courtesy of Photomap (K) Ltd.

This largest glacier on Mount Kenya is located less than 20 km to the south of the Equator at elevations between 5,000 and 4,600 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 last 12 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, start of the balance year is in March rather than in boreal autumn. For various of the years monitored since 1978, the entire glacier acted as an "ablation area". Topographic maps of the glacier in 1987 and 1990 can be found in Vol. 6 of the Fluctuations of Glaciers.

Both March 1989 to March 1990 and March 1990 to March 1991 were dry years with net mass losses of 1.01 and 0.81 m water equivalent, respectively. The ELA of both reported years are above glacier maximum elevation.

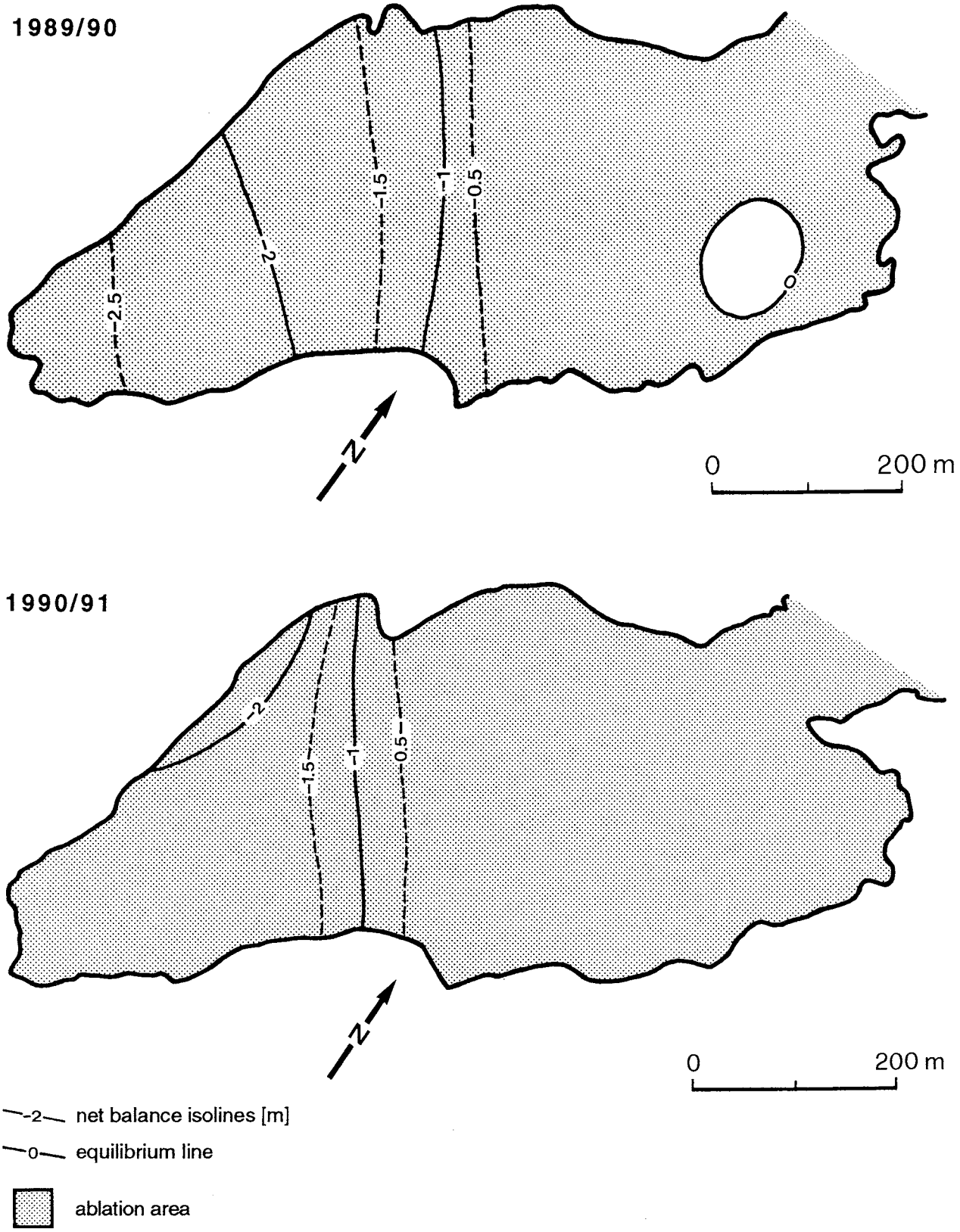
3.5.1 Topography and observational network

o ablation stakes

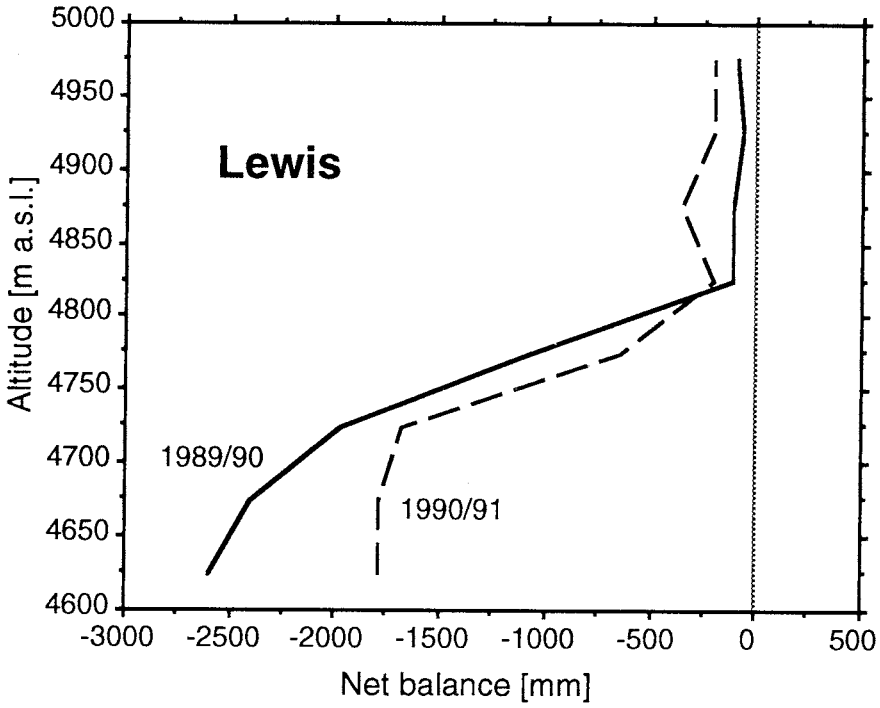


Lewis (KENYA)

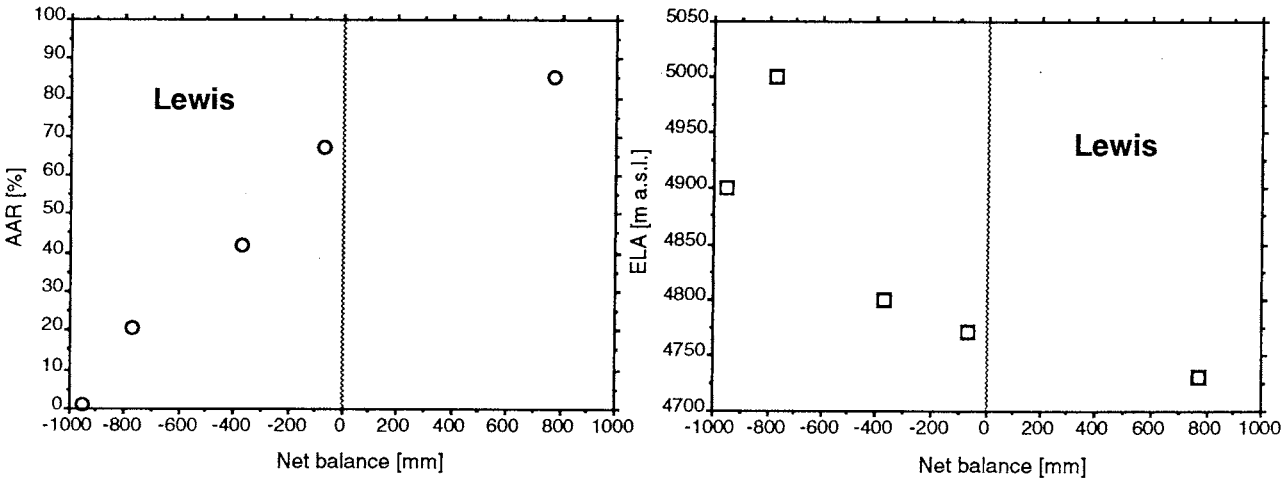
3.5.2 Net balance maps 1989/90 and 1990/91



3.5.3 Net balance versus altitude (1989/90 and 1990/91)



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



3.6 DJANKUAT (RUSSIA)

COORDINATES: 43° 12' N / 42° 46' E

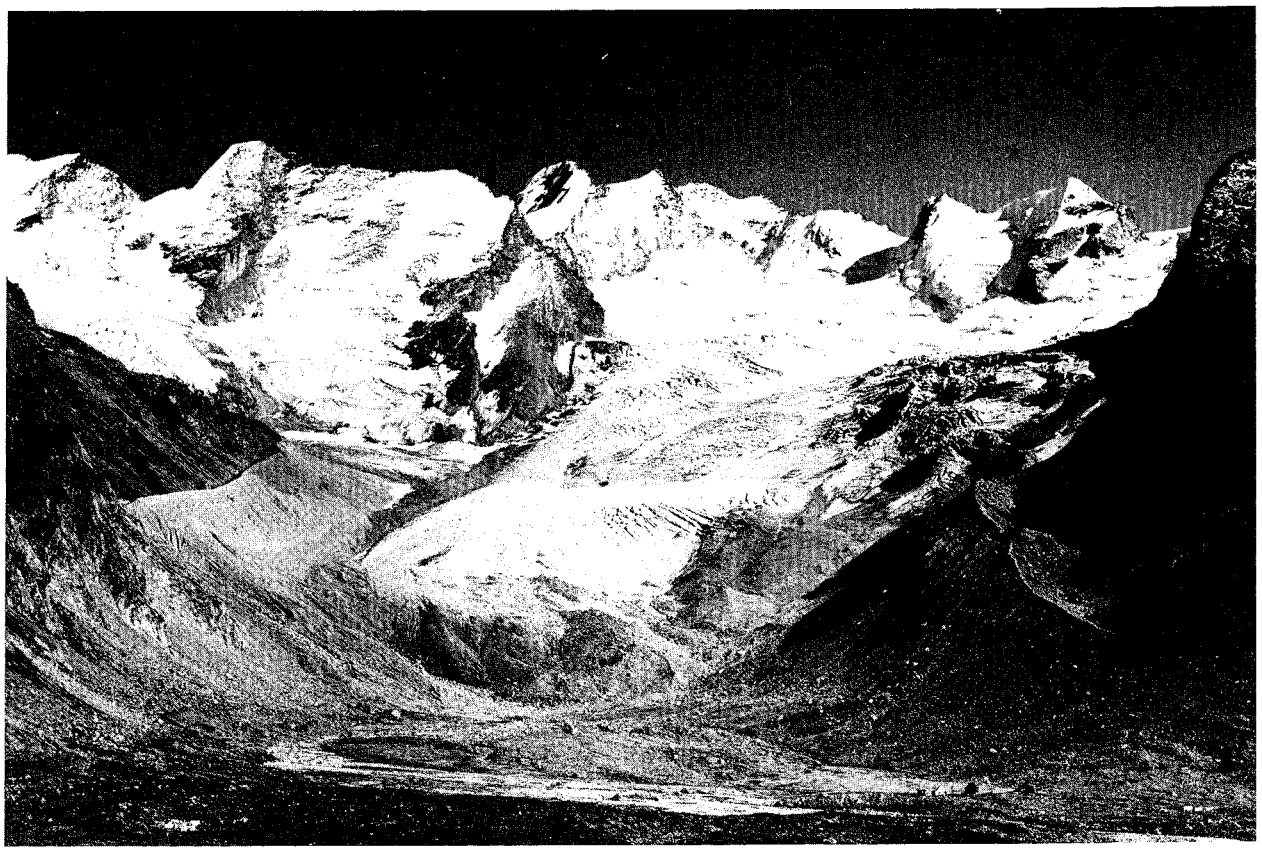
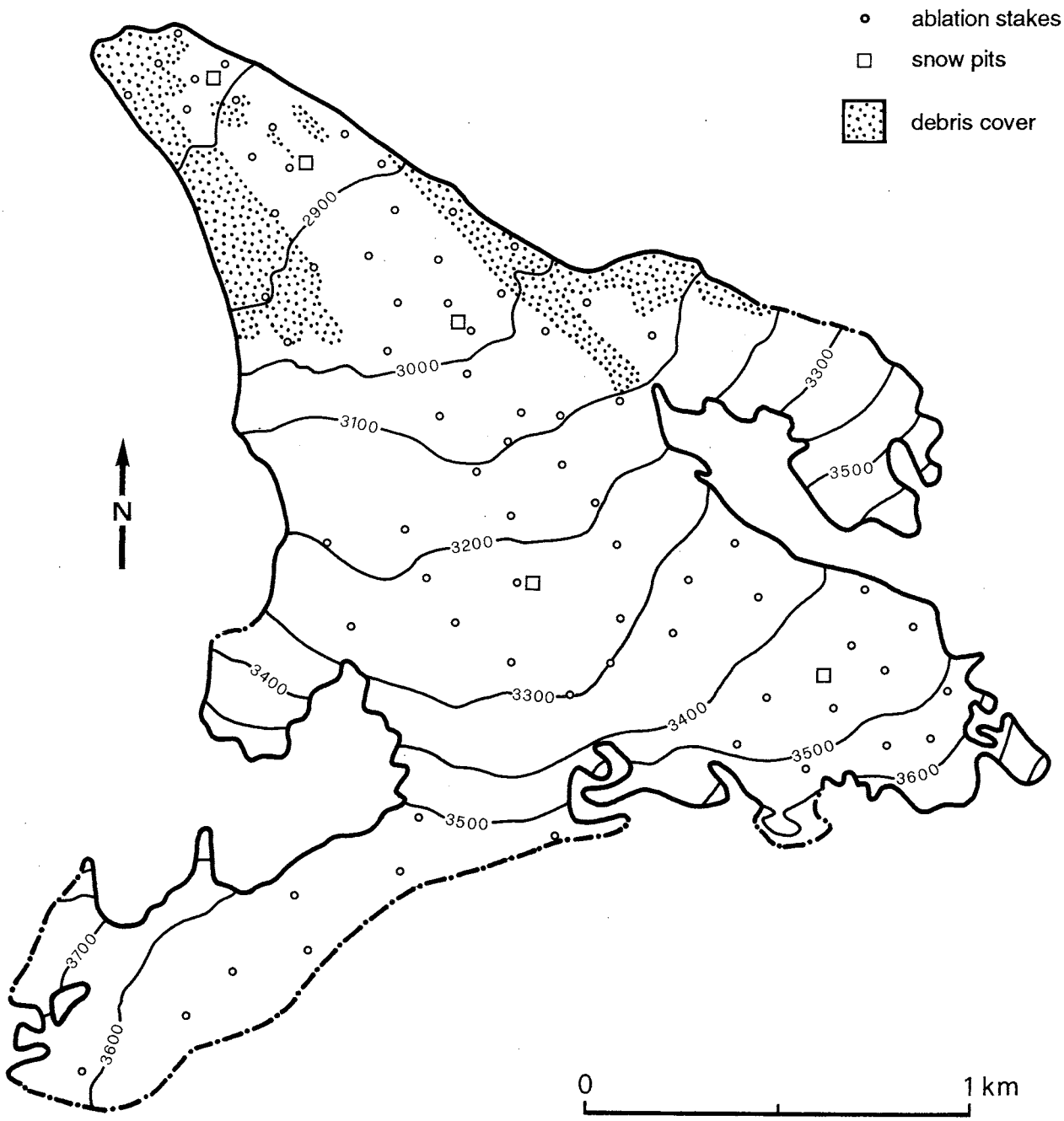


Photo taken by Ye. A. Zolotaryov and V. V. Popovnin in September 1985.

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.

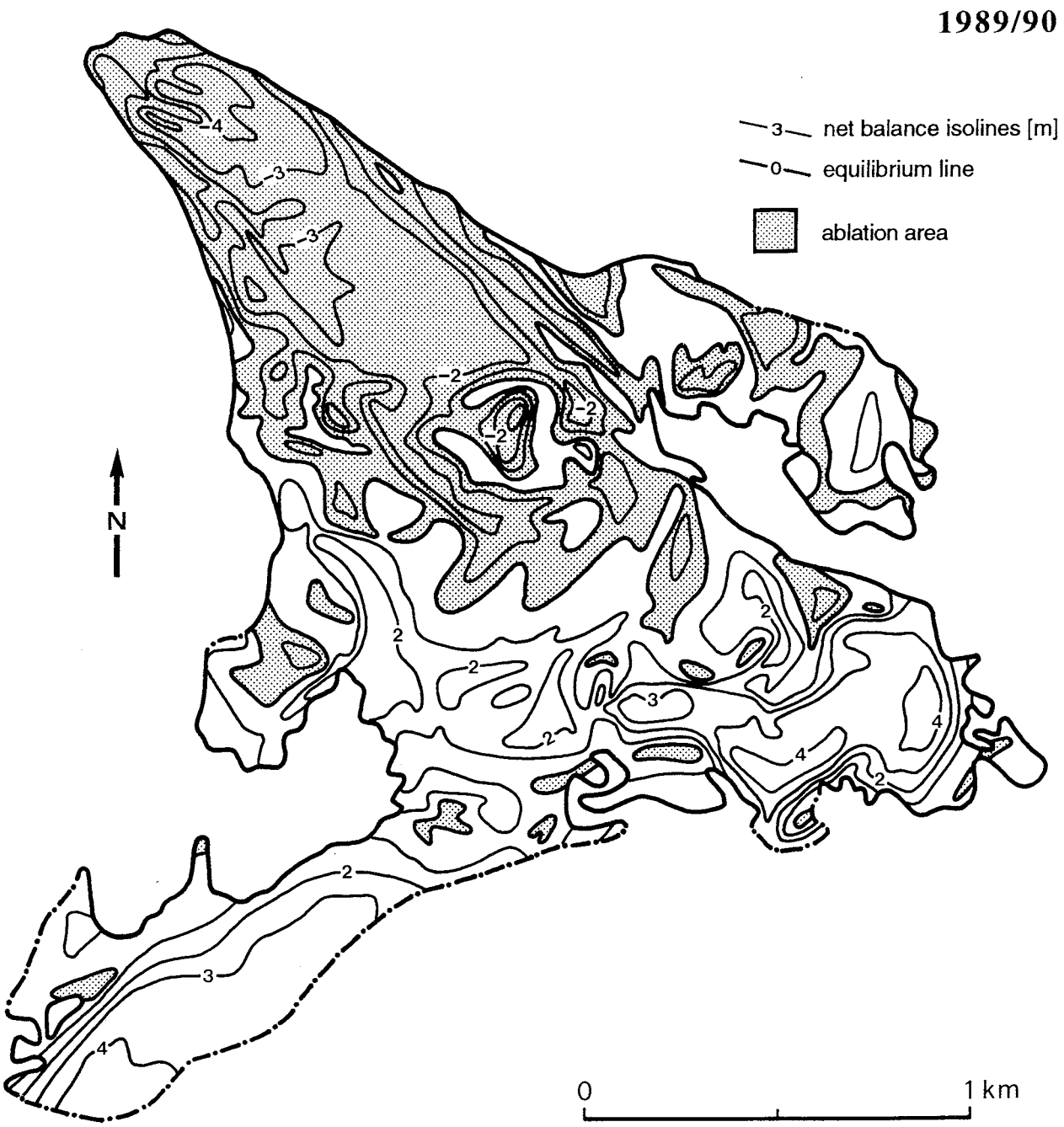
Winter accumulation was above average by 12 % in 1989/90 and by 4 % in 1990/91, thus conforming with the trend towards increased accumulation rates during the past years. The ablation season was slightly cooler than average in 1989/90, but very warm and extremely long-lasting (until the end of October) in 1990/91. With a gain of 0.34 m water equivalent in 1989/90 and a loss of 0.31 m water equivalent in 1990/91, the mass changes of the glacier were comparable in magnitude but opposite in sign during the two reported years. The last reported balance year interrupted the series of positive mass balances during the four previous years.

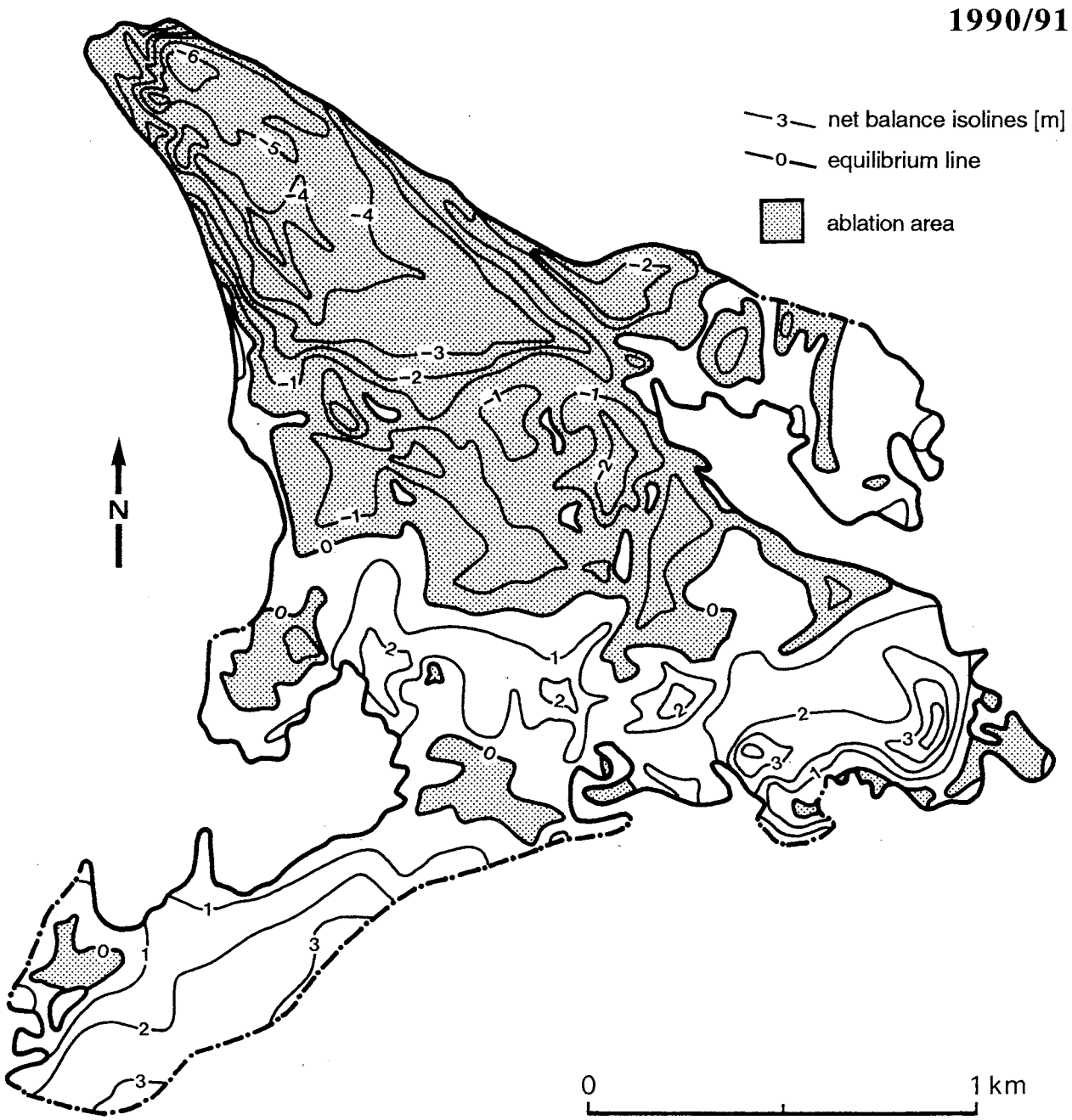
3.6.1 Topography and observational network



Djankuat (RUSSIA)

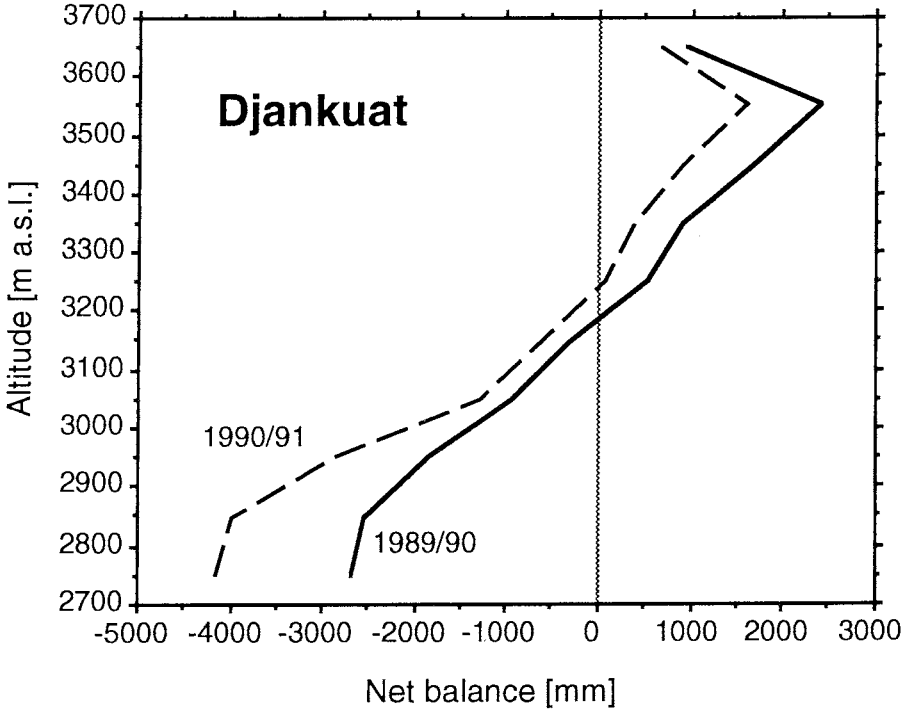
3.6.2 Net balance maps 1989/90 and 1990/91



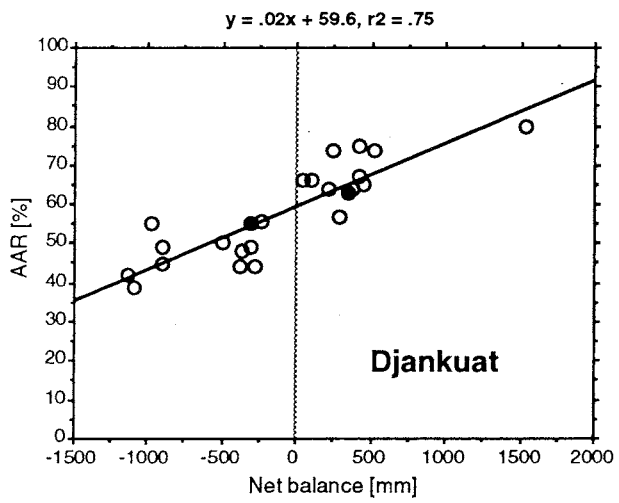


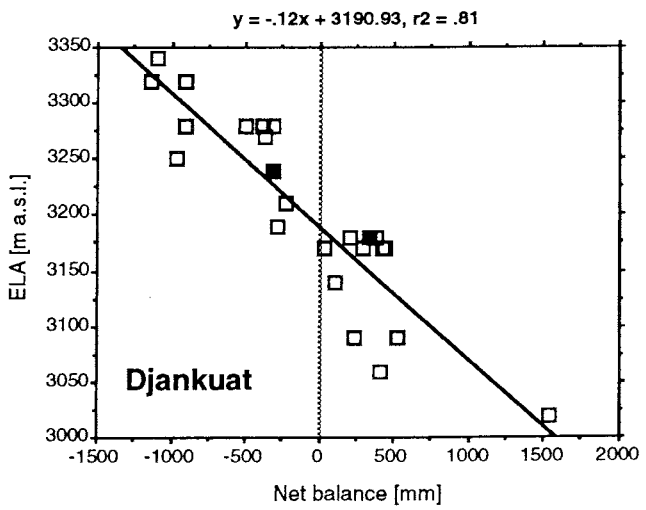
Djankuat (RUSSIA)

3.6.3 Net balance versus altitude (1989/90 and 1990/91)



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





3.7 KOZELSKIY (RUSSIA)

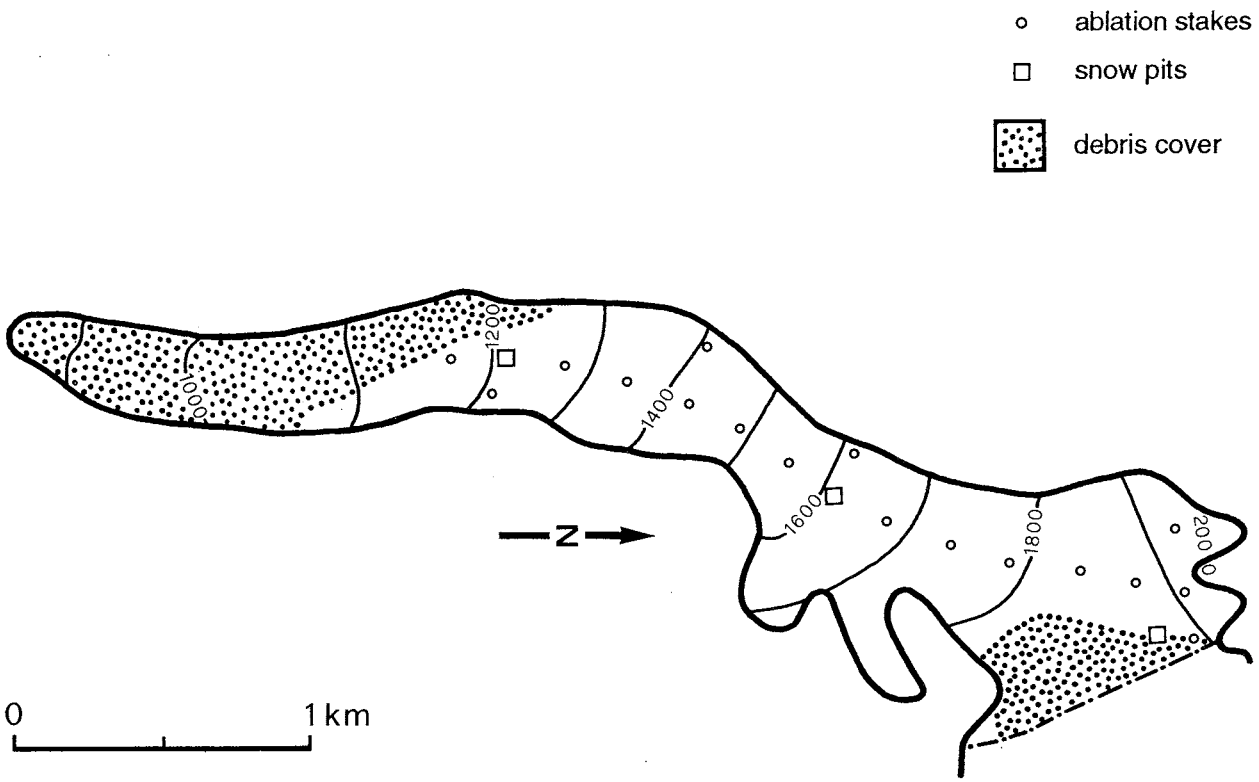
COORDINATES: 53° 14' N / 158° 49' E

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 normal regarding the winter balance, while summer conditions differed greatly. The year 1989/90 had the warmest summer for the last 45 years in the vicinity of the Petropavlovsk Kamchatskiy weather station, resulting in a strong mass loss of 1.28 m water equivalent at the end of the balance year. The resumption of the Avachinskiy Volcano eruptive activity in January 1991 caused the deposition of a thin ash layer at about 3 m depth within the winter snow cover. This contamination of the snow is assumed to have increased ablation by some 10 to 15 % but the cool summer of 1990/91 nevertheless enabled the glacier to obtain a mass gain of 0.46 m water equivalent.

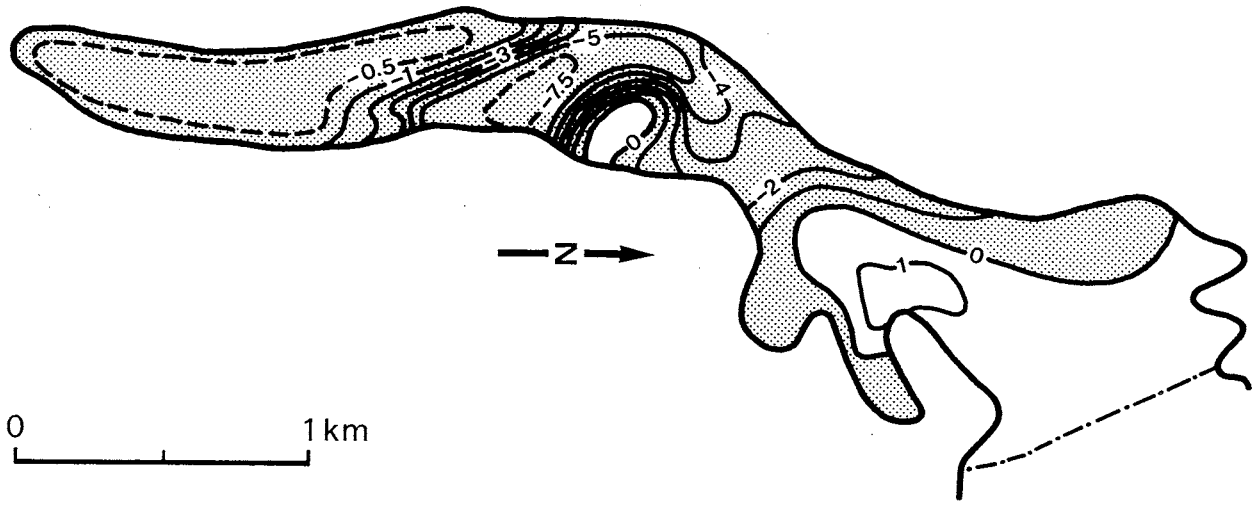
3.7.1 Topography and observational network



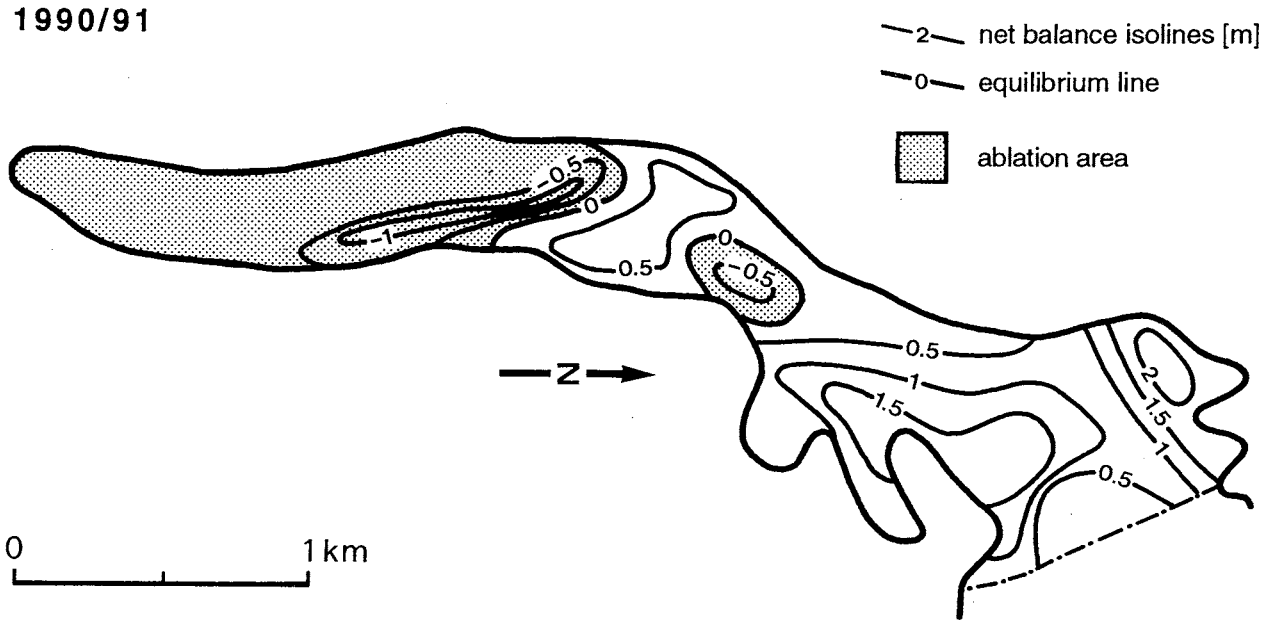
Kozelskiy (RUSSIA)

3.7.2 Net balance maps 1989/90 and 1990/91

1989/90

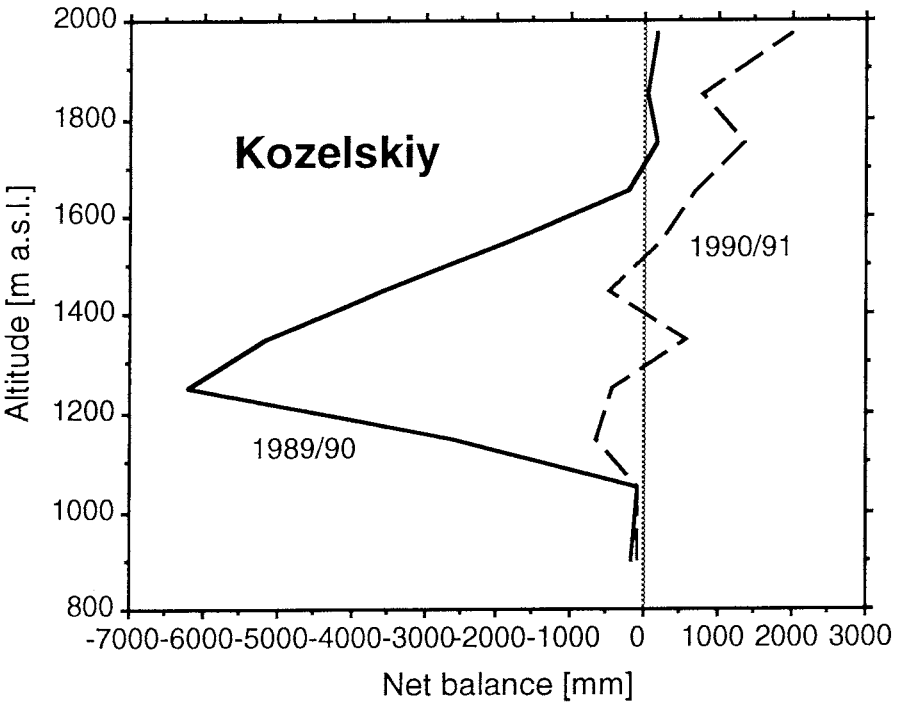


1990/91

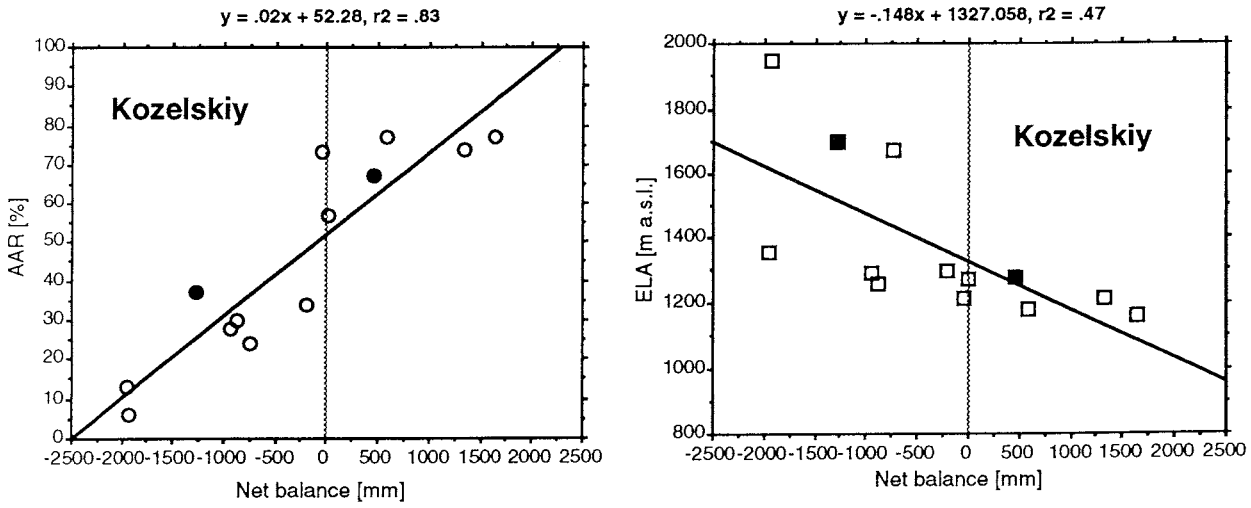


Kozelskiy (RUSSIA)

3.7.3 Net balance versus altitude (1989/90 and 1990/91)



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



3.8 ABRAMOV (TADJIKISTAN)

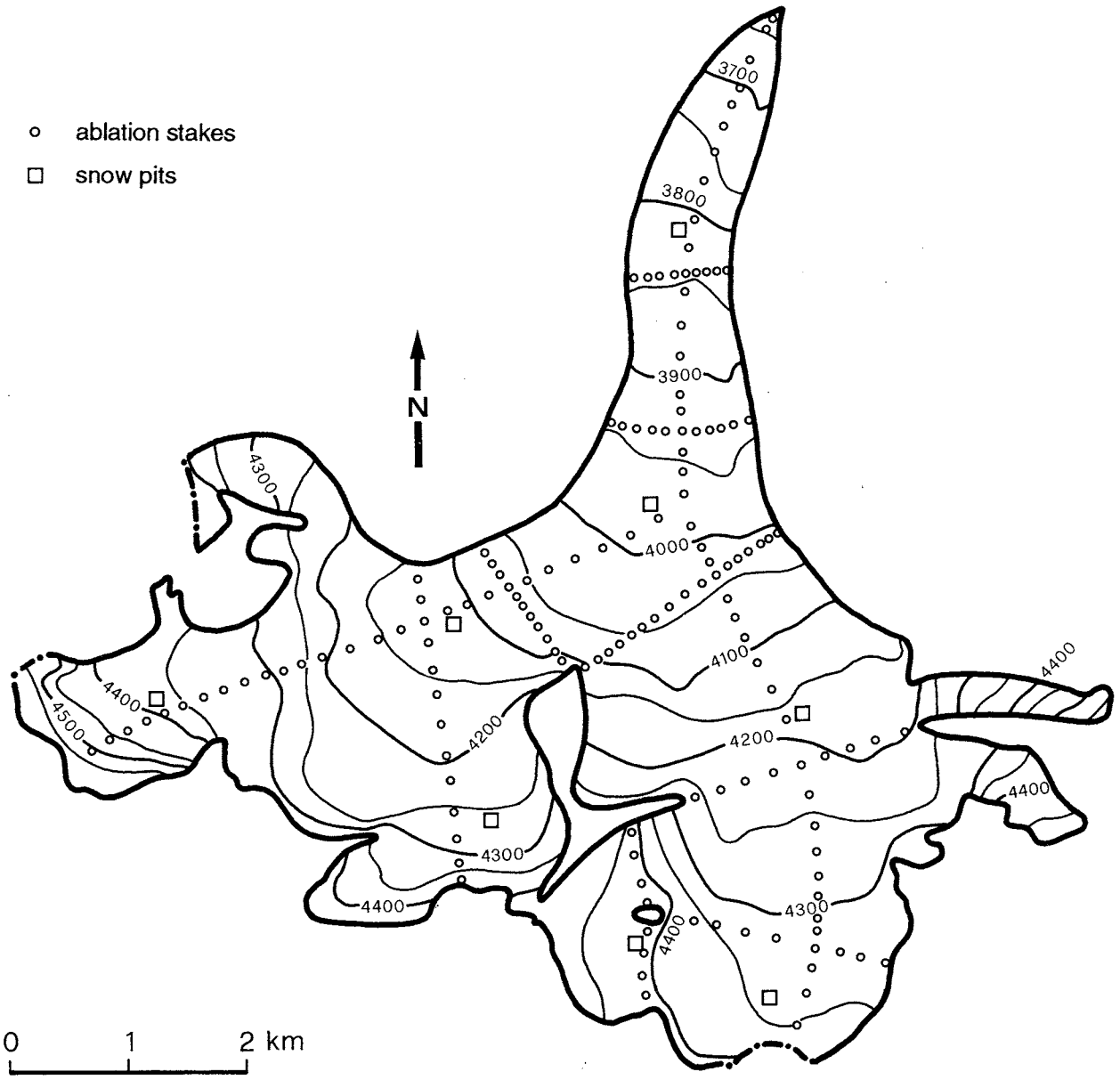
COORDINATES: 39° 39' N / 71° 38' E

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 1989/90 the glacier received about 20 % above the average precipitation but June-to-September air temperatures were 1.3 °C above the average. June and September in particular were extremely warm. With -0.54 m water equivalent, net mass loss of the glacier corresponds to the long-term mean. The year 1990/91 was normal both in precipitation as well as air temperature. Hence, mass balance (-0.42 m water equivalent) was again close to the long-term average. Equilibrium line altitude in both years slightly exceeded 4200 m a.s.l.

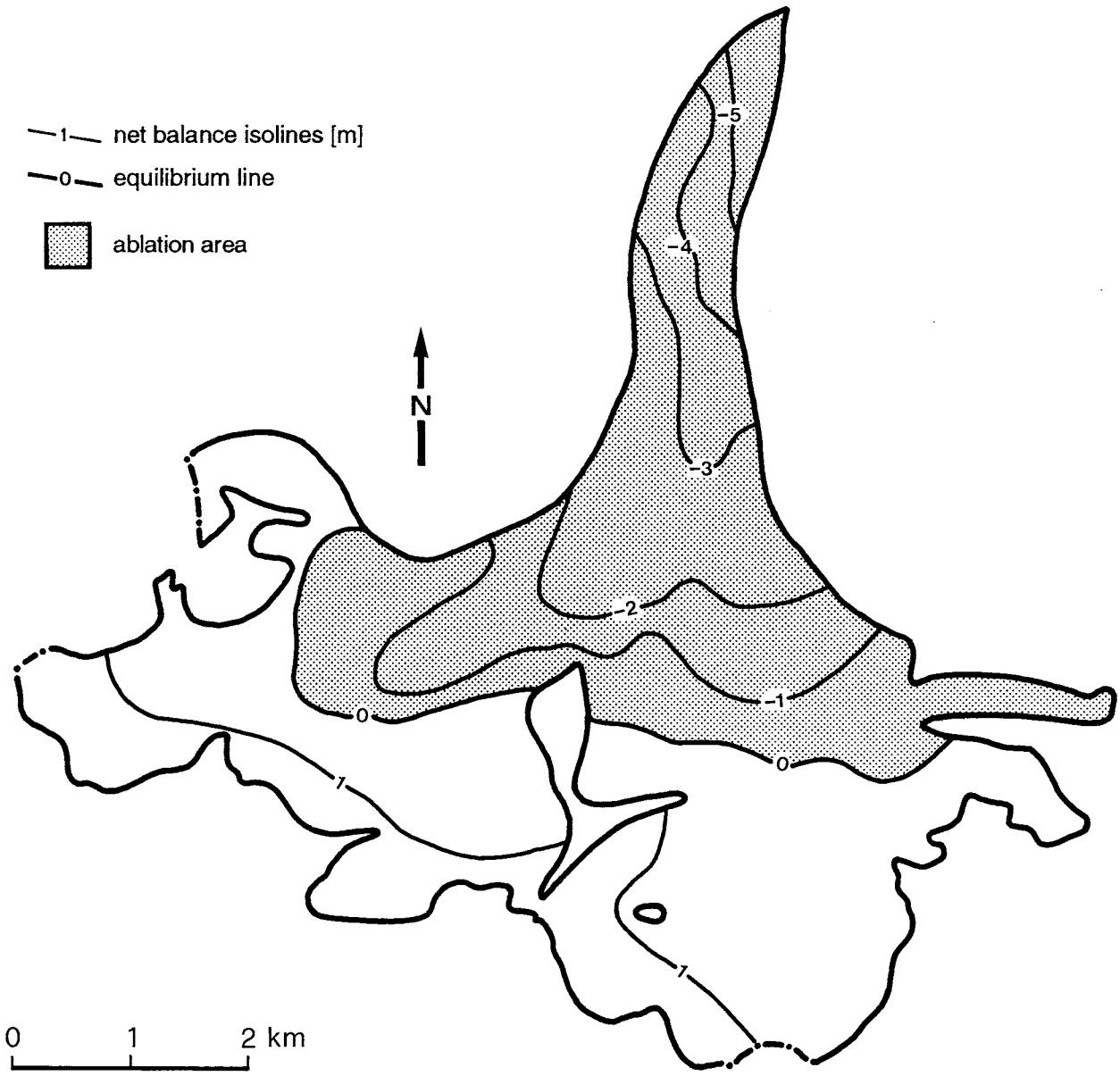
3.8.1 Topography and observational network



Abramov (TADJIKISTAN)

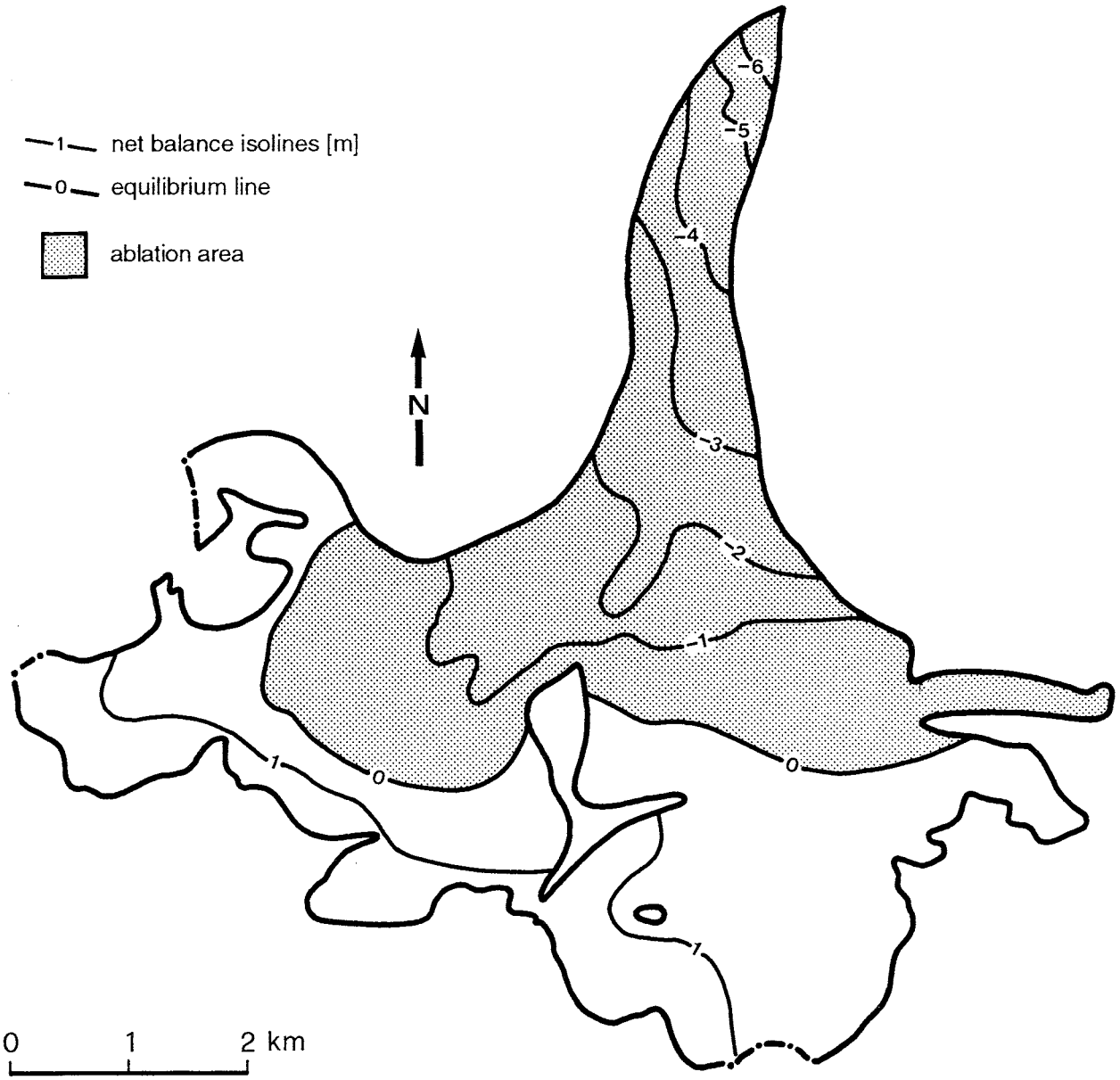
3.8.2 Net balance maps 1989/90 and 1990/91

1989/90

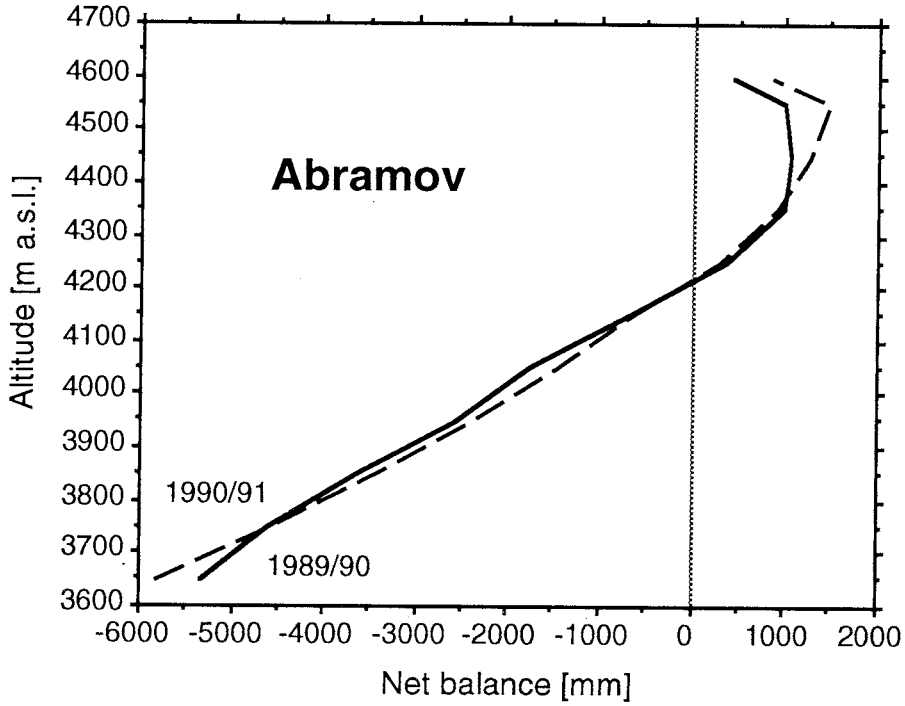


Abramov (TADJIKISTAN)

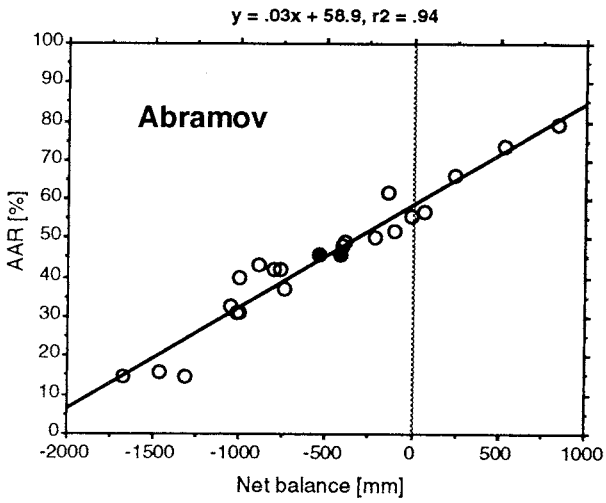
1990/91

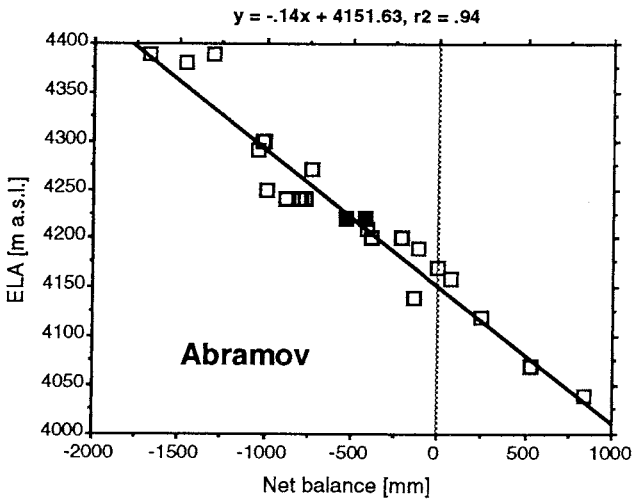

net balance isolines [m]
equilibrium line
ablation area
N
-6
-5
-4
-3
-2
-1
0
1
0
1
0
1
0 1 2 km

3.8.3 Net balance versus altitude (1989/90 and 1990/91)



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





3.9 TSENTRALNIY TUYUKSUYSKIY (KASAKHSTAN)

COORDINATES: 43° 03' N / 77° 05' E

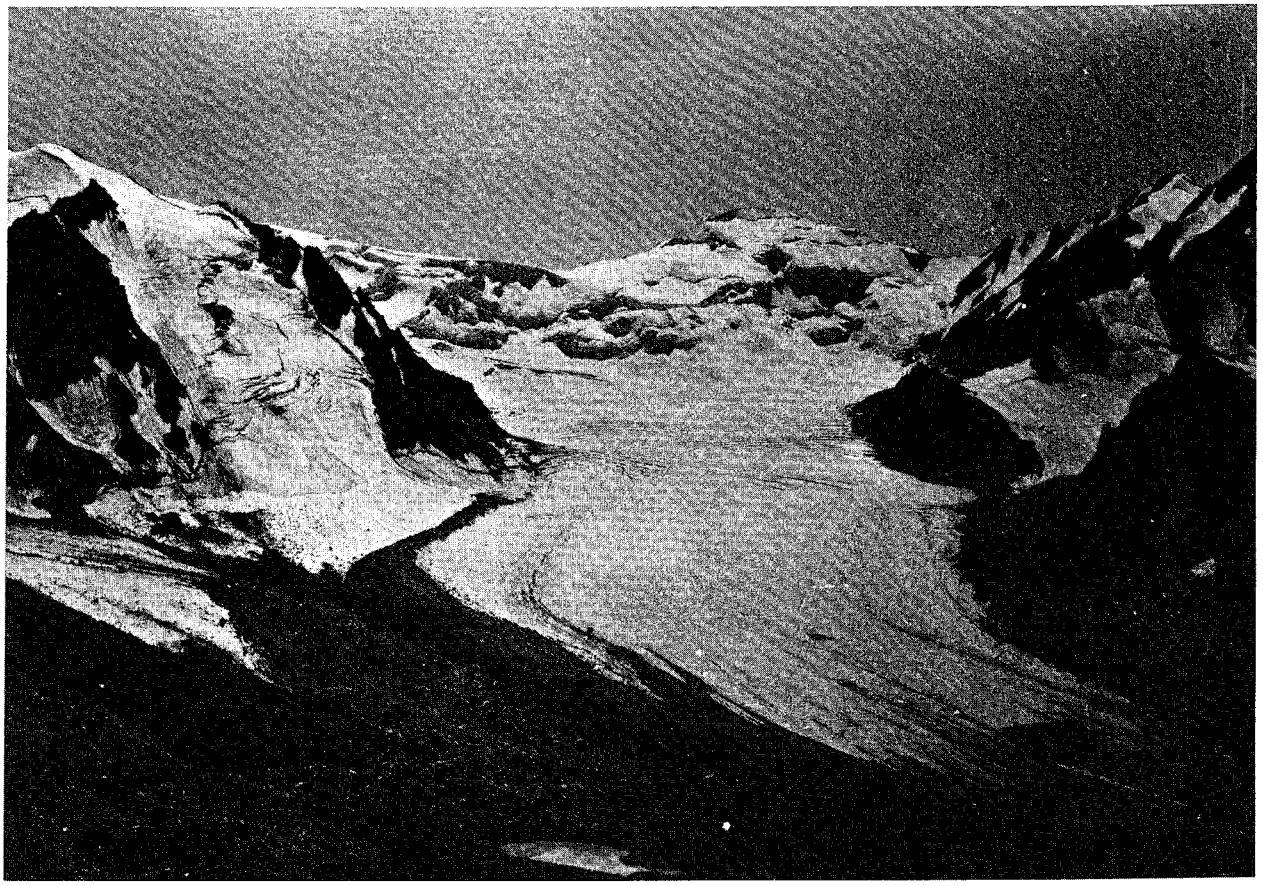
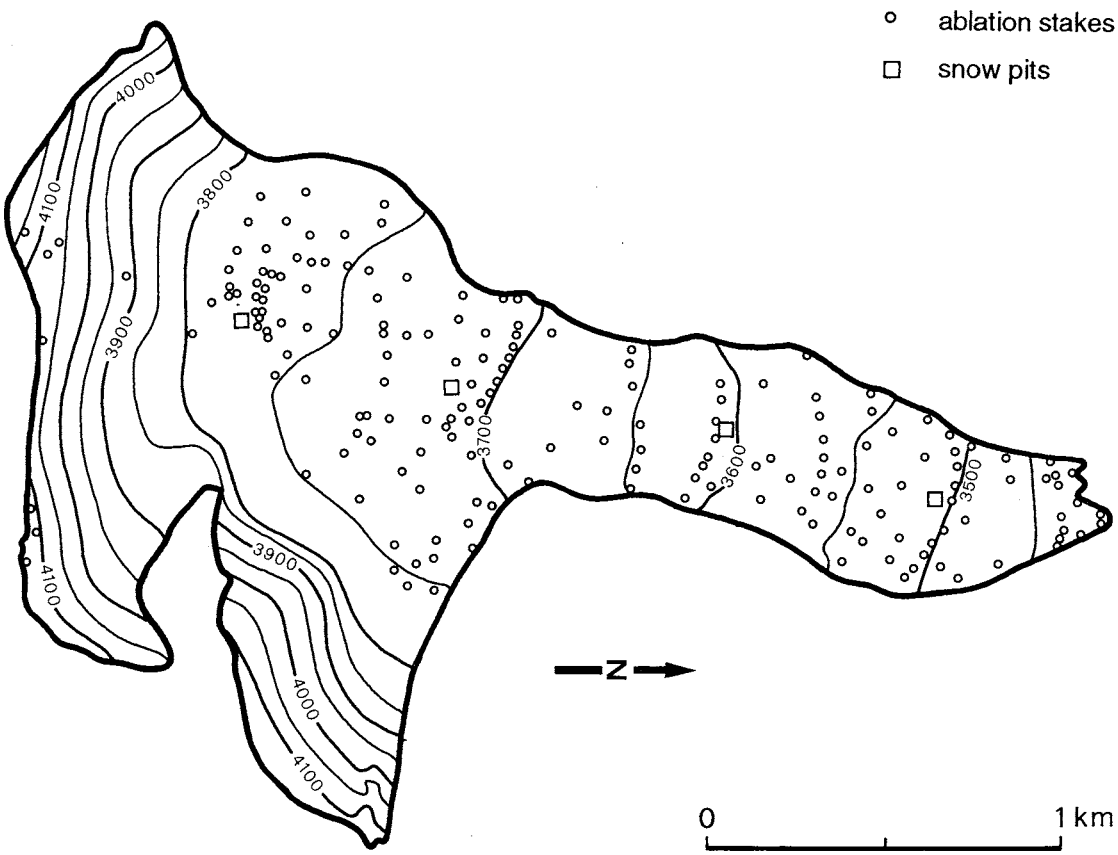


Photo taken by K.G. Makarevich in August 1970.

The valley-type glacier in the Zailiyskiy Alatau Range of the Kazakh 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).

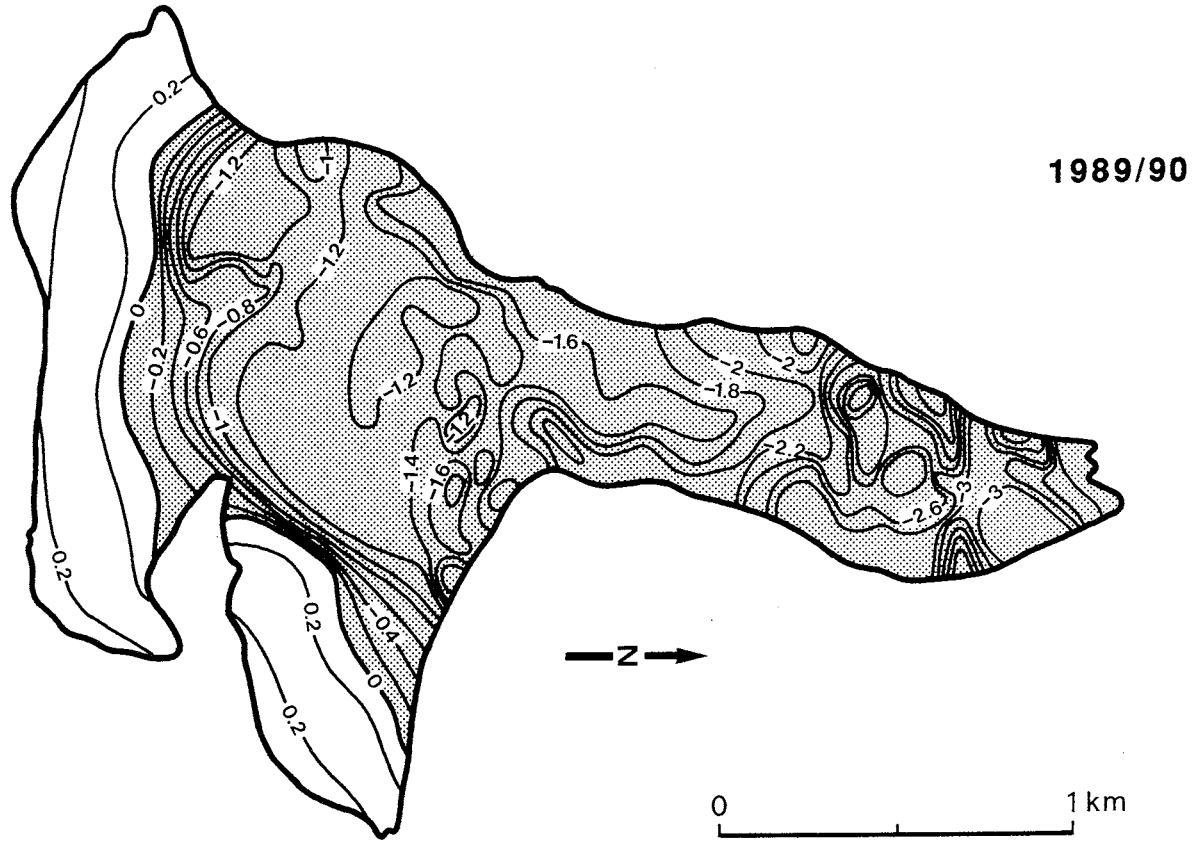
Both reported balance years were unfavourable for the health of the glacier. In 1989/90, winter balance remained below the average and ablation was higher than the long-term mean by a factor of 2.5. In 1990/91, accumulation amounted to only 62 % of the long-term mean while ablation exceeded its norm by a similar amount as in the previous summer. The resulting mass losses of -0.96 m water equivalent in 1989/90 and of -1.10 m water equivalent in 1990/91 deviate from the long-term mean by 0.62 and 0.76 m, respectively. The altitude of the equilibrium line was higher than average by 80 and 145 m. The peculiar feature of the reported balance years was the unusual predominance of the liquid phase in summer precipitation.

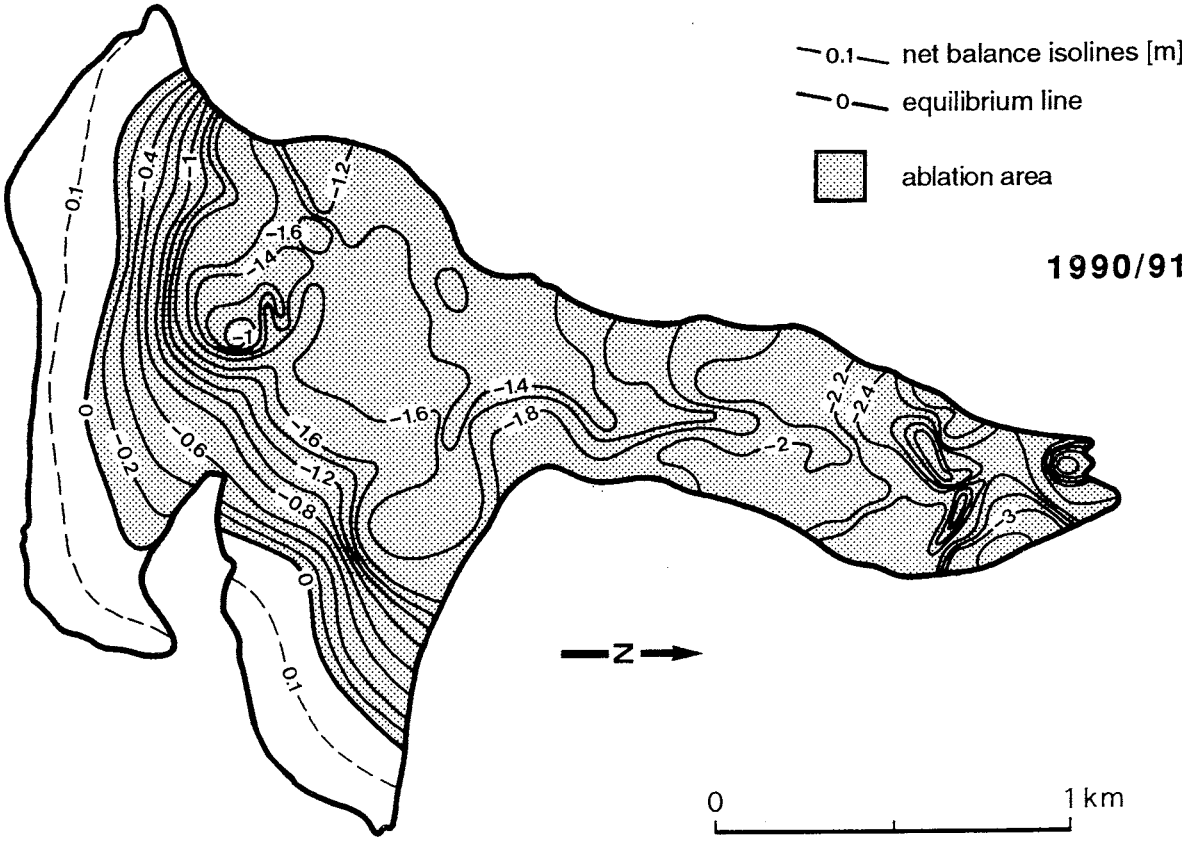
3.9.1 Topography and observational network



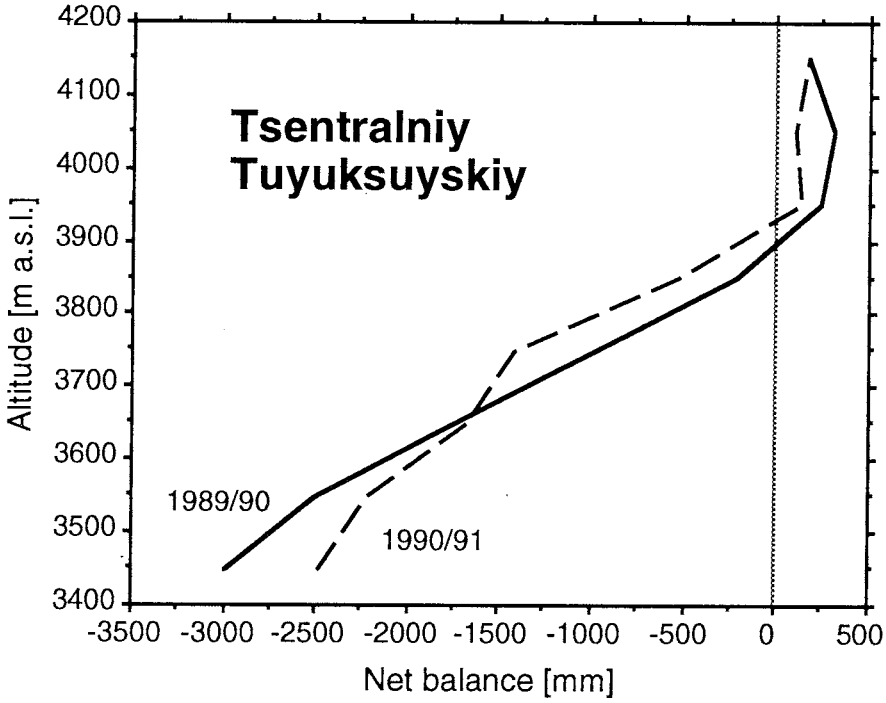
Tsentralniy Tuyuksuyskiy (KASAKHSTAN)

3.9.2 Net balance maps 1989/90 and 1990/91

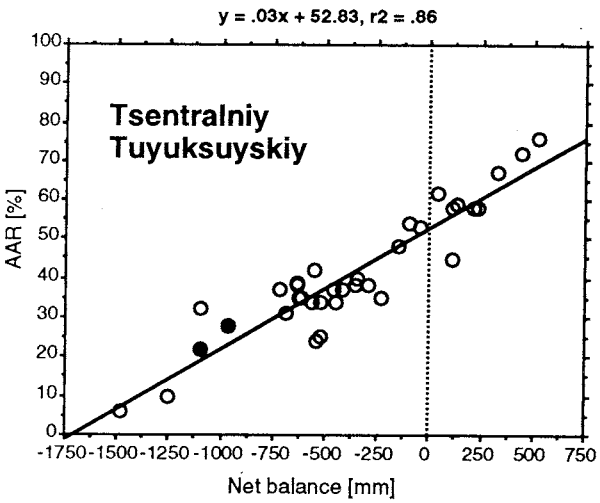


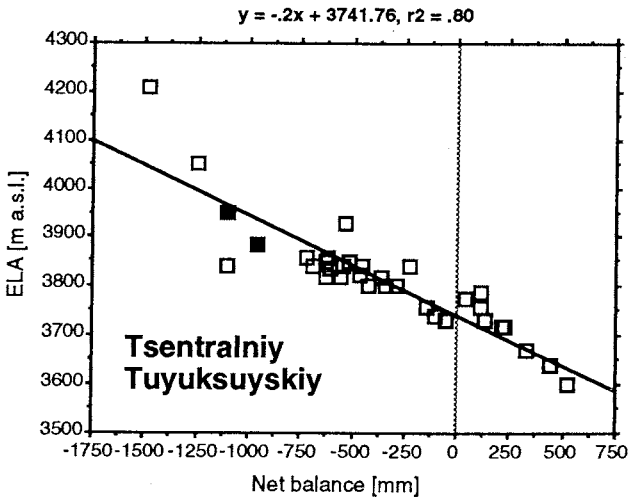


3.9.3 Net balance versus altitude (1989/90 and 1990/91)



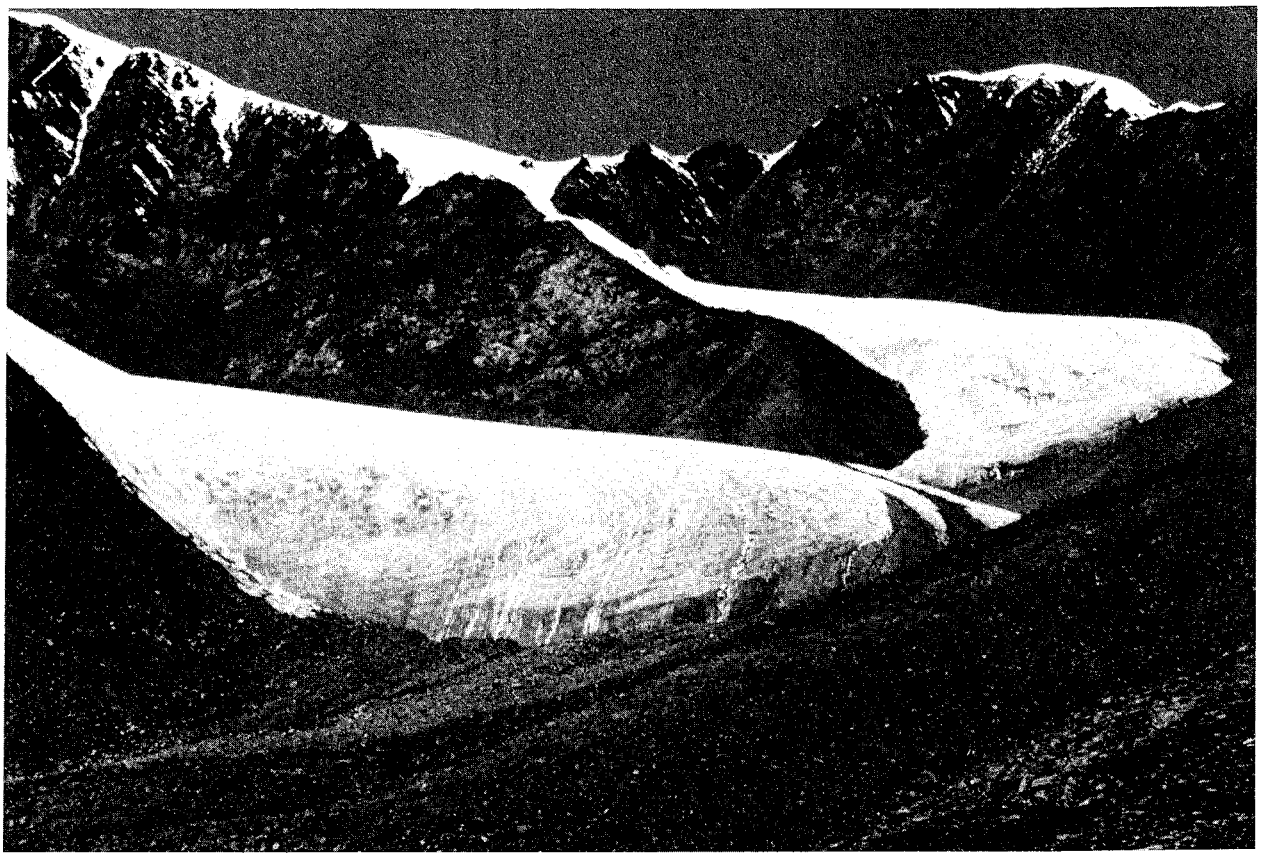
3.9.4 Accumulation area ratio (AAR) and equilibrium line altitude (ELA) versus specific net balance for the whole observation period





3.10 URUMQIHE S. NO. 1 (CHINA)

COORDINATES: 43° 05' N / 86° 49' E

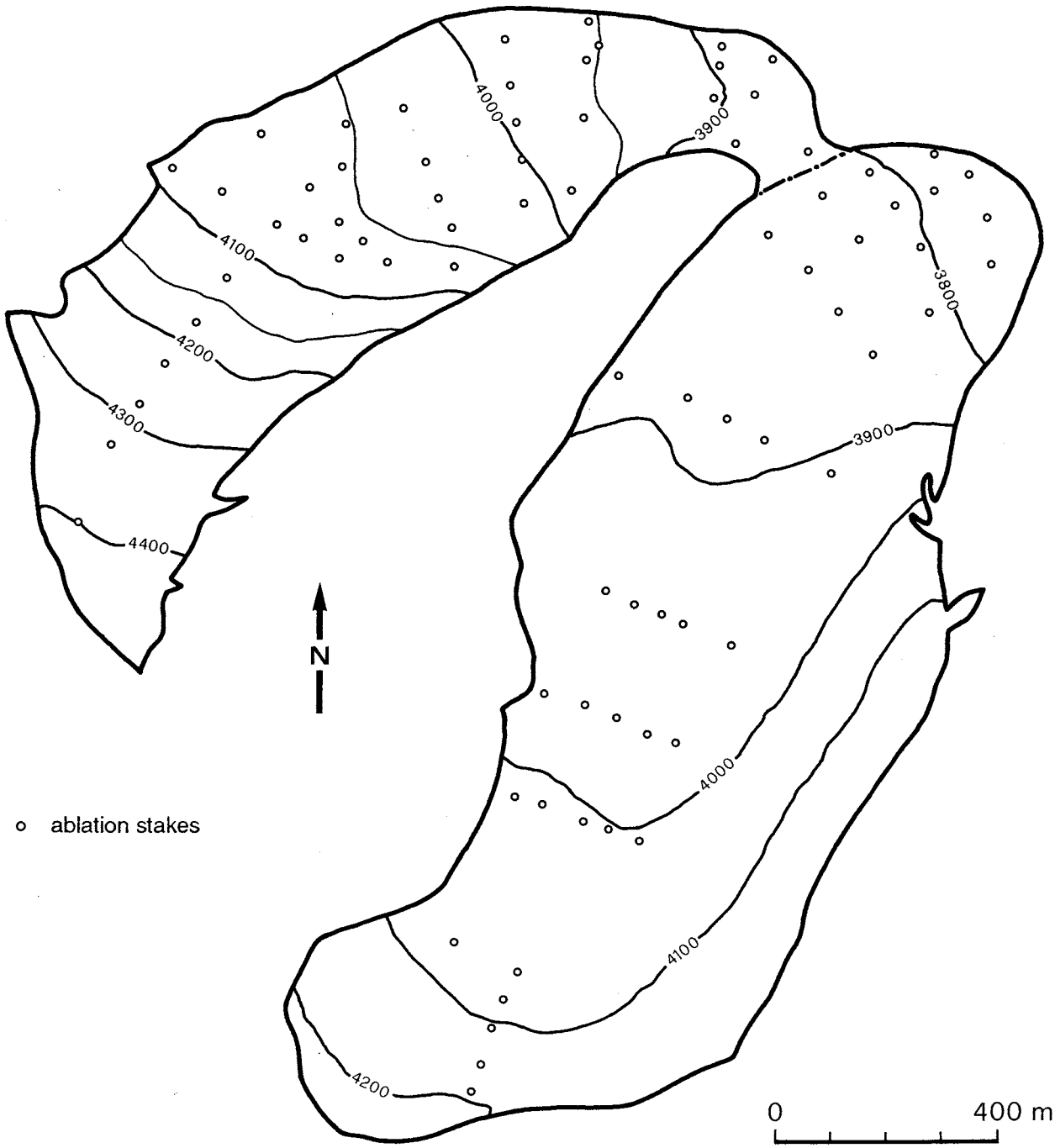


Author and date of Photo not reported.

The 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 3,740 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 take place primarily 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.

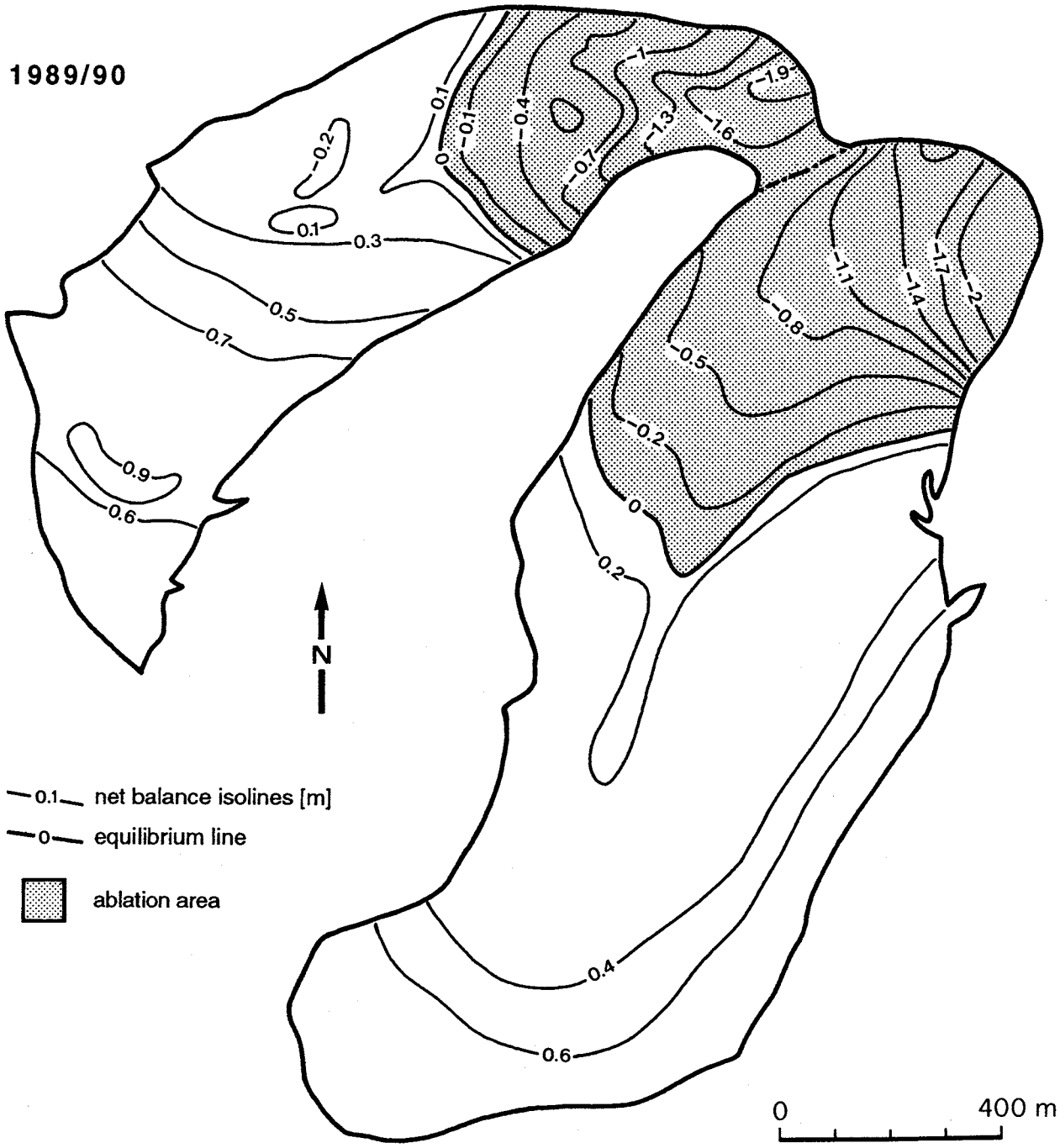
Precipitation in both reported balance years was near average but summer conditions differed markedly. Low summer temperatures, especially in July, caused a slight mass gain of 0.05 m water equivalent in 1989/90, whereas high June to August temperatures lead to a significant mass loss of 0.71 m water equivalent in 1990/91.

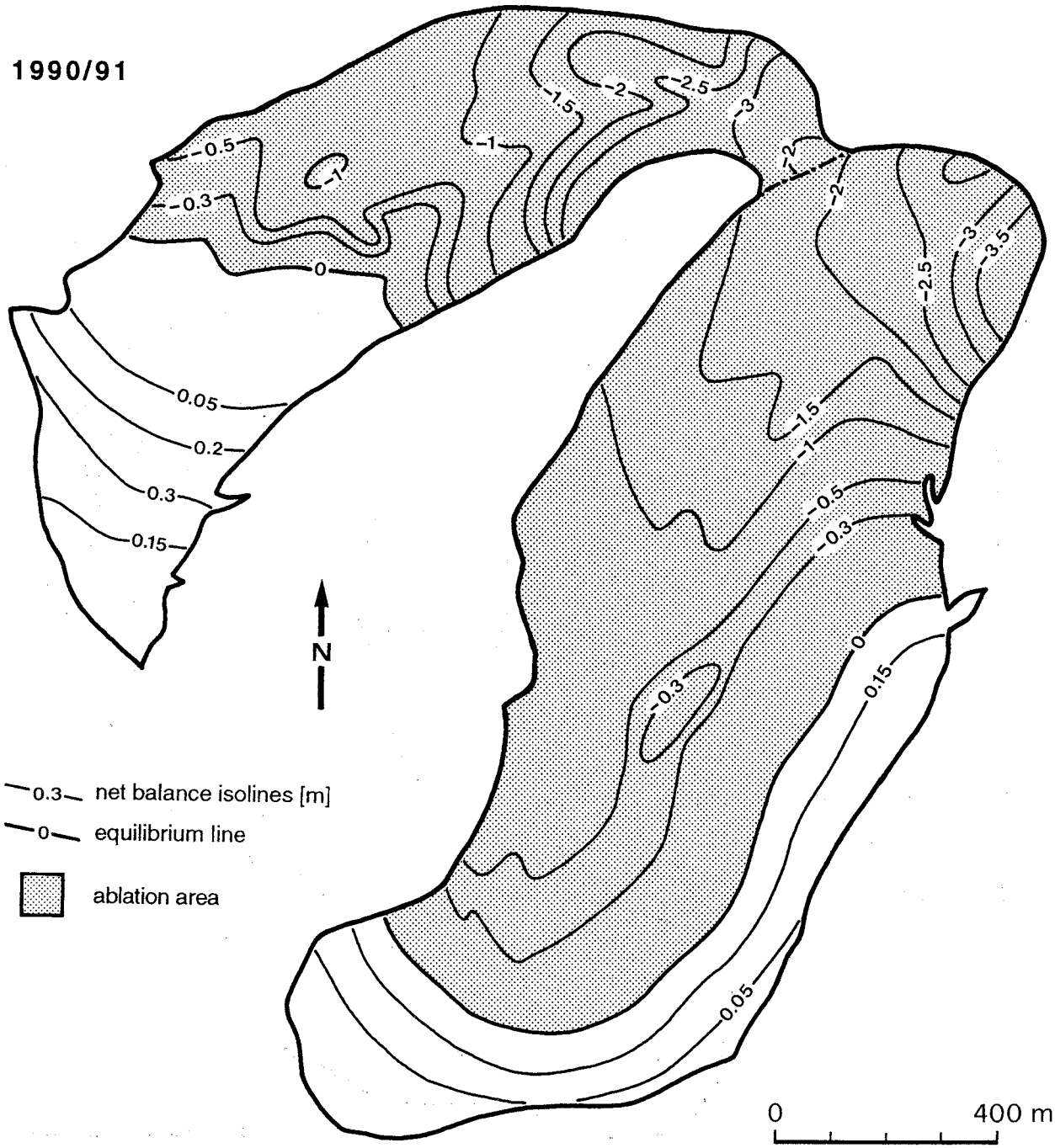
3.10.1 Topography and observational network



Urumqihe S. No. 1 (CHINA)

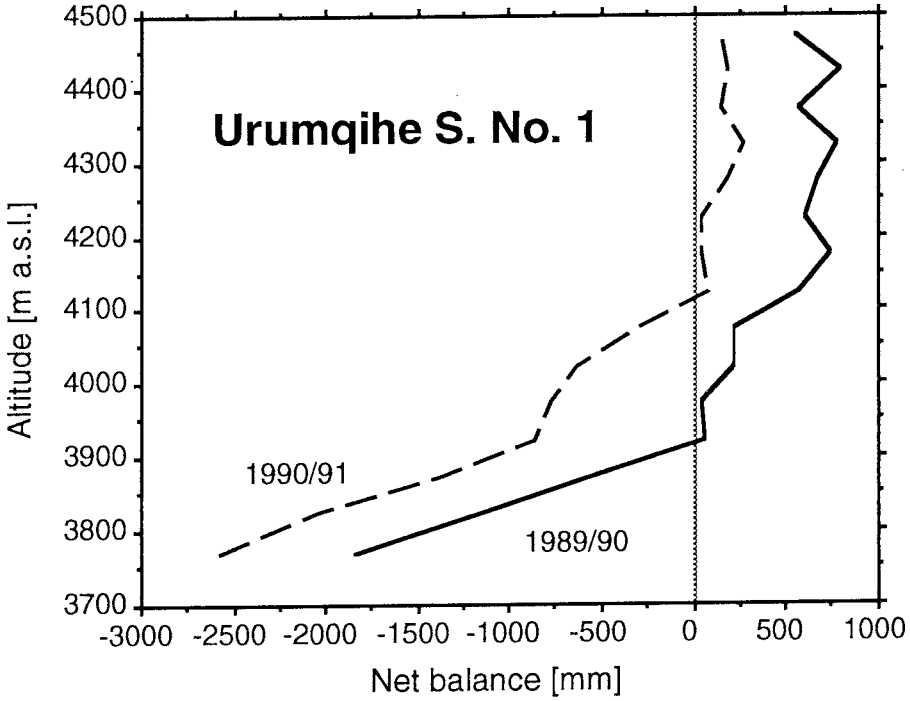
3.10.2 Net balance maps 1989/90 and 1990/91



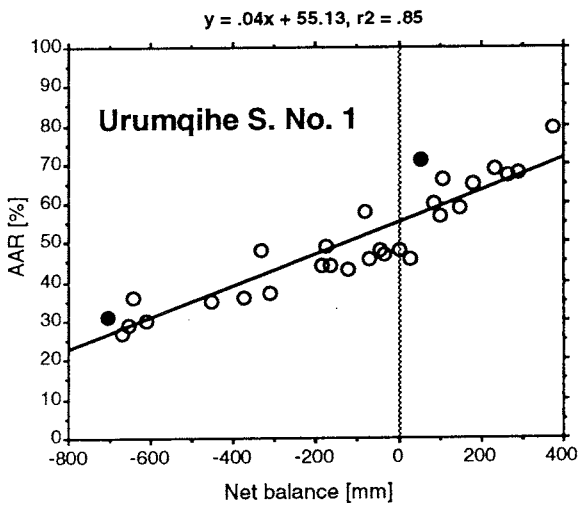


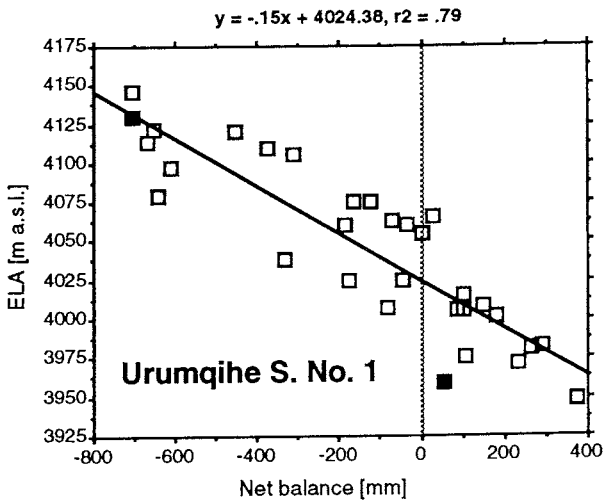
Urumqihe S. No. 1 (CHINA)

3.10.3 Net balance versus altitude (1989/90 and 1990/91)



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 27 glaciers, mass balance values are available for the decade 1980-1990 as well as for both years 1989/90 and 1990/91. The corresponding results of this sample of glaciers in North America, Eurasia and Africa can be summarized as follows:

	1980-1990	1989/90	1990/91
mean specific net balance:	- 353 mm	- 467 mm	- 521 mm
standard deviation:	± 496 mm	± 1099 mm	± 677 mm
minimum value:	- 1085 mm	- 2510 mm	- 1730 mm
maximum value:	+ 683 mm	+ 1790 mm	+ 790 mm
range:	1760 mm	4300 mm	2520 mm
positive balances:	22 %	30 %	26 %

Despite the great scatter indicated by the extremes as well as the range of extremes and the standard deviation of the mean, the statistics point to continued if not accelerated glacier melting in the northern hemisphere. Taking the two reported years together, the mean mass balance was negative by roughly half a meter of water equivalent per year, a value which is about one third higher than the decadal average. The proportion of positive mass balances remained below one third of the sample.

Further analysis requires detailed consideration of such aspects as glacier sensitivity, feedback mechanisms and representativity with respect to space and time. The reported balance values and curves of cumulative mass balances (Chapter 2) not only reflect 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 - and a (regional) climatic component - the change of mass balance with altitude or the mass balance gradient. The latter component tends to increase with increasing humidity and leads to stronger reactions of maritime than of continental glaciers. Rising snowlines and cumulative mass losses lead to changes in average albedo and continued surface lowering. Such effects cause pronounced positive feedbacks with respect to radiative and sensible heat fluxes. By building up over extended time periods such as a century, the mass balance/altitude feedback can, indeed, equal the result from pure atmospheric forcing as combined with albedo effects. The cumulative length change of glaciers is the result of all effects combined and constitutes the key to global intercomparison of secular mass losses.

Probably the most significant and spectacular event with regard to glacier shrinkage in the reported 2-year time interval was the finding of a human body which had been buried in ice of the Oetztal Alps (Austria) some 5,000 years ago. The body was found in a topographic depression at the former glacier bed in a slightly cold part of the accumulation area on top of a small mountain glacier where the ice must have had persisted over more than five millennia and thereby remained frozen to the bed. These circumstances explain the perfect conservation of the body which is of greatest interest to archeology. At the same time, however, the reappearance of the "Oetztal ice man" also constitutes the first sign from a glacier accumulation area that the Alpine ice volume may now be more reduced than ever before during the more recent part of the Holocene. At least in the Alps, where the best documentation exists, glacier shrinkage now seems to be passing at a high and possibly accelerating rate beyond the range of preindustrial variability.

Completion of the present Glacier Mass Balance Bulletin was made possible through the cooperation 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 Werner Nobs for drawing the maps and to Susan Braun for editing the English. Funding was mainly through GEMS / UNEP and FAGS / ICSU. It is planned to issue the third Glacier Mass Balance Bulletin in winter 1994/95. Suggestions for further improvement of the content and presentation of this new publication series are 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 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**
	Gulkana	R. March US Geological Survey Water Resources Division 800 Yukon Drive **USA - Fairbanks, Alaska 99775-5170**
ICELAND:	Hofsjökull North Hofsjökull East Hofsjökull Southwest	O. Sigurdsson National Energy Authority Hydrological Survey Orkustofnun Grensasvegi 9 **ICELAND - 108 Reykjavik**
NORWAY:	Austre Brøggerbreen Midtre Lovénbreen Kongsvegen	J.O. Hagen Norwegian Polar Research Institute Postboks 158 **NORWAY - 1330 Oslo lufthavn**
	Hansbreen	J. Jania University of Silesia Faculty of Earth Sciences Department of Geomorphology ul. Bedzinska 60 **POLAND - 41-200 Sosnowiec**

	Ålfotbreen Nigardsbreen Storbreen Gråsubreen Engabreen Langfjordjøkulen	B. Wold Norwegian Water Resources and Energy Administration Glacier Division P.O. Box 5091, Maj. **NORWAY - 0301 Oslo 3**
SWEDEN:	Storglaciären Rabots glaciär Tarfalaglaciären Riukojietna Mårmaglaciären	P. Holmlund and W. Karlén Department of Physical Geography University of Stockholm **SWEDEN - 106 91 Stockholm**
FRANCE:	Sarennes	F. Valla Cemagref-nivology B.P. 76 **FRANCE - 38402 St-Martin-d'Héres, Cedex**
	Saint Sorlin	L. Reynaud Laboratory of Glaciology and Environmental Geophysics (CNRS) B.P. 96 **FRANCE - 38402 St-Martin-d'Héres, Cedex**
SWITZERLAND:	Gries Silvretta	M. Aellen and M. Funk Laboratory of Hydraulics, Hydrology and Glaciology (VAW) Federal Institute of Technology ETH-Zentrum **SWITZERLAND - 8092 Zurich**
ITALY:	Careser	G. Zanon University of Padua Department of Geography Via del Santo, 26 **ITALY - 35123 Padua**
AUSTRIA:	Jamtalferner Ochsentalergletscher Vermuntgletscher Hintereisferner Kesselwandferner	G. Markl and M. Kuhn Institute of Meteorology and Geophysics University of Innsbruck Innrain 52 **AUSTRIA - 6020 Innsbruck**
	Sonnblickkees	H. Slupetzky Geographical Institute University of Salzburg Hellbrunnerstrasse 34 / III **AUSTRIA - 5020 Salzburg**

KENYA:	Lewis	S. Hastenrath Department of Meteorology University of Wisconsin-Madison 1225 West Dayton Street **USA - Madison, Wisconsin 53706**
RUSSIA:	Garabashi	A.B. Bazhev, O.V. Rototayeva and I.F. Khmelevskoy Institute of Geography Russian Academy of Sciences Staromonetniy, 29 **RUSSIA - 109017 Moscow**
	Djankuat	V.V. Popovnin Moscow State University Faculty of Geography Leninskiye Gory **RUSSIA - 119899 Moscow**
	Maliy Aktru Leviy Aktru Praviy Aktru No. 125	Yu. K. Narozhniy Tomsk State University Lenin Str., 36 **RUSSIA - 634010 Tomsk-10**
	Kozelskiy	Ya. D. Muravyov Institute of Volcanology Russian Academy of Sciences Far East Research Center Piyp Boulevard, 9 **RUSSIA - 683006 Petropavlovsk Kamchatskiy**
TADJIKISTAN:	Abramov	G.M. Kamnyanskiy SANIGMI Central Asian Regional Research Hydrometeorological Institute Observatorskaya Str., 72 **UZBEKISTAN - 700052 Tashkent-52**
KIRGHIZSTAN:	Golubin	F.Kh. Yar-Mukhamedov Kirghiz Hydrometeorological Committee Karasuyskaya, 1 **KIRGHIZSTAN - 720403 Bishkek**
	Suyok Zapadniy No. 131 Kara-Batkak	A.N. Dikikh and E.K. Bakov Tien-Shan Physical Geography Research Station Kirghiz Academy of Sciences Pionerskaya, 7 **KIRGHIZSTAN - Pokrovka, Issyk Kul Region**

KAZAKHSTAN:	Ts. Tuyuksuyskiy	K.G. Makarevich, S.G. Breusov and R.N. Iskhakov Institute of Geography Kazakh Academy of Sciences Pushkin Str., 99 **KAZAKHSTAN - 480100 Alma Ata**
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
AUSTRIA - 6020 Innsbruck

BOLIVIA:
E. Jordan
Physical Geography
Universität Vechta
Driverstrasse 22
GERMANY - 2848 Vechta

CANADA:
C.S. Ommanney
Hydrological Sciences Division
National Hydrology Research Institute
11, Innovation Boulevard
CANADA - Saskatoon, Saskatchewan S7N 3H5

CHILE:
G. Casassa
Ohio State University
Byrd Polar Research Center
103 Mendenhall Laboratory
125 Oval Mall
USA - Columbia, OH 43210-13

CHINA:
Yang Huyan
Lanzhou Institute of Glaciology and Cryopedology
Academia Sinica
CHINA - Lanzhou

FRANCE:
L. Reynaud
Laboratory of Glaciology and Environmental Geophysics (CNRS)
B.P. 96
FRANCE - 38402 St-Martin-d'Hères Cedex

GERMANY:
O. Reinwarth
Commission for Glaciology
Bayerische Akademie der Wissenschaften
Marstallplatz 8
GERMANY - 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:

Krishnamurthy
Geological Survey of India
27, Yawaharlal Nehru Road
INDIA - Calcutta - 700 016

ITALY:

G. Zanon
University of Padua
Department of Geography
Via del Santo, 26
ITALY - 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
MEXICO - Coyoacan 04510 D.F.

NEW ZEALAND:

T.J. Chinn
Ministry of Works and Development
P.O. Box 1479
NEW ZEALAND - Christchurch

NORWAY:

B. Wold
Norwegian Water Resources and Energy Administration
Glacier Division
P.O. Box 5091, Maj.
NORWAY - 0301 Oslo 3

PAKISTAN:

W. Kick
Macheinerweg 35
GERMANY - 8400 Regensburg

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
POLAND - 34500 Zakopane

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

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

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

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

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

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

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